UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC STUDIES OF THE SKI-JUMP SPILLWAY FOR CLEVELAND DAM GREATER VANCOUVER WATER DISTRICT VANCOUVER, BRITISH COLUMBIA, CANADA

Hydraulic Laboratory Report No. Hyd-369

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

May 19, 1953

CONTENTS

CONTENTS--Continued

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Design and Construction Division
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Denver, Colorado
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Laboratory Report No. Hyd-369
Hydraulic Laboratory Section
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Checked and
reviewed by: W.C. Case
J.W. Ball

Subject: Hydraulic studies of the ski-jump spillway for Cleveland Dam--Greater Vancouver Water District--Vancouver, British Columbia, Canada

PURPOSE OF STUDY

To determine the feasibility of substituting a ski-jump bucket for the original extensive rectangular stilling basin of Cleveland Dam spillway.

CONCLUSIONS

1. In general the spillway flow conditions were acceptable, particularly at the smaller discharges.

2. The ski-jump bucket slotted to form flow splitters, satisfactorily deflected the water into the river channel downstream away from the toe of the dam at all flows (Figures 9 through 14).

3. The slotted bucket,distributed the spillway flow over a larger area of the river bed than a plain curved bucket.

4. Subatmospheric pressures, sufficient to cause cavitation, occur on surfaces just below the sharp edges of the flow splitters (Figure 4). Cavitation can be eliminated by rounding the edges of the splitters, or its tendency reduced by chamfering the edges.

5. Water fins, caused by the flow from the crest spreading behind the piers and striking the training walls, overtopped the training walls at discharges of 33,500 cfs and more. The high quality rock of the canyon walls should preclude any damage to the spillway structure or dam by this overtopping. Reducing the offset distance between the downstream edges of the crest piers and the inside surfaces of the training walls would eliminate the fins and overtopping.

6. Water overtopped the crest piers, elevation 572.25, at spillway flows greater than 30,000 cfs. The reservoir elevation for the maximum discharge, 43,000 cfs, was 577. Floating debris will strike the upstream spillway bridge girder during capacity floods unless it is raised. The elevation of the water surface at the dam axis for this discharge will be about 574.5.

7. Removal of the flow splitters or the portion of the bucket between the slots to make the surface continuous, causes the spillway flow beyond the bucket to be more concentrated.

8. The spillway flow surface has the appearance of a corrugated surface with the grooves and ridges parallel to the direction of flow. The size of the corrugations or "ropes" increase as the flow increases. The roughness is accentuated by the narrowness of the spillway and by the upstream overhang of the crest.

INTRODUCTION

Cleveland Dam was originally designated Capilano Dam. Hydraulic model studies were conducted on the spillway of this early design in the Hydraulic Laboratory of the Bureau of Reclamation in 1946. The results of this study are contained in Hydraulic Laboratory Report No. Hyd-222, entitled "Hydraulic Model Studies on the Spillway for Capilano Dam" dated December 6, 1946. Report No. Hyd-222 is included as an Appendix to this report.

The spillway design was modified from the stilling basin type to the ski-jump type to realize a reduction in initial cost. The Bureau of Reclamation was authorized on December 22, 1952, to make hydraulic model studies of the modification. Field construction was in progress at the time the model studies were authorized, and it was expected that concrete would be placed in the bucket area by the middle of January 1953. The model was put into operation January 15, 1953. Mr. H. A. Halland, a representative from the Greater Vancouver Water District, witnessed the operation of the model on January 20. He was satisfied with the performance of the ski-jump to the extent that field construction could be continued without delay.

The primary features of the dam, except for the ski-jump, are discussed on page 1 of the Appendix, and their relative location shown on Figure 1 of the Appendix.

THE INVESTIGATION

The problem. The primary purpose of the model investigation was to study flow conditions in the ski-jump bucket and in the canyon and river bed immediately downstream from the dam.

The model. A 1:60 scale model was constructed for the study; complete with crest, chute, training walls, ski-jump, and topography downstream to a point about 780 feet below the axis of the dam. The drum gate was represented by a curved metal sheet hinged to the wooden crest. River outlets were omitted because it was considered that the flow from them would give conditions in the bucket similar to those for flow over the spillway.

The model is shown schematically on Figure 1. Sections of the prototype spillway are shown on Figure 2. A 4- by 5- by 8-foot deep head box made of sheathing and sheet metal lined was used to represent the spillway approach. The crest was set in the box so an inside edge of the box represented the upstream face of the dam. The spillway was constructed in three parts. The crest and piers were made as a unit of sugar pine. The straight portion of the chute and training walls were made of plywood. The ski-jump bucket and training walls were made of sugar pine. Special shaped blocks were individually glued to the surface of a plain curved bucket to form a slotted bucket. The blocks could be removed for study of the plain bucket. The chute was attached to the crest with a mortise joint, and the ski-jump bucket was secured with screws and glue to the face of the chute. All parts of the spillway were given a coat of glyptol base paint as waterproofing.

The tail box was framed with 2 by 4 stringers and studs and sheathed with plywood. The joints were sealed by covering with muslin and doping with the glyptol base paint. The topography immediately downstream from the dam conformed with the canyon wall scaling planned for the original rectangular stilling basin design. Vertical topography bents were used from the end of the ski-jump bucket to the point where the river channel angles to the left. From this point downstream, horizontal bents were used (Figure 5). The bents were covered with metal lath and plastered with 3/4 of an inch of concrete. The floor of the box represented elevation 260 and the topography was leveled off at the equivalent of elevation 390. The bottom of the box was covered with gravel to elevation 300 at the toe of the bucket and tapered to elevation 260 at the tailgate. The material was a random mixture, and varied in size from pea gravel to 1-1/2-inch maximum.

An 8-inch centrifugal pump was used to supply water through an 8-inch line to the model. Discharge was measured with a 6-inch standard Venturi meter. Reservoir elevations were measured with a hook gage in a well connected to the head box. Tail water was regulated to a staff gage fastened to the floor of the box upstream of the tailgate at a location corresponding to that of the gaging station, about 700 feet downstream from the dam axis.

Tests. The model was operated at discharges equivalent to 5,000, 15,000, 25,000, 35,000, and 43,000 cubic feet per second with

respective tail water elevations of 288, 299, 307, 314, and 319 feet. A piece of 14 gage sheet metal was curved to conform with the top surface of the drum gate and secured to the crest with piano hinge and discharges of 8,000, 14,000, and 22,000 cfs studied with a constant reservoir elevation of 570. A discharge, representing 1,750 cfs, was passed through a fire hose and short pipe nipple to represent flow conditions through the ski-jump bucket with the left outlet operating. The latter test was made to illustrate that the outlet flow will not be adversely affected by the ski-jump bucket.

A calibration of the free crest was made and pressures taken on the edge of one of the bucket flow splitters. Approximate surface velocities were taken in the river channel below the hydraulic jump where the jet from the bucket plunged into the tail water. These velocities were obtained by observing the time required for a small block of wood to travel a distance of 4 feet in the model.

The model was filmed with still and movie cameras to obtain a photographic record of flow conditions.

Test results. The calibration of the free crest (Figure 3) coincided with the calibration of the original model (Figure 6 of the Appendix), so no further calibration was performed. The curves in the Appendix can be used to determine flood quantities.

A limited study was made of the pressure on one of the edges of a bucket flow splitter. This test was planned after the model had been constructed, and only one piezometer was placed in the critical area near the edge of the splitter because of the difficulty of inserting tubes in wood. Location of the piezometer and the pressure curve for various discharges are given on Figure 4. Subatmospheric pressure occurred at high discharges. Low pressures can be expected along the splitter edges, with probable cavitation damage prevailing at smaller discharges than is indicated by the curve.

The crest piers, constructed to elevation 572.25, were overtopped at a discharge of 30,000 cfs so the height of the model piers was increased. In order to contain the maximum expected discharge of 43,000 cfs between the piers, the piers would have to extend to about elevation 577.

A plan view of the crest operating at different discharges is shown on Figures 6 to 8 inclusive. The flow over the crest is rough. The roughness becomes noticeable at 15,000 cfs (Figure 7A) and progresses with increases in the flow. The irregular flow produces corrugations or "ropes" down the spillway chute (Figures 21 and 22). This characteristic was observed in the original studies (Figures 9 and 10, Appendix). The "ropes" are accentuated by the combination of the contracted flow at the

piers, and the vertical flow past the overhanging portion of the crest. The rough flow on the model was improved but not eliminated by placing a fillet on the upstream face of the spillway to eliminate the overhang.

The downstream progression of the jet impingement on the river bed with increasing flow and the enlargement of the turbulent area wherein the flow energy is dissipated is shown on Figures 9 through 11. The water "ropes" sometimes give a straggly appearance to the jet as shown on the right side of the jet in Figure 11A. The slotted bucket produces alternate ridges and troughs in the flowing water spreading it longitudinally. This increases the area of impingement at the tail water surface over that for a plain curved bucket.

The left side of the ski-jump area with different discharges is shown on Figures 12 through 14. The right side is shown on Figures 15 through 17. The water was relatively undisturbed at the toe of the dam at all flows. The jet cleared the canyon walls above the water surface at all flows. Discharges of 25,000 cfs or more produced considerable splashing from underwater impingement in the region where the canyon is restricted by the protuberance in the right canyon wall.

The water fins formed by the impingement of the spillway flow on the training walls downstream from the crest piers began overtopping the training walls at a flow of 33,500 cfs. These fins formed at low flows and increased in size with increases in flow until they eventually overtopped the training walls (Figures 14 and 17). This condition was eliminated by holding temporary slightly converging walls in the model with the upstream ends near the backs of the crest piers. Splashing over the training walls occurred in the tests on the original model and is discussed on page 4 of the Appendix.

The water action in the narrow portion of the gorge below the dam is shown on Figures 18 and 19. At 43,000 cfs the prominent point on the left and just downstream from the deep narrow section of the gorge gets splashed and washed over occasionally from wave action. The model operating at various discharges is shown from downstream in Figures 20, 21, and 22.

Surface velocities measured in the channel downstream from the jump are tabulated below:

Discharge cfs	Velocity feet per second
5,000	9.1
15,000	11.9
25,000	15.5
35,000	22.1
43,000	23.9

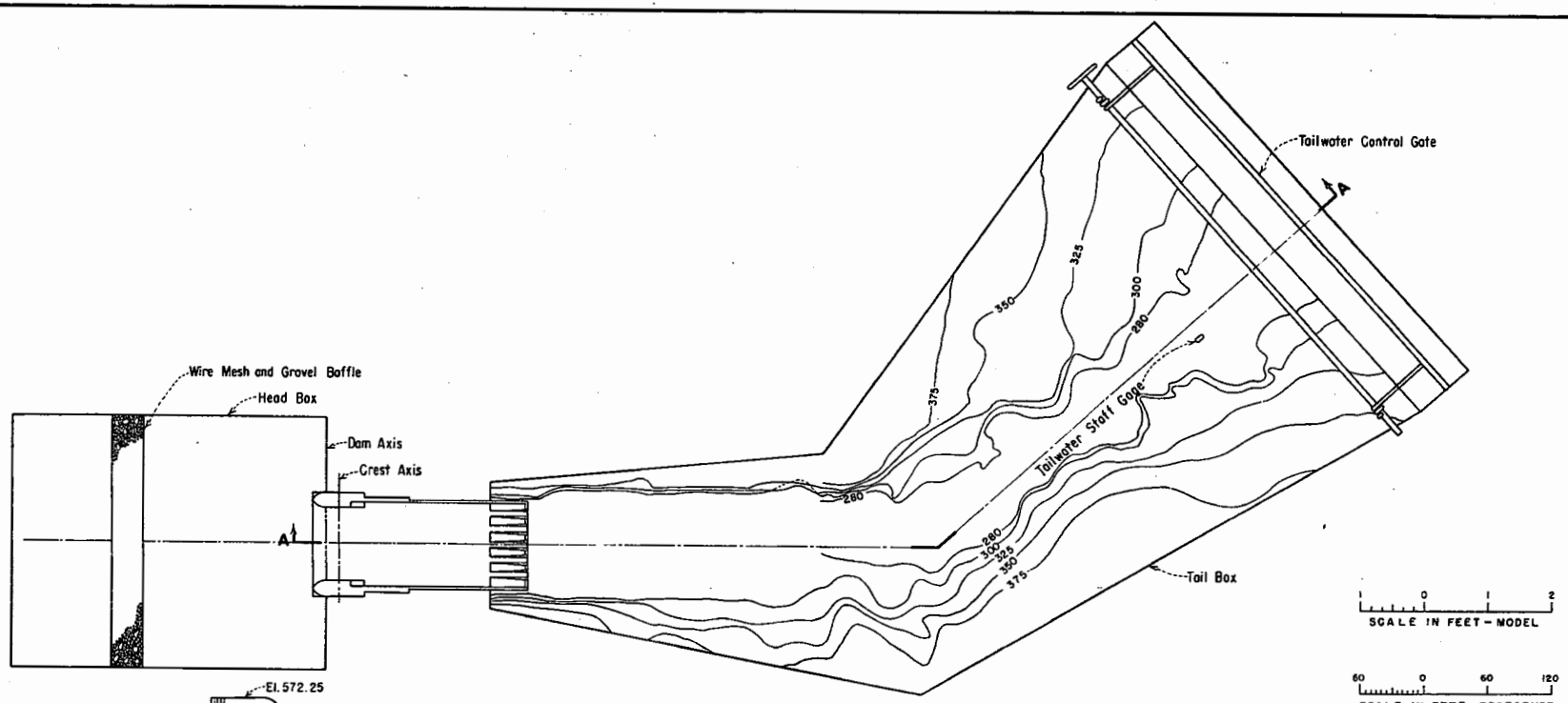
Detailed scour studies were not conducted but the general disposition of material by floods of various magnitude was noted, Figures 23 and 24. It appears that loose rock in the impingement area will be piled to form a bar at the bend in the stream channel.

Flow conditions on the spillway face with the gate holding a constant reservoir elevation of 570 are shown on Figures 26 and 27A. The gate position has no effect on the flow conditions in the ski-jump bucket. Additional information concerning the spillway flow is contained on page 4 and on Figures 6 and 8 of the Appendix.

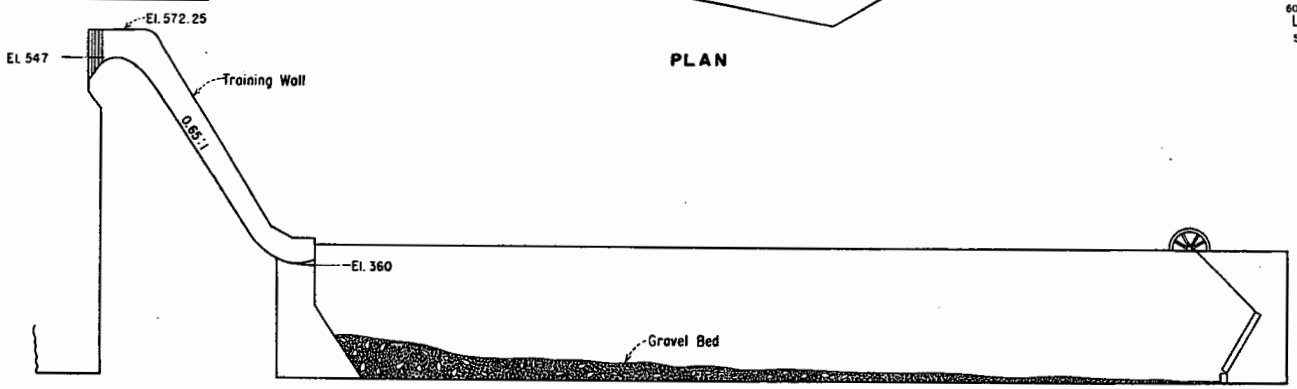
The assimilation of an outlet in operation on the model by a hose and pipe nipple was crude, but it illustrated how the flow from the outlets will pass down the face of the spillway and through the ski-jump bucket (Figure 27B).

Flow lines, obtained by taking a 1/10-second exposure photograph of confetti scattered on the water surface in the downstream river channel were obtained, for comparing velocities and flow patterns in the pumping plant and fishway areas, Figure 25. Too much of the main channel was covered in the first tests and the high velocity water made the flow lines valueless at high discharges. Exposures of 1/10 and 1/5 of a second were used in later pictures of the left side in the pumping plant area (Figures 33 through 36). At low flows the water flows downstream with little turbulence along the stream edges, Figure 33. Reverse flow occurs along the left bank with a relatively slow counterclockwise whorl in the pumping plant area. An increase in discharge carries the reverse flow farther upstream along the left bank with indications of small whorls forming inside the general whorl (Figures 34 through 36).

The model in operation with the plain curved bucket is shown on Figures 28 through 31. The only noticeable difference is in the jet downstream from the bucket. The jet is solid and not as thick as with the slotted bucket. The jet was more concentrated when it contacted the river bed and more scour occurred eroding a larger pool (Figure 32). The erosion would take place far enough downstream to preclude any damage to the structure.



PLAN

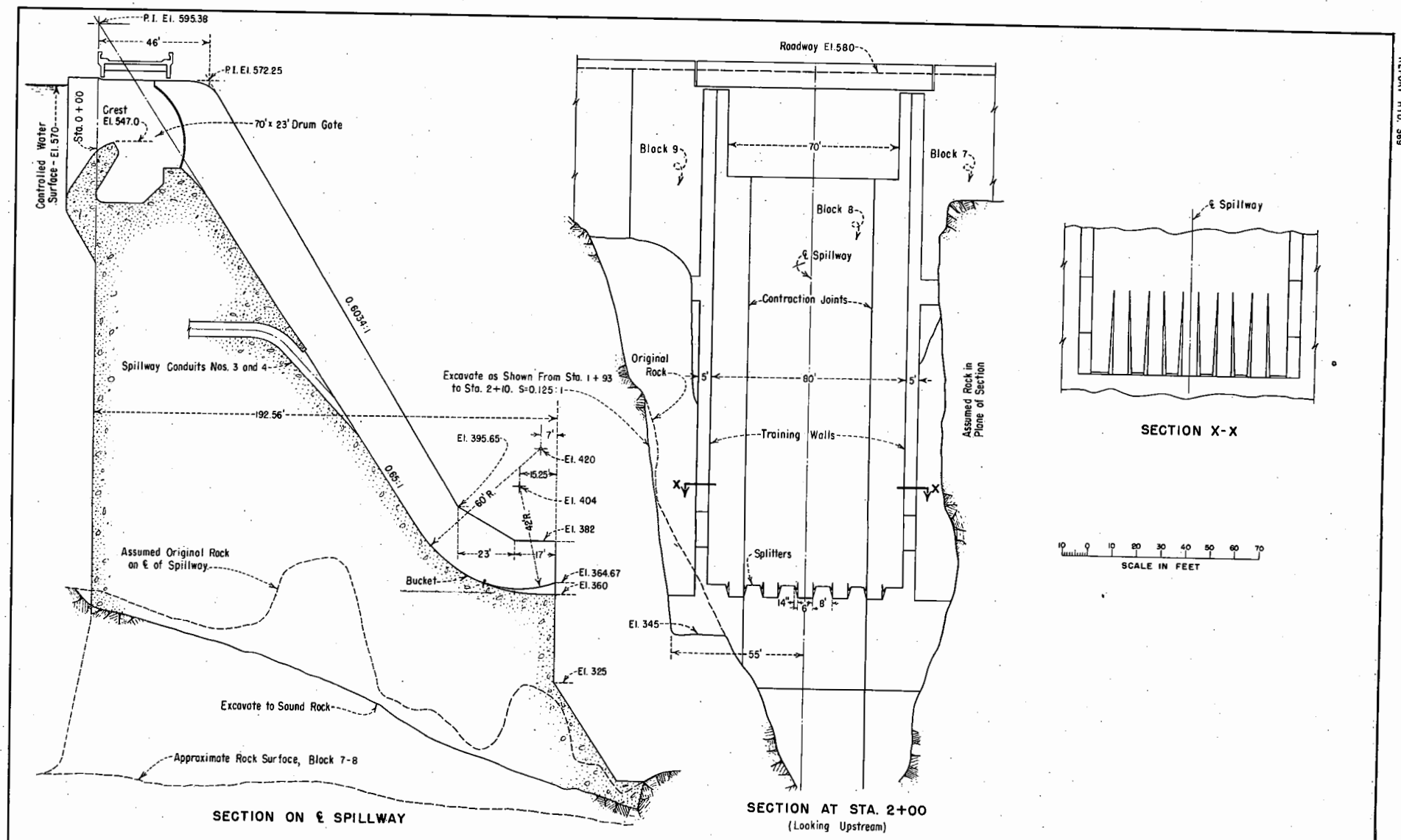


SECTION A-A

GREATER VANCOUVER WATER DISTRICT
VANCOUVER B.C.

CLEVELAND DAM
MODEL PLAN AND SECTION
MODEL SCALE 1:60

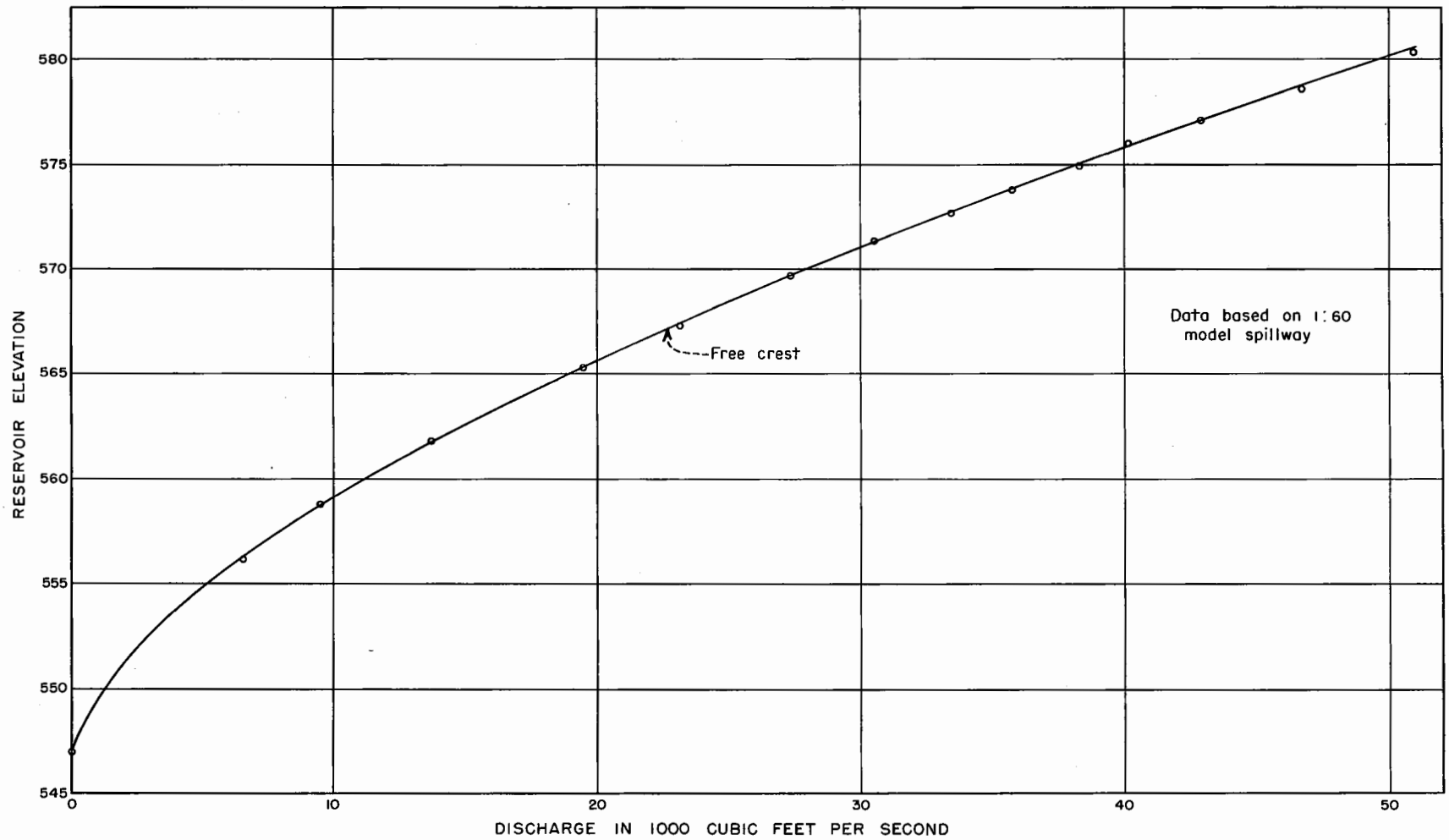
FIGURE I
REPORT HYD. 389



GREATER VANCOUVER WATER DISTRICT
VANCOUVER B.C.

CLEVELAND DAM
SPILLWAY SECTIONS

FIGURE 2
REPORT HYD. 369

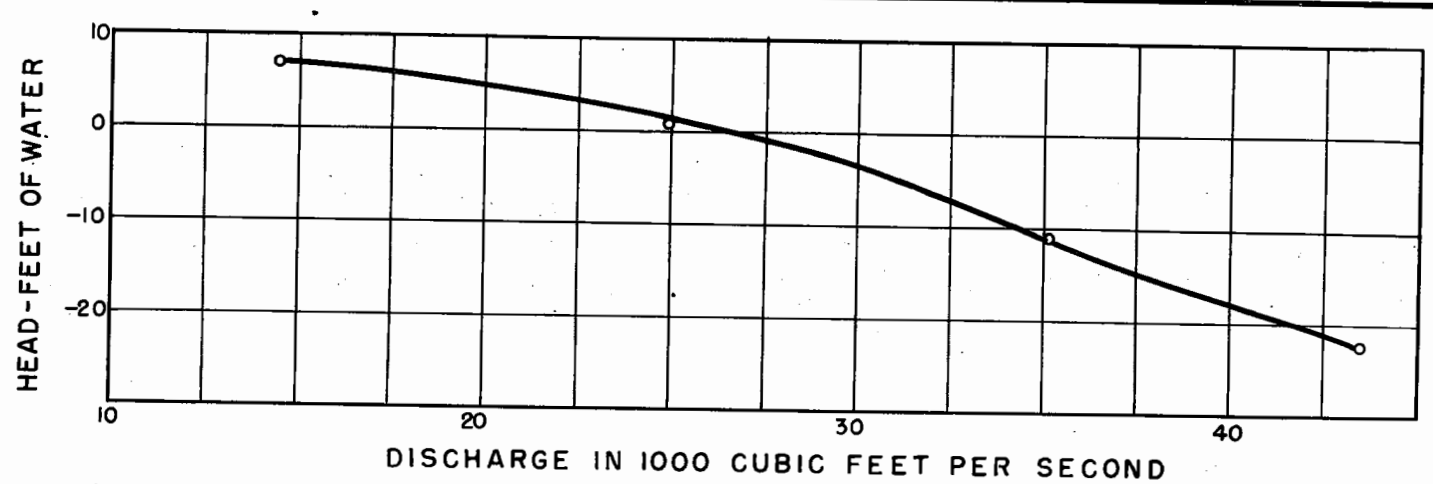


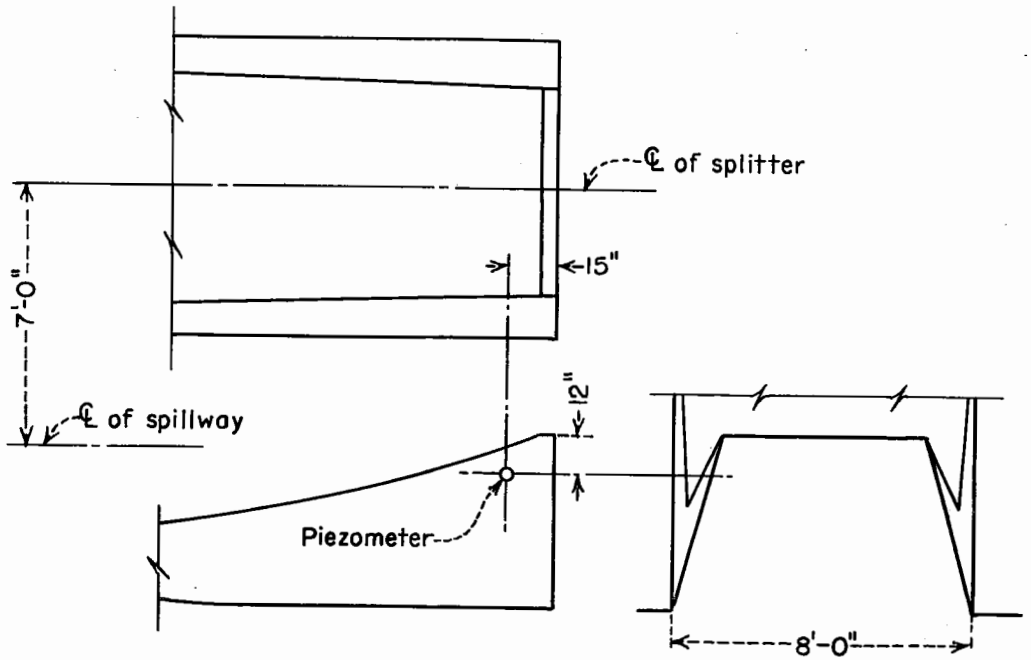
GREATER VANCOUVER WATER DISTRICT
VANCOUVER B.C.

CLEVELAND DAM

DISCHARGE CURVE – SPILLWAY CREST

FIGURE 3
REPORT HYD. 369

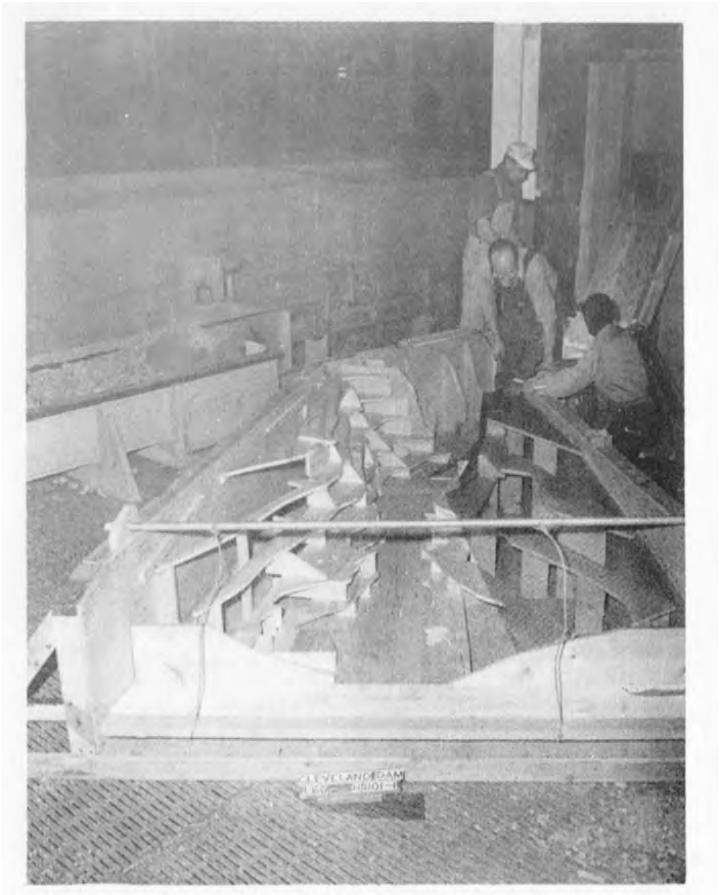




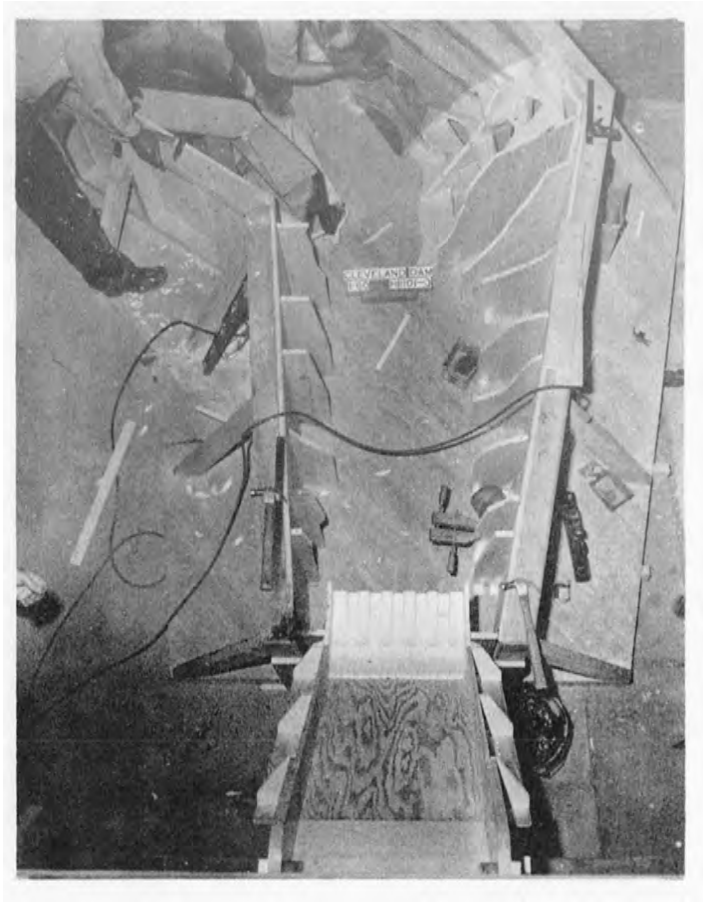
PIEZOMETER LOCATION

GREATER VANCOUVER WATER DISTRICT
VANCOUVER B.C.
CLEVELAND DAM
PRESSURE ON EDGE OF BUCKET FLOW SPLITTER
MODEL SCALE 1:60

FIGURE 4
REPORT HYD. 369



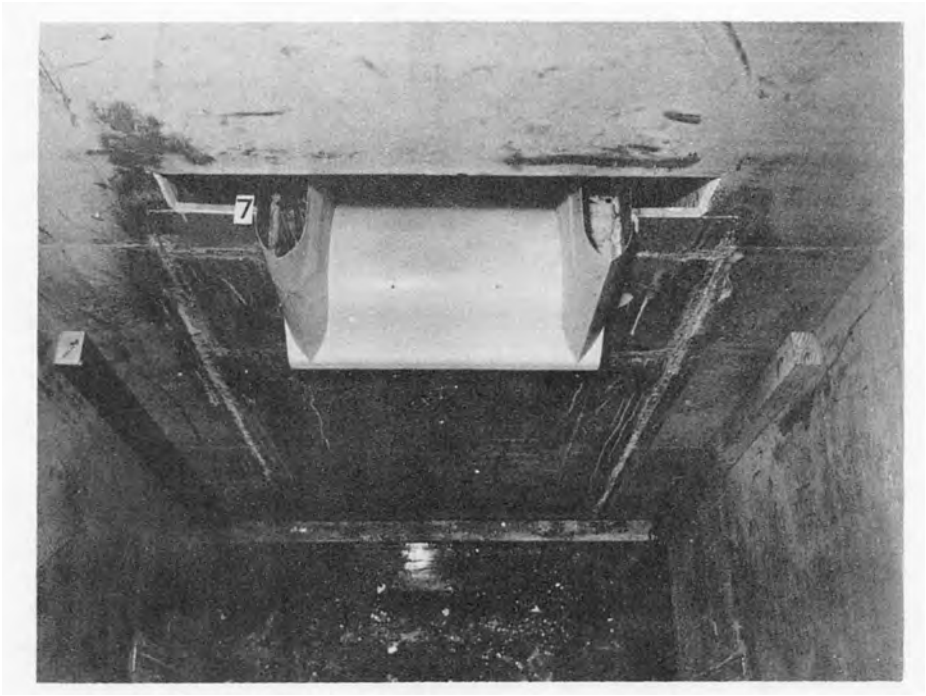
A. Contour bents from downstream



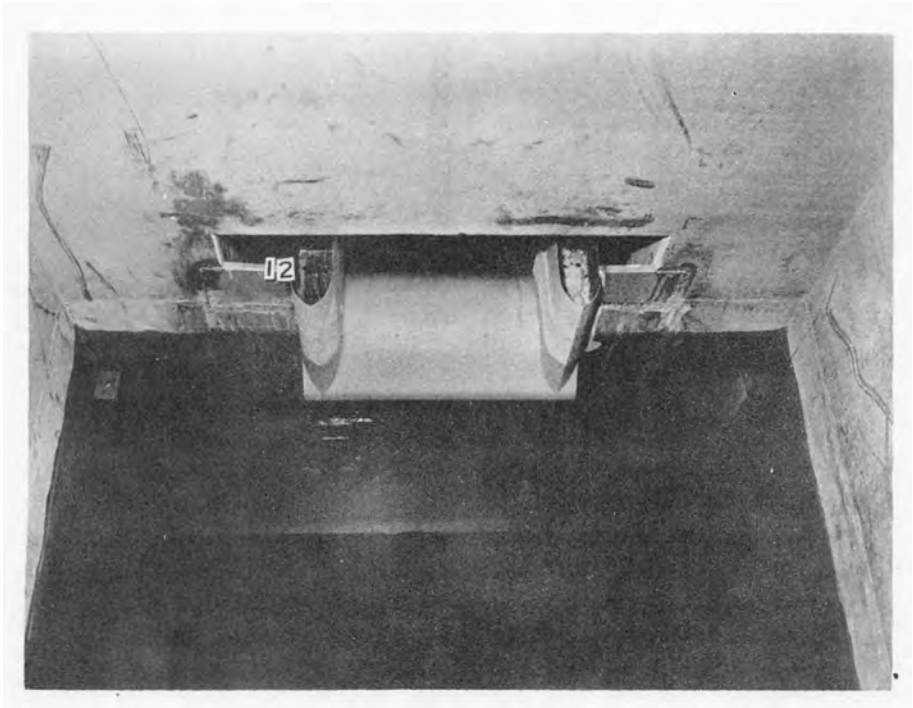
B. Plan view of spillway and contour bents

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway
Model Construction

FIGURE 5
REPORT Hyd-369



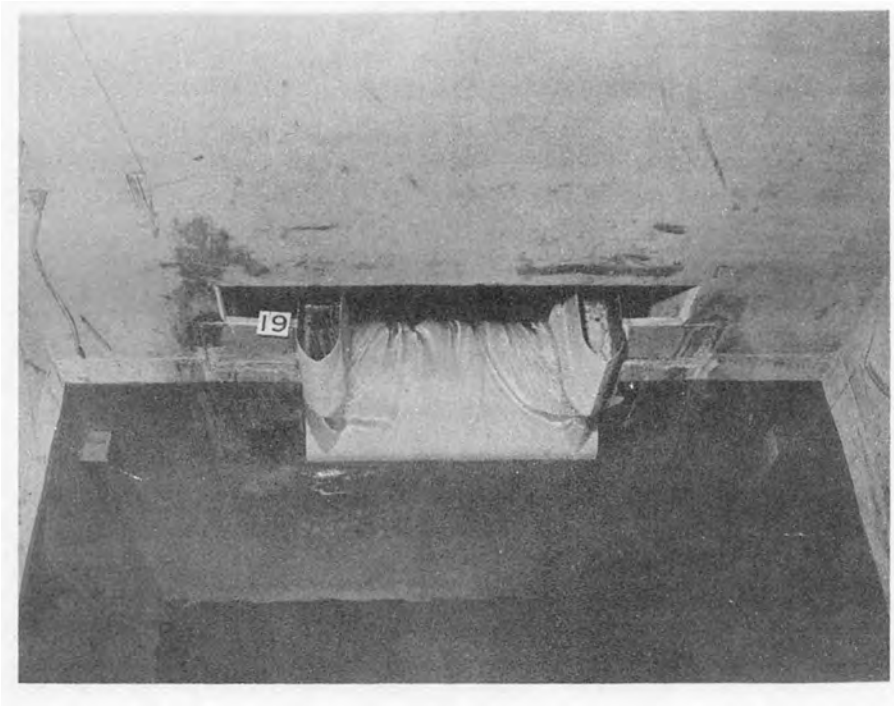
A. No discharge



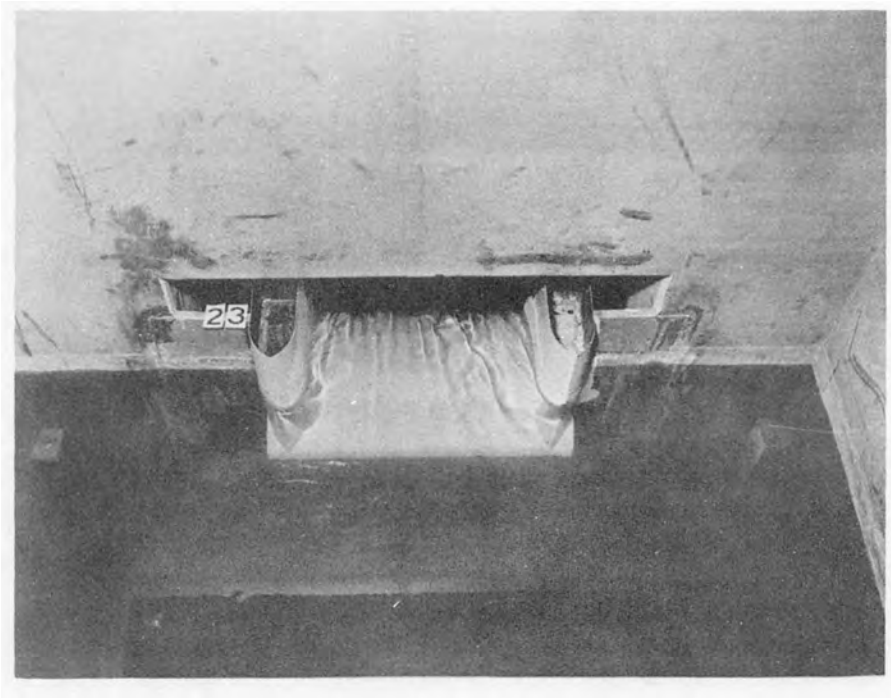
B. 5,000 cfs discharge

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flows of 0 and 5,000 cfs over crest
with gate down



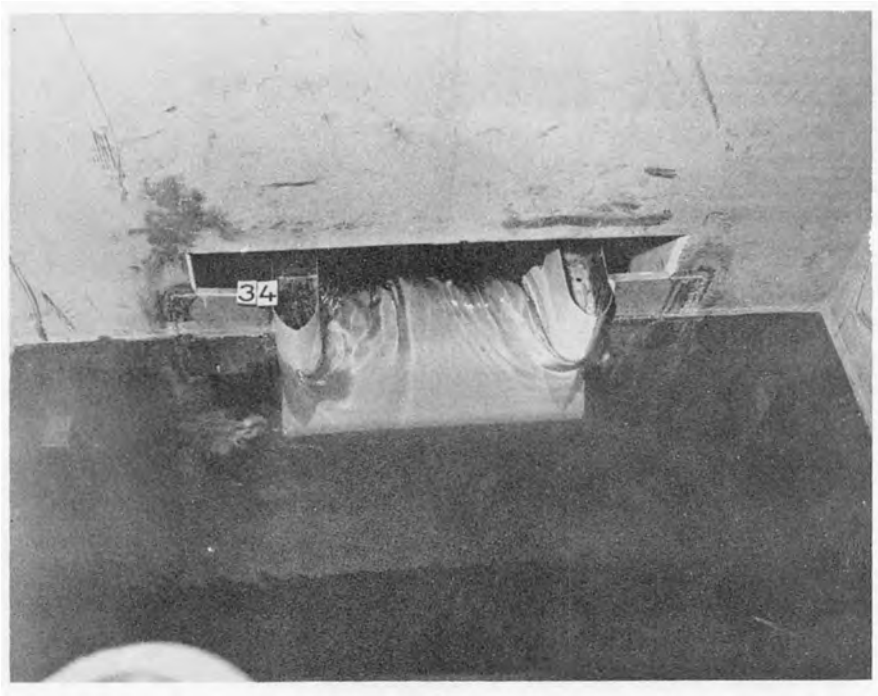
A. 15,000 cfs discharge



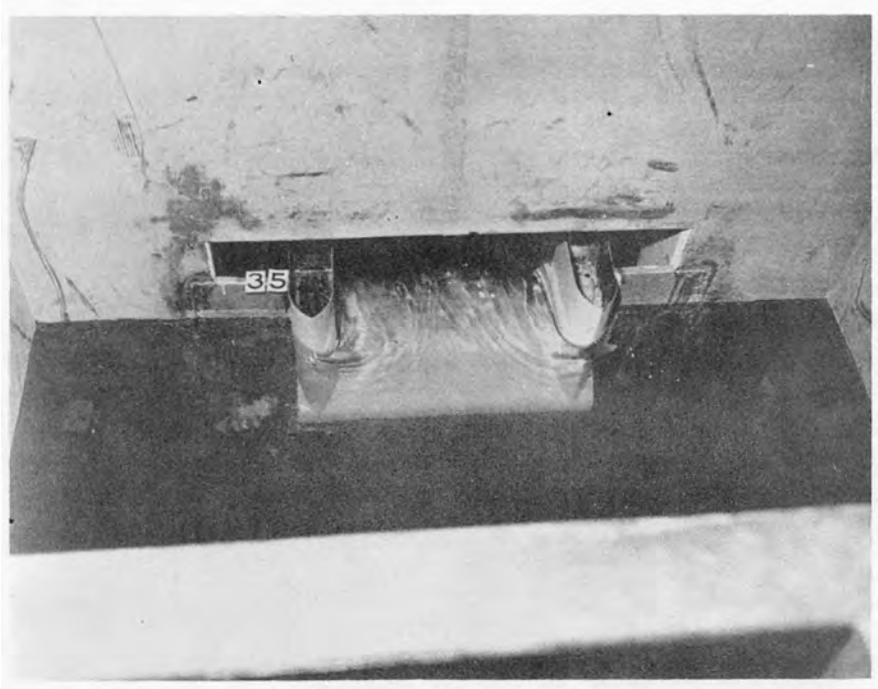
B. 25,000 cfs discharge

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flows of 15,000 and 25,000 cfs over crest
with gate down



A. 35,000 cfs discharge

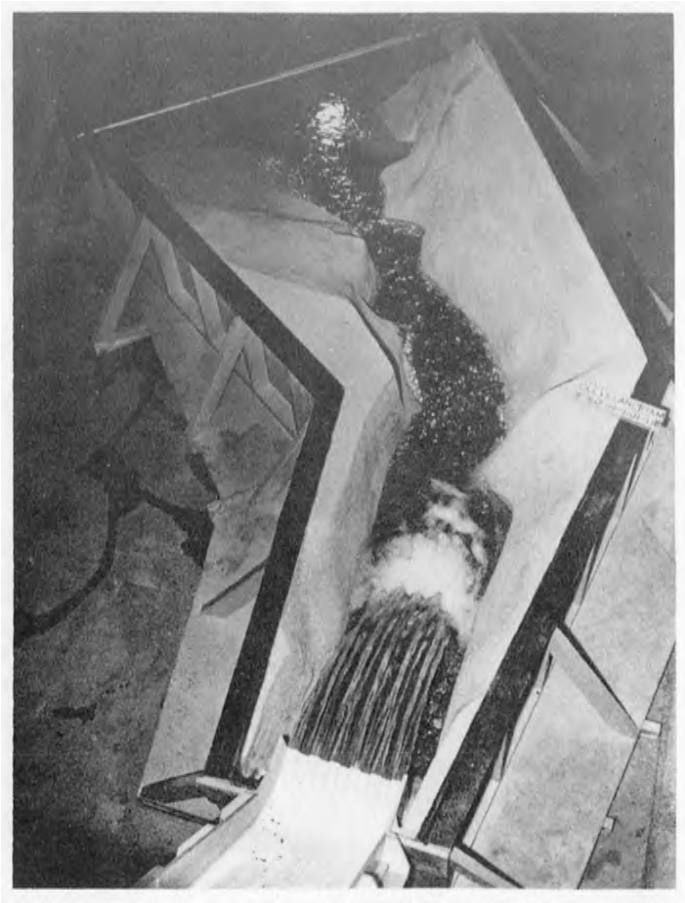


B. 43,000 cfs discharge

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flows of 35,000 and 43,000 cfs over crest
with gate down

A. No discharge

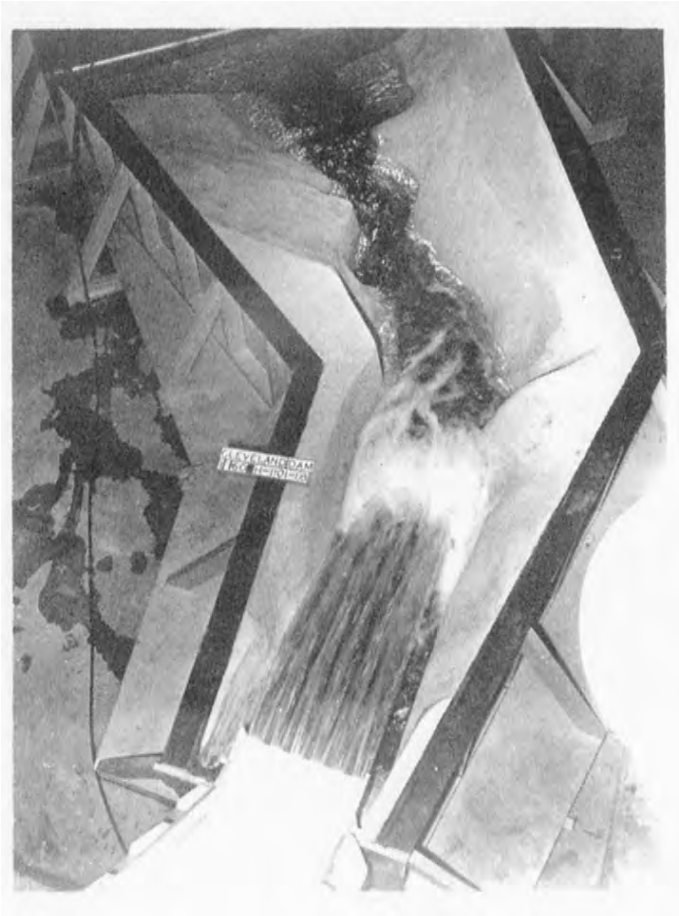


B. 5,000 cfs discharge
Tail water el. 288

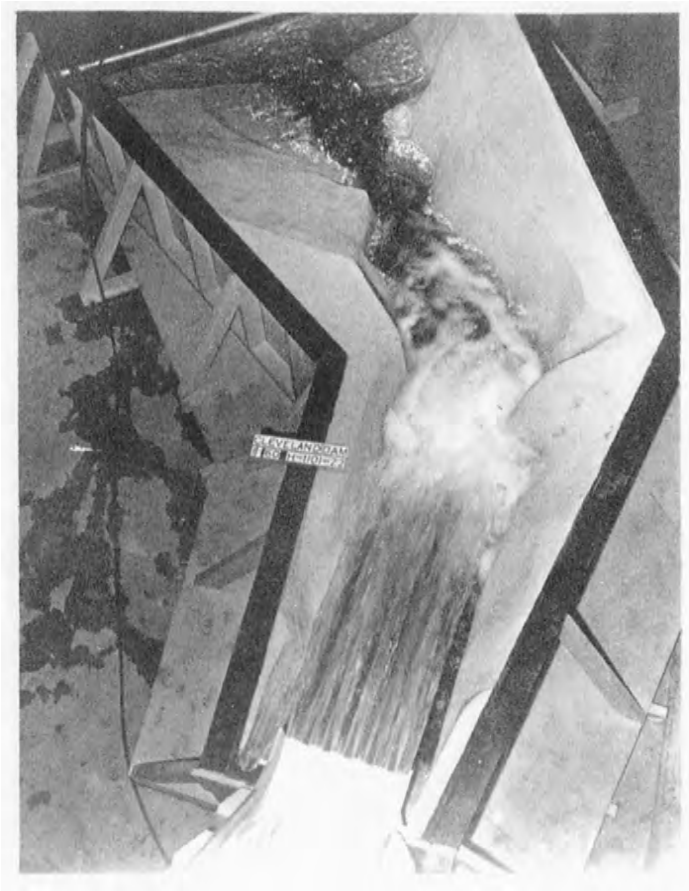
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Plan views of downstream river channel
with flows of 0 and 5,000 cfs

FIGURE 9
REPORT Hyd-369



A. 15,000 cfs discharge
Tail water el. 299

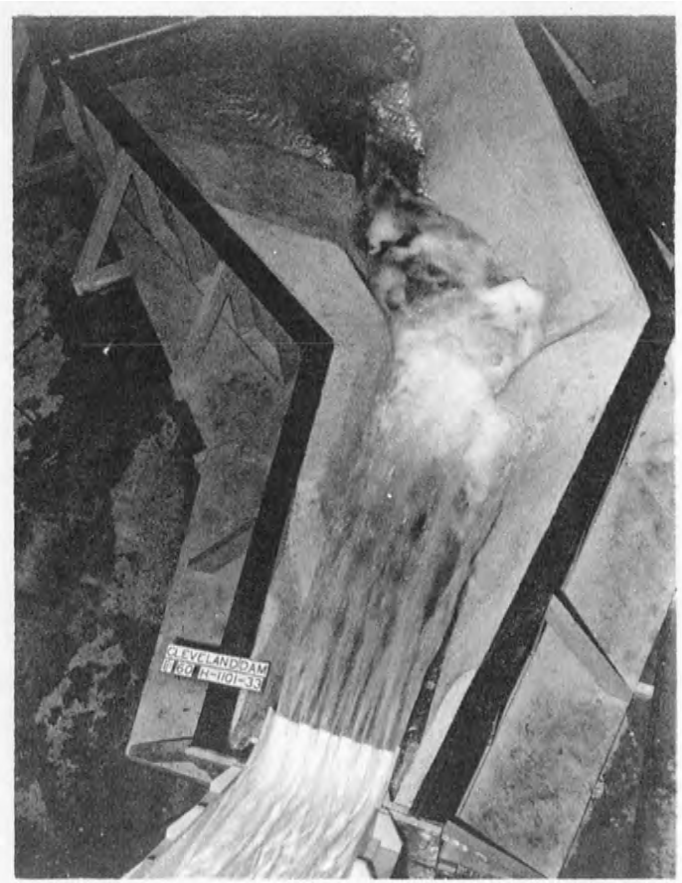


B. 25,000 cfs discharge
Tail water el. 307

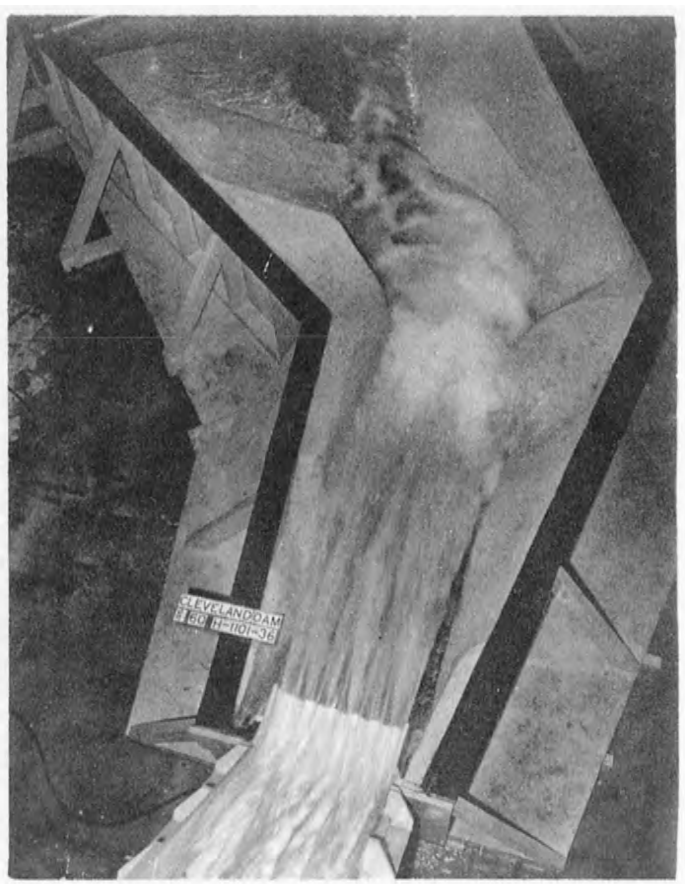
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Plan views of downstream river channel
with flows of 15,000 and 25,000 cfs

FIGURE 10
REPORT Hyd-369



A. 35,000 cfs discharge
Tail water el. 314



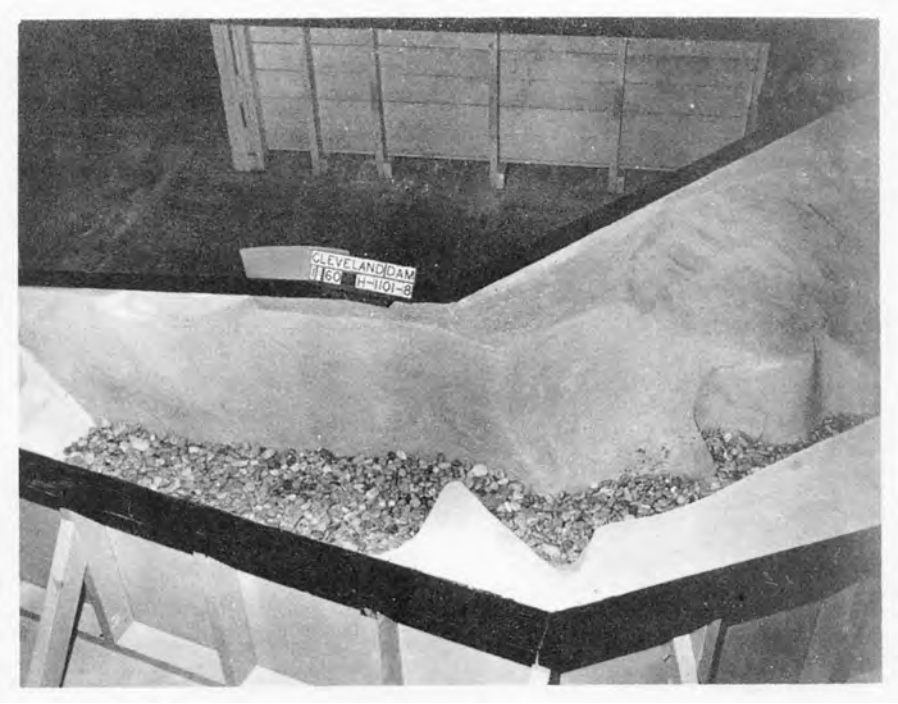
B. 43,000 cfs discharge
Tail water el. 319

Plan view of downstream river section

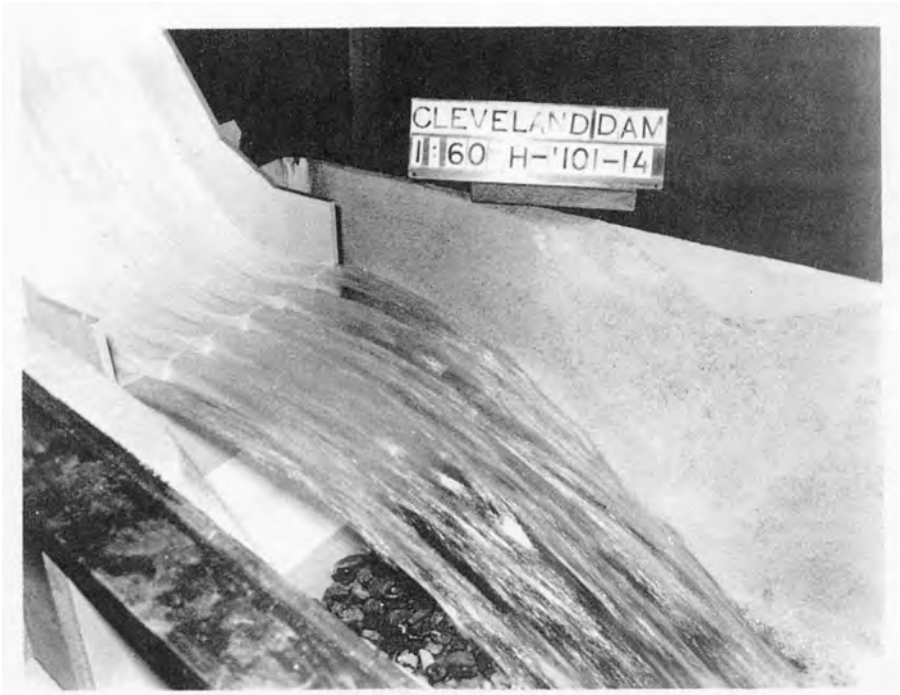
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Plan views of downstream river channel
with flows of 35,000 and 43,000 cfs

FIGURE 11
REPORT Hyd-369



A. No discharge

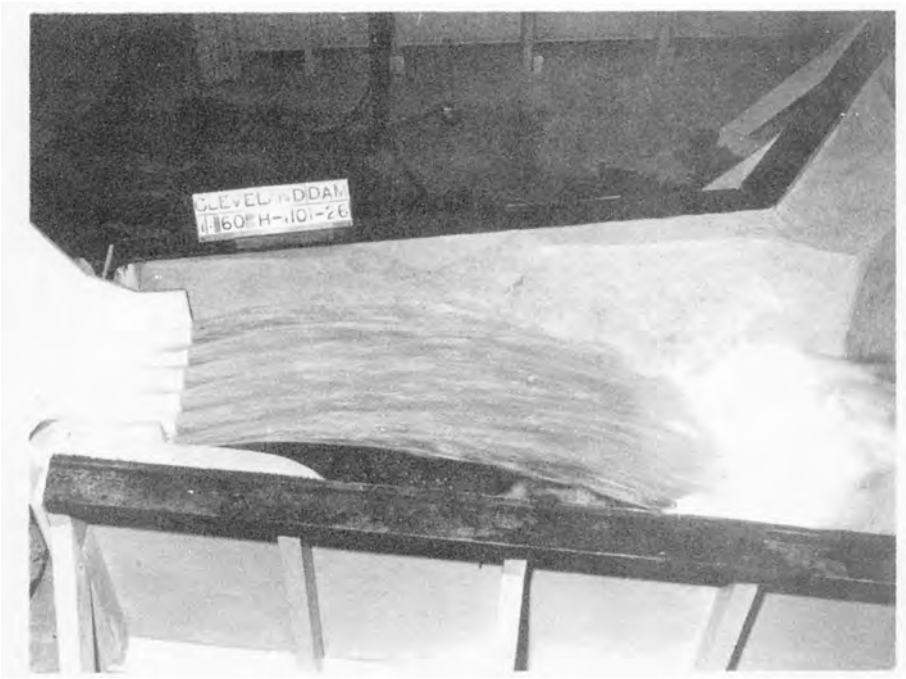


B. 5,000 cfs discharge
Tail water el. 288

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of left side in ski-jump area
with flows of 0 and 5,000 cfs

A. 15,000 cfs discharge
Tail water el. 299

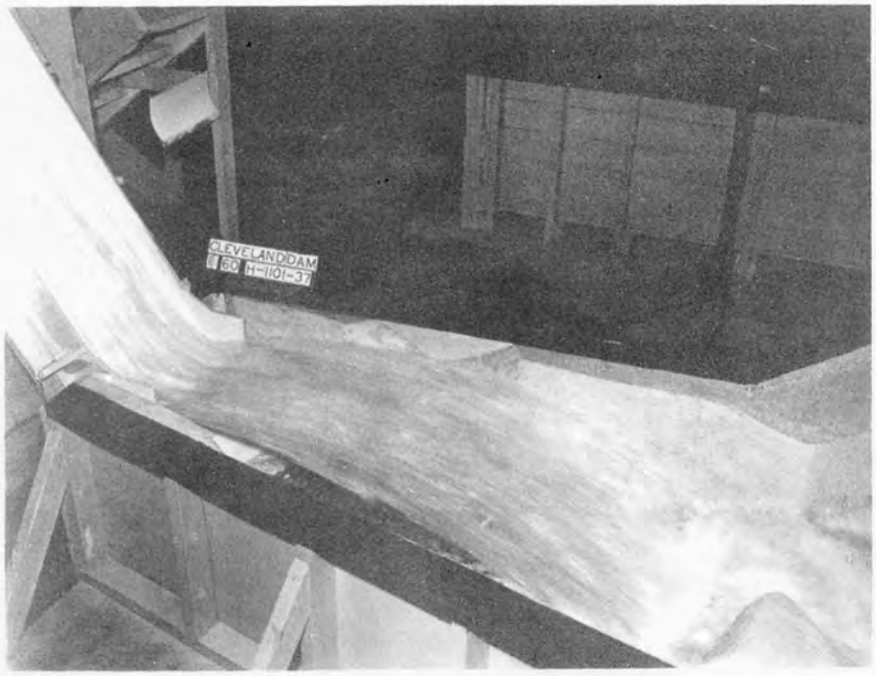


B. 25,000 cfs discharge
Tail water el. 307

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of right side in ski-jump area
with flows of 15,000 and 25,000 cfs

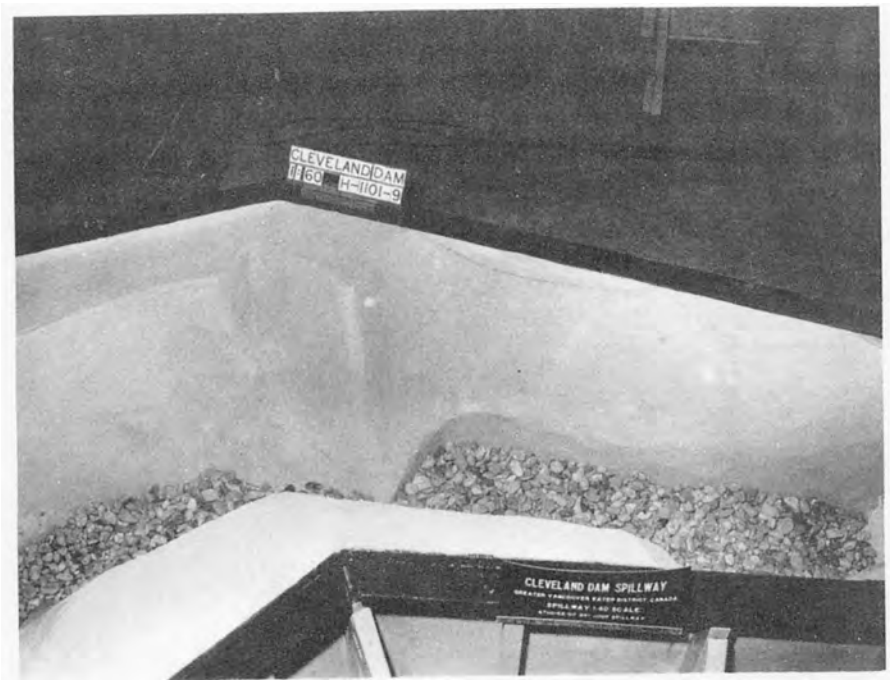
A. 35,000 cfs discharge
Tail water el. 314



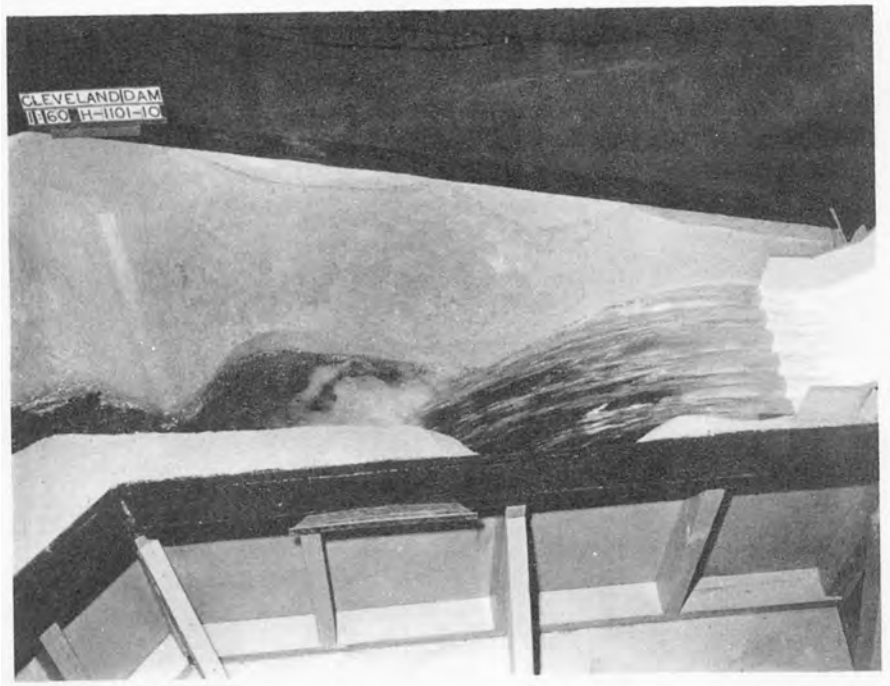
B. 43,000 cfs discharge
Tail water el. 319

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of right side in ski-jump area
with flows of 35,000 and 43,000 cfs



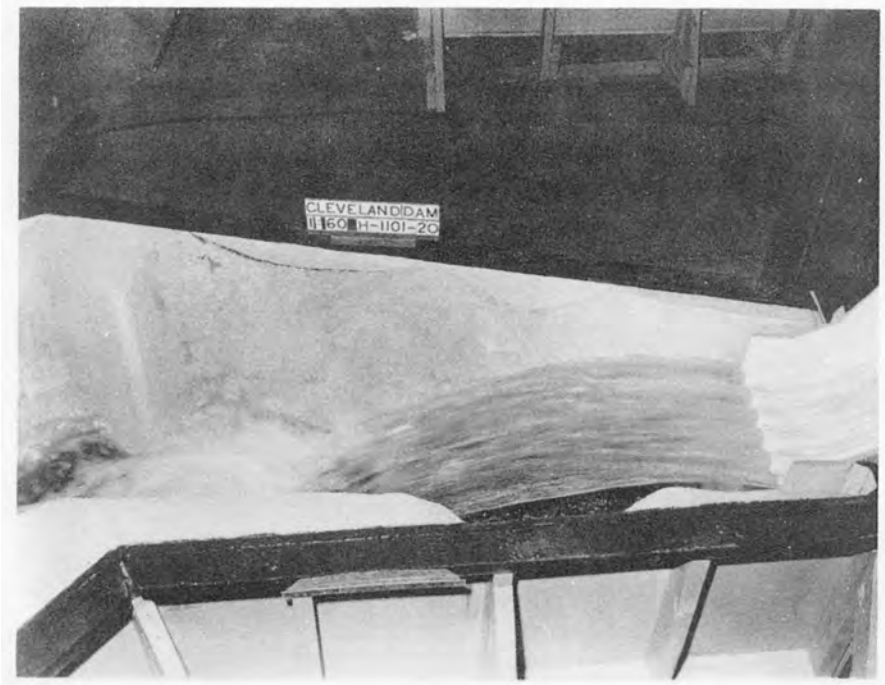
A. No discharge



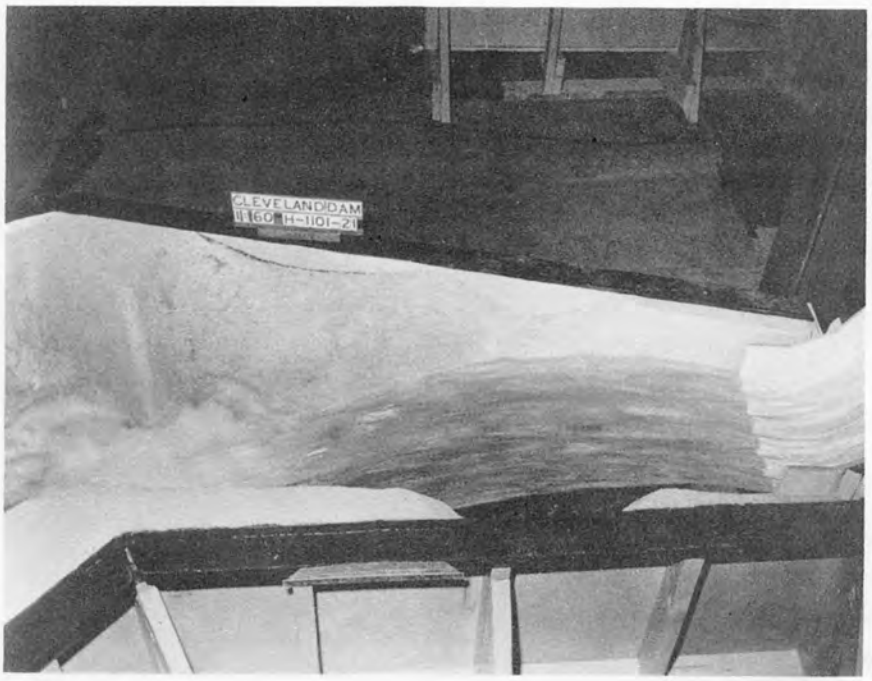
B. 5,000 cfs discharge
Tail water el. 288

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of right side in ski-jump area
with flows of 0 and 5,000 cfs



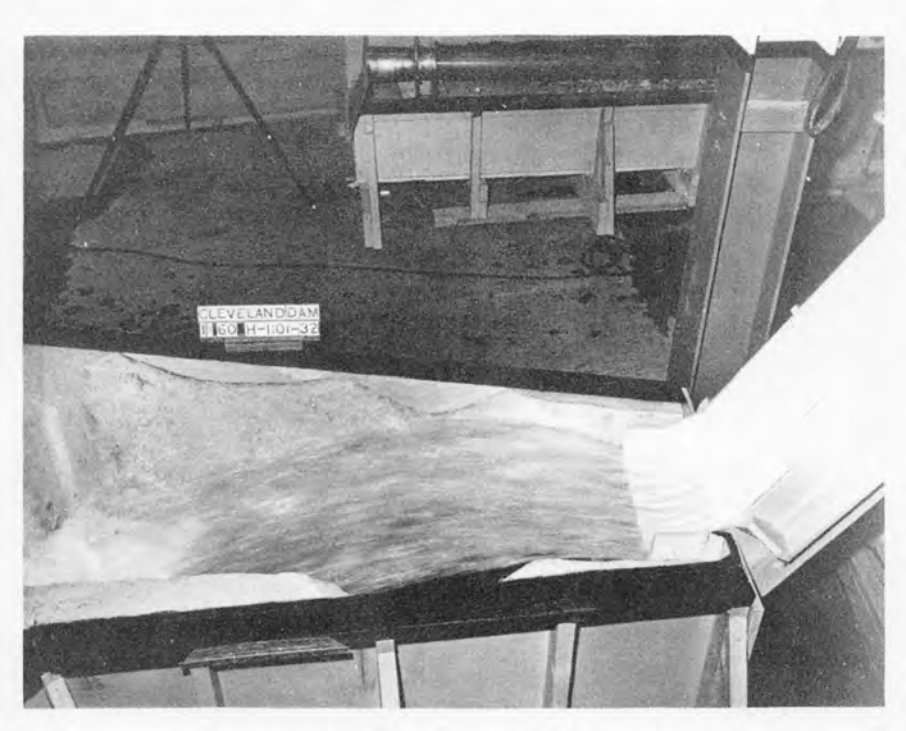
A. 15,000 cfs discharge
Tail water el. 299



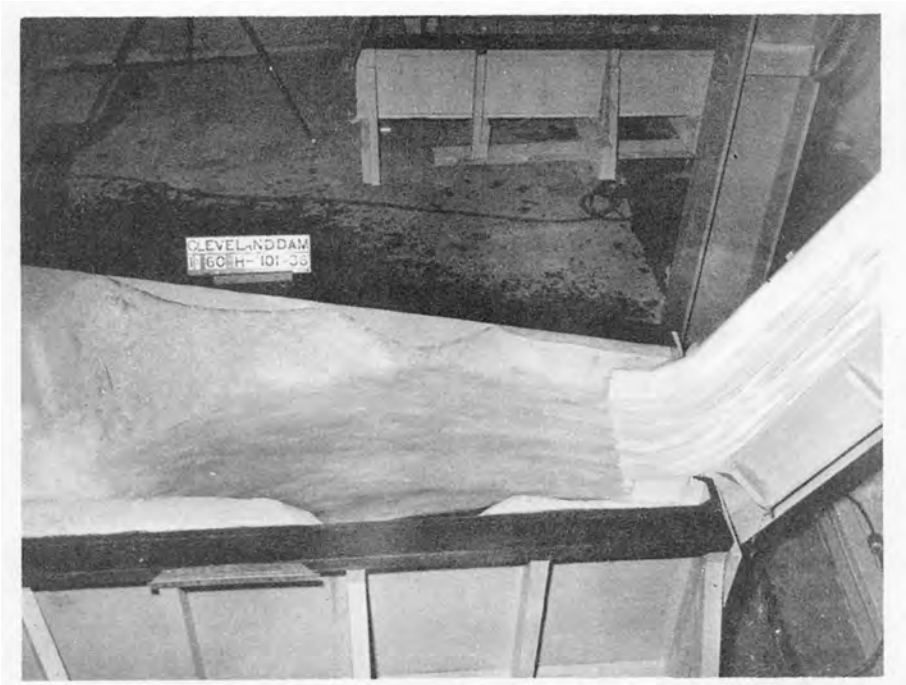
B. 25,000 cfs discharge
Tail water el. 307

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of left side in ski-jump area
with flows of 15,000 and 25,000 cfs



A. 35,000 cfs discharge
Tail water el. 314



B. 43,000 cfs discharge
Tail water el. 319

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of left side in ski-jump area
with flows of 35,000 and 43,000 cfs

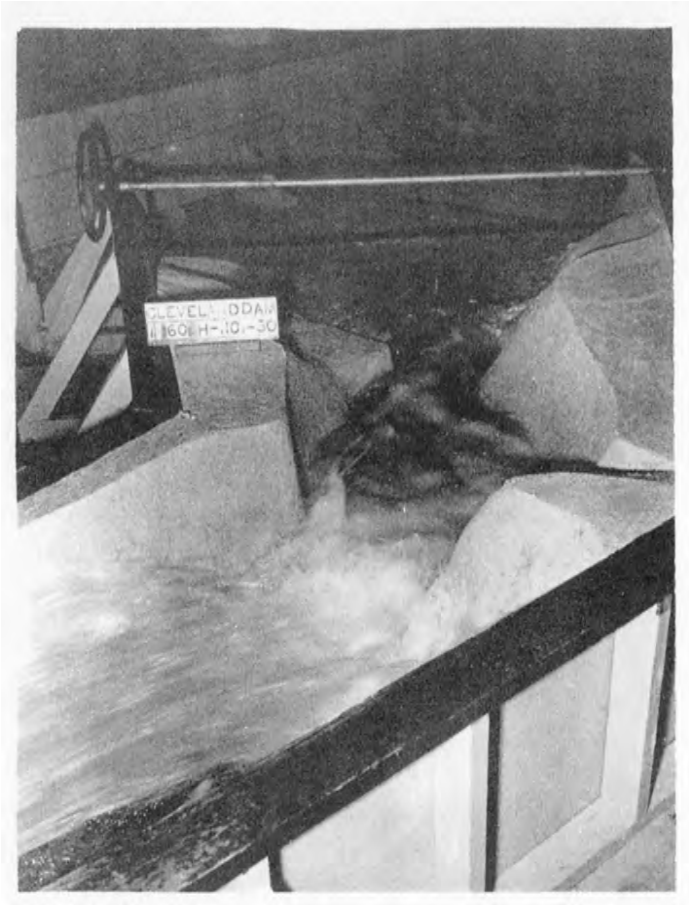
A. 15,000 cfs discharge
Tail water el. 299

B. 25,000 cfs discharge
Tail water el. 307

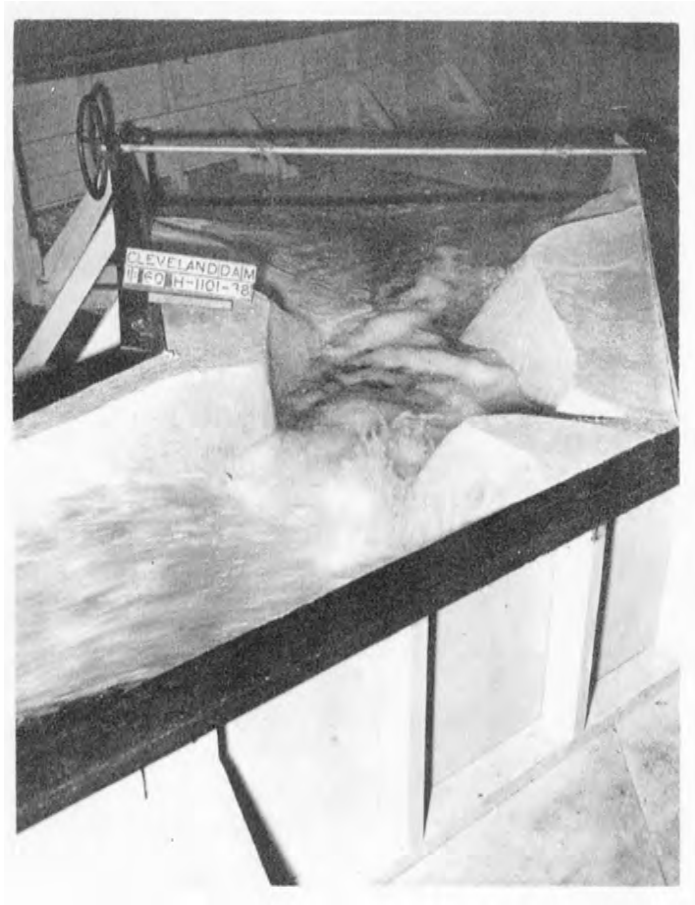
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of jet impingement and downstream river channel with flows of 15,000 and 25,000 cfs.

FIGURE 18
REPORT Hyd-369



A. 35,000 cfs discharge
Tail water el. 314

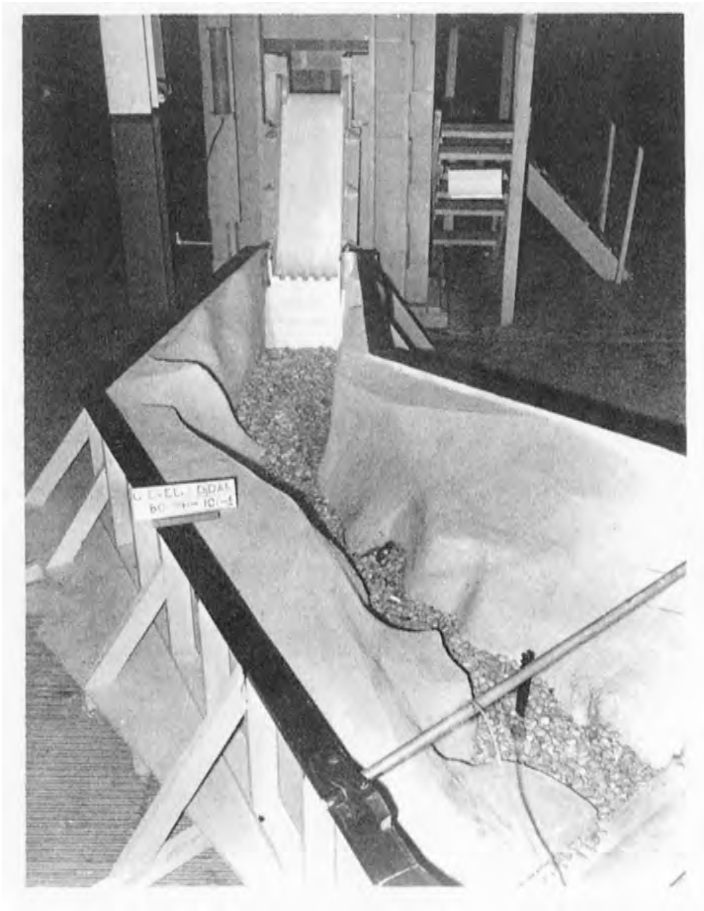


B. 43,000 cfs discharge
Tail water el. 319

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of jet impingement and downstream river channel with flows of 35,000 and 43,000 cfs.

FIGURE 19
REPORT Hyd 369



A. No discharge

B. 5,000 cfs discharge
Tail water el. 288

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of river channel and spillway
with flows of 0 and 5,000 cfs

FIGURE 20
REPORT Hyd-369

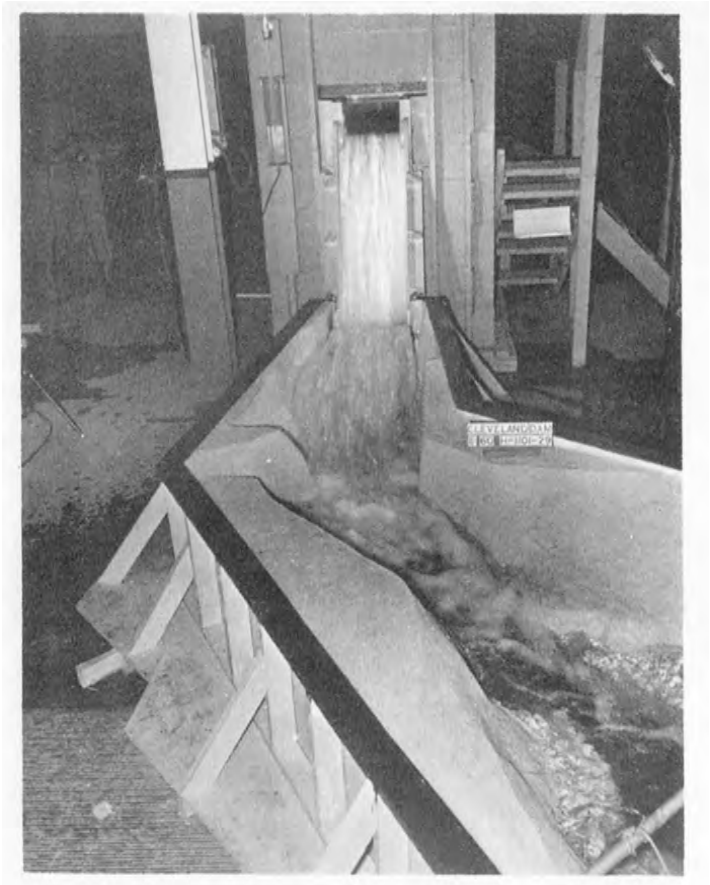
A. 15,000 cfs discharge
Tail water el. 299

B. 25,000 cfs discharge
Tail water el. 307

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of river channel and spillway
with flows of 15,000 and 25,000 cfs

FIGURE 21
REPORT Hyd-369



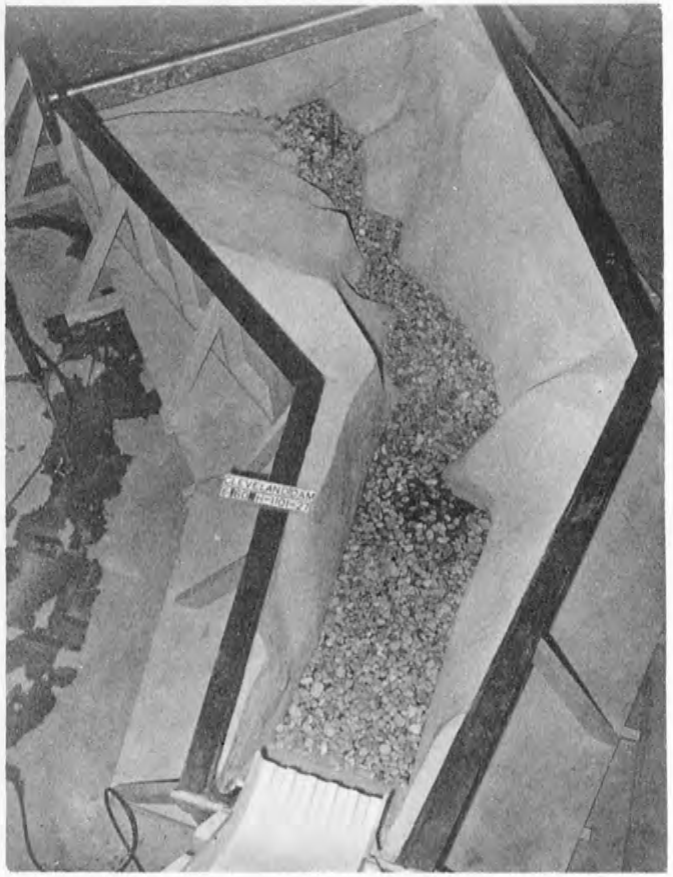
A. 35,000 cfs discharge
Tail water el. 314

B. 43,000 cfs discharge
Tail water el. 319

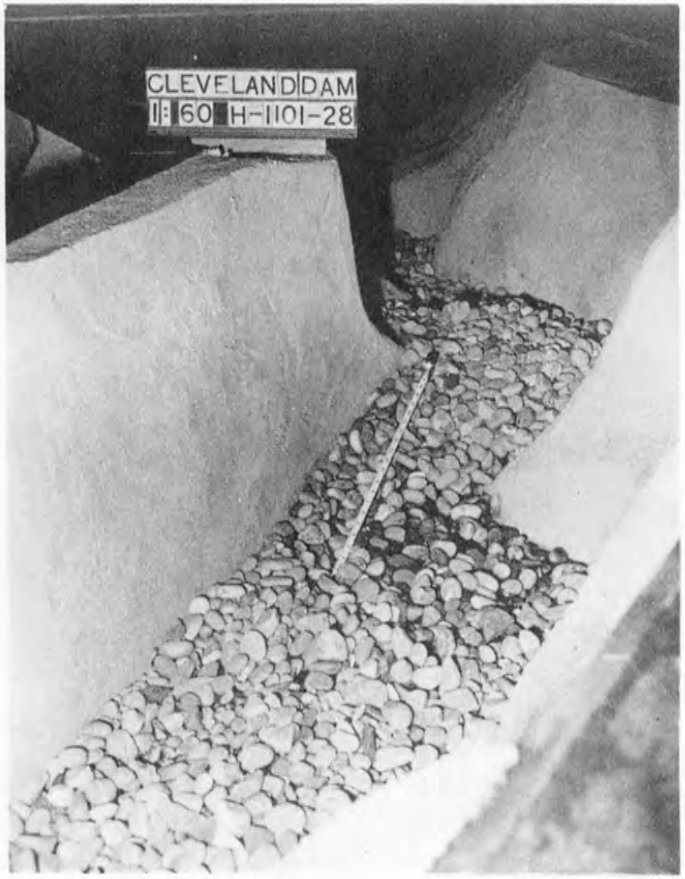
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

View of river channel and spillway
with flows of 35,000 and 43,000 cfs.

FIGURE 22
REPORT Hyd-369



A. Plan

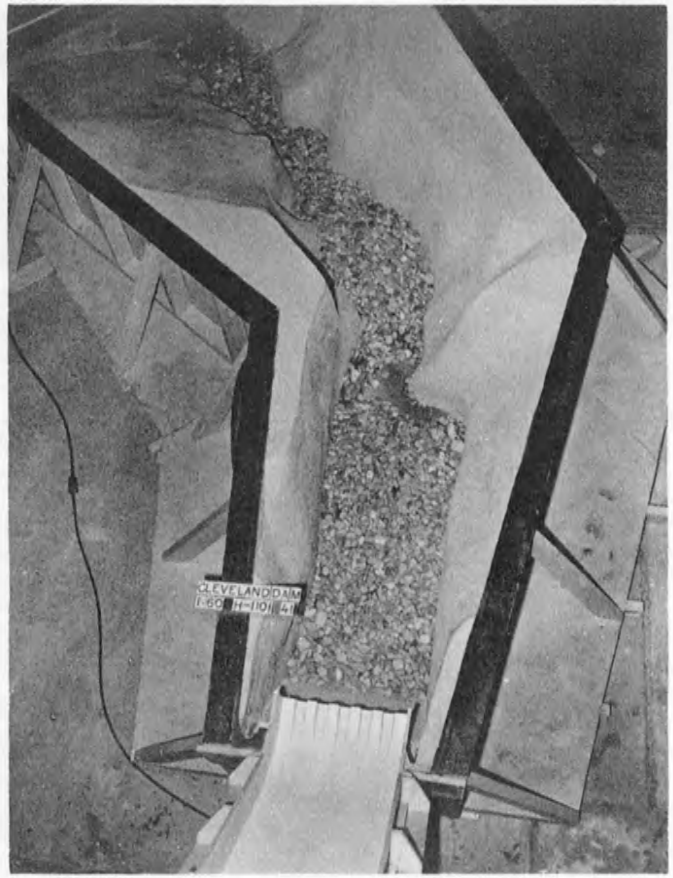


B. Close-up from right side

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Scour in river channel after discharge
of 35,000 cfs

FIGURE 23
REPORT Hyd-369



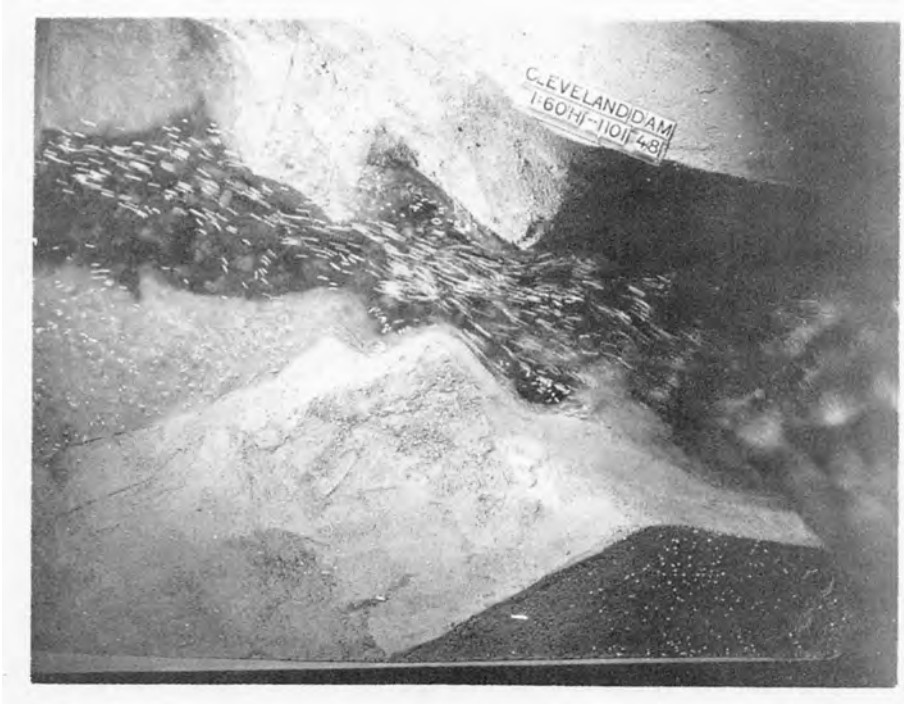
A. Plan

B. Close-up from right side

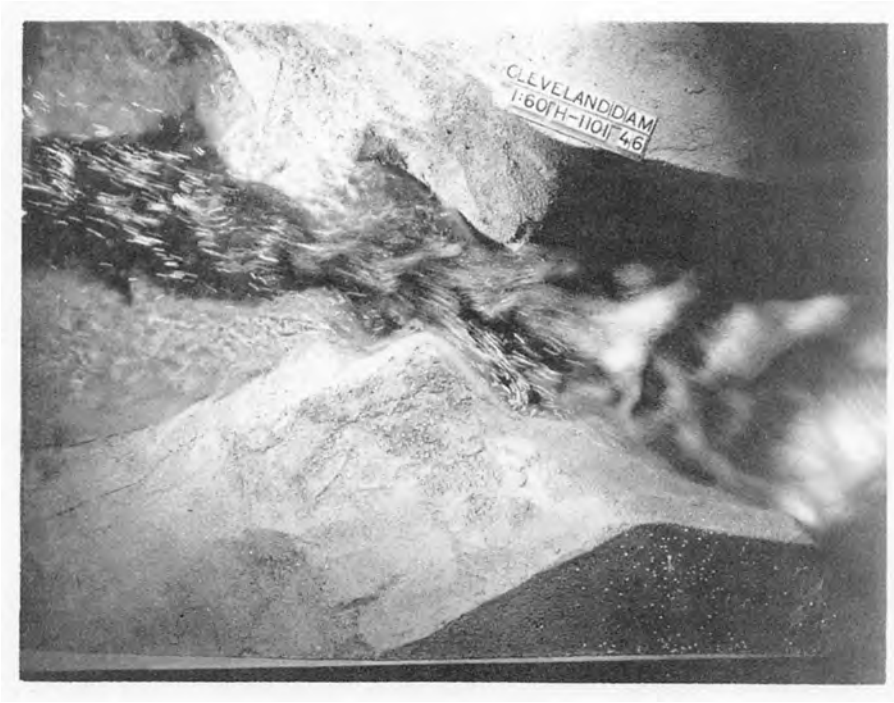
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Scour in river channel after
43,000 cfs discharge

FIGURE 24
REPORT Hyd-369



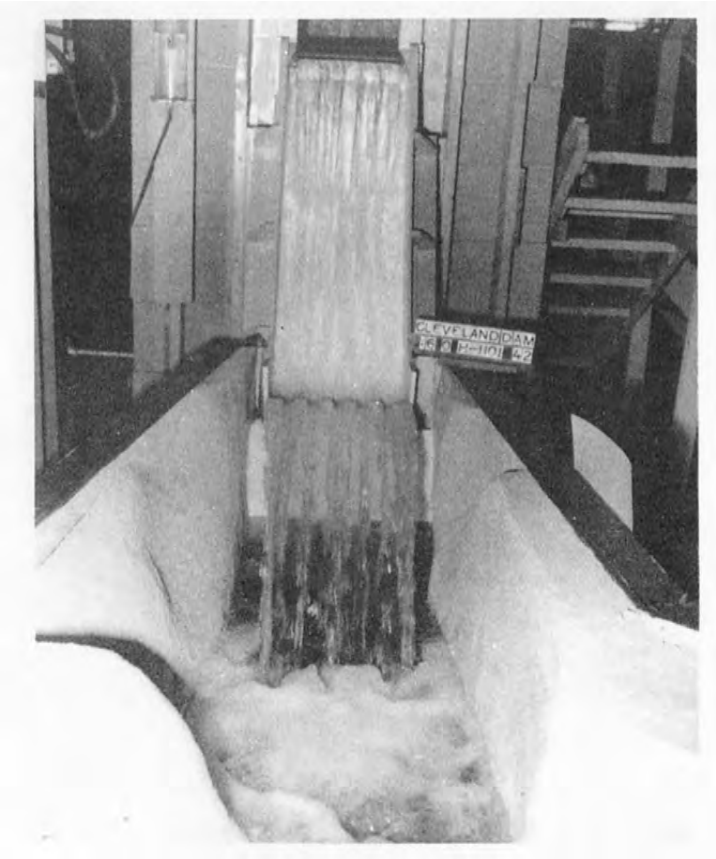
A. 15,000 cfs discharge



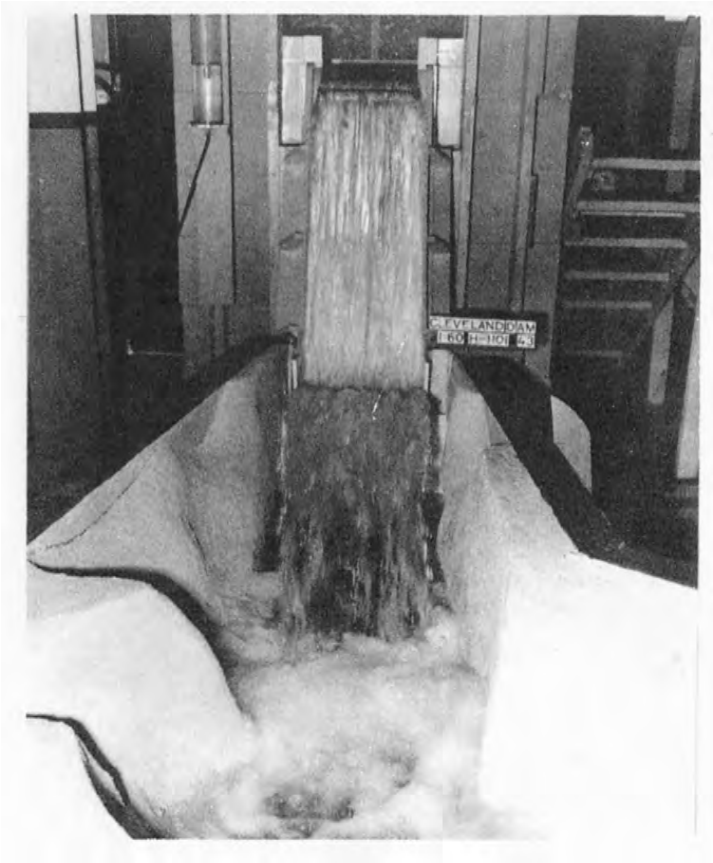
B. 25,000 cfs discharge

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow pattern in river channel as shown by floating confetti.



A. 8,000 cfs discharge

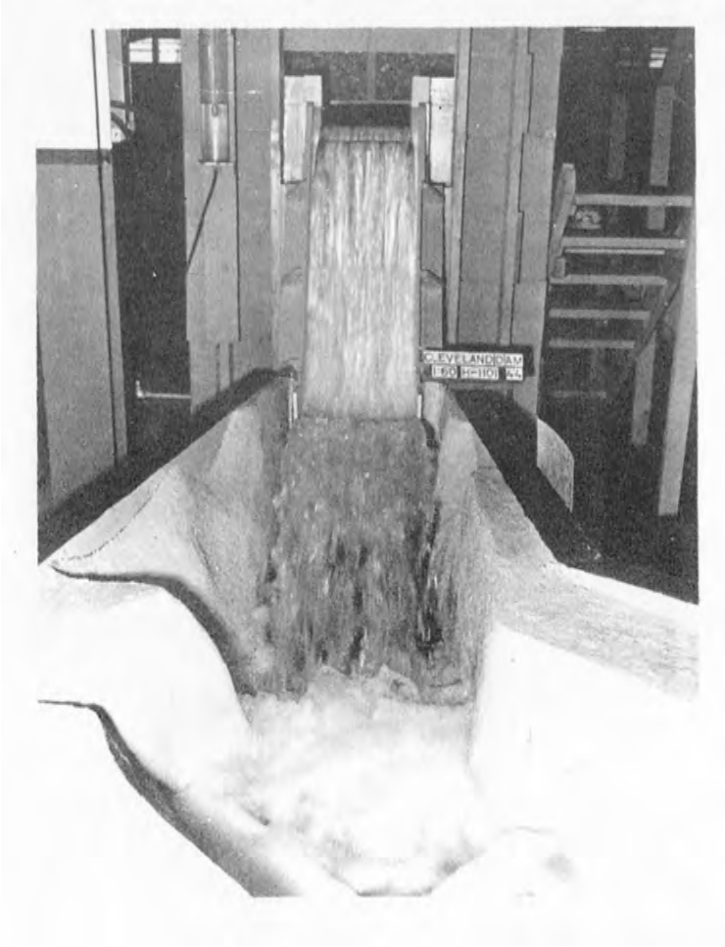


B. 14,500 cfs discharge

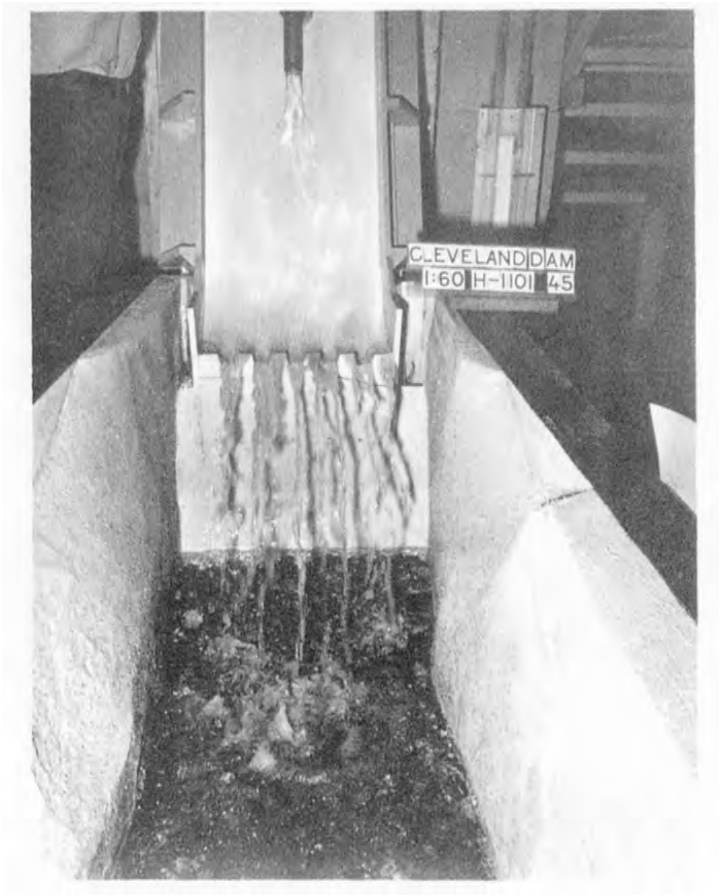
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow in spillway with gate maintaining water surface at el. 570.

FIGURE 26
REPORT Hyd-369



A. 22,000 cfs discharge
Gate raised reservoir el. 570

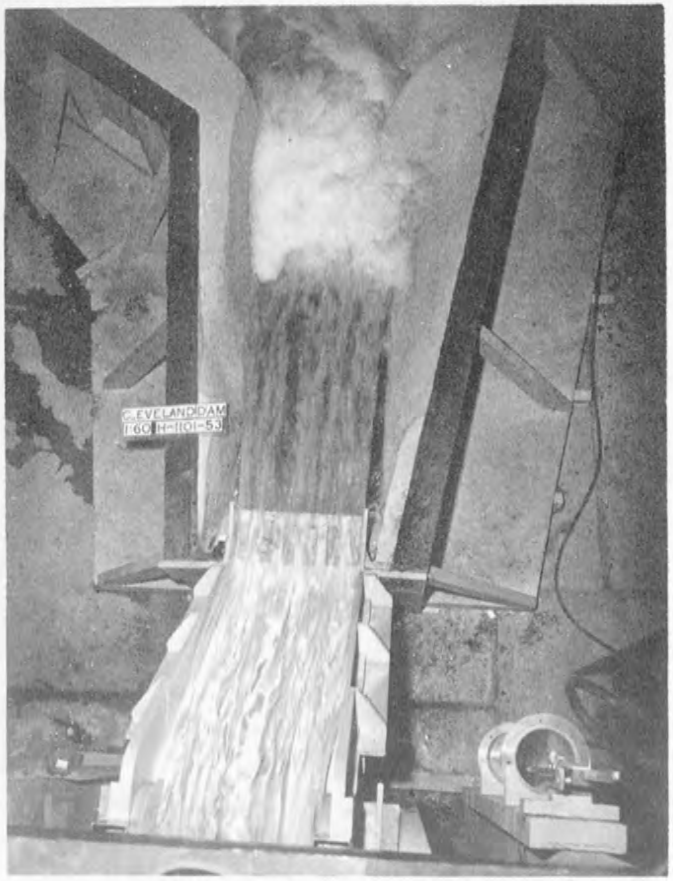


B. 1,750 cfs discharge
Assimilated outlet flow.

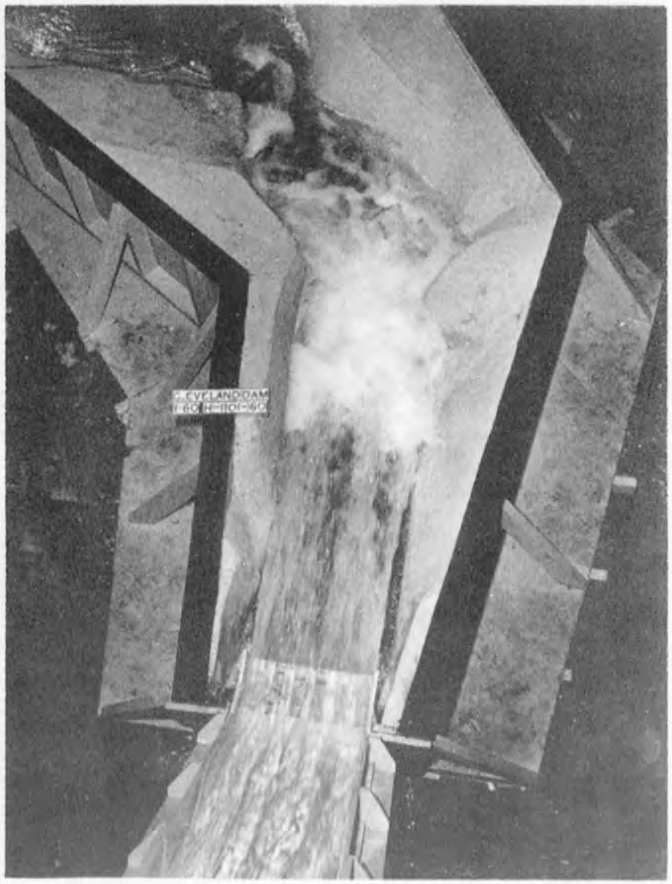
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow conditions for spillway and outlets

FIGURE 27
REPORT Hyd-369



A. 35,000 cfs discharge

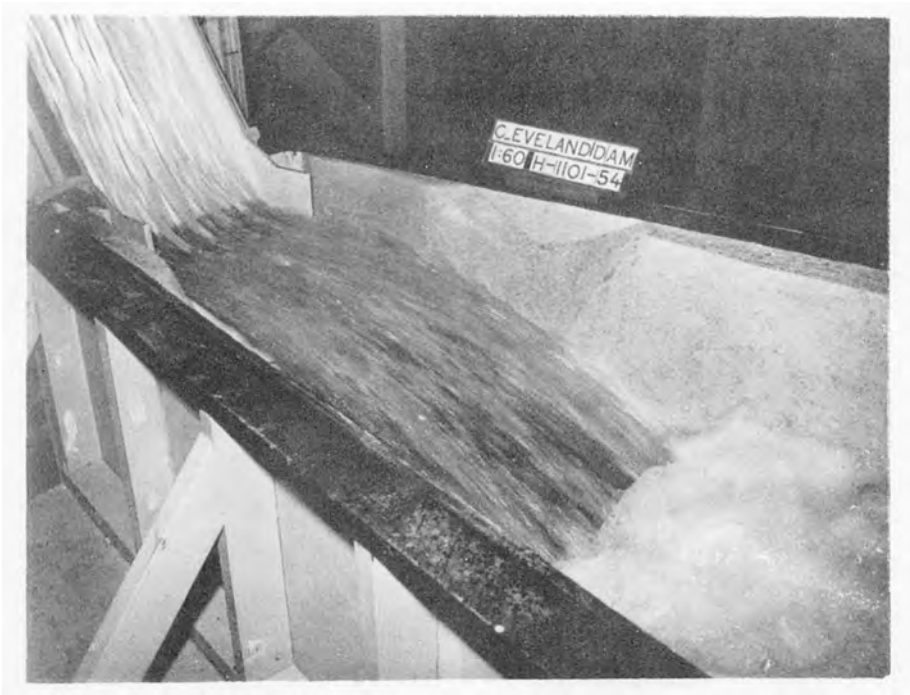


B. 43,000 cfs discharge

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow conditions in river channel with bucket splitters removed.

FIGURE 28
REPORT Hyd-369

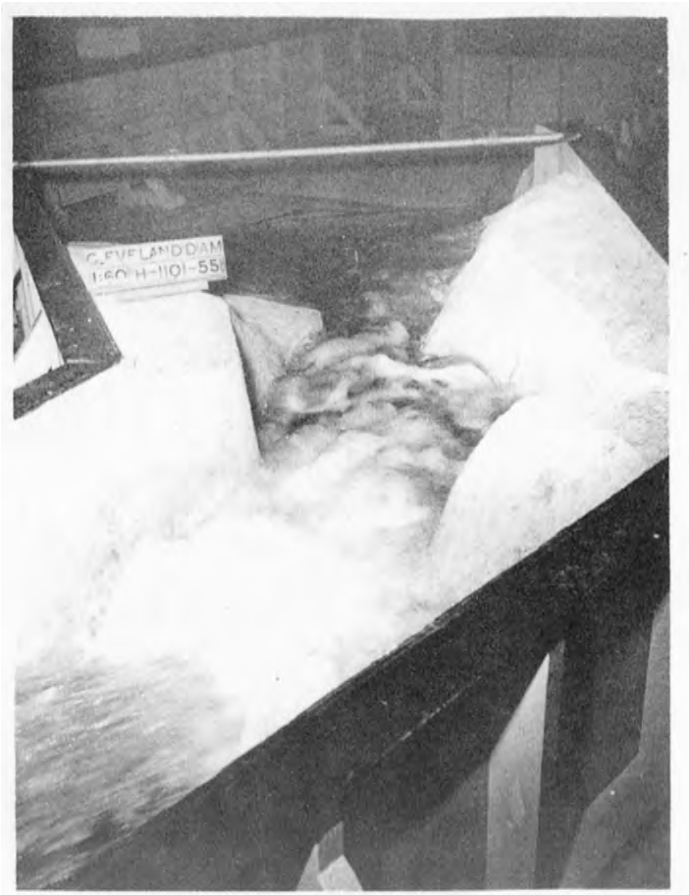


A. 35,000 cfs discharge

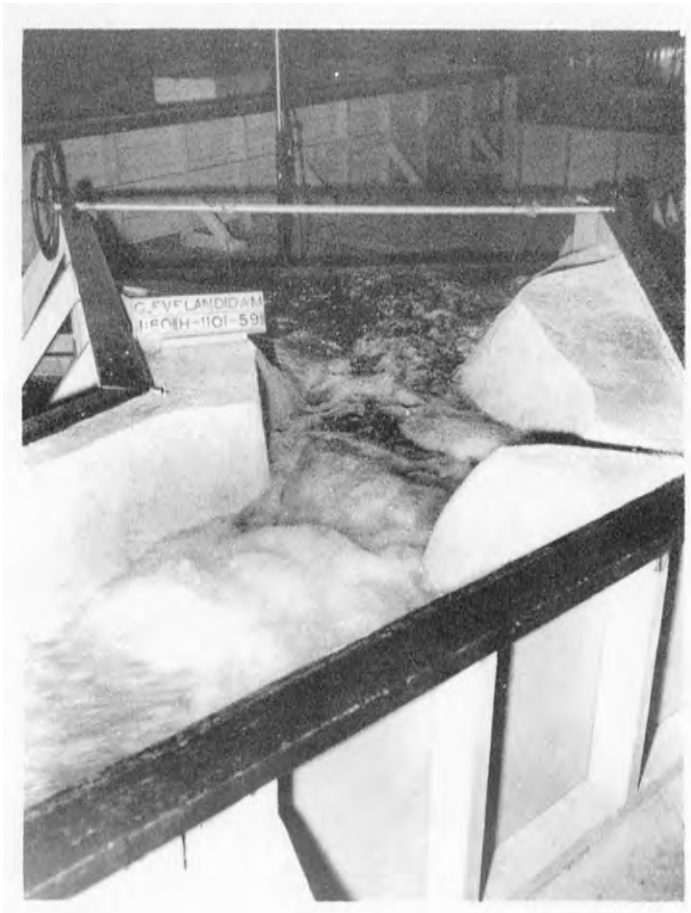
B. 43,000 cfs discharge

**Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway**

**Flow conditions at left bank
with bucket splitters removed**



A. 35,000 cfs discharge

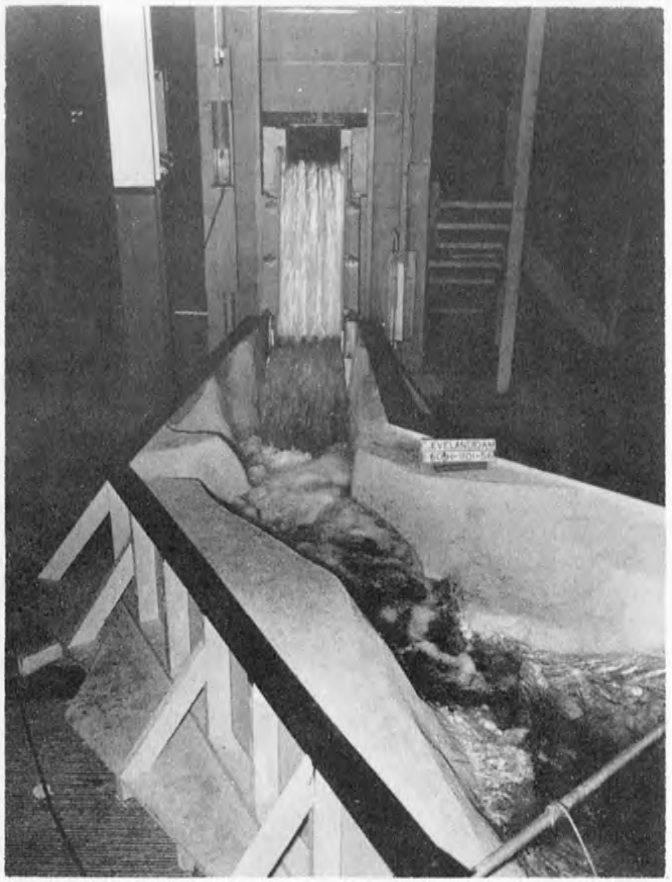


B. 43,000 cfs discharge

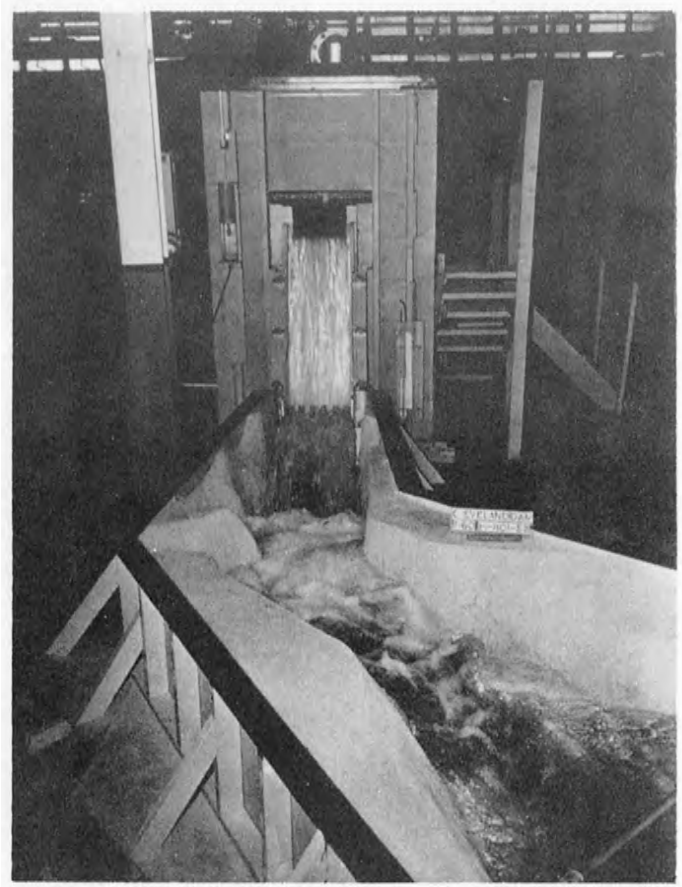
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow conditions in jet impingement
area with bucket splitters removed

FIGURE 30
REPORT Hyd-369



A. 35,000 cfs discharge

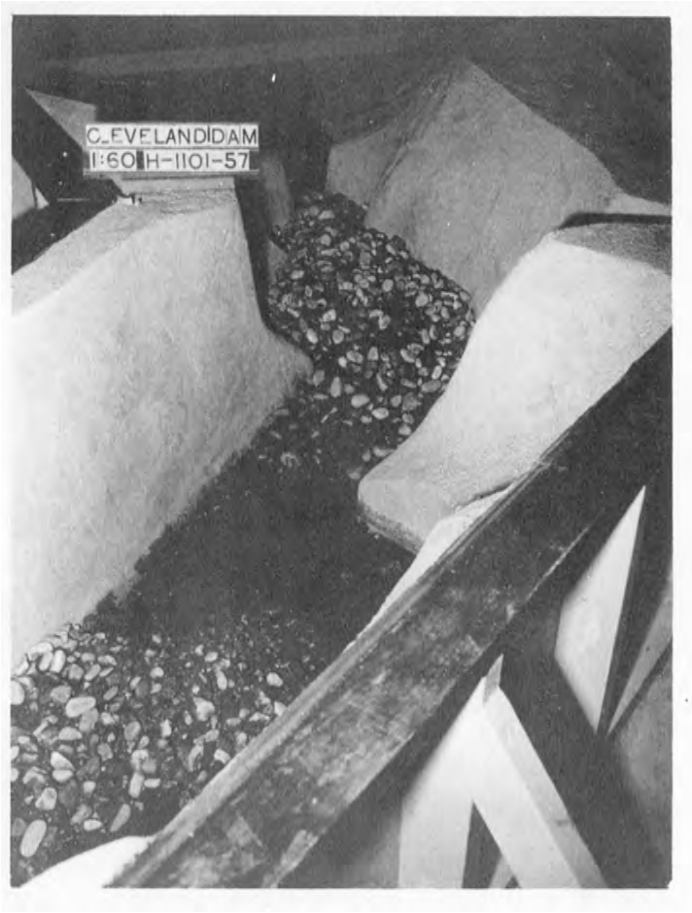


B. 43,000 cfs discharge

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow conditions in spillway and river channel bucket splitters removed.

FIGURE 31
REPORT Hyd-369



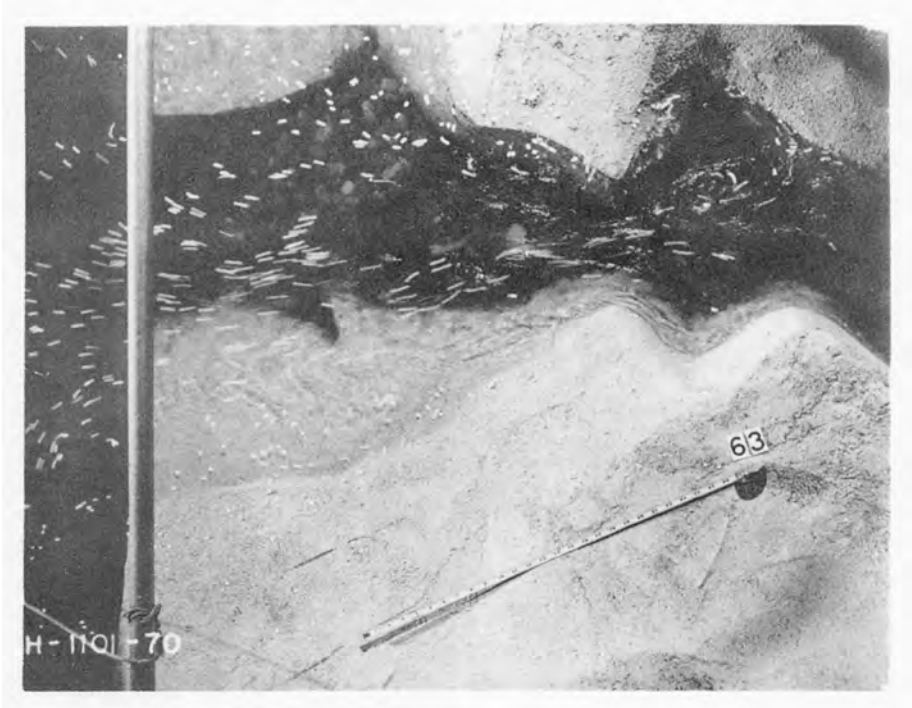
A. After 35,000 cfs

B. After 43,000 cfs

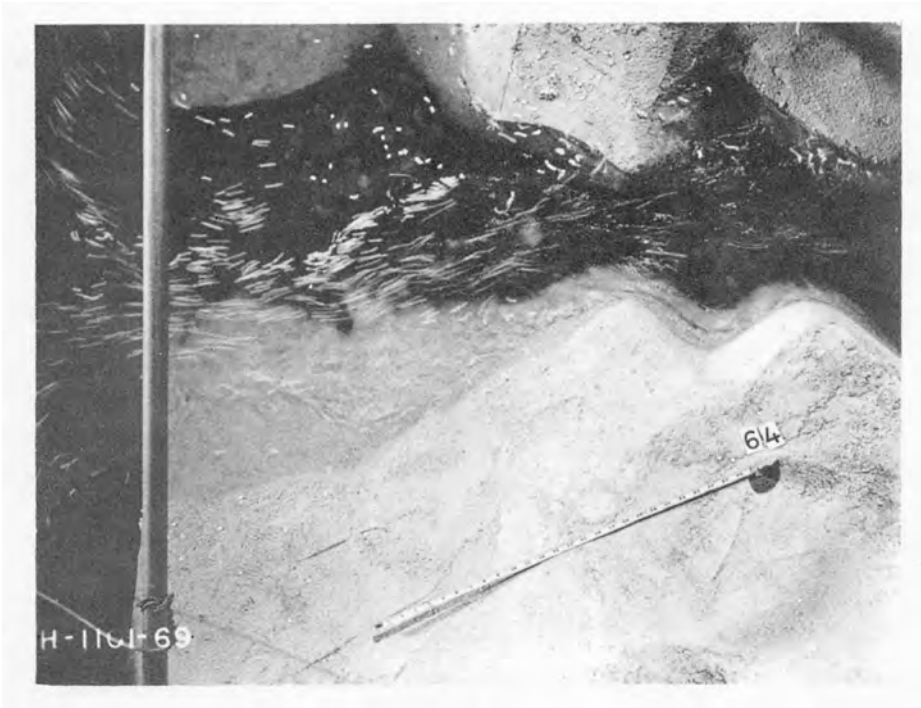
Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Scour of river channel for plain curved bucket (splitters removed).

FIGURE 32
REPORT Hyd-369



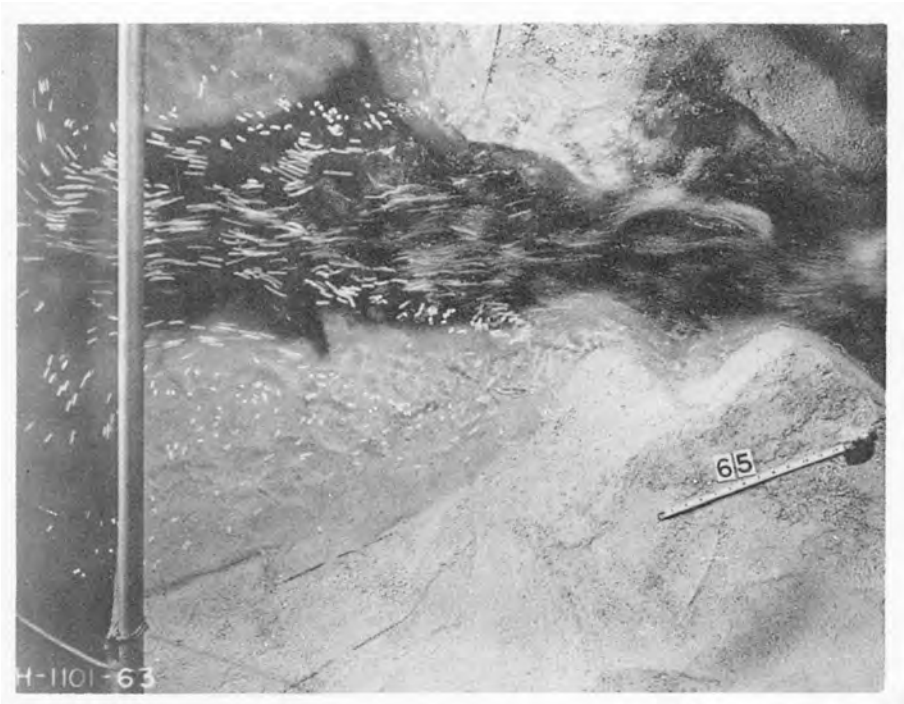
A. 1/10-second exposure



B. 1/5-second exposure

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow pattern in pumping plant and fishway area for 15,000 cfs discharge as shown by floating confetti.

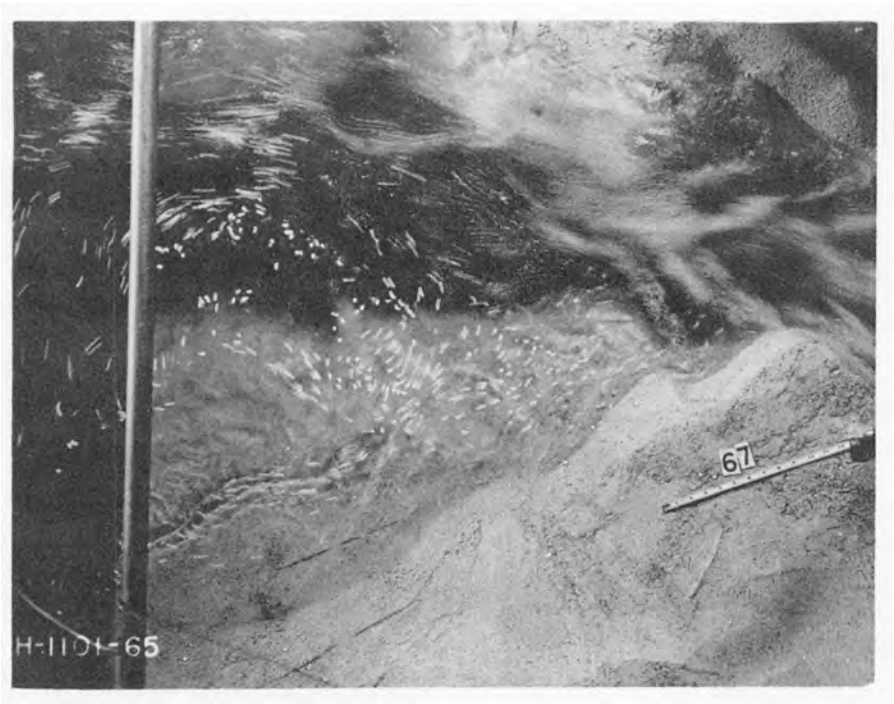


A. 1/10-second exposure

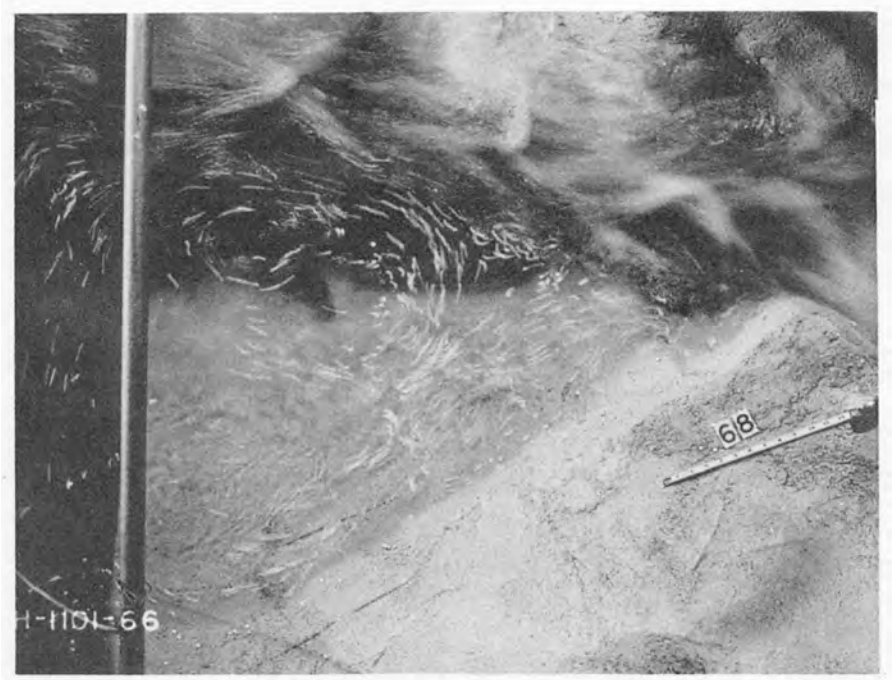
B. 1/5-second exposure

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow pattern in pumping plant and fishway area for 25,000 cfs discharge as shown by floating confetti.



A. 1/10-second exposure

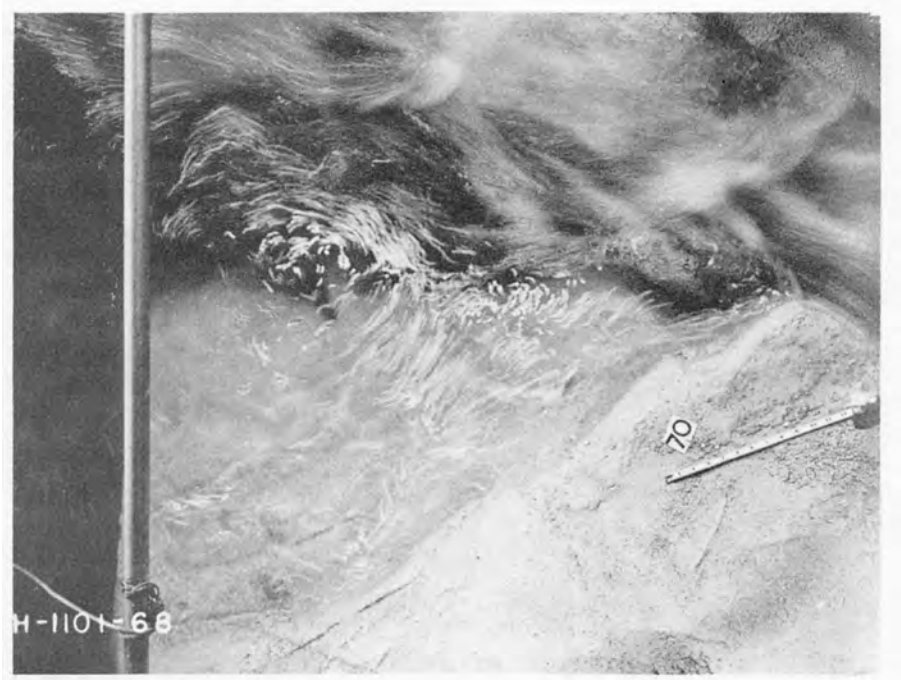


B. 1/5-second exposure

**Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway**

Flow pattern in pumping plant and fishway area for 35,000 cfs discharge as shown by floating confetti.

A. 1/10-second exposure



B. 1/5-second exposure

Greater Vancouver Water District
Vancouver, B.C., Canada
Cleveland Dam ski-jump spillway

Flow pattern in pumping plant and fishway area for 43,000 cfs discharge as shown by floating confetti.

Appendix

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
December 6, 1946

Laboratory Report No. 222
Hydraulic Laboratory
Compiled by: Ben R. Blackwell
Reviewed by: J. E. Warnock and
J. N. Bradley

Subject: Hydraulic model studies on the spillway for Capilano Dam—British Columbia, Canada.

INTRODUCTION

On March 22, 1946, an agreement (Contract No. I2r-15805) was made between the United States, represented by the Chief Engineer, Bureau of Reclamation, and the International Engineering Company, Denver, Colorado, whereby the Bureau of Reclamation would conduct hydraulic model tests of the spillway and outlet works for the Capilano Dam being designed for the City of Vancouver, British Columbia. The designs have been submitted by Mr. J. J. Hammond. Mr. John L. Savage is consulting engineer for the project.

The principal features of the design to be investigated were:

1. Flow conditions in the approach to the spillway
2. The characteristics and efficiency of the overflow crest section
3. Flow conditions in the chute and stilling-pool
4. The general operation of the outlet works.

The Capilano Dam of the Greater Vancouver Water District is located on the Capilano River 2 miles above North Vancouver, British Columbia, Figure 1. This concrete-gravity type structure will rise 300 feet above bedrock, Figure 2. The average hydraulic head will be 260 feet. River flow, past the dam, will be controlled by one 70- by 23-foot drum gate and by two river outlets with 5- by 6-foot

high-pressure slide gates. The spillway is designed for a maximum discharge (1,000-year flood) of 43,000 second-feet. The 100-year flood was considered to be 33,000 second-feet. The domestic water supply will be released through two 72-inch diameter tunnels and controlled by two 5- by 6-foot high-pressure slide gates. An 8-foot diameter connection will be provided in the face of the dam for a penstock for future power development.

SUMMARY

The results of the hydraulic model studies of the Capilano Dam may be summarized as follows:

1. The flow conditions in the approach to the spillway were satisfactory.

2. To pass the maximum discharge of 43,000 second-feet, the maximum reservoir elevation will be 577.

3. While there was considerable splashing over the chute training walls at the higher discharges, the operation was considered acceptable because of the excellent rock in the vicinity of the dam. Operation of the stilling-basin as originally designed was entirely satisfactory.

4. General exterior operation of the river outlets at full-gate opening was satisfactory for all combinations of flow.

DESCRIPTION OF THE MODEL

A 1:60 scale hydraulic model of Capilano Dam was constructed at the new Bureau of Reclamation Hydraulic Laboratory located in the Denver Federal Center, Denver, Colorado. Standard construction was used in the model. The head and outlet boxes were of timber and lined with sheet metal. The crest, river outlets, and upper part of the chute were constructed of sheet metal, while the stilling-basin was constructed of wood. The topography in the outlet box was constructed of wood and

metal lath frames covered with a thin layer of concrete. The model layout is shown in Figure 3. The model, ready for operation, is shown in Figure 4A.

THE INVESTIGATION

The approach. With the exception of the trashrack for the domestic water supply, the approach to the spillway is straight and symmetrical and, therefore, presents no hydraulic problem. The trashrack is located closer to the spillway than is customary, so model studies were made on the spillway operation and efficiency with and without the trashrack structure. The trashrack structure did not effect the operation or efficiency of the spillway in the model. Figure 5A shows the approach conditions at the maximum discharge of 43,000 second-feet.

The overflow crest section. Flow conditions at the crest were satisfactory for the design as submitted. The nappe was completely aerated with the drum gate in raised positions except at very low heads when the sheet of water from the crest did not clear the self-aerating piers. This latter condition, while not serious, may be avoided by using the river outlets instead of the spillway for very small discharges. The coefficient of discharge at maximum reservoir elevation of 575 feet was found to be 3.71, as compared to the design coefficient of approximately 4.14. The difference in coefficients resulted in a maximum free discharge of 38,400 second-feet, as compared to a discharge of 43,000 second-feet for the maximum design head. Due to the nature of the topography of the site, a longer spillway crest was found to be uneconomical. It was therefore decided to increase the maximum reservoir elevation by 2 feet to bring the spillway capacity to the required 43,000 second-feet. The model tests indicated a maximum reservoir water surface of elevation 577.0, as compared to the design water surface of elevation 575.0 feet. Head-discharge curves obtained from the model calibration are shown in Figure 6 for the free crest and several

raised gate positions. Coefficient of discharge curves for flow under the same conditions are shown on Figure 7.

The chute. There was considerable splashing over the chute training walls at spillway discharges of over 30,000 second-feet. The spillway jet expanding from the 70-foot spillway gate section to the 80-foot chute combined with the steep slope of the chute produced fins of water along the training walls. The majority of the splashing was produced by these fins. "Sea walls," Figure 5B, were effective in confining the splashing to the chute. Considering the solid rock in the canyon walls, the minor nature of the splashing, and the infrequency of occurrence of the higher discharges, the "sea wall" design was discarded and the original wall design retained.

Considerable splashing occurred within the chute during spillway operation with the drum gate in raised positions. For several combinations of discharge and gate opening the jet from the spillway impinged in the river outlet openings as is shown in Figure 8. The combinations of discharge and gate position that this can occur are so frequent that no attempt is being made to limit operation to avoid this condition. It is not expected that any damage will result from the spillway sheet striking the outlet troughs. A test on the prototype will be more convincing as to this point.

The stilling-pool. Operation of the stilling-pool was satisfactory at all discharges. At discharges of over 30,000 second-feet, the action over the end sill was rather rough but was not serious because of the solid rock in the canyon. At 43,000 second-feet, a drop in the tailwater elevation of over 6 feet below normal was required to sweep the hydraulic jump off the apron. At 33,000 second-feet, the drop in tailwater elevation was increased to 12 feet to accomplish the same result. At discharges of 25,000 second-feet and less, the control section in the river immediately downstream from the stilling-pool maintained sufficient tailwater elevation to prevent the jump washing off the apron under any condition. Stilling-pool operation with normal tailwater elevations is

shown for spillway discharges of 15,000, 25,000, 33,000, and 43,000 second-feet in Figures 9 and 10.

The river outlets. General exterior operation of the river outlets at full-gate openings was satisfactory. The outlets discharged smoothly down the face of the spillway and into the stilling-basin. Model operation of one and two outlets is shown in Figure 11. The action in the stilling-basin was satisfactory for all combinations of discharge with full-gate openings.

FIGURE 1

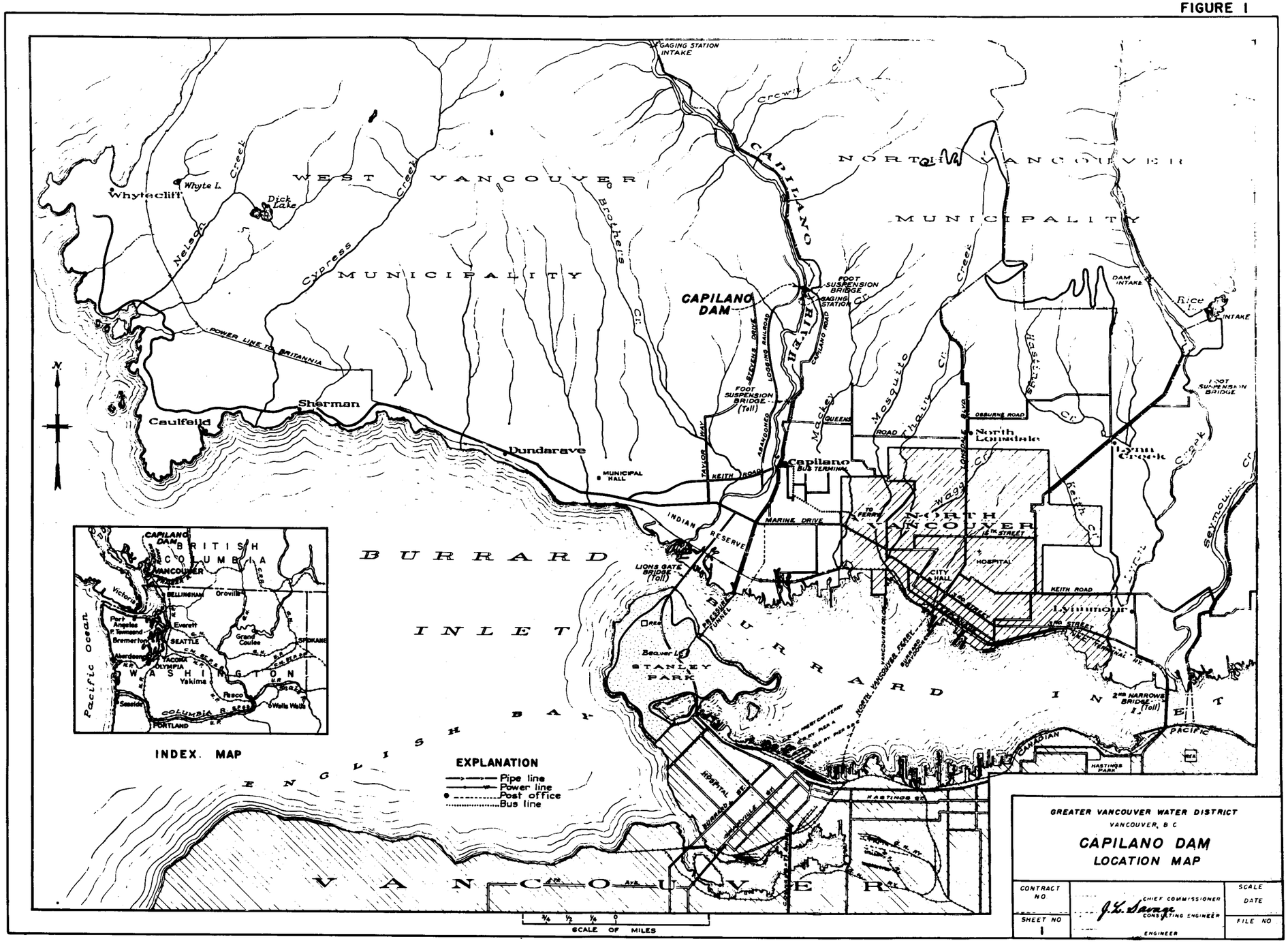
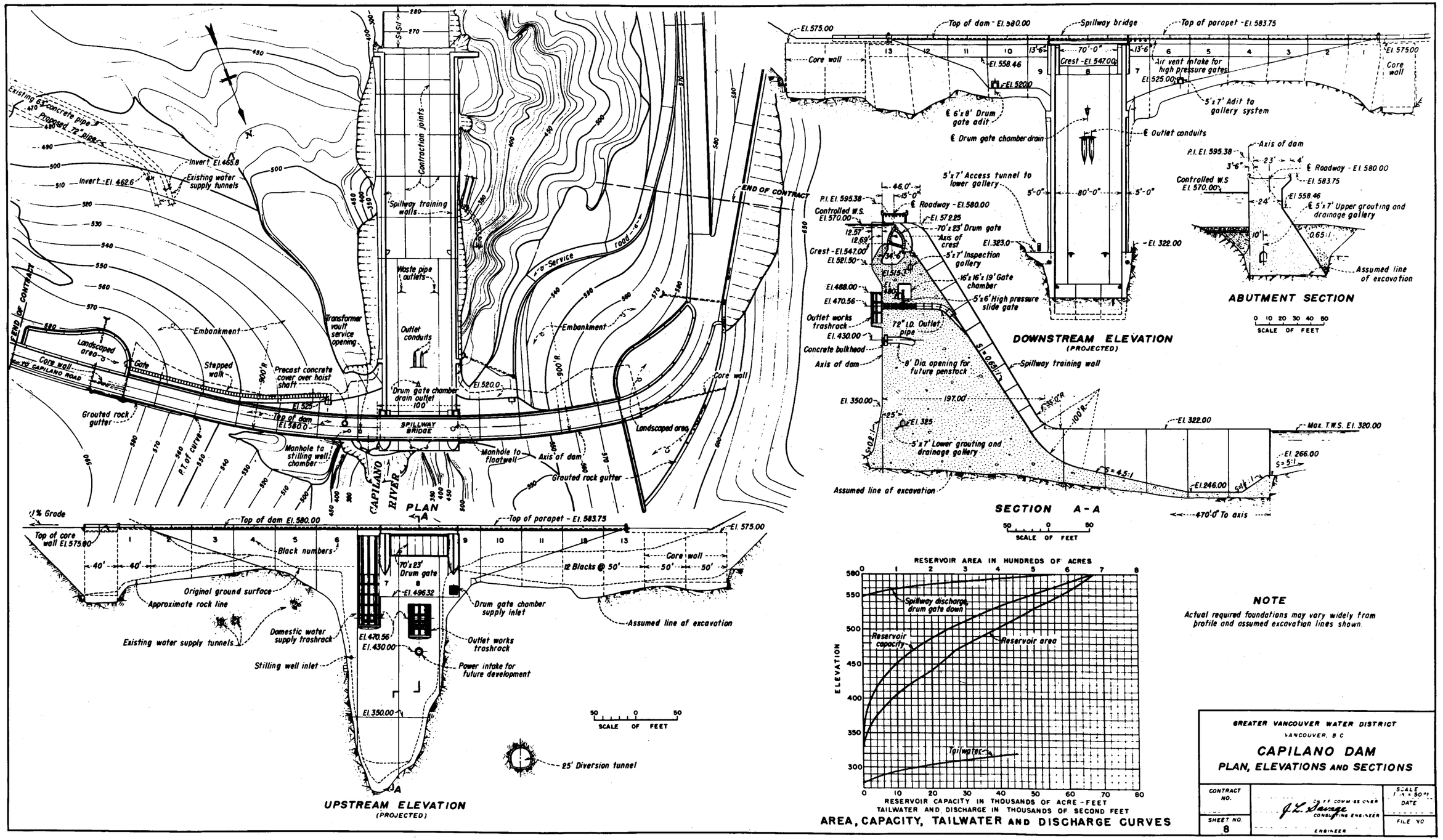

GAGING STATION INTAKE
WEST VANCOUVER MUNICIPALITY
NORTH VANCOUVER MUNICIPALITY
Whytecliff
Whyte L.
Dick Lake
Nelson Creek
Cypress Creek
Brothers Cr.
CAPILANO RIVER
CAPILANO DAM
FOOT SUSPENSION BRIDGE
GAGING STATION
DAM INTAKE
Rice L.
INTAKE
POWER LINE TO BRITANNIA
Sherman
Caulfeild
Dundarave
MUNICIPAL HALL
FOOT SUSPENSION BRIDGE (Toll)
Capilano BUS TERMINAL
North Lonsdale
Lynn Creek
MARINE DRIVE
INDIAN RESERVE
LIONS GATE BRIDGE (Toll)
BURRARD INLET
NORTH VANCOUVER
CITY HALL
HOSPITAL
KEITH ROAD
Lynnmour
STANLEY PARK
Beaver L.
2ND NARROWS BRIDGE (Toll)
PACIFIC
CANADIAN
HASTINGS PARK
HASTINGS ST.
ENGLISH BAY
VANCOUVER
INDEX MAP
BRITISH COLUMBIA
VANCOUVER
BELLINGHAM
Oroville
Victoria
Port Angeles
P. Townsend
Bremerton
Everett
SEATTLE
Grand Coulee
SPOKANE
Aberdeen
TACOMA
OLYMPIA
WASHINGTON
Yakima
Pasco
Walla Walla
Seattle
COLUMBIA R.
PORTLAND
Pacific Ocean
EXPLANATION
Pipe line
Power line
Post office
Bus line
SCALE OF MILES
GREATER VANCOUVER WATER DISTRICT
VANCOUVER, B.C.
CAPILANO DAM
LOCATION MAP
CONTRACT NO
SHEET NO 1
CHIEF COMMISSIONER
CONSULTING ENGINEER
ENGINEER
SCALE
DATE
FILE NO

FIGURE 2



AREA, CAPACITY, TAILWATER AND DISCHARGE CURVES

NOTE

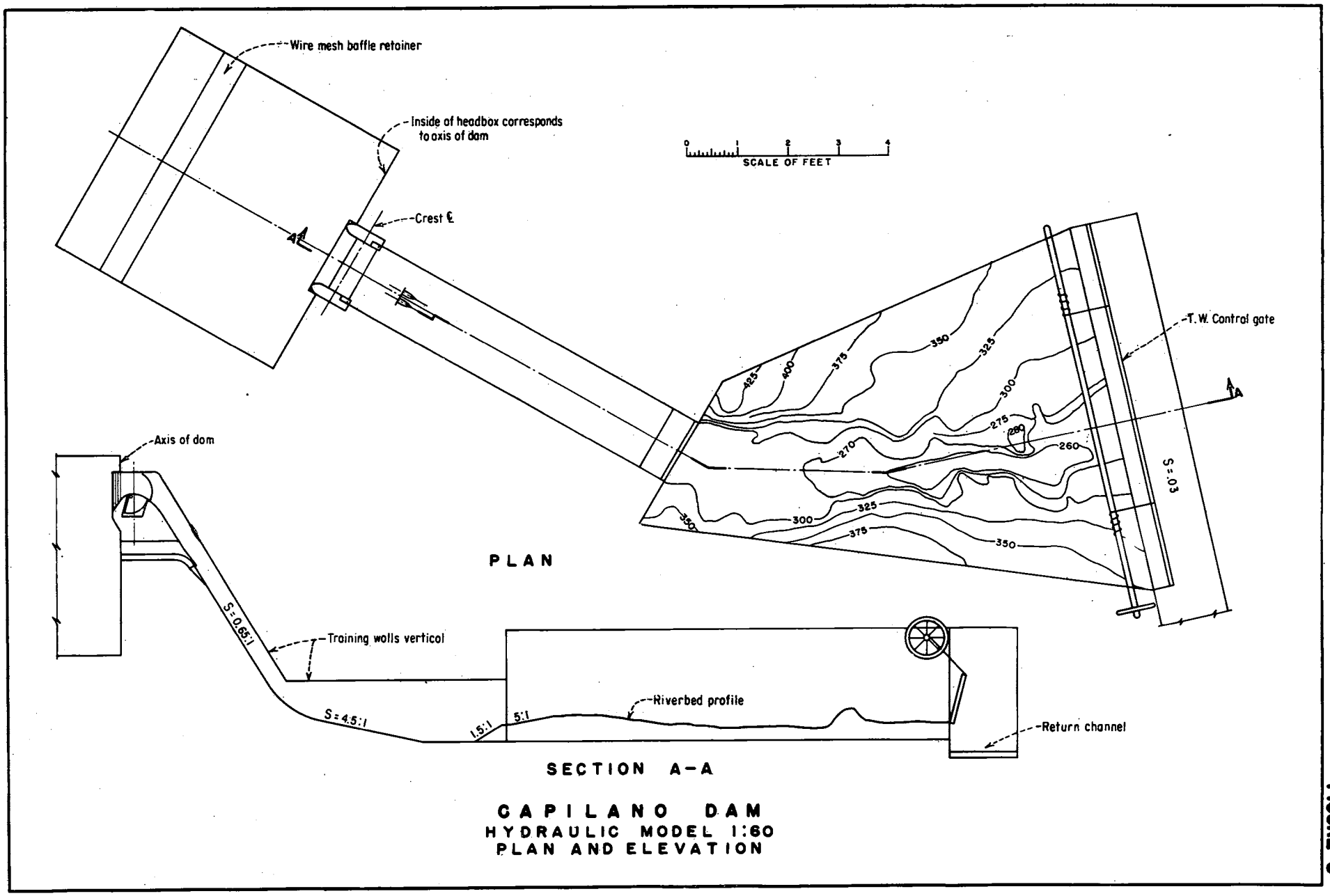
Actual required foundations may vary widely from profile and assumed excavation lines shown.

GREATER VANCOUVER WATER DISTRICT
VANCOUVER, B.C.

CAPILANO DAM

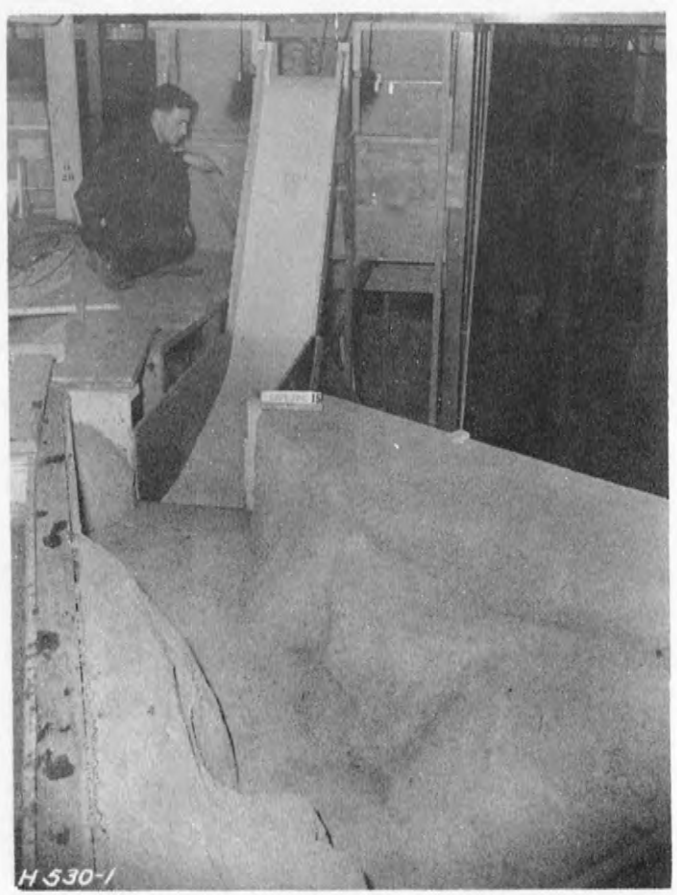
PLAN, ELEVATIONS AND SECTIONS

CONTRACT NO.	CHIEF COMMISSIONER J. L. Savage CONSULTING ENGINEER	SCALE 1 IN. = 50 FT.
SHEET NO. 8	ENGINEER	DATE
		FILE NO.



CAPILANO DAM
HYDRAULIC MODEL 1:60
PLAN AND ELEVATION

FIGURE 3



A. Spillway model ready for operation.

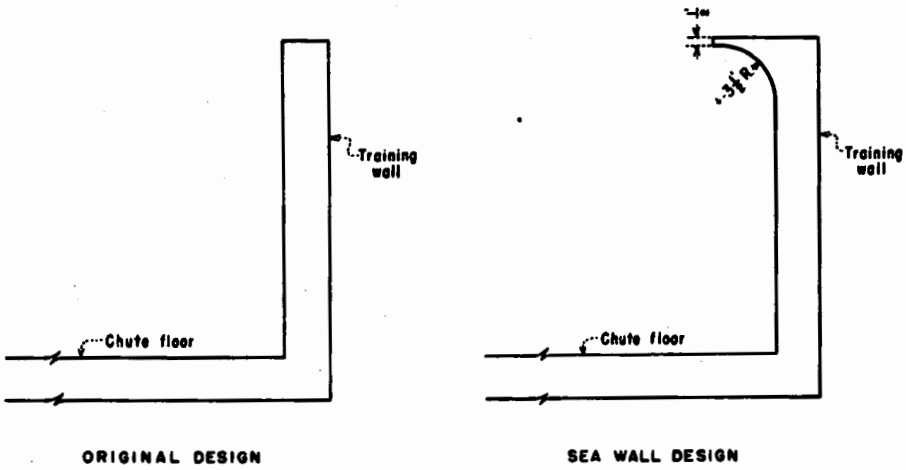
B. Spillway model operating Q=43,000 cfs.

CAPILANO DAM

1:60 SCALE MODEL

FIGURE 4

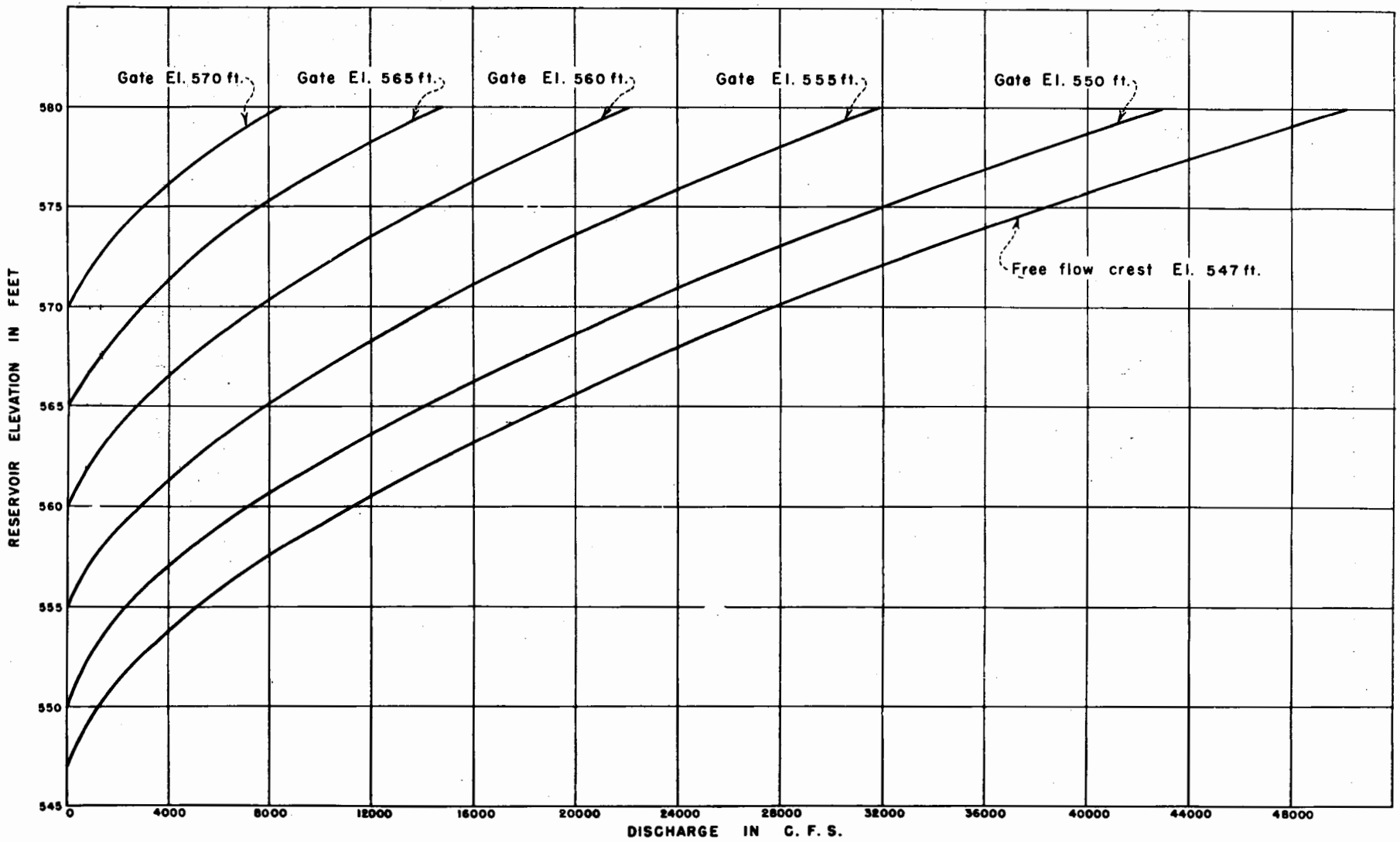
A. Spillway approach
Q=43,000 cfs.



B. Details of chute training-walls.

CAPILANO DAM

1:60 SCALE MODEL

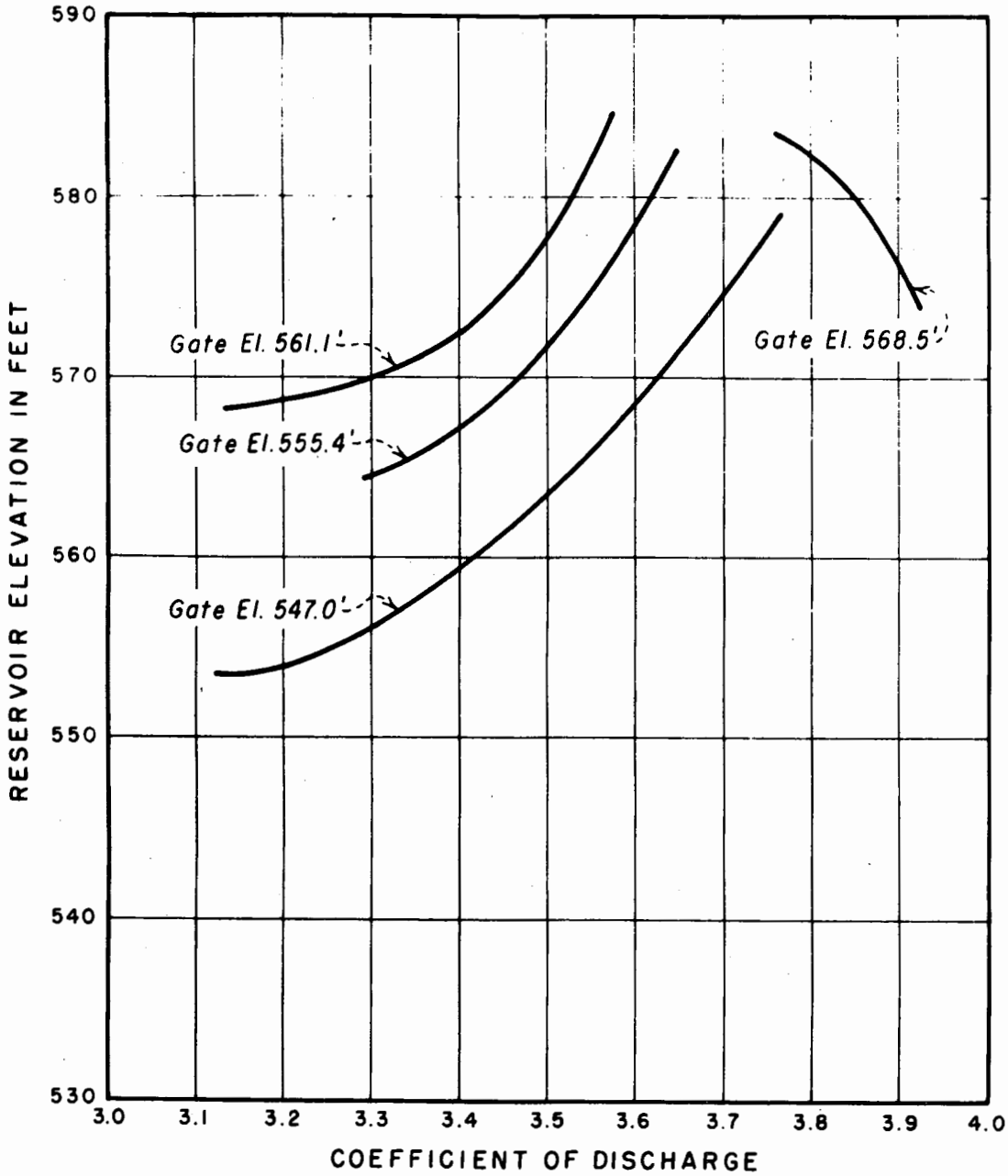


CAPILANO DAM

DISCHARGE CURVES FROM CALIBRATION OF 1:60 SCALE MODEL

FIGURE 6

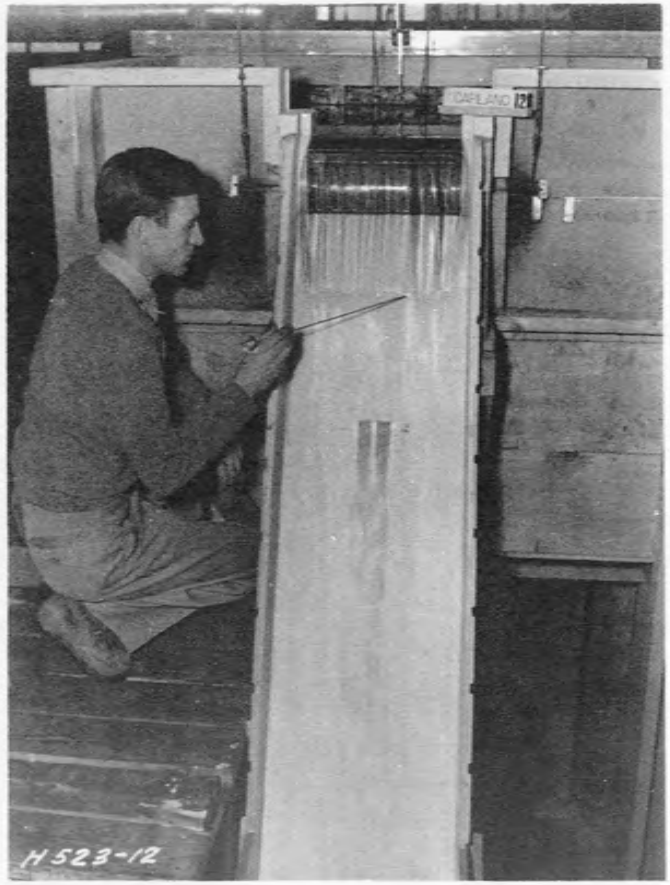
FIGURE 7



CAPILANO DAM

COEFFICIENT CURVES OBTAINED FROM CALIBRATION OF A 1:60 SCALE MODEL

Interior - Reclamation - Denver, Colo.



Spillway jet impinging above river outlet openings.

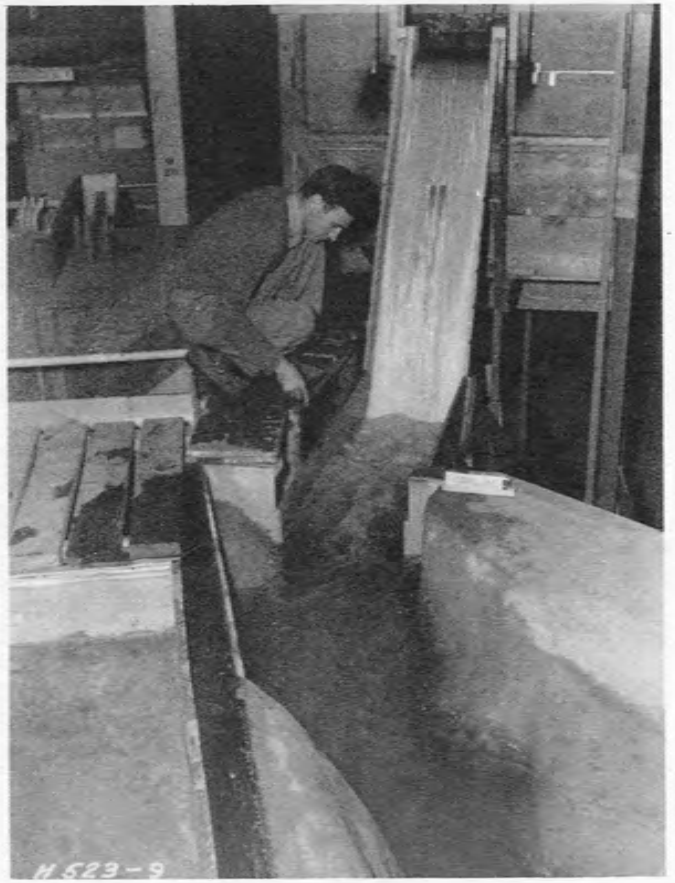
Spillway jet impinging in river outlet openings.

CAPILANO DAM

1:60 SCALE MODEL

SPILLWAY GATE PARTIALLY OPEN

FIGURE 8



Q=15,000 cfs.

Q=25,000 cfs.

CAPILANO DAM

1:60 SCALE MODEL

STILLING-POOL OPERATION

FIGURE 9

Q=33,000 cfs.

Q=43,000 cfs.

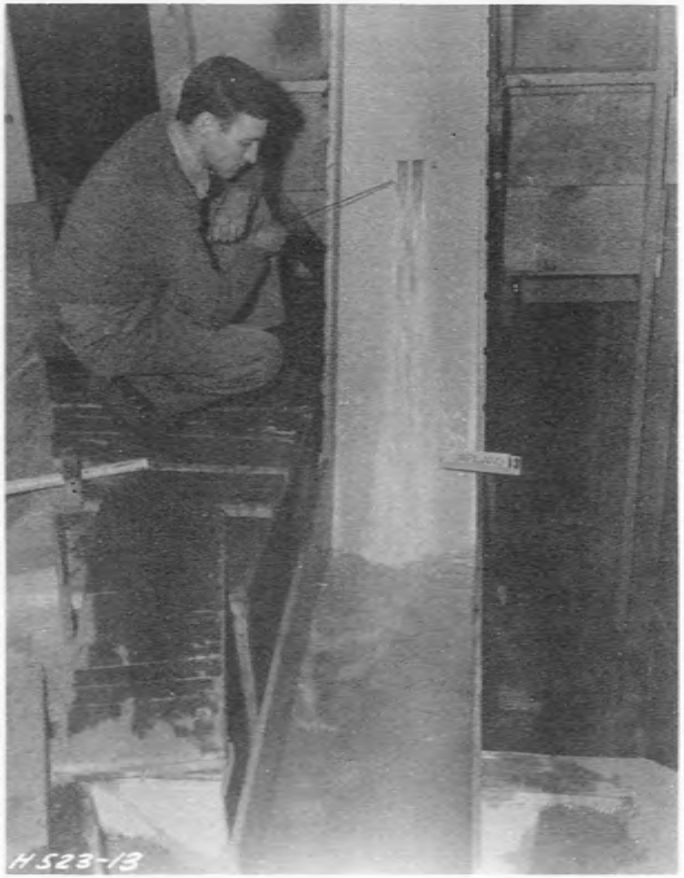
CAPILANO DAM

1:60 SCALE MODEL

STILLING-POOL OPERATION

FIGURE 10

One river outlet operating.



Two river outlets operating.

CAPILANO DAM

1:60 SCALE MODEL

FIGURE 11