UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES FOR THE MODIFICATION OF HORSESHOE DAM SPILLWAY

Report to Leeds, Hill and Jewett, Consulting Engineers
by
A. J. Peterka

Hydraulic Laboratory Report No. 248

RESEARCH AND GEOLOGY BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

October 4, 1948

Reply Attention: 290

Mr. Raymond A. Hill,
Leeds, Hill, and Jewett,
Consulting Engineers,
1000 Edison Building,
Los Angeles, Calif.

Dear Mr. Hill:

The hydraulic model tests on the Horseshoe Spillway, requested by you, have recently been completed in the Hydraulic Laboratory. The results of the tests, other than visual, are enclosed. Since you were present and witnessed the significant tests, no attempt has been made to describe certain visual results except to include photographs which provide a partial record of the performance of the structure as a whole.

The model was constructed to a scale of 1:60 according to your Drawing No. 10029-HS-34.1 and your telegram of September 1, 1948. The model included a portion of the upstream approach channel and the spillway itself, complete with piers, gates, and training-walls. The lower channel, which leads to the river was indicated in the model, but did not contain topography similar to the prototype. Piezometers were installed at intervals along the centerline of the spillway from the crest portion downstream to the drop off. The completed model in operation is shown in Figure 1.

Tests were made according to your telephone request to me on August 25, 1948, to determine:

a. The over-all capacity of the spillway as reduced by the addition of the piers for the spillway gate.

b. The disturbance caused by the piers and whether waves would get out of bounds of the spillway structure.

Miscellaneous tests to determine the operating characteristics of the structure were also made according to your verbal requests during your observation of the model.

Tests were first made without piers or gates, to determine the spillway capacity for free flow over the crest. The results are shown as Curve A of Figure 2 and Curve A of Figure 3. The spillway piers were then installed and similar curves determined. These are shown as Curve B of Figure 2 and Curve B of Figure 3. Flow over the crest is not affected by the piers for discharges less than 50,000 second-feet. At higher discharges, the flow is reduced by the piers, the differential becoming progressively greater until at maximum reservoir elevation 2036, the reduction is about 6 percent.

Also plotted on Figure 2 are three curves showing the discharges, for the entire range of headwater elevation, that may be passed with the gates fixed at the 10-, 20-, and 30.76-foot gate openings.

During the spillway calibration tests, measurements were made to determine the drawdown alongside the control house in the reservoir. Point gage measurements indicated that for a discharge of 242,000 second-feet the water surface at the control house was 0.9 foot lower than the true headwater elevation. For 100,000 second-feet the difference amounted to only 0.3 foot.

Tests with the piers in place indicated that pronounced diamond-shaped wave patterns were formed between the piers, Figure 4, and the patterns persisted over the entire spillway area, Figures 5, 6, and 7. At no time, however, was there a tendency toward overtopping the downstream spillway training-walls. For all heads, discharges, and gate openings with the gates operated uniformly, flow conditions were entirely satisfactory. Although the model scale, 1:60, was too small for the model to indicate splash, it is believed that no significant amount of splashing will occur.

The piers, considering the fact that they intercept the flow in a high-velocity area, performed satisfactorily. Although no comparative tests were made, it is believed that they offered a minimum of resistance to the flow.

Studies of the flow conditions in the spillway approach channel indicated that each of the sharp corners on the rock excavation caused a noticeable contraction in the flow. The eddy on the right side (looking downstream) of the spillway caused a rise in the water surface at the upstream end of the right training-wall and discharges above 200,000 second-feet overtopped the wall. The upstream end of this wall, as far downstream as the gate, should be raised 2 to 3 feet to correct this condition. A similar flow condition on the left side of the spillway caused a rise in water surface along the side of the pier nearest the left wall. To relieve this condition, the left approach corner was cut back 10 feet at elevation 1992 and a 1/2:1 slope was maintained until it ran out at the top. This reduced the elevation of the water surface along the pier face by approximately 5 feet for a discharge of 230,000 second-feet. Figure 8 shows the improved flow in the approach and Figure 9 shows the water surface profile along the pier face after the corner was removed.

Pressures were recorded for each condition tested. All pressures were found to be above atmospheric except for the condition with the gate fixed at the 10-foot open position. In this position, a small area of the crest showed pressures below atmospheric. This negative pressure increased with higher heads, but since it was only 4 feet below atmospheric for the maximum reservoir elevation, it was not considered dangerous. Figure 10 shows the pressures obtained for two of the 10-foot opening tests. No tests were made with gate openings less than 10 feet, since it was your opinion that the structure would never be operated with small gate openings. It is the opinion of the laboratory, however, that more severe subatmospheric pressures will exist if the gates are operated at small openings and high heads.

When the gates were operated nonuniformly, the flow was concentrated on the side of the spillway downstream from the widest open gate. Waves on that side of the spillway were somewhat higher than usual, and the flow tended to travel diagonally across the spillway. However, even for extremely different gate openings for the three gates, no harmful flow conditions developed.

An analysis of the calibration data indicated that the spillway crest profile was in effect a broad-crested weir and that it would be possible to design a crest having a higher coefficient. Accordingly, a new crest, designed to produce atmospheric or higher pressures for a discharge of 200,000 second-feet, was installed in the model in the position shown in Figure 11. The crest, at elevation 2000.0, was thus 2.0 feet higher than the original. No piezometers were installed in this crest because of your desire to expedite the model tests.

In operation the new crest performed very much as the original. No significant differences in operation were apparent from visual inspection except in the narrow bay on the left side of the spillway. As shown in Figure 12 for a discharge of 100,000 second-feet, the profile was practically level along the pier face nearest the camera. Surface velocities also were lower because of a very small standing wave which formed in the bay entrance just upstream from the pier nose. The difference in profile was believed to be due both to rounding the left approach corner as shown in Figure 13 and to the new crest profile, since altering the corner in the approach did not entirely change the profile to that shown in Figure 9. Flow on the spillway face for the same discharge is shown in Figure 14.

For a flow of 242,000 second-feet the water surface profile was for all practical purposes below the bottom edge of the gate when the gate was in the fully open position. The gate location was not changed when the new crest was installed. A comparison of Curves B and C of Figure 3 indicates that the coefficient for maximum discharge was raised from 3.02 to 3.36 and although the crest was raised 2 feet the new crest will pass 4,000 second-feet more water at reservoir elevation 2035, as shown by Curve C of Figure 2. The use of the new crest may result in some saving in concrete and if the gates can be made to seat on the crest a reduction in gate height would result.

The Horseshoe Spillway model will probably be kept intact in the laboratory for a month, at least, and if you require additional tests or data the model will be available for that purpose.

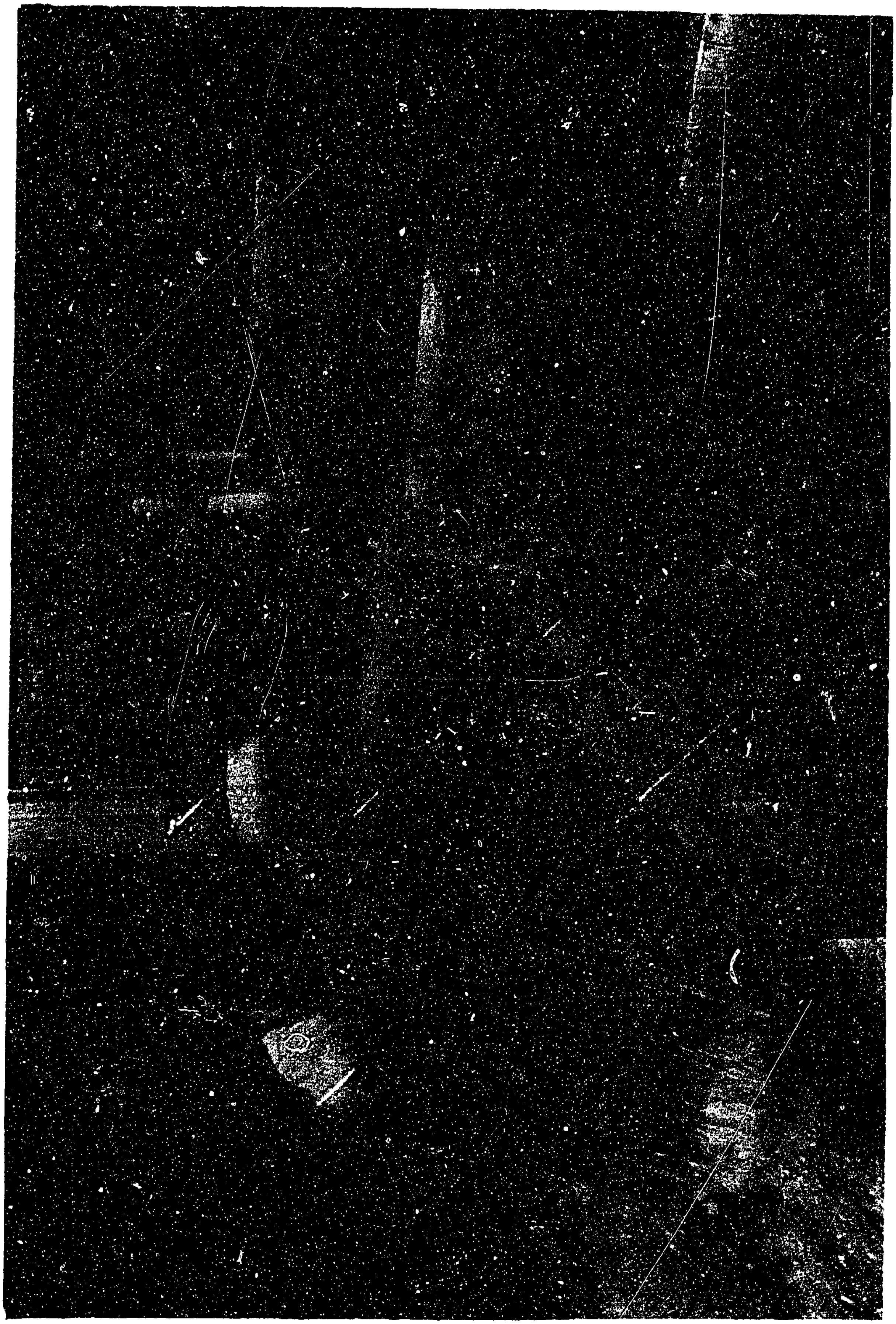
Sincerely yours,

L. N. McClellan,
Chief Engineer.

Enclosure

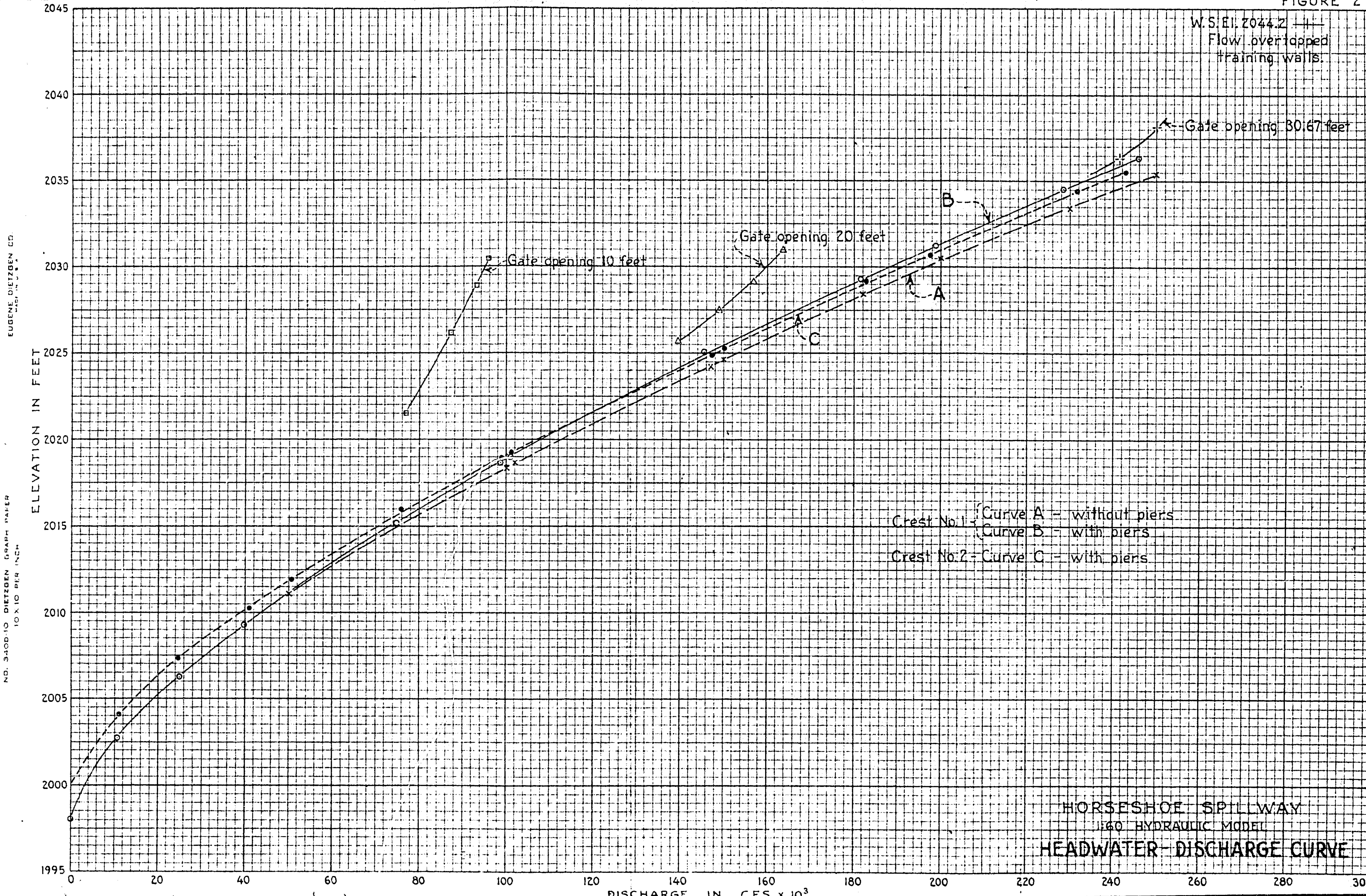
BC-Record copy
A.J.Peterka (2)

Figure 1



The completed 1:60 scale model of Horseshoe Dam Spillway in operation.
Discharge 230, 000 second-feet.

FIGURE 2



HORSESHOE SPILLWAY
1:60 HYDRAULIC MODEL
HEADWATER - DISCHARGE CURVE

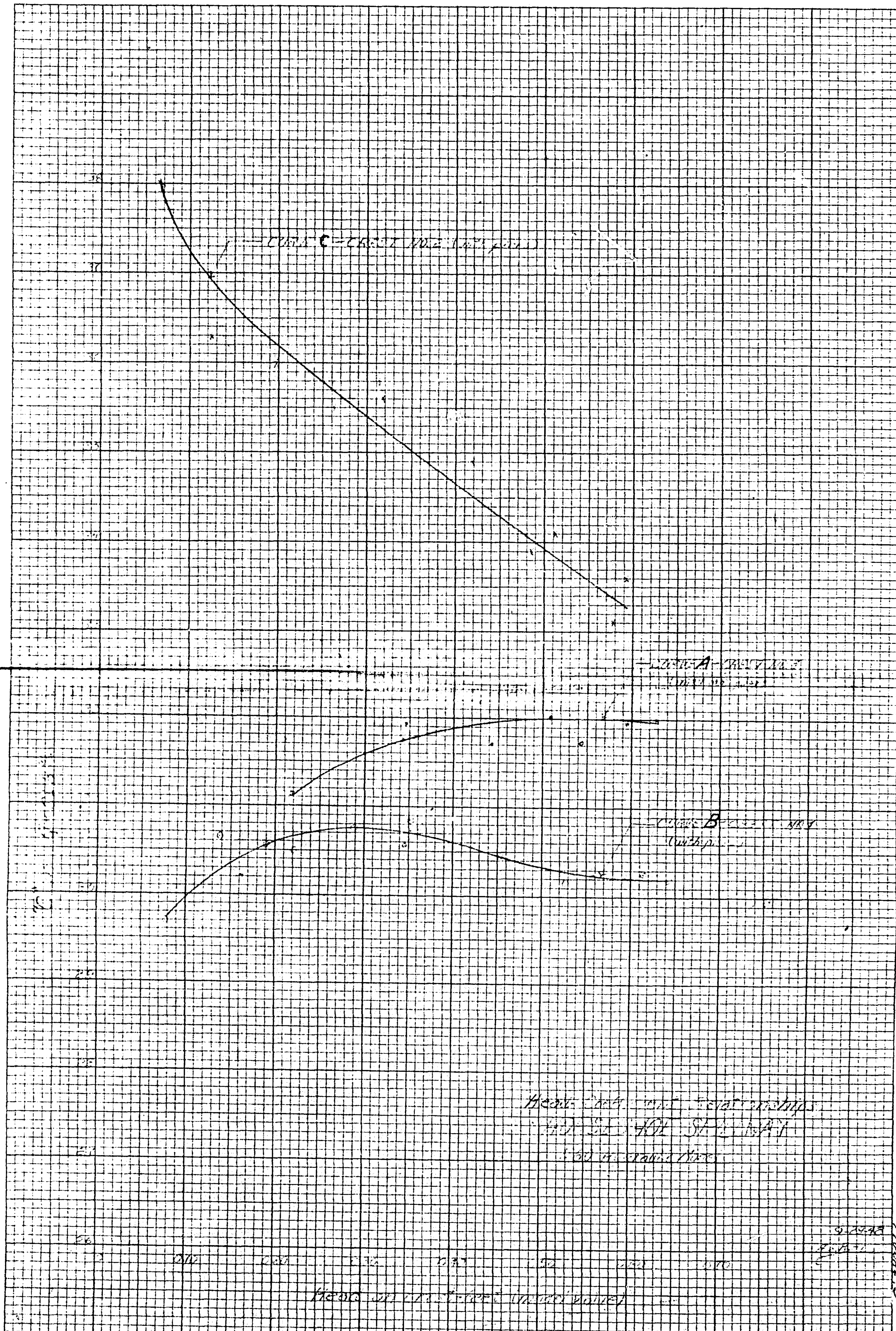
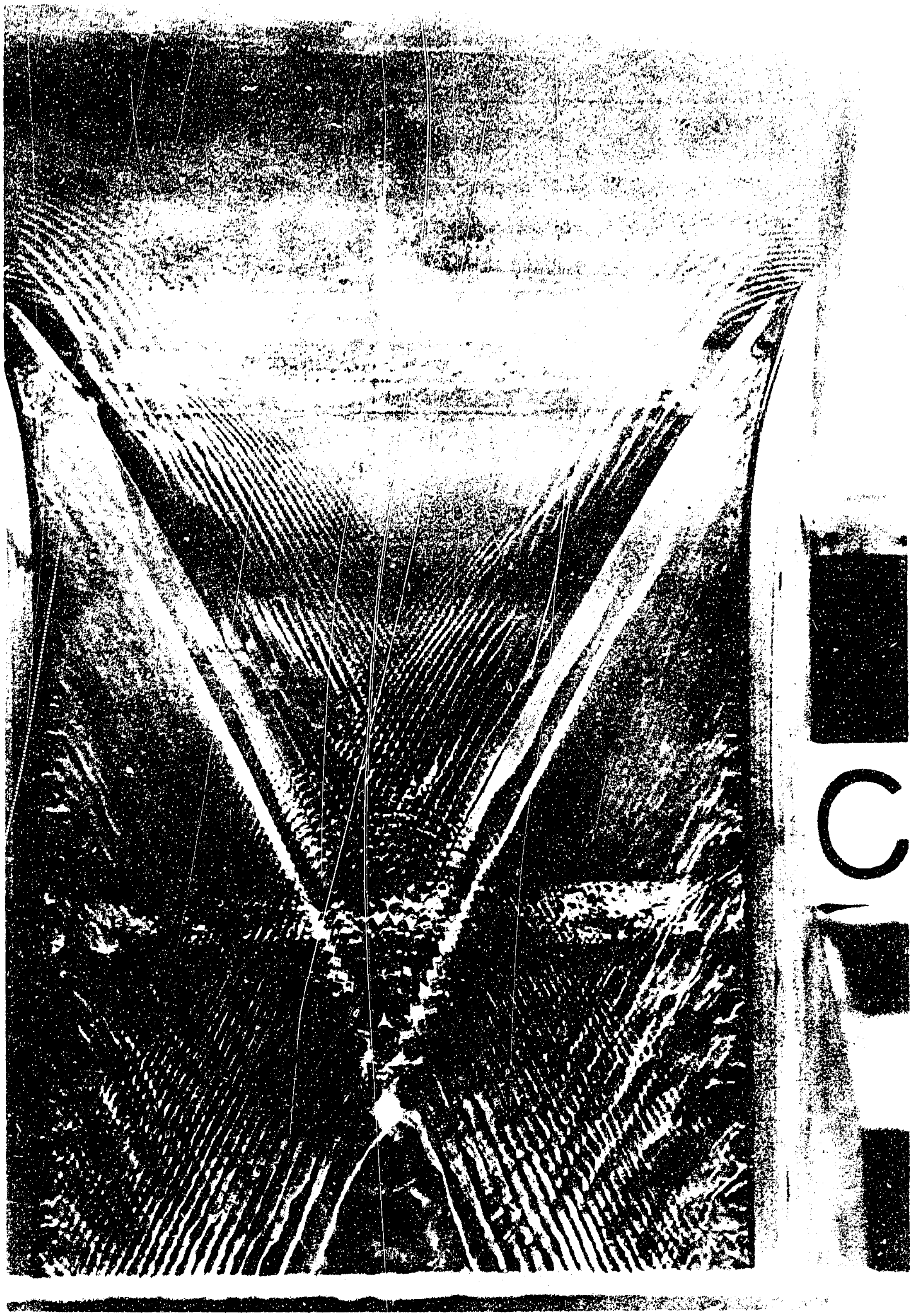


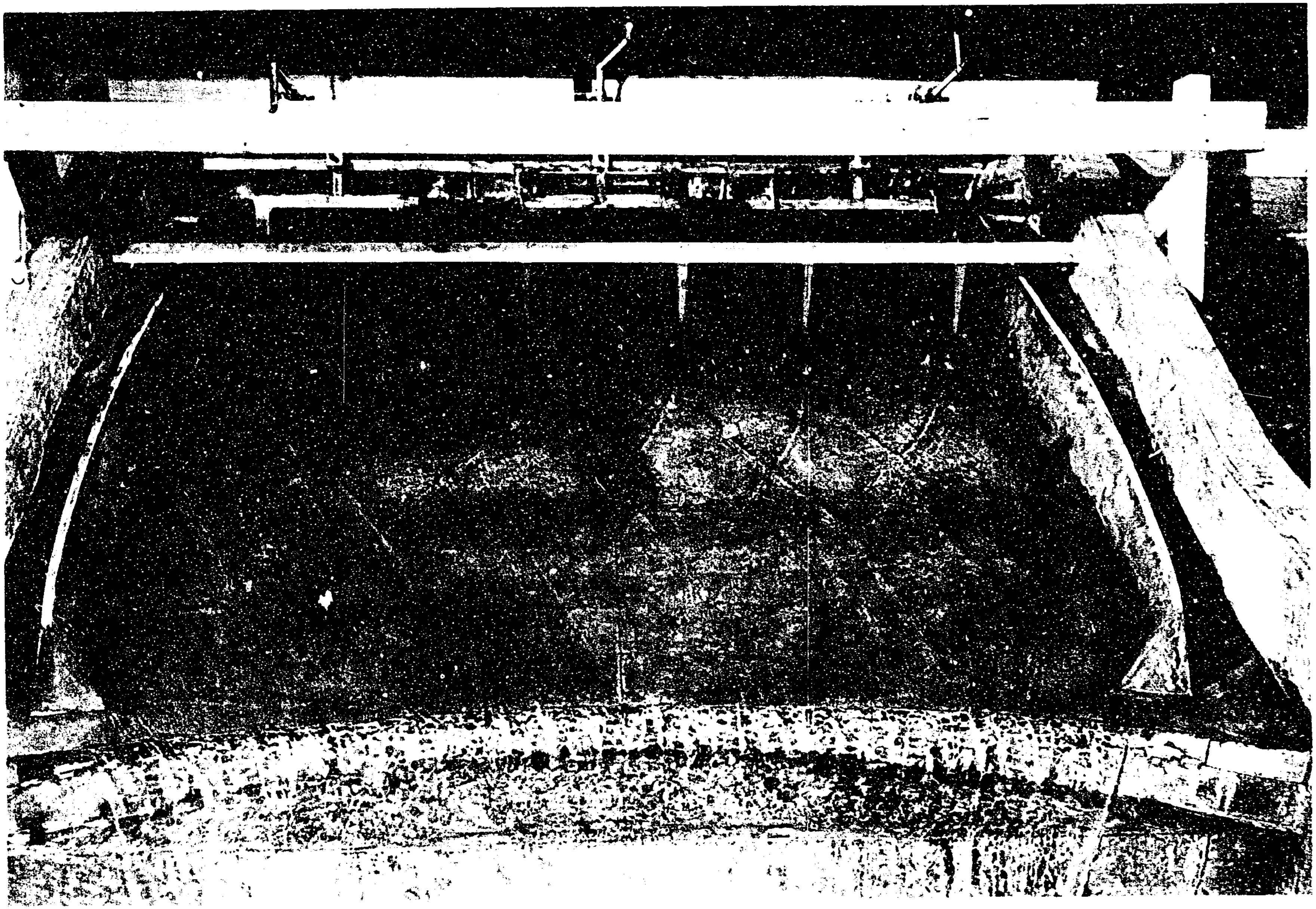
FIGURE 3

Figure 4



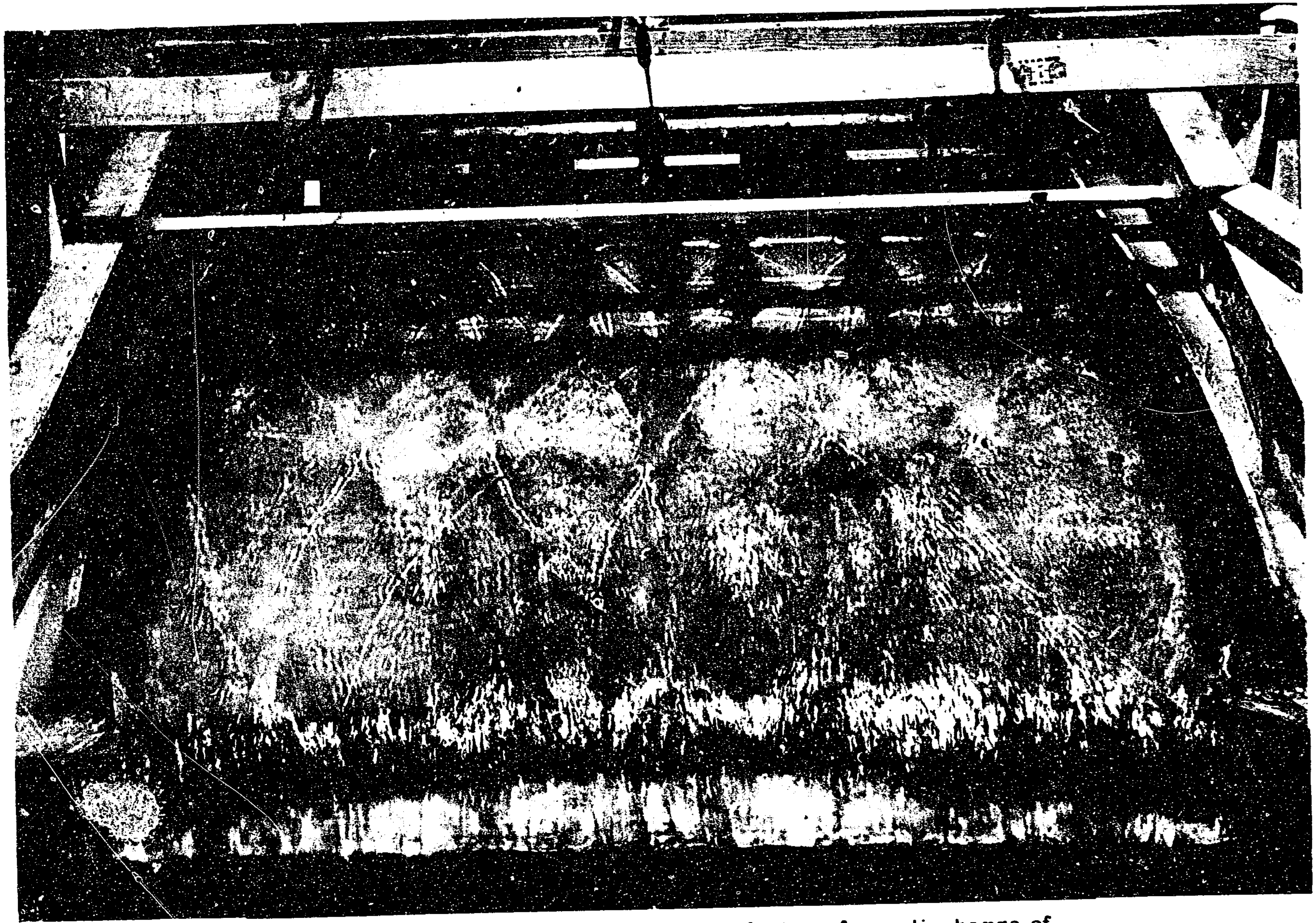
The diamond pattern between the piers originates at the pier noses. Wave pattern shown is for 10,000 second-feet.

Figure 5



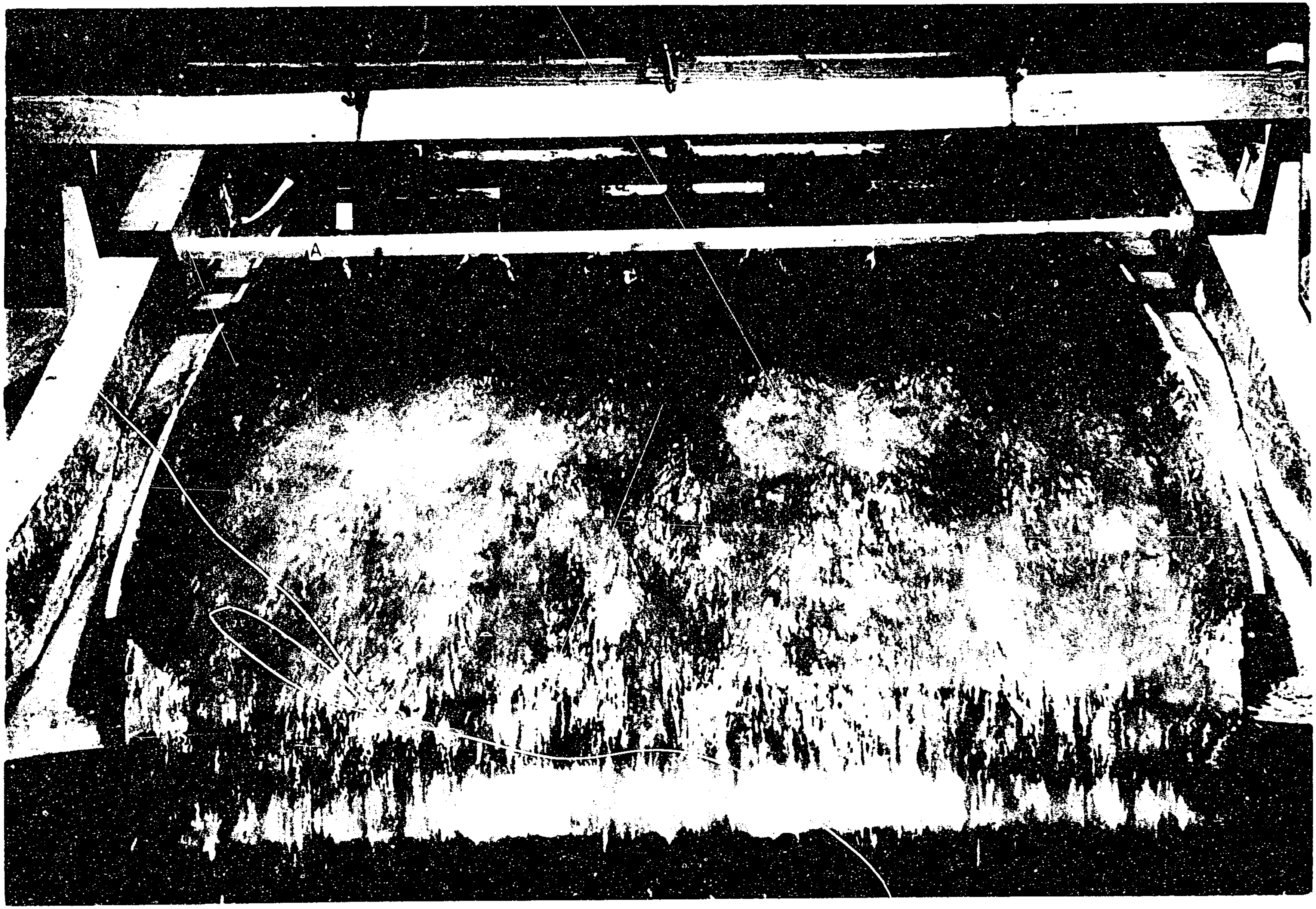
The diamond pattern on the spillway originates at the downstream end of the piers. Discharge 10,000 second-feet.

Figure 6



Flow conditions on the spillway are satisfactory for a discharge of 100,000 second-feet. The gates are raised free of the water surface.

Figure 7

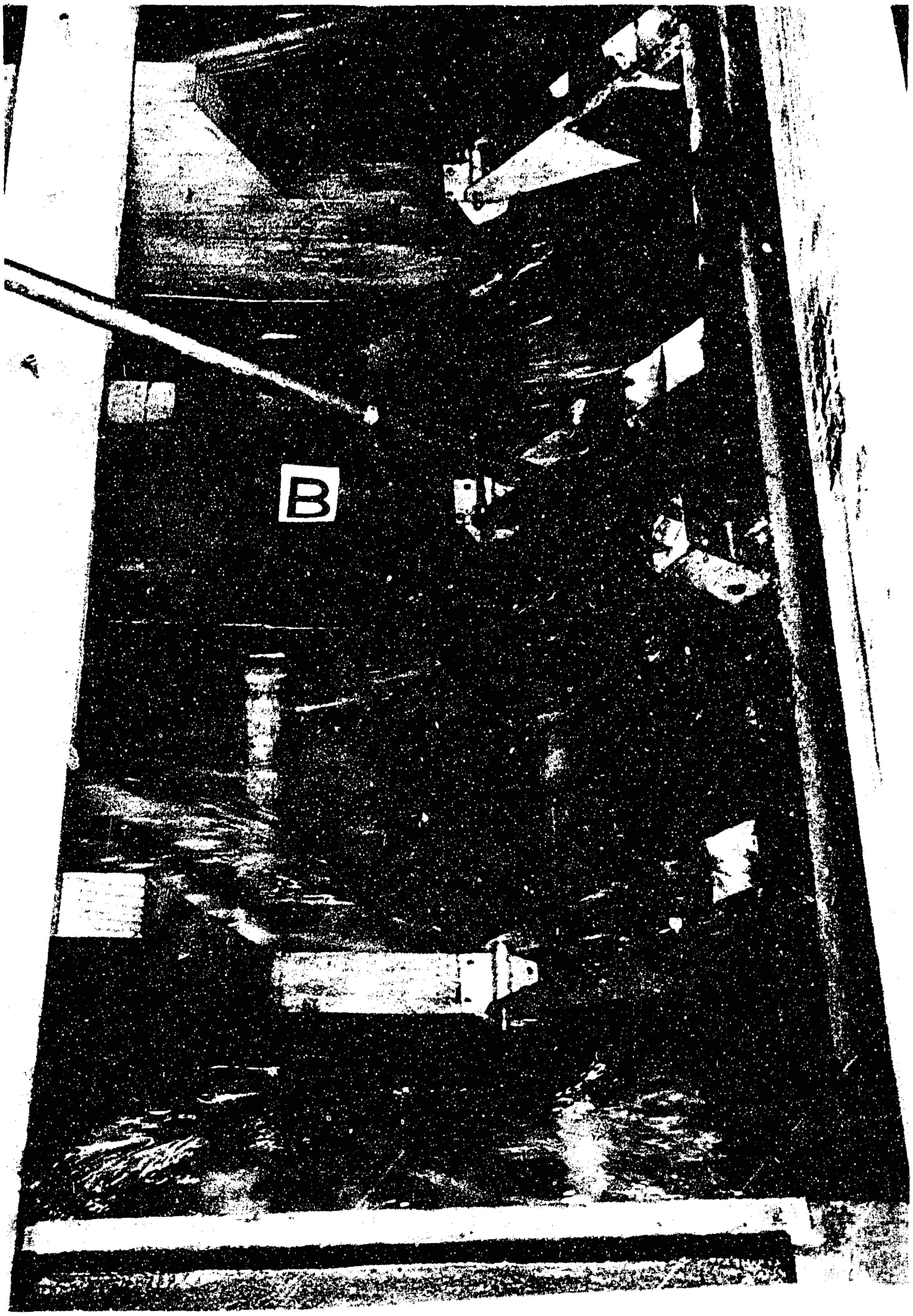


The height of the downstream training walls is adequate for a discharge of 230, 000 second-feet. The gates are clear of the water surface when set in the 30. 76 feet open position.

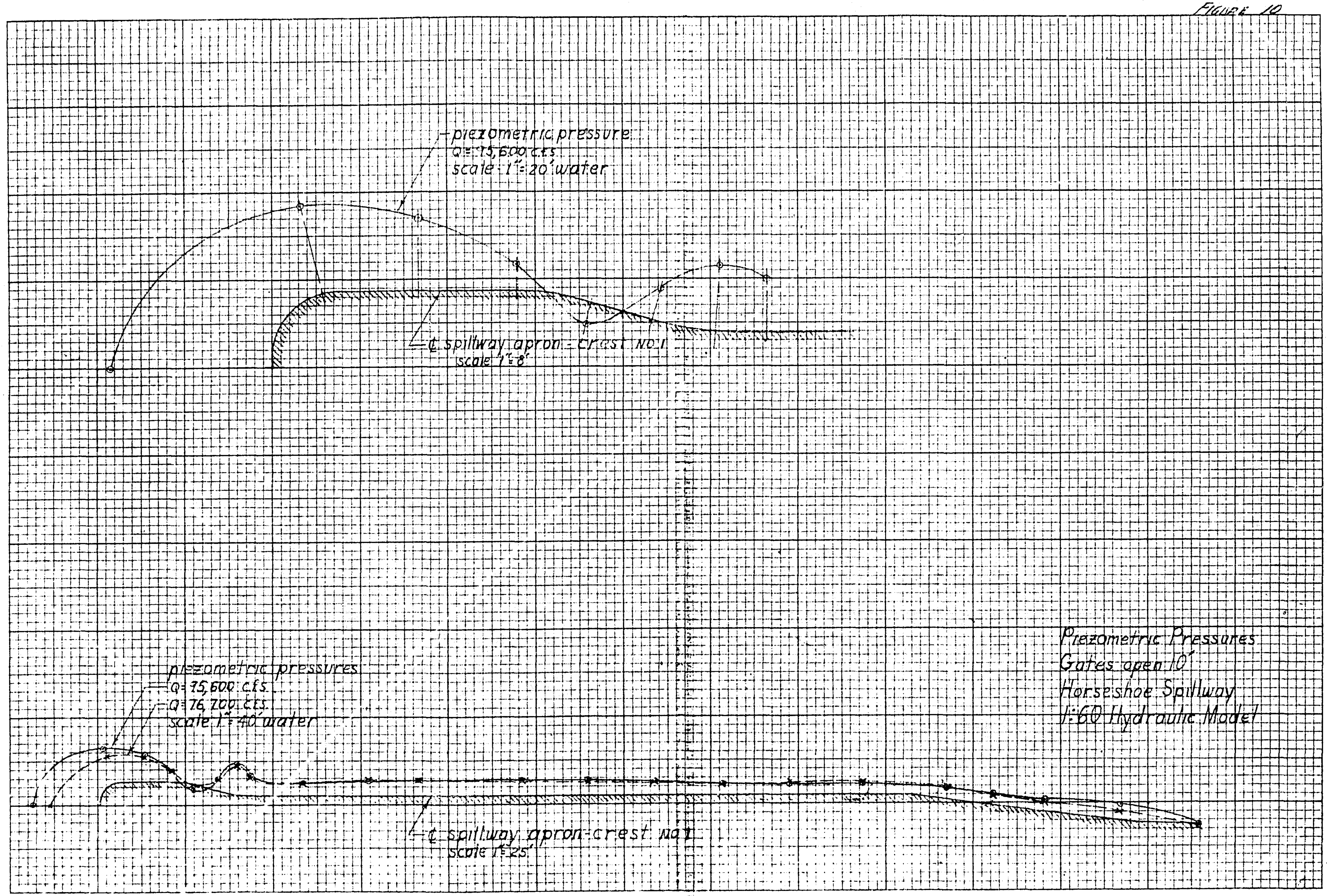
Figure 8

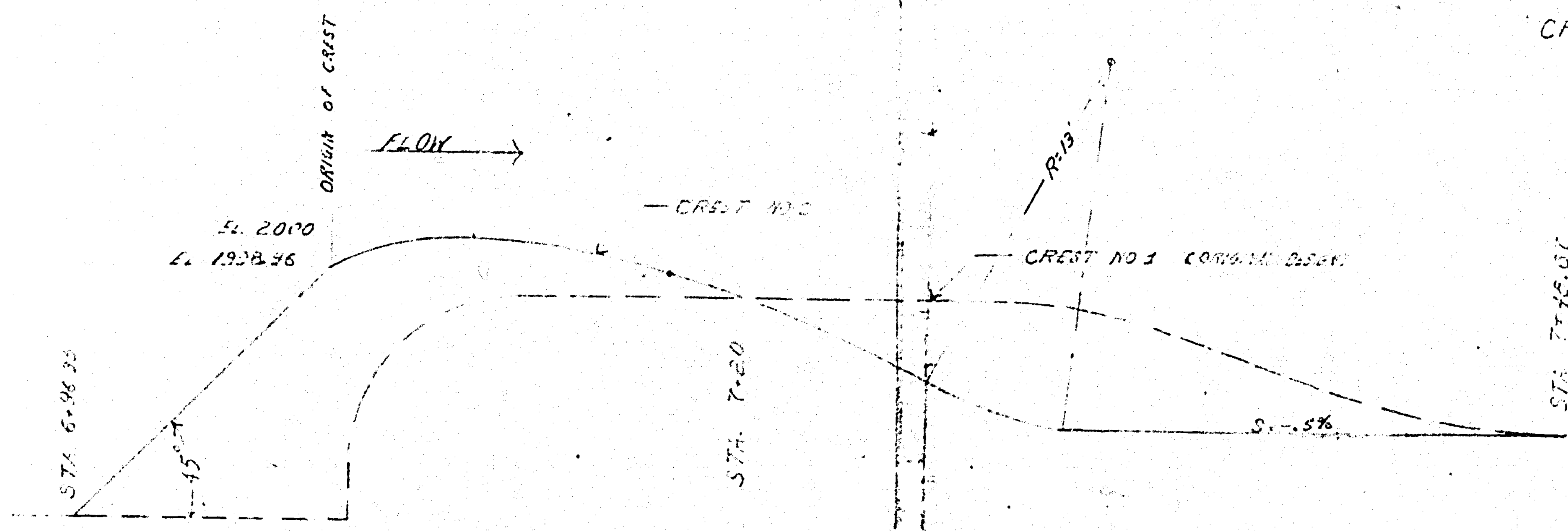
The effects of the contraction were reduced when the sharp corner in the approach channel was removed. Before removal a difference in water surface elevation of about 15 feet was evident at the corner.

Figure 9



Water surface profiles along the pier faces are satisfactory. The profile along the left face of the left pier (face nearest the camera) is still affected slightly by the contraction in the approach channel even though the sharp corner has been removed. The discharge is 100,000 second-feet.

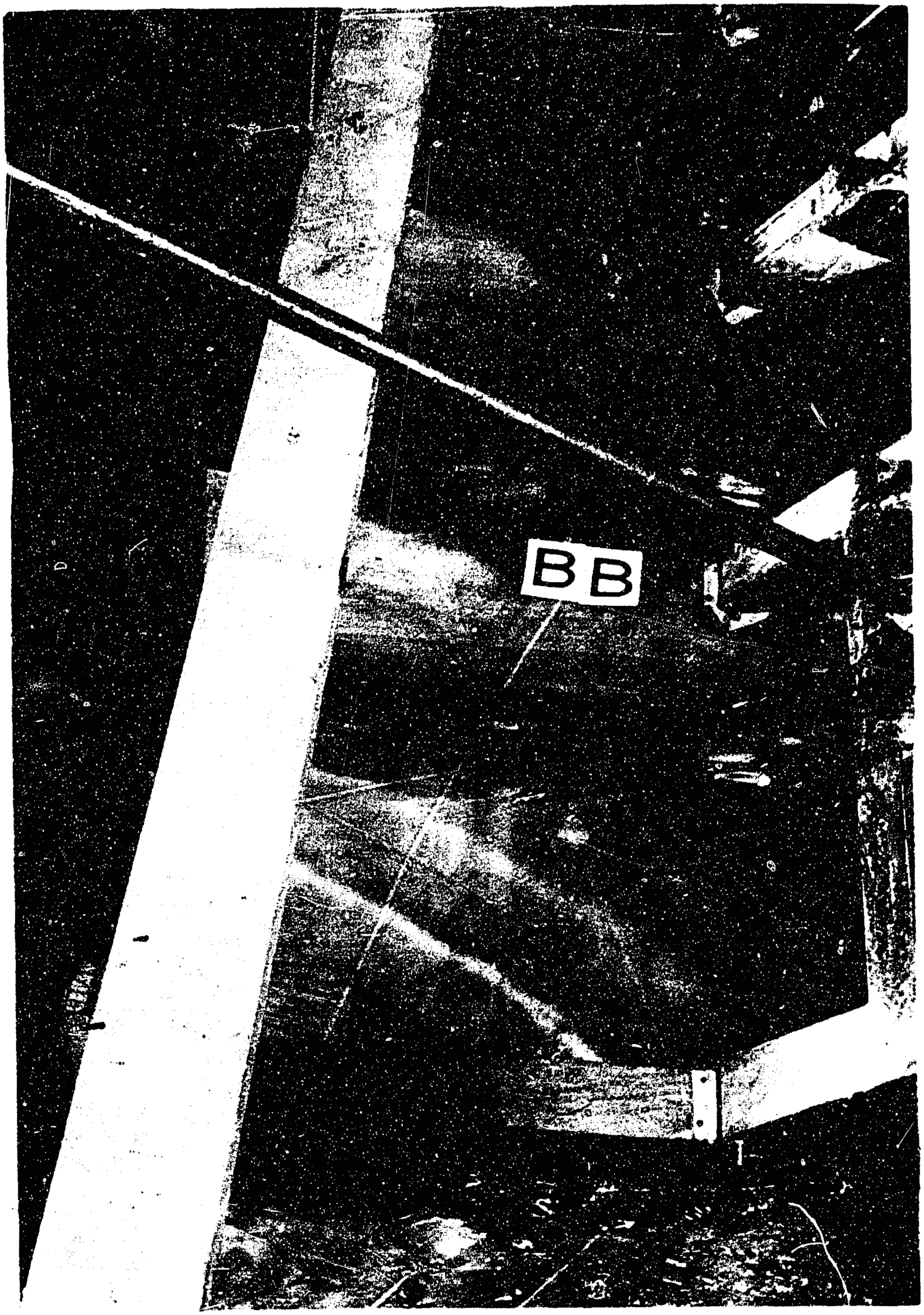

piezometric pressure
Q=15,600 c.f.s.
scale 1"=20' water
℄ spillway apron - crest No. 1
scale 1"=8'
piezometric pressures
Q=15,600 c.f.s.
Q=76,700 c.f.s.
scale 1"=40' water
℄ spillway apron - crest No. 1
scale 1"=25'
Piezometric Pressures
Gates open 10'
Horseshoe Spillway
1:60 Hydraulic Model



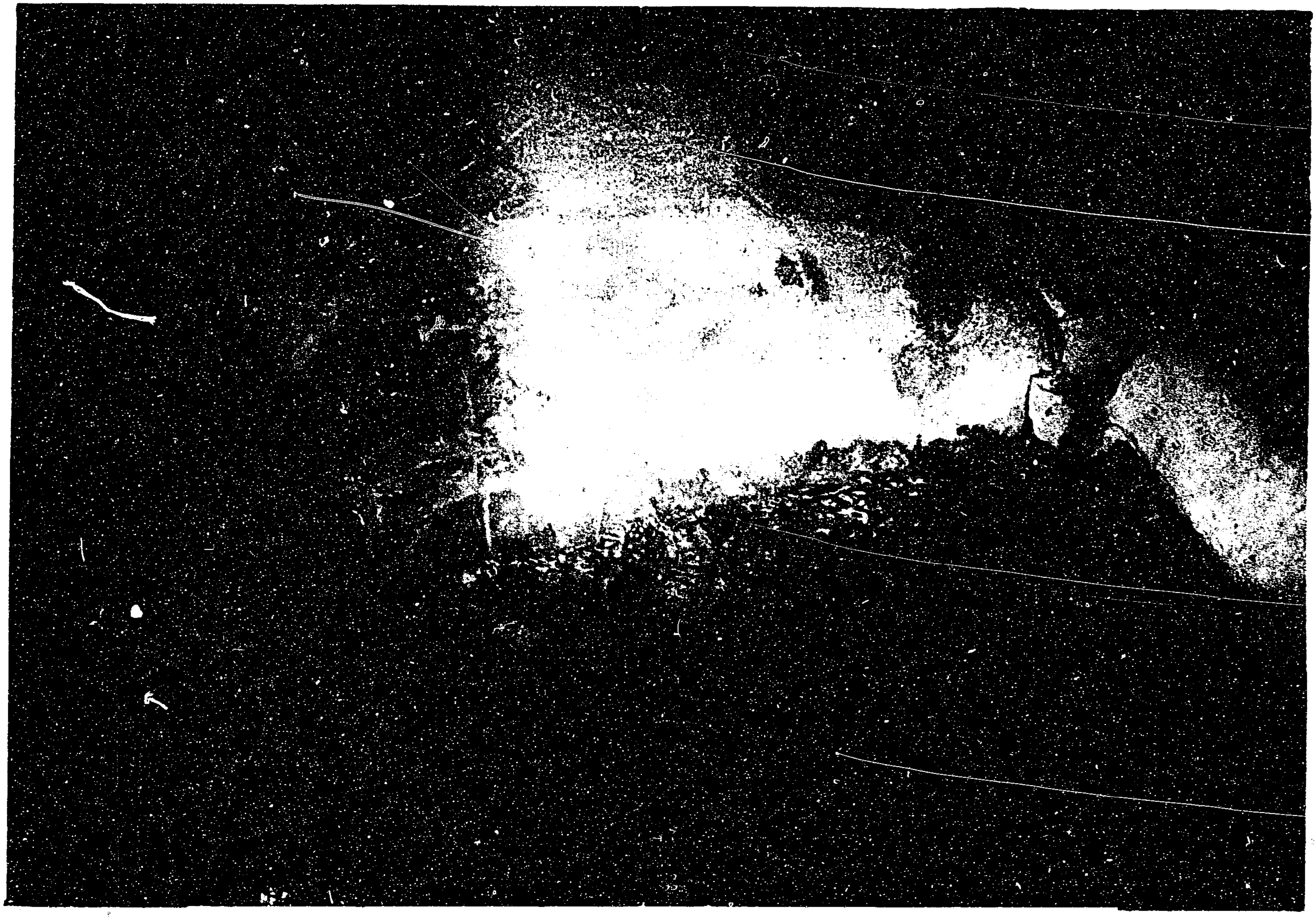
CREST COORDINATES-NO 2.

X	Y
0	0
1.49	.478
2.98	.536
5.97	1.045
8.96	.657
4.93	-1.13
20.90	-3.97

SPILLWAY CRESTS
HORSESHOE RESERVOIR
1:60 HYDRAULIC MODEL



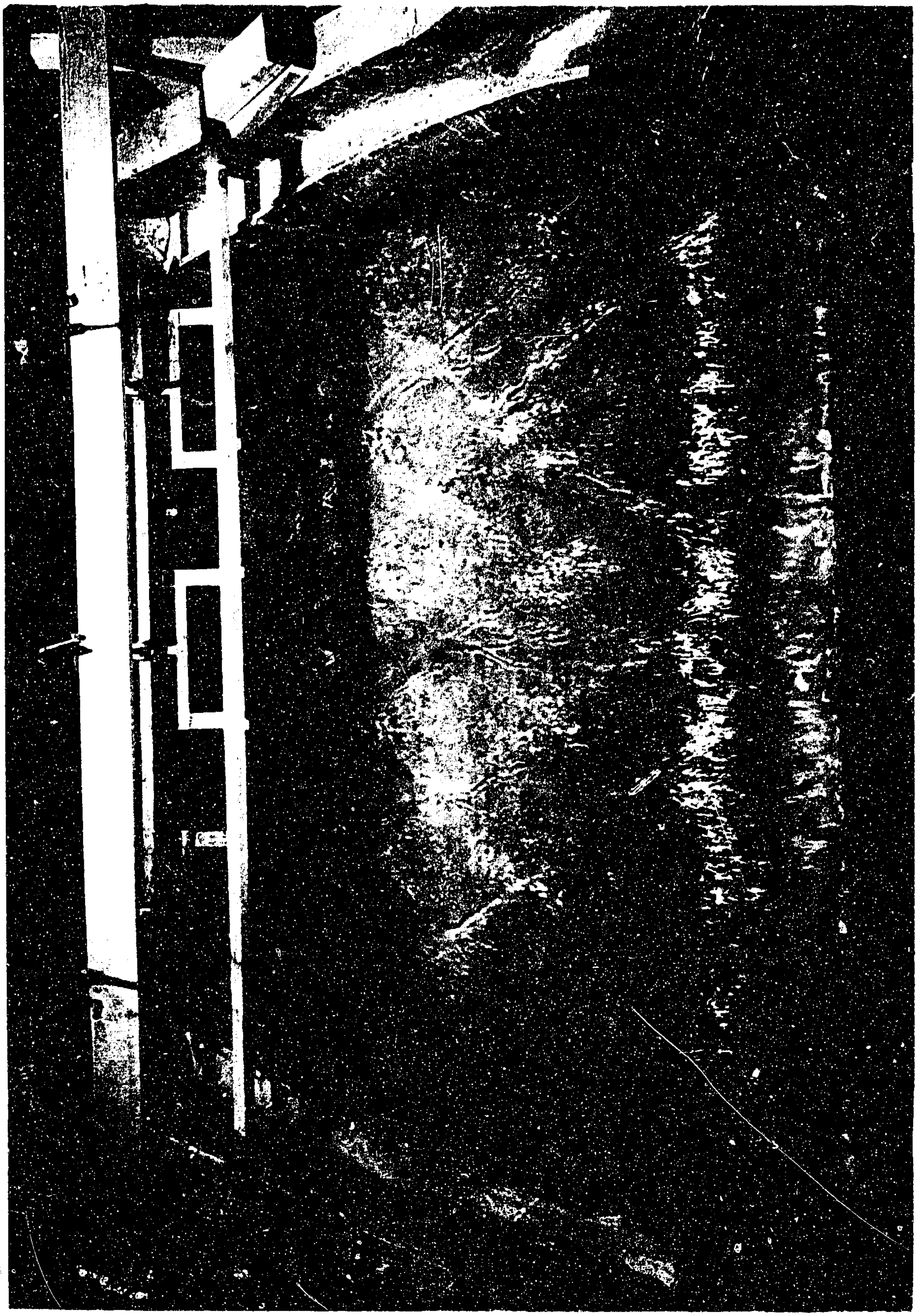
For a discharge of 100,000 second-feet the profile along the pier face nearest the camera is nearly level. Crest No. 2 is in place, and the left approach corner is rounded as shown in Figure 13.



Flow conditions near and downstream from the rounded approach corner are improved. Discharge 100,000 second-feet. Compare with Figure 8.

Figure 13

Figure 14



Flow on the spillway with Crest No. 2 in place is similar to that obtained with Crest No. 1. Discharge 100,000 second-feet.