UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE CONTROL STRUCTURES FOR TOOMA-TUMUT AND TOOMA-EUCUMBENE TUNNELS--SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY, AUSTRALIA

Hydraulic Laboratory Report No. Hyd-429

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

September 20, 1957

CONTENTS

CONTENTS (Continued)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Hydraulic Structures and
Equipment Section
Denver, Colorado
September 20, 1957

Laboratory Report No. Hyd-429
Compiled by: W. P. Simmons
Checked by: W. E. Wagner
Reviewed by: J. W. Ball
Submitted by: H. M. Martin

Subject: Hydraulic model studies of the control structures for Tooma-Tumut and Tooma-Eucumbene tunnels--Snowy Mountains Hydro-Electric Authority, Australia

PURPOSE

The studies were made to determine whether or not a particular type of slide gate[1/] was suitable for use in the tunnel control structures under free and submerged discharge conditions with differential heads up to 373 feet, and to determine the best shapes for the tunnels immediately downstream from the gates.

CONCLUSIONS

Slide Gate Performance

1. The slide gate design which uses a thick, flat leaf with a 45° sloping bottom, narrow gate slots, and outwardly offset downstream slot corners,[1/] was satisfactory for use at all heads and gate openings with either free discharge or high back pressure operating conditions. This design should be used in both tunnel control structures. In a limited range of low back pressure conditions (Figure 21D), serious negative pressures occurred on the walls near the floor immediately downstream from the slots when the gate openings were less than 5 percent. Operation within this range of low back pressures will be rare, but during such time, gate openings of 6 percent or greater must be used.

1/ "Hydraulic Model Studies of the 7-foot 6-inch by 9-foot 0-inch Palisades Regulating Slide Gate--Palisades Project, Idaho," Report No. Hyd-387.

Tumut Control Structure

1. The Tumut control structure performs best with the floor and walls of the conduit downstream from the gate in contact with the flow and with a 50-foot-long transition that guides the flow into the 11-foot 3-inch-diameter tunnel. The constant width conduit provided between the gate frame and the transition in the preliminary design is not needed. The structure should be simplified by moving the transition entrance up to the gate frame outlet.

2. The pressures in the transition and tunnel were satisfactory at all heads and gate openings for free discharge or submerged operating conditions. No adverse conditions were found when a hydraulic jump formed in the circular tunnel, or in the transition, or at the gate itself.

3. Great care must be taken to provide smooth straight surfaces on the conduit walls downstream from the gate so that local areas of low pressure and cavitation do not occur due to flow interference. Corrosion-proof steel plate should be anchored to the floor and lower walls to insure trouble-free operation.

4. An air vent 18 inches or more in diameter is required to supply the air demand of the gate and tunnel when a hydraulic jump occurs. Air is also required when the gate is near the full-open position with low back pressures. The branch line to the gate frame vents (Figure 6) should join the main vent at or above the elevation determined from Figure 17B, so that air will continue to be supplied as needed to the gate after the main vent seals off with water.

5. A floor drain of conventional design located in the path of the high velocity water from the gate would create flow disturbances that could result in cavitation. Although no tests were made, it is believed that slotlike drains, similar in cross section to the slots of the slide gate (Figures 7 and 19), should cause little disturbance and be cavitation free. Drains of this type should be placed between the upstream guard gate and the control gate, and downstream of the control gate.

6. A conduit design using a sudden expansion at the control gate requires a back pressure of 30 feet to keep the conduit full, and a back pressure of 69 feet to keep the tunnel pressures atmospheric near the gate. These requirements make the design not readily applicable to the Tumut control structure.

Eucumbene Control Structure

1. The Eucumbene control structure, which always operates deeply submerged, performs as satisfactorily with the 13-foot circular tunnel extended to the gate as with the square section of tunnel used in the preliminary design. The square section and the transition to the

13-foot-diameter tunnel may therefore be omitted from the design, and the circular tunnel extended to a headwall at the end of the gate frame.

2. No negative pressures were found on the control gate, the downstream guard gate, or the tunnel walls at any expected discharge or backwater condition.

3. A floor drain of the slot type should be used between the upstream guard gate and the control gate, and a modification of the design should be used between the control gate and the downstream guard gate.

4. The manhole into the gate chamber should be placed high enough on the wall to be above the flow jet for the 30 percent gate opening, and a good fit should be provided on the cover so that local areas of low pressure and cavitation will not form.

5. No air vents are required because the structure always operates with high back pressures.

6. Previous model studies of vertical-type stilling-wells[2/] indicated that a modification of the design could be used to dissipate the energy at the drain outlet. No stilling-well studies were made on the Eucumbene structure.

RECOMMENDATIONS

1. Do not operate the Tumut control gate at openings less than 5 percent when the back pressure is between the limits shown on Figure 21D.

2. Use the coefficient curves in Figure 21 for determining the flow through the Tumut and Eucumbene control structures.

ACKNOWLEDGEMENT

The testing and development program discussed in this report reflects the cooperative efforts of the Dams Branch, the Mechanical Branch, and the Hydraulic Laboratory Branch of the Commissioner's Office, Denver, Colorado.

2/ "Hydraulic Model Studies of the Stilling Well for the Blowoff Structure, Soap Lake (Inverted) Siphon, Columbia Basin Project," Report No. Hyd-277.

INTRODUCTION

The Snowy Mountains scheme, which is under the direction of the Snowy Mountains Hydro-Electric Authority, is concerned with gathering waters from both sides of the Great Dividing Range in Southeastern Australia and utilizing them for irrigation and power generation (Figures 1 and 2). The Tooma-Tumut Diversion Project is a part of this plan, and Tooma Reservoir will collect and temporarily store waters on Tooma River. From Tooma Reservoir the water is carried under a mountain range by the 9-mile-long Tooma-Tumut Tunnel into either Tumut Pond or Eucumbene-Tumut Tunnel (Figures 3 and 4). Additional waters will enter the Tooma-Tumut Tunnel at inlets provided where streams cross over it (Figure 3). These waters may flow directly into Tumut Pond, or into Adaminaby Reservoir through the Eucumbene-Tumut Tunnel, or may be stored temporarily in Tooma Reservoir.

Tumut Pond, which serves as the forebay for T-1 Powerplant, is fed directly by Tumut River, and by gravity flows through Tooma-Tumut Tunnel, and through the Eucumbene-Tumut Tunnel from Adaminaby Reservoir (Figure 2). Adaminaby Reservoir, which lies on the seaward side of the Great Dividing Range, is the principal storage reservoir of the scheme and, when full, has a water surface elevation of about 3822 feet (Figure 3). The water surface elevation of Tooma Reservoir will always be above 3850 feet and may be as high as 4021.5 feet, and the water in it may be transported by gravity to Adaminaby Reservoir. To accomplish the transfer of water, a bypass tunnel is provided near Tumut Pond to connect the Tooma-Tumut Tunnel with the Eucumbene-Tumut Tunnel (Figure 4). Control structures are provided in the main tunnels and in the connecting tunnel so that the route and the rate of flow can be controlled. The calculated tunnel losses, back pressures, and heads acting in the system are shown in Figure 5. Most of the model tests were made using the maximum design head.

Tumut Control Structure

The Tumut control structure, as initially proposed, consisted of an upstream guard gate, a 7-foot 6-inch by 9-foot 0-inch regulating slide gate, an 18-foot-long, constant width conduit just downstream from the gate, and a 50-foot-long transition to the 11-foot 3-inch-diameter tunnel downstream (Figure 6). At the tunnel outlet a bulkhead gate was provided so that the tunnel could be closed and emptied to permit inspections and maintenance work (Figure 4).

The flow in the tunnel downstream of the control gate may occur as shooting flow with a free water surface through the entire tunnel length, or as shooting flow for part of the length followed by a hydraulic jump, or as closed conduit flow with the tunnel filled and under pressure. This range of operating conditions occurs because the level of Tumut Pond, into which the tunnel empties, can vary from below the level of the tunnel outlet to about 159 feet above it. Normally Tumut Pond will be maintained at the highest elevations so that the highest possible heads will exist on the powerplant supplied by the pond. Thus, most of the operation of Tumut control structure will be under high back pressure conditions. Infrequent operation will occur at small submergences, or with no submergence, during the initial filling of Tumut Pond, and during subsequent low or filling periods.

When free discharge occurs, the differential head across the gate may become as high as 373 feet and the flow will leave the gate with velocities up to 155 feet per second. It is therefore important that the control gate and the conduit downstream be carefully designed and accurately constructed if satisfactory performance and service is expected.

At certain tail-water conditions, a hydraulic jump will occur in the tunnel and a great deal of air will be entrained and carried away. A venting system must therefore be provided with adequate capacity to supply this air demand without building up a large pressure differential between the atmosphere and the tunnel. If the vent is inadequate, the pressure within the tunnel will be lowered excessively and the risk of producing local areas of low pressure and cavitation due to flow disturbances at boundary irregularities will be great.

As the submergence on the tunnel increases, the tunnel will fill and the gate will operate against back pressure. The head differential across the gate will decrease as the back pressure increases, and at moderate and high submergences there should be no trouble with cavitation. At small back pressures, where the differential heads are high and the back pressures low, critical flow conditions can exist.

After considering the operating characteristics and the installation requirements of various types of gates and valves now in use in Bureau projects, it was decided that slide gates of the type developed for Palisades Dam Outlet Works[1/] were best suited for the Tumut control structure. This gate uses a thick, flat leaf with a 45° sloping bottom, narrow gate slots, and outwardly offset downstream slot corners (Figure 7). The gate was originally designed for free discharge regulation under heads up to 240 feet, but model tests made during its development showed that it could also be operated against back pressure. A gate of identical design was planned for the upstream guard gate. In the initial design, the conduit immediately downstream of the regulating gate was made with the walls and floor continuous with those of the gate so the flow remained in contact with and was guided by the surfaces for a considerable distance before entering the transition to the 11-foot 3-inch-diameter tunnel.

Eucumbene Control Structure

The design of the Eucumbene control structure (Figure 8), which may be subjected to differential heads up to 357 feet, was simplified by the fact that the tunnel will always operate submerged under heads of 80 or more feet (Figure 5). The proposed structure consisted of an upstream guard gate and a control gate identical to the ones in the Tumut control structure, and a bulkhead-type guard gate immediately downstream from the control gate. At the outlet of the 7-foot-6-inch by 9-foot 0-inch bulkhead gate the conduit enlarged abruptly into a 12-foot-square tunnel section which led through a transition into the 13-foot-diameter downstream tunnel. This sudden and appreciable enlargement allowed the jet from the regulating gate to enter a water "cushion" which was expected to spread and dissipate the high velocity stream without causing structural damage.

To assist in determining, and improving where necessary, the hydraulic performance of the two proposed control structures, hydraulic studies were made on 1:19 scale models. A discussion of these model studies and the results obtained therefrom are presented in this report.

THE MODELS

In the initial designs of the Tumut and Eucumbene control structures, the upstream tunnels, transitions, upstream guard gates, and regulating gates were identical and one model was used to represent these portions of both structures (Figure 9). The tunnels were initially to be 11 feet 6 inches in diameter and the model was made accordingly. Later the diameters were reduced to 11 feet 3 inches and the gravel trap was added in the Eucumbene structure. No changes were made in the model because the flow conditions at the gates would not be appreciably altered by these changes. The tunnel sections downstream of the control gates differed greatly from one another, and each was represented by appropriately shaped sections.

The control gate used in the model tests is shown in Figure 10. This gate, which was used in previous model studies, set a 1:19 scale ratio for the Tumut and Eucumbene models. Gate frame air vents were included in the roof of the gate. Two slight discrepancies existed between the modified model and the latest design for the prototype gates. First, the model leaf did not include the downward step of the flat surface at the leaf bottom, and second, the rate of convergence of the model sidewalls and roof downstream from the slots was greater than the slope in the prototype gates (Figures 19 and 7). These discrepancies do not materially affect the flow and pressure conditions within the gate and any slight differences will be in the direction of better conditions in the prototype gates.

The upstream guard gate was represented by a nonoperating gate with a flow passage identical to the passage in the fully opened regulating gate. The downstream guard gate in the Eucumbene structure was represented by a nonoperating gate, and its flow passage was the same as the shape anticipated for the fully opened bulkhead-type gate with narrow gate slots (Figure 9C). The downstream slot corners of this gate were set 1 inch outside of the line of the upstream walls, and there was no convergence on the short walls downstream from these corners.

The tunnel transitions were made of carefully formed sheet metal. The circular tunnels downstream from the gates were made of transparent plastic. Sections of transparent pipe were available in the laboratory in diameters approximately correct for the model and, as the diameters of the tunnel were not critical in these tests, the existing sections were used. The 11-foot 3-inch tunnel was therefore represented as being 12 feet 3 inches in diameter, and the 13-foot 0-inch tunnel was represented as being 12 feet 11 inches in diameter. The square section of conduit shown to be 12 feet square downstream of the Eucumbene gates (Figure 8) was modeled as 13 feet square in accordance with an earlier design.

The piezometers already in the model gate were satisfactory (Figure 10). Other piezometers were placed in the outlet conduits in areas considered to be critical. In the Tumut Tunnel these areas included the floor and lower portions of the walls in the constant-width section and in the transition section downstream from the gate, the circular conduit following the transition, and the conduit roof near the gate (Figure 11). In the Eucumbene connecting tunnel the areas included the downstream guard gate, the square to round transition, and the upstream end of the 13-foot-diameter tunnel (Figure 12). Piezometers were also provided in the inlet tunnel 1 diameter upstream from the transition to the gates, and in the outlet tunnels well downstream from the gates. From these piezometers the pressure upstream from the gate and the back pressure downstream of the gate could be determined. Most of the pressure measurements were made using single leg water manometers. When pressures exceeded the height of these manometers, a mercury gage was used. In cases where rapidly fluctuating low pressures were encountered, measurements were made using a strain gage-type pressure cell with suitable electrical recording equipment.

The models were connected directly to the central laboratory supply system and the rates of flow were measured by calibrated venturi meters. The back pressure in the model was adjusted by a valve near the end of the model tunnel. The flow leaving the model returned to the laboratory supply reservoir and was recirculated.

INVESTIGATION

Slide Gate Performance

Model tests made on the Tumut structure showed that for most operating conditions the flow and pressures within the slide gates were satisfactory (Figure 13A, 13B, and 15). During free discharge operation, and operation at large submergences, the conditions were good. But during operation at small submergences with gate openings between

0 and 5 percent, several areas with extremely low pressures were found on the gate frame walls downstream from the gate slots, Figure 13B. These areas did not show low pressures during free discharge operation with small gate openings because the water separated from the sidewalls and the areas were open to the atmosphere (Figure 14A). At openings larger than 5 percent the flow was in contact with the gate frame walls and the pressures were positive. The change from flow in contact with the walls to flow free of the walls occurred abruptly and was not accompanied by pressures appreciably below atmospheric pressure. At flows with the gate submerged, aeration cannot occur and the tendency of the flow to separate from the walls causes a reduction in pressure. If the back pressure is considerable, the hydraulic grade line will be high, and this pressure reduction will not lower the pressures to negative values. However, if the back pressure is small, the pressure can be reduced to the vapor pressure of water, and cavitation will result.

In the Tooma-Tumut Tunnel, operation in the range of low back pressures is not expected to occur often or for long periods, but such operation must be expected. One method of avoiding difficulty was to avoid operating the gate at openings less than 5 percent when the back pressure is low. But it was better to eliminate, insofar as was practicable, the trouble in the gate. Model studies were made to determine a practicable slide gate design that would be free of severe negative pressure at small openings with small back pressures.[3/] The studies did not, at this time, lead to a successful design. Although hydraulically satisfactory designs were obtained, seal problems were encountered which were too complex to be pioneered on a gate subjected to service as severe as that in the Tumut structure. It was finally judged best to use the Palisades-type gates without change (except the strengthening required by higher heads) and to avoid the 0 to 5 percent gate settings when the submergence is low. All tests reported herein were therefore made using this gate design, and the range of critical back pressure conditions at which operation from 0 to 5 percent gate openings must be avoided is shown in Figure 21D.

Tumut Control Structure

Preliminary Design--Constant-Width Conduit Between Gate and Transition

The flow conditions during free discharge releases were good and the flow left the gate in a smooth, clean jet to continue without disturbance through the constant-width conduit (Figure 15). Only minor disturbances were evident when the flow entered the transition section.

3/ "Hydraulic Model Studies Concerning Moving the Slots Upstream in Slide Gates and Concerning Reducing the Slot Size Near the Floor," Report No. Hyd-432.

The pressures measured on the gate frame, in the constant-width conduit, and in the transition were all satisfactory, even though small, negative pressures were found on the floor and low on the sidewalls of the constant-width conduit downstream from the gate frame (Figure 13). No negative pressures were found in the transition.

When the back pressure in the downstream tunnel was increased, a hydraulic jump occurred in the tunnel (Figure 14B). Large quantities of air were entrained by this jump and carried out of the tunnel. When the air supply to the tunnel was shut off, the tunnel pressure dropped and the jump moved upstream to a new point of equilibrium. When the air vent was opened, the pressure returned to its previous value and the jump moved downstream.

The front of the jump in the tunnel moved erratically up and downstream from an average equilibrium point for the particular operating condition. When the jump was near the gate, water intermittently splashed up onto the leaf and then was swept downstream. No large changes in pressure were found at piezometers in the areas where there was uninterrupted flow. When the back pressure was increased, the foamy water rose to the full height of the gate leaf and the piezometric pressures increased. When the back pressure was sufficient to make the roof pressure slightly positive at the gate frame air vents so that no air entered the conduit, quiet flow existed in the tunnel. All pressures were positive at all gate openings above 5 percent (Figure 13B). At openings of 2 and 3 percent, all pressures were positive except on the gate frame walls 3 inches above the floor 3 and 6 inches downstream of the slots. The pressures at these locations were negative, and fluctuated greatly. Figure 13B shows the pressures obtained from water manometers.

It was recognized that the inertia of the columns of water in the gage lines and gage glasses prevented accurate measurement of these rapidly fluctuating pressures, and more precise tests were made using a pressure cell with suitable electric recording equipment. These pressure cell measurements showed that the pressures were frequently so low that cavitation would occur in the prototype structure (Figure 16). The studies made to eliminate them were not completely successful in that they did not at this time produce a modified gate design that could be used for the Tumut control structure. It is therefore mandatory that the Tumut control gate be operated at openings greater than 5 percent whenever the back pressure is within the ranges given in Figure 21D for the particular elevation in Tooma Reservoir. With back pressures below line B (Figure 21D), free discharge flow conditions and aeration will occur at the gate and no trouble will be encountered. With back pressures above line A, Figure 21D, the wall pressures will be sufficiently high to prevent cavitation, and the operation should be trouble free. This restriction on gate openings is not expected to work a hardship on the operating schedules because the critical submergences will occur rarely, and a gate opening of 6 percent instead of 3 percent should cause no serious problem.

Recommended Design--Transition at Gate

A simpler and less costly structure would result if the constant width conduit between the gate and the transition were eliminated. To determine the flow conditions and pressures with this conduit removed and with the transition entrance at the gate outlet, the model was altered and piezometers were added to the transition to better cover the critical areas in the sidewall and floor (Figure 11B). The pressure on the downstream gate frame during free discharge and submerged operation remained about the same as shown in Figure 13, and all the observed pressures in the transition and in the circular tunnel were positive (Figure 17A). The flow conditions were good, and during free-discharge releases the jet entered and passed through the transition with no appreciable disturbances (Figure 18). It was concluded that the constant width conduit between the gate and transition was unnecessary, and that the transition could be placed immediately downstream from the gate. The limitations on gate openings between 0 and 5 percent with submergences between lines A and B (Figure 21D) remain applicable with this design.

The extremely high velocity flows that may occur across the surfaces of the transition will produce areas of low pressure and cavitation if these surfaces present any appreciable roughnesses or irregularities to the flow. If regions of slightly weak concrete should be present at the surfaces, washing may occur and produce a roughened surface that will cause damage due to cavitation and direct impact. To obtain and preserve the smooth, well-alined surfaces required for trouble-free operation, a corrosion-proof steel lining is recommended for the floor and lower sidewalls throughout the length of the transition. The sections of plates making up this lining must be well alined and well anchored, and incapable of drumming or vibrating. Any slight irregularities or misalinements that occur during installation should be ground away to produce smooth surfaces in the direction of flow.

Floor drains. Floor drains will be needed to empty the tunnel when inspections are to be made. Due to the 0.001 up-slope of the tunnel from the gates to the outlet portal, the low point of the tunnel and hence the best location for the downstream drain is close to the gate. This location also has the advantage of simplified piping because the access tunnel and waste facilities are near the gates. However, the discontinuity that would be produced in the floor by an ordinary drain could cause trouble due to cavitation because of the high velocity flows. Therefore, a number of modifications to the drain entrances were considered that might reduce any tendency for producing negative pressures. These included rounding the corners of the holes, tapering the surface downstream from the holes, and using different sizes, shapes, and spacings of holes. The ideas ultimately led to the selection of a slot-type drain which extends the full width of the passage and resembles a gate slot in cross section (Figure 19). No tests were authorized for determining the performance of this type drain, and none were made, but the drain is believed to be satisfactory.

Air vents. Provisions were made in the preliminary design for an air vent extending from the ground surface either vertically or diagonally downward 320 or more feet to the roof of the tunnel (Figure 4). A branch line from this vent supplies the air manifold in the roof of the downstream frame of the control gate (Figure 6). The demand for air occurs when a hydraulic jump forms in the tunnel. The peak demand was computed to be 600 cfs. This demand is based upon an experimentally determined relationship of air-to-water ratio and Froude number at the vena contracta. 4/

A 24-inch-diameter vent would carry the 600 cfs of air at a velocity of 193 feet per second and with a combined entrance, friction, and exit loss of about 2.4 feet of water. But the likelihood of ever reaching this peak air demand, which requires the peak flood storage in Tooma Reservoir and a Tumut Pond elevation just sufficient to hold the jump close to the control gate, was considered remote. Four hundred cfs was selected as a more reasonable rate of air flow and was used for design purposes. An 18-inch-diameter line would carry the 400 cfs at a velocity of 226 feet per second, and with a total head loss of 4.0 feet of water. This loss, which in effect will be the pressure difference from the atmosphere to the tunnel, was not excessive and the 18-inch-diameter vent, though inferior to the 24-inch one, was considered acceptable.

The most suitable location for a vent opening is close to the downstream face of the regulating gate leaf. Structural limitations prevented placing the opening in this region, and it was placed just downstream of the gate frame (Figure 6). Smaller vents were provided close to the leaf by the manifold built into the roof of the gate frame (Figure 7). Air to this manifold is supplied by a branch pipe that joins the main vent at a point above the roof of the conduit (Figure 6). During operation at small back pressures, there is a rising pressure gradient along the conduit (Figure 17A). Water will therefore rise in the main vent while the gate body vents are still demanding air. It is important that the branch pipe joins the main vent at a high enough elevation to keep the branch unflooded until sufficient back pressure has built up to make air unnecessary at the leaf. To establish the elevation for this junction, tests were made to determine the pressure profiles along the roof of the conduit downstream from the gate (Figure 17B). These tests were run with maximum head represented on the gate, and with the back pressure regulated to just maintain atmospheric pressure at the gate vents. From the data obtained (Figure 17B), the minimum junction elevation could be selected for the location chosen for the main vent opening.

Coefficient curves. The curve showing the relationship of coefficient of discharge and gate opening during free discharge conditions

---

4/ "Hydraulic Design Criteria," Sheets 050-1, U. S. Corps of Engineers.

is shown in Figure 21A. This curve is based upon the gate opening in percent of effective travel, the area of the 11-foot 3-inch-diameter conduit and the piezometric pressure at the Reference Station, one diameter upstream from the gate transition. The curve for submerged flow, based upon the gate opening, the conduit area, and the piezometric head drop from the Reference Station to the tunnel station 156 feet downstream of the control gate, is shown in Figure 21B.

Sudden Enlargement Downstream of Control Gate

Consideration was given to a design that provided a sudden enlargement immediately downstream of the control gate and that raised the tunnel outlet portal 10 feet to make the tunnel flow full. This design was intended to provide a water cushion around the high-velocity flow from the gate and to make the design similar to that of the Eucumbene structure.

Computations and tests showed that a back pressure of about 30 feet was required above the gate invert for sufficient downstream pressure to hold a hydraulic jump when releases at near maximum heads were made at 20 and 30 percent gate openings. Other tests showed that a back pressure of 69 feet was required to keep the wall pressures of a 13-foot-diameter tunnel atmospheric when releases were made at the maximum head with a 30 percent gate opening. These computations and tests showed that the required back pressures were much above the 10 feet to be provided by raising the outlet portal, and consequently trouble could be expected during operation with low water surface elevations in Tumut Pond. The tunnel portal could be raised enough to obtain acceptable pressure conditions, but other design problems would be introduced by this change. It was therefore considered best to retain the design in which the conduit surfaces remained in contact with the jet and gradually directed it into the circular tunnel.

Eucumbene Control Structure

Preliminary Design--Square Conduit Downstream of Gate

In the preliminary design, the conduit cross section downstream of the control and guard gates was a square 12 feet wide and 12 feet high (Figure 8). This 3-1/2-foot-long square section was followed by a 19-1/2-foot-long transition to the 13-foot-diameter tunnel. The square section was placed at the gate outlet to provide more space than the circular section provided for circulation of water between the issuing jet and the tunnel walls. Better circulation of water around the jet was expected to produce a more stable dispersion of the jet and less tendency for the jet to strike the walls.

Tests were made with a 13-foot square section represented downstream from the gates, and also with the 13-foot-diameter tunnel extended to the gates. Good flow and pressure conditions occurred with both designs. At the most severe operating conditions, which occurred in the range of 10 to 30 percent gate openings, the pressures in the round conduit were slightly higher at the top and bottom and slightly lower along the sides than in the square conduit. The differences were small and the stability of the jet was good in both designs. It was concluded that, because the circular conduit was as effective as the square one and was simpler and less expensive to build, the square conduit should be omitted and the circular conduit extended to the gates.

Recommended Design--13-foot-diameter Tunnel Downstream of Gates

The pressures on the control gate, on the downstream guard gate, and on the walls of the 13-foot-diameter tunnel were positive and satisfactory at all applicable operating conditions (Figure 13C). The tests were made with the maximum head represented on the gate and with the minimum back pressure, including friction, that will occur in the tunnel to Adaminaby Reservoir.

The flow dispersion within the tunnel was studied by admitting air through the gate frame vents to make the flow pattern visible (Figure 20). In the region 1 to 2 tunnel diameters downstream from the gate, strong upstream flow occurred over the top of the jet, and downward flow occurred between the sides of the jet and the tunnel walls. This down-flow was greatest close to the gates. The flow beneath the jet moved downstream. Four tunnel diameters downstream from the gate the flow direction in the upper part of the conduit was unstable and intermittently changed from upstream to downstream. At 5 tunnel diameters downstream from the gate the dispersion was sufficiently complete so that all the flow across the tunnel section moved downstream. No direct impingement of high-velocity flow occurred on the tunnel walls, and no undue pounding or slugging was present. The design in which the gates discharged directly into the 13-foot-diameter conduit was therefore recommended for use.

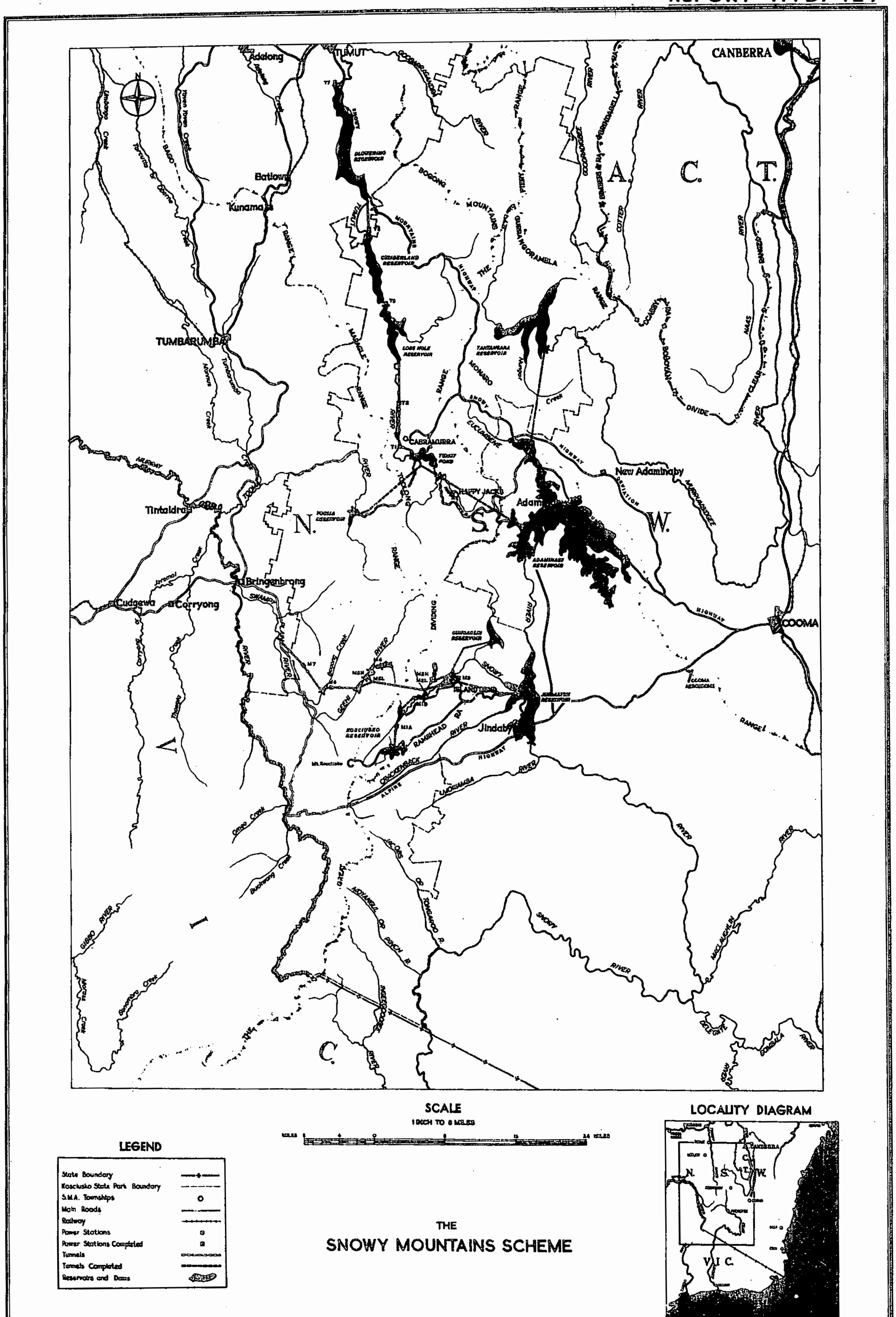
Floor drains. Floor drains were required between the upstream guard gate and the control gate, and between the control gate and the downstream guard gate, to empty these regions to permit inspection and maintenance work (Figure 8). For simplicity, the slot type drain, similar to the one recommended for the Tumut gate structure should be used downstream of the first guard gate in the Eucumbene structure (Figure 19). The drain between the control gate and the downstream guard gate can be placed in the space made available between the face of the downstream guard gate leaf and the downward step from the floor to the leaf seal (Figure 19).

Gravel trap, drain, and energy dissipator. A gravel trap and drain were provided upstream from the Eucumbene control structure (Figure 8). The head on the 12-inch drain line may at times be over 400 feet and care must be taken in releasing the water into the access tunnel. To control and dissipate the excess energy of the releases within the confined space available in the access tunnel, a well-type stilling basin[2] was laid horizontal with the basin discharge port facing upward (Figure 8). The well includes large corner fillets. No model studies were made on the horizontal well in the Eucumbene structure.

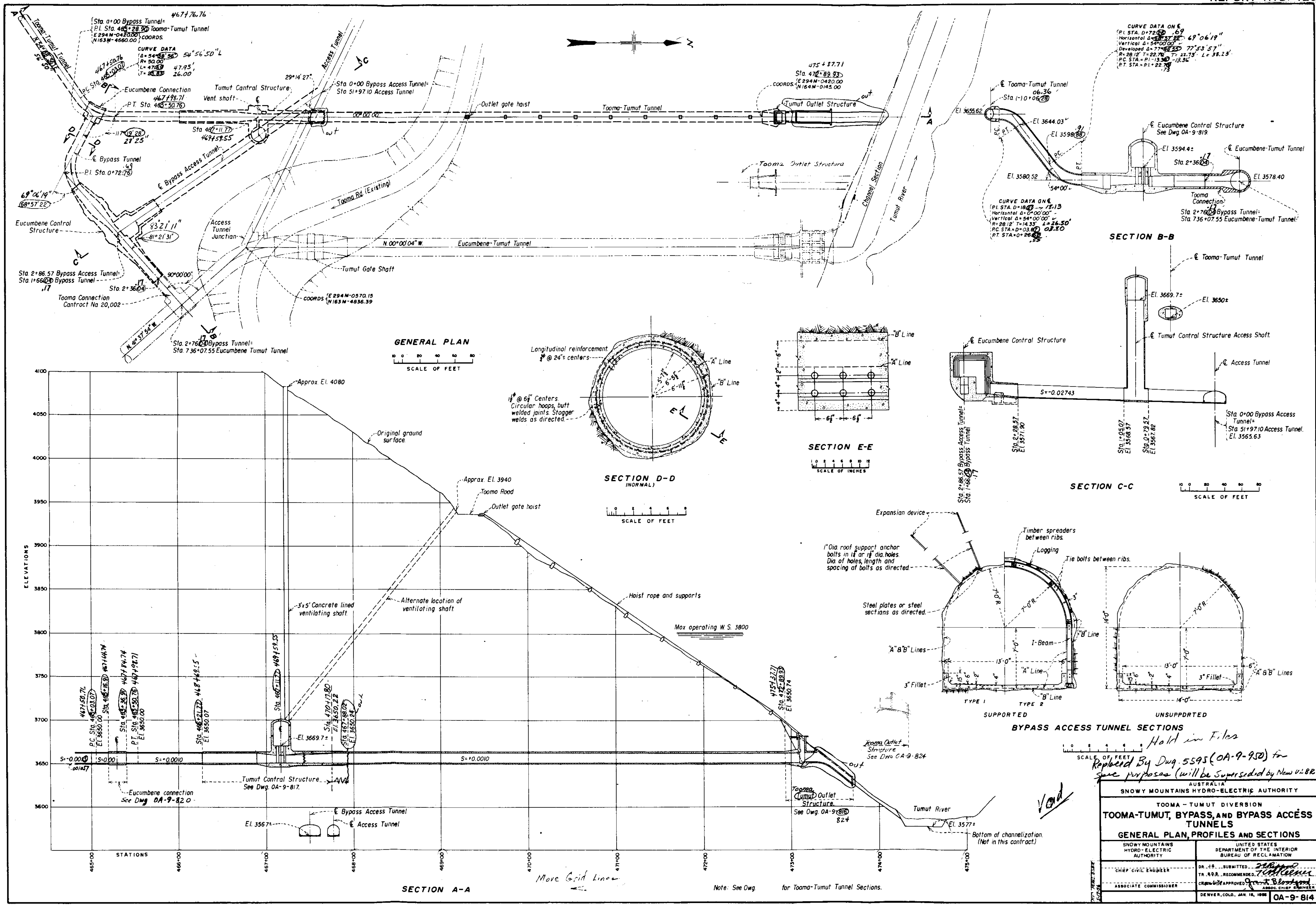
Manhole. An entrance port, or manhole, was required for access into the area between the control gate and the downstream guard gate (Figure 8). For convenience this port was placed relatively low on the left sidewall. It was, however, kept high enough to be above the elevation of the high velocity flows released at gate openings below about 30 percent. At gate openings larger than 30 percent the friction loss in the upstream tunnel reduces the effective head sufficiently so that extreme velocities no longer occur. Reasonable care should be taken to provide a smooth continuous flow surface along the sidewall and across the manhole cover.

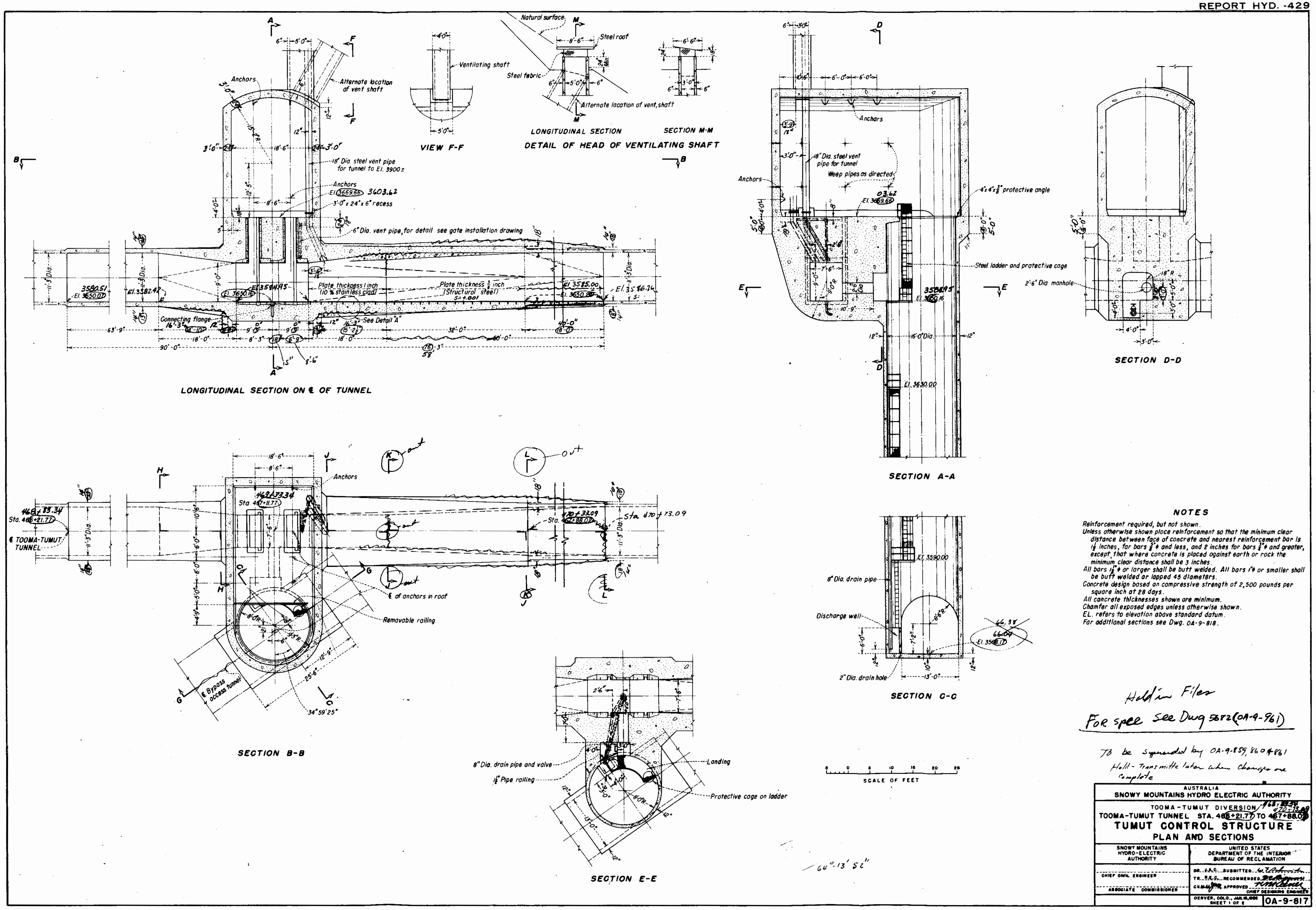
Air vents. No air vents were needed and none were provided in the Eucumbene control structure because the flow always occurs under high back pressures. All pressures in the gate structure were strongly positive.

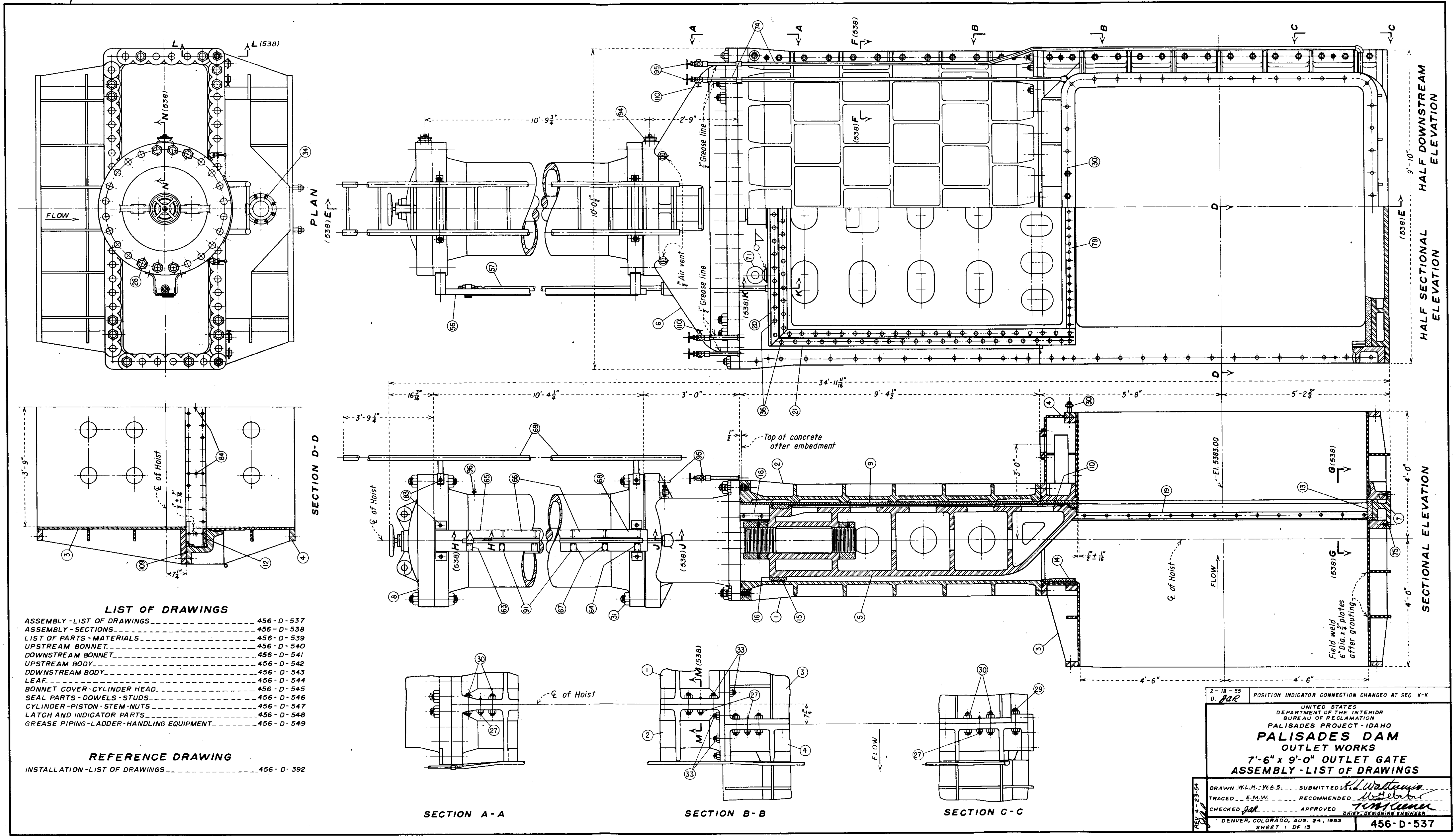
Coefficient curve. The curve showing the relationship of coefficient of discharge to gate opening, based upon the drop in piezometric head from the reference station upstream of the gate to the tunnel station 180 feet downstream of the guard gate, is presented in Figure 21C.

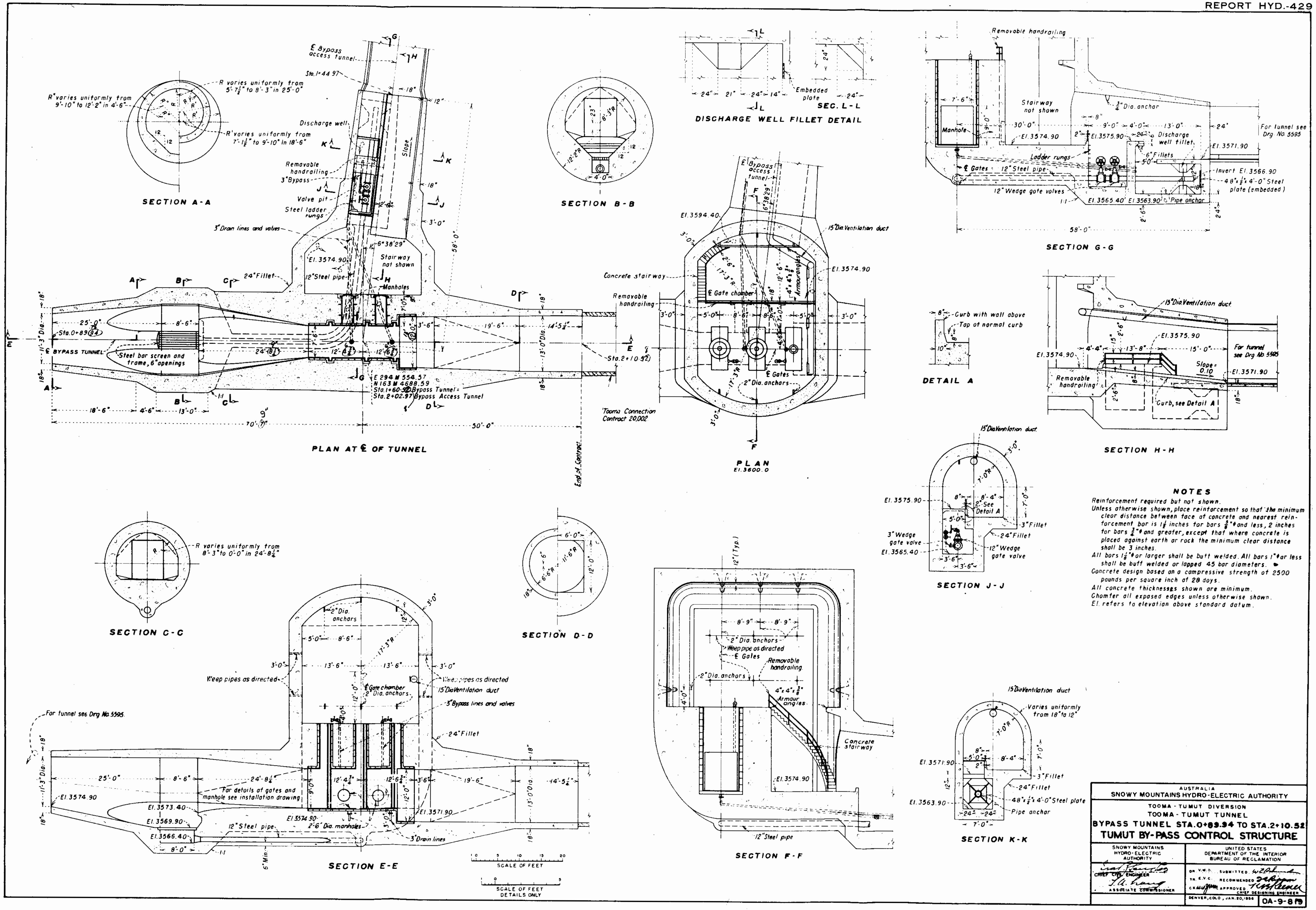


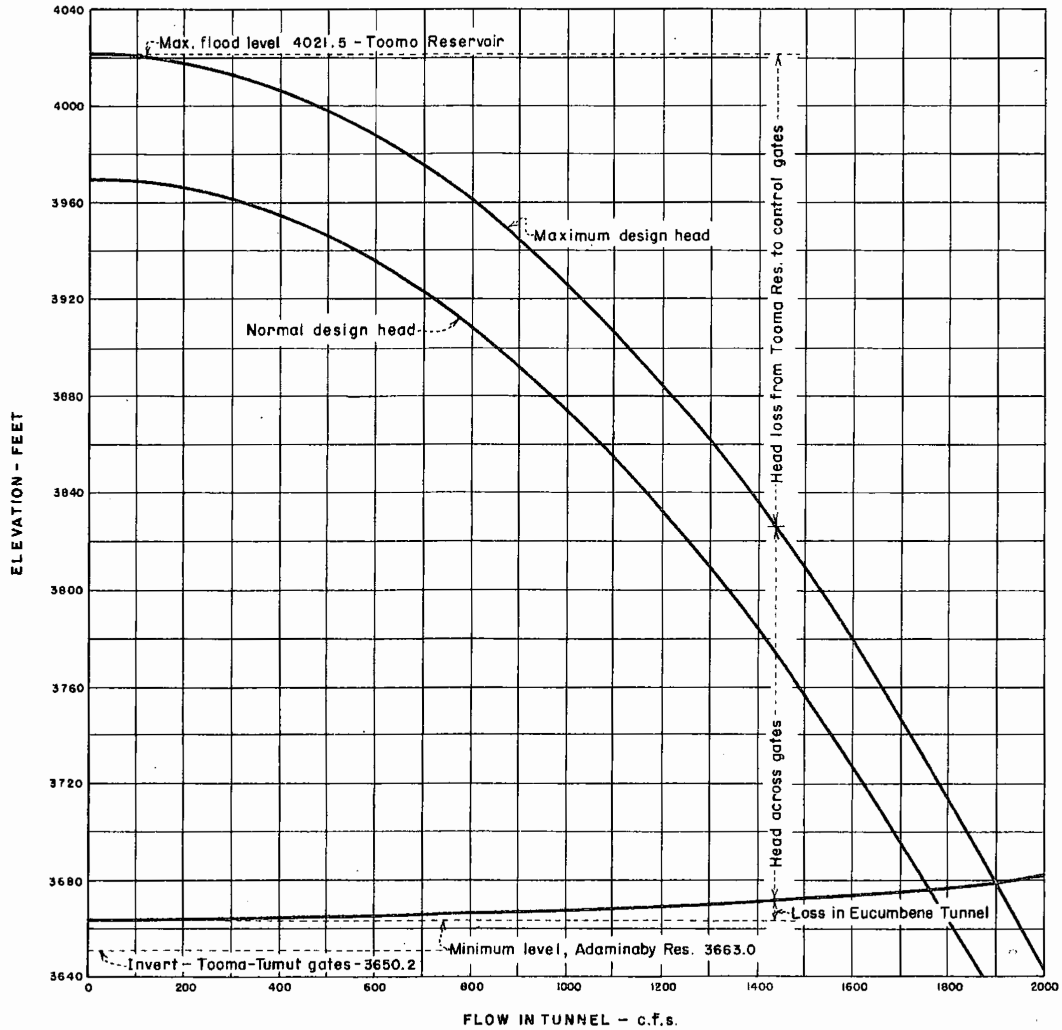
THE
SNOWY MOUNTAINS SCHEME


GENERAL PLAN
SCALE OF FEET
Tooma-Tumut Tunnel
Tumut Control Structure
Eucumbene Control Structure
Eucumbene-Tumut Tunnel
Tumut Outlet Structure
Tooma Rd (Existing)
Tumut River
Channel Section
SECTION D-D (NORMAL)
SECTION E-E
SECTION B-B
SECTION C-C
SECTION A-A
ELEVATIONS
STATIONS
Original ground surface
Hoist rope and supports
Max operating W.S. 3800
SUPPORTED
UNSUPPORTED
BYPASS ACCESS TUNNEL SECTIONS
Note: See Dwg for Tooma-Tumut Tunnel Sections.
AUSTRALIA
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
TOOMA - TUMUT DIVERSION
TOOMA-TUMUT, BYPASS, AND BYPASS ACCESS TUNNELS
GENERAL PLAN, PROFILES AND SECTIONS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
0A-9-814


LONGITUDINAL SECTION ON ℄ OF TUNNEL
VIEW F-F
DETAIL OF HEAD OF VENTILATING SHAFT
LONGITUDINAL SECTION
SECTION M-M
SECTION A-A
SECTION D-D
SECTION B-B
SECTION C-C
SECTION E-E
SCALE OF FEET
NOTES
Reinforcement required, but not shown.
Unless otherwise shown place reinforcement so that the minimum clear distance between face of concrete and nearest reinforcement bar is 1½ inches, for bars ⅝"ϕ and less, and 2 inches for bars ¾"ϕ and greater, except that where concrete is placed against earth or rock the minimum clear distance shall be 3 inches.
All bars 1⅛"ϕ or larger shall be butt welded. All bars 1"ϕ or smaller shall be butt welded or lapped 45 diameters.
Concrete design based on compressive strength of 2,500 pounds per square inch at 28 days.
All concrete thicknesses shown are minimum.
Chamfer all exposed edges unless otherwise shown.
EL. refers to elevation above standard datum.
For additional sections see Dwg. OA-9-818.
Hold in Files
For spec See Dwg 5872 (OA-9-961)
To be superseded by OA-9-859, 860 & 861
Hold - Transmitte later when changes are complete
AUSTRALIA
SNOWY MOUNTAINS HYDRO ELECTRIC AUTHORITY
TOOMA-TUMUT DIVERSION
TOOMA-TUMUT TUNNEL STA. 466+21.77 TO 467+88.07
TUMUT CONTROL STRUCTURE
PLAN AND SECTIONS
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
CHIEF CIVIL ENGINEER
ASSOCIATE COMMISSIONER
DR. J.A.C. SUBMITTED
TR. R.E.C. RECOMMENDED
CK. APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLO., JAN. 16, 1956
SHEET 1 OF 2
OA-9-817


PLAN
HALF DOWNSTREAM ELEVATION
HALF SECTIONAL ELEVATION
SECTIONAL ELEVATION
SECTION D-D
SECTION A-A
SECTION B-B
SECTION C-C
FLOW
℄ of Hoist
Top of concrete after embedment
El. 5383.00
½" Grease line
½" Air vent
Field weld 6" Dia. x ¾" plates after grouting
LIST OF DRAWINGS
ASSEMBLY - LIST OF DRAWINGS 456-D-537
ASSEMBLY - SECTIONS 456-D-538
LIST OF PARTS - MATERIALS 456-D-539
UPSTREAM BONNET 456-D-540
DOWNSTREAM BONNET 456-D-541
UPSTREAM BODY 456-D-542
DOWNSTREAM BODY 456-D-543
LEAF 456-D-544
BONNET COVER - CYLINDER HEAD 456-D-545
SEAL PARTS - DOWELS - STUDS 456-D-546
CYLINDER - PISTON - STEM - NUTS 456-D-547
LATCH AND INDICATOR PARTS 456-D-548
GREASE PIPING - LADDER - HANDLING EQUIPMENT 456-D-549
REFERENCE DRAWING
INSTALLATION - LIST OF DRAWINGS 456-D-392
2-18-55 POSITION INDICATOR CONNECTION CHANGED AT SEC. K-K
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PALISADES PROJECT - IDAHO
PALISADES DAM
OUTLET WORKS
7'-6" x 9'-0" OUTLET GATE
ASSEMBLY - LIST OF DRAWINGS
DRAWN W.L.H.-W.A.S. SUBMITTED
TRACED E.M.W. RECOMMENDED
CHECKED APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLORADO, AUG. 24, 1953
SHEET 1 OF 13
456-D-537


SECTION A-A
SECTION B-B
DISCHARGE WELL FILLET DETAIL
SEC. L-L
SECTION G-G
PLAN AT ℄ OF TUNNEL
PLAN
El. 3600.0
DETAIL A
SECTION H-H
SECTION J-J
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION K-K
SCALE OF FEET
SCALE OF FEET
DETAILS ONLY
NOTES
Reinforcement required but not shown.
Unless otherwise shown, place reinforcement so that the minimum clear distance between face of concrete and nearest reinforcement bar is 1½ inches for bars ⅝"ϕ and less, 2 inches for bars ¾"ϕ and greater, except that where concrete is placed against earth or rock the minimum clear distance shall be 3 inches.
All bars 1⅛"ϕ or larger shall be butt welded. All bars 1"ϕ or less shall be butt welded or lapped 45 bar diameters.
Concrete design based on a compressive strength of 2500 pounds per square inch at 28 days.
All concrete thicknesses shown are minimum.
Chamfer all exposed edges unless otherwise shown.
El. refers to elevation above standard datum.
AUSTRALIA
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
TOOMA - TUMUT DIVERSION
TOOMA - TUMUT TUNNEL
BYPASS TUNNEL STA.0+89.34 TO STA.2+10.52
TUMUT BY-PASS CONTROL STRUCTURE
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
CHIEF CIVIL ENGINEER
ASSOCIATE COMMISSIONER
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DR. V.M.D. SUBMITTED
TR. E.V.C. RECOMMENDED
CK. APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLO., JAN. 20, 1956
OA-9-819



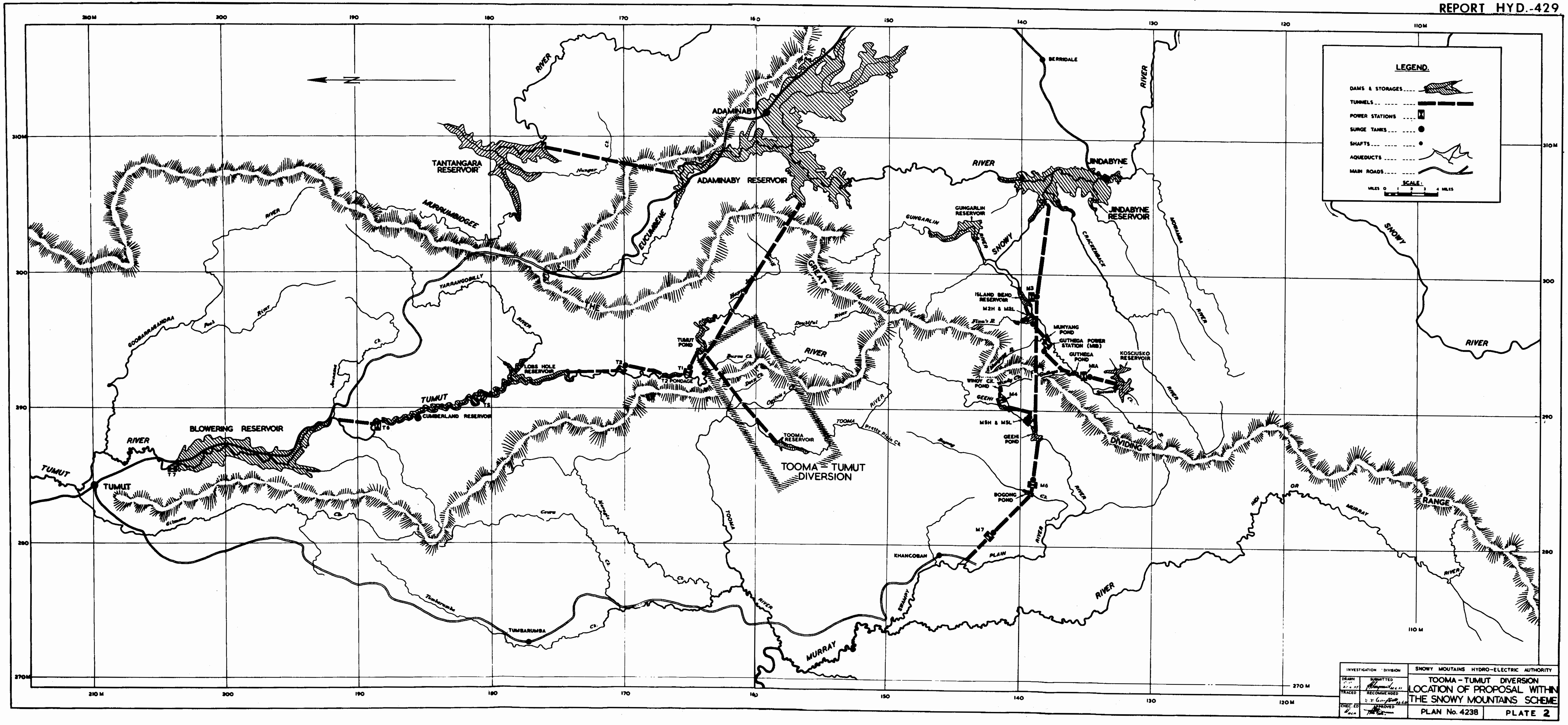
TUMUT AND EUCUMBENE CONTROL STRUCTURES

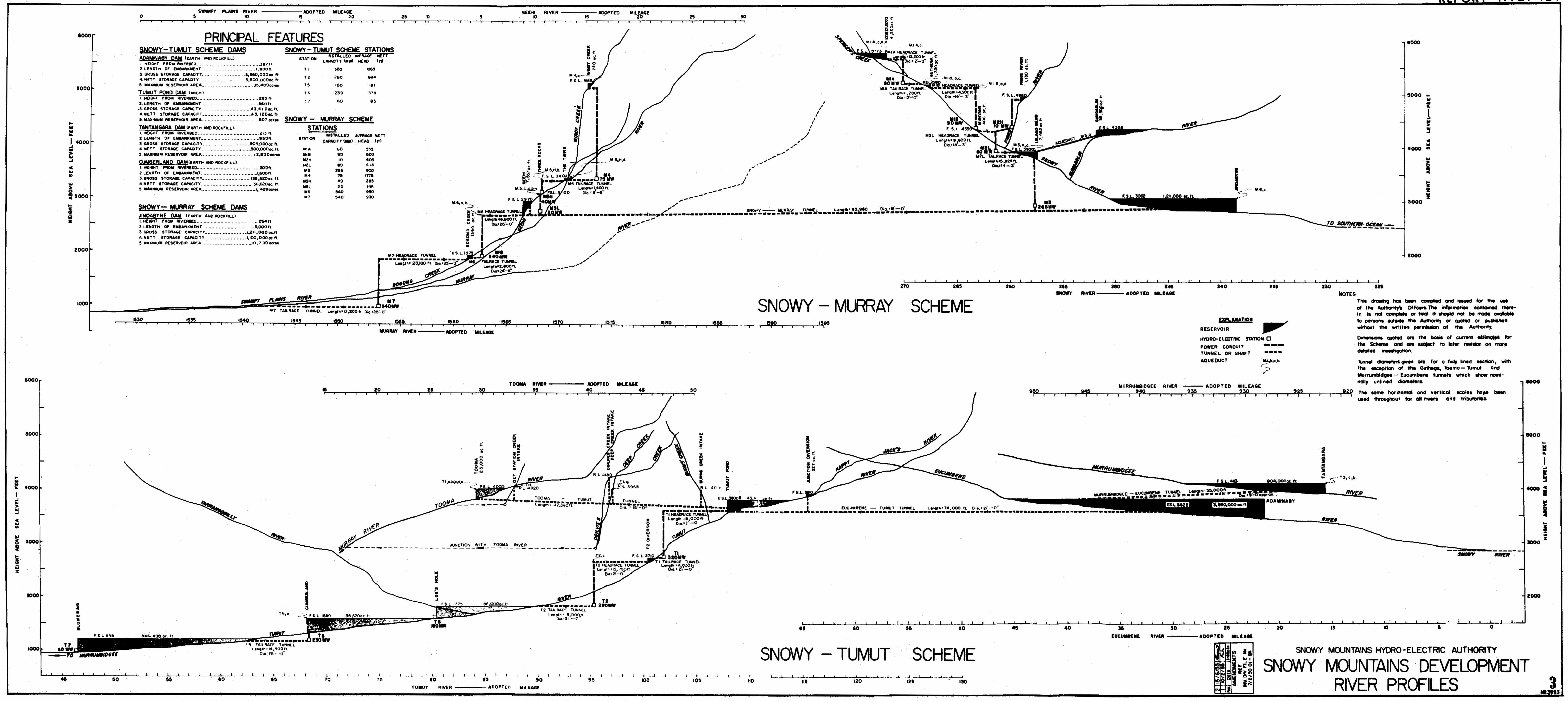
TOOMA-TUMUT DIVERSION

COMPUTED ENERGY LOSSES IN TUNNELS,
AND DIFFERENTIAL HEADS ACTING ON GATES

DATA BY M.E.S.

FIGURE 2
REPORT HYD.-429



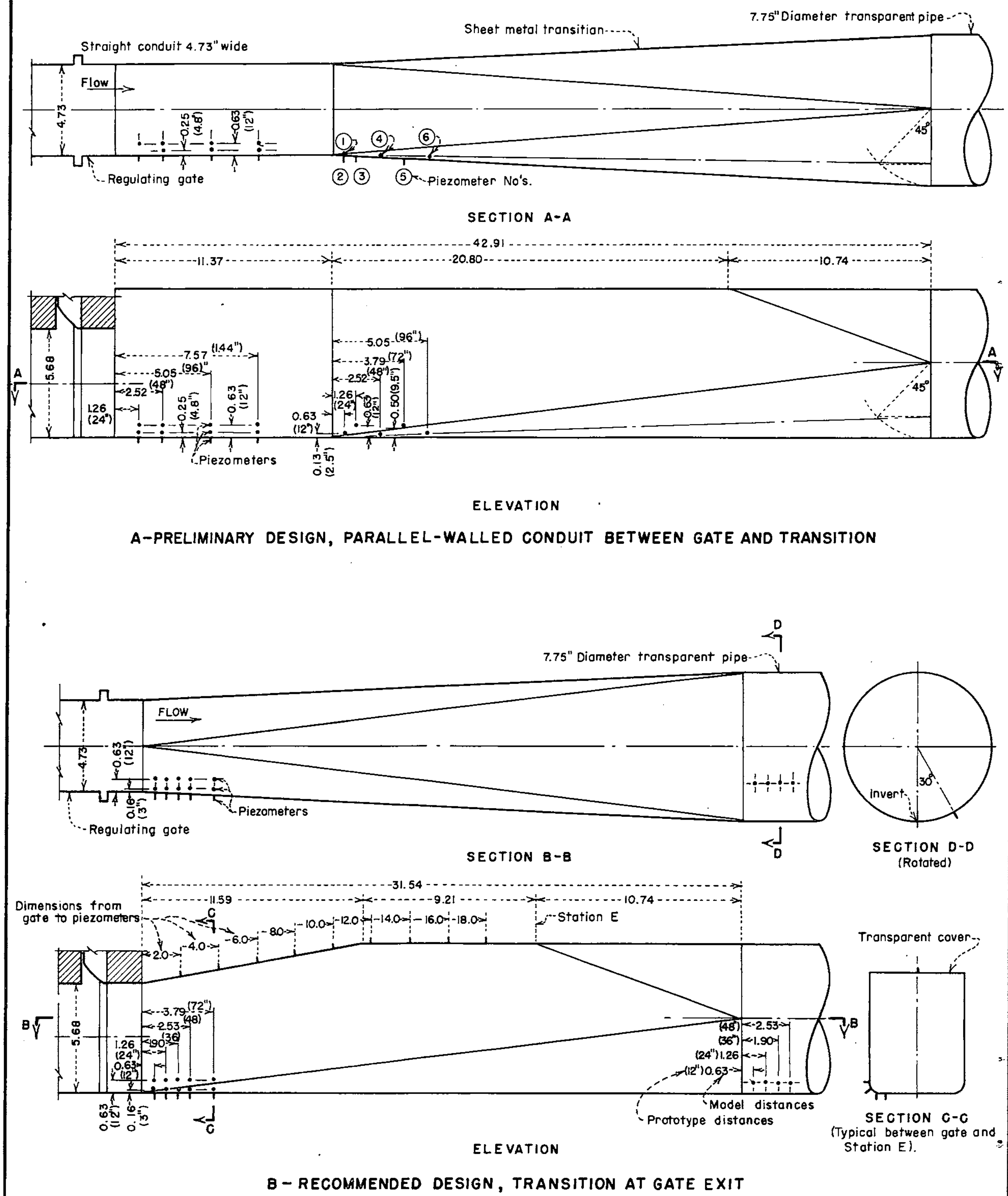


SNOWY–TUMUT SCHEME STATIONS

STATION	INSTALLED CAPACITY (MW)	AVERAGE NETT HEAD (ft)
T1	320	1065
T2	280	884
T5	180	191
T6	230	378
T7	60	195

SNOWY – MURRAY SCHEME STATIONS

STATION	INSTALLED CAPACITY (MW)	AVERAGE NETT HEAD (ft)
M1A	60	555
M1B	90	800
M2H	10	605
M2L	80	415
M3	265	900
M4	75	1775
M5H	40	285
M5L	20	145
M6	540	950
M7	540	930

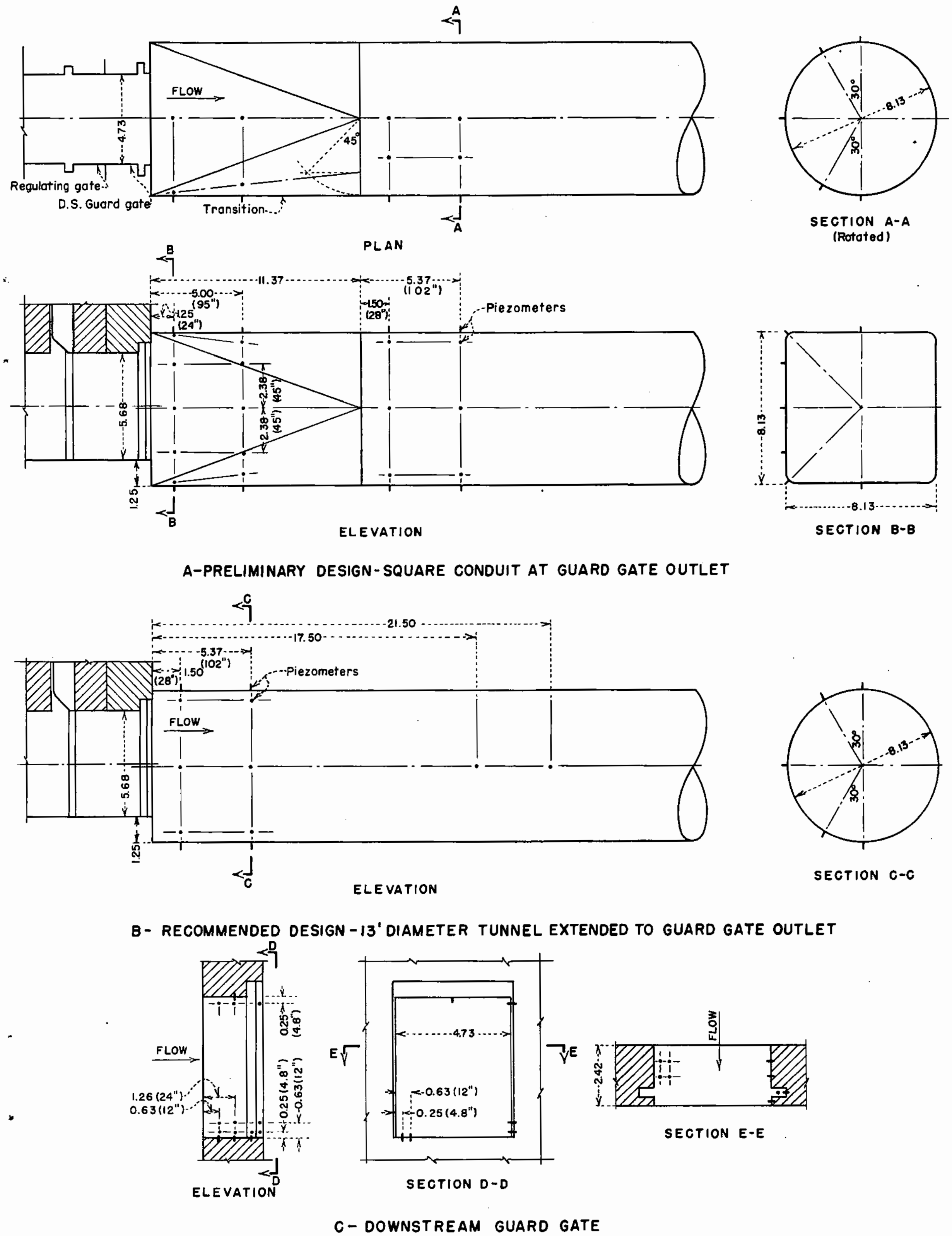


TUMUT CONTROL STRUCTURE
TOOMA-TUMUT DIVERSION

PRELIMINARY AND RECOMMENDED DESIGNS OF CONDUIT DOWNSTREAM FROM GATES, WITH PIEZOMETER LOCATIONS

1:19 SCALE MODEL

FIGURE 12
REPORT HYD. 429



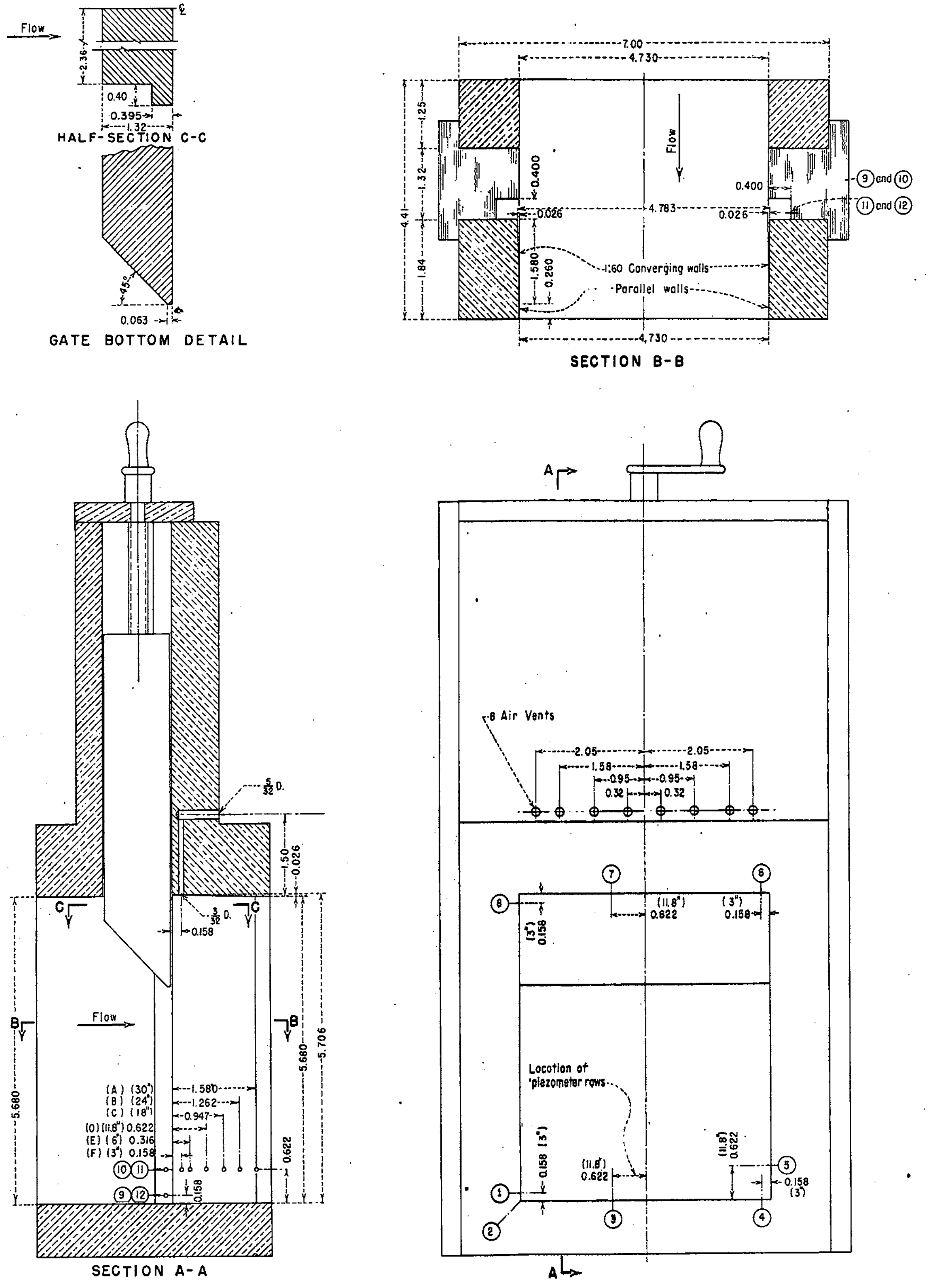
EUCUMBENE CONTROL STRUCTURE

TOOMA-TUMUT DIVERSION

PRELIMINARY AND RECOMMENDED DESIGNS OF CONDUIT
DOWNSTREAM FROM GATES, WITH PIEZOMETER LOCATIONS

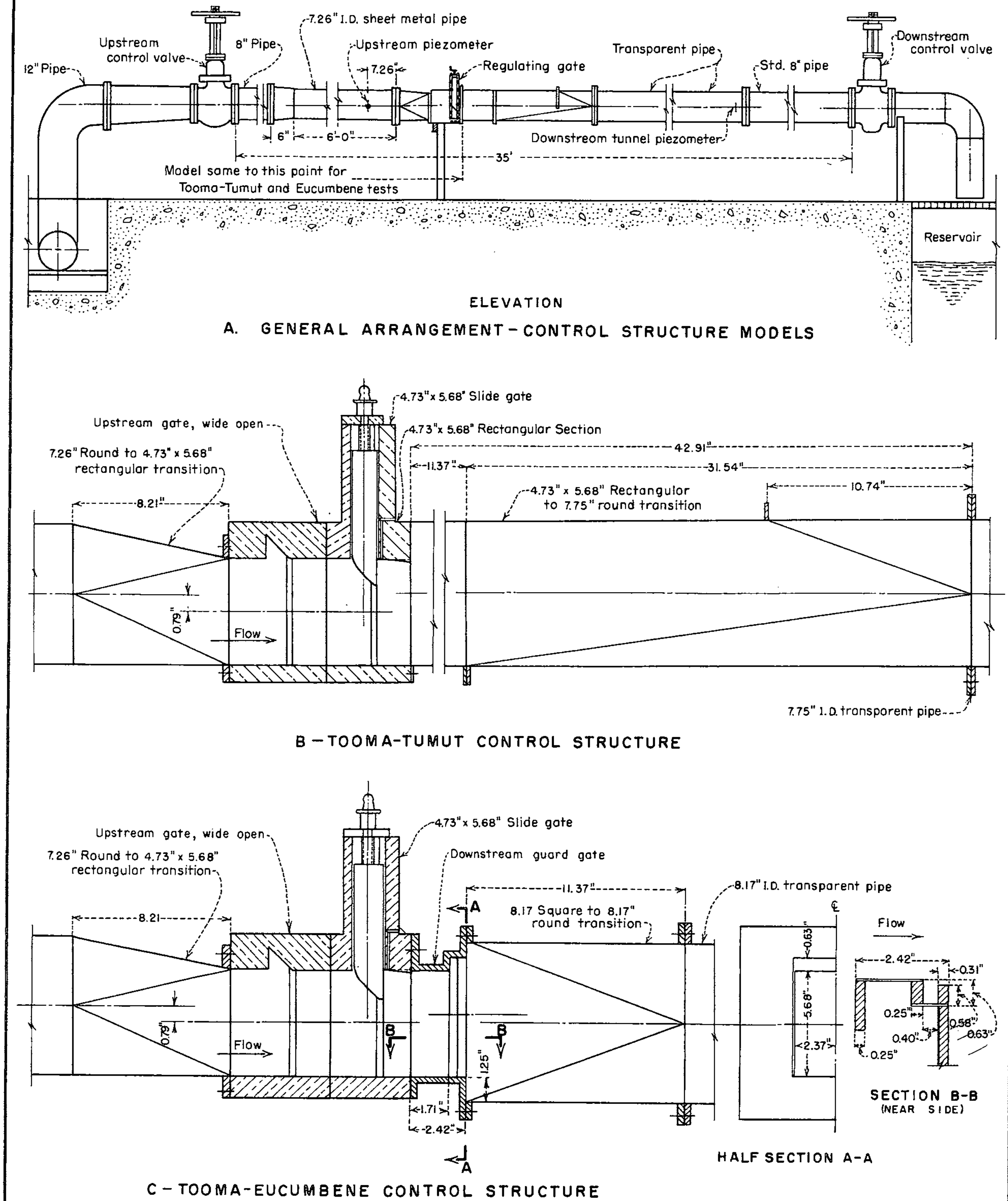
1:19 SCALE MODEL

535



(1), etc,- indicates station of piezometers
(5"), etc,- prototype distance
(A), etc,- piezometer designation

TUMUT AND EUCUMBENE CONTROL STRUCTURES
TOOMA – TUMUT DIVERSION
CONTROL GATE — 1:19 SCALE MODEL



TUMUT AND EUCUMBENE CONTROL STRUCTURES

TOOMA - TUMUT DIVERSION

THE 1:19 SCALE MODELS

635

PIEZOMETER / GATE OPENING	GATE FLOOR 3" FROM WALL						GATE CORNER OF FLOOR & WALL						GATE WALL 3" ABOVE FLOOR					
	DISTANCE FROM LEAF						DISTANCE FROM LEAF						DISTANCE FROM LEAF					
	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"
100 %	← Positive →						← Positive →						← Positive →					
99			"						"						"			
98			"						"						"			
97			"						"						"			
90			"						"						"			
50	34.2	31.9	28.3	25.3	21.3	17.7	36.5	34.0	30.2	26.0	22.8	19.6	35.7	33.6	29.8	25.5	21.9	18.2
30	65.0	57.8	44.8	35.9	26.2	18.2	68.4	60.6	48.6	36.3	28.9	20.5	66.7	59.5	47.5	35.3	26.6	17.9
20	86.3	72.2	68.8	35.5	21.5	12.0	90.1	76.4	55.1	36.1	25.7	15.0	86.1	74.7	52.3	32.5	20.5	9.7
10	86.8	61.6	29.3	18.8	10.3	5.5	80.2 TO 86.8	63.1 TO 65.7	35.5	16.3	12.0	6.5	81.1	62.1	32.3	13.7	7.6	0.8
7	62.5	40.9	21.7	14.3	9.1	5.7	73.1	45.6	21.7	12.2	13.9	8.4	38.2	21.5	15.0	6.5	6.5	4.0
5	53.2	23.2	11.8	13.9	7.6	7.2	7.2	29.1	16.0	9.5	12.4	8.0	above	flow	4.0	3.4	4.6	3.6
3	56.2	19.8	5.5	5.3	3.4	1.9	2.1	2.5	1.5	1.9	2.9	1.3	← Flow not on surface →					

PIEZOMETER / GATE OPENING	GATE WALL 11.8" ABOVE FLOOR						GATE ROOF 3" FROM WALL						GATE ROOF 11.8" FROM ℄					
	DISTANCE FROM LEAF						DISTANCE FROM LEAF						DISTANCE FROM LEAF					
	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"
100 %	← Positive →						← Positive →						← Positive →					
99			"						"						"			
98			"						"				← Flow not on surface →					
97			"				← Spray & Fins on surface →							"		"		
90			"				← Flow not on surface →							"		"		
50	33.4	31.0	26.6	22.6	18.8	14.4		"		"				"		"		
30	54.9	48.3	35.7	24.7	16.2	7.6		"		"				"		"		
20	50.0	44.5	29.5	18.8	11.8	3.8		"		"				"		"		
10	← Flow not on surface →							"		"				"		"		
7			"		"			"		"				"		"		
5			"		"			"		"				"		"		
3			"		"			"		"				"		"		

PIEZOMETER / GATE OPENING	CONDUIT FLOOR 12" FROM WALL				CONDUIT FLOOR 4.8" FROM WALL			CONDUIT CORNER		CONDUIT WALL 4.8" ABOVE FLOOR				CONDUIT WALL 12" ABOVE FLOOR				TRANSITION						REF. STATION
	DISTANCE FROM GATE				DISTANCE			DISTANCE		DISTANCE FROM GATE				DISTANCE FROM GATE				PIEZOMETER NUMBER						
	24"	48"	96"	144"	48"	96"	144"	24"	96"	24"	48"	96"	144"	24"	48"	96"	144"	1	2	3	4	5	6	
100 %	← Positive →				← Positive →			Positive		← Positive →				← Positive →				← Positive →						11.6
99		"				"			"			"			"					"				11.6
98		"				"			"			"			"					"				
97		"				"			"			"			"					"				12.7
90		"				"			"			"			"					"				17.3
50	10.6	8.2	2.9	3.2	7.8	3.8	3.2	10.6	2.7	9.3	6.1	2.5	2.7	8.0	3.6	2.5	2.3	3.6	4.6	4.8	5.5	4.0	4.6	63.7
30	7.2	9.1	0	1.7	6.5	3.0	1.5	7.6	-0.3	3.8	2.5	-0.2	0.4	2.5	-1.7	1.0	0.8	0.4	4.6	5.9	5.3	2.9	3.8	140.2
20	4.9	10.0	-1.3	1.0	6.7	3.2	1.0	5.3	-1.7	-1.0	0.6	-1.0	-0.6	0.6	-4.0	-1.0	1.5	4.9	6.1	7.6	5.9	1.1	3.4	209.0
10	4.9	14.4	-2.1	1.5	7.8	4.8	0.6	5.1	-2.5	-3.2	-0.2	-1.7	-1.3	4.5	-1.9	3.0	2.9	3.6	7.0	8.2	5.7	-1.3	3.4	302.7
7	4.8	5.1	-2.1	1.3	8.4	7.8	1.7	6.5	-0.6	-1.5	-0.8	0.2	0	-5.1	-1.1	1.5	1.0	10.7	7.0	5.5	4.9	0		322.8
5	4.8	5.3	-1.9	1.9	7.4	4.8	1.1	5.7	0.4	-1.3	-0.8	0.6	0.4	0.4	0.2	0.8	0.8	1.1	1.5	0.6	2.1	0.4		344.3
3	7.6	7.8	-2.9	2.7	5.9	1.7	0.6	1.0	0.4	0.6	0.6	0.4	0.4	0.6	0.6	0.6	0.4	1.3	0.6	0.4	0.8	0.8		542.6

A- TUMUT CONTROL STRUCTURE-FREE DISCHARGE

PIEZOMETER / GATE OPENING	GATE FLOOR 3" FROM WALL						GATE CORNER OF FLOOR & WALL						GATE WALL 3" ABOVE FLOOR					
	DISTANCE FROM LEAF						DISTANCE FROM LEAF						DISTANCE FROM LEAF					
	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"
100 %	← Positive →						← Positive →						← Positive →					
98			"						"						"			
97			"						"						"			
95			"						"						"			
90			"						"						"			
80			"						"						"			
70	27.4	27.0	25.8	23.6	22.0	20.9			"						"			
60	← Positive →								"						"			
50	← Strongly Positive →						← Strongly Positive →						← Strongly Positive →					
40		"		"				"		"				"		"		
30		"		"				"		"				"		"		
20		"		"				"		"				"		"		
10	97.3	71.4	39.5	29.5	21.3	16.3	91.8	73.5	45.4	28.1	23.6	18.4	86.8	68.6	40.5	23.4	18.1	13.3
5	61.4	32.7	21.1	24.1	19.0	16.0	52.4	36.5	26.6	21.3	23.2	20.1	22.0	29.6	23.6	17.9	16.9	14.6
3	33.4	20.7	7.0 TO 10.9	11.8	13.7	14.6	3.8 TO 9.5	0.4 TO 4.2	16.5 TO 20.3	23.8	25.7	22.3	-13.1 TO -18.8	0.2 TO -9.3	21.7	19.2	18.8	16.5
2	33.6	20.5	7.6	13.7	15.4	15.6	4.2 TO 8.0	3.2 TO 7.0	13.7	22.2	26.0	22.6	-1.7 TO -12.2	-9.3 TO -15.0	17.3 TO 22.0	19.8	19.2	16.7

PIEZOMETER / GATE OPENING	GATE WALL 11.8" ABOVE FLOOR						GATE ROOF 3" FROM WALL						GATE ROOF 11.8" FROM ℄					
	DISTANCE FROM LEAF						DISTANCE FROM LEAF						DISTANCE FROM LEAF					
	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"
100 %	← Positive →						← Positive →						← Positive →					
98			"						"				2.9	6.3	7.0	8.0	Positive	
97			"				2.3	3.8	7.6	—	9.7	8.4	4.0	3.6	5.5	7.2	"	
95			"				Positive- slightly lower than near ℄						4.0	3.8	3.4	3.2	4.0	5.3
90			"				← 4.2 →						← 4.2 →					
80			"				← 3.2 →						← 3.2 →					
70			"				← Positive →						← Positive →					
60			"				← 3.0 →						← 3.0 →					
50	← Strongly Positive →						← 4.0 →						← 4.0 →					
40		"		"			← Positive →						← Positive →					
30		"		"			← 3.8 →						← 3.8 →					
20	48.5	← Positive →				3.4	← 3.8 →						← 3.8 →					
10			11.6				← 3.0 →						← 3.0 →					
5			11.4				← 2.9 →						2.9	2.9	2.9	4.0	5.3	5.1
3			11.8				← 3.8 →						← 3.8 →					
2			12.2				← 4.2 →						← 4.2 →					

PIEZOMETER / GATE OPENING	CONDUIT FLOOR 12" FROM WALL				CONDUIT FLOOR 4.8" FROM WALL			CONDUIT CORNER		CONDUIT WALL 4.8" ABOVE FLOOR				CONDUIT WALL 12" ABOVE FLOOR				TRANSITION					TUNNEL 156 FROM GATE	REF. STATION
	DISTANCE FROM GATE				DISTANCE			DISTANCE		DISTANCE FROM GATE				DISTANCE FROM GATE				PIEZOMETER NUMBER						
	24"	48"	96"	144"	48"	96"	144"	24"	96"	24"	48"	96"	144	24"	48"	96"	144"	1	2	3	4	5		
100 %	← Positive →				← Positive →			Positive		← Positive →				← Positive →				← Positive →					11.8	14.3
98		"				"			"			"			"					"			16.6	19.0
97		"				"			"			"			"					"			17.5	20.1
95		"				"			"			"			"					"			17.5	20.6
90		"				"			"			"			"					"			17.3	23.5
80	← 3.4 →				← 3.4 →			← 3.4 →		← 3.4 →				← 3.4 →						"			18.6	30.0
70	17.7	15.4	12.0	11.8	15.6	12.4	11.6	17.5	11.8	16.9	14.6	11.4	11.2	15.4	13.3	11.2	10.8	12.0	12.2	12.4	12.3	12.9	21.0	39.9
60	← Positive →				← Positive →			Positive		← Positive →				← Positive →				← Positive →					24.7	53.8
50			12.0	12.6		"			"			"			"					"			28.7	73.8
40	← Positive →					"			"			"			"					"			32.5	103.2
30		"				"			"			"			"					"			35.2	148.2
20		"				"			"	6.8		"			"					"			35.5	218.6
10	16.5	18.2	8.6	11.4	19.3	14.6	11.2	18.4	12.0	9.5	10.6	9.3	9.9	11.8	12.5	14.6	12.2	12.0	16.0	15.8	14.8	10.5	36' APPROX	307.6
5	15.8	18.1	8.9	11.6	17.1	13.7	11.0	20.0	13.1	11.4	11.8	11.4	10.5	10.4	12.2	14.3	12.2	10.8	14.1	13.5	12.4	8.7	"	346.9
3	16.3	17.7	11.2	12.4	15.4	13.7	12.0	18.6	14.1	13.1	13.7	12.7	11.8	11.4	12.2	13.3	12.2	11.0	12.7	11.8	11.0	9.1	"	367.8
2	16.9	17.1	11.6	12.4	15.4	13.9	12.4	18.8	13.9	12.9	13.7	12.7	12.2	11.4	12.2	13.5	12.2	11.8	13.1	12.5	11.8	10.1	"	376.2

B- TUMUT CONTROL STRUCTURE- SUBMERGED DISCHARGE
(Submergence just sufficient to produce atmospheric pressure at gate frame vents)

PIEZOMETER / GATE OPENING	GATE FLOOR 3" FROM WALL						GATE CORNER OF FLOOR & WALL						GATE WALL 3" ABOVE FLOOR					
	DISTANCE FROM LEAF						DISTANCE FROM LEAF						DISTANCE FROM LEAF					
	3"	6"	11.8"	18"	24	30"	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"
100 %	99.7	99.6	99.4	99.3	99.0	98.8	99.7	99.6	99.4	99.3	—	98.9	99.6	99.4	99.3	99.2	98.9	98.9
98	← same →						← same →						← same →					
96	99.4	99.3	99.0	99.0	98.7	98.5	99.8	99.5	99.3	99.1	—	98.9	99.5	99.4	99.1	99.0	98.7	98.7
94	99.0	98.9	98.7	98.4	98.2	99.2	99.3	99.0	98.9	98.7	—	98.2	99.2	99.0	98.9	98.7	98.4	98.4
90	98.7	98.4	98.4	98.1	97.6	97.1	99.4	99.1	98.9	98.5	—	97.5	99.1	99.0	98.7	98.2	97.7	97.5
80	102.4	102.0	101.3	100.4	99.0	97.9	103.8	103.3	102.5	101.4	—	99.0	103.5	103.2	102.3	101.1	99.9	98.9
70	103.4	102.9	101.6	100.3	98.5	96.0	105.6	104.7	102.3	101.1	98.5	96.4	105.3	104.5	102.3	100.6	99.4	97.9
60	107.8	106.8	104.3	101.9	99.2	96.0	110.2	109.0	106.2	104.0	99.1	98.0	109.9	108.4	106.0	102.8	100.3	98.2
50	113.3	111.3	106.6	103.5	99.3	94.0	116.3	113.7	109.5	106.2	98.8	97.9	115.9	113.8	109.0	104.2	100.6	97.1
40	123.0	118.8	111.4	105.6	98.2	90.7	126.5	122.2	114.2	108.9	98.2	90.7	130.3	122.1	115.3	107.6	100.1	94.9
30	140.8	133.5	119.1	109.4	96.4	85.4	143.8	136.7	122.9	112.1	—	92.0	142.1	135.3	122.3	108.6	99.4	92.6
20	158.3	143.3	119.7	103.7	85.0	71.1	163.2	147.7	124.4	106.1	—	79.3	158.1	145.9	122.0	99.4	88.2	79.1
10	164.6	137.0	101.2	89.7	77.3	67.6	157.6	137.6	106.4	91.5	—	75.2	151.5	132.7	100.9	80.9	76.4	73.1
5	130.9	102.8	87.3	89.0	82.2	75.8	125.5	109.3	93.4	90.7	—	81.5	104.2	101.5	88.6	82.6	82.6	80.2
4	119.6	97.1	86.0	88.4	82.9	77.7	110.6	101.2	91.2	90.8	—	83.6	80.1	94.6	86.7	83.6	83.6	82.2
3	105.0	91.3	85.7	85.4	82.1	78.6	94.2	97.0	90.9	90.9	—	85.3	78.2	87.1	85.0	84.3	84.3	84.3
2	126.4	94.2	72.1	79.6	81.4	81.4	76.7	71.4	82.5	98.2	—	95.3	46.0	43.5	85.3	92.1	90.0	87.8

PIEZOMETER / GATE OPENING	GATE WALL 11.8" ABOVE FLOOR						GATE ROOF 3" FROM WALL						GATE ROOF 11.8" FROM ℄					
	DISTANCE FROM LEAF						DISTANCE FROM LEAF						DISTANCE FROM LEAF					
	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"	3"	6"	11.8"	18"	24"	30"
100 %	99.2	98.9	98.8	98.5	98.4	98.2	94.0	93.7	93.3	—	92.3	92.3	93.5	93.5	93.2	92.7	92.7	92.5
98	← same →						87.2	92.2	93.8	—	92.2	92.3	88.5	89.9	92.3	92.7	92.8	92.6
96	99.0	98.8	98.5	98.2	98.0	97.9	86.1	86.0	87.5	—	92.7	92.4	87.5	87.2	87.1	88.8	90.3	90.9
94	98.4	98.2	97.9	97.8	97.5	97.1	85.4	85.2	84.7	—	87.1	88.9	86.6	86.5	86.2	86.6	86.0	86.7
90	98.2	98.1	97.9	97.4	97.0	96.2	86.5	86.3	85.9	—	85.8	86.0	86.9	86.8	86.7	86.8	85.9	85.7
80	101.4	101.4	100.5	99.6	98.4	97.0	88.5	88.5	88.4	—	88.4	88.4	88.6	88.5	88.4	88.4	88.2	88.4
70	103.2	102.6	101.1	99.7	97.5	95.4	84.2	84.2	84.3	—	85.2	84.8	85.2	84.6	84.6	84.7	84.3	84.2
60	107.4	105.8	103.4	100.8	97.4	94.5	← 81.5 →						← 81.5 →					
50	113.1	110.5	105.9	101.7	97.3	92.7	← 76.0 →						← 76.0 →					
40	121.3	116.6	108.4	102.0	95.7	88.7	← 70.6 →						← 70.6 →					
30	130.0	122.6	108.0	96.6	87.4	79.3	← 63.6 →						← 63.6 →					
20	119.3	111.7	94.8	85.8	76.7	71.1	← 61.1 →						← 61.1 →					
10	← 72.5 →						← 65.1 →						← 65.1 →					
5	78.8	78.5	78.5	78.2	78.2	77.8	← 68.7 →						← 68.7 →					
4																		
3																		
2																		

PIEZOMETER / GATE OPENING	GUARD GATE FLOOR					GUARD WALL 4.8" UP				GUARD WALL 12" UP			GUARD WALL 4.8" DOWN			GUARD GATE ROOF	13' DIAMETER TUNNEL							REF. STATION
	4.8" FROM WALL		12" FROM WALL		SLOT	POSITION				POSITION			POSITION				HORIZONTAL ℄		CROWN		INVERT		℄	
	12"	24"	12"	24"		12"	24"	SLOT WALL	SLOT CORNER	12"	24"	SLOT CORNER	12"	24"	SLOT CORNER	24"	28"	103"	28"	103"	28"	103"	180 FT	
100 %	99.0	98.8	99.0	98.8	97.9	98.8	98.5	98.3	99.4	98.2	98.0	99.2	92.5	92.3	92.3	92.5	96.3	97.3	92.1	93.8	100.8	101.4	100.6	103.1
98	98.8	98.7	99.0	98.7	97.9	98.7	98.4	98.2	99.5	98.1	97.9	99.1	92.4	92.2	92.2	92.3	96.4	96.9	92.2	92.6	100.8	101.4	100.6	103.1
96	98.9	98.7	98.7	98.6	97.7	98.4	98.2	98.1	99.6	97.9	97.7	99.3	92.8	92.7	92.6	92.9	96.6	97.1	93.1	93.8	100.5	101.1	100.6	103.3
94	98.4	98.4	98.4	98.3	97.6	98.2	98.0	97.8	99.3	97.6	97.5	98.9	91.4	91.9	92.1	91.7	96.1	96.5	93.3	93.7	100.3	101.2	100.6	103.6
90	97.0	96.8	97.7	97.1	95.1	96.7	96.3	95.8	97.7	96.6	96.2	97.7	87.0	89.0	89.6	87.2	93.5	96.1	87.2	93.4	98.9	99.9	100.6	105.3
80	97.1	95.0	97.0	95.0	92.6	96.9	94.9	92.5	92.4	96.4	94.5	92.8	88.1	87.9	88.1	87.2	87.9	91.9	84.9	84.2	90.9	92.8	100.6	113.1
70	94.7	92.0	94.8	91.7	91.6	94.3	91.6	87.7	85.1	93.9	91.1	87.3	83.6	83.7	83.7	83.3	84.5	84.5	80.5	79.9	84.7	93.6	99.6	119.2
60	93.2	89.4	93.0	89.0	84.5	92.5	88.7	85.1	83.5	92.2	88.0	83.5	84.6	84.4	84.0	84.6	81.5	79.7	77.2	74.4	67.1	86.2	99.6	129.3
50	90.4	85.7	90.7	84.7	80.5	89.6	85.0	79.6	73.0	88.6	84.4	79.1	75.2	75.2	75.2	74.1	75.4	76.8	67.2	66.4	73.0	80.1	98.6	145.6
40	87.5	81.5	86.4	80.1	75.5	85.0	79.3	74.6	69.9	83.8	77.9	72.2	70.3	70.3	70.2	70.0	71.9	68.0	65.8	62.0	68.6	77.2	97.6	171.6
30	82.3	75.6	81.5	74.2	71.4	78.5	73.6	70.1	63.7	77.5	74.0	62.9	63.1	62.9	62.9	62.6	65.8	58.0	56.1	52.8	63.9	73.6	95.6	215.8
20	76.3	71.1	75.3	67.7	64.9	68.5	66.9	65.9	51.6	70.1	70.1	64.8	60.2	59.8	59.4	59.2	61.8	58.4	54.8	52.2	52.8	73.9	91.6	290.0
10	80.0	74.6	81.5	74.3	69.7	71.5	73.7	70.6	46.7	73.4	74.6	65.8	65.2	64.9	64.6	62.8	66.1	62.2	59.4	57.0	58.8	76.4	87.6	390.3
5	87.3	81.9	88.0		78.2	80.2	81.5	78.2	61.9	78.2	78.5	76.5	71.1	69.0	68.4	64.0	73.8	73.1	68.0	67.0	71.1	85.9	85.6	423.6
4																							84.6	430.6
3																							84.6	437.6
2																							84.6	441.6

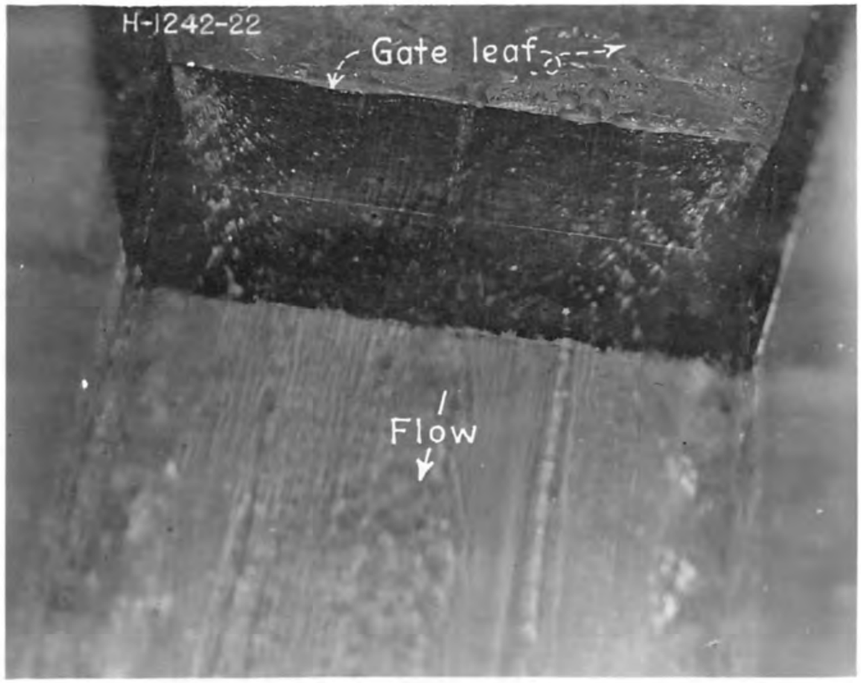
C- EUCUMBENE CONTROL STRUCTURE- SUBMERGED DISCHARGE
(With back pressure for minimum elevation of Adaminaby Reservoir)

NOTES

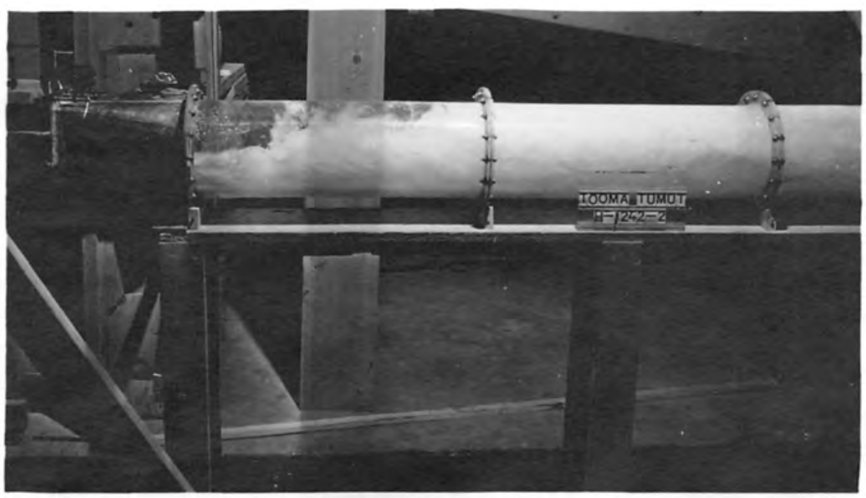
Pressures expressed in feet of water, Prototype,
Data from 1:19 scale model.

TUMUT AND EUCUMBENE CONTROL STRUCTURES
TOOMA-TUMUT DIVERSION

PRESSURES ON GATE FRAMES, TRANSITIONS, AND TUNNELS
PRELIMINARY DESIGN



A. Flow separates from sidewalls just downstream from gate slots at 5% and smaller openings. Operation shown is 5% open, Q = 400 cfs.



B. Hydraulic jump in tunnel downstream from control gate with gate set at 35% open, Q = 950 cfs.

TUMUT CONTROL STRUCTURE
TOOMA-TUMUT DIVERSION

Flow Separation From Gate Frame Walls, and Hydraulic Jump in Tunnel - Recommended Design

1:19 Scale Model

A. Gate 100% open
Q = 1910 cfs

B. Gate 97% open
Q = 1906 cfs

C. Gate 90% open
Q = 1900 cfs

D. Gate 50% open
Q = 1764 cfs

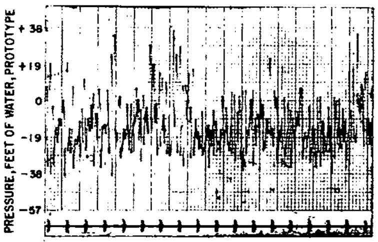
E. Gate 30% open
Q = 1512 cfs

F. Gate 10% open
Q = 788 cfs

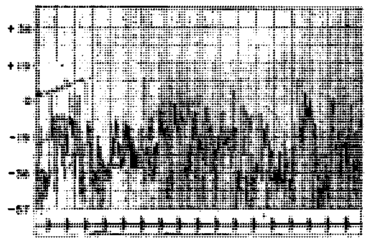
TUMUT CONTROL STRUCTURE
TOOMA-TUMUT DIVERSION

Flow Conditions in Straight Conduit and Transition Downstream From Control Gate - Preliminary Design

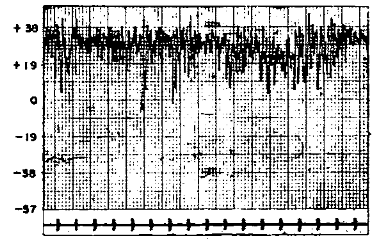
1:19 Scale Model



A. 3" DOWNSTREAM FROM SLOT

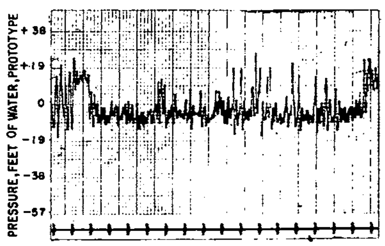


B. 6" DOWNSTREAM FROM SLOT

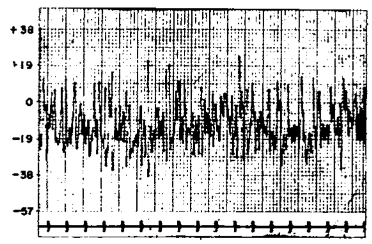


C 11.8" DOWNSTREAM FROM SLOT

GATE OPENING 2%



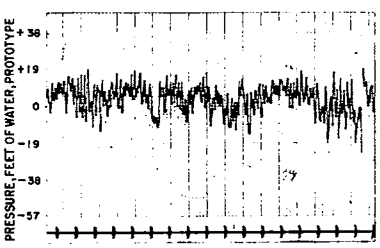
D. 3" DOWNSTREAM FROM SLOT



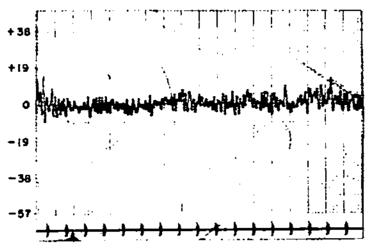
E. 6" DOWNSTREAM FROM SLOT

GATE OPENING 3%

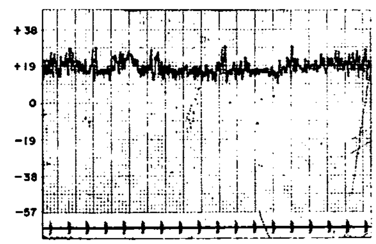
PIEZOMETERS IN SIDEWALL 3" ABOVE FLOOR



F. 3" DOWNSTREAM FROM SLOT

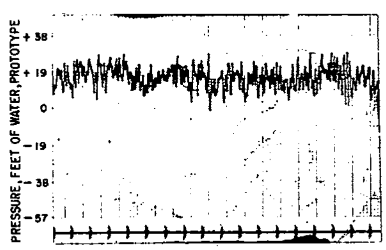


G. 6" DOWNSTREAM FROM SLOT



H 11.8" DOWNSTREAM FROM SLOT

GATE OPENING 2%



I. 3" DOWNSTREAM FROM SLOT

GATE OPENING 3%

PIEZOMETERS AT INTERSECTION OF FLOOR AND SIDEWALL

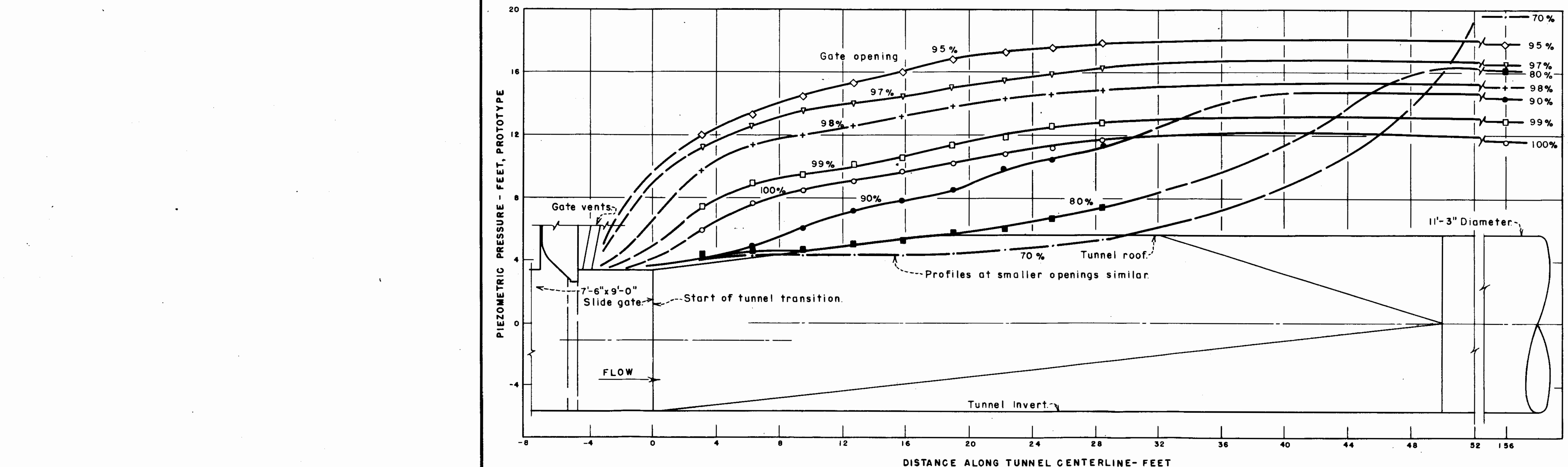
Data from 1:19 Scale Model

TUMUT CONTROL STRUCTURE
TOOMA-TUMUT DIVERSION

PRESSURE CELL TRACES OF GATE FRAME PRESSURES WITH
MAXIMUM HEAD AND 23 FOOT BACK PRESSURE

GATE OPENING	WALL 12" ABOVE FLOOR					WALL 3" ABOVE FLOOR					FLOOR 3" FROM WALL					FLOOR 12" FROM WALL					11'-3" DIA. TUNNEL				REFERENCE PIEZOMETER
	DISTANCE FROM GATE FRAME					DISTANCE FROM GATE FRAME					DISTANCE FROM GATE FRAME					DISTANCE FROM GATE FRAME					DISTANCE FROM TRANSITION				
	12"	24"	36"	48"	72"	12"	24"	36"	48"	72"	12"	24"	36"	48"	72"	12"	24"	36"	48"	72"	12"	24"	36"	48"	
30%	9.3	1.3	2.7	4.6	2.9	9.1	9.7	9.5	7.6	6.5	11.4	7.4	6.5	8.4	3.2	7.6	6.5	4.2	5.7	3.8	13.7	16.7	7.2	1.9	130.7
20	10.1	1.3	1.5	4.0	2.7	6.3	10.1	9.7	8.7	7.6	9.5	6.1	5.7	9.5	1.5	4.4	4.6	2.3	5.3	3.2	8.0	4.0	3.7	2.1	209.6
10	5.3	0.8	—	—	—	6.3	12.0	9.7	7.6	9.3	9.7	6.1	4.0	8.0	0.2	3.8	5.3	1.1	4.4	2.7	4.9	3.6	3.4	2.5	285.8
5	Flow not on surface					4.4	7.4	8.4	5.5	6.5	10.1	6.5	3.4	6.3	1.7	5.3	5.5	1.7	3.6	2.9	3.4	3.2	3.4	2.1	356.6

A - PRESSURES IN TRANSITION AND IN CIRCULAR TUNNEL



B-PRESSURE ALONG ℄ OF CONDUIT ROOF WITH SUBMERGENCE JUST SUFFICIENT TO PRODUCE ATMOSPHERIC PRESSURE AT GATE FRAME VENTS.

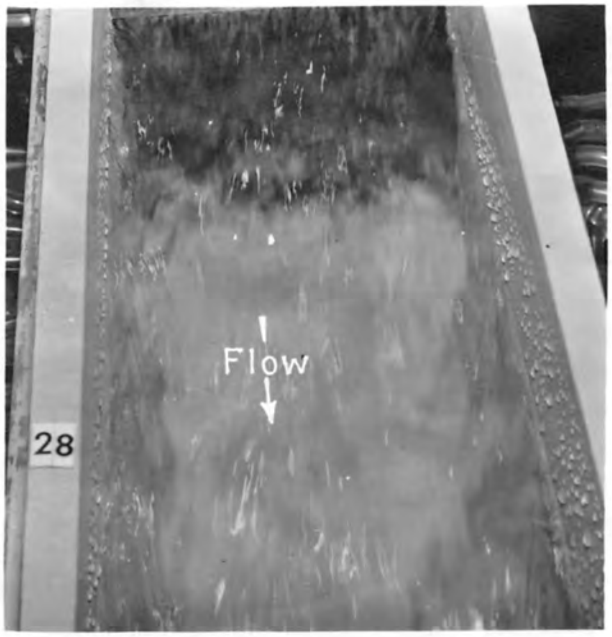
Note: Data from 1:19 scale model

TUMUT CONTROL STRUCTURE

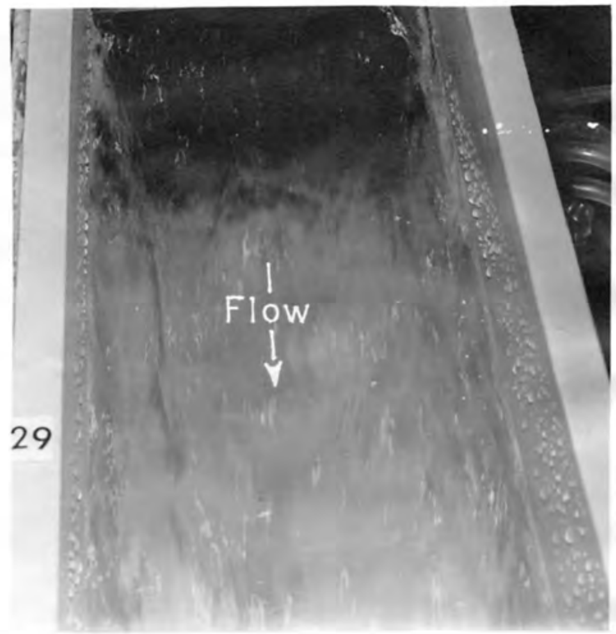
TOOMA - TUMUT DIVERSION

PRESSURES IN TRANSITION AND TUNNEL-RECOMMENDED DESIGN

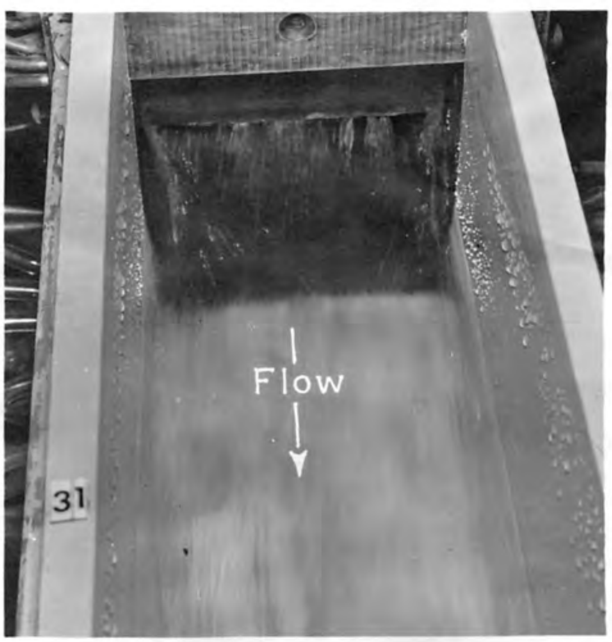
535



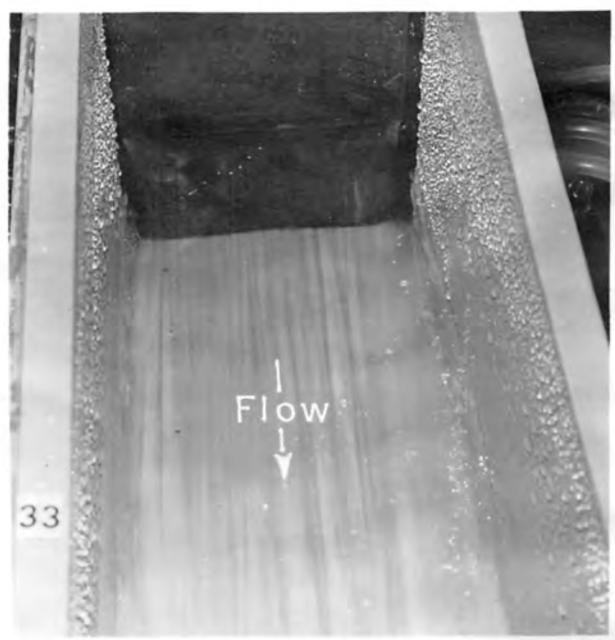
A. 100% gate opening, Q = 1910 cfs



B. 97% gate opening, Q = 1906 cfs



C. 50% gate opening, Q = 1764 cfs

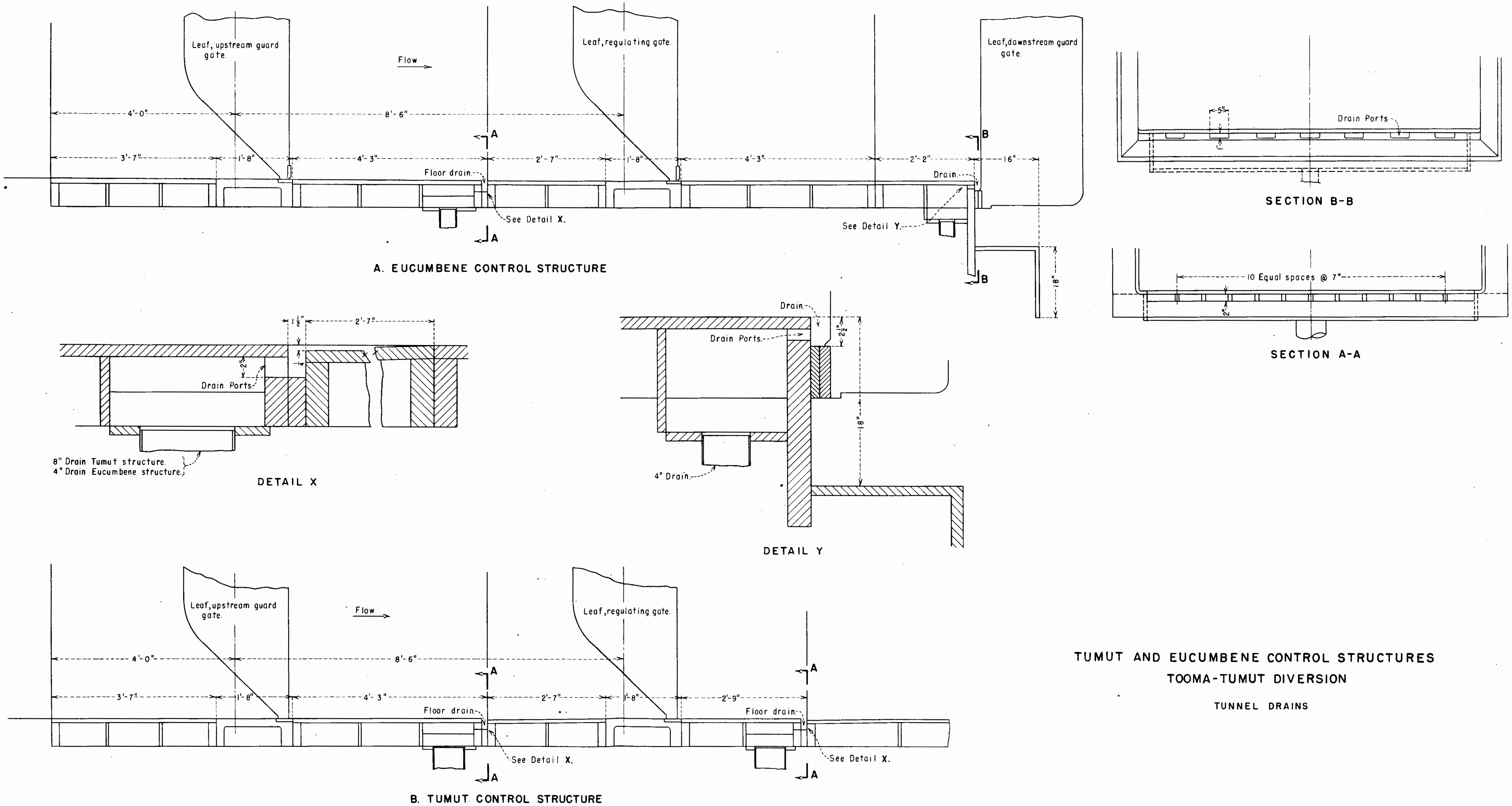


D. 10% gate opening, Q = 788 cfs

TUMUT CONTROL STRUCTURE
TOOMA-TUMUT DIVERSION

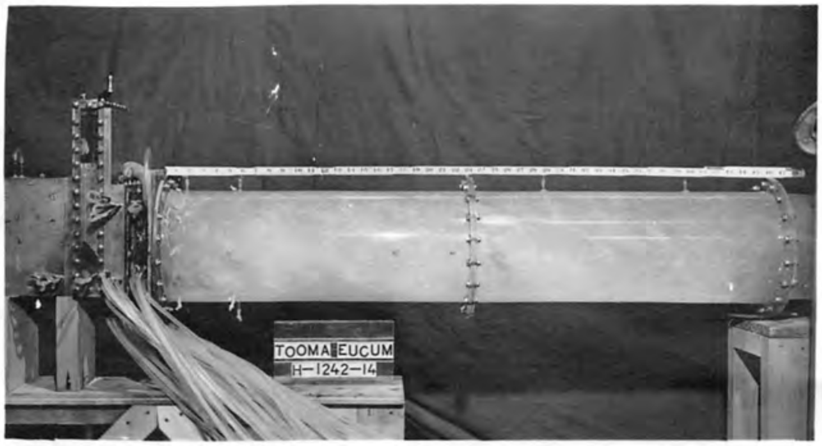
Free Flow Conditions in Transition Downstream of Control Gate
Recommended Design

1:19 Scale Model



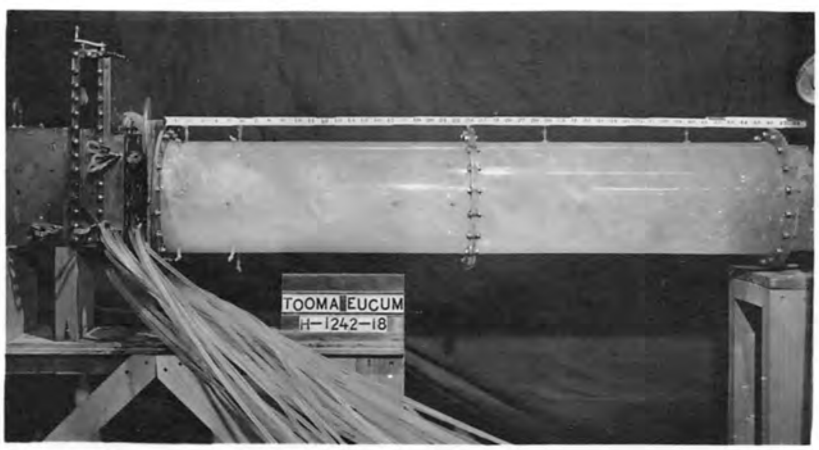
TUMUT AND EUCUMBENE CONTROL STRUCTURES
TOOMA-TUMUT DIVERSION
TUNNEL DRAINS

535 | 6301 | W.H.K.-21



A. Gate 30% open, Q = 1530 cfs

B. Gate 20% open, Q = 1270 cfs

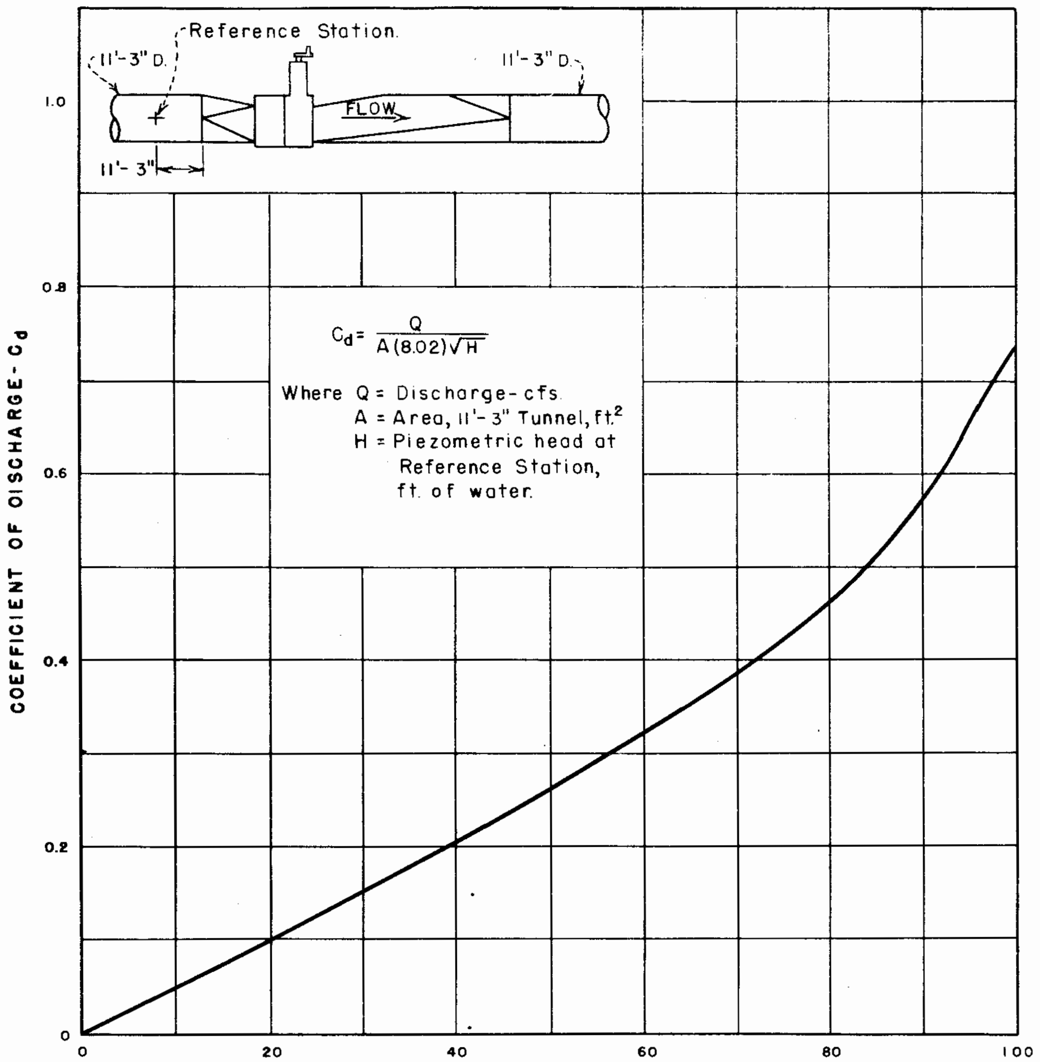


C. Gate 10% open, Q = 770 cfs

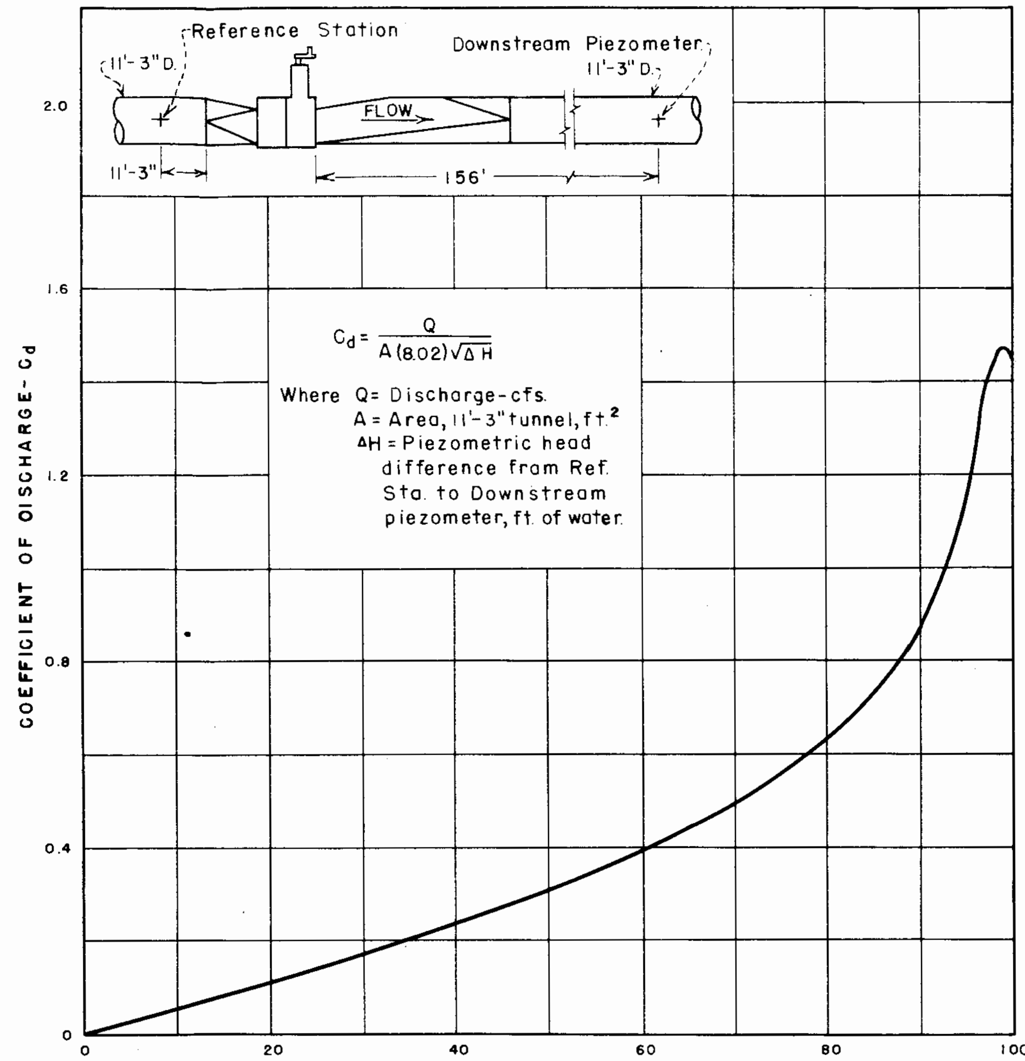
EUCUMBENE CONTROL STRUCTURE
TOOMA-TUMUT DIVERSION

Dispersion of Jet From Gate in 13'-0" Dia. Tunnel
(air introduced to make flow visible)

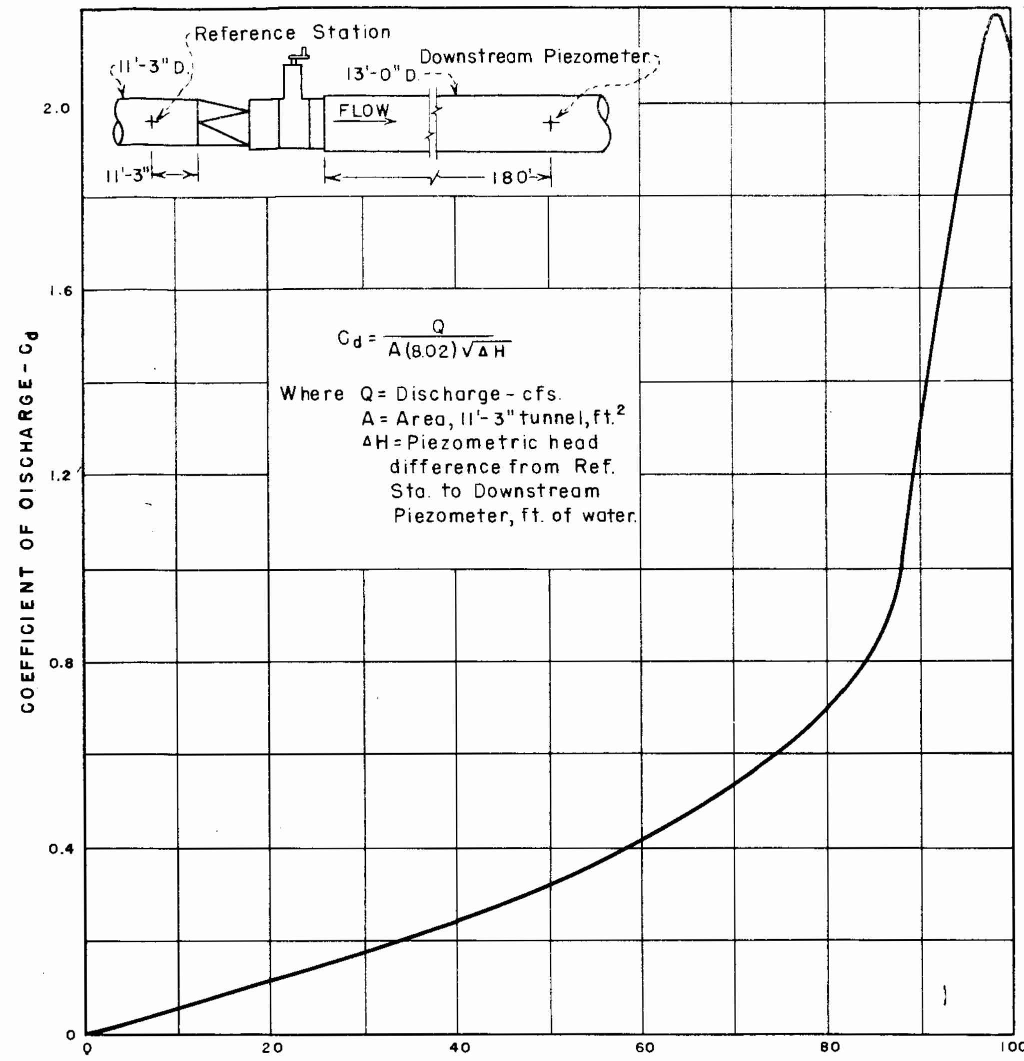
1:19 Scale Model



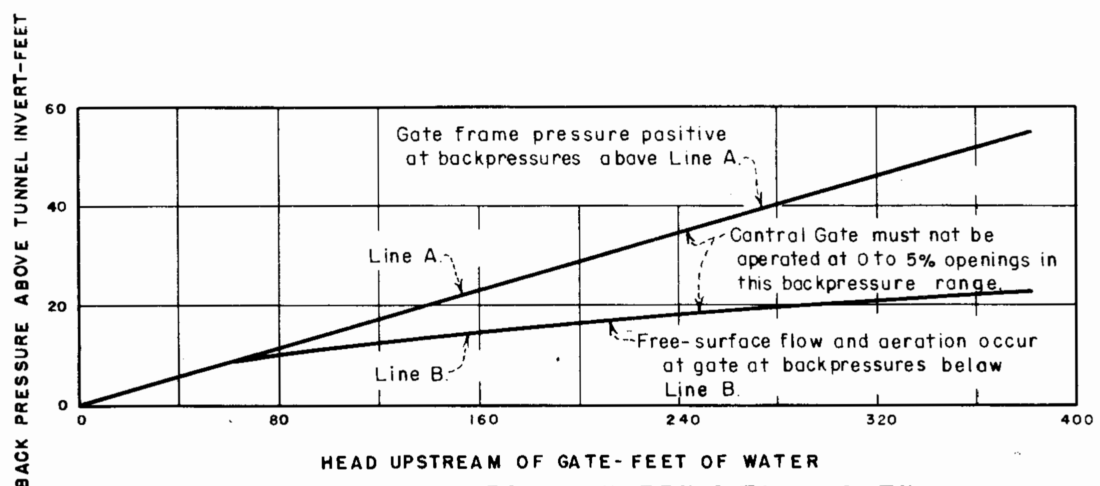
A-TUMUT CONTROL STRUCTURE-FREE DISCHARGE



B-TUMUT CONTROL STRUCTURE-SUBMERGED DISCHARGE



C-EUCUMBENE CONTROL STRUCTURE-SUBMERGED DISCHARGE



D-SUBMERGENCE RANGE WHERE 0 TO 5% GATE OPENINGS MUST BE AVOIDED-TUMUT STRUCTURE.

Data obtained from 1:19 scale model representing preliminary upstream conduit size and approximate downstream conduit sizes was adjusted to apply to final design conduit sizes.

TUMUT AND EUCUMBENE CONTROL STRUCTURES
TOOMA-TUMUT DIVERSION

COEFFICIENT CURVES FOR TUMUT AND EUCUMBENE STRUCTURES, AND CRITICAL TUMUT BACKPRESSURE RANGE

GPO 849415