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DESILTING STRUCTURE AT THE GUALANDAY CANAL HEADWORKS
COELLO PROJECT, COLOMBIA, S.A.

MODEL STUDY

Prepared for
Tipton and Kalmbach, Inc.
Denver, Colorado

by

S. S. Karaki

Colorado State University Research Foundation
Fort Collins, Colorado

April 1961

CER61SSK29

ENGINEERING RESEARCH

FEB 28 '74

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SYNOPSIS

Model studies were conducted in the Hydraulics Laboratory at Colorado State University to develop a more efficient sediment excluder to replace the existing desilting structure at the Gualanday Canal headworks. A plan of the recommended structure is shown in Fig. 13. The principal features of the excluder are: (1) a circular arc settling basin, 9.5 meters wide with a sloping bottom inclined radially at 4:1 and (2) two sluice tunnels connecting the settling basin to the existing sluice gates to discharge the sediment back into the river channel downstream of the diversion works. At the beginning of the sluice tunnels there is a circular arc sill raised to elevation of 459.9 m (except for a 3-meter section which is at elevation 456.0 m). The purposes for this sill are to increase the depth of water in the settling basin at low flows to encourage settling of suspended materials and to divert sediment free water into the canal. Also at high discharges the sill will deflect the flow, creating a local bend in the flow path and will convey much of the bed load by-passing the settling basin along the inside of the curve and over the control dam. The structure was estimated to be from 90 to 100 per cent effective for excluding the river bed load at discharges below 25 c.m.s. and from 75 to 95 per cent effective at discharges above 25 c.m.s.

INTRODUCTION

The diversion works for the Gualanday Canal of the Coello Project is located on Rio Coello near the town of Gualanday, Colombia. The diversion structure is located in a relatively straight section of the river, which averages about 90 meters wide near the diversion. The diversion works consist of a low control dam 3.4 meters high, canal headworks, desilting basin and sluice gates. A general plan of the arrangement is shown in Fig. 1.

The river is subjected to at least two flood periods annually during which times flows in excess of 300 cubic meters per second (c.m.s.) may be expected. The normal river discharge is about 25 c.m.s.

Because practically all of the river flow is diverted into the canal during normal periods, sediment exclusion at the canal headworks has proved to be a serious problem. The existing desilting works was not functionally adequate. Therefore, it was considered necessary to replace the existing structure with a more adequate facility.

Preliminary design of the new desilting works is shown in Fig. 2. The basic features of this design included: (1) a circular arc settling basin for collection of sediment, with the center of the circle located at the intersection of the right sluice wall and a line extended from the face of the control dam; (2) sluice tunnels connected to the settling basin and controlled by the existing radial gates to convey the sediment downstream; (3) diversion of the upper portion of the river flow in the canal, which is expected to be relatively clear of sediment.

In order to achieve partial settling of the suspended material in the basin, the depth of water would be increased by a sill, the top of which was 0.9 meters lower than the crest of the control dam.

The settling basin was 9.5 meters wide and extended an angular distance of 54 degrees into the river channel. The floor of the settling basin had a radial slope of 7:1. It was expected that this basin would intercept the majority of the sediment bearing river flow at normal river discharges.

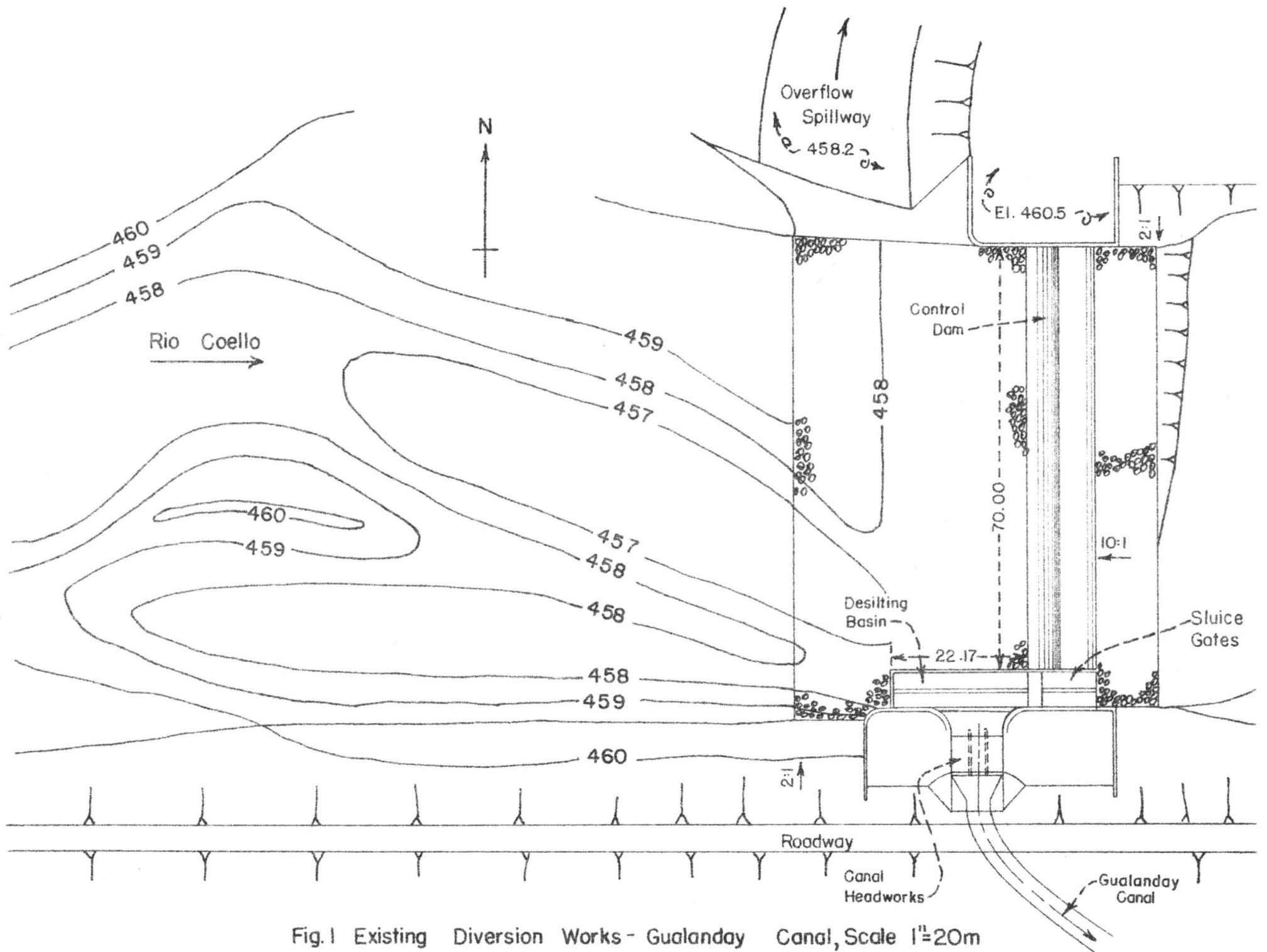


Fig.1 Existing Diversion Works - Gualanday Canal, Scale 1"=20m

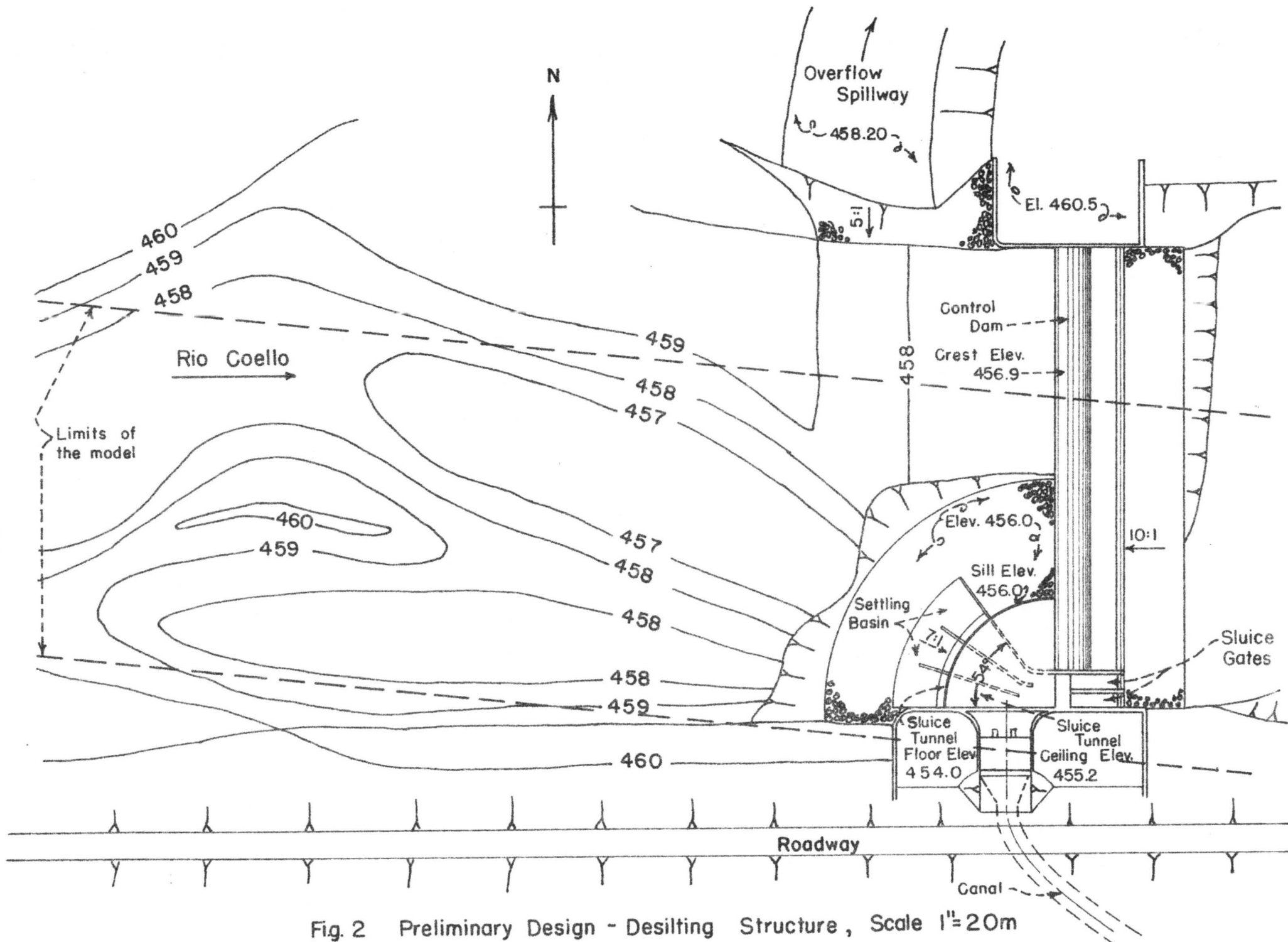


Fig. 2 Preliminary Design - Desilting Structure , Scale 1"=20m

A model study of the preliminary design of the desilting works was made to determine in a qualitative manner the adequacy for preventing sediment inflow into the canal and removal of sediment downstream of the diversion works. This report gives the results of the model studies and several modifications of the preliminary design which were considered desirable.

MODEL TESTS

Model

The model of the diversion works was constructed to a scale of 1:24, model to prototype. Sufficient extent of the river, both laterally from the desilting structure, and longitudinally, upstream from the control dam, was included to adequately reproduce approach flow conditions. The limits of the model are shown in Fig. 2. The entire model was set in an eight-foot wide flume. The general arrangement of the completed model is shown in Fig. 3, as viewed from upstream.

Certain simplifications were made in the model to avoid complications in model construction: (1) Instead of radial gates, two vertical slide gates were used in the model; and (2) the rounded approach to the canal headworks was squared, and compensated by slightly widening the approach to the canal headworks. A close-up photograph of the model arrangement is shown in Fig. 4. The cheesecloth shown in the photographs of Fig. 3 and Fig. 4 was used to stabilize the river bed configuration during tests. This was necessary because the bed material in the model was not dynamically to scale with the prototype and flow in the model could cause alterations in the river channel not in conformance with the prototype.

The top of the sluice tunnels was made with plastic to permit observation of sediment movement through the tunnels.

Model Test Results

A. Preliminary Design

The preliminary design of the desilting structure has been described in the preceding pages and is shown in Fig. 2. The two internal guide walls forming three sluice tunnels did not extend longitudinally to the sluice gates. The walls, or piers, within the settling basin extended vertically to elevation 457.0, 0.1 meter above the crest of the control weir.

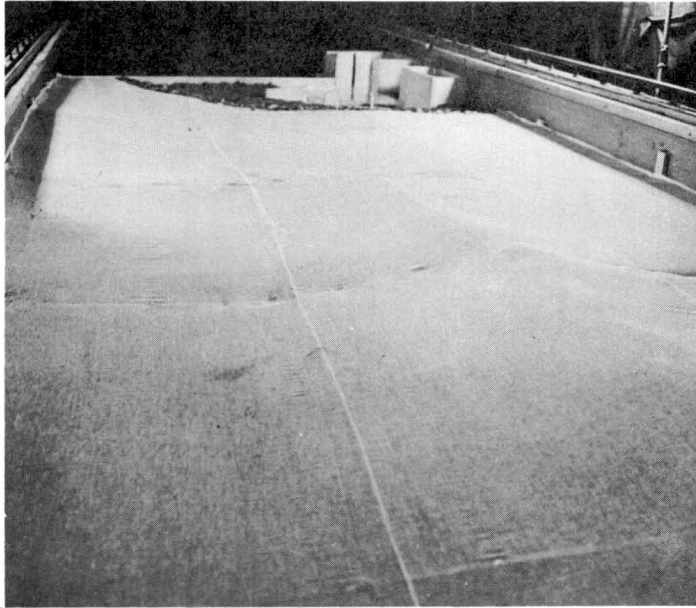


Fig. 3. Downstream view of the Completed model

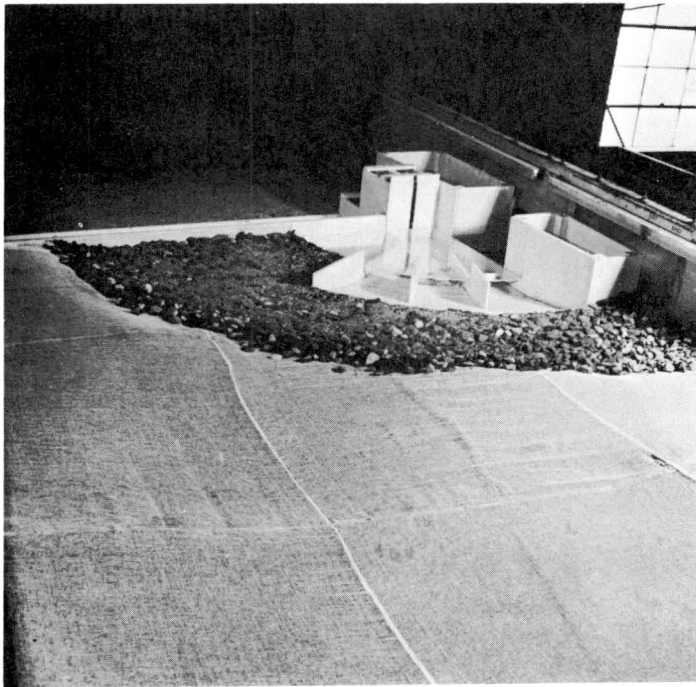


Fig. 4. Model arrangement of the preliminary design

Tests of this structure showed that because the guide walls did not extend to the sluice gates, sluicing of the entire settling basin was only partially effective, particularly with only one gate in operation. Opening either gate would cause flow in all three tunnels, with the discharge unevenly distributed. With both gates open the left and center tunnels sluiced satisfactorily. The right tunnel was only partly effective.

Flow conditions at the structure for river discharge of about 25 c.m.s. are shown in Fig. 5. At this discharge, and also at lower discharges, the river flow was directed toward the structure. Under this condition the settling basin intercepted nearly all of the bed load.

At discharges greater than 25 c.m.s., the stream flow direction in the vicinity of the structure changes to flow more normally to the control dam. At high discharges the left wall of the excluder, or pier, became obstructive to the flow and considerable turbulence was created downstream of the wall. This could cause erosion damage downstream from the pier. Furthermore, a horizontal vortex was created radially towards the canal intake, along the downstream side of the wall, which funnelled sediment into the canal intake.

A photograph of the flow conditions at the desilting structure at $Q = 25$ c.m.s. with both sluice gates open is shown in Fig. 6. The sluicing tests were made by beginning with the settling basin filled with sand. As the photograph shows, the left and center sluice tunnels are clear while a substantial deposit remains in the right tunnel.

An indication of the erosive potential of the flowing water near the structure is shown in Fig. 7. This was the result after a test with high river discharge and serves only to show where the greatest erosive force of the river flow concentrated with respect to the structure.

B. Modification A

In view of the inadequate sluicing action of the preliminary design the three sluice tunnels of the preliminary design were changed

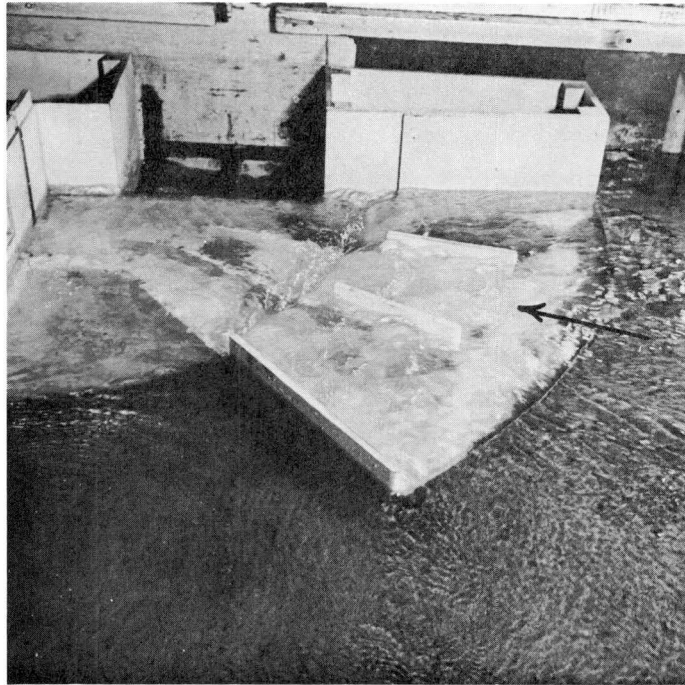


Fig. 5. $Q = 25 \text{ c.m.s.}$ - Sluice gates closed. Preliminary design



Fig. 6. River $Q = 25 \text{ c.m.s.}$ - Both sluice gates open. Preliminary design

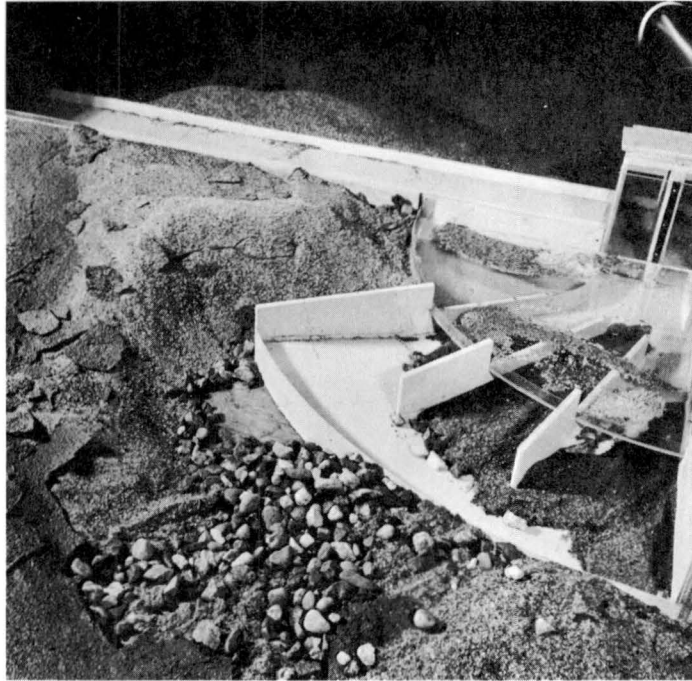


Fig. 7. Erosion at the structure

to two, with the center wall extending to the sluice gates as shown in Fig. 8. This was the only change involved in this modification, and tests were confined to study of sluicing action only. With each sluice gate independently controlling the flow through the tunnels, sluicing of the settling basin was greatly improved. The rate of sluicing and sluicing velocities could be better controlled.

C. Modification B

Modification B involved two items: (1) the left guide wall was reduced in height to elevation 456.3 m., and (2) the control sill within the settling basin was raised to elevation 456.9 m. The need for cutting down the height of the left wall was determined from tests of the preliminary design, especially at large discharges. It was considered undesirable to reduce the height of the wall to elevation 456.0., however, because the wall serves an important function of diverting the flow into the desilting structure at low flows. Therefore, a compromise wall height of approximately one foot (0.3 m) above the surrounding river bed level was considered. At low discharges the wall could direct the flow and at high discharges the wall height would not be sufficient to cause serious obstruction to the flow.

The change in sill height (item 2) in this modification was made for two reasons. First, by raising the sill height an attempt was made to artificially create a bend in the flow path. Because the settling basin extends into the river channel, a considerable portion of the bed load would continue to be intercepted and the suspended material may settle out in the basin at normal discharges because of the reduced velocity and increased depth. The second reason for the increased sill height was to prevent the carry-over of sediment, which deposited in the settling basin, over the sill and into the canal by the boils created in the settling basin at the intersection of the center wall and the sill.



Fig. 8. Modification A. Reduced three sluice tunnels to two.

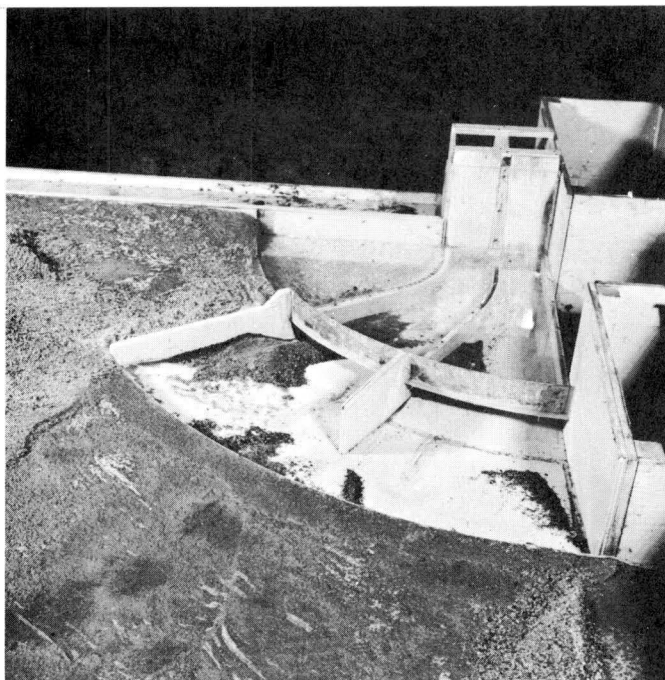


Fig. 9. Modification B.
(1) Reduced height of left wall
(2) Increased height of sill

The model arrangement of the modifications are shown in Fig. 9.

Flow conditions at the desilting structure with a very high sediment bed load at $Q = 25$ c.m.s. is shown in Fig. 10. The bed load was adequately intercepted by the settling basin and the flow direction was not radially altered. At a discharge of approximately 100 c.m.s. the sediment which was not intercepted by the settling basin by-passed the structure and flowed over the control dam as seen in Fig. 11. This condition would apply to discharges greater than about 100 c.m.s. Some amount of sediment was noted to flow into the canal, although the amount was small.

D. Modification C

Fig. 12 shows the modification of the settling basin floor slope from 7:1 to 4:1. The sluicing studies with the preliminary flow slope indicated that not all of the sediment in the basin could be sluiced out, hence, the greater depth provided by the 7:1 slope would be effective only temporarily for settlement of the suspended materials. The greater floor slope proved to be more effective in flushing the sediment out of the settling basin.

E. Modification D

The tests for modification B resulted in successfully turning part of the river flow away from the canal headworks at discharges greater than 25 c.m.s. In so doing, a pool of relatively quiet and hence clear water was created near the south or right bank. It was noted also that the higher sill height would prevent diversion of all of the river flow into the canal with river flow at 25 c.m.s.

In order to intercept the entire river flow at $Q = 25$ c.m.s. it was necessary to lower the sill height. This was done effectively by locally reducing the sill height to its original elevation of 456.0 m. with



Fig. 10. Modification B. $Q = 25$ c.m.s.
Sediment is shown entering settling basin with sluice gates closed.

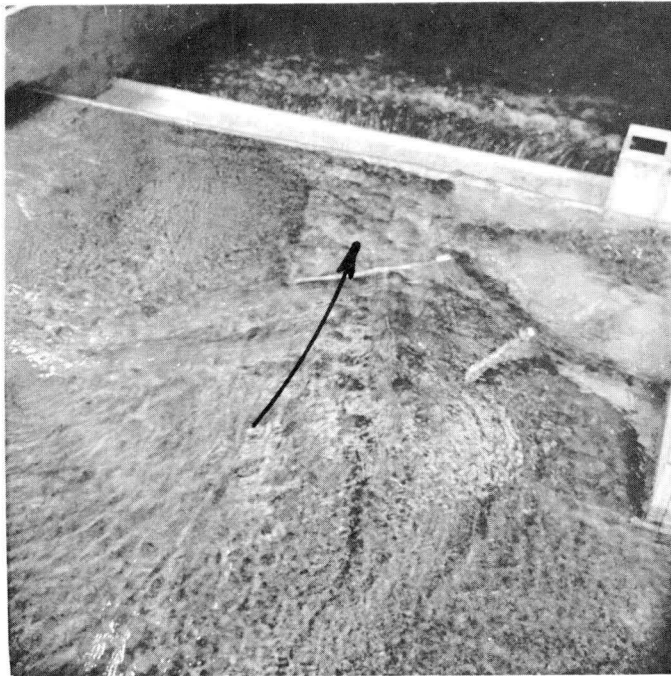


Fig. 11. $Q = 100$ c.m.s. Part of the sediment load by-passes the settling basin and flows over the control dam along the inside of the bend in the flow path.

an opening length of about 3.0 meters near the right bank. By lowering this local section it was also possible to divert the clear water along the south bank into the canal.

Modification D also included construction of a fillet on the downstream side of the left guide wall to prevent creation of a vortex and movement of sediment through the vortex into the canal intake.

All modifications, A through D are recommended for the desilting structure at the Gualanday Canal and are shown as a composite structure in Fig. 13. Several photographs at various discharges are shown for the recommended structure in Figs. 14 - 17. The collection of sediment in the desilting structure appeared satisfactory and at high discharges a considerable portion of the sediment load was transported over the control weir. It was noted however that some small amount of sediment entered the canal.

Figs. 17 and 18 show sluicing of the settling basin with low river flow. Satisfactory sluicing was obtained at all discharges, although the time interval for complete sluicing was greater at the lower discharges. If the settling basin needs to be sluiced at low discharges practically all of the river flow would be required for short intervals of time for the sluicing operation leaving little flow for diversion into the canal.

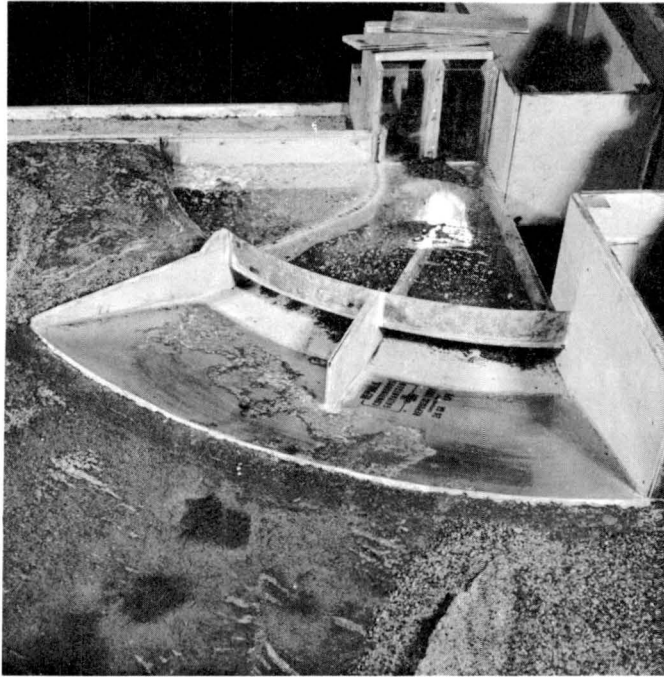


Fig. 12. Modification C Incorporates changes of A and B and an increased basin floor slope of 4:1

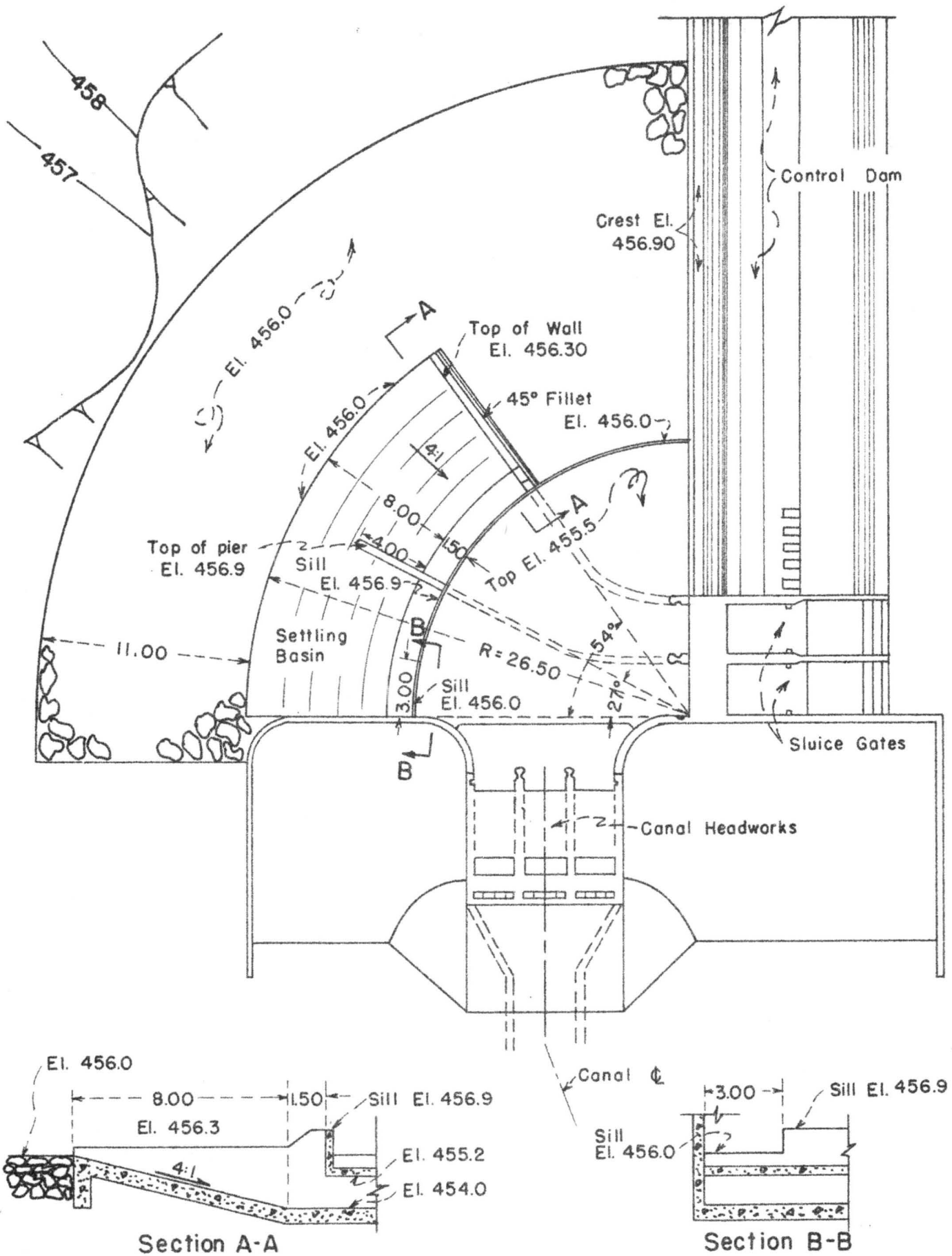


Fig. 13 Recommended Design Desilting Structure



Fig. 14. Recommended structure
 $Q = 300 \text{ c.m.s.}$



Fig. 15. Recommended structure
 $Q = 100 \text{ c.m.s.}$

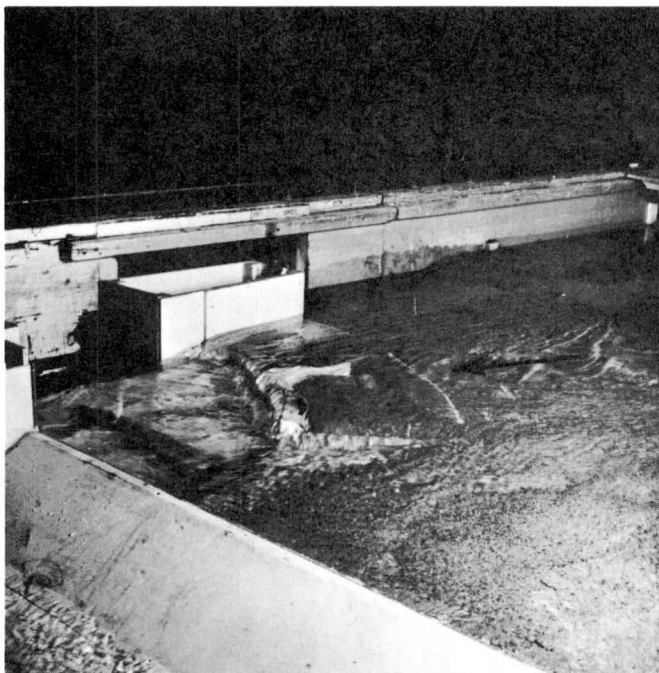


Fig. 16. Recommended structure
 $Q = 25 \text{ c.m.s.}$

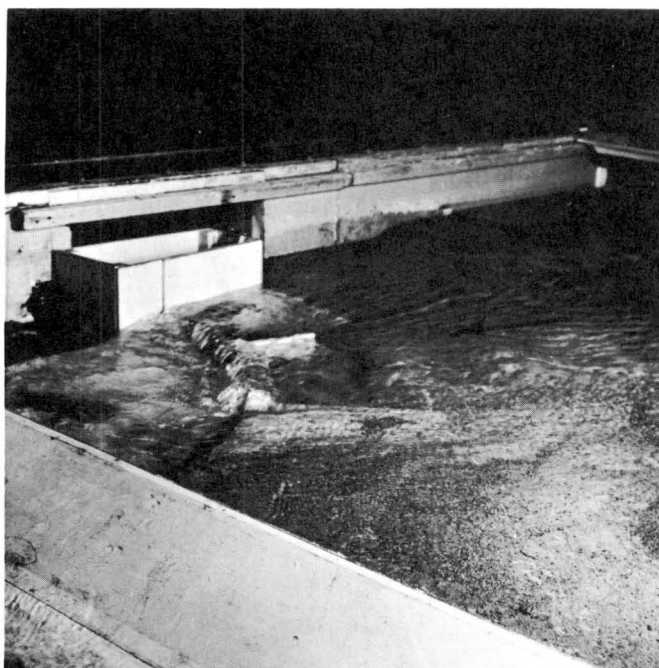


Fig. 17. Recommended structure
 $Q = \text{approximately } 15 \text{ c.m.s.}$

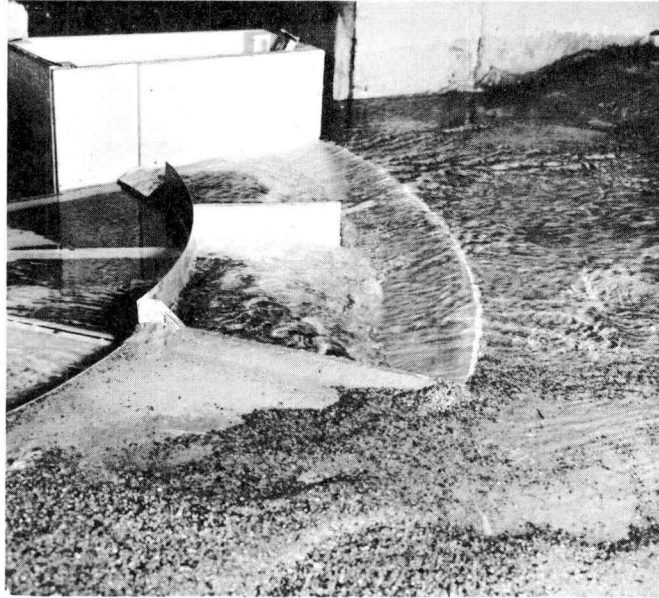


Fig. 18. Recommended structure
Sluicing at $Q \approx 15$ c.m.s.



Fig. 19. Recommended structure
Sluicing at $Q \approx 15$ c.m.s.

CONCLUSIONS

The qualitative model results indicated that the desilting structure with the modifications as arranged in Fig. 13 would operate satisfactorily at the Gualanday Canal headworks. It was estimated that at discharges less than 25 c.m.s. in the river, approximately 90 to 100 per cent of the bed load would be excluded. At river discharges greater than 25 c.m.s. the excluder would be from 75 to 95 per cent effective in preventing sediment, transported as bed load, from entering the canal. The settling basin could be cleaned through the sluice tunnels at any discharge, although, the sluicing operation would require a smaller time interval at high discharge. The control sill on the excluder was effective in changing the flow direction of the river at high discharges and a considerable amount of the sediment load was transported along the inside of the flow bend and over the control dam. It is recommended that the structure as shown in Fig. 13 be designed for construction.