TECHNICAL REPORT NO. 156-1

SPILLWAY MODIFICATIONS FOR CHIEF JOSEPH DAM
COLUMBIA RIVER, WASHINGTON

HYDRAULIC MODEL INVESTIGATION

MAY 1979

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U.S. ARMY ENGINEER DIVISION
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DIVISION HYDRAULIC LABORATORY
U.S. ARMY ENGINEER DIVISION, NORTH PACIFIC
CORPS OF ENGINEERS
BONNEVILLE, OREGON

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Spillway modifications were required in plans to increase power production by raising the level of the forebay pool and adding generating units. Pool was to be raised 10 ft initially and later an additional 14 ft. Effect of heads on the crest 1.33 to 1.70 times the design head was studied initially in a 1:42.47-scale model of Lower Granite spillway. Pressures on the spillway were satisfactory with gated flows but indicated cavitation with free flow. Surging occurred in the bays during gated flow. Preliminary studies indicated surging
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20. Continued.

could be controlled by modifications. A modified Chief Joseph spillway with the existing crest, 36-ft-wide bays, and higher gates was studied with heads as high as 1.65 times the design head in a 1:43.35-scale, 4-bay sectional model. Pressures on the spillway and the stilling basin baffles were satisfactory with all free and gated flows. The existing stilling basin was adequate with the higher-head flows. Surging in the gated bays was controlled with vertical suppressors attached to the side of the piers. A flow deflector on the spillway just below tailwater was developed to divert the nappe of discharges as large as the 10-year flood along the surface of the tailwater in the stilling basin to reduce the amount of air forced into solution. Large quantities of dissolved air, often called nitrogen supersaturation, can be harmful to fish. Wave deflectors attached to the downstream edge of the piers of the end bays were developed to reduce spray created by the flow deflector. In a 1:72-scale comprehensive model of the project, flow conditions with the modified spillway without a flow deflector were satisfactory. The spillway also functioned satisfactorily with a flow deflector when the spill was regulated to avoid surging in the stilling basin. If surging was permitted, high long-period waves occurred along the powerhouse and on the south bank at Foster Creek. Existing riprap on the north bank of the tailrace was adequate with the high head flows.

PREFACE

Studies of structural changes to Chief Joseph Dam resulting from a proposal to raise the pool elevation and add additional power units beyond 27 were authorized by the Office, Chief Of Engineer (OCE), on 29 March 1967, at the request of the U. S. Army Engineer District, Seattle (NPS). Under that authorization preliminary hydraulic model tests were made to determine the effect of heads from 1.33 to 1.70 times the design head on performance of a standard ogee spillway. Model studies to develop a modification of the spillway and stilling basin for higher heads were authorized by OCE on 20 August 1969 at the request of NPS. Model studies to develop flow deflectors for the spillway chute to reduce the amount of dissolved gases forced into solution during spill were authorized by OCE on 17 November 1972 at the request of the North Pacific Division.

The studies were conducted at the North Pacific Division Hydraulic Laboratory from April 1967 to March 1975 under the supervision of Messrs. H. P. Theus and P. M. Smith, in turn, Director, and A. J. Chanda, Chief of the Hydraulics Branch. The studies were conducted by Messrs. B. B. Bradfield, R. L. Johnson, A. G. Nissila, P. M. Smith, and D. D. Zimbelman assisted by Messrs. F. S. Bahler, G. D. Bocksler, and D. E. Fox. This report was prepared by Messrs. Bradfield and Johnson.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.283168	cubic metres per second
pounds (mass)	0.4535924	kilograms
kilowatt-hours	3,600,000	joules

SPILLWAY MODIFICATION FOR CHIEF JOSEPH DAM

COLUMBIA RIVER, WASHINGTON

Hydraulic Model Investigations

PART I: INTRODUCTION

The Prototype

1. Chief Joseph Dam is located on the Columbia River in the north central portion of the state of Washington. A vicinity map is shown in fig. 1. Principal features of the existing project (plate 1) include a 19-bay spillway and a powerhouse for 16 Francis turbines (total rating 1,024,000 kilowatts) with provision for 11 more units.* There are no facilities for passage of fish or navigation past the dam. Overall length of the concrete sections is 4,300 ft; maximum height above foundation rock is 230 ft.

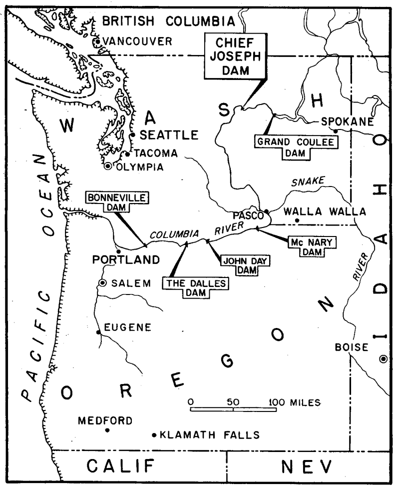

Fig. 1. Vicinity map.

2. Details of the existing spillway and stilling basin are shown on plate 2. The spillway is designed to pass 1,250,000 cfs at a head of approximately 54 ft on the crest (reservoir pool elev 955.5**). The ogee section corresponds to the Corps of Engineers' high dam shape for which the design head (41.6 ft) equals 0.75 of the maximum head on the crest. Flow is controlled with 40-ft-wide, 49-ft-high tainter gates supported by 9.0-ft-wide piers. Normal full pool is at elev 946. The horizontal hydraulic jump stilling basin has one row of baffles and a stepped end sill.

3. Planning studies by the Seattle District indicated that after

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is shown on page iii.

** All elevations are in feet above mean sea level.

storage was increased by the construction of upstream dams the eleven additional turbine-generators should be added and the dam modified to accommodate raising the normal full forebay pool from elev 946 to 956 with provisions to raise to elev 970. The increased upstream storage would reduce the spillway design flood about 4 percent to 1,200,000 cfs.

Problems of Modifying Spillway

4. Modifications for pools higher than elev 956 required raising the crest to retain the ratio of design head to maximum head of 1:1.33 or, disregarding this ratio, installing higher gates supported by wider piers. Research at the U. S. Army Engineer Waterways Experiment Station* had shown that severe surging at partial gate openings might occur with narrow, deep spillway bays. Cavitation on the crest and piers is also likely when discharging free flow under heads greater than 1.3 times the design head. Velocities in the stilling basin and velocities and wave action in the tailrace would increase, and modifications of the stilling basin and bank protection might be required.

5. Reduction in the amount of air forced into solution during spill was a concern in planning the modifications because highly saturated water can kill fish. This condition, called nitrogen supersaturation, can occur when air entrained in spillway flow is carried deep into a stilling basin and forced into solution by the high pressure. Model studies of other projects and prototype tests had indicated that flow deflectors on a spillway just below tailwater would deflect the lower-discharge flows along the water surface of the stilling basin and reduce the amount of gas forced into solution. Length of deflectors and placement with respect to tailwater were critical.

Purpose of Model Studies

6. A preliminary model study was made to determine the hydraulic characteristics of a standard high dam spillway crest operating with heads

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* Pickering, G. A., "Spillway for Kaysinger Bluff Dam, Osage River, Missouri," Technical Report No. 2-809, Jan 68, U. S. Army Engineer Waterways Experiment Station, CE, Vickburg, MS.

1.33 to 1.70 times the design head. The data were to aid in determining the feasibility of using the Chief Joseph crest under higher heads. Studies with sectional and comprehensive spillway models were made to develop a safe and satisfactory modification for operation with higher heads and with a flow deflector to limit dissolved gas in the water during spill.

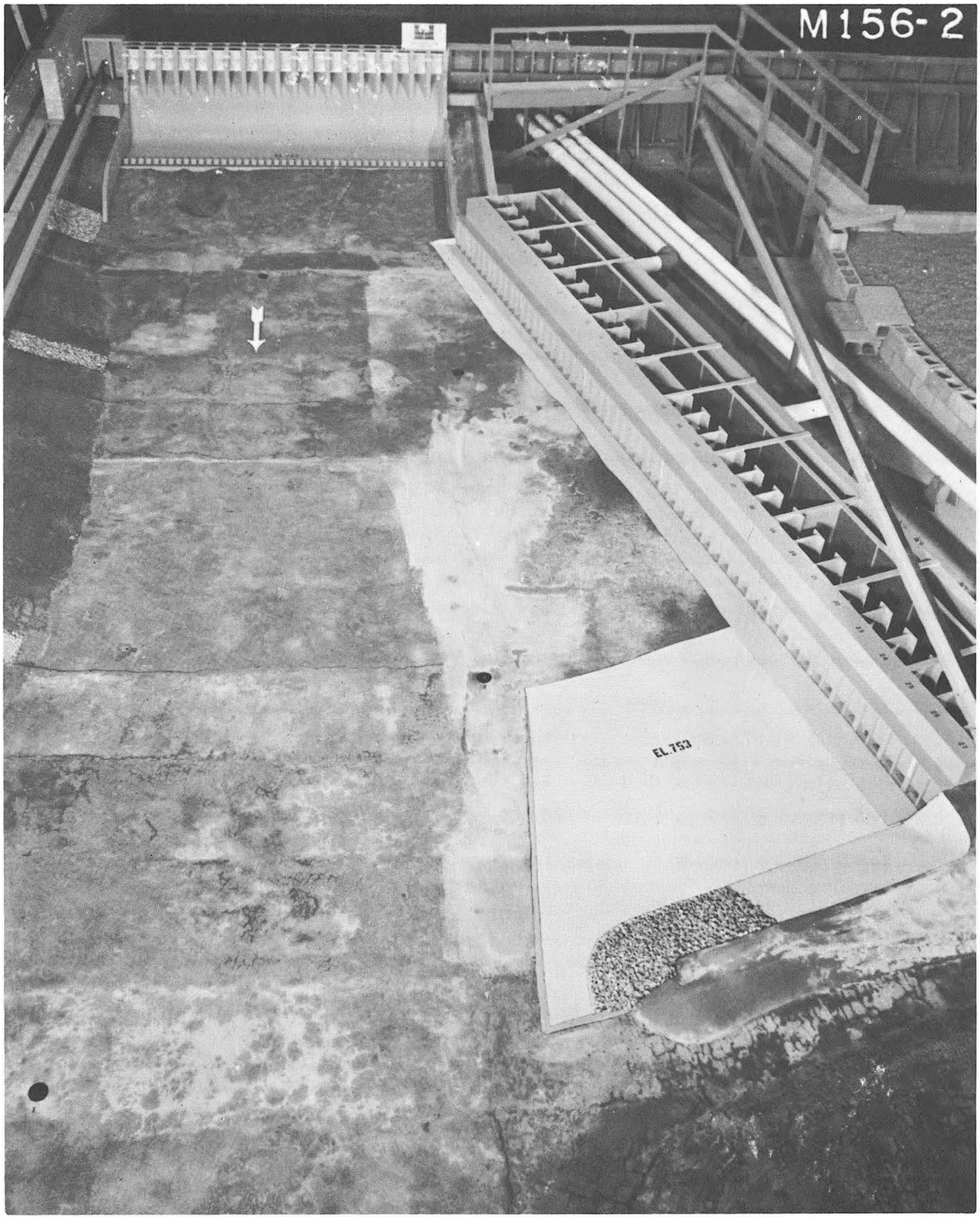


Fig. 2. 1:72-scale comprehensive model

PART II: THE MODELS

7. Three models were used to study proposed modifications of the spillway and to develop a satisfactory design.

a. An existing 3-bay, 1:42.47-scale model of the Lower Granite spillway (plates 3 and 4) was used to obtain preliminary information concerning pressures and flow characteristics for heads 1.33 to 1.70 times the crest design head (H_d). Lower Granite spillway has a standard high dam crest shape (H_d = 48 ft) and piers with elliptical noses. The piers were increased in height and curtain walls were added across the downstream ends to prevent overtopping at the higher pool elevations.

b. The 1:43.35-scale Chief Joseph spillway model (photograph 1 and plates 5 to 7) reproduced a 4-bay section of the existing upstream approach, crest, stilling basin, and tailrace. To provide for higher heads, the piers were 13 ft thick with tops at elev 978.75 (36-ft-wide bays), and the gates had a radius of 55 ft with trunnions at elev 922. The design was designated plan B.

c. The 1:72-scale Chief Joseph comprehensive model (fig. 2 and plate 8) reproduced approximately 420 ft of spillway forebay, the final design plan B spillway, the existing 16-unit powerhouse extended to 27 units, and the tailrace channel to the mouth of Foster Creek. Topography in the tailrace reproduced a 1973 survey and proposed excavation downstream from units 17 to 27. Riprap representing the existing rock protection used along the north bank (450- to 23,400-pound stone) was placed on four areas along the north bank and on two areas on the south bank at the downstream end of the powerhouse. The forebay channel leading to the powerhouse intakes was not reproduced. Water was piped from the spillway forebay to the powerhouse.

8. Tailwater data furnished by the Seattle District (plate 9) were used in all tests. Tailwater elevations in the sectional models were set at a point on the center line of the model 1,000 ft downstream from the crest axis. Tailwater in the 1:72-scale comprehensive model was set at gage 3 (plate 8). Water-surface elevations in the forebays of the

sectional models were set (or measured with free flow) about 300 ft upstream from the crest axis. Pool elevations in the comprehensive model were measured in the still water near spillway bay 19. Standard laboratory instruments and procedures were used to measure discharges, pressures, water-surface elevations, wave heights, and velocities. Model measurements were converted to prototype values with equations of similitude based on the Froude model law. Pressures lower than -33 ft of water indicated vaporization in the prototype and had no other significance except to show relative pressure conditions in the model.

PART III: MODIFICATIONS FOR INCREASED POOL ELEVATIONS

Preliminary Studies

9. The characteristics of spillway flow with heads on the crest 1.33 to 1.70 times the design head were observed in the Lower Granite model. Pressures on the crest and piers at the locations shown on plate 4 were acceptable for all gated flows. The minimum pressure was -11 ft, which occurred at the center of the bay approximately 33 ft downstream from the gate seat when the head ratio was 1.70. Pressures with free flow indicated cavitation part or all of the time with all of the high heads (table A). The lowest pressure (-20 to -46 ft) occurred immediately downstream from the stop log slot (piezometer P-8). Minimum pressure in the center of the bay was -24 ft at piezometer C-5. Discharge with the high heads is shown on plate 10.

10. As anticipated from the studies at the Waterways Experiment Station (WES), surging occurred in the spillway bays upstream from the gates with all gated flows when head ratios were 1.33 to 1.70. The surge near the center of the bay (highest to lowest water surface) varied from 5 ft with a head ratio of 1.34 to 14 ft with a ratio of 1.62. The magnitude of the surge was the same with 1- and 3-bay operation and with the crest 51 and 154 ft above the approach channel bottom. No surging occurred when the tainter gate was replaced with a vertical gate at the same opening or a vertical curtain wall was placed 5 or 10 ft into the water directly above the gate lip. Those observations with gate trunnion position 1 prompted similar surge observations with three other trunnion positions (plate 11). Those surge data indicated that less water-surface area within the bay created by moving the gate upstream and a more nearly vertical gate face at the water surface created by raising the trunnion decreased the magnitude of the surging. The data reinforced the conclusions drawn from the WES studies and led to the selection of a Chief Joseph modification (plan B) with narrower bays (thicker piers) and higher, larger gates for study.

Initial Plan B Spillway

11. Pressures on the initial plan B spillway (plate 5) and performance of the stilling basin were satisfactory with the increased pool elevations, but surging in the spillway bays exceeded the maximum acceptable height of 2 ft. Pressures are listed in tables B and C. The minimum of -12 ft of water on the crest and -14 ft on the stilling basin baffles occurred with the spillway design flood, 1,200,000 cfs, and pool elev 970. The spillway design flood passed as free flow with pool elev 958.8 and at a gate opening of 43 ft with pool elev 970. A good hydraulic jump occurred in the stilling basin with both conditions. With pool elev 956 the surge was approximately 1 ft with flows to 37,000 cfs per bay (total spillway discharge 703,000 cfs) and 4 ft with higher discharges (table D). With pool elev 970 maximum surge was 11.3 ft. The maximum observed occurred with pool elev 967.7 (12.5 ft).

12. Additional surge data observed with various heads, pier lengths, and gate trunnion locations are listed in tables D and E. Reducing the pier length between the pier noses and the gates by shortening the noses and moving the gates upstream decreased the surge height, but no variation was free of surge. The least surge, 2 ft or less with pool elev 956, occurred with shorter pier noses (11.75 ft, photograph 2) and gate trunnions at elev 930 or 932 and 59 ft from the crest axis. In the Lower Granite spillway model surge was eliminated when the tainter gate was replaced by a vertical gate or a curtain wall was placed above the gate lip (paragraph 10). Neither was effective with the Chief Joseph spillway.

13. Piers with round noses 14.75 ft upstream from the crest axis and gate trunnions at elev 927 (62.33 ft downstream from the axis) and elev 918 (57.53 ft from the axis) were also studied. Surges were smaller with the higher trunnions (4.2 versus 5.6 ft). However, the higher trunnions were structurally less desirable and were not studied further when pier nose extensions, suppressors on the sides of the piers, and gate lip modification were found to be more effective (plate 12). The suppressors were effective in reducing maximum surge to 3 ft, which at that point in the study was considered acceptable. Elliptical pier noses 18 ft from

the crest axis were less effective than round noses 14.75 ft from the axis.

Final Design Spillway

14. The final design spillway was the same as the original plan B except that the stop log slots were smaller, the gate trunnions were lower and farther downstream, and surge suppressors were attached to the side of the piers. Details are shown on plates 5 and 13. The suppressors extended from just above the maximum free-flow water surface to just above the maximum pool elevation, so they would be effective with gated flow but not disturb or retard free flow.

15. Pressures on the crest and piers (table F) were satisfactory and essentially the same as with the original plan B spillway (tables B and C). With gated flow the minimum pressure was -12 ft at the center of the bay just downstream from the gate (piezometer C-24, plate 6). With free flow the minimum was -10 ft at the stop log slot. Pressures and flow conditions in the stilling basin were the same as observed with the original design (paragraph 11).

16. Discharge ratings with pool elev 956 and free flow are listed in table G. The maximum water-surface profile along the right wall of the spillway is shown on plate 14.

17. Surge heights with and without the suppressors on the piers are shown on plate 15. With the suppressors the maximum surge was 2.8 ft, which occurred with maximum pool elev 970. With pool elev 956 the maximum was 2.2 ft. Without suppressors the maximum was 10.8 ft. Flow conditions with pool elev 956.2 and suppressors (1.6-ft surge) and with the spillway design flood (free flow) are shown in photograph 3.

PART IV: DEFLECTORS

Flow Deflector

18. Flow conditions that would occur in the stilling basin with the final design plan B spillway and tailwater created by the Wells pool at elev 779 are shown in photographs 4 and 5 and on plate 16. Heavy concentrations of entrained air would be carried to the bottom of the basin and dispursed throughout most or all of the basin. The pressure of the deep water would force part of the air into solution and result in supersaturation of the water with dissolved gases, which could be harmful to fish. A flow deflector on the downstream face of the spillway (photograph 6) was developed to divert the aerated flow of lower discharges along the water surface of the basin where the pressure would be lower and less air would be forced into solution. The deflector was short in order that the thicker nappe of higher discharges would override it and plunge into the basin for adequate energy dissipation.

19. Ten flow deflector designs shown on plate 17 were studied. Three flow conditions occurred in the stilling basin with each plan: skimming, unstable, and plunging. The unstable flow alternated between skimming and plunging and created surging in the basin. Plans A and B were longer than necessary. The deflectors at higher elevations had a smaller range of skimming flow because of insufficient tailwater. The deflectors at lower elevations had too much tailwater, which caused an uplift of the nappe and excessive air entrainment. In general, the lower deflectors caused greater surging. With major emphasis on flow stability and range of skimming flow, plan F at elev 775 was selected as the optimum design (photograph 6).

20. Aeration and flow conditions in the stilling basin with the final design deflector and tailwater created by the Wells pool at elev 779 are shown in photographs 7 to 9 and on plates 18 and 19. The 12.5-ft length of the deflector was sufficient to turn the nappe along the water surface with all flows of a 10-year frequency or less when 18 or more powerhouse units were operating. The larger flows plunged into the basin and were

adequately dissipated. Skimming flow occurred with discharges as high as 7,500 cfs per bay with nine powerhouse units operating and 15,000 cfs per bay with 27 units operating. For comparison flow conditions with the plan F deflector at elev 772 (3 ft lower) are shown on plate 19. With the lower deflector skimming flow occurred with slightly higher discharges but the range of unstable flow was much greater.

21. Pressures on the plan F deflector at elev 775 at the piezometer locations shown on plate 20 were satisfactory. The maximum pressure, 133 ft of water, occurred at piezometer DC-2 with a discharge of 63,160 cfs per bay (spillway design flood). The minimum pressure, -8 ft, occurred at piezometer DC-5 on the downstream face of the deflector with a discharge of 23,370 cfs per bay (100-year flood with no powerhouse operation). With a deflector on the spillway, pressures on the stilling basin baffles were positive with all spillway discharges. The minimum pressure was 10 ft of water.

Wave Deflectors

22. Turning of the flow by the flow deflector caused the nappes of the individual bays to expand laterally, impinge on one another downstream from the spillway piers, and create spray. At the end bays the spray was objectionable because it went over the stilling basin training walls. The spray would drain to the powerhouse deck at the left wall and into the bank protection at the right wall. Waves along the spillway piers intensified the spray problem. Wave deflectors were developed for the downstream edges of the piers of the two bays at each end of the spillway as shown on plate 21. The deflectors reduced the amount of spray over the walls but did not eliminate it. Other flow disturbances on the flow deflector and turbulence in the basin created some of the spray. Water-surface profiles in a bay with deflectors are shown on plate 22.

23. Waves created by turbulence in the basin also occasionally overtopped the walls. Those waves were not subject to control by the deflectors. The waves were intensified by high tailwater. Reducing the discharges through the end bays alleviated the condition.

PART V: PERFORMANCE OF MODIFIED PROJECT

24. Flow conditions with the modified spillway, 27 unit powerhouse, and proposed south bank just upstream from Foster Creek were observed in the 1:72-scale comprehensive model of the project. Details of the model are described in paragraph 7 and shown in fig. 2 and on plate 8. Observations were made with and without surge suppressors and the plan F flow deflector at elev 775 on the spillway. Wave deflectors on the spillway piers near the flow deflector were not studied because the decision had been made not to use them in the prototype.

Without Spillway Flow Deflector

25. Flow conditions downstream from the spillway and powerhouse without a flow deflector on the spillway are shown on plates 23 to 27 for discharges of 190,000, 260,000, 305,000, and 440,000 cfs through the spillway only and 400,000 cfs through the spillway and 27 powerhouse units. Selected flow conditions with discharges of 260,000, 440,000, and 750,000 cfs are shown in photographs 10 to 12. Wave heights and rideup with all the discharges are listed in table H. All the flow conditions were with uniformly gated spill, pool elev 956, and minimum tailwater (Wells pool elev 773, plate 9). The maximum wave heights, measured from lowest random trough to highest random peak, occurred with spillway flow only. The maximums varied from 4 to 10 ft along the powerhouse and from 1 to 4 ft along the north (right) bank. The smallest maximum occurred with a discharge of 190,000 cfs, and the largest occurred with 440,000 cfs, the 100-year flood. The powerhouse tailrace deck and the south bank at the downstream end of the powerhouse were overtopped by 5- and 7-ft waves during the 750,000-cfs discharge but were not overtopped with the lesser flows. A maximum wave rideup of 9 ft occurred on the north bank near the stilling basin with a spillway flow of 440,000 cfs. With a spill of 750,000 cfs, the maximum rideup was 8 ft. No riprap was displaced.

With Spillway Flow Deflector

26. Flow conditions with the flow deflector on the spillway and

discharges of 190,000 to 750,000 cfs with spillway flow only and 440,000 cfs with 27 powerhouse units operating are shown in photographs 13, 14, and 20 and on plates 28 to 32. All flows were with pool elev 956, uniform spillway operation, and minimum tailwater. Wave heights and rideup are listed in table H. The operating conditions were the same as those observed without a flow deflector (paragraph 25). With skimming flow in the stilling basin the deflector affected flow conditions in the vicinity of the spillway only. With all the discharges, velocities along the powerhouse, at Foster Creek, and along the north bank were essentially the same as those without the deflector. Except near the stilling basin, wave heights and rideup were reduced with the deflector. Maximum wave heights were 2.5 to 7.0 ft at the powerhouse and 1.0 to 2.5 ft along the banks. Maximum rideup on the north bank was 9 ft at the end of the north training wall. No riprap was displaced.

27. Adjacent to the stilling basin, velocities and turbulence near the surface were greater with the deflector. Flow returned along the bottom into the basin when skimming flow occurred. With all discharges flow along the spray walls struck the deflector and caused spray that overtopped the basin training walls. With the higher tailwater of a river discharge of 440,000 cfs and 27 powerhouse units operating, solid water occasionally overtopped the north training wall between stations 13+80 and 14+30.

28. As in the sectional model, unstable, surging flow occurred in the stilling basin with certain discharges and tailwater elevations. Occasionally flow from individual bays changed between skimming and plunging independently, but usually flows from several bays changed together with the surging being more pronounced. Short- and long-period waves created by disturbances in the stilling basin propogated along the powerhouse and usually were greatest at unit 27 (tables I and J). The maximum wave height with uniform spillway operation was 29.6 ft; the maximum difference between random wave peaks and troughs was 37.6 ft (photograph 15).

29. The type of flow that occurred in the stilling basin with

different discharges and tailwaters is listed in tables K to M and shown on plate 33. Surging did not occur with spillway flow only and uniform spill. However, surging did occur with a wide range of river discharges with uniform spill and the powerhouse in operation. Surging was avoided by operating four or five bays at each end of the spillway with a common discharge that produced either skimming or plunging flow and the remaining center bays with a discharge that caused the other type of flow. Crowned spillway operation (higher discharges through the center bays) was best with nine powerhouse units operating (photographs 16 and 17). Reverse crowning (lower discharges through center bays) was best with 18 and 27 units (photographs 18 and 19). Either type of operation, however, was satisfactory. Other patterns of nonuniform spill were tested and found to be less satisfactory.

30. A stable hydraulic jump formed in the stilling basin with the spillway design flood of 1,200,000 cfs, and the training walls were overtopped by bulked water and spray (photographs 20 and 21). The powerhouse tailrace deck and the south bank at the downstream end of the powerhouse (elev 810) were flooded by tailwater, which was at elev 825 (photograph 22).

31. The surge suppressors on the spillway piers (plate 13) were satisfactory with all discharges. Flow conditions with and without suppressors with the 100-year flood are shown in photograph 23.

PART VI: SUMMARY

32. Flow through the Lower Granite spillway with heads on the crest 1.33 to 1.70 times the design head produced acceptable pressures with gated flow conditions; however, cavitation pressures occurred at the stop log slots and the center of the ogee with free flow. Surging occurred in the bays upstream from the gates. Preliminary tests indicated the surging might be held to an acceptable magnitude with modifications. As a result of the studies, a modification of the Chief Joseph spillway that utilized a higher head on the existing crest (1.65 times design head) and would not require free flow was selected for study.

33. The modified Chief Joseph spillway had satisfactory pressures on the piers, crest, and stilling basin baffles and satisfactory energy dissipation in the basin with all gated and free flow conditions. Surging in the bays with gated flows was restrained to an acceptable maximum of 2.8 ft with surge suppressors attached to the piers upstream from the gates.

34. A flow deflector to be attached to the spillway just below tailwater was developed to reduce the amount of air forced into solution during spill because gas supersaturated water can be harmful to fish. The optimum design was a horizontal deflector 12.5 ft long at elev 775. Spray from the deflector created in part by waves along the side of the piers overtopped the stilling basin training walls. The spray was reduced by wave deflectors attached to the downstream edges of the piers.

35. In the comprehensive model of the modified Chief Joseph project the spillway functioned satisfactorily without a flow deflector on the spillway. The spillway also functioned satisfactorily with a flow deflector when the spill was regulated to avoid surging in the stilling basin. If surging in the basin was permitted, unacceptable waves occurred along the face of the powerhouse and on the south bank at Foster Creek. Existing riprap on the north bank of the tailrace was satisfactory with the high head flows.

36. The surge suppressors will be installed in the prototype. The wave and flow deflectors will not be used.

TABLE A

PRESSURES WITH FREE FLOW IN LOWER GRANITE SPILLWAY MODEL

Crest Design Head 48.0 Feet

H_c=64.0 Ft (1.33 Design Head) Discharge 104,000 CFS per Bay				H_c=69.6 Ft (1.45 Design Head) Discharge 120,600 CFS per Bay				H_c=75.8 Ft (1.58 Design Head) Discharge 138,000 CFS per Bay				H_c=81.6 Ft (1.70 Design Head) Discharge 157,500 CFS per Bay			
Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water	Piezometer No.	Pressure in Feet of Water
C- 1	92	C-33	26	C- 1	98	C-33	23	C- 1	106	C-33	18	C- 1	109	C-33	15
C- 2	69	C-34	32	C- 2	74	C-34	30	C- 2	80	C-34	27	C- 2	85	C-34	25
C- 3	46	C-35	23	C- 3	48	C-35	9	C- 3	49	C-35	1	C- 3	48	C-35	- 4
C- 4	5			C- 4	0			C- 4	- 9			C- 4	-14		
C- 5	- 4			C- 5	-10			C- 5	-19			C- 5	-24		
C- 6	- 4	P- 1	38	C- 6	- 9	P- 1	37	C- 6	-16	P- 1	35	C- 6	-21	P- 1	35
C- 7	- 3	P- 2	42	C- 7	- 8	P- 2	41	C- 7	-14	P- 2	40	C- 7	-19	P- 2	39
C- 8	- 4	P- 3	16	C- 8	- 8	P- 3	12	C- 8	-13	P- 3	7	C- 8	-18	P- 3	4
C- 9	- 5	P- 4	19	C- 9	- 9	P- 4	17	C- 9	-13	P- 4	13	C- 9	-17	P- 4	9
C-10	- 3	P- 5	- 1	C-10	- 7	P- 5	-11	C-10	-10	P- 5	-20	C-10	-12	P- 5	-23
C-11	- 4	P- 6	10	C-11	- 6	P- 6	4	C-11	- 8	P- 6	- 1	C-11	-10	P- 6	-11
C-12	7	P- 7	2	C-12	6	P- 7	- 7	C-12	6	P- 7	-14	C-12	6	P- 7	-21
C-13	15	P- 8	-20	C-13	19	P- 8	-28	C-13	17	P- 8	-39	C-13	25	P- 8	-46
C-17	42	P- 9	- 2	C-17	54	P- 9	- 7	C-17	54	P- 9	-14	C-17	56	P- 9	-19
C-18	20	P-10	-17	C-18	17	P-10	-23	C-18	12	P-10	-35	C-18	9	P-10	-41
C-19	1	P-11	- 1	C-19	- 4	P-11	- 5	C-19	-14	P-11	-11	C-19	-19	P-11	-16
C-20	- 7	P-12	3	C-20	-15	P-12	- 7	C-20	-27	P-12	-14	C-20	-32	P-12	-20
C-21	- 9	P-13	- 1	C-21	-18	P-13	- 4	C-21	-29	P-13	-10	C-21	-34	P-13	-14
C-22	- 5	P-14	- 1	C-22	-13	P-14	- 5	C-22	-23	P-14	-11	C-22	-29	P-14	-15
C-23	- 2	P-15	- 1	C-23	- 8	P-15	- 4	C-23	-14	P-15	-10	C-23	-19	P-15	-13
C-24	- 1	P-16	- 2	C-24	- 5	P-16	- 5	C-24	-11	P-16	-10	C-24	-15	P-16	-14
C-25	- 1	P-17	- 1	C-25	- 6	P-17	- 4	C-25	-10	P-17	- 8	C-25	-14	P-17	-12
C-26	- 2	P-18	- 2	C-26	- 6	P-18	- 5	C-26	-10	P-18	-10	C-26	-13	P-18	-13
C-27	- 1	P-19	37	C-27	- 5	P-19	36	C-27	- 8	P-19	36	C-27	-10	P-19	36
C-28	- 1	P-20	31	C-28	- 3	P-20	31	C-28	- 5	P-20	40	C-28	- 6	P-20	40
C-29	8	P-21	- 1	C-29	8	P-21	- 5	C-29	7	P-21	-14	C-29	8	P-21	-18
C-30	5	P-22	-15	C-30	6	P-22	-22	C-30	9	P-22	-43	C-30	11	P-22	-39
C-31	- 4	P-23	- 2	C-31	-12	P-23	- 6	C-31	-18	P-23	-13	C-31	-29	P-23	-19
C-32	19	P-24	-14	C-32	18	P-24	-21	C-32	11	P-24	-30	C-32	7	P-24	-39

NOTES: 1. Spillway details are shown on plate 3.

2. Piezometer locations are shown on plate 4.

TABLE B

PRESSURES

Plan B Spillway

Pool Elevations 956.0 and 958.8

Gate Opening in Feet								Free Flow			
5.0				40.0							
Pool Elevation											
956.0				956.0				958.8			
Tailwater Elevation											
781.1				817.2				825.0			
Total Spillway Discharge in CFS											
133,000				961,430				1,200,000			
Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water
C- 1	59	P- 1	58	C- 1	28	P- 1	36	C- 1	16	P- 1	28
C- 2	55	P- 2	51	C- 2	23	P- 2	-3	C- 2	1	P- 2	-9
C- 3	53	P- 3	50	C- 3	9	P- 3	1	C- 3	-7	P- 3	-11
C- 4	50	P- 4	47	C- 4	4	P- 4	4	C- 4	-10	P- 4	-9
C- 5	48	P- 5	40	C- 5	6	P- 5	9	C- 5	-8	P- 5	-7
C- 6	42	P- 6	23	C- 6	9	P- 6	6	C- 6	-7	P- 6	-5
C- 7	23	P- 7	3	C- 7	8	P- 7	5	C- 7	-6	P- 7	-3
C- 8	2	P- 8	-1	C- 8	5	P- 8	0	C- 8	-4	P- 8	-3
C- 9	-2	P- 9	-1	C- 9	-1	P- 9	-3	C- 9	-4	P- 9	-3
C-10	-2	P-10	0	C-10	-3	P-10	-2	C-10	-5	P-10	-2
C-11	0			C-11	-2			C-11	-3		
C-12	0			C-12	-2			C-12	-3		
C-13	0	B- 1	30	C-13	1	B- 1	30	C-13	0	B- 1	23
C-14	1	B- 2	28	C-14	2	B- 2	16	C-14	2	B- 2	2
C-15	58	B- 3	26	C-15	18	B- 3	3	C-15	1	B- 3	-9
		B- 4	25			B- 4	10			B- 4	2
C-16	54	B- 5	27	C-16	10	B- 5	3	C-16	-4	B- 5	-10
C-17	53			C-17	10			C-17	-3		
C-18	51	B- 6	30	C-18	6	B- 6	7	C-18	-6	B- 6	-6
C-19	47	B- 7	27	C-19	4	B- 7	12	C-19	-7	B- 7	1
C-20	41	B- 8	35	C-20	4	B- 8	43	C-20	-6	B- 8	38
		B- 9	27			B- 9	-2			B- 9	-8
C-21	25	B-10	28	C-21	3	B-10	3	C-21	-5	B-10	-7
C-22	2	B-11	30	C-22	1	B-11	6	C-22	-7	B-11	-3
C-23	-3			C-23	-3			C-23	-7		
C-24	-2			C-24	-5			C-24	-7		
C-25	-1			C-25	-3			C-25	-5		
C-26	-1			C-26	-3			C-26	-3		
C-27	0			C-27	0			C-27	-1		
C-28	0			C-28	4			C-28	3		
C-29	1			C-29	6			C-29	7		
C-30	2			C-30	9			C-30	10		
C-31	2			C-31	9			C-31	12		

NOTES: 1. Spillway details are shown on plate 5.

2. Piezometer locations are shown on plates 6 and 7.

TABLE C

PRESSURES

Plan B Spillway

Pool Elevation 970.0

Gate Opening in Feet											
5.0				20.0				43.0			
Tailwater Elevation											
782.2				802.8				825.0			
Total Spillway Discharge in CFS											
150,000				562,500				1,200,000			
Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water	Piezometer Number	Pressure in Feet of Water
C- 1	73	P- 1	72	C- 1	61	P- 1	63	C- 1	35	P- 1	44
C- 2	69	P- 2	64	C- 2	54	P- 2	31	C- 2	30	P- 2	-7
C- 3	67	P- 3	63	C- 3	47	P- 3	29	C- 3	15	P- 3	-1
C- 4	64	P- 4	59	C- 4	34	P- 4	28	C- 4	6	P- 4	5
C- 5	60	P- 5	51	C- 5	31	P- 5	24	C- 5	8	P- 5	9
C- 6	52	P- 6	29	C- 6	27	P- 6	15	C- 6	11	P- 6	7
C- 7	29	P- 7	4	C- 7	16	P- 7	5	C- 7	7	P- 7	3
C- 8	2	P- 8	-2	C- 8	4	P- 8	-7	C- 8	1	P- 8	-6
C- 9	-4	P- 9	-1	C- 9	-9	P- 9	-8	C- 9	-8	P- 9	-9
C-10	-2	P-10	0	C-10	-9	P-10	-5	C-10	-10	P-10	-6
C-11	0			C-11	-4			C-11	-7		
C-12	0			C-12	-4			C-12	-5		
C-13	0	B- 1	33	C-13	-1	B- 1	54	C-13	-1	B- 1	23
C-14	0	B- 2	30	C-14	1	B- 2	44	C-14	2	B- 2	1
C-15	1	B- 3	29	C-15	56	B- 3	38	C-15	21	B- 3	-12
		B- 4	29			B- 4	34			B- 4	-2
C-16	68	B- 5	29	C-16	46	B- 5	34	C-16	11	B- 5	-14
C-17	67			C-17	42			C-17	11		
C-18	64	B- 6	32	C-18	33	B- 6	31	C-18	5	B- 6	-8
C-19	60	B- 7	29	C-19	25	B- 7	32	C-19	2	B- 7	1
C-20	52	B- 8	37	C-20	19	B- 8	46	C-20	1	B- 8	35
		B- 9	28			B- 9	30			B- 9	-12
C-21	31	B-10	29	C-21	11	B-10	31	C-21	0	B-10	-9
C-22	2	B-11	32	C-22	1	B-11	33	C-22	-4	B-11	-5
C-23	-4			C-23	-10			C-23	-10		
C-24	-3			C-24	-10			C-24	-12		
C-25	-2			C-25	-6			C-25	-9		
C-26	-1			C-26	-4			C-26	-7		
C-27	-1			C-27	-2			C-27	-3		
C-28	0			C-28	1			C-28	2		
C-29	2			C-29	4			C-29	6		
C-30	2			C-30	5			C-30	9		
C-31	2			C-31	5			C-31	10		

NOTES: 1. Spillway details are shown on plate 5.

2. Piezometer locations are shown on plates 6 and 7.

TABLE D

SURGE DATA

Plan B Spillway With Various Gate Locations

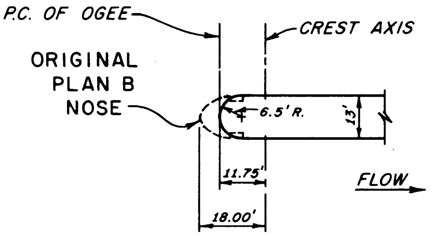
Gate Trunnion Location		Gate Opening in Feet	Pool Elevation	Discharge in CFS per Bay	Station	W. S. Elevations		Surge Height in Ft
Station	Elevation					Maximum	Minimum	
10+68.35	927.0	25.0	956.0	27,370	10+11	955.8	954.7	1.1
		30.0	956.0	32,840		956.2	953.7	2.5
		35.0	956.0	38,950		955.9	952.1	3.8
		40.0	956.1	45,415		955.4	950.5	4.9
10+61.83	920.0	30.0	956.2	38,245	10+13	956.6	953.3	3.3
		35.0	956.0	44,810		956.1	951.6	4.5
		37.0	956.0	48,120		955.8	951.0	4.8
10+59.00	922.0	30.0	956.0	37,790	10+11	956.3	955.2	1.1
			960.8	40,050		961.6	959.5	2.1
(Original Plan B Location)			964.4	41,630		964.9	963.3	1.6
			967.5	42,940		967.8	966.4	1.4
			970.0	43,950		970.2	968.7	1.5
		35.0	956.0	44,125		957.4	953.4	4.0
			960.1	45,965		962.1	957.4	4.7
			964.5	48,115		965.9	962.4	3.5
			967.8	49,625		968.3	966.1	2.2
			970.0	51,015		970.4	968.1	2.3
		40.0	956.0	50,600		956.6	952.5	4.1
			961.0	53,550		961.6	957.5	4.1
			964.0	55,415		966.8	956.0	10.8
			967.7	57,435		970.8	958.3	12.5
			970.0	58,255		972.9	961.6	11.3
10+59.00	930.0	30.0	956.0	36,210	10+04	956.0	954.5	1.5
		35.0	956.1	41,755		956.0	954.0	2.0
		40.0	956.1	47,220		955.9	953.6	2.3
		41.0	956.1	48,720		955.1	952.7	2.4
10+59.00	932.0	35.0	956.1	41,050	10+04	956.2	954.6	1.6
		40.0	956.1	46,620		955.6	953.7	1.9
		41.0	956.2	47,220		955.7	953.5	2.2
10+55.00	930.0	35.0	956.0	42,460	9+99	956.0	954.0	2.0
		40.0	956.1	48,120		955.7	953.3	2.4
		41.0	956.1	49,325		955.7	953.0	2.7
10+50.00	930.0	35.0	956.1	43,860	9+95	956.0	954.3	1.7
		40.0	956.1	48,720		955.8	953.8	2.0
		41.0	956.1	49,625		955.6	953.3	2.3

NOTES:
1. Spillway details are shown on plate 5.
2. Surge was measured at center of spillway bay.
3. Gates adjacent to operating bay were closed.

TABLE E

SURGE DATA

Plan B Spillway With Short, Round-Nosed Piers



PIER NOSE DETAILS

Gate Trunnion Location		Gate Opening in Feet	Pool Eleva-tion	Discharge in CFS per Bay	Station	W. S. Elevations		Surge Height in Ft
Station	Elevation					Maximum	Minimum	
10+68.35	927.0	25.0	956.1	27,370	10+11	956.4	954.4	2.0
		30.0	956.2	32,840		956.7	953.4	3.3
		35.0	956.1	38,950		957.3	950.4	6.9
		37.0	956.0	41,400		956.1	951.5	4.6
		40.0	956.1	45,415		955.7	951.3	4.4
		35.0	970.0	45,115		970.2	966.5	3.7
		40.0	970.1	52,330		971.9	963.2	8.7
		43.0	970.0	57,310		972.8	961.1	11.7
		45.0	970.0	60,525		972.6	961.5	11.1
		47.0	970.0	63,370		970.5	061.6	8.9
		50.0	970.0	69,050		968.3	959.7	8.6
10+61.83	920.0	35.0	956.1	44,150	10+13	956.0	954.2	1.8
		37.0	956.1	47,520		955.9	953.8	2.1
10+59.00	930.0	35.0	956.1	42,105	10+04	956.1	954.7	1.4
		40.0	956.1	47,520		955.7	953.9	1.8
		41.0	956.1	48,120		955.7	953.7	2.0
10+59.00	932.0	35.0	956.1	41,050	10+04	956.0	954.6	1.4
		40.0	956.1	46,315		955.9	954.3	1.6
		41.0	956.1	46,920		955.8	953.9	1.9
		35.0	970.1	48,105	10+11	970.1	968.9	1.2
		40.0	970.1	55,265		971.5	967.2	4.3
		41.0	970.0	56,580		971.7	966.8	4.9
		43.0	970.1	58,715		972.0	966.6	5.4
		45.0	970.0	61,285		970.4	967.7	2.7

NOTES:
1. Spillway details are shown on plate 5.
2. Surge was measured at center of spillway bay
3. Gates adjacent to operating bay were closed.

TABLE F

PRESSURES

Final Design Spillway

Piezometer Number	Gate Opening in Feet								Free Flow		
	5	15	25	30	33	35	30	40			
	Pool Elevation										
	956.0	956.1	956.1	956.2	956.3	956.4	970.6	970.1	916.0	935.0	958.8
	Total Spillway Discharge in CFS										
	126,780	364,160	690,600	731,400	804,700	861,700	847,750	1,142,050	128,860	489,925	1,200,000
C- 1	59	53	45	40	36	35	48	35	17	23	14
C- 2	55	46	36	30	26	24	38	21	11	13	-3
C- 3	54	44	32	25	20	16	32	13	10	9	-9
C- 4	52	36	19	15	11	8	18	4	8	6	-10
C- 5	51	34	22	17	14	12	21	8	7	8	-9
C- 6	48	30	20	17	14	13	20	10	7	8	-7
C- 7	39	21	15	12	11	10	13	7	6	8	-6
C- 8	12	10	8	7	6	6	5	2	5	6	-5
C- 9	7	-4	-3	-2	-2	-2	-6	-7	3	3	-4
C-10	-2	-5	-5	-5	-4	-4	-10	-10	2	2	-4
C-11	0	-2	-1	-2	-2	-2	-6	-6	2	2	-2
C-12	-1	-2	-2	-2	-2	-2	-4	-5	1	1	-2
C-13	0	-1	0	0	0	0	-1	-1	0	1	0
C-14	0	0	1	3	2	2	2	2	0	1	2
C-15	59	51	40	33	28	26	40	24	16	19	-1
C-16	55	45	32	25	22	18	31	10	12	13	-6
C-17	54	43	30	24	19	17	29	9	10	12	-5
C-18	52	37	24	19	15	13	22	9	8	9	-7
C-19	50	32	20	15	12	10	17	6	7	8	-8
C-20	48	27	17	14	11	10	14	6	7	8	-6
C-21	40	20	14	10	9	8	10	4	6	7	-5
C-22	14	8	6	6	4	4	3	-1	5	6	-7
C-23	-2	-4	-2	-3	-3	-3	-8	-8	3	3	-7
C-24	-2	-5	-6	-6	-5	-6	-11	-12	2	1	-7
C-25	-1	-3	-4	-4	-4	-4	-8	-9	1	1	-5
C-26	0	-2	-3	-3	-3	-3	-5	-6	1	1	-4
C-27	0	-1	-1	-1	-1	-1	-3	-3	1	1	-1
C-28	0	1	2	3	3	3	2	2	1	3	3
C-29	1	3	5	6	6	6	6	6	1	4	7
C-30	2	4	6	7	8	8	7	13	2	6	10
C-31	1	3	5	6	7	8	7	26	1	4	12
P- 1	58	54	48	43	38	40	54	47	16	26	26
P- 2	52	38	20	11	7	3	14	-6	9	8	-7
P- 3	51	37	19	13	10	6	15	0	8	7	-10
P- 4	50	34	22	17	15	13	21	9	6	8	-9
P- 5	47	29	20	16	14	13	20	10	6	8	-7
P- 6	38	21	15	13	12	11	14	8	5	7	-6
P- 7	13	11	9	8	8	8	7	3	4	6	-4
P- 8	-1	-3	-1	-1	0	0	-5	-5	3	4	-4
P- 9	-1	-4	-5	-2	-3	-3	-9	-5	2	2	-4
P-10	0	-2	-3	-2	-2	-2	-5	-5	1	2	-2

NOTES: 1. Spillway details are shown on plate 5.

2. Piezometer locations are shown on plate 6.

TABLE G

Spillway Discharge

Final Design Spillway

Gated Flow, Pool Elev 956.0			Free Flow		
Gate Opening in Feet	Discharge in CFS		Pool Elevation	Discharge in CFS	
	Total	Per Bay		Total	Per Bay
5	126,780	6,673	909.1	52,000	2,737
10	249,430	13,128	916.0	128,860	6,782
15	363,650	19,140	925.0	277,390	14,600
20	488,490	25,710	935.0	489,925	25,786
25	610,750	32,145	944.0	740,020	38,948
30	726,240	38,223	953.0	1,008,175	53,062
33	795,160	41,851	958.8	1,200,000	63,158
35	847,280	44,594			
38	937,340	49,334			

NOTE: Spillway details shown on plates 5 and 13.

TABLE H

WAVE DATA WITH AND WITHOUT PLAN F FLOW DEFLECTOR AT ELEV 775.0

Pool Elev 956.0, Uniform Spillway Operation

River Discharge in CFS	Tailwater Elevation at Gage 3	Wave Height at Powerhouse in Feet					Wave Heights at Bank in Feet					Rideup Elevations on Banks			
		Units	With Deflectors		Without Deflectors		Riprap Section Station	With Deflectors		Without Deflectors		With Deflectors		Without Deflectors	
			Maximum	Average	Maximum	Average		Maximum	Average	Maximum	Average	High	Low	High	Low
190,000	784.4	1-2	4.5	3.0	4.0	3.0	North Bank 17+80	2.0	1.5	1.5	1.0	-	-	-	-
		6-7	3.0	2.5	4.0	3.0	24+30	1.5	1.0	1.5	1.0	-	-	-	-
Power		11-12	2.5	2.0	4.0	2.0	33+50	1.0	1.0	1.0	1.0	-	-	-	-
Units		14-15	3.0	2.0	4.0	2.0	41+40	1.0	1.0	1.0	1.0	-	-	-	-
Closed		20-21	3.0	2.0	4.0	2.0	South Bank 38+00	1.5	1.0	2.5	1.5	-	-	-	-
		26-27	4.0	2.5	4.0	2.0	39+20	1.5	1.0	2.0	1.0	-	-	-	-
260,000	788.2	1-2	4.0	1.5	6.0	3.0	North Bank 17+80	2.0	1.5	2.0	1.0	-	-	-	-
		6-7	3.0	1.5	5.0	3.0	24+30	1.5	1.0	2.0	1.0	-	-	-	-
Power		11-12	3.0	2.0	4.0	2.5	33+50	1.0	1.0	1.0	1.0	-	-	-	-
Units		14-15	2.5	2.0	4.0	2.5	41+40	1.0	1.0	1.5	1.0	-	-	-	-
Closed		20-21	3.0	1.5	5.0	2.5	South Bank 38+00	1.5	1.0	2.5	1.5	-	-	-	-
		26-27	3.0	1.5	5.0	2.5	39+20	1.0	1.0	2.0	1.5	-	-	-	-
305,000	790.9	1-2	3.5	2.5	6.0	4.0	North Bank 17+80	2.5	2.0	2.0	1.5	-	-	-	-
		6-7	3.5	2.0	5.0	3.5	24+30	2.0	1.0	1.5	1.0	-	-	-	-
Power		11-12	3.0	1.5	5.0	3.5	33+50	1.5	1.0	1.5	1.0	-	-	-	-
Units		14-15	3.5	2.0	5.0	3.5	41+40	1.0	0.5	1.5	1.0	-	-	-	-
Closed		20-21	3.5	2.0	5.0	3.5	South Bank 38+00	2.0	1.0	3.5	2.0	-	-	-	-
		26-27	4.0	2.5	5.0	3.0	39+20	1.5	1.0	1.5	1.5	-	-	-	-
440,000	797.5	1-2	5.0	2.5	9.0	5.0	North Bank 17+80	2.0	1.0	4.0	2.0	805	797	807	798
		6-7	4.0	2.5	9.0	4.0	24+30	2.0	2.0	3.5	2.0	803	795	803	795
Power		11-12	3.5	1.5	8.0	4.0	33+50	2.0	1.5	2.5	1.5	801	795	802	795
Units		14-15	3.5	2.5	9.0	4.5	41+40	1.5	1.0	2.0	1.5	799	795	800	796
Closed		20-21	3.5	2.5	9.0	5.0	South Bank 38+00	2.0	1.5	3.5	2.0	803	795	802	795
		26-27	4.0	2.5	10.0	4.0	39+20	2.0	1.0	3.5	2.0	802	795	801	795
750,000	809.8	1-2	6.0	4.0	7.0	6.0	North Bank 17+80	-	-	-	-	818	809	820	812
		6-7	3.0	2.5	5.0	4.0	24+30	-	-	-	-	816	810	815	808
Power		11-12	2.5	2.5	6.0	4.0	33+50	-	-	-	-	811	808	813	808
Units		14-15	2.5	2.0	5.0	3.5	41+40	-	-	-	-	812	808	812	807
Closed		20-21	2.5	2.0	5.0	3.5	South Bank 38+00	-	-	-	-	810	807	810	808
		26-27	3.0	2.0	5.0	3.0	39+20	-	-	-	-	810	809	810	807
440,000	797.5	1-2	7.0	3.0	5.0	2.5	North Bank 17+80	2.0	1.5	2.0	1.0	804	798	805	800
		6-7	4.0	2.5	3.0	1.5	24+30	1.5	1.0	1.5	1.0	802	797	802	797
Power		11-12	3.0	2.0	3.0	1.5	33+50	1.0	1.0	1.0	0.5	800	796	800	797
Units		14-15	3.0	1.5	3.0	1.5	41+40	1.0	0.5	1.5	0.5	798	795	798	795
1-27		20-21	3.0	1.5	3.5	1.5	South Bank 38+00	1.5	1.0	2.0	1.0	800	795	800	794
Operated		26-27	3.0	2.0	2.0	1.0	39+20	1.5	1.0	2.0	1.0	800	794	800	794

NOTES: 1. Waves were observed along face of powerhouse and 25 ft from shore over riprap sections.

2. Maximum and average wave heights were determined from random peaks and troughs.

TABLE I

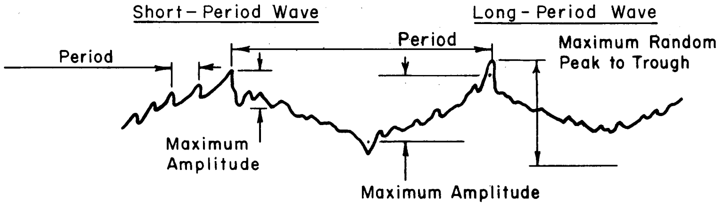
WAVE HEIGHTS AND PERIODS AT POWERHOUSE

Plan F Flow Deflector at Elev 775.0

Pool Elev 956.0, Uniform Spillway Operation

River Discharge in CFS	Tailwater Elevation at Gage 3	Powerhouse		Wave Gage at Powerhouse Unit	Short-Period Wave[1]		Long-Period Wave[1]		Maximum Random Peak to Trough in Feet[1]
		Discharge in CFS	Units Operating		Maximum Amplitude in Feet	Average Period in Sec	Maximum Amplitude in Feet	Average Period in Sec	
260,000	788.2	0	0	1	5.6	4.0	0	0	6.6
				14	4.9	4.9	0	0	5.9
				27	6.1	5.0	0	0	7.0
260,000	788.2	65,700	1-9	1	5.0	4.3	0.9	60.8	6.2
				14	6.5	4.6	2.0	55.2	7.0
				27	11.6	3.9	3.8	88.7	14.3
260,000	788.2	131,400	1-18	1	3.5	2.7	0	0	4.2
				14	2.0	5.1	0	0	2.0
				27	4.3	4.6	0	0	6.2
260,000	788.2	131,400	10-27	1	4.5	3.8	0	0	5.8
				14	2.2	4.7	0	0	2.8
				27	2.5	4.6	1.0	86.6	3.2
260,000	788.2	197,100	1-27	1	1.6	2.8	0	0	2.5
				14	0.8	4.3	0	0	1.2
				27	1.4	4.8	0	0	1.5
305,000	790.9	65,700	1-9	1	6.5	3.3	2.2	84.9	8.3
				14	–	–	–	–	–
				27	7.5	4.3	12.7	82.4	21.5
397,400	795.4	131,400	1-18	1	5.0	4.0	4.1	78.2	10.6
				14	–	–	–	–	–
				27	6.1	4.1	14.7	80.5	21.8
440,000	797.5	0	0	1	5.0	5.2	0	0	6.1
				14	5.3	4.4	0	0	6.0
				27	6.0	5.0	0	0	8.3
440,000	797.5	131,400	1-18	1	8.0	5.2	4.0	78.2	11.6
				14	5.3	4.9	3.0	80.7	8.0
				27	10.0	4.4	29.0	77.5	37.6
440,000	797.5	131,400	10-27	1	7.5	4.0	2.8	74.7	11.8
				14	3.5	4.7	4.3	79.0	8.8
				27	11.0	5.1	29.6	78.5	34.7
440,000	797.5	197,100	1-27	1	9.1	3.6	0	0	9.1
				14	3.7	4.4	0	0	4.2
				27	4.9	4.5	0	0	5.6

[1] See sketch for definition of terms.



DEFINITION SKETCH

TABLE J

WAVE HEIGHTS AND PERIODS AT POWERHOUSE

Plan F Flow Deflector at Elev 775.0

Pool Elev 956.0, Nonuniform Spillway Operation

River Discharge in CFS	Tailwater Elevation at Gage 3	Powerhouse		Spillway Discharge in CFS per Bay	Wave Gage at Power-house Unit	Short-Period Wave		Long-Period Wave		Maximum Random Peak to Trough in Feet
		Discharge in CFS	Units Operating			Maximum Amplitude in Feet	Average Period in Sec	Maximum Amplitude in Feet	Average Period in Sec	
260,000	788.2	65,700	1- 9	1- 4= 8,255	1	6.8	4.3	1.4	66.6	7.3
				5-14=12,000	14	5.0	4.6	1.3	56.2	6.1
				15-19= 8,255	27	10.9	4.7	3.2	56.2	12.7
305,000	790.9	65,700	1- 9	1- 4= 9,922	1	4.0	2.9	1.1	42.5	5.2
				5-14=15,000	14	-	-	-	-	-
				15-19= 9,922	27	6.6	4.4	3.2	83.6	7.5
397,400	795.4	131,400	1-18	1- 5=18,000	1	4.0	5.0	0	0	6.1
				6-14= 9,555	14	3.7	4.6	1.9	53.2	5.8
				15-19=18,000	27	6.2	3.6	5.7	59.0	12.5
440,000	797.5	131,400	1-18	1- 5=21,000	1	5.3	3.2	1.2	58.9	7.0
				6-14=10,955	14	-	-	-	-	-
				15-19=21,000	27	7.5	4.5	3.3	74.7	10.6

NOTES: 1. Spillway discharge was adjusted to eliminate surging.

2. See sketch on table I for definition of terms.

TABLE K

FLOW CONDITIONS IN STILLING BASIN

Plan F Flow Deflector at Elev 775.0

Pool Elev 956.0, Uniform Spillway Operation

River Discharge in CFS	Powerhouse Discharge in CFS	Spillway Discharge in CFS		Tailwater Elevation at Gage 3	Type of Flow
		Total	Per Bay		
Powerhouse Units 1-9 Operating					
225,000	65,700	159,300	8,385	786.5	Skimming
350,000	65,700	284,300	14,965	793.1	Surging
397,400	65,700	331,700	17,460	795.4	Surging
440,000	65,700	374,300	19,700	797.5	Plunging
Powerhouse Units 1-14 Operating					
292,200	102,200	190,000	10,000	790.0	Skimming
387,200	102,200	285,000	15,000	795.0	Surging
Powerhouse Units 1-14 Operating					
375,000	131,400	243,600	12,820	794.4	Skimming
397,400	131,400	266,000	14,000	795.4	Surging
575,375	131,400	443,975	23,345	803.4	Surging
600,000	131,400	468,600	24,665	804.0	Plunging
Powerhouse Units 1-22 Operating					
521,600	160,600	361,000	19,000	801.3	Surging

NOTES:

1. Skimming flow was downstream on the surface with upstream flow along the stilling basin floor.
2. Plunging flow was downstream along the floor with upstream surface flow.
3. Surging flow was unstable and fluctuated between skimming and plunging conditions. This condition was indentified by the visual presence of long-period waves at powerhouse unit 27.

TABLE L

FLOW CONDITIONS IN STILLING BASIN

Plan F Flow Deflector at Elev 775.0

Pool Elev 956.0, Nonuniform Spillway Operation

River Discharge in CFS	Spillway Discharge in CFS		Tailwater Elevation at Gage 3	Type of Flow
	Total	Per Bay		
Powerhouse Units 1-14 Operating, Discharge 102,200 CFS				
292,200	190,000	1-5, 15-19=11,000	790.0	Surging
		6-14= 8,890		Surging
		1-5, 15-19=12,000		Skimming
		6-14= 7,780		Plunging
		1-4, 15-19= 8,890		Skimming
		5-14=11,000		Skimming
		1-4, 15-19= 7,780		Skimming
		5-14=12,000		Skimming
387,200	285,000	1-5, 15-19=17,000	795.0	Surging
		6-14=12,780		Surging
		1-5, 15-19=19,000		Plunging
		6-14=10,550		Skimming
		1-4, 15-19=12,780		Surging
		5-14=17,000		Plunging
		1-4, 15-19=10,550		Skimming
		6-14=19,000		Plunging
Powerhouse Units 1-22 Operating, Discharge 160,000 CFS				
521,600	361,000	1-5, 15-19=21,000	801.3	Surging
		6-14=16,780		Surging
		1-5, 15-19=23,000		Plunging
		6-14=14,550		Skimming
		1-4, 15-19=16,780		Surging
		5-14=21,000		Surging
		1-4, 15-19=14,550		Skimming
		6-14=23,000		Plunging
Powerhouse Units 1-27 Operating, Discharge 197,100 CFS				
672,100	475,000	1-5, 15-19=28,000	806.8	Plunging
		6-14=21,665		Skimming

TABLE M

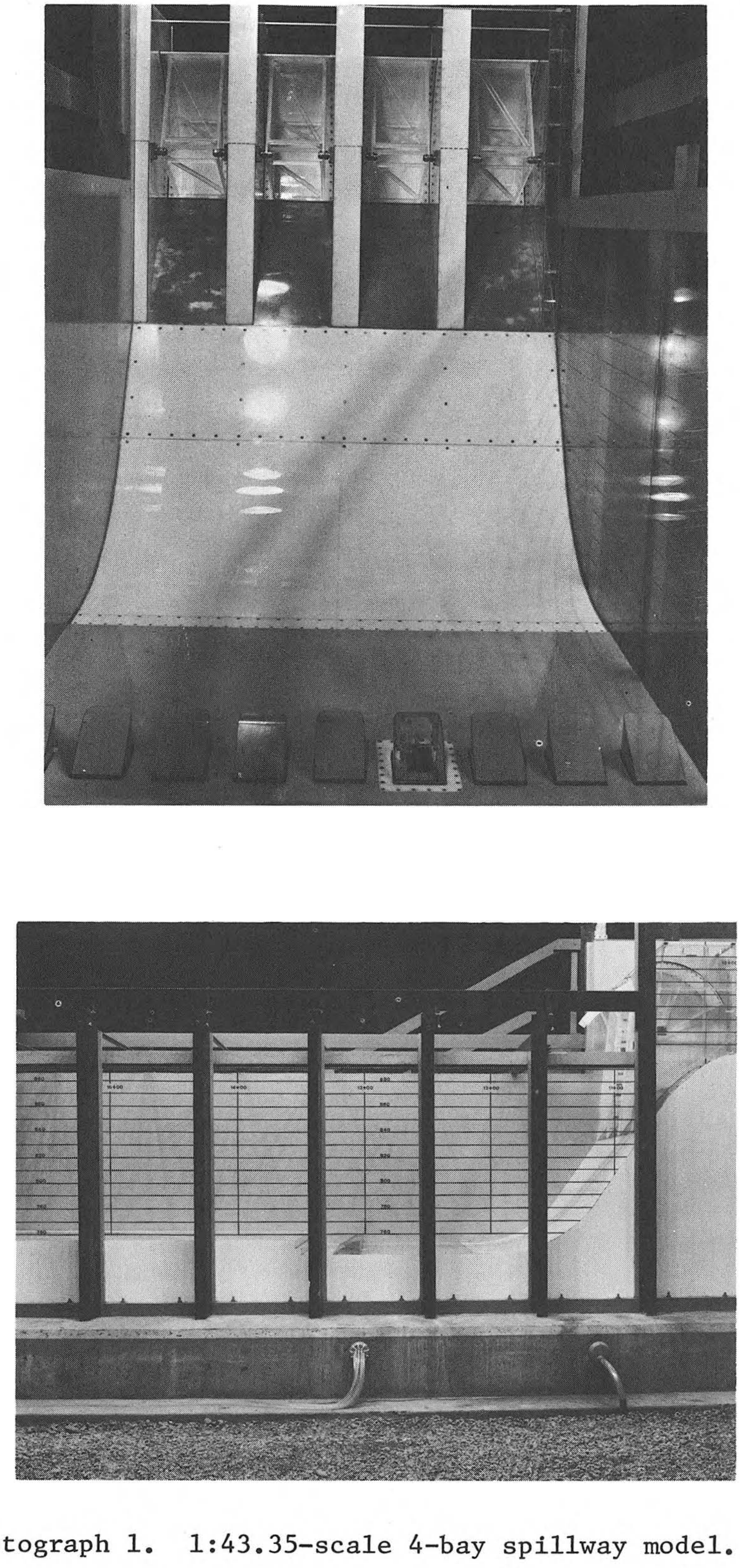
FLOW CONDITIONS IN STILLING BASIN

Plan F Flow Deflector at Elev 775.0

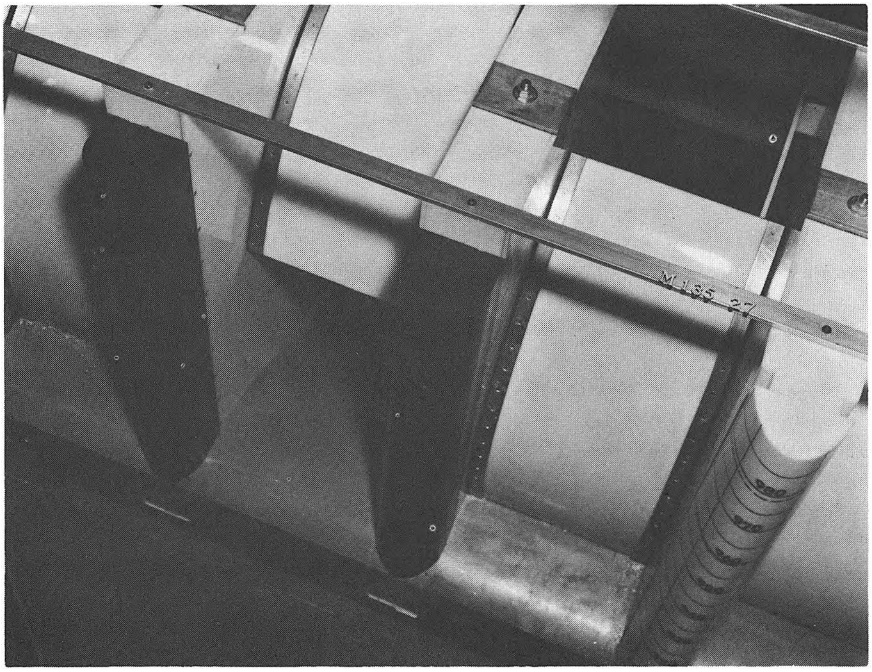
Pool Elev 956.0, Nonuniform Spillway Operation

Powerhouse Units 1-18 Operating, Discharge 131,400 CFS

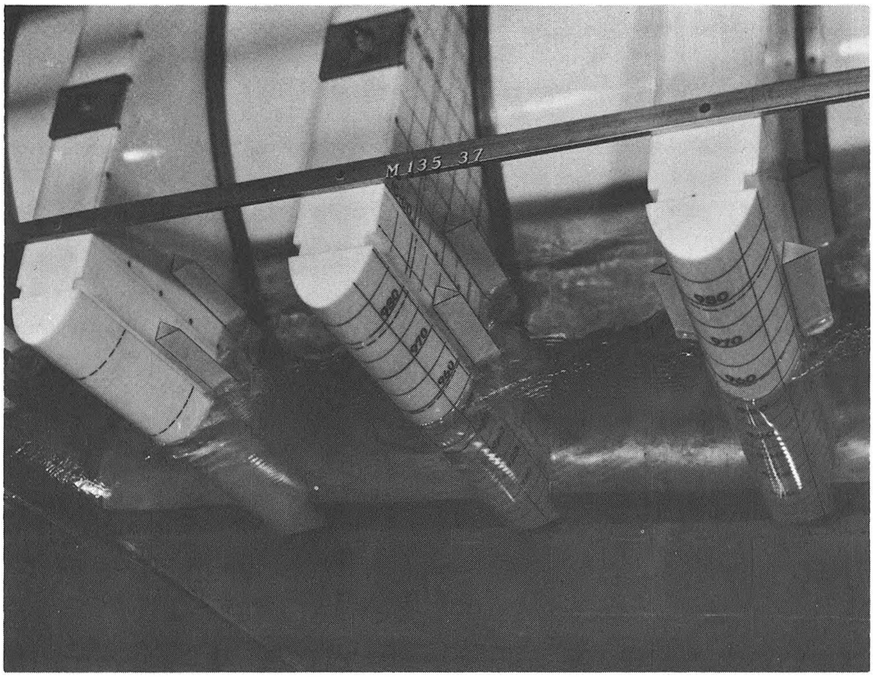
River Discharge in CFS	Spillway Discharge in CFS		Tailwater Elevation at Gage 3	Type of Flow
	Total	Per Bay		
302,400	171,000	1-5, 15-19=10,955 6-14= 6,830	790.5	Skimming Skimming
		1-5, 15-19=12,400 6-14= 5,220		Skimming Skimming
325,000	193,600	1-5, 15-19=12,000 6-14= 8,220	791.9	Skimming Skimming
		1-5, 15-19=13,900 6-14= 6,110		Skimming Skimming
350,000	218,600	1-5, 15-19=12,860 6-14=10,000	793.1	Surging Surging
		1-5, 15-19=14,120 6-14= 8,600		Surging Skimming
		1-5, 15-19=15,380 6-14= 7,200		Surging Skimming
375,000	243,600	1-5, 15-19=14,500 6-14=10,955	794.4	Surging Surging
		1-5, 15-19=16,400 6-14= 8,845		Surging Skimming
		1-5, 15-19=18,000 6-14= 7,065		Surging Skimming
397,400	266,000	1-5, 15-19=18,000 6-14= 9,555	795.4	Plunging Skimming
530,400	399,000	1-5, 15-19=23,000 6-14=18,780	801.5	Surging Surging
		1-5, 15-19=23,880 6-14=17,800		Plunging Skimming
		1-5, 15-19=24,500 6-14=17,110		Plunging Skimming
		1-5, 15-19=26,000 6-14=15,445		Plunging Skimming
		1-5, 15-19=14,200 6-14=28,555		Skimming Plunging



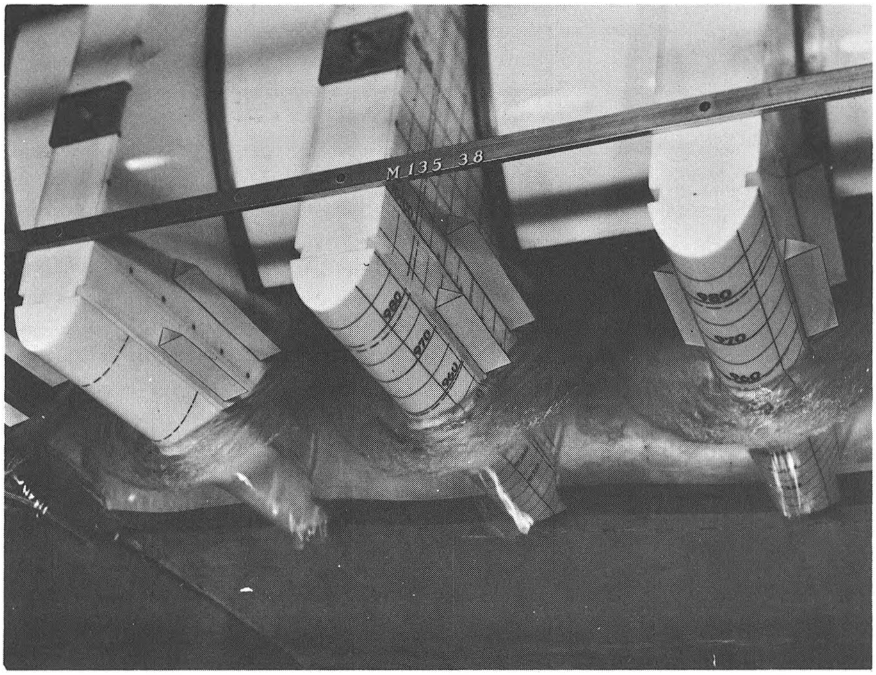
Photograph 1. 1:43.35-scale 4-bay spillway model.



Photograph 2. Plan B spillway with short, round pier noses.

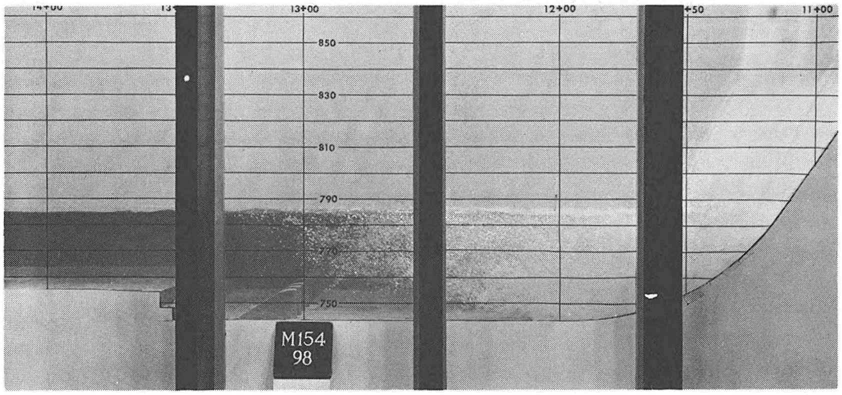


Gates opened 30 ft; pool elev 956.2,
total spillway discharge 731,400 cfs.

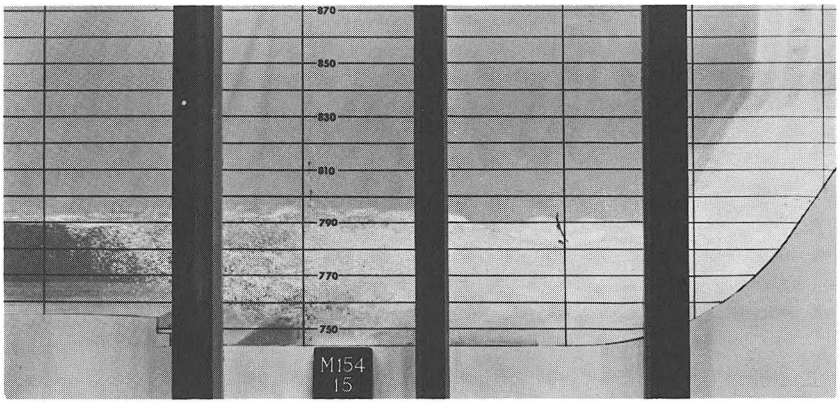


Free flow at pool elev 958.8, total spillway
discharge 1,200,000 cfs.

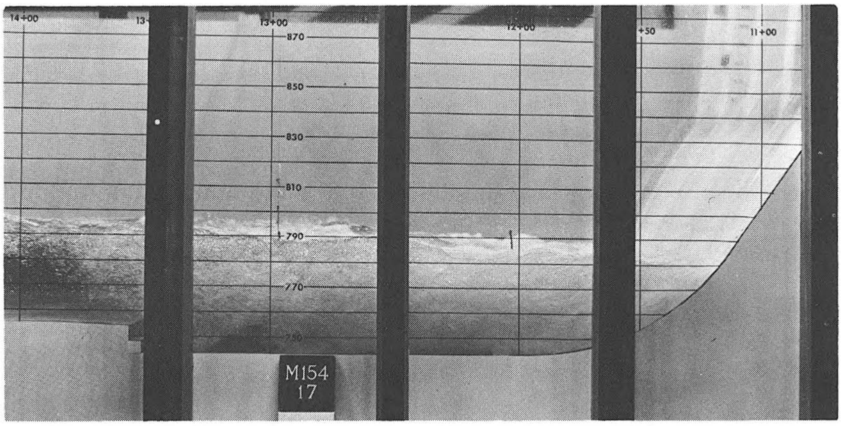
Photograph 3. Flow conditions with surge suppressors on piers (final design).



River discharge 190,000 cfs (2,930 cfs per bay), 2-year flood, tailwater elev 786.2.

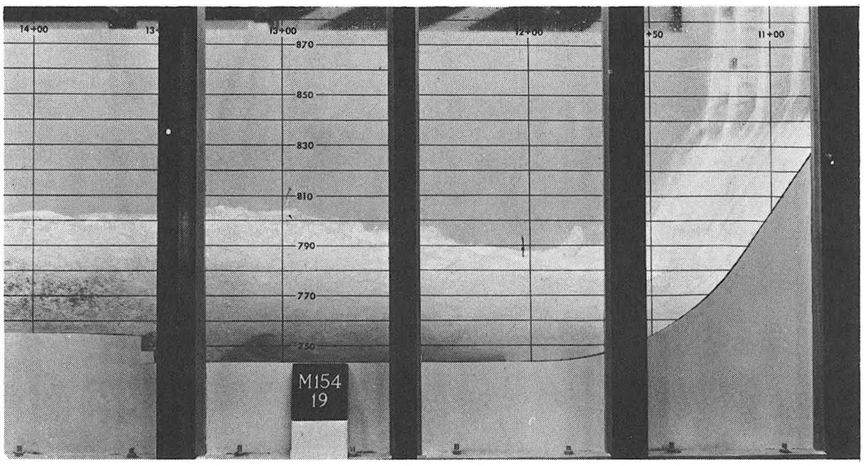


River discharge 260,000 cfs (6,720 cfs per bay), 5-year flood, tailwater elev 790.0.

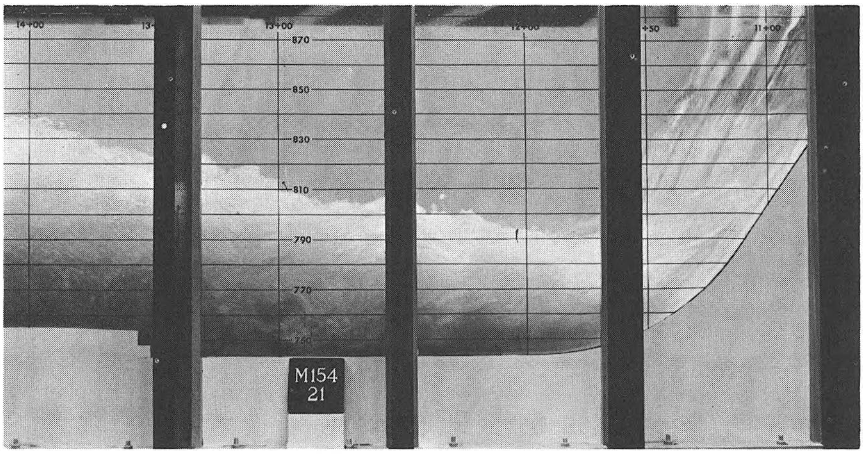


River discharge 305,000 cfs (9,150 cfs per bay), 10-year flood, tailwater elev 792.3.

Photograph 4. Flow conditions in stilling basin without flow deflector; pool elev 956.0, 18 powerhouse units operating.

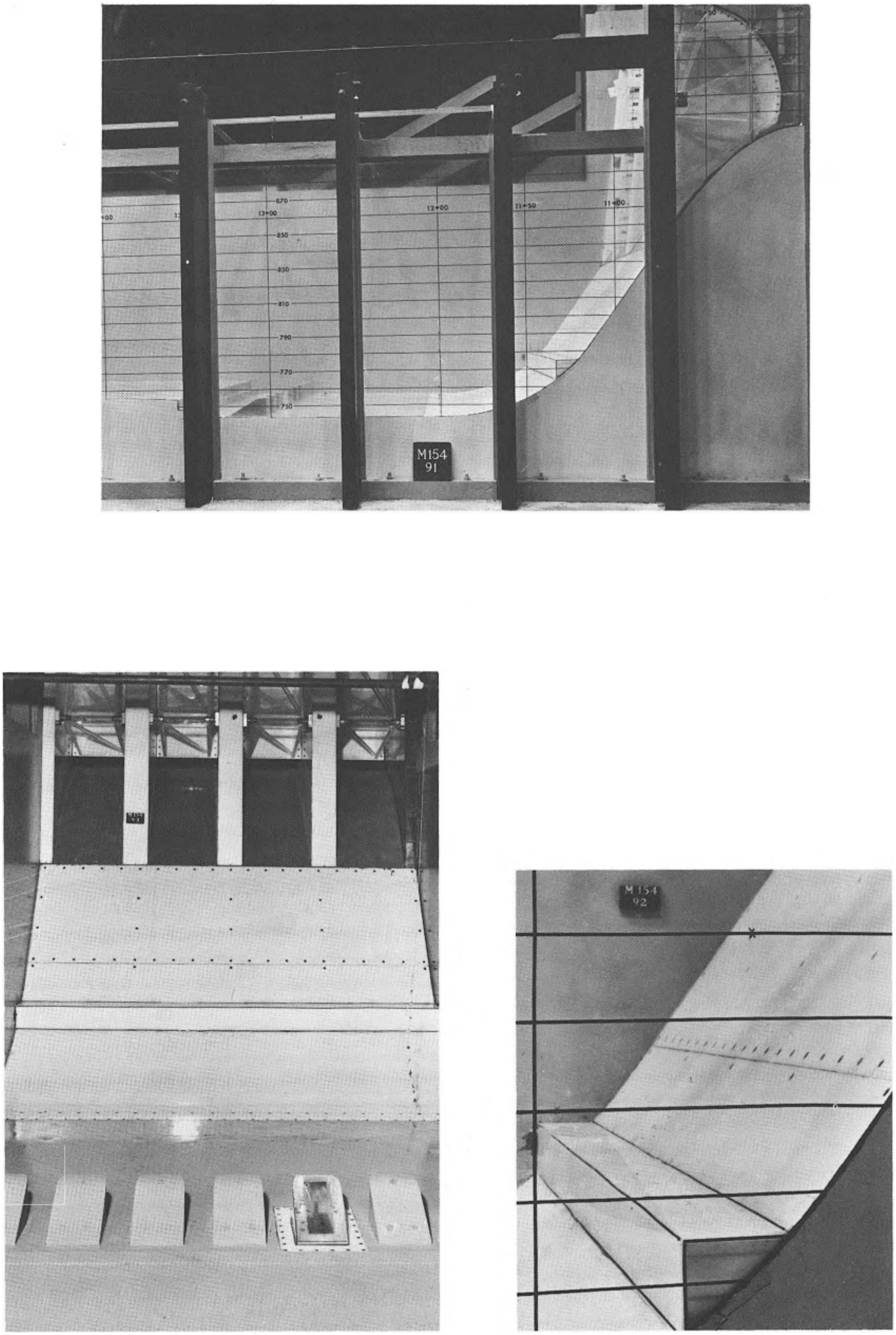


River discharge 440,000 cfs (16,390 cfs per bay),
100-year flood, pool elev 956.0, tailwater elev 798.5,
18 powerhouse units operating

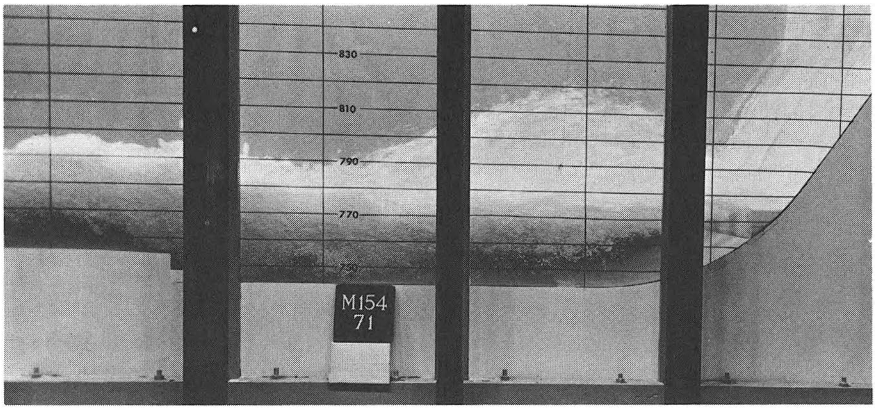


River discharge 1,200,000 cfs (63,160 cfs per bay),
spillway design flood, pool elev 958.8,
tailwater elev 825.0, no powerhouse operation.

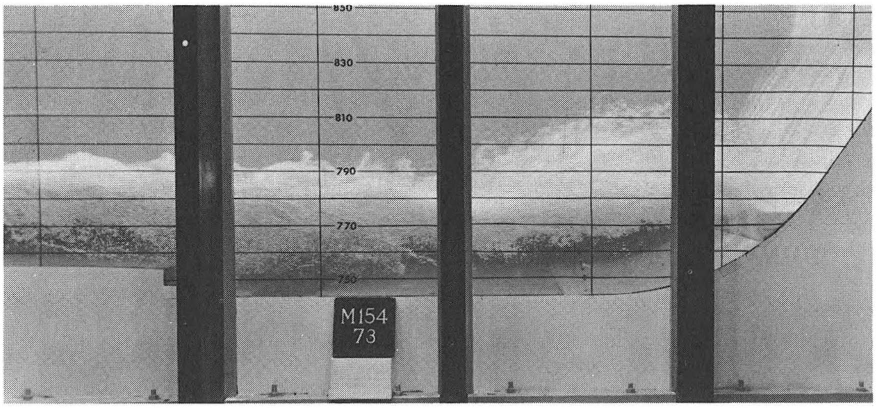
Photograph 5. Flow conditions in stilling basin without flow deflector.



Photograph 6. Plan F flow deflector at elev 775.0
(final design).



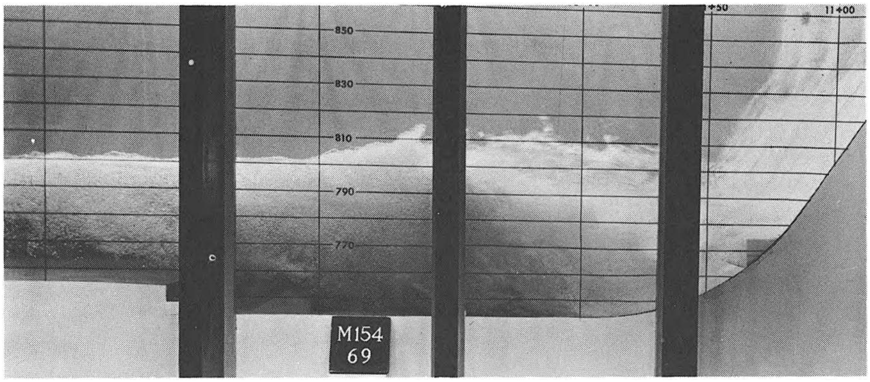
River discharge 190,000 cfs (2,930 cfs per bay), 2-year flood, tailwater elev 786.2.



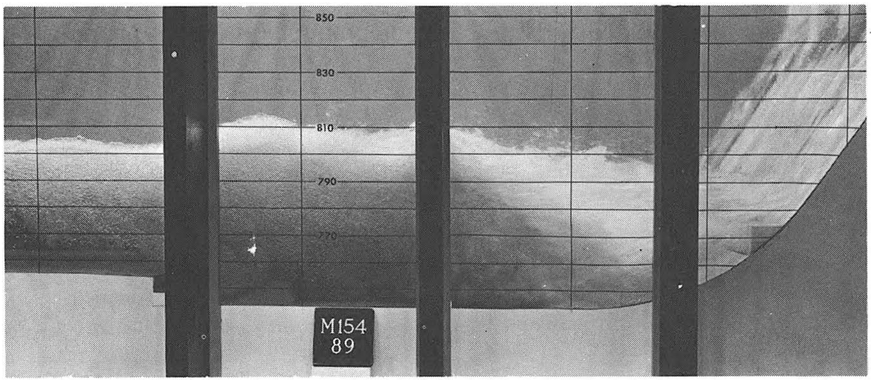
River discharge 260,000 cfs (6,720 cfs per bay), 5-year flood, tailwater elev 790.0.

River discharge 305,000 cfs (9,150 cfs per bay), 10-year flood, tailwater elev 792.3.

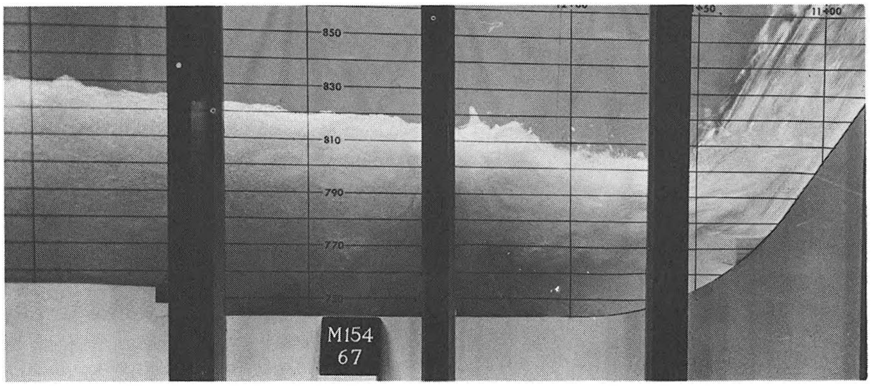
Photograph 7. Flow conditions in stilling basin with final design flow deflector; pool elev 956.0, 18 powerhouse units operating.



River discharge 440,000 cfs (16,390 cfs per bay), 100-year flood, pool elev 956.0, tailwater elev 798.5, 18 powerhouse units operating.



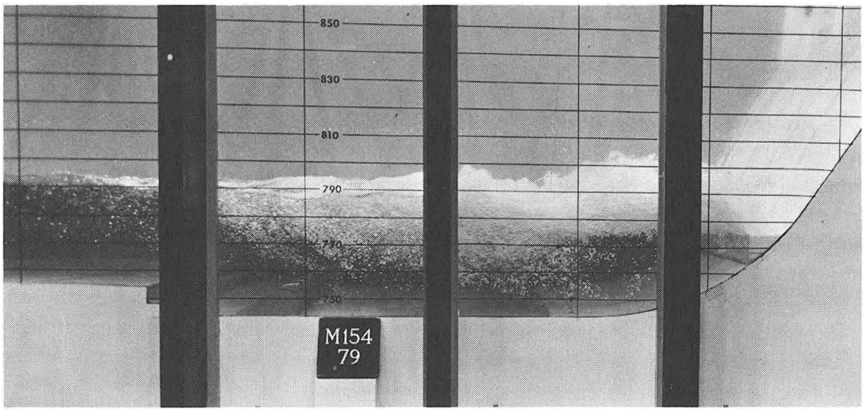
River discharge 440,000 cfs (23,370 cfs per bay), 100-year flood, pool elev 956.0, tailwater elev 798.5, no powerhouse operation.



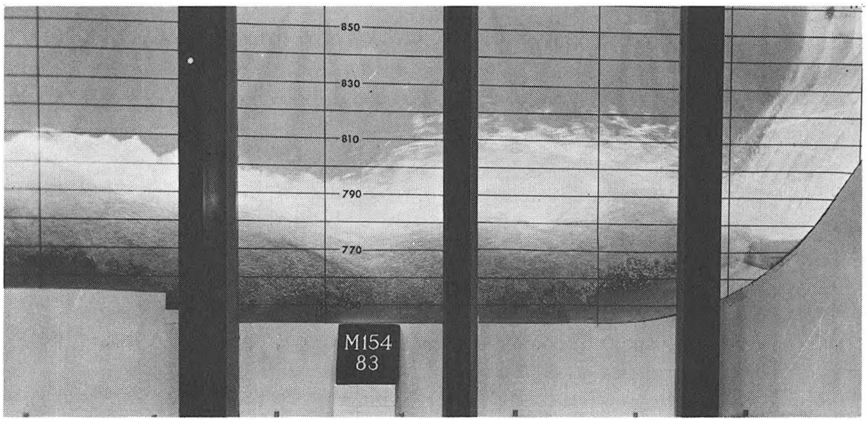
River discharge 1,200,000 cfs (63,160 cfs per bay), spillway design flood, pool elev 958.8, tailwater elev 825.0, no powerhouse operation.

Photograph 8. Flow conditions in stilling basin with final design flow deflector.

River discharge 260,000 cfs (3,240 cfs per bay), 5-year flood, tailwater elev 790.0.

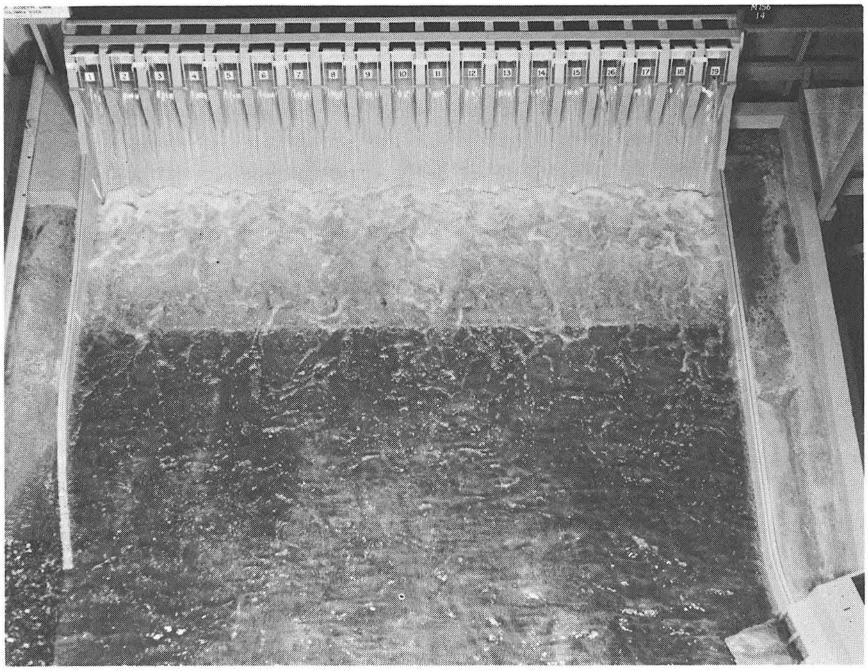


River discharge 305,000 cfs (5,690 cfs per bay), 10-year flood, tailwater elev 792.3.

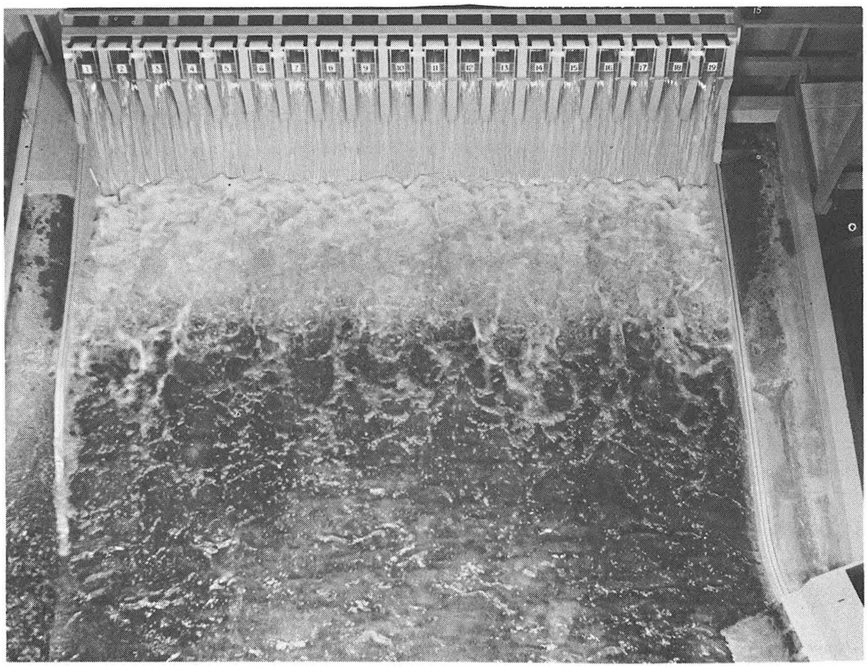


River discharge 440,000 cfs (13,010 cfs per bay), 100-year flood, tailwater elev 798.5.

Photograph 9. Flow conditions in stilling basin with final design flow deflector; pool elev 956.0, 27 powerhouse units operating.

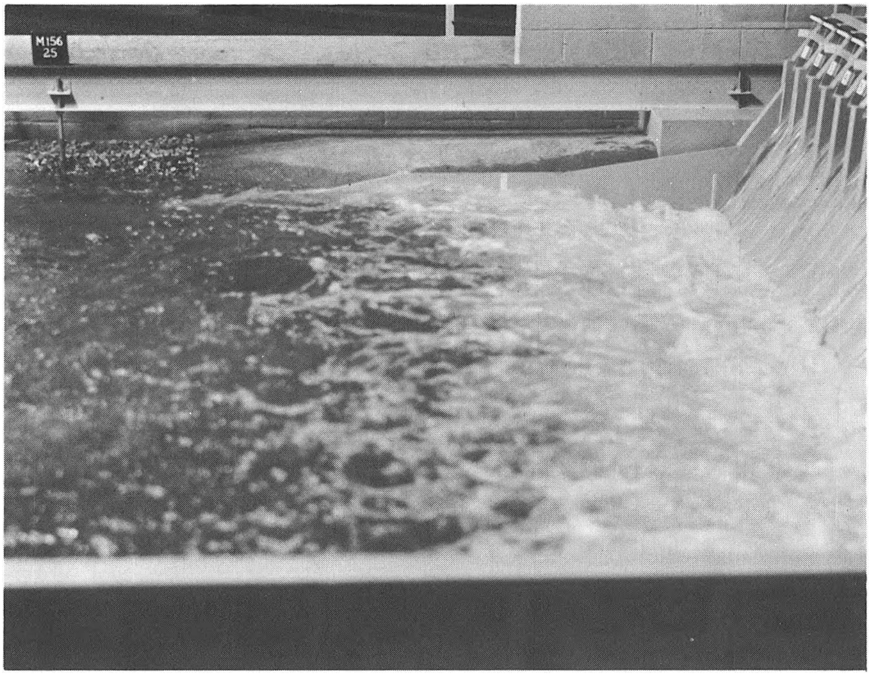


Spillway discharge 260,000 cfs, tailwater elev 788.2.

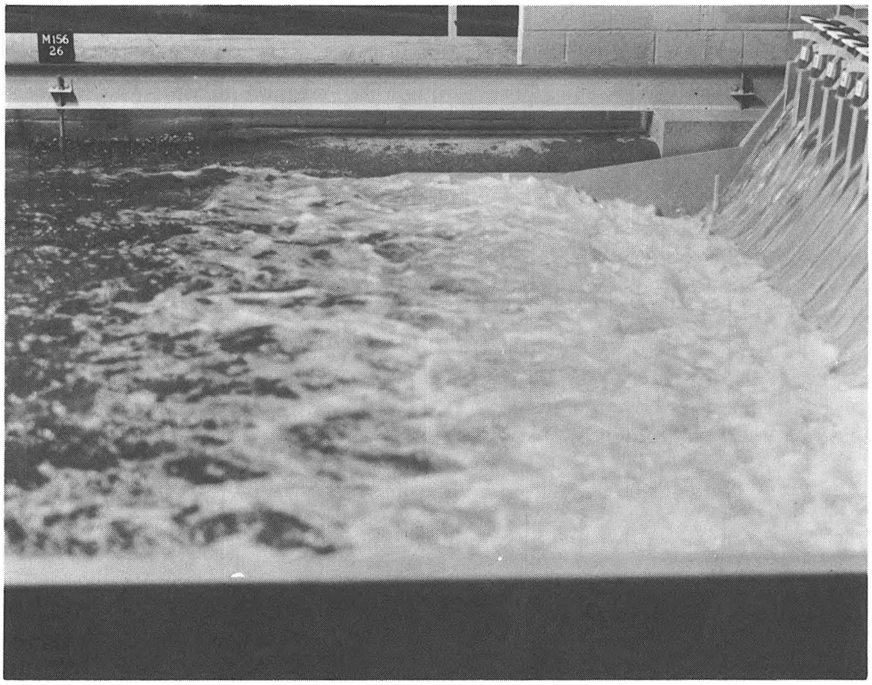


Spillway discharge 440,000 cfs, tailwater elev 797.5.

Photograph 10. Flow conditions in stilling basin without flow deflector on spillway; uniform spillway operation, no powerhouse operation.

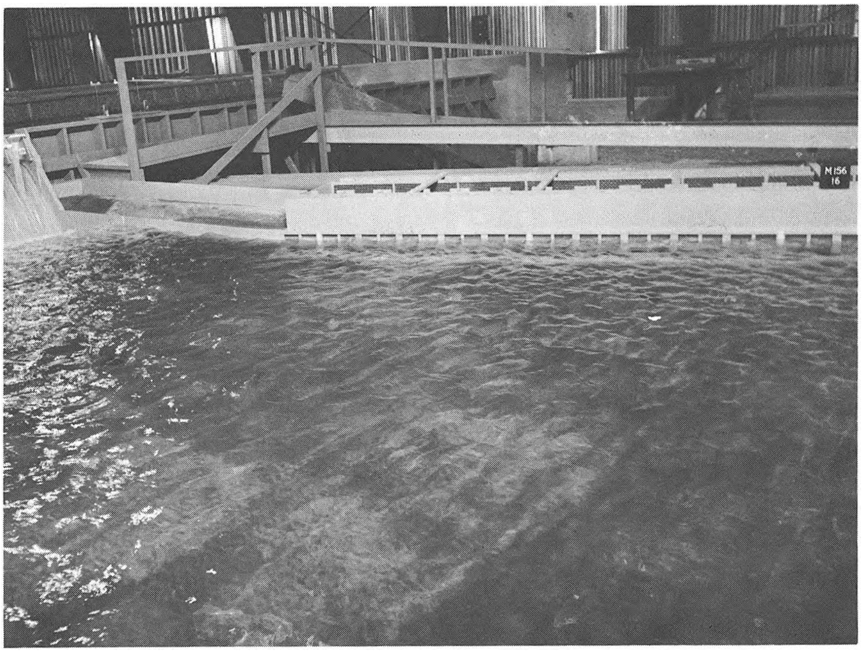


Spillway discharge 440,000 cfs, tailwater elev 797.5.

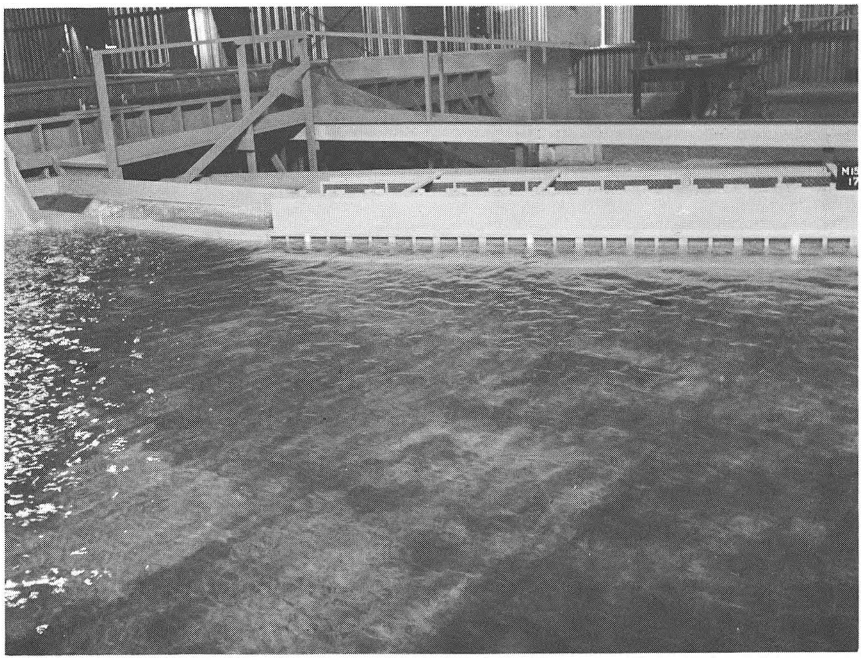


Spillway discharge 750,000 cfs, tailwater elev 809.8.

Photograph 11. Flow conditions in stilling basin, along north training wall, and at riprap test section without flow deflector on spillway; uniform spillway operation, no powerhouse operation.



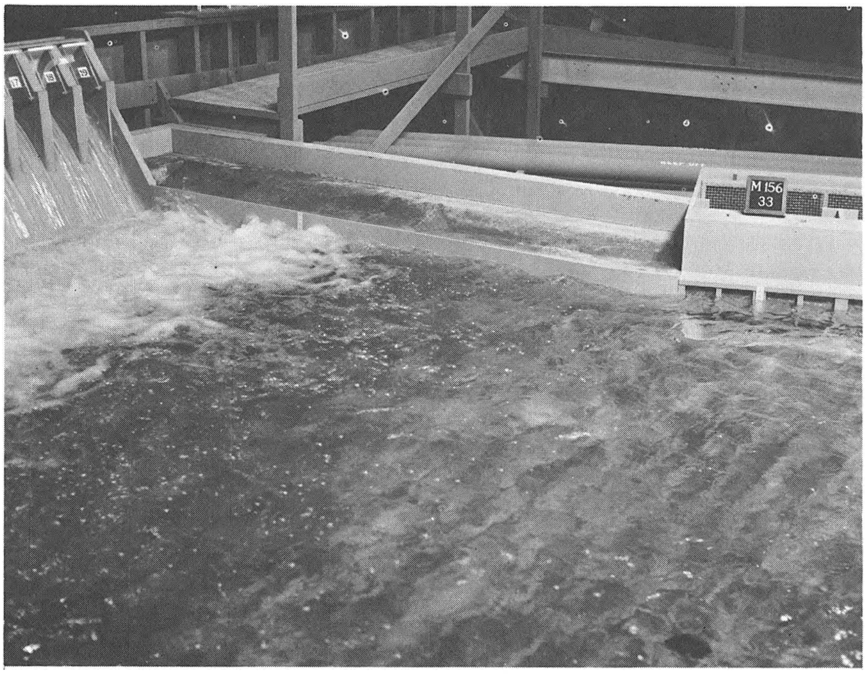
Spillway discharge 440,000 cfs.



Spillway discharge 242,000 cfs, 27 powerhouse units operating.

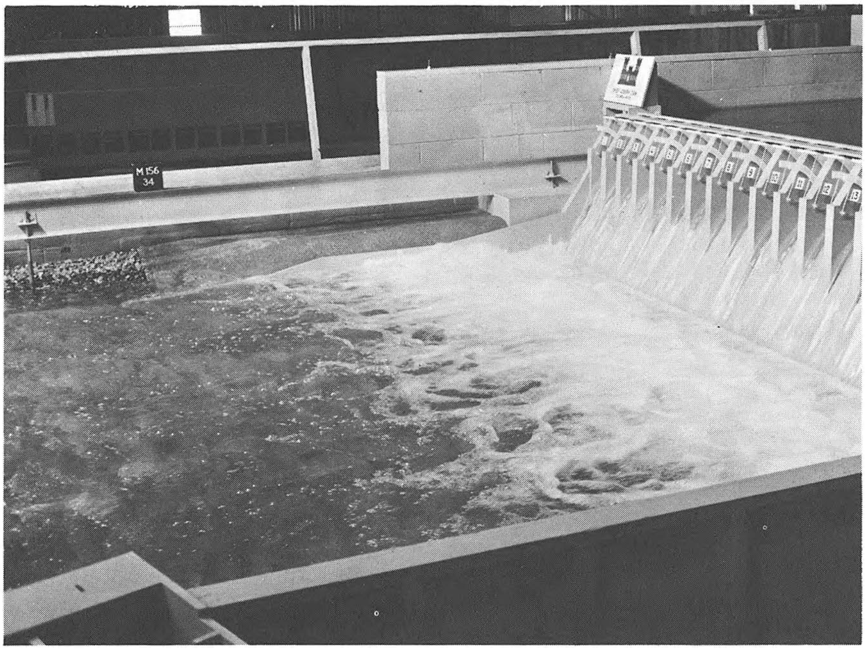
Photograph 12. Flow conditions at south training wall and powerhouse units 1 to 10 without flow deflector on spillway, uniform spillway operation, river discharge 440,000 cfs, tailwater elev 797.5.

Spillway discharge 440,000 cfs.

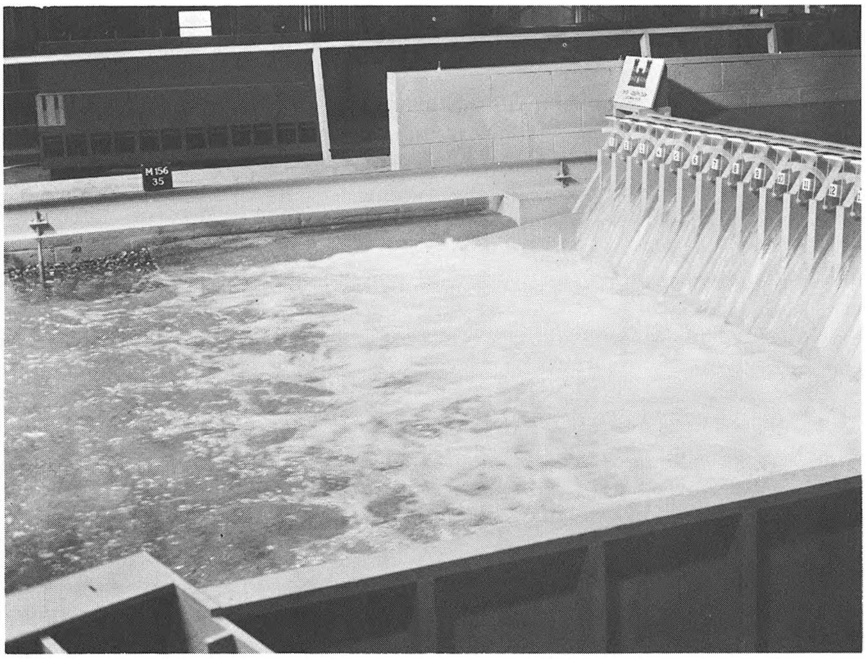


Spillway discharge 242,000 cfs, 27 powerhouse units operating.

Photograph 13. Flow conditions at south training wall and upstream end of powerhouse with flow deflector on spillway; uniform spillway operation, river discharge 440,000 cfs, tailwater elev 797.5.



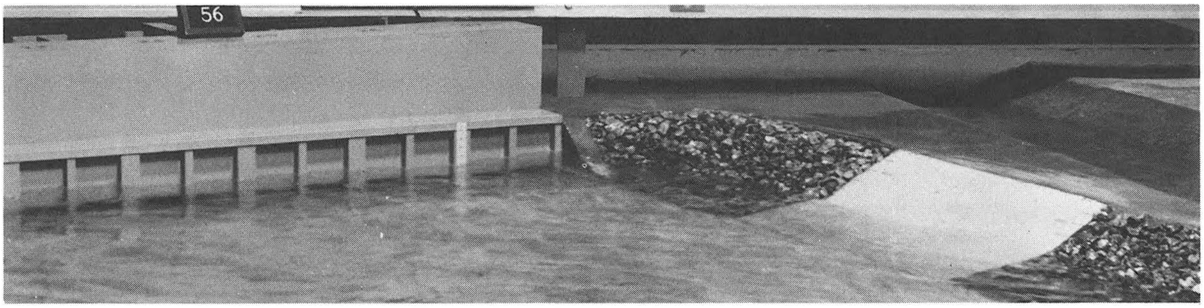
Spillway discharge 440,000 cfs, tailwater elev 797.5.



Spillway discharge 750,000 cfs, tailwater elev 809.8.

Photograph 14. Flow conditions in stilling basin, along north training wall, and at riprap test section with flow deflector on spillway; uniform spillway operation, no powerhouse operation.

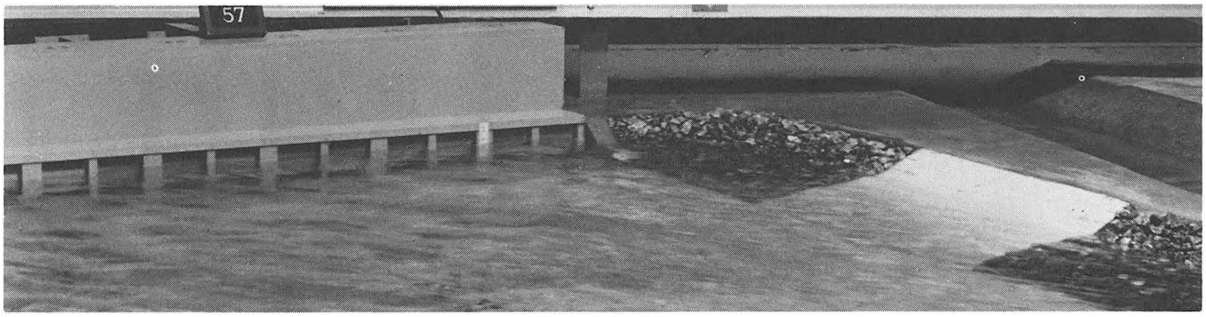
Peak of long-term wave.



Trough of long-term wave.

Uniform spillway operation; maximum peak to trough 37.6 ft.

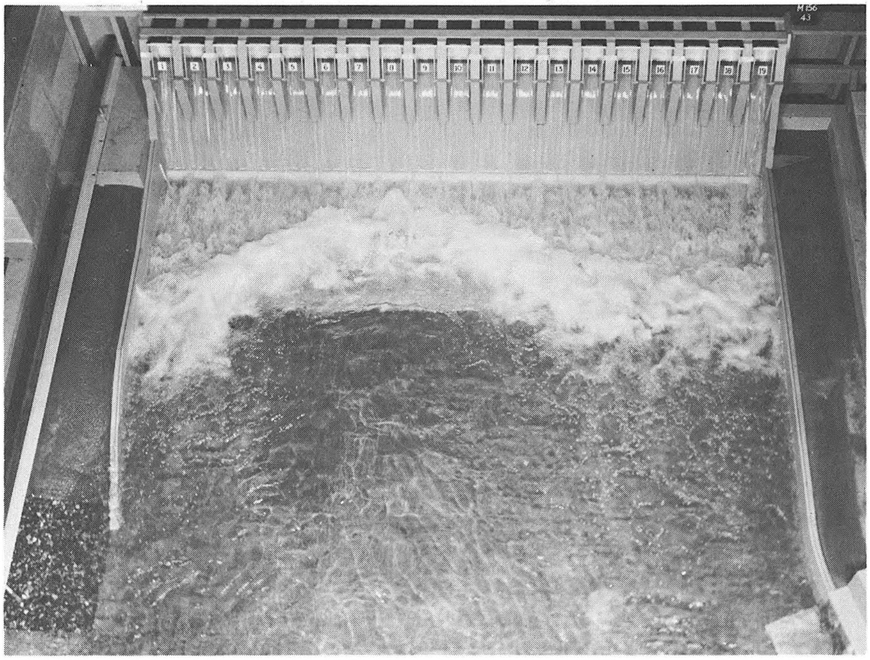
Peak of long-term wave.



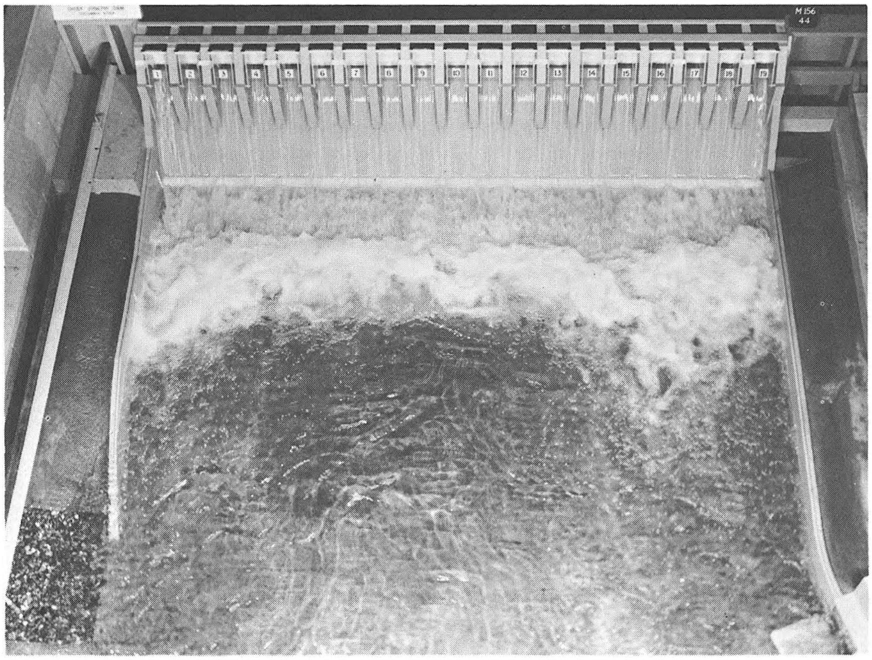
Trough of long-term wave.

Nonuniform spillway operation; maximum peak to trough 10.6 ft.

Photograph 15. Flow conditions at powerhouse unit 27; river discharge 440,000 cfs, 18 units operating, tailwater elev 797.5.

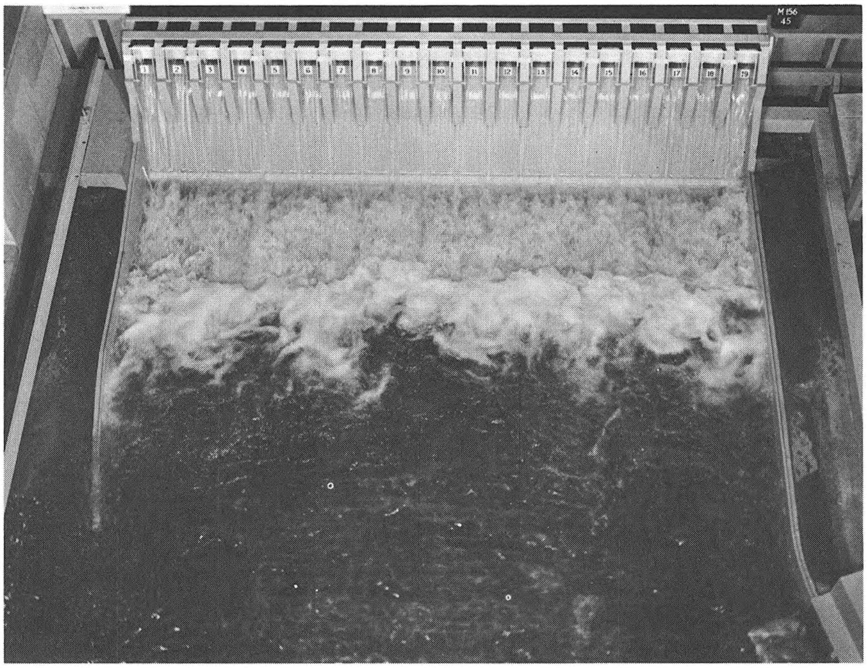


Uniform spillway operation (surging in stilling basin and large long-term waves at powerhouse).

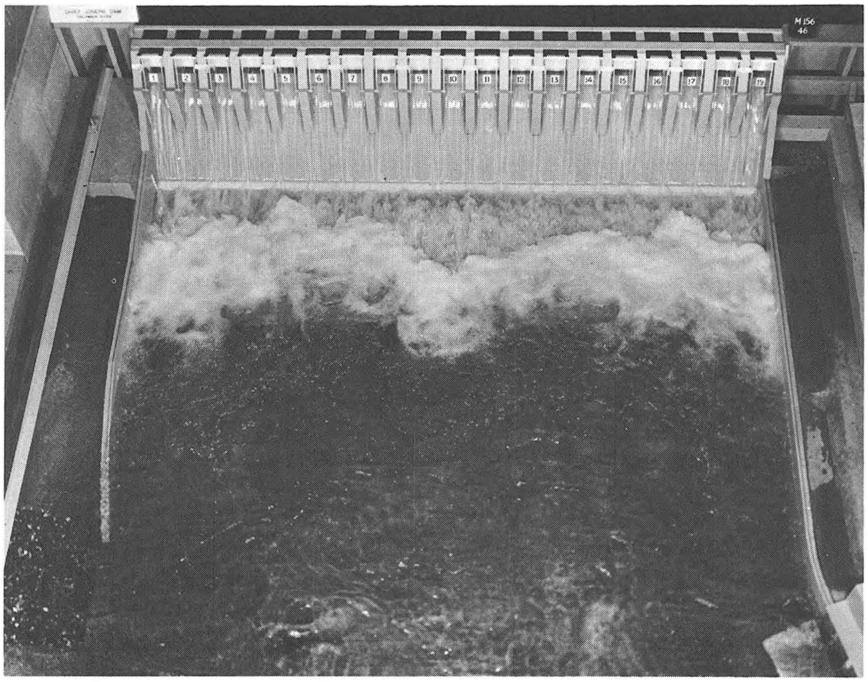


Nonuniform spillway operation (no surging).

Photograph 16. Spillway operation with flow deflector on spillway; river discharge 260,000 cfs, spillway discharge 194,300 cfs, 9 powerhouse units operating, tailwater elev 788.2.

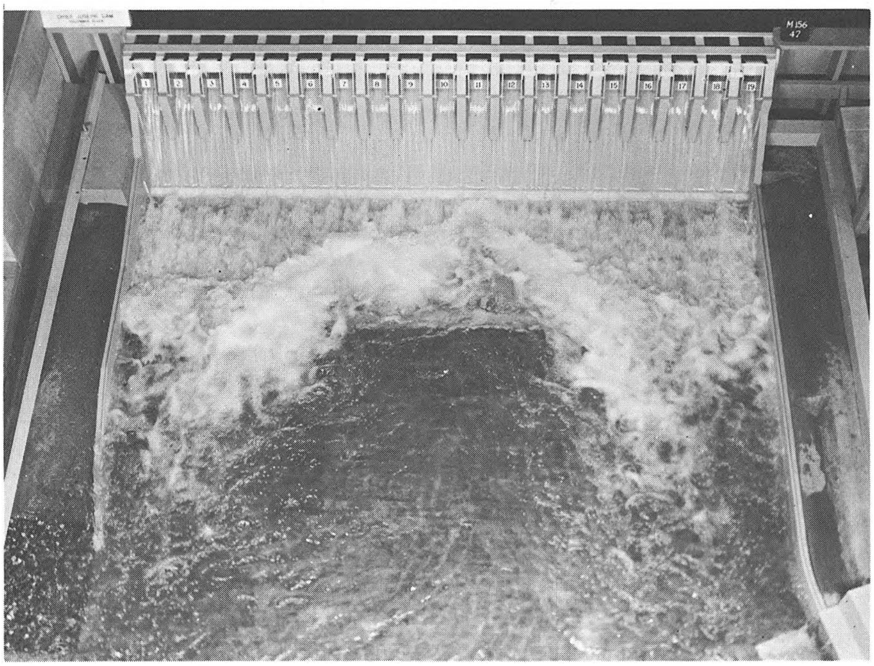


Uniform spillway operation (surging in stilling basin and large long-term waves at powerhouse).

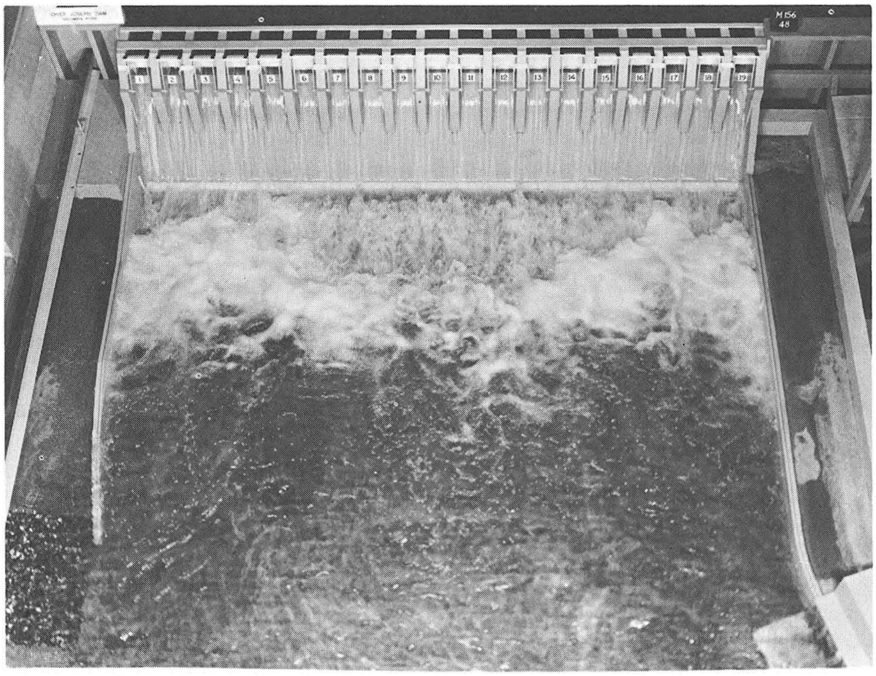


Nonuniform spillway operation (no surging).

Photograph 17. Spillway operation with flow deflector on spillway; river discharge 305,000 cfs, spillway discharge 239,300 cfs, 9 powerhouse units operating, tailwater elev 790.9.

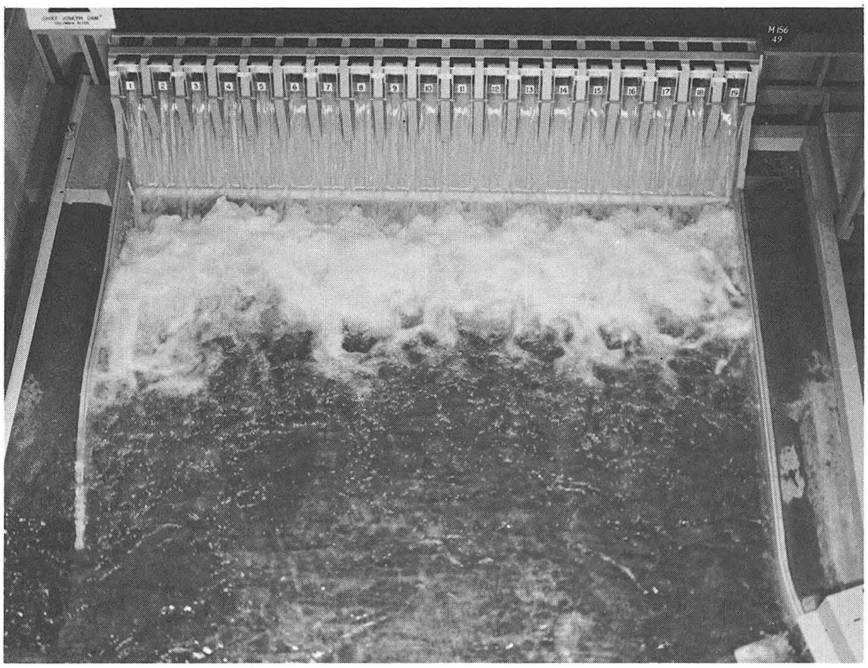


Uniform spillway operation (surging in stilling basin and large long-term waves at

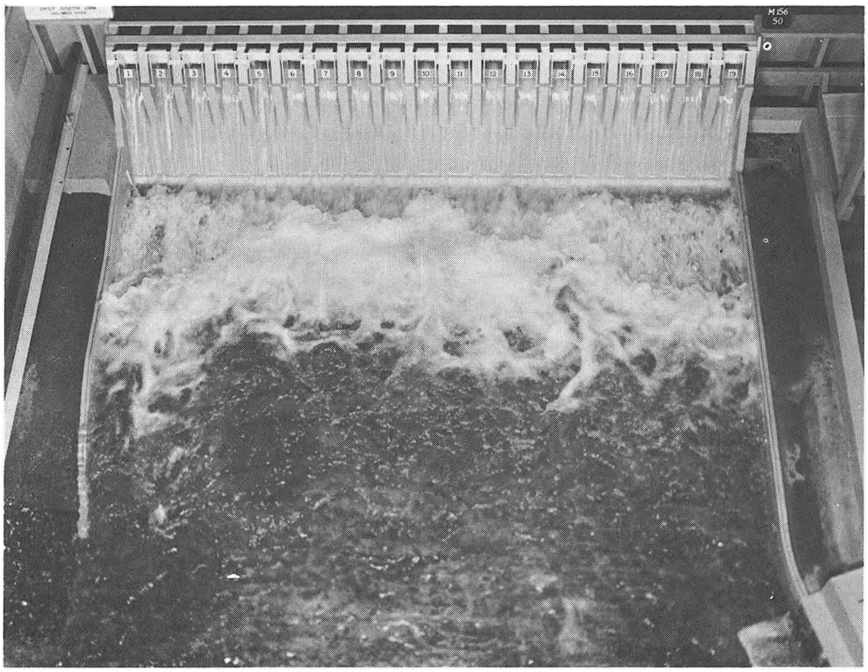


Nonuniform spillway operation (no surging).

Photograph 18. Spillway operation with flow deflector on spillway; river discharge 397,400 cfs, spillway discharge 266,000 cfs, 18 powerhouse units operating, tailwater elev 795.4.

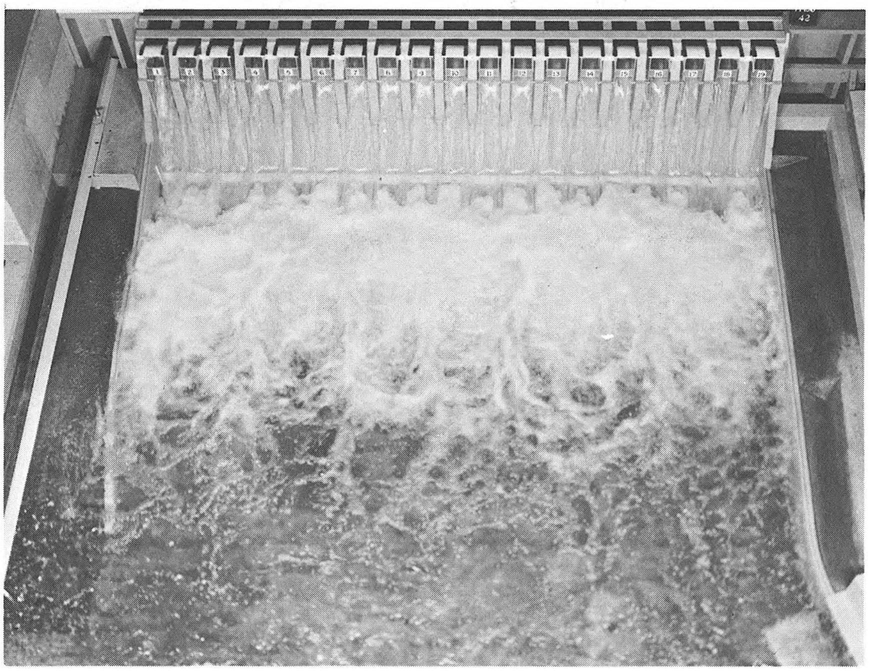


Uniform spillway operation (surging in stilling basin and large long-term waves at powerhouse).

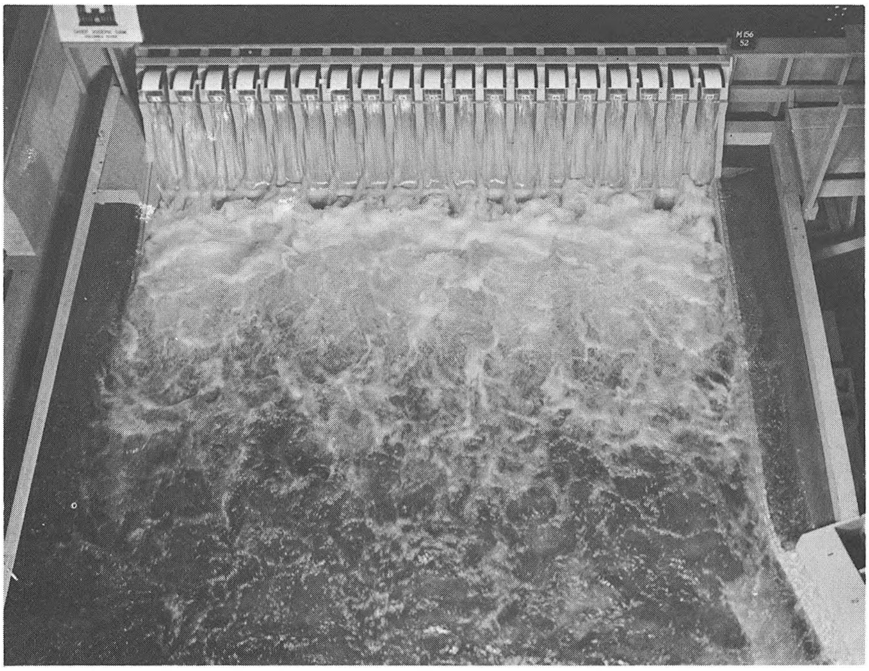


Nonuniform spillway operation (no surging).

Photograph 19. Spillway operation with flow deflector on spillway; river discharge 440,000 cfs, spillway discharge 308,600 cfs, 18 powerhouse units operating, tailwater elev 797.5.

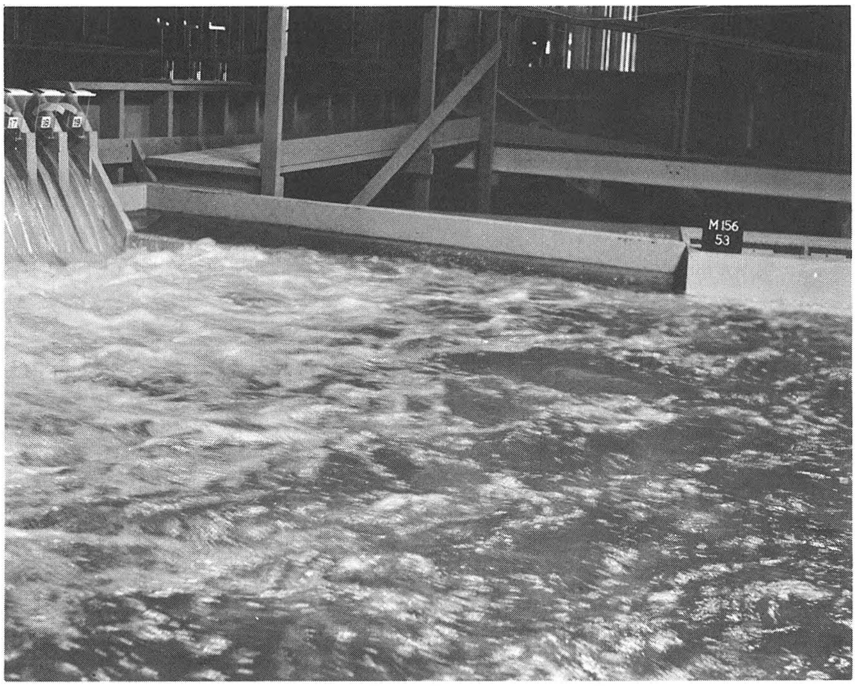


River and spillway discharge 750,000 cfs,
tailwater elev 809.8.

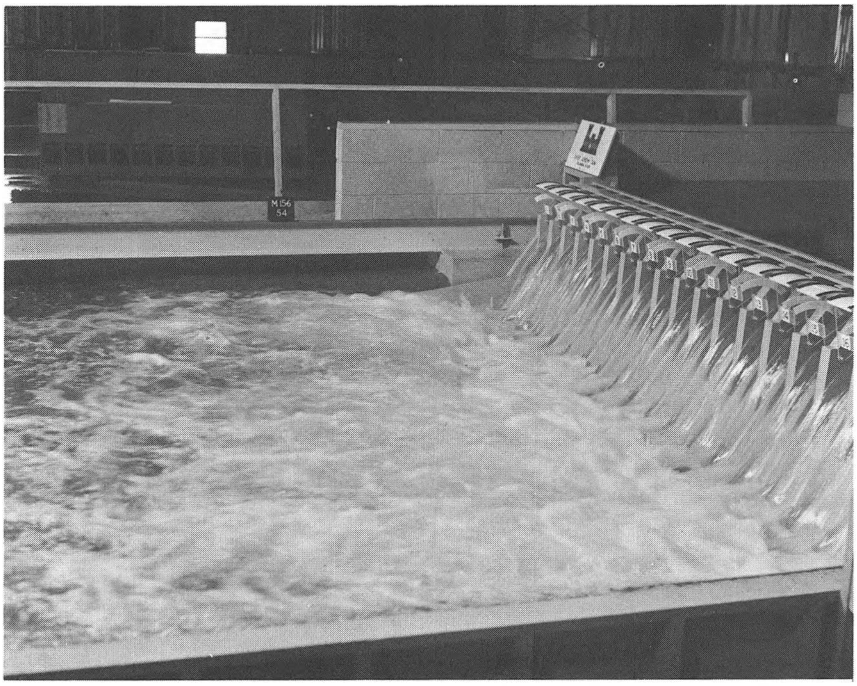


River and spillway discharge 1,200,000 cfs,
tailwater elev 825.0.

Photograph 20. Flow conditions in stilling basin with flow deflector on spillway; uniform spillway operation.

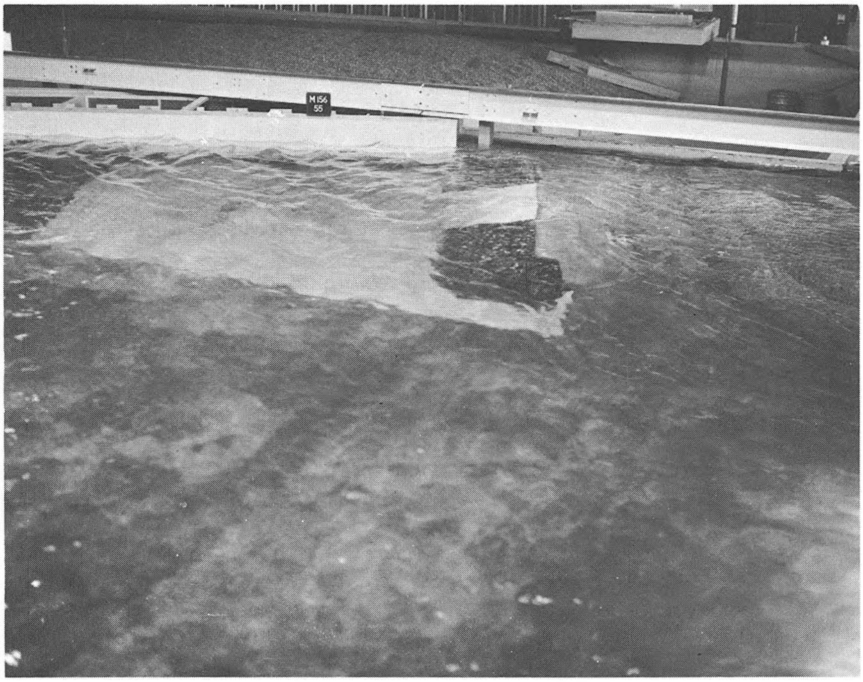


South training wall.

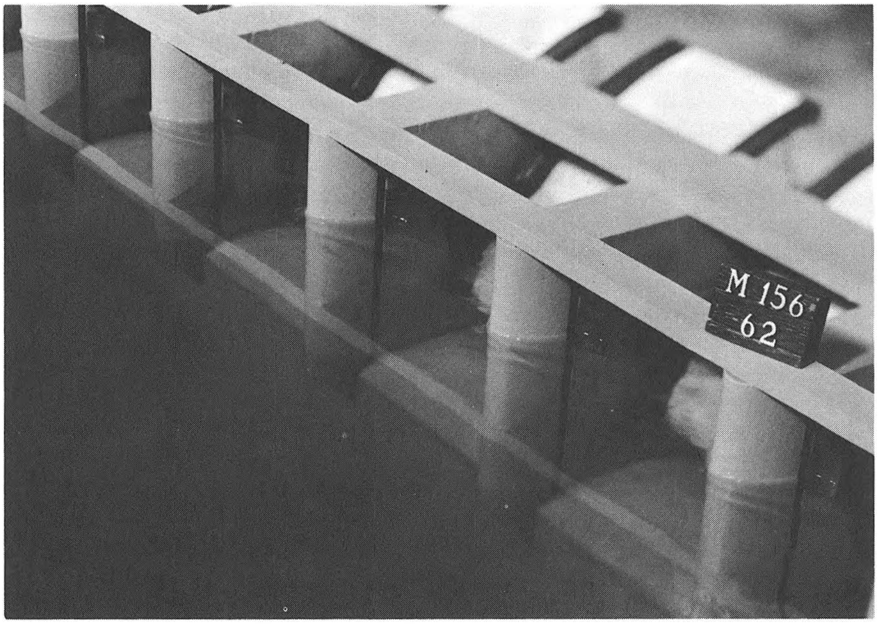


Stilling basin and north training wall.

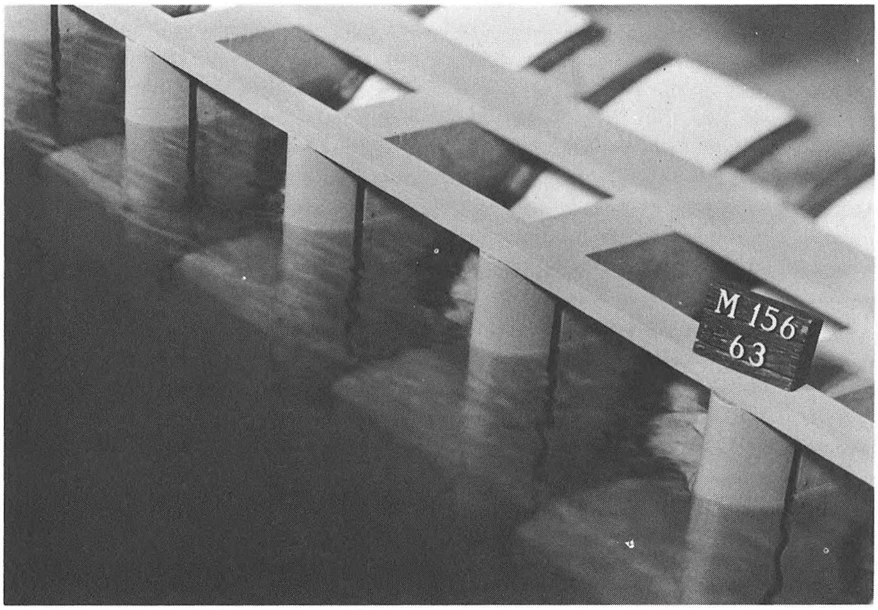
Photograph 21. Flow conditions with flow deflector on spillway; river and spillway discharge 1,200,000 cfs, tailwater elev 825.0.



Photograph 22. Flow conditions at downstream end of powerhouse and Foster Creek; river and spillway discharge 1,200,000 cfs, tailwater elev 825.0.

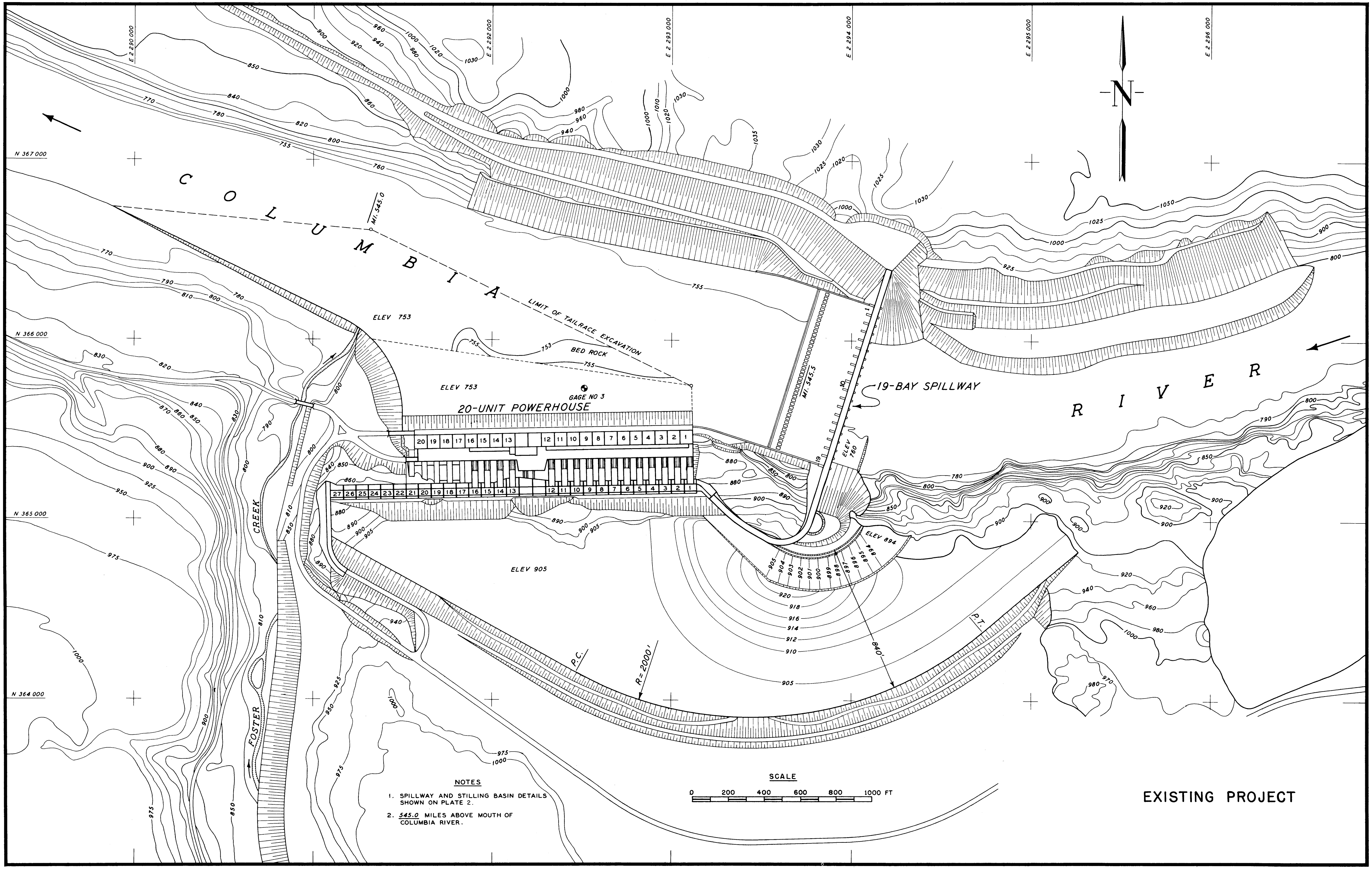


Piers with surge suppressors.



Piers without surge suppressors.

Photograph 23. Flow conditions with and without surge suppressors on spillway piers; spillway discharge 440,000 cfs, gated flow, pool elev 956.0.

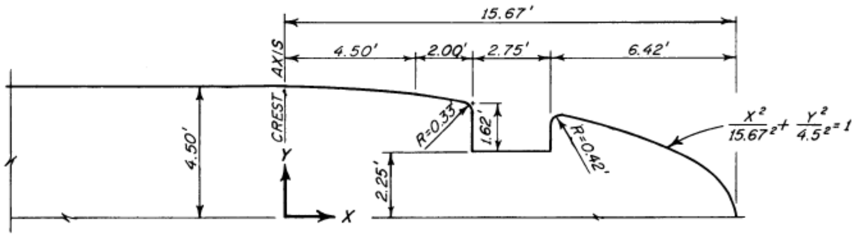


NOTES

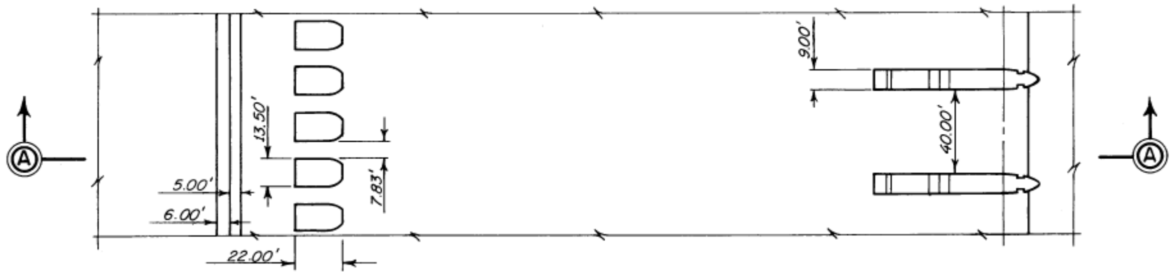
1. SPILLWAY AND STILLING BASIN DETAILS SHOWN ON PLATE 2.
2. 545.0 MILES ABOVE MOUTH OF COLUMBIA RIVER.

EXISTING PROJECT

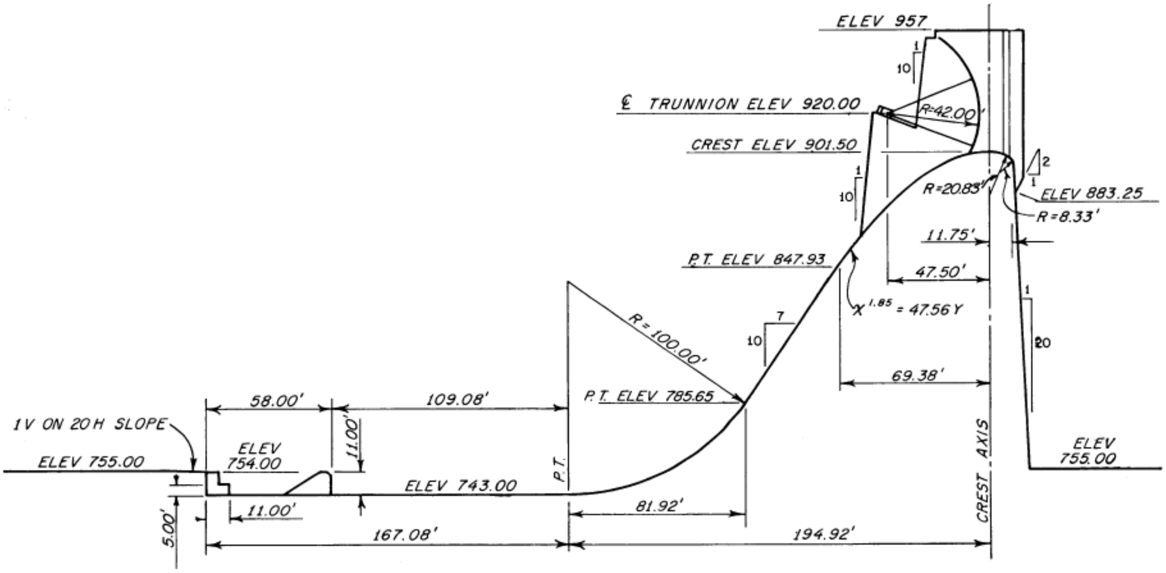
PLATE 1



HALF PLAN
PIER DETAIL

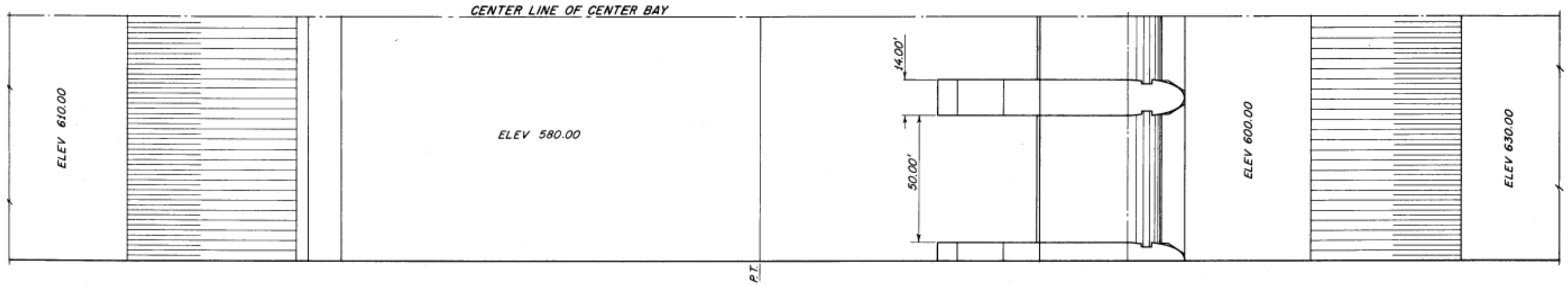


PLAN

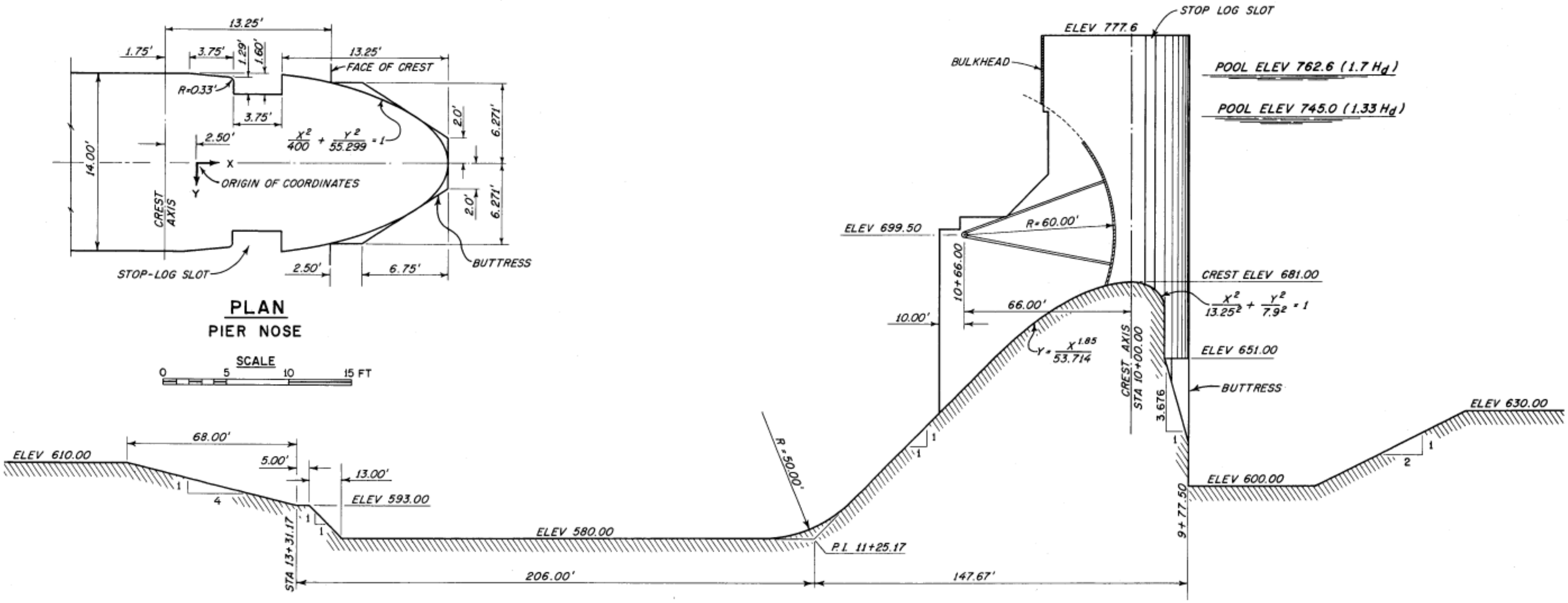


SECTION A-A

SPILLWAY DETAILS
EXISTING DESIGN



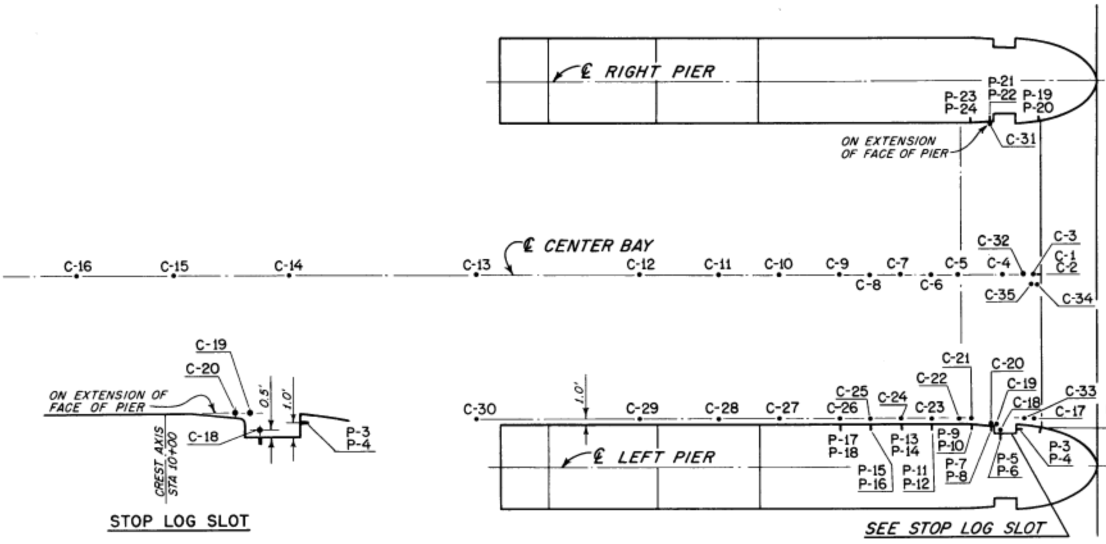
HALF PLAN



PLAN
PIER NOSE

SECTION ALONG CENTER LINE OF BAY

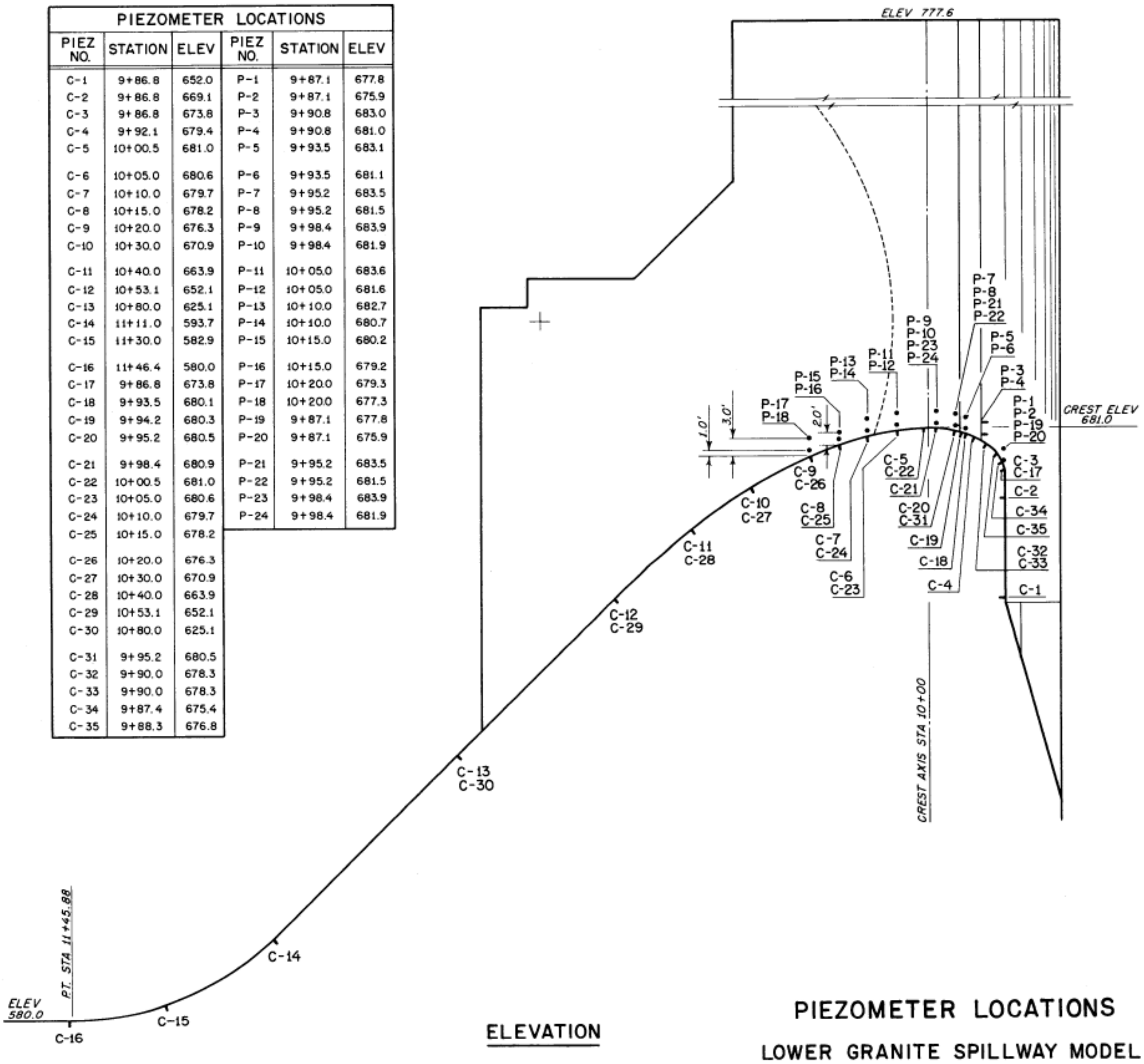
LOWER GRANITE SPILLWAY MODEL



STOP LOG SLOT

PLAN

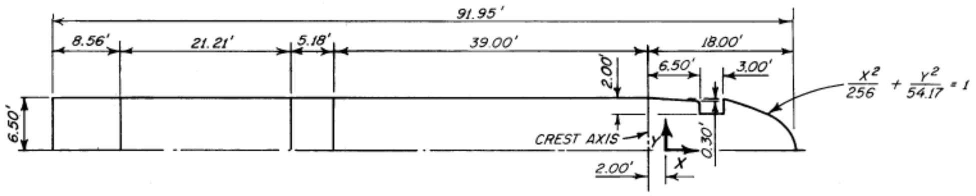
PIEZOMETER LOCATIONS					
PIEZ NO.	STATION	ELEV	PIEZ NO.	STATION	ELEV
C-1	9+86.8	652.0	P-1	9+87.1	677.8
C-2	9+86.8	669.1	P-2	9+87.1	675.9
C-3	9+86.8	673.8	P-3	9+90.8	683.0
C-4	9+92.1	679.4	P-4	9+90.8	681.0
C-5	10+00.5	681.0	P-5	9+93.5	683.1
C-6	10+05.0	680.6	P-6	9+93.5	681.1
C-7	10+10.0	679.7	P-7	9+95.2	683.5
C-8	10+15.0	678.2	P-8	9+95.2	681.5
C-9	10+20.0	676.3	P-9	9+98.4	683.9
C-10	10+30.0	670.9	P-10	9+98.4	681.9
C-11	10+40.0	663.9	P-11	10+05.0	683.6
C-12	10+53.1	652.1	P-12	10+05.0	681.6
C-13	10+80.0	625.1	P-13	10+10.0	682.7
C-14	11+11.0	593.7	P-14	10+10.0	680.7
C-15	11+30.0	582.9	P-15	10+15.0	680.2
C-16	11+46.4	580.0	P-16	10+15.0	679.2
C-17	9+86.8	673.8	P-17	10+20.0	679.3
C-18	9+93.5	680.1	P-18	10+20.0	677.3
C-19	9+94.2	680.3	P-19	9+87.1	677.8
C-20	9+95.2	680.5	P-20	9+87.1	675.9
C-21	9+98.4	680.9	P-21	9+95.2	683.5
C-22	10+00.5	681.0	P-22	9+95.2	681.5
C-23	10+05.0	680.6	P-23	9+98.4	683.9
C-24	10+10.0	679.7	P-24	9+98.4	681.9
C-25	10+15.0	678.2			
C-26	10+20.0	676.3			
C-27	10+30.0	670.9			
C-28	10+40.0	663.9			
C-29	10+53.1	652.1			
C-30	10+80.0	625.1			
C-31	9+95.2	680.5			
C-32	9+90.0	678.3			
C-33	9+90.0	678.3			
C-34	9+87.4	675.4			
C-35	9+88.3	676.8			



ELEVATION

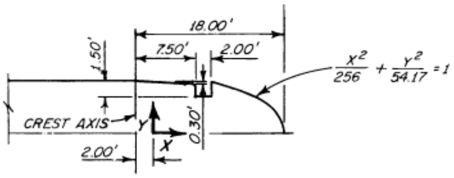
PIEZOMETER LOCATIONS

LOWER GRANITE SPILLWAY MODEL



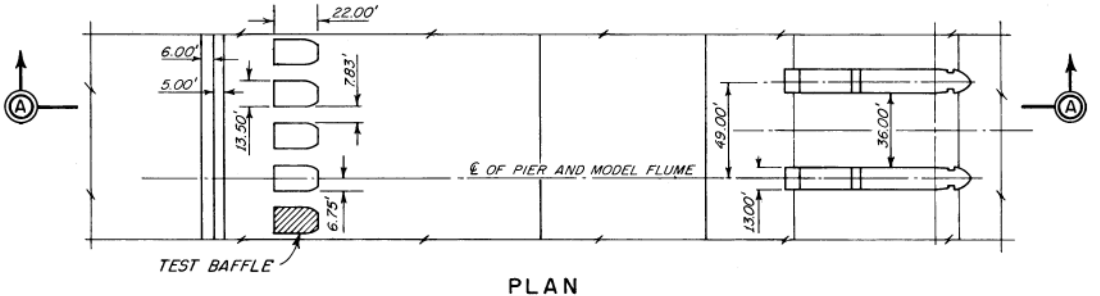
HALF PLAN

PLAN B PIER

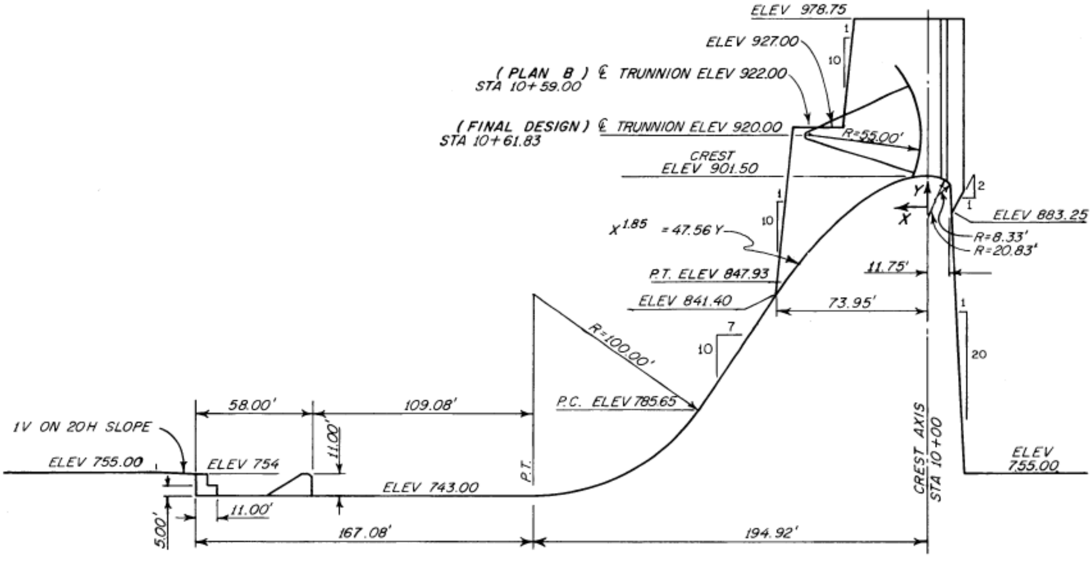


DETAIL

FINAL DESIGN PIER



PLAN



SECTION A-A

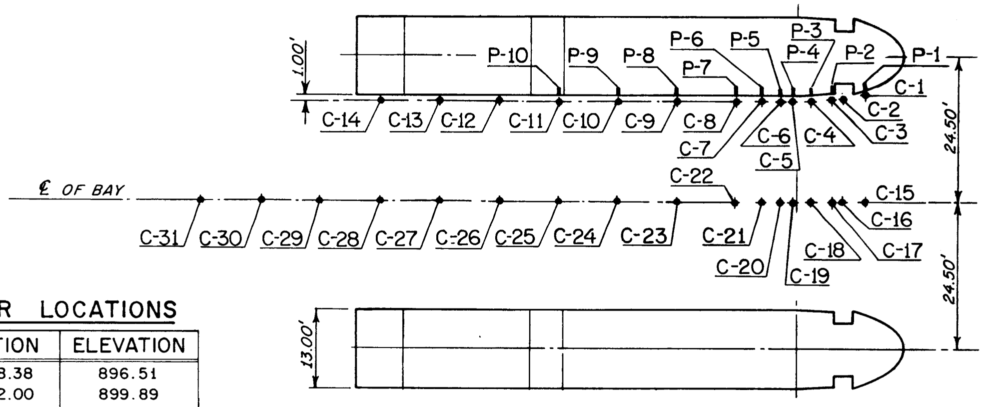
NOTE

FINAL DESIGN PIER IDENTICAL TO PLAN B EXCEPT FOR STOP LOG SLOT AND TRUNNION LOCATION.

CHIEF JOSEPH SPILLWAY MODEL

EXISTING CREST AND STILLING BASIN

PLAN B AND FINAL DESIGN PIERS
AND TRUNNION LOCATIONS

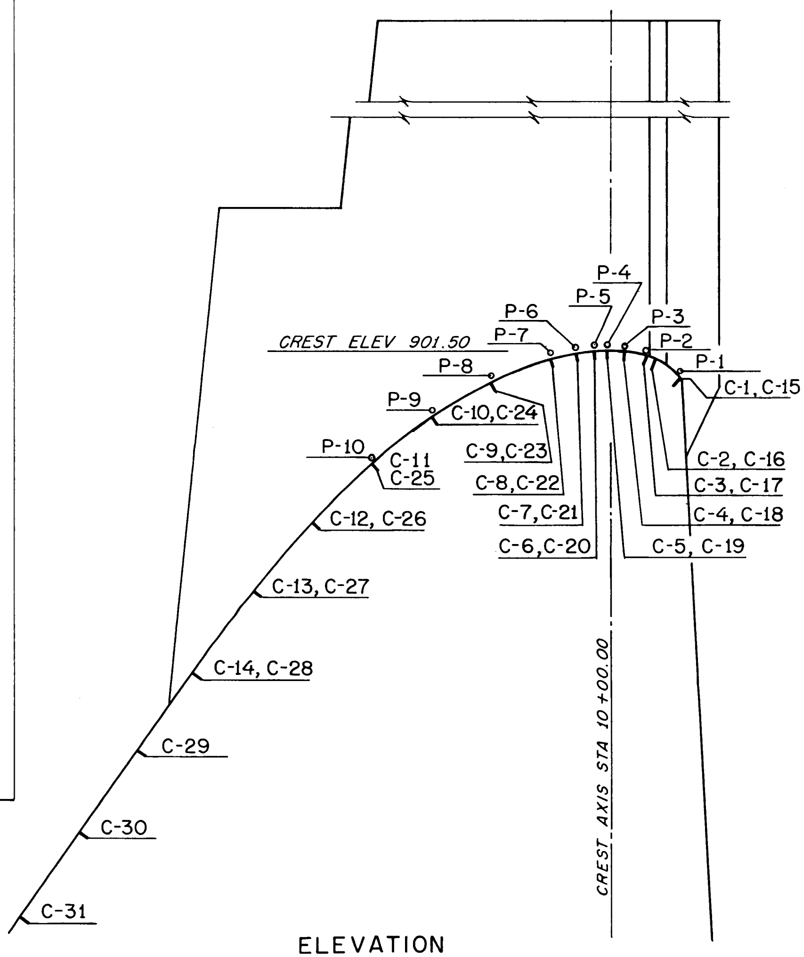


PLAN

PIEZOMETER LOCATIONS

NO.	STATION	ELEVATION
C-1	9+88.38	896.51
C-2	9+92.00	899.89
C-3	9+94.00	900.62
C-4	9+97.67	901.37
C-5	10+00.47	901.50
C-6	10+03.00	901.34
C-7	10+06.00	900.92
C-8	10+10.00	900.01
C-9	10+20.00	896.13
C-10	10+30.00	890.14
C-11	10+40.00	882.16
C-12	10+50.00	872.27
C-13	10+60.00	860.54
C-14	10+70.00	847.04
C-15	9+88.38	896.51
C-16	9+92.00	899.89
C-17	9+94.00	900.62
C-18	9+97.67	901.37
C-19	10+00.47	901.50
C-20	10+03.00	901.34
C-21	10+06.00	900.92
C-22	10+10.00	900.01
C-23	10+20.00	896.13
C-24	10+30.00	890.14
C-25	10+40.00	882.16
C-26	10+50.00	872.27
C-27	10+60.00	860.54
C-28	10+70.00	847.04
C-29	10+80.00	832.75
C-30	10+90.00	818.47
C-31	11+00.00	804.18
P-1	9+88.38	897.51
P-2 *	9+94.00	901.62
P-3 *	9+97.67	902.37
P-4	10+00.47	902.50
P-5	10+03.00	902.34
P-6	10+06.00	901.92
P-7	10+10.00	901.01
P-8	10+20.00	897.13
P-9	10+30.00	891.14
P-10	10+40.00	883.16

* FINAL DESIGN
P-2 AT STA 9+93.00
P-3 AT STA 9+96.67



ELEVATION

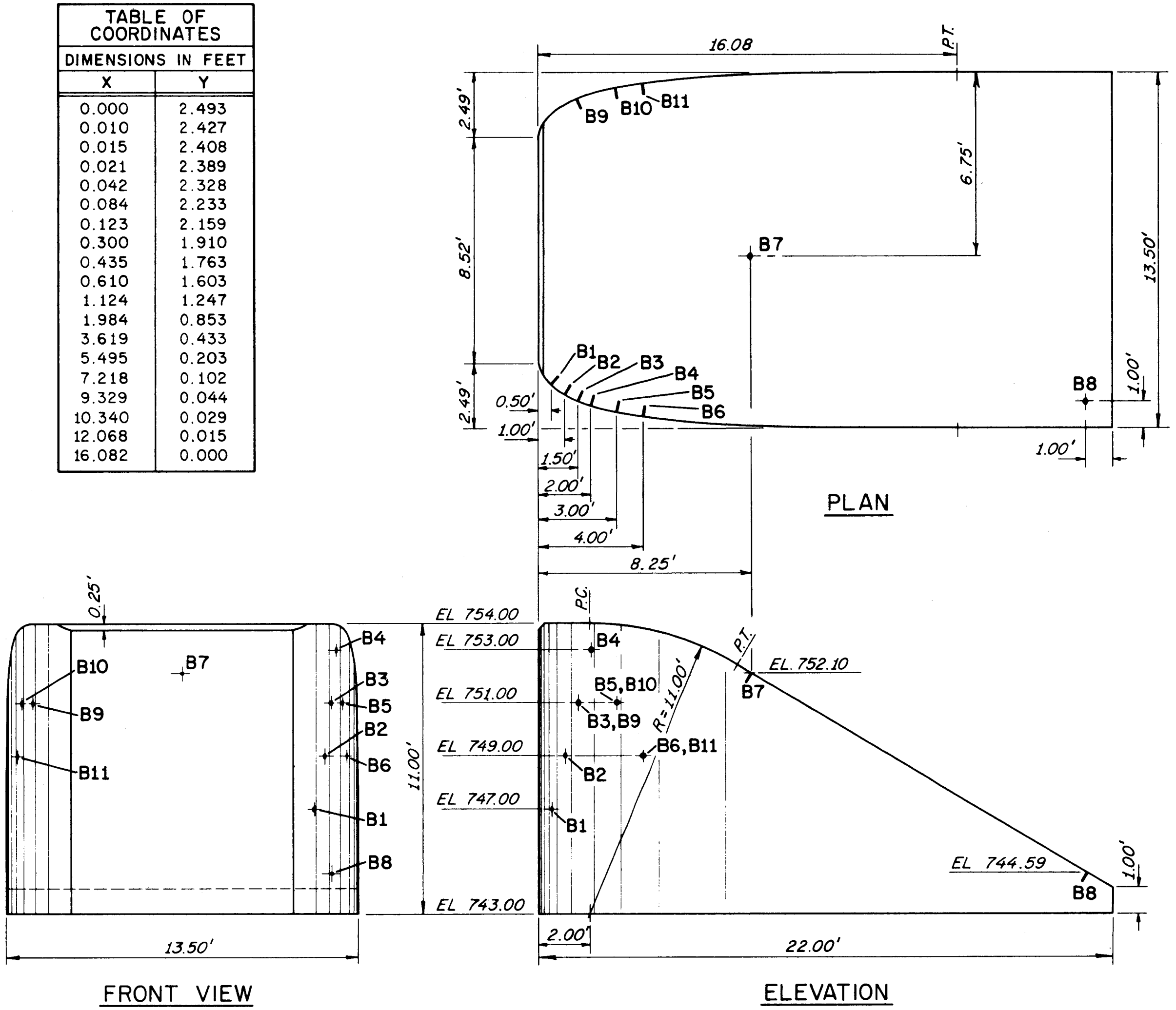
NOTE

PIER AND CREST DETAILS SHOWN ON PLATE 5.

CHIEF JOSEPH SPILLWAY MODEL
PIEZOMETER LOCATIONS
EXISTING CREST, PLAN B AND
FINAL DESIGN PIERS

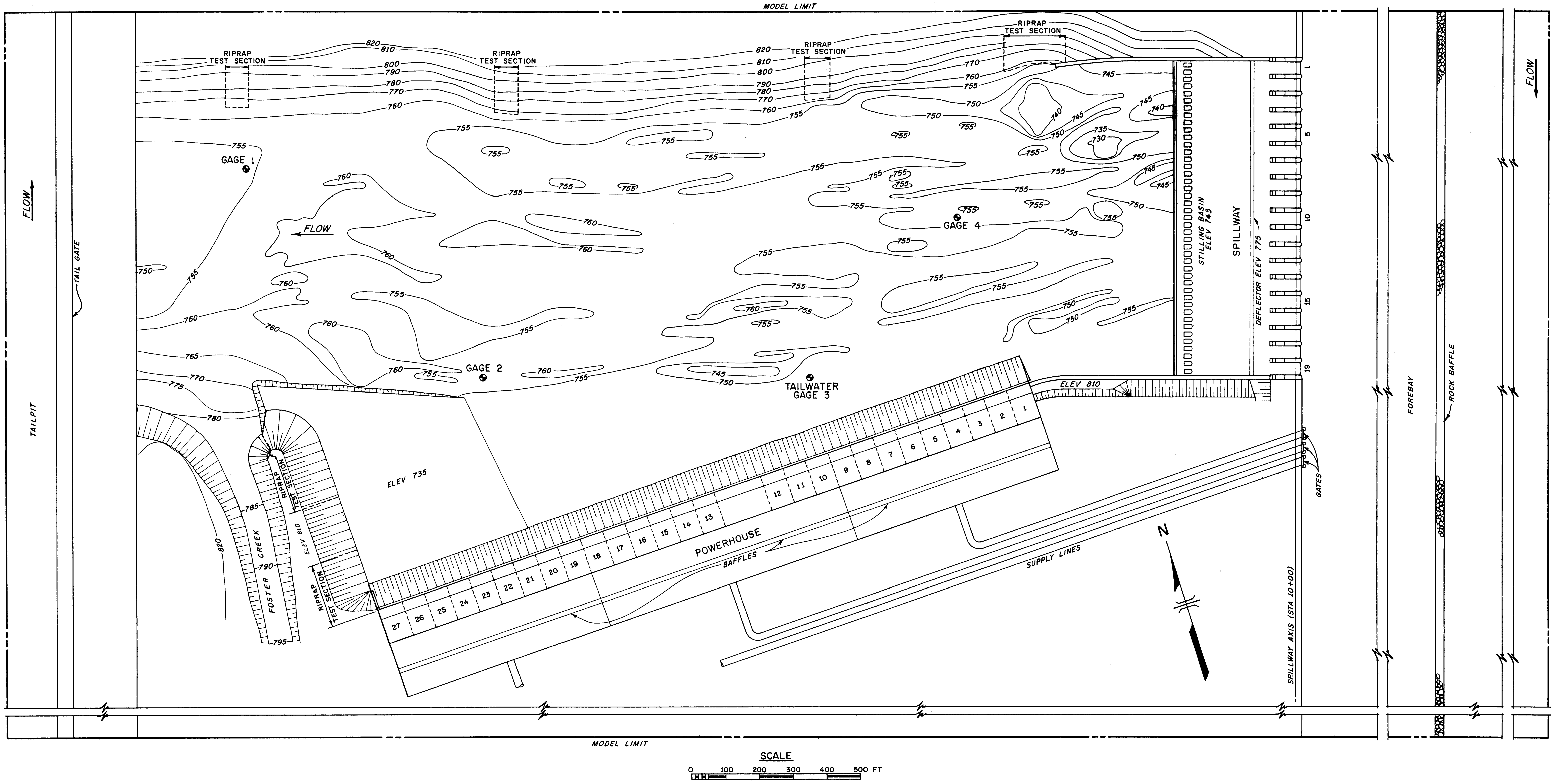
PLATE 7

TABLE OF COORDINATES	
DIMENSIONS IN FEET	
X	Y
0.000	2.493
0.010	2.427
0.015	2.408
0.021	2.389
0.042	2.328
0.084	2.233
0.123	2.159
0.300	1.910
0.435	1.763
0.610	1.603
1.124	1.247
1.984	0.853
3.619	0.433
5.495	0.203
7.218	0.102
9.329	0.044
10.340	0.029
12.068	0.015
16.082	0.000

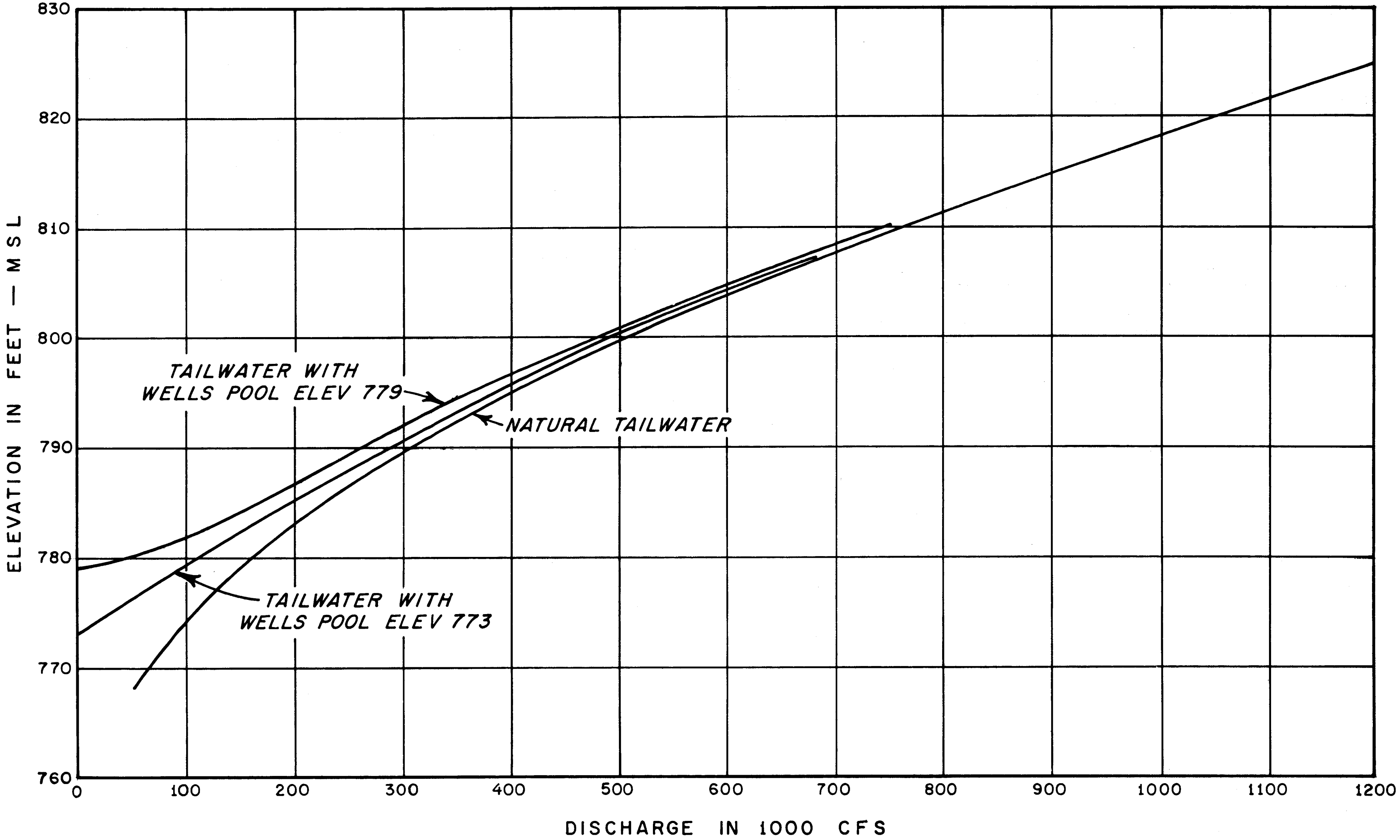


CHIEF JOSEPH SPILLWAY MODEL

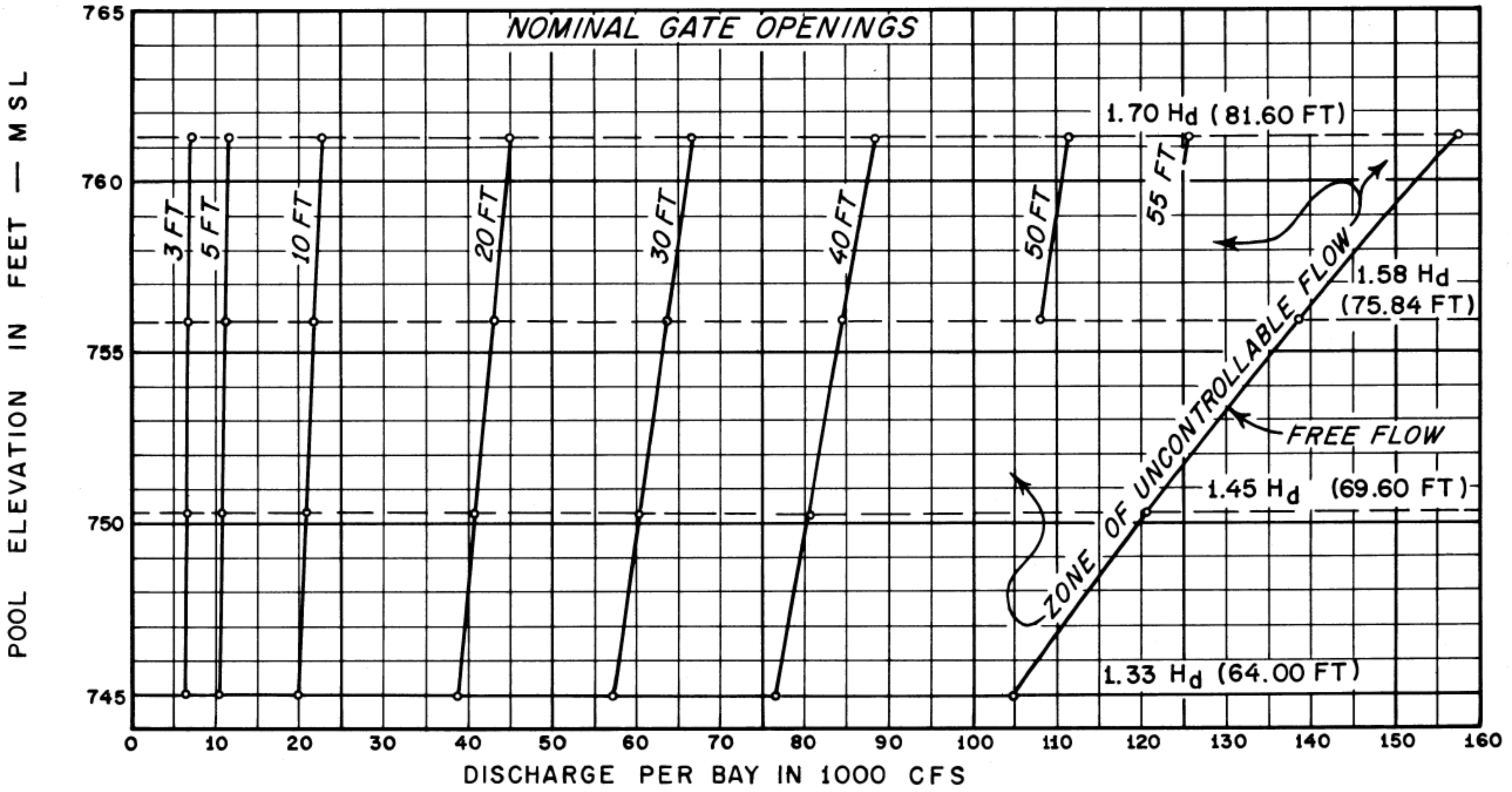
DETAILS AND PIEZOMETER LOCATIONS
EXISTING STILLING BASIN BAFFLE



CHIEF JOSEPH COMPREHENSIVE MODEL



TAILWATER RATING CURVES



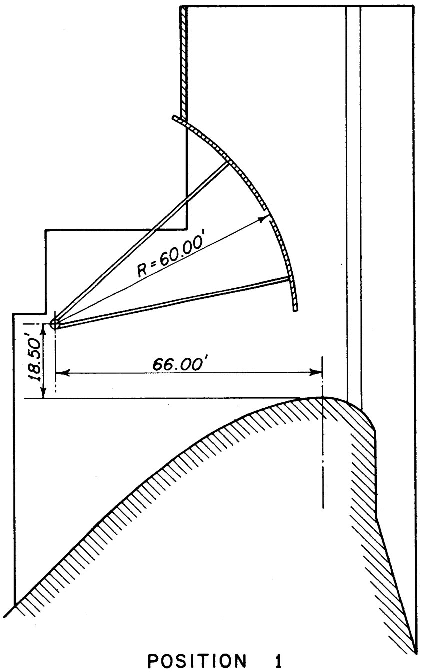
NOTES

1. DETAILS OF SPILLWAY SHOWN ON PLATE 3.
2. DESIGN HEAD, H_d, 48 FT.

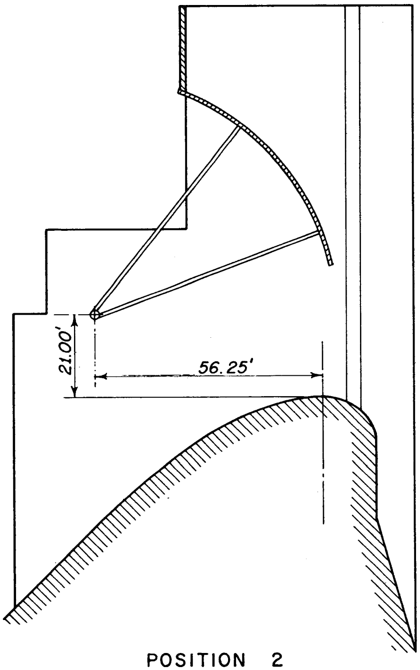
LOWER GRANITE SPILLWAY MODEL

SPILLWAY DISCHARGE

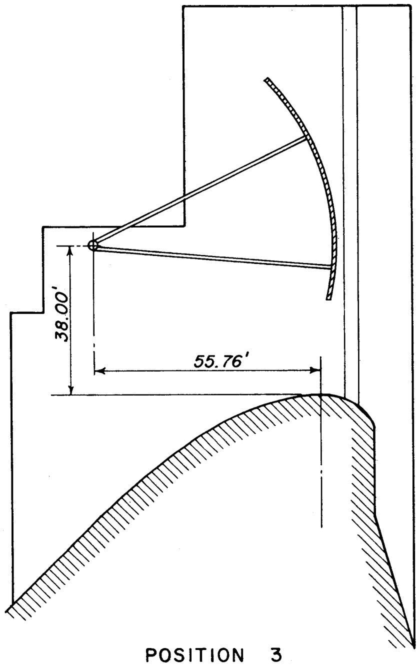
1.33 TO 1.70 DESIGN HEAD
MULTIPLE BAY OPERATION



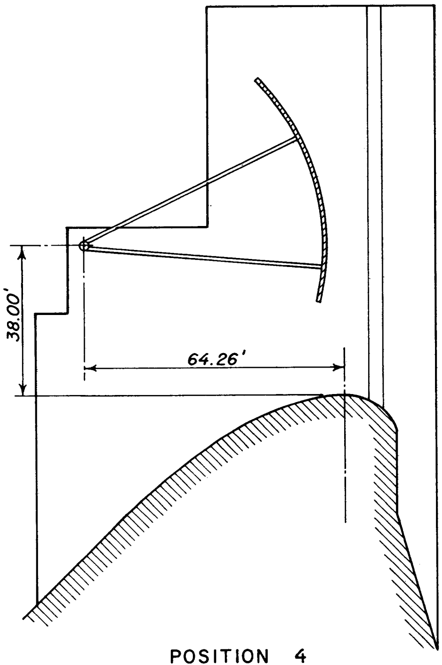
POSITION 1



POSITION 2



POSITION 3

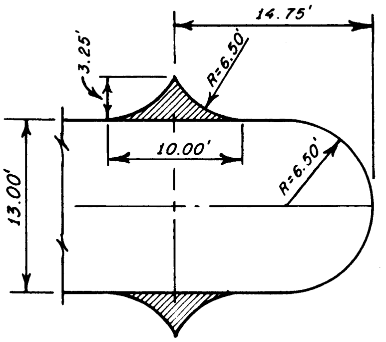


POSITION 4

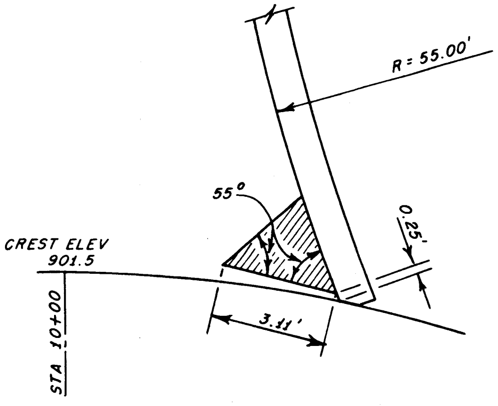
NOTE

SPILLWAY DETAILS SHOWN ON
PLATE 3.

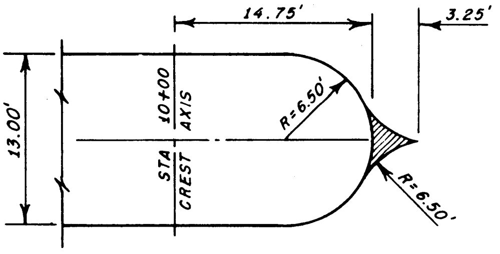
GATE TRUNNION POSITIONS



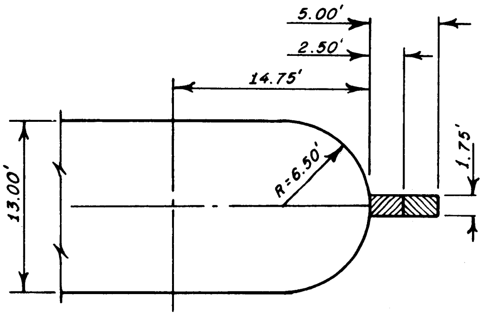
SUPPRESSOR NO. 1



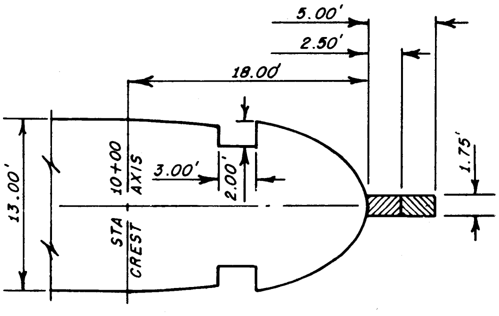
MODIFIED GATE LIP



MODIFICATION NO. 1



ROUND PIER NOSE



ELLIPTICAL PIER NOSE

MODIFICATION NO. 2 = 2.50' EXTENSION

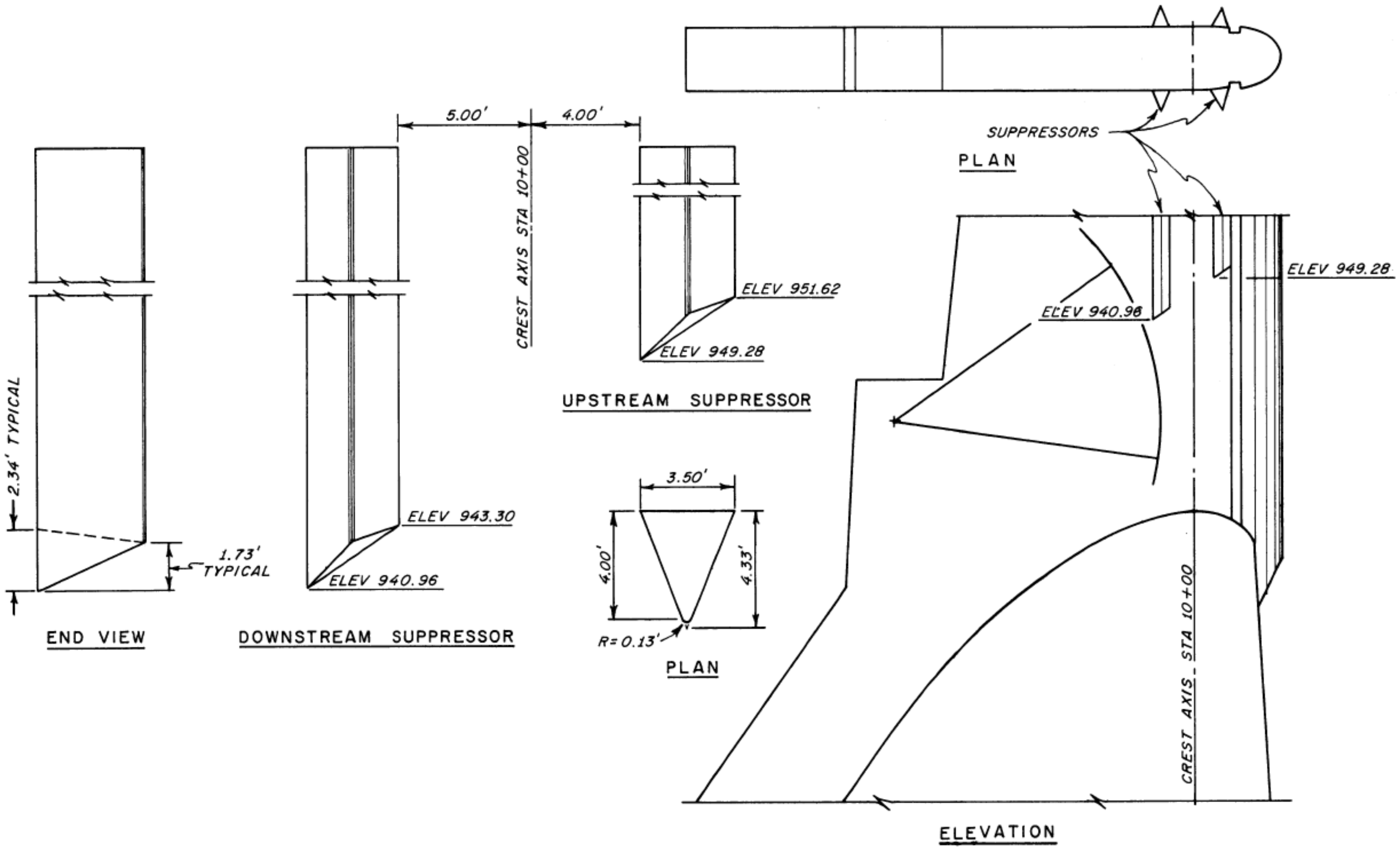
MODIFICATION NO. 3 = 5.00' EXTENSION

NOTES

1. BOTTOMS OF EXTENSIONS AT ELEVATION 894.45, TOPS ABOVE WATER-SURFACE.
2. BOTTOM OF SUPPRESSOR ABOVE MAXIMUM FREE FLOW NAPPE, TOP ABOVE WATER-SURFACE.
3. SUPPRESSOR NO. 2 (FINAL DESIGN) SHOWN ON PLATE 13.

PIER NOSE AND GATE LIP

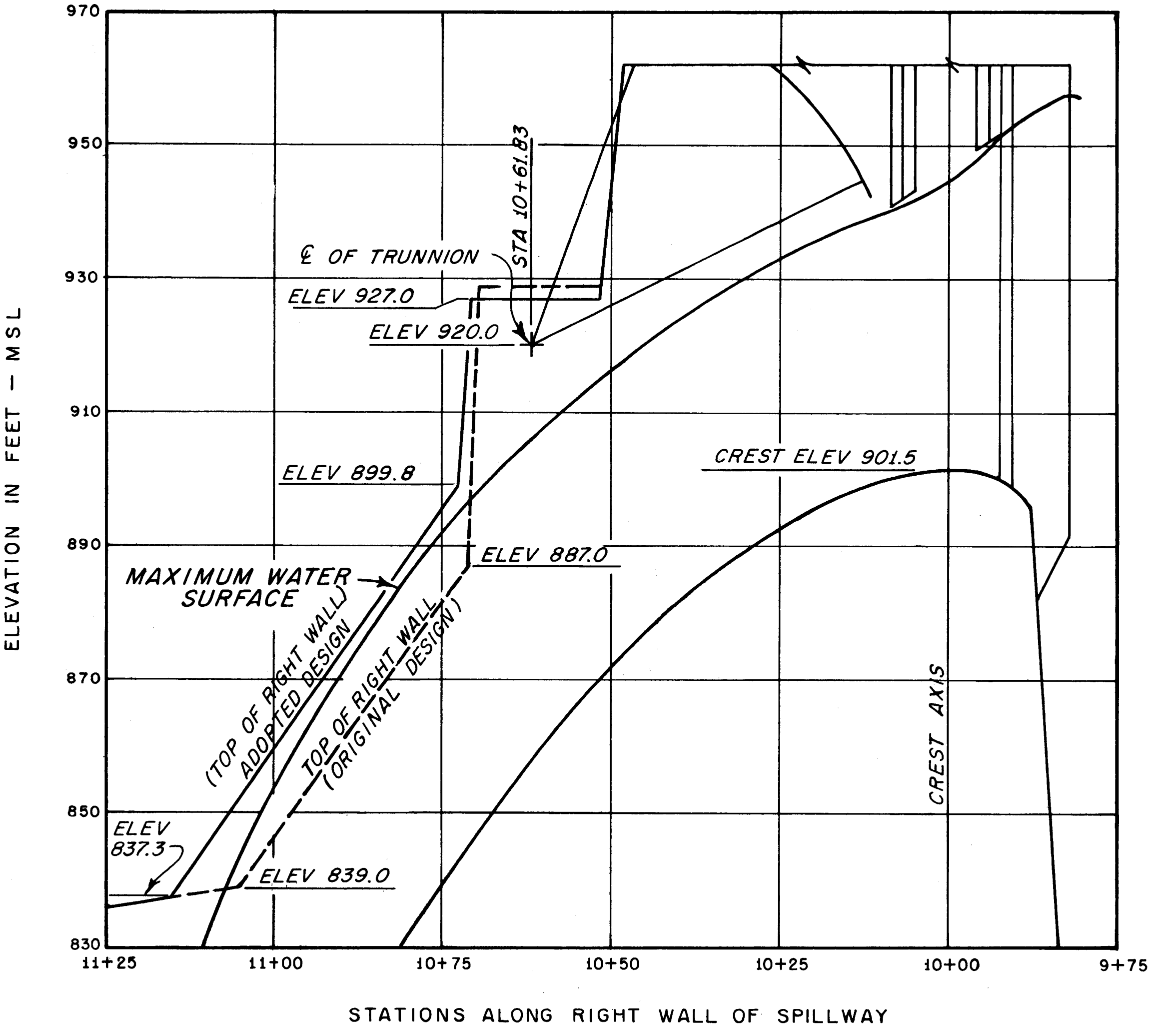
MODIFICATIONS TESTED



NOTE

BOTTOM OF SUPPRESSOR ABOVE MAXIMUM FREE FLOW NAPPE, TOP ABOVE WATER SURFACE.

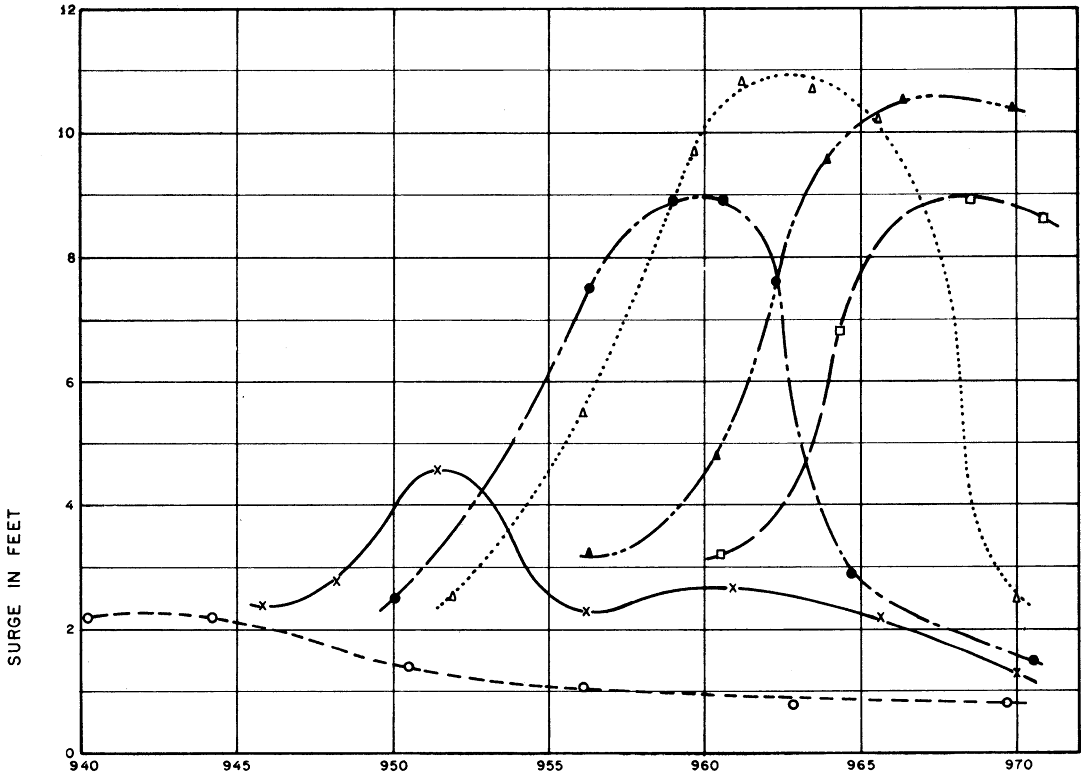
LOCATIONS AND DETAILS
OF SURGE SUPPRESSORS
ON FINAL DESIGN PIERS



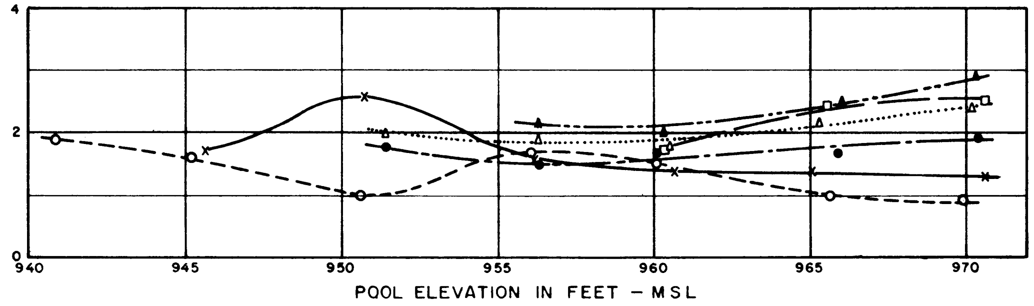
WATER-SURFACE PROFILE ALONG RIGHT WALL

FREE FLOW

SPILLWAY DISCHARGE 1 200 000 CFS



WITHOUT SURGE SUPPRESSORS



WITH SURGE SUPPRESSORS

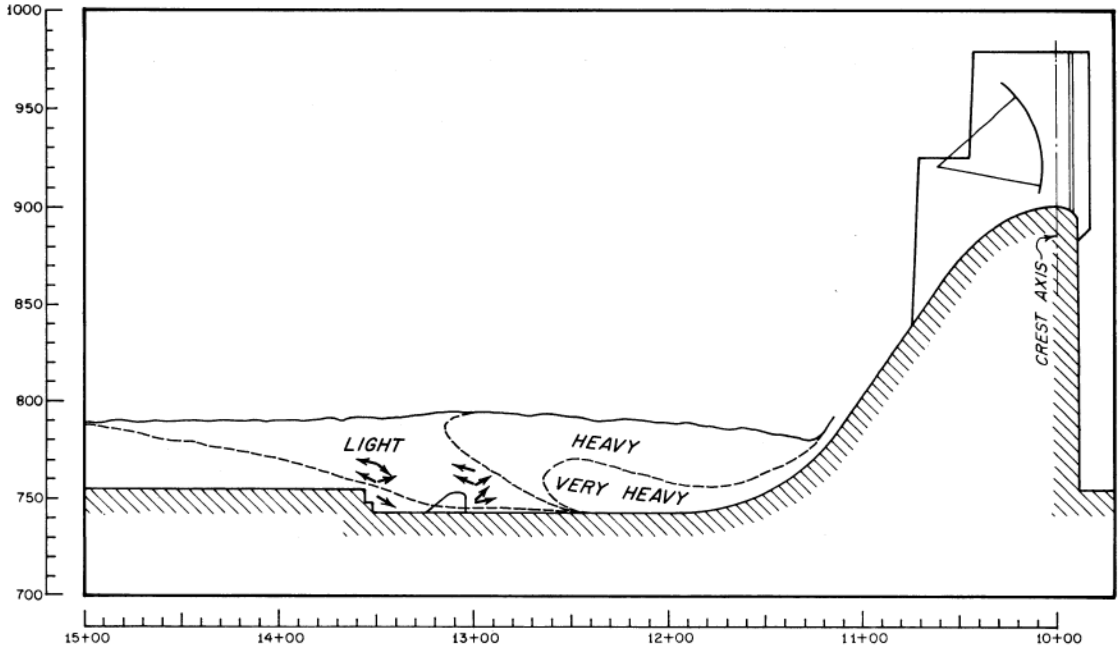
LEGEND

SYMBOL	GATE OPENING IN FEET
– – –○– – –	25
———×———	30
—— ● – ——	33
·······△·······	35
— · —▲— · —	38
——□— ——	40

NOTE

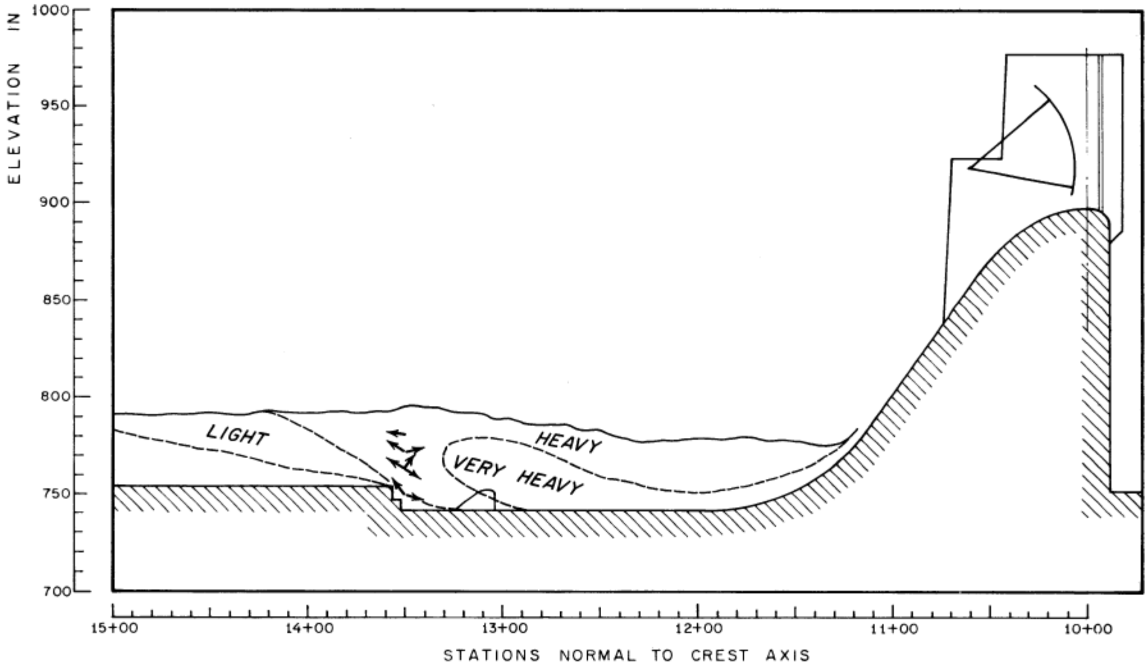
DETAILS OF SURGE SUPPRESSORS SHOWN ON PLATE 13.

SURGE VS POOL ELEVATION



DISCHARGE PER BAY 6 720 CFS

TAILWATER ELEV 790.0



DISCHARGE PER BAY 9 150 CFS

TAILWATER ELEV 792.3

LEGEND

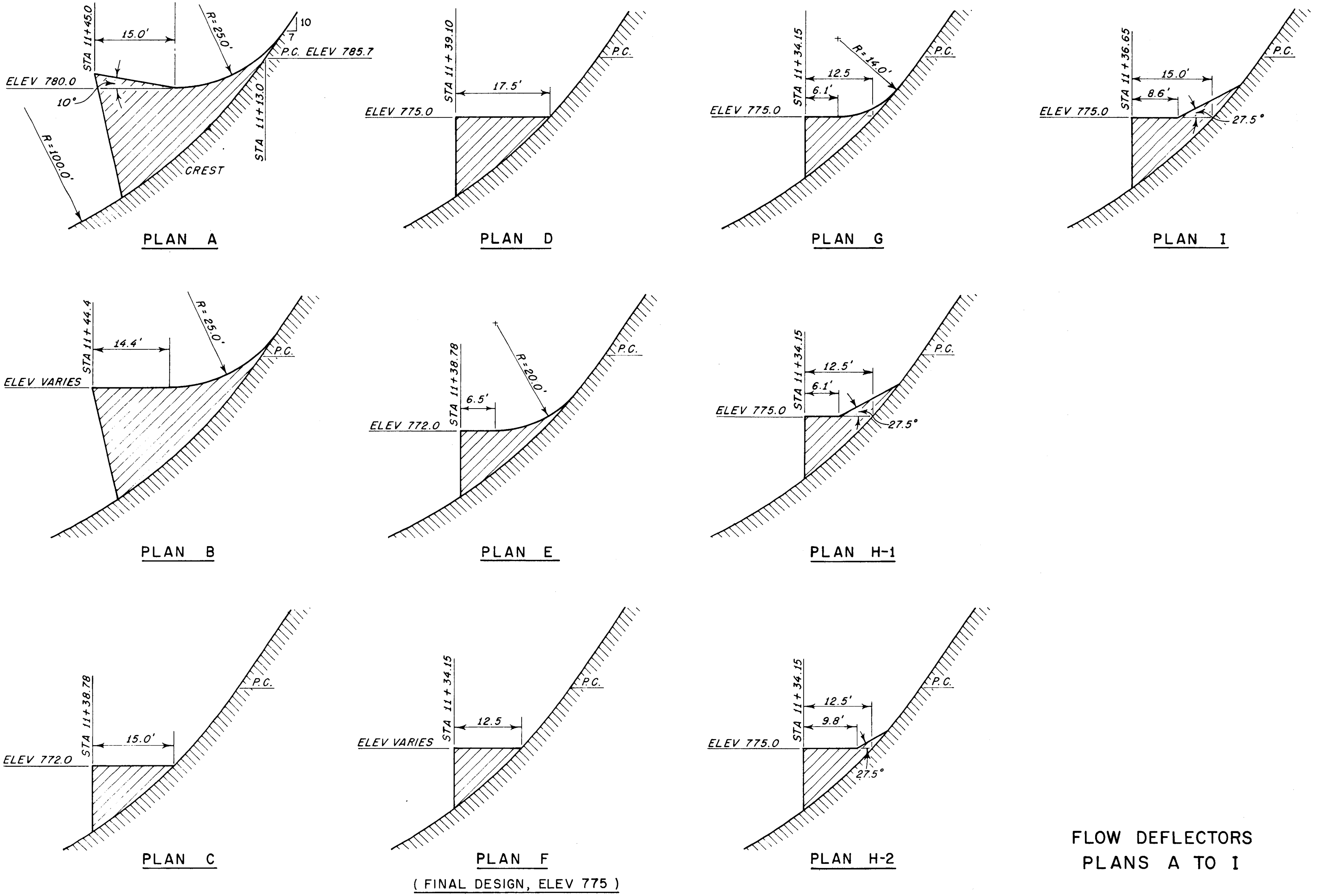
-------- ZONES OF AERATION

NOTES

1. 19-BAY SPILLWAY OPERATION
2. POOL ELEVATION 956.0

AERATION AND FLOW CONDITIONS IN STILLING BASIN

WITHOUT FLOW DEFLECTOR



PLAN A

PLAN D

PLAN G

PLAN I

PLAN B

PLAN E

PLAN H-1

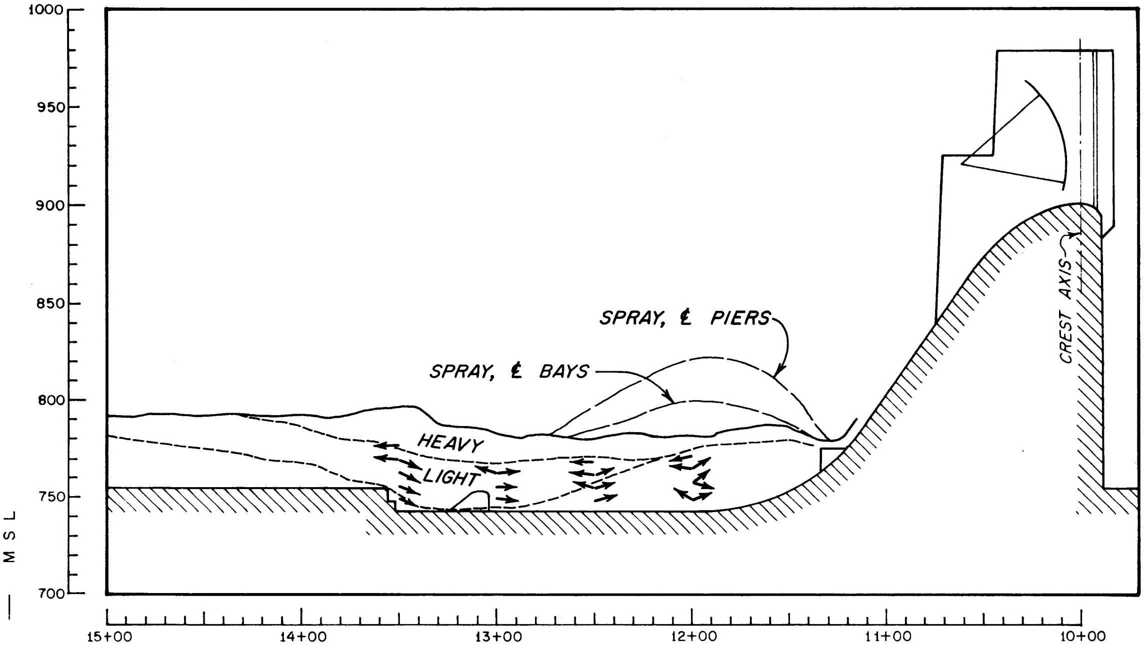
PLAN C

PLAN F

(FINAL DESIGN, ELEV 775)

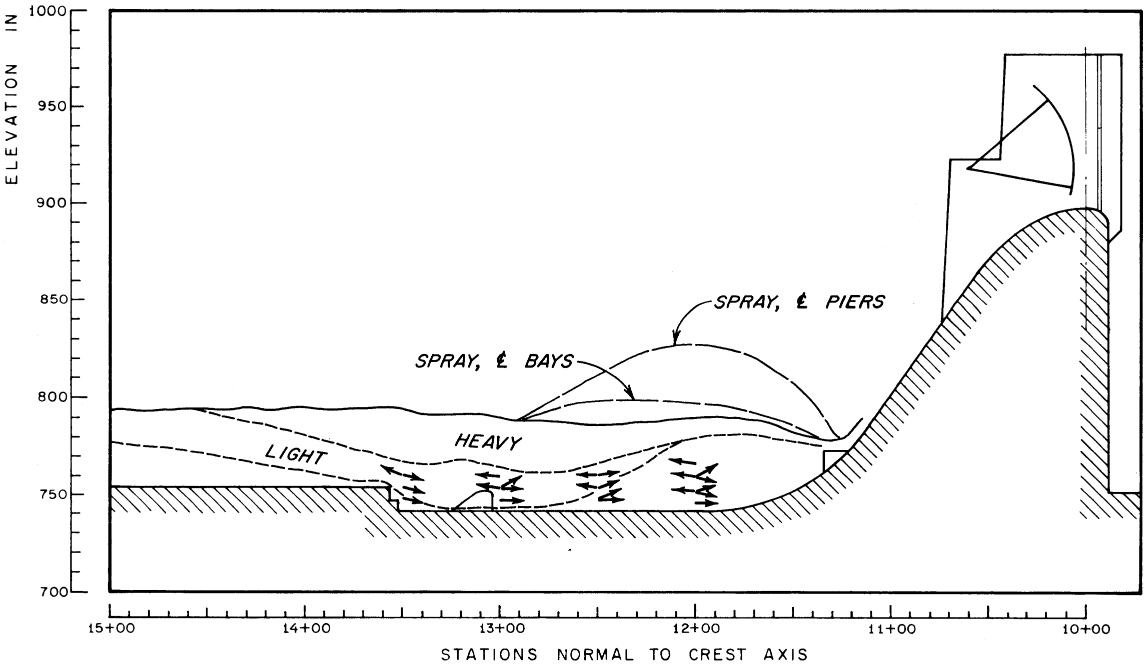
PLAN H-2

FLOW DEFLECTORS
PLANS A TO I



DISCHARGE PER BAY 6 720 CFS

TAILWATER ELEV 790.0



DISCHARGE PER BAY 9 150 CFS

TAILWATER ELEV 792.3

LEGEND

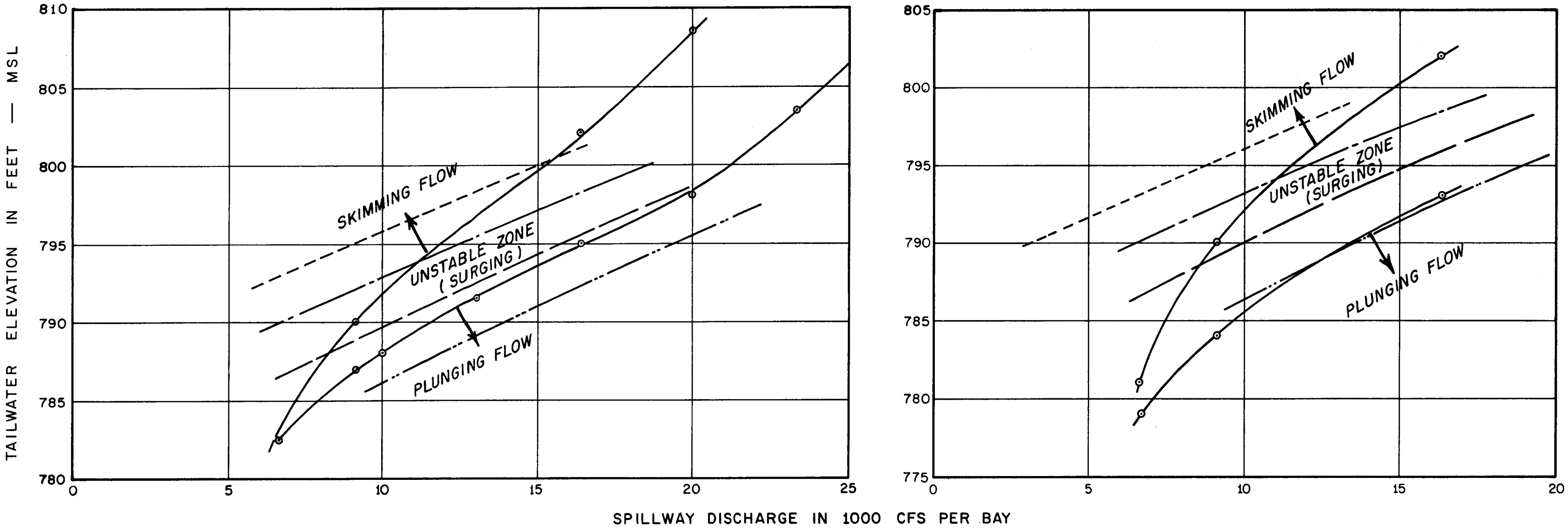
--------ZONES OF AERATION

NOTES

1. 19-BAY SPILLWAY OPERATION
2. POOL ELEVATION 956.0

AERATION AND FLOW CONDITIONS IN STILLING BASIN

PLAN F DEFLECTOR, ELEV 775
FINAL DESIGN



PLAN F DEFLECTOR AT ELEV 775
FINAL DESIGN

PLAN F DEFLECTOR AT ELEV 772

LEGEND

NORMAL TAILWATER WITH POWERHOUSE OPERATION:

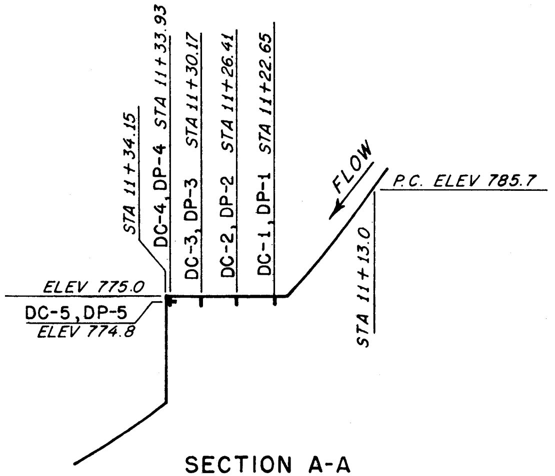
——————··—————— 0 UNITS
——— ——— ——— 9 UNITS
——————-—————— 18 UNITS
– – – – – – – – – 27 UNITS

NOTES

1. 19-BAY SPILLWAY OPERATION
2. POOL ELEVATION 956.0

FLOW CONDITIONS IN STILLING BASIN

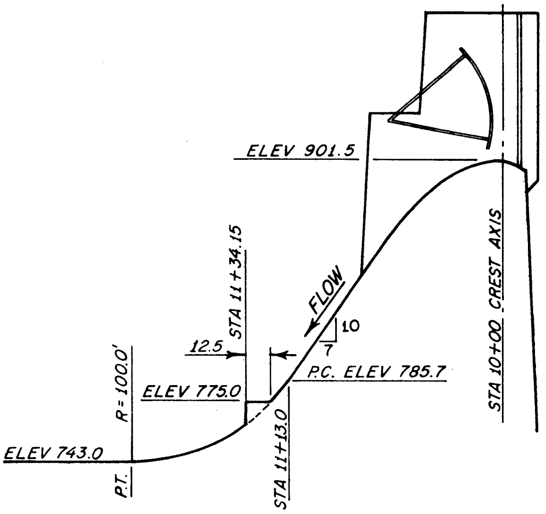
PLAN F DEFLECTOR, ELEV 775 AND 772



SECTION A-A

SCALE

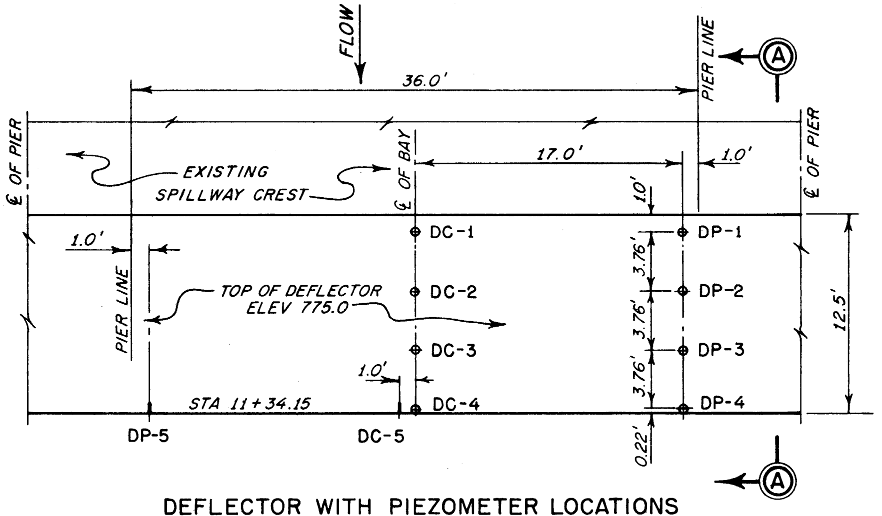
0 5 10 15 20 25 FT



SECTION THROUGH SPILLWAY

SCALE

0 25 50 75 100 FT



DEFLECTOR WITH PIEZOMETER LOCATIONS

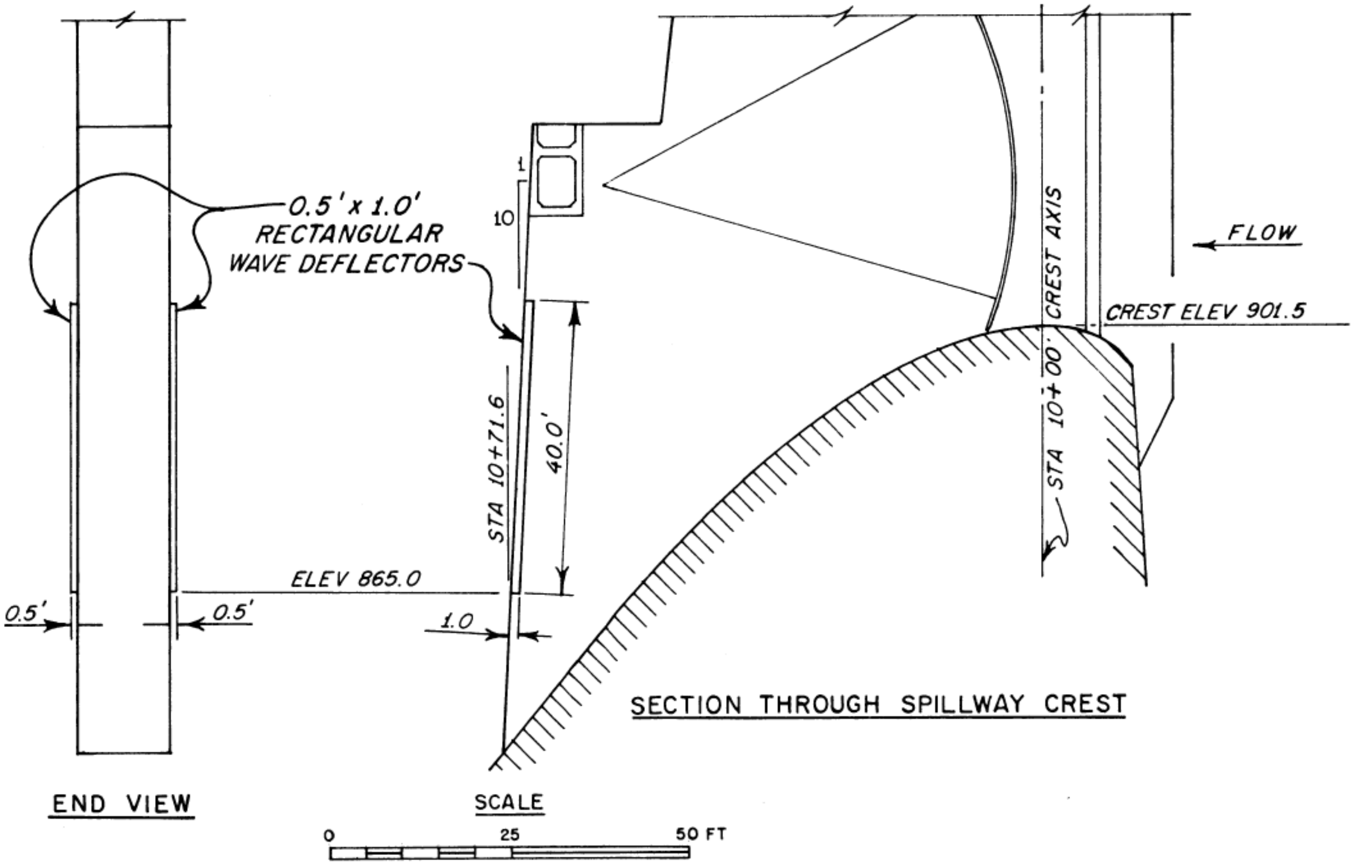
SCALE

0 5 10 15 20 FT

DETAILS AND PIEZOMETER LOCATIONS

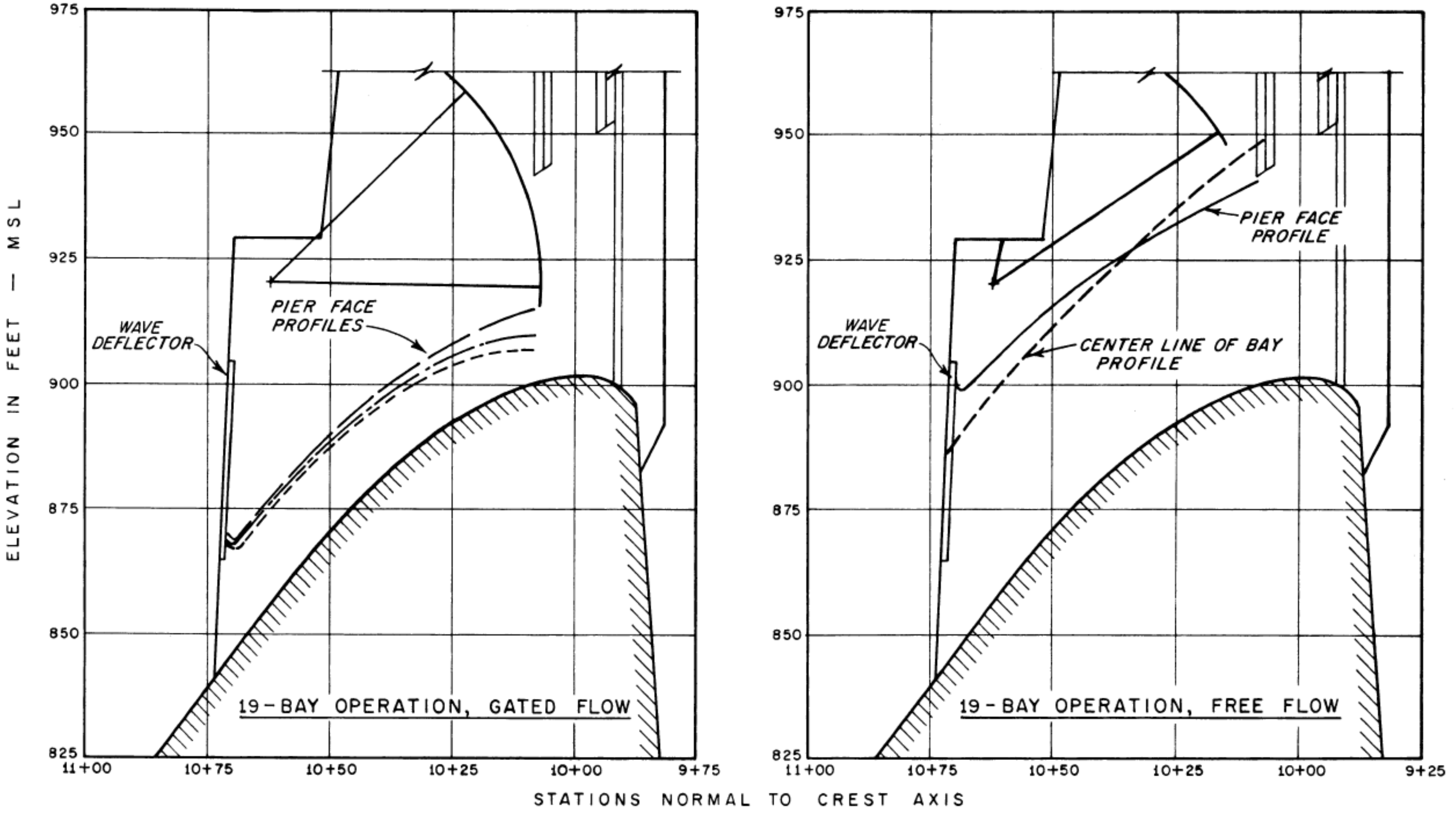
PLAN F DEFLECTOR, ELEV 775

FINAL DESIGN



WAVE DEFLECTORS

BAYS 1, 2, 18 AND 19
FINAL DESIGN



RIVER DISCHARGE 440 000 CFS
POOL ELEVATION 956.0

RIVER DISCHARGE 1 200 000 CFS
POOL ELEVATION 958.8

LEGEND

SPILLWAY DISCHARGE IN CFS PER BAY		POWERHOUSE OPERATION
- - - - - - - -	13 010	27 UNITS
—— - —— -	16 390	18 UNITS
—— —— ——	23 370	CLOSED
————————	63 160	CLOSED

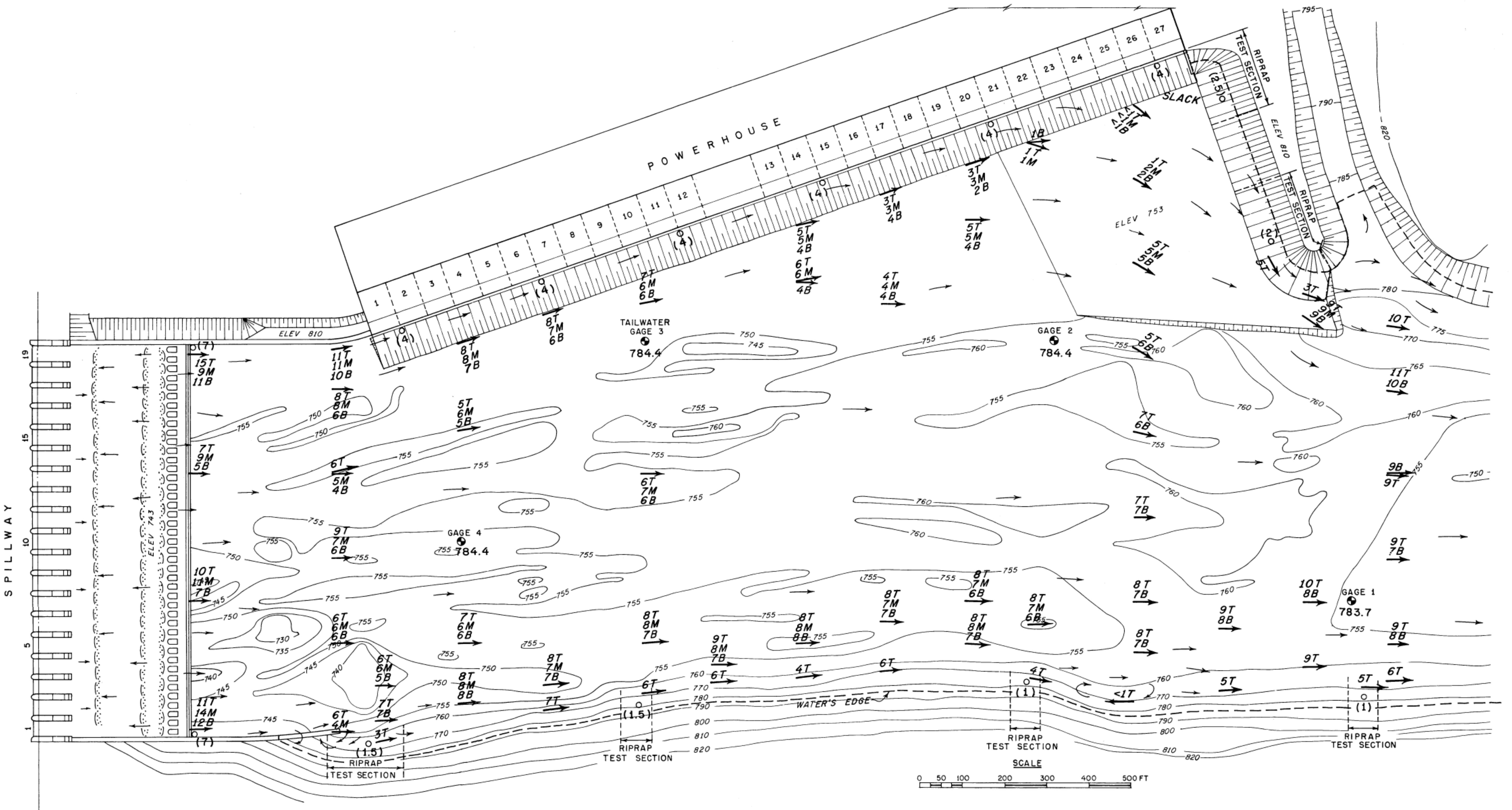
NOTES

1. WAVE DEFLECTORS ARE SHOWN ON PLATE 21.
2. PROFILES SHOWN IN BAYS 2 AND 18.

WATER-SURFACE PROFILES

GATED AND FREE FLOW

WAVE DEFLECTORS ON PIERS IN BAYS 1, 2, 18 AND 19



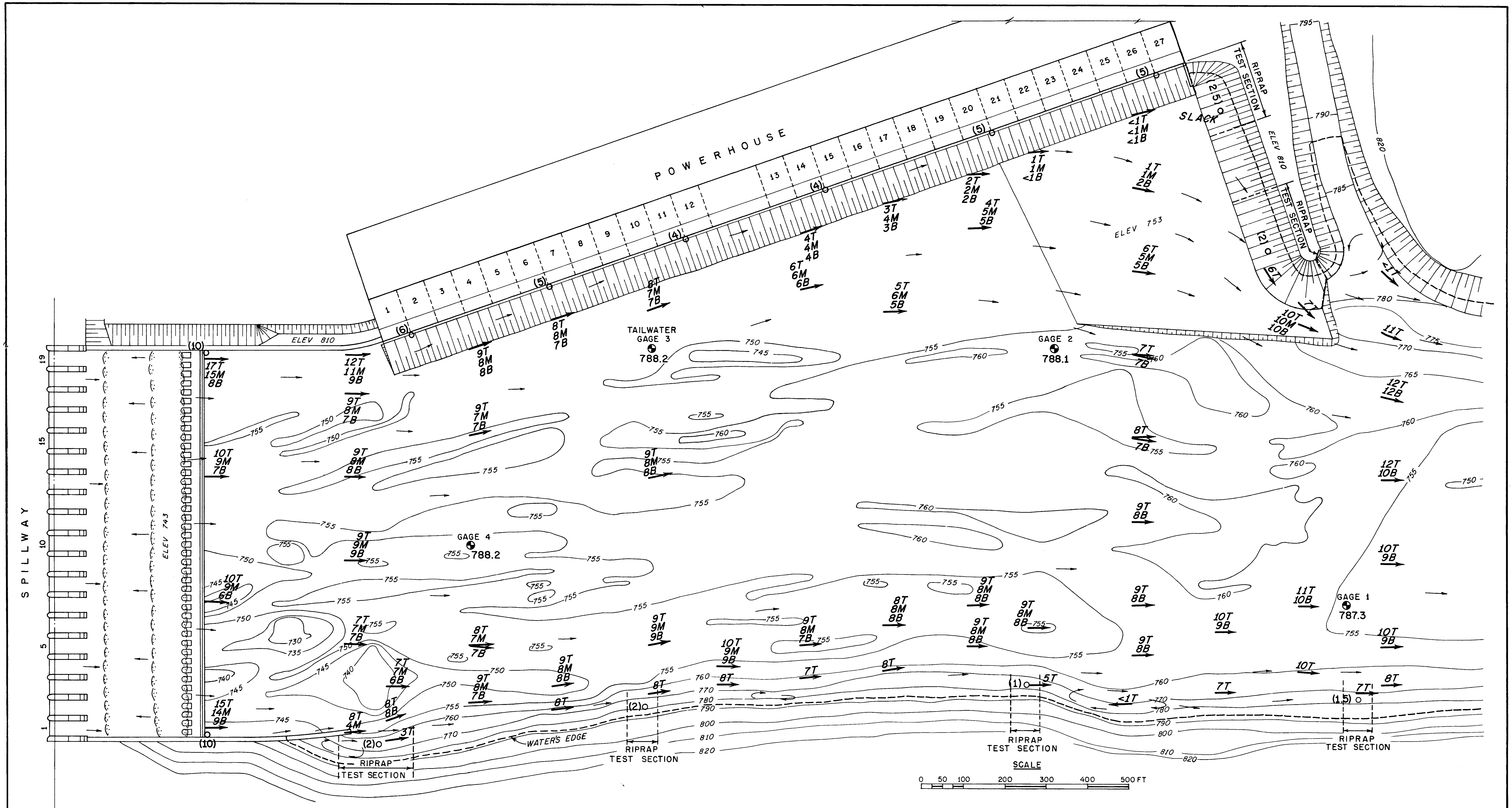
LEGEND

← 4	VELOCITY IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
(5) ○	MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	190 000 CFS

FLOW CONDITIONS
WITHOUT DEFLECTOR
RIVER DISCHARGE 190 000 CFS
POWERHOUSE UNITS CLOSED



LEGEND

- VELOCITY IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- (5) ○ MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

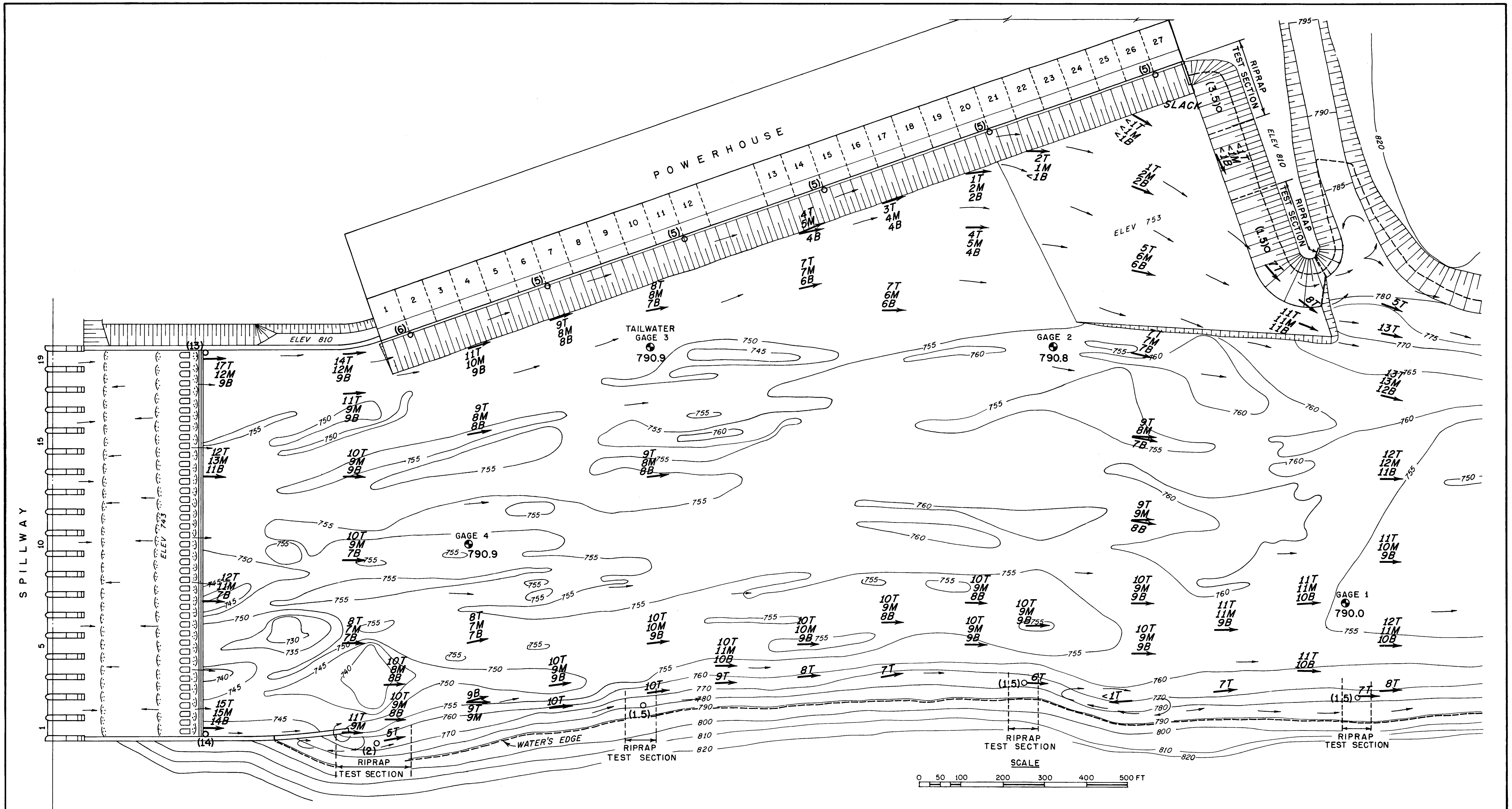
POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	260 000 CFS

FLOW CONDITIONS

WITHOUT DEFLECTOR

RIVER DISCHARGE 260 000 CFS

POWERHOUSE UNITS CLOSED



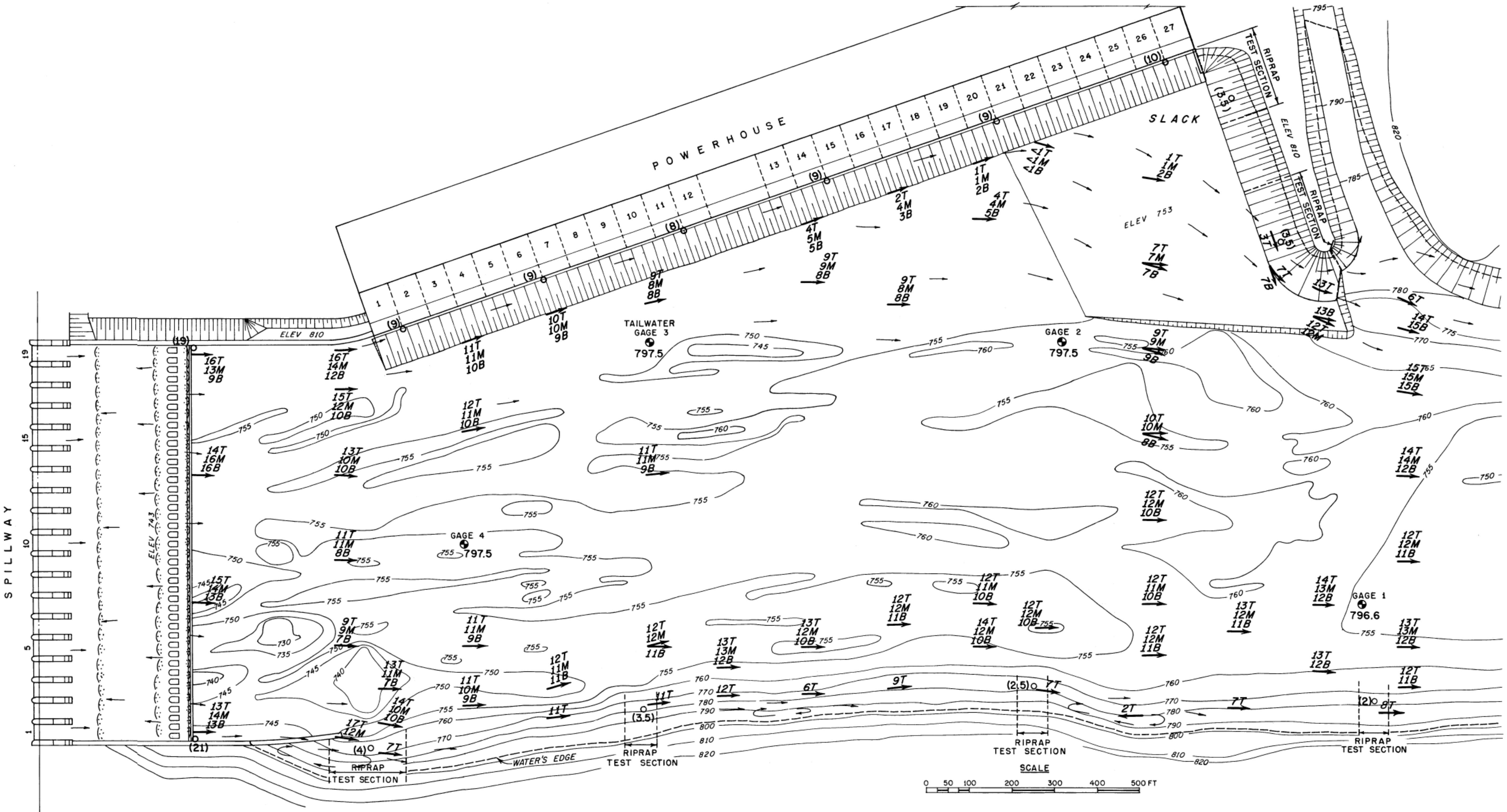
LEGEND

4 ← VELOCITY IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
(5) ○ MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	305 000 CFS

FLOW CONDITIONS
WITHOUT DEFLECTOR
RIVER DISCHARGE 305 000 CFS
POWERHOUSE UNITS CLOSED



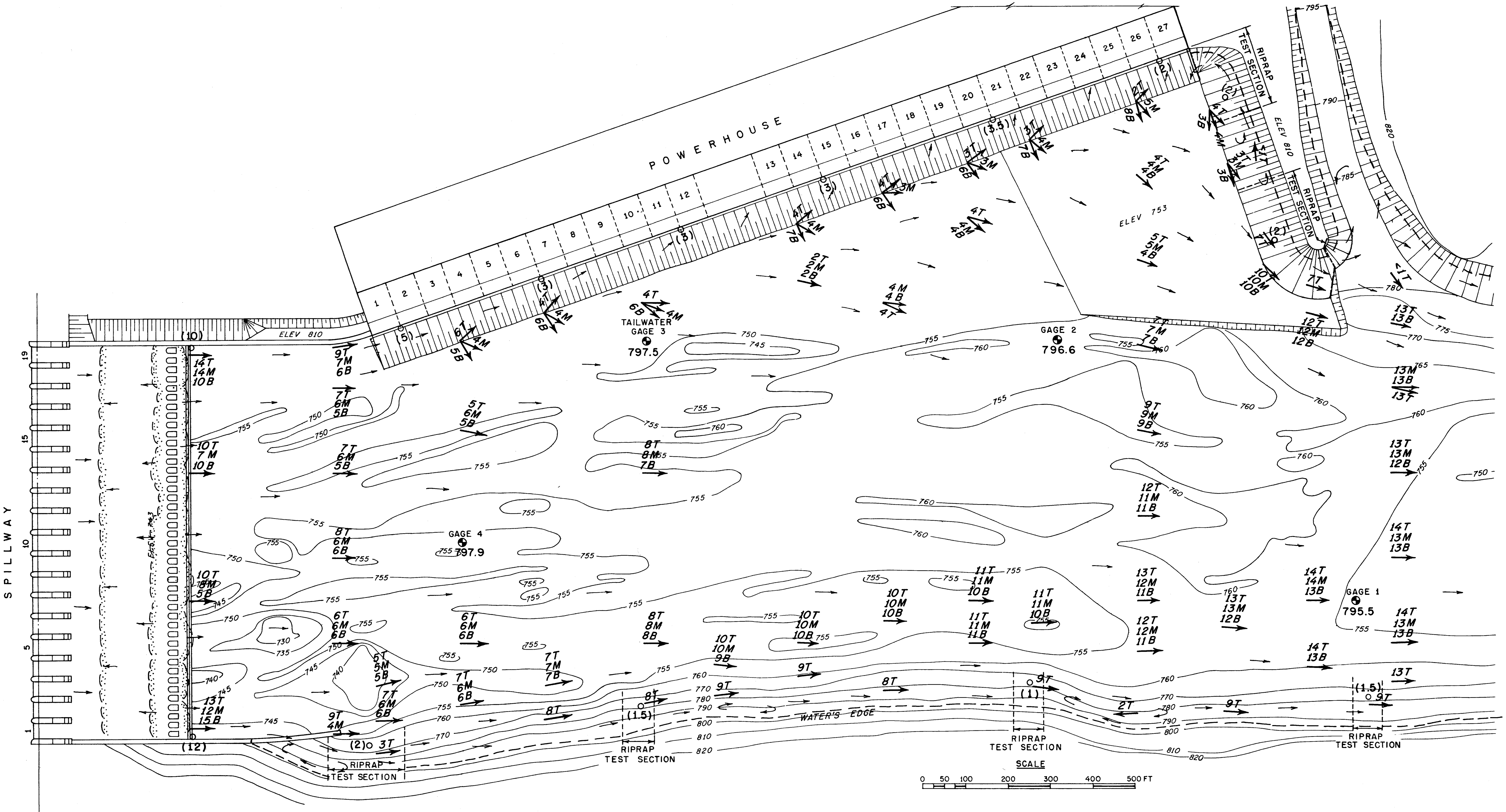
LEGEND

← 4	VELOCITY IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
(5) ○	MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	440000 CFS

FLOW CONDITIONS
WITHOUT DEFLECTOR
RIVER DISCHARGE 440000 CFS
POWERHOUSE UNITS CLOSED



LEGEND

←4	VELOCITY IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
(5) ○	MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

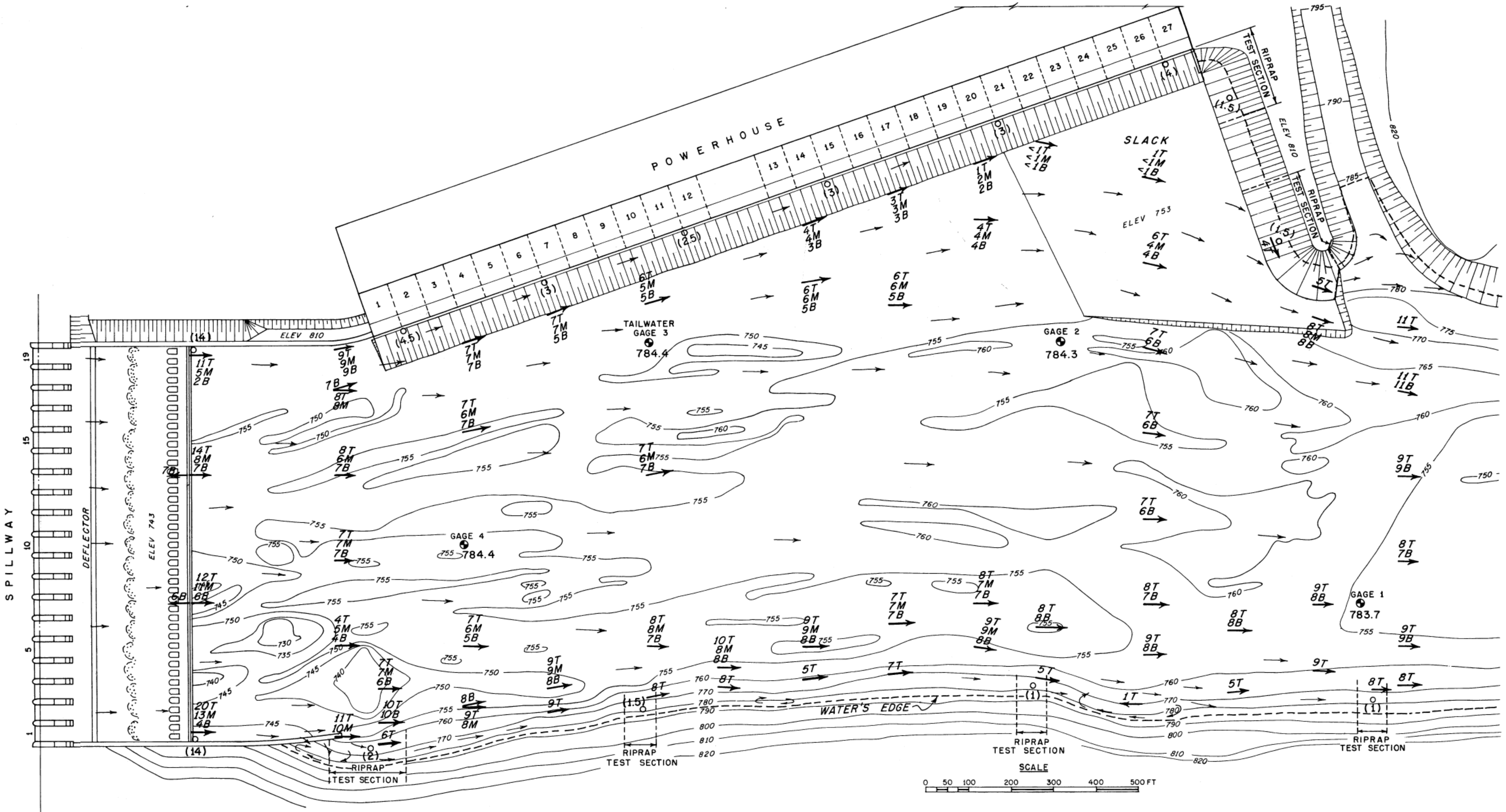
POWERHOUSE UNITS 1 TO 27	197 100 CFS
SPILLWAY BAYS 1 TO 19	242 900 CFS

FLOW CONDITIONS

WITHOUT DEFLECTOR

RIVER DISCHARGE 440 000 CFS

POWERHOUSE UNITS 1 TO 27



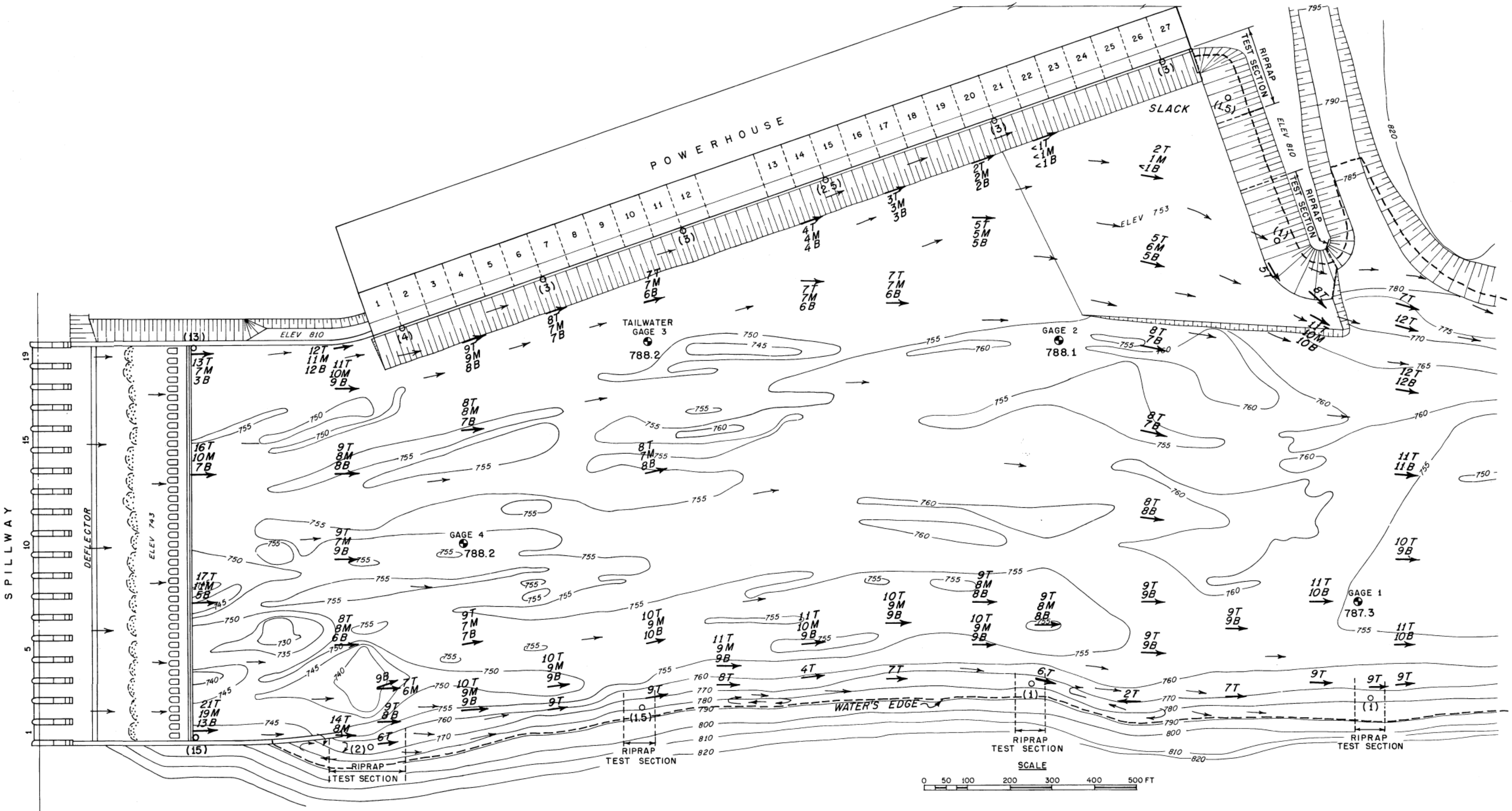
LEGEND

- ← 4 VELOCITY IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- (5) ○ MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	105 000 CFS

FLOW CONDITIONS
WITH PLAN F DEFLECTOR
RIVER DISCHARGE 190 000 CFS
POWERHOUSE UNITS CLOSED



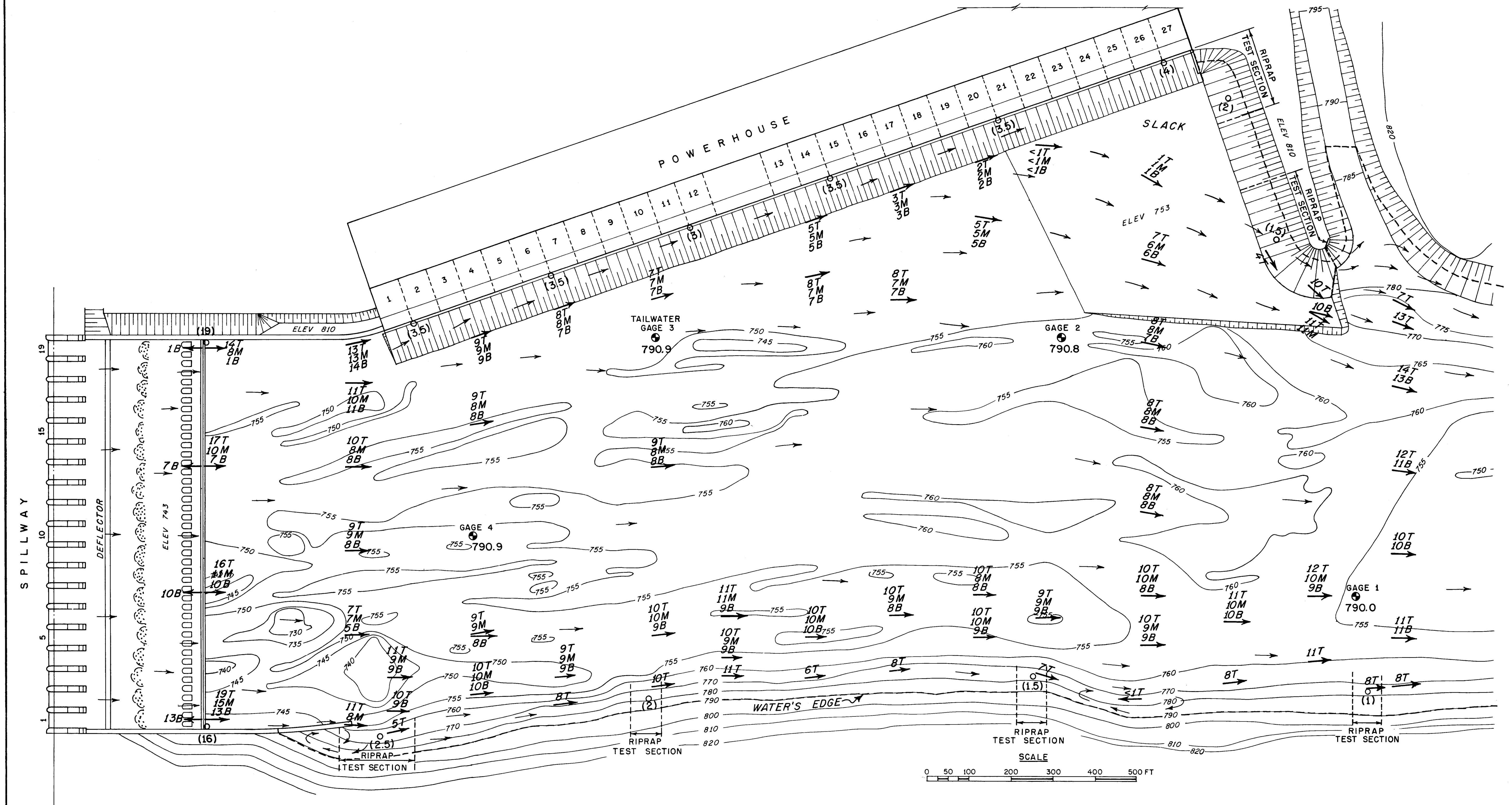
LEGEND

- 4 → VELOCITY IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- (5) ○ MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	260 000 CFS

FLOW CONDITIONS
WITH PLAN F DEFLECTOR
RIVER DISCHARGE 260 000 CFS
POWERHOUSE UNITS CLOSED



LEGEND

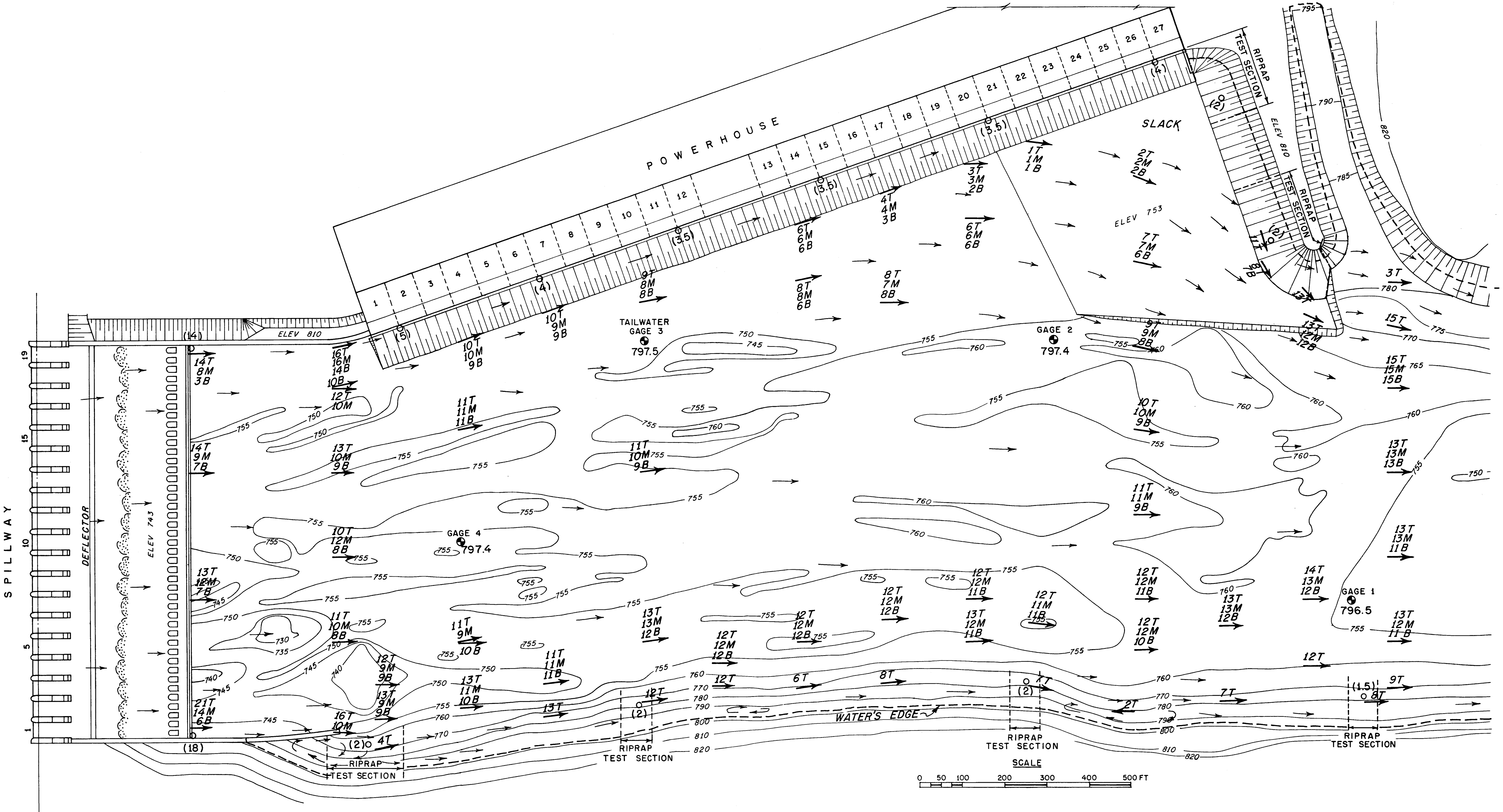
- ← 4 VELOCITY IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- (5) O MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	305 000 CFS

FLOW CONDITIONS
WITH PLAN F DEFLECTOR
RIVER DISCHARGE 305 000 CFS
POWERHOUSE UNITS CLOSED

PLATE 30



LEGEND

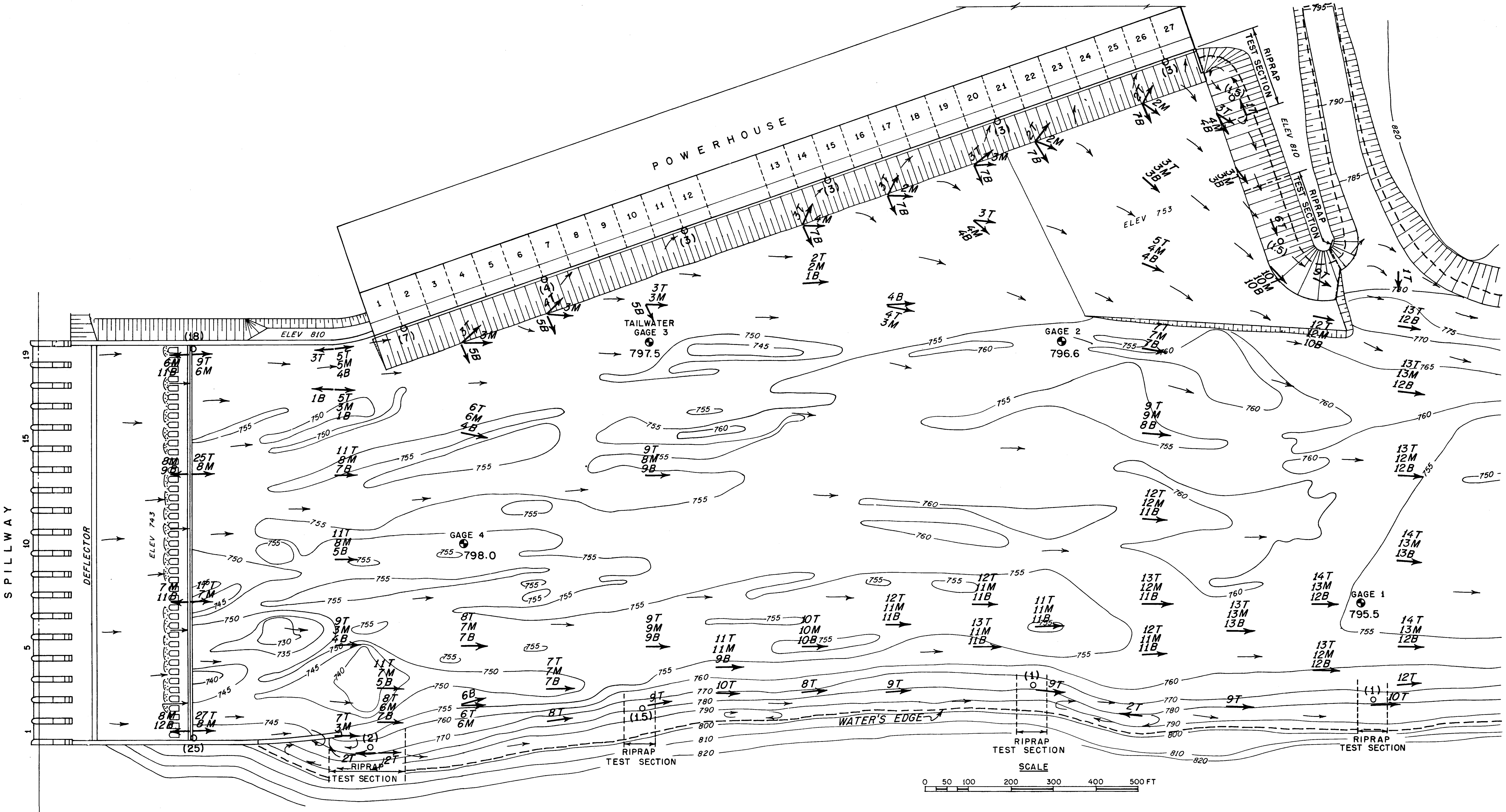
←4	VELOCITY IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
(5) ○	MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

POWERHOUSE	CLOSED
SPILLWAY BAYS 1 TO 19	440 000 CFS

FLOW CONDITIONS
WITH PLAN F DEFLECTOR
RIVER DISCHARGE 440 000 CFS
POWERHOUSE UNITS CLOSED

PLATE 31



LEGEND

- 4 VELOCITY IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- (5) ○ MAXIMUM WAVE HEIGHT IN FEET

OPERATING CONDITIONS

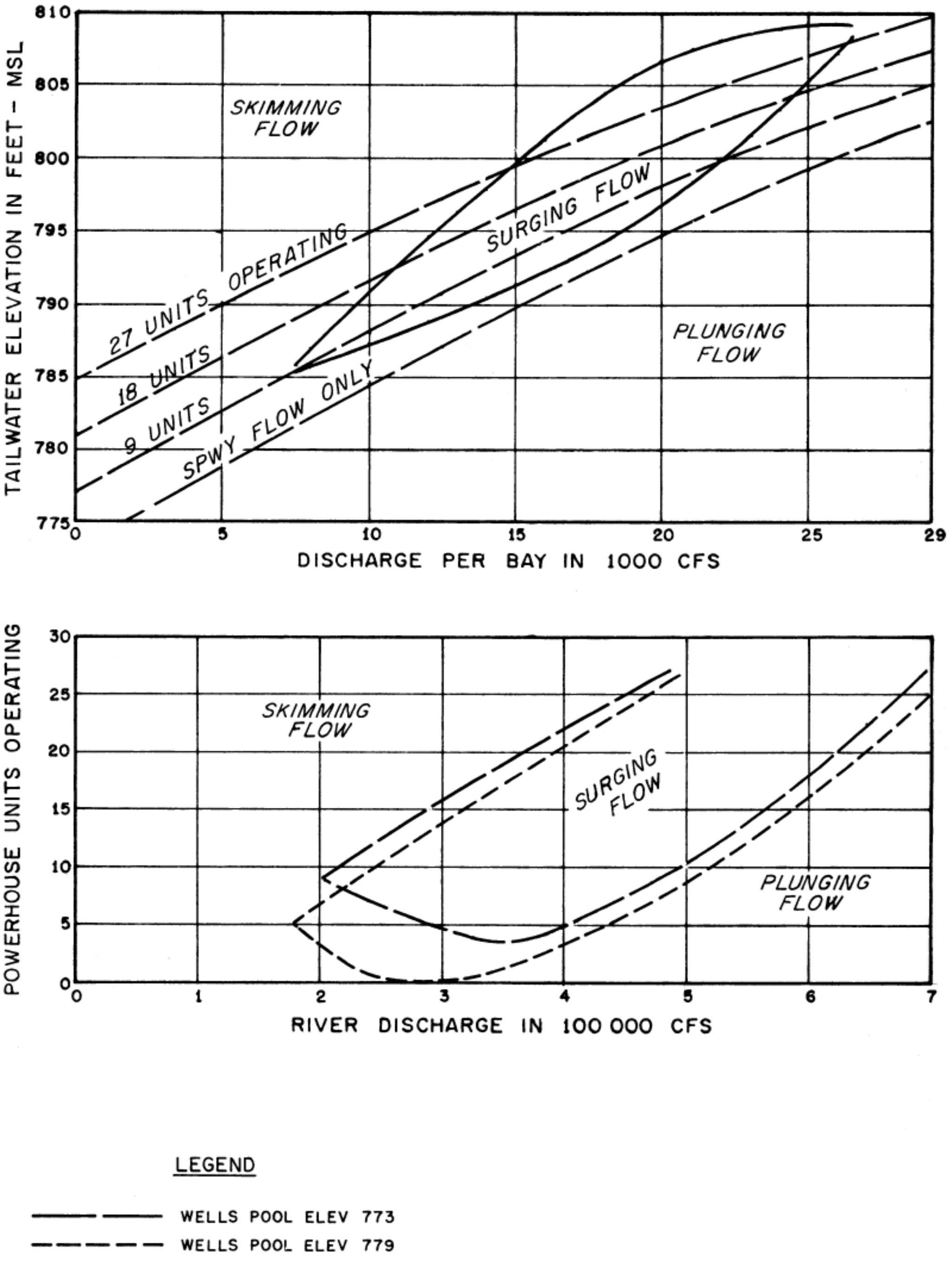
POWERHOUSE UNITS 1 TO 27	197 100 CFS
SPILLWAY BAYS 1 TO 19	242 900 CFS

FLOW CONDITIONS

WITH PLAN F DEFLECTOR

RIVER DISCHARGE 440 000 CFS

POWERHOUSE UNITS 1 TO 27



STILLING BASIN
FLOW CHARACTERISTICS

WITH PLAN F DEFLECTOR