UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF BLUE MESA DAM SPILLWAY, COLORADO RIVER STORAGE PROJECT, COLORADO

Report No. Hyd-515

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

July 8, 1964

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ABSTRACT

Model studies were conducted to develop the hydraulic design of the approach channel, gate structure, tunnel transition, steeply inclined tunnel, vertical bend, nearly horizontal tunnel, flip bucket, and the downstream river channel improvement. Reshaping of the approach channel improved the flow pattern through the spillway approach, gate structure, tunnel transition, and inclined tunnel. Less air entrainment and better ventilation of the tunnel was provided by reducing the width and length of the center pier in the tunnel transition which diminished the magnitude of the fin of water through the inclined tunnel. Converging the right wall of the flip bucket 3° deflected the jet away from the excavated right bank of the downstream channel. The angle between the bucket tangent and the downward sloping face of the bucket lip was increased to eliminate severe subatmospheric pressures in this area. A tailwater control structure operated successfully in maintaining adequate tailwater depths in the powerplant tailrace and outlet works stilling basin.

DESCRIPTORS--*Spillways/ spillway crests/ tunnels/ bends/ *flip buckets/ piers/ radial gates/ discharge coefficients/ roughness coefficients/ *hydraulic models/ piezometers/ transducers/ stream flow/ tailrace/ powerplants/ outlet works/ diversion tunnels/ channel improvements/

IDENTIFIERS--Tailwater control structure/ *approach channels/ subatmospheric pressures/ gate structure/ *tunnel transitions/

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Report No. Hyd-515
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PURPOSE

The studies were conducted to develop the hydraulic design of the spillway approach channel, the gate structure, the tunnel transition section, the steeply inclined tunnel, the vertical bend, the nearly horizontal tunnel, the flip bucket, and stream channel improvement.

CONCLUSIONS

1. The general concept of the preliminary design was satisfactory.

2. The capacity of the spillway was determined to be about 33,400 cubic feet per second (cfs) at maximum reservoir water surface elevation 7519.4, Figure 20. A minimum gate opening of 22 feet above crest elevation was required to clear the water surface at the maximum flow.

3. The approach channel was reshaped to improve the flow pattern through the spillway approach, gate structure, tunnel transition, and steeply inclined tunnel. Compare Figures 8 and 9 with 11 and 12.

4. The roof of the transition section was raised at the outside corners to prevent a fluctuating ridge of water from striking the entrance portal section, and the center pier was modified to reduce a fin of water that extended downstream through the steeply inclined tunnel.

5. The spillway gates should be operated symmetrically to maintain good flow distribution throughout the tunnel and flip bucket.

6. The lip of the flip bucket was modified to prevent severe subatmospheric pressures along the bucket lip. The right wall of the bucket was converged inward 3° to deflect the jet away from the excavated right bank of the stream channel.

7. The tailwater control structure, Figure 3, downstream from the powerplant and outlet works, was found necessary and satisfactory as designed.

8. Motion pictures of the flow through the model structure are available in the Hydraulics Branch.

ACKNOWLEDGMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the Spillway and Outlet Works Section and the Hydraulics Branch during the period September 1961 through August 1962. Photography by W. M. Batts, Office Services Branch.

INTRODUCTION

Blue Mesa Dam, a part of the Curecanti Unit of the Gunnison Division of the Colorado River Storage Project, is located in mountainous country on the Gunnison River about 25 miles west of Gunnison, Colorado, Figure 1. The purpose of the unit is primarily to develop the water storage and hydroelectric power generating potential along a 40-mile section of the Gunnison River above Black Canyon of the Gunnison National Monument. Other purposes of the unit are irrigation, recreation, and flood control.

The dam, Figure 2, is an earthfill structure approximately 800 feet long at the crest and approximately 340 feet high above the riverbed. It will impound a reservoir 19 miles long with a storage capacity of 940,800 acre-feet. A 60,000-kilovolt powerplant is located at the toe of the dam.

The spillway, Figures 3 and 4, located in the right abutment, has a capacity of about 33,400 cfs at maximum reservoir water surface elevation 7519.4. It discharges through a gate section, tunnel transition section, tapering inclined tunnel, vertical bend, nearly horizontal tunnel, and a flip bucket.

Two 25.0- by 33.5-foot radial gates control the flow. The flip bucket directs the flow into the river channel approximately 500 feet downstream from the powerplant.

During construction of the dam, the nearly horizontal portion of the tunnel and the flip bucket are used for diversion flows, Figure 4.

The outlet works is approximately 300 feet upstream from the flip bucket and adjacent to the left side of the powerplant, Figure 3. The outlet works consists of two 84-inch hollow-jet valves discharging into a stilling basin and has a capacity of 5,400 cfs at maximum reservoir water surface elevation 7519.4 with powerplant not operating. The powerplant will discharge about 3,080 cfs at rated head of 280 feet.

A tailwater control structure, Figure 3, extends across the river channel downstream from the powerplant and outlet works, and upstream from the spillway flip bucket. It is designed to maintain a minimum tailwater elevation in the powerplant tailrace and in the outlet works stilling basin.

Approximately 3,300 feet of the stream channel downstream from the powerplant will be improved, Figures 3 and 5. The first 1,800 feet will be stripped to bedrock and the remainder excavated to a trapezoidal shape. The anticipated tailwater elevation at river Station 45+00, approximately 1,000 feet downstream from the flip bucket, is shown in Figure 6 for the existing and the improved channels. The tailwater curve for the existing channel applies only to the diversion flows since the river channel will be improved prior to operation of the completed spillway.

Dimensions of the hydraulic features are listed in Table 1 for both English and metric units. A Hydraulic Conversion Table is located on the inside back cover of this report for conversion of dimensions in English units to metric units.

THE MODEL

Scope

The model, Figure 7, was a 1:32.78 scale reproduction of the spillway, including the immediate reservoir area surrounding the approach channel, the tunnel, and a reach of river channel extending approximately 1,400 feet downstream from the powerplant. Flows from the outlet works stilling basin and powerplant were also represented in the model.

Scaled head losses due to friction in the model are usually greater than prototype losses because model surfaces sufficiently smooth to represent prototype roughnesses are difficult to obtain. Therefore, to obtain the proper scale velocity of the flow through the flip bucket, the water supply was pumped directly to the nearly horizontal tunnel downstream from the vertical bend, bypassing the reservoir and steeply inclined tunnel during the development of the flip bucket. This procedure also made it possible to study the flip bucket for diversion flows and for spillway flows while the reservoir head box and inclined tunnel were under construction. The flow depth and velocity of the flow at the outlet portal of the tunnel were controlled by means of a slide gate installed 400 prototype feet upstream from the portal, Figure 7.

Reservoir

The reservoir area was contained in an 11- by 14-foot head box which allowed reproduction of the topography along the right bank of the reservoir for approximately 300 feet upstream from the spillway crest and about 200 feet to the right and left of the spillway centerline, Figure 7. The topography was reproduced from elevation 7397 up to the dam crest at elevation 7528. Topography in the reservoir area was molded of concrete mortar placed on expanded metal lath which had been nailed over wooden templates shaped to the ground surface contours. The surface was given a rough finish to simulate the natural topography of the prototype. Excavated surfaces were given a smoother finish. A 6-inch-wide rock baffle was installed along the left and upstream sides of the box to quiet the flow as it entered the reservoir area.

The reservoir water surface elevation was measured by means of a hook gage mounted in a well attached to the side of the head box and connected to a piezometer tap located in the floor upstream and to the left of the outlet works intake tower where the velocity of approach was negligible.

Gate Structure

The spillway crest was modeled in concrete screeded to sheet metal templates. The sidewalls, center pier, and radial gates of the gate structure were constructed of No. 16-gage sheet metal. Piezometers were installed in the spillway crest and consisted of 1/16-inch-inside-diameter brass tubes soldered normal to the profile shape and filed flush.

Tunnel

The spillway tunnel between the intake structure and the flip bucket, Figure 7, was constructed of transparent plastic. The portion of the center pier that extended into the tunnel transition section was fabricated in sugar pine. Plastic piezometers having a 1/16-inch-inside diameter were installed in the transition section and along the invert of the tunnel. The constant diameter tunnel downstream from the vertical bend was made from 7-11/16-inch-inside-diameter extruded plastic pipe. The inside diameter of this pipe represented the 21-foot diameter prototype tunnel.

Flip Bucket

The flip bucket at the downstream end of the tunnel, Figure 7, was molded in concrete. Piezometers made from 1/16-inch-inside-diameter brass tubing were installed along the bucket invert, end sill, and in the right wall.

Powerplant and Outlet Works

The exterior walls and floor of the powerplant tailrace and outlet works stilling basin were represented in the model and were constructed of wood, Figure 7. The quantity and velocity of the flow from the powerplant and outlet works were represented. The tailwater control weirs downstream from the powerplant and outlet works were constructed of concrete and accurately represented in the model.

River Channel

The river channel was molded of concrete in the same manner as the reservoir area. Tailwater staff gages were installed in the powerplant tailrace and outlet works stilling basin upstream and downstream of the tailwater control structure, and at river Station 45+00, about 1,300 feet downstream from the powerplant, near the model tailwater control gate, Figure 7.

Water Supply

Water was supplied to the model spillway from the laboratory permanent supply system. For preliminary studies of the flip bucket, the water supply was pumped directly to the nearly horizontal tunnel downstream from the vertical bend. The depth and velocity of flow at the exit portal of the tunnel were controlled by means of a slide gage installed 12 feet 1-1/4 inches upstream from the portal, Figure 7.

Water was supplied to the powerplant and outlet works from a separate portable pump through an 8-inch supply line equipped with an orifice-venturi meter. Slide gates at the baffle through which the powerplant and outlet works water supply passed were used to control the proper division of the flow between the powerplant and outlet works.

THE INVESTIGATION

The investigation was concerned with flow conditions in the spillway approach channel, the gate structure, the tunnel transition section, the steeply inclined tunnel, the vertical bend, the nearly horizontal tunnel, and the flip bucket. The investigation was also concerned with flow conditions in the river channel when the powerplant, outlet works, or spillway, were discharging in any combination. The spillway was designed for a theoretically computed maximum discharge of 33, 700 cfs at maximum reservoir water surface elevation 7519.4. The outlet works was initially designed for a maximum discharge of 5, 100 cfs and the powerplant for a discharge of 3, 080 cfs at rated head of 280 feet. Although the model was tested for simultaneous operation of the powerplant and outlet works at 3, 080 and 5, 100 cfs, respectively, the actual combined flow is not expected to exceed 6, 030 cfs.

Preliminary Observations

Flow characteristics in the approach channel. --Flow in the preliminary spillway approach channel was satisfactory; however, some water surface disturbances occurred at both right and left banks, Figures 8 and 9. Flow around the upstream end of the cut in the right bank caused a large slow eddy and some water surface roughness along the bank. Flow from along the left bank moved toward the center pier while flow currents from deep in the reservoir boiled to the surface along the left bank line and approach wingwall, Figure 9.

Flow characteristics in the gate structure. --Flow entering and passing through the gate structure, Figure 9, was satisfactory. However, for the design flow of 33. 700 cfs, a ridge of water formed along the left wall, Figure 9C, and intermittently struck the roof corner at the tunnel portal.

Flow characteristics in the transition and inclined tunnel. --Flow in the transition section and steeply inclined tunnel was steady and fairly uniform in cross section. However, the steeply inclined tunnel appeared to be too small for the computed maximum flow. The depth of flow was approximately 0. 8 of the tunnel diameter; however, a fin of water formed downstream from the pier and crowded the tunnel crown, Figure 10. The flow from the two bays came together downstream from the center pier and formed the fin that extended into the vertical bend. An air pocket, open at the top, formed between the downstream end of the pier and the beginning of the fin. It was feared that the fin would contribute to the crowded condition by entraining a large amount of air in the prototype flow which would hinder the normal passage of air required for proper ventilation and thus cause unsteady flow condition to exist in the tunnel. This condition was difficult to fully evaluate since air entrainment is not represented to scale in the model. The problem did not exist for flows below 75 percent of maximum since the depth of flow was less than two-thirds of the tunnel diameter and the top of the fin did not impinge upon the crown of the tunnel.

Flow characteristics in the vertical bend and horizontal tunnel.--Flow in the vertical bend and nearly horizontal tunnel was steady and uniformly distributed in cross section. Very little dishing of the water surface occurred downstream from the bend when both gates in the gate structure were open an equal amount. Flow in the bend was very much as expected based on previous model-tested bend designs summarized in Report No. Hyd-498.1/ With single-gate operation, flow spun over the crown of the tunnel bend and oscillated from side to side throughout the nearly horizontal tunnel.

Discharge capacity.--The model discharge capacity was determined to be approximately 33,000 cfs at maximum reservoir water surface elevation 7519.4, or 700 cfs less than the computed maximum. The computed maximum flow of 33,700 cfs was discharged at reservoir elevation 7519.8.

Modifications

Several approach schemes and pier modifications were tested to try to eliminate the disturbances in the approach, to lower the flow along the outside walls of the gate structure, to reduce the fin, and to increase the discharge at maximum reservoir water surface elevation.

The left wingwall of the gate structure was first modified by extending it outward into the reservoir on a 45° angle. In addition, the downstream end of the center pier was widened to 5 feet to reduce the angle at which the flow from the two bays merged. Neither alteration improved the flow conditions. The center fin began farther downstream but was not reduced and turbulence still occurred along the approach wingwall.

The approach wingwalls were further modified by extending both left and right walls 30 feet straight upstream into the reservoir. This modification raised the water surface along the walls of the transition section and reduced the height of the center fin so that it did not impinge upon the crown of the tunnel for any flow. However, this modification raised the reservoir water surface elevation for the computed maximum discharge by 1-1/2 feet. To lower the reservoir water surface elevation the upstream ends of the wingwalls were rounded by the addition of a 90° segment of a circle. However, the reservoir water surface was still about 1 foot above the elevation for the preliminary design and therefore was not tolerable. Lowering the approach floor had very little effect on the flow characteristics in the tunnel.

Additional excavation to the left and right banks of the approach channel improved the flow characteristics in the approach area

1/Hyd-498 "Hydraulic Model Studies of Whiskeytown Dam Spillway," by G. L. Beichley.

considerably and offered some improvement to flow conditions in the gate structure and tunnel. Also, several lengths, thicknesses, and heights of center piers were tested with varying degrees of success in reducing the magnitude of the center fin.

Operation of the Recommended Structure

Flow characteristics in the approach.--Rounding the upstream corner of the right bank and flaring the corner of the left bank, Figure 3, provided smooth water surface flow lines in the approach. Originally, it was determined that the left approach wingwall should curve 90° outward from the gate structure and then continue on a tangent line to the left bank topography, similar to the right approach wingwall. During prototype construction, it was found that the wall would rest on a sounder foundation if the wall continued to curve 180° as shown in Figure 3. The model tests showed that ideal flow conditions would prevail with these modifications, Figures 11 and 12.

Flow characteristics in the gate structure.--The recommended approach modifications lowered the average water surface a few inches along the walls of the gate structure; however, the roof of the tunnel portal at both left and right corners was raised approximately 1 foot to be certain of clearing the fluctuating ridge of water that formed at maximum discharge. It was also recommended that the gates be operated symmetrically to provide uniform distribution of the flow through the tunnel and flip bucket.

Flow characteristics in the transition and inclined tunnel.--The recommended approach provided some improvement in flow conditions through the transition and steeply inclined tunnel; however, additional improvement was made by tapering the pier to a thickness of 18 inches rather than 24 inches at the downstream end, and by reducing the length along the invert from 53 to 41 feet, Figure 13. The extent of shortening and thinning of the center pier was limited since the pier was needed for structural support of the tunnel roof near the tunnel entrance portal.

This modification reduced the size of the air pocket and provided more flow area through the transition. The water surface along the outside walls of the transition was lowered, Figure 14. The fin of water was reduced in size and was better centered in the inclined tunnel. Flow through the tunnel, Figure 15, was uniformly distributed in cross section and steady for all flows. This assured an adequate air supply through the tunnel from the gate section to the flip bucket.

Flow characteristics through the vertical bend and horizontal tunnel.--Flow in the vertical bend and nearly horizontal tunnel was excellent, Figure 16. The flow was steady and uniformly distributed in cross section. Very little dishing of the water surface occurred during symmetrical operation of the gates. With single-gate operation the flow spun over the crown of the tunnel in the bend and oscillated from side to side in the nearly horizontal tunnel.

Pressures.--Pressures on the crest profile along the centerline of the right bay were recorded for 33,700 and 16,800 cfs, Figure 17. All observed crest pressures for both flows were above atmospheric. Pressures recorded in the transition for these flows, Figure 18, showed one area on the tunnel wall near the downstream end of the transition to be subjected to subatmospheric pressures. However, these pressures did not exceed 5 feet of water below atmospheric. Pressures on the sides of the steeply inclined tunnel and vertical bend were above atmospheric for 33,700 cfs, and for 16,800 cfs the pressures were near atmospheric since the water surface was approximately at the level of the piezometers, Figure 19. Pressures along the invert of the steeply inclined tunnel and vertical bend were not measured since previous studies had shown that these pressures would be above atmospheric.

Discharge capacity.--Installation of the recommended approach to the gate structure increased the discharge capacity from 33,000 cfs to about 33,400 cfs at maximum reservoir water surface elevation 7519.4. A complete range of uncontrolled and gate controlled flows was calibrated, Figure 20.

It was determined that the radial gates should be capable of opening a minimum of 22 feet above crest elevation to clear the water surface for 33,400 cfs discharge.

Preliminary Flip Bucket

Test procedures.--The flip bucket investigations were made with the water supply pumped directly to the nearly horizontal portion of the tunnel. A slide gate installed about 400 feet upstream from the flip bucket controlled the depth of flow in accordance with the computed depths plotted in Figure 21.

Pressures.--Pressures along the invert of the bucket, Figure 22, were similar to those determined in other studies.2/ The pressures were above atmospheric, except at the bucket lip where the pressures were sometimes slightly subatmospheric on both the upstream and downstream sides of the lip. The subatmospheric pressures at the bucket lip were lower at a point 45° above the invert than at the invert. This is due to the smaller change in slope between the tangent and the downward slope of the lip at this point

2/ Paper No. 3236, ASCE Transactions, Volume 126, Part I, 1961, page 1270, "Improved Tunnel Flip Buckets" by T. J. Rhone and A. J. Peterka.

than at the invert. At the invert, the change in slope is 45° and diminishes to 0° at the sidewalls of the bucket. A minimum change in slope of 32° has been recommended at other structures.2/

When the tailwater beneath the jet was high enough to contact the underside of the jet, the pressures along the lip fluctuated, Figure 23. Those pressures along the lip at 45° from the invert, fluctuated severely below atmospheric, as illustrated by Piezometers 9 and 10 in Figure 23.

Flow characteristics in the flip bucket and stream channel.--Preliminary tests showed that the flip bucket jet spread and impinged upon the excavated right bank of the stream channel, Figure 24. At the smaller discharges, a large eddy formed along the left bank when the spillway only was operating. Flow from the powerplant and outlet works eliminated the eddy. The spillway flows were concentrated near the right bank for all flow conditions.

For spillway flows less than 1/2-computed maximum discharge, with the powerplant and outlet works discharging, the flip bucket jet did not depress the water surface downstream from the powerplant tailrace and outlet works stilling basin sufficiently to warrant the need for the tailwater control structure. However, for spillway flows of approximately 1/2-computed maximum flow or larger, the jet sufficiently lowered the water surface in the tailrace and stilling basin that the need for the tailwater control structure was apparent.

Recommended Flip Bucket

Description.--The full length of the right training wall of the flip bucket, Figure 25, was turned inward 3° to deflect the flow away from the excavated right bank and to provide better flow distribution across the channel downstream from the jet. The deflection angle of the bucket invert was increased about 2° to raise the invert of the bucket lip 1.21 feet. The high point of the bucket lip was in a vertical plane across the width of the bucket rather than in a plane normal to the bucket invert. This makes a steep change in slope between the tangent and the downward slope of the bucket lip across the full width of the bucket.

Pressures.--Pressures recorded at the piezometer locations shown in Figure 26 are plotted in Figures 27, 28, and 29. Those pressures along the invert and 45° to the left of the invert were near atmospheric or above, Figure 27. At Piezometers 10, 11, and 12 near the bucket lip the pressures were approximately atmospheric.

2/ Paper No. 3236, ASCE Transactions, Volume 126, Part I, 1961, page 1270, "Improved Tunnel Flip Buckets" by T. J. Rhone and A. J. Peterka.

Pressures on and near the base of the right wall were above atmospheric except near the downstream end of the wall, Figure 28. Pressures near the downstream end of the right wall were slightly below atmospheric. The lowest pressure measured by water manometer was about 5 feet of water below atmospheric at Piezometer 16. Instantaneous minimum pressure reached 7 feet below atmospheric at Piezometer 16, Figure 28.

All pressures shown in Figures 27 and 28 were recorded when the flow velocity in the tunnel was controlled by the slide gate. For comparison the flip bucket pressures were again recorded for 33,700 cfs with the tunnel connected to the model reservoir. The agreement was very good, Figure 29. At Piezometer 1 in the invert of the tunnel the pressure obtained by free flow from the reservoir was higher indicating that the free-flow velocity was less than the gate-controlled velocity. In the bucket the impact pressures for free flow were lower than those obtained by gate-control flow. The slide gate-controlled flows provide the more representative results.

Flow characteristics in the flip bucket.--After completion of the reservoir portion of the model, the water to the flip bucket was supplied from the reservoir through the spillway intake. It was noted that the flow distribution in the stream channel could be changed by manipulation of the spillway gates. Operation at unequal gate openings at small discharges produced an unsymmetrical flow through the tunnel that was reflected in the flip bucket jet, Figure 30. The jets for the larger flows were not affected since both gates were fully open or nearly fully open to pass the discharge. For best flow distribution at all discharges, both gates should be opened approximately the same amount.

The recommended bucket with the right wall deflected inward and the higher lip elevation offered more resistance to the spillway flows than did the preliminary bucket. When the flow of 33,400 cfs was exceeded by 1,400 cfs, the exit portal filled, causing the entire nearly horizontal portion of the tunnel to gradually fill as the air was evacuated from that portion of the tunnel. Increasing the flow to 36,800 cfs caused the steeply inclined portion of the tunnel to fill to the transition section. In view of the fact that the model tunnel roughness was proportionately greater than the roughness in the prototype, there is a sufficient safety factor against filling of the prototype tunnel at maximum design flow.

The recommended bucket, with the right wall converged inward 3°, deflected the jet away from the excavated right bank. This was an improvement over the preliminary design. (Compare Figures 31 and 32 with Figure 24.) Dimensions of the jet are recorded in Figure 33. These dimensions were obtained when the flow was controlled by the slide gate.

Flow characteristics in the stream channel.--To conform with the most recent information from the prototype site the model streambed in the vicinity of the jet impact area was lowered and the left bank moved to the right, Figure 34A. This revision improved the flow distribution in the channel by reducing the area for the return eddy flow.

Flow characteristics in the stream channel for various combinations of spillway, powerplant, and outlet works flows are shown in Figures 34 through 39. These flow combinations shown are for the tailwater elevation in the improved channel, Figure 6. Photographs of other flow and tailwater combinations are on file in the Hydraulic Laboratory. The smaller spillway flows still moved downstream along the right bank, without spreading to the full channel width, especially when the powerplant and outlet works were discharging (compare Figure 37B with 37F). Spray from the higher spillway flows dampened the roadway high on the left bank as shown in Photographs C, D, G, and H in Figure 37.

Ideal flow characteristics would be difficult to obtain for all possible flow conditions. However, no serious objectionable flow characteristics were detected for the various combinations of discharges and tailwater elevations that were tested.

Flow characteristics in the powerplant and outlet works area were satisfactory with or without the spillway operating, Figures 38 and 39. It was clearly demonstrated that the tailwater control structure was needed to maintain the minimum tailwater elevation for the powerplant tailrace and outlet works stilling basin for spillway discharges exceeding about 15,000 cfs. Should the tailwater elevation be less than anticipated, the control structure will be needed for even smaller spillway flows. Tailwater elevations upstream and downstream of the structure were recorded for various combinations of flows and are tabulated in Table 2.

The tailwater elevation at river Station 45+00 was recorded for a range of flows when the tailwater surface contacted the underside of the jet at the end of the bucket, Figure 40. For the normal tailwater elevation in the improved river channel, the tailwater contacted the underside of the jet for flows ranging from approximately 5,000 cfs to approximately 13,000 cfs when both the powerplant and outlet works were discharging. This produced a ragged appearance of the underside of the jet, Figures 34D and 36A.

Diversion Flow

During the construction of the dam the nearly horizontal portion of the spillway tunnel and the flip bucket will be used for diversion of the riverflow. The 14,100-cfs maximum discharge for a 25-year flood and the 6,400-cfs maximum discharge for one-half of a 10-year flood are shown discharging from the flip bucket, Figure 41. Two extreme tailwater conditions were tested since it was not known how much channel improvement would be accomplished at the time that a diversion flood might occur. However, for the range of tail-waters tested in the model no serious hydraulic problems were detected. As an additional safety factor the tunnel was to be vented for diversion flows by a bore through the steeply inclined tunnel section.

A model diversion flow of approximately 100 cfs was also observed by representatives of the contractor to aid in planning the channel improvement work.

Flip bucket surface pressures were recorded for the maximum discharges for the 25-year flood, 10-year flood, and one-half of a 10-year flood, for two different tailwater conditions, Figure 42. The pressures were satisfactory.

Table 1

DIMENSIONS OF HYDRAULIC FEATURES

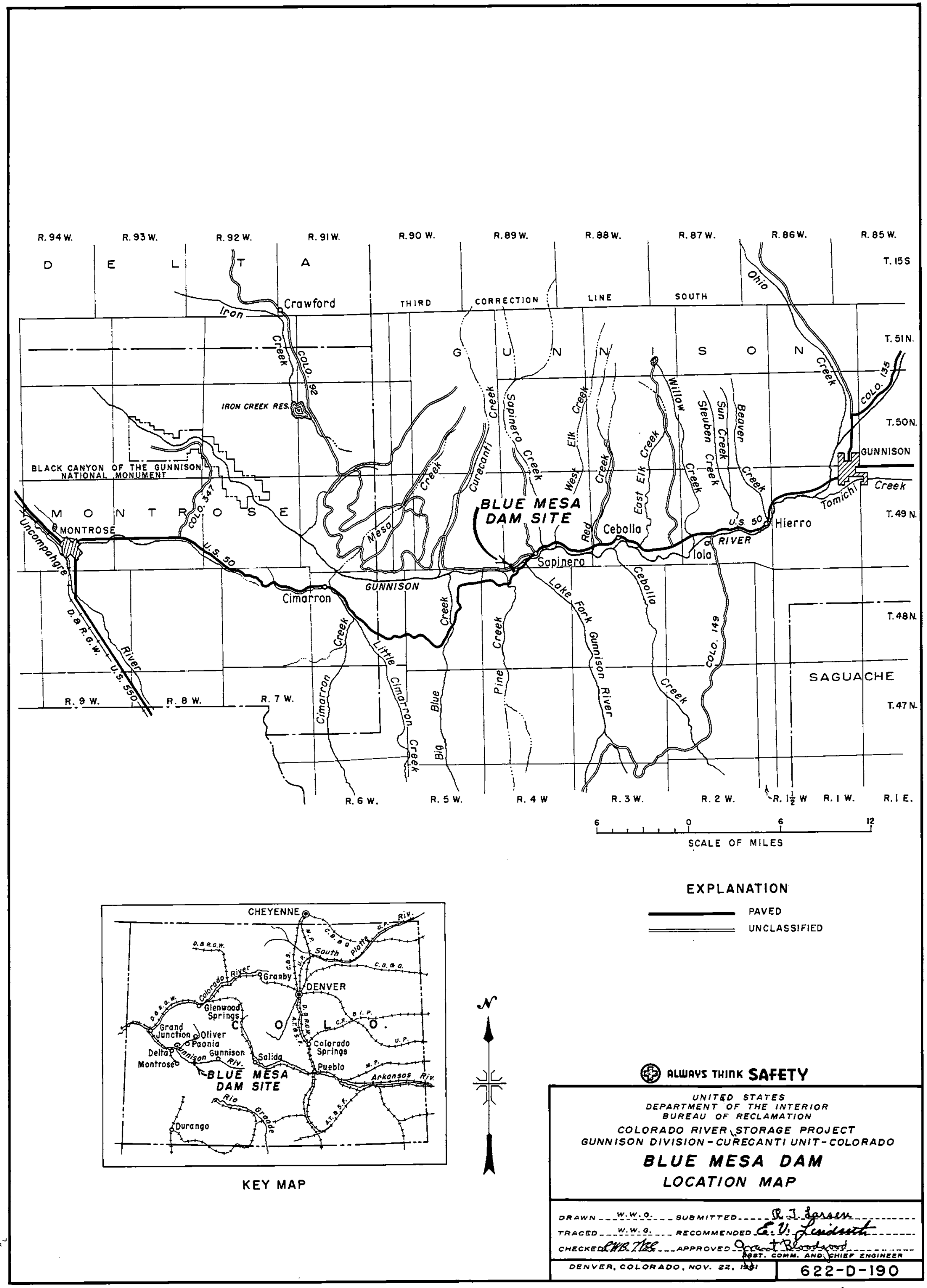
Feature	English units	Metric units
Height of Dam	342 feet	104.24 meters
Length of Dam at Crest	800 feet	243.84 meters
Volume of Earth and Rockfill	3,000,000 cubic yards	2,293,900 cubic meters
Volume of Concrete in Dam	37,460 cubic yards	28,640 cubic meters
Storage Capacity	940,800 acre-feet	1.16 billion cubic meters
Size of Gates	25 by 33.5 feet	7.62 by 10.21 meters
Diameter of Tunnel Spillway	21 feet	6.40 meters
Head on Spillway Crest at Maximum Discharge	31.5 feet	9.60 meters
Spillway Capacity	33,400 cfs	945 cubic meters per second
Outlet Works Capacity	5,400 cfs	152.82 cubic meters per second
Powerplant Discharge at Rated Head	3,080 cfs at 280 feet	87 cubic meters per second at 85.34 meters
25-year Diversion Flood	14,100 cfs	399 cubic meters per second
Hollow-jet Valve Diameter	84 inches	2.13 meters

Table 2

TAILWATER ELEVATIONS

Figure reference	Discharge (cfs)			Tailwater elevation			
	Spillway	Power-plant	Outlet works	Power-plant	Outlet works	Downstream of weir control	River Station 45+00 (controlled)
34B	5,500	--	--	7158.0	7158.0	7158.0	7164.0
35	9,500 through 33,650	--	--	--	--	Dry	7167.8 to 7182.0
38A	--	3,080	--	7161.5	--	7160.5	7160.5*
34C	5,500	3,080	--	7164.0	--	7164.0	7166.9
	9,500	3,080	--	7163.5	--	7163.5	7170.3
39A	15,500	3,080	--	7160.0	--	7158.0	7174.5
	21,500	3,080	--	7160.0	--	7157.0	7178.0
	28,000	3,080	--	7160.0	--	7157.0	7180.8
38B	--	--	5,100	--	7164.0	7163.5	7163.5
	5,500	--	5,100	--	7165.0	7165.0	7168.6
	9,500	--	5,100	--	7164.5	7164.5	7171.8
39B	15,500	--	5,100	--	7163.0	7160.5	7175.8
36C	21,500	--	5,100	--	7162.5	7158.5	7178.8
36D	28,000	--	5,100	--	7162.5	7158.5	7181.6
	33,650	--	5,100	--	7162.5	7156.5	7184.0
38C	--	3,080	5,100	7163.5	7164.0	7163.5	7163.5
34D	5,500	3,080	5,100	7168.0	7168.0	7168.0	7171.0
36A	9,500	3,080	5,100	7167.5	7167.5	7167.5	7173.9
36B and	15,500	3,080	5,100	7164.0	7164.0	7164.0	7177.2
39C	21,500	3,080	5,100	7162.5	7162.5	7161.5	7180.0
	33,650	3,080	5,100	7162.0	7163.5	7161.0	7185.0

*Morrow Point Reservoir drawn down.


DELTA
GUNNISON
MONTROSE
SAGUACHE
Crawford
Iron Creek
COLO. 92
IRON CREEK RES.
BLACK CANYON OF THE GUNNISON NATIONAL MONUMENT
MONTROSE
COLO. 347
Uncompahgre River
D. & R.G.W.
U.S. 550
U.S. 50
Cimarron
GUNNISON RIVER
Mesa Creek
Curecanti Creek
Sapinero Creek
West Elk Creek
Red Creek
East Elk Creek
Willow Creek
Steuben Creek
Sun Creek
Beaver Creek
Ohio Creek
COLO. 135
GUNNISON
Tomichi Creek
Hierro
Cebolla
Iola
Sapinero
BLUE MESA DAM SITE
Lake Fork Gunnison River
Cebolla Creek
COLO. 149
Pine Creek
Big Blue Creek
Little Cimarron Creek
Cimarron Creek
THIRD CORRECTION LINE SOUTH
R. 94 W.
R. 93 W.
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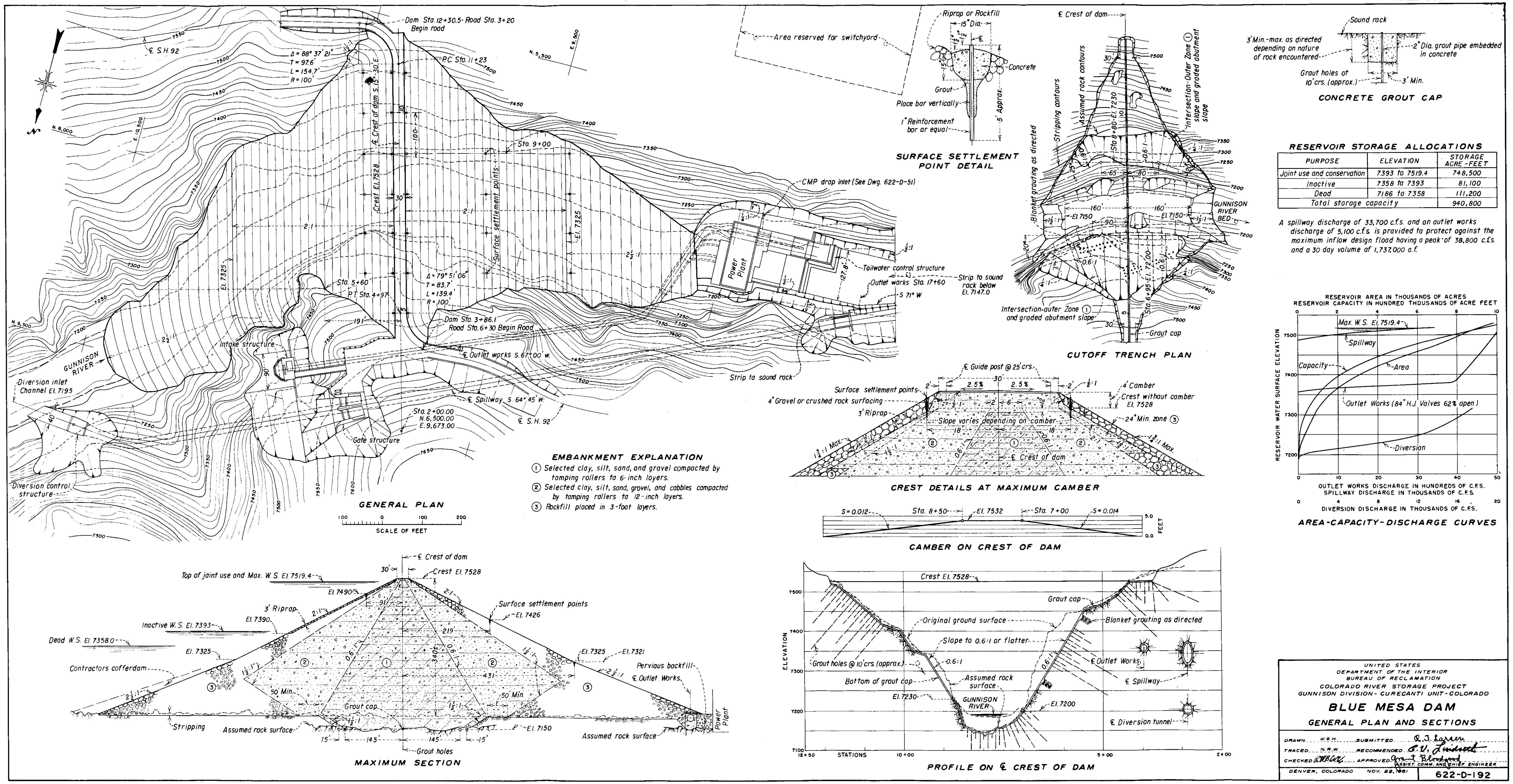
R. 88 W.
R. 87 W.
R. 86 W.
R. 85 W.
T. 15 S
T. 51 N.
T. 50 N.
T. 49 N.
T. 48 N.
T. 47 N.
R. 9 W.
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
R. 4 W
R. 3 W.
R. 2 W.
R. 1½ W
R. 1 W.
R. 1 E.
6 0 6 12
SCALE OF MILES
EXPLANATION
PAVED
UNCLASSIFIED
CHEYENNE
DENVER
Granby
Colorado River
South Platte Riv.
Glenwood Springs
Grand Junction
Oliver
Paonia
Delta
Montrose
Gunnison
Gunnison Riv.
Salida
Colorado Springs
Pueblo
Arkansas Riv.
BLUE MESA DAM SITE
Rio Grande
Durango
COLO.
KEY MAP
N
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GUNNISON DIVISION - CURECANTI UNIT - COLORADO
BLUE MESA DAM
LOCATION MAP
DRAWN W.W.O. SUBMITTED R. J. Larsen
TRACED W.W.O. RECOMMENDED E. V. Lindseth
CHECKED CWB 7BB APPROVED Grant Bloodgood
ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO, NOV. 22, 1961
622-D-190

FIGURE 2
REPORT HYD. 515



EMBANKMENT EXPLANATION

① Selected clay, silt, sand, and gravel compacted by tamping rollers to 6-inch layers.
② Selected clay, silt, sand, gravel, and cobbles compacted by tamping rollers to 12-inch layers.
③ Rockfill placed in 3-foot layers.

RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATION	STORAGE ACRE-FEET
Joint use and conservation	7393 to 7519.4	748,500
Inactive	7358 to 7393	81,100
Dead	7186 to 7358	111,200
Total storage capacity		940,800

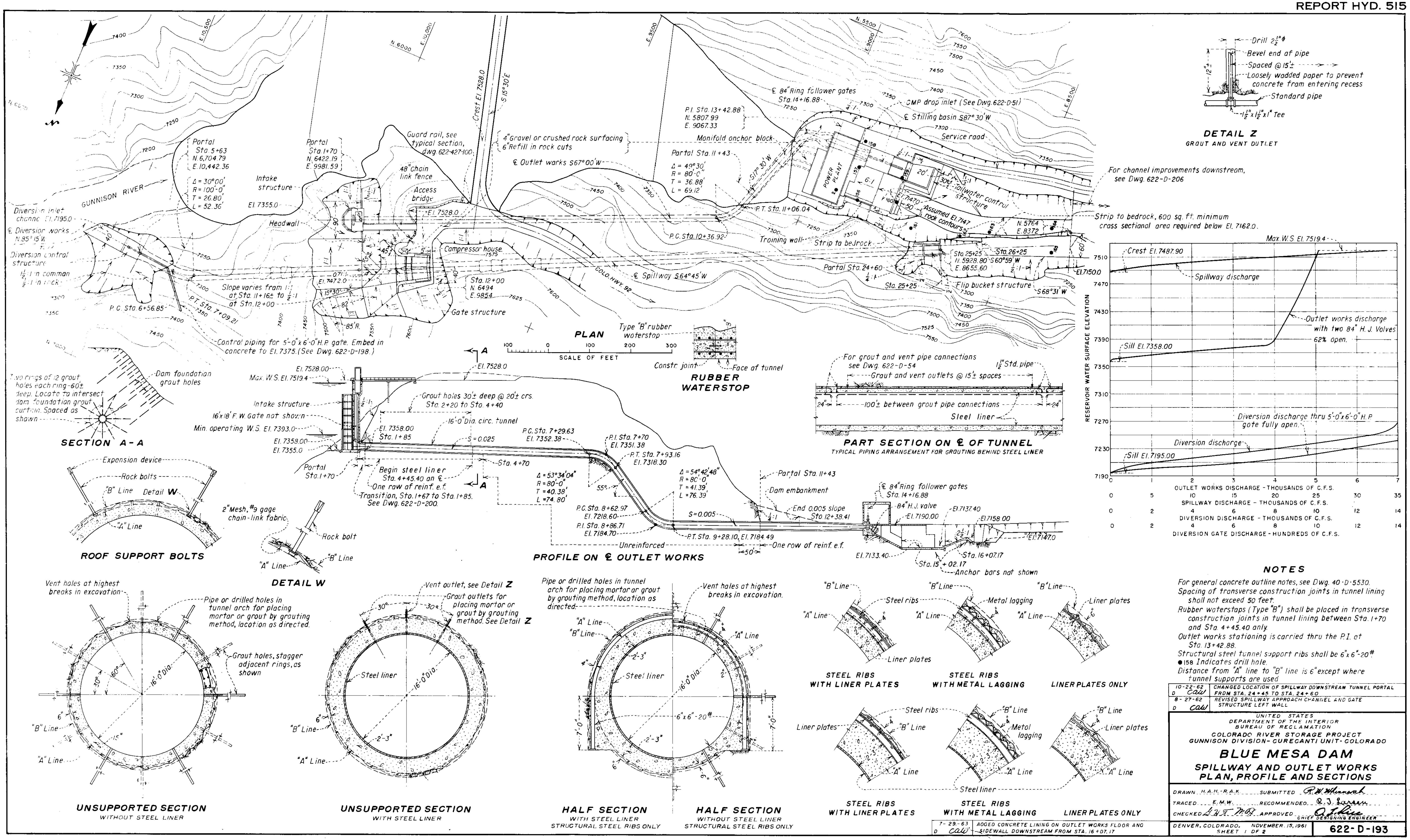
A spillway discharge of 33,700 c.f.s. and an outlet works discharge of 5,100 c.f.s. is provided to protect against the maximum inflow design flood having a peak of 38,800 c.f.s. and a 30 day volume of 1,737,000 a.f.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GUNNISON DIVISION - CURECANTI UNIT - COLORADO

BLUE MESA DAM

GENERAL PLAN AND SECTIONS

DRAWN W.G.H. SUBMITTED
TRACED N.R.W. RECOMMENDED
CHECKED APPROVED
ASSIST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO NOV. 22, 1961 622-D-192


PLAN
SCALE OF FEET
PROFILE ON ℄ OUTLET WORKS
SECTION A-A
ROOF SUPPORT BOLTS
DETAIL W
DETAIL Z
GROUT AND VENT OUTLET
RUBBER WATERSTOP
PART SECTION ON ℄ OF TUNNEL
TYPICAL PIPING ARRANGEMENT FOR GROUTING BEHIND STEEL LINER
UNSUPPORTED SECTION
WITHOUT STEEL LINER
UNSUPPORTED SECTION
WITH STEEL LINER
HALF SECTION
WITH STEEL LINER
STRUCTURAL STEEL RIBS ONLY
HALF SECTION
WITHOUT STEEL LINER
STRUCTURAL STEEL RIBS ONLY
STEEL RIBS WITH LINER PLATES
STEEL RIBS WITH METAL LAGGING
LINER PLATES ONLY
GUNNISON RIVER
Intake structure
Gate structure
Compressor house
Power plant
Tailwater control structure
Flip bucket structure
Service road
COLO. HWY. 92
℄ Outlet works S67°00'W
℄ Spillway S64°45'W
For channel improvements downstream, see Dwg. 622-D-206
Strip to bedrock, 600 sq. ft. minimum cross sectional area required below El. 7162.0.
Max. W.S. El. 7519.4
Crest El. 7487.90
Spillway discharge
Outlet works discharge with two 84" H.J. Valves 62% open.
Sill El. 7358.00
Diversion discharge thru 5'-0"x6'-0" H.P gate fully open.
Diversion discharge
Sill El. 7195.00
RESERVOIR WATER SURFACE ELEVATION
OUTLET WORKS DISCHARGE - THOUSANDS OF C.F.S.
SPILLWAY DISCHARGE - THOUSANDS OF C.F.S.
DIVERSION DISCHARGE - THOUSANDS OF C.F.S.
DIVERSION GATE DISCHARGE - HUNDREDS OF C.F.S.
NOTES
For general concrete outline notes, see Dwg. 40-D-5530.
Spacing of transverse construction joints in tunnel lining shall not exceed 50 feet.
Rubber waterstops (Type "B") shall be placed in transverse construction joints in tunnel lining between Sta. 1+70 and Sta. 4+45.40 only.
Outlet works stationing is carried thru the P.I. at Sta. 13+42.88.
Structural steel tunnel support ribs shall be 6"x6"-20#
● 158 Indicates drill hole.
Distance from "A" line to "B" line is 6" except where tunnel supports are used.
10-22-62 CHANGED LOCATION OF SPILLWAY DOWNSTREAM TUNNEL PORTAL FROM STA. 24+45 TO STA. 24+60
8-27-62 REVISED SPILLWAY APPROACH CHANNEL AND GATE STRUCTURE LEFT WALL
7-29-63 ADDED CONCRETE LINING ON OUTLET WORKS FLOOR AND SIDEWALL DOWNSTREAM FROM STA. 16+07.17
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GUNNISON DIVISION - CURECANTI UNIT - COLORADO
BLUE MESA DAM
SPILLWAY AND OUTLET WORKS
PLAN, PROFILE AND SECTIONS
DRAWN H.A.H.-R.A.K. SUBMITTED
TRACED E.M.W. RECOMMENDED
CHECKED APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLORADO. NOVEMBER 15, 1961
SHEET 1 OF 2
622-D-193

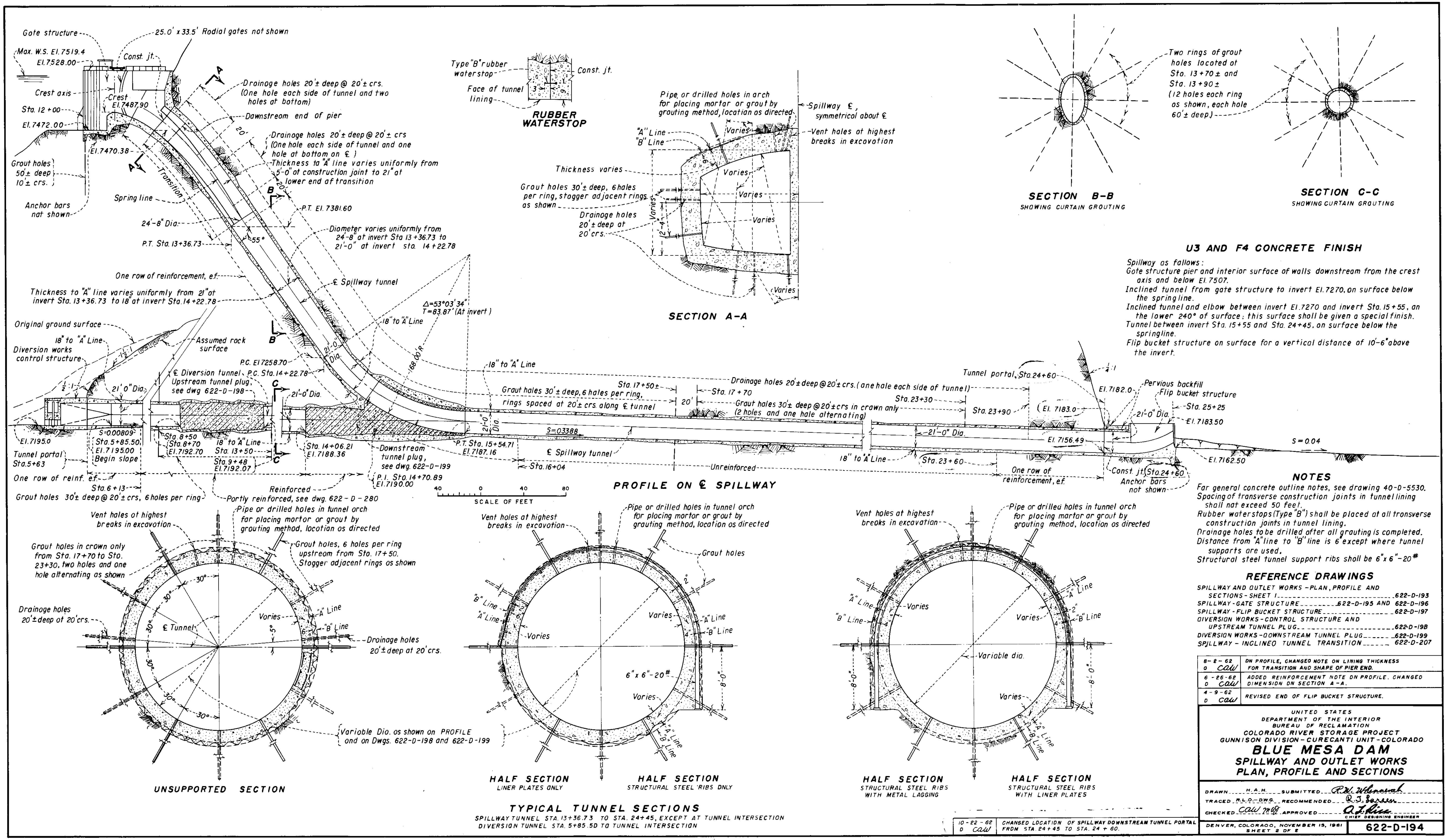
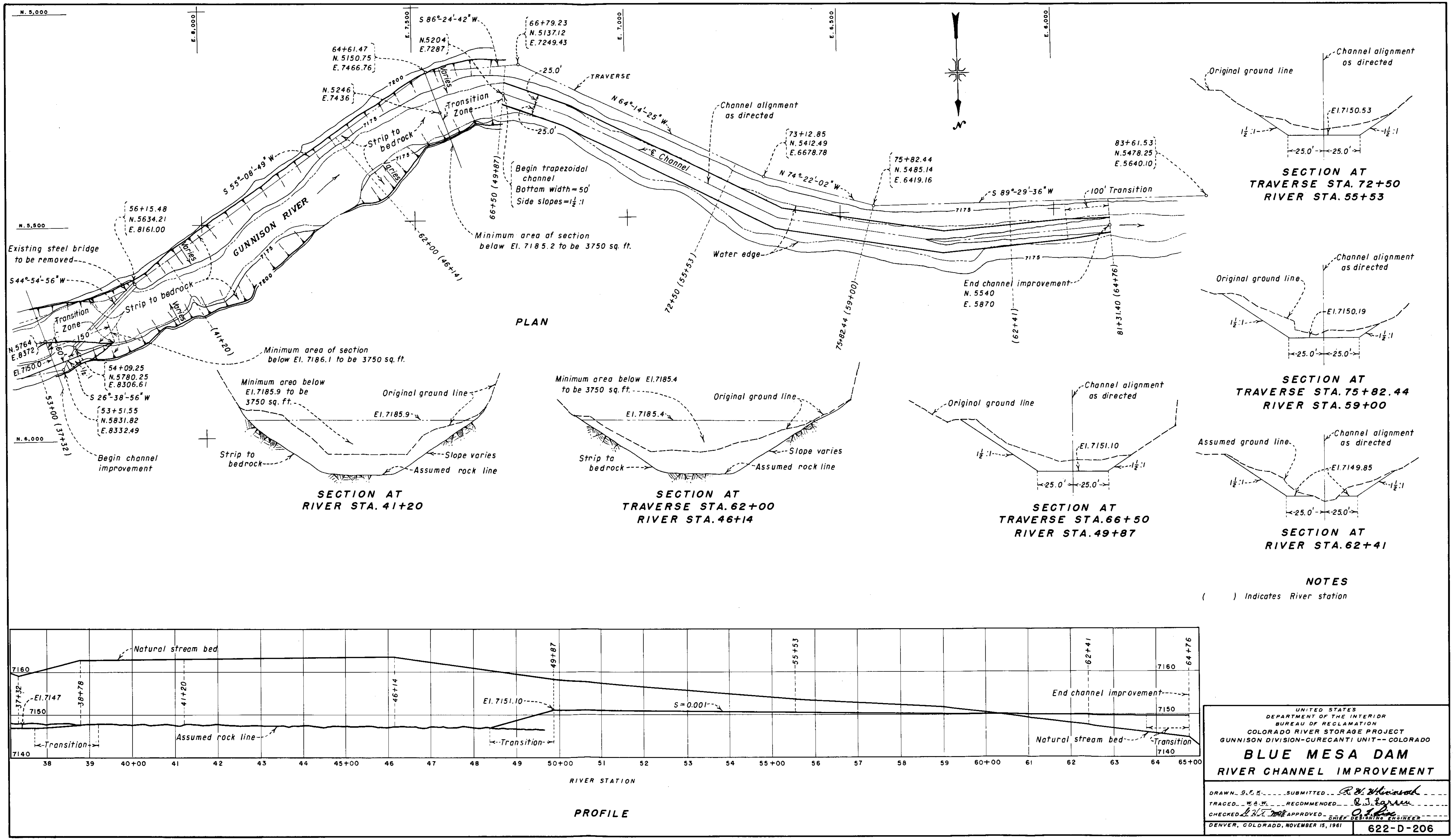
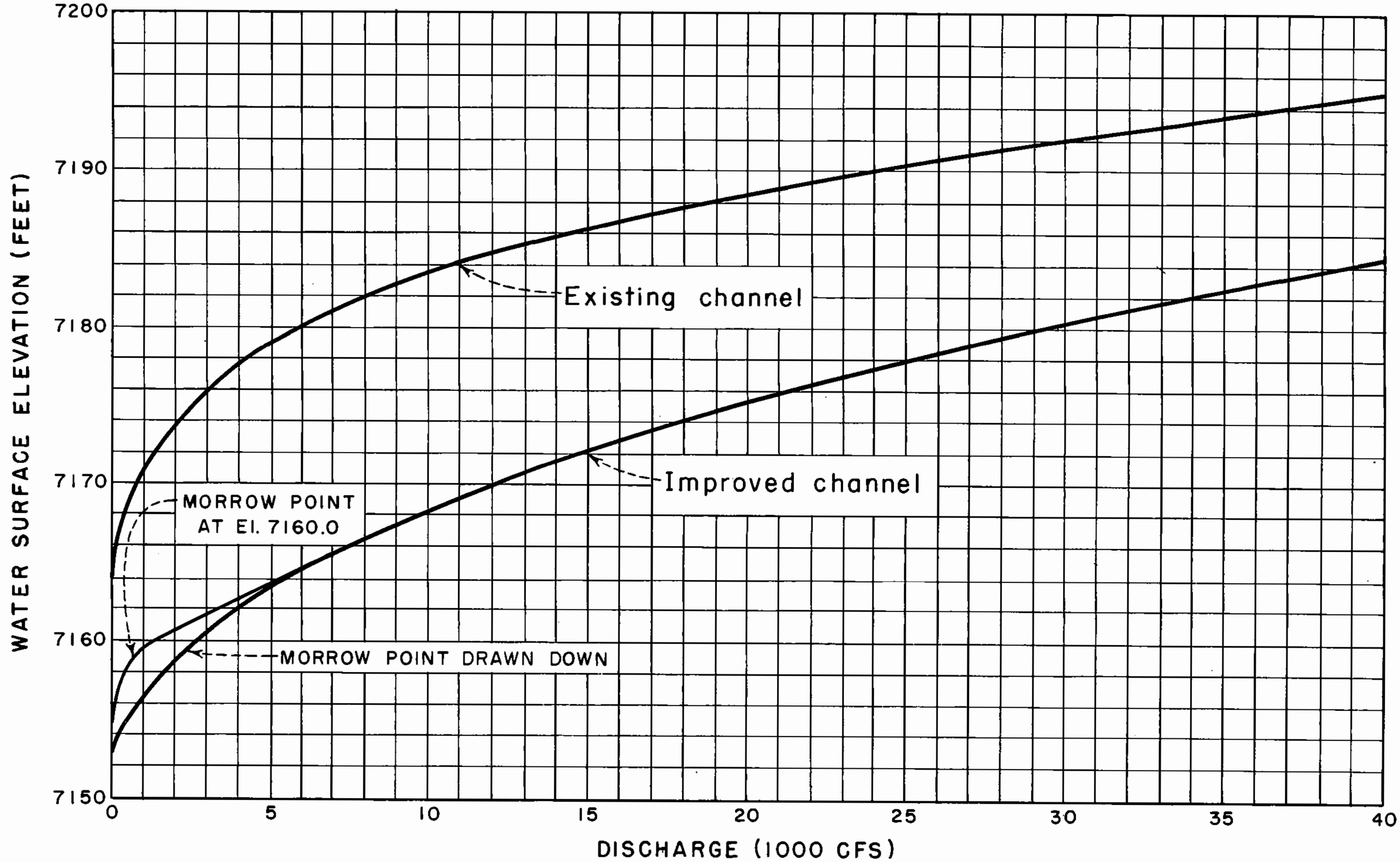

PROFILE ON ℄ SPILLWAY
SCALE OF FEET
SECTION A-A
SECTION B-B
SHOWING CURTAIN GROUTING
SECTION C-C
SHOWING CURTAIN GROUTING
RUBBER WATERSTOP
UNSUPPORTED SECTION
HALF SECTION
LINER PLATES ONLY
HALF SECTION
STRUCTURAL STEEL RIBS ONLY
HALF SECTION
STRUCTURAL STEEL RIBS WITH METAL LAGGING
HALF SECTION
STRUCTURAL STEEL RIBS WITH LINER PLATES
TYPICAL TUNNEL SECTIONS
SPILLWAY TUNNEL STA. 13+36.73 TO STA. 24+45, EXCEPT AT TUNNEL INTERSECTION
DIVERSION TUNNEL STA. 5+85.50 TO TUNNEL INTERSECTION
Gate structure
25.0' x 33.5' Radial gates not shown
Max. W.S. El. 7519.4
El. 7528.00
Crest axis
Crest El. 7487.90
Sta. 12+00
El. 7472.00
El. 7470.38
Grout holes 50± deep 10± crs.
Anchor bars not shown
Spring line
Transition
24'-8" Dia.
P.T. Sta. 13+36.73
P.T. El. 7381.60
Diameter varies uniformly from 24'-8" at invert Sta 13+36.73 to 21'-0" at invert sta. 14+22.78
One row of reinforcement, e.f.
Thickness to "A" line varies uniformly from 21" at invert Sta. 13+36.73 to 18" at invert Sta. 14+22.78
℄ Spillway tunnel
Δ=53°03'34"
T=83.87' (At invert)
Original ground surface
Assumed rock surface
Diversion works control structure
P.C. El 7258.70
P.C. Sta. 14+22.78
℄ Diversion tunnel
Upstream tunnel plug, see dwg 622-D-198
Downstream tunnel plug, see dwg. 622-D-199
Drainage holes 20'± deep @ 20'± crs. (one hole each side of tunnel)
Grout holes 30'± deep, 6 holes per ring, rings spaced at 20± crs. along ℄ tunnel
Grout holes 30'± deep @ 20'± crs in crown only (2 holes and one hole alternating)
Tunnel portal, Sta. 24+60
Pervious backfill
Flip bucket structure
Sta. 25+25
El. 7183.50
S=0.04
El. 7162.50
El. 7156.49
S=.03388
S=0.00809
El. 7195.0
Tunnel portal Sta. 5+63
Sta. 5+85.50 El. 7195.00 Begin slope
One row of reinf. e.f.
Sta. 6+13
Grout holes 30'± deep @ 20'± crs, 6 holes per ring
Portly reinforced, see dwg. 622-D-280
Reinforced
Unreinforced
One row of reinforcement, e.f.
Anchor bars not shown
U3 AND F4 CONCRETE FINISH
Spillway as follows:
Gate structure pier and interior surface of walls downstream from the crest axis and below El. 7507.
Inclined tunnel from gate structure to invert El. 7270, on surface below the springline.
Inclined tunnel and elbow between invert El. 7270 and invert Sta. 15+55, on the lower 240° of surface; this surface shall be given a special finish.
Tunnel between invert Sta. 15+55 and Sta. 24+45, on surface below the springline.
Flip bucket structure on surface for a vertical distance of 10'-6" above the invert.
NOTES
For general concrete outline notes, see drawing 40-D-5530.
Spacing of transverse construction joints in tunnel lining shall not exceed 50 feet.
Rubber waterstops (Type "B") shall be placed at all transverse construction joints in tunnel lining.
Drainage holes to be drilled after all grouting is completed.
Distance from "A" line to "B" line is 6" except where tunnel supports are used.
Structural steel tunnel support ribs shall be 6" x 6" - 20#
REFERENCE DRAWINGS
SPILLWAY AND OUTLET WORKS - PLAN, PROFILE AND SECTIONS - SHEET 1 ... 622-D-193
SPILLWAY - GATE STRUCTURE ... 622-D-195 AND 622-D-196
SPILLWAY - FLIP BUCKET STRUCTURE ... 622-D-197
DIVERSION WORKS - CONTROL STRUCTURE AND UPSTREAM TUNNEL PLUG ... 622-D-198
DIVERSION WORKS - DOWNSTREAM TUNNEL PLUG ... 622-D-199
SPILLWAY - INCLINED TUNNEL TRANSITION ... 622-D-207
8-2-62 ON PROFILE, CHANGED NOTE ON LINING THICKNESS FOR TRANSITION AND SHAPE OF PIER END.
6-26-62 ADDED REINFORCEMENT NOTE ON PROFILE. CHANGED DIMENSION ON SECTION A-A.
4-9-62 REVISED END OF FLIP BUCKET STRUCTURE.
10-22-62 CHANGED LOCATION OF SPILLWAY DOWNSTREAM TUNNEL PORTAL FROM STA 24+45 TO STA. 24+60.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GUNNISON DIVISION - CURECANTI UNIT - COLORADO
BLUE MESA DAM
SPILLWAY AND OUTLET WORKS
PLAN, PROFILE AND SECTIONS
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLORADO, NOVEMBER 15, 1961
SHEET 2 OF 2
622-D-194

FIGURE 5
REPORT HYD. 515



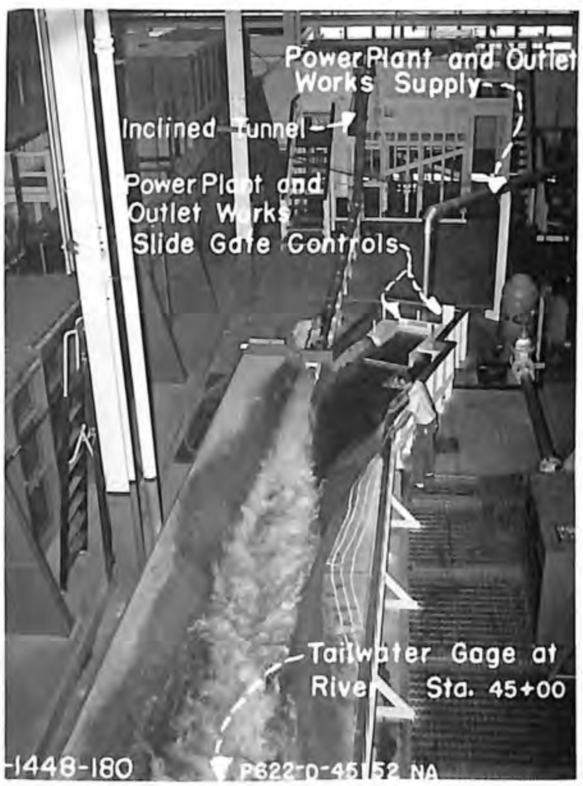


BLUE MESA DAM SPILLWAY

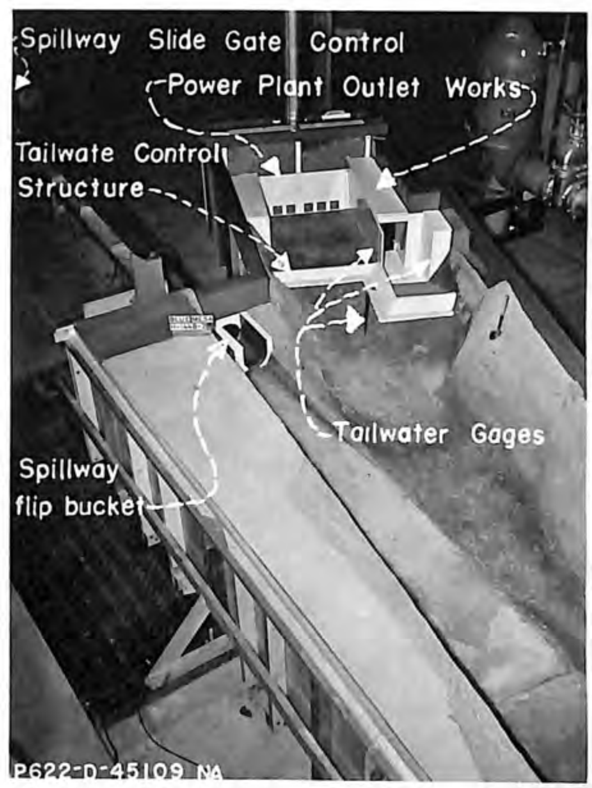
TAILWATER ELEVATION AT RIVER STATION 45+00

FIGURE 6
REPORT HYD-515

A. Looking downstream from reservoir
(Recommended Approach Channel)



B. Looking upstream
Spillway, 33,700 cfs
Powerplant, 5,100 cfs
Outlet works, 3,080 cfs



C. Slide gate control in spillway tunnel, prior to construction of the model reservoir and inclined tunnel

BLUE MESA DAM SPILLWAY

The 1:32.78 Scale Model

A. Preliminary approach channel

B. 16,800 cfs

C. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow in preliminary approach channel
1:32.78 scale model

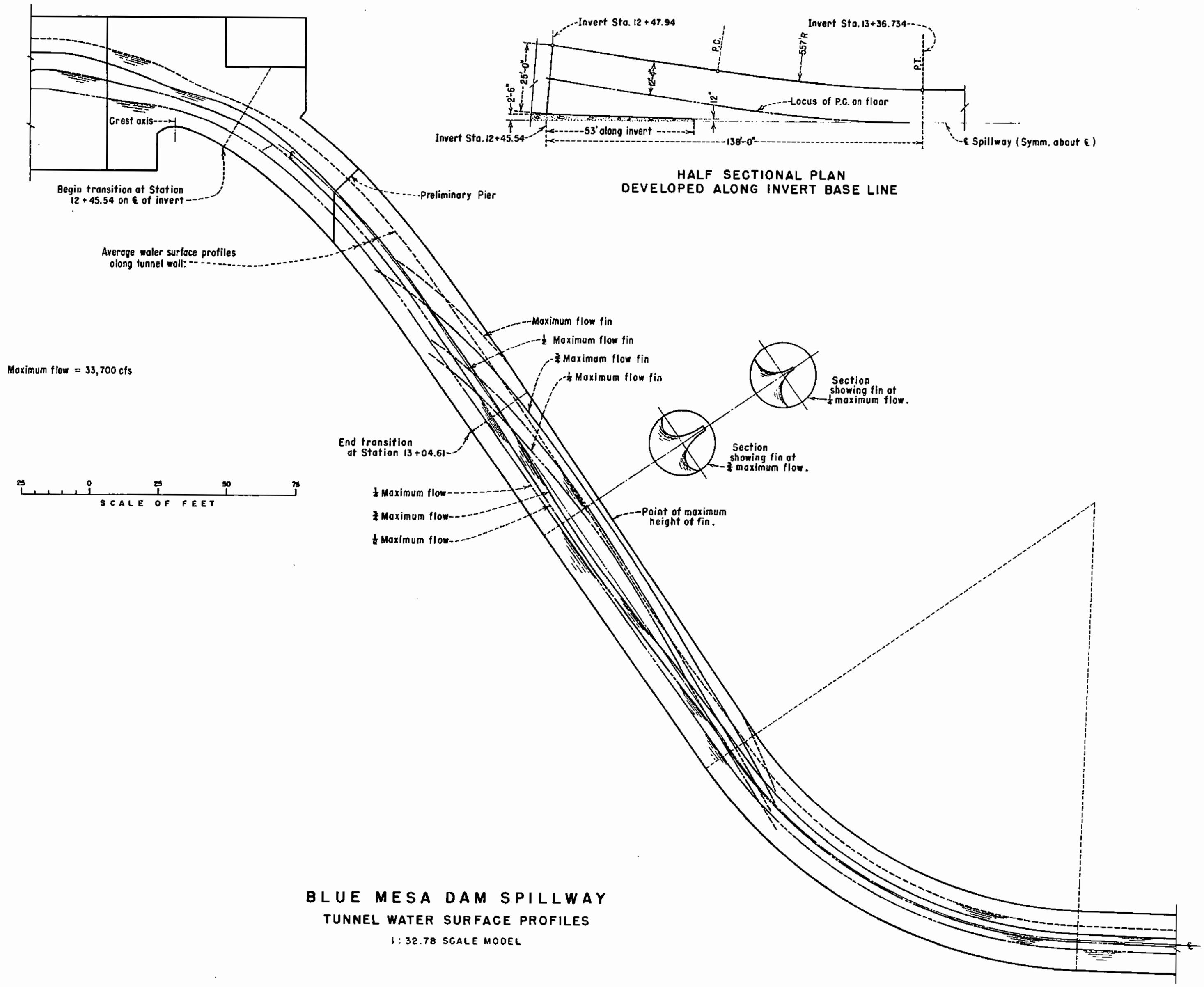
A. 8,400 cfs

B. 16,850 cfs

C. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow entering preliminary gate structure
1:32.78 scale model



BLUE MESA DAM SPILLWAY

TUNNEL WATER SURFACE PROFILES

1:32.78 SCALE MODEL

FIGURE 10
REPORT HYD. 515

A. 8,400 cfs

B. 16,850 cfs

C. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow in recommended approach channel
1:32.78 scale model

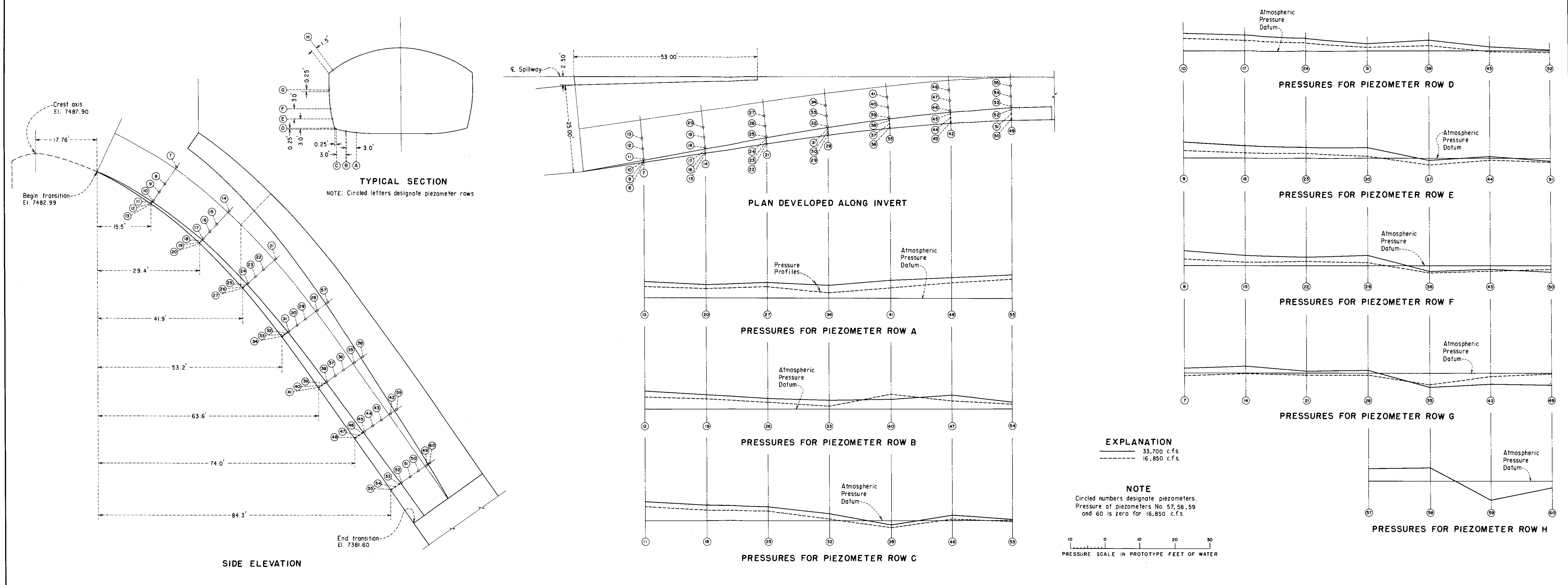
A. 8,400 cfs

B. 16,850 cfs

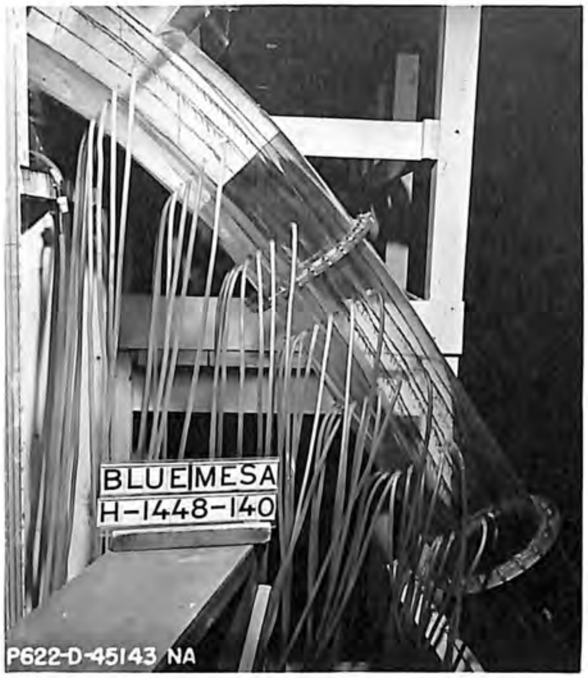
C. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow entering recommended gate structure
1:32.78 scale model



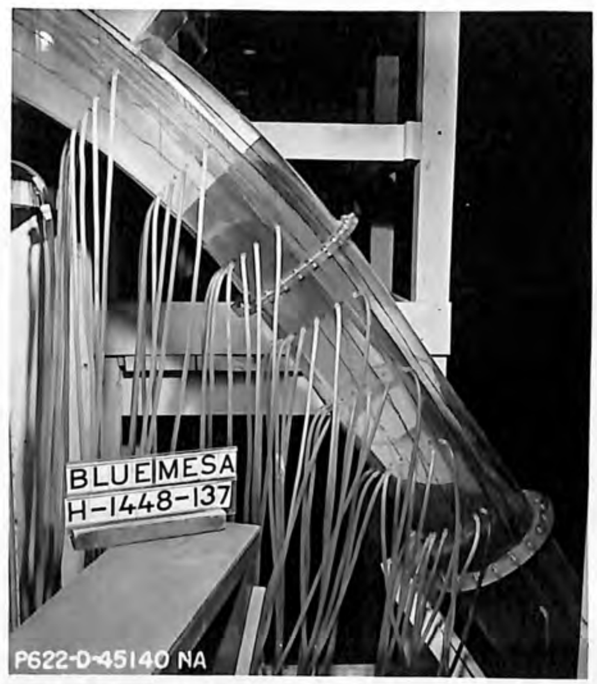
BLUE MESA DAM SPILLWAY
TUNNEL TRANSISTION PRESSURES
1:32.78 SCALE MODEL



A. 8,400 cfs

B. 16,850 cfs

C. 25,250 cfs



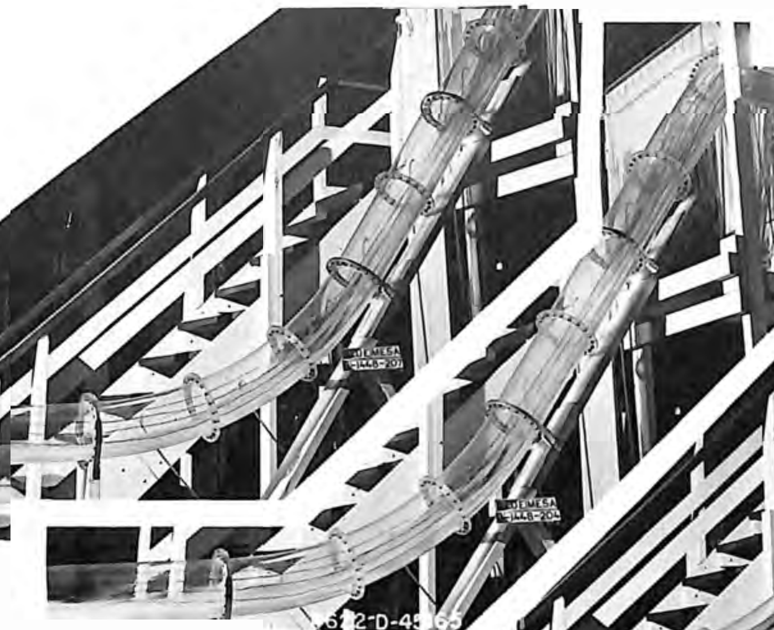
D. 33,700 cfs

Note: The recommended pier is installed in transition section. The water surface on tunnel walls for recommended design is marked by the hatched lines. The line above each hatched line is water surface for the preliminary design.

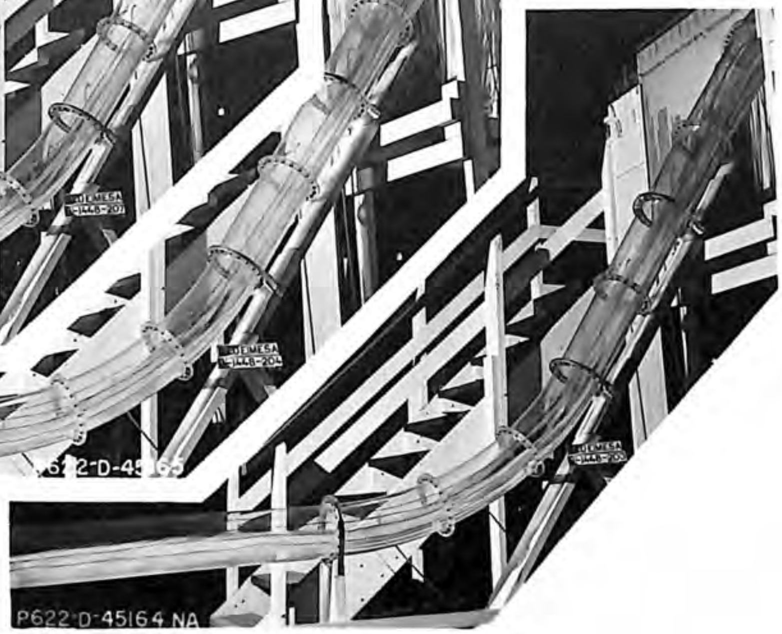
BLUE MESA DAM SPILLWAY

Flow in transition
1:32.78 scale model

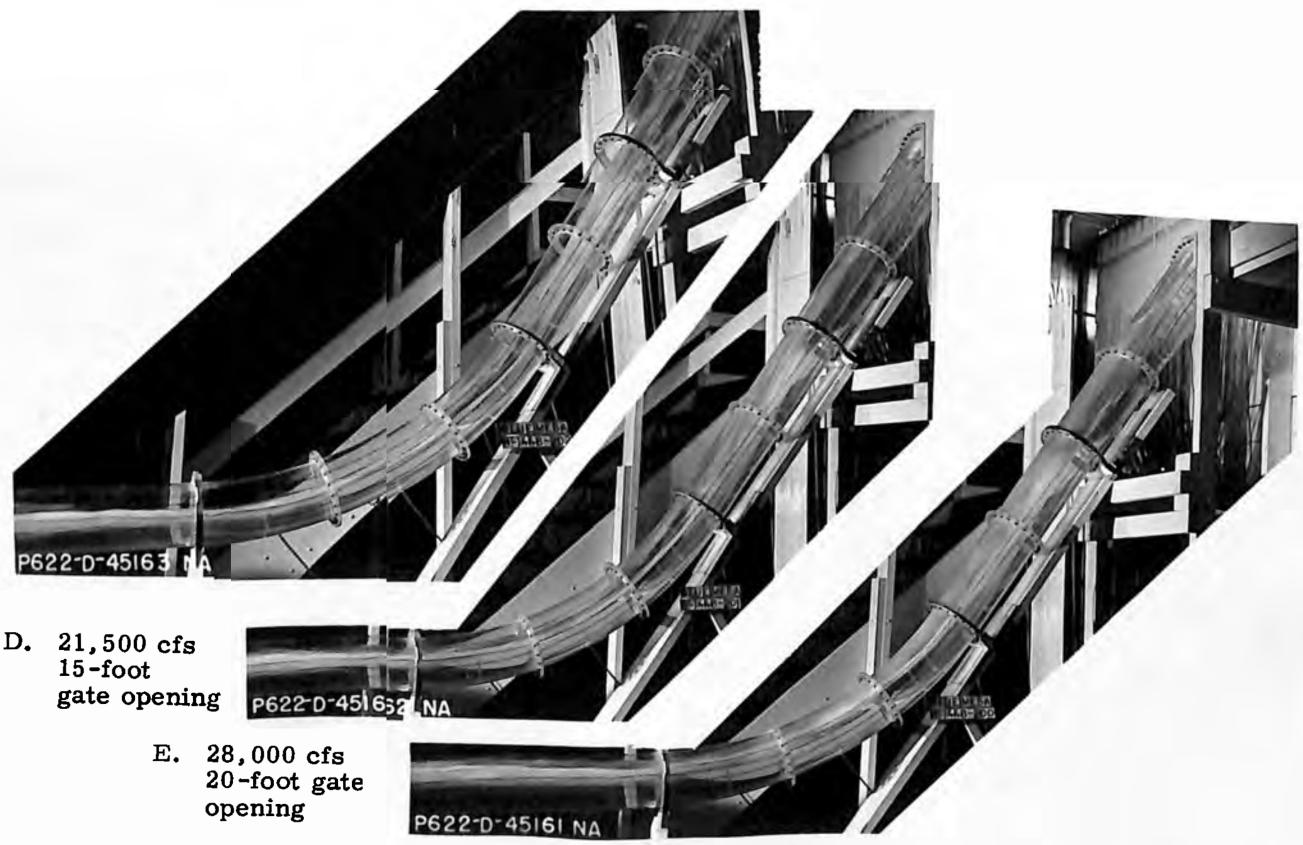
A. 5,500 cfs
4-foot gate
opening



B. 9,500 cfs
7-foot gate
opening



C. 15,500 cfs--10-foot gate opening



D. 21,500 cfs
15-foot
gate opening

E. 28,000 cfs
20-foot gate
opening

F. 33,700 cfs (free flow)

BLUE MESA DAM SPILLWAY

Flow in inclined tunnel
1:32.78 scale model

A. 9,500 cfs--7-foot gate opening

B. 9,500 cfs--free flow

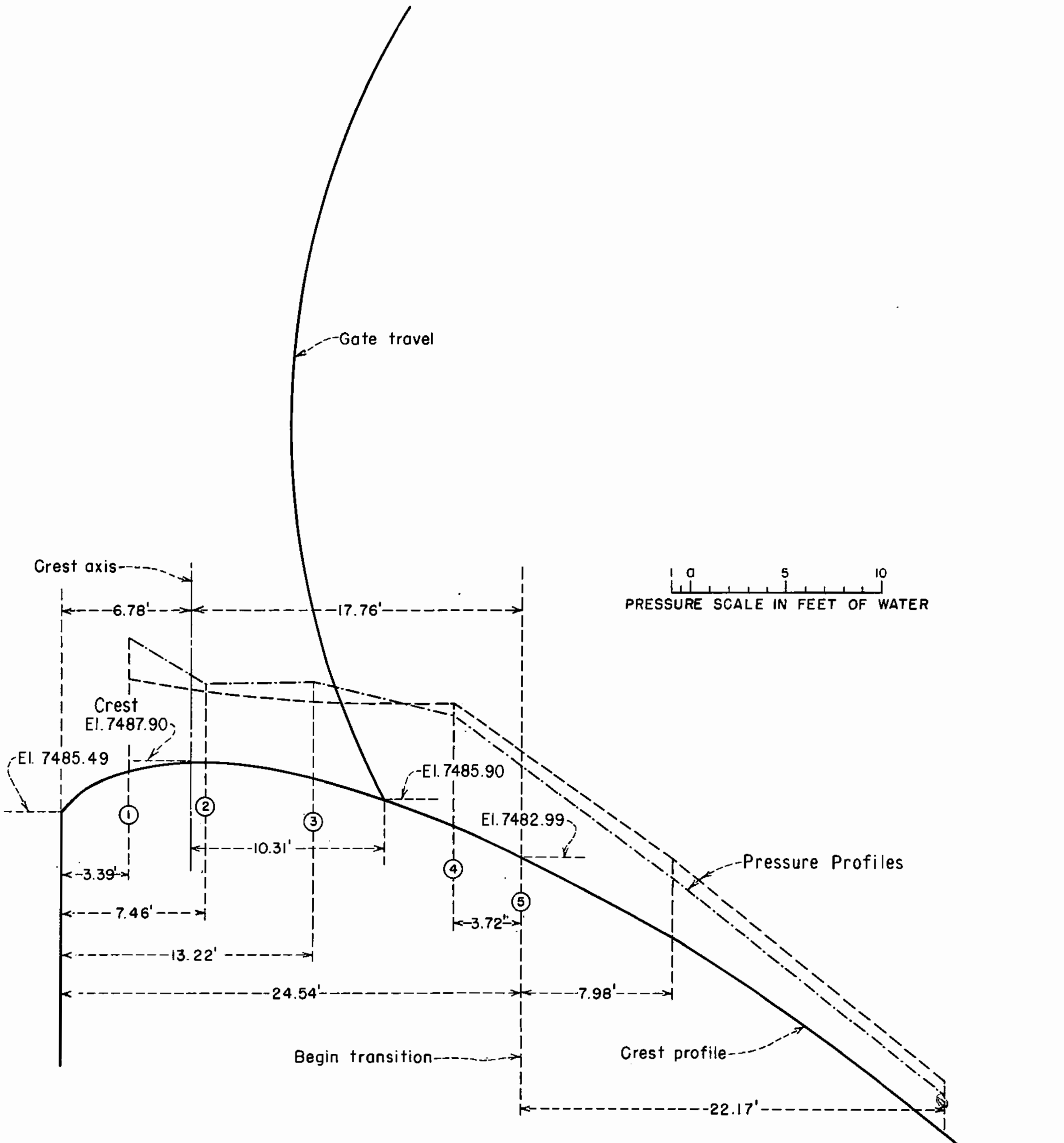
C. 9,500 cfs--right gate closed

D. 9,500 cfs--left gate closed

E. 33,700 cfs--free flow

BLUE MESA DAM SPILLWAY

Flow in vertical bend
1:32.78 scale model



SECTION ON ℄ OF RIGHT BAY

EXPLANATION

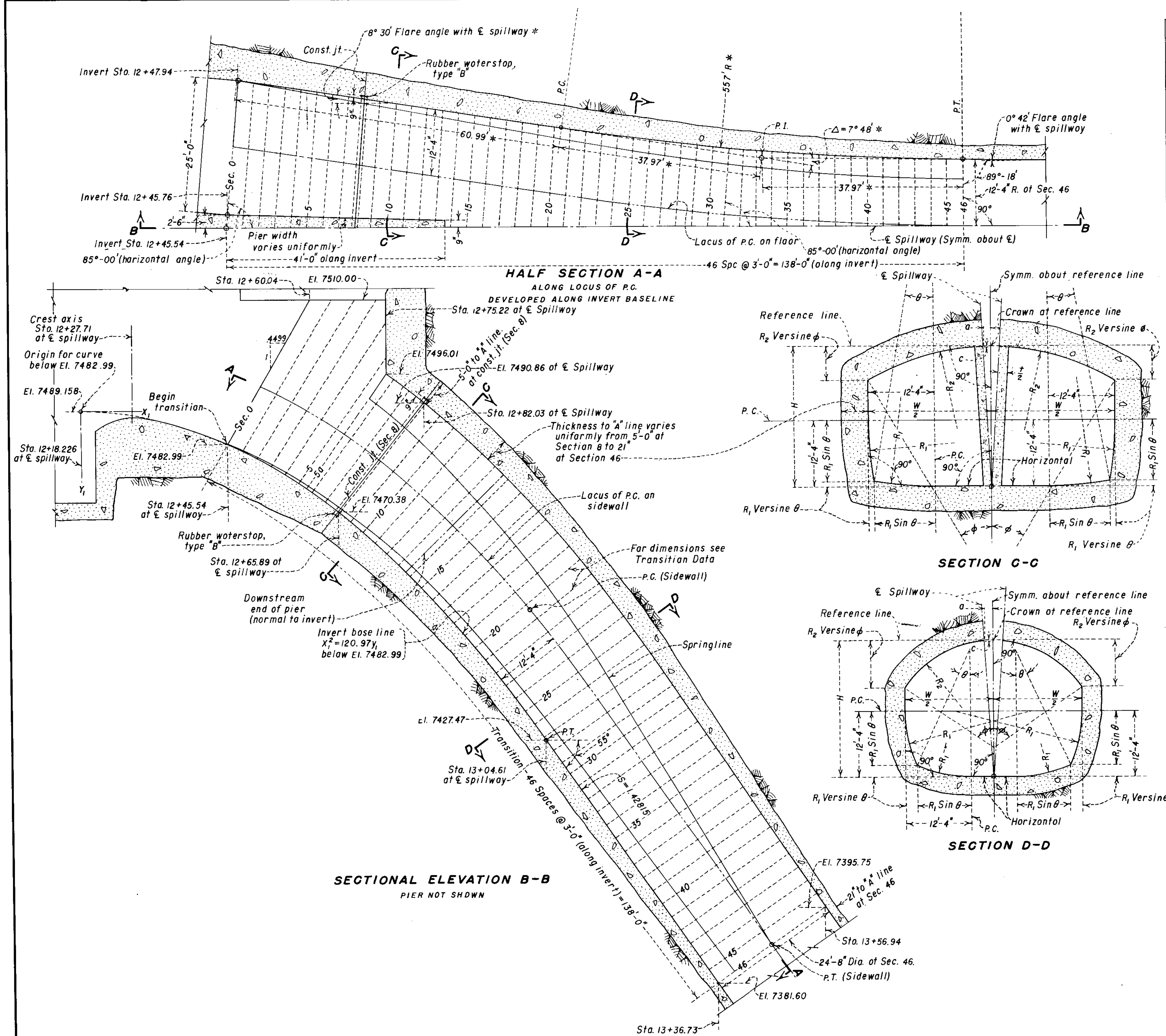
- - - - - - 33,700 C.F.S.
-·-·-·- 16,850 C.F.S.

NOTE

(NO) Designates piezometer location.
Pressures are above atmospheric and plotted vertically upward. Crest profile is atmospheric pressure datum.

BLUE MESA DAM SPILLWAY
CREST PRESSURES
1 : 32.78 SCALE MODEL

665



TRANSITION DATA

OFFSET a	OFFSET c	SEC.	DIST. FROM SEC. 0 ALONG ℄ SPY. ON INVERT	DIST. FROM SEC. 0 ALONG LOCUS OF P.C. ON SIDEWALL	DIST. FROM SEC. 46 ALONG ℄ SPY. ON CROWN	STA. OF INVERT ON ℄ SPY.	ELEV. OF INVERT	$\frac{W}{2}$ See Notes	H Normal to Invert	R_1	$R_1 \sin\theta$	R_1 VERS θ	R_2	R_2 VERS φ
		0	0	0		12+45.54	7482.99	27.510'		∞	12.333'	0		
		1	3.00'	3.44'		12+48.25	7481.706	27.066		700.60'	12.227	.106'		
		2	6.00	6.87		12+50.91	7480.326	26.621		347.33	12.122	.212		
		3	9.00	10.27		12+53.52	7478.856	26.177		229.64	12.018	.315		
		4	12.00	13.64		12+56.096	7477.303	25.733		170.84	11.917	.416		
		5	15.00	17.00		12+58.615	7475.674	25.289		135.59	11.817	.517		
1.303'	.015'	5a	17.02		130.09'	12+60.283	7474.537		26.167'				58.45'	5.612'
1.319	.016	6	18.00	20.33	128.87	12+61.086	7473.974	24.844	26.153	112.11	11.719	.614	57.30	5.667
1.365	.017	7	21.00	23.65	125.18	12+63.511	7472.207	24.400	26.116	95.37	11.623	.711	53.95	5.833
1.408	.019	8	24.00	26.95	121.54	12+65.890	7470.379	23.956	26.079	82.83	11.527	.806	50.82	6.000
1.448	.022	9	27.00	30.23	117.93	12+68.224	7468.495	23.512	26.042	73.09	11.433	.900	47.90	6.167
1.484	.024	10	30.00	33.50	114.35	12+70.515	7466.558	23.067	26.005	65.31	11.341	.992	45.18	6.333
1.517	.027	11	33.00	36.75	110.81	12+72.764	7464.572	22.623	25.968	58.96	11.250	1.083	42.62	6.500
1.546	.030	12	36.00	39.98	107.30	12+74.972	7462.541	22.179	25.930	53.68	11.161	1.173	40.23	6.667
1.575	.033	13	39.00	43.21	103.81	12+77.140	7460.468	21.735	25.893	49.22	11.072	1.262	37.98	6.833
1.602	.036	14	42.00	46.42	100.35	12+79.270	7458.356	21.290	25.856	45.41	10.986	1.349	35.88	7.000
1.626	.039	15	45.00	49.62	96.92	12+81.364	7456.207	20.846	25.819	42.11	10.899	1.435	33.90	7.167
1.648	.042	16	48.00	52.82	93.51	12+83.421	7454.024	20.402	25.782	39.23	10.813	1.520	32.05	7.333
1.669	.046	17	51.00	56.00	90.11	12+85.445	7451.809	19.958	25.745	36.70	10.730	1.604	30.31	7.500
1.688	.050	18	54.00	59.17	86.74	12+87.435	7449.565	19.513	25.707	34.45	10.646	1.686	28.67	7.667
1.705	.054	19	57.00	62.33	83.39	12+89.394	7447.292	19.069	25.670	32.45	10.565	1.768	27.13	7.833
1.721	.058	20	60.00	65.49	80.05	12+91.321	7444.994	18.625	25.633	30.65	10.483	1.849	25.68	8.000
1.736	.062	21	63.00	68.64	76.73	12+93.219	7442.670	18.187	25.596	29.03	10.403	1.928	24.33	8.167
1.750	.066	22	66.00	71.78	73.42	12+95.089	7440.323	17.762	25.559	27.56	10.324	2.007	23.10	8.333
1.763	.071	23	69.00	74.91	70.13	12+96.930	7437.956	17.353	25.522	26.23	10.249	2.085	21.96	8.500
1.775	.075	24	72.00	78.04	66.85	12+98.745	7435.567	16.960	25.485	25.01	10.173	2.162	20.93	8.667
1.786	.080	25	75.00	81.16	63.58	13+00.534	7433.159	16.582	25.447	23.89	10.096	2.238	19.98	8.833
1.796	.085	26	78.00	84.27	60.32	13+02.299	7430.732	16.221	25.410	22.86	10.021	2.314	19.12	9.000
1.806	.089	27	81.00	87.38	57.08	13+04.039	7428.288	15.877	25.373	21.91	9.947	2.388	18.33	9.167
1.807	.093	28	84.00	90.41	54.00	13+05.761	7425.832	15.547	25.336	21.03	9.873	2.462	17.62	9.333
1.804	.096	29	87.00	93.40	51.00	13+07.482	7423.375	15.234	25.299	20.21	9.798	2.534	16.96	9.500
1.801	.099	30	90.00	96.39	48.00	13+09.202	7420.917	14.937	25.262	19.45	9.725	2.606	16.37	9.667
1.798	.102	31	93.00	99.37	45.00	13+10.923	7418.460	14.656	25.224	18.75	9.657	2.678	15.84	9.833
1.765	.102	32	96.00	102.34	42.00	13+12.644	7416.002	14.392	25.187	18.09	9.586	2.749	15.36	10.000
1.637	.090	33	99.00	105.26	39.00	13+14.365	7413.545	14.142	25.150	17.47	9.515	2.818	14.92	10.167
1.510	.079	34	102.00	108.18	36.00	13+16.085	7411.087	13.909	25.113	16.89	9.445	2.888	14.53	10.333
1.383	.068	35	105.00	111.10	33.00	13+17.806	7408.630	13.690	25.076	16.35	9.378	2.957	14.18	10.500
1.256	.057	36	108.00	114.02	30.00	13+19.527	7406.172	13.489	25.039	15.84	9.310	3.025	13.86	10.667
1.129	.047	37	111.00	116.94	27.00	13+21.248	7403.715	13.302	25.001	15.36	9.244	3.093	13.58	10.833
1.003	.038	38	114.00	119.87	24.00	13+22.968	7401.257	13.131	24.964	14.90	9.173	3.159	13.34	11.000
.876	.029	39	117.00	122.80	21.00	13+24.689	7398.800	12.976	24.927	14.47	9.106	3.225	13.12	11.167
.751	.022	40	120.00	125.72	18.00	13+26.410	7396.342	12.837	24.890	14.07	9.044	3.292	12.94	11.333
.625	.015	41	123.00	128.65	15.00	13+28.130	7393.885	12.713	24.853	13.68	8.975	3.356	12.78	11.500
.499	.010	42	126.00	131.58	12.00	13+29.851	7391.428	12.606	24.816	13.32	8.913	3.421	12.64	11.667
.374	.006	43	129.00	134.52	9.00	13+31.572	7388.970	12.514	24.778	12.97	8.846	3.484	12.53	11.833
.249	.002	44	132.00	137.45	6.00	13+33.293	7386.513	12.437	24.741	12.65	8.787	3.550	12.44	12.000
.124	.001	45	135.00	140.39	3.00	13+35.013	7384.055	12.377	24.704	12.33	8.721	3.612	12.38	12.167
0	0	46	138.00	143.32	0	13+36.734	7381.598	12.333	24.667	12.33	8.721	3.612	12.33	12.333

NOTES

For general concrete outline notes, see Dwg. 40-D-5530.

Concrete finish to be U3 and F4 on gate structure pier and interior surface of walls below El. 7507 downstream from the crest axis, and on surface of inclined tunnel transition below the springline.

On Sectional Elevation B-B, sections are taken normal to invert. On Half Section A-A, sections 0 to 31 are taken at 85° (horizontal angle) with ℄ spillway; sections 32 to 45 are taken normal to sidewall.

* Indicates relative data based on developed invert baseline, used only for computing transition data in table.

REFERENCE DRAWINGS

SPILLWAY AND OUTLET WORKS-PLAN, PROFILE AND SECTIONS .... 622-D-193 AND -194
SPILLWAY-GATE STRUCTURE .... 622-D-195 AND -196
SPILLWAY-INCLINED TUNNEL TRANSITION-REINFORCEMENT 622-D-279

3-11-63 D CAW	REVISED SECTIONS C-C AND D-D. ADDED DATA FOR DIMENSIONS a AND c.
11-21-62 D CAW	TRACED. CHANGED DATA FOR SEC. 5a.

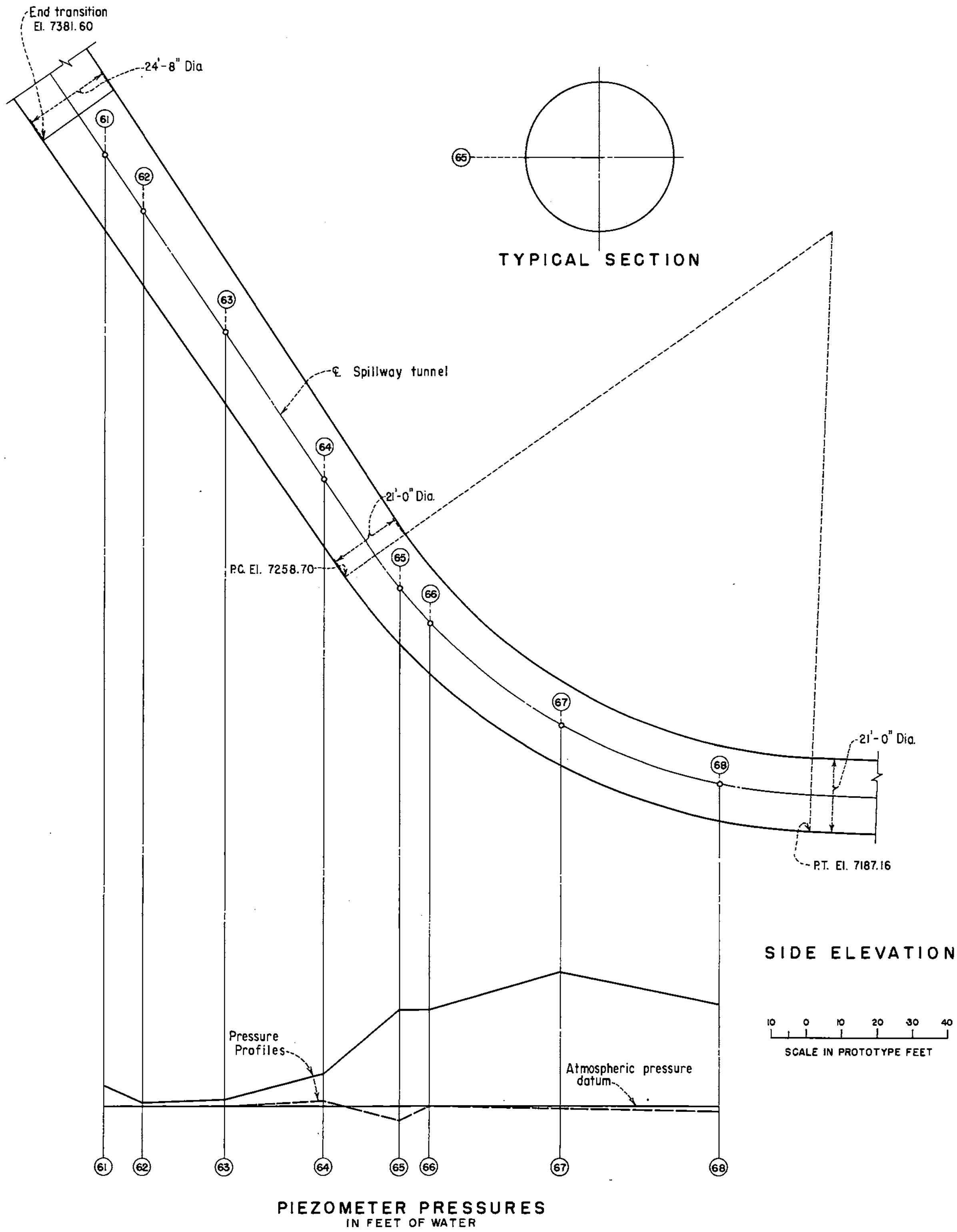
ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GUNNISON DIVISION–CURECANTI UNIT–COLORADO

BLUE MESA DAM

SPILLWAY
GATE STRUCTURE AND INCLINED TUNNEL-TRANSITION

DRAWN H.A.H. SUBMITTED M.A. Jabara
TRACED B.S.B. RECOMMENDED R.W. Whinnerah
CHECKED C.A.W. APPROVED R.T. Larsen, CHIEF, DAMS BRANCH
DENVER, COLORADO AUG. 7, 1962 — 622-D-207



EXPLANATION

——— 33,700 c.f.s.
— — — 16,850 c.f.s.

NOTES.

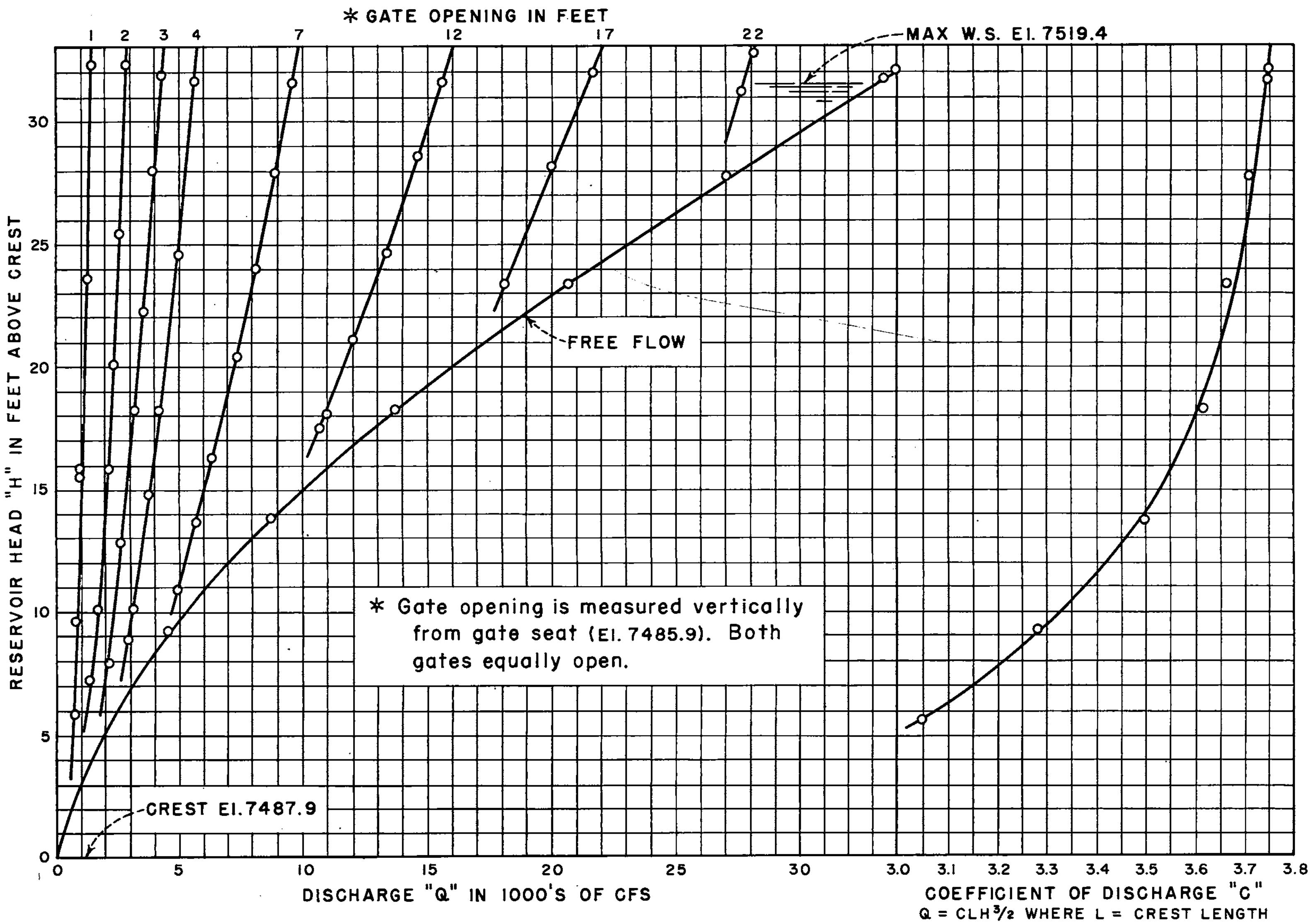
Circled numbers designate piezometers.
Pressure at piezometers No. 61, 62, 63, and 66 is zero for 16,850 c.f.s.

BLUE MESA DAM SPILLWAY

TUNNEL PRESSURES

1 : 32.78 SCALE MODEL

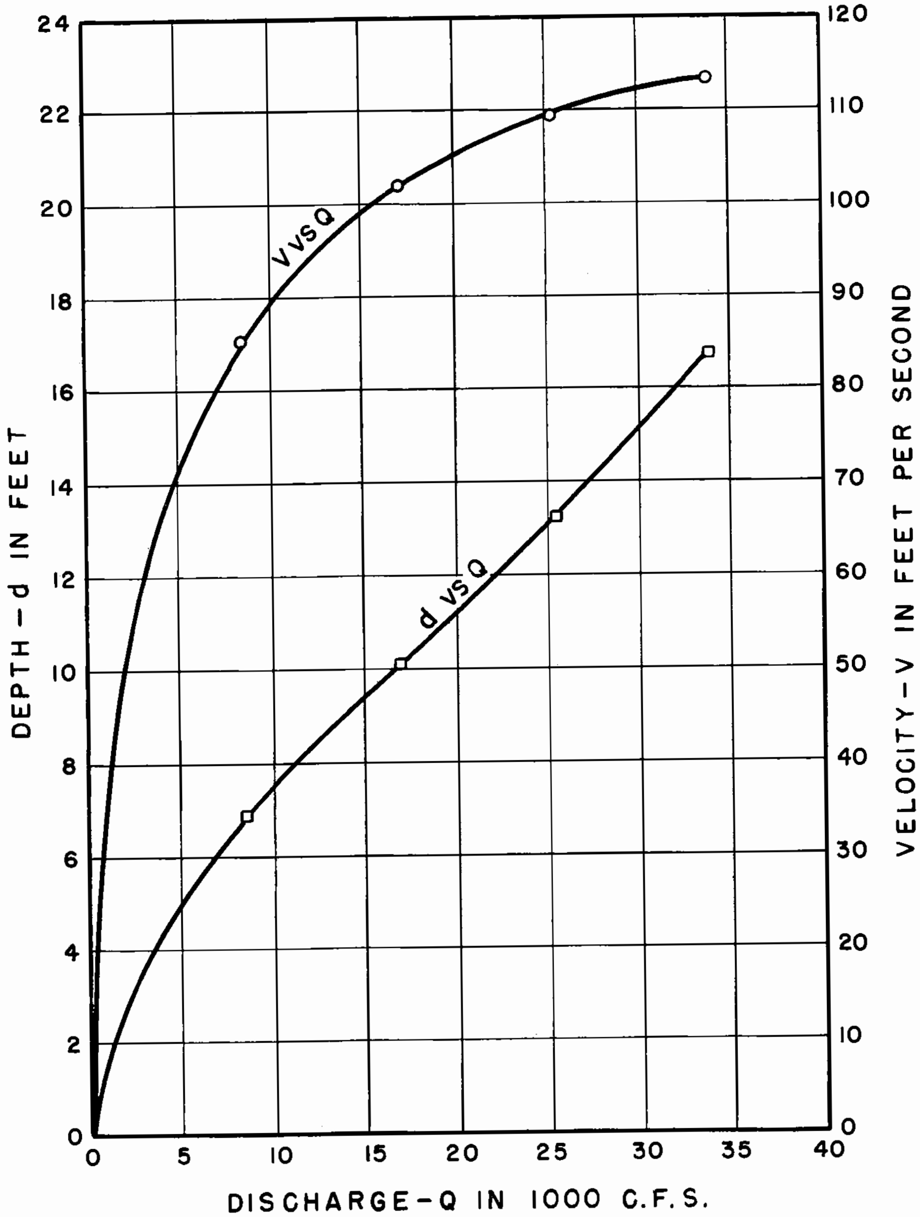
665



BLUE MESA DAM SPILLWAY

DISCHARGE CAPACITY AND COEFFICIENT CURVES FOR RECOMMENDED DESIGN

1 : 32.78 SCALE MODEL

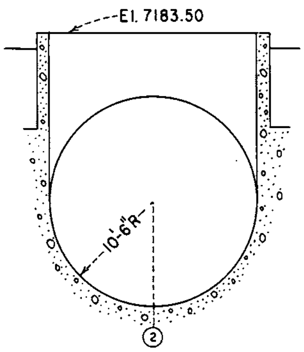


Q IN C.F.S.	d IN FT.	V IN F./S.	FROUDE NO. F *
8,425	6.88	85.23	5.73
16,850	10.10	102.09	5.66
25,250	13.25	109.63	5.31
33,700	16.80	113.28	4.81

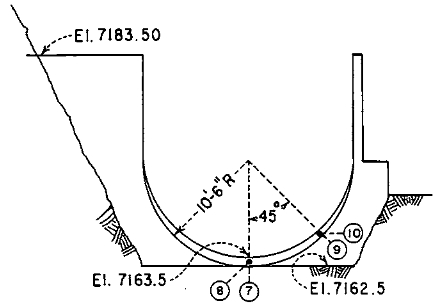
$* F = \frac{V}{\sqrt{gd}}$

BLUE MESA DAM SPILLWAY

VELOCITY AND DEPTH OF FLOW AT PORTAL



SECTION A-A



SECTION B-B

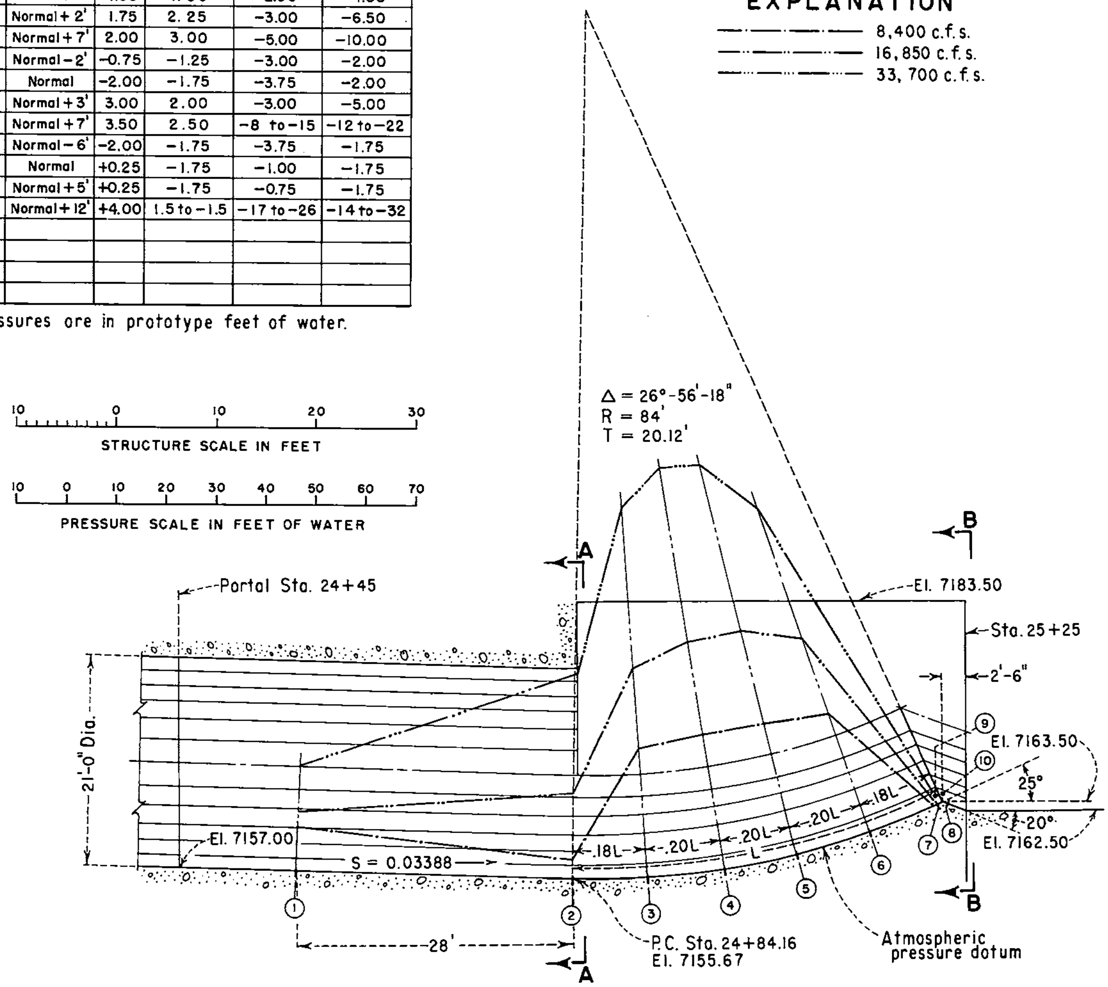
(NO) Designates piezometer location

EXPLANATION

8,400 c.f.s.
16,850 c.f.s.
33,700 c.f.s.

DISCHARGE C. F. S.	T. W. EL.	*PIEZOMETER NO.			
		7	8	9	10
8400	Normal	1.00	1.50	-2.50	-4.50
8400	Normal + 2'	1.75	2.25	-3.00	-6.50
8400	Normal + 7'	2.00	3.00	-5.00	-10.00
8400	Normal - 2'	-0.75	-1.25	-3.00	-2.00
16,850	Normal	-2.00	-1.75	-3.75	-2.00
16,850	Normal + 3'	3.00	2.00	-3.00	-5.00
16,850	Normal + 7'	3.50	2.50	-8 to -15	-12 to -22
16,850	Normal - 6'	-2.00	-1.75	-3.75	-1.75
33,700	Normal	+0.25	-1.75	-1.00	-1.75
33,700	Normal + 5'	+0.25	-1.75	-0.75	-1.75
33,700	Normal + 12'	+4.00	1.5 to -1.5	-17 to -26	-14 to -32

* All pressures are in prototype feet of water.

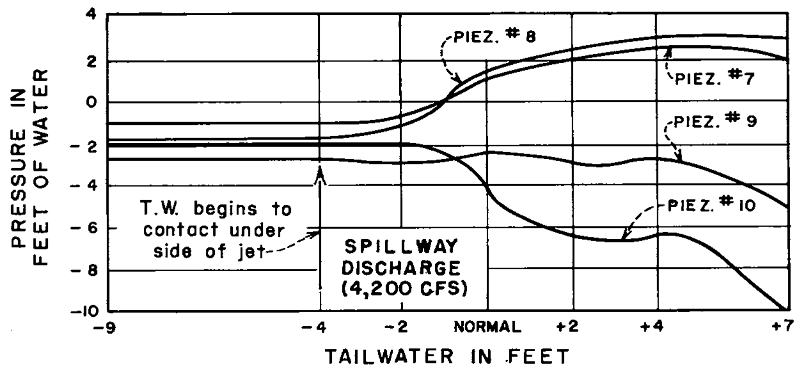


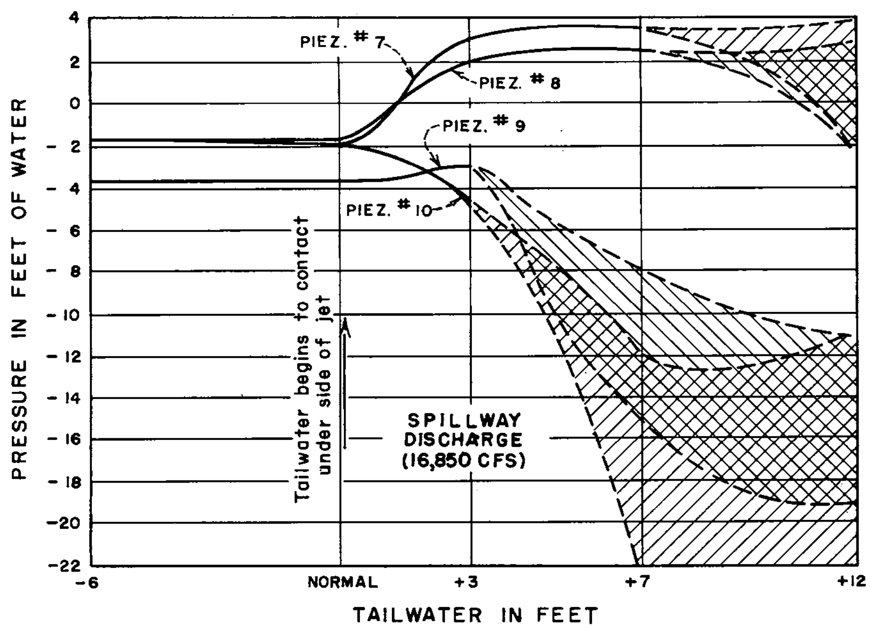
SECTION ON ℄ OF SPILLWAY

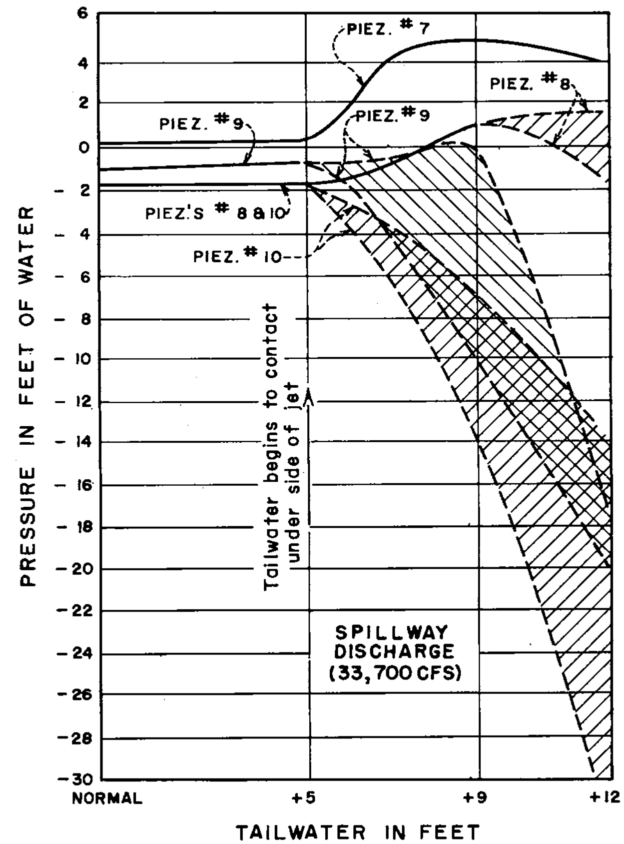
BLUE MESA DAM SPILLWAY

PRESSURES IN THE PRELIMINARY FLIP - BUCKET

1 : 32.78 SCALE MODEL







NOTE

Piezometer locations are shown in Figure 22. Zero pressure is atmospheric. Normal tailwater is for the improved channel. The power plant and outlet works were discharging 8,180 c.f.s. in addition to the spillway flow.

BLUE MESA DAM SPILLWAY

PRESSURE FLUCTUATIONS IN THE PRELIMINARY FLIP - BUCKET

1 : 32.78 SCALE MODEL

FIGURE 23
REPORT HYD-515

A. 4,200 cfs

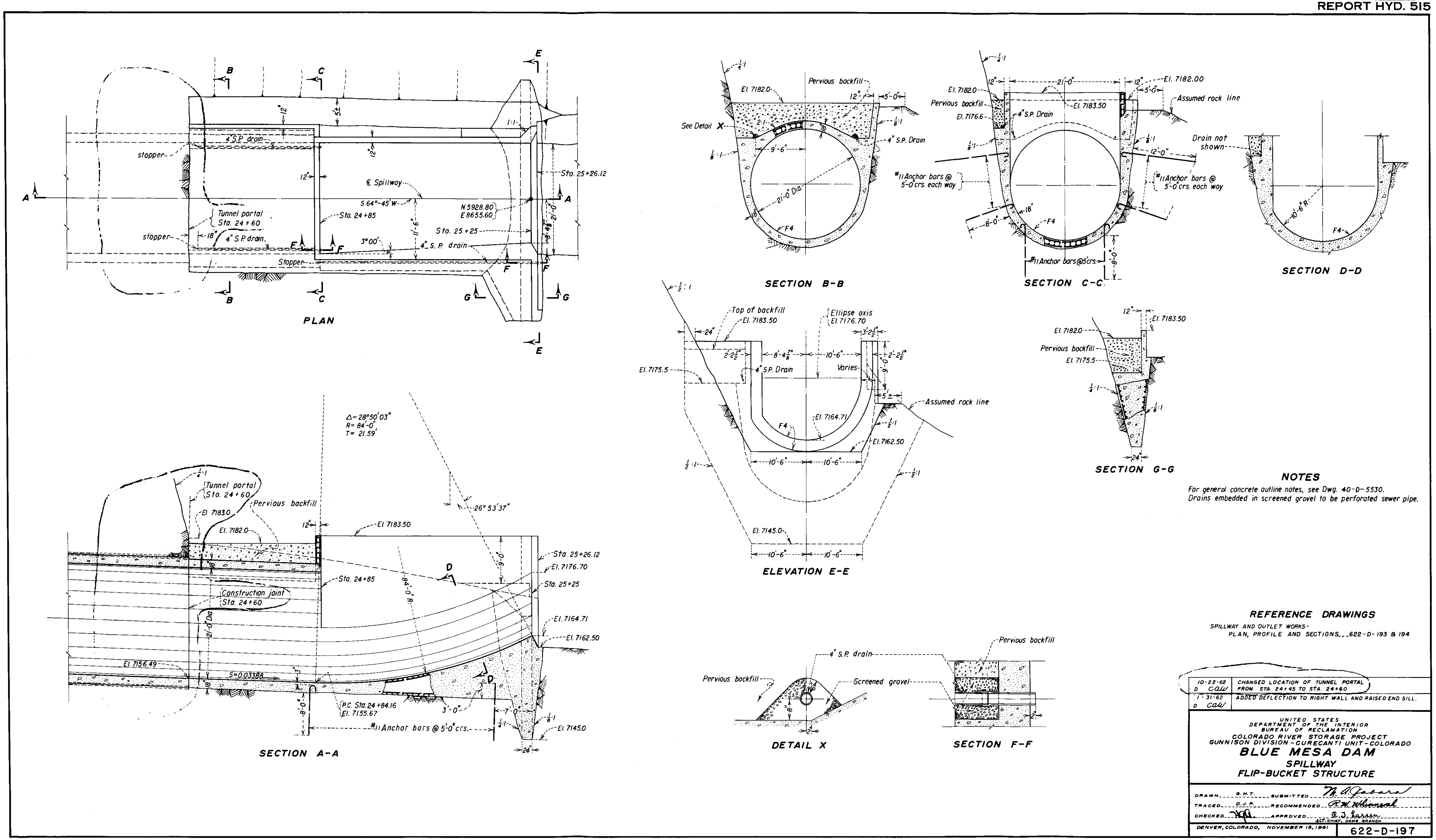
B. 8,400 cfs

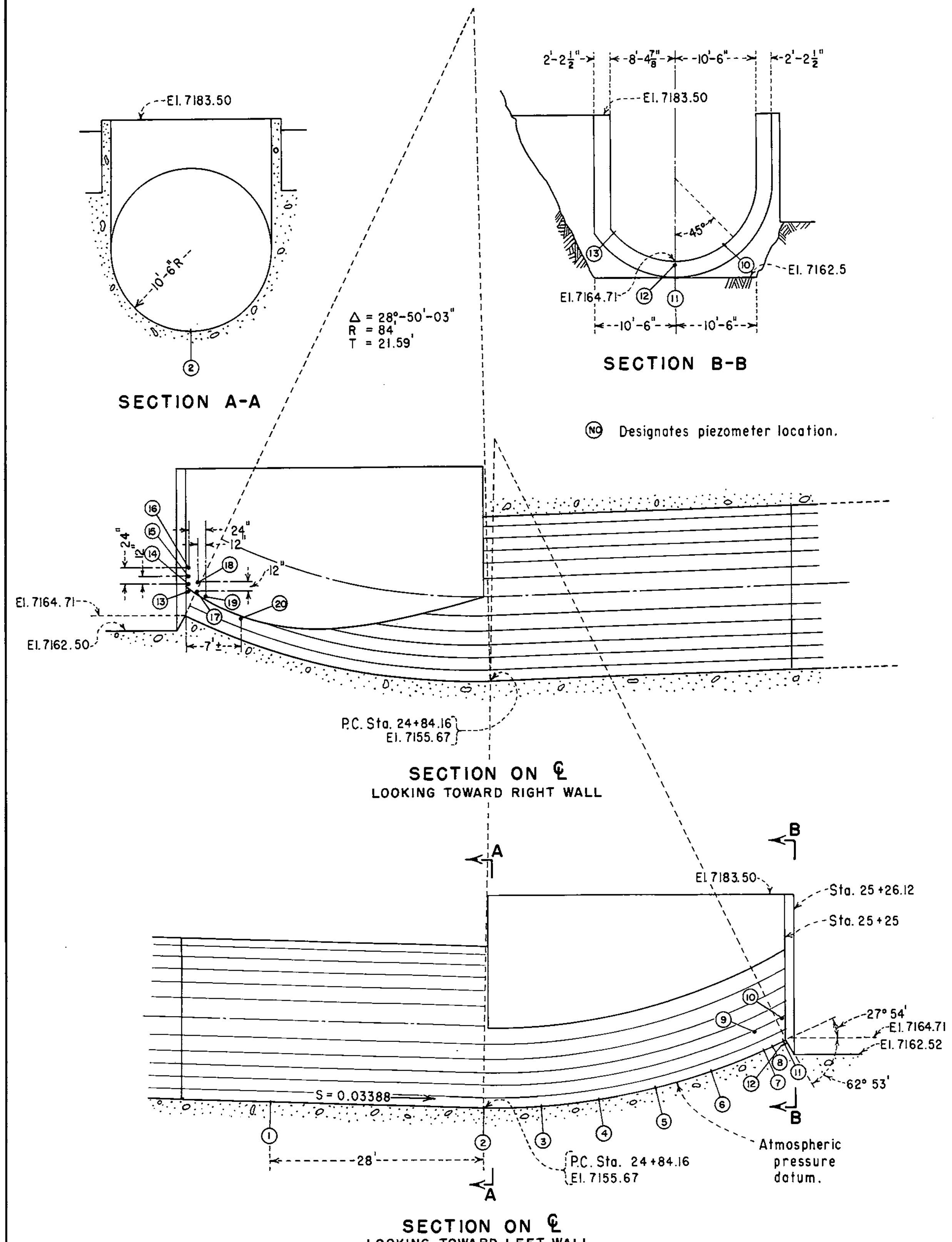
C. 16,850 cfs

D. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow from preliminary flip bucket--
powerplant and outlet works operating
1:32.78 scale model

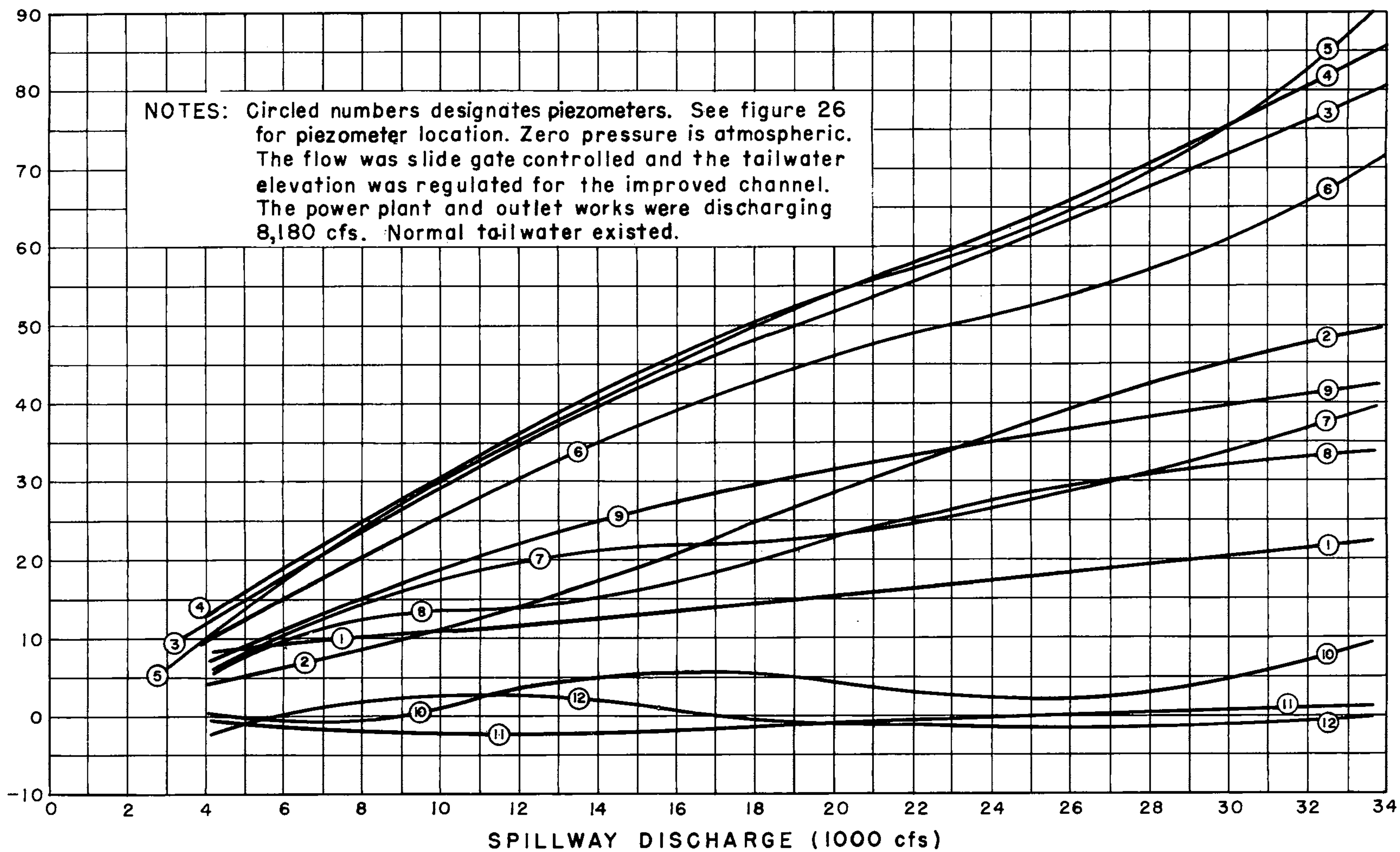

PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
ELEVATION E-E
SECTION G-G
DETAIL X
SECTION F-F
Tunnel portal Sta. 24+60
Sta. 24+85
Sta. 25+25
Sta. 25+26.12
℄ Spillway
S 64°-45' W
N 5928.80
E 8655.60
4" S.P. drain
stopper
Stopper
Pervious backfill
Screened gravel
Assumed rock line
Construction joint Sta. 24+60
P.C. Sta. 24+84.16
El. 7155.67
#11 Anchor bars @ 5'-0" crs.
#11 Anchor bars @ 5'-0" crs. each way
Δ= 28°50'03"
R= 84'-0"
T= 21.59'
S=0.03388
El. 7183.50
El. 7182.0
El. 7176.70
El. 7164.71
El. 7162.50
El. 7156.49
El. 7145.0
El. 7175.5
21'-0" Dia.
Drain not shown
Top of backfill
Ellipse axis
See Detail X
NOTES
For general concrete outline notes, see Dwg. 40-D-5530.
Drains embedded in screened gravel to be perforated sewer pipe.
REFERENCE DRAWINGS
SPILLWAY AND OUTLET WORKS-
PLAN, PROFILE AND SECTIONS...622-D-193 & 194
10-22-62 CHANGED LOCATION OF TUNNEL PORTAL FROM STA. 24+45 TO STA. 24+60
1-31-62 ADDED DEFLECTION TO RIGHT WALL AND RAISED END SILL.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GUNNISON DIVISION - CURECANTI UNIT - COLORADO
BLUE MESA DAM
SPILLWAY
FLIP-BUCKET STRUCTURE
DRAWN G.H.T. SUBMITTED
TRACED D.J.P. RECOMMENDED
CHECKED APPROVED
ACT. CHIEF, DAMS BRANCH
DENVER, COLORADO, NOVEMBER 15, 1961
622-D-197



BLUE MESA DAM SPILLWAY

PIEZOMETERS IN THE RECOMMENDED FLIP-BUCKET

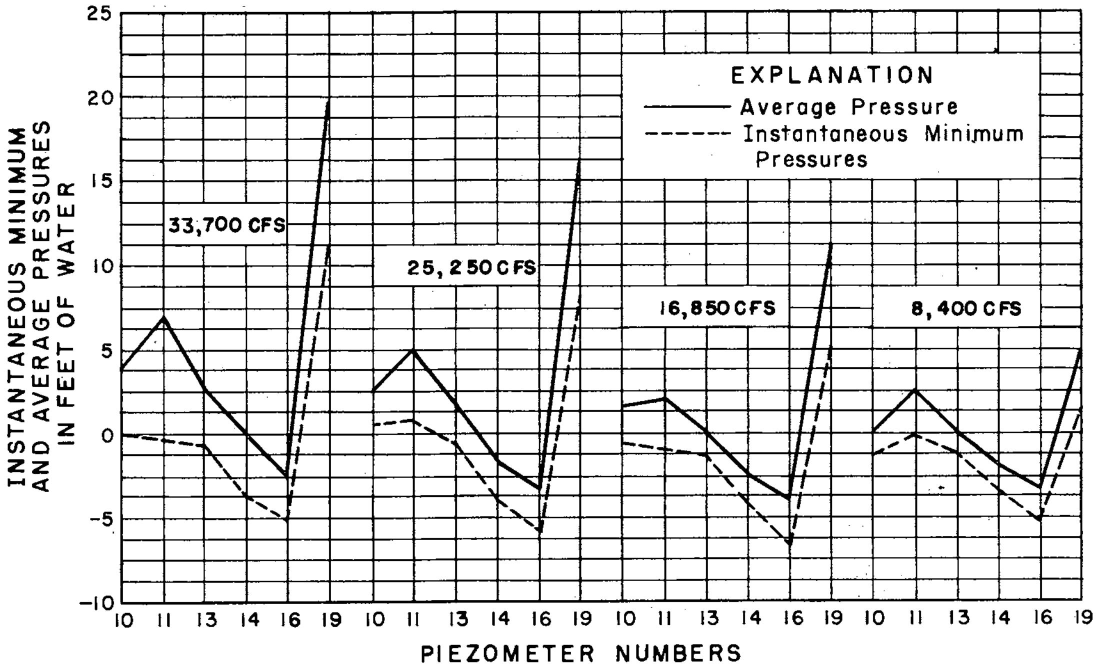
1:32.78 SCALE MODEL

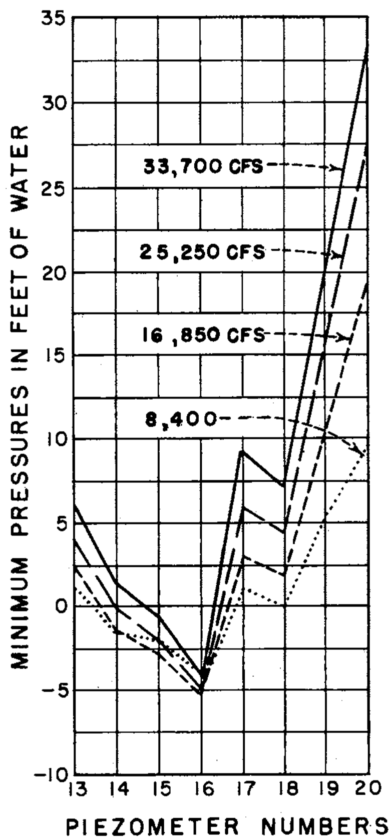


BLUE MESA DAM SPILLWAY

PRESSURES IN THE RECOMMENDED FLIP - BUCKET

1 : 32.78 SCALE MODEL





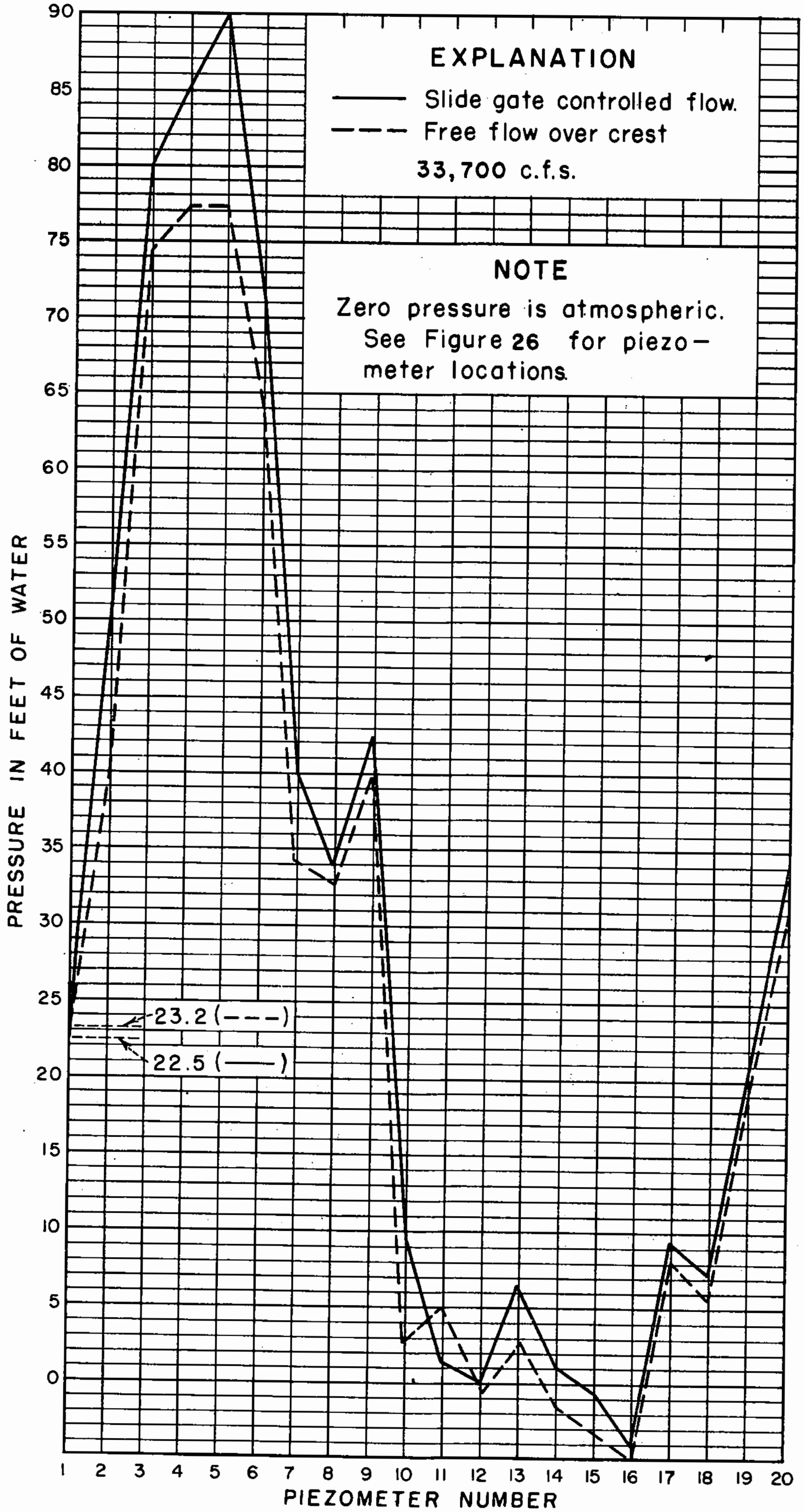
NOTES

Pressure transducers were used to measure the average and minimum pressures in the diagram above. Water manometers were used to measure the minimum pressures in the diagram on the left. Zero pressure is atmospheric pressure. The flow was slide gate controlled from the spillway. An additional 8,180 cfs. was being discharged from the powerplant and outlet works. The tailwater elevation was normal for the improved channel. See Figure 26 for piezometer location.

BLUE MESA DAM SPILLWAY

PRESSURES IN THE RECOMMENDED FLIP — BUCKET

1 : 32.78 SCALE MODEL



BLUE MESA DAM SPILLWAY

PRESSURES IN THE RECOMMENDED FLIP — BUCKET

1 : 32.78 SCALE MODEL

A. Both spillway gates open 5 feet

B. Left gate closed, right gate full open

C. Right gate closed, left gate full open

Discharge = 9,500 cfs

BLUE MESA DAM SPILLWAY

Spillway gate controlled flow from flip bucket
1:32.78 scale model

A. Spillway 8,400 cfs
Outlet works 5,100 cfs
Powerplant 3,080 cfs

B. Spillway 16,850 cfs
Outlet works 5,100 cfs

C. Spillway 25,250 cfs
Outlet works 5,100 cfs

D. Spillway 33,700 cfs
Outlet works 5,100 cfs

BLUE MESA DAM SPILLWAY

Flow from recommended flip bucket--
outlet works operating
1:32.78 scale model

A. 8,400 cfs

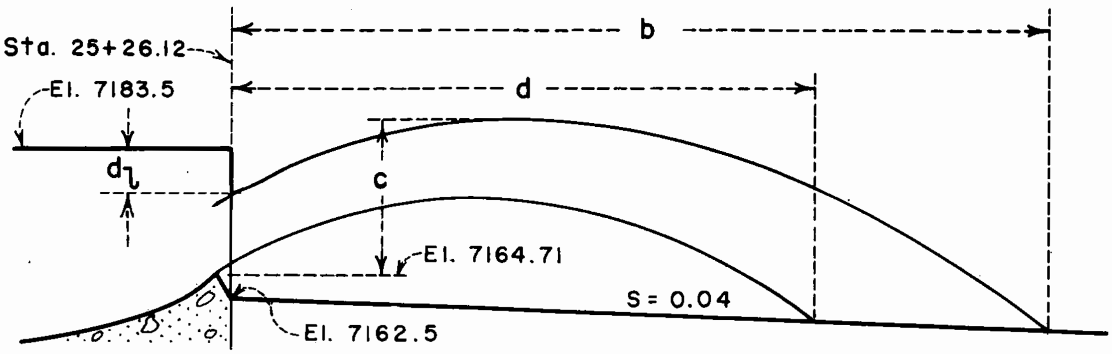
B. 16,850 cfs

C. 25,250 cfs

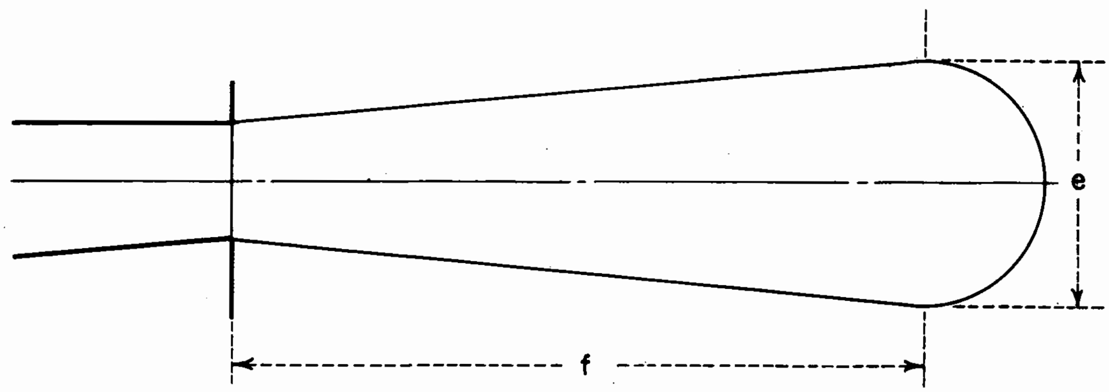
D. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow from recommended flip-bucket--no flow
from outlet works or powerplant
1:32.78 scale model



CENTER LINE PROFILE



PLAN

DISCHARGE C.F.S.	a	b	c	*d_R	*d_L	e	f
33,700	237	388	57	-5.5	-6.8	55	347
25,225	197	347	52	0	1.3	55	325
16,825	183	295	46	4.0	5.5	49	273
8,400	131	224	36	8.8	8.2	38	180
4,200	55	123	22	11.6	11.6	25	68

All dimensions are in feet.
*d_r is on right hand wall and d_l is on left hand wall.

BLUE MESA DAM SPILLWAY

JET DIMENSIONS IN THE RECOMMENDED FLIP-BUCKET

1 : 32.78 SCALE MODEL

A. Revised streambed and left bank topography

B. 5,500 cfs spillway

C. 5,500 cfs spillway
3,080 cfs powerplant

D. 5,500 cfs spillway
5,100 cfs outlet works
3,080 cfs powerplant

BLUE MESA DAM SPILLWAY

Flow from powerplant, outlet works, and recommended flip bucket
1:32.78 scale model

A. 9,500 cfs

B. 15,500 cfs

C. 21,500 cfs

D. 33,700 cfs

BLUE MESA DAM SPILLWAY

Flow from recommended flip bucket
1:32.78 scale model

A. 9,500 cfs spillway
5,100 cfs outlet works
3,080 cfs powerplant

B. 15,500 cfs spillway
5,100 cfs outlet works
3,080 cfs powerplant

C. 21,500 cfs spillway
5,100 cfs outlet works

D. 28,000 cfs spillway
5,100 cfs outlet works

BLUE MESA DAM SPILLWAY

Flow from powerplant, outlet works, and
recommended flip bucket
1:32.78 scale model

A. Spillway--5,500 cfs

B. Spillway--9,500 cfs

C. Spillway--15,500 cfs

D. Spillway--21,500 cfs

E. Spillway--5,500 cfs
Outlet works--5,100 cfs
Powerplant--3,080 cfs

F. Spillway--9,500 cfs
Outlet works--5,100 cfs
Powerplant--3,080 cfs

G. Spillway--21,500 cfs
Outlet works--5,100 cfs

H. Spillway--28,000 cfs
Outlet works--5,100 cfs

Note: Dark areas on roadway in C, D, F, G, and H is result of spray from jet.

BLUE MESA DAM SPILLWAY

Flow in stream channel--recommended flip bucket
1:32.78 scale model

A. 3,080 cfs powerplant

B. 5,100 cfs outlet works

C. 5,100 cfs outlet works
3,080 cfs powerplant

BLUE MESA DAM SPILLWAY

Flow over tailwater control structure--
no flow in spillway
1:32.78 scale model

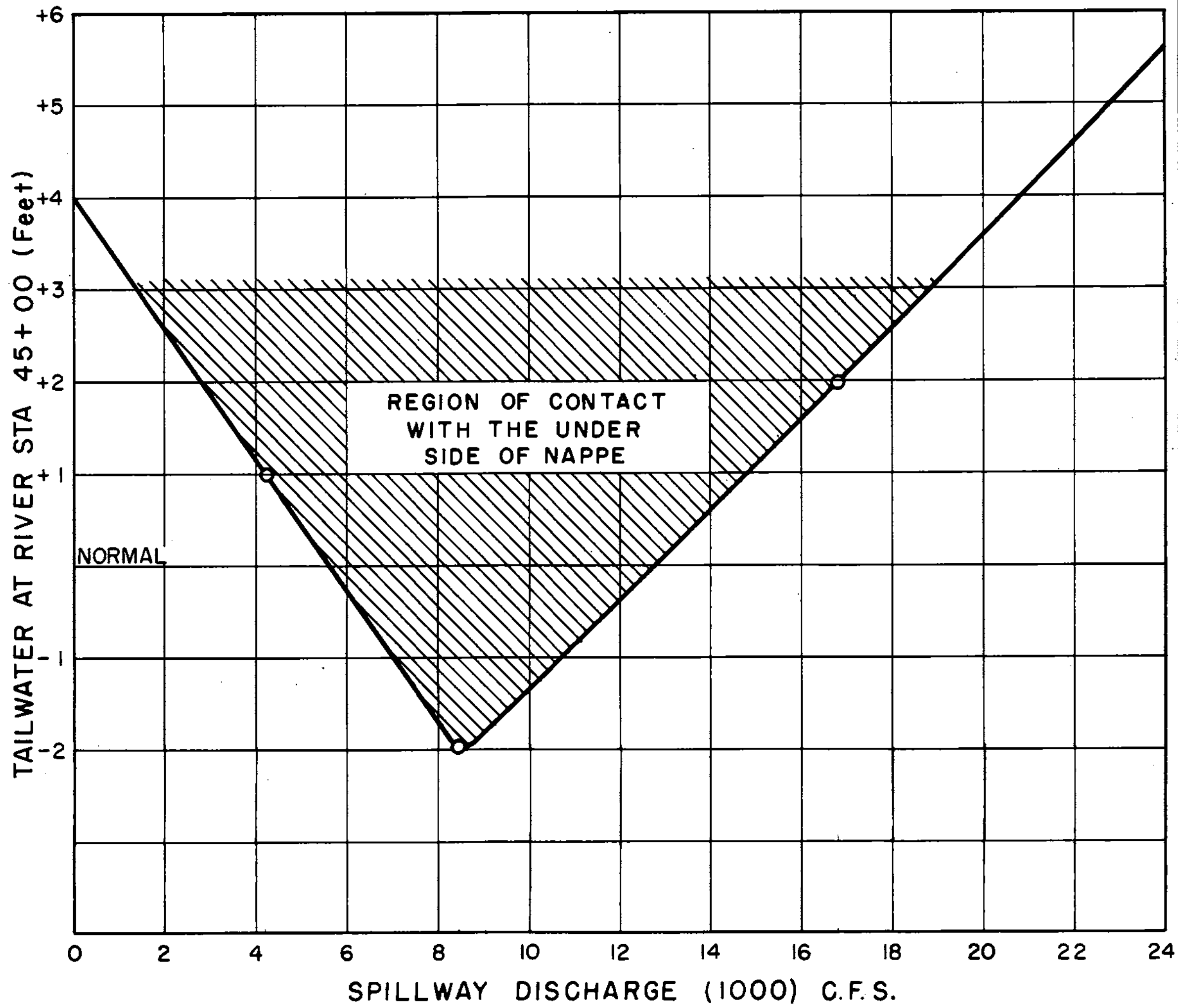
A. 15,500 cfs spillway
3,080 cfs powerplant

B. 15,500 cfs spillway
5,100 cfs outlet works

C. 15,500 cfs spillway
5,100 cfs outlet works
3,080 cfs powerplant

BLUE MESA DAM SPILLWAY

Flow over tailwater control structure--
spillway operating
1:32.78 scale model



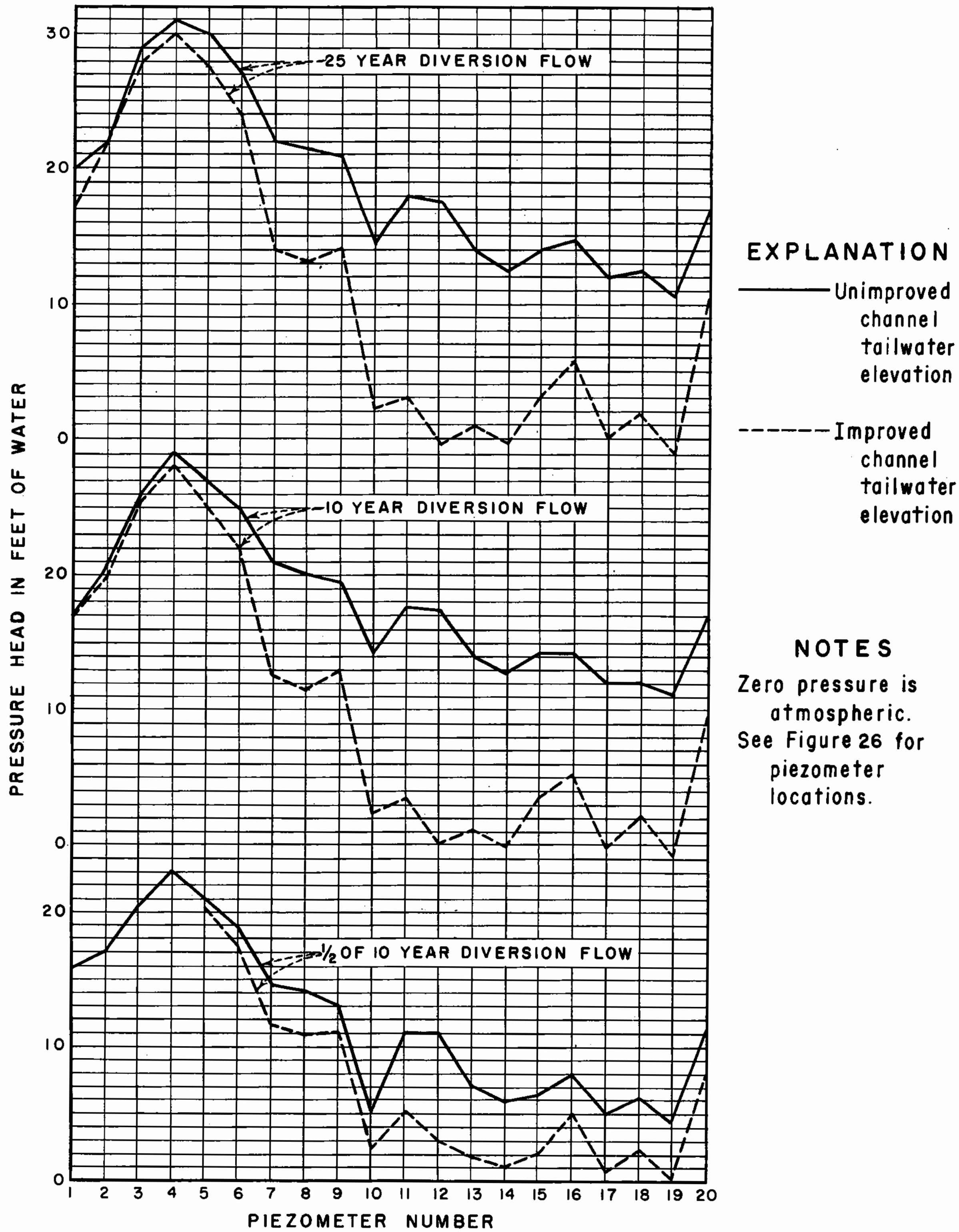
NOTE

Normal tailwater is for the improved channel.
The power plant and outlet works were discharging 8,180 c.f.s. in addition to the spillway discharge.
Circles (o) are data points.

BLUE MESA DAM SPILLWAY

WATER SURFACE CONTACTS UNDER SIDE OF JET

1 : 32.78 SCALE MODEL



BLUE MESA DAM SPILLWAY

DIVERSION FLOW PRESSURES IN THE FLIP-BUCKET

1:32.78 SCALE MODEL

665

A. 6,400 cfs, unimproved channel

B. 6,400 cfs, improved channel

C. 14,100 cfs, unimproved channel

D. 14,100 cfs, improved channel

BLUE MESA DAM SPILLWAY

Diversion flows in flip bucket

Figure 41
Report Hyd-515