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TECHNICAL REPORT NO. 90-1

JOHN DAY DAM

COLUMBIA RIVER, OREGON AND WASHINGTON

HYDRAULIC MODEL INVESTIGATIONS

BY

R.L. JOHNSON
L.Z. PERKINS

JUNE 1972

SPONSORED BY

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA

CONDUCTED BY

DIVISION HYDRAULIC LABORATORY
U.S. ARMY ENGINEER DIVISION, NORTH PACIFIC

CORPS OF ENGINEERS

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THIS DOCUMENT HAS BEEN APPROVED FOR PUBLIC RELEASE

PREFACE

A general hydraulic model study of the John Day Project was approved 14 February 1956 by the Office, Chief of Engineers, at the request of the U. S. Army Engineer District, Walla Walla, through the U. S. Army Engineer Division, North Pacific. Approval to model test proposed changes of the powerhouse skeleton units was given by the Office, Chief of Engineers in letters dated 7 and 27 August 1964. Tests in the general model were conducted from January 1957 to August 1963 and in the skeleton unit model from January through June 1965 at the North Pacific Division Hydraulic Laboratory, Bonneville, Oregon. The Bonneville Hydraulic Laboratory was renamed the North Pacific Division Hydraulic Laboratory when it was transferred 1 July 1963 from the Portland District to the North Pacific Division.

Personnel of the Office, Chief of Engineers, and the Portland and Walla Walla Engineer Districts visited the Hydraulic Laboratory to observe flow conditions in the models, to discuss test results, and to correlate the test results with design work that was in progress. Flow conditions in the general model were demonstrated to representatives of the fisheries and navigation interests.

Mr. R. L. Johnson, engineer in charge of the general model studies, was assisted by Messrs. J. J. Smith, A. L. Nissila, F. E. Bahler, and others. Mr. P. M. Smith, assisted by Mr. D. E. Fox, conducted the skeleton unit model studies. Both studies were supervised by Messrs. H. P. Theus, Director of the Laboratory, and A. J. Chanda, Chief of the Hydraulics Branch of the Laboratory. This report was prepared by R. L. Johnson and L. Z. Perkins.

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers
square feet	0.092903	square meters
acre-feet	1233.482	cubic meters
feet per second	0.3048	meters per second
cubic feet per second	0.0283168	cubic meters per second
pounds	0.45359237	kilograms
tons	907.185	kilograms

CONTENTS

SUMMARY

Excavation requirements, adequacy of cofferdam and diversion plans, project layout, structures designs, and proposed methods for operation of the John Day Project were investigated in a 1:80-scale general model. Water-surface data from the general model were used to regulate a 1:25-scale model in which satisfactory designs for the skeleton powerhouse units were developed. The general model was verified with natural water-surface elevations (before construction of The Dalles Dam) and with similar data after The Dalles pool was filled. Agreement between model and prototype flow patterns and water-surface elevations was satisfactory for both conditions.

The first-step cofferdam, designed for river flows to 700,000 cfs, enclosed the north 19.5 bays of the spillway by means of 15 sheet-pile cells and flanking embankments. Tests in the model indicated that river traffic and migrant fish could pass upstream without difficulty at the 700,000-cfs flow, but the upstream embankment needed more protection against scouring velocities. The downstream cell was moved to the upstream corner of the cofferdam, freeboard at the two upstream cells was increased, and riprap was used at the bases of these cells.

Tests of alternative plans for removing the first-step cofferdam and constructing the second-step cofferdam indicated the following: cells 1 to 3 of the first-step cofferdam should be removed before the downstream embankment was breached; cells 17 to 22 of the second-step cofferdam could be constructed without difficulty by means of floating plant during river flows less than 160,000 cfs; and a temporary cofferdam could be extended from the Oregon shore to about 860 ft from cell 17 without causing velocities in the open river channel to exceed 12 fps during the design discharge of 700,000 cfs.

The original second-step cofferdam, with six cells upstream from the spillway axis at bay 19 and with no temporary fishway, was not satisfactory. High velocities would have blocked fish passage through the low spillway bays, and erosion at the riverward corner of the upstream fill was indicated. Although the danger of erosion was not eliminated, performance of the adopted cofferdam, with additional upstream cells and a temporary fishway, was acceptable.

Limits for excavation along the right bank upstream from the low-bay spillway were established along a line where velocities were about 3 fps. Cost studies favored making the low bays as high as possible in the initial construction phase. Tests in the model indicated that the crest in bays 1 and 19 could be poured to final elev 210.0, and the overflow section in bays 2 to 18 could be completed to elev 135.0. The piers should taper from 16 ft at elev 135.0 to 12 ft at elev 195.0; the stilling basin in bays 1, 2, and 19 could be completed; and a removable blockout should be added to protect the downstream face of the spillway and stilling basin of bays 3 to 18.

The original upstream navigation lock approach, for use during second-step diversion, turned riverward about 1060 ft from the project axis. This alignment was undesirable because river traffic might be forced into the uncontrolled spillway. An excavated channel along an extension of the lock center line was satisfactory. Nine plans for the excavated downstream lock approach were investigated. The widest portion of the adopted elev 139 channel was on the right (landward) side of the extended lock center line. The left side of the channel was to be protected by a reinforced concrete breakwater.

The temporary fishway of original design at the north end of the spillway released fish just upstream from a nonoverflow section between the spillway and navigation lock. This location for the fishway exit was not desirable because fish might be swept downstream through the low spillway bays. The adopted fishway was extended into the upstream navigation lock approach. Flow conditions at the fishway entrance were satisfactory when spillway bay 1 was closed, pier 1 was extended 80 ft downstream, and the right bank was realigned. Acceptable flow conditions for fish passage existed at both ends of a temporary fishway with entrance in spillway pier 19 and exit in cell 19 of the adopted second-step cofferdam.

The location of barge mooring facilities at the south end of the powerhouse during third-step construction was satisfactory. Velocities in the docking area were less than 3 fps for river discharges to 400,000 cfs.

The skeleton powerhouse units were designed to pass a winter flood of 300,000 cfs without overtopping the elev 172 third-step cofferdam and a spring flood of 400,000 cfs without overtopping the tailrace deck at elev 185. Tests in a 1:25-scale model showed that the original contract design for skeleton units 11 to 14 (minimum throat area 1355 sq ft) would not pass the required discharges. The adopted designs for skeleton units 11 to 19 (open area 1614 sq ft) and unit 20 (1617 sq ft) were adequate. However, the third-stage cofferdam would be overtopped by the 300,000-cfs flow unless The Dalles pool was lowered 3 ft to elev 157.

Flow conditions upstream from the original structures were satisfactory. Those in the powerhouse tailrace and lower lock approach, at the north fishway entrance, and along the Oregon shore needed improvement. The original powerhouse tailrace was excavated to elev 145 from the station service bay to unit 7. Alternative tailrace plans, excavated to elev 130 from the left bank to unit 10, had little influence on velocities that would affect the upstream migration of fish when eight powerhouse units were operated. None of the tailrace plans was entirely satisfactory when 20 units (ultimate installation) were used. The maximum increase in head on the powerhouse produced by any tailrace plan

(0.6 ft) occurred during a river discharge of 600,000 cfs. Performance of the powerhouse fish collection system was better with the plan G (final design) tailrace than it was with previous plans.

Tests of alternative designs for the downstream navigation lock approach and the north fishway entrance began during studies of the second-step cofferdam and continued during tests of the principal structures. As a result, the 272-ft-wide downstream approach was excavated to elev 139, the wider portion (200 ft) was on the right side of the lock axis, and the left side was protected by a concrete breakwater about 1850 ft long. Excavation along the right bank extended downstream approximately 3800 ft. An extension of the approach was excavated through a 2600-ft-wide shoal about one mile downstream from the lock structure.

Performance of the north fishway entrance, which was satisfactory when tested with the second-step cofferdam, was unsatisfactory during tests of the original structures. Flow conditions were improved by extending pier 1 downstream 80 ft and installing three 10-ft-wide by 12-ft-high baffle piers in bay 2 just upstream from the end of extended pier 1. The need for a side entrance to collect fish from bay 1 was indicated by the tests. An alternative location for the north fishway entrance, at the downstream end of the stilling basin, also was acceptable.

Tests of the south fishway entrance and adjacent auxiliary water intake resulted in the selection of a plan with 12-ft-wide fishway entrance and an intake that were directed downstream at an angle to the left bank.

Comprehensive tests of the final structures and excavation plan indicated that head on the powerhouse would not be increased by passing spillway flows through a minimum number of gates. With normal pool and tailwater elevations, the average head on 10 powerhouse units diminished from 104.4 ft at a river discharge of 100,000 cfs to 84.1 ft at 1,060,000 cfs. Different methods of project operation had little effect on flow conditions upstream from the dam. The best conditions for river navigation and fish passage downstream from the project existed when the spillway was closed or all gates were opened uniformly.

Satisfactory conditions also existed when operating bays were kept together and increasing flow was regulated by opening each succeeding gate 1.0 ft (starting with bay 1) until a discharge of 40,000 cfs was passed with all 20 gates open 1.0 ft. Flow directions at the north fishway entrance were not satisfactory when the central or south bays were used to pass initial flow over the spillway.

JOHN DAY DAM

COLUMBIA RIVER, OREGON AND WASHINGTON

Hydraulic Model Investigations

PART I: INTRODUCTION

The Prototype

1. The John Day Project, at Columbia River mile 215.6, is about 29 highway miles upstream from the city of The Dalles, Oregon. Lake Wallula, the reservoir formed by the project, extends 76 miles upstream to McNary Dam*. Fig. 1 is a vicinity map of the area. The reservoir will vary above and below normal pool elev 265** to provide flood-control storage of 500,000 acre-feet between maximum controlled pool elev 268 and minimum pool elev 257. The project includes a 20-bay, tainter gate-controlled spillway with crest at elev 210, a 20-unit powerhouse having an initial total overload capacity of 2,484,000 kilowatts from 16 generators and an ultimate total capacity of 3,105,000 kilowatts from 20 units, a single-lift navigation lock 86 ft wide by 675 ft long with a maximum lift of 113 ft, a 24-ft-wide fish ladder on each bank of the river, concrete nonoverflow sections, and flanking embankments (plate 1). Overall length of the project along the roadway is about 5900 ft.

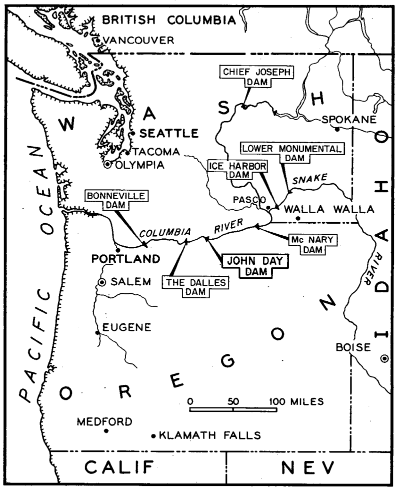

Fig. 1. Vicinity map

2. The 1894 flood, the largest in 100 years of record and adopted as the standard project flood, will be reduced by existing upstream storage from about 1,230,000 cfs to 1,060,000 cfs. The latter flow can pass through the spillway at maximum controlled

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* A table of factors for converting British units of measurement to metric units is presented on page v.

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

pool elev 268 without using one bay at each end of the structure. The maximum probable or project design flood of 2,250,000 cfs can be passed over the spillway at pool elev 276 under a computed head of 66.3 ft on the crest.

Purpose Of Model Studies

3. Early construction of a 1:80-scale general model was desirable to provide hydraulic data required for design of the project. Information concerning diversion methods, conditions for river navigation and fish passage, and water-surface elevations obtained from the model was to be included in a General Design Memorandum that was scheduled for December 1957. The initial purposes of the study were to:

a. Determine the magnitude and directions of currents adjacent to the project for each proposed arrangement of structures.

b. Investigate the effect of modifications in design to improve flow conditions or to reduce construction costs.

4. As design of the project progressed, several elements of the project were studied in detail. Owing to scale limitations, accurate hydraulic data within specific structures could not be measured in a model of the general or comprehensive type. Other models, constructed to scales of from 1:10 to 1:41.143, were used to study the spillway, navigation lock, fishways, fishway diffusion chambers, and powerhouse skeleton units. This report includes the results of tests that were made in the general model and the powerhouse skeleton unit model. Separate reports covering tests in the other models are in preparation.

The Models

Description

5. The Columbia River channel and pertinent overbank areas from river mile 213.8 to 216.7 were reproduced in a 1:80-scale model (plate 2). Topography in the model was molded of concrete between templets that conformed with a 1956 survey. The navigation lock, powerhouse, spillway, stilling basin, and north shore pumphouse were constructed of waterproofed wood and plywood (fig. 2). Concrete was used for the low-bay spillway crest and for most of the cofferdam cells. All parts of the model were shaped to close conformity with the prototype.

6. A powerhouse skeleton unit was reproduced to a scale of 1:25 in a flume with a plywood floor and one glass side (fig. 3). The plywood and concrete interior of the unit was carefully formed to prototype dimensions.

7. Flow conditions adjacent to a barge cargo facility that would be used during third-stage construction were studied in the 1:100-scale Little Goose general model. This was accomplished by approximating the John Day topography in the area to be studied and by installing temporary fills downstream from the spillway and a portion of the powerhouse. Representative flows of 100,000 to 400,000 cfs through 10 skeletonized powerhouse units were used to determine velocities and current directions that will affect river traffic moving upstream to transfer cargo.

8. Discharge into each model was supplied by a recirculating system and was measured by venturi meters or calibrated orifices in the supply lines. Velocities in the general model were measured by means of a Bentzel tube, a pygmy current meter, or by timing the movement of floats, dye, or confetti over known distances. Flow patterns were recorded by means of confetti streaks in time-exposure photographs and by the use of dye. Electronic point gages, wave-height gages, and open-tube manometers were used to measure water-surface elevations. Piezometers that corresponded to prototype river gages were placed in the

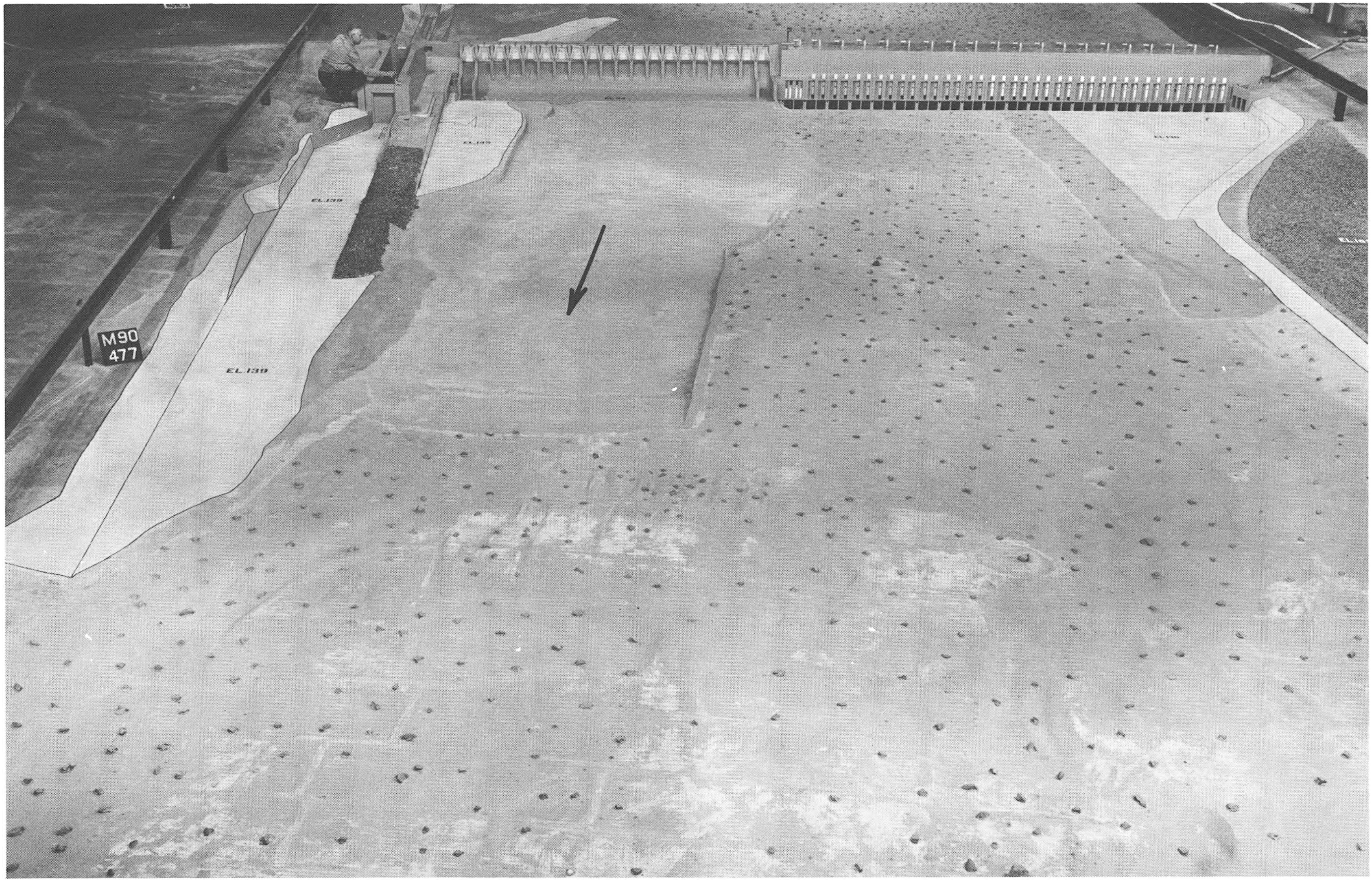
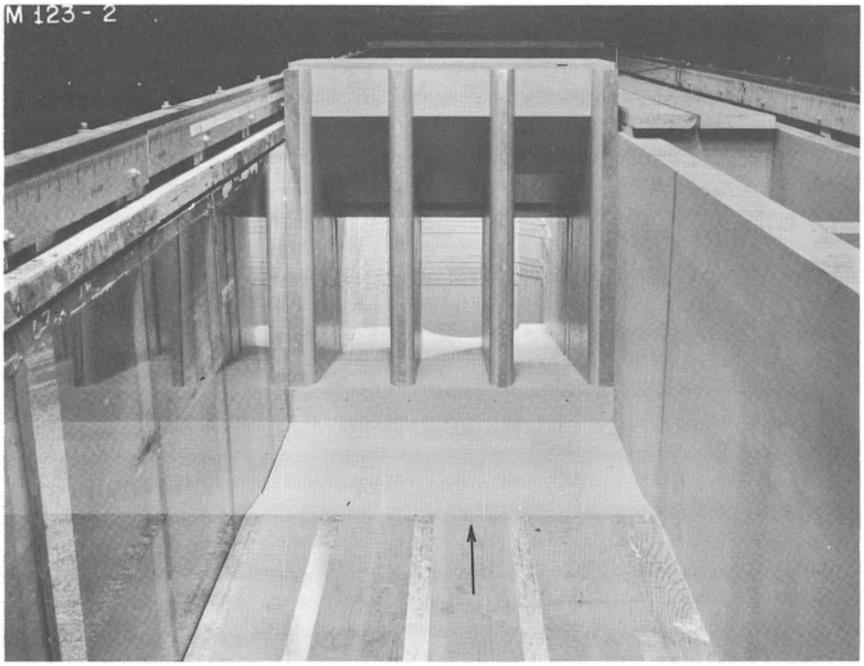
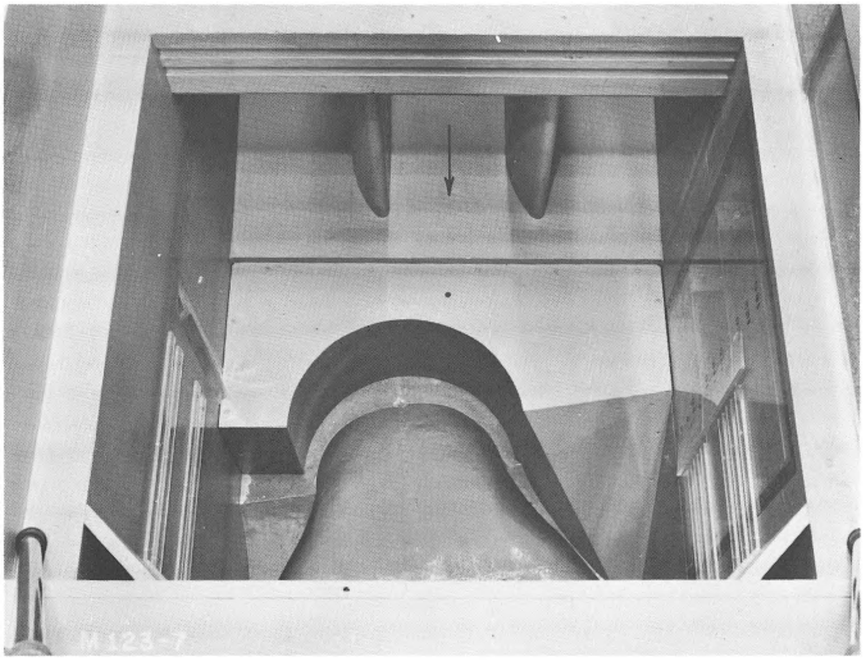


Fig. 2. Final design structures in the 1:80-scale general model



Looking into 3-bay intake



View from tailrace deck

Fig. 3. Views of 1:25-scale powerhouse skeleton unit model

general model and were piped to stilling wells in a centrally located gage pit. Tailwater elevations in the general model were controlled at river mile 214.0 (gage 28) in accordance with the observed and computed tailwater rating curves that are shown on plate 3. Tailwater elevations in the 1:25-scale model were regulated by means of water-surface elevations that existed at the downstream face of the powerhouse in the general model. Machined steel rails, accurately set to grade on the models, were used to establish longitudinal stations and to support crossbeams on which various instruments were mounted.

Scale Relations

9. The models were geometrically similar to the prototype and were operated in accordance with Froude's law. Scale relations, model to prototype were as follows:

Dimension	Ratio	General Model	Skeleton Unit Model
Length	L_r	1 : 80	1 : 25
Area	$A_r=L_r^2$	1 : 6400	1 : 625
Velocity	$V_r=L_r^{1/2}$	1 : 8.94	1 : 5
Time	$T_r=L_r^{1/2}$	1 : 8.94	1 : 5
Discharge	$Q_r=L_r^{5/2}$	1 : 57,243	1 : 3125
Force	$F_r=L_r^3$	1 : 512,000	1 : 15,625
Roughness (Manning's "n")	$N_r=L_r^{1/6}$	1 : 2.076	1 : 1.710

PART II: VERIFICATION OF THE GENERAL MODEL

10. During verification, roughness of the model river-bed was adjusted until prototype flow patterns, velocities, and water-surface elevations were reproduced with acceptable accuracy. Since exact duplication of prototype roughness was impractical, the hydraulic effects rather than the physical characteristics of the roughness were simulated. Prototype data used in verification of the model consisted of water-surface profiles and velocity measurements that were obtained before and after The Dalles forebay was raised to elev 155 (1956 and 1957 conditions, respectively). In the process of verification, stippled concrete stucco and 2-in.-minus gravel were placed on the model and adjusted generally and in local areas by trial and error until close agreement was obtained between model and prototype gage readings and velocities. Comparisons of model-prototype water-surface profiles for natural conditions and river discharges between 138,000 and 792,000 cfs are shown on plate 4. Profiles with The Dalles pool at elev 155 and 160 are shown on plate 5.

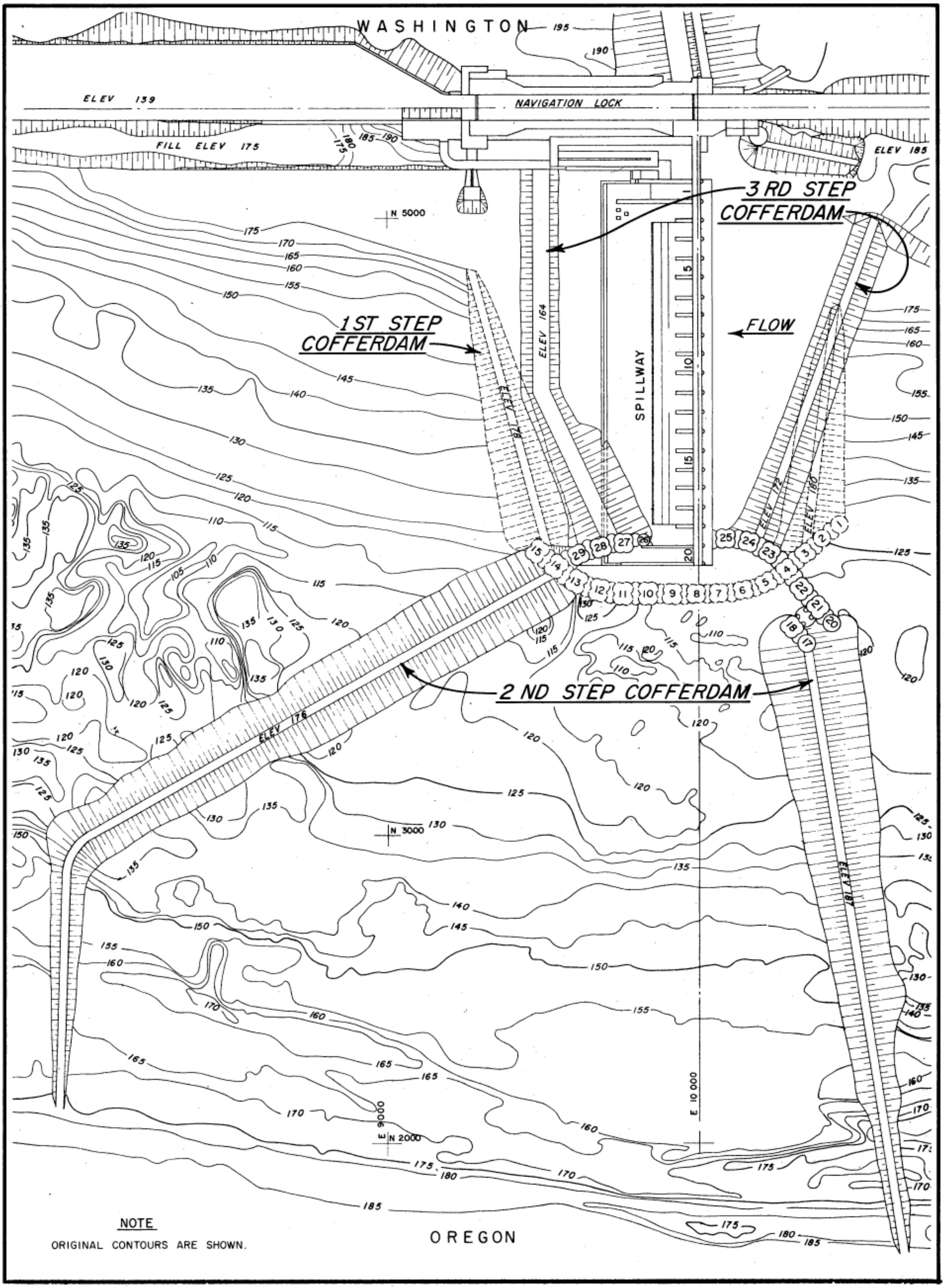


Fig. 4. Cofferdam layouts

PART III: COFFERDAM AND DIVERSION STUDIES

First-Step Cofferdam

Description and Design Criteria

11. Fig. 4 shows the principal cofferdams that were required during construction of John Day Project. The first-step cofferdam, on the right bank of the river, included 15 sheet-pile cells and flanking embankments that enclosed the north 19.5 bays of the spillway. The cellular portion of the cofferdam was designed to be overtopped at a river flow of 700,000 cfs (about a 5-year flood frequency); the embankments were made safe against overtopping by discharges up to 800,000 cfs (once in 10 years). Normal river traffic past the first-step cofferdam was expected for discharges to at least 400,000 cfs. The upper limit for navigation on the Columbia River above Bonneville Dam is about 800,000 cfs. Velocities up to 8 miles per hour (7.1 knots, or about 12 fps) were considered the practical upper limit of velocities through which barge traffic can move upstream without assistance. No temporary fish passing facilities were considered necessary or planned for use during the first phase of construction.

Test Results

12. Flow conditions in the model indicated that navigation and fish moving upstream past the first-step cofferdam would experience little difficulty for river flows less than 700,000 cfs (plates 6 to 8). Velocities and water-surface elevations adjacent to the plan A cofferdam (original design) are presented on plates 9 and 10, respectively. These tests were made with tailwater elevations that would occur after The Dalles pool was raised to elev 160.0. After reviewing the test results and observing the model in operation, engineers of the Walla Walla District decided that the upstream embankment needed more protection against scouring velocities.

13. Cell 15 was eliminated, and a new cell (1-A), aligned with cells 1 to 3, was added at the upstream end of the cofferdam

(plates 11 and 12). A layer of riprap was added to protect the embankment adjacent to cells 1 and 1-A. These cells were constructed to elev 176 to increase freeboard at the upstream corner of the cofferdam (see water-surface profile on plate 10). The data on plates 10 to 13 indicated that the revised first-step cofferdam would be satisfactory. The cells were renumbered as shown in fig. 4 during succeeding tests.

Transition Between First- And Second-Step Cofferdams

Purpose of Tests

14. Removal of the first-step cofferdam and completion of the second-step cofferdam shown in fig. 4 were expected to proceed without unusual problems and on schedule. For this reason, conditions during the transition period were not investigated during initial tests of the cofferdams. Prototype construction of first-step structures was ahead of schedule by the end of 1961, but revision of some elements of the navigation lock were required. These changes delayed construction so much that the lock might not be ready for use when the second-step cofferdam was completed during the low-water season in 1962-1963. Then a strike of steelworkers halted nearly all heavy construction in the Pacific Northwest during the spring of 1962. These events forced the following construction method to be considered. The first-step cofferdam would be removed, second-step cells 17 to 22 completed, and portions of the second-step embankments extended from the Oregon shore. During this period, river flows to 700,000 cfs must be passed without hindering river navigation or fish passage. As before, the limiting velocity of 12 fps for upstream movement of barge tows was assumed.

Proposed Construction Schedule

15. Initial plans for construction of the project envisioned that the first-step contractor would remove embankments of the first-step cofferdam. Cells 1 to 3 of the first-step cofferdam were to be removed under a subsequent contract. This sequence, termed transition stages I and I-A, respectively, is shown on plate 14. Cells 17 to 22 of the second-step cofferdam would be constructed by means of floating equipment in stage II (plates 15 and 16). Under normal conditions, the river would have been closed by means of two embankments that extended from the south bank to cells 14 and 17, respectively (fig. 4). Under the emergency conditions described above, protective works for powerhouse excavation along the Oregon shore were to be completed during the remainder of 1962 and before high water in 1963. This called for constructing a temporary cofferdam on the Oregon shore and excavating to elev 130 the area outlined on plate 15. Early completion of the temporary cofferdam (stage III) was desired because material to be removed from this portion of the powerhouse and tailrace excavation was needed for railroad relocation along the Oregon shore. Closure of the main river channel could begin as soon as the 1963 spring freshet subsided to a discharge of approximately 200,000 cfs. Flow would pass through the low spillway bays after the second-step cofferdam was completed.

Model Revisions

16. Prior to tests of the transition stages, all final design structures south of the navigation lock were removed from the model. Then the low spillway bays at elev 135, first-step cells 1 to 15, and second-step cells 23 to 29 were reinstalled. Original topography, as modified by first-step excavation, was reproduced upstream from the spillway; the riverbed south of cells 1 to 15 conformed to a prototype survey that was made during first-step construction. Topography downstream from the spillway was the same as it was during previous tests of the second-step cofferdam (intermediate scour, see plates 30 to 34).

Effects of Cells 1 to 3

17. Cells 1 to 3 of the first-step cofferdam could be dismantled during construction of second-step cells 17 to 22 (stage I), or they could be removed with the upstream fill (stage I-A). Velocities and current directions in spillway bays 15 to 18 and adjacent to the upstream cofferdam are presented for stages I and I-A on plate 14. Patterns of surface flow for the same conditions and river discharge (400,000 cfs) are shown in photograph 1. Unequal distribution of flow through bays at the south end of the spillway and high velocities around the cells indicated that cells 1 to 3 should be dismantled before the downstream earth fill was removed and flow was passed through the low spillway bays.

Flow Conditions During Steps II and III

18. Experience at other projects has shown that steel piling used for the outer shell of cellular cofferdams is difficult to place in deep water having velocities greater than 6 fps. Cells 17 to 22 of the second-step cofferdam would have to be constructed in velocities higher than 6 fps unless the downstream leg of the first-step cofferdam was removed on schedule during the fall of 1962.

19. With the downstream leg of the first-step cofferdam in place, tests indicated that velocities at the locations of cells 17 to 22 would be less than 6 fps until a river discharge of 160,000 cfs was exceeded. With stages II and III (photograph 2), maximum velocities along cells 17 and 20 exceeded 6 fps during river discharges of 400,000 cfs and 200,000 cfs, respectively (plates 16 and 17). Constricted flow and high velocities at cell 17 indicated that the stage III cofferdam along the Oregon shore should be revised to provide better streamlining and a wider channel. Velocities along the cells after completion of the downstream leg (stage IV, plate 18) are shown on plate 19. Flow patterns along the cofferdam are illustrated in photograph 3.

Development of Design for Interim Cofferdam

20. Before the stage III cofferdam along the Oregon shore could be revised, information was required concerning how far the adjacent fills of the second-step cofferdam could be extended without causing velocities higher than 12 fps in the open river. The downstream fill was raised to elev 176 so that it would not be overtopped if part of the temporary river leg was constructed before the first-step cofferdam was removed. Flow conditions in the model indicated that the respective fills could be extended to within approximately 860 and 930 ft of cells 17 and 14. The adopted design, designated stage II-E by the Walla Walla District, is shown on plates 20 to 23.

21. If relatively low velocities of from 5 to 6 fps were maintained along the river face of the cofferdam, there would be no need for riprap in this area. A rock groin, constructed to elev 162, was located at the upstream limit of the river leg to reduce velocities. The locations and sizes of other groins that might be required to prevent erosion or to improve conditions for navigation and fish passage were to be determined in the model.

22. With the stage II-E cofferdam, maximum velocities in the open portion of the river ranged from 6 fps at 200,000 cfs to 12 fps at 700,000 cfs (plates 20 to 23). Fish could migrate upstream through the low spillway bays, which were completed to elev 135, during river discharges less than 600,000 cfs (plates 24 and 25). A temporary fishway would be required to pass fish upstream when the discharge equalled or exceeded 600,000 cfs (plates 22, 23, and 25). The single rock groin reduced bottom velocities along the fill to 5 fps; additional groins were not required. Conditions for river traffic were acceptable.

Second-Step Cofferdam

23. Investigations of flow conditions during second-step diversion were among the most important studies that were made in the 1:80-scale general model. As design and construction of the project progressed, numerous changes were made in the structures and excavation plans that

were reproduced. Different combinations of plans (listed in table A) were tested to determine:

a. Excavation requirements for diversion through the uncompleted spillway.

b. Optimum elevation of low-bay spillway for diversion.

c. Heights of steel cells and embankments required to protect the work area.

d. Alignment of cells and embankments.

e. Water-surface elevations adjacent to the cofferdam.

f. Flow conditions affecting navigation and fish passage.

g. Lateral loading on spillway piers.

h. Effects of riverbed scour adjacent to the spillway.

Description of Plans

24. The second-step cofferdam of original design (plan A) included six cells upstream and seven cells downstream from the spillway axis at bay 19 (plates 26 and 27). The rockfill embankments that formed the upstream and downstream legs of the cofferdam enclosed the area between the south abutment and spillway bay 19. The steel cells were designed to overtop at a river discharge of 700,000 cfs; the embankments were designed to prevent overtopping for river flows to 800,000 cfs. River diversion was to be accomplished through spillway bays 1 to 18, which would be poured to elev 130 within the first-stage cofferdam and completed to elev 210 within the third-step cofferdam. River traffic was to use the uncompleted navigation lock with the upper sill at elev 147 during the second phase of construction (from about January 1962 to January 1967). Temporary fishways were considered necessary, but no location for these facilities was selected until after model tests of the original cofferdam indicated where they should be situated.

25. Cell 20 was added in plan B to protect the upstream fill against erosion, and a temporary fishway entrance was placed between cells 24 and 25 (plate 28). The vertical-slot-type temporary fishway, located inside the cofferdam, was not reproduced in the model. Cell 19 was added upstream from cell 20 in plan C (plate 29). In plan D, cells 17 to 19 were added, the temporary fishway entrance between cells 24 and 25 was moved downstream to an opening in extended pier 19, and the fishway exit

was passed through a low cell (cell 19) between cells 18 and 21 (plates 30 to 34).

26. Erosion was expected to occur adjacent to the spillway during second-step diversion. Original riverbed contours were reproduced for studies of the plan A cofferdam (plates 26 and 27). Assumed intermediate erosion in the forebay was simulated during most tests of the second-step cofferdam and first-stage structures. In later tests, plates 30 to 34, topography south of the first-step cofferdam conformed to a prototype survey that was made during first-stage construction.

Test Results

27. The test data shown on plates 26 and 27 indicated that the plan A cofferdam was satisfactory in most respects. However, velocities of from 14 to 25 fps along the river face of the cofferdam downstream to cell 24 were high enough to erode the upstream embankment and to block fish migrating upstream through spillway bay 18. Although the danger of erosion along the upstream embankment was reduced with cofferdam plans B and C (plates 28 and 29), high velocities through the spillway would have prevented fish from reaching the temporary fishway entrance between cells 24 and 25. The increase in velocities resulted from raising the low spillway bays to elev 137.5 (plan D spillway) and streamlining the cofferdam.

28. Flow patterns in the diversion channel and along the plan D second-step cofferdam (final design) are shown in photographs 4 to 9. Water-surface elevations along spillway piers of two designs (see paragraph 31), at the principal first-stage structures, and at river gages in the model are presented in tables B to D. Velocities over the elev 135 spillway that was tested with the plan D cofferdam were low enough (7 fps) to allow fish to pass upstream through the low bays during a river flow of 100,000 cfs (plate 30). The fish probably would have to use the temporary fishways during river discharges of 200,000 cfs and higher (plates 31 to 33). Flow conditions at the entrance and exit of the temporary fishway adjacent to the second-step cofferdam were satisfactory for river flows to 700,000 cfs. The need to protect the toe of the embankment at the base of cell 20 was indicated by bottom velocities

of 10 to 15 fps during discharges of 400,000 cfs and higher. Freeboard along the cells (plate 35) and embankments (plate 34) was adequate for design discharges of 700,000 and 800,000 cfs, respectively.

Spillway Approach

Plans Tested

29. Five plans for an excavated approach to the low-bay spillway (plate 36) were investigated during tests of the second-step cofferdam. The first plan (plan A) was tested with original riverbed contours and with the low spillway bays at elev 130. With approach plans B to E, the spillway elevation varied (see paragraph 31); maximum erosion was assumed within portions of the elev 145 approach.

Test Results

30. Tests made with the original upstream approach, original second-step cofferdam, and elev 130 spillway (plate 26) showed that the excavated approach channel should be realigned to improve flow distribution through the spillway and to reduce velocities in the vicinity of gage 13. As a result, the toe of the right bank was located where velocities were about 3 fps. Velocities along the right bank of spillway approach plans B to D are shown on plate 37. Flow conditions with the adopted right bank (plan E) and second-step cofferdam (plan D) are presented in photographs 5 to 9 and on plates 30 to 33.

Low-Bay Spillway

Plans Tested

31. According to initial plans for construction of the project, the concrete in spillway bays 1 through 18 would be placed to elev 130 within the first-step cofferdam (plate 27). Since cost studies favored making the low bays as high as possible in the first phase, spillway plans B and C were at elevs 135 and 140, respectively. In plan D the crest was lowered to elev 137.5. The piers were 12 ft thick in spillway plans A to D. In plans E to G the piers were provided with a 30-to-1 batter below elev 195. This reduced the clear width of the low bays from 50.0 ft to 46.2 ft at crest elev 137.5 in plan E and to 42.0 ft at crest elev 135.0 in plans F and G. In plan F, bays 1 and 19 were completed to final

elev 210. In plan G, the stilling basin in bays 1, 2, and 19 was completed and a blockout filled with removable concrete was added at the toe of bays 3 to 18. The removable section instead of final concrete would be eroded during second-step diversion. Repairs would be made during the third phase of construction.

Test Results

32. Previous tests had indicated that the cells and embankments were high enough to prevent overtopping during the cofferdam design discharge of 700,000 cfs (paragraphs 27 and 30 and plates 26 and 27). Fish could pass upstream through velocities of 5 fps in bay 18, but velocities of 19 to 23 fps would not allow them to progress beyond cell 24. For these conditions, a temporary fishway entrance between cells 24 and 25 was indicated.

33. Low-bay spillway plans B (elev 135), C (elev 140), and D (elev 137.5) were investigated during tests of the plan B second-step cofferdam that is shown on plate 28. At this time, the plan B forebay excavation (plate 36), plan B tailrace, and original riverbed (no scour) adjacent to the structure (plate 26) were used in the model.

34. As shown on plate 28, increasing the elevation of the low bays and improving the streamlining of the plan B second-step cofferdam increased velocities in bay 18 to 28 fps. Therefore, fish could not pass upstream through this bay during the 700,000-cfs discharge, and the temporary fishway entrance would have to be located just upstream from cell 26. Visual observations indicated that the cofferdam must be higher if the spillway was completed to elev 140. Only minor increases in the heights of cells 28 and 29 were needed to prevent overtopping by wave action when the low bays were completed to elev 137.5 (plate 28). The original elevations of the cells and embankments were satisfactory when the spillway was at elev 135.

35. With the low bays at elev 137.5, flow angled toward the right (plate 38). A 16-ft difference in water-surface elevations existed on opposite sides of the plan A pier 11 during a river flow of 700,000 cfs (table B). The large differential led to the decision that for adequate stability the piers should taper from a thickness of 12 ft at elev 195

to about 16 ft at the spillway crest. This change, termed plan B piers, increased the maximum differential to 19.5 ft. The decrease in spillway capacity caused by the thicker piers and by closing bay 1 to improve conditions at the temporary north fishway entrance resulted in lowering the spillway to elev 135. Flow conditions with the plan G spillway (final design) were satisfactory (plates 30 to 33). Freeboard along the cofferdam was adquate for a discharge slightly higher than 700,000 cfs (plate 35). Velocities and a water-surface profile for an overtopping discharge of 800,000 cfs are shown on plate 34. Water-surface elevations for the conditions presented on plates 30 to 35 are summarized in tables C and D.

Navigation Lock Approaches

Plans Tested

36. Except for the sill block and gate at the upstream end of the lock chamber, the navigation lock was to be completed during first-step construction. Excavation of a temporary upstream approach, to be used during the entire second stage and a portion of third-stage construction, and the permanent downstream approach was scheduled to begin before completion of the first-step cofferdam. Two plans for the upstream and downstream approaches for the navigation lock were studied during initial tests of the second-step cofferdam. The final design for the downstream approach was developed during subsequent tests of the original and final structures and excavation plans (see paragraphs 59 to 62).

37. The original (plan A) upstream approach, excavated to a minimum width of 90 ft at elev 145, followed an extension of the lock center line for about 1060 ft from the project axis. Then it turned abruptly toward the river (plates 26 and 36). The original downstream approach, with a 250-ft-wide bottom at elev 139, was excavated with the widest portion on the left or river side of the lock axis (plate 26). The plan B upstream approach followed the lock axis as shown on plates 30 to 33. The plan B downstream approach, also 250 ft wide, was excavated with the widest portion on the right side of the lock center line and with the downstream end angled toward the river (photograph 4).

Test Results

38. The upstream lock approach of original design was not acceptable. High-velocity currents during second-step construction might sweep river traffic downstream against the spillway piers (plate 26). Conditions with the plan B upstream approach (plates 30 to 33) were satisfactory except where flow in the excavated channel turned riverward through an old watercourse near gage 14. Navigation interests stated that cross-flow in this area would cause difficulties for traffic moving downstream unless a riverside fill or other protection was provided. The test results on plate 39 showed that two temporary steel fender cells and a 310-ft-long fill at elev 185 were advisable.

39. High-velocity flow from the spillway overtopped the left side of the excavated downstream approach and caused undesirable conditions for navigation (approach plans A and B, photograph 4 and plate 26). The narrow strip of land that formed the left side of the downstream approach channel was of erodible material, and some form of breakwater was essential. A satisfactory rock breakwater (plan H) was developed during studies that were made with completed structures (see paragraphs 59 and 60. A concrete breakwater, supported on piling in critical areas, was selected by the Walla Walla District after test borings showed that the foundation materials would not support a rockfill embankment. Details of the adopted breakwater (plan I) are shown on plate 40. The plan I downstream lock approach was satisfactory when river discharges of 600,000 and 700,000 cfs were passed through the low spillway bays (plate 41).

North Temporary Fishway

Plans Tested

40. Several schemes for a temporary fishway at the north end of the low spillway bays were considered. The first plan included vertical-slot baffles in a 10-ft-wide channel leading from the permanent fish ladder entrances through the north side of spillway bay 1 to an exit just upstream from the north nonoverflow section. This plan was abandoned when the decision was made to complete bay 1 during the

first stage of construction. In subsequent plans, a 12-ft-wide temporary fishway was passed through the north nonoverflow section. A ladder exit located just upstream from the north nonoverflow section was considered undesirable because fish would be released into an eddy that would lead fish to the spillway. The fisheries agencies requested that the upstream leg of the ladder be extended into the navigation lock approach and that the lock filling valves and downstream gate be opened slightly to create a minimum transportation velocity of 1 fps in the upstream lock approach channel. The fishway entrance was the only portion of the structure that was reproduced during tests of the second-step cofferdam. The prototype entrance consists of three 12-ft-wide openings that are controlled by adjustable vertical weirs. Two openings face downstream and one (the side entrance) faces the spillway stilling basin (plate 42). Only two of the three openings were used at the same time during the model studies.

41. During operation of the temporary fish ladder, a pumped attraction flow of 600 cfs and discharge down the ladder were to provide an average velocity of 4 fps at the two entrance weirs. During tests in the model, attraction flows of from 670 to 1100 cfs were admitted through a diffusion chamber in the floor of the permanent fish ladder. The desired velocity of 4 fps was obtained by raising or lowering vertical weirs in the fishway entrances.

Test Results

42. With the spillway completed to elev 130, plan A tailrace and spillway pier 1 (downstream end of pier 125.3 ft from lower end of stilling basin), velocities along the right bank and adjacent to the fishway entrance were high enough to repel fish (greater than 10 fps) when a river discharge of 700,000 cfs was passed through 18 low bays (plate 26). The data on plates 30 to 33 were obtained during the second series of tests of the second-step cofferdam (with plan G spillway at elev 135). Flow conditions at the north fishway entrance were improved when spillway bay 1 was closed, pier 1 was extended 80 ft downstream, and the diversion channel was eroded (intermediate scour). Detailed

studies of flow conditions at the fishway entrance, made with pier 1 extended 60 ft, indicated that the temporary facility would be satisfactory for river discharges to 700,000 cfs (plate 42).

South Temporary Fishway

Plans Tested

43. Two locations for a vertical-slot temporary fish ladder adjacent to the cofferdam cells were considered. Following tests of the plan A cofferdam, a fishway entrance was located in the connector between cells 24 and 25 (plate 28). Since this location was tentative, the ladder exit was not reproduced in the model during tests of cofferdam plans B and C (plates 28 and 29). With the plan D cofferdam, the downstream entrance was located in an opening through pier 19; the exit was in cell 19 (plate 30).

Test Results

44. As explained in paragraph 34, a fishway entrance between cells 24 and 25 of the plan B second-step cofferdam was not satisfactory. With the plan C cofferdam and with the low spillway bays at elev 135, high velocities through bay 18 would force fish into the small eddy immediately upstream from cell 26 (plate 29). Therefore, the fishway entrance was moved downstream to collect fish from this location. Acceptable velocities and current directions existed at both ends of the temporary fish ladder during tests of the plan D second-step cofferdam (plates 30 to 33).

Barge Unloading Facilities For Third-Step Construction

45. The third-step cofferdam (fig. 4) would enclose the spillway during one low-water season while flow was diverted through the powerhouse skeleton units and while the spillway and upstream sill of the navigation lock were raised to their final elevations. Navigation past the project was to be halted during the last three months of third-step construction. With the lock closed, barge cargoes (petroleum products, cement, and grain) were to be transferred over the dam by means of a pumping facility at the Oregon end of the powerhouse.

46. The need for a model study of flow conditions during third-step construction was not realized until after all tests in the John Day general model were completed and the model was destroyed. For this reason, conditions at John Day were simulated in a 1:100-scale model of the Little Goose Project. The test results indicated that the proposed location for barge mooring and unloading facilities at the south end of the powerhouse would be satisfactory. Maximum velocities along the Oregon shore did not exceed 7 fps for river discharges to 400,000 cfs; velocities in the docking area were lower than 3 fps.*

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* The lack of suitable moorage space, both upstream and downstream, caused the above plan to be abandoned. A pumping station for petroleum and other liquid products was installed on the north shore. Shipments of cement and grain were suspended.

PART IV: TESTS OF SKELETON POWERHOUSE UNITS

Design Considerations

47. The powerhouse substructure was to be constructed within the second-step cofferdam while the river was diverted through low bays of the partially-completed spillway (plates 30 to 33). Units 1 to 10, at the south end of the powerhouse (plate 1), were to be completed initially; units 11 to 20 would be partially completed and used for diversion during one low-water season while the low spillway bays and upper sill of the navigation lock were raised to final elevations in the third phase of construction. To accommodate this diversion, the interiors of skeleton units 11 through 20 were to be streamlined and protected as much as feasible. The original design for the skeleton units (plate 43) was revised from plans of skeleton units at The Dalles Dam by adding a concrete section that included the bottom of the draft tube.

48. In October 1964, the construction schedule for John Day Project was accelerated and four additional units (11 to 14) were added to the initial installation. Owing to the accelerated schedule, as much concrete as river diversion would allow was to be placed in units 11 to 14. Completion of the draft tubes to elev 81.5 and the draft tube liner blockouts to elev 106.5 was desired in these units. The space between the intermediate piers and the downstream wall could be left open above elev 106.5. Skeleton units 11 through 20 must pass a winter flood of 300,000 cfs without overtopping the upstream leg of the third-step cofferdam (elev 172). They must also pass 400,000 cfs without overtopping the elev 185 tailrace deck from inside the units. Tailwater would be controlled between elevs 155 and 160 by operation of The Dalles Dam.

Tests And Results

Plans Tested

49. Sectional views of the draft tube plans that were reproduced in a 1:25-scale model of one John Day powerhouse skeleton unit are shown on plates 43 to 46. Only those elements and dimensions that influenced flow conditions or head-discharge relationships are discussed in this report.

Plan A, plate 43: This was the contract design when the tests began. It provided a minimum open area of 1355 sq ft in the draft tube.

Plan B, plate 44: With this plan, mass concrete in the draft tubes would be completed to elev 106.5 and the minimum open area would be reduced to 871 sq ft. Units 11 to 14 could be finished soon after diversion. Skeleton structures with more discharge capacity would be selected for units 15 to 20.

Plan C, plate 44: This was an adaptation of the Little Goose contract plan. The minimum area for flow was increased to 1450 sq ft.

Plan D, plate 44: A section of plan C draft tube roof was removed to provide a flow area of 1557 sq ft.

Plan E, plate 45: A modification of plan D (similar to The Dalles design) to show effect of removing additional rock and mass concrete inside unit. The minimum area for flow was 1557 sq ft.

Plan F, plate 45: Plan D with roof changed for easier construction; flow area increased to 1607 sq ft.

Plan G, plate 45: Final design for units 11 to 19; with drainage tunnel in roof over draft tubes and flow area of 1614 sq ft.

Plans H and I, plate 46: Alternative designs for draft tube in unit 20 (no drainage tunnel). Minimum flow area was 1614 sq ft in plan H and 1617 sq ft in plan I.

Plan J, plate 46: This was the original contract plan. The draft tube and downstream portion of the center section were similar to those of plan A. The upstream part of the center section represented 1 ft of protective concrete over rock excavation. The minimum area for flow was 1355 sq ft.

Test Results

50. Water-surface elevations and discharges observed in the model were used to compute discharge rating data that are shown in tables E to I. These data, generalized by reduction to differentials from the energy grade line at the tailwater gage and capacity ratings with The Dalles pool elevs 155 and 160, are presented on plates 47 to 56. The head drop through plans A to H intake structures is shown as a function of discharge on plate 57. Turbulence caused surges that splashed over the tailrace deck before the estimated average water-surface elevation inside the unit reached elev 185. The maximum discharges that could be passed through 10 skeletonized powerhouse bays without overtopping the third-step cofferdam or the tailrace deck were as follows:

Discharge Capacities in CFS (10 Units)

Skeleton Powerhouse Plans A to J

Skeleton Unit Plan	Without Overtopping 3rd-Step Cofferdam		Without Overtopping Pwhse Tailrace Deck	
	The Dalles Pool Elevation			
	155	160	155	160
A	239,000	215,000	330,000	313,000
B	202,000	178,000	287,000	270,000
C	278,000	248,000	380,000	367,000
D	289,000	260,000	396,000	375,000
E	309,000	277,000	432,000	409,000
F	278,000	251,000	379,000	363,000
G	312,000	281,000	428,000	407,000
J	245,000	282,000	340,000	322,000
G,H*	312,000	281,000	428,000	407,000
G,I**	317,000	282,000	440,000	414,000

* Plan G in units 11 to 19, plan H in unit 20
** Plan G in units 11 to 19, plan I in unit 20

51. As a result of the tests, skeleton units 11 to 19 will conform to the plan G design. Plan I was selected for unit 20. With these plans, the third-step cofferdam will be overtopped by a winter flood of 300,000 cfs unless The Dalles pool is lowered to approximate elev 157. The powerhouse tailrace deck will not be overtopped by a spring flood of 400,000 cfs.

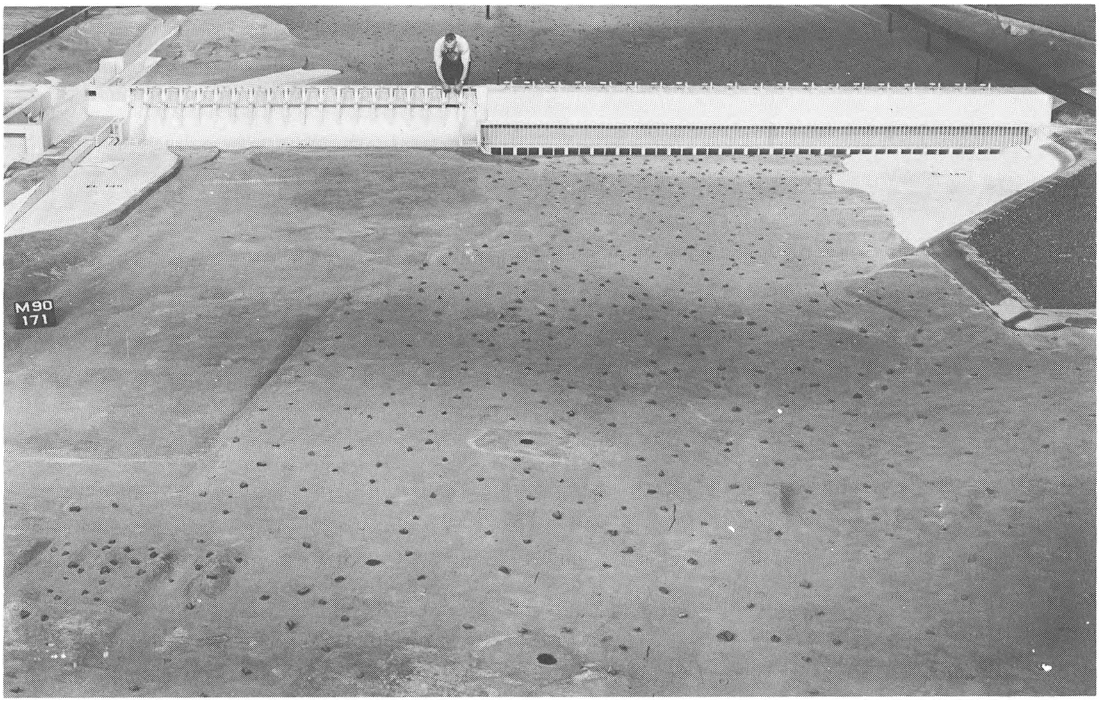

Fig. 5. Plan A (original design) structures

PART V: TESTS OF PERMANENT FEATURES

Development Of Design

Description of Original Design

52. The original structures and excavation plan (except for spillway pier 1, which was tentatively extended 80 or 60 ft in previous tests (see paragraph 42) is shown in fig. 5 and on plates 58 to 66. Riverbed contours adjacent to the spillway were the same as those during tests of the plan D second-step cofferdam (intermediate scour, plates 30 to 34). A 2-ft-high sill, located 151.33 ft downstream from the crest axis in spillway bay 1, was intended to produce upwelling and downstream surface flow past a fishway entrance at the right side of the stilling basin. The sill was similar to one that was developed during hydraulic model studies of the spillway for Ice Harbor Dam.* The powerhouse tailrace and left bank disposal area of original design are described in paragraph 55. Base tests of the original design were made to provide data for comparison with data from tests of alternative structures and excavation plans. Tests were made with river discharges between 100,000 and 700,000 cfs and with either 10 or 20 powerhouse units in operation (except 18 or 20 units at 420,000 cfs).

Test Results

53. Flow conditions for selected discharges and methods of project operation are shown on plates 58 to 66. Water-surface elevations at all river gages and main structures are summarized in tables J and K. With the plan A tailrace, average head on 10 powerhouse units decreased from 102.9 ft at a river flow of 200,000 cfs to 92.1 ft at 700,000 cfs (table J).

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* U.S. Army Engineer Division, North Pacific, Division Hydraulic Laboratory, CE,"Spillway and Stilling Basin For Ice Harbor Dam, Snake River, Washington,"Technical Report No. 31-1, January 1965

54. Although flow conditions upstream from the project were satisfactory, those in the powerhouse tailrace, the downstream approach to the navigation lock, at the north fishway entrance, and along the Oregon shore needed improvement. High-velocity flow crossed the downstream lock approach and impinged against the right bank during river flows equal to or greater than 600,000 cfs (plates 63 to 66). With 10 powerhouse units in operation, high velocities along the right bank downstream from the spillway would hinder the upstream progress of fish that approached the north fishway entrance during river flows greater than 420,000 cfs. Maximum velocities of from 7 to 10 fps along the elev 185 fill on the Oregon shore were believed high enough and extensive enough to delay the upstream passage of fish.

Powerhouse Tailrace And Left Bank Disposal Area

Plans Tested

55. The plan A tailrace was excavated to elev 145 within a triangle bounded by the north side of unit 7, the south end of the station service bay, and a point about 1900 ft downstream from the project axis (plates 58 to 66). The downstream limit of the plan A disposal area was 2300 ft west of the downstream side of the powerhouse, and the maximum width of fill was about 750 ft north of contour elev 185 on the left bank. The substation, switch yard, and transmission towers were to be located on this fill. Since a large area was needed for these items, the disposal fill was to be extended riverward as far as possible without restricting flow or reducing head on the powerhouse. Tests of the original structures, powerhouse tailrace, and left bank disposal area were made with at least 10 powerhouse units in operation. The number of units to be completed initially was to be decided later.

56. Tailrace plans B to G, excavated to elev 130 (plates 67 to 72), were tested in efforts to improve conditions for fish passage, to increase head on the powerhouse, and to distribute head uniformly among the powerhouse units. To provide a conservative design, tailrace plans B to G were studied with the minimum and maximum number of powerhouse units that probably would be operated at river discharges of 400,000

and 600,000 cfs (8 or 20). Except for plan F, with maximum practical limits of excavation (plate 71), the general outlines of tailrace plans B to G were similar. The principal differences were in slight modifications at the upstream end or in the alignment and downstream limit of the disposal area (photographs 10 to 14). Tailrace plan C and disposal plans C and D (plate 68) were tested with a preliminary design for the powerhouse in which the draft tube outlets were at different elevations (elev 68.7 at units 1 and 2; elev 63.2 at units 3 to 20). The draft tube outlets were at elev 69.0 during tests of the other tailrace plans. Following tests of the plan D tailrace (plate 69), the substation and switch yard were moved to the Washington shore; the transmission towers were left on the Oregon shore. This reduced the length but not the width of the disposal area on the left bank.

Test Results

57. With 10 powerhouse units in operation, velocities along the Oregon shore were high enough to discourage fish migrating upstream in the plan A tailrace during river flows of 200,000, 300,000 and 600,000 cfs (plates 59, 60, and 63). With tailrace plans B to G and eight units (plates 67 to 72), velocities to be encountered by fish were about as high as they were when 10 units were operated with plan A tailrace. The information in photographs 10 to 14 and on plates 67 to 72 indicated that the alternative tailrace designs had little effect on velocities or flow patterns along the left bank when eight powerhouse units were in operation. Owing to velocities of 9 or 10 fps near gage 20, none of the tailrace plans was entirely satisfactory for fish passage when all 20 units were operated at a river flow of 600,000 cfs. However, areas of lower velocities in midstream would permit fish to reach the powerhouse fish collection system during all operating conditions that were studied.

58. Water-surface elevations along the downstream face of the powerhouse and average head on the powerhouse units operated during tests of tailrace plans A to G are presented in table J. The maximum

increase in head (0.6 ft) that was produced by any of the tailrace plans occurred with 20 powerhouse units during a river flow of 600,000 cfs (compare plans E to G with plan A). To simplify operation of the powerhouse fish collection system (less regulation of entrance weirs or orifices), tailwater should slope from unit 1 to unit 20. Based on tailwater elevations at powerhouse units 1 and 19, performance of the fish collection system was better with the plan G tailrace than it was with the other tailrace plans. Therefore, the plan G tailrace and left bank disposal area were selected for prototype construction. Flow patterns in the plan G tailrace are shown on plate 72.

Downstream Approach To Navigation Lock

Plans Tested

59. Development of a design for the downstream navigation lock approach began during tests of the second-step cofferdam and continued with the original structures and excavation plan (plates 58 to 66 and 73 to 78). The following downstream lock approach plans were tested:

Plan A: Widest portion of approach channel excavated on left or river side of lock axis (plate 26).

Plan B: Widest portion of approach channel on right side of lock axis; downstream end angled toward river (photograph 4).

Plan C: Widest portion as above; alignment along an extension of lock center line; natural topography between spillway tailrace and lock entrance canal (plate 73).

Plan D: Similar to plan C except for scour to elev 139 of riverside topography downstream from station 64+00 (plate 74).

Plan E: Similar to plan D, but erosion to bedrock or to elev 139 in a gap through left side of channel between stations 56+80 and 58+25 (plate 76).

Plan F: As above, but with rockfill at elev 165 between stations 54+50 and 60+00 (plate 76).

Plan G: Similar to plan E, but with elev 175 fill between stations 51+50 and 60+50 (plate 77).

Plan H: As above, but with the elev 175 fill extended downstream to about station 63+50 (plate 78).

Plan I: Similar to plan H, but the rockfill was replaced by a concrete breakwater (plate 40).

Test Results

60. Downstream approach plans A to C were not acceptable because high velocities and strong eddies occurred at the entrance (photographs 4 and 15 and plates 63 to 66 and 73). Flow patterns for selected tests of approach plans C to H are shown in photographs 15 to 17. Cross-flow in the navigation channel increased as erosion of the narrow spit of land along the left side of the excavated channel progressed upstream in plans D and E (photographs 15 and 16 and plates 74 and 75). A 500-ft-long fill at elev 165 (plan F) was relatively ineffective (photograph 16 and plate 76). The fill was raised to elev 175 and its length was increased from about 900 ft in plan G (photograph 17 and plate 77) to 1250 ft in plan H (plate 78). The plan H approach was satisfactory; therefore, it was tentatively adopted and used during tests of the final structures and excavation plan (plates 96 to 115).

61. Following tests of the final structures and excavation plan, the plan I breakwater was installed in the model and the elev 139 excavation in the lower lock approach channel was extended downstream through two submerged ridges between stations 97+50 and 117+00 (plates 79 to 82). Flow conditions in and adjacent to the extended navigation channel were studied at river discharges of 100,000 to 800,000 cfs with 0, 10, and 20 powerhouse units in operation, and with uniform distribution of flow through spillway bays 2 to 20. A discharge of 2700 cfs was passed through spillway bay 1 for fish attraction.

62. Velocities along the sailing line (from 2 or 3 fps at 100,000 cfs to 12 fps at 800,000 cfs) were approximately the same as they were before the channel was extended. Although wave heights were not observed for all test conditions, 3.5-ft-high waves occurred along the right bank between stations 70+00 and 75+00 when 10 powerhouse units were operated during the 800,000-cfs flow (plate 82). Wave heights were reduced to 1.0 ft or less when 20 units were operated at the same discharge. Velocities and wave heights in the extended channel were

lower than they were in the lower lock approach between stations 65+00 and 80+00. Shoaling may occur in excavated areas of the extended channel during low river flows.

North Fishway Entrance

Plans Tested

63. As stated in paragraphs 40 to 42, a tentative design for the north fishway entrance was developed during tests of the second-step cofferdam. However, performance of the facility was not satisfactory when it was operated under higher heads that existed when permanent structures were installed (paragraph 54). After viewing flow conditions in the model, representatives of the fisheries agencies suggested that pier 1, and possibly pier 2, be extended as far as the downstream end of the stilling basin to prevent spillway flow from blocking the north fishway entrance. They also suggested a 12-ft-wide slot in the extended portion of pier 1 opposite a side entrance to the fishway and the use of baffle piers in spillway bay 2. Flow through the side entrance and slot would attract fish from the stilling basin when spillway bays 2 to 20 were closed. The baffle piers were intended to stabilize the position of the hydraulic jump near the end of pier 1 and to reduce or eliminate return flow around the end of that pier. Tests included a detailed study of a fishway entrance in line with the end sill of the stilling basin (plan B entrance, plates 89 to 91).

Test Results

64. Patterns of surface flow for some of the pier extensions that were tested are shown in photographs 18 and 19. With pier 1 extended 60 ft and with 10 powerhouse units in operation at a river discharge of 600,000 cfs, velocities were such that fish could approach the north fishway entrance and collect downstream from the entrance and in bay 1 of the spillway (plate 83). Adult salmon could overcome velocities of from 5 to 9 fps around the end of pier 1 and escape from the hydraulic jump in the main portion of the stilling basin. Flow conditions were not satisfactory when the discharge increased to 700,000 cfs. Surface

velocities along the right bank exceeded 9 fps, the eddy adjacent to the north fishway entrance was smaller and swifter, and velocities of 18 fps at the end of pier 1 would sweep fish into the stilling basin.

65. With pier 1 extended 80 ft (plate 84), flow conditions at the north fishway entrance were excellent when either 10 or 20 powerhouse units were operated during a river discharge of 600,000 cfs. Detailed observations of flow directions and velocities at the north fishway entrance were not made with the plan A structures and 80-ft extension of pier 1 for a river flow of 700,000 cfs. However, velocities in the tailrace indicated that fish would have difficulty reaching the north fishway entrance when 10 powerhouse units were in operation at this river flow (plate 65). Approach conditions were satisfactory when 20 units were operated (plate 66).

66. Extending pier 1 to the end sill, or extending piers 1 and 2 60 ft (photograph 19), improved conditions at the north fishway entrance. Extending both piers to the end sill almost eliminated the undesirable conditions that existed with the original design and with shorter piers. This plan was abandoned because of its higher cost and because fish might be trapped in the stilling basin between extended piers at low spillway flows.

67. The data presented on plates 85 to 88 were obtained with 10-ft-high baffle piers in bay 2 and pier 1 extended 80 ft. The number, size, and positions of the plan S (final design) baffles used in the general model were developed in the 1:41.143-scale John Day spillway model.* Except for upstream flow along the right bank, the flow patterns and velocities shown on plate 85 were satisfactory for river discharges of 600,000 and 700,000 cfs. Attraction flows of 2700 cfs from spillway bay 1 and 1600 to 1900 cfs from the north fishway entrance were adequate. The action of dye injected into the water indicated that the baffle piers in bay 2 reduced return flow into the stilling basin around the end of pier 1.

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* U.S. Army Engineer Division, North Pacific, Division Hydraulic Laboratory, CE, "Spillway And Stilling Basin, John Day Dam, Columbia River, Oregon And Washington", Technical Report No. 97-1, (in preparation)

68. Flow patterns for two methods of operating the plan A north fishway entrance (side opening closed, or north opening closed) during river discharges between 300,000 and 700,000 cfs are shown on plates 86 to 88. Fish could enter the north fishway entrance and spillway bay 1 at all river flows that were studied. Use of the side entrance to allow escapement of fish from bay 1 was indicated.

69. The small attraction flow from a 12-ft-wide opening in the extended pier opposite the side opening of the north fishway entrance traveled at least 150 ft across the stilling basin when the gates in spillway bays 2 to 20 were closed.

70. Moving the north fishway entrance downstream to the end sill of the stilling basin (plan B entrance) eliminated the large eddy adjacent to the stilling basin and produced downstream flow along the right bank (photograph 20 and plates 89 to 91). The best attraction flows resulted when the spillway gates were opened uniformly for river flows less than 500,000 cfs. For higher discharges, gate openings in spillway bays 1 and 2 should be reduced to prevent roller action off the end sill from blocking the fishway entrance. In addition to improved flow conditions, the plan B entrance would eliminate the need for an extension to pier 1 and baffle piers in bay 2. However, the plan B fishway entrance would require more excavation and greater costs for reinforced concrete.

71. Most of those who attended a model demonstration 9 March 1960 favored leaving the north fishway entrance in its original position, a sill in bay 1,* baffle piers in bay 2 of the spillway, and pier 1 extended 80 ft. Satisfactory conditions for fish passage could be obtained at all river flows to 700,000 cfs by varying the amount of discharge through bay 1. No agreement was reached concerning the need for an opening in extended pier 1.

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* The sill in bay 1 remained in the general model during tests of the final structures and excavation plan (paragraphs 80 to 88). This element was not constructed in the prototype because it was found unnecessary in previously constructed Ice Harbor spillway.

South Fishway Entrance And Auxiliary Water Intake

Plans Tested

72. Fish facilities on the south shore include a powerhouse fish collection system and a 24-ft-wide fish ladder leading through the nonoverflow dam. Discharge in the fish ladder (112.5 cfs during tests in the general model) must be augmented to provide required transportation velocities and attraction flows in lower portions of the ladder, the powerhouse collection system, and the south and unit 20 entrances. In the adopted design, flow in the south fish ladder will vary from 75 to 96 cfs. Auxiliary flow up to 4170 cfs will be supplied from the tailrace by means of three turbine-driven pumps located in the assembly bay of the powerhouse.

73. Flow conditions for six designs of the south fishway entrance and eight plans for the auxiliary water intake were investigated. Schematic layouts of alternative designs for these elements are shown on plate 92. The south fishway entrance was tested as follows:

Plan A: Four 10-ft-long weirs with submerged orifices directed downstream above draft tubes of two station service units discharging a total of 400 cfs. Discharge through fishway entrance 700 cfs.

Plans B and C: Three 10-ft-long weirs facing north at the south end of powerhouse unit 1. Discharge of 1280 cfs through the entrance included 1100 cfs from two station service units. In plan C, a vertical sill or baffle either 7 or 9 ft high was located 12 ft downstream from outlets of the station service units.

Plan D: Two 6-ft-wide openings, one normal to and one directed downstream at a 30-degree angle to the sloped face of structure. Discharge through entrance 700 cfs. Station service units deleted in plans D to F.

Plan E: As above, but face of structure was vertical.

Plan F: One 12-ft-long weir directed downstream at an angle of 30 degrees from a line normal to powerhouse at south end of unit 1. Discharge through entrance 700 cfs.

74. The plan A auxiliary water intake, with invert at elev 86 (plates 92 and 93), drew water through two 20-ft-wide by 46-ft-high openings downstream from and normal to the south end of the station service bay. In other designs, the size of openings remained the same, but the angle of the intake structure with respect to the left bank and powerhouse was varied. Fig. 6 shows the plan F fishway entrance and plan H intake (final designs).

Fig. 6. General view of plan F south fishway entrance and plan H pumphouse intake (final designs).

Test procedure

75. Fishway entrance plans A to C and intake plans A to E were tested with the plan B powerhouse tailrace and with powerhouse units 1 to 8 in operation. The plan G tailrace (final design, plate 72) was used during tests of fishway entrance plans D to F and intake plans F to H. Tests of the final design (plan F fishway entrance and intake plan H, plates 116 to 120) were made with 10 powerhouse units and with fishway and pumped flows that were furnished by the Walla Walla

District (table L). In operation of the model, fish attraction water at the south fishway entrance and at the upstream end of the powerhouse collection channel was supplied by means of separate orifice-controlled discharges from the forebay. Measured discharges were drawn through the auxiliary water intakes and returned to the forebay to compensate for flows required by the system.

Test Results

76. Flow conditions at the south fishway entrance and auxiliary water intake of original design were not satisfactory. Upstream flow over the elev 150 berm along the left bank could have led fish away from the fishway entrance (plates 93 and 94). Discharge from the fishway diffused into the auxiliary water intake, and there was no definite attraction flow toward the fishway entrance. Excessive turbulence and upwelling resulted as outflows from the station service units impinged against the left bank.

77. Flow conditions for several alternative designs that were tested are shown on plate 95. With the plan B fishway entrance and intake, upstream flow around the intakes was objectionable because fish might be diverted from the entrance. The eddy was reduced by intake plans C and D, but upstream flow and nonuniform current directions were intensified by the plan C fishway entrance and plan E intake. Sloping (plan D) and vertical (plan E) faces for the fishway entrance were equally satisfactory. With both entrance gates open, discharge through the upstream opening reduced the effectiveness of attraction flow from the powerhouse collection channel at unit 1.

78. The plan F fishway entrance was clearly superior to any of the previous designs when it was tested with intake plans G and H. Flow conditions at the plan F fishway entrance were investigated for various river discharges and methods of project operation. The river discharge had little effect on current patterns at the south fishway entrance when powerhouse units 1 to 8 were operated. With powerhouse unit 1 or units 1 and 2 closed during a river discharge of 200,000 cfs, large counter-clockwise eddies downstream from the closed units

blocked the path of fish that would move upstream along the Oregon shore. A discharge of 700 cfs from the plan F fishway entrance penetrated tailwater far enough to attract fish from this eddy (photograph 21).

79. Distribution of flow at the plan F pumphouse intake was uniform, but velocities of 4 to 6 fps were high enough to smother small fish against the screened openings (plate 95). Turbulence resulted as flow from the powerhouse impinged against a rock shoulder at the downstream end of the intake structure. The impingement was eliminated when the intake was normal to the powerhouse, but distribution of flow into the plan G intake was not uniform. In plan H, the rock shoulder at the downstream end of the plan F intake was removed. This reduced eddy currents and upwelling, decreased maximum velocities, and eliminated the danger that small fish might be held against the intake screens (plates 116 to 120). As a result of the foregoing tests, the plan F fishway entrance and the plan H pumphouse intake were selected as the final design.

Final Design

Operating Conditions

80. Adopted designs for all except two elements of the project were reproduced in the 1:80-scale general model for comprehensive tests of the final structures and excavation plan. The concrete breakwater along the river side of the downstream navigation lock approach and the extended downstream navigation approach channel were selected later. These changes did not affect the accuracy of data at other locations in the model. Operating conditions that were used during the comprehensive tests are shown in table L. The orifices in the powerhouse collection system (two per unit) were submerged 4 ft. The entrance weirs in the north fishway at unit 20 of the powerhouse were set to maintain velocities of 4 and 6 fps, respectively, for river discharges below 400,000 cfs and 8 fps for river flows above 400,000 cfs. The weir in the south fishway entrance was set to maintain velocities of 6 fps for river discharges to 400,000 cfs and 7 fps for higher flows.

Test Results

81. Water-surface elevations at all river gages are summarized in table M. Water-surface elevations adjacent to the principal structures are shown in table N. With normal pool elev 265.0 and normal tailwater elevations at river mile 214.0, the average head on 10 powerhouse units diminished from 104.4 ft for a river discharge of 100,000 cfs to 84.1 ft at 1,060,000 cfs. Head on the powerhouse did not increase when flow was passed through a minimum number of gates at the north, center, or south portions of the spillway. With The Dalles forebay at elev 160.0, the difference in tailwater elevations at opposite ends of the powerhouse was only 0.1 ft when a river discharge of 100,000 cfs was passed through units 1 to 10 of the powerhouse (table N). The differential increased to 0.6 ft when 20 units were operated during river flows of 400,000 and 600,000 cfs. The higher water-surface elevations at the south end of the powerhouse were desirable from the standpoint of fishway operation (see paragraph 58).

82. Owing to the depth of water and the large forebay, different methods of project operation had little effect on flow conditions upstream from the structures (plates 96 to 115). The best flow conditions for river navigation and fish passage downstream from the project existed when the spillway was closed or operated with uniform gate openings (photographs 22 to 34). Conditions were less desirable when different groups of spillway gates were opened (plates 102 to 104 and 108 to 110) or when the gate openings increased toward the center of the spillway (crowned operation, plates 101 and 107). Eddies that formed downstream from closed gates or gates with reduced openings would interfere with good fish passage.

83. Velocities and current patterns at the fishway entrances are presented on plates 116 to 120. These data, obtained with uniform distribution of flow through the spillway, indicated that the fishway entrances should be satisfactory.

Nonuniform Spillway Operation

84. Experience at other large dams has shown that control of spillway discharge by means of uniform gate openings often is impractical. Constant adjustment of the gates is necessary to regulate fluctuating streamflows that result from power peaking operations of upstream projects. Operation of the spillway at John Day Dam will begin before any of the powerhouse units will be ready for use, and several flood seasons will elapse before all units of the initial installation plan will be completed.* With 10 units, considerable daily variation in the amount of water passed over the spillway may be expected just before and just after the spring freshet (March to May, and mid-June to August, respectively). Since these periods coincide with the arrival of important runs of salmon at the dam, variable use of the spillway must not interfere with attraction flows from the north fishway entrance or produce undesirable eddies and backflow into the stilling basin.

Operating Conditions

85. On the basis of earlier tests, representative conditions at the north fishway entrance and within the stilling basin would be provided with John Day pool elev 265.0, 20,000 cfs through each of 10 powerhouse units, scheduled outflows from the north fishway entrance (table L), and tailwater with The Dalles forebay at elev 160.0. The best method for passing spillway flows between 10,000 and 402,246 cfs (river discharges 210,000 to 602,246 cfs) was to be determined in the model.

Test Results

86. The tests indicated that the best flow conditions were obtained by keeping the operating bays together and increasing flow by opening each succeeding gate 1.0 ft (starting in bay 1) until a total spillway discharge of 40,000 cfs was passed with all gates open 1.0 ft (table O and plates 121 to 123). At higher spillway flows, variations in openings between adjacent gates could be increased (plates 124 to 128). Passing initial flow through the center or south spillway bays was not

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* Sixteen units are to be completed initially. See paragraph 1.

satisfactory. Large eddies along the north shore created poor conditions for fish attraction at the north fishway entrance.

87. Satisfactory conditions at the north fishway entrance require that the hydraulic jump in spillway bays 1 and 2 be located to ensure downstream flow at the entrance and at the end of the training wall between bays 1 and 2. Observations at The Dalles and McNary Dams have indicated that jets from small openings of the spillway gates become aerated and do not plunge as deeply into the stilling basin as they do in the model. For this reason, the bay 1 gate openings used in the model study should be checked in the prototype.

88. With flow in bay 1 limited to 2000 cfs, conditions for fish attraction were satisfactory for spillway flows to 69,000 cfs (plates 121 to 124). Reasonably good conditions for fish attraction were obtained by increasing the bay 1 discharge to 4900 cfs for spillway flows between 69,000 and 402,000 cfs (plates 125 to 128). As shown by plate 129, increasing the flow in bay 1 from 4900 to 13,960 cfs at a spillway discharge of approximately 402,000 cfs improved flow patterns and velocities along the north shore, but upwelling of the hydraulic jump occurred downstream of the fishway entrance. The resulting eddy action and cross-flow would decrease the effectiveness of attraction flow from the entrance. To maintain downstream currents along the north shore, the flow in bay 2 was increased for spillway discharges of 69,000 to 323,600 cfs (plates 124 to 127), and larger gate openings in bays 3 and 4 were required for spillway discharges of 148,000 cfs and greater (table 0 and plates 128 and 129).

Miscellaneous Tests

89. Information regarding the following miscellaneous subjects was obtained during development of final designs for various elements of the project: approximate limits for a disposal fill along the upstream left bank; location of a shear boom to divert debris through the spillway; forces required to hold a typical river barge away from the north

fishway pumphouse intakes; maximum heights and frequencies of waves downstream from the project; and effect of peaking operation of the powerhouse on navigation between John Day and The Dalles Dams.

90. Studies of four proposed outlines for a disposal fill along the upstream left bank indicated that velocities adjacent to the fill usually ranged from 1 to 2 fps. The respective fills had no appreciable effect on head loss in the powerhouse approach for river flows to 600,000 cfs when 20 powerhouse units were in operation. Riverward limits for the fill were adjusted until all flow conditions were satisfactory.

91. A shear boom between pier 1 at the north end of the spillway and the navigation lock guide wall was proposed as a means of diverting floating debris through the spillway. Waterproofed wooden dowels, which reproduced 3-ft-diam logs, attached end-to-end, were used for the model boom. Floating debris was simulated by means of aerosol-treated wooden dowels (logs 2 to 3 ft in diameter and from 25 to 56 ft long) and confetti. The boom was attached to the nose of spillway pier 1 and extended either to the midpoint or to the upstream end of the navigation lock guide wall. There was little tendency for debris to accumulate along the boom or for the boom to sag downstream during river flows of 200,000 and 700,000 cfs. However, the tests indicated that debris may be trapped within the upstream lock approach.

92. Forces required to hold a 42.5-ft-wide by 220-ft-long barge in the downstream lock approach away from the north fishway pumphouse were measured by calibrated bronze springs mounted at each end of the barge. The average forces obtained by this method were considered accurate within plus or minus 25 percent of the actual forces. The maximum force of 3 tons was obtained when the river discharge was 75,000 cfs, the barge was loaded to a 12-ft draft, and either four or six pumps were operated (pump discharge 1200 to 1800 cfs). A minimum force of 0.5 ton occurred when the river discharge was 700,000 cfs, the barge draft was 9 ft, and six pumps were operated. Subsurface velocities, directed toward the pump intakes, were lower than 0.5 fps for all test conditions.

93. Wave data were obtained at several locations downstream from the structures. Wave heights at each location increased with river discharge. The maximum wave, 18.9 ft high, occurred adjacent to the right training wall. Waves 6.5 ft high occurred at the left side of the plan C downstream lock approach; the average wave frequency (model) was 27 cycles per minute during a river and spillway discharge of 1,060,000 cfs. With a river discharge of 700,000 cfs, a spillway flow of 500,000 cfs and 10 powerhouse units in operation, waves 7.2 ft high were measured at the north fishway entrance.

94. Large fluctuations in discharge occur downstream from power projects that are used as "peaking plants". The following tests were made to determine whether this type of operation would have a detrimental effect on river traffic in the area between John Day and The Dalles Dams:

a. A river and powerhouse discharge of 420,000 cfs through 20 units was suddenly reduced to 210,000 cfs through 10 units.

b. As above, but discharge was reduced to 130,000 cfs (five units).

c. A river and powerhouse discharge of 130,000 cfs was suddenly increased to 420,000 cfs.

The tests indicated that, owing to the size of The Dalles pool, peaking operation of the John Day Project will have little effect on river traffic.

TABLE A

FEATURES TESTED

Second - Step Cofferdam, First - Stage Structures

Feature	Plan Of Feature Reproduced In Model For Each Test													
Cofferdam	A	A	A	B	B	B	B	B	C	C	C	D	D	D
Spillway Crest	A	B	B	B	C	D	D	E	F	F	F	G	G	G
Spillway Approach	A	A	A	B	B	B	B	B	B	C	D	E	E	E
Spillway Tailrace	A	A	B	B	B	B	C	C	C	C	C	C	C	C
Temporary Fishways														
North	A	A	A	A	A	A	A	A	A	A	A	A	A	A
South	-	-	-	A	A	A	A	A	A	A	A	B	B	B
Navigation Lock Approaches														
Upstream	A	A	A	A	A	A	B	B	B	B	B	B	B	B
Downstream	A	A	A	A	A	A	B	B	B	B	B	G*	H	I
Highway Detour Fill	-	-	-	-	-	-	-		-	-	-	A	A	A
Disposal Areas**														
Upstream	-	-	-	-	-	-	-		-	-	-	G	G	G
Downstream	-	-	-	-	-	-	-		-	-	-	E	E	E

* Downstream navigation lock approach plans C to F were studied with permanent structures.

** Disposal plans not shown were studied with permanent structures.

TABLE B

WATER - SURFACE ELEVATIONS ALONG CREST PIERS

Plan D Spillway, Plans A and B Piers
Second-Step Cofferdam, First-Stage Structures
River Discharge 700,000 CFS

Feet From	Pier 11		Pier 12		Pier 13		Pier 14	
Crest Axis	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
	Water-Surface Elevations In Feet MSL							
	PLAN A PIERS							
-20	182.2	182.0	179.9	179.8	181.0	180.9	182.1	182.0
-10	181.0	171.0	178.2	167.0	179.0	170.5	179.0	173.0
0	176.5	161.5	176.2	161.3	175.0	161.6	174.2	165.1
10	174.0	158.0	173.0	161.2	172.0	157.2	171.0	162.0
20	171.0	158.3	170.0	165.5	169.0	156.2	168.8	162.0
30	168.4	161.1	165.5	168.2	167.5	157.2	167.5	164.0
40	165.8	167.7	163.2	169.0	165.9	160.8	166.4	169.0
50	163.8	172.4	161.2	169.7	164.4	167.1	165.5	172.7
60	163.0	173.5	160.1	169.0	163.6	171.0	165.0	172.0
70	163.9	171.4	162.8	168.4	164.8	171.2	165.9	170.4
75	165.2	169.0	165.0	167.0	166.2	170.2	167.0	169.3
	PLAN B PIERS							
-30	182.6	182.0	183.0	182.0	183.0	182.4	182.5	182.5
-20	175.5	156.0	176.0	159.5	175.9	160.0	173.1	163.8
-10	171.2	158.2	172.7	161.0	171.0	159.3	170.5	162.0
0	167.0	169.0	168.1	163.9	168.0	162.0	167.5	164.0
10	163.7	167.7	165.5	166.2	166.1	167.2	166.4	166.4
20	162.0	168.6	163.1	167.8	164.8	170.0	165.2	169.7
30	159.1	169.1	161.0	167.4	163.8	169.3	164.0	170.8
40	158.5	168.9	160.1	166.8	162.2	168.0	163.1	169.8
50	161.0	167.1	162.0	166.9	162.2	166.7	163.2	169.0
60	161.8	167.0	164.2	167.1	163.4	167.0	164.5	168.7
70	162.4	166.9	166.4	167.6	165.1	167.3	166.1	167.6
75	163.0	167.0	167.8	168.0	166.2	167.6	167.0	168.4

NOTES
1. Low bays were completed to elev 137.5.
2. The river flow was diverted through spillway bays 1 to 18.
3. Flow directions and velocities are shown on plate 38.
4. Distances are shown looking downstream.

TABLE C

WATER-SURFACE ELEVATIONS AT PRINCIPAL STRUCTURES

Plan D Second-Step Cofferdam, First-Stage Structures

Location of Observations	River Discharge In 1000 CFS				
	100	200	400	700	800
	Water - Surface Elevations in Feet MSL				
Cofferdam Cells					
19	161.1	163.7	170.8	181.9	186.3
20	161.0	163.4	168.7	178.0	181.2
21	161.1	163.5	169.6	179.5	183.8
4	161.0	163.4	168.8	178.0	181.1
23	161.1	163.3	168.6	177.3	181.0
24	161.0	163.4	168.6	177.4	181.1
25	161.0	163.1	169.6	178.0	181.7
26	160.3	161.6	164.1	168.9	169.6
27	160.7	162.3	166.3	172.0	171.9
28	160.7	162.5	166.7	172.8	174.4
29	160.5	162.3	166.7	173.0	175.7
15	160.4	162.3	166.3	173.1	174.5
Navigation Lock					
Upstream	161.1	163.8	170.9	182.5	-
Downstream	160.6	162.2	166.3	173.4	-
Spillway Pier 1					
Upstream	160.7	162.7	168.3	178.2	-
Downstream	160.4	161.7	163.9	169.0	-
Spillway Pier 8					
Upstream	160.7	162.2	166.2	175.5	-
Downstream	160.5	161.7	164.8	168.3	-
Spillway Pier 15					
Upstream	160.7	163.0	169.2	178.8	-
Downstream	160.6	161.8	165.0	167.6	-
North Fishway Pumphouse	160.6	162.2	166.3	173.4	-

NOTES:

1. Designations of adopted designs for respective elements are listed in table A.
2. Flow conditions for the above river discharges are shown on plates 30 to 33.
3. Water-surface elevations at river gages are presented in table D.

TABLE D

WATER-SURFACE ELEVATIONS AT RIVER GAGES

Plan D Second-Step Cofferdam, First-Stage Structures

Gage	River Discharge In 1000 CFS						
No.	100	200	400	600	700	750*	800**
	Water-Surface Elevations In Feet M.S.L.						
F - 1	160.8	163.1	169.5	176.1	179.8	181.7	183.8
10	161.0	163.6	170.7	178.0	181.9	183.9	186.1
11	160.9	163.5	170.6	177.9	182.0	183.9	186.2
12	160.9	163.5	170.7	178.1	182.1	184.2	186.3
13	160.7	163.0	169.1	175.6	179.4	181.3	183.5
14	160.9	163.6	170.7	178.2	182.3	184.3	186.4
16	161.0	163.7	170.8	178.3	182.3	184.3	186.5
20	160.5	162.0	166.0	170.5	172.7	173.9	174.9
21	160.5	162.0	166.3	170.7	173.1	174.2	175.2
22	160.5	162.1	166.3	170.7	173.1	174.0	175.1
23	160.5	162.1	166.5	171.3	173.8	174.9	176.0
24	160.4	162.8	166.1	171.0	173.4	174.6	175.6
25	160.4	161.8	165.9	170.3	172.7	173.6	174.7
26	160.4	161.8	165.8	170.6	173.0	174.2	175.3
27	160.4	161.8	165.8	170.5	172.9	174.0	175.1
28	160.4	161.7	165.4	169.8	172.2	173.3	174.3
T W	160.4	161.7	165.4	169.8	172.2	173.3	174.3

* Downstream cells of cofferdam overtopped

** Downstream embankment overtopped

NOTES: 1. Locations of gages (except gage F-1) are shown on plate 2.

2. The location of gage F-1 and flow conditions for selected river discharges are shown on plates 30 to 33.

TABLE E

DISCHARGE RATINGS AND WATER-SURFACE ELEVATIONS

Plans A to C Skeleton Units

Discharge Per Unit In CFS (Q)	Head On Unit In Ft (H)	Energy Grade Line In Feet MSL		Minimum Area Of Draft Tube In Sq Ft (A)	Discharge Coefficient	Water-Surface Elevation In Feet MSL		
							Tailwater	
		Forebay	Tailrace		$C = Q/A\sqrt{2gH}$	Inside Unit	D/S Face Pwhse	TW Gage
				Plan A				
5,000	0.57	161.0	160.4	1355	0.61	161	160.3	160.4
10,000	1.76	162.5	160.7		0.69	162	160.4	160.6
20,100	7.0	166.9	159.9		0.70	166.5	158.4	159.4
31,300	17.3	185.1	167.8		0.69	184	164.4	166.9
31,300	17.3	180.0	162.7		0.69	179	159.4	161.6
				Plan B				
5,000	0.92	162.3	161.3	871	0.75	162	161.2	161.3
10,000	3.26	165.1	161.8		0.79	165	161.5	161.7
20,000	11.8	174.8	163.0		0.83	174	161.8	162.6
25,500	18.5	181.5	163.0		0.85	180	161.5	162.3
25,500	18.3	181.5	163.2		0.85	180.5	161.8	162.5
28,470	22.9	185.3	162.4		0.85	184.5	160.8	161.5
28,470	22.8	181.7	158.9		0.85	179.5	157.0	157.8
				Plan C				
5,000	0.42	160.8	160.4	1450	0.66	160.5	160.2	160.3
10,000	1.18	162.0	160.8		0.79	161.5	160.5	160.7
15,000	2.69	164.7	162.0		0.79	164	161.2	161.7
20,000	4.8	167.8	163.0		0.78	167.5	161.7	162.5
25,000	7.4	172.3	164.9		0.79	171	162.9	164.3
25,000	7.5	172.5	165.0		0.79	171.5	162.9	164.4
30,000	10.7	177.3	166.6		0.79	176	164.0	165.9
30,000	10.6	177.3	166.7		0.79	176	164.0	165.8
36,000	16.0	185.3	169.3		0.77	183	165.7	168.2
36,100	16.0	185.0	169.0		0.78	183	165.3	167.9
37,800	17.6	185.1	167.5		0.78	183	163.3	166.2
40,200	19.9	183.8	163.9		0.78	182	160.0	162.2

NOTES:
1. Forebay and tailwater gages located 265 ft upstream and 531 ft downstream from CBL (plate 43).
2. Details of skeleton units shown on plates 43 (plan A) and 44 (plans B and C).
3. Average water-surface elevation inside unit estimated to nearest 0.5 ft.

TABLE F

DISCHARGE RATINGS AND WATER-SURFACE ELEVATIONS

Plans D and E Skeleton Units

Discharge Per Unit In CFS (Q)	Head On Unit In Ft (H)	Energy Grade Line In Feet MSL		Minimum Area Of Draft Tube In Sq Ft (A)	Discharge Coefficient $C = Q/A\sqrt{2gH}$	Water-Surface Elevation In Feet MSL		
						Inside Unit	Tailwater	
		Forebay	Tailrace				D/S Face Pwhse	TW Gage
Plan D								
5,000	0.32	160.8	160.5	1557	0.71	160.5	160.3	160.5
10,000	0.94	161.4	160.5		0.83	161.5	160.0	160.4
15,000	2.27	164.1	161.8		0.80	163.5	161.2	161.5
20,000	3.9	166.9	163.0		0.81	166	161.8	162.6
20,000	4.0	166.5	162.5		0.80	166	161.2	162.0
25,000	6.5	171.2	164.7		0.79	170	162.9	164.1
25,500	6.8	169.6	162.8		0.78	168.5	160.9	162.1
26,000	7.0	170.7	163.7		0.79	170	161.8	163.0
30,000	9.4	173.2	163.8		0.78	172	161.3	162.8
35,000	12.6	180.7	168.1		0.79	179	165.0	167.0
35,000	12.9	181.0	168.1		0.78	179	165.1	167.1
38,000	14.8	184.7	169.9		0.79	183	166.3	168.7
39,000	15.8	185.9	170.1		0.79	183	166.3	168.8
40,800	17.1	185.4	168.3		0.79	183	164.3	166.9
42,000	18.2	185.5	167.3		0.79	183	162.8	165.6
42,000	17.9	184.9	167.0		0.80	183	162.7	165.4
Plan E								
5,000	0.40	159.5	159.1	1557	0.63	159	158.9	159.1
5,000	0.20	160.3	160.1		0.89	160	159.8	160.0
10,000	0.83	161.2	160.4		0.88	160.5	160.0	160.3
10,000	0.87	160.8	159.9		0.86	160.5	159.6	159.8
15,000	1.92	162.6	160.7		0.87	162	160.0	160.4
20,000	3.3	164.8	161.5		0.88	164.5	160.3	161.1
20,800	3.6	166.4	162.8		0.88	166	161.6	162.4
25,100	5.1	169.3	164.2		0.89	168.5	162.6	163.6
30,000	7.4	172.8	165.4		0.88	171.5	162.9	164.5
32,200	8.6	175.8	167.2		0.88	174.5	164.5	166.3
35,000	10.0	177.9	167.9		0.89	176.5	164.9	166.8
36,700	11.1	179.1	168.0		0.88	177	164.5	166.8
39,000	12.5	182.7	170.2		0.88	180	166.3	169.0
40,000	13.0	182.7	169.7		0.89	180.5	165.7	168.4
40,200	13.3	183.6	170.3		0.88	181	166.3	169.0
40,300	13.3	183.7	170.4		0.88	181	166.5	169.1
42,000	14.2	185.8	171.6		0.89	183	167.3	170.2
45,000	16.5	186.1	169.6		0.89	183	164.7	167.9

NOTES 1. Forebay and tailwater gages located 265 ft upstream and 531 ft downstream from CBL (plate 43).

2. Details of skeleton units shown on plates 44 and 45, respectively.

3. Average water-surface elevation inside unit estimated to nearest 0.5 ft.

TABLE G

DISCHARGE RATINGS AND WATER-SURFACE ELEVATIONS

Plans F and G Skeleton Units

Discharge Per Unit In CFS (Q)	Head On Unit In Ft (H)	Energy Grade Line In Feet MSL		Minimum Area Of Draft Tube In Sq Ft (A)	Discharge Coefficient C = Q/A$\sqrt{2gH}$	Water-Surface Elevation In Feet MSL		
		Forebay	Tailrace			Inside Unit	Tailwater D/S Face Pwhse	Tailwater TW Gage
				Plan F				
5,000	0.34	161.6	161.3	1607	0.67	161.5	160.8	161.3
10,000	1.11	161.3	160.2		0.74	161	160.0	160.0
15,000	2.54	163.3	160.7		0.73	163	160.0	160.5
20,000	4.4	166.4	162.0		0.74	166	160.7	161.6
25,000	6.9	170.5	163.6		0.74	169.5	161.8	163.0
25,000	7.1	171.5	164.4		0.73	170.5	162.3	163.8
27,000	8.2	173.0	164.8		0.73	172	162.1	164.1
28,000	8.7	174.2	165.5		0.74	173	162.8	164.7
30,000	10.0	177.1	167.1		0.74	176	164.0	166.3
33,800	13.3	181.0	167.8		0.72	179	163.8	166.8
35,000	14.0	182.7	168.7		0.73	180.5	164.6	167.7
37,000	15.8	185.5	169.7		0.72	183	165.3	168.6
38,000	16.8	185.4	168.6		0.72	183	163.7	167.4
38,900	17.5	185.2	167.7		0.72	182.5	162.8	166.3
40,300	18.6	184.2	165.6		0.73	181.5	160.0	164.0
41,900	20.0	185.7	165.7		0.73	182.5	159.8	164.0
				Plan G				
5,000	0.45	162.0	161.5	1614	0.58	162	161.5	161.5
10,000	1.00	160.7	159.7		0.77	160.5	159.5	159.6
15,000	1.94	162.5	160.6		0.83	162	160.0	160.3
20,000	3.26	166.5	163.3		0.85	166	162.3	162.9
24,700	5.1	166.9	161.8		0.85	166	160.3	161.1
27,900	6.3	170.0	163.7		0.86	169	161.9	162.9
30,000	7.2	175.1	167.9		0.86	174	165.7	167.1
31,400	8.1	175.3	167.2		0.85	174	164.8	166.3
31,700	8.2	176.9	168.7		0.86	175.5	166.3	167.9
34,200	9.6	177.3	167.7		0.85	176	165.0	166.7
37,700	11.8	180.6	168.8		0.85	178	165.5	167.6
39,600	13.2	180.3	167.2		0.84	177.5	163.5	165.7
40,200	13.5	183.0	169.5		0.85	180	165.8	168.2
42,500	15.0	184.3	169.3		0.85	181	165.2	167.8

NOTES: 1. Forebay and tailwater gages located 265 ft upstream and 531 ft downstream from CBL (plate 43).

2. Details of skeleton units shown on plate 46.

3. Average water-surface elevation inside unit estimated to nearest 0.5 ft.

TABLE H

DISCHARGE RATINGS AND WATER-SURFACE ELEVATIONS

Plans H and I Skeleton Units

Discharge Per Unit In CFS (Q)	Head On Unit In Ft (H)	Energy Grade Line In Feet MSL		Minimum Area Of Draft Tube In Sq Ft (A)	Discharge Coefficient $C = Q/A\sqrt{2gH}$	Water-Surface Elevation In Feet MSL		
		Forebay	Tailrace			Inside Unit	Tailwater	
							D/S Face Pwhse	TW Gage
				Plan H				
5,000	0.37	159.4	159.0	1614	0.63	159	158.9	159.0
7,800	0.59	163.5	162.9		0.78	163.5	162.7	162.8
10,000	0.91	161.4	160.5		0.81	161	160.0	160.4
15,000	2.09	162.6	160.6		0.80	162	159.8	160.3
20,000	3.51	166.7	163.2		0.82	166	161.9	162.7
25,000	5.4	168.3	162.9		0.83	167.5	161.2	162.2
27,900	6.9	171.1	164.2		0.82	170	162.1	163.4
30,000	8.1	173.4	165.3		0.81	172	162.9	164.4
32,200	9.1	176.4	167.3		0.82	175	164.6	166.4
35,000	10.8	177.7	166.9		0.82	176	163.5	165.7
38,000	13.4	182.0	168.6		0.80	179.5	164.8	167.4
39,000	14.1	184.5	170.4		0.80	182	166.2	169.2
40,000	14.8	184.7	169.9		0.80	182	165.6	168.6
41,000	15.5	183.4	167.9		0.80	180.5	163.3	166.4
42,000	16.3	183.8	167.5		0.80	181	162.6	165.9
44,000	18.0	185.6	167.6		0.80	182.5	162.5	165.9
				Plan I				
5,000	0.44	161.5	161.0	1617	0.58	161	161.0	161.0
8,000	0.72	163.0	162.3		0.73	162.5	162.0	162.2
10,000	0.78	161.7	160.9		0.87	161	160.6	160.8
13,900	1.56	162.5	160.9		0.86	162	160.5	160.7
15,000	1.77	160.7	159.0		0.87	160.5	158.5	158.7
20,000	3.16	165.8	162.7		0.87	165.5	161.8	162.2
25,000	4.9	166.1	161.2		0.87	165	159.7	160.4
28,000	6.3	168.8	162.5		0.86	168	160.8	161.7
30,000	6.8	171.1	164.3		0.89	170	162.3	163.3
32,100	8.1	173.9	165.8		0.87	172.5	163.6	164.8
35,000	9.4	176.5	167.1		0.88	175	164.5	166.0
38,000	11.4	180.0	168.6		0.87	177.5	165.3	167.3
40,000	12.6	181.8	169.2		0.87	179	166.0	167.9
42,000	14.0	184.4	170.4		0.87	181	166.5	168.9
43,100	14.8	184.2	169.4		0.87	181	165.1	167.8
44,800	15.8	183.1	167.3		0.87	179.5	162.8	165.4

NOTES:
1. Forebay and tailwater gages located 265 ft upstream and 531 ft downstream from CBL (plate 43).
2. Details of skeleton units shown on plate 46.
3. Average water-surface elevation inside unit estimated to nearest 0.5 ft.

TABLE I

DISCHARGE RATINGS AND WATER-SURFACE ELEVATIONS

Plan J Skeleton Unit

Discharge Per Unit In CFS (Q)	Head On Unit In Ft (H)	Energy Grade Line In Feet MSL		Minimum Area Of Draft Tube In Sq Ft (A)	Discharge Coefficient C = $Q/A\sqrt{2gH}$	Water-Surface Elevation In Feet MSL		
							Tailwater	
		Forebay	Tailrace			Inside Unit	D/S Face Pwhse	TW Gage
5,000	0.77	159.2	158.5	1355	0.52	158.5	157.8	158.4
5,880	0.97	157.1	156.1		0.55	156.5	156.0	156.1
8,060	1.17	160.4	159.2		0.69	159.5	158.9	159.2
10,000	1.79	160.7	158.9		0.69	159.5	158.3	158.8
14,660	3.74	162.0	158.3		0.70	161	157.2	158.0
15,000	3.82	164.6	160.7		0.71	164.5	159.9	160.5
20,220	6.8	167.2	160.3		0.71	166	158.8	159.8
20,500	7.1	168.9	161.8		0.71	168.5	160.1	161.3
25,000	10.7	174.9	164.2		0.70	174	162.0	163.6
27,200	12.5	178.3	165.8		0.71	177	163.0	165.1
28,780	14.0	179.1	165.2		0.71	178	162.1	164.4
29,400	14.5	179.5	165.0		0.71	178	162.1	164.2
32,670	18.0	186.0	168.0		0.71	184	164.5	167.1
34,270	19.6	186.0	166.5		0.71	184	162.7	165.4
36,500	22.4	186.6	164.2		0.71	184	159.4	162.8
43,370	31.1	187.0	155.9		0.71	183.5	149.5	152.5

NOTES:

1. Forebay and tailwater gages located 265 ft upstream and 531 ft downstream from CBL (plate 43).
2. Details of skeleton units shown on plate 46.
3. Average water-surface elevation inside unit estimated to nearest 0.5 ft.

TABLE J

WATER-SURFACE ELEVATIONS AND AVERAGE HEAD ON POWERHOUSE

Powerhouse Tailrace Plans A to G

Discharge In CFS		Powerhouse Units Operating	Tailrace Plan	Water-Surface Elevations on Center Line of Powerhouse Units *										Average WS Elev at Operating Units	Average Head** On Powerhouse Units in Ft
River	Powerhouse			1	3	5	7	9	11	13	15	17	19		
700,000	200,000	1 to 10	A	172.9	172.9	172.9	172.8	172.9	172.9	172.9	172.9	173.0	173.0	172.9	92.1
	400,000	1 to 20	A	173.4	173.4	173.4	173.3	173.3	173.2	173.2	173.0	173.0	172.8	173.2	91.8
600,000	200,000	1 to 10	A	170.5	170.5	170.4	170.4	170.3	170.3	170.3	170.3	170.3	170.3	170.4	94.6
	400,000	1 to 20	A	171.0	171.0	171.0	170.9	170.8	170.7	170.6	170.5	170.4	170.3	170.7	94.3
	184,000	1 to 8	B	170.6	170.6	170.5	170.5	170.6	170.7	170.7	170.7	170.8	170.8	170.6	94.4
	460,000	1 to 20	B	170.9	171.0	171.0	171.0	171.0	170.9	170.8	170.7	170.6	170.6	170.8	94.2
	184,000	1 to 8	C	170.6	170.6	170.6	170.6	170.6	170.6	170.6	170.6	170.7	170.7	170.6	94.4
	460,000	1 to 20	C	170.8	170.9	171.0	171.0	171.0	170.9	170.8	170.7	170.7	170.6	170.8	94.2
	184,000	1 to 8	D	170.4	170.5	170.5	170.5	170.5	170.6	170.6	170.6	170.7	170.7	170.5	94.5
	460,000	1 to 20	D	171.0	171.1	171.1	171.1	171.0	170.8	170.7	170.7	170.7	170.6	170.9	94.1
	184,000	1 to 8	E	170.8	170.8	170.8	170.7	170.7	170.7	170.7	170.7	170.7	170.7	170.8	94.2
	460,000	1 to 20	E	171.5	171.6	171.5	171.5	171.4	171.3	171.3	171.2	171.1	170.9	171.3	93.7
	184,000	1 to 8	F	170.5	170.9	170.8	170.7	170.7	170.7	170.7	170.7	170.8	170.9	170.8	94.2
	460,000	1 to 20	F	171.3	171.6	171.5	171.4	171.4	171.3	171.2	171.1	171.0	170.9	171.3	93.7
	184,000	1 to 8	G	170.9	170.9	170.9	170.8	170.8	170.8	170.8	170.8	170.8	170.8	170.9	94.1
	460,000	1 to 20	G	171.7	171.6	171.5	171.4	171.4	171.3	171.2	171.2	171.1	170.9	171.3	93.7
420,000	360,000	1 to 18	A	167.0	167.0	166.8	166.7	166.6	166.5	166.5	166.4	166.3	166.3	166.6	98.4
	412,700	1 to 20	A	167.1	167.1	167.1	166.8	166.7	166.5	166.4	166.3	166.2	166.2	166.4	98.6
400,000	171,200	1 to 8	B	166.2	166.2	166.2	166.0	166.1	166.1	166.1	166.2	166.2	166.1	166.2	98.8
	399,400	1 to 19	B	166.3	166.3	166.3	166.2	166.1	165.9	165.9	165.9	165.9	165.9	166.1	98.9
	171,200	1 to 8	D	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.2	166.2	166.2	166.3	98.7
	398,680	1 to 19	D	166.8	166.8	166.7	166.6	166.6	166.5	166.3	166.2	166.2	166.2	166.5	98.5
	171,200	1 to 8	E	166.3	166.3	166.3	166.3	166.3	166.3	166.3	166.2	166.2	166.2	166.3	98.7
	398,680	1 to 19	E	166.7	166.8	166.7	166.6	166.6	166.5	166.3	166.2	166.2	166.2	166.4	98.6
	171,200	1 to 8	F	166.3	166.3	166.3	166.2	166.2	166.2	166.2	166.2	166.2	166.2	166.3	98.7
	398,680	1 to 19	F	166.4	166.6	166.5	166.4	166.4	166.3	166.2	166.2	166.1	166.1	166.3	98.7
	171,200	1 to 8	G	166.3	166.3	166.3	166.3	166.3	166.2	166.2	166.2	166.3	166.3	166.3	98.7
	398,680	1 to 19	G	166.7	166.6	166.5	166.5	166.4	166.3	166.2	166.2	166.2	166.2	166.4	98.6
300,000	200,000	1 to 10	A	164.4	164.4	164.4	164.3	164.2	164.1	164.1	164.1	164.0	164.0	164.3	100.7
200,000	199,300	1 to 10	A	162.3	162.2	162.2	161.9	161.9	161.9	161.9	161.8	161.9	161.8	162.1	102.9
	162,400	1 to 8	B	161.9	161.9	161.9	161.9	161.9	161.9	161.9	162.0	161.9	161.9	161.9	103.1
	162,400	1 to 8	D	162.2	162.2	162.1	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.1	102.9
	162,400	1 to 8	E	162.1	162.2	162.1	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.2	102.8
	162,400	1 to 8	F	162.1	162.1	162.1	161.9	161.9	161.9	161.9	161.9	161.9	161.9	162.0	103.0
	162,400	1 to 8	G	162.2	162.1	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	103.0
	162,400	1 to 8	G'	158.5	158.6	158.5	158.3	158.4	158.4	158.4	158.4	158.4	158.4	158.5	106.5
100,000	99,780	1 to 8	G'	156.0	156.0	156.0	156.0	155.9	155.9	155.9	155.9	155.9	155.9	156.0	109.0

* Water-surface elevations measured at downstream face of powerhouse on center line of units 1, 5, 11, 15, 18, and 20

** Difference between average water-surface elevation and normal pool elev 265.0

G' Forebay elev 155.0 at The Dalles Dam

NOTES:
1. Tailrace designs tested are shown on plates 66 to 72.
2. The effects of normal pool elev 160.0 at The Dalles Dam were simulated in all tests except G'.

TABLE K

WATER-SURFACE ELEVATIONS

Original Structures and Excavation Plan

Flow Distribution in CFS					Water-Surface Elevations Downstream From Main Structures														Water-Surface Elevations In Forebay						
River	Powerhouse		Spillway		River Gages						Powerhouse Units						Fwy Entrances		River Gages				Powerhouse Units		
	Unit Nos.	Total Flow	Bays Open	Total Flow	20	21	22	23	TW	Lock Outlet	1	5	9	13	17	19	North	Unit 20	11	12	13	14	5	11	18
					Water-Surface Elevations In Feet M.S.L.																				
100,000	1-10	100,000*	None	None	160.3	160.3	160.3	160.3	160.3	160.3	160.4	160.3	160.3	160.3	160.2	160.2	160.3	160.3	265.0	265.0	265.0	265.0	265.0	265.0	265.0
200,000	1-10	200,000*	None	None	161.4	161.9	161.9	161.9	161.7	162.0	162.3	162.2	161.9	161.9	161.9	161.9	162.0	161.9	265.0	265.0	265.0	265.0	265.0	265.0	265.0
300,000	1-10	200,000	2-20	100,000*	163.9	164.2	164.1	164.1	163.5	164.2	164.4	164.4	164.2	164.1	164.0	164.0	163.5	164.0	265.0	265.0	265.0	265.0	265.0	265.0	265.0
420,000	1-18	360,000	2-19	60,000*	166.8	166.9	166.7	166.9	165.9	167.0	167.0	166.8	166.6	166.5	166.3	166.3	166.6	166.5	265.0	265.0	265.0	265.0	265.0	265.0	265.0
420,000	1-20	412,270	1	7,730*	166.5	166.7	166.7	166.8	165.9	166.8	167.1	167.1	166.7	166.4	166.2	166.2	166.7	165.9	265.0	265.0	265.0	265.0	265.0	265.0	265.0
600,000	1-10	200,000	2-19	400,000*	171.0	171.3	171.1	171.3	169.8	171.3	170.5	170.4	170.3	170.3	170.3	170.3	169.8	170.7	265.0	265.0	265.0	265.0	265.0	265.0	265.0
600,000	1-20	400,000	2-19	200,000*	171.2	171.5	171.1	171.5	169.8	171.3	171.0	171.0	170.8	170.6	170.4	170.3	170.4	170.3	265.0	265.0	265.0	265.1	265.0	265.0	264.9
600,000	1-10	200,000	2-20	400,000*	171.1	171.2	171.1	171.3	169.8	169.8	170.8	170.8	170.7	170.7	170.8	170.9	169.5	170.7	265.0	265.0	265.0	265.0	265.0	265.0	265.0
600,000	1-20	400,000	2-20	200,000*	171.1	171.5	171.1	171.3	169.8	171.2	171.4	171.2	171.1	170.9	170.7	170.7	170.8	170.5	265.0	265.0	265.0	265.1	265.0	265.0	265.0
700,000	1-10	200,000	2-19	500,000*	173.4	173.5	173.5	173.8	172.2	173.7	172.9	172.9	172.8	172.9	173.0	173.0	170.5	173.2	265.0	265.0	264.9	265.0	265.0	265.0	264.9
700,000	1-20	400,000	2-19	300,000*	173.8	174.1	173.6	174.0	172.2	173.5	173.4	173.4	173.3	173.2	173.0	172.8	172.7	172.7	265.0	265.0	265.0	265.0	265.0	265.0	265.0
700,000	1-10	200,000	2-20	500,000*	173.6	173.8	173.7	173.9	172.2	172.9	173.2	173.2	173.1	173.1	173.1	173.3	171.7	173.1	265.1	265.1	265.1	265.1	265.0	265.0	265.0
700,000	1-20	400,000	2-20	300,000*	173.6	174.0	173.5	173.8	172.2	173.6	173.3	173.3	173.1	173.0	172.7	172.7	172.9	172.8	265.0	265.0	265.0	265.0	265.0	265.0	265.0

* Includes fish attraction flow

NOTES: 1. Gage locations are shown on plate 2.

2. Structures layout and flow conditions for selected discharges are presented on plates 58 to 66.

TABLE L

OPERATING CONDITIONS

Final Structures and Excavation Plan

Flow Distribution In CFS														Water-Surface Elevations At River Gages		
River	Powerhouse			Spillway			Fishway Entrances					Pumphouses				
	Unit Nos.	Flow Per Unit	Total Flow	Gates Open	Flow Per Bay	Total Flow	North		South		Unit 20	North	South	Gage 12 (Pool)	Mile 214 (TW)	The Dalles Pool
							Pumped	Total	Pumped	Total						
100,000	1-10	9,978	99,775	None	-	-	600	700	320	445	700	600	3300	265.0	155.6	155.0
100,000	1-10	9,978	99,775	None	-	-	600	700	475	600	700	600	3455	265.0	160.4	160.0
200,000	1-10	19,978	199,775	None	-	-	900	1000	405	530	700	900	3385	265.0	157.7	155.0
200,000	1-10	19,978	199,775	None	--	-	900	1000	495	620	700	900	3475	265.0	161.7	160.0
400,000	1-10	21,400	214,000	2-20	9,636	183,075	1200	1300	875	1000	1000	1200	4155	265.0	165.4	160.0
400,000	1-19	21,040	399,775	None	-	-	1200	1300	875	1000	1000	1200	4155	265.0	165.4	160.0
400,000	1-10	21,400	214,000	Crowned	Varied	183,075	1200	1300	875	1000	1000	1200	4155	265.0	165.4	160.0
400,000	1-10	21,400	214,000	2-11	18,308	183,075	1200	1300	875	1000	1000	1200	4155	265.0	165.4	160.0
400,000	1-10	21,400	214,000	11-20	18,308	183,075	1200	1300	875	1000	1000	1200	4155	265.0	165.4	160.0
400,000	1-10	21,400	214,000	6-15	18,308	183,075	1200	1300	875	1000	1000	1200	4155	265.0	165.4	160.0
600,000	1-10	23,000	230,000	2-20	19,320	367,075	1500	1600	875	1000	1000	1500	4155	265.0	169.8	160.0
600,000	1-20	23,000	460,000	2-20	7,214	137,075	1500	1600	875	1000	1000	1500	4155	265.0	169.8	160.0
600,000	1-10	23,000	230,000	Crowned	Varied	367,075	1500	1600	875	1000	1000	1500	4155	265.0	169.8	160.0
600,000	1-10	23,000	230,000	2-14	28,237	367,075	1500	1600	875	1000	1000	1500	4155	265.0	169.8	160.0
600,000	1-10	23,000	230,000	8-20	28,237	367,075	1500	1600	875	1000	1000	1500	4155	265.0	169.8	160.0
600,000	1-10	23,000	230,000	5-17	28,237	367,075	1500	1600	875	1000	1000	1500	4155	265.0	169.8	160.0
800,000	1-10	23,400	234,000	2-20	29,636	563,075	1700	1800	875	1000	1000	1700	4155	265.0	174.3	160.0
800,000	1-20	23,400	468,000	2-20	17,320	329,075	1700	1800	875	1000	1000	1700	4155	265.0	174.3	160.0
1,060,000	1-10	23,200	232,000	1-20	41,389	827,775	1700	1800	875	1000	1000	1700	4155	268.0	179.8	160.0
1,060,000	1-20	23,200	464,000	1-20	29,789	595,775	1700	1800	875	1000	1000	1700	4155	268.0	179.8	160.0
2,250,000	Closed	-	-	1-20	112,500	2,250,000	-	Closed	-	Closed	Closed	Closed	Closed	277.9	203.0	182.3

NOTES: 1. Tailwater elevations at river mile 214 were based on backwater computations upstream from The Dalles Dam (river mile 192.5).

2. The following fish attraction flows were introduced from the model forebay: spillway bay 1, 2700 cfs for river discharges between 400,000 and 800,000 cfs; north fishway entrance, 100 cfs; unit 20 fishway entrance 125 cfs; and powerhouse collection system 2280 cfs.

3. The north and unit 20 fishway entrance weirs were set to obtain 4 or 6 fps for river flows below 400,000 cfs and 8 fps for higher flows.

4. The south fishway entrance weirs were set for 6 fps for river discharges below 400,000 cfs and 7 fps for higher flows.

5. The powerhouse collection system orifices (two per unit) were submerged 4 ft below tailwater.

TABLE M

WATER-SURFACE ELEVATIONS AT RIVER GAGES

Final Structures and Excavation Plan

River Discharge In CFS	Forebay Gages				Downstream Gages								
	11	12	13	14	19	20	21	22	23	24	25	26	TW
100,000	265.0	265.0	265.0	265.0	155.8	155.8	155.9	155.9	155.9	155.7	155.7	155.7	155.6
100,000	265.0	265.0	265.0	265.0	160.5	160.4	160.5	160.5	160.5	160.5	160.4	160.5	160.4
200,000	265.0	265.0	265.0	265.0	158.2	158.0	158.4	158.2	158.3	158.1	158.0	158.0	157.7
200,000	265.0	265.0	265.0	265.0	161.9	161.9	161.9	161.9	161.9	161.9	161.8	161.8	161.7
400,000	265.0	265.0	265.0	265.0	166.4	166.3	166.5	166.3	166.4	165.9	165.9	165.8	165.4
400,000	265.0	265.0	265.0	265.0	166.3	166.1	166.2	166.2	166.4	166.1	165.9	165.8	165.4
400,000	265.0	265.0	265.0	265.0	165.7	166.1	165.9	166.2	166.7	166.1	165.9	165.8	165.4
400,000	265.0	265.0	265.0	265.0	165.3	166.0	165.2	166.1	166.4	166.0	165.9	165.8	165.4
400,000	265.0	265.0	265.0	265.0	165.4	165.9	162.3	165.9	166.8	165.9	165.5	165.8	165.4
400,000	265.0	265.0	265.0	265.0	165.2	166.1	165.5	166.2	166.5	166.0	165.9	165.8	165.4
600,000	265.0	265.0	265.0	265.0	170.9	171.1	171.2	171.1	171.4	170.8	170.5	170.4	169.8
600,000	265.0	265.0	265.0	265.0	171.0	171.1	171.5	171.1	171.4	170.9	170.6	170.4	169.8
600,000	265.0	265.0	265.0	265.0	169.4	170.2	169.3	170.2	171.1	170.5	169.8	170.3	169.8
600,000	265.0	265.0	265.0	265.0	169.4	170.3	169.7	170.3	170.9	170.3	169.9	170.3	169.8
600,000	265.0	265.0	265.0	265.0	169.8	170.3	165.0	170.3	171.7	170.3	169.5	170.2	169.8
600,000	265.0	265.0	265.0	265.0	169.3	170.3	169.1	170.3	171.0	170.7	170.1	170.4	169.8
800,000	265.0	265.0	265.0	265.0	175.5	175.6	176.7	175.9	176.1	175.6	175.1	175.1	174.3
800,000	265.0	265.0	265.0	265.0	175.7	175.9	176.5	175.9	176.2	175.7	175.3	175.2	174.3
1,060,000	268.0	268.0	268.0	268.1	181.0	181.3	181.5	181.2	181.7	180.1	180.3	180.7	179.8
1,060,000	268.0	268.0	268.0	268.1	181.1	181.7	182.1	181.5	181.9	180.3	180.5	180.6	179.8
2,250,000	277.8	277.9	277.1	277.9	200.2	199.7	201.0	199.1	203.1	200.5	202.0	204.0	203.0

NOTES: 1. Discharges and flow distribution are in the same order as those shown in table L.

2. Gages 12 and TW were forebay and tailwater control gages in the model.

TABLE N

WATER-SURFACE ELEVATIONS AT STRUCTURES

Final Structures and Excavation Plan

River Discharge In CFS	Upstream Of Structures			Downstream Face Of Powerhouse At Unit No.							Fwy Entrances		Pumphouses		Navig. Lock Outlet
	Gage P	Unit 20	N.Fwy Exit	2	5	8	11	15	18	20	North	South	North	South	
100,000	265.0	265.0	265.0	156.1	156.1	156.1	155.9	155.9	155.9	155.9	155.9	156.0	156.0	156.1	156.0
100,000	265.0	265.0	265.0	160.6	160.6	160.6	160.5	160.5	160.5	160.5	160.5	160.6	160.5	160.6	160.5
200,000	265.0	265.0	265.0	158.7	158.7	158.5	158.4	158.4	158.4	158.3	158.3	158.8	158.3	158.9	158.4
200,000	265.0	265.0	265.0	162.2	162.2	162.1	161.9	161.9	161.9	161.9	161.9	162.2	162.0	162.2	161.9
400,000	265.0	265.0	265.0	166.6	166.6	166.6	166.5	166.5	166.5	166.4	166.1	166.6	166.6	166.6	166.5
400,000	265.0	265.0	265.0	166.8	166.8	166.7	166.8	166.4	166.3	166.3	166.3	166.7	166.5	166.9	166.3
400,000	265.0	265.0	265.0	165.9	165.9	165.8	165.8	165.8	165.7	165.7	165.2	165.9	166.5	165.9	165.2
400,000	265.0	265.0	265.0	165.6	165.6	165.5	165.4	165.4	165.4	165.4	166.7	165.6	166.4	165.6	167.1
400,000	265.0	265.0	265.0	165.7	165.6	165.5	165.5	165.5	165.4	165.4	164.3	165.7	167.1	165.8	165.1
400,000	265.0	265.0	265.0	165.7	165.6	165.5	165.4	165.4	165.3	165.2	163.1	165.6	166.3	165.7	166.2
600,000	265.0	265.0	265.0	171.0	171.0	170.9	170.9	170.9	170.9	170.9	170.5	170.9	171.5	171.0	171.0
600,000	265.0	265.0	265.0	171.6	171.6	171.5	171.3	171.2	171.1	171.0	171.1	171.6	171.5	171.6	171.5
600,000	265.0	265.0	265.0	169.7	169.7	169.7	169.5	169.5	169.5	169.4	167.7	169.7	170.6	169.8	167.3
600,000	265.0	265.0	265.0	169.5	169.5	169.4	169.4	169.4	169.4	169.4	169.8	169.5	170.7	169.6	172.3
600,000	265.0	265.0	265.0	169.9	169.9	169.7	169.7	169.7	169.8	169.8	168.5	169.8	171.7	169.9	167.0
600,000	265.0	265.0	265.0	169.6	169.6	169.5	169.5	169.5	169.4	169.4	167.9	169.5	170.7	169.5	172.1
800,000	265.0	265.0	265.0	175.5	175.5	175.5	175.5	175.5	175.5	175.5	175.4	175.5	176.1	175.5	175.1
800,000	265.0	265.0	265.0	176.3	176.3	176.3	176.2	176.0	175.8	175.7	175.7	176.2	176.3	176.1	176.1
1,060,000	268.1	267.9	267.9	180.9	180.9	180.9	180.9	180.9	181.0	181.0	175.9	180.9	181.5	180.8	181.7
1,060,000	268.1	268.1	267.9	181.6	181.6	181.6	181.5	181.4	181.3	181.1	177.2	181.7	181.8	181.5	181.8

NOTES: 1. Discharges and flow distribution are in the same order as those shown in table L.

2. Water-surface elevations at unit 20 fishway entrance and downstream face of unit 20 were equal.

TABLE O

RECOMMENDED GATE OPENING SCHEDULE

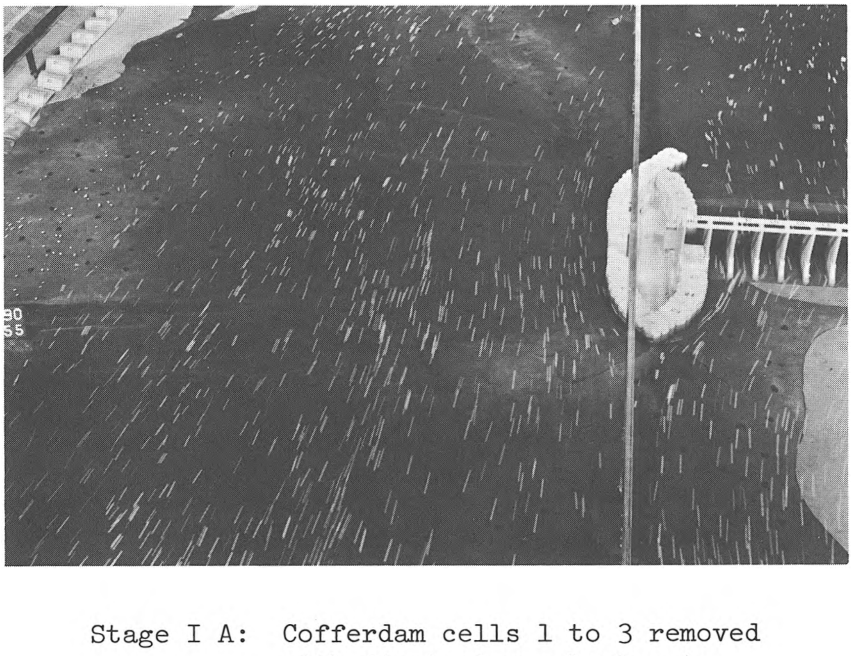
Nonuniform Spillway Operation

River Flow In 1000 CFS	Spillway Bay Number																				Total Spillway Flow In 1000 CFS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
	Gate Openings In Feet																				
210.0	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
222.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-	-	-	-	-	22
240.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	40
269.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	69
348.6	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	2.5	5.0	148.6
434.5	2.5	10.0	5.0	7.5	5.0	7.5	5.0	7.5	5.0	7.5	5.0	7.5	5.0	7.5	5.0	7.5	5.0	7.5	5.0	7.5	234.5
523.6	2.5	10.0	10.0	12.5	10.0	7.5	10.0	7.5	10.0	7.5	10.0	7.5	10.0	7.5	10.0	7.5	10.0	7.5	10.0	7.5	323.6
601.9	7.5	10.0	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	402.2
602.2	2.5	10.0	15.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	10.0	12.5	401.8
	Discharge Per Bay In 1000 CFS																				
210.0	2.0	2.0	2.0	2.0	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
222.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	-	-	-	-	-	-	-	-	-	22
240.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	40
269.0	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	2.0	4.9	69
348.6	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	4.9	9.5	148.6
434.5	4.9	18.44	9.5	13.96	9.5	13.96	9.5	13.96	9.5	13.96	9.5	13.96	9.5	13.96	9.5	13.96	9.5	13.96	9.5	13.96	234.5
523.6	4.9	18.44	18.44	22.65	18.44	13.96	18.44	13.96	18.44	13.96	18.44	13.96	18.44	13.96	18.44	13.96	18.44	13.96	18.44	13.96	323.6
601.9	13.96	18.44	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	402.2
602.2	4.9	18.44	27.13	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	18.44	22.65	401.8

\- Spillway gate closed

NOTES:
1. Gate openings shown to nearest 0.5 ft.
2. Discharges shown to nearest 100 cfs.
3. Spillway flow distributions are in the same order as those on plates 121 to 129, respectively.

Stage I: Cofferdam cells 1 to 3 left after removal of first-step embankments



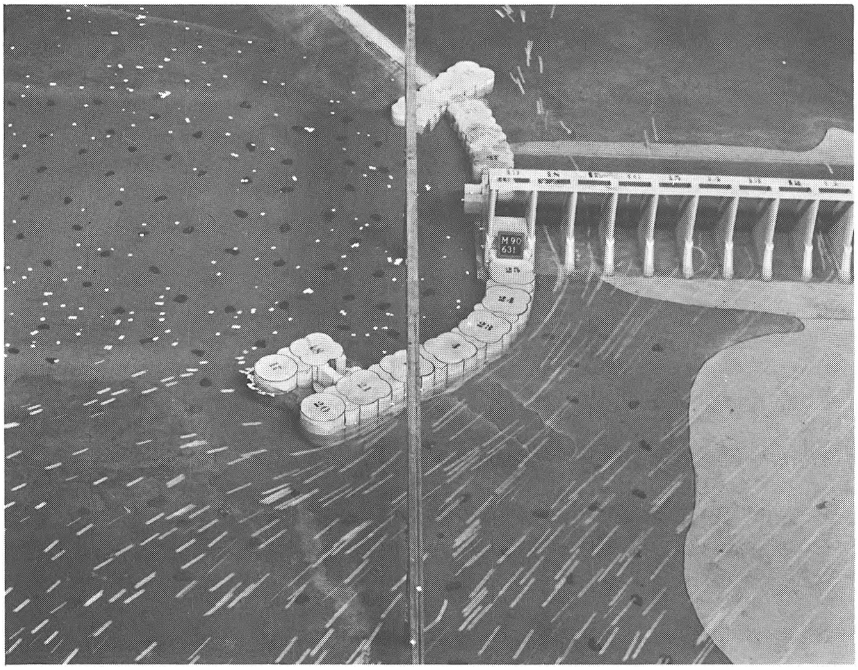
Stage I A: Cofferdam cells 1 to 3 removed with first-step embankments

Photograph 1. Flow patterns during transition between first- and second-step cofferdams; river discharge 400,000 cfs.

Stage II: Second-step cells 17 to 22 completed

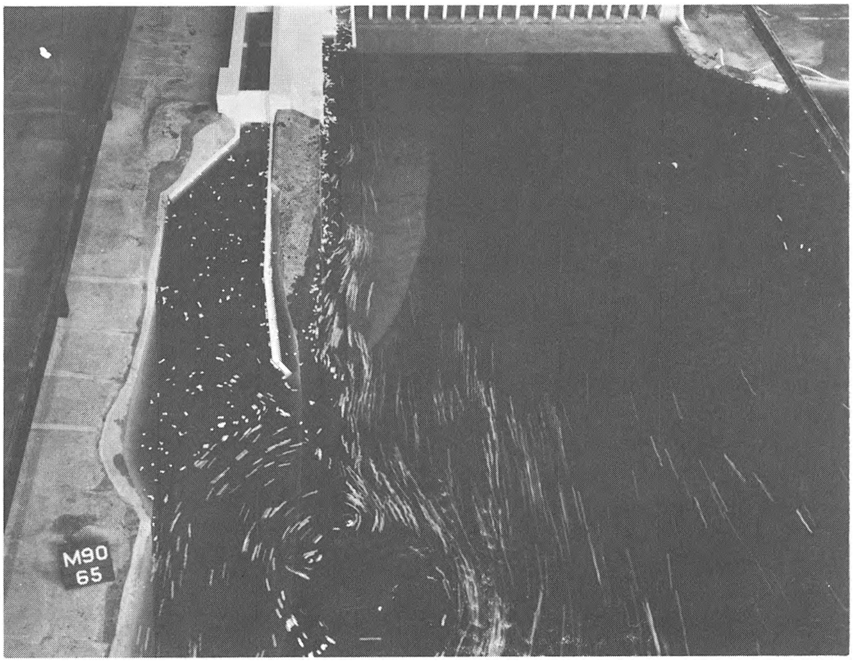
Stage III: Junior cofferdam along left bank

Photograph 2. Flow patterns during transition between first- and second-step cofferdam; river discharge 200,000 cfs.



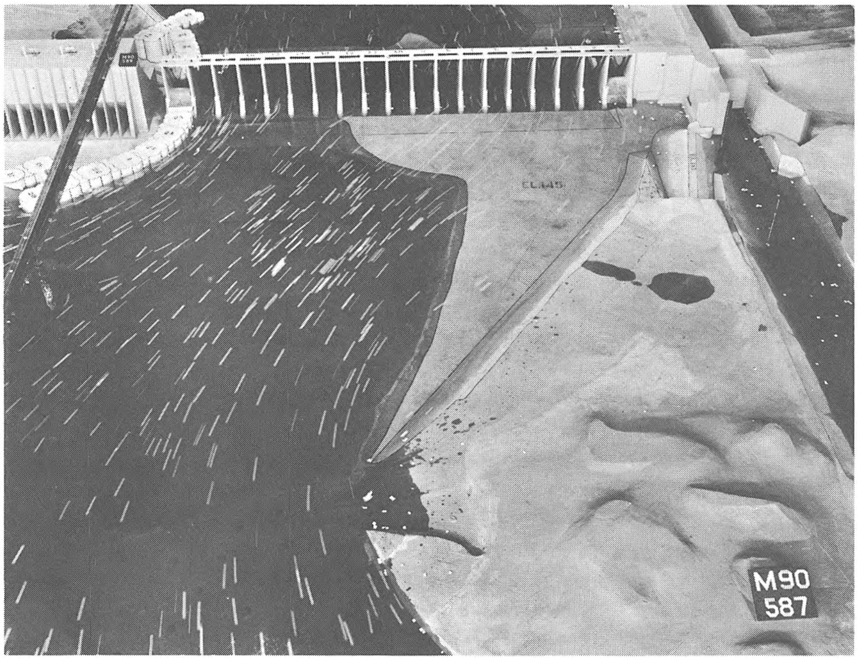
Photograph 3. Flow patterns after downstream embankment of second-step cofferdam was completed (transition stage IV); river discharge 200,000 cfs.

Plan A

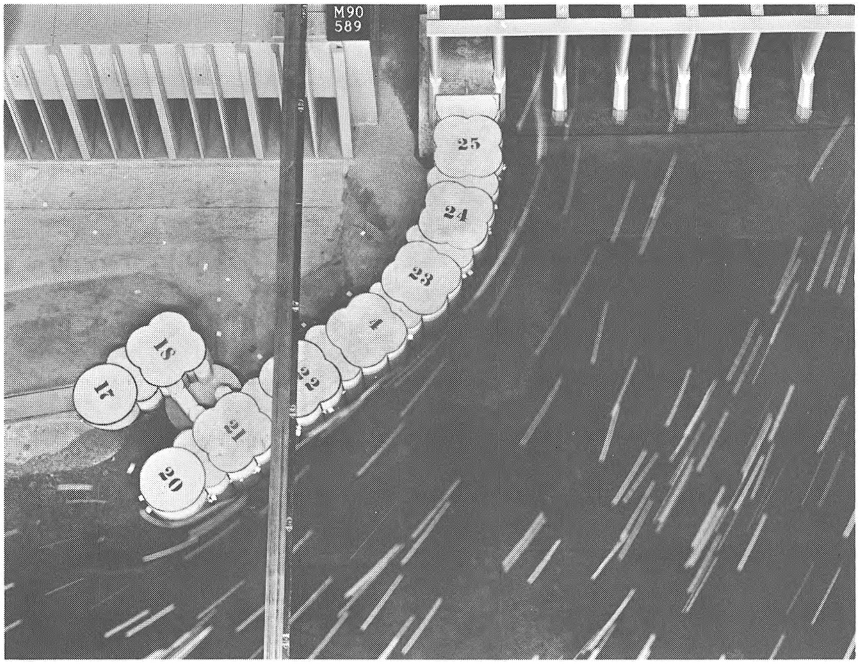


Plan B

Photograph 4. Flow patterns at plans A and B downstream navigation lock approach; plan D second-step cofferdam; river discharge 700,000 cfs.



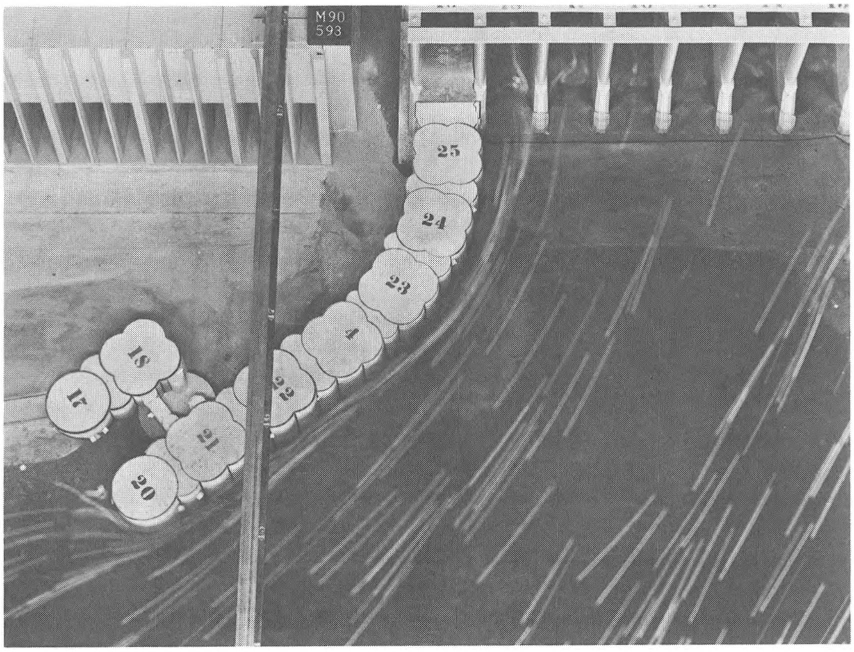
Forebay and north bank



Upstream leg

Photograph 5. Flow patterns along plan D second-step cofferdam (final design); river discharge 200,000 cfs.

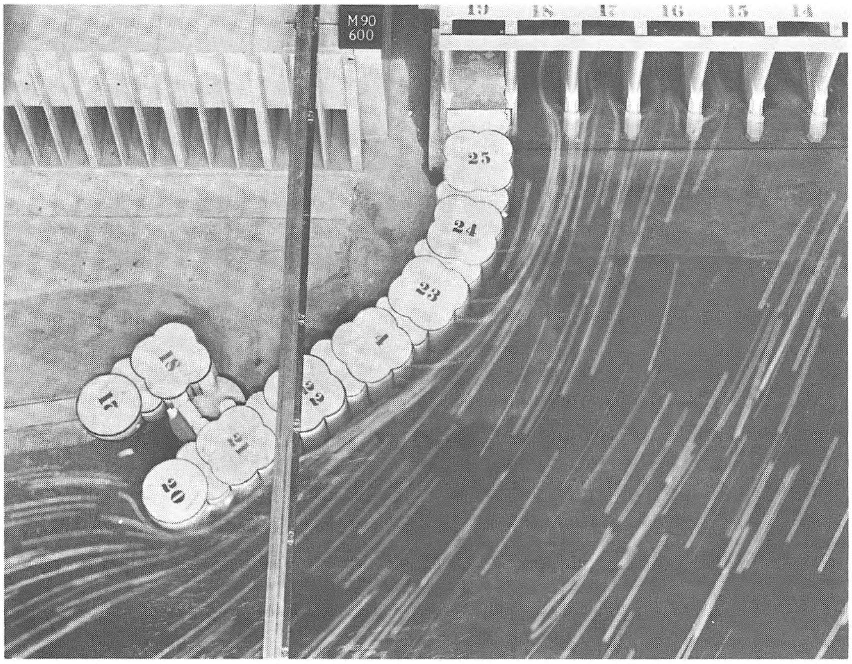
Forebay and north bank



Upstream leg

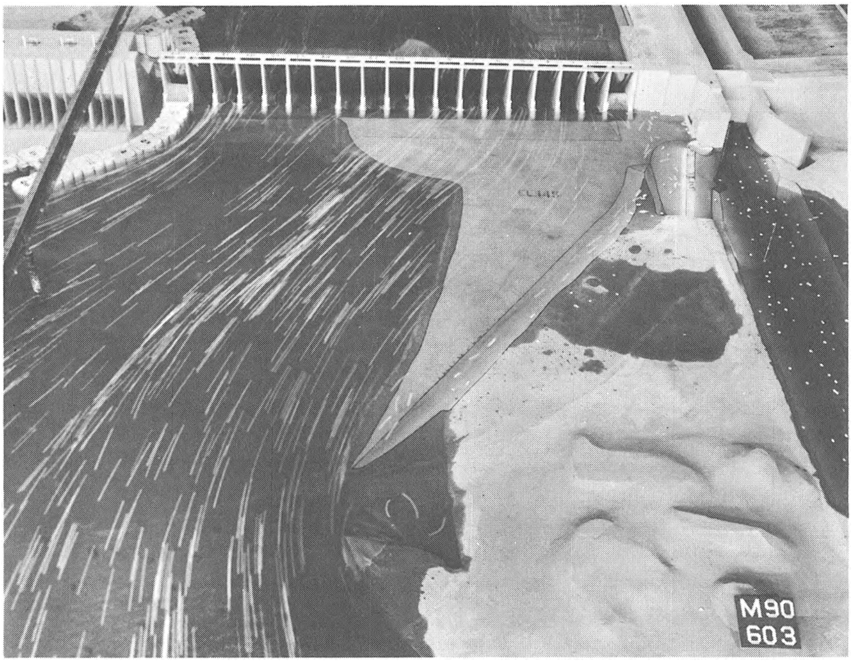
Photograph 6. Flow patterns along plan D second-step cofferdam; river discharge 400,000 cfs.

Forebay and north bank

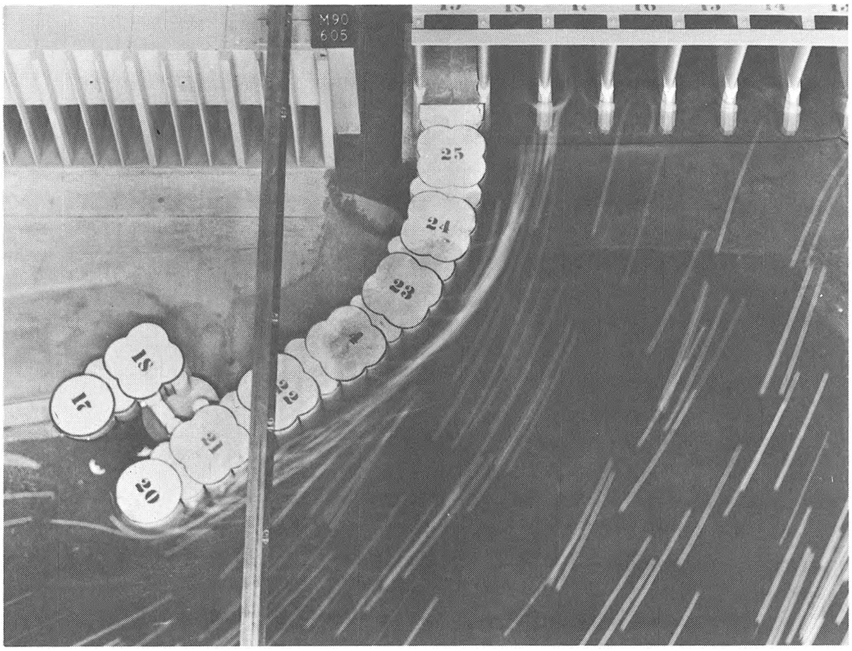


Upstream leg

Photograph 7. Flow patterns along plan D second-step cofferdam; river discharge 600,000 cfs.

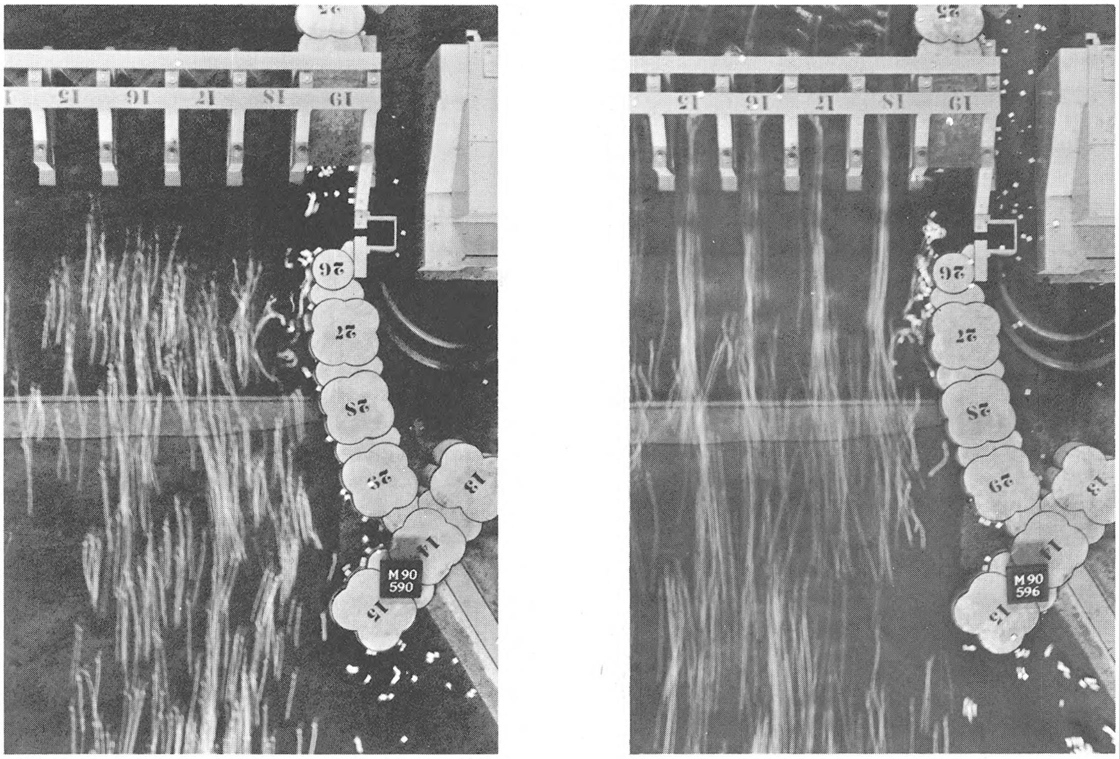


Forebay and north bank



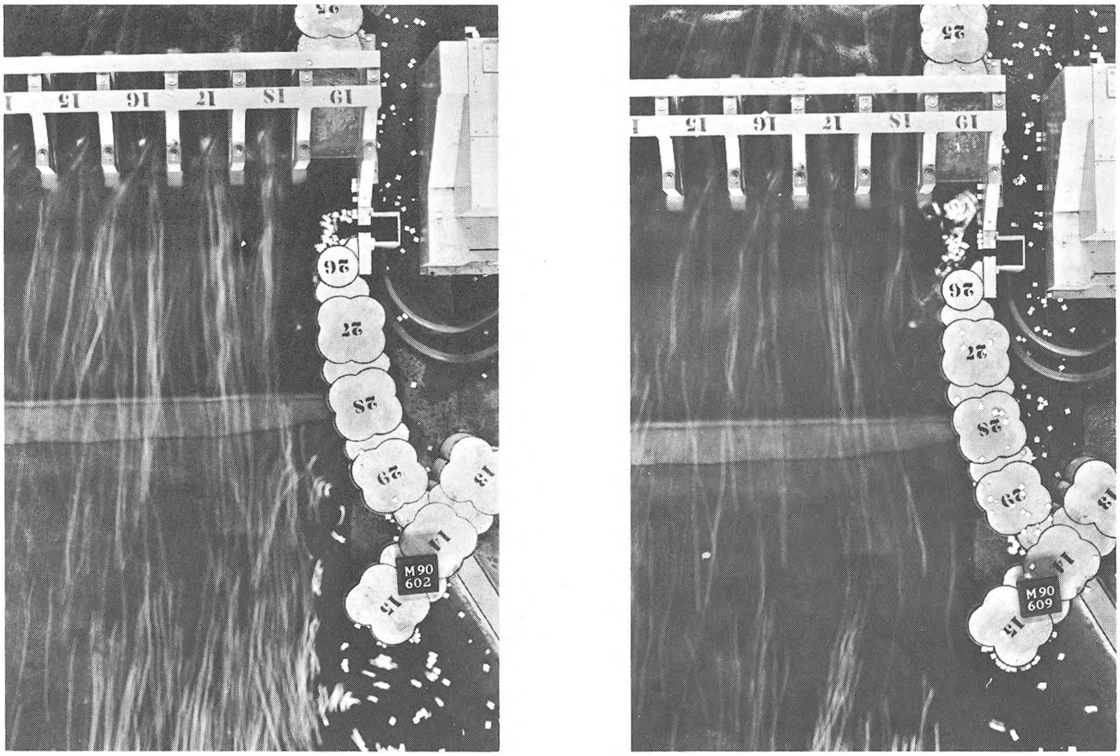
Upstream leg

Photograph 8. Flow patterns along plan D second-step cofferdam; river discharge 700,000 cfs.



200,000 cfs

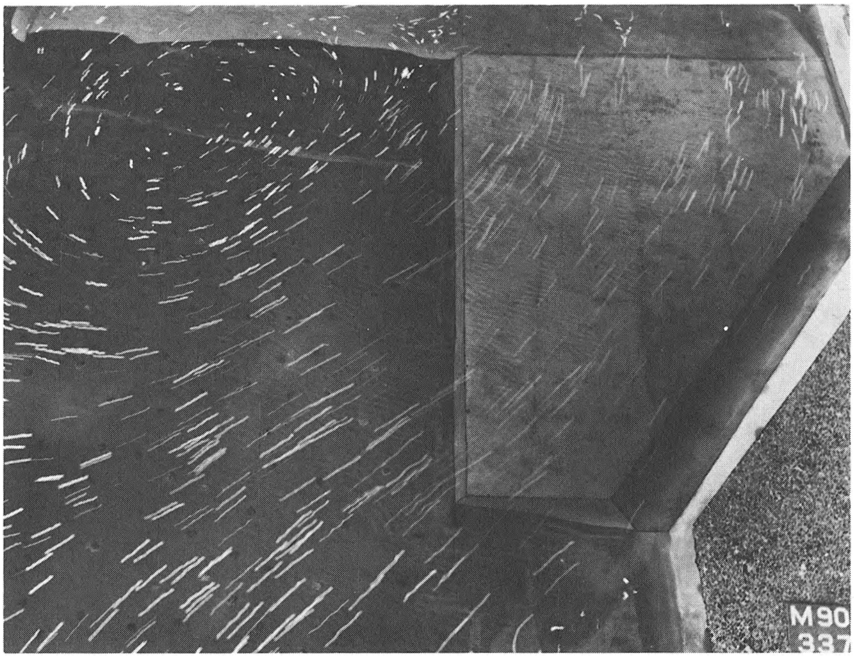
400,000 cfs



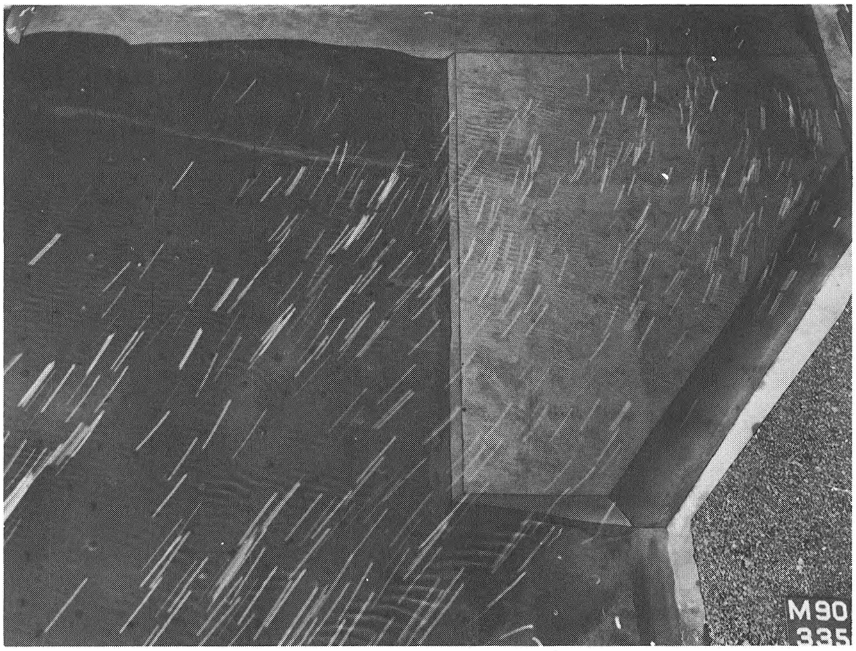
600,000 cfs

700,000 cfs

Photograph 9. Flow patterns along downstream leg and temporary fishway entrance of plan D second-step cofferdam.

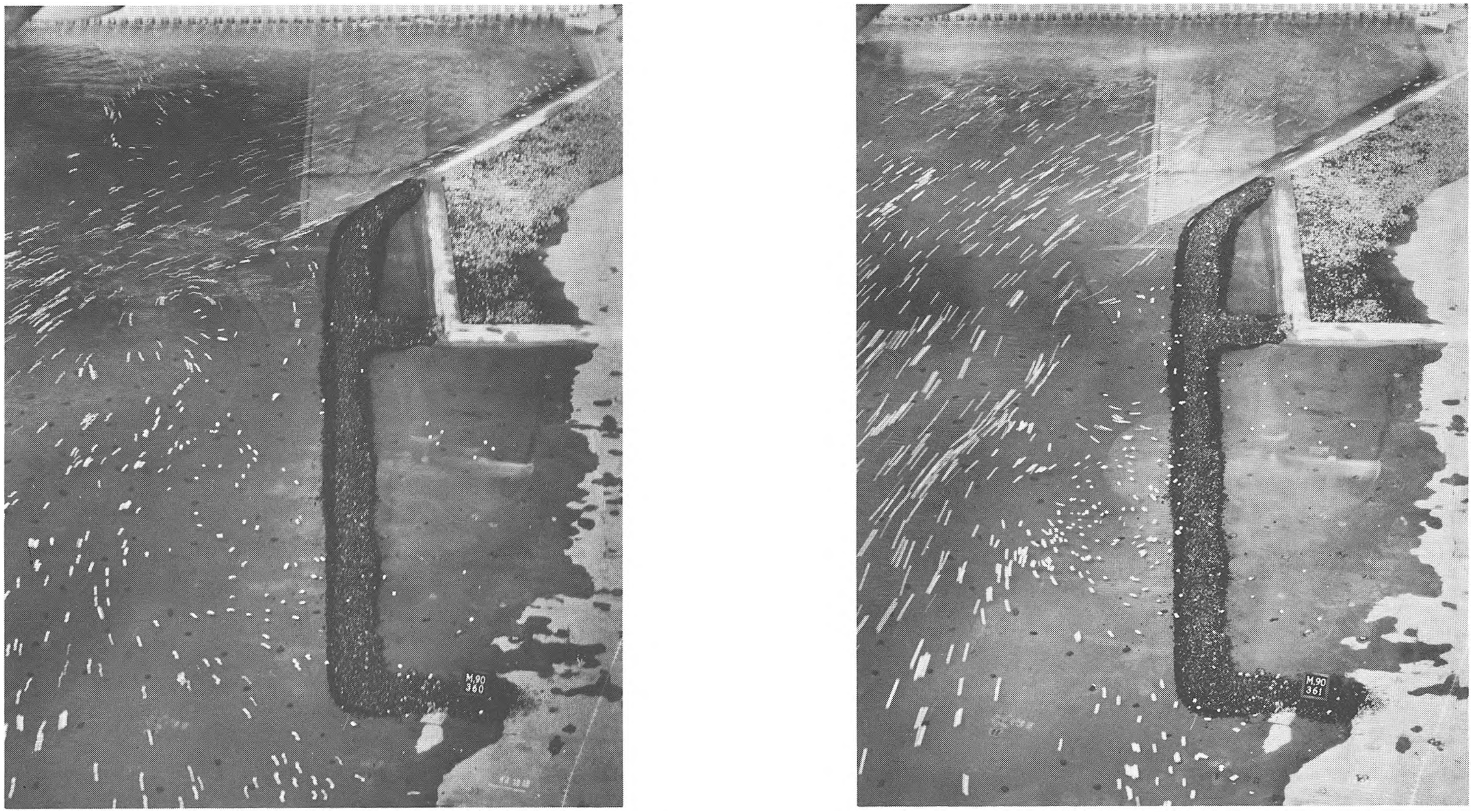


Powerhouse discharge 171,200 cfs, units 1 to 8



Powerhouse discharge 400,000 cfs, units 1 to 20

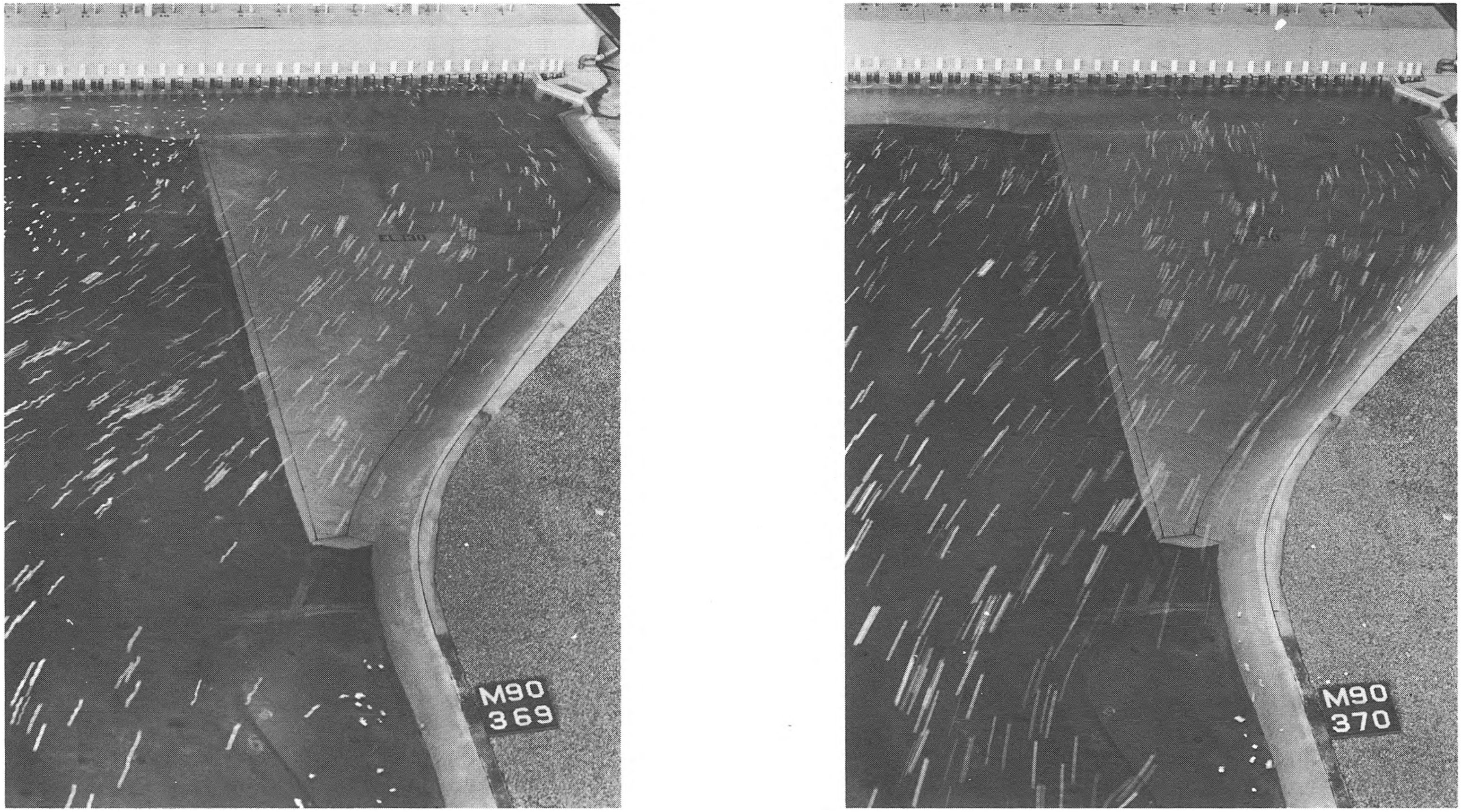
Photograph 10. Flow patterns in plan B powerhouse tailrace; river discharge 400,000 cfs.



Powerhouse discharge 184,000 cfs, units 1 to 8

Powerhouse discharge 460,000 cfs, units 1 to 20

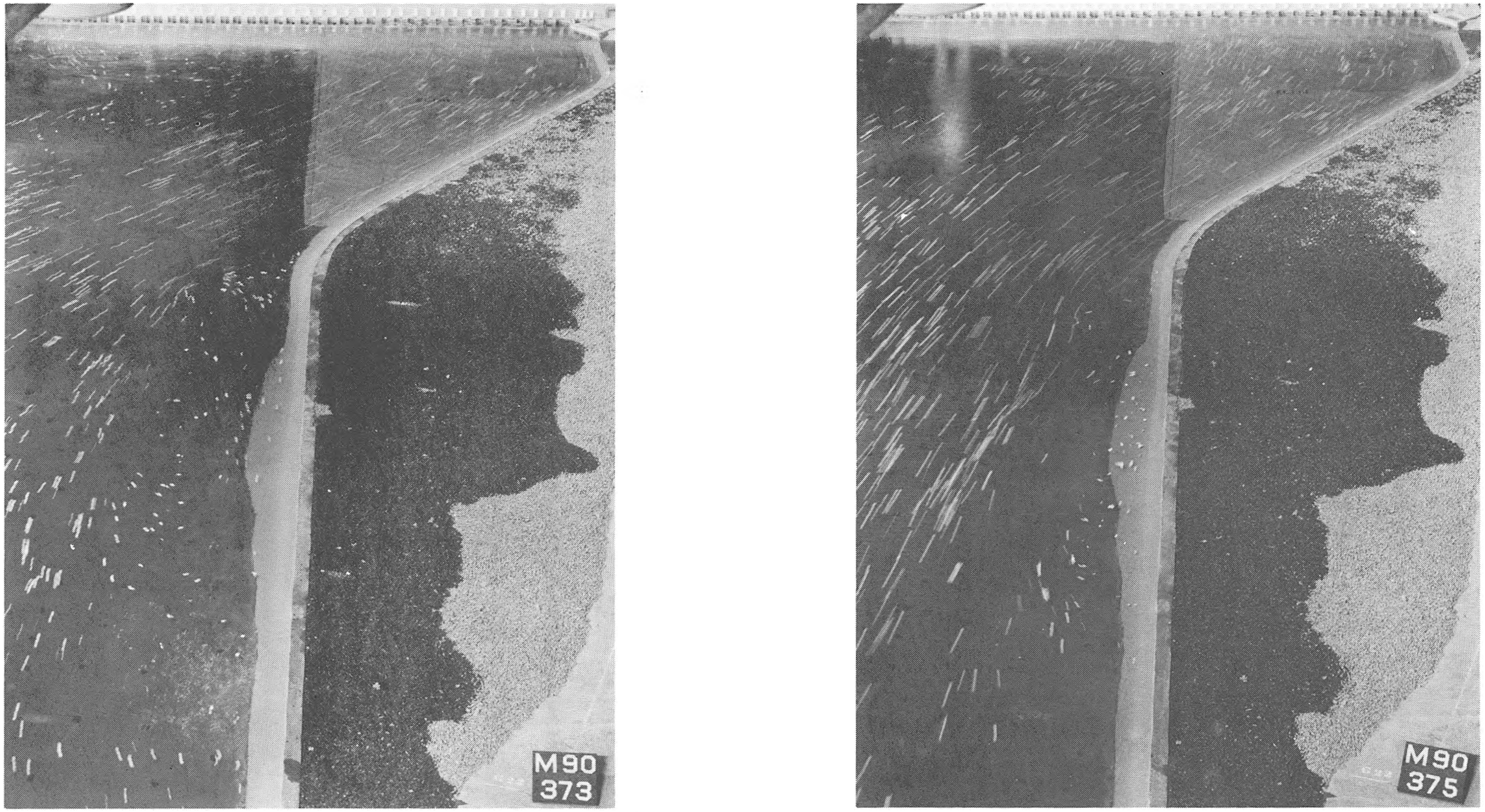
Photograph 11. Flow patterns in plan C powerhouse tailrace; river discharge 600,000 cfs.



Powerhouse discharge 184,000 cfs, units 1 to 8

Powerhouse discharge 460,000 cfs, units 1 to 20

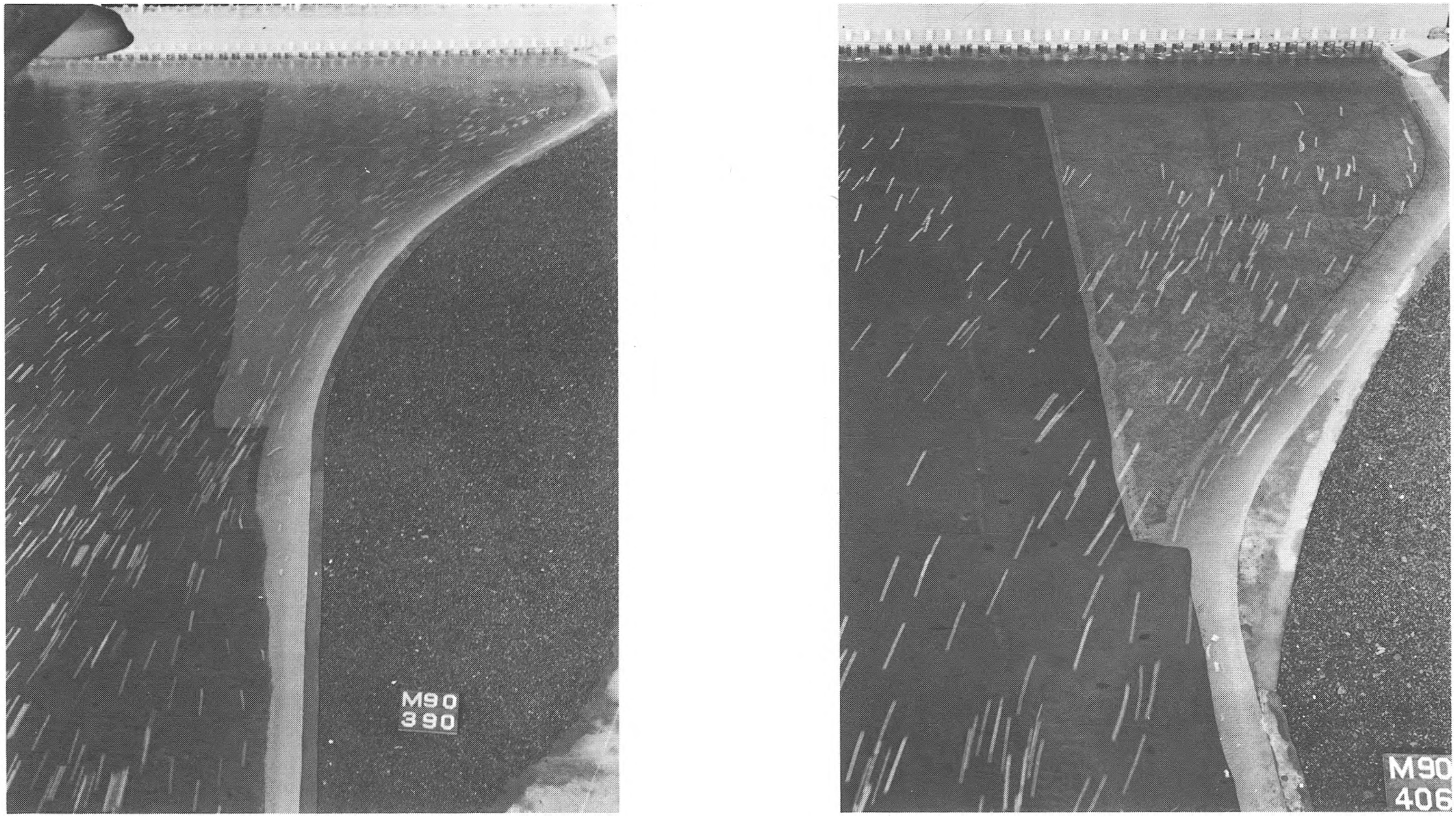
Photograph 12. Flow patterns in plan D powerhouse tailrace; river discharge 600,000 cfs.



Powerhouse discharge 184,000 cfs, units 1 to 8

Powerhouse discharge 460,000 cfs, units 1 to 20

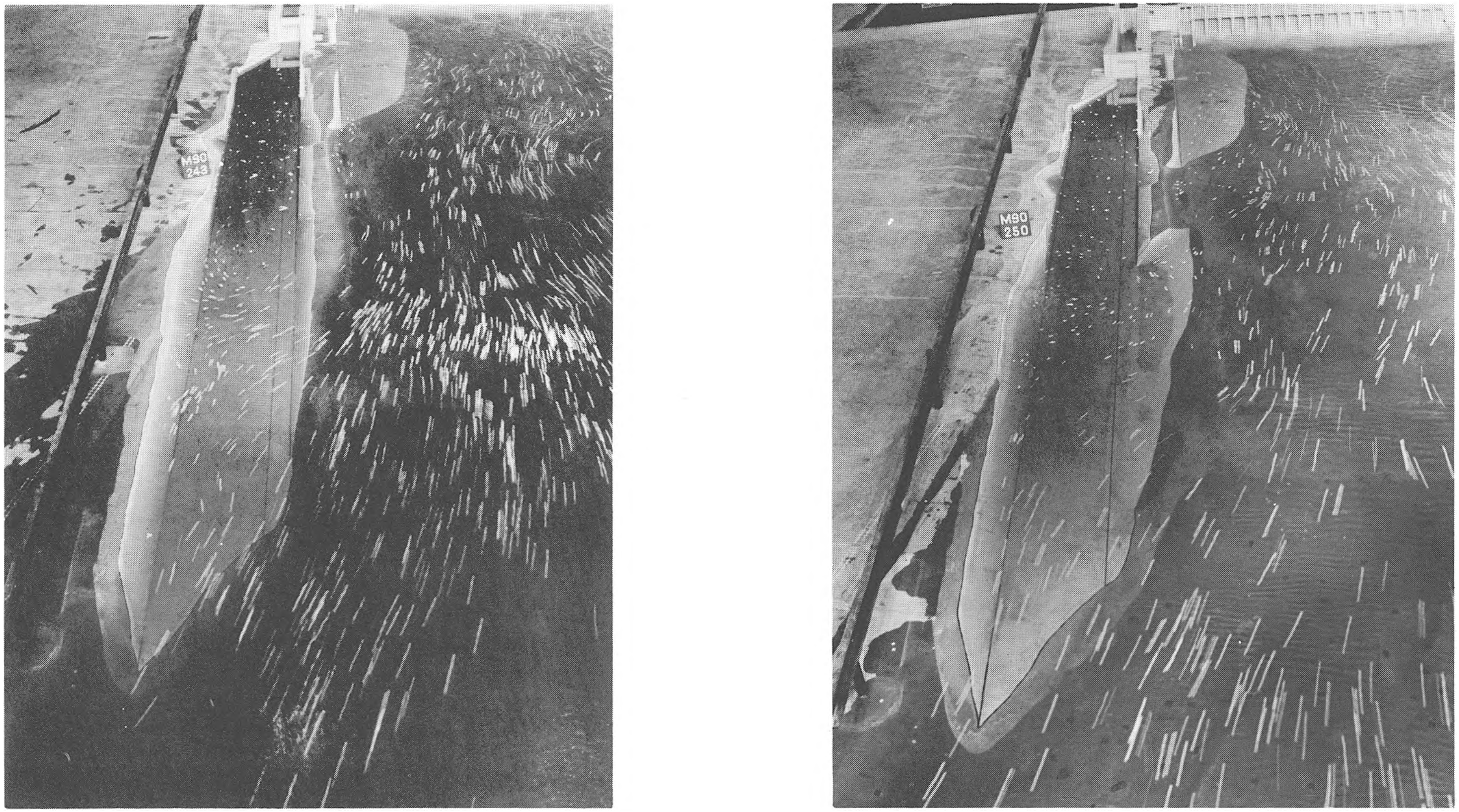
Photograph 13. Flow patterns in plan E powerhouse tailrace; river discharge 600,000 cfs.



Plan F

Plan G (final design)

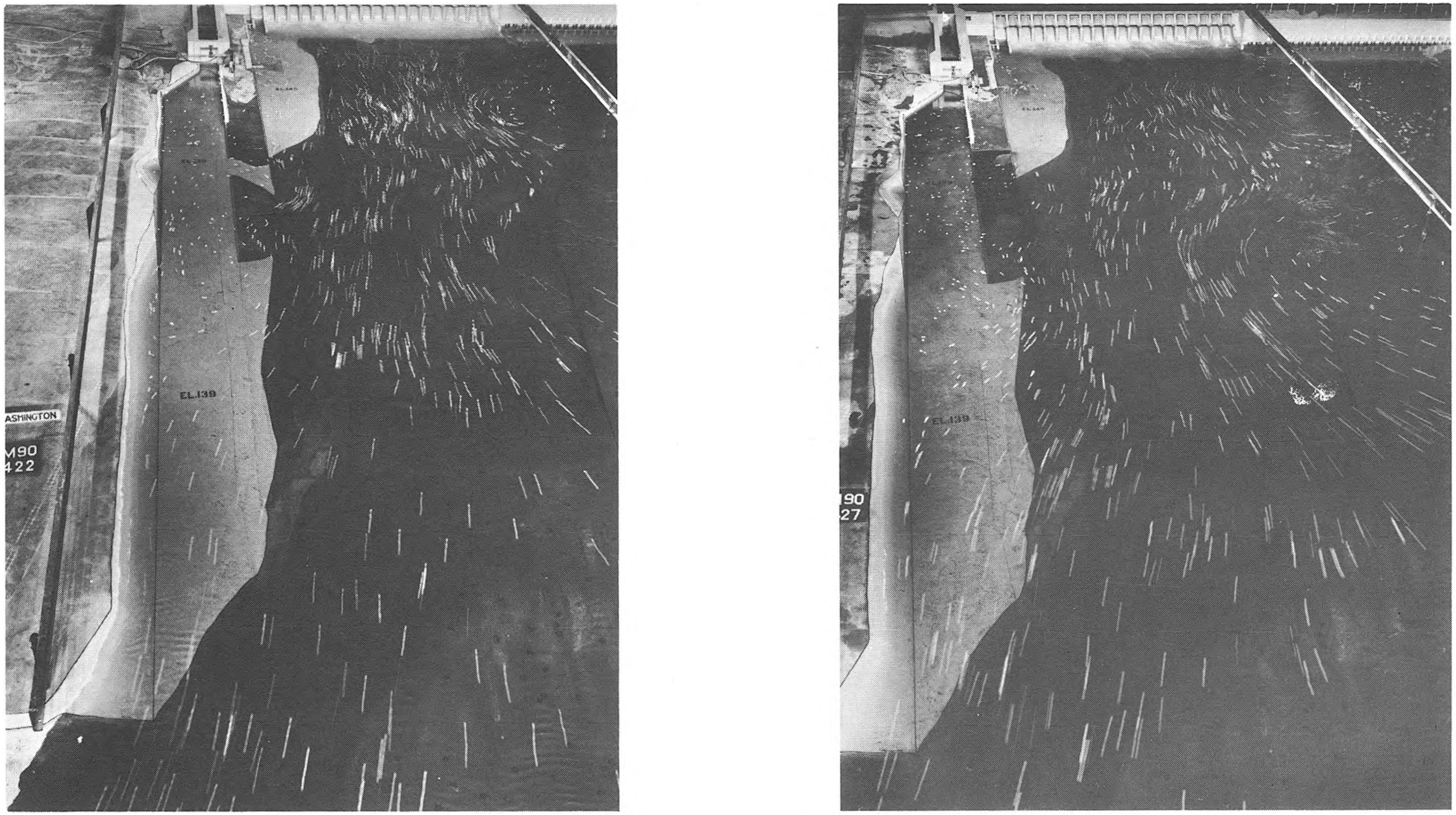
Photograph 14. Flow patterns in plans F and G powerhouse tailraces; river discharge 600,000 cfs; powerhouse discharge 460,000 cfs, units 1 to 20.



Plan C

Plan D

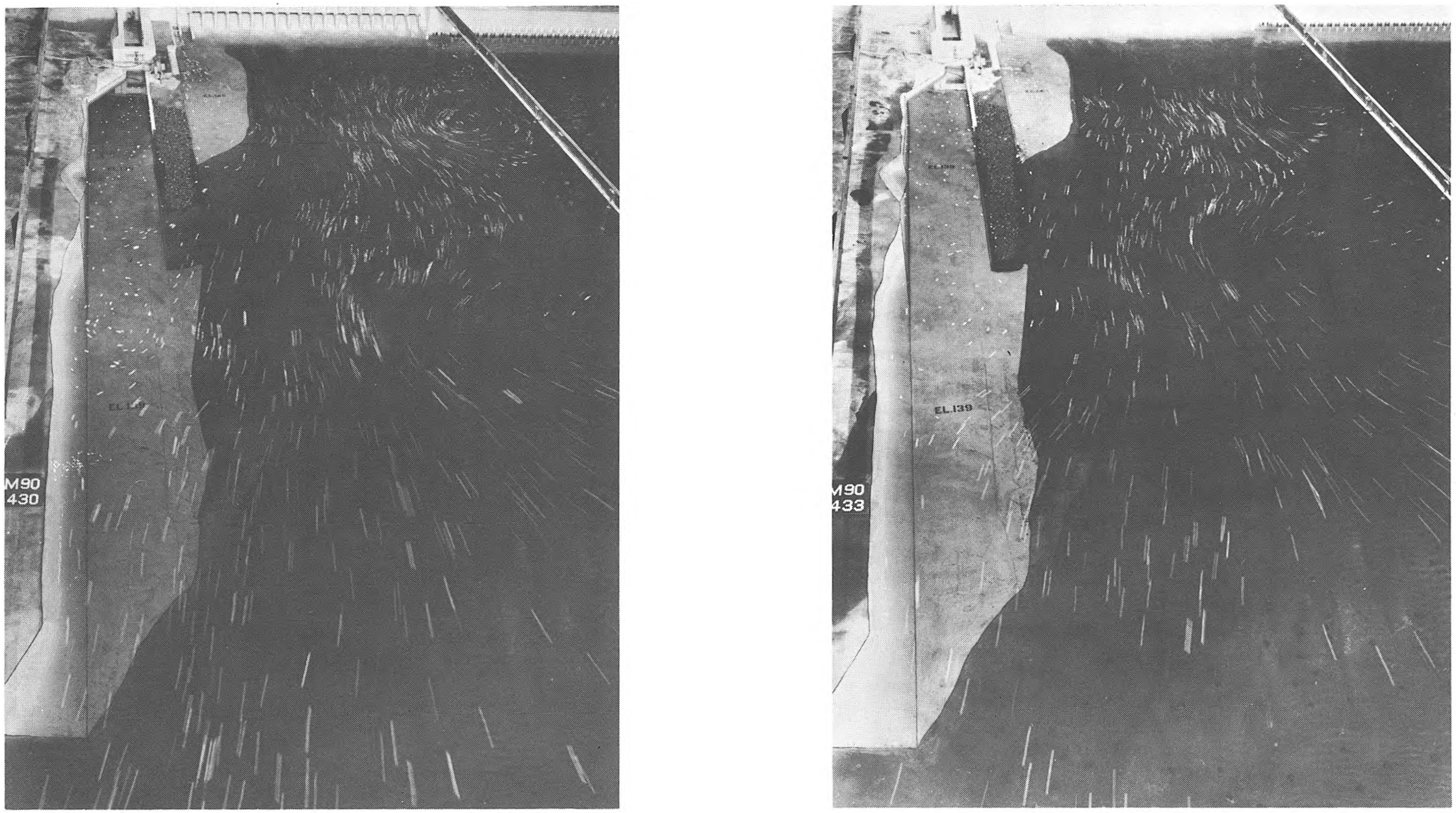
Photograph 15. Flow patterns in plans C and D downstream lock approach; river discharge 600,000 cfs; powerhouse discharge 200,000 cfs, units 1 to 10.



Plan E

Plan F

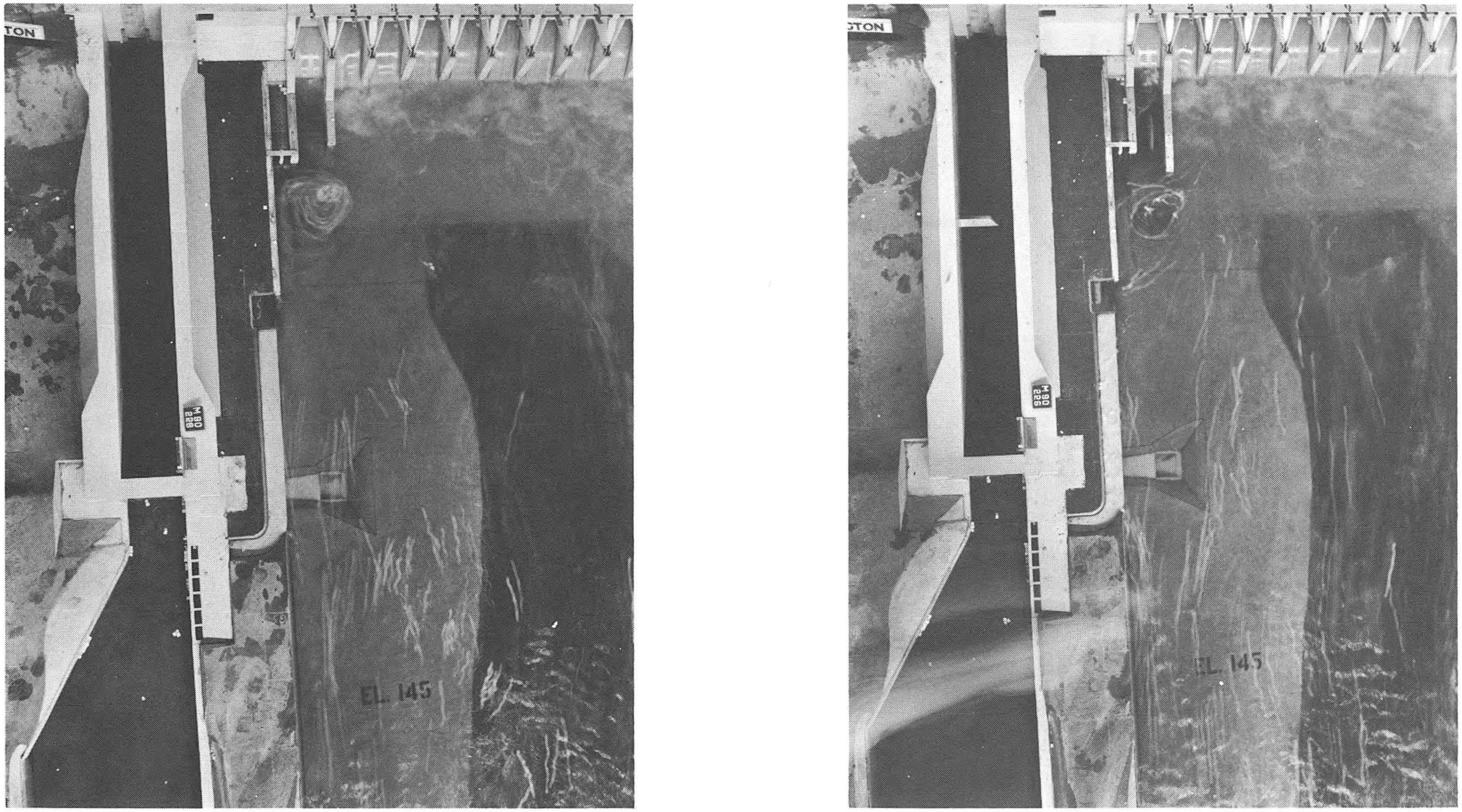
Photograph 16. Flow patterns in plans E and F downstream lock approach; river discharge 600,000 cfs; powerhouse discharge 184,000 cfs, units 1 to 8.



Plan G

Plan H

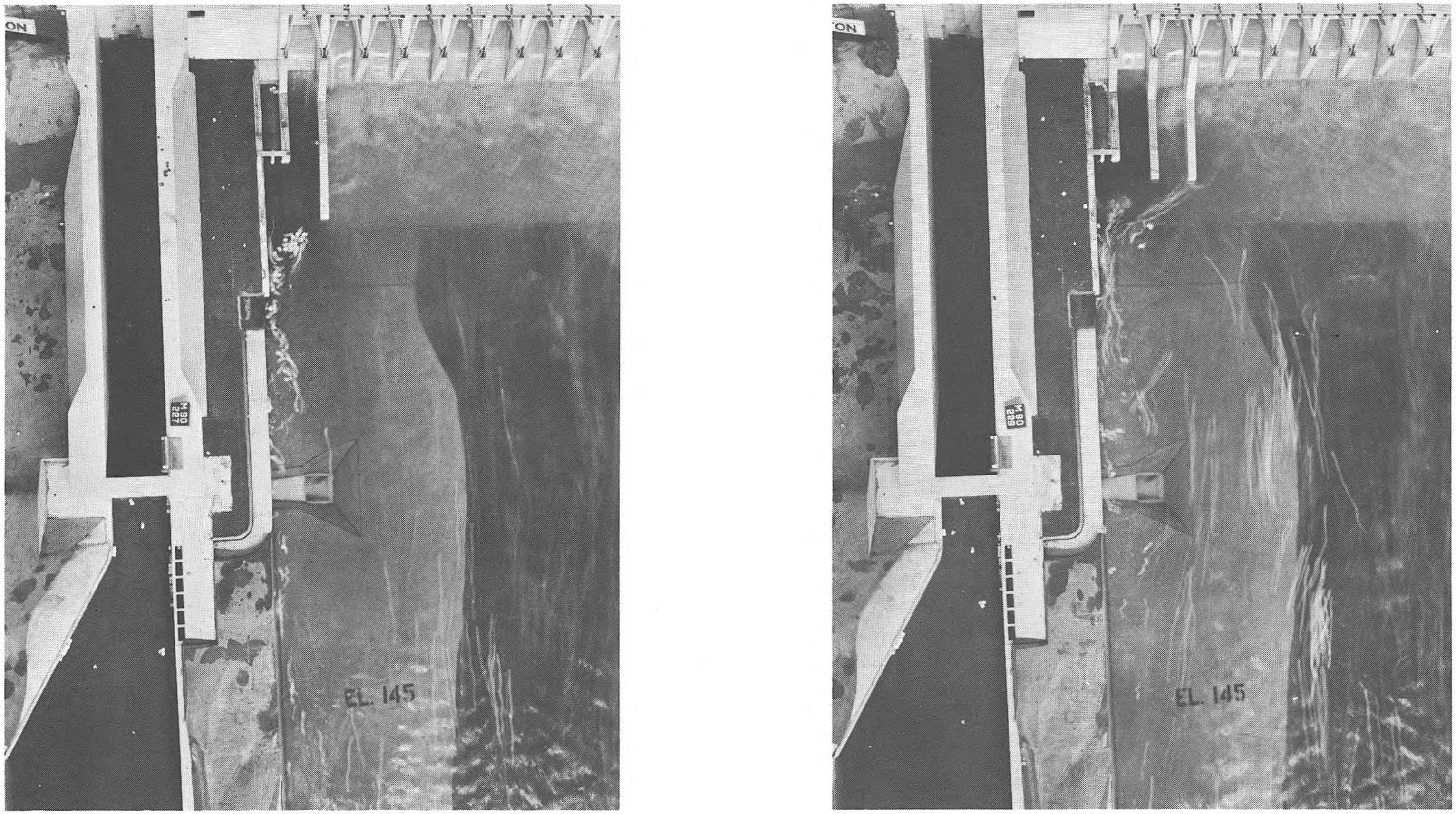
Photograph 17. Flow patterns in plans G and H downstream lock approach; river discharge 600,000 cfs; powerhouse discharge 184,000 cfs, units 1 to 8.



Pier 1 of original length

Pier 1 extended 60 ft

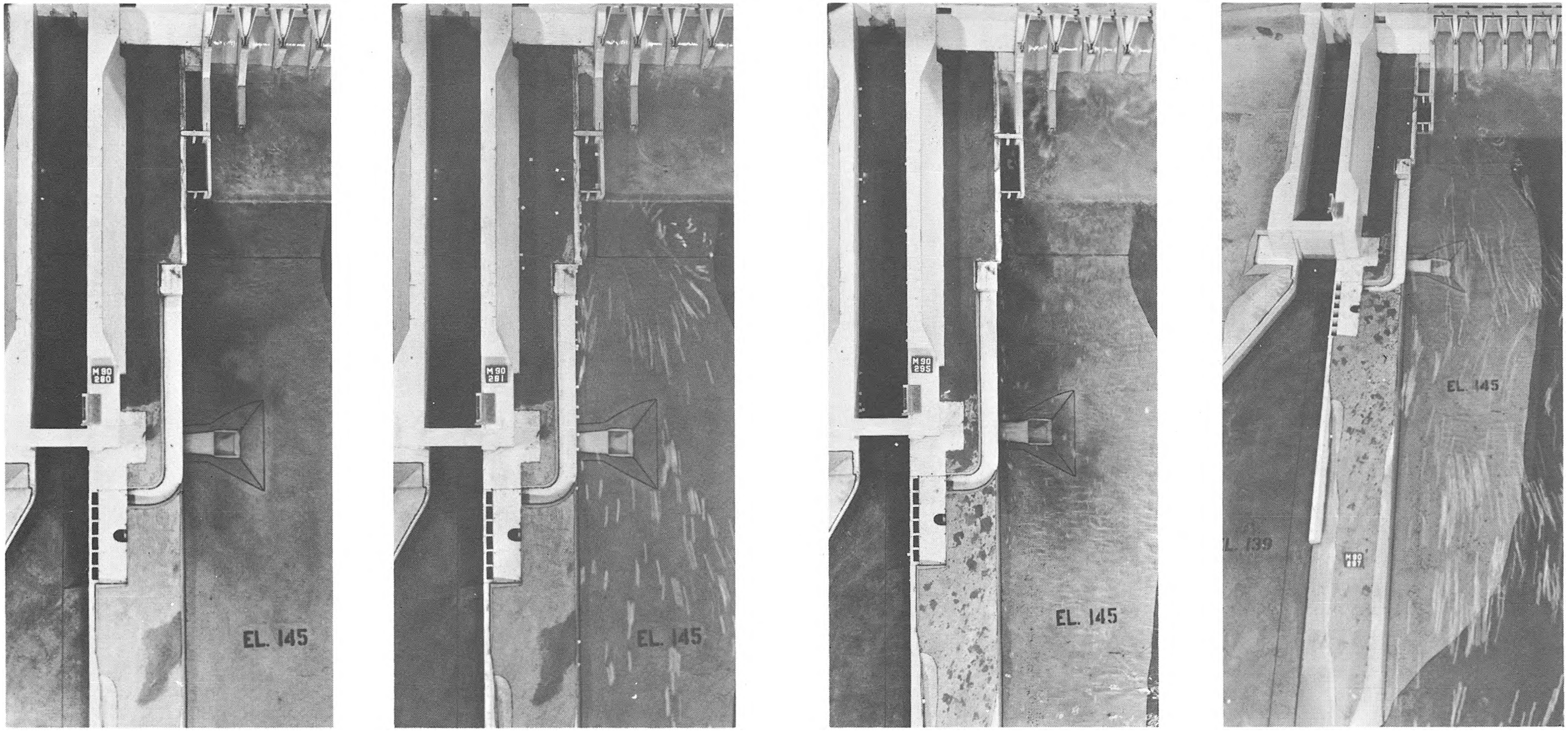
Photograph 18. Flow patterns at north fishway entrance; river discharge 700,000 cfs; spillway discharge 478,100 cfs, uniformly distributed among bays 2 to 20; bay 1 discharge 2000 cfs.



Pier 1 extended to end sill

Piers 1 and 2 extended 60 ft

Photograph 19. Flow patterns at north fishway entrance; river discharge 700,000 cfs; spillway discharge 478,100 cfs, uniformly distributed among bays 2 to 20; bay 1 discharge 2000 cfs.

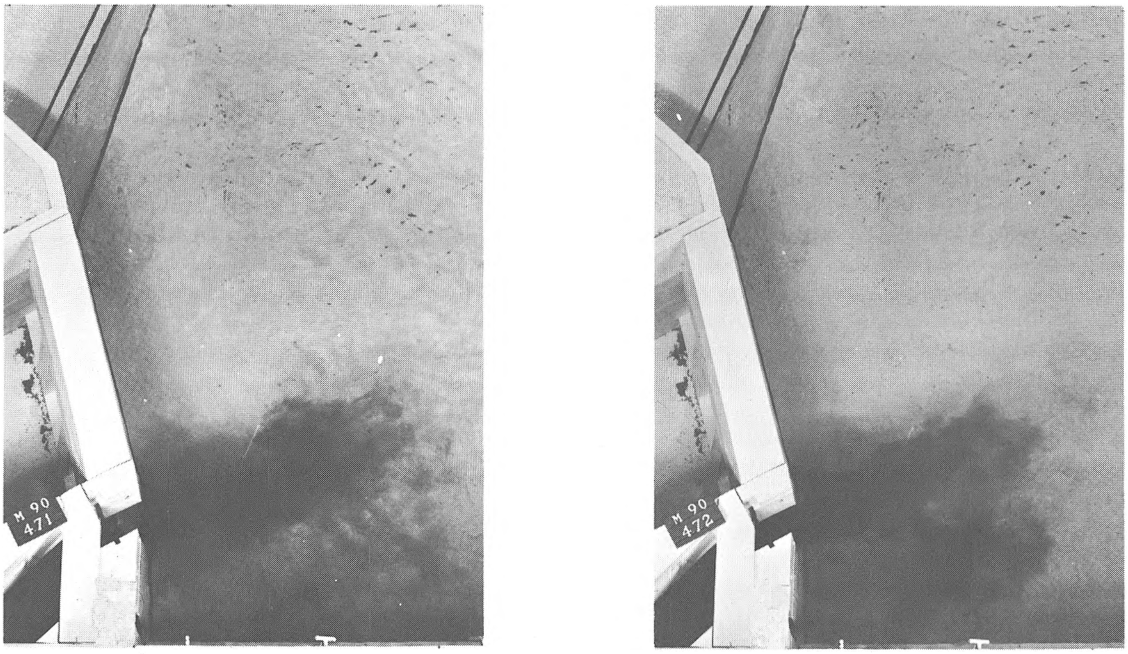


River discharge 300,000 cfs; powerhouse discharge 200,000 cfs, units 1 to 10; spillway discharge 98,700 cfs, uniformly distributed among bays 1 to 20; north fishway entrance flow 1300 cfs.

River discharge 500,000 cfs; powerhouse discharge 200,000 cfs, units 1 to 10; spillway discharge 298,400 cfs, uniformly distributed among bays 1 to 20; north fishway entrance flow 1600 cfs.

Photograph 20. Subsurface (dye) and surface (confetti) patterns at plan B north fishway entrance. In this design, the entrance was moved to the downstream end of the stilling basin.

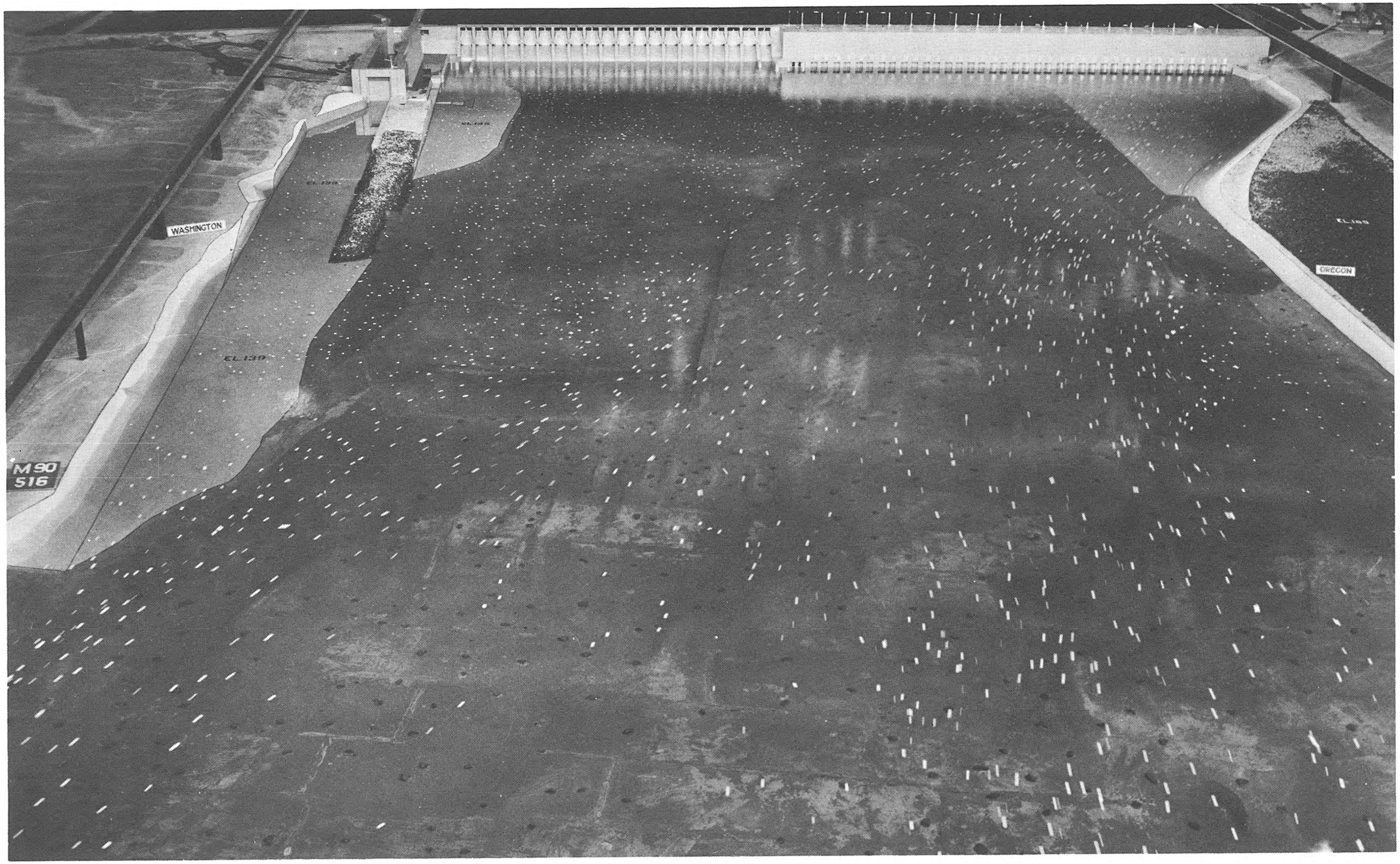
Powerhouse units 1 to 8 operated



Powerhouse units 2 to 9 operated

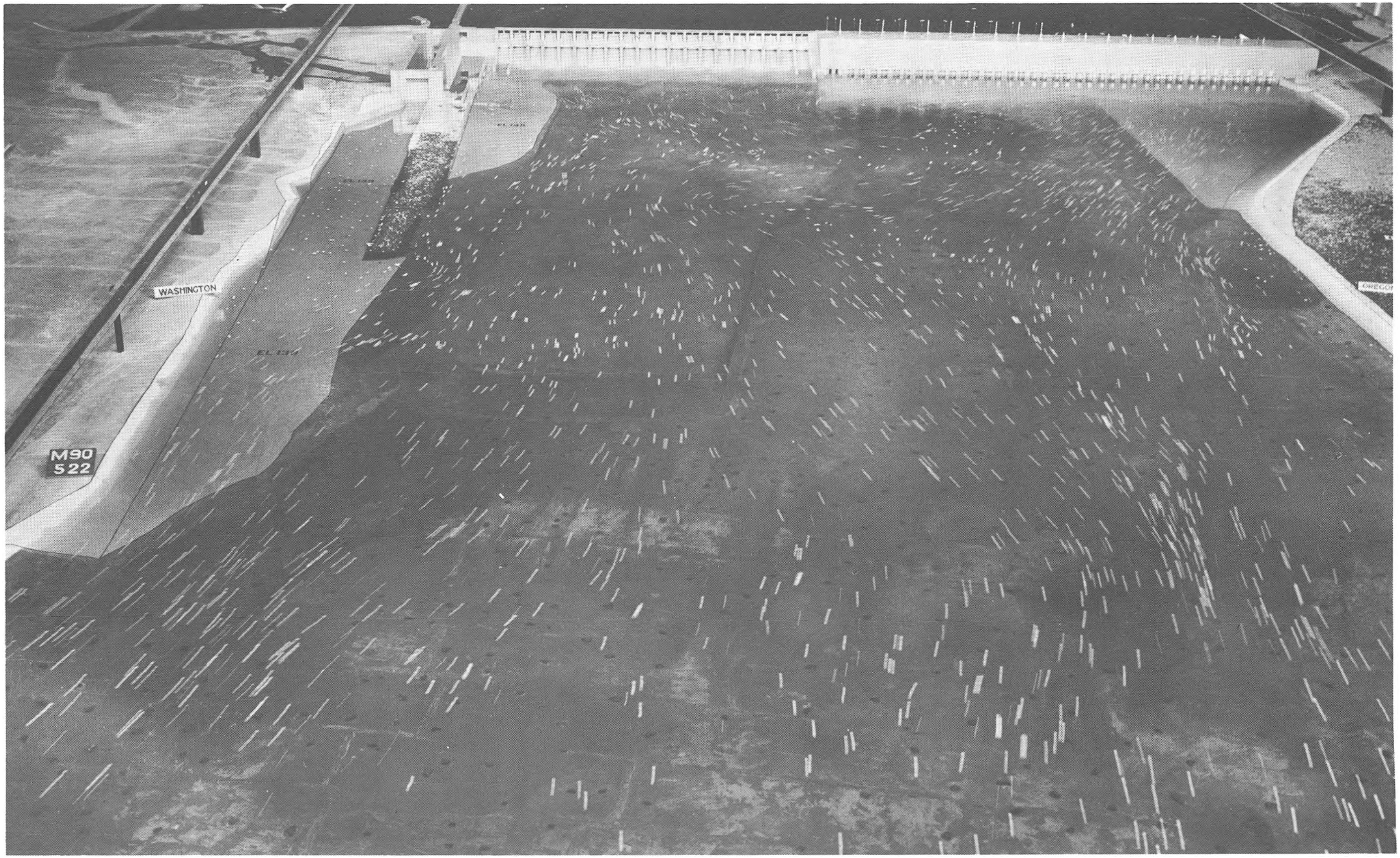
Powerhouse units 3 to 10 operated

Photograph 21. Dye introduced into flow from plan F south fishway entrance (final design). River discharge 200,000 cfs; powerhouse discharge 162,400 cfs through various units; south fishway entrance flow 700 cfs; plan H pump intake draft 3310 cfs.



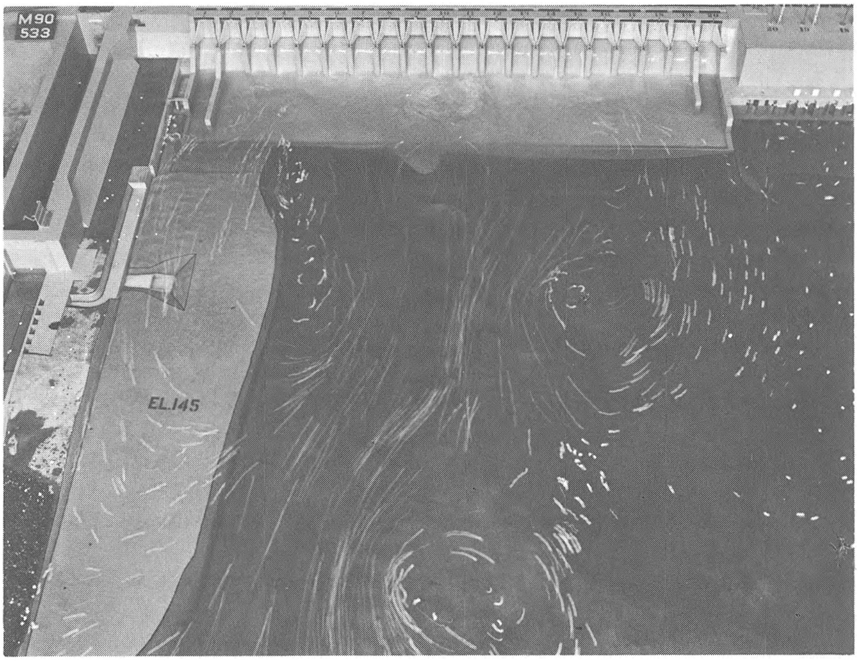
Photograph 22. Flow patterns downstream from final design structures; river discharge 100,000 cfs; powerhouse discharge 99,775 cfs, units 1 to 10; spillway closed; fishway flow 225 cfs.

Photograph 23. Flow patterns downstream from final design structures; river discharge 200,000 cfs; powerhouse discharge 199,775 cfs, units 1 to 10; spillway closed; fishway flow 225 cfs.

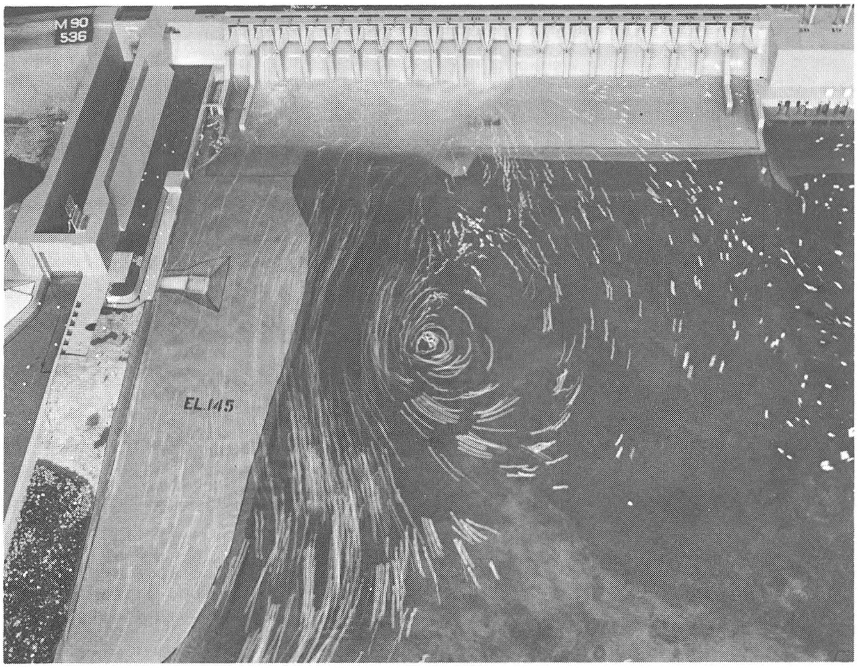


Photograph 24. Flow patterns downstream from final design structures; river discharge 400,000 cfs; powerhouse discharge 214,000 cfs, units 1 to 10; spillway discharge 183,075 cfs, uniformly distributed among bays 2 to 20, 2700 cfs through bay 1; fishway flow 225 cfs.

Photograph 25. Flow patterns downstream from final design structures; river discharge 400,000 cfs; powerhouse discharge 499,775 cfs, units 1 to 19; spillway closed; fishway flow 225 cfs.

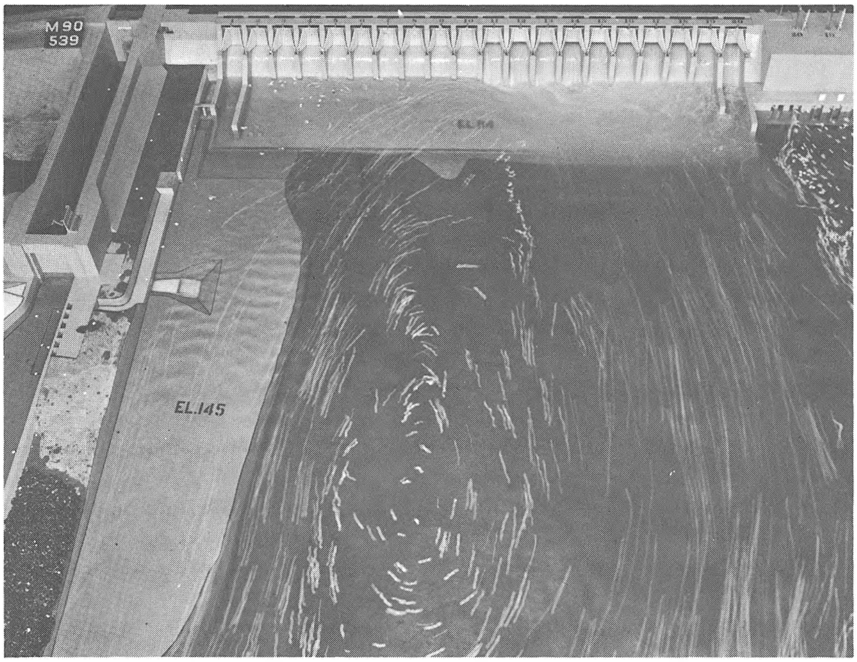


Spillway bays 2 to 20 crowned

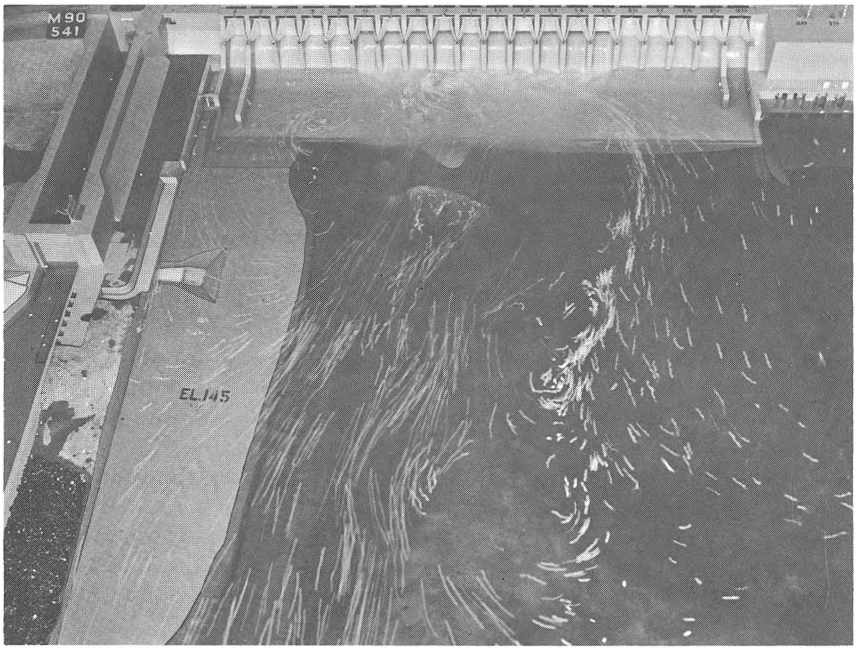


Spillway bays 2 to 11 opened uniformly, bays 12 to 20 closed

Photograph 26. Flow patterns, final design structures; river discharge 400,000 cfs; powerhouse discharge 214,000 cfs, units 1 to 10; spillway operation varied.

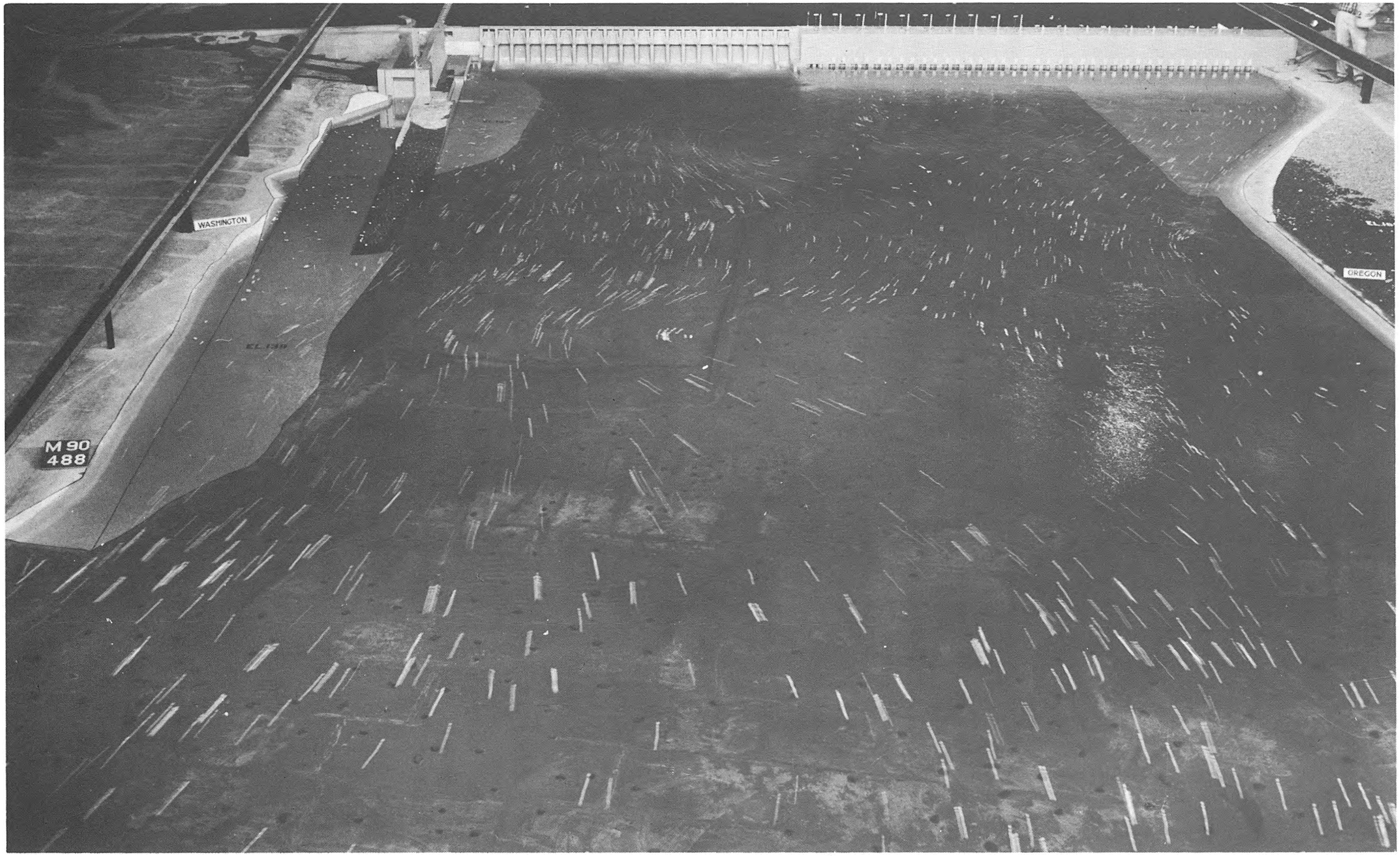


Spillway bays 11 to 20 opened uniformly, bays 2 to 10 closed

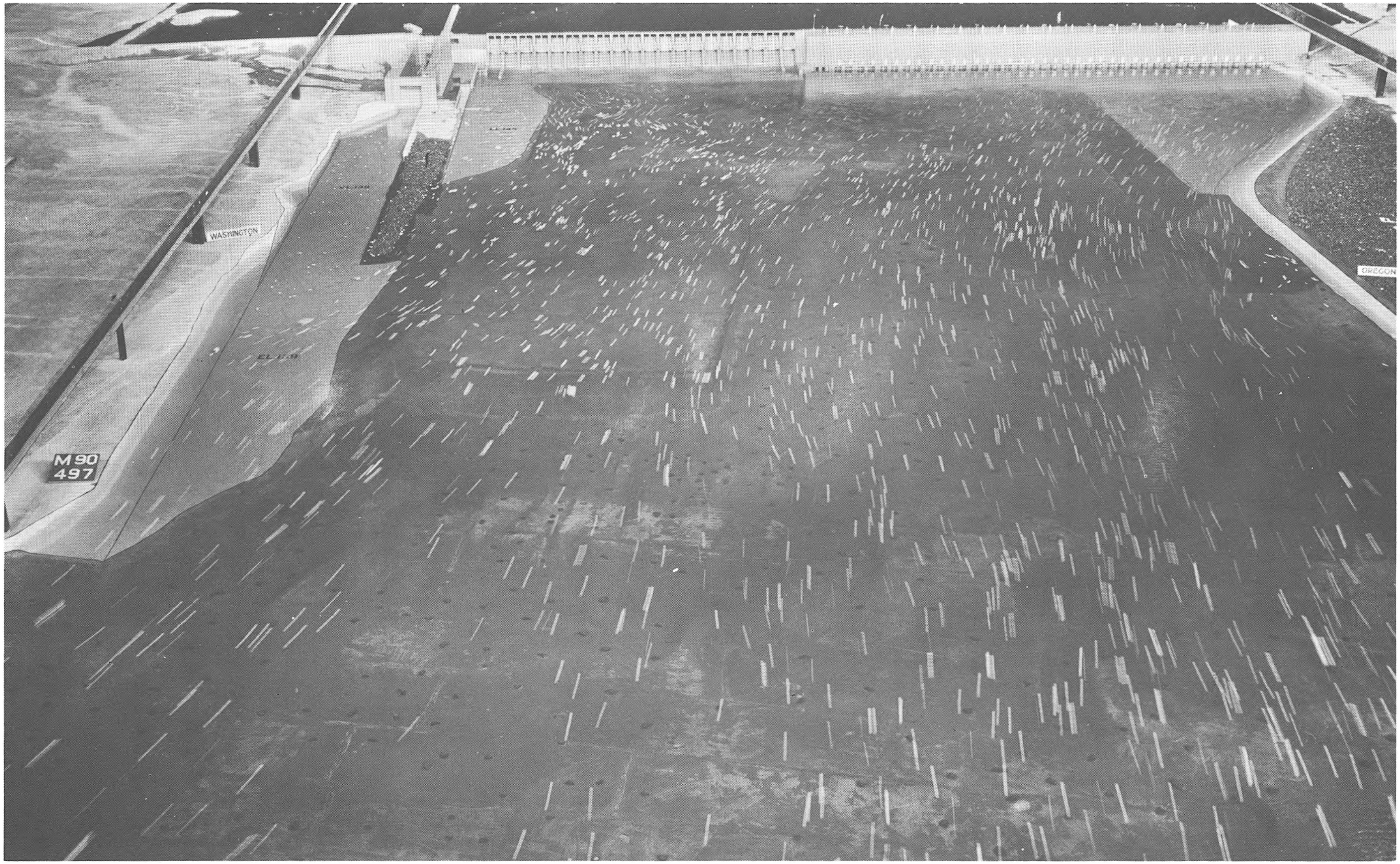


Spillway bays 6 to 15 opened uniformly,
bays 2 to 5 and 16 to 20 closed

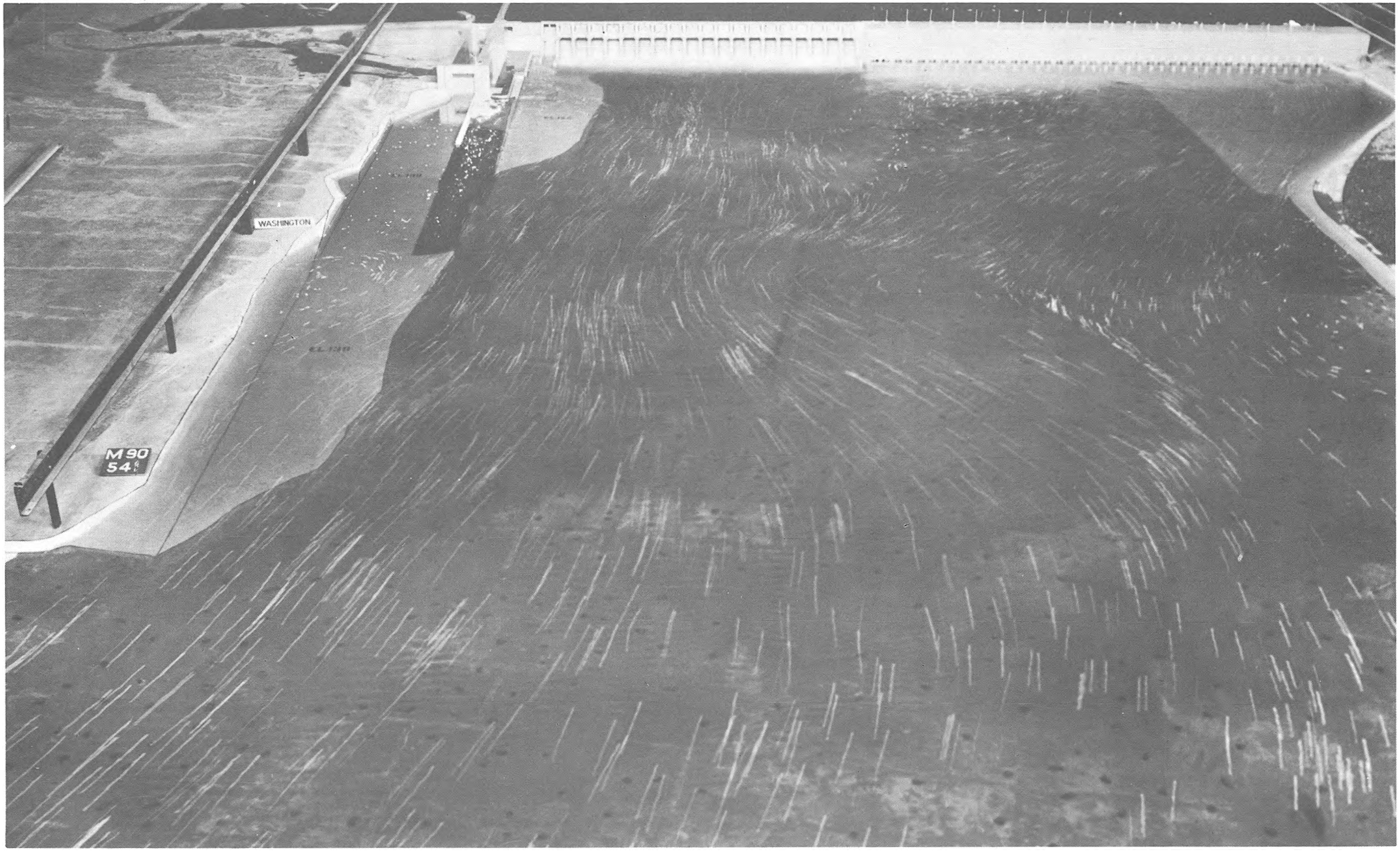
Photograph 27. Flow patterns, final design structures; river discharge 400,000 cfs; powerhouse discharge 214,000 cfs, units 1 to 10; spillway operation varied.



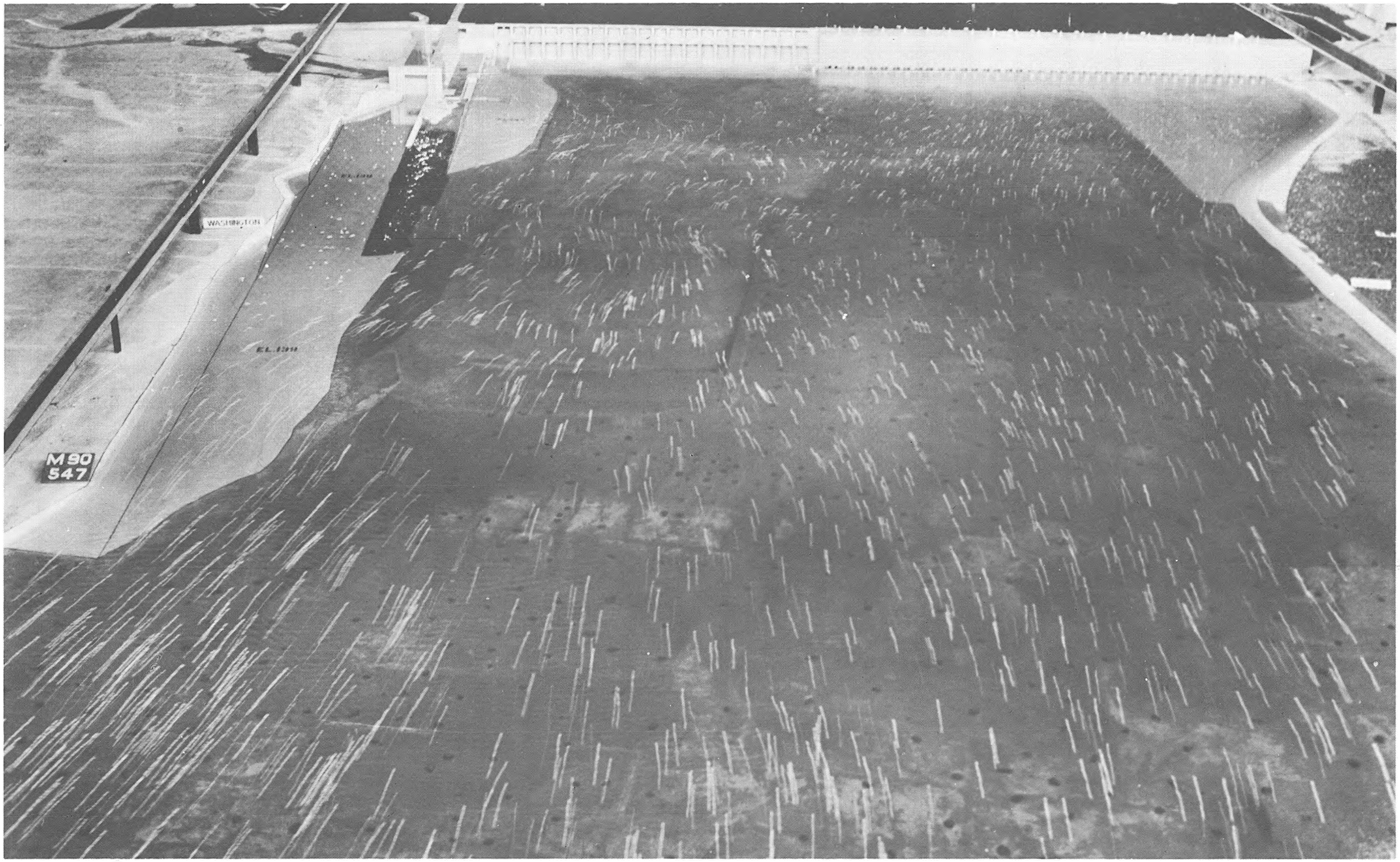
Photograph 28. Flow patterns downstream from final design structures; river discharge 600,000 cfs; powerhouse discharge 230,000 cfs, units 1 to 10; spillway discharge 367,075 cfs, uniformly distributed among bays 2 to 20, 2700 cfs through bay 1; fishway flow 225 cfs.



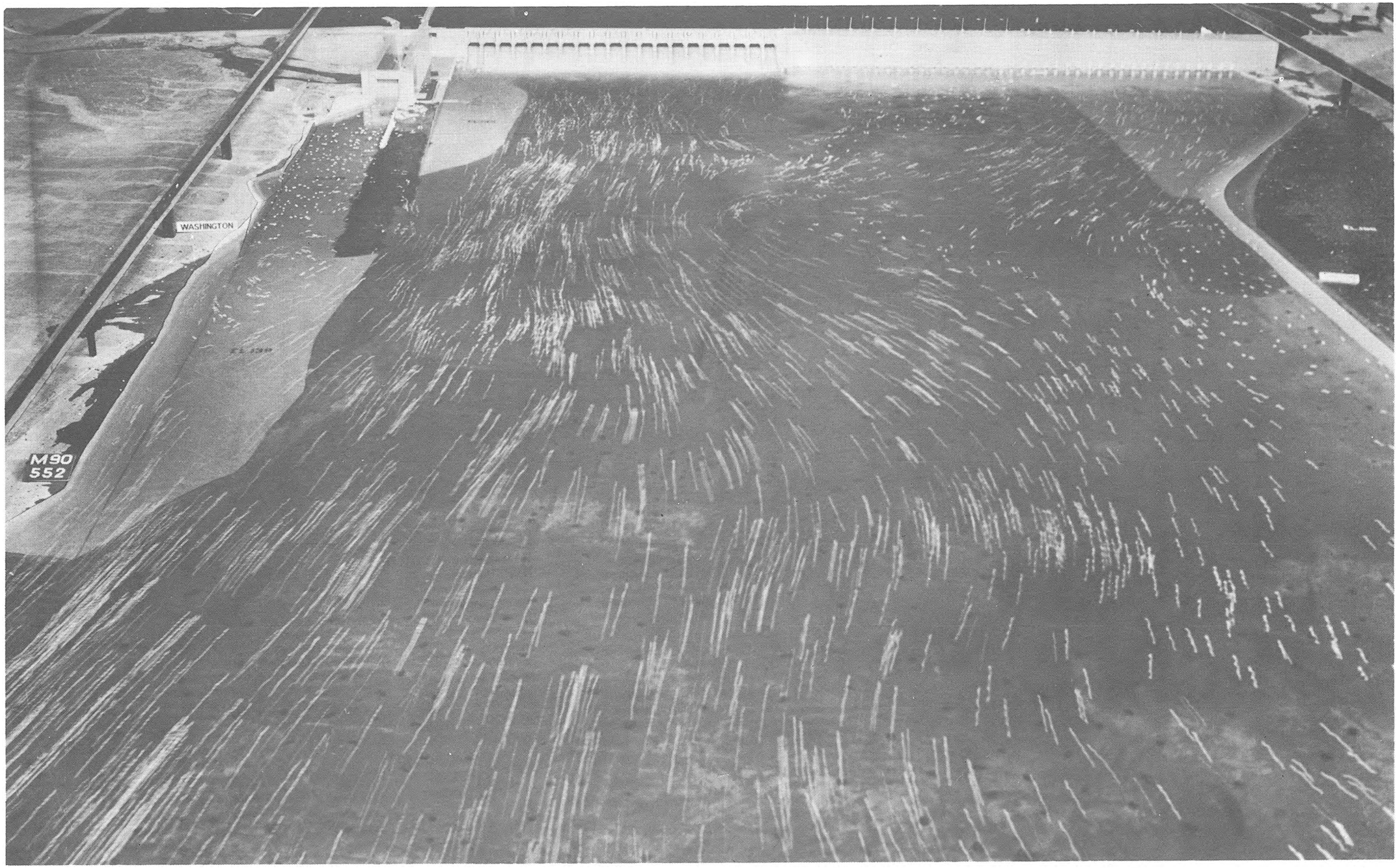
Photograph 29. Flow patterns downstream from final design structures; river discharge 600,000 cfs; powerhouse discharge 460,000 cfs, units 1 to 20; spillway discharge 137,075 cfs, uniformly distributed among bays 2 to 20, 2700 cfs through bay 1; fishway flow 225 cfs.



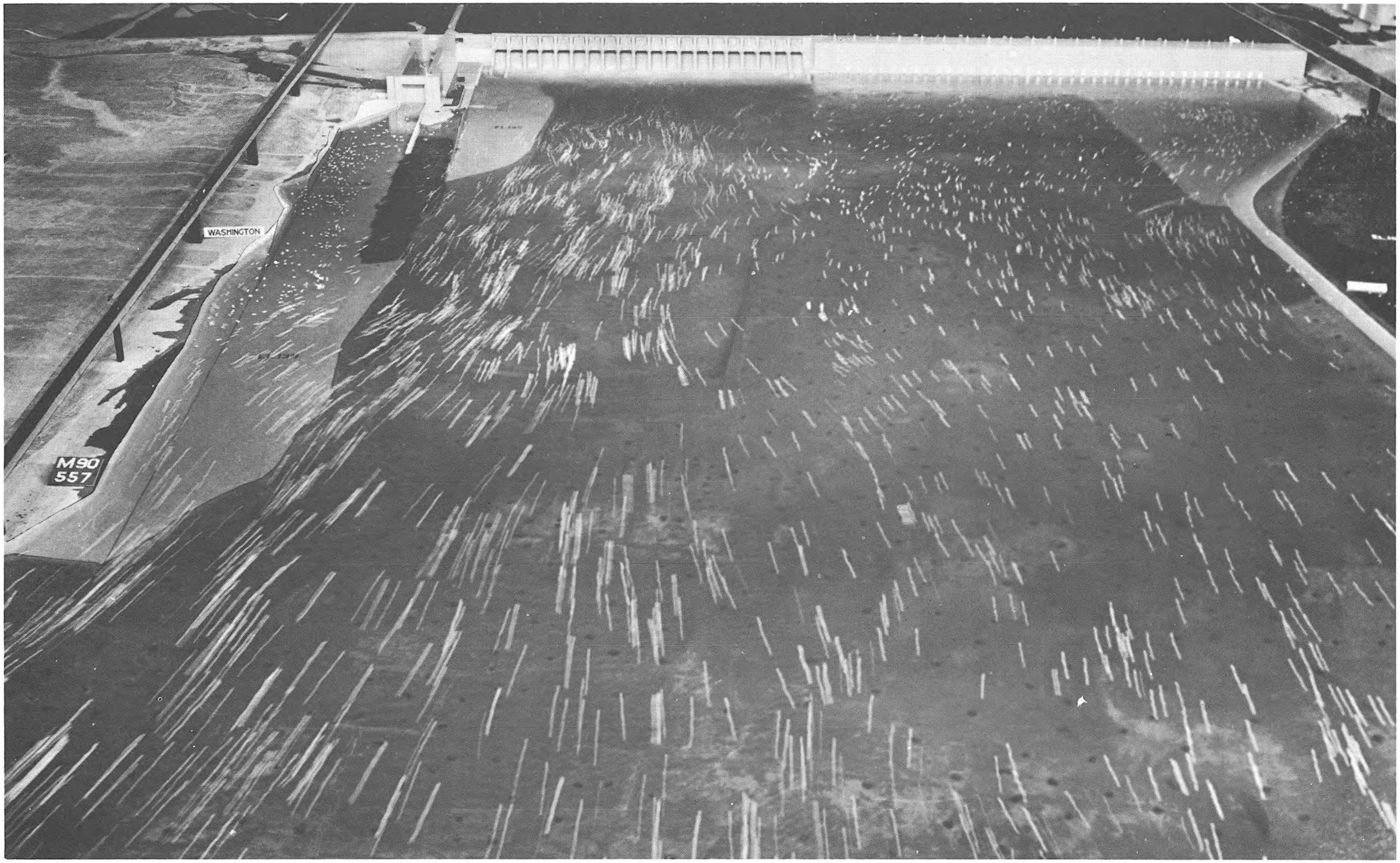
Photograph 30. Flow patterns downstream from final design structures; river discharge 800,000 cfs; powerhouse discharge 234,000 cfs, units 1 to 10; spillway discharge 563,075 cfs, uniformly distributed among bays 2 to 20, 2700 cfs through bay 1; fishway flow 225 cfs.



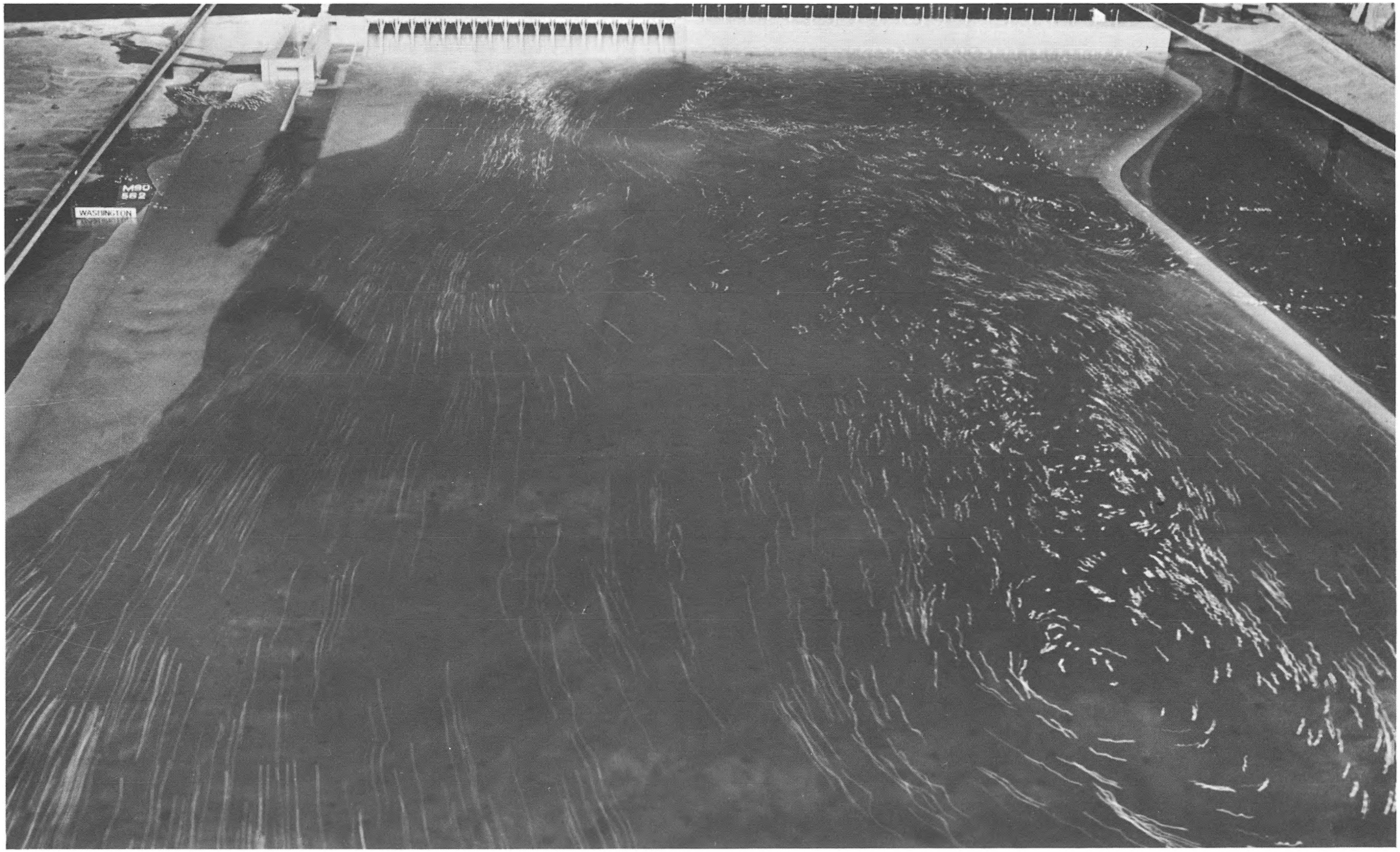
Photograph 31. Flow patterns downstream from final design structures; river discharge 800,000 cfs; powerhouse discharge 468,000 cfs, units 1 to 20; spillway discharge 329,075 cfs, uniformly distributed among bays 2 to 20, 2700 cfs through bay 1; fishway flow 225 cfs.



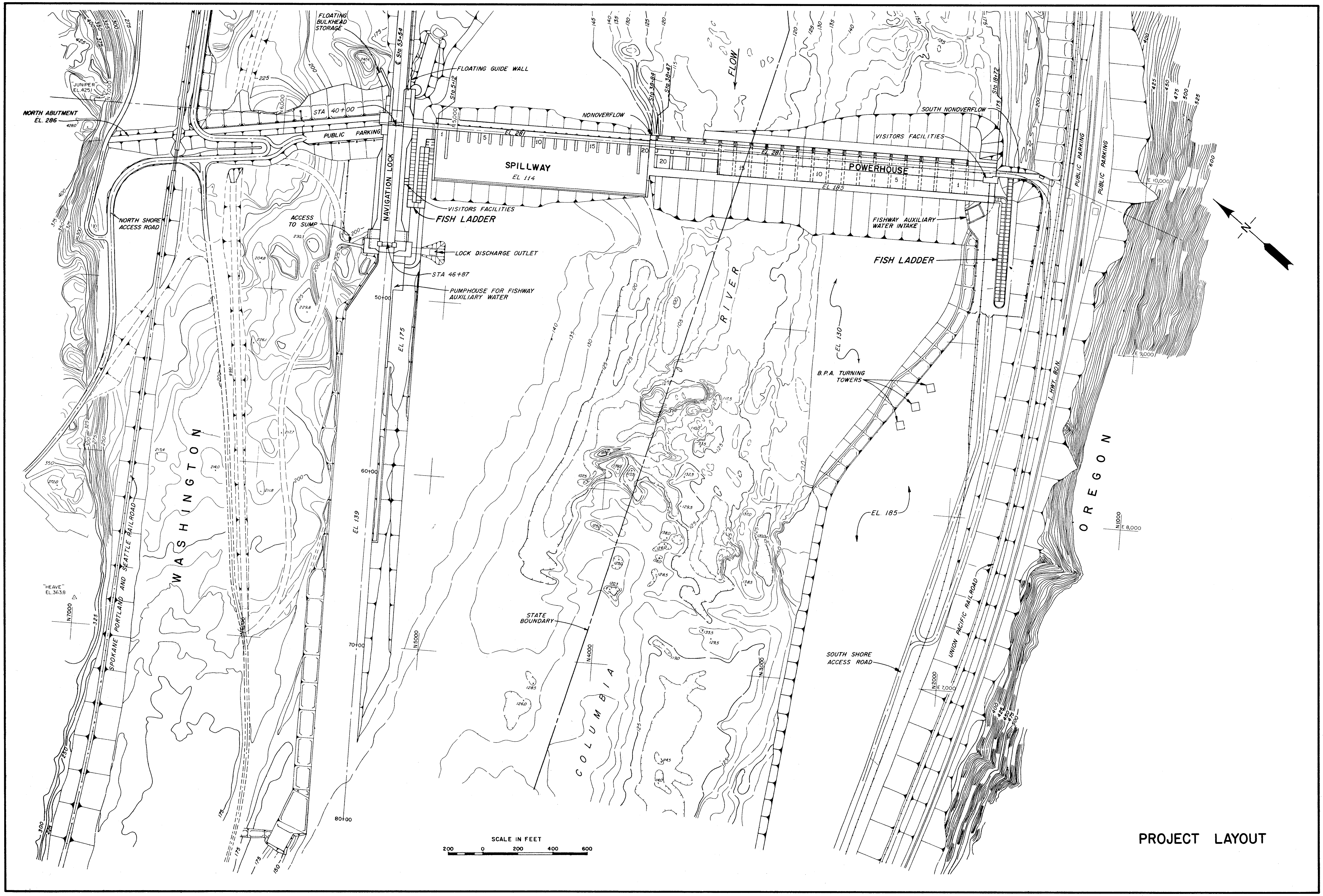
Photograph 32. Flow patterns downstream from final design structures; river discharge 1,060,000 cfs powerhouse discharge 232,000 cfs, units 1 to 10; spillway discharge 827,775 cfs, uniformly distributed among bays 1 to 20; fishway flow 225 cfs.



Photograph 33. Flow patterns downstream from final design structures; river discharge 1,060,000 cfs powerhouse discharge 464,000 cfs, units 1 to 20; spillway discharge 595,775 cfs, uniformly distributed among bays 1 to 20; fishway discharge 225 cfs.

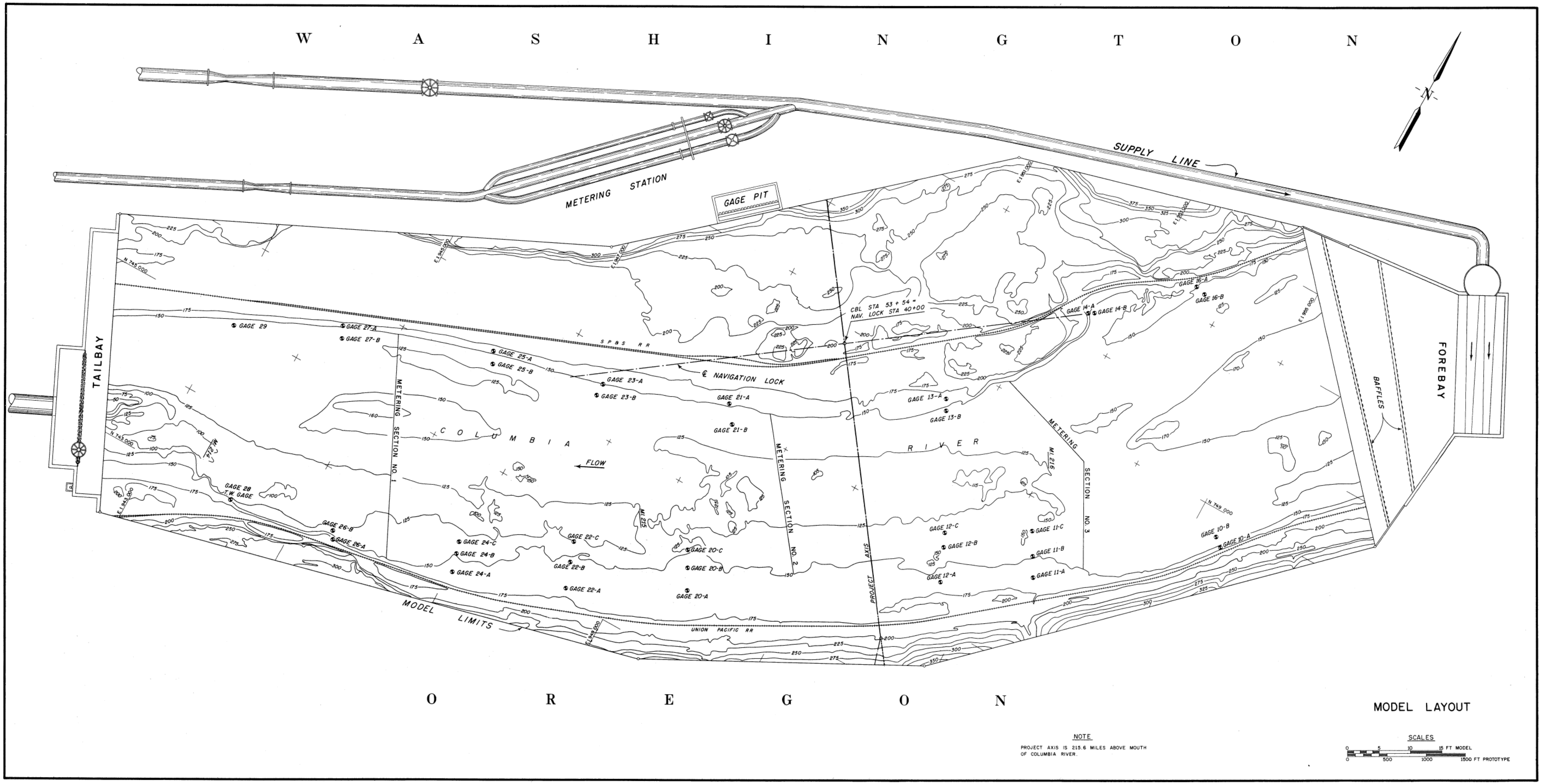


Photograph 34. Flow patterns downstream from final design structures; river discharge 2,250,000 cfs uniformly distributed among spillway bays 1 to 20; powerhouse and fishways closed.



PROJECT LAYOUT

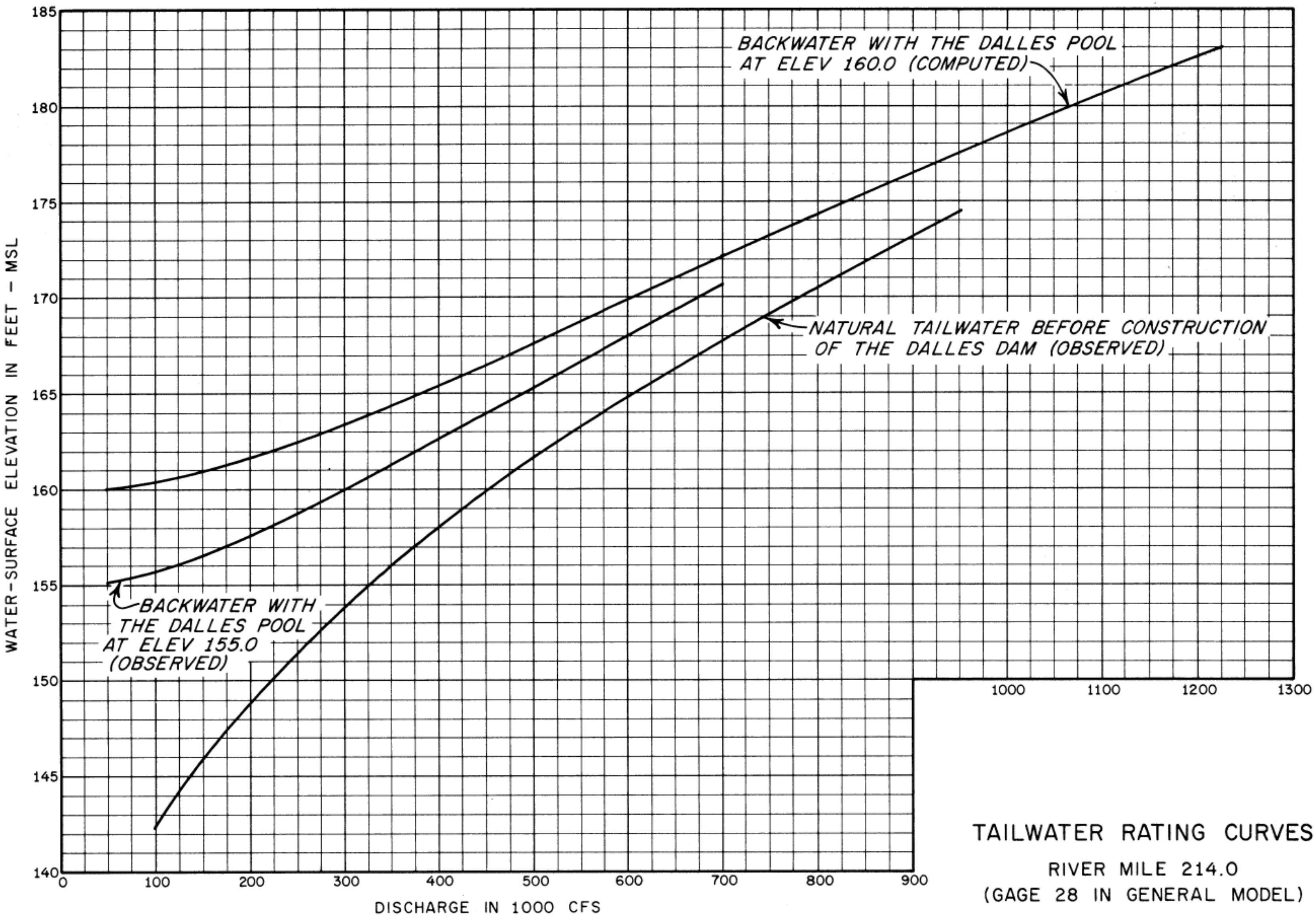
PLATE 1



MODEL LAYOUT

NOTE

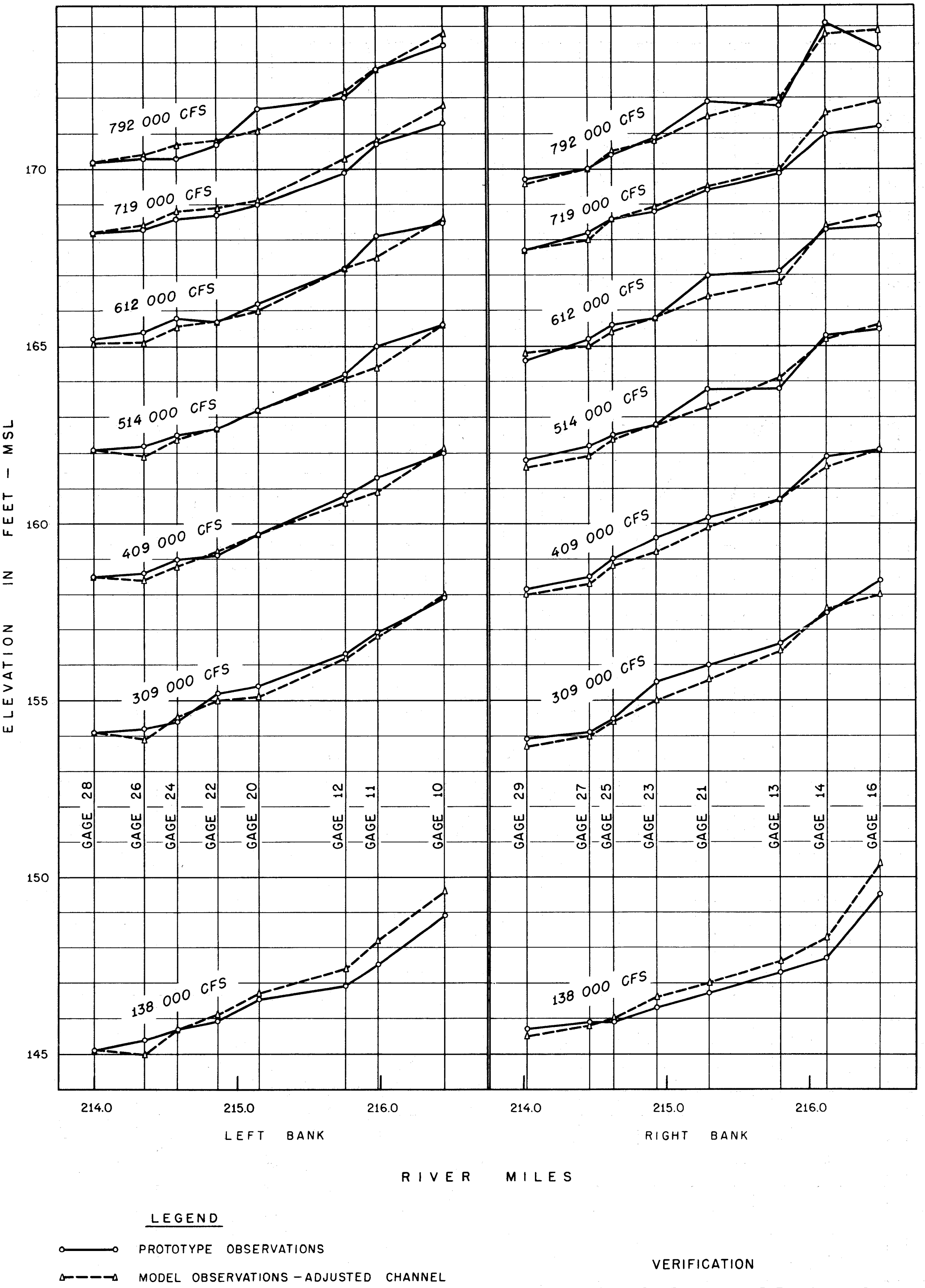
PROJECT AXIS IS 215.6 MILES ABOVE MOUTH OF COLUMBIA RIVER.



TAILWATER RATING CURVES

RIVER MILE 214.0

(GAGE 28 IN GENERAL MODEL)



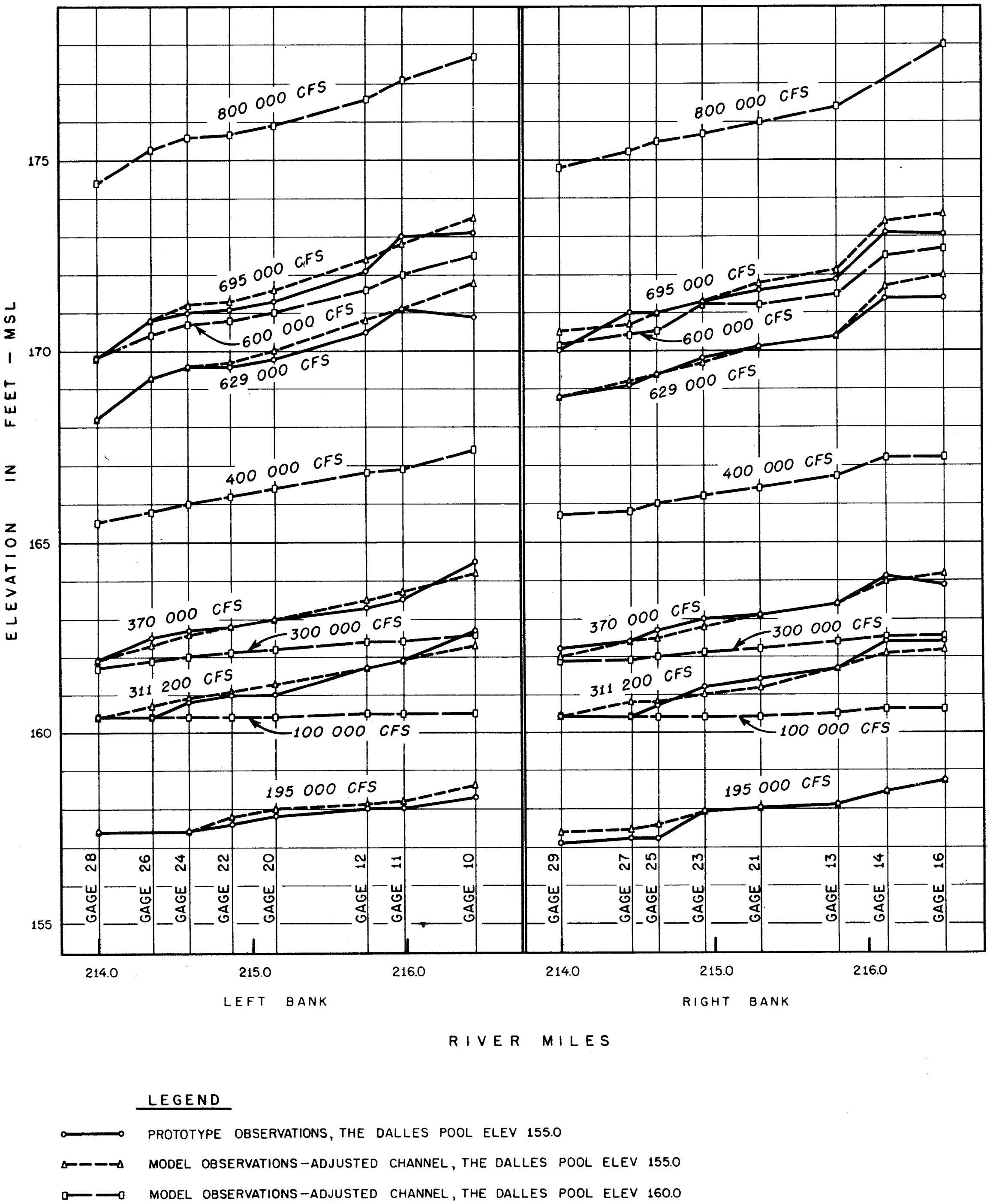
NOTE

GAGE LOCATIONS SHOWN ON PLATE 2.

VERIFICATION

WATER - SURFACE PROFILES

RIVER DISCHARGE 138 000 TO 792 000 CFS



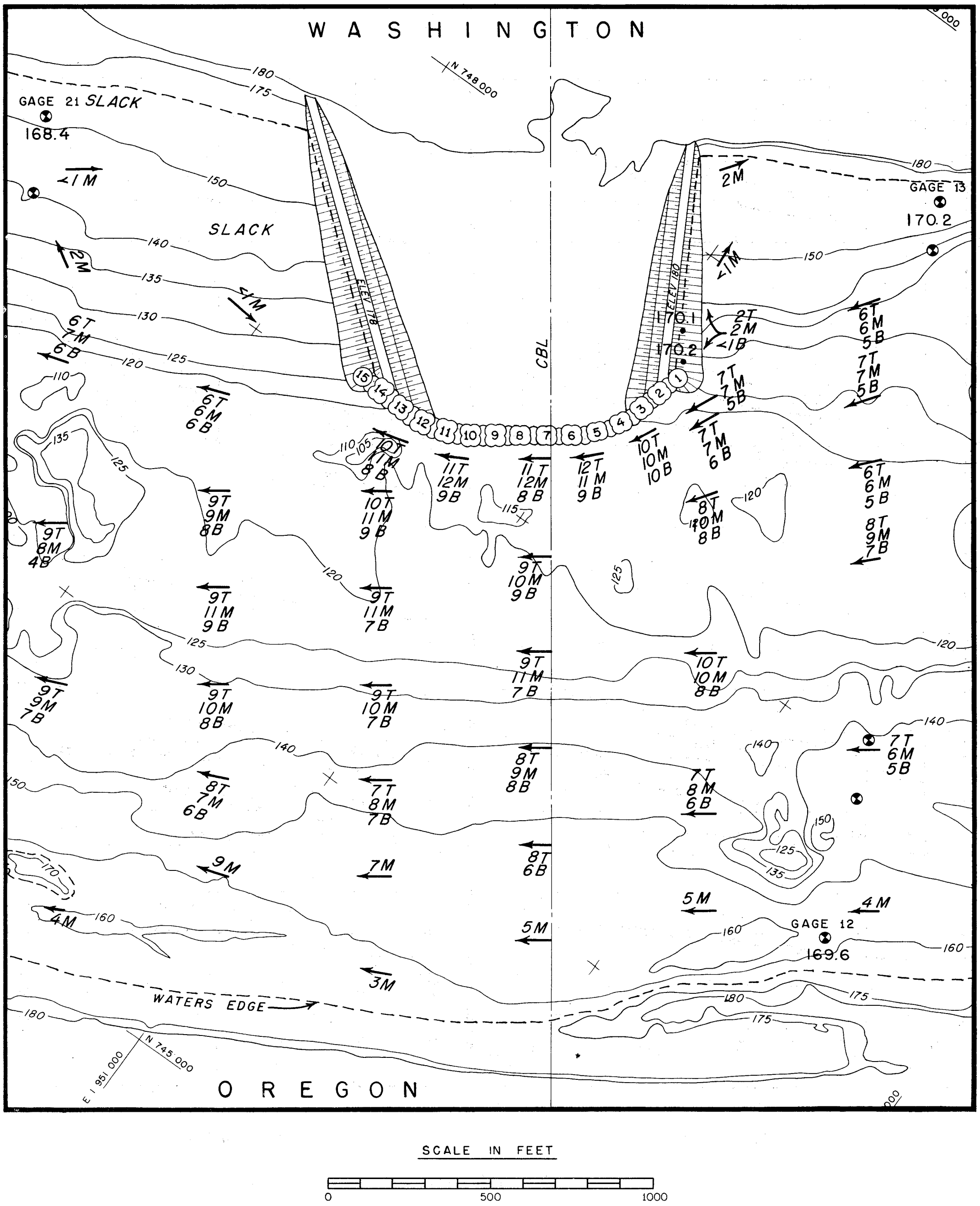
NOTE

GAGE LOCATIONS SHOWN ON PLATE 2.

VERIFICATION

WATER - SURFACE PROFILES

THE DALLES POOL ELEVS 155.0 TO 160.0



LEGEND

2 ← VELOCITY MEASUREMENTS IN FPS

T 5-FT DEPTH

M MID-DEPTH

B 5 FT ABOVE BOTTOM

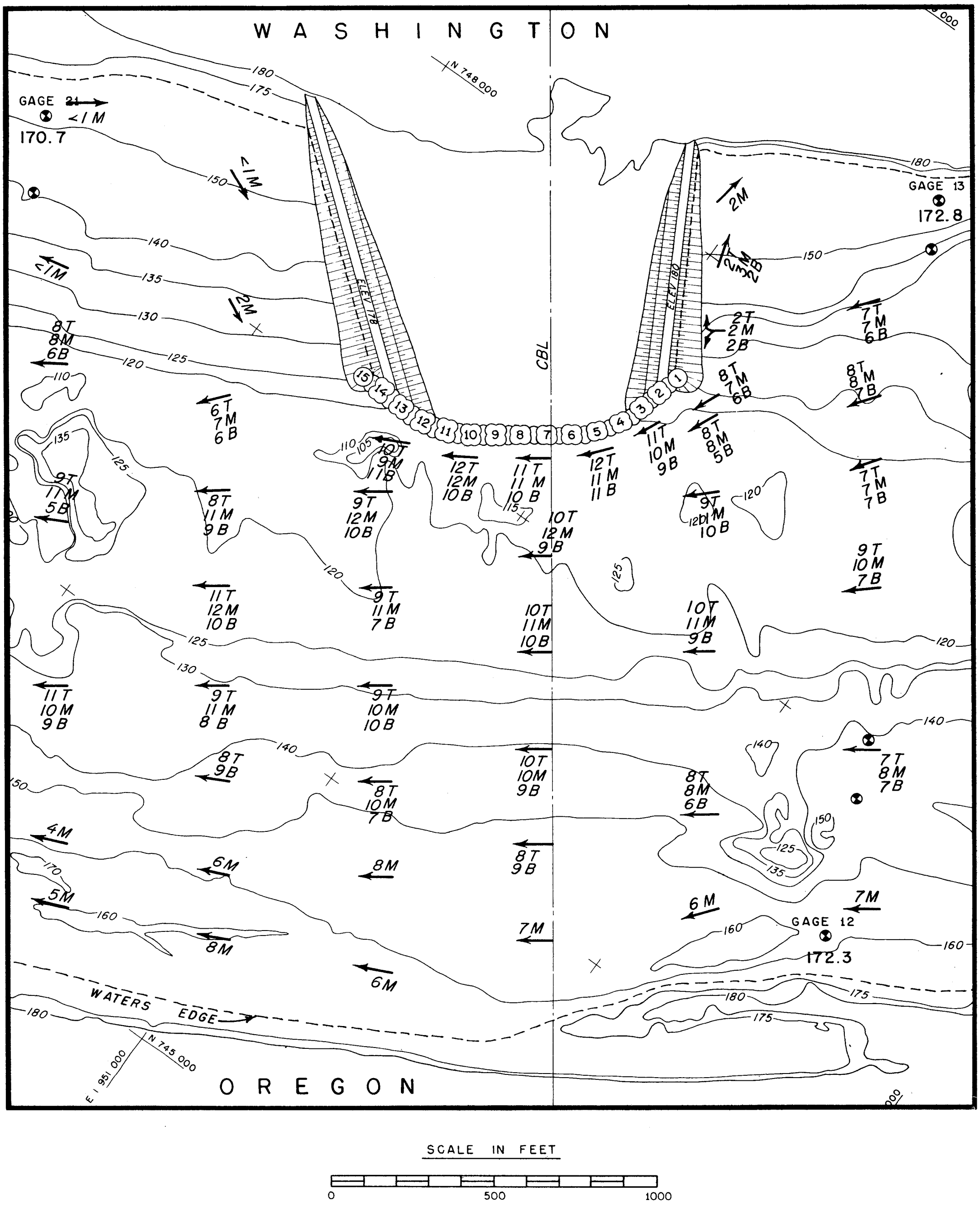
FLOW CONDITIONS

FIRST-STEP COFFERDAM

ORIGINAL DESIGN

RIVER DISCHARGE 500 000 CFS

TAILWATER ELEVATION 167.6



LEGEND

← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM

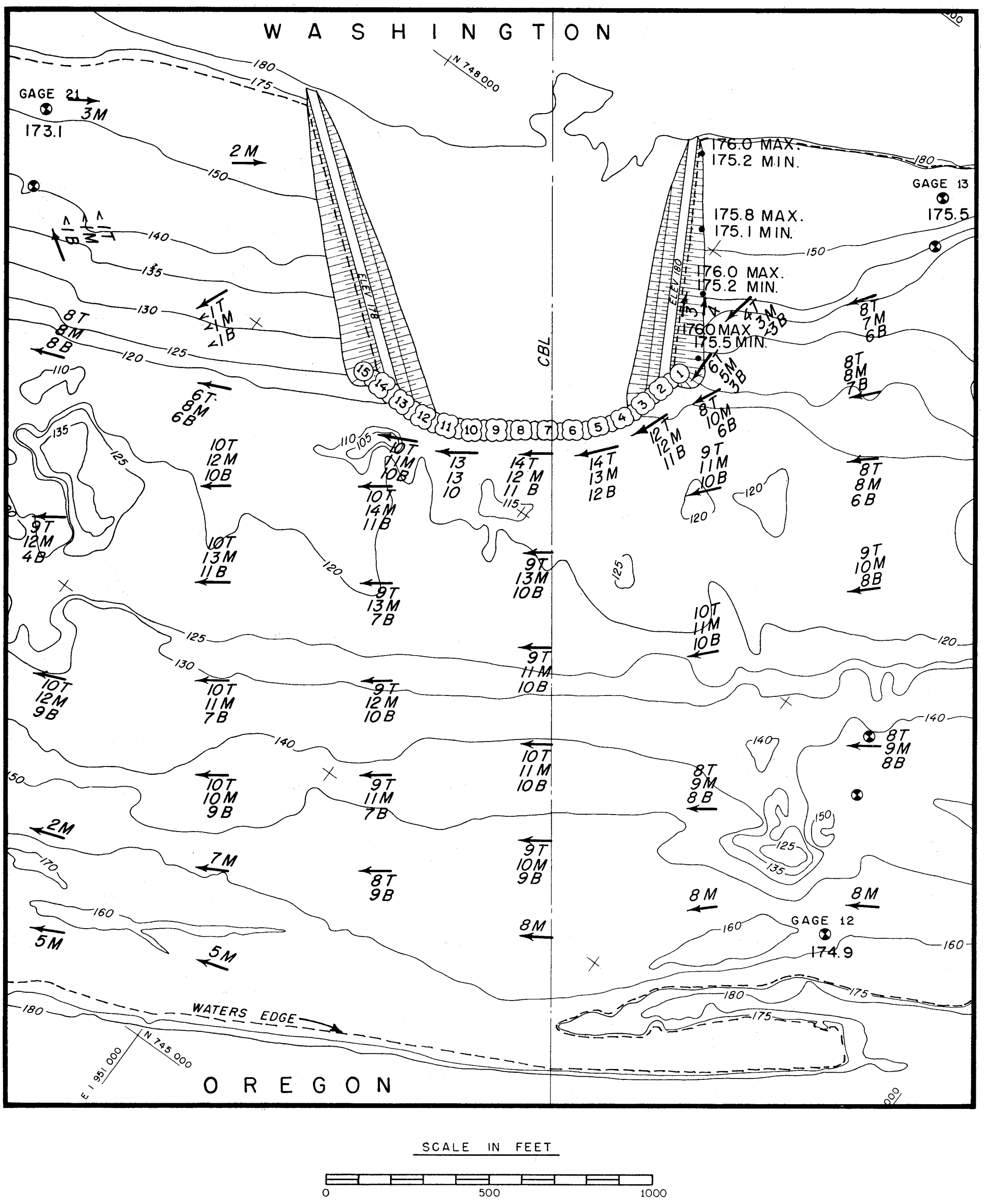
FLOW CONDITIONS

FIRST-STEP COFFERDAM

ORIGINAL DESIGN

RIVER DISCHARGE 600 000 CFS

TAILWATER ELEVATION 169.8



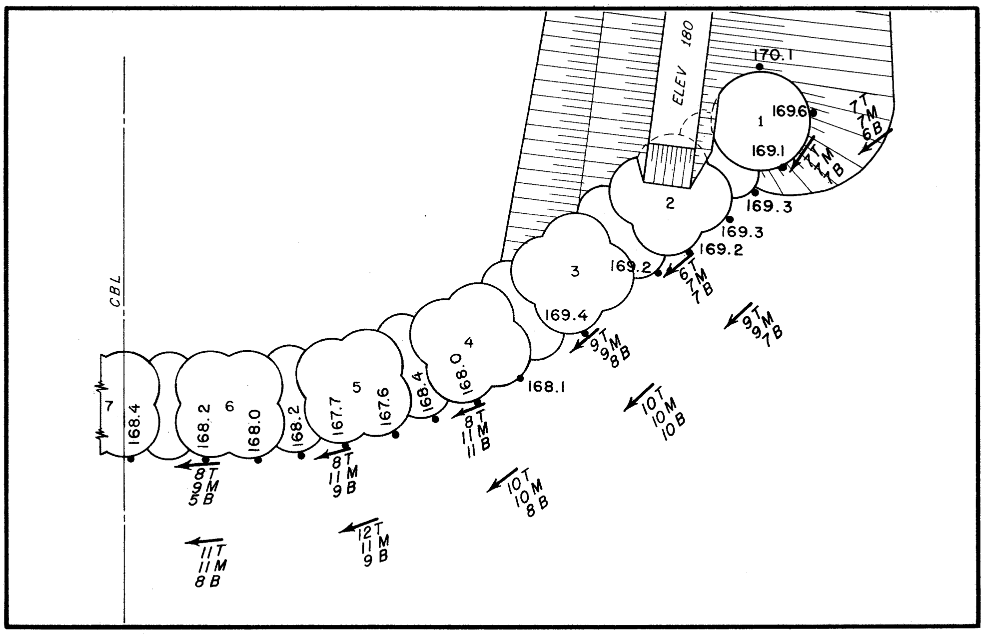
LEGEND

← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
● 175.5	WATER-SURFACE ELEVATIONS

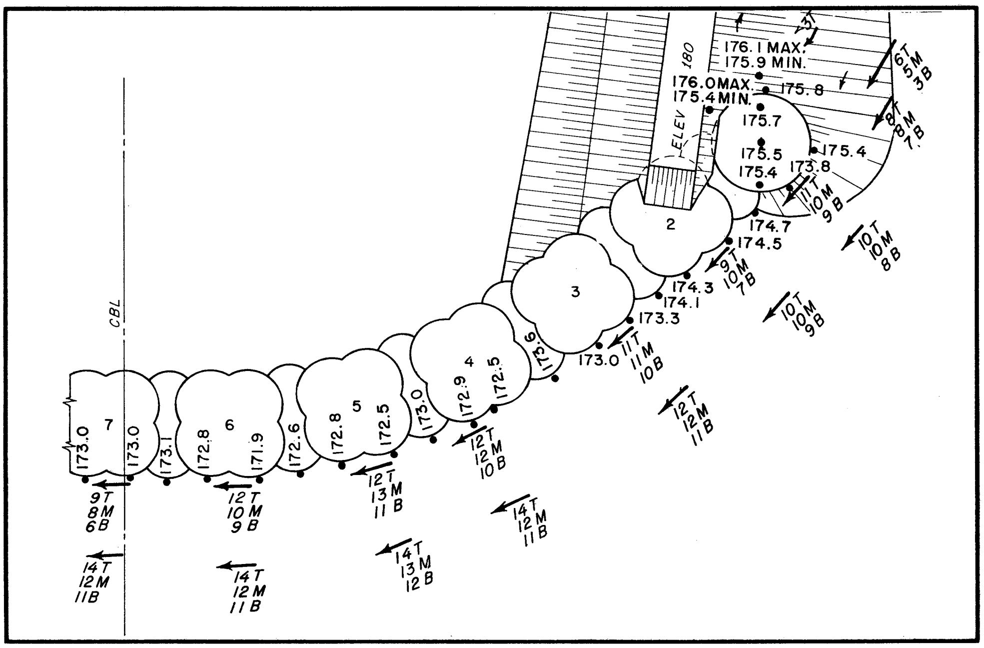
FLOW CONDITIONS
FIRST-STEP COFFERDAM
ORIGINAL DESIGN

RIVER DISCHARGE 700 000 CFS

TAILWATER ELEVATION 172.2



RIVER DISCHARGE 500 000 CFS



RIVER DISCHARGE 700 000 CFS

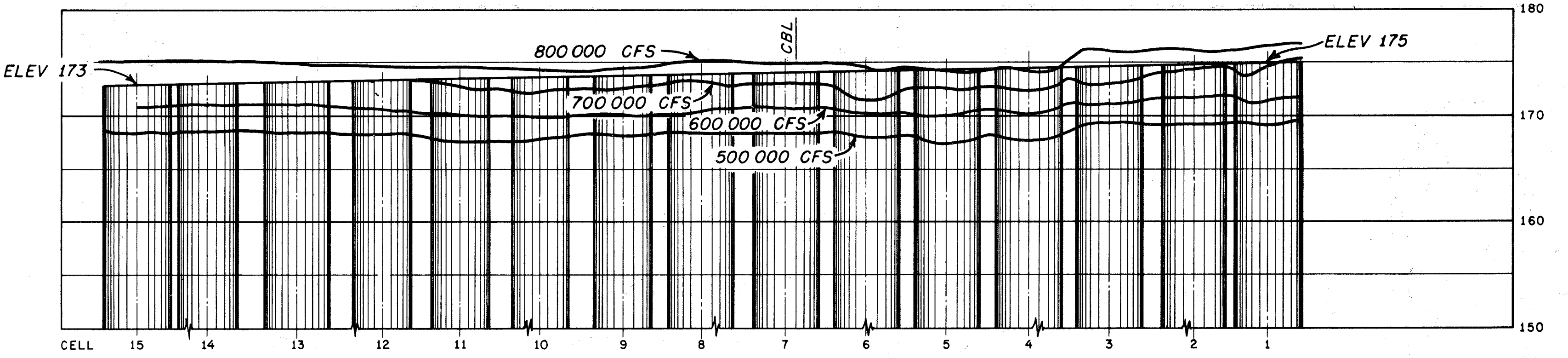
NOTES

1. CELL LOCATIONS SHOWN ON PLATES 6 TO 8.
2. CELL PROFILES SHOWN ON PLATE 10.
3. COFFERDAM DESIGN DISCHARGE 700 000 CFS.

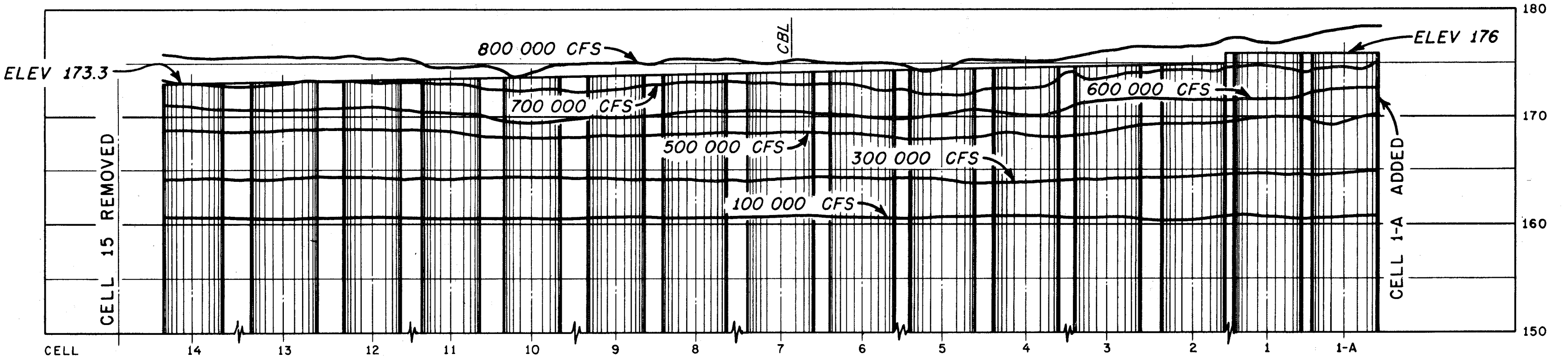
LEGEND

← 7 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
172.5 ● WATER-SURFACE ELEVATIONS

VELOCITIES
FIRST-STEP COFFERDAM
ORIGINAL DESIGN



ORIGINAL DESIGN



FINAL DESIGN

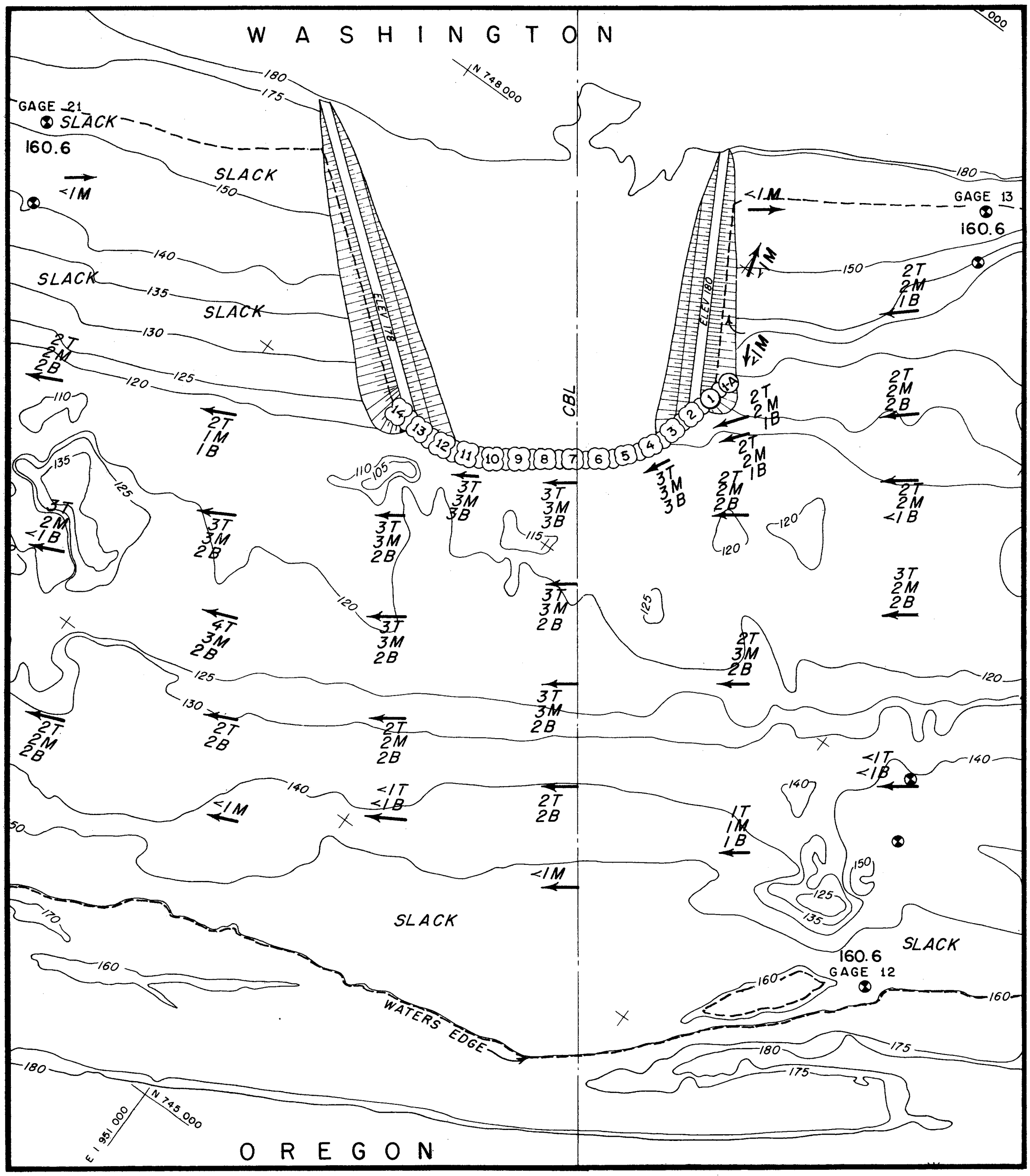
WATER-SURFACE PROFILES

FIRST STEP-COFFERDAM

ORIGINAL AND FINAL DESIGNS

NOTE

CELL LOCATIONS SHOWN ON PLATES 8 (ORIGINAL DESIGN) 11 (FINAL DESIGN).



SCALE IN FEET

0 500 1000

LEGEND

← 2 VELOCITY MEASUREMENTS IN FPS

T 5-FT DEPTH

M MID-DEPTH

B 5 FT ABOVE BOTTOM

NOTE

CELL PROFILES SHOWN ON PLATE 10.

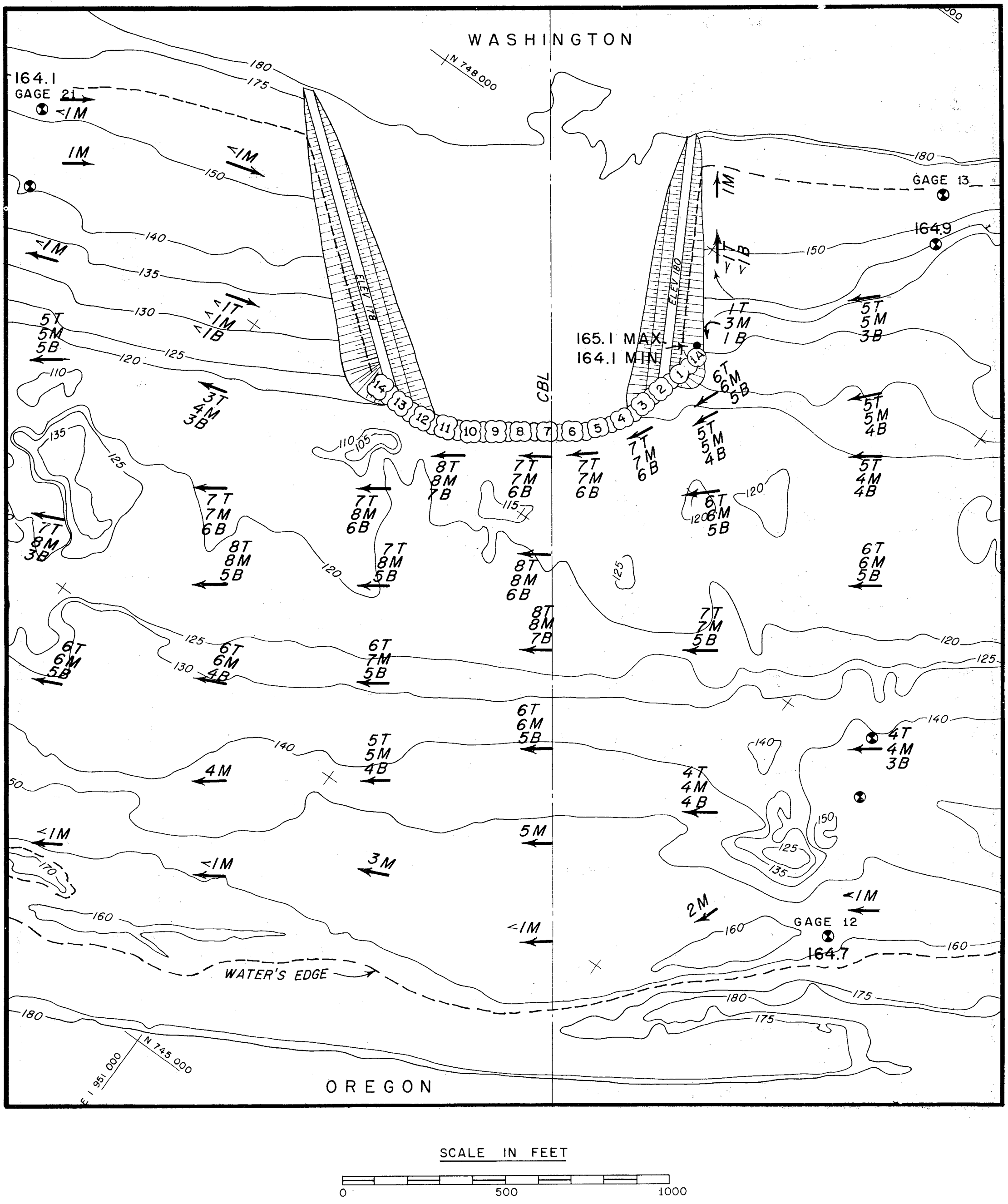
FLOW CONDITIONS

FIRST-STEP COFFERDAM

FINAL DESIGN

RIVER DISCHARGE 100 000 CFS

TAILWATER ELEVATION 160.4



LEGEND

$\xleftarrow{4}$ VELOCITY MEASUREMENTS IN FPS.

T 5-FT DEPTH

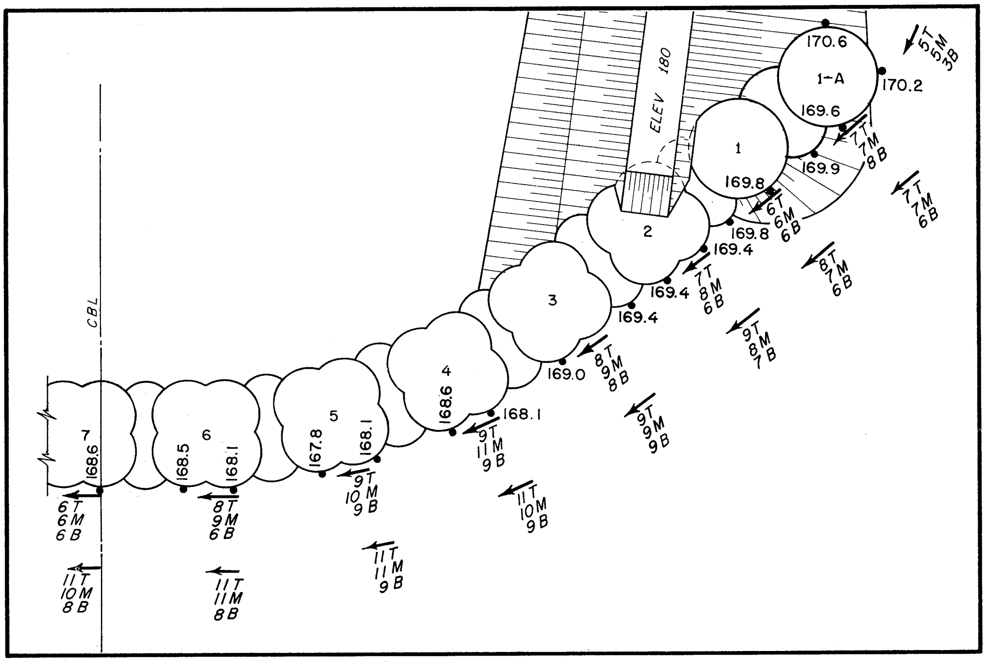
M MID-DEPTH

B 5 FT ABOVE BOTTOM

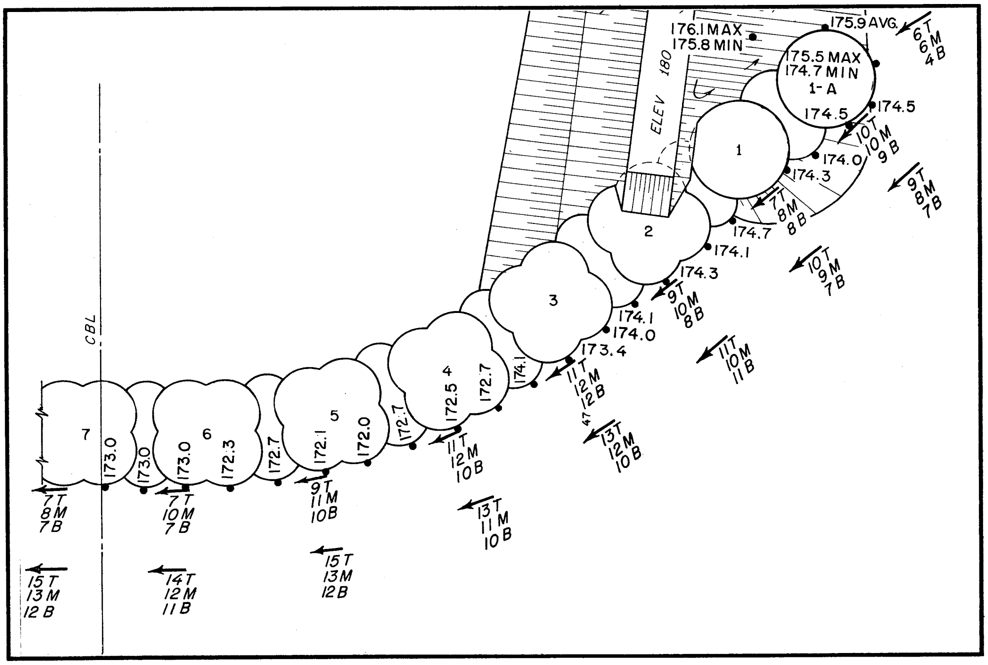
NOTE

CELL PROFILES SHOWN ON PLATE 10.

FLOW CONDITIONS
FIRST-STEP COFFERDAM
FINAL DESIGN
RIVER DISCHARGE 300 000 CFS
TAILWATER ELEVATION 163.5



RIVER DISCHARGE 500 000 CFS



RIVER DISCHARGE 700 000 CFS

NOTES

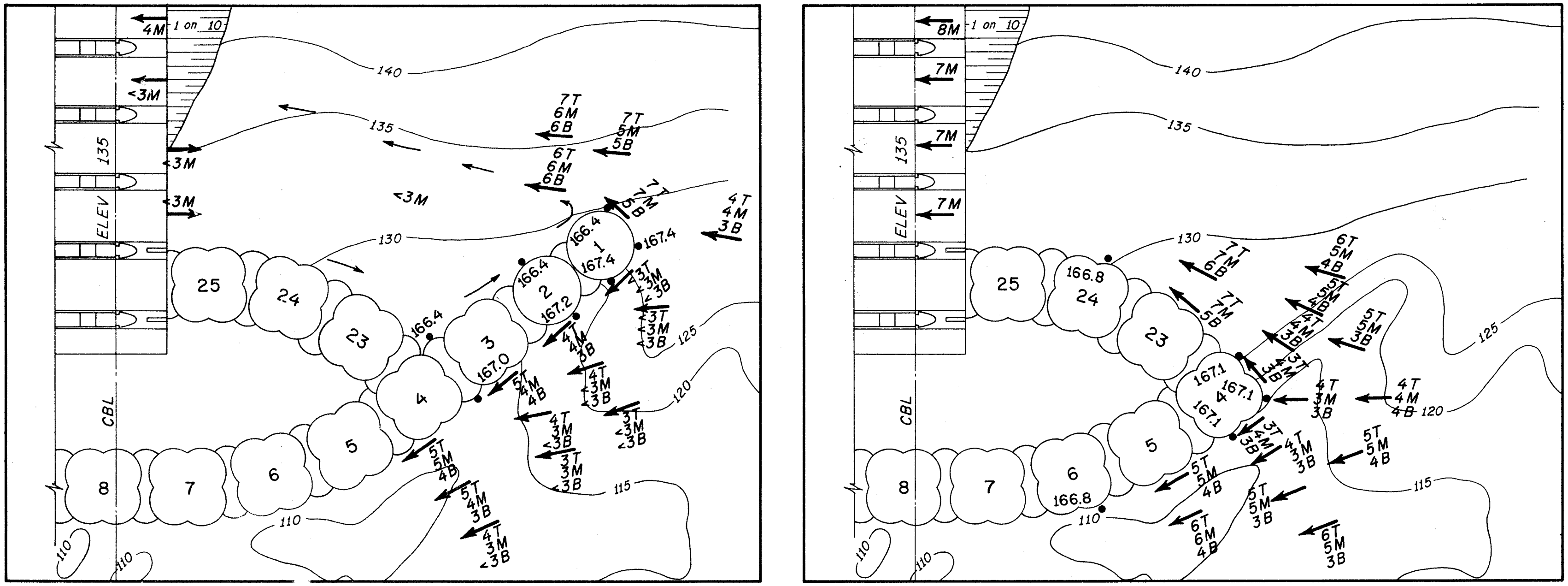
1. CELL LOCATIONS SHOWN ON PLATES 11 AND 12.
2. CELL PROFILES SHOWN ON PLATE 10.
3 COFFERDAM DESIGN DISCHARGE 700 000 CFS.

LEGEND

← 7	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
172.5 ●	WATER-SURFACE ELEVATIONS

VELOCITIES
FIRST-STEP COFFERDAM
FINAL DESIGN

PLATE 14



STAGE I

STAGE IA

LEGEND

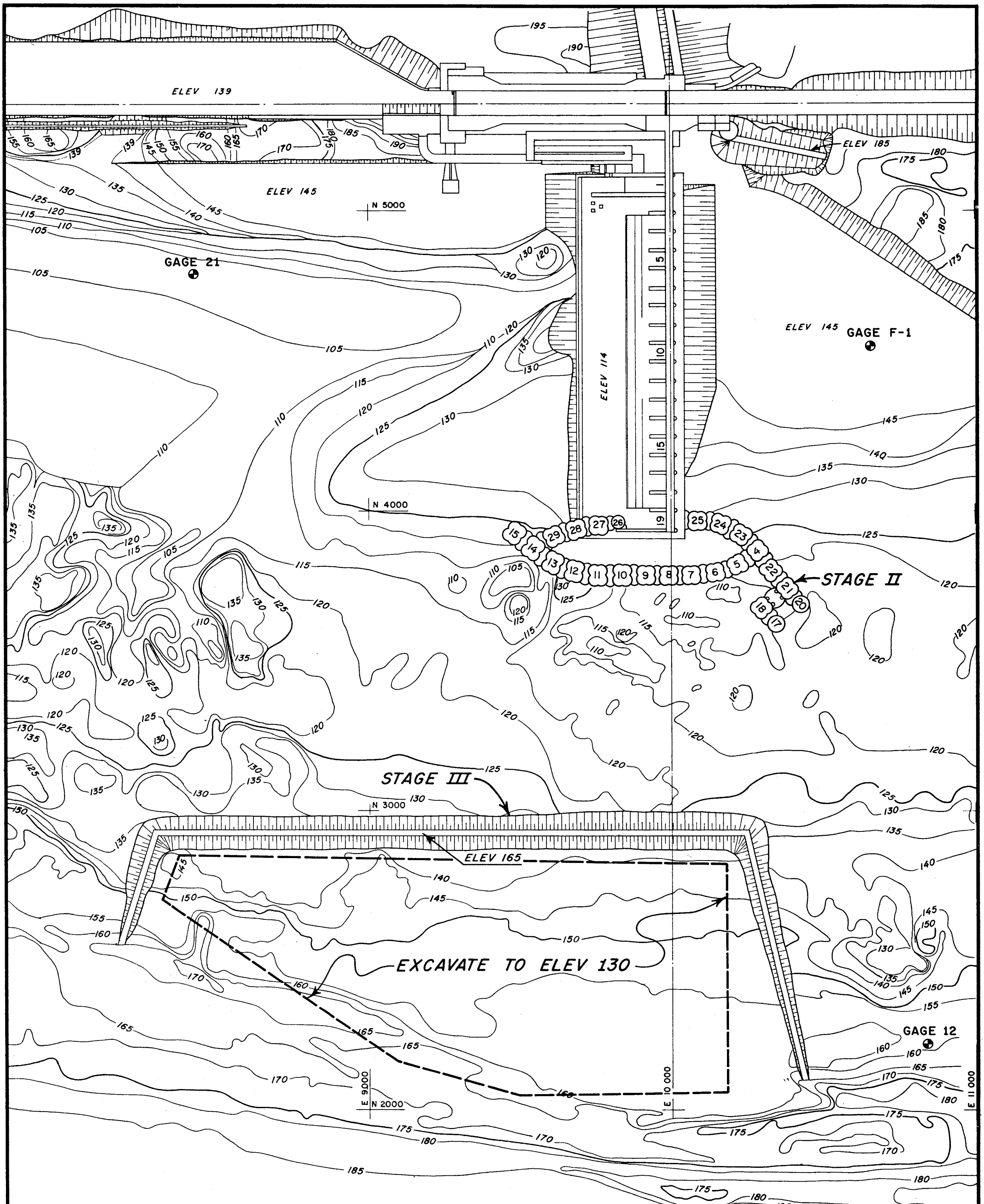
← 7	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
167.0 ●	WATER-SURFACE ELEVATIONS

VELOCITIES

TRANSITION STAGES I AND I-A

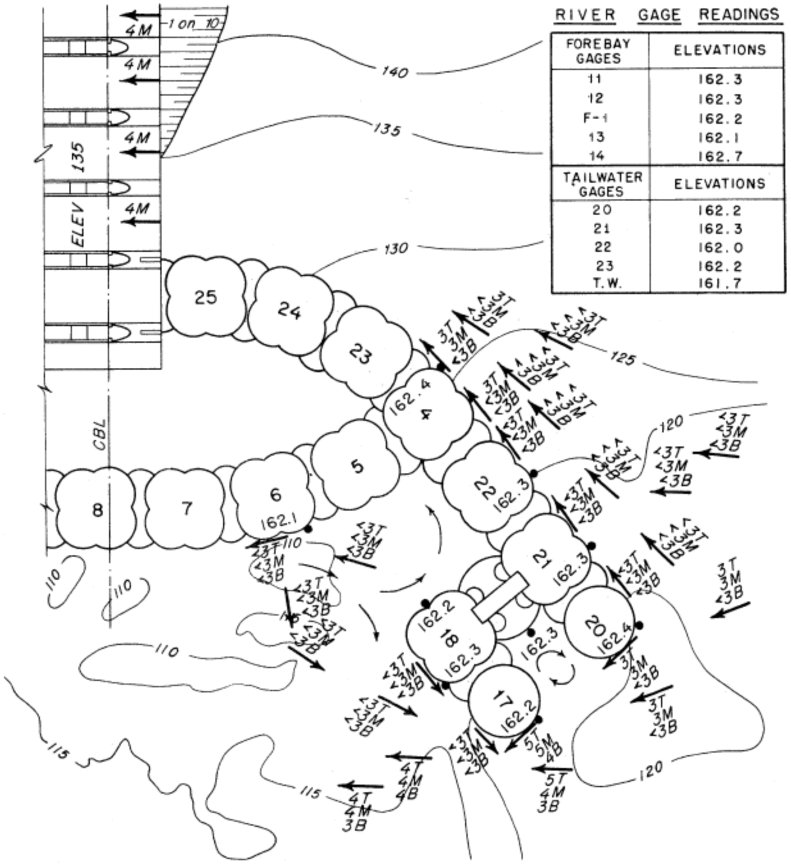
BETWEEN FIRST- AND SECOND-STEP COFFERDAMS

RIVER DISCHARGE 400 000 CFS



TRANSITION STAGES II AND III

BETWEEN FIRST AND SECOND – STEP COFFERDAMS

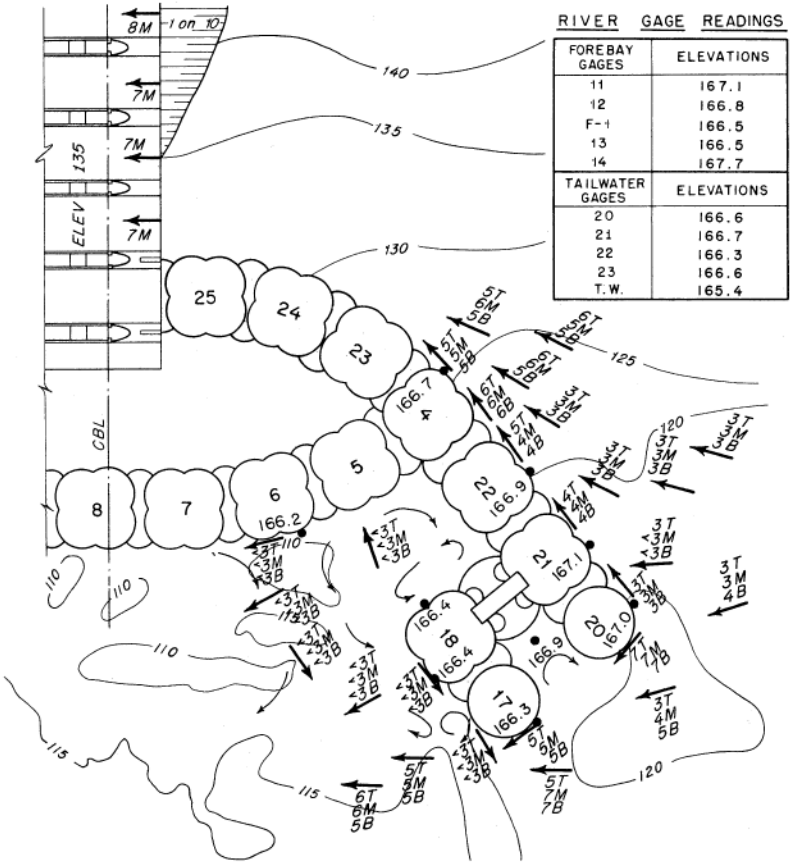


RIVER GAGE READINGS

FOREBAY GAGES	ELEVATIONS
11	162.3
12	162.3
F-1	162.2
13	162.1
14	162.7

TAILWATER GAGES	ELEVATIONS
20	162.2
21	162.3
22	162.0
23	162.2
T.W.	161.7

RIVER DISCHARGE 200 000 CFS



RIVER GAGE READINGS

FOREBAY GAGES	ELEVATIONS
11	167.1
12	166.8
F-1	166.5
13	166.5
14	167.7

TAILWATER GAGES	ELEVATIONS
20	166.6
21	166.7
22	166.3
23	166.6
T.W.	165.4

RIVER DISCHARGE 400 000 CFS

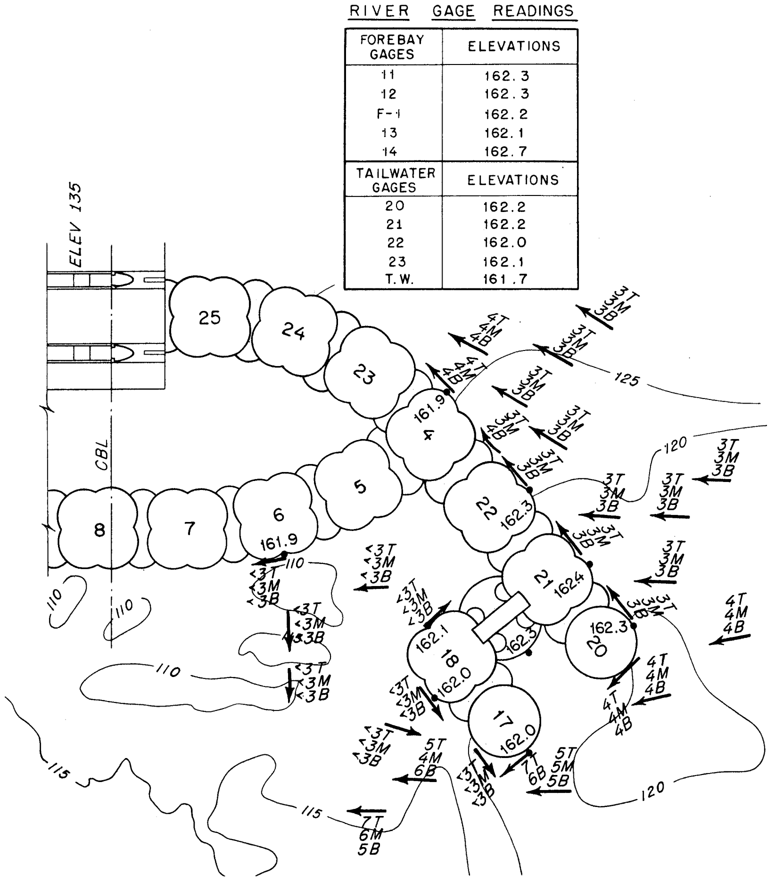
LEGEND

←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATIONS

NOTES

1. GAGE LOCATIONS SHOWN ON PLATE 2.
2. LAYOUT OF TRANSITION STAGE II SHOWN ON PLATE 15.

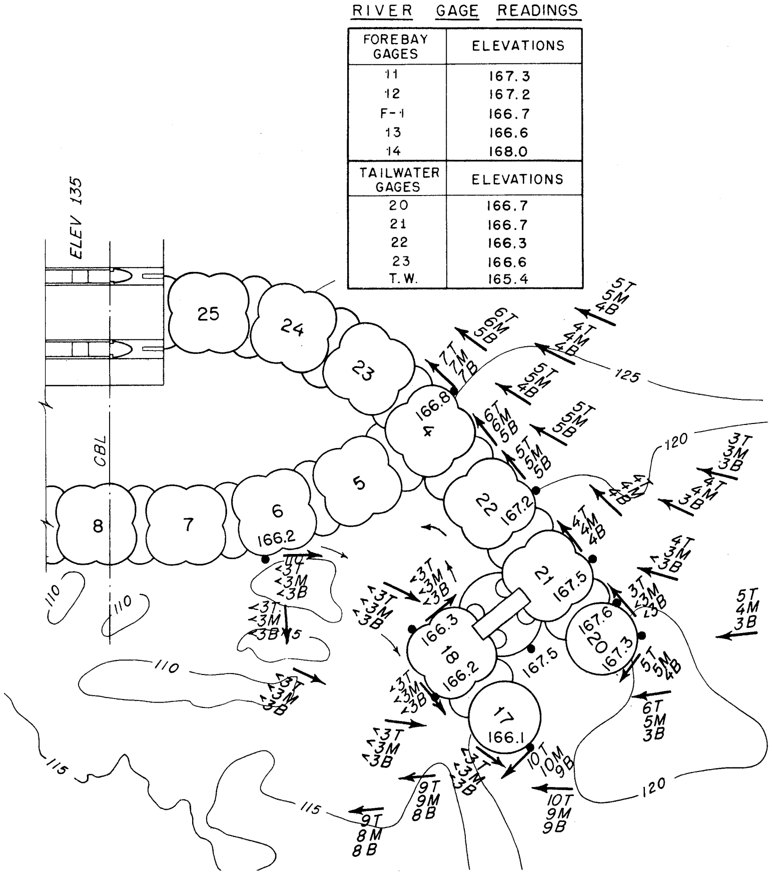
VELOCITIES
TRANSITION STAGE II
BETWEEN FIRST AND SECOND-STEP COFFERDAMS



RIVER GAGE READINGS

FOREBAY GAGES	ELEVATIONS
11	162.3
12	162.3
F-1	162.2
13	162.1
14	162.7
TAILWATER GAGES	**ELEVATIONS**
20	162.2
21	162.2
22	162.0
23	162.1
T.W.	161.7

RIVER DISCHARGE 200 000 CFS



RIVER GAGE READINGS

FOREBAY GAGES	ELEVATIONS
11	167.3
12	167.2
F-1	166.7
13	166.6
14	168.0
TAILWATER GAGES	**ELEVATIONS**
20	166.7
21	166.7
22	166.3
23	166.6
T.W.	165.4

RIVER DISCHARGE 400 000 CFS

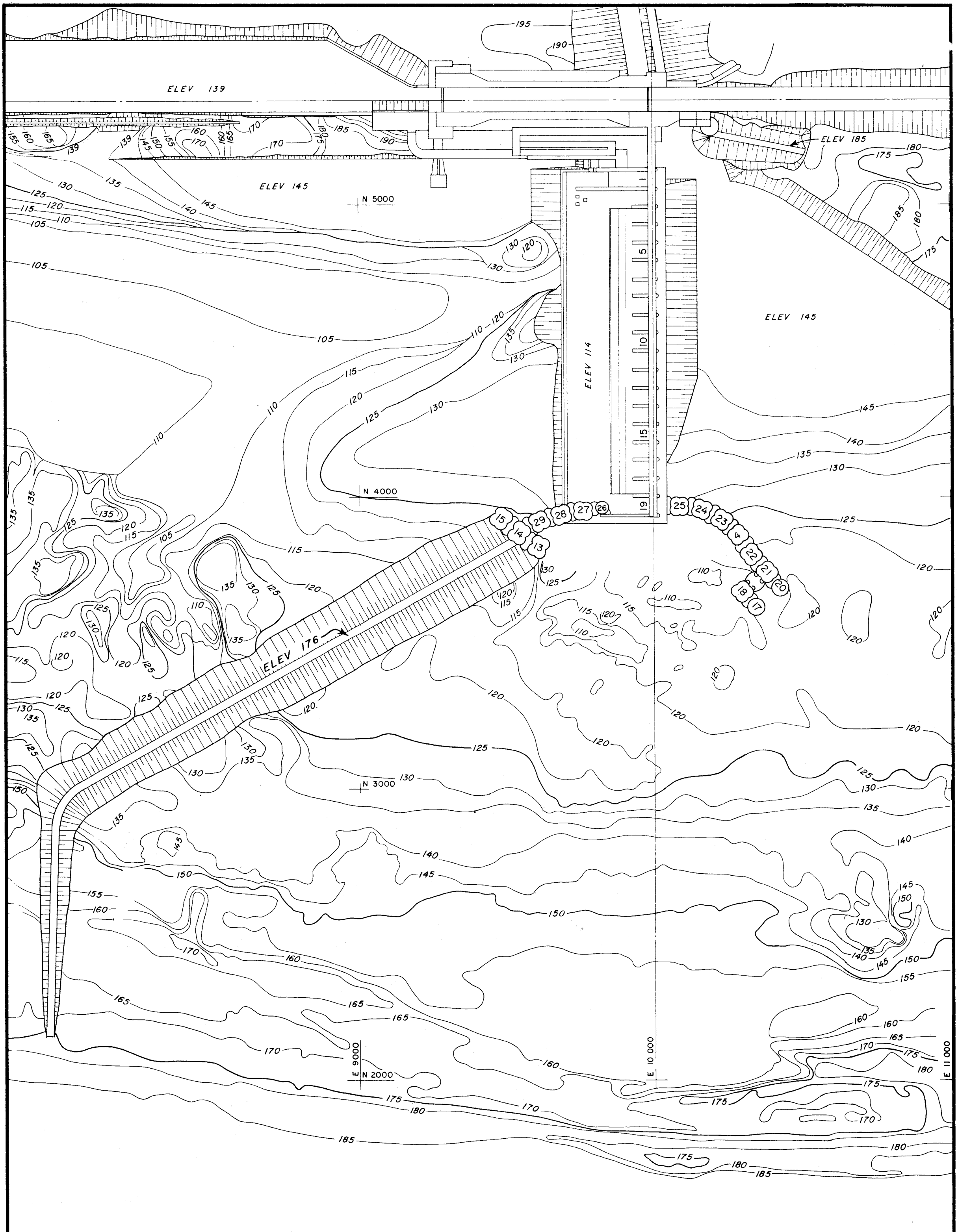
NOTES

1. GAGE LOCATIONS SHOWN ON PLATE 2.
2. LAYOUT OF TRANSITION STAGE III SHOWN ON PLATE 15.

LEGEND

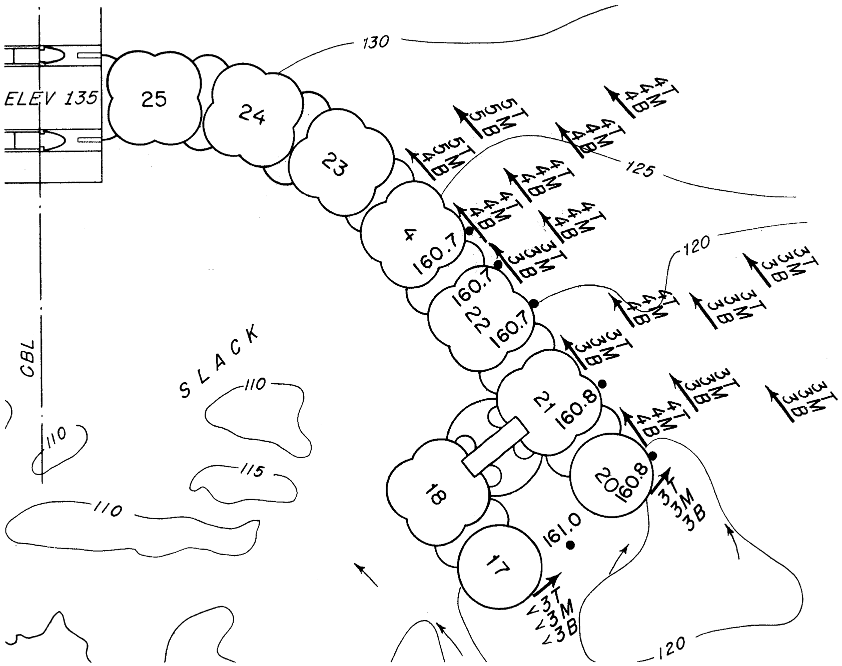
←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATIONS

VELOCITIES
TRANSITION STAGE III
BETWEEN FIRST AND SECOND-STEP COFFERDAMS

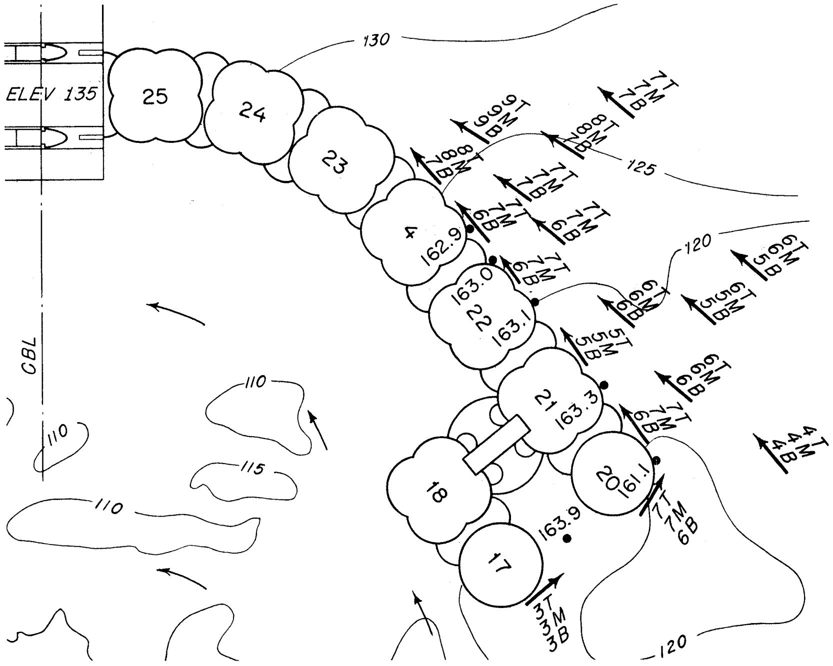


TRANSITION STAGE IV

BETWEEN FIRST AND SECOND-STEP COFFERDAMS



RIVER DISCHARGE 100 000 CFS



RIVER DISCHARGE 200 000 CFS

RIVER GAGE READINGS

FOREBAY GAGES	100 000 CFS	200 000 CFS
11	161.0	163.9
12	161.0	163.9
F-1	160.5	162.6
13	160.7	163.2
14	161.1	164.2
TAILWATER GAGES		
20	160.5	162.0
21	160.5	162.1
22	160.5	162.1
23	160.5	162.1
T.W.	160.4	161.7

NOTES

1. GAGE LOCATIONS SHOWN ON PLATE 2.
2. LAYOUT OF TRANSITION STAGE IV SHOWN ON PLATE 18.

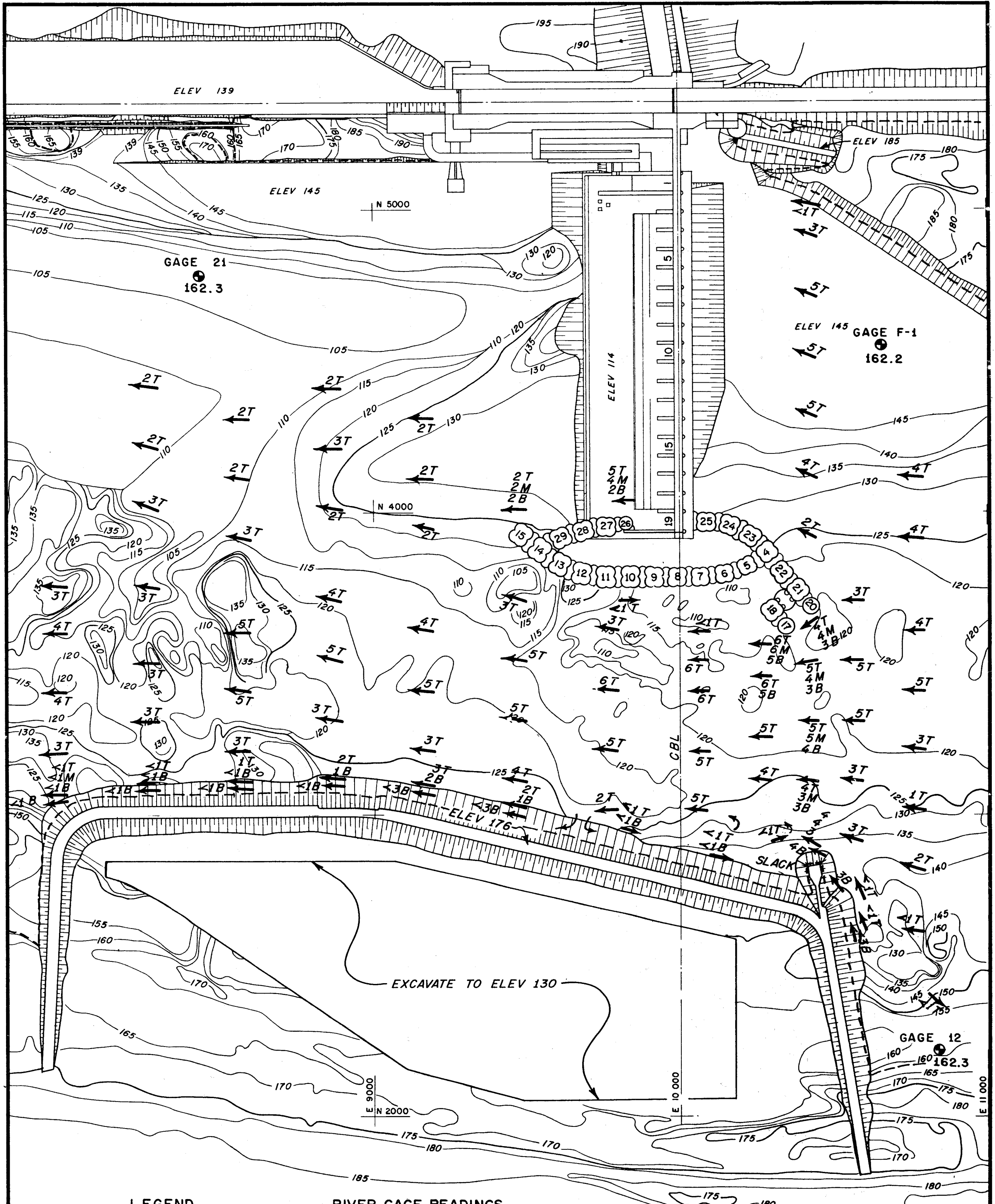
LEGEND

← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATIONS

VELOCITIES

TRANSITION STAGE IV

BETWEEN FIRST AND SECOND-STEP COFFERDAMS



LEGEND

←5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM

NOTE

1. GAGE LOCATIONS SHOWN ON PLATE 2.

RIVER GAGE READINGS

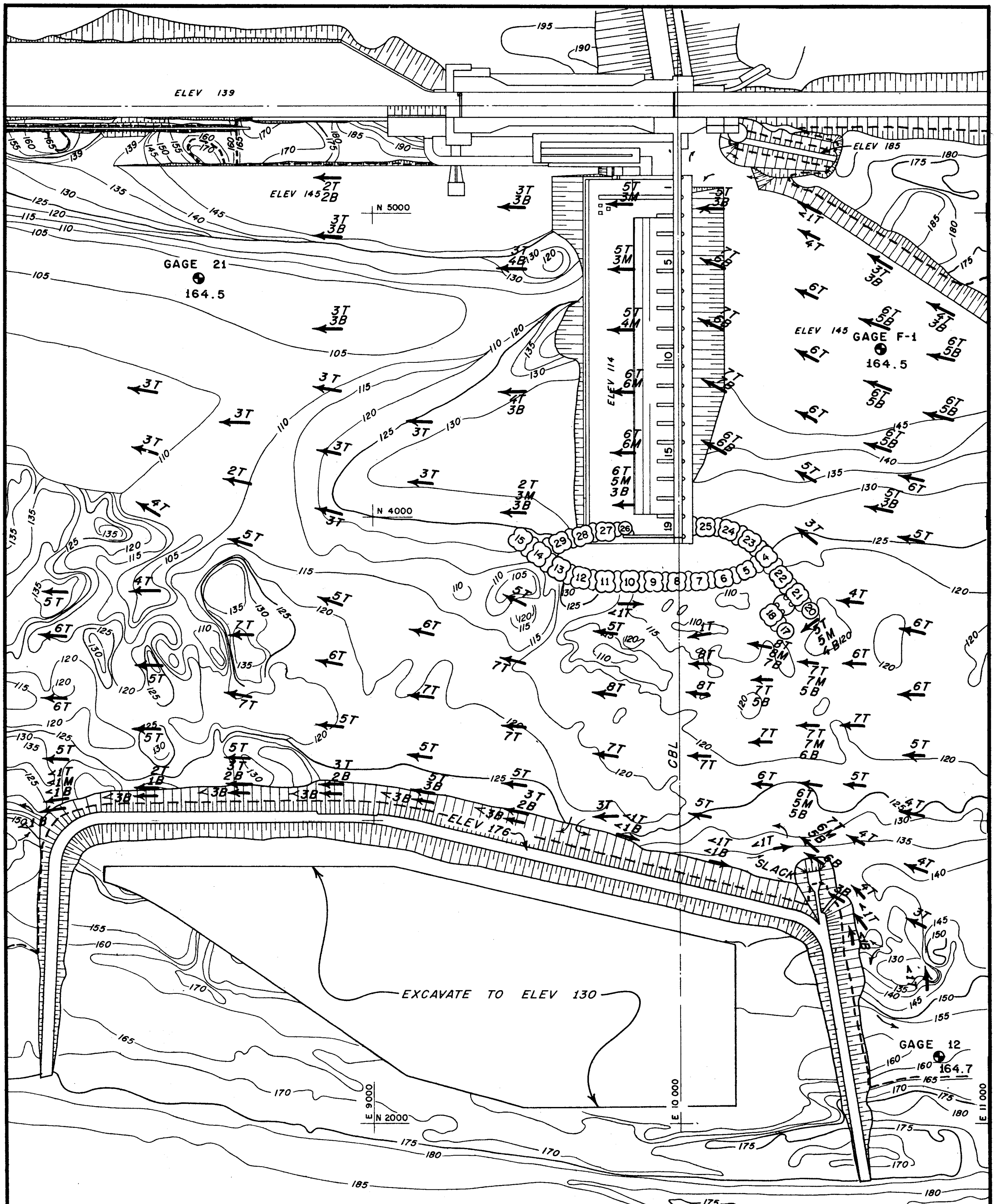
FOREBAY GAGES	ELEVATIONS
11	162.3
12	162.3
F-1	162.2
13	162.1
14	162.7
TAILWATER GAGES	ELEVATIONS
20	162.2
21	162.3
22	162.0
23	162.2
T. W.	161.7

FLOW CONDITIONS

TRANSITION STAGE II E

BETWEEN FIRST AND SECOND-STEP COFFERDAMS

RIVER DISCHARGE 200 000 CFS



LEGEND

←5 VELOCITY MEASUREMENTS IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM

NOTE

GAGE LOCATIONS SHOWN ON PLATE 2.

RIVER GAGE READINGS

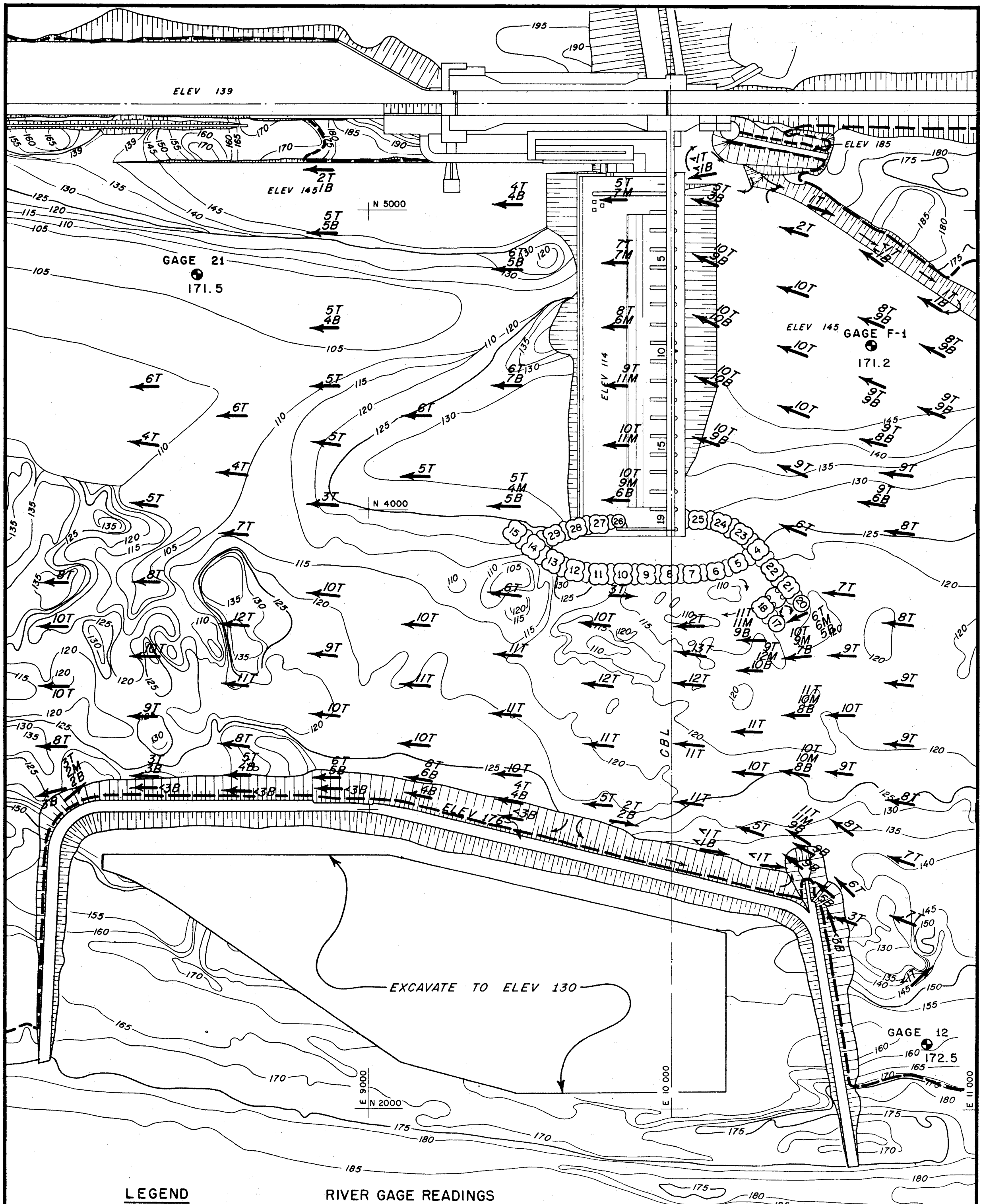
FOREBAY GAGES	ELEVATIONS
11	164.9
12	164.7
F-1	164.5
13	164.4
14	165.3
TAILWATER GAGES	ELEVATIONS
20	164.4
21	164.5
22	164.3
23	164.4
T.W.	163.5

FLOW CONDITIONS

TRANSITION STAGE IIE

BETWEEN FIRST AND SECOND-STEP COFFERDAMS

RIVER DISCHARGE 300 000 CFS



LEGEND

←5 VELOCITY MEASUREMENTS IN FPS

T 5-FT DEPTH

M MID-DEPTH

B 5 FT ABOVE BOTTOM

NOTE

GAGE LOCATIONS SHOWN ON PLATE 2.

RIVER GAGE READINGS

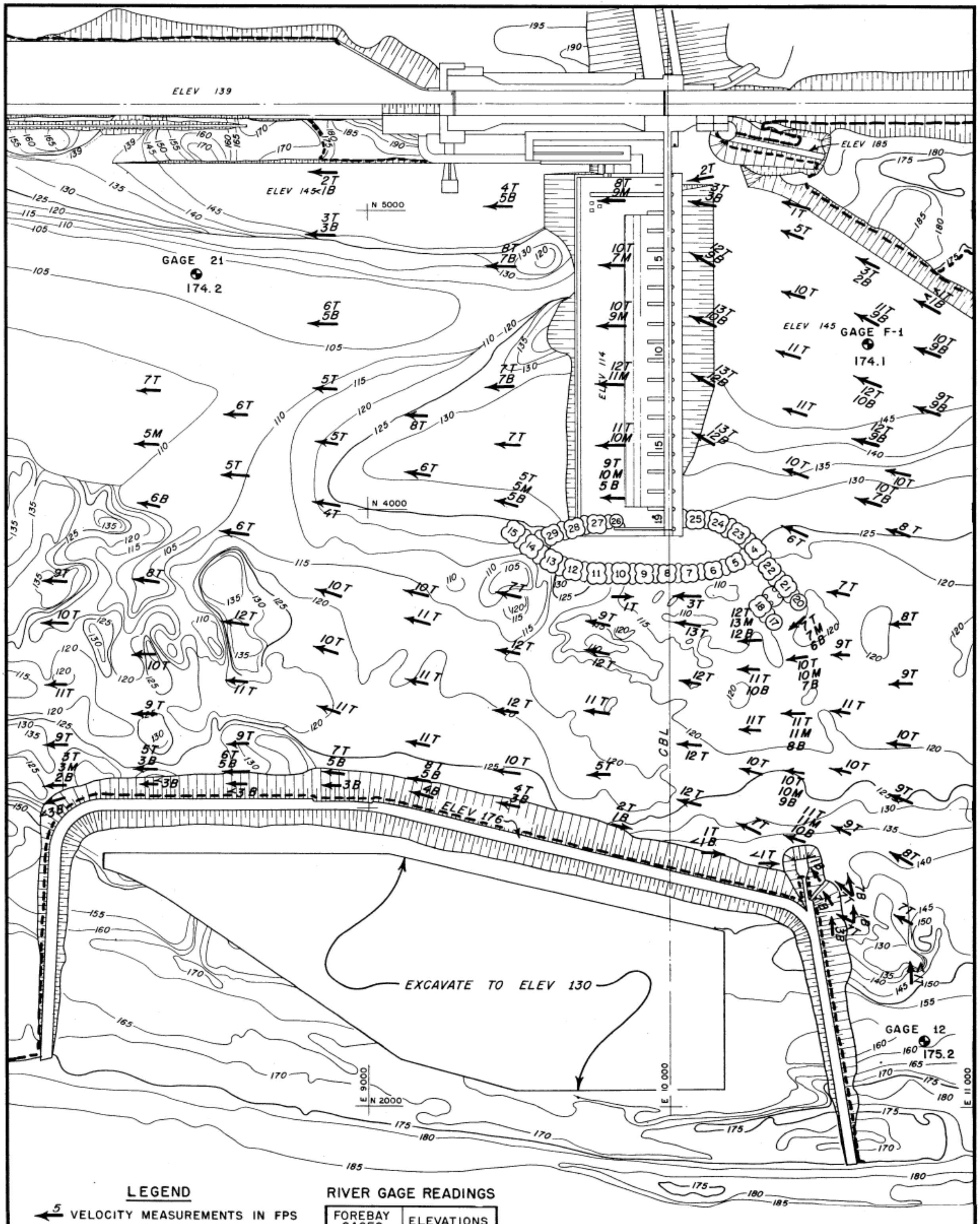
FOREBAY GAGES	ELEVATIONS
11	172.7
12	172.5
F-1	171.2
13	171.3
14	173.5
TAILWATER GAGES	ELEVATIONS
20	171.4
21	171.5
22	171.2
23	171.4
T.W.	169.8

FLOW CONDITIONS

TRANSITION STAGE IIE

BETWEEN FIRST AND SECOND-STEP COFFERDAMS

RIVER DISCHARGE 600 000 CFS



LEGEND

← 5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM

NOTE

GAGE LOCATIONS SHOWN ON PLATE 2.

RIVER GAGE READINGS

FOREBAY GAGES	ELEVATIONS
11	175.4
12	175.2
F-1	174.1
13	173.7
14	176.3
TAILWATER GAGES	**ELEVATIONS**
20	173.9
21	174.2
22	173.9
23	174.0
T. W.	172.2

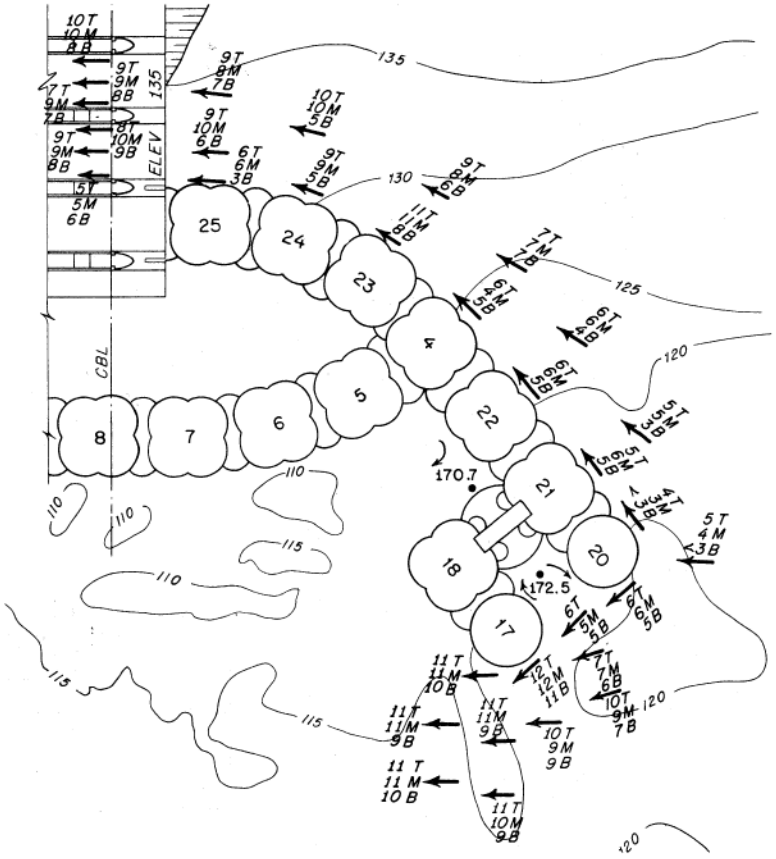
FLOW CONDITIONS

TRANSITION STAGE IIE

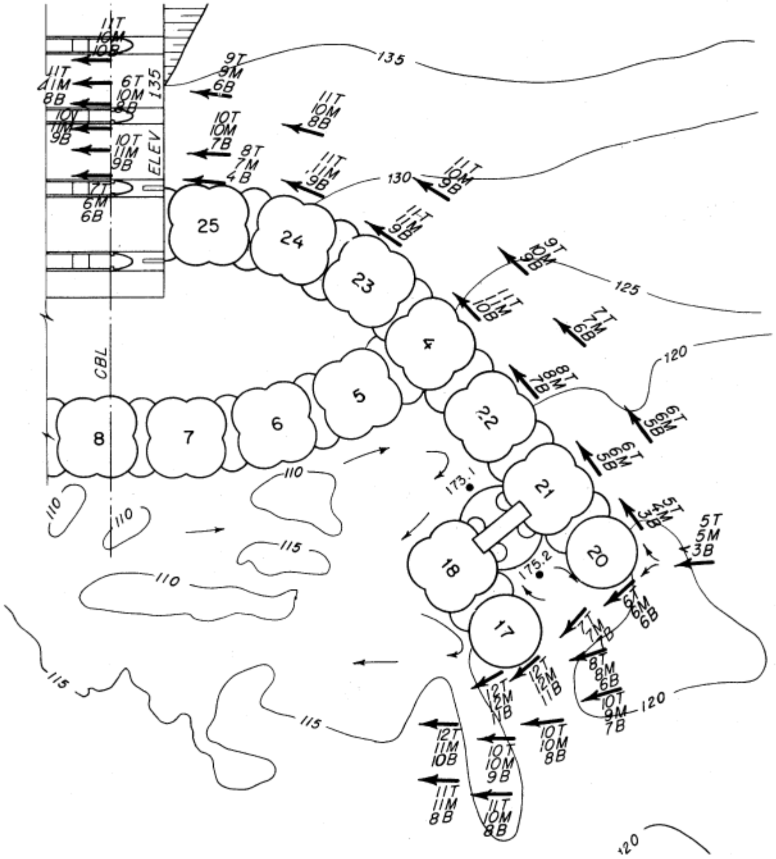
BETWEEN FIRST AND SECOND-STEP COFFERDAMS

RIVER DISCHARGE 700 000 CFS

PLATE 24



RIVER DISCHARGE 600 000 CFS



RIVER DISCHARGE 700 000 CFS

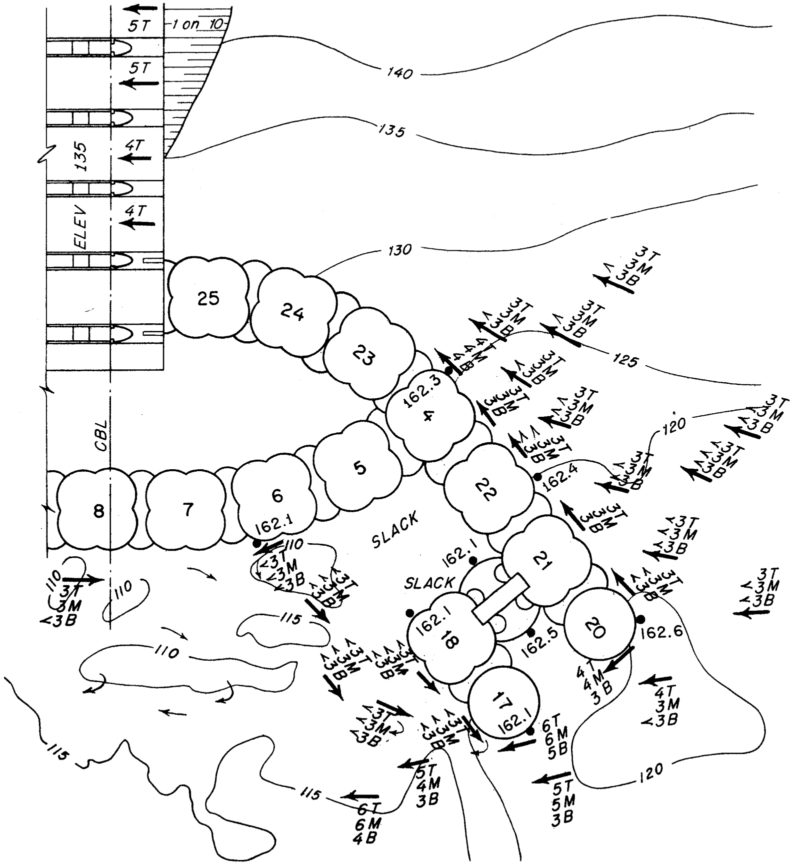
NOTE

1. LAYOUT OF TRANSITION STAGE II E SHOWN ON PLATES 20 TO 23.

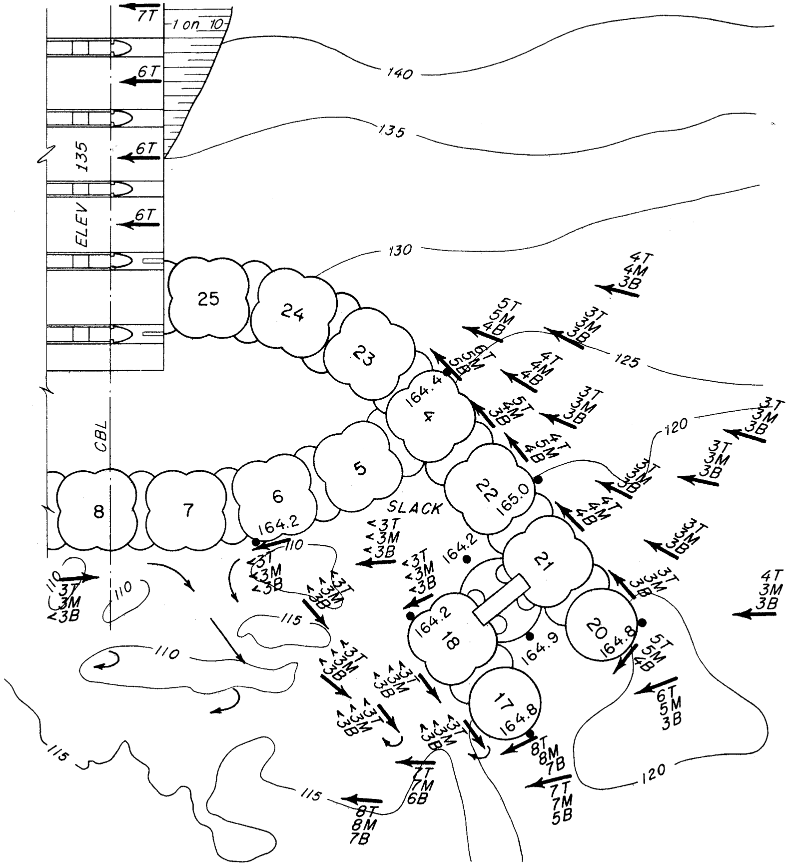
LEGEND

← 5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
● WATER-SURFACE ELEVATIONS

VELOCITIES
TRANSITION STAGE II E
BETWEEN FIRST AND SECOND-STEP COFFERDAMS



RIVER DISCHARGE 200 000 CFS



RIVER DISCHARGE 300 000 CFS

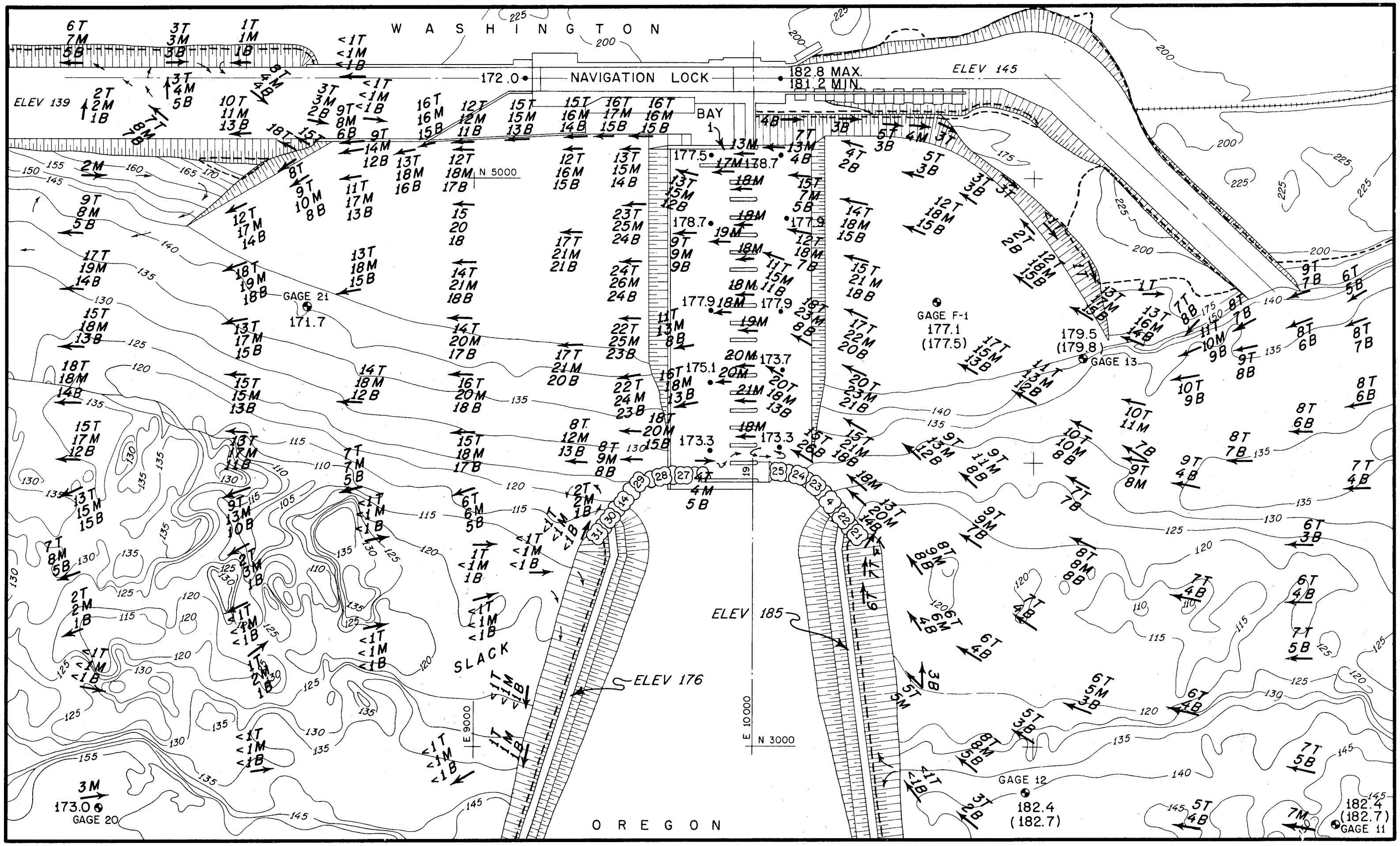
LEGEND

- ←4 VELOCITY MEASUREMENTS IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- ● WATER-SURFACE ELEVATIONS

NOTE

1. LAYOUT OF TRANSITION STAGE IIE SHOWN ON PLATES 20 TO 23.

VELOCITIES
TRANSITION STAGE IIE
BETWEEN FIRST AND SECOND-STEP COFFERDAMS



LEGEND

←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
172.0	WATER-SURFACE ELEVATIONS
(182.7)	WATER-SURFACE ELEVATIONS BAY 1 CLOSED

SCALE

0 500 1000 FT

FLOW CONDITIONS

SECOND-STEP COFFERDAM
ORIGINAL DESIGN

RIVER DISCHARGE 700 000 CFS

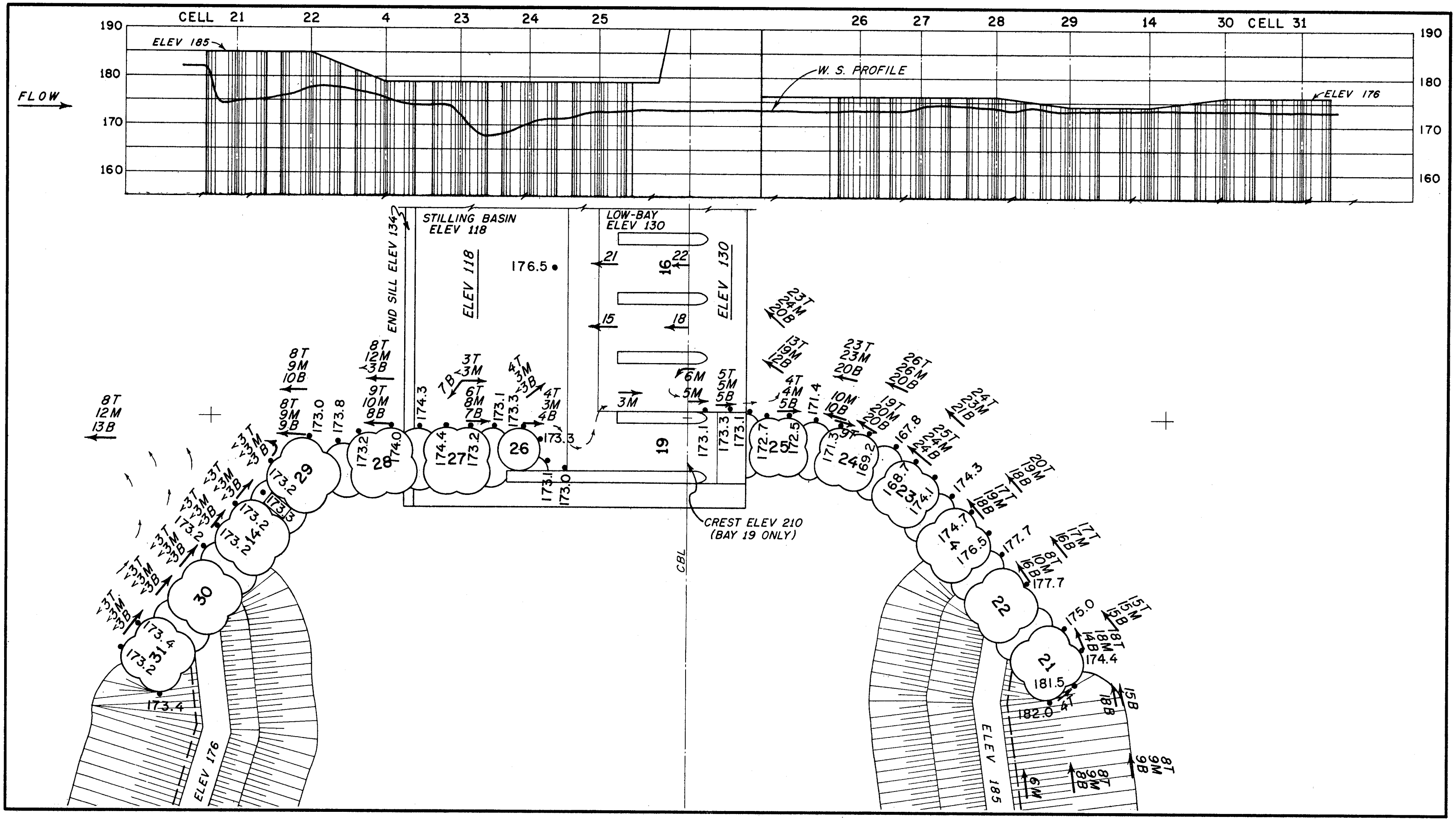
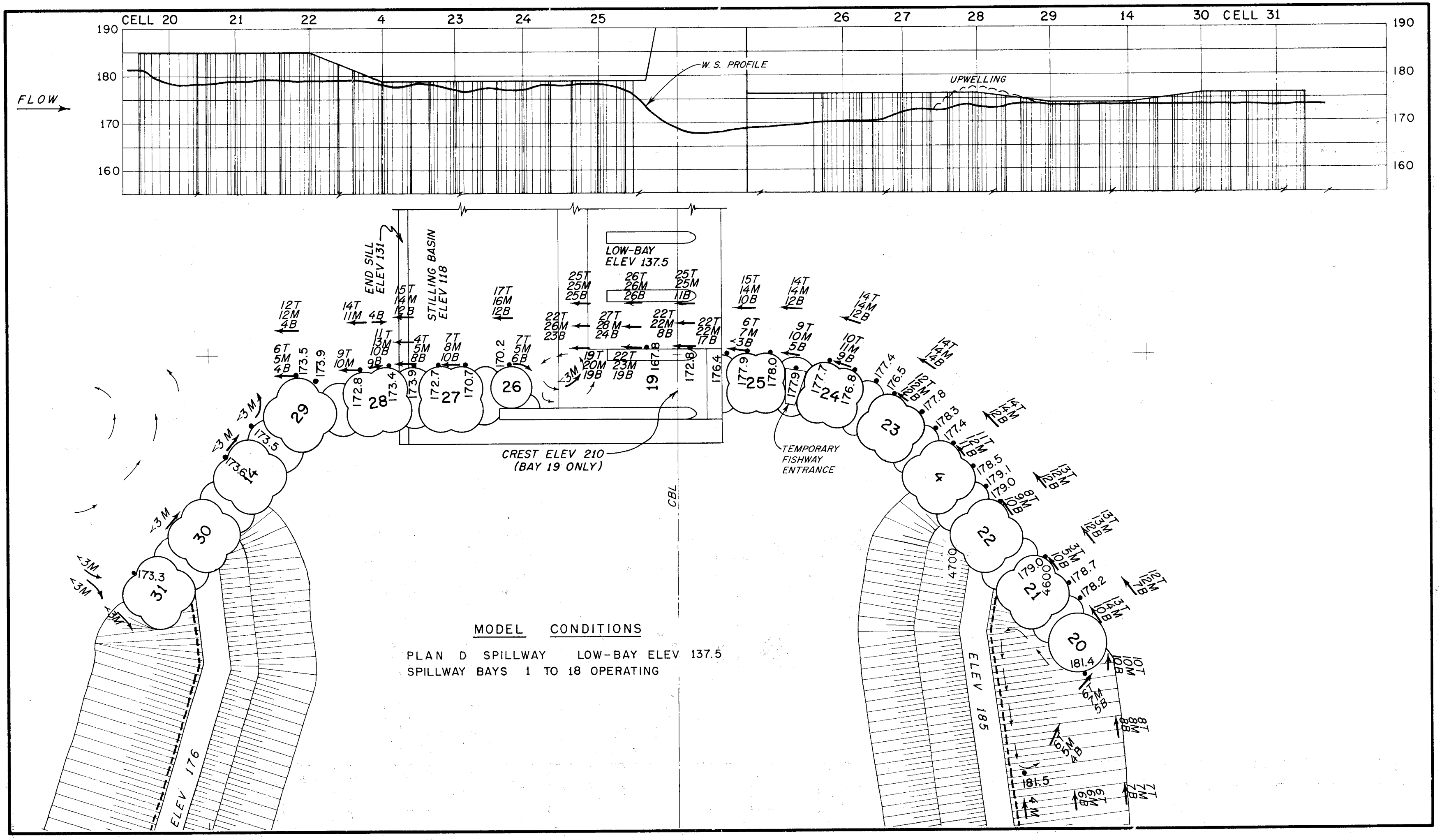


PLATE 27

LEGEND

← 8 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
● 174.7 WATER-SURFACE ELEVATIONS

VELOCITIES AND WATER-SURFACE ELEVATIONS
PLAN A SECOND-STEP COFFERDAM (ORIGINAL DESIGN)
RIVER DISCHARGE 700 000 CFS



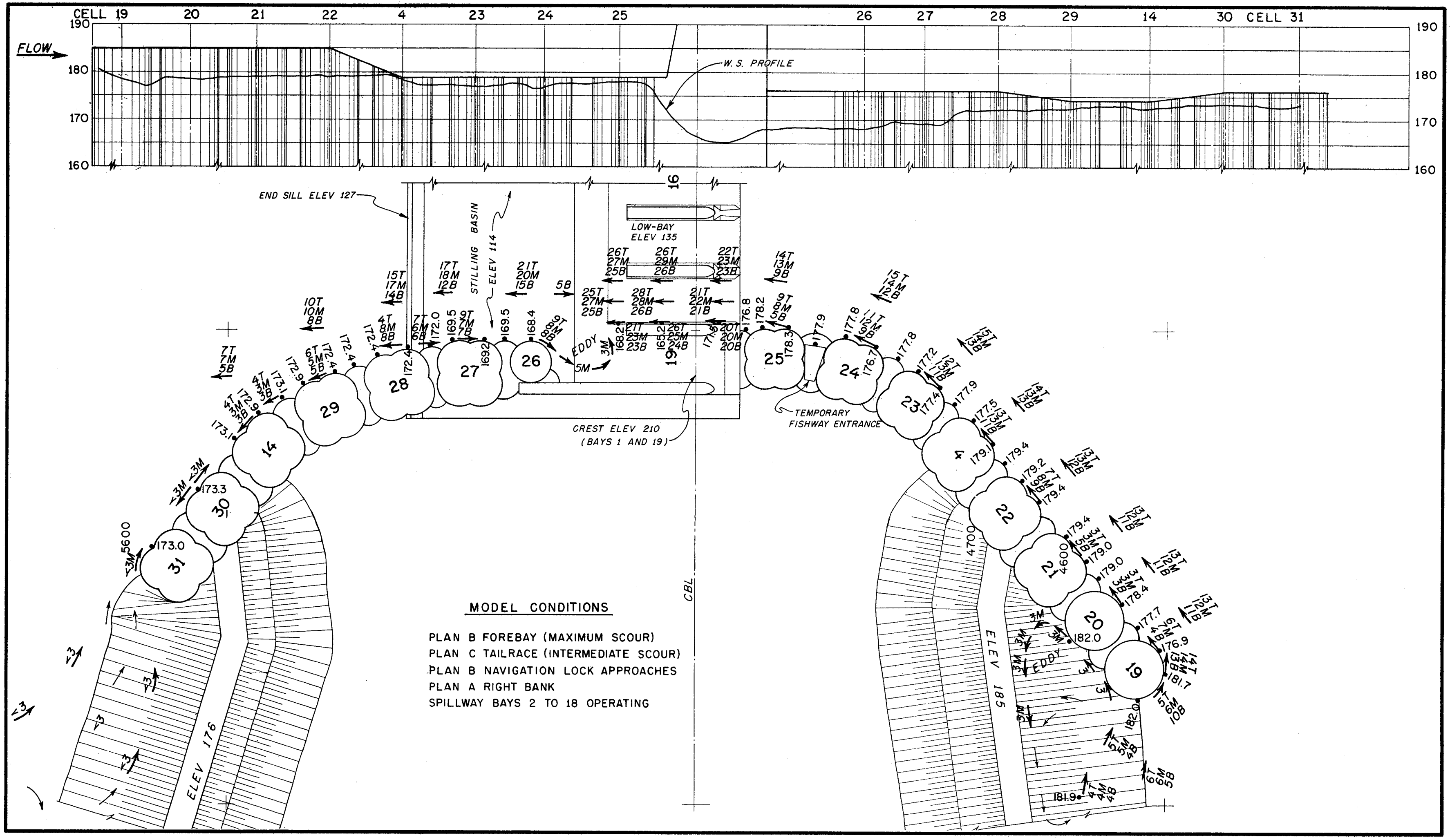
LEGEND

←8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
● 181.5	WATER-SURFACE ELEVATIONS

VELOCITIES AND WATER-SURFACE ELEVATIONS

PLAN B SECOND-STEP COFFERDAM

RIVER DISCHARGE 700 000 CFS



MODEL CONDITIONS

PLAN B FOREBAY (MAXIMUM SCOUR)
PLAN C TAILRACE (INTERMEDIATE SCOUR)
PLAN B NAVIGATION LOCK APPROACHES
PLAN A RIGHT BANK
SPILLWAY BAYS 2 TO 18 OPERATING

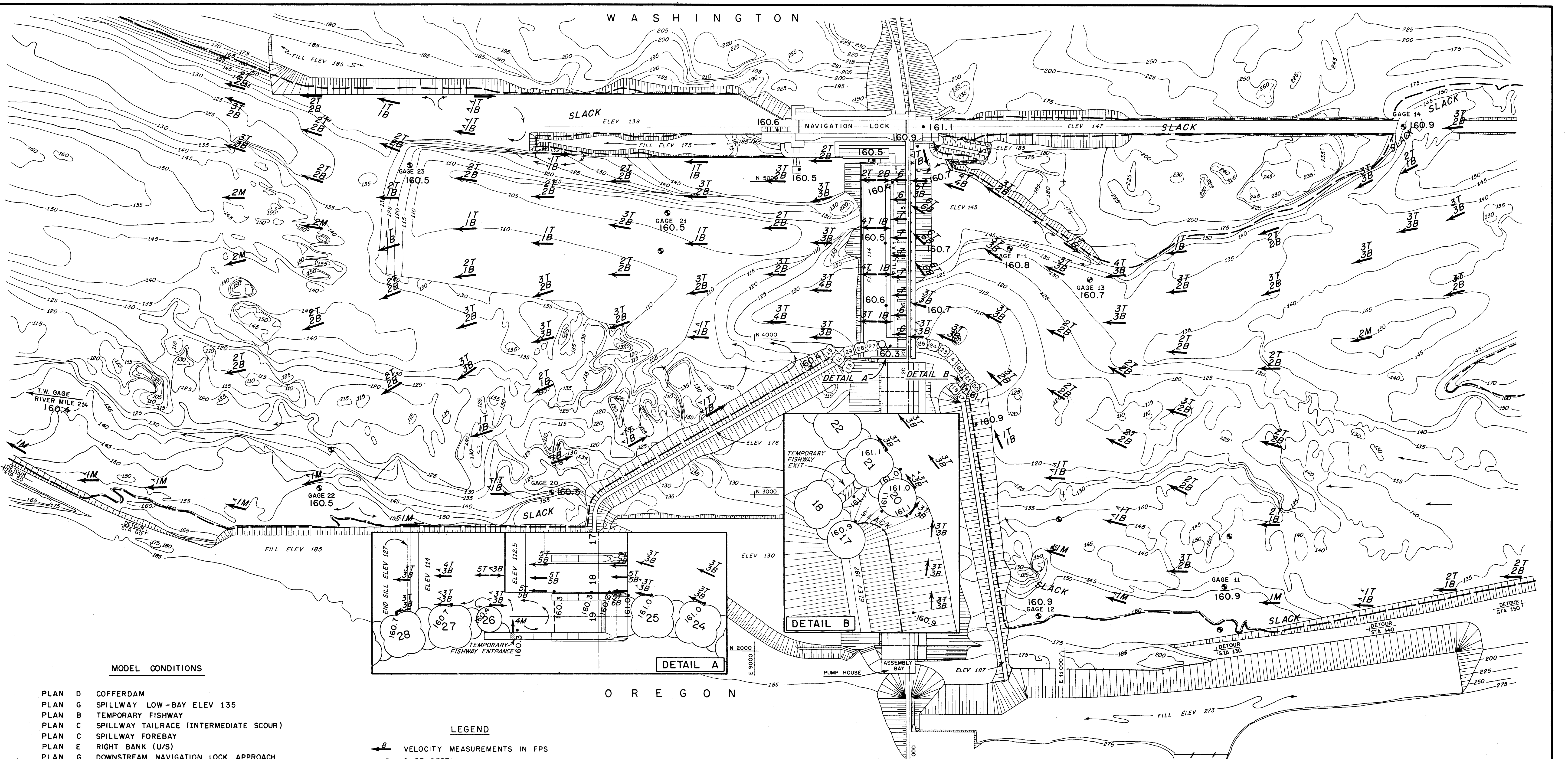
LEGEND

←8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
● 181.7	WATER-SURFACE ELEVATIONS

VELOCITIES AND WATER-SURFACE ELEVATIONS

PLAN C SECOND-STEP COFFERDAM

RIVER DISCHARGE 700 000 CFS



MODEL CONDITIONS

PLAN	D	COFFERDAM
PLAN	G	SPILLWAY LOW-BAY ELEV 135
PLAN	B	TEMPORARY FISHWAY
PLAN	C	SPILLWAY TAILRACE (INTERMEDIATE SCOUR)
PLAN	C	SPILLWAY FOREBAY
PLAN	E	RIGHT BANK (U/S)
PLAN	G	DOWNSTREAM NAVIGATION LOCK APPROACH
PLAN	B	UPSTREAM NAVIGATION LOCK APPROACH
PLAN	A	HIGHWAY DETOUR FILL (U/S AND D/S)
PLAN	G	LEFT BANK DISPOSAL AREA (D/S)
PLAN	E	LEFT BANK DISPOSAL AREA (U/S)

LEGEND

←8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATIONS

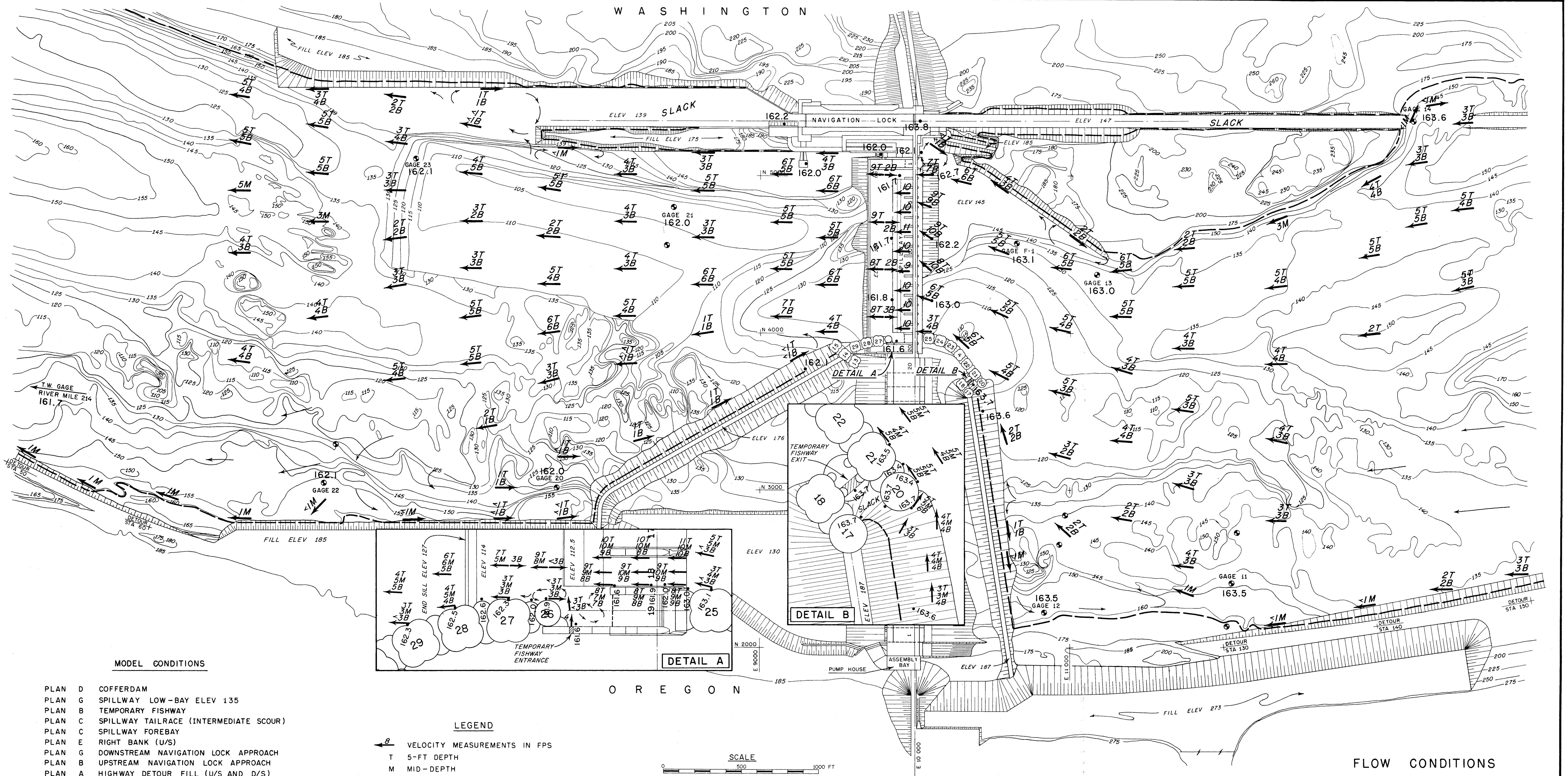
SCALE

0 500 1000 FT

FLOW CONDITIONS

SECOND STEP COFFERDAM — FIRST STAGE STRUCTURES

RIVER DISCHARGE 100 000 CFS



MODEL CONDITIONS

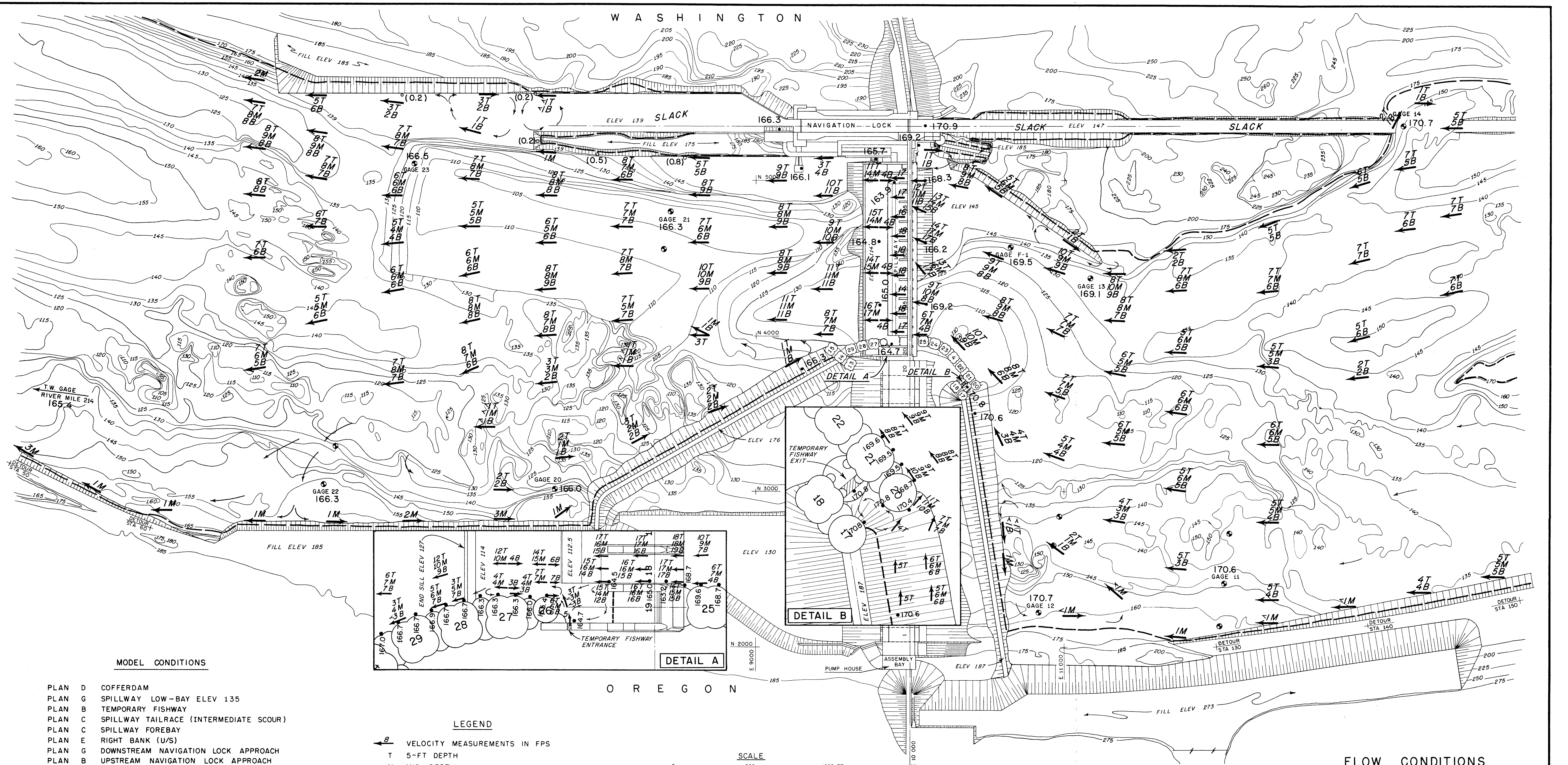
PLAN D COFFERDAM
PLAN G SPILLWAY LOW-BAY ELEV 135
PLAN B TEMPORARY FISHWAY
PLAN C SPILLWAY TAILRACE (INTERMEDIATE SCOUR)
PLAN C SPILLWAY FOREBAY
PLAN E RIGHT BANK (U/S)
PLAN G DOWNSTREAM NAVIGATION LOCK APPROACH
PLAN B UPSTREAM NAVIGATION LOCK APPROACH
PLAN A HIGHWAY DETOUR FILL (U/S AND D/S)
PLAN G LEFT BANK DISPOSAL AREA (D/S)
PLAN E LEFT BANK DISPOSAL AREA (U/S)

LEGEND

←8 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
● WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

SECOND STEP COFFERDAM — FIRST STAGE STRUCTURES
RIVER DISCHARGE 200 000 CFS



MODEL CONDITIONS

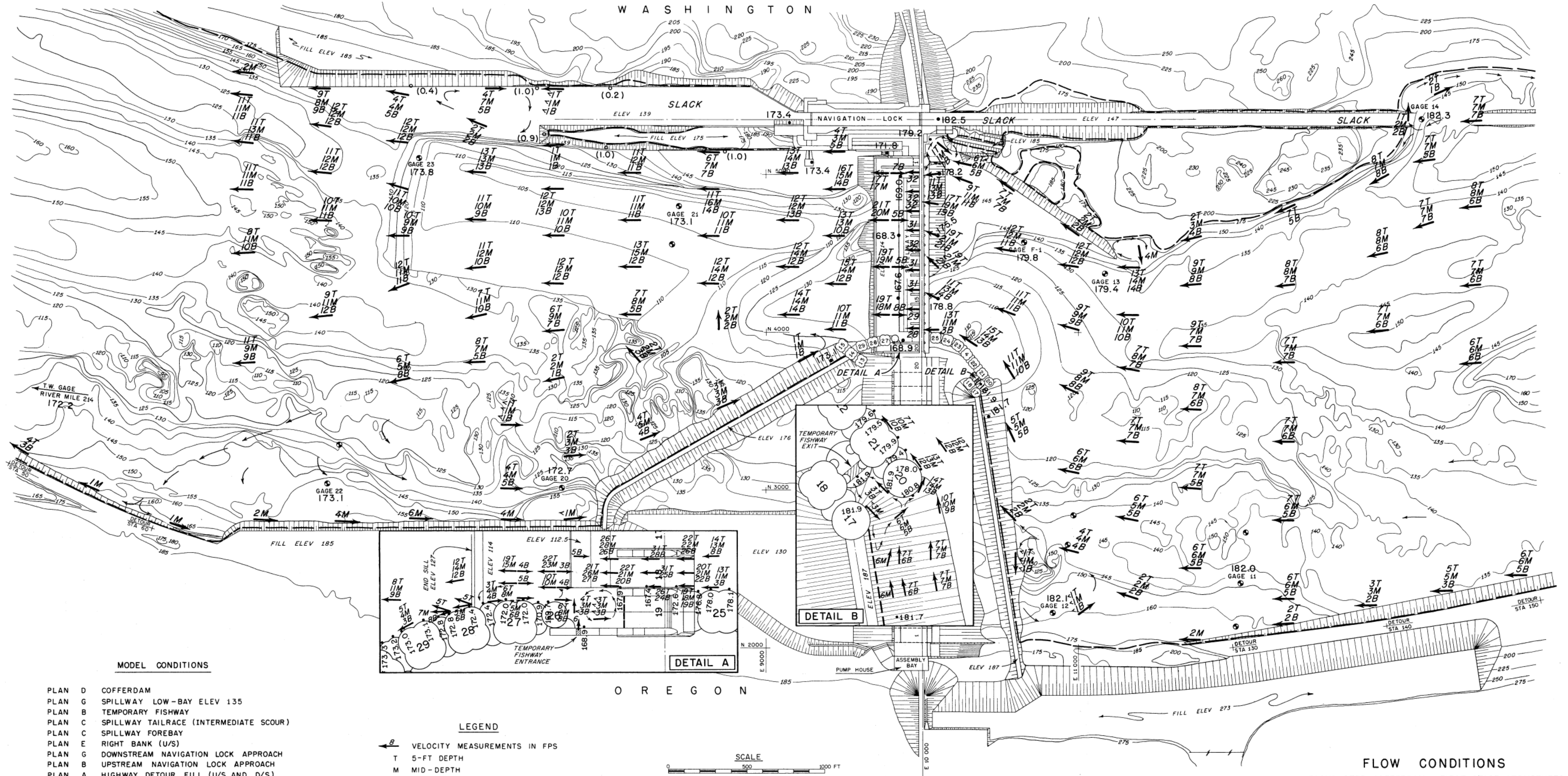
PLAN	D	COFFERDAM
PLAN	G	SPILLWAY LOW-BAY ELEV 135
PLAN	B	TEMPORARY FISHWAY
PLAN	C	SPILLWAY TAILRACE (INTERMEDIATE SCOUR)
PLAN	C	SPILLWAY FOREBAY
PLAN	E	RIGHT BANK (U/S)
PLAN	G	DOWNSTREAM NAVIGATION LOCK APPROACH
PLAN	B	UPSTREAM NAVIGATION LOCK APPROACH
PLAN	A	HIGHWAY DETOUR FILL (U/S AND D/S)
PLAN	G	LEFT BANK DISPOSAL AREA (D/S)
PLAN	E	LEFT BANK DISPOSAL AREA (U/S)

LEGEND

← 8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATIONS
(0.2) ○	WAVE HEIGHTS IN FEET

FLOW CONDITIONS

SECOND STEP COFFERDAM — FIRST STAGE STRUCTURES
RIVER DISCHARGE 400 000 CFS



MODEL CONDITIONS

PLAN	D	COFFERDAM
PLAN	G	SPILLWAY LOW-BAY ELEV 135
PLAN	B	TEMPORARY FISHWAY
PLAN	C	SPILLWAY TAILRACE (INTERMEDIATE SCOUR)
PLAN	C	SPILLWAY FOREBAY
PLAN	E	RIGHT BANK (U/S)
PLAN	G	DOWNSTREAM NAVIGATION LOCK APPROACH
PLAN	B	UPSTREAM NAVIGATION LOCK APPROACH
PLAN	A	HIGHWAY DETOUR FILL (U/S AND D/S)
PLAN	G	LEFT BANK DISPOSAL AREA (D/S)
PLAN	E	LEFT BANK DISPOSAL AREA (U/S)

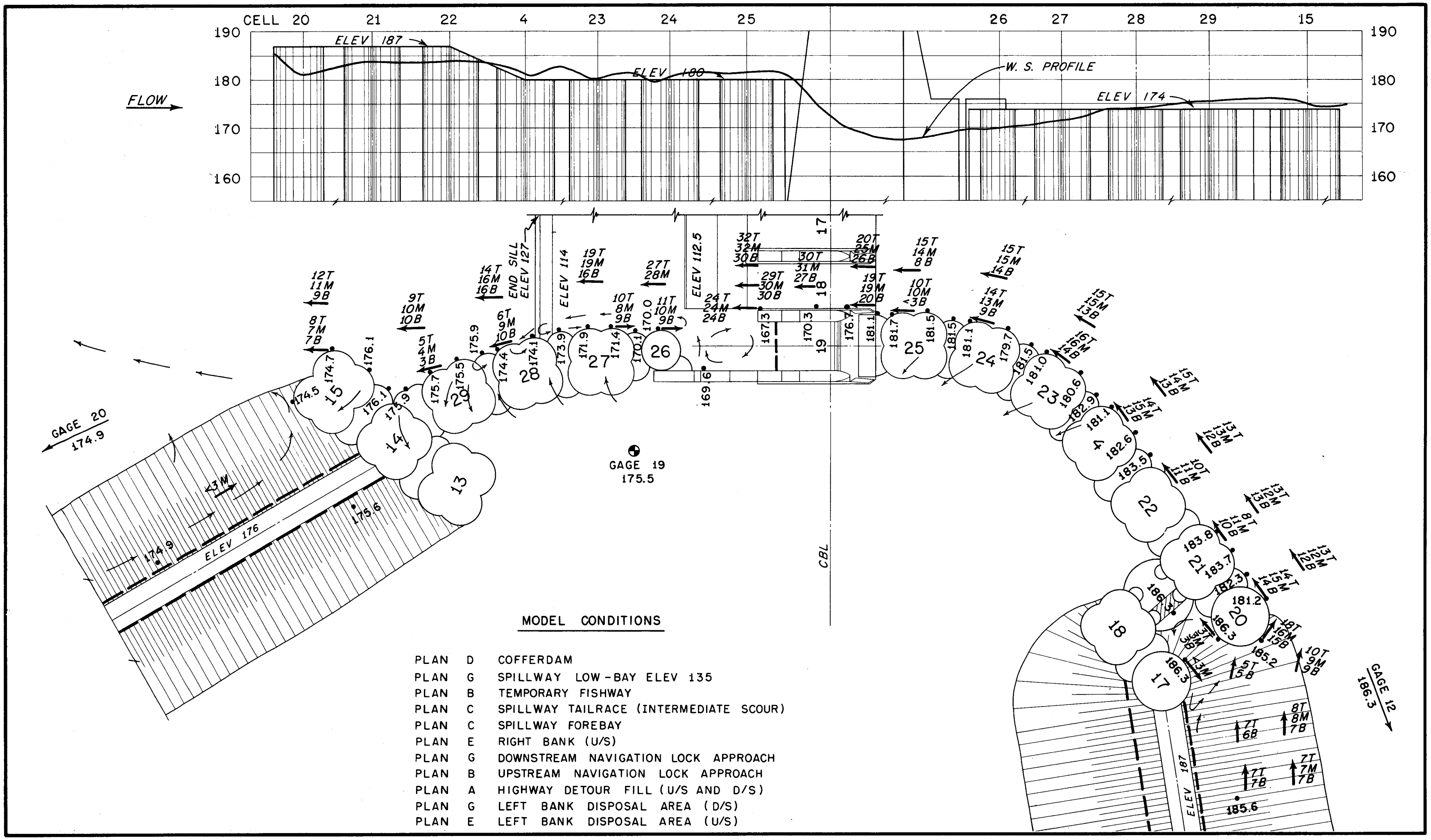
LEGEND

← 8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATIONS
(1.0) ○	WAVE HEIGHTS IN FEET

FLOW CONDITIONS

SECOND STEP COFFERDAM — FIRST STAGE STRUCTURES

RIVER DISCHARGE 700 000 CFS



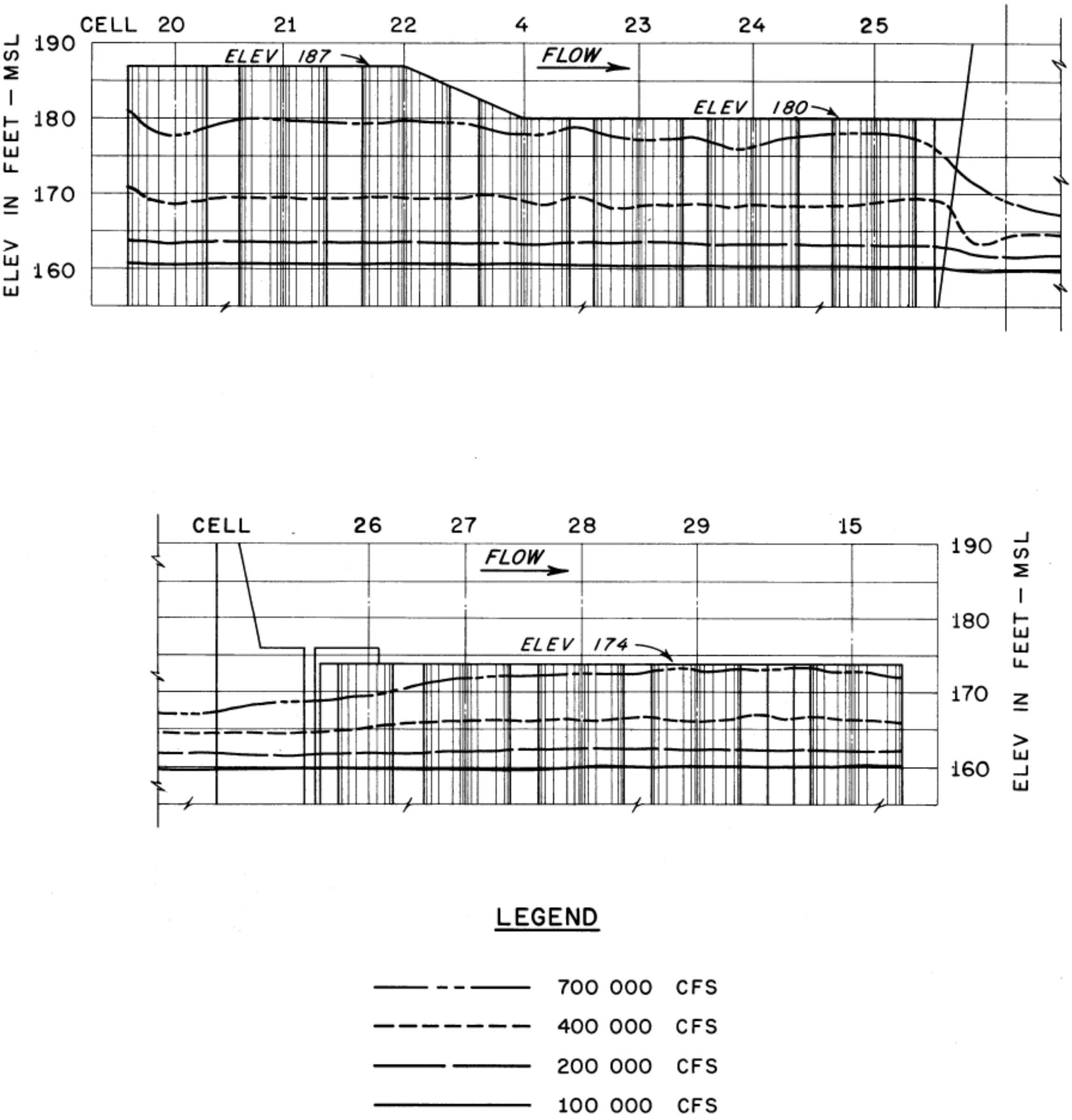
MODEL CONDITIONS

PLAN	D	COFFERDAM
PLAN	G	SPILLWAY LOW-BAY ELEV 135
PLAN	B	TEMPORARY FISHWAY
PLAN	C	SPILLWAY TAILRACE (INTERMEDIATE SCOUR)
PLAN	C	SPILLWAY FOREBAY
PLAN	E	RIGHT BANK (U/S)
PLAN	G	DOWNSTREAM NAVIGATION LOCK APPROACH
PLAN	B	UPSTREAM NAVIGATION LOCK APPROACH
PLAN	A	HIGHWAY DETOUR FILL (U/S AND D/S)
PLAN	G	LEFT BANK DISPOSAL AREA (D/S)
PLAN	E	LEFT BANK DISPOSAL AREA (U/S)

LEGEND

←8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
● 181.7	WATER- SURFACE ELEVATIONS

VELOCITIES AND WATER-SURFACE ELEVATIONS
PLAN D SECOND-STEP COFFERDAM (FINAL DESIGN)
RIVER DISCHARGE 800 000 CFS



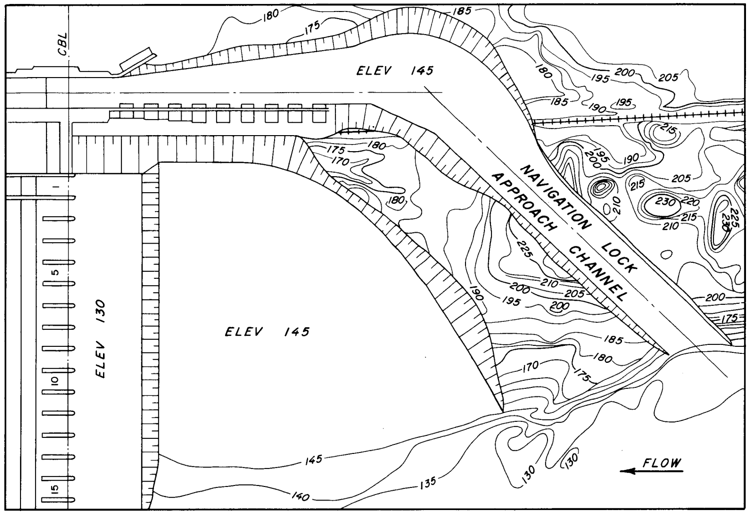
NOTE

COFFERDAM LAYOUT AND FLOW CONDITIONS ARE SHOWN ON PLATES 31 TO 34.

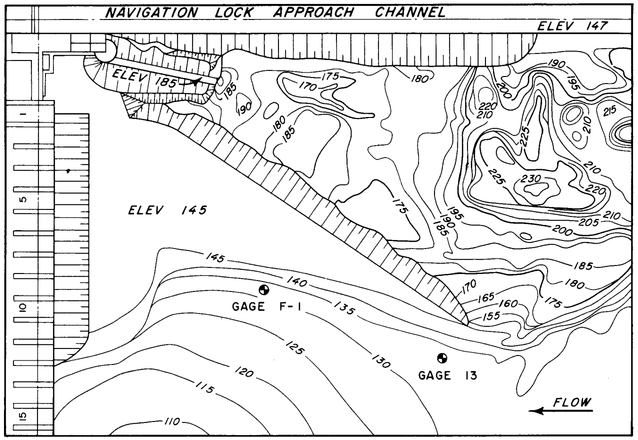
WATER-SURFACE PROFILES

PLAN D SECOND-STEP COFFERDAM

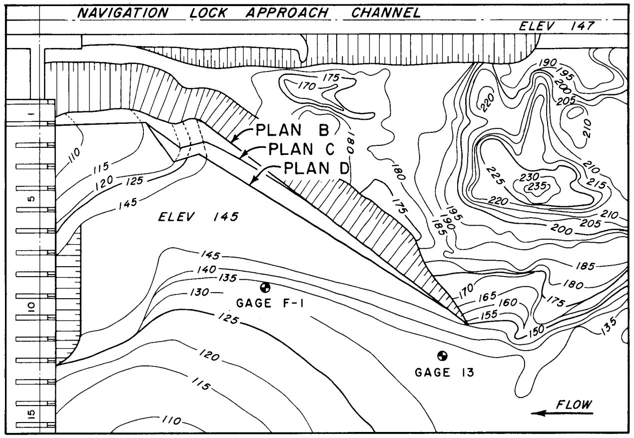
RIVER DISCHARGE 100 000 TO 700 000 CFS



PLAN A - ORIGINAL DESIGN



PLAN E - FINAL DESIGN



PLANS B TO D

NOTE

SEE PLATES 31 TO 34 FOR COFFERDAM LAYOUT.

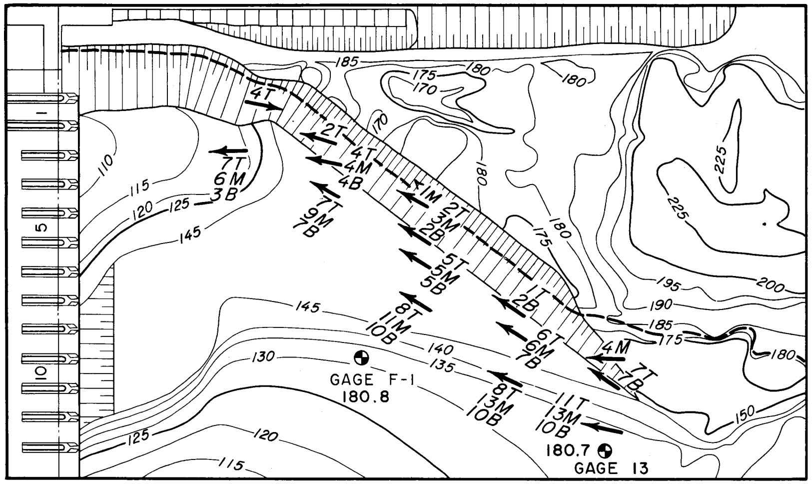
SCALE

0 500 1000 FT

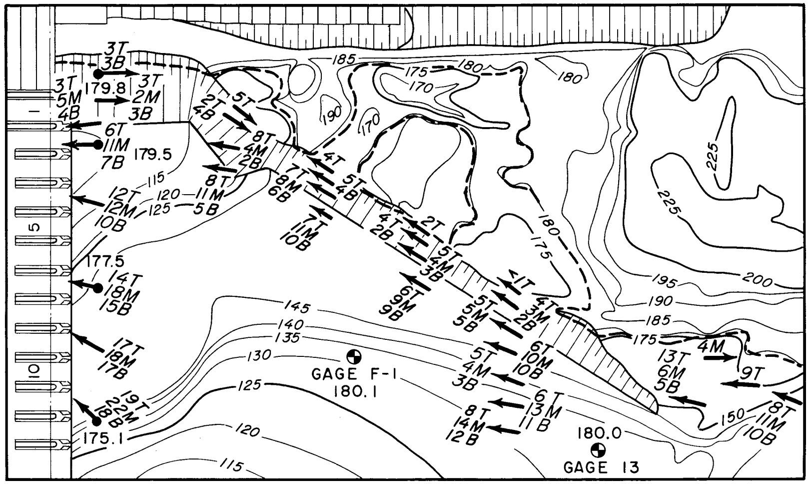
SPILLWAY APPROACH PLANS A TO E

SECOND-STEP COFFERDAM, FIRST-STAGE STRUCTURES

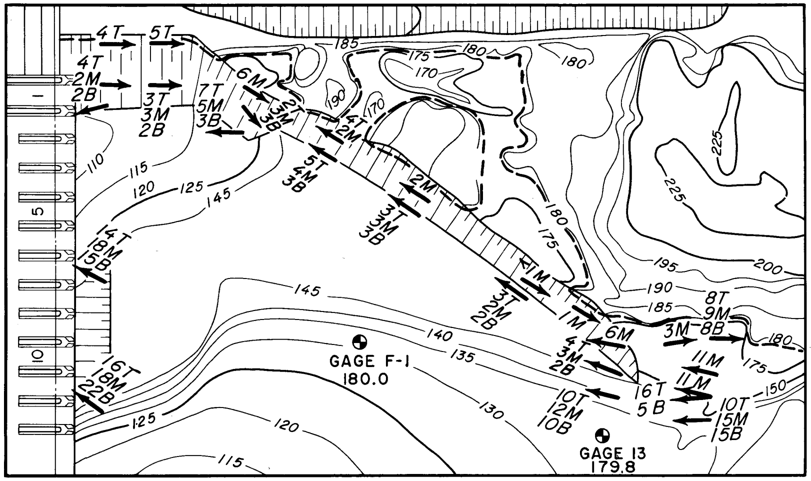
PLATE 37



PLAN B



PLAN D



PLAN C

LEGEND

← 7	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
180.0 ●	WATER-SURFACE ELEVATIONS

NOTE

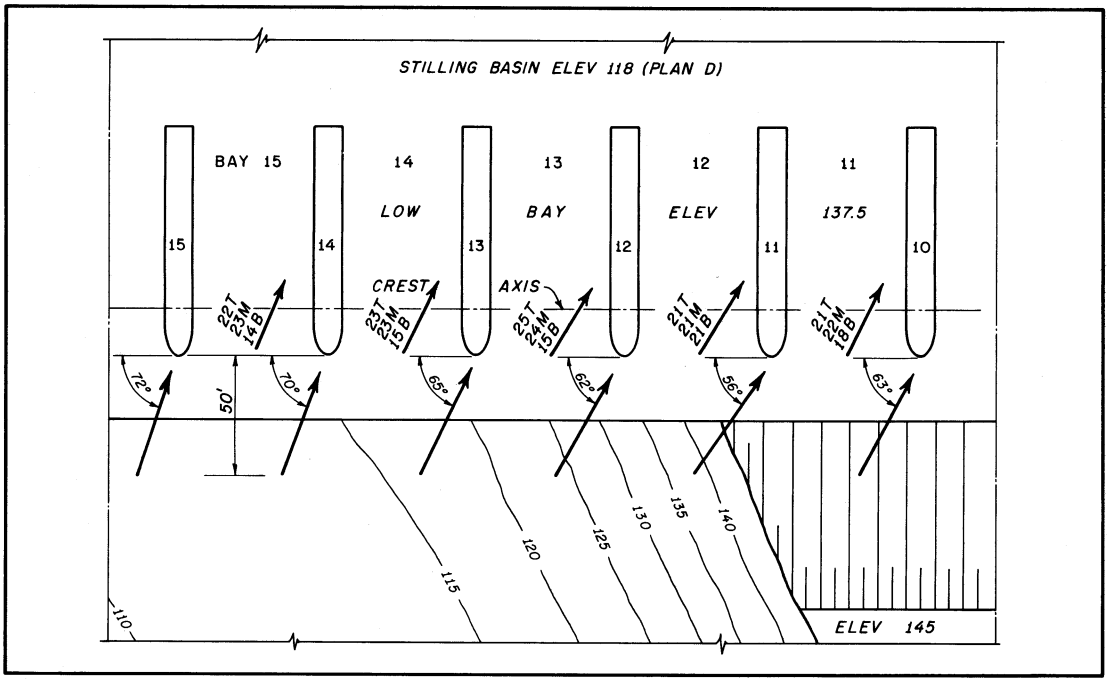
SEE PLATES 31 TO 34 FOR COFFERDAM LAYOUT.

VELOCITIES

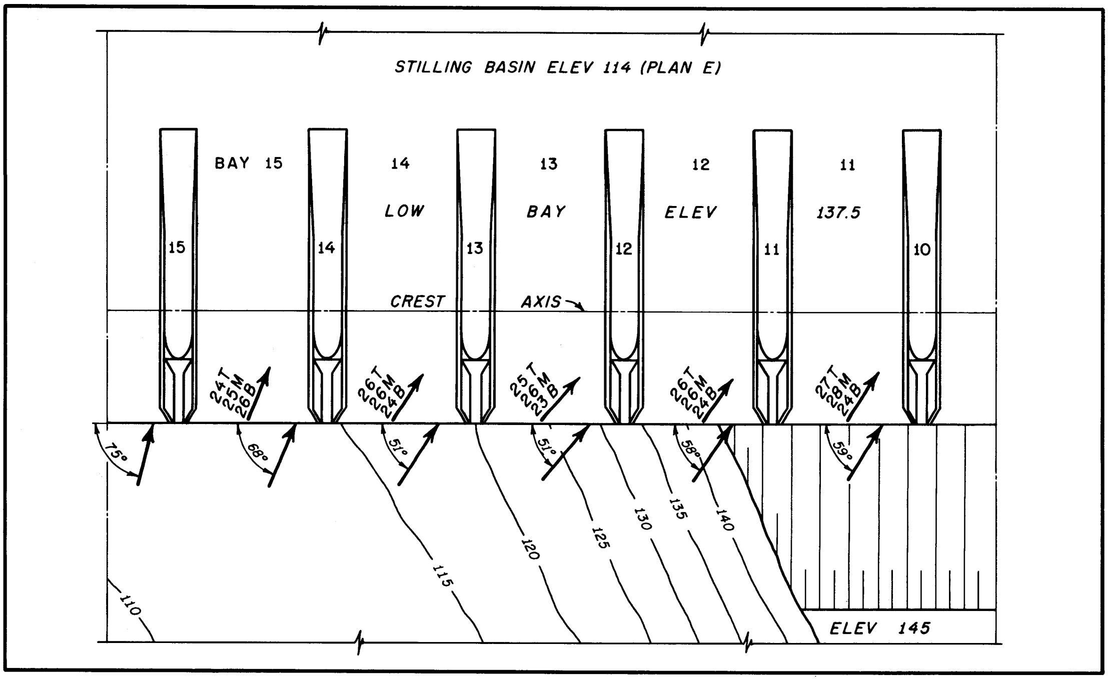
SPILLWAY APPROACH PLANS B TO D

SECOND-STEP COFFERDAM, FIRST-STAGE STRUCTURES

RIVER DISCHARGE 700 000 CFS



PLAN A PIERS

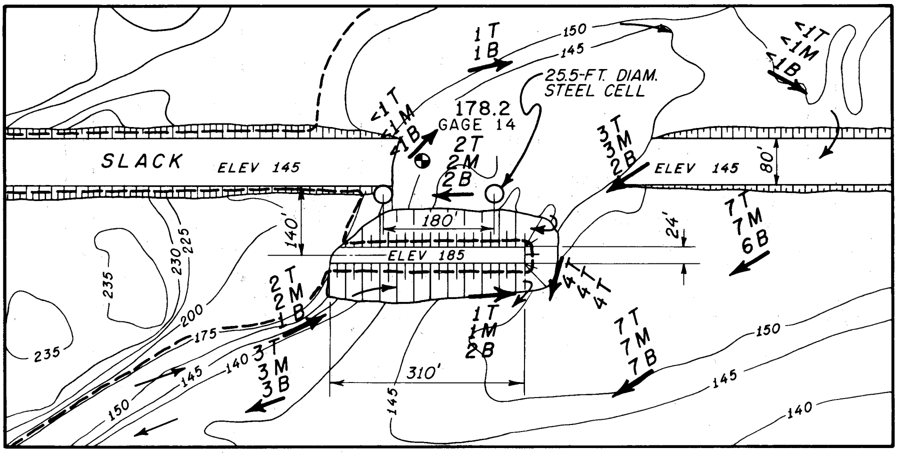


PLAN B PIERS

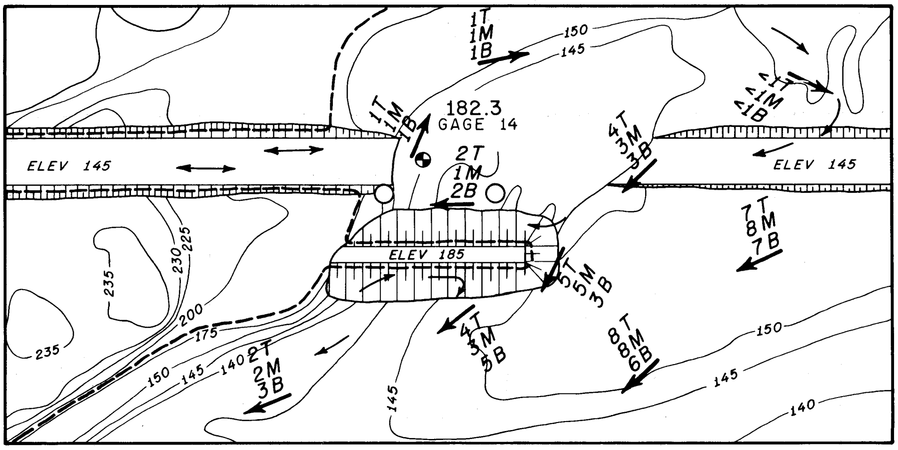
LEGEND

← 23	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM

SPILLWAY APPROACH CONDITIONS
PLAN B SECOND-STEP COFFERDAM
RIVER DISCHARGE 700 000 CFS



600 000 CFS



700 000 CFS

LEGEND

←7	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM

MODEL CONDITIONS

PLAN D SECOND-STEP COFFERDAM
PLAN G LOW-BAY SPILLWAY

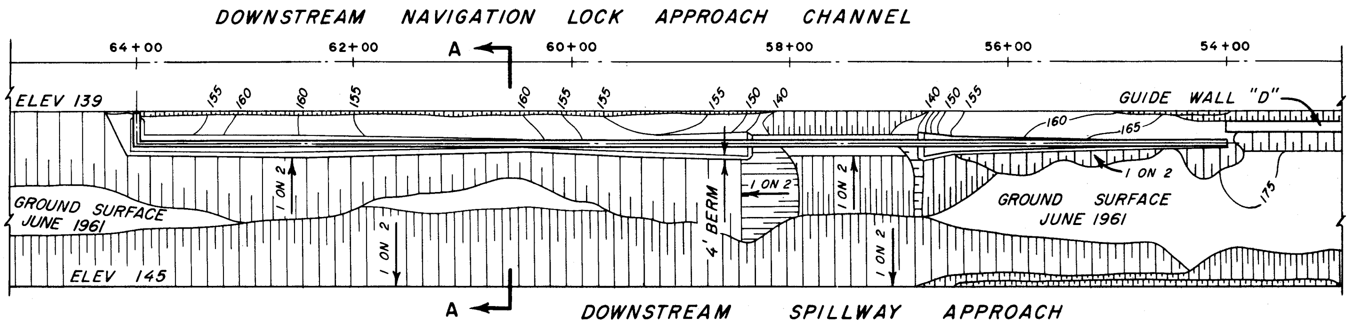
NOTE

1. FLOW CONDITIONS WITHOUT ROCK FILL (700 000 CFS ONLY) ARE SHOWN ON PLATE 33.

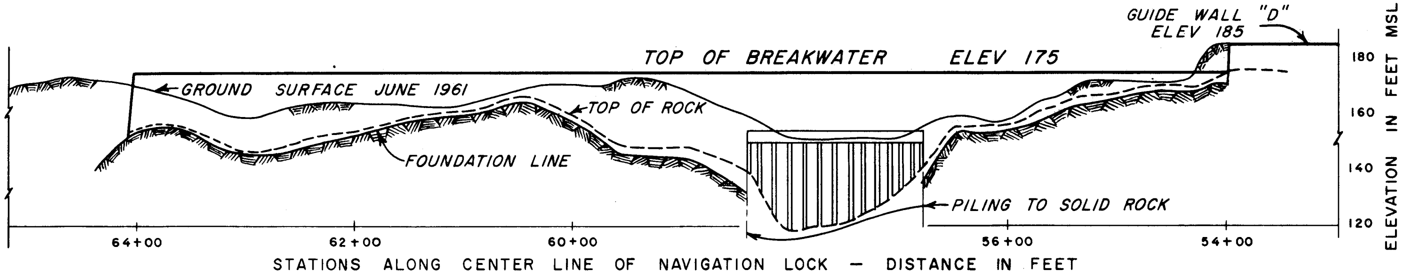
FLOW CONDITIONS

ROCK FILL ADJACENT TO UPSTREAM LOCK APPROACH

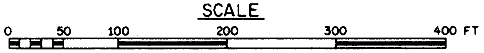
SECOND-STEP COFFERDAM, FIRST-STAGE STRUCTURES



PLAN

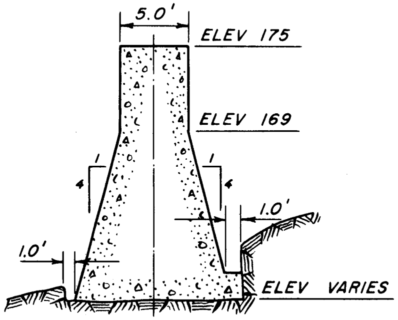


ELEVATION

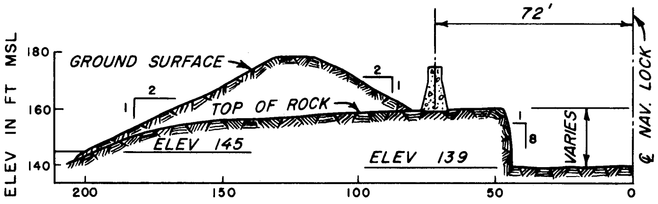


NOTE

NAVIGATION LOCK STATION 40+00 = CBL
STA 53+54 (SEE PLATES 1 AND 2).



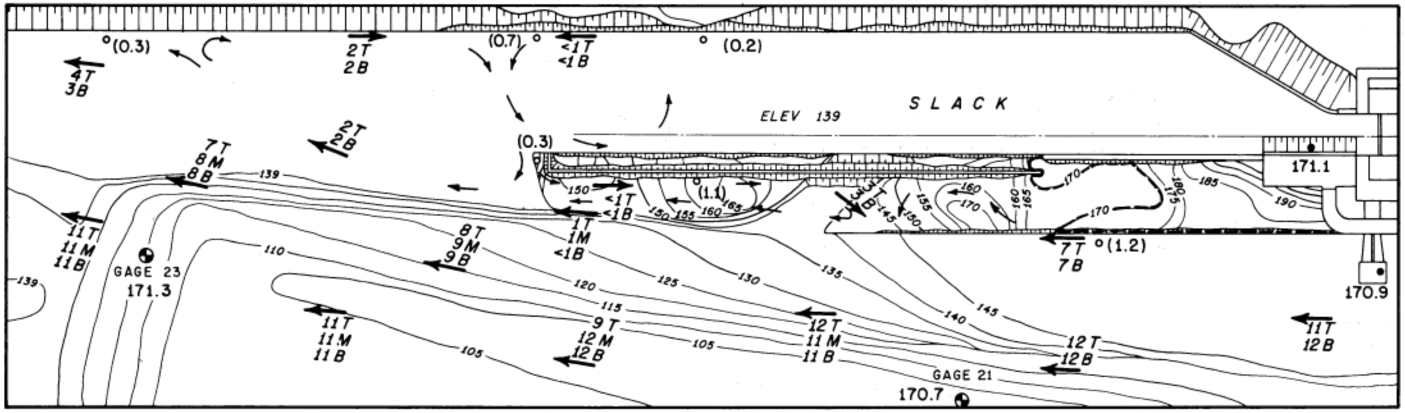
TYPICAL SECTION



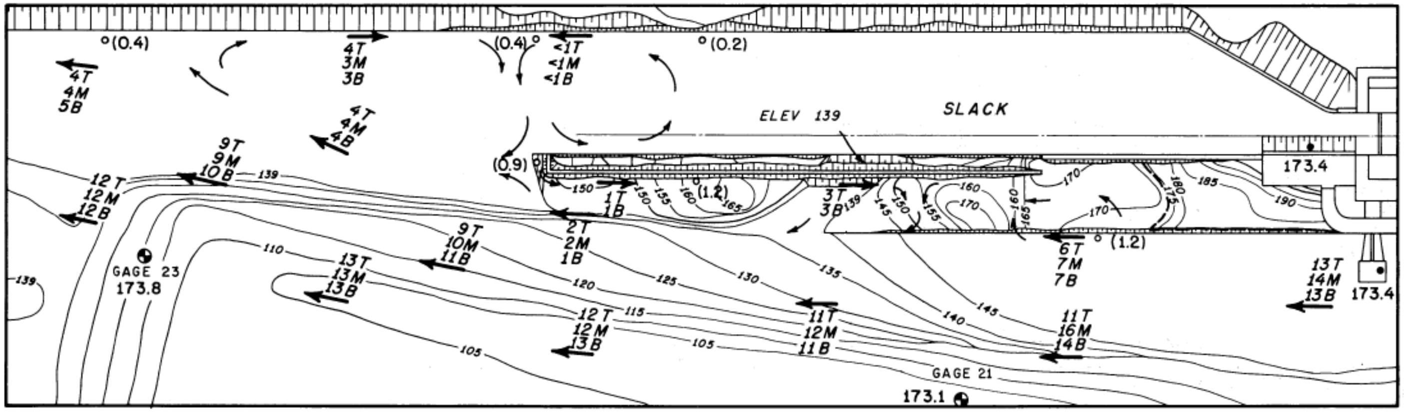
SECTION A-A

DETAILS OF BREAKWATER

DOWNSTREAM LOCK APPROACH



RIVER DISCHARGE 600 000 CFS



RIVER DISCHARGE 700 000 CFS

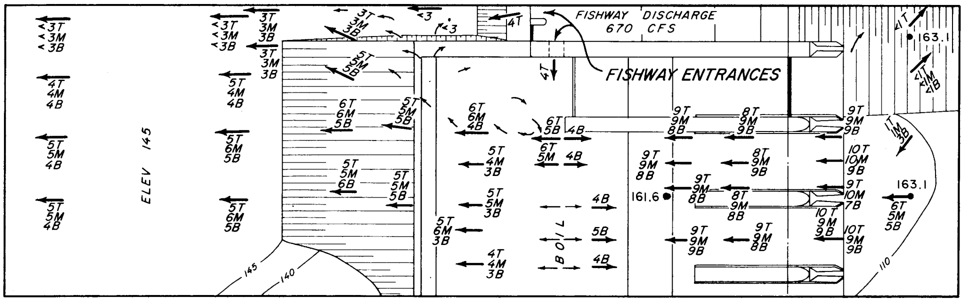
LEGEND

7 ← VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
170.9 ● WATER-SURFACE ELEVATIONS
(0.2) ○ WAVE HEIGHTS IN FEET

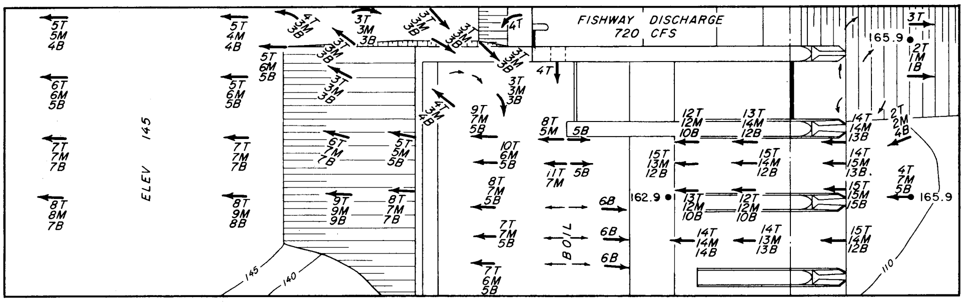
MODEL CONDITIONS

PLAN D COFFERDAM
PLAN G SPILLWAY
PLAN C SPILLWAY TAILRACE
(INTERMEDIATE SCOUR)

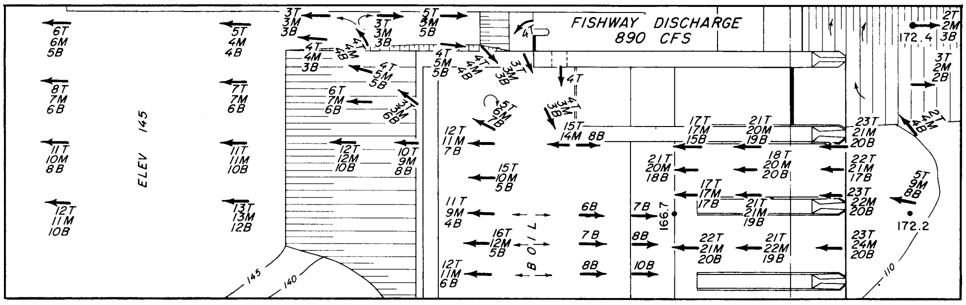
FLOW CONDITIONS
DOWNSTREAM LOCK APPROACH
SECOND-STEP COFFERDAM, FIRST-STAGE STRUCTURES



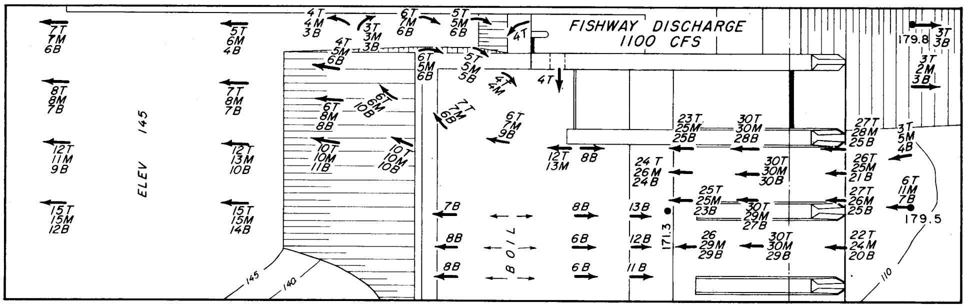
200 000 CFS



300 000 CFS



500 000 CFS



700 000 CFS

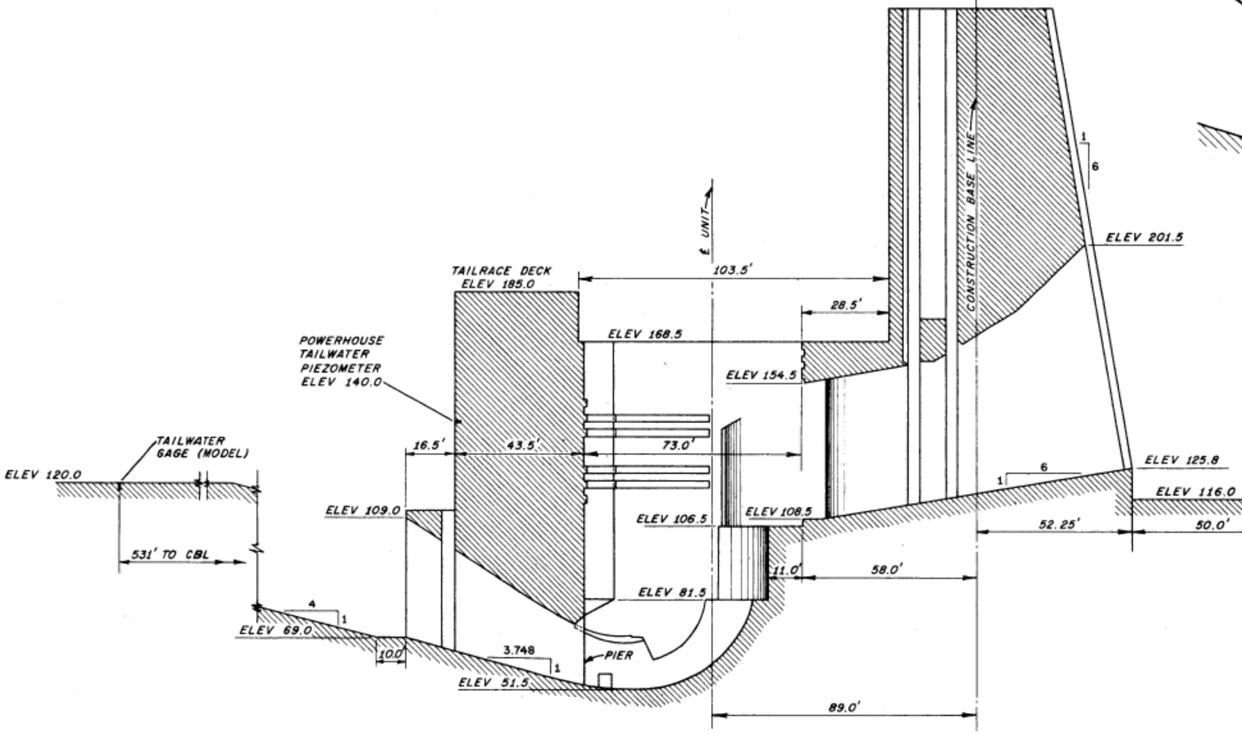
LEGEND

←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
179.5●	WATER-SURFACE ELEVATIONS

MODEL CONDITIONS

PLAN F SPILLWAY LOW BAY ELEV 135
PLAN D FOREBAY (MAXIMUM SCOUR)
PLAN C TAILRACE (INTERMEDIATE SCOUR)
PLAN C COFFERDAM
PLAN B NAVIGATION LOCK APPROACHES
SPILLWAY BAYS 2 TO 18 OPERATING

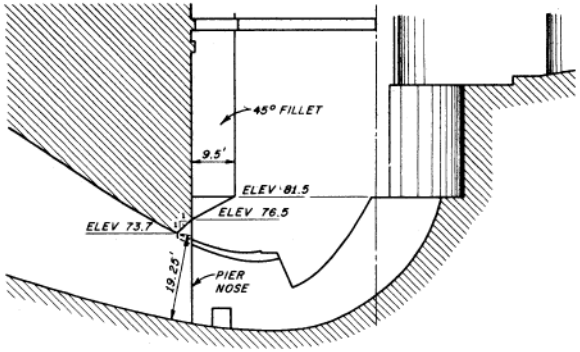
FLOW CONDITIONS
NORTH FISHWAY ENTRANCE
SECOND-STEP COFFERDAM
FIRST-STAGE STRUCTURE
RIVER DISCHARGES 200000 TO 700000 CFS



SECTION THROUGH UNIT

SCALE

0 25 50 75 FT



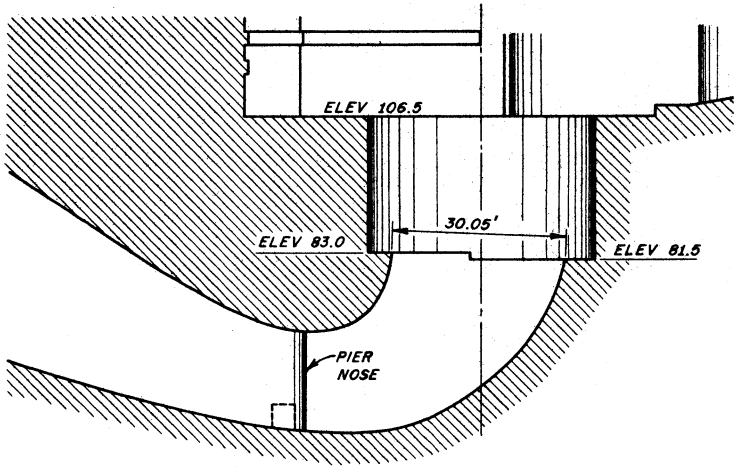
FILLET DETAILS

SCALE

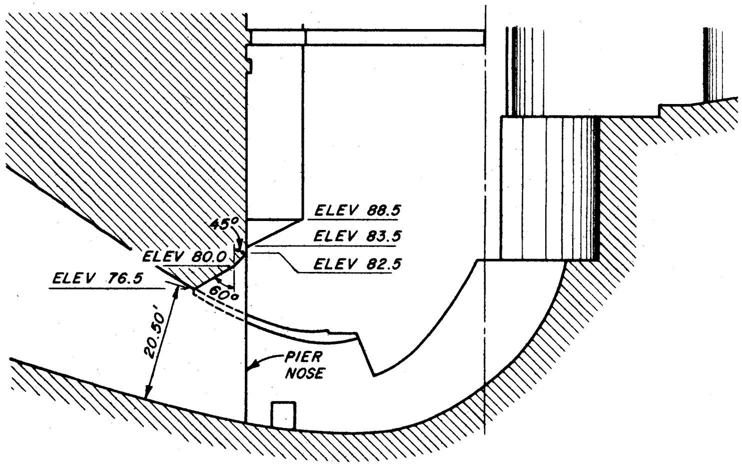
0 25 50 75 FT

PLAN A SKELETON UNIT

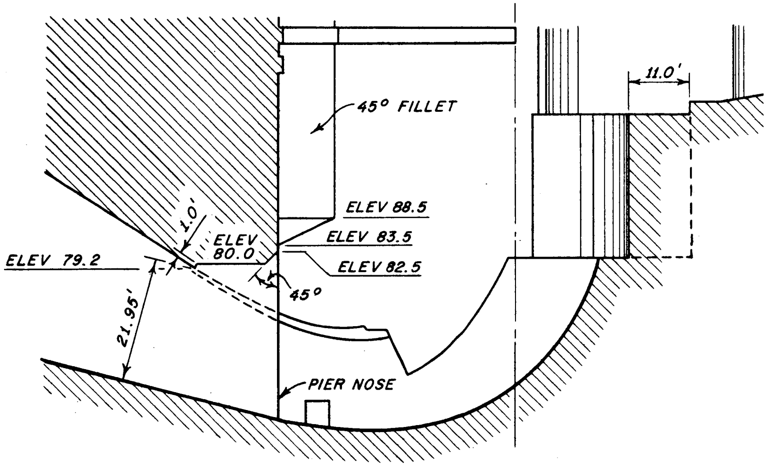
ORIGINAL CONTRACT PLAN



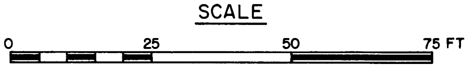
PLAN B



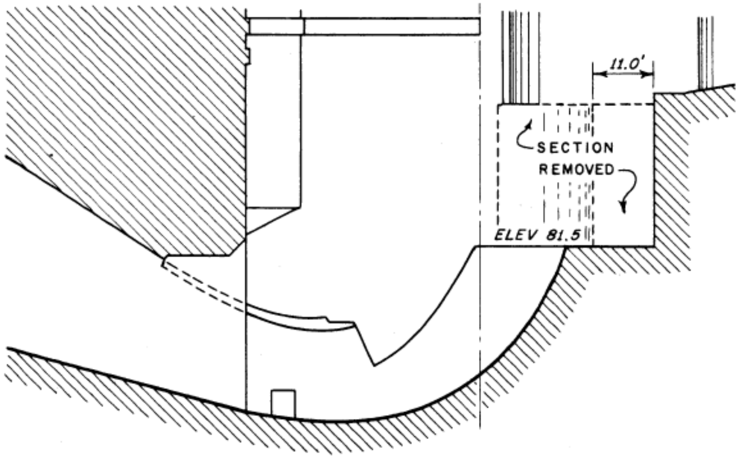
PLAN C



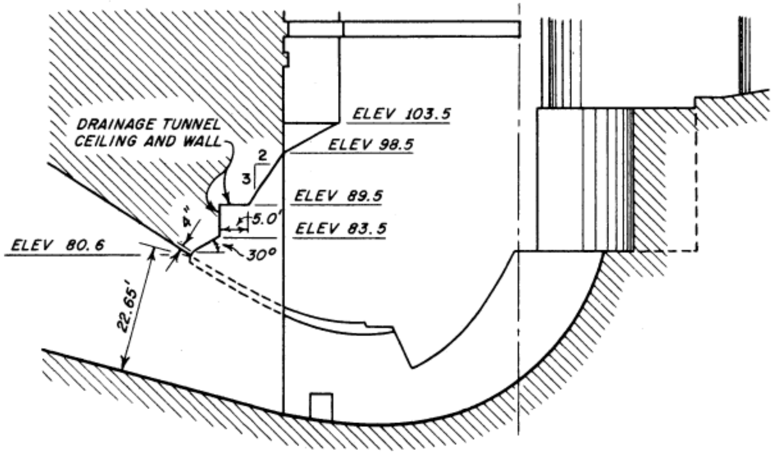
PLAN D



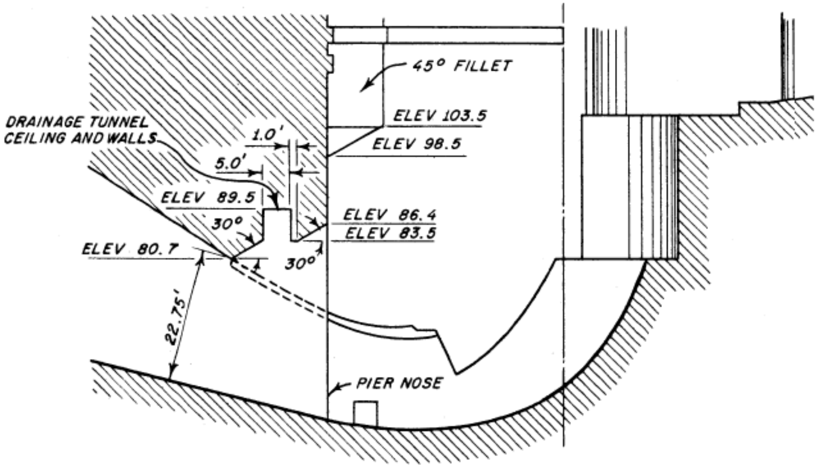
SKELETON UNIT PLANS B TO D



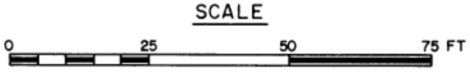
PLAN E



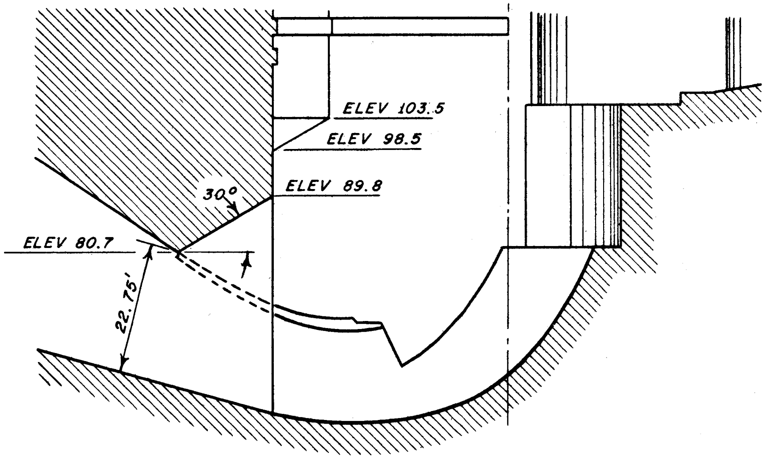
PLAN F



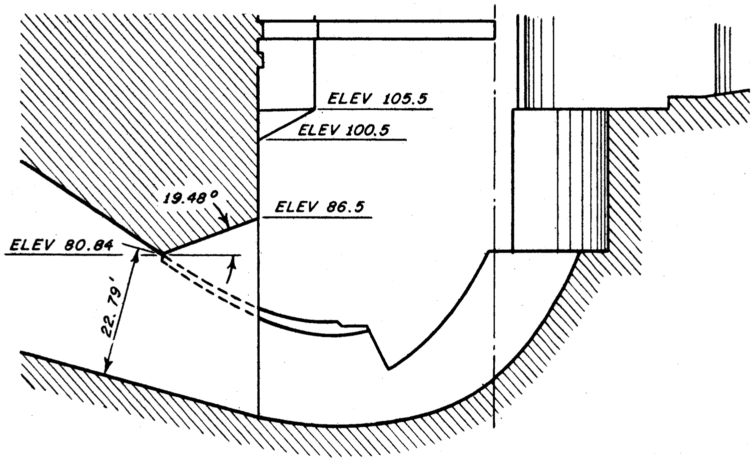
PLAN G



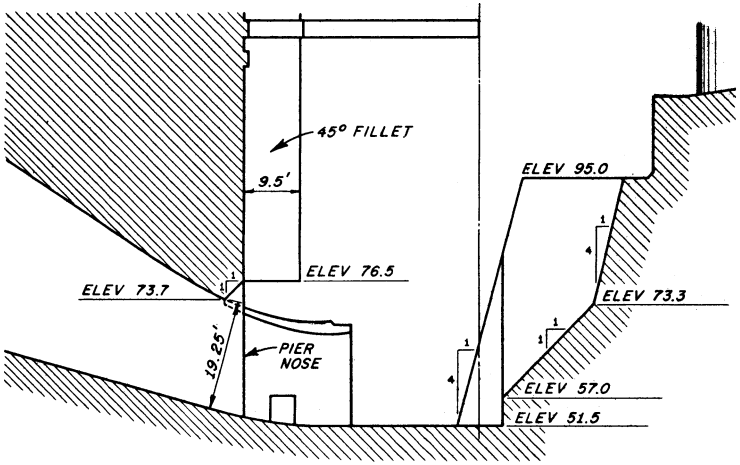
SKELETON UNIT PLANS E TO G



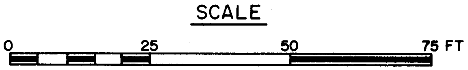
PLAN H



PLAN I

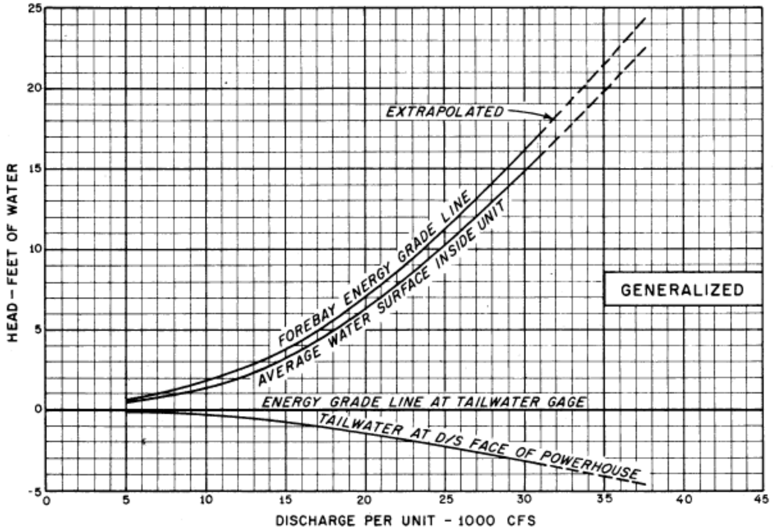


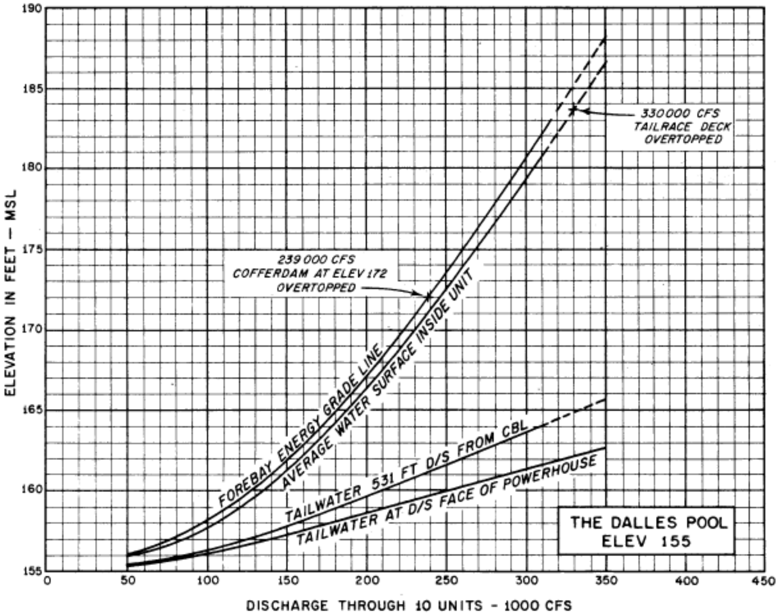
PLAN J

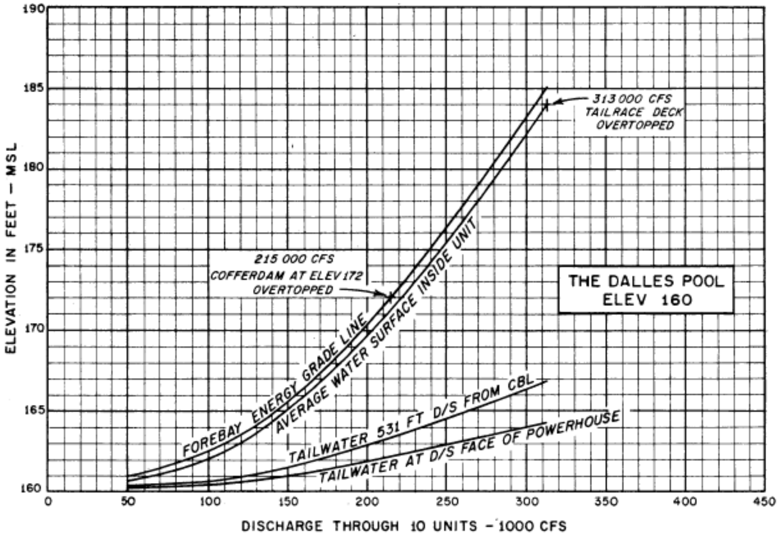


SKELETON UNIT PLANS H TO J

PLATE 46



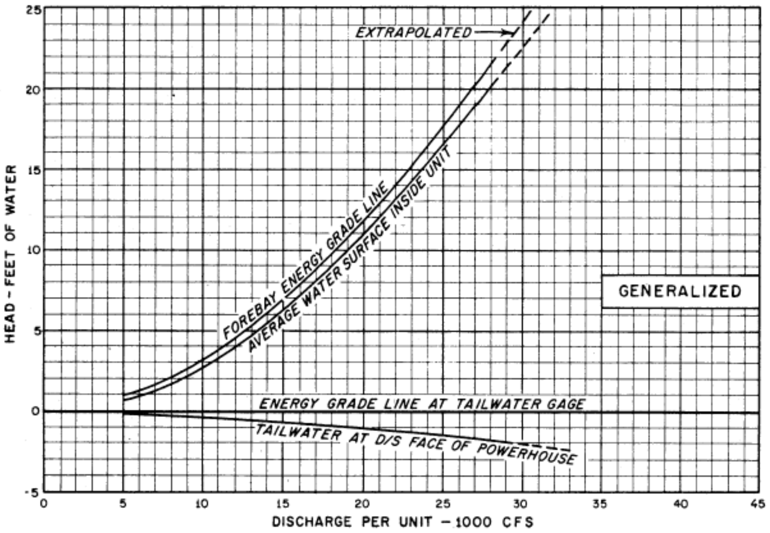


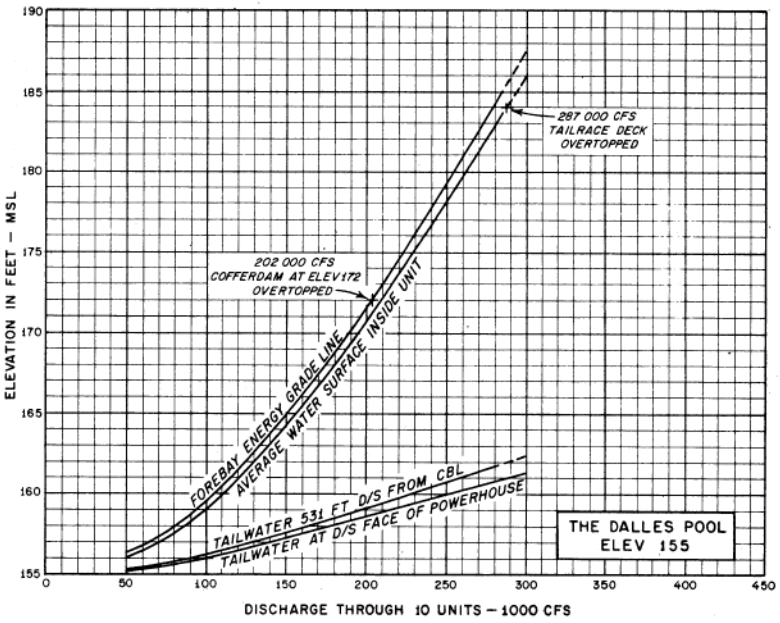


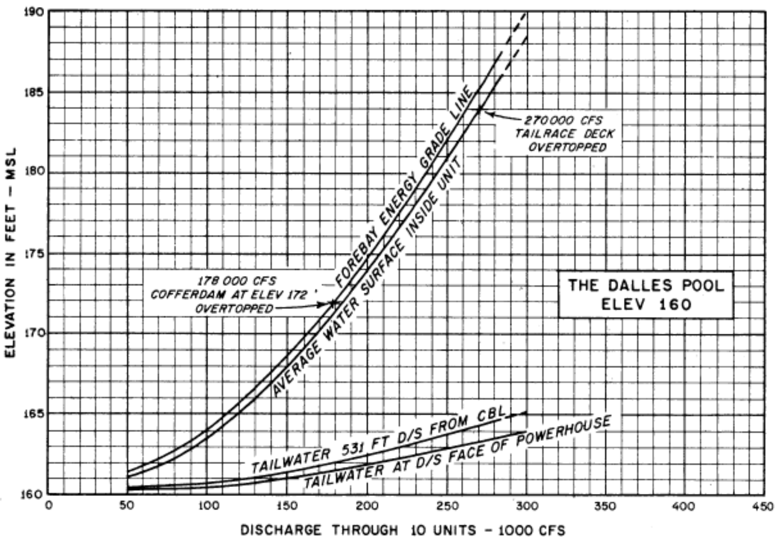
NOTE

DETAILS OF PLAN A SKELETON UNIT ARE SHOWN ON PLATE 43.

RATING DATA
PLAN A SKELETON UNIT





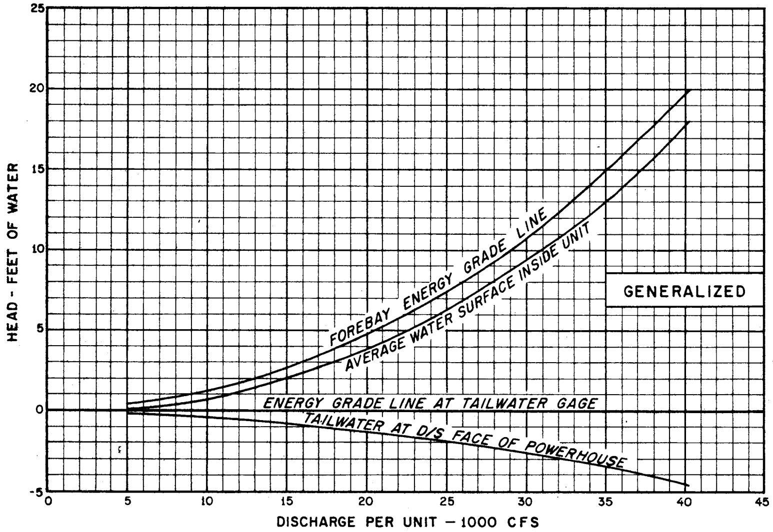


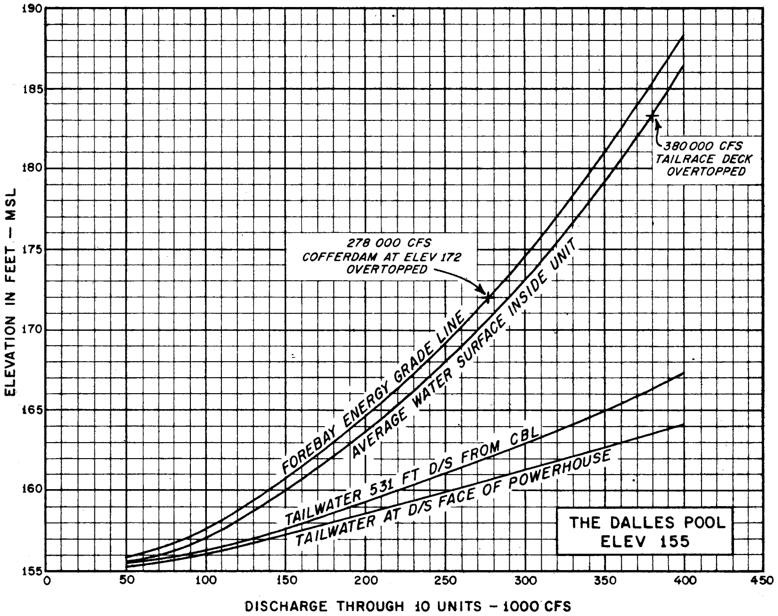
NOTE

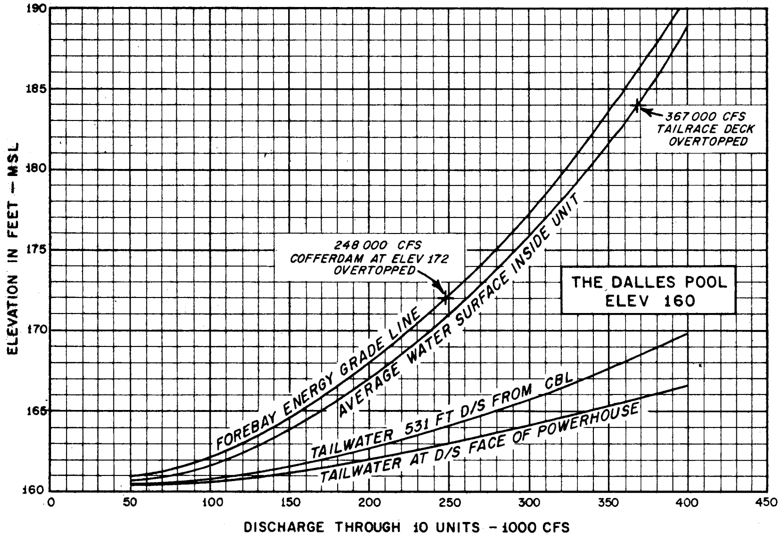
DETAILS OF PLAN B SKELETON UNIT ARE SHOWN ON PLATE 44.

RATING DATA

PLAN B SKELETON UNIT





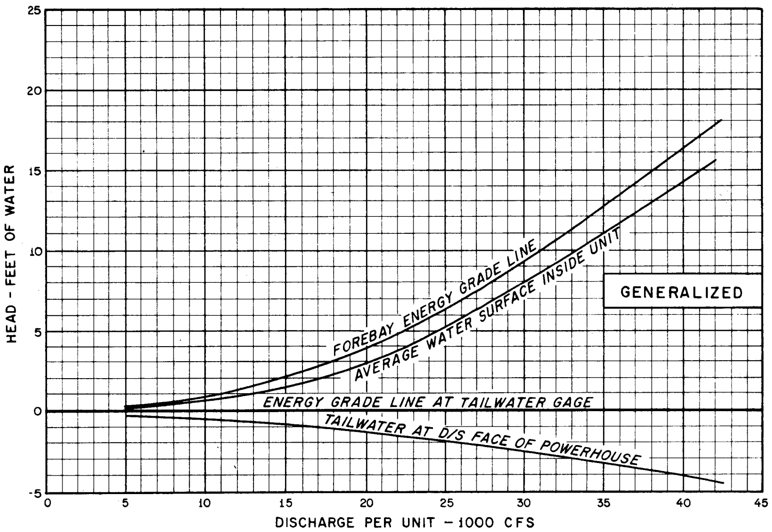


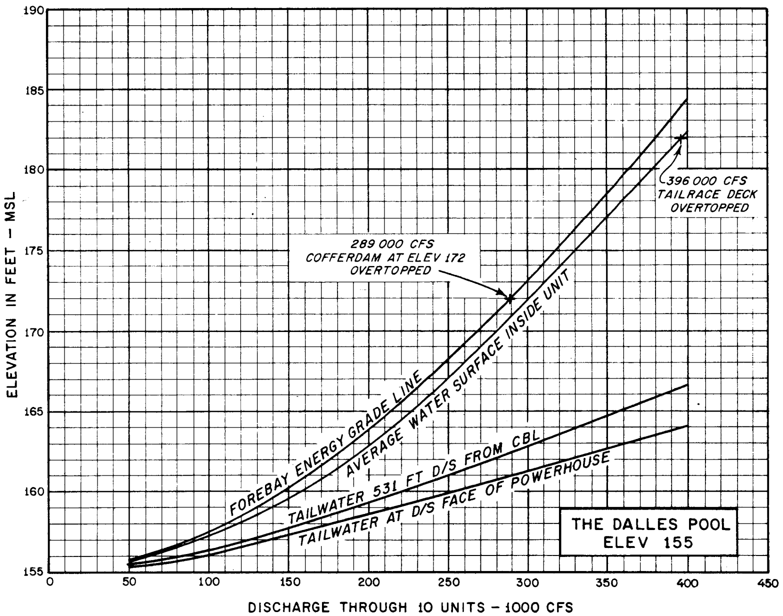
NOTE

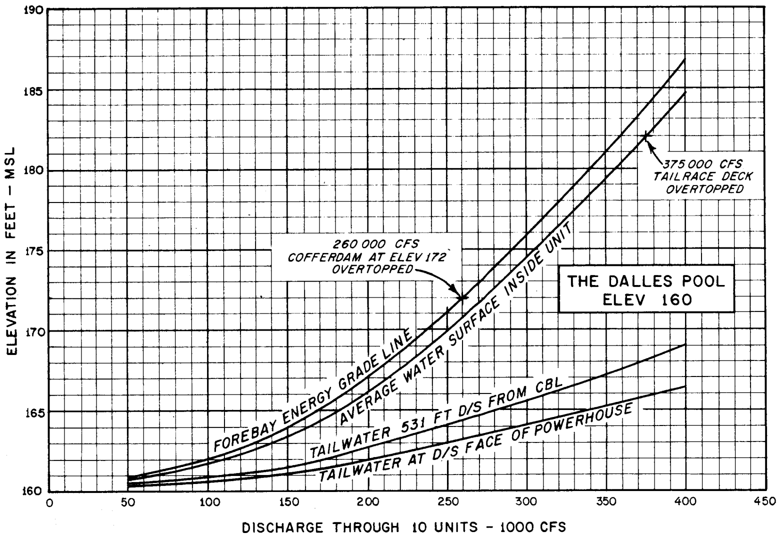
DETAILS OF PLAN C SKELETON UNIT ARE SHOWN ON PLATE 44.

RATING DATA

PLAN C SKELETON UNIT





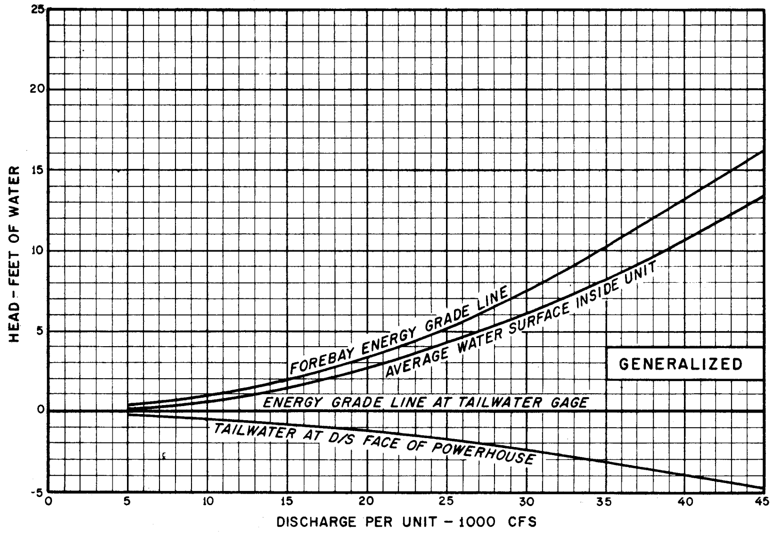


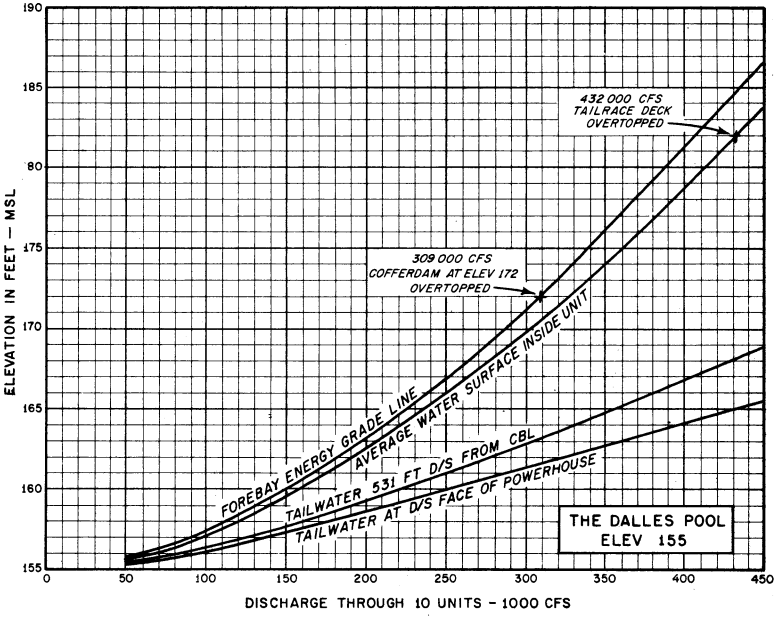
NOTE

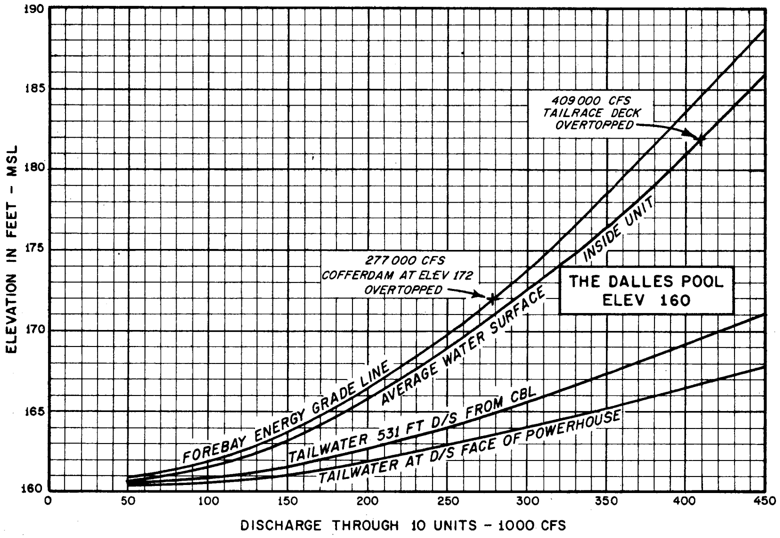
DETAILS OF PLAN D SKELETON UNIT ARE SHOWN ON PLATE 44.

RATING DATA

PLAN D SKELETON UNIT





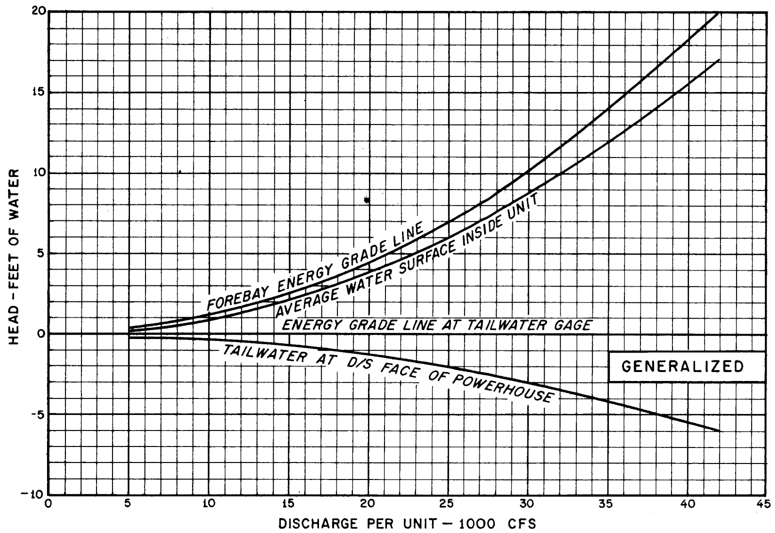


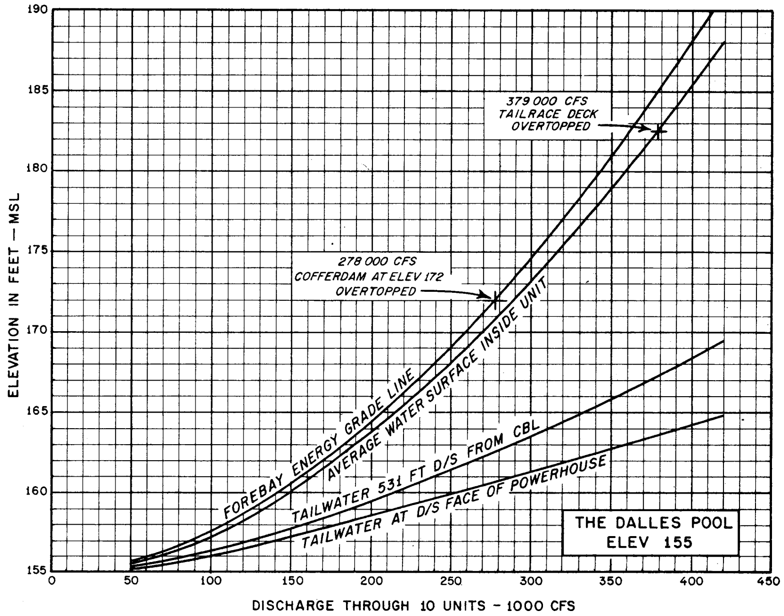
NOTE

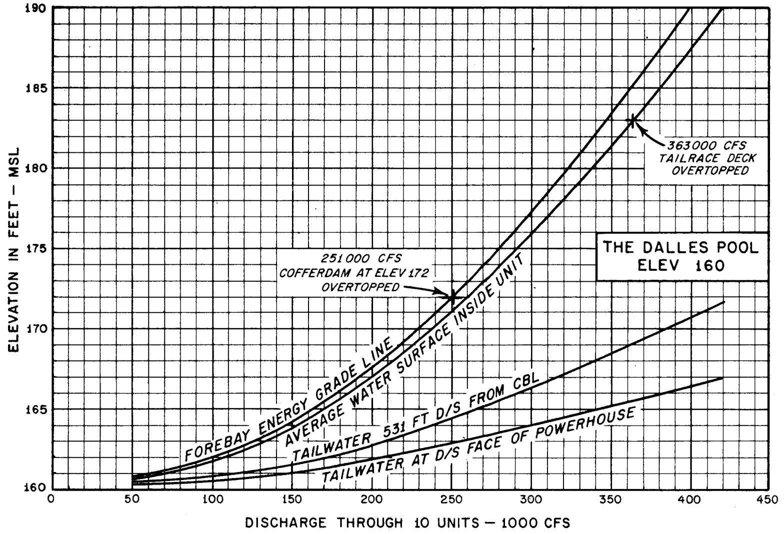
DETAILS OF PLAN E SKELETON UNIT
ARE SHOWN ON PLATE 45.

RATING DATA

PLAN E SKELETON UNIT





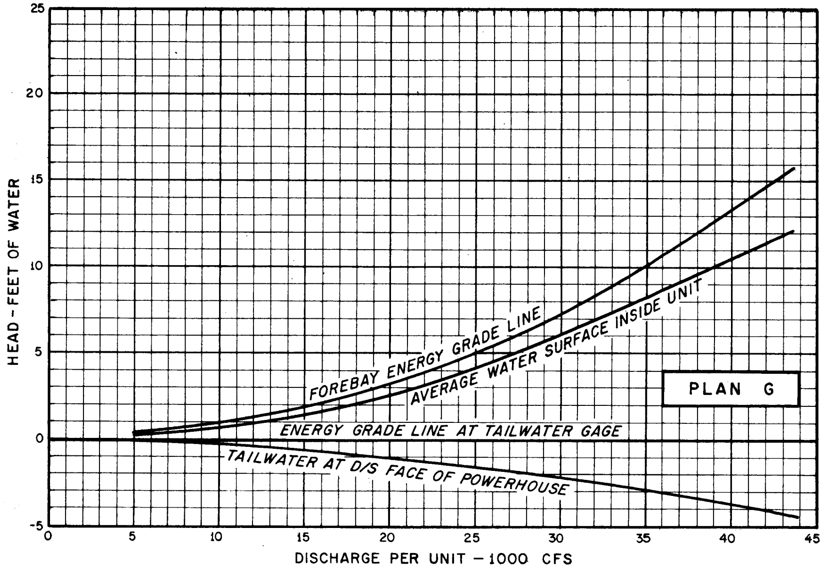


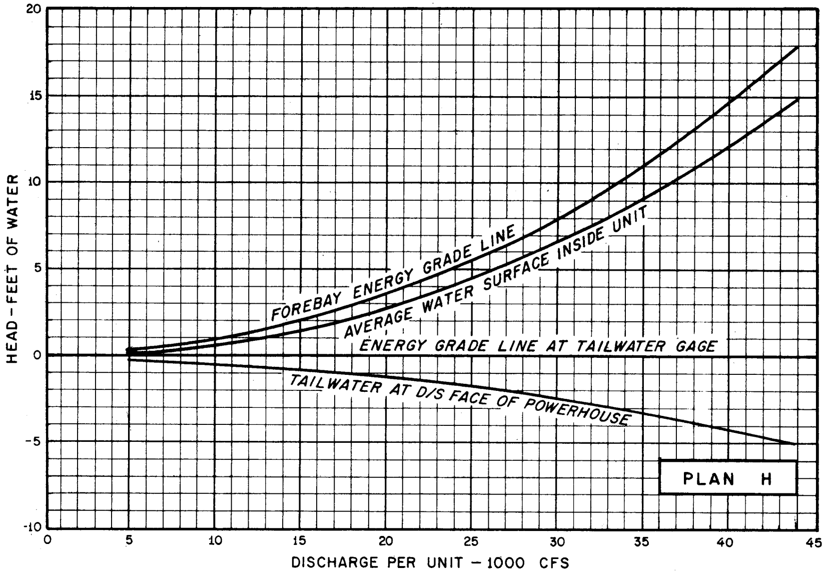
NOTE

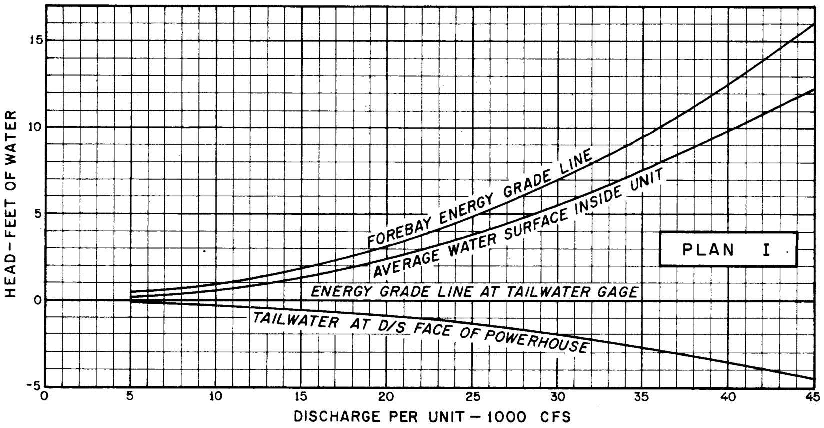
DETAILS OF PLAN F SKELETON UNIT ARE SHOWN ON PLATE 45.

RATING DATA

PLAN F SKELETON UNIT





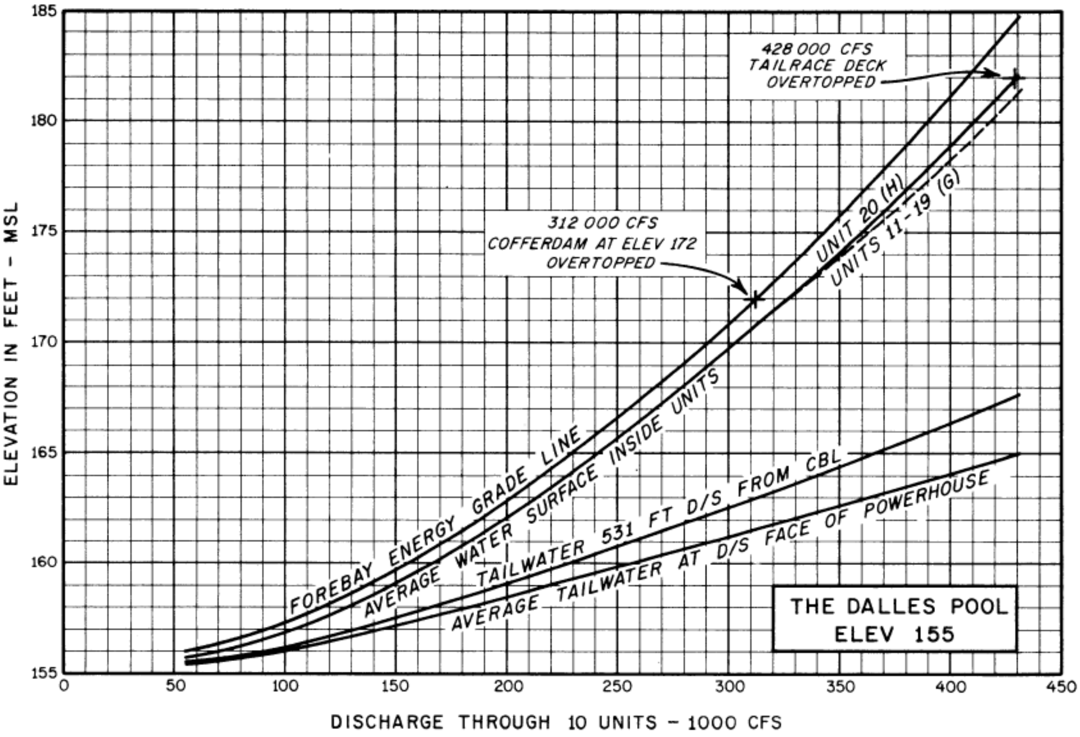


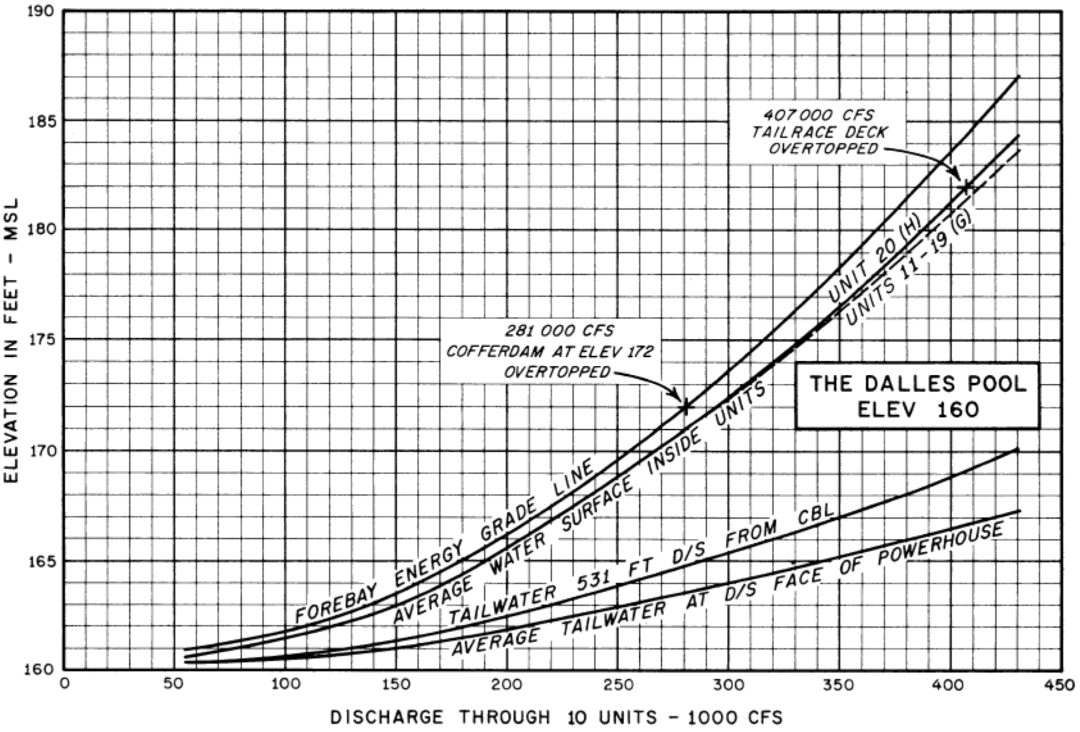
NOTE

DETAILS OF SKELETON UNITS ARE SHOWN ON PLATES 45 (PLAN G) AND 46 (PLANS H AND I).

GENERALIZED RATING DATA

PLANS G, H, AND I SKELETON UNITS



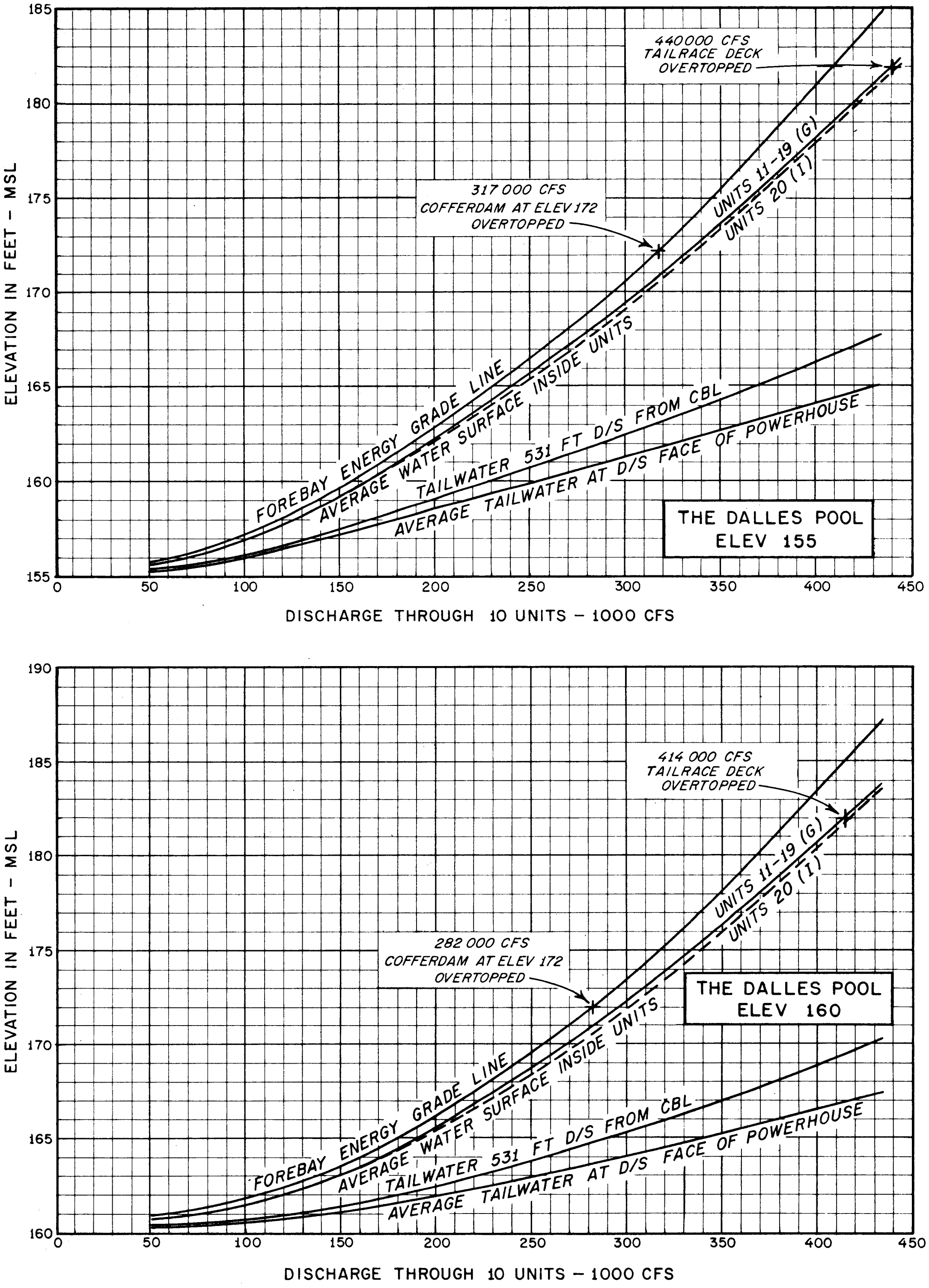


NOTE

DETAILS OF SKELETON UNITS ARE SHOWN ON PLATES 45 (PLAN G) AND 46 (PLAN H).

RATING DATA

PLANS G AND H SKELETON UNITS

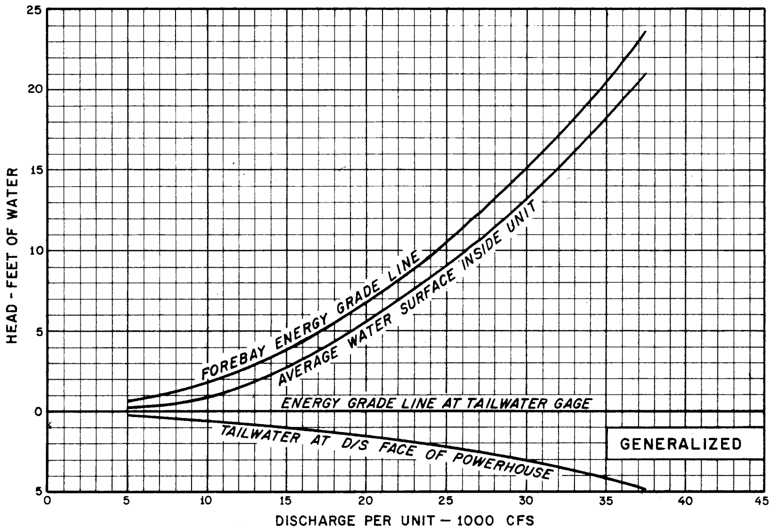


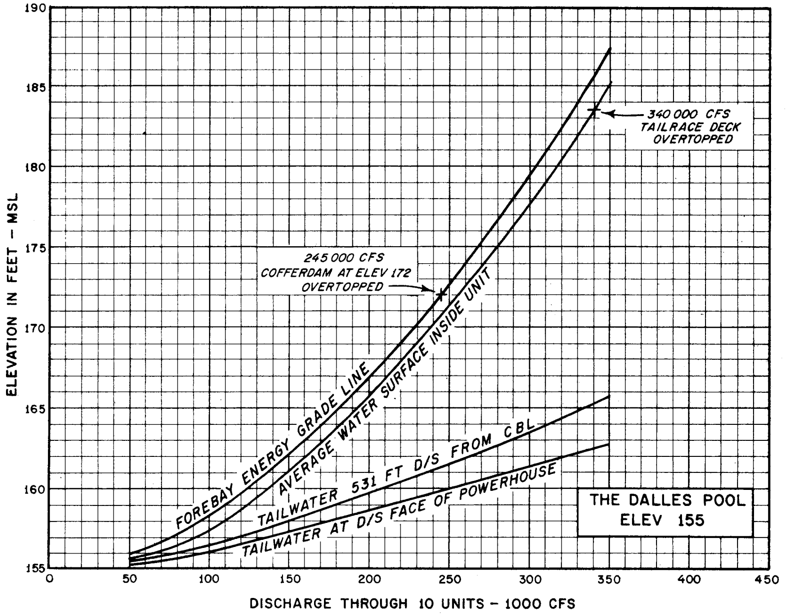
NOTE

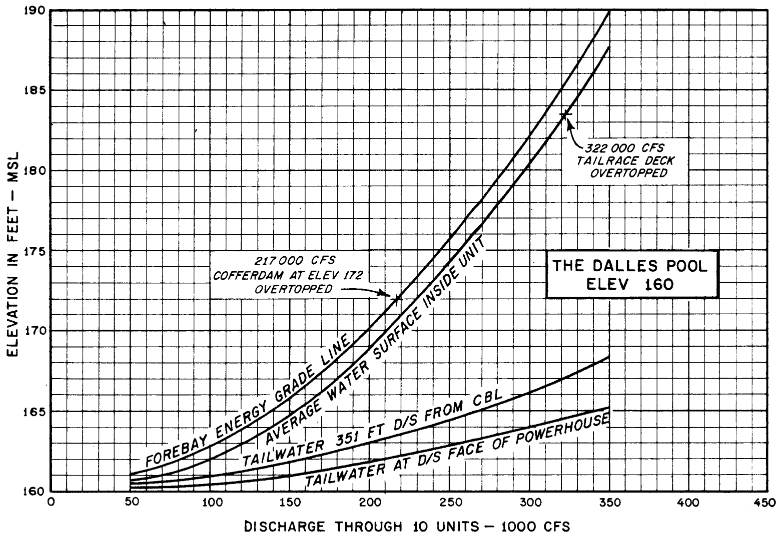
DETAILS OF SKELETON UNITS ARE SHOWN
ON PLATES 45 (PLAN G) AND 46 (PLAN I).

RATING DATA

PLANS G AND I SKELETON UNITS





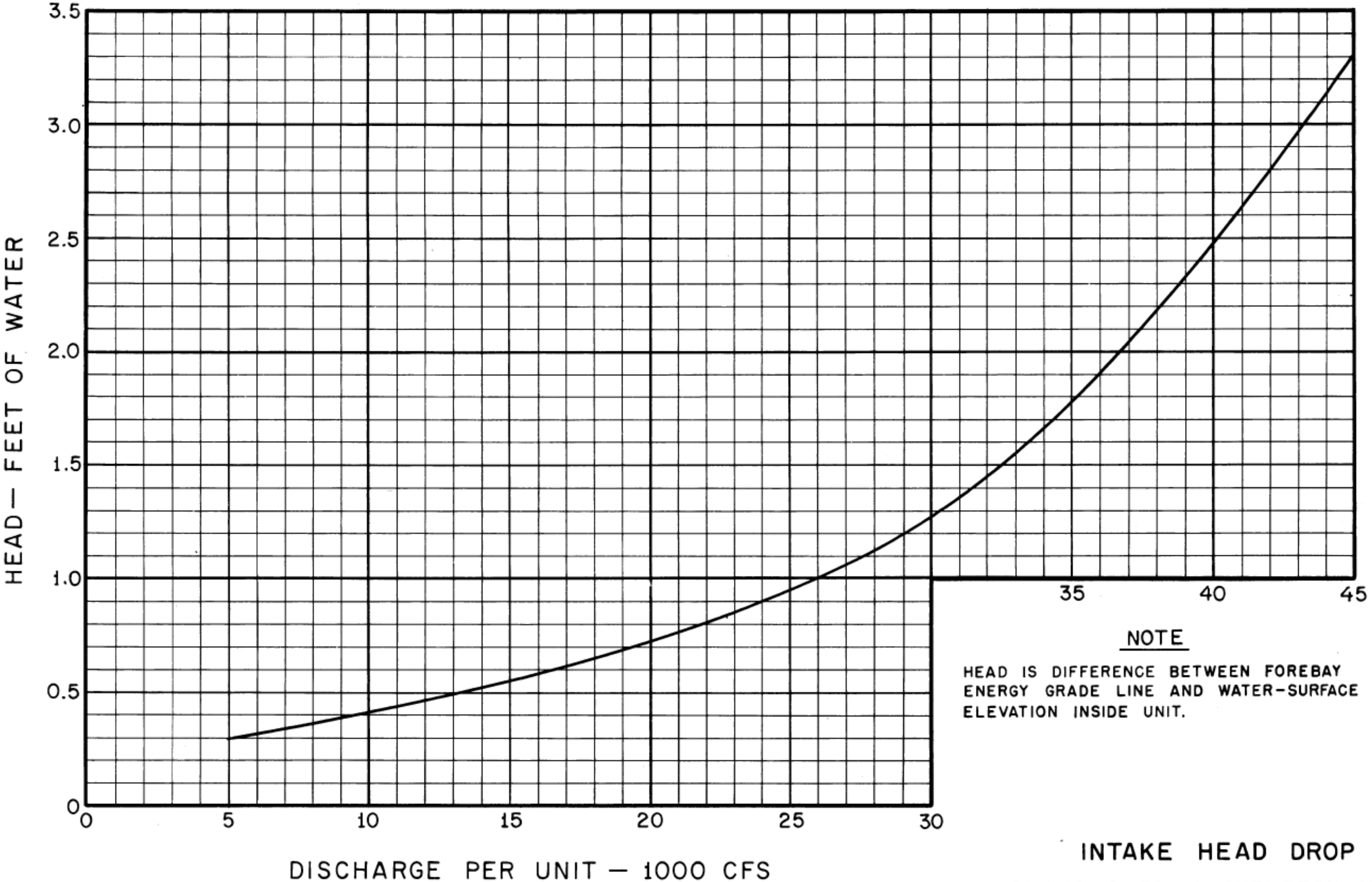


NOTE

DETAILS OF PLAN J SKELETON UNIT ARE SHOWN ON PLATE 46.

RATING DATA

PLAN J SKELETON UNIT

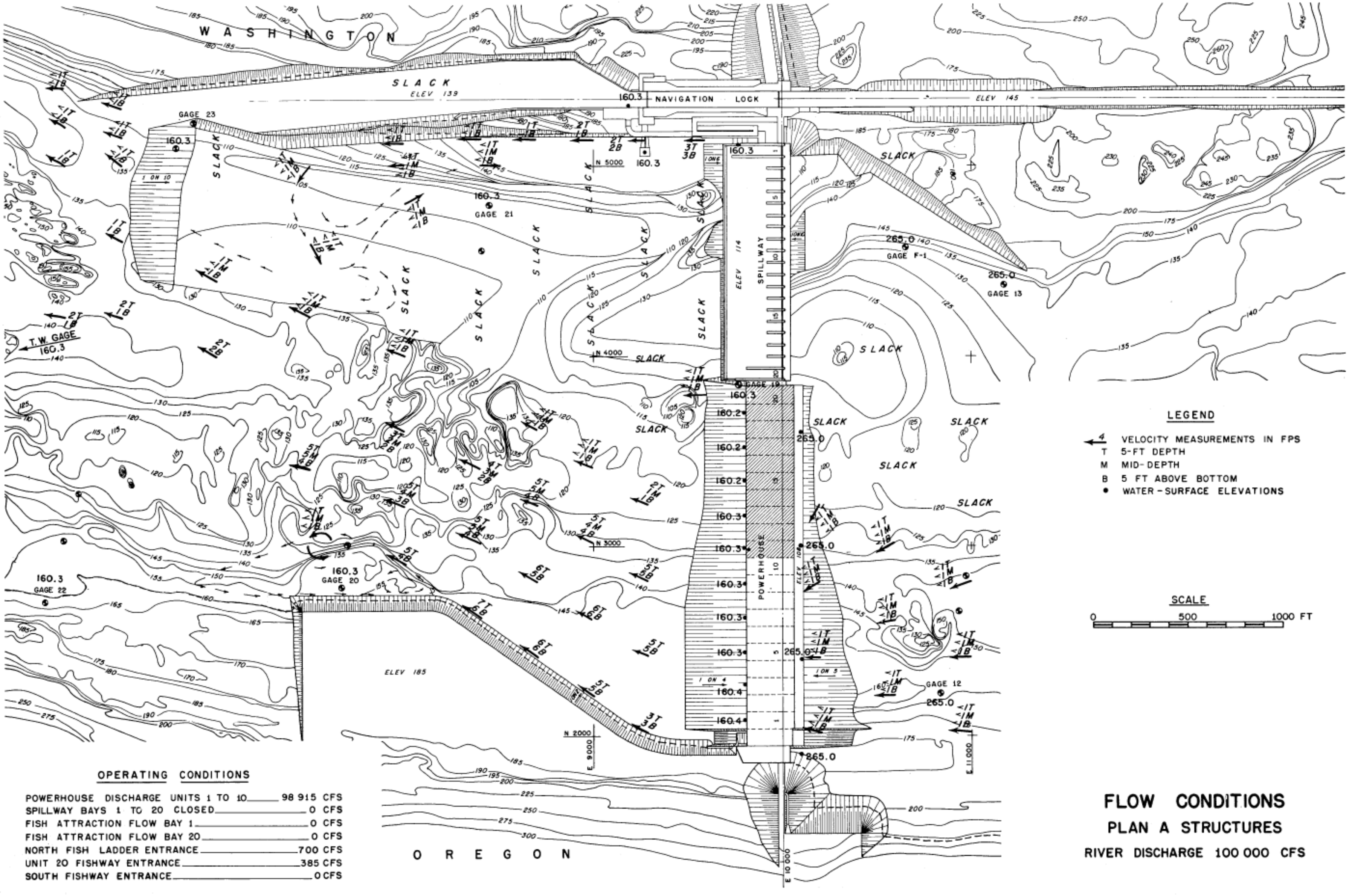


NOTE

HEAD IS DIFFERENCE BETWEEN FOREBAY ENERGY GRADE LINE AND WATER-SURFACE ELEVATION INSIDE UNIT.

INTAKE HEAD DROP

PLANS A TO H SKELETON UNITS

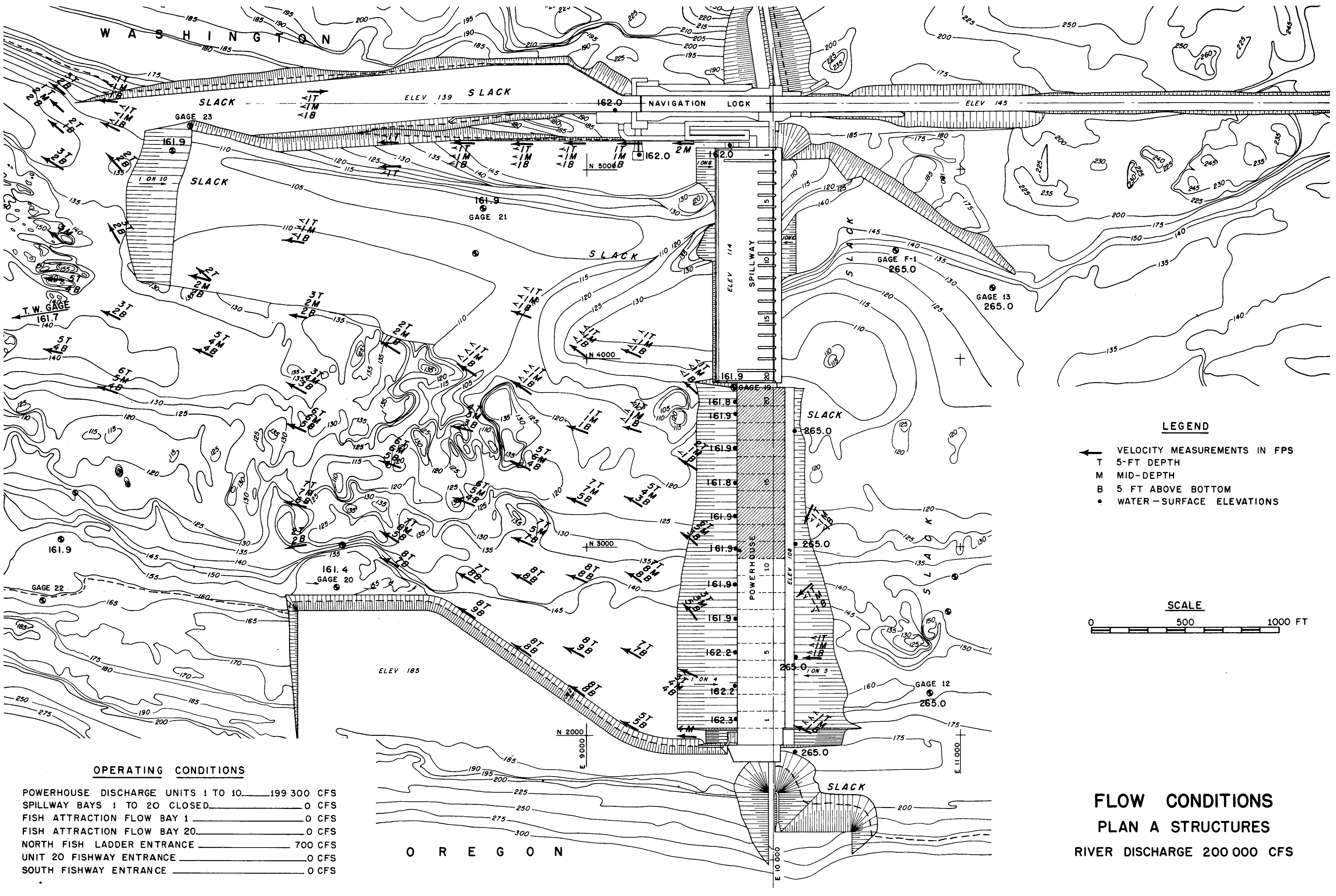


OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	98 915 CFS
SPILLWAY BAYS 1 TO 20 CLOSED	0 CFS
FISH ATTRACTION FLOW BAY 1	0 CFS
FISH ATTRACTION FLOW BAY 20	0 CFS
NORTH FISH LADDER ENTRANCE	700 CFS
UNIT 20 FISHWAY ENTRANCE	385 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS
PLAN A STRUCTURES
RIVER DISCHARGE 100 000 CFS

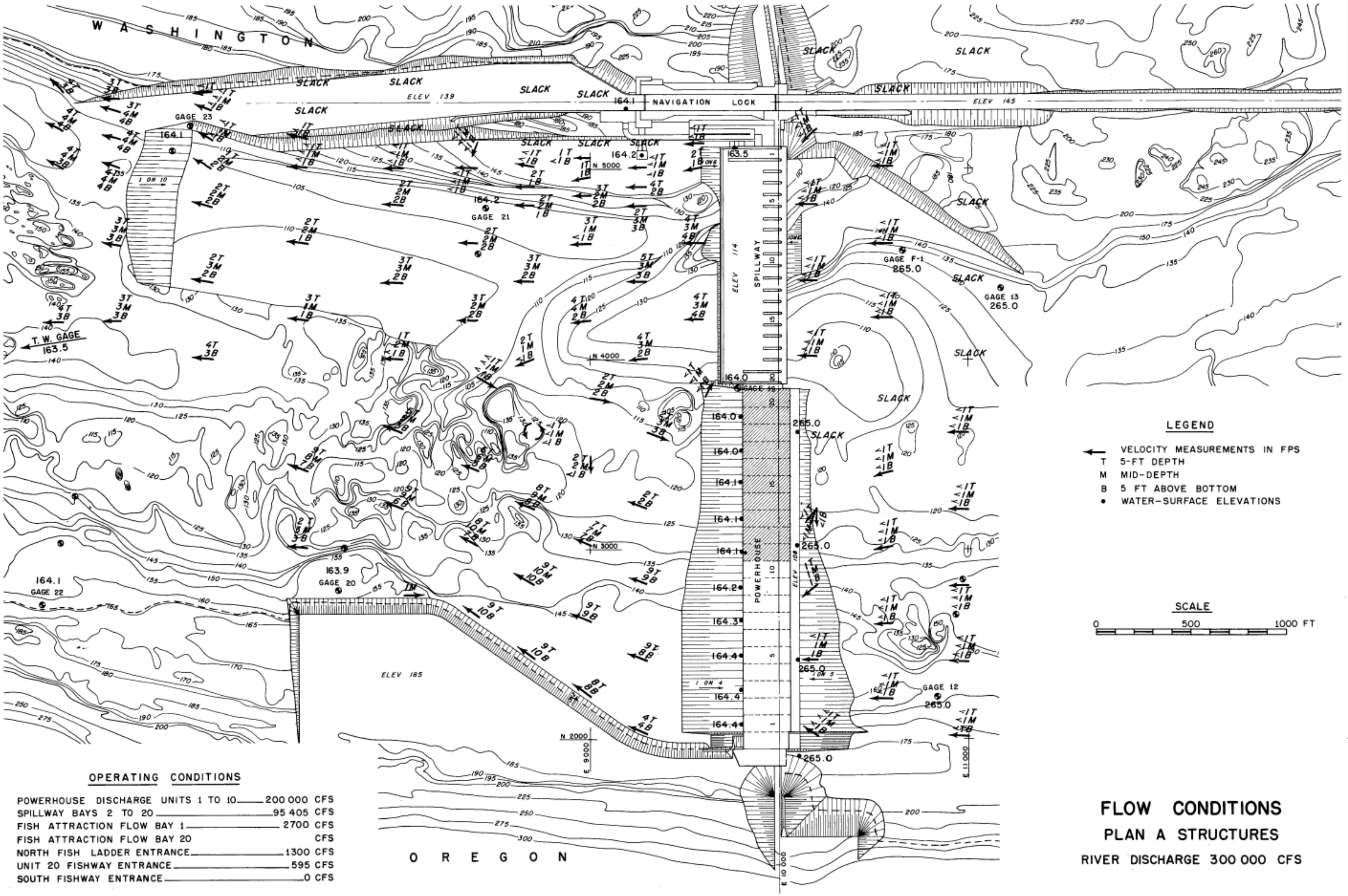
PLATE 59



OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	199 300 CFS
SPILLWAY BAYS 1 TO 20 CLOSED	0 CFS
FISH ATTRACTION FLOW BAY 1	0 CFS
FISH ATTRACTION FLOW BAY 20	0 CFS
NORTH FISH LADDER ENTRANCE	700 CFS
UNIT 20 FISHWAY ENTRANCE	0 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS
PLAN A STRUCTURES
RIVER DISCHARGE 200 000 CFS



LEGEND

- ← VELOCITY MEASUREMENTS IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- ● WATER-SURFACE ELEVATIONS

SCALE

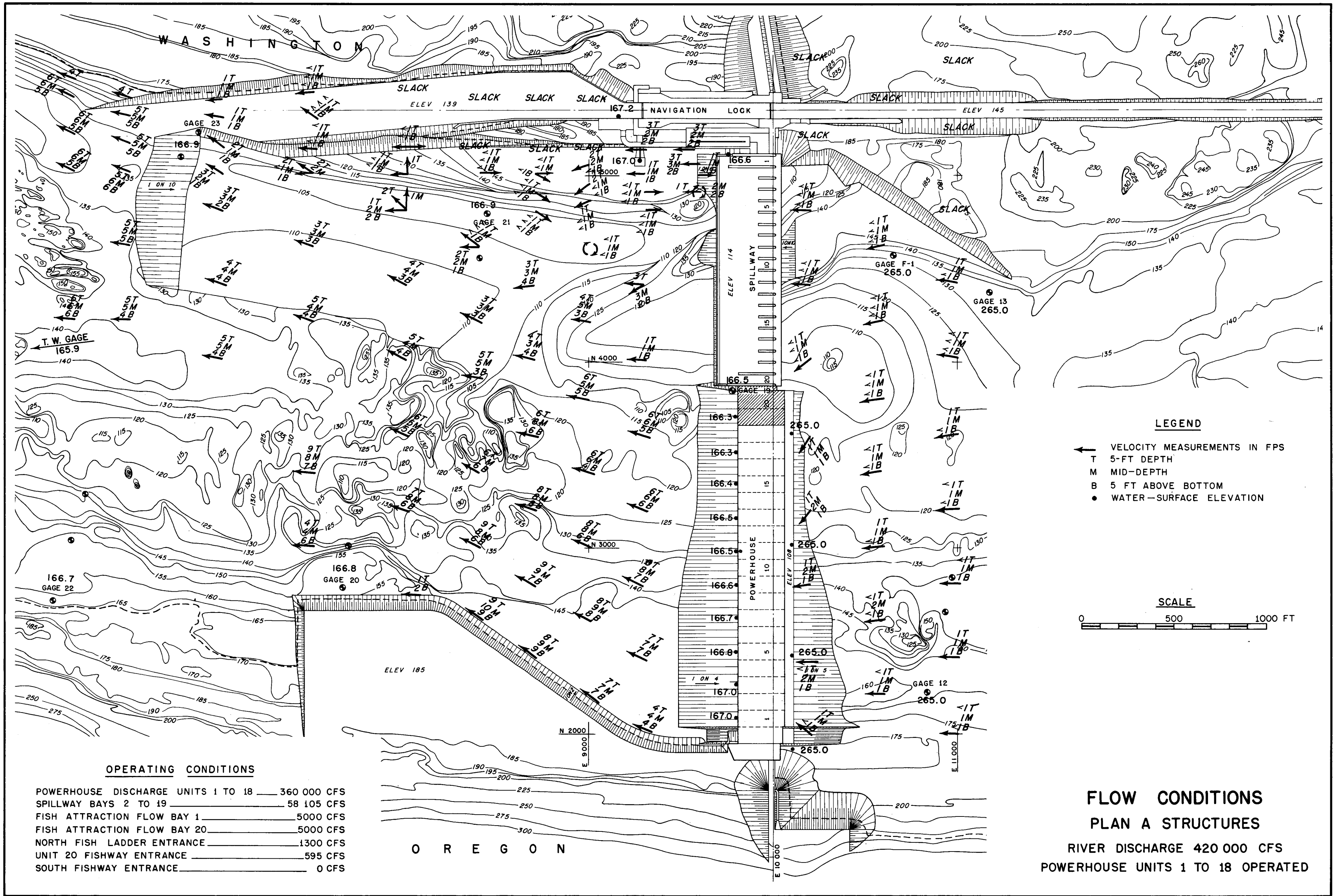
0 500 1000 FT

OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	200 000 CFS
SPILLWAY BAYS 2 TO 20	95 405 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS
FISH ATTRACTION FLOW BAY 20	CFS
NORTH FISH LADDER ENTRANCE	1300 CFS
UNIT 20 FISHWAY ENTRANCE	595 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS
PLAN A STRUCTURES
RIVER DISCHARGE 300 000 CFS

PLATE 60



OPERATING CONDITIONS

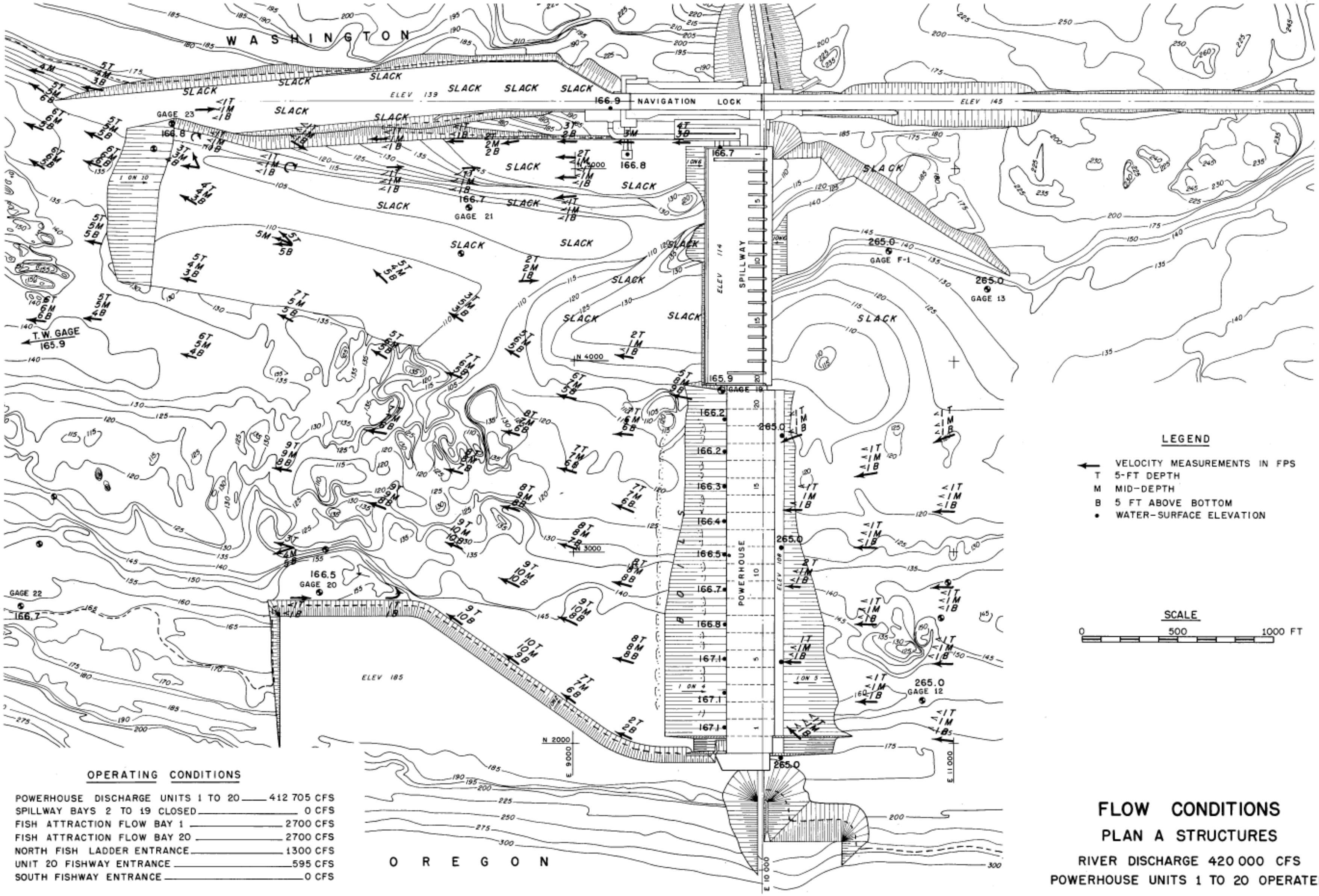
POWERHOUSE DISCHARGE UNITS 1 TO 18	360 000 CFS
SPILLWAY BAYS 2 TO 19	58 105 CFS
FISH ATTRACTION FLOW BAY 1	5000 CFS
FISH ATTRACTION FLOW BAY 20	5000 CFS
NORTH FISH LADDER ENTRANCE	1300 CFS
UNIT 20 FISHWAY ENTRANCE	595 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS

PLAN A STRUCTURES

RIVER DISCHARGE 420 000 CFS

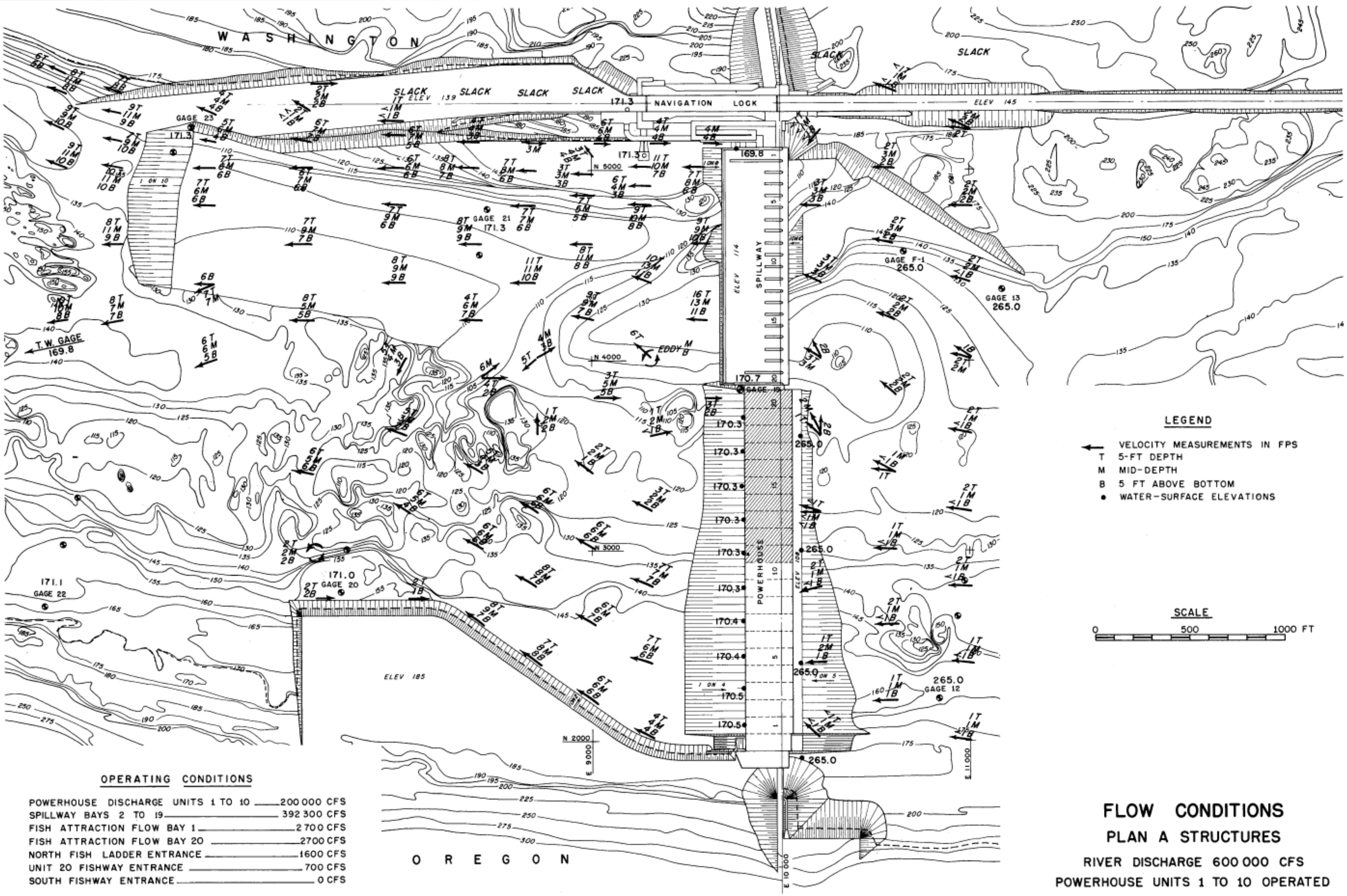
POWERHOUSE UNITS 1 TO 18 OPERATED



OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 20	412 705 CFS
SPILLWAY BAYS 2 TO 19 CLOSED	0 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS
FISH ATTRACTION FLOW BAY 20	2700 CFS
NORTH FISH LADDER ENTRANCE	1300 CFS
UNIT 20 FISHWAY ENTRANCE	595 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

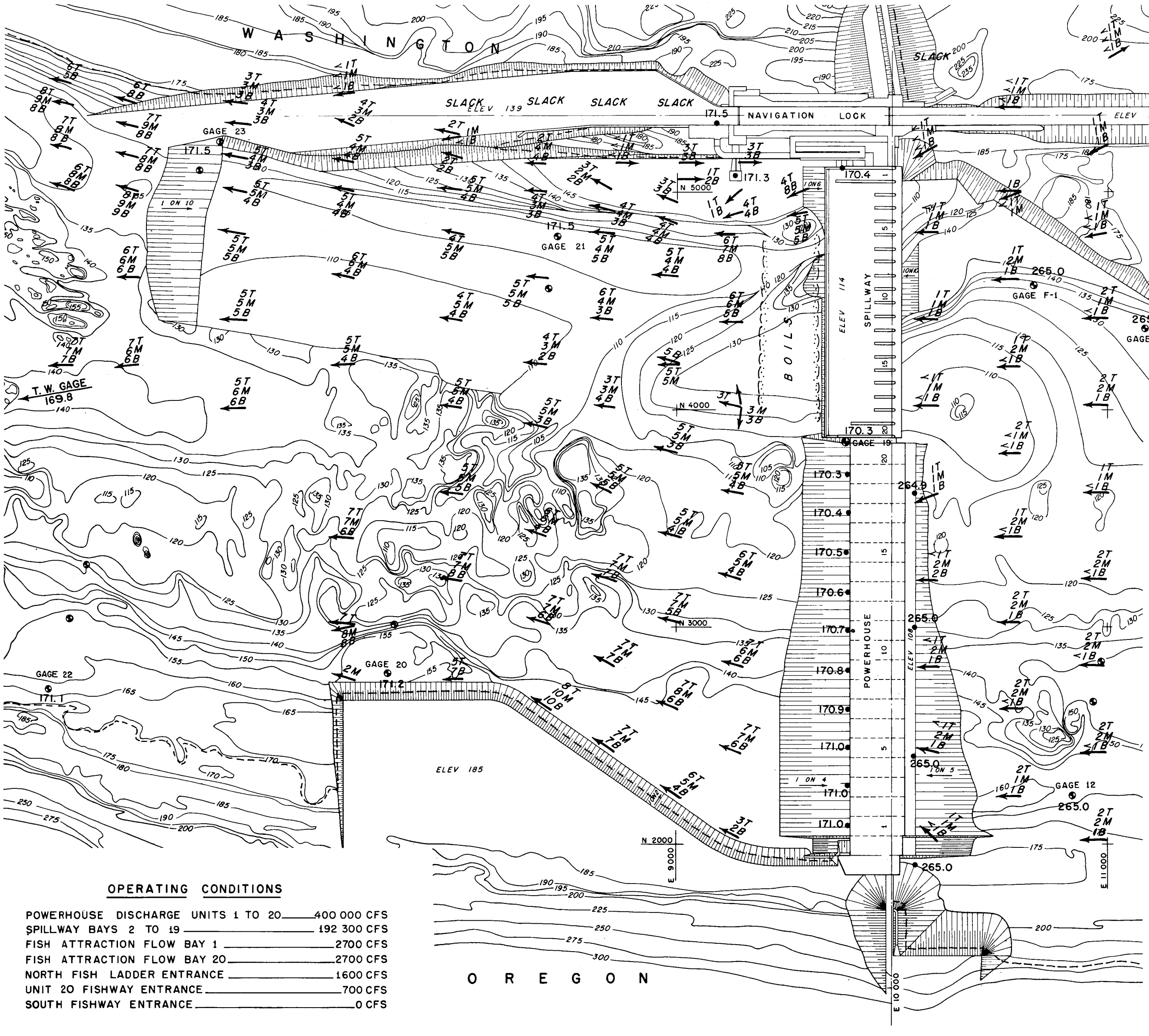
FLOW CONDITIONS
PLAN A STRUCTURES
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 20 OPERATED



OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	200 000 CFS
SPILLWAY BAYS 2 TO 19	392 300 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS
FISH ATTRACTION FLOW BAY 20	2700 CFS
NORTH FISH LADDER ENTRANCE	1600 CFS
UNIT 20 FISHWAY ENTRANCE	700 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS
PLAN A STRUCTURES
RIVER DISCHARGE 600 000 CFS
POWERHOUSE UNITS 1 TO 10 OPERATED



LEGEND

←	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
●	WATER-SURFACE ELEVATION

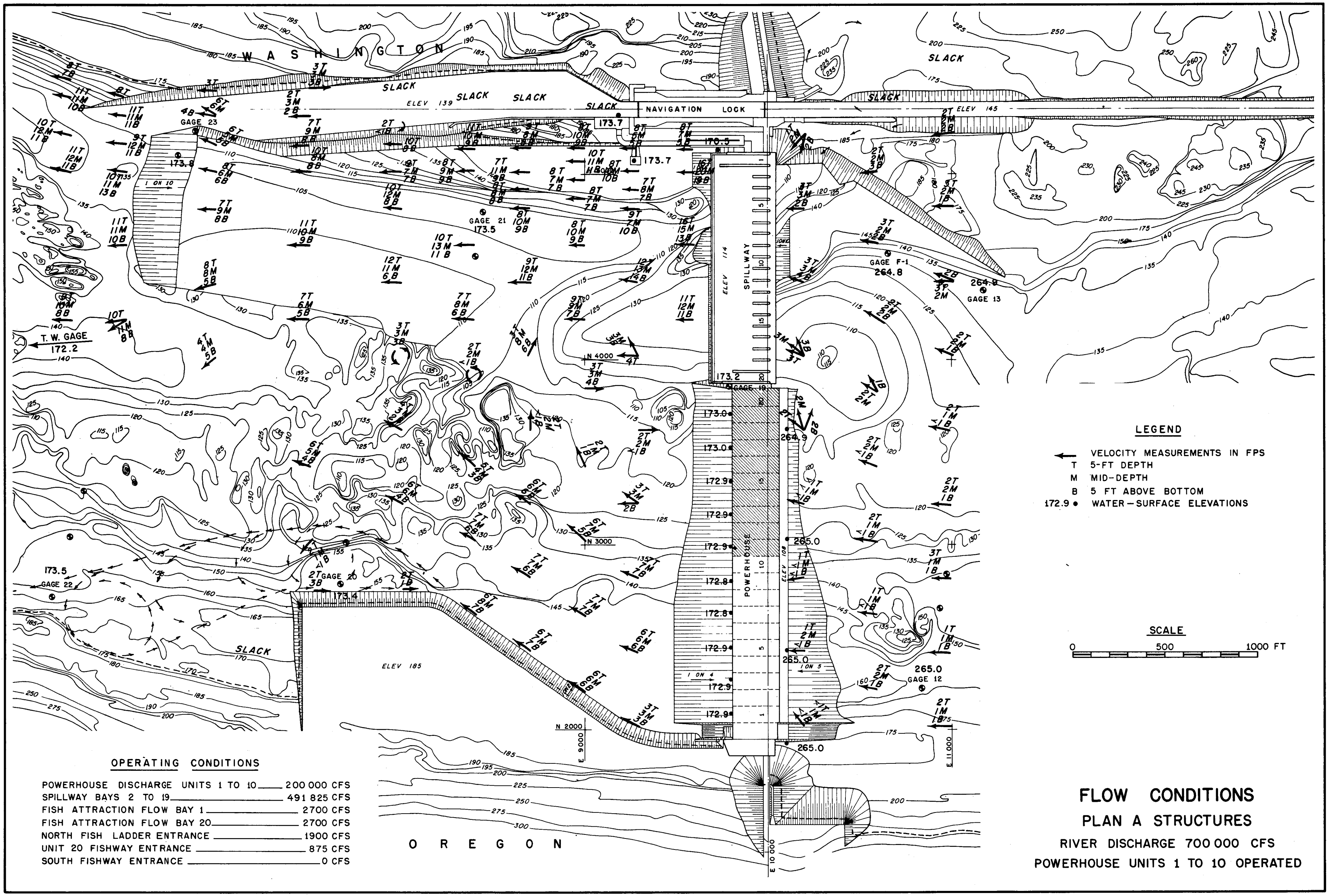
SCALE

0 500 1000 FT

OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 20	400 000 CFS
SPILLWAY BAYS 2 TO 19	192 300 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS
FISH ATTRACTION FLOW BAY 20	2700 CFS
NORTH FISH LADDER ENTRANCE	1600 CFS
UNIT 20 FISHWAY ENTRANCE	700 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS
PLAN A STRUCTURES
RIVER DISCHARGE 600 000 CFS
POWERHOUSE UNITS 1 TO 20 OPERATED



OPERATING CONDITIONS

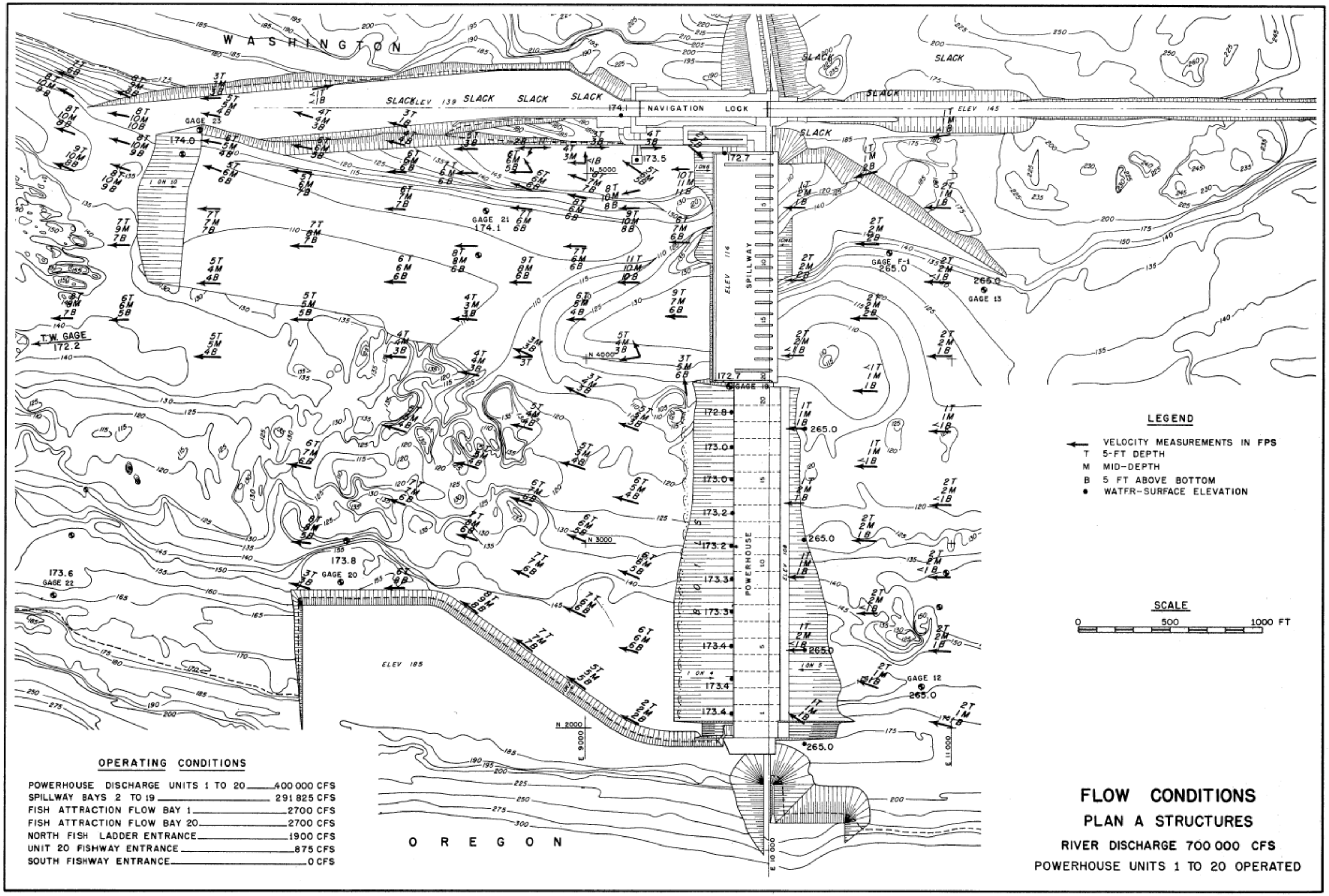
POWERHOUSE DISCHARGE UNITS 1 TO 10	200 000 CFS
SPILLWAY BAYS 2 TO 19	491 825 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS
FISH ATTRACTION FLOW BAY 20	2700 CFS
NORTH FISH LADDER ENTRANCE	1900 CFS
UNIT 20 FISHWAY ENTRANCE	875 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS

PLAN A STRUCTURES

RIVER DISCHARGE 700 000 CFS

POWERHOUSE UNITS 1 TO 10 OPERATED

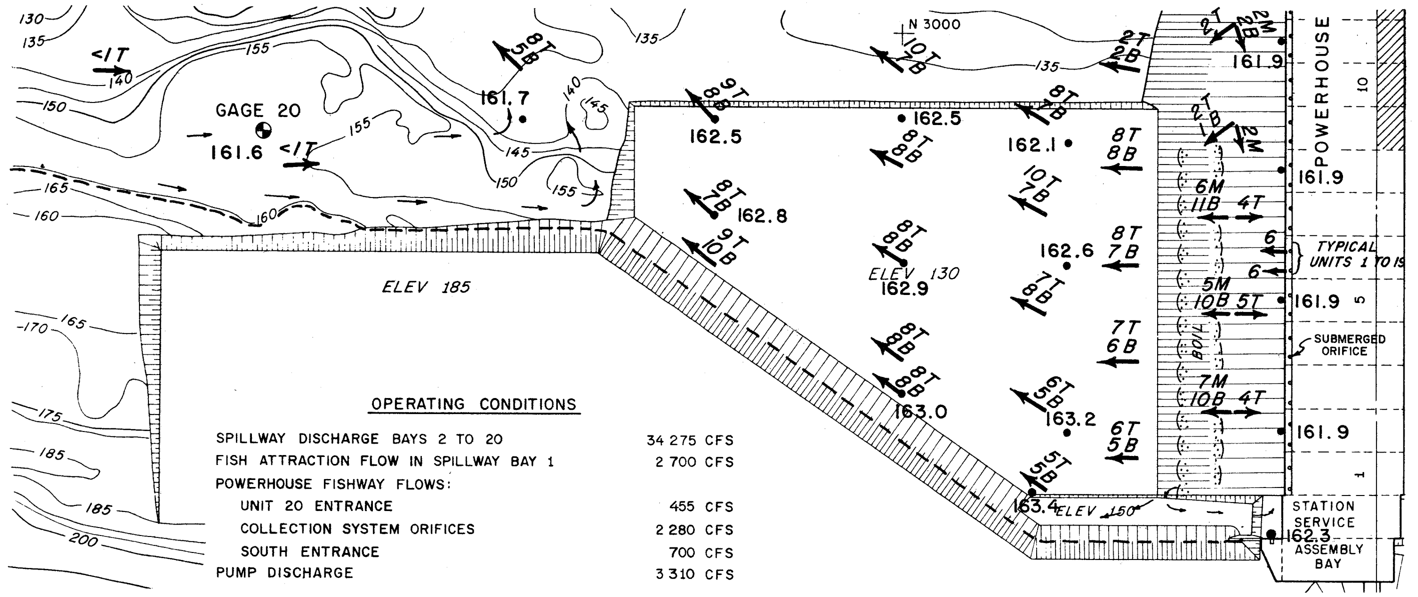


OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 20	400 000 CFS
SPILLWAY BAYS 2 TO 19	291 825 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS
FISH ATTRACTION FLOW BAY 20	2700 CFS
NORTH FISH LADDER ENTRANCE	1900 CFS
UNIT 20 FISHWAY ENTRANCE	875 CFS
SOUTH FISHWAY ENTRANCE	0 CFS

FLOW CONDITIONS
PLAN A STRUCTURES

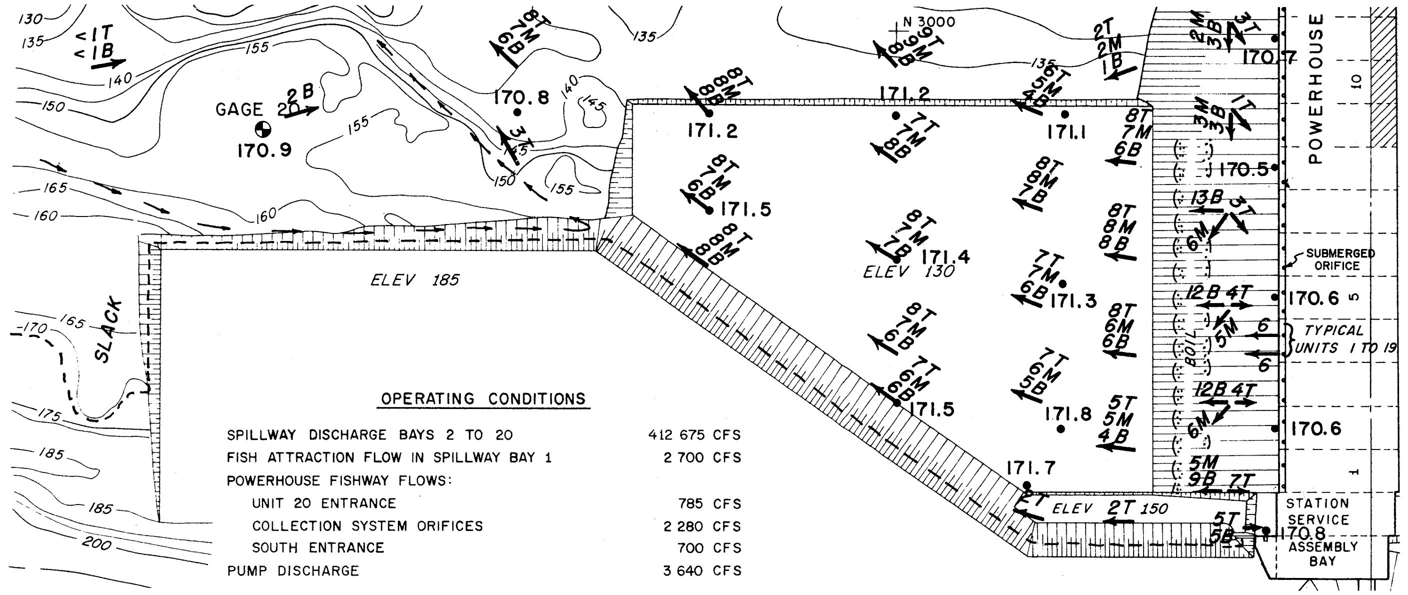
RIVER DISCHARGE 700 000 CFS
POWERHOUSE UNITS 1 TO 20 OPERATED



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	34 275 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	455 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	700 CFS
PUMP DISCHARGE	3 310 CFS

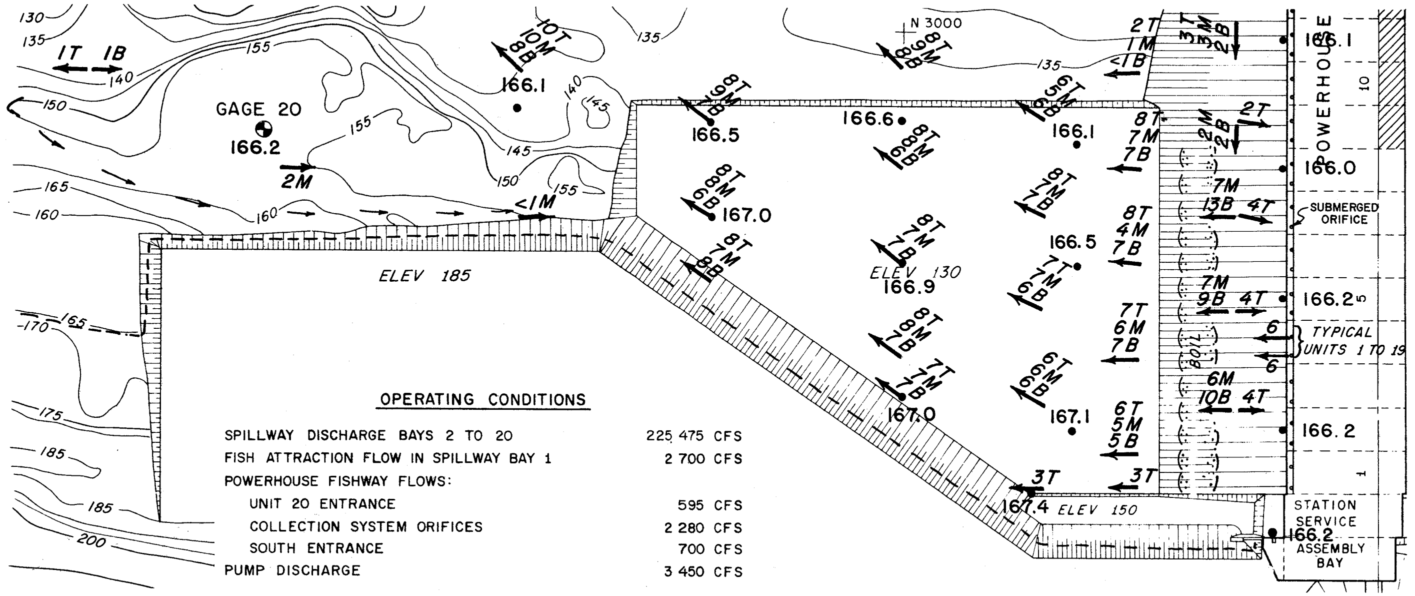
RIVER DISCHARGE 200 000 CFS; POWERHOUSE DISCHARGE 162 400 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	412 675 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	700 CFS
PUMP DISCHARGE	3 640 CFS

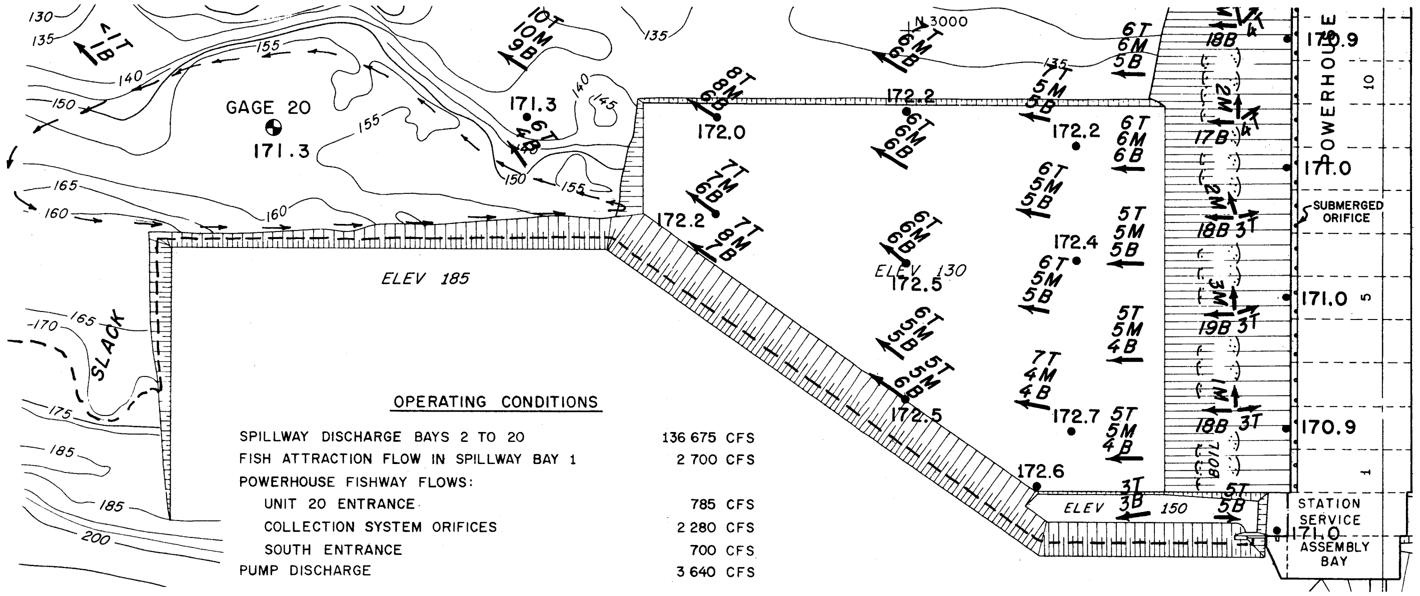
RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	225 475 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	595 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	700 CFS
PUMP DISCHARGE	3 450 CFS

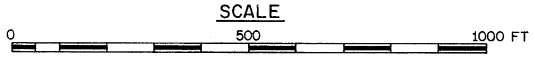
RIVER DISCHARGE 400 000 CFS; POWERHOUSE DISCHARGE 171 200 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	136 675 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	700 CFS
PUMP DISCHARGE	3 640 CFS

RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20



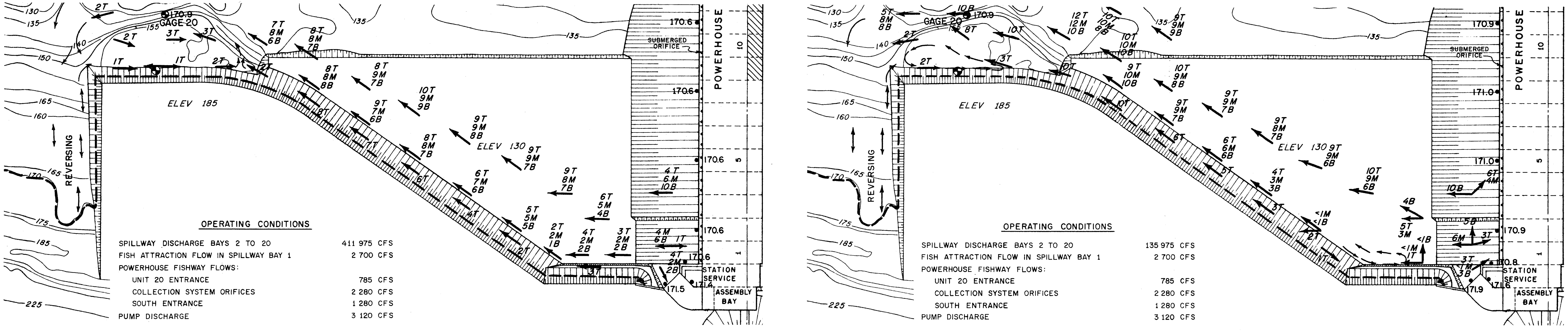
LEGEND

← 4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
167.0 ●	WATER-SURFACE ELEVATIONS
----	WATER'S EDGE

FLOW PATTERNS

PLAN B POWERHOUSE TAILRACE

RIVER DISCHARGE 200 000 TO 600 000 CFS



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	411 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

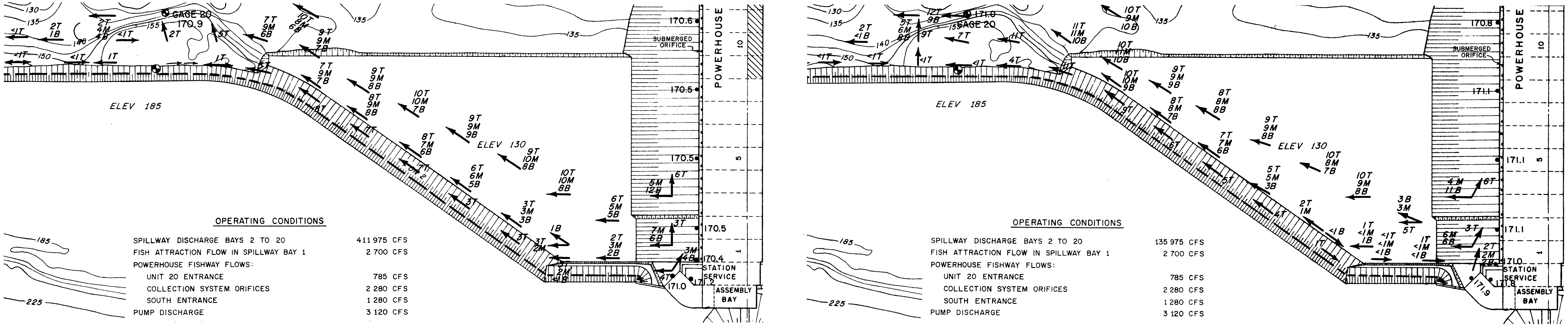
POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8

OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	135 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20

PLAN C DISPOSAL AREA



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	411 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8

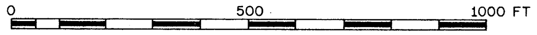
OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	135 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20

PLAN D DISPOSAL AREA

SCALE

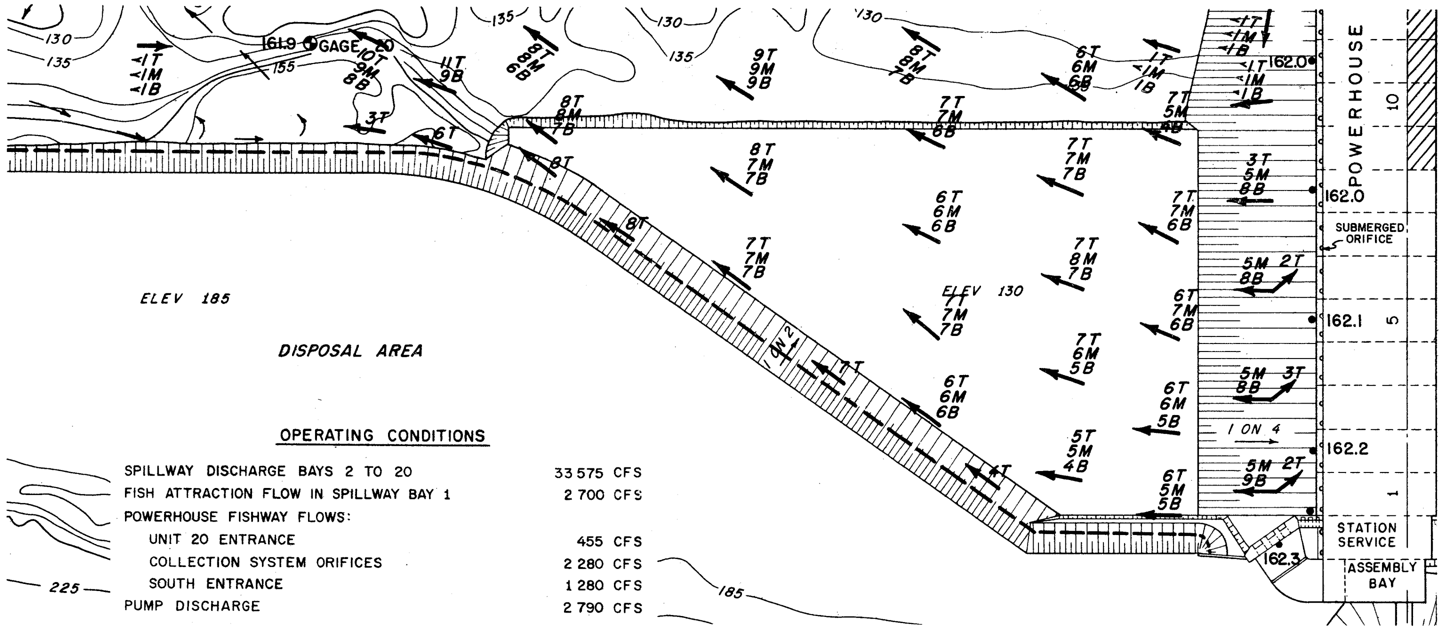


LEGEND

← 4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.0 ●	WATER-SURFACE ELEVATIONS
----	WATER'S EDGE

FLOW PATTERNS

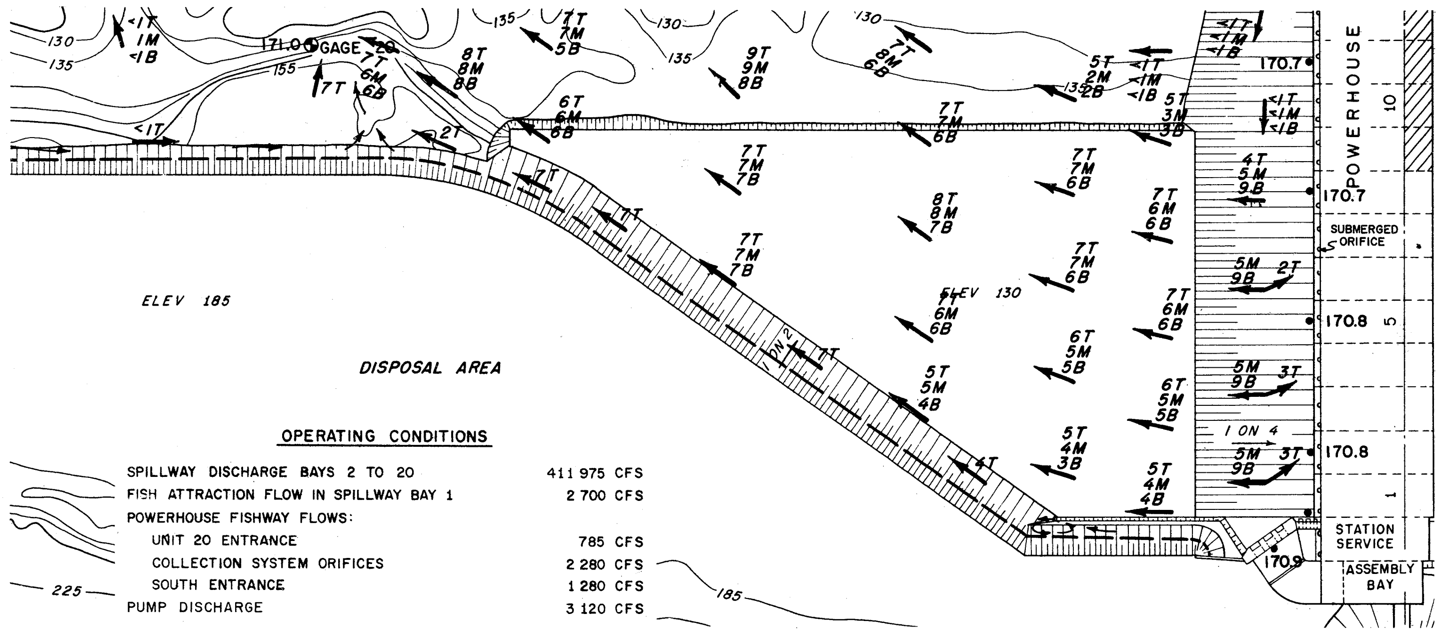
PLAN C POWERHOUSE TAILRACE
PLANS C AND D DISPOSAL AREAS
RIVER DISCHARGE 600 000 CFS



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	33 575 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	455 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	2 790 CFS

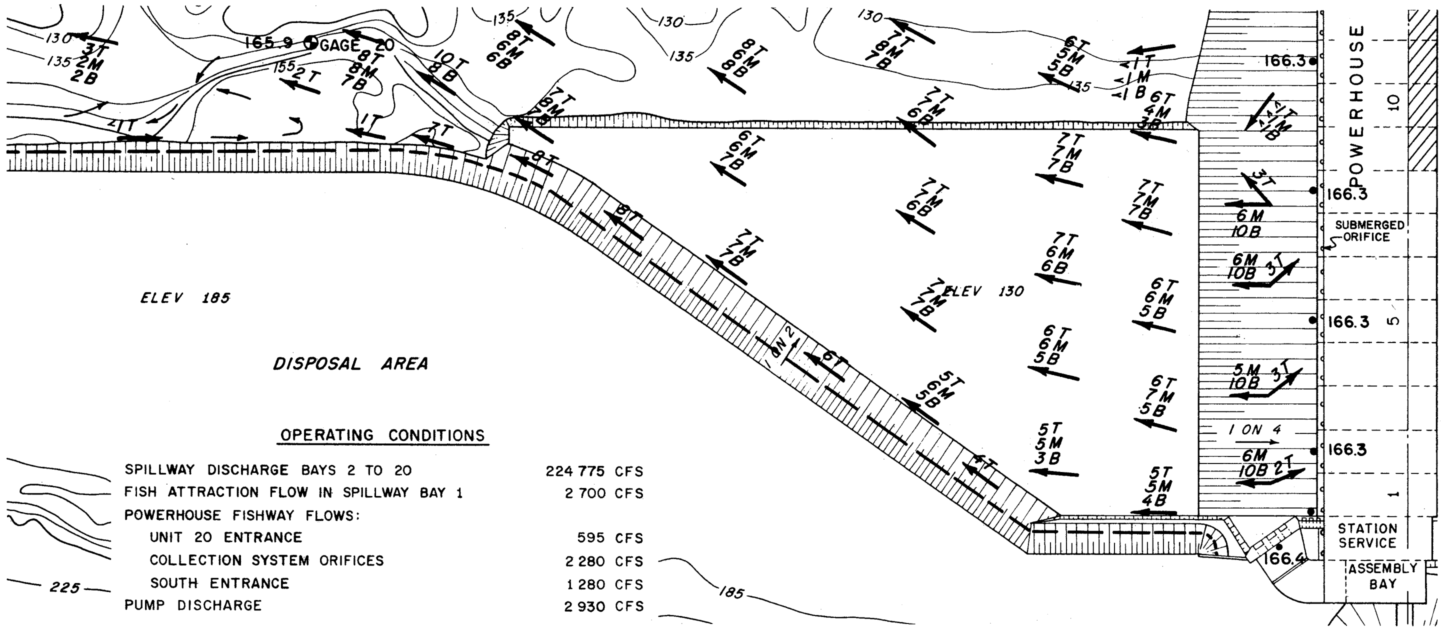
RIVER DISCHARGE 200 000 CFS; POWERHOUSE DISCHARGE 162 400 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	411 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

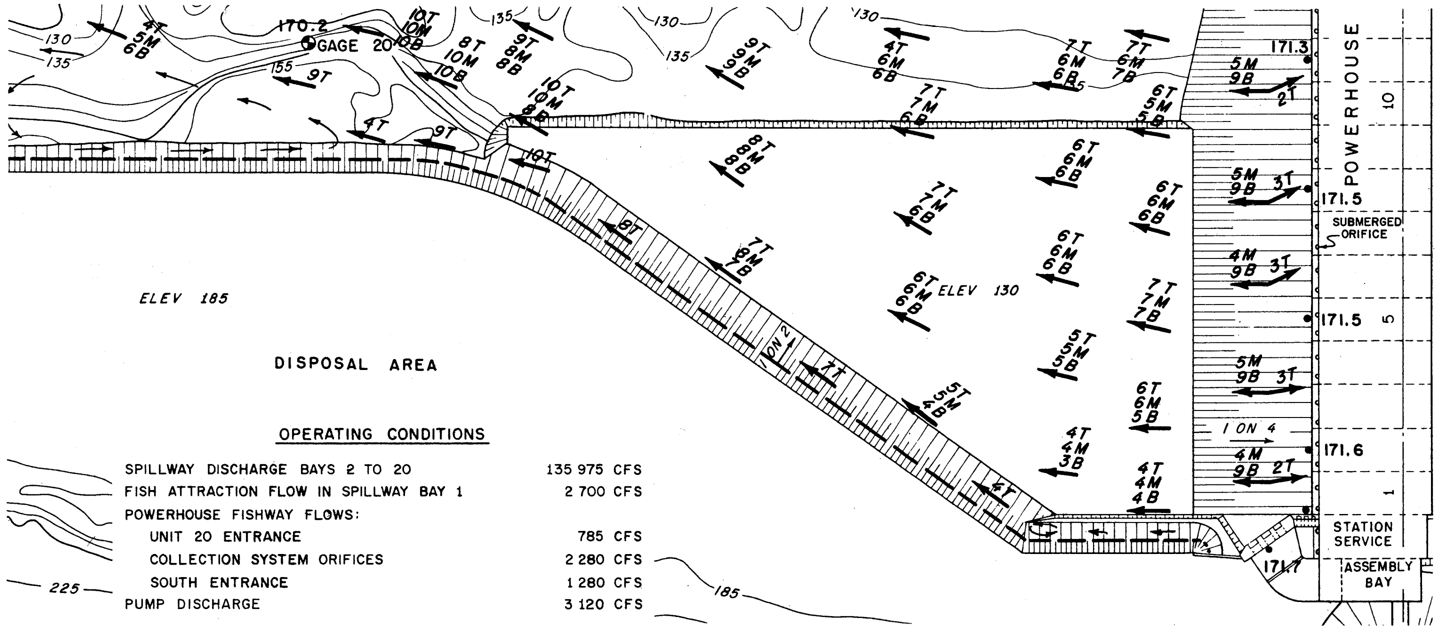
RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	224 775 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	595 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	2 930 CFS

RIVER DISCHARGE 400 000 CFS; POWERHOUSE DISCHARGE 171 200 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	135 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20

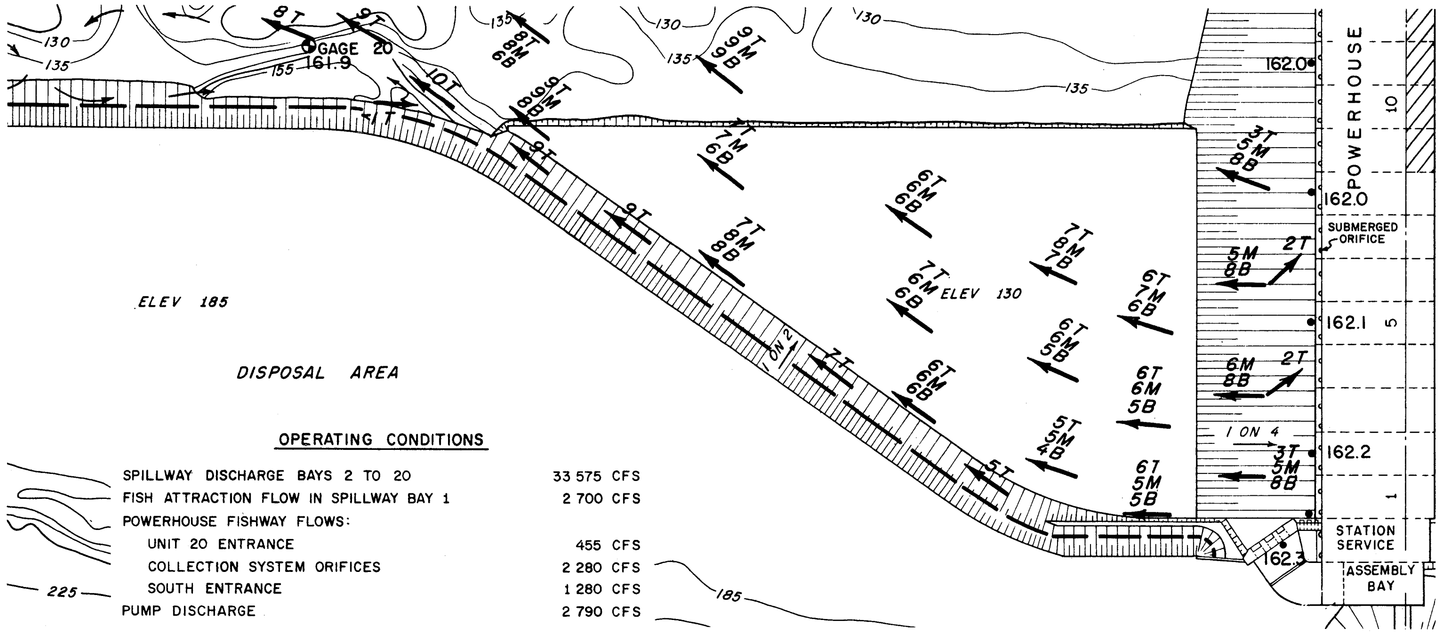
LEGEND

←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.2 ●	WATER-SURFACE ELEVATIONS
------	WATER'S EDGE

FLOW PATTERNS

PLAN D POWERHOUSE TAILRACE

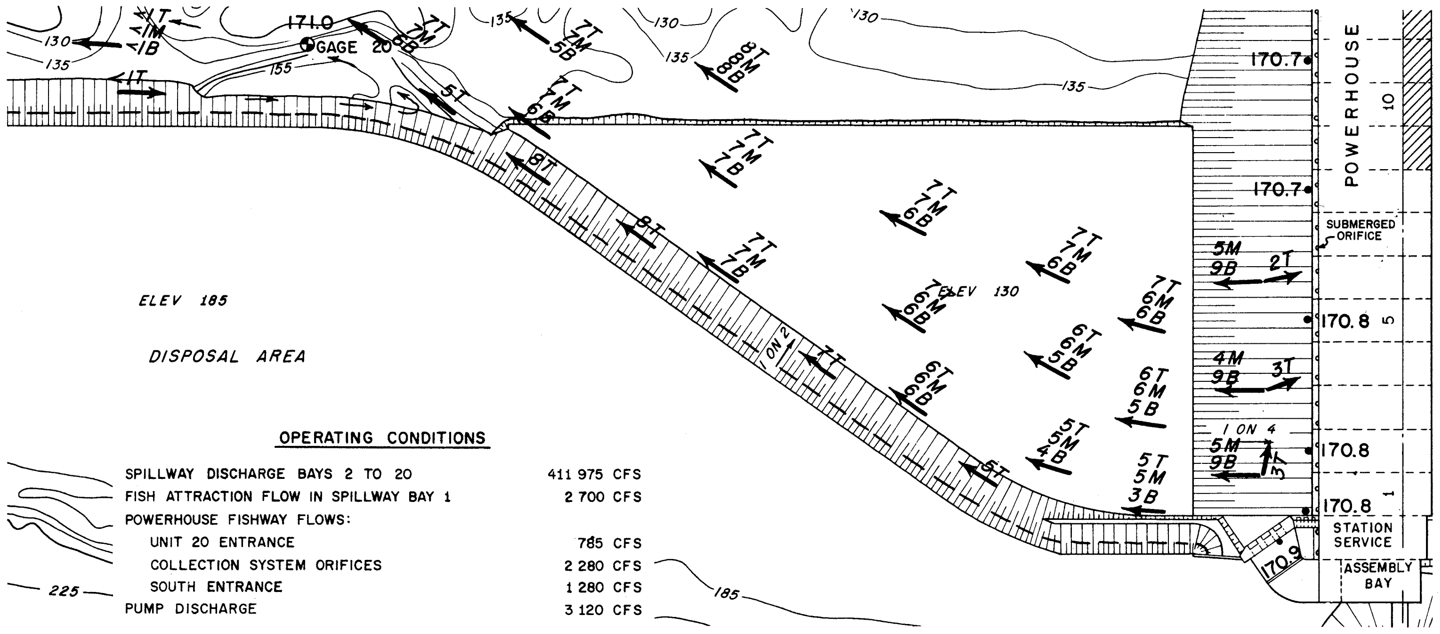
RIVER DISCHARGE 200 000 TO 600 000 CFS



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	33 575 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	455 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	2 790 CFS

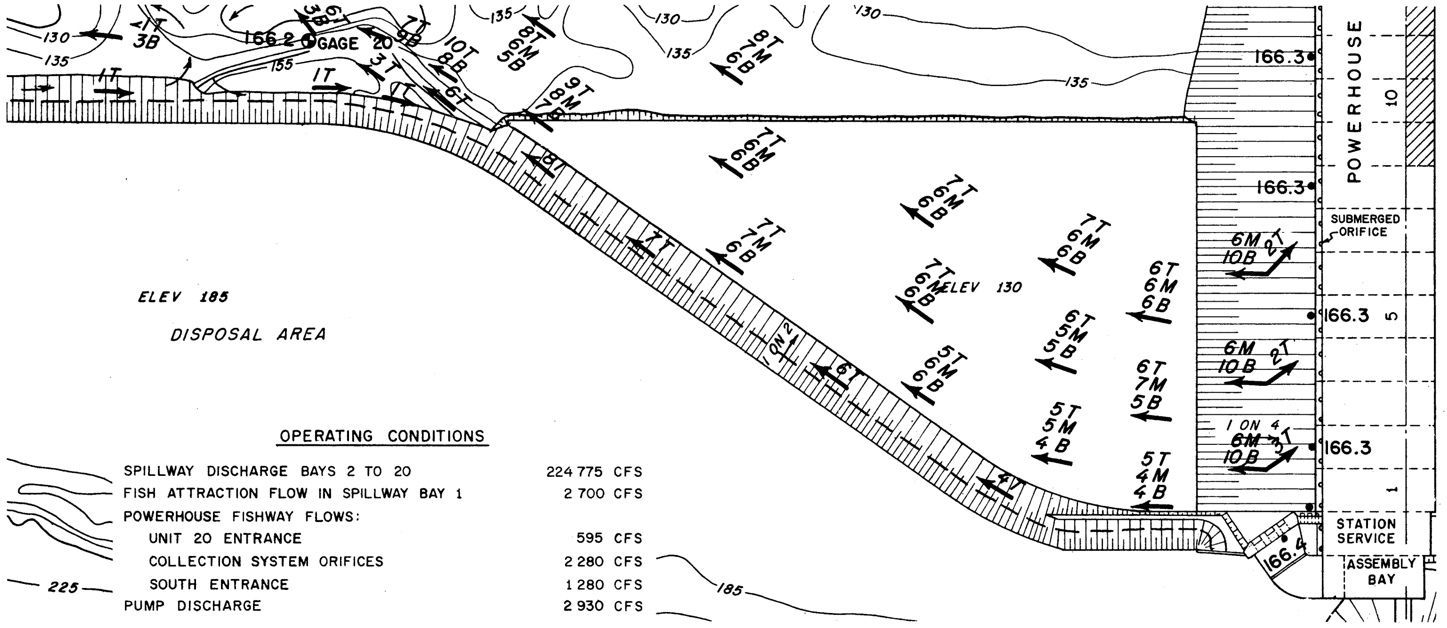
RIVER DISCHARGE 200 000 CFS; POWERHOUSE DISCHARGE 162 400 CFS, UNITS 1 TO 80



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	411 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

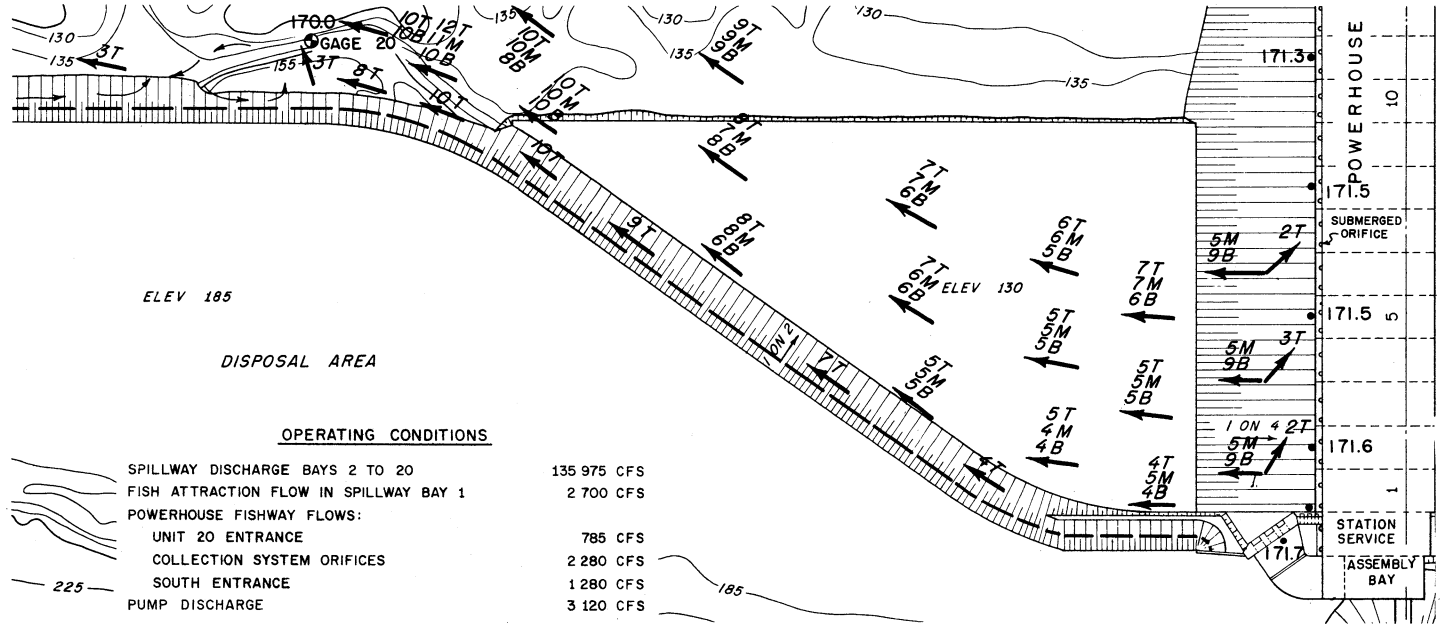
RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	224 775 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	595 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	2 930 CFS

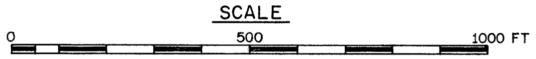
RIVER DISCHARGE 400 000 CFS; POWERHOUSE DISCHARGE 171 200 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	135 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20



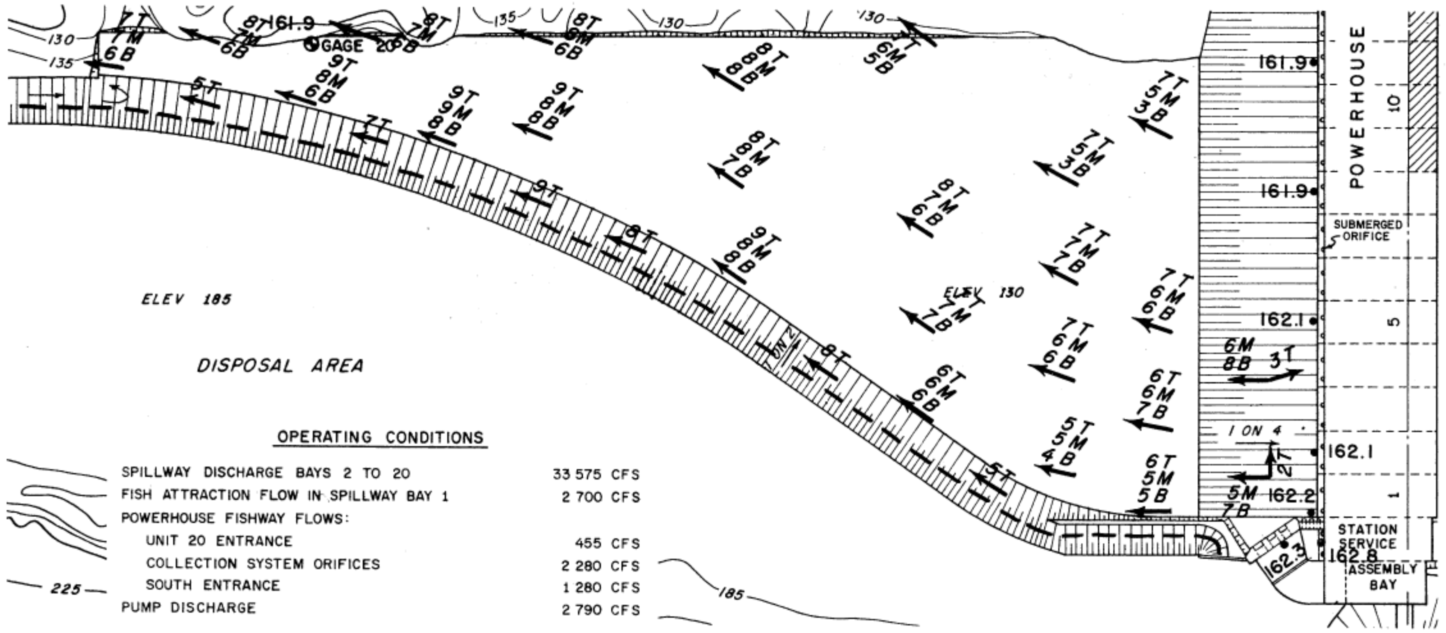
LEGEND

← 6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.0 ●	WATER-SURFACE ELEVATIONS
- - - -	WATER'S EDGE

FLOW PATTERNS

PLAN E POWERHOUSE TAILRACE

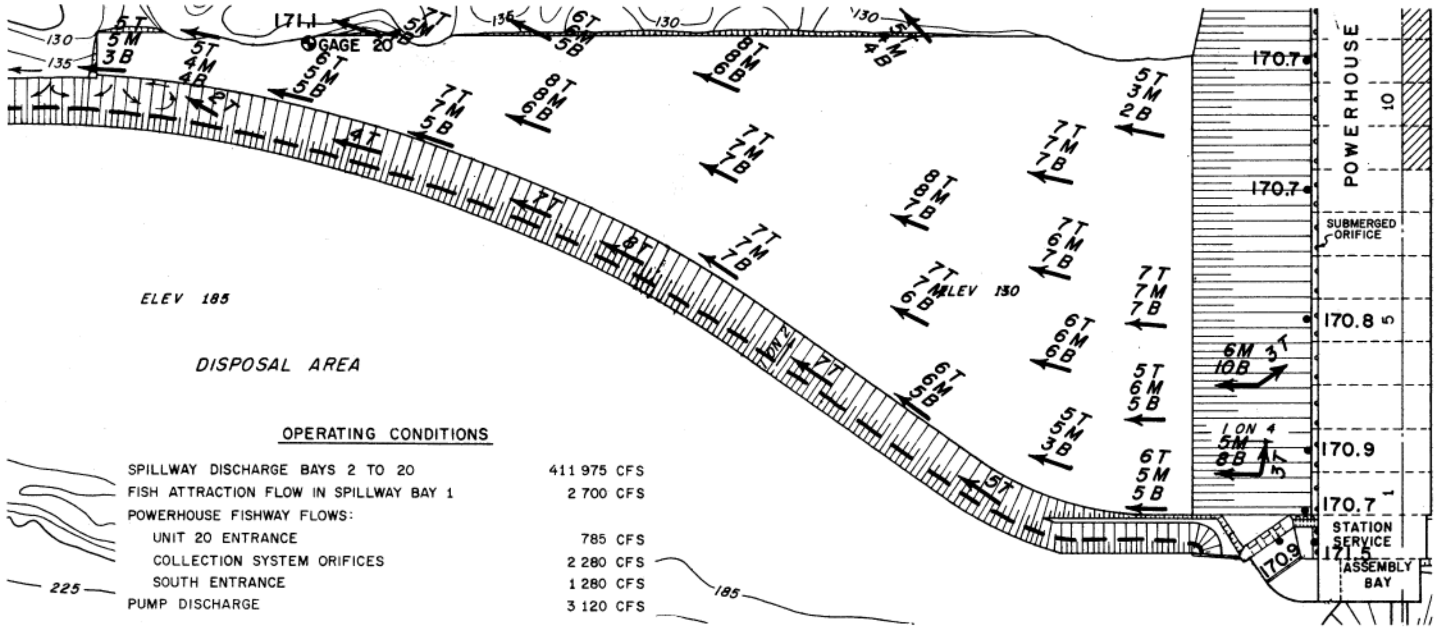
RIVER DISCHARGE 200 000 TO 600 000 CFS



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	33 575 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	455 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	2 790 CFS

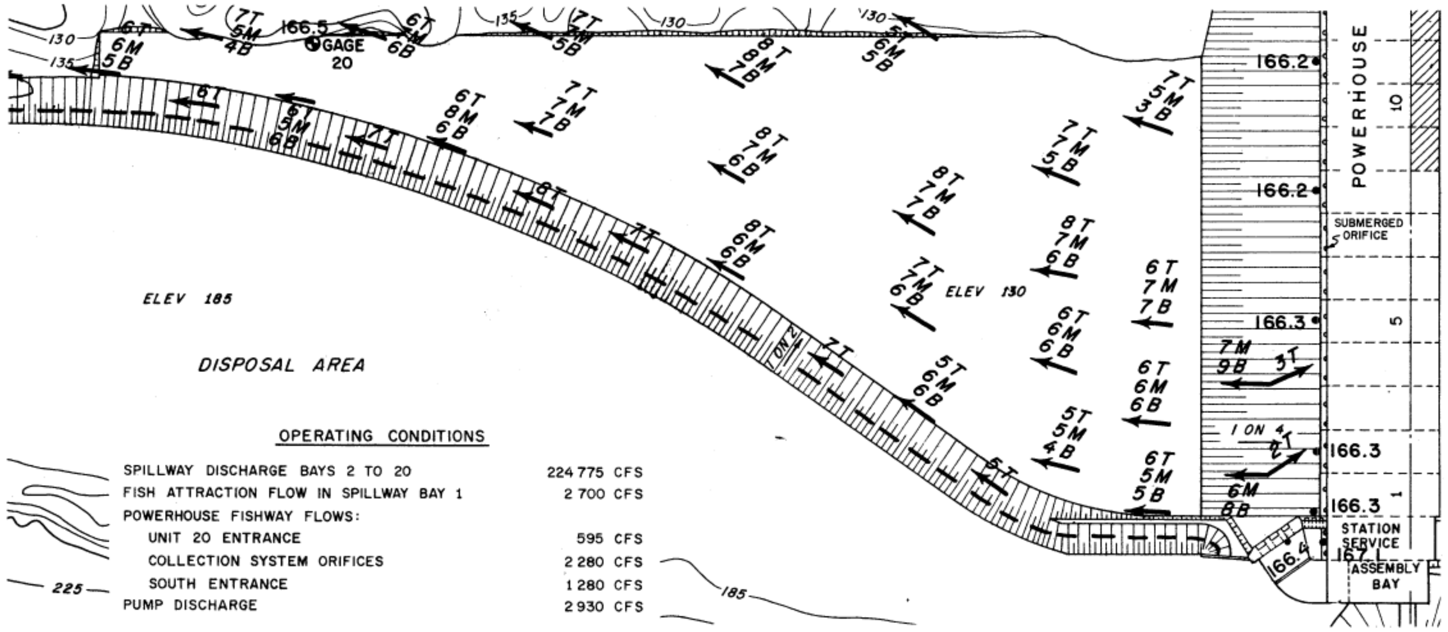
RIVER DISCHARGE 200 000 CFS; POWERHOUSE DISCHARGE 162 400 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	411 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

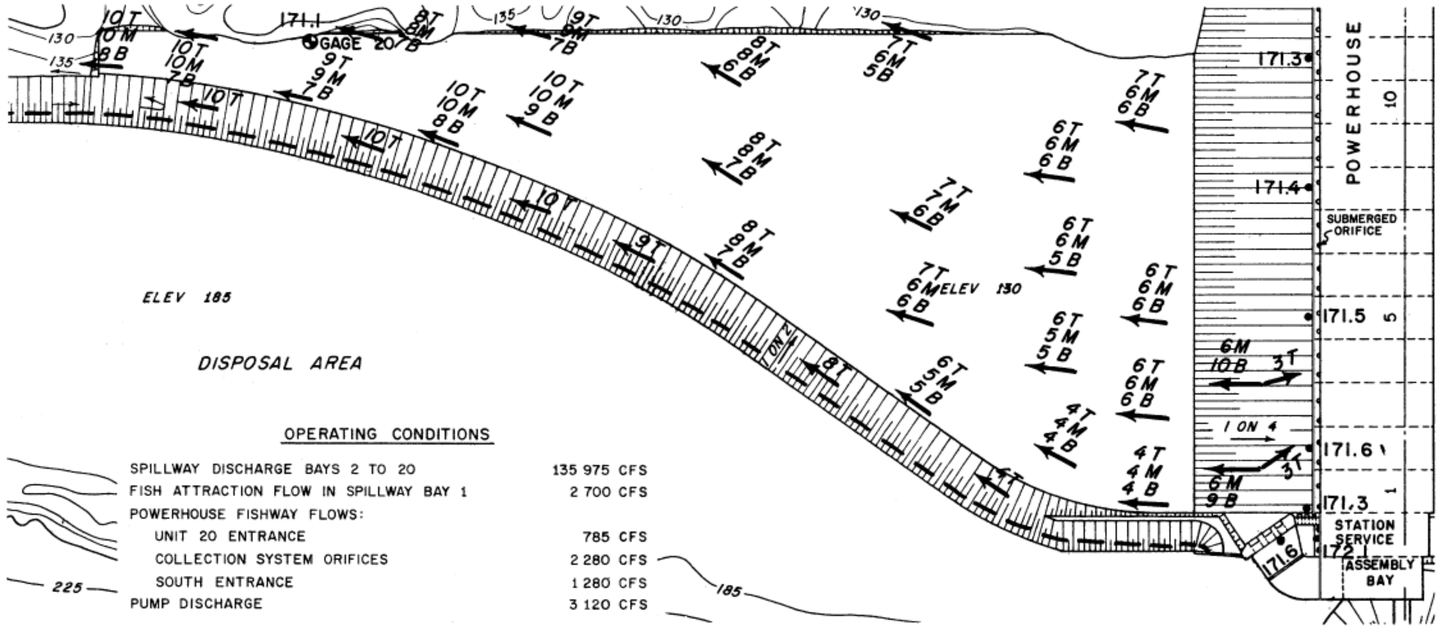
RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	224 775 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	595 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	2 930 CFS

RIVER DISCHARGE 400 000 CFS; POWERHOUSE DISCHARGE 171 200 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	135 975 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 120 CFS

RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20

SCALE

0 500 1000 FT

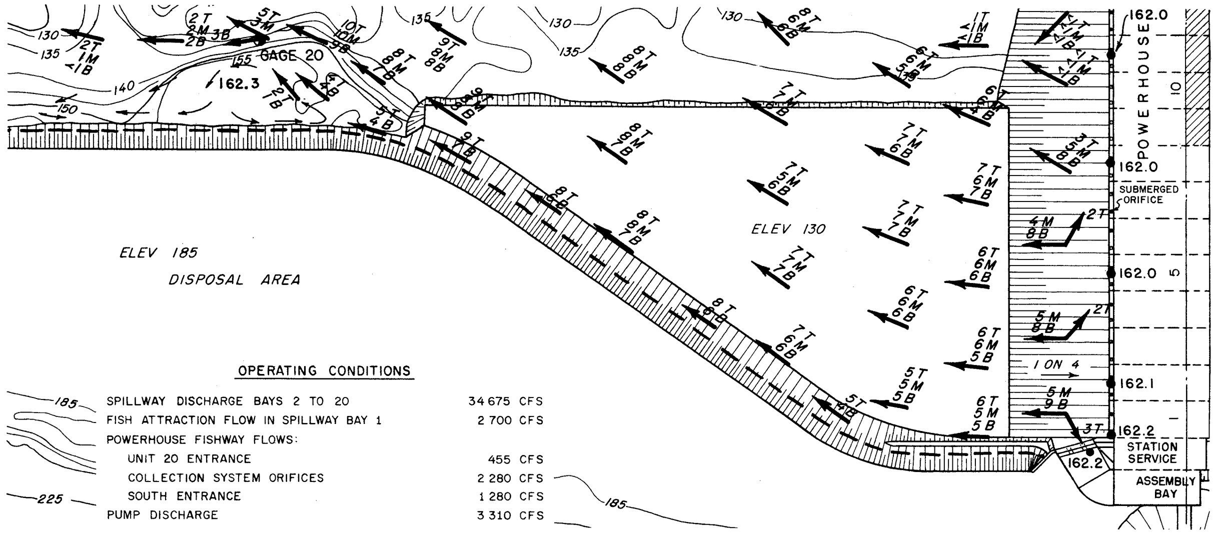
LEGEND

← 6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS
----	WATER'S EDGE

FLOW PATTERNS

PLAN F POWERHOUSE TAILRACE

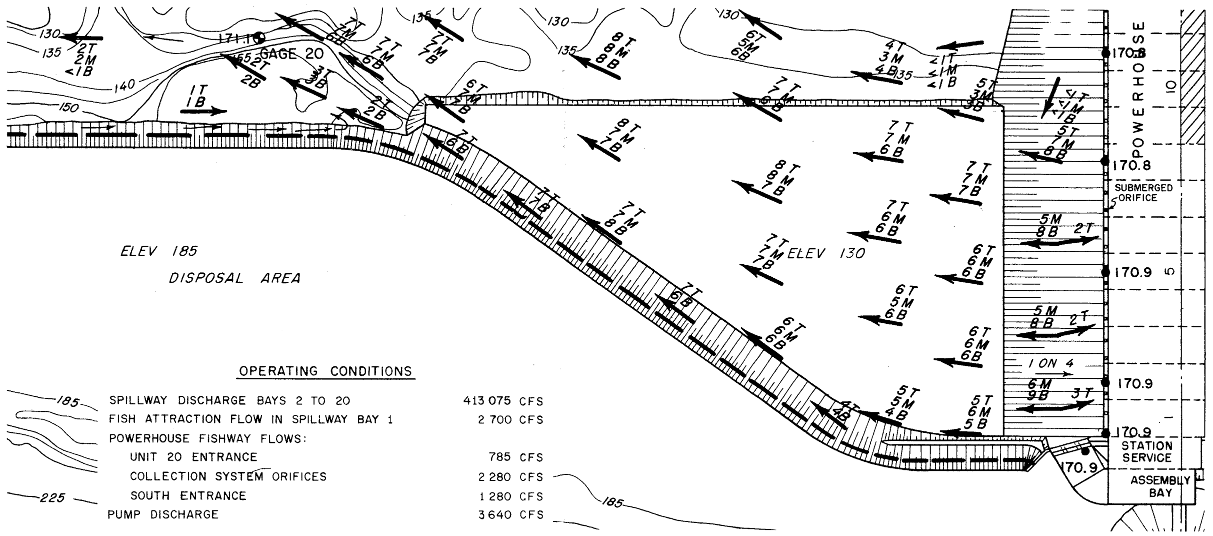
RIVER DISCHARGE 200 000 TO 600 000 CFS



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	34 675 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	455 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 310 CFS

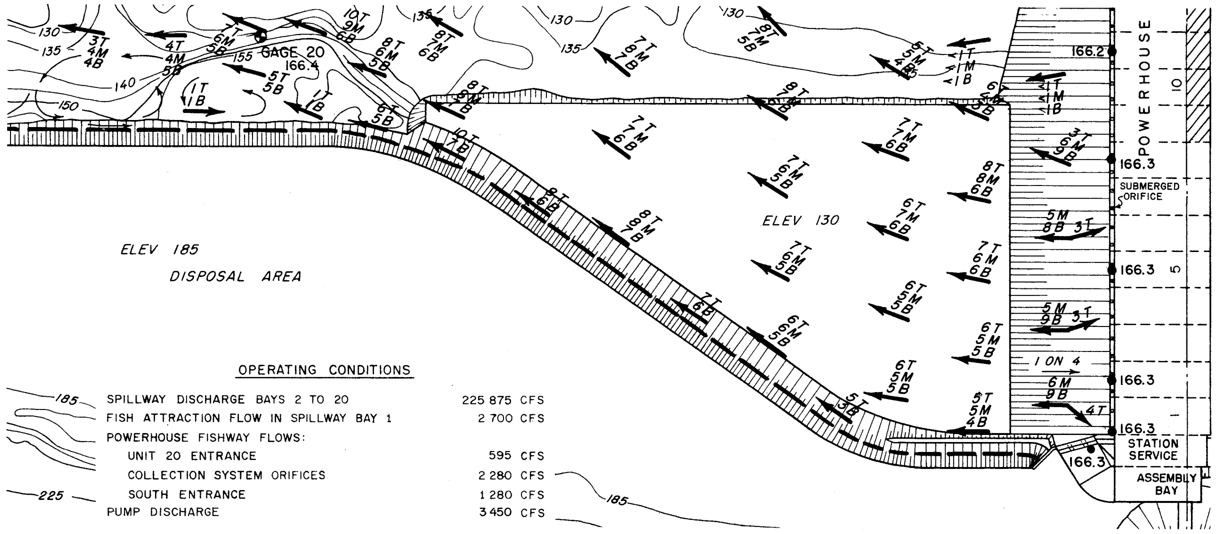
RIVER DISCHARGE 200 000 CFS; POWERHOUSE DISCHARGE 162 400 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	413 075 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 640 CFS

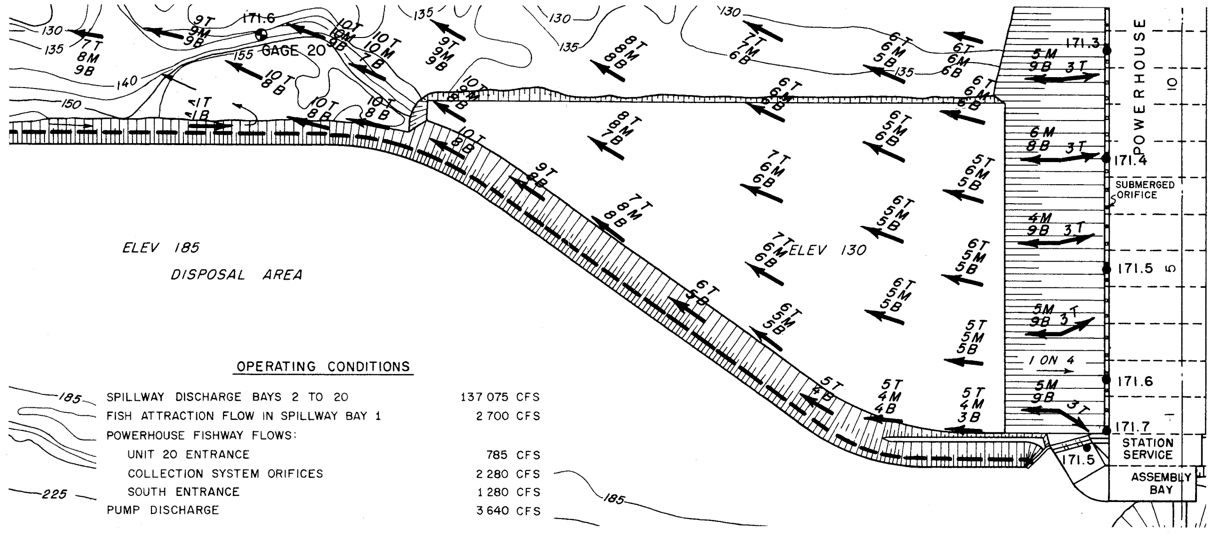
RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	225 875 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	595 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 450 CFS

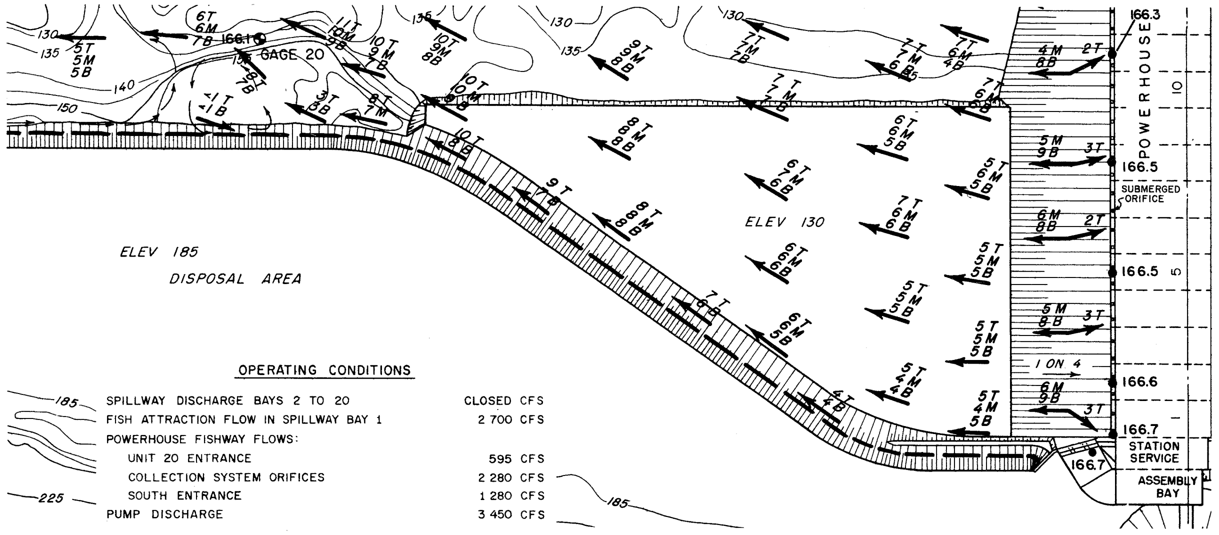
RIVER DISCHARGE 400 000 CFS; POWERHOUSE DISCHARGE 171 200 CFS, UNITS 1 TO 8



OPERATING CONDITIONS

SPILLWAY DISCHARGE BAYS 2 TO 20	137 075 CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	785 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 640 CFS

RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 460 000 CFS, UNITS 1 TO 20



OPERATING CONDITIONS

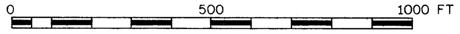
SPILLWAY DISCHARGE BAYS 2 TO 20	CLOSED CFS
FISH ATTRACTION FLOW IN SPILLWAY BAY 1	2 700 CFS
POWERHOUSE FISHWAY FLOWS:	
UNIT 20 ENTRANCE	595 CFS
COLLECTION SYSTEM ORIFICES	2 280 CFS
SOUTH ENTRANCE	1 280 CFS
PUMP DISCHARGE	3 450 CFS

RIVER DISCHARGE 400 000 CFS; POWERHOUSE DISCHARGE 399 780 CFS, UNITS 1 TO 19

LEGEND

← 6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.1 ●	WATER-SURFACE ELEVATIONS
– – – –	WATER'S EDGE

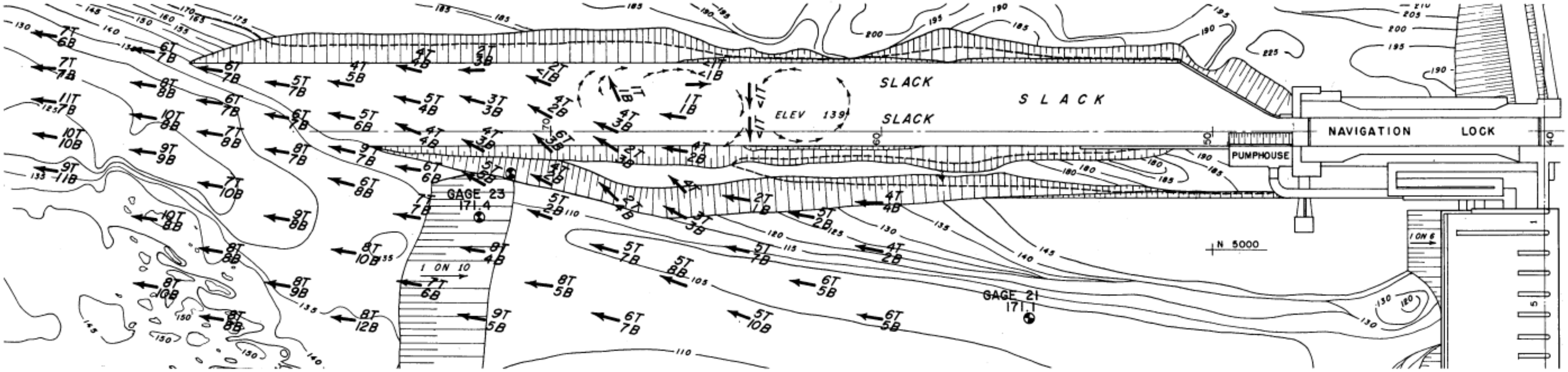
SCALE



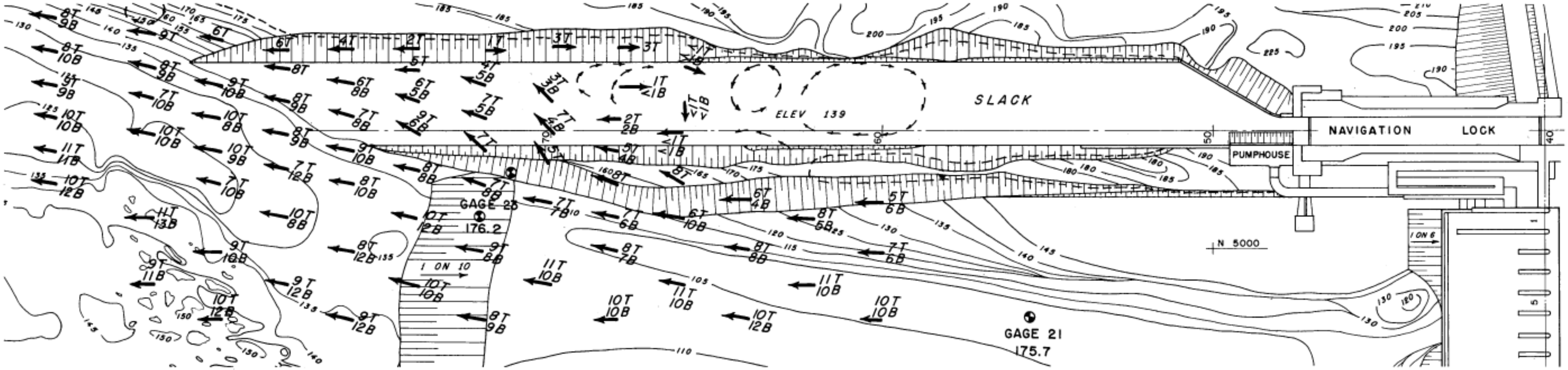
FLOW PATTERNS

PLAN G POWERHOUSE TAILRACE

RIVER DISCHARGE 200 000 TO 600 000 CFS



RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 200 000 CFS



RIVER DISCHARGE 800 000 CFS; POWERHOUSE DISCHARGE 200 000 CFS

LEGEND

← 6 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
171.1 ● WATER-SURFACE ELEVATIONS

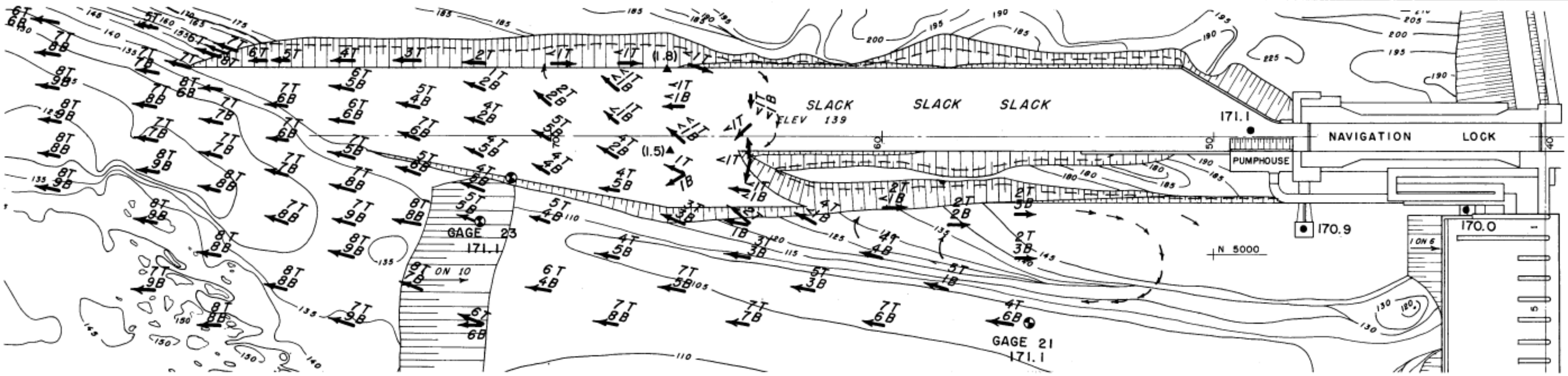
SCALE
0 100 200 300 400 500 FT

NOTE

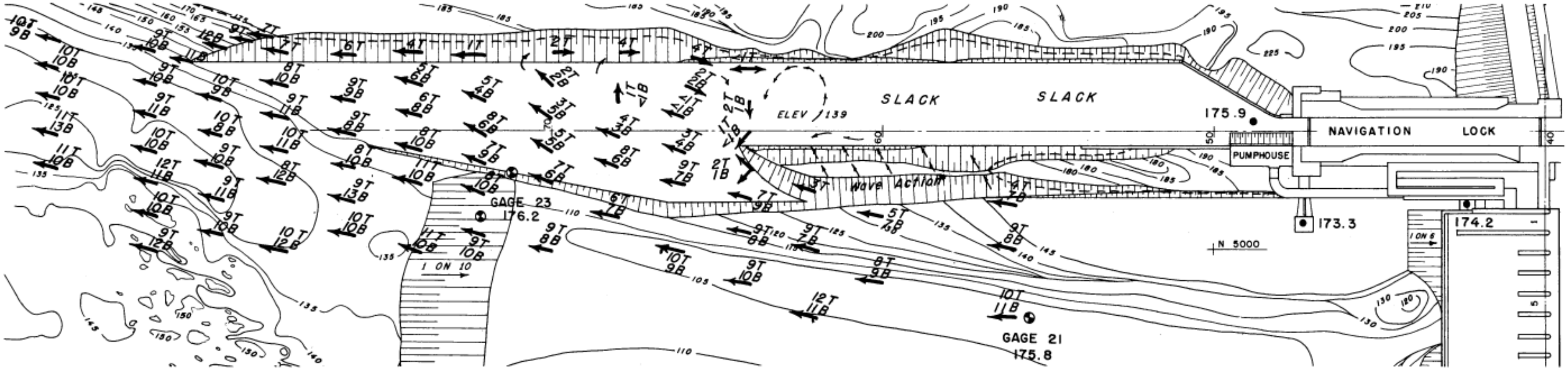
POWERHOUSE FLOW THROUGH UNITS 1 TO 10.

FLOW CONDITIONS

PLAN C DOWNSTREAM LOCK APPROACH



RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 200 000 CFS



RIVER DISCHARGE 800 000 CFS; POWERHOUSE DISCHARGE 200 000 CFS

LEGEND

←8	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
176.2 ●	WATER-SURFACE ELEVATIONS
(1.5)▲	MAXIMUM WAVE HEIGHTS IN FEET

SCALE

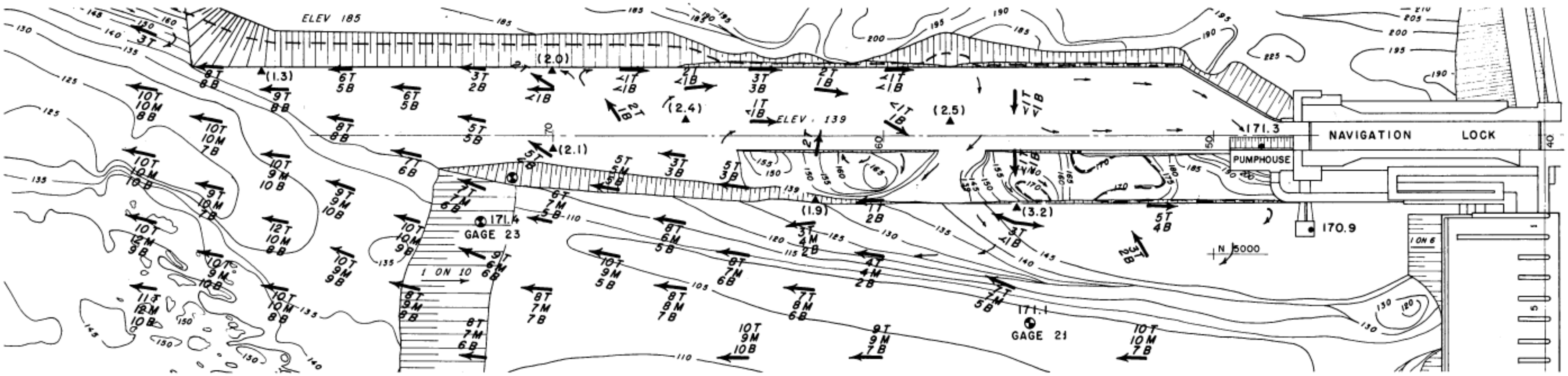
0 100 200 300 400 500 FT

NOTE

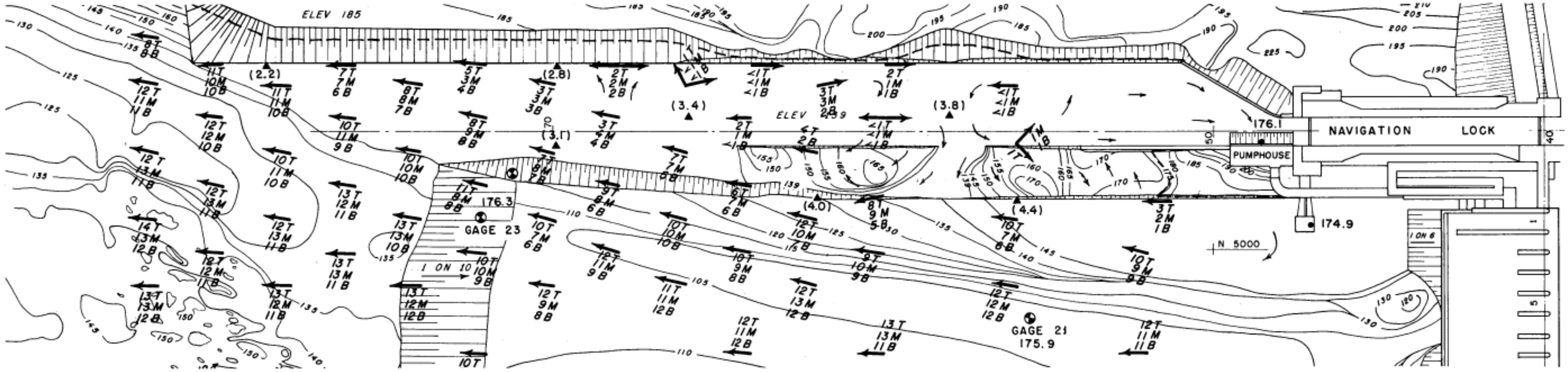
POWERHOUSE FLOW THROUGH UNITS 1 TO 10.

FLOW CONDITIONS

PLAN D DOWNSTREAM LOCK APPROACH



RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS



RIVER DISCHARGE 800 000 CFS; POWERHOUSE DISCHARGE 187 200 CFS

SCALE
0 100 200 300 400 500 FT

LEGEND

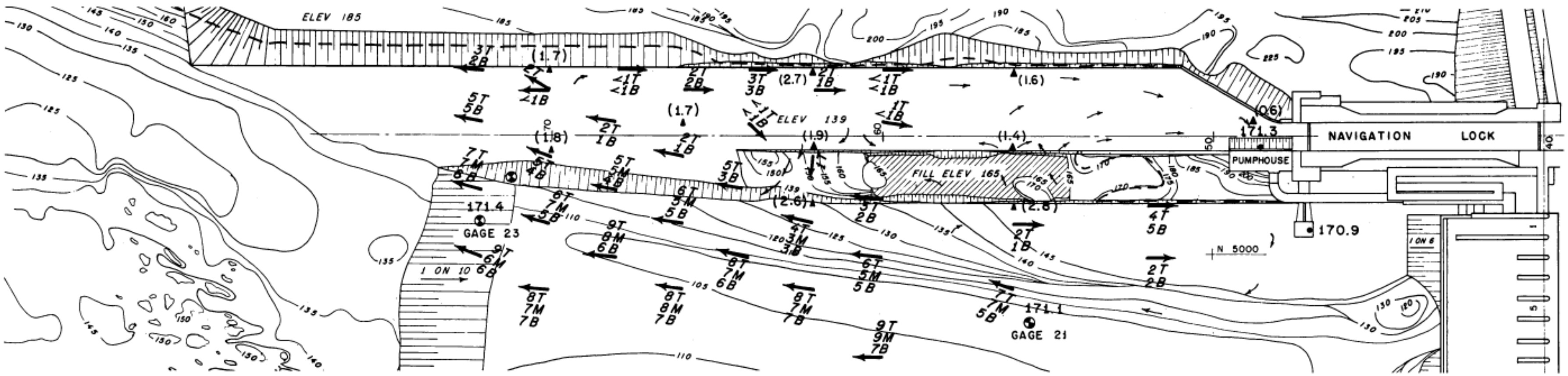
← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS
(3.4) ▲	MAXIMUM WAVE HEIGHTS IN FEET

NOTE

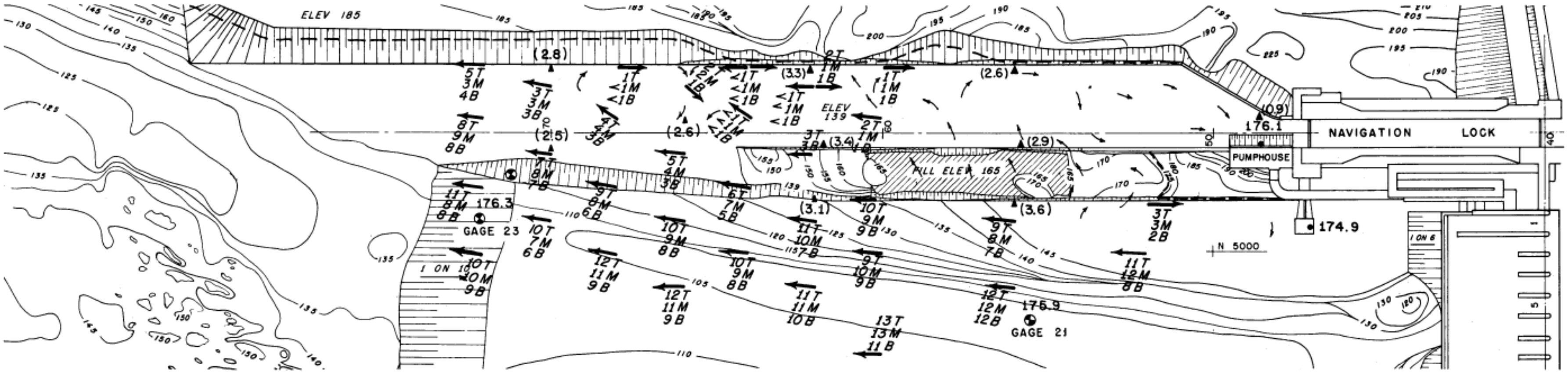
POWERHOUSE FLOW THROUGH UNITS 1 TO 8.

FLOW CONDITIONS

PLAN E DOWNSTREAM LOCK APPROACH



RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS



RIVER DISCHARGE 800 000 CFS; POWERHOUSE DISCHARGE 187 200 CFS

LEGEND

← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS
(2.6) ▲	MAXIMUM WAVE HEIGHTS IN FEET

SCALE

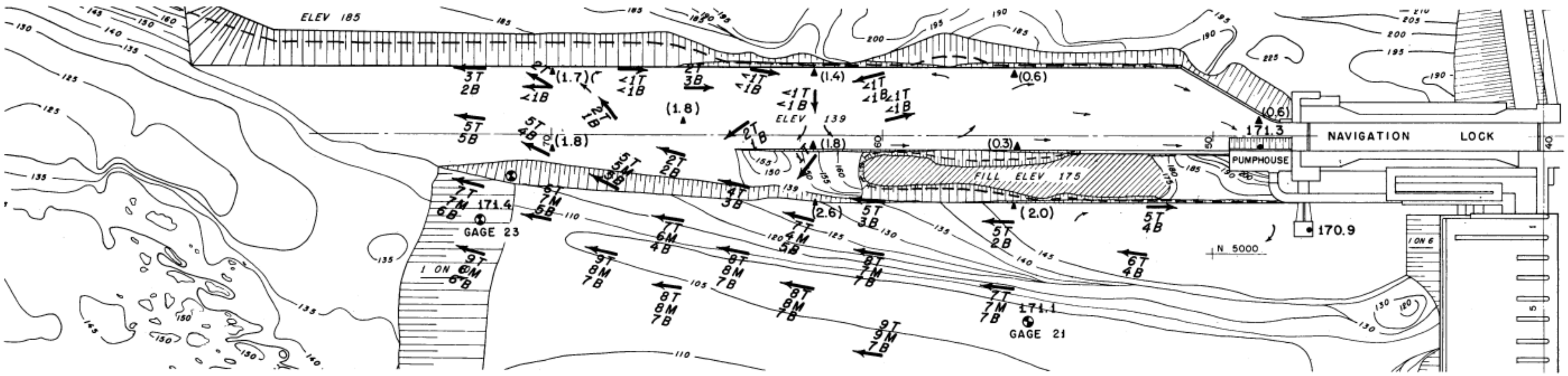
0 100 200 300 400 500 FT

NOTE

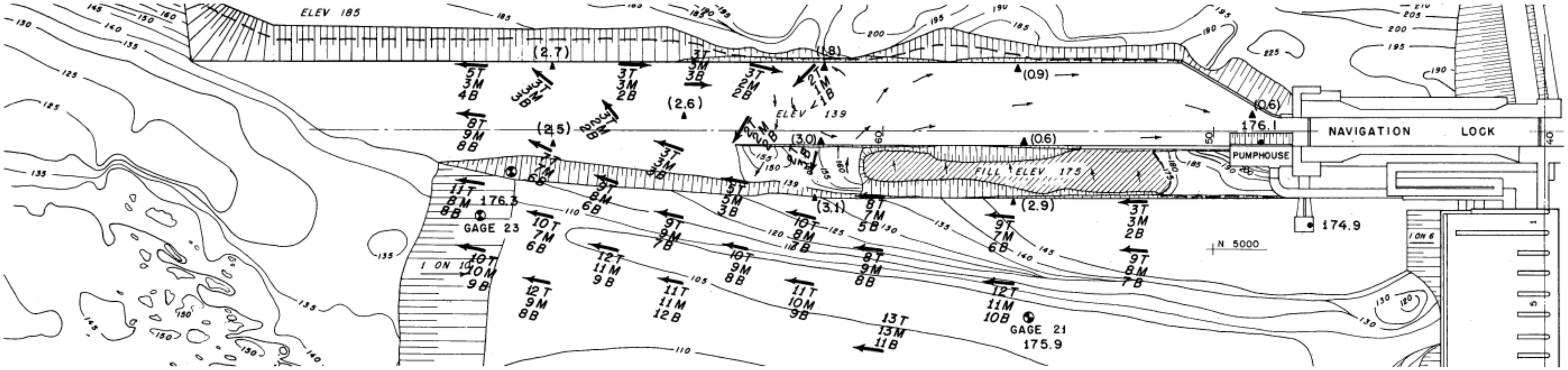
POWERHOUSE FLOW THROUGH UNITS 1 TO 8.

FLOW CONDITIONS

PLAN F DOWNSTREAM LOCK APPROACH



RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS



RIVER DISCHARGE 800 000 CFS; POWERHOUSE DISCHARGE 187 200 CFS

LEGEND

← 7	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS
(1.8) ▲	MAXIMUM WAVE HEIGHTS IN FEET

SCALE

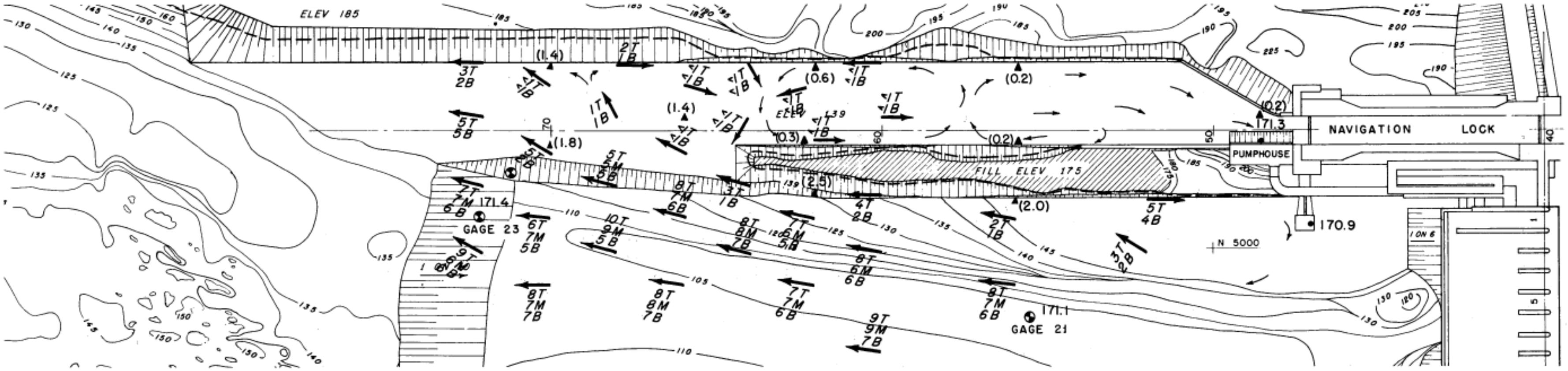
0 100 200 300 400 500 FT

NOTE

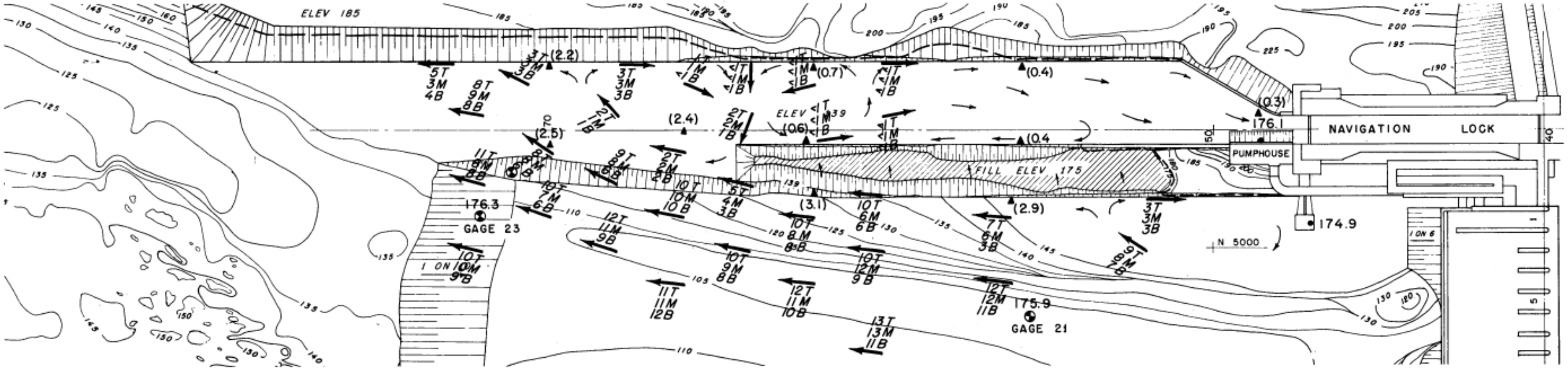
POWERHOUSE FLOW THROUGH UNITS 1 TO 8.

FLOW CONDITIONS

PLAN G DOWNSTREAM LOCK APPROACH



RIVER DISCHARGE 600 000 CFS; POWERHOUSE DISCHARGE 184 000 CFS



RIVER DISCHARGE 800 000 CFS; POWERHOUSE DISCHARGE 187 200 CFS

LEGEND

← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
176.1 ●	WATER-SURFACE ELEVATIONS
(2.4) ▲	MAXIMUM WAVE HEIGHTS IN FEET

SCALE

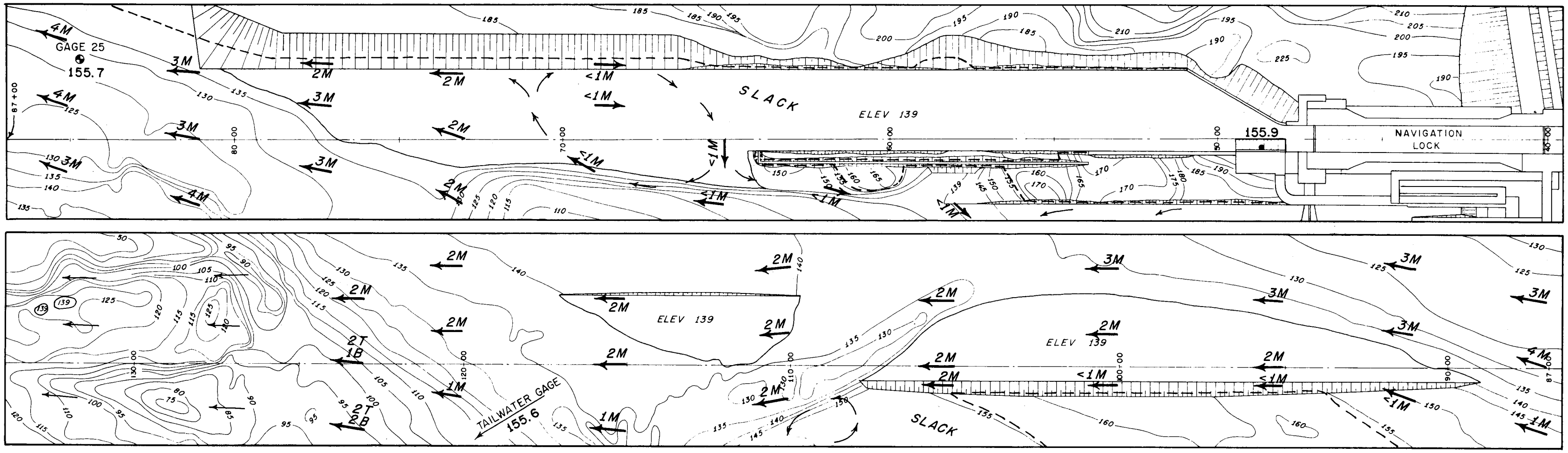
0 100 200 300 400 500 FT

NOTE

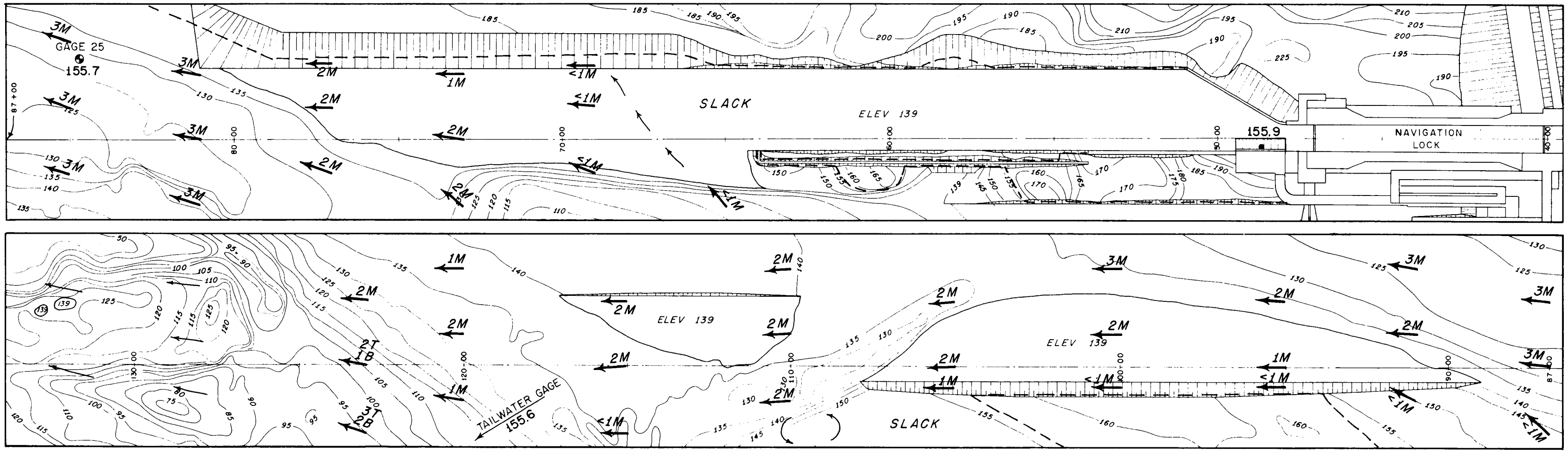
POWERHOUSE FLOW THROUGH UNITS 1 TO 8.

FLOW CONDITIONS

PLAN H DOWNSTREAM LOCK APPROACH



SPILLWAY DISCHARGE 100 000 CFS; POWERHOUSE CLOSED

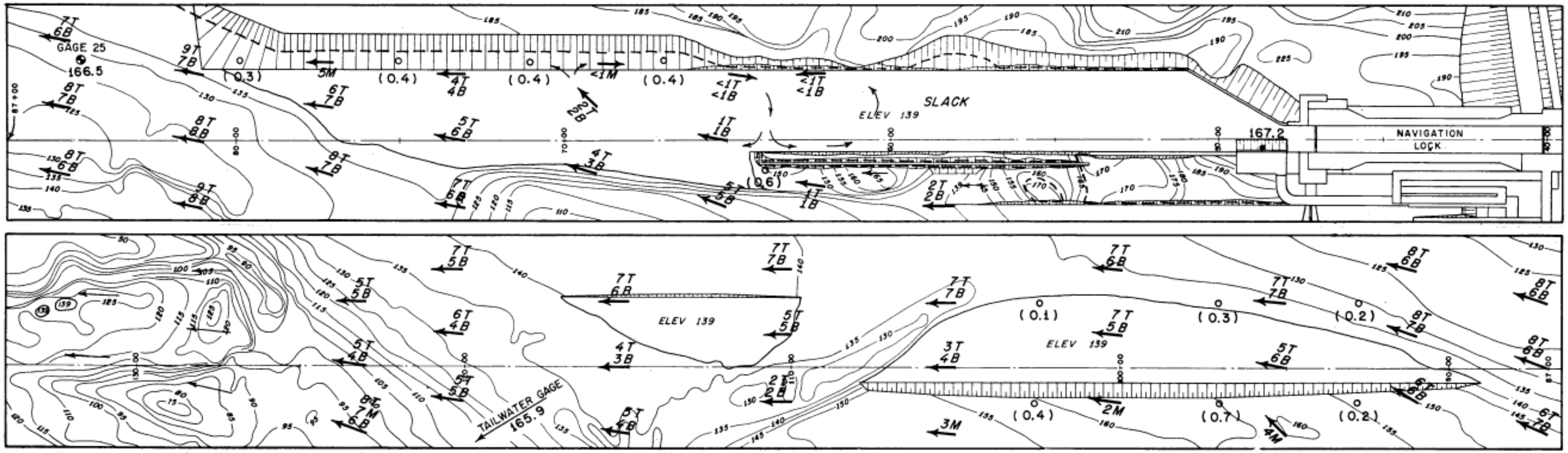


SPILLWAY CLOSED; POWERHOUSE DISCHARGE 100 000 CFS (UNITS 1 TO 10)

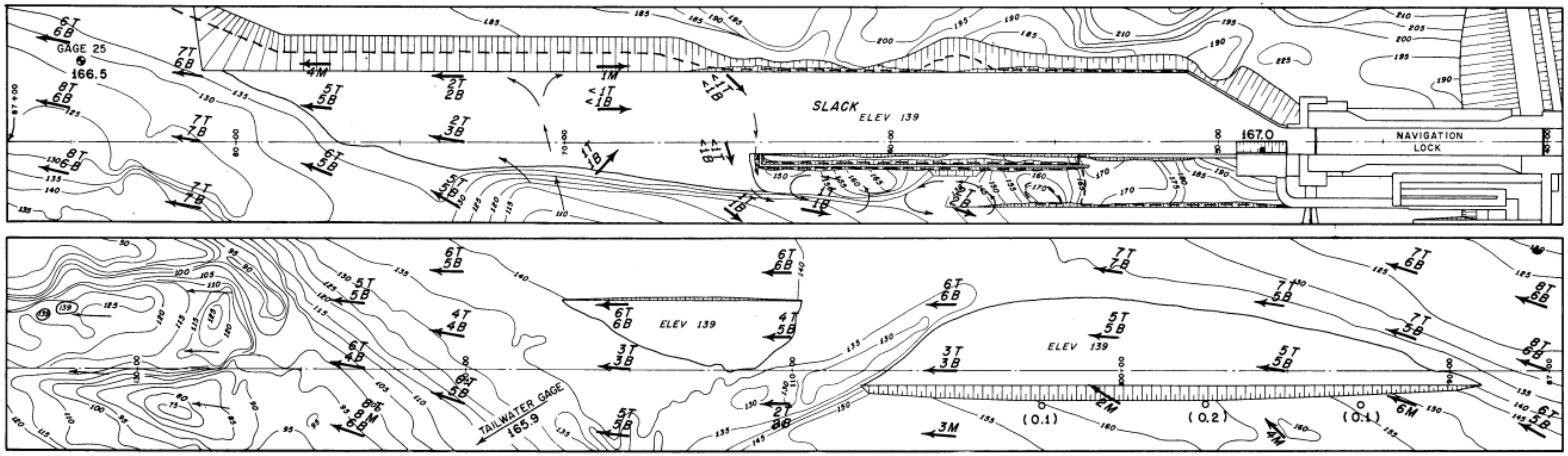
LEGEND

←3	VELOCITY MEASUREMENTS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
155.9 ●	WATER-SURFACE ELEVATION

FLOW CONDITIONS
EXTENDED NAVIGATION CHANNEL
RIVER DISCHARGE 100 000 CFS



SPILLWAY DISCHARGE 210 000 CFS; POWERHOUSE DISCHARGE 210 000 CFS (UNITS 1 TO 10)



SPILLWAY CLOSED; POWERHOUSE DISCHARGE 420 000 CFS (UNITS 1 TO 20)

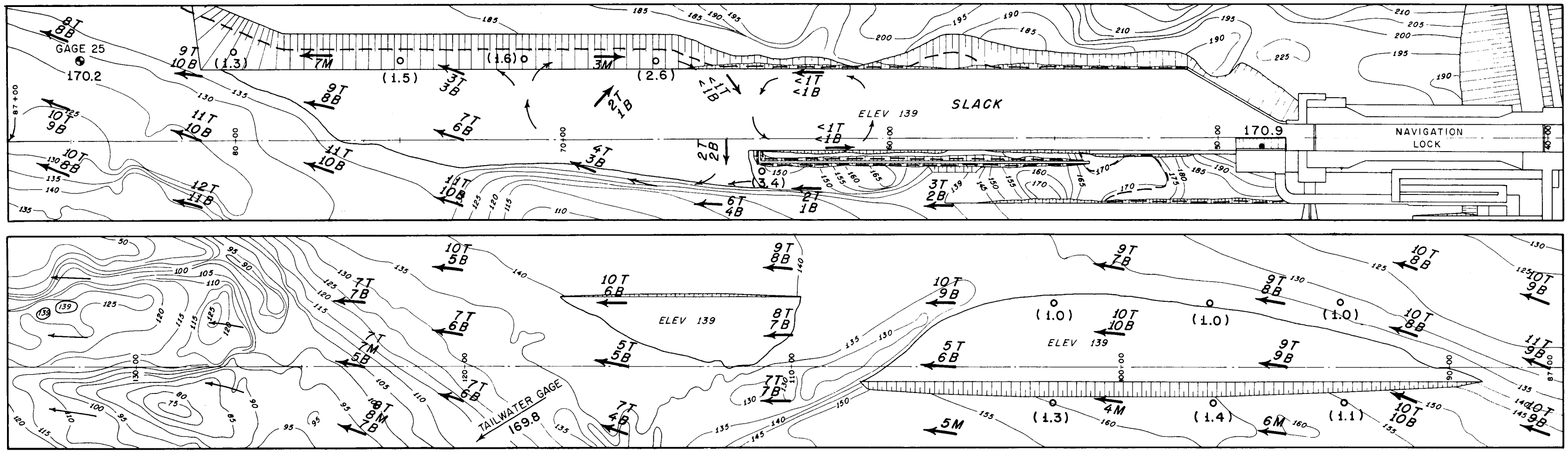
LEGEND

←6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
167.0 ●	WATER-SURFACE ELEVATION
(0.2) ○	WAVE HEIGHT IN FEET

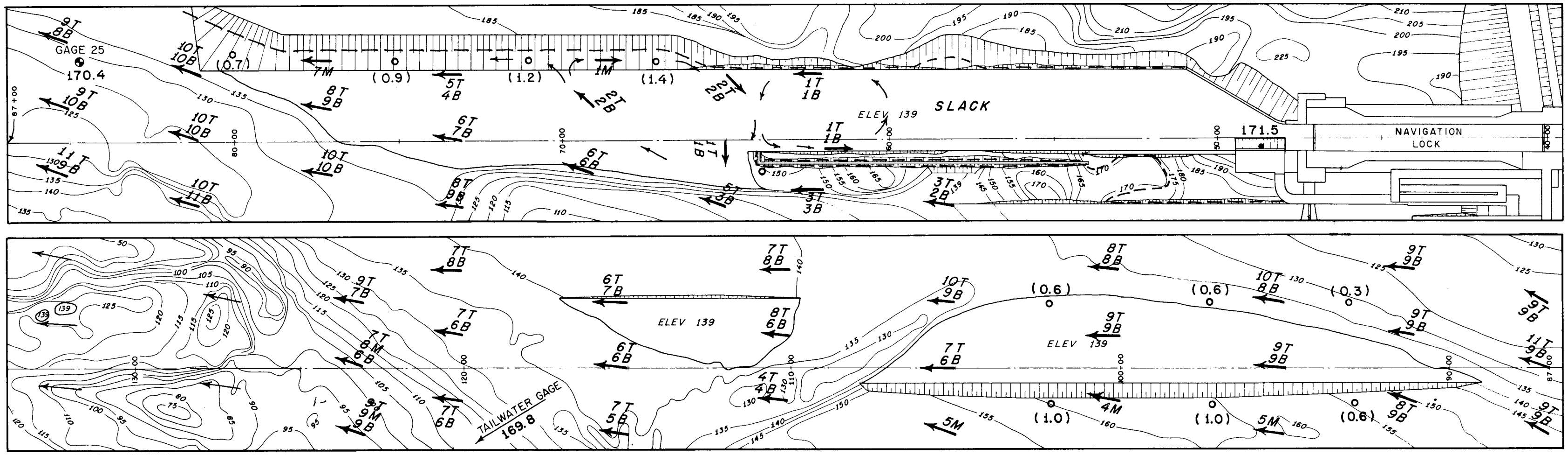
FLOW CONDITIONS

EXTENDED NAVIGATION CHANNEL

RIVER DISCHARGE 420 000 CFS



SPILLWAY DISCHARGE 600 000 CFS; POWERHOUSE CLOSED



SPILLWAY DISCHARGE 366 000 CFS; POWERHOUSE DISCHARGE 234 000 CFS (UNITS 1 TO 10)

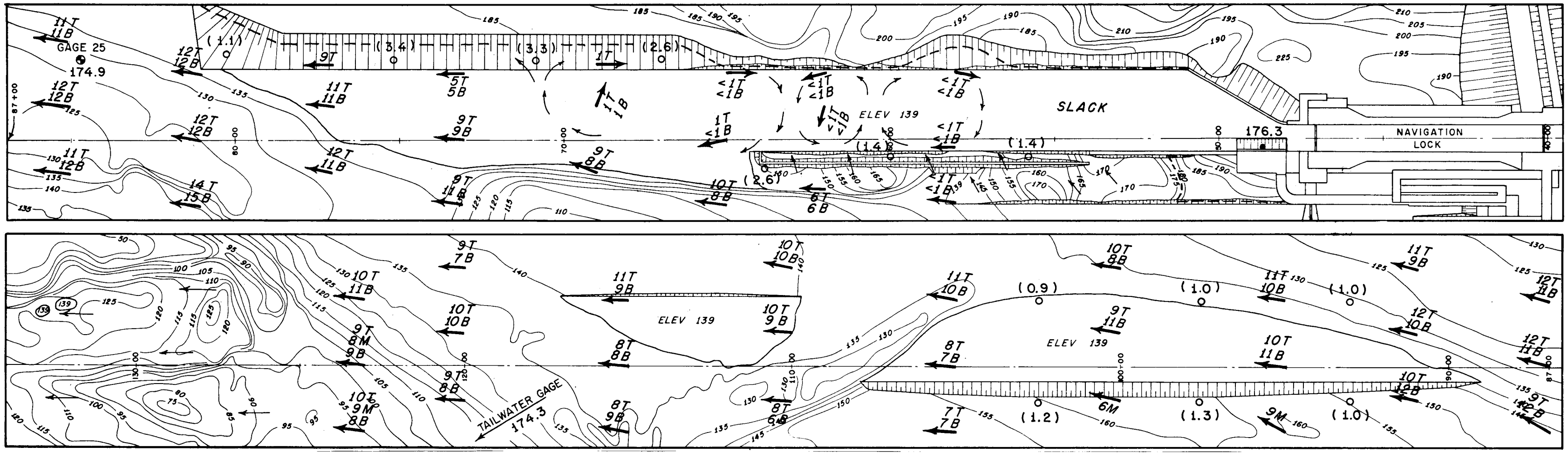
LEGEND

← 3	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.9 ●	WATER-SURFACE ELEVATION
(1.3) ○	WAVE HEIGHT IN FEET

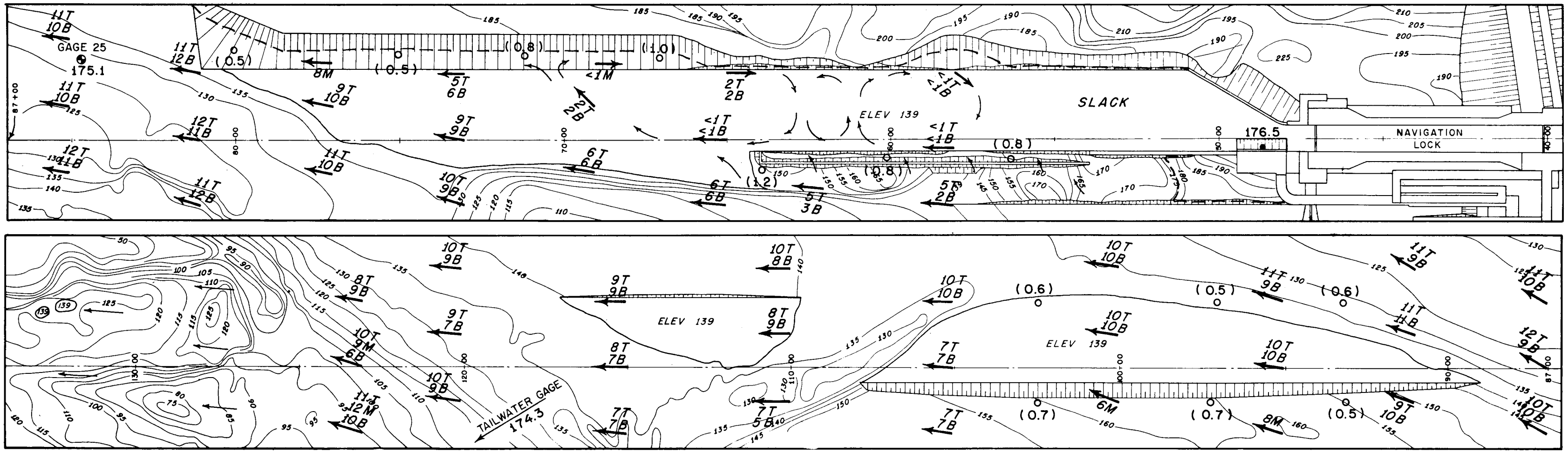
FLOW CONDITIONS

EXTENDED NAVIGATION CHANNEL

RIVER DISCHARGE 600 000 CFS



SPILLWAY DISCHARGE 566 000 CFS; POWERHOUSE DISCHARGE 234 000 CFS (UNITS 1 TO 10)

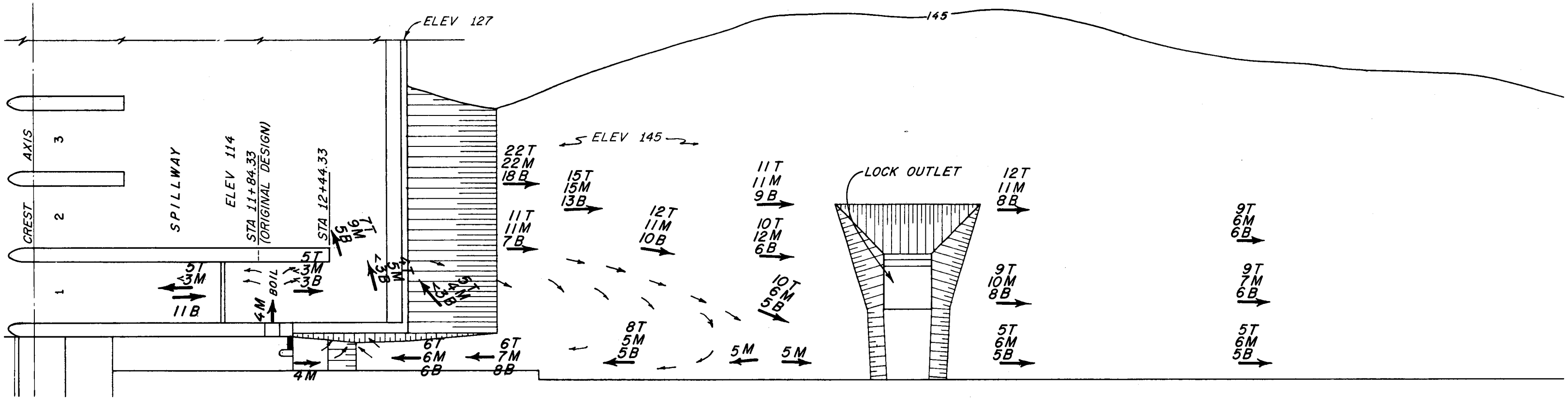


SPILLWAY DISCHARGE 332 000 CFS; POWERHOUSE DISCHARGE 468 000 CFS (UNITS 1 TO 20)

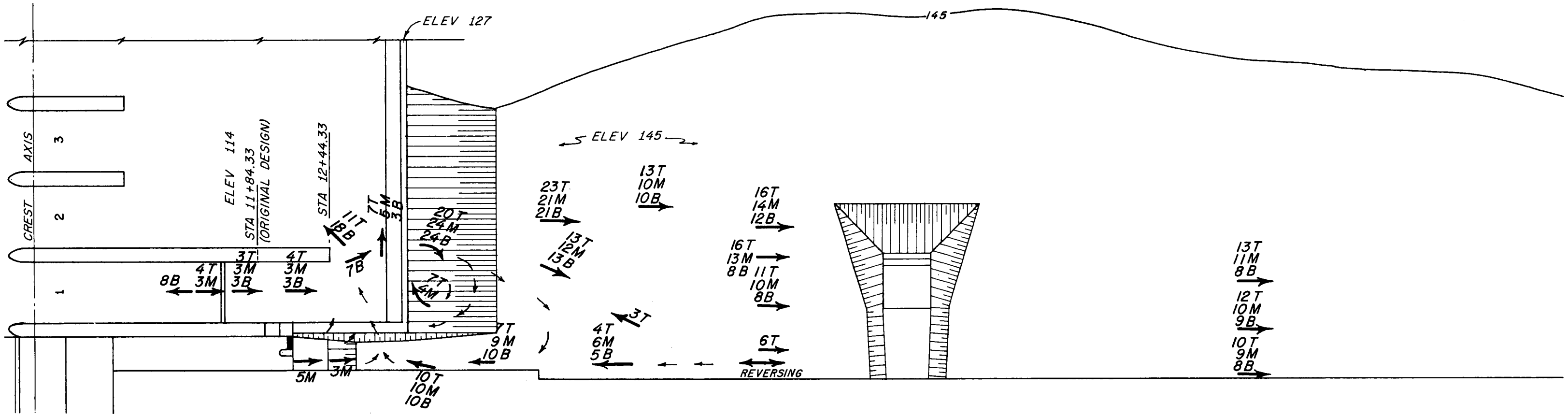
LEGEND

← 5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
176.3 ● WATER-SURFACE ELEVATION
(1.2) ○ WAVE HEIGHT IN FEET

FLOW CONDITIONS
EXTENDED NAVIGATION CHANNEL
RIVER DISCHARGE 800 000 CFS



RIVER DISCHARGE 600 000 CFS
POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 2 TO 19 392 300 CFS
FISH ATTRACTION FLOW SPILLWAY BAYS 1 AND 20 5400 CFS — FISH LADDER ENTRANCE FLOW 1600 CFS

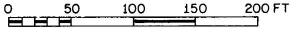


RIVER DISCHARGE 700 000 CFS
POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 2 TO 19 491 825 CFS
FISH ATTRACTION FLOW SPILLWAY BAYS 1 AND 20 5400 CFS — FISH LADDER ENTRANCE FLOW 1900 CFS

LEGEND

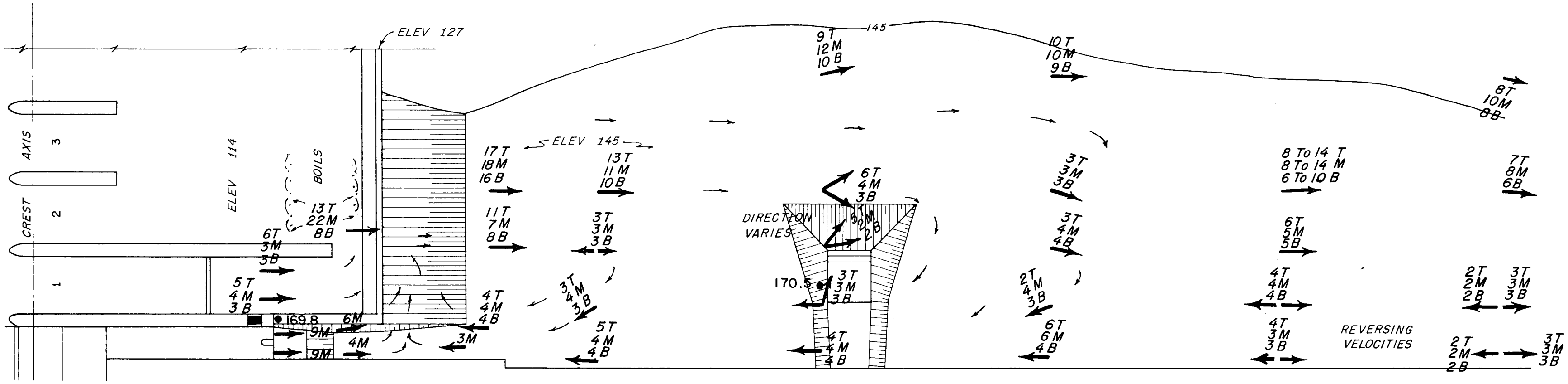
←3	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM

SCALE

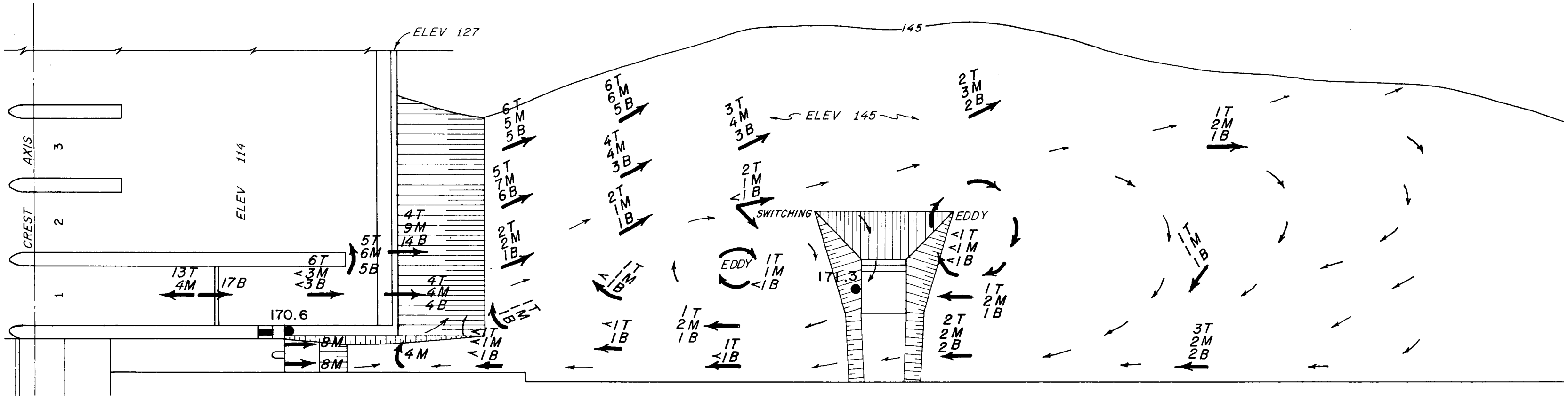


FLOW CONDITIONS

PLAN A NORTH FISH LADDER ENTRANCE
PIER 1 EXTENDED 60 FT
RIVER DISCHARGES 600 000 AND 700 000 CFS



POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS
SPILLWAY DISCHARGE BAYS 2 TO 20 395 000 CFS — FISH ATTRACTION FLOW SPILLWAY BAY 1 2 700 CFS
FISH LADDER ENTRANCE FLOW 1600 CFS



POWERHOUSE DISCHARGE UNITS 1 TO 20 400 000 CFS
SPILLWAY DISCHARGE BAYS 2 TO 20 195 000 CFS — FISH ATTRACTION FLOW SPILLWAY BAY 1 2700 CFS
FISH LADDER ENTRANCE FLOW 1600 CFS

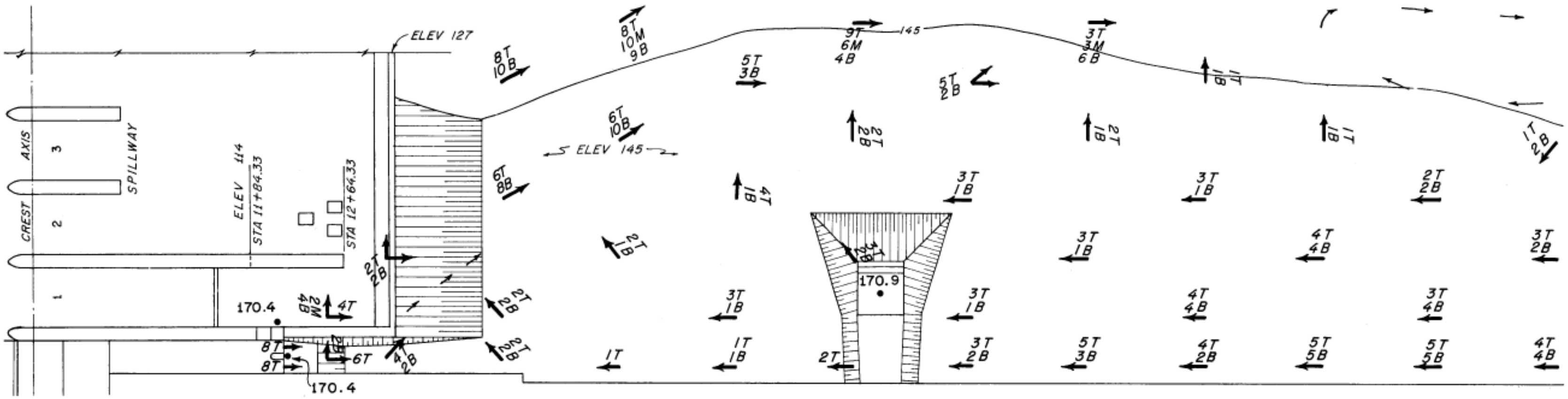
LEGEND

←3 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
170.6● WATER-SURFACE ELEVATIONS

SCALE
0 50 100 150 200 FT

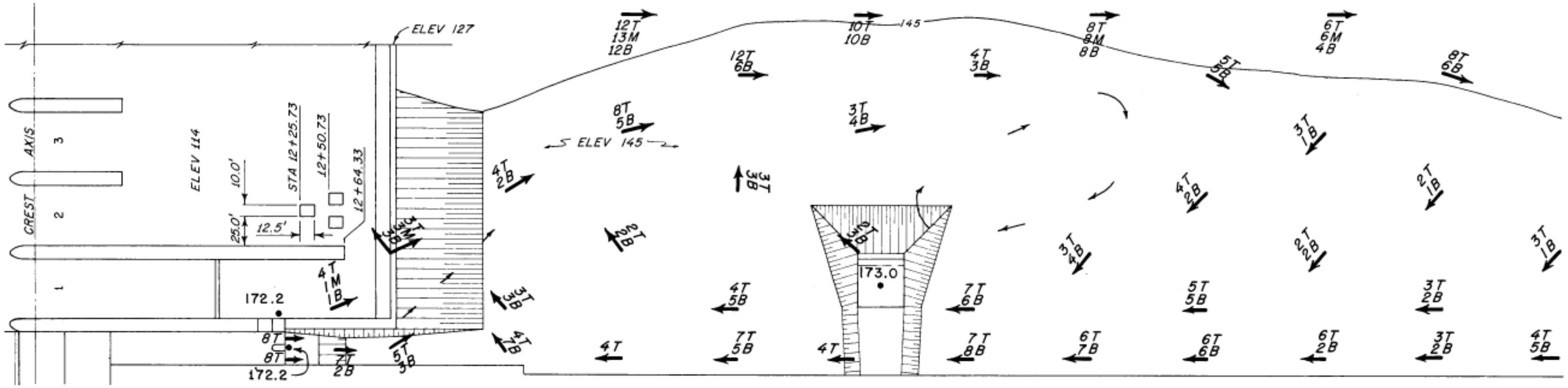
FLOW CONDITIONS

PLAN A NORTH FISH LADDER ENTRANCE
PIER 1 EXTENDED 80 FT
RIVER DISCHARGE 600 000 CFS



RIVER DISCHARGE 600 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS— SPILLWAY DISCHARGE BAYS 3 TO 20 374 870 CFS
SPILLWAY DISCHARGE BAY 2 20 830 CFS
FISH ATTRACTION FLOW BAY 1 2700 CFS— NORTH FISH LADDER ENTRANCE 1600 CFS



RIVER DISCHARGE 700 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS— SPILLWAY DISCHARGE BAYS 3 TO 20 474 400 CFS
SPILLWAY DISCHARGE BAY 2 21 000 CFS
FISH ATTRACTION FLOW BAY 1 2700 CFS—NORTH FISH LADDER ENTRANCE 1900 CFS

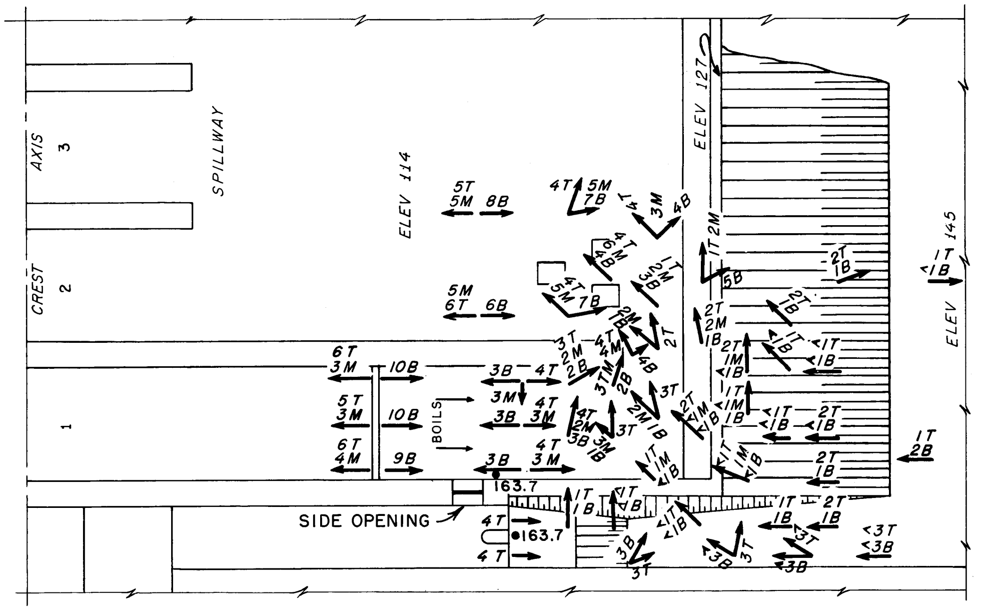
LEGEND

←3	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
172.2 ●	WATER-SURFACE ELEVATIONS

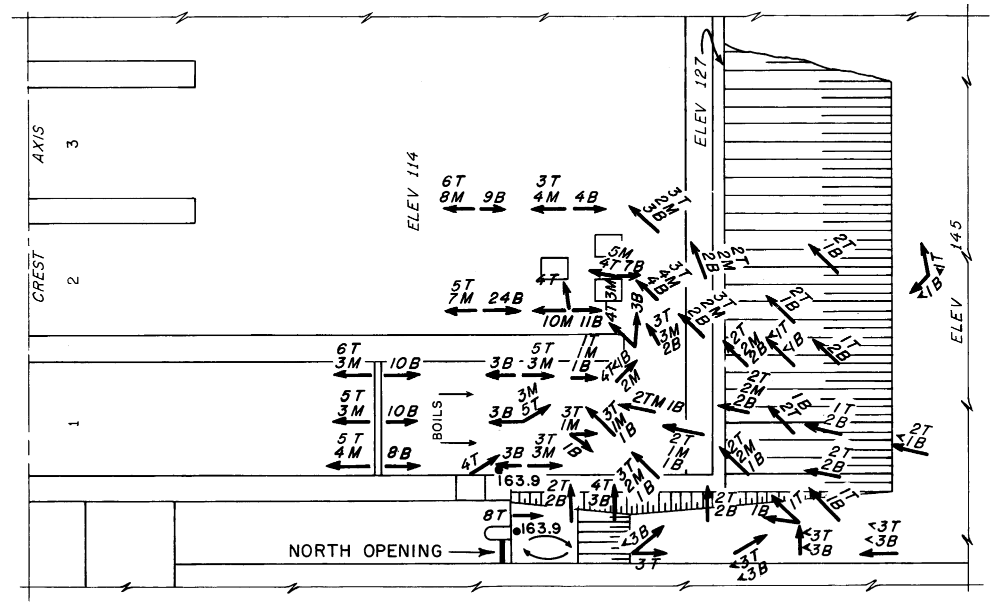
SCALE
0 50 100 150 200 FT

FLOW CONDITIONS

PLAN A NORTH FISH LADDER ENTRANCE
PIER 1 EXTENDED 80 FT — PLAN S BAFFLES IN BAY 2
RIVER DISCHARGES 600 000 AND 700 000 CFS



SIDE OPENING CLOSED



NORTH OPENING CLOSED

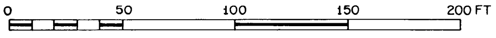
OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	200 000 CFS
SPILLWAY DISCHARGE BAYS 3 TO 20	90 950 CFS
SPILLWAY DISCHARGE BAY 2	5 050 CFS
FISH ATTRACTION FLOW BAY 1	2 700 CFS
NORTH FISH LADDER ENTRANCE	1 300 CFS

NOTES

1. PIER 1 EXTENDED 80 FT.
2. PLAN S BAFFLES IN BAY 2.

SCALE



LEGEND

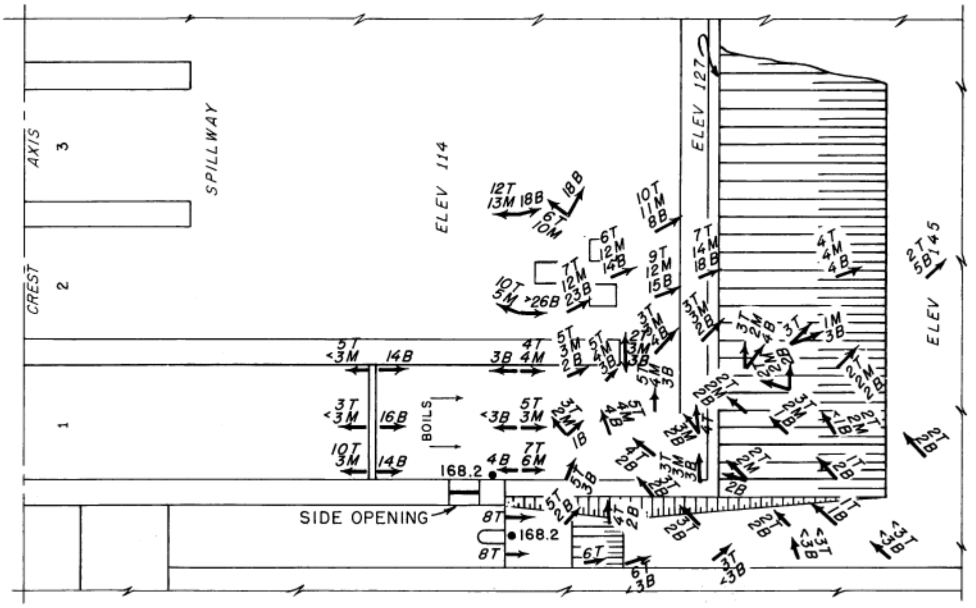
←3	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
163.9 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

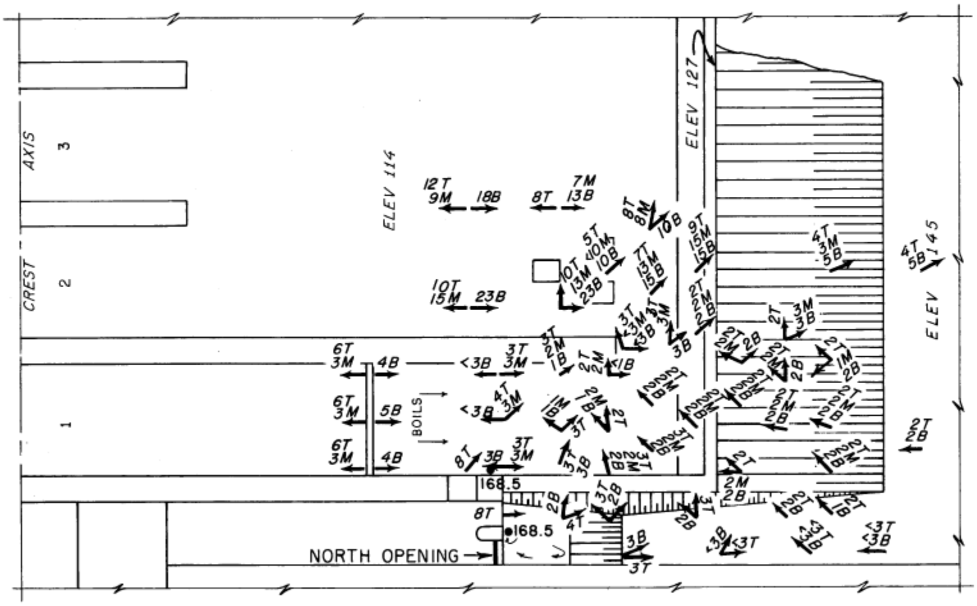
PLAN A NORTH FISH LADDER ENTRANCE

SIDE OR NORTH OPENINGS CLOSED

RIVER DISCHARGE 300 000 CFS



SIDE OPENING CLOSED



NORTH OPENING CLOSED

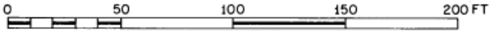
OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	200 000 CFS
SPILLWAY DISCHARGE BAYS 3 TO 20	280 140 CFS
SPILLWAY DISCHARGE BAY 2	15 560 CFS
FISH ATTRACTION FLOW BAY 1	2 700 CFS
NORTH FISH LADDER ENTRANCE	1 600 CFS

NOTES

1. PIER 1 EXTENDED 80 FT.
2. PLAN S BAFFLES IN BAY 2.

SCALE



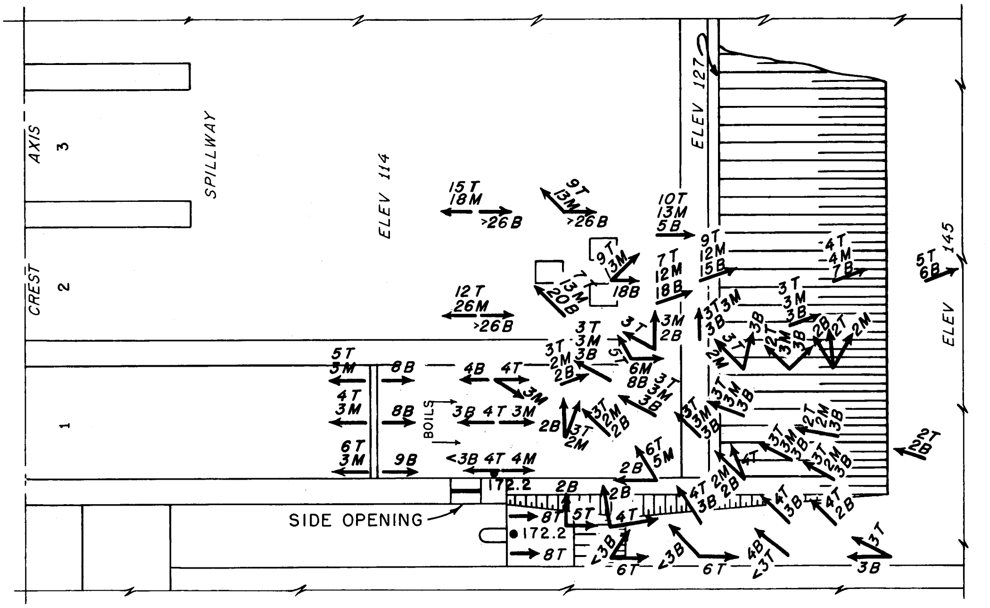
LEGEND

←3 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
168.5 ● WATER-SURFACE ELEVATIONS

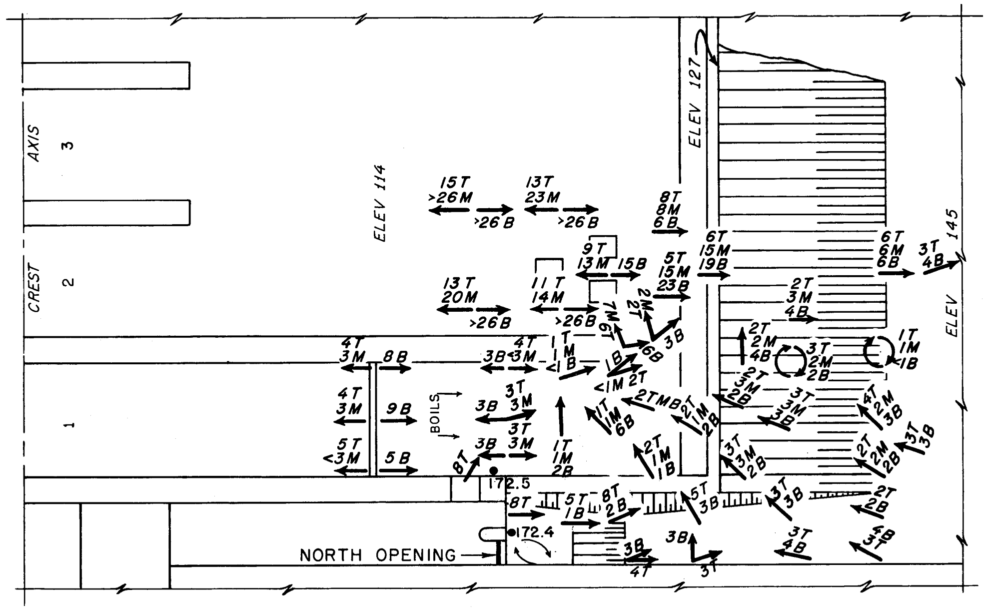
FLOW CONDITIONS

PLAN A NORTH FISH LADDER ENTRANCE

SIDE OR NORTH OPENINGS CLOSED
RIVER DISCHARGE 500 000 CFS



SIDE OPENING CLOSED



NORTH OPENING CLOSED

OPERATING CONDITIONS

POWERHOUSE DISCHARGE UNITS 1 TO 10	200 000 CFS
SPILLWAY DISCHARGE BAYS 3 TO 20	474 400 CFS
SPILLWAY DISCHARGE BAY 2	21 000 CFS
FISH ATTRACTION FLOW BAY 1	2 700 CFS
NORTH FISH LADDER ENTRANCE	1 900 CFS

NOTES

1. PIER 1 EXTENDED 80 FT.
2. PLAN S BAFFLES IN BAY 2.

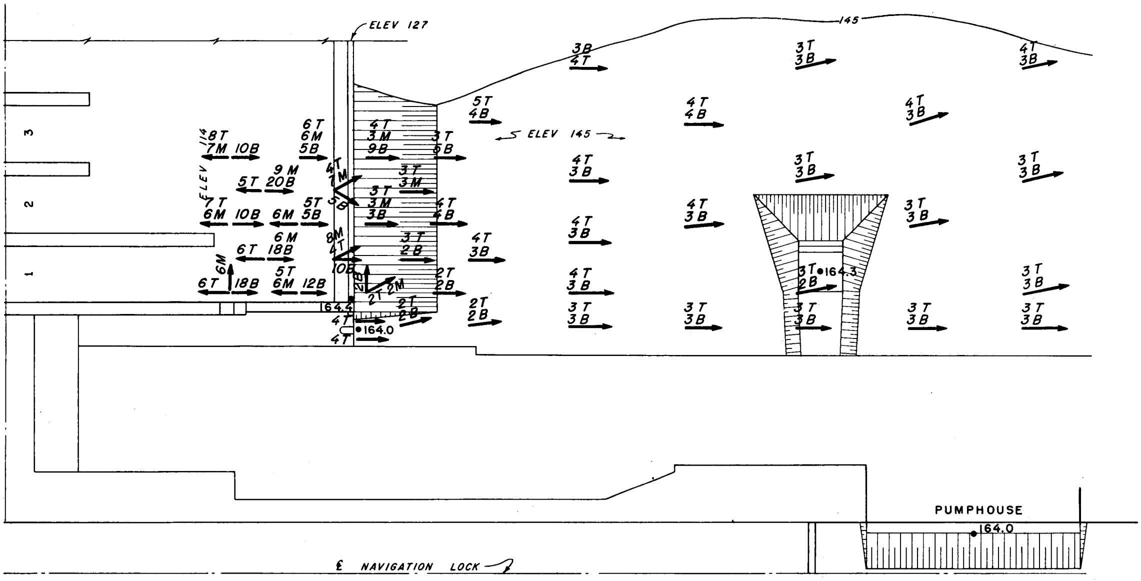
SCALE

0 50 100 150 200 FT

LEGEND

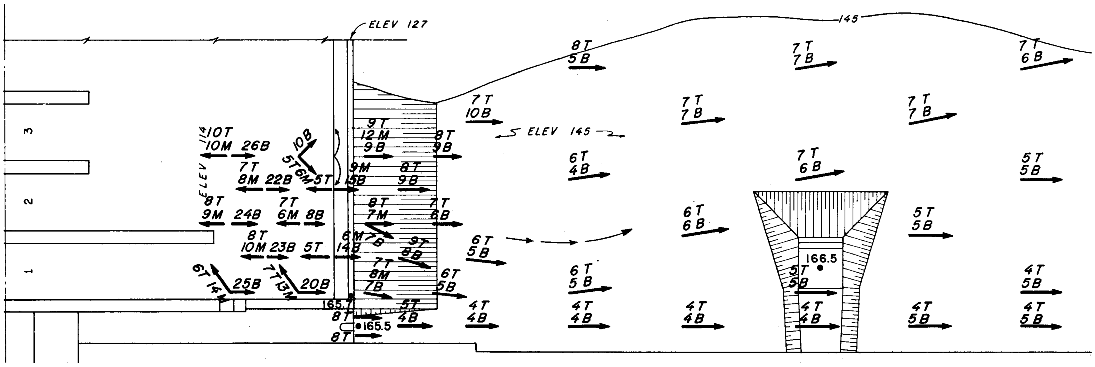
← 3 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
172.4 ● WATER-SURFACE ELEVATIONS

FLOW CONDITIONS
PLAN A NORTH FISH LADDER ENTRANCE
SIDE OR NORTH OPENINGS CLOSED
RIVER DISCHARGE 700 000 CFS



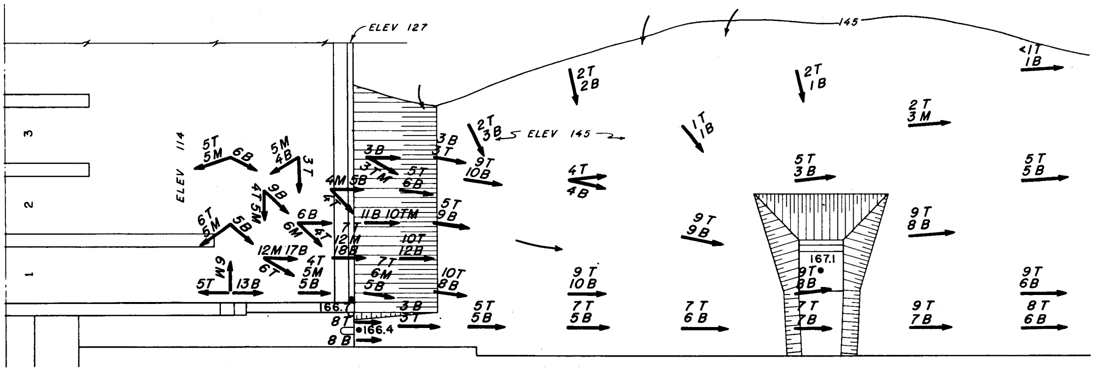
RIVER DISCHARGE 300 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 98 700 CFS
FISH LADDER ENTRANCE FLOW 1 300 CFS



RIVER DISCHARGE 400 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 198 700 CFS
FISH LADDER ENTRANCE FLOW 1 300 CFS



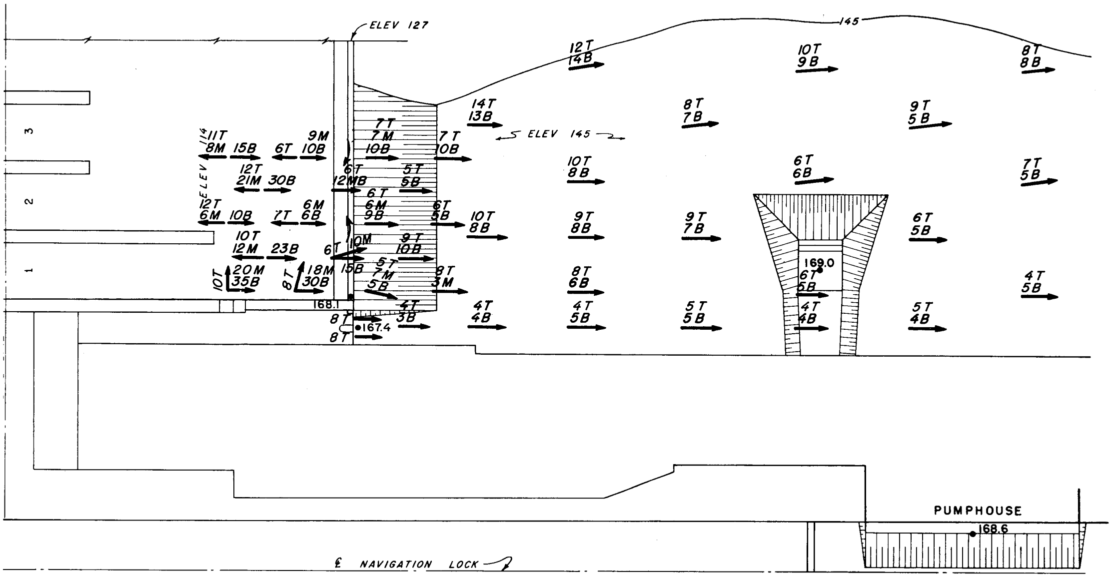
RIVER DISCHARGE 420 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 18 360 000 CFS — SPILLWAY DISCHARGE BAYS 2 TO 19 38 700 CFS
SPILLWAY DISCHARGE BAYS 1 AND 20 20 000 CFS — FISH LADDER ENTRANCE FLOW 1 300 CFS

LEGEND

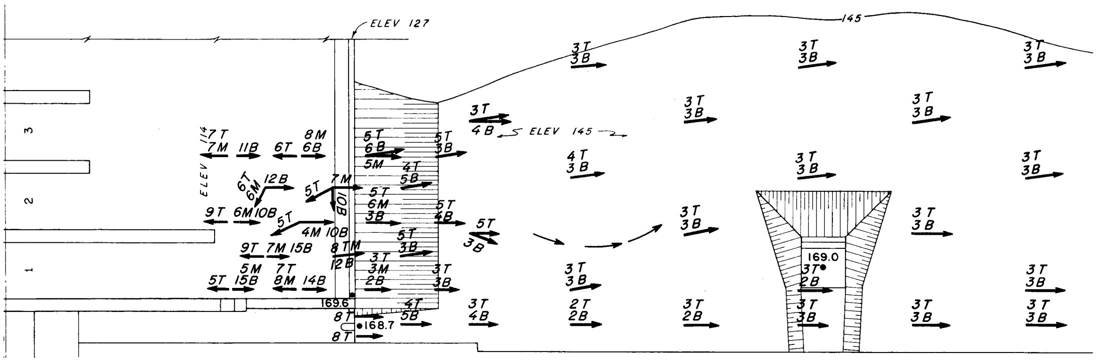
←5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.4 ●	WATER-SURFACE ELEVATION

FLOW CONDITIONS
PLAN B NORTH FISH LADDER ENTRANCE
RIVER DISCHARGES 300 000 TO 420 000 CFS



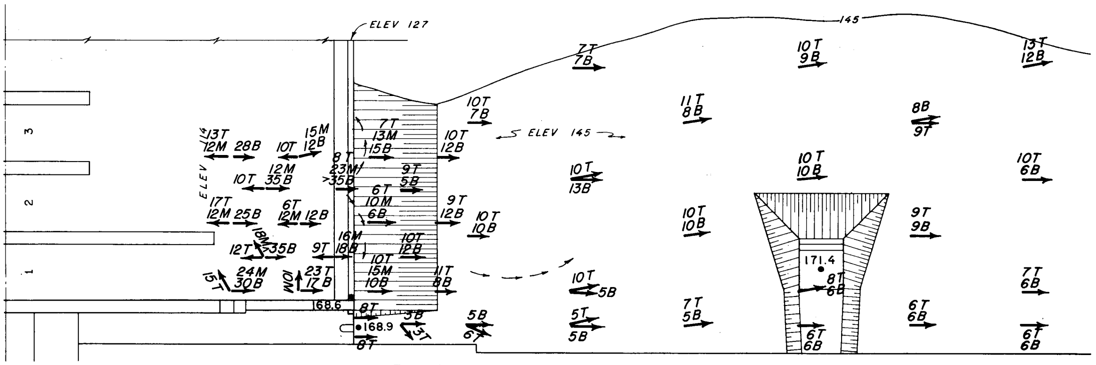
RIVER DISCHARGE 500 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 298 400 CFS
FISH LADDER ENTRANCE FLOW 1 600 CFS



RIVER DISCHARGE 500 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 20 400 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 98 400 CFS
FISH LADDER ENTRANCE FLOW 1 600 CFS



RIVER DISCHARGE 600 000 CFS

POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 398 400 CFS
FISH LADDER ENTRANCE FLOW 1 600 CFS

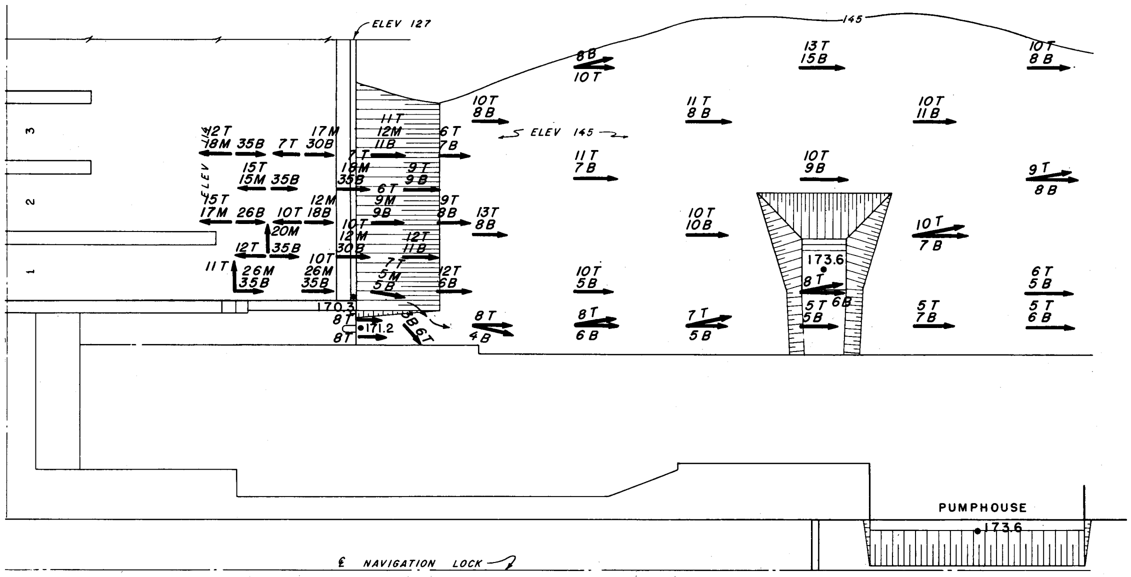
LEGEND

← 5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
168.7 ● WATER-SURFACE ELEVATION

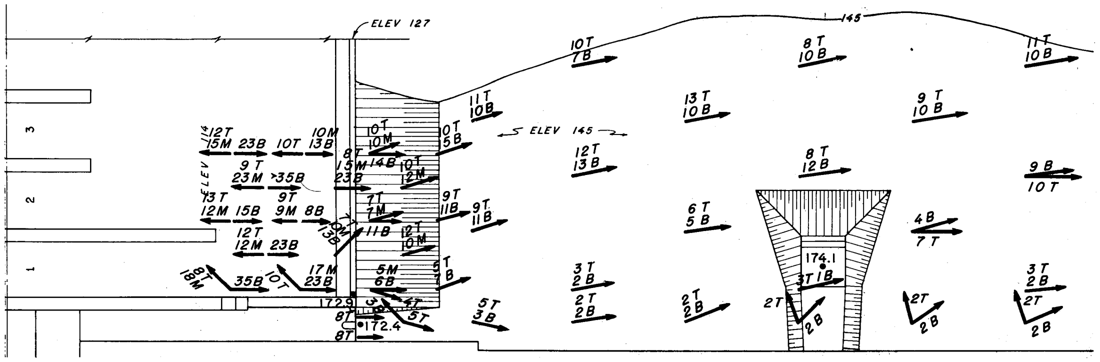
FLOW CONDITIONS

PLAN B NORTH FISH LADDER ENTRANCE

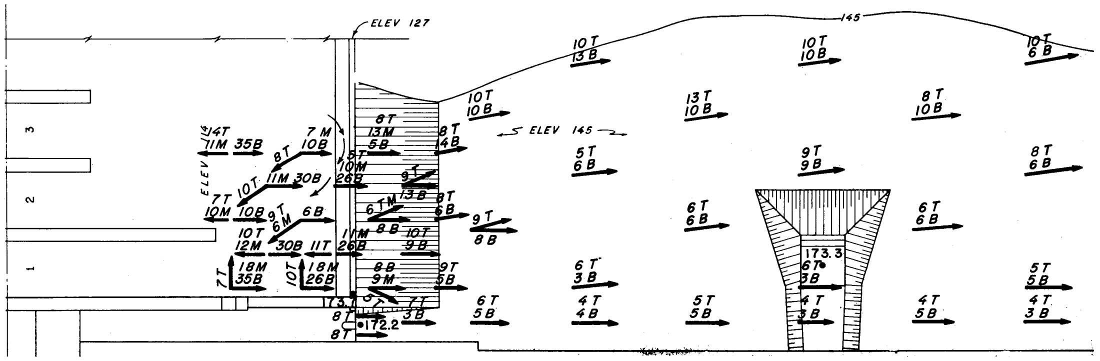
RIVER DISCHARGES 500 000 TO 600 000 CFS



POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 498 100 CFS
FISH LADDER ENTRANCE FLOW 1 900 CFS



POWERHOUSE DISCHARGE UNITS 1 TO 10 200 000 CFS — SPILLWAY DISCHARGE BAYS 2 TO 20 478 100 CFS
SPILLWAY DISCHARGE BAY 1 20 000 CFS — FISH LADDER ENTRANCE FLOW 1 900 CFS



POWERHOUSE DISCHARGE UNITS 1 TO 20 400 000 CFS — SPILLWAY DISCHARGE BAYS 1 TO 20 298 100 CFS
FISH LADDER ENTRANCE FLOW 1 900 CFS

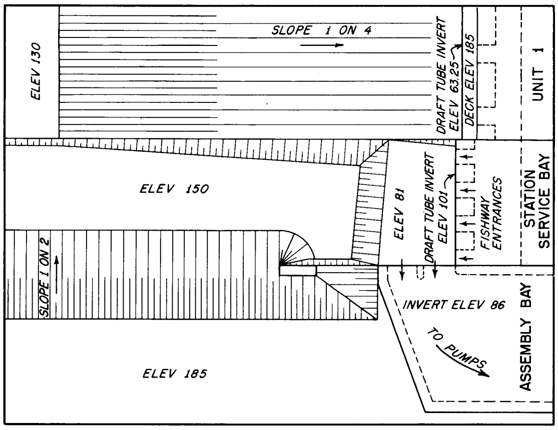
LEGEND

←5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
172.2 ● WATER-SURFACE ELEVATION

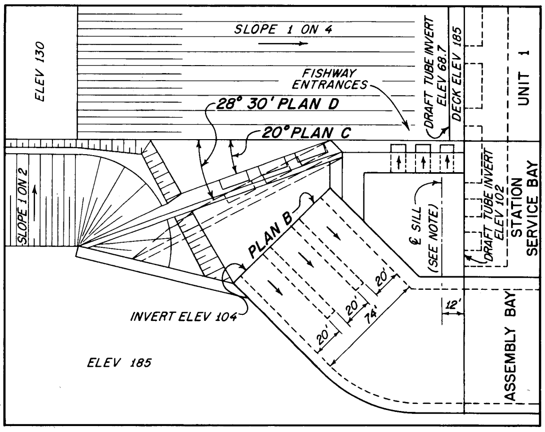
FLOW CONDITIONS

PLAN B NORTH FISH LADDER ENTRANCE

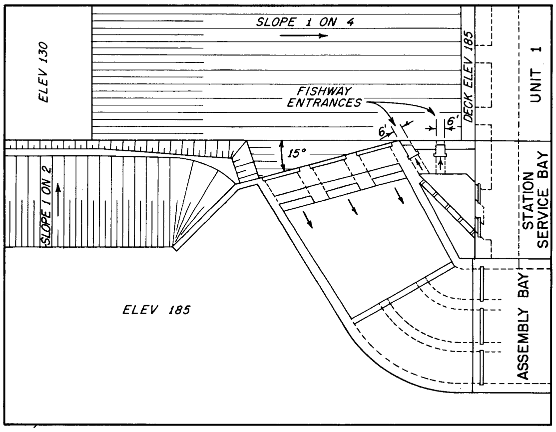
RIVER DISCHARGE 700 000 CFS



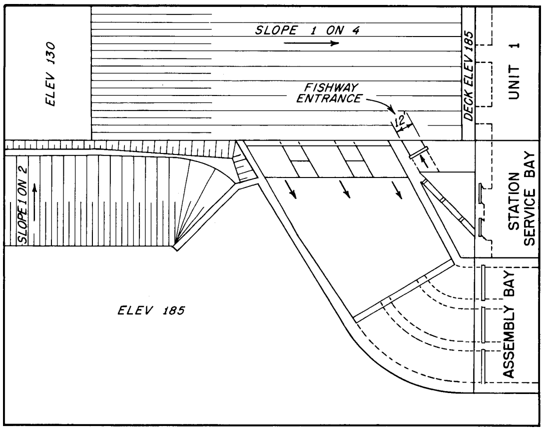
PLAN A (ORIGINAL DESIGN)



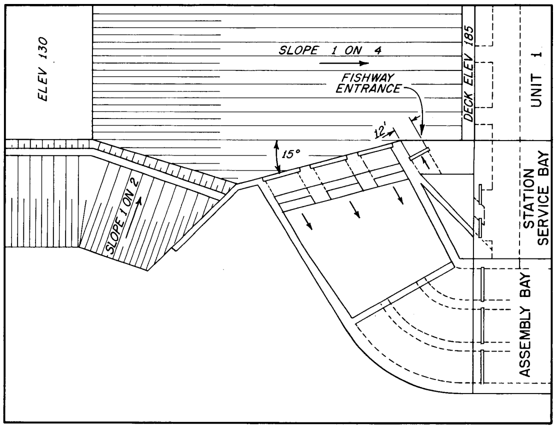
PLANS B AND C FISHWAY ENTRANCE
PLANS B TO D INTAKE



PLANS D AND E FISHWAY ENTRANCE
PLAN F INTAKE

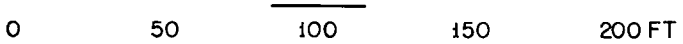


PLAN F FISHWAY ENTRANCE
PLAN G INTAKE



PLAN F FISHWAY ENTRANCE
PLAN H INTAKE
(FINAL DESIGN)

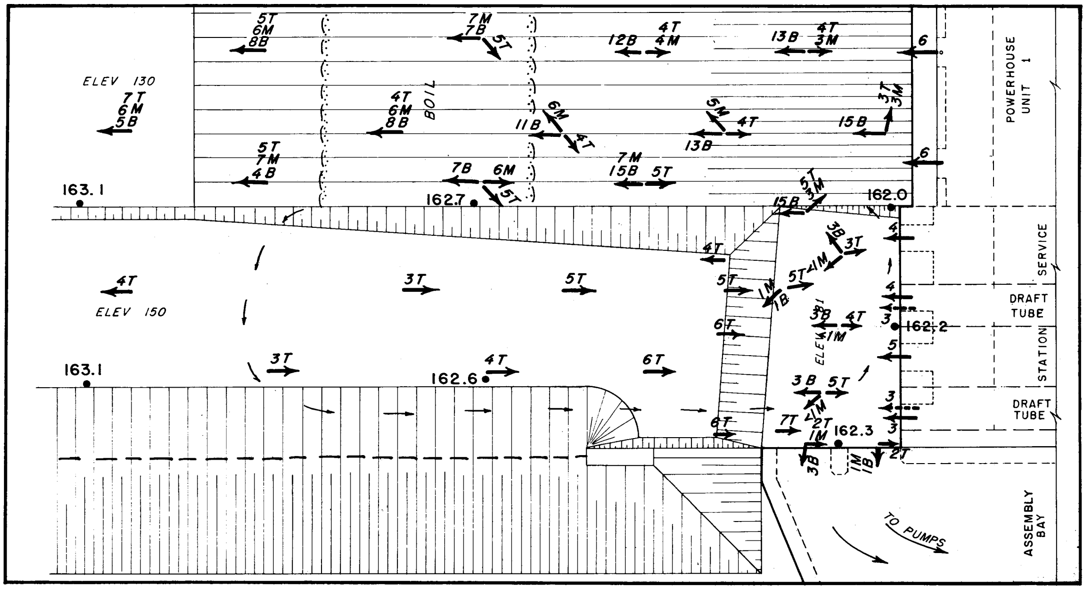
SCALE



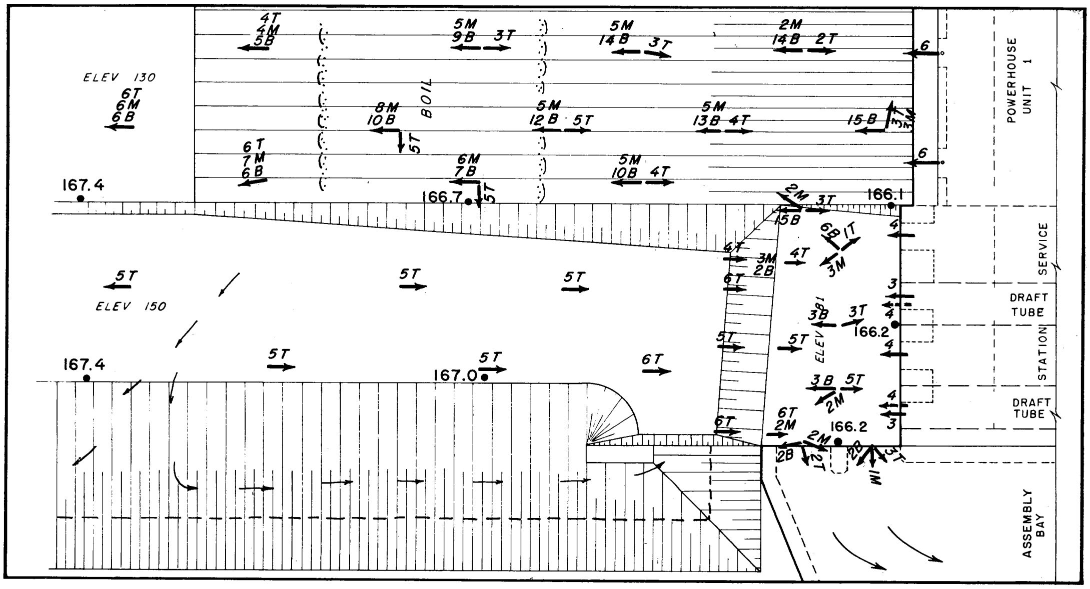
NOTES

1. THE PLAN C FISHWAY ENTRANCE INCLUDED A SILL EITHER 7 FT OR 9 FT HIGH (BOTH TESTED) LOCATED 12 FT DOWNSTREAM FROM OUTLETS OF STATION SERVICE UNITS.
2. STATION SERVICE UNITS WERE DELETED AFTER TESTS OF PLAN C FISHWAY ENTRANCE AND PLAN D INTAKE.
3. THE PLAN E INTAKE (NOT SHOWN) WAS INTERMEDIATE BETWEEN INTAKE PLANS D AND F.

SOUTH FISHWAY ENTRANCE PLANS A TO F
AUXILIARY WATER INTAKE PLANS A TO H



RIVER DISCHARGE 200 000 CFS



RIVER DISCHARGE 400 000 CFS

OPERATING CONDITIONS

RIVER DISCHARGE		200 000 CFS	400 000 CFS
POWERHOUSE DISCHARGE UNITS 1 TO 8		162 400 CFS	171 200 CFS
SPILLWAY BAYS 2 TO 20		34 275 CFS	225 475 CFS
FISH ATTRACTION FLOW BAY 1		2700 CFS	2700 CFS
NORTH FISH LADDER ENTRANCE		1000 CFS	1300 CFS
UNIT 20 FISHWAY ENTRANCE		455 CFS	595 CFS
POWERHOUSE FISHWAY ORIFICES		2280 CFS	2280 CFS
SOUTH FISHWAY ENTRANCE		700 CFS	700 CFS
STATION SERVICE UNITS		400 CFS	400 CFS
PUMP DISCHARGE	SOUTH	3310 CFS	3450 CFS
	NORTH	900 CFS	1200 CFS

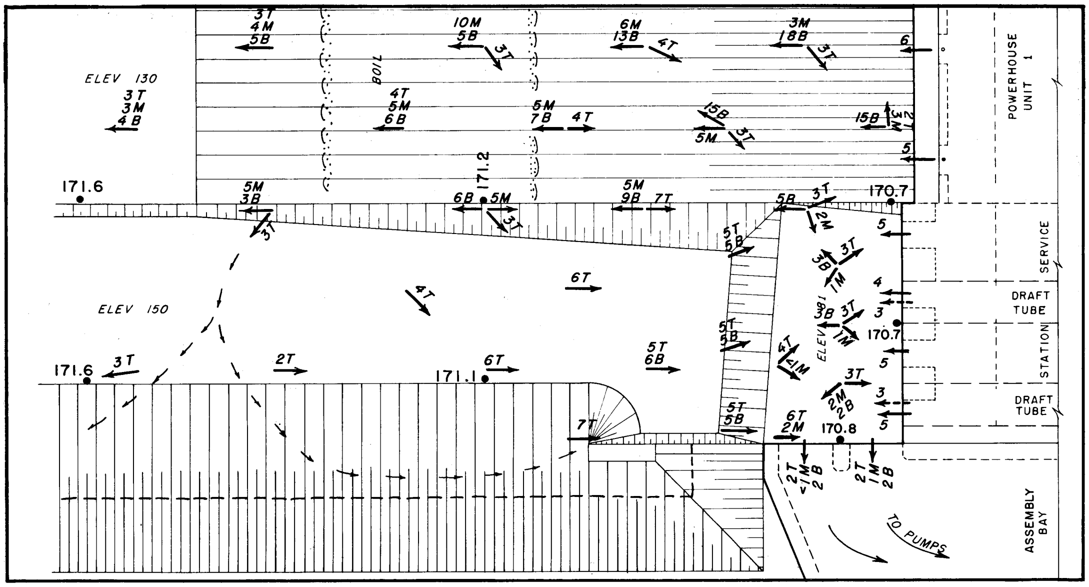
LEGEND

← 6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
167.0 ●	WATER-SURFACE ELEVATION
⇠ 4	VELOCITY FROM DRAFT TUBE IN FPS

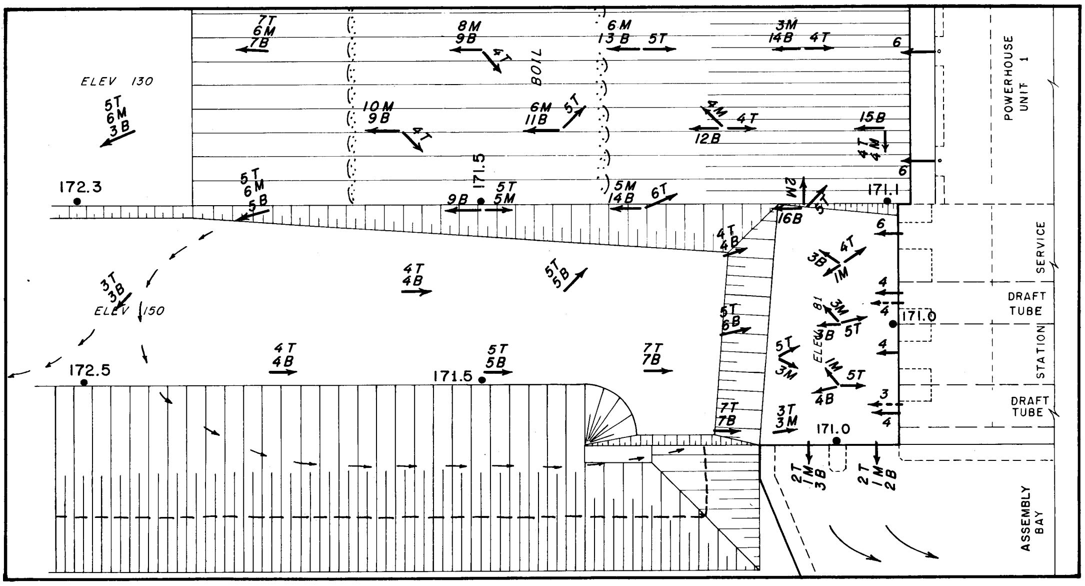
FLOW CONDITIONS

PLAN A SOUTH FISHWAY ENTRANCE AND AUXILIARY WATER INTAKE

RIVER DISCHARGE 200 000 AND 400 000 CFS



POWERHOUSE UNITS 1 TO 8



POWERHOUSE UNITS 1 TO 20

OPERATING CONDITIONS

POWERHOUSE UNITS	1 TO 8	1 TO 20
POWERHOUSE DISCHARGE	184 000 CFS	460 000 CFS
SPILLWAY BAYS 2 TO 20	412 675 CFS	136 675 CFS
FISH ATTRACTION FLOW BAY 1	2700 CFS	2700 CFS
NORTH FISH LADDER ENTRANCE	1600 CFS	1600 CFS
UNIT 20 FISHWAY ENTRANCE	785 CFS	785 CFS
POWERHOUSE FISHWAY ENTRANCES	2280 CFS	2280 CFS
SOUTH FISHWAY ENTRANCE	700 CFS	700 CFS
STATION SERVICE UNITS	400 CFS	400 CFS
PUMP DISCHARGE SOUTH	3640 CFS	3640 CFS
NORTH	1500 CFS	1500 CFS

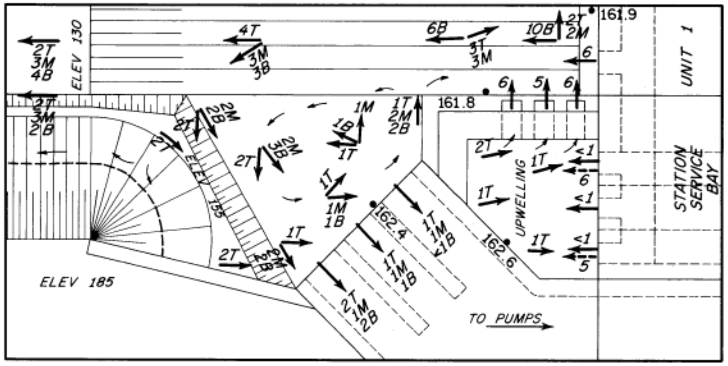
LEGEND

←6—	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
172.3 ●	WATER-SURFACE ELEVATIONS
←4--	VELOCITY FROM DRAFT TUBE

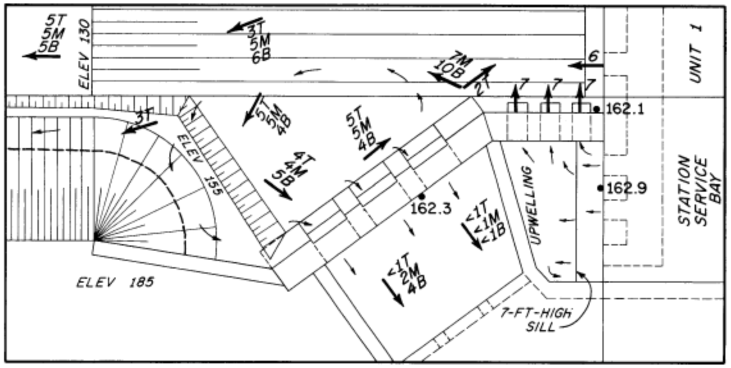
FLOW CONDITIONS

PLAN A SOUTH FISHWAY ENTRANCE AND AUXILIARY WATER INTAKE

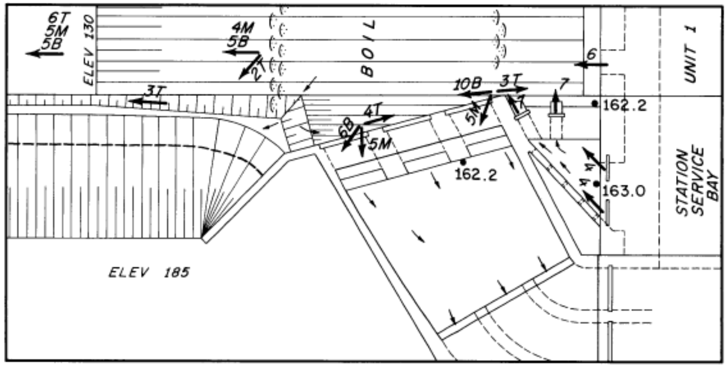
RIVER DISCHARGE 600 000 CFS



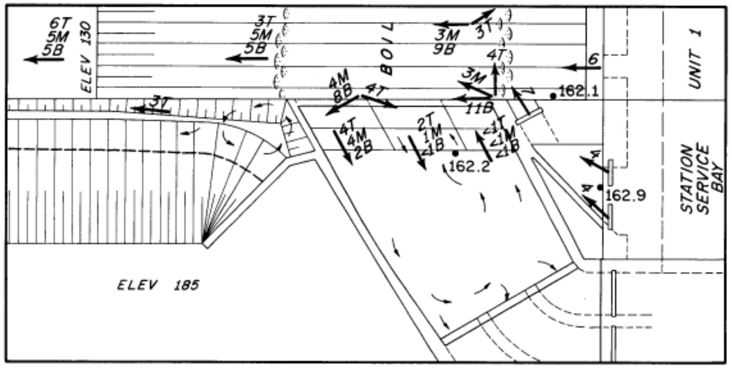
PLAN B FISHWAY ENTRANCE AND INTAKE



PLAN C FISHWAY ENTRANCE, PLAN E INTAKE



PLAN D FISHWAY ENTRANCE, PLAN F INTAKE



PLAN F FISHWAY ENTRANCE, PLAN G INTAKE

SCALE

OPERATING CONDITIONS

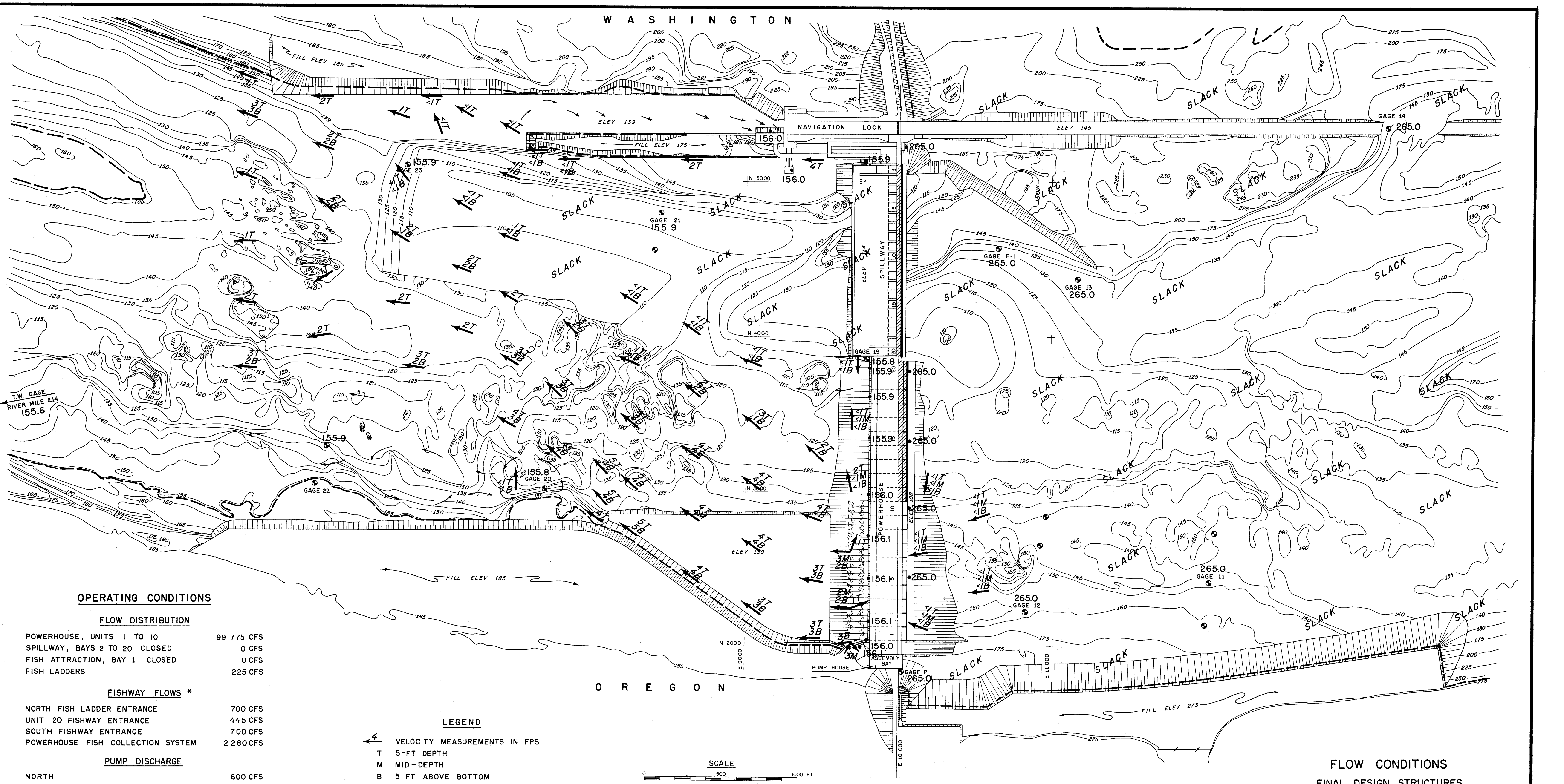
POWERHOUSE DISCHARGE UNITS 1 TO 8	162 400 CFS
SPILLWAY BAYS 2 TO 20	VARIES
FISH ATTRACTION FLOW BAY 1	2 700 CFS
NORTH FISH LADDER ENTRANCE	1 000 CFS
UNIT 20 FISHWAY ENTRANCE	455 CFS
POWERHOUSE FISHWAY ORIFICES	2 280 CFS
SOUTH FISHWAY ENTRANCE	1280 CFS, PLANS B AND C; 700 CFS, PLANS D AND F
PUMP DISCHARGE	2790 CFS, PLANS B AND E; 3310 CFS, PLAN F AND G
STATION SERVICE UNITS	1100 CFS, PLANS B AND C; NONE PLANS D AND F

LEGEND

←6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
162.2 ●	WATER-SURFACE ELEVATION
←-6-	VELOCITY FROM DRAFT TUBE IN FPS

FLOW CONDITIONS

SOUTH FISHWAY ENTRANCE PLANS B, C, D, AND F
AUXILIARY WATER INTAKE PLANS B AND E TO G
RIVER DISCHARGE 200 000 CFS



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	99 775 CFS
SPILLWAY, BAYS 2 TO 20 CLOSED	0 CFS
FISH ATTRACTION, BAY 1 CLOSED	0 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	700 CFS
UNIT 20 FISHWAY ENTRANCE	445 CFS
SOUTH FISHWAY ENTRANCE	700 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	600 CFS
SOUTH	3300 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

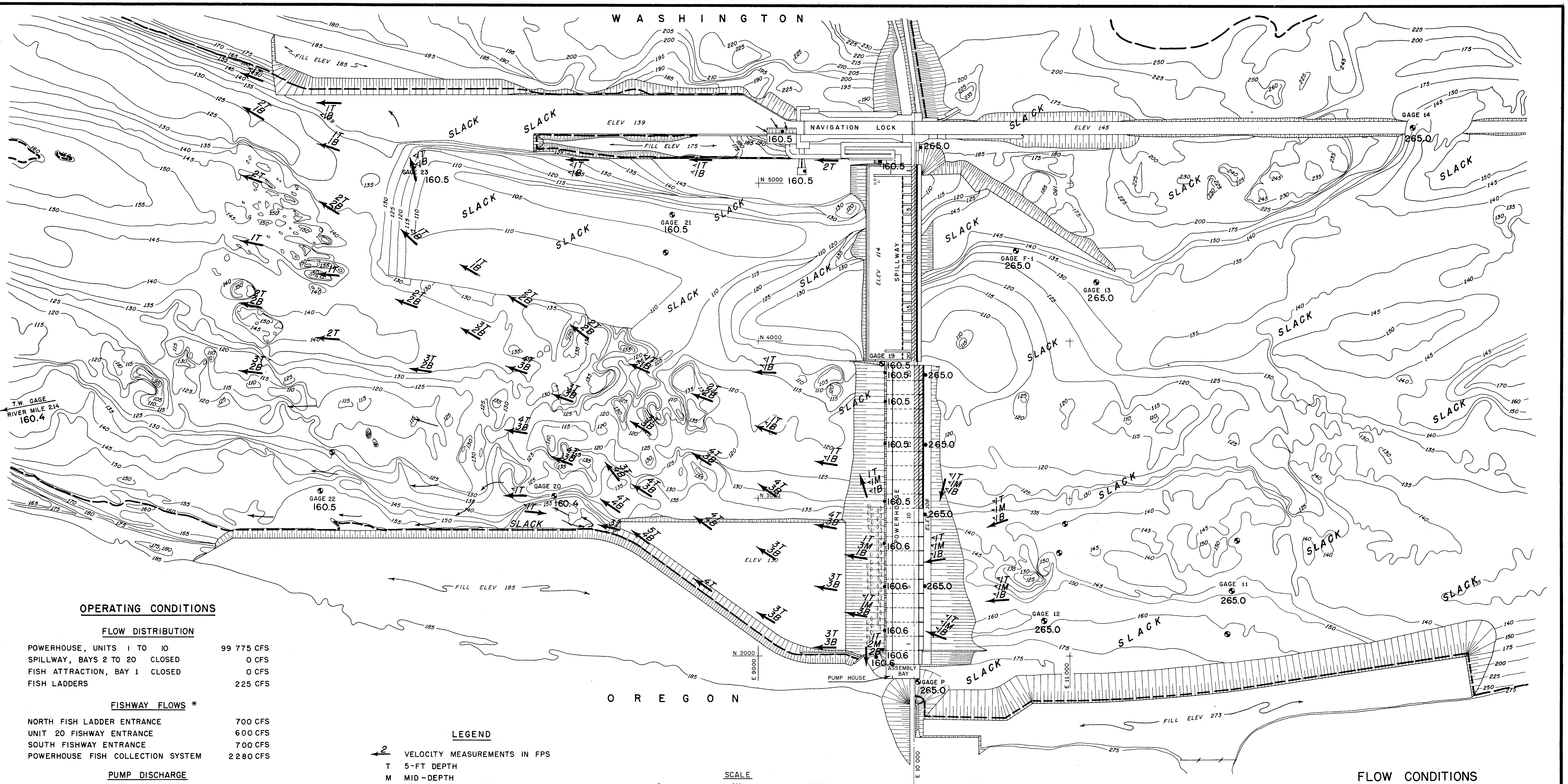
LEGEND

←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
155.9 •	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 100 000 CFS
TAILWATER ELEV 155.6 (THE DALLES POOL ELEV 155.0)



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	99 775 CFS
SPILLWAY, BAYS 2 TO 20 CLOSED	0 CFS
FISH ATTRACTION, BAY 1 CLOSED	0 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	700 CFS
UNIT 20 FISHWAY ENTRANCE	600 CFS
SOUTH FISHWAY ENTRANCE	700 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

NORTH	600 CFS
SOUTH	3455 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

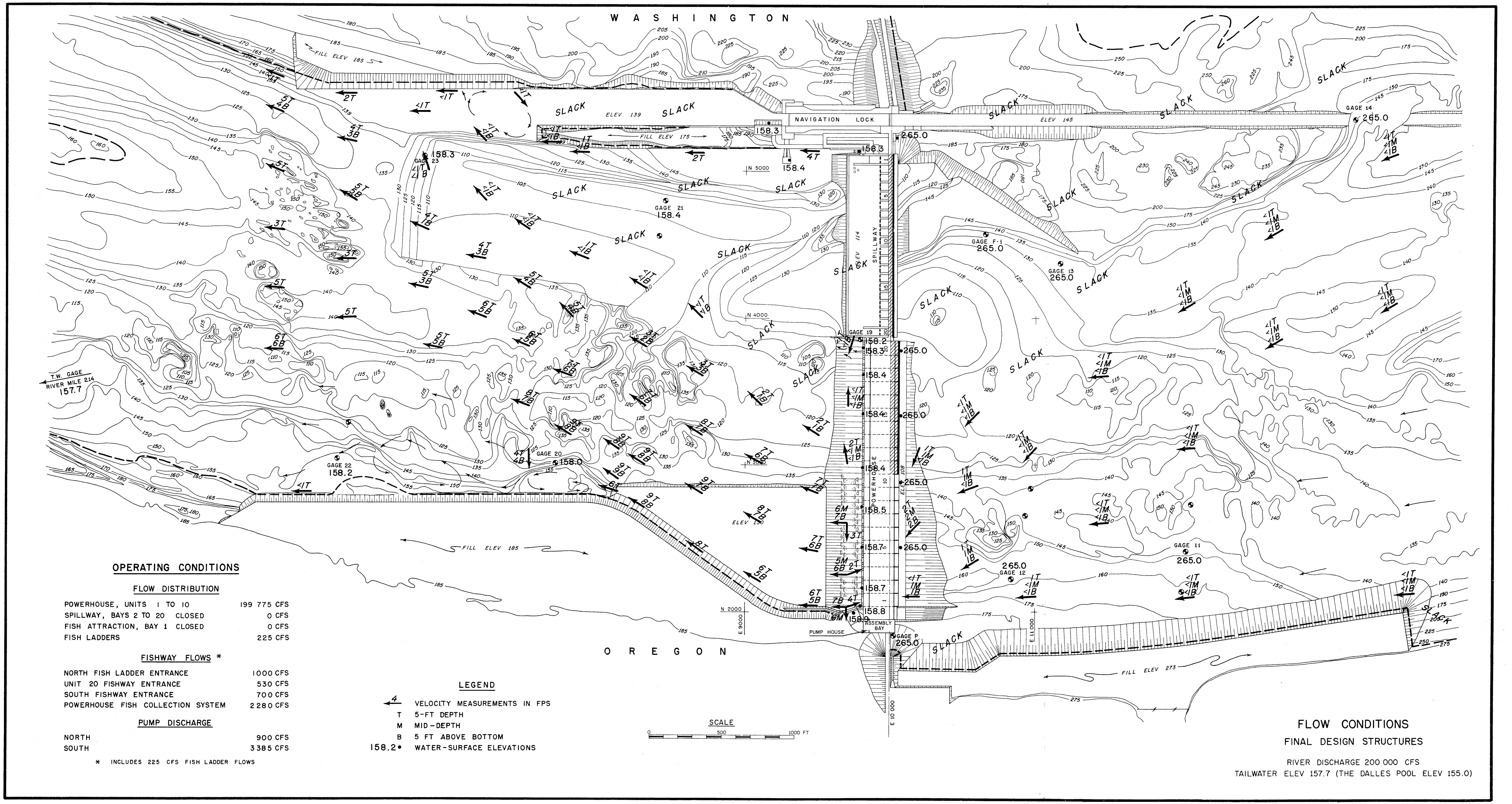
← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
160.5 ●	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 100 000 CFS
TAILWATER ELEV 160.4 (THE DALLES POOL ELEV 160.0)



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	199 775 CFS
SPILLWAY, BAYS 2 TO 20 CLOSED	0 CFS
FISH ATTRACTION, BAY 1 CLOSED	0 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1000 CFS
UNIT 20 FISHWAY ENTRANCE	530 CFS
SOUTH FISHWAY ENTRANCE	700 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

NORTH	900 CFS
SOUTH	3385 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

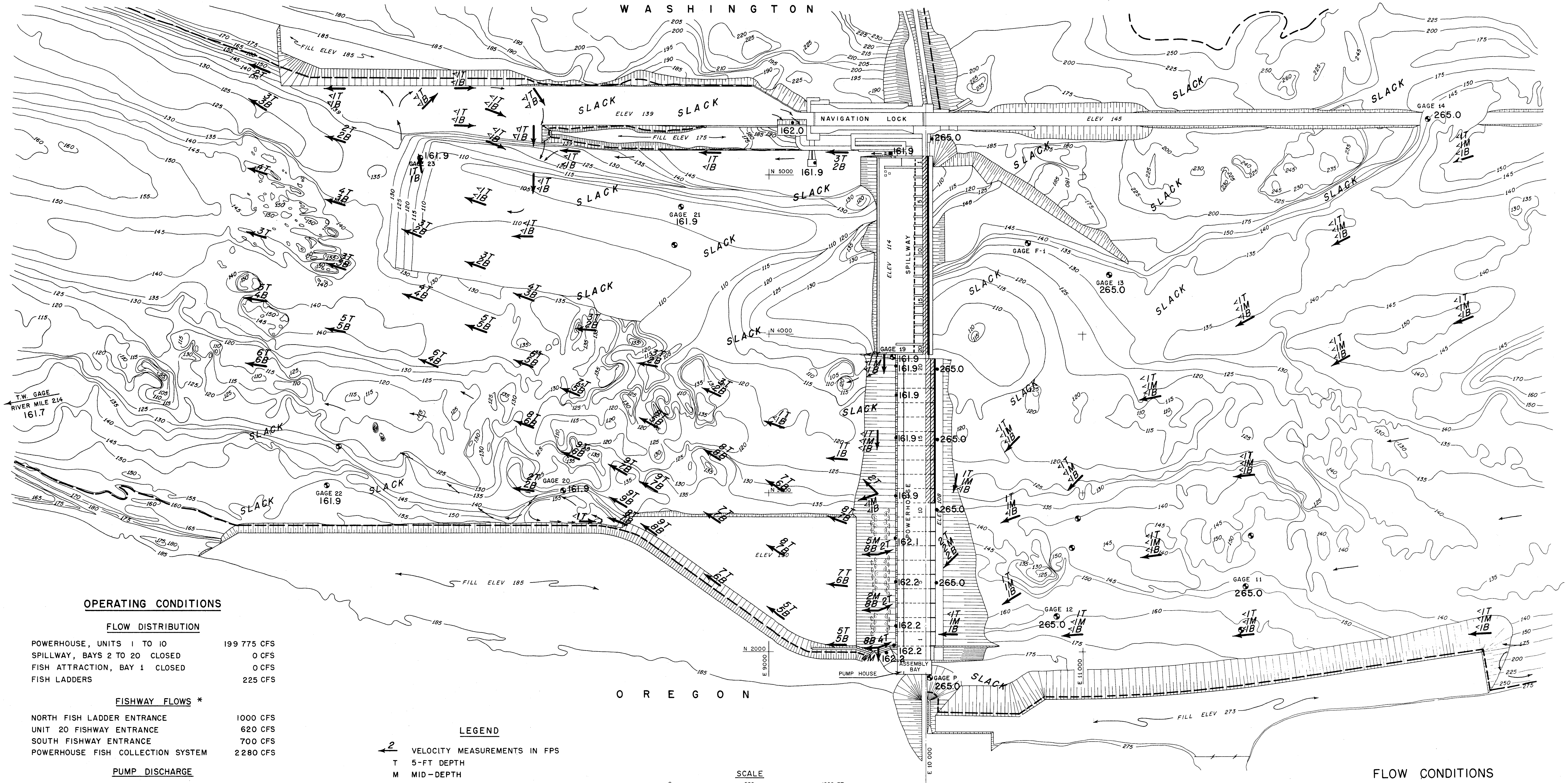
LEGEND

←4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
158.2•	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 200 000 CFS
TAILWATER ELEV 157.7 (THE DALLES POOL ELEV 155.0)



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	199 775 CFS
SPILLWAY, BAYS 2 TO 20 CLOSED	0 CFS
FISH ATTRACTION, BAY 1 CLOSED	0 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1000 CFS
UNIT 20 FISHWAY ENTRANCE	620 CFS
SOUTH FISHWAY ENTRANCE	700 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

NORTH	900 CFS
SOUTH	3475 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

$\xleftarrow{2}$	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
161.9 •	WATER-SURFACE ELEVATIONS

SCALE

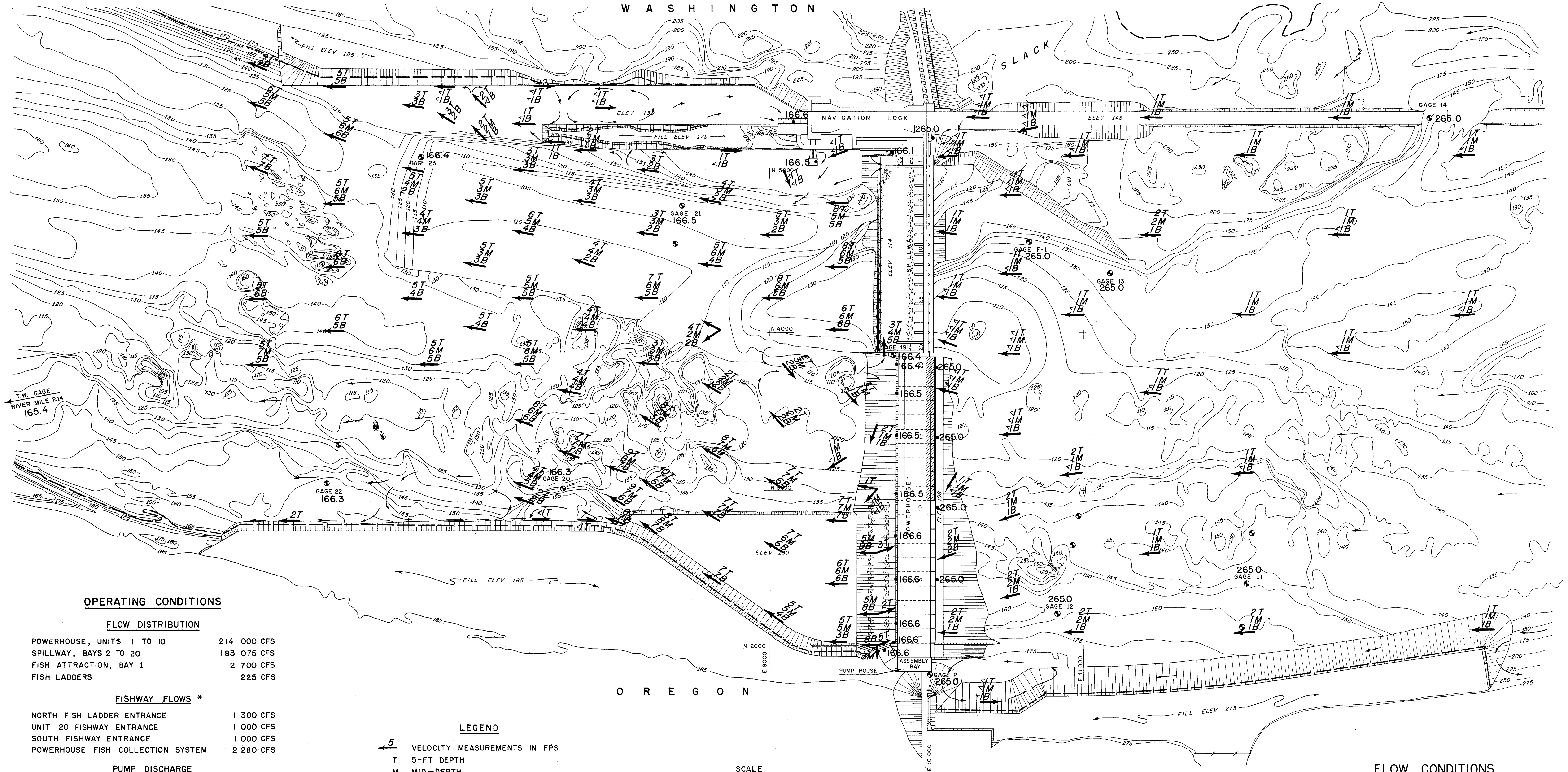
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 200 000 CFS

TAILWATER ELEV 161.7 (THE DALLES POOL ELEV 160.0)



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	214 000 CFS
SPILLWAY, BAYS 2 TO 20	183 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 300 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 200 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

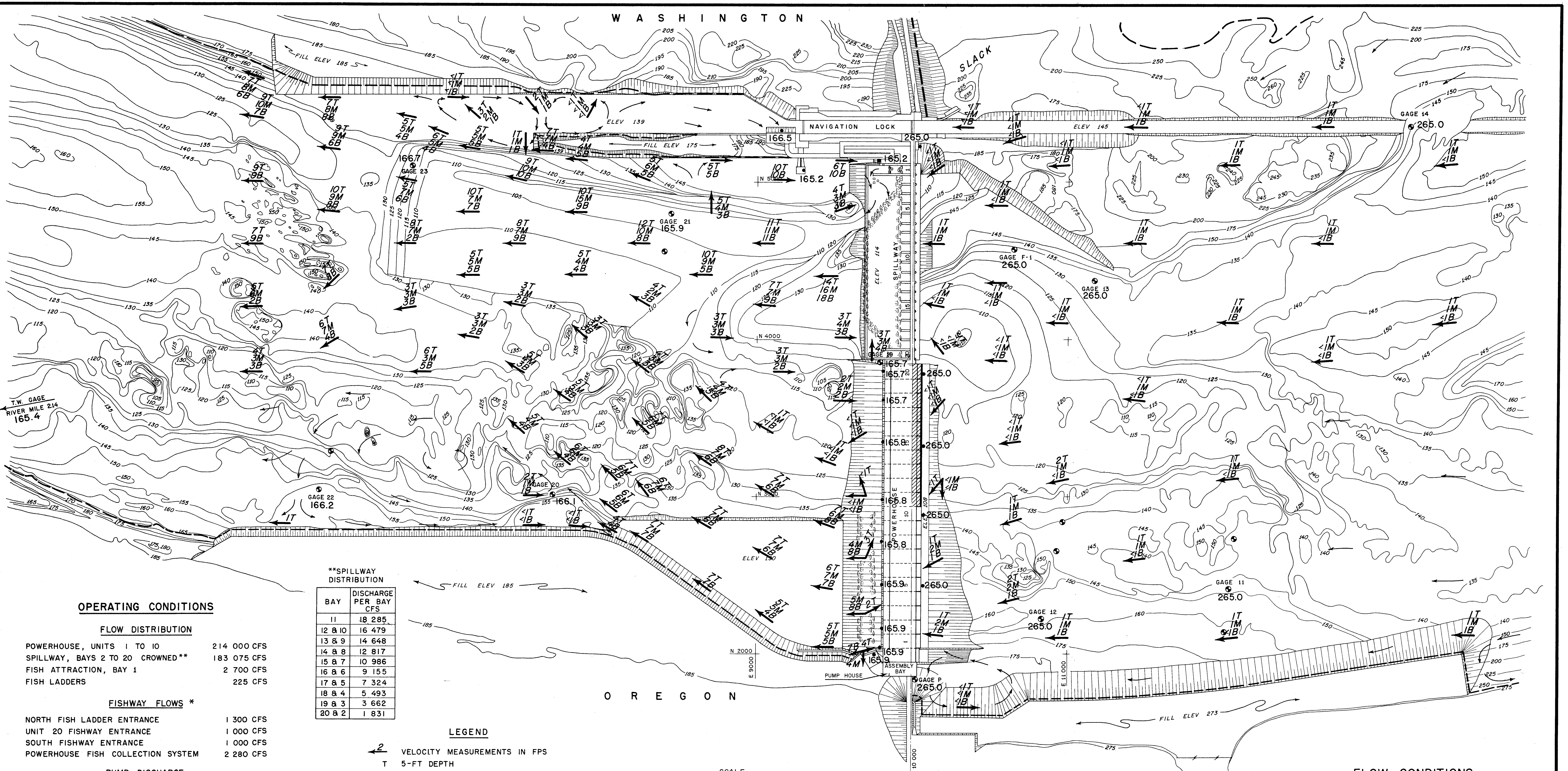
LEGEND

← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.6 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 400 000 CFS
SPILLWAY GATES 2 TO 20 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	214 000 CFS
SPILLWAY, BAYS 2 TO 20 CROWNED**	183 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 300 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 200 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

**SPILLWAY DISTRIBUTION

BAY	DISCHARGE PER BAY CFS
11	18 285
12 & 10	16 479
13 & 9	14 648
14 & 8	12 817
15 & 7	10 986
16 & 6	9 155
17 & 5	7 324
18 & 4	5 493
19 & 3	3 662
20 & 2	1 831

LEGEND

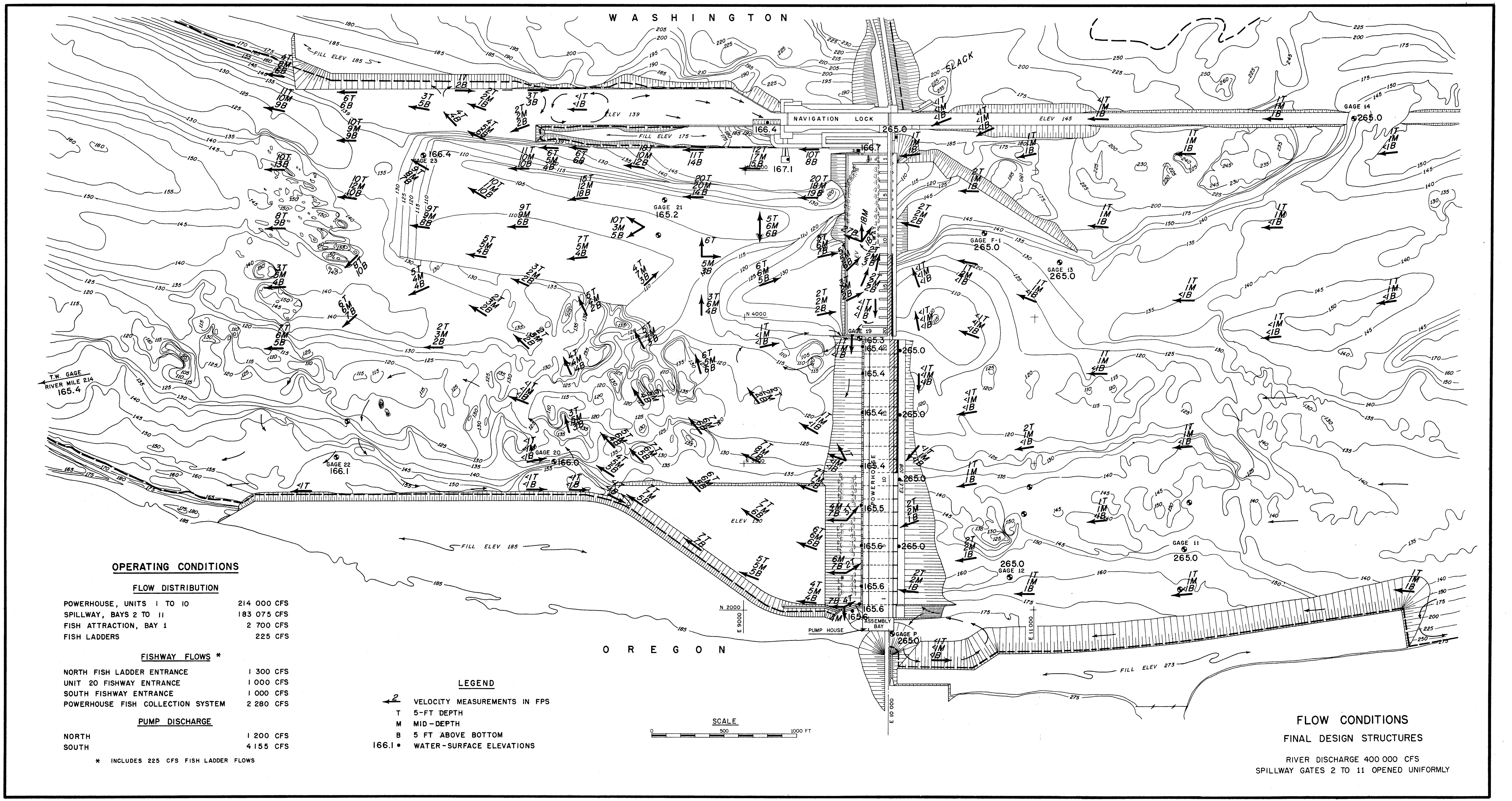
←2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.2 ●	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

FLOW CONDITIONS
FINAL DESIGN STRUCTURES

RIVER DISCHARGE 400 000 CFS
SPILLWAY GATES 2 TO 20 CROWNED

PLATE 101



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	214 000 CFS
SPILLWAY, BAYS 2 TO 11	183 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 300 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 200 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

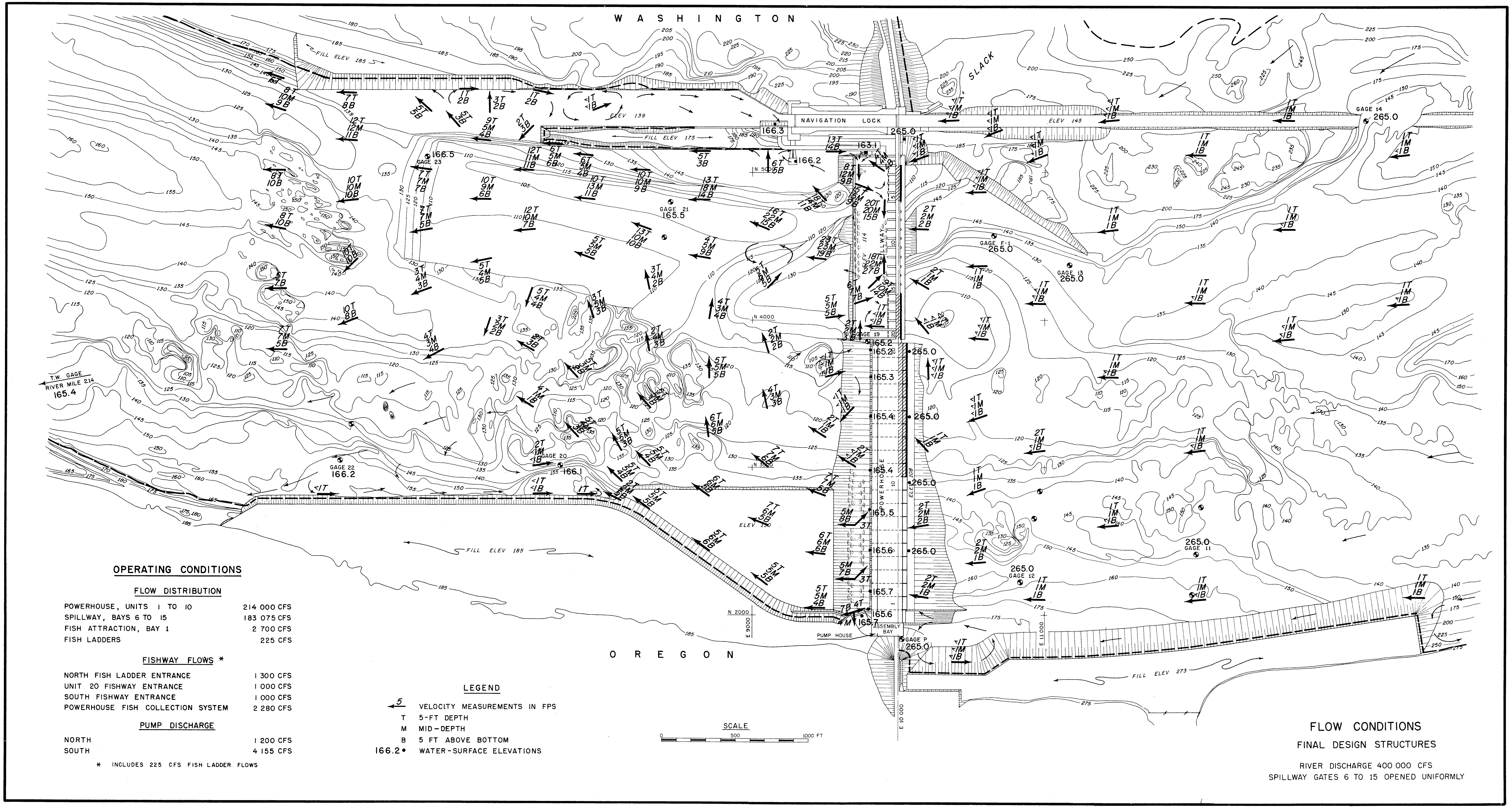
LEGEND

←2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.1 •	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 400 000 CFS
SPILLWAY GATES 2 TO 11 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	214 000 CFS
SPILLWAY, BAYS 6 TO 15	183 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 300 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 200 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.2 ●	WATER-SURFACE ELEVATIONS

SCALE

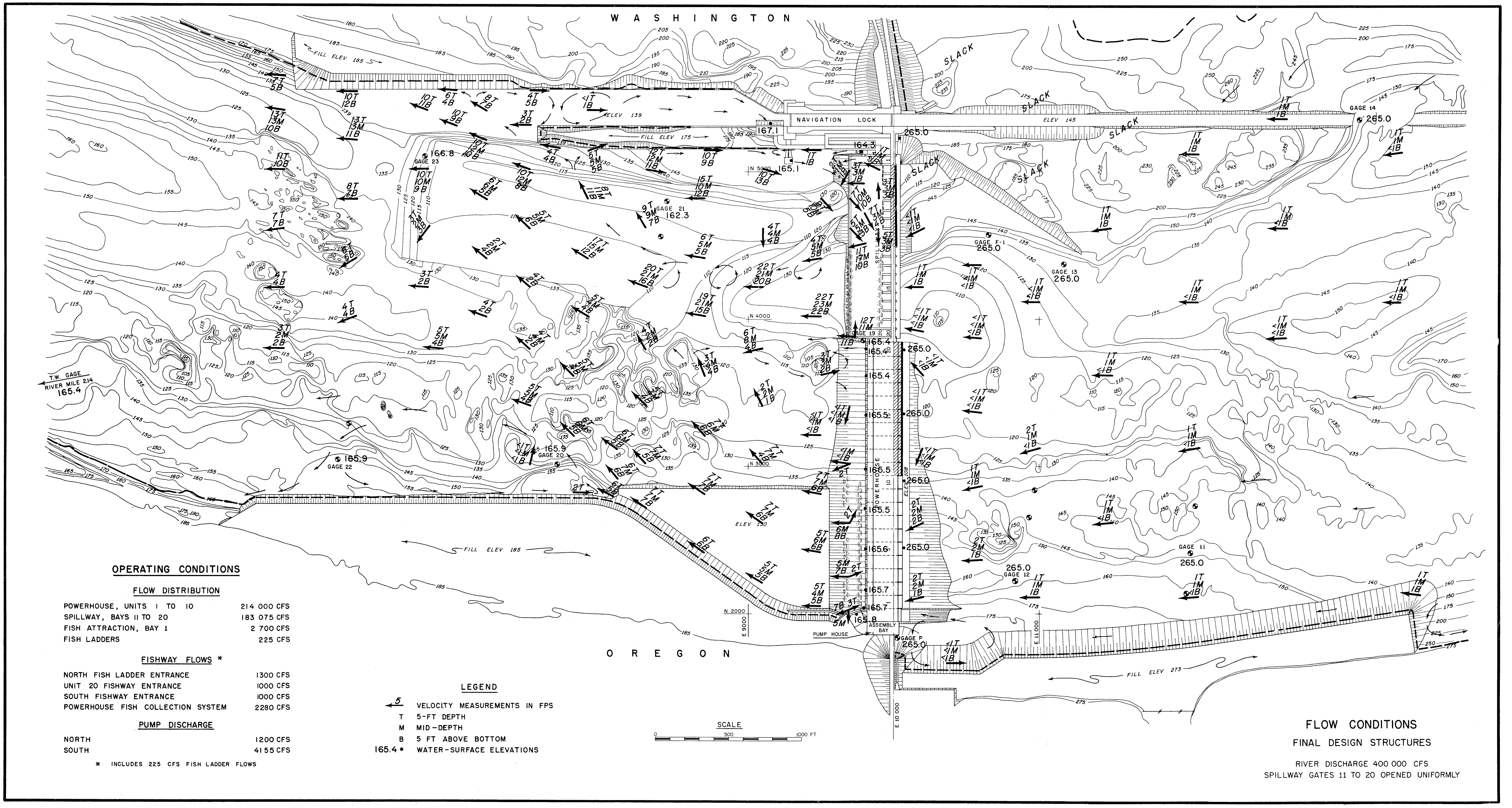
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 400 000 CFS

SPILLWAY GATES 6 TO 15 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	214 000 CFS
SPILLWAY, BAYS 11 TO 20	183 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1300 CFS
UNIT 20 FISHWAY ENTRANCE	1000 CFS
SOUTH FISHWAY ENTRANCE	1000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

NORTH	1200 CFS
SOUTH	4155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

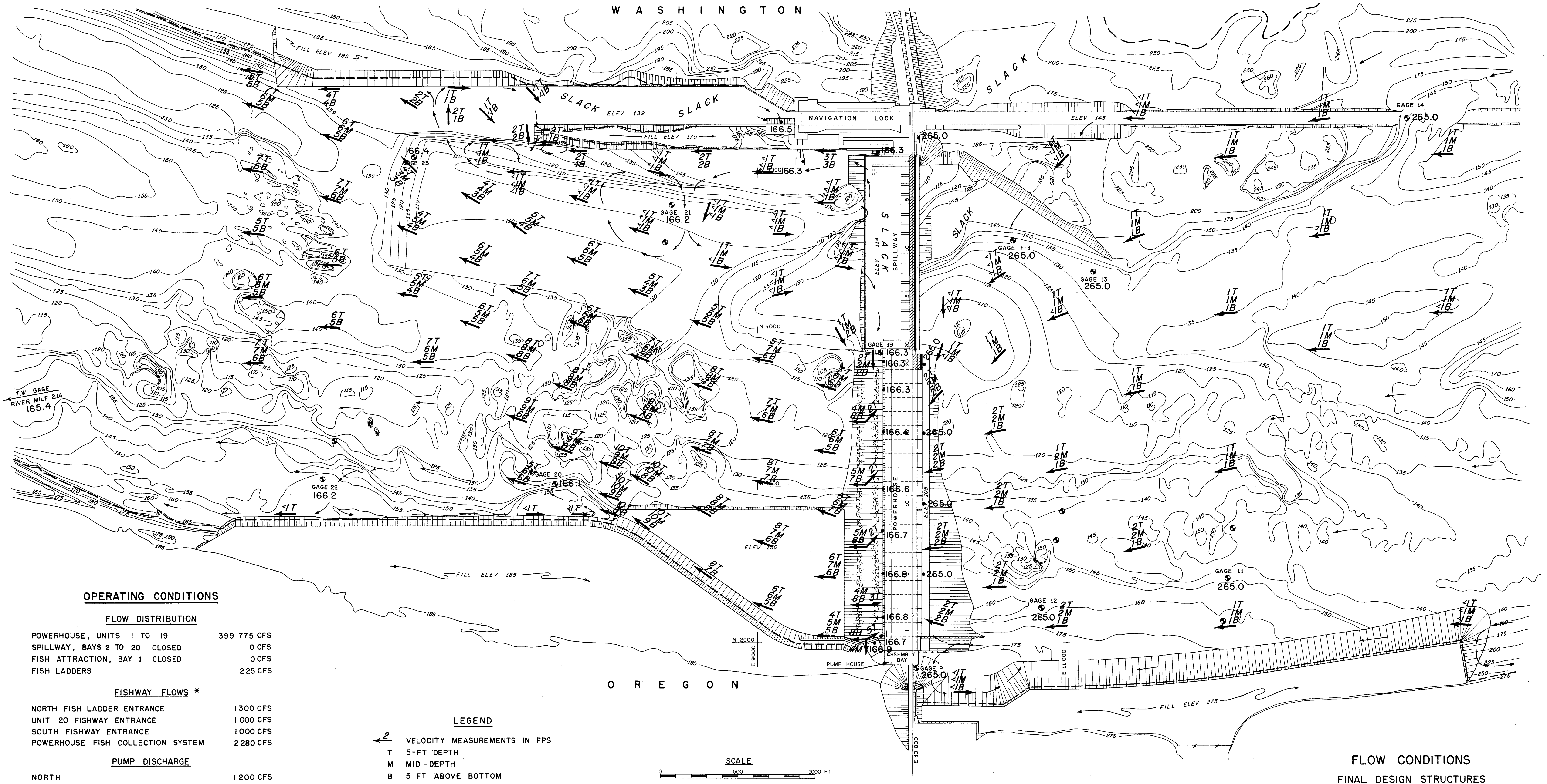
LEGEND

←5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
165.4 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 400 000 CFS
SPILLWAY GATES 11 TO 20 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 19	399 775 CFS
SPILLWAY, BAYS 2 TO 20 CLOSED	0 CFS
FISH ATTRACTION, BAY 1 CLOSED	0 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 300 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 200 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

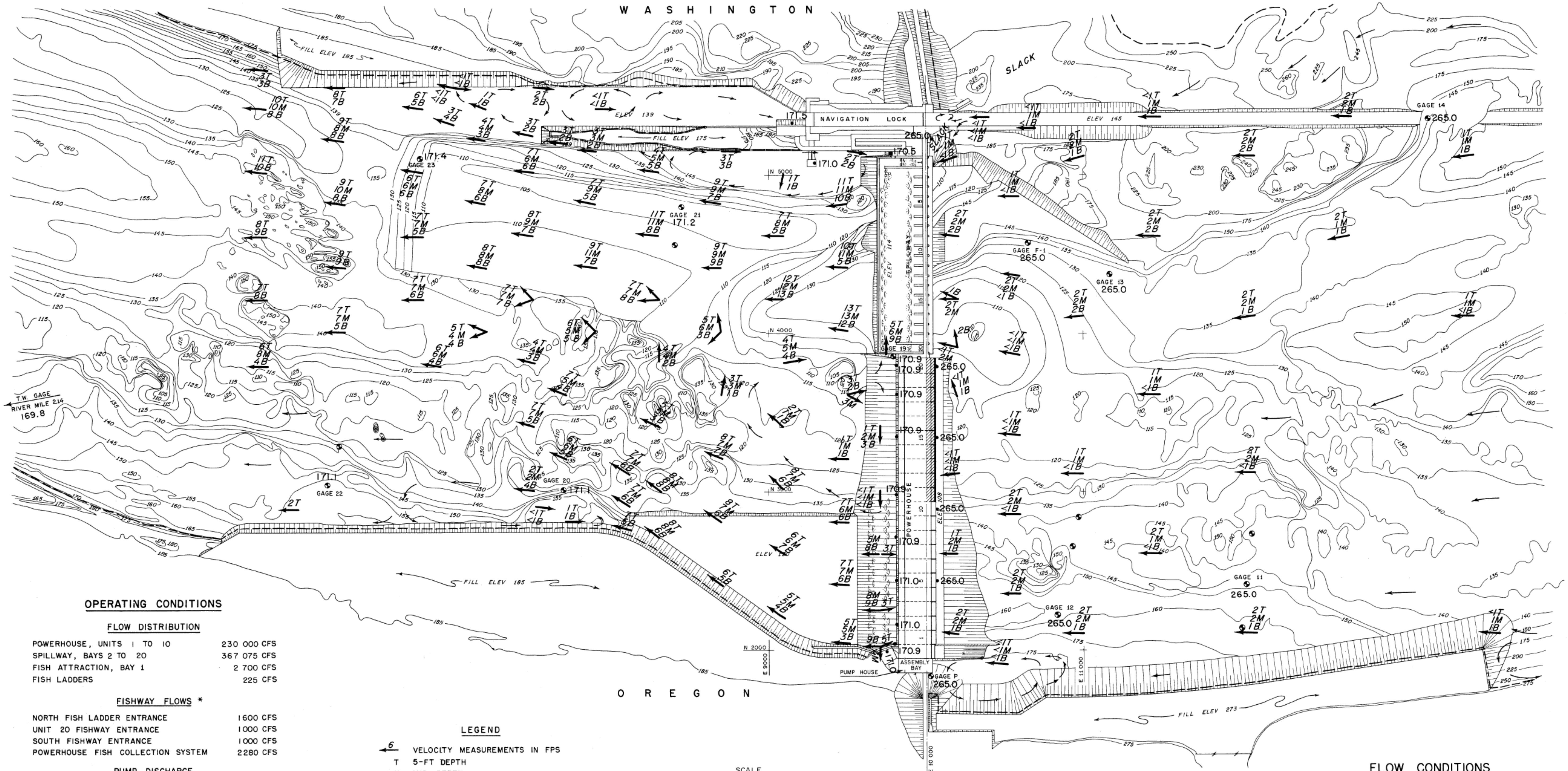
LEGEND

← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
166.2 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 400 000 CFS
19 POWER HOUSE UNITS OPERATED; SPILLWAY CLOSED



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	230 000 CFS
SPILLWAY, BAYS 2 TO 20	367 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1600 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

NORTH	1500 CFS
SOUTH	4155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

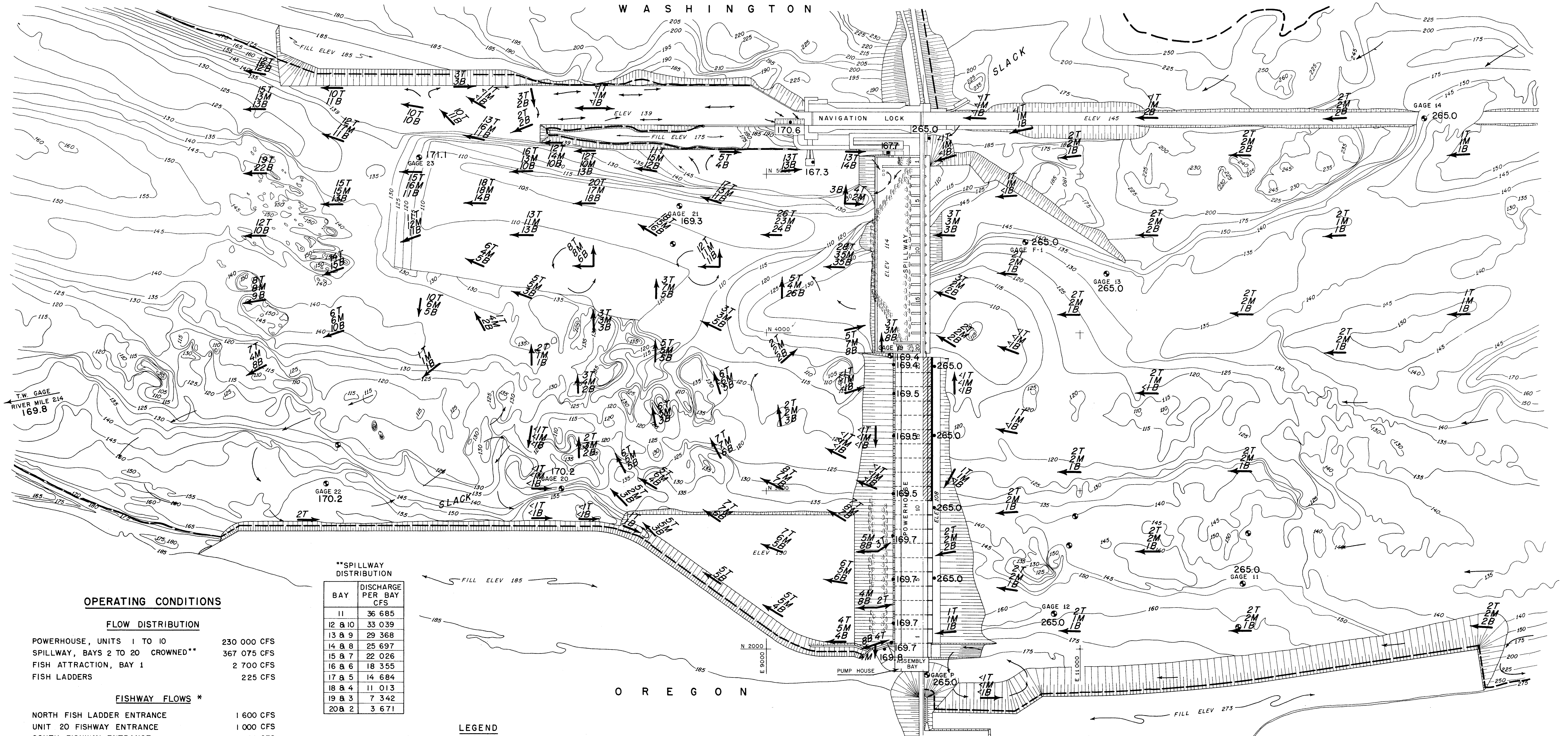
LEGEND

←6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 600 000 CFS
SPILLWAY GATES 2 TO 20 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	230 000 CFS
SPILLWAY, BAYS 2 TO 20 CROWNED**	367 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 600 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 500 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

**SPILLWAY DISTRIBUTION

BAY	DISCHARGE PER BAY CFS
11	36 685
12 & 10	33 039
13 & 9	29 368
14 & 8	25 697
15 & 7	22 026
16 & 6	18 355
17 & 5	14 684
18 & 4	11 013
19 & 3	7 342
20 & 2	3 671

LEGEND

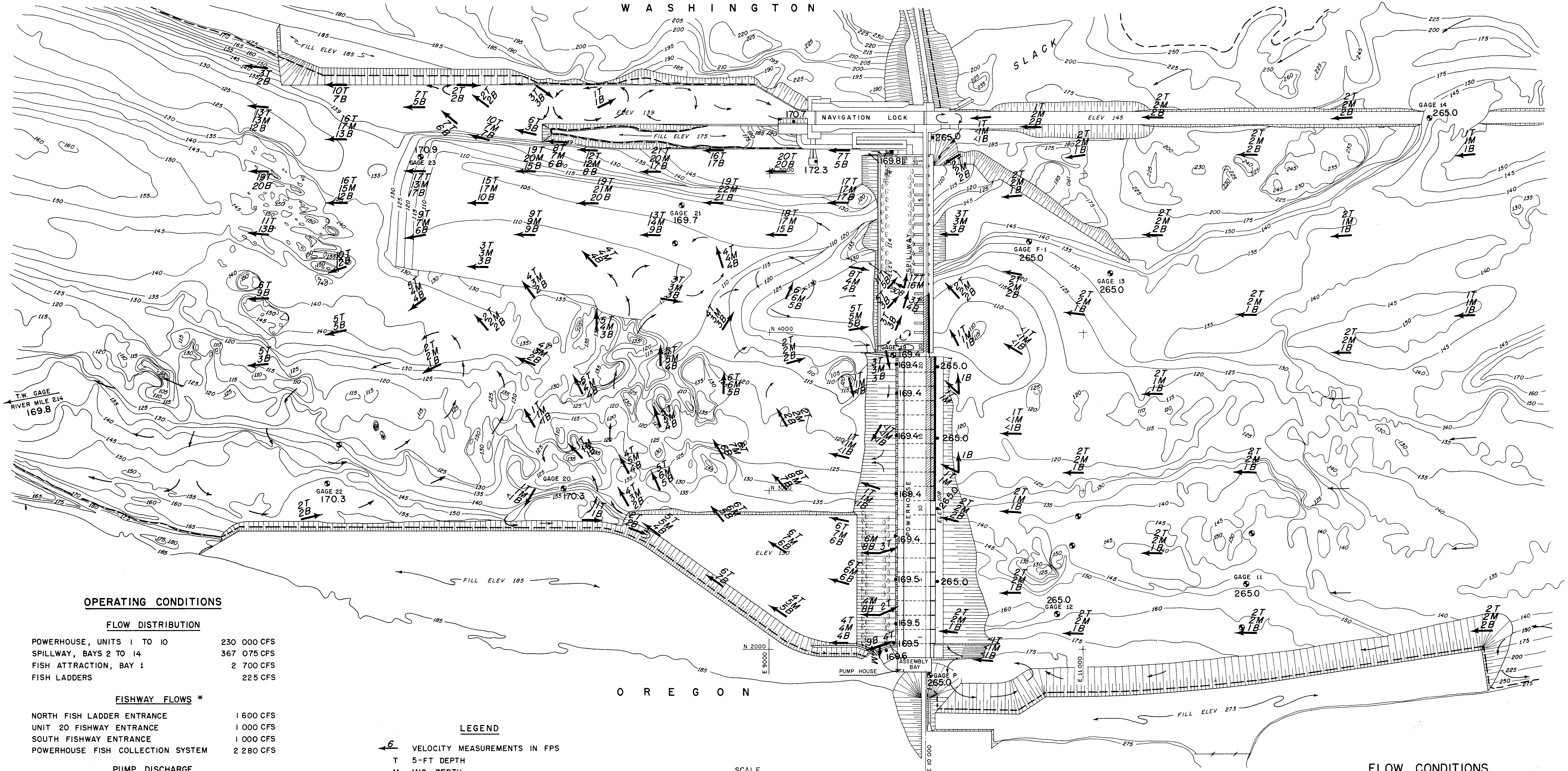
←5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.2 ●	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 600 000 CFS
SPILLWAY GATES 2 TO 20 CROWNED



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	230 000 CFS
SPILLWAY, BAYS 2 TO 14	367 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 600 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 500 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

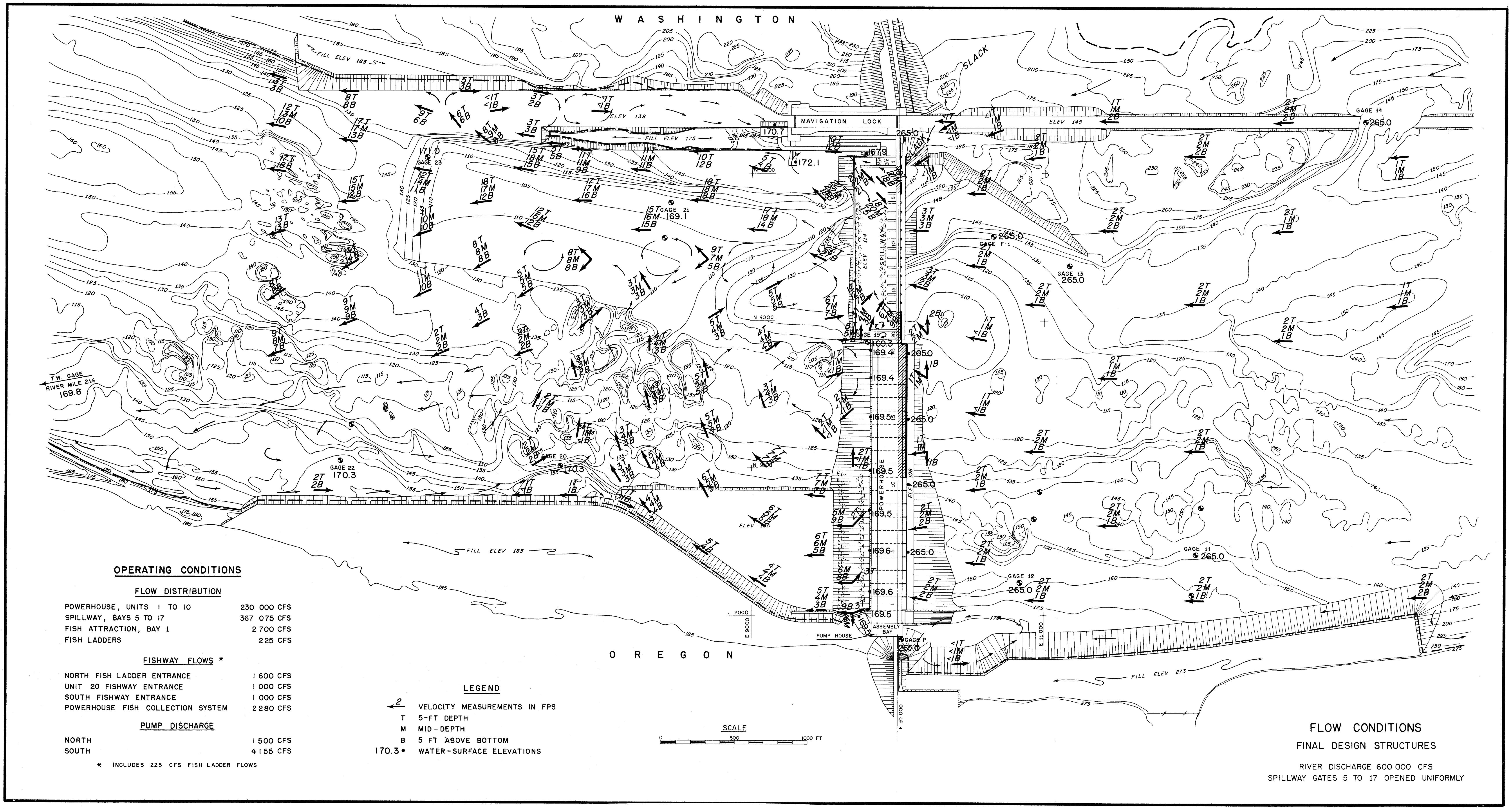
6 ←	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.3 •	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 600 000 CFS
SPILLWAY GATES 2 TO 14 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	230 000 CFS
SPILLWAY, BAYS 5 TO 17	367 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 600 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 500 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

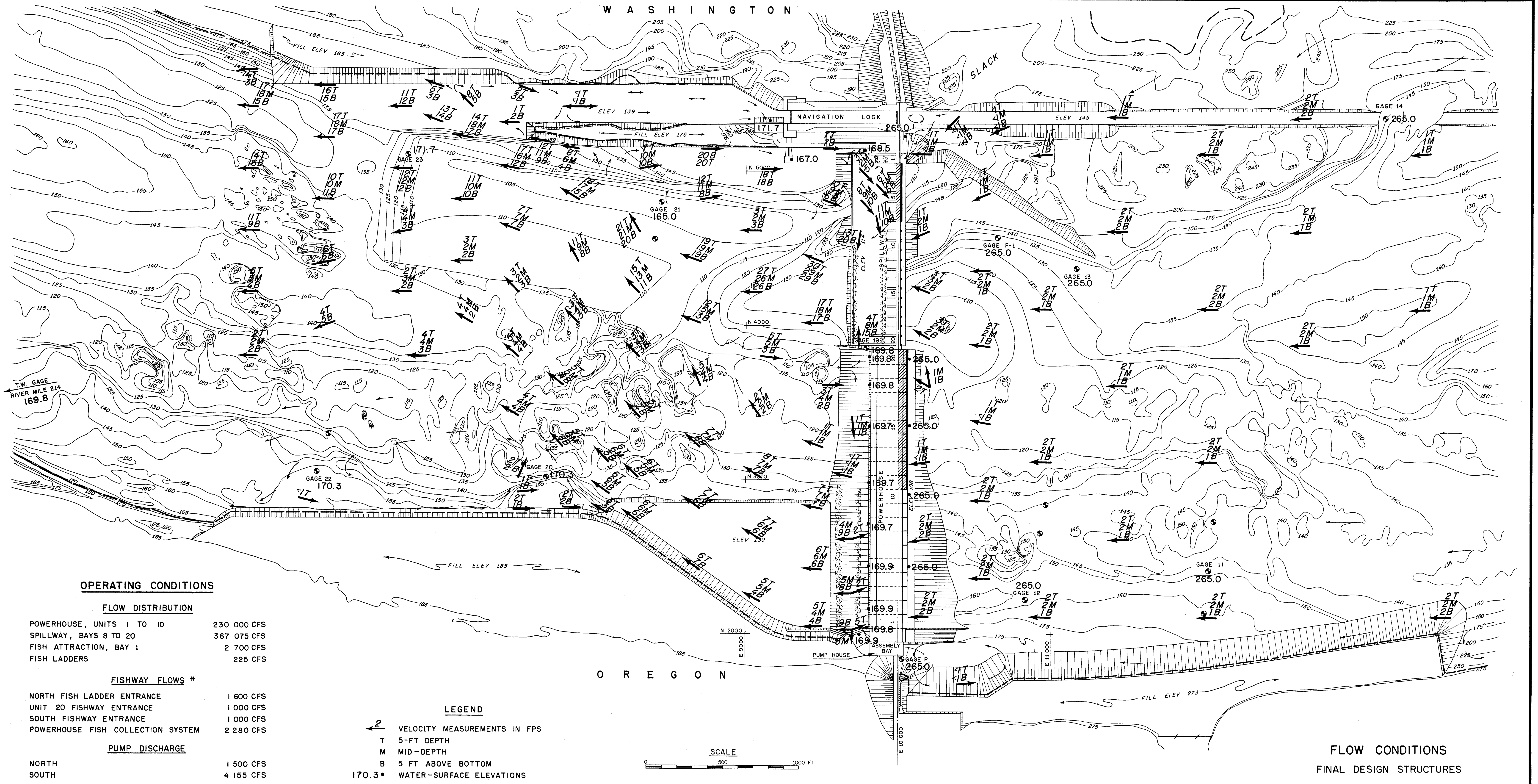
← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.3 ●	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 600 000 CFS
SPILLWAY GATES 5 TO 17 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	230 000 CFS
SPILLWAY, BAYS 8 TO 20	367 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 600 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 500 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

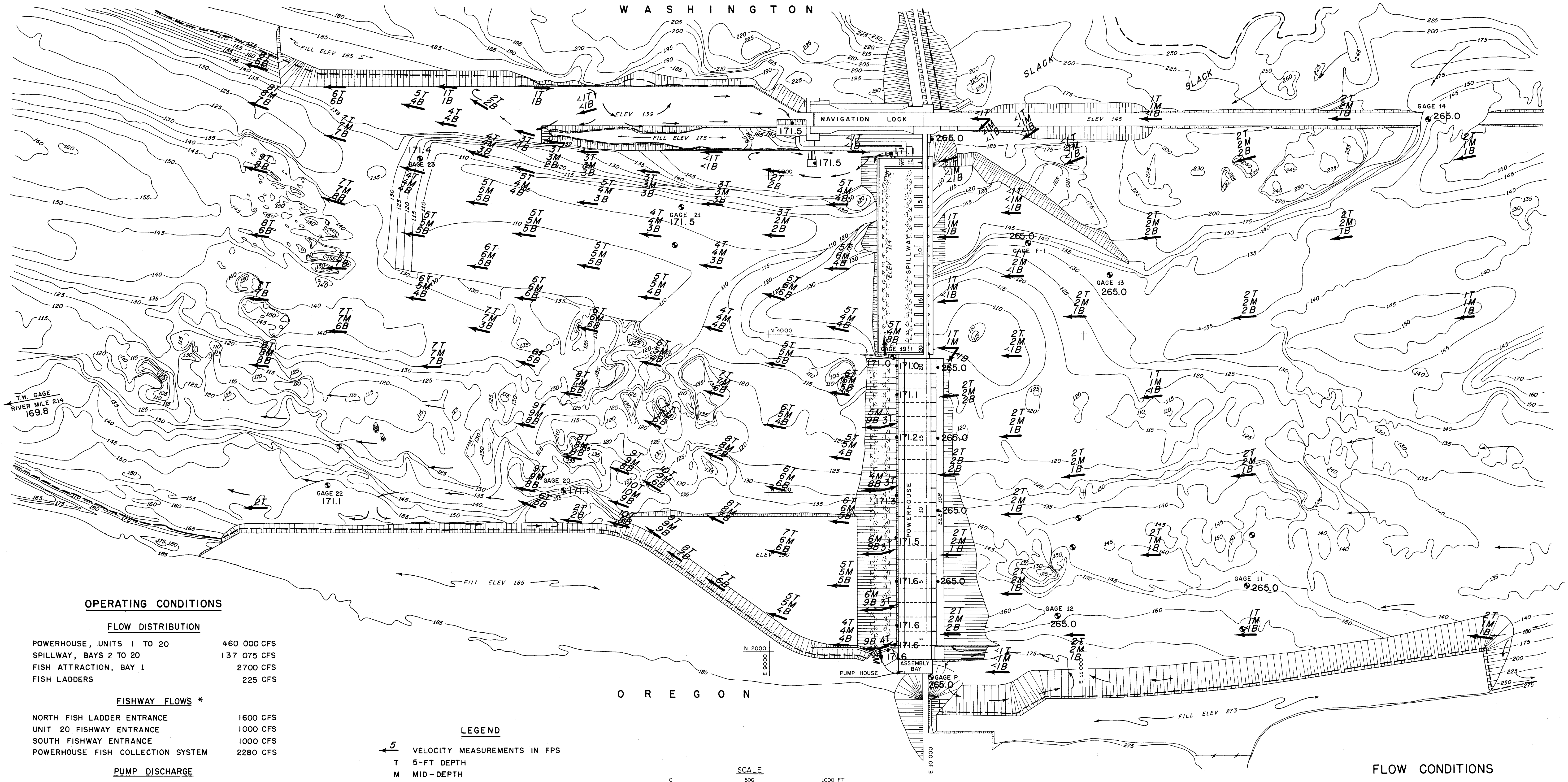
LEGEND

← 2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
170.3 •	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 600 000 CFS
SPILLWAY GATES 8 TO 20 OPENED UNIFORMLY



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 20	460 000 CFS
SPILLWAY, BAYS 2 TO 20	137 075 CFS
FISH ATTRACTION, BAY 1	2700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1600 CFS
UNIT 20 FISHWAY ENTRANCE	1000 CFS
SOUTH FISHWAY ENTRANCE	1000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

NORTH	1500 CFS
SOUTH	4155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

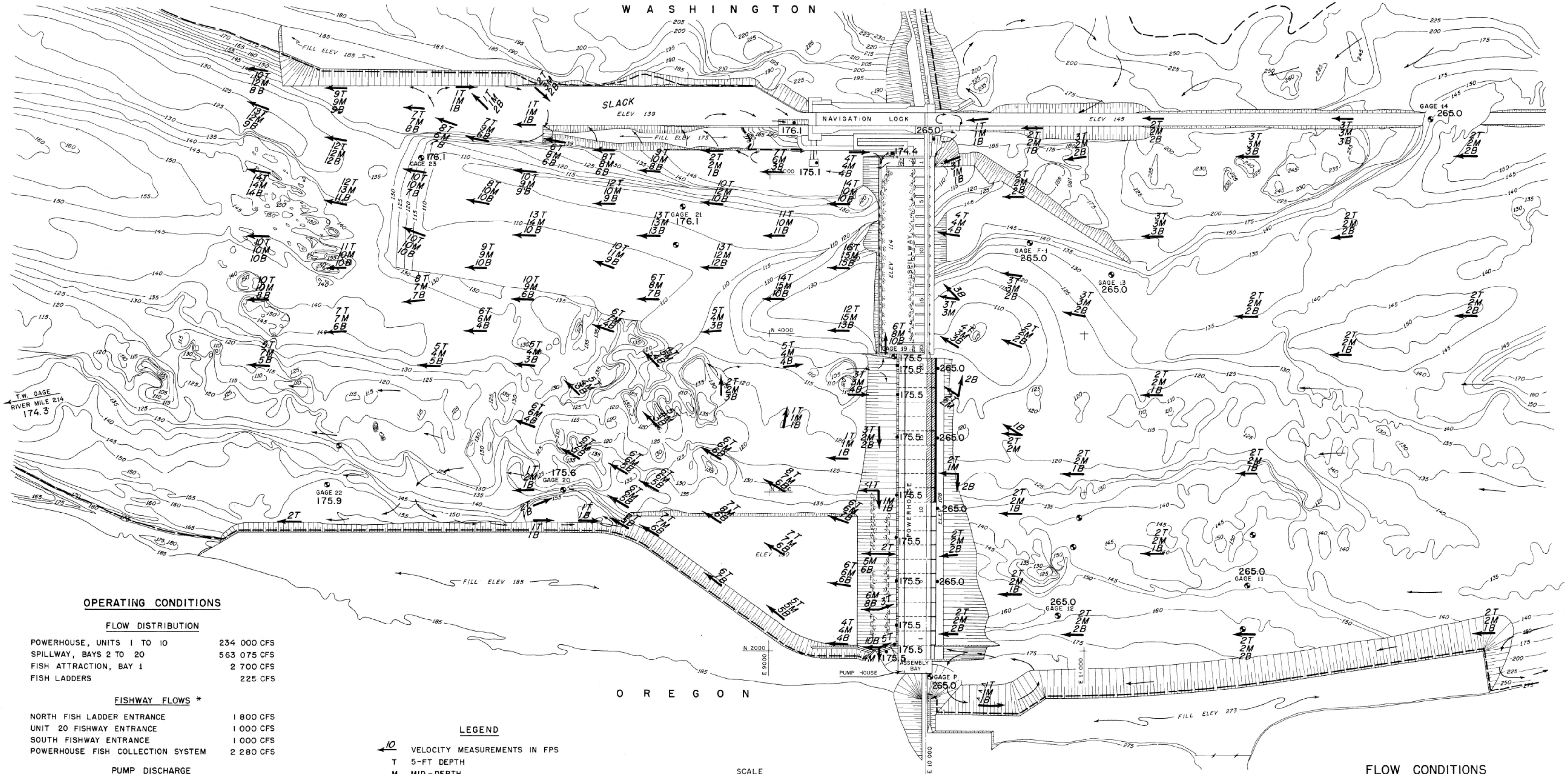
← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 600 000 CFS
20 POWER HOUSE UNITS OPERATED

PLATE 111



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	234 000 CFS
SPILLWAY, BAYS 2 TO 20	563 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 800 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 700 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

← 10	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
175.9 ●	WATER-SURFACE ELEVATIONS

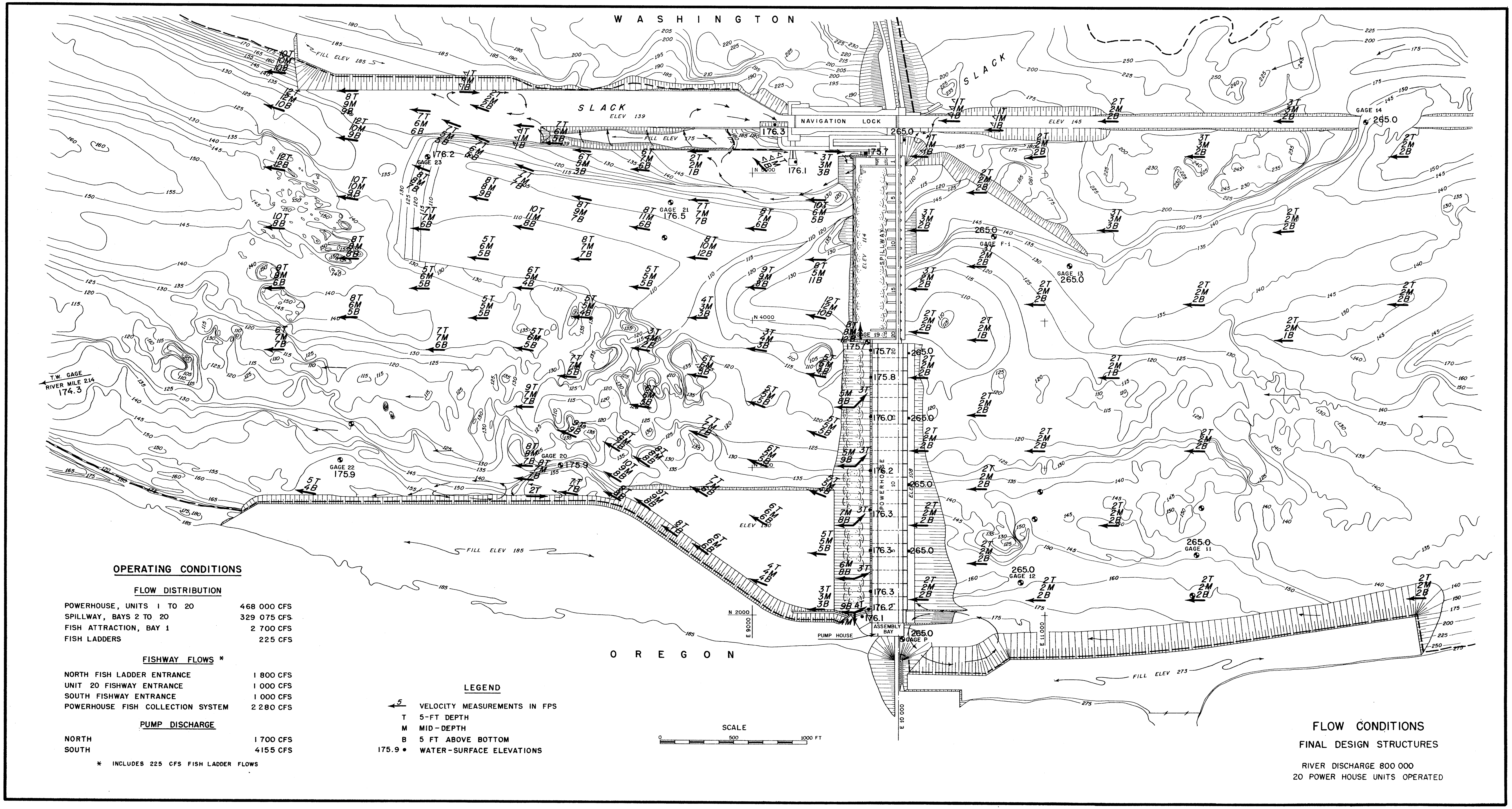
SCALE

0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 800 000 CFS
10 POWER HOUSE UNITS OPERATED



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 20	468 000 CFS
SPILLWAY, BAYS 2 TO 20	329 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 800 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 700 CFS
SOUTH	4155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

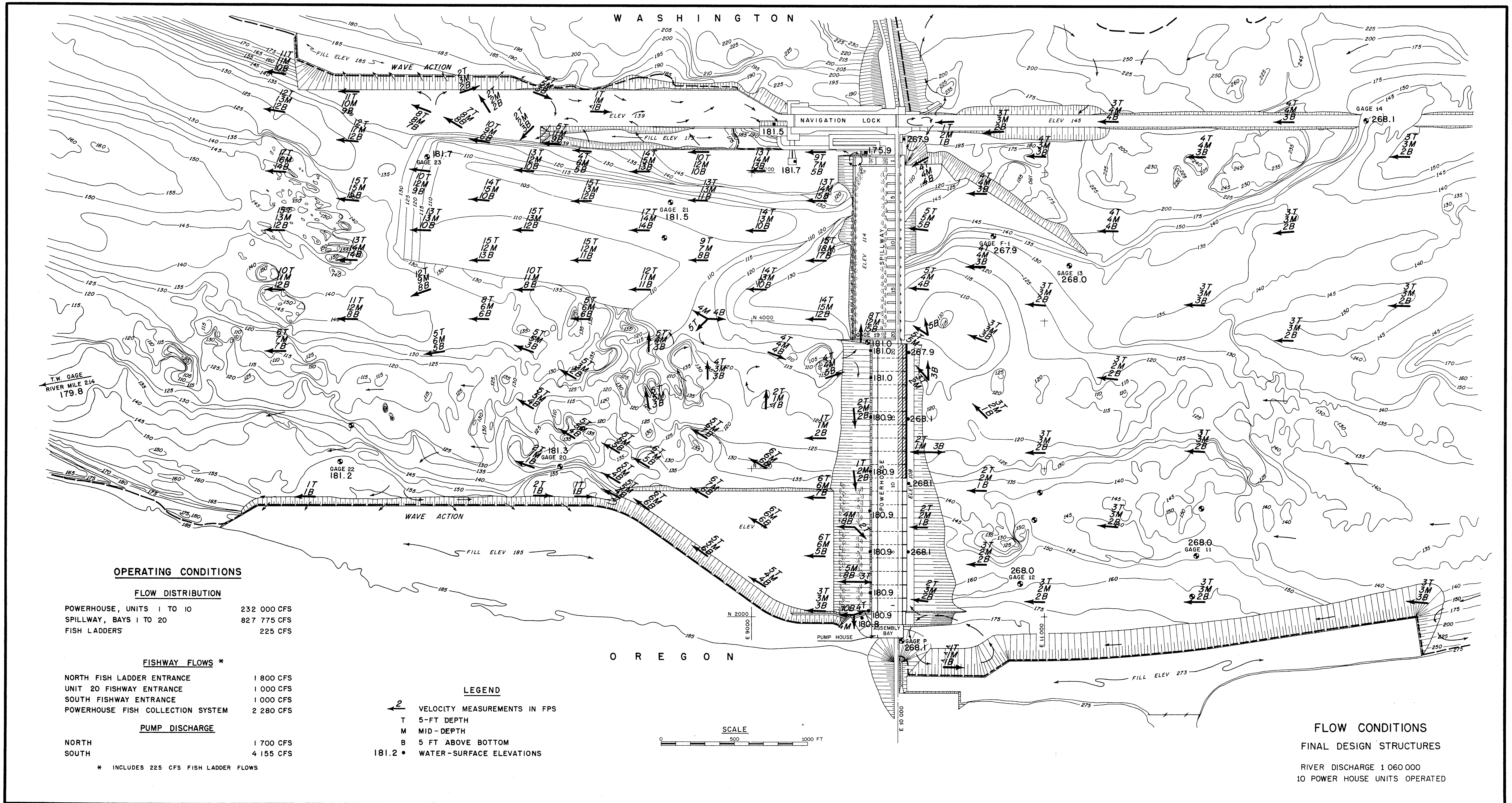
← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
175.9 ●	WATER-SURFACE ELEVATIONS

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 800 000
20 POWER HOUSE UNITS OPERATED

PLATE 113



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	232 000 CFS
SPILLWAY, BAYS 1 TO 20	827 775 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 800 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 700 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

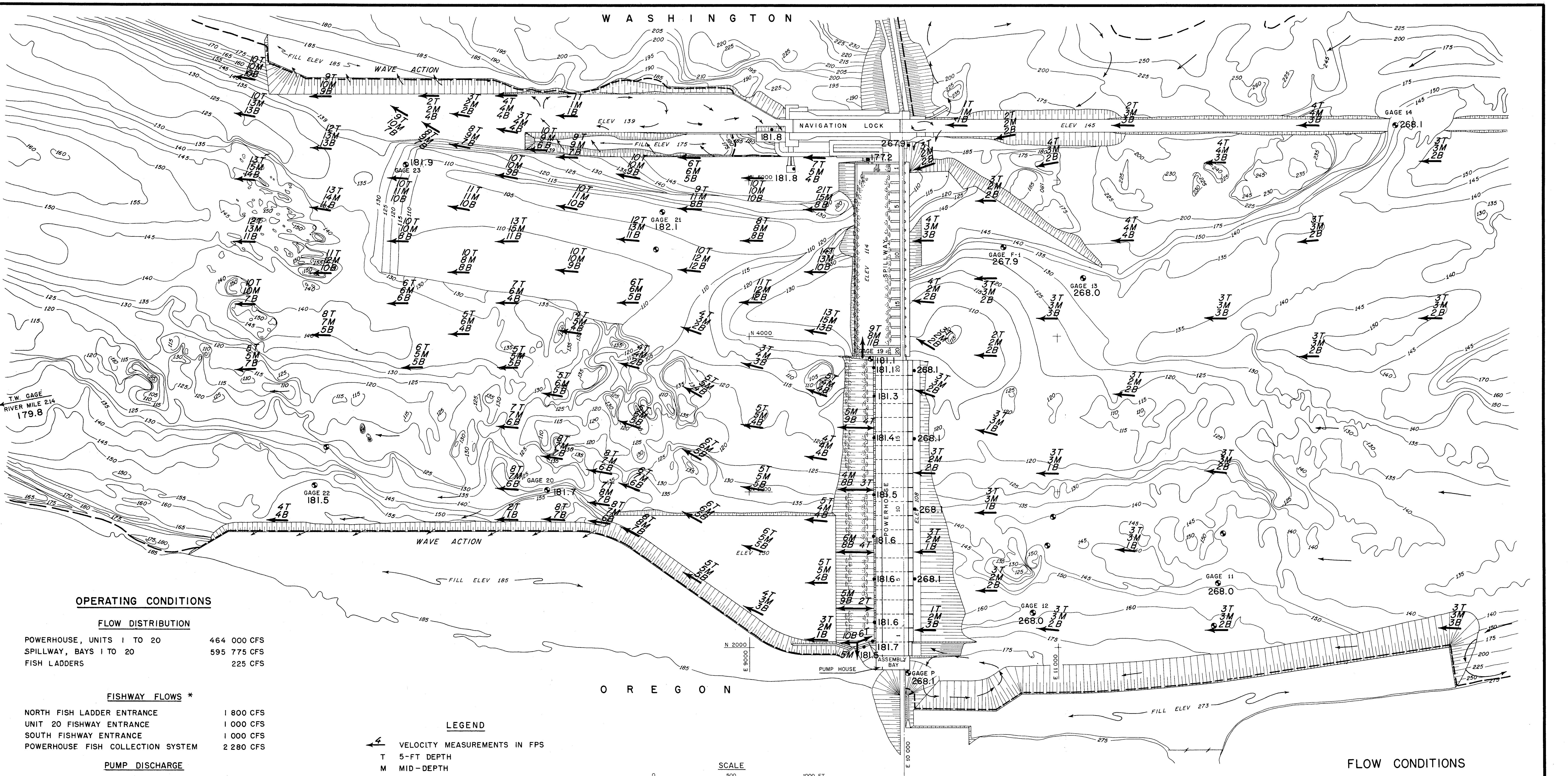
←2	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
181.2 •	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

FLOW CONDITIONS

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 1 060 000
10 POWER HOUSE UNITS OPERATED



OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 20	464 000 CFS
SPILLWAY, BAYS 1 TO 20	595 775 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 800 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

NORTH	1 700 CFS
SOUTH	4 155 CFS

* INCLUDES 225 CFS FISH LADDER FLOWS

LEGEND

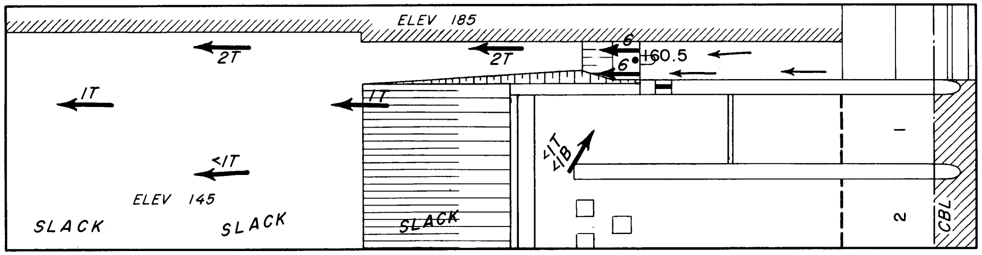
↙4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
181.5 ●	WATER-SURFACE ELEVATIONS

SCALE
0 500 1000 FT

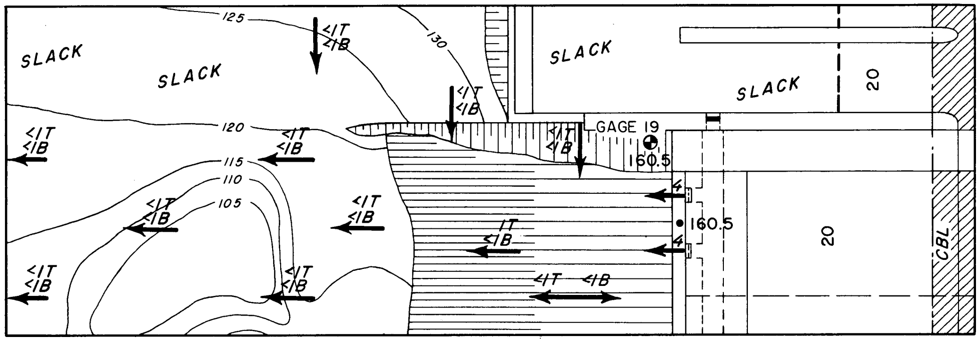
FLOW CONDITIONS

FINAL DESIGN STRUCTURES

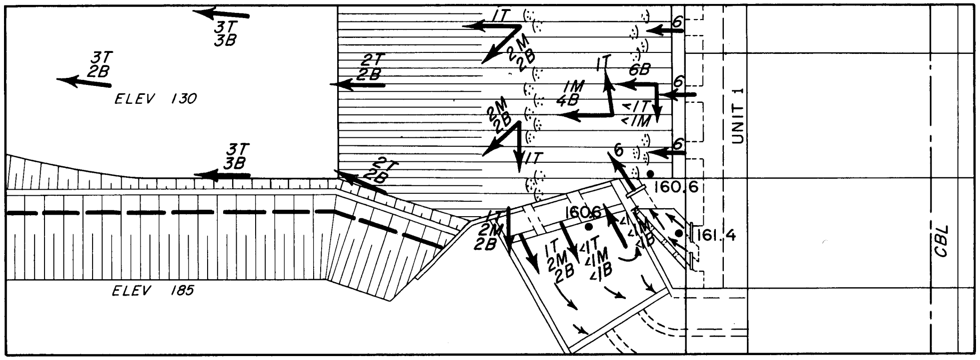
RIVER DISCHARGE 1 060 000 CFS
20 POWER HOUSE UNITS OPERATED



NORTH FISH LADDER ENTRANCE



UNIT 20 FISHWAY ENTRANCE



SOUTH FISHWAY ENTRANCE

LEGEND

← 6	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
160.5 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10		99 775 CFS
SPILLWAY BAYS 2 TO 20	CLOSED	0 CFS
FISH ATTRACTION, BAY 1	CLOSED	0 CFS
FISH LADDERS		225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	700 CFS
UNIT 20 FISHWAY ENTRANCE	600 CFS
SOUTH FISHWAY ENTRANCE	700 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

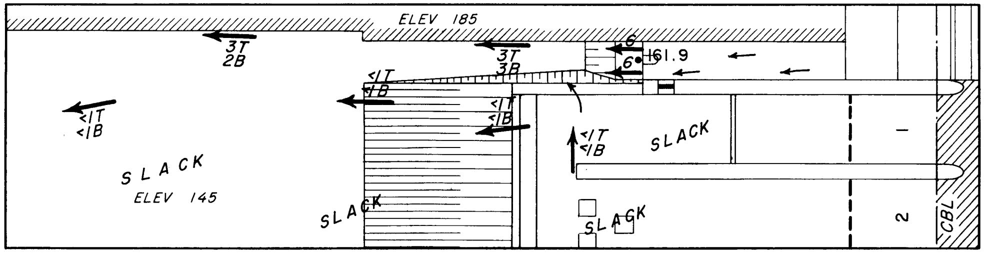
NORTH	600 CFS
SOUTH	3455 CFS

*INCLUDES 112.5 CFS IN EACH FISH LADDER

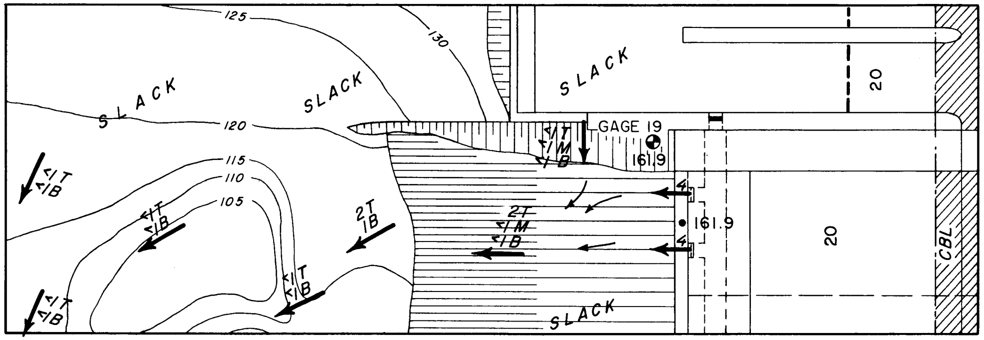
VELOCITIES AT FISHWAY ENTRANCES

FINAL DESIGN STRUCTURES

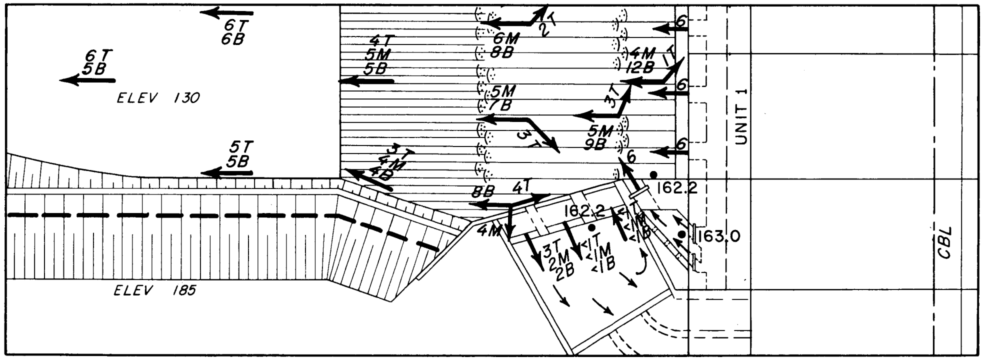
RIVER DISCHARGE 100 000 CFS



NORTH FISH LADDER ENTRANCE



UNIT 20 FISHWAY ENTRANCE



SOUTH FISHWAY ENTRANCE

LEGEND

←5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
161.9 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	199 775 CFS
SPILLWAY BAYS 2 TO 20 CLOSED	0 CFS
FISH ATTRACTION, BAY 1 CLOSED	0 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1000 CFS
UNIT 20 FISHWAY ENTRANCE	620 CFS
SOUTH FISHWAY ENTRANCE	700 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

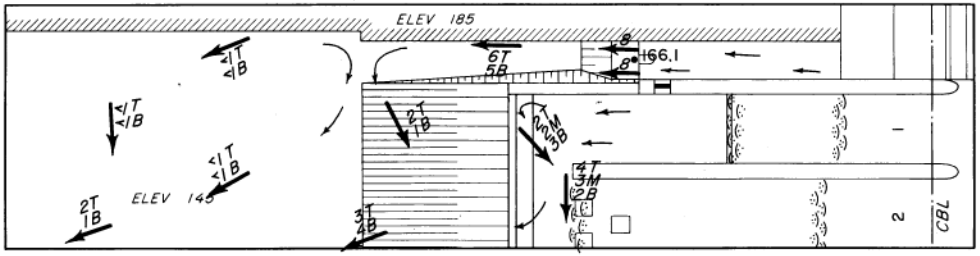
NORTH	900 CFS
SOUTH	3 475 CFS

* INCLUDES 112.5 CFS IN EACH FISH LADDER

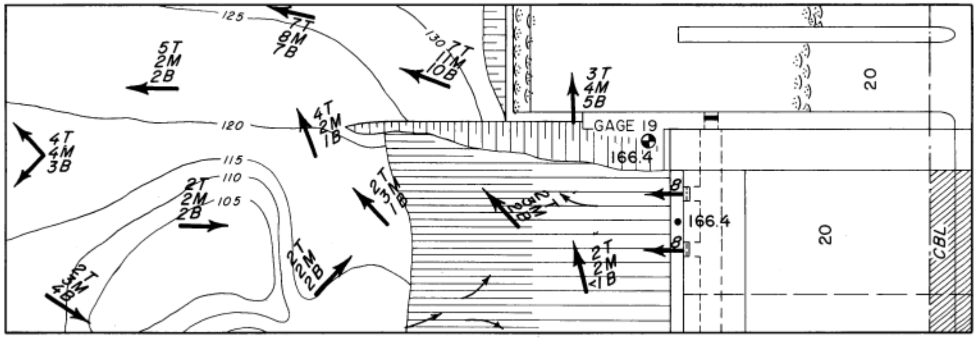
VELOCITIES AT FISHWAY ENTRANCES

FINAL DESIGN STRUCTURES

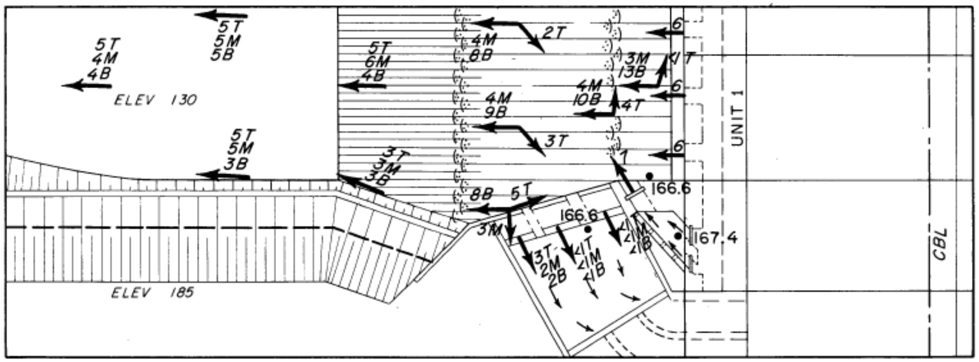
RIVER DISCHARGE 200 000 CFS



NORTH FISH LADDER ENTRANCE



UNIT 20 FISHWAY ENTRANCE



SOUTH FISHWAY ENTRANCE

LEGEND

← 5 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
166.6 ● WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	214 000 CFS
SPILLWAY BAYS 2 TO 20	183 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 300 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

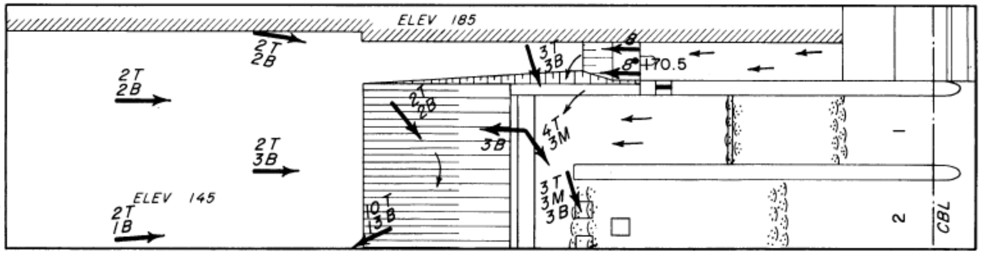
NORTH	1 200 CFS
SOUTH	4 155 CFS

*INCLUDES 112.5 CFS IN EACH FISH LADDER

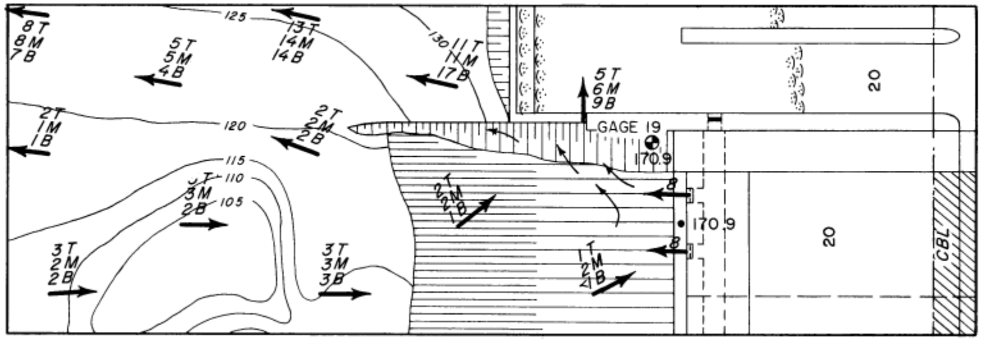
VELOCITIES AT FISHWAY ENTRANCES

FINAL DESIGN STRUCTURES

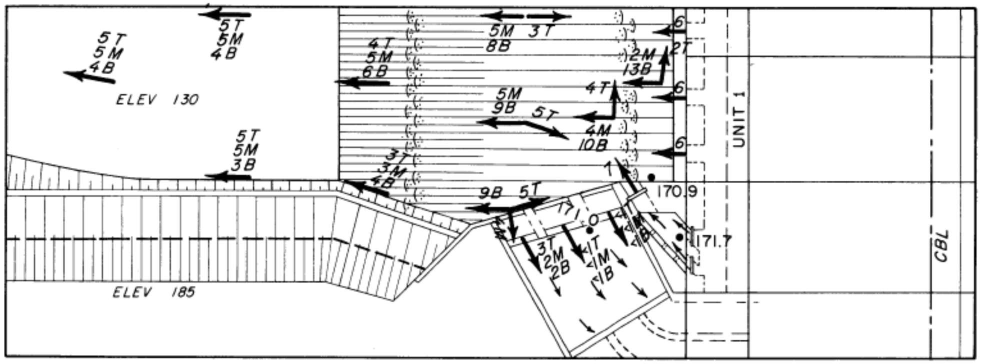
RIVER DISCHARGE 400 000 CFS



NORTH FISH LADDER ENTRANCE



UNIT 20 FISHWAY ENTRANCE



SOUTH FISHWAY ENTRANCE

LEGEND

← 2 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
170.5 ● WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	230 000 CFS
SPILLWAY BAYS 2 TO 20	367 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1600 CFS
UNIT 20 FISHWAY ENTRANCE	1000 CFS
SOUTH FISHWAY ENTRANCE	1000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2280 CFS

PUMP DISCHARGE

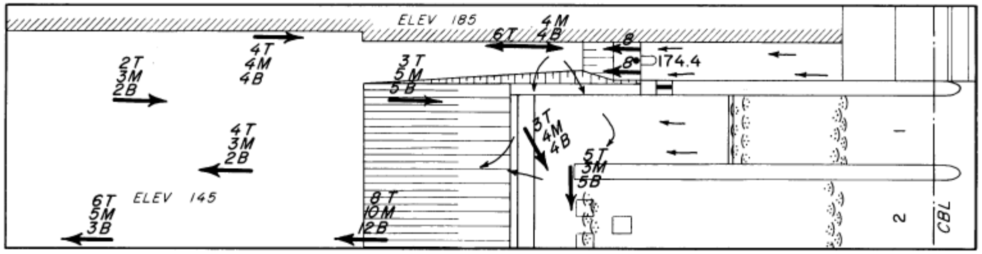
NORTH	1500 CFS
SOUTH	4155 CFS

* INCLUDES 112.5 CFS IN EACH FISH LADDER

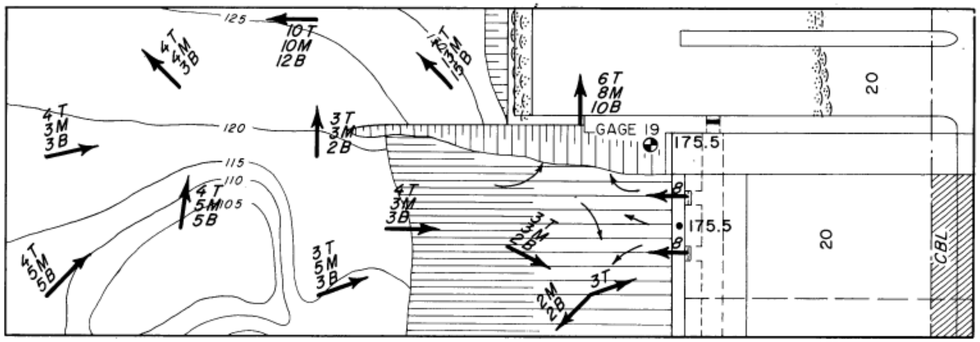
VELOCITIES AT FISHWAY ENTRANCES

FINAL DESIGN STRUCTURES

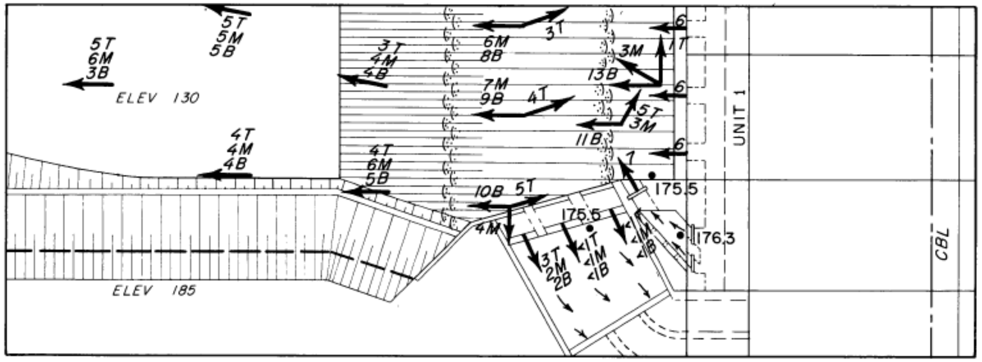
RIVER DISCHARGE 600 000 CFS



NORTH FISH LADDER ENTRANCE



UNIT 20 FISHWAY ENTRANCE



SOUTH FISHWAY ENTRANCE

LEGEND

← 5	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
174.4 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

FLOW DISTRIBUTION

POWERHOUSE, UNITS 1 TO 10	234 000 CFS
SPILLWAY BAYS 2 TO 20	563 075 CFS
FISH ATTRACTION, BAY 1	2 700 CFS
FISH LADDERS	225 CFS

FISHWAY FLOWS *

NORTH FISH LADDER ENTRANCE	1 800 CFS
UNIT 20 FISHWAY ENTRANCE	1 000 CFS
SOUTH FISHWAY ENTRANCE	1 000 CFS
POWERHOUSE FISH COLLECTION SYSTEM	2 280 CFS

PUMP DISCHARGE

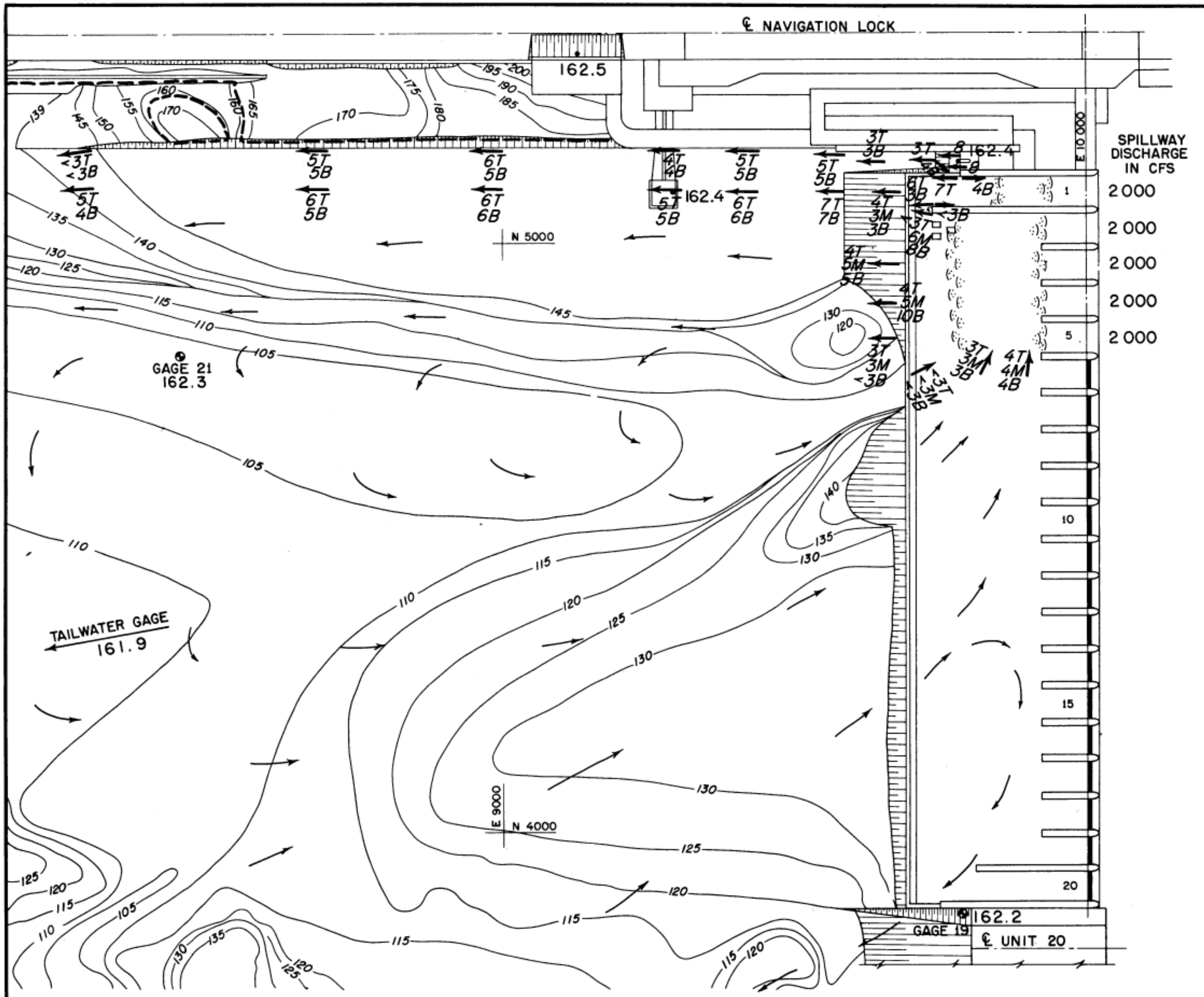
NORTH	1 700 CFS
SOUTH	4 155 CFS

* INCLUDES 112.5 CFS IN EACH FISH LADDER

VELOCITIES AT FISHWAY ENTRANCES

FINAL DESIGN STRUCTURES

RIVER DISCHARGE 800 000 CFS



LEGEND

$\xleftarrow{4}$	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
162.2 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

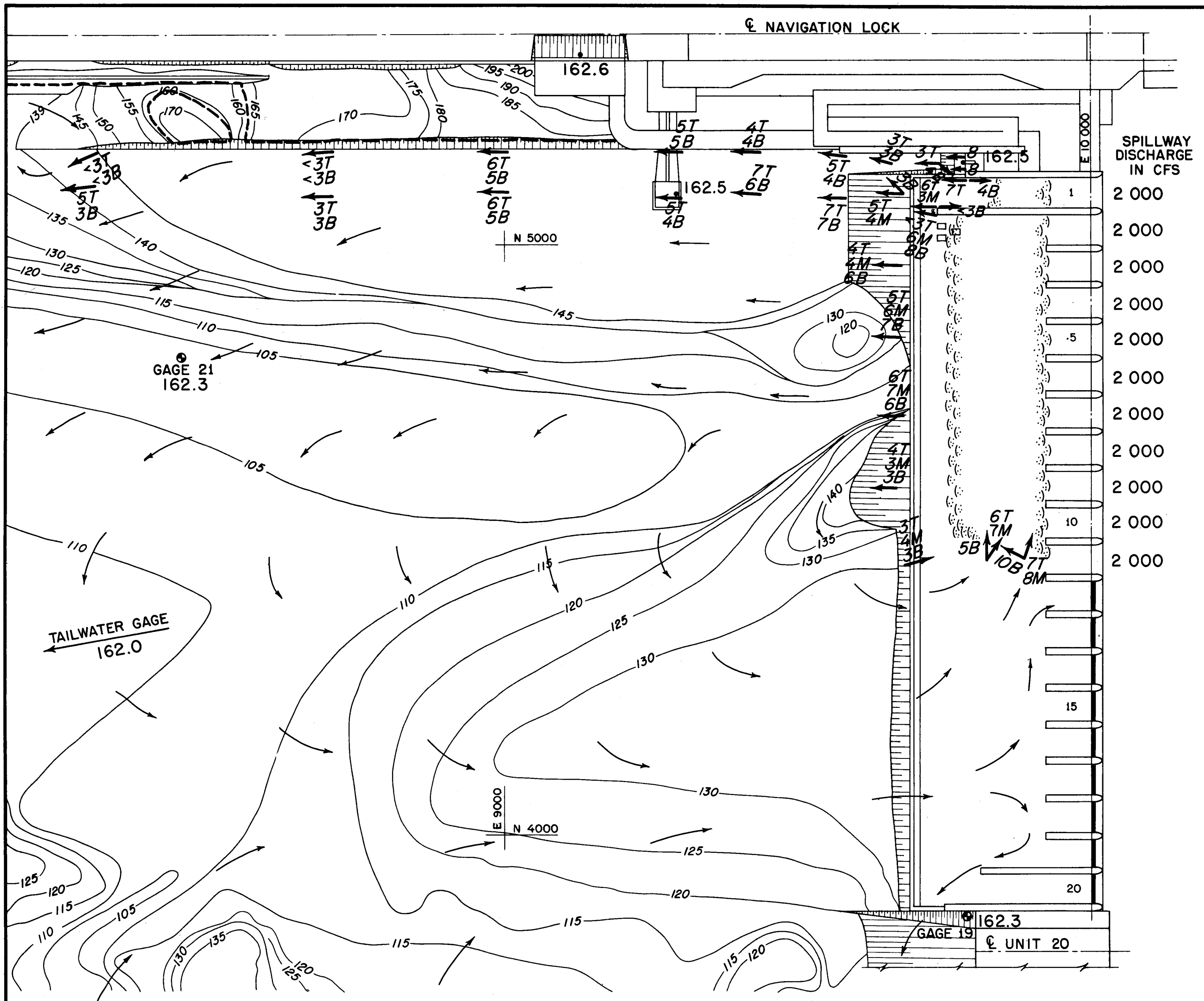
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	10 000 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 210 000 CFS



LEGEND

← 4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
162.3●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

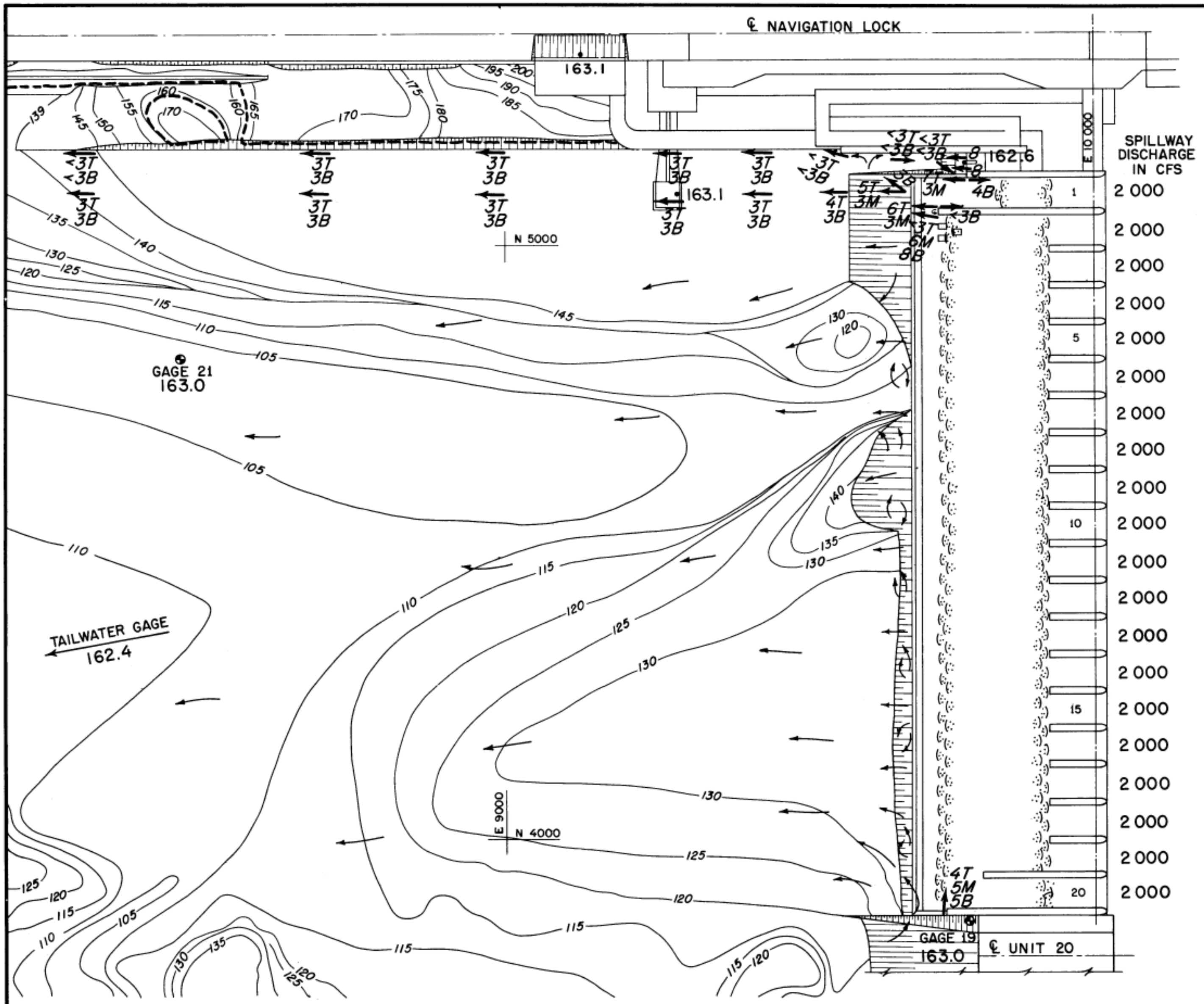
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	22 000 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 222 000 CFS



LEGEND

← 4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
163.0 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

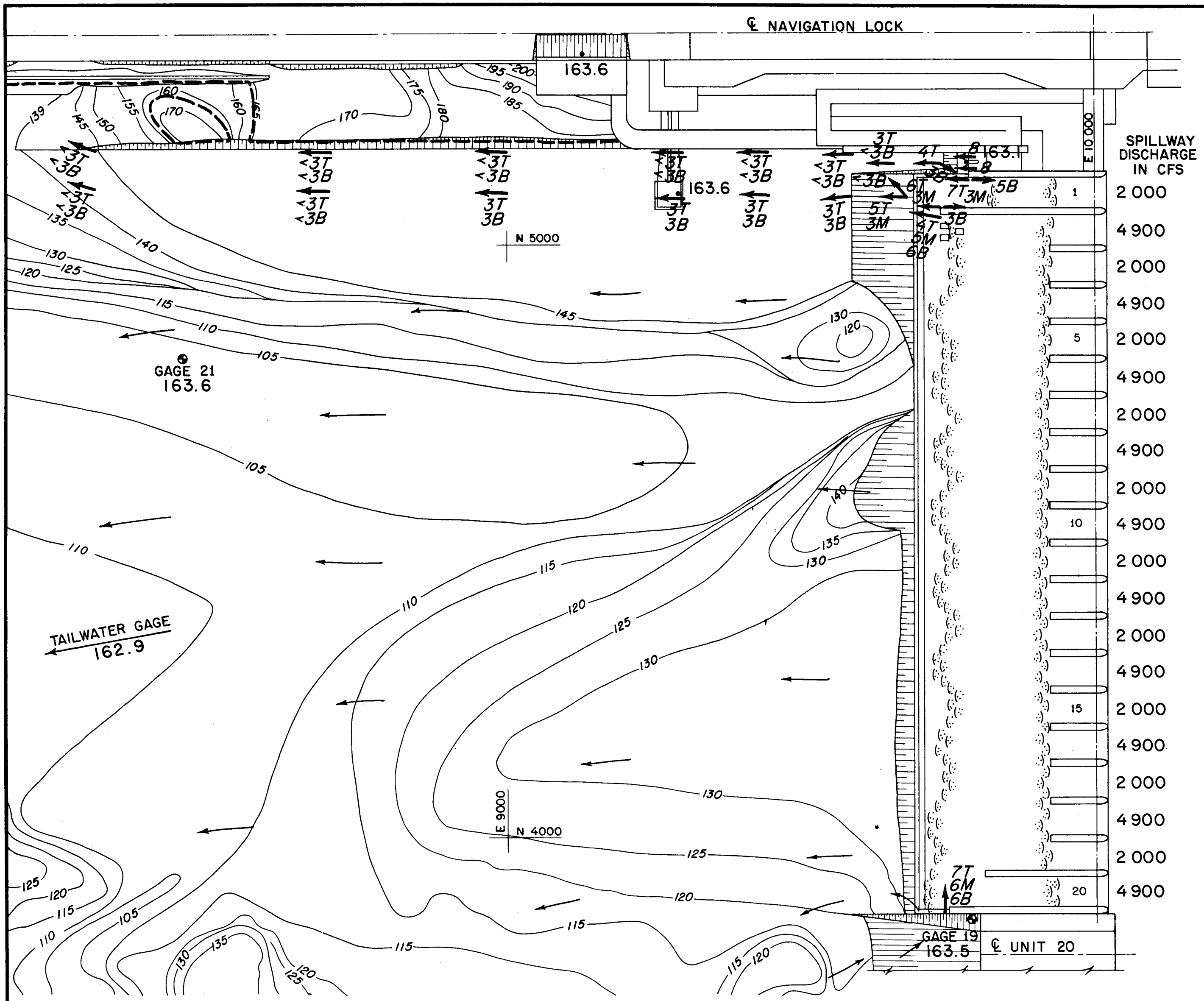
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	40 000 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 240 000 CFS



LEGEND

4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
163.5 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

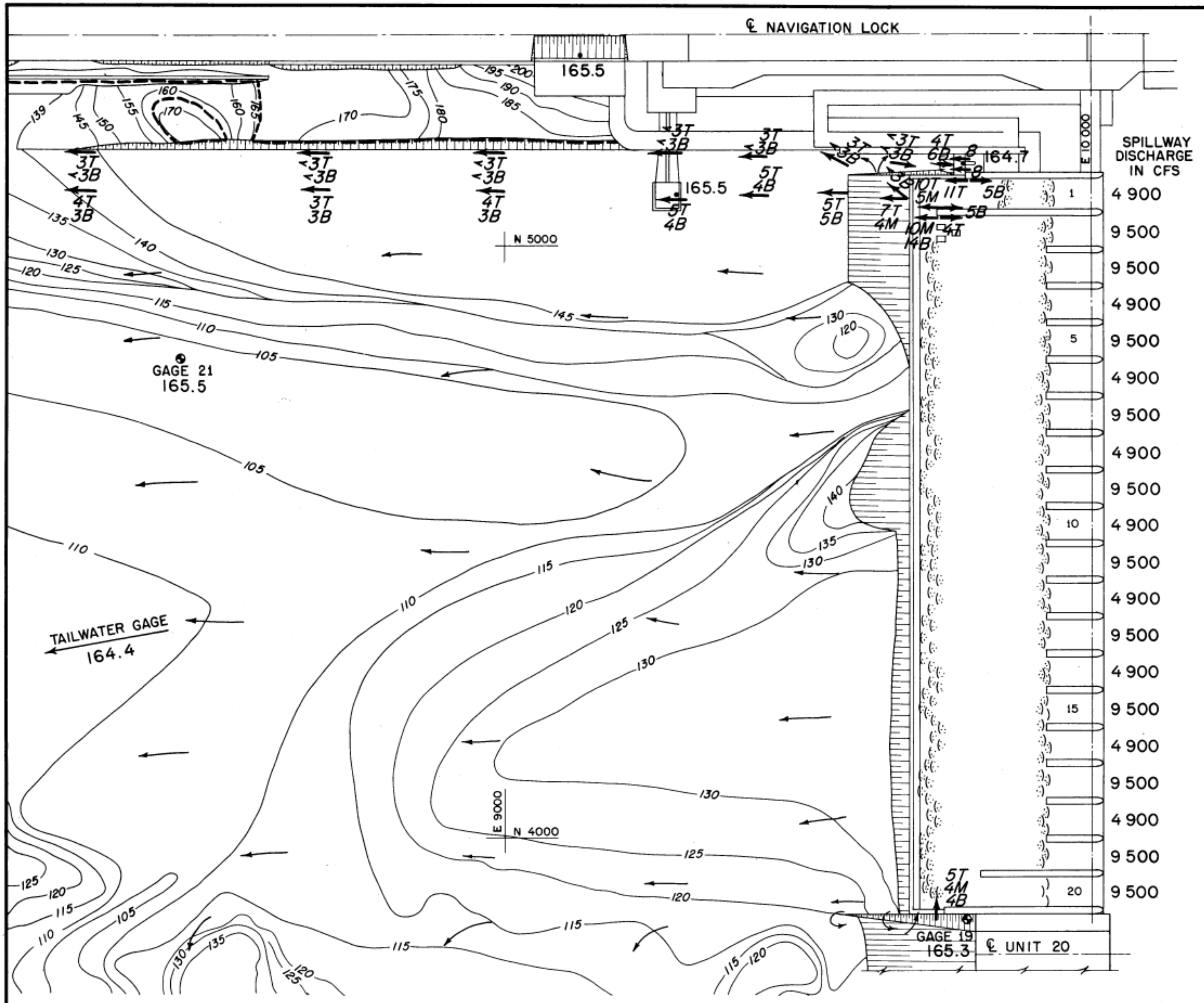
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	69 000 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 269 000 CFS



LEGEND

4 (arrow)	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
165.3 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

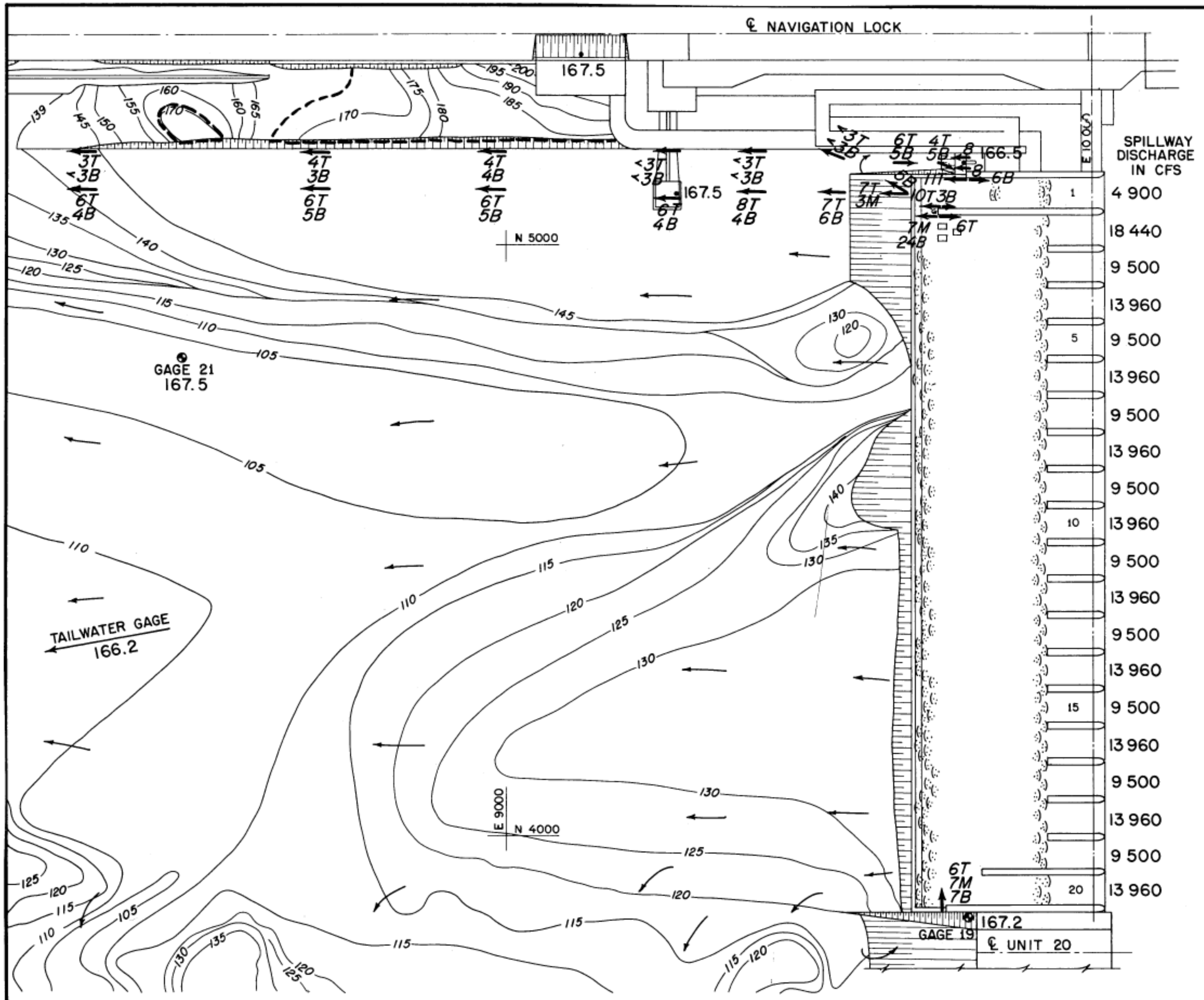
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	148 600 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 348 600 CFS



LEGEND

4 ← VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
167.2 ● WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

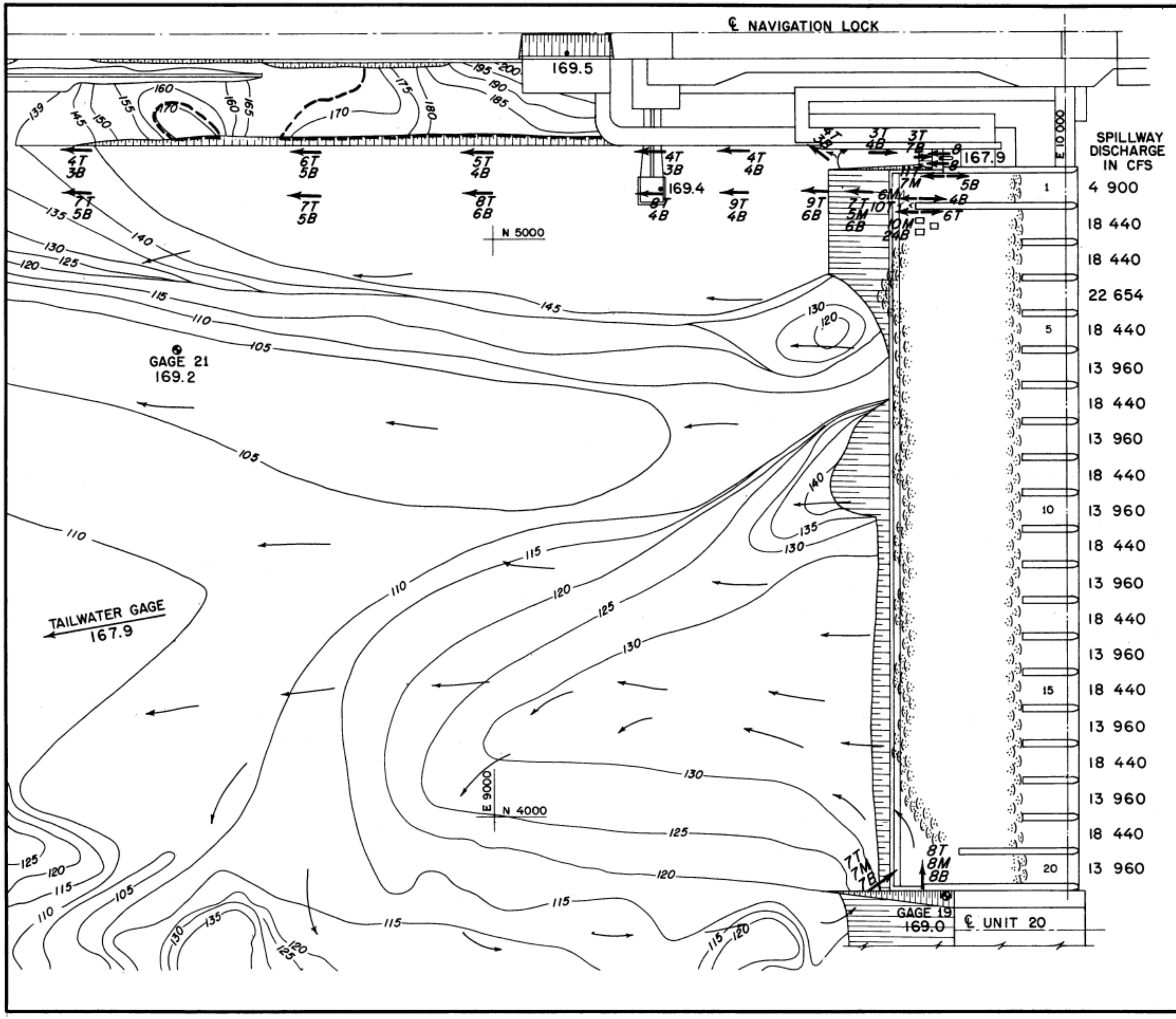
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	234 480 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 434 480 CFS



LEGEND

← 4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
167.9 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

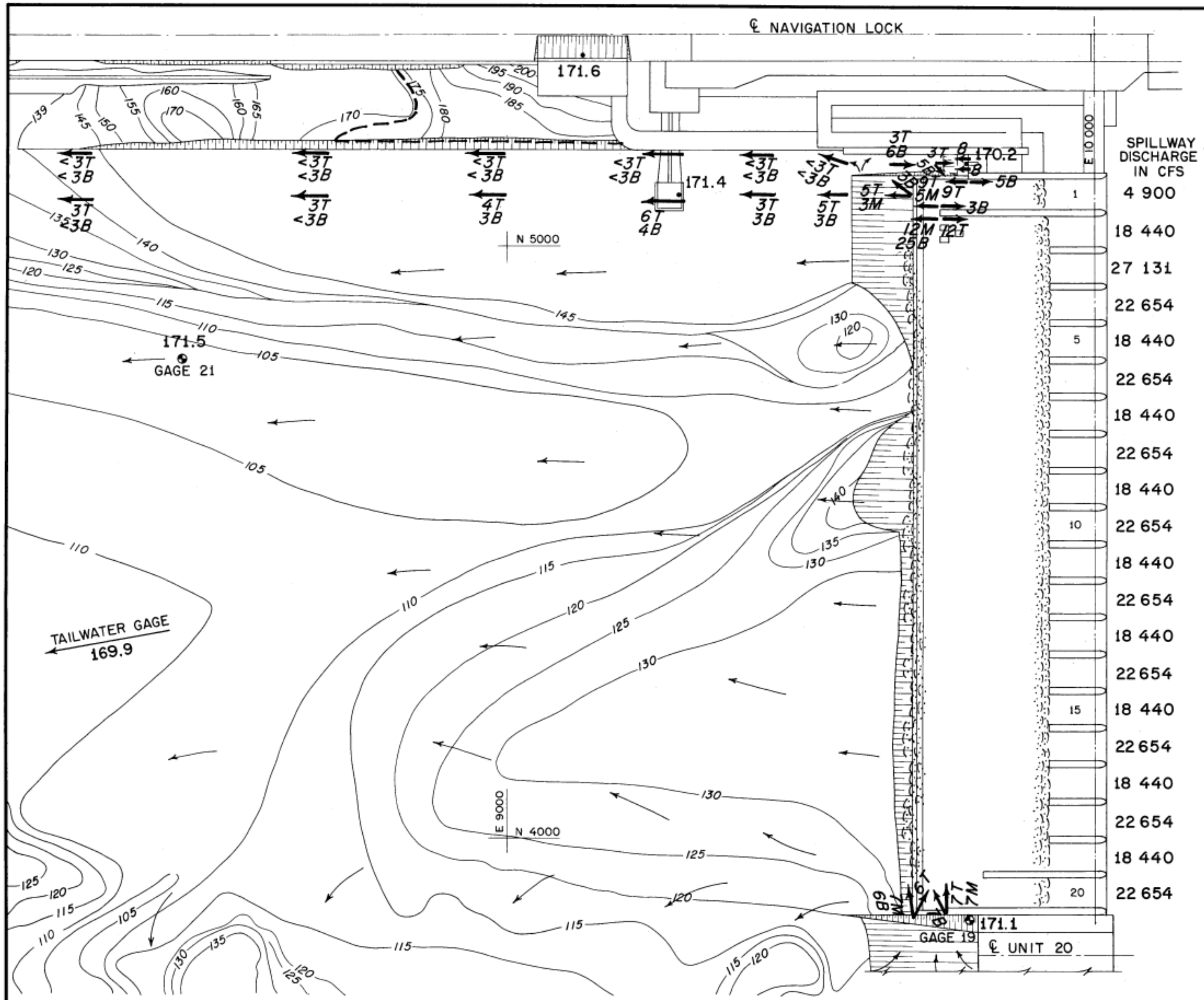
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	323 634 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 523 634 CFS



LEGEND

← 4	VELOCITY MEASUREMENTS IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
171.1 ●	WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

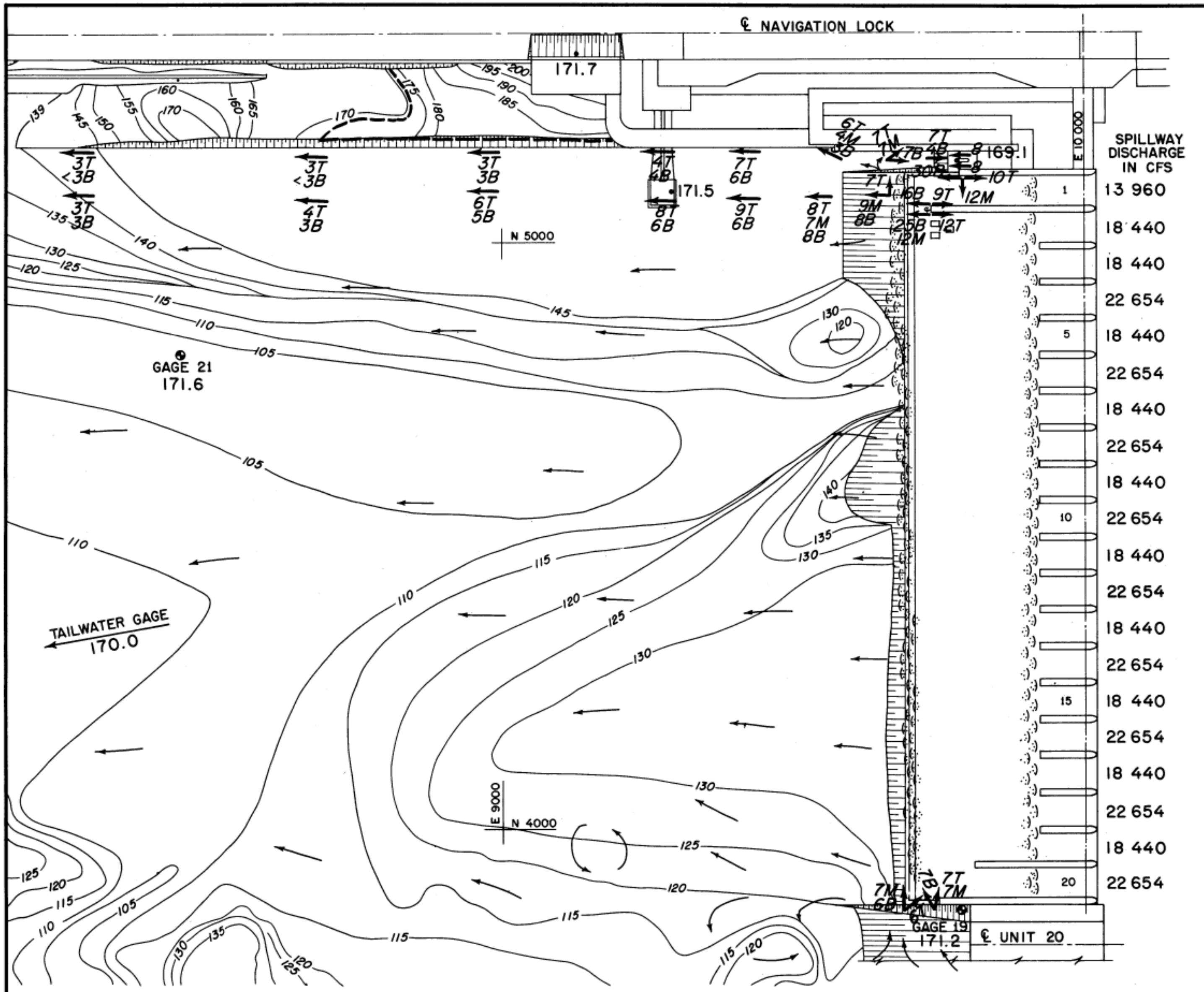
POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	401 877 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

RIVER DISCHARGE 601 877 CFS



LEGEND

← 4 VELOCITY MEASUREMENTS IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
171.2 • WATER-SURFACE ELEVATIONS

OPERATING CONDITIONS

POWERHOUSE DISCHARGE	200 000 CFS
SPILLWAY DISCHARGE	402 246 CFS
THE DALLES POOL ELEV	160.0
JOHN DAY POOL ELEV	265.0

POWERHOUSE UNITS 1 TO 10 OPERATING

FLOW CONDITIONS

NONUNIFORM SPILLWAY OPERATION

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13. ABSTRACT

The John Day Project includes a 20-bay spillway, a 20-unit powerhouse (ultimate installation), a single-lift navigation lock 86 ft wide by 675 ft long with a maximum lift of 113 ft, and a 24-ft-wide fish ladder on each bank of the river. Average head on the structures is about 105 ft. Excavation requirements, diversion plans, structures locations, and methods of project operation were studied in a 1:80-scale model that reproduced 2.9 miles of river channel and pertinent overbank topography. A 1:25-scale model was used to determine maximum limits for completion of skeleton powerhouse units through which the river would be diverted during third-stage construction. Improved designs were developed for the first- and second-step cofferdams, navigation lock approaches, temporary and permanent fishway entrances, auxiliary water intake for the Oregon shore fishway, powerhouse tailrace, skeleton units, and disposal fills. Limits for an interim cofferdam on the Oregon shore were evaluated; and satisfactory methods for operation of the completed spillway and fishway entrances were determined.

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NPDEN-WC-L

14 July 1972

SUBJECT: Technical Report, Hydraulic Model Investigations

Chief, Hydraulic Laboratory Branch
Bureau of Reclamation, Hydraulic Laboratory
Building 53, Denver Federal Center
Denver, Colorado 80201

1. Inclosed for your retention is Technical Report No. 90-1, John Day Dam, Columbia River, Oregon and Washington. The report describes two of the hydraulic model studies that were made for this project by the North Pacific Division Hydraulic Laboratory. The studies were sponsored by the Walla Walla District, Corps of Engineers.

2. The project includes a 20-bay spillway, a 20-unit powerhouse, (ultimate installation), a navigation lock with a maximum single lift of 113 ft, and a fish ladder on each side of the river. A 1:80-scale model that reproduced 2.9 miles of river channel, pertinent overbank topography, and successive construction stages was used to study overall flow conditions at the project. A 1:25-scale model was used to determine maximum limits for completion of skeleton powerhouse units through which the river would be diverted during third-step construction.

FOR THE DIVISION ENGINEER:

Robert W. Baumach

1 Incl
as

GORDON H. FERNALD, JR.
Chief, Engineering Division
for