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CORPS OF ENGINEERS, U. S. ARMY

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SPILLWAY FOR FOLSOM DAM  
AMERICAN RIVER, CALIFORNIA

HYDRAULIC MODEL INVESTIGATION



TECHNICAL MEMORANDUM NO. 2-369

CONDUCTED FOR

SACRAMENTO DISTRICT, CORPS OF ENGINEERS

BY

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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## PREFACE

Model investigations of the spillway for Folsom Dam were authorized by teletype, dated 21 September 1950, from the Division Engineer, South Pacific Division, to the Director, Waterways Experiment Station. The studies were conducted in the Hydraulics Division of the Waterways Experiment Station during the period December 1950-September 1951, by Messrs. J. W. Bolin, Jr., J. N. Strange, W. H. Sadler, and J. N. Palermo, under the general supervision of Messrs. F. R. Brown and T. J. Buntin.

Messrs. J. H. Douma, Office, Chief of Engineers; W. C. Cassidy and B. F. Jakobsen of the South Pacific Division; and H. A. Johnson, A. Hoggard, and J. M. Groves, of the Sacramento District, visited the Waterways Experiment Station at frequent intervals during the course of the studies to discuss test results and correlate these results with design work concurrently being accomplished in the District Office. Messrs. O. L. Rice, L. G. Puls, and J. N. Bradley, of the Bureau of Reclamation, also visited the Experiment Station for conferences with Corps of Engineers personnel on the work in progress. Many of the revisions investigated represent the ideas and suggestions of the Bureau of Reclamation personnel.

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## SUMMARY

The spillway for Folsom Dam, flow over which will be controlled by eight gates, was studied concurrently on two almost identical 1:80-scale models. Two models were necessary because of the urgent need for a decision as to the type energy dissipator to use at the toe of the spillway. A flip-bucket type energy dissipator was investigated on one model while a conventional type stilling basin was tested on the other.

Although tests revealed that the flip-bucket type energy dissipator was adequate as far as the safety of the dam was concerned, the stilling basin type was adopted for construction downstream from the five gate bays adjacent to the right abutment because it will afford greater safety to the powerhouse and reduce possible maintenance costs after completion of the dam. The extra cost of the stilling basin was considered warranted in view of the increased energy dissipation secured. The stilling basin selected for construction has been designated type 22 in this report. The flip-bucket type energy dissipator also will be constructed downstream from the three gates adjacent to the left abutment. However, flow will be confined to the five spillway bays discharging into the stilling basin except for extreme emergencies.

# SPILLWAY FOR FOLSOM DAM, AMERICAN RIVER, CALIFORNIA

## Hydraulic Model Investigation

### PART I: INTRODUCTION

#### History of Authorization and Design of the Dam

1. Folsom Dam, a multiple-purpose structure being constructed on the American River below the confluence of the North and South Forks about 2-1/2 miles northeast of Folsom, California (fig. 1), was authorized

initially for construction by the Corps of Engineers. However, a subsequent act of Congress reauthorized the project making construction of the dam and reservoir the responsibility of the Corps of Engineers, and construction of a 120,000-kw power plant as well as maintenance and operation of all project facilities, including the dam and reservoir after completion,

the responsibility of the Bureau of Reclamation. This reauthorization resulted in the need for close and careful coordination of the Corps of Engineers' and Bureau of Reclamation's technical designs and construction programs. The Bureau of Reclamation advocated a considerable number of changes in the design of the structures as prepared by the Sacramento District. One of the major changes was a request for a

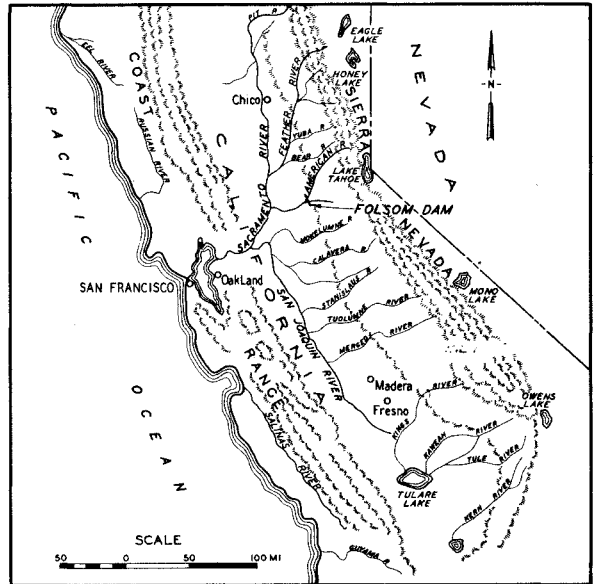


Fig. 1. Vicinity map

conventional apron-type stilling basin at the toe of the spillway for energy dissipation instead of the flip-bucket type energy dissipator proposed by the Sacramento District. This change was advocated by the Bureau of Reclamation from the standpoint of its responsibility for the maintenance and safety of the structure after completion and because of possible detrimental effects of the flip-bucket in the vicinity of the powerhouse.

### Pertinent Design Features

2. The adopted plan for the main dam provides for a straight concrete-gravity type main river section with earthen wing dams at both abutments. The maximum height of the concrete section will be about 340 ft and the over-all length of the dam will be about 1400 ft. The reservoir created by the dam will have a storage capacity of 1,120,000 acre-ft at maximum pool elevation of 475.4\*.

3. The spillway will be of the ogee type with a maximum drop of 303 ft from crest (elevation 418) to stilling basin (elevation 115) and will be located in the central portion of the concrete river section (plates 1 and 2). The spillway is designed to pass an outflow of 567,000 cfs under a head of 57.4 ft; the shape of the spillway crest is in accordance with a design head of 50 ft, which is about 87 per cent of the maximum flood-control head. Flow over the spillway will be controlled by eight 42-ft-wide by 50-ft-high radial gates, supported by crest piers 8 ft in thickness. Thus, the gross width of the spillway will be 392 ft and the net width will be 336 ft. Two types of energy

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\* All elevations are referred to feet above mean sea level.

dissipators at the toe of the spillway were proposed for model investigation. As a result of the model study, a conventional apron-type stilling basin was selected for construction in the prototype downstream from the five spillway crest gates located adjacent to the right spillway abutment, and a 50-ft-radius flip bucket with invert at elevation 276.98 was selected for construction downstream from the three spillway gates adjacent to the left spillway abutment. Discharges as large as 300,000 cfs (pool elev 466) will be passed through the five spillway crest bays upstream from the hydraulic-jump type dissipator; the spillway design outflow of 567,000 cfs (pool elev 475.4) will be passed through all eight spillway bays. The three bays upstream from the flip-bucket type energy dissipator will be operated only in case of necessity. The stilling basin when completed will consist of a horizontal apron 146.8 ft in length at elevation 115, which will be joined to the crest section at elevation 140 by a 1-on-8 sloping ramp. Over-all length of ramp and basin will be 346.8 ft. A 15-ft-high end sill will be located on the end of the basin. The flip-bucket type energy dissipator downstream from the left three spillway bays will have a lip height and angle of 3.02 ft and 20 degrees, respectively.

4. Two sets of training walls are necessary to confine flow in the flip bucket and horizontal apron-type energy dissipators: The walls (type A) adjacent to the flip bucket will be 10 ft in height and will terminate at the end of the bucket lip. The walls of the stilling-basin type energy dissipator will be of different heights; the right training wall having a top elevation of 210 and the left wall a top elevation of 183.

5. Normal flow regulation for irrigation and flood control will be accomplished by eight 5-ft-wide by 9-ft-high curved sluices through the spillway section. These sluices will be located in two tiers of four each at elevations 210 and 280, respectively. Maximum capacity of the sluices is estimated to be 31,600 cfs with the pool at elevation 475.4.

6. Three 14-ft-3-in.-diameter penstocks will be located to the right of the spillway. When all units have been installed the total power output will be 120,000 kilowatts. The Bureau of Reclamation plans the removal of an existing private power plant downstream together with river gravel lying between the Folsom Dam site and the downstream dam. A substantial amount of rock also will be removed from the same stretch of river for the purpose of obtaining additional power head on the Folsom power plant. Such gravel and rock excavation will lower the present tailwater elevation in the vicinity of the Folsom powerhouse by about 70 ft.

#### The Problem

7. Model analyses of the Folsom Dam spillway were considered necessary to provide information on which to base the selection of the type energy dissipator that should be constructed. Other information concerning flow over the spillway crest, height and length of training walls, and flow conditions in the vicinity of the powerhouse and exit area, also was to be secured for design purposes.

#### Design Criteria

8. The principal design criterion was that all structures should

be safe against failure for the spillway design flood of 567,000 cfs. Also, if the conventional type stilling basin were selected, good hydraulic jump action should exist over the apron for flows up to 200,000 cfs and the right training wall should be capable of protecting the power plant from flooding for all flows up to 250,000 cfs. If the flip-bucket type energy dissipator were selected, discharges up to 250,000 cfs should be projected far enough downstream so as not to interfere with power operation. Neither objectionable spray nor turbulence that might hinder operation should occur in the vicinity of the powerhouse.

## PART II: THE MODELS

Description

9. Two models of the same scale ratio (1:80) were constructed and operated concurrently, one model for tests of the flip-bucket energy dissipator and the other for tests of a conventional type stilling basin. The two almost identical models were necessary because of the short time available for conducting tests on the two types of energy dissipators proposed.

10. One model, designated as Model A in this report, was constructed in a brick and concrete flume for tests of the flip-bucket type energy dissipator. The entire spillway and conduits were reproduced, together with about 290 ft of nonoverflow section on the right and 140 ft of nonoverflow section on the left, 450 ft of approach channel, the power penstocks and powerhouse, and about 1950 ft of the exit channel (fig. 2 and plate 3).

11. The other model, designated Model B throughout this report and used for tests of the stilling-basin energy dissipator, was reproduced in a slightly smaller concrete and brick flume. Model B included the entire spillway and conduits, together with about 200 ft of nonoverflow section on the right side and 30 ft of nonoverflow section on the left side, 400 ft of approach channel, the stilling basin, the high flip bucket, the power penstocks and powerhouse, and about 950 ft of the exit channel (fig. 3 and plate 4). After tests indicated the use of the stilling-basin type energy dissipator, Model A was destroyed and Model B was moved into the larger flume for tests of additional refinements to the stilling-basin design.

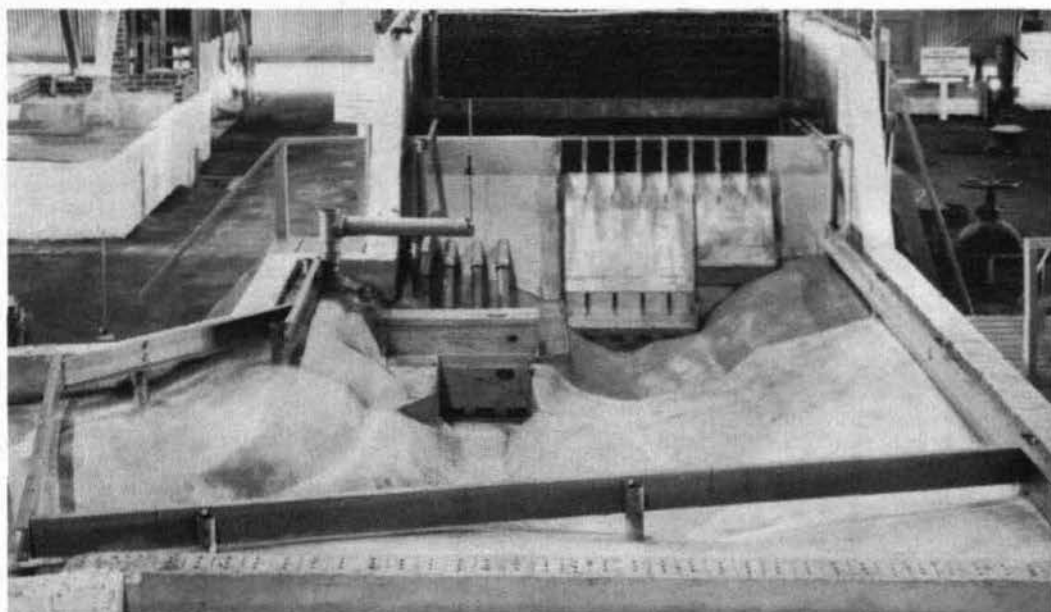


Fig. 2. Details of Model A

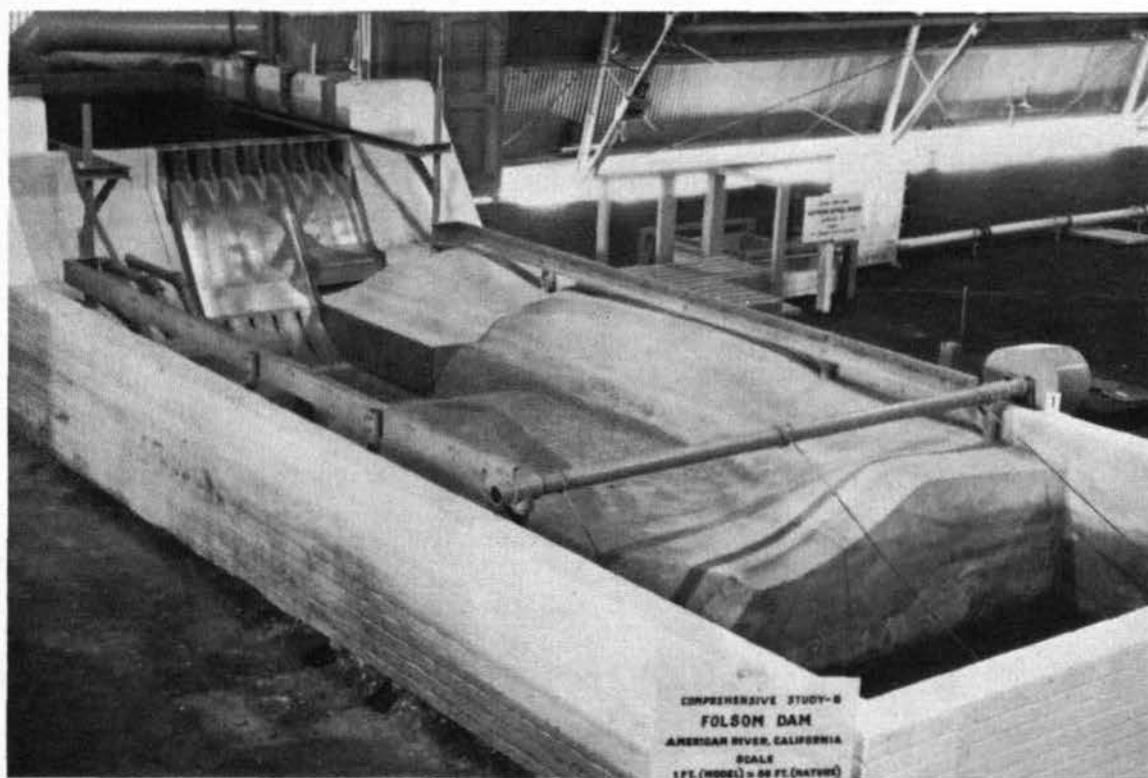


Fig. 3. Details of Model B

12. Similar type construction was used for both models. The approach channels and the nonoverflow sections of the dam were molded in concrete to masonite templets. The spillway crest sections were formed of aluminum sheets fastened to accurately shaped sheet metal templets and were surmounted with crest piers constructed of plastic. Conduits through the spillway section were fabricated of sheet metal while the powerhouse and stilling basin were of wood; the flip bucket was formed in sheet metal. The exit area was capped with a thin layer of cement mortar for velocity measurements. A few erosion tests were conducted wherein the exit area was molded in sand or gravel.

#### Model Appurtenances and Their Application

13. Water used in the operation of the models was supplied by centrifugal and axial-flow pumps connected in such a manner as to allow for flexibility of operation. The water was drawn from a large sump, and measured by means of venturi meters. The flow from the supply line discharged into the headbay of each model where it was stilled by baffles prior to its passage into the models. After passing through the models, the water was returned to the sump by gravity flow through return lines. Tailwater elevations in the lower end of the models were adjusted by means of a tailgate operated by a worm gear hoist. Steel rails set to grade alongside the models provided datum planes for use of measuring devices. Water-surface elevations were measured by means of point gages mounted on an aluminum channel supported by the above-mentioned steel rails, and by means of piezometers. Velocities were measured with a pitot tube. Pressures over the spillway

were measured in manometers connected by tubes to piezometer openings in the models. Soundings over the sand or gravel bed downstream from the bucket and stilling basin were taken with a portable sounding rod. Discharges through the powerhouse were controlled by means of a Van Leer weir.

### Scale Relationships

14. The requirements for geometric and dynamic similarity between model and prototype were satisfied by constructing all elements of the models to an undistorted linear scale ratio, and testing all hydraulic quantities in their proper relationships as derived from the Froude law. General scale relationships were as follows:

<u>Dimension</u>	<u>Ratio</u>	<u>Scale Relationship</u>
Length	$L_r = L$	1:80
Velocity	$V_r = L_r^{1/2}$	1:8.94
Time	$T_r = L_r^{1/2}$	1:8.94
Discharge	$Q_r = L_r^{5/2}$	1:57,240

## PART III: NARRATIVE OF TESTS -- MODEL A (FLIP-BUCKET TYPE)

Spillway Crest

15. The maximum drop from the spillway crest at elevation 418 to the invert of the 50-ft-radius bucket below the five bays nearest the right abutment (elevation 176.98) was 241.02 ft, whereas the drop to the bucket invert below the three bays adjacent to the left abutment was 141.02 ft. The alignment of the downstream portion of the spillway followed the equation  $Y = 0.01798X^{1.85}$  whereas the upstream portion of the spillway was shaped to a compound curve with radii of 25 and 10 ft. Dimensions of the radial gates and crest piers have been described previously in paragraph 3. Complete details of the spillway crest are shown on plate 5.

16. Satisfactory flow conditions obtained over the spillway weir of model A throughout the range in discharge for free and controlled overflow. The semicircular shape of the upstream portion of the crest piers permitted smooth passage of flow through the gated sections.

17. Measurements of head-discharge relations revealed that slightly more than the computed flow was passed through the model (plate 6). At the spillway flood pool (elevation 475.4) and with eight bays open full, computations indicated a maximum discharge of 567,000 cfs, whereas an equivalent discharge of 588,000 cfs was passed over the model crest. A discharge of 358,000 cfs was passed through five gate bays with a pool elevation of 475.4 as compared to a computed discharge of 353,000 cfs. The coefficients of discharge for the above discharge conditions and an assumed pier contraction coefficient of 0.015 are 4.09 and 4.20,

respectively. These coefficients are slightly higher than those found in other experiments; this is attributed to the conservative pier contraction coefficient assumed.

18. Measurements of water-surface profiles for conditions of full and partial gate openings are shown on plates 7-11. These profiles indicate the abutment walls to be of adequate height to confine flood flows and to clear the gate trunnions. No pressure data were recorded over the crest of Model A but data were recorded on Model B and are presented later.

#### Flip-bucket Type Energy Dissipator

19. Six bucket designs (plate 12) were investigated in an effort to develop a design that would satisfy the conditions outlined in paragraph 8. All alterations were confined to the bucket below the five gate bays (gates 1-5) adjacent to the right abutment. Tests were conducted for the discharges and gate operation outlined in table 1 and for the tailwater conditions shown on plate 13. Tests involved (a) observation of bucket action, (b) determination of water-surface profiles, (c) investigation of erosion tendencies in exit area, (d) measurement of velocities and their distribution in the area downstream from the bucket, and (e) measurement of surge waves and their frequency in the vicinity of the powerhouse. Complete data were procured only on the original design since the five alterations afforded little or no improvement in bucket performance and consequently did not warrant detailed investigation.

#### Type 1 (original design) bucket

20. Description. The bucket originally proposed for the Folsom Dam spillway had a radius of 50 ft and was placed at two elevations. The

242-ft section of the bucket adjoining the right training wall was at elevation 176.98 (plate 12) and the 150-ft section adjoining the left training wall was at elevation 276.98 (plate 1). Elevations of the left and right training walls were 212 and 290, respectively.

21. Flow conditions. It was observed that the sheet of water passing over and downstream from the bucket lip had a very flat trajectory (photographs 1-6). This condition was unexpected as a 20-degree lip slope in tests of other structures had given entirely different results. The flat trajectory was attributed to the close proximity of the rock bed immediately downstream from the bucket which caused a reduced pressure area immediately downstream from the bucket thus tending to depress the overflowing sheet of water. Removal of a portion of the bedrock in the immediate vicinity of the bucket (photograph 7) permitted the aeration of the underside of the nappe resulting in a steeper trajectory of flow and improved downstream conditions (photographs 8-10). The area immediately downstream from the basin was practically unwatered by the overflowing nappe and remained so up to a discharge slightly in excess of 300,000 cfs when the tailwater became sufficiently deep to form a roller under the nappe. High velocities existed in the exit area downstream of the point of impingement of the nappe. Eddies were formed on the left and right banks of the channel, the size and location of which were dependent upon the discharge.

22. Water-surface profiles. Average water-surface profiles measured through the flip bucket and exit channel immediately downstream are shown on plates 7-11. These profiles indicate that the nappe impinged about 400 ft downstream from the bucket for a discharge of 250,000 cfs. The powerhouse was located about 400 ft downstream from the bucket.

23. Surface-current directions. Surface-current directions in the exit area for various combinations of discharges over the spillway and through the powerhouse are shown on plates 14-18. The eddy conditions described above are shown on the referenced plates.

24. Erosion tests. An erosion test was conducted with a discharge of 108,000 cfs over the spillway and 7,000 cfs through the powerhouse. For this test the exit area was molded in pea gravel to the configuration shown on plate 19. The scour developed in the pea gravel bed (fig. 4) was considerable, being about 35-40 ft where the nappe impinged on the river bed. Maximum scour occurred along the right training wall with a considerable portion of the scoured material being deposited in the tailrace area. Flow conditions in the



Fig. 4. Bed downstream from flip bucket after 1-hour scour, Model A. Discharge, 115,000 cfs; pool elev, 466.0

exit area were improved after erosion of the bed (photographs 11 and 12). The tailwater could not be lowered below elevation 187 because of the deposit of pea gravel in the exit area. A second scour test was conducted for the same discharge conditions but with the bed molded of larger gravel (gravel that was retained on a 1-1/2-in. screen) to more nearly simulate prototype conditions (photograph 13). This test showed approximately 50 ft of scour along the right training wall and a lesser amount downstream from the bucket (photograph 14). A smaller amount of material also was deposited in the tailrace. Attention should be given the relative location of scouring attack rather than the depth of scour, since it has not yet been found possible to reproduce quantitatively in a model the resistance to erosion of a prototype bed material. The scour data also are useful in providing a measure of the effectiveness of the type energy dissipator under study.

25. Bottom velocities. Velocities recorded 2 ft above the bed of the exit area for various discharges are shown on plates 20-25. Velocity measurements were very difficult to obtain in view of the turbulent condition of flow in the exit area. The data indicate that velocities as high as 103 ft per sec existed in the area where the nappe from the bucket fell into the exit channel. Velocities in the tailrace area were in the range of 20-25 ft per sec. Measurements over the exit area for a total discharge of 115,000 cfs after erosion of the bed had occurred (plate 26) revealed some decrease in velocities. However, they were still high and could prove troublesome in the prototype.

26. Surge observations. Surge observations or variations in water level were recorded in the vicinity of the powerhouse (plate 19) for the

various test discharges. These data (table 2) indicate that the amount of surge increased as the discharge was increased. For the critical discharge of 250,000 cfs, the variation in water surface was from 4 to 9 ft at the three test locations. Surge frequency ranged from only about 13 to 17 cycles per minute; a surge frequency of 30-50 cycles per minute was considered critical for power generation.

#### Alternate bucket designs (types 2-6)

27. Description. The alternate bucket designs were developed with a view toward breaking up the sheet of water as it passed over the bucket lip or throwing it farther downstream away from the powerhouse. In one design (type 6) the bucket was lowered with a view to dissipating energy by submerging the nappe passing over the bucket lip. Photographic data only were procured on these alternate bucket designs. Details of the designs are shown on plate 12 and are described below:

- a. Type 2 bucket had a radius of 50 ft, an invert elevation of 173.3 and a 30-degree terminal angle ending at station 12+52.07.
- b. Type 3 bucket had an invert elevation of 165.24 at station 12+32.38 and was joined to the spillway with a 50-ft radius; downstream from station 12+32.38 the bucket was horizontal to station 13+00.
- c. Type 4 bucket had a radius of 50 ft, an invert elevation of 165.24, and a 5-degree terminal angle ending at station 13+00.
- d. Type 5 bucket was similar to type 4 except that 16-ft-wide by 9-ft-high dentates were located on the 5-degree terminal angle with a clear distance between dentates of 16 ft.
- e. Type 6 bucket had a radius of 50 ft, an invert elevation of 126.98, and a 20-degree terminal angle.

28. Test results. The 30-degree terminal angle of the type 2

bucket caused the nappe to be deflected higher and farther downstream before it impinged on the bed of the exit area (photographs 15-20).

However, the trajectory of the nappe was such that flow overtopped the

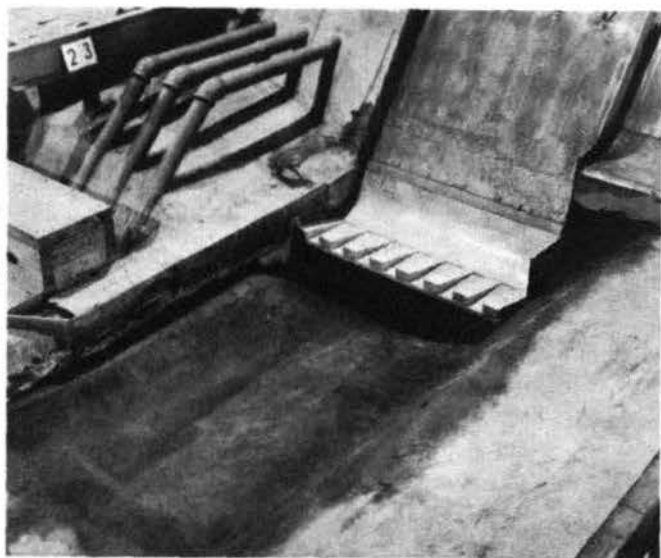


Fig. 5. View of type 5 bucket with dentates installed

right training wall in the vicinity of the powerhouse, which could endanger the structure. Flow over the bucket of type 3 design (photographs 21-23) caused the tailwater to be swept downstream and resulted in high velocities over the exit area. The addition of the 5-degree slope (type 4)

altered flow conditions only slightly. The use of the dentates of the type 5 bucket design (fig. 5) resulted in about the same conditions in the exit area as were observed with the bucket of original design (photographs 24-26). Since none of the types 2-5 alterations improved flow conditions over the bucket and in the exit area, the type 6 bucket (fig. 6) was developed. It was thought



Fig. 6. View of type 6 flip bucket

that the low elevation of this bucket would provide a type of hydraulic jump action that would not erode the exit area too much. The resulting flow conditions (photographs 27-29) revealed that a form of hydraulic jump type action existed. However, flow was very turbulent in the vicinity of the powerhouse. Fig. 7 illustrates the scour that resulted after successive discharges of 115,000, 200,000, and 300,000 cfs for a period of 15 min (model).

#### Discussion of results

29. It was decided from the results of all tests that the original design bucket at elevation 176.98 was as economical to construct and performed as well as any of those investigated. It also was the



Fig. 7. View of the bed downstream of the type 6 flip bucket, Model A. Scour after successive discharges of 115,000, 200,000 and 300,000 cfs for 15 minutes of model operation

consensus of representatives of all the interested agencies that, while the bucket of original design was adequate as far as the safety of the dam was concerned, it was not desirable that the nappe strike the bed of the exit area in the vicinity of the powerhouse. It was agreed that the resulting high velocities downstream could fill the tailrace with debris thus reducing the head available for power generation.

### Conduits

30. Although conduits were installed through the spillway section of the model, no data were procured, as the design was changed after initiation of the model study. The size also was reduced from 5.67 ft by 9.68 ft to 5.0 ft by 9.0 ft and the alignment was altered. Plate 1 shows the location and alignment of the conduits as redesigned. The redesigned conduits were neither installed nor tested in the model.

## PART IV: NARRATIVE OF TESTS -- MODEL B (STILLING-BASIN TYPE)

Spillway Crest

31. The spillway crest reproduced in Model B was identical to the crest used in Model A and described in paragraph 15. Details of the crest are shown on plate 5.

32. Measurements of head-discharge relations were practically the same as those recorded previously for the crest of Model A (plate 6). Pressure data recorded over the crest of Model B are shown on plates 27-31 and in table 3. These data indicate only slight negative pressures with the gates at partial opening. Pressures were all above atmospheric for uncontrolled flow over the crest. No comparable pressure data were obtained on Model A.

Stilling-basin Type Energy Dissipator

33. Table 4 shows the 25 types of stilling-basin designs tested on Model B together with references to plates and photographs that present data pertaining to each design. Many of the designs were similar except for revisions of the height of end sill and baffle piers or alterations in the slope and elevation of the apron. As was the case during tests of the flip-bucket type energy dissipator, the high bucket downstream from gates 6, 7, and 8 adjacent to the left spillway abutment was not altered. Tests were conducted for the discharges and gate operation outlined in table 1 and for the tailwater conditions shown on plate 13. For the most part tests involved observations of flow conditions, measurements of water-surface elevations, determination of erosion tendencies, and

measurement of velocities and determination of their distribution. Only observation tests were conducted on certain of the designs where minor changes or alterations had been made.

Type 1 (original design) stilling basin

34. Description. The initial design of the stilling-basin type energy dissipator proposed for Folsom Dam consisted of an apron with an over-all length of 276.1, starting at elevation 119.35, extending on a 1-on-6 slope to elevation 115 and then horizontally for a distance of 250 ft (table 4 and fig. 8). An end sill 5 ft in height was placed on the end of the apron to deflect all high velocity bottom cur-

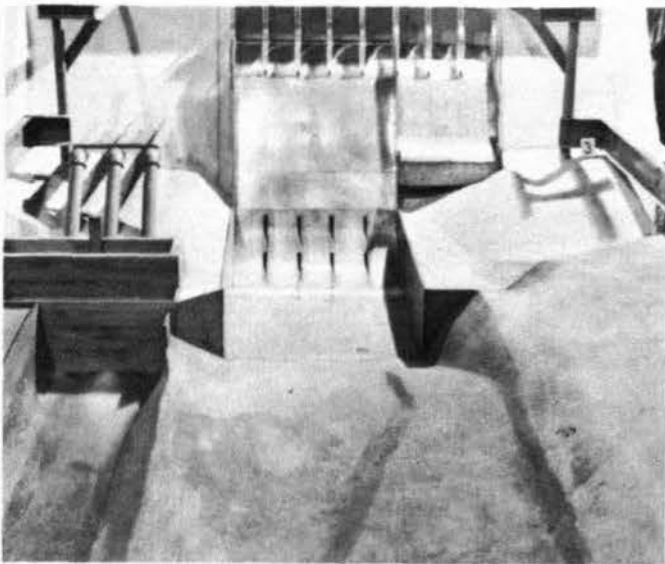


Fig. 8. View of type 1 stilling basin, Model B

rents away from the exit area immediately downstream. The elevation selected for the horizontal basin was about that required to provide the theoretical depth for formation of a hydraulic jump for a discharge of 115,000 cfs.

35. Flow conditions.

Observation of flow conditions throughout the range in discharge (photographs 30-33) revealed that hydraulic jump action existed for all flows. However, the tailwater elevation appeared to be slightly low and flow within the basin proper was quite turbulent. For discharges in excess of 115,000 cfs, the jump appeared to extend beyond the confines of the basin into the exit area. Variations of the

tailwater elevation revealed that best jump action obtained with the tailwater increased about 5 to 10 ft (plate 32). The tailwater also could be lowered about 15 ft before spray action occurred with a discharge of 200,000 cfs; the margin of safety against spray increased as the discharge increased. Surface currents through the stilling basin and in the exit channel downstream are shown on plates 33-37.

36. Water-surface profiles. Water-surface profiles along the center line of the stilling basin for spillway discharges of 108,000, 193,000, 243,000, 300,000, and 567,000 cfs are shown on plates 27-31. These data indicate that a hydraulic jump formed on the apron at all discharges and that the training walls were of sufficient height to contain all flows up to about 300,000 cfs. The data also indicate that the jump extended into the exit area for discharges in excess of about 115,000 cfs.

37. Velocities. Bottom velocities in the stilling basin and downstream therefrom for the test discharges are shown on plates 38-43. Bottom velocities over the end sill varied from a maximum of 13.4 ft per sec at a discharge of 50,000 cfs to a maximum of 68.1 ft per sec at a discharge of 300,000 cfs. Maximum velocities in the exit area for the same discharges were 10 and 26 ft per sec, respectively. Velocities for a discharge of 567,000 cfs were about the same as those observed with a discharge of 300,000 cfs. Although velocities over the end sill and in the exit area were still higher than desired, they were considerably lower than had been observed with the flip-bucket type energy dissipator at corresponding discharges. The effect of tailwater elevation on velocities at the end sill is shown on plate 44. These data reveal that the

tailwater conditions existing with a basin elevation of 115 resulted in optimum conditions.

### Type 2 stilling basin

38. Description. The type 2 basin was evolved to place the top of the sloping ramp or upstream end of the stilling basin at a higher elevation. This revision would increase the thickness of the concrete at the toe of the spillway, which was considered desirable for reasons of stability. The possible loss of basin efficiency was compensated for by addition of 8-ft-high dentates to the ramp and an increase in the height of end sill to 15 ft. The type 2 basin consisted of a 1-on-9.95 sloping ramp, beginning at station 12+39.7 at elevation 140 and ending at station 14+88.5 at elevation 115. The 8-ft-high dentates were placed on the sloping ramp at station 13+50.9. Use of the long slope in the upstream portion of the basin reduced the length of the horizontal apron to 82.4 ft. Details of the type 2 basin are shown in

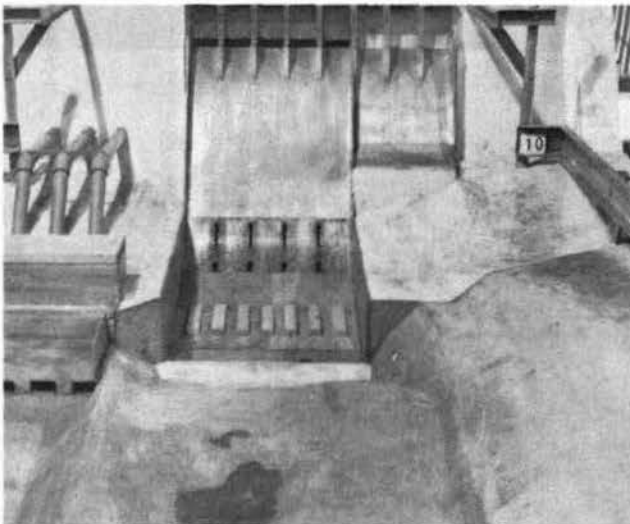


Fig. 9. Details of the type 2 stilling basin

table 4 and fig. 9.

39. Test results. Flow conditions within the stilling basin appeared to be improved by the revisions to the basin elements (photographs 34-37). A good hydraulic jump existed for a discharge of 108,000 cfs over the spillway. Plate 45 shows water-surface profiles

through the stilling basin and plate 46 shows bottom velocities for a

spillway discharge of 193,000 cfs. The data indicate that the exit channel velocities were increased from a maximum of 13.4 ft per sec for the type 1 basin to 19.0 ft per sec with the type 2 basin. The variations in water level in the vicinity of the powerhouse, caused by turbulent conditions created by stilling-basin action, are shown in table 2. Similar data recorded with the flip-bucket type energy dissipator have been discussed in paragraph 26. For a discharge of 250,000 cfs the variation in water surface was from 7 to 8 ft and was slightly more than observed with the flip-bucket type energy dissipator (4 to 9 ft). Surge frequency was about 14 to 16 cycles per minute.

#### Types 3-5 stilling basins

40. Description. The types 3-5 basins differed from the type 1 basin only in the length of the horizontal apron and height of end sill. The end sill height was maintained at 15 ft and the length of the apron was shortened 25, 50, and 75 ft, respectively, for the types 3, 4 and 5 basins (table 4).

41. Test results. Observation of flow conditions in the three basins revealed that, as the basin was shortened, basin action became more turbulent and impact of flow on the end sill increased. Flow conditions for a discharge of 108,000 cfs were fair, however, with the basin shortened as much as 75 ft. For discharges in excess of 108,000 cfs basin conditions were poor (photographs 38-40).

#### Type 6 stilling basin

42. The type 6 stilling basin was identical to type 2 except that the height of the end sill was reduced from 15 to 10 ft in an effort to improve flow conditions over the end sill. The reduction in sill height

had little or no effect on basin performance.

#### Types 7-9 stilling basins

43. Description. Types 7-9 basins were investigated to study the possibility of raising the elevation of the upstream portion of the sloping apron higher than was done in the type 2 design. The sloping apron of the types 7, 8, and 9 designs intersected the spillway at elevations 200.26, 153.46, and 143.97, respectively (table 4).

44. Test results. Flow conditions within the type 7 basin were unsatisfactory (photographs 41-43). The slope of the apron began at too high an elevation and was too steep, and the stilling basin was dependent upon the end sill to form the hydraulic jump. Flow conditions with the types 8 and 9 basins (photographs 44-46) were similar and about the same as those observed with the type 1 original basin. However, the hydraulic jump still extended into the exit channel for discharges in excess of 200,000 cfs.

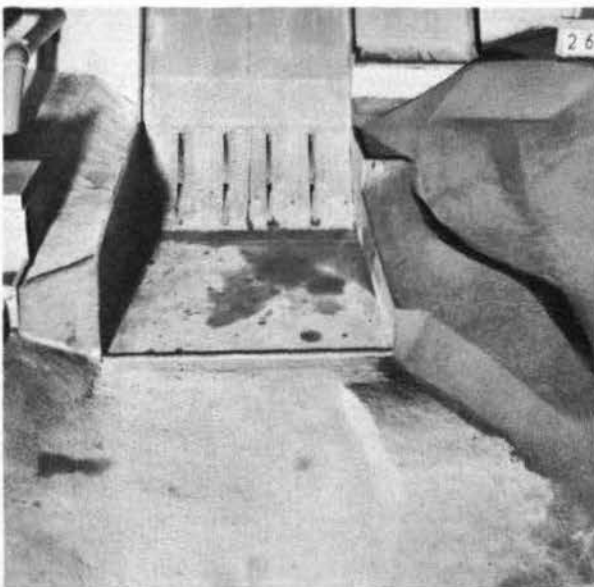


Fig. 10. Details of the type 10 stilling basin, Model B

#### Type 10 stilling basin

45. Description. The type 10 stilling basin was the first design which considered training wall height. The basin proper was similar to type 1. The left intermediate training wall was lowered from elevation 210 to elevation 165 (top of firm rock) at the downstream end (table 4 and fig. 10). This alteration

not only would effect economies in construction but it was thought that it might improve basin conditions at high discharges by permitting the tailwater to flow into the basin from the side over the low wall.

46. Test results. Flow conditions were similar to those observed with the type 1 design. The low intermediate wall was still of such height as to exclude practically all tailwater up to a discharge of about 200,000 cfs. For the maximum discharge of 567,000 cfs the drowning of the jump by tailwater flowing over the low wall was a definite improvement. However, basin action for the type 10 basin was considered unsatisfactory for discharges in excess of 108,000 cfs (photographs 47-50). The elevation of the left training wall, as tested, was considered satisfactory.

#### Type 11 stilling basin

47. The type 11 basin was similar to type 7 except the horizontal portion of the basin at elevation 115 and training walls were extended 85.9 ft downstream (table 4). Although the longer basin and training walls produced better flow conditions (photographs 51-53) over the end sill than were observed with type 7 basin, the increased cost of construction was not worth the improved performance secured. The toe of the hydraulic jump also occurred too far downstream from the junction of the apron and the crest section.

#### Type 12 stilling basin

48. Description. The type 12 basin was developed after a series of intermediate observation tests wherein flow conditions were observed with various slopes and tailwater elevations. The design giving most promise consisted of a 1-on-8 sloping apron beginning at elevation 147.5

at station 12+28.5 and ending at elevation 115 at station 14+88.5 (table 4). Over-all length of the original spillway structure was maintained.

49. Test results. Observation of flow conditions revealed good basin action at a low discharge (108,000 cfs) and fair action for the higher discharges (photographs 54-56). The hydraulic jump formed just downstream from the beginning of the stilling basin. Thus it appeared that a 1-on-8 sloping apron was about the steepest that could be used without an increase in the length of the basin.

#### Types 13-19 stilling basins

50. Description. The types 13-19 stilling basins (table 4) represent designs developed to effect refinements in the type 12 basin with its 1-on-8 sloping apron. Such refinements involved variations in (a) length and elevation of the horizontal apron, (b) point of intersection of apron with spillway, and (c) use of dentates or baffle piers. During the course of this series of tests a decision was made in a conference between representatives of the Corps of Engineers and the Bureau of Reclamation to incorporate the stilling-basin type energy dissipator in final plans for construction. This was done to afford greater safety to the powerhouse and reduce possible maintenance costs. Following this decision, the stilling basin was moved into the larger flume, formerly occupied by Model A, and testing was continued.

51. Test results. Data obtained with the types 13-19 stilling basins consisted of observations of flow conditions and comparative erosion tests. The scour tests were conducted with the exit area

molded flat in sand to elevation 115 (plates 47-58). The scour data indicated the possibility of increasing the elevation of the horizontal portion of the basin from 115 to 125, and the elimination of dentates from the sloping portion of the apron. Two of the basins, types 18 and 19, showed considerable improvement in flow conditions and bottom velocities were measured in the stilling basin and exit area (plates 59 and 60). The velocity data indicate a reduction in end sill velocities from 90 ft per sec to 30 ft per sec as a result of baffle piers. However, with velocities of the magnitude recorded baffle piers would, in all probability, be damaged by cavitation. Therefore, their use was not considered desirable.

#### Types 20-21 stilling basins

52. The type 20 basin involved the use of a flat sloping apron throughout its length. The type 21 design involved use of an almost horizontal basin adjacent to the training walls with a depressed center section. Details of both basins are presented in table 4. Neither basin resulted in improved performance; consequently no data thereon are presented.

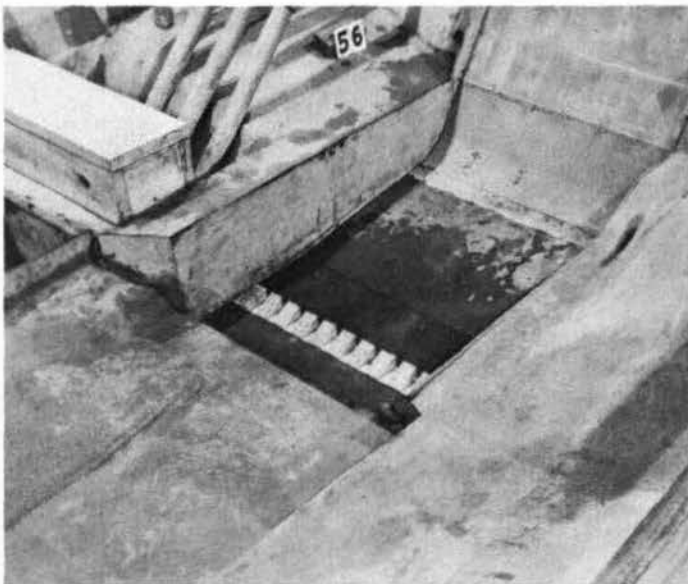
#### Types 22-25 stilling basins

53. Description. The type 22 stilling basin was developed after a conference at the Waterways Experiment Station between representatives of the Sacramento District, the South Pacific Division, the Office, Chief of Engineers, the Bureau of Reclamation, and the Experiment Station, during which all model data were reviewed. The type 22 basin (table 4 and plate 1) is a compilation of all the best features of the previously tested designs. At the above-mentioned conference it also was decided

that bottom velocities over the exit area immediately downstream from the end sill should not exceed 30 ft per sec. The types 23, 24, and 25 basins (table 4) were the same as type 22 except that one row of baffle piers 8, 10, and 12 ft high, respectively, was used to reduce bottom velocities.

54. Flow conditions. Photographs 57-61 show flow conditions in the type 22 basin for discharges of 108,000, 193,000, 300,000, and 567,000 cfs. These photographs indicate excellent hydraulic jump action for a discharge of 108,000 cfs, good action for 193,000 cfs, and fair action at discharges of 300,000 and 567,000 cfs. The use of 10-ft-high baffle piers (type 24 basin, fig. 11) improved flow conditions slightly at the higher discharges (photographs 62-64). The 8- and 12-ft-high baffle piers of types 23 and 25 basins resulted in about the same type of flow action.

55. Bottom velocities and water-surface profiles. Plates 61-74



show bottom velocities and water-surface profiles with the types 22-25 basins. Data are presented both with the bed of the exit area molded to natural configuration and with a simulated scour hole, approximately 400 ft in length and with a maximum depth of 32 ft, reproduced downstream

Fig. 11. Details of type 24 stilling basin.  
Row of 10-ft baffles at sta 14+94.2

from the end sill. The data presented indicate that velocities immediately downstream from the end sill of the type 22 basin reached a maximum of 57.4 ft per sec for a discharge of 300,000 cfs, which is in excess of the 30-ft-per-sec limit mentioned in paragraph 53; for a discharge of 115,000 and 200,000 cfs maximum velocities were 16 and 35.2 ft per sec, respectively. With a scour hole simulated downstream from the end sill, maximum bottom velocities were only 12.4 ft per sec and were upstream in direction. Maximum bottom velocities over the exit area molded to natural configuration were generally decreased by the use of either 8-, 10-, or 12-ft baffle piers and were within the 30-ft-per-sec limit established. However, flow conditions indicated that the baffle piers would be subjected to high impact forces, especially at high flows, and damage through cavitation action appeared possible. Excavation of the exit area downstream from the end sill or erosion of this area by flow would result in bottom velocities within the range desired without the use of baffle piers. Water-surface profiles for each of the four basins for the two exit area conditions also are shown on plates 61-74.

#### Intermediate Training Wall of High Bucket

56. Although it was planned to retain the flip-bucket type energy dissipator downstream from gates 6, 7, and 8, it was desired to reduce the height of the intermediate wall adjacent to the high bucket, thus reducing the lateral pressure exerted by flow over the curved bucket. General details of the three type walls investigated are shown on plates 75 and 76 and photographs 65-67.

57. Pressure measurements were made at the locations shown on

plates 75 and 76 and are shown in table 5 for various head conditions. The use of types B and C walls resulted in a decrease in lateral pressure but diverted some of the flow laterally into the stilling basin (photograph 68) below gates 1-5. This extra flow into the stilling basin had no effect on basin performance.

## PART V: CONCLUSIONS

58. Conclusions based upon the model findings are:

- a. The conventional apron-type stilling basin should be constructed in the prototype instead of the flip-bucket type. While the safety of the dam would not be endangered through use of the more economical flip-bucket type energy dissipator, construction of the stilling-basin type dissipator was considered desirable in view of the increased safety to the powerhouse and the reduced maintenance costs with less eroded material entering the tailrace area.
- b. The type 22 stilling basin was the most feasible from the standpoint of economy, stability of the dam, and performance.
- c. The type 22 stilling basin resulted in good hydraulic jump action for discharges up to 200,000 cfs; jump action was only fair for discharges from 200,000 to 567,000 cfs. Maximum bottom velocities immediately downstream from the end sill slightly exceeded the limit of 30 ft per sec. However, after a small amount of erosion has occurred the velocities will be within the limits desired.
- d. The type 24 stilling basin produced lower velocities in the exit area but is not recommended in view of possible damage to the baffle piers through cavitation action.
- e. If the prototype discharge ever exceeds 300,000 cfs and it becomes necessary to release flow through gates 6, 7, and 8, some erosion downstream from the flip bucket and damage to the left training wall adjacent to the stilling basin may occur.
- f. Pressure and flow conditions over the spillway crest were satisfactory.
- g. Surge conditions in the powerhouse area for a spillway discharge of 250,000 cfs, with the stilling-basin type energy dissipator, ranged from 7 to 8 ft, but the frequency was such that no difficulty should be incurred in power operations.

## TABLES

Table 1

TEST CONDITIONS FOR DEVELOPMENT OF DESIGN OF ENERGY DISSIPATOR

Test No.	Outflow in 1,000 Cfs										Pool Elevation (Computed)
	Total Penstocks	Spillway Gates									
		1	2	3	4	5	6	7	8		
1	57	7	10	10	10	10	10	0	0	0	466
2	115	7	22	22	22	22	20	0	0	0	445
3	200	7	39	39	39	39	37	0	0	0	466
4	250	7	49	49	49	49	47	0	0	0	466
5	300	0	60	60	60	60	60	0	0	0	466+
6	567	0	71	71	71	71	71	71	71	70	475

Note: No flow through conduits.

Table 2

SURGE ACTION IN VICINITY OF POWERHOUSE, MODELS A AND B

<u>Total Discharge Cfs</u>	<u>Gate Opening Ft</u>	<u>Normal Tailwater Elevation</u>	<u>Station</u>	<u>Maximum Surge, Elev Model A</u>	<u>Minimum Surge, Elev Model A</u>	<u>Range of Surge, Ft Model A</u>	<u>Maximum Surge, Elev Model B</u>	<u>Minimum Surge, Elev Model B</u>	<u>Range of Surge, Ft Model B</u>
57,000	6.0	176.5	1	180.0	177.0	3.0	176.0	174.0	2.0
			2	181.0	179.0	2.0	176.5	174.5	2.0
			3	179.0	177.0	2.0	176.0	175.0	1.0
115,000	14.0	179.2	1	184.0	182.0	2.0	180.0	179.0	1.0
			2	184.0	182.0	2.0	181.0	179.0	2.0
			3	186.0	183.0	3.0	181.0	178.0	3.0
200,000	28.0	196.0	1	198.0	193.0	5.0	201.0	195.0	6.0
			2	199.0	195.0	4.0	202.0	196.0	6.0
			3	200.0	195.0	5.0	201.0	196.0	5.0
250,000	33.75	205.4	1	207.0	203.0	4.0	210.0	202.0	8.0
			2	210.0	204.0	6.0	210.0	203.0	7.0
			3	212.0	203.0	9.0	212.0	204.0	8.0
300,000	Full	212.6	1	214.0	209.0	5.0	217.0	208.0	9.0
			2	217.0	210.0	7.0	216.0	209.0	7.0
			3	217.0	210.0	7.0	217.0	209.0	8.0
567,000	Full	242.0	1	248.0	234.0	14.0	246.0	234.0	12.0
			2	251.0	236.0	15.0	245.0	236.0	9.0
			3	257.0	236.0	21.0	248.0	236.0	12.0

Note: Locations of stations where surge action was obtained shown on plate 19.

Table 3

PRESSURES OVER SPILLWAY CREST

MODEL B

Piezometer Number	Piezometer Zero	Pressures, Spillway Gates 1 through 5 Operating						Pressures, All Gates Operating
		Disch, 50,000 Cfs Pool Elev, 466.0 Gates Open 6.0 Ft	Disch, 108,000 Cfs Pool Elev, 445.0 Gates Open Full	Disch, 108,000 Cfs Pool Elev, 466.0 Gates Open 14.0 Ft	Disch, 193,000 Cfs Pool Elev, 466.0 Gates Open 28.0 Ft	Disch, 243,000 Cfs Pool Elev, 466.0 Gates Open 33.75 Ft	Disch, 300,000 Cfs Pool Elev, 468.6 Gates Open Full	Disch, 567,000 Cfs Pool Elev, 473.0 Gates Open Full
1	411.71	55.29	26.29	52.29	39.29	37.29	18.70	27.00
2	416.42	49.58	17.58	43.58	30.58	23.58	13.58	14.60
3	418.00	45.00	12.00	33.00	21.00	17.00	7.00	6.00
4	413.42	- 0.42	6.58	- 0.42	5.58	4.58	2.58	1.60
5	401.46	1.54	3.54	0.54	1.54	1.54	1.54	0.50
6	382.92	1.08	2.08	0.08	0.08	1.08	0.08	0.10
7	358.31	4.69	3.69	4.69	6.69	4.69	5.69	4.70
8	328.96	4.04	5.04	5.04	8.04	8.04	10.04	11.00
9	299.11	2.89	4.89	4.89	6.89	7.89	8.89	10.90
10	269.26	2.74	3.74	3.74	5.74	6.74	7.74	8.70

**Notes:** Pressures are recorded in prototype feet of water. Piezometer locations are shown on plate 27.

**Table 4**  
**MODEL B**  
**STILLING BASIN DESIGNS INVESTIGATED**

TYPE NUMBER	SECTION ALONG CENTERLINE	REFERENCE	REMARKS
1		Photographs 30-33 Plates 27-44	Stilling basin as originally designed
2		Photographs 34-37 Plates 45-46	1-on-9.95 sloping basin beginning at sta 12+39.70 at elev 140.00 and ending at sta 14+88.50 at elev 115.00. Placed on the slope at sta 13+50.9 were dentates 16 ft wide, 8 ft high, and 96 ft long. At the end of the basin, sta 15+64.10, was located a 15-ft end sill
3			Same as type 1 design, except the end sill was 25 ft upstream at sta 15+39.10 and was 15 ft high with 30 degree sloping front face
4			Same as type 1 design, except end sill was 50 ft upstream at sta 15+14.10 and was 15 ft high with 30 degree sloping front face
5		Photographs 38-40	Same as type 1 design, except end sill was 75 ft upstream at sta 14+89.10 and was 15 ft high with 30 degree sloping front face
6			Same as type 2 design, except 10-ft vertical sill replaced 15-ft sloping sill
7		Photographs 41-43	1-on-3.33 sloping basin beginning at sta 14+68.00 at elev 200.26 and ending at sta 14+68.00 at elev 115.00; at end of basin at sta 15+64.10 was a 15-ft-high end sill

Table 4 (Cont'd)

**MODEL B  
STILLING BASIN DESIGNS INVESTIGATED**

TYPE NUMBER	SECTION ALONG CENTERLINE	REFERENCE	REMARKS
8			1-on-3.33 sloping basin beginning at sta 12+21.79 at elev 153.46 and ending at sta 13+50.00 at elev 115.00; at end of basin at sta 15+64.10 was a 15-ft-high end sill
9		Photographs 44-46	1-on-4 sloping basin beginning at sta 12+34.09 at elev 143.97 and ending at sta 13+50 at elev 115; at end of basin at sta 15+64.10 was a 15-ft-high end sill
10		Photographs 47-50	Same as type 1 design, except for left training wall lowered as shown
11		Photographs 51-53	1-on-3.33 sloping basin beginning at sta 11+83.80 at elev 200.26 and ending at sta 14+68.00 at elev 115.00; at end of basin at sta 16+50.00 was a 15-ft-high end sill
12		Photographs 54-56	1-on-8 sloping basin beginning at sta 12+28.50 at elev 147.50 and ending at sta 14+88.50 at elev 115.00; at end of basin at sta 15+64.10 was a 15-ft-high end sill
13		Plates 47-49	1-on-7.25 sloping basin beginning at sta 12+28.15 at elev 148.7 and ending at sta 14+72.48 at elev 115.00; at end of basin at sta 15+64.10 was a 15-ft-high end sill
14		Plates 50-52	1-on-8 sloping basin beginning at sta 12+18.10 at elev 158.5 and ending at sta 15+64.10 at elev 115.00; at end of basin at sta 15+64.10 was a 15-ft-high end sill

Table 4 (Cont'd)

MODEL B  
STILLING BASIN DESIGNS INVESTIGATED

TYPE NUMBER	SECTION ALONG CENTERLINE	REFERENCE	REMARKS
15		Plate 53	Same as type 14 design, except dentates 10 ft high, 16 ft wide added on 32-ft centers at sta 12+77.00
16		Plate 54	1-on-8 sloping basin beginning at sta 12+16.10 at elev 158.5 and ending at sta 14+84.10 at elev 125.00. Placed on the 1-on-8 sloping ramp at sta 12+77.00 were dentates 10 ft high and 16 ft wide on 32-ft centers; at end of basin, sta 15+64.1, was a 15-ft-high end sill
17		Plate 55	Same as type 16 design with dentates removed
18		Plates 56-59	1-on-8 sloping basin beginning at sta 12+28.50 at elev 147.5 and ending at sta 14+09.46 at elev 125; at end of basin at sta 15+64.10 was a 15-ft-high end sill
19		Plate 60	Same as type 18 except a row of dentates 8 ft high, 16 ft wide and 96 ft long was placed on the 1-on-8 sloping ramp and 2 rows of baffle piers 8 ft high were added to the horizontal portion of the basin at sta 14+50.00 and sta 14+90.00
20			1-on-14.9+ sloping basin beginning at sta 12+28.50 at elev 147.50 and ending at sta 15+64.10 at elev 125.00; at end of basin at sta 15+64.10 was a 15-ft-high end sill
21			1-on-8 sloping basin, 142 ft wide, beginning at sta 12+29.06 at elev 147.20 and ending at sta 14+06.66 at elev 125.0. On the right and left sides a 1-on-4.7.5 sloping basin, 50 ft wide, beginning at sta 12+29.06 at elev 147.20 and ending at sta 15+70.90 at elev 140.00. On the end of the basin on both sides and center section was an end sill 15 ft high

Table 4 (Cont'd)

MODEL B  
STILLING BASIN DESIGNS INVESTIGATED

TYPE NUMBER	SECTION ALONG CENTERLINE	REFERENCE	REMARKS
22		<p>Photographs 57-61 Plates 61-66</p>	<p>1-on-8 sloping basin beginning at sta 12+46.83 at elev 137.17 and ending at sta 14+24.20 at elev 115.00; on the end of basin was a 15-ft-high end sill</p>
23		<p>Plate 67</p>	<p>Same as type 22 design, except a row of baffles 8 ft high added at sta 14+94.2</p>
24		<p>Photographs 62-64 Plates 68-73</p>	<p>Same as type 22 design, except a row of baffles 10 ft high added at sta 14+94.2</p>
25		<p>Plate 74</p>	<p>Same as type 22 design, except a row of baffles 12 ft high added at sta 14+94.2 and left training wall revised</p>

Table 5

PRESSURES ON TRAINING WALL, HIGH BUCKET

<u>Head on Crest, Ft</u>	<u>Type A Wall</u>		<u>Type B Wall</u>		<u>Type C Wall</u>	
	<u>Piez</u>	<u>Piez</u>	<u>Piez</u>	<u>Piez</u>	<u>Piez</u>	<u>Piez</u>
	<u>1</u>	<u>2</u>	<u>1</u>	<u>2</u>	<u>1</u>	<u>2</u>
23.8	Air	6.4				
32.2			Air	23.0	Air	12.0
35.8	2.0	32.0	Air	31.0	0.8	21.6
46.6	30.8	65.6	8.4	47.0	25.6	47.2
55.6	62.4	91.2	19.6	67.0	43.2	64.8

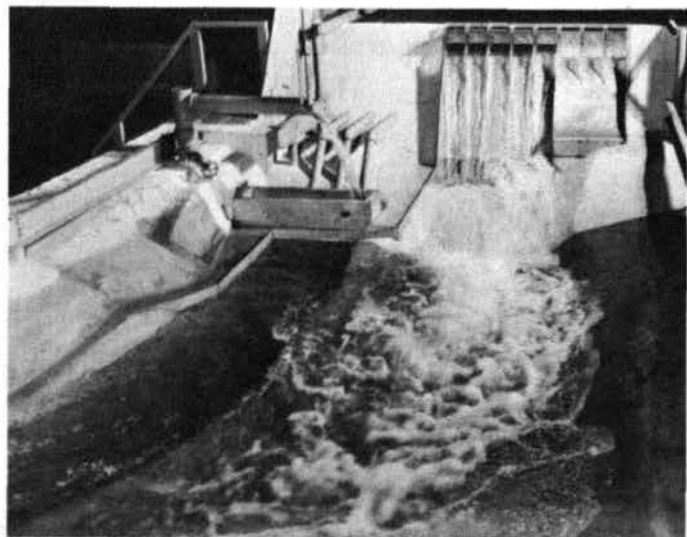
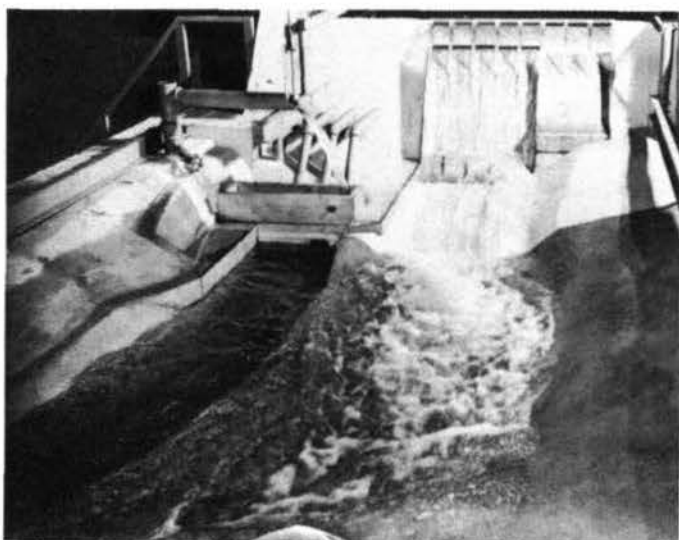
Note: Locations of piezometers are shown on plates 75 and 76. Pressures are recorded in prototype feet of water.

## PHOTOGRAPHS



Photograph 1. Spillway gates 1 through 5 open 6 ft; crest dischg, 50,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 176.5

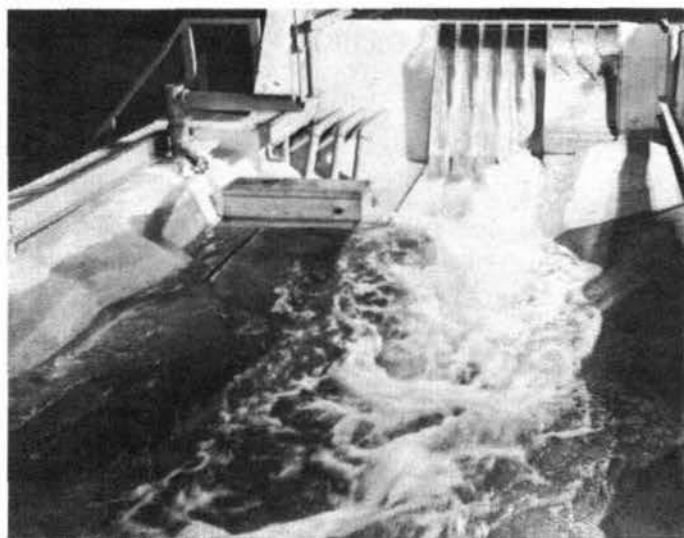
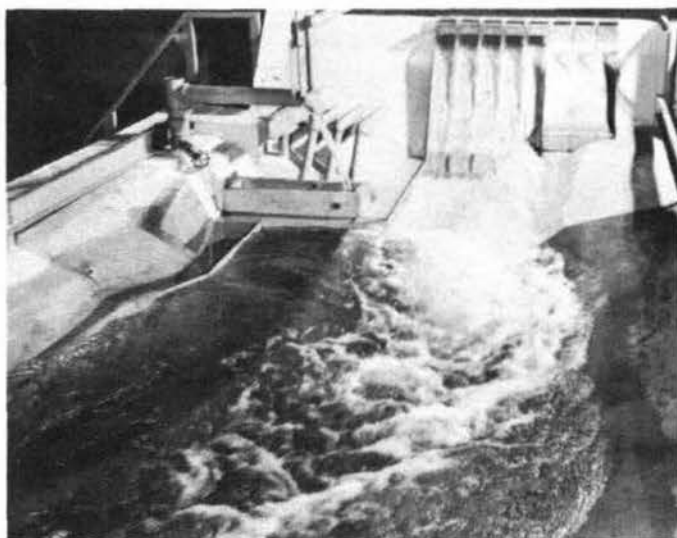
Photograph 2. Spillway gates 1 through 5 open 14 ft; crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 179.2



Photograph 3. Spillway gates 1 through 5 open 28 ft; crest dischg, 193,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 196.0

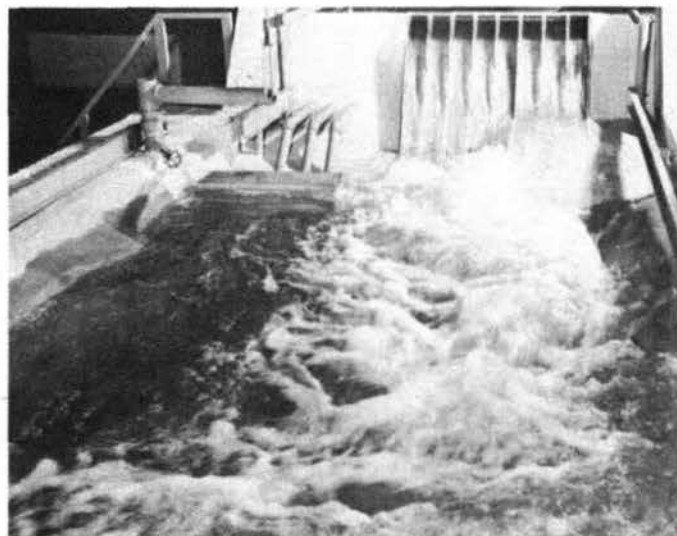
Flow conditions below the bucket of original design for discharges of 50,000, 108,000, and 193,000 cfs

Photograph 4. Spillway gates 1 through 5 open 33.75 ft; crest dischg, 243,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 205.4

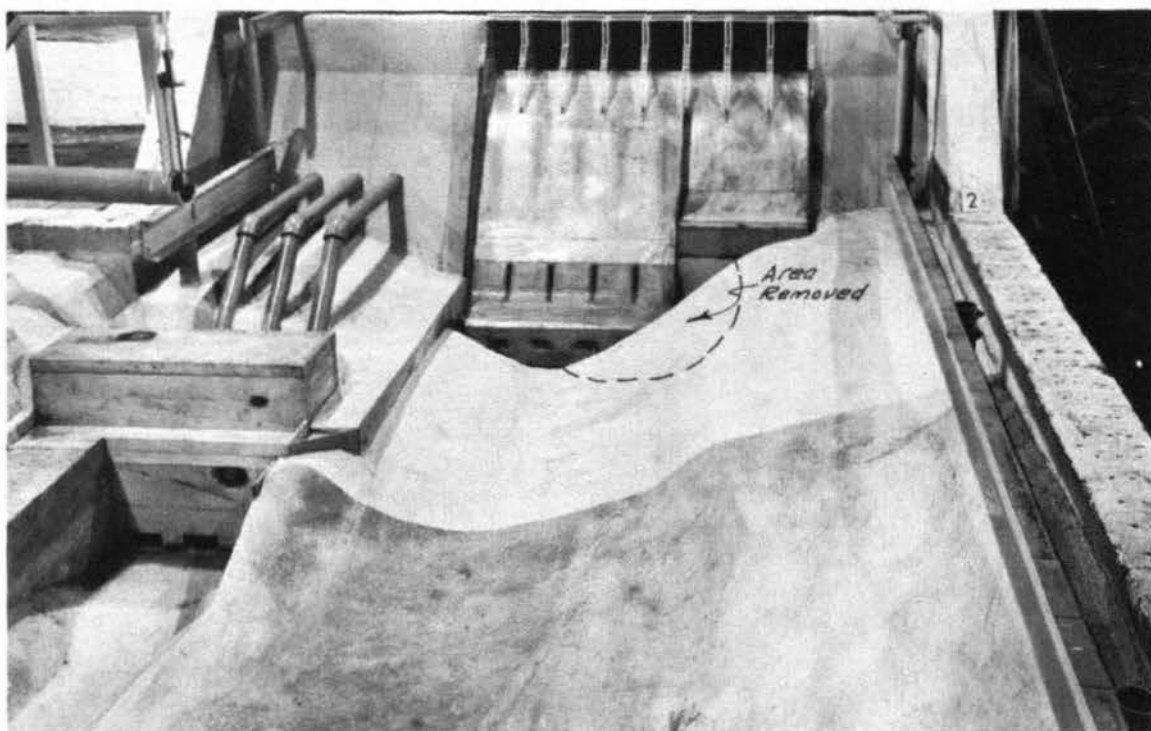


Photograph 5. Spillway gates 1 through 5 open full; crest dischg, 300,000 cfs; penstocks closed; pool elev, 469.4; tailwater elev, 212.6

Photograph 6. Spillway gates 1 through 8 open full; crest dischg, 567,000 cfs; penstocks closed; pool elev, 473.80; tailwater elev, 242.0



Flow conditions below the bucket of original design for discharges of 243,000, 300,000, and 567,000 cfs



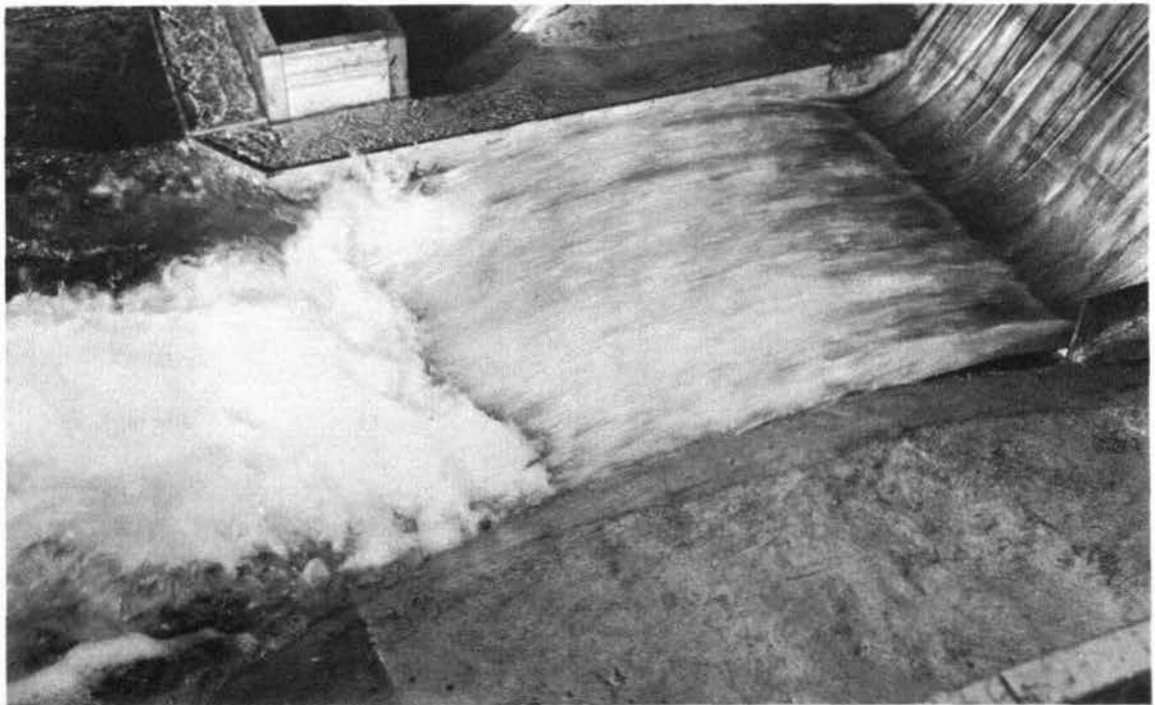
Photograph 7. Area removed on left bank downstream from main spillway bucket of original design



Photograph 8. Flow conditions below bucket of original design with contour area altered on the left bank. Spillway gates 1 through 5 open 14 ft. Crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 179.2

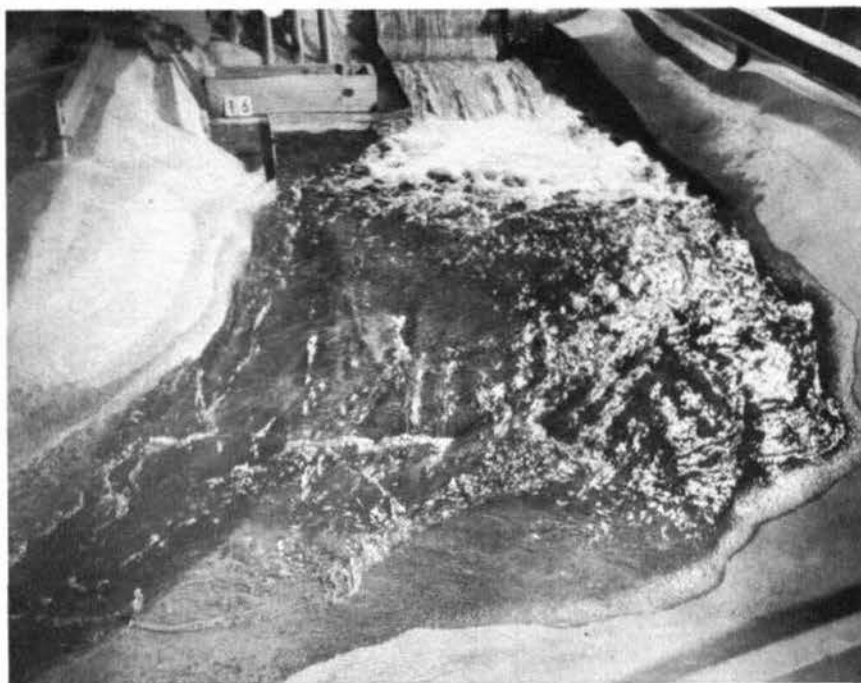


Photograph 9. Gates 1 through 5 open 28 ft; crest dischg, 193,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 196.0

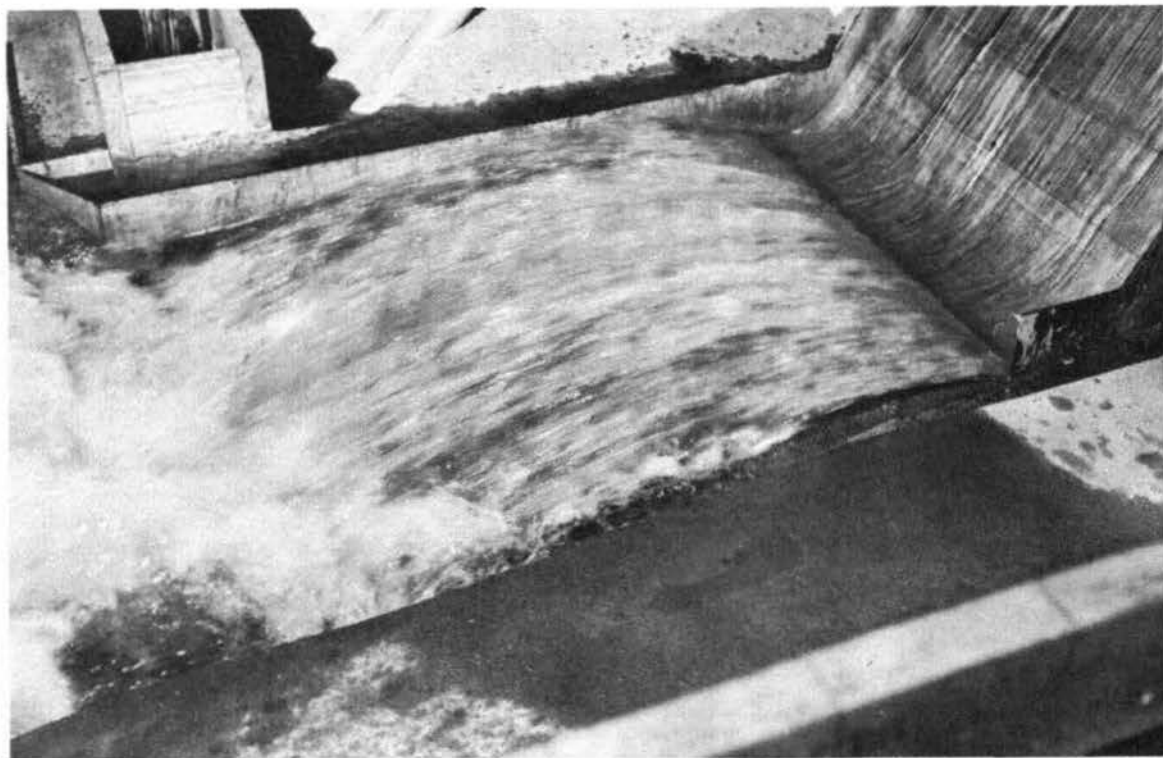


Photograph 10. Gates 1 through 5 open full; crest dischg, 300,000 cfs; penstocks closed; pool elev, 469.4; tailwater elev, 212.6

Flow conditions below bucket of original design with contour area downstream from main spillway bucket altered on left bank



Photograph 11. Flow conditions downstream from flip bucket after one-hour scour



Photograph 12. Jet action below scoured basin

Spillway gates 1 through 5 open 14 ft. Crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 187.0



Photograph 13. View of bed downstream from original flip bucket before scour test. Note large gravel as a bed material replacing pea gravel

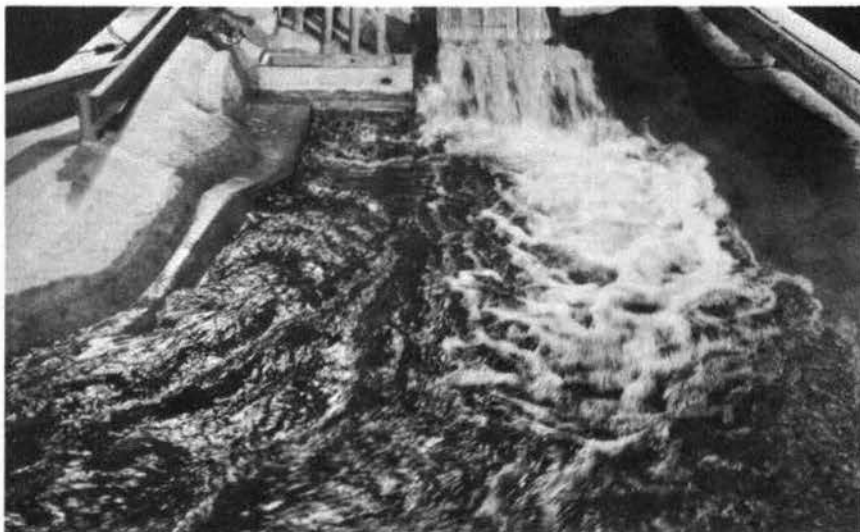
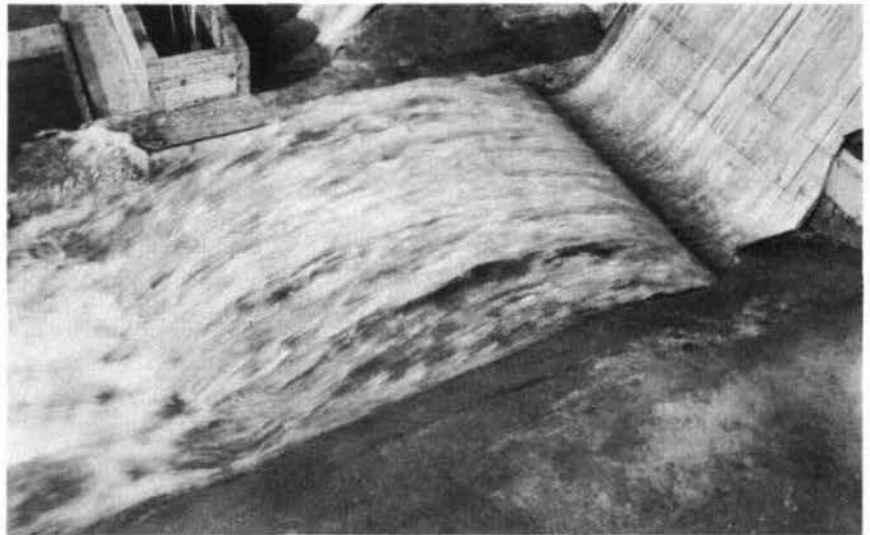


Photograph 14. View of bed downstream from original flip bucket after one-hour scour. Spillway gates 1 through 5 open 14 ft; crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 179.2



Photograph 15.  
Flow conditions  
with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2

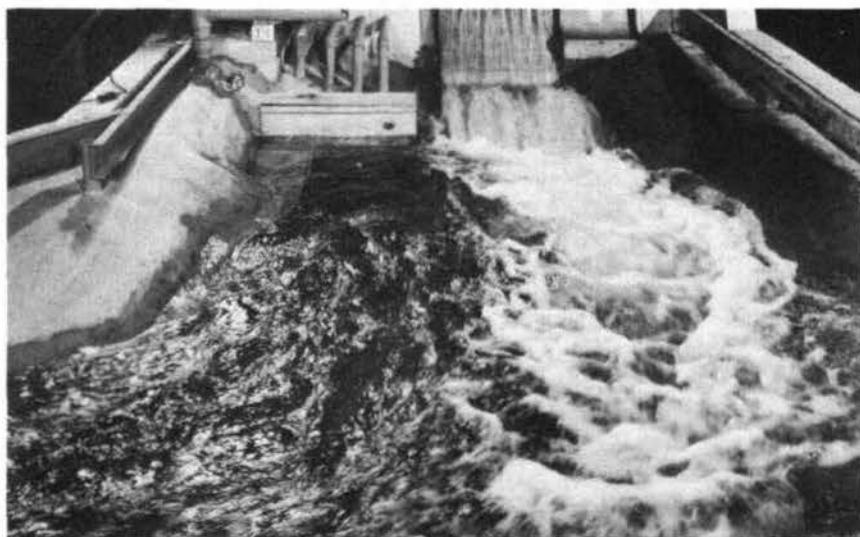
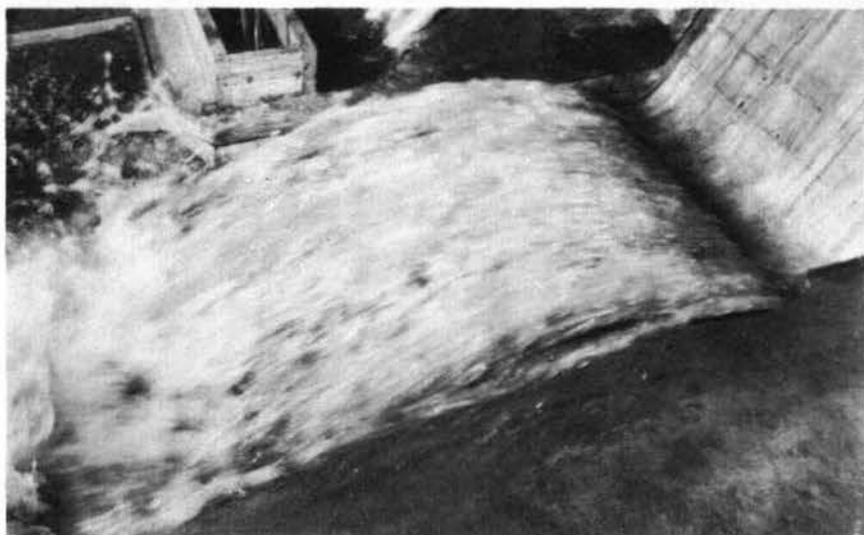
Photograph 16.  
Jet action of  
bucket.  
Gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2



Photograph 17.  
Flow conditions  
with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

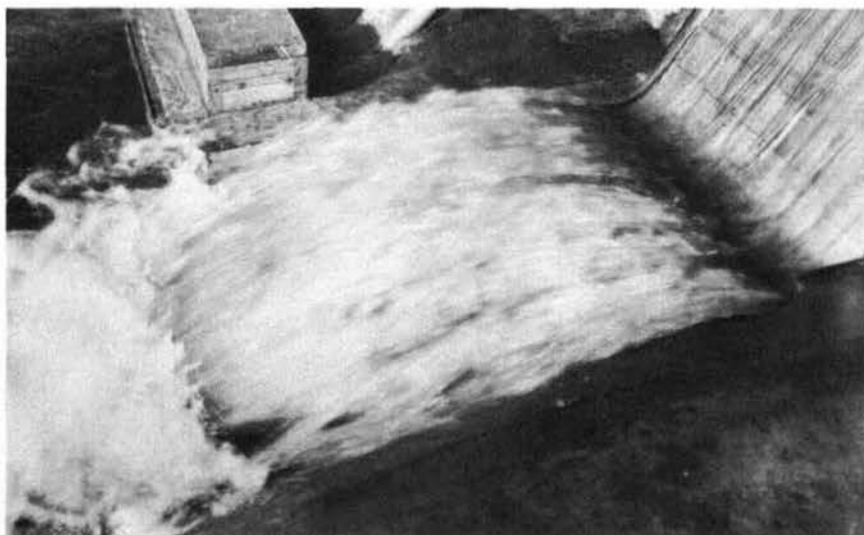
Flow conditions and jet action of flip bucket having a 30-degree terminal angle at elev 180.0 (type 2 bucket)

Photograph 18.  
Jet action of  
bucket.  
Gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0



Photograph 19.  
Flow conditions  
with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
469.4;  
tailwater elev,  
212.6

Photograph 20.  
Jet action of  
bucket.  
Gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
469.4;  
tailwater elev,  
212.6

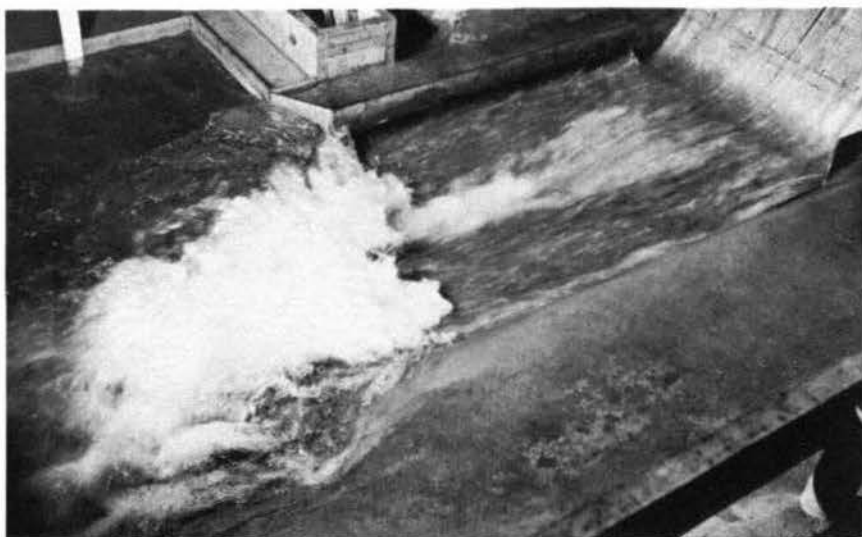


Downstream flow conditions and jet action of type 2 bucket



Photograph 21.  
 Jet action of  
 bucket.  
 Gates 1 through  
 5 open 14 ft;  
 crest dischg,  
 108,000 cfs;  
 penstock dischg,  
 7,000 cfs;  
 pool elev,  
 466.0;  
 tailwater elev,  
 179.2

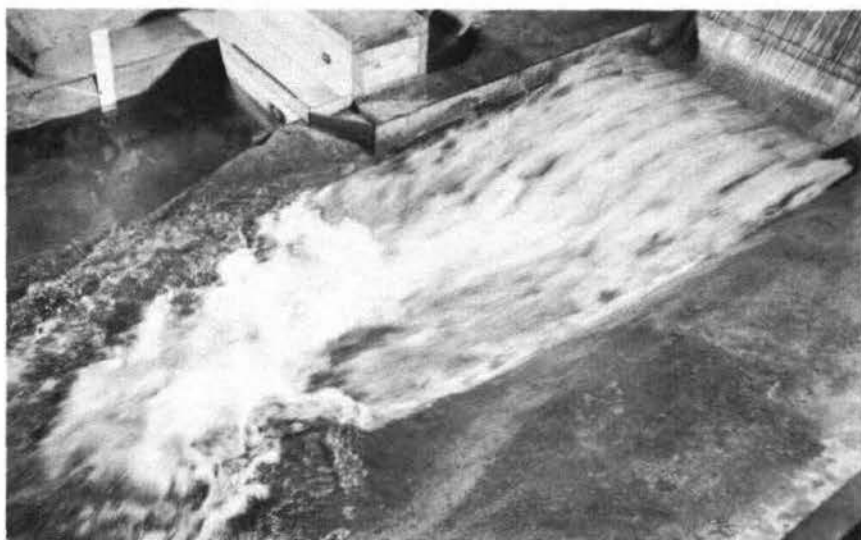
Photograph 22.  
 Jet action of  
 bucket.  
 Gates 1 through  
 5 open 28 ft;  
 crest dischg,  
 193,000 cfs;  
 penstock dischg,  
 7,000 cfs;  
 pool elev,  
 466.0;  
 tailwater elev,  
 196.0



Photograph 23.  
 Jet action of  
 bucket.  
 Gates 1 through  
 5 open full;  
 crest dischg,  
 300,000 cfs;  
 penstocks  
 closed;  
 pool elev,  
 469.4;  
 tailwater elev,  
 212.6

Jet action of the type 3 flip bucket

Photograph 24.  
Jet action of  
bucket.  
Gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2



Photograph 25.  
Jet action of  
bucket.  
Gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

Photograph 26.  
Jet action of  
bucket.  
Gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
469.4;  
tailwater elev,  
212.6

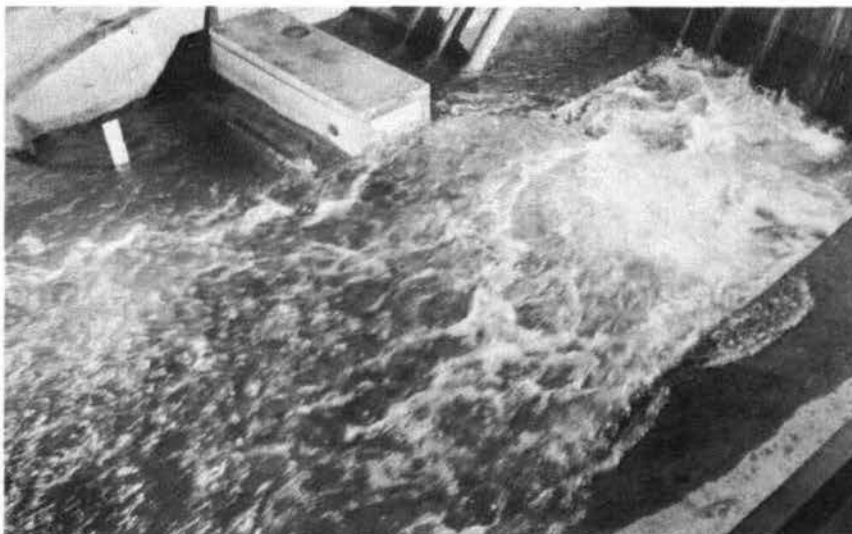
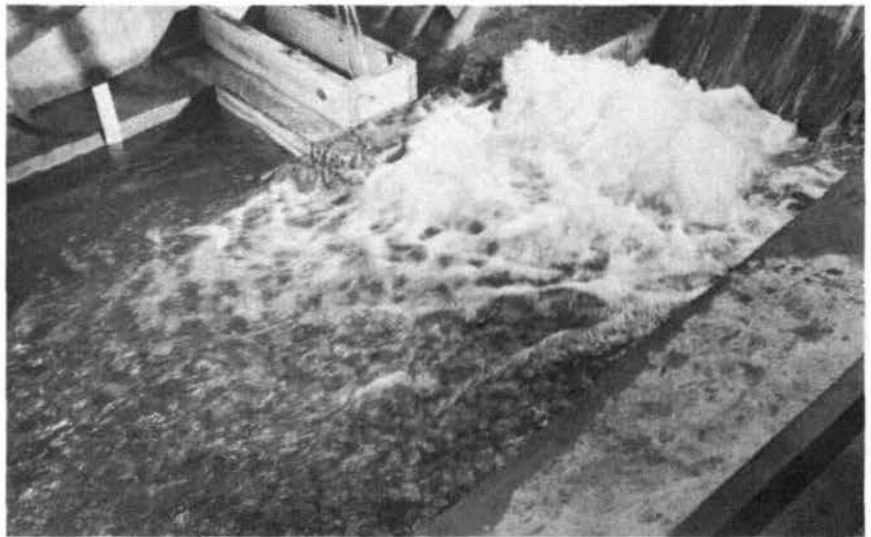


Jet action of the type 5 flip bucket



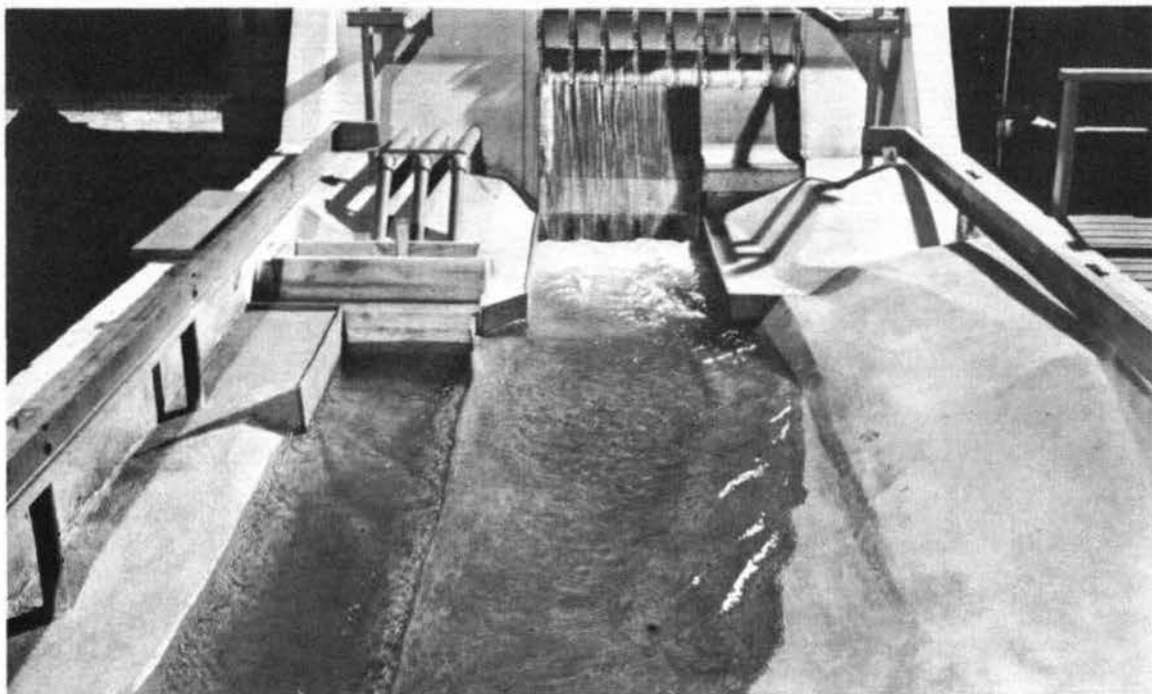
Photograph 27.  
 Jet action of  
 bucket.  
 Gates 1 through  
 5 open 14 ft;  
 crest dischg,  
 108,000 cfs;  
 penstock dischg,  
 7,000 cfs;  
 pool elev,  
 466.0;  
 tailwater elev,  
 179.2

Photograph 28.  
 Jet action of  
 bucket.  
 Gates 1 through  
 5 open 28 ft;  
 crest dischg,  
 193,000 cfs;  
 penstock dischg,  
 7,000 cfs;  
 pool elev,  
 466.0;  
 tailwater elev,  
 196.0

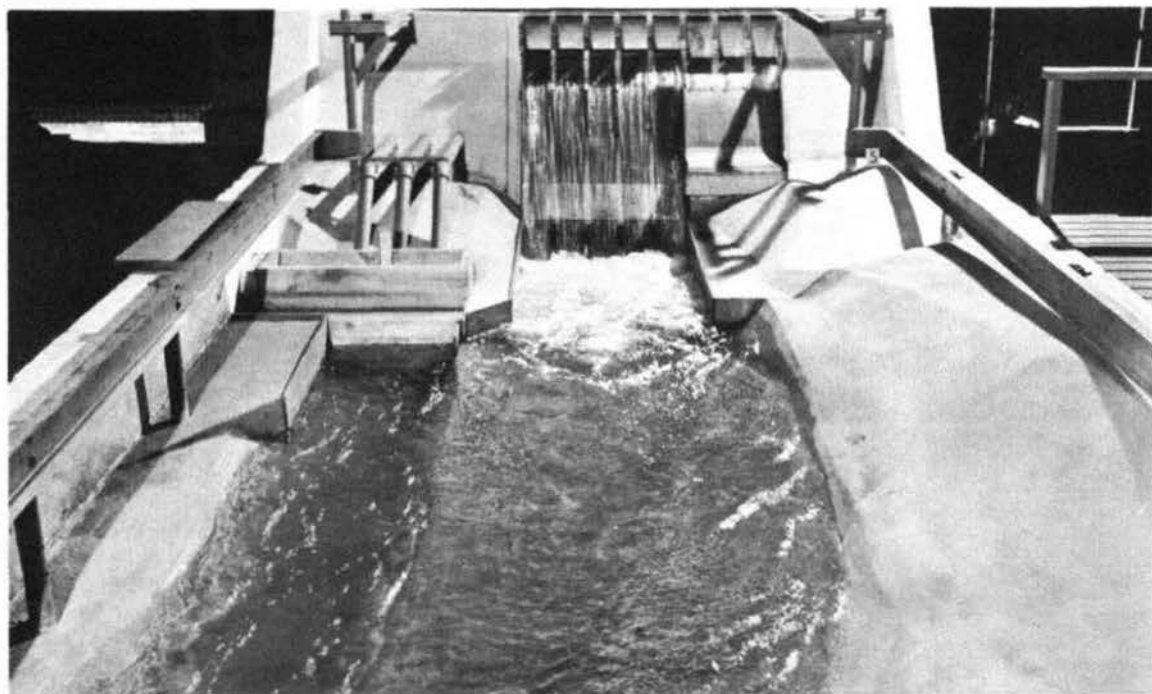


Photograph 29.  
 Jet action of  
 bucket.  
 Gates 1 through  
 5 open full;  
 crest dischg,  
 300,000 cfs;  
 penstocks  
 closed;  
 pool elev,  
 469.4;  
 tailwater elev,  
 212.6

Jet action of the type 6 flip bucket

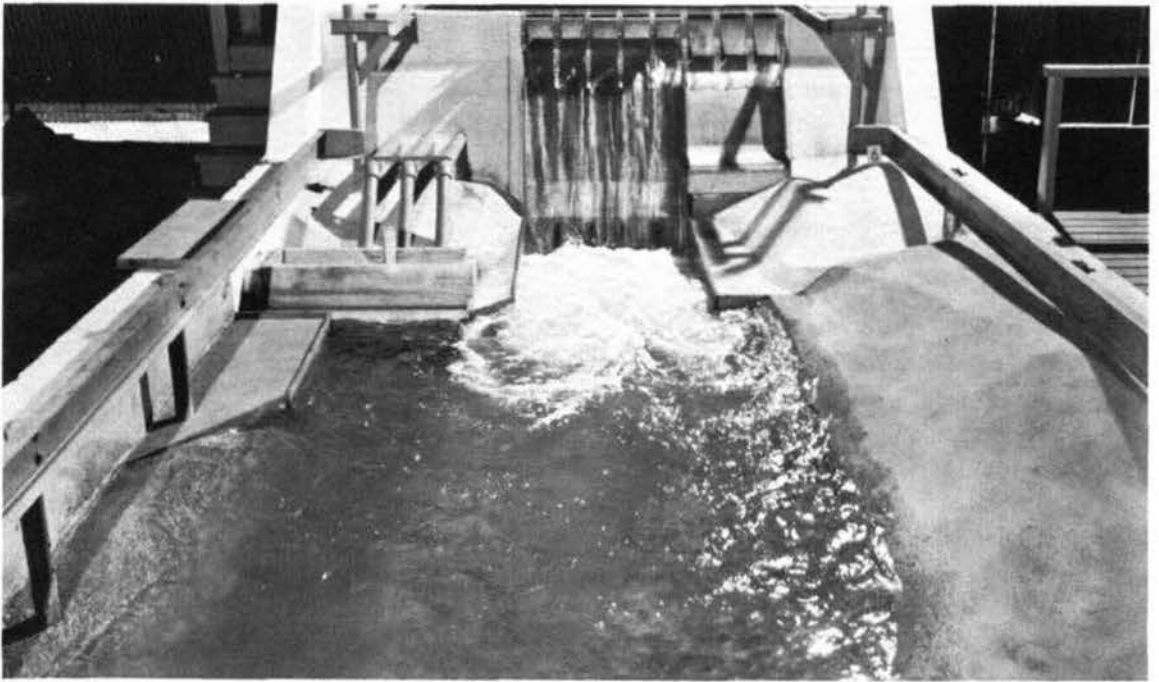


Photograph 30. Spillway gates 1 through 5 open 6 ft; crest dischg, 50,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 176.5

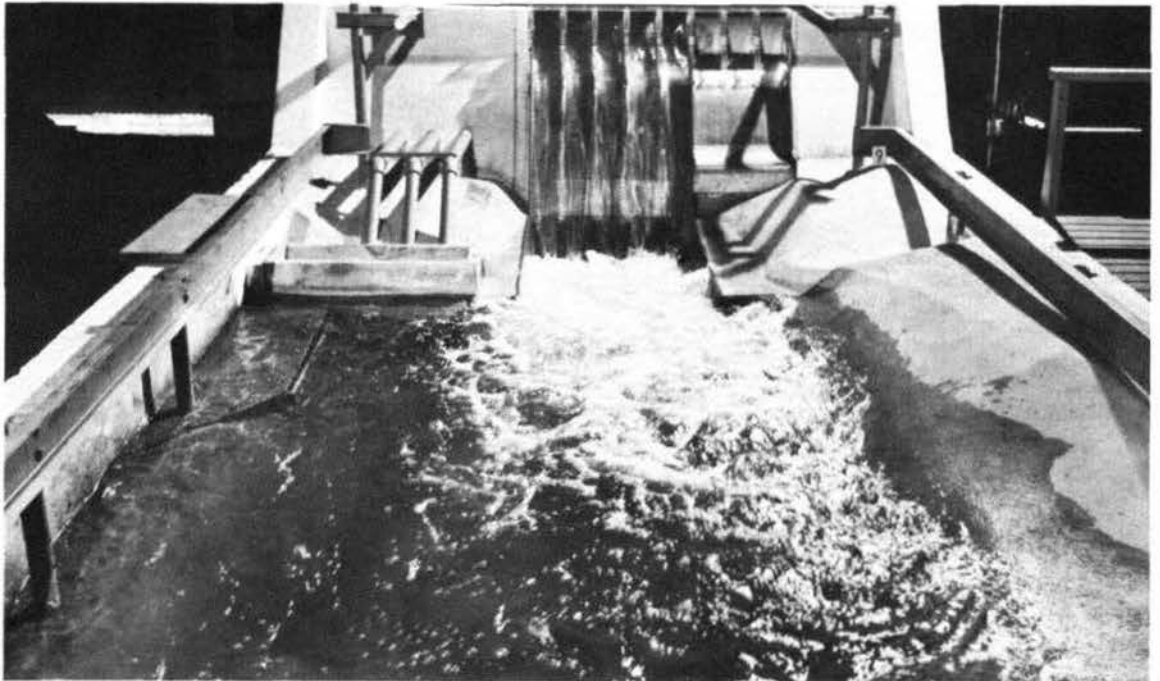


Photograph 31. Spillway gates 1 through 5 open 14 ft; crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 179.2

Flow conditions below stilling basin of original design for discharges of 50,000 and 108,000 cfs



Photograph 32. Spillway gates 1 through 5 open 28 ft; crest dischg, 193,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 196.0



Photograph 33. Spillway gates 1 through 5 open full; crest dischg, 300,000 cfs; penstocks closed; pool elev, 468.6; tailwater elev, 212.6

Flow conditions below stilling basin of original design for discharges of 193,000 and 300,000 cfs

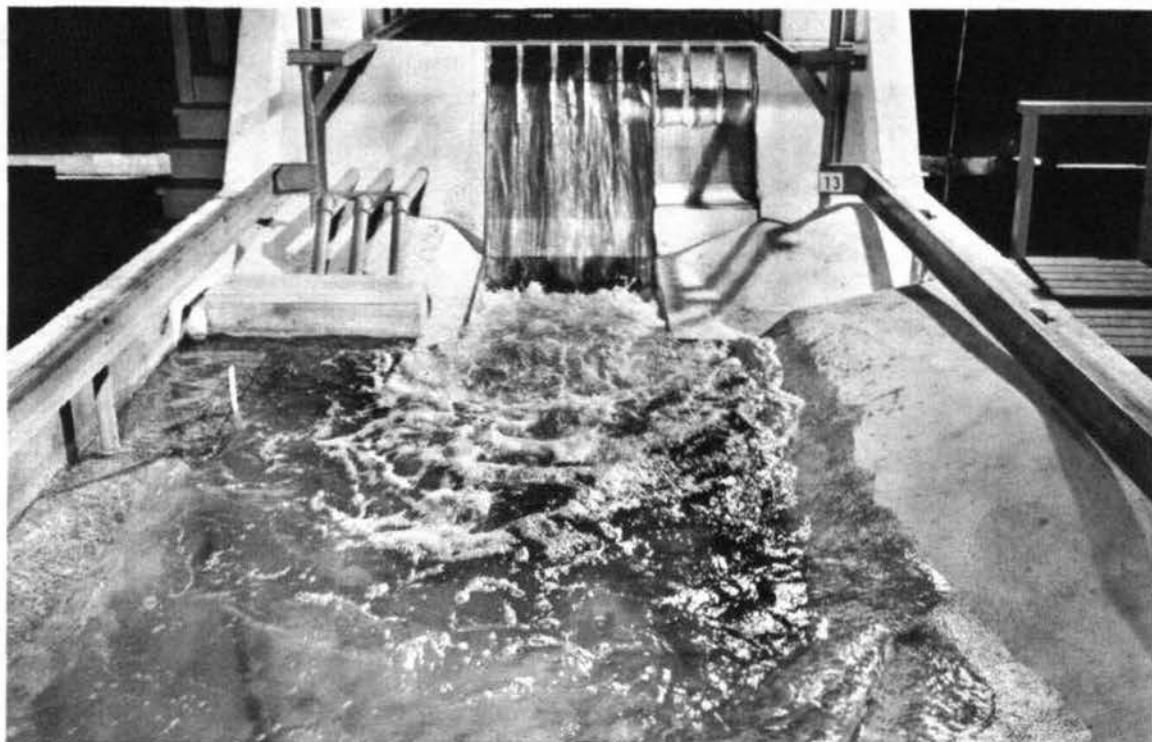


Photograph 34. Gates 1 through 5 open 14 ft; crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 179.2



Photograph 35. Gates 1 through 5 open 28 ft; crest dischg, 193,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 196.0

Stilling-basin action in the type 2 stilling basin



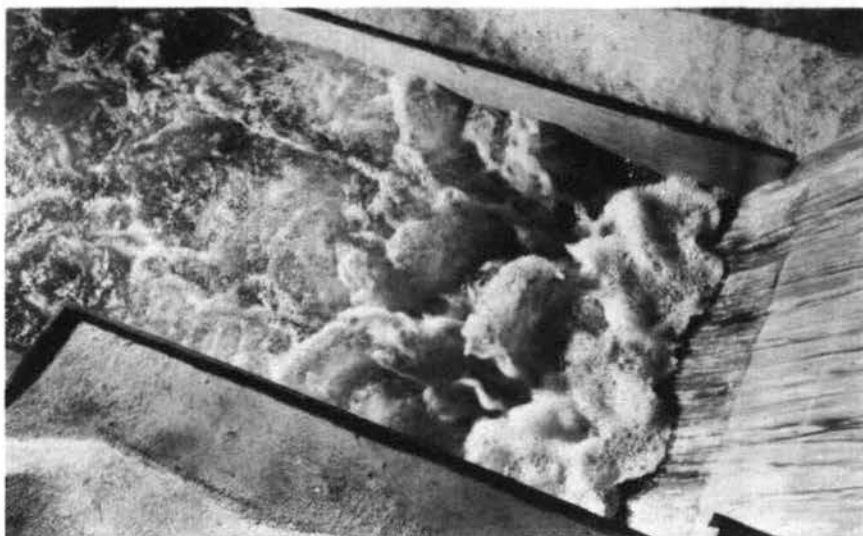
Photograph 36. Flow conditions below the type 2 stilling basin



Photograph 37. Stilling-basin action in the type 2 stilling basin

Spillway gates 1 through 5 open full; crest dischg, 300,000 cfs; penstocks closed; pool elev, 468.6; tailwater elev, 212.6

Photograph 38.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2



Photograph 39.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

Photograph 40.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6



Stilling-basin action in the type 5 stilling basin



Photograph 41.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2

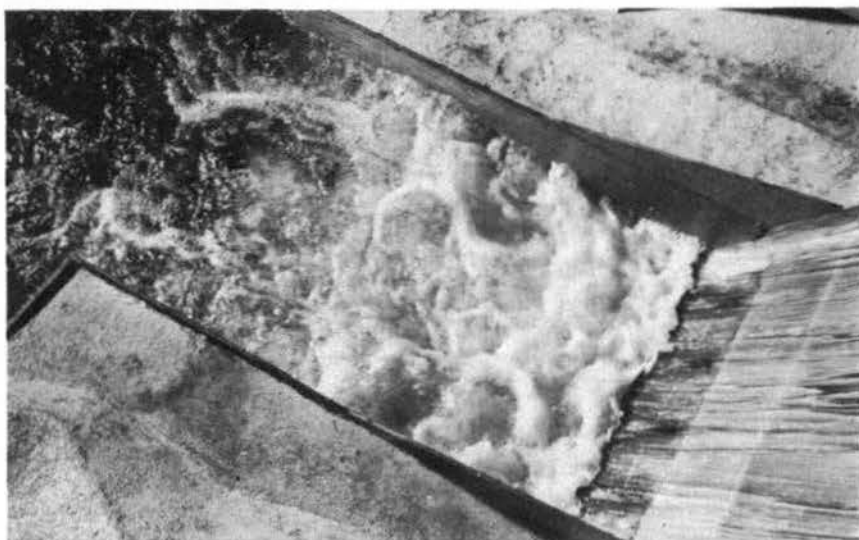
Photograph 42.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0



Photograph 43.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6

Stilling-basin action in the type 7 stilling basin

Photograph 44.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2

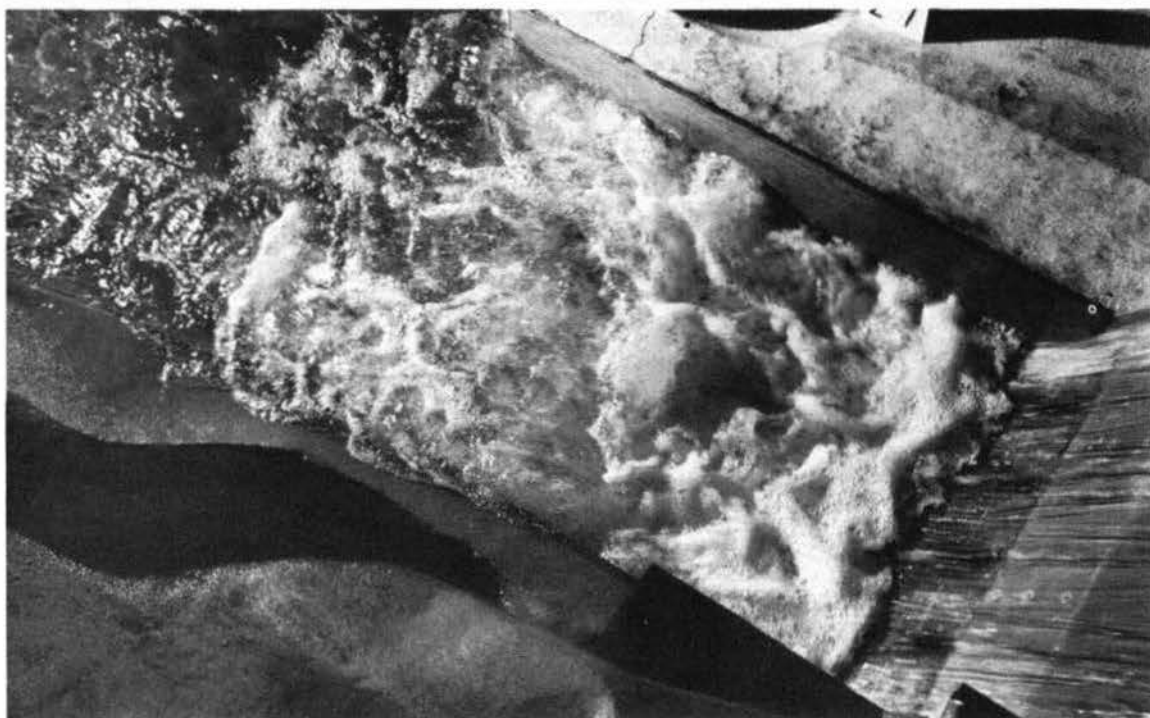


Photograph 45.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

Photograph 46.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6



Stilling-basin action in the type 9 stilling basin



Photograph 47. Gates 1 through 5 open 14 ft; crest dischg, 108,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 179.2



Photograph 48. Gates 1 through 5 open 28 ft; crest dischg, 193,000 cfs; penstock dischg, 7,000 cfs; pool elev, 466.0; tailwater elev, 196.0

Stilling-basin action in the type 10 stilling basin for discharges of 108,000 and 193,000 cfs

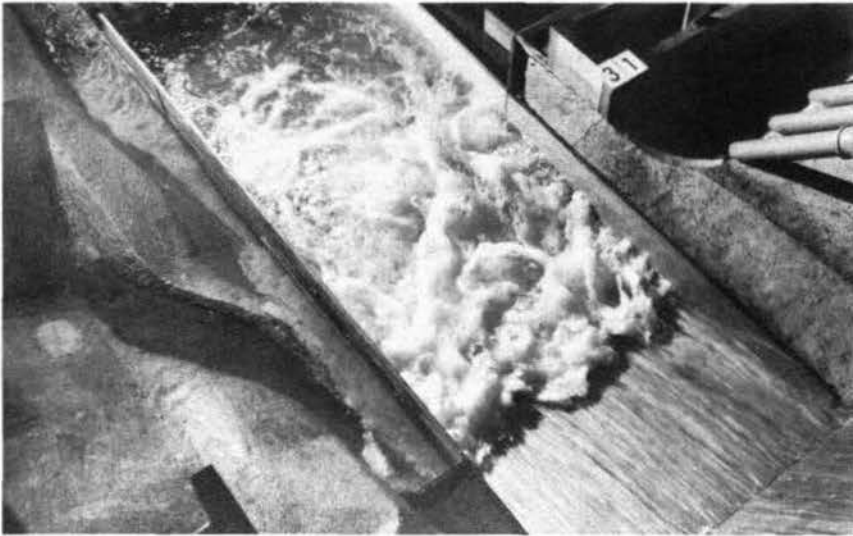


Photograph 49. Gates 1 through 5 open full; crest dischg, 300,000 cfs; penstocks closed; pool elev, 468.6; tailwater elev, 212.6



Photograph 50. Gates 1 through 8 open full; crest dischg, 567,000 cfs; penstocks closed; pool elev, 473.0; tailwater elev, 242.0

Stilling-basin action in the type 10 stilling basin for discharges of 300,000 and 567,000 cfs



Photograph 51.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2

Photograph 52.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0



Photograph 53.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6

Stilling-basin action in the type 11 stilling basin

Photograph 54.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2



Photograph 55.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

Photograph 56.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6



Stilling-basin action in the type 12 stilling basin



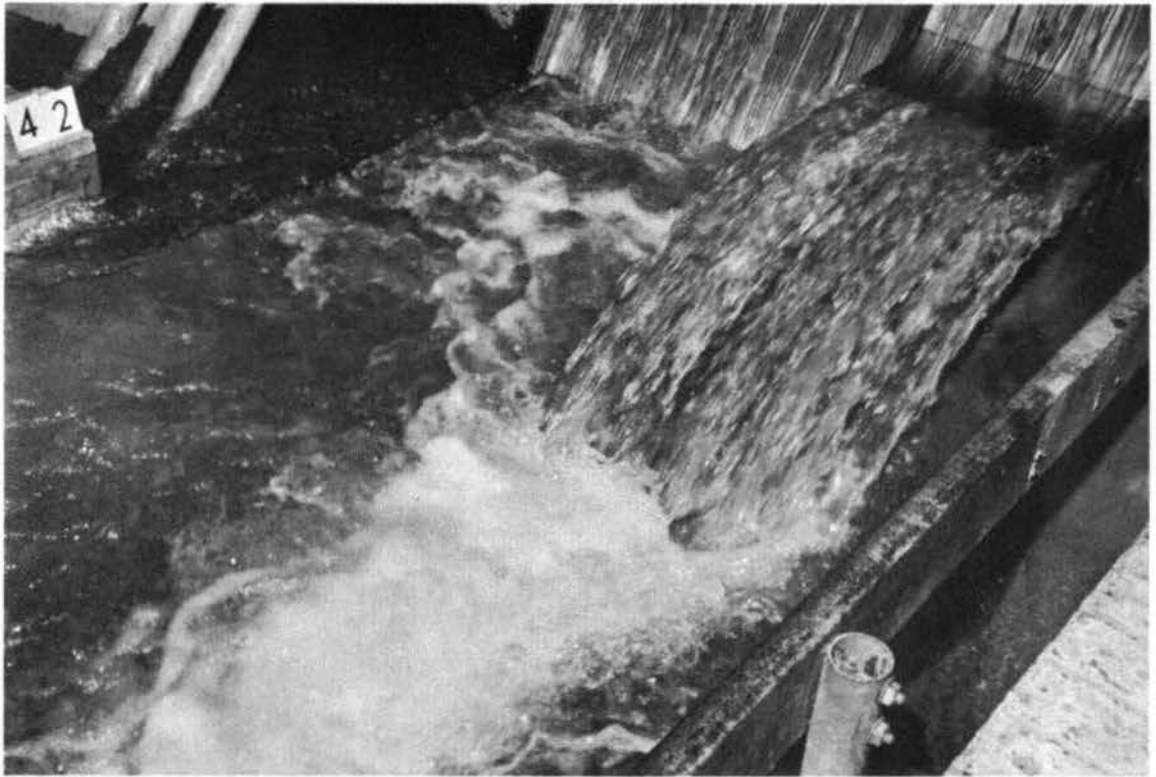
Photograph 57.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2

Photograph 58.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

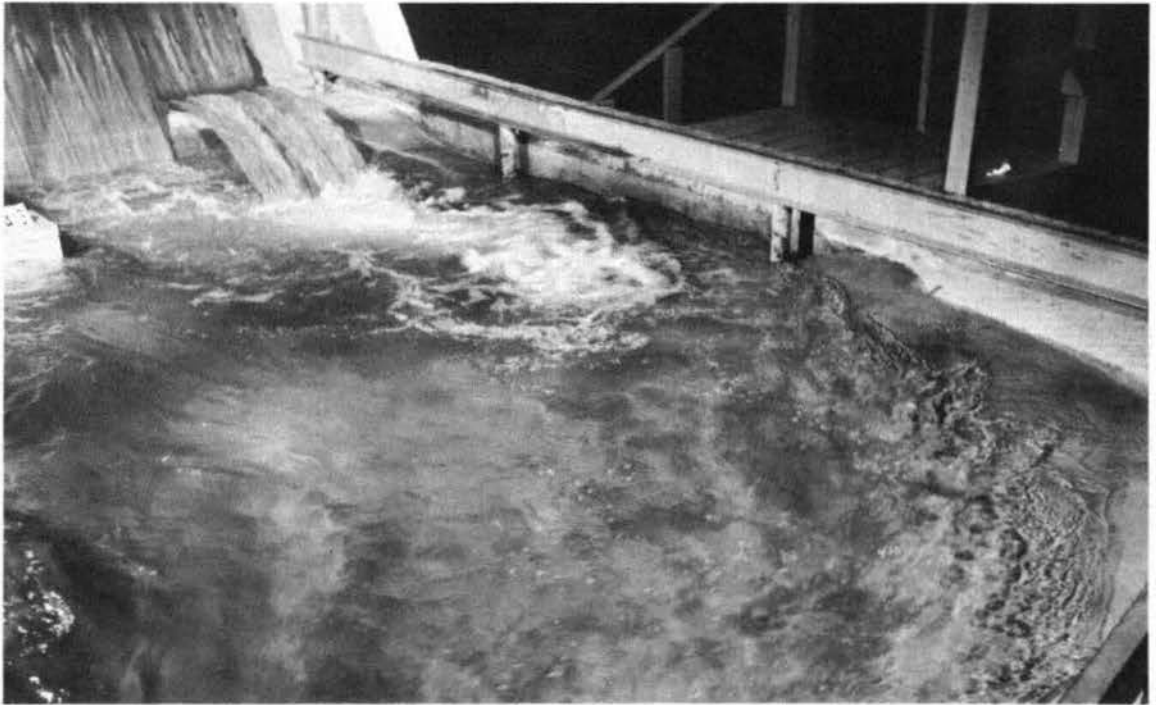


Photograph 59.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6

Stilling-basin action in the type 22 stilling basin



Photograph 60. Stilling-basin action in the type 22 stilling basin



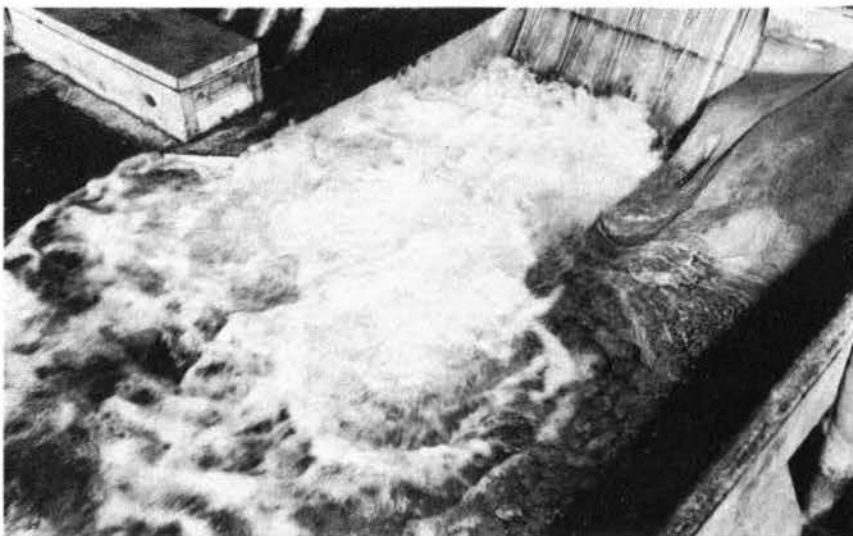
Photograph 61. Flow conditions below the type 22 stilling basin

Gates 1 through 8 open full; crest dischg, 567,000 cfs; penstocks closed;  
pool elev, 473.8; tailwater elev, 242.0



Photograph 62.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 14 ft;  
crest dischg,  
108,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
179.2

Photograph 63.  
Flow conditions  
of basin with:  
gates 1 through  
5 open 28 ft;  
crest dischg,  
193,000 cfs;  
penstock dischg,  
7,000 cfs;  
pool elev,  
466.0;  
tailwater elev,  
196.0

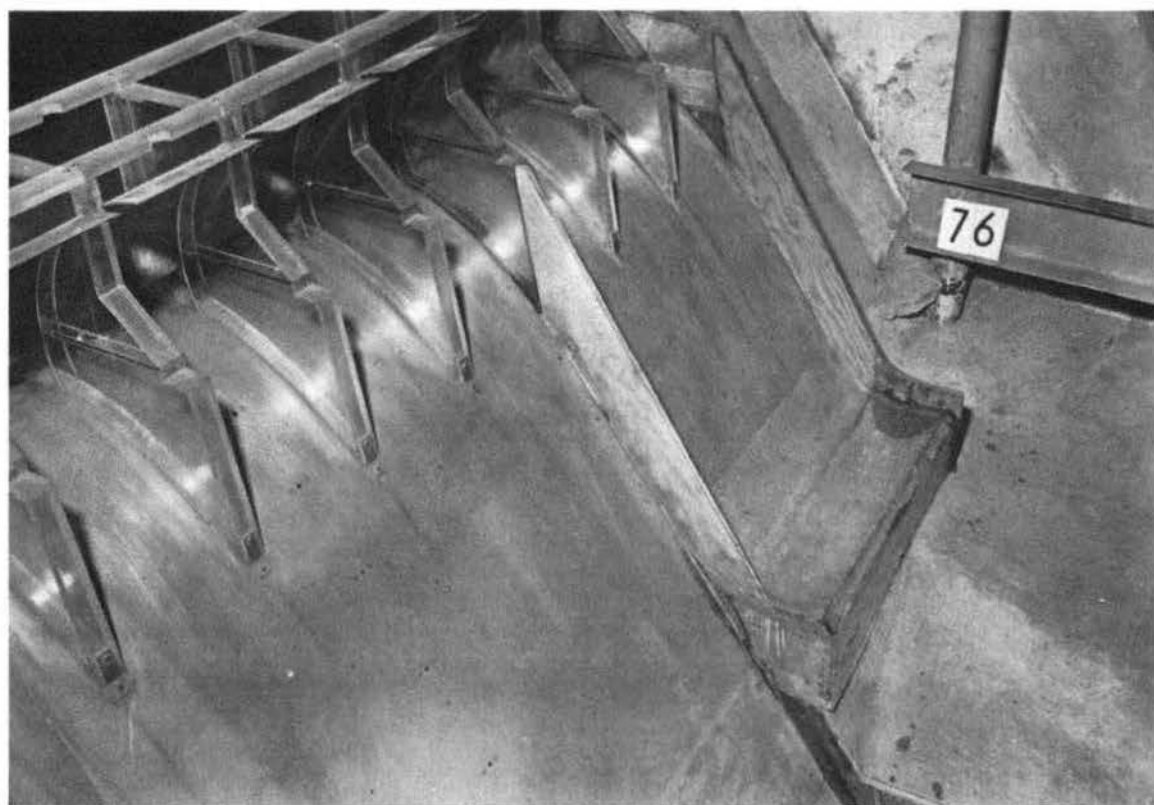


Photograph 64.  
Flow conditions  
of basin with:  
gates 1 through  
5 open full;  
crest dischg,  
300,000 cfs;  
penstocks  
closed;  
pool elev,  
468.6;  
tailwater elev,  
212.6

Stilling-basin action in the type 24 stilling basin



Photograph 65. Details of the type A center training wall



Photograph 66. Details of the type B center training wall



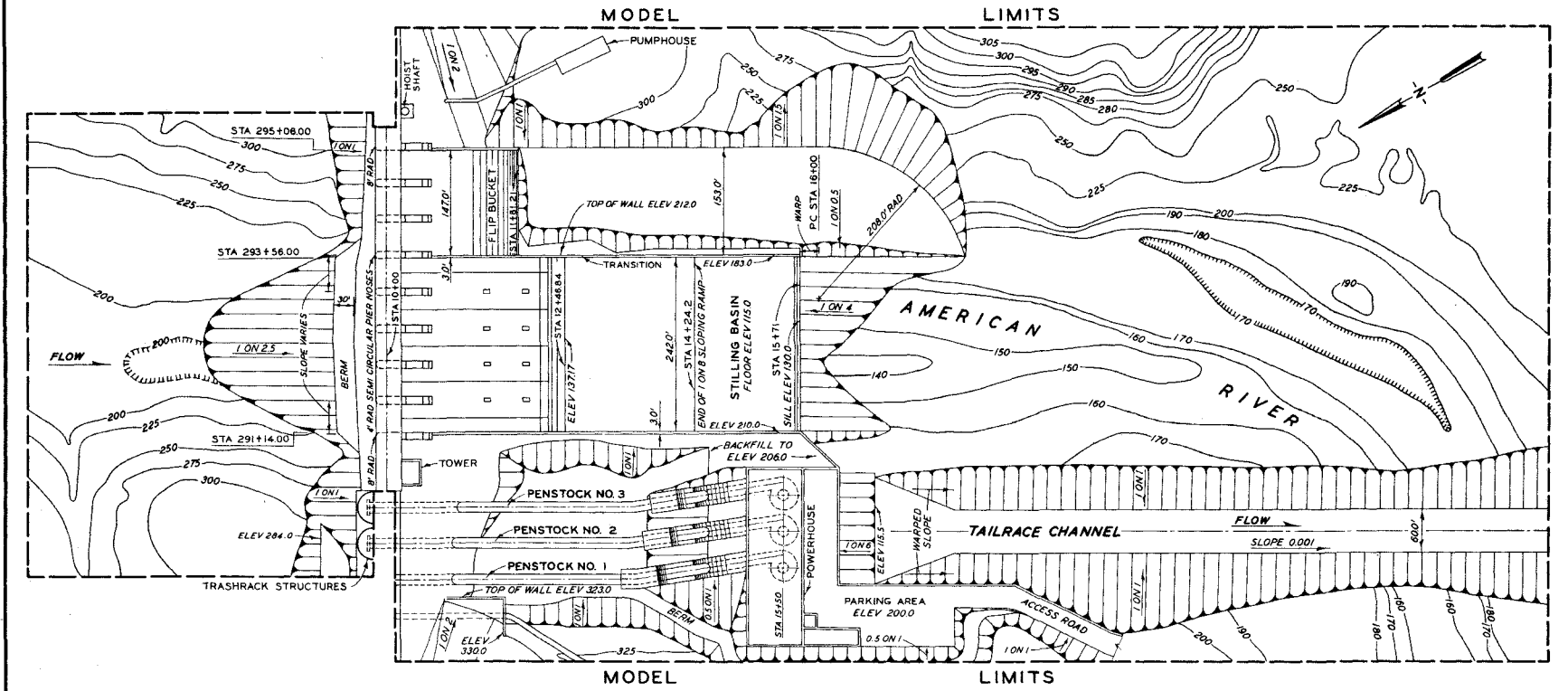
Photograph 67. Details of type C center training wall



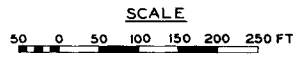
Photograph 68. Flow conditions along type B center training wall. Gates 1 through 8 open full. Crest dischg, 567,000 cfs; pool elev, 473.8

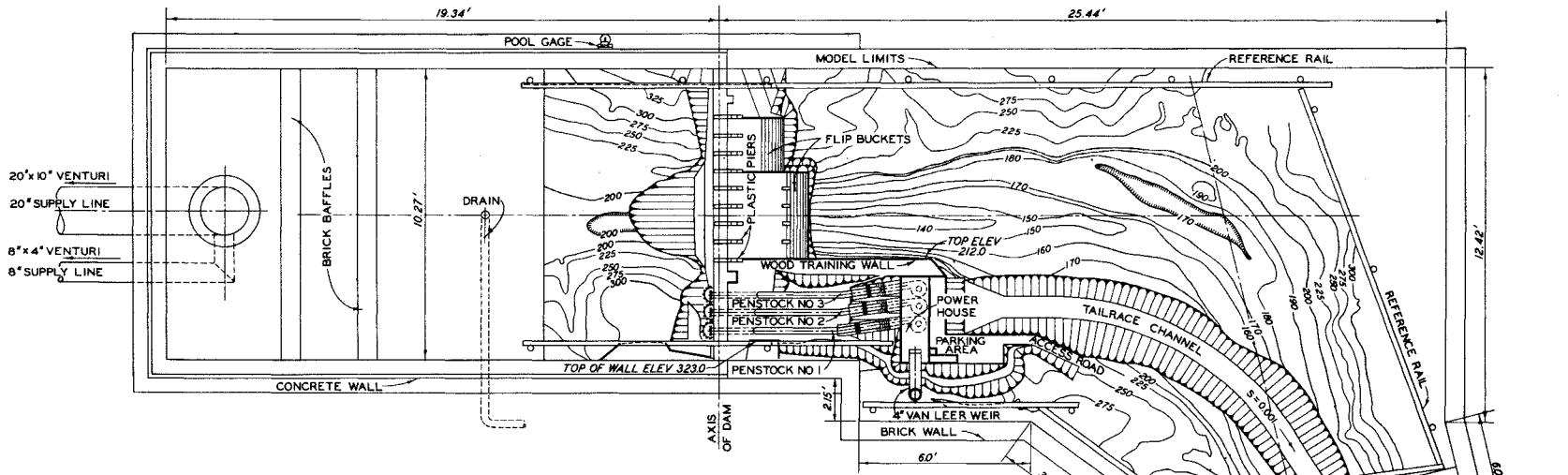
## PLATES



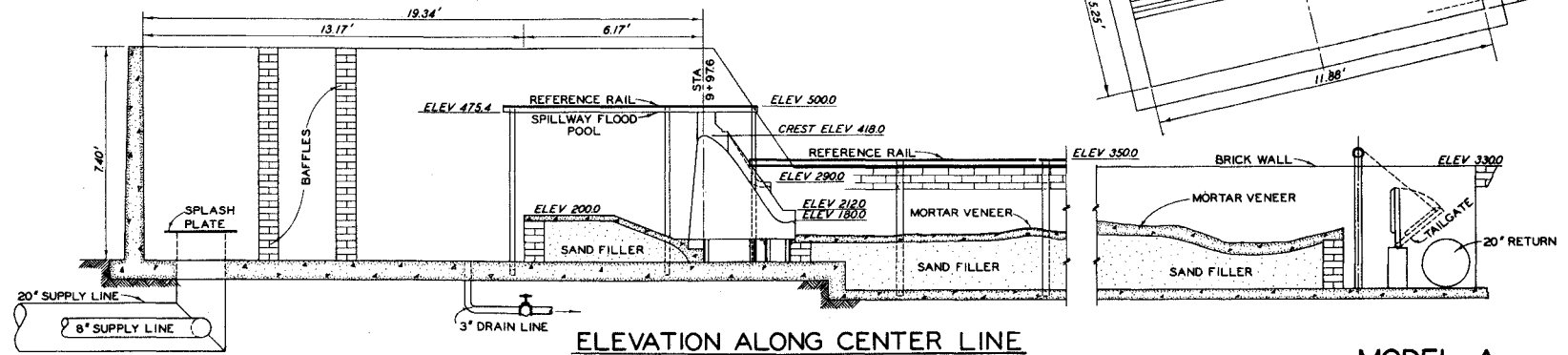


GENERAL PLAN



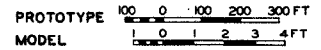


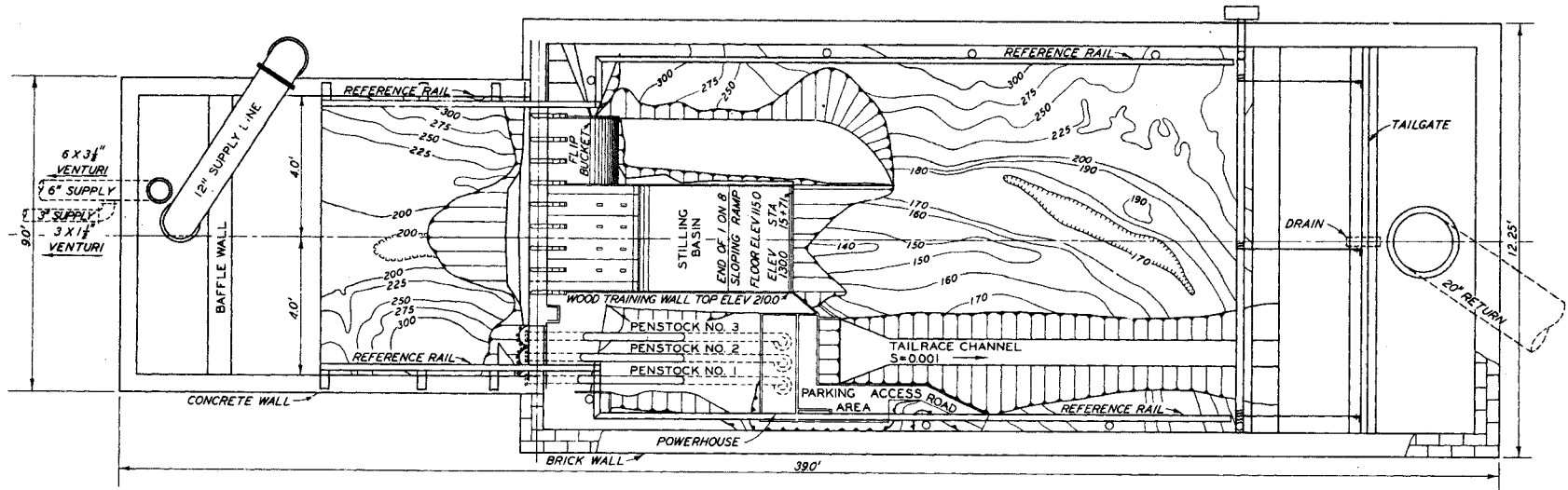
PLAN



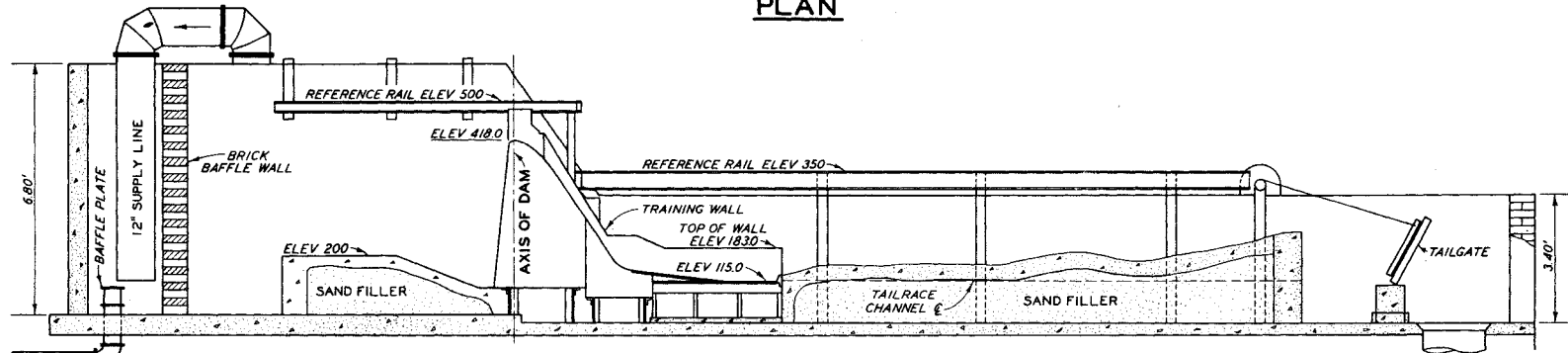
ELEVATION ALONG CENTER LINE

MODEL A  
MODEL LAYOUT  
SCALES



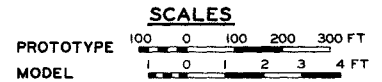


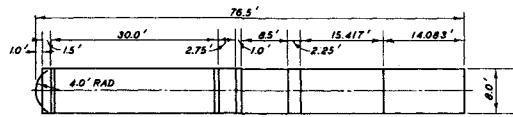
PLAN



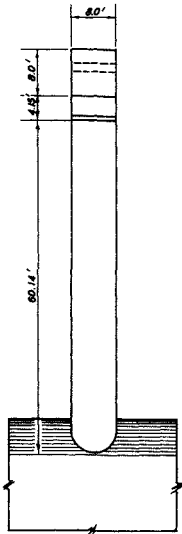
ELEVATION ALONG CENTER LINE

MODEL B  
MODEL LAYOUT

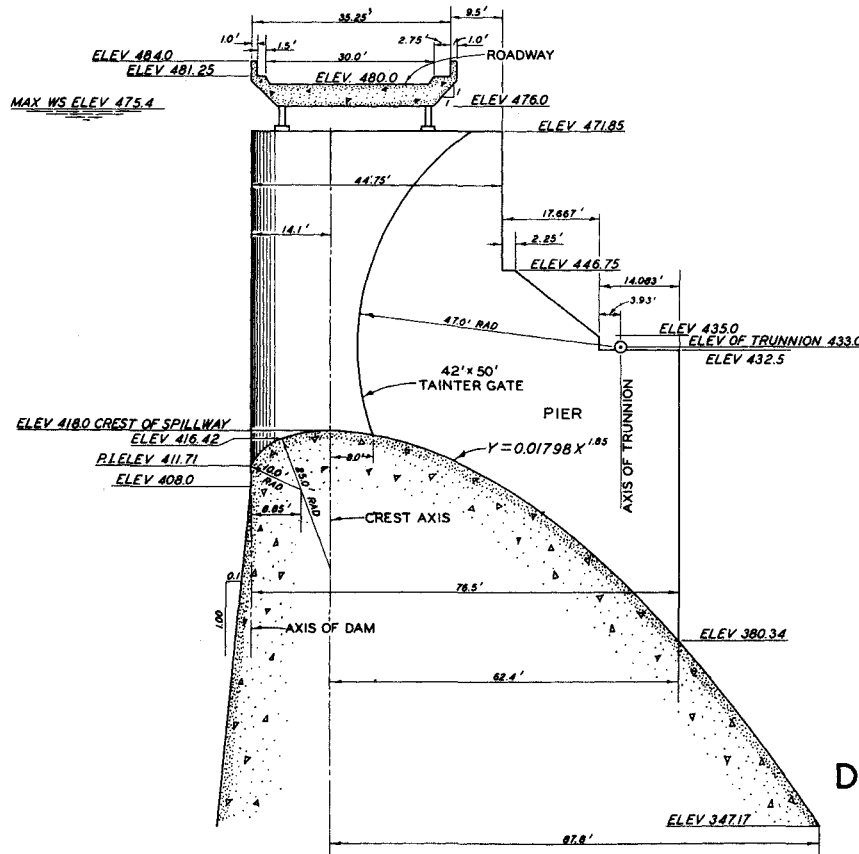




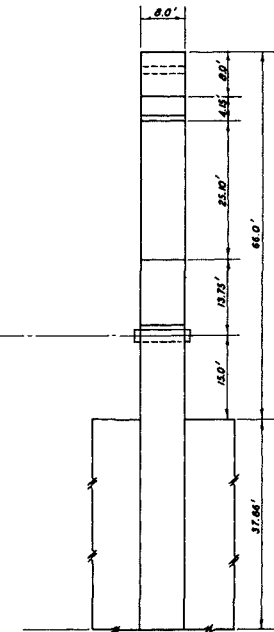
PLAN



UPSTREAM ELEVATION

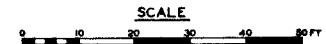


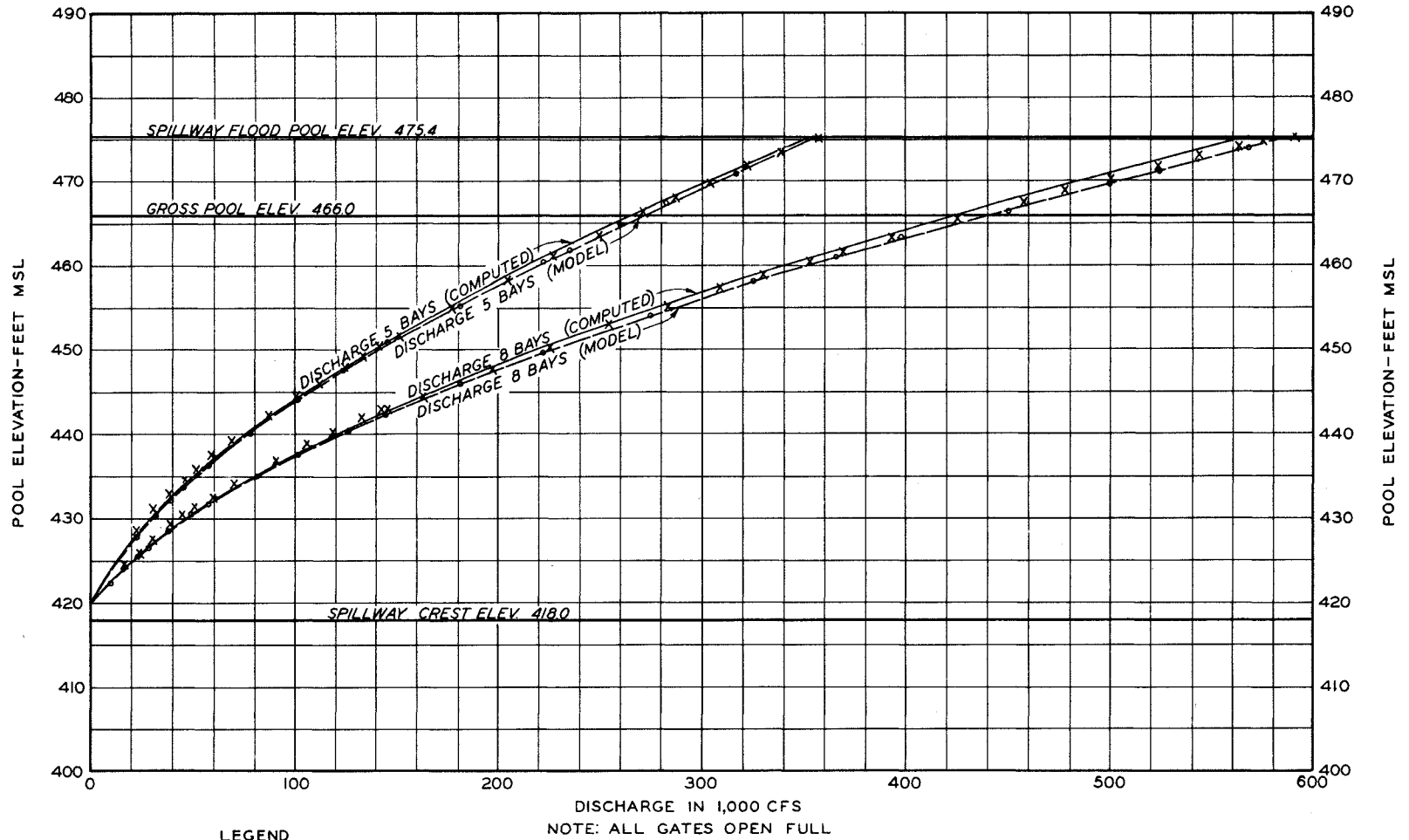
SIDE ELEVATION



DOWNSTREAM ELEVATION

DETAILS OF SPILLWAY CREST  
MODELS A AND B

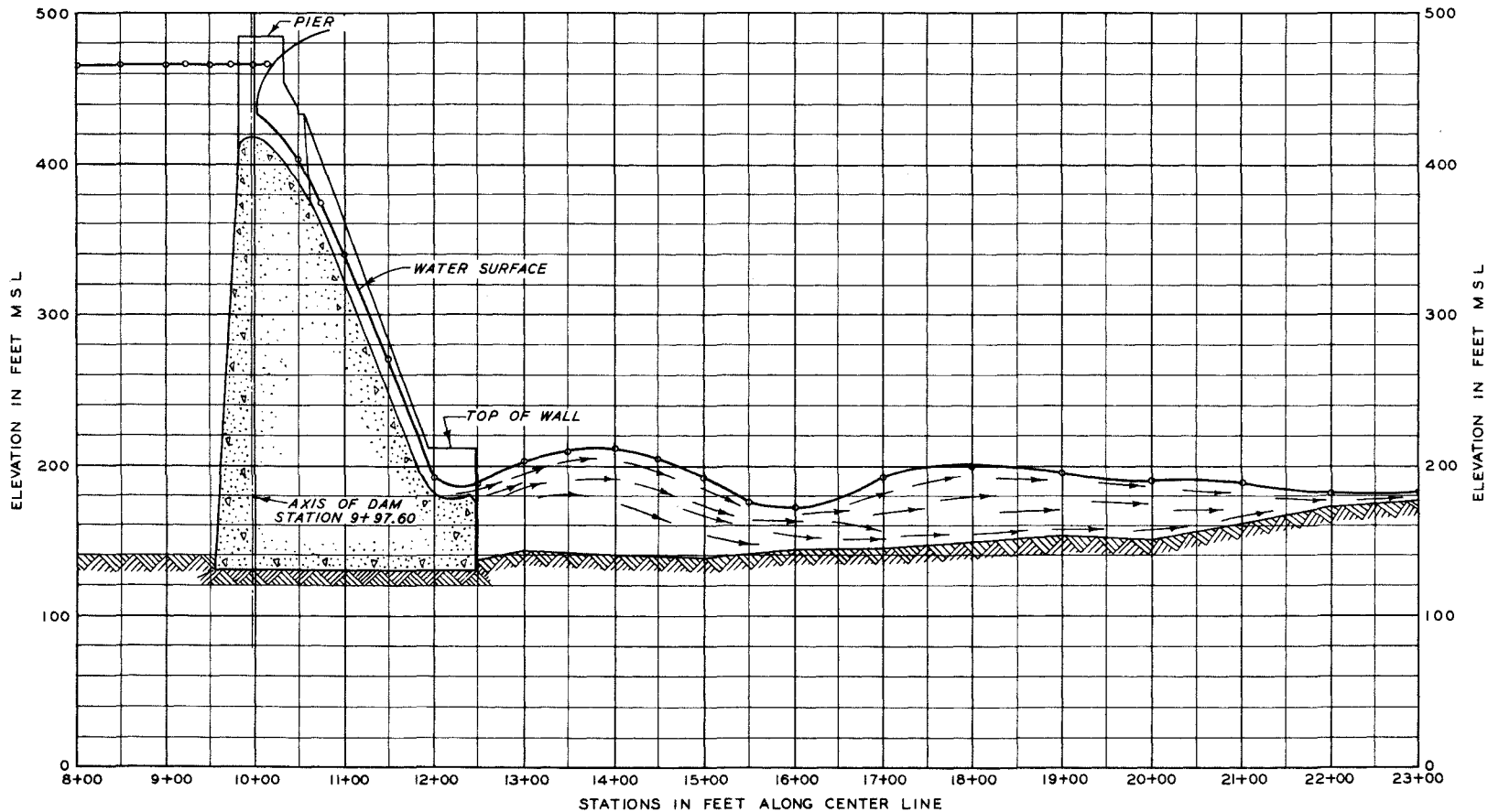




**LEGEND**

- O MODEL A
- X MODEL B

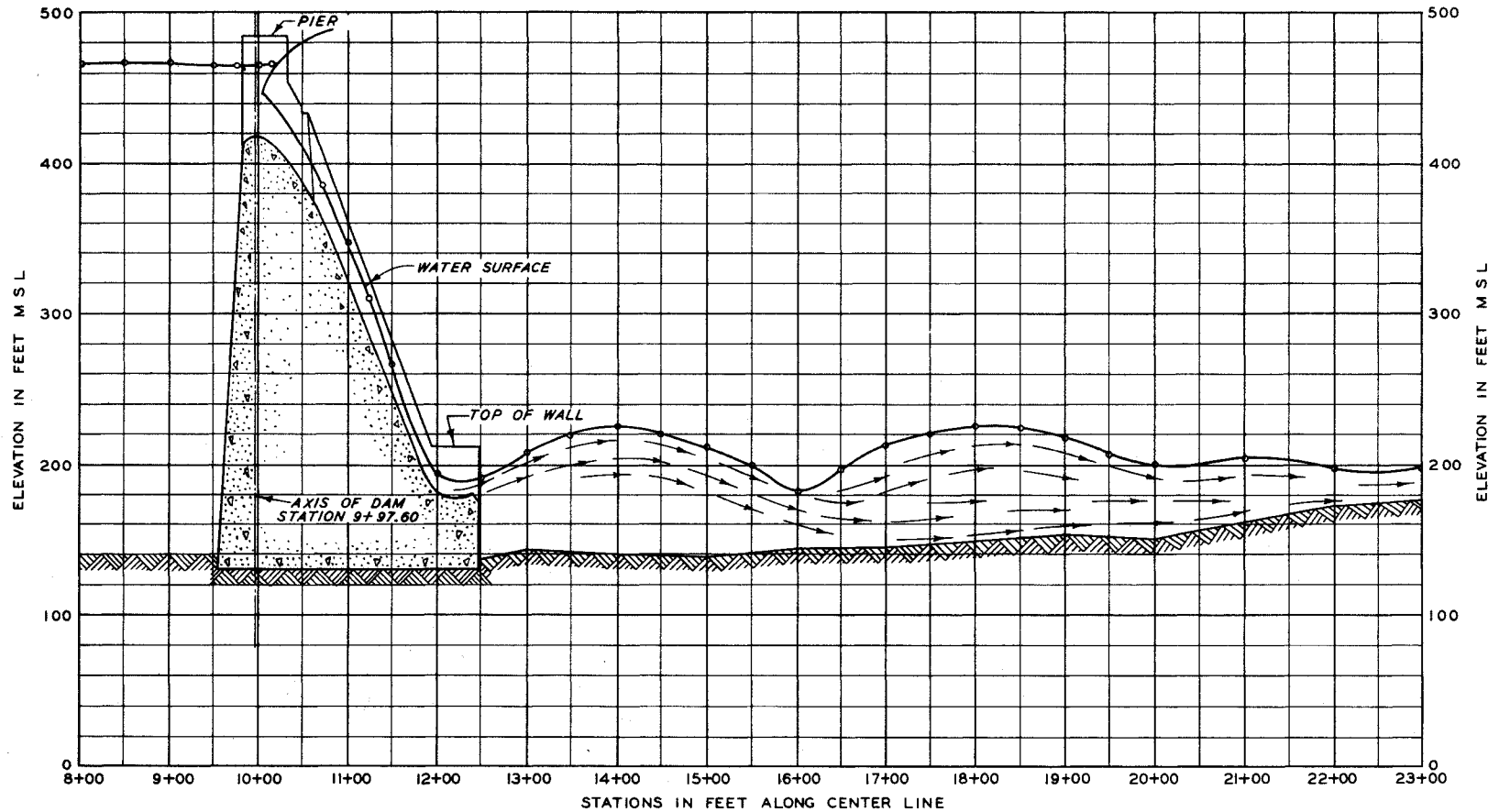
**DISCHARGE CURVES  
ORIGINAL DESIGN**



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 179.20 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 ± FT (6,7 & 8 CLOSED)

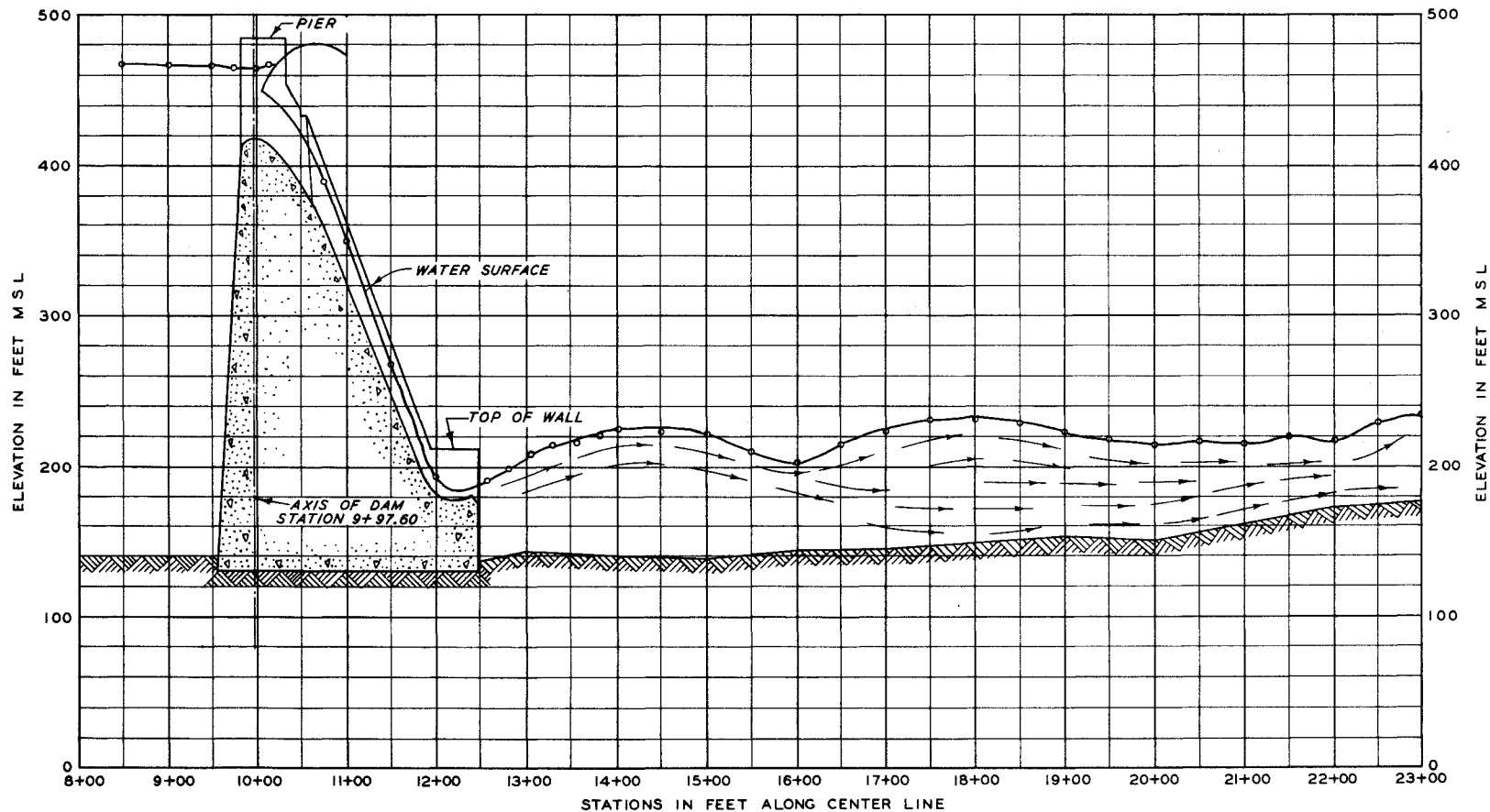
MODEL A  
**WATER-SURFACE PROFILE**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 108,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

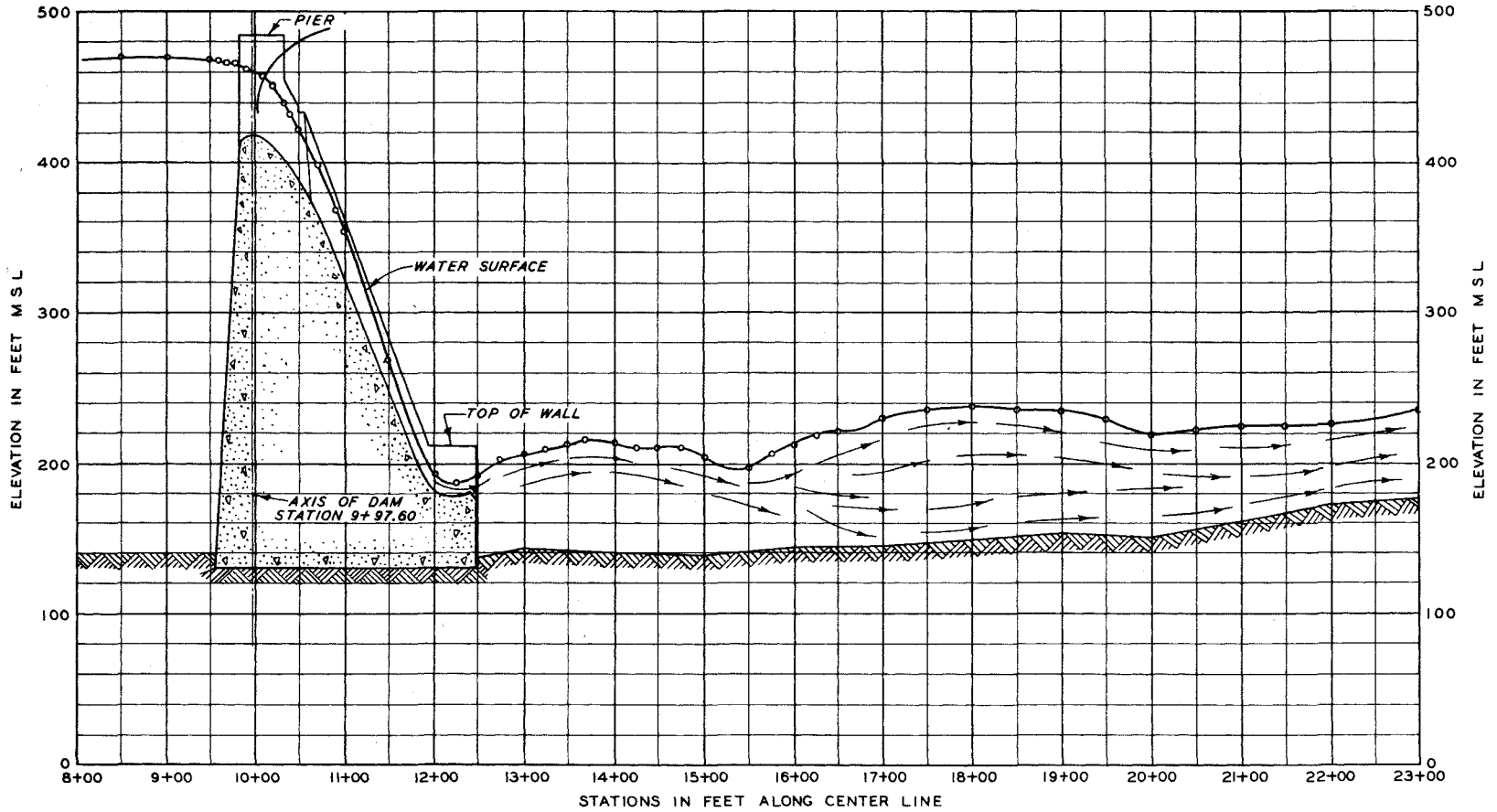
MODEL A  
**WATER-SURFACE PROFILE**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 193,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 205.40 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 33.75 FT (6,7 & 8 CLOSED)

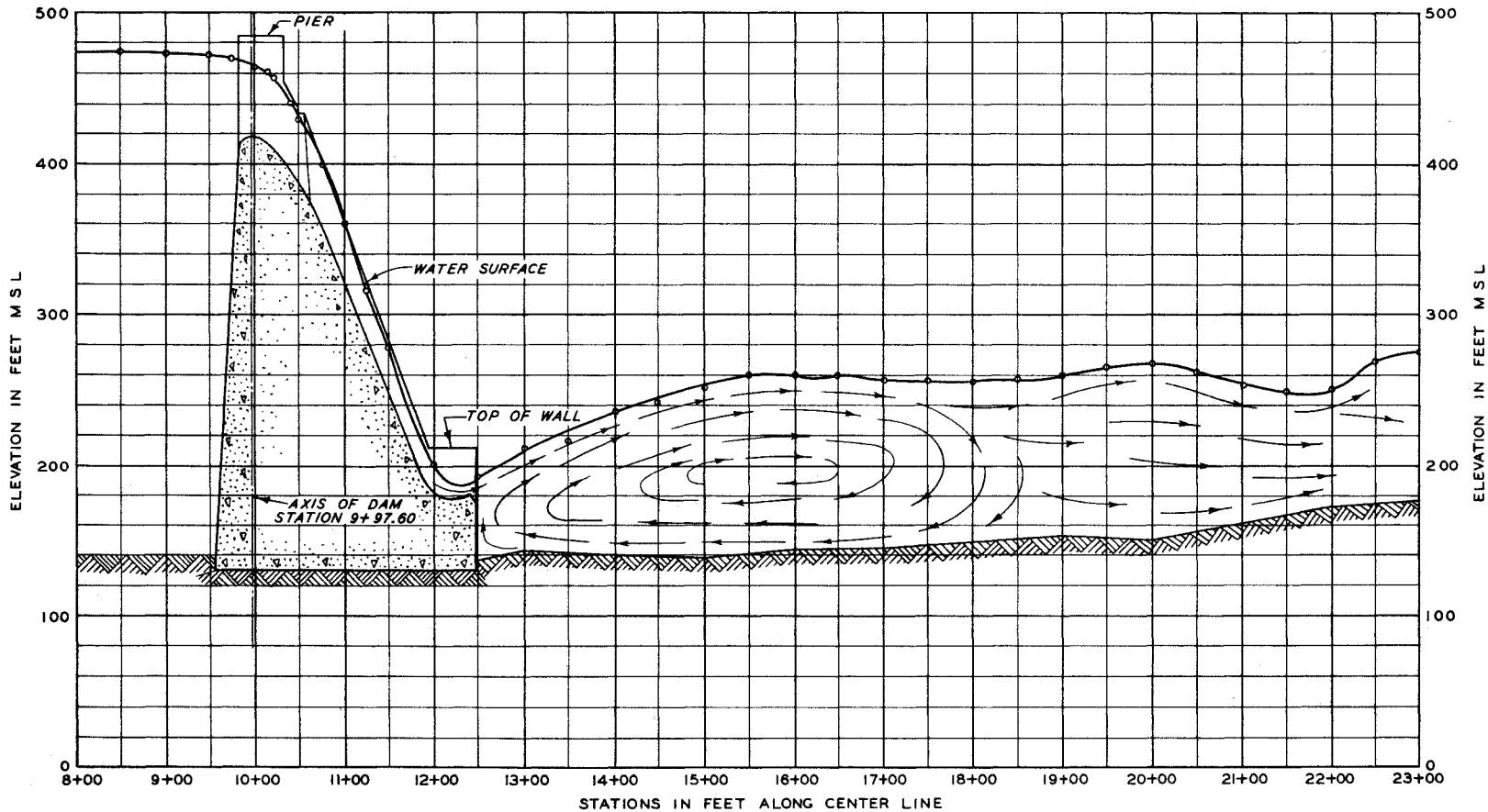
MODEL A  
**WATER-SURFACE PROFILE**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 243,000 CFS



TEST CONDITIONS

ORIGINAL DESIGN  
 POOL ELEV        469.40 FT  
 TAILWATER ELEV   212.60 FT  
 PENSTOCKS & CONDUITS CLOSED  
 5 BAYS OPEN FULL (6,7 & 8 CLOSED)

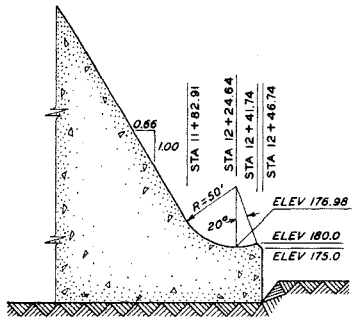
MODEL A  
**WATER-SURFACE PROFILE**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 300,000 CFS



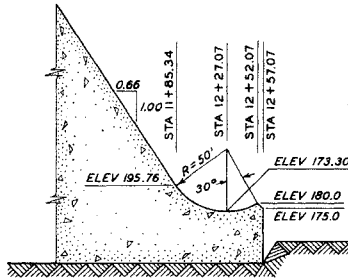
**TEST CONDITIONS**

ORIGINAL DESIGN  
 POOL ELEV 473.80 FT  
 TAILWATER ELEV 242.00 FT  
 PENSTOCKS & CONDUITS CLOSED  
 8 BAYS OPEN FULL

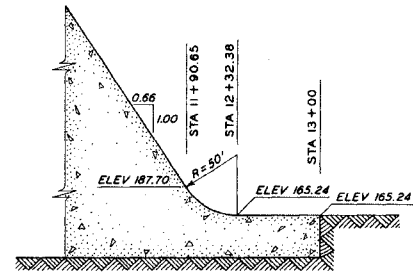
MODEL A  
**WATER-SURFACE PROFILE**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 567,000 CFS



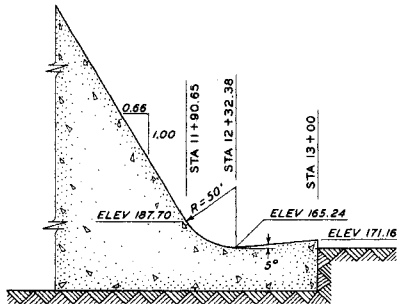
TYPE 1 BUCKET  
ORIGINAL DESIGN



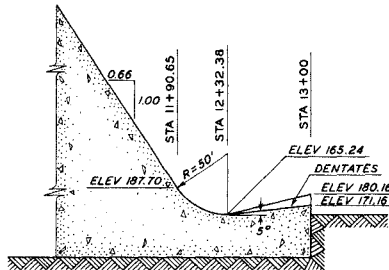
TYPE 2 BUCKET



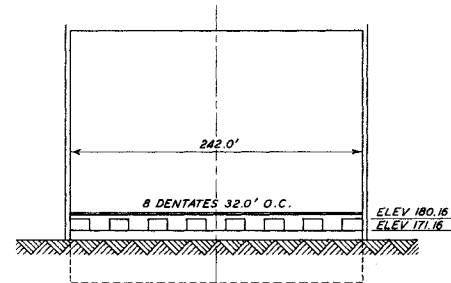
TYPE 3 BUCKET



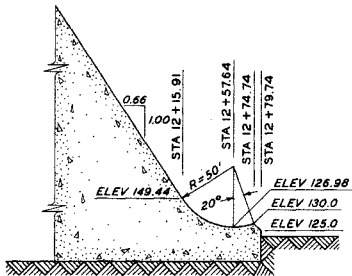
TYPE 4 BUCKET



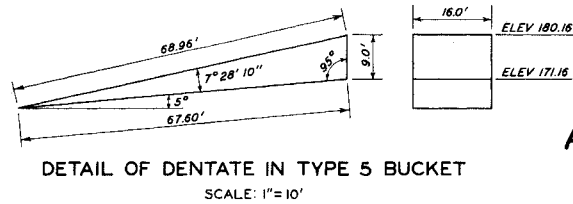
TYPE 5 BUCKET



UPSTREAM ELEVATION  
TYPE 5 BUCKET



TYPE 6 BUCKET



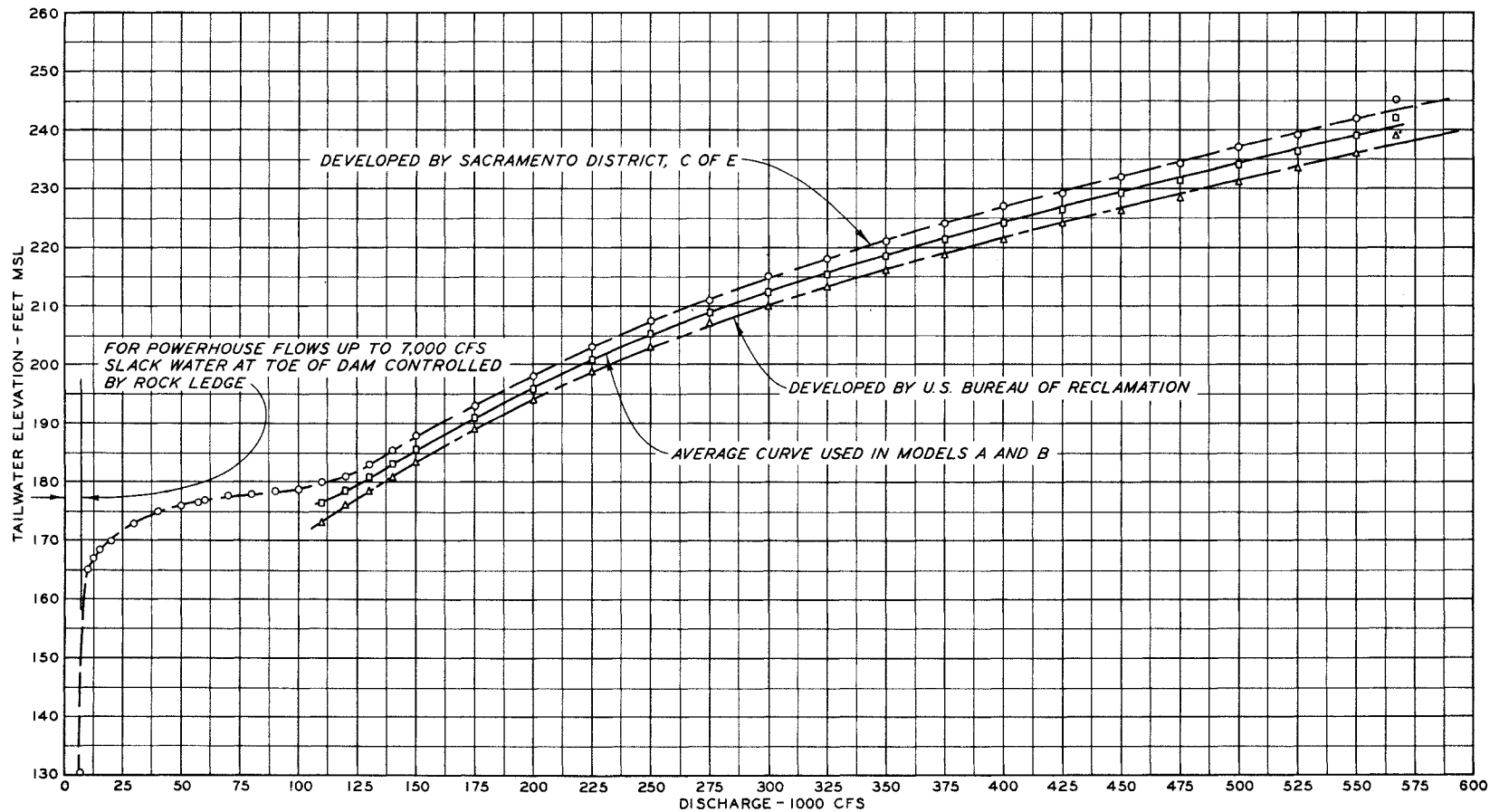
DETAIL OF DENTATE IN TYPE 5 BUCKET

SCALE: 1" = 10'

MODEL A  
ALTERNATE BUCKET DESIGNS  
TYPE 1 TO 6

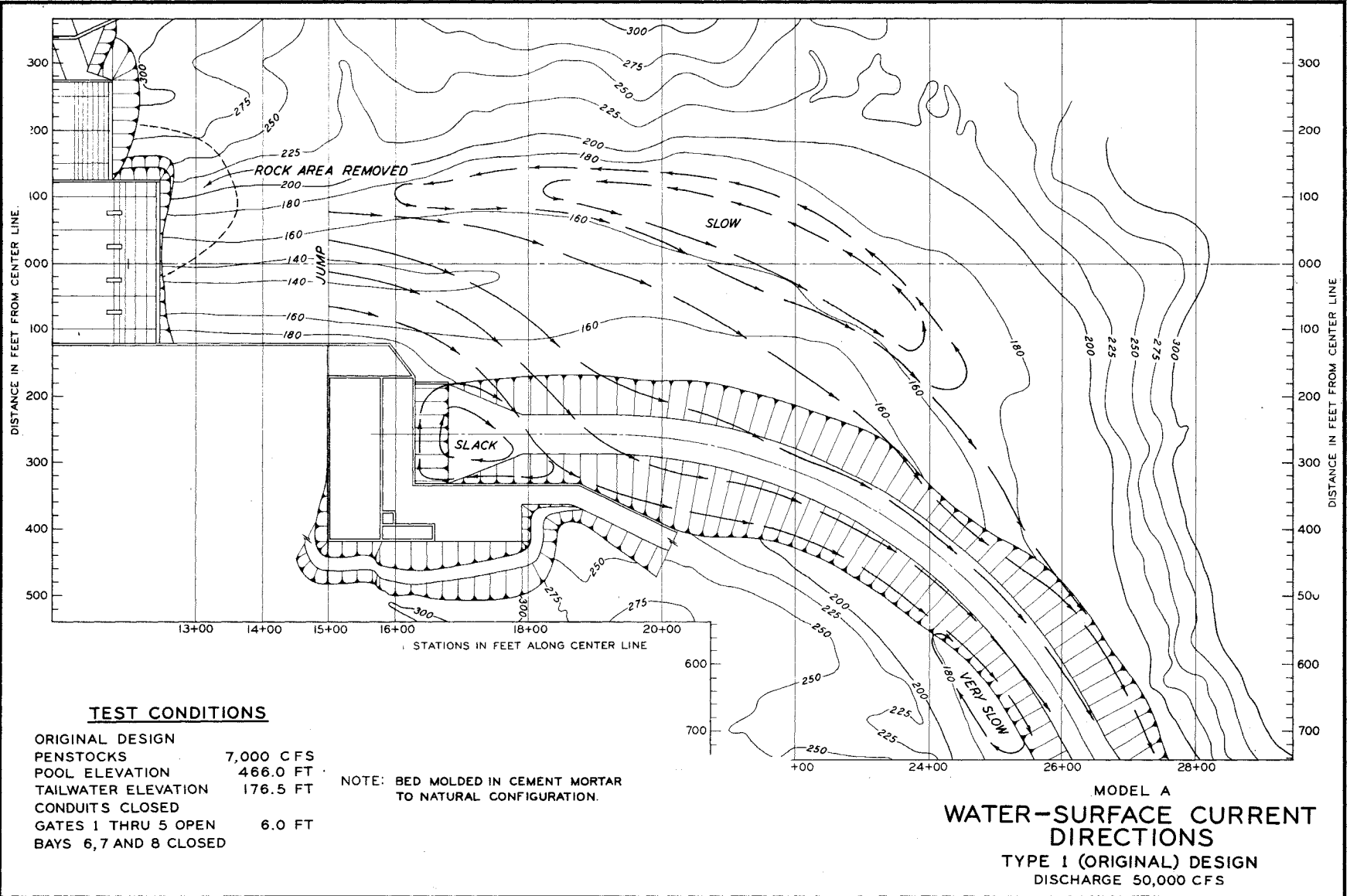
SCALES





NOTE: TAILWATER RATINGS AT STATION 29 + 50.  
U.S.C.E. TAILWATER RATING CURVE USED IN  
THE MODEL FOR DISCHARGES BELOW  
100,000 CFS.

## MODELS A AND B TAILWATER RATING CURVES

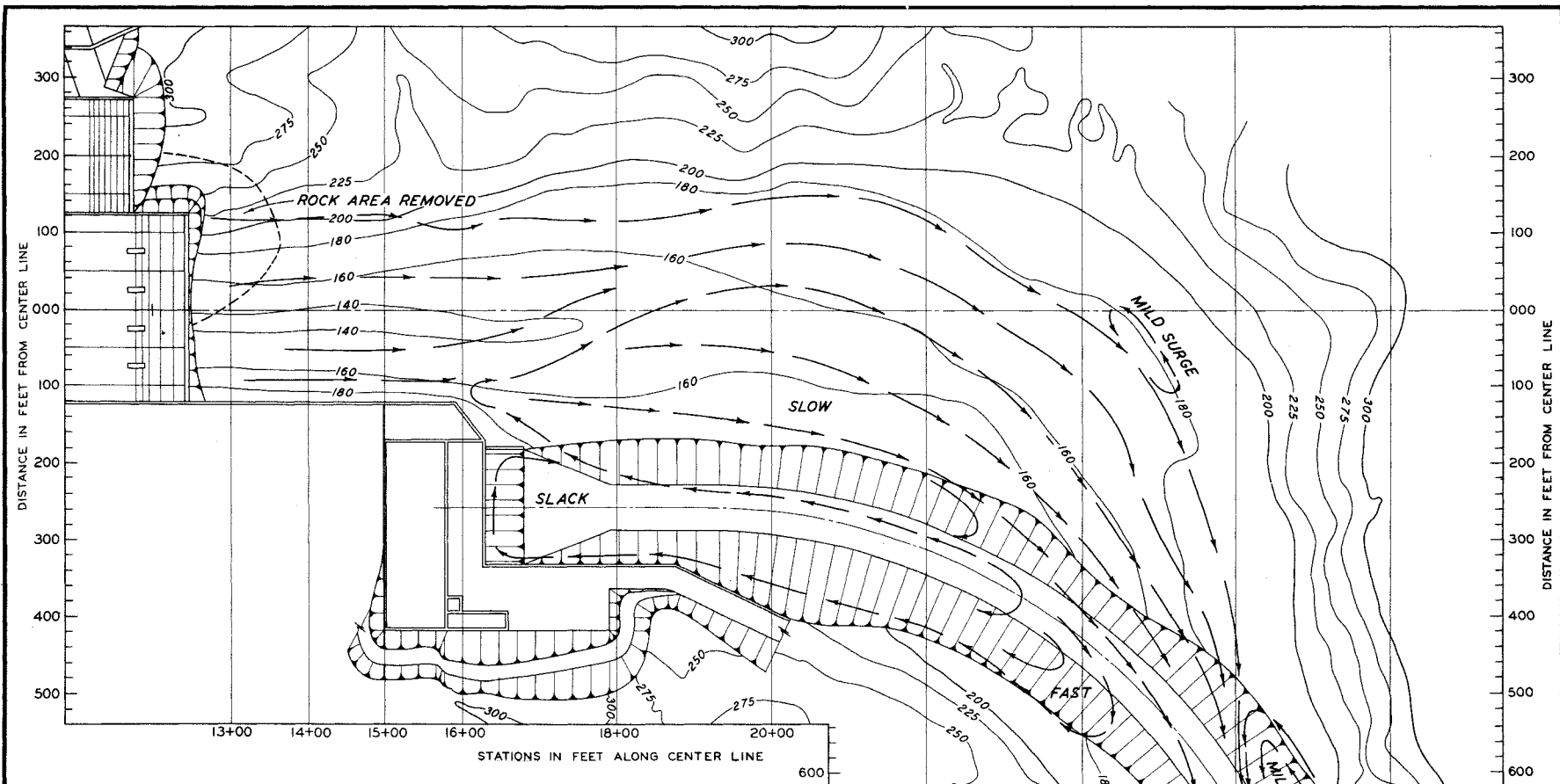


**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.0 FT  
 TAILWATER ELEVATION 176.5 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN 6.0 FT  
 BAYS 6,7 AND 8 CLOSED

NOTE: BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**WATER-SURFACE CURRENT DIRECTIONS**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 50,000 CFS

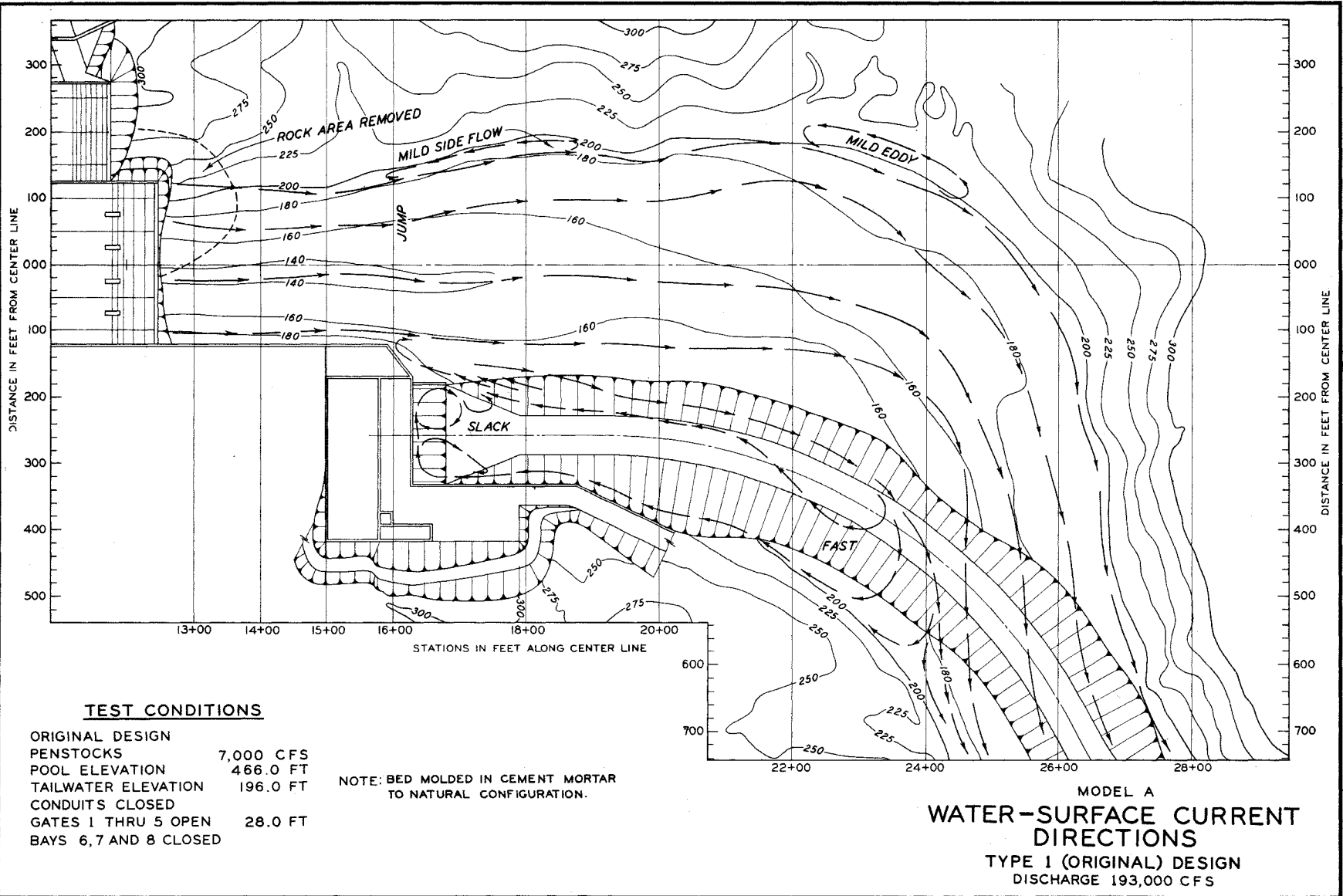


**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.0 FT  
 TAILWATER ELEVATION 179.2 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN 14.0 FT  
 BAYS 6, 7 AND 8 CLOSED

NOTE: BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**WATER-SURFACE CURRENT DIRECTIONS**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 108,000 CFS



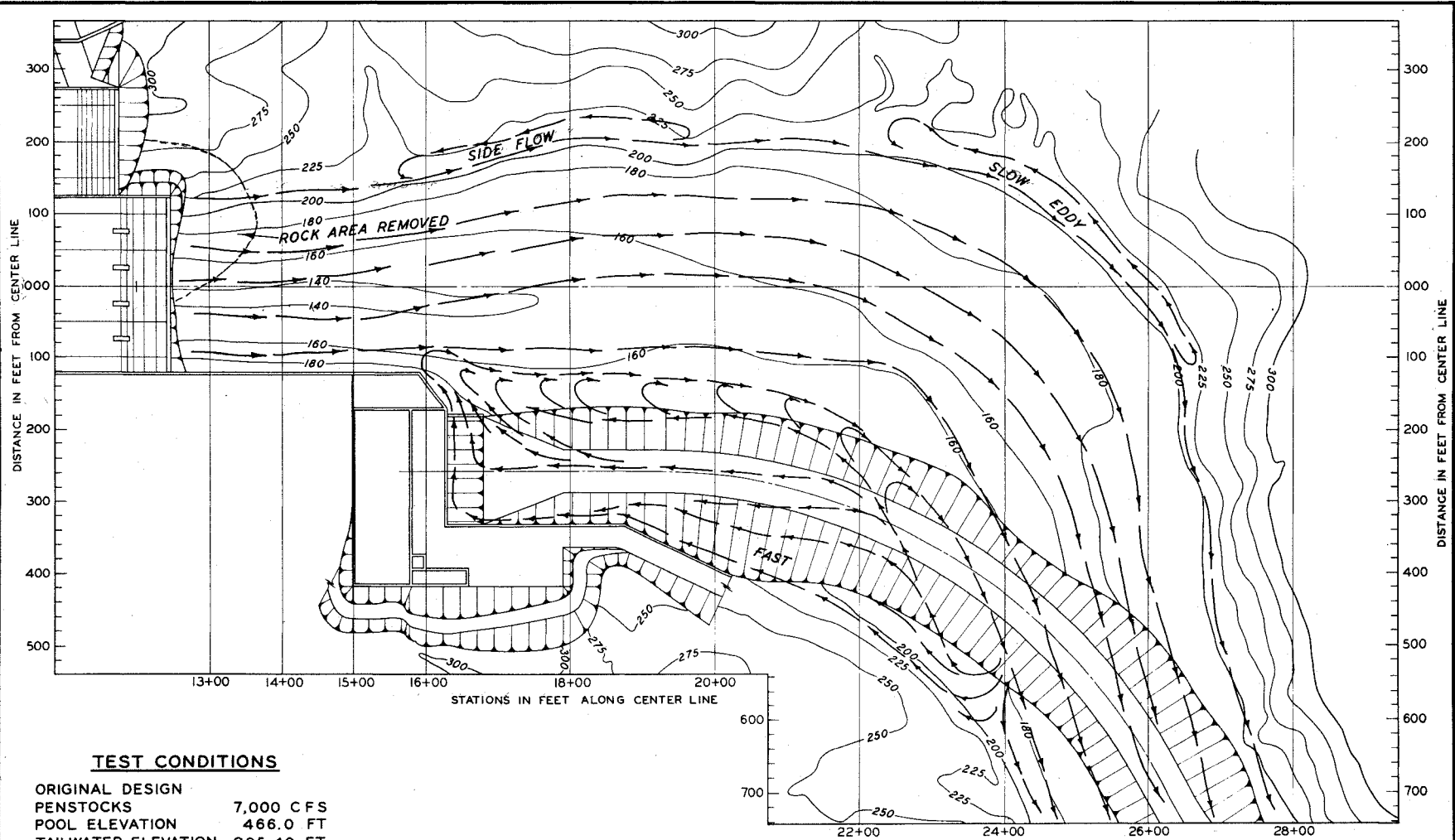
**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.0 FT  
 TAILWATER ELEVATION 196.0 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN 28.0 FT  
 BAYS 6, 7 AND 8 CLOSED

NOTE: BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

**MODEL A  
 WATER-SURFACE CURRENT DIRECTIONS**

TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 193,000 CFS



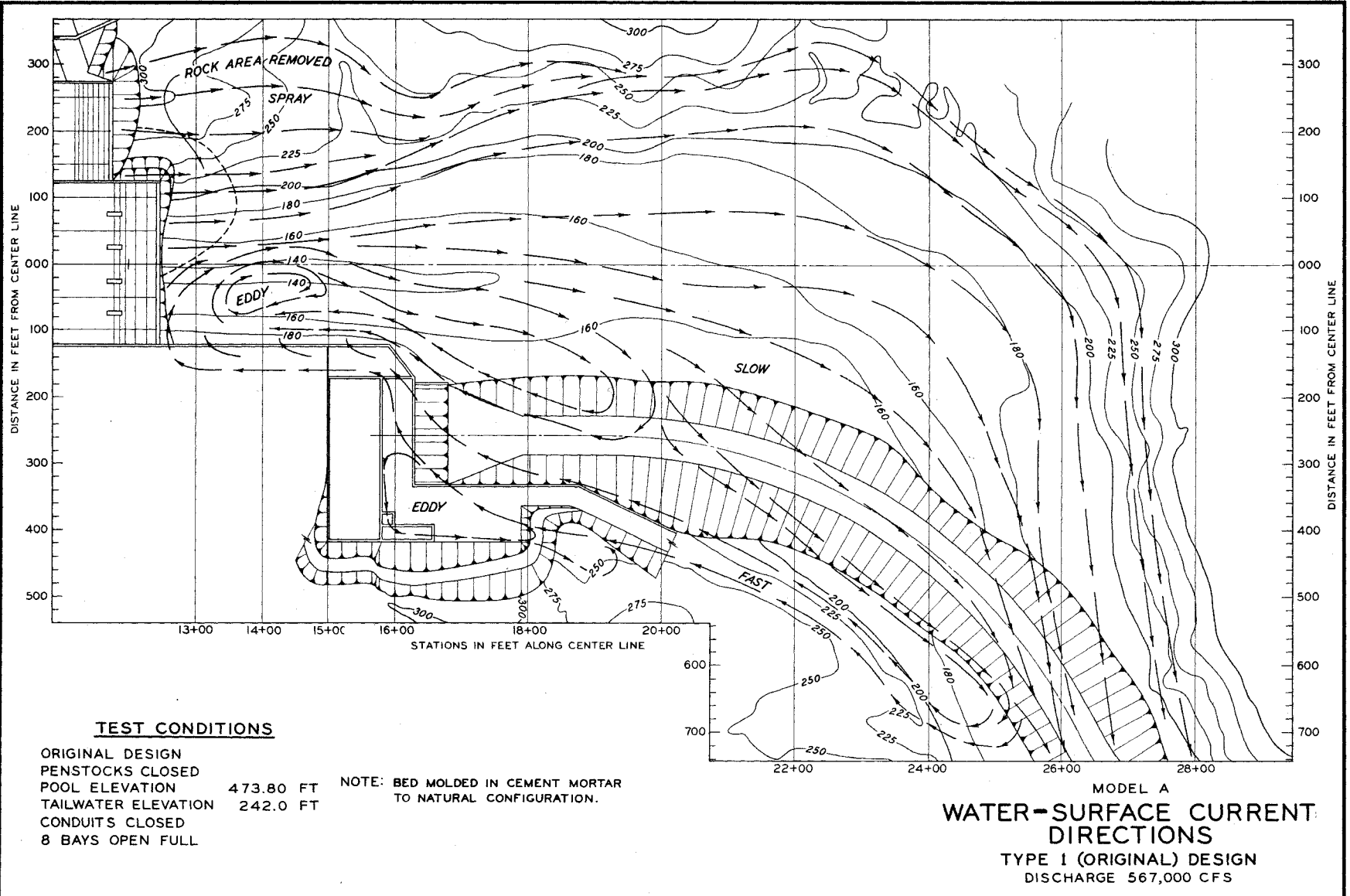
**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.0 FT  
 TAILWATER ELEVATION 205.40 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN 33.75 ± FT  
 BAYS 6, 7 AND 8 CLOSED

NOTE: BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**WATER-SURFACE CURRENT DIRECTIONS**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 243,000 CFS

PLATE 17

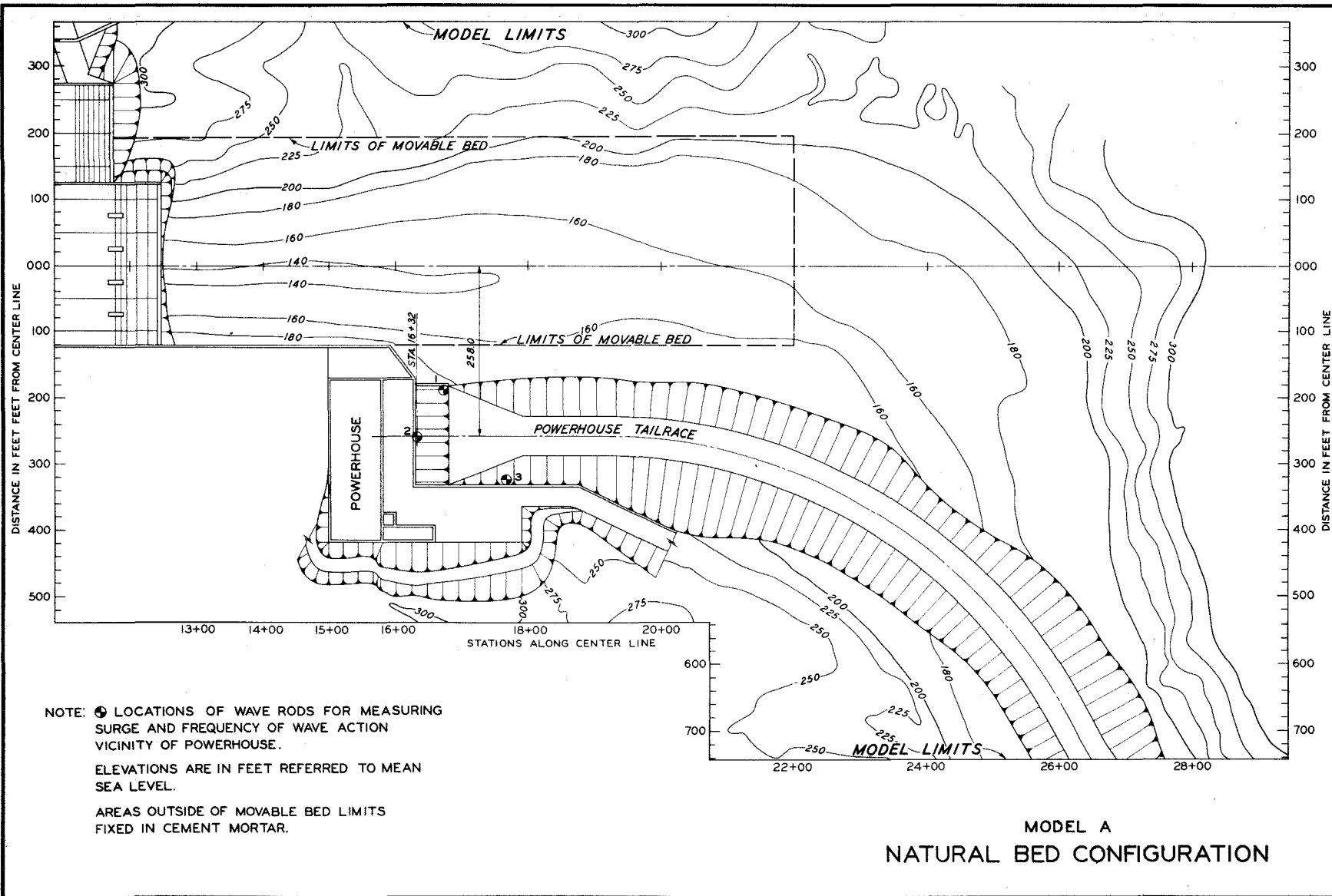


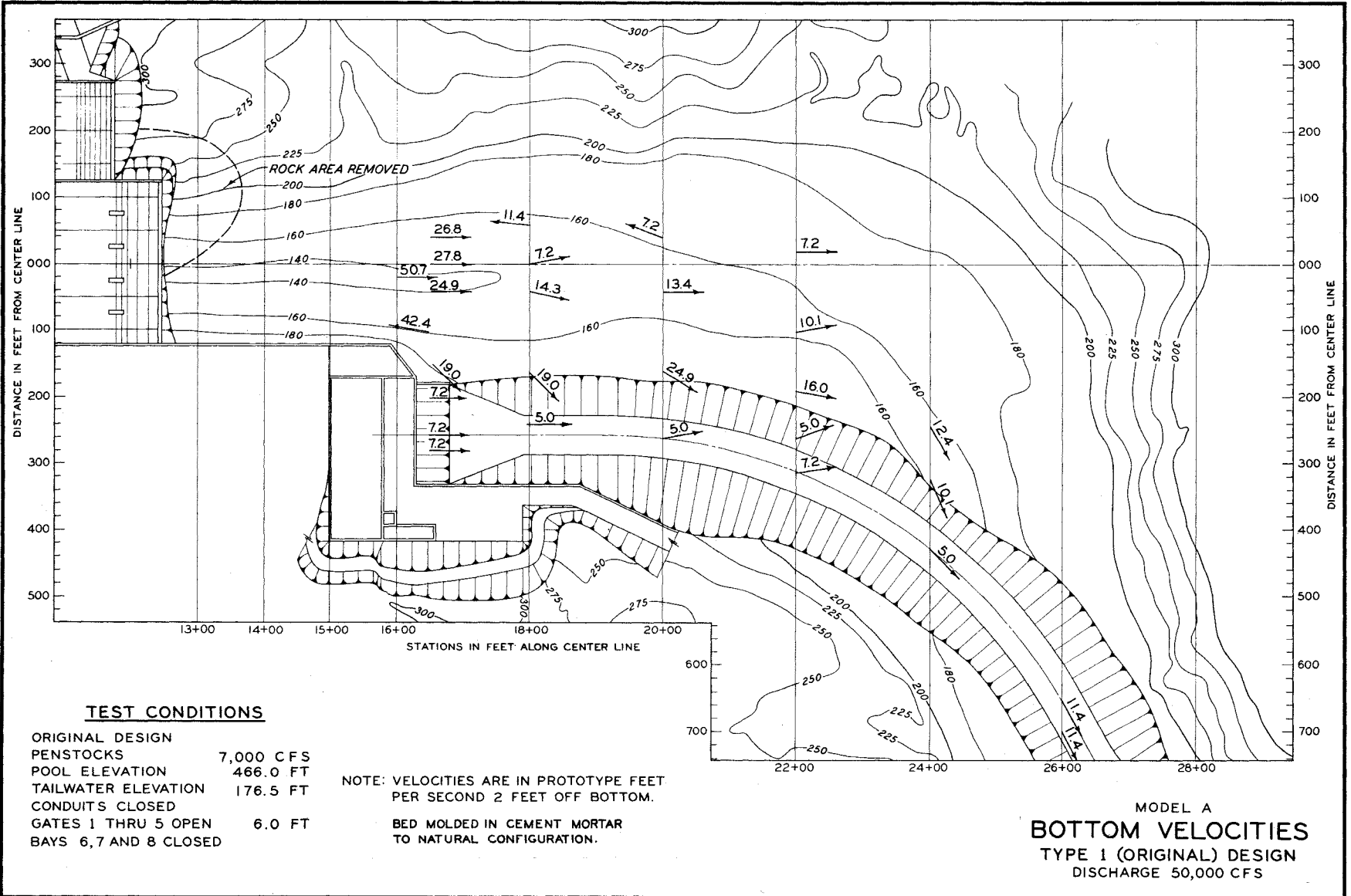
**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS CLOSED  
 POOL ELEVATION 473.80 FT  
 TAILWATER ELEVATION 242.0 FT  
 CONDUITS CLOSED  
 8 BAYS OPEN FULL

NOTE: BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**WATER-SURFACE CURRENT DIRECTIONS**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 567,000 CFS





**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.0 FT  
 TAILWATER ELEVATION 176.5 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN 6.0 FT  
 BAYS 6,7 AND 8 CLOSED

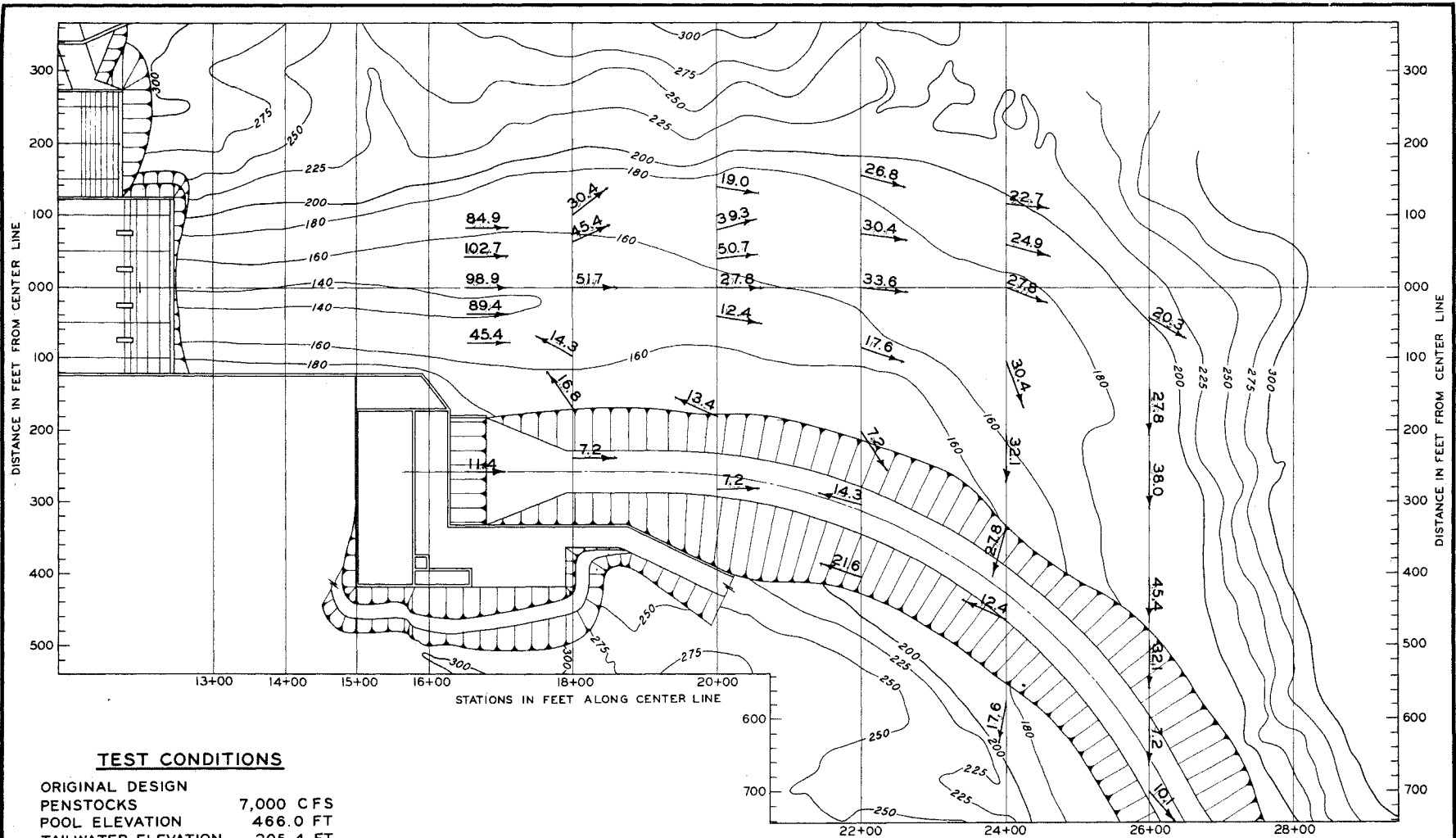
NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2 FEET OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**BOTTOM VELOCITIES**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 50,000 CFS







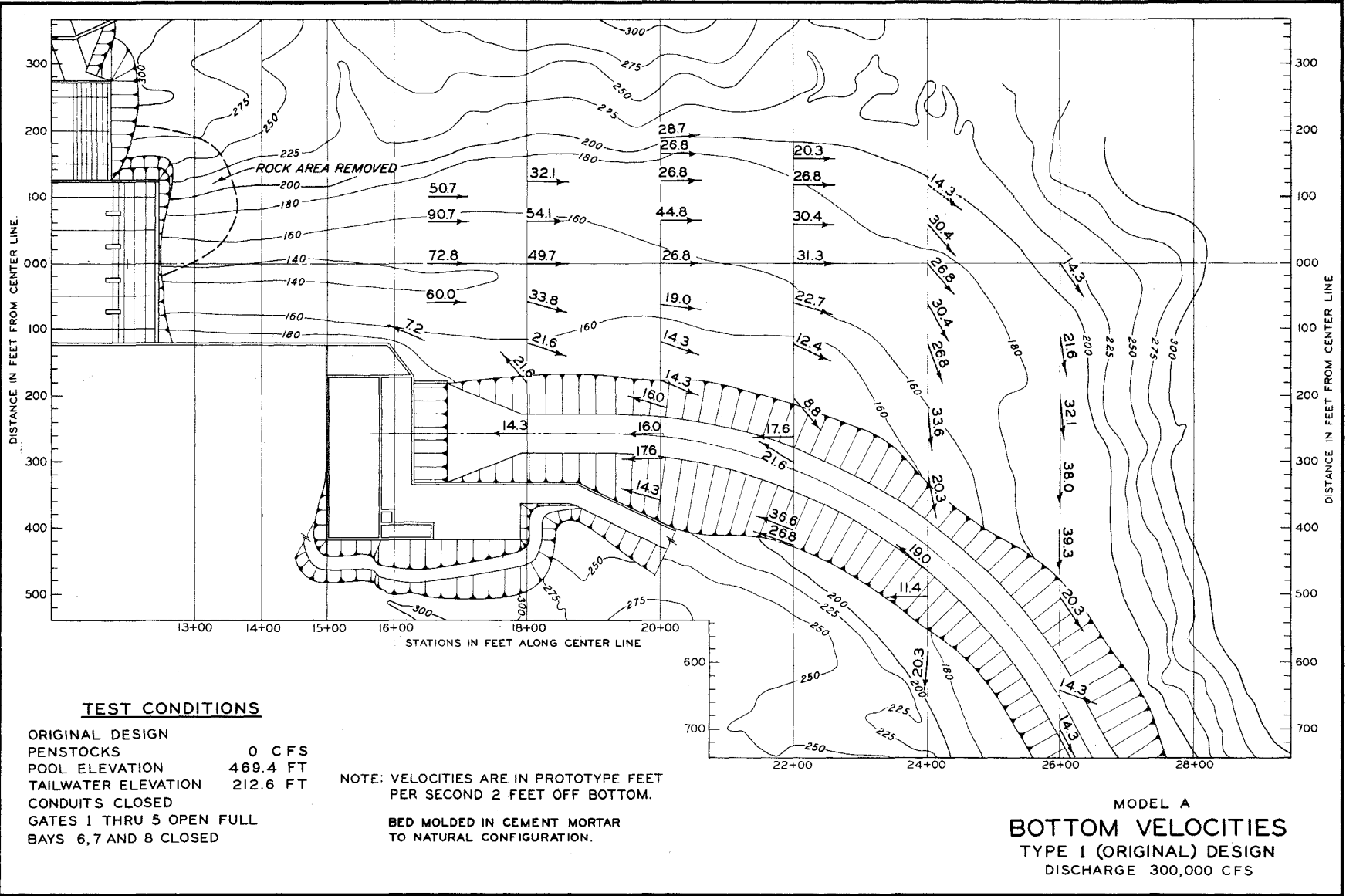
**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.0 FT  
 TAILWATER ELEVATION 205.4 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN 33.75 ± FT  
 BAYS 6, 7 AND 8 CLOSED

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2 FEET OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**BOTTOM VELOCITIES**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 243,000 CFS



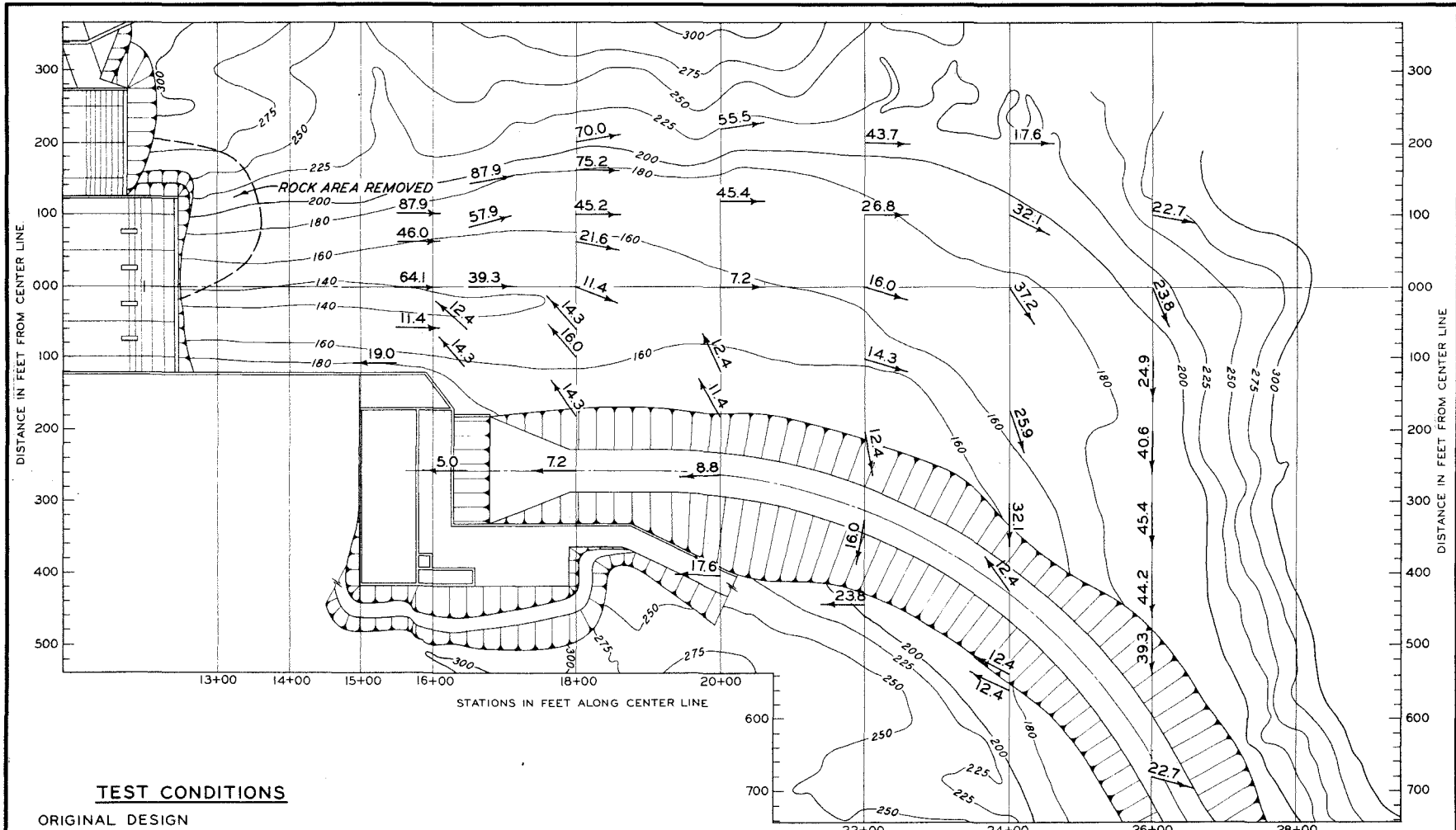
**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 469.4 FT  
 TAILWATER ELEVATION 212.6 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN FULL  
 BAYS 6, 7 AND 8 CLOSED

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2 FEET OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**BOTTOM VELOCITIES**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 300,000 CFS

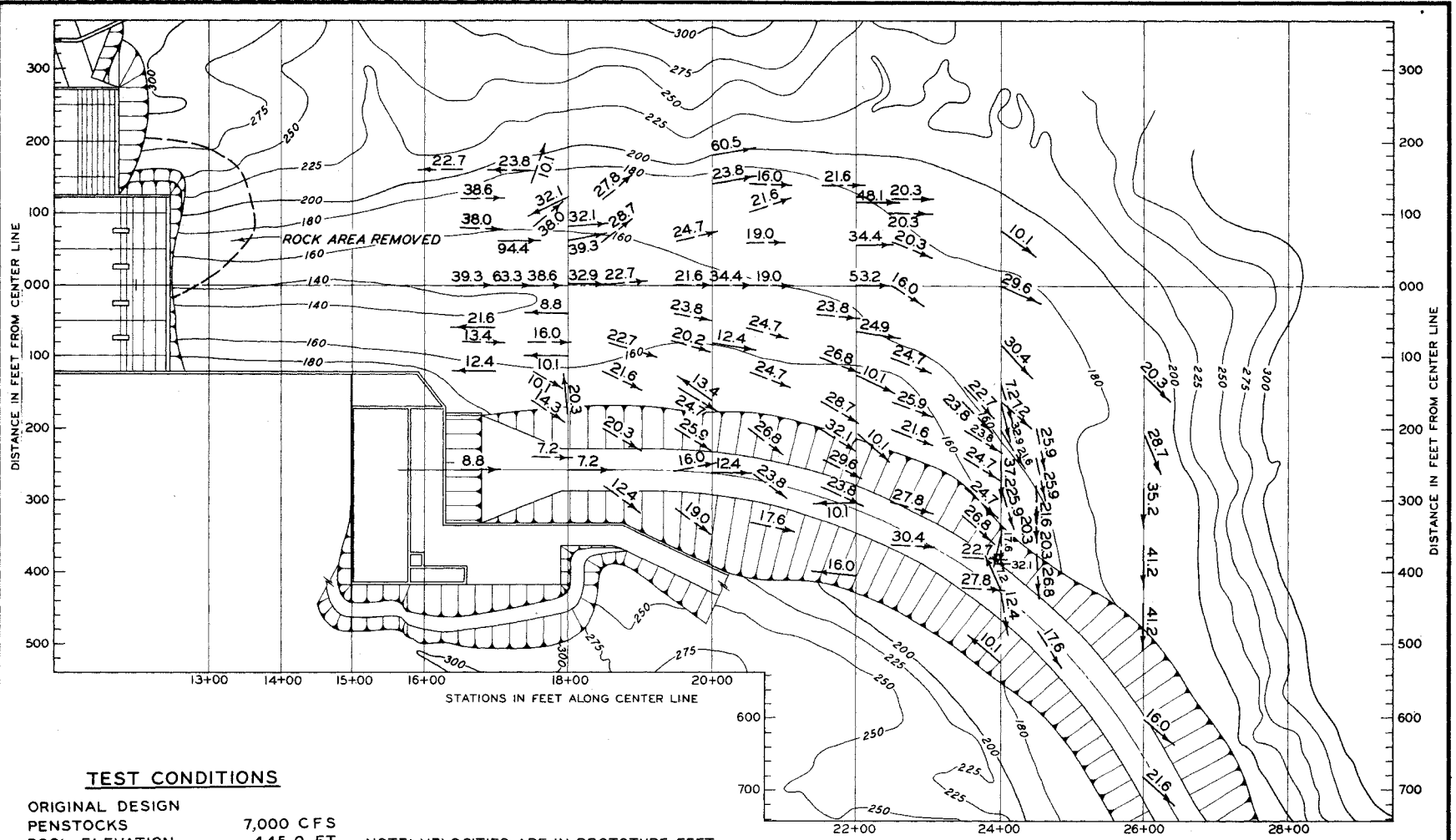


**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 473.8 FT  
 TAILWATER ELEVATION 242.0 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 8 OPEN FULL

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL A  
**BOTTOM VELOCITIES**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 567,000 CFS



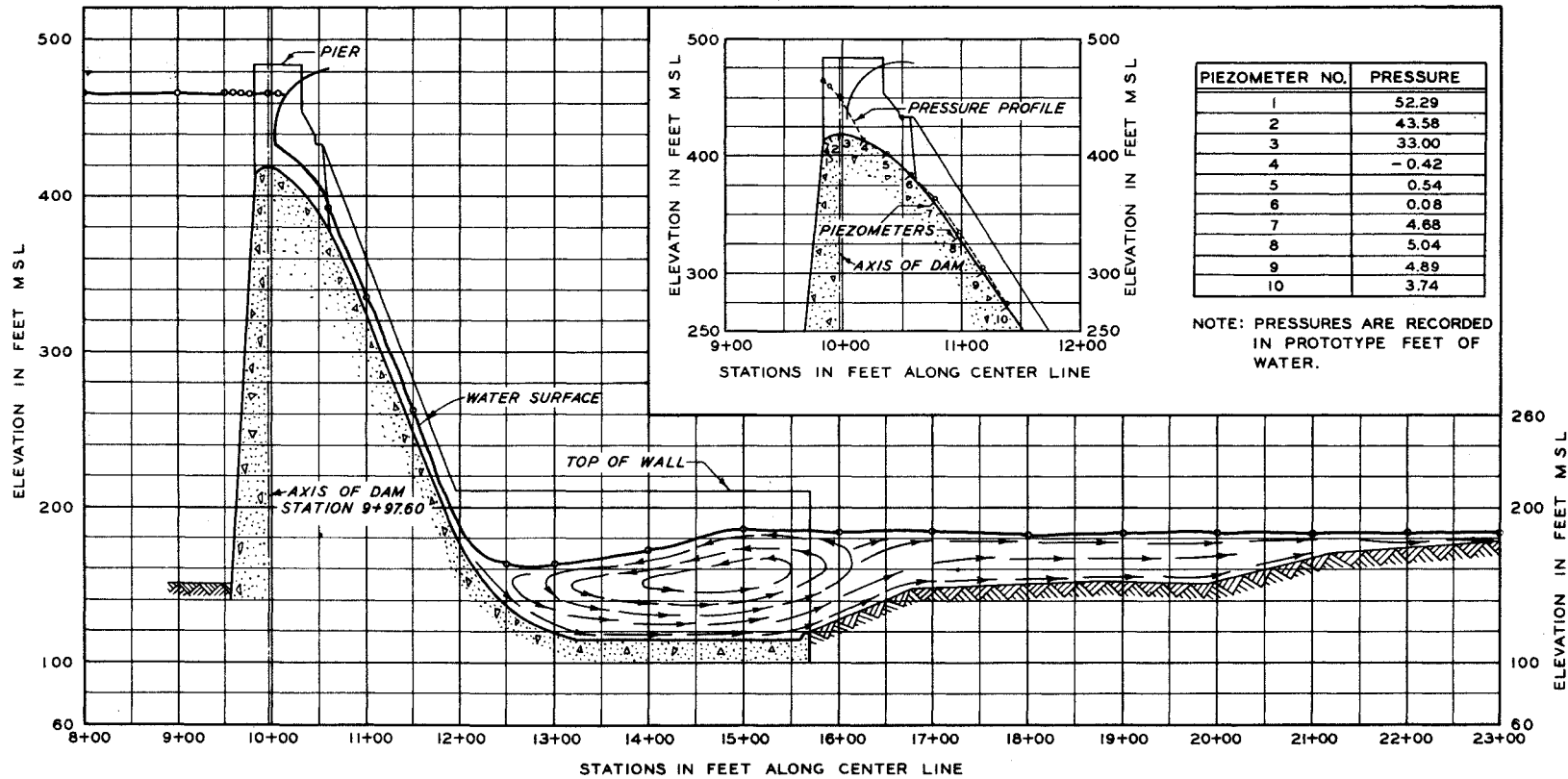
**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 445.0 FT  
 TAILWATER ELEVATION 179.2 FT  
 CONDUITS CLOSED  
 GATES 1 THRU 5 OPEN FULL  
 BAYS 6, 7 AND 8 CLOSED

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2 FEET OFF BOTTOM.

- VELOCITIES TAKEN AFTER ONE HOUR SCOUR.
- VELOCITIES BEFORE SCOUR.

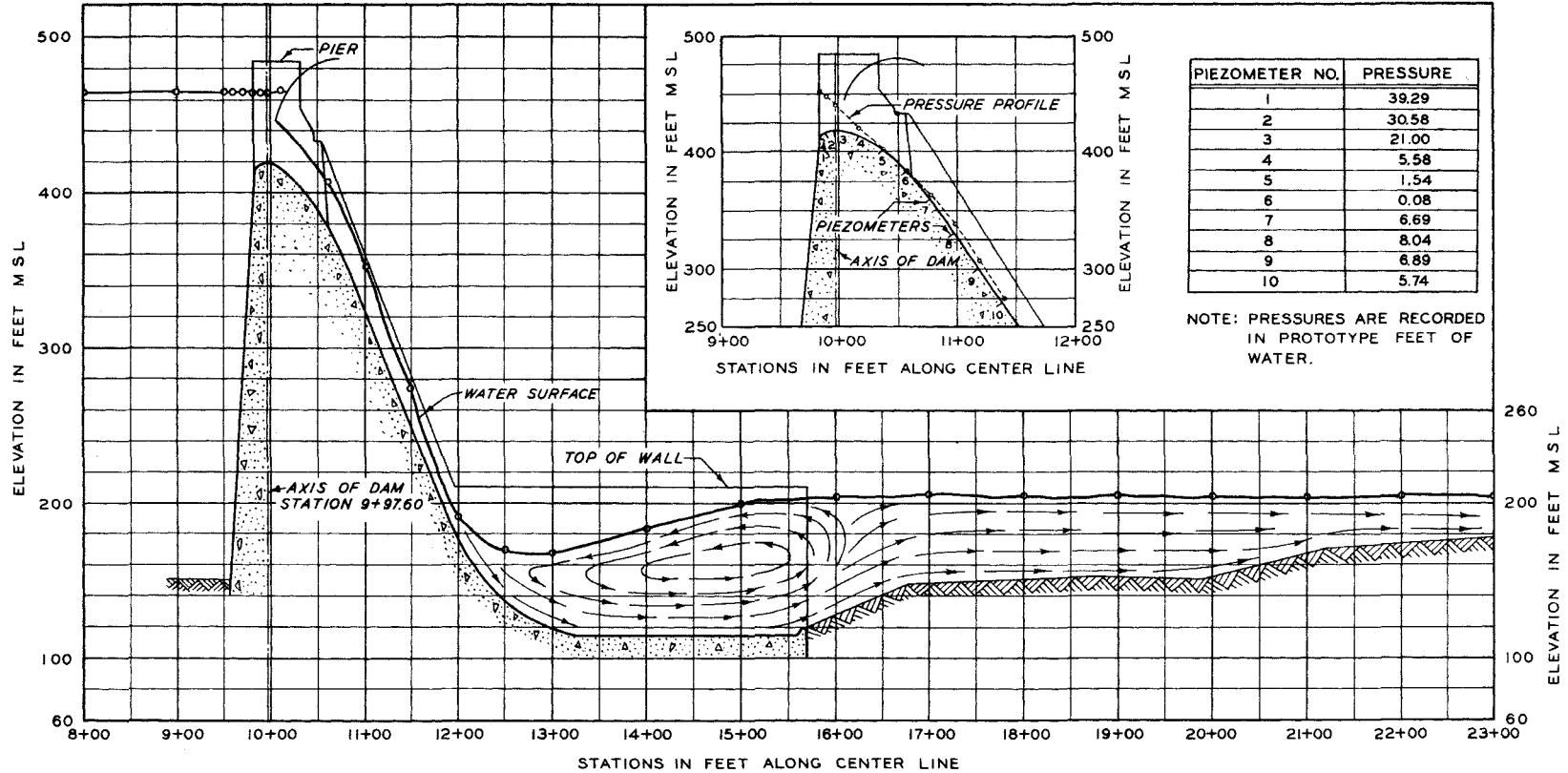
MODEL A  
**BOTTOM VELOCITIES**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 108,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 446.00 FT  
 TAILWATER ELEV 179.20 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

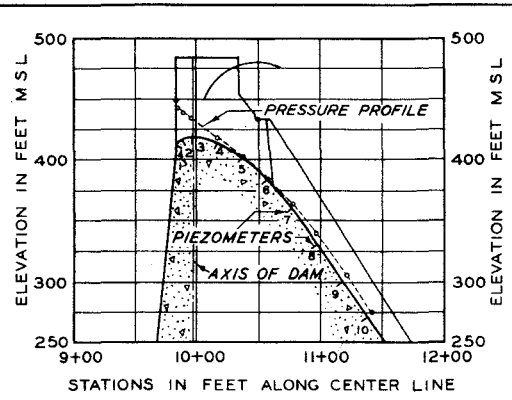
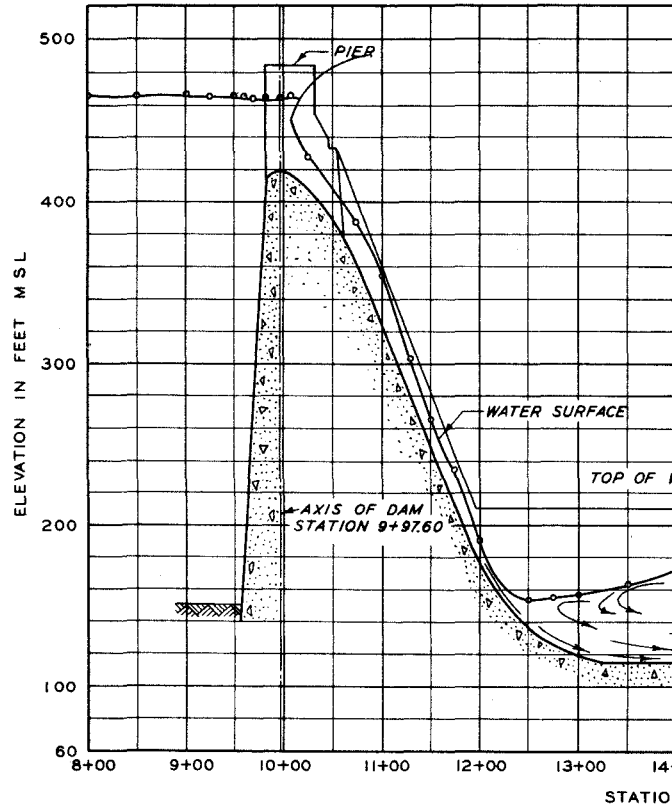
**MODEL B**  
**WATER-SURFACE**  
**AND PRESSURE PROFILES**  
**TYPE 1 (ORIGINAL) DESIGN**  
 DISCHARGE 108,000 CFS



TEST CONDITIONS

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

MODEL B  
 WATER-SURFACE  
 AND PRESSURE PROFILES  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 193,000 CFS

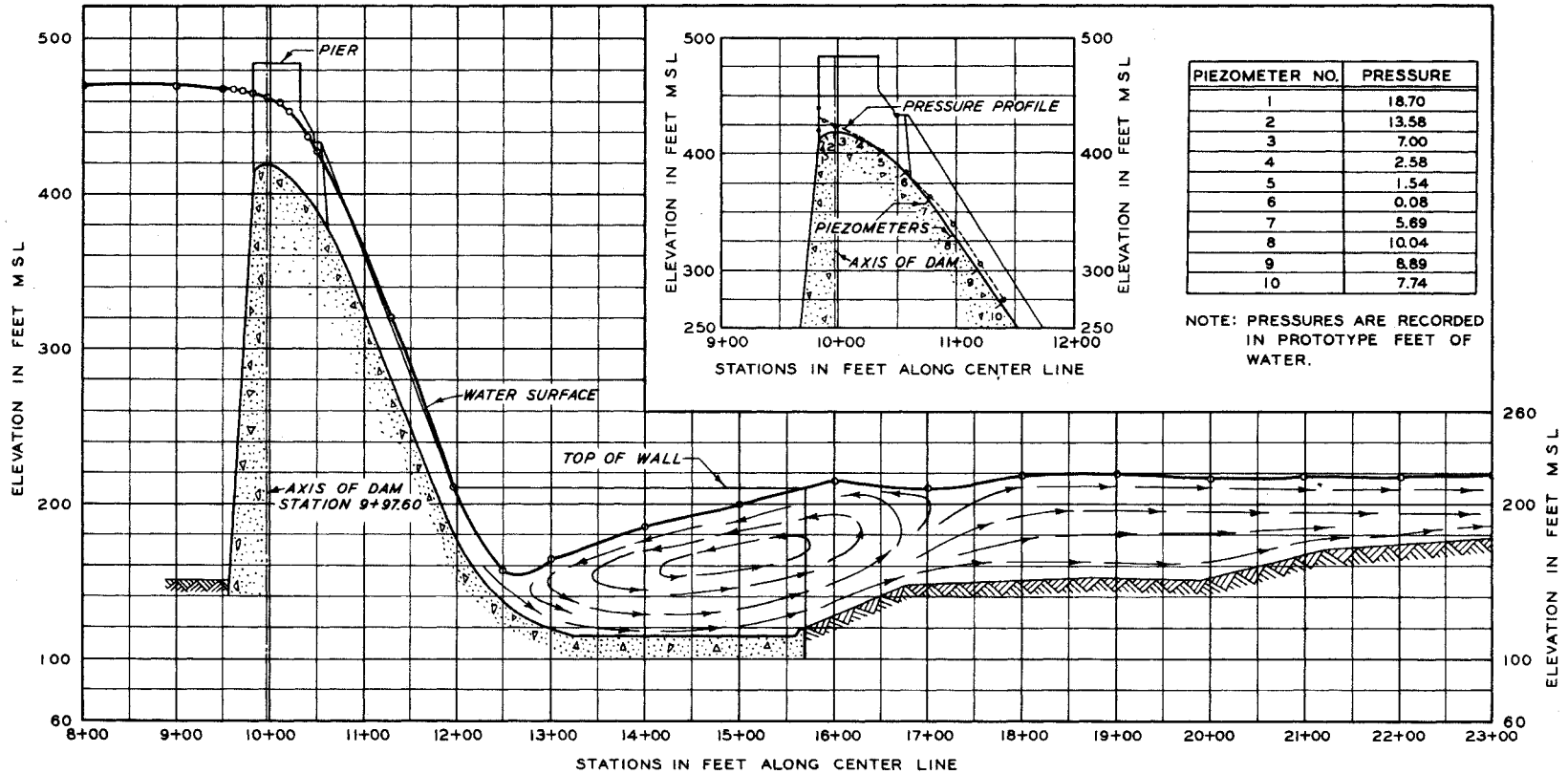


PIEZOMETER NO.	PRESSURE
1	37.29
2	23.58
3	17.00
4	4.58
5	1.54
6	1.08
7	4.69
8	8.04
9	7.89
10	6.74

NOTE: PRESSURES ARE RECORDED IN PROTOTYPE FEET OF WATER.

**TEST CONDITIONS**  
 ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 205.40 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 33.75 ± FT (6,7 & 8 CLOSED)

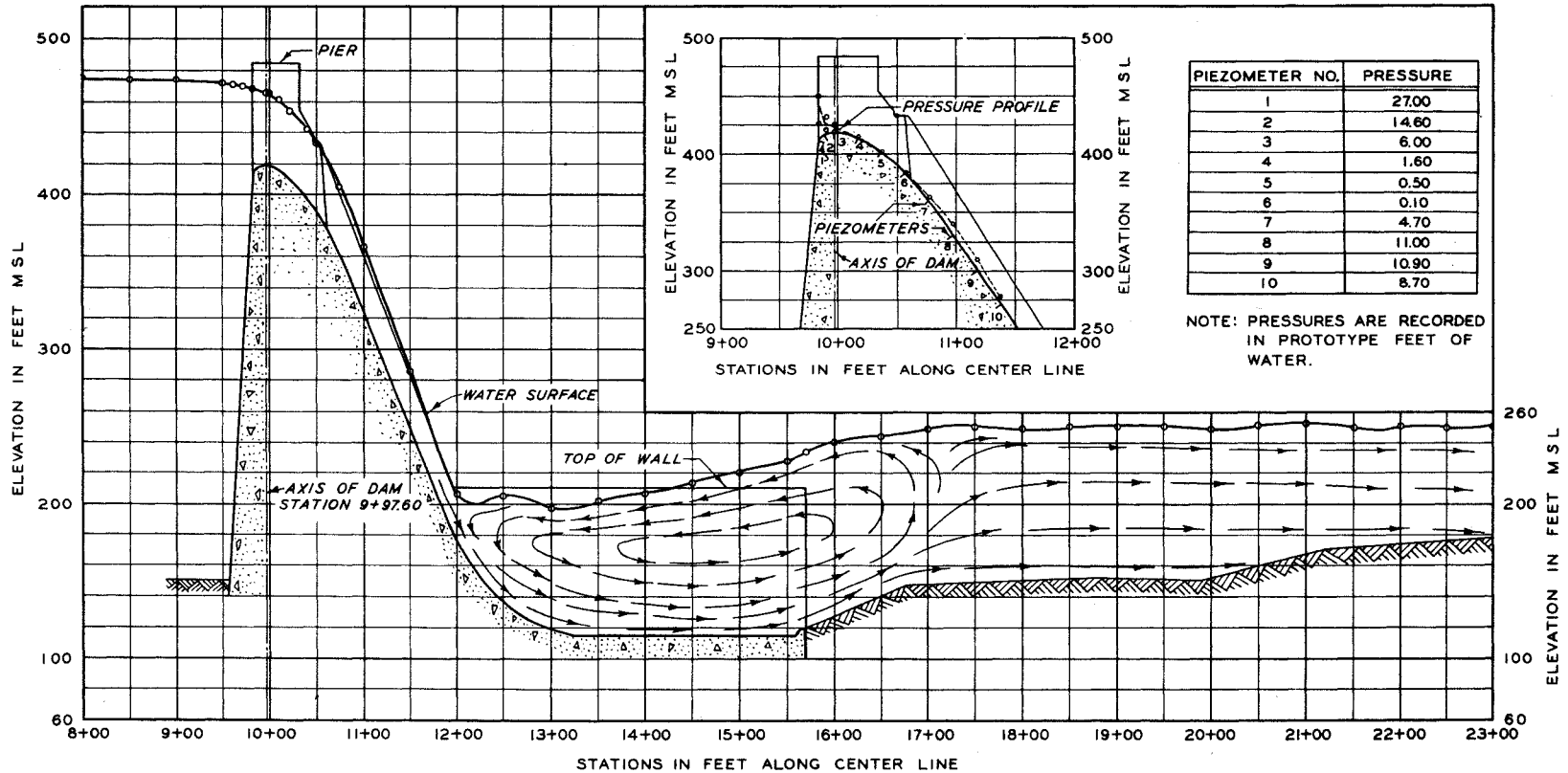
**MODEL B**  
**WATER-SURFACE**  
**AND PRESSURE PROFILES**  
**TYPE 1 (ORIGINAL) DESIGN**  
 DISCHARGE 243,000 CFS



TEST CONDITIONS

ORIGINAL DESIGN  
 POOL ELEV 468.60 FT  
 TAILWATER ELEV 212.60 FT  
 PENSTOCKS & CONDUITS CLOSED  
 5 BAYS OPEN FULL (6,7 & 8 CLOSED)

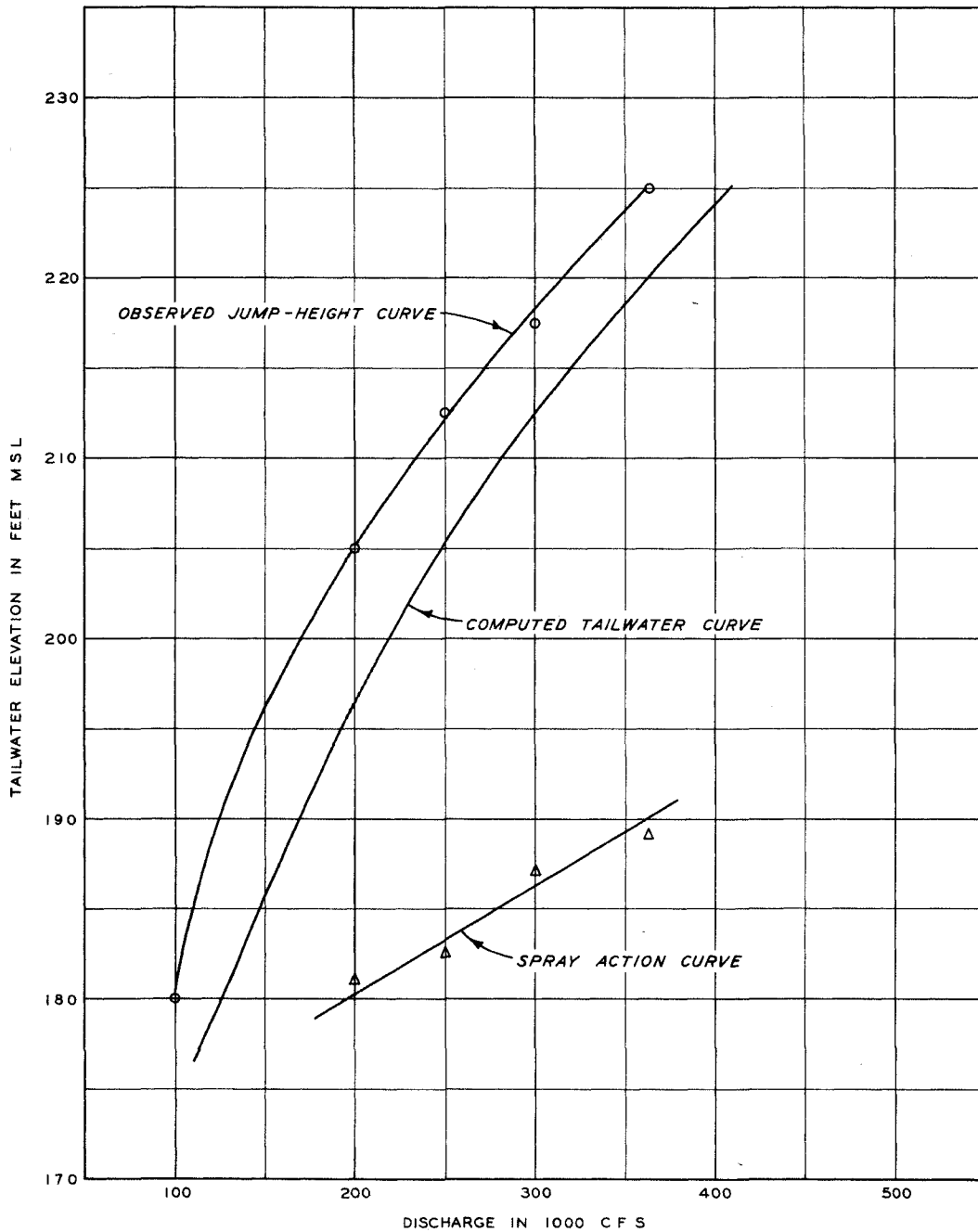
MODEL B  
**WATER-SURFACE  
 AND PRESSURE PROFILES**  
 TYPE 1 (ORIGINAL) DESIGN  
 DISCHARGE 300,000 CFS



**TEST CONDITIONS**

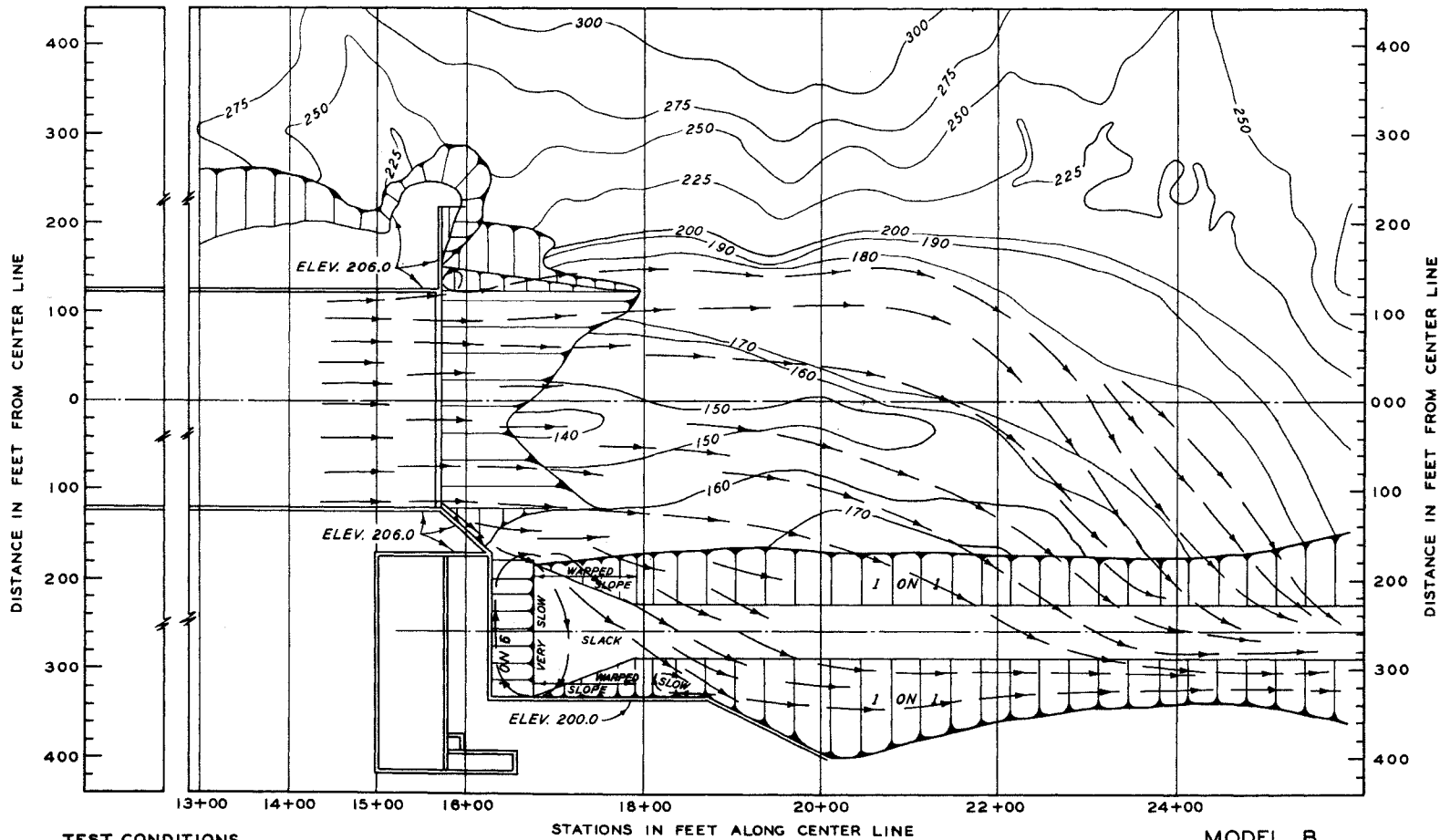
ORIGINAL DESIGN  
 POOL ELEV 473.00 FT  
 TAILWATER ELEV 242.00 FT  
 PENSTOCKS & CONDUITS CLOSED  
 8 BAYS OPEN FULL

**MODEL B**  
**WATER-SURFACE**  
**AND PRESSURE PROFILES**  
**TYPE 1 (ORIGINAL) DESIGN**  
 DISCHARGE 567,000 CFS



NOTE: EXIT AREA FIXED IN CEMENT MORTAR TO NATURAL CONFIGURATIONS.  
 JUMP-HEIGHT CURVE INDICATES TAILWATER ELEVATION AT WHICH BEST JUMP ACTION OCCURS.  
 SPRAY ACTION CURVE INDICATES TAILWATER ELEVATION AT WHICH SPRAY OCCURS.  
 5 SPILLWAY BAYS OPEN FULL.

MODEL B  
 TAILWATER RATING CURVES  
 TYPE 1 (ORIGINAL) DESIGN

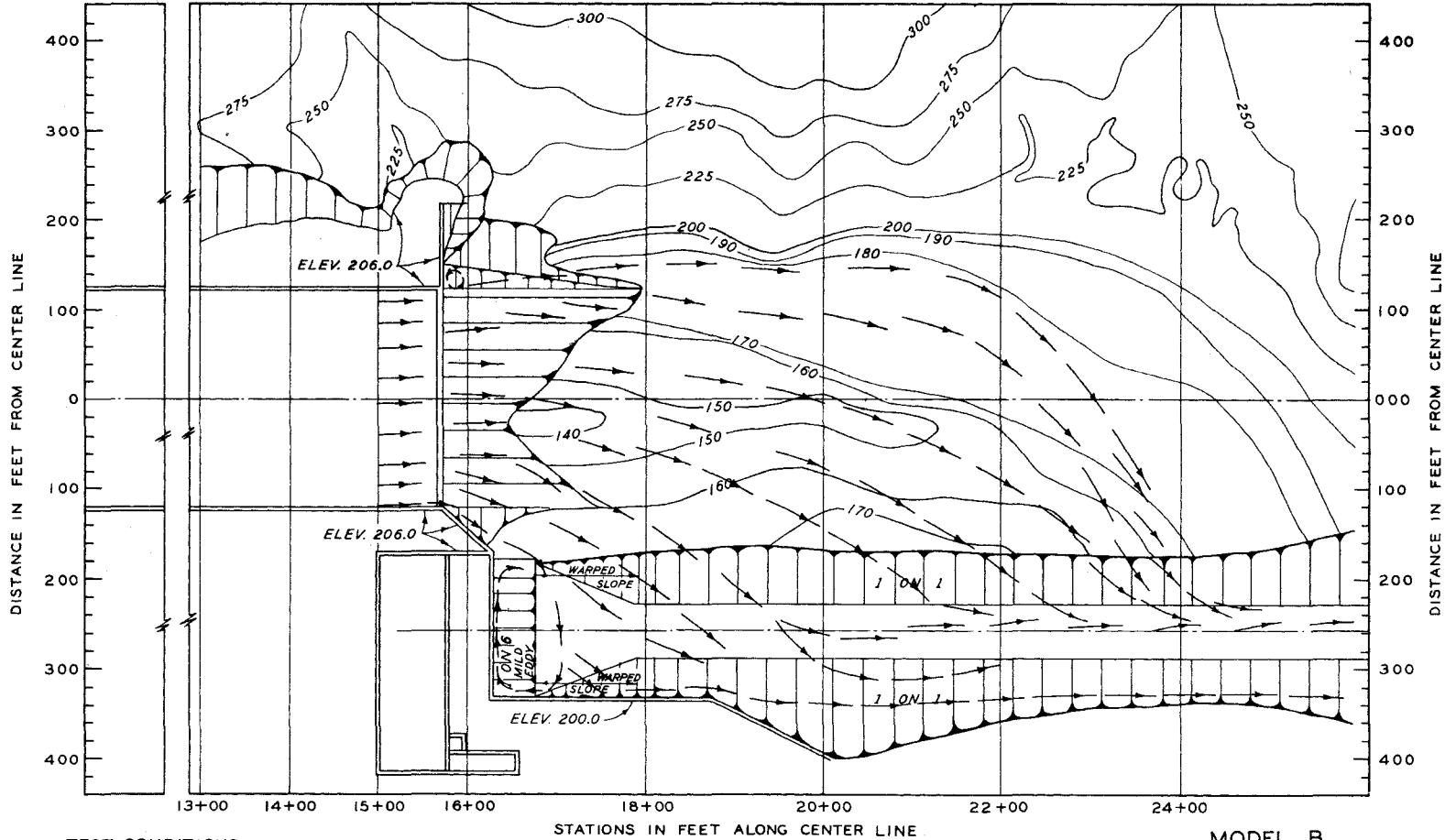


**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 486.00 FT  
 TAILWATER ELEV 178.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 8.0 FT (6,7 & 8 CLOSED)

**MODEL B**

**WATER-SURFACE  
 CURRENT DIRECTIONS**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 50,000 CFS



**TEST CONDITIONS**

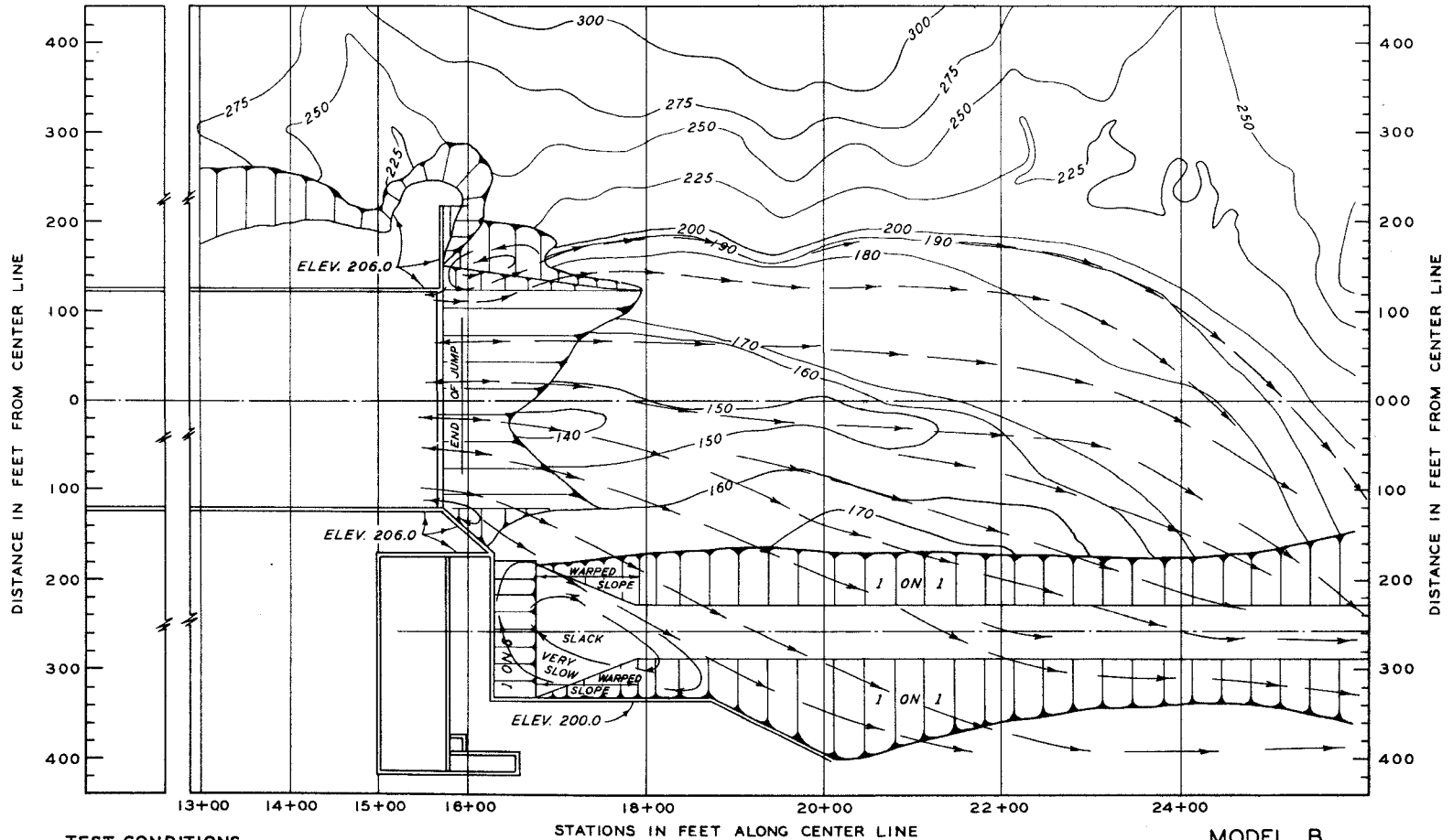
ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 179.20 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

MODEL B

**WATER-SURFACE  
 CURRENT DIRECTIONS**

TYPE I (ORIGINAL) DESIGN

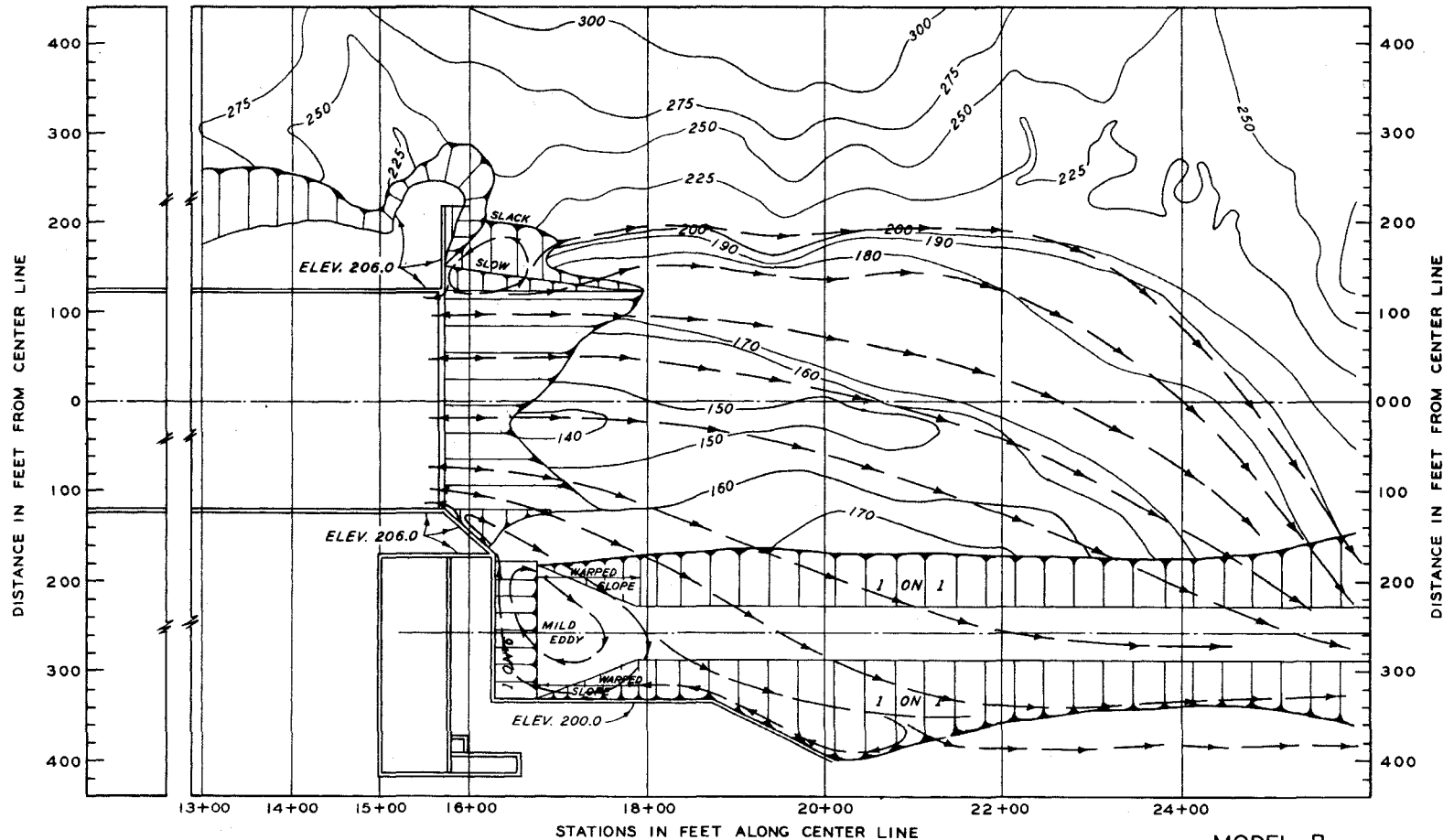
DISCHARGE 108,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 198.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7&8 CLOSED)

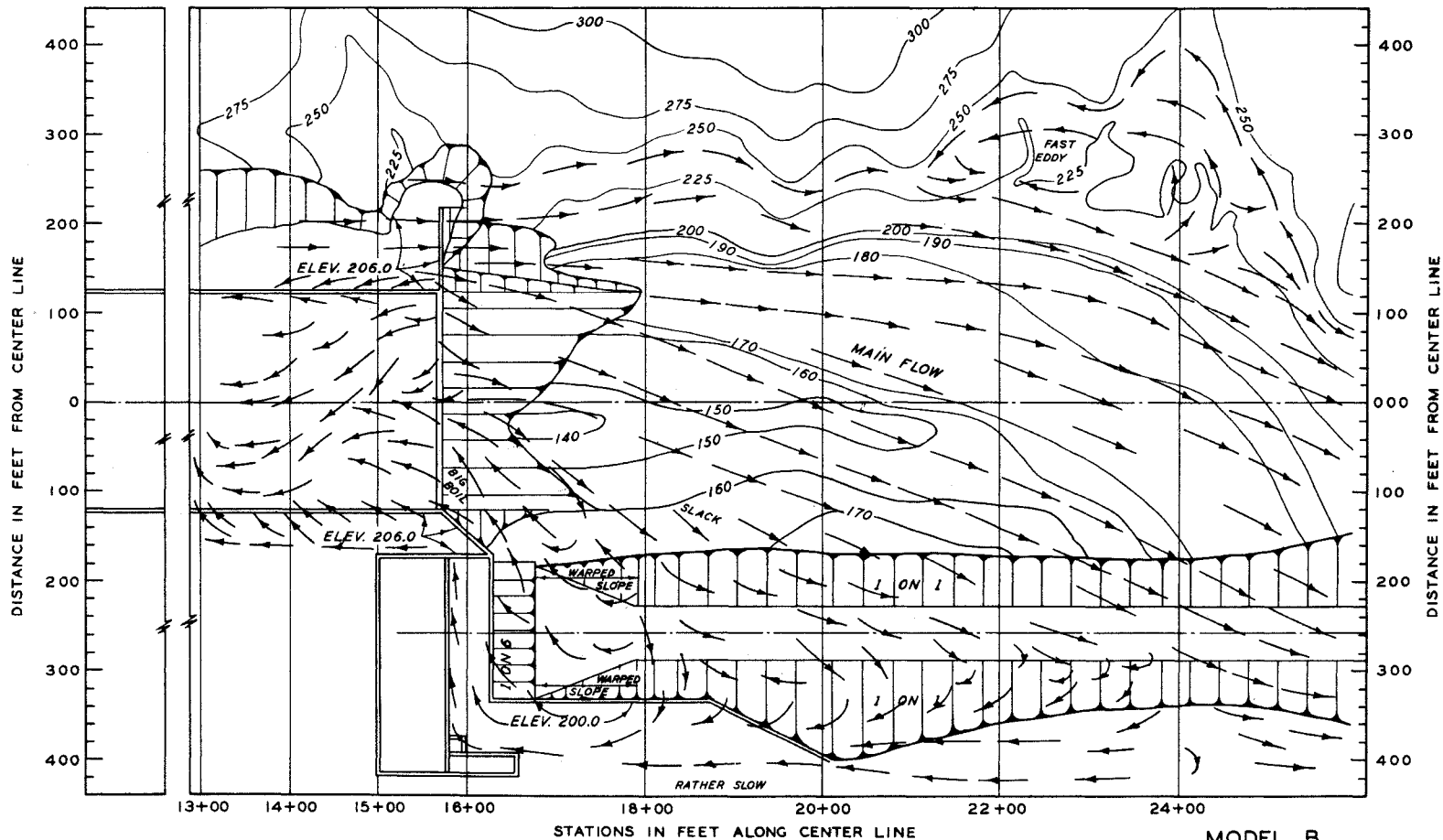
MODEL B  
**WATER-SURFACE  
 CURRENT DIRECTIONS**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 193,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 205.40 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 33.75 ± FT (6,7 & 8 CLOSED)

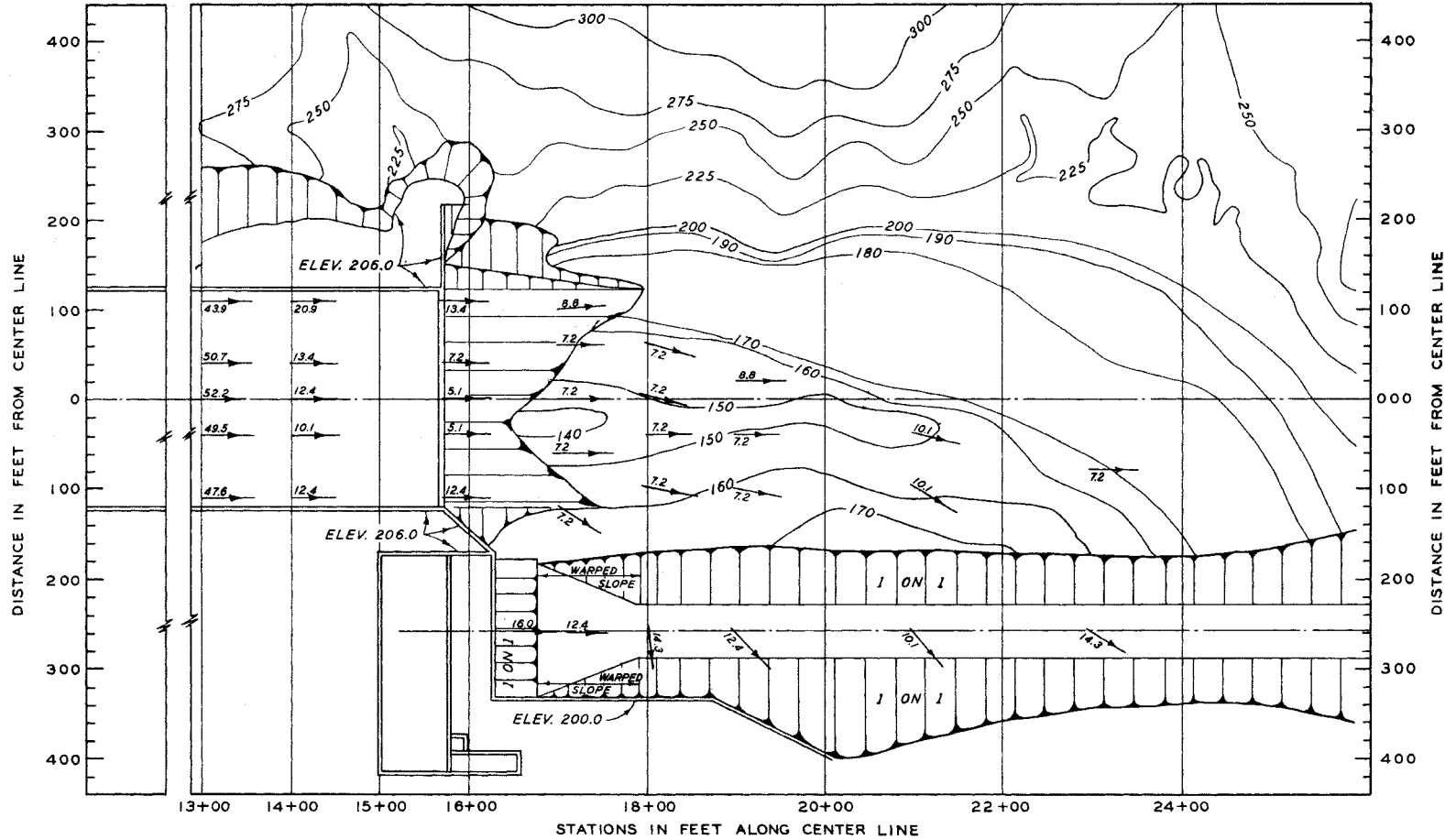
MODEL B  
**WATER-SURFACE  
 CURRENT DIRECTIONS**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 243,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 POOL ELEV 473.00 FT  
 TAILWATER ELEV 242.00 FT  
 CONDUITS AND PENSTOCKS CLOSED  
 8 BAYS OPEN FULL

**MODEL B**  
**WATER-SURFACE**  
**CURRENT DIRECTIONS**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 567,000 CFS

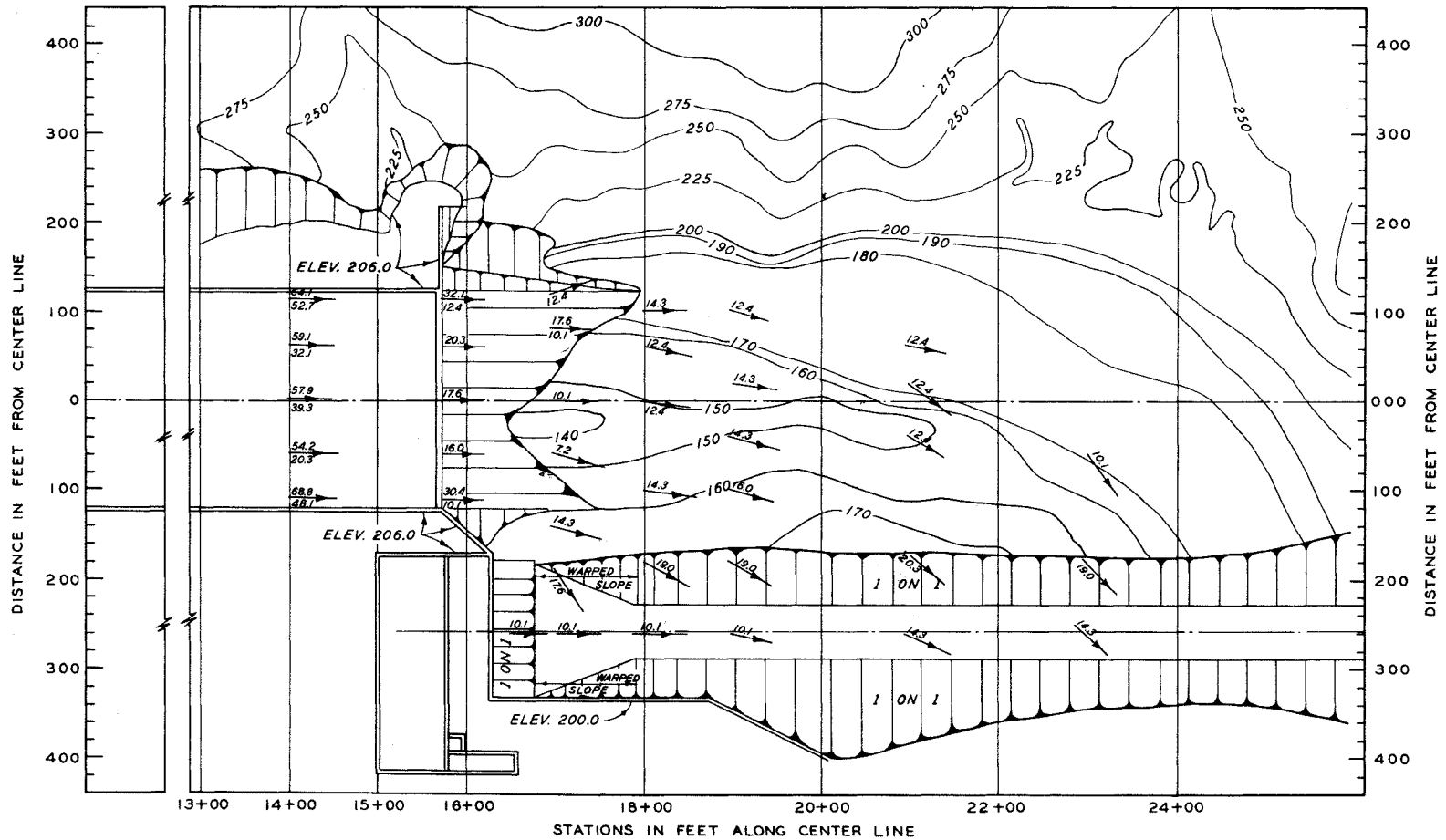


**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 6 FT (6,7 & 8 CLOSED)

NOTE VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2 FT OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 50,000 CFS



**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 445.00 FT  
 TAILWATER ELEV 179.20 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN (6,7 & 8 CLOSED)

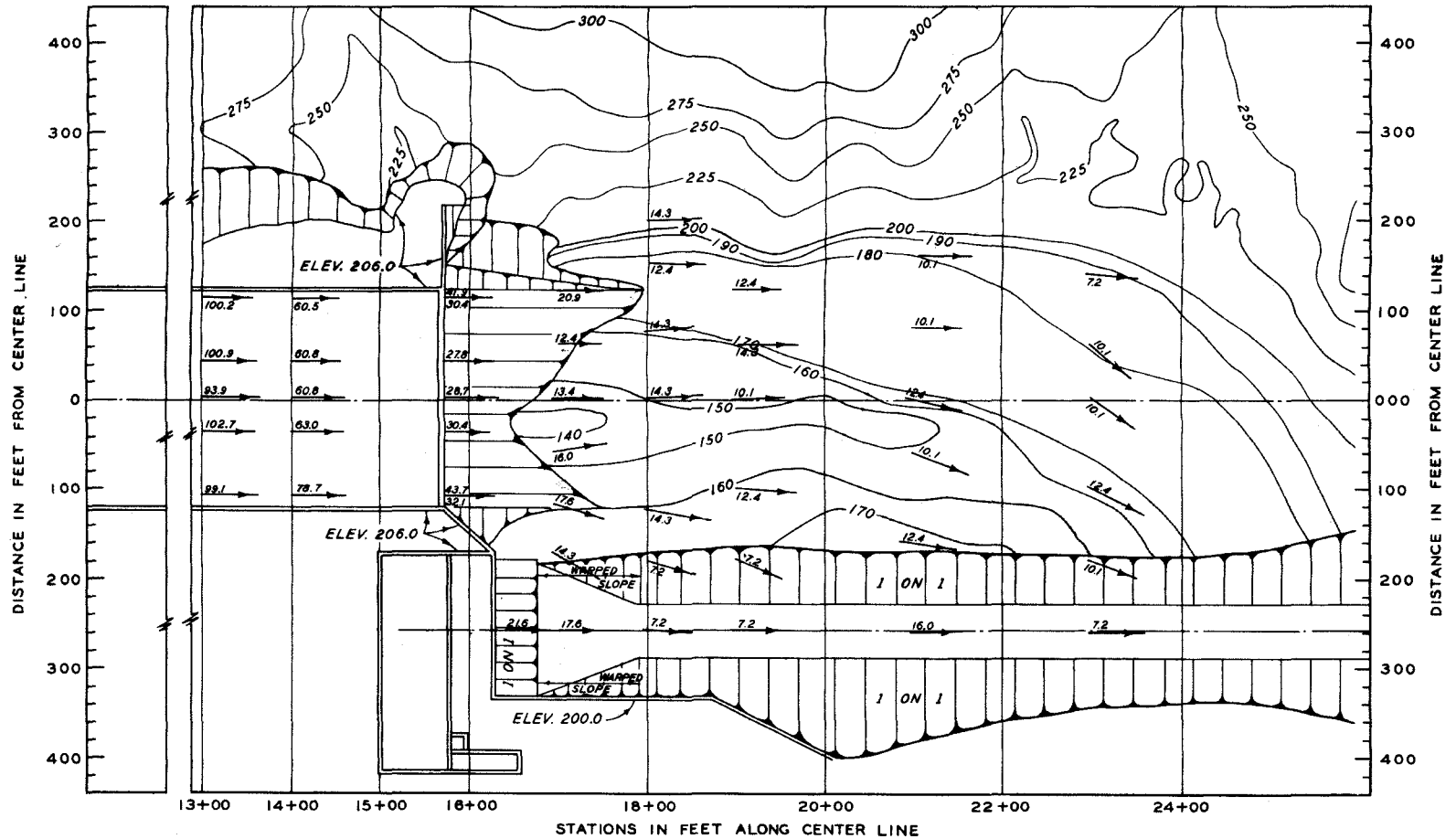
NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2 FT OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B

**BOTTOM VELOCITIES**

TYPE I (ORIGINAL) DESIGN

DISCHARGE 108,000 CFS

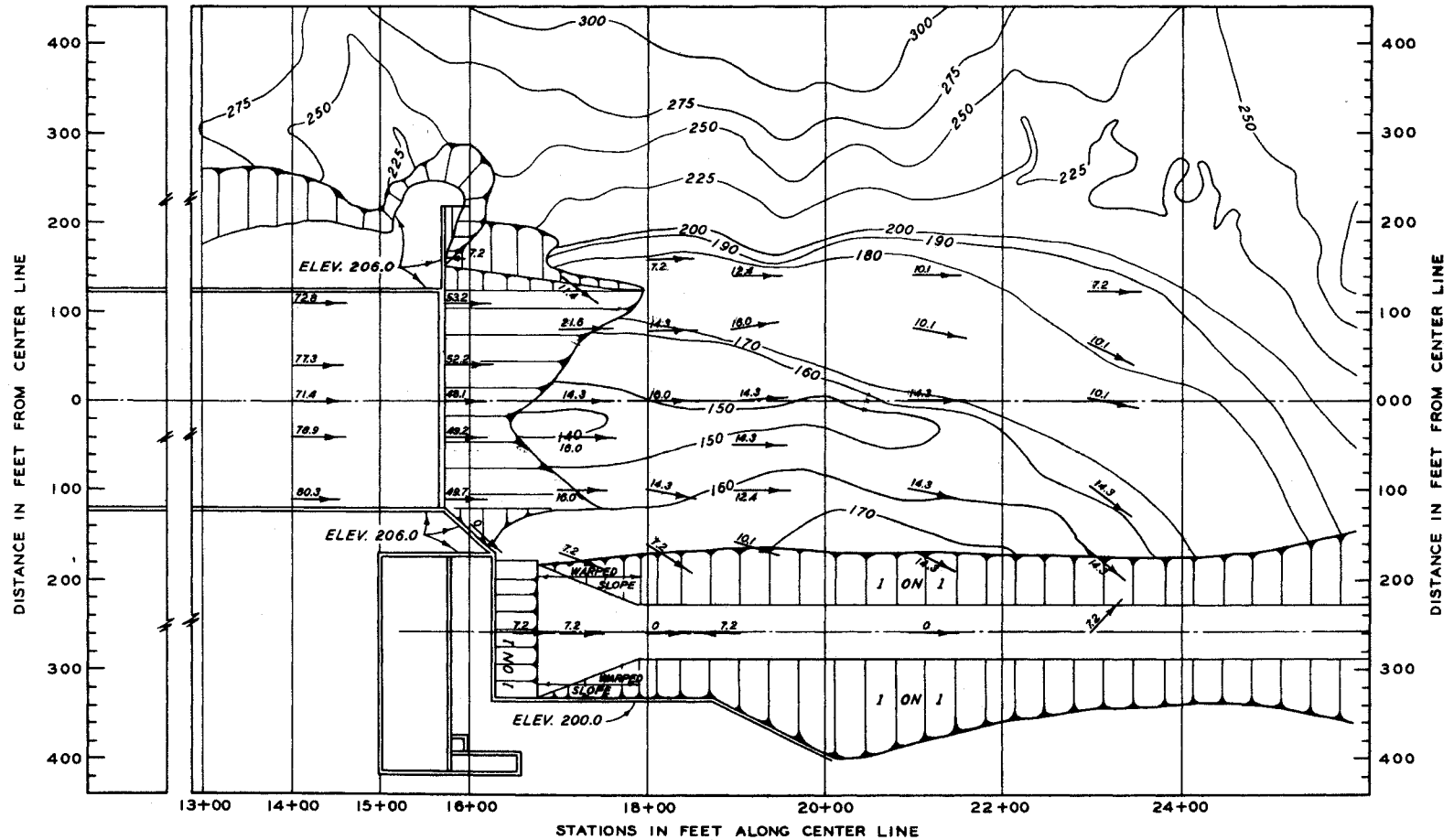


**TEST CONDITIONS**

ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28 FT (6,7&8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2 FT OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 193,000 CFS



**TEST CONDITIONS**

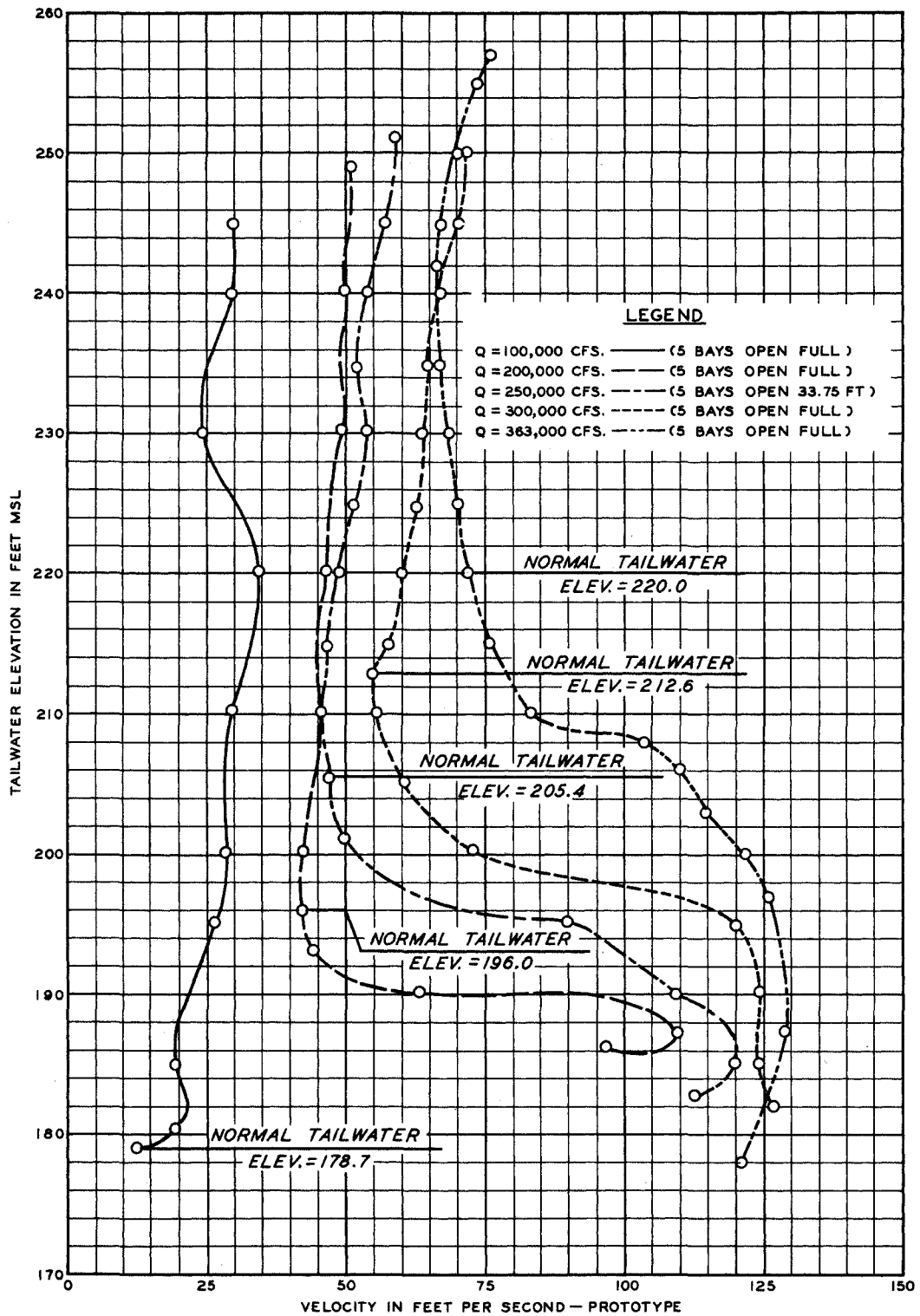
ORIGINAL DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEV 466.00 FT  
 TAILWATER ELEV 205.40 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 33.75 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2 FT OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE I (ORIGINAL) DESIGN  
 DISCHARGE 243,000 CFS



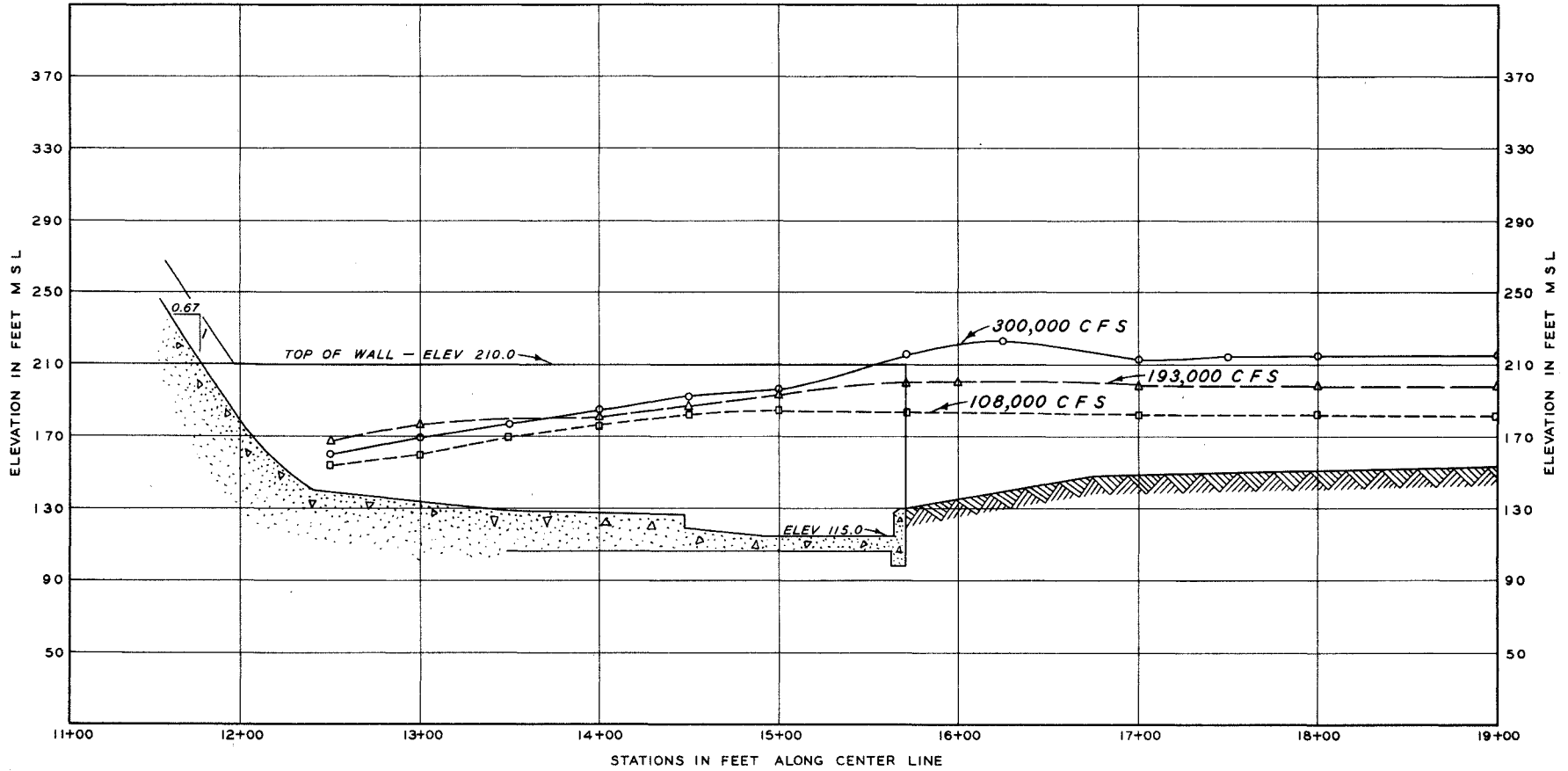




NOTE: VELOCITIES MEASURED AT END OF APRON ON TOP OF 5.0 FT. END SILL. BED FIXED IN CEMENT MORTAR TO NATURAL CONFIGURATIONS.

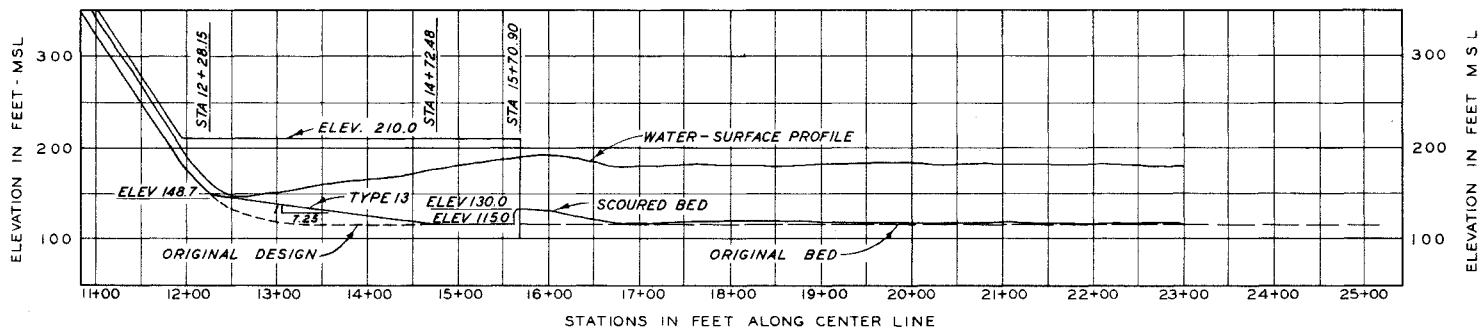
MODEL B

EFFECT OF TAILWATER ELEVATIONS  
ORIGINAL DESIGN

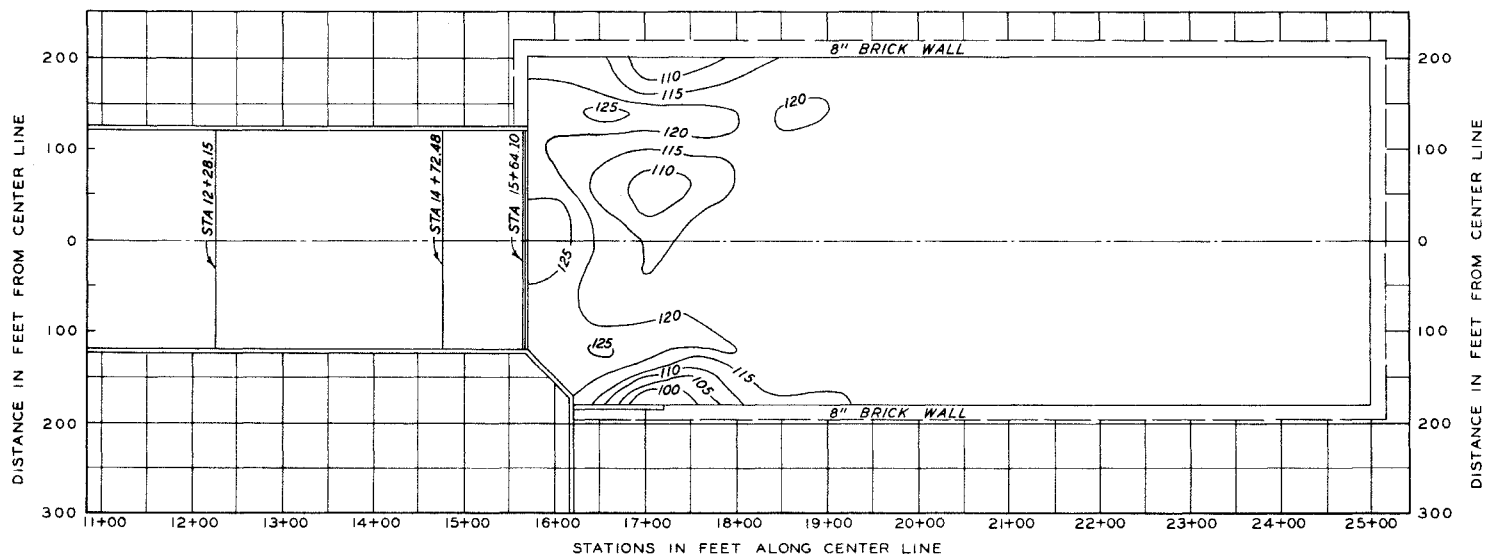


MODEL B  
 WATER-SURFACE PROFILES  
 TYPE 2 DESIGN





**PROFILE**



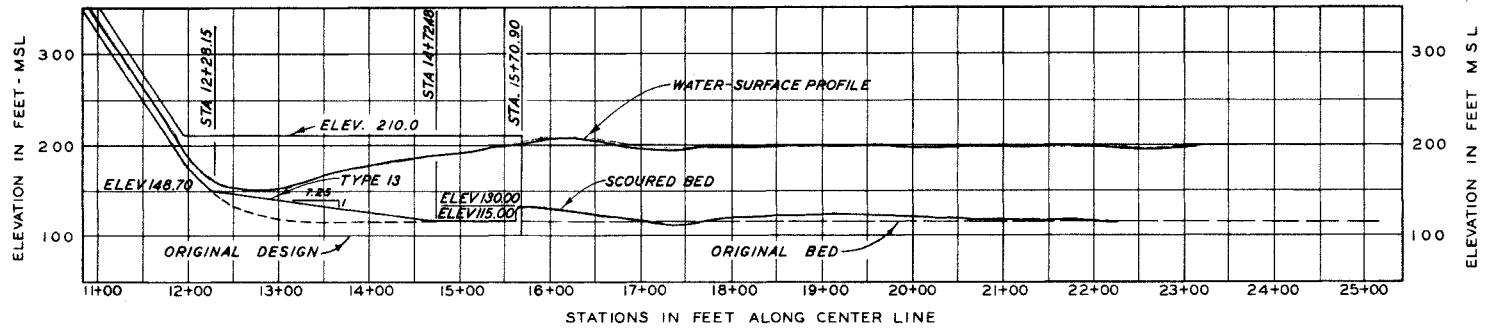
**PLAN**

**TEST CONDITIONS**

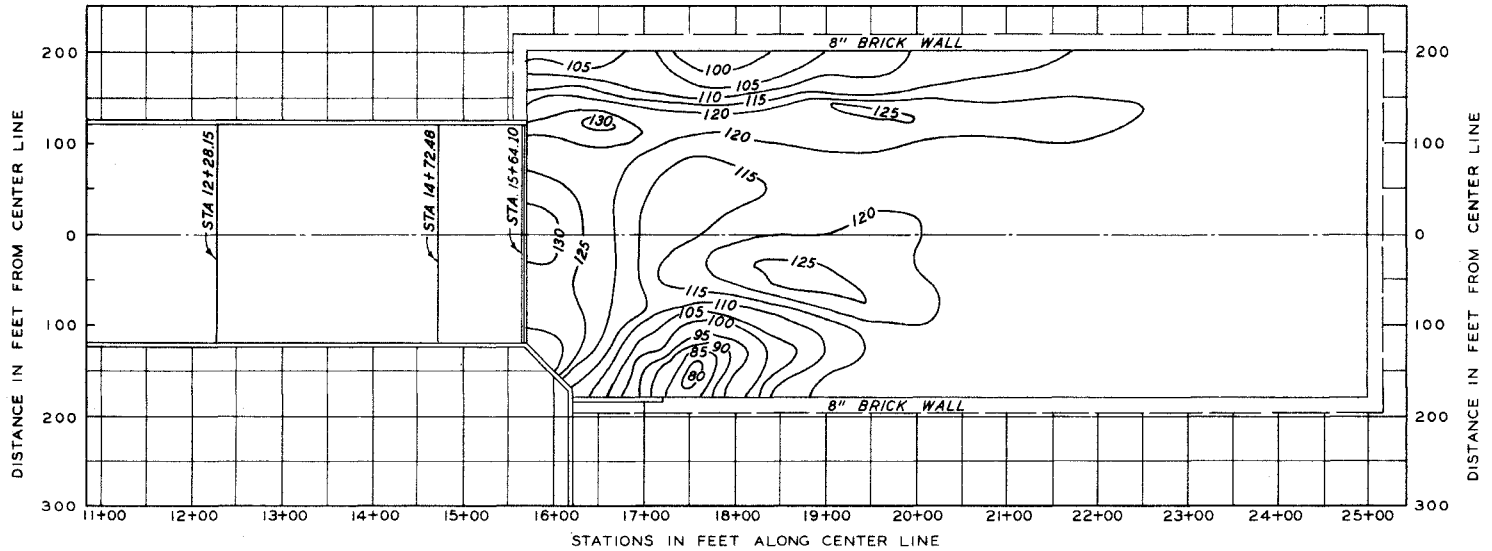
TYPE 13 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

NOTE: SAND MOLDED FLAT TO  
 ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 13 STILLING BASIN  
 DISCHARGE 108,000 CFS



**PROFILE**



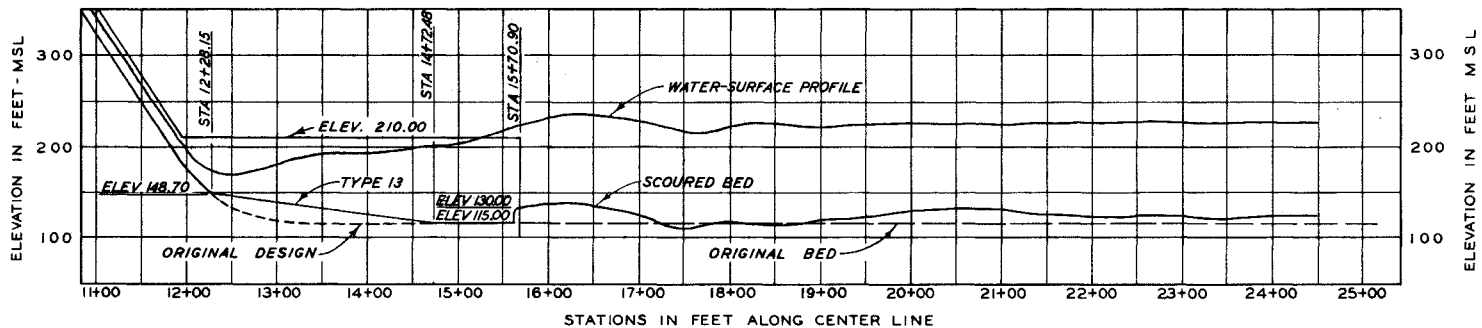
**PLAN**

**TEST CONDITIONS**

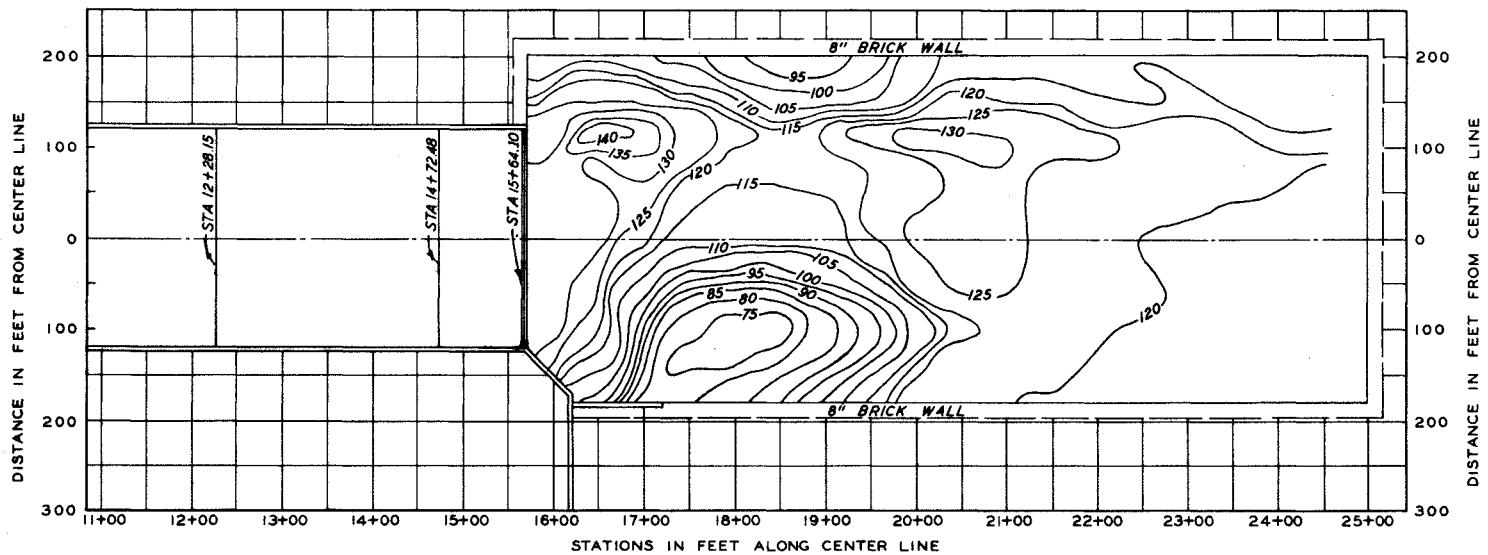
TYPE 13 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 195.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: SAND MOLDED FLAT TO  
 ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 13 STILLING BASIN  
 DISCHARGE 193,000 CFS



**PROFILE**



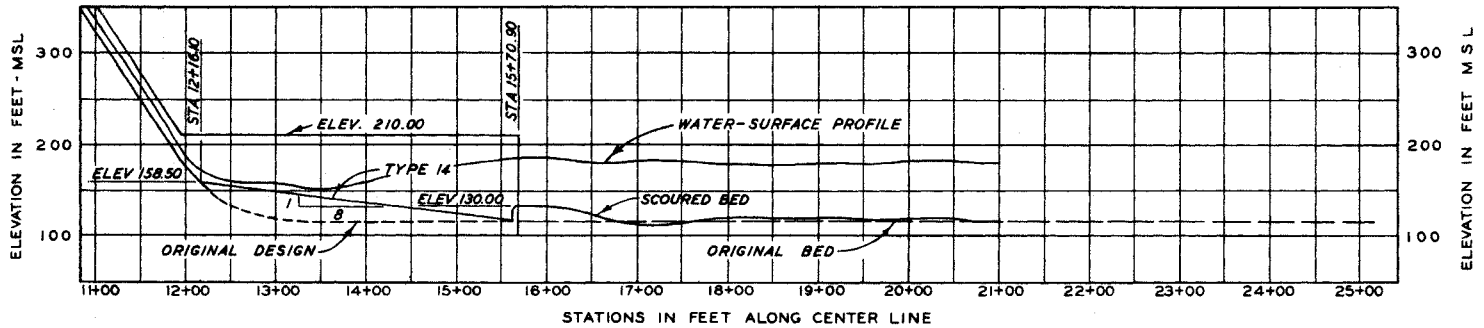
**PLAN**

**TEST CONDITIONS**

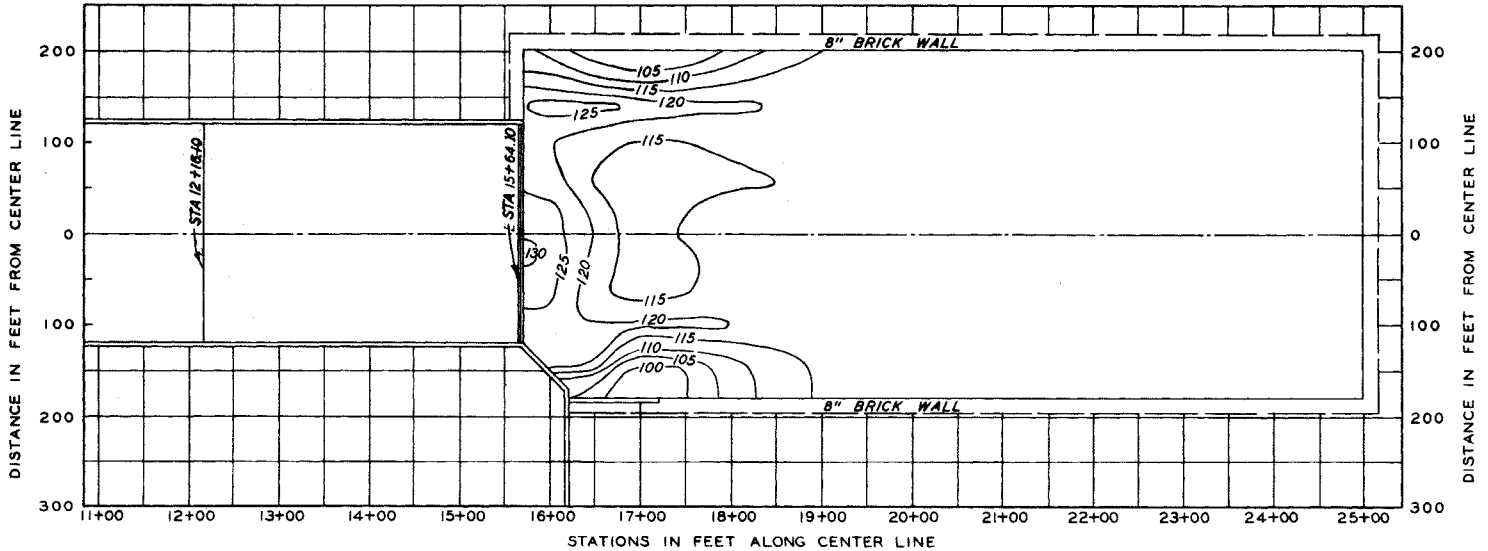
TYPE 13 DESIGN  
 POOL ELEVATION 468.60 FT  
 TAILWATER ELEVATION 212.60 FT  
 CONDUITS & PENSTOCKS CLOSED  
 5 BAYS OPEN FULL (6, 7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 13 STILLING BASIN  
 DISCHARGE 300,000 CFS



**PROFILE**



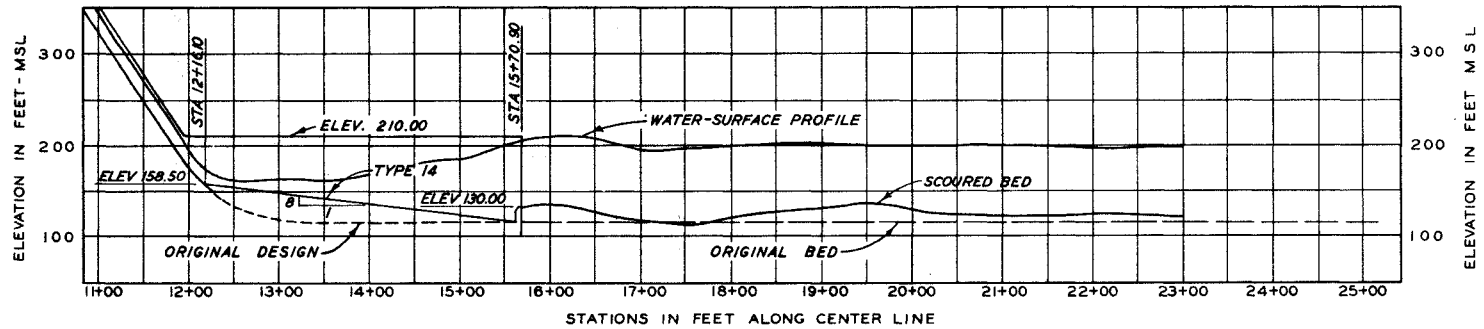
**PLAN**

**TEST CONDITIONS**

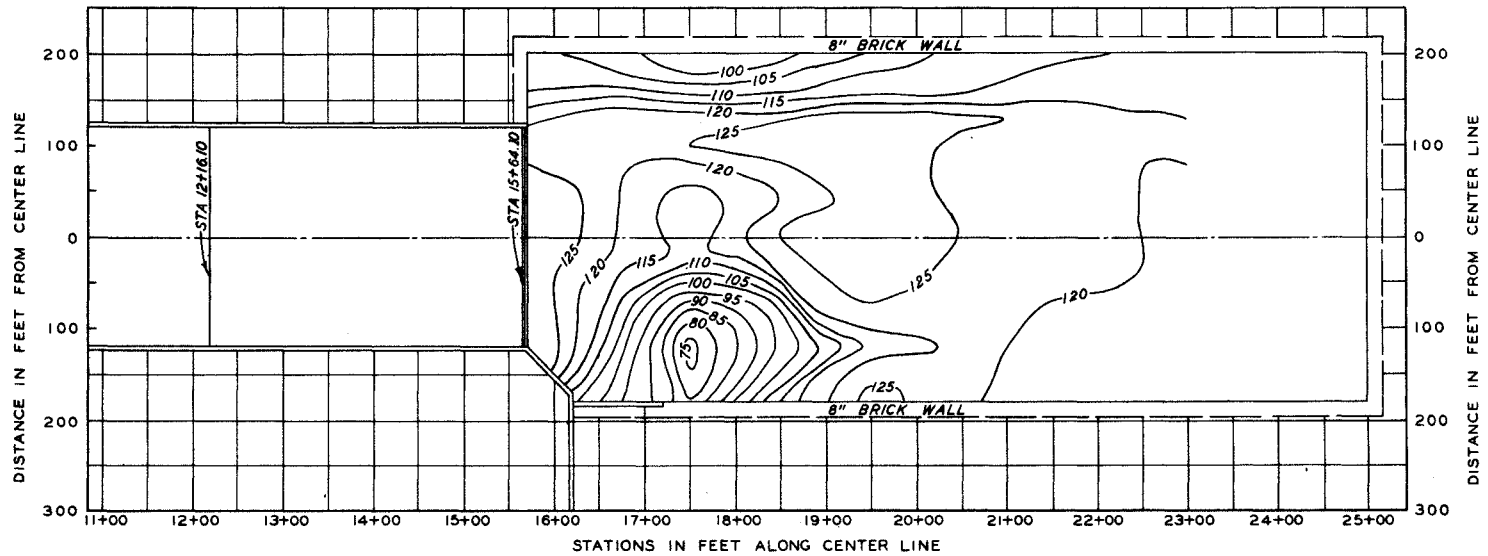
TYPE 14 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.0 FT M.S.L.

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 14 STILLING BASIN  
 DISCHARGE 108,000 CFS



**PROFILE**



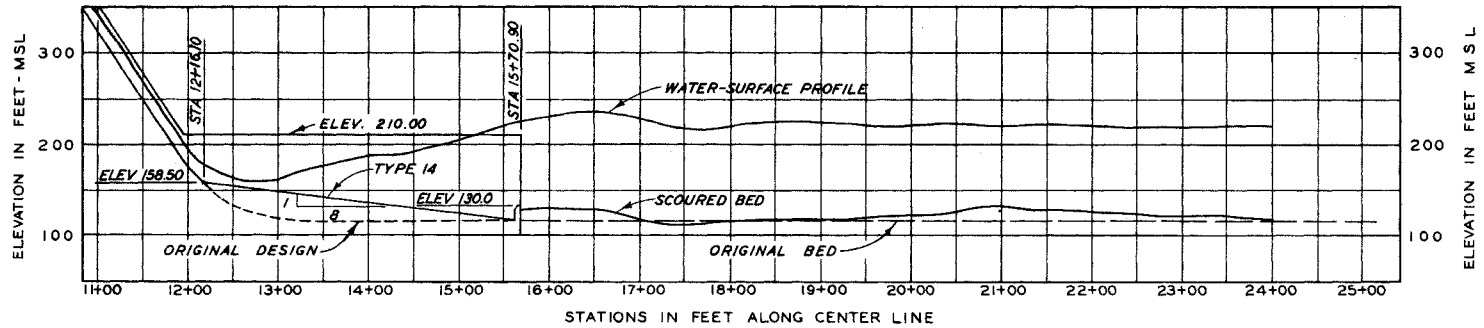
**PLAN**

**TEST CONDITIONS**

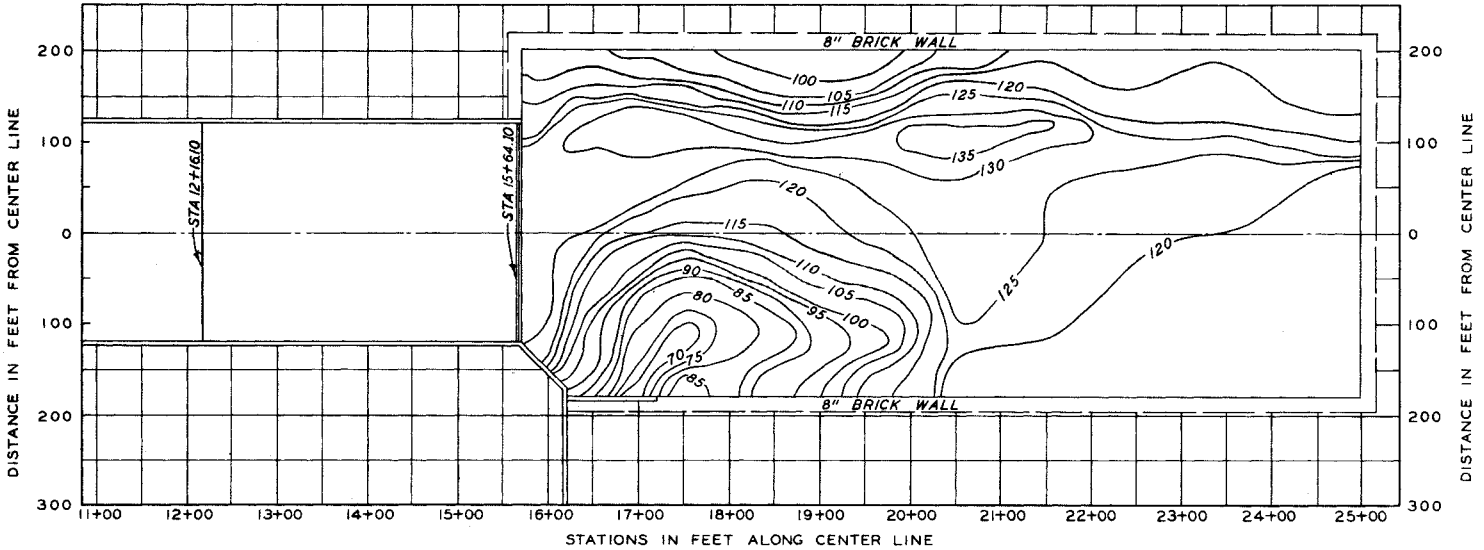
TYPE 14 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 488.00 FT  
 TAILWATER ELEVATION 195.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.0 FT M.S.L.

**MODEL B**  
**WATER-SURFACE PROFILE**  
**AND SCOUR PATTERN**  
 TYPE 14 STILLING BASIN  
 DISCHARGE 193,000 CFS



**PROFILE**



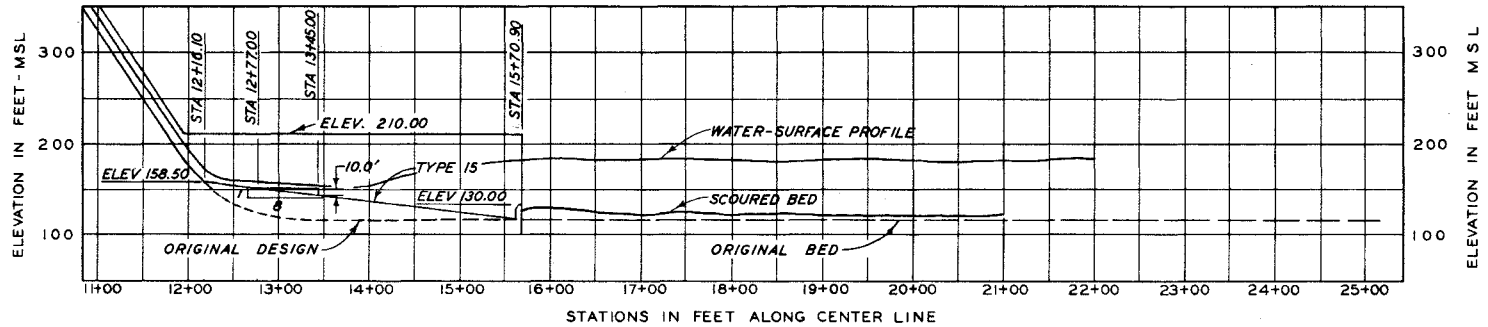
**PLAN**

**TEST CONDITIONS**

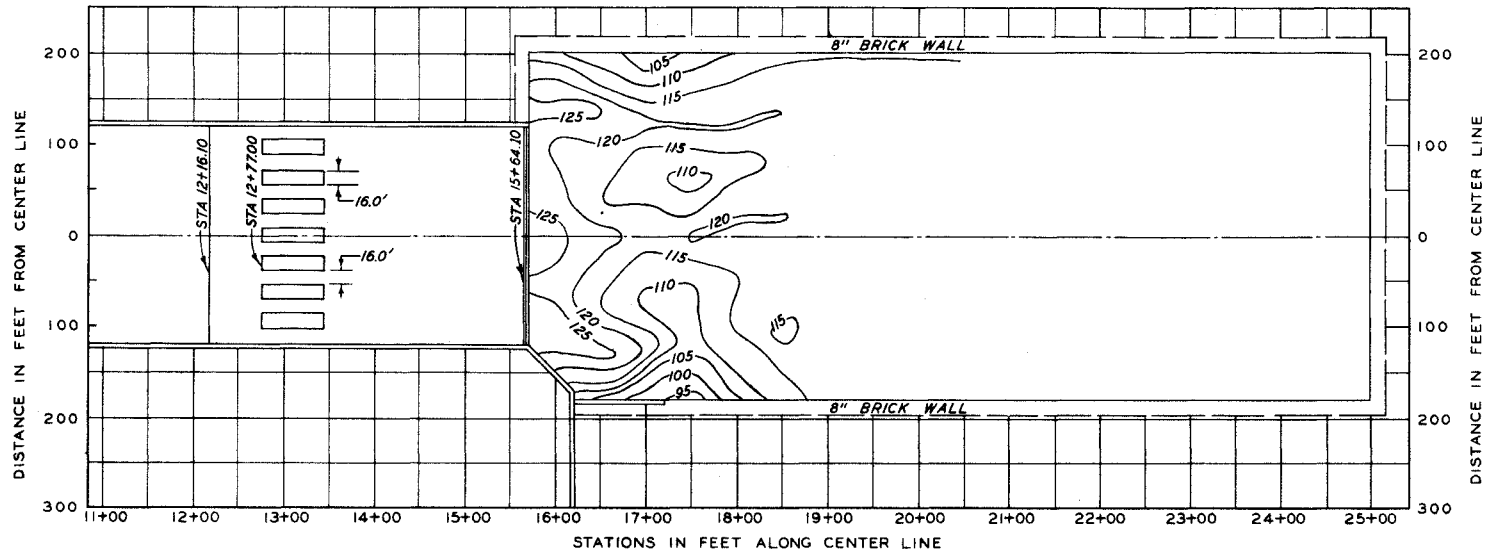
TYPE 14 DESIGN  
 POOL ELEVATION 488.60 FT  
 TAILWATER ELEVATION 212.60 FT  
 CONDUITS & PENSTOCKS CLOSED  
 5 BAYS OPEN FULL (6 7&8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.00 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 14 STILLING BASIN  
 DISCHARGE 300,000 CFS



**PROFILE**



**PLAN**

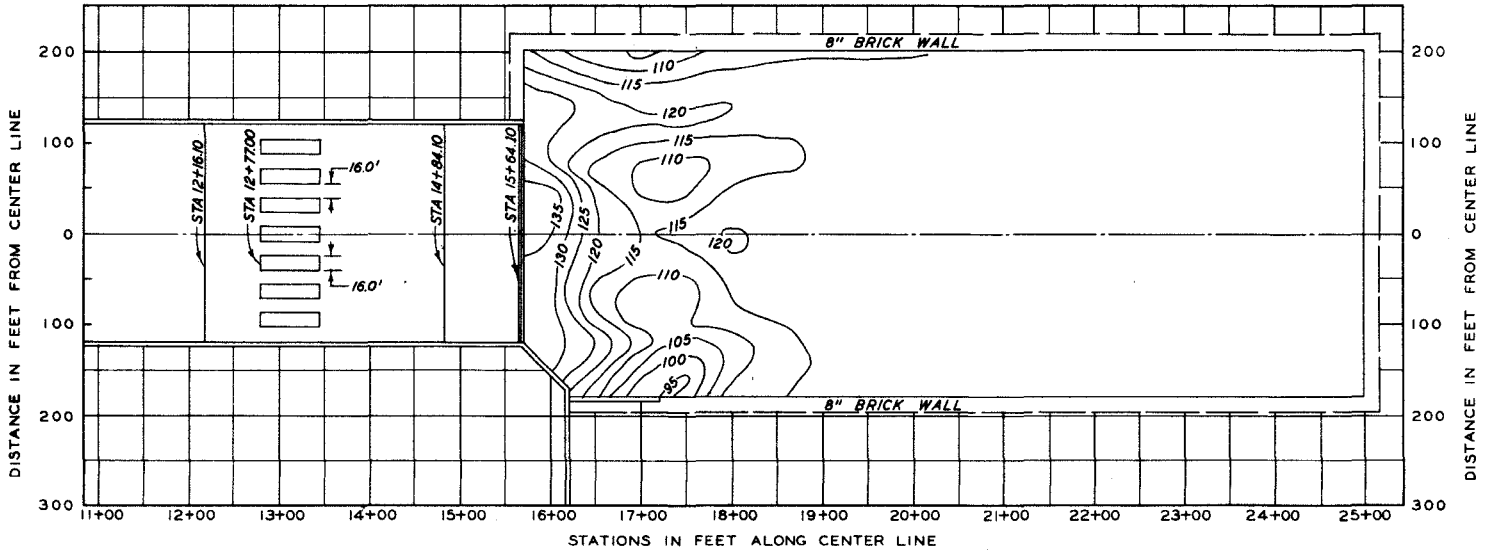
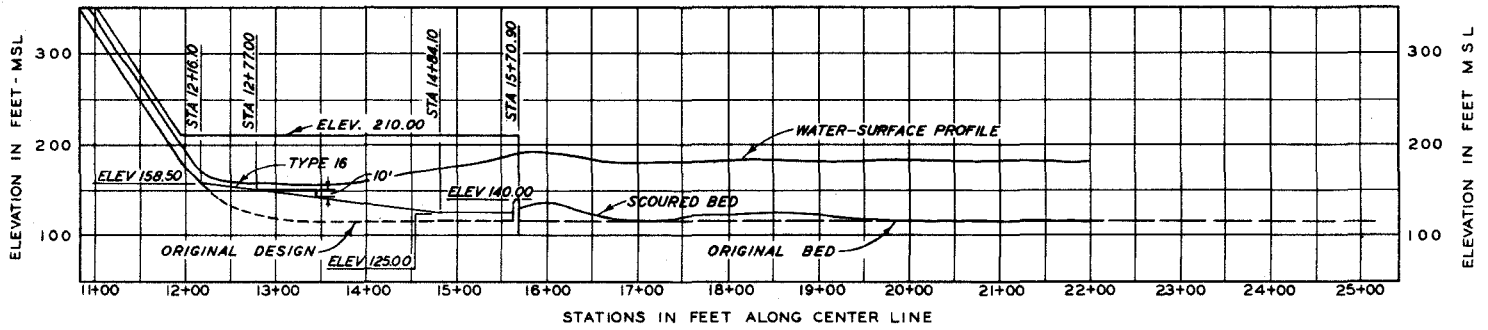
**TEST CONDITIONS**

TYPE 15 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7&8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.00 FT MSL

**MODEL B  
 WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**

**TYPE 15 STILLING BASIN  
 DISCHARGE 108,000 CFS**

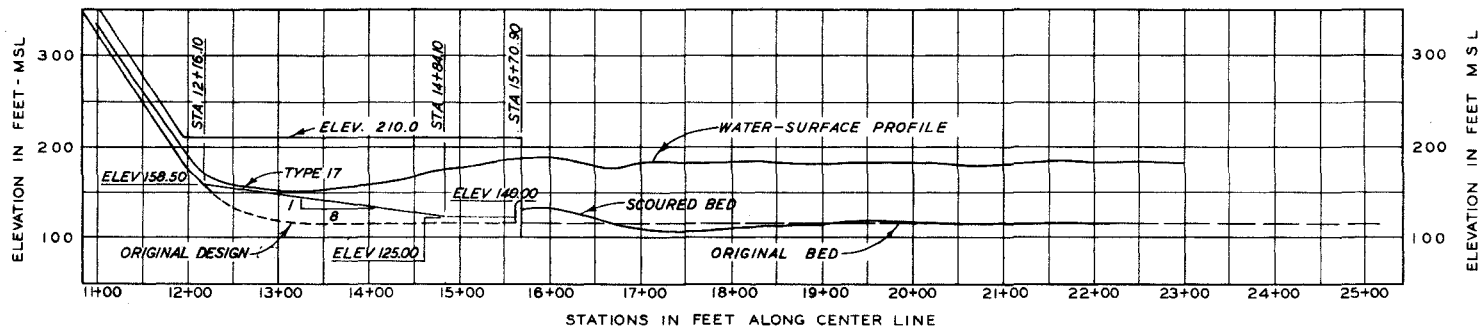


**TEST CONDITIONS**

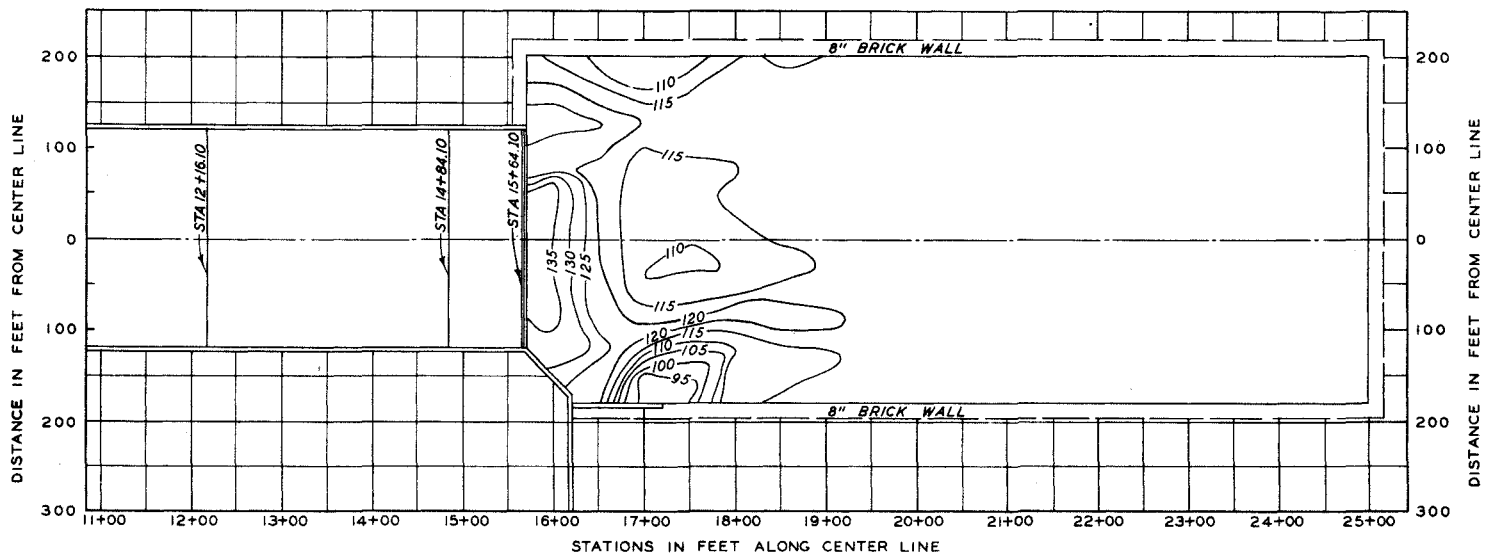
TYPE 16 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.00 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 16 STILLING BASIN  
 DISCHARGE 108,000 CFS



**PROFILE**



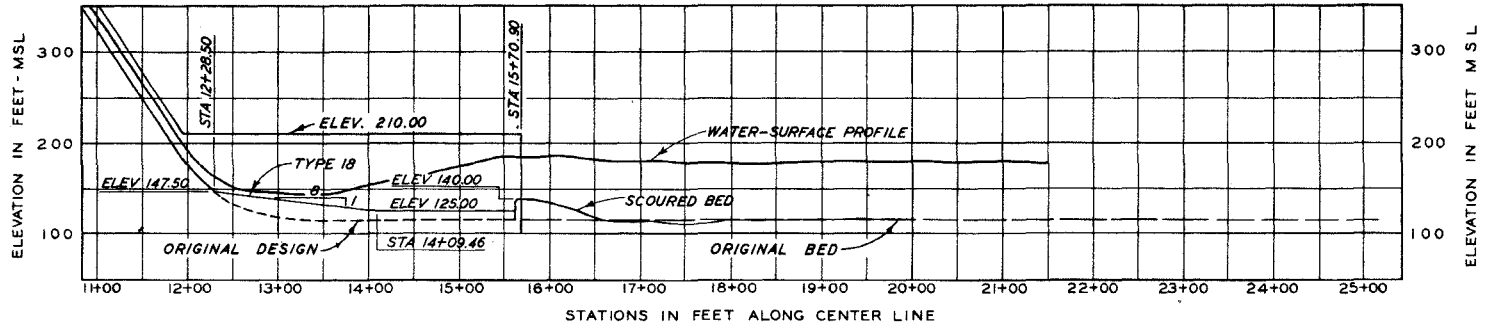
**PLAN**

**TEST CONDITIONS**

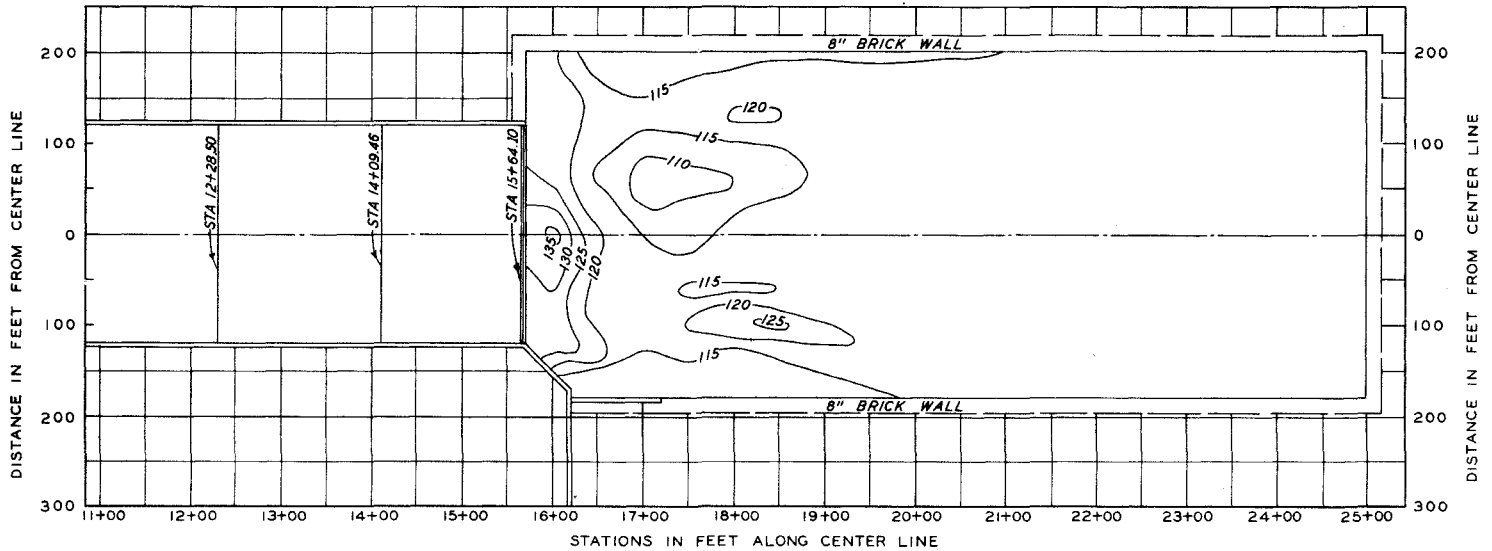
TYPE 17 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 486.00 FT  
 TAILWATER ELEVATION 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 17 STILLING BASIN  
 DISCHARGE 108,000 CFS



**PROFILE**



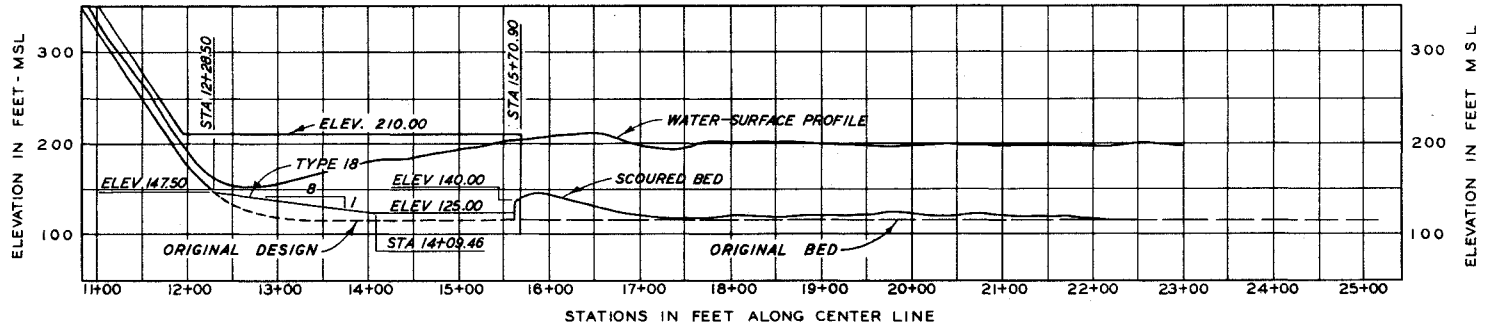
**PLAN**

**TEST CONDITIONS**

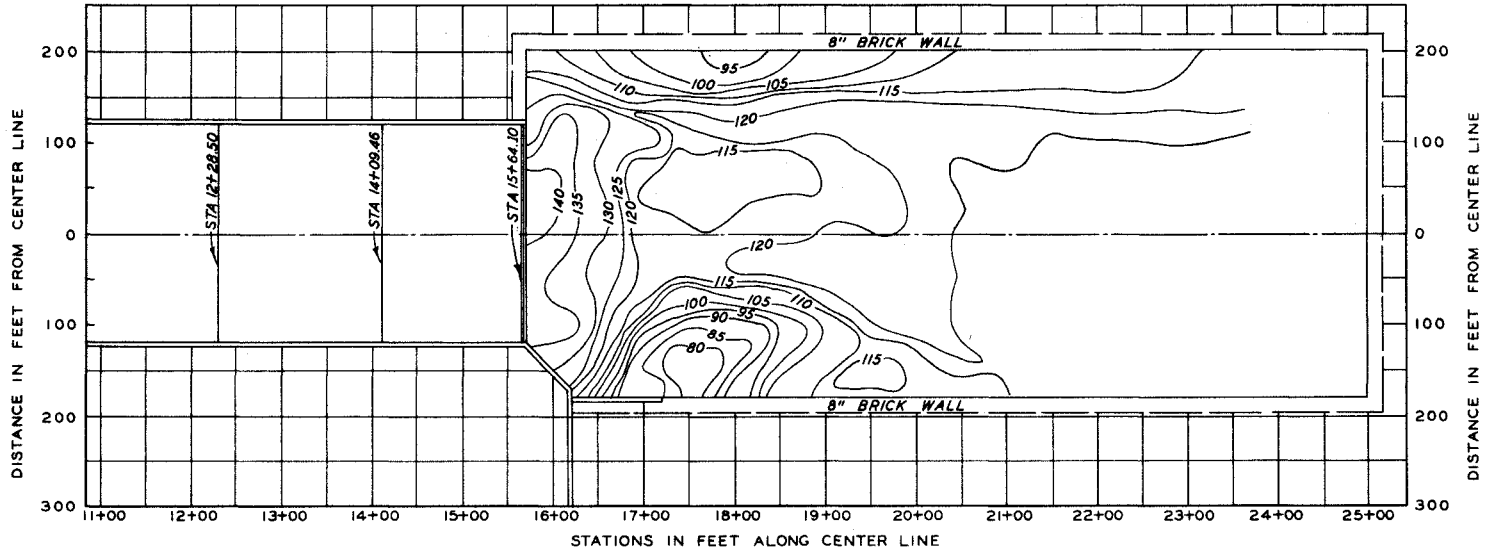
TYPE 18 DESIGN  
 PENSTOCKS 10 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 176.50 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (8, 7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 18 STILLING BASIN  
 DISCHARGE 108,000 CFS



**PROFILE**



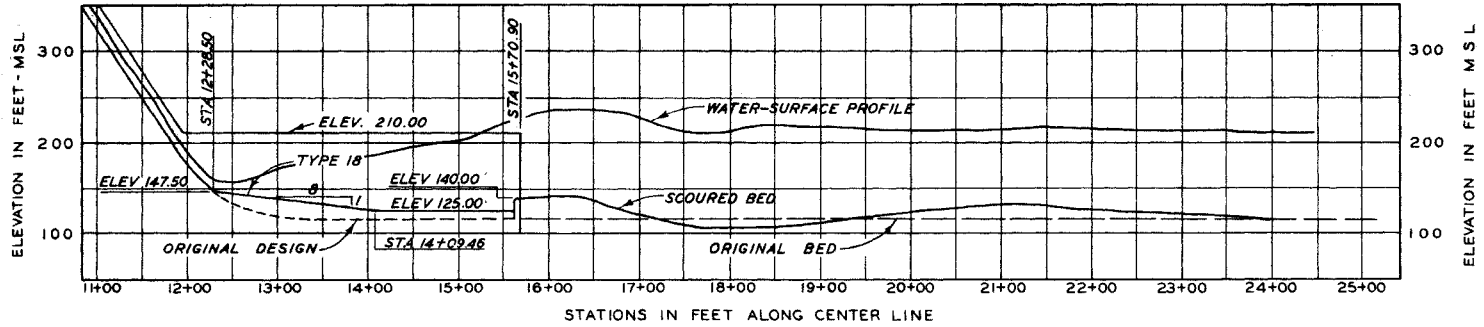
**PLAN**

**TEST CONDITIONS**

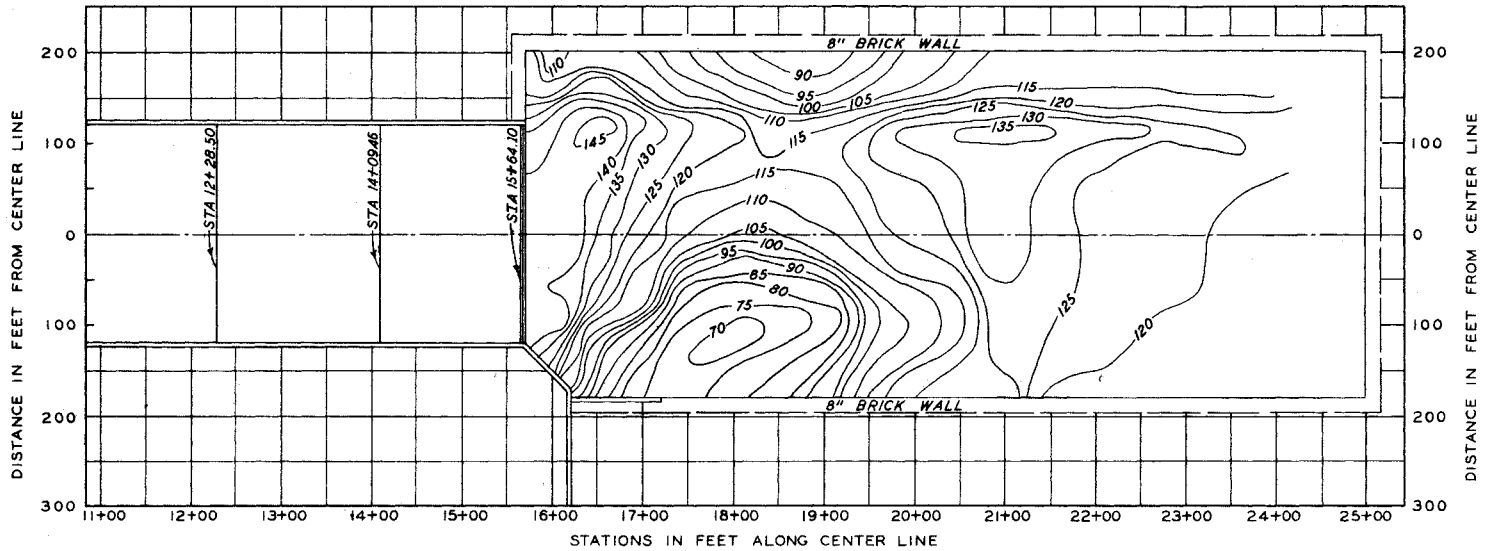
TYPE 18 DESIGN  
 PENSTOCKS 0 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 195.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: SAND BED MOLDED FLAT TO  
 ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 18 STILLING BASIN  
 DISCHARGE 193,000 CFS



**PROFILE**



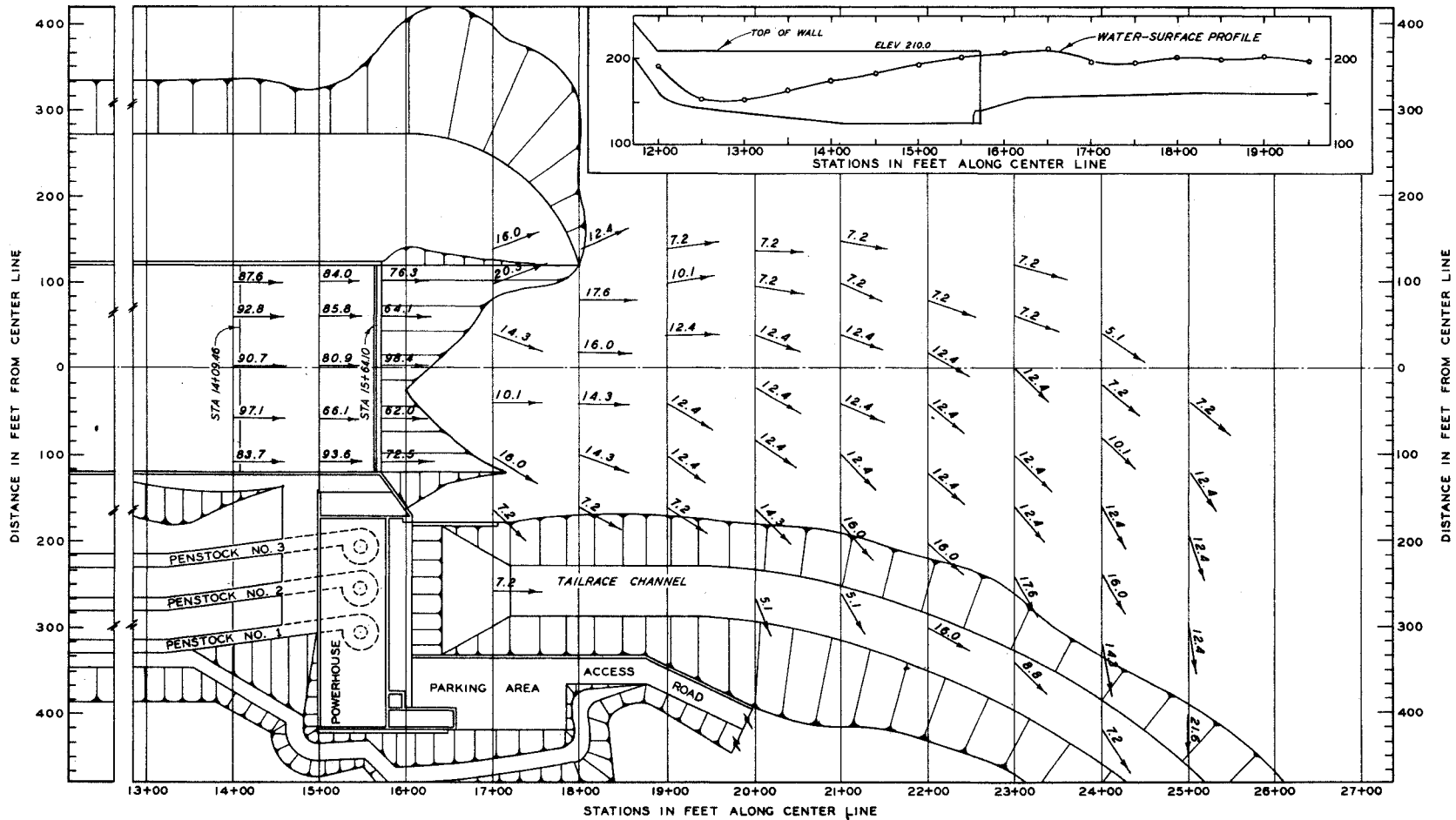
**PLAN**

**TEST CONDITIONS**

TYPE 18 DESIGN  
 POOL ELEVATION 488.60 FT  
 TAILWATER ELEVATION 212.60 FT  
 CONDUITS & PENSTOCKS CLOSED  
 5 BAYS OPEN FULL (6 7 & 8 CLOSED)

NOTE: SAND MOLDED FLAT TO ELEVATION 115.0 FT MSL

MODEL B  
**WATER-SURFACE PROFILE  
 AND SCOUR PATTERN**  
 TYPE 18 STILLING BASIN  
 DISCHARGE 300,000 CFS

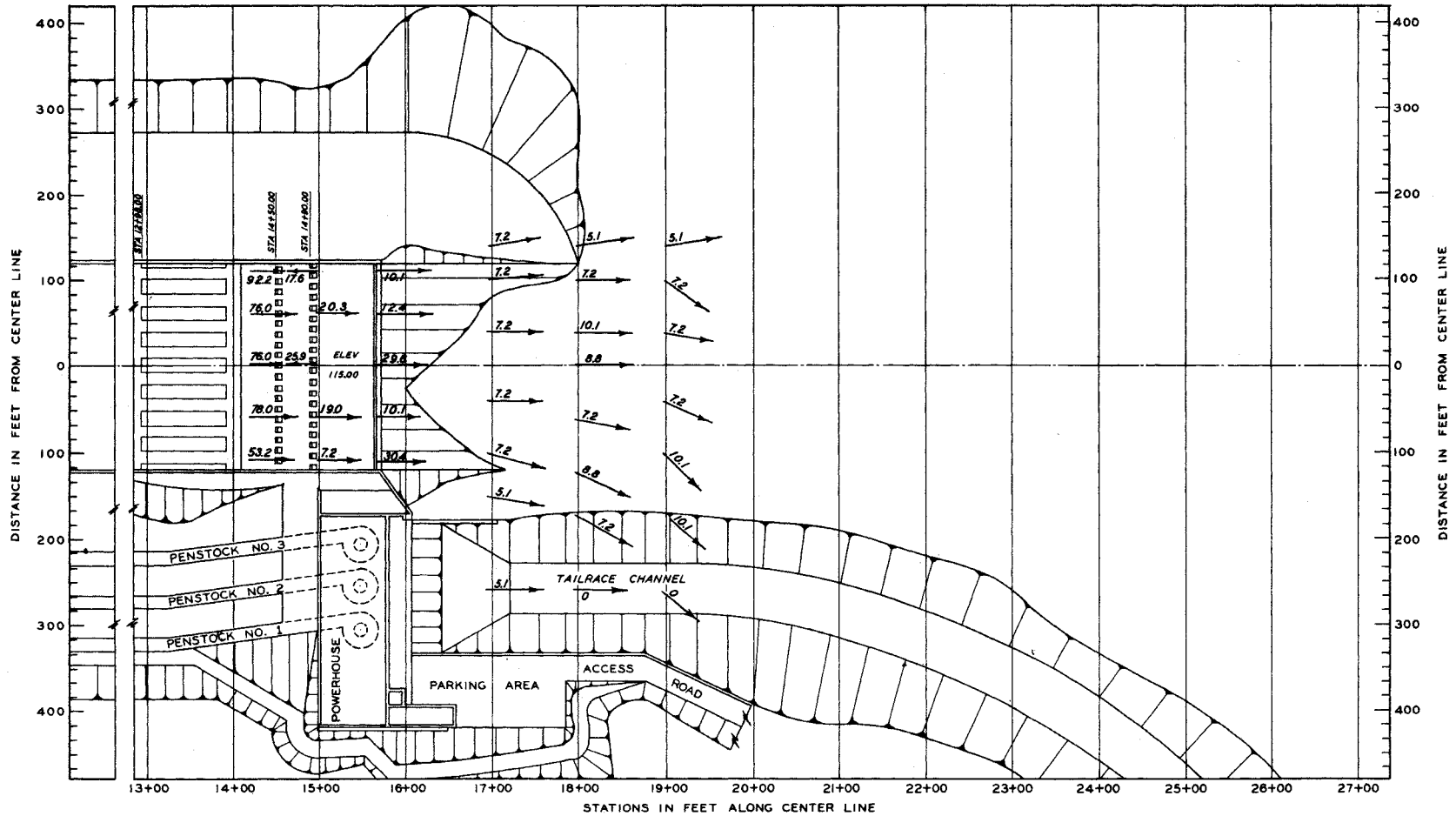


**TEST CONDITIONS**

TYPE 18 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 486.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 18 STILLING BASIN  
 DISCHARGE 193,000 CFS



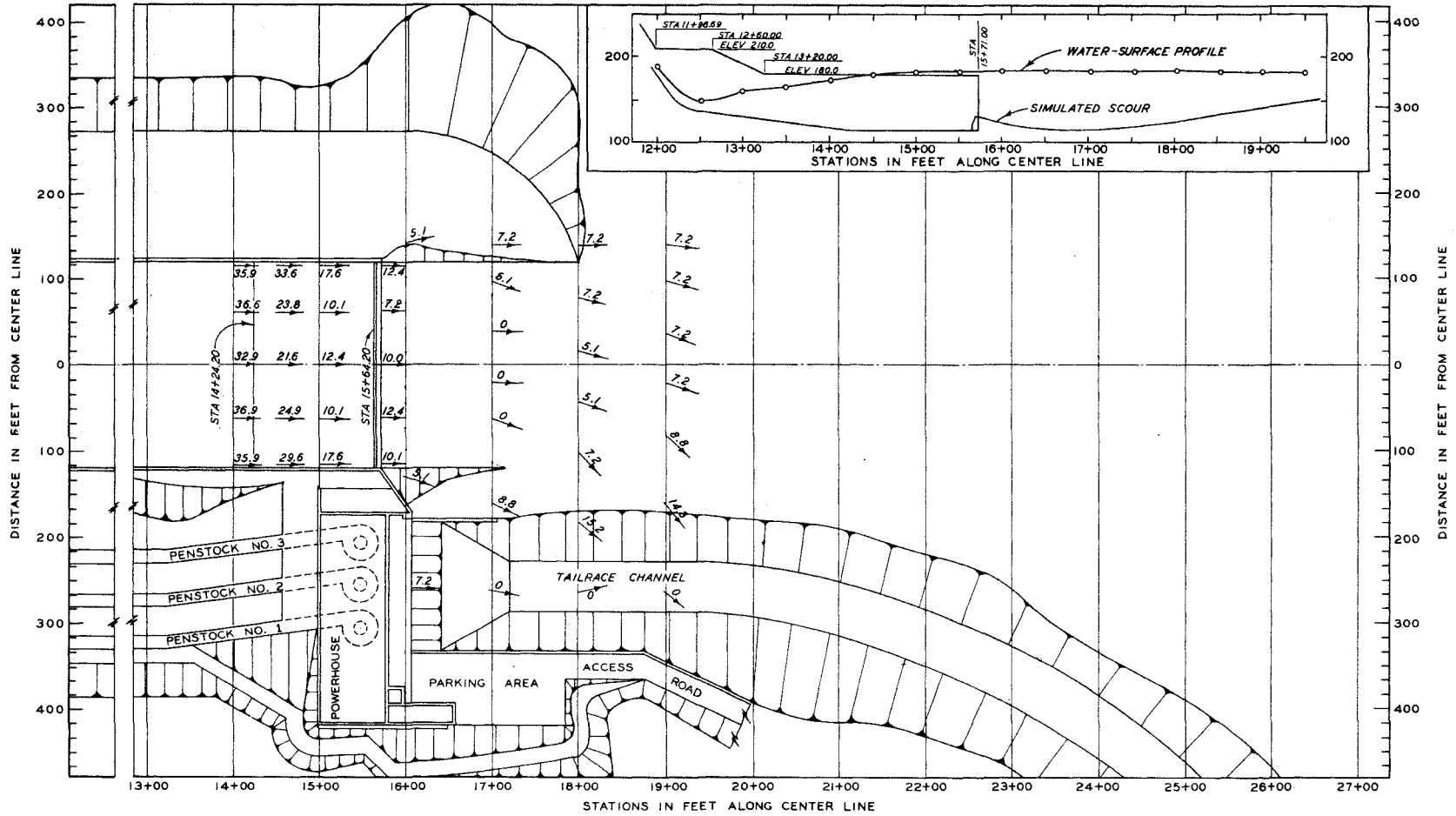
**TEST CONDITIONS**

TYPE 19 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 19 STILLING BASIN  
 DISCHARGE 193,000 CFS





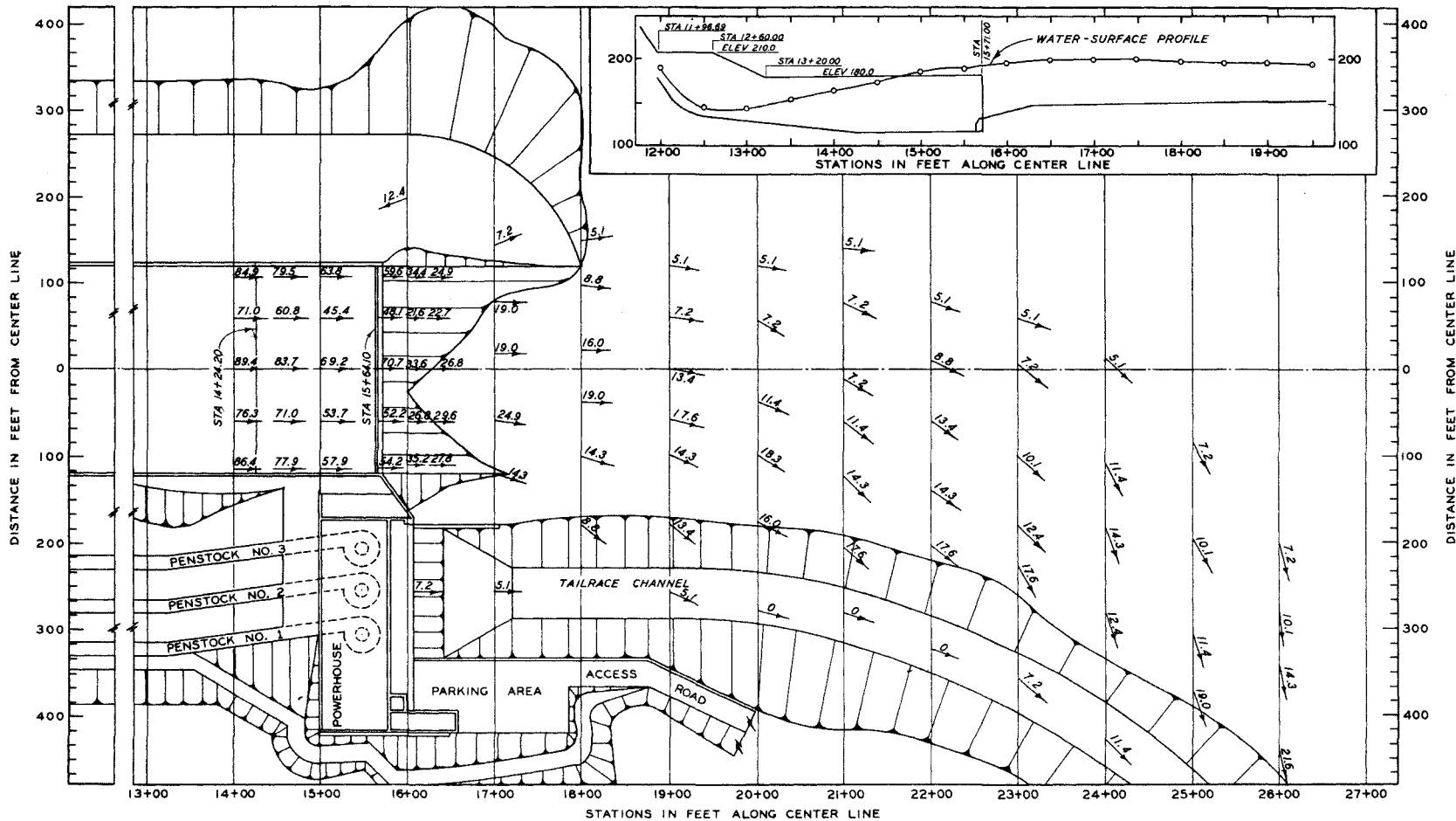
**TEST CONDITIONS**

TYPE 22 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 179.20 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7,8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2.0 FEET OFF BOTTOM. BED MOLDED IN CEMENT MORTAR TO SIMULATED SCOUR.

**MODEL B  
 BOTTOM VELOCITIES**

TYPE 22 STILLING BASIN  
 DISCHARGE 108,000 CFS  
 BED MOLDED TO SIMULATED SCOUR

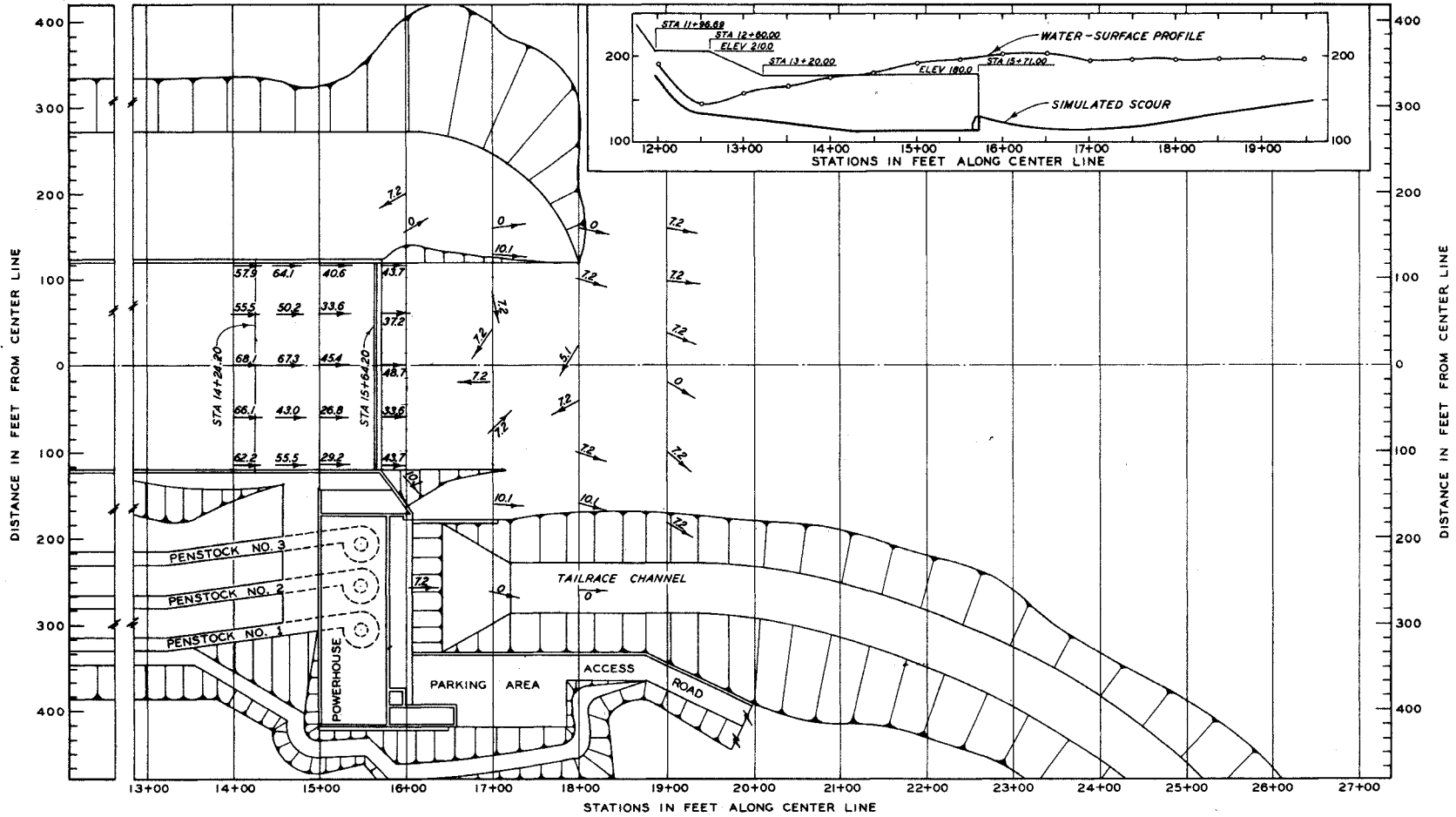


**TEST CONDITIONS**

TYPE 22 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 22 STILLING BASIN  
 DISCHARGE 193,000 CFS  
 BED MOLDED TO NATURAL CONFIGURATION



**TEST CONDITIONS**

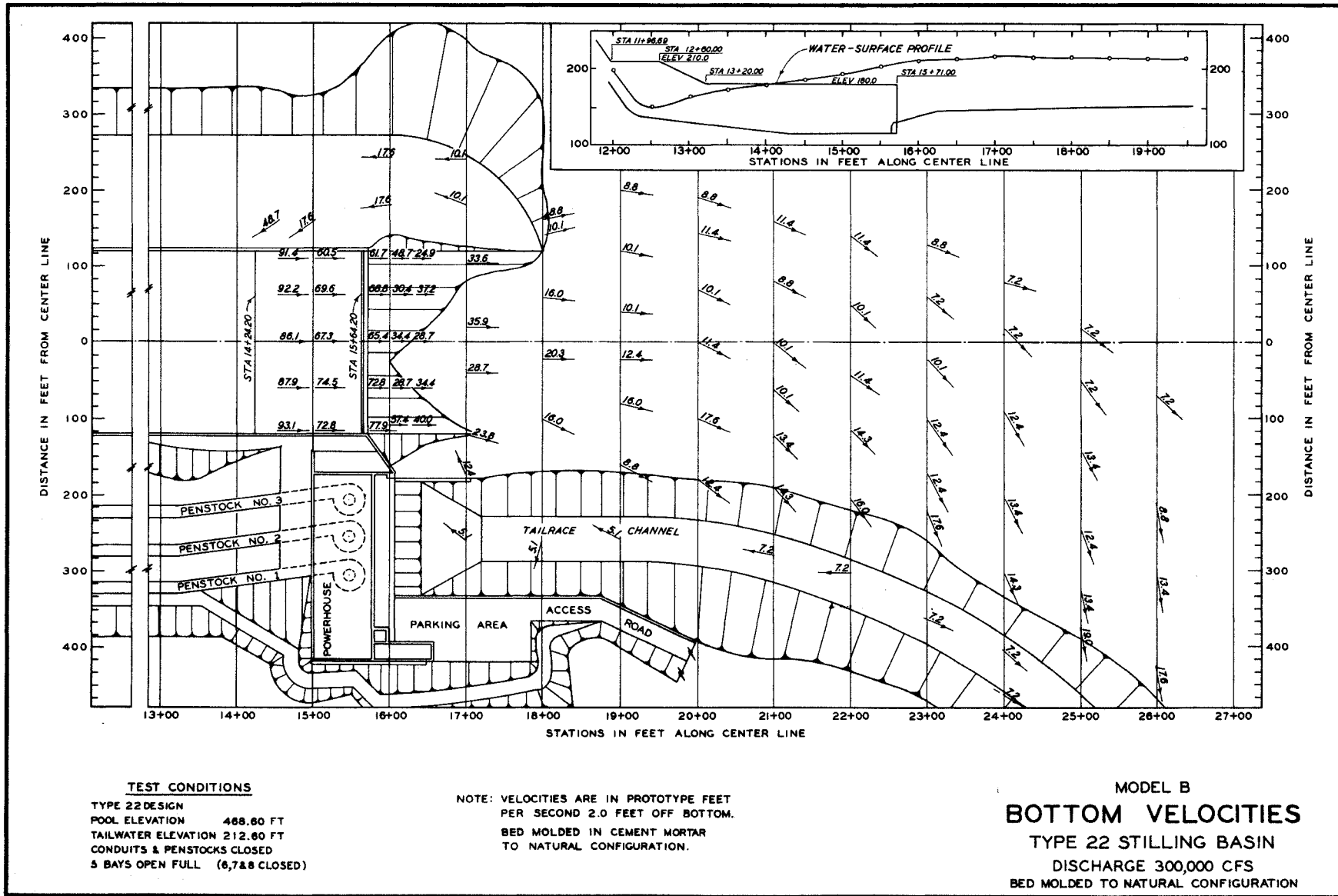
TYPE 22 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 486.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2.0 FEET OFF BOTTOM. BED MOLDED IN CEMENT MORTAR TO SIMULATED SCOUR.

**MODEL B  
 BOTTOM VELOCITIES**

TYPE 22 STILLING BASIN

DISCHARGE 193,000 CFS  
 BED MOLDED TO SIMULATED SCOUR

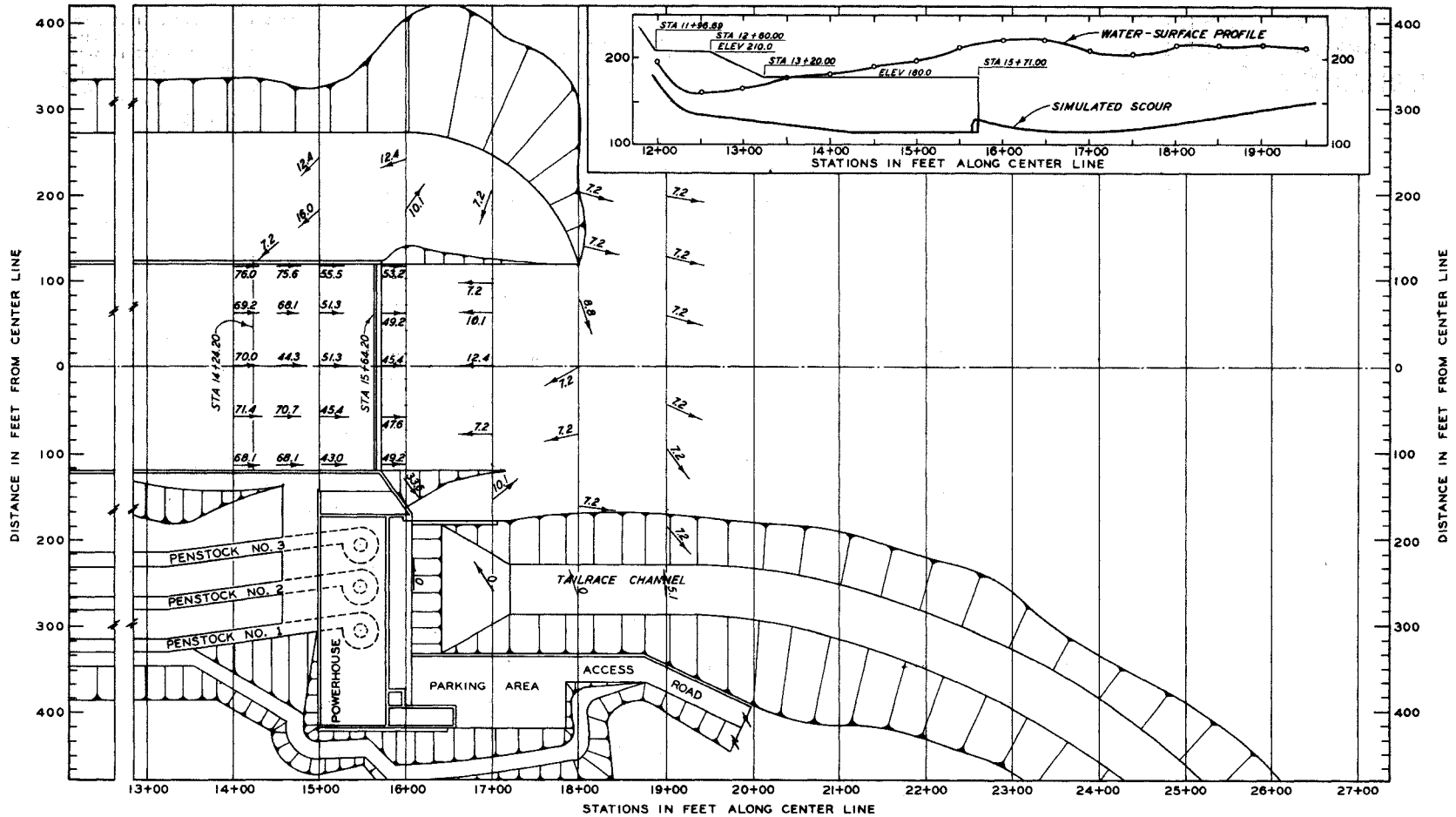


**TEST CONDITIONS**

TYPE 22 DESIGN  
 POOL ELEVATION 468.60 FT  
 TAILWATER ELEVATION 212.60 FT  
 CONDUITS & PENSTOCKS CLOSED  
 3 BAYS OPEN FULL (6,7&8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 22 STILLING BASIN  
 DISCHARGE 300,000 CFS  
 BED MOLDED TO NATURAL CONFIGURATION

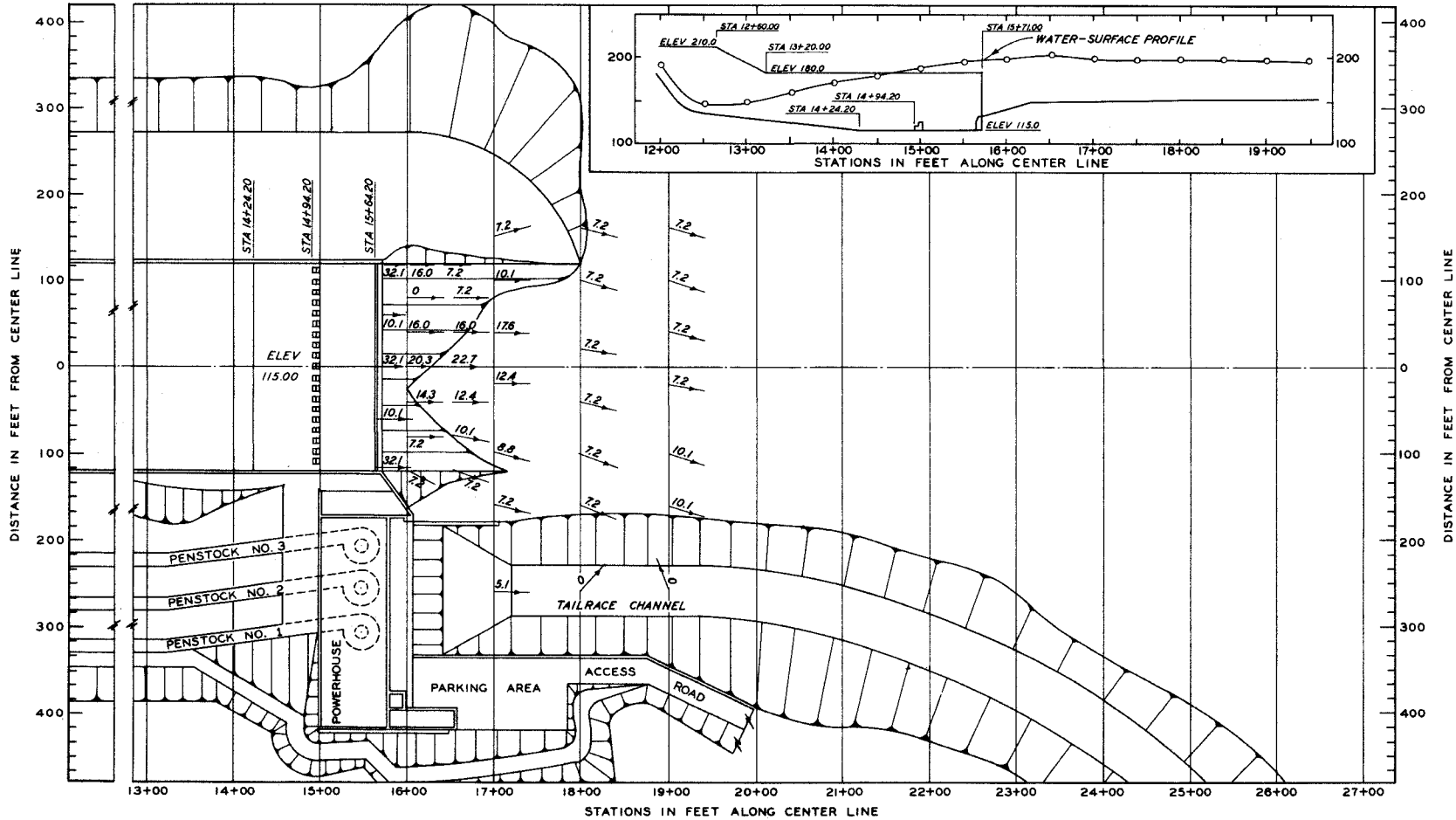


**TEST CONDITIONS**

TYPE 22 DESIGN  
 POOL ELEVATION 468.60 FT  
 TAILWATER ELEVATION 212.60 FT  
 CONDUITS & PENSTOCKS CLOSED  
 5 BAYS OPEN FULL (6,7&8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2.0 FEET OFF BOTTOM. BED MOLDED IN CEMENT MORTAR TO SIMULATED SCOUR.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 22 STILLING BASIN  
 DISCHARGE 300,000 CFS  
 BED MOLDED TO SIMULATED SCOUR

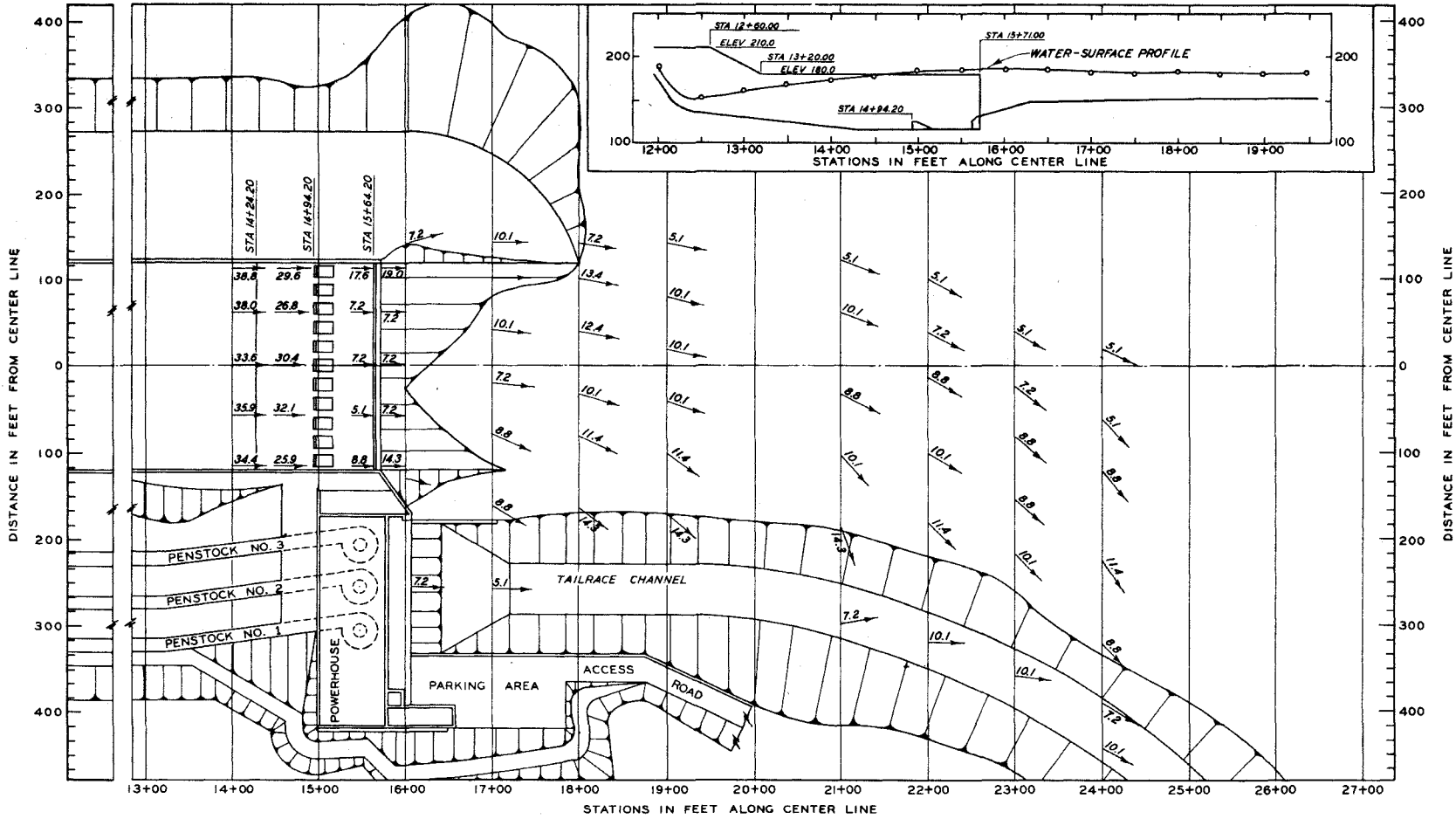


**TEST CONDITIONS**

TYPE 23 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 488.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7&8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 23 STILLING BASIN  
 DISCHARGE 193,000 CFS



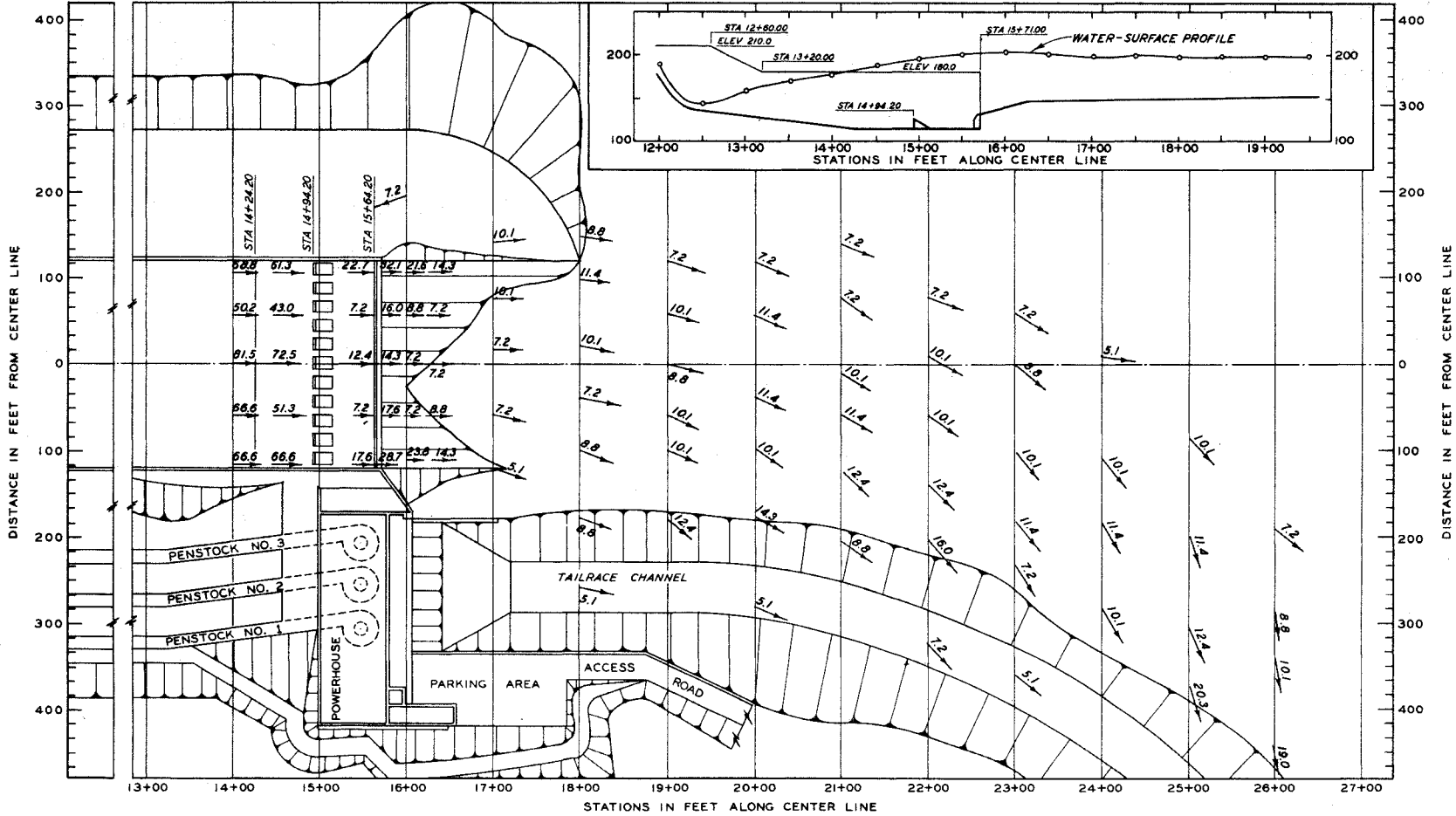
**TEST CONDITIONS**

TYPE 24 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 466.00 FT  
 TAILWATER ELEVATION 179.20 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 14.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 24 STILLING BASIN  
 DISCHARGE 108,000 CFS  
 BED MOLDED TO NATURAL CONFIGURATION



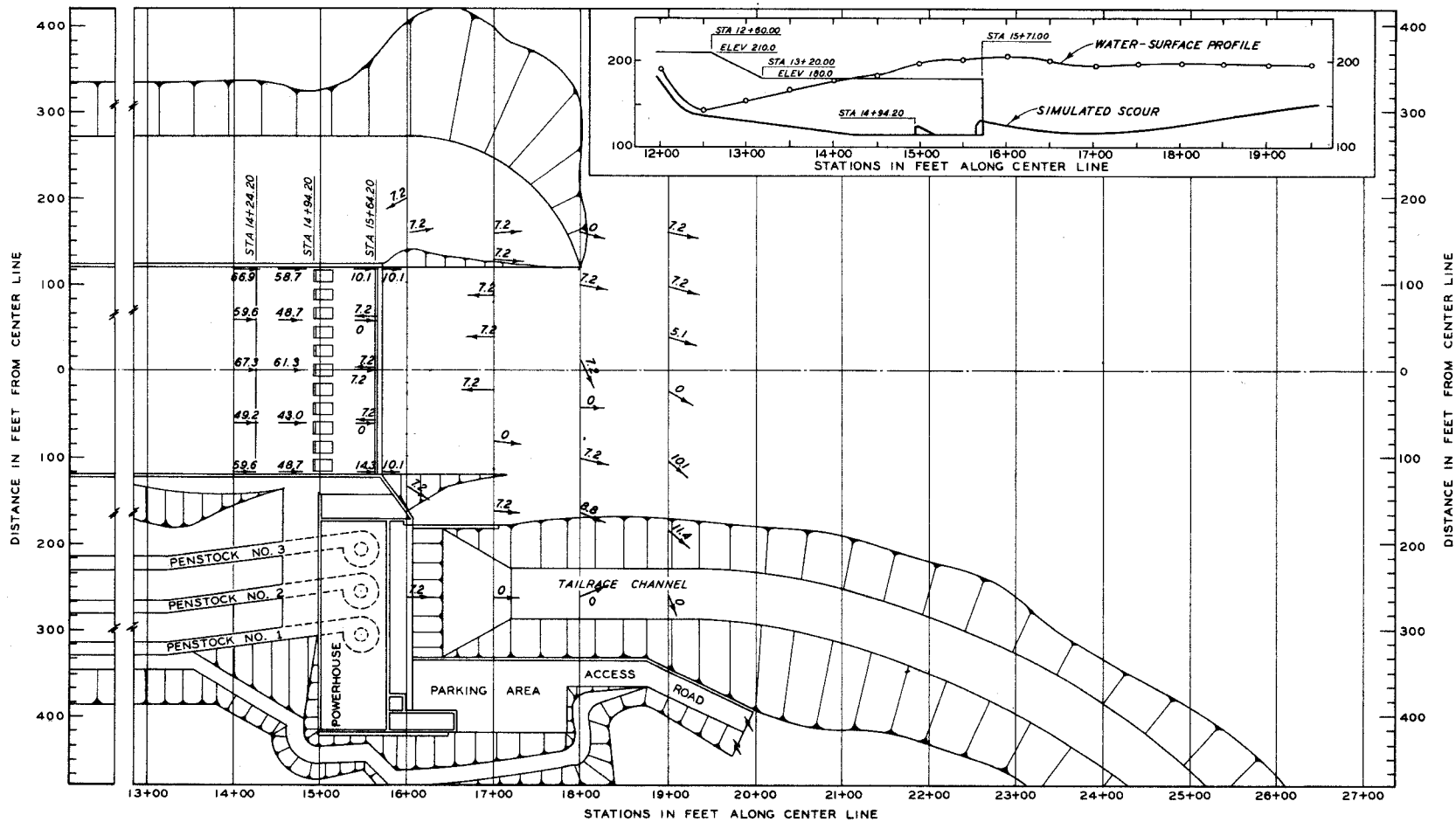


**TEST CONDITIONS**

TYPE 24 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 486.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2.0 FEET OFF BOTTOM. BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 24 STILLING BASIN  
 DISCHARGE 193,000 CFS  
 BED MOLDED TO NATURAL CONFIGURATION



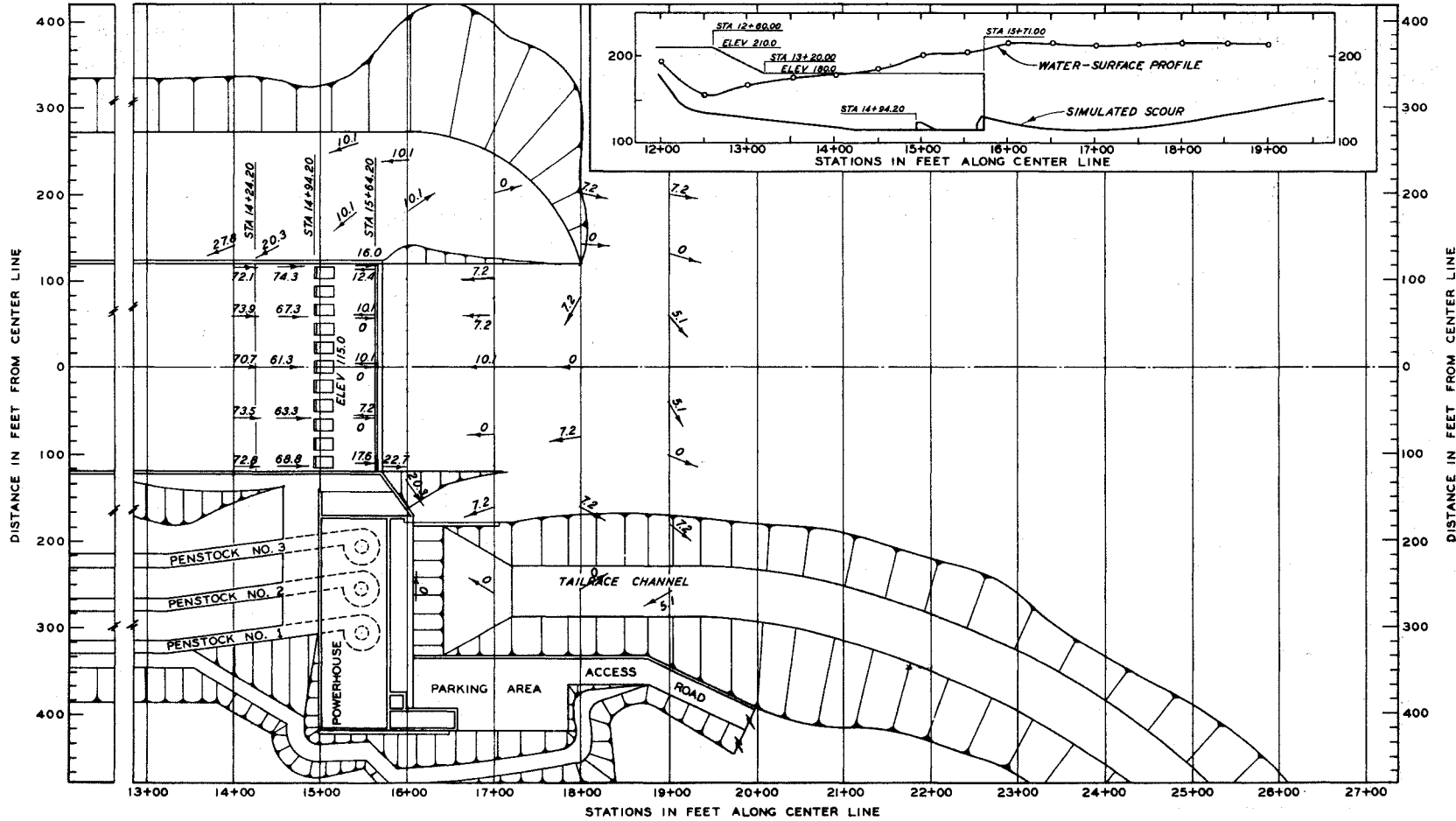
**TEST CONDITIONS**

TYPE 24 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 486.00 FT  
 TAILWATER ELEVATION 196.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO SIMULATED SCOUR.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 24 STILLING BASIN  
 DISCHARGE 193,000 CFS  
 BED MOLDED TO SIMULATED SCOUR



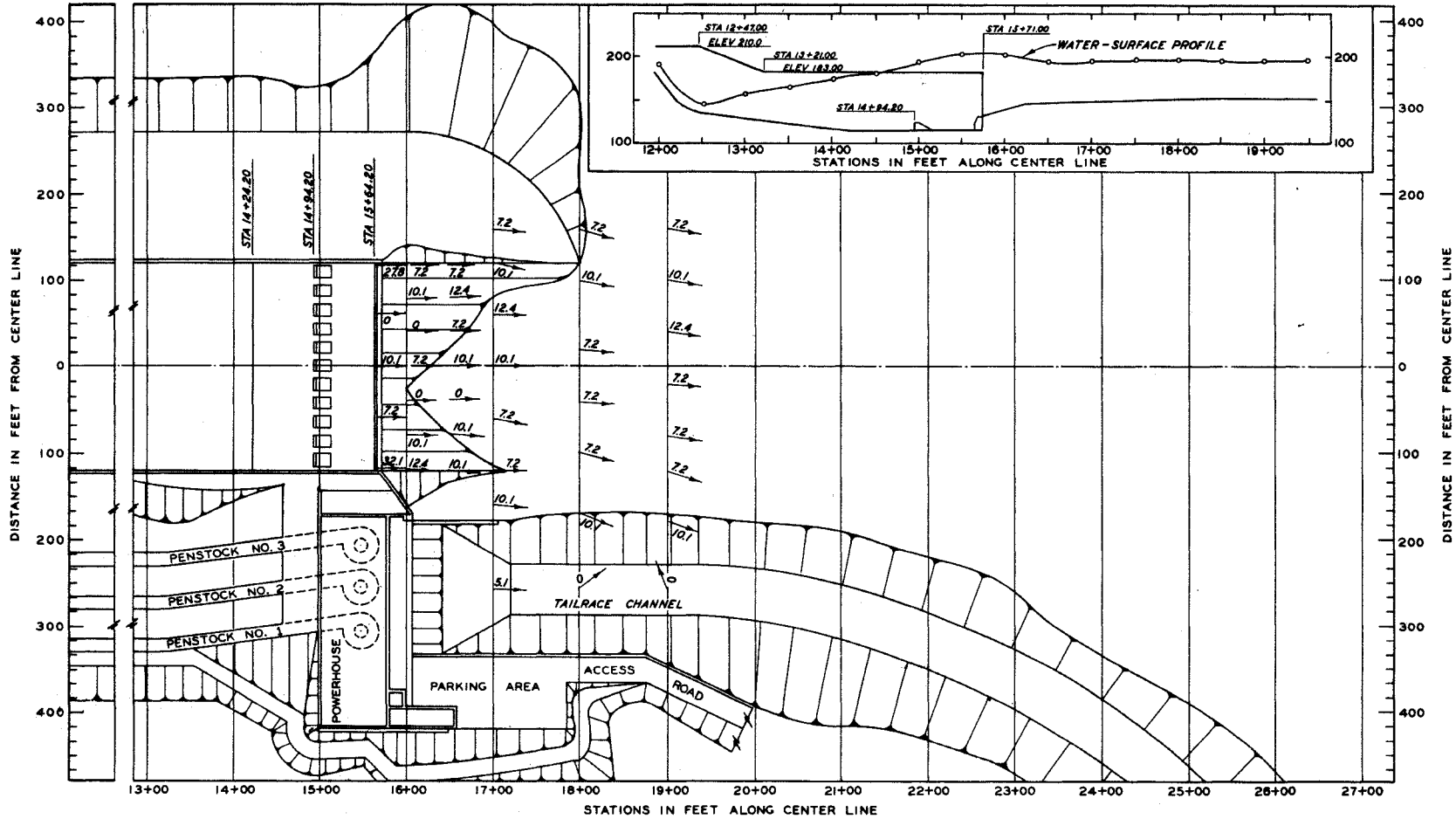


**TEST CONDITIONS**

TYPE 24 DESIGN  
 POOL ELEVATION 468.60 FT  
 TAILWATER ELEVATION 212.80 FT  
 CONDUITS & PENSTOCKS CLOSED  
 5 BAYS OPEN FULL (6 7&8 CLOSED)

NOTE: VELOCITIES ARE IN PROTOTYPE FEET  
 PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR  
 TO SIMULATED SCOUR

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 24 STILLING BASIN  
 DISCHARGE 300,000 CFS  
 BED MOLDED TO SIMULATED SCOUR

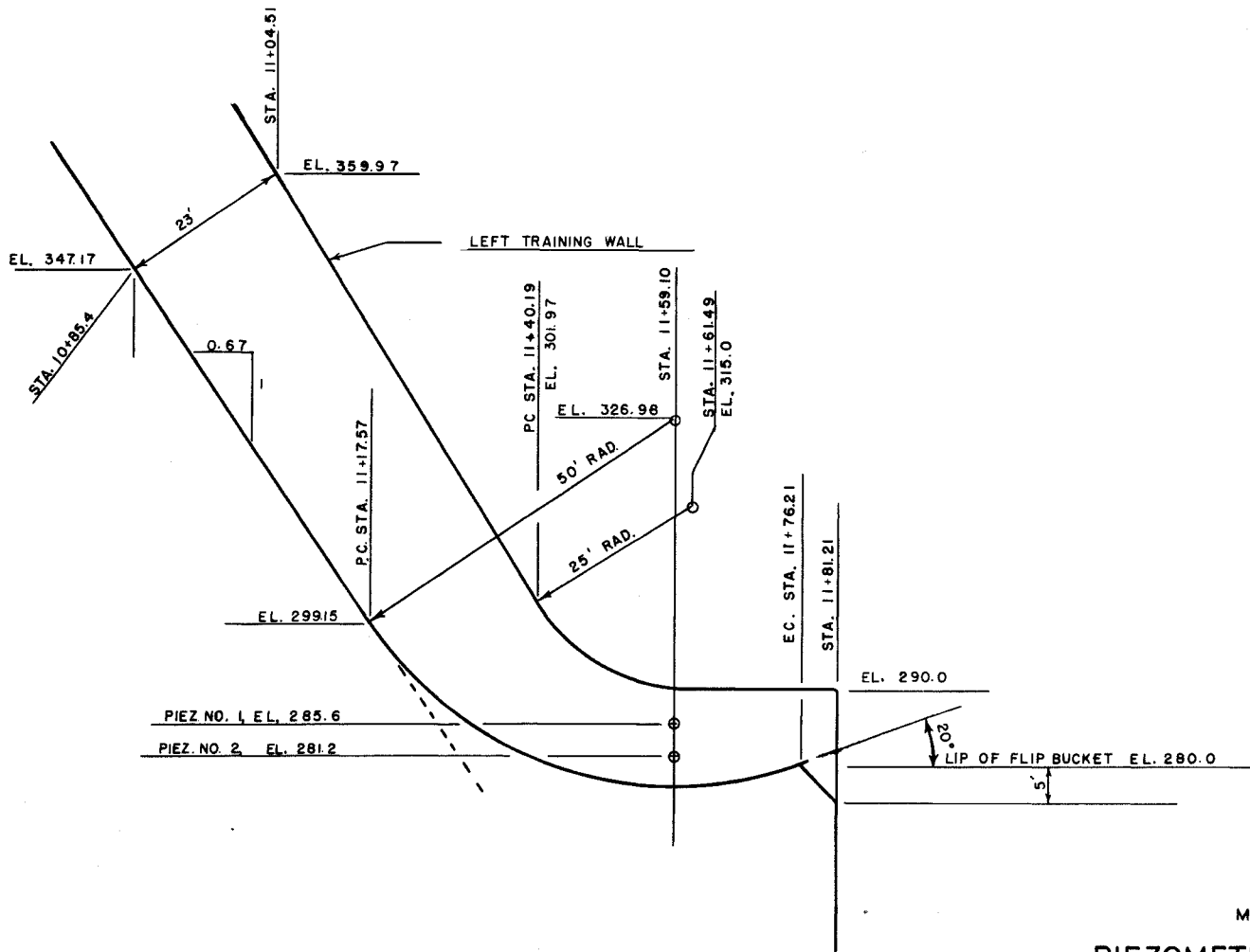


**TEST CONDITIONS**

TYPE 25 DESIGN  
 PENSTOCKS 7,000 CFS  
 POOL ELEVATION 468.00 FT  
 TAILWATER ELEVATION 198.00 FT  
 CONDUITS CLOSED  
 5 BAYS OPEN 28.0 FT (6,7 & 8 CLOSED)

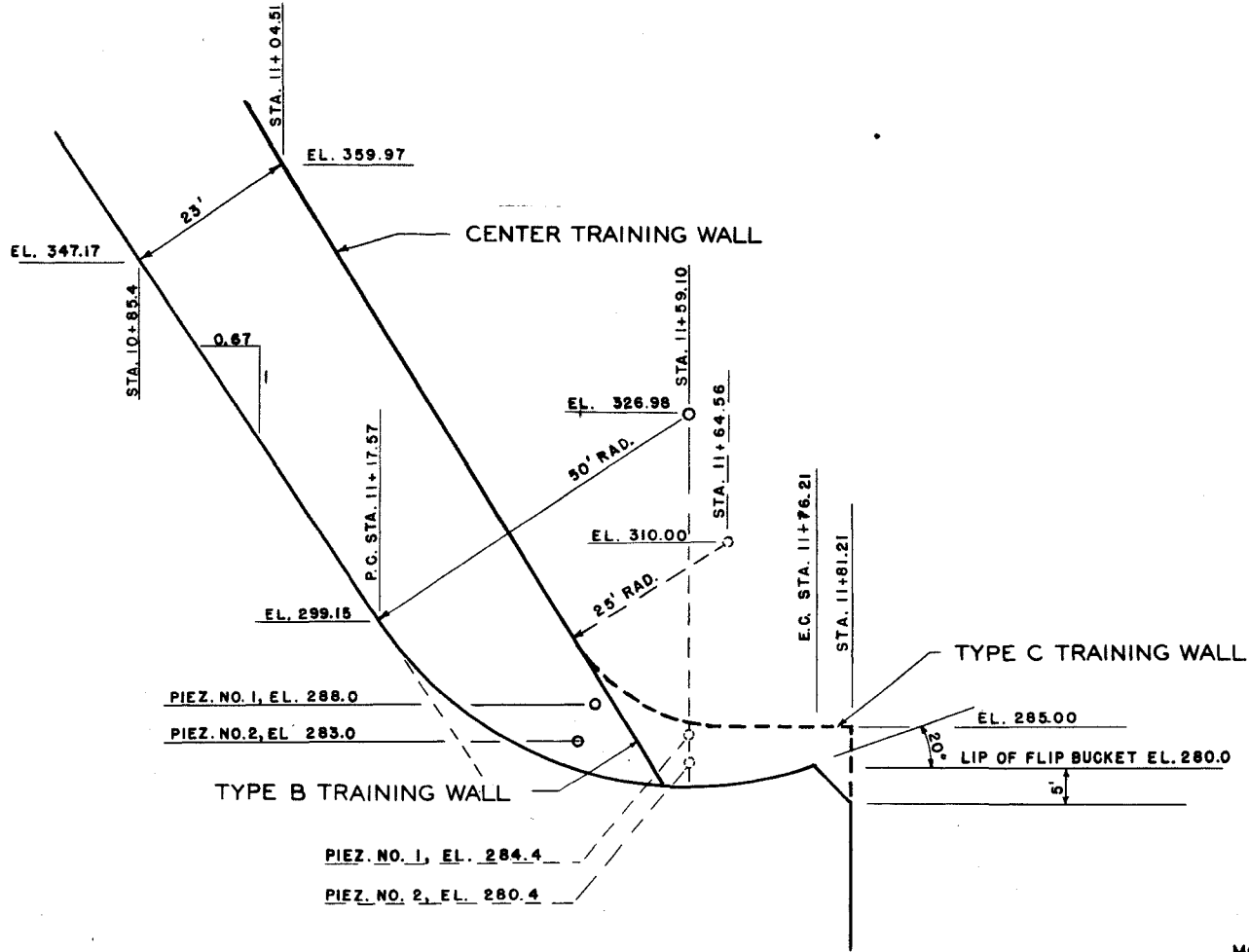
NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND 2.0 FEET OFF BOTTOM.  
 BED MOLDED IN CEMENT MORTAR TO NATURAL CONFIGURATION.

MODEL B  
**BOTTOM VELOCITIES**  
 TYPE 25 STILLING BASIN  
 DISCHARGE 193,000 CFS



ELEVATION

MODEL B  
PIEZOMETER LOCATIONS  
TYPE A TRAINING WALL  
ORIGINAL DESIGN



ELEVATION

MODEL B

PIEZOMETER LOCATIONS  
TYPES B AND C TRAINING WALL