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HYD 454

UNITED STATES
DEPARTMENT OF THE INTERIOR
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HYDRAULIC MODEL STUDIES FOR THE REHABILITATION OF THE OUTLET WORKS AND SPILLWAY FOR SHERBURNE LAKE DAM-- MILK RIVER PROJECT, MONTANA

Hydraulic Laboratory Report No. Hyd-454

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

August 7, 1959

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Commissioner's Office--Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Denver, Colorado
Date: August 7, 1959

Laboratory Report No. Hyd-454
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Submitted by: H. M. Martin

Subject: Hydraulic model studies for the rehabilitation of the outlet works and spillway for Sherburne Lake Dam--Milk River Project, Montana

PURPOSE

Studies were made to determine which of two spillway and outlet works arrangements was hydraulically better for modifying and improving the badly deteriorated, existing control structure.

CONCLUSIONS

1. Scheme A, which places two new gates within the inner control tower, produced much better outlet flow conditions than Scheme B, which places the gates between the inner and outer towers (Figure 4).

2. The Scheme A spillway, located on the outer tower and discharging down between the towers, performed satisfactorily.

3. The initial bellmouth inlets ahead of the Scheme A gates were unsatisfactory because the surfaces curved too abruptly and produced severe negative pressures at large gate openings. The more generously curved inlets shown in Figure 21 were not studied by model tests, but are believed to be satisfactory for prototype use.

4. The transitions from the flat floors of the gate passages to the curved floors of the conduits should be shaped so that abrupt changes in alinement and consequent severe negative pressures are avoided (Figure 21).

5. A flip bucket with wing walls is necessary at the outlets of the discharge conduits to properly direct the flow to minimize river channel scour and structural undermining (Figure 20).

6. Radial gates perform as well as slide gates in the Scheme A arrangement.

7. The Scheme B arrangement directs outlet flows against the inner walls of the conduits where the sediment and gravel being transported would produce abrasive damage (Figures 18 and 19). The flow also climbed the walls and crossed over the conduit crowns to produce undesirable conditions in the tunnels. Scheme B was therefore considered unsatisfactory.

8. Scheme A offers definite hydraulic advantages over Scheme B and is the better choice for use in the prototype rehabilitation program. The final design shown in Figures 20, 21, 22, and 23 are based on Scheme A.

ACKNOWLEDGMENT

The designs discussed, tested, and developed in this study were the result of close cooperation between the staffs of the Spillway and Outlet Works Section of the Dams Branch and the Hydraulic Laboratory.

INTRODUCTION

Sherburne Lake Dam is an earthfill structure completed in about 1918 and located on Swiftcurrent Creek in northwestern Montana (Figures 1 and 2). A gate-controlled overflow spillway in the left abutment, and an outlet works through the dam, were provided in the original structure. Unstable foundation conditions which developed during the construction period necessitated completing the spillway on a temporary basis using timber construction. Continuing foundation displacements and deterioration of the timber eventually required the abandonment and complete closure of the spillway with an earth embankment. Since this closure, all flows past the dam have necessarily gone through the outlet structure. The performance of this outlet structure was never satisfactory due to vibrations on the cylinder gates and surging within the towers. Also, the large quantities of debris that flushed through the system tended to bind the gates. These deficiencies, added to normal deterioration, resulted in the cylinder gates becoming inoperative a number of years ago. During subsequent years, regulation of all flows was by the six slide gates in the passages leading to the intake structure (Figure 3). These gates were originally intended as emergency gates, but recently have been used as service gates and were the sole means of flow regulation in the structure.

The general deterioration of the intake structure and the insecurity of operation without independent emergency gates have led to a general rehabilitation and revamping of the structure. Now, both a spillway and an outlet works will be combined within the tower. The original spillway in the left abutment will remain inoperative and the earthen dike across it will be raised and strengthened.

Two plans, or schemes, were proposed for modifying the tower. In Scheme A, two service outlet gates would be placed within the inner tower, and a spillway would be placed on top of the outer tower (Figure 4).

With this arrangement, the outlet works flows would discharge in line with, and directly into, the two outlet conduits that pass through the dam to the river. Spillway flows would pass over the new crest, downward through the passage between the inner and outer towers, and into the outlet conduits. The spillway crest would extend only about two-thirds of the way around the tower because this provides all the crest length needed to pass expected discharges. Scheme A had the advantages of directing the outlet flows straight into the conduits with minimum disturbances, and of relatively large spillway discharges with little rise in reservoir elevation due to the long crest. It had the disadvantage of additional cost.

In Scheme B, the two service gates would be placed between the inner and outer towers, and the spillway crest would be cut through the inner tower (Figure 4). The outlet works flows would be directed at an angle to the line of the outlet conduits and flow disturbances were expected at the tunnel entrances. The spillway flows would pass down in the inner tower and directly into the outlet conduits. Scheme B had the advantages of a less expensive spillway, and of directing the spillway flows straight into the conduits. It had the disadvantages of more turbulence at the conduit entrances with outlet works flows, and of reduced spillway capacity.

To determine the relative advantages and disadvantages of the two schemes, and which would be more suitable for use in the prototype structure, hydraulic model studies were made. The models used in these studies, and the results that were obtained, are discussed in this report.

THE MODEL

A scale ratio of 1:15 was selected as the best compromise between size of model needed for accurate results, and the construction costs, laboratory space, and water supply limitations. The model consisted of a large head box containing the intake tower and gate assembly; the conduits; and the tail box containing the conduit outlets and the river channel (Figure 5). The metal-lined wooden head box contained a rock baffle for distributing the flow to provide smooth approach conditions in the reservoir, and a representative section of the earthfill dam. The outlet approach channel and control tower were situated in this earth dam section (Figures 5 and 6A). Part of the outlet tower extended above the specially shaped downstream end of the head box while the remainder of the tower with the outlet works proper was exposed beneath the box (Figure 6B). This construction allowed access to the gates and conduits for operation and for visual inspection of the flow. To facilitate this inspection, transparent plastic was used on most of the model. The downstream portion of the conduits, their outlet structure, and the toe of the dam were located in the metal-lined tail box (Figure 6C). A section of river channel downstream from the conduit outlets led to the tail gate used to regulate the model tail water (Figure 10A).

Suitable point gages were provided to measure the reservoir water surface elevation in the head box, and the tail water elevation in the tail box. One-sixteenth-inch-diameter piezometers were placed in the bellmouth entrances ahead of the gates, and at critical areas near the gates and in the

conduits, to enable determination of the pressure conditions. The pressures were read in terms of feet of water on single leg water manometers. The rate of flow in the water entering the model was measured by calibrated Venturi meters in the permanent laboratory supply system. The water leaving the models was returned to the laboratory reservoir for recirculation.

INVESTIGATION

Conduit Outlets and Flip Buckets

Tests were first made to determine the outlet portal design needed for discharging water from the conduits into the river channel without producing excessive scour in the channel and on the toe of the dam. The existing apron at the end of the conduits was 20 feet long, level, and with side walls spaced 21 feet apart. The distance between the outer walls of the conduits was 14 feet, which resulted in 3-1/2-foot outward offsets between the outer conduit walls and the side walls of the apron. Experience has shown that these offsets or setbacks are undesirable because the flow spreads after leaving the conduits and impinges on the walls to form large, undesirable fins. To prevent this spreading and impingement, the walls on the model apron were placed 14 feet apart and flush with the outer conduit walls. The apron was set at elevation 4718.5 and was level with the bed of the river. The walls were 8 feet high.

Tests showed that as the water discharged from the apron and passed along the riverbed, it caused severe eddying and scour (Figure 7). This scour occurred not only in the riverbed, but on the toe of the dam, and the apron was seriously undermined. Also, the walls were too low, and large quantities of water poured over them and onto the flow emerging from the conduits. This flow condition tended to depress the jets and increase the scour.

Greatly improved conditions were obtained by installing an upward curve at the end of the apron to form a ski jump or flip bucket, and by raising the wall tops to elevation 4732.0 (Figures 5 and 8). The radius of bucket curvature was 15 feet, prototype, and the curve was continued to produce a 4-foot rise above the upstream apron floor. Forty-five degree wing walls 15 feet long were added at the downstream ends of the higher walls to protect the structure from undermining.

This flip bucket and wing wall arrangement lifted and directed the moderate and high velocity flows to greatly reduce the eddying and scouring near the dam (Figures 8 and 9). Low velocity flows passed smoothly over the bucket lip and into the tail water (Figure 11). No appreciable scour occurred. The wing walls protected the bucket from undermining and reduced the erosion on the toe of the dam at all flows.

At small discharges and low velocity flows, hydraulic jumps formed in the conduits due to the back pressure, or depth, created by the 4-foot rise

of the flip buckets (Figure 14F). These jumps took place without undue commotion, but pumped a great deal of air out of the conduits. This air can be readily supplied through the spillway passages when the reservoir is below crest level. When the reservoir level is above the crest, the vents at the outlet gates will meet the air demand.

The 14-foot wide flip bucket with high training walls and 45° wing walls was considered satisfactory for prototype use.

Scheme A Outlet Works

Outlet Works Using Slide Gates

Water passed smoothly through the two 4-foot wide by 5-foot high slide gates within the inner tower and entered the outlet conduits. Disturbances then occurred due to the spreading of the jets as they left the 4-foot wide gate conduits and impinged on the inner and outer walls of the 6-foot wide tunnels. No confining walls could be placed along the jets on the outer side of each conduit because openings were needed for the entry of spillway flows into the conduits. The inner sides of the jets from the gates were unconfined also.

Upon entering the conduits, the flow reached the transitions where the flat floor of the gate passages blended into the curved inverts of the conduits (Figure 5). This transition, which was most severe at the walls, aggravated the tendency for fins to form in the conduit. Fortunately, the fins were relatively thin and did not seriously affect the performance or the free passage of air through the conduits. Pressures measured at areas believed critical on and near the transitioning surface were for the most part positive at all gate openings and reservoir elevations (Figure 10B). Pressures observed at Piezometer 4, which is on the curved invert just downstream from the end of the transition surface, were slightly below atmospheric. The pressures were not low enough to indicate cavitation in the prototype structure. Rounding at the intersection of the transition and the conduit inverts would reduce the tendencies for subatmospheric pressures and provide a greater safety factor for local pressure reductions at surface irregularities.

Single gate operation was entirely satisfactory in the tower and conduits. A slight sideward flow component existed in the flip bucket, but no undue difficulties were caused by it (Figure 14). When only one gate operated, the other conduit stood partly full of water. The second gate could be satisfactorily brought into operation against this ponded water by opening it reasonably slowly.

Outlet Works Using Radial Gates

A proposal was made to use 5-foot wide by 4-foot high radial gates instead of slide gates because radial gates might prove less costly (Figure 15). The decreased height of the gate made it possible to raise the passage

inverts to elevation 4721.0, which was level with the intersection line of the curved conduit floors with the side walls. The passage floors downstream from the gates dropped on trajectory curves to meet the existing conduit inverts. New bellmouth sections were laid out using the same design criteria as used on the initial bellmouths.

Model tests showed that the radial gates performed satisfactorily and much the same as the slide gates. The modified gate passage inverts and transitions to the conduit floors produced somewhat better flow conditions on the floor and the conduit walls. The pressures in the corners of the bellmouth sections ahead of the gates were quite low, and therefore unsatisfactory, for both symmetrical and unsymmetrical gate operation.

A later decision was made against using the radial gates because their light construction, compared with slide gates, would be less well adapted to resisting the flow turbulences, pressure surges, and vibrations likely to occur when the conduits fill during spillway discharges. No further tests were made with radial gates.

Scheme A Spillway

Water passed smoothly over the Scheme A spillway crest and into the passage between the inner and outer towers (Figures 16 and 17). Conditions were turbulent in the lower part of the passage as the flows plunged into the pool at the base of the intake tower. At flows up to about 700 cfs, the conduits flowed partly full. At larger flows, the conduits filled completely.

Great quantities of air were entrained by the water falling from the crest and plunging into the pool in the tower (Figures 16 and 17). This air was carried into and through the conduits and part of it accumulated into pockets. Upon reaching the portals, the pockets burst forth into the open and created considerable spray. The water, with the remainder of the entrained air, passed reasonably smoothly through the flip bucket and into the river channel.

When the reservoir elevation was raised and the spillway flows increased, the pool within the tower rose. Thus, less drop occurred from the reservoir surface to the pool, and more tranquil flow with less entrainment of air took place in the tower. At a spillway discharge of about 2,300 cfs, the pool within the tower was high enough to submerge the crest and prevent any appreciable entrainment of air.

In the area just above the outlet conduit entrances, the inner and outer towers are connected by a concrete section (Figures 16 and 17). Square corners were initially to be used on the ends of the section. Tests showed that the flow passing around these squares ends had a pronounced tendency to separate from the surfaces and produce negative pressures. Rounded ends on the prototype structure will reduce these difficulties and the pressures should be satisfactory (Figure 21, Section F-F). No tests were made of the rounded ends.

Scheme B Outlet Works

The flow through outlet gates placed between the inner and outer towers was smooth (Figures 4, 18, and 19). However, the water from the gates approached the conduits at an appreciable angle and impinged heavily on the inner walls. It then climbed the walls and crossed over the roofs to drop down the outer walls. The action was moderate at small gate openings and became progressively worse at larger openings. When just one gate operated, a pool of water was held in the other conduit by the elevated lip of the flip bucket. This water moved upstream in the unused conduit and then swept around the nose of the pier between the conduits and into the high velocity flow of the operating conduit.

A serious objection to the design was that excessive abrasive and impact damage would occur on the conduit inner walls where they would be struck by the sediment-laden flows from the gates. A further objection was that severely negative pressures occurred on the conduit outer walls at their junction with the angled outer walls leading from the gates (Figures 4 and 10C). This intersection was rounded to a considerable degree in the initial design but an even greater rounding would be necessary to obtain satisfactory pressures.

The flow continued through the conduits, alternately climbing the inner and outer walls. The height of climb gradually decreased, but was still appreciable when the flow reached the flip bucket. Unsymmetrical flows through the bucket tended to slightly increase the disturbances in the river channel and aggravate the scouring.

It was concluded that even though the initial cost of Scheme B was less than for Scheme A, the deficiencies in outlet works performance in Scheme B were enough to rule out its use. Therefore, no further tests were made with the Scheme B outlet works, and no model representation was made of the spillway structure.

Final Design--Outlet Works and Spillway

Outlet Works

The Scheme A arrangement was used for the final design. (Figures 20, 21, 22, and 23.) Two 4-foot wide by 5-foot high slide gates were placed 8 feet apart within the center tower, with their inverts at elevation 2720.0. New bellmouth sections were provided upstream from the gates. These bellmouths were formed with elliptical surfaces having major axes three times the length of the minor axes. No curved surface was provided at the top of the passage because it was level with the inlet roof. The major axis of the sidewall curves was equal to the 4-foot width of the passage. The major axis of the invert ellipse would, by the same process, equal the height of the passage if a top convergence were provided. In this structure, there is no top convergence and the flat roof approximately represents the center line position in a symmetrical conduit, insofar as flow pattern is concerned. The

equivalent height of a symmetrical passage providing a companion top convergence would therefore be twice this 5-foot passage height, or 10 feet. There was insufficient length within the tower section to allow using this 10-foot axis, however, and it was necessary to compromise with a 6-foot major axis. It is believed that with the moderate heads that act on the Sherburne Lake outlet works, this compromise curve will produce pressures high enough to be entirely safe. No model studies were made of the final bellmouth section.

The conduit walls downstream from the gates were made parallel to keep the water from spreading excessively (Figure 21). After leaving this straight conduit, the water travels a short distance without sidewall confinement, and then enters the outlet conduits. To reduce the tendency for fins to form and negative pressures to occur, the floor transitions from the flat to the curved surfaces were made with curving elements. These curves will be produced in the existing prototype concrete by dressing the present straight surfaces.

No model studies were made of the final design outlet works because of inadequate funds. Thus, there are no model-determined calibration curves. A computed discharge curve is presented in Figure 20.

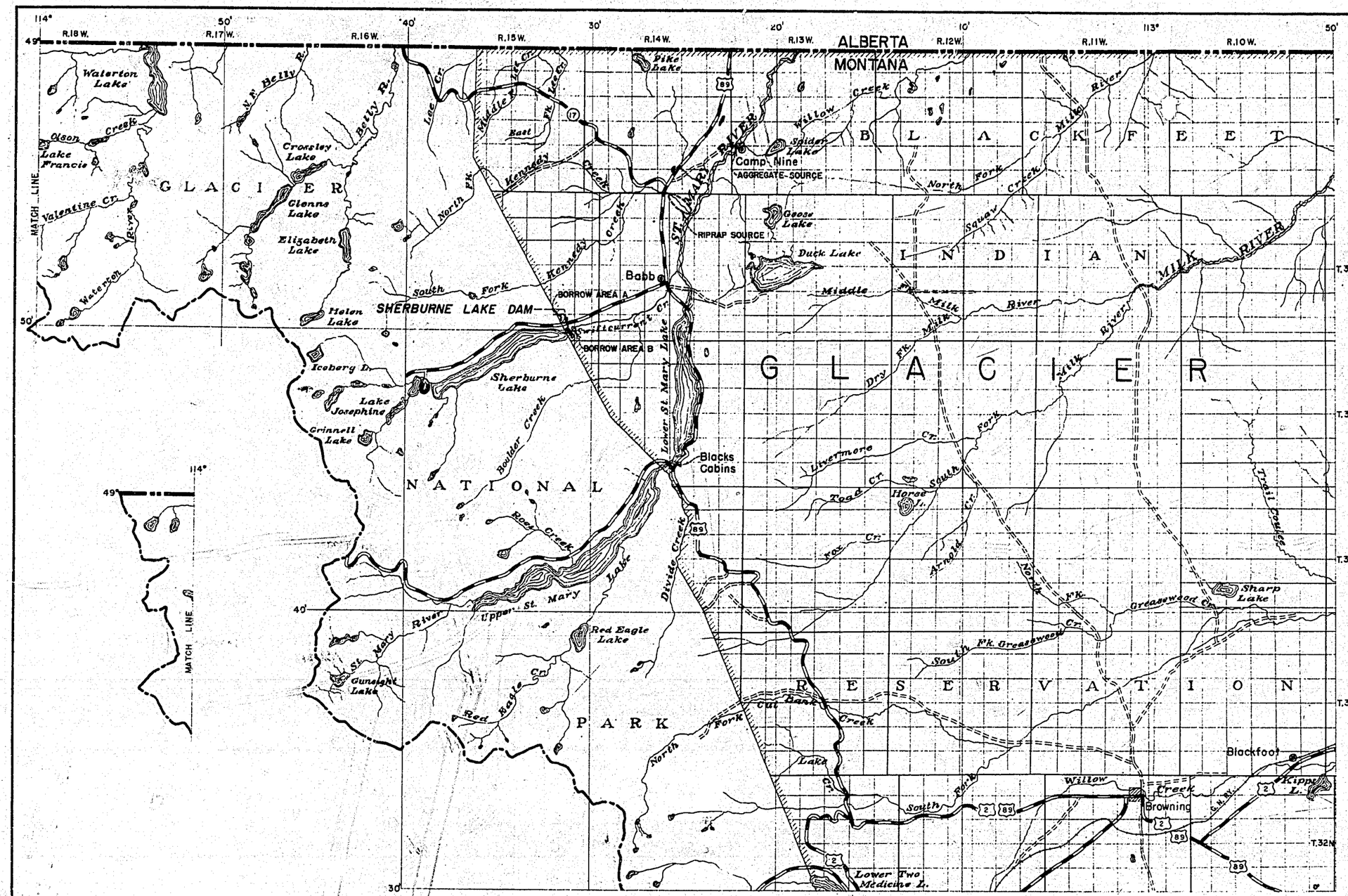
Spillway

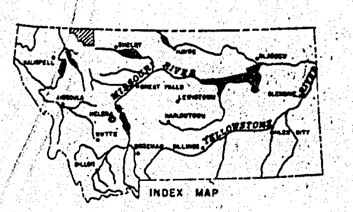
The final spillway was about the same as the one tested in the model (Figure 22). The principal difference is that the final crest extends around to existing walls on and in the towers instead of stopping at new walls that would have been constructed. This resulted in a longer crest, and a probable tendency for minor flow interferences at the crest ends. Trash bars and their necessary supporting structures were also included on the spillway. No model studies were made of this final design and no model calibration curves are available. A computed curve based upon the increased crest length, with allowances for trash bar losses, is presented in Figure 20.

Flip Bucket

The final flip bucket was basically the same as the one developed in the early part of the model test program (Figure 20). Two design improvements were made. These consisted of continuing the curved inverts of the conduits downstream to where they intersect the upward curve of the bucket, and providing a 3-foot wide, flat top downstream from the bucket lip. The performance of this bucket is expected to be satisfactory for all outlet works and spillway flows. No model studies were made on it because of inadequate funds.

FIGURE 1
REPORT HYD. 454





LEGEND

- U.S. & STATE HIGHWAYS
- ROADS
- RAILROADS
- CANAL
- INDIAN RESERVATION BOUNDARY
- FOREST BOUNDARY

N

SCALE OF MILES

11-19-38 D-1462	CONSTRUCTION MATERIALS SOURCES ADDED

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MILK RIVER PROJECT - MONT.
ST. MARY STORAGE DIVISION

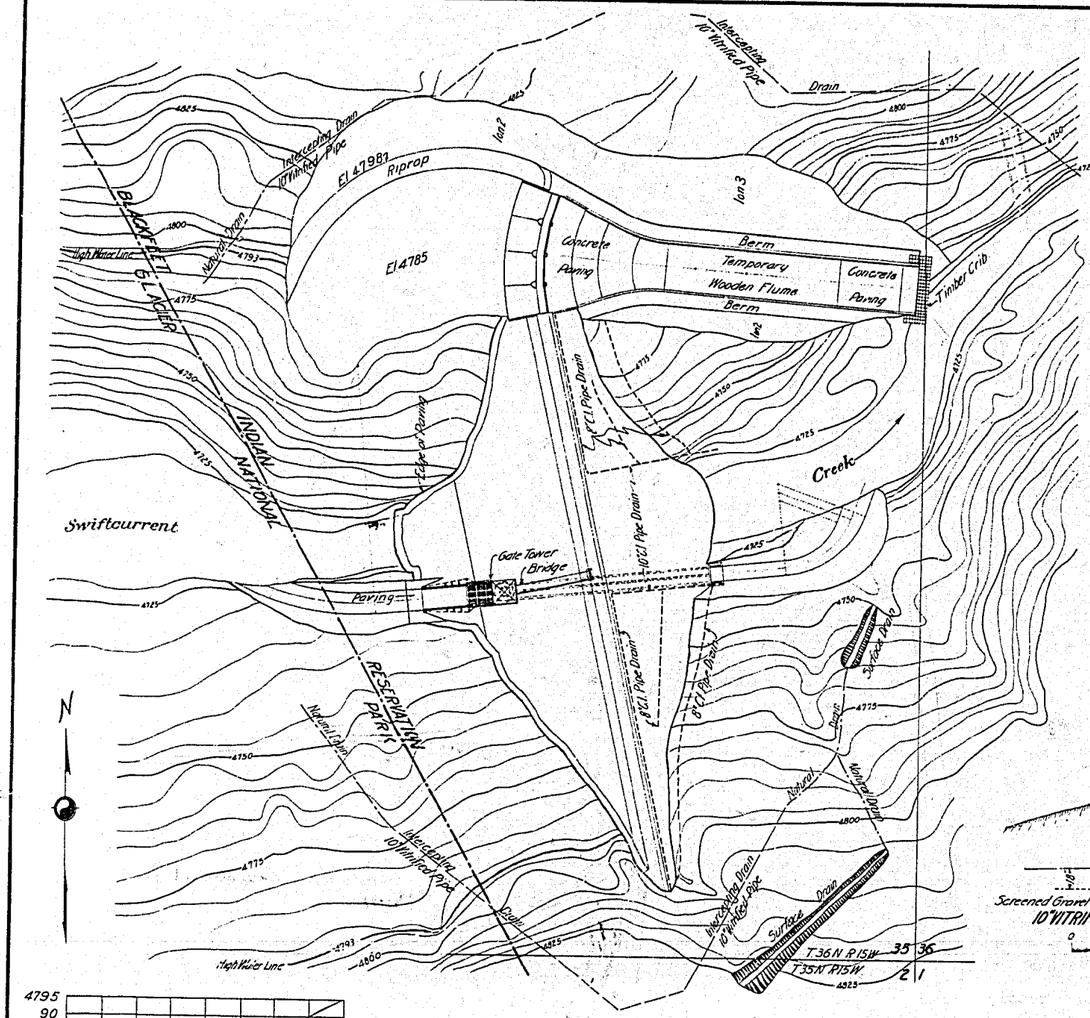
SHERBURNE LAKE DAM

LOCATION MAP

DRAWN C.R.L. SUBMITTED U.W. Stone
TRACED M.P.S. RECOMMENDED
CHECKED W.H.S. APPROVED
GREAT FALLS, MONTANA, JUNE 20, 1938

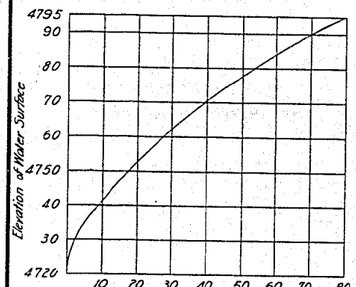
15-604-169

FIGURE 2
REPORT HYD. 454



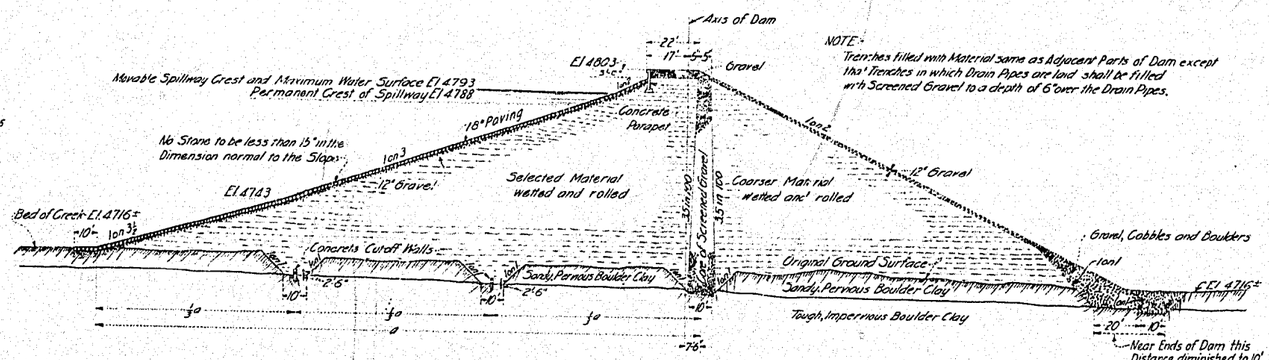
PLAN

SCALE

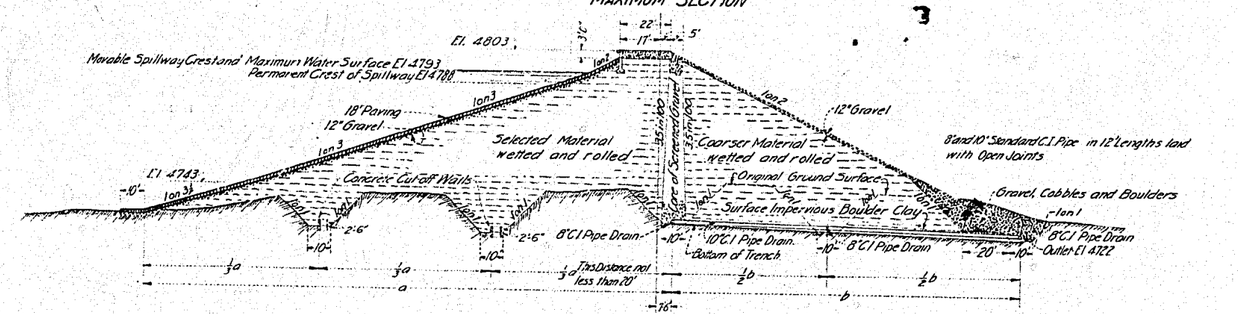


CAPACITY CURVE

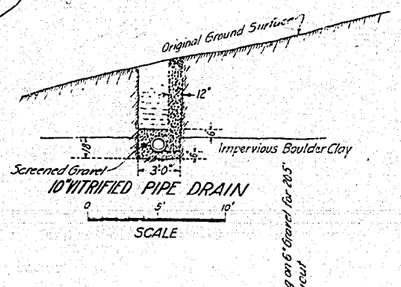
CAM

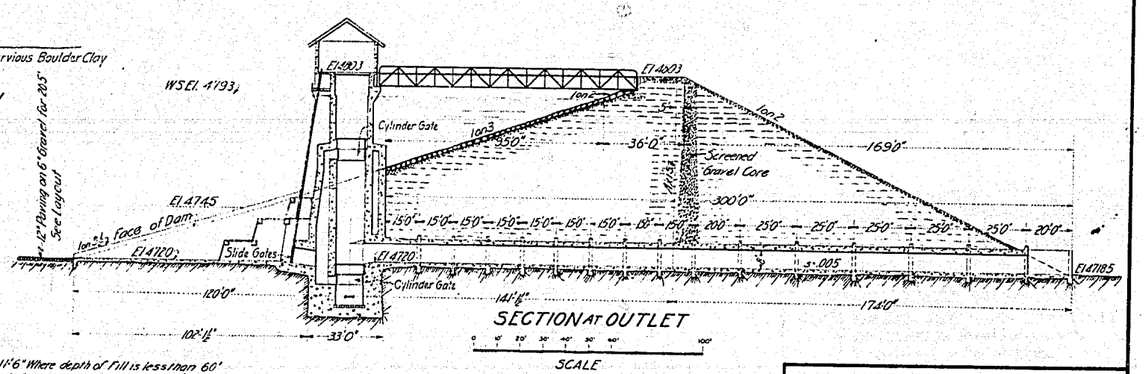


MAXIMUM SECTION



SECTION AT DRAIN

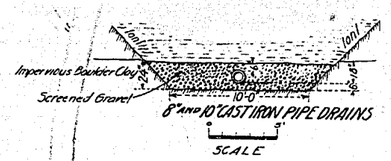


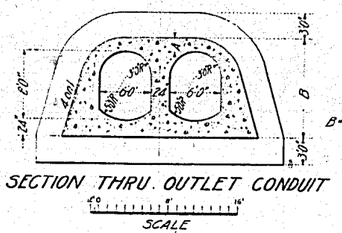


SECTION AT OUTLET

SCALE

A = 18" Where depth of Fill is less than 60'
2'0" " " " 60' to 80'
2'6" " " " 80' " 100'





B = 11'6" Where depth of Fill is less than 60'
11'9" " " " 60' to 80'
12'0" " " " 80' 100'

NOTE:-This Drawing compiled from Design Drawings made in the Washington and Project Offices

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
MILK RIVER PROJECT- MONTANA
SHERBURNE LAKES OUTLET WORKS
LAYOUT AND DAM SECTIONS

Drawn C.A.M. Recommended J.L. Savage
Checked T.A.G. Approved A.P. Davis
Denver, Colorado, March 1, 1920
Sheet 1 of 6
16-C-14

SECTIONAL ELEVATION E-E

HALF SECTIONAL PLANS C-C AND D-D

NOTES:
1. Length of three upper Guard Piers 110' Length of Lower Guard Pier on Stem 5, 15'-5½".
2. Rear Diaphragm extend full height of double Wall with One Diaphragm extend full height double Wall with three Openings Lower Openings extends 12' above Sill of El 4735, middle Openings extends to Sill of El 4735 and upper Openings to Sill of El 4752.
3. Concrete Reinforcement not shown.

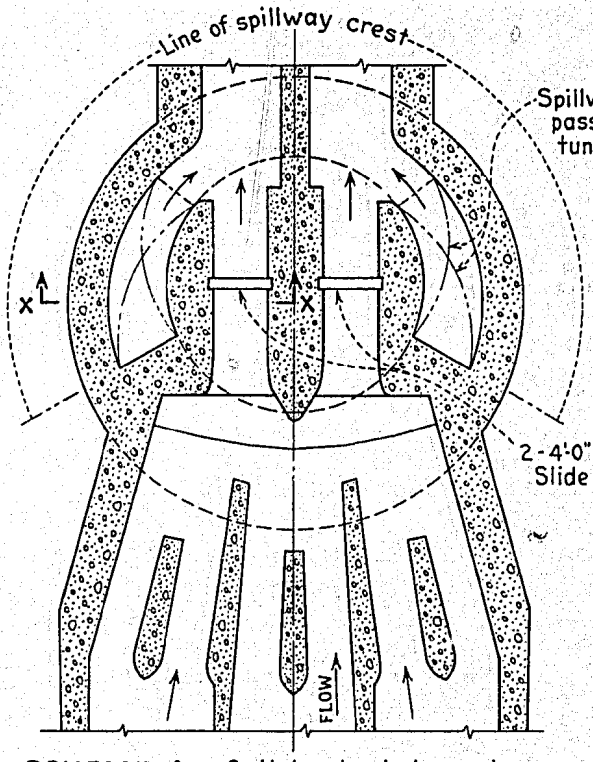
NOTE: This Drawing compiled from Design Drawings made in the Washington and Project Offices

SCALE

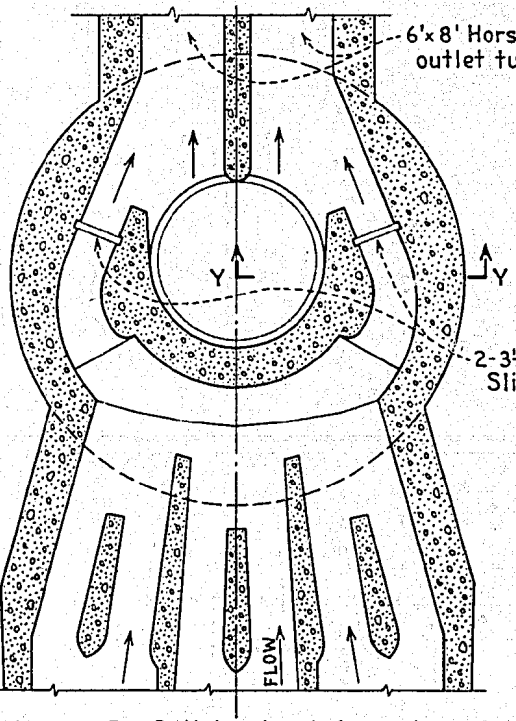
DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
MILK RIVER PROJECT- MONTANA
SHERBURNE LAKES OUTLET WORKS
GATE TOWER - SECTIONS

Drawn: ETB & CAM Recommended: J. L. Savage
Checked: J. A. H. Approved: F. E. Weymouth

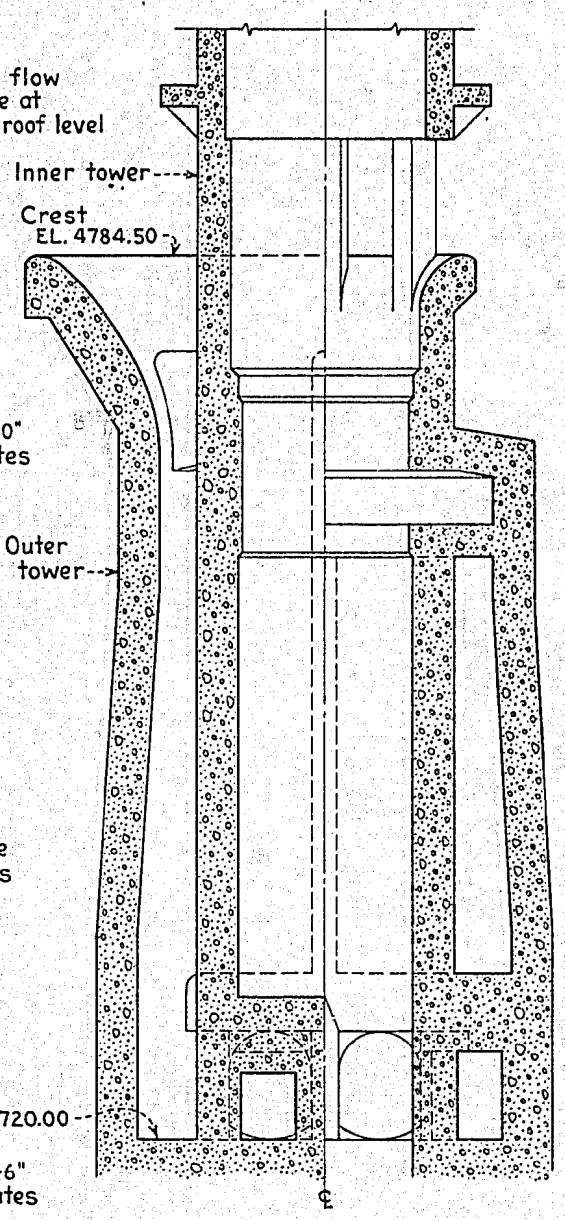
20417 | Denver, Colorado March 1, 1920. Sheet 3 of 6. | 16-C-16



SCHEME A – Outlet gates in inner tower with spillway flows passing between inner and outer towers.



SCHEME B – Outlet gates between inner and outer towers with spillway flow passing into inner tower.

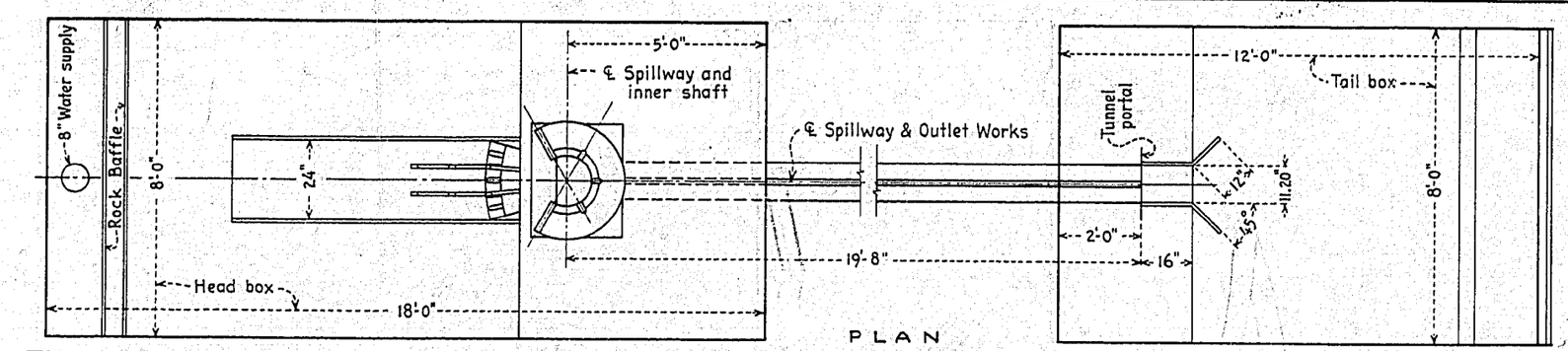


SECTION X-X
SYMMETRICAL ABOUT ℄
(SCHEME A)

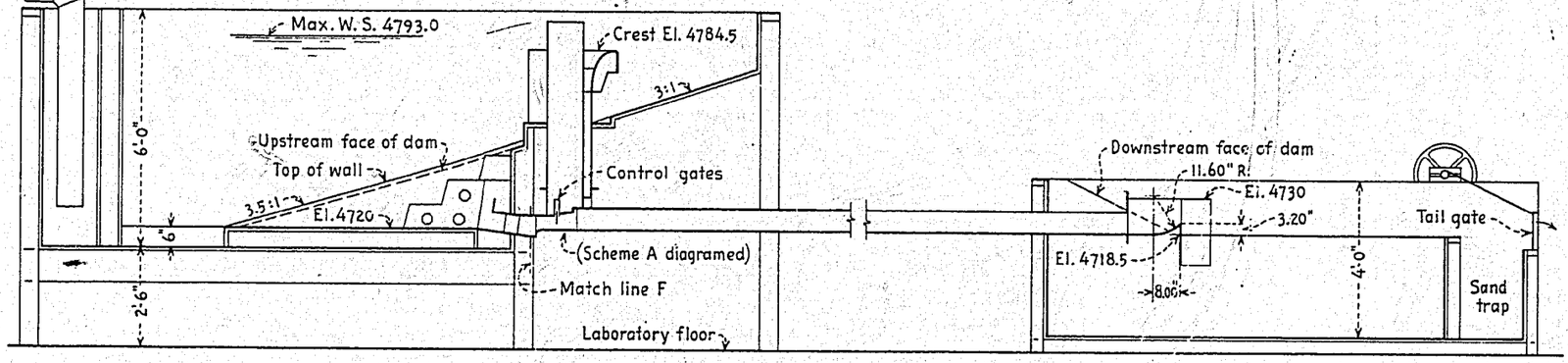
SECTION Y-Y
SYMMETRICAL ABOUT ℄
(SCHEME B)

SHERBURNE LAKE
SPILLWAY AND OUTLET WORKS

PROPOSED SCHEME A AND SCHEME B REVISIONS FOR REHABILITATING STRUCTURE

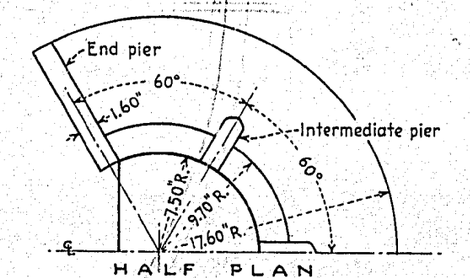


PLAN

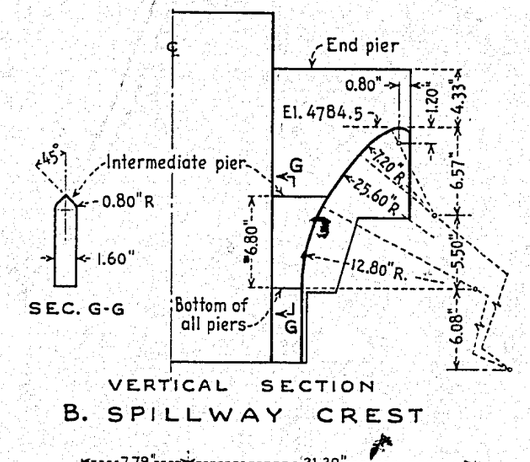


LONGITUDINAL SECTION

A. MODEL ASSEMBLY



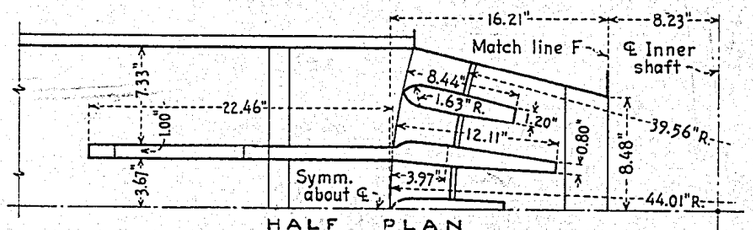
HALF PLAN



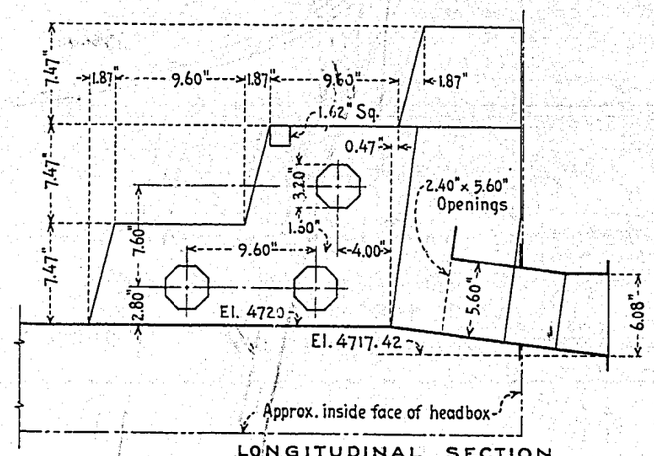
SEC. G-G

VERTICAL SECTION

B. SPILLWAY CREST

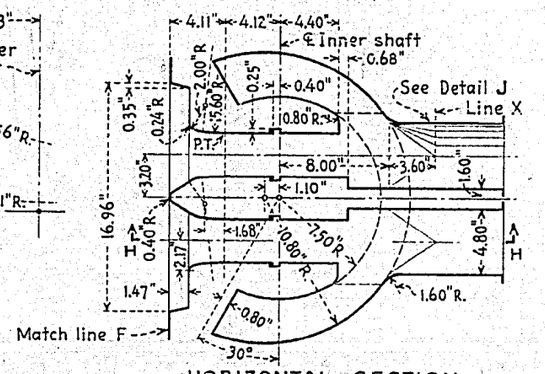


HALF PLAN

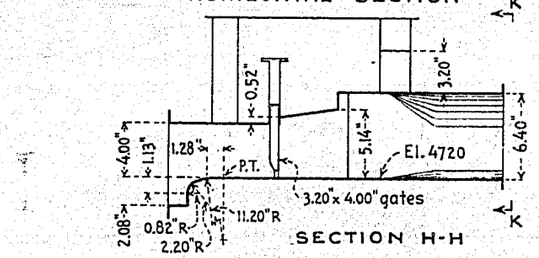


LONGITUDINAL SECTION

C. OUTLET WORKS ENTRANCE CHANNEL

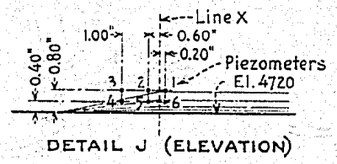


HORIZONTAL SECTION

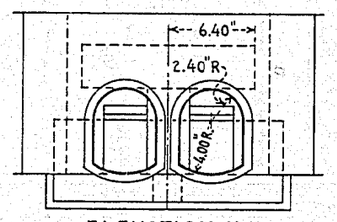


SECTION H-H

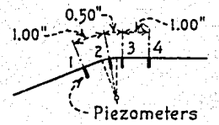
D. OUTLETS THROUGH INNER TOWER (SCHEME A)



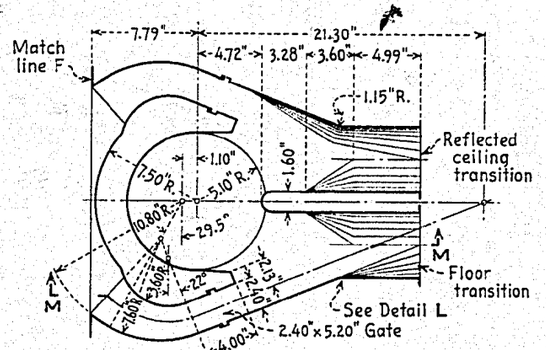
DETAIL J (ELEVATION)



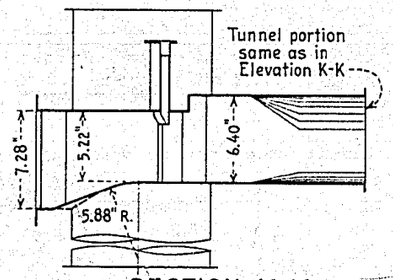
ELEVATION K-K



DETAIL L (PLAN)



HORIZONTAL SECTION

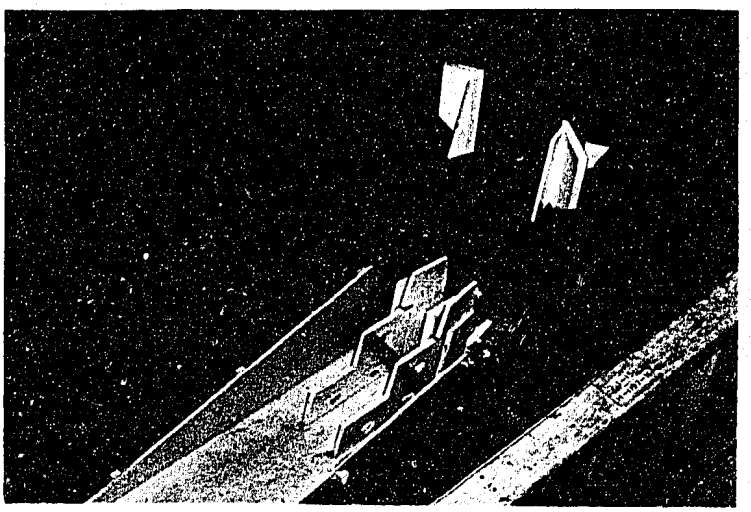


SECTION M-M

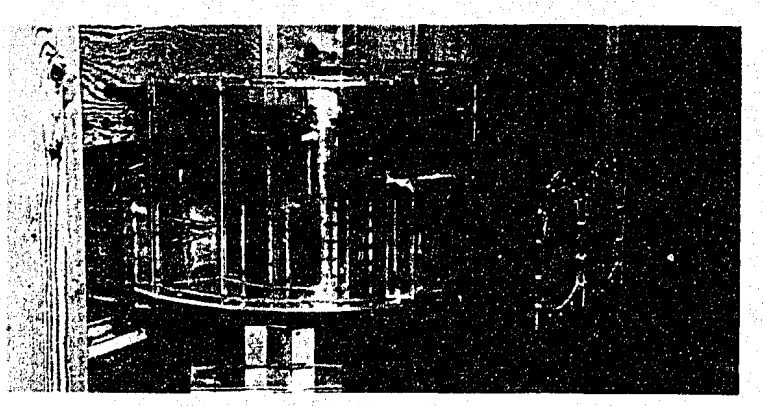
E. OUTLETS BETWEEN INNER & OUTER TOWERS (SCHEME B)

SHERBURNE LAKE
SPILLWAY AND OUTLET WORKS
1:15 SCALE HYDRAULIC MODEL
SCHEMATIC VIEWS

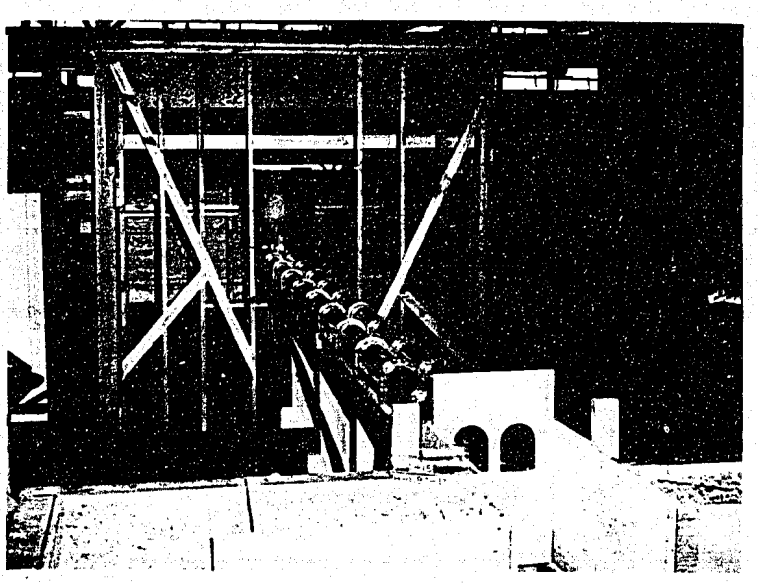
512



A. Interior of head box with approach channel and Scheme A spillway.



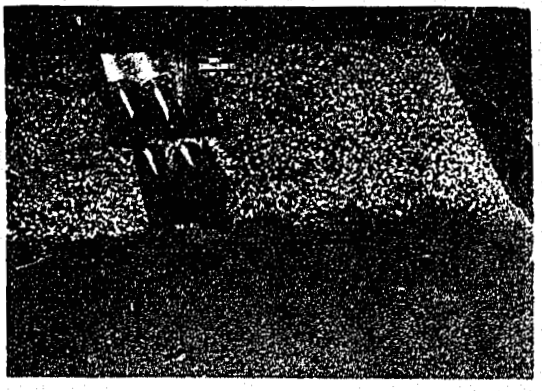
B. Gate and tower section - Scheme A.



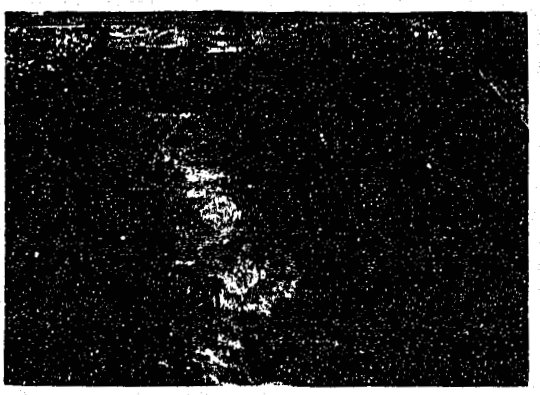
C. Outlet conduits leading to tail box in foreground.

SHERBURNE LAKE SPILLWAY AND OUTLET WORKS

1:15 Scale Model

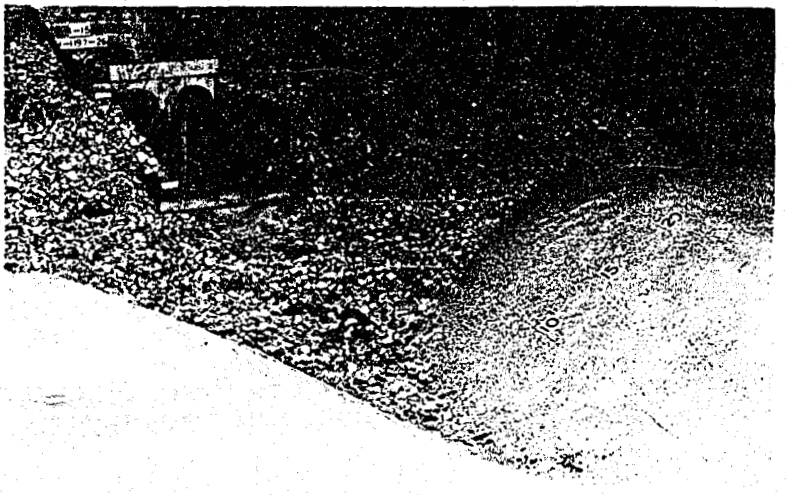


A. Bed prior to tests.



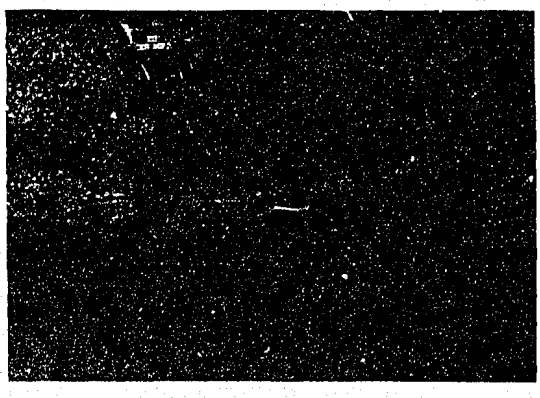
B. High angle view of flow.

C. Low angle view of flow.

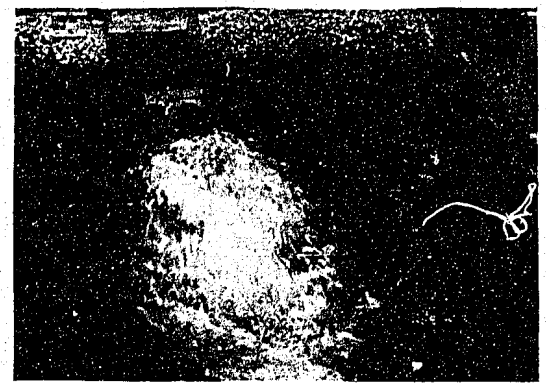


D. Erosion after operating model 1 hour.

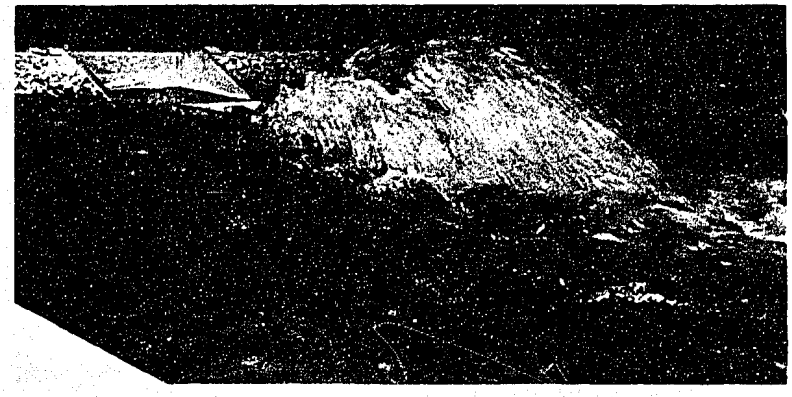
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
2, 330 cfs Outlet Works Flow from Initial Conduit Apron
Res. Elev. 4784 T. W. Elev. 4728. 2
1:15 Scale Model



A. Bed prior to tests.



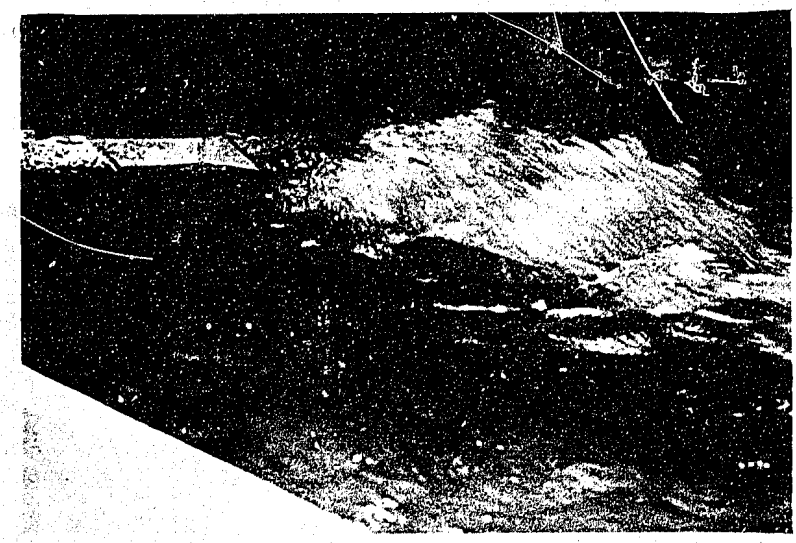
B. High angle view of flow.



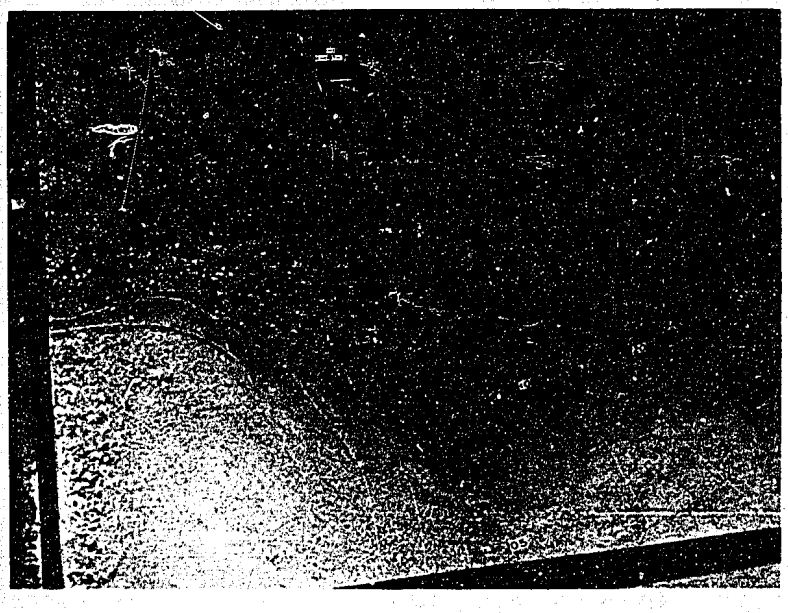
C. Low angle view of flow.

D. Erosion after operating model 1 hour.

SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
2,330 cfs Outlet Works Flow From Final Flip Bucket
Res. Elev. 4784 T.W. Elev. 4728.2
1:15 Scale Model

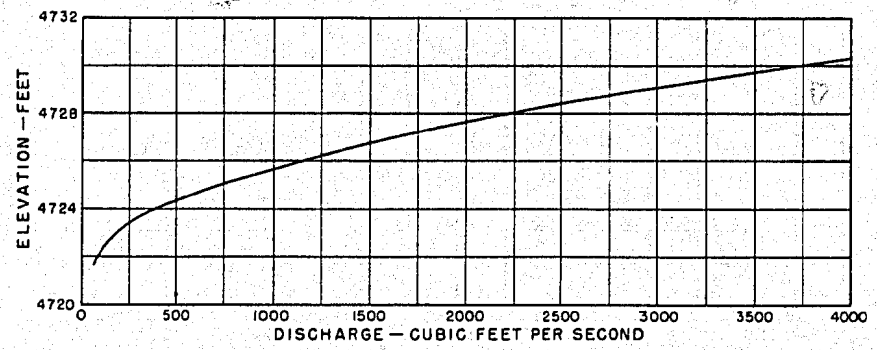


A. Flow pattern.

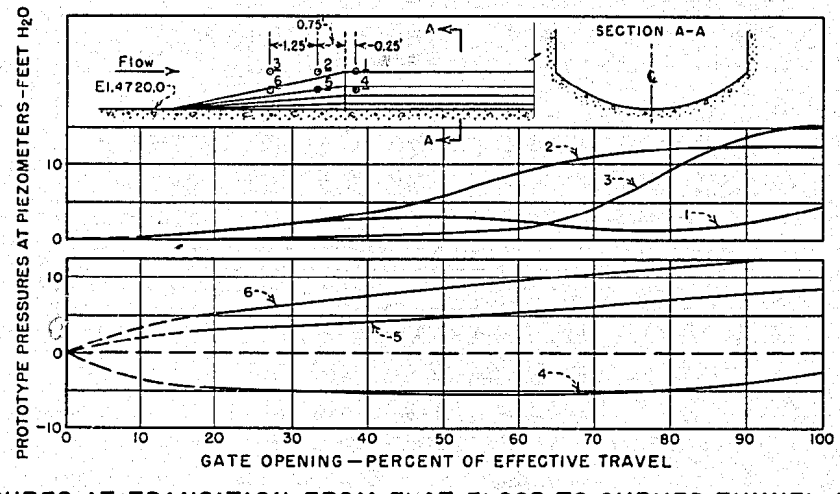


B. Erosion after operating model 1 hour.

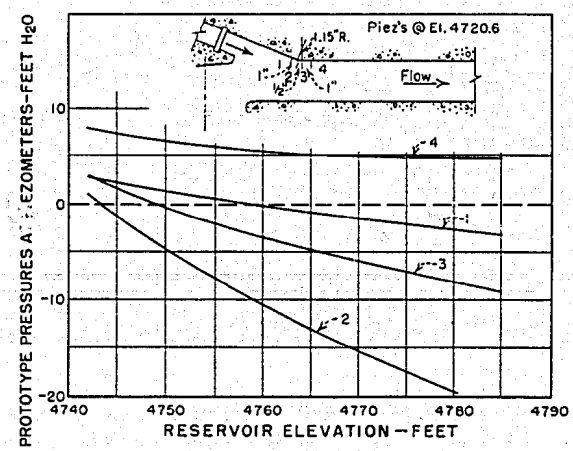
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
3,880 cfs Combined Spillway and Outlet Flows From Final Flip Bucket
Res. Elev. 4793 T.W. Elev. 4730.2
1:15 Scale Model



A. TAILWATER ELEVATION



B. PRESSURES AT TRANSITION FROM FLAT FLOOR TO CURVED TUNNEL INVERT
SCHEME A

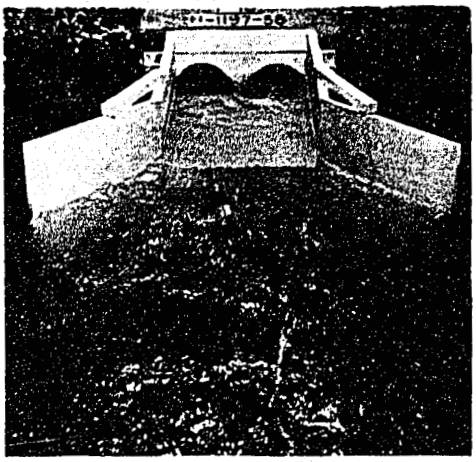


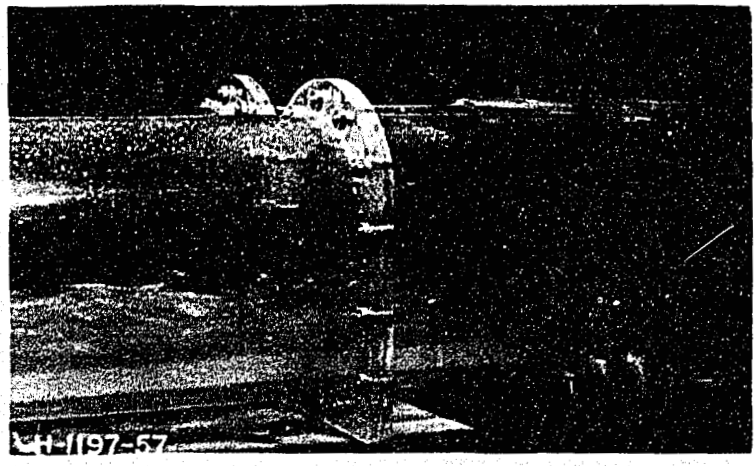
C. PRESSURES AT CHANGE OF SIDEWALL ALINEMENT
SCHEME B

SHERBURNE LAKE SPILLWAY AND OUTLET WORKS

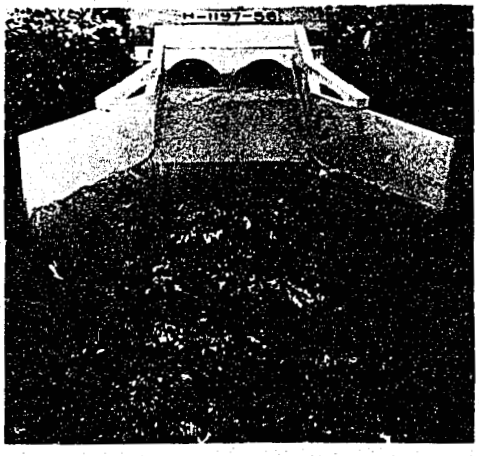
TAILWATER CURVE, AND PIEZOMETRIC PRESSURES FOR OUTLET WORKS

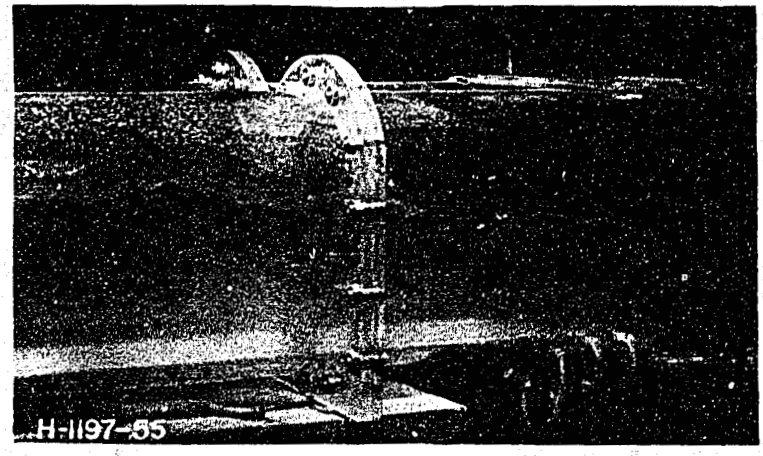
1:15 SCALE MODEL



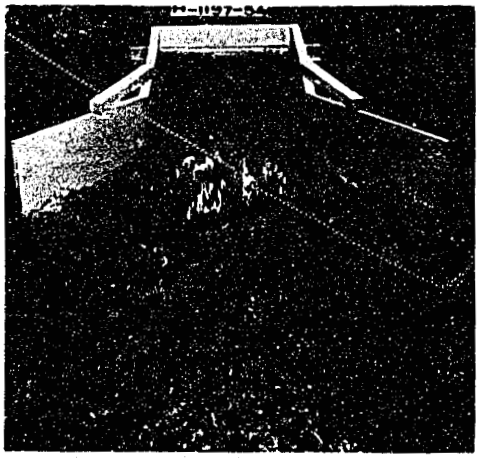


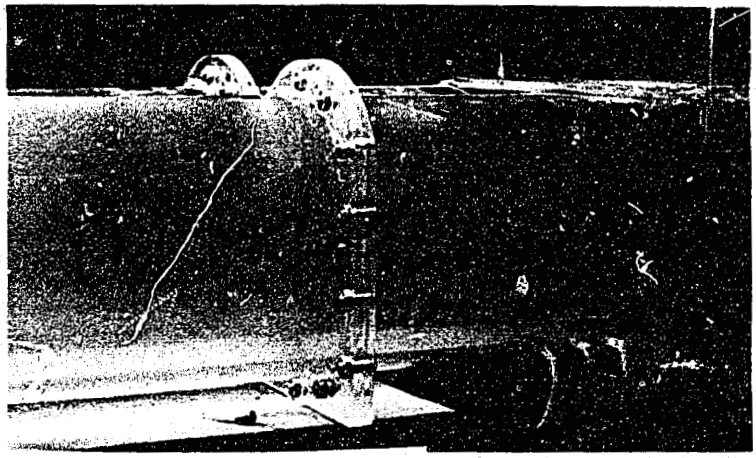
A. Q = 250 cfs. One gate 49% open. T. W. = 4723.4.
A jump occurs in the conduit.





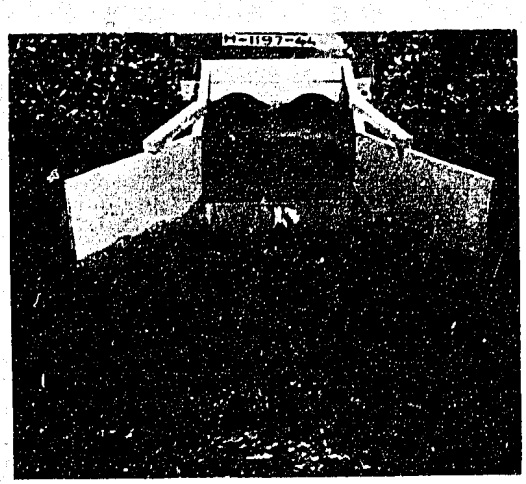
B. Q = 250 cfs. Both gates 36% open. T. W. = 4723.4.
A jump occurs in the conduit.

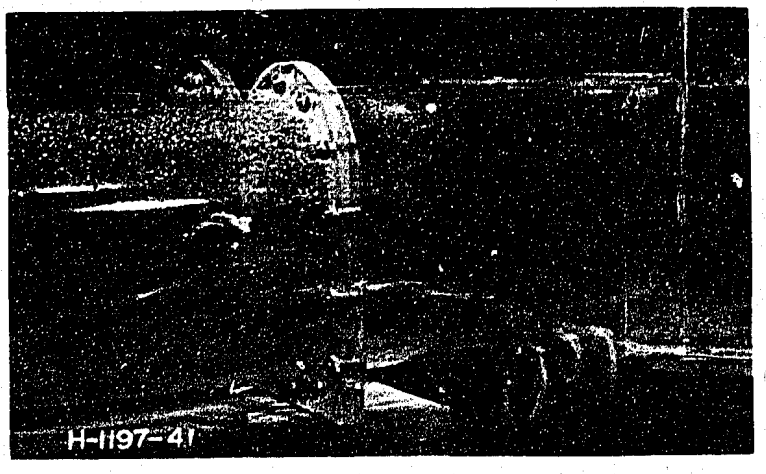




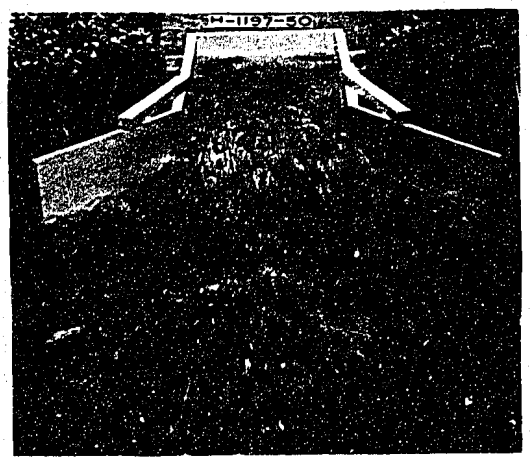
C. Q = 582 cfs. Both gates full open. T. W. = 4724.4.
Conduits flow full.

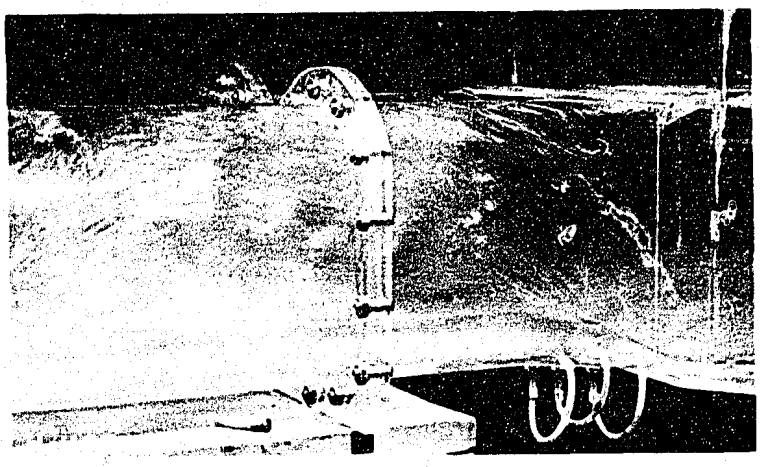
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme A - Outlet Works Flows at Conduit Entrances and Exits
Reservoir Elev. 4730
1:15 Scale Model



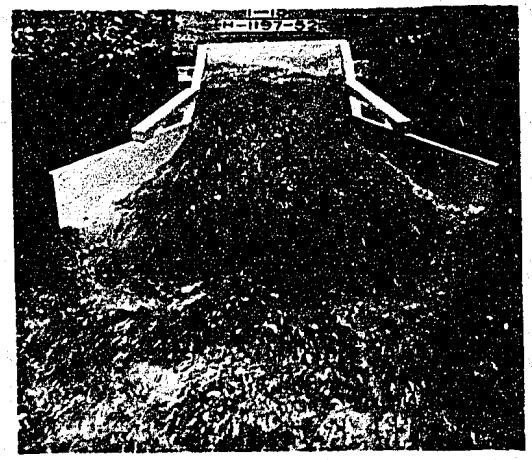


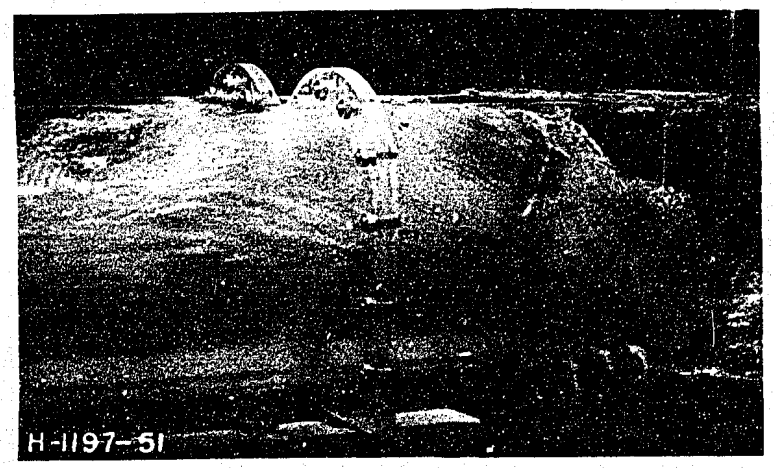
A. Q = 250 cfs. Gates 20% open. T. W. Elev. = 4723.4.
A jump occurs in the conduit.





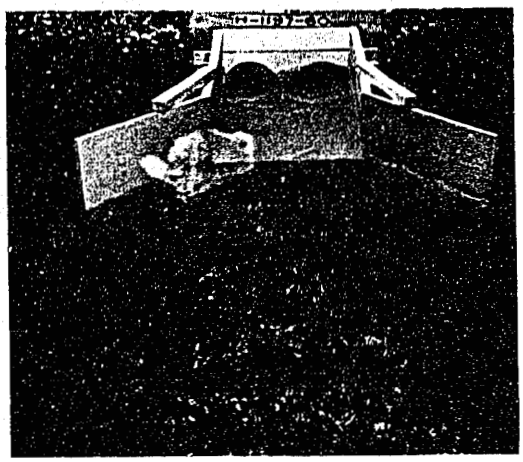
B. Q = 1,000 cfs. Gates 73% open. T. W. Elev. = 4725.7.
A jump occurs in the conduit.

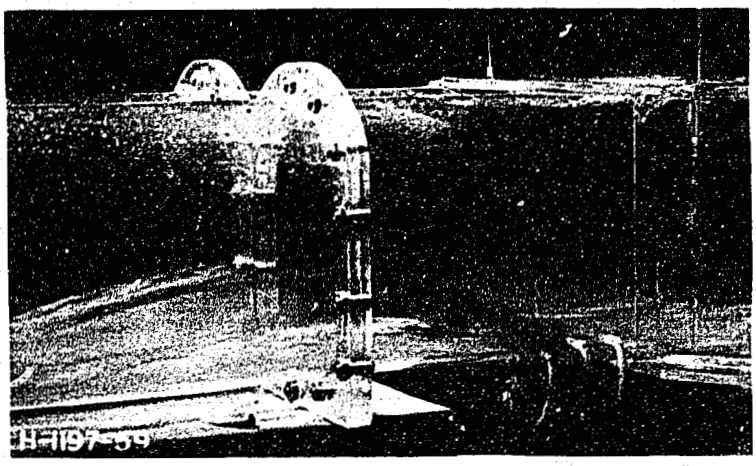




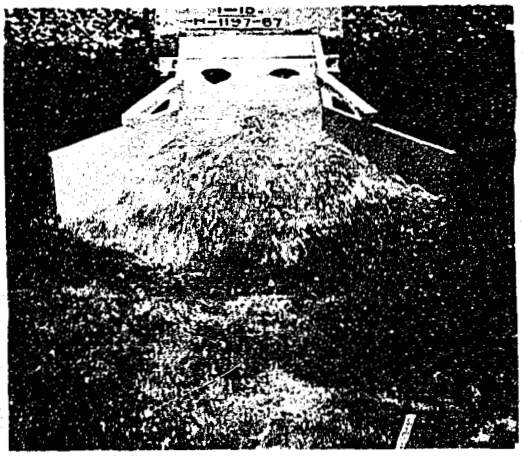
C. Q = 1,530 cfs. Gate 100% open. T. W. Elev. = 4726.9.
A jump occurs in the conduits at outlet portals.

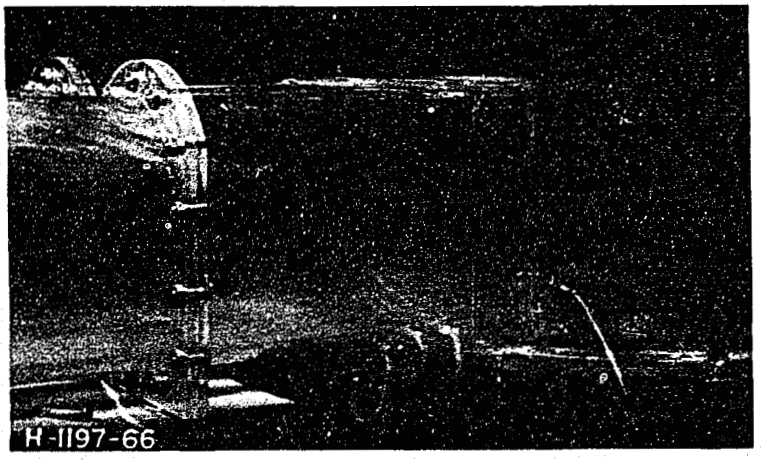
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme A - Outlet Works Flows at Conduit Entrances and Exits
Reservoir Elev. 4750
1:15 Scale Model



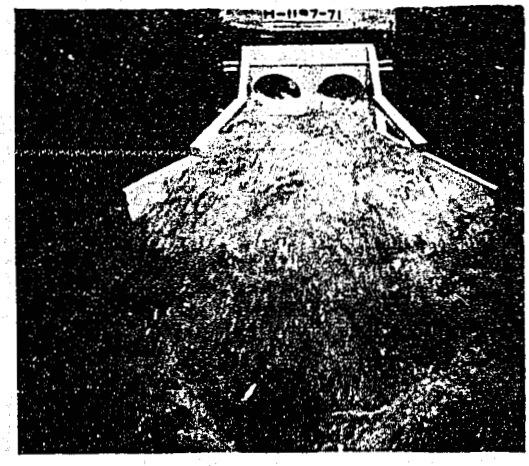


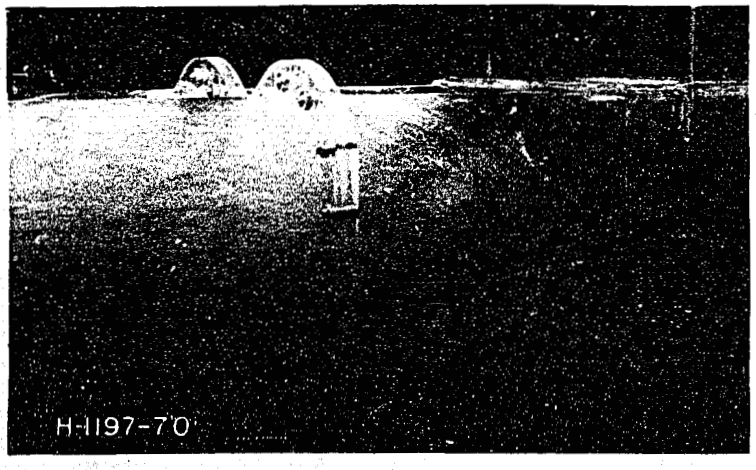
A. Q = 250 cfs. Gates 15% open. T. W. Elev. = 4723.4.
A jump occurs in the conduit.





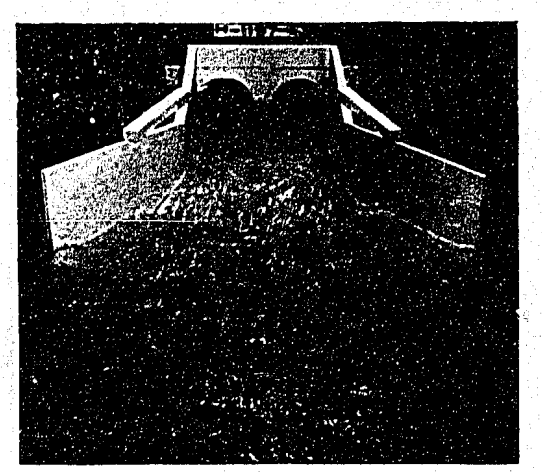
B. Q = 1,000 cfs. Gates 61% open. T. W. = 4725.7.
No jump in the conduits.





C. Q = 2,030 cfs. Gates full open. T. W. = 4727.8.
No jump in the conduits.

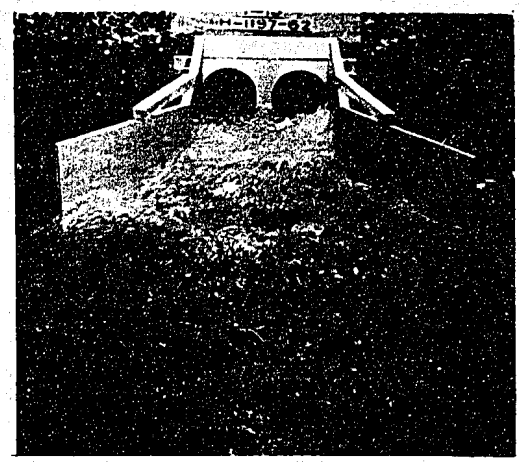
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme A - Outlet Works Flows at Conduit Entrances and Exits
Reservoir Elev. 4770
1:15 Scale Model



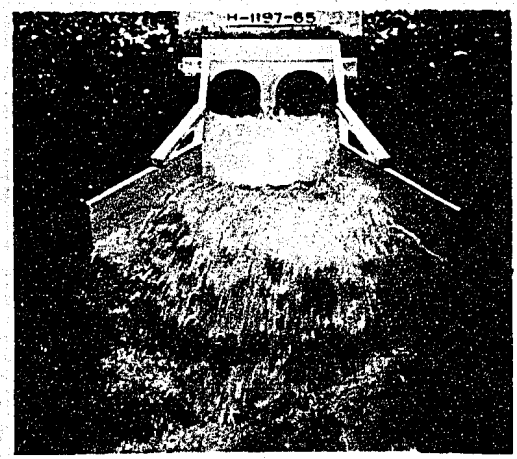
A. One gate open 42%. Q = 250 cfs.
T. W. Elev. 4723.4.

B. One gate open 77%. Q = 500 cfs.
T. W. Elev. 4724.3.

Reservoir Elev. 4750

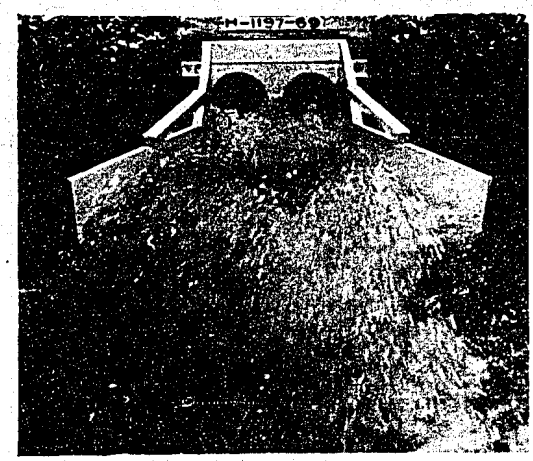


C. One gate open 31%. Q = 250 cfs.
T. W. Elev. 4723.4.



D. One gate open 63%. Q = 500 cfs.
T. W. Elev. 4724.3

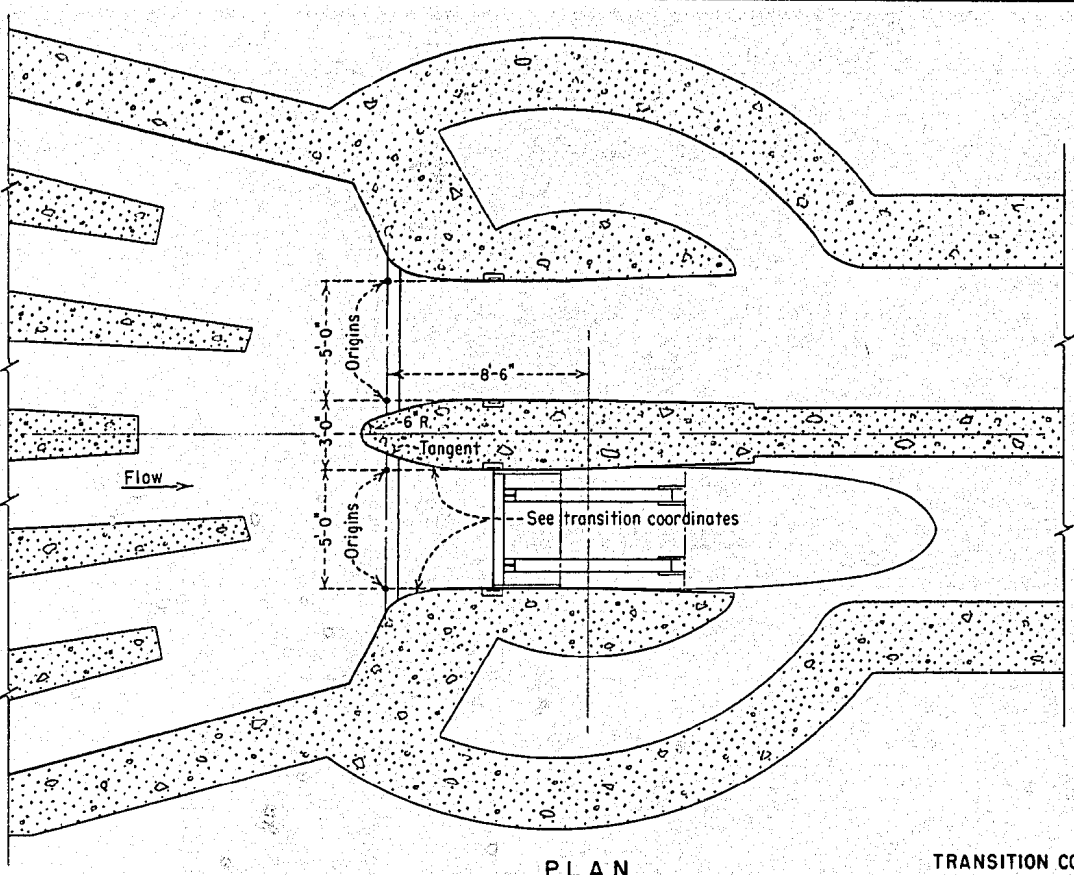
Reservoir Elev. 4770



E. One gate open full. Q = 1,016 cfs.
T. W. El. 4725.7 Res. El. 4770

F. Typical hydraulic jump in conduits.
Two gates open 42%. Q = 500 cfs.

SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme A - Single-Gate Outlet Flows At Conduit Exits,
and Hydraulic Jump in Conduits
1:15 Scale Model

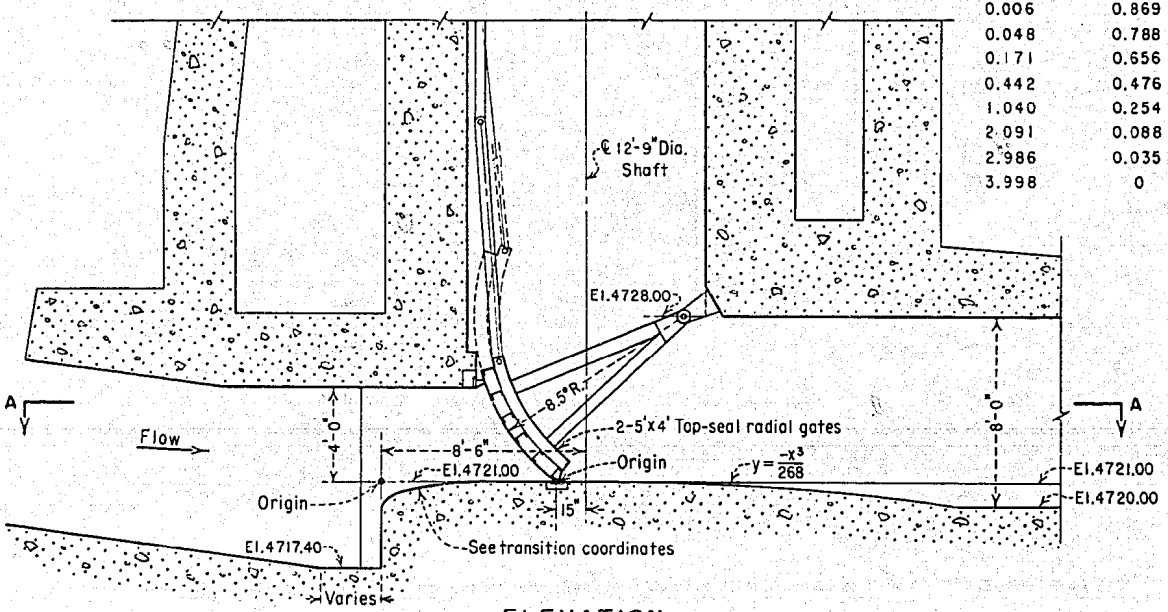


PLAN

SECTION A-A

TRANSITION COORDINATES

X	Y
0	0.897
0.006	0.869
0.048	0.788
0.171	0.656
0.442	0.476
1.040	0.254
2.091	0.088
2.986	0.035
3.998	0

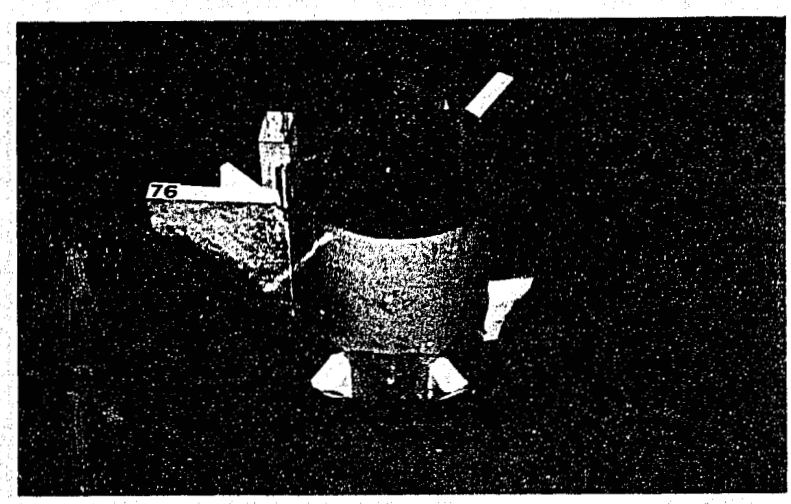


ELEVATION

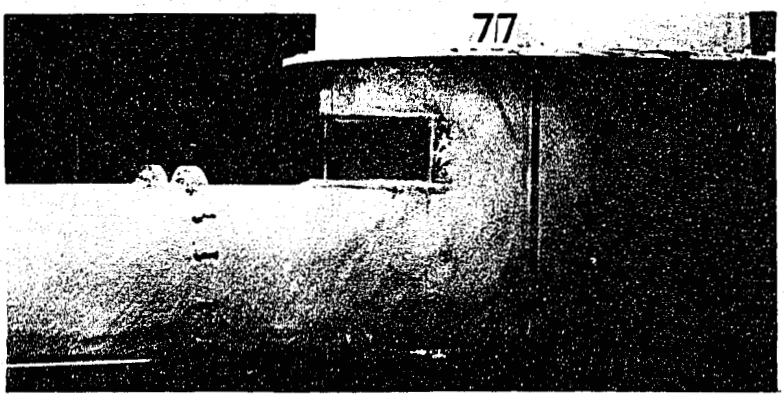
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS

PROPOSED TOP SEAL RADIAL GATE INSTALLATION

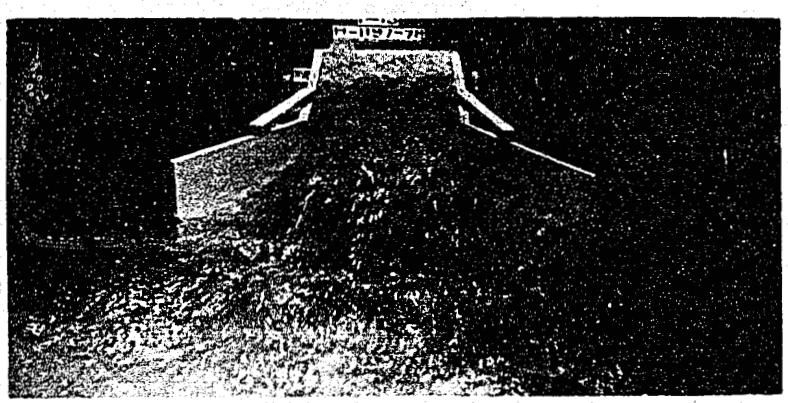
512



A. Flow over the crest is smooth and the water drops far before striking the pool within the towers.

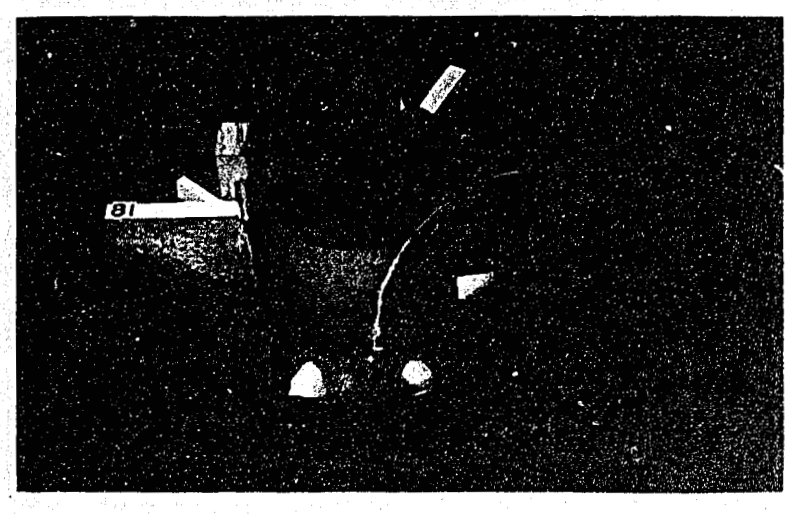


B. Much air is entrained and carried into the filled outlet conduits.

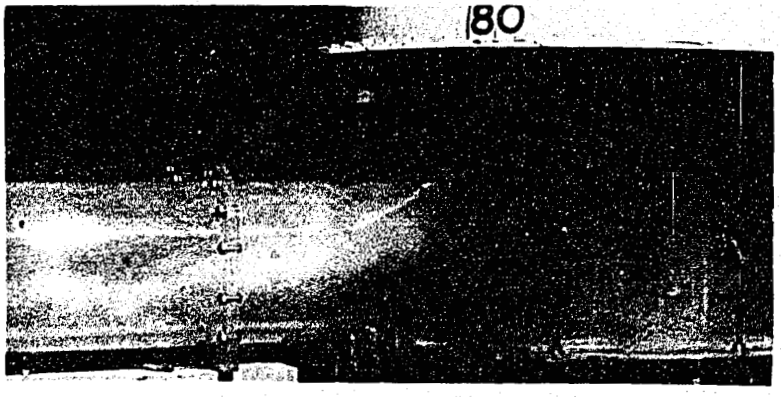


C. Air bursts out of the conduit portals. The flip bucket performs satisfactorily. T. W. 4725.7.

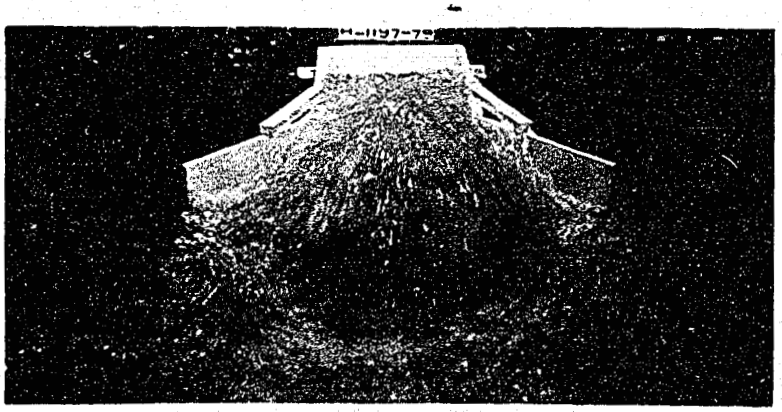
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme A - Spillway Flow of 1,000 cfs
1:15 Scale Model



A. Flow over the crest is smooth, and the water drops only a short distance to the backed up pool.

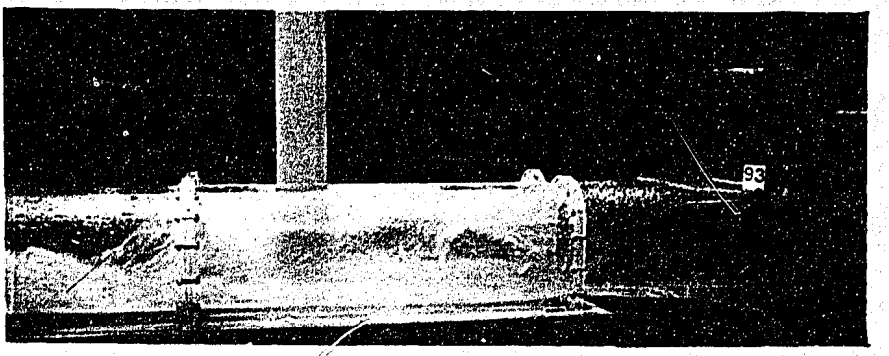


B. Air entrainment is relatively light. Flow spirals down the conduits.

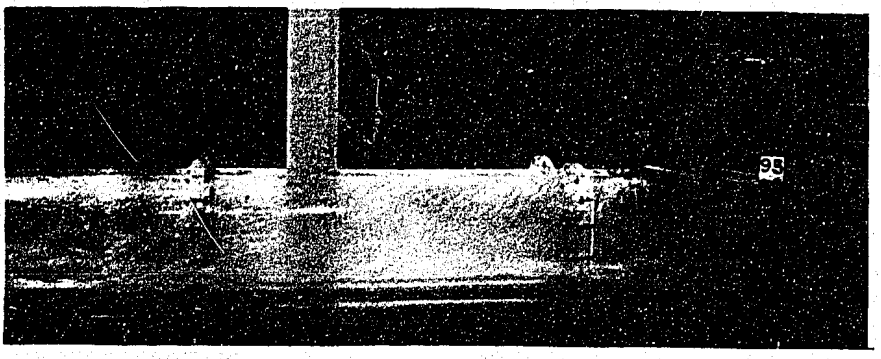


C. The flip bucket performs well. T.W. 4727.7.

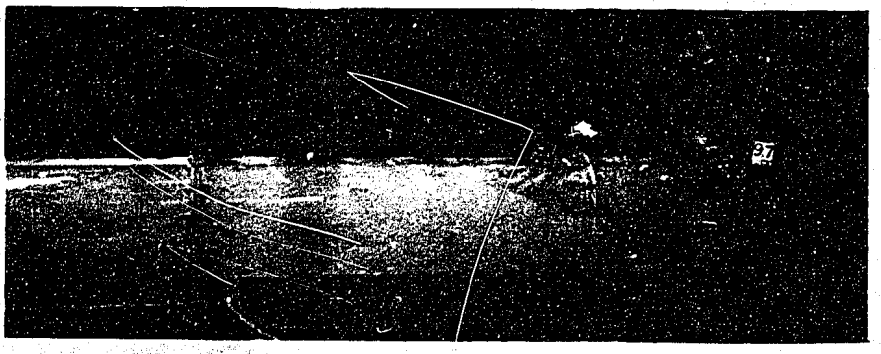
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme A - Spillway Flow of 2,000 cfs
1:15 Scale Model



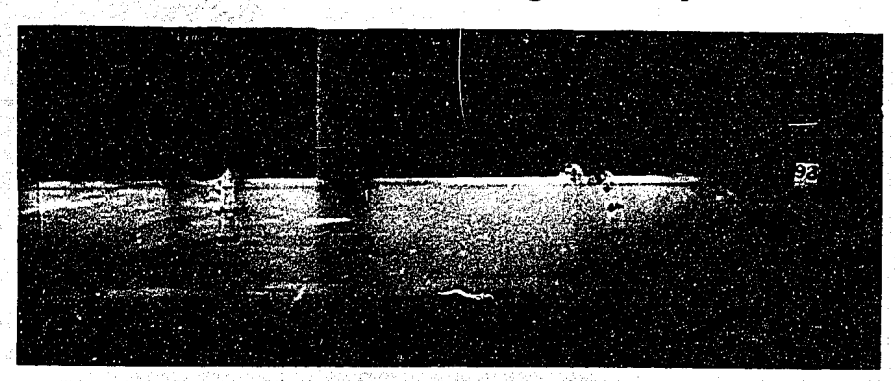
A. Q = 250 cfs. Both gates 22% open.



B. Q = 500 cfs. Both gates 43% open.

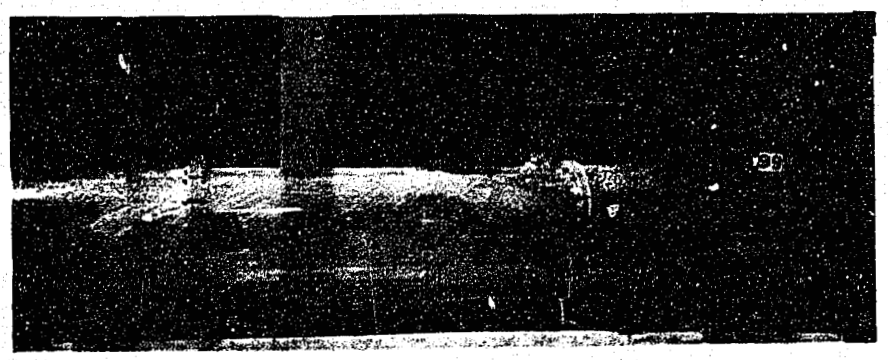


C. Q = 1,000 cfs. Both gates 72% open.

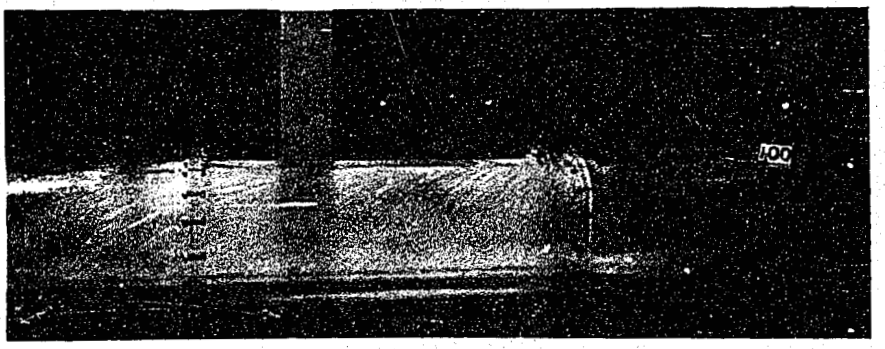


D. Q = 1,430 cfs. Both gates fully open.

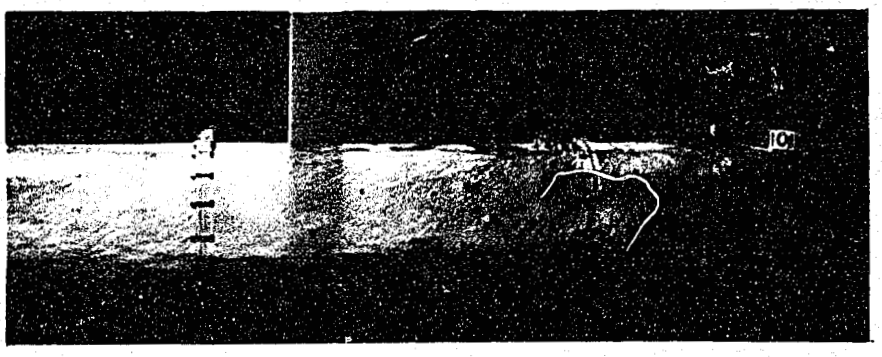
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme B - Outlet Works Flows At Conduit Entrances
Reservoir Elev. 4750
1:15 Scale Model



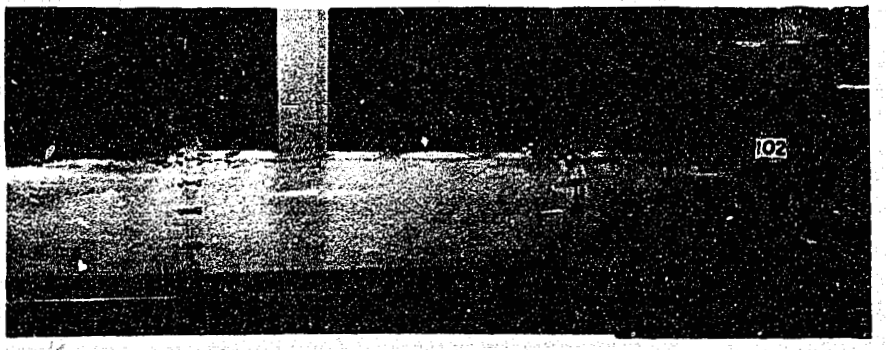
A. Q = 250 cfs. Both gates 17% open.



B. Q = 500 cfs. Both gates 35% open.



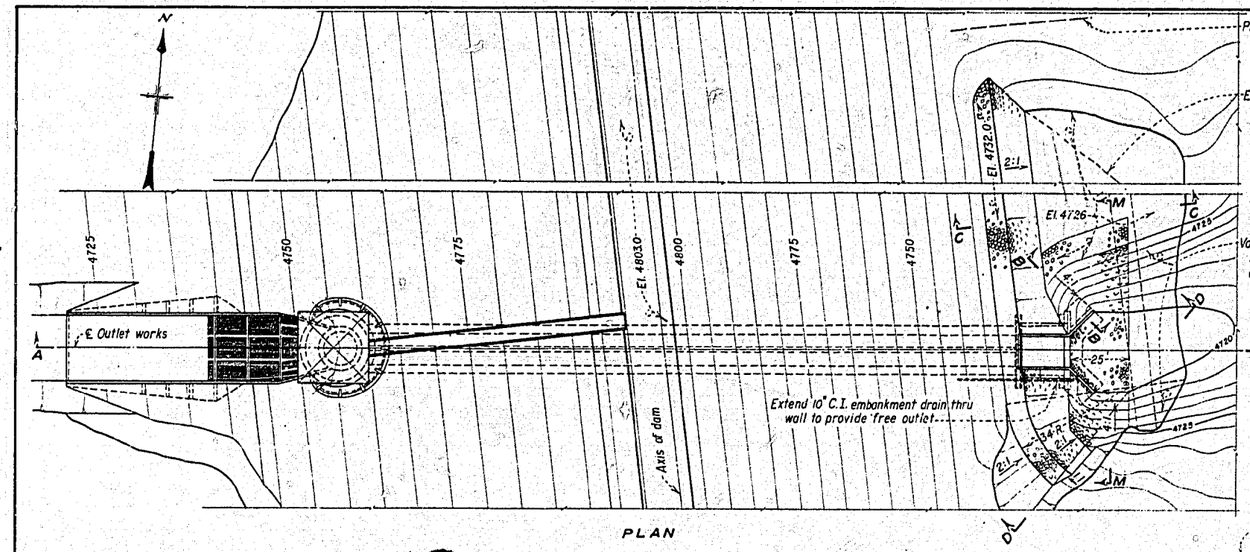
C. Q = 1,000 cfs. Both gates 61% open.



D. Q = 1,920 cfs. Both gates fully open.

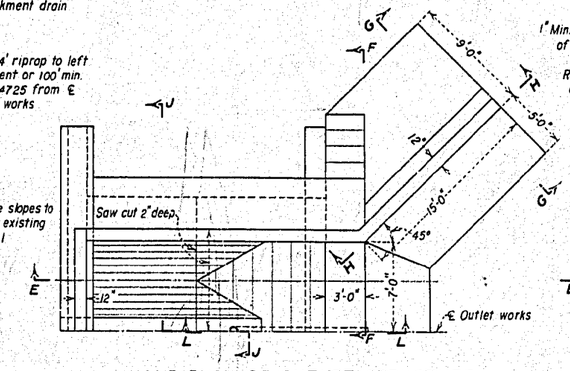
SHERBURNE LAKE SPILLWAY AND OUTLET WORKS
Scheme B - Outlet Works Flows At Conduit Entrances
Reservoir Elev. 4770
1:15 Scale Model

FIGURE 20
REPORT HYD. 454

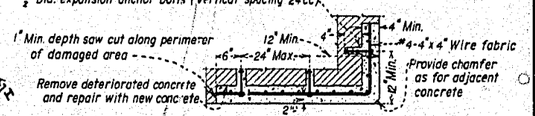


PLAN

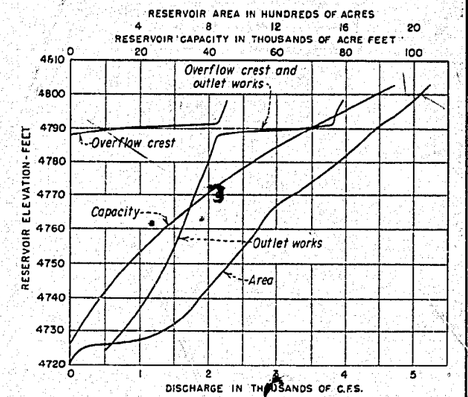
SCALE OF FEET
30 0 30 60



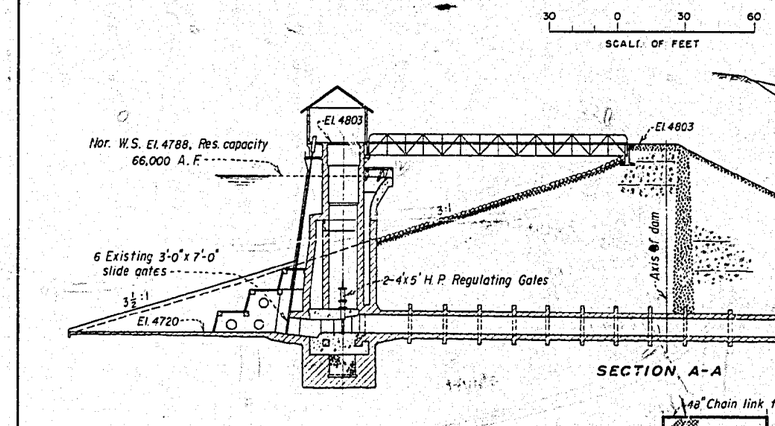
HALF PLAN OF OUTLET STRUCTURE



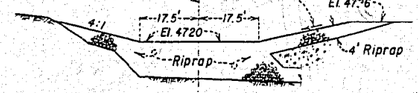
DETAIL OF REPAIR OF DAMAGED CONCRETE
FOR ANCHORAGE DETAIL SEE DWG. 15-D-214



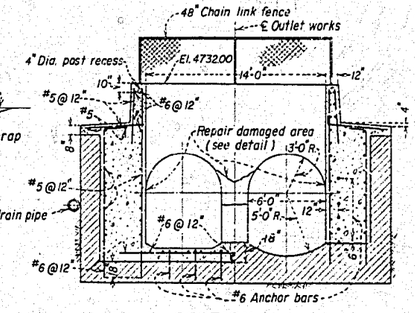
AREA-CAPACITY-DISCHARGE CURVES



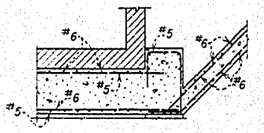
SECTION A-A



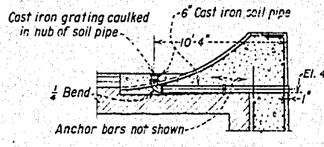
SECTION M-M



SECTION J-J



SECTION K-K



SECTION L-L

CONCRETE FINISHES

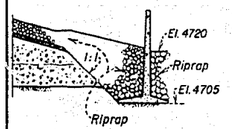
Surfaces covered by fill: F1, U1.
Water passage from portal to end of sill: F4, U3.
Intake structure water passages below El. 4732: F4, U3.
All other surfaces: F2, U2

NOTES

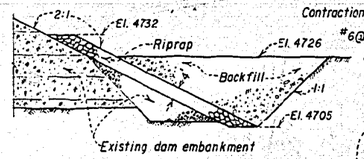
For general concrete outline notes see Dwg. 40-D-5530
For general reinforcement notes see Dwg. 40-D-5586

REFERENCE DRAWINGS

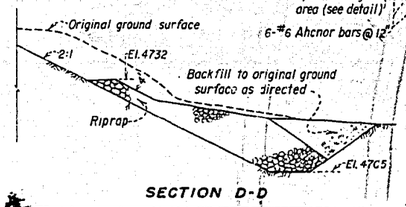
OUTLET WORKS REHABILITATION-INTAKE STRUCTURE SHEET 1 OF 2 ..... 15-D-213
OUTLET WORKS REHABILITATION-INTAKE STRUCTURE SHEET 2 OF 2 ..... 15-D-214
SHERBURNE LAKES OUTLET WORKS LAYOUT AND DAM SECTIONS 16-C-14
SHERBURNE LAKES RESERVOIR DAM OUTLET CONDUIT 15-612-3393



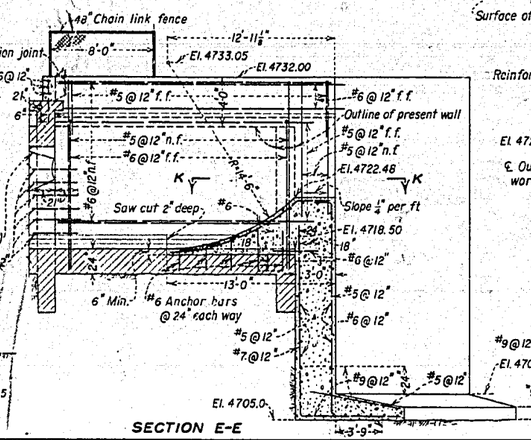
SECTION B-B



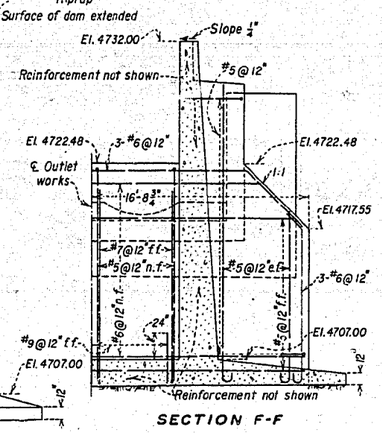
SECTION C-C



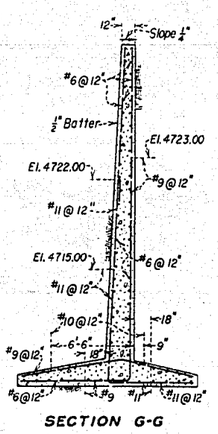
SECTION D-D



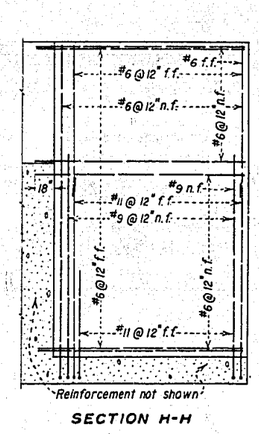
SECTION E-E



SECTION F-F



SECTION G-G



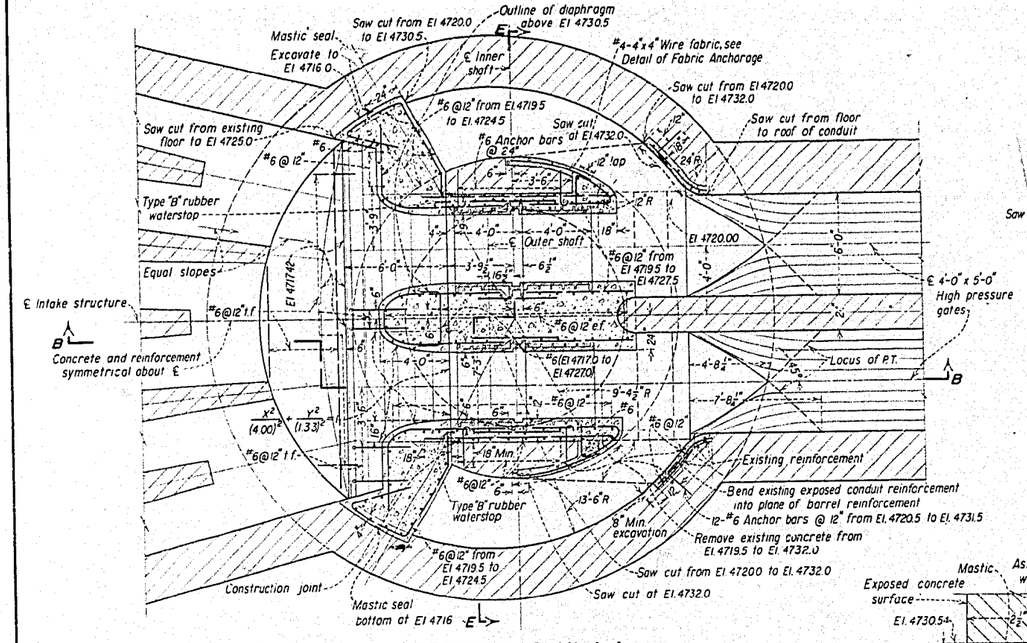
SECTION H-H

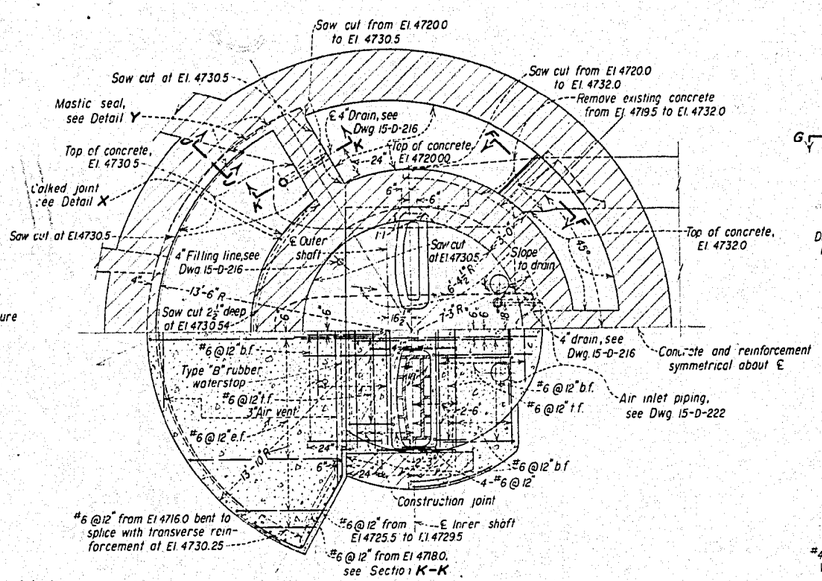
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MILK RIVER PROJECT-MONT.

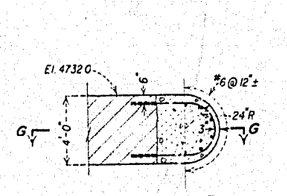
SHERBURNE LAKE DAM
OUTLET WORKS REHABILITATION
PLAN AND SECTIONS

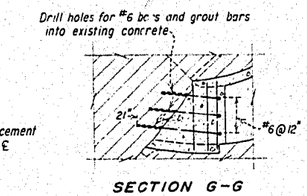
DRAWN ..... J.M.S. ..... SUBMITTED. R.W. Winsor
TRACED ..... N.B.W. ..... RECOMMENDED. A.J. Peterka
CHECKED. J.E.A. APPROVED. E.O. Larson
CHIEF DESIGNING ENGINEER
DENVER, COLORADO, FEB. 2, 1959

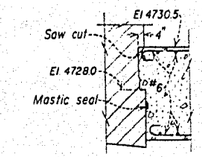
15-D-212

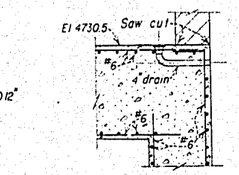


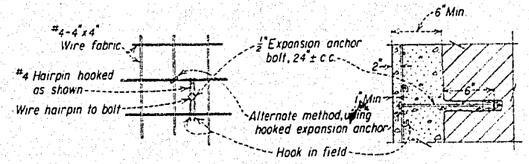


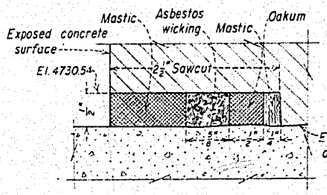


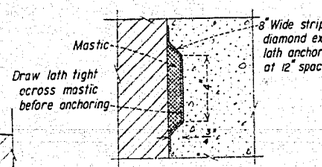


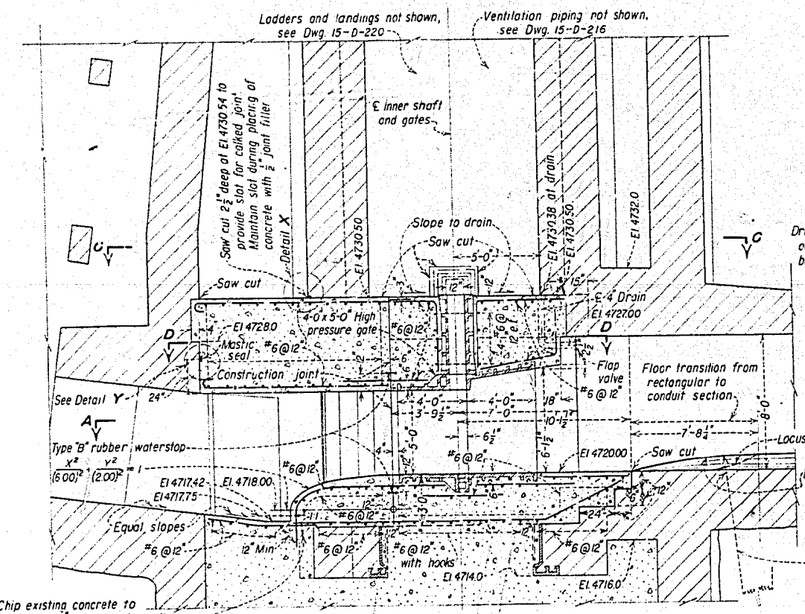


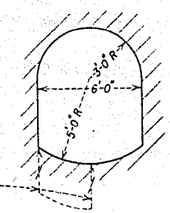


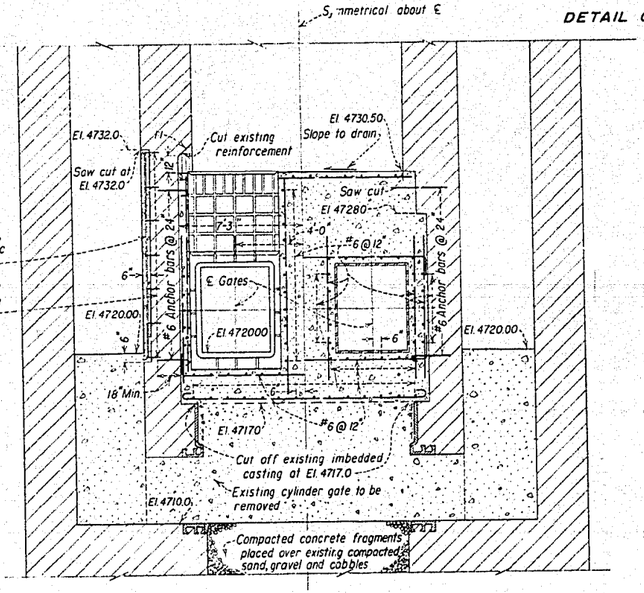












NOTES

For general notes and list of reference drawings see Sheet 1 of 2.
All saw cuts 1 inch deep except as noted.
Clean and preserve as directed, 40 bar diameters of existing reinforcement exposed by removal of concrete, where extension of reinforcement will be into new concrete.

COMPANION DRAWING

SHEET 1 OF 2 ..... 15-D-213

5-11-59 D-3442	SUBSTITUTED MASTIC SEAL FOR PORTION OF CALKED JOINTS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MILK RIVER PROJECT - MONTANA

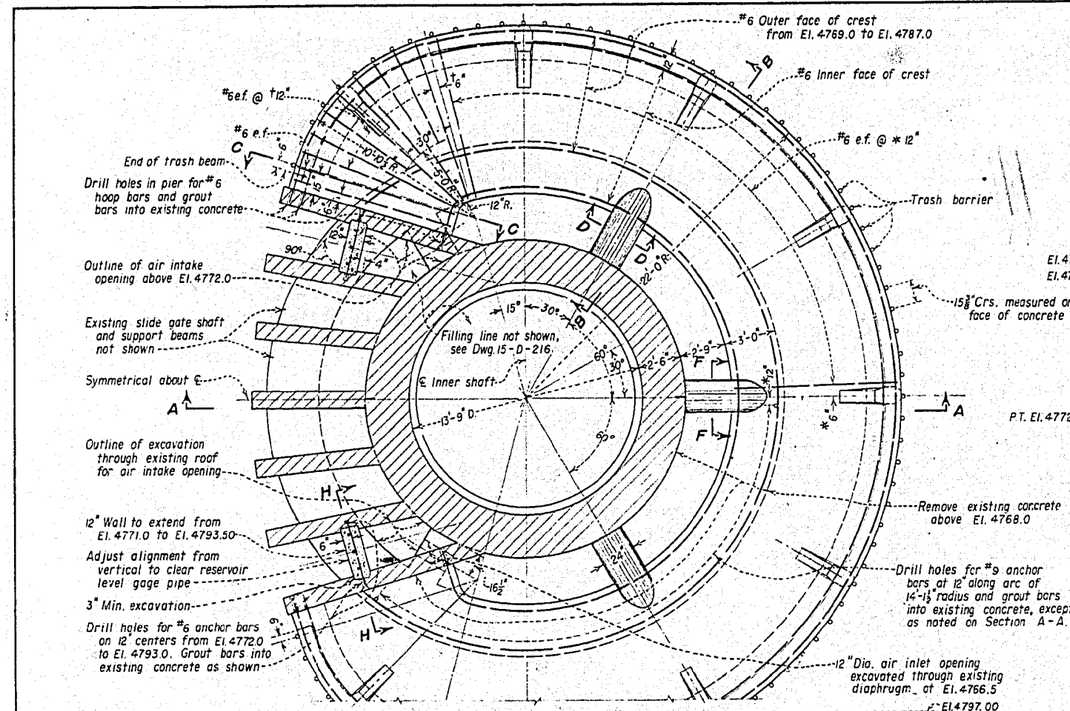
SHERBURNE LAKE DAM
OUTLET WORKS REHABILITATION
INTAKE STRUCTURE

DRAWN R.L.B. SUBMITTED: A.H. Martin
TRACED R.O.M. RECOMMENDED: R.W. Ulmanock
CHECKED C.T.S. APPROVED: O.J. Liss, CHIEF, DAMS BRANCH

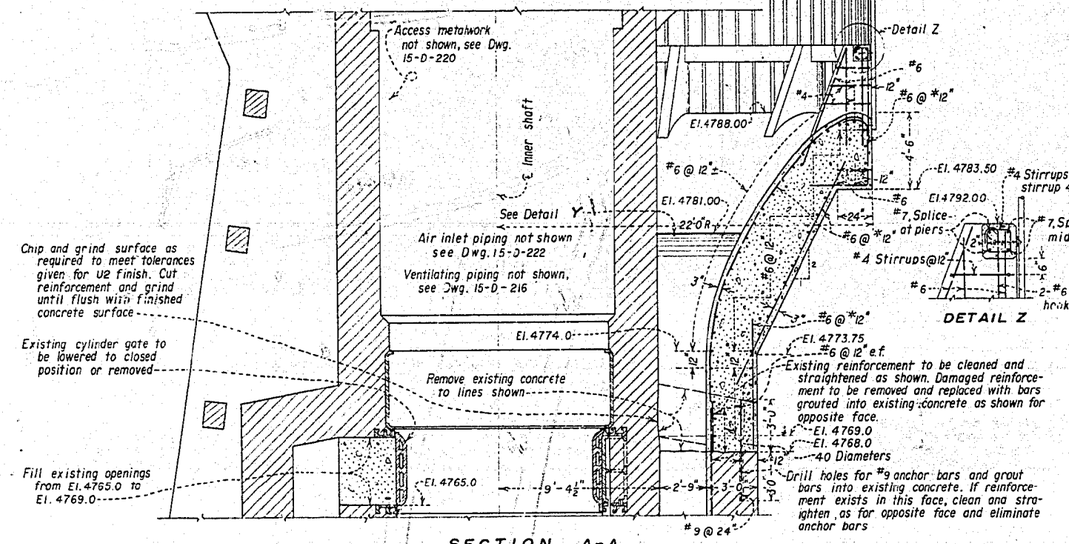
DENVER, COLORADO, FEB. 2, 1959.
SHEET 2 OF 2

15-D-214

FIGURE 22
REPORT HYD. 454

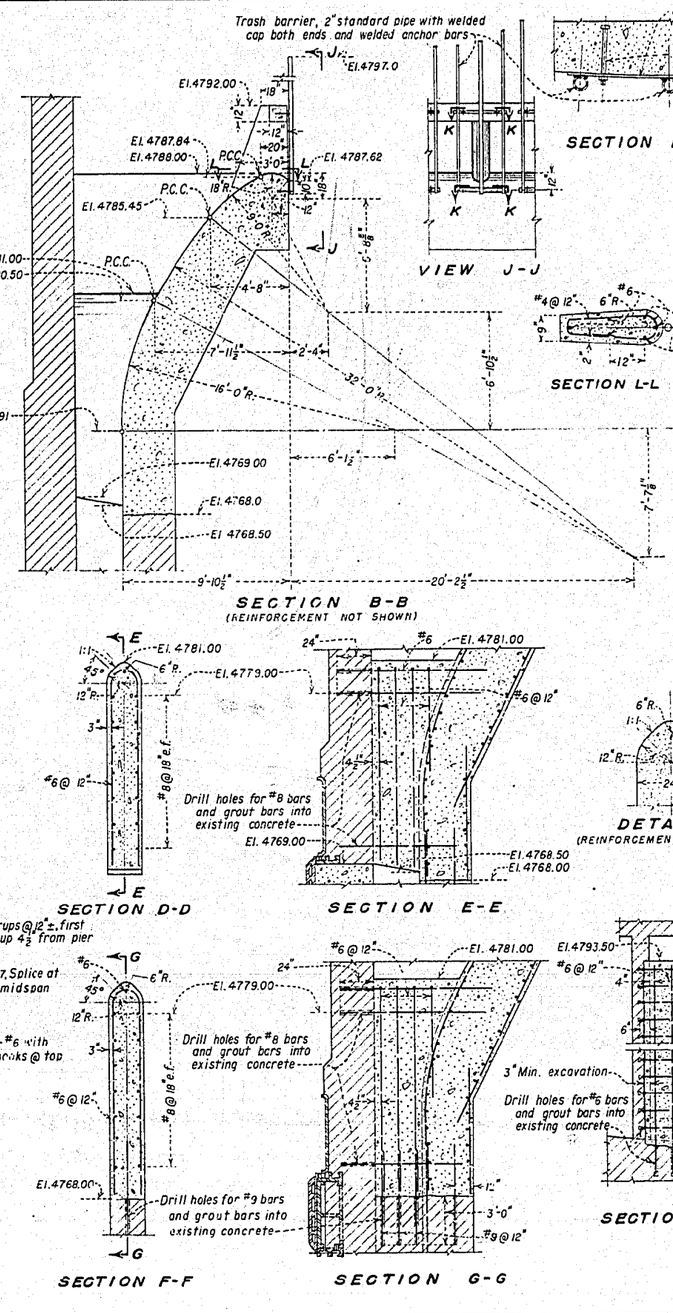


SECTIONAL PLAN AT EL. 4792.00



SECTION A-A

DETAIL Z



SECTION B-B
(REINFORCEMENT NOT SHOWN)

SECTION K-K

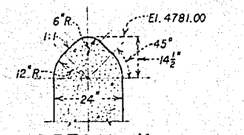
VIEW J-J

SECTION L-L

SECTION C-C

SECTION D-D

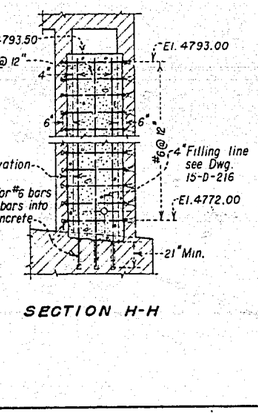
SECTION E-E



DETAIL Y
(REINFORCEMENT NOT SHOWN)

SECTION F-F

SECTION G-G



SECTION H-H

NOTES

For general concrete outline notes see Dwg. 40-D-5530.
For general reinforcement notes, see Dwg 40-D-5586.
* Indicates dimension measured along arc of a 14-1½" radius.
† Indicates dimension measured along arc of a 8'-0 radius.
For concrete finishes see Dwg. 15-D-212.

REFERENCE DRAWINGS

OUTLET WORKS REHABILITATION - PLAN AND SECTIONS AND SECTIONS	15-D-212
VENTILATION SYSTEM, FILLING LINE, VENT AND DRAINS	15-D-216
ACCESS METALWORK	15-D-220
SHERBURNE LAKES OUTLET WORKS- GATE TOWER ELEVATION AND SECTIONS	16-C-15
SHERBURNE LAKES OUTLET WORKS - GATE TOWER - SECTIONS	16-C-16
AIR INLET PIPING	15-D-222

COMPANION DRAWING

SHEET 2 OF 2 — 15-D-214

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MILK RIVER PROJECT - MONTANA

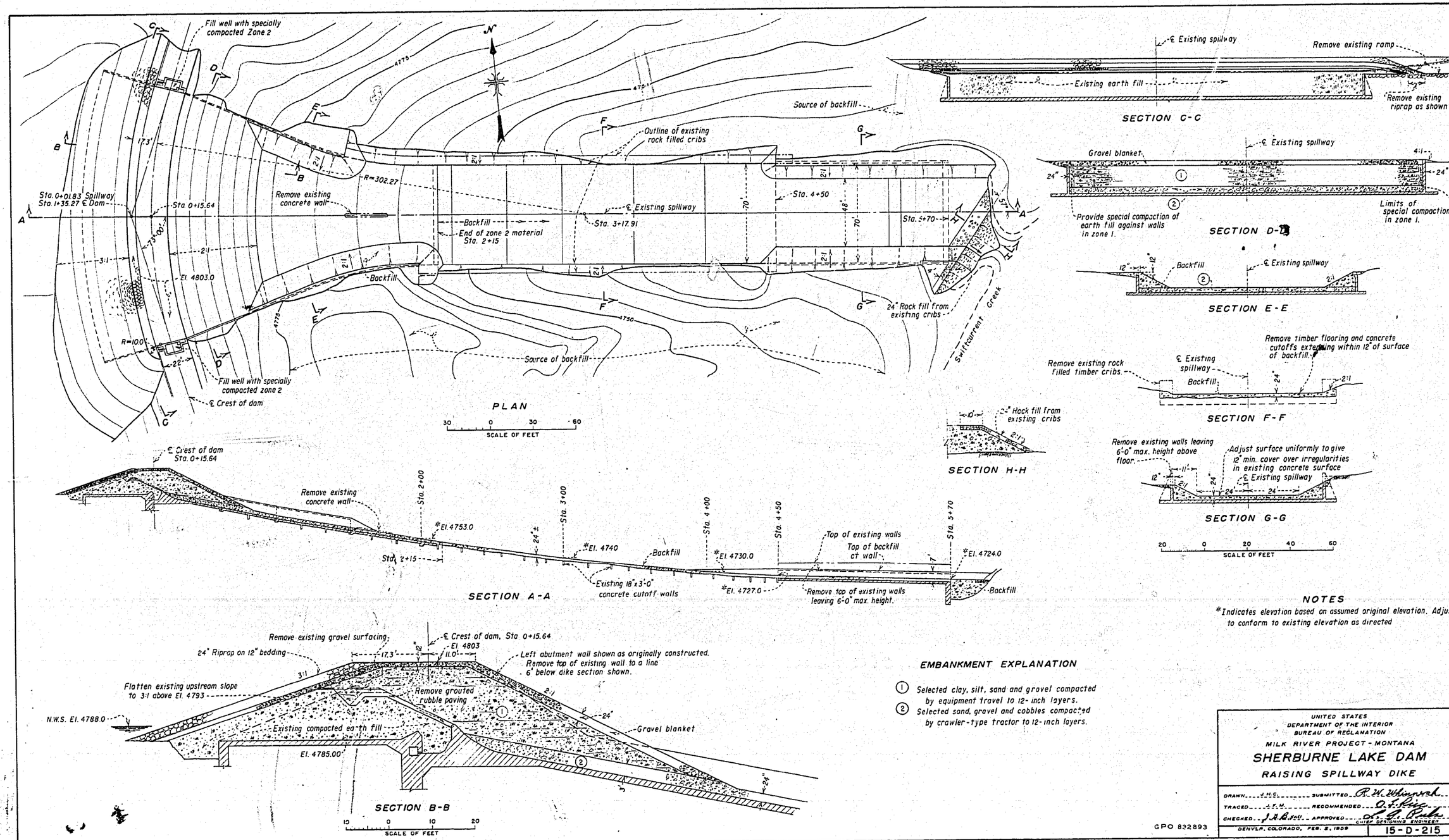
SHERBURNE LAKE DAM
OUTLET WORKS REHABILITATION
INTAKE STRUCTURE

DRAWN A.L.O. SUBMITTED M.H. Dietz
TRACED A.T.B. RECOMMENDED R.W. Whitesell
CHECKED E.F.S. APPROVED D.F. Pence, CHIEF, DAMS BRANCH

DENVER, COLORADO, FEB. 2, 1959
SHEET 1 OF 2

15-D-213

FIGURE 23
REPORT HYD. 454



NOTES

*Indicates elevation based on assumed original elevation. Adjust to conform to existing elevation as directed

EMBANKMENT EXPLANATION

1. Selected clay, silt, sand and gravel compacted by equipment travel to 12-inch layers.
2. Selected sand, gravel and cobbles compacted by crawler-type tractor to 12-inch layers.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MILK RIVER PROJECT - MONTANA

SHERBURNE LAKE DAM

RAISING SPILLWAY DIKE

DRAWN J.H.C. SUBMITTED R. W. Whinnerah
TRACED J.F.M. RECOMMENDED O. F. Rice
CHECKED J.A.B. APPROVED L. G. Puls
CHIEF DESIGNING ENGINEER
DENVER, COLORADO, FEB. 2, 1959

15-D-215

GPO 832893