UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES ON THE SPILLWAY FOR CAPILANO DAM

BRITISH COLUMBIA, CANADA

Hydraulic Laboratory Report No. Hyd. 222

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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DEPARTMENT OF THE INTERIOR
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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.

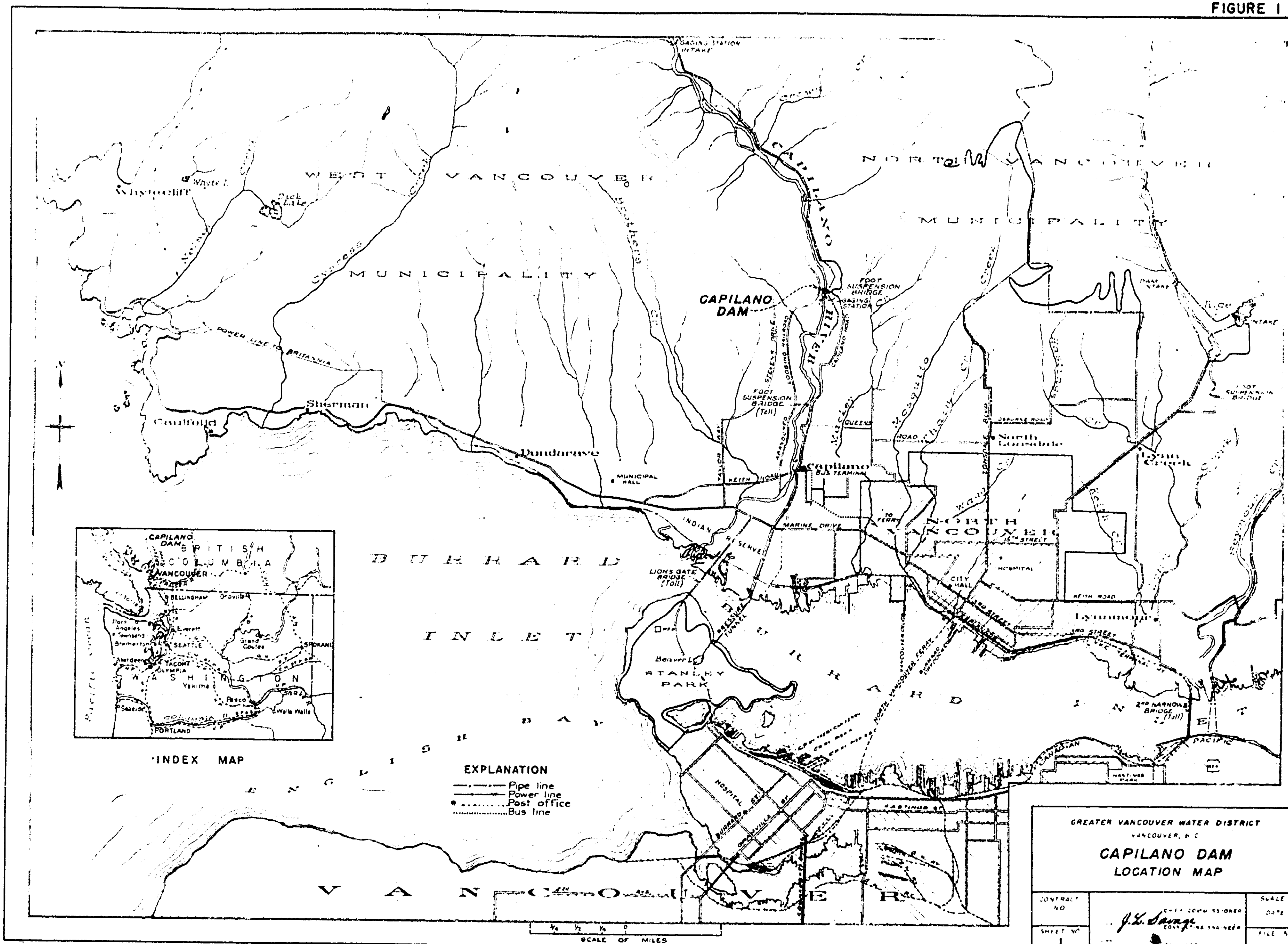
The chute. There was considerable splashing over the chute training walls at spillway discharges of over 30,000 second-feet. The spillway jet expanding from the 70-foot spillway gate section to the 80-foot chute combined with the steep slope of the chute produced fins of water along the training walls. 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.

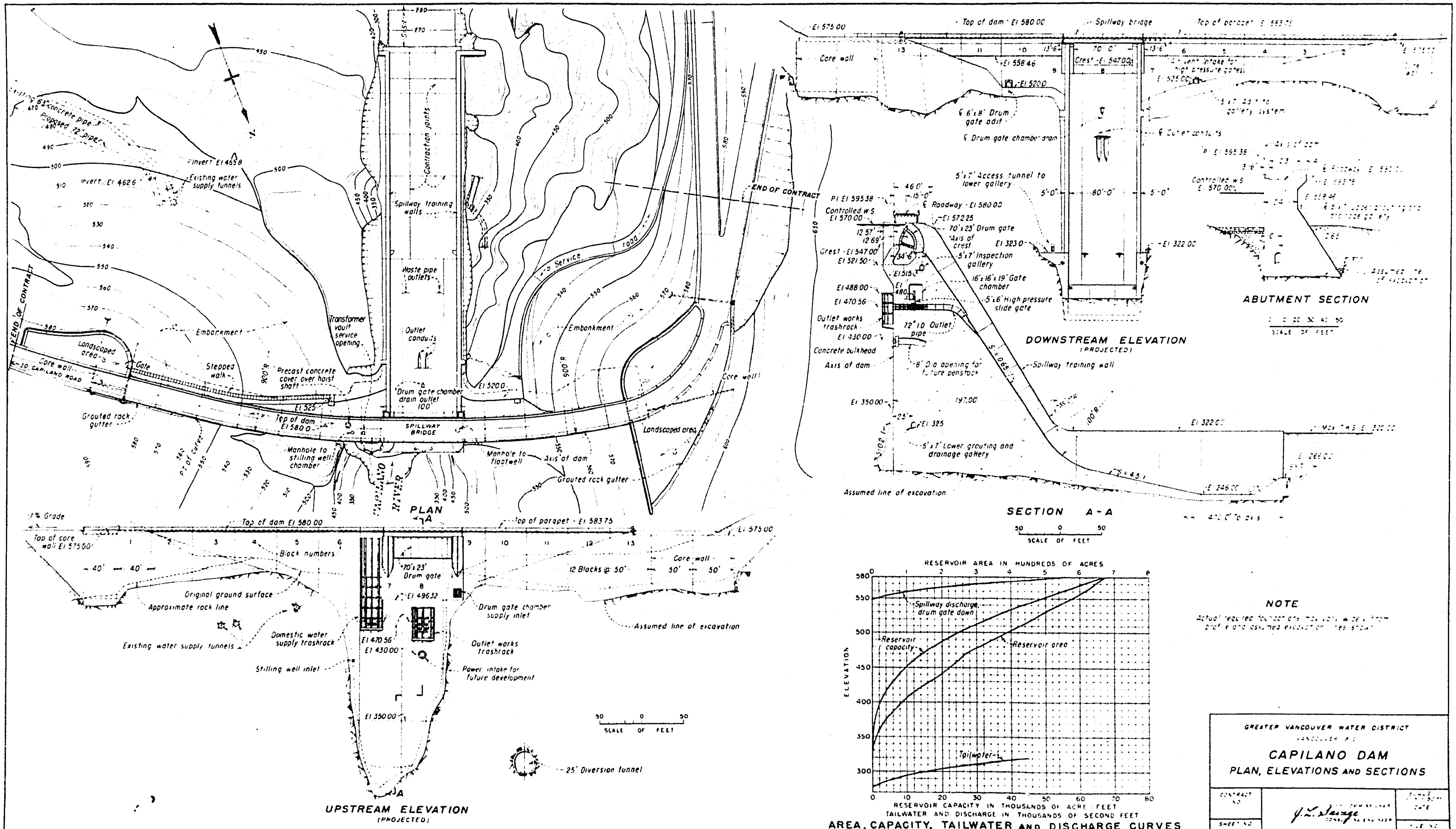
The river outlets. General exterior operation of the river outlets at full-gate openings was satisfactory. The outlets discharged smoothly down the face of the spillway and into the stilling-basin. Model operation of one and two outlets is shown in Figure 11. The action in the stilling-basin was satisfactory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

FIGURE 1



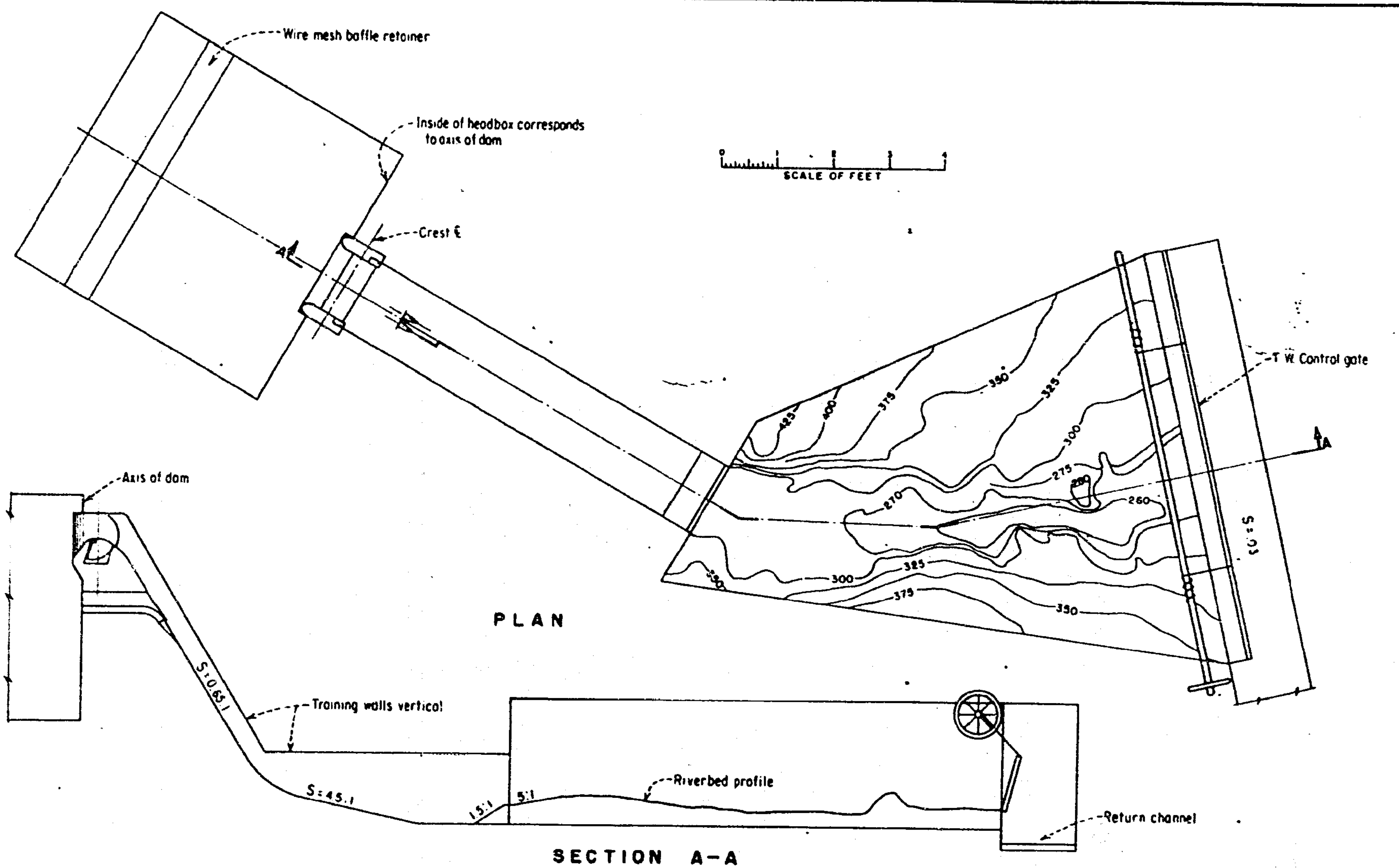
WEST VANCOUVER MUNICIPALITY
NORTH VANCOUVER MUNICIPALITY
CAPILANO RIVER
CAPILANO DAM
FOOT SUSPENSION BRIDGE
GAGING STATION
GAGING STATION INTAKE
POWER LINE TO BRITANNIA
Whytecliff
Whyte L.
Eagle Lake
Sherman
Caulfeild
Dundarave
MUNICIPAL HALL
Capilano
BUS TERMINAL
KEITH ROAD
MARINE DRIVE
INDIAN RESERVE
LIONS GATE BRIDGE (Toll)
FOOT SUSPENSION BRIDGE (Toll)
NORTH VANCOUVER
CITY HALL
HOSPITAL
North Lonsdale
Lynn Creek
Lynnmour
2ND NARROWS BRIDGE (Toll)
BURRARD INLET
STANLEY PARK
Beaver L.
ENGLISH BAY
VANCOUVER
HASTINGS PARK
HOSPITAL
INDEX MAP
CAPILANO DAM
BRITISH COLUMBIA
VANCOUVER
BELLINGHAM
Oroville
Port Angeles
Pt Townsend
Everett
Bremerton
SEATTLE
Grand Coulee
SPOKANE
Aberdeen
TACOMA
OLYMPIA
WASHINGTON
Yakima
Pasco
Walla Walla
Seaside
PORTLAND
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



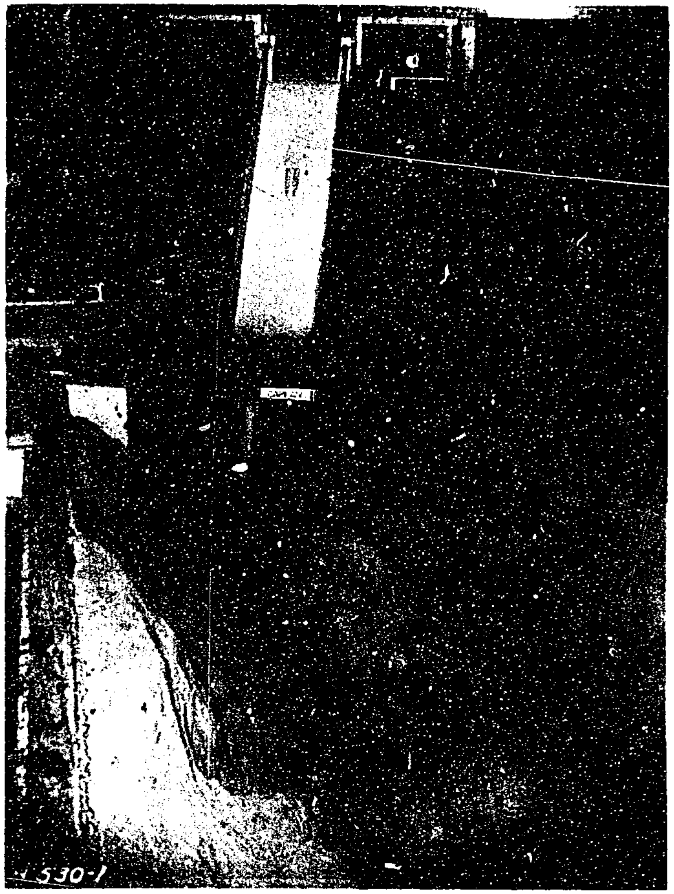
PLAN
UPSTREAM ELEVATION
(PROJECTED)
DOWNSTREAM ELEVATION
(PROJECTED)
SECTION A-A
ABUTMENT SECTION
AREA, CAPACITY, TAILWATER AND DISCHARGE CURVES
RESERVOIR AREA IN HUNDREDS OF ACRES
RESERVOIR CAPACITY IN THOUSANDS OF ACRE FEET
TAILWATER AND DISCHARGE IN THOUSANDS OF SECOND FEET
ELEVATION
Spillway discharge, drum gate down
Reservoir capacity
Reservoir area
Tailwater
END OF CONTRACT
Existing 63" concrete pipe
Proposed 72" pipe
Invert El 465.8
Invert El 462.6
Existing water supply tunnels
Contraction joints
Spillway training walls
Waste pipe outlets
Outlet conduits
Transformer vault service opening
Embankment
Landscaped area
Gate
Stepped walk
Precast concrete cover over hoist shaft
Drum gate chamber drain outlet
Core wall
Capilano Road
Grouted rock gutter
Top of dam El 580.0
SPILLWAY BRIDGE
Manhole to stilling well chamber
Manhole to floatwell
Axis of dam
Service road
Landscaped area
CAPILANO RIVER
Top of dam El 580.00
Top of parapet - El 583.75
Top of core wall El 575.00
Block numbers
70'x23' Drum gate
El 496.32
12 Blocks @ 50'
Original ground surface
Approximate rock line
Domestic water supply trashrack
Existing water supply tunnels
Drum gate chamber supply inlet
Outlet works trashrack
Power intake for future development
Stilling well inlet
El 470.56
El 430.00
El 350.00
25' Diversion tunnel
Assumed line of excavation
Spillway bridge
Top of parapet El 583.75
Core wall
Crest El 547.00
6'x8' Drum gate adit
Drum gate chamber drain
Outlet conduits
5'x7' Access tunnel to lower gallery
Roadway - El 580.00
Controlled W.S. El 570.00
70'x23' Drum gate
Axis of crest
5'x7' Inspection gallery
16'x16'x19' Gate chamber
5'x6' High pressure slide gate
72" I.D. Outlet pipe
Outlet works trashrack
Concrete bulkhead
Axis of dam
8' Dia. opening for future penstock
Spillway training wall
5'x7' Lower grouting and drainage gallery
Assumed line of excavation
SCALE OF FEET
NOTE
GREATER VANCOUVER WATER DISTRICT
CAPILANO DAM
PLAN, ELEVATIONS AND SECTIONS
SHEET NO 8

FIGURE 3

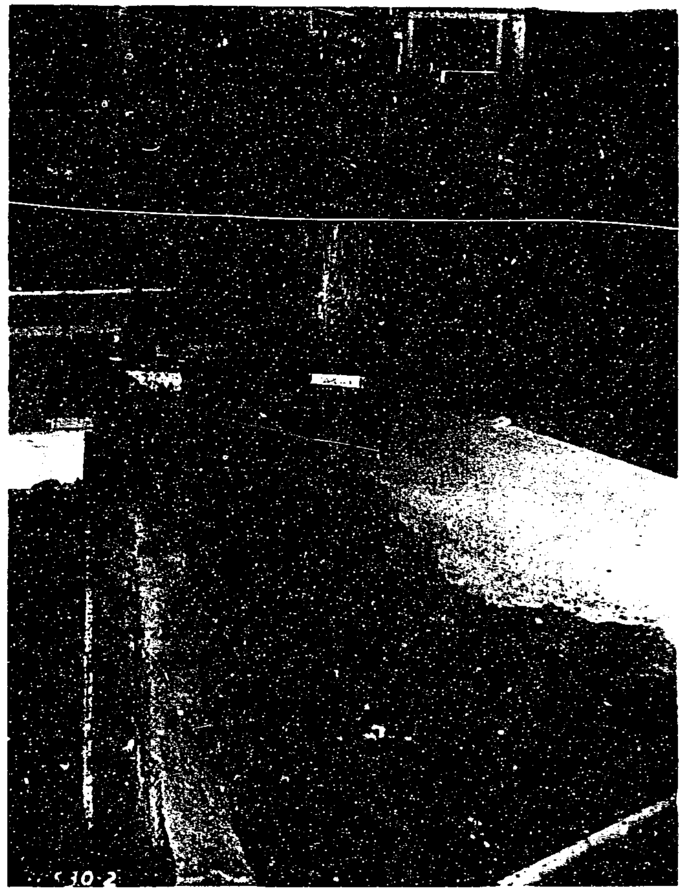


CAPILANO DAM
HYDRAULIC MODEL 1:60
PLAN AND ELEVATION

FIGURE 4



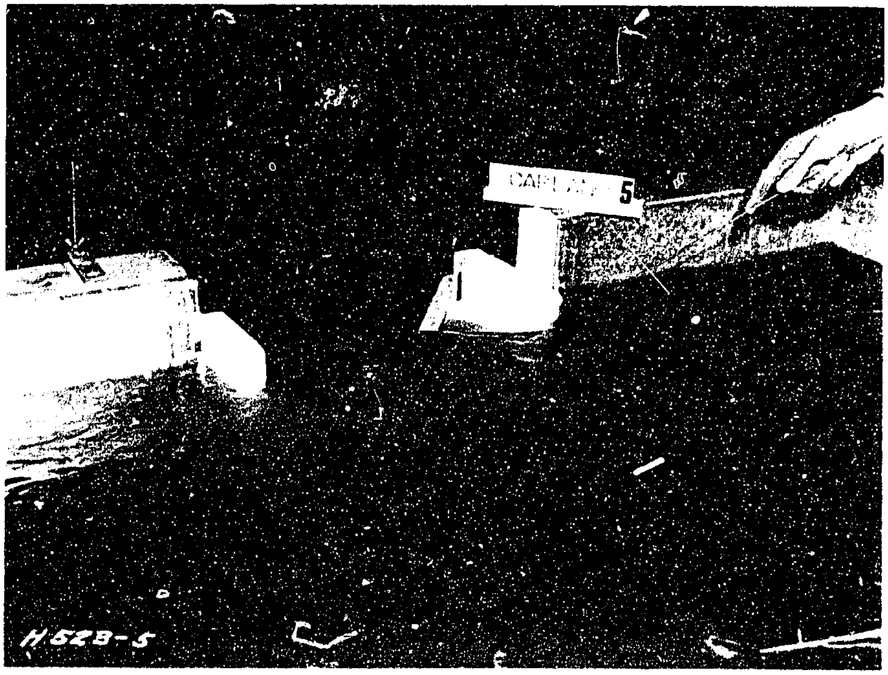
A. Spillway model ready for operation.



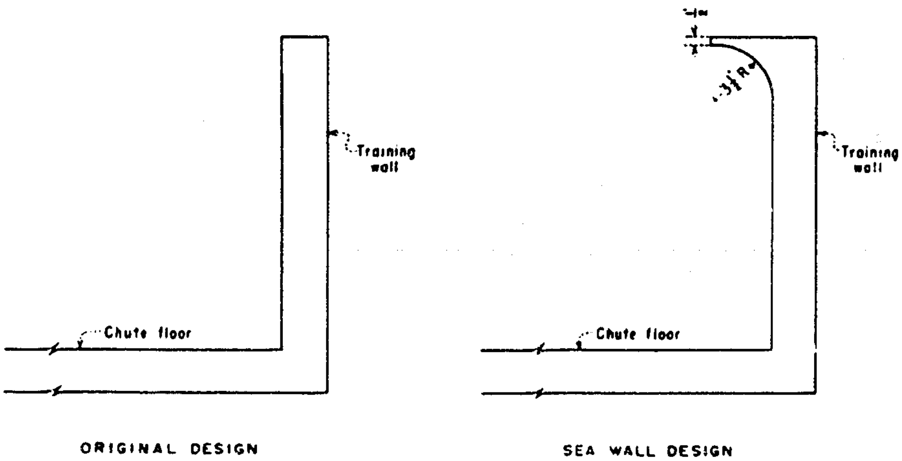
B. Spillway model operating Q=43,000 cfs.

CAPILANO DAM

1:60 SCALE MODEL



A. Spillway approach
Q=43,000 cfs.

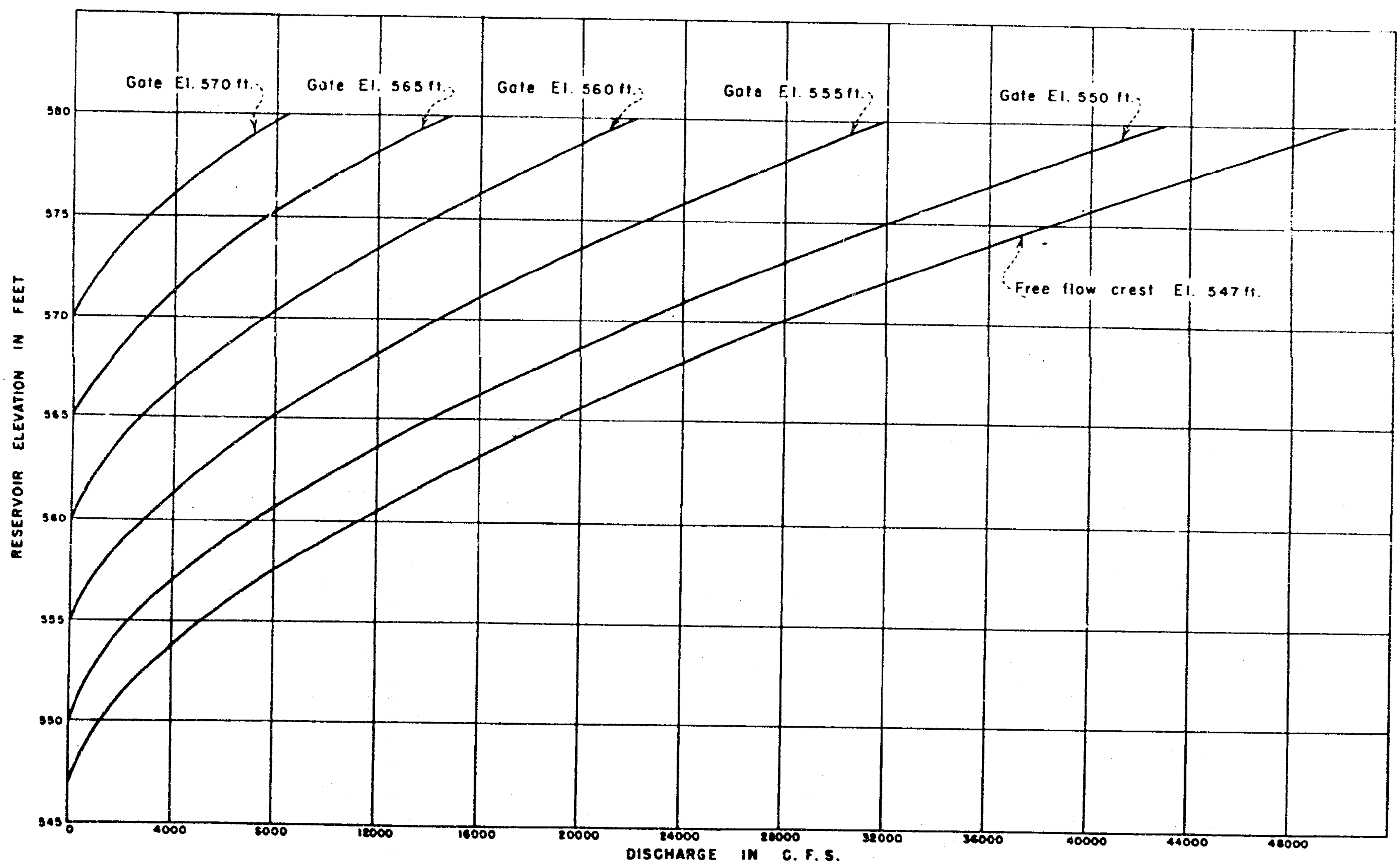


B. Details of chute training-walls.

CAPILANO DAM

1:60 SCALE MODEL

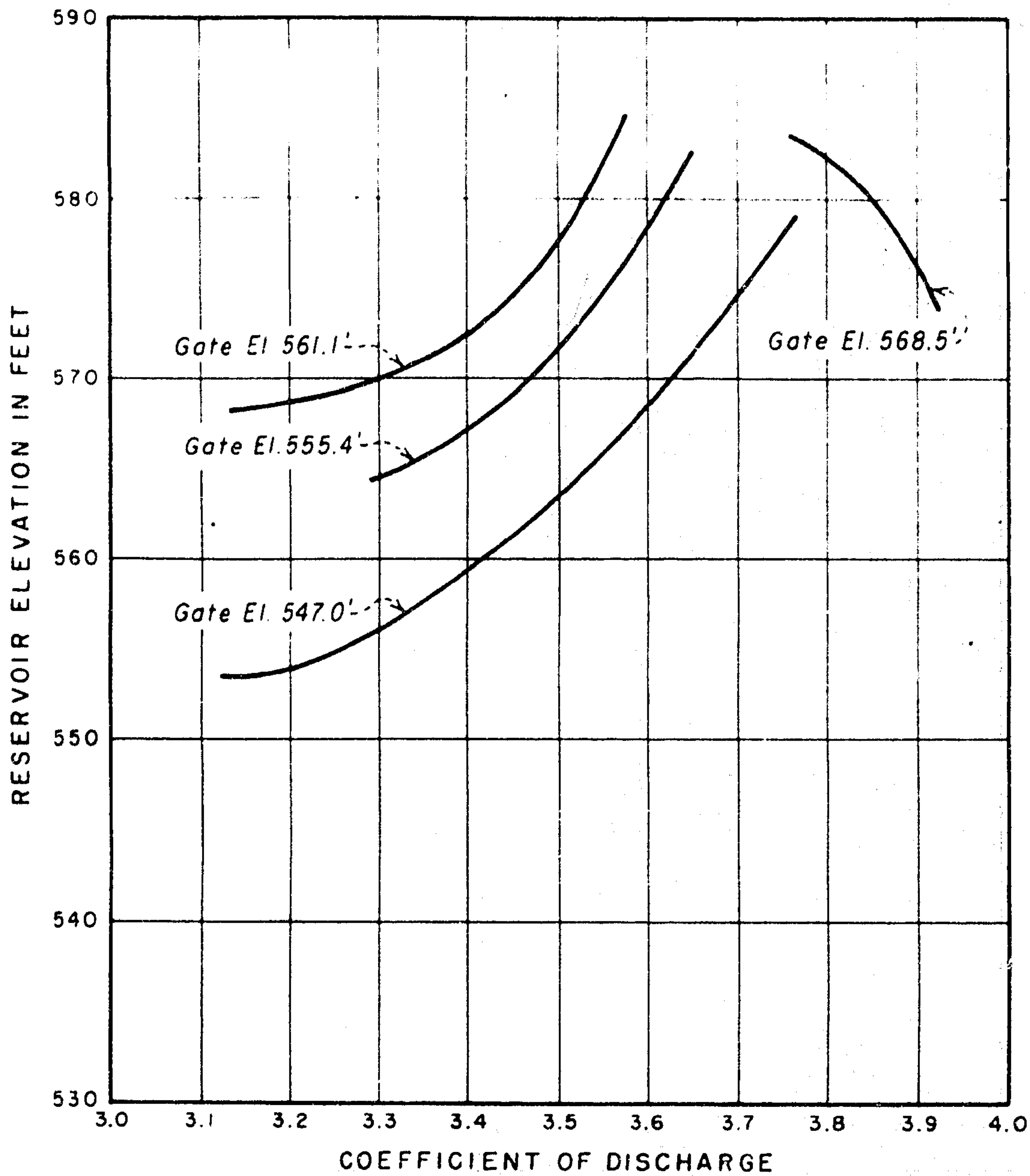
FIGURE 6



CAPILANO DAM

DISCHARGE CURVES FROM CALIBRATION OF 1:60 SCALE MODEL

34

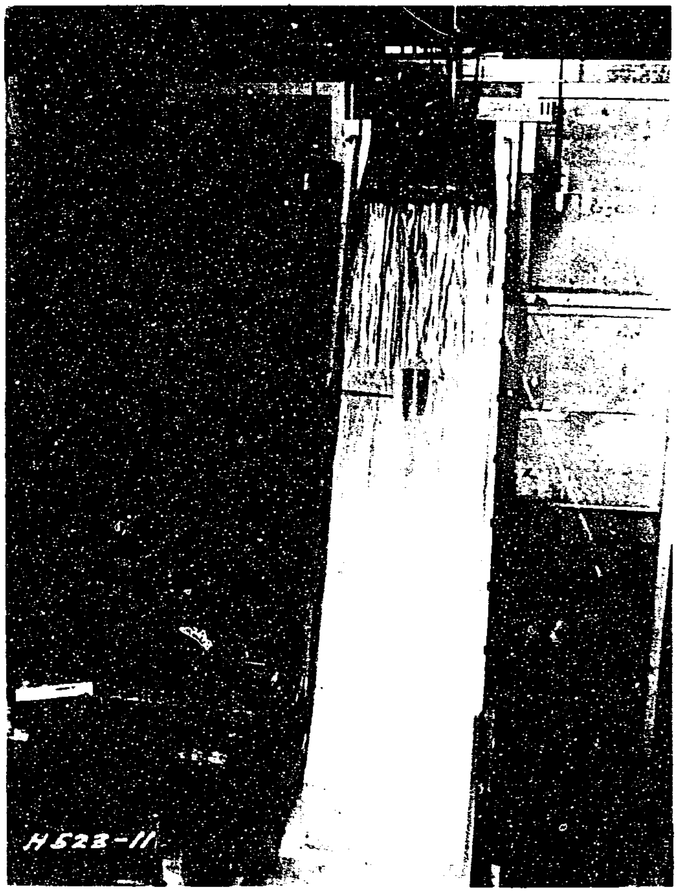


CAPILANO DAM

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

FIGURE 8

Spillway jet impinging above river outlet openings.

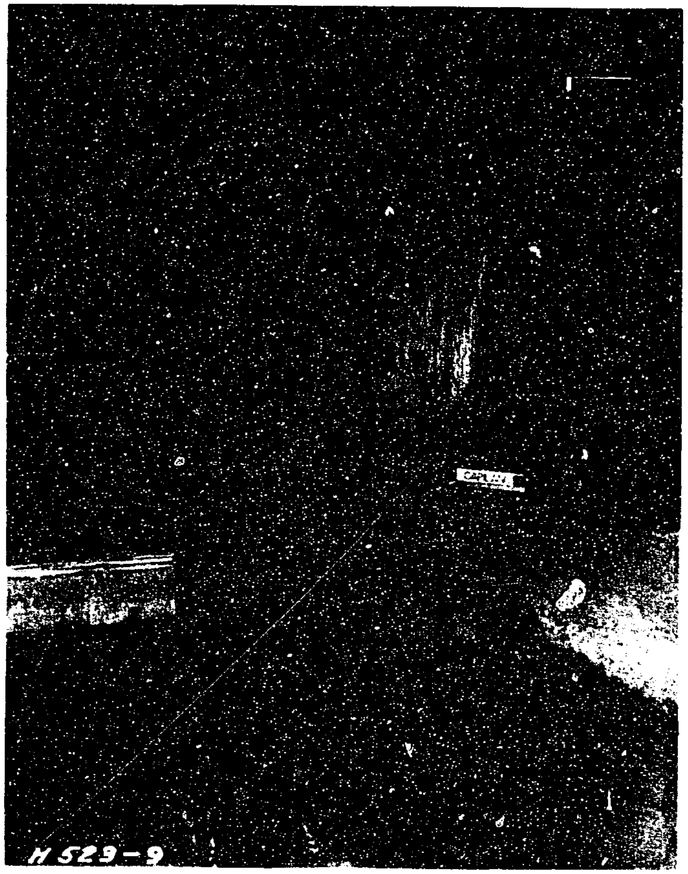


Spillway jet impinging in river outlet openings.

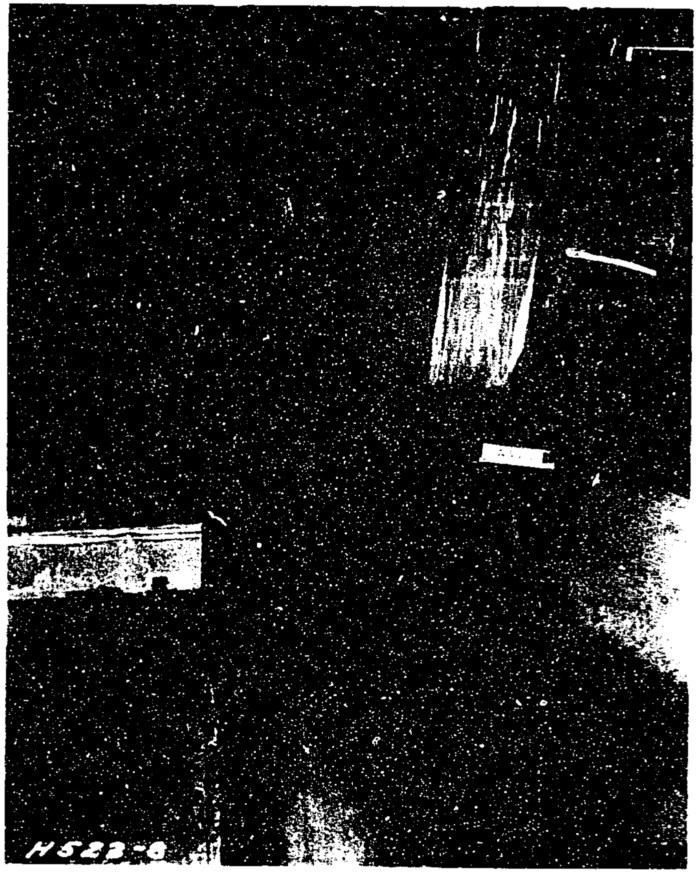
CAPILANO DAM

1:80 SCALE MODEL

SPILLWAY GATE PARTIALLY OPEN



Q=15,000 cfs.



Q=25,000 cfs.

CAPILANO DAM

1:60 SCALE MODEL

STILLING-POOL OPERATION

FIGURE 10

Q=33,000 cfs.

Q=43,000 cfs.

CAPILANO DAM

1:60 SCALE MODEL

STILLING-POOL OPERATION

FIGURE 11

One river outlet operating.

Two river outlets operating.

CAPILANO DAM

1:60 SCALE MODEL