UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE ISLAND BEND CONTROL GATE - EUCUMBENE-SNOWY PROJECT SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY AUSTRALIA

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Subject: Hydraulic model studies of the Island Bend control gate--Eucumbene-Snowy Project--Snowy Mountains Hydro-Electric Authority--Australia

PURPOSE

The purpose of the studies was to develop a trouble-free control gate capable of regulating flows ranging from 50 to 7,000 cfs at head differentials up to 400 feet. The gate is used in a tunnel system where submerged flow conditions prevail.

CONCLUSIONS

1. A gate to satisfy the severe operating requirements, particularly the very low rates of flow under the very highest head differentials, can be obtained with a 9-foot-wide by 16-foot-high structure with weir-like restriction plates placed normal to the flow and flush with the downstream face of the leaf to reduce the effective gate width at small openings (Figures 13 and 20).

2. Severe cavitation damage can occur to a structure operating under such high heads. To overcome this danger, an enlarged tunnel section was provided downstream from the gate to form a pool for the high velocity jet to enter. By making the downstream frame short, providing reentrant flow into critical areas, and moving the downstream boundaries outward away from the cavity collapse zones (Figures 4 and 20), cavitation damage to the structure is negated.

3. Corner fillers to reduce the passage width near the gate bottom (Figure 9) were unsatisfactory due to the occurrence of severely negative (subatmospheric) pressures on the surfaces. Cavitation on these surfaces would have been inevitable.

4. Weir-like restriction plates placed normal to the flow and flush with the downstream face of the leaf (Figure 10) provided good pressure and flow conditions. The flow, after leaving these plates, formed its

own boundaries within the fluid. The space behind the plates allowed reentrant flow between the jet and the walls and relieved negative pressures. Plates with convex flow edges (Figure 10C) provided best results.

5. The floor of the downstream gate body must be sloped downward to obtain a more rapid degree of conduit expansion. A vertical 12-inch downward step at the downstream face of the restriction plates, followed by a 45° downslope to elevation 3503.25 (Figures 11 and 20), gave good results.

6. Ideally, the enlarged tunnel section should be placed as close as possible to the gate leaf to prevent cavitation damage and to obtain the best recirculation around the discharging jet. However, structural considerations required that the downstream conduit width be the same as the upstream width for a sufficient distance to resist the gate leaf thrust. A good hydraulic and structural balance was obtained with 7-foot-long parallel walls 9 feet apart, followed by 11-1/2-inch outward offsets and 18° outward flares (Figure 13).

7. Outwardly offset downstream slot corners, followed by curved walls to return the passage width to normal, did not improve the slot and wall pressures in this gate. A square-cornered rectangular slot (Figure 12) performed as well as the offset ones and offered design and construction economies. The back pressure acting on this structure was the main factor permitting the selection of the square-cornered slot design.

8. The usual open-beam shape of gate leaf bottom for this downstream seal, roller-mounted gate leaf was unsatisfactory due to poor local pressure conditions. Much better performance was obtained with an elliptically shaped bottom (Figure 13).

9. The position and shape of the gate leaf seal that seats against the upstream face of the restriction plates greatly affected the pressures near the leaf bottom. Satisfactory pressures are expected with the seal placed as low as possible on the downstream face of the leaf and projecting only 9/32 inch beyond the seal bar (Figure 10F).

10. The pressure and flow conditions for the gate should be entirely satisfactory for all operation with the Island Bend and Geehi Pond water surface elevations within their normal ranges. Even at the extreme but unlikely condition of Island Bend Pond completely full and Geehi Pond completely empty, but with a 30-foot back pressure, the operation will be acceptable. There will be a slight tendency for light, sporadic, local cavitation near the flow surfaces.

11. When Geehi Pond is empty and low flows are passed to it through the Island Bend gate, it will be necessary to check Geehi gate to maintain a back pressure of at least 30 feet on the Island Bend gate, measured from the upstream center line.

12. The Island Bend gate may be operated at any gate opening greater than 6 inches under any applicable head conditions for any length of time. The gate opening limitation will pose no handicap on the gate or on the operation of the overall tunnel and reservoir system because the minimum specified discharge of 50 cfs at the greatest possible head differential is expected to be obtained with an opening slightly greater than 6 inches.

13. Stainless steel plates are needed in the Island Bend gate on the parallel 7-foot-long walls downstream from the slots to provide and maintain smooth, well alined, corrosion- and erosion-resistant surfaces. Such surfaces are mandatory on these parts of a structure that operates submerged at practically any opening, under very high differential heads, for very long periods of time, and where minimum maintenance is important due to the difficulties, loss of time, and heavy expenditures necessary in gaining access to the gate.

14. A measurement of downstream head is needed in addition to knowledge of gate opening and upstream head to set given discharges through the Island Bend gate. This measurement can be made with a float well in the gate shaft, the well being connected to an opening in the side of the 28-foot-diameter enlarged tunnel 100 feet downstream from the gate.

15. The downpull forces acting on the gate due to pressure decreases on the bottom surface when flow passes beneath the leaf will reach a maximum of about 442,000 pounds (Figure 19A). This load will occur at a gate opening of about 60 percent and is for the severe condition of Island Bend Pond full and Geehi Pond empty. Less downpull occurs as Geehi Pond fills.

16. Identical gate leaves and structures can be used at Island Bend and Geehi control stations. This provides certain design economies and flexibilities and will insure having a gate at Geehi that will satisfactorily handle the very severe operating conditions that can be imposed on it.

17. Tests made without restriction plates in the gate body, thus representing the Eucumbene gate, and with Lake Eucumbene considered at minimum operating level and Island Bend Pond full, showed an approximate maximum downpull of 429,000 pounds (Figure 19B).

18. Tests made without restriction plates and with the tunnel empty downstream from the Eucumbene gate, as could prevail during initial filling of the Eucumbene Tunnel if attempted from Island Bend, showed a maximum downpull force of approximately 1,070,000 pounds (Figure 19C).

INTRODUCTION

The Snowy Mountains Hydro-Electric Scheme in southeastern Australia is a comprehensive engineering and construction program for collecting waters from the seaward and landward sides of the Great Dividing Range and using them for irrigation and power generation (Figures 1 and 2). The scheme is under the direction of the Snowy Mountains Hydro-Electric Authority. The Eucumbene-Snowy-Geehi Diversion System is a part of this scheme and will transfer Snowy River water into M-6 (later changed to Murray 1) and subsequent power stations, or into the main storage in Lake Eucumbene, or from Lake Eucumbene directly into the Murray-series power stations (Figure 2). The Island Bend control structure is a part of the Eucumbene-Snowy-Geehi Diversion plan (Figure 3). Its function is to regulate the flows released from Island Bend Reservoir into the tunnel system, while maintaining the Island Bend inlet shaft and tunnel full of water so that air is not entrained and carried into the system.

The question of whether or not to allow air to enter the tunnel system was carefully considered. Attention was particularly given to problems that would arise if air were present. It was believed that pockets or accumulations of air would build up along the crown of the gradually sloped tunnels, particularly in the unlined sections, and would move intermittently along with the flow. Upon reaching the tunnel outlets, which are normally deeply submerged at the reservoirs, the air pockets would quickly vent themselves, and water would rush into the vacated space. Heavy shock loads and water hammer would then occur as the waters moving into the vacated areas collided. These shocks would be damaging to the structures and undesirable from an operational standpoint. In addition, violent and undesirable boiling and wave action would occur in the ponds.

Vents placed at strategic locations could alleviate these difficulties by providing controlled release of the air. The problem would then resolve itself into obtaining satisfactory separation of the air from the water and providing suitably located collectors and vents to exhaust it. Preliminary studies of methods to achieve this controlled removal of air from the tunnels showed that several unknowns were involved. Foremost of these was the rate of rise of various-sized bubbles in the turbulent flow in the tunnels. Because of the unknowns, it was not possible, on the basis of available data, to say what type, size, and placement of air separation chambers and vents would be needed to release the entrained air from the water and vent it to the atmosphere. It was finally decided best to avoid these problems by adopting a design which prevented the entrance of air by making the inlet flow full at all times. The entrance (Figures 4 and 5) was therefore made somewhat similar to the inlet for the junction shaft in the Eucumbene-Tumut Tunnel.1/ The regulation in the Island Bend structure will be accomplished by a gate in the horizontal section of tunnel between the Island Bend intake and the connection with the Eucumbene-Snowy and Snowy-Geehi Tunnels. This gate will at all times be operated to keep the intake structure flowing full so that no air is entrained and carried into the system.

The operating conditions imposed on the control structure are severe. The maximum flow will be about 6,400 cfs. The minimum is about 50 cfs. Prior to the initial filling, and possibly on rare occasions thereafter, Geehi Pond may be completely empty. During the early stages of filling Geehi Pond, free flow discharge conditions can prevail at Island Bend gate because the gate invert is above the minimum water surface level of Geehi Pond (Figure 4). No operational problems are anticipated with the free discharge operation if the gate is operated to fill the pond.

As the water level rises in Geehi Pond, the tunnel will fill and submerged discharge conditions will prevail at Island Bend gate. This type of operation greatly alters the flow and pressure conditions at the gate and produces the most severe operating conditions. A head differential of 390 feet can occur across the gate when the 28-foot-diameter conduit is just full. Frictional losses in the tunnels will add back pressure as the rate of flow increases. Computed frictional losses for the largest and smallest probable roughness values and the back pressures on the center line of the Island Bend gate with minimum pond at Geehi are shown in Figure 6B. As the pond continues to fill to reach normal operating levels, and/or as the discharge increases, the back pressure increases while the head differential decreases. Progressively less severe operating conditions result. A similar but less severe situation exists with flows to the Eucumbene-Snowy Tunnel (Figure 6A).

A number of different gate designs were considered for the Island Bend control structure. One included placing 3 moderately sized gates side by side with only 1 operating when releases were small. Another plan included a large single gate with a small gate built into the main leaf. These and other designs were eventually eliminated from consideration and a single 9-foot-wide by 16-foot-high gate was selected. Extremely small gate openings during releases of very small flows were rendered unnecessary by decreasing the width of the lower part of the gate

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1/ Numbers refer to References at end of report.

body. This reduction in passage width was carried to the point where openings of 6 or more inches could be set for releasing the minimum anticipated discharge of 50 cfs.

In systems where high velocity flows enter a pool or filled conduit under moderate or low back pressures, cavitation can occur.2/3/ This cavitation takes place within the low pressure cores of rapidly whirling vortices created by shearing between the high velocity jet and the surrounding water. As long as the vortex action is severe and the pressure regime is moderate or low, the inception, formation, and decay of vapor cavities continue. If these multitudes of vapor pockets collapse on or near the boundary walls, damage of serious proportions can occur. It is therefore imperative, for long structural life, that the boundary surfaces of such a structure be placed well away from areas where this inevitable cavitation collapse will take place.

Design data, unpublished at the time of this writing, were available in the Bureau of Reclamation laboratories to help in determining the conduit arrangement for the Island Bend gate. Studies using a 400-foot head differential across a partly opened, 3-inch, 300-pound gate valve showed that no damage would occur on the downstream conduit provided its diameter were 1.75 or more times the nominal gate body diameter and the back pressure in the conduit were 20 or more feet. A review of the Island Bend installation showed that it would almost always operate submerged and that its back pressure could become as low as 20 to 30 feet. Further decreases in back pressure with the possibility of undesirable shifting between submerged and free discharge flow conditions would be prevented by throttling the Geehi control gate located a short distance downstream. The severest Island Bend operating condition was therefore submerged flow regulation with a 410-foot upstream head and about a 30-foot downstream head. On the basis of the laboratory data, the downstream conduit diameter, D, was made 1.75 times the 16-foot diameter of the upstream conduit, or 28 feet. The length, based on the same data, was made 5D, or 140 feet, to provide ample room for flow redistribution before the water reentered the 16-foot-diameter tunnel farther downstream (Figure 4). Later tests showed this design to be satisfactory.

Several hydraulic problems were apparent in the design of this unusual control structure. Cavitation and cavitation-erosion were an ever-present threat and could be encountered not only in the mixing zone of the jet but on the walls, gate slots, leaf, or other parts of the structure. Positive means for controlling the cavitation had to be found if satisfactory service life and dependability were to be achieved. In this respect, there was uncertainty about the shape of the restrictions to be used within the gate body to narrow it near the invert. Also, the shape of the gate leaf bottom and the style and placement of the seals were uncertain. Furthermore, the shape of the abrupt expansion downstream from the point of control in the structure had to be determined and balanced against a sound structural design capable of withstanding the terrific thrust loads on the leaf. To determine what these shapes and designs should be for the overall control structure, hydraulic model studies were made. Descriptions of the test facilities used in the studies, and discussions of the results obtained, are presented in this report.

THE MODELS

All preliminary studies were made with air because air model tests are convenient, fast, inexpensive, and reliable. The air facilities used for the tests consisted of a centrifugal blower which drew air in through a 12-inch-diameter inlet pipe and forced it out through a 10-inch pipe to the gate section (Figure 7A). After the flow passed through the gate section, it entered an enlarged conduit similar to the enlarged downstream tunnel proposed for the prototype structure. The air then discharged freely back into the atmosphere. The rate of air flow was measured by appropriately sized flat plate orifices located on the entrance to the 12-inch blower inlet. The flow velocities within the gate were maintained below 300 feet per second so that the compressibility of the air would be negligible. The pressure measurements were obtained with piezometers and water-filled manometers read to the nearest 0.01 of an inch. In cases where pressure fluctuations were small or moderate, the average pressures were recorded. In other cases, where fluctuations were severe, the most negative pressures were recorded in addition to the average ones.

The gate section for the 1:19.2 scale air model was constructed of wood, light gage sheet metal, and transparent sheet plastic (Figure 7B). The design shown consisted of the 5.6-inch-wide by 10.0-inch-high gate section, the 2.77-inch-thick gate leaf, and the 5.6-inch-wide by 14.25-inch-high downstream frame 8.13 inches long. The enlarged downstream conduit was represented by a 20.5-inch-diameter sheet metal pipe. Piezometers were provided on the flow surfaces believed to be critical.

The final model tests, including calibrations and downpull measurements, were made with a 1:24 scale hydraulic model (Figures 8A and 13). The water facilities for making the tests consisted of the permanent laboratory water supply system, the upstream pipeline or tunnel section, the gate itself, the downstream pipeline or tunnel section, the back pressure regulating valve, and the waste line to the laboratory reservoir. Water was supplied to the model by a 12-inch centrifugal pump, and the rate of flow was measured by calibrated Venturi meters within the permanent laboratory supply system. Water approached the gate through an 8-inch-diameter pipe 12.5 feet long. A transition similar to the one proposed for the field structure carried the flow into the 4.5-inch-wide by 8.0-inch-high gate. A 14-inch-diameter pipe represented the 28-foot-diameter enlarged conduit downstream, and a 12-inch gate valve regulated the back pressure. The water returned to the laboratory storage reservoir for recirculation.

The gate section of the hydraulic model was constructed of brass plate and 1/2-inch-thick transparent plastic (Figures 8B and 13). It consisted of the 4.5- by 8.0-inch upstream frame, the 2.22-inch-thick gate leaf, and the downstream gate body with a downwardly flared floor. Piezometers were provided at areas found to be critical in the air model studies so that final pressure measurements could be made. Care was taken to make the hydraulic model strong and capable of withstanding relatively high heads. This was necessary because reasonably high velocities were required to obtain Reynolds number values high enough for good model-prototype similitude.4/

Pressure measurements were read on water-filled, single leg manometers, mercury-filled single and double legged manometers, and in some cases, from pressure cell recording charts. The charts were obtained at those piezometer stations where the pressures were particularly low and/or where the pressures fluctuated greatly.

INVESTIGATION

Studies for Narrowing Lower Part of Gate Body--Air Model

Triangular Corner Fillers

The first attempts to narrow the lower portion of the 9-foot 5-1/2-inch-wide preliminary gate body were made by inserting corner fillers in the passage (Figure 9). These fillers were triangular in cross section and extended the full 12 feet from the gate slots to the abrupt expansion into the 28-foot-diameter tunnel. The upstream ends of the fillers were shaped to produce elliptical surfaces. The flow passage formed at small gate openings by the gate leaf bottom, the sloping walls of the specially shaped fillers, and the floor was trapezoidal in cross section and of small area.

The major and minor axes of the first elliptical section were 3.0 and 0.96 feet (prototype), respectively, forming a 1:3.13 ellipse (No. 1, Figure 9B). The ellipses lay in a plane parallel to the gate floor and the fillers were 3 feet apart at the floor. The spring lines, or lines where the elliptical curvature started at the vertical upstream faces of the fillers, were 4 feet 11 inches apart at the floor. The design therefore produced a downstream gate body 4 feet 11 inches wide at the floor, gradually widening to the full 9-foot 5-1/2-inch passage width at a height of 5.45 feet. The full height of the fillers at and beyond the end of the elliptical section was 6 feet 5-1/2 inches.

Severely negative pressures occurred on both the curved and straight surfaces of the fillers. The pressures were particularly low at the piezometer located 10 inches downstream from the start of the fillers and 10 inches above the floor at a 13 percent gate opening. Apparently the 13 percent gate position placed severe flow contractions directly over the piezometer station.

A second shape was investigated using an ellipse with prototype major and minor axes of 5.0 and 1.0 feet, respectively (1:5 ellipse) (No. 2, Figure 9B). These fillers were larger than the first ones, and the width between the parallel portions was reduced to 1.5 feet at the floor. The spring lines were 3 feet 6 inches apart at the floor and met the side walls 5 feet 11-1/2 inches above the floor. The overall height was 7 feet 11-5/8 inches.

Low pressures were again encountered on the curved surfaces near the gate leaf, and to a lesser extent on the straight sides of the fillers. Pressures measured on the floor near the intersection with the fillers showed moderately negative pressures. The gate position had considerable effect upon the pressures near the spring lines of the ellipses, and the lowest pressures on any particular piezometers occurred when the leaf bottom was about level with the piezometer openings.

In the above two designs, the ellipses were laid out in planes parallel to the floor. Actually, the flow tends to travel normal to the spring line. It was thus more appropriate to lay out the ellipses in a plane normal to the spring line and hence normal to the slope of the filler surfaces. A third bellmouth was made up in this manner with major and minor axes of 6.25 and 1.25 feet prototype (1:5 ellipse) (No. 3, Figure 9B). The spring lines were 3 feet 3-1/4 inches apart at the floor and met the side walls at a height of 6 feet 2-1/4 inches. The total filler height was 8 feet 11-1/2 inches.

The pressure conditions were better with this design, but serious negative pressures still occurred near the leaf. This suggested that even more gentle curvature was needed, with larger major and minor axes for the ellipses. However, attempting to maintain the spring lines close enough together to properly narrow the passage, and yet attempting to use fillers with larger ellipses, was inconsistent and impracticable. No further increase in minor axis was therefore reasonable, and no further tests were made with the triangular fillers.

Rectangular Corner Fillers

It was believed that part of the reason for severe negative pressures on the upstream parts of the fillers was that an acute angle was formed by the horizontal bottom of the gate leaf and the sloping walls of the triangular fillers. To increase this angle as much as practicable, fillers with vertical sides were tried in the model (Figure 9C). Elliptical surfaces with 6.25- and 1.25-foot (prototype) axes were formed on the sides and tops of the fillers. The vertical spring lines were 4 feet 4-3/4 inches apart, and the horizontal spring lines at the filler tops were 5 feet 1-3/4 inches above the floor. The full filler height was 6 feet 4-3/4 inches. The distance between the parallel portions was 1 foot 7-1/2 inches.

Somewhat better pressure conditions occurred with the rectangular fillers when the gate leaf was below the top spring lines. However, when the leaf was raised to just allow flow over the top of the fillers, negative pressures occurred on the top and on the corner surfaces that connected the vertical and horizontal ellipses. Also, small increases in gate opening in this range produced large changes in the quantity of water released. This was undesirable because it made the setting of small discharge changes difficult. At large gate openings, the pressures on the fillers were satisfactory.

Triangular Restriction Plates

The difficulties encountered in using solid corner fillers to reduce the passage width led to an entirely different concept. It was reasoned that if the water were allowed to form its own flow boundaries after leaving the control section at the leaf, and no structural surfaces were near these flow boundaries, there would be less difficulty with negative pressures. Heavy flat triangular weir-like plates were therefore fastened vertically in the gate body normal to the passage and flush with the downstream face of the gate leaf (Figure 10). These restriction plates represented the front surfaces of the previous fillers and narrowed the passage in the same manner. After the flow left the edges or spring lines of the plates (Figure 10E), it was free to take its natural flow path. The space behind the plates allowed reentrant flow between the jet and the gate body to relieve negative pressures. It, in effect, provided an abrupt expansion downstream from the leaf.

The first tests were made with triangular plates 4 feet 5-3/4 inches wide and 8 feet 11-1/2 inches high, prototype (Figure 10B). This left a passage width at the floor of 6 inches. Better pressure conditions were encountered on the floor and walls downstream from the plates than on the boundary surfaces with any previous designs. Tests were continued with variations in width and height of the plates to obtain a design that combined acceptable pressure conditions, ample flow recirculation behind the restrictions, sufficient reduction in passage width for controlling small flows, and access room for maintenance men and equipment. At the same time, the overall width of the downstream gate body was reduced to an even 9 feet. Best results were obtained with triangular plates having a bottom width of 4 feet and a height of 6 feet.

Curved Edged Restriction Plates

Continued studies with restriction plates showed that better performance could be obtained if the flow edges or spring lines were convex instead of straight (Figure 10C). The convex shape restricted the flow passage a little more and provided more room for reentry of water between the jet and walls. The results were that the pressures on the floor and walls were better, and the flow was more stable. Best performance was produced by sharply curved plates, but the difficulty of supporting such plates in the prototype structure made their use unwise. An excellent compromise was achieved with moderately curved plates, and this design is recommended for prototype use (Figure 10C).

Leaf Bottom Shape and Bottom Downstream Seal--Air Model

An important factor learned from the studies with corner fillers and restriction plates was that the shape of the gate leaf bottom and the placement of the downstream seal had a marked effect upon local pressure conditions. The downstream bottom seal, which is necessary for sealing along the face of the plates, was first placed well above the gate leaf bottom (Figure 10D). This produced a restricted space between the rear of the gate leaf and the face of the plates, and local high velocity flows occurred. These flows caused extremely low pressures and were undesirable. The difficulty was largely overcome by moving the seal close to the bottom of the gate and by keeping the extension of the seal beyond the clamping bars to a minimum (Figures 10F and 20). Thus, no appreciable passage remained and no large flows were present between the leaf and the plates.

The bottom geometry of the initial leaf was of the type frequently used with fixed-wheel or roller train gates (Figure 10D). It was formed by the undersurface of the large I-beam used horizontally at the bottom of the leaf, the plate extensions at the downstream face, and vertical stiffener plates from the beam to the extension. The bottom seal, which rests on the floor at gate closure, was carried on the extension plates. As initially proposed, the seal extended downward beyond the plates about 3/8 of an inch, and there was a sharp corner at the bottom upstream edge of the plate. Tests showed extreme negative pressures on this leaf bottom. Minor revisions like beveling and rounding the upstream bottom corner and reducing the extension of the seal beyond the plates improved the pressure conditions only moderately.

A major change in bottom geometry greatly improved the pressures and flow conditions. This change consisted of extending an elliptically shaped steel plate from the front face to the bottom downstream edge of the leaf (Figures 10A, 10F, and 20). The elliptical shape is recommended for the prototype leaf (Figure 20) and was used for all subsequent model tests.

Flared Floor and Walls--Air Model

Floor Downstream from Gate Leaf

The basic principle used in the design of the gate was that of providing an enlarged section for the high velocity flow to enter. For this principle to be workable, the enlarged section must be large enough to give good flow circulation around the jet. Ideally, this enlargement would be achieved just downstream from the gate control section. However, for structural reasons, it was necessary to continue the gate body, or conduit, for an appreciable distance downstream from the slots so that the slots would be capable of withstanding the thrust loads of the leaf. This extended conduit restricted the flow recirculation and caused a general lowering of the pressures and some instability in the jet.

Increased expansion, or enlargement of the passage, was obtained by changing the alinement of the downstream floor (Figure 11). To accomplish this in the model, the downstream frame was modified by dropping the horizontal floor to the level where the bottom corners just intersected the walls of the 28-foot-diameter tunnel. This represented the greatest permissible drop in floor elevation of 6.8 feet, prototype. Tests were then made with horizontal fillers inserted to represent level floors 1.7 and 3.4 feet below the upstream floor. The pressures and flows became progressively better as the floor was lowered, and the best conditions were obtained with the lowest possible floor level of 6.8 feet below the upstream frame (Figure 11A). An appreciable amount of turbulence and pressure fluctuation remained in the system.

Other floor fillers were tested. One provided a 45° slope from the upstream floor level to the fully lowered level floor downstream (Figure 11B). Good flow and pressure conditions resulted. The second filler provided a more gradual slope that started from the upstream floor level and reached the fully lowered floor at the downstream end of the 13-foot-long body section. This design was less satisfactory than the 45° slope.

Further tests were made to determine the pressure conditions on the 45° slope just downstream from its intersection with the upstream floor. Severe negative pressures occurred at and near this change of alinement unless an appreciable vertical step, or offset, was provided (Figure 11B). A step of 3/4-inch prototype was first tested but was found entirely inadequate. The step, or offset, was eventually increased to 12 inches prototype, and this amount of offset represented a satisfactory compromise between structural and hydraulic considerations in the system. The 45° slope, together with the 12-inch vertical offset, is recommended for prototype use.

Walls Downstream from Gate Leaf

The 9-foot-wide by 13-foot-long walls downstream from the leaf still formed too long and narrow a passage to allow adequate flow recirculation around the main jet. Detailed stress studies showed that it would be possible to flare the downstream 6-foot sections of the 13-foot-long walls while still retaining adequate strength to withstand the extreme thrust loads of the leaf. Tests were made with these walls flared 30°, 20°, 10°, 0°, and -10° relative to the passage center line (Figure 11C) and using the 45° sloping floor with a 12-inch vertical step at the restriction plates. The best pressure and stability conditions occurred with the maximum flare, and progressively poorer results occurred as the walls were moved inward. The worst conditions occurred with the walls converging at the -10° flare. At the maximum flare of 30°, the pressures measured on the 7-foot-long parallel sections of wall, and at critical locations on the flaring walls, were satisfactory for all expected flow conditions.

Shape at Downstream Slot Corners--Air Model

Preliminary tests using an early gate leaf design showed negative pressures on the walls just downstream from the square slot corners (Figure 12). Attempts were made to reduce these negative pressures by providing outwardly offset slot corners, followed by long radius curves that returned the passage width to that of the upstream frame (Figure 12B). Outward offsets at the slot corners of 1.5 and 3.0 inches, prototype, were tested. The curves from the slot corners to the parallel walls downstream were made with a 30-foot radius. This curved portion of wall extended vertically from the ceiling to the top of the restriction plates. The full square slot shape was used from the top of the plates down to the floor. A ledge was present at the top of each restriction plate (Figure 12A).

Tests made using the final gate leaf design showed that the pressure conditions with the two offset slot designs were about the same as with the original square-shaped slot (Figure 12C). When the gate bottom was at or slightly below the ledge, negative pressures occurred above the ledge and on the slot corner just beneath the leaf bottom. These pressures, which were calculated for the very minimum back pressure conditions on the gate, were more negative than desired. They should nevertheless not be detrimental for limited operation at minimum back pressures, and should be entirely satisfactory for all operation at the greater back pressures that occur under normal operating conditions. There appeared to be no advantage in using the offset slot corners in place of the in line square ones, and the square ones are recommended for prototype use.

It is to be emphasized that a most important factor in these slot pressures being satisfactory is that back pressure occurs on the gate. Pressure reductions in local areas are held above critical values by this back pressure, thus maintaining reasonable pressure values. Tunnel friction provides a great deal of back pressure at large flows, and additional back pressure at all flows will normally be present due to ponding at Geehi. If it were not for the back pressures expected to occur, these slot designs could not be used for high velocity releases under submerged conditions.

Recommended Design--Hydraulic Model

Final Model

An hydraulic model incorporating the best features obtained through the previous air model studies was constructed on a 1:24 scale (Figure 13). The moderately curved restriction plates were used. The conduit floor stepped vertically downward the equivalent of 12 inches at the downstream face of the plates and then continued downward on a 45° slope to the short horizontal section at elevation 3503.25. The walls of the gate were 9 feet apart and parallel for 7 feet beyond the gate slots. The walls then stepped outward 11-1/2 inches on each side and continued with outward flares until intersecting the 28-foot-diameter tunnel. Flare angles of 30° and 18° relative to the conduit center line were investigated. The roof of the gate continued horizontally 7 feet from the slots and then sloped upward. The gate slots were rectangular with the upstream and downstream corners in line. The gate leaf incorporated the elliptical bottom, the enclosure boxes for the roller trains, and a downstream seal.

Piezometers were included in the model in areas likely to be critical so the pressure conditions could be observed. These pressures were read with single leg water manometers and a mercury gage. In cases where the pressures were negative or fluctuating widely, the measurements were also made with a pressure cell and electronic recording equipment.

Gate Performance

The first tests were made with 30° side wall flares. All pressure conditions were satisfactory at appropriate settings of upstream and downstream heads.

Tests were then made with 18° flares because the lesser flare angle permitted a more desirable construction with greater strength for resisting thrust loads on the leaf. The pressure conditions and flow stability were not as good as with 30° flares, but were nevertheless within reasonable limits for even the most severe operating conditions. The 18° flares were thus found satisfactory for prototype use, and all subsequent tests were made with them.

The pressures obtained from the model are presented in two forms. The data were first converted into pressure factors, $PF = \frac{h_x - h_2}{H_t - h_2}$, where h_x is pressure at the piezometers, h_2 is the pressure head in the conduit downstream from the gate, and H_t is the total head at the reference station just upstream from the gate. The pressure factors for Island Bend gate are shown in Figure 14A. By using these pressure factors and the pressure conditions expected to occur upstream and downstream from the gate for the most severe operating condition (Island Bend full and Geehi empty), the pressures at critical piezometers were computed (Figure 14A). The tunnel pressures used in the calculations are shown in Figure 15B. Tunnel pressures for more nearly normal operation with Geehi Pond full are shown in Figure 15A. With the latter operating conditions, all pressures on the gate structure will be strongly positive. By use of the pressure factor data, individual pressures can be computed for any desired operating condition. The coefficient of discharge for various gate openings is shown in Figure 16. Prototype discharges may be estimated, when the upstream and downstream pressure heads are known, by using the nomograph in Figure 17.

Pressure cell records of the most severely negative and/or the most fluctuating pressures (Figure 18) illustrate the most critical prototype conditions to be encountered if the gate is throttled with Geehi Pond empty and Island Bend Reservoir full. The worst conditions occur at gate openings between 25 and 45 percent. The most critical locations were between the restriction plates on the vertical step in the floor (Piezometers 21 and 22) and on the walls downstream from the plates (Piezometers 15 and 16). In cases of small discharge where friction losses would be insufficient to maintain back pressure at Island Bend, it was assumed that Geehi control gate would be throttled to maintain the tunnel full with a 30-foot back pressure above the Island Bend gate upstream center line (Figure 15B). It will be noted that at these most severe operating conditions, the instantaneous pressures occasionally and briefly extend downward into the cavitation range (Figure 18). The fact that these pressure excursions are brief, occur only under this unlikely operating condition, and are on areas where cavitation collapse is unlikely due to the flow patterns makes this problem relatively minor. As Geehi Pond fills, the back pressure at Island Bend increases and the head differentials across the gate drop. The operating conditions thus become progressively less severe as normal operating conditions are approached.

At gate openings below 25 percent, all pressures are steady and well positive and the gate performance is smooth at all applicable flow conditions. At gate openings between 25 and 45 percent, random pressure fluctuations occur, apparently due to the discharging jet swinging erratically in the downstream passage. The fluctuations are most severe when Island Bend Reservoir is full and Geehi Pond is completely empty. This operating condition is, at best, only a remote possibility, but if it does occur, consideration should be given to operating the gate at openings either smaller than 25 percent or larger than 45 percent. As the back pressure rises, due to filling Geehi Pond, the pressure fluctuations decrease rapidly. At gate openings larger than 45 percent, even with Geehi Pond empty, the pressure fluctuations decrease, and good operation is expected.

Hydraulic Downpull

When flow occurs under the gate leaf, pressure head is converted into velocity head and the pressures on the leaf bottom become low relative to the pressures on the leaf top. This pressure difference, applied over the cross-sectional area of the leaf, produces a downward force which must be considered in designing the gate-lifting mechanisms, stems, and supporting structures.

The downpull forces were determined by pressures measured with piezometers in the leaf bottom and in the gate bonnet. The averages of these pressures were applied to appropriate areas on the leaf, and the overall approximate downpull was then computed. No measurements of stem loads were made because the model was not built to permit direct measurements. These direct measurements require a nearly frictionless suspension for the leaf within the gate body, a condition not easily obtained in a model of a very high head gate.

The pressures in the bonnet and on the bottom of the Island Bend gate leaf are shown in Figure 14A, Piezometers 44 through 59. These pressures are for the severe condition of Island Bend Pond full and Geehi Pond empty. The approximate maximum downpull, based on the difference between the pressure acting downward on the top beam of the gate and the arithmetic average of the applicable pressures in each piezometer row acting upward on the leaf bottom, and the areas affected, is shown in Figure 19A. The greatest force occurs at about a 60 percent gate opening and reaches 442,000 pounds.

Tests were also made with the restriction plates removed from the body and with the severest head conditions that would apply to the Eucumbene gate. This test was made to determine the forces to be expected if emergency or other closures are made with the Eucumbene gate. The very different discharge characteristics of the design without restriction plates produced a very different downpull curve (Figure 19B). Relatively low pressures, considering the submergence due to Lake Eucumbene (Figure 14B), occurred on the leaf bottom across the entire passage to produce the maximum downpull of 429,000 pounds at about a 22 percent gate opening. The pressures at the gate slots had an important effect on the curve, being strongly positive at 10 percent and smaller openings and decreasing rapidly as the gate was opened from 10 to 20 percent. At larger openings, with attendant tunnel back pressure increases and hence differential head decreases, the downpull progressively decreased. Pressure factors and discharge coefficients for the above operation are given in Figure 14B.

A last series of downpull tests was made with the restriction plates removed and with free discharge conditions downstream from the gate. This approximates the conditions that would possibly occur during early filling operations in the Eucumbene-Island Bend Tunnel. With an upstream head of 410 feet, cavitation pressures occurred on the leaf bottom at gate openings of 40 percent or more (Figure 14C). The maximum downpull occurred at about a 52 percent gate opening and reached 1,015,000 pounds (Figure 19C). The downpull computations were made using -30 feet for all pressures indicated within the cavitation range.

The pressure data and discharge coefficients for the free discharge operating condition are presented dimensionlessly in Figure 14C. These data, like the other pressure factor data, may be used for a wide range of pressure conditions. It is therefore usable for other operating conditions on this structure and for other structures that are geometrically similar.

Stainless Steel Liner Plates

The severe operating conditions on the Island Bend gate, and the fact that it is extremely difficult and expensive to reach for maintenance purposes, make it mandatory to provide smooth, well alined, corrosion- and erosion-resistant surfaces wherever high velocity flows will occur in the gate. Typical surfaces in need of special care are found on the parallel, 7-foot-long walls downstream from the gate slots and on the restriction plates where the downstream gate seal makes contact. It is believed that carefully placed, firmly supported, and accurately alined heavy stainless steel plates will provide the best possible and longest-lived surfaces for these critical areas. Such plates are therefore provided in the design of the prototype gate (Figure 21).

Measuring Station for Downstream Tunnel Pressure

The rate of discharge through the gate will depend not only upon the elevation of Island Bend Pond and the gate opening but also upon the head, or back pressure, in the 28-foot-diameter tunnel downstream. To measure this head, a float well is provided and is connected to the 28-foot-diameter tunnel at a point 100 feet downstream from the Island Bend gate (Figure 4). This distance allows reasonable redistribution of flow downstream from the gate and is far enough upstream from the contraction to the 16-foot tunnel to avoid interference. The opening into the tunnel is placed on the horizontal center line instead of the vertical one to avoid any accumulations of separated air.

REFERENCES

1. Schuster, J. C., "Hydraulic Model Studies of the Eucumbene-Tumut Tunnel Junction Shaft for the Australian Snowy Mountains Hydro-Electric Authority," Bureau of Reclamation Report No. Hyd-392, August 31, 1954

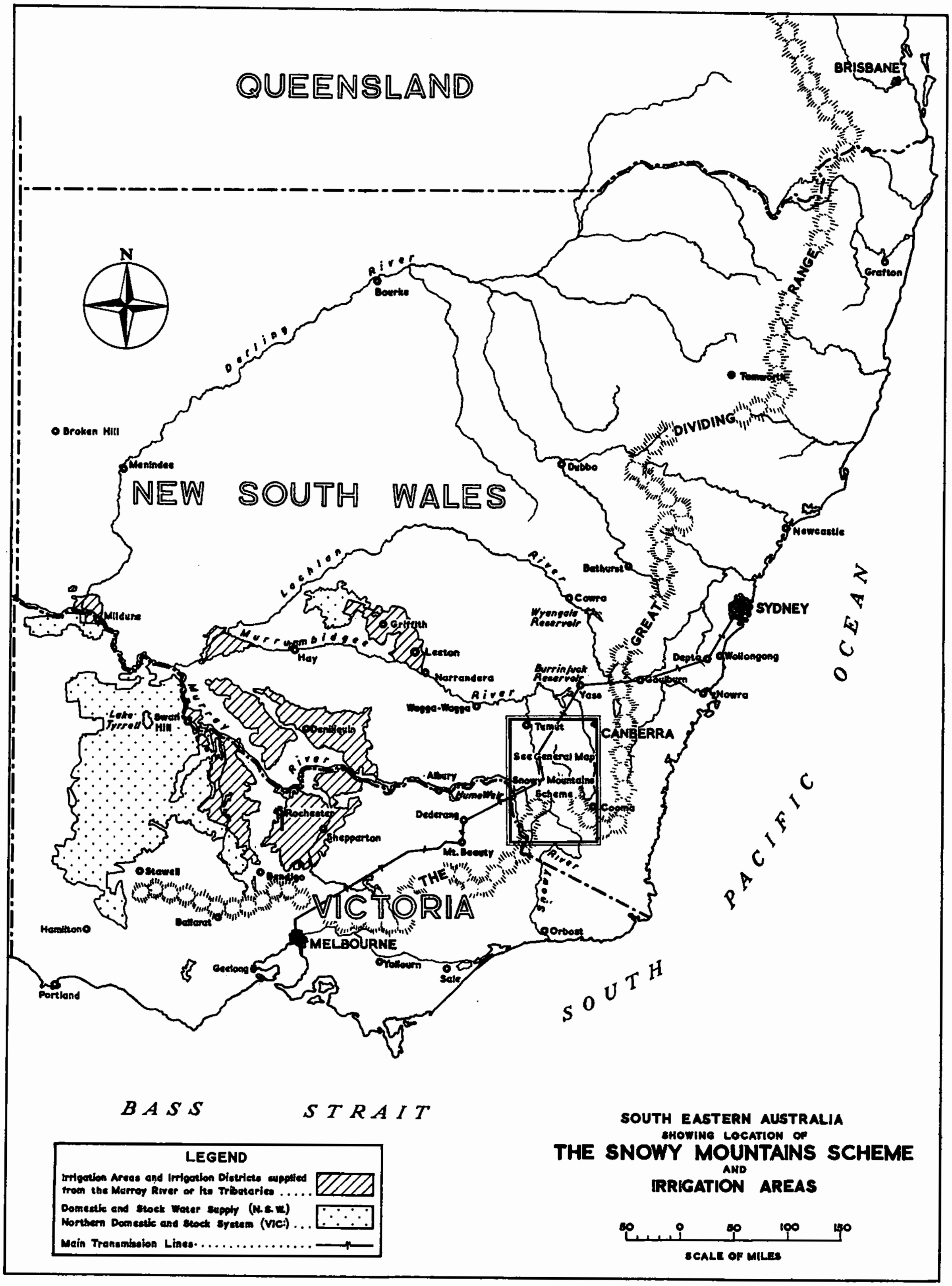
2. Rouse, Hunter, "Cavitation in the Mixing Zone of a Submerged Jet," La Houille Blanche, January-February 1953, pp 9-19

3. Ball, J. W., "Cavitation Characteristics of Gate Valves and Globe Valves Used as Flow Regulators Under Heads up to About 125 Feet," Transactions ASME, August 1957, pp 1275-1283

4. Simmons, W. P., Jr., "Models Primarily Dependent on the Reynolds Number," a paper presented at the ASCE, Washington, D. C. Convention, October 1959

GPO 838018

FIGURE I
REPORT HYD. 462



SOUTH EASTERN AUSTRALIA
SHOWING LOCATION OF
THE SNOWY MOUNTAINS SCHEME
AND
IRRIGATION AREAS

FIGURE 2
REPORT HYD. 462

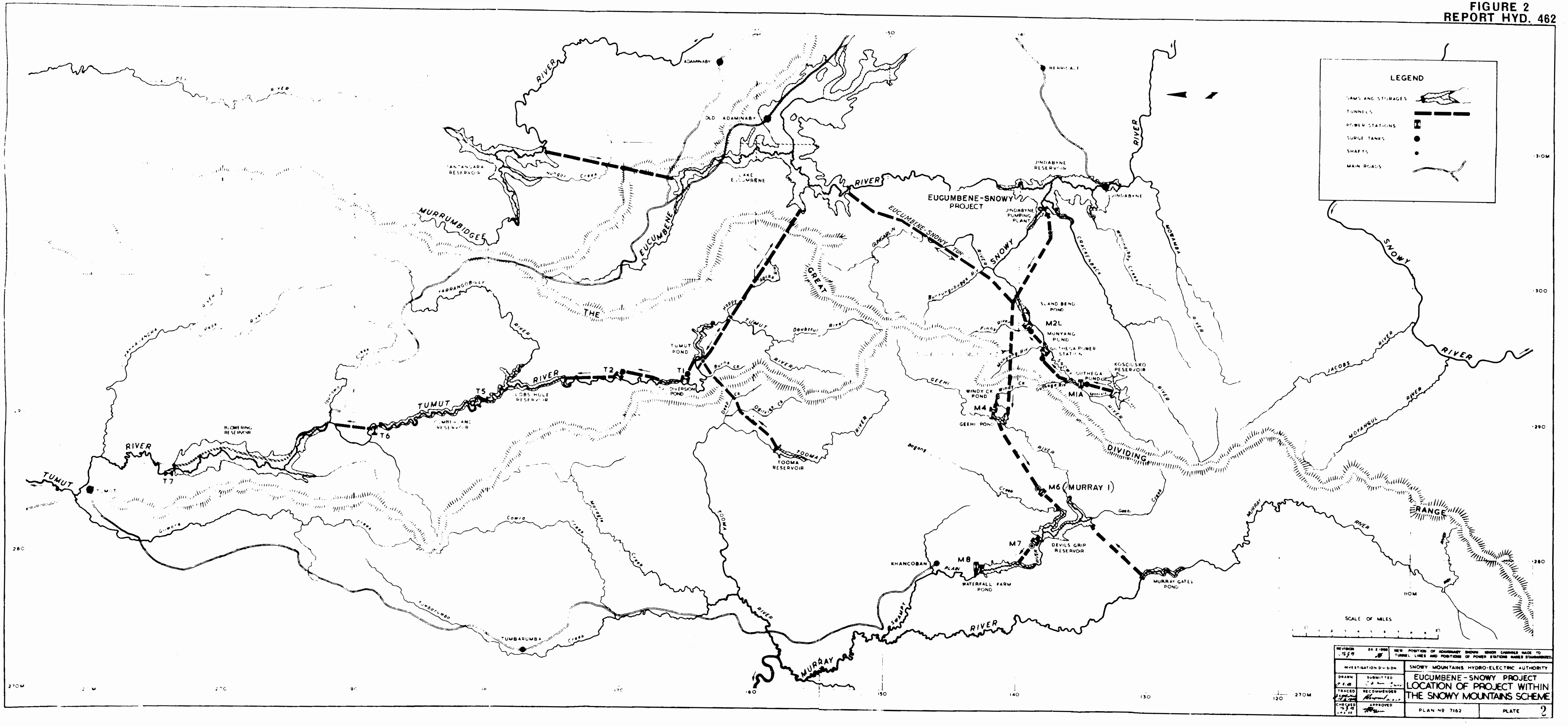
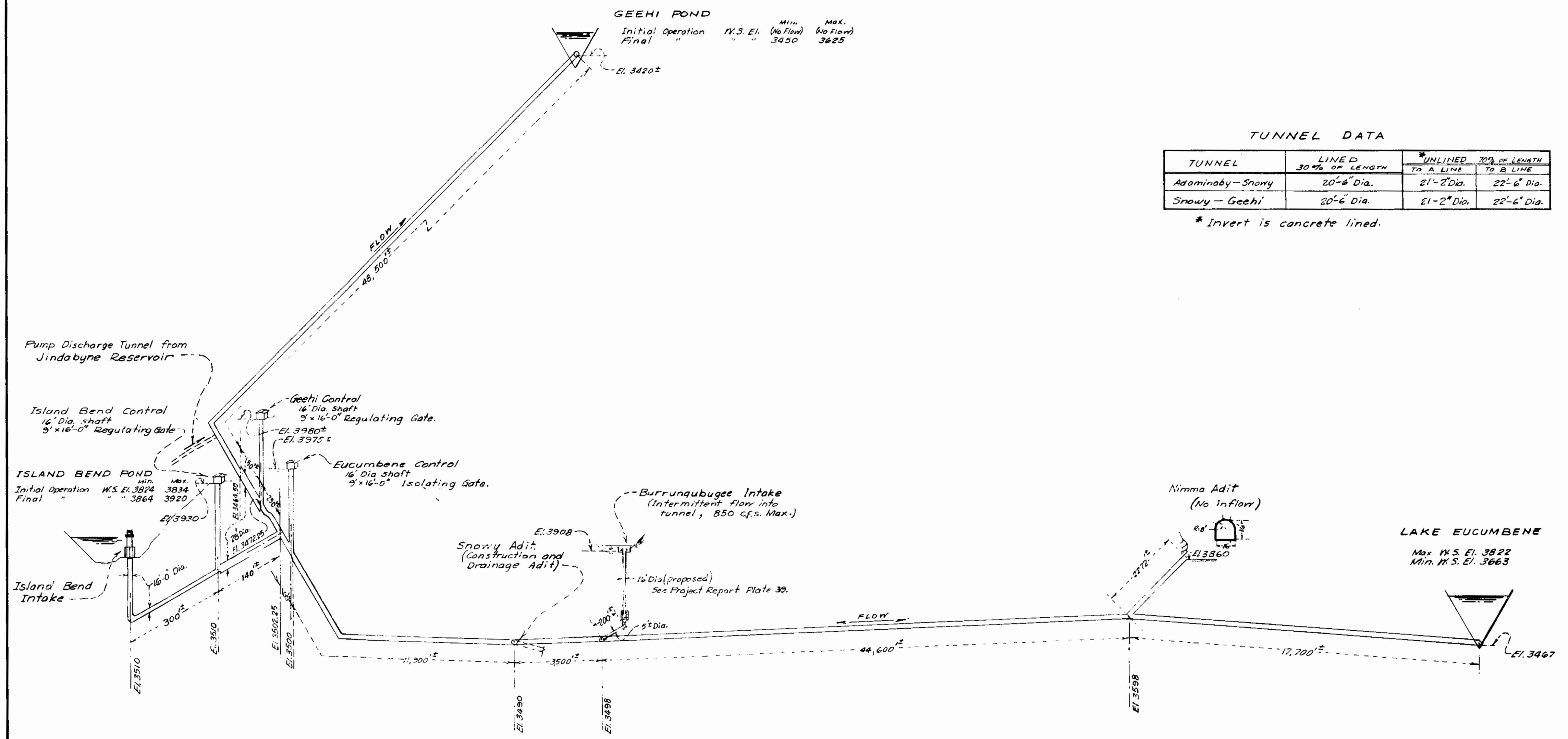


FIGURE 3
REPORT HYD. 462



TUNNEL DATA

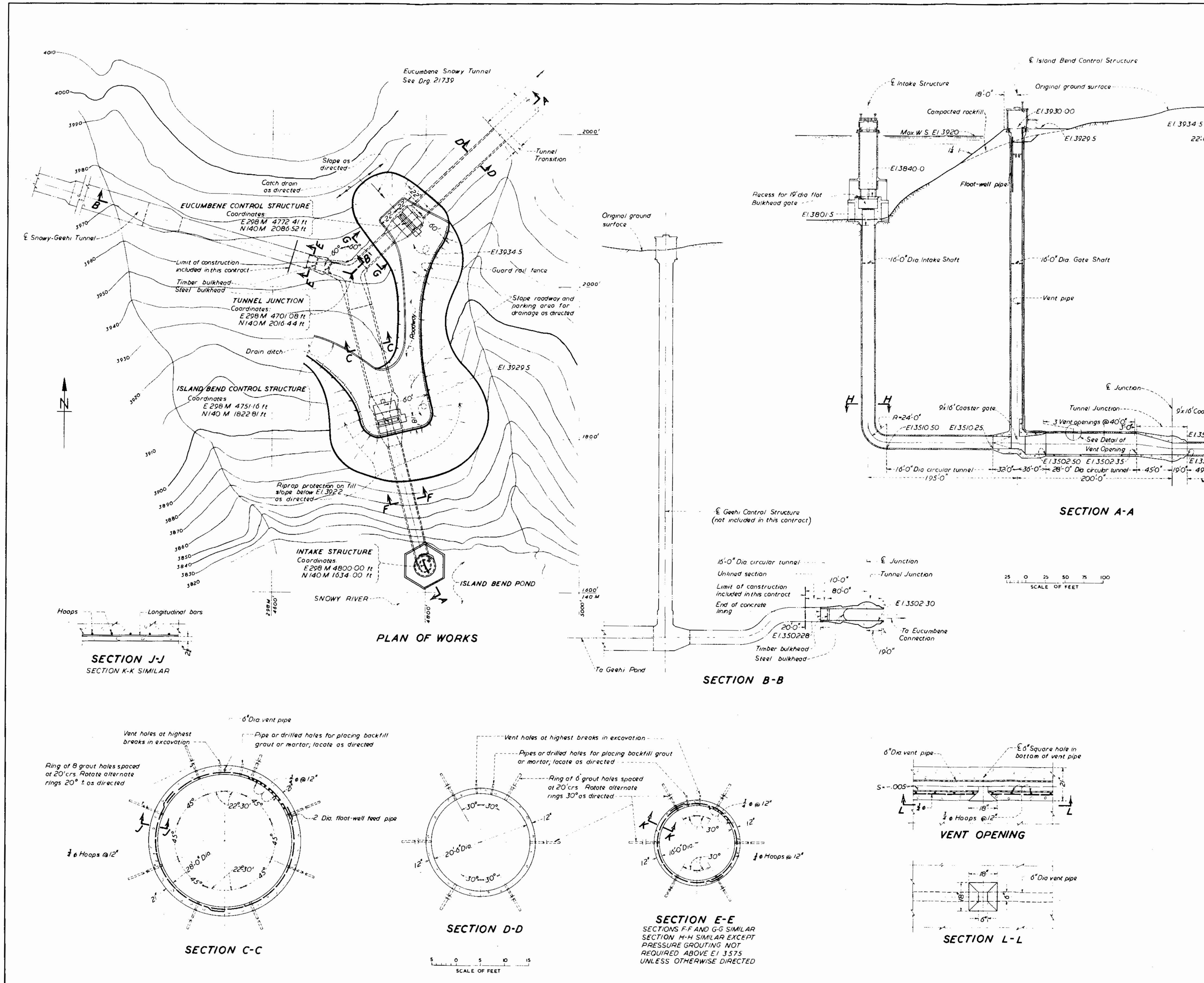
TUNNEL	LINED 30% OF LENGTH	*UNLINED 70% OF LENGTH TO A LINE	TO B LINE
Adaminaby—Snowy	20'-6" Dia.	21'-2" Dia.	22'-6" Dia.
Snowy — Geehi	20'-6" Dia.	21'-2" Dia.	22'-6" Dia.

* Invert is concrete lined.

REV. 7-25-58	Changed length of intake reach, Min W.S.
REV. 6-18-58	Changed dimentions of shafts, gates and pools.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
S. M. H. E. A.
ADAMINABY—SNOWY PROJECT
ISLAND BEND POND — GEEHI POND — LAKE EUCUMBENE
SCHEMATIC DIAGRAM OF OPERATING FEATURES

DRAWN R.E.M. D.B.M. SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED
DENVER, COLO., APRIL 28, 1958 OA-9-CT-29



NOTES

Concrete design based on a compressive strength of 2500 pounds per square inch.
El refers to elevation above standard datum.
Lap bars 45 diameters where lapped splices are used.
Coordinates shown refer to the Snowy Mountains area grid system.
All sections of shafts and tunnels below El 3575 to be pressure grouted.

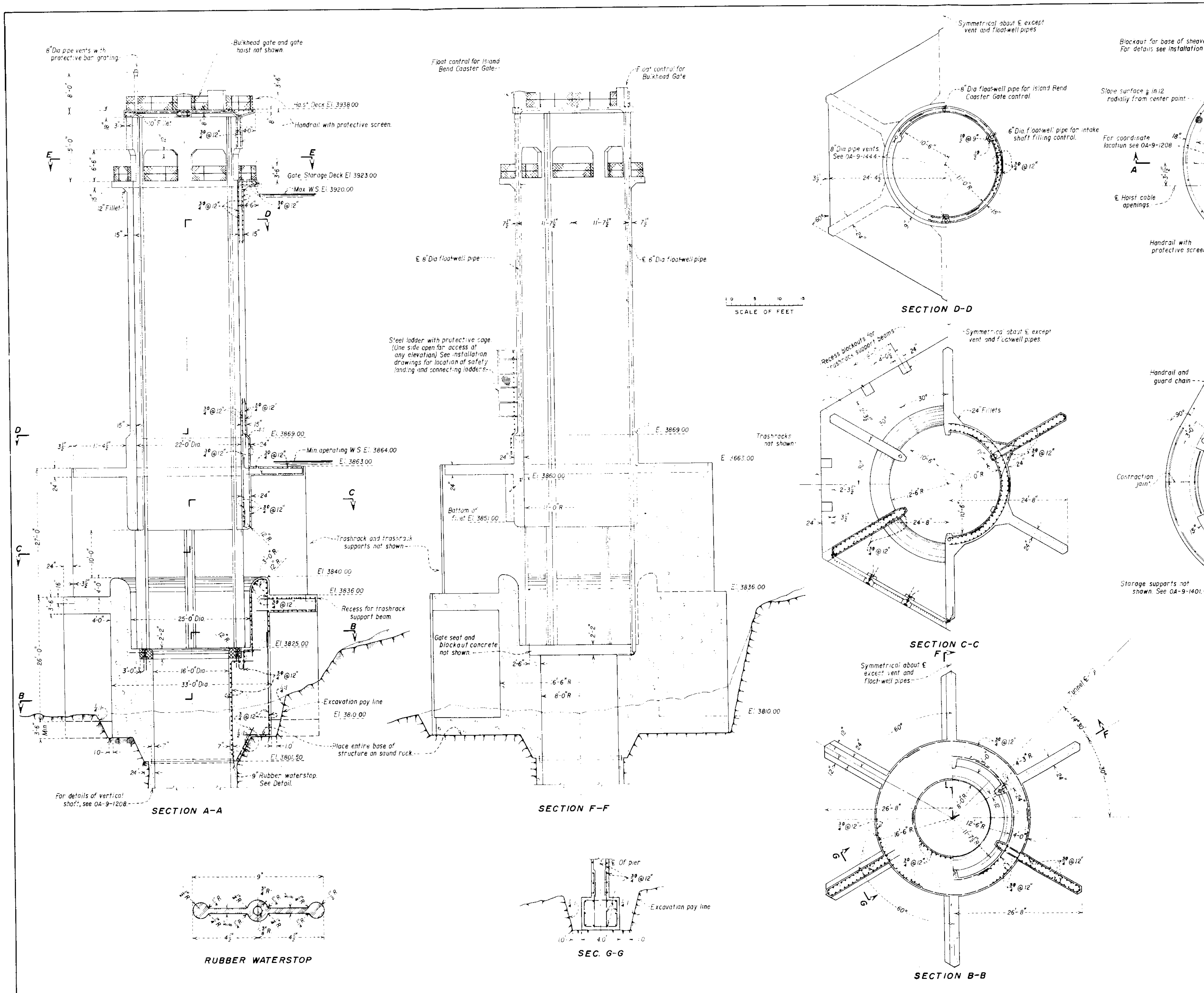
REFERENCE DRAWINGS

INTAKE STRUCTURE OA-9-1209
ISLAND BEND CONTROL STRUCTURE OA-9-1547
TUNNEL JUNCTION OA-9-1217
EUCUMBENE CONTROL STRUCTURE OA-9-1212
EUCUMBENE SNOWY TUNNEL—
ALIGNMENT PROFILE & SECTIONS 21739

18-8-59 U.S.B.R.	Removed Min. Op. W.S.; Changed downstream shapes of Island Bend and Eucumbene control structures; Added Float Well and Float-Well Feed Pipe.
Drawing re-drawn S.R.H. 17-7-59	Revised layout

AUSTRALIA
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
EUCUMBENE - SNOWY PROJECT
ISLAND BEND WORKS
GENERAL ARRANGEMENT

SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY	UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
CHIEF ENGINEER CIVIL DESIGN & SC. SER.	DR. L.R.H. SUBMITTED W.E. SCHNEIDER
	TR. D.P.G. RECOMMENDED R.N. TERRELL
ASSOCIATE COMMISSIONER	CK. J.M. APPROVED L.G. PULS CHIEF DESIGNING ENGINEER
COOMA N.S.W. JAN 1959	DENVER COLORADO OCT 16 1958 OA-9-1208

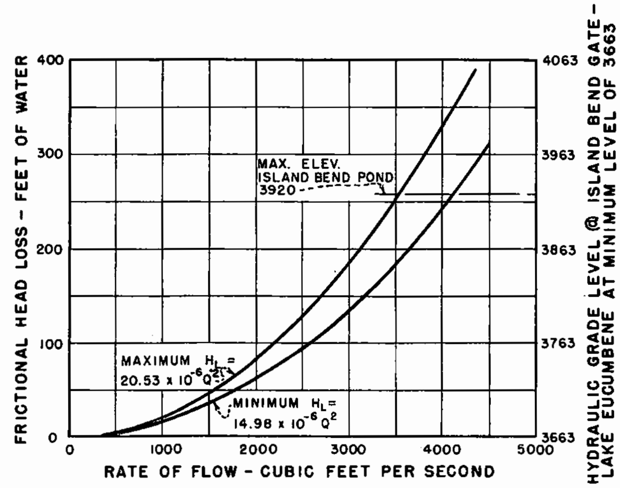


NOTES

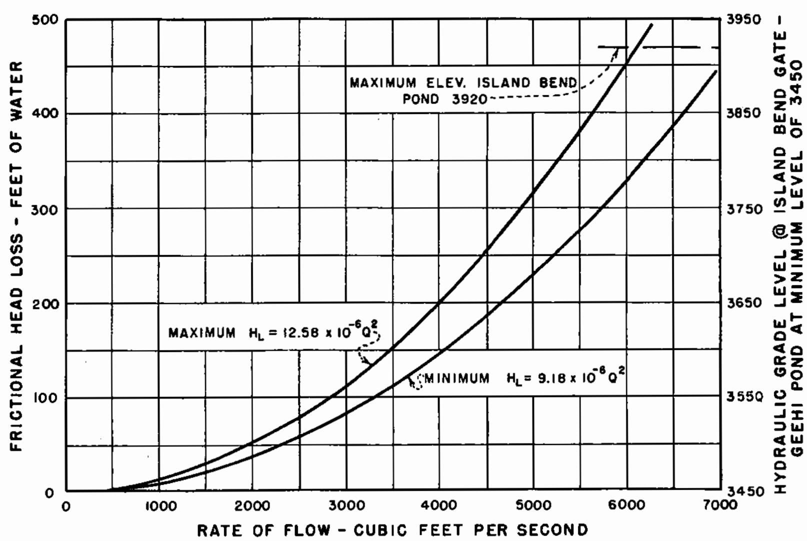
Unless otherwise shown, place reinforcement so that the clear distance between face of concrete and nearest reinforcement is 2" except provide a clear distance from face of concrete placed against earth or rock of 3".
Lap bars 45 diameters where lapped splices are used.
Concrete design based on a compressive strength of 2500 pounds per square inch.
All exposed edges shall be chamfered $\frac{3}{4}$" unless otherwise shown.
El. refers to elevation above standard datum.
For General Arrangement of Island Bend Works, see OA-9-1208.
For bulkhead gate, gate seat, guides, hoist and storage supports, see OA-9-1401.
For details of air vents and floatwell piping see OA-9-1444.
For details of metal work, anchor bolts and embedments, see installation drawings.

AUSTRALIA
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
ADAMINABY-SNOWY PROJECT
ISLAND BEND WORKS
INTAKE STRUCTURE
PLAN AND SECTIONS

SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY	UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
CHIEF ENGINEER, CIVIL DESIGN & SC. SER.	SUBMITTED
ASSOCIATE COMMISSIONER	RECOMMENDED
	APPROVED CHIEF ENGINEER
	DENVER, COLORADO OCT. 6, 1958 — OA-9-1209



A. EUCUMBENE - SNOWY TUNNEL



B. SNOWY - GEEHI TUNNEL

FRICTION FACTORS - MANNING EQUATION

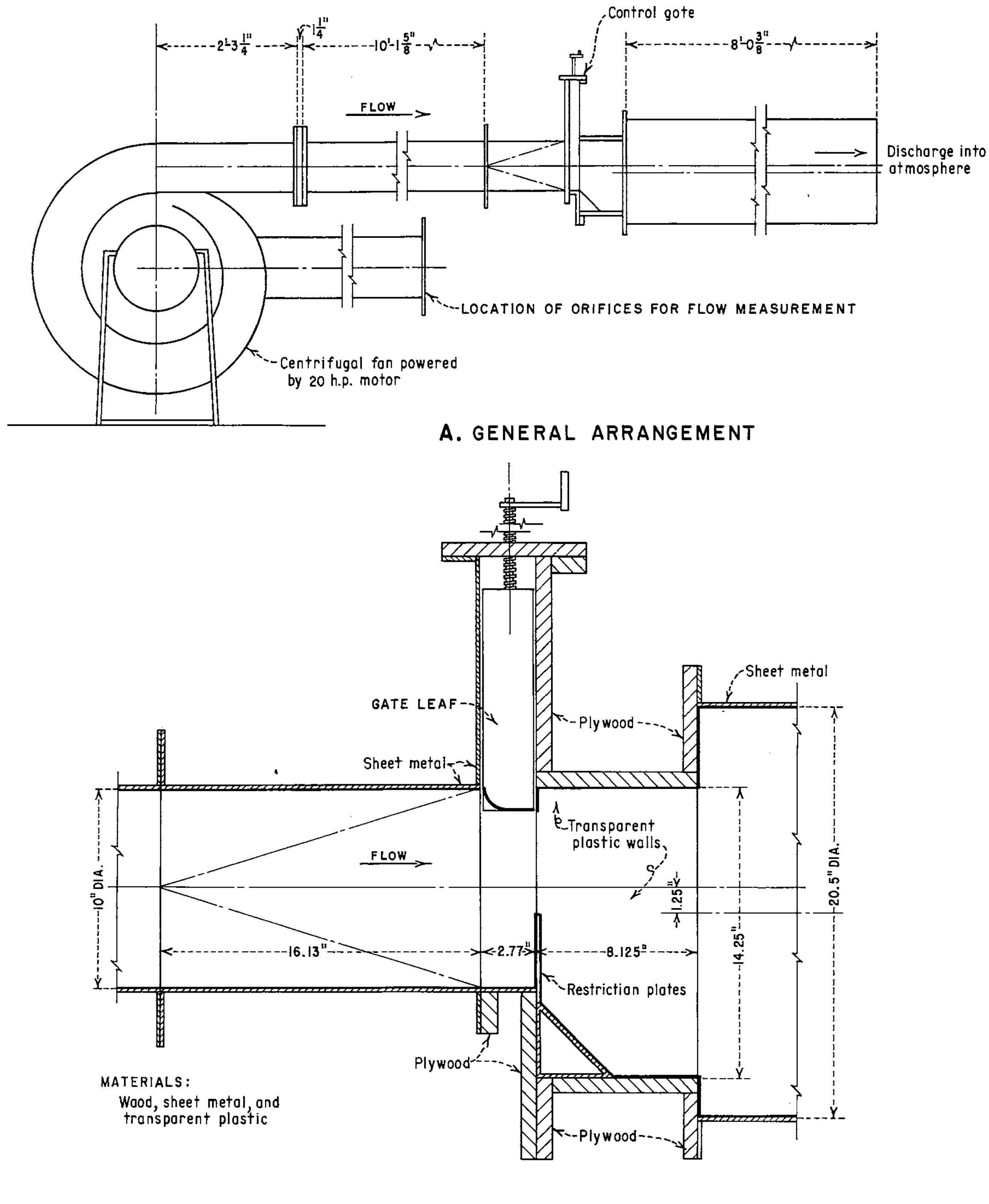
MAXIMUM LOSS CONDITIONS
n = .029 for 70% of tunnel - rock with lined invert D = 21.17'
n = .014 for 30% of tunnel - concrete lined D = 20.5'

MINIMUM LOSS CONDITIONS
n = .025 & n = .011

Note: Tunnel sizes from Dwg. DT-J-11

ISLAND BEND CONTROL GATE
COMPUTED TUNNEL FRICTION LOSSES, AND HYDRAULIC GRADES AT ISLAND BEND GATE

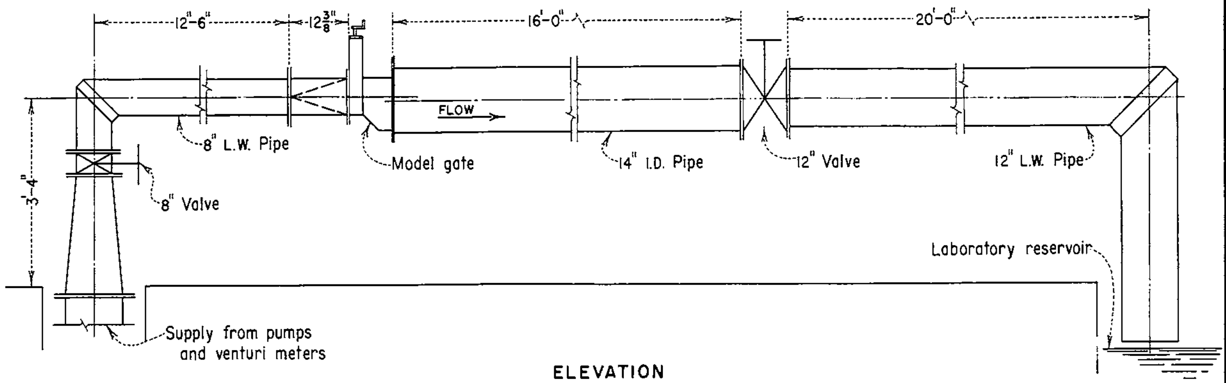
613



A. GENERAL ARRANGEMENT

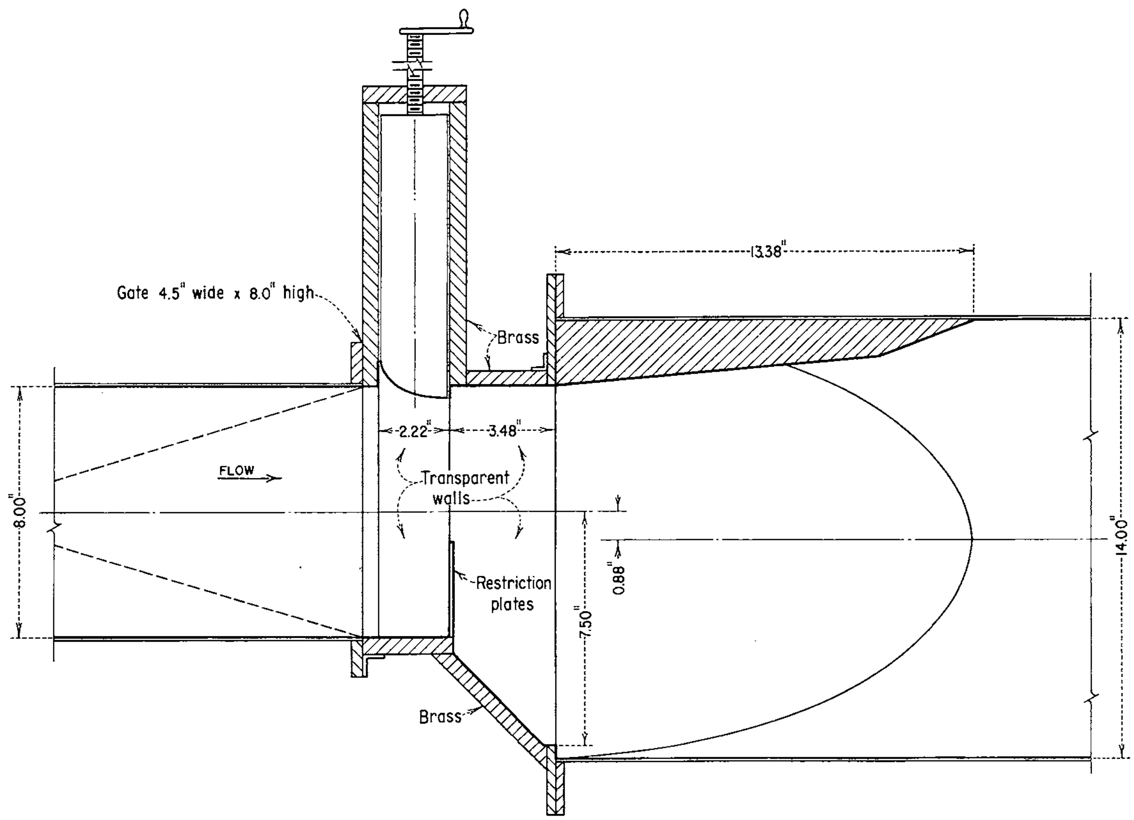
B. DETAIL OF GATE SECTION

ISLAND BEND CONTROL GATE
1:19.2 SCALE AIR MODEL



ELEVATION

A. GENERAL ARRANGEMENT



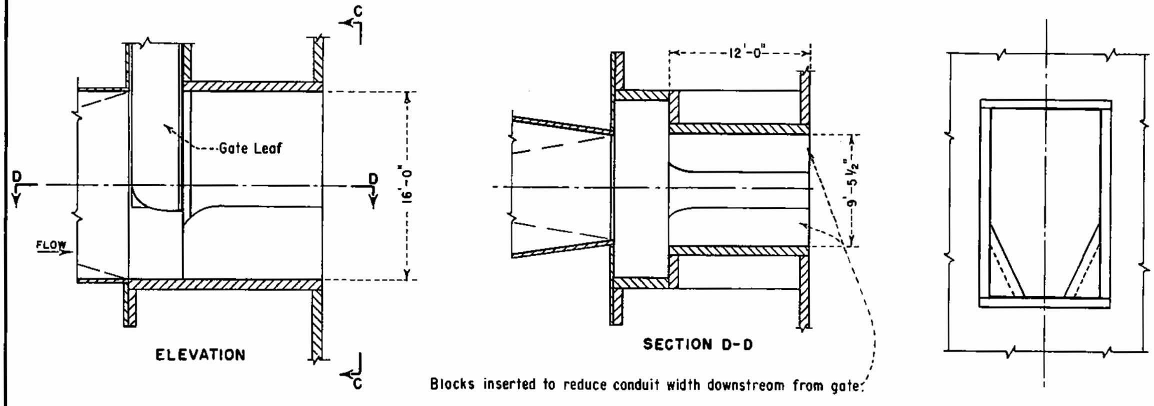
SECTIONAL ELEVATION

B. DETAIL OF TEST SECTION

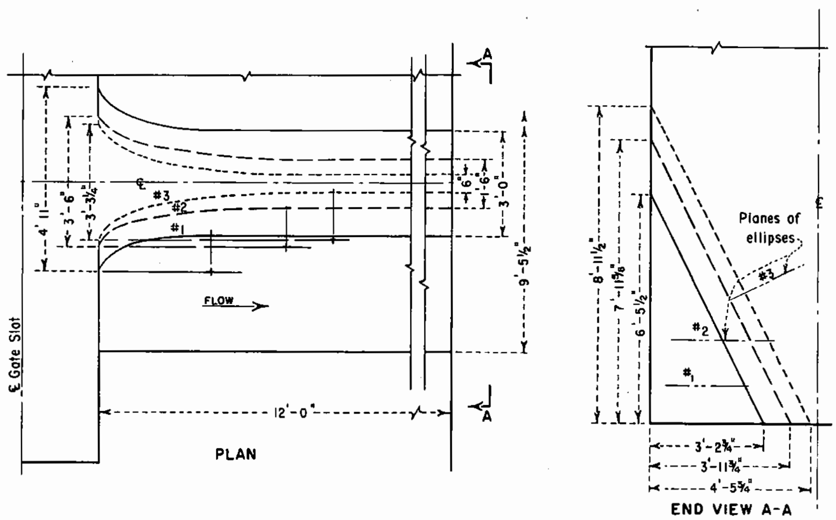
ISLAND BEND CONTROL GATE

1:24 SCALE HYDRAULIC MODEL

613



A. TYPICAL INSTALLATION

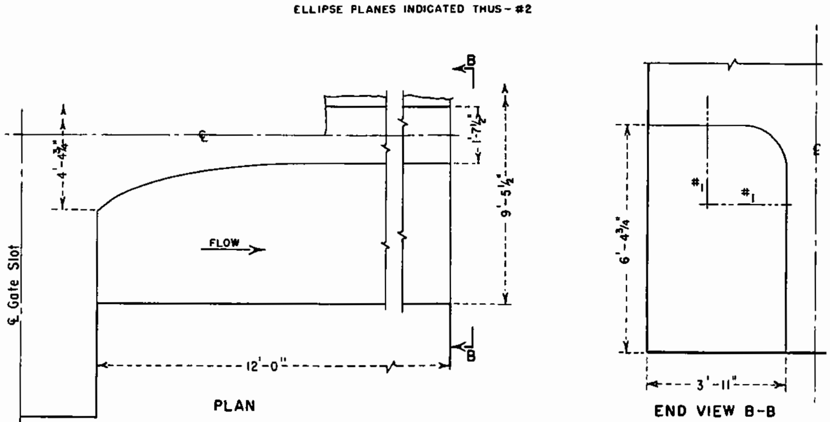


B. TRAPEZOIDAL BELLMOUTH SECTIONS

ELLIPSE PLANES INDICATED THUS - #2

#1		#2		#3	
x	y	x	y	x	y
0.00	0.9602	0	1.00	0.0	1.25
0.25	0.9569	0.50	0.999	0.50	1.246
0.5	0.9468	1.00	0.995	1.00	1.234
1.0	0.9053	1.50	0.9758	2.00	1.184
1.5	0.8316	2.00	0.9165	3.00	1.097
1.75	0.7799	2.50	0.8660	4.00	0.960
2.00	0.7157	3.00	0.800	4.50	0.868
2.25	0.6351	3.50	0.7141	5.00	0.750
2.5	0.5308	4.00	0.6000	5.50	0.594
2.75	0.3837	4.25	0.5268	5.75	0.490
2.90	0.2459	4.50	0.4360	6.00	0.350
3.00	0	4.75	0.3122	6.125	0.2487
		4.875	0.2222	6.18	0.1864
		5.00	0	6.25	0

ELLIPSE COORDINATES (FEET)
TRAPEZOIDAL SECTIONS



C. RECTANGULAR BELLMOUTH SECTIONS

ELLIPSE PLANES INDICATED THUS - #1

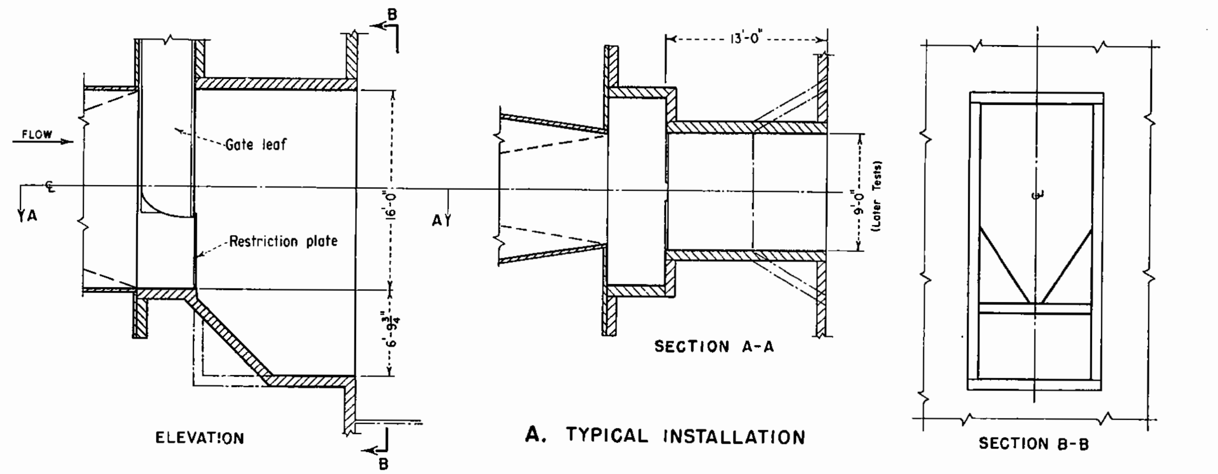
#1	
x	y
0.0	1.25
0.50	1.246
1.00	1.234
2.00	1.184
3.00	1.097
4.00	0.960
4.50	0.868
5.00	0.750
5.50	0.594
5.75	0.490
6.00	0.350
6.125	0.2487
6.18	0.1864
6.25	0

ELLIPSE COORDINATES (FEET)

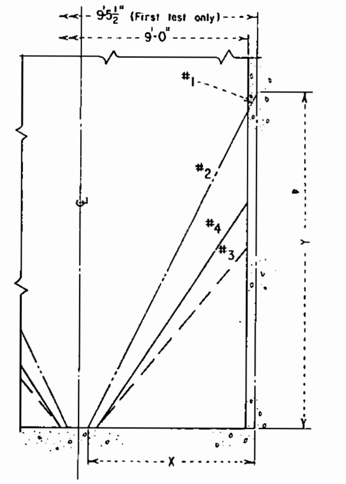
Note: Dimensions in feet, Prototype

ISLAND BEND CONTROL GATE
CORNER FILLERS FOR NARROWING GATE BODY
1:19.2 SCALE, AIR MODEL

613



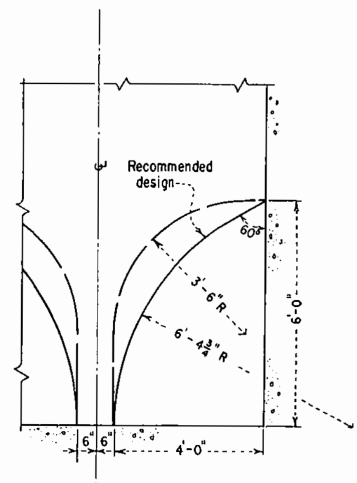
A. TYPICAL INSTALLATION



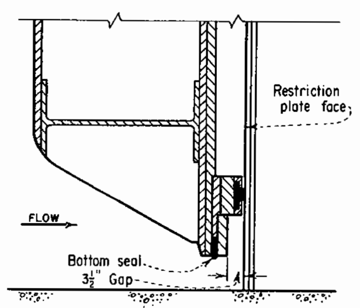
B. STRAIGHT RESTRICTION PLATES

	#1	#2	#3	#4
X	4'-5¾"	4'-3"	4'-0"	4'-0"
Y	8'-11¾"	8'-6"	4'-9½"	6'-0"

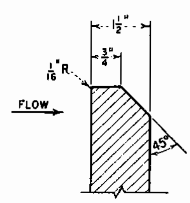
COORDINATES



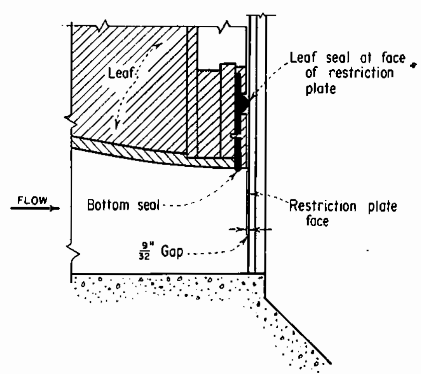
C. CURVED RESTRICTION PLATES



D. INITIAL LEAF AND BOTTOM SEALS



E. CROSS SECTION OF PLATE

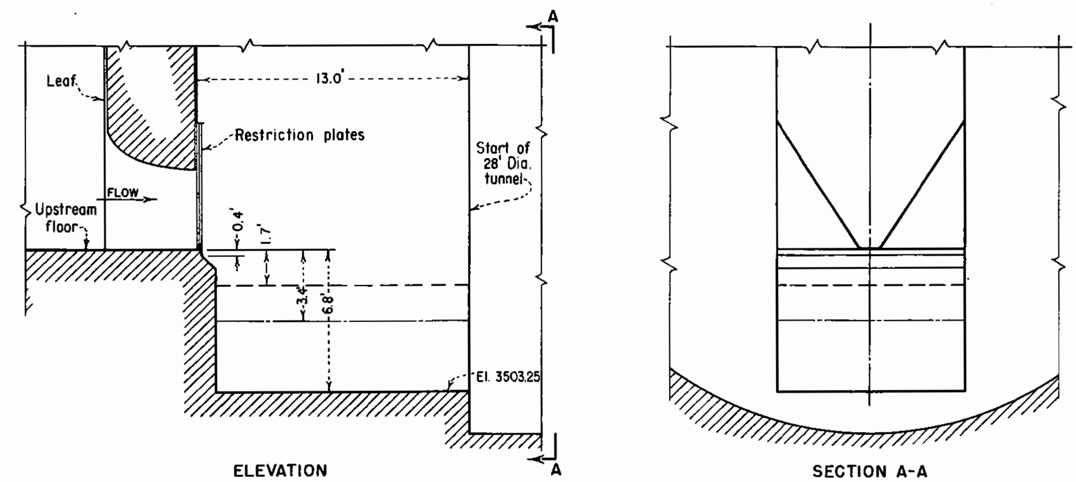


F. FINAL LEAF AND BOTTOM SEALS

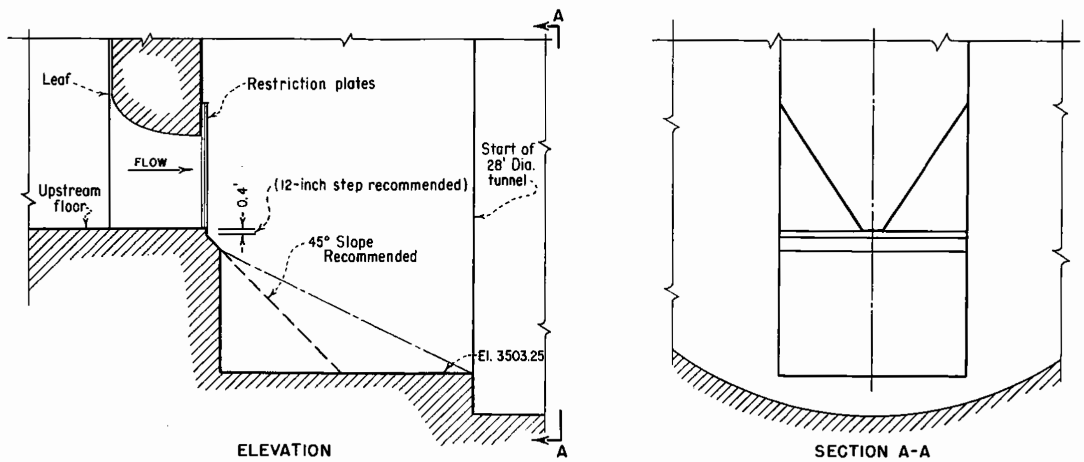
Note: Dimensions in feet, Prototype

ISLAND BEND CONTROL GATE
RESTRICTION PLATES FOR NARROWING GATE BODY
1:19.2 SCALE, AIR MODEL

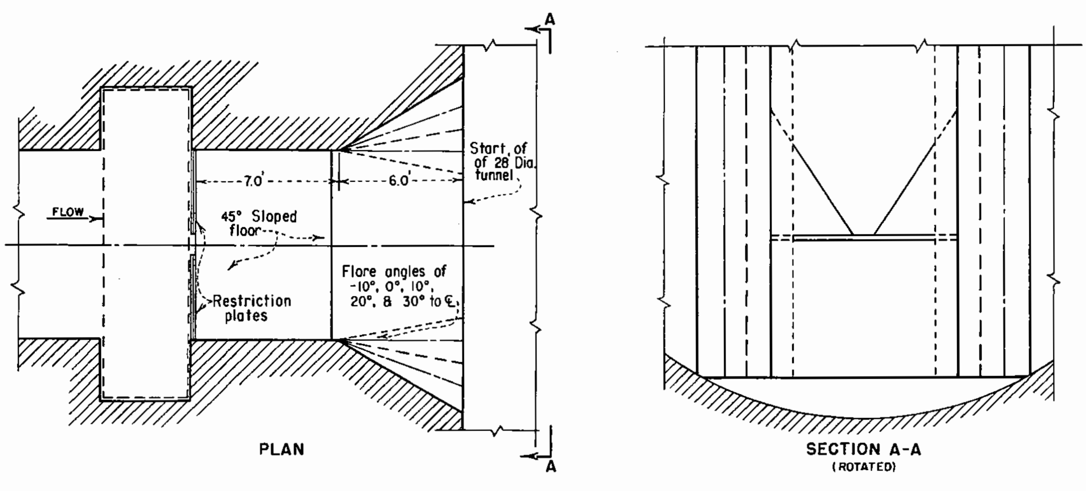
613



A. FLOOR ALINEMENTS - HORIZONTAL DESIGNS



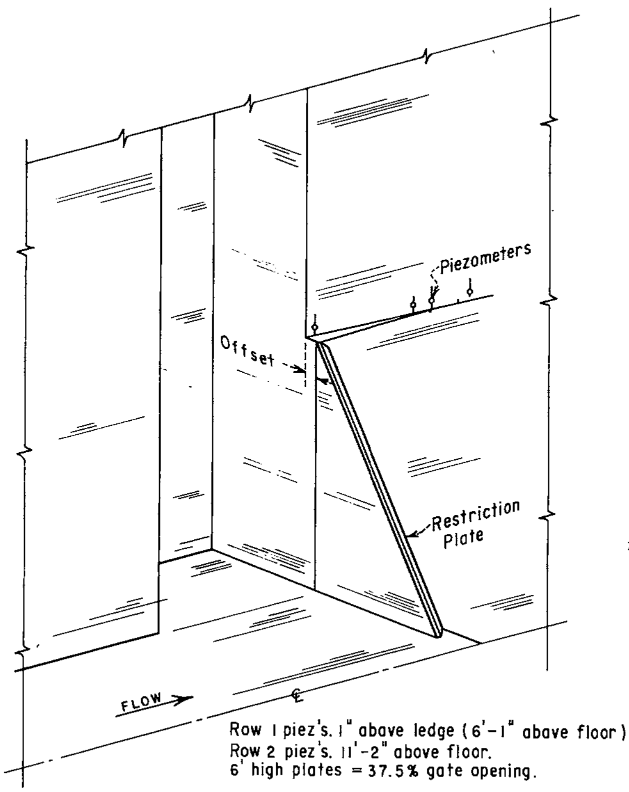
B. FLOOR ALINEMENTS - SLOPING DESIGNS

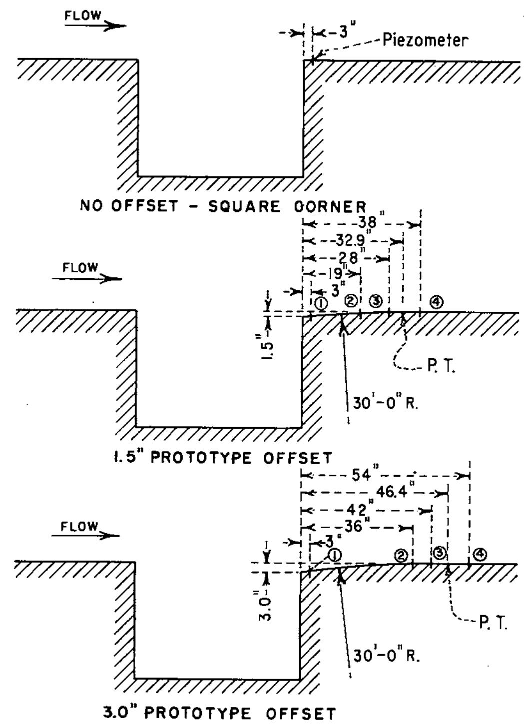


C. WALL ALINEMENTS

Note: Dimensions in feet, Prototype

ISLAND BEND CONTROL GATE
FLOOR AND WALL ALINEMENTS
FROM GATE LEAF TO 28-FEET DIAMETER CONDUIT
1:19.2 SCALE, AIR MODEL





B. SLOT SHAPES TESTED

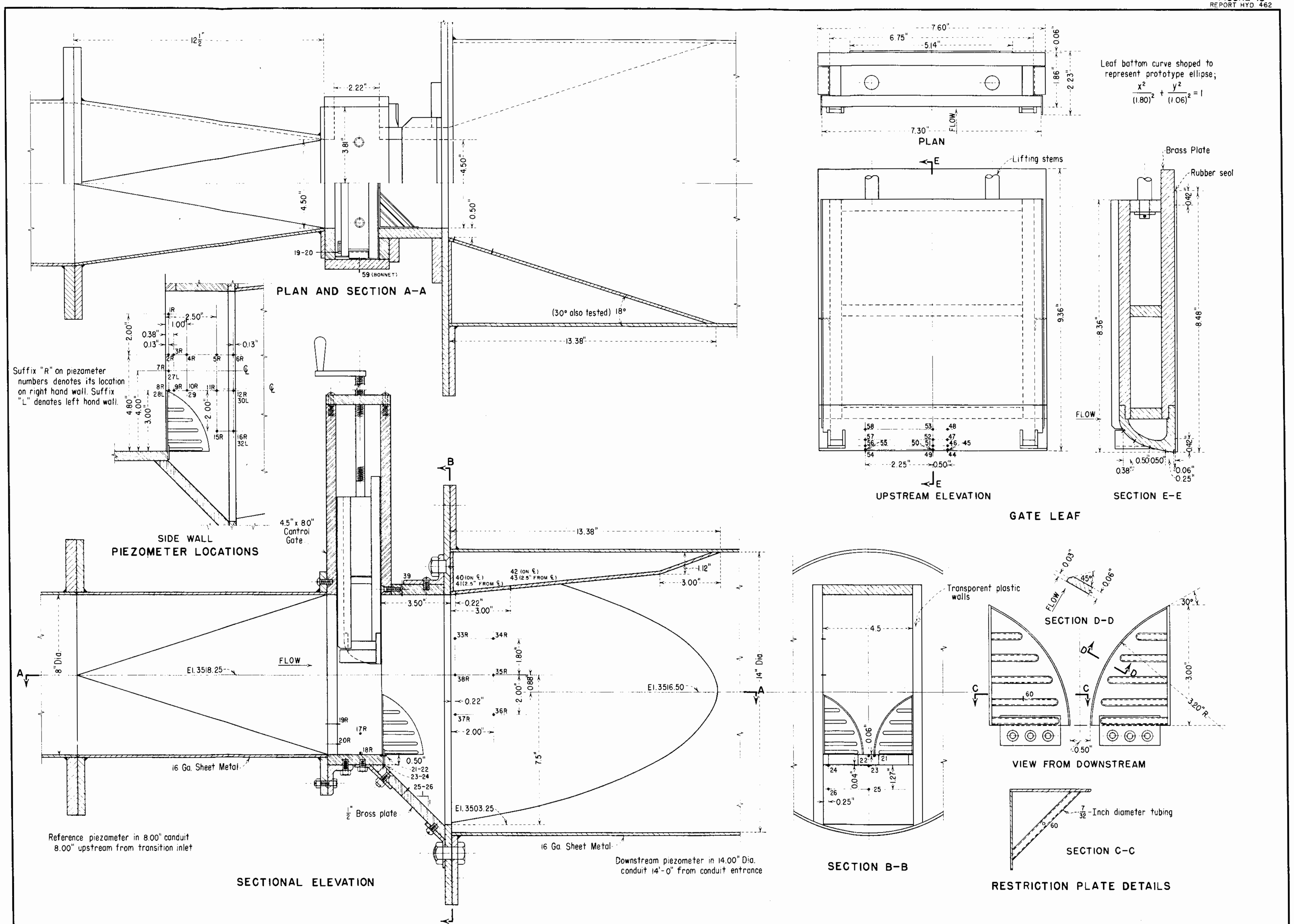
A. OFFSET SLOT CORNER ABOVE RESTRICTION PLATES

SLOT SHAPE	PIEZ. NO.	GATE OPENING													
		32.5 %		37.5%		40%		45%		72.5%		80%		100%	
		ROW 1	ROW 2	ROW 1	ROW 2	ROW 1	ROW 2	ROW 1	ROW 2	ROW 1	ROW 2	ROW 1	ROW 2	ROW 1	ROW 2
NO OFFSET	1	-12	-14	7	16	36	37	56	69	205	-18	100		280	257
	2														
	3														
	4														
1.5" OFFSET	1	-12	-14	7	16	36	37	62	69	205	-18			280	257
	2	-7	-14	16	16	38	32	83	69	196	122			270	267
	3	-9	-14	16	16	36	37	83	67	189	124			265	267
	4	-9	-14	16	16	36	37	83	65	185	125			261	267
3.0" OFFSET	1	-9	-14	14	18	18	39	68	76	201	19			267	261
	2	-9	-14	20	16	36	37	76	65	187	126			264	266
	3	-9	-14	16	16	36	37	76	65	189	124			264	266
	4	-9	-14	16	16	34	37	76	65	187	126			264	266

C. PIEZOMETRIC PRESSURES - FEET OF WATER, PROTOTYPE, INCLUDING MINIMUM BACK PRESSURE
(Tests Mode With Elliptical Bottom on Gate Leaf)

Note: Data from 1:19.2 scale, air model

ISLAND BEND CONTROL GATE
GATE SLOT DESIGNS AND PRESSURES



ISLAND BEND CONTROL GATE
MODEL GATE DETAILS AND PIEZOMETER LOCATIONS
RECOMMENDED DESIGN
1:24 SCALE HYDRAULIC MODEL

OPENING \ PIEZ.	1	2	3	4	5	6	7	8	9	10	11	12	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	33
100%	259	275	292	296	290	278	291	288	288	287	288	285	289	289	375	362	372	379	285	284	292	293	292	293	292	291	288	284	290	265
90	201	232	265	273	270	263	267	274	274	274	274	272	274	277	363	363	376	380	278	270	278	280	280	280	267	274	274	274	276	258
80	212	166	194	228	227	223	202	243	243	241	241	238	243	246	364	360	373	380	247	238	248	249	249	250	204	249	245	240	246	210
70	174	148	152	165	173	175	111	198	198	196	196	191	196	198	361	360	377	379	187	188	203	205	205	205	117	201	196	194	200	165
60	111	93	99	105	106	110	87	127	128	127	127	123	128	132	361	364	389	381	120	114	135	138	139	139	81	127	125	124	132	102
50	32	32	33	31	32	35	30	41	46	46	47	47	50	53	381	391	392	400	38	29	58	61	62	62	30	47	47	39	53	35
40	4	0	0	0	4	4	-2	8	9	8	7	5	8	14	380	388	387	392	12	-4	21	25	26	26	1	11	11	8	11	4
30	15	17	17	18	18	18	20	22	22	22	21	21	22	22	403	405	403	406	23	16	29	28	27	26	20	22	21	20	20	15
20	20	24	24	23	23	23	26	28	28	26	26	26	30	30	407	408	407	407	30	30	27	26	24	24	26	26	26	24	29	22
10	29	27	27	27	27	27	25	23	23	24	24	24	13	13	414	413	411	412	15	18	16	16	13	13	25	23	24	24	20	29
5																														

OPENING \ PIEZ.	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	REF.	DOWN-STREAM
100%	282	286	290	290	283	300	270	278	277	293	300	304	327	338	340	290	303	325	338	339	319	329	334	353	344	340	286	372	310
90	270	274	276	276	264	246	280	267	275	276	243	249	284	323	375	239	250	283	322	373	316	316	330	349	363	365	264	374	298
80	235	242	245	245	238	206	237	234	251	243	221	228	263	298	345	216	228	260	297	341	298	302	321	346	353	374	240	377	268
70	186	192	200	199	184	168	174	183	189	197	188	199	243	278	328	184	199	239	278	322	278	308	304	325	328	375	195	381	223
60	120	123	132	133	118	105	111	114	128	126	141	160	223	261	316	134	162	219	263	309	252	304	322	319	303	373	128	386	156
50	38	41	54	55	41	27	33	39	60	50	100	144	235	283	332	91	146	232	283	326	243	299	346	348	332	384	44	391	77
40	4	6	15	16	7	0	6	4	21	1	112	186	288	321	353	104	182	278	323	351	298	323	363	367	363	369	13	395	30
30	15	18	22	23	19	12	12	12	13	11	186	280	359	373	391	173	268	352	377	388	398	395	399	397	393	373	24	400	30
20	21	24	28	28	24	17	17	17	16	16	277	356	391	396	405	235	233	386	398	400	404	403	403	403	405	376	30	401	30
10	29	26	22	22	26	26	26	26	25	25	379	379	400	407	407	399	407	403	407	407	406	400	403	404	407	380	18	402	30
5											386	392	399	401	403	308	376	398	401	402	401	402	402	402	402			402	30

PRESSURES—Island Bend Res. El. 3920 Geehi Pond Empty 30' Minimum Back Pressure

OPENING \ PIEZ.	1	2	3	4	5	6	7	8	9	10	11	12	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	33
100%	-.627	-.434	-.221	-.169	-.243	-.392	-.240	-.273	-.273	-.277	-.270	-.310	-.259	-.256	+.796	+.632	+.756	+.848	-.302	-.324	-.223	-.215	-.220	-.214	-.221	-.237	-.272	-.315	-.246	-.556
90	-1.020	-.691	-.349	-.258	-.288	-.371	-.328	-.245	-.245	-.247	-.247	-.270	-.247	-.221	+.692	+.693	+.826	+.872	-.203	-.294	-.203	-.193	-.188	-.188	-.324	-.254	-.246	-.252	-.233	-.414
80	-.446	-.822	-.596	-.323	-.329	-.361	-.528	-.204	-.201	-.214	-.215	-.244	-.198	-.178	+.766	+.739	+.843	+.894	-.169	-.240	-.162	-.154	-.149	-.147	-.513	-.154	-.188	-.223	-.178	-.467
70	-.288	-.437	-.413	-.337	-.295	-.281	-.656	-.149	-.149	-.159	-.159	-.186	-.159	-.144	+.807	+.799	+.902	+.912	-.213	-.203	-.115	-.107	-.103	-.107	-.619	-.127	-.158	-.171	-.135	-.341
60	-.186	-.261	-.238	-.212	-.208	-.194	-.290	-.120	-.118	-.120	-.120	-.138	-.118	-.102	+.855	+.868	+.972	+.939	-.151	-.174	-.087	-.077	-.072	-.071	-.315	-.121	-.129	-.135	-.100	-.226
50	-.142	-.140	-.137	-.143	-.141	-.131	-.146	-.113	-.096	-.095	-.094	-.095	-.084	-.074	+.948	+.977	+.981	+1.008	-.121	-.150	-.058	-.049	-.046	-.046	-.146	-.094	-.094	-.120	-.075	-.129
40	-.072	-.083	-.082	-.081	-.070	-.072	-.087	-.060	-.058	-.060	-.064	-.067	-.060	-.044	+.954	+.974	+.973	+.985	-.050	-.092	-.024	-.015	-.012	-.011	-.079	-.051	-.051	-.061	-.053	-.070
30	-.041	-.034	-.034	-.032	-.034	-.034	-.026	-.021	-.021	-.021	-.024	-.025	-.021	-.022	+1.005	+1.011	+1.006	+1.013	-.019	-.039	-.003	-.005	-.009	-.011	-.028	-.023	-.024	-.027	-.027	-.041
20	-.027	-.016	-.016	-.018	-.020	-.020	-.011	-.006	-.007	-.010	-.011	-.012	+.001	0	+1.015	+1.017	+1.016	+1.014	-.001	-.001	-.008	-.011	-.018	-.018	-.011	-.011	-.011	-.015	-.002	-.022
10	-.003	-.008	-.008	-.008	-.008	-.008	-.014	+.018	+.018	+.017	+.017	+.017	-.028	-.028	+1.032	+1.029	+1.024	+1.026	-.040	-.031	-.037	-.037	-.045	-.045	-.013	-.018	-.018	-.017	-.028	-.003
5																														

OPENING \ PIEZ.	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	REF.	DISCH. COEFF.
100%	-.348	-.293	-.250	-.250	-.338	-.121	-.495	-.391	-.330	-.208	-.124	-.080	+.204	+.344	+.364	+.246	-.081	+.182	+.344	+.355	+.114	+.235	+.296	+.531	+.422	+.365	-.298	+.763	.6810
90	-.292	-.254	-.223	-.223	-.359	-.550	-.181	-.325	-.240	-.229	-.578	-.511	-.140	+.267	+.815	-.618	-.506	-.152	+.256	+.797	+.199	+.191	+.343	+.540	+.692	+.716	-.359	+.808	.6105
80	-.264	-.212	-.183	-.183	-.242	-.499	-.249	-.274	-.136	-.198	-.378	-.319	-.044	+.237	+.620	-.417	-.319	-.061	+.230	+.588	+.236	+.274	+.428	+.628	+.681	+.849	-.224	+.874	.4950
70	-.221	-.182	-.133	-.141	-.228	-.321	-.285	-.233	-.201	-.155	-.202	-.142	+.119	+.321	+.612	-.228	-.142	+.094	+.321	+.581	+.320	+.496	+.472	+.596	+.614	+.887	-.164	+.925	.3830
60	-.151	-.137	-.100	-.097	-.158	-.213	-.188	-.174	-.117	-.127	-.063	+.018	+.280	+.438	+.667	-.091	+.023	+.261	+.446	+.638	+.401	+.618	+.691	+.679	+.611	+.905	-.116	+.959	.2820
50	-.122	-.112	-.073	-.067	-.113	-.155	-.139	-.118	-.052	-.085	+.073	+.210	+.493	+.641	+.796	+.043	+.216	+.482	+.641	+.775	+.517	+.692	+.837	+.844	+.793	+.958	-.103	+.980	.1899
40	-.072	-.064	-.040	-.037	-.063	-.082	-.065	-.072	-.026	-.079	+.224	+.424	+.703	+.793	+.880	+.201	+.415	+.677	+.799	+.875	+.731	+.799	+.907	+.919	+.908	+.924	-.045	+.993	.1125
30	-.042	-.034	-.021	-.020	-.031	-.048	-.048	-.050	-.046	-.051	+.420	+.675	+.887	+.926	+.973	+.387	+.643	+.868	+.937	+.965	+.992	+.985	+.995	+.989	+.980	+.928	-.016	+.999	.0533
20	-.024	-.016	-.006	-.005	-.015	-.036	-.035	-.035	-.037	-.037	+.664	+.878	+.972	+.986	+1.009	+.553	+.816	+.959	+.990	+.995	+1.005	+1.003	+1.003	+1.004	+1.009	+.932	-.001	+1.000	.0237
10	-.003	-.012	-.022	-.023	-.012	-.010	-.011	-.011	-.013	-.013	+.938	+.940	+.996	+1.015	+1.015	+.993	+1.013	+1.005	+1.015	+1.015	+1.011	+.995	+1.005	+1.005	+1.015	+.940	-.031	+1.000	.0091
5											+.958	+.974	+.992	+.997	+1.003	+.748	+.930	+.989	+.997	+1.000	+.999	+1.000	+1.000	+1.000	+1.000	+1.000		+1.000	.0040

PRESSURE FACTORS

A. ISLAND BEND GATE—DOWNSTREAM TUNNEL FULL

OPENING \ PIEZ.	1	2	3	7	8	9	10	11	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	REF.	DOWN-STREAM
100%	388	388	388	388	389	390	390	389	386	385	394	395	385	386	386	393	392	384	387	387	388	387	385	385	401	399
90	360	374	377	375	375	378	380	382	368	365	370	382	403	366	364	368	382	403	388	382	376	380	392	392	400	392
80	369	366	369	366	367	373	374	375	366	360	361	367	387	364	360	359	367	386	384	382	372	371	378	397	401	385
70	366	352	362	356	356	364	366	366	361	354	352	355	374	359	354	351	355	371	378	375	366	364	367	398	403	375
60	351	349	352	328	332	343	349	350	344	334	332	334	357	342	334	329	334	354	369	368	355	349	341	397	403	362
50	327	329	329	326	271	314	329	327	321	310	309	311	338	320	311	306	311	334	355	358	342	330	314	394	403	344
40	303	307	307	308	259	309	308	308	298	287	289	294	324	295	287	285	293	319	321	355	331	314	296	396	407	319
30	258	262	260	263	264	264	263	263	256	246	258	271	308	255	250	252	270	302	306	340	321	301	279	392	407	275
20	221	224	224	224	225	225	224	225	228	227	258	283	325	223	226	251	281	323	311	338	346	319	300	395	409	235
10	169	172	172	173	174	174	173	173	187	199	268	309	332	181	197	259	309	354	318	350	359	358	358	389	411	180
5	158	160	160	161	162	162	161	161	177	197	293	359	387	170	195	285	359	387	306	341	365	386	392	396	412	166

PRESSURES Island Bend Res. El. 3920 Lake Eucumbene El. 3663

OPENING \ PIEZ.	1	2	3	7	8	9	10	11	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	REF.	DISCH. COEFF.
100%	-.775	-.811	-.789	-.767	-.674	-.670	-.648	-.696	-.938	-.969	-.357	-.278	-1.040	-.938	-.951	-.388	-.449	-1.053	-.833	-.877	-.811	-.850	-.969	-.982	+.211	1.238
90	-1.638	-.992	-.788	-.870	-.884	-.730	-.601	-.539	-1.249	-1.382	-1.119	-.495	+.543	-1.317	-1.416	-1.236	-.529	+.522	-.225	-.505	-.799	-.604	-.027	+.010	+.392	1.087
80	-.556	-.671	-.553	-.661	-.638	-.436	-.375	-.352	-.691	-.885	-.865	-.630	+.082	-.735	-.893	-.929	-.643	+.046	-.005	-.087	-.469	-.485	-.232	+.462	+.607	0.875
70	-.234	-.587	-.334	-.492	-.507	-.292	-.230	-.239	-.366	-.550	-.602	-.521	-.027	-.404	-.555	-.641	-.516	-.083	+.083	+.014	-.237	-.293	-.189	+.664	+.764	0.725
60	-.217	-.263	-.210	-.686	-.610	-.390	-.267	-.237	-.366	-.555	-.599	-.555	-.099	-.410	-.564	-.655	-.567	-.170	+.147	+.113	-.150	-.261	-.426	+.701	+.814	0.602
50	-.250	-.218	-.216	-.264	-1.078	-.438	-.214	-.244	-.332	-.496	-.520	-.480	-.088	-.354	-.492	-.560	-.490	-.154	+.156	+.206	-.034	-.210	-.440	+.730	+.872	0.491
40	-.169	-.128	-.132	-.119	-.651	-.108	-.119	-.116	-.224	-.348	-.319	-.271	+.052	-.254	-.348	-.362	-.276	-.001	+.015	+.353	+.128	+.050	-.244	+.829	+.951	0.382
30	-.122	-.097	-.100	-.089	-.080	-.083	-.085	-.086	-.141	-.213	-.121	-.031	+.238	-.149	-.181	-.167	-.039	+.197	+.224	+.473	+.333	+.187	+.032	+.848	+.961	0.277
20	-.078	-.065	-.065	-.060	-.055	-.056	-.059	-.060	-.039	-.044	+.129	+.270	+.510	-.069	-.053	+.087	+.261	+.472	+.427	+.582	+.571	+.474	+.365	+.905	+.984	0.177
10	-.048	-.034	-.036	-.033	-.028	-.028	-.032	-.032	+.032	+.083	+.378	+.555	+.740	+.005	+.073	+.340	+.555	+.749	+.593	+.733	+.770	+.769	+.767	+.901	+.997	0.085
5	-.034	-.023	-.023	-.019	-.015	-.016	-.020	-.020	+.044	+.127	+.514	+.781	+.896	+.015	+.118	+.481	+.781	+.896	+.565	+.708	+.807	+.890	+.913	+.930	+.998	0.043

PRESSURE FACTORS

B. GATE WITHOUT RESTRICTION PLATES—DOWNSTREAM TUNNEL FULL

(Approximating Eucumbene Gate)

OPENING \ PIEZ.	2	7	8	9	10	11	14	17	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	REF.
100%	-37	-40	-33	-26	-14	-5	-3	-25	-70	-79	61	193	-150	-80	-79	60	182	-138	-2	-65	-35	-57	-99	-87	202
90	-54	-65	-58	-44	-18	2	-9	89	-54	-13	-59	-4	240	-59	-93	-74	-3	242	170	102	-5	35	170	172	265
80	-17	-22	-11	-6	0	11	0	153	39	17	-79	-17	176	38	10	-94	-22	162	162	135	19	13	81	269	304
70	NO FLOW	-7	-11	-9	-3	9	9	163	43	18	-82	-51	109	42	10	-99	-56	94	157	127	42	26	67	297	331
60								200	-26	-70	-82	-56	84	-18	-51	-90	-58	68	172	156	73	42	1	310	355
50								227	-37	-69	-57	-37	86	-52	-74	-73	-39	67	171	187	103	47	-20	318	373
40		No Flow						246	-17	-40	-20	7	110	-30	-45	-35	2	94	172	213	143	88	26	324	388
30		on surfaces						277	-12	-18	24	62	156	-16	-20	10	58	140	149	240	194	144	89	332	398
20								317	-2	37	77	138	226	-8	3	64	134	215	205	254	260	221	185	329	404
10								368	1	42	178	245	321	-2	30	138	241	314	238	302	321	323	314	335	409
6								395	5	43	188	301	363	-4	38	181	298	360	231	289	337	362	367	331	410

PRESSURES—Island Bend Res. El. 3920 Downstream Tunnel Empty

OPENING \ PIEZ.	2	7	8	9	10	11	14	17	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	DISCH. COEFF.
100%	-.584	-.590	-.574	-.556	-.528	-.505	-.500	-.554	-.664	-.685	-.344	-.023	-.859	-.688	-.685	-.346	[illegible]	-.831	-.497	-.651	-.5 9	-.631	-.733	-.705	0.993
90	-.779	-.805	-.788	-.754	-.691	-.641	-.668	-.429	-.777	-.678	-.792	-.656	-.061	-.0792	-.872	-.826	-.653	-.055	-.231	-.397	-.658	-.561	-.231	-.227	0.829
80	-.83	-.795	-.768	-.756	-.742	-.715	-.742	-.370	-.647	-.699	-.933	-.783	-.312	-.649	-.718	-.970	-.796	-.346	-.346	-.412	-.696	-.709	-.544	-.085	0.709
70		-.825	-.835	-.830	-.815	-.785	-.809	-.410	-.703	-.764	-1.008	-.932	-.541	-.704	-.784	-1.048	-.943	-.578	-.424	-.498	-.704	-.743	-.644	-.083	0.607
60								-.377	-.930	-1.036	-1.065	-1.002	-.660	-.909	-.990	-1.086	-1.007	-.699	-.447	-.486	-.687	-.763	-.864	-.110	0.513
50								-.357	-1.001	-1.077	-1.049	-.993	-.701	-1.037	-1.091	-1.087	-1.005	-.747	-.492	-.454	-.658	-.796	-.959	-.135	0.423
40		No Flow						-.346	-.987	-1.045	-.995	-.930	-.678	-1.020	-1.057	-1.032	-.941	-.716	-.527	-.428	-.597	-.733	-.883	-.156	0.340
30		on surfaces						-.295	-1.000	-1.014	-.913	-.819	-.590	-1.011	-1.022	-.946	-.829	-.630	-.607	-.386	-.497	-.620	-.755	-.161	0.258
20								-.213	-.991	-.896	-.797	-.648	-.435	-1.005	-.978	-.829	-.659	-.462	-.485	-.367	-.351	-.447	-.534	-.184	0.170
10								-.101	-.995	-.894	-.563	-.400	-.215	-1.003	-.925	-.661	-.409	-.232	-.416	-.261	-.214	-.209	-.233	-.179	0.086
6								-.036	-.988	-.896	-.565	-.266	-.115	-1.009	-.908	-.559	-.272	-.123	-.436	-.296	-.177	-.117	-.106	-.192	0.052

PRESSURE FACTORS

C. GATE WITHOUT RESTRICTION PLATES—FREE DISCHARGE

(Approximating Eucumbene Gate)

SUBMERGED DISCHARGE

Pressure Factor $= \frac{h_x - h_2}{H_T - h_2}$

where h_x = head at piezometer, h_2 = head in downstream conduit, and H_T = total head at reference station ahead of gate $(h_o + h_v)$

$$C_d = \frac{Q}{A\sqrt{2g\,(H_T - h_2)}}$$

A = area of gate body – 9'-0" x 16'-0"

FREE DISCHARGE

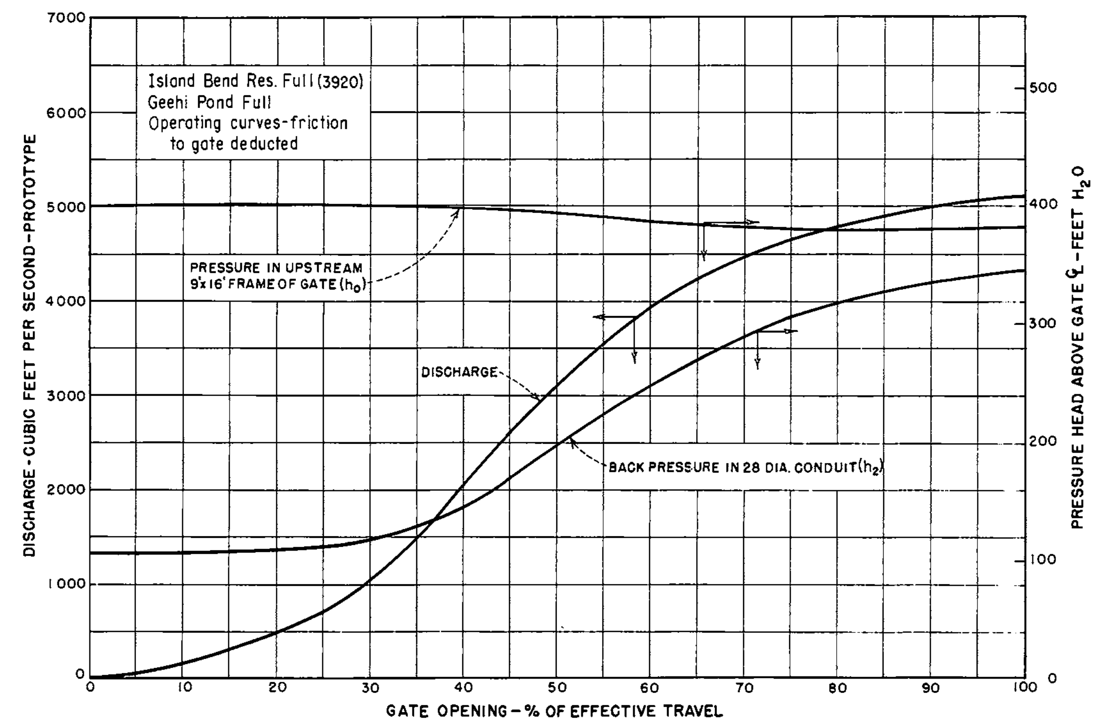
Pressure Factor $= \frac{h_x - h_o}{h_o + h_v}$

where h_x = head at piezometer, h_o = head at the reference station upstream from the gate, and h_v = velocity head at the reference station

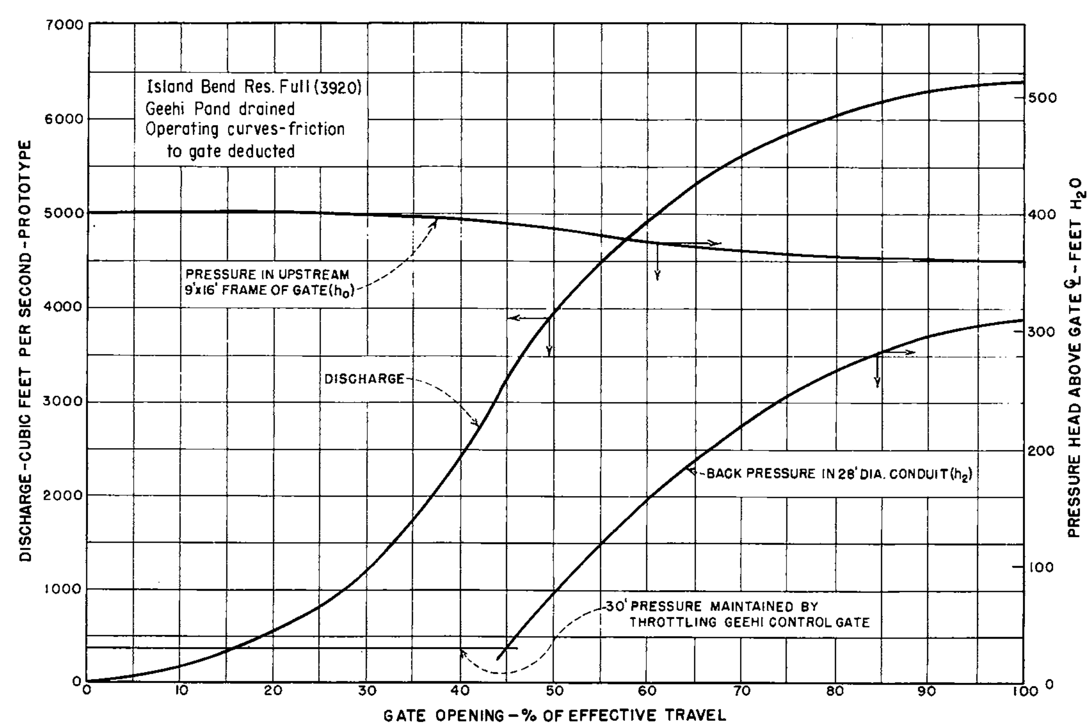
$$C_d = \frac{Q}{A\sqrt{2g\,(h_o + h_v)}}$$

Computed pressures lower than about –30 feet, gage, are fictitious because no pressures lower than absolute zero can be obtained. In practice, cavitation will occur at –30 feet, and lower computed pressures indicate the cavitation severity.

ISLAND BEND CONTROL GATE
AVERAGE PRESSURES AND PRESSURE FACTORS
1:24 SCALE HYDRAULIC MODEL



A. ISLAND BEND RESERVOIR FULL-GEEHI POND FULL



B. ISLAND BEND RESERVOIR FULL-GEEHI POND EMPTY

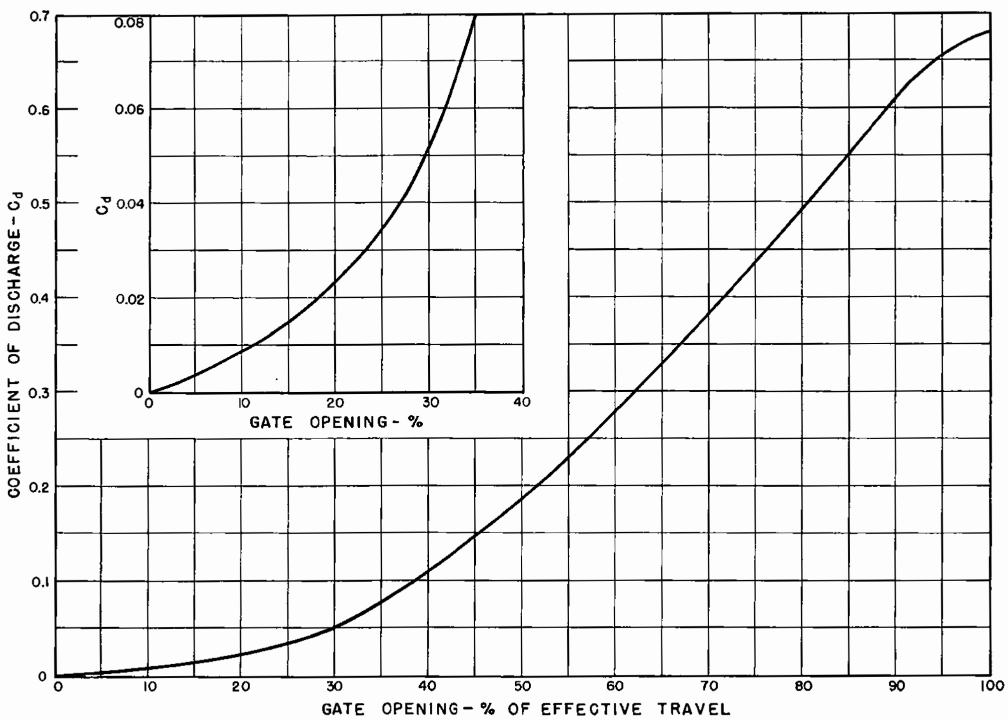
Note: Discharge from 1:24 scale hydraulic model

ISLAND BEND CONTROL GATE

HEAD, DISCHARGE, AND BACK PRESSURE AT CONTROL GATE

RECOMMENDED DESIGN

613



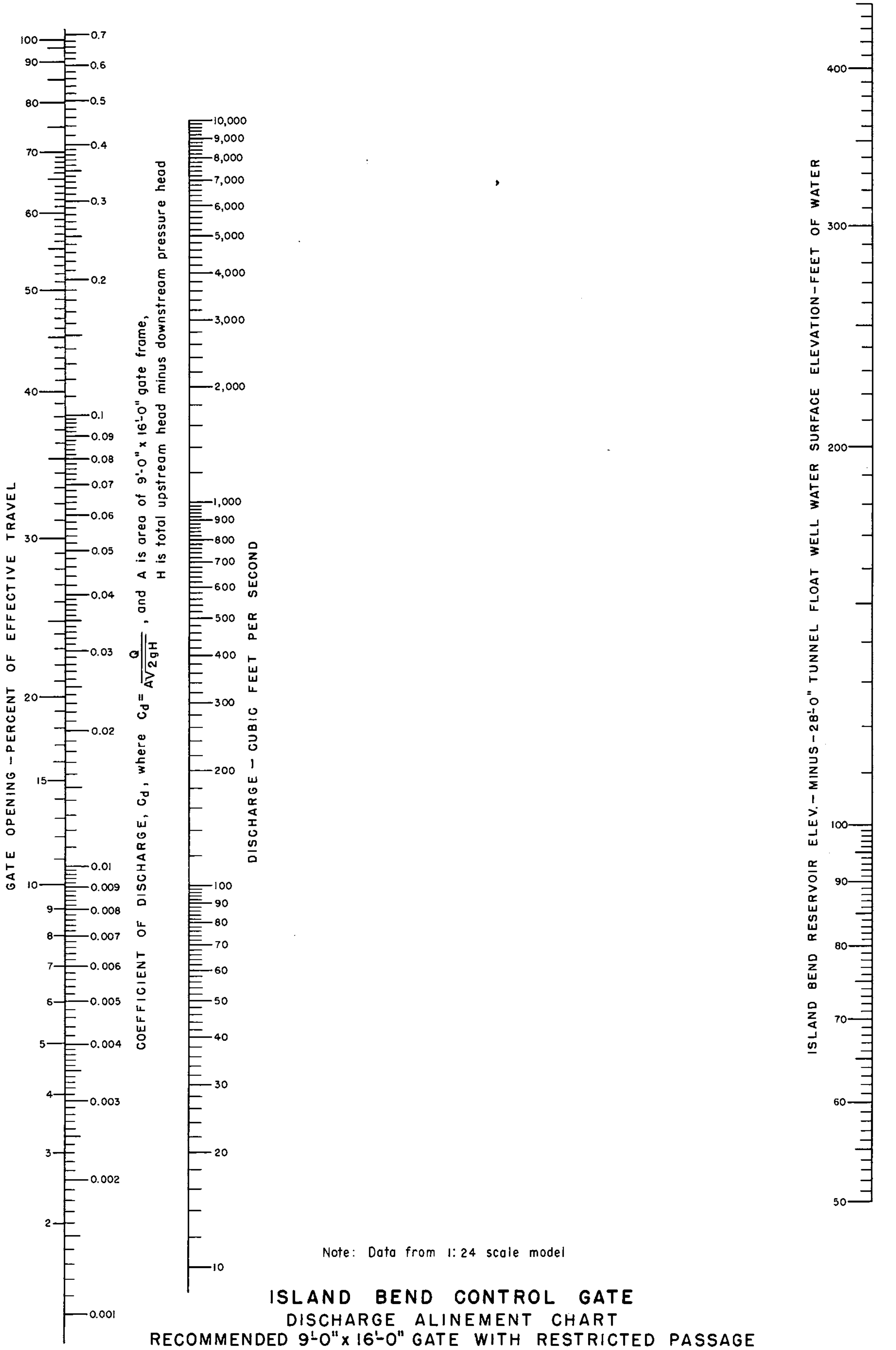
$$C_d = \frac{Q}{A\sqrt{2gH}}$$

Where Q = discharge, cfs
A = area of gate body passage, just upstream from leaf (8'-0" x 16'-0" prototype)
H = $h_o + h_v - h_2$
h_o = head at reference station in circular conduit 1 diameter upstream from transition to gate
h_v = velocity head at reference station
h_2 = head in enlarged tunnel 100' downstream from leaf (prototype)

Note: Data from 1:24 scale hydraulic model

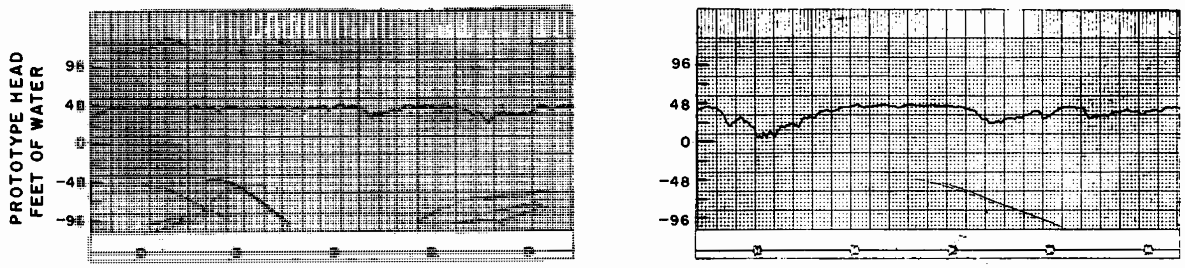
ISLAND BEND CONTROL GATE
COEFFICIENT OF DISCHARGE VS GATE OPENING
RECOMMENDED DESIGN

613

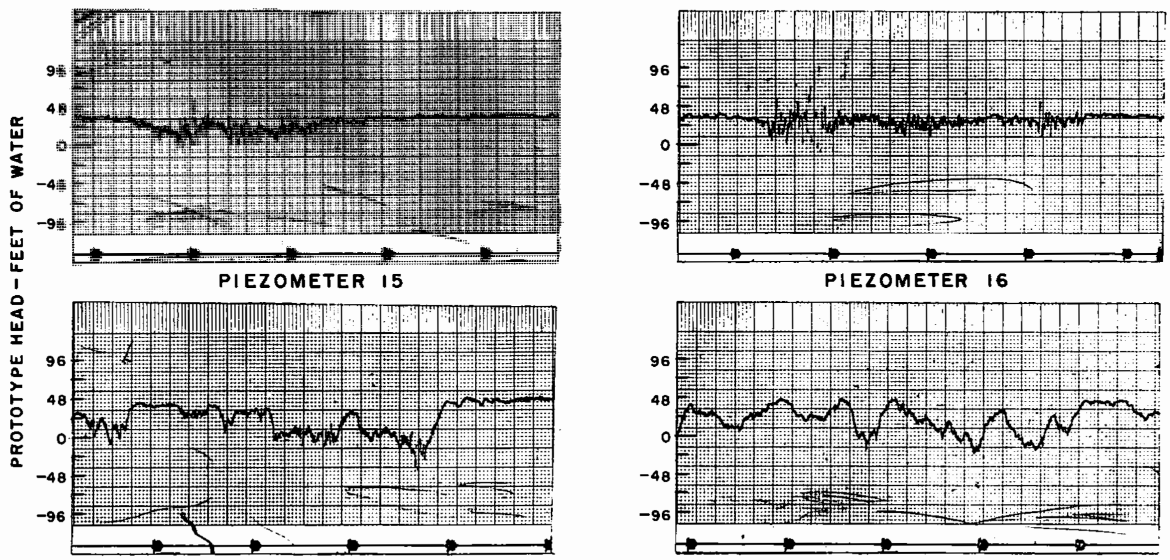


ISLAND BEND CONTROL GATE
DISCHARGE ALINEMENT CHART
RECOMMENDED 9'-0" x 16'-0" GATE WITH RESTRICTED PASSAGE
1:19.2 SCALE, AIR MODEL

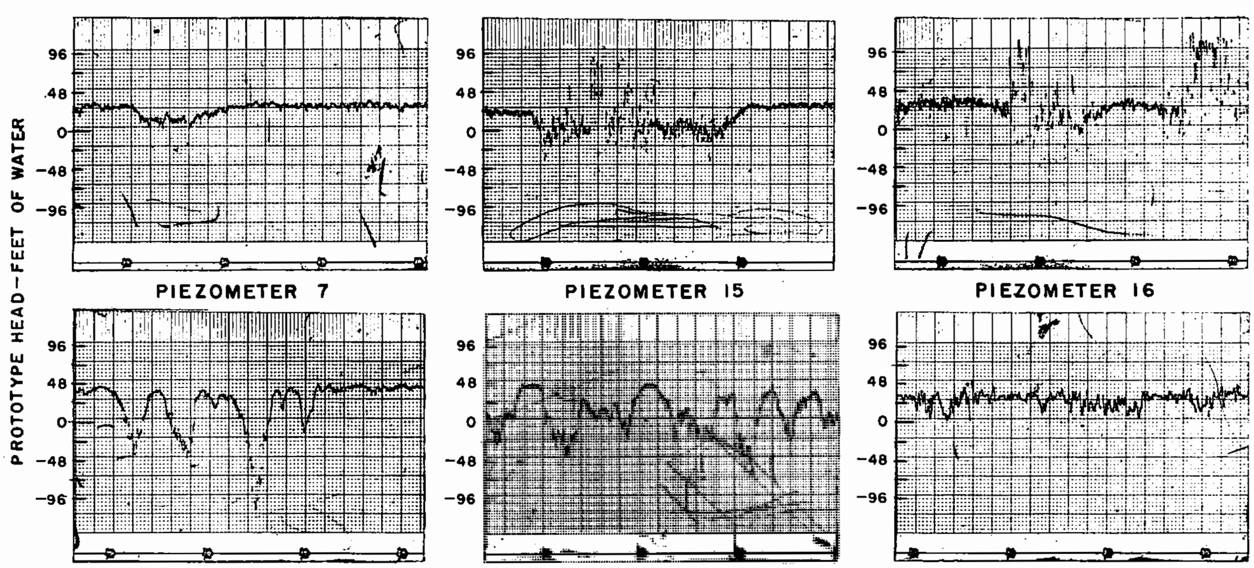
613



A. 20% GATE OPENING



B. 30% GATE OPENING



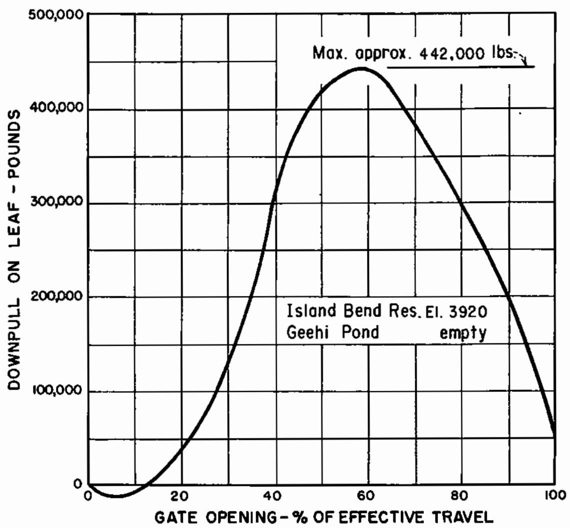
C. 40% GATE OPENING

Note: Heads are for full Island Bend Reservoir, 30-foot back pressure.

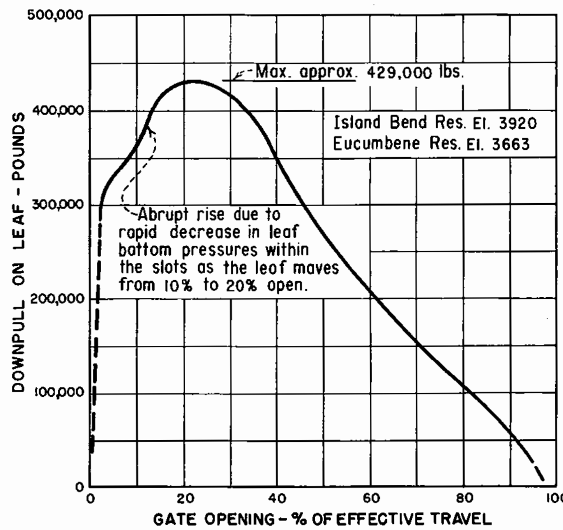
ISLAND BEND CONTROL GATE
PRESSURE CELL RECORDS OF MOST NEGATIVE AND MOST FLUCTUATING PRESSURES-RECOMMENDED DESIGN

ISLAND BEND FULL AND GEEHI EMPTY

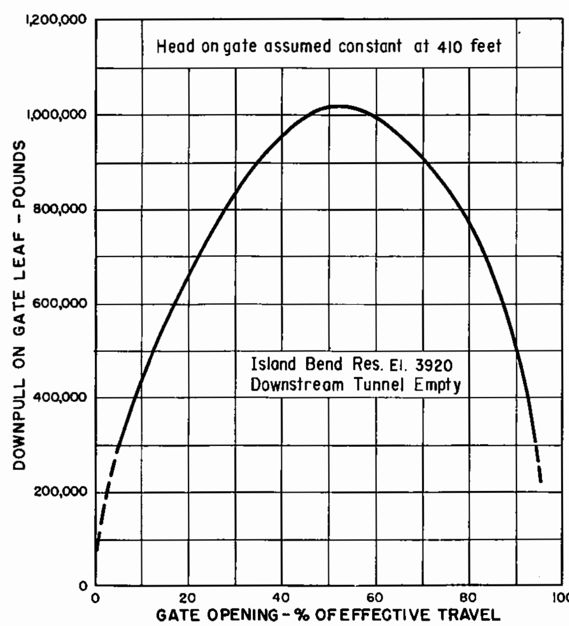
1:24 SCALE HYDRAULIC MODEL



A. ISLAND BEND GATE
Flow to Geehi



B. EUCUMBENE GATE - SUBMERGED
Flow to Eucumbene



C. EUCUMBENE GATE - FREE DISCHARGE
Flow to Eucumbene

Note: Computations based on pressure data from 1:24 scale hydraulic model

ISLAND BEND AND EUCUMBENE CONTROL GATES
HYDRAULIC DOWNPULL FORCES ON THE GATE LEAF
RECOMMENDED DESIGN

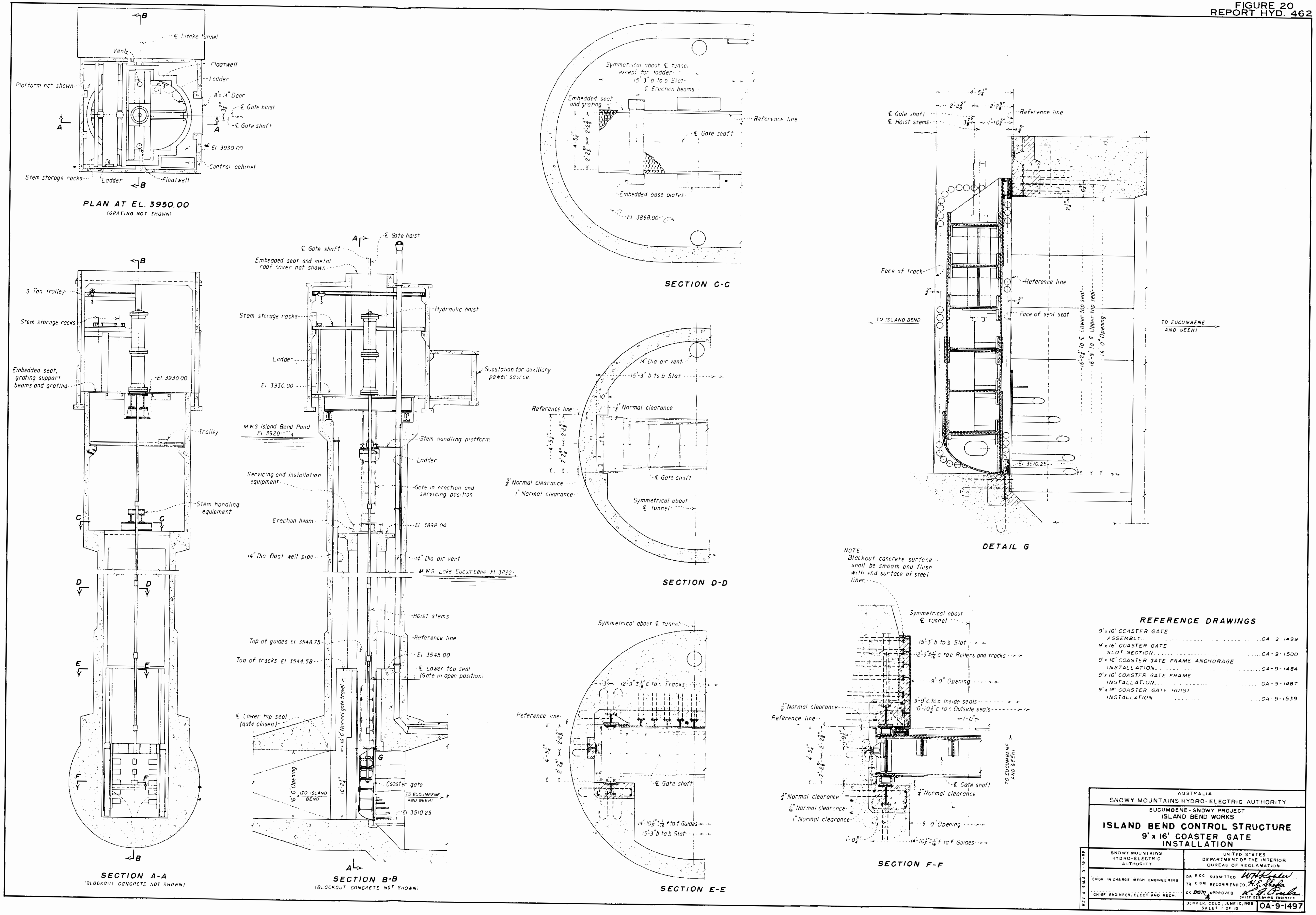
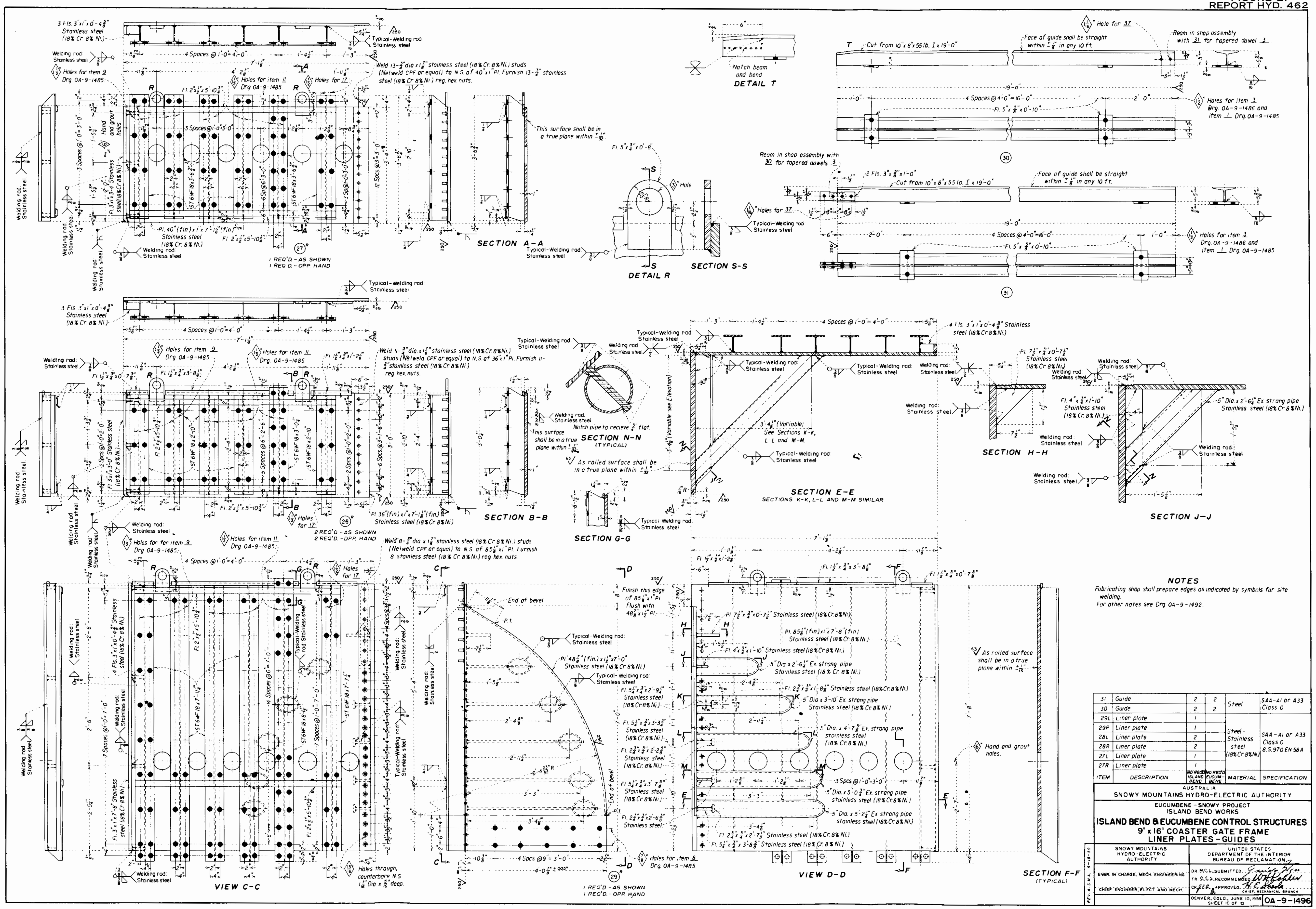

PLAN AT EL. 3950.00
(GRATING NOT SHOWN)
SECTION A-A
(BLOCKOUT CONCRETE NOT SHOWN)
SECTION B-B
(BLOCKOUT CONCRETE NOT SHOWN)
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
DETAIL G
NOTE:
Blockout concrete surface shall be smooth and flush with end surface of steel liner.
TO ISLAND BEND
TO EUCUMBENE AND GEEHI
REFERENCE DRAWINGS
9'x16' COASTER GATE ASSEMBLY OA-9-1499
9'x16' COASTER GATE SLOT SECTION OA-9-1500
9'x16' COASTER GATE FRAME ANCHORAGE INSTALLATION OA-9-1484
9'x16' COASTER GATE FRAME INSTALLATION OA-9-1487
9'x16' COASTER GATE HOIST INSTALLATION OA-9-1539
AUSTRALIA
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
EUCUMBENE-SNOWY PROJECT
ISLAND BEND WORKS
ISLAND BEND CONTROL STRUCTURE
9' x 16' COASTER GATE
INSTALLATION
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER, COLO., JUNE 10, 1959
SHEET 1 OF 12
OA-9-1497

FIGURE 21
REPORT HYD. 462



NOTES

Fabricating shop shall prepare edges as indicated by symbols for site welding.
For other notes see Drg. OA-9-1492.

ITEM	DESCRIPTION	NO REQ'D ISLAND BEND	NO REQ'D EUCUMBENE	MATERIAL	SPECIFICATION
31	Guide	2	2	Steel	SAA-A1 or A33 Class 0
30	Guide	2	2		
29L	Liner plate	1		Steel - Stainless steel (18% Cr. 8% Ni.)	SAA-A1 or A33 Class 0 B.S. 970 EN 58A
29R	Liner plate	1			
28L	Liner plate	2			
28R	Liner plate	2			
27L	Liner plate	1			
27R	Liner plate	1			

AUSTRALIA
SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY

EUCUMBENE - SNOWY PROJECT
ISLAND BEND WORKS

ISLAND BEND & EUCUMBENE CONTROL STRUCTURES
9' x 16' COASTER GATE FRAME
LINER PLATES - GUIDES

SNOWY MOUNTAINS HYDRO-ELECTRIC AUTHORITY	UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
ENGR. IN CHARGE, MECH. ENGINEERING	DR. M.C.L. SUBMITTED [signature]
	TR. C.E.S. RECOMMENDED W.H. Kohler
CHIEF ENGINEER, ELECT. AND MECH.	CK. J.E.R. APPROVED H.E. Shade CHIEF, MECHANICAL BRANCH
	DENVER, COLO., JUNE 10, 1959 SHEET 10 OF 10 — OA-9-1496

REV. A. S.M.A. 9-15-59