SPILLWAY AND STILLING BASIN
COLUMBIA DAM, CHATTAHOOCHEE RIVER
ALABAMA AND GEORGIA

Hydraulic Model Investigation

TECHNICAL REPORT NO. 2-578

October 1961

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

PREFACE

The model investigations reported herein were authorized by the Chief of Engineers on 3 September 1958 at the request of the U. S. Army Engineer District, Mobile. The studies were conducted in the Hydraulics Division of the U. S. Army Engineer Waterways Experiment Station during the period October 1958 to June 1959 under the direction of Mr. E. P. Fortson, Jr., Chief of the Hydraulics Division, and Mr. F. R. Brown, Chief of the Hydrodynamics Branch. The tests were conducted by Messrs. E. S. Melsheimer, C. C. Kestenbaum, and N. V. Cowan, under the supervision of Mr. T. E. Murphy. This report was prepared by Messrs. Melsheimer and Murphy.

During the course of the investigations Messrs. G. W. Gaines, F. F. Escoffier, A. M. Cronenberg, A. F. Baer, A. W. Kerr, and J. W. McGee of the Mobile District visited the Experiment Station at frequent intervals to discuss test results and to correlate these results with design work concurrently under way in the District Office.

Director of the Waterways Experiment Station during the course of this study and the preparation of this report was Col. Edmund H. Lang, CE. Technical Director was Mr. J. B. Tiffany.

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SUMMARY

This report presents the results of tests conducted on section models of the gated and fixed-crest spillways for Columbia Dam, a navigation structure proposed for construction on the Chattahoochee River. The models were constructed to undistorted scales of 1:27.2 (gated spillway) and 1:36 (fixed-crest spillway). The original design provided stilling basins below each of the spillways, but model tests demonstrated the feasibility of eliminating energy-dissipating devices. Pressure measurements on the sill of the gated spillway revealed no unusual conditions.

SPILLWAY AND STILLING BASIN, COLUMBIA DAM

CHATTAHOOCHEE RIVER, ALABAMA AND GEORGIA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Columbia Lock and Dam is a navigation structure proposed for construction on the Chattahoochee River 46.5 miles above Jim Woodruff Dam and 28.7 miles below Walter F. George Dam (see fig. 1). It is about 17 miles east of Dothan, Alabama, and one mile south of Columbia, Alabama. The lock and dam is one unit of a comprehensive plan to provide a 9-ft depth for navigation on the Chattahoochee River to Columbus, Georgia. The project is a part of the Apalachicola River system which comprises Buford, Walter F. George, and Jim Woodruff Dams. The proposed structure will consist of a dam with its axis normal to the river channel, providing a 25-ft pool differential between elevations 102 and 77* and a single navigable pool to Walter F. George Lock and Dam, a distance of about 29 miles. The principal features of the dam are shown in fig. 2 and from right to left bank consist of: (a) a conventional concrete, gravity-type ogee overflow section with crest

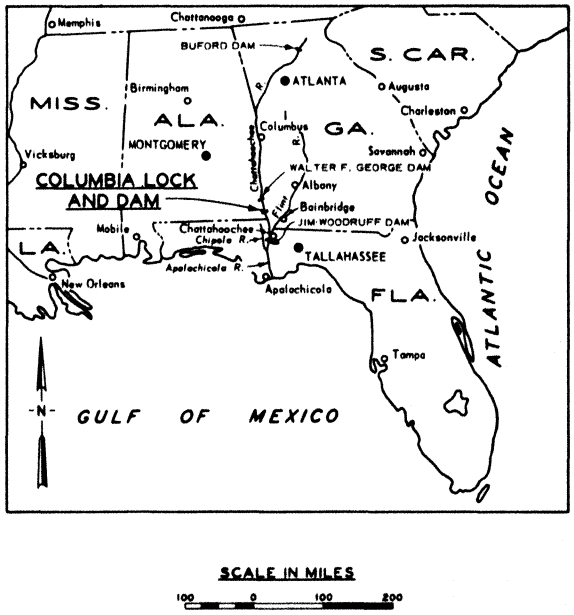

Fig. 1. Location map

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* All elevations are in feet above mean sea level.

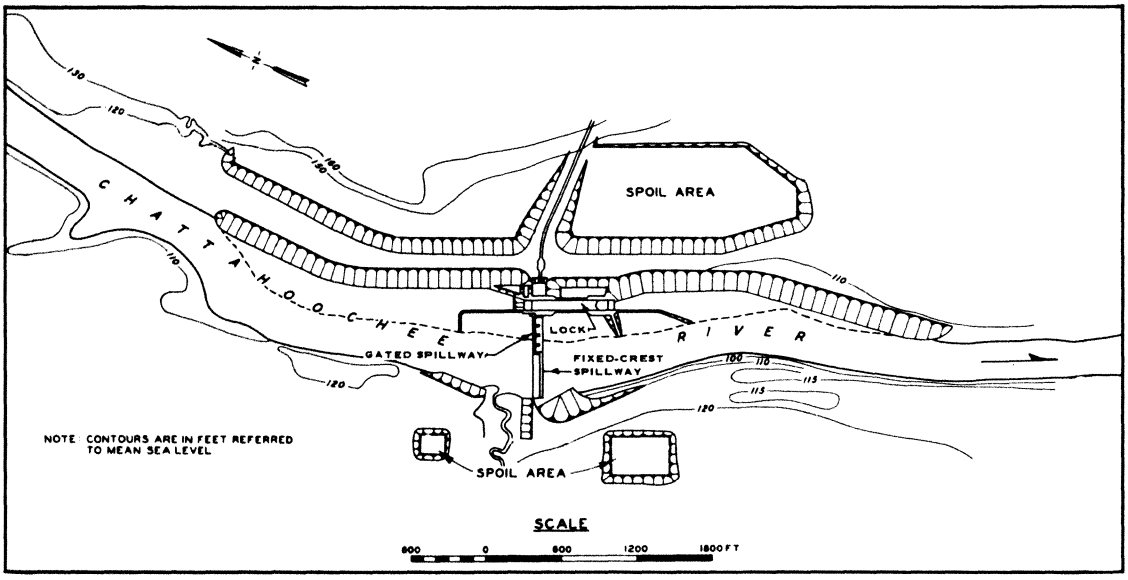


Fig. 2. Site map

at elevation 102; (b) a gated spillway with crest at elevation 82, having four 21- by 60-ft tainter gates; and (c) a single-lift lock 82 ft wide by 450 ft long.

2. Principal features of the gated and fixed-crest spillways are shown in plate 1. The model studies were concerned only with the hydraulic performance of the spillways and their respective stilling basins. Data pertinent to the structural and hydraulic features of the dam are:

a. Structural

Number of spillway tainter gates	4 (21 by 60 ft)
Length of gated spillway (gross)	280 ft
Length of gated spillway (net)	240 ft
Elevation of gated spillway crest	82.0
Elevation of gated spillway stilling basin	53.0 to 55.0
Length of fixed-crest spillway	340 ft
Elevation of fixed-crest spillway crest	102.0
Elevation of fixed-crest spillway stilling basin	50.0 to 54.0

b. Hydraulic

Spillway design flood	659,000 cfs
Stage (i.e. elevation) for design flood	135.8
Maximum flood of record	203,000 cfs
Elevation of normal upper pool	102.0
Elevation of minimum tailwater	77.0
Discharge at bankfull stage	96,000 cfs

Additional details of the spillways and stilling basins are described where appropriate in the text of the report.

Purpose of Model Studies

3. The general purpose of the model studies was the determination of flow characteristics over the spillways and verification of the adequacy of the stilling basin designs. Also, measurement was to be made of pressure fluctuations on the downstream face of the gate sill of the gated spillway.

PART II: THE MODELS

Description

4. Two section models were used in the investigation: (a) a 1:27.2-scale model of one central bay of the gated spillway, and (b) a 1:36-scale model of a 36-ft-wide section of the fixed-crest spillway.

5. The 1:27.2-scale model of the gated spillway was contained in a glass-sided flume and reproduced 500 ft of the approach and exit areas, one central gate bay, and a 68-ft-wide section of the stilling basin (fig. 3). The approach and exit areas were molded in cement mortar to sheet-metal templates. The spillway gate was fabricated of sheet metal, the gate piers were made of transparent plastic, and the stilling basin elements were modeled of wood and treated with waterproofing compound to prevent expansion. For scour tests, that portion of the model below the stilling basin was molded in pea gravel.

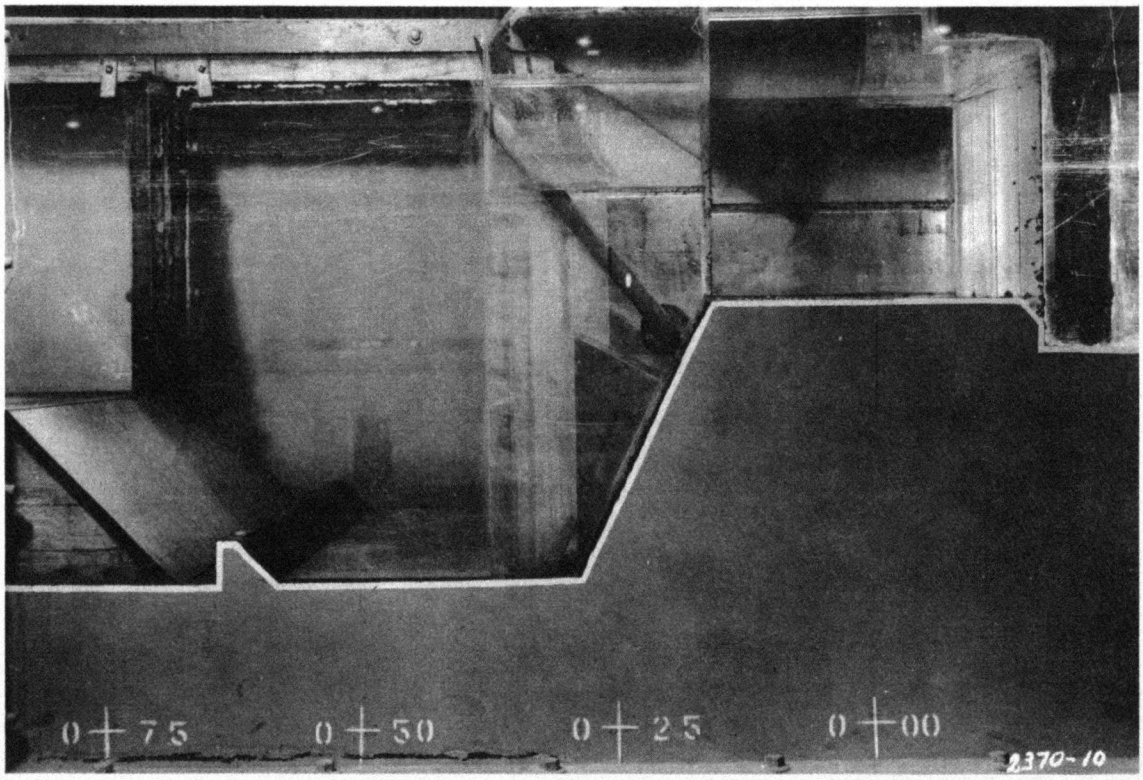


Fig. 3. 1:27.2-scale section model of original design gated spillway

6. The 1:36-scale model of the fixed-crest spillway was also contained in a glass-sided flume and reproduced 250 ft of the approach area, a 36-ft-wide section of the spillway and stilling basin, and 300 ft of the exit area (fig. 4). Portions of the model representing the approach and exit areas, and the spillway and stilling basin were molded in cement mortar to sheet-metal templates.

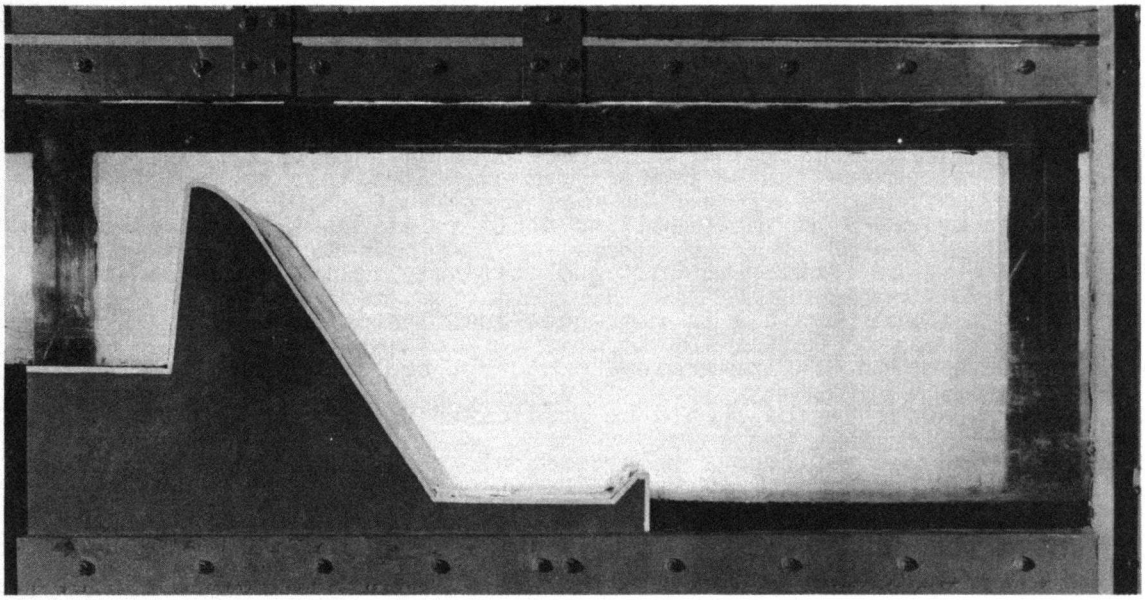


Fig. 4. 1:36-scale section model of original design fixed-crest spillway

7. Water used in the operation of both models was supplied by pumps, and discharges were measured by venturi meters. Steel rails set to grade along the sides of the flumes provided a reference plane for measuring devices. Water-surface elevations were measured by means of point gages. Velocities were measured with a pitot tube. Tailwater elevations were regulated by flap gates at the end of each flume.

Scale Relations

8. The accepted equations of hydraulic similitude, based on Froude's law, were used to express mathematical relations between dimensions and hydraulic quantities of the model and the prototype. General relations for the transference of model data to prototype equivalents were as follows:

Dimension	Ratio	Scale Relations: 1:27.2-scale Section Model	Scale Relations: 1:36-scale Section Model
Length	L_r	1:27.2	1:36
Area	$A_r = L_r^2$	1:740	1:1296
Velocity	$V_r = L_r^{1/2}$	1:5.22	1:6
Discharge	$Q_r = L_r^{5/2}$	1:3340	1:7776

9. Model measurements of discharge, water-surface elevations, pressures, and velocities can be transferred quantitatively to prototype equivalents by means of the preceding scale relations. Evidences of scour, however, are to be considered only qualitatively reliable, since it has not yet been found possible to reproduce quantitatively in a model the resistance to erosion of fine-grained prototype bed material. Determination of prototype scour depths should be predicated upon the magnitude of bottom velocities and the resistance to erosion of the prototype bed material.

PART III: TESTS AND RESULTS

Gated Spillway

Description

10. The gated spillway (plate 1) will comprise four tainter gates 21 ft high by 60 ft wide, supported by crest piers 8 ft wide. The gate sill will be founded in a limestone rock at about elevation 55 and will have a 33-ft-wide horizontal crest at elevation 82. The upstream face of the gate sill will slope 1 on 1 to elevation 79 and then extend vertically into the rock, while the downstream face will slope 1 on 2 from the crest to a split-level, horizontal stilling basin, half at elevation 55 below gate bays 1 and 2 (adjacent to lock), and half at elevation 53 below gate bays 3 and 4. The stilling basin aprons at elevations 53 and 55 will be 35 and 34 ft long, respectively, and will be terminated by sloping-faced end sills 4 ft high. Overburden in the approach and exit channels, consisting of sand and gravel, will be excavated to elevations 77 and 72, respectively.

Calibration

11. Tailwater-discharge relations with one gate at full and partial openings and the upper pool at elevations 96, 98, 100, 102, and 103 are plotted in plates 2-6. These data were obtained with the approach channel fixed in the model at elevation 77 and the exit channel fixed at elevation 72. Although normal upper pool will be at elevation 102, a hinged-pool-type operation is planned to minimize overbank flooding in the upper reaches of the pool. Calibration data were obtained at various pools to assist in formulating an operating schedule for the gates.

Velocities in approach

12. With the approach channel fixed in the model at elevation 77 a maximum bottom velocity of 6 fps was measured at a simulated discharge of 46,000 cfs. Riprap protection immediately upstream from the gate sill should be predicated upon this velocity.

Pressures

13. Pressure cells were installed in the gate sill and piezometers in the stilling basin end sill (plate 7). Of particular concern were

pressure fluctuations near the intersection of the top and downstream face of the gate sill. Data collected are listed in tables 1 and 2. Under normal operating conditions, pressures on the gate sill were positive and pressure fluctuations did not exceed 1 ft (table 1). An observation made with the approach channel at elevation 72 revealed pressure fluctuations of as much as 2.5 ft at cell A but no change in conditions at the other cells. Pressures on the stilling basin end sill exceeded the static pressure due to tailwater by a maximum of 7.5 ft at a 6-ft gate opening (table 2).

Passage of drift

14. Observations were made with twigs, simulating trees up to about 30 ft high, introduced into the model to determine minimum gate openings required for passage of drift. With the pool at elevation 102 some drift was drawn under a gate open 6 ft and all drift was drawn under a gate open 10 ft.

Stilling basin

15. In establishing conditions under which the stilling basin below the gated spillway would be required to operate, it was assumed that the gates would be operated in increments of no more than 2 ft and that the maximum difference in opening of any two gates would not be allowed to exceed 2 ft. Consideration of this plan of operation together with gate rating curves for pool elevation 102 (plate 5) and the tailwater rating curve furnished by the design engineers (plate 8) resulted in establishment of tailwater limits for each gate position (plate 9). The minimum tailwater curve in plate 9 represents the tailwater which will obtain below the first gate moved to a higher position immediately after this gate is raised. The maximum tailwater curve represents the tailwater below the first gate moved to a lower position immediately after this gate is lowered.

16. Original design (type 1). Tests on the original design stilling basin below the gated spillway (see plate 1) were concerned with flow patterns and bottom velocities with the exit channel immediately downstream from the structure fixed at elevations 72, 64, and 55 (types 1, 2, and 3 exits, respectively, plate 10) to represent different stages of exit degradation.

17. Flow patterns observed with the types 1 and 2 exits are shown

in photographs 1-4; flow action with the type 3 exit was similar.

18. Water-surface profiles and flow characteristics at normal tailwater elevations (all gates assumed at equal openings) are shown in plates 11, 13, and 15. Maximum bottom velocities and stilling basin actions for a range of tailwater elevations are plotted in plates 12, 14, and 16. With the type 1 exit, bottom velocities as high as 18 fps were encountered within the expected range of tailwater elevations. With the types 2 and 3 exit channels, maximum bottom velocities within the expected range of tailwater elevations did not exceed 8 and 7 fps, respectively.

19. Type 2 design. Since in the original design flow separated from the downstream face of the gate sill and passed over the stilling basin into the exit channel, a curved downstream face was added to the gate sill in order to guide flow into the stilling basin (fig. 5). This design was tested with the types 1 and 3 exit channels.

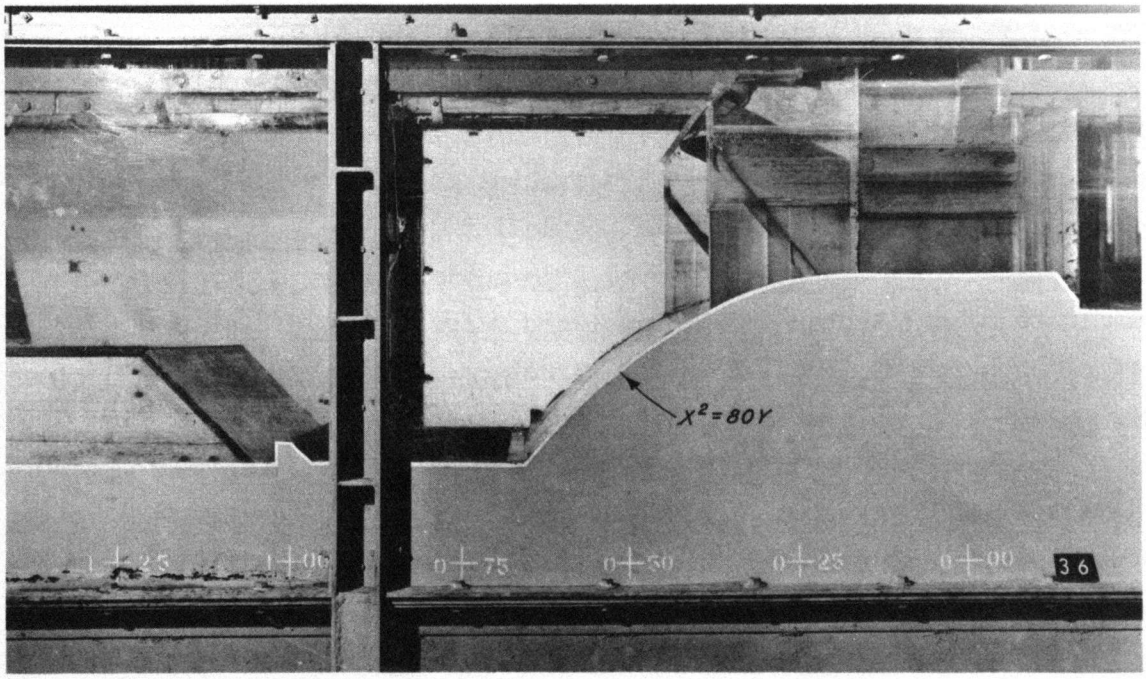


Fig. 5. Curved downstream face on gate sill, type 2 design

20. The curved face on the gate sill successfully guided the jet into the stilling basin and a roller-type basin action (photographs 5 and 6) occurred throughout the expected range of operation. Water-surface profiles and flow characteristics at normal tailwater elevations with the

types 1 and 3 exits are shown in plates 17 and 18. Maximum bottom velocities in the type 1 exit for a range of tailwater elevations are plotted in plate 19. In the expected operating range bottom velocities did not exceed 10 fps.

21. Adopted design. Tests on the types 1 and 2 stilling basins led to conclusions as follows:

a. A curved downstream face, requiring an appreciable amount of concrete, must be added to the gate sill in order to make a stilling basin at elevation 55 effective.

b. Without an effective stilling basin, removal of all overburden will result in velocities on the top of the rock at elevation 55 of only about 7 fps.

Consideration of these conclusions led to a decision to eliminate the stilling basin below the gated spillway. Thus, it is planned that the prototype will be constructed with the downstream face of the gate sill sloped 1 on 2 from the crest to bedrock. Overburden in the exit channel will be left as high as elevation 72.

22. Observations were made in the model with pea gravel simulating the prototype overburden. At an 8-ft gate opening all four types of basin action shown in photographs 1-4 were encountered within the expected tailwater range. The plunging jet and undulating jet (free nappe) types of action resulted in a 6.5-ft-deep scour hole approximately 80 ft downstream from the gate sill (plate 20). Displaced material was deposited in the form of a bar about 150 ft from the structure. The surface jet and, to some extent, the undulating jet (submerged nappe) types of action developed ground rollers which tended to redeposit the eroded material in the scour hole along the downstream face of the gate sill. With the tailwater at about elevation 96 (normal), basin action periodically oscillated between the undulating jet (free nappe) and surface jet types of action. This oscillation appeared to be influenced by the degree of development of the scour hole and bar.

Fixed-Crest Spillway

Description

23. The fixed-crest spillway will comprise an ogee weir with its

crest at elevation 102. It is planned that the pool will not be allowed to rise above this elevation until the four spillway gates are fully open. At this time a discharge of about 46,000 cfs would be passing through the gated spillway and tailwater would be at about elevation 101, only 1 ft below the crest of the fixed-crest spillway.

24. The shape of the ogee weir for the fixed-crest spillway (see plate 1 and fig. 4) was based on a design head of 6 ft. The selection of the design head was complicated by the fact that at high discharges the tailwater rises rapidly to submerge the crest. At some point between 0.6 and 0.8 submergence the overflowing sheet of water will cease to follow the downstream face of the spillway and will ride atop the tailwater (photograph 7). The design head of 6 ft was taken as the maximum head at which the nappe will adhere to the downstream face of the spillway. The upstream portion of the crest will be shaped to follow two circular curves with radii of 3.0 and 1.2 ft. The downstream portion of the crest will be shaped to a parabolic curve $X^{1.85} = 2.0\ H^{0.85}\ Y$, in which H is the design head and X and Y are coordinates referred to the crest as origin. With the design head of 6 ft, the downstream shape of the weir crest will follow the curve $X^{1.85} = 9.17\ Y$.

Velocities over crest

25. Although navigation over the fixed-crest spillway is not planned, surface velocities were measured to furnish an indication of the erosive effects on the riverbanks. Velocity measurements obtained over the crest indicated a maximum velocity of 7 fps for a discharge of 19,000 cfs. For this discharge a swellhead of 0.7 ft was observed in the model. Typical plots of velocity data and water-surface profiles are shown in plate 21.

Calibration

26. Tests also were conducted on the section model of the fixed-crest spillway to determine the coefficient of discharge for free and submerged flows. The spillway first was calibrated for free flow (plate 22), and a discharge coefficient curve (plate 23) based on these data was computed from the formula,

$$Q = CLH^{3/2}$$

where

Q = discharge in cfs

C = coefficient of discharge

L = length of spillway in ft

H = head on spillway crest (including velocity head) in ft

The spillway was then recalibrated for various conditions involving submergence. This was accomplished by setting several constant discharges and then varying the tailwater for each from an elevation where no interference in spillway flow was evident to an elevation where spillway flow was practically 100 per cent submerged. The family of curves obtained is shown in plate 24. Discharge coefficients were determined from these curves for various conditions involving submergence. These coefficients, expressed in per cent of free-flow coefficient, are plotted in plate 25.

Stilling basin

27. Original design. The original design stilling basin below the fixed-crest spillway consisted of a 34-ft-long horizontal apron terminated by a 4-ft-high sloped end sill (see plate 1). Under normal tailwater conditions, flow over the weir separated from the downstream face of the weir and flowed along the surface of the tailwater at a pool elevation greater than about 104.5. Under no conditions were measurable bottom velocities encountered in the exit area.

28. Alternative designs. Consideration was given to elimination of the stilling basin entirely or replacement of the apron by a curved bucket. Since normal operation resulted in negligible velocities at the toe of the spillway, tests to determine the need for a bucket and the effectiveness of several bucket designs were conducted with the tailwater held at minimum elevation (77) and the pool varied. It was considered possible that surges in the pool, resulting from operation of the Walter F. George powerhouse, could result in flow over the fixed-crest spillway with the gated spillway closed. Tests involved measurement of bottom velocities and determination of conditions under which simulated dumped riprap would begin to move.

29. Tests were conducted on three bucket designs and without any energy-dissipating device, with two types of exit channels (see plate 26). Bottom velocities are plotted and conditions at which the riprap began to move are noted in plate 26. The type 3 bucket resulted in minimum

bottom velocities and stable riprap under the greatest head conditions. With no energy dissipator, riprap began to move at a bottom velocity of about 9.5 fps which resulted from a head of 1.5 ft on the crest. For the various designs tested, the riprap moved at different bottom velocities, thus indicating that angle of attack and turbulence are critical factors in riprap design.

30. Adopted design. It was considered unlikely that surges in the pool would produce a head on the fixed-crest spillway exceeding 1 ft, and thus decision was made to eliminate the energy dissipator. Further, since the structure is founded on a good limestone, no riprap will be provided.

PART IV: DISCUSSION

Gated Spillway

31. Tests on the section model of the gated spillway for Columbia Dam revealed unusual types of stilling action. The steep slope on the downstream face of the gate sill resulted in separation of the jet from this face and formation of a roller along the gate sill. Under normal tailwater conditions this roller exerted various degrees of pressure on the bottom of the jet and caused the jet either to plunge through the tailwater beyond the face of the sill (plunging jet, photograph 1), ride the surface of the tailwater (surface jet, photograph 2), or rise above the surface of the tailwater immediately below the gate and undulate through the tailwater (undulating jet, photographs 3 and 4). Flow passed over the original design (34-ft-long apron) stilling basin and attacked the exit channel; an unusually long stilling basin apron would be required for effective energy dissipation. However, the structure is founded on limestone at about elevation 55, and it was found that minimum tailwater at elevation 77 provided a sufficient cushion to warrant elimination of an energy-dissipating device.

32. Since there was separation of the jet from the downstream face of the gate sill some concern was felt regarding the possibility of large pressure fluctuations near the intersection of the top and downstream face of the gate sill. However, pressure cells installed in this location revealed pressure fluctuations of less than 1 ft.

Fixed-Crest Spillway

33. The fixed-crest spillway, with its crest at elevation 102, is designed to be overtopped only after the gated spillway is fully opened. Under this condition there will be only about 1 ft of differential between the upper and lower pools. This spillway also is founded on limestone at about elevation 55, and decision was made to eliminate any energy-dissipating device since the deep tailwater provides adequate protection against erosion. Should the pool inadvertently be allowed to rise as much as 1 ft above the crest, no harmful conditions will result even with minimum tailwater.

Table 1

Pressures on Gated Spillway

Approach Channel Elevation 77

Pool Elevation 102, Tailwater Elevation Varied

Pressure Cell	Cell Zero	Tailwater El	Pressures in Prototype Feet of Water at Indicated Gate Openings			
			2 ft	6 ft	10 ft	Full
A	82.0	77	20.0			
B	82.0	77	1.8			
C	81.2	77	0	*	*	*
D	78.4	77	0			
A	82.0	82	20.0	20.0	15.8	
B	82.0	82	1.5	3.3	5.0	*
C	81.2	82	0	0.6	2.3	
D	78.4	82	2.6	3.4	5.1	
A	82.0	87	20.0	20.0	18.8	17.0
B	82.0	87	3.0	4.3	5.5	9.0
C	81.2	87	4.6	2.6	3.2	6.3
D	78.4	87	7.4	5.4	6.1	9.1
A	82.0	92	20.0	20.0	18.8	17.0
B	82.0	92	9.5	7.8	8.0	10.0
C	81.2	92	10.8	8.8	7.6	8.3
D	78.4	92	13.8	11.6	10.4	11.1
A	82.0	97	20.0	20.0	19.0	17.5
B	82.0	97	16.5	14.5	14.3	14.0
C	81.2	97	17.3	15.6	15.3	14.6
D	78.4	97	20.1	18.4	18.1	17.4

Note: Pressure cell locations shown in plate 7.
Maximum instantaneous pressure fluctuations did not exceed 1.0 ft of water.
* Tailwater elevation controlled by exit elevation.

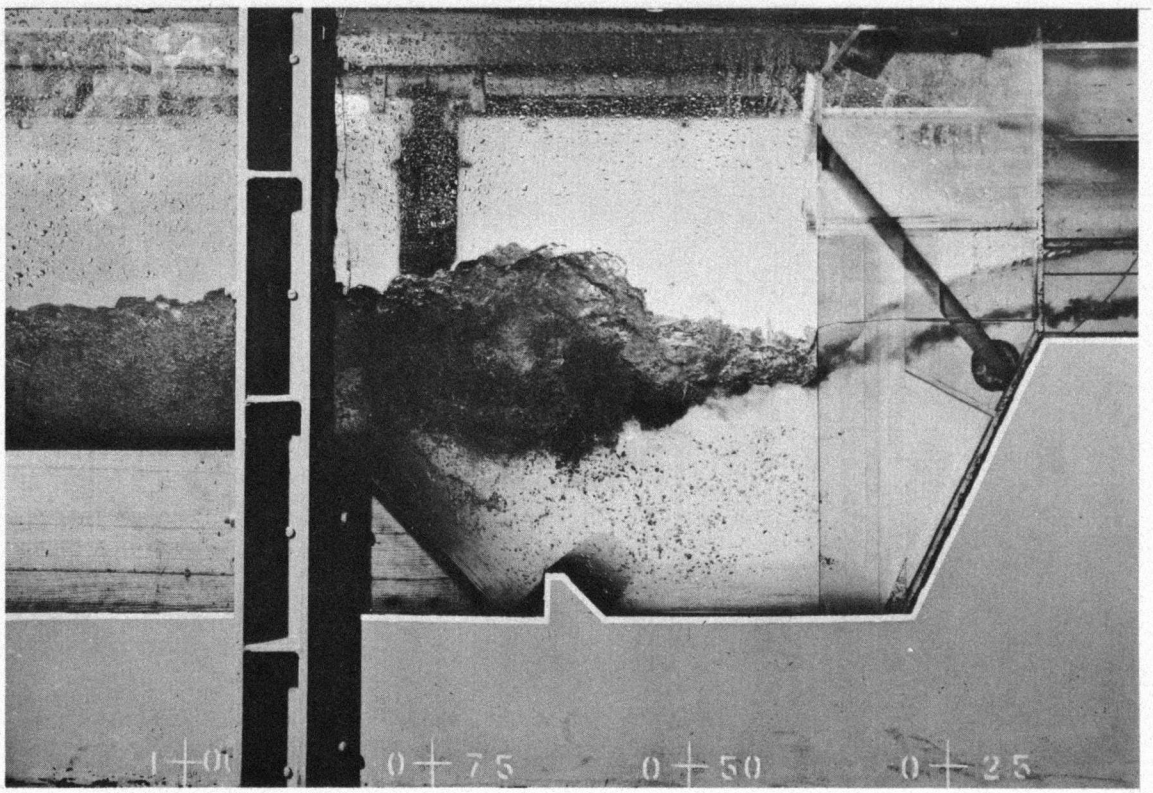
Table 2

Pressures on Stilling Basin End Sill Below Gated Spillway

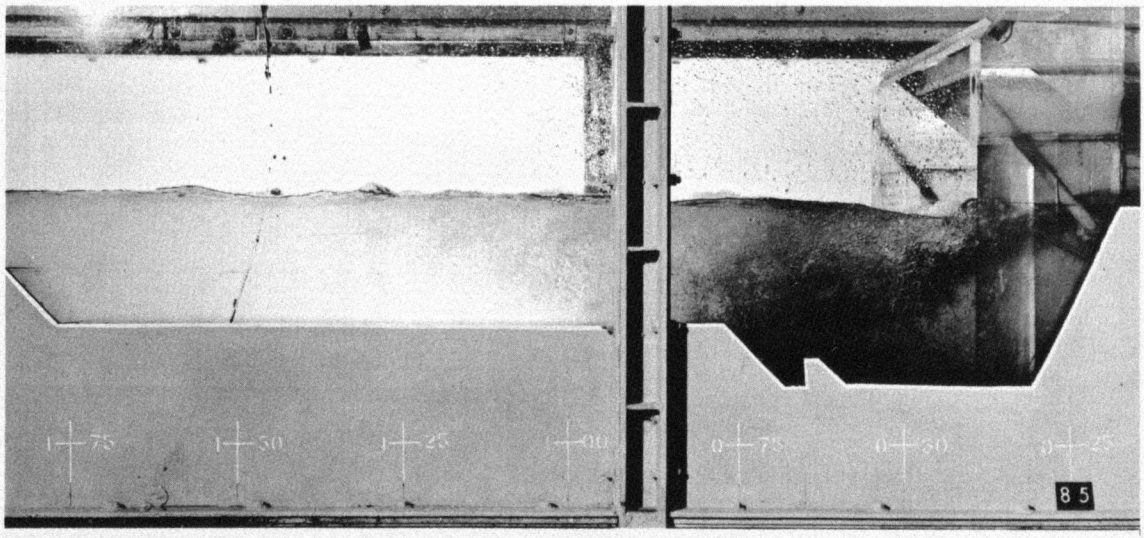
Pool Elevation 102, Tailwater Elevation Varied

Piezometer No.	Piezometer Zero	Gate Opening, ft	Tailwater El	Pressures in Prototype Feet of Water
1	56.0	2	77	25.0
		4	79	30.0
		6	80	28.5
		8	82	28.5
		10	82	29.0
		Full	87	33.0
2	57.0	2	77	24.0
		4	79	29.0
		6	80	28.0
		8	82	28.5
		10	82	28.5
		Full	87	32.0
3	58.0	2	77	23.0
		4	79	27.0
		6	80	29.5
		8	82	28.0
		10	82	29.0
		Full	87	31.0

Note: Piezometers are located on the center line of the end sill (see plate 7).
Maximum pressure fluctuations did not exceed 5.0 ft of water.
Approach elevation 77.
Exit elevations 64 and 72 (split level).

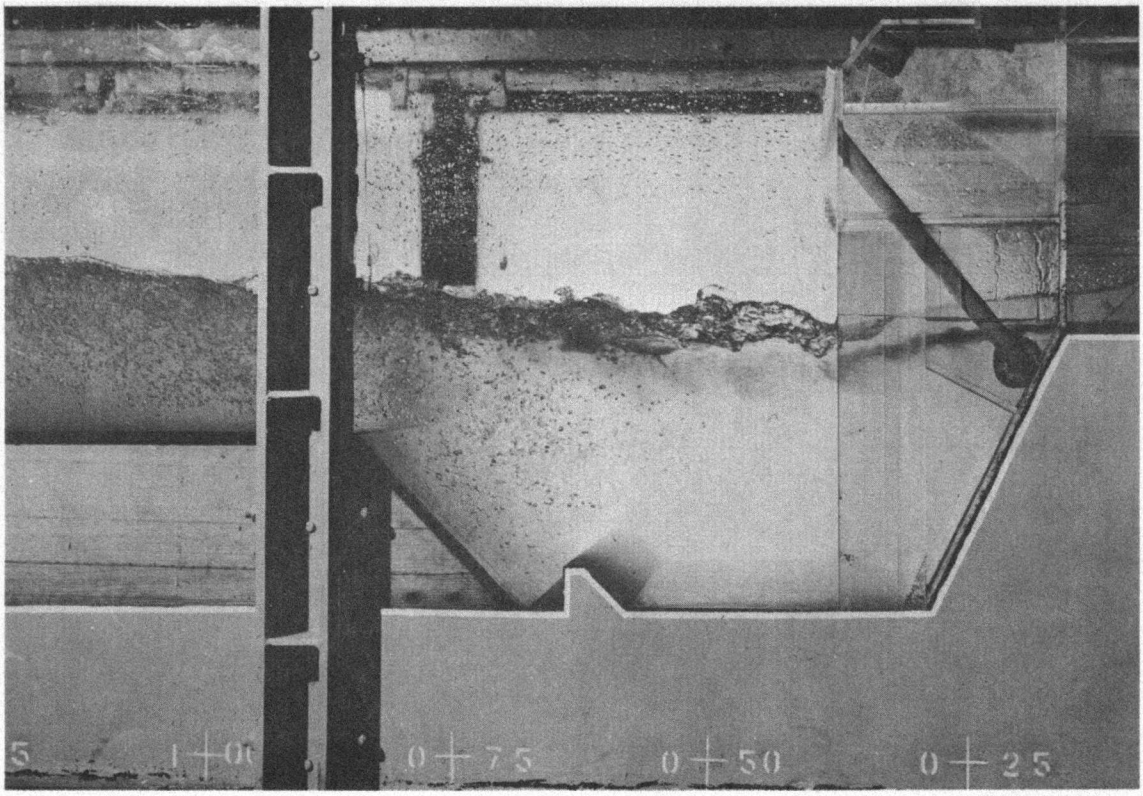


a. Type 1 exit



b. Type 2 exit

Photograph 1. Plunging jet action in type 1 (original) design stilling basin below gated spillway. Jet dives through tailwater over top of end sill and impinges on floor of exit channel



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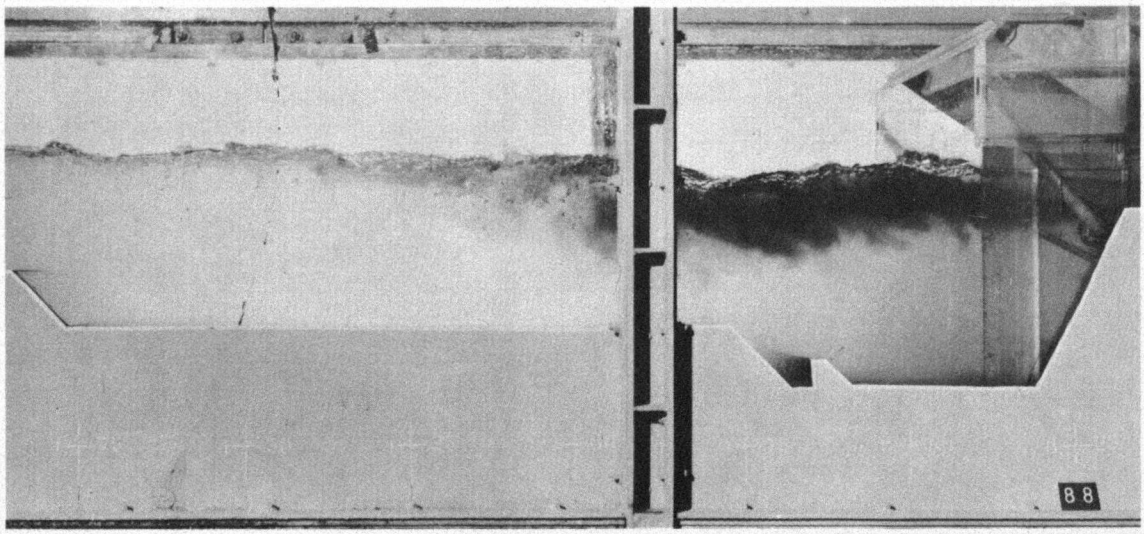
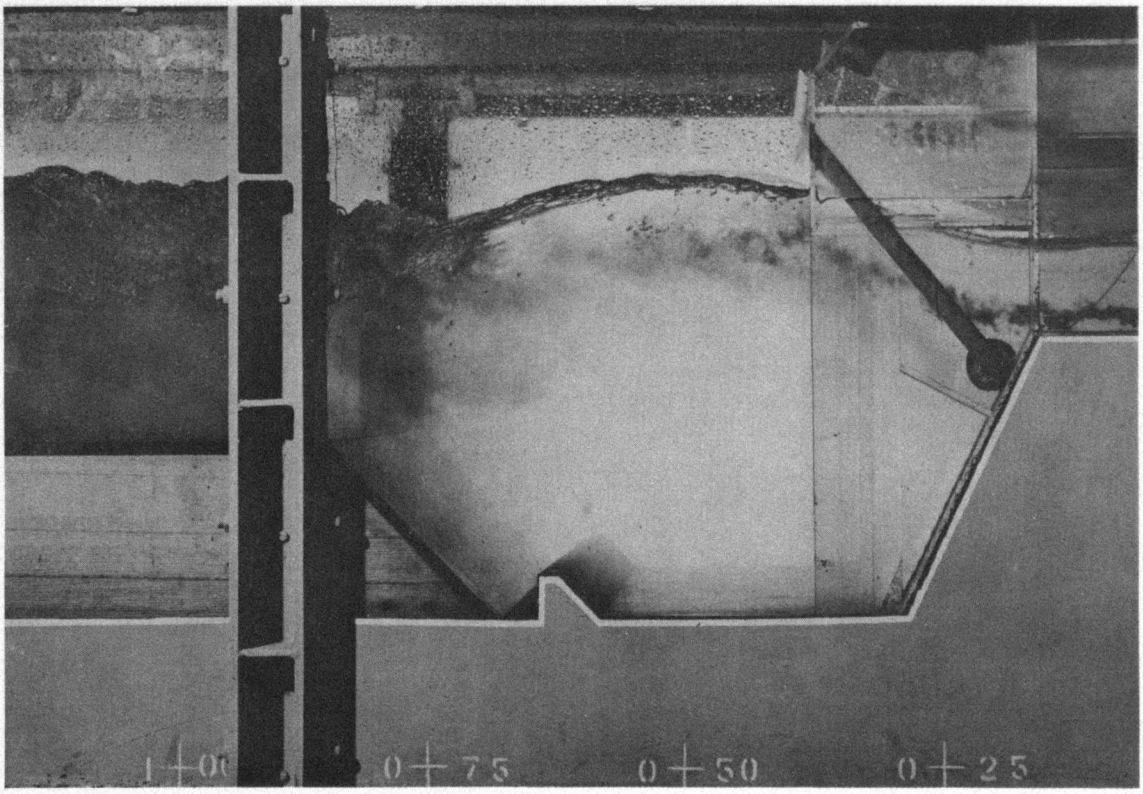
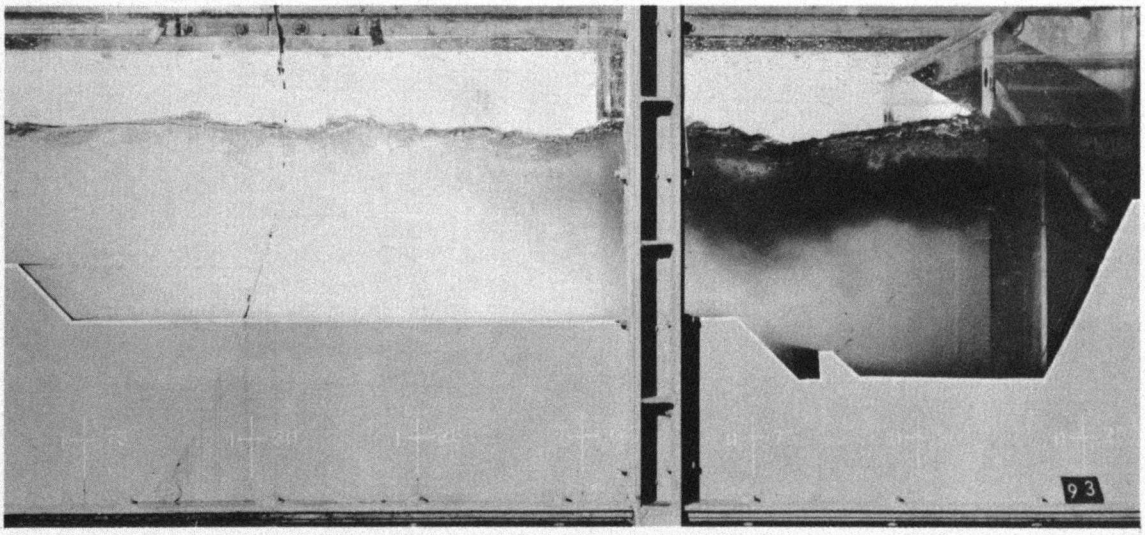


b. Type 2 exit

Photograph 2. Surface jet action in type 1 (original) design stilling basin below gated spillway. Jet rides surface of tailwater; bottom velocities usually upstream in direction and very low in magnitude. However, high-velocity surface flow continues downstream and could cause serious bank erosion or undesirable navigation conditions

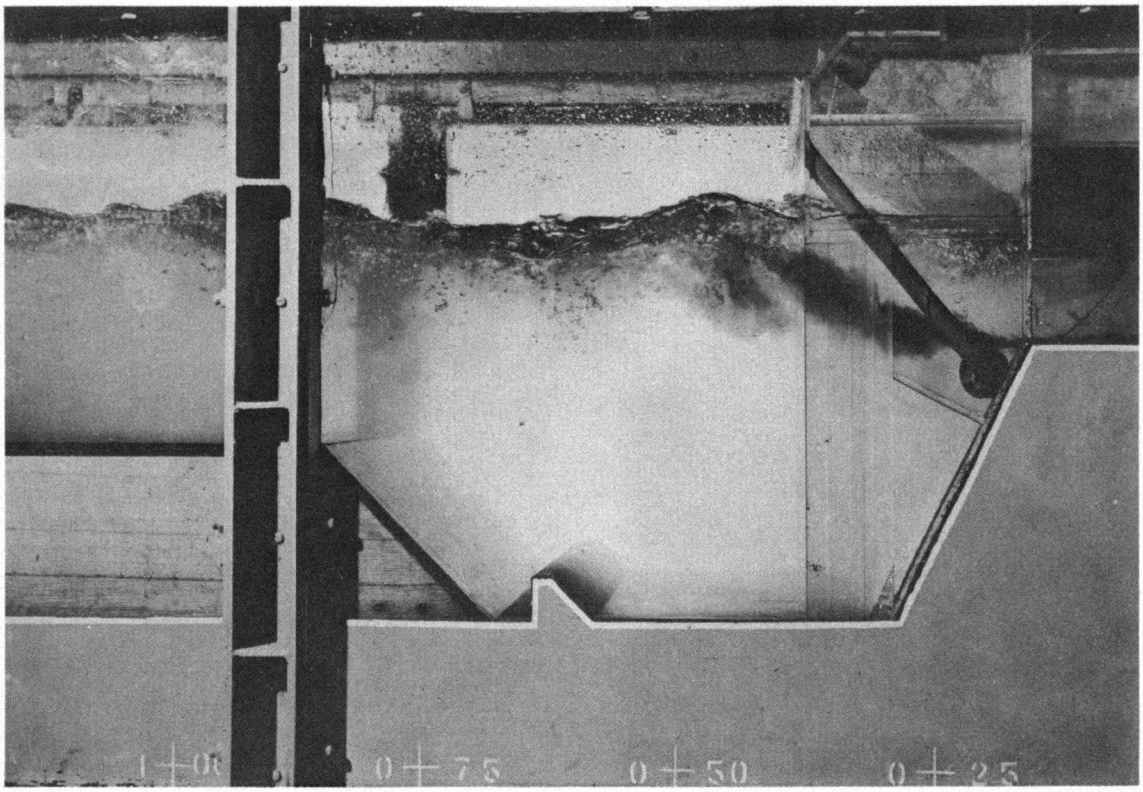


a. Type 1 exit

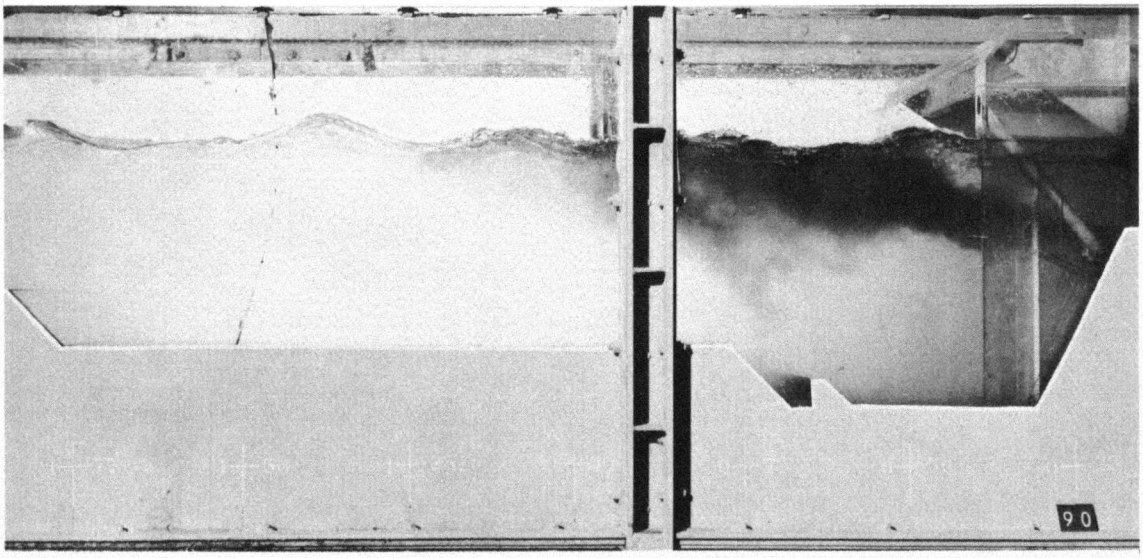


b. Type 2 exit

Photograph 3. Undulating jet (free nappe) action in type 1 (original) design stilling basin below gated spillway. Jet forced to surface immediately below gate and then dives through tailwater to bottom

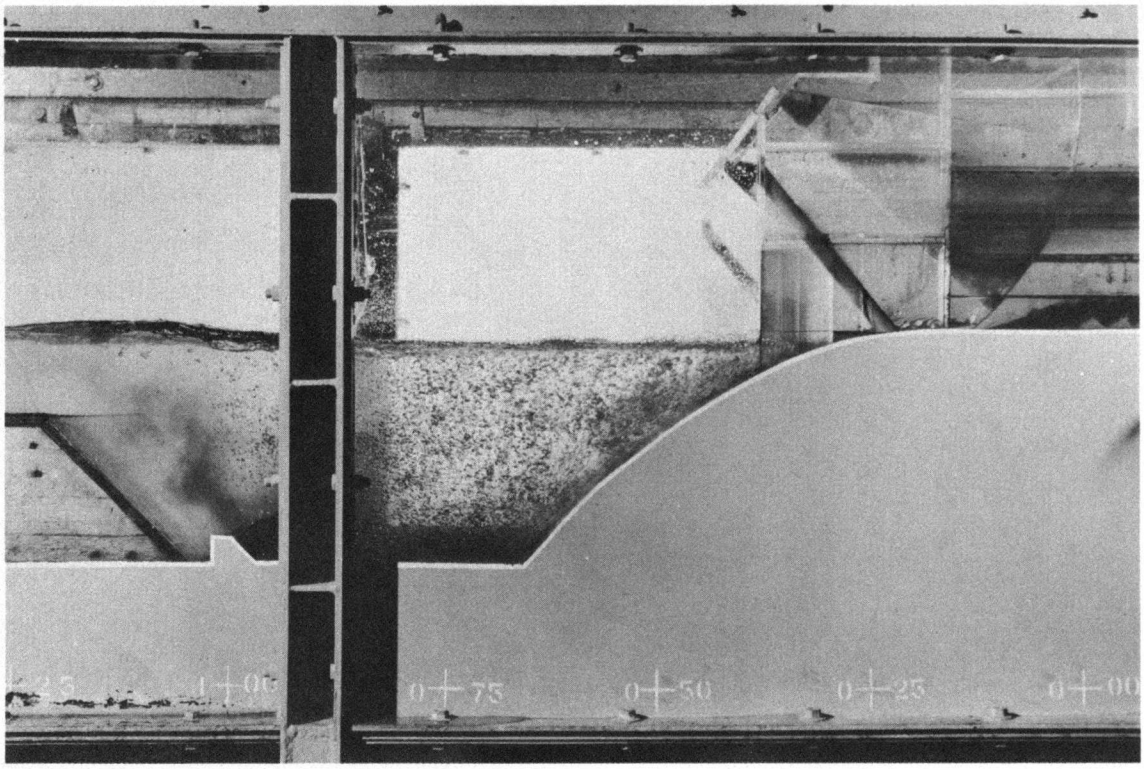


a. Type 1 exit

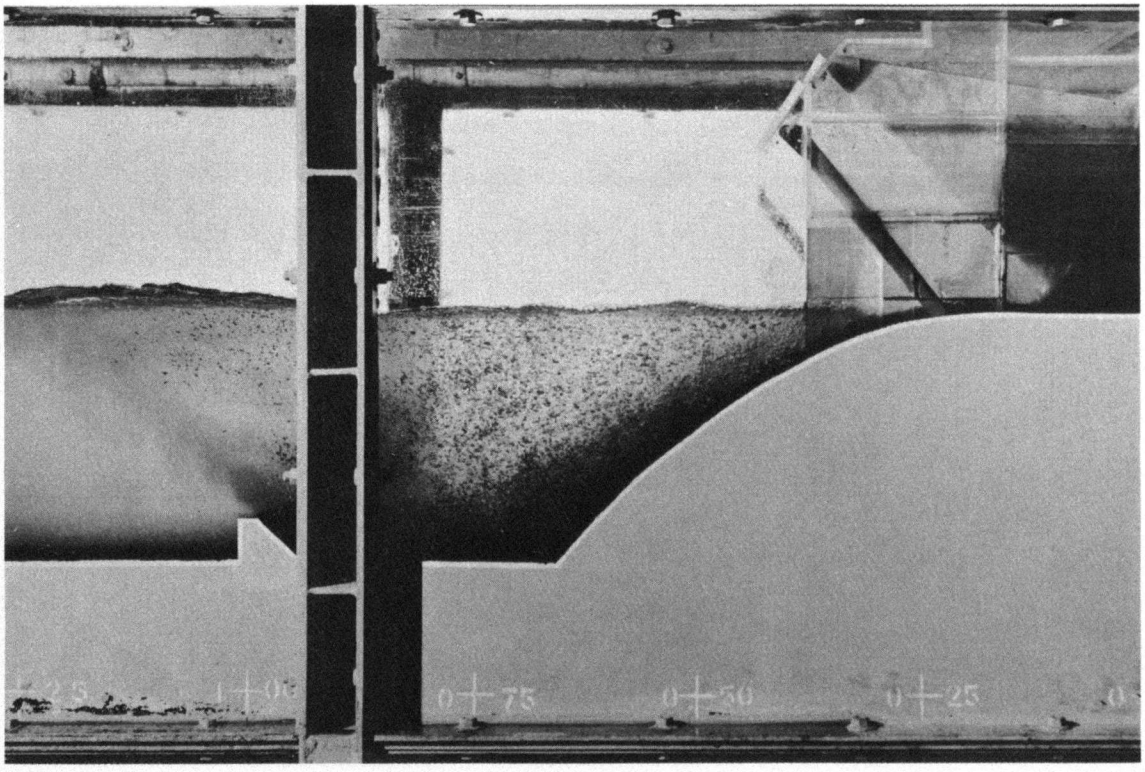


b. Type 2 exit

Photograph 4. Undulating jet (submerged nappe) action in type 1 (original) stilling basin below gated spillway. Jet generally same as undulating jet (free nappe) except tailwater submerges nappe immediately below gate. Characterized by considerable surface wave action

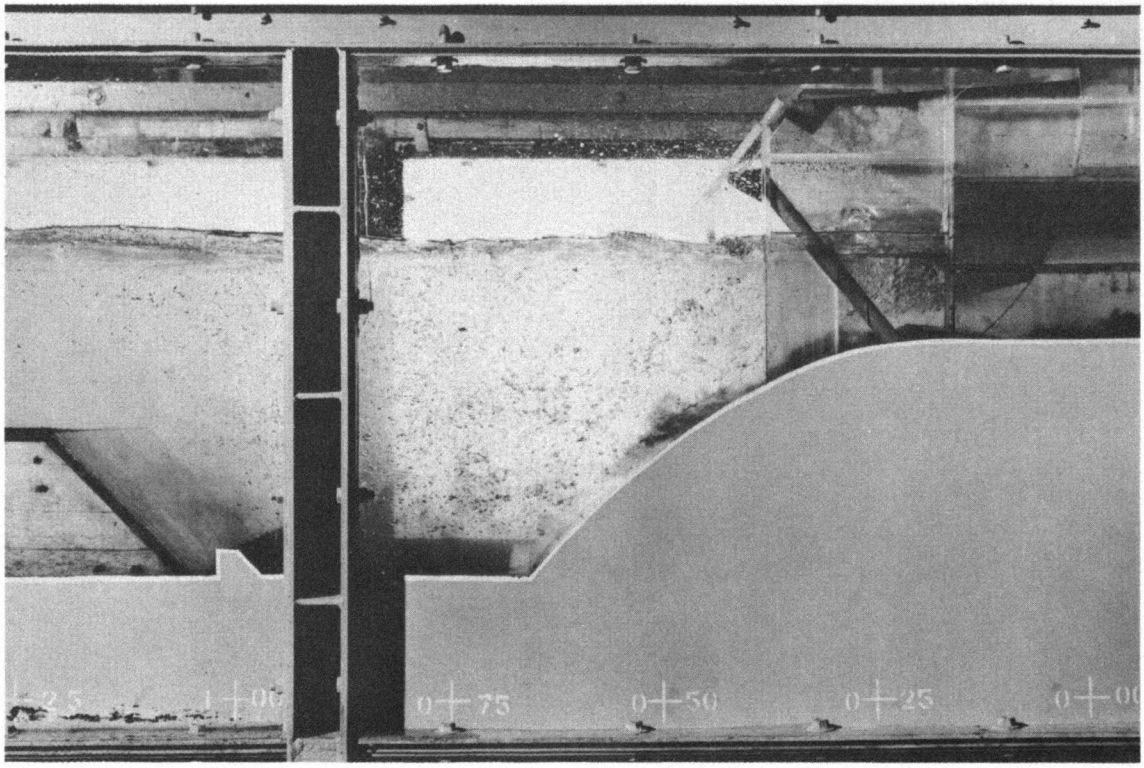


a. Type 1 exit

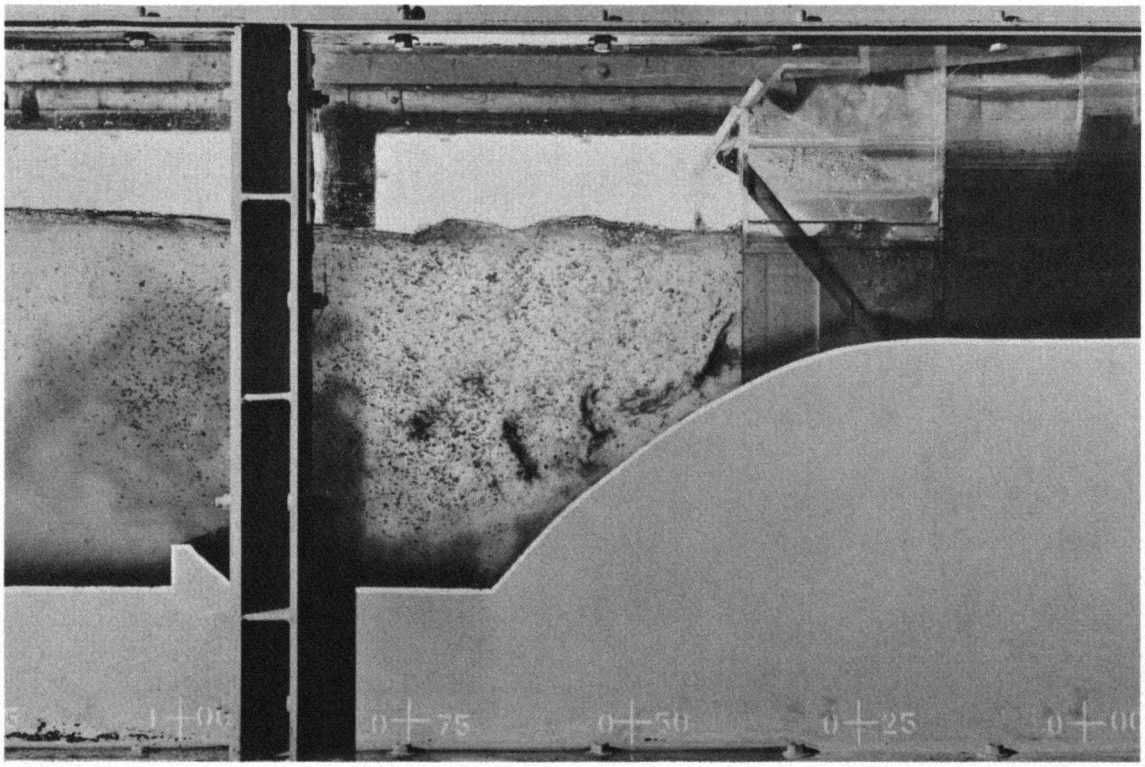


b. Type 3 exit

Photograph 5. Roller-type action in type 2 stilling basin below gated spillway, 2-ft gate opening

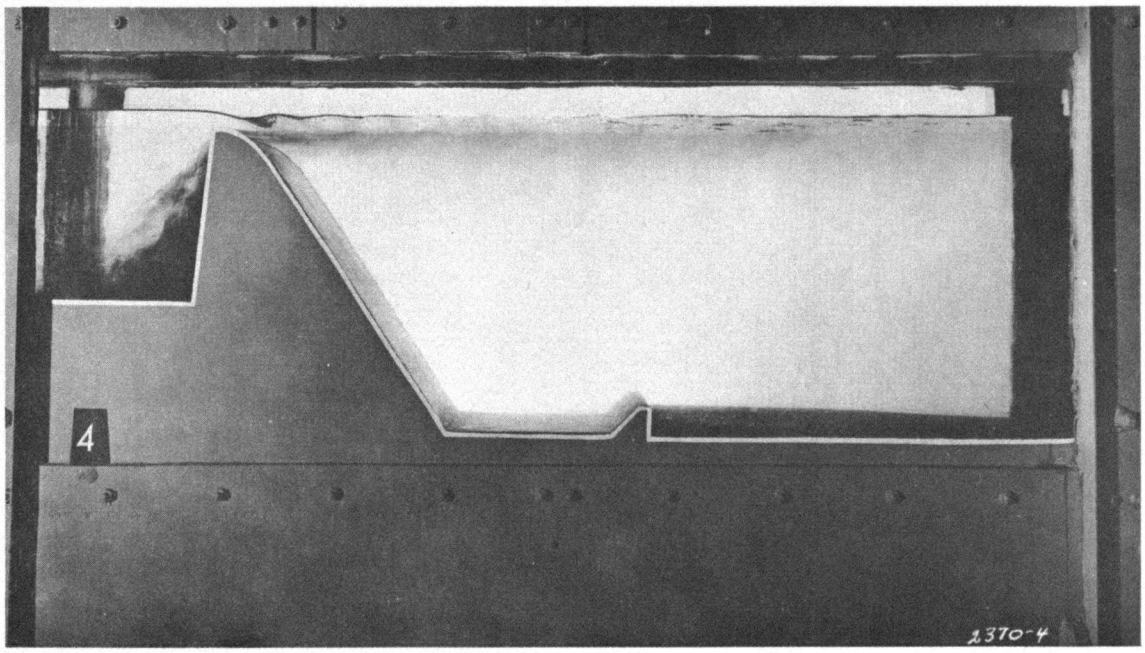


a. Type 1 exit

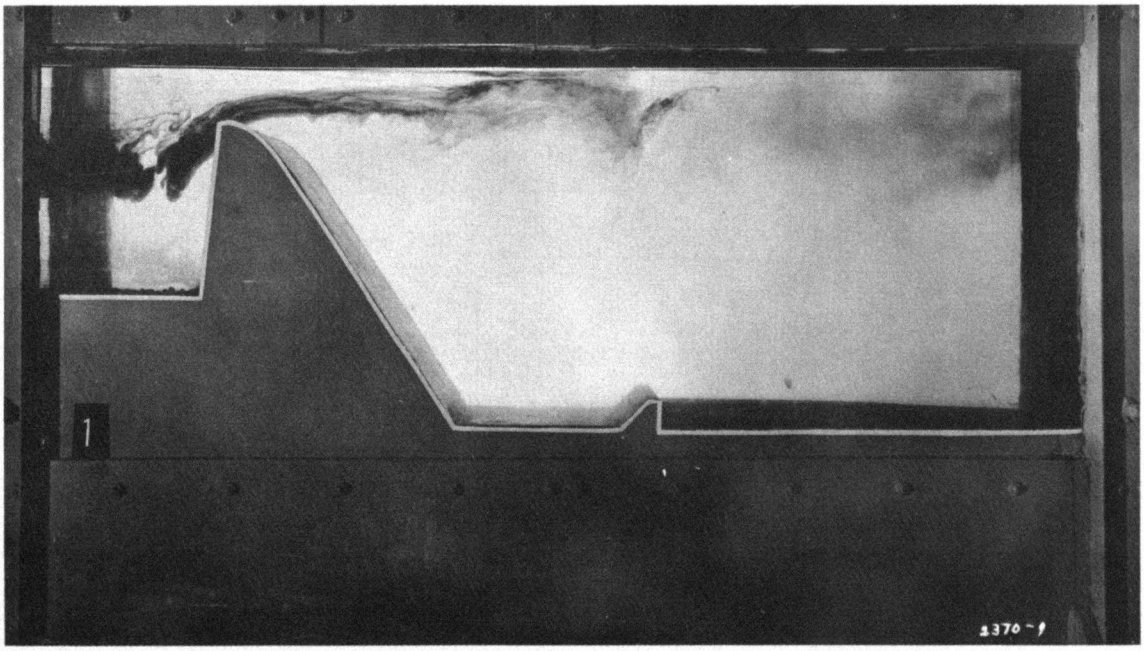


b. Type 3 exit

Photograph 6. Roller-type action in type 2 stilling basin below gated spillway, 8-ft gate opening

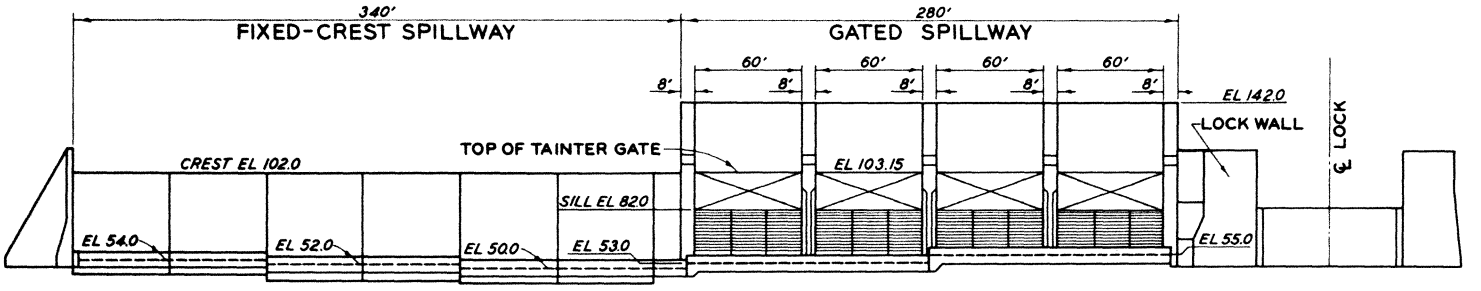


a. Pool el 105.0, tailwater el 104.3



b. Pool el 111.0, tailwater el 110.3

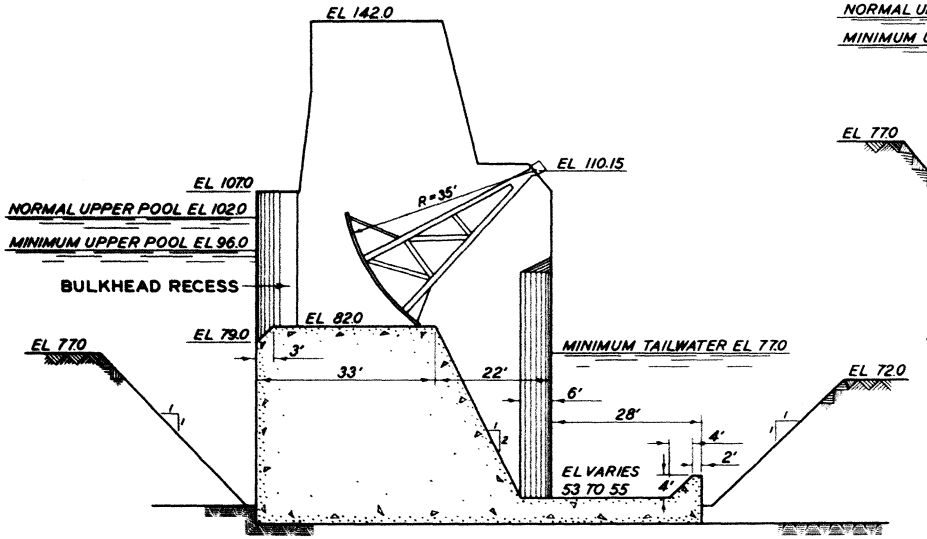
Photograph 7. Flow over fixed-crest spillway



DOWNSTREAM ELEVATION

SCALE IN FEET

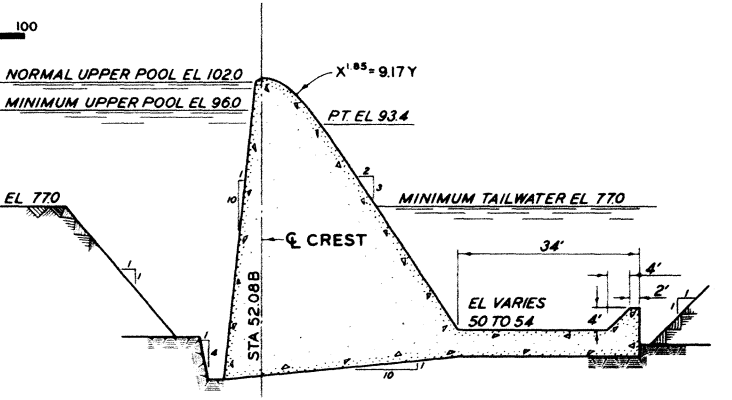
20 0 20 40 60 80 100



TYPICAL SECTION OF GATED SPILLWAY

SCALE IN FEET

10 0 10 20 30 40



TYPICAL SECTION OF FIXED-CREST SPILLWAY

SCALE IN FEET

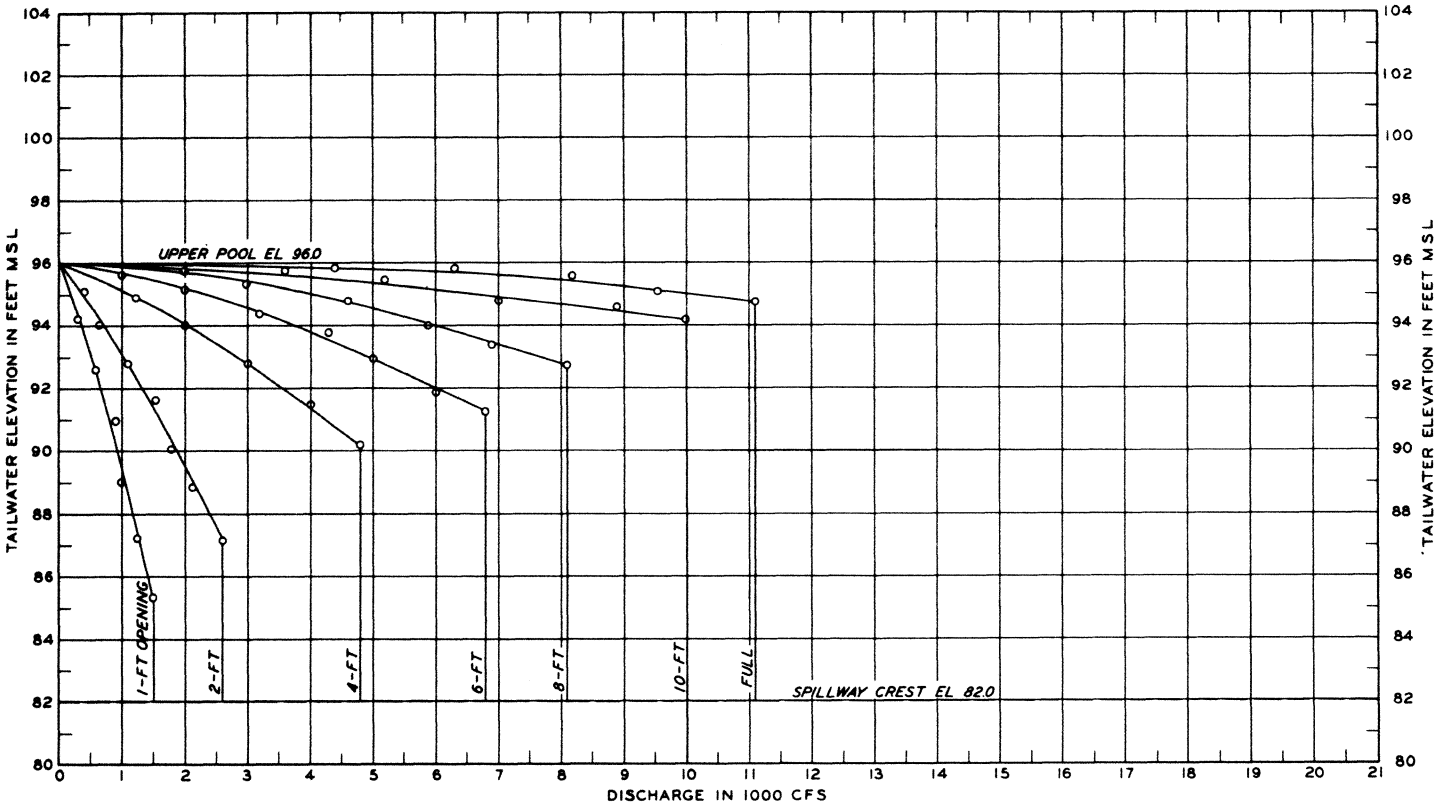
10 0 10 20 30 40

DETAILS OF SPILLWAYS AND STILLING BASINS

TYPE I (ORIGINAL) DESIGN

PLATE I

PLATE 2

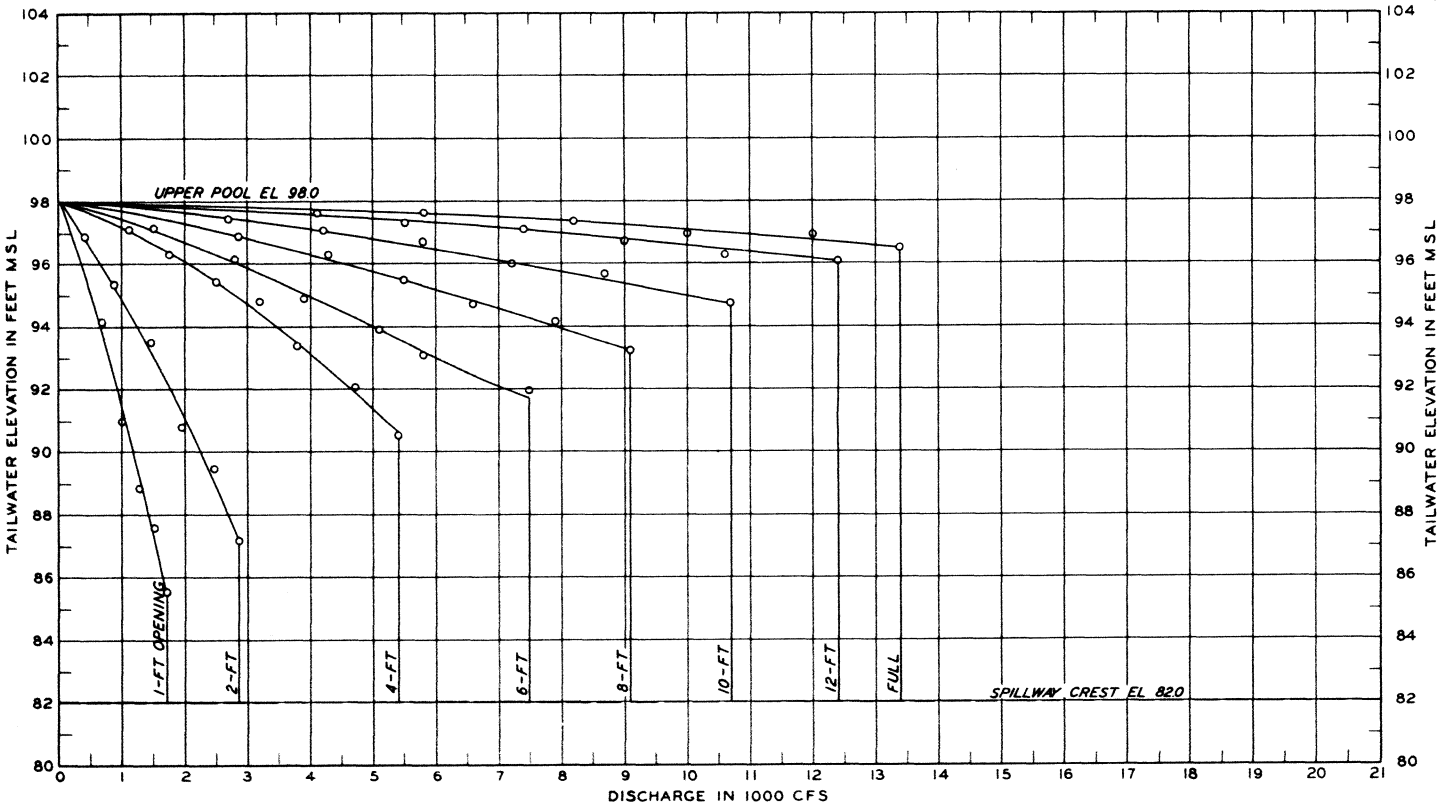


NOTE: DISCHARGE BASED ON FLOW THROUGH ONE GATE BAY.

EFFECT OF TAILWATER ELEVATION ON DISCHARGE

GATED SPILLWAY

ONE GATE AT FULL AND PARTIAL OPENINGS
UPPER POOL ELEVATION 96.0

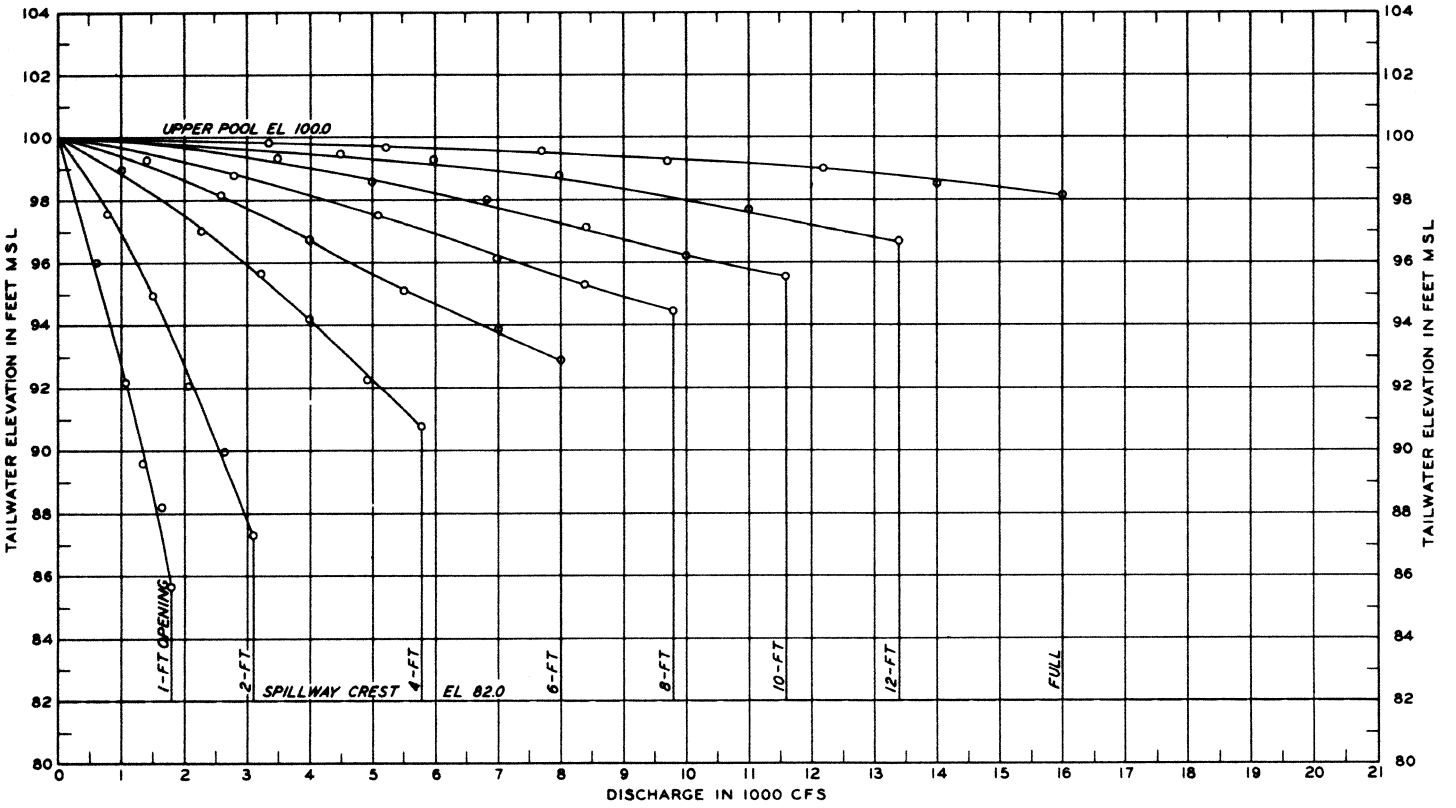


NOTE: DISCHARGE BASED ON FLOW THROUGH ONE GATE BAY.

EFFECT OF TAILWATER ELEVATION ON DISCHARGE

GATED SPILLWAY

ONE GATE AT FULL AND PARTIAL OPENINGS
UPPER POOL ELEVATION 98.0

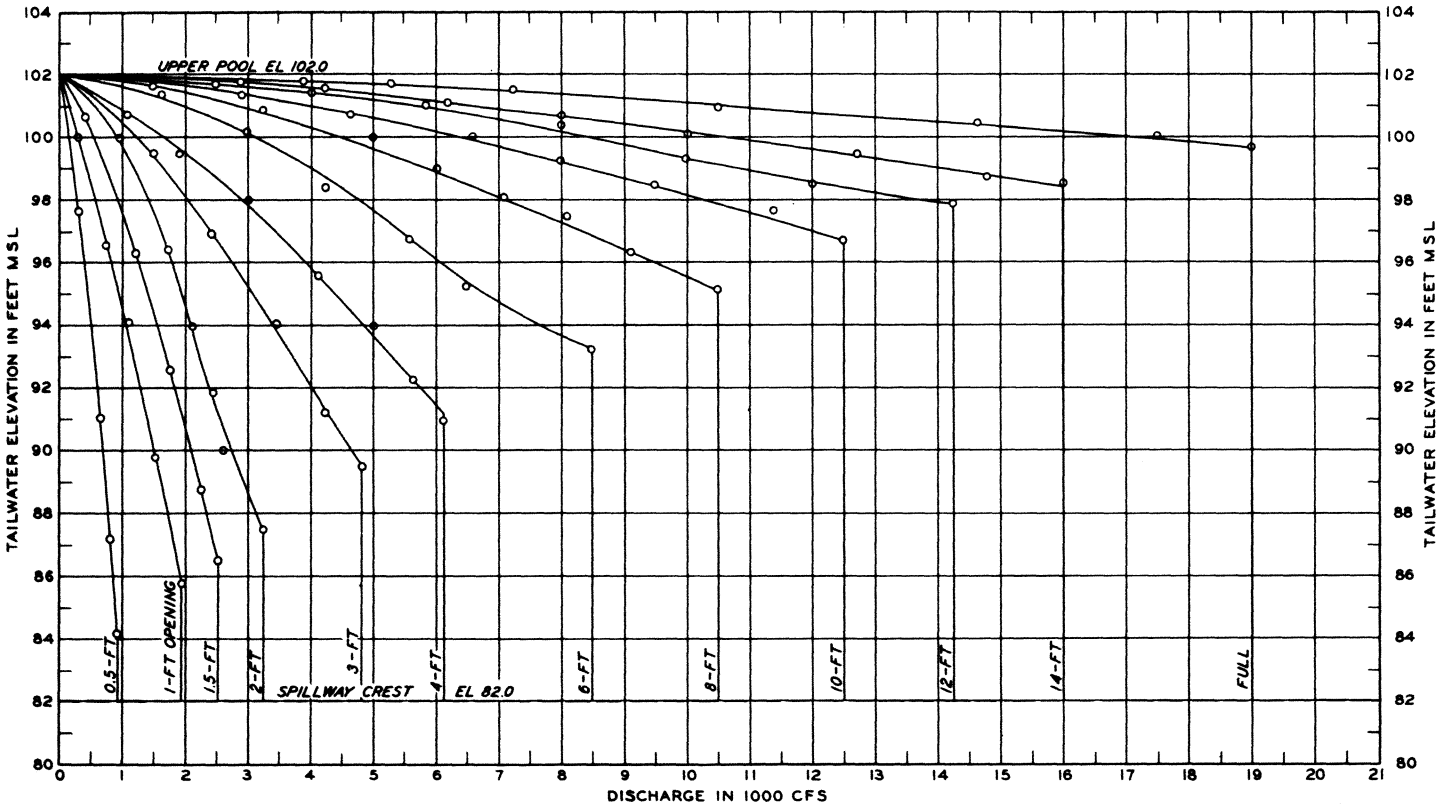


NOTE: DISCHARGE BASED ON FLOW THROUGH ONE GATE BAY.

EFFECT OF TAILWATER ELEVATION ON DISCHARGE

GATED SPILLWAY

ONE GATE AT FULL AND PARTIAL OPENINGS
UPPER POOL ELEVATION 100.0

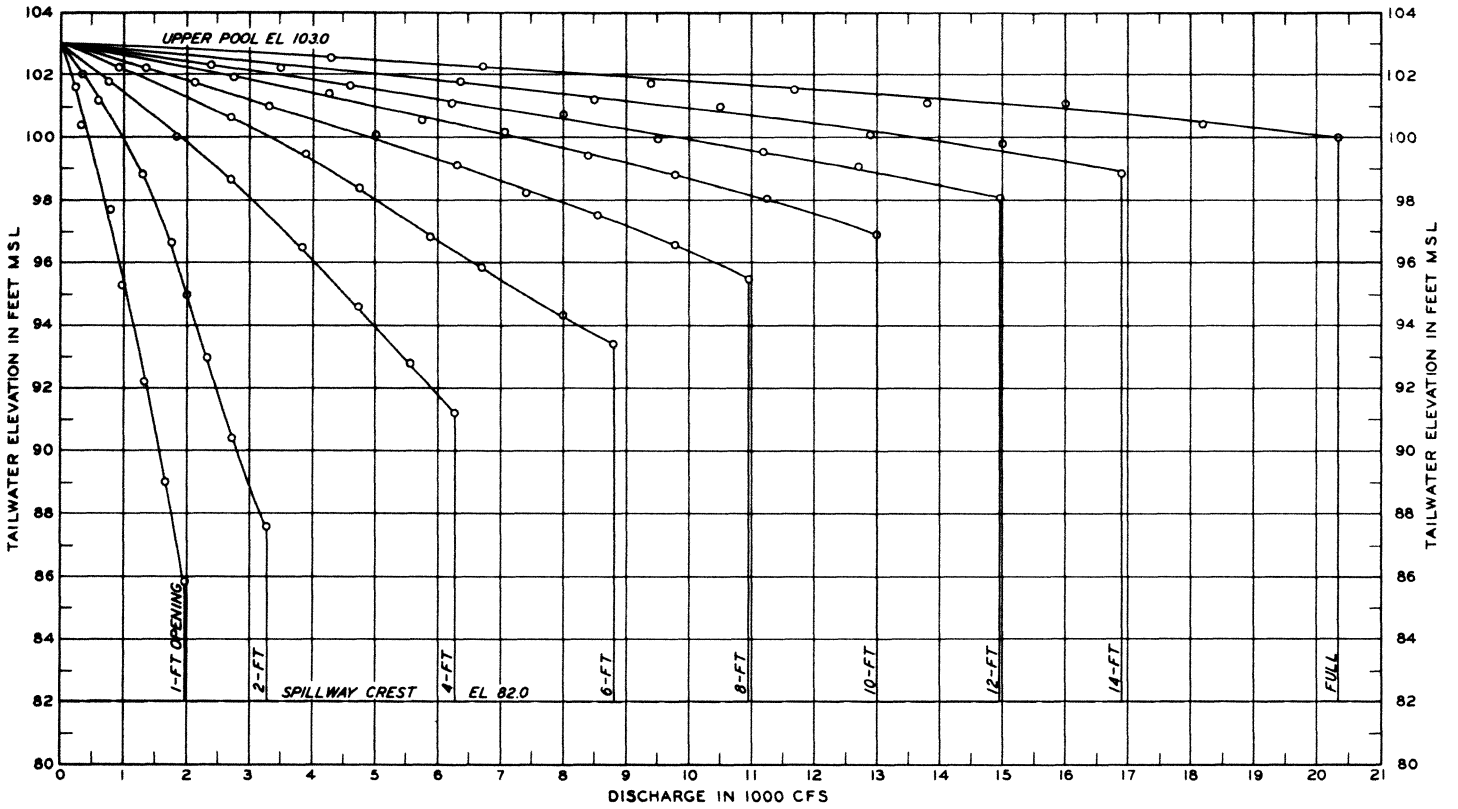


NOTE: DISCHARGE BASED ON FLOW THROUGH ONE GATE BAY.

EFFECT OF TAILWATER ELEVATION ON DISCHARGE

GATED SPILLWAY

ONE GATE AT FULL AND PARTIAL OPENINGS
UPPER POOL ELEVATION 102.0

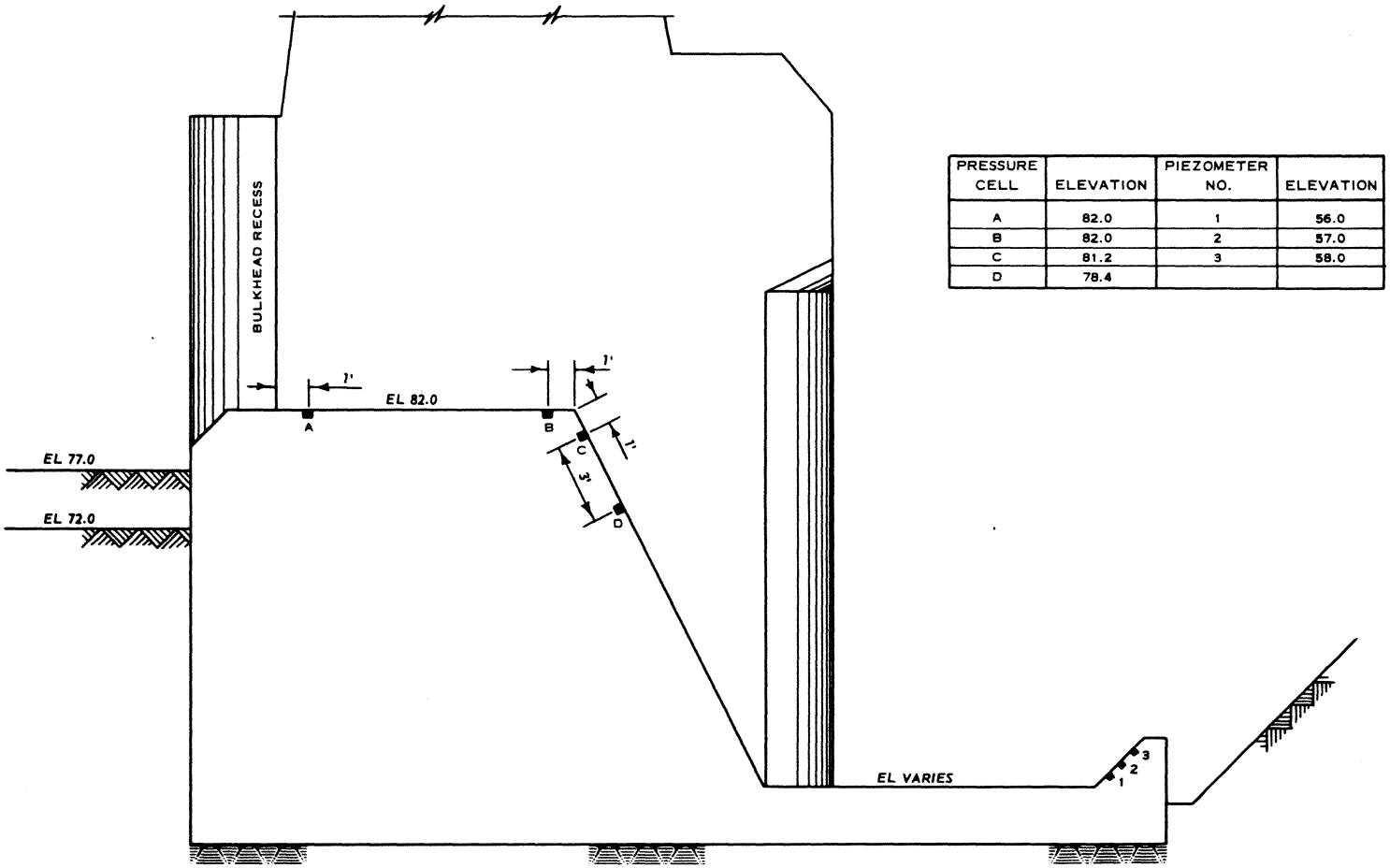


NOTE: DISCHARGE BASED ON FLOW THROUGH ONE GATE BAY.

EFFECT OF TAILWATER ELEVATION ON DISCHARGE

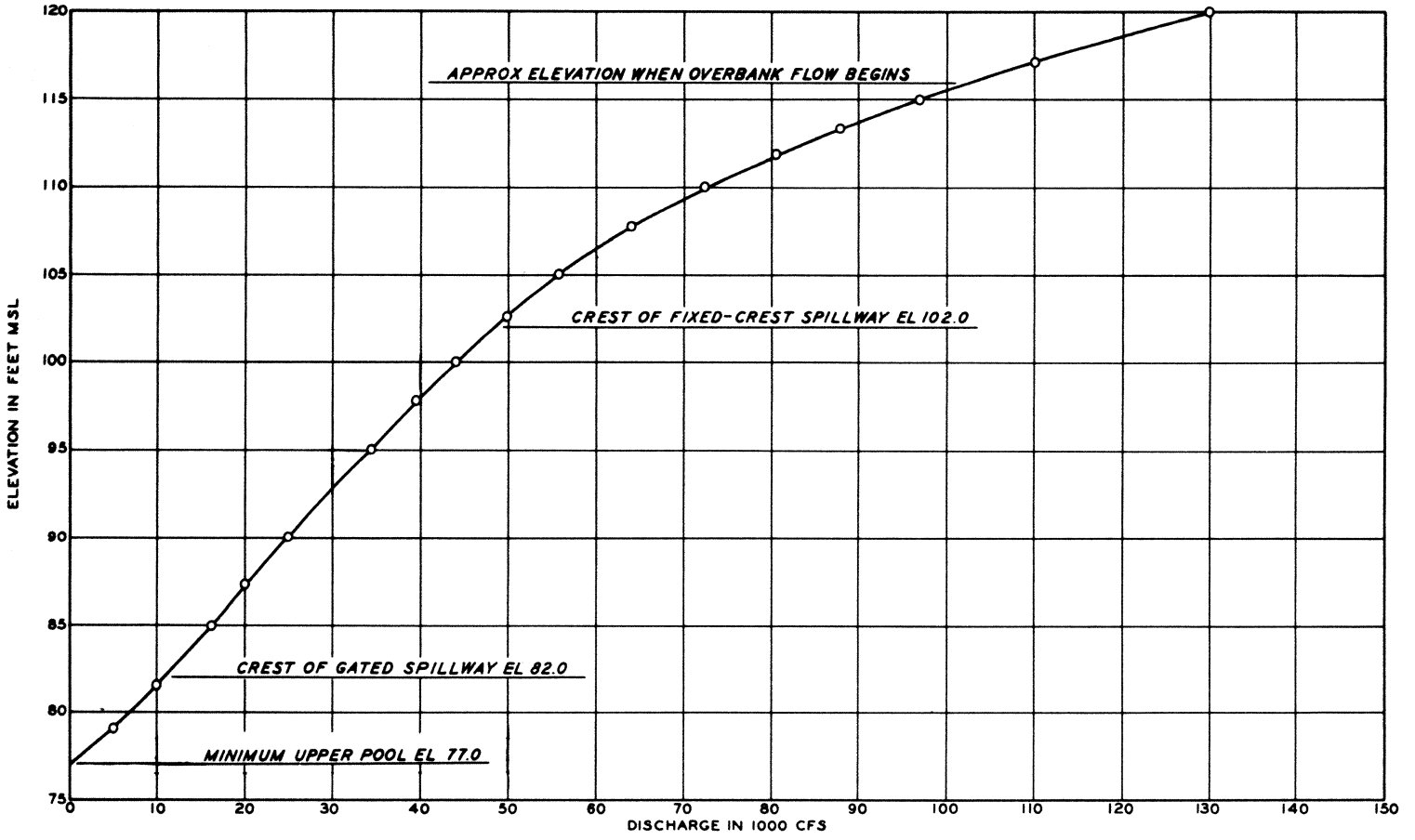
GATED SPILLWAY

ONE GATE AT FULL AND PARTIAL OPENINGS
UPPER POOL ELEVATION 103.0

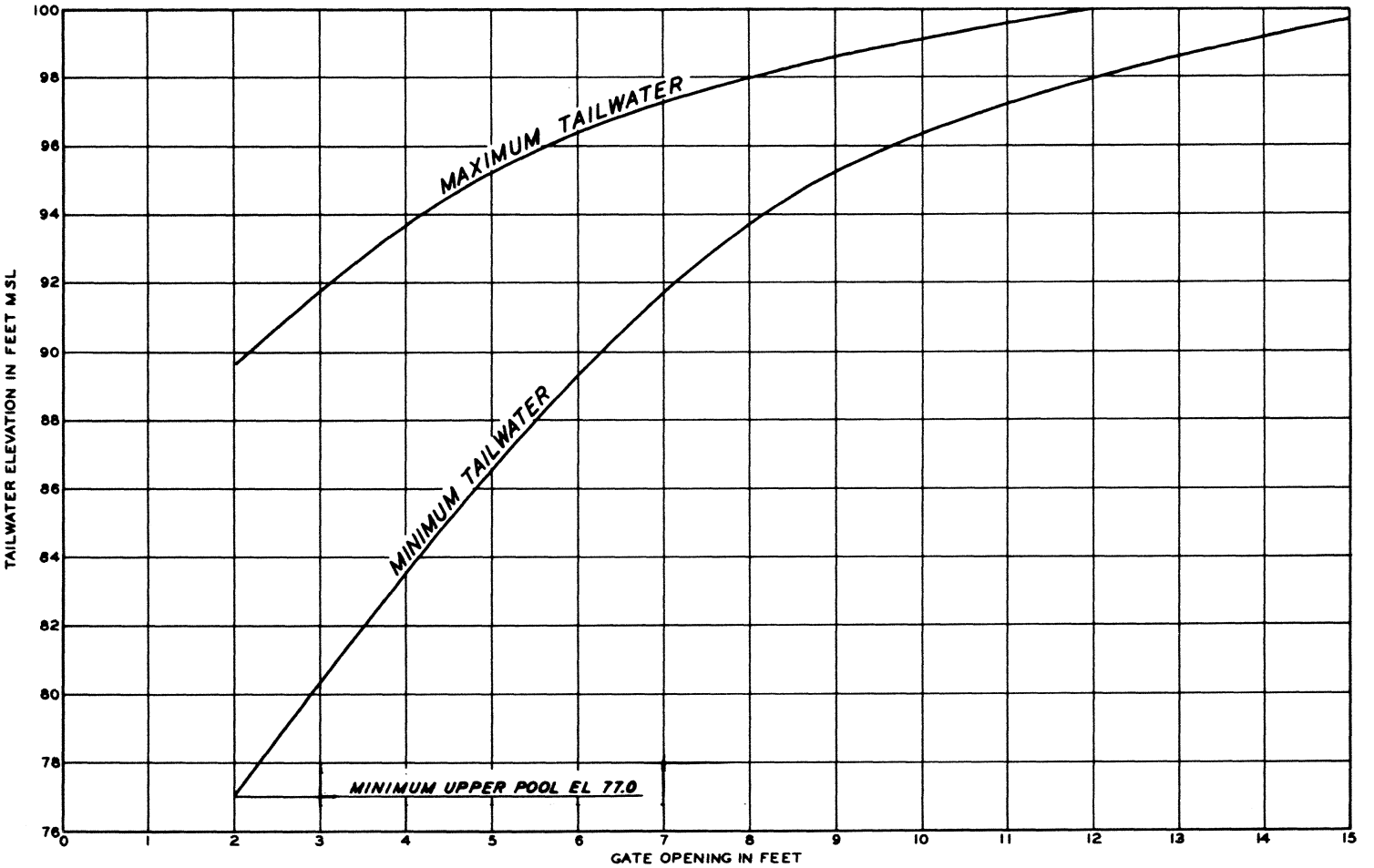


PRESSURE CELL	ELEVATION	PIEZOMETER NO.	ELEVATION
A	82.0	1	56.0
B	82.0	2	57.0
C	81.2	3	58.0
D	78.4		

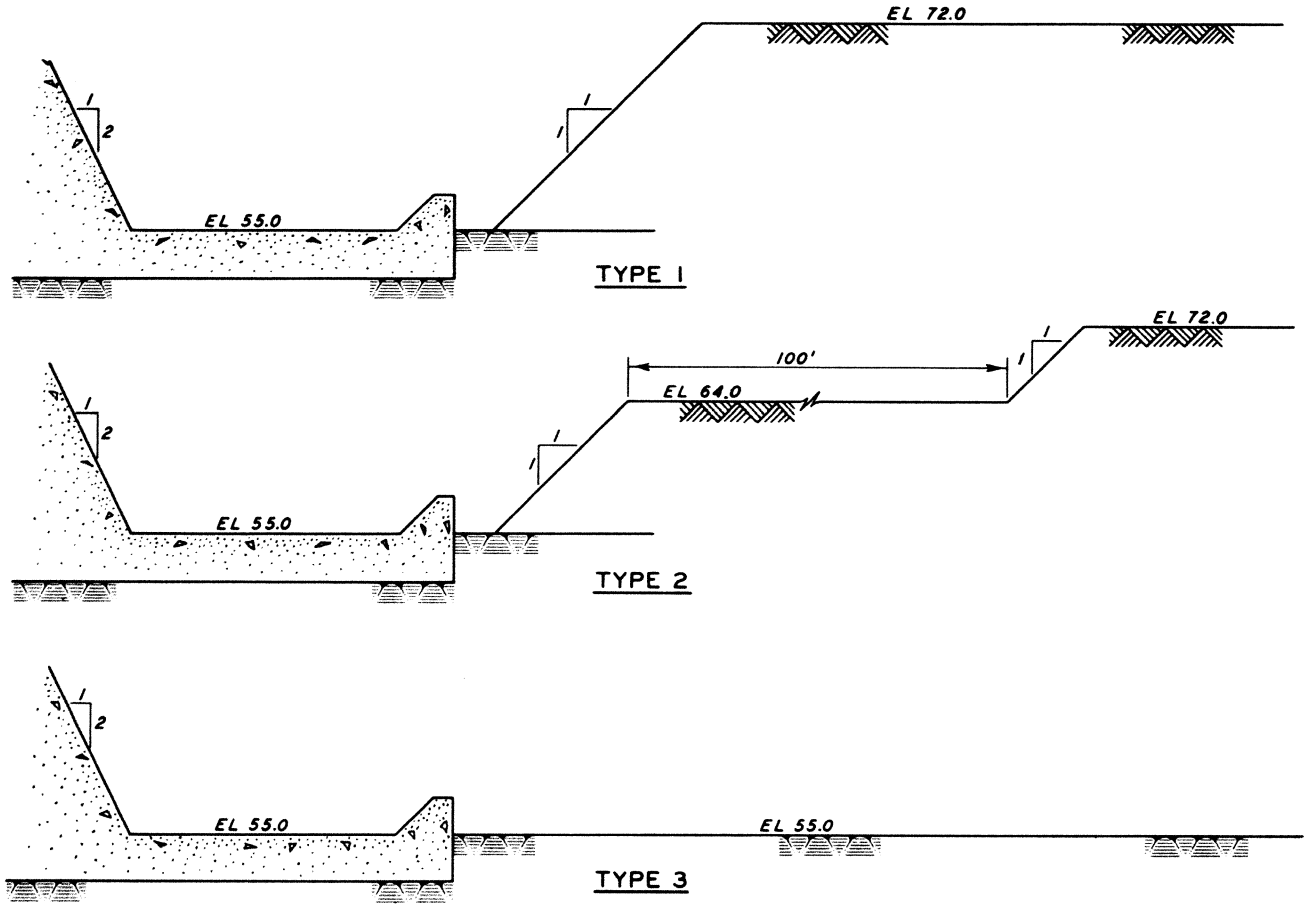
PIEZOMETER AND PRESSURE CELL LOCATION
GATED SPILLWAY



TAILWATER CURVE

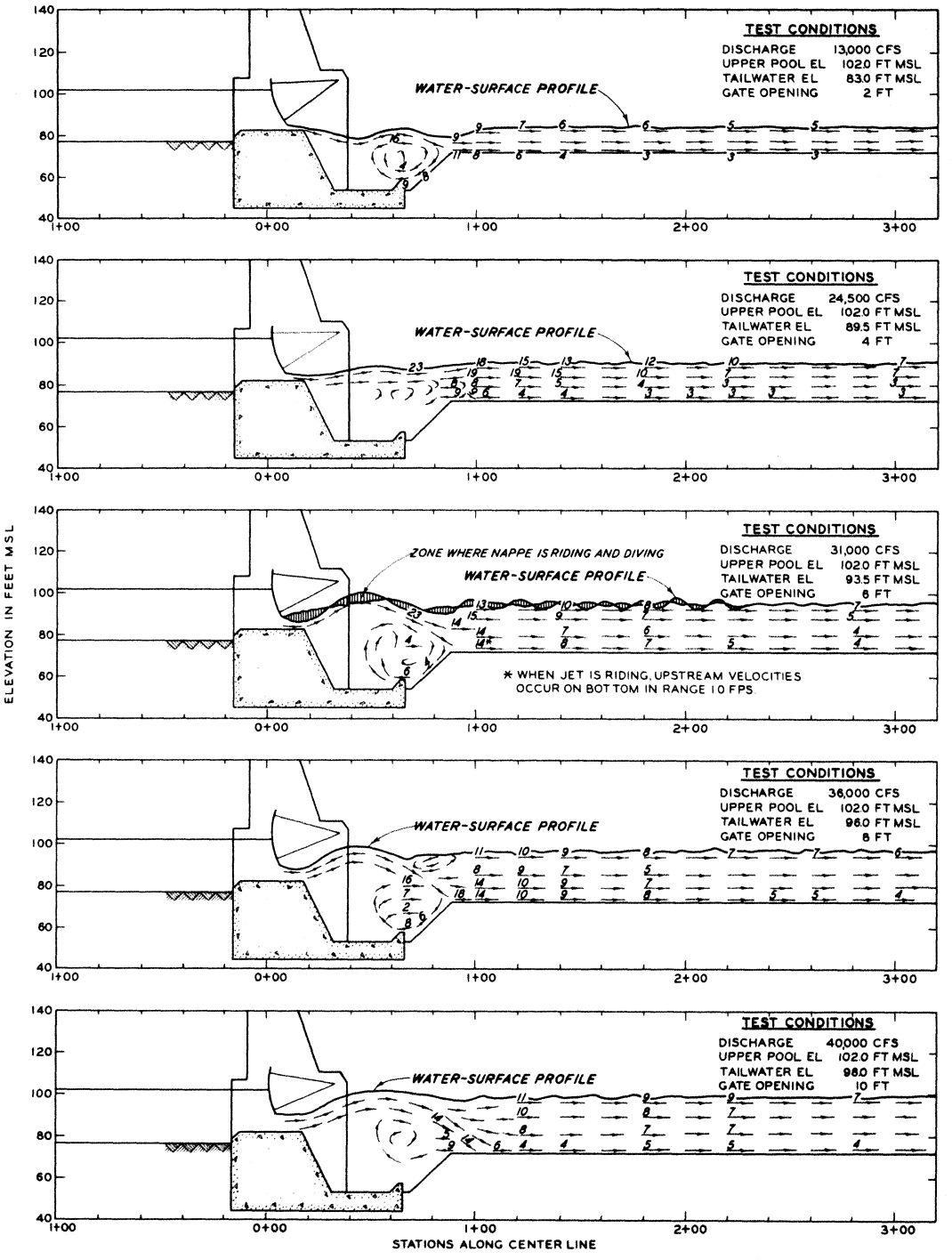


TAILWATER LIMITS



TYPES 1-3 EXIT CHANNELS

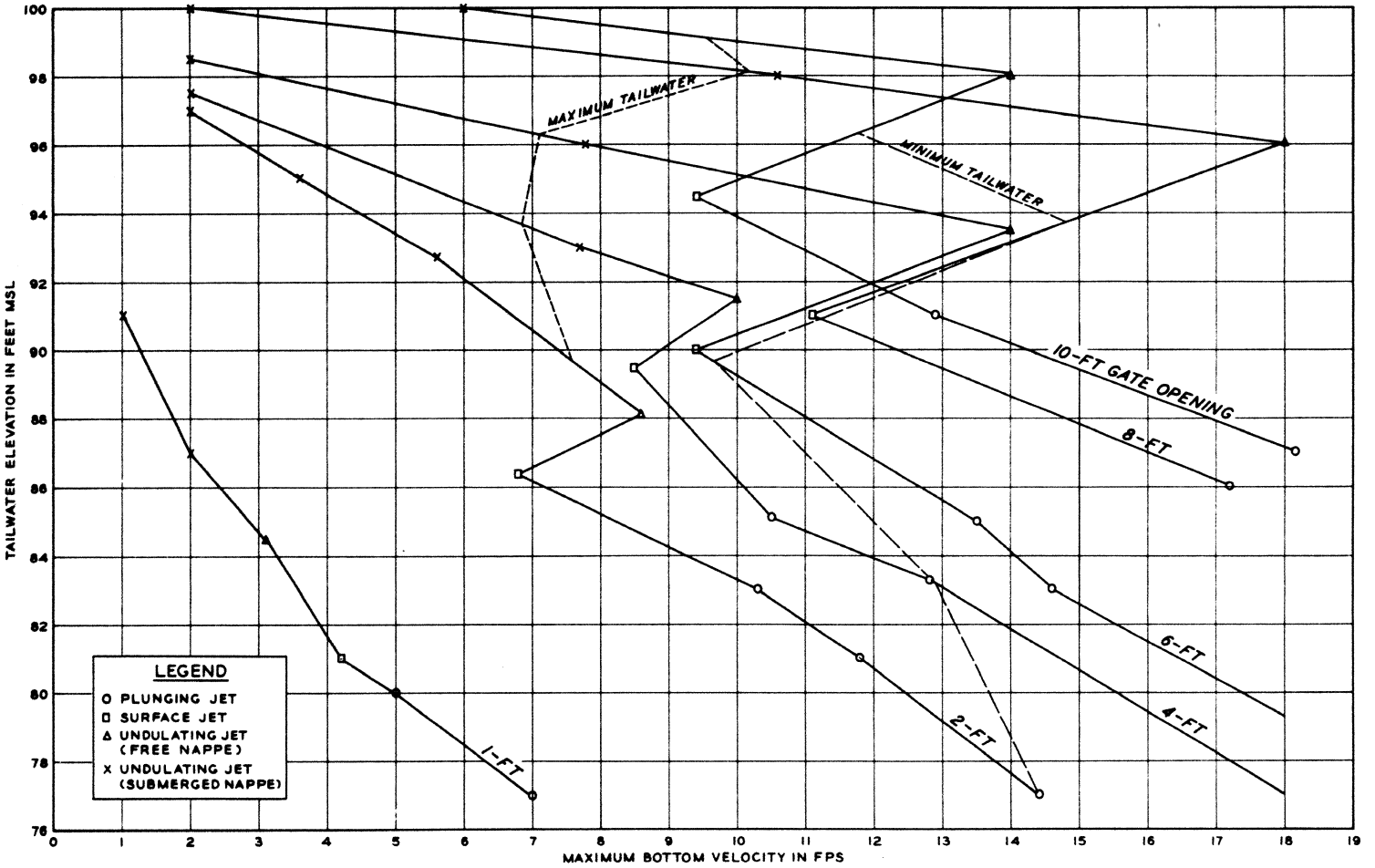
GATED SPILLWAY



NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL.
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

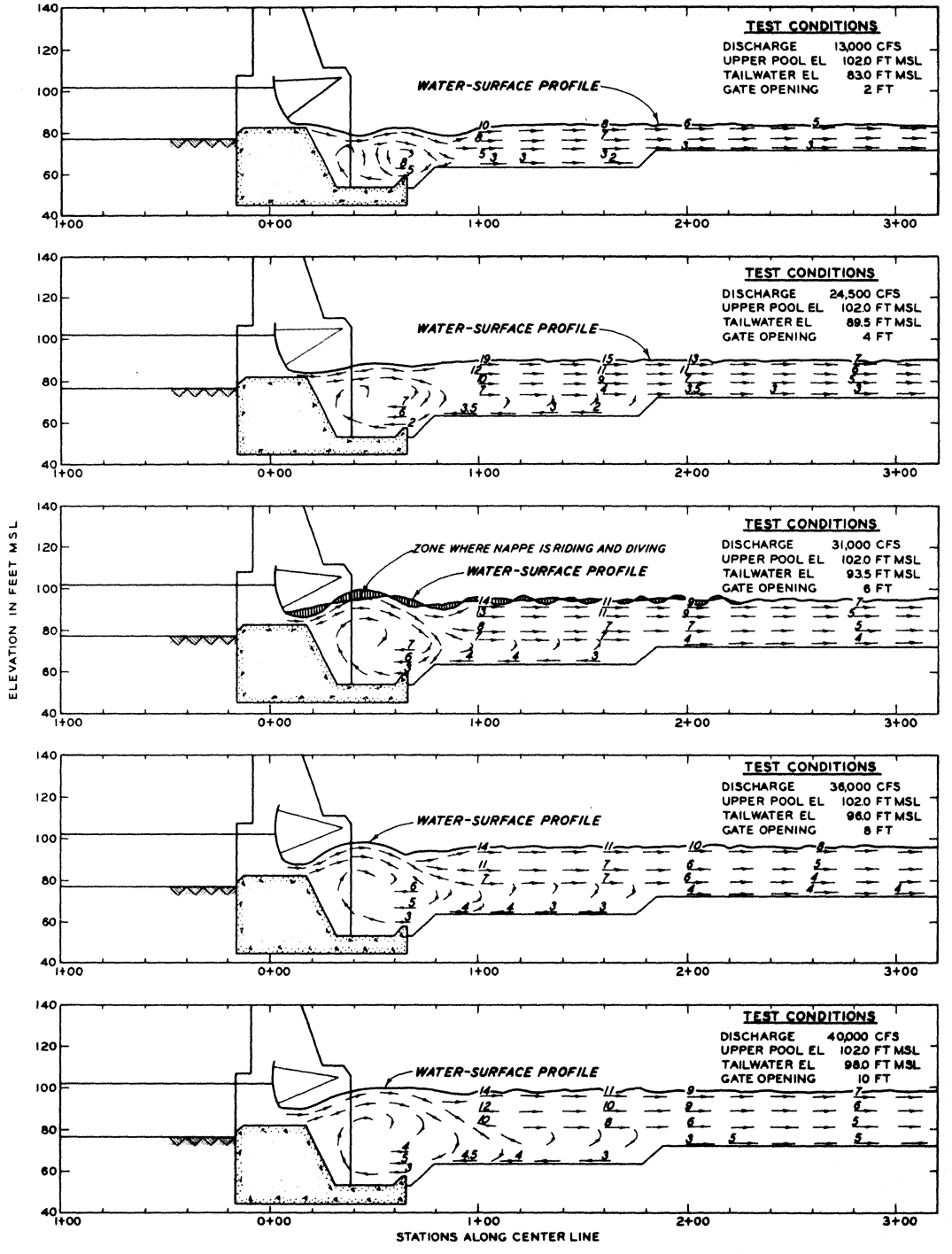
GATED SPILLWAY
TYPE I (ORIGINAL) BASIN
TYPE I EXIT



MAXIMUM BOTTOM VELOCITIES AND STILLING BASIN ACTIONS

GATED SPILLWAY

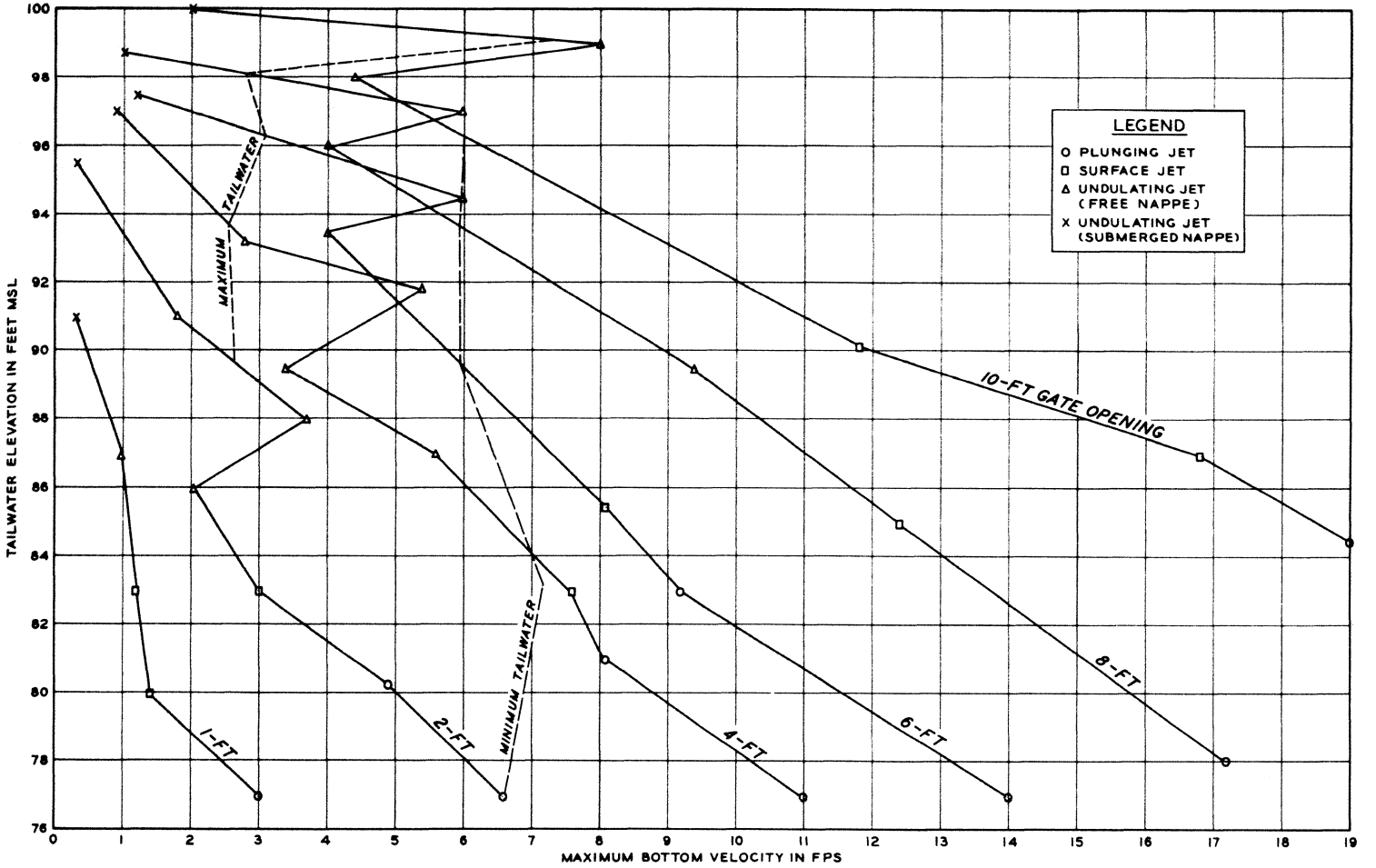
TYPE I BASIN - TYPE I EXIT



NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL.
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

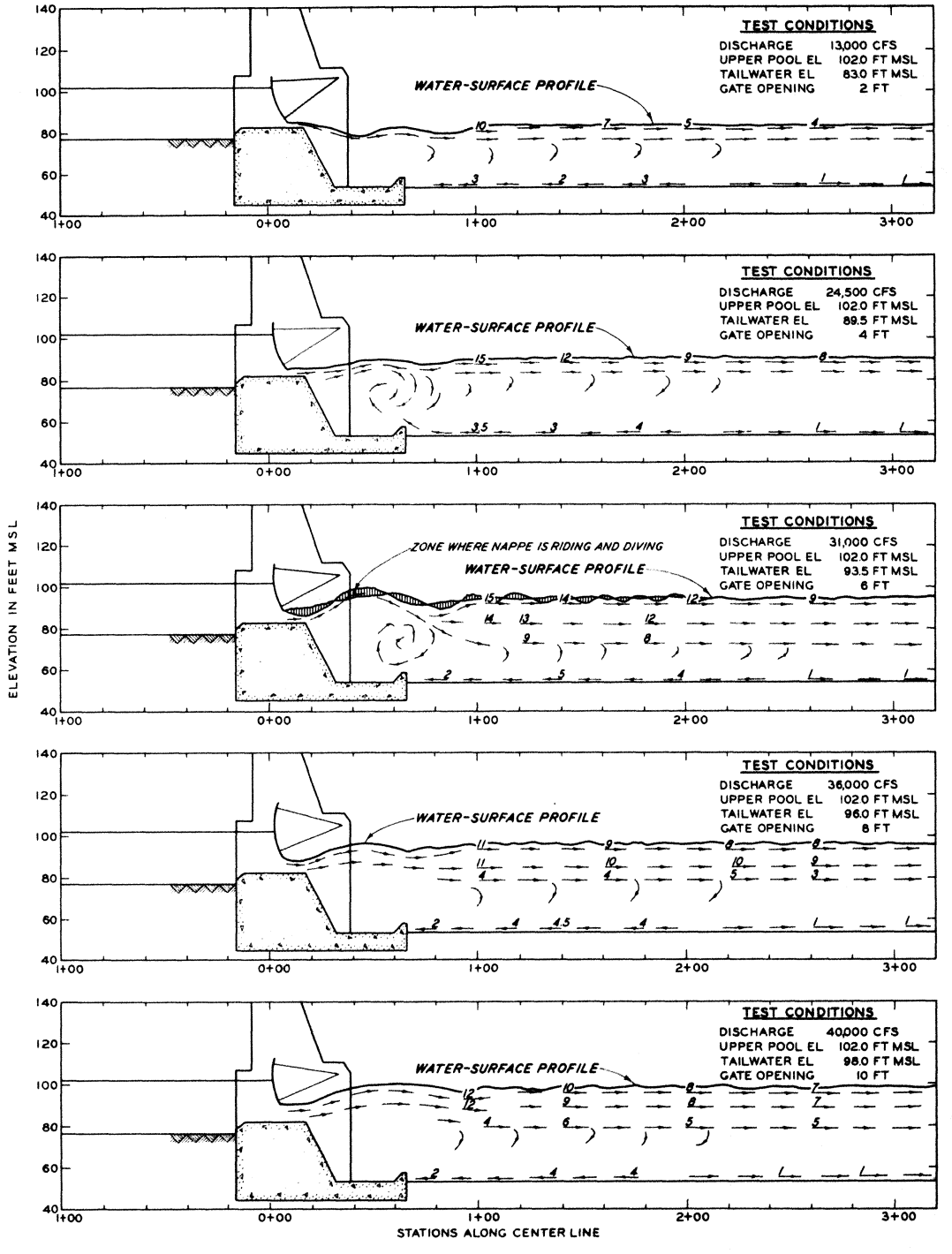
GATED SPILLWAY
TYPE 1 (ORIGINAL) BASIN
TYPE 2 EXIT



MAXIMUM BOTTOM VELOCITIES AND STILLING BASIN ACTIONS

GATED SPILLWAY

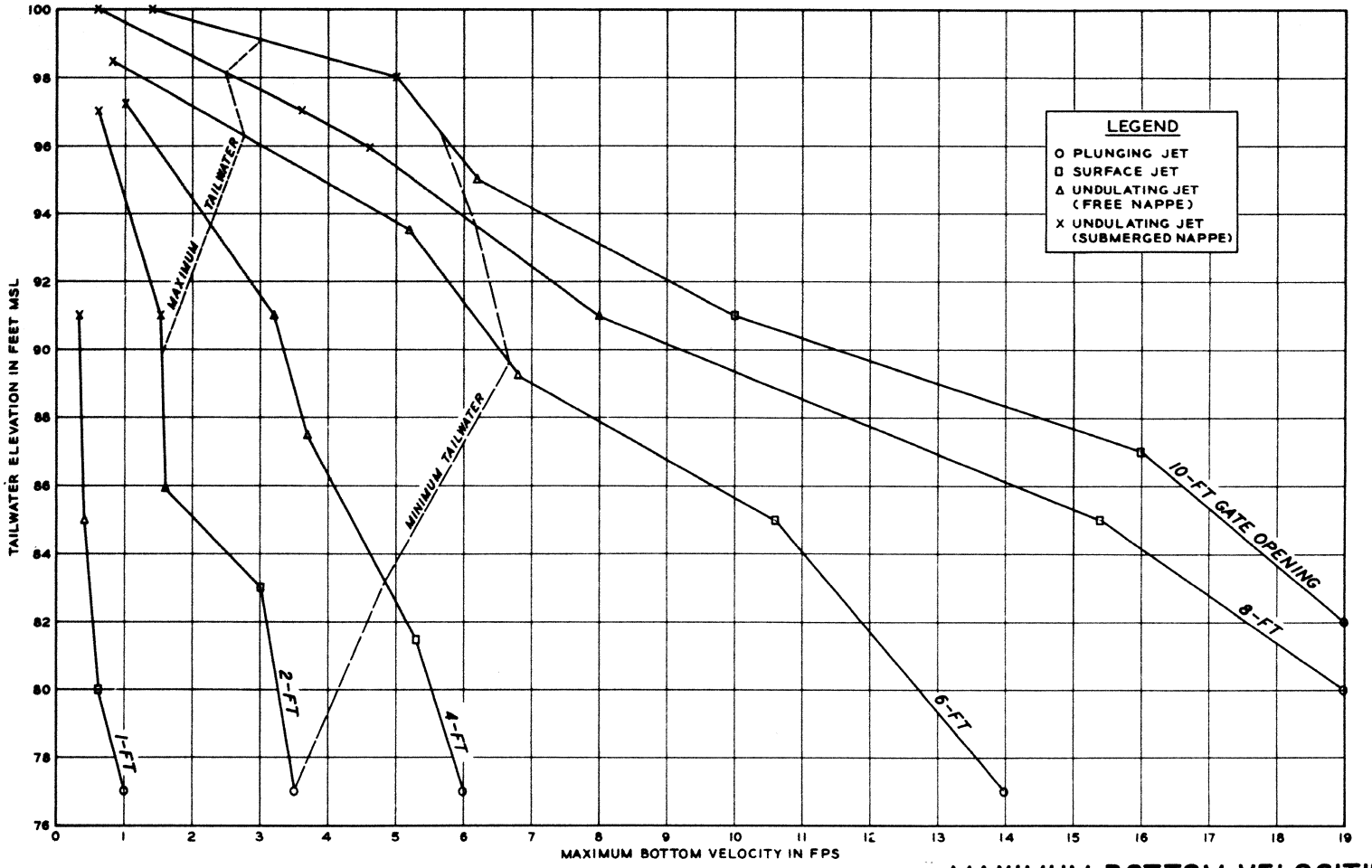
TYPE 1 BASIN - TYPE 2 EXIT



NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL.
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

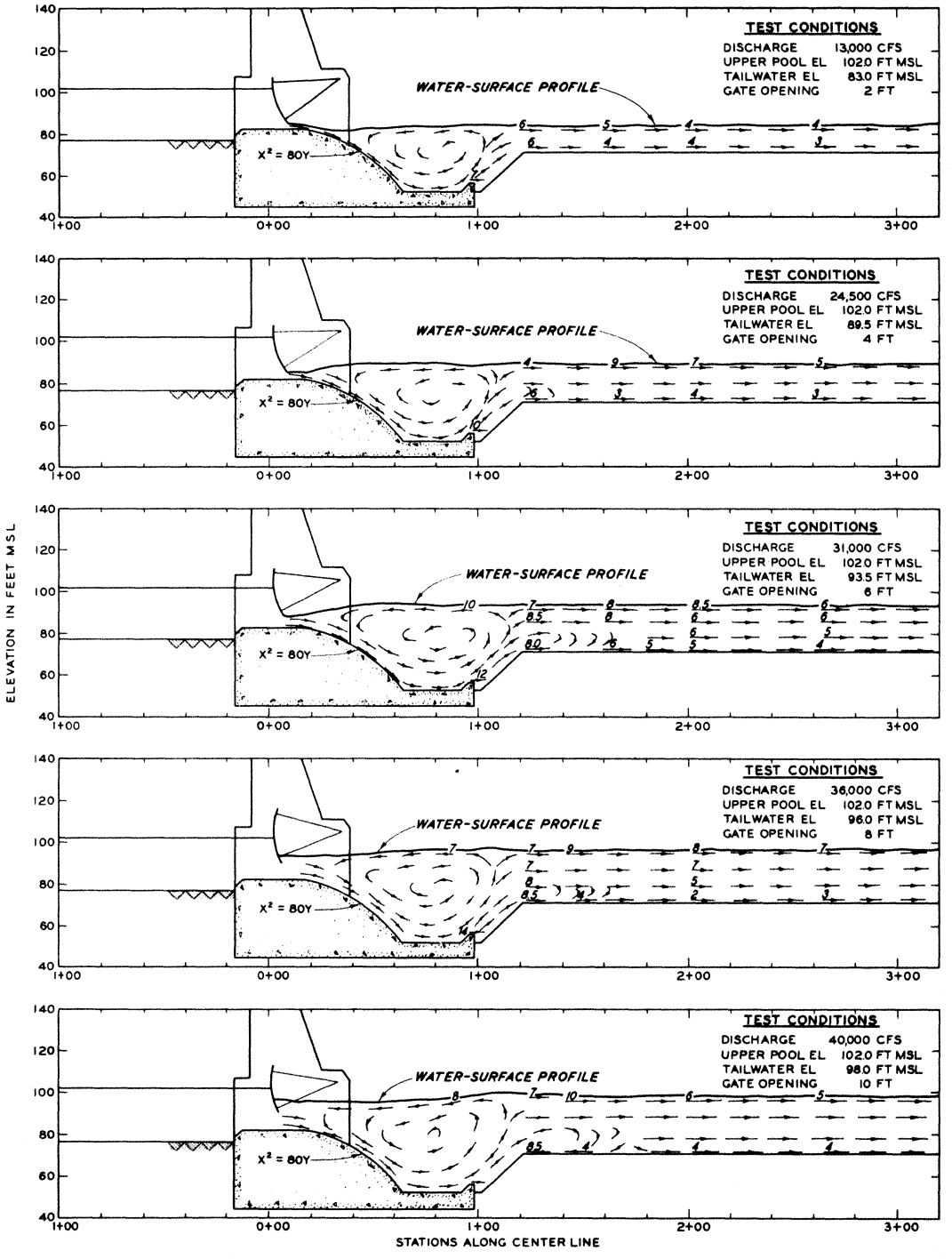
GATED SPILLWAY
TYPE I (ORIGINAL) BASIN
TYPE 3 EXIT



MAXIMUM BOTTOM VELOCITIES AND STILLING BASIN ACTIONS

GATED SPILLWAY

TYPE I BASIN – TYPE 3 EXIT

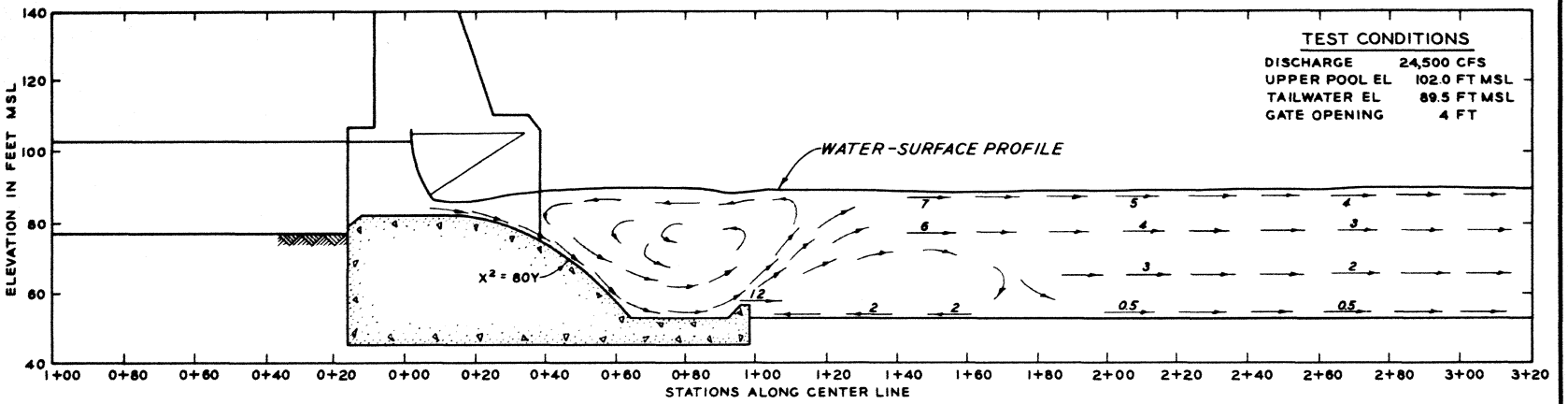


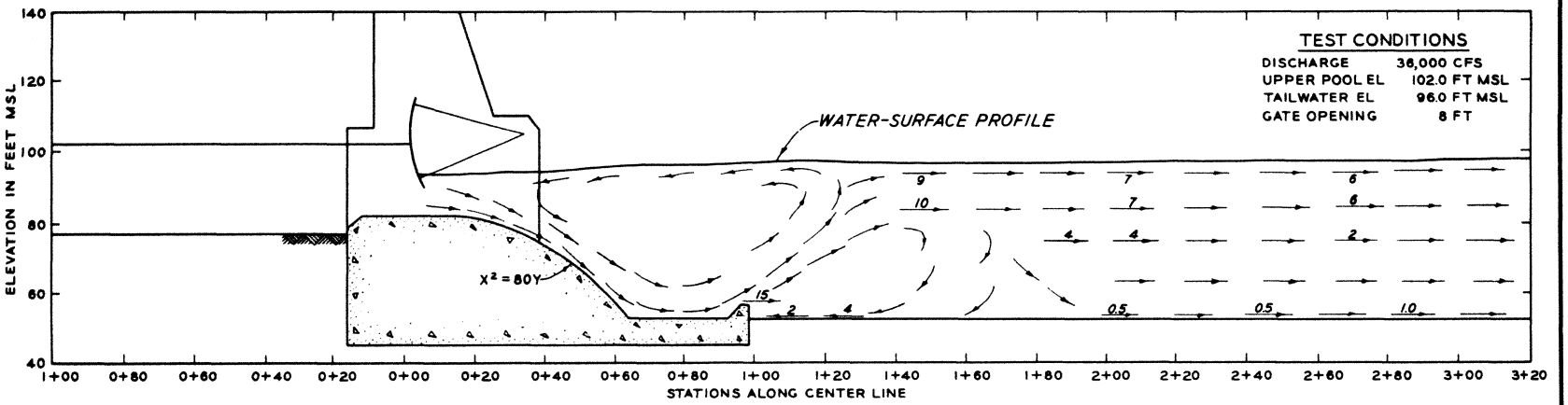
NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL.
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

GATED SPILLWAY

TYPE 2 BASIN - TYPE 1 EXIT

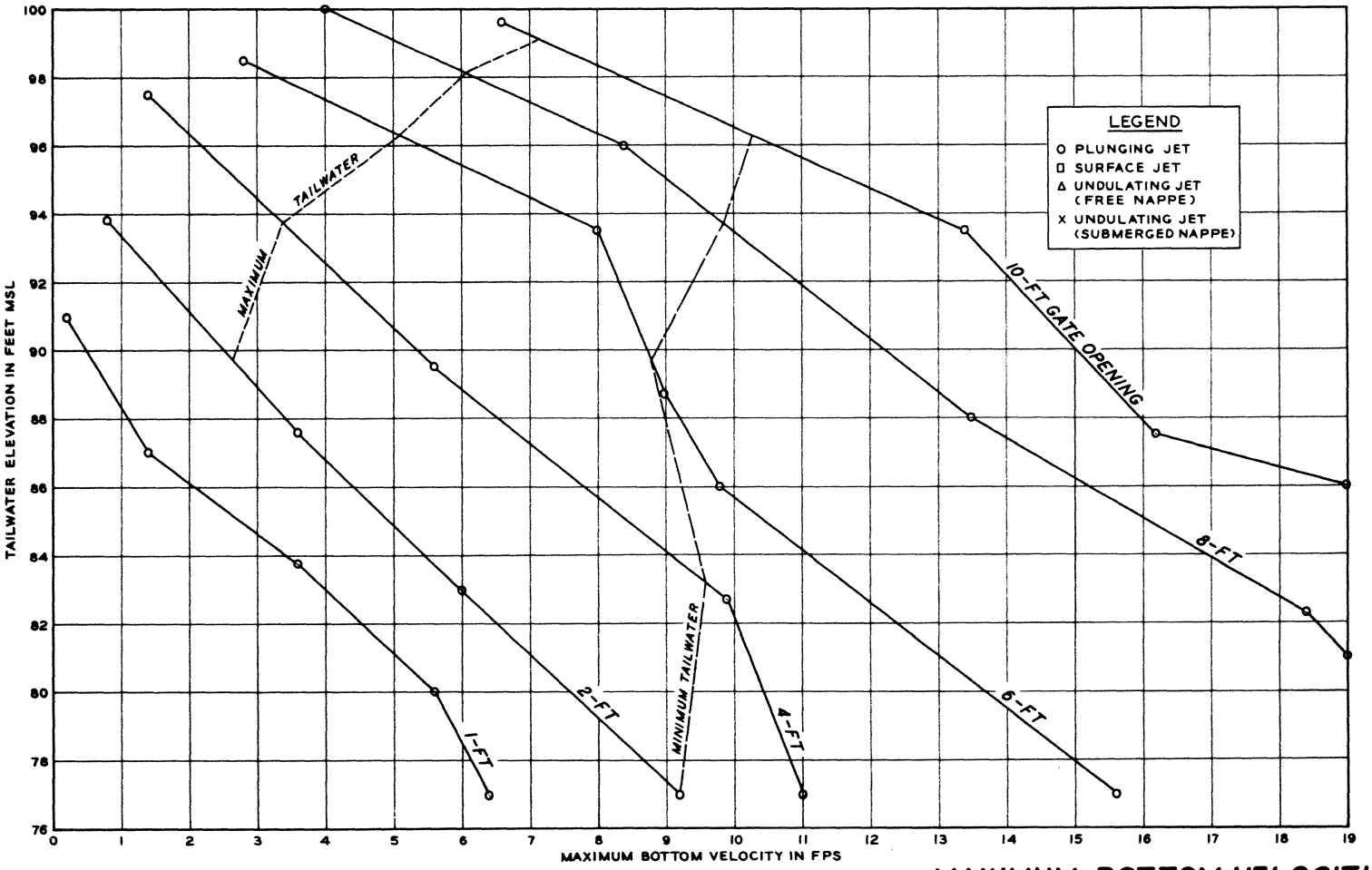




NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND

WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

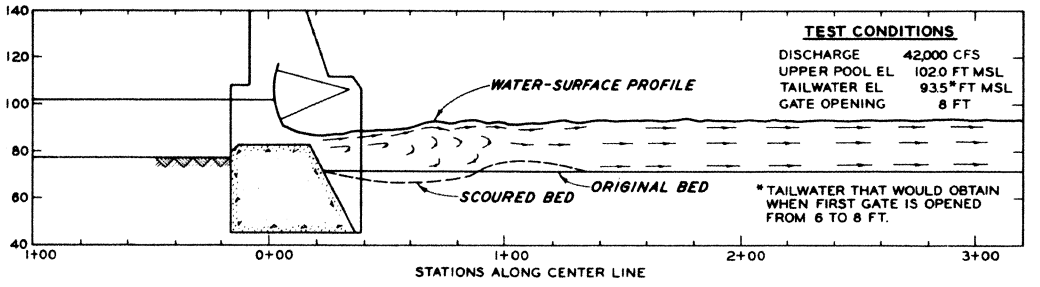
GATED SPILLWAY
TYPE 2 BASIN - TYPE 3 EXIT



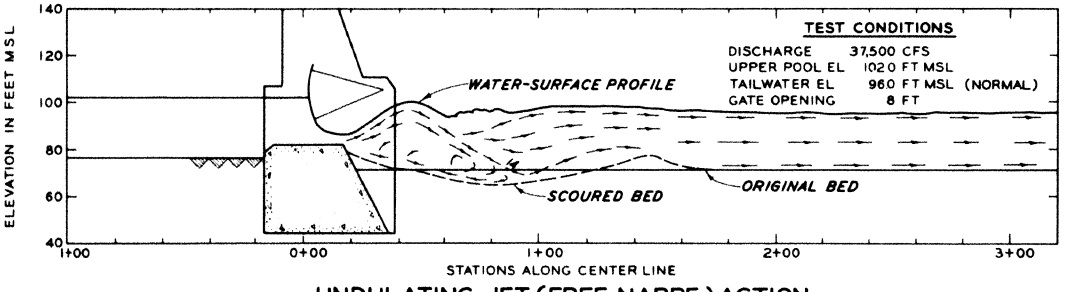
MAXIMUM BOTTOM VELOCITIES AND STILLING BASIN ACTIONS

GATED SPILLWAY

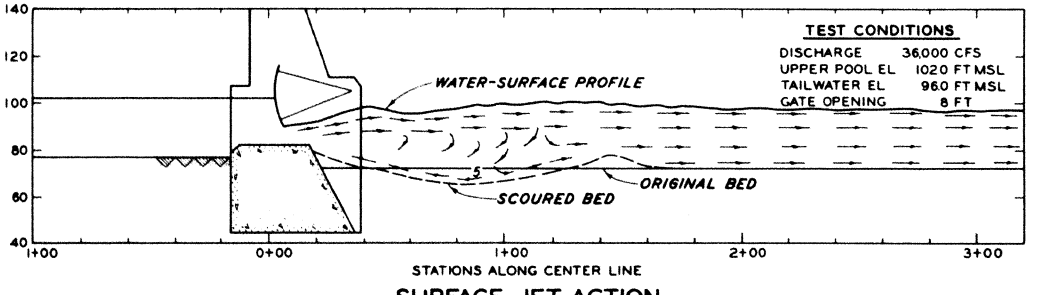
TYPE 2 BASIN - TYPE 1 EXIT



SURFACE JET ACTION



UNDULATING JET (FREE NAPPE) ACTION



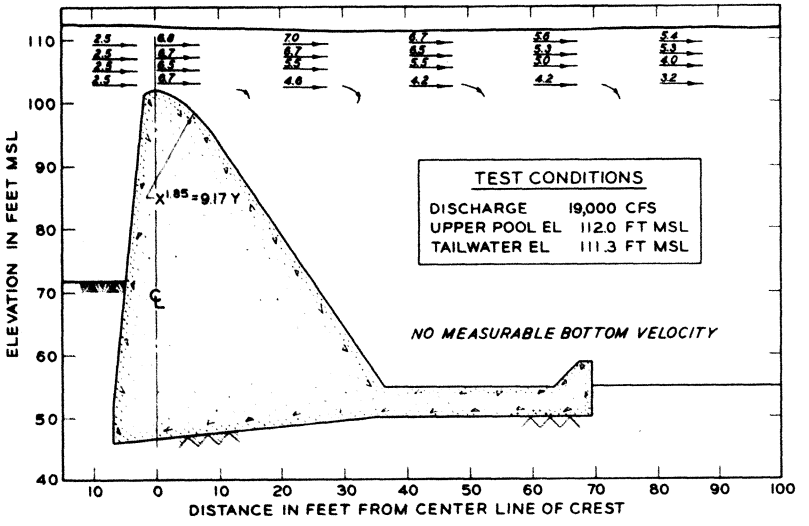
SURFACE JET ACTION

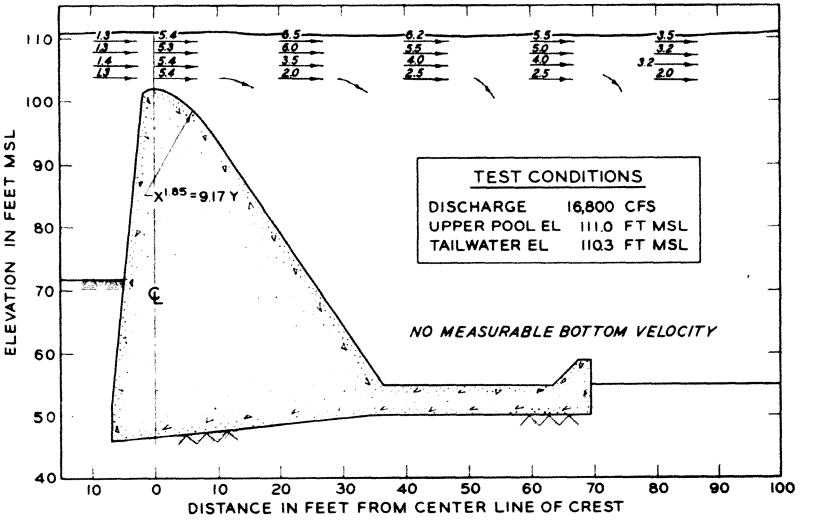
NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL.
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.
EXIT AREA MOLDED IN PEA GRAVEL FOR TESTS TO DETERMINE SCOUR PATTERN.
MODEL OPERATED TWO HOURS TO OBTAIN SCOUR PATTERN.

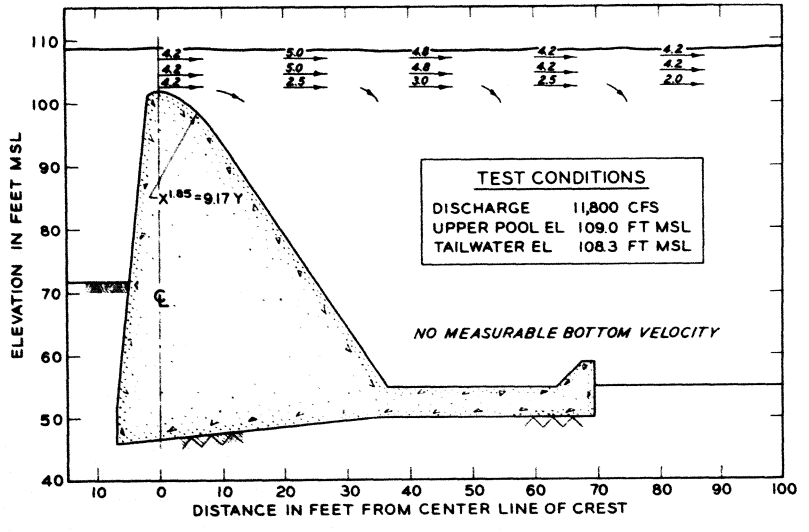
WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

GATED SPILLWAY

ADOPTED DESIGN (i.e., NO STILLING BASIN)







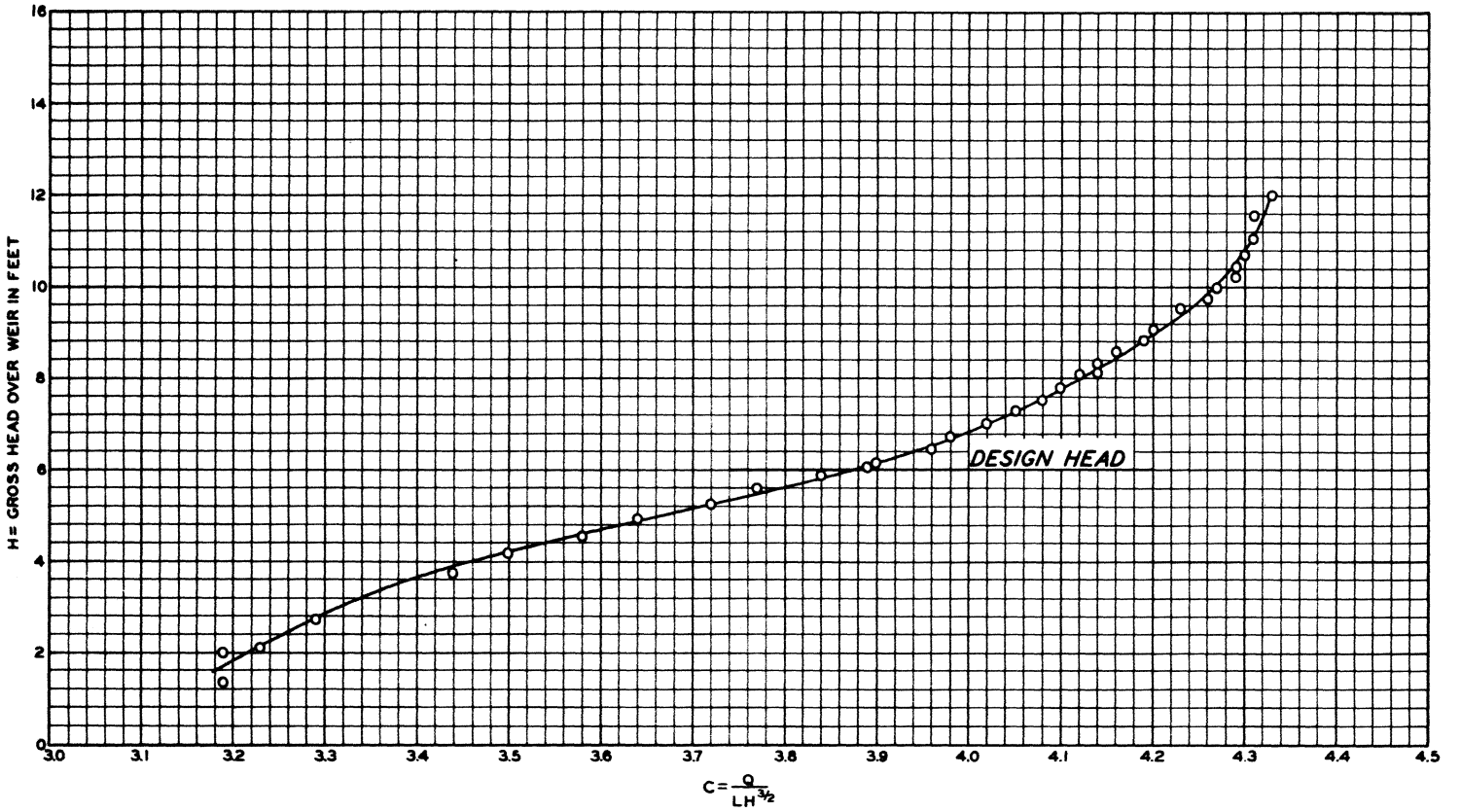
NOTE: WATER-SURFACE PROFILES MEASURED ALONG CENTER LINE OF MODEL.
VELOCITIES ARE IN PROTOTYPE FEET PER SECOND.

WATER-SURFACE PROFILES AND FLOW CHARACTERISTICS

FIXED-CREST SPILLWAY
TYPE I (ORIGINAL) DESIGN

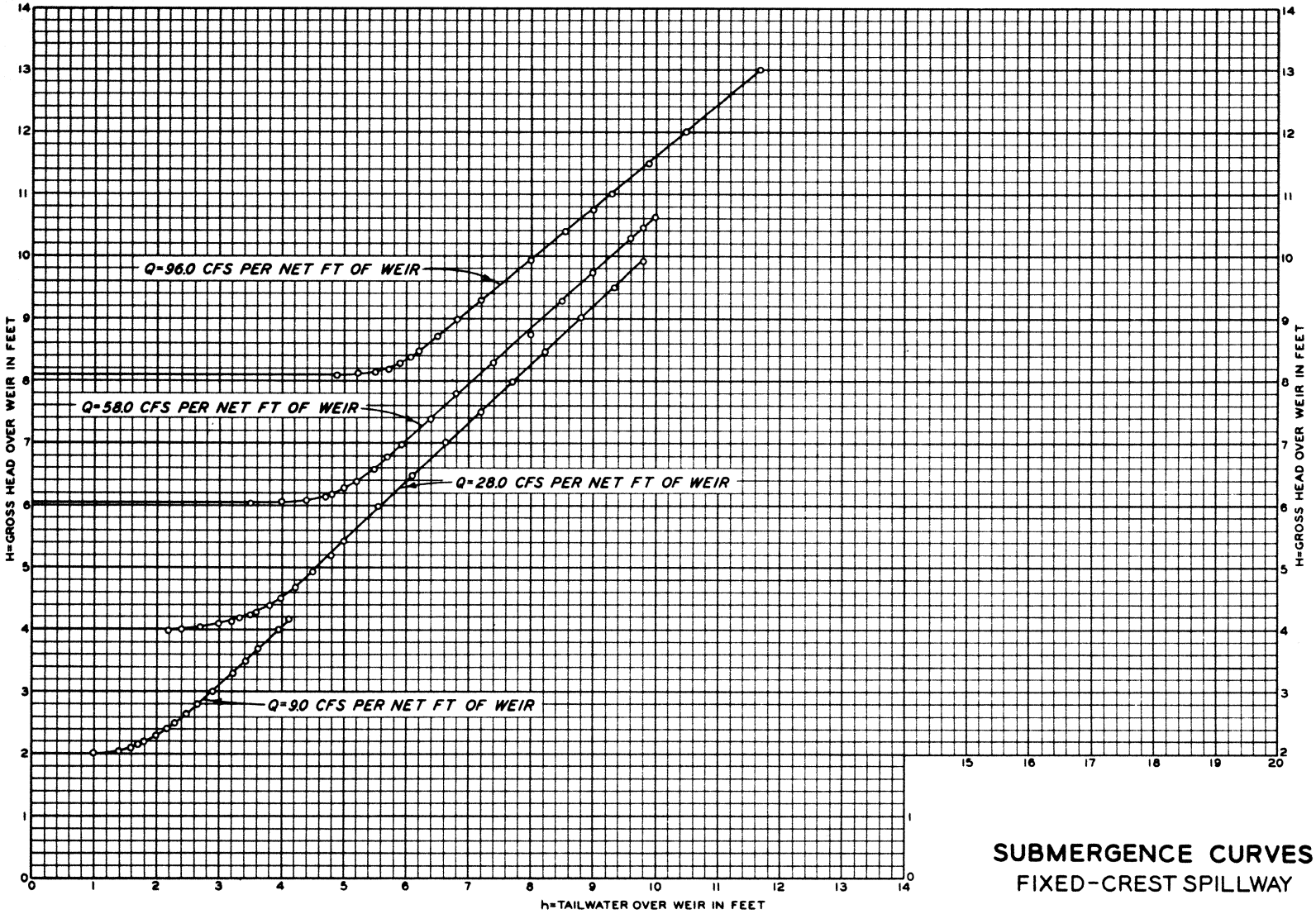
SPILLWAY RATING CURVE

FIXED-CREST SPILLWAY

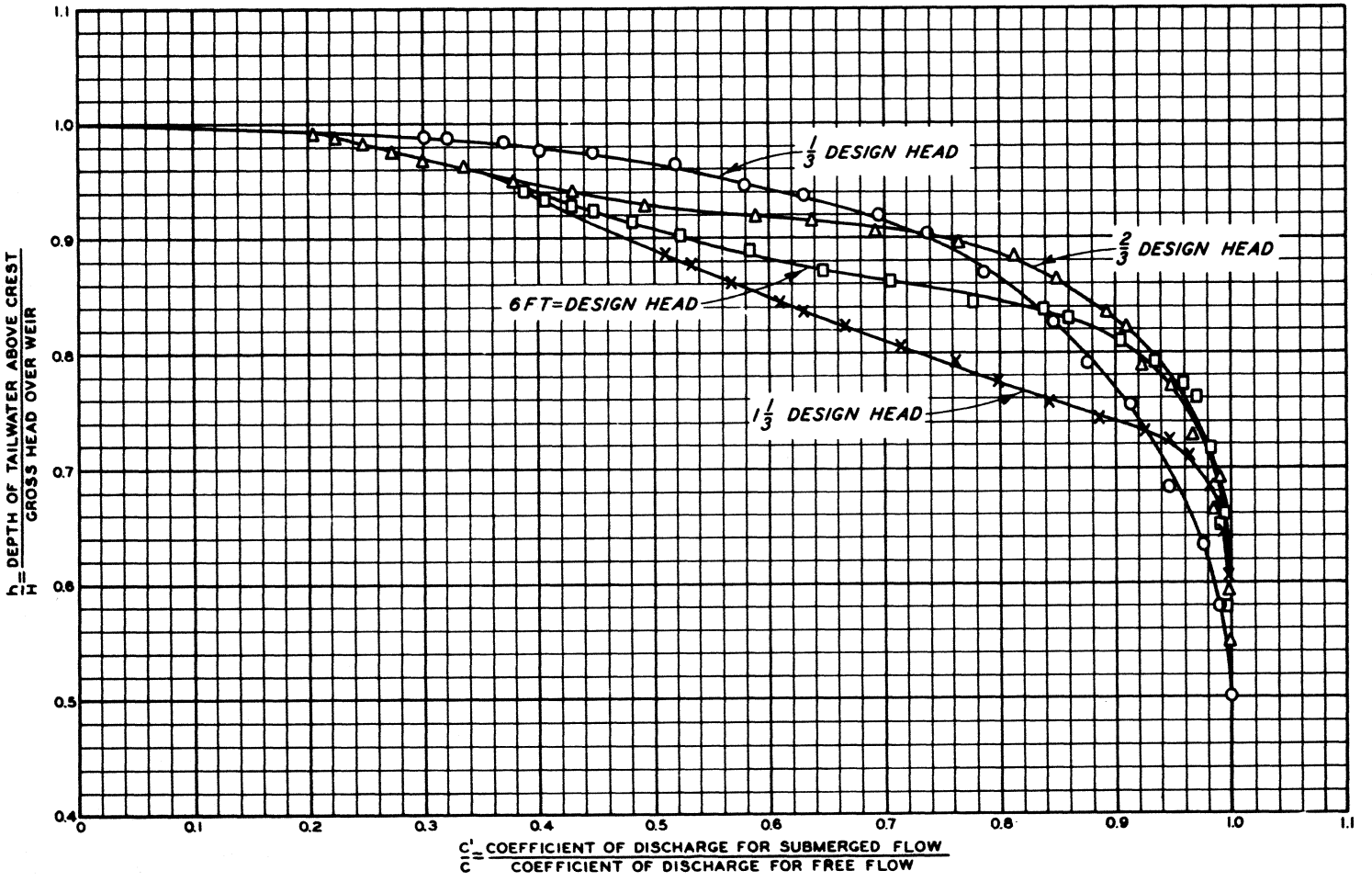


SPILLWAY DISCHARGE COEFFICIENT

FIXED-CREST SPILLWAY



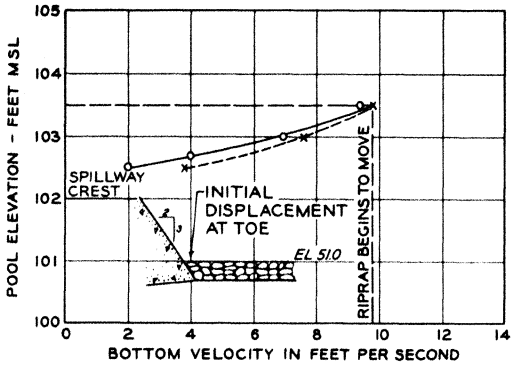
SUBMERGENCE CURVES
FIXED-CREST SPILLWAY



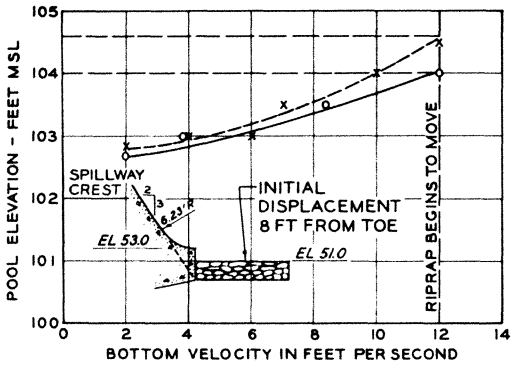
SUBMERGENCE COEFFICIENTS

FIXED-CREST SPILLWAY

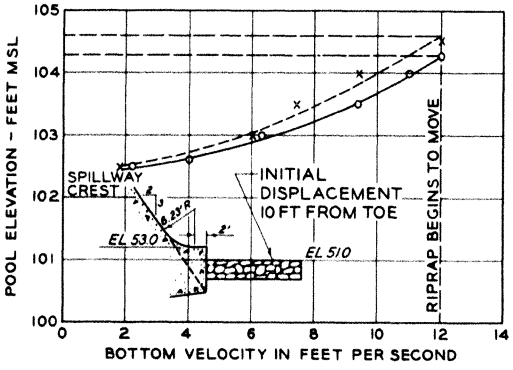
PLATE 25



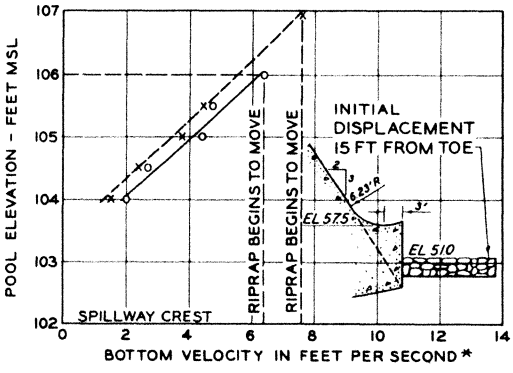
NO ENERGY DISSIPATOR



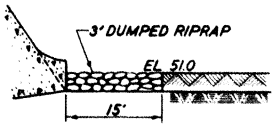
TYPE 1 BUCKET



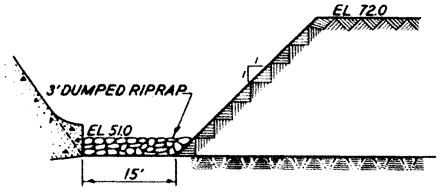
TYPE 2 BUCKET



TYPE 3 BUCKET



TYPE 1 EXIT



TYPE 2 EXIT

PROTOTYPE RIPRAP GRADATION

APPROXIMATE PER CENT TOTAL WEIGHT	WEIGHT OF PIECES, LB
NOT MORE THAN 10	75 - 200
NOT MORE THAN 50	30 - 75
NOT MORE THAN 30	10 - 30
NOT MORE THAN 10	LESS THAN 10

LEGEND

o———o TYPE 1 EXIT

x- - - - -x TYPE 2 EXIT

NOTE: BOTTOM VELOCITIES OBTAINED 0.25 FT OFF BOTTOM AT POINTS OF INITIAL DISPLACEMENT.

* BOTTOM VELOCITIES IN AN UPSTREAM DIRECTION.

TAILWATER ELEVATION 770.

CRITICAL VELOCITIES FOR DISPLACEMENT OF GRADED DUMPED RIPRAP BELOW FIXED-CREST SPILLWAY