UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COMBINATION ROAD CROSSING, CHECK DROP, AND OUTLET STRUCTURE MADERA DISTRIBUTION SYSTEM CENTRAL VALLEY PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd. 361

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

November 12, 1952

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Laboratory Report No. Hyd-361
Hydraulic Laboratory Section
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Subject: Combination road crossing, check drop, and outlet structure--Madera Distribution System--Central Valley Project, California

PURPOSE

Determine the minimum size of structure that combines a canal road crossing, vertical check drop, and irrigation turnout.

CONCLUSIONS

The following conclusions apply to a structure having a 2:1 upward slope on the pipe entering the head wall.

1. The recommended design (Figure 2) gives the best all-around performance.

2. No flow straightener is required in the turnouts ahead of the totalizing meter with the recommended design.

3. The "in line" forebay (Figure 1) would be adequate under conditions where no regulating gate is used on the turnout or where a flow straightener is used ahead of the flow meter.

4. The shape of the forebay has an effect on the turnout entrance loss.

5. Some erosion will occur at the junction of the stilling basin and canal. Riprap protection should be provided immediately downstream of the structure.

6. The energy is not dissipated in the stilling basin when the tail water is above the crest of the check wall. High surface velocities with considerable turbulence are present (Figure 4A). The beam baffle shown in Figures 2 and 4B will give satisfactory conditions when the tail water is at or above the top of the check wall.

7. The top or crest of the vertical check wall should not be lower than the crown of the inlet.

RECOMMENDATIONS

1. Use the design shown in Figure 2 for a structure combining a road crossing, check drop, and turnout. The dimensions given are considered minimum.

2. Use a minimum head-loss of 0.75 of the turnout velocity head for the turnout entrance.

3. Protect the canal bottom and side slopes with riprap for a short distance below the stilling basin.

4. Place a beam baffle across the stilling basin where high tail water will exist.

ACKNOWLEDGMENT

The limiting dimensions of the recommended structure were determined by members of the Canals and the Engineering Laboratories Branches.

INTRODUCTION

Twenty road crossings were contemplated for construction at the time of this investigation, with perhaps two or three times this number anticipated for future construction in the Madera System. It was proposed to combine the road crossing, vertical check, and irrigation turnout into one structure where feasible. This combination was expected to result in a savings in material and labor as compared to building three individual units. Four different size canal road crossings were to be constructed using 48-, 42-, 36-, and 30-inch concrete pipe. Some of the structures will contain two turnouts and the remainder single turnouts of either 30- or 24-inch concrete pipe. Dimensions, discharges, etc. given in this report refer to prototype unless stated otherwise.

PRELIMINARY INVESTIGATION

The Problem

The problem was to determine the minimum construction required between the head wall of the road crossing and the vertical check wall to prevent surging over the check wall. The preliminary design is shown on Figure 1.

The Model

An existing laboratory model was used for the study. In this installation a 15-inch metergate discharged into a 3- by 3- by 11-foot flume. A vertical check, whose top elevation was identical to the top of the gate opening, was placed in the flume downstream from the gate to represent a 6- by 6-foot forebay. No turnouts were provided and the flume was too narrow to provide a geometrically similar stilling basin. The model represented the most severe condition which was the 48-inch road crossing discharging 60 cfs at 4.77-feet-per-second velocity. These conditions established a model ratio of 1:3.2. The discharge was measured through an 8-inch venturi meter.

Tests

The discharge representing 60 cfs was passed over the vertical check wall and the tail-water elevation varied. Water action in the forebay was quite rough, piling up along the sides with reverse flow. There was no surging over the check wall. The disturbances in the forebay indicated that the volume was too small. Considering the narrow width of the flume, the flow conditions in the pool were quite smooth until the tail water was elevated higher than the top of the check wall. The high tail water produced an undesirable high-velocity surface stream.

The vertical check was moved to a distance equivalent of 12 feet downstream. The width was maintained as 6 feet for a distance of 6 feet upstream from the check and then widened to 9-1/2 feet for the remaining 6 feet to the head wall, forming a "tee-shaped" forebay. This change helped eliminate the disturbances in the forebay and maintained a quiet area of water where the turnouts would be located.

Conclusions

1. The 6- by 6-foot-square forebay as originally contemplated was inadequate.

2. The "tee-shaped" forebay was ample with no surge over the vertical check.

3. Additional test would be required to obtain answers to the additional problems voiced by designers. These problems were:

   a. What effect would a turnout have on the flow in the forebay?

   b. Would flow in the turnout be uniform and without a spiral motion?

   c. Where should the turnout be located with respect to the forebay?

d. What should be the size and shape of the stilling basin below the drop?

e. What effect would the 2:1 rise in the road crossing pipe have on the forebay and turnout flows?

f. Could an adequate structure be designed in dimensionless terms that would meet all the requirements of the different diameters of the road crossings and outlets?

The test results were too limited to answer the additional questions so another model study was proposed.

SECONDARY INVESTIGATION

The Model

A redesign of the structure was made (Figure 2) by modifying the preliminary design (Figure 1) on the basis of information obtained from the preliminary tests. On Figure 2 the numbers identified by a bar are the prototype dimensions used in the model; e.g., 6. The boxed dimensions ($\boxed{d}$) are the recommended design dimensions. A 1:4 model was fabricated mainly of plywood and lumber. The road crossing was represented by a 12-inch pipe entering the forebay on a 2:1 slope. The only plastic pipe available for representing the turnouts was 8.11 inches in diameter which was somewhat oversize to represent a 30-inch turnout. Both a right and left turnout were provided. A tail box was placed at the end of the turnout to adjust the downstream submergence. The water was conducted away from the tail box by a wooden waste flume.

Test Facilities

The discharge into the model was measured through an 8-inch venturi meter. A sheet-metal weir plate was placed at the end of the waste flume and calibrated to measure the discharge through the turnout. A point gage was used to measure the head on the weir. Because of the roughness of the water surface, accurate readings were not obtainable so the turnout discharges were approximate only.

A piezometer tap was placed in the forebay floor, and one in the turnout pipe 6-3/4 diameters downstream from the inlet of the turnout, for studying losses.

A point gage mounted on the stilling basin was used to maintain tail-water elevations. Flow characteristics in the stilling basin, forebay, and turnout were judged by visual observation.

Performance

Stilling basin. Three variations of stilling pools were investigated. The first was the recommended design (Figures 2 and 3). The total discharge representing 60 cfs was passed over the vertical check wall without the turnouts operating, to study the effect of the maximum discharge in the stilling pool. Operation at normal tail water or less was satisfactory, although a boil formed in the water surface at the intersection of the stilling basin and the canal. Sand was placed in the model where the boil formed. The sand was displaced on the canal slope at the top corners only, and was not disturbed on the bottom of the canal.

A high-velocity surface stream was created when the tail water was raised above the top elevation of the vertical check wall. This condition was readily alleviated by using a vertical beam baffle downstream from the check (Figure 4).

The stilling basin was modified to the preliminary design by sloping the side walls to intersect the canal side slope, forming a "broken back" transition. This eliminated the corner disturbance of the recommended design but concentrated the water in the center of the canal. Studies with sand showed that the bottom of the canal was being considerably disturbed for some distance downstream. Figure 5 shows the set-up and the pool in action.

The model was again modified by sloping the bottom of the basin upward to the floor of the canal. This modification gave the best surface condition (Figure 6) but gave the worst scouring effect on the canal sides and bottom. Large whirls were also formed in the downstream corners of the pool.

Forebay. Three forebays were investigated, a "tee" shape, an "ell" shape, and an "in line." Both turnouts were opened using the "tee" shape and the maximum discharge run through the model. Operation was satisfactory with quiet conditions in the forebay.

The majority of the turnouts in these structures will be single instead of double so the left turnout was closed. Figure 7A shows the single turnout in operation in the "tee" forebay and Figure 8B shows the over-all model. Conditions were good except for a vortex that formed in the upstream corner near the turnout entrance. The vortex became more pronounced as the head on the turnout was reduced and eventually separated into several vortexes.

The "ell-shaped" forebay was evolved to save space and material where only one turnout was included. The operation of this forebay is shown in Figure 7B. Operation was satisfactory but a vortex formed as in the "tee" shape.

The "in line" shape was tried during head loss studies. The forebay was made the equivalent of 6 feet wide from the head wall to the vertical check. It is shown in operation in Figure 8A. Action in the forebay was good, contrary to the same shape in the preliminary model. No pile-up of water along the sides or reverse flow occurred. The improved performance was probably due to the upward velocity in the 2:1 slope of the road crossing pipe which was not incorporated into the preliminary model.

A study was made using baffles to eliminate the vortexes that formed in the forebays. No simple solution was determined. These vortexes admitted an appreciable amount of air and created an unstable water surface near the turnout, but no operational difficulties were indicated.

Turnouts

Irrespective of forebay shape, the water had a tendency toward spiral flow in the turnout. The spiral was clockwise in the right turnout looking downstream and counterclockwise in the left turnout. The use of a propeller-type totalizing meter is contemplated for measuring turnout discharge in the Madera System. It was anticipated that the spiral flow might affect the accuracy of the meter by speeding up with spiral flow in one direction and slowing down in the opposite.

A meter was installed and tested in the turnout having the "tee-shaped" forebay with and without a flow straightener upstream from the meter. No difference was detected in the measurement by the meter. The meter used had a 6-inch propeller.

The field structure will have regulating gates on the turnouts. No gates were installed on the model but a round sheet-metal disc was placed on the turnout entrance at different openings to represent a gate. In the "tee-" and "ell-shaped" forebays the gate helps to eliminate the spiral condition. The gate in the "in line" forebay increased the spiral flow to a great extent.

An attempt was made to study the turnout loss. Two conditions handicapped the measurements and the results should be used judiciously. The first condition was the location of the piezometer tap in the forebay. In studying losses in the "tee-shaped" forebay, the piezometer tap was located in the floor in the corner at the turnout and head wall, and the average loss was found to be about 0.75 of the turnout velocity head. In the "in line" forebay the piezometer tap was located first in the floor in the center of the forebay; this resulted in a loss of 0.4 of the turnout velocity head. The piezometer was then located in the center of the extreme left outlet wall, utilizing the space between the inner and outer wall as a stilling-well. The new loss was 0.5 of the turnout velocity head. Using this piezometer location for the "ell-shaped" forebay, the loss was one velocity head.

The second condition affecting the losses was the turnout discharge measurement. Head on the weir in the waste flume was measured by a point gage. The water surface in the flume was too rough for accurate point gage readings.

The results indicate that the "tee-" and "ell-shaped" forebays introduce more loss than the "in line" forebay. However, if the turnout inlet were moved closer to the road crossing jet than 1/4 diameter of the road crossing pipe, it is expected that the head loss would increase appreciably and would probably exceed that for the "tee-" and "ell-shaped" forebays. The "tee" and "ell" shape designs are recommended where open-flow meters are to be used in the turnouts since the flow conditions in the turnout pipe are more favorable as regards the accuracy of the meter.

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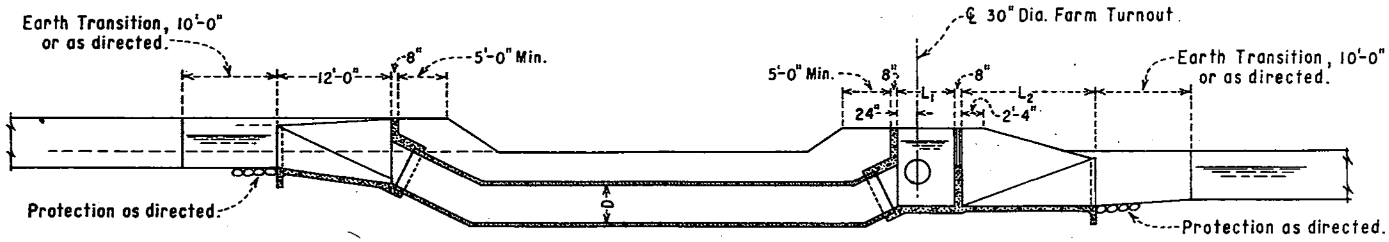
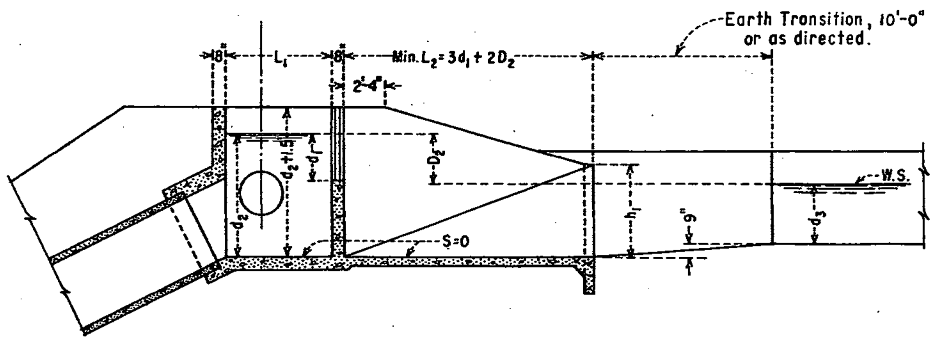
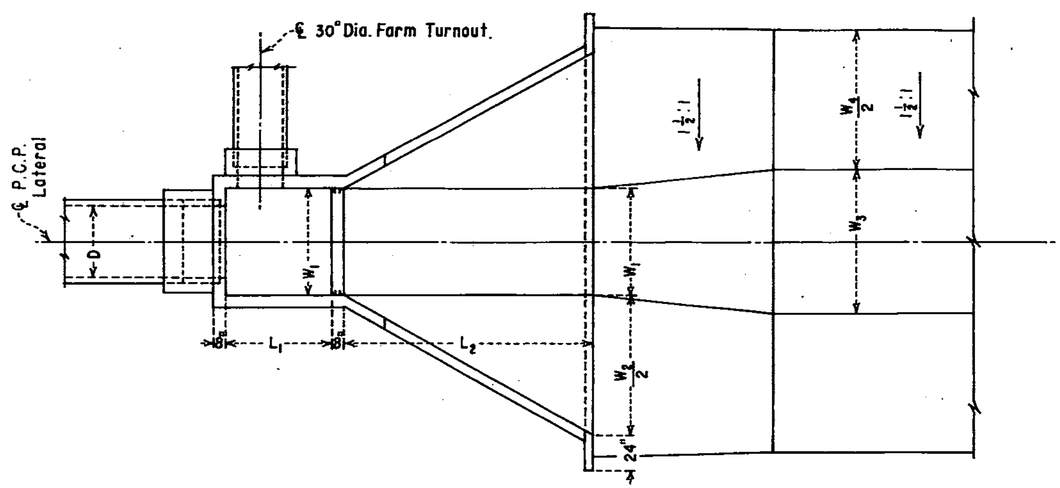


TYPICAL PROFILE OF ROAD CROSSING, TURNOUT & CHECK-DROP



LONGITUDINAL SECTION AT OUTLET END

Q	P.C.P.		CANAL BELOW			TURNOUT CHECK SECTION				DROP SECTION			
	Dia.	V	W_3	d_3	V	L_1	W_1	d_1	d_2	L_2	D_2	W_1	h_1
15	30"	3.05	6.0'	1.85'	.92		6.0'	.9'±			.5'-3.4'	6.0'	3.5'
30	36"	4.24	6.0'	2.66'	1.14		6.0'	1.5'±			.5'-4.2'	6.0'	4.5'
45	42"	4.68	8.0'	2.89'	1.26		6.0'	1.9'±			2'-3.5'	6.0'	4.83'
60	48"	4.77	8.0'	3.36'	1.38		6.0'	2.3'±			1.5'-3.5'	6.0'	5.17'

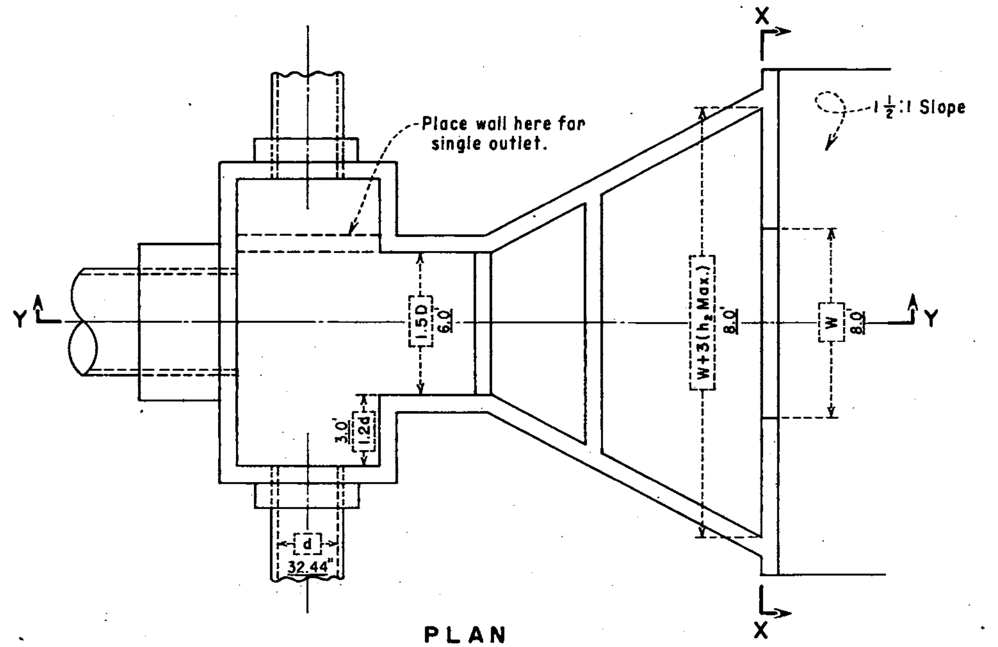


PLAN AT OUTLET END

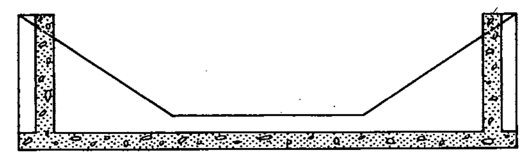
CENTRAL VALLEY PROJECT—CALIFORNIA
MADERA DISTRIBUTION SYSTEM
COMBINATION ROAD CROSSING
CHECK DROP AND OUTLET
PRELIMINARY DESIGN

FIGURE 1
REPORT HYD. 361

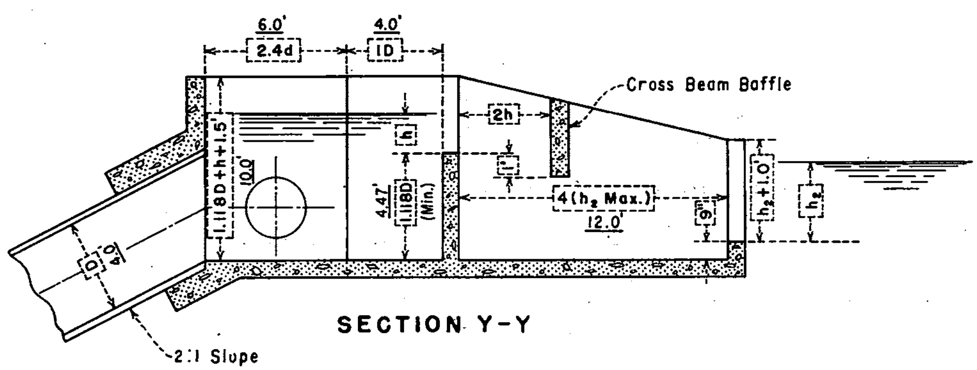
FIGURE 2
REPORT HYD. 36.



PLAN



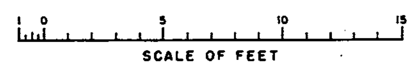
SECTION X-X



SECTION Y-Y

NOTES

This sketch applies to inside dimensions only, and does not reflect footings, wall thickness, etc.
Dimensions underlined with a bar (6) are prototype dimensions used in the model construction.
Boxed dimensions ([d]) are recommended design.



CENTRAL VALLEY PROJECT – CALIFORNIA
MADERA DISTRIBUTION SYSTEM

COMBINATION ROAD CROSSING CHECK DROP AND OUTLET

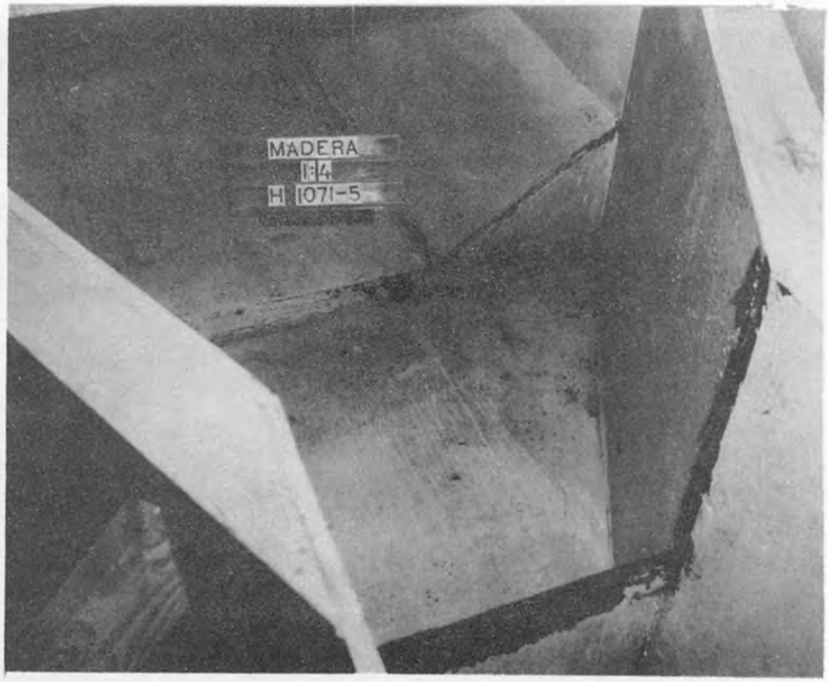
RECOMMENDED DESIGN

(A) No Discharge

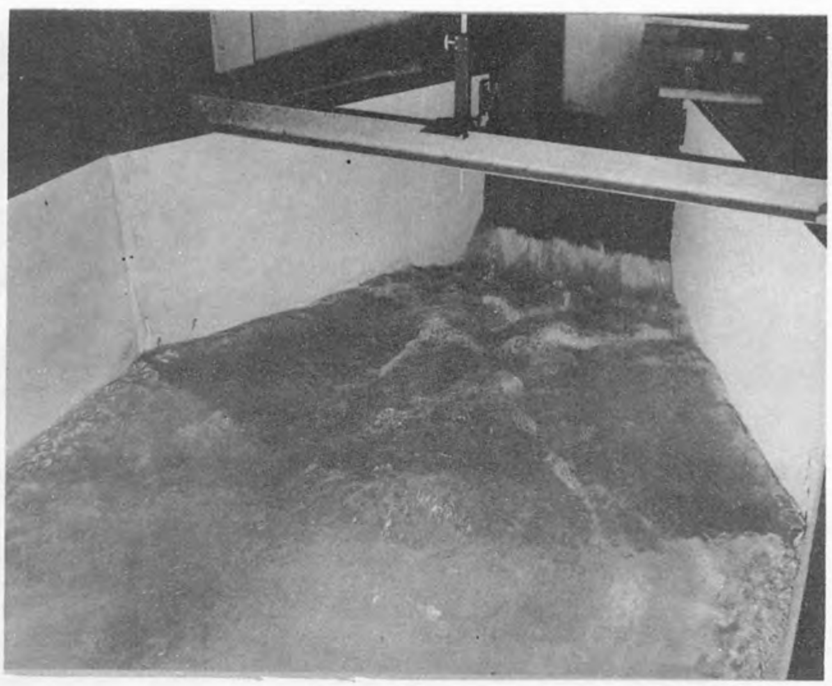
(B) Normal Maximum Tailwater--Discharging 60 cfs

RECOMMENDED STILLING BASIN

Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System
Central Valley Project--California



(A) No Discharge

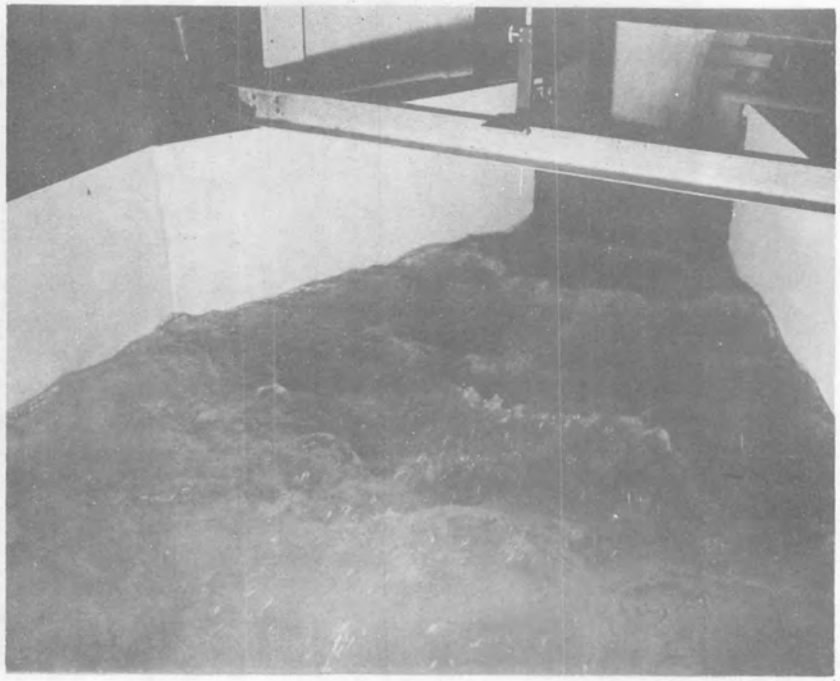


(B) Normal Maximum Tailwater--Discharging 60 cfs

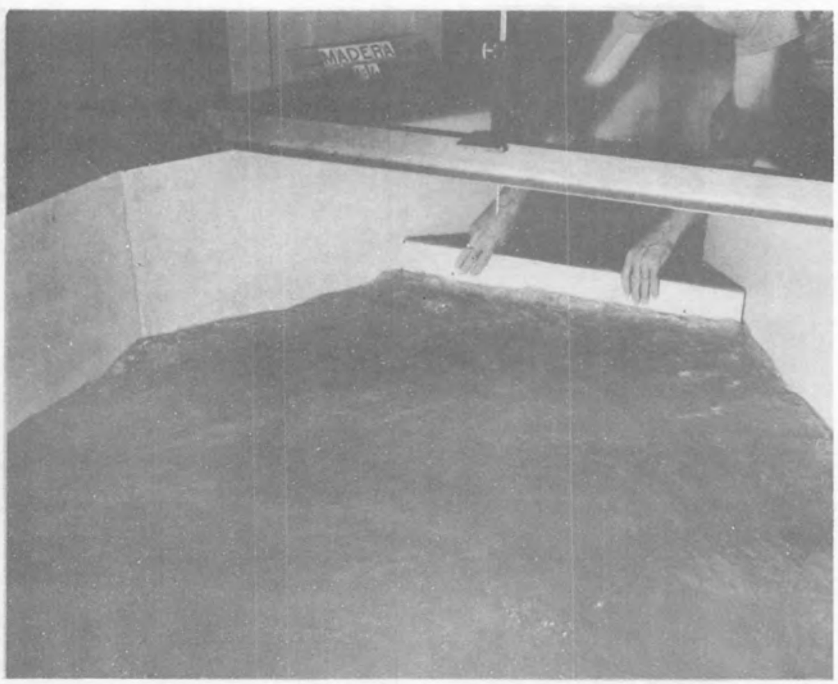
RECOMMENDED STILLING BASIN

Combination Road Crossing, Check-drop and Outlet
Structure--Madera Distribution System
Central Valley Project--California

Figure 4
Report Hyd. 361



(A) Recommended Stilling Basin--Discharging 60 cfs

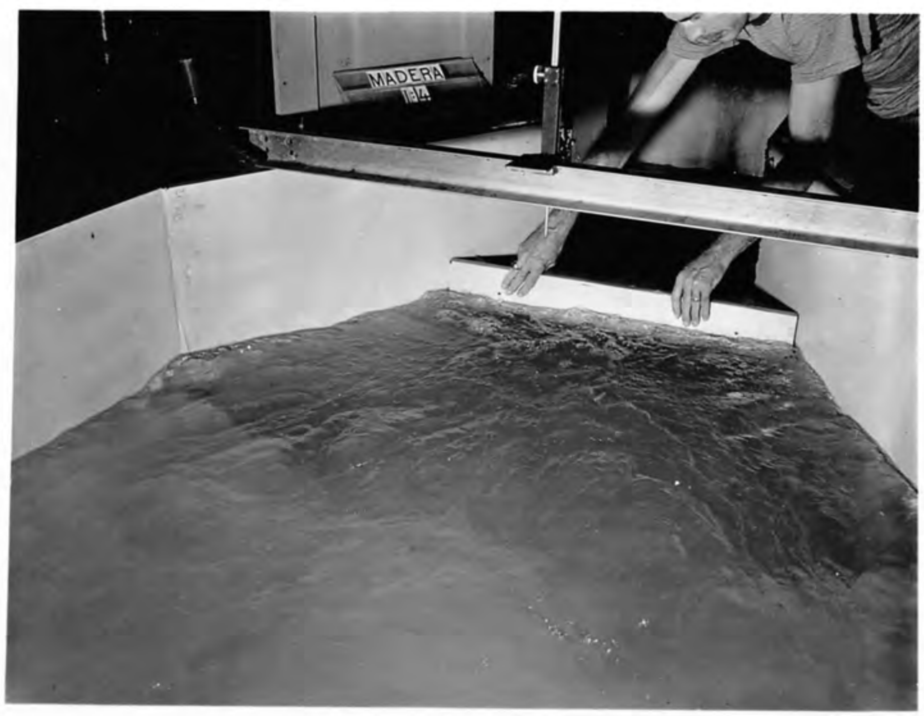


(B) Recommended Stilling Basin--With Baffle--
Discharging 60 cfs

RECOMMENDED STILLING BASIN WITH HIGH TAILWATER

Combination Road Crossing, Check-drop and Outlet
Structure--Madera Distribution System
Central Valley Project--California

(A) Recommended Stilling Basin--Discharging 60 cfs



(B) Recommended Stilling Basin--With Baffle--
Discharging 60 cfs

RECOMMENDED STILLING BASIN WITH HIGH TAILWATER

Combination Road Crossing, Check-drop and Outlet
Structure--Madera Distribution System
Central Valley Project--California

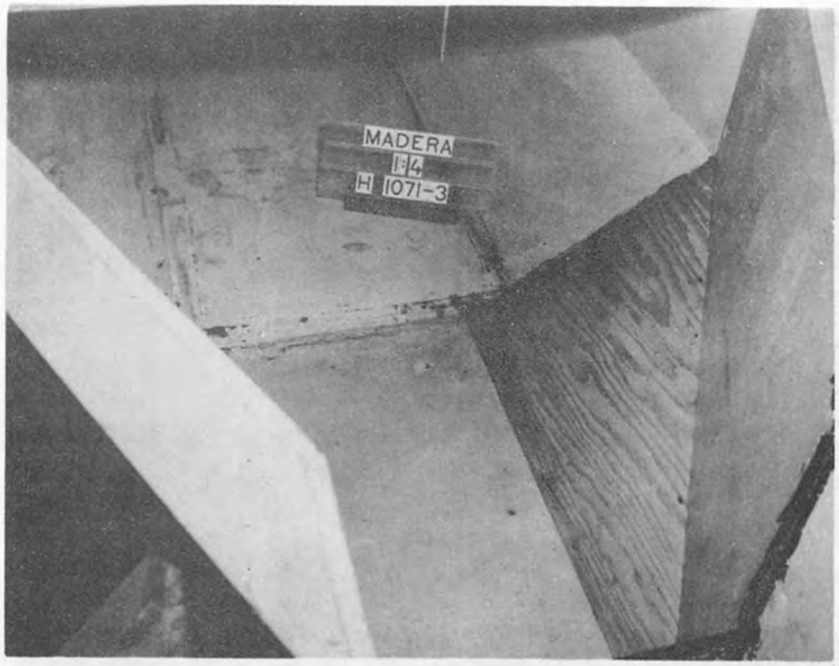
(A) No Discharge

(B) Discharging 60 cfs

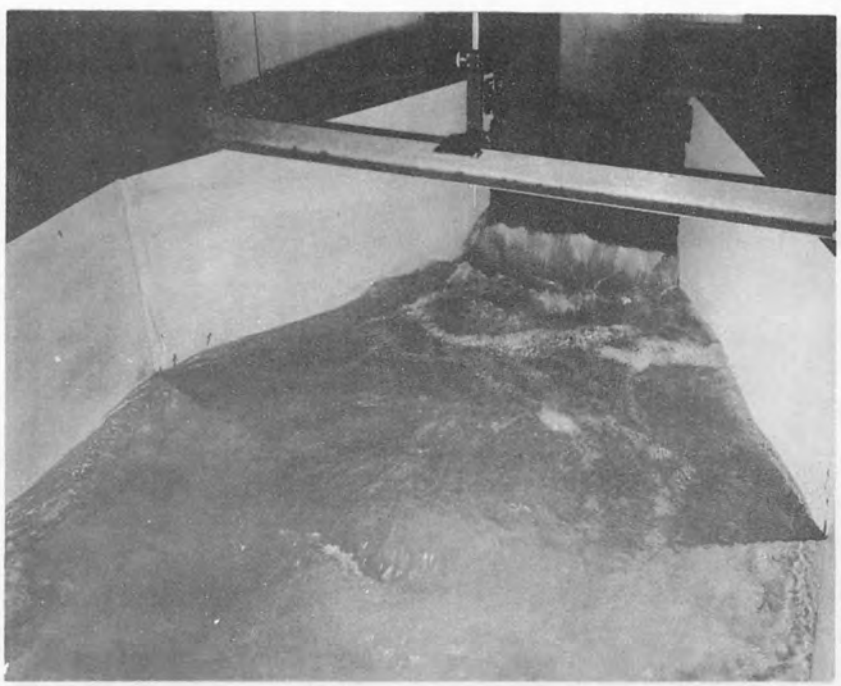
STILLING BASIN WITH "BROKEN BACK" TRANSITION

Combination Road Crossing, Check-drop and Outlet
Structure--Madera Distribution System
Central Valley Project--California

Figure 5
Report Hyd. 361



(A) No Discharge

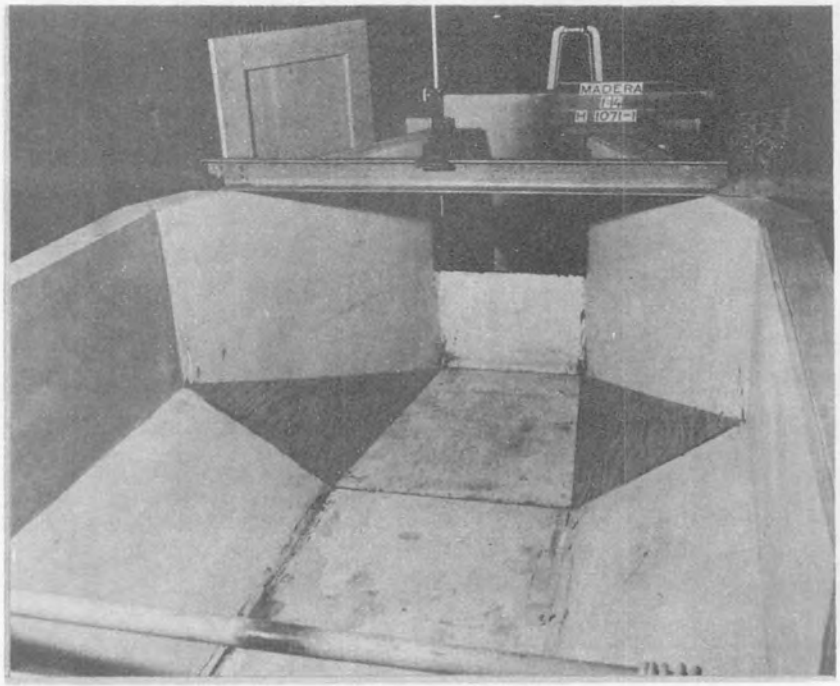


(B) Discharging 60 cfs

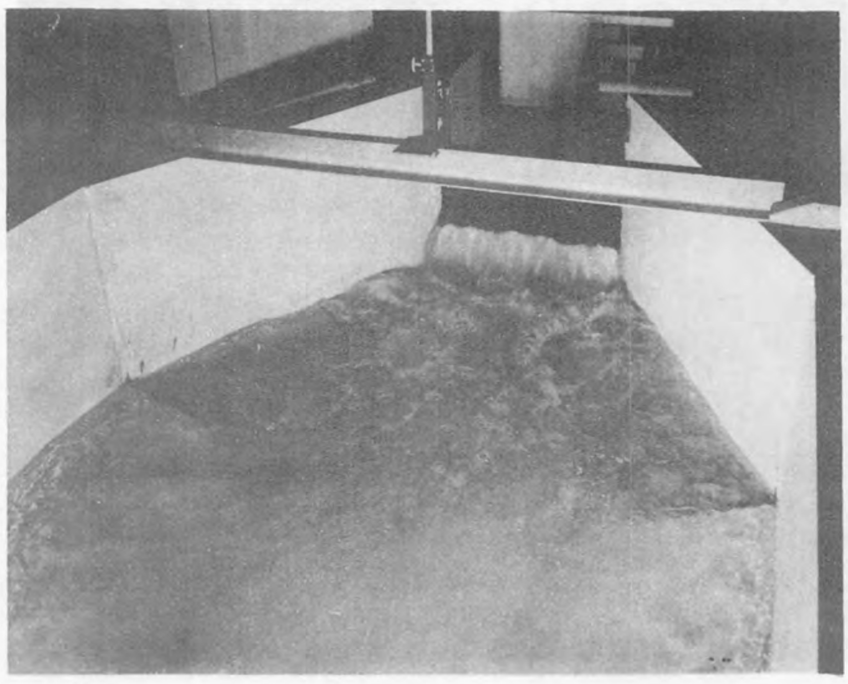
STILLING BASIN WITH "BROKEN BACK" TRANSITION

Combination Road Crossing, Check-drop and Outlet
Structure--Madera Distribution System
Central Valley Project--California

Figure 6
Report Hyd. 361



(A) "Broken-Back" Stilling Basin with Sloping Floor

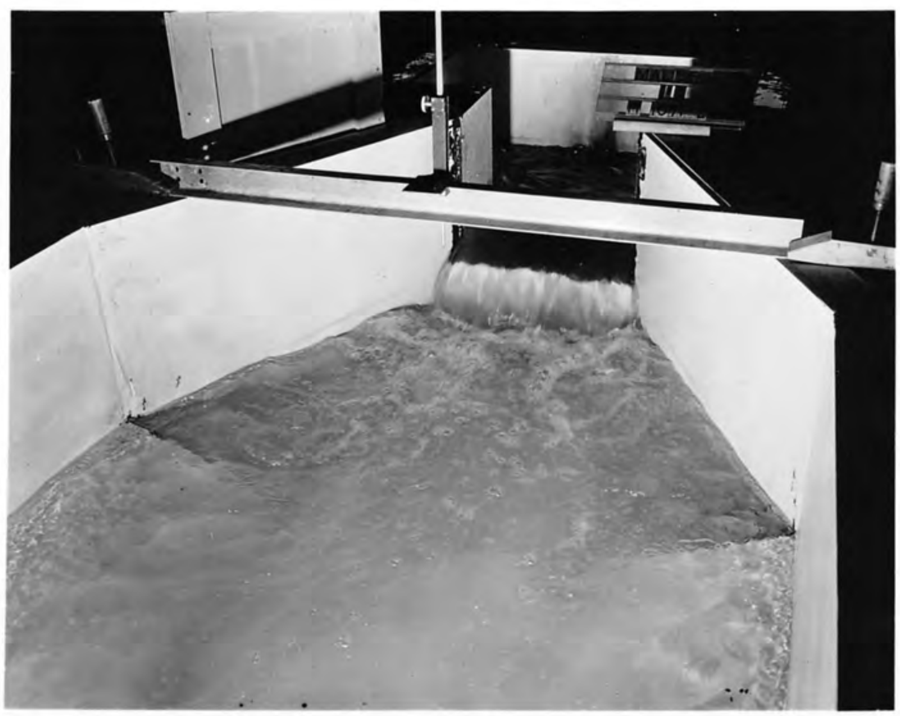


"Broken-Back" Stilling Basin with Sloping Floor and Discharging 60 cfs

STILLING BASIN WITH "BROKEN BACK" TRANSITION AND SLOPING FLOOR

Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System
Central Valley Project--California

(A) "Broken-Back" Stilling Basin with Sloping Floor



"Broken-Back" Stilling Basin with Sloping Floor and Discharging 60 cfs

STILLING BASIN WITH "BROKEN BACK" TRANSITION AND SLOPING FLOOR

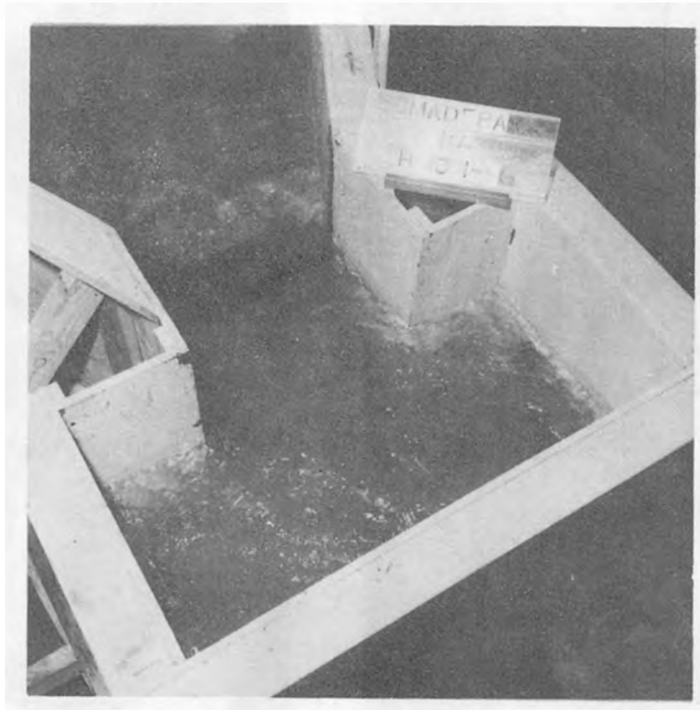
Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System
Central Valley Project--California

(A) Tee-Shaped Forebay--60 cfs Total Discharge with Right Turnout Operating

(B) Ell-shaped Forebay--60 cfs Total Discharge with Turnout at Right Operating

RECOMMENDED FOREBAY DESIGNS

Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System
Central Valley Project--California



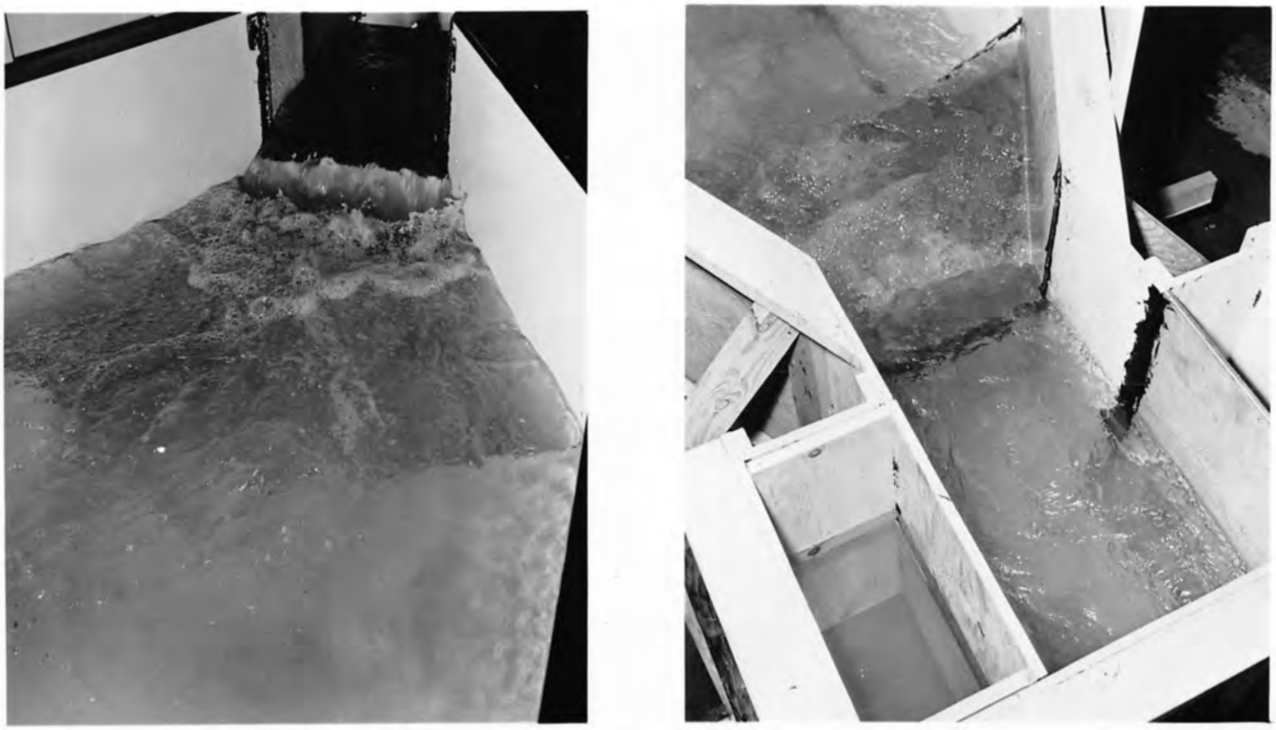
(A) Tee-Shaped Forebay--60 cfs Total Discharge with Right Turnout Operating

(B) Ell-shaped Forebay--60 cfs Total Discharge with Turnout at Right Operating

RECOMMENDED FOREBAY DESIGNS

Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System
Central Valley Project--California

Figure 8
Report Hyd. 361

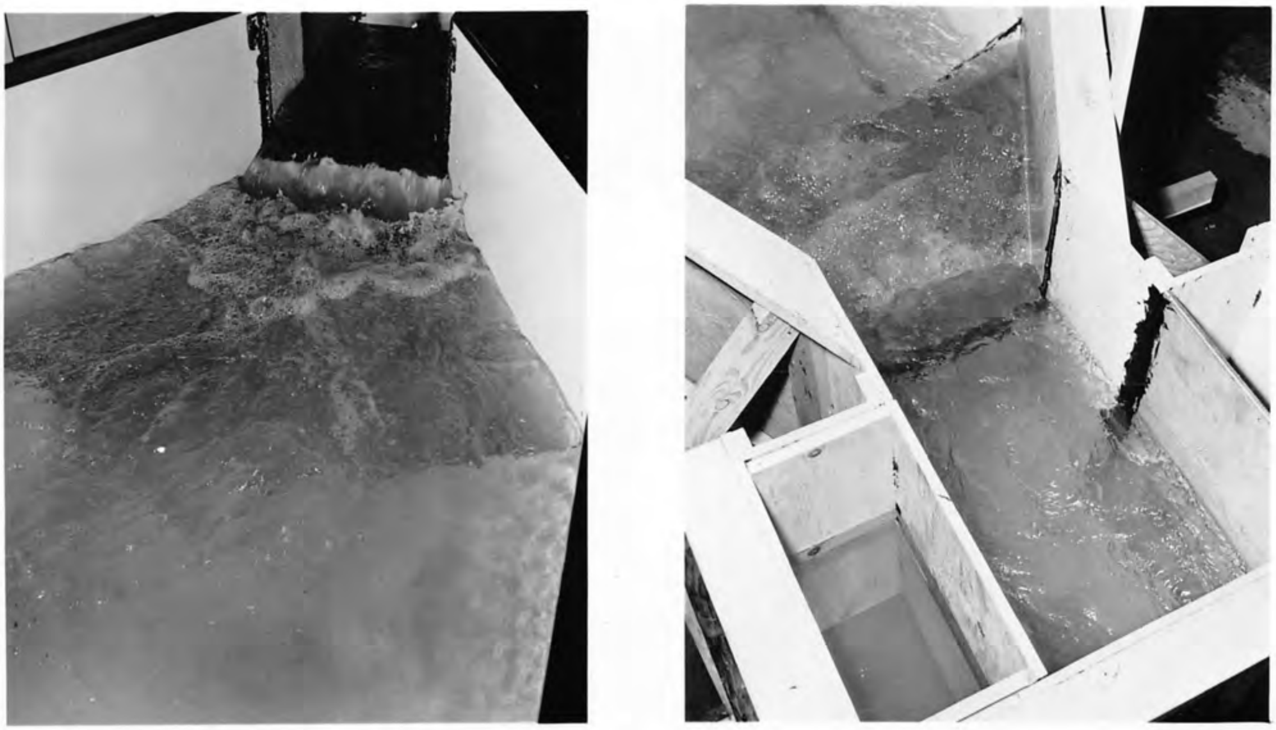


(A) In-Line Forebay--60 cfs Total Discharge with Right Outlet Operating

(B) Over-all View with Tee-shaped Forebay--60 cfs Total Discharge with Right Outlet Operating

"TEE-SHAPED" AND IN-LINE FOREBAYS

Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System Central Valley Project--California



(A) In-Line Forebay--60 cfs Total Discharge with Right Outlet Operating

(B) Over-all View with Tee-shaped Forebay--60 cfs Total Discharge with Right Outlet Operating

"TEE-SHAPED" AND IN-LINE FOREBAYS

Combination Road Crossing, Check-drop and Outlet Structure--Madera Distribution System
Central Valley Project--California