R. J. Tipton Associated, Engineers, Inc.,
Denver, Colorado

Final Report

MODEL STUDIES FOR BOCONO DAM ,

Venezuela, South America

by
Kersi S. Davar
and
M. Shaarawi Amin

Colorado State University Research Foundation
Civil Engineering Section
Fort Collins, Colorado

May 1958

CER58ARC24

R. J. Tipton Associated, Engineers, Inc.,
Denver, Colorado

Final Report

MODEL STUDIES FOR BOCONO DAM ,

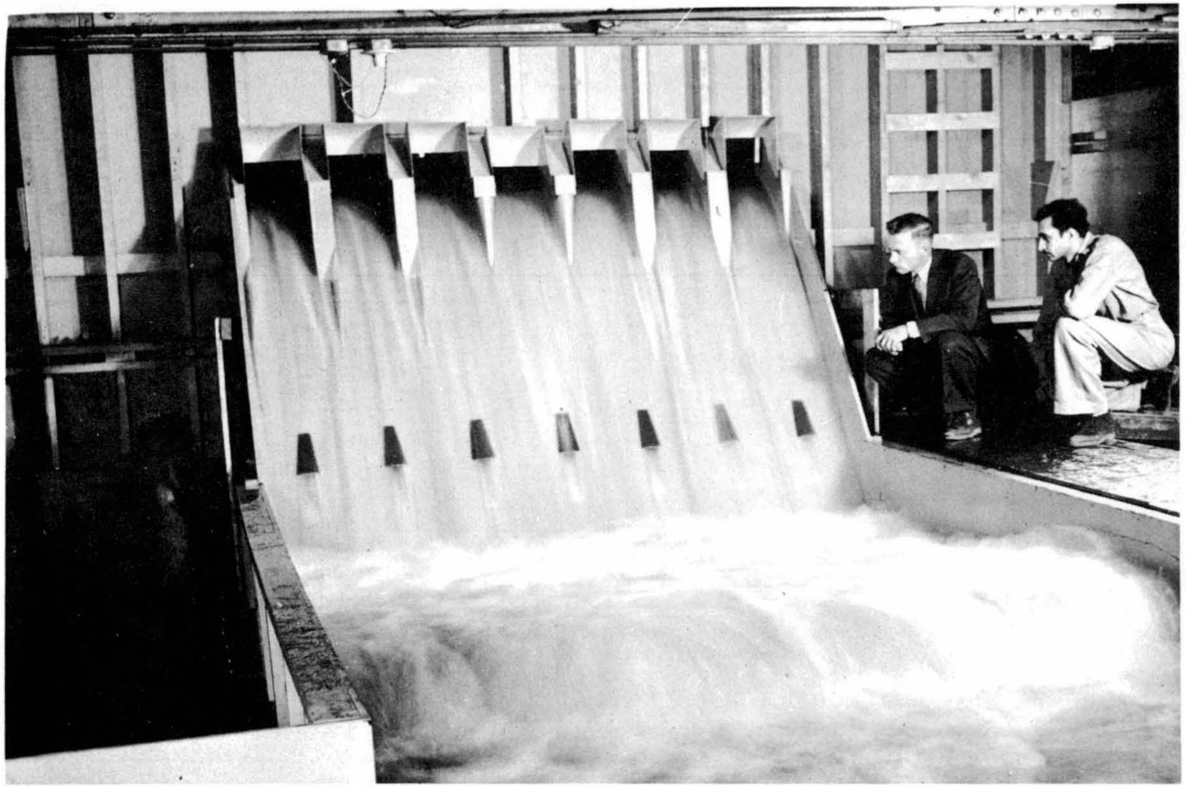
Venezuela, South America

by
Kersi S. Davar
and
M. Shaarawi Amin

Colorado State University Research Foundation
Civil Engineering Section
Fort Collins, Colorado

May 1958

CER58ARC24



THE GENERAL MODEL (Scale 1 : 49.2)

FOREWORD

The model studies described in this report were made to check the adequacy of design and performance characteristics of various hydraulic features of Bocono Dam, to be constructed on the Bocono River in Venezuela. The investigations were authorized by contract between R. J. Tipton Associated Engineers, Inc., Denver, Colorado and Colorado State University Research Foundation, Fort Collins, Colorado. The studies were made during the period March 1957 to April 1958 under the Civil Engineering Section's Project No. 752.

The investigation was under the direct technical and administrative supervision of A. R. Chamberlain, Chief, Civil Engineering Section. Overall planning of the models and tests was done in consultation with A. J. Peterka, U. S. Bureau of Reclamation, who gave invaluable guidance as consultant to the project. The design and construction of the model was initiated by Wiley McFarland, assisted by H. Makarechian, B. D'Utry, R. Malhotra and R. Hall. For an interim period Erik Plate also assisted the project team. In September 1957 the writers assumed charge of model design, testing operations, and data analysis.

All features of the models, including the 1:20 plastic model of the river outlet elbow, were fabricated in the hydraulic laboratory workshop. Shop supervisor R. V. Asmus incorporated many of his original ideas in the building of the testing equipment and models.

SYNOPSIS

The hydraulic characteristics of several features of the Bocono Dam were investigated by means of three models constructed and tested in the Colorado State University Hydraulic Laboratory at Fort Collins, Colorado. The studies included investigations of the stilling basins, the spillway, the river outlets and the draft tube exits discharging into the stilling basin. Measurements, photographs and graphical records were made to evaluate the preliminary and modified designs.

The spillway and stilling basins were tested for flows up to the design maximum flood of 10,000 m^3/s. The river outlet tests were made for flows occurring at reservoir water levels up to the maximum design level, El 290.0 m, with various gate openings. The draft tube investigations were made for flows which ranged from a minimum of 8.65 m^3/s (305 cfs) to a maximum of 39.9 m^3/s (1,410 cfs) through each turbine, with the discharge in the stilling basin varying from 2,500 to 9,000 m^3/s.

The spillway with the modified undercut piers developed during the model tests is shown in Fig. 15. These piers helped to provide smooth flow over the crest and reduced the height of the fins which formed on the spillway face. The piers reduced the fin height from about 8 m with the original square-tailed piers to 4 m with the modified piers at the maximum design discharge of 10,000 m^3/s (see Fig. 16). Along the lower third of the sloping training walls, for discharges exceeding 7,000 m^3/s, the fin height almost equals the height of the training wall. (see Fig. 19).

Increasing the height of the training wall in this region will be necessary to prevent overtopping and spray formation, especially in the vicinity of the powerhouse on the right bank. Spillway discharges passed smoothly over the eye-brow deflectors on the spillway. The flow did not enter the outlet openings or splash as it came back onto the spillway face. The spillway rating curve for uncontrolled and gate controlled flows, obtained by calibration of the model spillway is shown on Fig. 21.

The stilling basin developed in these studies is shown in Fig. 4; performance was excellent for the entire range of discharges including the design maximum flood of 10,000 m^3/s. The water surface was smooth and there was no tendency to produce excessive scour at the downstream end of the stilling basin. Although the twelve tailrace outlets in the secondary dam lowered the water surface upstream of the secondary dam by 2.5 m at the design maximum discharge of 10,000 m^3/s, making the resultant depth downstream of the jump about 0.5 m less than the required theoretical conjugate depth, the basin still performed satisfactorily (see Fig. 14). There was no tendency for the jump to sweep out of the primary basin. To obtain the theoretical conjugate depth necessary for best jump action, two of the tailrace outlets should be eliminated but computations indicate that this would raise the tailwater level at the draft tube exits by about 0.4 m when there is no flow over the spillway and the power plant is operating with four units each discharging 40.0 m^3/s. For spillway flows up to about 9,600 m^3/s, the measured depth exceeds the theoretical conjugate depth required in the primary basin, Fig. 14.

In the secondary basin flows exceeding 7,000 m^3/s topped the training walls. It was found that the walls should be raised about 3 m to provide sufficient height to prevent waves from overtopping the walls (see Fig. 11).

A protective apron of riprap varying in size from 0.2 m to 1.6 m laid on a 6:1 slope downstream from the end of the paved apron is expected to be able to prevent erosion of the river bed. Specifications for the riprap are given in the text.

The river outlet studies showed the proposed design to be satisfactory. The maximum positive pressure was found to be 21.3 m (70.0 feet of water) on the crown, inside the elbow (see Fig. 26). The lowest negative pressure was -2.28 m (-7.5 feet of water) below atmospheric pressure and occurred on the invert of the elbow in a vented air pocket (see Fig. 26). Since the flow does not come in contact with the boundary in the low pressure area, no cavitation should occur. The two 21-inch diameter ducts connected to the 30-inch air supply duct were found to provide an ample air supply at the jet-flow gate, thus minimizing cavitation tendencies and ensuring stable flow conditions in the conduit.

The draft tube investigations showed that pressure surges in the stilling basin caused by spillway discharges were transmitted into the draft tubes. The pressure changes inside the draft tubes for spillway discharges up to 5,400 m^3/s did not exceed 1.8 m of change in 35 seconds (about 1 foot in 5 seconds), Fig. 39. It is therefore expected that the spillway may be operated up to 5,400 m^3/s, or more, without seriously affecting the power plant performance. For discharges of greater magnitude it is not known whether the stilling basin operation will adversely affect the performance of the turbines. Reference should be made to turbine manufacturer's recommendations to determine whether the turbines may be operated safely at very high spillway discharges.

CONTENTS

LIST OF FIGURES

Figure No.

LIST OF FIGURES -- Continued

INTRODUCTION

The Bocono Dam includes hydraulic structures for which there is no precedent to help provide a satisfactory design. A conventional hydraulic jump stilling basin is not feasible, and the powerhouse is located so that the turbine draft tubes discharge into the stilling basin. Model studies were therefore considered desirable to develop and check the design of these and other hydraulic features, and also to investigate the operating characteristics of the spillway and river outlets.

Scope of the Investigations

The investigation program was drawn up to study the following problems:

1. Develop the hydraulic design and determine the minimum dimensions of a stilling basin which would function satisfactorily as an energy dissipator for flows up to 10,000 m^3/s.

2. Examine the flow pattern on the spillway and make modifications to improve the flow conditions. Determine the spillway rating curve for free flow and gate controlled flows.

3. Study the pressure distribution and flow pattern in the vicinity of the downstream end of the river outlets.

4. Study the effect of stilling basin operation on pressures within the draft tubes which discharge directly into the stilling basin.

The Prototype Structure

Bocono Dam will form a reservoir having a capacity of 6,800 million cubic meters. The dam will provide flood control and the impounded water will be used for irrigation of downstream lands and generation of hydroelectric power.

The dam will be of the concrete gravity type with a maximum height of 111 m above the foundation. The central section forming the spillway will be straight and the abutment sections on either side curved in plan. The total length of the dam crest will be about 560 m. These features are shown in Fig. 1.

The spillway will be of the overflow type, across the center section of the dam, and will have an over-all length of 126 m. The spillway will be controlled by seven 13.5 by 11.8 m radial gates operated by electrically driven hoists. A bridge will be constructed across the spillway and the gate hoists will be mounted on the bridge deck (see Fig. 2).

The stilling basin at the toe of the dam will be of the horizontal hydraulic jump type. The necessary tailwater depth will be obtained by building an auxiliary concrete gravity dam downstream. The second hydraulic jump stilling basin will be followed by a riprap apron sloping up to the river bed. Dimensions of the stilling basin as determined from the model studies are shown in Figs. 2, 5 and 6. Straight concrete walls about 32 m high form the side walls of the primary stilling basin.

River outlets constructed through the dam will discharge onto the downstream face and into the stilling basin as shown on Fig. 23. The discharge may be regulated by 84-inch diameter jet flow gates.

The power plant is integral with and forms a part of the right side wall of the stilling basin (see Figs. 33 and 34). The total ultimate installed capacity of the powerplant will be 100,000 kw in five 20,000 kw units driven by hydraulic turbines. A single penstock 6.5 m in diameter will be installed through the dam, connected by a manifold to the hydraulic turbines. The turbine draft tubes will discharge directly into the stilling basin.

The Models

Three models were used to investigate the hydraulic performance of the dam structures and appurtenant works. The first model, a 1:49.2 scale two-dimensional model of the stilling basin, was used for preliminary tests to determine the basin type and the approximate dimensions. The second model, a 1:49.2 scale general model of the spillway, river outlets, stilling basin, and downstream channel with bank topography was used to check the over-all performance and develop the structure. This model, shown in Fig. 3, included the turbine draft tubes which were installed in the right training wall of the stilling basin and were used to investigate pressure conditions in the draft tube passages during stilling basin operation. The third model, a 1:20 scale transparent plastic model of the downstream section of one river outlet was used to investigate pressure distributions and flow patterns in the elbow and is shown in Figs. 24 and 25.

Part I STILLING BASIN STUDIES

To provide the depth necessary for a hydraulic jump stilling basin, a secondary dam was used by the dam designers. The two alternative stilling basins initially tested are shown in Fig. 4, as Type I and Type II_A. Investigations were first conducted in a two-dimensional model to determine the general features and approximate size of a satisfactory stilling basin. The resulting basin was later installed and tested in the general model. The recommended stilling basin is shown in Fig. 4, Type II_C.

Investigations in the Two-dimensional Model

The Two-dimensional Model

A 1:49.2 scale two-dimensional model of the preliminary design for the stilling basin was constructed in a 2 foot wide flume. A glass side wall made it possible to observe, photograph, and study the stilling action from the water surface to the apron. The model was assembled in the flume so that modifications could be easily made. Water entered the stilling basin after passing over a 2 foot wide section of the spillway built at the upstream end of the flume. A head box with a spillway crest provided a smooth entry to the stilling basin. The tailwater level was controlled by a tailgate at the exit end of the flume. The preliminary models and subsequent modifications were tested for flows of 3,000 to 10,000 m^3/s.

Development of the Stilling Basin

The first tests were concerned with determining the necessary height of the secondary dam and the length of the primary stilling basin. Basin Type I shown on Fig. 4 was constructed and investigated but was abandoned after preliminary tests. The flow passed over the secondary dam without the excess energy being dissipated. The secondary basin was too shallow to produce good stilling action, and erosion of the riprap and surging in the downstream channel resulted.

Basin Type II_A shown in Fig. 4 was then constructed and investigated. The tests established the fact that a secondary dam about 15 m high was necessary to contain the jump in the primary basin. The primary basin performed satisfactorily for the entire range of discharges including the design maximum flow of 10,000 m^3/s. For discharges between 3,000 and 7,500 m^3/s vortices were observed near the upstream face of the secondary dam, but since they were located in a region of low velocity and energy they were not considered serious. It appeared feasible to reduce the length of primary basin from 110 to 105 m and this was later done in the general model.

The secondary basin of Type II_A shown in Fig. 4, which utilized 6 m x 6 m blocks at the toe of the secondary dam, a sloping sill at the end of the apron, and a 6:1 riprap slope was found to perform satisfactorily. This basin practically eliminated the surges that passed over the secondary dam and produced smooth flow in the downstream channel at all discharges.

Riprap Apron

The riprap apron laid on a slope of 6:1 was designed to prevent river bed erosion downstream from the secondary stilling basin. The necessary size of the individual stones was estimated from the equation given in U. S. Bureau of Reclamation, Hydraulic Lab. Report No. Hyd-409, page 5.

$$d = 0.15\, V^2 \quad .$$

Where:

d = mean diameter of stone (inches)

V = bottom velocity (feet per second) .

The bottom velocity at the upstream end of the gravel apron, based on model observations, was estimated to be 19.8 feet per second for the prototype, hence

$$d = 0.15\,(19.8)^2$$

$$= 59 \text{ inches or } 1.52 \text{ m for prototype}$$

$$= 1.52/49.2 \text{ or } 1.35 \text{ inches for model} .$$

Gravel having a mean diameter of 1.25 inches was used to form the riprap in the model. The riprap was found to be stable for discharges up to 10,000 m^3/s . After tests on several other sizes of riprap the following specifications were drawn up for the riprap apron:

Within a distance of 20 m from the end sill use riprap of which:

50% is larger or equal to 1.6 m mean diameter, 50% fits into the interstices of the larger riprap but not more than

2% should be smaller than 0.2 m mean diameter.

For the reach between 40 to 55 m from the end sill use riprap of which:

50% is larger or equal to 0.7 m mean diameter,

50% fits into the interstices of the larger riprap, but not more than

2% should be smaller than 0.2 m mean diameter.

For the intermediate 20 to 40 m reach, the size of riprap should be varied between the limits specified above.

Riprap as specified should provide adequate protection against erosion and deposits against the end sill. Since the riprap in the model consisted of rounded stones and the prototype riprap will probably be rough and irregular, the prototype riprap will interlock to a greater degree and provide a more stable river bed than was observed in the model.

Complete photographic records of the glass-walled flume tests were obtained, recording the performance of the Type II_A stilling basin and riprap apron. This information was presented previously in an Interim Report dated October 7, 1957.

Investigations in the General Model

Model Features

The main features of the general model are shown in Fig. 3; the headbox, spillway section, and operating features are described in Part II Spillway Studies. The stilling basin elements as installed in the general model are indicated as Types II_B and II_C in Fig. 4. The stilling basin was similar to the Type II_A basin developed in the two-dimensional model but its length was reduced 5 m . Also, the secondary dam was increased 1 m in height, the apron of the secondary basin was lowered 2 m and reduced 2 m in length, and the blocks at the toe of the secondary dam were increased to 7 x 7 x 4 m.

Initial tests were run without the openings in the secondary dam. This basin design was designated Type II_B. Later 12 circular openings were installed in the secondary dam having areas equivalent to the 3.5 x 2.1 m tailrace outlets for the prototype shown in Fig. 6. This latter basin design was designated Type II_C. The dimensions tentatively adopted by the design engineers on the basis of these studies are shown in Figs. 2, 5 and 6.

The downstream river channel was reproduced in sufficient detail to show the flow conditions at the end of the stilling basin and for about 350 m downstream. The tailwater was controlled by an adjustable gate at the end of the tailbox.

Stilling Basin Performance

Most of the tests were made on the Type II_B basin without the tailrace outlets in the secondary dam; these were added later. The stilling basin performance and water surface profiles along the right training wall and center line of the basin were recorded photographically for flows ranging from 2,000 to 9,200 m^3/s. Typical profiles are shown in Figs. 7 to 10. The water surface profile along the right training wall may be read directly on the grid painted on the training wall. The grid indicates distances from the axis of the dam and elevations in 5 m increments. The profile along the center line of the basin was recorded by means of a horizontal scale with its lower edge at El 220.0. Vertical scales graduated in 1 m intervals were suspended from the horizontal scale at 10 m intervals, and these enable the direct reading of water surface elevations. Water surface profiles are summarized in Fig. 11. There was no appreciable difference between the profiles along the center line and along the training wall.

The performance of the primary basin was somewhat rough at the very high discharges. This is attributable to the short apron which had been reduced in length to the practical minimum. However, the basin was considered satisfactory since the secondary basin performed exceptionally well in dissipating energy and smoothing the surges in the flow. The very smooth flow in the downstream channel was due to the action of the large chute blocks shown on Fig. 12. The blocks direct a jet of water at the base of the roller in the hydraulic jump, strengthening it and reducing surges and waves to a minimum.

Twelve tailrace outlets were then placed in the secondary dam. The purpose of the outlets is to minimize the submergence of the draft tubes and increase the power head when only the power plant is operating. The rectangular openings in the prototype shown in Fig. 6 were represented in the model by circular tubes of equivalent area. The circular openings were used because pipe could be installed inexpensively in the model. Check runs were made for flows ranging from 2,500 to 9,200 m^3/s to determine whether the reduction in tailwater depth upstream from the secondary dam would impair the jump action. The performance at 9,200 m^3/s is shown in Fig. 13. The jump height was reduced about 2.5 m at 10,000 m^3/s but the hydraulic jump displayed no tendency to sweep out of the basin. This was evidenced by the fact that the toe of the jump did not move away from the toe of the spillway. Runs were also made with 2, 4, 6, and 8 outlets closed to investigate the effect on the height of jump. The data obtained are plotted in Fig. 14 which also shows the theoretical conjugate depth required for various discharges in the basin.

From the performance observed in the primary basin and a study of Fig. 14, it was concluded that the primary basin will operate safely and satisfactorily with the twelve openings at all discharges including the design maximum flow of 10,000 m^3/s. To attain the theoretical conjugate depth in the primary basin, two of the outlets would have to be eliminated. Computations based on model test data indicate that closing two outlets would raise the tailwater level at the draft tube exits by about 0.4 m when the spillway is not operating and the four turbines are discharging a total flow of 1,600 m^3/s.

The training walls with top at El 220.6 m in the primary basin appear satisfactory. But, in the secondary basin the top of the training wall on the left bank and the approach road to the powerhouse on the right bank at El 204.0 are too low. Flows exceeding 7,000 m^3/s will overtop these low points as indicated on Fig. 11 unless walls at least 3 m higher are constructed. This additional height includes 2 m for the height of the flow and 1 m for the height of waves and surges.

Concluding Remarks

1. The two-dimensional model permitted a rapid and convenient means of developing a stilling basin having optimum performance characteristics.

2. The general model confirmed the satisfactory performance of the stilling basin for discharges up to 10,000 m^3/s, even when the twelve tailrace outlets were installed in the secondary dam.

3. The training walls of the primary basin are of adequate height with top El 220.6 m; in the secondary basin they need to be raised at least 3 m to avoid overtopping at flows greater than 7,000 m^3/s.

Part II SPILLWAY STUDIES

The spillway studies included an investigation of flow conditions at the crest and piers, an examination of the flow conditions over the eyebrow deflectors, calibration of the spillway for discharge capacities at different reservoir levels and gate openings, and an over-all study of spillway operations. The features of the prototype spillway are shown in Fig. 15. The undercut piers shown on these drawings were developed from the model studies described below.

Model Features

The spillway investigations were conducted on the 1:49.2 general model shown in Fig. 3. The head box contained the approach topography on the right bank. Water was delivered to the head box by a 19-inch pipe manifold and passed through an 8-inch thick gravel baffle before entering the spillway headbay. A 9-inch damping board floating on the water surface near the gravel baffle also helped to provide smooth approach flow to the spillway. Discharges were measured by means of a 15-inch diameter calibrated orifice plate in the 19-inch supply main. The headwater elevations were measured in a stilling-well located to the right of the spillway. The stilling-well inlet pipe was located 2 feet below spillway crest level and projected about 3 feet upstream into the head box to avoid the effects of water surface drawdown near the crest. The stilling-well was equipped with a point gage which could be read to one-thousandth of a foot.

Crest and Piers

Flow over the preliminary spillway crest had a somewhat rough appearance, indicating an inefficient spillway. Minor modifications were made to improve the flow appearance: (a) the 2 m dimension on the corbel, Fig. 15, was increased to 10 m, (b) the upstream faces of the end piers were extended parallel to the dam for a length of about 3 m, and (c) the original square-tailed piers were replaced by undercut piers. The pier modifications consisted of undercutting and streamlining the nose from El 288.0 downward; the pier tail or downstream end was battered vertically and streamlined in plan. Modification (c) is shown in Fig. 16.

The crest and pier modifications helped to smooth the approach flow by providing smoother curved boundaries at the corbel and end piers. With the original square-tailed piers the flow did not merge smoothly at the downstream end; the sudden ending of the pier allowed the flow to converge too rapidly causing a vertical fin to form on the spillway face, Figs. 17 and 18. The fins oscillated with the flow and generated a large amount of spray. The streamlined pier tail guided the flow so that the water merged more gradually at the downstream end of the pier and thus reduced the height of fin. The reduction in fin height effect for several discharges is plotted on Fig. 16. The pier modifications approximately halved the height of the fin at the higher discharges. For example at a discharge of 10,000 m^3/s the fin height was reduced from 8 m with the original square-tailed piers to 4 m with the modified shape. The reduction in fin height is important since there will be less spray near the powerhouse.

Along the spillway training walls the fins were about 1 m higher than the fins below the intermediate piers. Even with the modified end piers the average height of fin along the lower third of the training wall was about equal to the height of wall for discharges greater than 7,000 m^3/s as shown in Fig. 19. The fins along the end walls showed a tendency to oscillate with minor disturbances in the flow and run up the face of the wall. The training walls should be raised to avoid overtopping at the higher discharges. To allow for bulking of the prototype flow caused by air entrainment, the walls should be raised to provide a 2 m freeboard above the water surface elevation shown by the model.

Eye-brow Deflectors

The eye-brow deflectors over the exit of the river outlets gave satisfactory flow conditions at all discharges. The flow leaped completely over the trough of the river outlet and met the spillway face at a distance varying from 2 m to 10 m from the downstream end of the trough as the discharge was varied from 3,000 to 10,000 m^3/s. Flow trajectories at 3,000 and 5,400 m^3/s are shown in Fig. 20; the river outlets were closed during these tests. Pressures on the eye-brow deflector and at important locations in its vicinity were not excessive.

Spillway Calibration

For reservoirs with gated spillways a rating curve is essential for releasing scheduled discharges. With the gates lifted clear of the water surface free discharge occurs over the spillway crest. When the headwater is above the bottom edge of the gate, the efflux characteristics vary from those of an orifice to those of free discharge, as the ratio of gate opening to head on the crest increases and approaches unity. Additional variables such as the curvature of the radial gate, the shape of the crest, and the relative positioning of the gate and crest, affect the discharge capacity at a particular opening. Since each factor is represented to scale in the general model and since flow over the spillway is primarily governed by the Froude criterion, model calibrations afford a convenient and accurate means of determining the spillway capacities. The rating curve for the spillway in terms of one gate operation, is shown in Fig. 21; it was obtained from tests on the 1:49.2 scale model.

The curve for free flow over the crest was obtained by operating one or more spillway bays with the gates fully raised. The discharge for one gate was obtained by dividing the total flow over the spillway by the number of gates fully open. Total flows were measured at the 15-inch orifice in the supply main, and reservoir elevations were read at the head-water stilling well. The free discharge curve was defined by eight points uniformly spaced for discharges varying from 300 to 1,300 m^3/s per gate. Discharges per gate were the same whether all the gates, only alternate gates, or various combinations of gates were open. The coefficient of discharge C, which may be used to compute discharges from the relation $Q = CLH^{3/2}$, is shown plotted to the right in Fig. 21.

The curves for one partly open gate, shown branching upward from the free flow curve of Fig. 21, were obtained by raising the gates in 1 m increments, increasing the discharge, and reading the head water elevations at the stilling well. The curve for each gate opening was defined by at least four uniformly spaced points. The lower extremities of these curves are shown dashed because they were extrapolated; as the head water was lowered and approached the bottom edge of the gate, the flow became unstable and the water surface dropped abruptly below the gate lip, resulting in free flow over the crest. Measurements in this transition region cannot be made with accuracy.

Gate Operating Procedure

For best hydraulic performance of the stilling basin, all gates should be opened uniformly, and the rate of rise of gates should be synchronized with the rate of rise of tailwater in the river channel. When all gates are not required to be opened, symmetrical combinations should be operated.

The effects of unsymmetrical gate operation are shown in Fig. 22. The three gates on the right end of the spillway were opened fully and the remaining gates were closed. Under this condition the spillway discharged only about one third of the design flood of 10,000 m^3/s but the stilling action in the primary basin was completely disrupted. The flow entering the stilling basin from one side generated a great eddy with water surface differentials of approximately 10 to 15 m in the basin. Conditions such as these in the prototype might cause damage to the power plant and erode the downstream river channel. While such operations are not normally expected, this study served to illustrate the possible dangers resulting from unsymmetrical operation of the spillway gates.

Concluding Remarks

1. Generally, the flow conditions at the crest were acceptable. Smoother flow will result if the corbel is extended about 10 m downward, and the upstream faces of the end piers are extended along the dam for a length of 3 m.

2. The undercut type of piers with streamlined tails, as developed in these tests, considerably improved flow conditions on the spillway face (see Fig. 17). The height of the fin formed below the piers was almost halved at the higher discharges. The lower third of the spillway training walls needs to be raised 2 m to prevent overtopping.

3. The flow and pressure conditions over the eye-brow deflectors of the river outlets were satisfactory.

4. The spillway rating curve obtained by calibrating the model indicates the gate opening required at various reservoir levels or the head-water elevation required for free flow conditions to release scheduled quantities of water (see Fig. 21).

5. The studies covering unsymmetrical gate operation serve to illustrate the possible dangers resulting from asymmetrical gate operation (Fig. 22).

Part III RIVER OUTLET STUDIES

Tests were made to investigate the pressure distribution and flow conditions in the elbow of the river outlets for varying reservoir elevations, gate openings, and air vent openings. The prototype river outlets are shown in Fig. 23.

The Model

A 1:20 scale model of one river outlet was constructed as shown on Figs. 24 and 25. The main conduit downstream of the regulating gate was of horseshoe section $4\frac{13}{16}$ inches high by $4\frac{13}{16}$ inches wide. A part of the conduit upstream from the elbow, and the entire elbow, were made from transparent plastic to permit visual observation of flow through the outlet. In all, 44 piezometers were installed on the walls of the elbow, located as shown in Fig. 24.

The air vent downstream from the regulating gate was represented by a 2-inch diameter gate valve which was normally adjusted to give 1.77 square inches of open area. This corresponded to the area of the 30-inch diameter header on the prototype. The gate valve opening was varied for some of the tests to observe its effect on flow characteristics in the outlet conduit and elbow. The side air vents at the stepped transition from the horseshoe conduit to the approximately square shaped elbow section were represented by short lengths of plastic pipe each of 0.5 inch inside diameter, corresponding to the four 10-inch diameter vents on the prototype. These vents were left open for all tests.

The regulating gate used (see schematic view on Fig. 24) was a simple vertical leaf gate sliding between two flange plates. The upstream flange consisted of a flat plate with a circular opening 4.2 inches in diameter corresponding to the control section of the 84-inch jet-flow gate.

Discharges through the jet-flow regulating gate were computed for various reservoir levels and gate-openings from the equation $Q = 0.8A\sqrt{2gh}$ where A = area of gate opening and h = head at the gate. The model discharge Q_M was obtained in terms of the prototype discharge Q_P from the relation $Q_M = (L_r)^{5/2} Q_P$, where L_r is the model scale ratio, 1:20.

The Investigation

Flow conditions corresponding to the following combinations of reservoir levels and gate openings for the prototype were investigated.

1. Max. Reservoir Level (El 290.0)

   Gate opening 100% Q = 104.0 m^3/s (3,670 cfs)

   80% Q = 82.2 m^3/s (2,900 cfs)

2. Reservoir Level at Spillcrest (El 276.5)

   Gate opening 100% Q = 93.3 m^3/s (3,290 cfs)

   80% Q = 73.5 m^3/s (2,585 cfs)

3. Reservoir Level below Spillcrest (El 260.0)

   Gate opening 80% Q = 61.5 m^3/s (2,170 cfs)

   60% Q = 46.8 m^3/s (1,652 cfs)

   (Only qualitative data were obtained for this last case)

For each test the slide gate representing the jet-flow gate on the prototype was adjusted to give the desired area of opening; the model discharge was set to correspond to the prototype discharge. With the flow established, the vent at the slide gate and the four vents at the stepped junction were inspected to see that they were functioning properly. Pressures in the elbow were read on a bank of water manometers, while pressures upstream of the slide gate, being much greater, were checked on a mercury manometer.

The pressure distributions observed on the crown, bottom, and sides of the elbow are shown in Figs. 26, 27 and Table 1 of Fig. 28. Photographs of typical tests are shown in Figs. 29 and 30. Sketches indicating the flow patterns for the cases tested are summarized in Fig. 31. Pressure variations in the elbow caused by changes in vent area at the regulating gate were measured on a few representative piezometers selected from zones of critical pressures. Typical pressure variations are shown plotted on Fig. 32. The adequacy of venting provided in the design was investigated at 80% gate opening, as the maximum air demand for a regulating gate in a concrete dam is believed to occur at about 60 to 80% gate opening, (see references 1 and 2 listed below).

Discussion of Tests

With maximum reservoir level (El 290.0) and 100% gate opening the conduit section upstream from the elbow appeared to flow full but the top layer of the flow contained a large quantity of entrained air. In the

[1] U. S. Corps of Engineers, Hydraulic Design Criteria, Sheet 050-1, paragraph 4.

[2] U. S. Bureau of Reclamation, Hydraulic Lab. Report No. 201, Fig. 18.

elbow the flow was not in contact with the crown in the vicinity of the top vents at the stepped junction but farther downstream it impinged on the roof and built up large positive pressures between piezometers 26 and 31, (see Figs. 26 and 31). In the same region flow was free of the bottom and negative pressures in the air pocket were fairly uniform. With 80% gate opening, free or open channel flow occurred up to the point of impingement against the crown between piezometers 26 and 30; the flow was free of the bottom as before.

With reservoir level at the crest of the spillway (El 276.5) the flow patterns for 100% and 80% gate openings were similar to the corresponding flow patterns obtained with the reservoir at El 290.0. The flow patterns are shown on Figs. 26, 29 and 31.

For flows with the reservoir at El 260.0 the conduit flowed partly full. From the stepped junction the flow emerged as a free jet that did not contact the inside of the elbow until it impinged against the crown farther downstream; this can be seen in Fig. 30. Flow patterns for lower reservoir levels are expected to be similar; however, at very low heads, the water will merely flow along the invert of the elbow.

The air vent area provided at the regulating slide gate was found to have considerable effect on the character of flow and pressures within the elbow for values up to about 3% of the conduit area; beyond this value further increases in air vent area had no appreciable effect as indicated in Fig. 32. For the smaller vent areas the zone of impingement moved upstream along the crown, and at the bottom the flow tended to adhere to the boundary.

Negative pressures along the bottom increased to about 1.5 times the value for fully vented flow. With less air the flow through the elbow was less turbulent and the efflux showed less tendency to spread and disintegrate.

Results of Tests

Complete data on pressure measurements are presented in Figs. 26, 27 and 28. The significant results are summarized below:

	Max. positive pressure head (in feet of water)	Max. negative pressure head (in feet of water)	Remarks
RWL 290.0			
100%	18.9 m (62.6 ft)	-2.16 m (-7.1 ft)	Refer Figs. 26 and 27
80%	22.2 m (73.0 ft)	-1.92 m (-6.3 ft)	Section X-X
RWL 276.5			
100%	16.0 m (52.4 ft)	-2.32 m (-7.6 ft)	Max. positive pressures occurred
80%	21.6 m (70.8 ft)	-2.01 m (-6.6 ft)	away from center line
			Min. negative pressures occurred along center line

The positive pressures were maximum at the zone of impingement. The maximum sub-atmospheric pressures occurred along the bottom; considering that the flow does not come in contact with the lower boundary and that the space is vented, no cavitation tendencies should be expected.

The pressure conditions and flow pattern in the elbow remained stable when the vent area at the regulating slide gate was increased beyond 3% of the conduit area. The air vent specified (12.8%) has a greater area and should therefore provide satisfactory venting. The air vent area should not be reduced as a result of these tests since the model-prototype relations for air flow in installations of this type are not fully understood.

Concluding Remarks

1. The pressures which will be obtained when the reservoir is at the spillway crest and the gate opening is 80% are shown in Fig. 27 and stated below:

   (i) Maximum positive pressure head will reach about 21.6 m (70.8 ft of water) on the crown of the elbow.

   (ii) Maximum negative pressure head will reach about -2.3 m (7.6 ft of water) sub-atmospheric along the invert of the elbow. No cavitation should occur since adequate venting is provided.

2. For maximum reservoir El 290.0, the greatest positive pressure head on the crown will be 22.2 m (73.0 ft of water); the maximum negative pressure head will be nearly the same as for reservoir El 276.5, that is -2.16 m (-7.1 ft of water) on the invert (see Fig. 26).

3. The vent area provided at the regulating gate, 12.8% of the conduit area, should be adequate.

Part IV DRAFT TUBE TESTS

The powerhouse is located in the right training wall of the stilling basin and the turbine draft tubes discharge directly into the primary stilling basin. This arrangement, shown in Figs. 1 and 33, makes the power plant performance dependent to some extent on conditions in the primary stilling basin. Under normal conditions the tailrace outlets in the secondary dam (Figs. 2 and 5) maintain a pool level in the primary basin sufficiently high to ensure proper submergence of the draft tubes. However, during flood discharges over the spillway, the draft tubes will be submerged to a greater degree and pressure variations caused by the highly turbulent conditions in the primary basin will be transmitted to the hydraulic turbines through the draft tubes. It was therefore necessary to investigate the degree to which the fluctuating stilling basin pressures were transmitted to the draft tubes and to determine the rate at which these pressures changed within the draft tube.

The Model

Since the average velocity through the draft tubes is relatively low, it was believed that sufficiently reliable data could be obtained if the draft tube passages were reproduced for a distance of about 10 m, measured upstream from the face of the stilling basin training wall. The upstream part of the prototype draft tube which turned vertically upward was omitted in the model. The prototype draft tubes are shown in Figs. 33 and 34; the model is shown in Figs. 35 and 36. The water supply was provided from a 5-inch pipe representing the penstock. Four branches from the penstock, each with an adjustable gate valve, supplied the draft tubes. Before entering the draft tubes the flow passed through a pressure chamber and gravel baffle which represented the turbines in the prototype and served to provide the proper velocity and distribution in the draft tubes. The discharges through the drafttube model were measured by means of a 3-inch orifice in the 5-inch penstock. Each valve was singly adjusted while the other three were closed to give the desired discharge corresponding to the tailwater conditions in the primary basin. When the settings for each valve had been individually determined, it was possible to make tests with any combination of units operating. The pressure measurements were made with six piezometers in each draft tube, located as shown in Fig. 35.

The Investigation

Pressure variations in the draft tube passages were obtained for the following combinations of flows through the draft tubes (Q_{DT}) and in the primary stilling basin (Q_{SB}):

Flows through 4 draft tubes		Flows in Stilling Basin	
Max Q_{DT}	= 4 x 1,410 cfs = 5,640 cfs = 159.6 m^3/s	For each Q_{DT}	= 2,500 m^3/s 5,400 m^3/s 7,500 m^3/s 9,500 m^3/s
Min Q_{DT}	= 4 x 305 cfs = 1,200 cfs = 34.6 m^3/s		

The maximum discharge through each turbine is expected to be about 45.2 m^3/s (1,410 cfs) at full gate setting and maximum operating head. The minimum operational flow is estimated to be 9.8 m^3/s (305 cfs). Only four units were installed in the model, as it was believed that sufficient data would be obtained to indicate the conditions likely to obtain in the provisional fifth unit.

The data obtained from these tests are shown in Figs. 37, 38 and 39. The first two drawings indicate the range of pressure variations observed in the draft tubes for draft tube discharges of 159.6 m^3/s (maximum) and 34.6 m^3/s (minimum), and stilling basin discharges of 2,500, 5,400, 7,500, and 9,500 m^3/s. The cross-hatched band on the drawings indicates the range of pressure variations measured at the piezometers in the draft tube passages, the clear areas in the same band represent the space occupied by piers and abutments. The pressures (in feet of water) have been plotted to correlate them with the water surface elevations in the primary stilling basin. The rate at which the pressure fluctuations occurred is shown in Fig. 39.

These investigations were made before the openings were installed in the secondary dam. When tests were run with the 12 openings in the secondary dam, the ambient pressure readings in the draft tubes dropped from 1 to 2 m for stilling basin operation between 2,500 to 5,400 m^3/s. These pressure reductions were nearly the same as the drop in the water surface in the primary basin caused by the tailrace openings. However, the pressure differentials, indicating the range of pressure fluctuations, remained practically unchanged.

Interpretation of Tests

An examination of the results showed that the pressure fluctuations were influenced principally by the character of the hydraulic jump opposite the draft-tube exits. The pressure differentials generally became larger with increasing discharges in the primary basin. For example, when the discharge through the draft tubes Q_{DT} = 159.6 m^3/s (Fig. 37) the pressure differentials in the right exit of the first draft tube increased from 0.5 m to about 1.5 m, when the discharge in the stilling basin Q_{SB} was increased from 2,500 to 9,500 m^3/s.

For the same discharge in the stilling basin, larger flows through the draft tubes tended to increase the magnitude of the pressures and their range of fluctuation. At the maximum discharge through the draft tubes Q_{DT} = 159.6 m^3/s the largest pressure variation was about 3 m. This variation occurred in the left passage of the first draft tube when Q_{SB} = 7,500 m^3/s, (Fig. 37). At the minimum discharge through the draft tubes, Q_{DT} = 34.6 m^3/s, the largest fluctuation was about 2.3 m and occurred at the same location.

The rate of pressure fluctuation was well represented by the action at piezometers P_5 and P_{12} located as shown on the plan view in Fig. 39. The rate of fluctuation in the model has been converted to prototype time by the usual relations for hydraulic models operating according to the Froude law:

$$T_r = (L_r)^{1/2} = (49.2)^{1/2} = 7.0 \text{ (Approx)}$$

where:

$$L_r = \frac{\text{Length on prototype}}{\text{Length on model}} = 49.2$$

$$T_r = \frac{\text{Time for prototype}}{\text{Time for model}} \quad .$$

When the discharges in the stilling basin were between 2,500 and 5,400 m^3/s, the maximum rate of pressure fluctuation in the prototype was indicated to be 1.8 m in 35 seconds (about 1 ft in 5 seconds).

Concluding Remarks

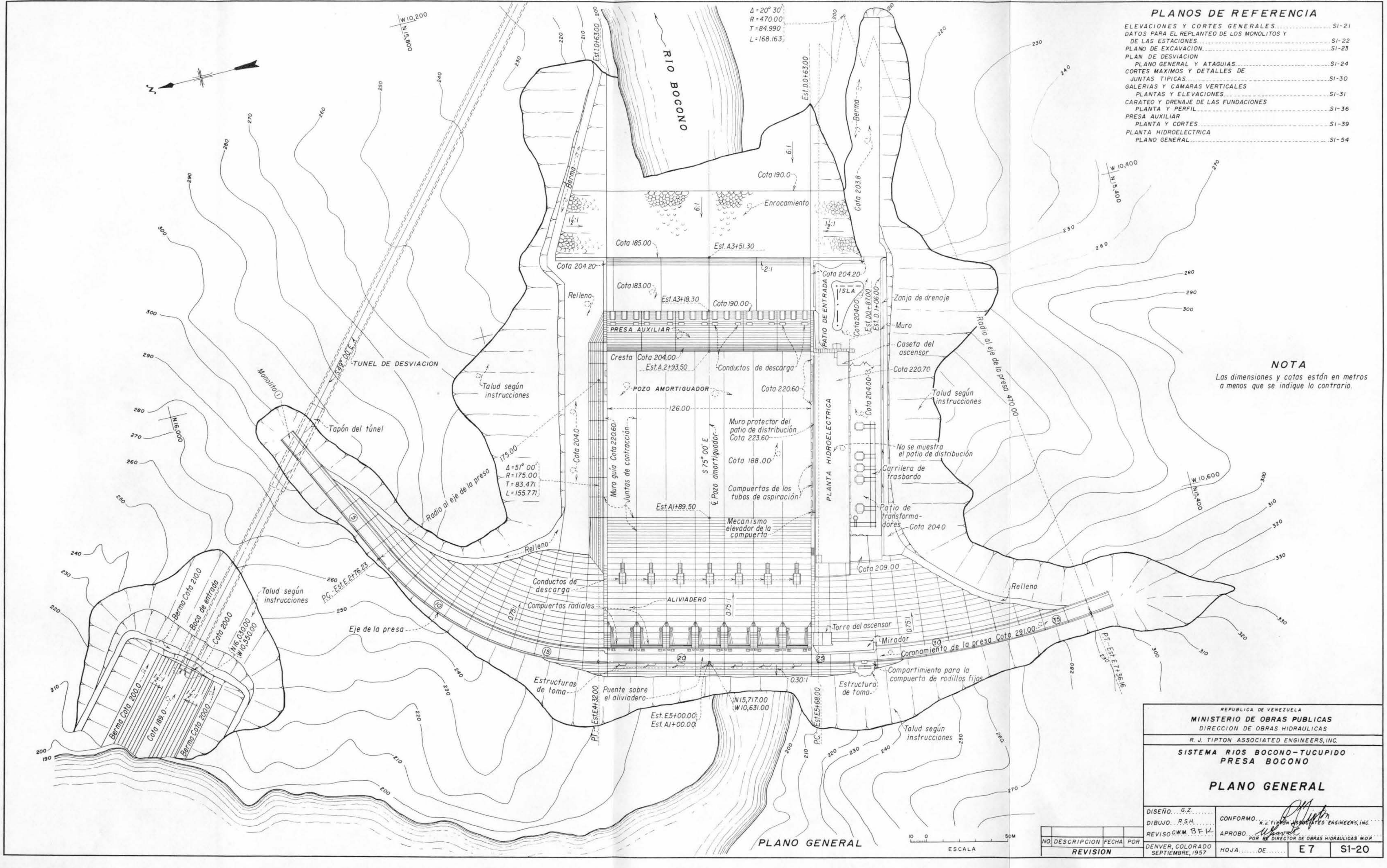
In establishing criteria for power plant operations the following factors may be given careful consideration:

1. The pressure fluctuations in the draft tubes generally increase with increasing discharges in the primary basin.
2. For a fixed discharge in the primary basin, the draft tube pressure fluctuations tend to increase with larger flows through the draft tubes.
3. The maximum rate of pressure change was about 1.8 m in 35 seconds when the discharge in the stilling basin ranged between 2,500 and 5,400 m^3/s.

The limiting conditions for power plant operation with stilling basin in operation may be determined from the information in Figs. 37, 38 and 39, and the recommendations of the turbine manufacturers.

FIGURES

FIGURE 1



PLANOS DE REFERENCIA

NOTA

Las dimensiones y cotas están en metros a menos que se indique lo contrario.

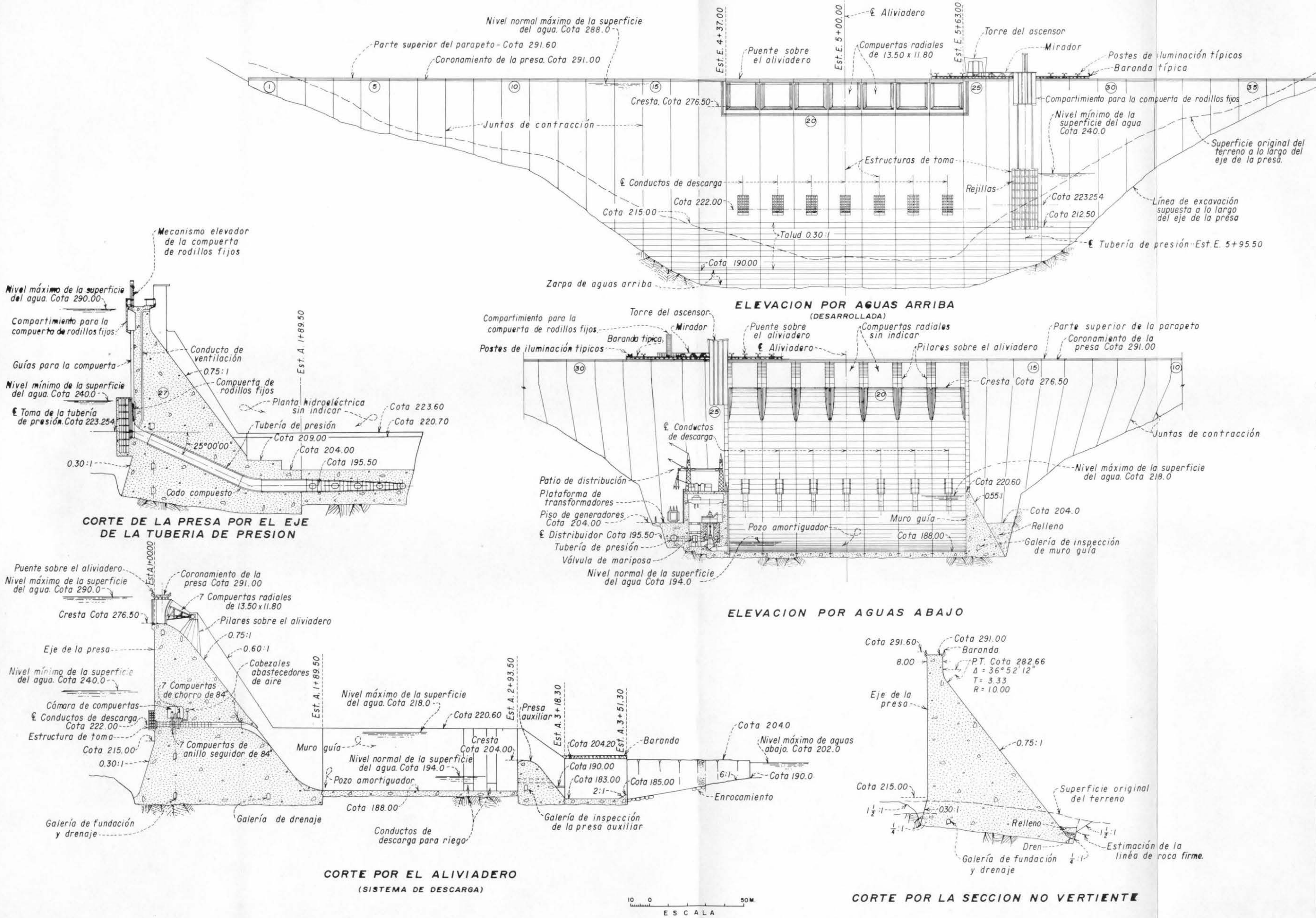
NO	DESCRIPCION	FECHA	POR
	REVISION		

REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS
R. J. TIPTON ASSOCIATED ENGINEERS, INC.

SISTEMA RIOS BOCONO–TUCUPIDO
PRESA BOCONO

PLANO GENERAL

DISEÑO G.Z.
DIBUJO R.S.H.
REVISO CWM BFK
CONFORMO R. J. TIPTON ASSOCIATED ENGINEERS, INC.
APROBO POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.
DENVER, COLORADO SEPTIEMBRE, 1957
HOJA ...... DE ...... E 7 SI-20



PLANO DE REFERENCIA

PLANO GENERAL SI-20

NOTAS ESTRUCTURALES GENERALES

El diseño y la construcción en concreto estructural deben ceñirse a los requisitos del "Building Code Requirements for Reinforced Concrete (ACI 318-56)" del American Concrete Institute.

Todo el concreto estructural debe tener una resistencia mínima de 3000 lb/pulg² a la compresión a los 28 días.

No se indica el refuerzo. Oportunamente se entregarán los planos de refuerzo.

El refuerzo será de acero intermedio, en barras corrugadas, de 20,000 lb/pulg²

El traslapo para adherencia del refuerzo en muros verticales y en columnas debe ser equivalente a 20 diámetros. Todos los otros traslapos deben ser de 24 diámetros.

A menos que se indique lo contrario, el refuerzo debe quedar con un recubrimiento de 0.05 excepto cuando esté contra la tierra o la roca y en este caso el recubrimiento será de 0.075.

Todas las esquinas al descubierto deben tener chaflanes de 0.020 a menos que se indique lo contrario.

Todo el diseño del acero estructural debe ceñirse a los requisitos de la última edición de la "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings" del American Institute of Steel Construction.

NOTA

Las dimensiones y cotas están en metros a menos que se indique lo contrario.

REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS

R. J. TIPTON ASSOCIATED ENGINEERS, INC.

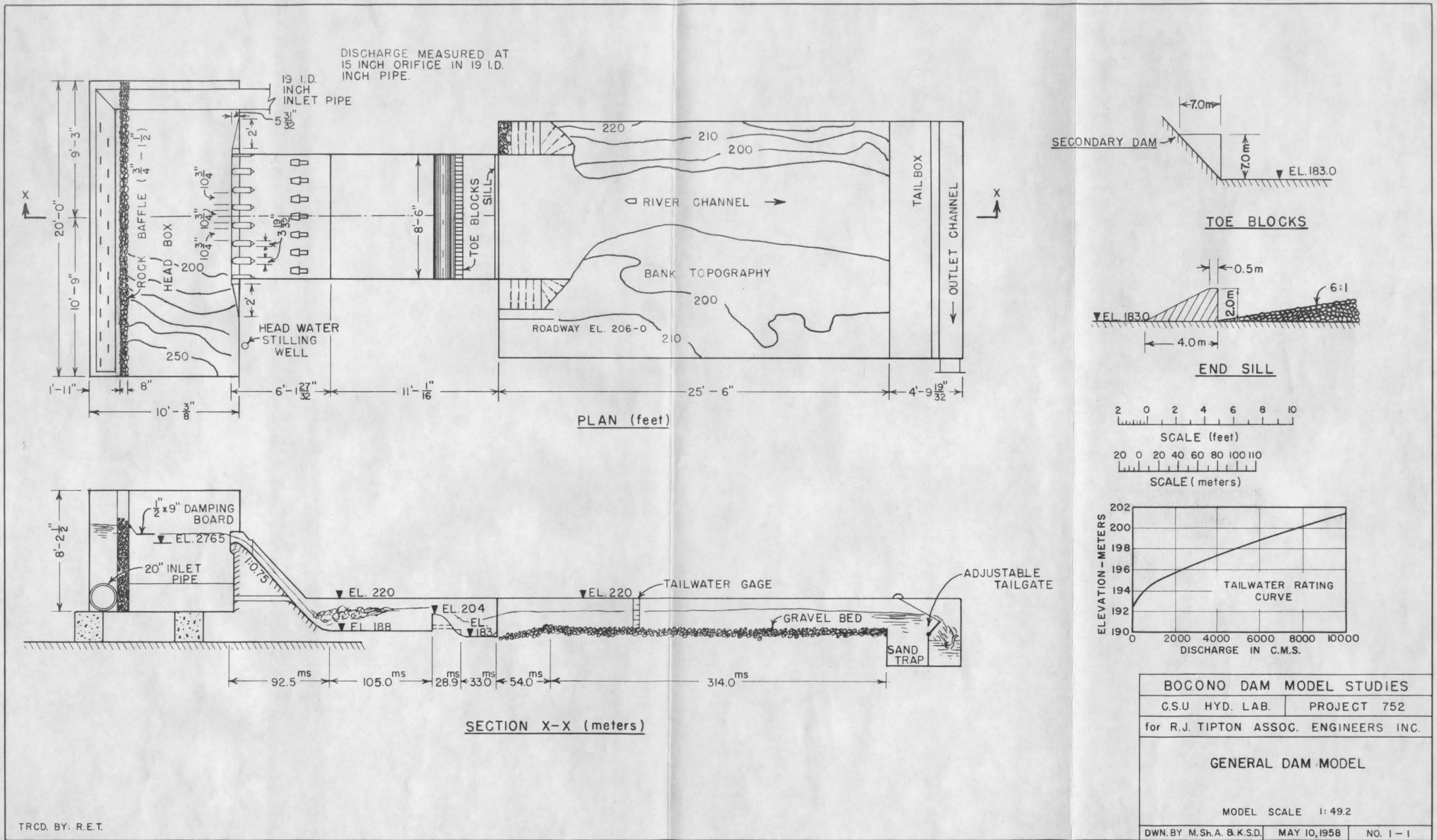
SISTEMA RIOS BOCONO-TUCUPIDO
PRESA BOCONO

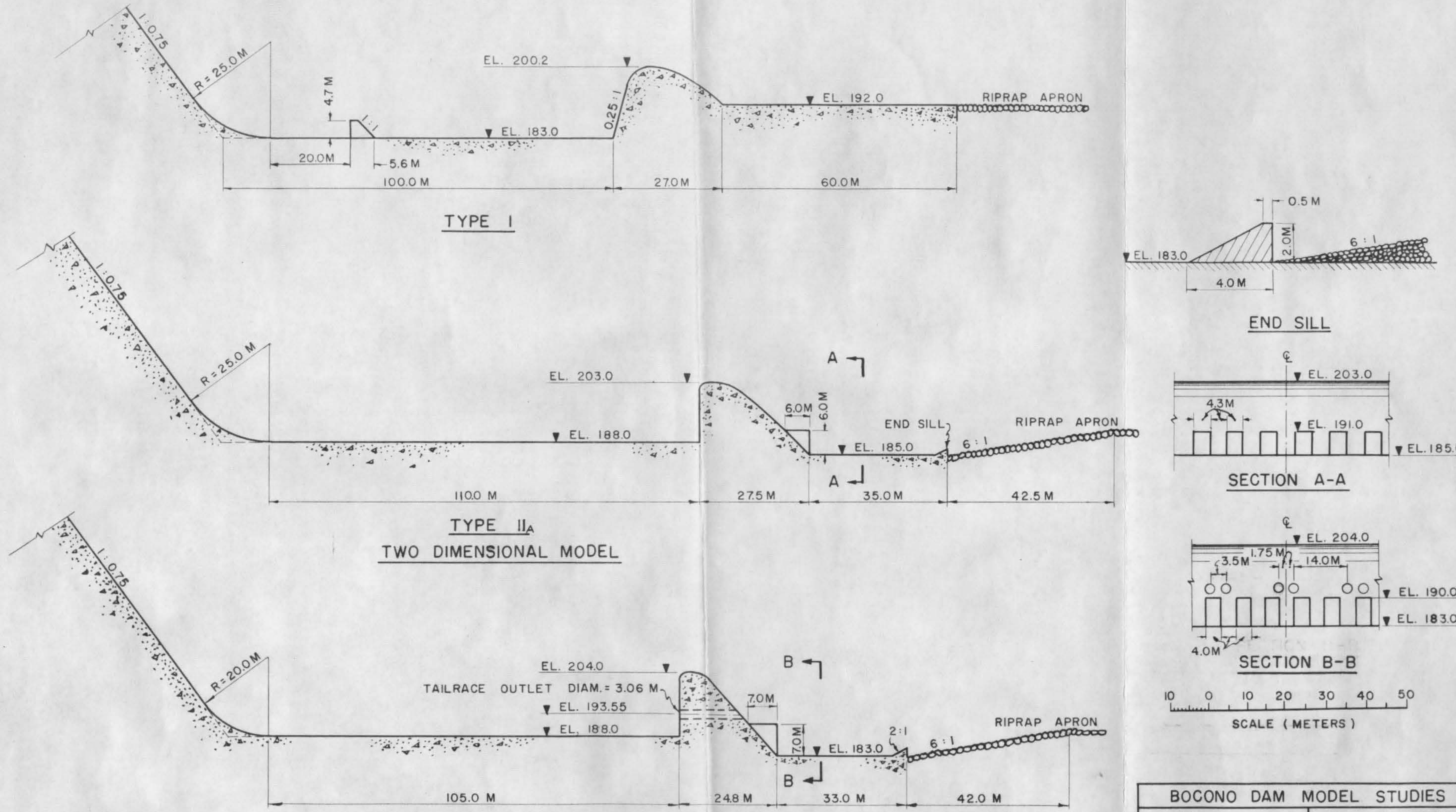
ELEVACIONES Y CORTES GENERALES

DISEÑO. G.Z.	CONFORMO. R. J. TIPTON ASSOCIATED ENGINEERS, INC.	
DIBUJO. G.R.C.-O.K.W.		
REVISO. F.V.W. B.F.K.	APROBO. POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.	
DENVER, COLORADO SEPTIEMBRE, 1957	HOJA ...... DE	E7 SI-21

NO	DESCRIPCION	FECHA	POR
REVISION			

FIGURE 3

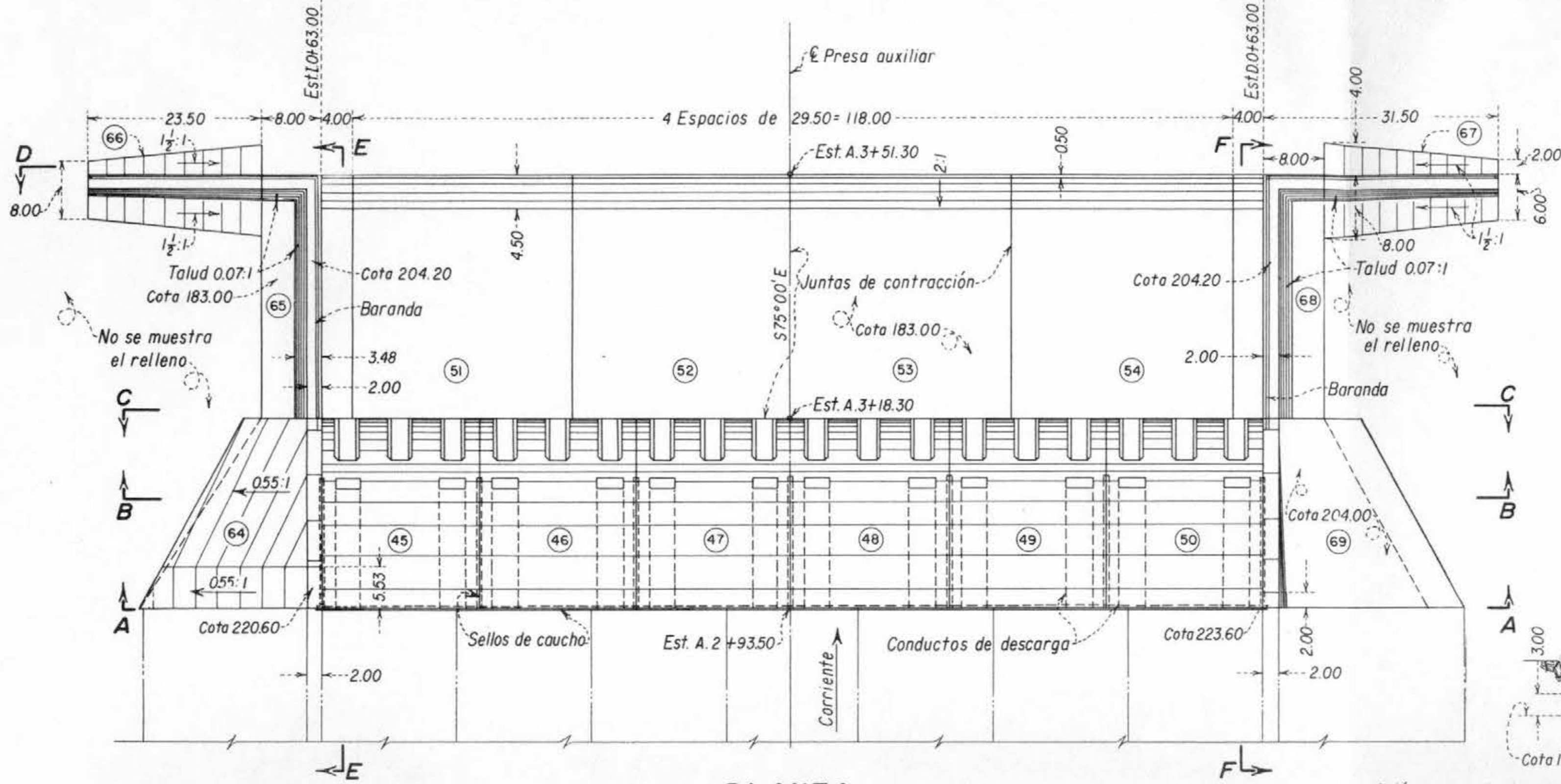

DISCHARGE MEASURED AT 15 INCH ORIFICE IN 19 I.D. INCH PIPE.
19 I.D. INCH INLET PIPE
ROCK BAFFLE (3/4" - 1 1/2")
HEAD BOX
HEAD WATER STILLING WELL
TOE BLOCKS
SILL
RIVER CHANNEL
BANK TOPOGRAPHY
ROADWAY EL. 206-0
TAIL BOX
OUTLET CHANNEL
PLAN (feet)
20'-0"
9'-3"
10'-9"
8'-6"
1'-11"
8"
10'-3/8"
6'-1 27/32"
11'-1/16"
25'-6"
4'-9 19/32"
SECONDARY DAM
7.0m
EL. 183.0
TOE BLOCKS
0.5m
6:1
2.0m
EL. 183.0
4.0m
END SILL
SCALE (feet)
SCALE (meters)
1/2" x 9" DAMPING BOARD
EL. 2765
20" INLET PIPE
8'-2 1/2"
1:0.75
EL. 220
EL. 188
EL. 204
EL 183
EL. 220
TAILWATER GAGE
GRAVEL BED
ADJUSTABLE TAILGATE
SAND TRAP
92.5 ms
105.0 ms
28.9 ms
33.0 ms
54.0 ms
314.0 ms
SECTION X-X (meters)
ELEVATION-METERS
DISCHARGE IN C.M.S.
TAILWATER RATING CURVE
BOCONO DAM MODEL STUDIES
C.S.U HYD. LAB.
PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.
GENERAL DAM MODEL
MODEL SCALE 1: 49.2
DWN. BY M.Sh.A. & K.S.D.
MAY 10, 1958
NO. 1 - 1
TRCD. BY: R.E.T.



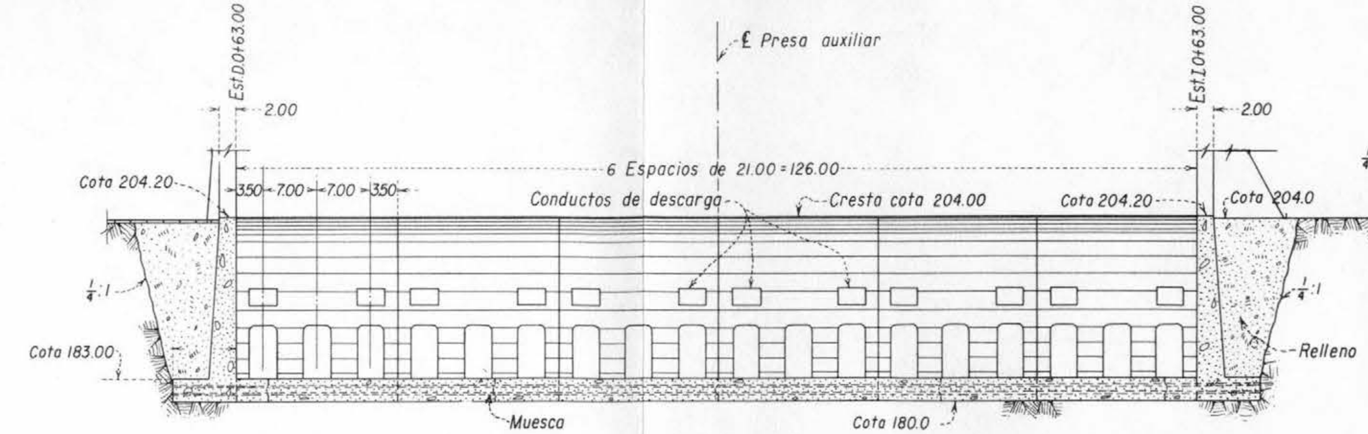
NOTE TYPE II_B WAS SIMILAR TO TYPE II_C BUT DID NOT HAVE THE 12 TAILRACE OUTLETS IN THE SECONDARY DAM.

BOCONO DAM MODEL STUDIES	
C.S.U. HYD. LAB.	PROJECT 752
FOR R.J.TIPTON ASSOC. ENGINEERS INC.	
DEVELOPMENT OF STILLING BASIN MODEL SCALE 1 : 49.2	
DWN BY: M.SH.A. & K.S.D.	APRIL 30, 1958 NO. SB-1

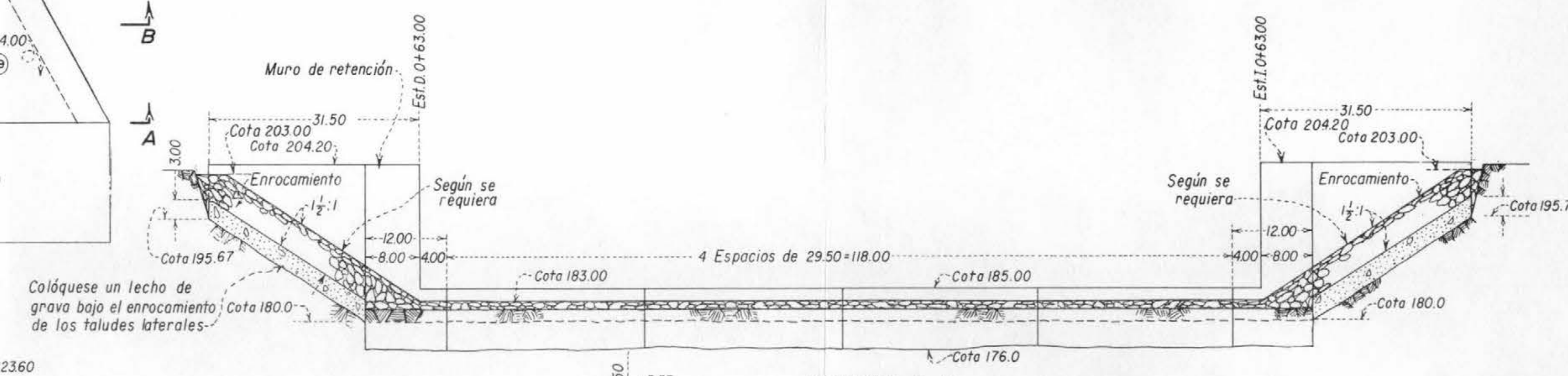
FIGURE 5



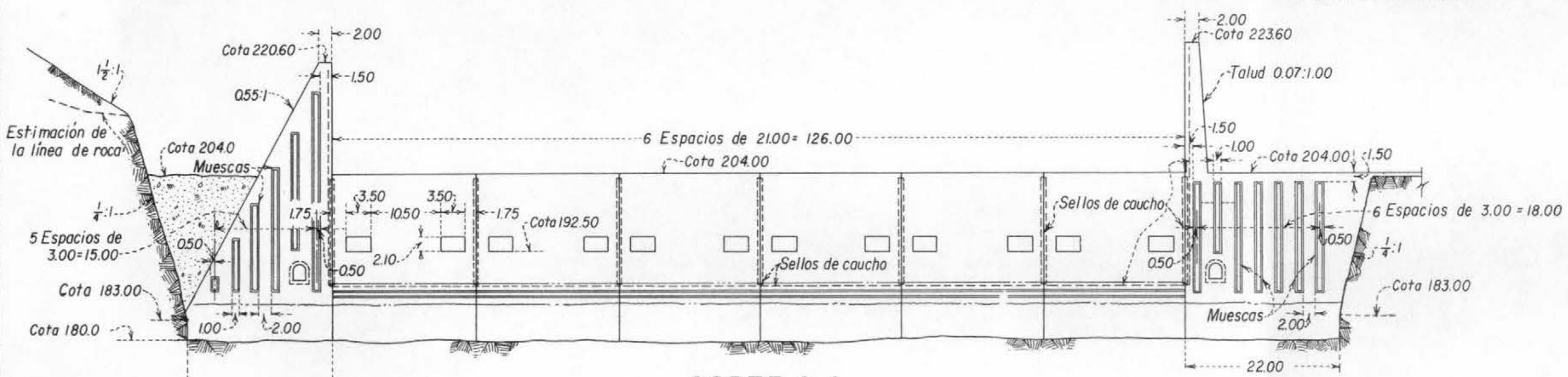
PLANTA



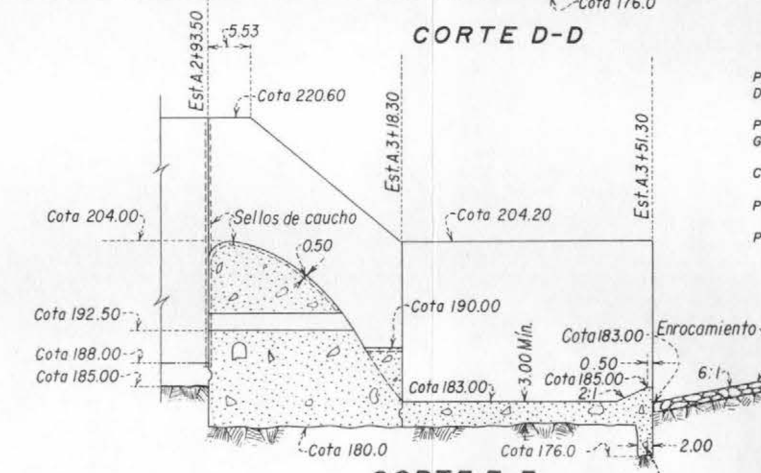
CORTE C-C



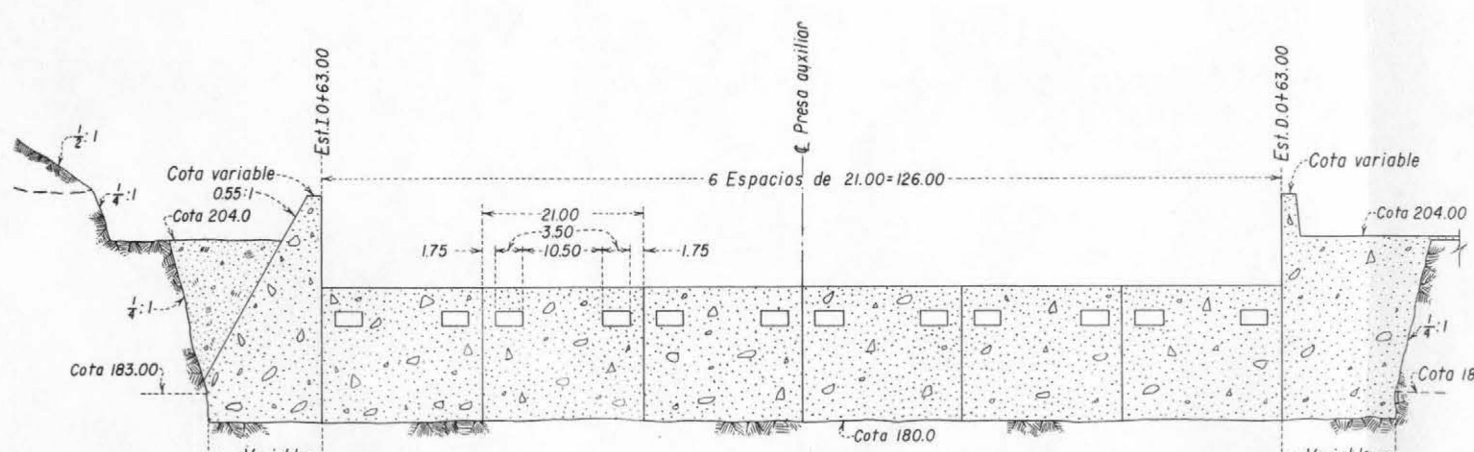
CORTE D-D



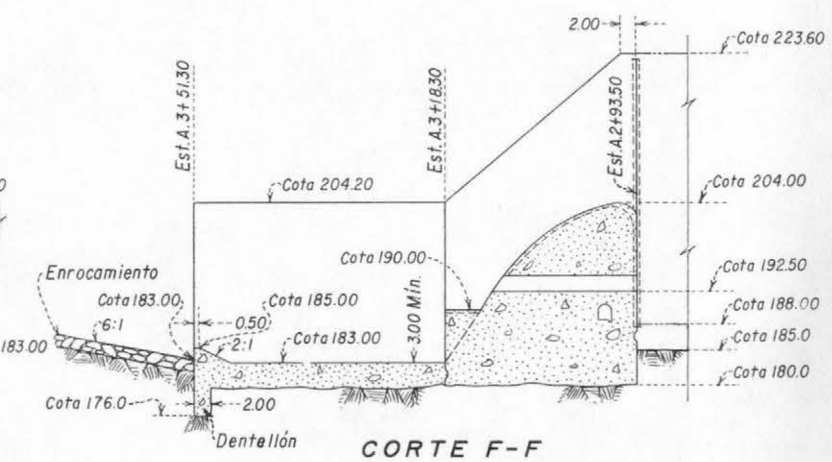
CORTE A-A



CORTE E-E



CORTE B-B



CORTE F-F

ESCALA (10 – 0 – 40 M.)

PLANOS DE REFERENCIA

PLANO GENERAL	SI-20
DATOS PARA EL REPLANTEO DE LOS MONOLITOS Y DE LAS ESTACIONES	SI-22
PLANO DE EXCAVACION	SI-23
GALERIAS Y CAMARAS VERTICALES PLANTAS, ELEVACIONES Y CORTES	SI-32
CARATEO Y DRENAJE DE LAS FUNDACIONES PLANTA Y CORTES DEL SUBDRENAJE	SI-38
PRESA AUXILIAR DETALLES	SI-40
PLANTA HIDROELECTRICA PLANO GENERAL	SI-54

NOTAS

Las dimensiones y cotas están en metros a menos que se indique lo contrario.
Para las Notas Estructurales Generales véase el Plano SI-21

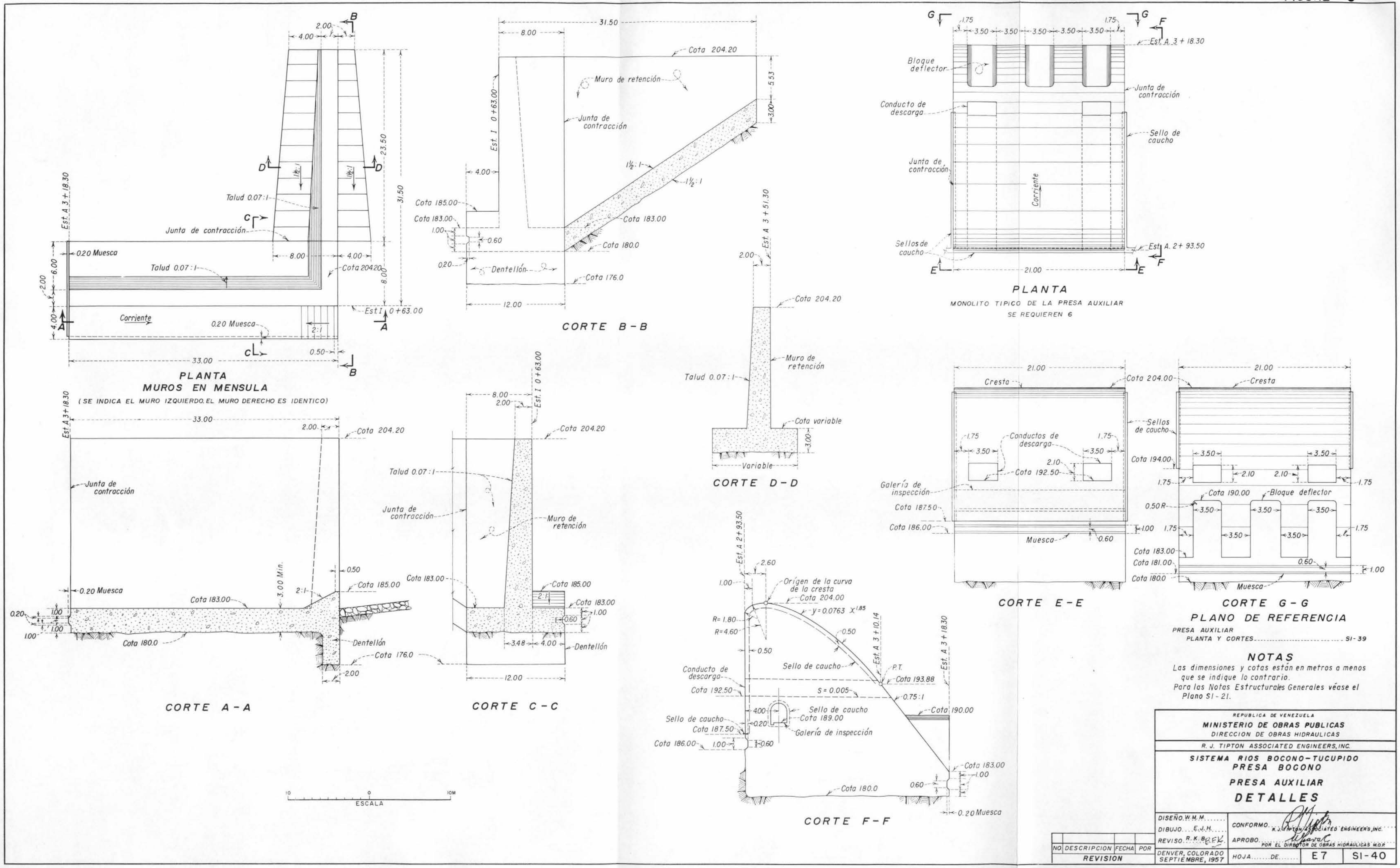
NO.	DESCRIPCION	FECHA	POR
REVISION			

REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS
R. J. TIPTON ASSOCIATED ENGINEERS, INC.

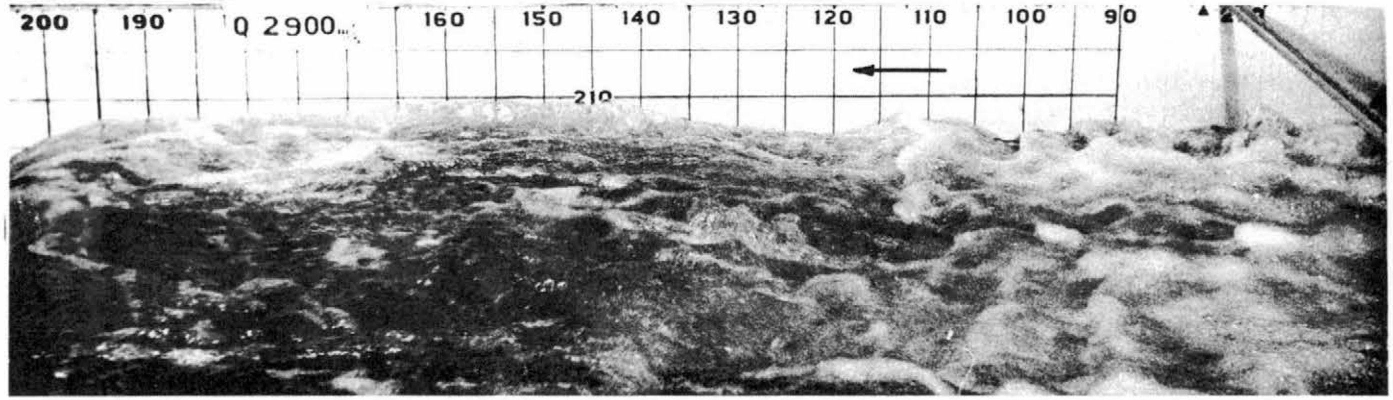
SISTEMA RIOS BOCONO-TUCUPIDO
PRESA BOCONO
PRESA AUXILIAR
PLANTA Y CORTES

DISEÑO R.K.B.
DIBUJO R.S.H.
REVISO C.W.M.
CONFORMO R. J. TIPTON ASSOCIATED ENGINEERS, INC.
APROBO POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.
DENVER, COLORADO SEPTIEMBRE, 1957
HOJA ...... DE ......
E7
SI-39

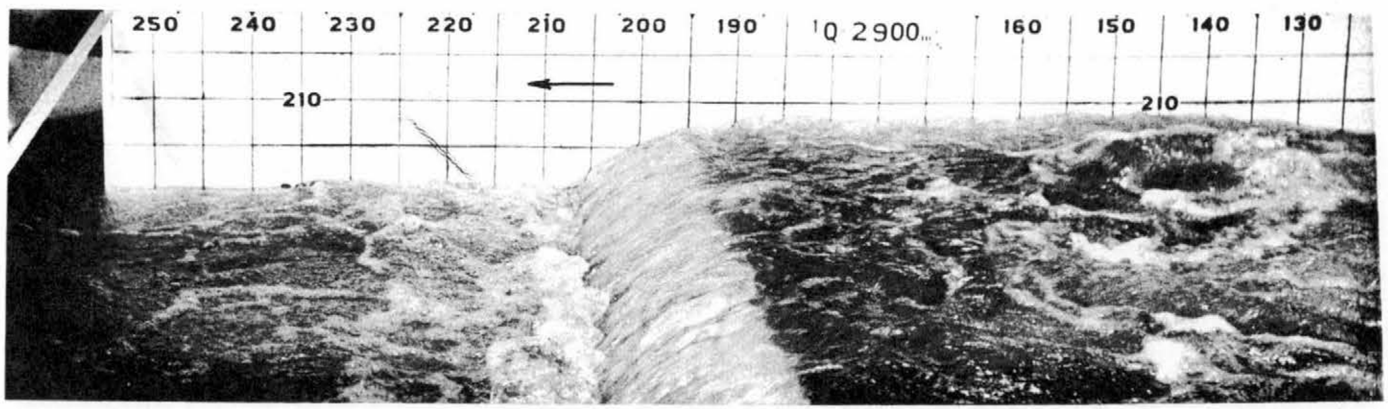
FIGURE 6


PLANTA
MUROS EN MENSULA
(SE INDICA EL MURO IZQUIERDO. EL MURO DERECHO ES IDENTICO)
Junta de contracción
Talud 0.07:1
0.20 Muesca
Corriente
Est. A 3 + 18.30
Est. I 0 + 63.00
Cota 204.20
CORTE B-B
Muro de retención
Junta de contracción
Cota 185.00
Cota 183.00
Cota 180.0
Cota 176.0
Dentellón
CORTE D-D
Talud 0.07:1
Muro de retención
Cota variable
Variable
CORTE A-A
CORTE C-C
PLANTA
MONOLITO TIPICO DE LA PRESA AUXILIAR
SE REQUIEREN 6
Bloque deflector
Conducto de descarga
Junta de contracción
Sello de caucho
Sellos de caucho
Corriente
Est. A. 2 + 93.50
CORTE E-E
Cresta
Cota 204.00
Sellos de caucho
Conductos de descarga
Cota 192.50
Galería de inspección
Cota 187.50
Cota 186.00
Muesca
CORTE G-G
Cota 194.00
Cota 190.00
Cota 181.00
CORTE F-F
Orígen de la curva de la cresta
Cota 204.00
y = 0.0763 x^1.85
Sello de caucho
S = 0.005
Cota 189.00
Galería de inspección
P.T.
Cota 193.88
0.75:1
Est. A 3 + 10.14
0.20 Muesca
ESCALA
PLANO DE REFERENCIA
PRESA AUXILIAR
PLANTA Y CORTES SI-39
NOTAS
Las dimensiones y cotas están en metros a menos que se indique lo contrario.
Para las Notas Estructurales Generales véase el Plano SI-21.
REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS
R. J. TIPTON ASSOCIATED ENGINEERS, INC.
SISTEMA RIOS BOCONO-TUCUPIDO
PRESA BOCONO
PRESA AUXILIAR
DETALLES
DISEÑO W.M.M.
DIBUJO E.J.H.
REVISO R.K.B.
CONFORMO
APROBO
POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.
DENVER, COLORADO
SEPTIEMBRE, 1957
HOJA ... DE ...
E7
SI-40
NO DESCRIPCION FECHA POR
REVISION

The General Model (scale 1 : 49.2)



A. The Primary Basin



B. The Secondary Basin

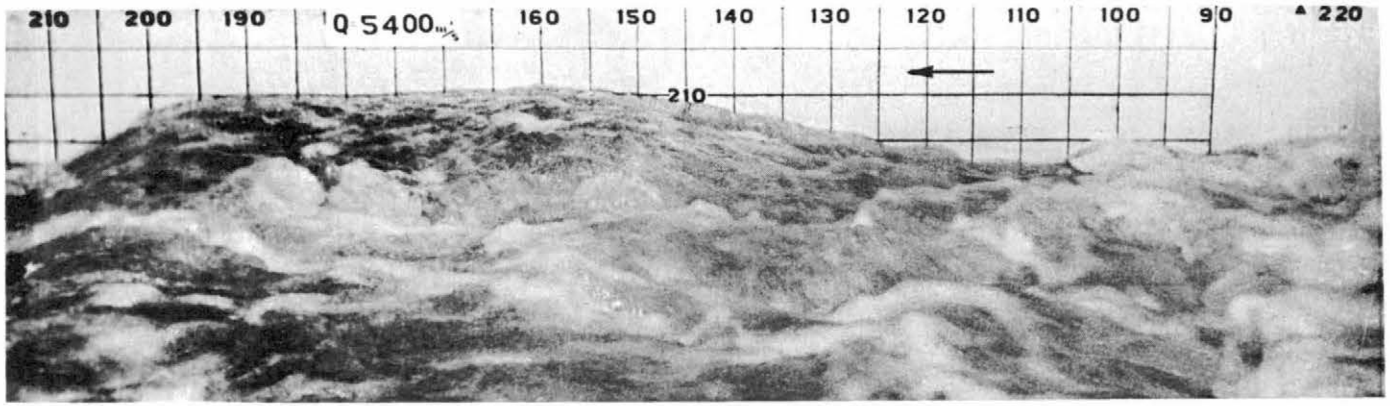
WATER SURFACE PROFILE ALONG RIGHT TRAINING WALL

Stilling Basin Type-II_B (no outlets in secondary dam) Q = 2,900 m^3/s

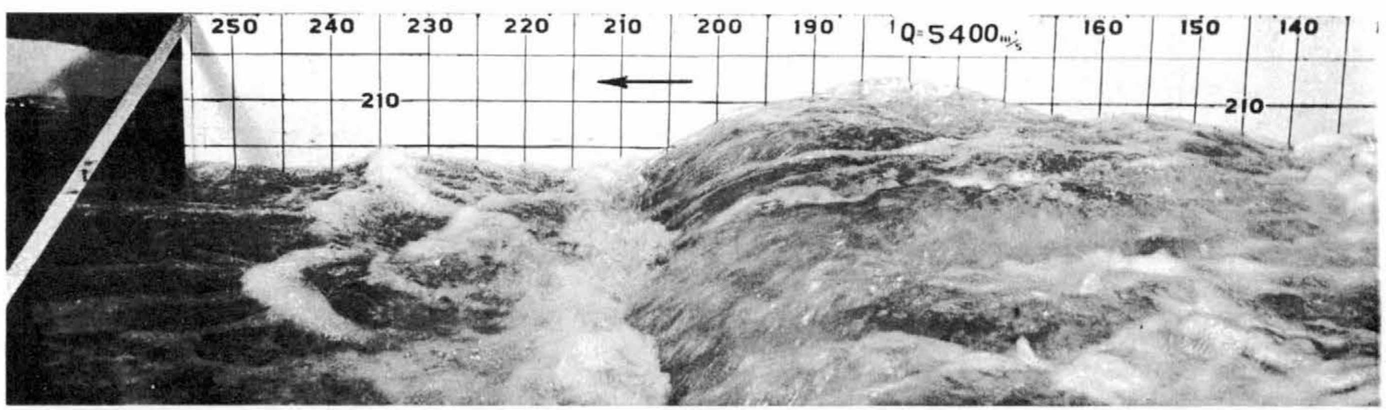
FIG. 7

FIGURE 7

The General Model (scale 1 : 49.2)



A. The Primary Basin



B. The Secondary Basin

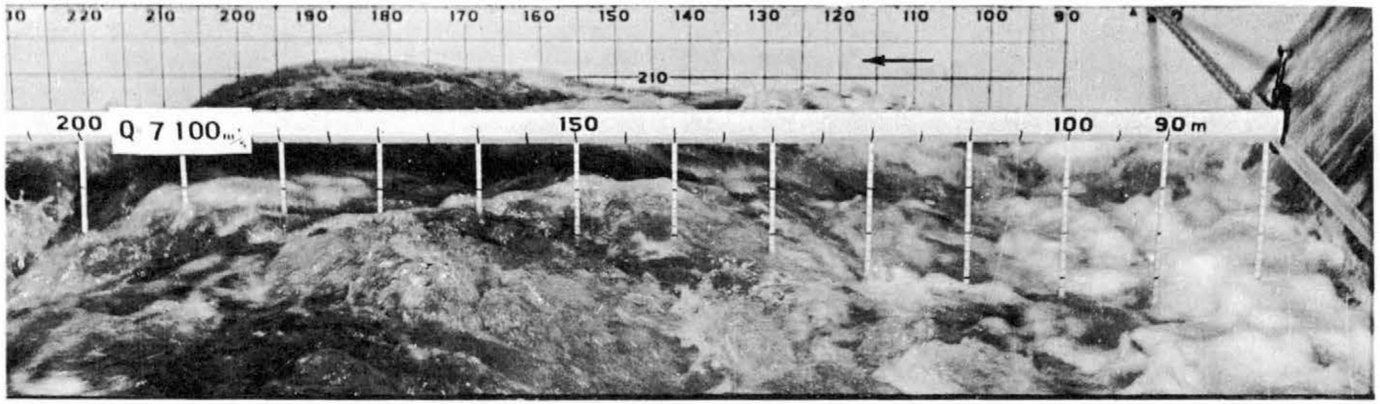
WATER SURFACE PROFILE ALONG RIGHT TRAINING WALL

Stilling Basin Type - II_B (no outlets in secondary dam) Q = 5,400 m^3/s

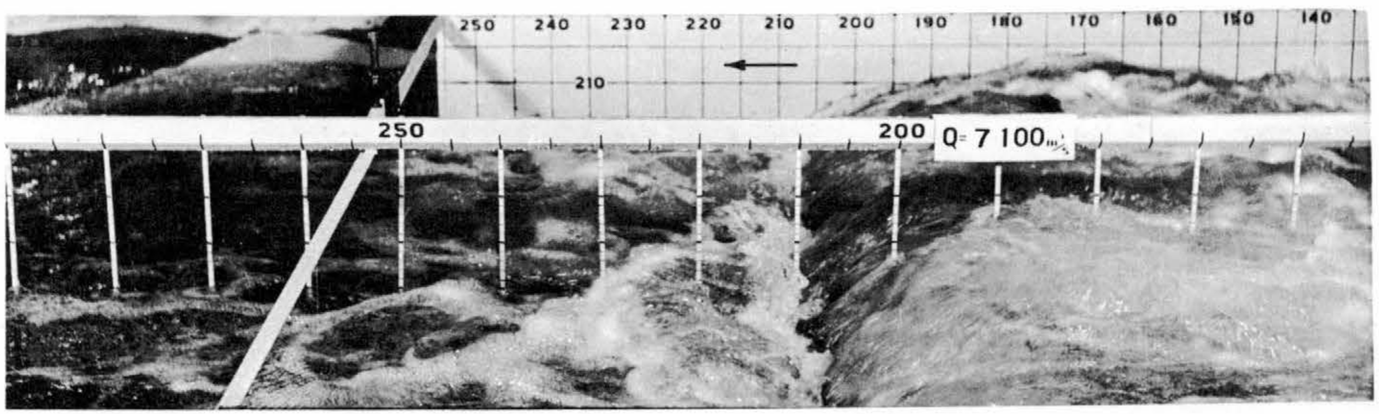
FIG. 8

FIGURE 8

The General Model (scale 1 : 49.2)



A. The Primary Basin



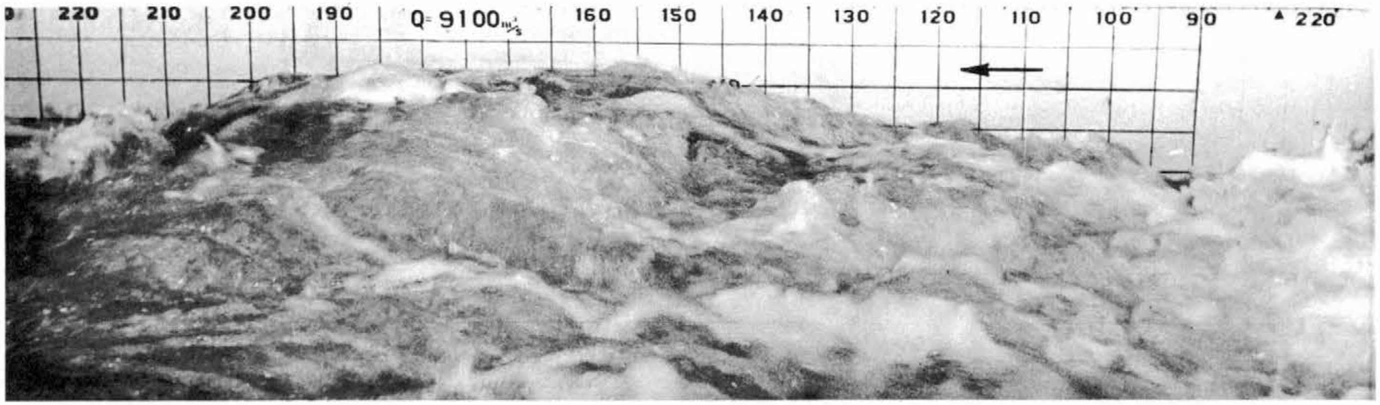
B. The Secondary Basin

WATER SURFACE PROFILE ALONG CENTER LINE OF BASIN
Stilling Basin Type – II_B (no outlets in secondary dam) Q = 7,100 m^3/s

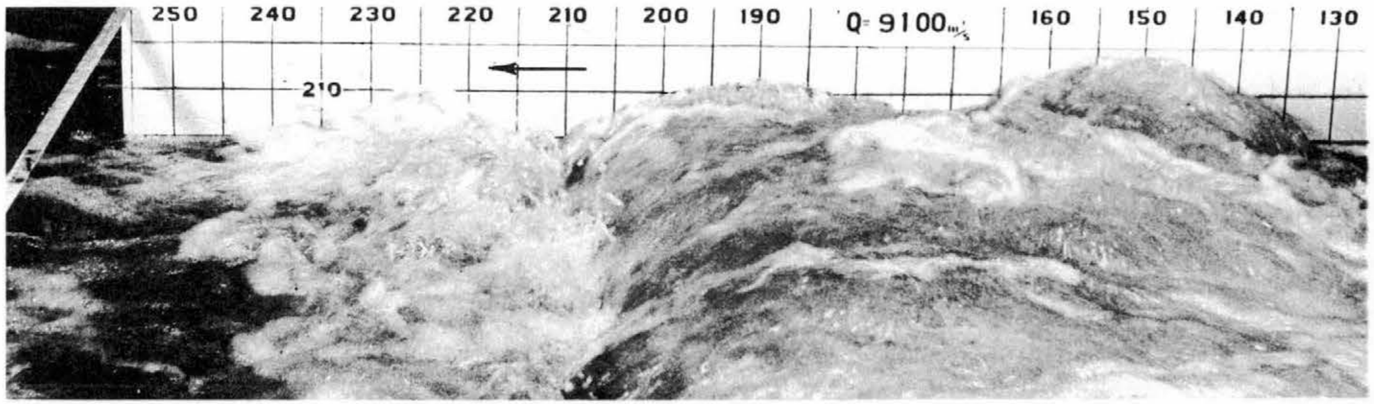
FIG. 9

FIGURE 9

The General Model (scale 1 : 49.2)



A. The Primary Basin



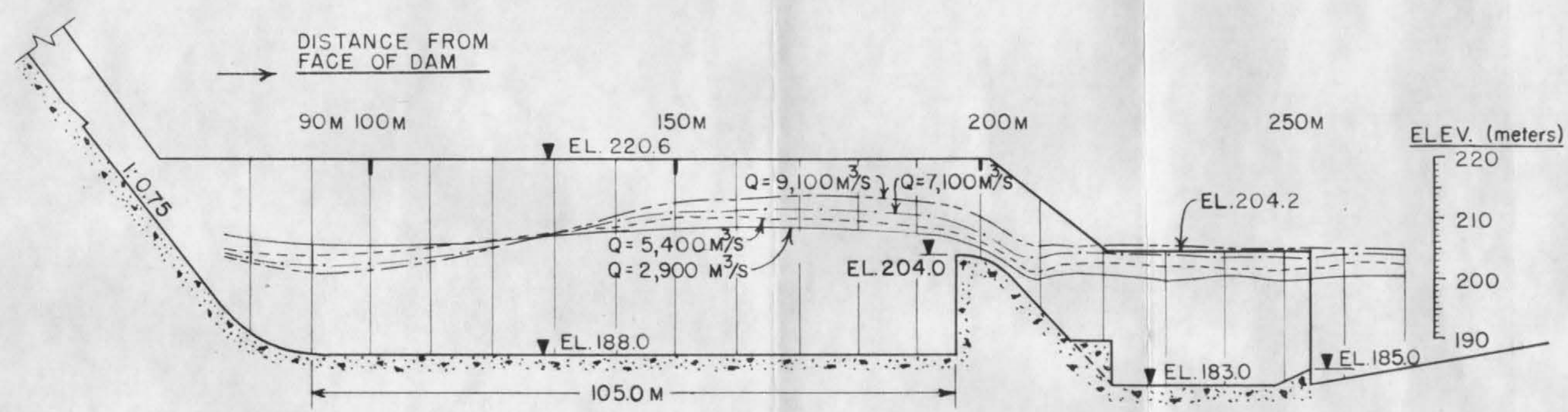
B. The Secondary Basin

WATER SURFACE PROFILE ALONG RIGHT TRAINING WALL

Stilling Basin Type – II_B (no outlets in secondary dam) Q = 9,100 m^3/s

FIG. 10

FIGURE 10



PROFILES ALONG CENTERLINE OF BASIN TYPE II_B
(FINAL DESIGN)

10 5 0 10 20 30 40 50
SCALE (meters)

NOTE:

NO OPENINGS IN SECONDARY DAM. FOR EFFECT OF OPENINGS, REFER TO FIG. 14

LEGEND:

- ——— Q = 2,900 M^3/S
- - - - - - Q = 5,400 M^3/S
- —·— Q = 7,100 M^3/S
- — - - — Q = 9,100 M^3/S

BOCONO DAM MODEL STUDIES	
C.S.U. HYD. LAB.	PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.	

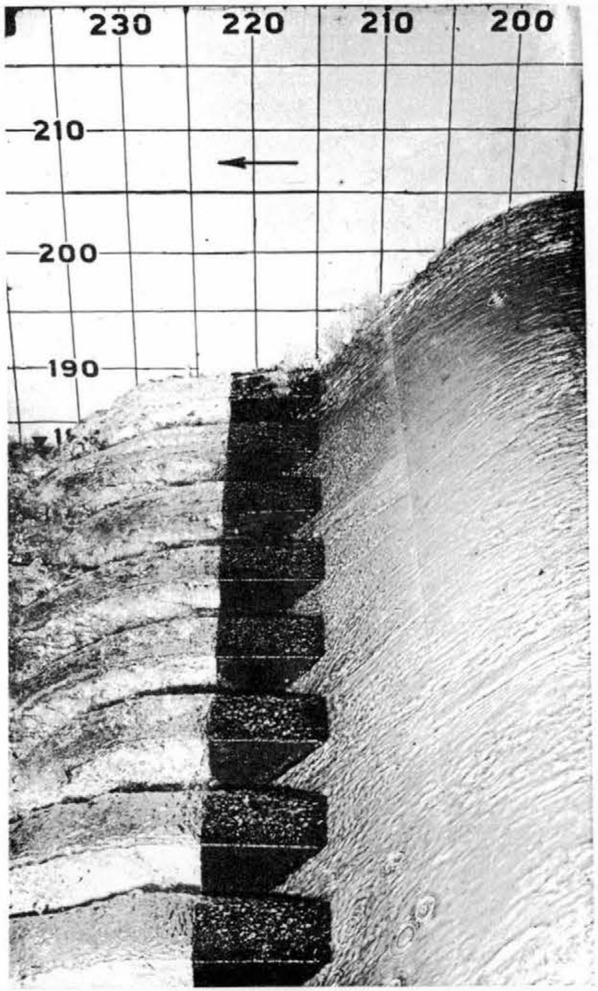
WATER SURFACE PROFILES
IN STILLING BASIN

MODEL SCALE 1:49.2

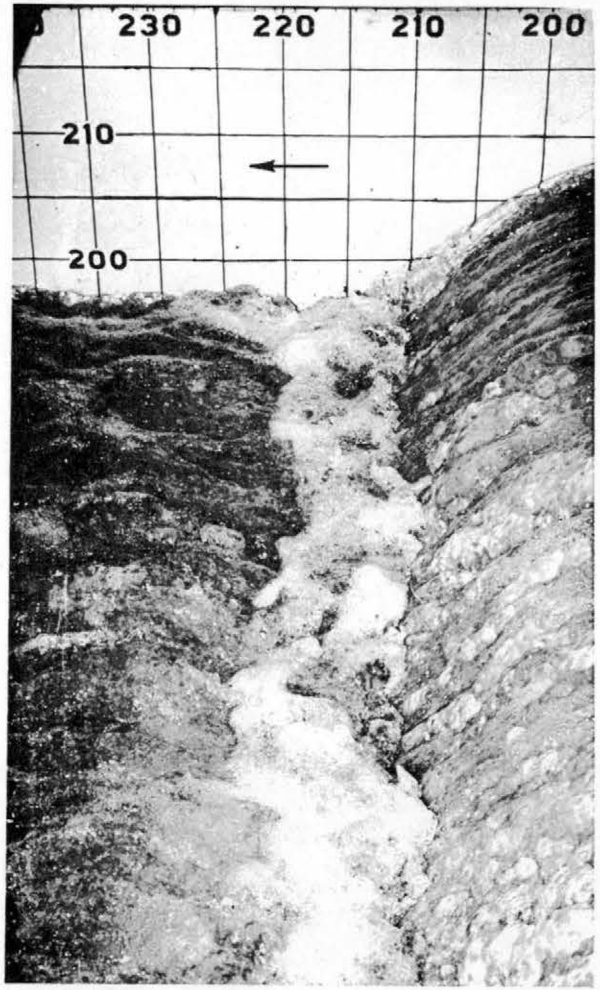
DWN. BY: S.A.& K.S.D.	MAY 9, 1958	NO. S.B.-2

TRCD. BY: R.E.T.

The General Model (scale 1 : 49.2)



A. Unsubmerged



B. Submerged

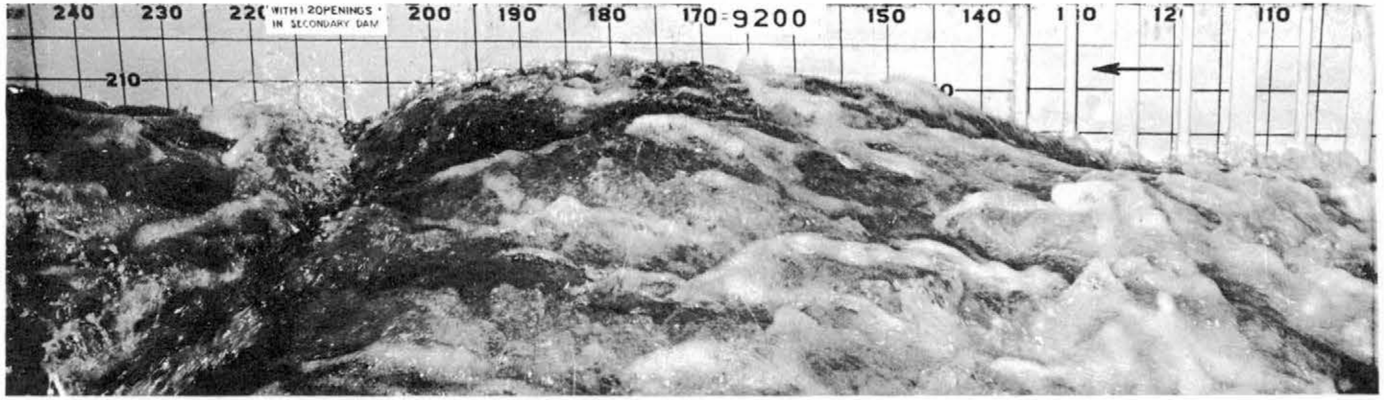
ACTION OF BLOCKS AT TOE OF SECONDARY DAM

Stilling Basin Type – II_B

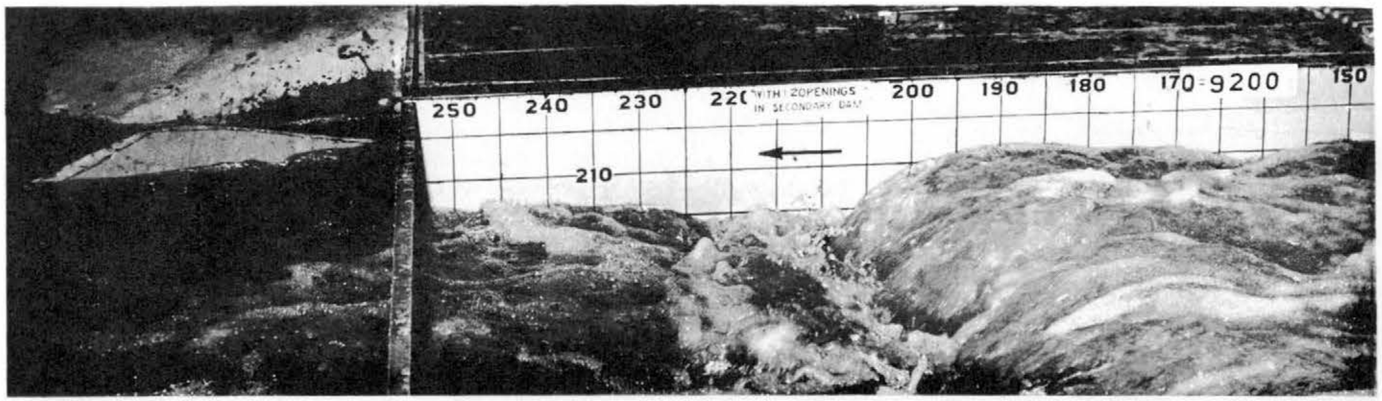
FIG. 12

FIGURE 12

The General Model (scale 1 : 49.2)



A. The Primary Basin



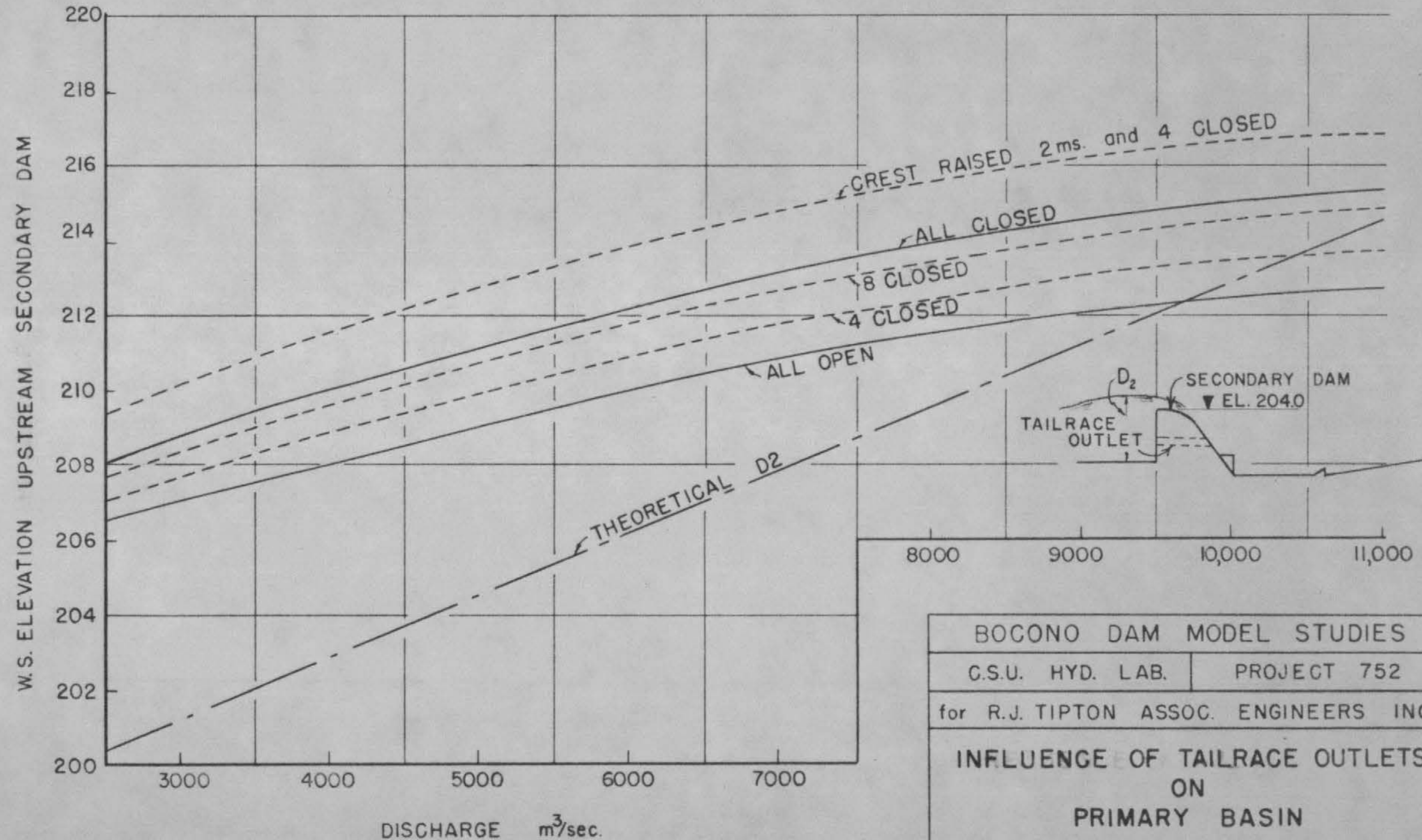
B. The Secondary Basin

WATER SURFACE PROFILE ALONG RIGHT TRAINING WALL

Stilling Basin Type – II_c (12 tailrace outlets in secondary dam) Q = 9,200 m^3/s

FIG. 13

FIGURE 13



BOCONO DAM MODEL STUDIES

C.S.U. HYD. LAB. | PROJECT 752

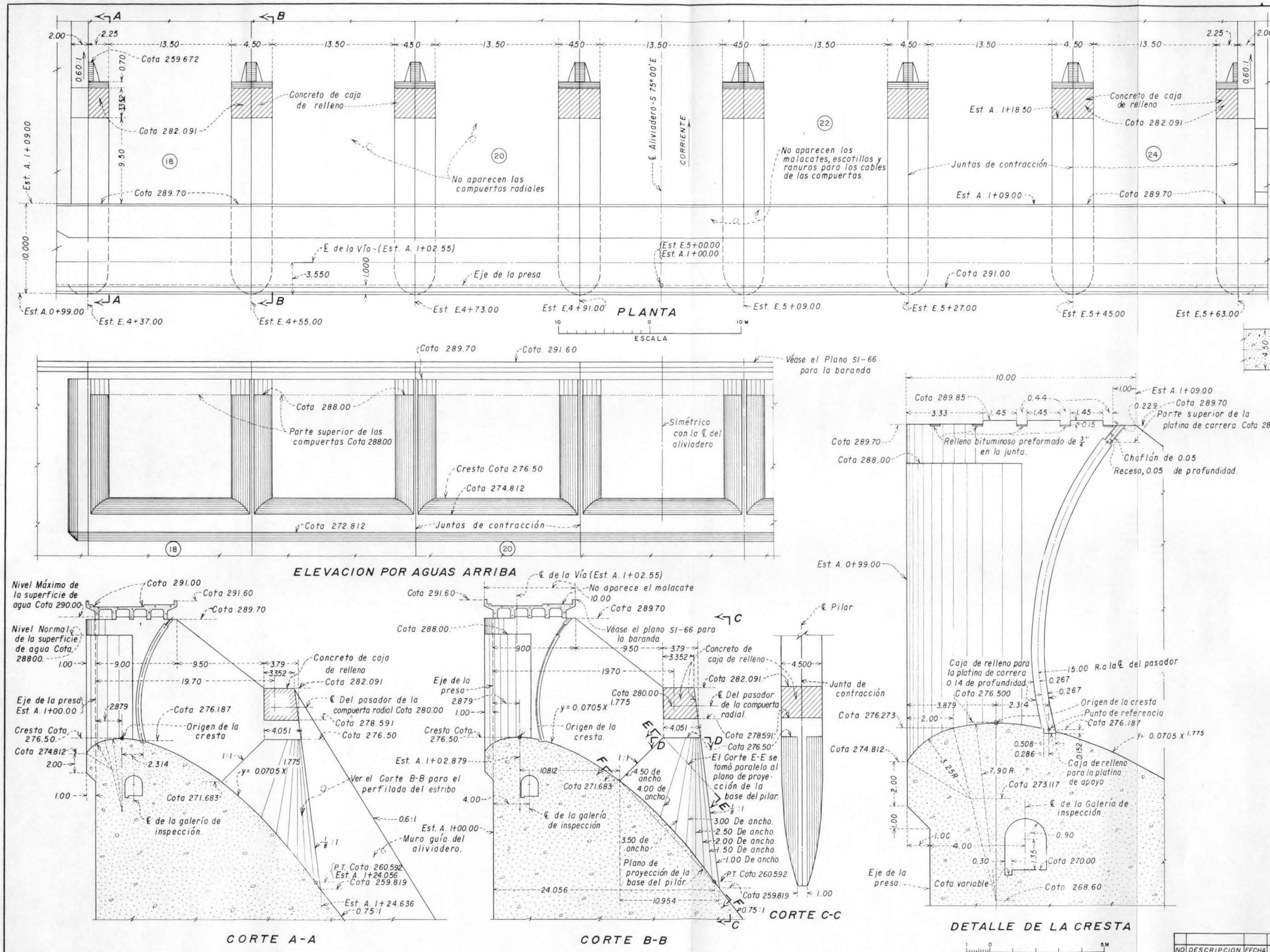
for R.J. TIPTON ASSOC. ENGINEERS INC.

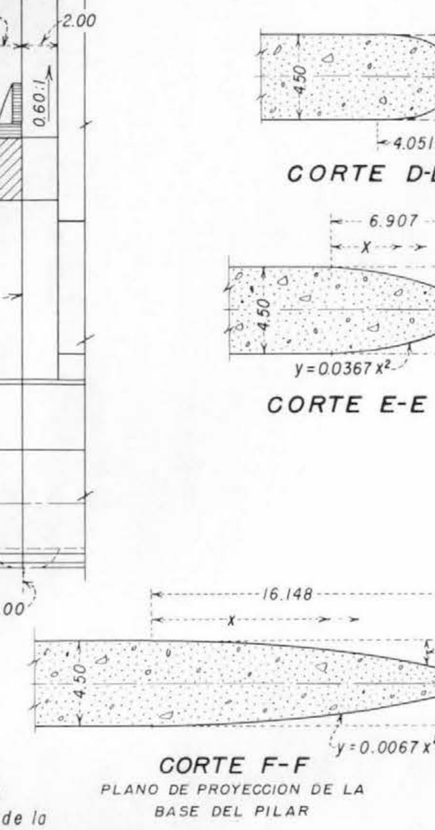
INFLUENCE OF TAILRACE OUTLETS ON PRIMARY BASIN

DWN. BY: M. Sh.A. & K.S.D. | MAY 19, 1958 | NO. S.B.- 3

TRCD. BY: R.E.T.

FIGURE 14





y=0.0367x²	
y	x
0	0
0.250	2.611
0.500	3.692
0.750	4.522
1.000	5.221
1.250	5.838
1.500	6.395
1.750	6.907

y=0.0067x²	
y	x
0	0
0.250	6.103
0.500	8.631
0.750	10.571
1.000	12.207
1.250	13.648
1.500	14.950
1.750	16.148

PLANOS DE REFERENCIA

- PLANO GENERAL SI-20
- DATOS PARA EL REPLANTEO DE LOS MONOLITOS Y DE LAS ESTACIONES SI-22
- PLANO DE EXCAVACION SI-23
- GALERIAS Y CAMARAS VERTICALES PLANTAS Y ELEVACIONES SI-31
- CARATEO Y DRENAJE DE LAS FUNDACIONES PLANTA Y PERFIL
- ALIVIADERO
  - PLANTAS, CORTES Y DETALLES DE LOS PILARES SI-42
  - PLANTA, CORTES Y DETALLES DEL PUENTE SI-43
  - INSTALACION DE LAS COMPUERTAS RADIALES SI-44
  - MURO GUIA IZQUIERO SI-45
  - MURO GUIA DERECHO Y DETALLES DE LOS MONOLITOS 25 A 28 .... SI-46

NOTAS

Las dimensiones y cotas están en metros a menos que se indique lo contrario.

No se indica la magnitud de la contra flecha en el puente. La contra flecha en toda luz del puente, después que se remueva el encofrado, será de 0.04.

Para las Notas Estructurales Generales véase el plano SI-21

NO	DESCRIPCION	FECHA	POR
REVISION			

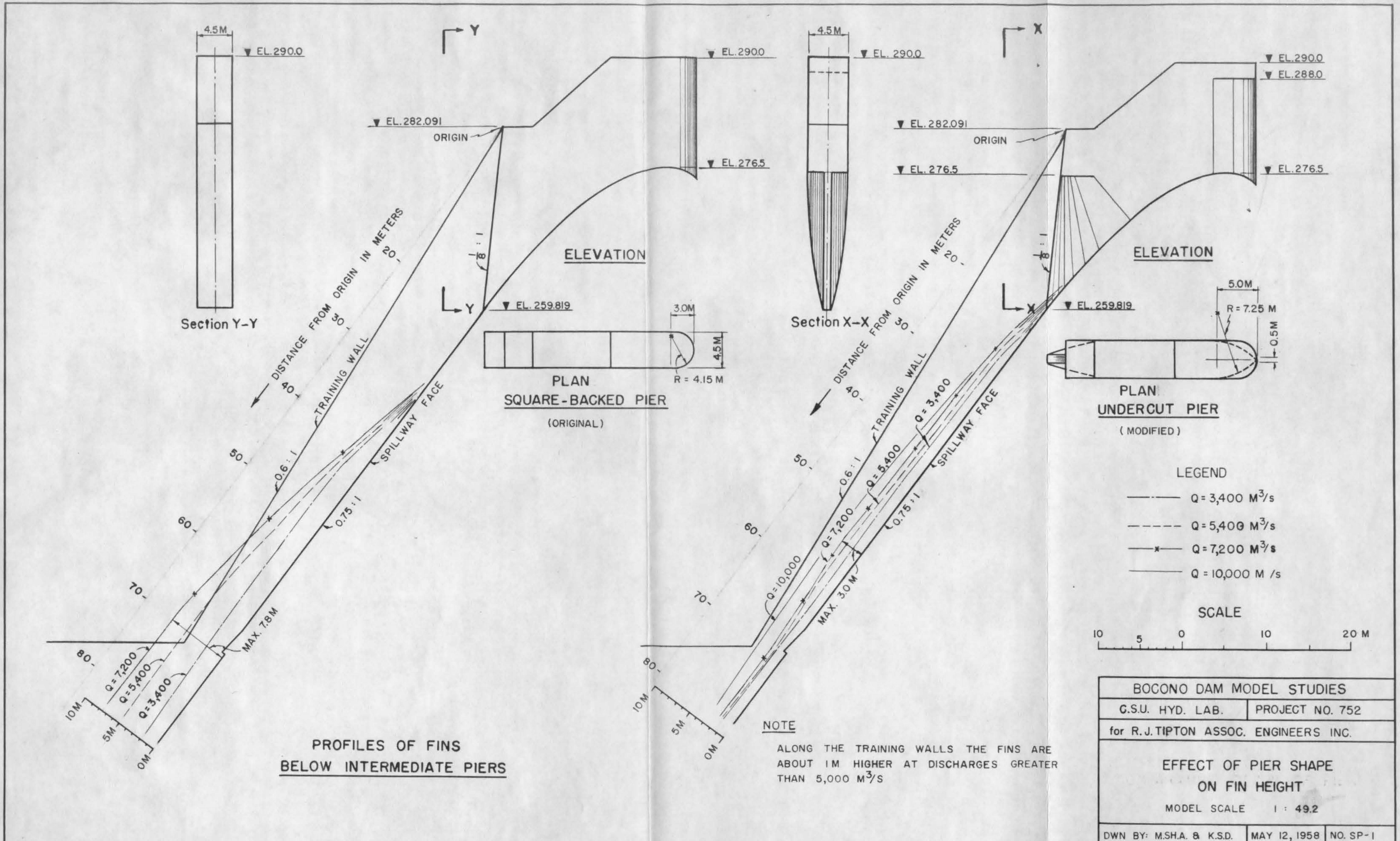
REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS

R. J. TIPTON ASSOCIATED ENGINEERS, INC.

SISTEMA RIOS BOCONO-TUCUPIDO
PRESA BOCONO
ALIVIADERO

CRESTA Y PILARES

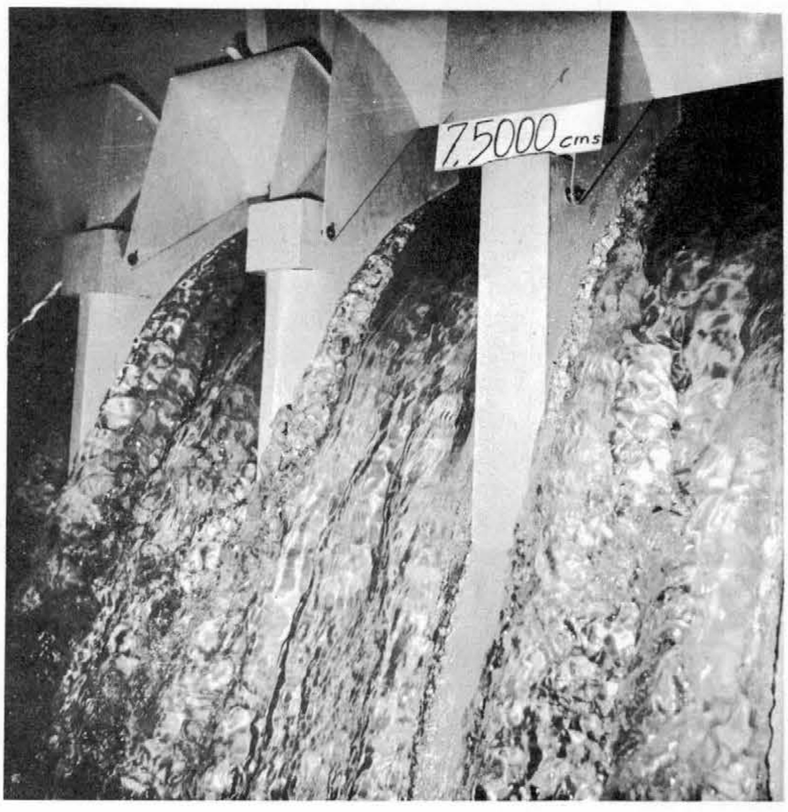
DISEÑO E.T.S.
DIBUJO G.R.C.-L.R.H.
REVISO G.H.A.-F.V.W. BFK
CONFORMO R.J. TIPTON ASSOCIATED ENGINEERS, INC.
APROBO POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.
DENVER, COLORADO SEPTIEMBRE, 1957
HOJA ...... DE ......
E7
SI-41



4.5M
EL. 290.0
Section Y-Y
Y
EL. 282.091
ORIGIN
EL. 276.5
ELEVATION
EL. 259.819
3.0M
4.5M
R = 4.15 M
PLAN
SQUARE-BACKED PIER
(ORIGINAL)
DISTANCE FROM ORIGIN IN METERS
TRAINING WALL
SPILLWAY FACE
0.6 : 1
0.75 : 1
MAX. 7.8M
Q = 7,200
Q = 5,400
Q = 3,400
10M
5M
0M
PROFILES OF FINS
BELOW INTERMEDIATE PIERS
Section X-X
X
EL. 290.0
EL. 288.0
EL. 282.091
ORIGIN
EL. 276.5
ELEVATION
EL. 259.819
5.0M
R = 7.25 M
0.5M
PLAN
UNDERCUT PIER
(MODIFIED)
Q = 10,000
MAX. 3.0 M
LEGEND
Q = 3,400 M³/s
Q = 5,400 M³/s
Q = 7,200 M³/s
Q = 10,000 M /s
SCALE
10 5 0 10 20 M
NOTE
ALONG THE TRAINING WALLS THE FINS ARE ABOUT 1M HIGHER AT DISCHARGES GREATER THAN 5,000 M³/S
BOCONO DAM MODEL STUDIES
C.S.U. HYD. LAB.
PROJECT NO. 752
for R. J. TIPTON ASSOC. ENGINEERS INC.
EFFECT OF PIER SHAPE
ON FIN HEIGHT
MODEL SCALE 1 : 49.2
DWN BY: M.SH.A. & K.S.D.
MAY 12, 1958
NO. SP-1

The General Model (scale 1 : 49.2)

A. Separation below square-backed piers augmented fin formation on spillway face. The smooth joining of flows below undercut piers reduced height of fins.



B. Note smooth merging of flow below undercut pier versus separation below square-backed pier.

COMPARATIVE PERFORMANCE OF SPILLWAY PIERS

Square-backed piers originally proposed, undercut piers developed from model studies.

FIG. 17

The General Model (scale 1 : 49.2)

A. Fins below undercut piers greatly reduced in height.

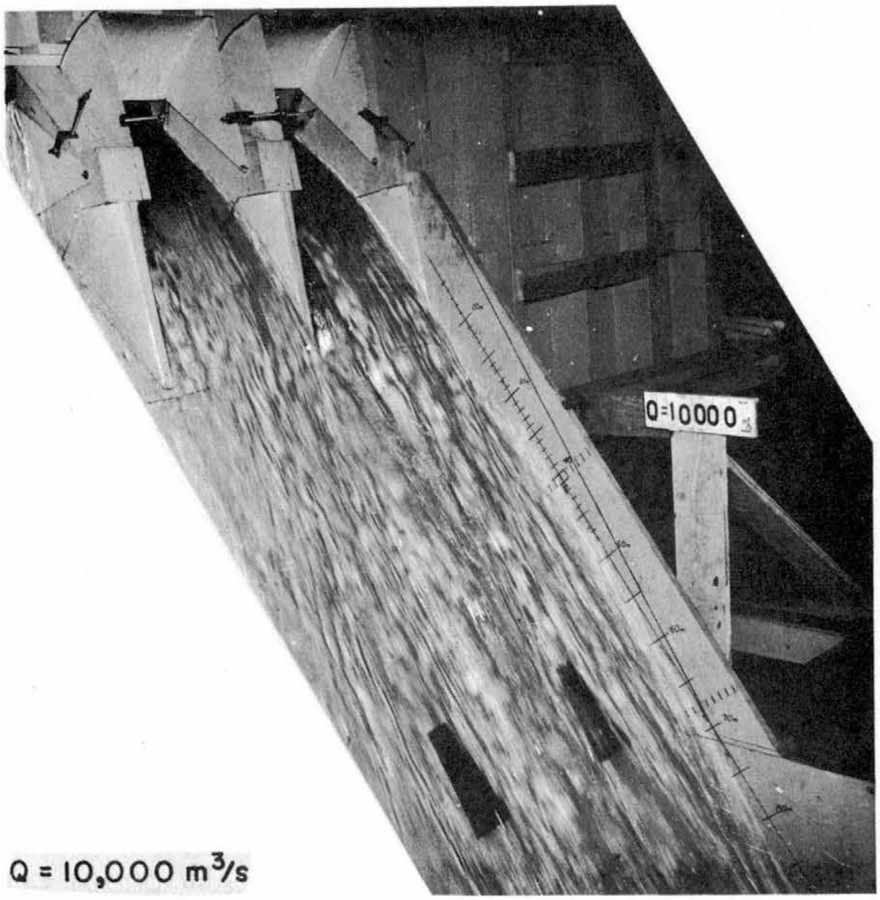
B. Fins below square-backed piers photographed at high speed.

COMPARISON OF FINS FORMED BELOW SQUARE-BACKED AND UNDERCUT PIERS

FIG. 18

FIGURE 18

The General Model (scale 1 : 49.2)



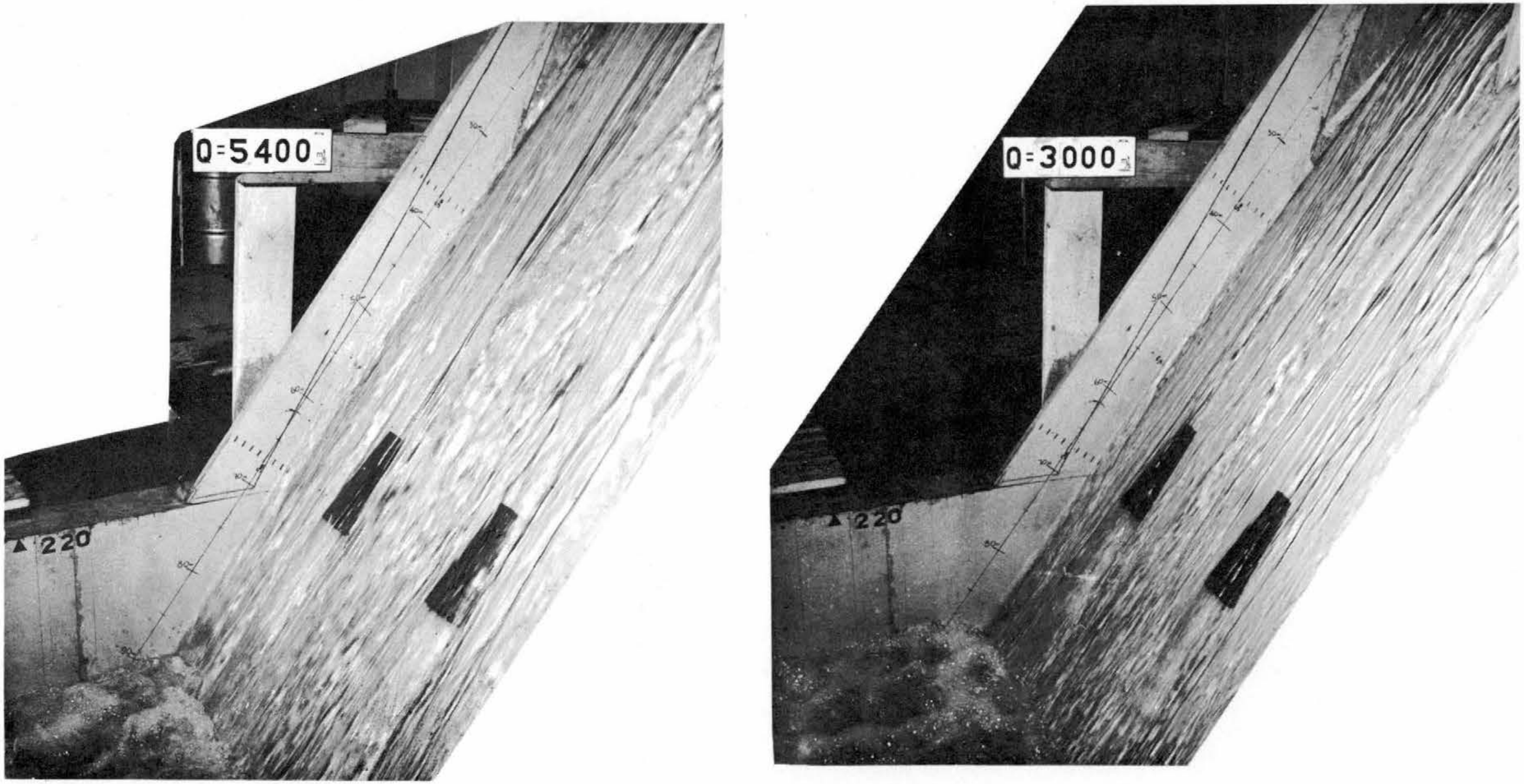
Q = 10,000 m^3/s

FIN FORMATION AT LEFT TRAINING WALL OF SPILLWAY

The average height of fin at the toe of training wall was almost the same as height of training wall (shown by plain black); as the fin oscillated it tended to run up the wall and overtop it.

FIG. 19

The General Model (scale 1 : 49.2)

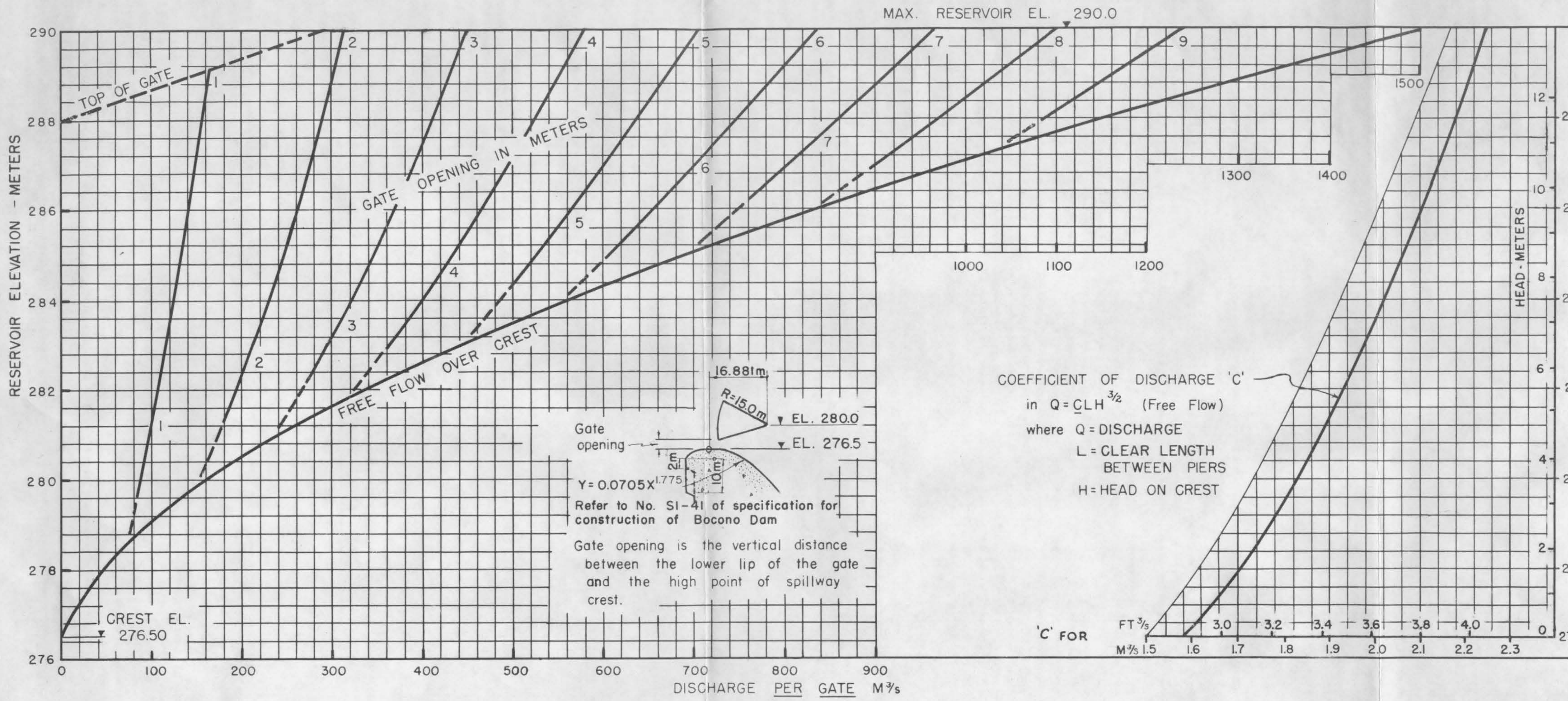


FLOW OVER EYEBROW DEFLECTORS

For discharges ranging from 3,000 to 10,000 m^3/s the flow trajectory over eyebrow deflector cleared the trough of the river outlet and impinged 2 to 10 m downstream of it.

FIG. 20

FIGURE 20



Notes
- Curves are for one gate
- Determine discharge for each gate separately then add to obtain total flow through spillway.
- Gates should be operated symmetrically.
- Rate of rise of gates should be synchronized with the rate of rise of the tail water.

BOCONO DAM MODEL STUDIES	
C.S.U. HYD. LAB.	PROJECT 752
for R. J. TIPTON ASSOC. ENGINEERS INC.	
SPILLWAY RATING CURVES FOR FREE FLOW & PARTIAL OPENINGS MODEL SCALE 1:49.2	
DRAWN M. Sh. A. — DEC. 20, 1957	No. SP.-2

The General Model (scale 1 : 49.2)

EFFECT OF UNSYMMETRICAL SPILLWAY OPERATION ON PRIMARY STILLING BASIN

$Q = 3{,}000\ m^3/s$ (about one-third of design maximum discharge). A large eddy is formed which disrupts stilling action in primary basin. Surges which would erode the channel downstream sweep over the secondary dam.

FIG. 22

FIGURE 22

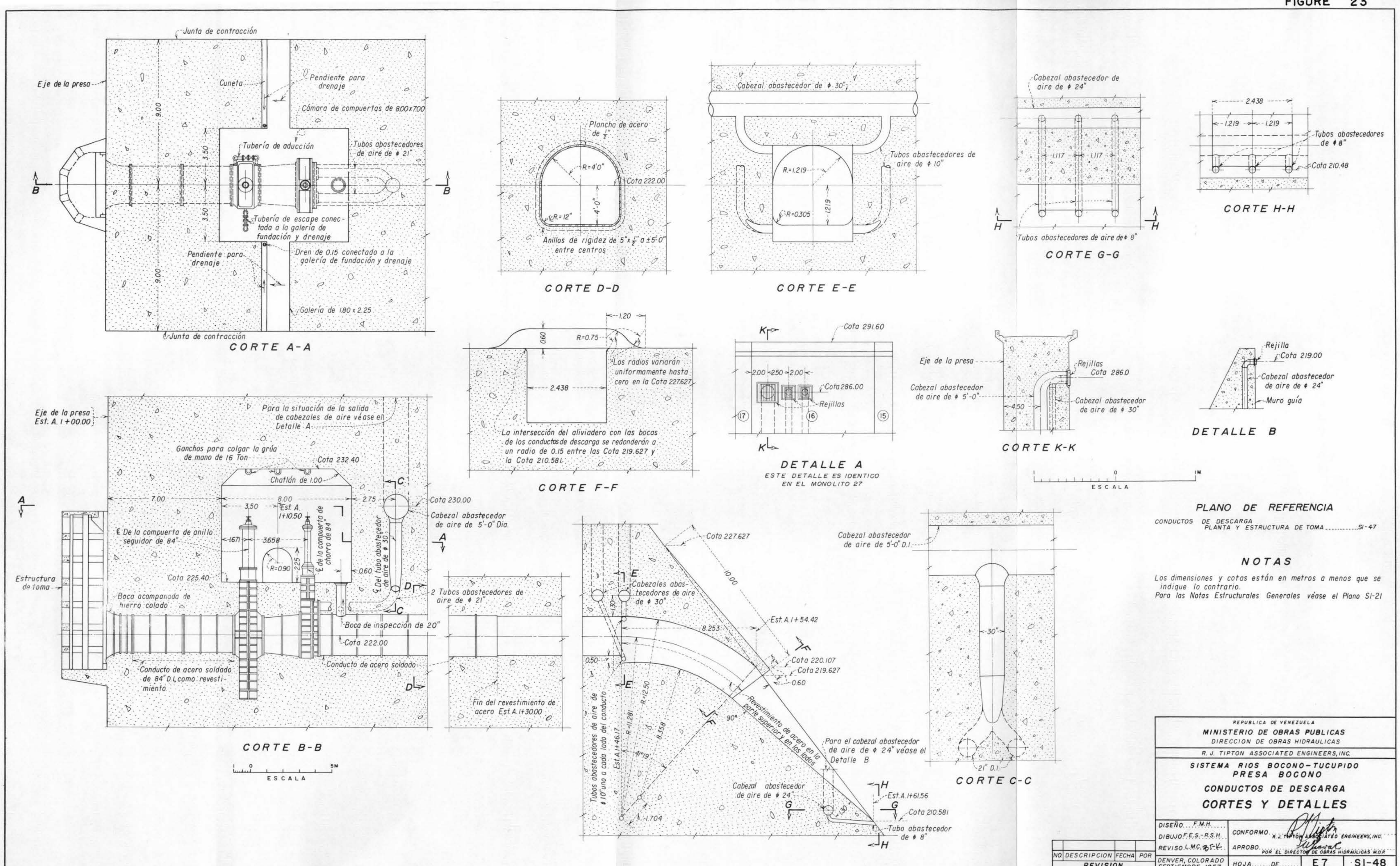
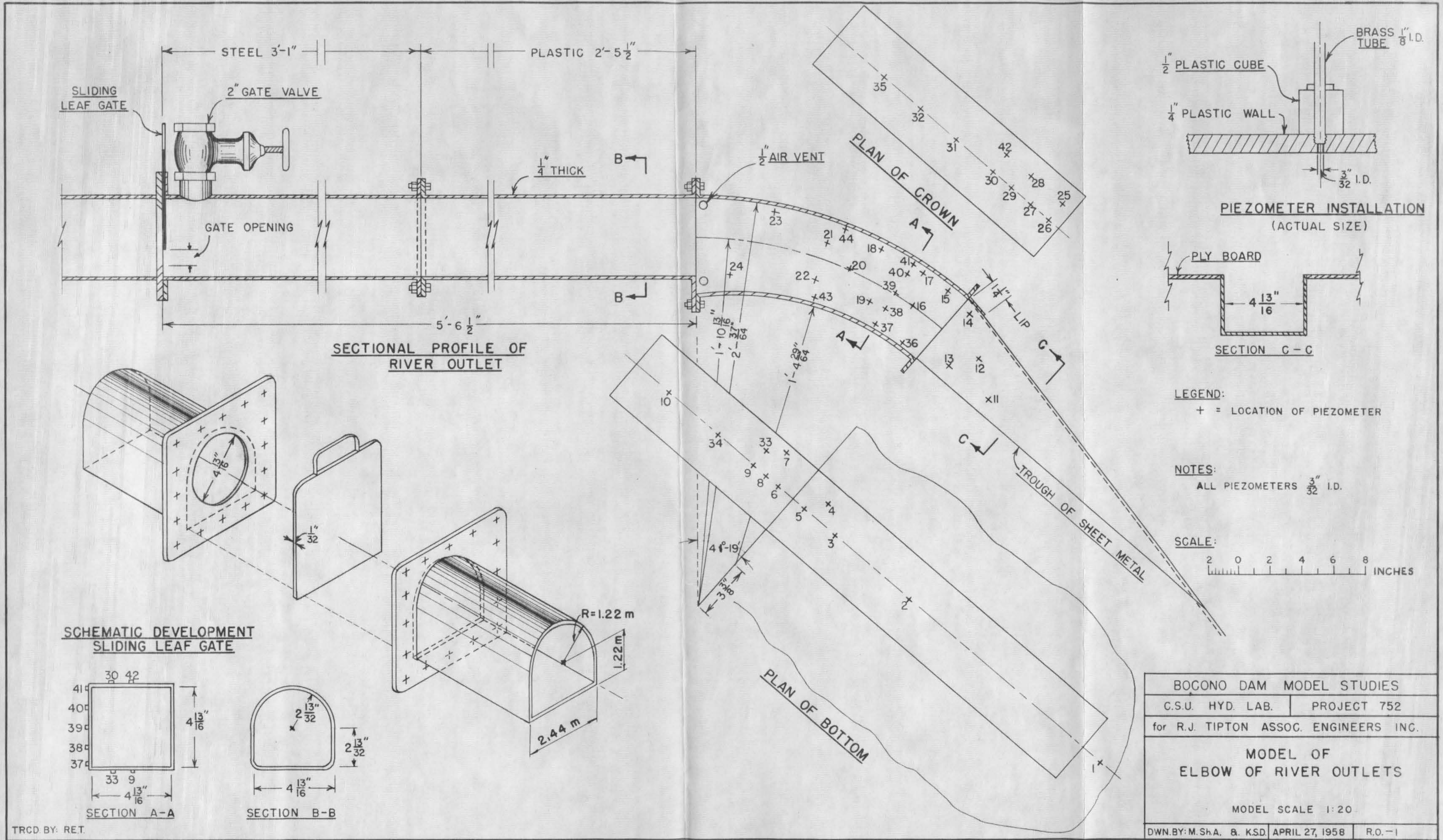
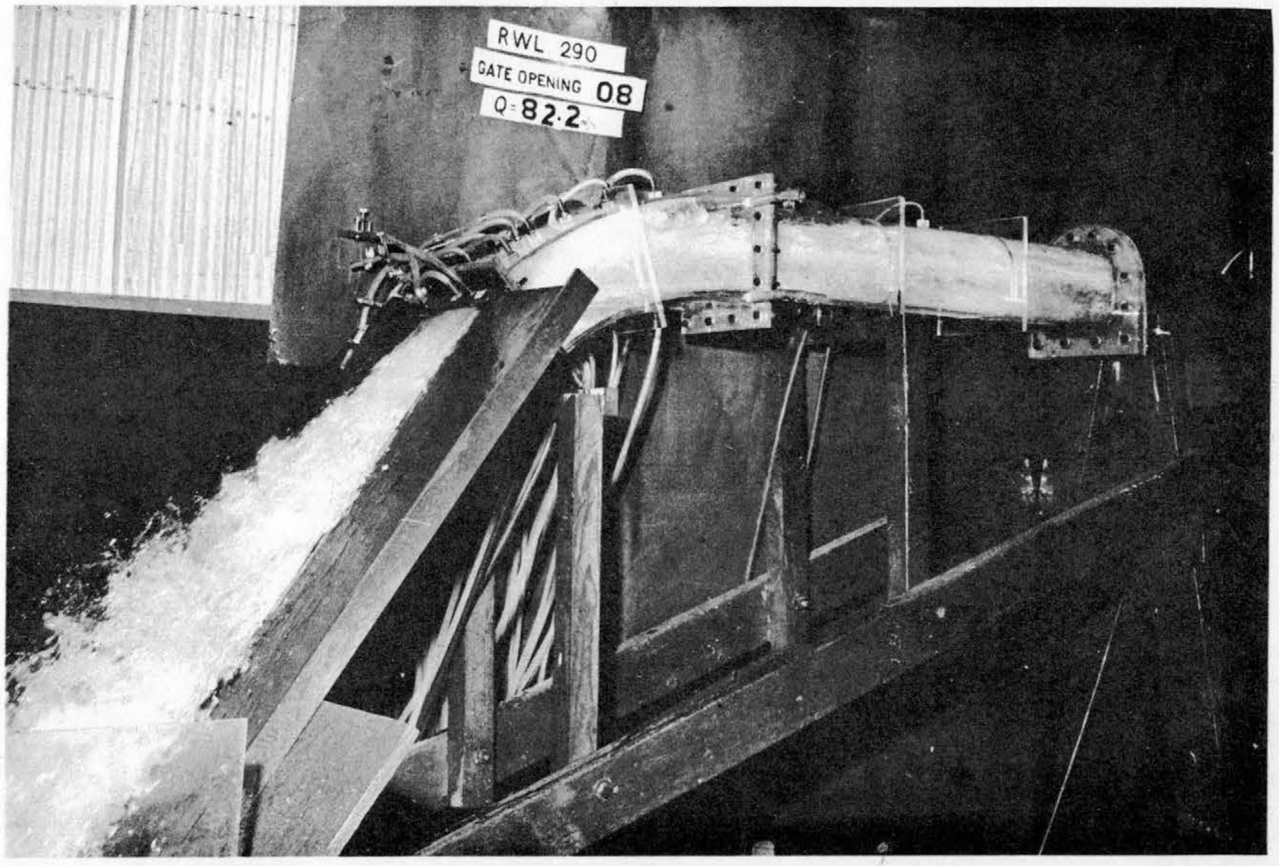


FIGURE 23
Junta de contracción
Eje de la presa
Cuneta
Pendiente para drenaje
Cámara de compuertas de 8.00x7.00
Tubería de aducción
Tubos abastecedores de aire de ϕ 21"
Tubería de escape conectada a la galería de fundación y drenaje
Pendiente para drenaje
Dren de 0.15 conectado a la galería de fundación y drenaje
Galería de 1.80 x 2.25
9.00
3.50
3.50
9.00
CORTE A-A
Plancha de acero de 1/2"
R=4'0"
Cota 222.00
R=12"
4'-0"
Anillos de rigidez de 5"x 1/2" a ±5'-0" entre centros
CORTE D-D
Cabezal abastecedor de ϕ 30"
Tubos abastecedores de aire de ϕ 10"
R=1.219
1.219
R=0.305
CORTE E-E
Cabezal abastecedor de aire de ϕ 24"
1.117
1.117
Tubos abastecedores de aire de ϕ 8"
CORTE G-G
2.438
1.219
1.219
Tubos abastecedores de ϕ 8"
Cota 210.48
CORTE H-H
1.20
0.60
R=0.75
Los radios variarán uniformemente hasta cero en la Cota 227.627
2.438
La intersección del aliviadero con las bocas de los conductos de descarga se redondearán a un radio de 0.15 entre las Cota 219.627 y la Cota 210.581
CORTE F-F
Cota 291.60
2.00
2.50
2.00
Cota 286.00
Rejillas
DETALLE A
ESTE DETALLE ES IDENTICO EN EL MONOLITO 27
Eje de la presa
Cabezal abastecedor de aire de ϕ 5'-0"
Rejillas
Cota 286.0
4.50
Cabezal abastecedor de aire de ϕ 30"
CORTE K-K
ESCALA
Rejilla
Cota 219.00
Cabezal abastecedor de aire de ϕ 24"
Muro guía
DETALLE B
Eje de la presa
Est. A. 1+00.00
Para la situación de la salida de cabezales de aire véase el Detalle A
Ganchos para colgar la grúa de mano de 16 Ton
Cota 232.40
Chaflán de 1.00
7.00
8.00
3.50
Est A. 1+10.50
2.75
Cota 230.00
Cabezal abastecedor de aire de 5'-0" Dia.
℄ De la compuerta de anillo seguidor de 84"
1.671
3.658
℄ de la compuerta de chorro de 84"
℄ Del tubo abastecedor de aire de ϕ 30"
R=0.90
2.25
0.60
Estructura de toma
Cota 225.40
Boca acampanada de hierro colado
2 Tubos abastecedores de aire de ϕ 21"
Boca de inspección de 20"
Cota 222.00
Conducto de acero soldado
Conducto de acero soldado de 84" D.I. como revestimiento
Fin del revestimiento de acero Est. A. 1+30.00
CORTE B-B
ESCALA
Cota 227.627
Cabezales abastecedores de aire de ϕ 30"
10.00
Est. A. 1+54.42
8.253
Cota 220.107
Cota 219.627
0.60
0.50
R=12.50
R=11.281
8.358
Revestimiento de acero en la parte superior y en los lados
90°
Tubos abastecedores de aire de ϕ 10" uno a cada lado del conducto
Est. A. 1+46.17
1.704
Para el cabezal abastecedor de aire de ϕ 24" véase el Detalle B
Cabezal abastecedor de aire de ϕ 24"
Est. A. 1+61.56
Cota 210.581
Tubo abastecedor de ϕ 8"
Cabezal abastecedor de aire de 5'-0" D.I.
30"
21" D.I.
CORTE C-C
PLANO DE REFERENCIA
CONDUCTOS DE DESCARGA PLANTA Y ESTRUCTURA DE TOMA SI-47
NOTAS
Los dimensiones y cotas están en metros a menos que se indique lo contrario.
Para las Notas Estructurales Generales véase el Plano SI-21
REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS
R. J. TIPTON ASSOCIATED ENGINEERS, INC.
SISTEMA RIOS BOCONO-TUCUPIDO
PRESA BOCONO
CONDUCTOS DE DESCARGA
CORTES Y DETALLES
DISEÑO F.M.H.
DIBUJO F.E.S.-R.S.H.
REVISO L.M.C.
CONFORMO R. J. TIPTON ASSOCIATED ENGINEERS, INC.
APROBO POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.
NO DESCRIPCION FECHA POR
REVISION
DENVER, COLORADO SEPTIEMBRE, 1957
HOJA ... DE ...
E7
SI-48

FIGURE 24


STEEL 3'-1"
PLASTIC 2'-5 1/2"
SLIDING LEAF GATE
2" GATE VALVE
1/4" THICK
B
1/2" AIR VENT
GATE OPENING
5'-6 1/2"
SECTIONAL PROFILE OF RIVER OUTLET
PLAN OF CROWN
PLAN OF BOTTOM
A
C
LIP
1 1/4"
TROUGH OF SHEET METAL
1'-10 13/16"
2'-3 37/64"
1'-4 29/64"
41°-19'
3 5/8"
R=1.22 m
1.22 m
2.44 m
1/32"
4 13/16"
SCHEMATIC DEVELOPMENT SLIDING LEAF GATE
SECTION A-A
SECTION B-B
2 13/32"
BRASS TUBE 1/8" I.D.
1/2" PLASTIC CUBE
1/4" PLASTIC WALL
3/32" I.D.
PIEZOMETER INSTALLATION
(ACTUAL SIZE)
PLY BOARD
SECTION C-C
LEGEND:
+ = LOCATION OF PIEZOMETER
NOTES:
ALL PIEZOMETERS 3/32" I.D.
SCALE:
2 0 2 4 6 8 INCHES
BOCONO DAM MODEL STUDIES
C.S.U. HYD. LAB.
PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.
MODEL OF ELBOW OF RIVER OUTLETS
MODEL SCALE 1:20
DWN. BY: M.Sh.A. & K.S.D.
APRIL 27, 1958
R.O.-1
TRCD. BY: R.E.T.

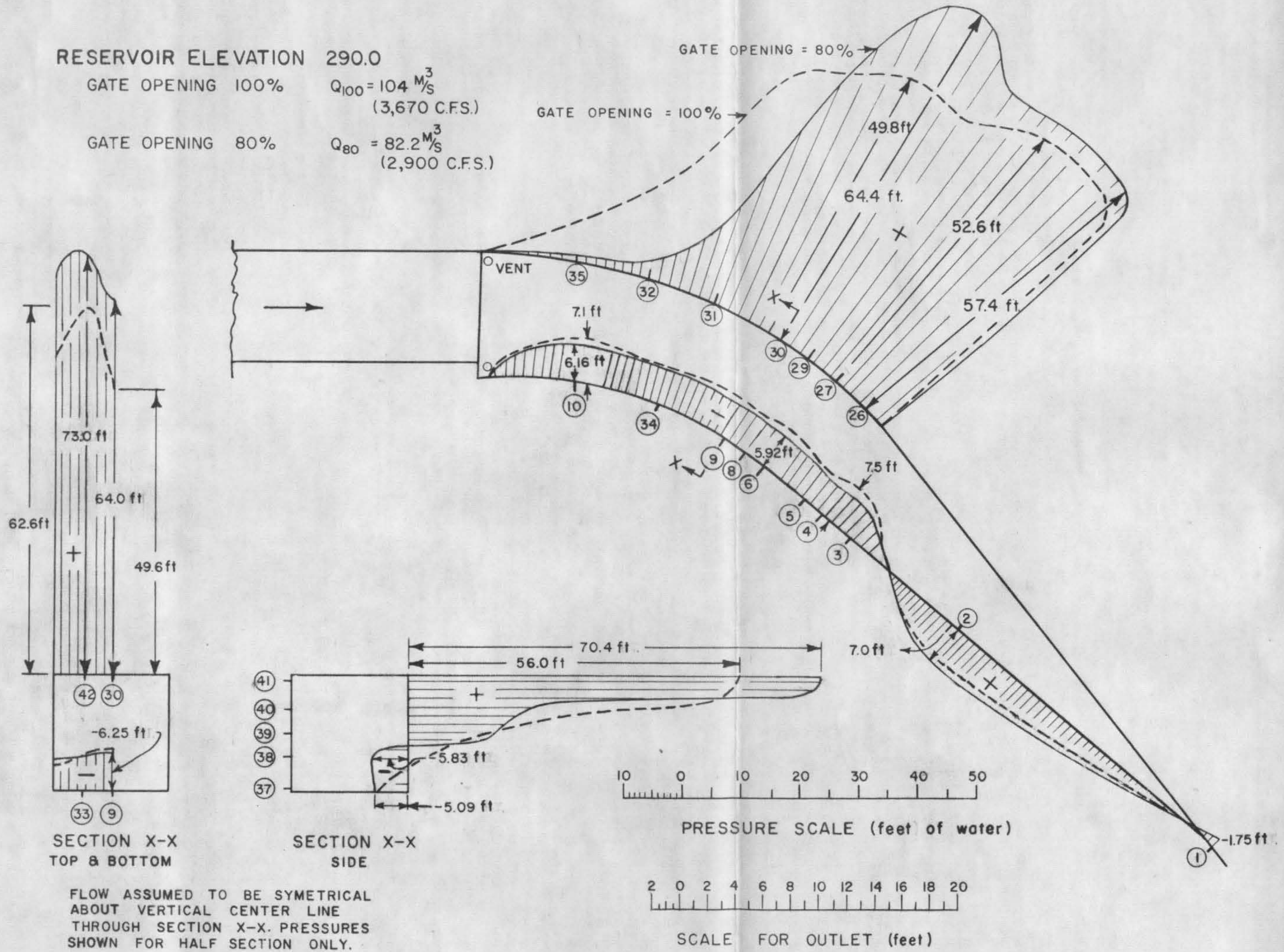


GENERAL VIEW OF MODEL OF RIVER OUTLETS (scale 1 : 20)

The discharge was controlled by a sliding gate representing the 84" diameter jet-flow gate on the prototype. It is located upstream and not seen in this photograph.

FIG. 25

FIGURE 26



LEGEND:

- (31) = NUMBER OF PIEZOMETER
- + = PRESSURES ABOVE ATMOSPHERIC
- − = PRESSURES BELOW ATMOSPHERIC
- – – – = PRESSURES FOR GATE OPENING = 100%
- ——— PRESSURES FOR GATE OPENING = 80%
- Q_{100} = DISCHARGE FOR 100% GATE OPENING
- Q_{80} = DISCHARGE FOR 80% GATE OPENING

NOTES:

1. DISCHARGE FOR JET-FLOW GATE COMPUTED FROM $Q = 0.8A\sqrt{2gh}$.
2. ALL VENT OPENINGS REPRODUCED TO SCALE. THEY WERE FULLY OPEN DURING THESE TESTS.
3. PRESSURES ON CROWN AND BOTTOM OF ELBOW WERE MEASURED ALONG THE CENTER LINE.

TRCD. BY: R.E.T.

BOCONO DAM MODEL STUDIES	
C.S.U. HYD. LAB.	PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.	

PRESSURE DISTRIBUTION IN ELBOW OF RIVER OUTLETS

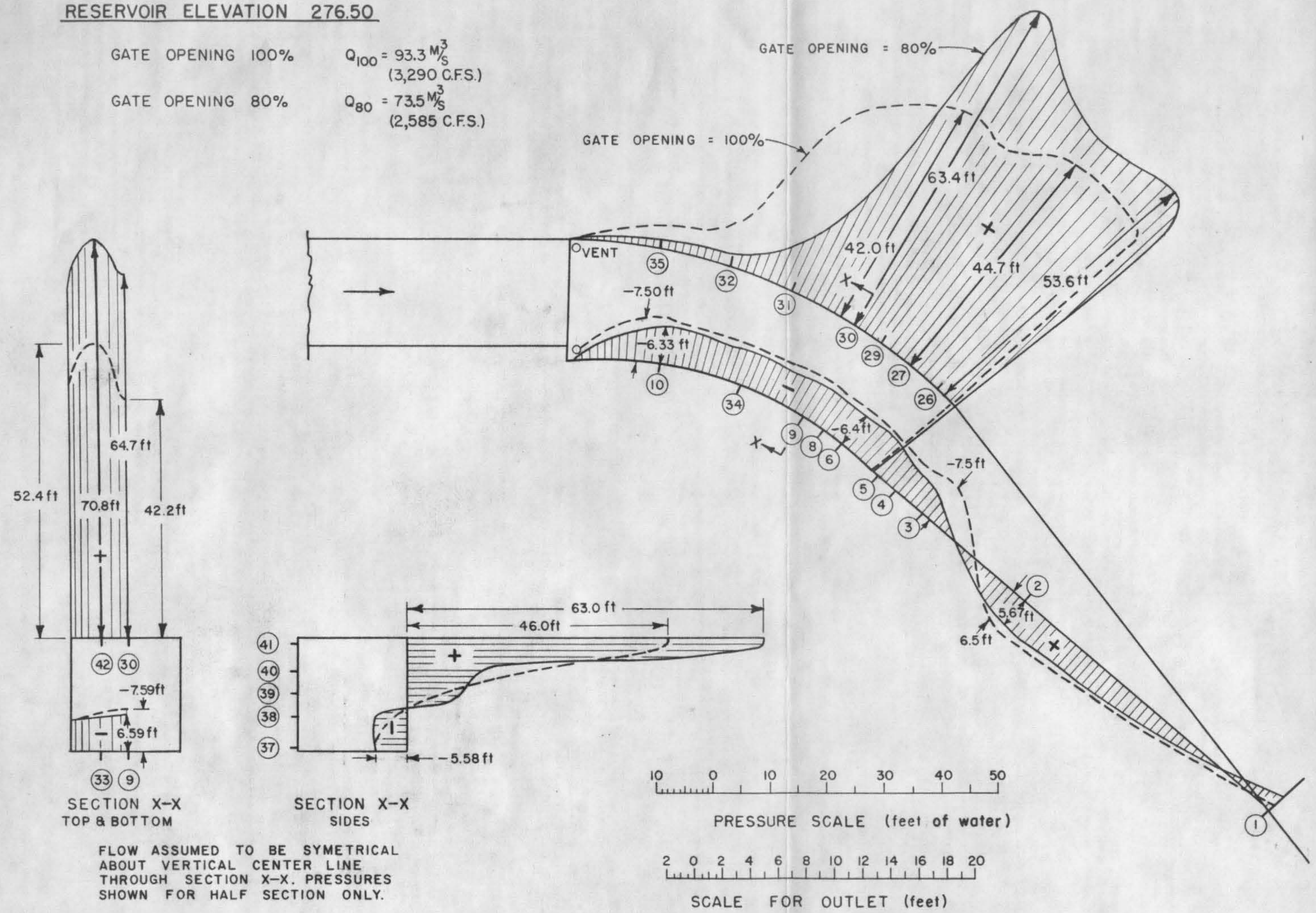
RWL = 290.0
MODEL SCALE 1:20

DWN. BY: M. Sh. A. & K.S.D.	MARCH 5, 1958	NO. R.O-2

RESERVOIR ELEVATION 276.50

GATE OPENING 100% $Q_{100} = 93.3\ M^3/S$ (3,290 C.F.S.)

GATE OPENING 80% $Q_{80} = 73.5\ M^3/S$ (2,585 C.F.S.)



FLOW ASSUMED TO BE SYMETRICAL ABOUT VERTICAL CENTER LINE THROUGH SECTION X–X. PRESSURES SHOWN FOR HALF SECTION ONLY.

LEGEND:

- (31) = NUMBER OF PIEZOMETER
- + = PRESSURES ABOVE ATMOSPHERIC
- − = PRESSURES BELOW ATMOSPHERIC
- – – – = PRESSURES FOR GATE OPENING = 100%
- —— = PRESSURES FOR GATE OPENING = 80%
- Q_{100} = DISCHARGE FOR 100% GATE OPENING
- Q_{80} = DISCHARGE FOR 80% GATE OPENING

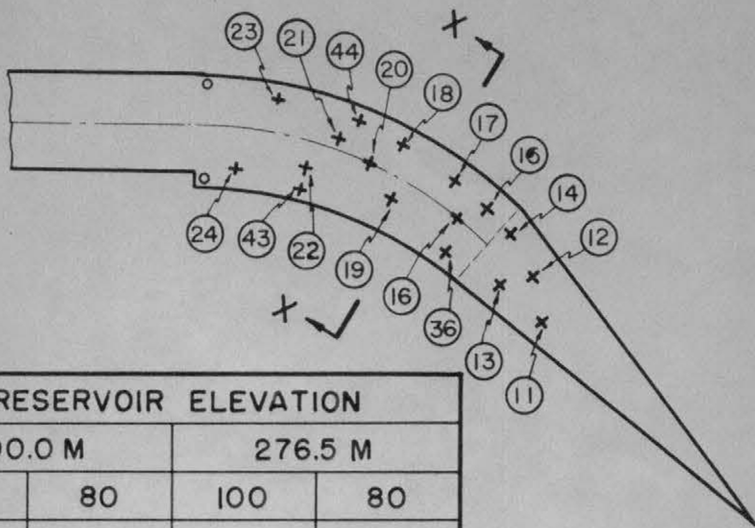
NOTES:

1. DISCHARGE FOR JET-FLOW GATE COMPUTED FROM $Q = 0.8A\sqrt{2gh}$
2. ALL VENT OPENINGS REPRODUCED TO SCALE. THEY WERE FULLY OPEN DURING THESE TESTS.
3. PRESSURES ON CROWN AND BOTTOM OF ELBOW WERE MEASURED ALONG THE CENTER LINE.

BOCONO DAM MODEL STUDIES	
C.S.U. HYD. LAB.	PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.	
PRESSURE DISTRIBUTION IN ELBOW OF RIVER OUTLETS RWL = 276.50 MODEL SCALE 1:20	
DWN. BY: M. Sh. A. & K.S.D. MARCH 12, 1958	NO. R.O.–3

TRCD. BY: R.E.T.

TABLE I

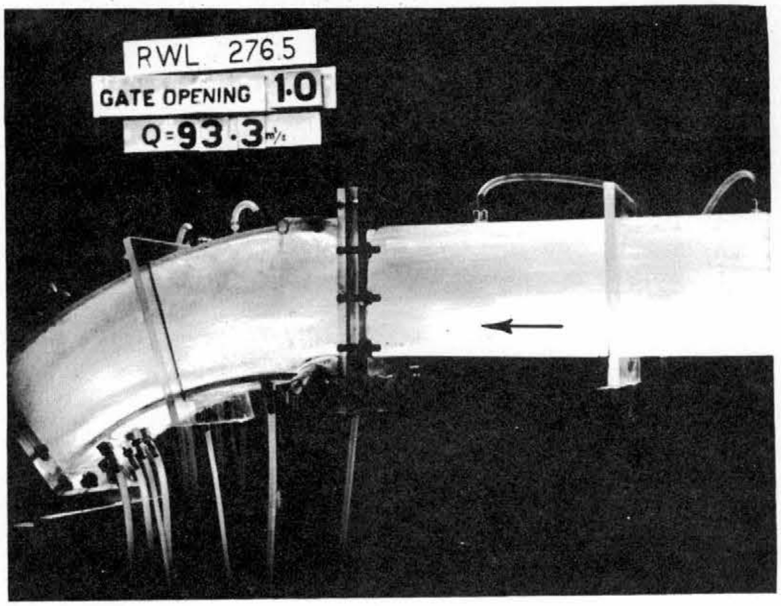


		RESERVOIR ELEVATION			
		290.0 M		276.5 M	
GATE OPENING %		100	80	100	80
DISCHARGE M^3/S		104.0	82.2	93.3	73.5
		PRESSURE IN FEET OF WATER			
PIEZOMETER NUMBER	11	− 9.1	− 7.3	− 8.9	− 7.6
	12	−12.7	−17.6	−12.2	−15.7
	13	+ 5.3	− 0.8	+ 3.3	+ 2.5
	14	+18.0	+ 7.0	+15.5	+ 7.8
	15	+51.7	+61.0	+46.1	+57.3
	16	+ 6.3	+ 7.8	+ 3.8	+ 4.3
	17	+48.2	+53.3	+43.4	+48.0
	18	+ 4.0	+22.2	+32.5	+ 5.5
	19	+ 1.3	− 3.8	+ 0.8	− 4.3
	20	+15.6	+ 6.4	+12.2	+ 1.8
	21	+15.0	+ 2.2	+18.8	+ 0.3
	22	+ 3.0	− 1.3	+ 1.3	− 2.3
	23	+ 6.7	− 6.2	+ 4.0	0.0
	24	+ 2.5	− 3.8	− 3.5	− 4.8
	36	− 3.3	− 5.3	− 3.0	− 5.5
	43	− 6.3	− 5.8	− 6.3	− 5.9
	44	+30.4	+ 4.5	+1.6.7	+ 0.1

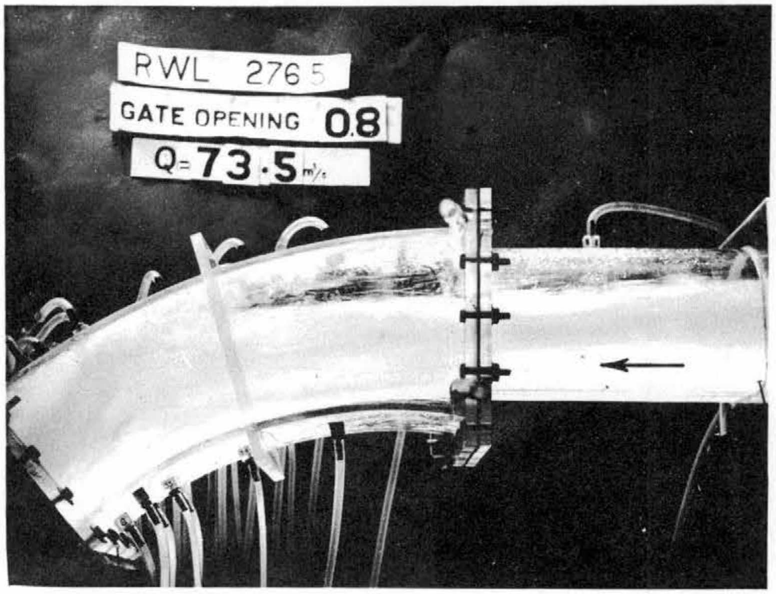
PRESSURE DISTRIBUTION ON THE SIDES OF THE ELBOW

M.Sh.A./K.S.D.

Model of River Outlets (scale 1 : 20)



A. Flow in elbow impinged along crown; it separated from lower boundary due to vents at bottom of stepped junction.



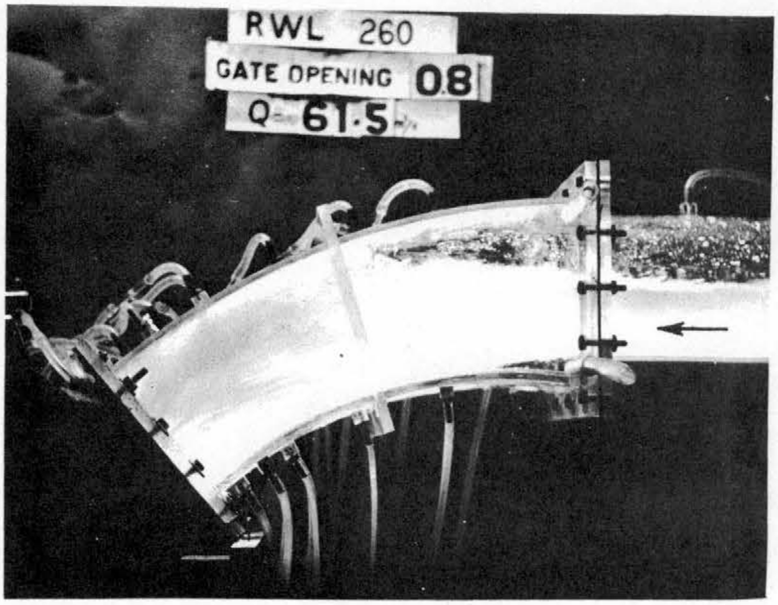
B. Conduit flowing partly full. Note concentration of flow at lower region of crown.

FLOW PATTERN IN ELBOW OF RIVER OUTLET RWL 276.5

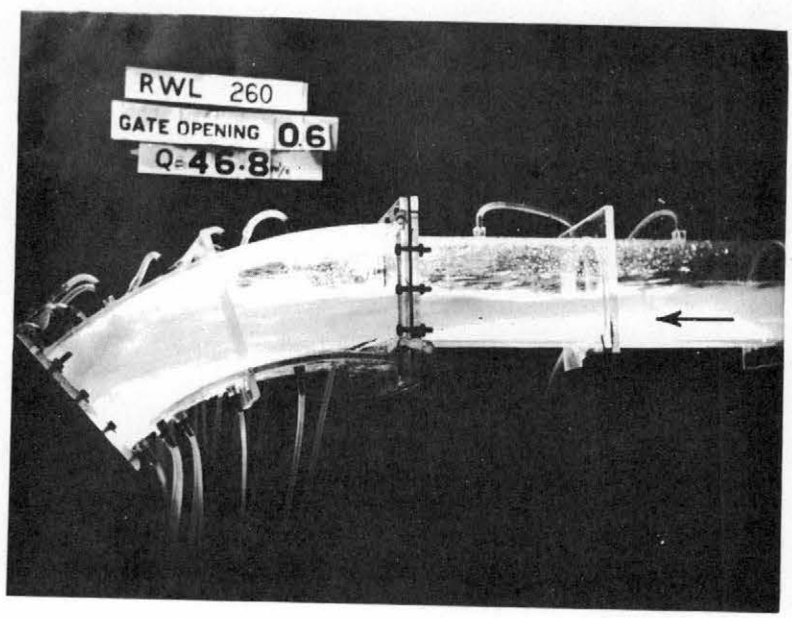
Discharges corresponding to reservoir surface at El. 276.5, the elevation of the spillway crest.

FIG. 29

Model of River Outlet (scale 1 : 20)



A. Conduit flowing partly full. Note separation from lower boundary at stepped junction which is vented at top and bottom.



B. Jet from conduit kept free from invert of elbow and impinged directly on crown of elbow.

FLOW PATTERN IN ELBOW OF RIVER OUTLET RWL 260.0

This flow pattern may be considered typical for discharges with reservoir level below spillway crest.

FIG. 30

RWL 290.0

GATE OPENING = 100%

Q_{100} = 104.0 M^3/S
(3,670 C.F.S.)

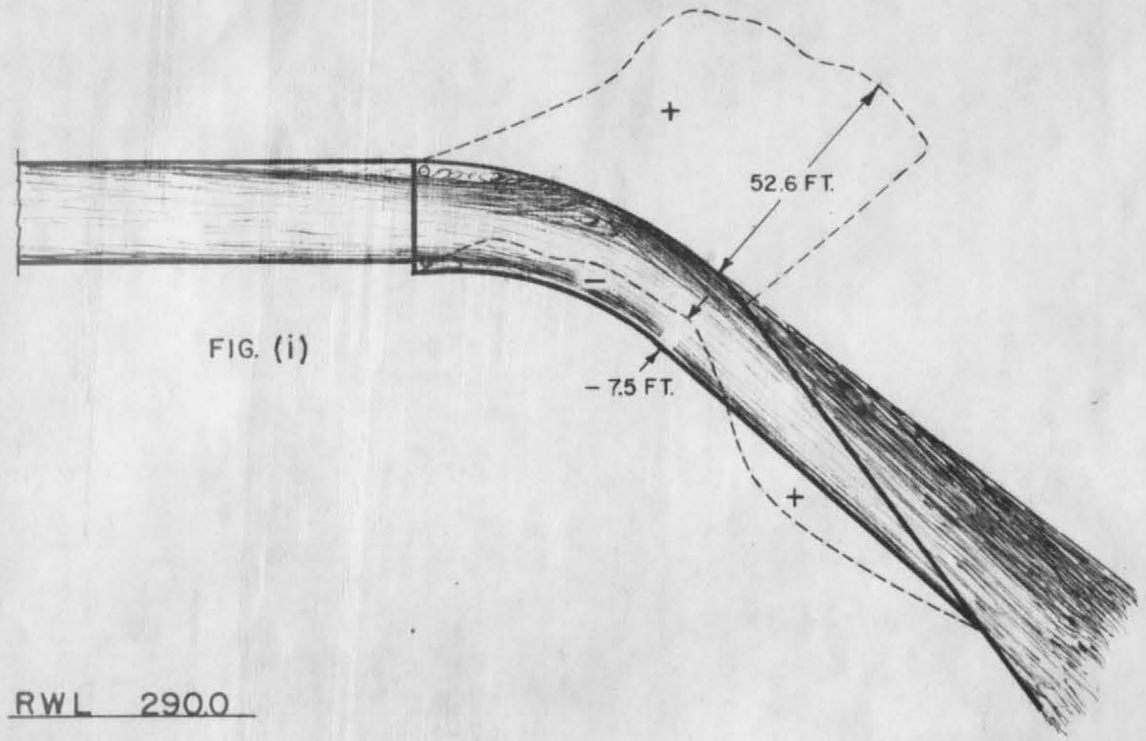


FIG. (i)

RWL 276.5

GATE OPENING = 100%

Q_{100} = 93.3 M^3/S
(3,290 C.F.S.)

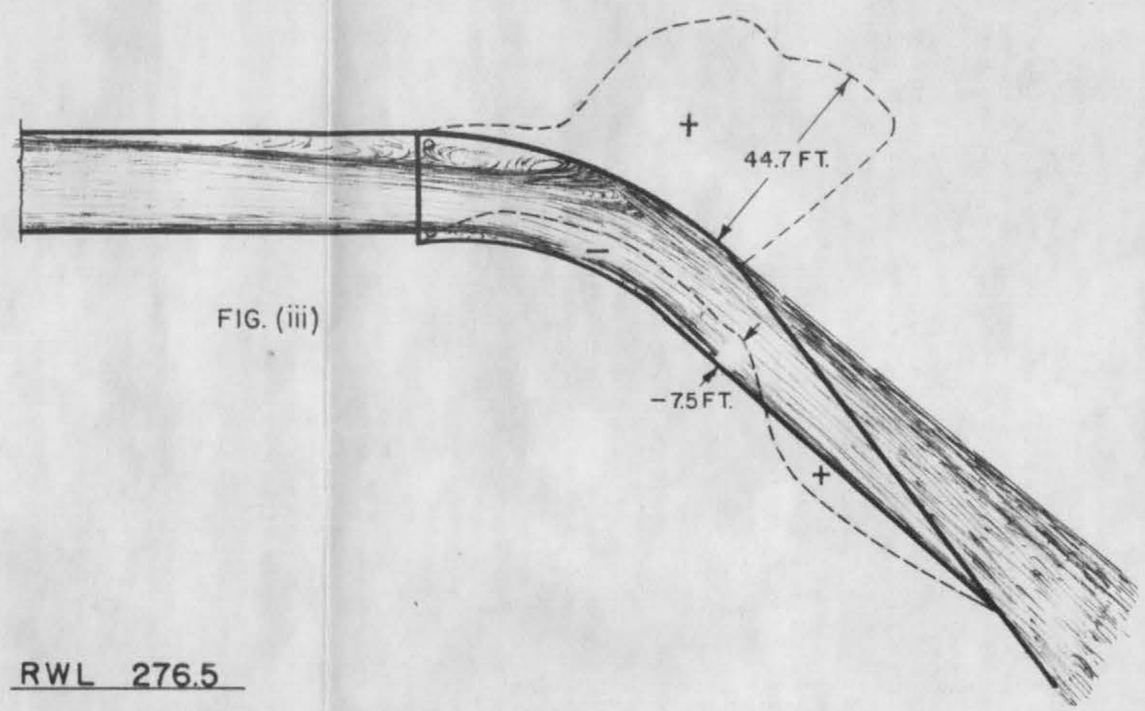


FIG. (iii)

RWL 290.0

GATE OPENING = 80%

Q_{80} = 82.2 M^3/S
(2,900 C.F.S.)

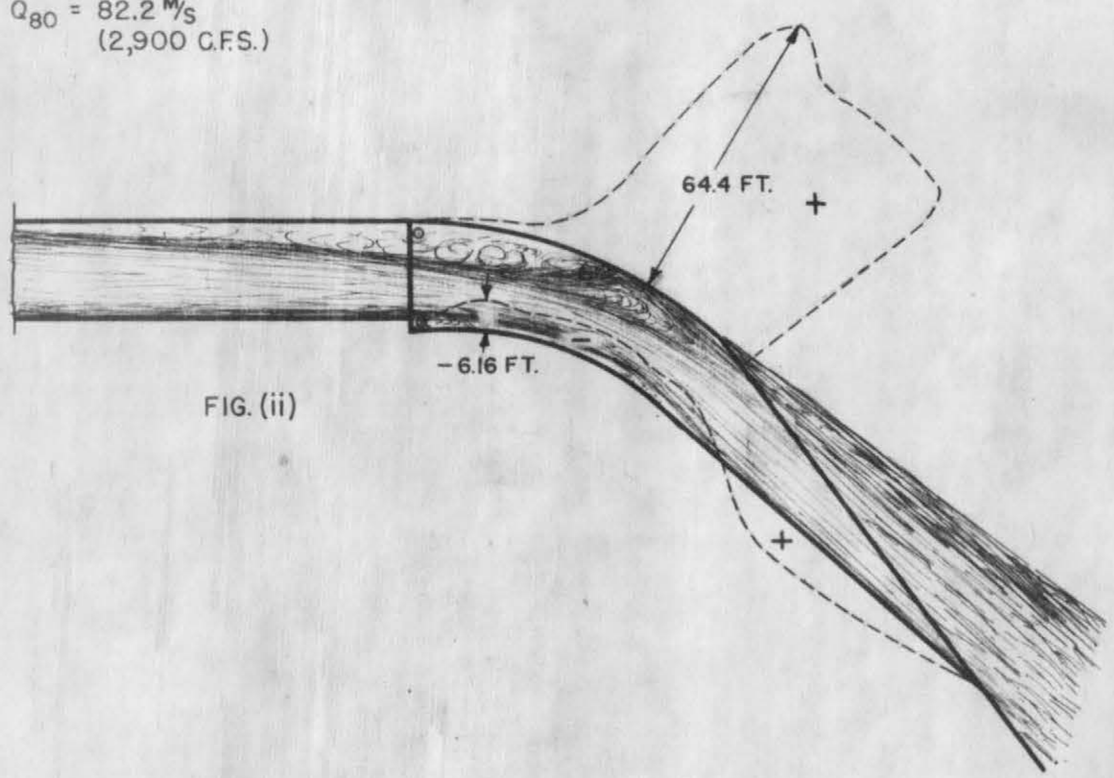


FIG. (ii)

RWL 276.5

GATE OPENING = 80%

Q_{80} = 73.5 M^3/S
(2,585 C.F.S.)

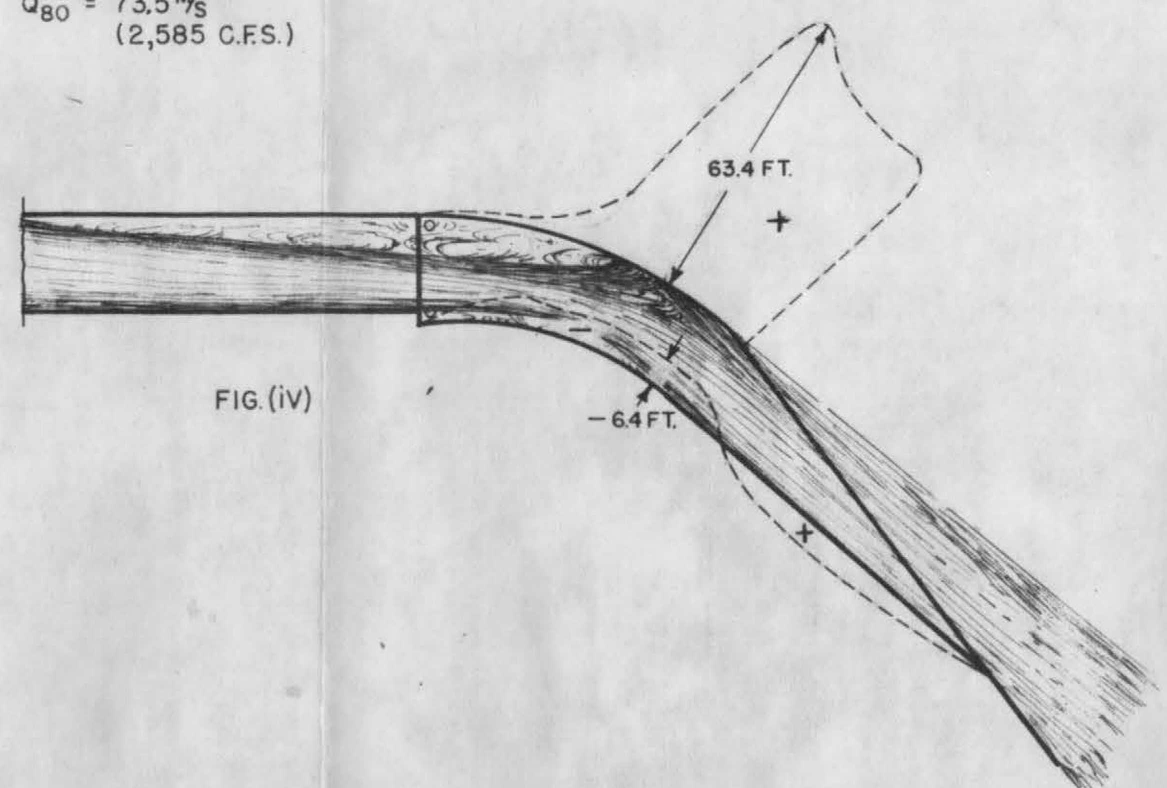


FIG. (iV)

LEGEND:

RWL = RESERVOIR WATER LEVEL

Q_{100} = DISCHARGE FOR 100% GATE OPENING

Q_{80} = DISCHARGE FOR 80% GATE OPENING

NOTES:

1. DISCHARGE FOR JET-FLOW GATE COMPUTED FROM $Q = 0.8A\sqrt{2gh}$
2. ALL VENT OPENINGS REPRODUCED TO SCALE. THEY WERE FULLY OPEN DURING THESE TESTS.
3. PRESSURES ON CROWN AND BOTTOM OF ELBOW WERE MEASURED ALONG THE CENTER LINE.

10 0 10 20 30 40 50

PRESSURE SCALE
(feet of water)

0 4 8 12 16 20

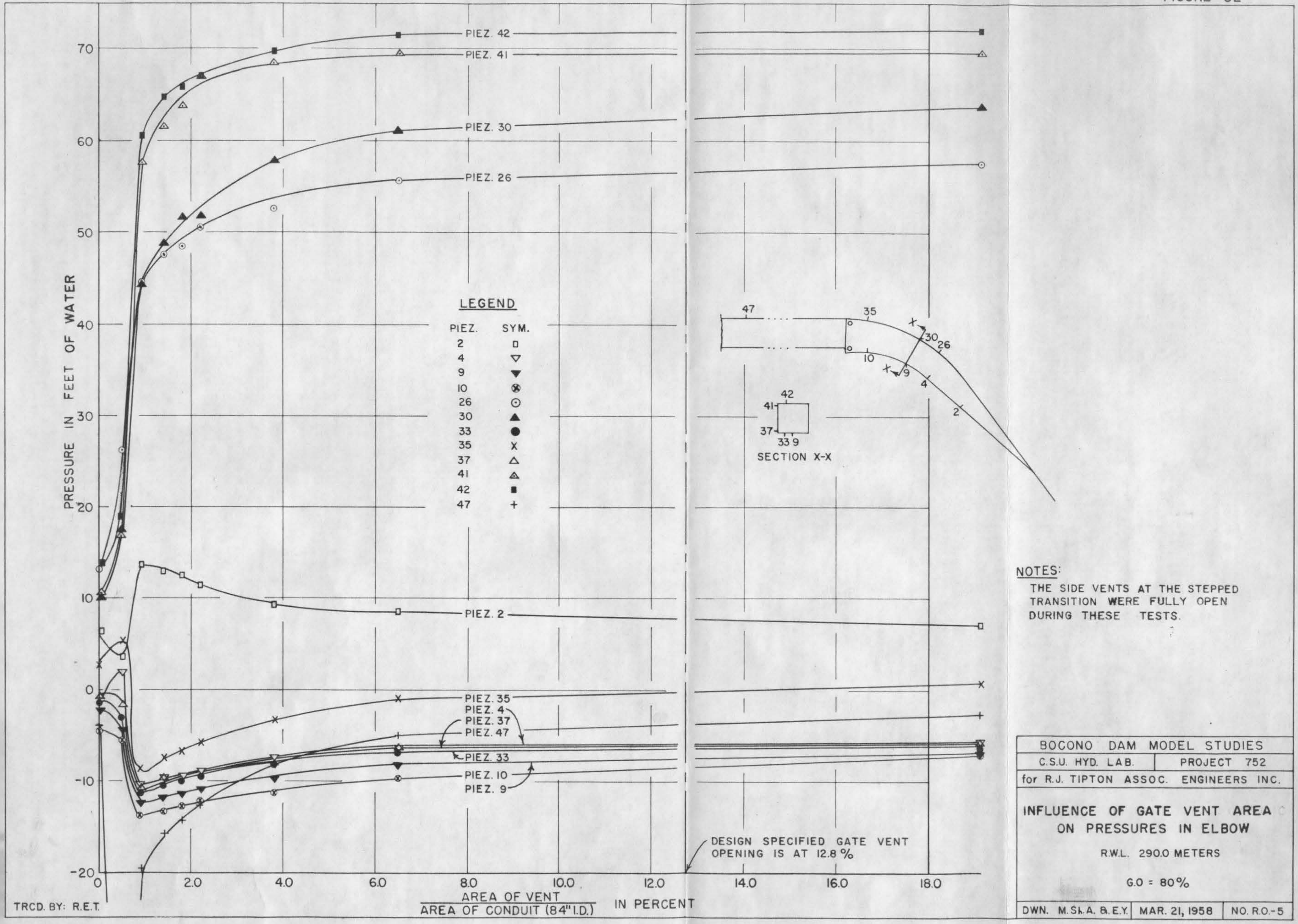
SCALE OF DRAWING
(feet)

THE FLOWS AND PRESSURES SHOWN ARE ALONG ℄ OF OUTLET

TRCD. BY: R.E.T.

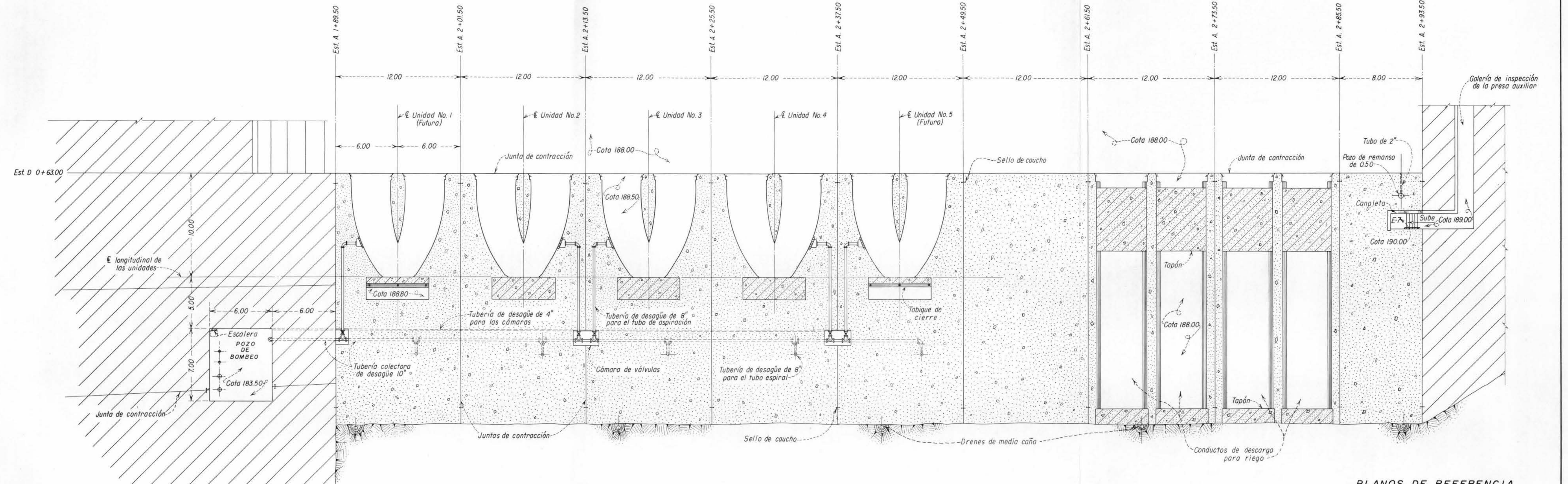
BOCONO DAM MODEL STUDIES		
C.S.U. HYD. LAB.	PROJECT 752	
for R.J. TIPTON ASSOC. ENGINEERS INC.		
SUMMARY OF FLOW PATTERNS IN ELBOW MODEL SCALE 1:20		
DWN. BY: M.Sh.A & K.S.D	MARCH 15, 1958	NO. R.O.–4

FIGURE 32



PRESSURE IN FEET OF WATER
70
60
50
40
30
20
10
0
-10
-20
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
AREA OF VENT / AREA OF CONDUIT (84" I.D.) IN PERCENT
PIEZ. 42
PIEZ. 41
PIEZ. 30
PIEZ. 26
PIEZ. 2
PIEZ. 35
PIEZ. 4
PIEZ. 37
PIEZ. 47
PIEZ. 33
PIEZ. 10
PIEZ. 9
LEGEND
PIEZ. SYM.
2 □
4 ▽
9 ▼
10 ⊗
26 ⊙
30 ▲
33 ●
35 X
37 △
41 ◬
42 ■
47 +
47
35
30
26
10
9
4
2
X
42
41
37
33 9
SECTION X-X
DESIGN SPECIFIED GATE VENT OPENING IS AT 12.8 %
NOTES:
THE SIDE VENTS AT THE STEPPED TRANSITION WERE FULLY OPEN DURING THESE TESTS.
BOCONO DAM MODEL STUDIES
C.S.U. HYD. LAB.
PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.
INFLUENCE OF GATE VENT AREA ON PRESSURES IN ELBOW
R.W.L. 290.0 METERS
G.O = 80%
DWN. M.S. & A. & E.Y.
MAR. 21, 1958
NO. R.O.-5
TRCD. BY: R.E.T.

FIGURE 33



PLANTA POR LOS TUBOS DE ASPIRACION

CONVENCIONES

- Concreto de primera etapa
- Concreto de segunda etapa
- Concreto de la presa

ESCALA 0 5 10M

NOTAS ESTRUCTURALES GENERALES

El diseño y la construcción en concreto estructural deben ceñirse a los requisitos del "Building Code Requirements for Reinforced Concrete (ACI 318-56)" del American Concrete Institute.
Todo el concreto estructural debe tener una resistencia mínima de 3000 lb/pulg.^{2} a la compresión a los 28 días.
No se indica el refuerzo. Oportunamente se entregarán los planos de refuerzo.
El refuerzo será de acero intermedio, en barras corrugadas, de 20,000 lb/pulg^2
El traslapo para adherencia del refuerzo en muros verticales y en columnas debe ser equivalente a 20 diámetros. Todos los otros traslapos deben ser de 24 diámetros.
A menos que se indique lo contrario, el refuerzo debe quedar con un recubrimiento de 0.05 excepto cuando esté contra la tierra o la roca y en este caso el recubrimiento será de 0.075.
Todas las esquinas al descubierto deben tener chaflanes de 0.020 a menos que se indique lo contrario.
Todo el diseño del acero estructural debe ceñirse a los requisitos de la última edición de la "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings" del American Institute of Steel Construction.

PLANOS DE REFERENCIA

PLANO GENERAL .... SI-54.
SISTEMA A TIERRA .... SI-76.

NOTA

Las dimensiones y cotas están en metros a menos que se indique lo contrario.

NO	DESCRIPCION	FECHA	POR
REVISION			

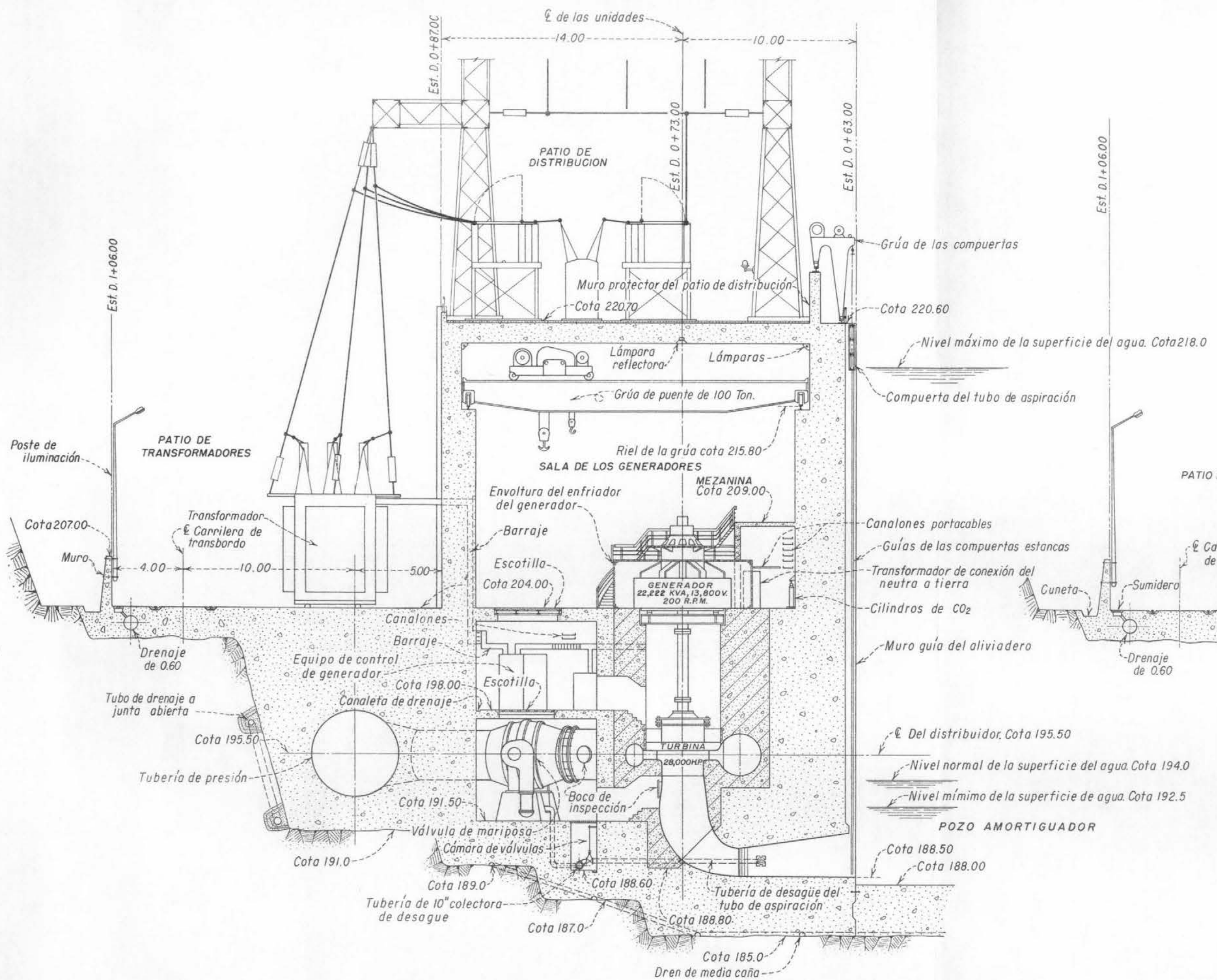
REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS

R. J. TIPTON ASSOCIATED ENGINEERS, INC.

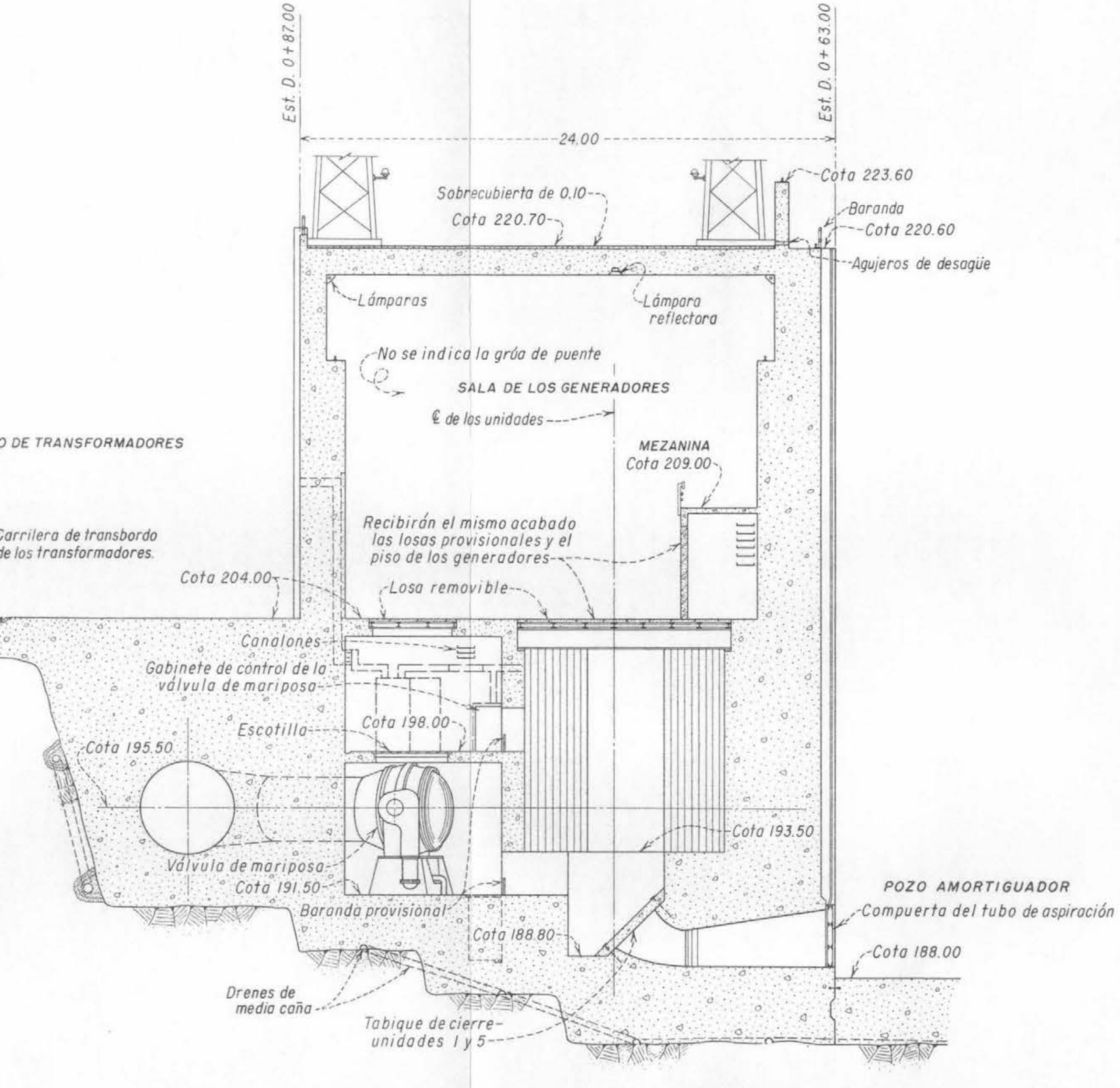
SISTEMA RIOS BOCONO–TUCUPIDO
PRESA BOCONO
PLANTA HIDROELECTRICA
DISTRIBUCION GENERAL

PLANTA POR LOS TUBOS DE ASPIRACION

DISEÑO D.L.D.
DIBUJO R.G.H.
REVISO C.J.R. / B.F.K.
CONFORMO R. J. TIPTON ASSOCIATED ENGINEERS, INC.
APROBO POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.
DENVER, COLORADO SEPTIEMBRE, 1957
HOJA ... DE ...
E 7
SI-55



CORTE TRANSVERSAL POR EL EJE DE UNA UNIDAD



CORTE TRANSVERSAL POR EL EJE DE UNA UNIDAD FUTURA

0 5 10M
ESCALA

NOTAS

Las dimensions y cotas están en metros a menos que se indique lo contrario.
Para las Notas Estructurales Generales, véase el Plano No. SI-55.

PLANOS DE REFERENCIA

PLANO GENERAL .... SI-54.
CORTES DEL PATIO DE DISTRIBUCION .... SI-62.
SISTEMA DE ILUMINACION .... SI-78 A SI-80.

CONVENCIONES

Concreto de primera etapa
Concreto de segunda etapa
Concreto de la presa

REPUBLICA DE VENEZUELA
MINISTERIO DE OBRAS PUBLICAS
DIRECCION DE OBRAS HIDRAULICAS

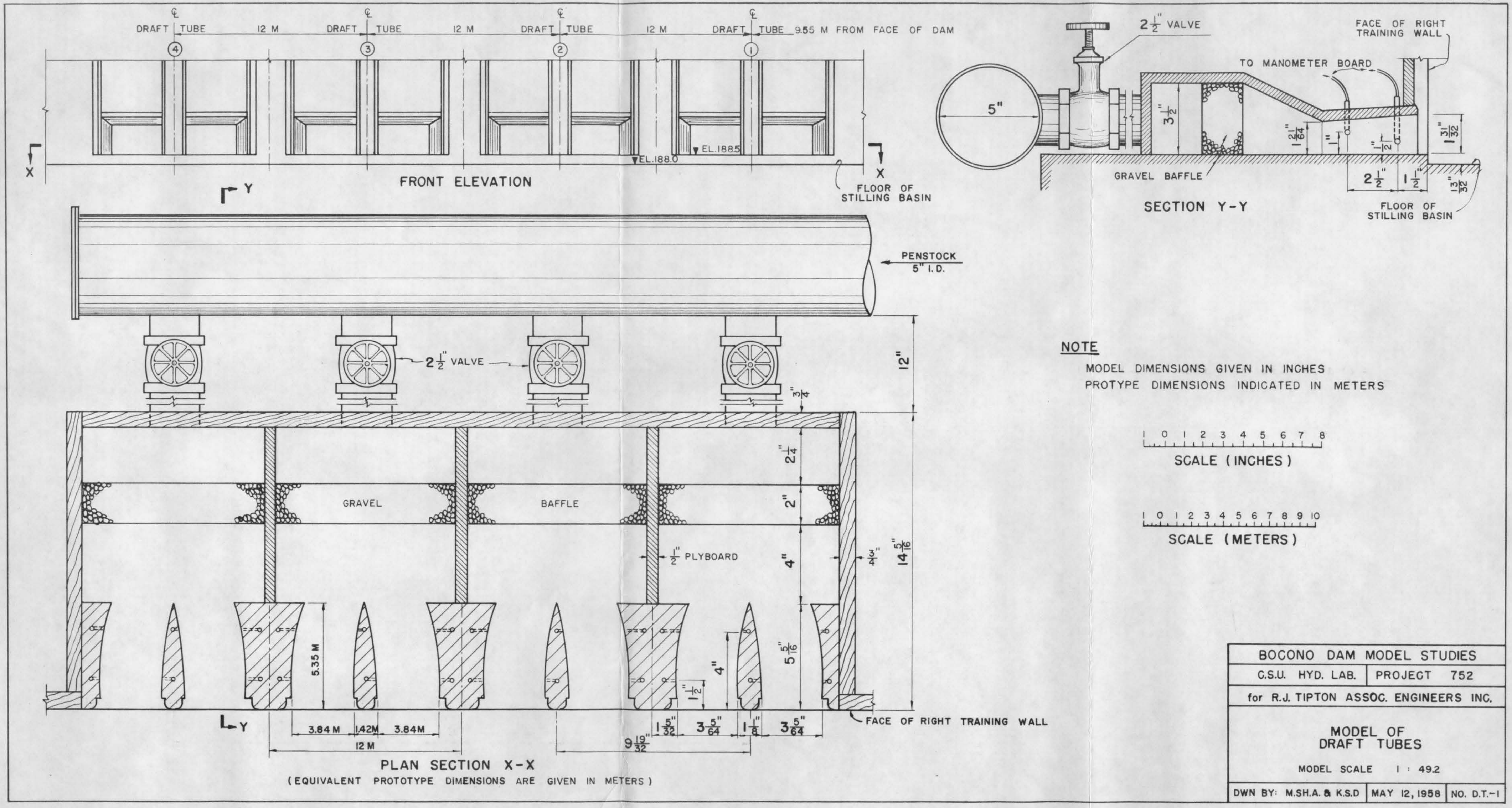
R. J. TIPTON ASSOCIATED ENGINEERS, INC.

SISTEMA RIOS BOCONO-TUCUPIDO
PRESA BOCONO
PLANTA HIDROELECTRICA
DISTRIBUCION GENERAL

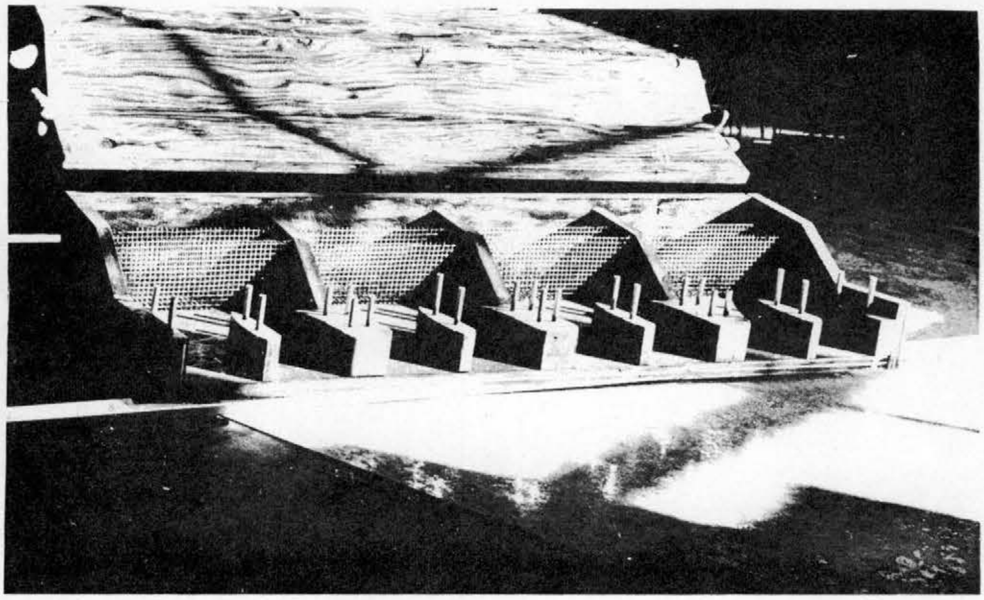
CORTES TRANSVERSALES A TRAVES DE LAS UNIDADES

DISEÑO G.Z.	CONFORMO R. J. TIPTON ASSOCIATED ENGINEERS, INC.		
DIBUJO M.E.K.			
REVISO C.J.R. B.F.K.	APROBO POR EL DIRECTOR DE OBRAS HIDRAULICAS M.O.P.		
DENVER, COLORADO SEPTIEMBRE, 1957	HOJA ...... DE	E7	SI-61

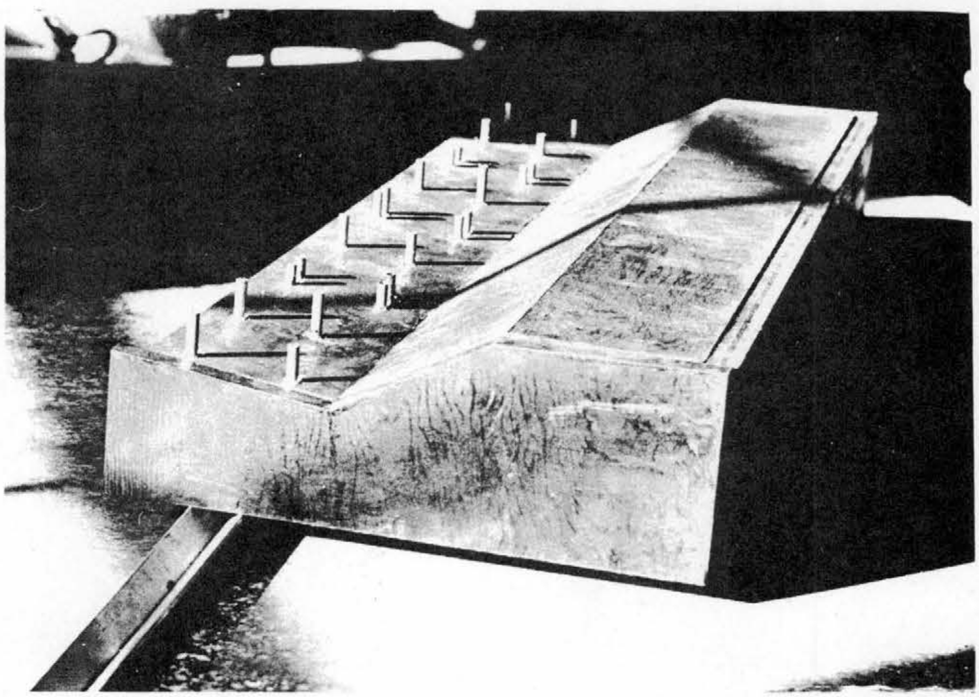
NO	DESCRIPCION	FECHA	POR
REVISION			



DRAFT TUBE
12 M
DRAFT TUBE
12 M
DRAFT TUBE
12 M
DRAFT TUBE 9.55 M FROM FACE OF DAM
EL.188.0
EL.188.5
X
X
FRONT ELEVATION
FLOOR OF STILLING BASIN
Y
PENSTOCK 5" I.D.
2 1/2" VALVE
12"
3/4"
2 1/4"
GRAVEL
BAFFLE
2"
1/2" PLYBOARD
4"
3/4"
14 5/16"
5.35 M
5 5/16"
4"
1 1/2"
Y
3.84 M
1.42M
3.84M
12 M
1 5/32
3 5/64
1 1/8"
3 5/64"
9 19/32"
FACE OF RIGHT TRAINING WALL
PLAN SECTION X-X
(EQUIVALENT PROTOTYPE DIMENSIONS ARE GIVEN IN METERS)
2 1/2" VALVE
FACE OF RIGHT TRAINING WALL
TO MANOMETER BOARD
5"
3 1/2"
1 21/64"
1"
1/2"
1 31/32"
GRAVEL BAFFLE
2 1/2"
1 1/2"
13/32"
FLOOR OF STILLING BASIN
SECTION Y-Y
NOTE
MODEL DIMENSIONS GIVEN IN INCHES
PROTYPE DIMENSIONS INDICATED IN METERS
SCALE (INCHES)
SCALE (METERS)
BOCONO DAM MODEL STUDIES
C.S.U. HYD. LAB.
PROJECT 752
for R.J. TIPTON ASSOC. ENGINEERS INC.
MODEL OF DRAFT TUBES
MODEL SCALE 1 : 49.2
DWN BY: M.SH.A. & K.S.D
MAY 12, 1958
NO. D.T.-1



A. Inside of model showing draft-tube passages.

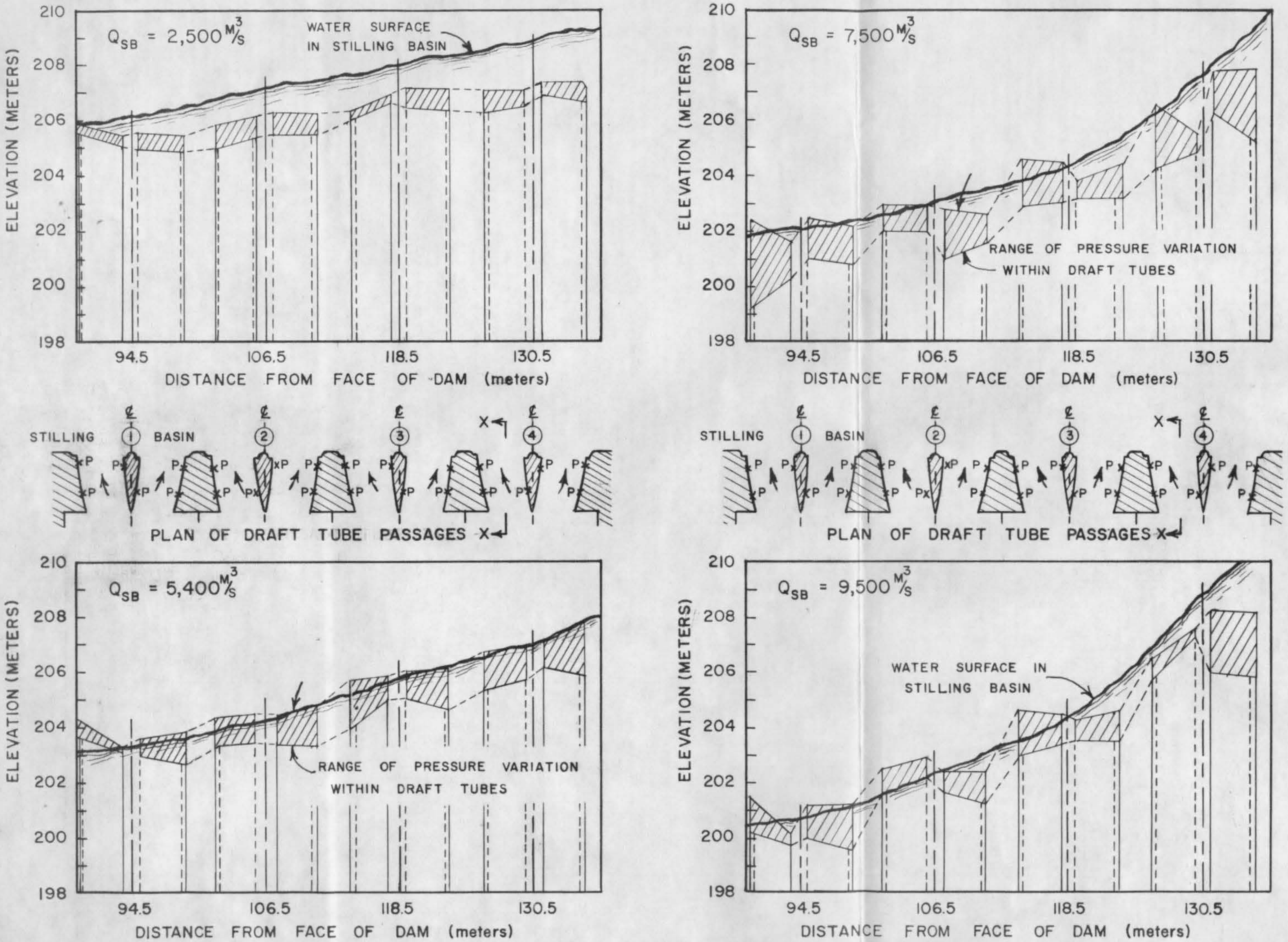


B. Model with roof on.

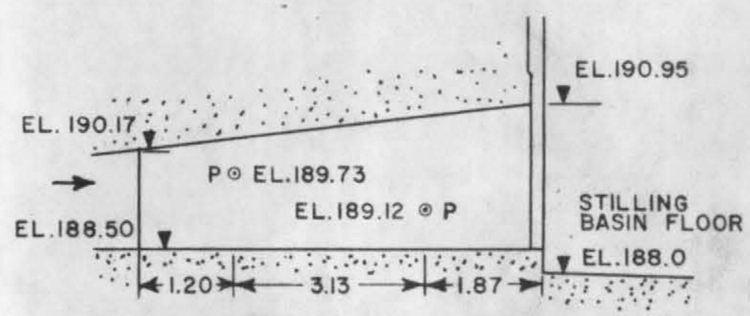
MODEL OF DRAFT-TUBE EXITS (scale 1 : 49.2)

The completed model representing the exit sections of draft-tubes 1 to 4 was installed in right training wall of the general model.

FIG. 36



LEGEND:
- P = PIEZOMETER
- Q_{SB} = FLOW THROUGH STILLING BASIN
- Q_{DT} = FLOW THROUGH DRAFT TUBES
- ——— ORDINATES FOR PIEZOMETERS LOCATED CLOSE TO STILLING BASIN
- - - - ORDINATES FOR PIEZOMETERS REMOTE FROM STILLING BASIN



SECTIONAL ELEVATION X-X

NOTES:
1. Q_{DT} WAS KEPT CONSTANT AT THE MAX. SPECIFIED FLOW = 1,410 C.F.S THROUGH EACH UNIT.
2. PRESSURES WERE RECORDED WHILE THE SPILLWAY WAS DISCHARGING THE Q_{SB} INDICATED ON EACH FIGURE.
3. ONLY 4 DRAFT TUBES WERE INSTALLED IN MODEL.

BOCONO DAM MODEL STUDIES

C.S.U HYD. LAB. | PROJECT 752

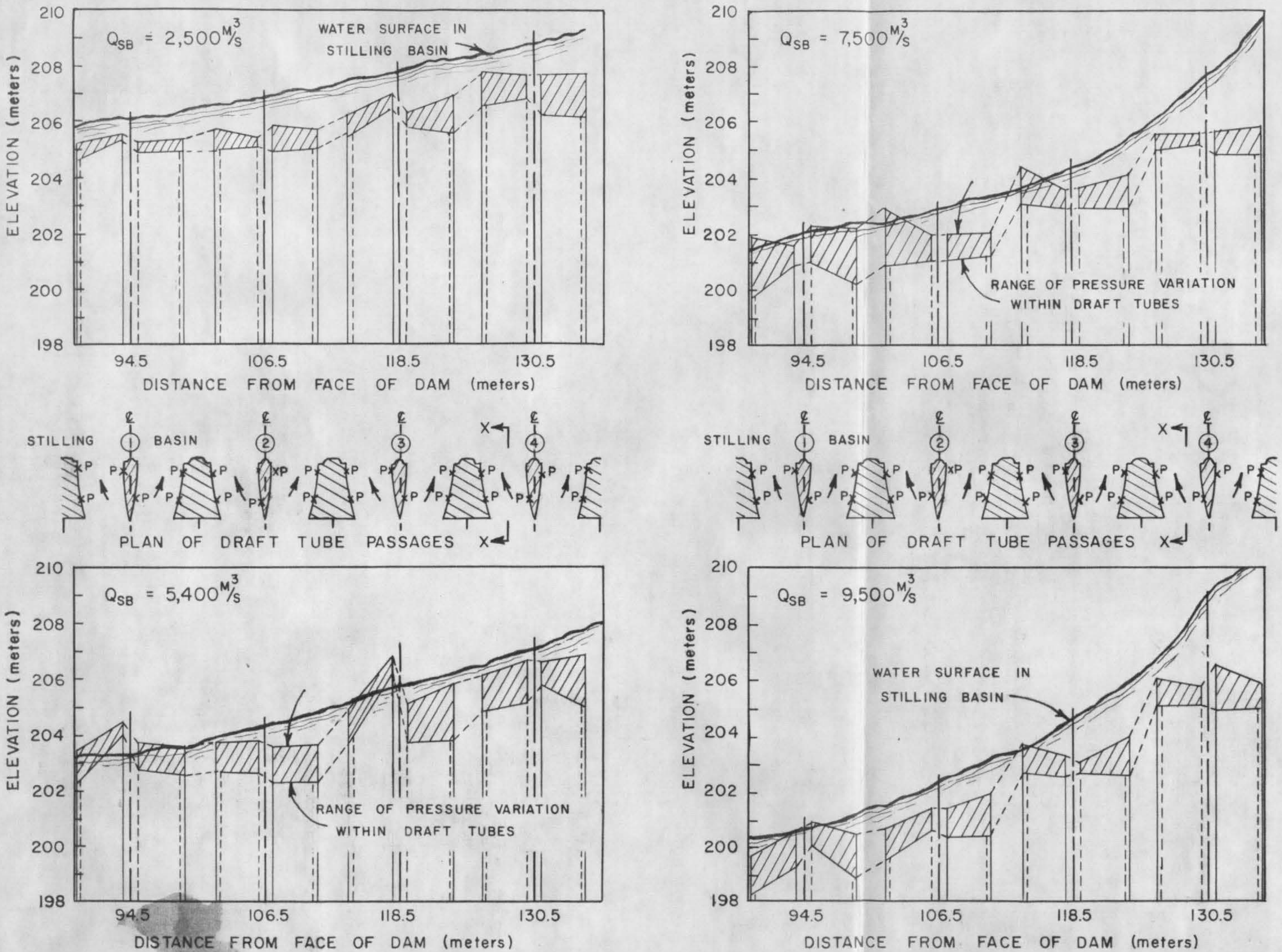
for R.J. TIPTON ASSOC. ENGINEERS INC.

PRESSURE VARIATIONS IN DRAFT TUBE PASSAGES

MAX. Q_{DT} = 5,640 CFS = 159.6 M³/S

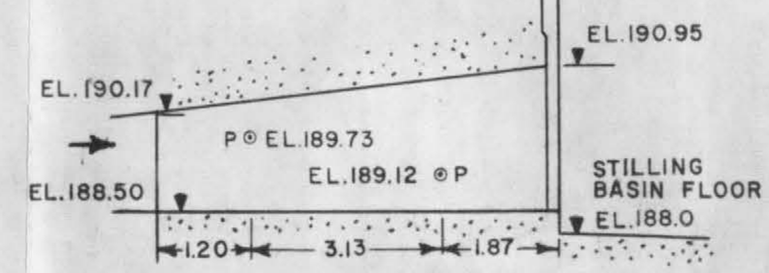
MODEL SCALE 1:49.2

DWN. BY: M.Sh.A & K.S.D | FEB. 22, 1958 | NO. DT-2



LEGEND:

- P = PIEZOMETER
- Q_{SB} = FLOW THROUGH STILLING BASIN
- Q_{DT} = FLOW THROUGH DRAFT TUBES
- ——— ORDINATES FOR PIEZOMETERS LOCATED CLOSE TO STILLING BASIN
- - - - - ORDINATES FOR PIEZOMETERS REMOTE FROM STILLING BASIN

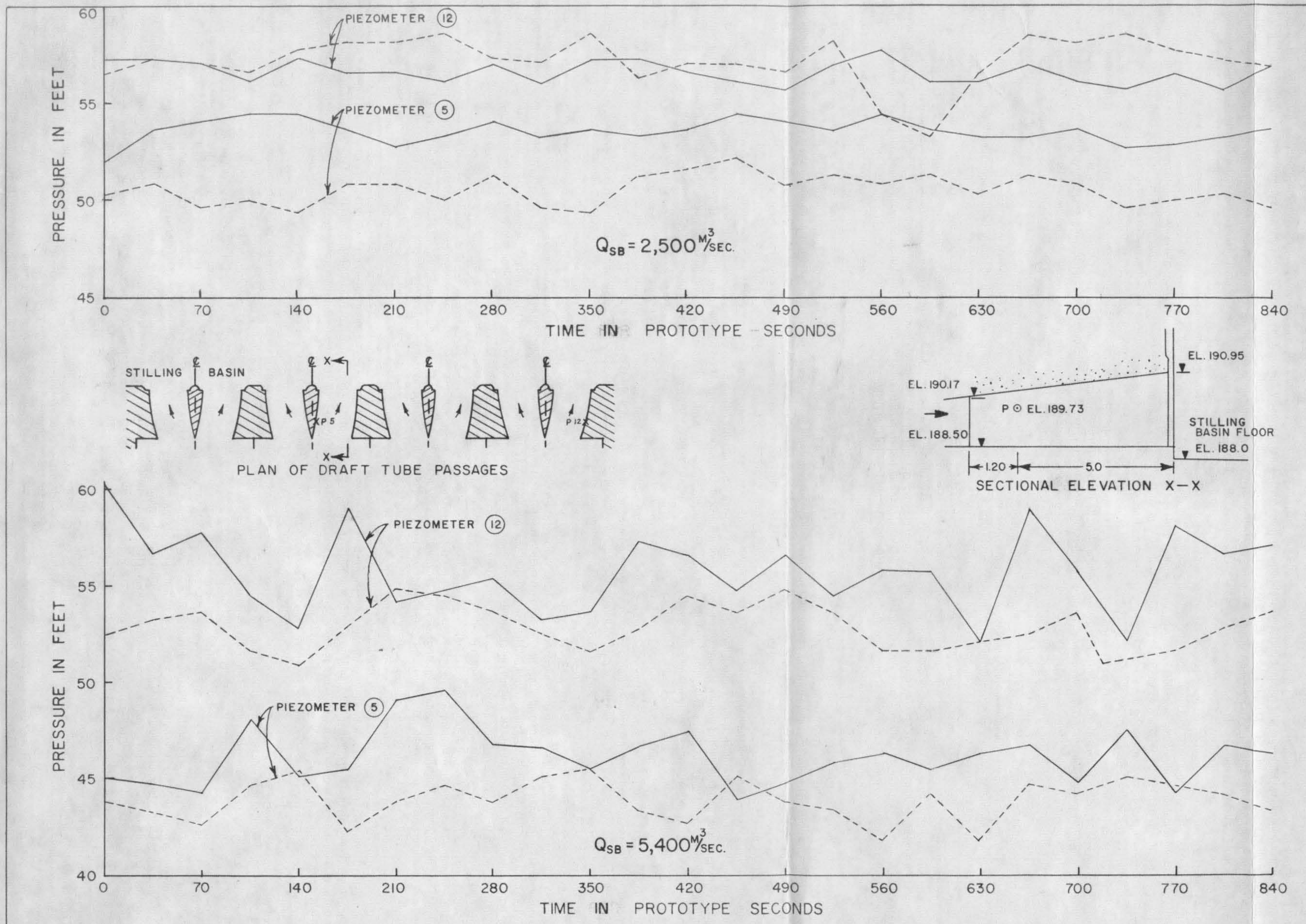


SECTIONAL ELEVATION X–X

NOTES:

1. Q_{DT} WAS KEPT CONSTANT AT THE MIN. SPECIFIED FLOW = 305 C.F.S THROUGH EACH UNIT.
2. PRESSURES WERE RECORDED WHILE THE SPILLWAY WAS DISCHARGING THE Q_{SB} INDICATED ON EACH FIGURE.
3. ONLY 4 DRAFT TUBES WERE INSTALLED IN MODEL.

BOCONO DAM MODEL STUDIES		
C.S.U HYD. LAB.	PROJECT 752	
for R.J. TIPTON ASSOC. ENGINEERS INC.		
PRESSURE VARIATIONS IN DRAFT TUBE PASSAGES MIN. Q_{DT} = 1,200 CFS = 34.6 M^3/S MODEL SCALE 1:49.2		
DWN. BY: M. Sh. A. & K.S.D	FEB. 22, 1958	NO. DT-3



LEGEND:

- P = PIEZOMETER
- Q_{SB} = FLOW THROUGH STILLING BASIN
- Q_{DT} = FLOW THROUGH DRAFT TUBES
- ——— MAX. FLOW THROUGH DRAFT TUBE Q_{DT} = 4 X 1,410 = 5,640 C.F.S.
- – – – MIN. FLOW THROUGH DRAFT TUBE Q_{DT} = 4 X 305 = 1,220 C.F.S.

NOTES:

1. SCALE RATIO L_r = 49.2
   TIME RATIO $T_r = (L_r)^{\frac{1}{2}} = (49.2)^{\frac{1}{2}}$ = 7.00 (APPROX.)
2. PRESSURES WERE RECORDED WHILE THE SPILLWAY WAS DISCHARGING THE Q_{SB} INDICATED ON EACH FIGURE.
3. ONLY 4 DRAFT TUBES WERE INSTALLED IN MODEL.

BOCONO DAM MODEL STUDIES		
C.S.U. HYD. LAB.	PROJECT 752	
for R.J. TIPTON ASSOC. ENGINEERS INC.		
PRESSURE FLUCTUATIONS IN DRAFT TUBE PASSAGES MODEL SCALE 1:49.2		
DWN. BY: M. ShA. & K.S.D.	FEB. 26, 1958	NO. DT-4