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TECHNICAL REPORT NO. 104-1

HYDRAULIC MODEL INVESTIGATION

Spillway Deflectors at Bonneville, John Day and McNary Dams on Columbia River, Oregon-Washington and Ice Harbor, Lower Monumental and Little Goose Dams on Snake River, Washington

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U. S. ARMY CORPS OF ENGINEERS
PORTLAND AND WALLA WALLA DISTRICTS

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

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McNary Dam	Spillway Deflector
Ice Harbor Dam	Columbia River
Lower Monumental Dam	Snake River

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Highly aerated water flowing over the spillways and plunging into the deep stilling basins of dams increases the nitrogen levels of the rivers to a supersaturated condition hazardous to migrating fish. The report presents data and results of model studies conducted in development of spillway deflectors for six projects on the lower Snake and Columbia Rivers. The deflectors prevent the plunging action and cause a more skimming-type flow near

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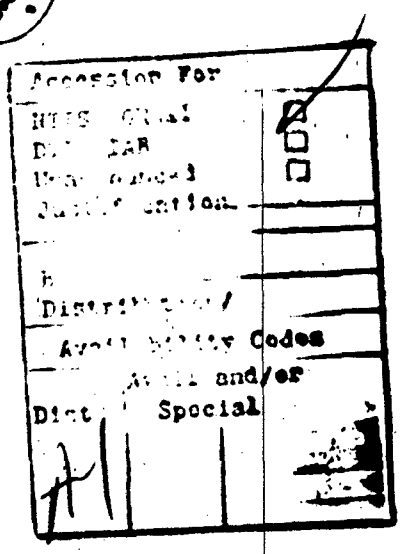
the surface of stilling basin resulting in reduced nitrogen saturation levels. The models were used to design the deflector geometries and to assist in evaluating their effect on fishway attraction flow near downstream fishway entrances at each project. Prototype measurements indicate that the deflectors have been effective in reducing nitrogen levels at the projects.



PREFACE

Hydraulic model studies for developing suitable deflectors for the spillways of the following dams were requested by the respective U.S. Army Engineer Districts, Portland (NPP) and Walla Walla (NPW) and authorized by the Division Engineer, U.S. Army Engineer Division, North Pacific (NPD) on dates indicated:

Dam	River	District	Authorization Date
Bonneville	Columbia	Portland	Not Available
John Day	Columbia	Portland	Not Available
McNary	Columbia	Walla Walla	20 Mar 1972
Ice Harbor	Snake	Walla Walla	18 Oct 1972
Lower Monumental	Snake	Walla Walla	27 Jan 1959
Little Goose	Snake	Walla Walla	30 Jul 1974

All model studies were conducted at the NPD Hydraulic Laboratory during the period August 1971 to August 1976. Similar studies for the Lower Granite project on the Snake River are published in Technical Report 121-1, Lower Granite Dam, Snake River, Washington, Hydraulic Model Investigation dated August 1984.

Personnel involved in the tests were Messrs. B. B. Bradfield, R. L. Johnson, A. G. Nissila, D. E. Fox, and R. W. Parker under the supervision of Messrs. P. E. Smith, R. L. Johnson, and A. J. Chanda (Chief, Hydraulics Branch). Director of the Laboratory was Mr. H. P. Theus. Draft reports for individual dams were prepared by Messrs. L. Z. Perkins and R. L. Johnson. This comprehensive model report of all six dams was prepared by Mr. M. M. Kubo, Seattle District Hydraulics Section.

During the course of the studies representatives from NPD, NPP, NPW, National Marine Fisheries Service, Oregon Fish and Wildlife Department, Washington Department of Fish and Game, Idaho Fish and

Game Department, and Idaho Cooperative Fisheries Unit visited the Laboratory to observe flow conditions in the models, to discuss test results, and to correlate those results with design work that was in progress. Messrs. C. O. Junge and B. E. Carnegie of the Oregon Fish and Wildlife Department assisted in the development of spillway operation schedules that provided the best possible conditions for fish passage both before and after deflectors were installed at the prototype projects.

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

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

Multiply	By	To Obtain
feet	0.3048	metres
miles	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.028317	cubic metres per second
pounds (mass)	0.4535924	kilograms
kilowatt-hours	3,600,000	joules

PART I

INTRODUCTION

SPILLWAY DEFLECTORS AT

BONNEVILLE, JOHN DAY AND MCNARY DAMS ON COLUMBIA RIVER, OREGON/WASHINGTON

AND

ICE HARBOR, LOWER MONUMENTAL AND LITTLE GOOSE DAMS ON SNAKE RIVER, WASHINGTON

Hydraulic Model Investigations

PART I: INTRODUCTION

Physical Locations

1. Bonneville, John Day, and McNary Dams are located on the Columbia River at River Miles (RM) 146.1, 215.6, and 292.0, respectively, measured from the mouth of the river where it meets the Pacific Ocean.* The imaginary center of the river is the boundary for the States of Oregon and Washington. Ice Harbor, Lower Monumental, and Little Goose Dams are located in the southeastern corner of the State of Washington and on the Snake River at RM 9.7, 41.6, and 70.3, respectively, measured from the mouth at the confluence with the Columbia River. Figure 1 is a location map for all six dams. The salient features of each dam are discussed individually in subsequent paragraphs.

2. Highly aerated and turbulent flows over the spillways and plunging into the deep stilling basins of the lower Snake and Columbia River Dams increase the nitrogen saturation of the rivers to a supersaturated state considered hazardous to the migrating fish. Feasible methods of reducing spillway flows and accompanying nitrogen supersaturation included use of upstream storage to control spring freshets, installation of additional powerhouse units, diversion through skeleton bays of the powerhouse units, and structurally modifying the spillway by construction of spillway deflectors to prevent normal spillway flows

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

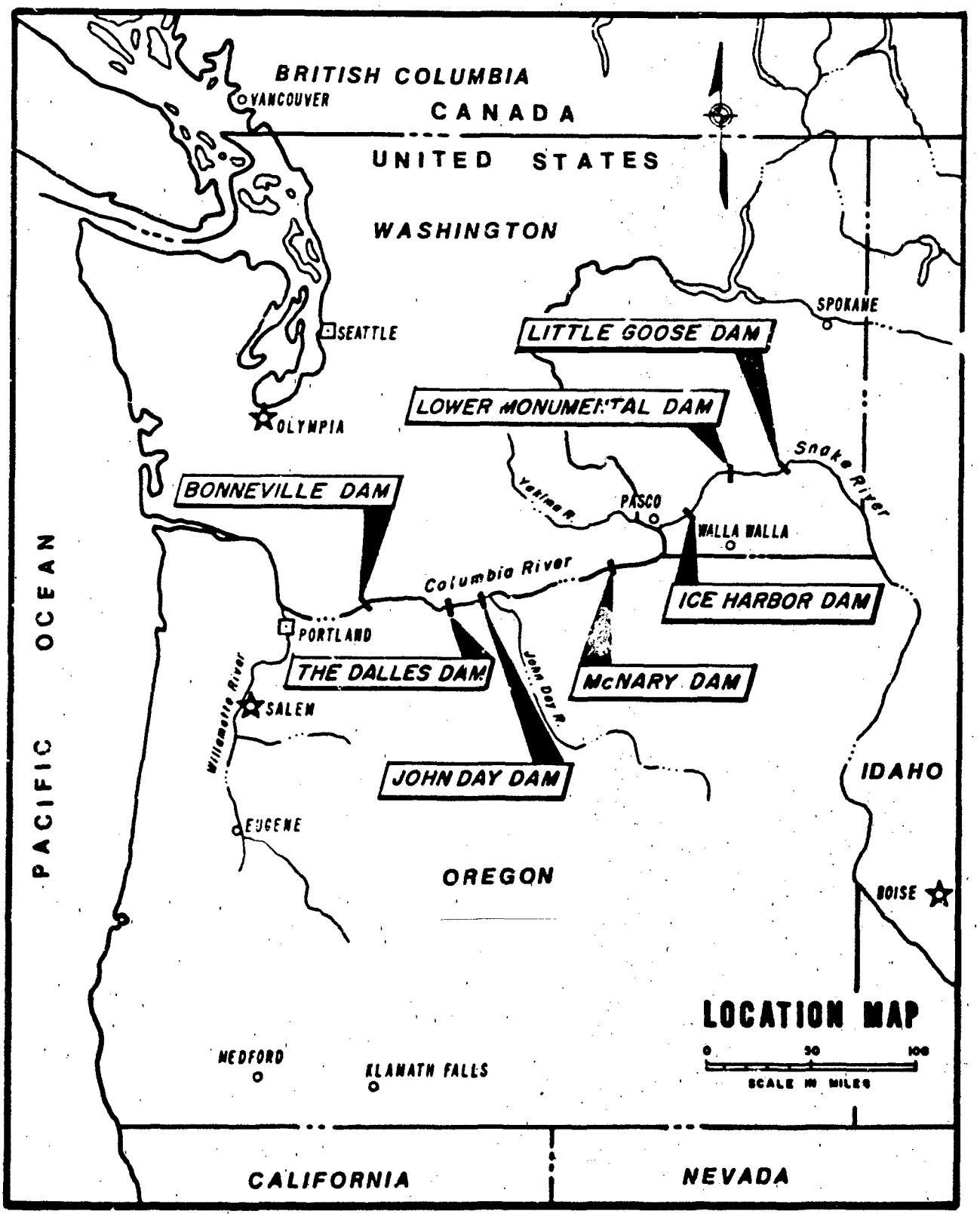
BRITISH COLUMBIA
VANCOUVER
CANADA
UNITED STATES
WASHINGTON
SEATTLE
SPOKANE
LITTLE GOOSE DAM
LOWER MONUMENTAL DAM
OLYMPIA
Snake River
BONNEVILLE DAM
Yakima R.
PASCO
WALLA WALLA
PACIFIC OCEAN
Columbia River
ICE HARBOR DAM
PORTLAND
THE DALLES DAM
McNARY DAM
John Day R.
Willamette River
SALEM
JOHN DAY DAM
IDAHO
EUGENE
OREGON
BOISE
LOCATION MAP
0 50 100
SCALE IN MILES
MEDFORD
KLAMATH FALLS
CALIFORNIA
NEVADA

Figure 1

from plunging deep into the stilling basin. Although all of these methods would help to reduce supersaturation, spillway deflectors were considered to be the most expeditious and efficient method to alleviate the problem.

Need for Model Studies

3. The unknown effects of spillway deflectors on flow conditions in stilling basins, at existing fishway entrances, and in the channel downstream from the spillway made the hydraulic model studies necessary. Each project has individual characteristics; i.e., bank and channel configuration, location of fishway entrances, and stilling-basin or roller-bucket design which necessitated individual model studies to determine the location and geometry of deflectors and the spillway operation required to provide optimum fish-passage conditions. Prototype development of the deflectors would be extremely costly and time consuming.

The Models

4. Due to the differences in size and channel capacity of each project, a variety of scale models was used to achieve the best results. Both sectional spillway and comprehensive models were used to develop the deflector designs for all projects except John Day where only a sectional model was used. Larger-scale models were used as the sectional spillway models and smaller scales were used in the comprehensive models. The main purposes for the comprehensive models were to determine the effects of the recommended deflectors on flow conditions both in and downstream from the stilling basins and to establish spillway operation schedules for optimum passage of fish. Where appropriate, acrylic plastic was used to simulate all spillway crests, gates, piers, deflectors, and roller buckets. All approach channels, tailwater channels, stilling basins, etc., were made of waterproofed wood and plywood. The exit channels for comprehensive models were made of molded concrete and contoured to match the latest available topography for each project.

5. Standard laboratory instruments and procedures were used to measure discharges, pressures in the sectional model, water surface elevations, velocities, and other related measurements. Still or timed-exposure photographs were obtained during the tests.

Scale Relationships

6. Except for the simulation of air entrainment in spillway flows, hydraulic similitude was based on the Froudian relationships of dimensions and hydraulic quantities between the models and the prototypes. The performances of spillway deflectors in hydraulic models cannot be used to determine reductions of prototype nitrogen supersaturation because air entrainment and the effects of pressures on dissolved gases are not duplicated in Froude-law scaled models. Prototype tests must be conducted to determine the total effect in reduction of supersaturation.

PART II

BONNEVILLE DAM

PART II: BONNEVILLE DAM TESTS AND RESULTS

The Prototype

7. The salient features of Bonneville Dam (plate 1) include an 18-bay (each 50-feet-wide) spillway, a 10-unit powerhouse on the left bank, an 8-unit powerhouse on the right bank, two fish ladders, and a single-lift navigation lock. The spillway is controlled by split-leaf, vertical-lift gates and designed to pass 1,600,000 cfs at maximum pool. The end bays are separated from the remaining portion of the structure by training walls to improve flow conditions adjacent to the project fish-passage facilities. The stilling basin is 81 feet long and includes two rows of 6-foot-high baffles. The basin floor is at elevation -16 feet.*

The Models

8. The 1:25-scale model simulating one bay of the existing spillway and the stilling basin is shown on photograph 1. A separate comprehensive model (primarily constructed for the Bonneville second powerhouse study which ultimately was constructed in 1982) at a scale of 1:100 was used to evaluate the overall performance of the deflectors (photograph 2).

Tests

9. Test data consisted of flow profiles indicating zones of aeration and flow directions, photographs, and pressures on the deflectors and baffle piers which were tested on the 1:25-scale model. The river flow used in most of the study was the combined discharges of the spillway, the 10-unit powerhouse (140,000 cfs), and the fishways.

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* All elevations in this report are in feet NGVD.

Combined discharges of 220,000, 300,000, and 400,000 cfs were selected for the initial tests which simulated discharges of 4,700, 9,750, and 16,000 cfs per bay, respectively, with 16 of 18 spillway bays in operation. With the existing spillway, flow with all three discharges followed the concrete outline of the ogee and plunged to the bottom of the stilling basin. Profile views indicating zones of aeration and flow directions with these discharges are shown in photograph 3 and on plate 2.

10. Initially, a 6-foot-long deflector connected to the ogee upstream by a 6-foot-radius fillet was studied at elevation 12 (photograph 4 and on plate 3). Observations of zones of aeration and flow directions for the three test flows are shown in photograph 5 and on plate 4. Standing waves developed on the water surface, with the largest one located between the deflector and first row of baffles. Lowering the tailwater elevation (to decrease the submergence of the deflector) reduced the waves and therefore indicated the deflector was too low.

11. Various combinations of deflector lengths and elevations were investigated in the sectional model to determine the optimum design. These tests indicated that the 12-foot-long deflector was the most effective and that it should be located higher than elevation 12 due to the standing waves that occurred with the deflector at that elevation (photograph 6). Tests of the 1:100-scale model with the deflector set at elevation 12 also indicated that the deflector should be located above elevation 12 to prevent formation of strong eddies adjacent to both fishway entrances.

12. Based on the preceding tests, elevation 17 was selected for further tests with the 6- and 12-foot-long deflectors. Details of the 12-foot deflector and piezometer locations are shown on plate 5. Flow conditions for the two deflectors with 220,000, 300,000, and 400,000 cfs are shown in photographs 7 and 8. Since there was less air entrainment and smaller standing waves with the 12-foot deflector,

most of the subsequent studies were conducted with this design. Pressures on the deflector were positive with spillway flows of 1,152,000 and 1,200,000 cfs (table A) and with all other discharges tested. Pressures measured on the stilling basin baffles at the locations shown on plate 6 approximated the depth of water above the piezometers. While determining the minimum tailwater required for skimming flow with the 12-foot deflectors in the sectional model, similar tests were conducted with 16 bays ot the spillway in the 1:100-scale comprehensive model (also used for the Bonneville second powerhouse study). Minimum tailwater to maintain skimming flow in both models is shown on plate 7. For flows below 17,000 cfs per bay, the 16-bay operation required a higher tailwater than exists at the prototype. Without the interaction of adjacent bays, the single-bay model indicated a lower tailwater limit for plunging flow. At a discharge of 300,000 cfs with 10 bays operating, surging, plunging flow occurred in the stilling basin of the single-bay model (photograph 9). With a river discharge of 1,610,000 cfs (89,000 cfs per bay), the flow both skimmed and plunged with normal tailwater elevation 70.8 (photograph 10). Skimming flow persisted when the tailwater rose from a lower skimming condition while the discharge was increasing.

13. Since lowering the deflector also lowered the required tailwater for skimming flow, the 12-foot deflector was subsequently tested at elevation 14. Flow conditions with the deflector at elevation 14 were acceptable with river discharges of 220,000 to 510,000 cfs (photograph 11 and plates 8 and 9). Although the standing wave height just downstream of the deflector was greater than that which occurred with the deflector at elevation 17, there was little increase in the entrained air at the lower depths of the basin. Pressures on the deflector and baffle piers were positive.

14. With the deflectors installed at elevation 14 (photographs 12 and 13), the tailwater required to produce skimming flow was determined for both 16- and 10-bay operation (plates 10 and 11). With the 16-bay operation, normal tailwater produced stable, skimming flow for

discharges as low as 11,500 cfs per bay (river discharge was 325,000 cfs). This was an improvement over the deflector at elevation 17 which developed unstable flow with discharges less than 18,000 cfs per bay. Photograph 14 shows flow conditions in the stilling basin for 10-bay spillway operation with a discharge of 181,000 cfs and normal tailwater while photograph 15 illustrates flow conditions with a discharge of 221,000 cfs and the minimum tailwater required for skimming flow. Tests indicated that the 12-foot deflector at elevation 14 provided the best overall results with regard to flow stability, entrained air, and pressures on baffle piers.

BONNEVILLE DAM

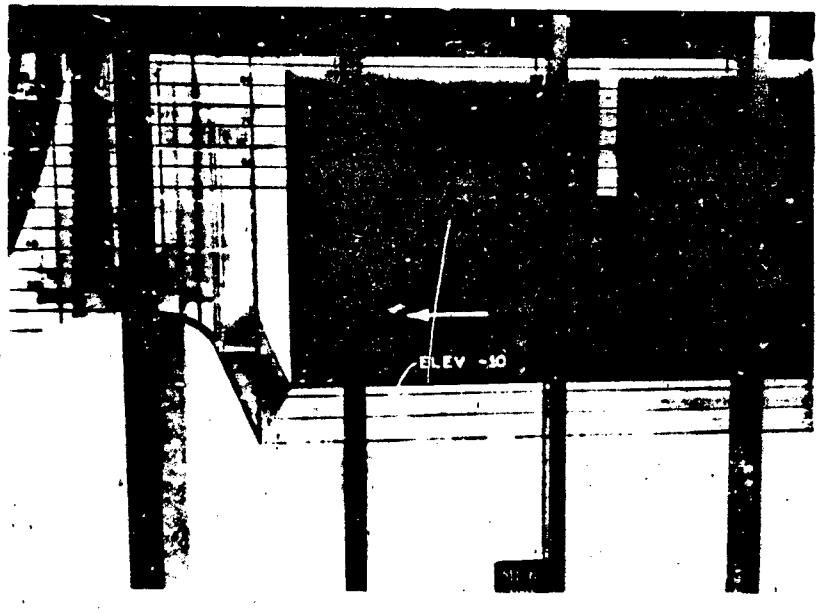
Table A

Pressures on 12-Ft Deflector At Elevation 17
Ungated Flow, 18 Bays

Piezometer Number	River Discharge in CFS									
	1,152,000						1,200,000			
	Discharge per Bay in CFS									
	64,000						66,667			
	Pool Elevation in Feet - MSL									
	75.5						77.3		78.3	
	Tailwater Elevation in Feet - MSL									
	14.0		36.2		43.7		52.2		60.3	
	Pressure in Feet of Water									
	Low	High	Low	High	Low	High	Low	High	Low	High
L-1	8.8	10.8	9.8	11.3	13.3	15.8	25.2	28.2	41.7	44.7
L-2	8.5	12.5	8.8	13.5	13.0	17.5	22.0	26.5	38.5	41.5
L-3	5.3	9.7	5.8	10.9	9.8	14.3	19.2	23.2	34.7	39.2
L-4	9.6	12.5	10.5	13.4	13.0	16.5	22.0	24.5	36.0	40.0
L-5	24.5	26.3	24.8	26.2	25.0	28.0	31.0	32.0	38.0	42.0
L-6	32.0	33.5	32.5	34.0	33.3	35.0	37.0	38.5	42.0	45.0
L-7	39.5	41.3	39.2	40.2	40.0	41.5	42.0	44.0	45.0	48.0
L-8	39.8	41.5	39.5	42.0	40.0	42.3	42.5	44.5	45.0	48.0

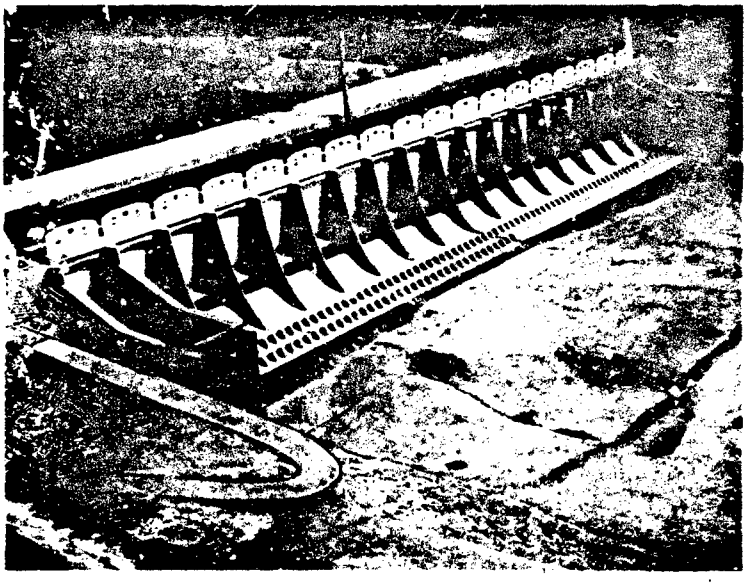
NOTES: 1. Observations made with quick-acting water manometers.
2. Piezometer locations shown on plate 5.

TABLE A



Bonneville Dam

Photograph 1. Dry bed of 1:25-scale model showing existing spillway.

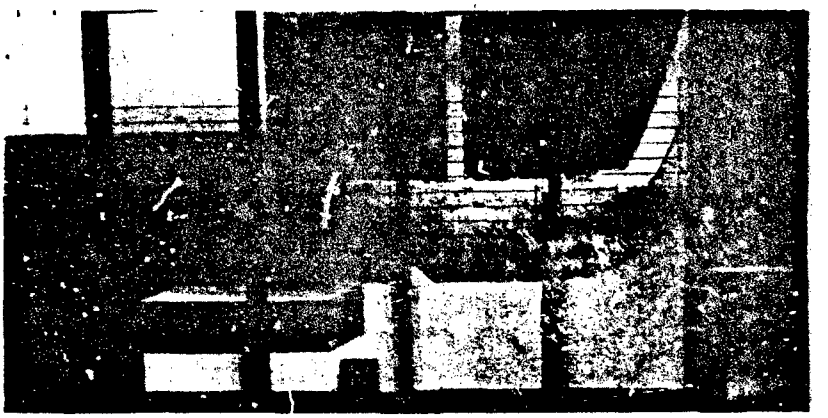


Spillway with deflectors at elevation 14.

Bay 18 with deflector at elevation 14.

Bonneville Dam

Photograph 2. Dry bed of 1:100-scale comprehensive model.



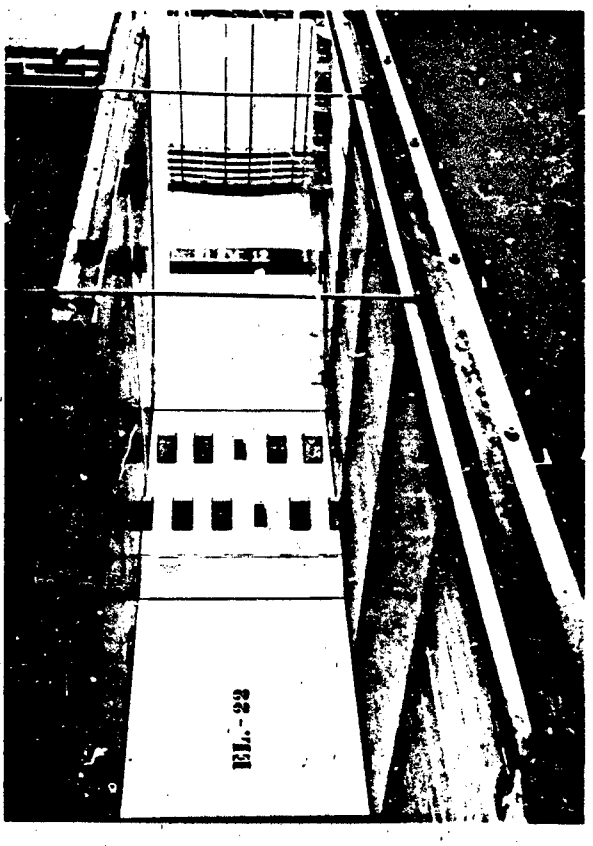
River discharge 220,000 cfs (4,700 cfs per bay).
Plunging flow, tailwater elevation 20.1.

River discharge 300,000 cfs (9,750 cfs per bay).
Plunging flow, tailwater elevation 25.4.

River discharge 400,000 cfs (16,000 cfs per bay).
Plunging flow, tailwater elevation 31.2

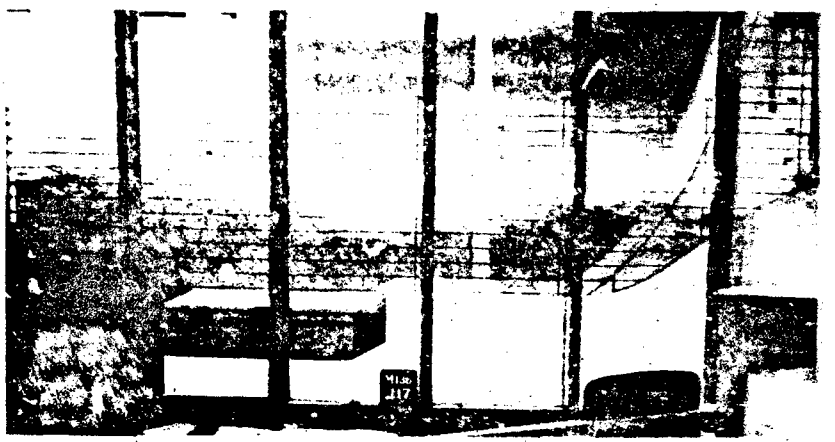
Bonneville Dam

Photograph 3. Existing prototype conditions with normal tailwater. Pool elevation 74.0, powerhouse discharge 140,000 cfs.

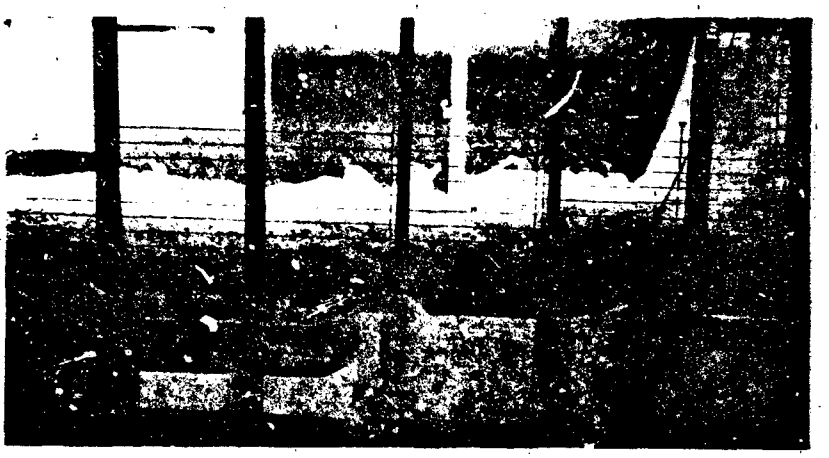


Bonneville Dam

Photograph 4. Dry bed showing 6-foot deflector at elevation 12.



River discharge 220,000 cfs (4,700 cfs per bay).
Skimming flow, tailwater elevation 20.1.

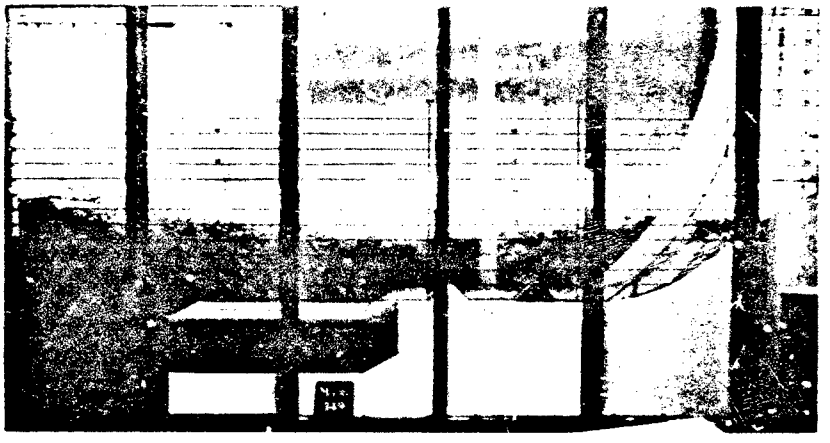


River discharge 300,000 cfs (9,750 cfs per bay).
Skimming flow, tailwater elevation 25.4.

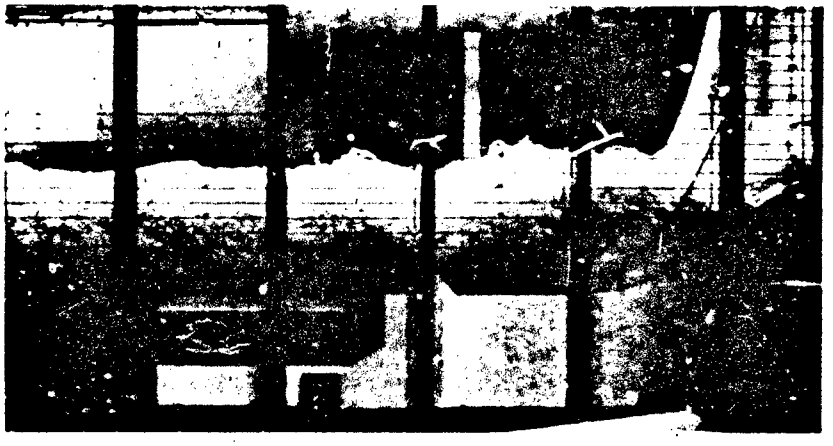
River discharge 400,000 cfs (16,000 cfs per bay).
Skimming flow, tailwater elevation 31.2.

Bonneville Dam

Photograph 5. 6-foot deflector at elevation 12 with normal tailwater. Pool elevation 74.0, powerhouse discharge 140,000 cfs.



River discharge 220,000 cfs (4,700 cfs per bay).
Skimming flow, tailwater elevation 20.1.

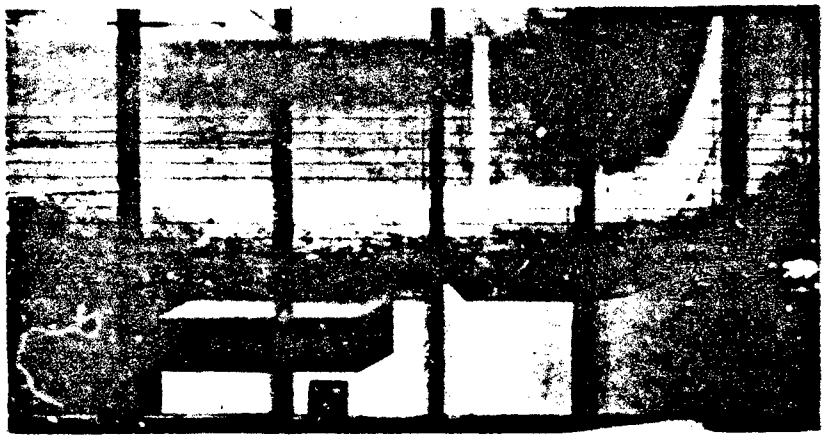


River discharge 300,000 cfs (9,750 cfs per bay).
Skimming flow, tailwater elevation 25.4.

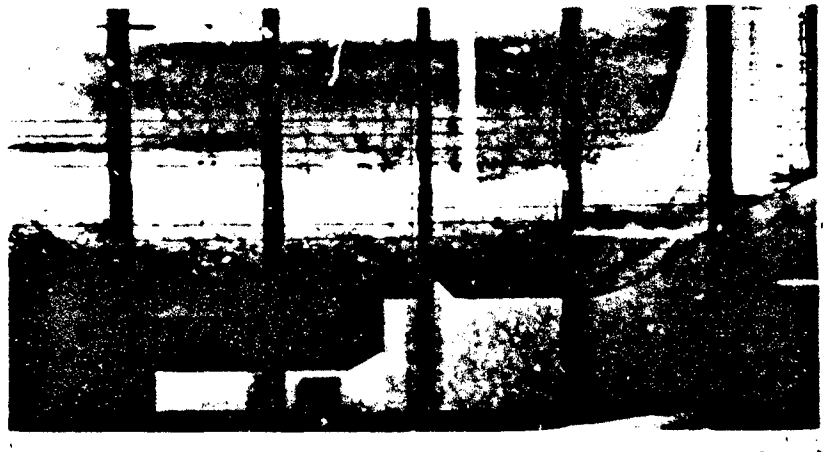
River discharge 400,000 cfs (16,000 cfs per bay).
Skimming flow, tailwater elevation 31.2.

Bonneville Dam

Photograph 6. 12-foot deflector at elevation 12 with normal tailwater. Pool elevation 74.0, powerhouse discharge 140,000 cfs.



River discharge 220,000 cfs (4,700 cfs per bay). Skimming flow, tailwater elevation 20.1.

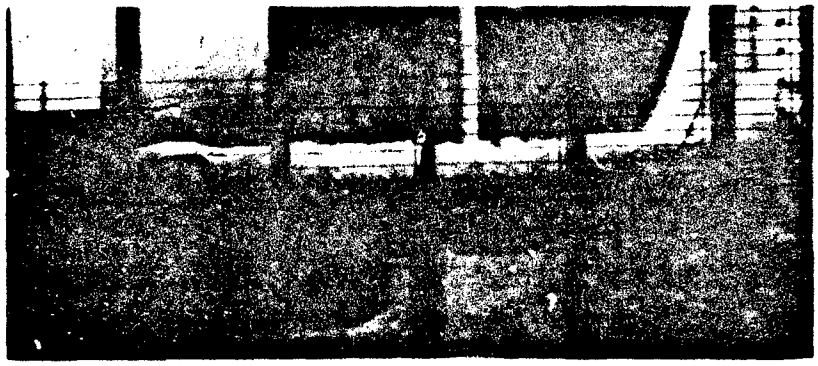


River discharge 300,000 cfs (9,750 cfs per bay). Skimming flow, tailwater elevation 25.4.

River discharge 400,000 cfs (16,000 cfs per bay). Skimming flow, tailwater elevation 31.2.

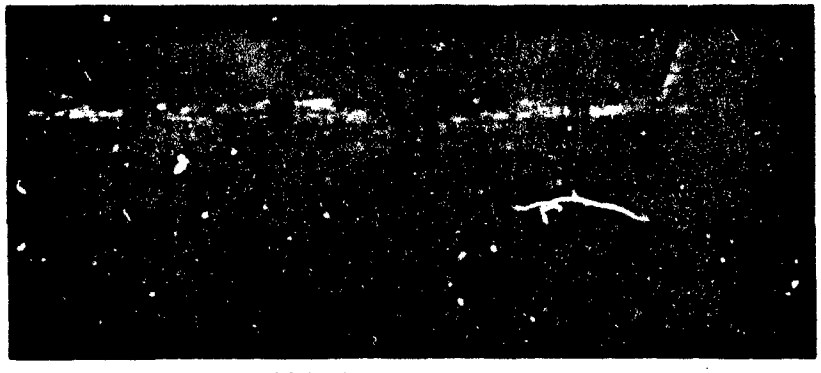
Bonneville Dam

Photograph 7. 6-foot deflector at elevation 17 with normal tailwater. Pool elevation 74.0, powerhouse discharge 140,000 cfs.



River discharge 220,000 cfs (4,700 cfs per bay).
Skimming flow, tailwater elevation 20.1.

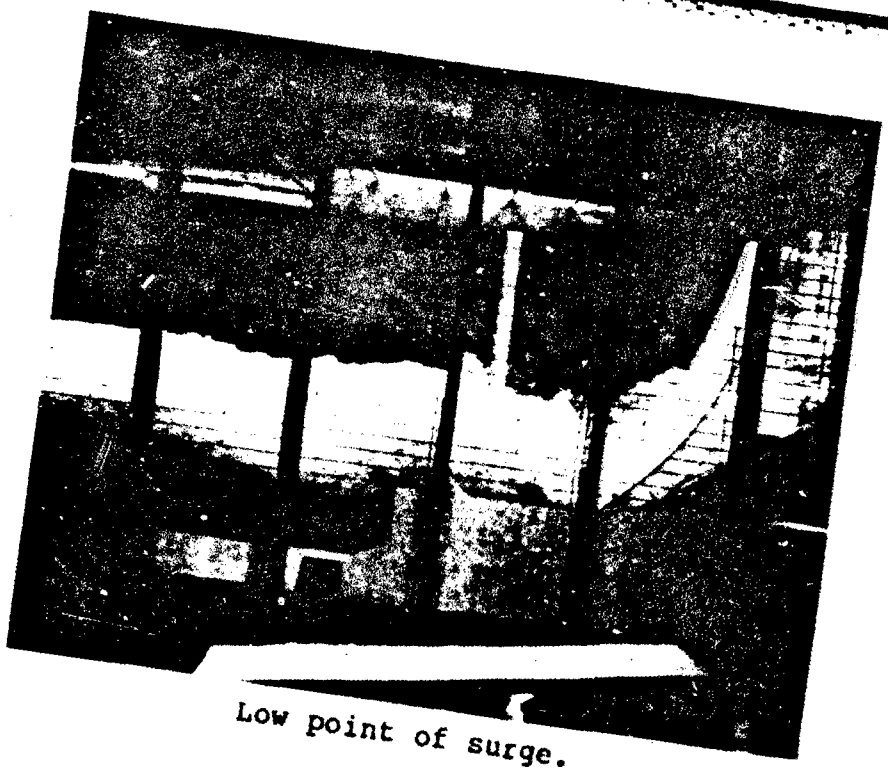
River discharge 300,000 cfs (9,750 cfs per bay).
Skimming flow, tailwater elevation 25.4.



River discharge 400,000 cfs (16,000 cfs per bay).
Skimming flow, tailwater elevation 31.2.

Bonneville Dam

Photograph 8. 12-foot deflector at elevation 17 with normal tailwater. Pool elevation 74.0, powerhouse discharge 140,000 cfs.

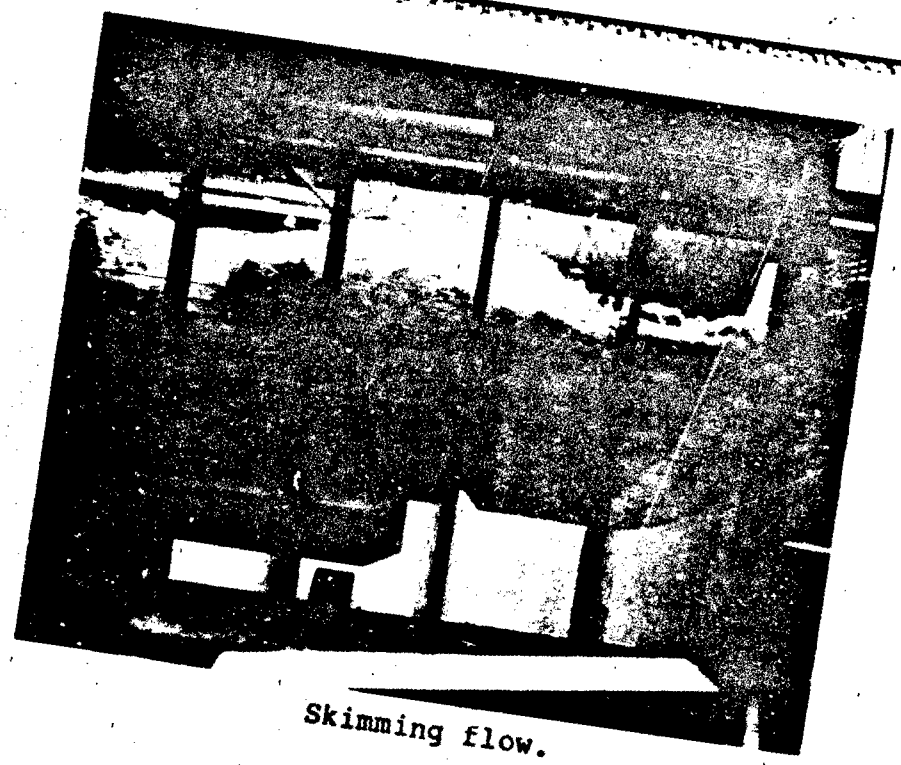


Low point of surge.

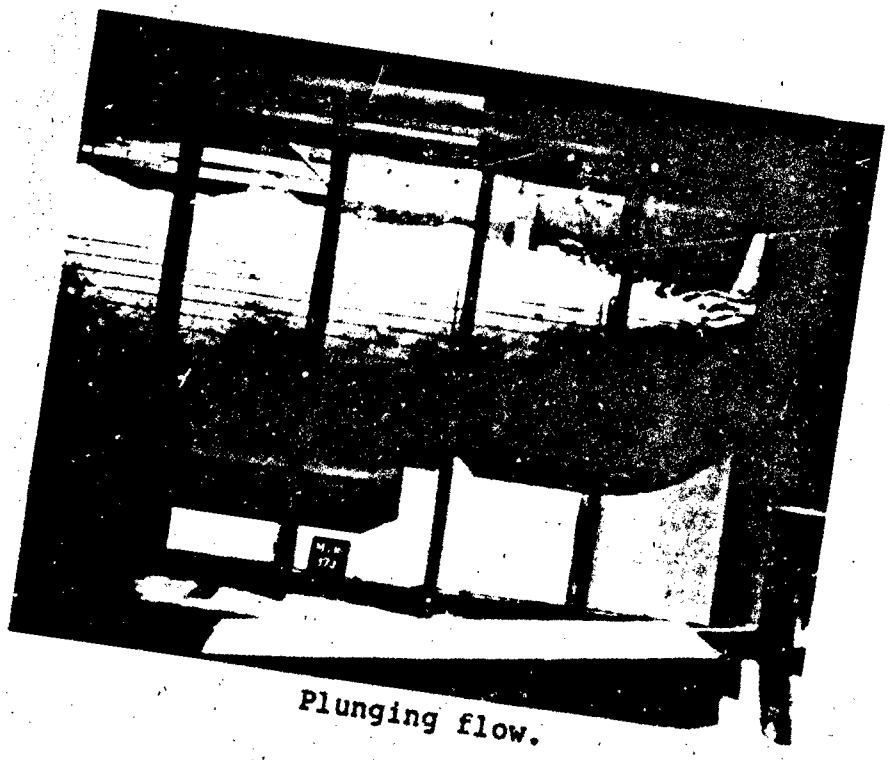
High point of surge.

Bonneville Dam

Photograph 9. Unstable flow with 12-foot deflector at elevation 17 with normal tailwater elevation 25.4. River discharge 300,000 cfs (16,000 cfs per bay), pool elevation 74.0.



Skimming flow.



Plunging flow.

Bonneville Dam

Photograph 10. 12-foot deflector at elevation 17 with normal tailwater elevation 70.8. River discharge 1,610,000 cfs (89,500 cfs per bay). Pool elevation 89.8.

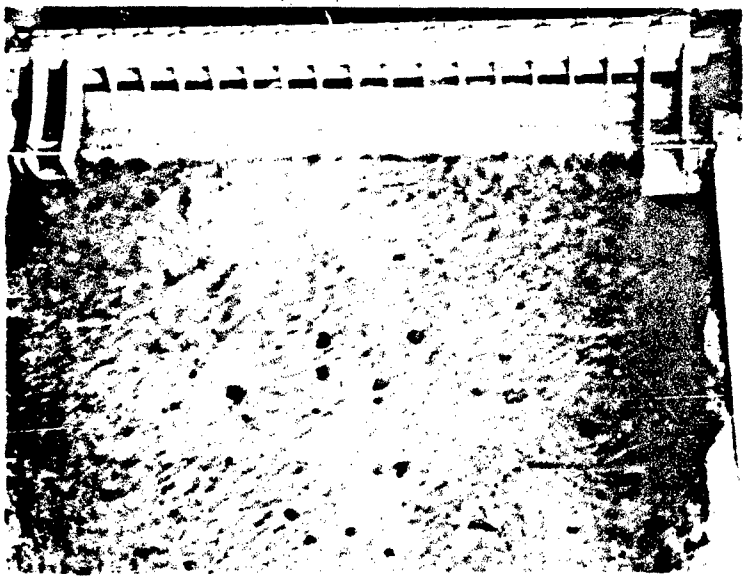
River discharge 220,000 cfs (4,700 cfs per bay).
Skimming flow, tailwater elevation 20.1.

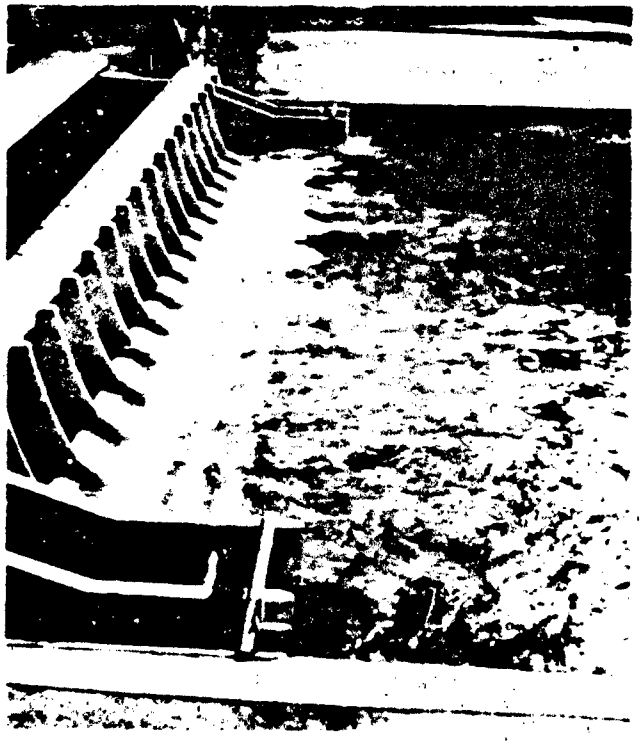
River discharge 300,000 cfs (9,750 cfs per bay).
Skimming flow, tailwater elevation 25.4.

River discharge 400,000 cfs (16,000 cfs per bay).
Skimming flow, tailwater elevation 31.2.

Bonneville Dam

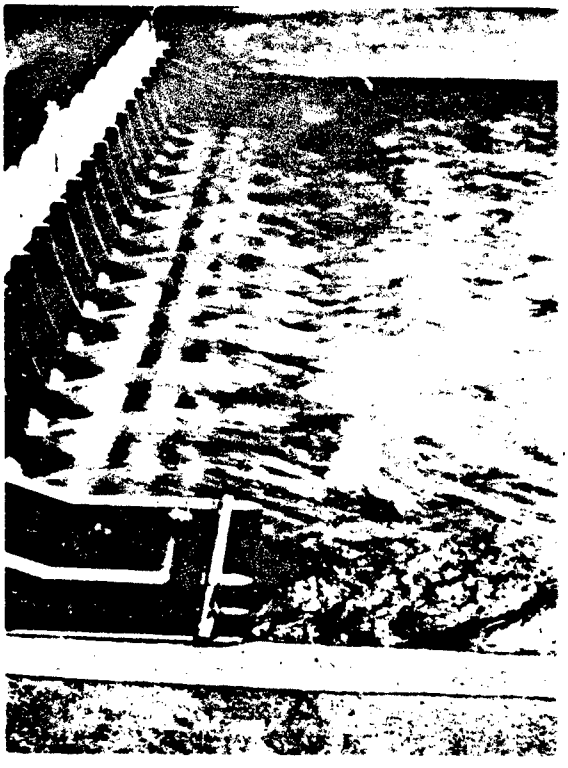
Photograph 11. 12-foot deflector at elevation 14 with normal tailwater. Pool elevation 74.0, powerhouse discharge 140,000 cfs.

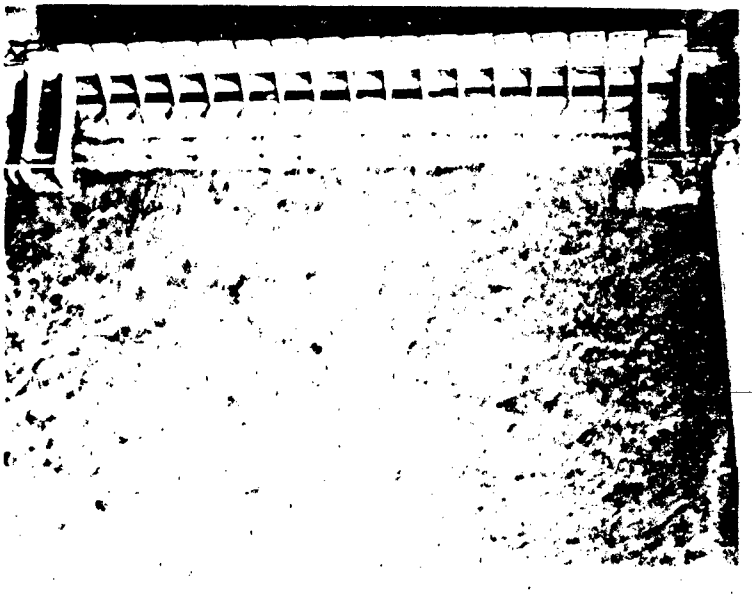




Bonneville Dam

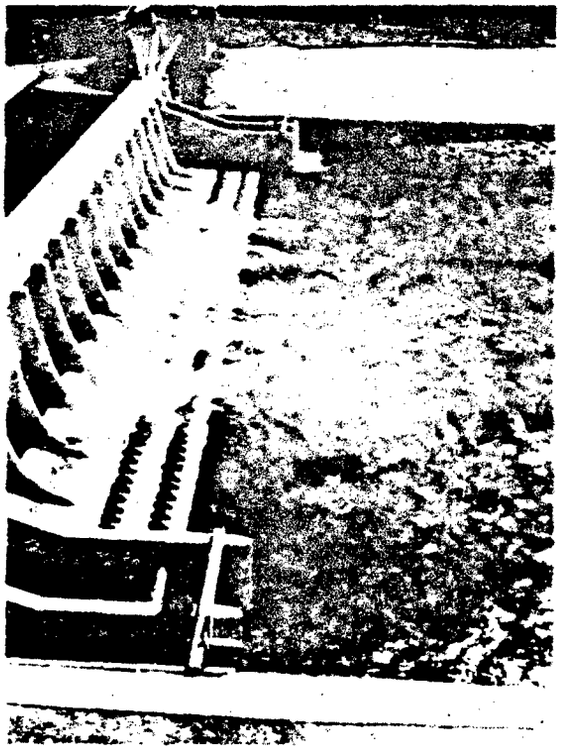
Photograph 12. Flow conditions with deflectors at elevation 14. 16-bay spillway operation, 6,000 cfs per bay. Normal tailwater elevation 21.3. River discharge 237,000 cfs.

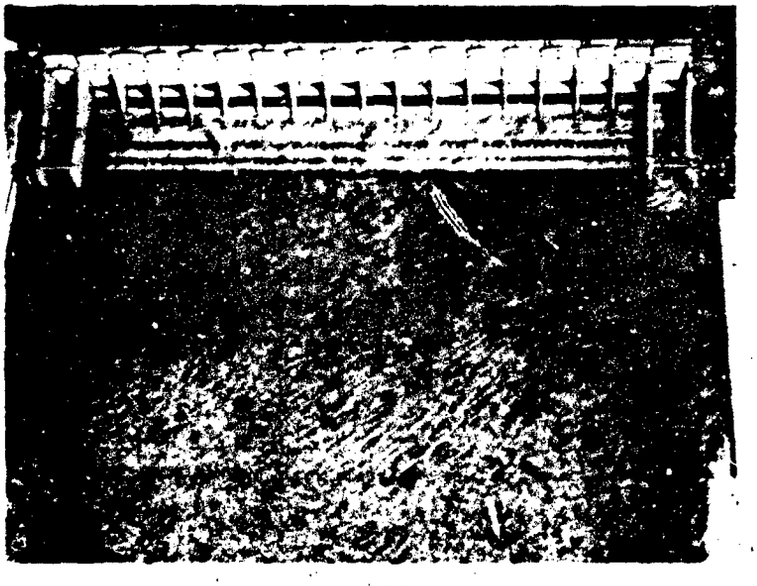




Bonneville Dam

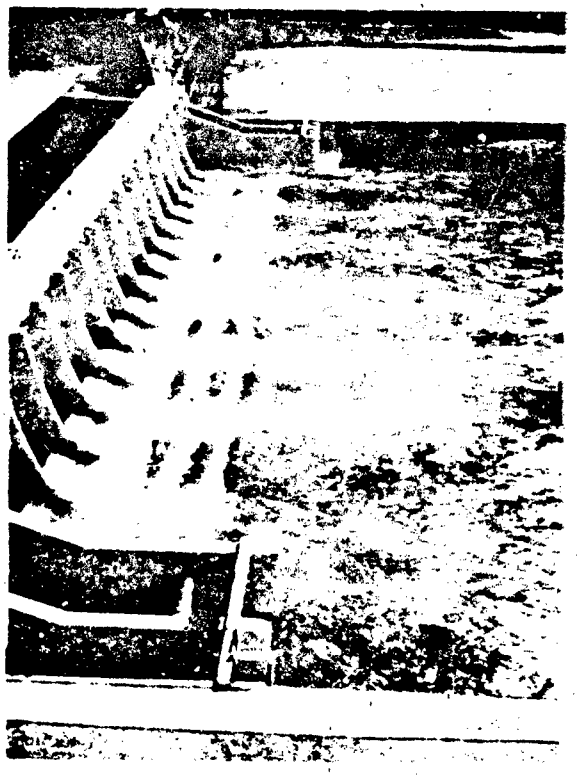
Photograph 13. 16-bay spillway operation, 35,000 cfs per bay. Minimum tailwater required for skimming flow elevation 41.7. River discharge 701,000 cfs. Deflectors at elevation 14.

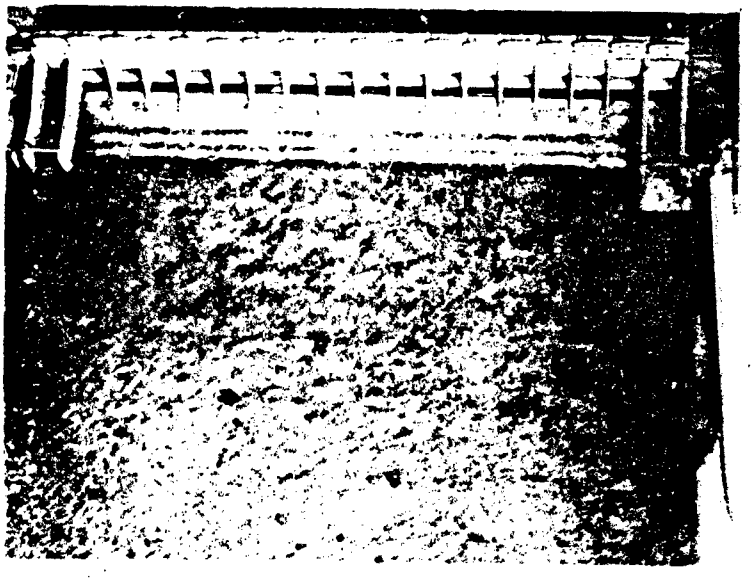




Bonneville Dam

Photograph 14. 10-bay spillway operation. Bays 5-14 passing 40,000 cfs. Normal tailwater elevation 17.5 at gage T-1, river discharge 181,000 cfs. Deflectors at elevation 14.





Bonneville Dam

Photograph 15. 10-Bay spillway operation. Bays 2, 3, 5, 7, 9, 10, 12, 14, 16, 17 passing 80,000 cfs. Minimum tailwater elevation 23.3 required for skimming flow, river discharge 221,000 cfs. Deflectors at elevation 14.

REPRODUCED AT GOVERNMENT EXPENSE

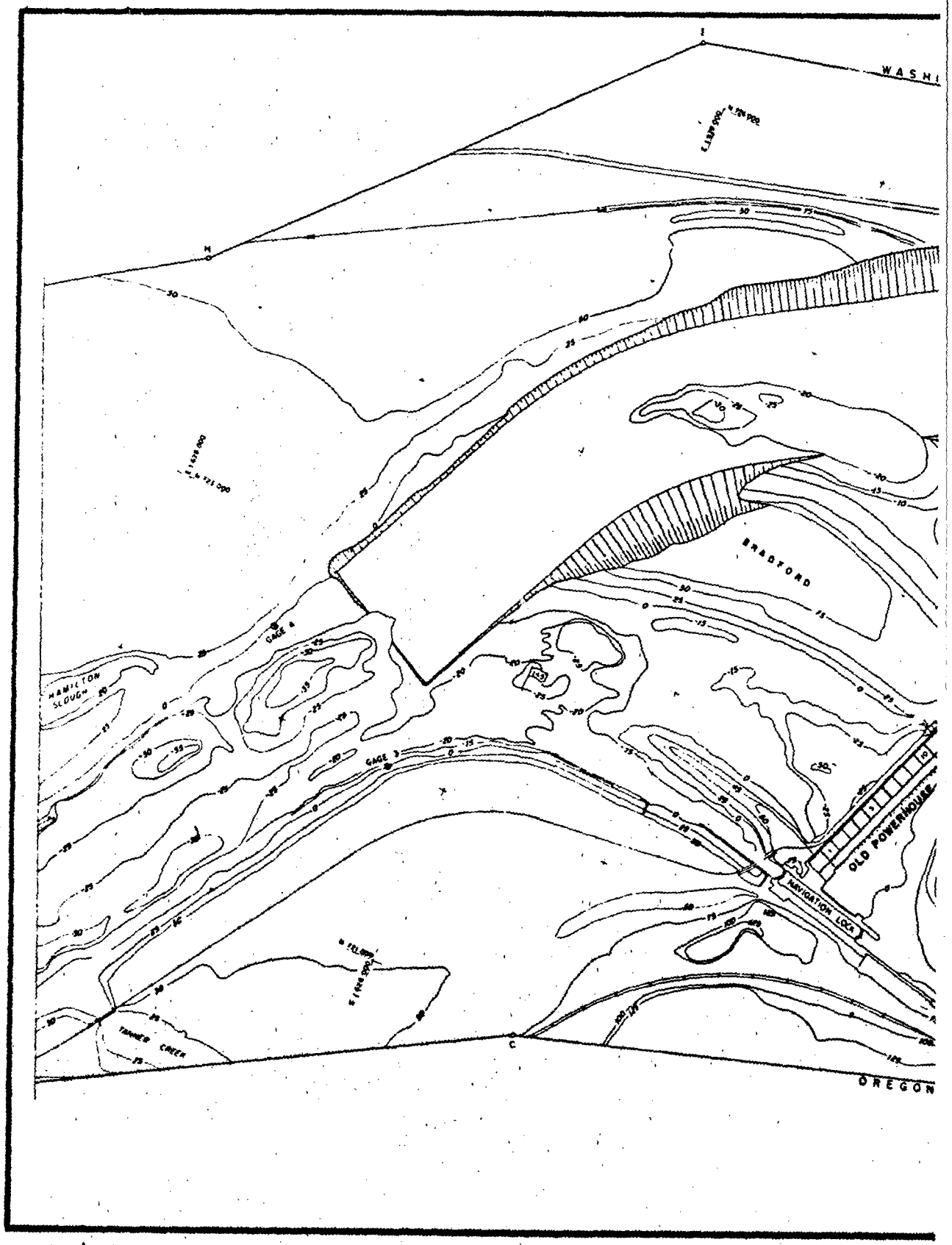
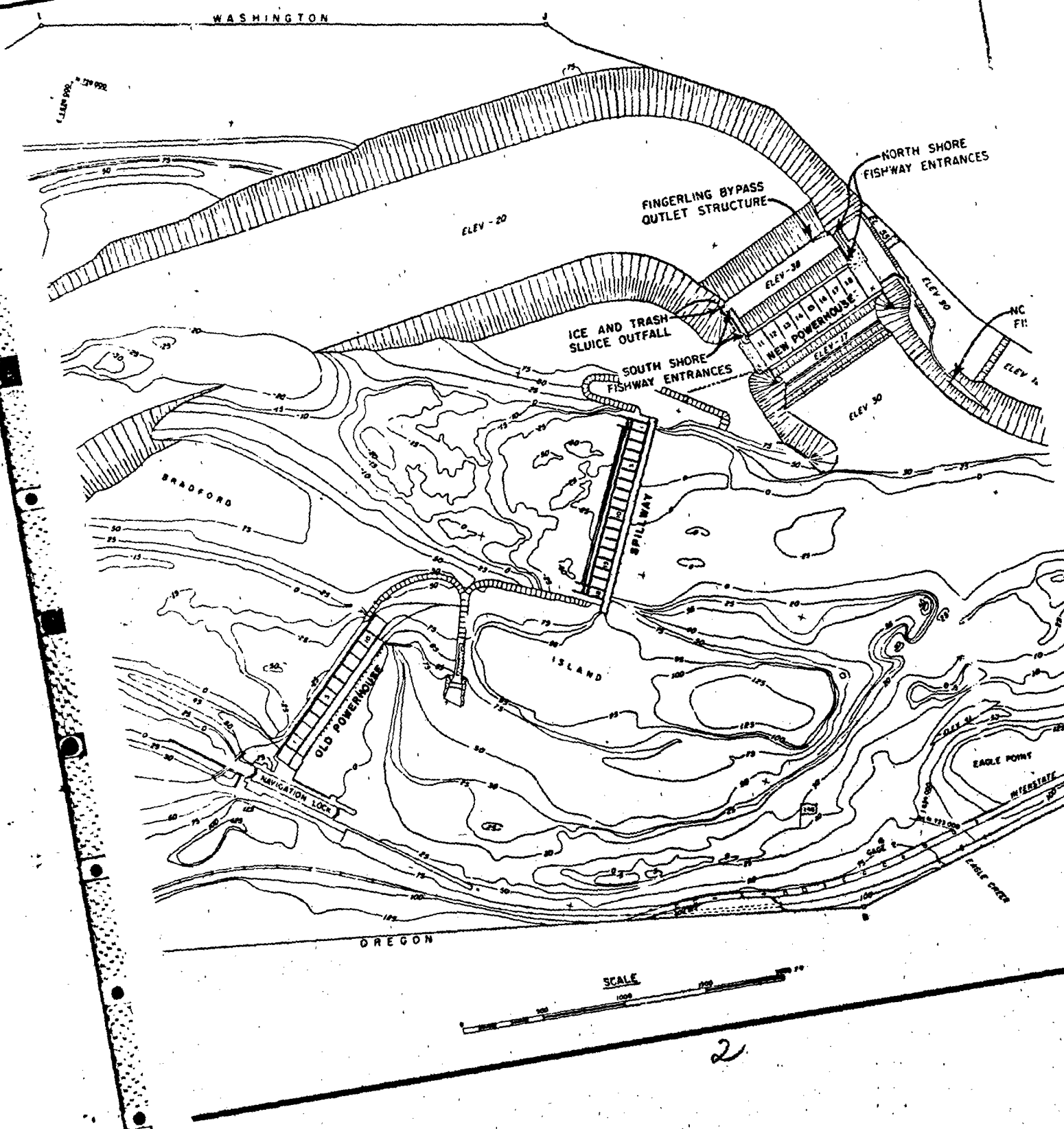


Plate 1

REPRODUCED AT GOVERNMENT EXPENSE



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REPRODUCED AT GOVERNMENT EXPENSE

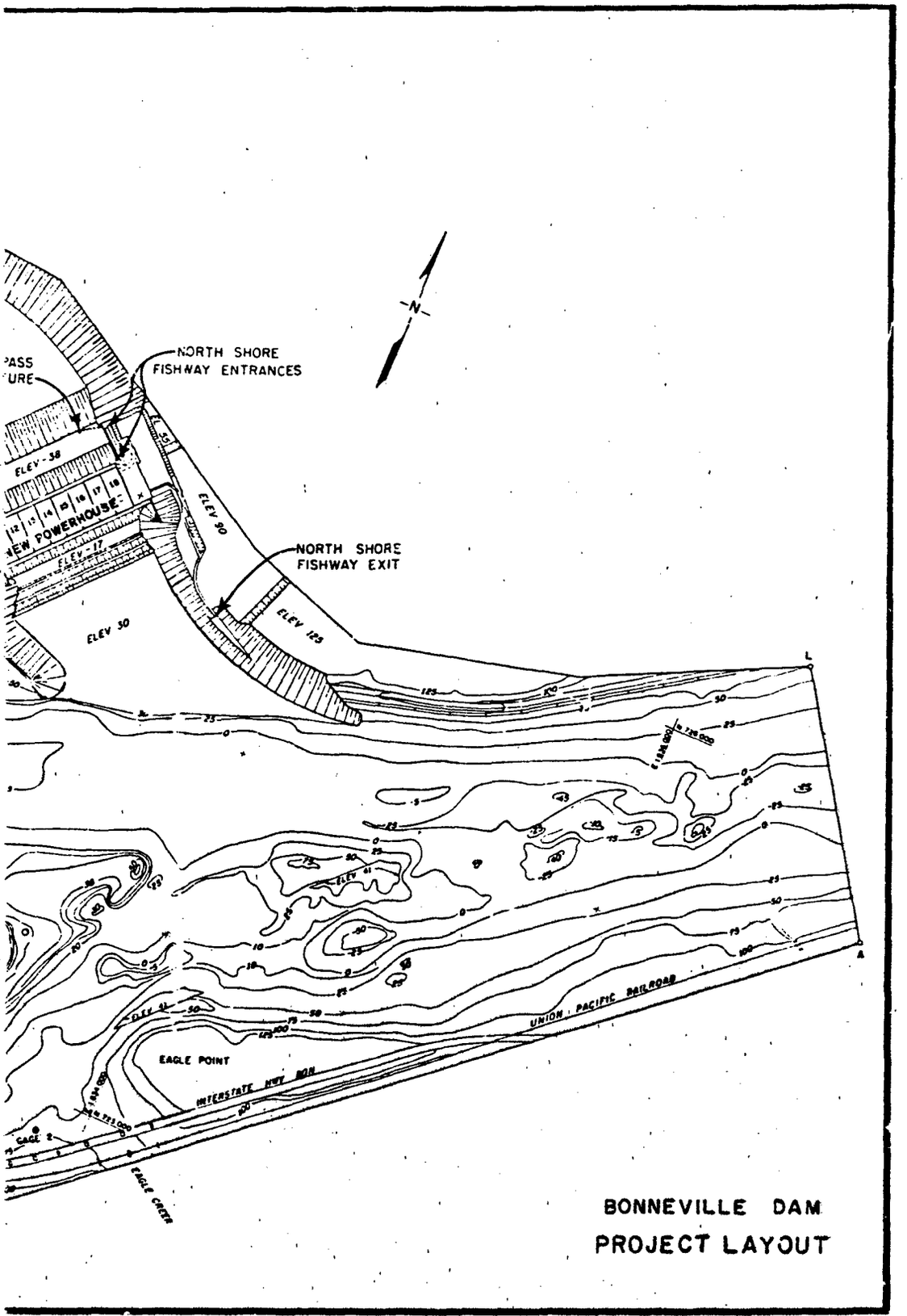
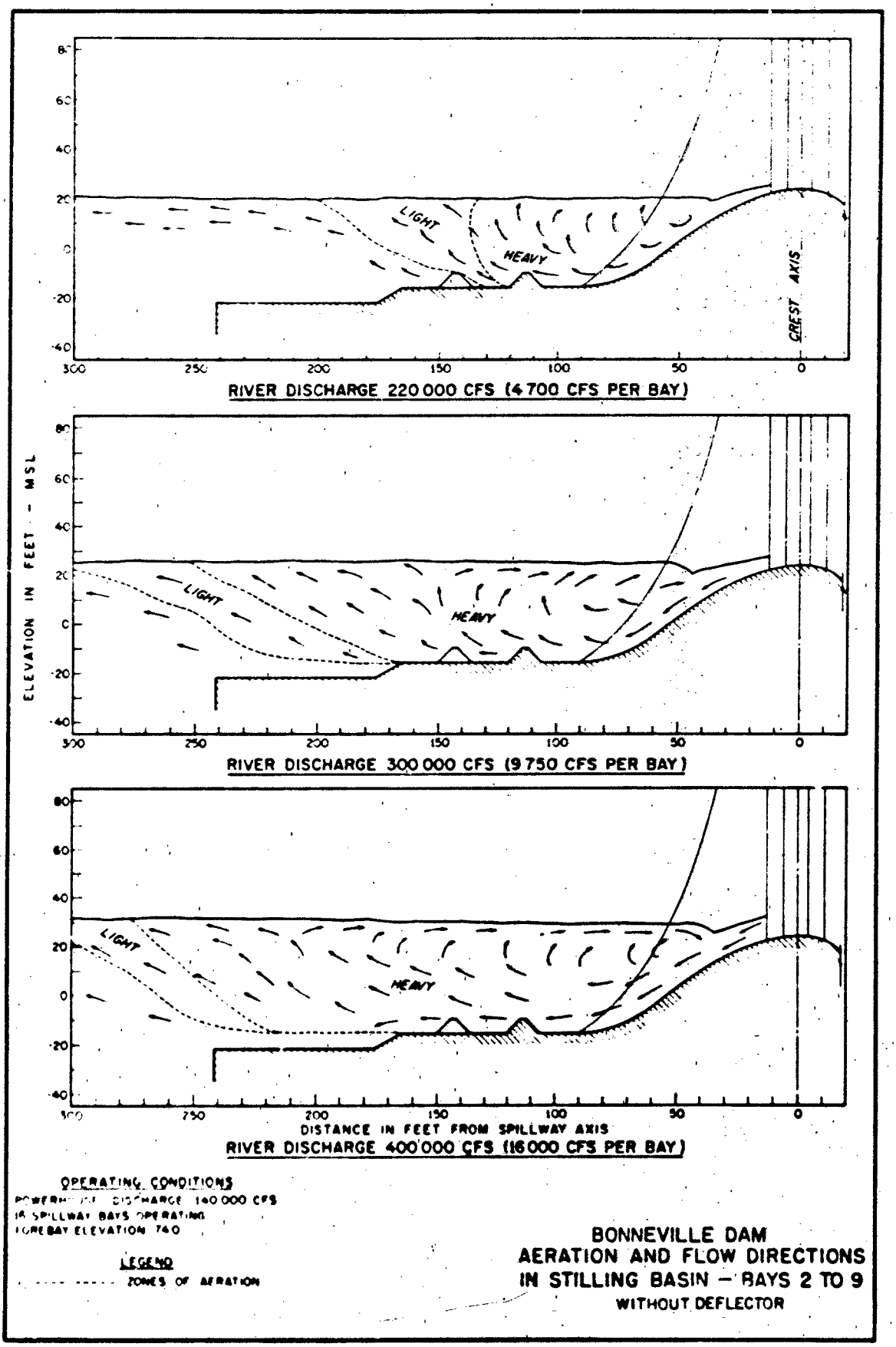


PLATE 1

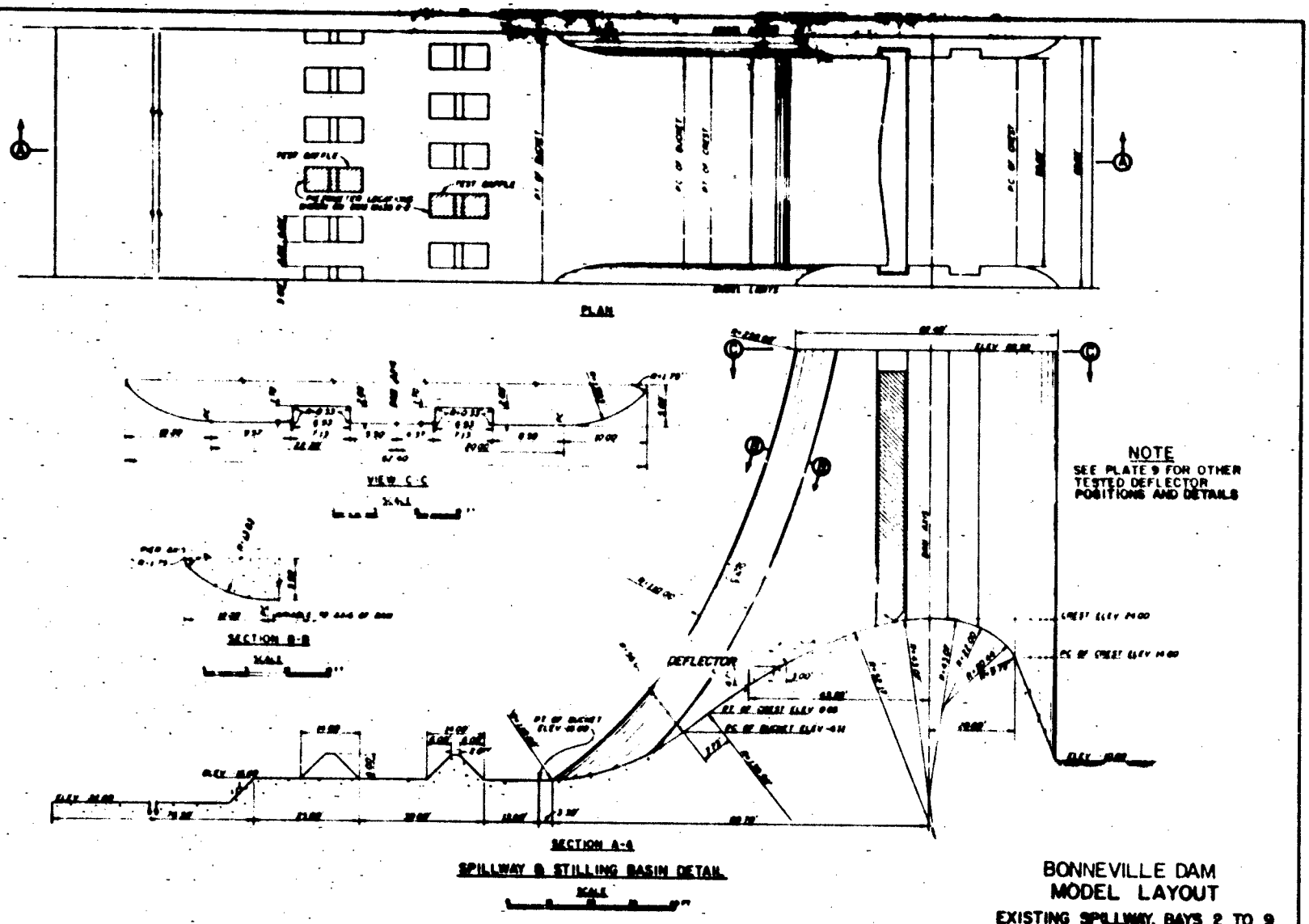
3 of 3



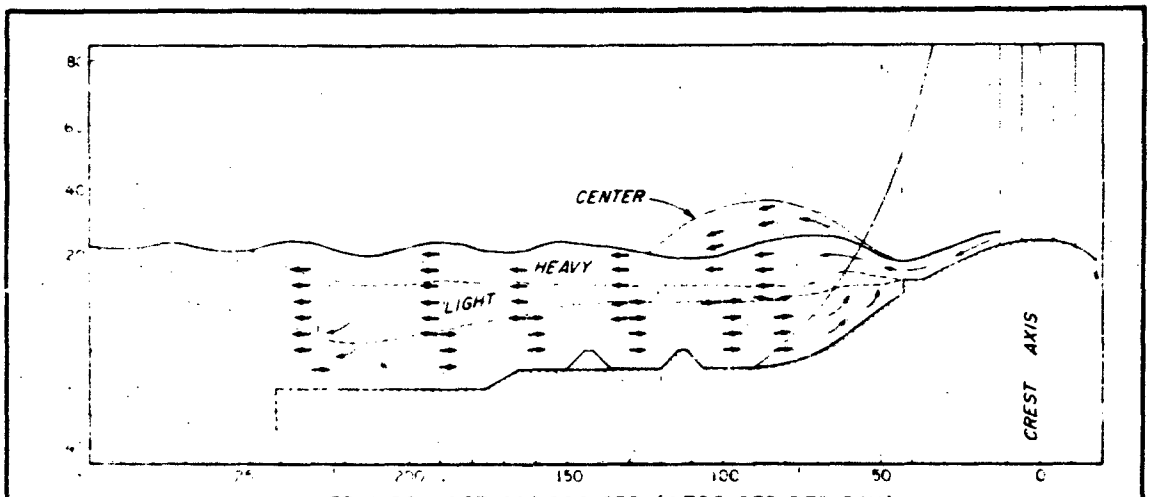
BONNEVILLE DAM
AERATION AND FLOW DIRECTIONS
IN STILLING BASIN — BAYS 2 TO 9
WITHOUT DEFLECTOR

PLATE 2

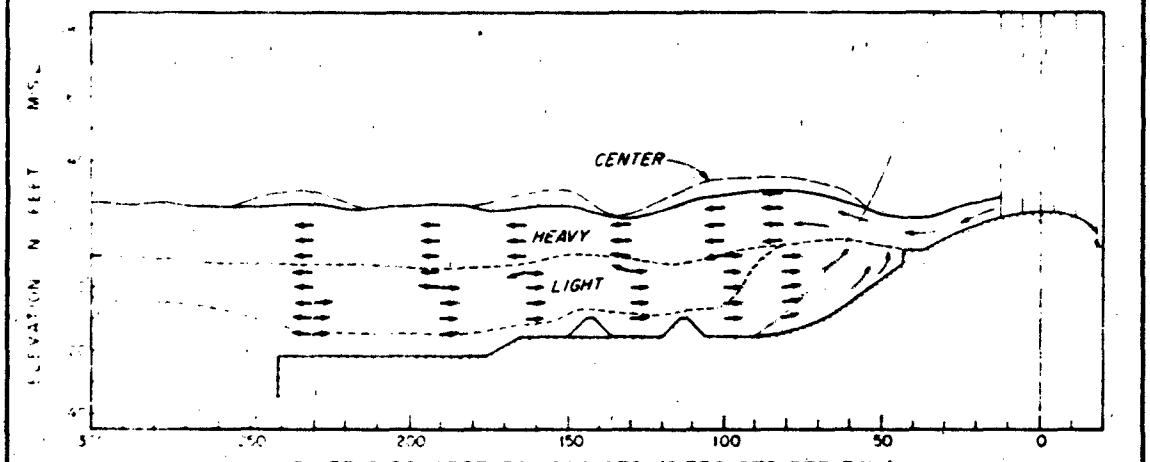
PLATE 3



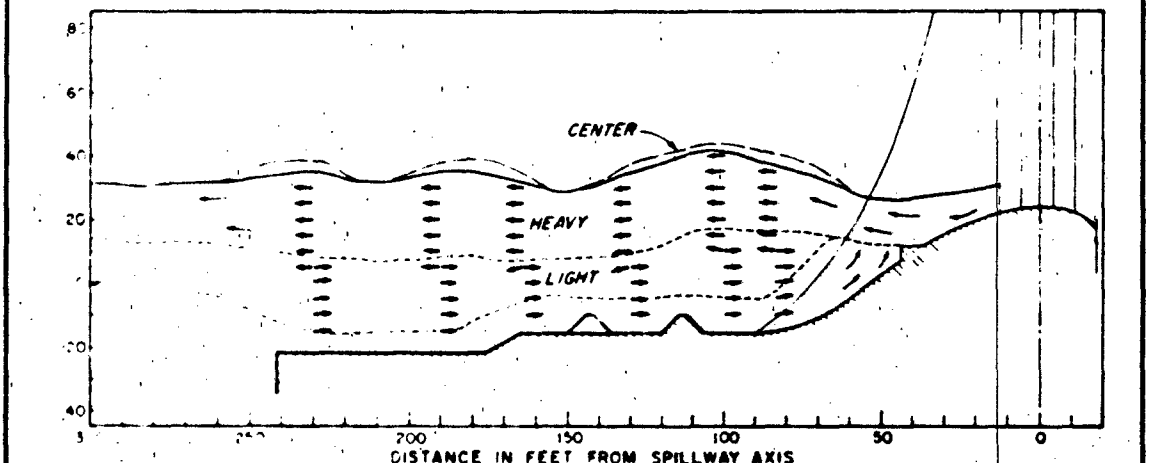
BONNEVILLE DAM
MODEL LAYOUT
EXISTING SPILLWAY, BAYS 2 TO 9



RIVER DISCHARGE 220 000 CFS (4 700 CFS PER BAY)



RIVER DISCHARGE 300 000 CFS (9 750 CFS PER BAY)



RIVER DISCHARGE 400 000 CFS (16 000 CFS PER BAY)

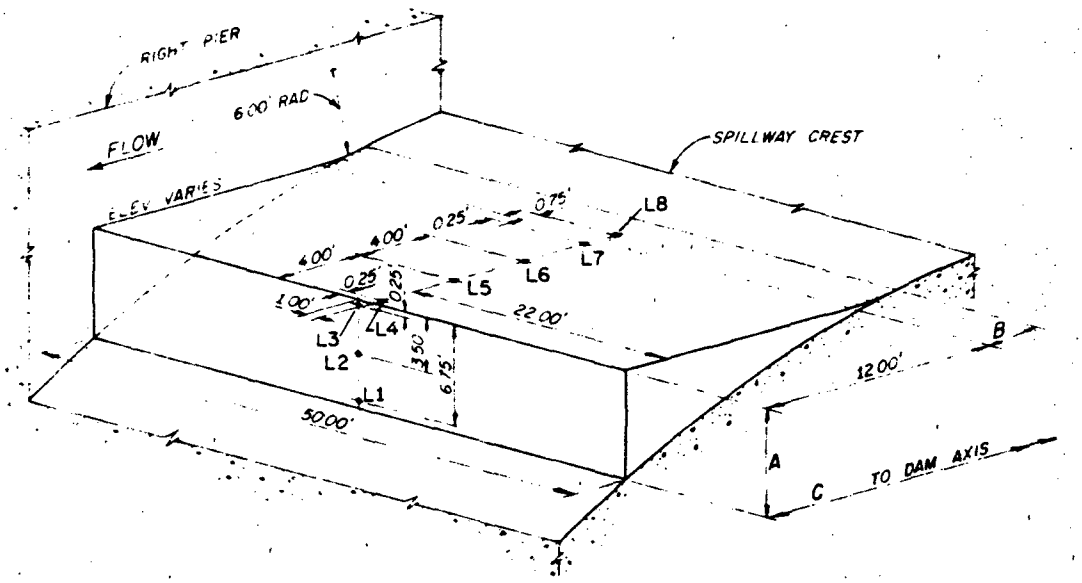
OPERATING CONDITIONS

LEGEND

LINES OF AERATION

BONNEVILLE DAM
AERATION AND FLOW DIRECTIONS
IN STILLING BASIN — BAYS 2 TO 9
6-FT. DEFLECTOR AT ELEV 12

PLATE 4

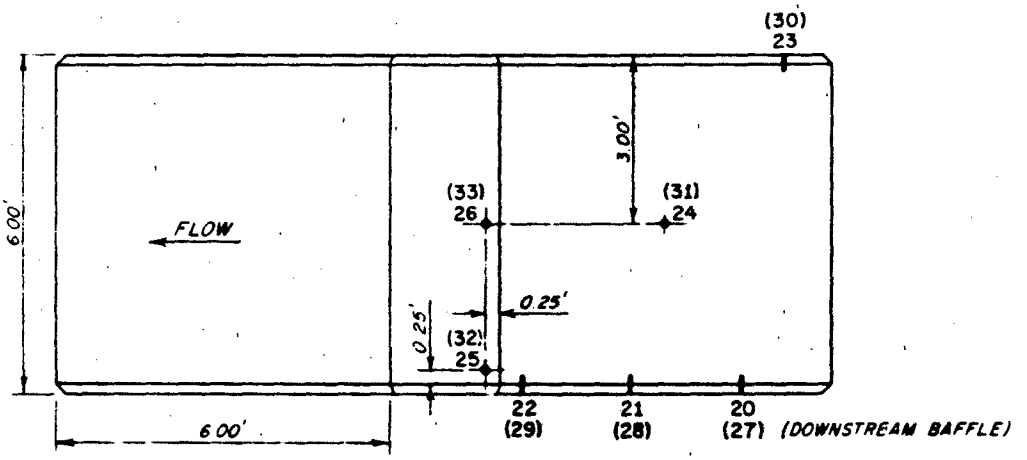


DEFLECTOR FLEVATION	DIMENSIONS IN FEET		
	A	B	C
*22.00	5.15	1.60	26.15
17.00	7.25	2.45	39.35
14.00	8.155	2.73	45.32

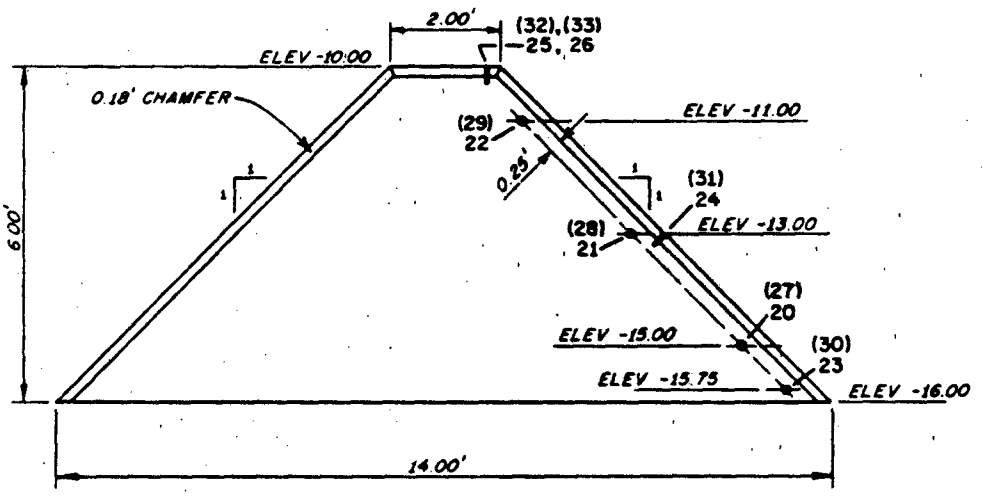
*NO PIEZOMETERS AT ELEV 22.00

BONNEVILLE DAM
12-FT DEFLECTOR DETAILS AND
PIEZOMETER LOCATIONS

PLATE 5



PLAN

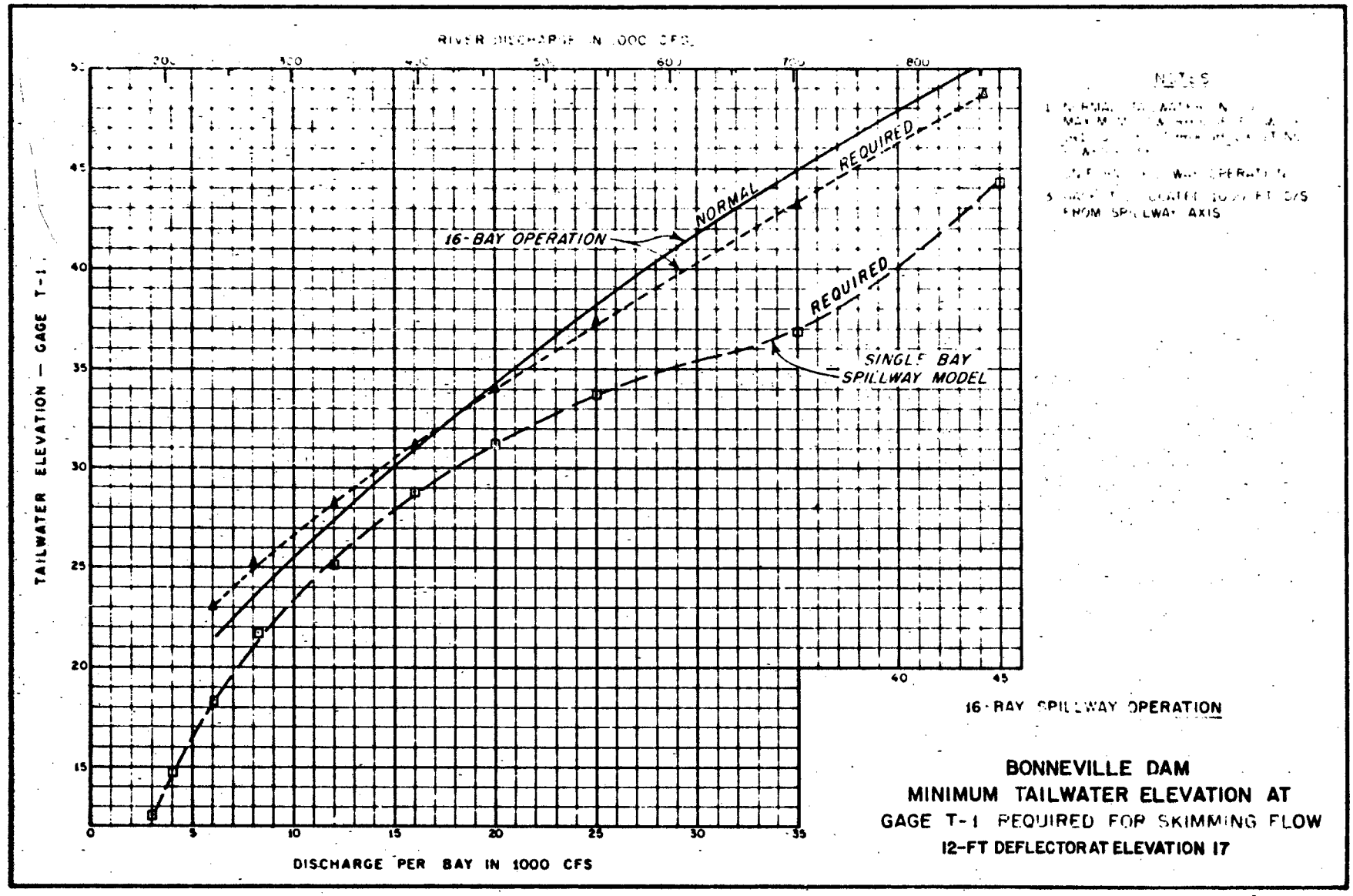


ELEVATION

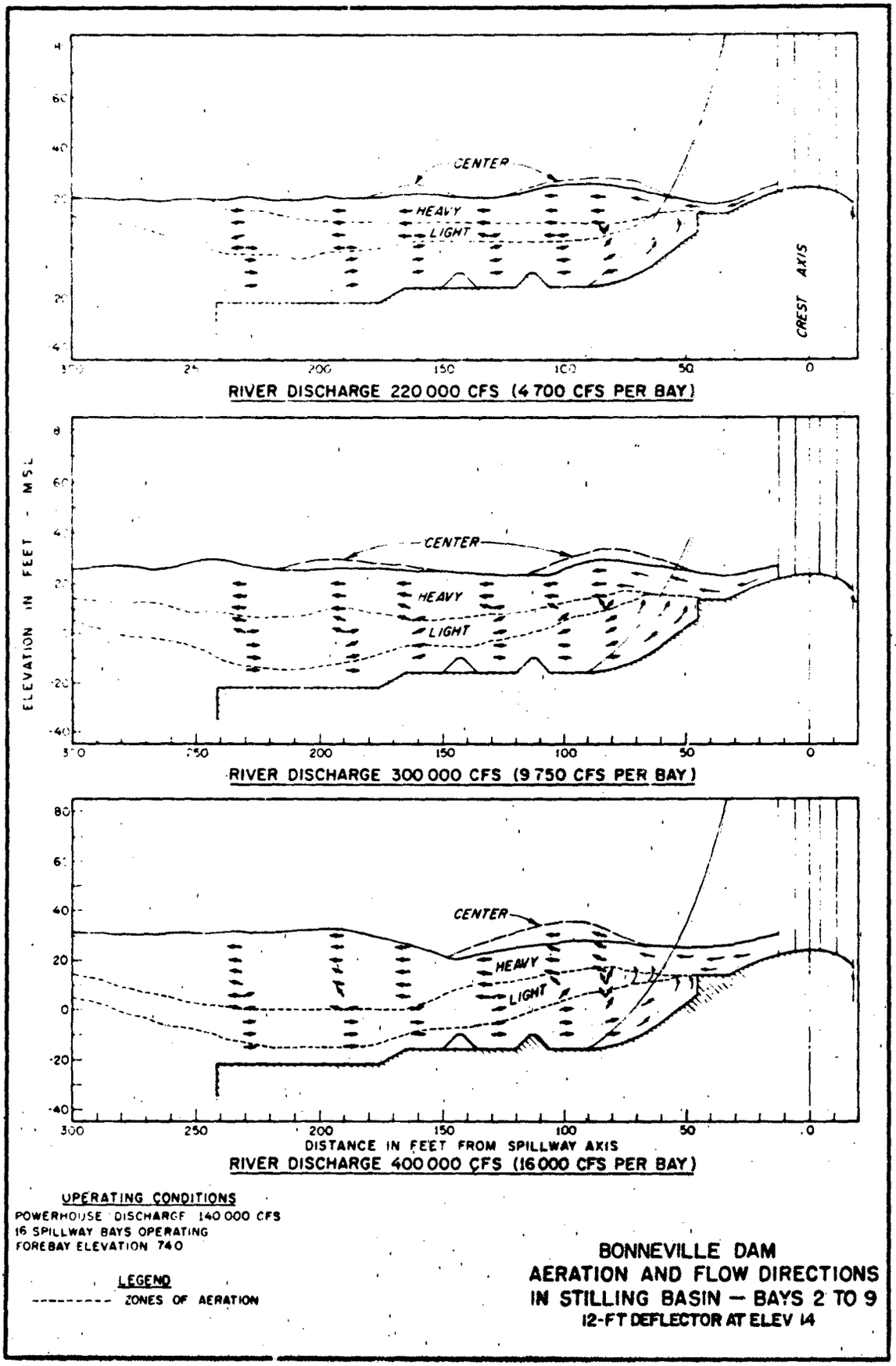
BONNEVILLE DAM
DETAILS AND PIEZOMETER LOCATIONS
TEST SPILLWAY BAFFLES - BAYS 2 TO 9

PLATE 6

PLATE 7



BONNEVILLE DAM
MINIMUM TAILWATER ELEVATION AT
GAGE T-1 REQUIRED FOR SKIMMING FLOW
12-FT DEFLECTOR AT ELEVATION 17



OPERATING CONDITIONS

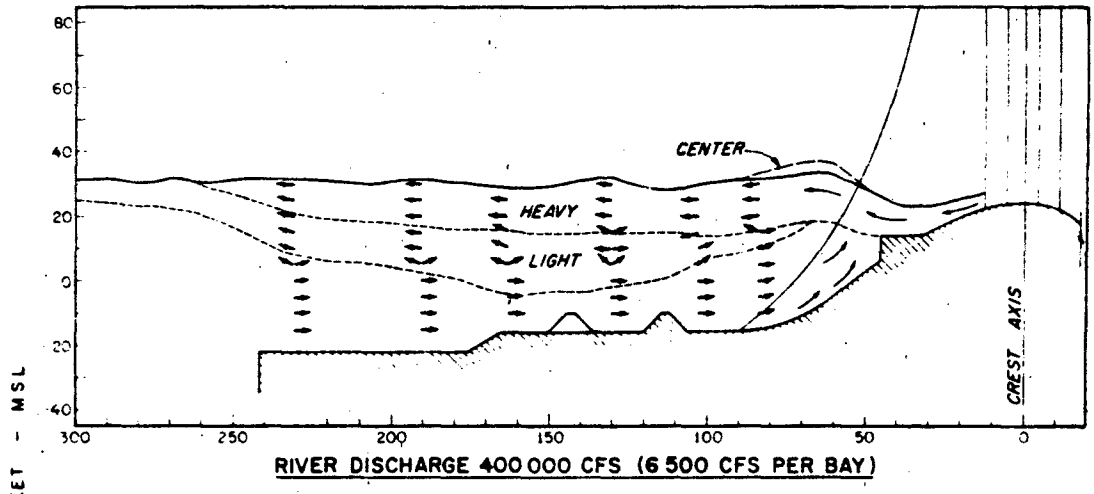
POWERHOUSE DISCHARGE 140 000 CFS
16 SPILLWAY BAYS OPERATING
FOREBAY ELEVATION 740

LEGEND

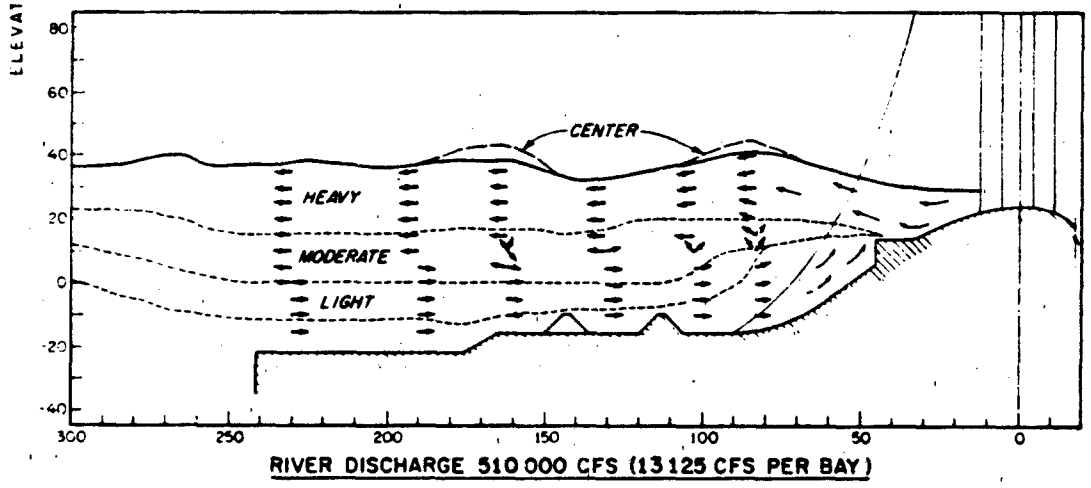
--------- ZONES OF AERATION

BONNEVILLE DAM
AERATION AND FLOW DIRECTIONS
IN STILLING BASIN — BAYS 2 TO 9
12-FT DEFLECTOR AT ELEV 14

PLATE 8



RIVER DISCHARGE 400 000 CFS (6 500 CFS PER BAY)



RIVER DISCHARGE 510 000 CFS (13 125 CFS PER BAY)

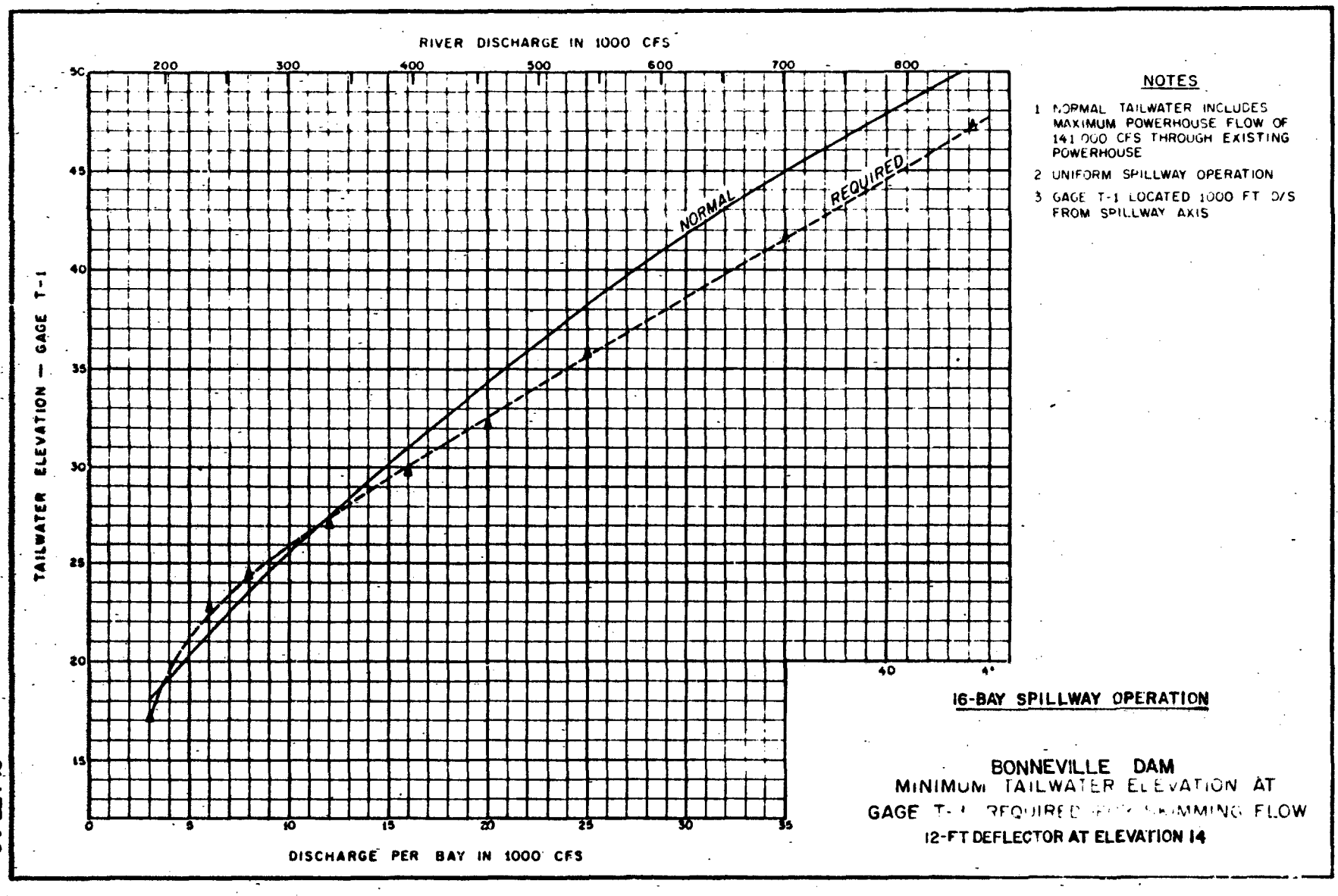
ELEVATION IN FEET - MSL

OPERATING CONDITIONS
POWERHOUSE DISCHARGE 300 000 CFS
16 SPILLWAY BAYS OPERATING
FOREBAY ELEVATION 740

LEGEND
---------- ZONES OF AERATION

BONNEVILLE DAM
AERATION AND FLOW DIRECTIONS
IN STILLING BASIN – BAYS 2 TO 9
12-FT. DEFLECTOR AT ELEV 14

PLATE 9



NOTES

1 NORMAL TAILWATER INCLUDES MAXIMUM POWERHOUSE FLOW OF 141 000 CFS THROUGH EXISTING POWERHOUSE

2 UNIFORM SPILLWAY OPERATION

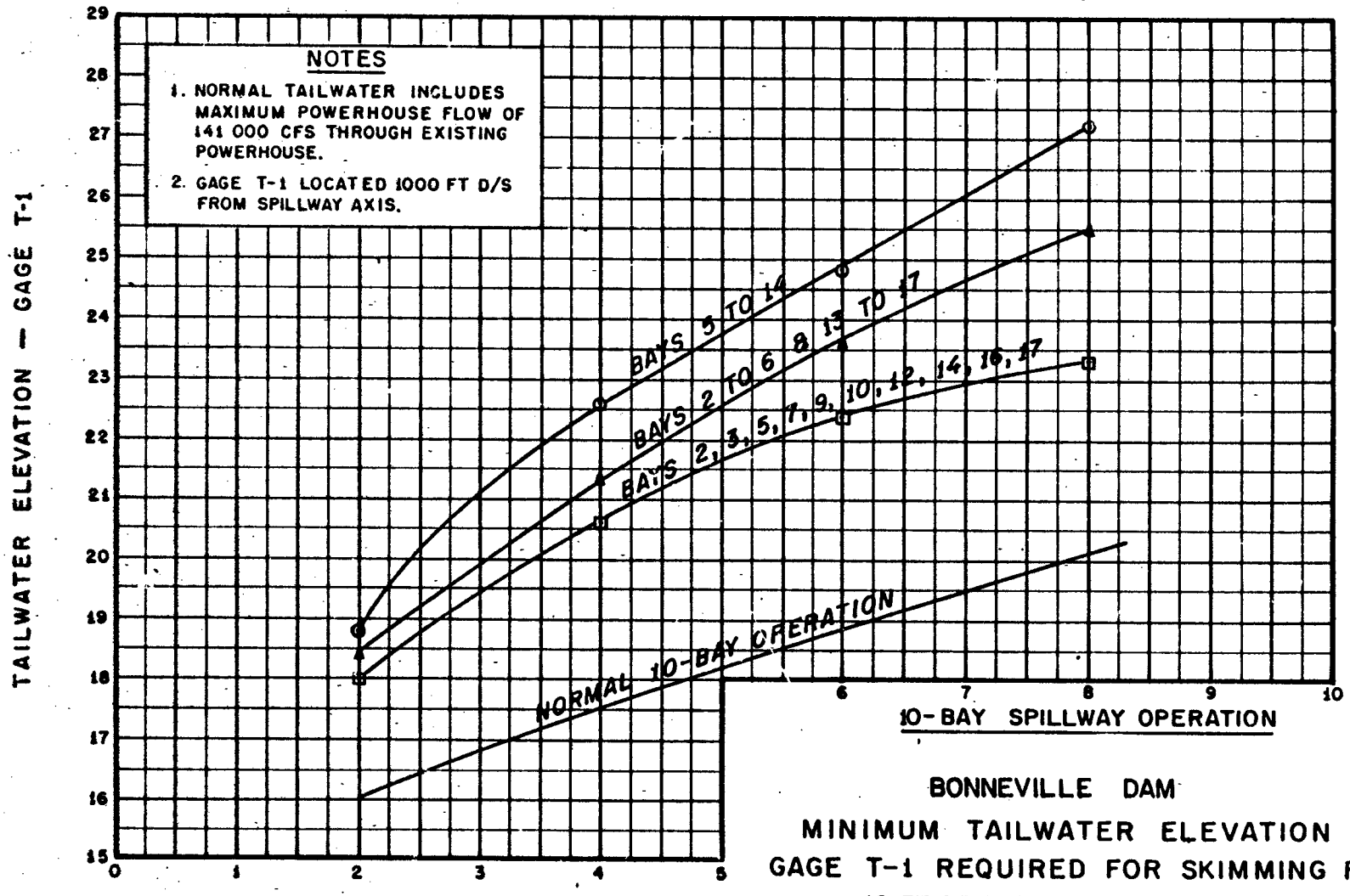
3 GAGE T-1 LOCATED 1000 FT D/S FROM SPILLWAY AXIS

16-BAY SPILLWAY OPERATION

BONNEVILLE DAM
MINIMUM TAILWATER ELEVATION AT
GAGE T-1 REQUIRED FOR SPAWNING FLOW
12-FT DEFLECTOR AT ELEVATION 14

PLATE 10

PLATE 11



BONNEVILLE DAM

MINIMUM TAILWATER ELEVATION AT GAGE T-1 REQUIRED FOR SKIMMING FLOW

12-FT DEFLECTORS AT ELEVATION 14

PART III

JOHN DAY DAM

PART III: JOHN DAY DAM TESTS AND RESULTS

The Prototype

15. The salient features of John Day Dam (plate 12) include a 20-bay spillway, a 20-unit powerhouse, a single-lift navigation lock, a 24-foot-wide fish ladder on each bank of the river, concrete non-overflow sections, and flanking embankments. The spillway is controlled by tainter gates and is designed to pass 2,250,000 cfs. Spillway energy is dissipated in a 185-foot-long stilling basin having a 13-foot-high sloping end sill. A section through the spillway and stilling basin is shown on plate 13.

The Model

16. The 1:41.14-scale model consisted of a three-bay section of the 20-bay spillway and stilling basin. The model initially was a reproduction of the spillway, stilling basin, upstream topography at elevation 135, and downstream topography at elevation 145. Subsequent to the initial tests, a resurvey of the topography immediately downstream from the stilling basin indicated the channel bed was lower than that reproduced in the model and that elevation 115 would be more representative of the average bottom elevation. Photograph 16 and plates 13 and 14 show the model with both downstream channel elevations.

Tests

17. Initial tests were conducted with downstream channel topography at elevation 145 to observe flow conditions and air entrainment under existing conditions with varying operating conditions (photographs 17 and 18, and plate 15). With all flows, the nappe, heavily entrained with air, was carried to the bottom of the stilling basin and resulted in mixing throughout the full depth of the basin.

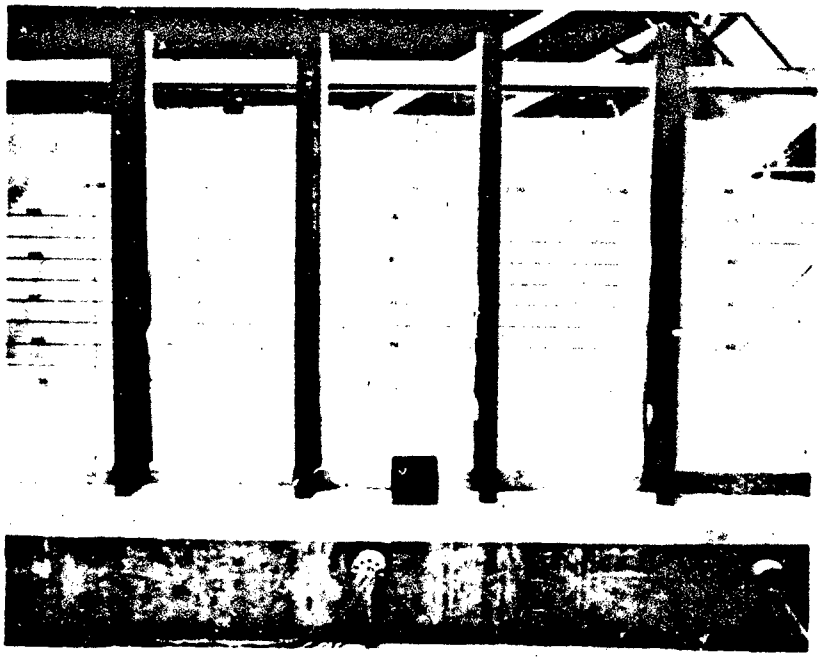
18. After comparing the flow performance of different length deflectors (plate 16), the 12.5-foot-long deflector was recommended and chosen for the optimum design. A factor in selecting the optimum location of the 12.5-foot-long deflectors was flow stability in the stilling basin. Plate 17 shows discharge and tailwater relationships for both stable and unstable flow conditions occurring with the four lip elevations tested. With the deflectors at elevation 149, stable skimming flow occurred with discharges up to approximately 16,000 cfs per bay with 5 powerhouse units in operation (minimum nighttime load). Tailwater limits are shown for powerhouse operation varying between 5 and 16 units with The Dalles pool at elevation 160. Plate 17 also shows discharge and tailwater relationships for the skimming nappe uplifted by excessive depth on the deflector lip. The uplift resulted in a diving flow downstream and tended to increase the depth of air penetration in the basin. Uplift was less of a problem at lower discharges and tailwater depths. Although spillway discharges for 16-unit powerhouse operation (maximum daytime load) fell within the excessive uplift area, the deterioration from good skimming flow conditions was borderline but not considered serious. This condition would improve with The Dalles pool at less than elevation 160. Tests were conducted to determine an elevation of the deflector lip which would provide the best performance in the stilling basin for discharges equivalent to the 10-year-frequency flood. Several combinations of deflector elevations and discharges were used. Only minor changes occurred in degree, concentration, and depth of air penetration by varying the deflector elevations. Regardless of location, the area susceptible to the drawdown effect of aerated flow was in the vicinity of the stilling basin end sill where velocities in the deep return flow were generally high enough to pull surface aeration downward. With the downstream topography set at elevation 145, the optimum deflector elevation was 149 since the least amount of air was entrained with the lower discharges and the best energy dissipation occurred within the stilling basin with higher discharges (photographs 19 through 25 and plates 18 and 19). Energy dissipation (photographs 24 and 25) was satisfactory with the standard project flood (33,900 cfs per bay) and the maximum design

discharge (112,500 cfs per bay). Deflector lengths of 10 and 15 feet at elevation 149 were tested to observe the flow conditions in the stilling basin. This scheme was discontinued, however, since flow conditions were either less effective or showed no improvement over the 12.5-foot deflector.

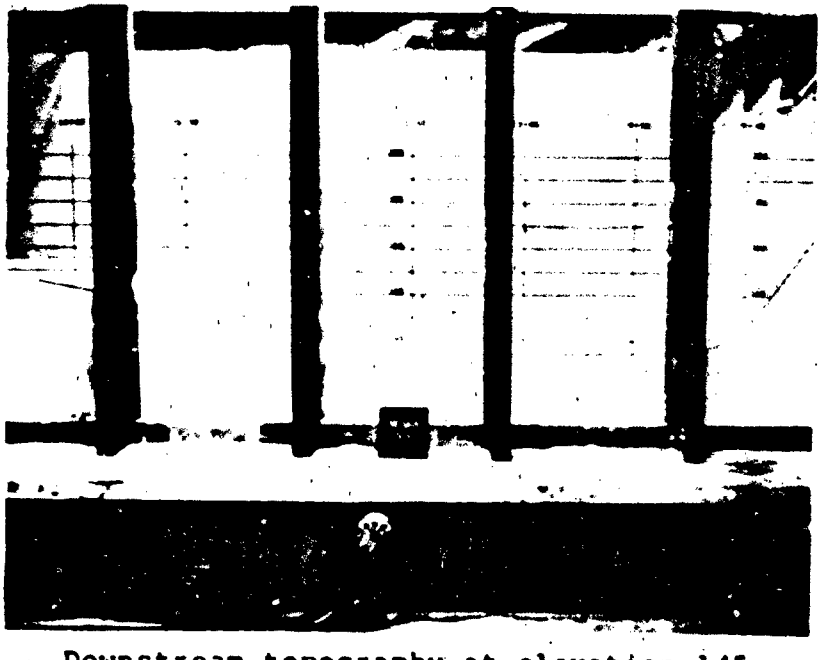
19. Similar tests were conducted with the downstream channel elevation at 115. Air entrainment and flow directions in the stilling basin with deflectors at elevation 149 for discharges of 3,000, 7,200, 12,000, and 19,300 cfs per bay are shown on plate 20. Comparisons of depth and quantity of air penetration in the basin with downstream channel topography at elevations 115 and 145 are shown in photographs 26 through 29. The tests conducted indicated that elevation of downstream topography had little or no effect on depth of air entrainment within the stilling basin. The quantity of air entrainment for higher discharges was less with the lower downstream topography elevation.

20. The discharge/tailwater relationship for stable and unstable flow conditions occurring with deflectors at elevation 149 and downstream topography at elevation 115 are shown on plate 21. Discharges ranging from 3,000 to 19,300 cfs per bay were observed. Tailwater limits are shown for powerhouse operation varying between 5 and 16 units with The Dalles reservoir at elevation 160. Stable skimming flow occurred to approximately 16,000 cfs per bay with five powerhouse units in operation (minimum nighttime load).

21. The performance of the 12.5-foot deflectors at elevation 149 was satisfactory with downstream channel topography at elevation 115. Deflectors installed at elevation 149 provided the best overall performance with regard to flow stability, quantity and depth of air penetration in the stilling basin, and energy dissipation with higher discharges.



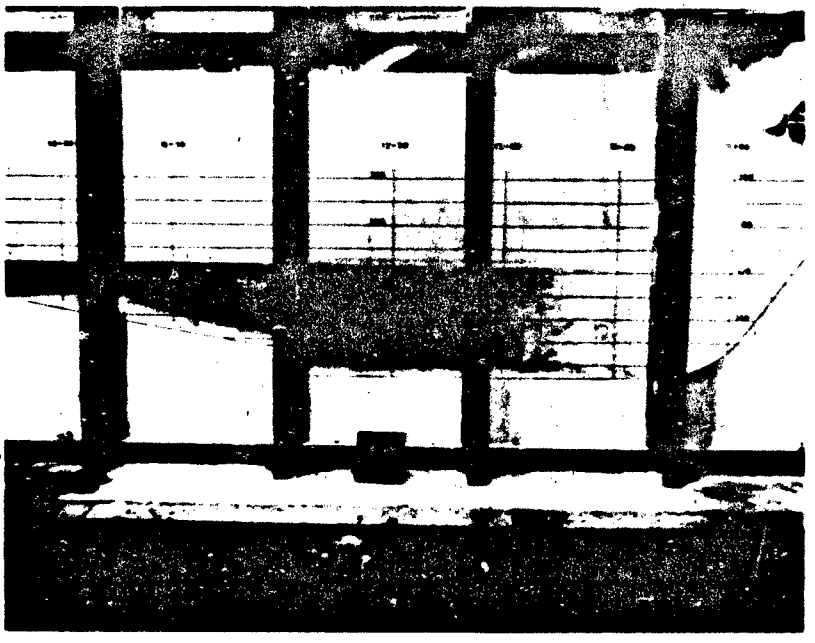
Downstream topography at elevation 115.



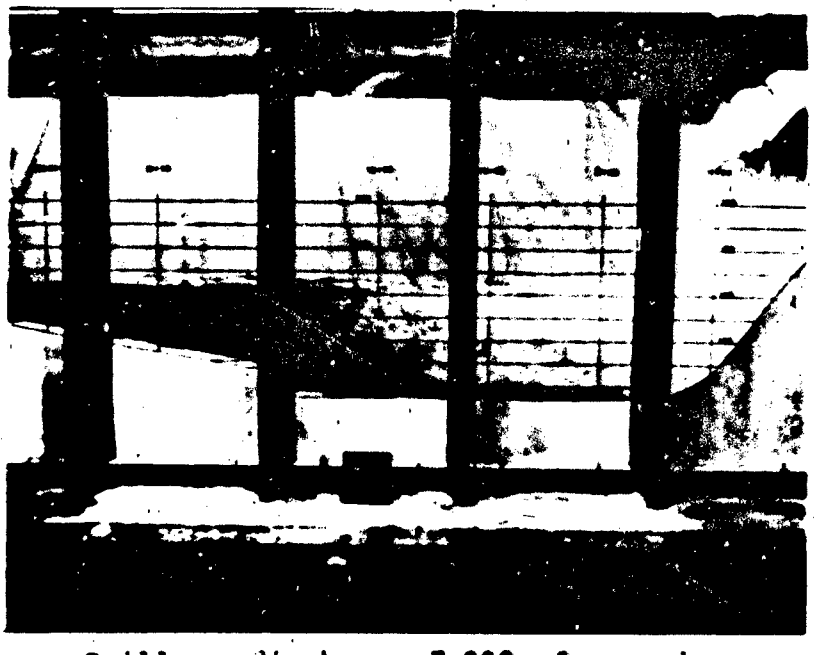
Downstream topography at elevation 145.

John Day Dam

Photograph 16. Dry bed of spillway with 12.5-foot deflectors at elevation 149.



Spillway discharge 3,000 cfs per bay.
9 powerhouse units in operation.



Spillway discharge 7,200 cfs per bay.
5 powerhouse units in operation.

John Day Dam

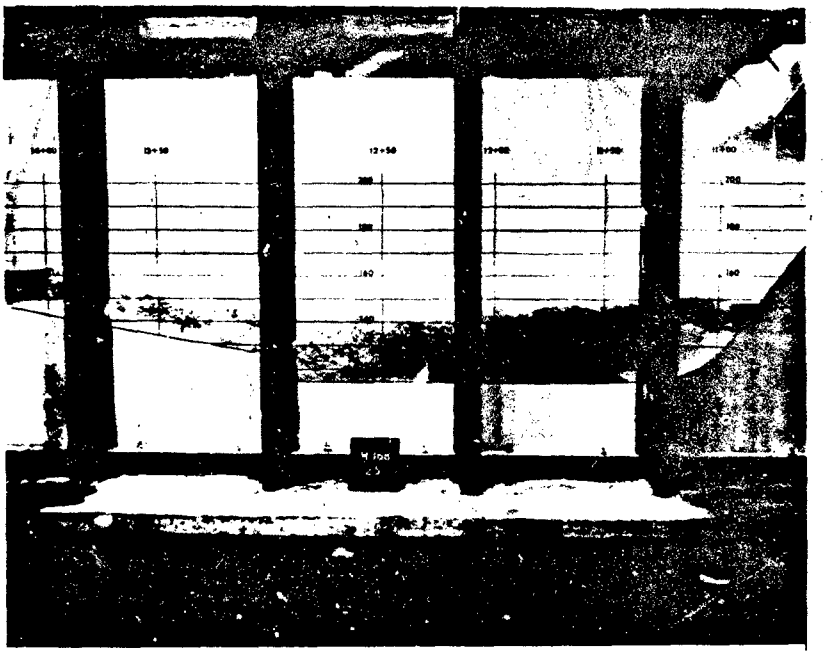
Photograph 17. Flow conditions with existing spillway and stilling basin (no deflectors). River discharge 250,000 cfs. Pool elevation 265; tailwater elevation 163.0.

John Day Dam

Photograph 18. Flow conditions with existing spillway and stilling basin (no deflectors). Spillway discharge 112,500 cfs per bay. River discharge 2,250,000 cfs. Pool elevation 277.9; tailwater elevation 201.0. No powerhouse units in operation.

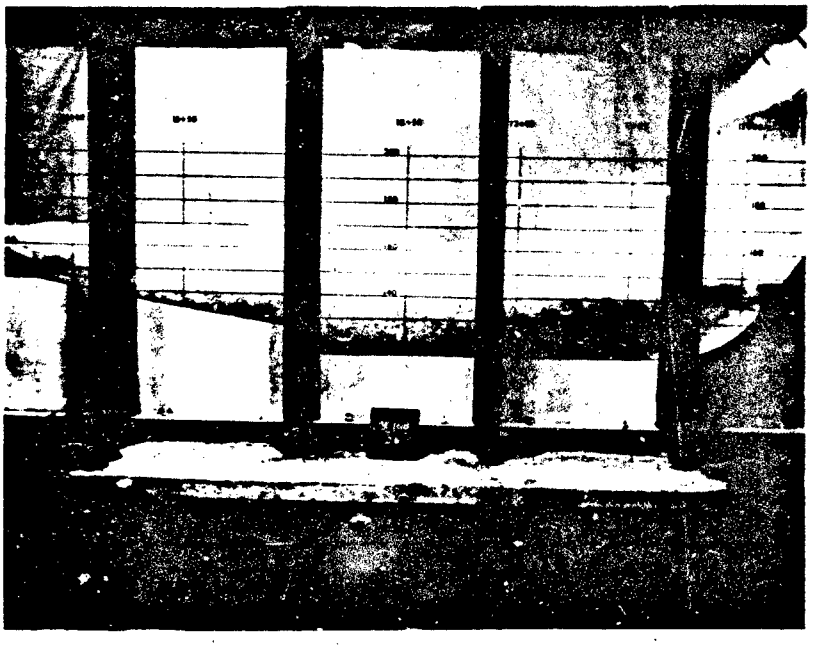
John Day Dam

Photograph 19. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 3,000 cfs per bay. River discharge 250,000 cfs. Pool elevation 265; tailwater elevation 163.0. 9 powerhouse units in operation.



John Day Dam

Photograph 20. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 7,200 cfs per bay. River discharge 250,000 cfs. Pool elevation 265; tailwater elevation 163.0. 5 powerhouse units in operation.

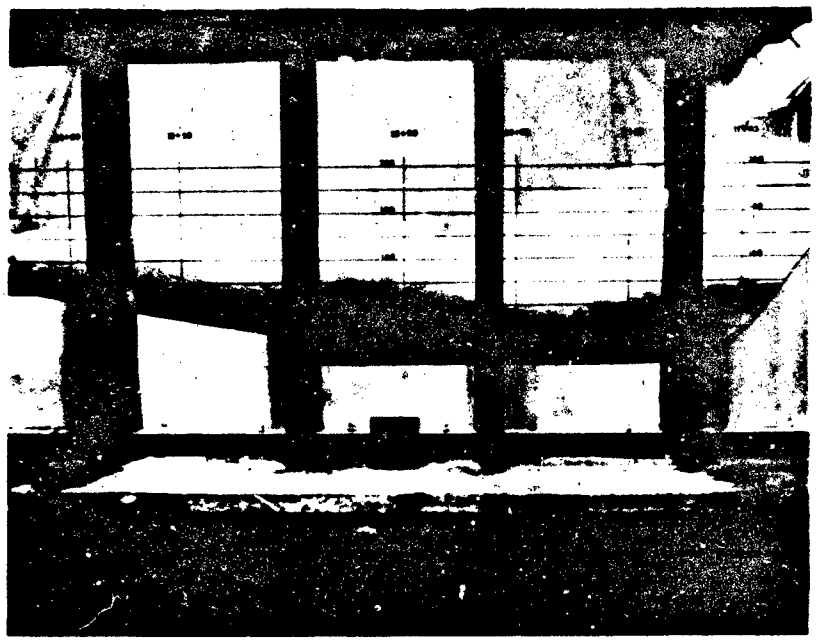


John Day Dam

Photograph 21. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 12,000 cfs per bay. River discharge 350,000 cfs. Pool elevation 265; tailwater elevation 165.3. 5 powerhouse units in operation.

John Day Dam

Photograph 22. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 16,500 cfs per bay. River discharge 440,000 cfs. Pool elevation 265; tailwater elevation 167.4. 5 powerhouse units in operation.

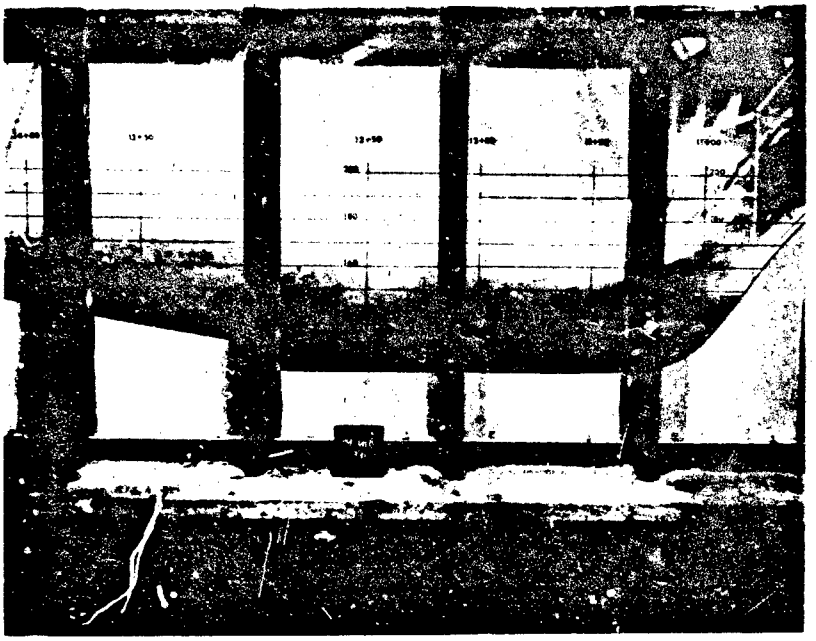


John Day Dam

Photograph 23. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 19,300 cfs per bay. River discharge 500,000 cfs. Pool elevation 265; tailwater elevation 168.8. 5 powerhouse units in operation.

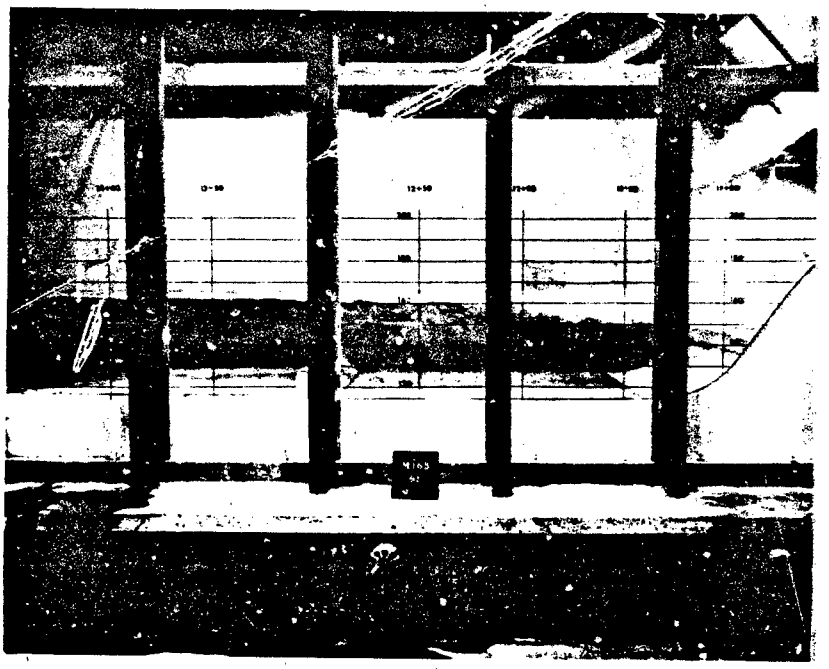
John Day Dam

Photograph 24. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 33,900 cfs per bay. River discharge 800,000 cfs. Pool elevation 265; tailwater elevation 176.7. 5 powerhouse units in operation.



John Day Dam

Photograph 25. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 112,500 cfs per bay. River discharge 2,250,000 cfs. Pool elevation 277.9; tailwater elevation 201.0. No powerhouse units in operation.

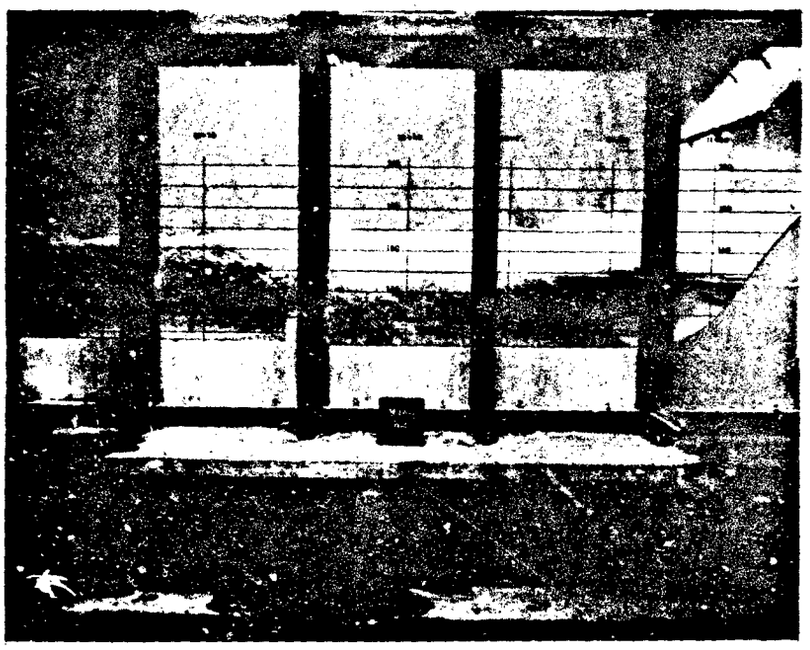


Downstream topography at elevation 115.

Downstream topography at elevation 145.

John Day Dam

Photograph 26. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 3,000 cfs per bay. River discharge 250,000 cfs. Pool elevation 265; tailwater elevation 163.0. 9 powerhouse units in operation.

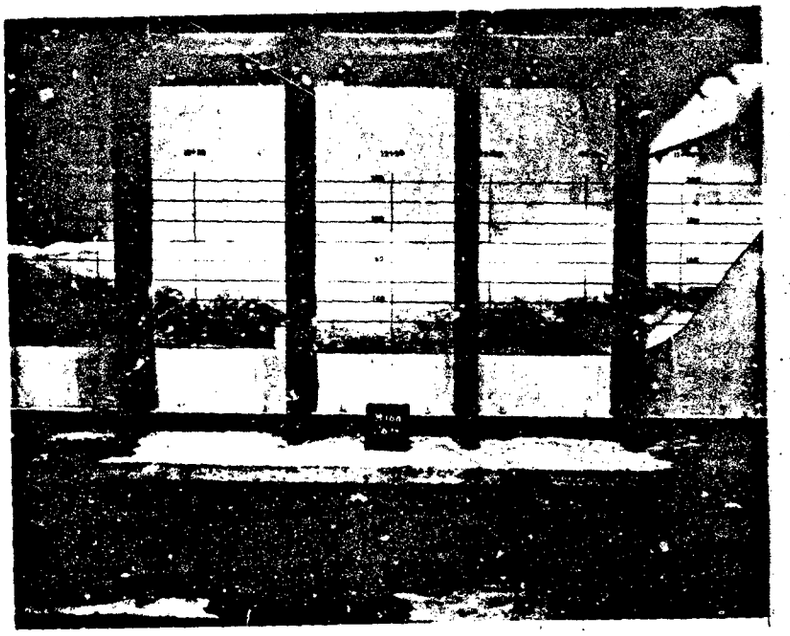


Downstream topography at elevation 115.

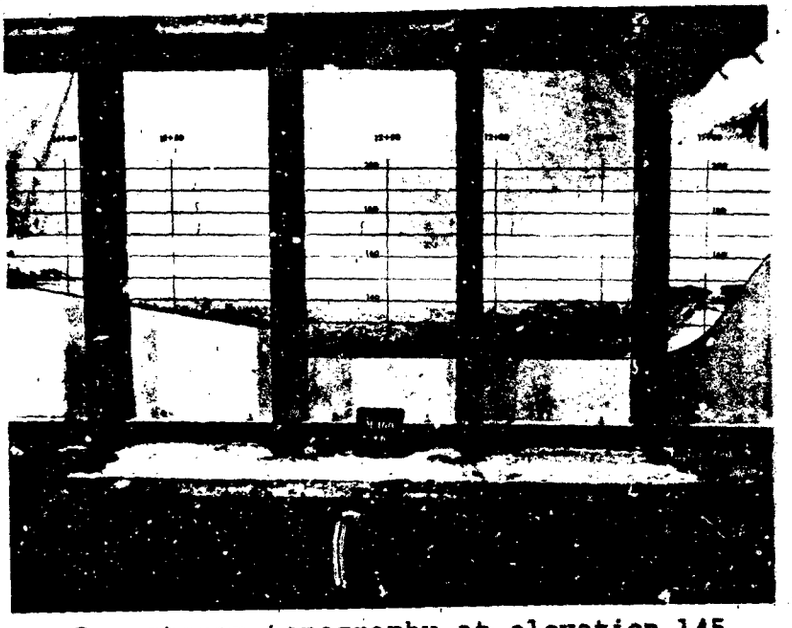
Downstream topography at elevation 145.

John Day Dam

Photograph 27. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 7,200 cfs per bay. River discharge 250,000 cfs. Pool elevation 265; tailwater elevation 163.0. 5 powerhouse units in operation.



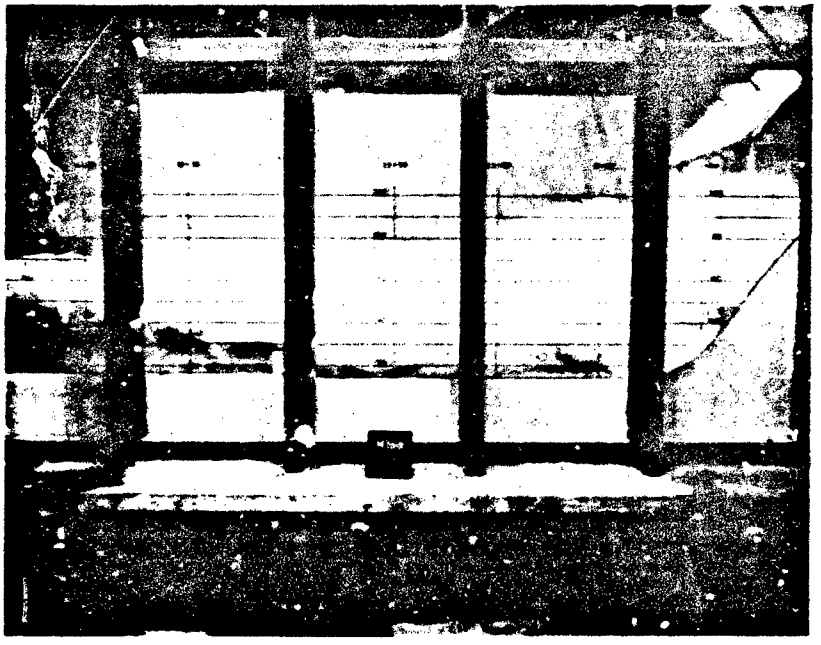
Downstream topography at elevation 115.



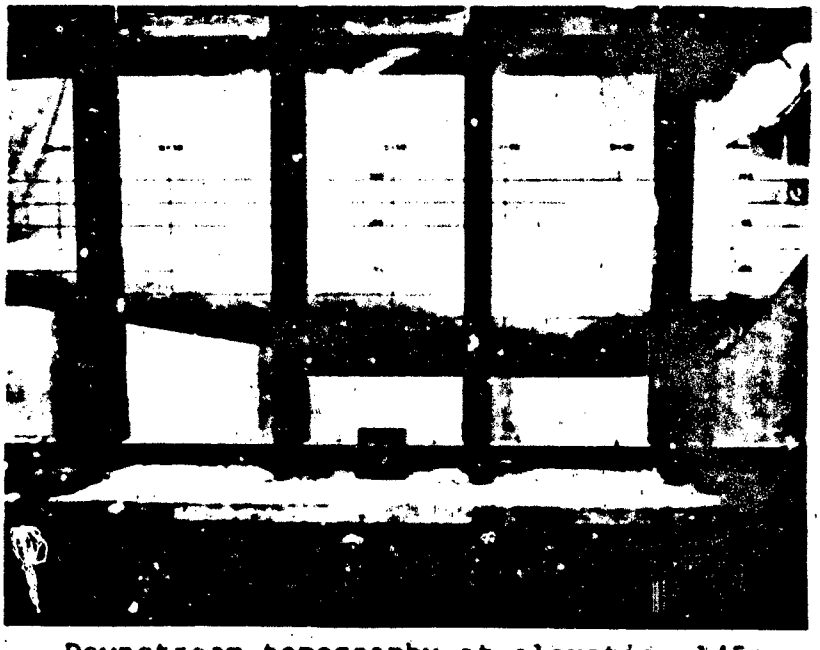
Downstream topography at elevation 145.

John Day Dam

Photograph 28. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 12,000 cfs per bay. River discharge 350,000 cfs. Pool elevation 265; tailwater elevation 165.3. 5 powerhouse units in operation.



Downstream topography at elevation 115.

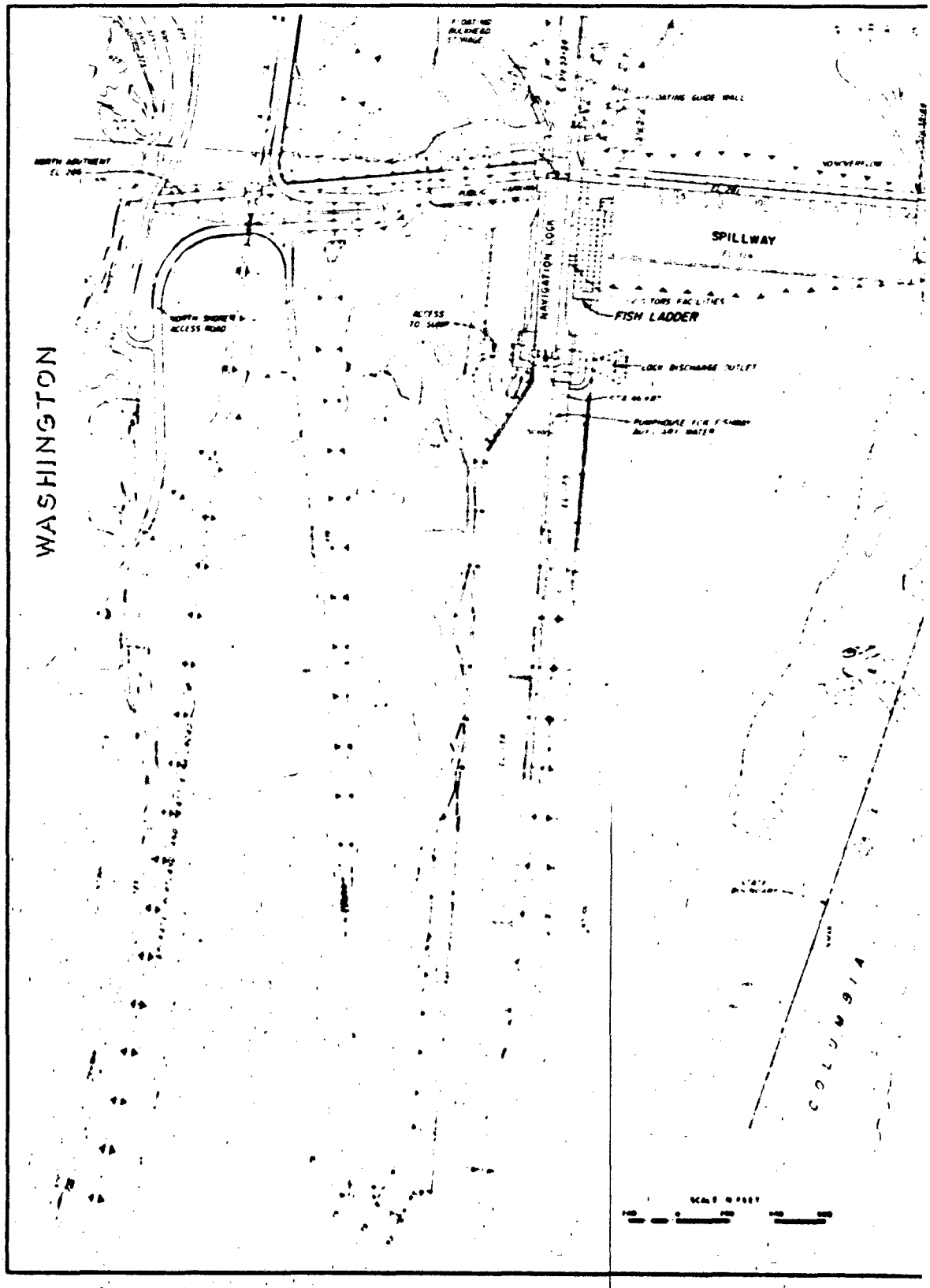


Downstream topography at elevation 145.

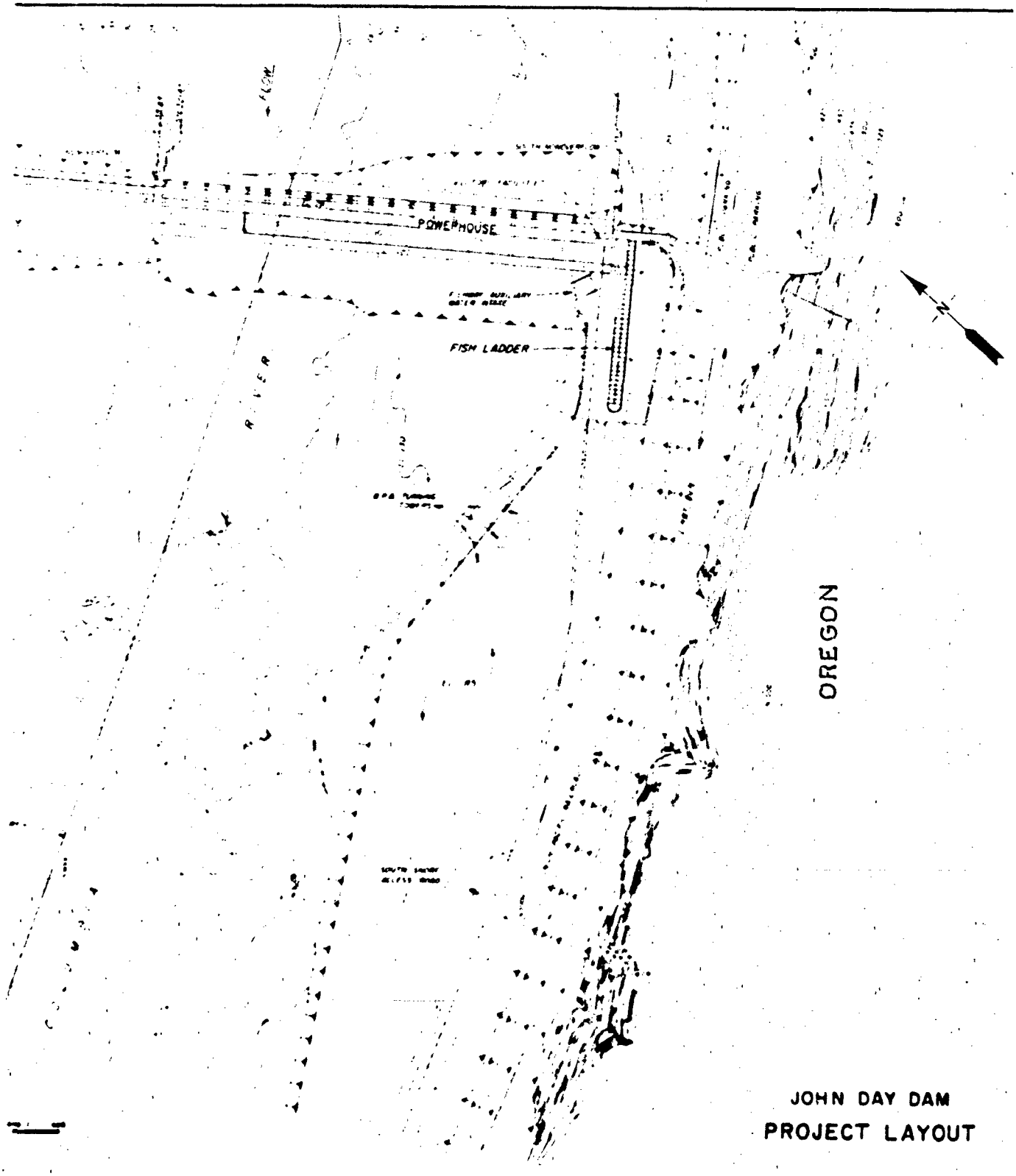
John Day Dam

Photograph 29. Flow conditions with 12.5-foot deflectors at elevation 149. Spillway discharge 19,300 cfs per bay. River discharge 500,000 cfs. Pool elevation 265; tailwater elevation 168.8. 5 powerhouse units in operation.

REPRODUCED AT GOVERNMENT EXPENSE



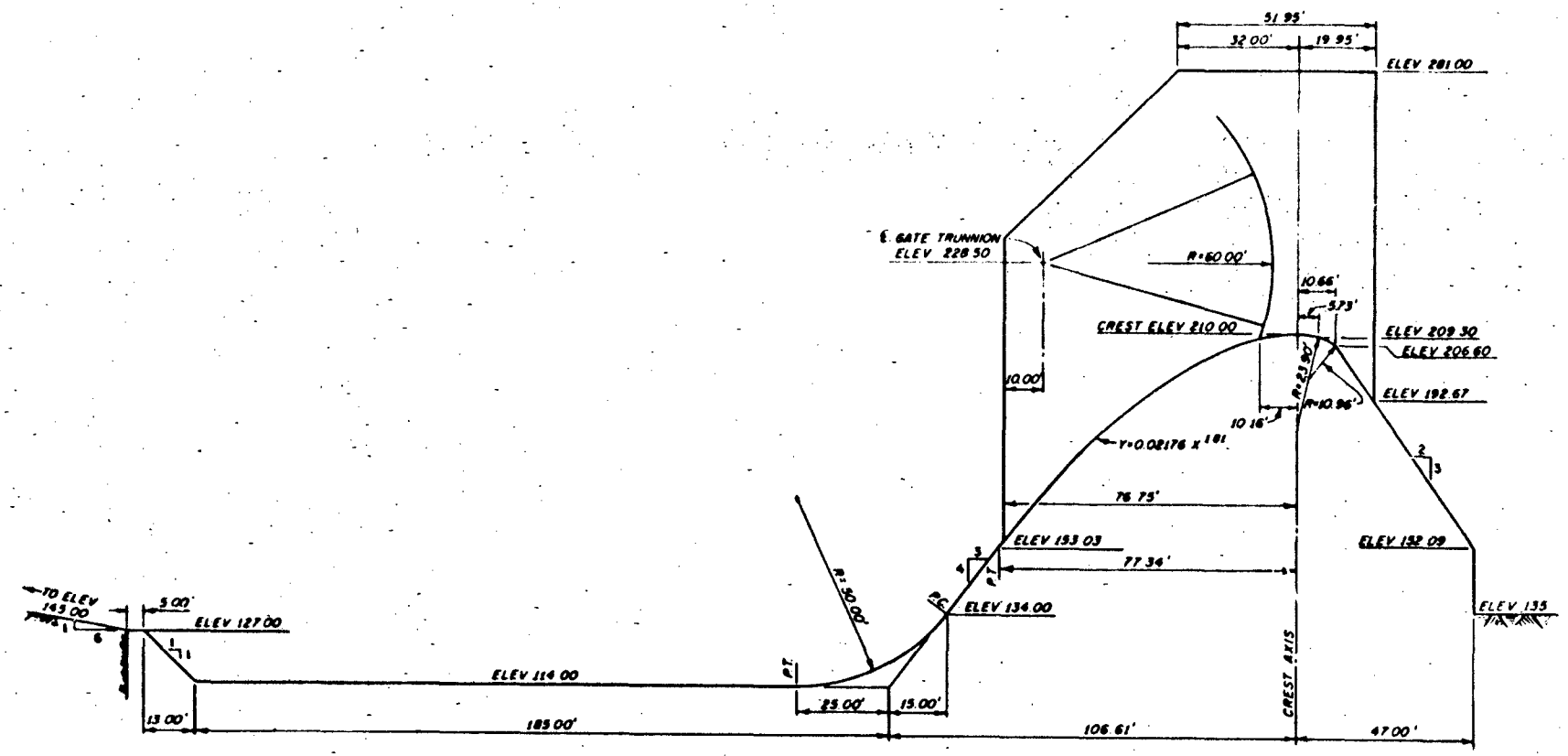
REPRODUCED AT GOVERNMENT EXPENSE



JOHN DAY DAM
PROJECT LAYOUT

PLATE 1

3 of 5



SECTION THROUGH SPILLWAY

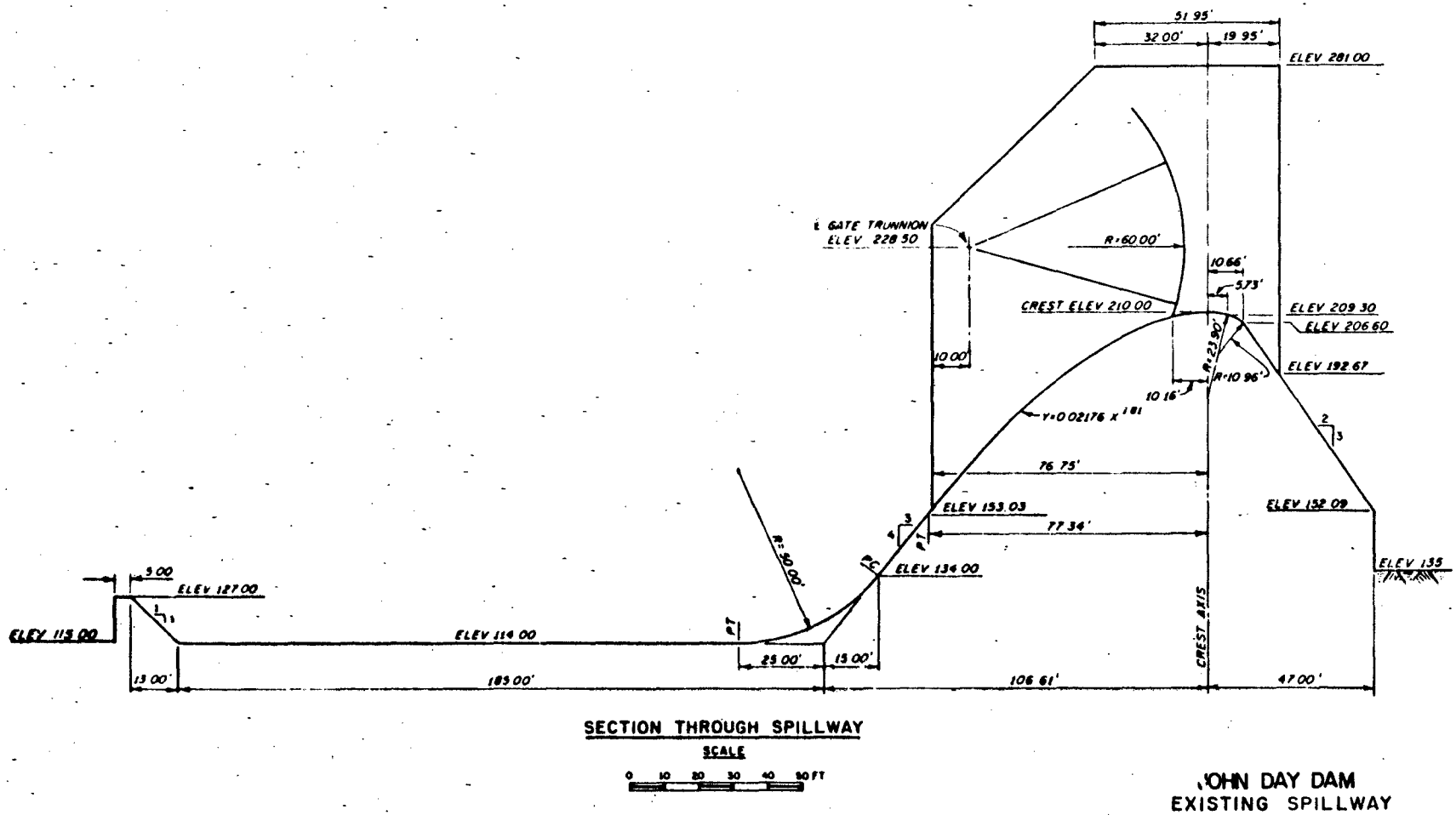
SCALE

0 10 20 30 40 50 FT

JOHN DAY DAM
EXISTING SPILLWAY
AND STILLING BASIN

PLATE 13

PLATE 14

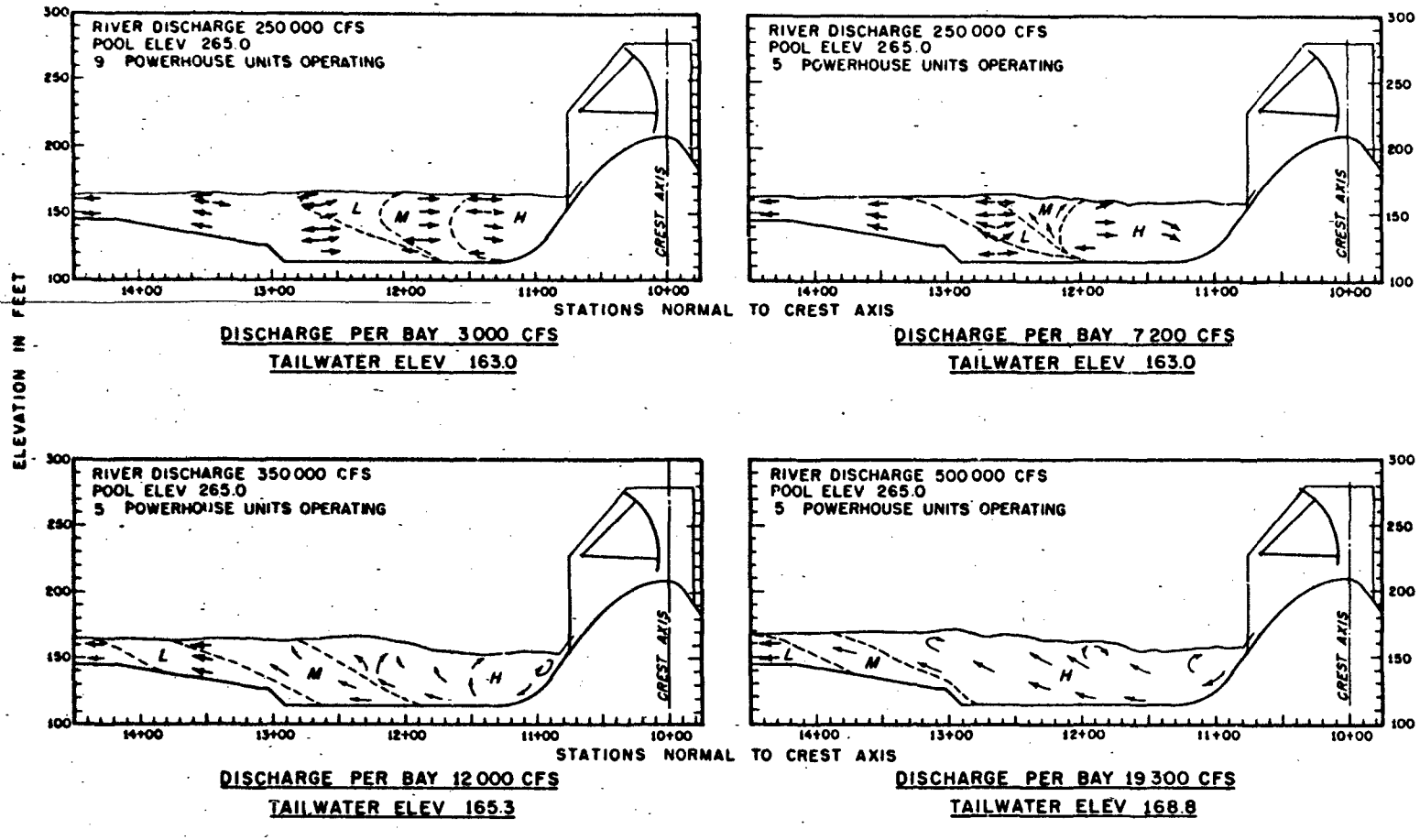


SECTION THROUGH SPILLWAY

SCALE

0 10 20 30 40 50 FT

JOHN DAY DAM
EXISTING SPILLWAY
AND STILLING BASIN
DOWNSTREAM TOPOGRAPHY AT ELEV 115



DISCHARGE PER BAY 3000 CFS
TAILWATER ELEV 163.0

DISCHARGE PER BAY 7200 CFS
TAILWATER ELEV 163.0

DISCHARGE PER BAY 12 000 CFS
TAILWATER ELEV 165.3

DISCHARGE PER BAY 19 300 CFS
TAILWATER ELEV 168.8

OPERATING CONDITION

20 SPILLWAY BAYS; END BAYS REGULATED FOR FISH ATTRACTION.

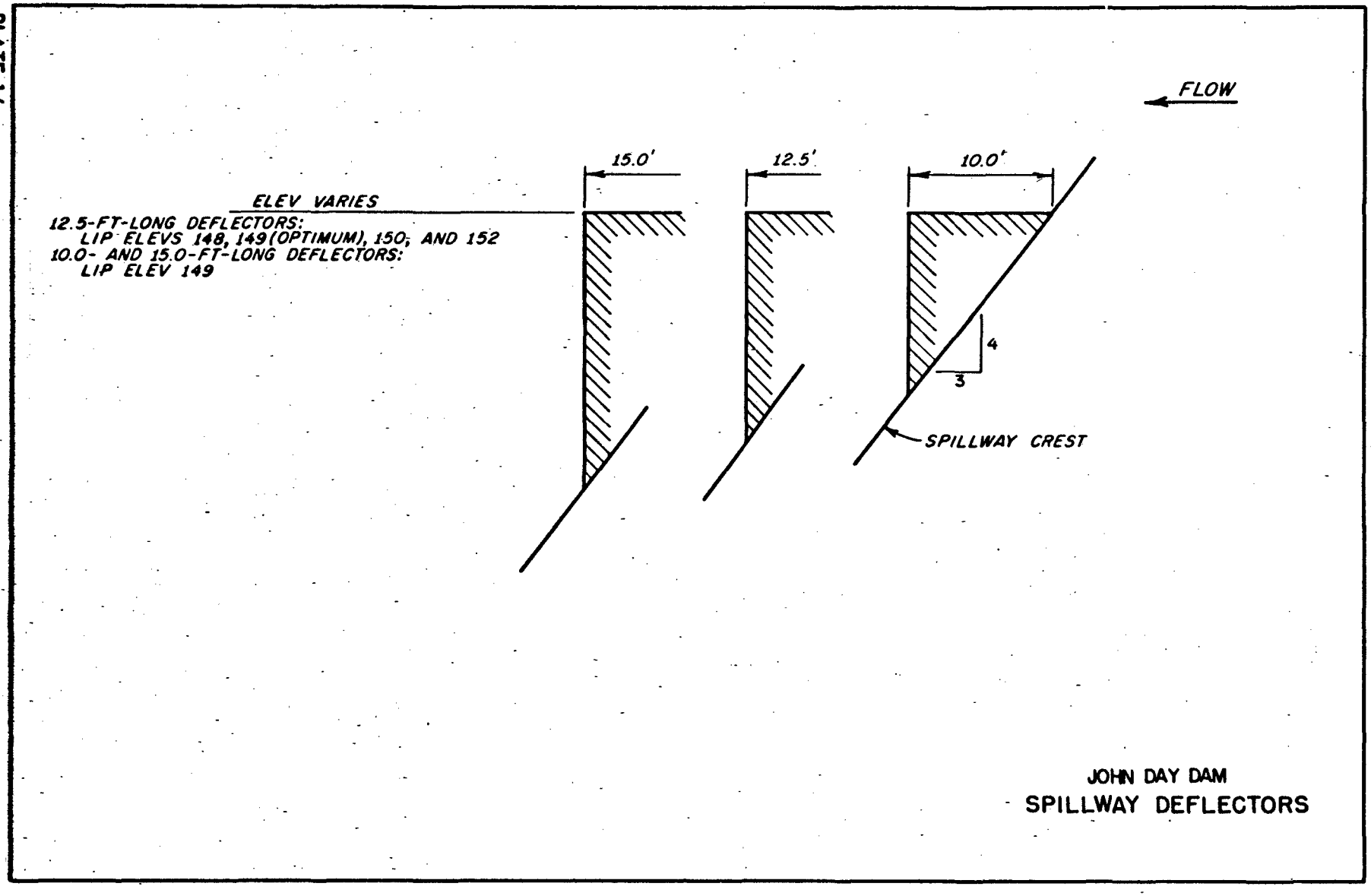
LEGEND

-------- ZONES OF AERATION (H, HEAVY; M, MEDIUM; L, LIGHT).

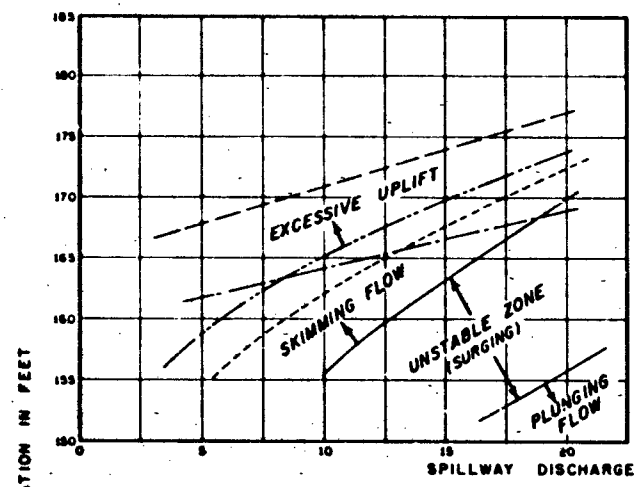
JOHN DAY DAM
AERATION AND FLOW DIRECTIONS
NO DEFLECTORS

PLATE 15

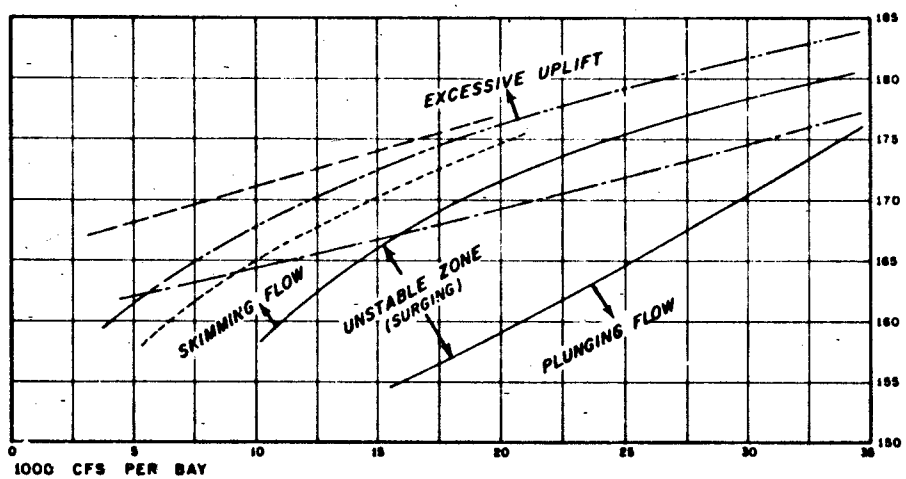
PLATE 16



JOHN DAY DAM
SPILLWAY DEFLECTORS



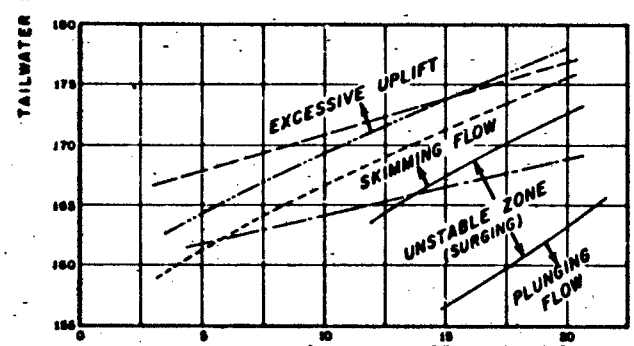
12.5-FT DEFLECTORS AT ELEV 148



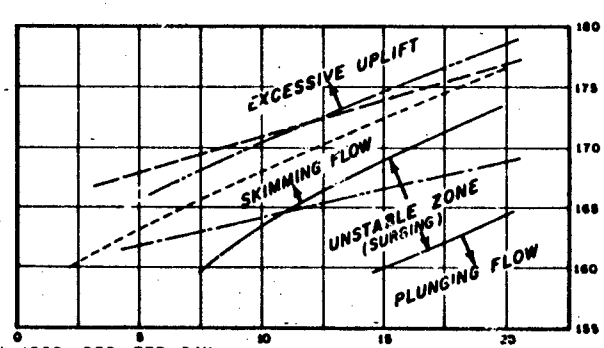
12.5-AND 15.0-FT DEFLECTORS AT ELEV 149

TAILWATER ELEVATION IN FEET

SPILLWAY DISCHARGE IN 1000 CFS PER BAY



12.5-FT DEFLECTORS AT ELEV 150



12.5-FT DEFLECTORS AT ELEV 152

NOTES

1 POOL ELEV 265

2 TAILWATER SHOWN FOR THE DALLES POOL ELEV 160.

LEGEND

——— NORMAL TAILWATER 16 POWERHOUSE UNITS OPERATING

———— NORMAL TAILWATER 8 POWERHOUSE UNITS OPERATING

- - - - - - - BEST SKIMMING FLOW

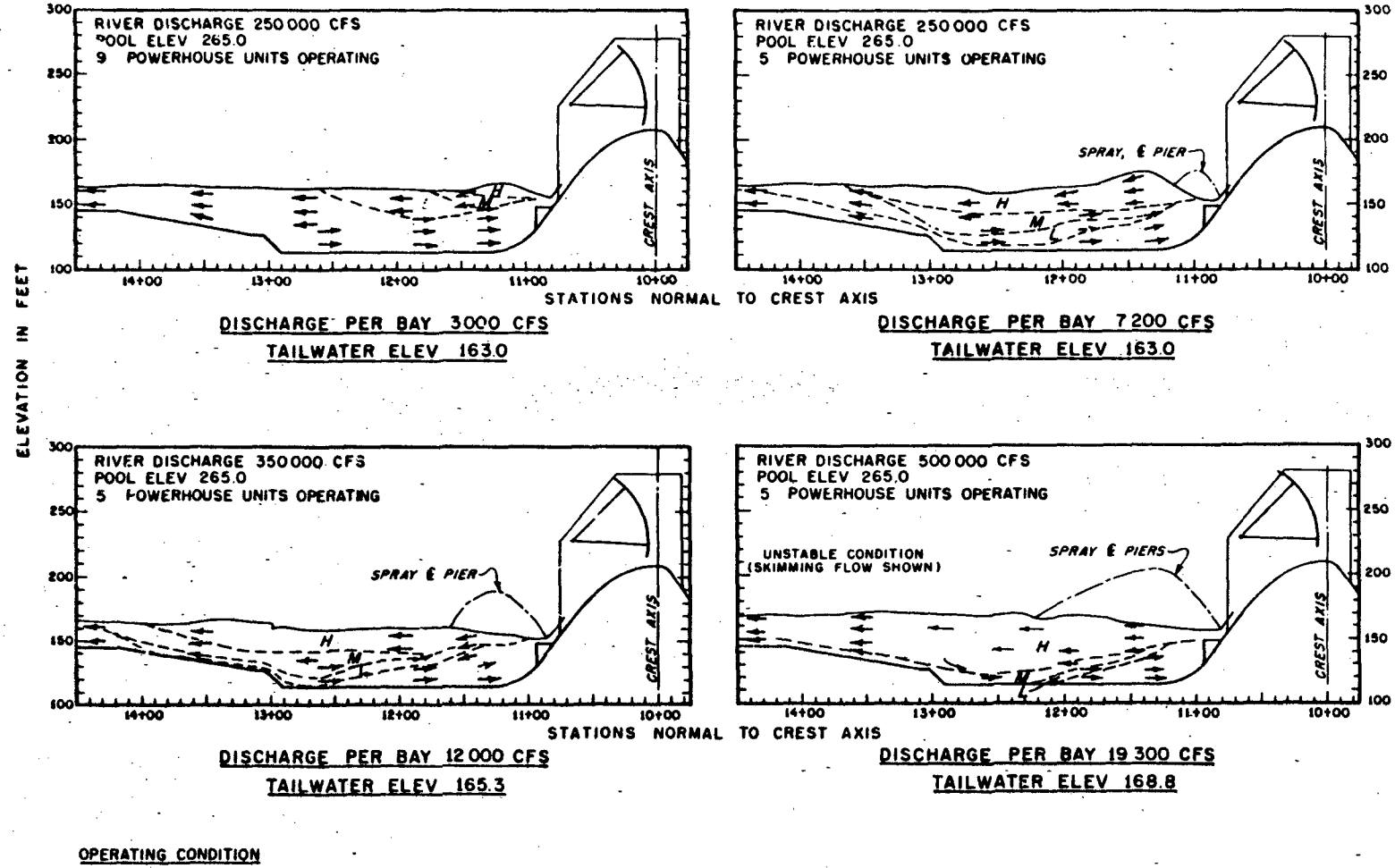
PLATE 17

JOHN DAY DAM

FLOW CONDITIONS IN STILLING BASIN

12.5-AND 15.0-FT DEFLECTORS

PLATE 18



DISCHARGE PER BAY 3000 CFS
TAILWATER ELEV 163.0

DISCHARGE PER BAY 7200 CFS
TAILWATER ELEV 163.0

DISCHARGE PER BAY 12 000 CFS
TAILWATER ELEV 165.3

DISCHARGE PER BAY 19 300 CFS
TAILWATER ELEV 168.8

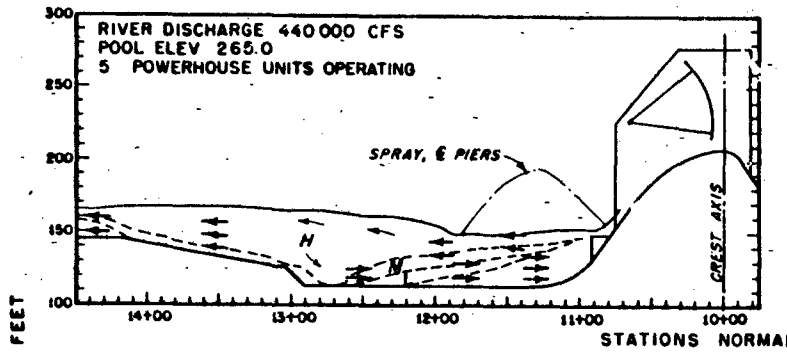
OPERATING CONDITION

20 SPILLWAY BAYS; END BAYS REGULATED FOR FISH ATTRACTION.

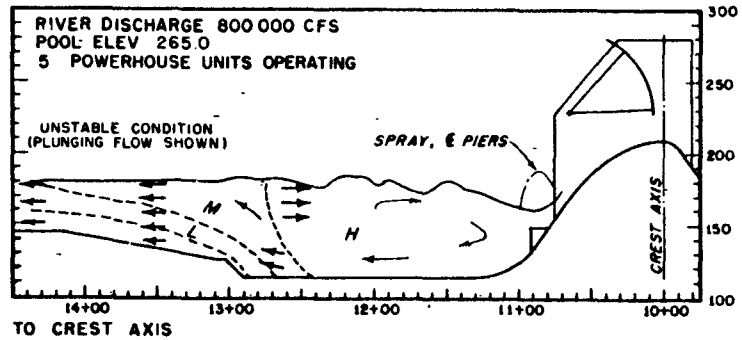
LEGEND

-------- ZONES OF AERATION (H, HEAVY; M, MEDIUM; L, LIGHT).

JOHN DAY DAM
AERATION AND FLOW DIRECTIONS
12.5-FT DEFLECTORS AT ELEV 149



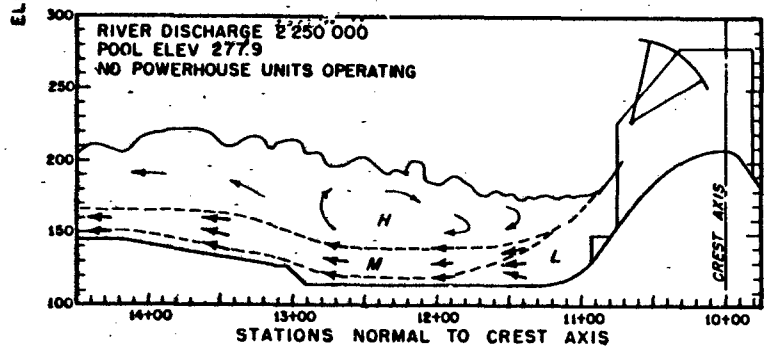
DISCHARGE PER BAY 16 500 CFS
TAILWATER ELEV 167.4



ELEVATION IN FEET

STATIONS NORMAL TO CREST AXIS

DISCHARGE PER BAY 33 900 CFS
TAILWATER ELEV 176.7



STATIONS NORMAL TO CREST AXIS

DISCHARGE PER BAY 112 500 CFS
TAILWATER ELEV 201.0

OPERATING CONDITION

20 SPILLWAY BAYS; END BAYS REGULATED FOR FISH ATTRACTION.

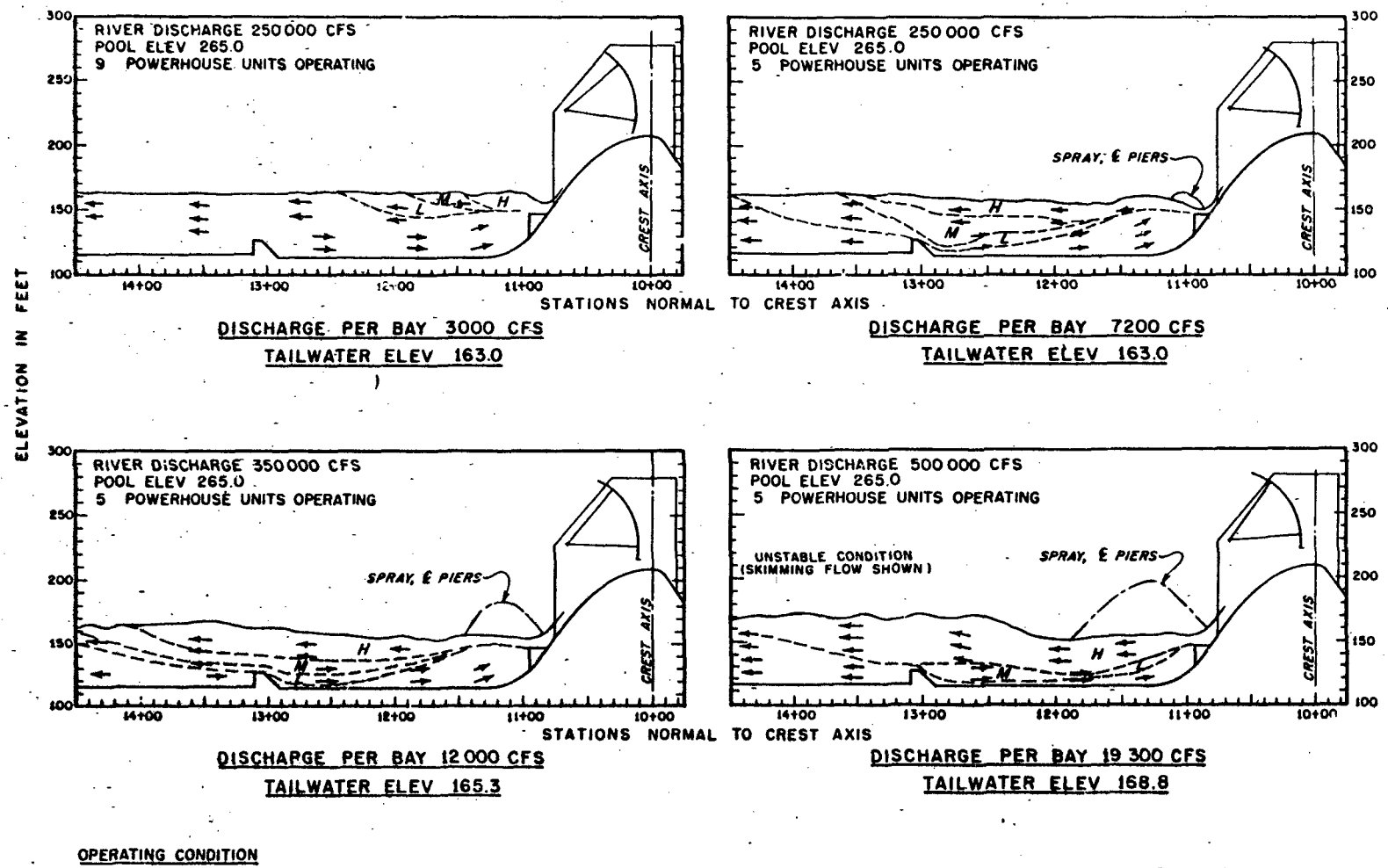
LEGEND

-------- ZONES OF AERATION (H, HEAVY; M, MEDIUM; L, LIGHT).

JOHN DAY DAM
AERATION AND FLOW DIRECTIONS
12.5-FT DEFLECTORS AT ELEV 149

PLATE 19

PLATE 20



OPERATING CONDITION

20 SPILLWAY BAYS; END BAYS REGULATED FOR FISH ATTRACTION.

LEGEND

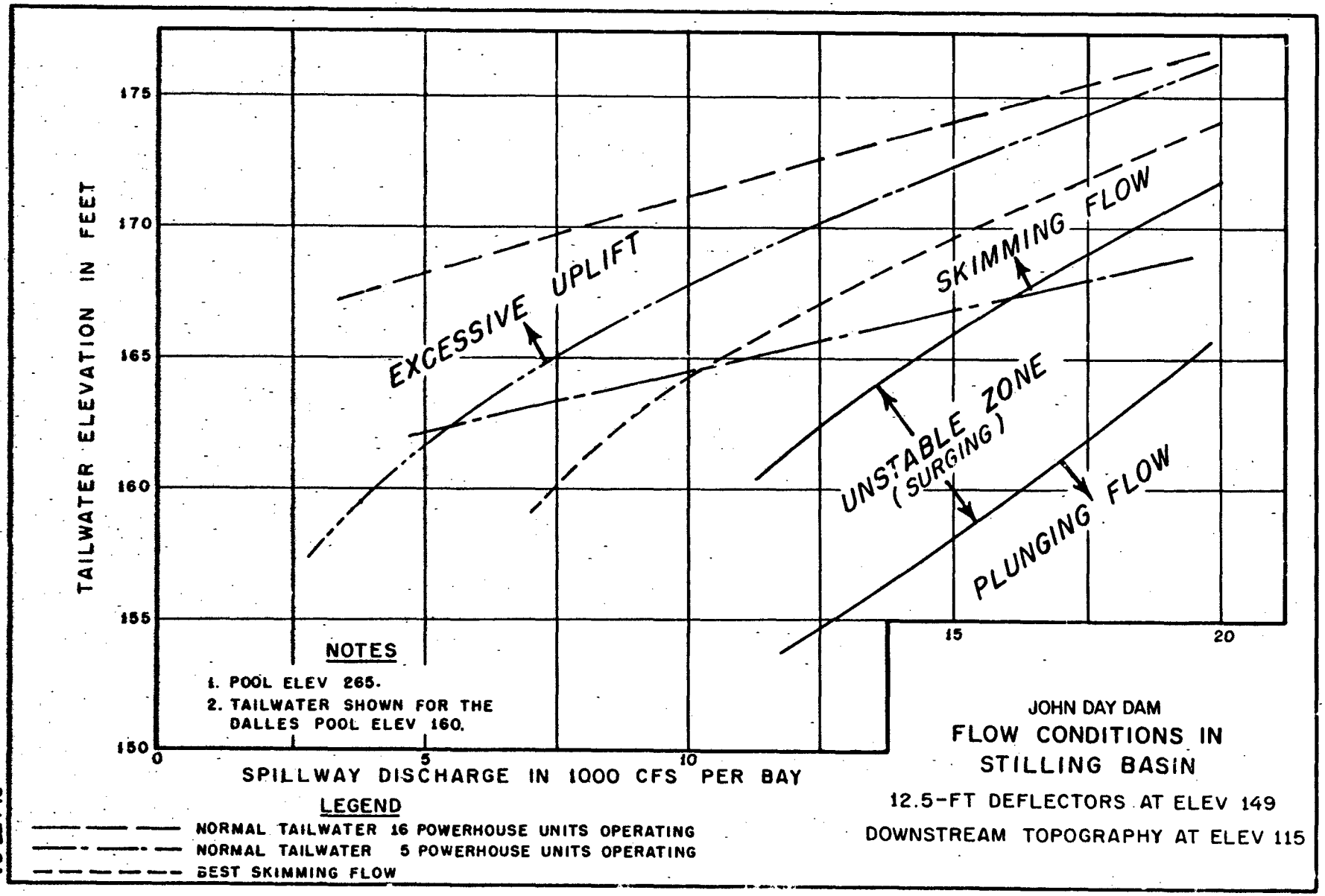
ZONES OF AERATION (H, HEAVY; M, MEDIUM; L, LIGHT).

JOHN DAY DAM

AERATION AND FLOW DIRECTIONS

12.5-FT DEFLECTORS AT ELEV 149

DOWNSTREAM TOPOGRAPHY AT ELEV 115



JOHN DAY DAM

FLOW CONDITIONS IN STILLING BASIN

12.5-FT DEFLECTORS AT ELEV 149

DOWNSTREAM TOPOGRAPHY AT ELEV 115

PLATE 21

PART IV

McNARY DAM

PART IV: MCNARY DAM TESTS AND RESULTS

The Prototype

22. The salient features of McNary Dam (plate 22) include a 22-bay spillway, a 14-unit powerhouse, a single-lift navigation lock, a fish ladder on each side of the river, and flanking embankments. The spillway is designed to pass 2,200,000 cfs at pool elevation 356.5 and 1,439,000 cfs at normal pool elevation 340.0. Spillway discharge is controlled by split-leaf vertical-lift gates. Spillway energy is dissipated in a 270-foot-long stilling basin having a floor elevation of 228 with two rows of 10.5-foot-high baffle piers and a 10.5-foot-high vertical end sill. Two bays at each end of the spillway are separated from the rest of the structure by training walls and are used to provide additional attraction flow or to improve current patterns and velocities at the adjacent fishway entrances.

The Models

23. A 1:40-scale three-bay sectional model of the spillway, stilling basin, and a portion of the downstream channel (photograph 30 and plate 23) was used to establish the deflector geometry. The spillway crest and toe curve were constructed of sheet metal that was attached to plywood ribs. The upstream faces and ends of the gates and the test deflectors were made of acrylic plastic; other elements of the model were constructed of waterproofed wood and plywood. Pool elevation 340.0 was maintained by the spillway gates (except during free flow with the project design discharge of 2,200,000 cfs at pool elevation 356.5). Tailwater elevations (plate 24) were controlled by a vaned tailgate and measured on the centerline of the model 1,000 feet downstream from the crest axis.

24. The 1:50-scale comprehensive model (photograph 31 and plate 25) was used to determine the effects of the recommended deflector on flow conditions and to establish spillway operation schedules for

optimum passage of fish. The comprehensive model was a reproduction of a portion of the forebay, the spillway and adjacent fishway entrances, powerhouse units 9 through 14, and about 1,600 feet of downstream channel. The model structures were made of plastic, waterproofed wood, and plywood, and the exit channel was contoured in cement to conform with a 1974 hydrographic survey at the project. Pool elevation 340.0 was controlled by the spillway gates, and tailwater elevations were set at a gage approximately 2,000 feet downstream from the crest axis.

Tests

25. Tests were accomplished to evaluate flow stability in the stilling basin and air penetration and flow directions in and downstream of the stilling basin both without and with spillway deflectors. Pressures on the deflectors were measured with two different methods of gate operation--flow under the gates and flow between the upper and lower sections of the gates. Spillway discharges of 13,500 cfs or less per bay were of primary interest as they are the prevalent flows during upstream migrations of fish at the project. Discharges used in the study were as follows:

Spillway Flow in cfs per Bay	Number of Operating Bays	Number of Powerhouse Units	River Discharge in cfs
3,000	20	14	290,000
6,000	20	14	350,000
10,500	20	14	440,000
13,500	20	14	500,000
28,500	20	14	800,000
100,000	22	0	2,200,000

Tests were conducted with two tailwater conditions to simulate John Day Dam pool elevations 257 and 265; however, no data was recorded in the 1:50-scale comprehensive model with John Day pool elevation 257.

Existing Conditions (Without Deflector)

26. Flow conditions of varied spillway discharges with flow under the gates and between the top and bottom gate leafs are shown in photographs 32 through 36 and on plates 26 through 32. With all discharges and spillway gate conditions, aerated water plunged to the stilling basin floor and created conditions conducive for maximum nitrogen supersaturation of the flow leaving the basin. With all flow conditions tested, more spill was required through the end bays than through the center bays to create downstream flow adjacent to the fishway entrances (plates 33 through 35). As a result an eddy or very slow current existed downstream from the center bays. Flow near the Washington-shore fish ladder entrance was downstream with a small eddy along the ladder wall 150 to 200 feet downstream from the entrance. Maximum upstream velocities in the eddy increased from 1 to 2 fps at 300,000 cfs to 5 fps at 500,000 cfs. A good path of attraction flow toward the entrance existed along the right bank for all discharges. Flow from the spillway/powerhouse fishway entrance was affected by powerhouse discharge that moved diagonally across the end of the trash sluice and carried the attraction flow downstream in that area. An eddy existed along the north side of the trash sluice but did not interfere with fishway attraction flow since a flow path to the entrance existed with all river discharges. Fishway attraction flows were satisfactory with all tailwater conditions tested.

Deflector

27. Deflector designs (plate 36) varying in length from 12.5 to 20.0 feet and located on the spillway crest between elevations 254 and 264 were tested with discharges up to 100,000 cfs per bay. Conditions with the deflector lip sloped upward at 10 degrees were not acceptable--excessive uplift of the nappe occurred causing aerated water to plunge to the stilling basin floor just upstream from the baffle piers.

28. The discharge-tailwater relationships for which stable and unstable flow occurred in the model for various deflector lengths and locations are shown on plate 37. With flow under the gate, the 12.5-foot deflector located at elevation 256 had the greatest range of skimming flow and the smallest zone of surging between skimming and plunging flow. Varying the deflector elevation made only minor changes in the concentration and depth of air penetration in the stilling basin. The highest and lowest elevations caused either plunging flow or surface undulations. With discharge between the two gate leaves, a 20-foot-long deflector would be required because the 12.5-foot-long deflector was too short to intercept the nappe. However, due primarily to cost considerations, the decision was made to construct the smaller 12.5-foot-long deflectors and adopt a spillway operation with all flow to be passed under the gate.

29. Pressures on the 12.5-foot deflector were measured at the piezometers shown on plate 38. There were no negative pressures observed for the range of discharges tested (table B). The highest pressures occurred on the upstream portion of the horizontal lip (piezometers 1 through 4) for discharges to 28,500 cfs per bay. A pressure of 78 feet of water existed at piezometer D-5 during the project design discharge of 100,000 cfs per bay.

30. Flow conditions with the 12.5-foot deflector are shown in photographs 37 through 41 and on plates 39 and 40. With deflectors located on the two end bays on both sides of the spillway, excessive turbulence existed at the fishway entrances. The turbulence could only be eliminated by increasing discharge through the end bays until plunging flow occurred. Since the plunging flow condition would not reduce the nitrogen supersaturation problem, deflectors were included only on bays 3 through 20.

31. The skimming flow off the deflector required different spill patterns than those which were effective without the deflector. Two different methods of spillway operation--flow between gate sections in

the end bays and flow under all other gates--were tested with river discharges of 350,000 to 500,000 cfs. The first method produced generally uniform flow patterns in the tailrace and acceptable conditions at the fishway entrances (plates 41 through 46). The second method (plates 47 through 49), developed in cooperation with the Oregon Fish and Wildlife Commission, minimized wave action and cross currents near the respective fishway entrances without reducing attraction-flow velocities. However, with this method of operation, a shorter flow path with lower velocities existed downstream from the Washington-shore fishway entrance, and upstream flow along the fish ladder wall was present for all discharges except 350,000 cfs.

32. The skimming flow from bays 3 through 20 extended farther downstream and was more stable when the John Day pool was at elevation 257 as compared to a pool elevation of 265. With discharges of 300,000 to 350,000 cfs, the eddy extending to the end of the Washington fish ladder was narrower with the lower John Day pool elevation. Although powerhouse flow crossed the end of the trash sluice more abruptly as tailwater decreased, there were no unsatisfactory conditions noticed for the range of tailwater elevations tested in the model.

McNARY DAM

Table B

PRESSURES

12.5-Ft Deflector, Elevation 256.0

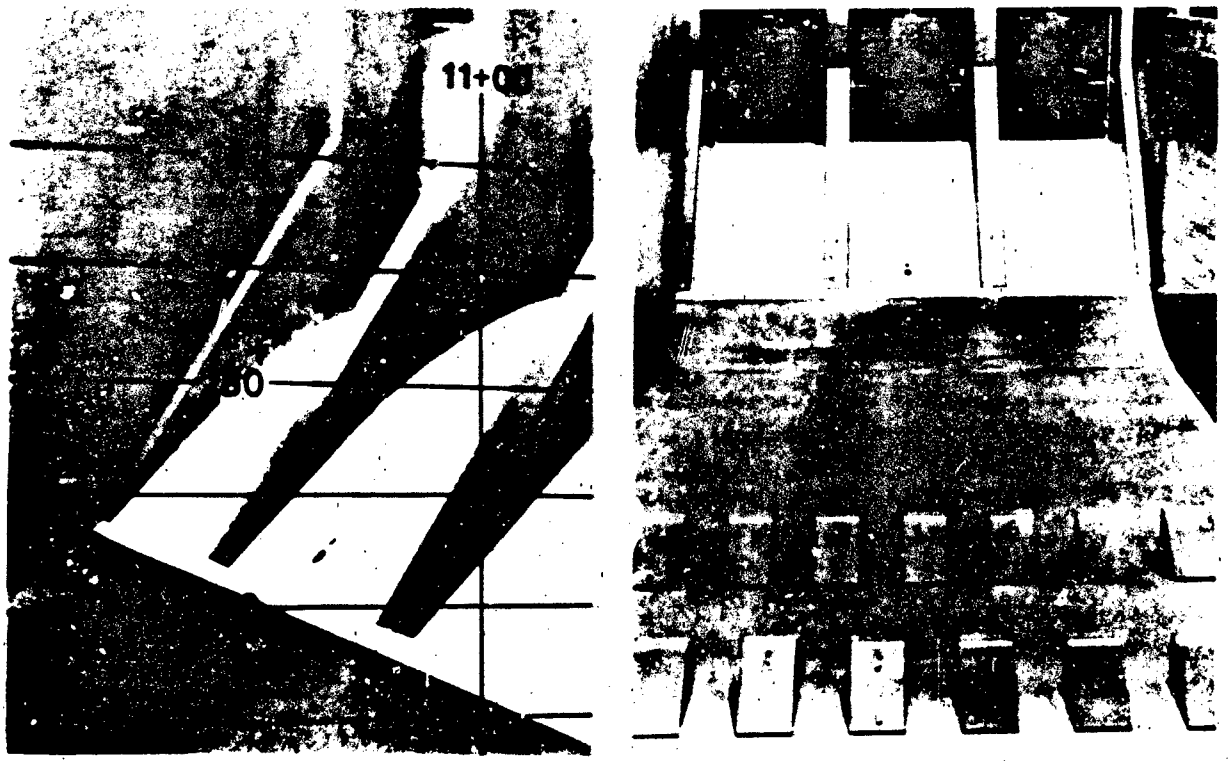
Piezometer			River Flow 350,000 CFS Spillway Discharge 6,000 CFS Per Bay						River Flow 440,000 CFS Spillway Discharge 10,500 CFS Per Bay					
			Tailwater Elev 266.9 (J.Day Pool Elev 257)			Tailwater Elev 270.5 (J.Day Pool Elev 265)			Tailwater Elev 269.9 (J.Day Pool Elev 257)			Tailwater Elev 273.5 (J.Day Pool Elev 265)		
			Pressure in Feet of Water											
No.	Station	Elevation	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
D-1	10+68.66	256.0	47	30	36	46	34	38	54	39	46	53	37	45
D-2	10+68.66	256.0	47	23	36	45	25	35	52	35	46	51	30	44
D-3	10+69.66	256.0	46	24	35	46	28	34	51	35	41	52	28	44
D-4	10+69.66	256.0	47	27	35	47	28	34	52	35	41	51	36	45
D-5	10+71.66	256.0	26	9	14	25	12	17	40	26	32	41	25	32
D-6	10+71.66	256.0	26	10	14	26	11	17	40	27	32	43	26	33
D-7	10+78.46	256.0	9	1	3	8	3	5	10	4	5	12	5	6
D-8	10+78.46	256.0	10	1	5	7	3	5	9	4	5	13	5	6
D-9	10+80.16	255.8	7	4	6	12	10	11	7	4	5	10	7	9
D-10	10+80.16	255.8	7	4	6	12	10	11	7	4	5	10	7	9

Piezometer			River Flow 500,000 CFS Spillway Discharge 13,500 CFS Per Bay						River Flow 800,000 CFS Spillway Discharge 28,500 CFS Per Bay Tailwater Elev 281.0 (J.Day Pool Elev 268)			River Flow 2,200,000 CFS Spillway Discharge 130,000 CFS Per Bay Tailwater Elev 302.6		
			Tailwater Elev 271.7 (J.Day Pool elev 257)			Tailwater Elev 274.0 (J.Day Pool Elev 265)								
			Pressure in Feet of Water											
No.	Station	Elevation	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
D-1	10+68.66	256.0	55	39	50	53	43	50	61	49	56	66	62	64
D-2	10+68.66	256.0	54	37	50	53	43	50	60	49	56	66	62	64
D-3	10+69.66	256.0	54	38	49	53	43	49	65	50	55	71	64	67
D-4	10+69.66	256.0	55	42	49	53	43	49	63	50	55	71	64	67
D-5	10+71.66	256.0	44	34	39	42	34	36	56	49	54	78	69	71
D-6	10+71.66	256.0	42	34	38	42	34	36	57	51	54	74	65	68
D-7	10+78.46	256.0	15	7	8	11	4	8	28	23	25	57	54	55
D-8	10+78.46	256.0	14	6	8	12	4	8	26	23	25	57	54	55
D-9	10+80.16	255.8	7	3	5	9	4	7	16	8	13	36	31	33
D-10	10+80.16	255.8	7	3	5	9	4	7	17	9	13	36	31	33

NOTES: 1. Piezometer locations shown on plate 38.
2. River flow includes powerhouse flow from 14 operating units, except for 2,200,000 cfs (all spillway flow).
3. Spillway flow based on 20-bay operation, except for 2,200,000 cfs (22-bay operation).
4. Flow under lower gate leaf.

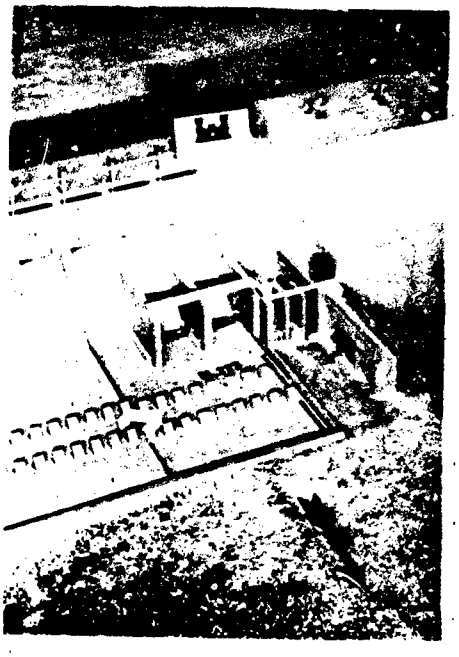
Table B

REPRODUCED AT GOVERNMENT EXPENSE



McNary Dam

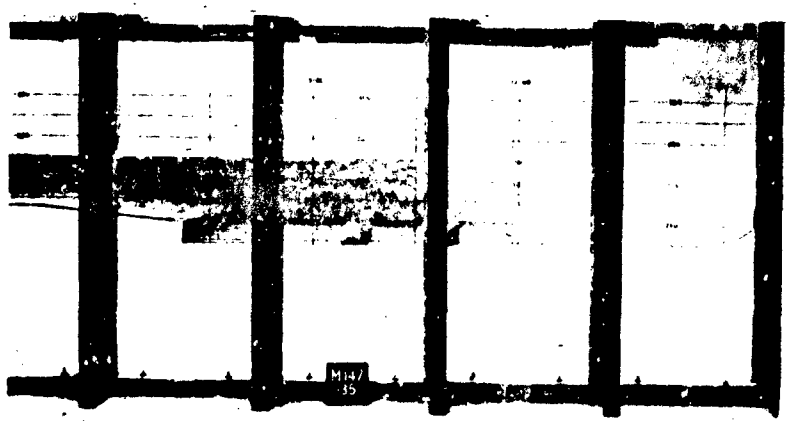
Photograph 30. Existing spillway and stilling basin in 1:40-scale sectional model.



McNary Dam

Photograph 31. Existing structures in 1:50-scale comprehensive model.

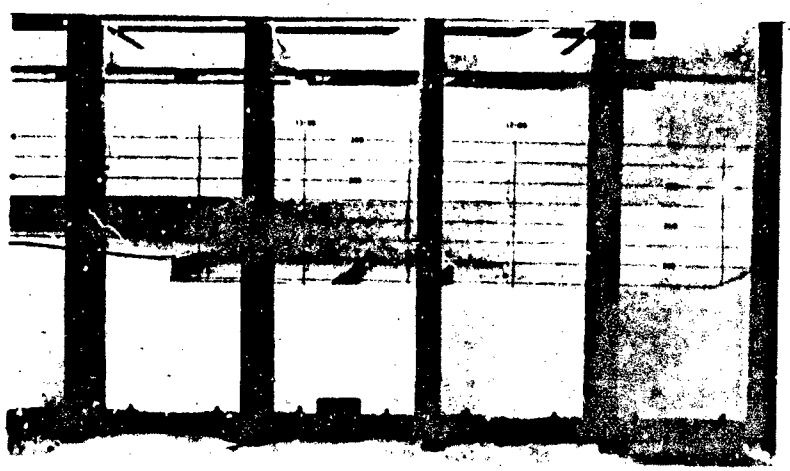
Tailwater elevation 266.9.
John Day pool elevation 257.



Tailwater elevation 270.5.
John Day pool elevation 265.

Flow under gates.

Tailwater elevation 266.9.
John Day pool elevation 257.

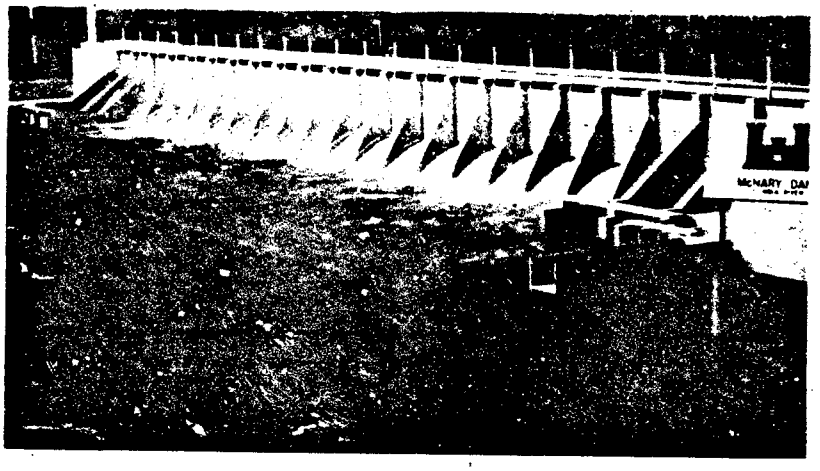


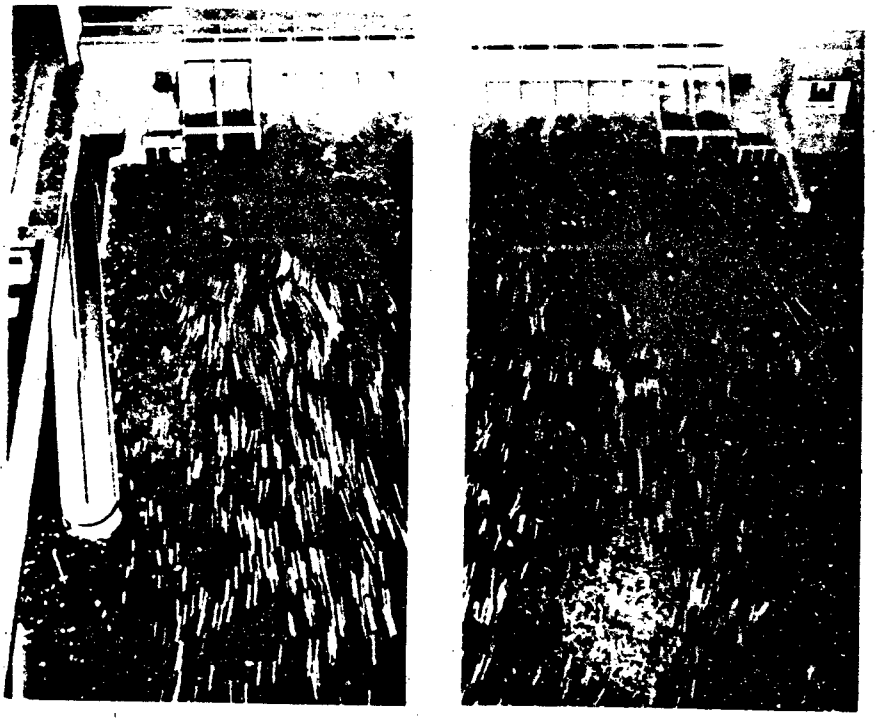
Tailwater elevation 270.5.
John Day pool elevation 265.

McNary Dam

Flow between gate sections.

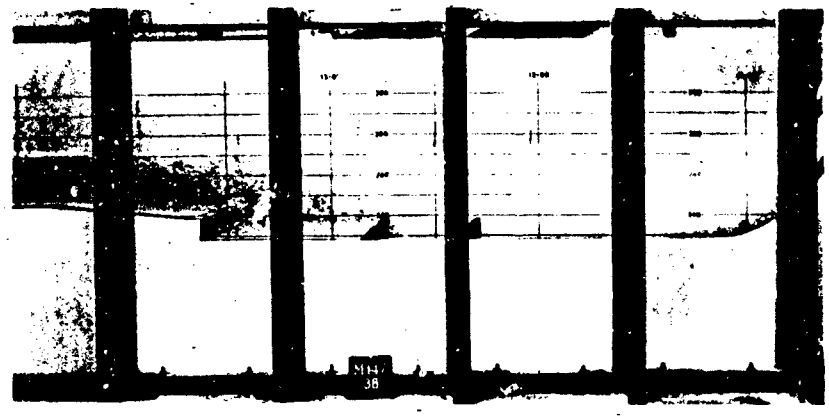
Photograph 32. Flow conditions with existing spillway and stilling basin; spillway discharge 6,000 cfs per bay (river discharge 350,000 cfs).



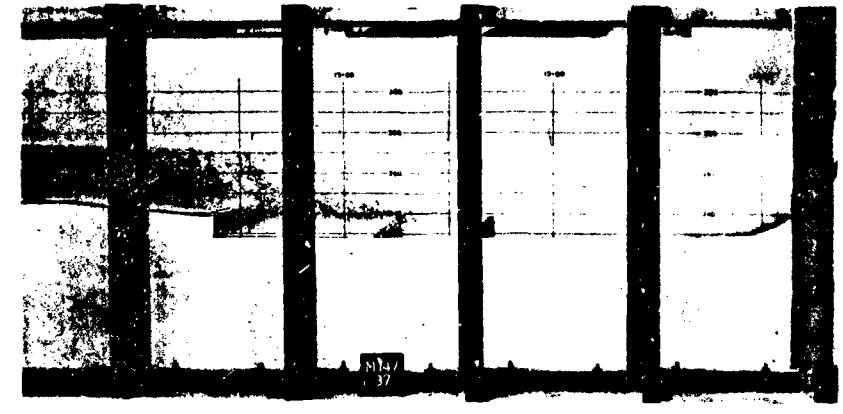


McNary Dam

Photograph 33. Surface flow patterns without deflector; river discharge 350,000 cfs; 14 powerhouse units operating.



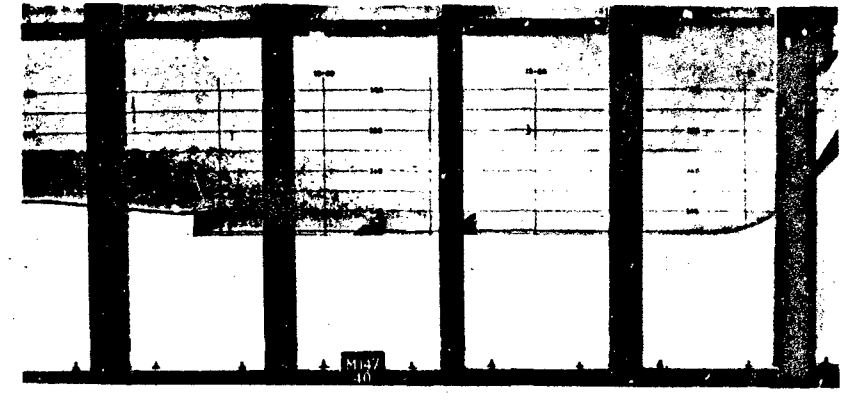
Tailwater elevation 271.7.
John Day pool elevation 257.



Tailwater elevation 274.0.
John Day pool elevation 265.

Flow under gates.

Tailwater elevation 271.7.
John Day pool elevation 257.

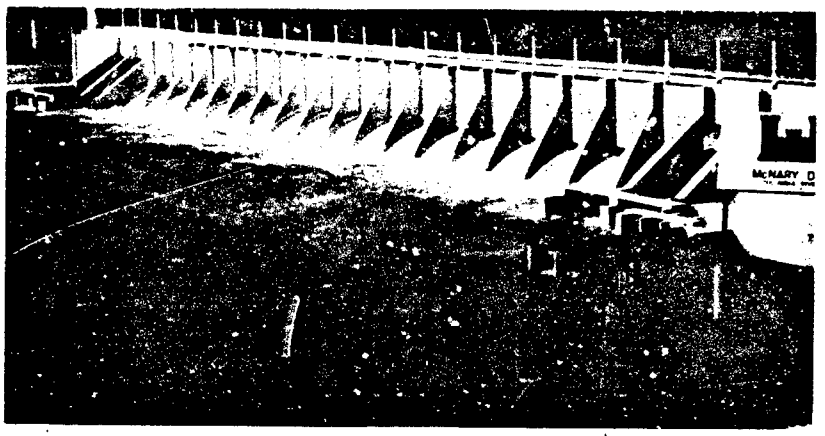


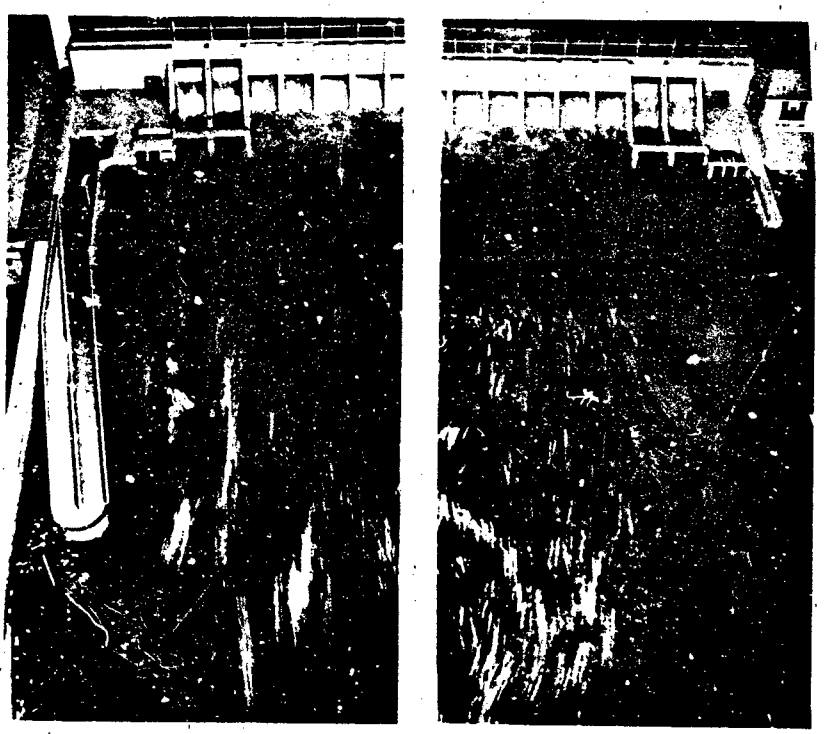
Tailwater elevation 274.0.
John Day pool elevation 265.

McNary Dam

Flow between gate sections.

Photograph 34. Flow conditions with existing spillway and stilling basin; spillway discharge 13,500 cfs per bay (river discharge 500,000 cfs).

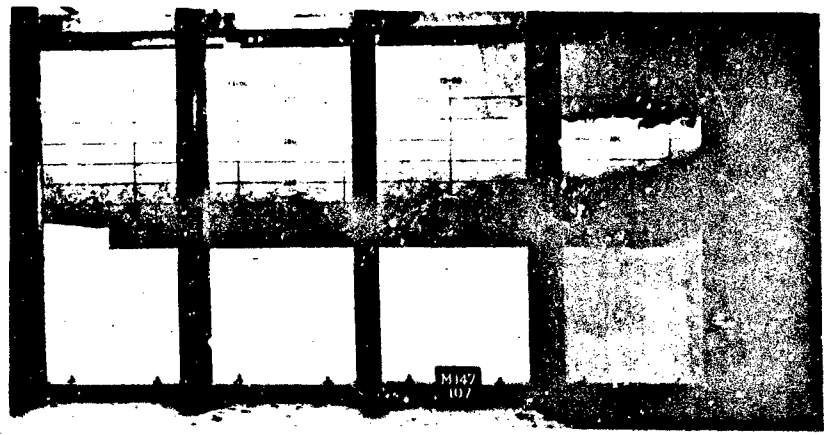




McNary Dam

Photograph 35. Surface flow patterns without deflector; river discharge 500,000 cfs; 14 powerhouse units operating.

Spillway discharge 28,500 cfs per bay. River discharge 800,000 cfs. Tailwater elevation 281.0. John Day pool elevation 268. Flow under gates.



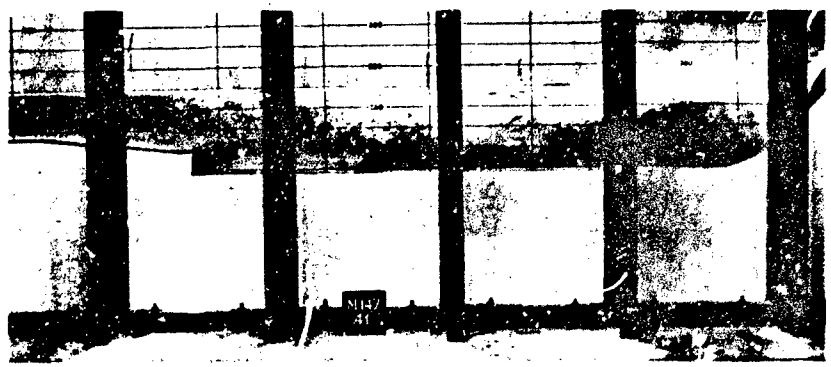
Spillway discharge 100,000 cfs per bay. River discharge 2,200,000 cfs. Tailwater elevation 302.6. Free flow.

McNary Dam

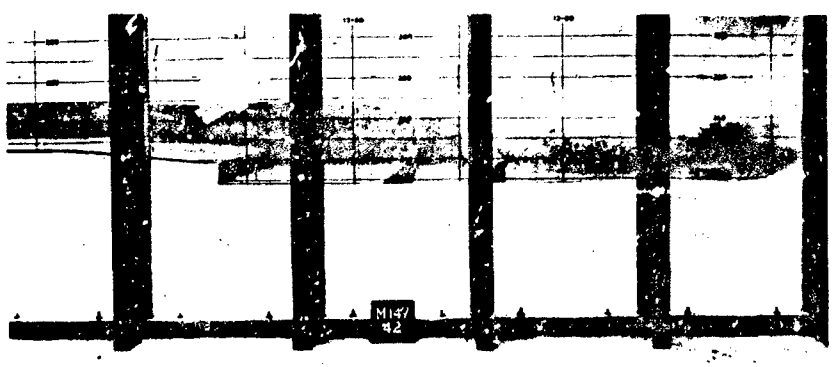
Photograph 36. Flow conditions with existing spillway and stilling basin.

Tailwater elevation 266.9.
John Day pool elevation 257.

Tailwater elevation 266.9.
John Day pool elevation 257.



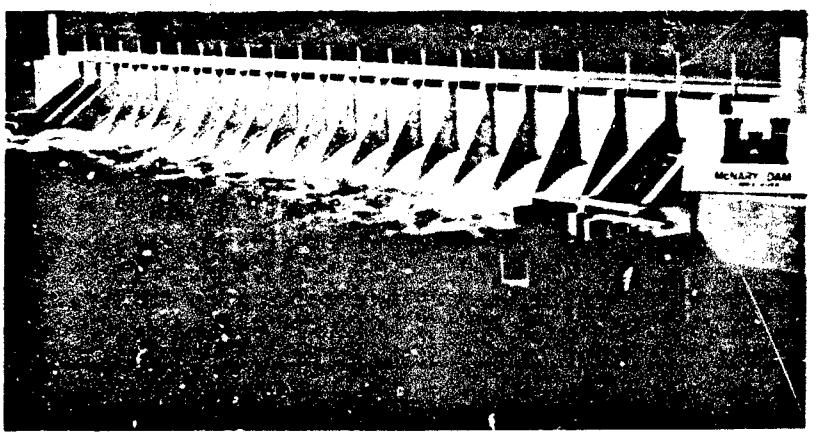
Tailwater elevation 266.9.
John Day pool elevation 257.

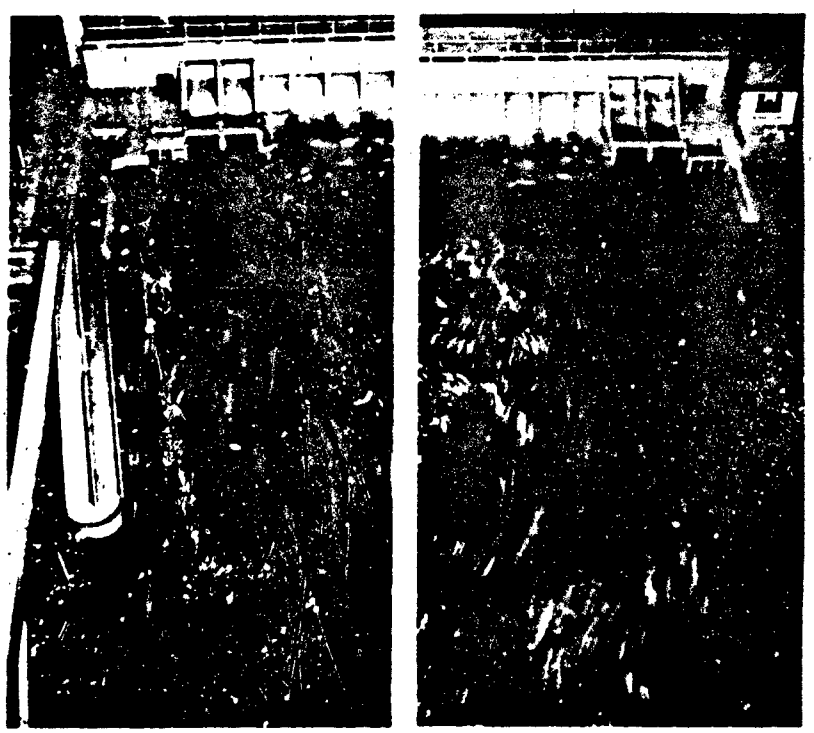


Tailwater elevation 270.5.
John Day pool elevation 265.

McNary Dam

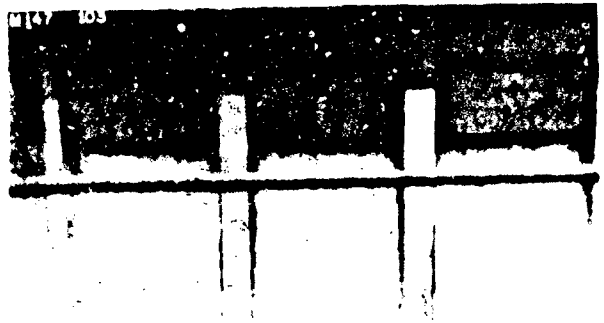
Photograph 37. Flow conditions, 12.5-foot deflector at elevation 256; spillway discharge 6,000 cfs per bay (river discharge 350,000 cfs), flow under gates.



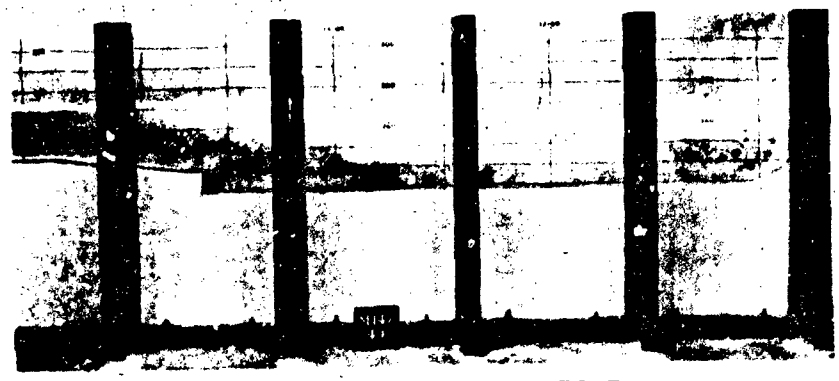


McNary Dam

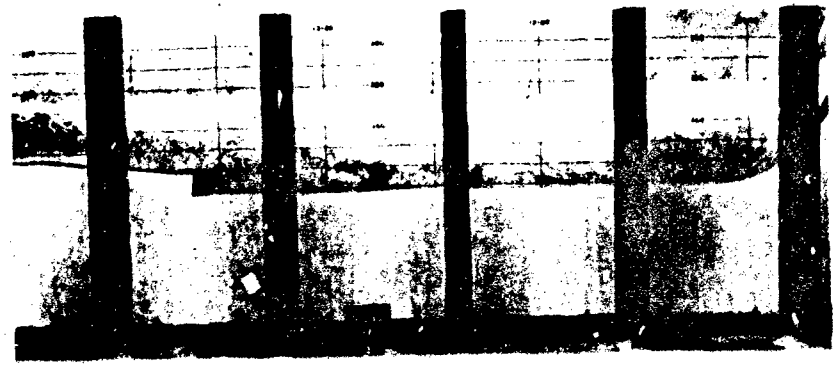
Photograph 38. Surface flow patterns with deflector in spillway bays 3 to 20; river discharge 350,000 cfs; 14 powerhouse units operating.



Tailwater elevation 271.7.
John Day pool elevation 257.



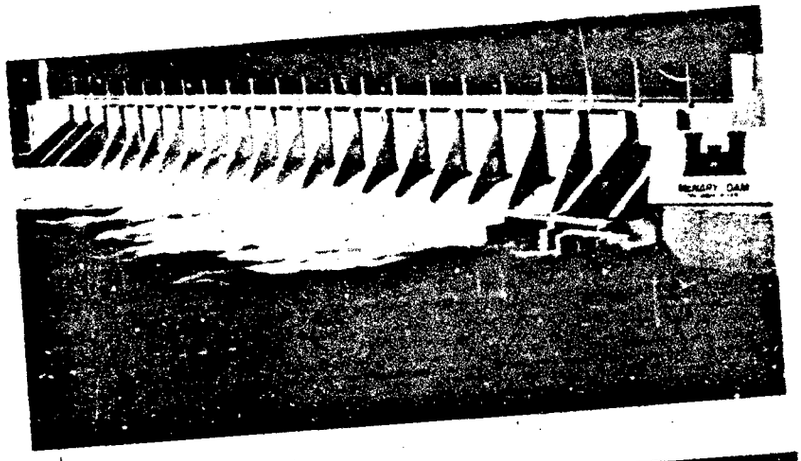
Tailwater elevation 271.7.
John Day pool elevation 257.

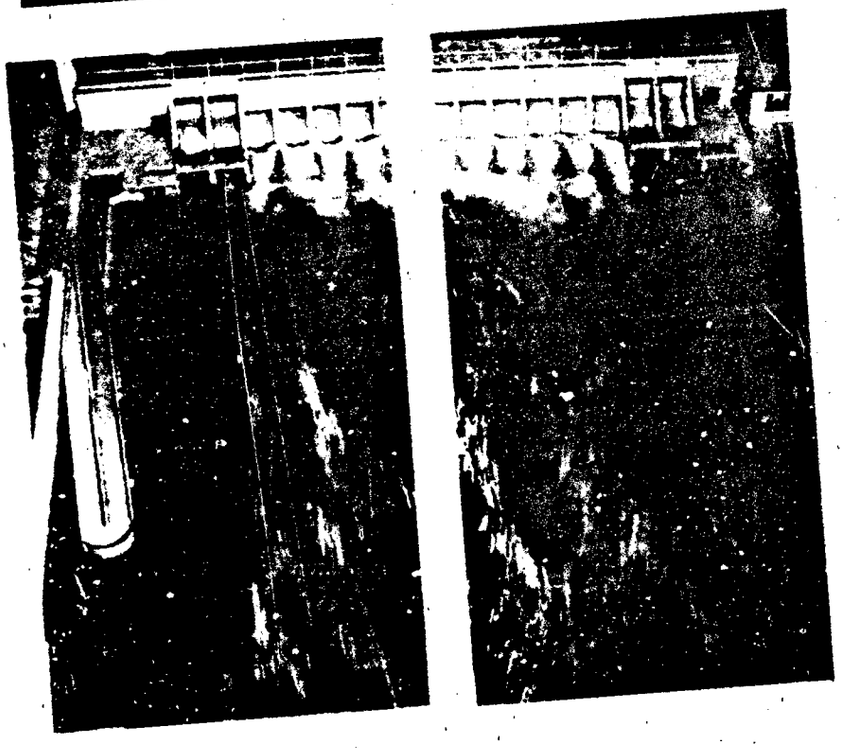


Tailwater elevation 274.0.
John Day pool elevation 265.

McNary Dam

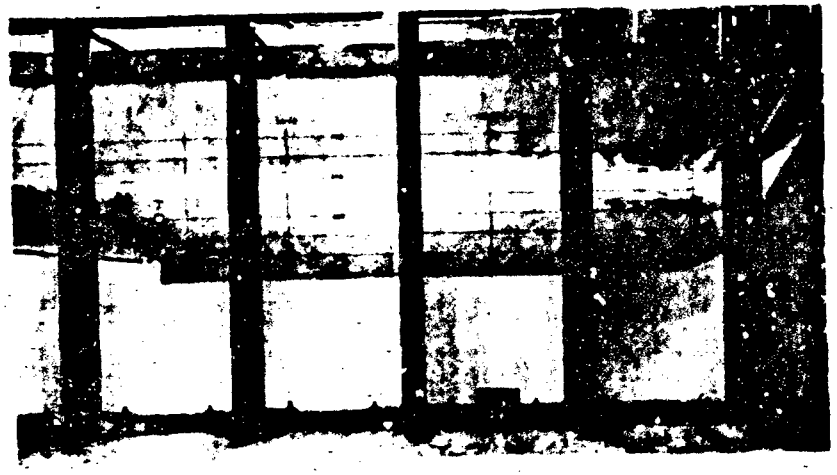
Photograph 39. Flow conditions, 12.5-foot deflector at elevation 256; spillway discharge 13,500 cfs per bay (river discharge 500,000 cfs), flow under gates.





McNary Dam

Photograph 40. Surface flow patterns with deflector in spillway bays 3 to 20; river discharge 500,000 cfs; 14 powerhouse units operating.



Spillway discharge 28,500 cfs per bay. River discharge 800,000 cfs. Tailwater elevation 281.0. John Day pool elevation 268.

Spillway discharge 100,000 cfs per bay. River discharge 2,200,000 cfs. Tailwater elevation 302.6.

McNary Dam

Photograph 41. Flow conditions with 12.5-ft deflector at elevation 256; flow under gates.

REPRODUCED AT GOVERNMENT EXPENSE

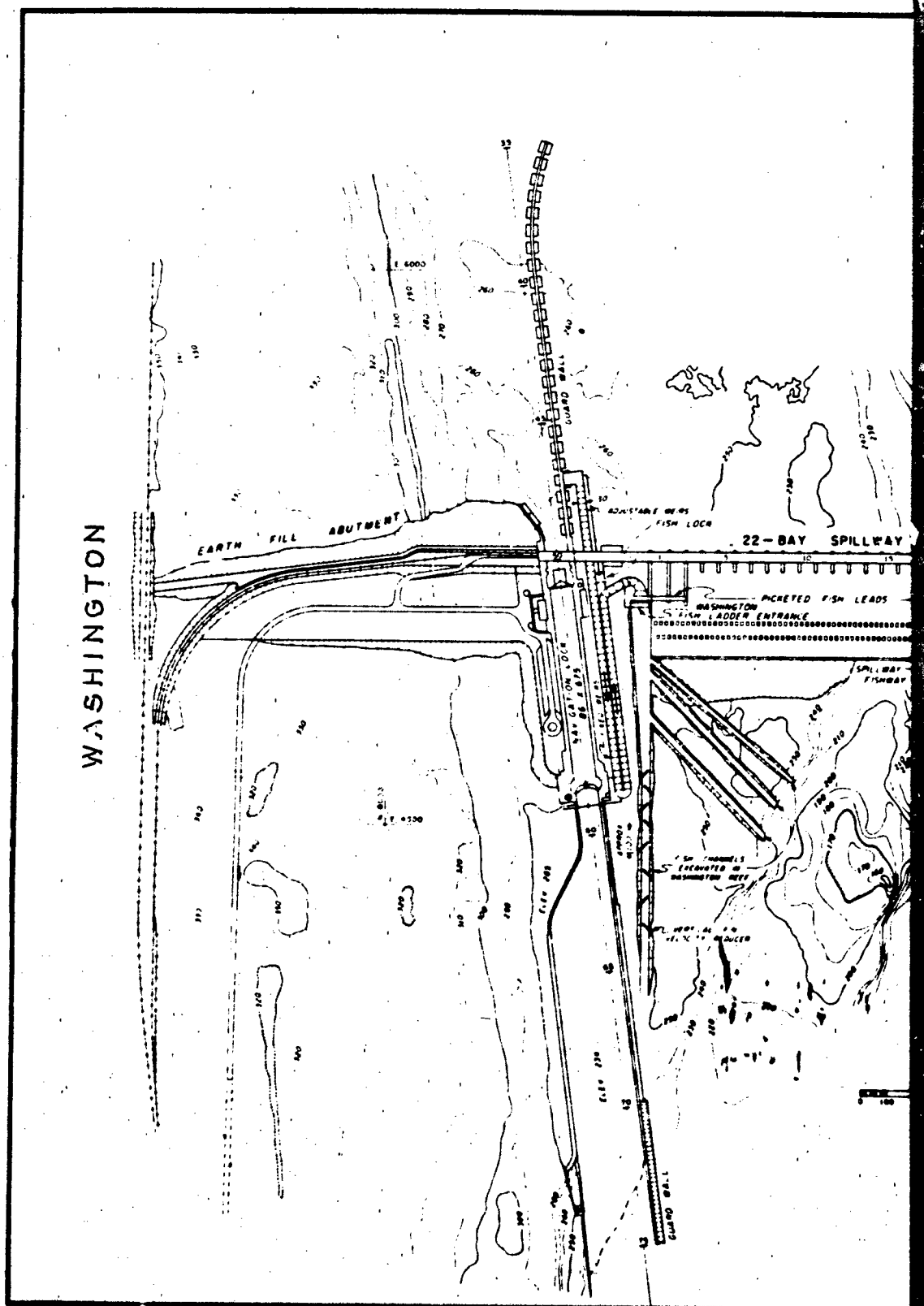
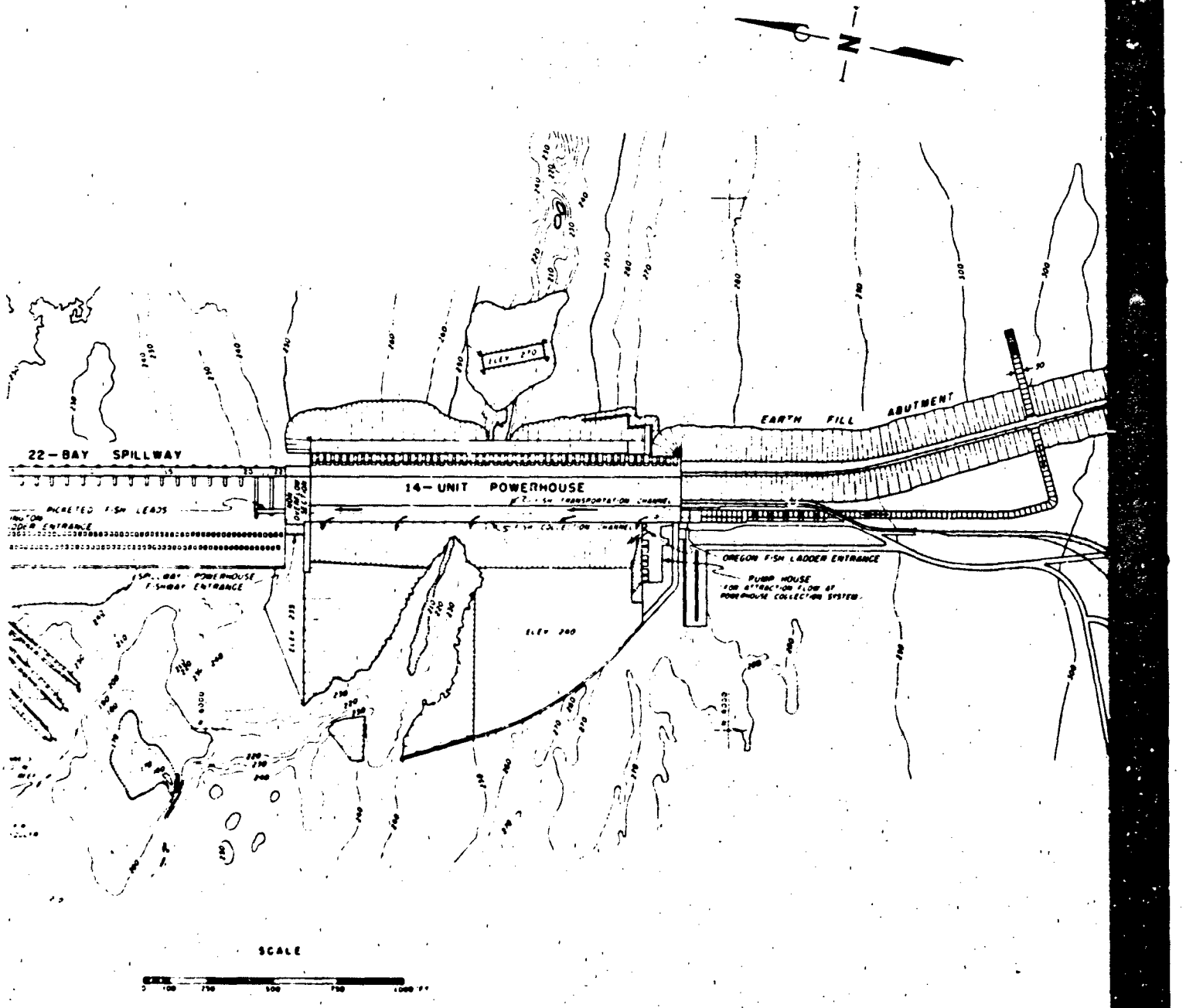


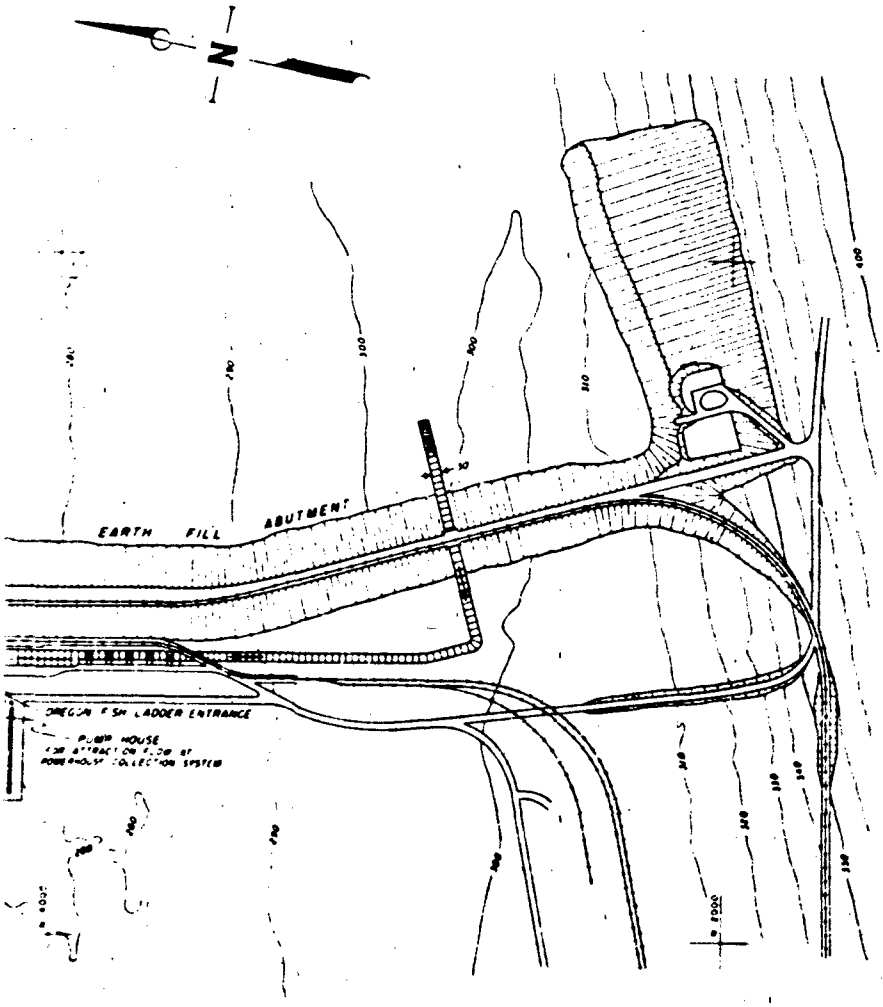
Plate 22

1

REPRODUCED AT GOVERNMENT EXPENSE



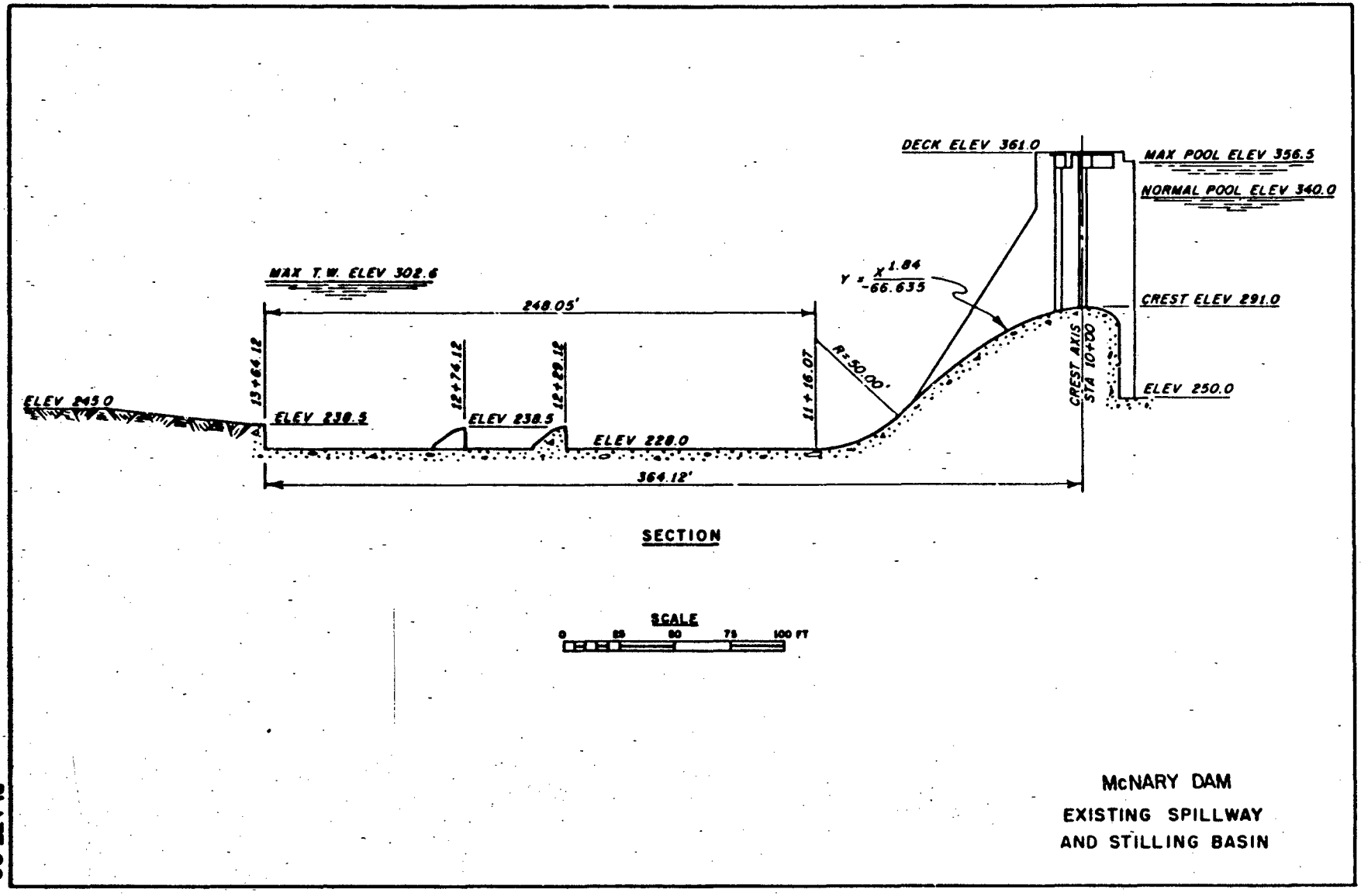
REPRODUCED AT GOVERNMENT EXPENSE



McNARY DAM
PROJECT LAYOUT

PLATE 22

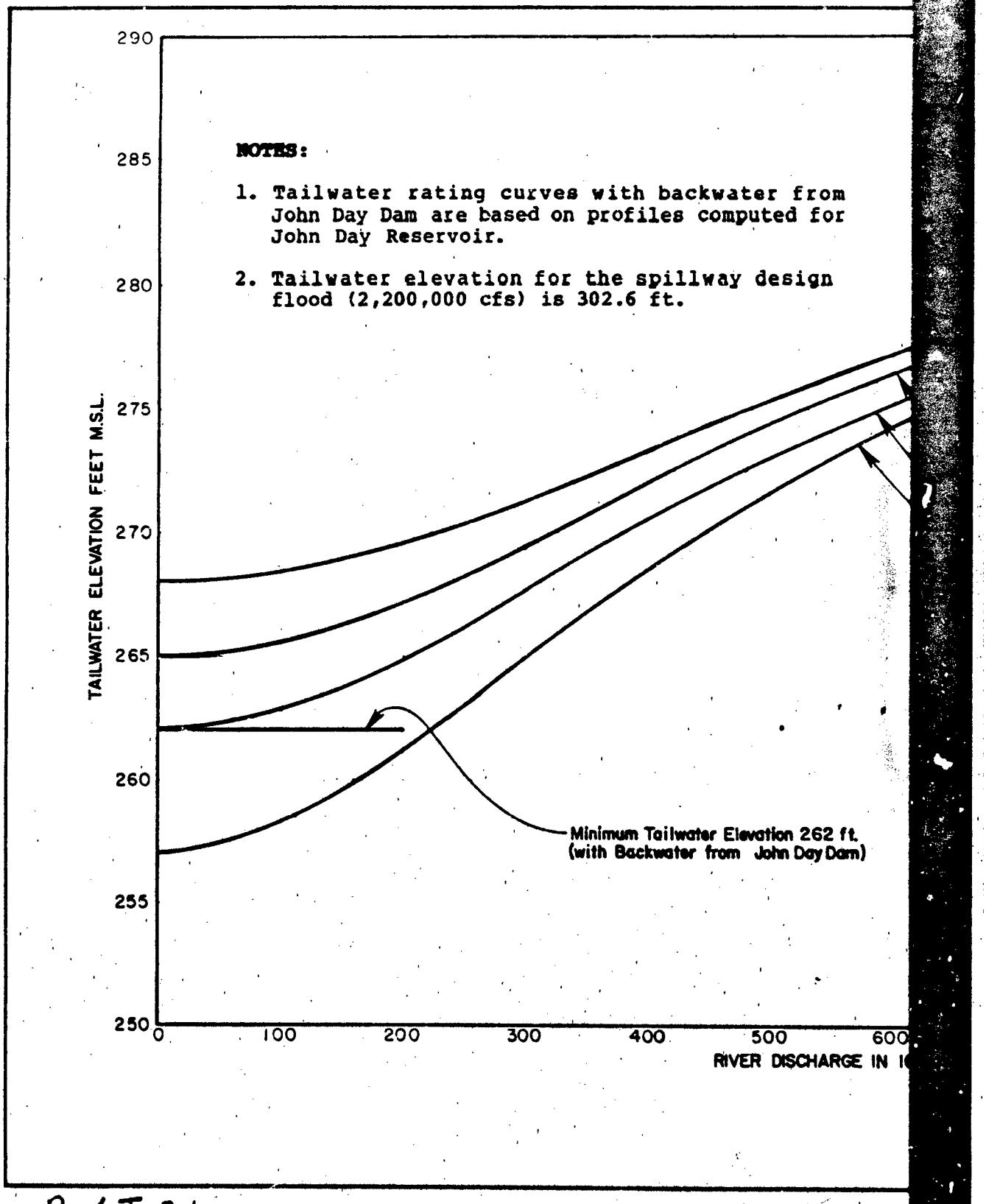
3 of 3



McNARY DAM
EXISTING SPILLWAY
AND STILLING BASIN

PLATE 23

REPRODUCED AT GOVERNMENT EXPENSE

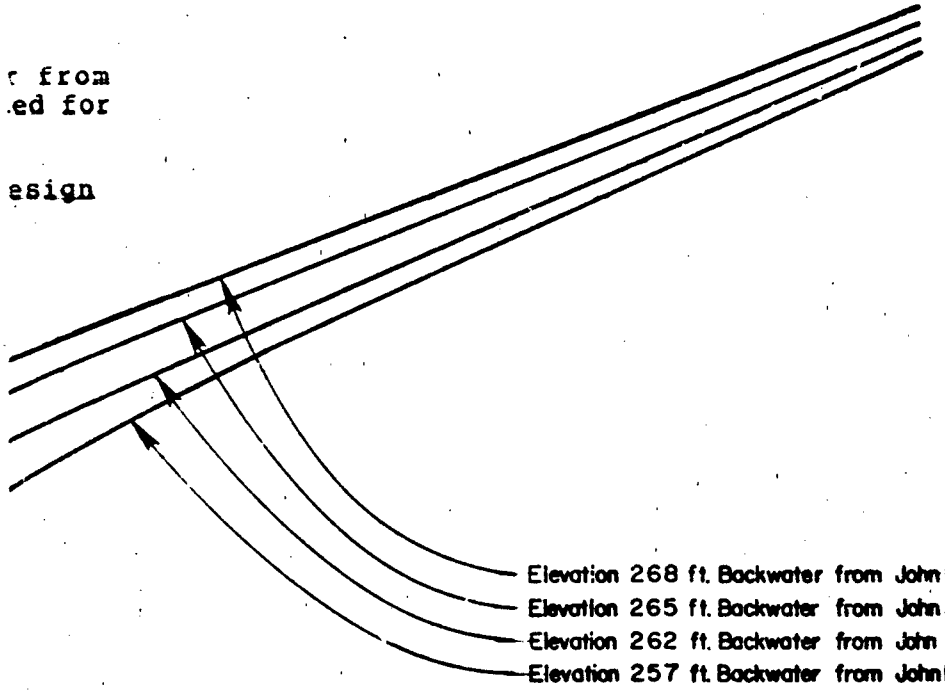


P. 1 T 24

1 of 2

r from
ed for

esign



tion 262 ft.
ohn Day Dam)

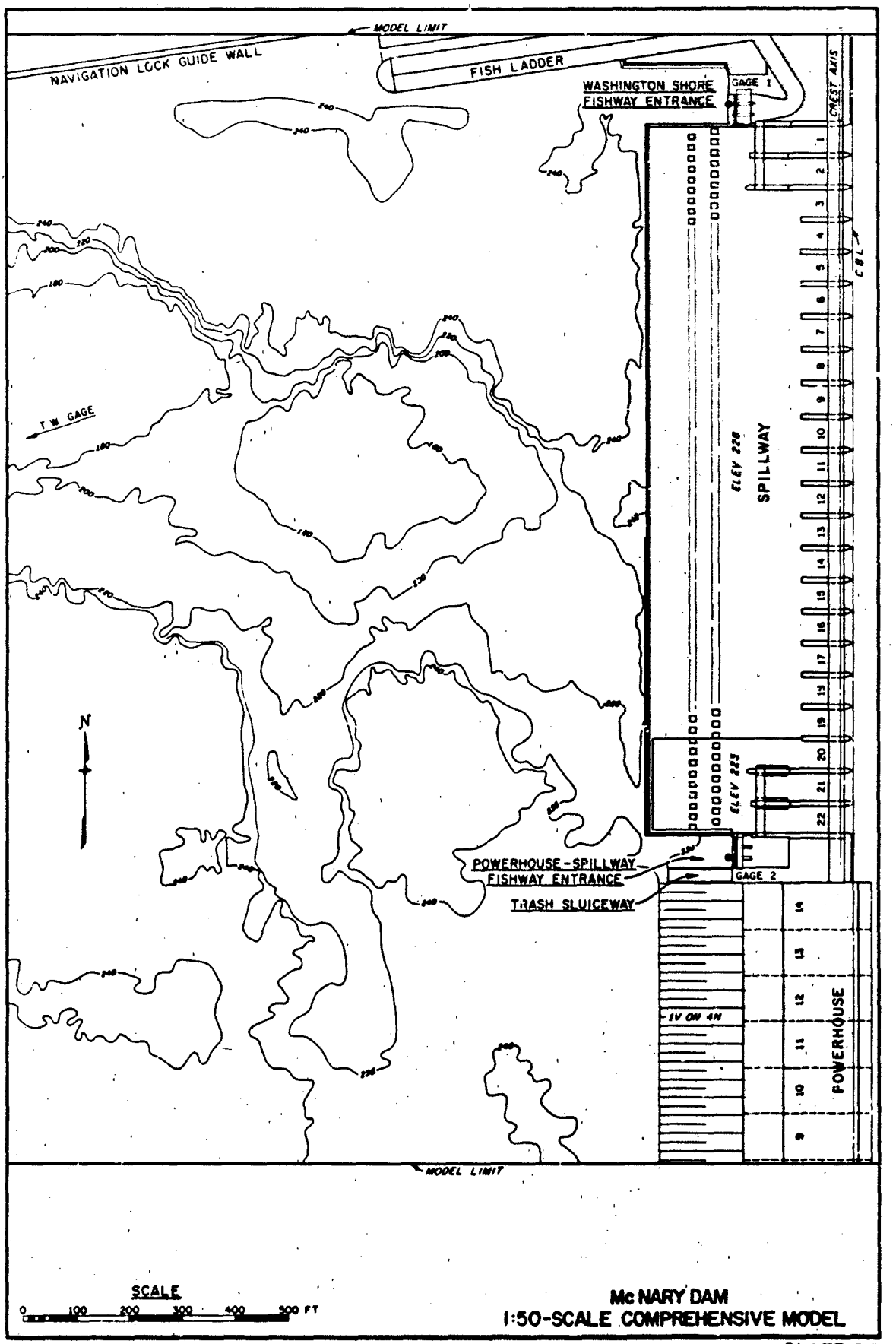
00 600 700 800 900 1000 1100 1200

DISCHARGE IN 1000 CFS

McNARY DAM
TAILWATER RATING CURVES

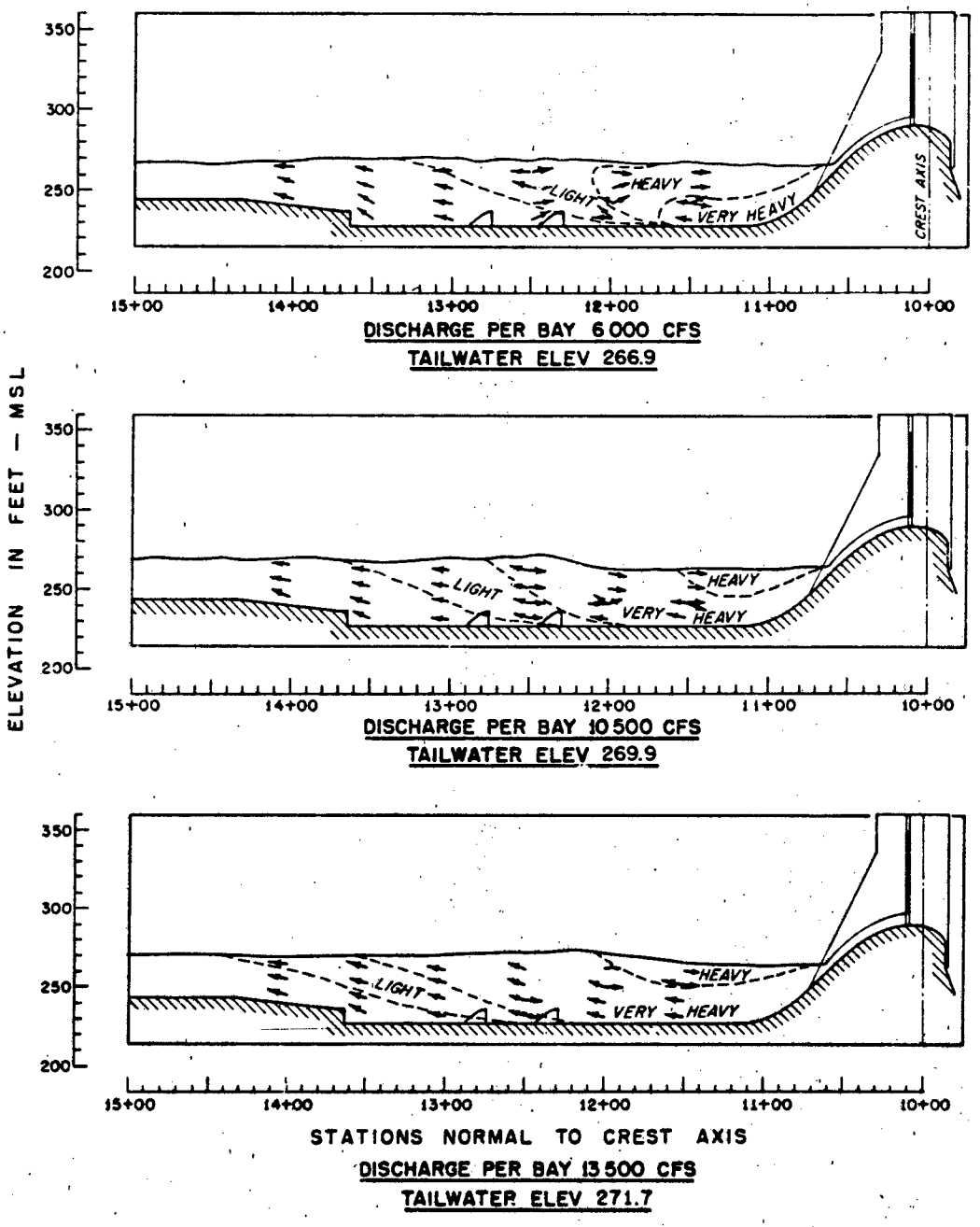
P. / T 24

2 of 2



Mc NARY DAM
1:50-SCALE COMPREHENSIVE MODEL

PLATE 25



McNARY DAM

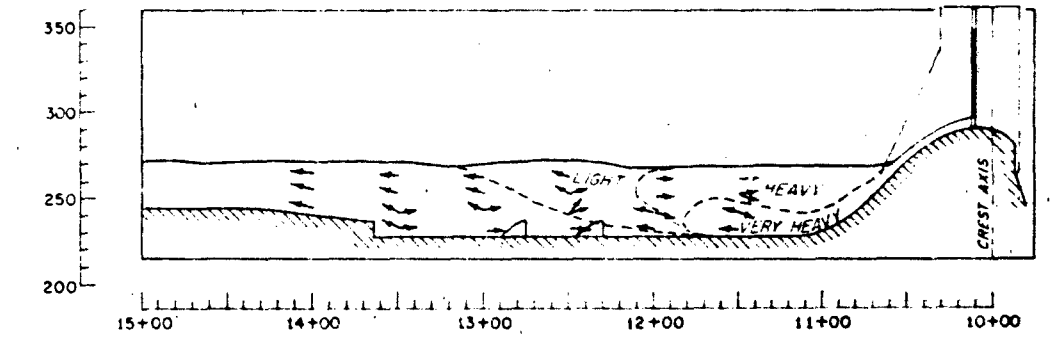
AERATION AND FLOW DIRECTIONS.

NO DEFLECTORS

FLOW UNDER LOWER GATE LEAF

JOHN DAY POOL ELEV 257

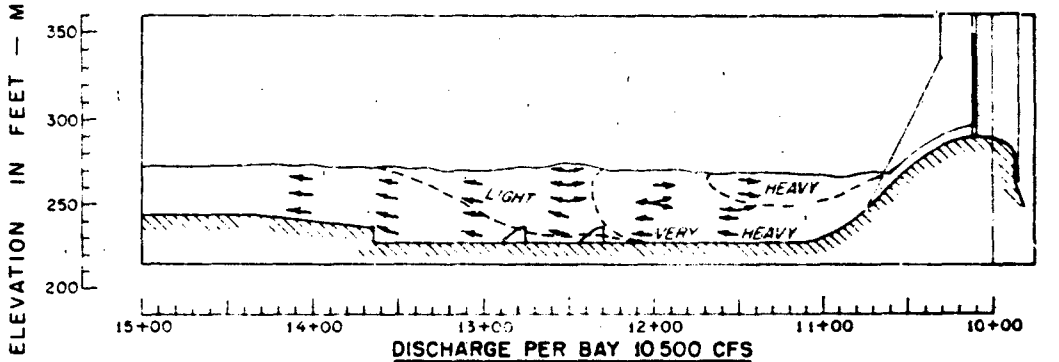
PLATE 26



DISCHARGE PER BAY 6 000 CFS

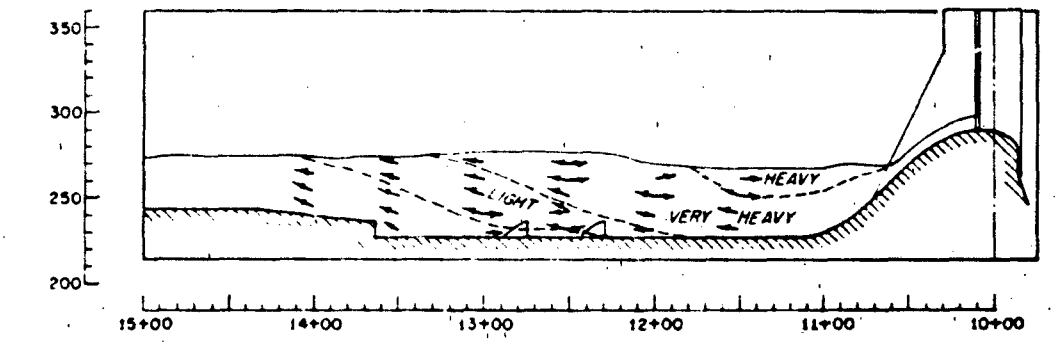
TAILWATER ELEV 270.5

ELEVATION IN FEET — MSL



DISCHARGE PER BAY 10 500 CFS

TAILWATER ELEV 272.6



STATIONS NORMAL TO CREST AXIS

DISCHARGE PER BAY 13 500 CFS

TAILWATER ELEV 274.0

LEGEND

--------- ZONES OF AERATION

Mc NARY DAM

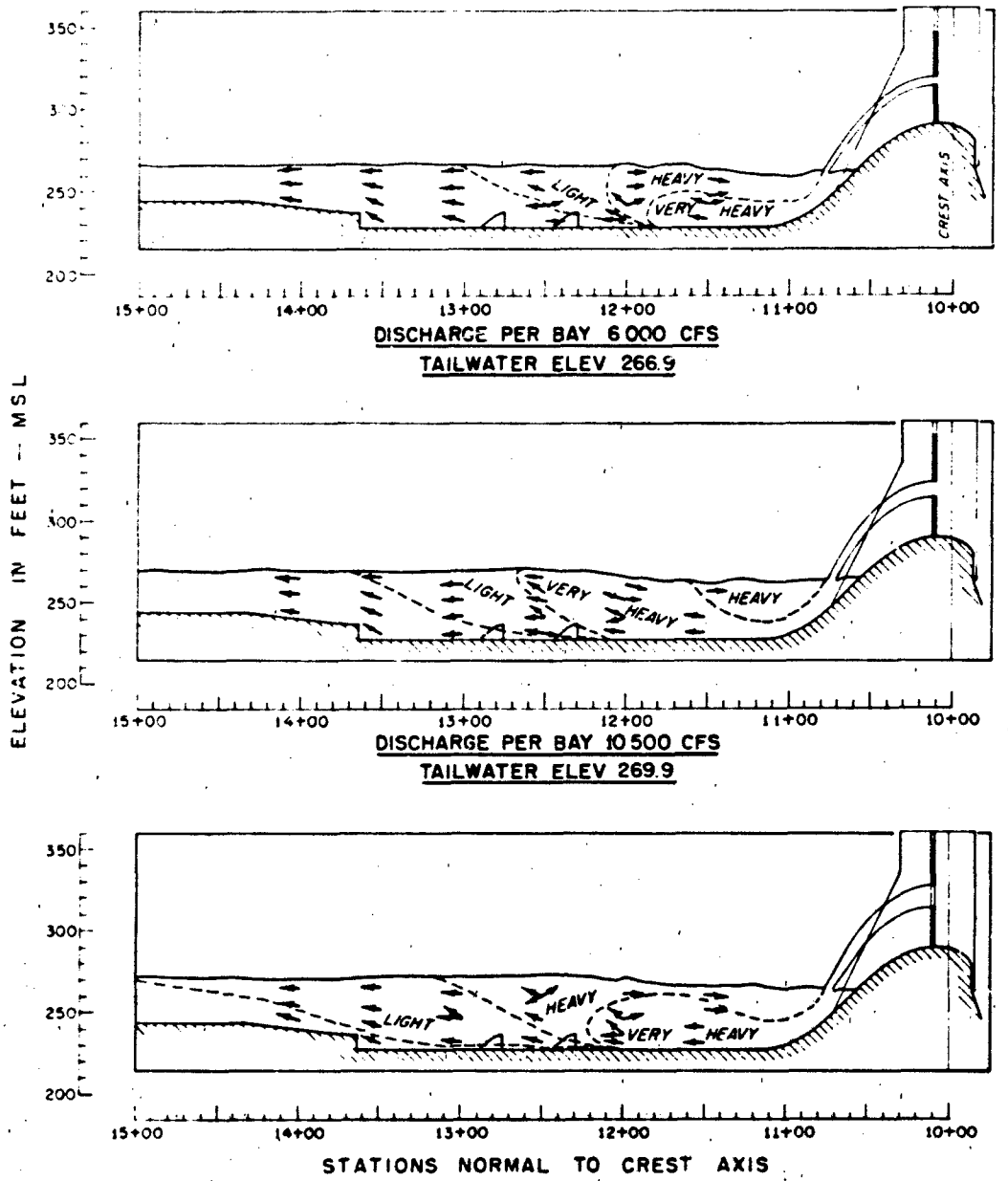
AERATION AND FLOW DIRECTIONS

NO DEFLECTORS

FLOW UNDER LOWER GATE LEAF

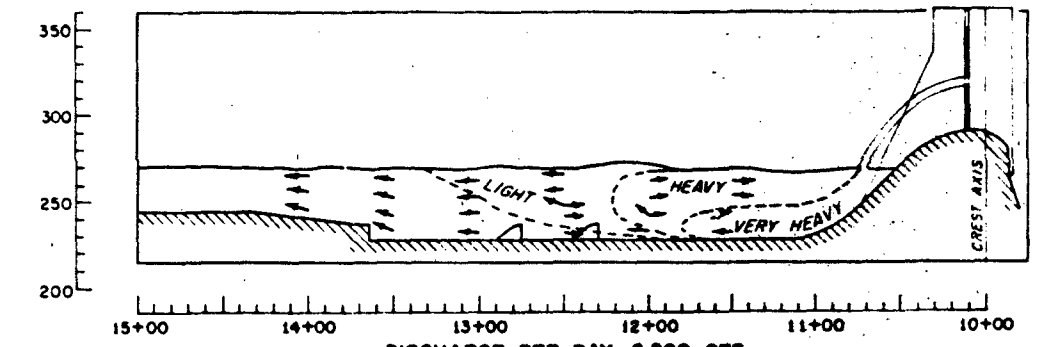
JOHN DAY POOL ELEV 265

PLATE 27



McNARY DAM
AERATION AND FLOW DIRECTIONS
NO DEFLECTORS
FLOW BETWEEN GATE LEAVES
JOHN DAY POOL ELEV 257

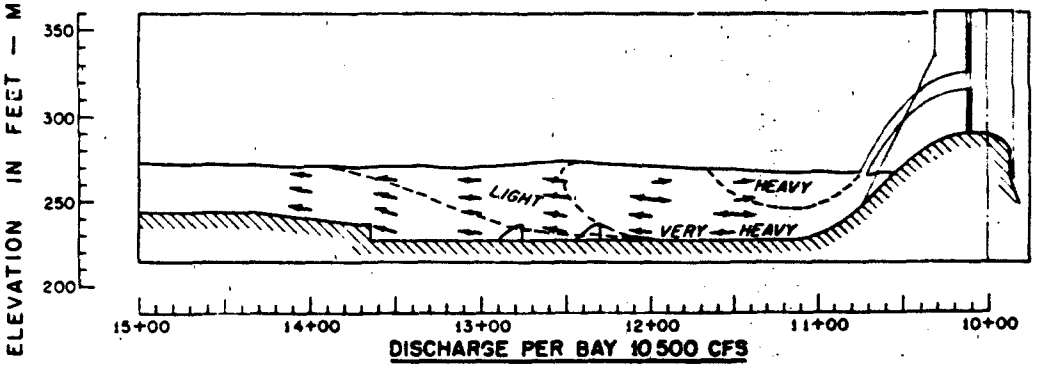
PLATE 28



DISCHARGE PER BAY 6 000 CFS

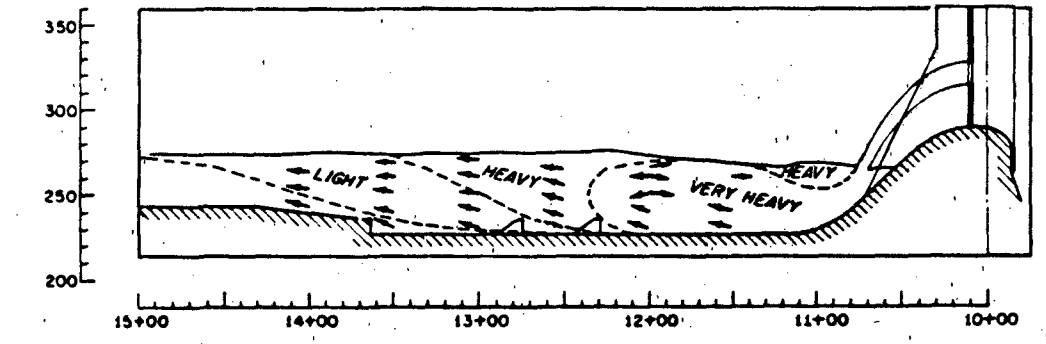
TAILWATER ELEV 270.5

ELEVATION IN FEET — MSL



DISCHARGE PER BAY 10 500 CFS

TAILWATER ELEV 272.6



STATIONS NORMAL TO CREST AXIS

DISCHARGE PER BAY 13 500 CFS

TAILWATER ELEV 274.0

LEGEND

--------- ZONES OF AERATION

McNARY DAM

AERATION AND FLOW DIRECTIONS

NO DEFLECTORS

FLOW BETWEEN GATE LEAVES

JOHN DAY POOL ELEV 265

PLATE 29

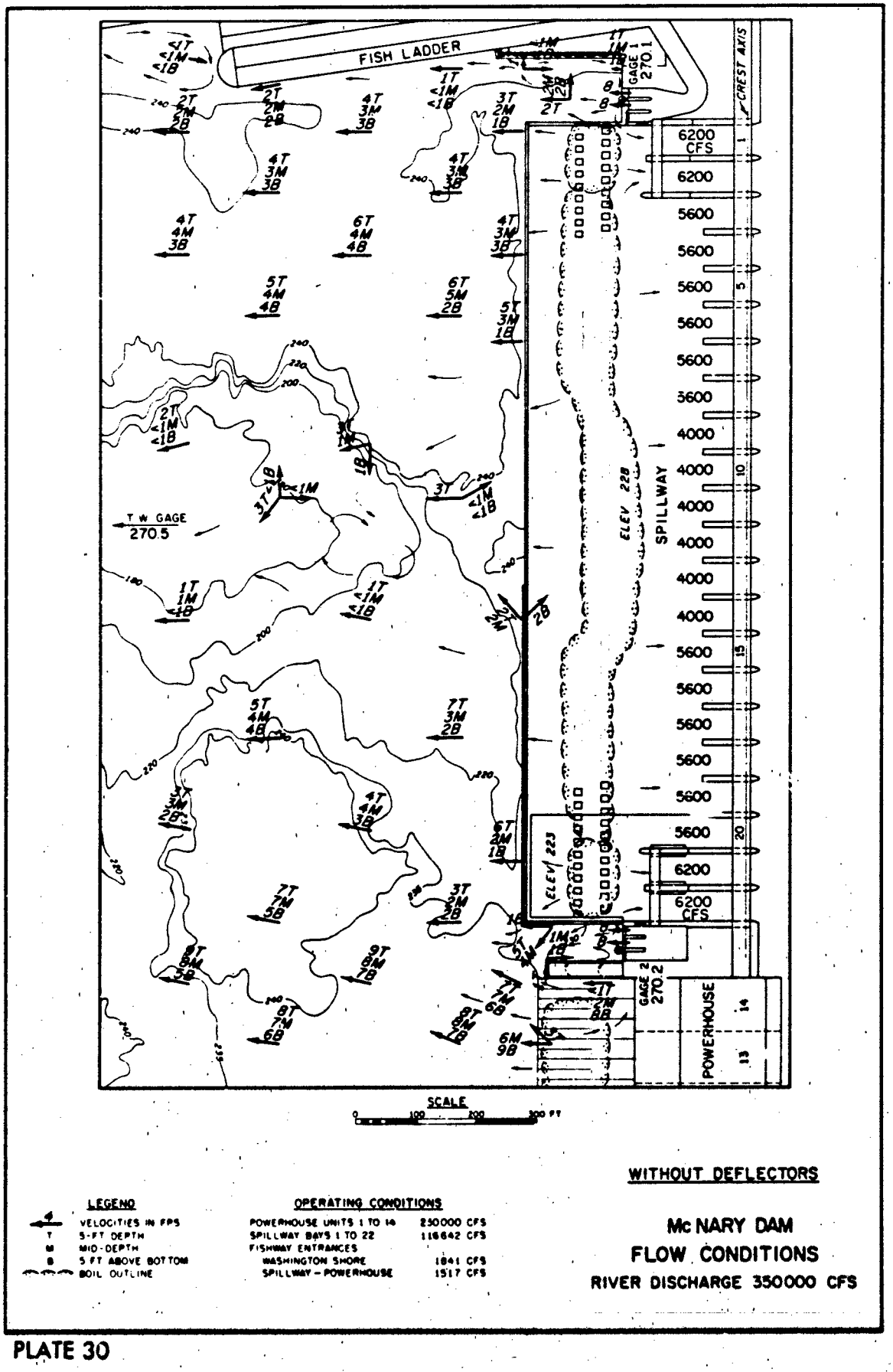
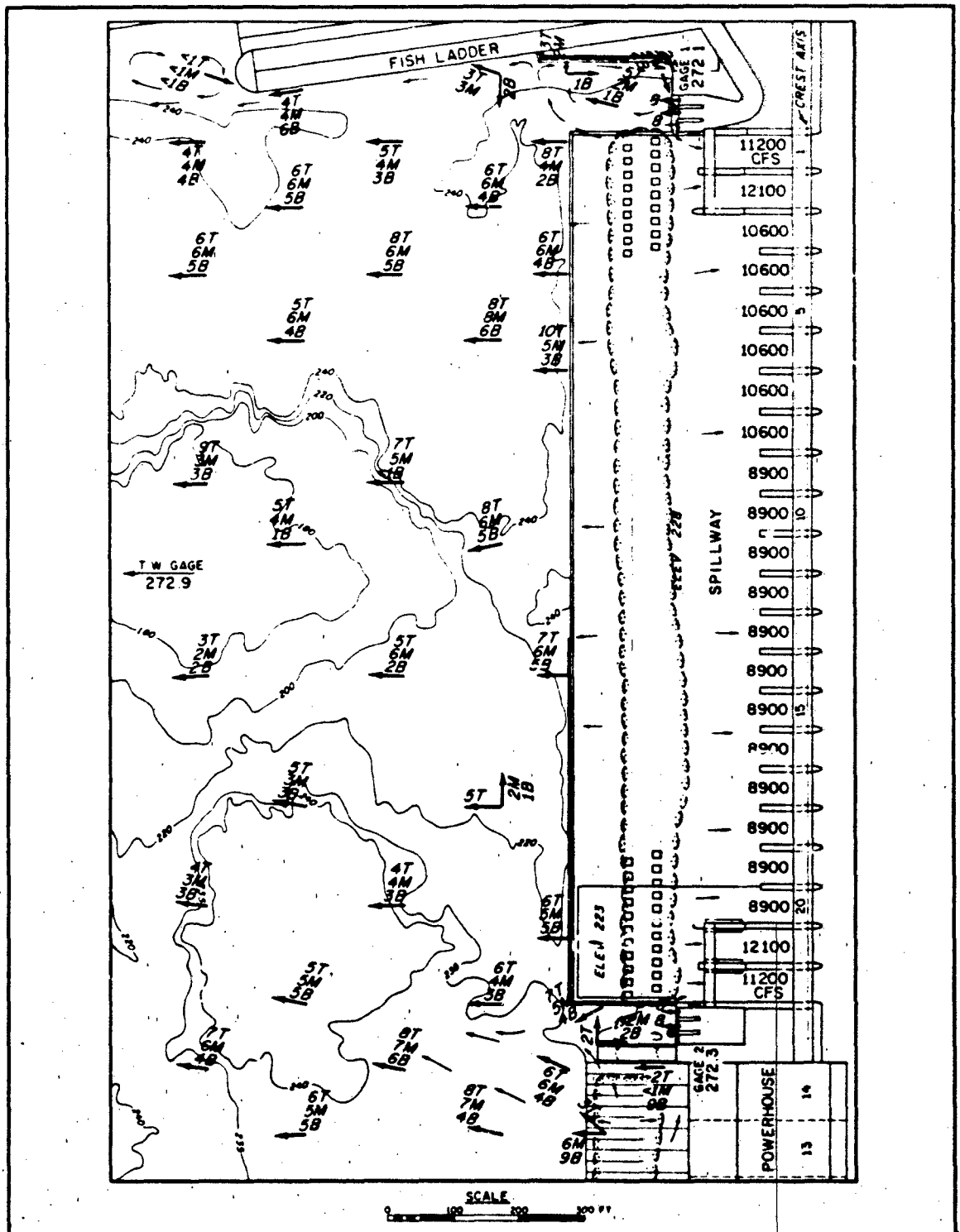

FISH LADDER
GAGE 1
270.1
CREST AXIS
6200 CFS
6200
5600
4000
SPILLWAY
ELEV 228
ELEV 223
6200 CFS
GAGE 2
270.2
POWERHOUSE
T W GAGE
270.5
SCALE
0 100 200 300 FT
WITHOUT DEFLECTORS
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
BOIL OUTLINE
OPERATING CONDITIONS
POWERHOUSE UNITS 1 TO 14 230000 CFS
SPILLWAY BAYS 1 TO 22 116642 CFS
FISHWAY ENTRANCES
WASHINGTON SHORE 1841 CFS
SPILLWAY – POWERHOUSE 1517 CFS
Mc NARY DAM
FLOW CONDITIONS
RIVER DISCHARGE 350000 CFS

PLATE 30



WITHOUT DEFLECTORS

LEGEND

4	VELOCITIES IN FPS
T	5-FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
	BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 14	230000 CFS
SPILLWAY BAYS 1 TO 22	218133 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2260 CFS
SPILLWAY – POWERHOUSE	1607 CFS

McNARY DAM
FLOW CONDITIONS
RIVER DISCHARGE 450000 CFS

PLATE 31

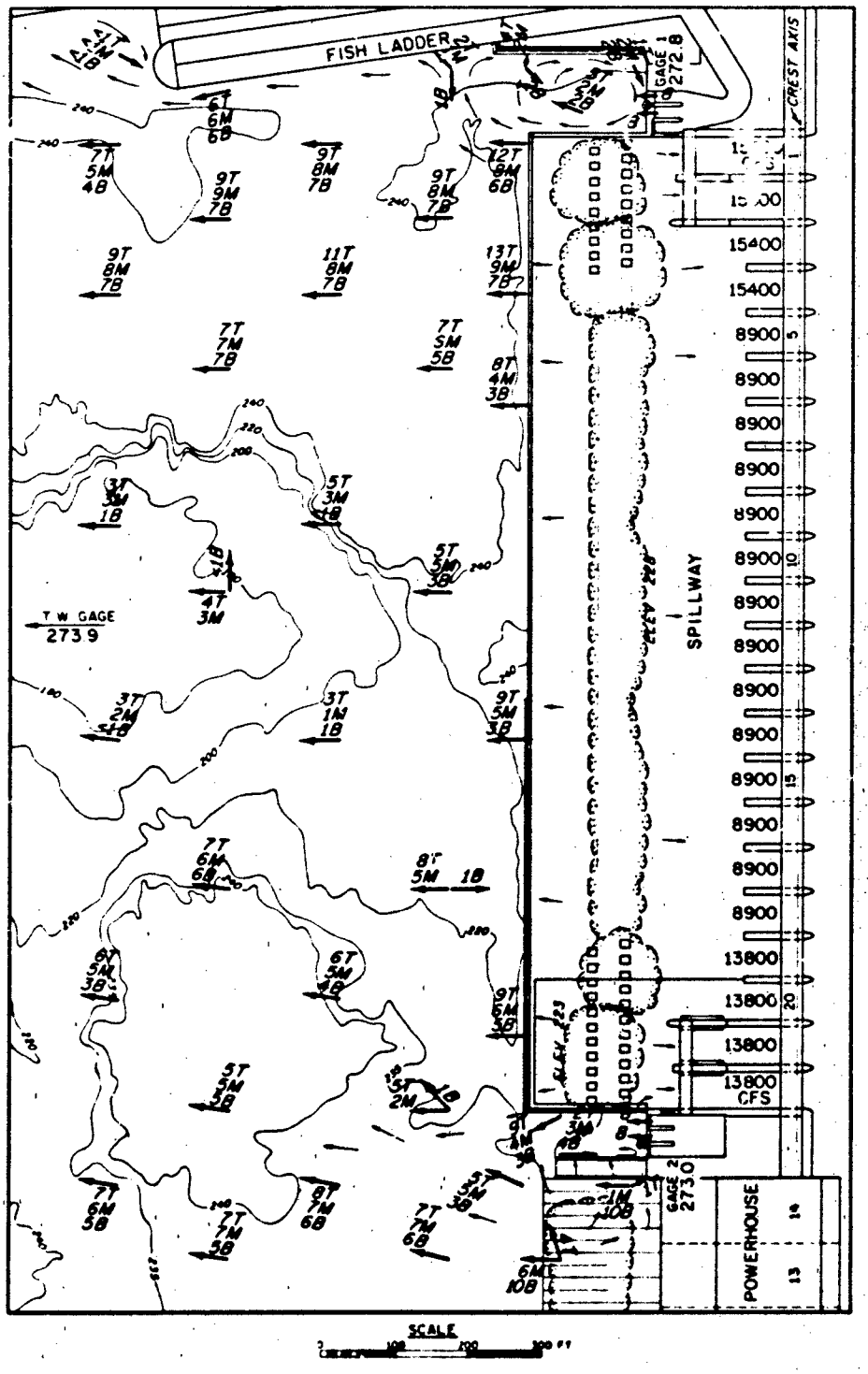
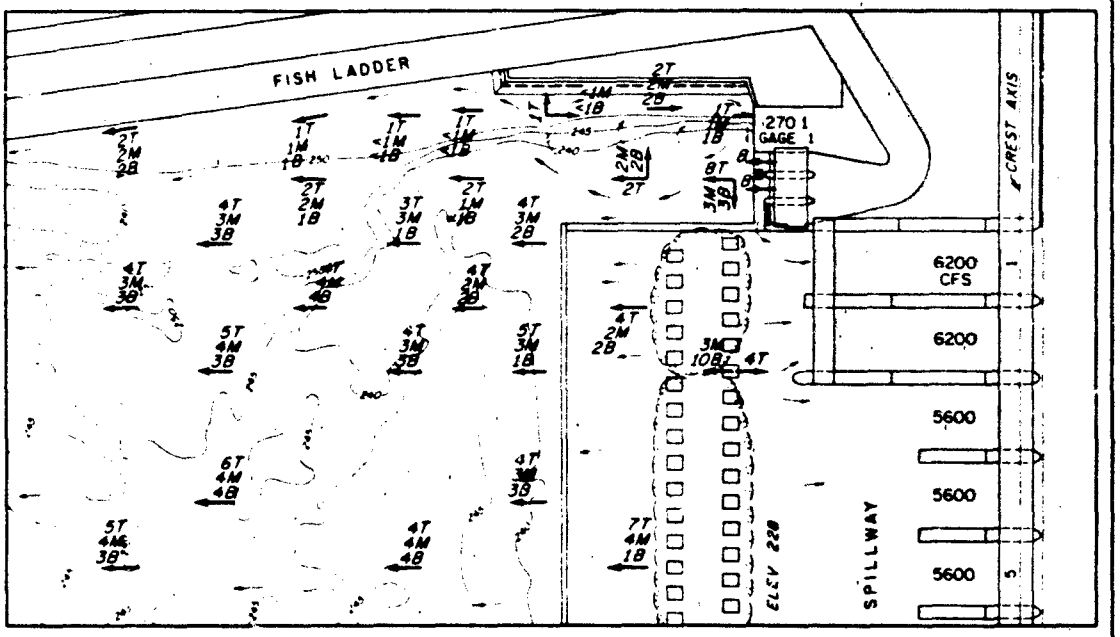
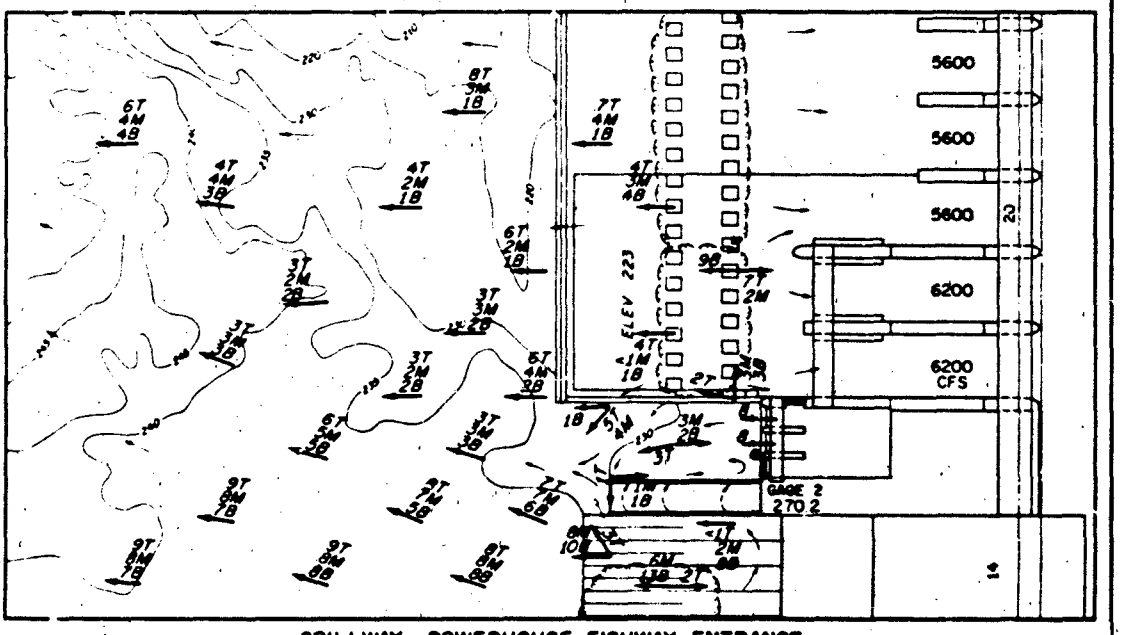

FISH LADDER
GAGE 1
272.8
CREST AXIS
SPILLWAY
TW GAGE
273.9
GAGE 2
273.0
POWERHOUSE
15400
15400
8900
8900
8900
8900
8900
8900
8900
8900
8900
8900
8900
8900
8900
8900
13800
13800
13800
13800
CFS
SCALE
LEGEND
VELOCITIES IN FPS
T 5 FT DEPTH
M MID DEPTH
B 5 FT ABOVE BOTTOM
BOIL OUTLINE
OPERATING CONDITIONS
POWERHOUSE UNITS 1 TO 14 250000 CFS
SPILLWAY BAYS 1 TO 22 266091 CFS
FISHWAY ENTRANCES
WASHINGTON SHORE 2246 CFS
SPILLWAY – POWERHOUSE 1703 CFS
WITHOUT DEFLECTORS
Mc NARY DAM
FLOW CONDITIONS
RIVER DISCHARGE 500000 CFS

PLATE 32



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 200 300 FT

LEGEND

- VELOCITIES IN FPS
- S-FT DEPTH
- MID-DEPTH
- 5 FT OFF BOTTOM
- BOIL OUTLINE

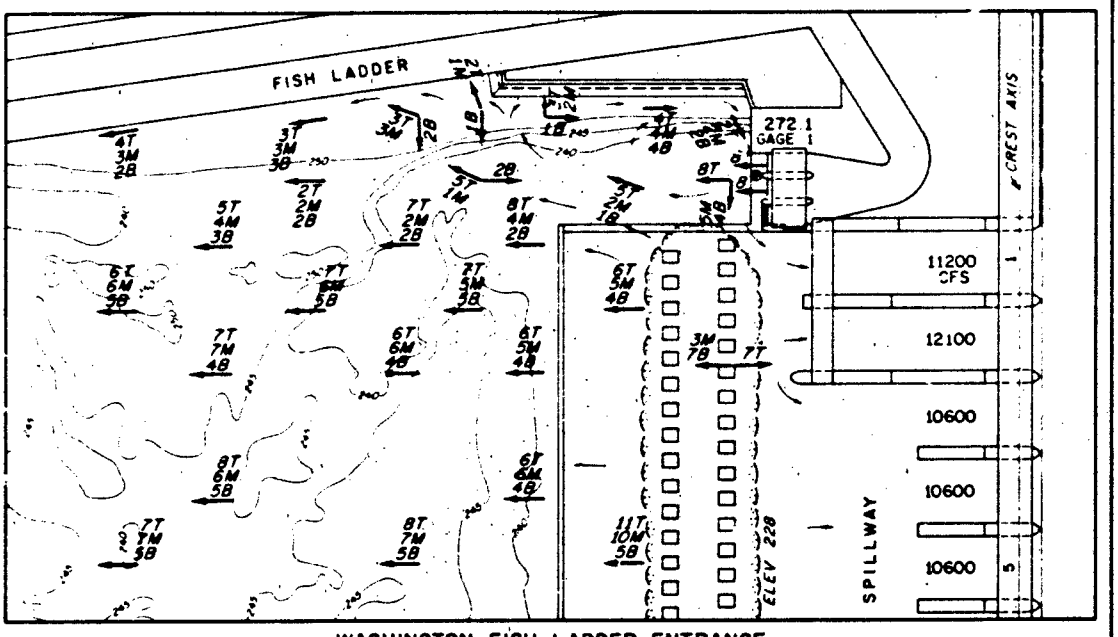
OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 14	237000 CFS
SPILLWAY BAYS 1 TO 22	110142 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	1841 CFS
SPILLWAY - POWERHOUSE	1917 CFS

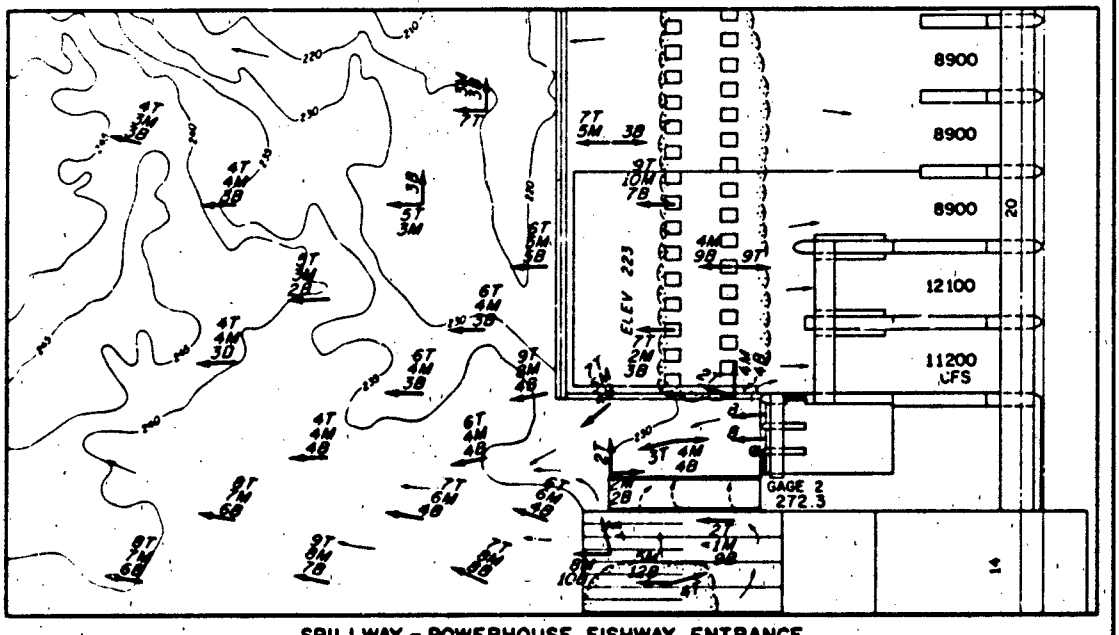
WITHOUT DEFLECTORS

McNARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 350000 CFS

PLATE 33



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 200 300 FT

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- BOIL OUTLINE

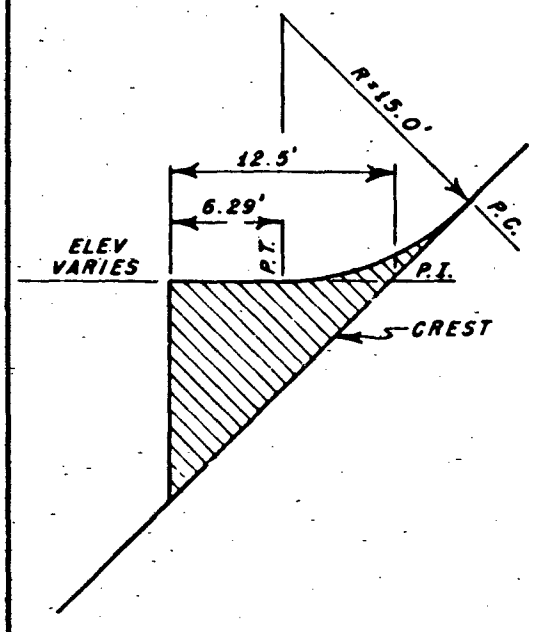
OPERATING CONDITIONS	
POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	218 133 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2260 CFS
SPILLWAY - POWERHOUSE	1607 CFS

WITHOUT DEFLECTORS

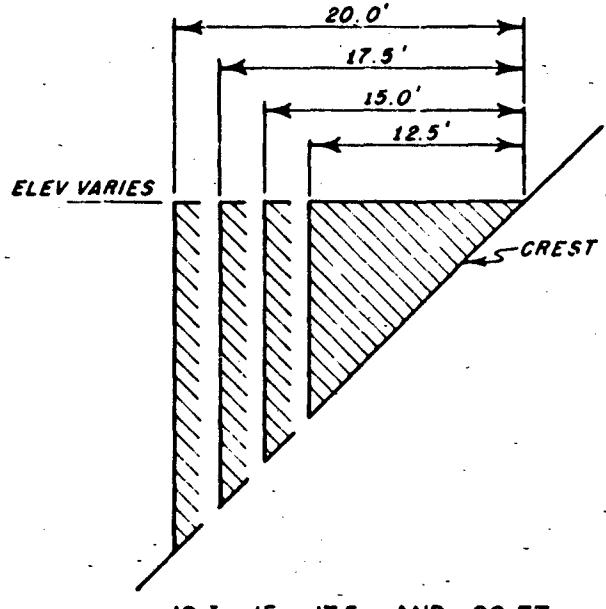
McNARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 450000 CFS

PLATE 34

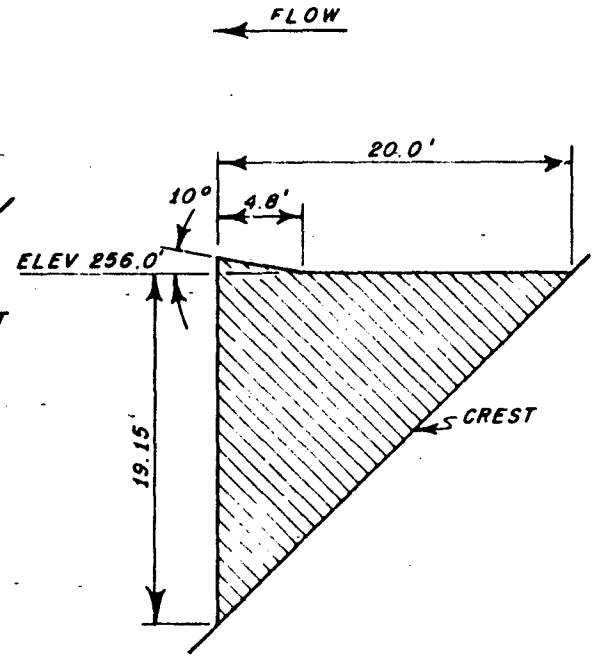
PLATE 36



12.5-FT DEFLECTOR WITH BUCKET



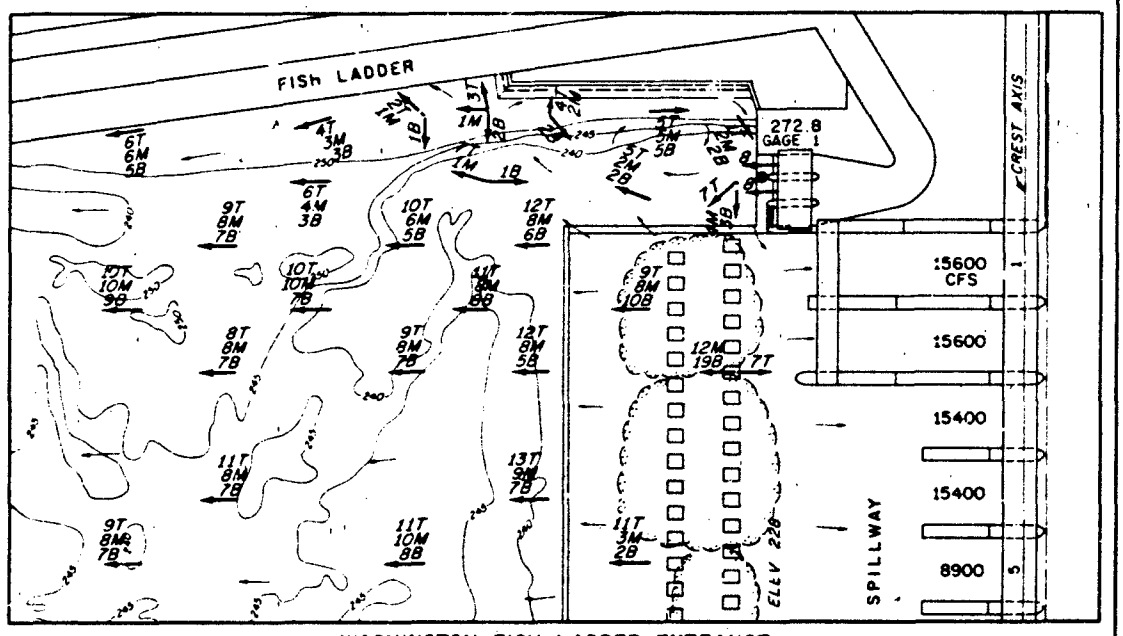
12.5-, 15-, 17.5- AND 20-FT DEFLECTORS.



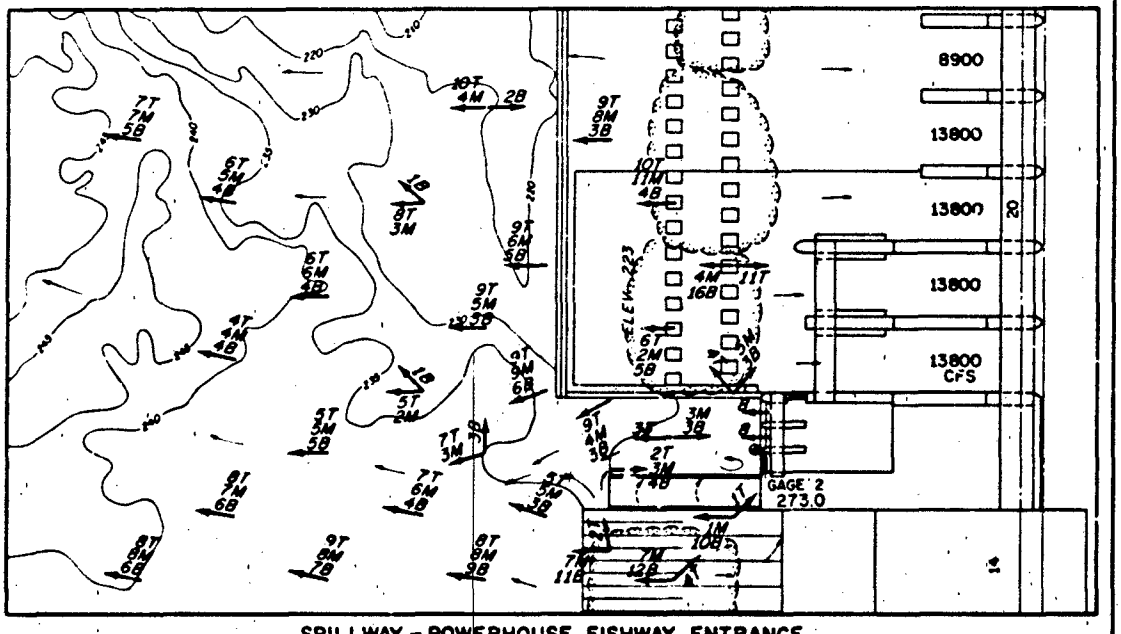
10° LIP ON 20-FT DEFLECTOR

McNARY DAM

SPILLWAY DEFLECTORS



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 100 200 FT

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- BOIL OUTLINE

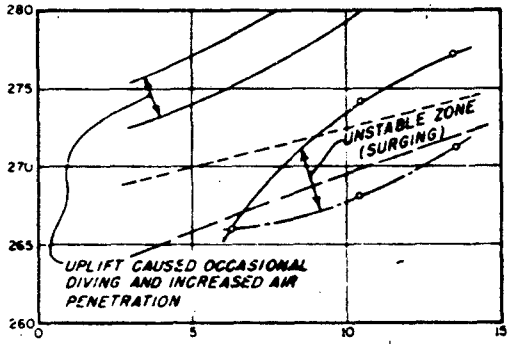
OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	266 051 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2246 CFS
SPILLWAY - POWERHOUSE	1703 CFS

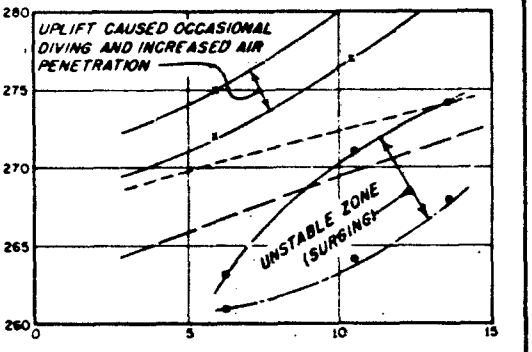
WITHOUT DEFLECTORS

Mc NARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 500 000 CFS

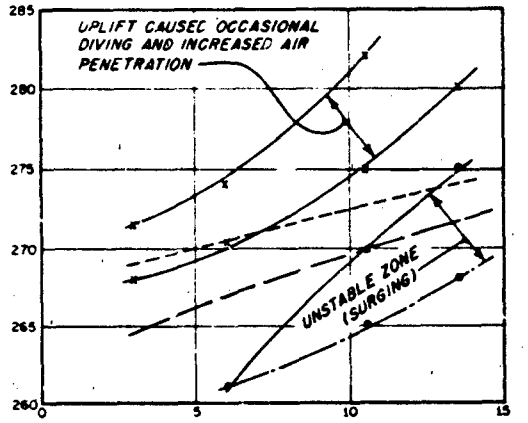
PLATE 35



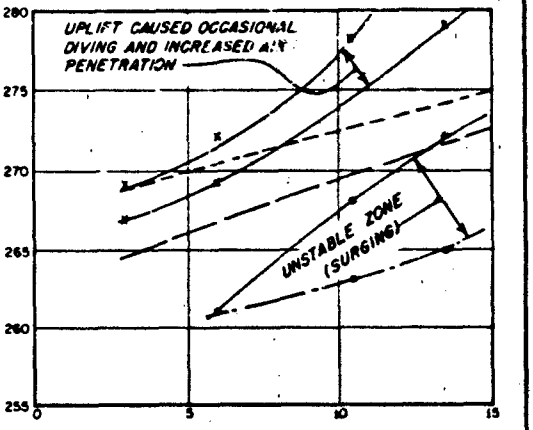
12.5-FT DEFLECTOR AT ELEV 264



12.5-FT DEFLECTOR AT ELEV 260

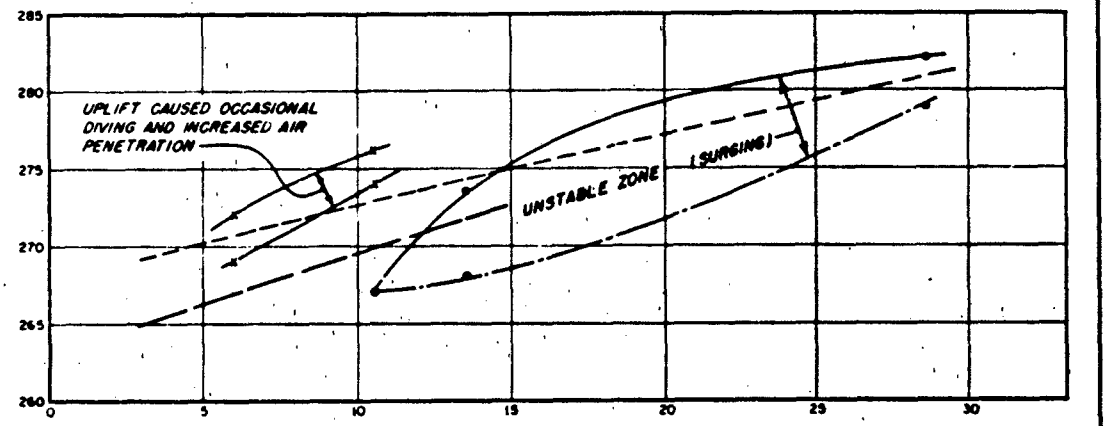


12.5-FT DEFLECTOR AT ELEV 258



12.5-FT DEFLECTOR AT ELEV 256

TAILWATER - ELEVATION



SPILLWAY DISCHARGE IN 1000 CFS PER BAY

20-FT DEFLECTOR AT ELEV 256

LEGEND

- T.W. (JOHN DAY POOL ELEV 265)
- T.W. (JOHN DAY POOL ELEV 257)
- MIN T.W. FOR STABLE SKIMMING FLOW
- MAX T.W. FOR STABLE PLUNGING FLOW

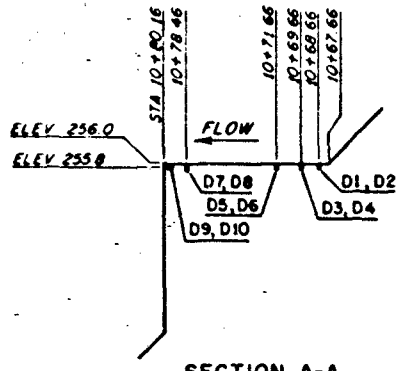
NOTES

TAILWATER INCLUDES FLOW FROM 14 POWERHOUSE UNITS.

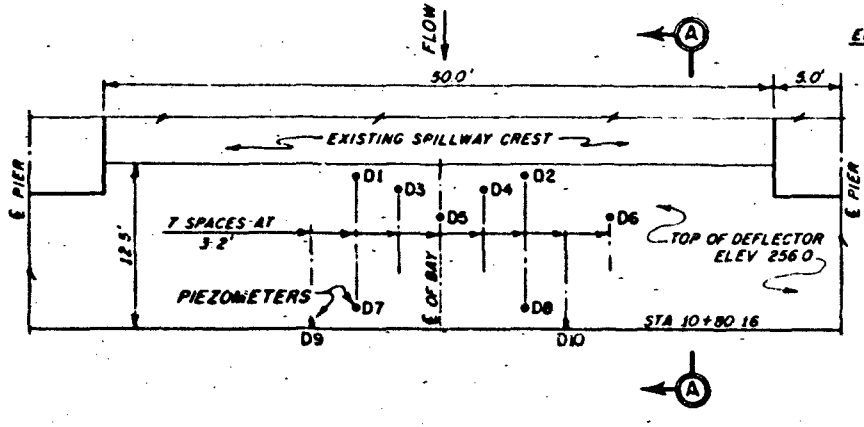
McNARY DAM
FLOW CONDITIONS IN STILLING BASIN
12.5- AND 20-FT DEFLECTORS
FLOW UNDER LOWER GATE LEAF

PLATE 37

PLATE 38



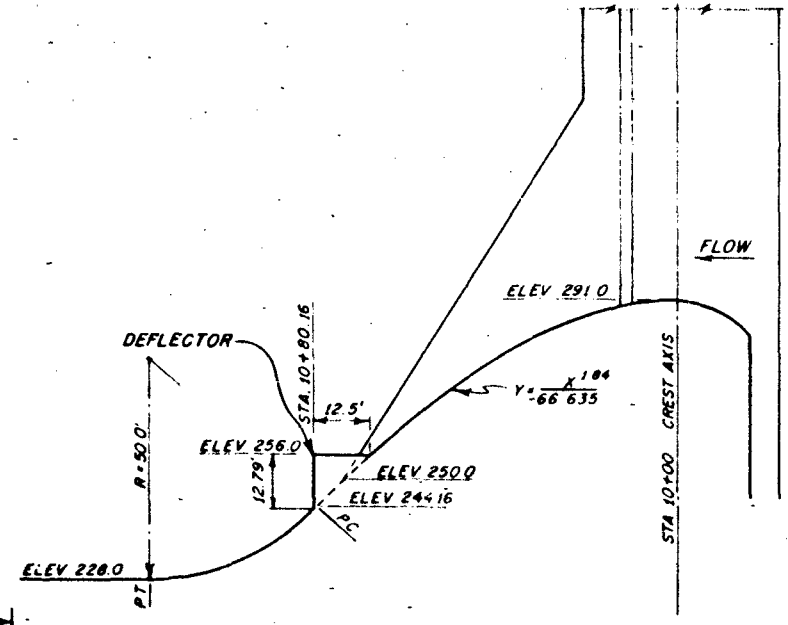
SECTION A-A



DEFLECTOR WITH PIEZOMETER LOCATIONS

SCALE

0 5 10 15 20 FT



SECTION THROUGH SPILLWAY

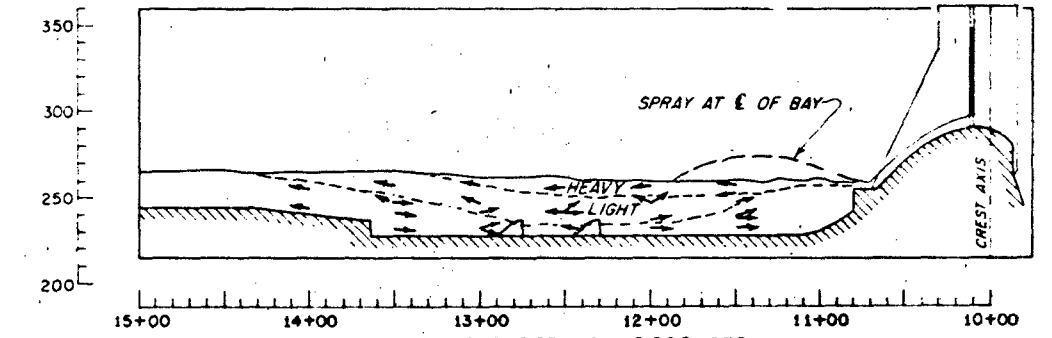
SCALE

0 20 40 60 FT

McNARY DAM

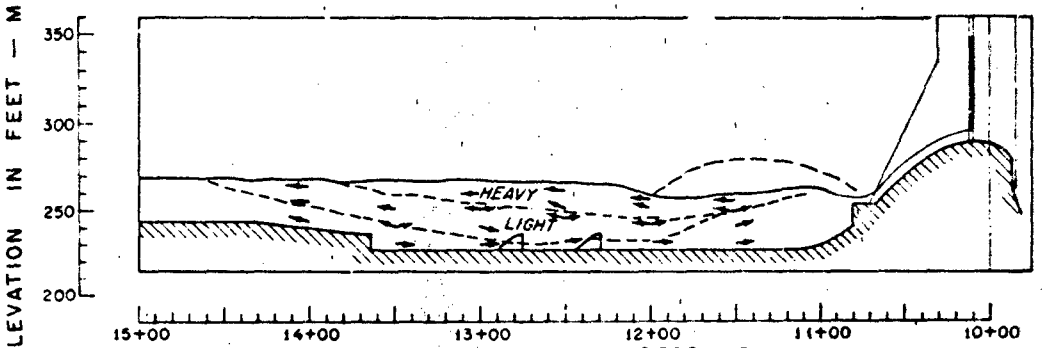
DETAILS AND PIEZOMETER LOCATIONS

12.5-FT DEFLECTOR, ELEV 256

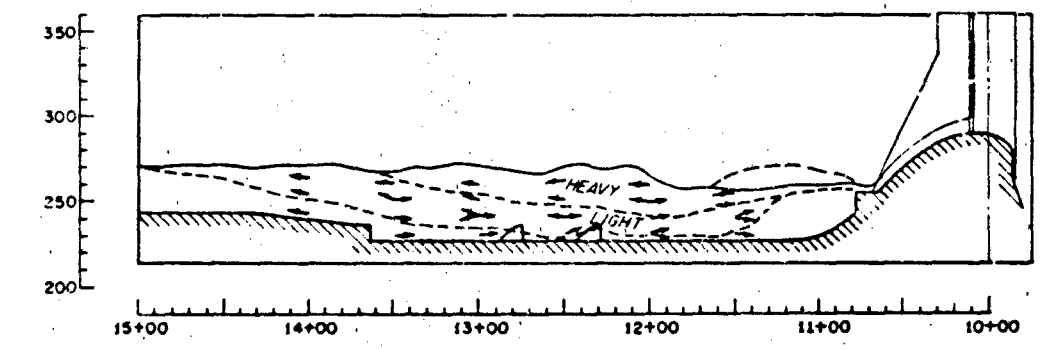


DISCHARGE PER BAY 6 000 CFS
TAILWATER ELEV 266.9

ELEVATION IN FEET — MSL



DISCHARGE PER BAY 10 500 CFS
TAILWATER ELEV 269.9



STATIONS NORMAL TO CREST AXIS
DISCHARGE PER BAY 13 500 CFS
TAILWATER ELEV 271.7

LEGEND

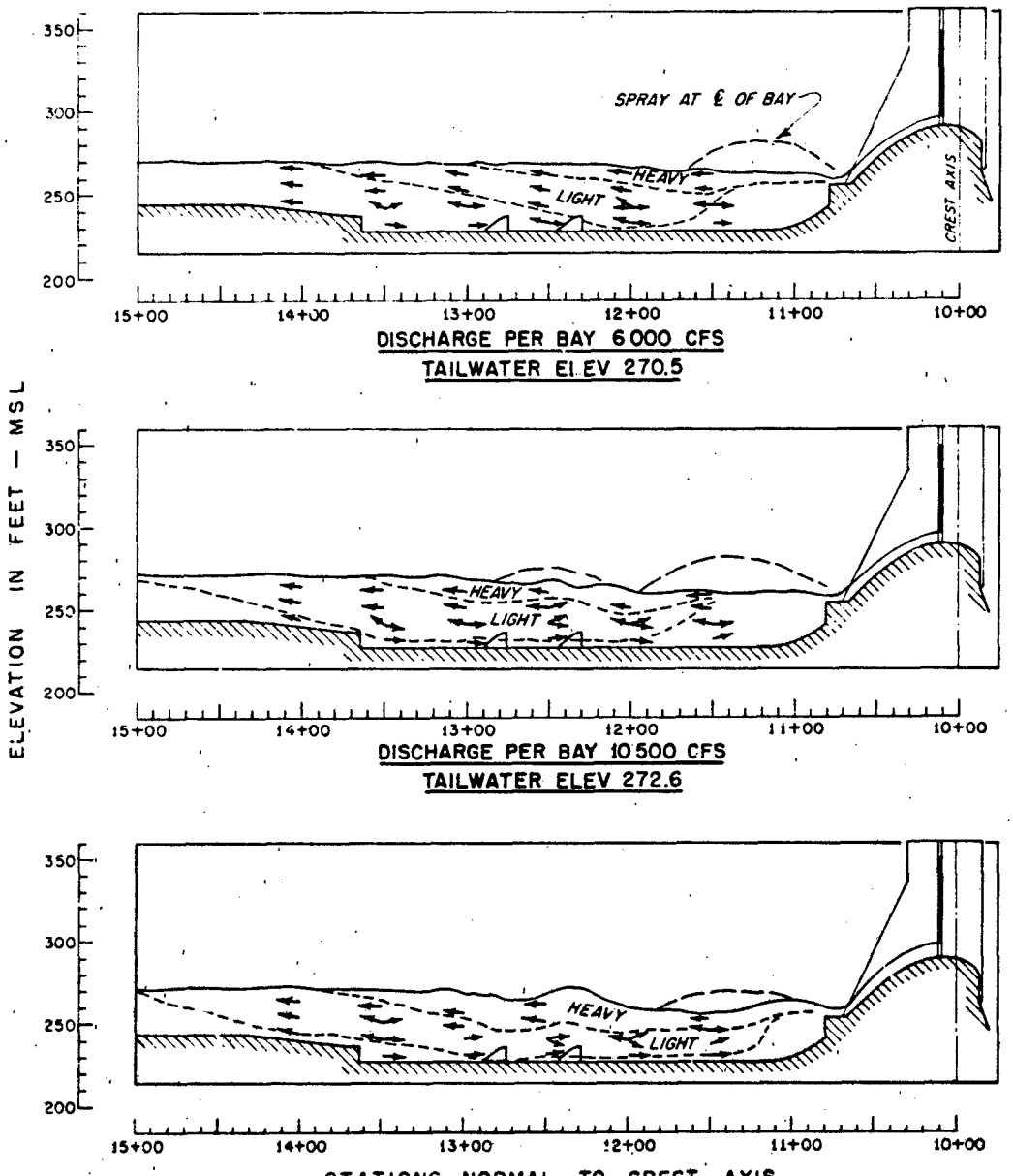
---------- ZONES OF AERATION

NOTE

DETAILS OF DEFLECTOR SHOWN ON PLATES 36 AND 38.

Mc NARY DAM
AERATION AND FLOW DIRECTIONS
12.5-FT DEFLECTOR AT ELEV 256
FLOW UNDER GATE
JOHN DAY POOL ELEV 257

PLATE 39



LEGEND

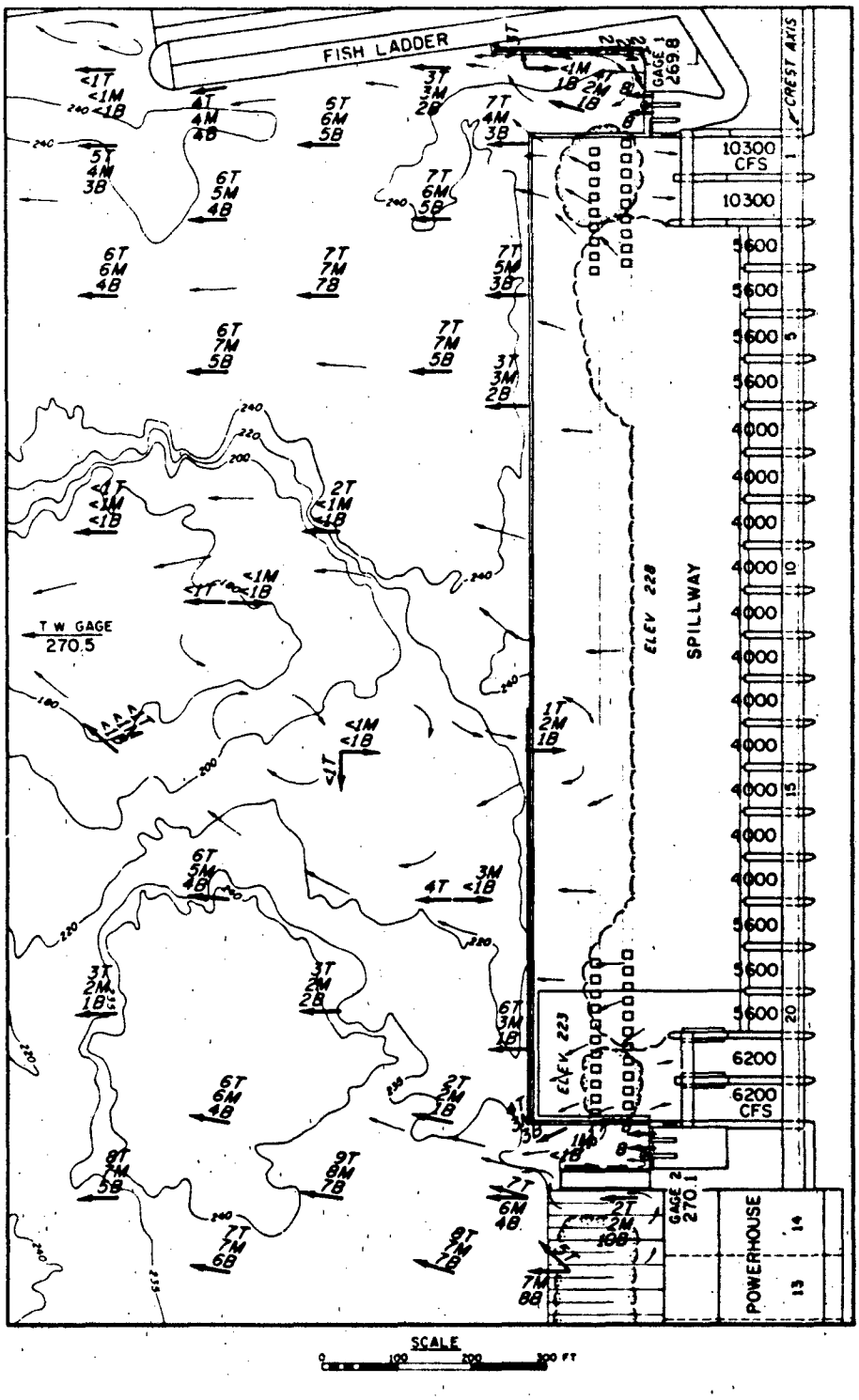
---------- ZONES OF AERATION

NOTE

DETAILS OF DEFLECTOR SHOWN ON PLATES 36 AND 38.

McNARY DAM
AERATION AND FLOW DIRECTIONS
12.5-FT DEFLECTOR AT ELEV 256
FLOW UNDER GATE
JOHN DAY POOL ELEV 265

PLATE 40



DEFLECTORS IN BAYS 3 TO 20

LEGEND

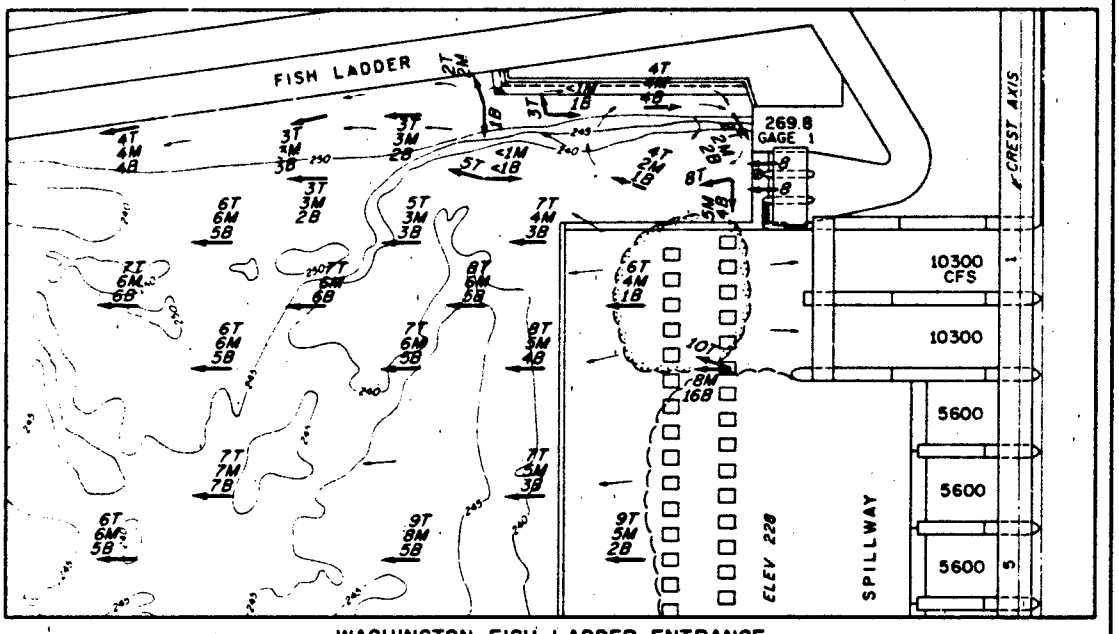
4	VELOCITIES IN FPS
T	5 FT DEPTH
M	MID-DEPTH
B	5 FT ABOVE BOTTOM
	SKIMMING FLOW OUTLINE
	BOIL OUTLINE

OPERATING CONDITIONS

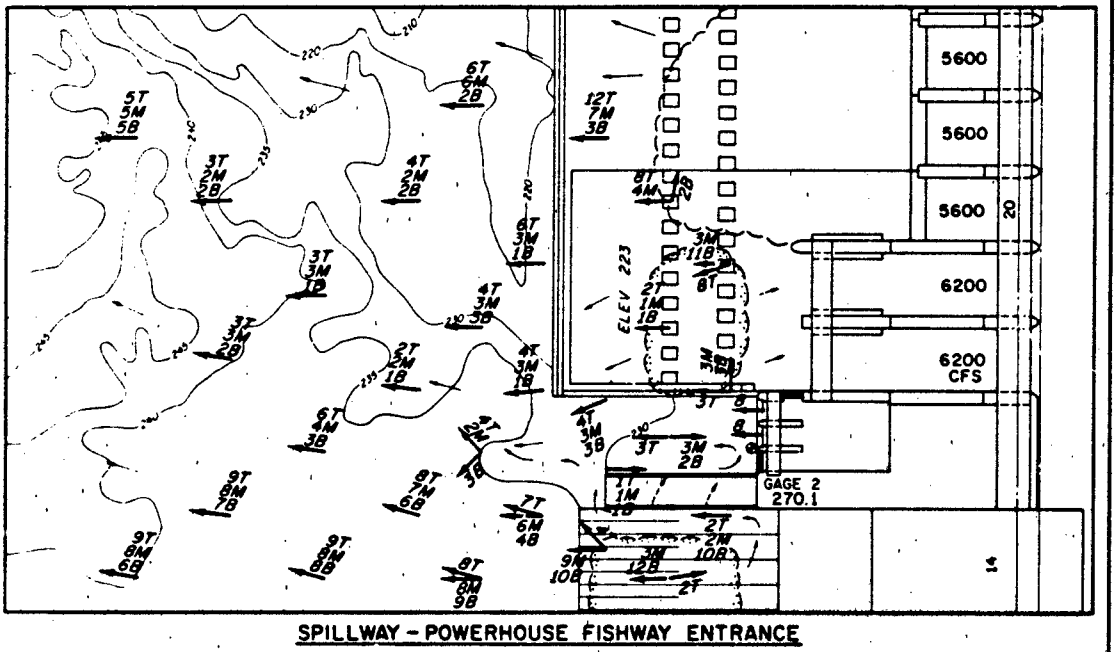
POWERHOUSE UNITS 1 TO 14	230000 CFS
SPILLWAY BAYS 1 TO 22	116642 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	1841 CFS
SPILLWAY – POWERHOUSE	1517 CFS

McNARY DAM
FLOW CONDITIONS
RIVER DISCHARGE 350000 CFS

PLATE 41



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 100 200 300 FT

DEFLECTORS IN BAYS 3 TO 20

LEGEND

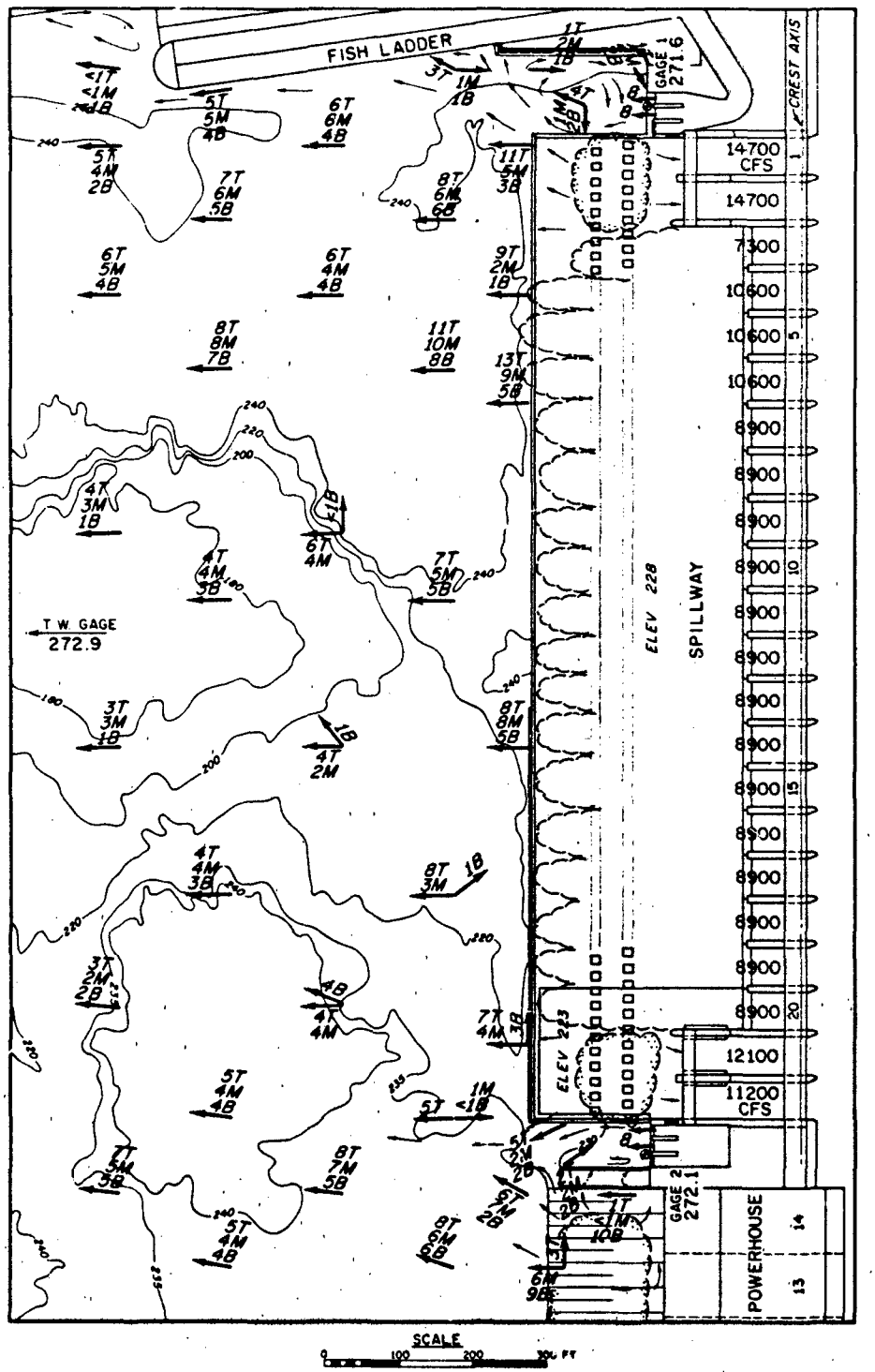
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	116642 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	1841 CFS
SPILLWAY - POWERHOUSE	1517 CFS

Mc NARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 350000 CFS

PLATE 42



DEFLECTORS IN BAYS 3 TO 20

LEGEND

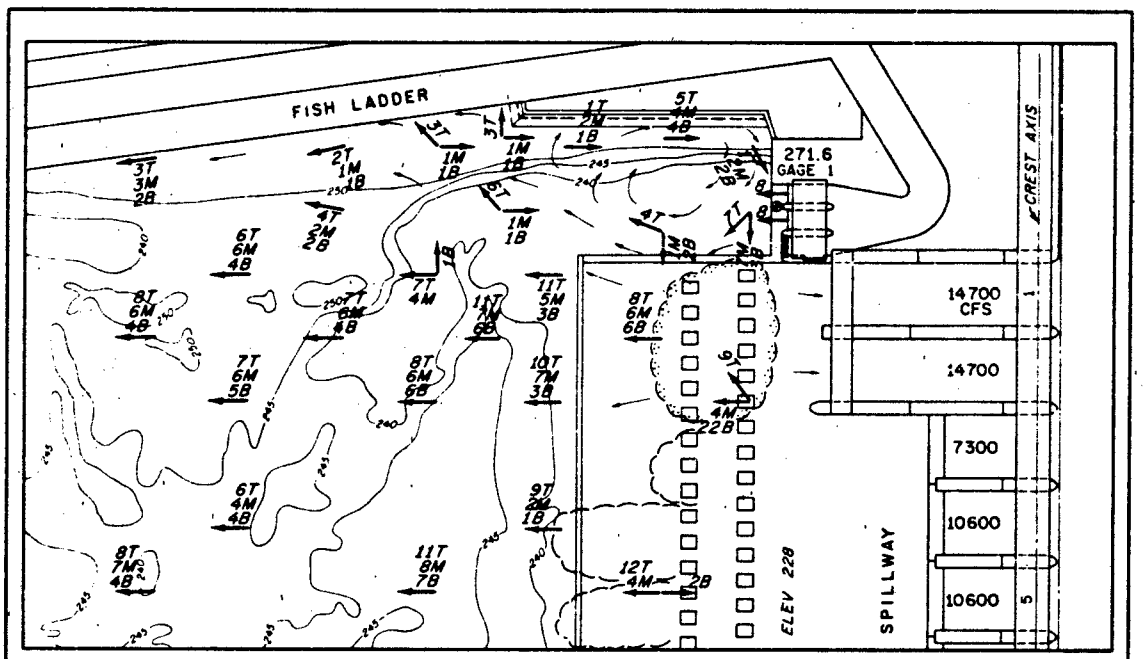
- 4 ← VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

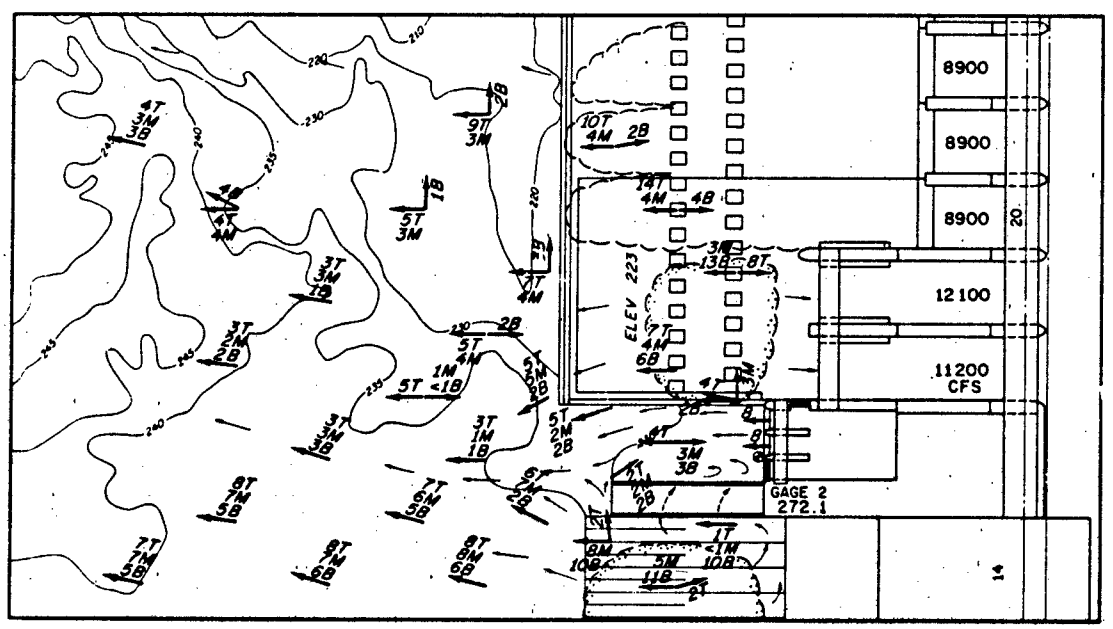
POWERHOUSE UNITS 1 TO 14	230000 CFS
SPILLWAY BAYS 1 TO 22	216133 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2260 CFS
SPILLWAY – POWERHOUSE	1607 CFS

McNARY DAM
FLOW CONDITIONS
RIVER DISCHARGE 450000 CFS

PLATE 43



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 200 300 FT

DEFLECTORS IN BAYS 3 TO 20

LEGEND

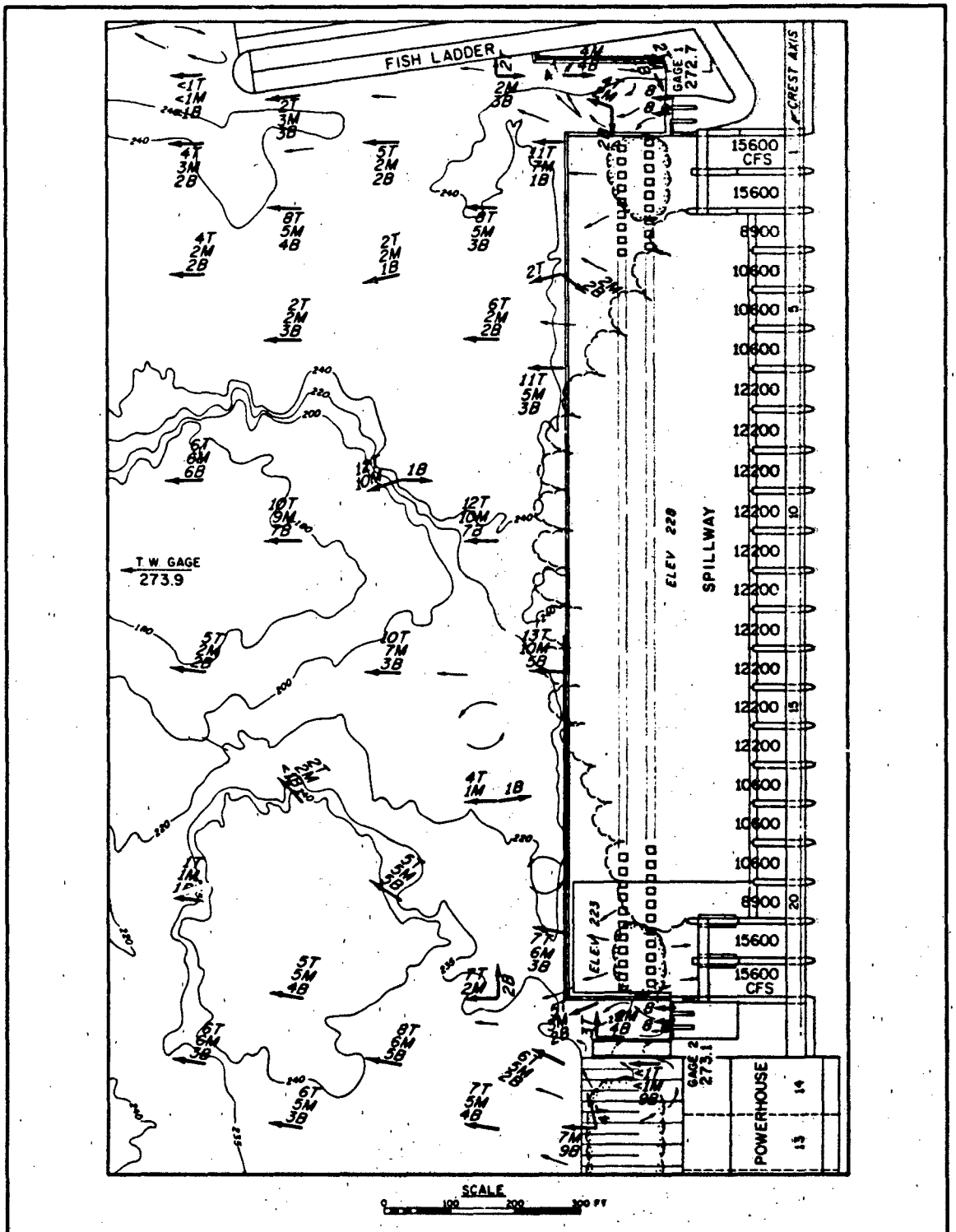
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	216 133 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2 280 CFS
SPILLWAY - POWERHOUSE	1607 CFS

Mc NARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 450000 CFS

PLATE 44



DEFLECTORS IN BAYS 3 TO 20

LEGEND

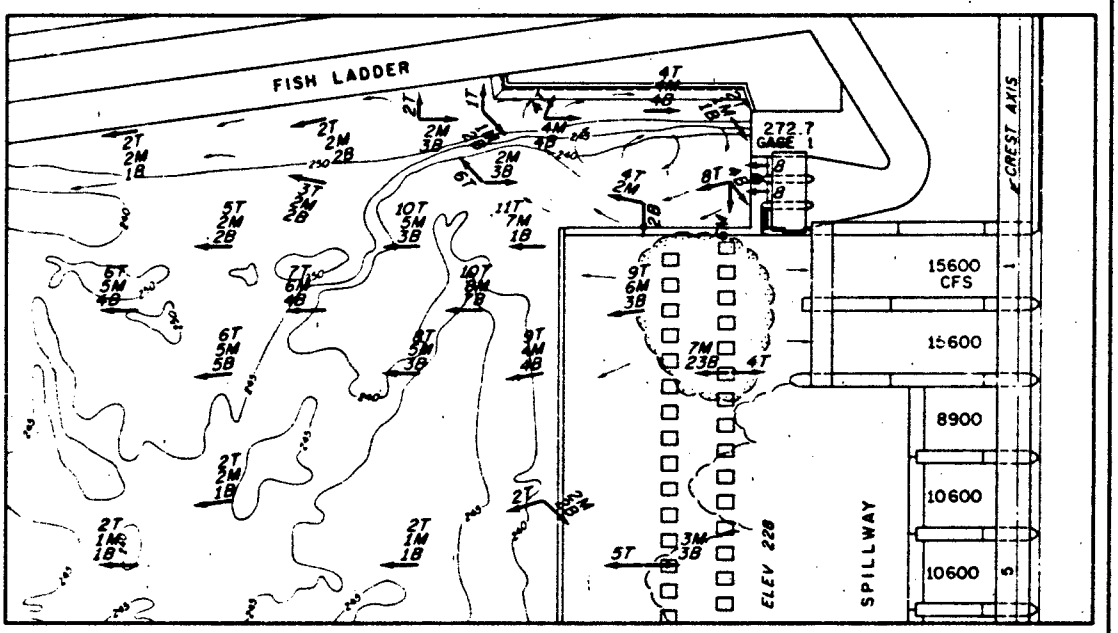
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

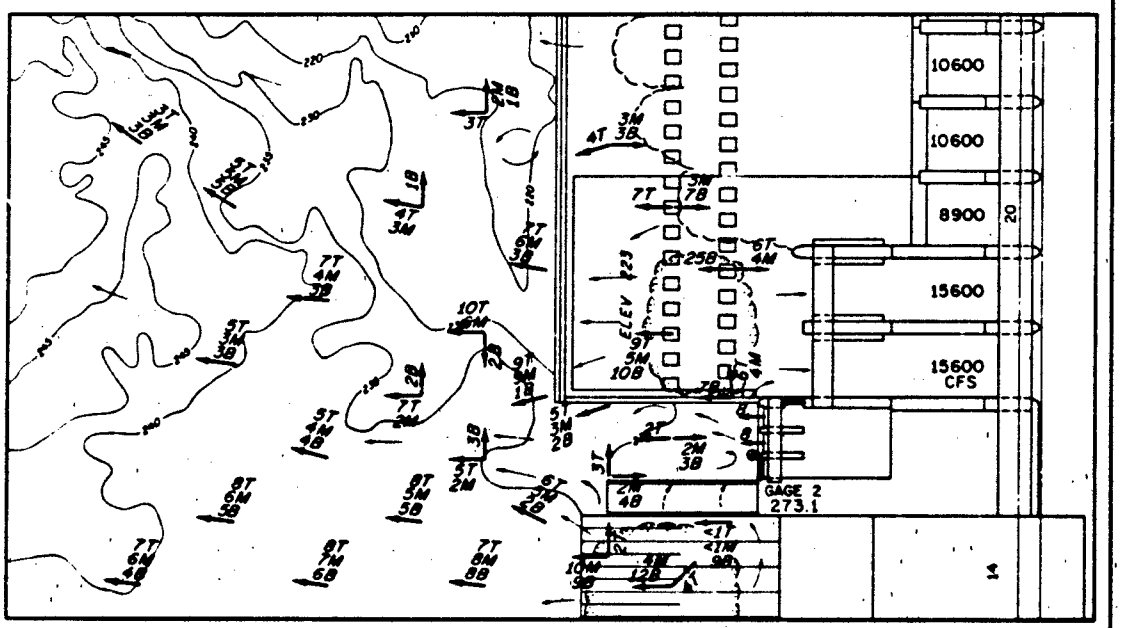
POWERHOUSE UNITS 1 TO 14	230000 CFS
SPILLWAY BAYS 1 TO 22	266051 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2246 CFS
SPILLWAY – POWERHOUSE	1703 CFS

McNARY DAM
FLOW CONDITIONS
RIVER DISCHARGE 500000 CFS

PLATE 45



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 200 300 FT

DEFLECTORS IN BAYS 3 TO 20

LEGEND

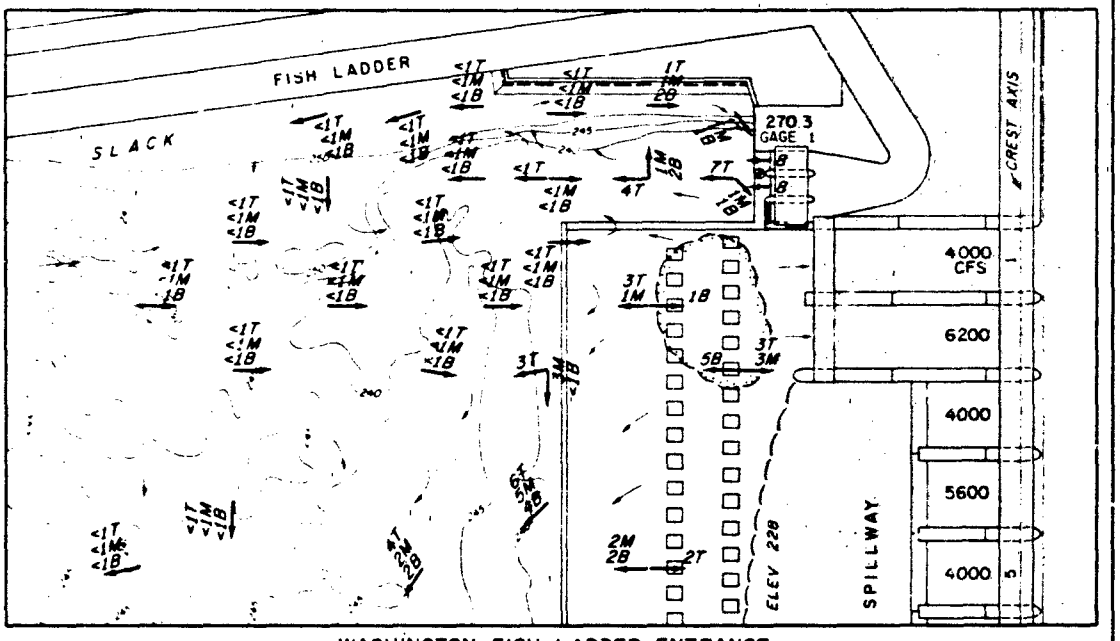
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

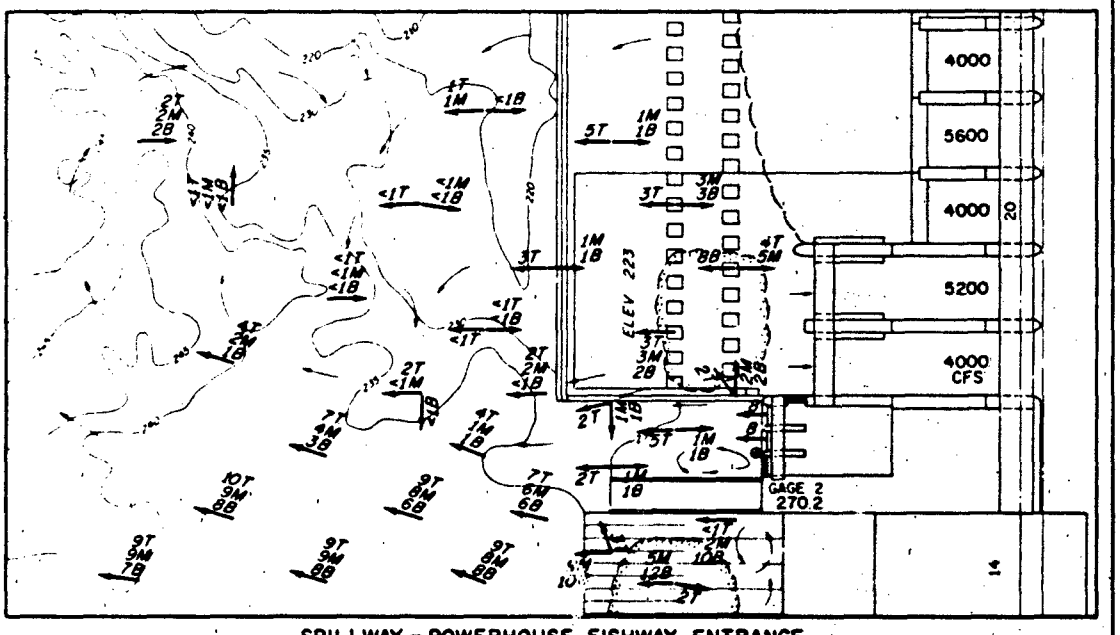
POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	266 051 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2 246 CFS
SPILLWAY - POWERHOUSE	1703 CFS

McNARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 500000 CFS

PLATE 46



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 200 300 FT

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION

DEFLECTORS IN BAYS 3 TO 20

LEGEND

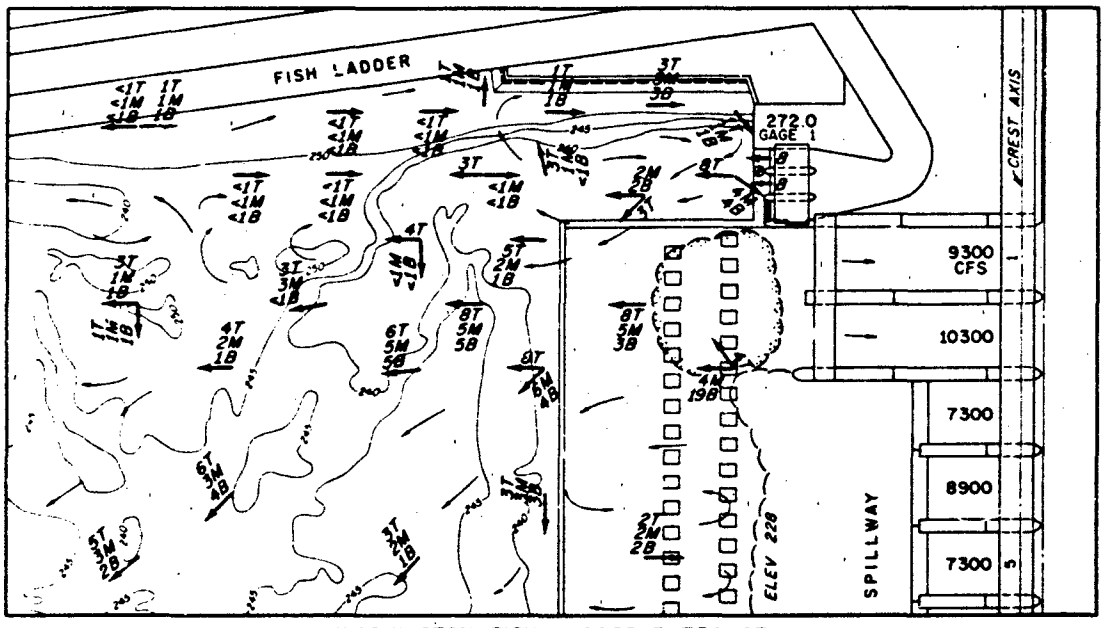
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

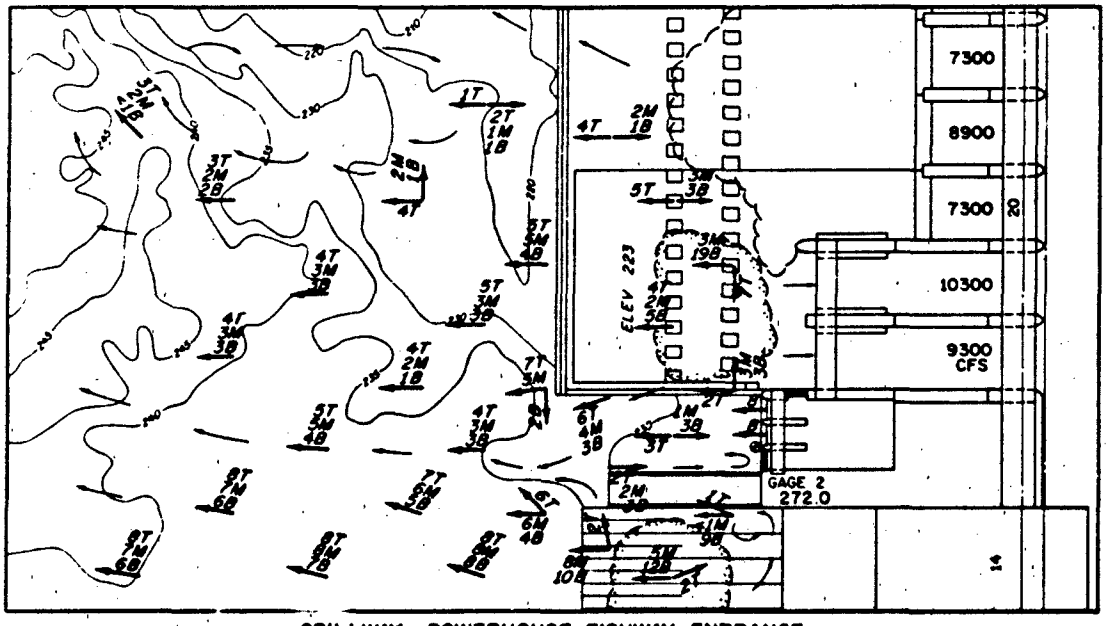
POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	118 642 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	1841 CFS
SPILLWAY - POWERHOUSE	1517 CFS

Mc NARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 350000 CFS

PLATE 47



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 50 100 200 300 FT

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

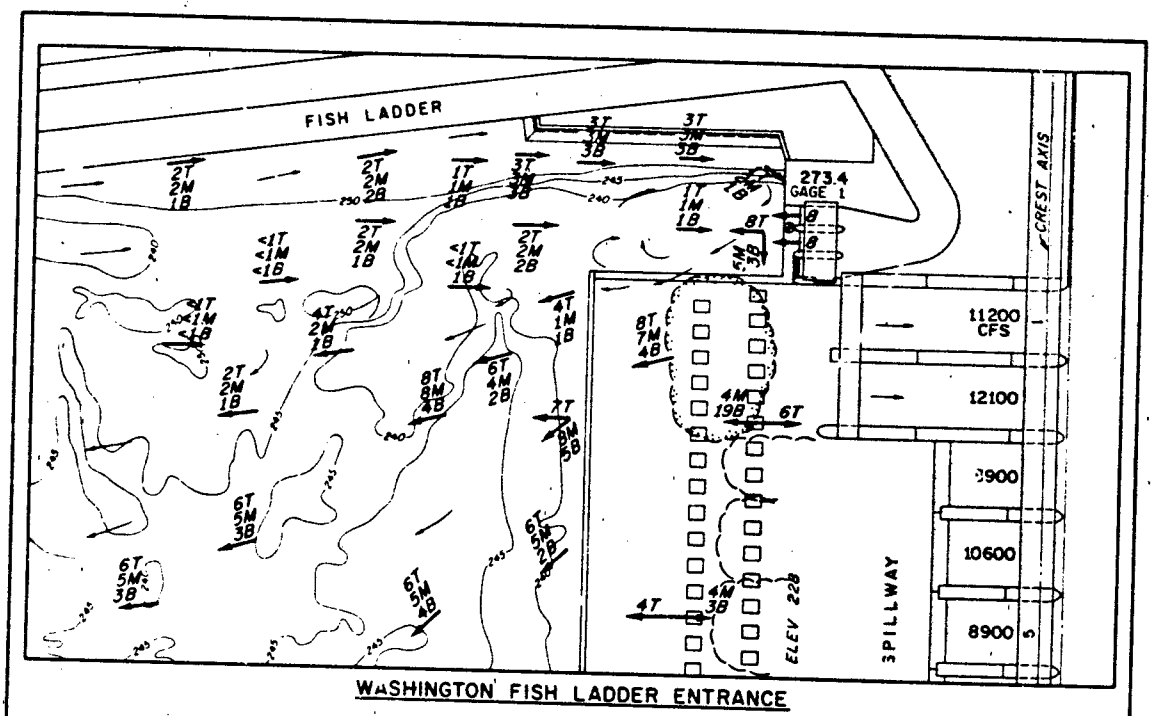
POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	216 133 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2260 CFS
SPILLWAY - POWERHOUSE	1607 CFS

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION

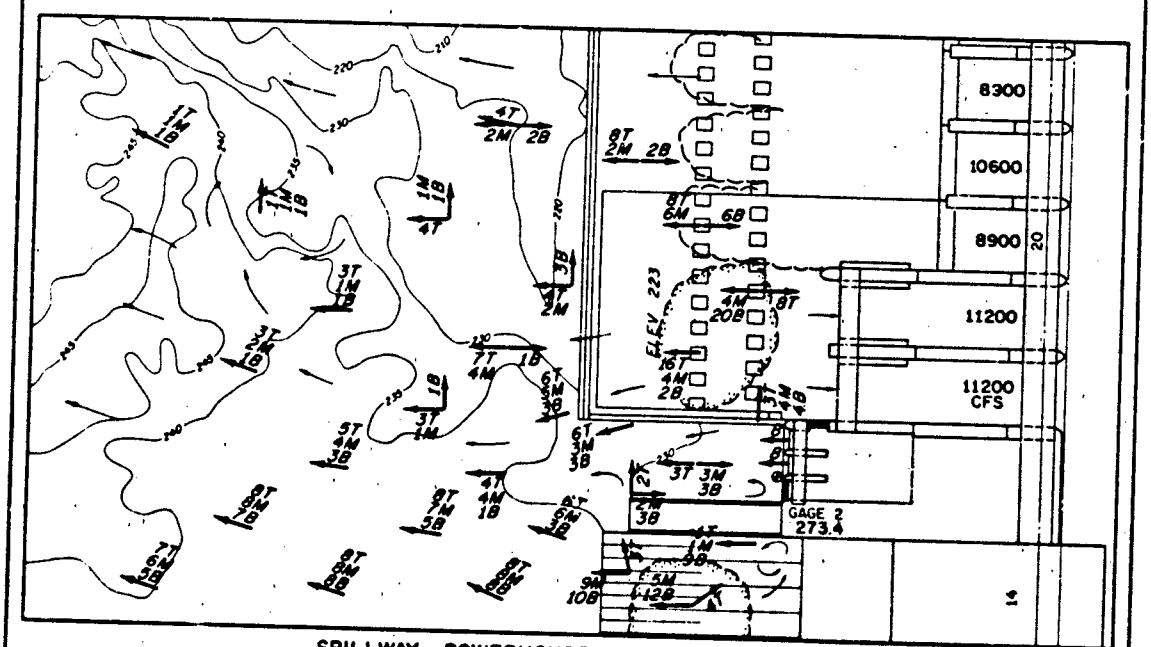
DEFLECTORS IN BAYS 3 TO 20

McNARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 450000 CFS

PLATE 48



WASHINGTON FISH LADDER ENTRANCE



SPILLWAY - POWERHOUSE FISHWAY ENTRANCE

SCALE

0 30 100 200 300 FT

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 14	230 000 CFS
SPILLWAY BAYS 1 TO 22	266 051 CFS
FISHWAY ENTRANCES	
WASHINGTON SHORE	2246 CFS
SPILLWAY - POWERHOUSE	1703 CFS

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION
DEFLECTORS IN BAYS 3 TO 20

McNARY DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 500000 CFS

PLATE 49

PART V

ICE HARBOR DAM

PART V: ICE HARBOR DAM TESTS AND RESULTS

The Prototype

33. The salient features of Ice Harbor Dam include a 10-bay spillway, a 6-unit powerhouse, a single-lift navigation lock, a fish ladder on each side of the river, and flanking embankments (plate 50). The spillway is controlled by 50-foot-wide by 53-foot-high tainter gates and is designed to pass 850,000 cfs at pool elevation 446.4. At each end of the spillway one bay is separated from the rest of the structure by a training wall. Discharges in the end bays can be adjusted to provide fish attraction flow or to adjust flow patterns and velocities at the adjacent fishway entrances. Spillway energy is dissipated in a 168-foot-long stilling basin having one row of 8-foot-high baffle piers and a 23-foot-high vertical end sill. A section through the spillway is shown on plate 51.

The Models

34. A 1:40-scale sectional model reproducing a three-bay section of the approach, spillway, stilling basin, and exit channel (photograph 42) was used to develop the optimum design of the spillway deflector. The model crest, piers, gates, and toe curve were made of acrylic plastic; the stilling basin and the approach and exit areas were constructed of waterproofed wood and plywood. The pool elevation was maintained by the spillway gates. The tailwater elevations furnished by NPW were controlled by a vaned tailgate and were set at a gage on the centerline of the model 1,000 feet downstream from the crest axis.

35. A 1:50-scale comprehensive model (photograph 43) was used to determine the effects of the recommended deflector on flow conditions and to establish spillway operation schedules for optimum passage of fish. This model was a reproduction of a portion of the forebay, the

spillway, the powerhouse, adjacent fishway entrances, and about 1,600 feet of downstream channel. The model structures were made of plastic, waterproofed wood, and plywood. The exit channel was contoured in cement to conform with a 1975-1976 hydrographic survey at the project. The pool elevation was controlled by the spillway gates; tailwater elevations were set at a gage approximately 1,000 feet downstream from the crest axis.

Tests

36. Spillway discharges of primary concern in the study were 6,500, 12,500, and 17,500 cfs per bay which correspond to the 2-, 5- and 10-year-frequency floods at the project. Performance of the deflectors was also evaluated with discharges of 420,000 (standard project flood) and 850,000 cfs (85,000 cfs per bay, project design discharge).

Existing Spillway

37. Flow conditions in the existing spillway and stilling basin with discharges of 6,500 to 85,000 cfs per bay (photograph 44 and plate 52) were observed for comparison with conditions after the deflectors were installed. With all flows tested, the nappe plunged to the stilling basin floor and entrained air was distributed throughout the basin. Supersaturation of tailwater with atmospheric gases would occur with these conditions.

Deflectors

38. Details of the deflectors and appurtenances that were tested are shown on plate 53. Since previous model studies of deflectors for spillways at other projects had indicated that the 12.5-foot length was adequate, this length was generally used in the Ice Harbor study. A 20-foot deflector was tested only at the finally selected elevation and was used during tests of slotted bulkheads (paragraph 44).

39. The 12.5-foot deflector located at various elevations between 332 to 344 was tested with 8-, 9-, and 10-bay operation. Varying the deflector elevation had little effect on the degree, concentration, and depth of air penetration in the stilling basin. In all deflector locations, the area susceptible to drawdown of aerated flow was in the vicinity of the end sill and baffle piers where velocities in the deep recurn flow were high enough to pull the surface currents downward. This tendency would be greater in the prototype than in the model due to higher amounts of entrained air.

40. Flow stability in the stilling basin was a major factor in selecting optimum location for the 12.5-foot deflector. Discharge tailwater relationships for which unstable flow conditions existed in the stilling basin with eight-bay spillway operation during the 2-, 5-, and 10-year floods are shown on plates 54 and 55. With normal tailwater elevations, surging did not occur in the stilling basin for the 2-year flood (6,500 cfs per bay) with any of the six deflector elevations that were tested. With deflector elevation 338 and above, surging occurred with the 5-year flood (12,500 cfs per bay). With all deflector elevations tested, surging during the 10-year flood (17,500 cfs per bay) became more severe as the deflector elevation decreased. The greatest range of skimming flow for the three discharges tested was obtained with the deflector at elevation 336. Higher elevations caused the nappe to plunge excessively upstream from the baffle piers (tailwater depth over deflector was insufficient). Lower elevations resulted in uplift of the nappe and undesirable surface undulation (too much tailwater depth over deflector).

41. Flow conditions and zones of aeration in the stilling basin with the deflectors at the recommended elevation of 336 and discharges of 6,500 through 17,500 cfs per bay are shown on photograph 45 and plate 56. Photograph 46 shows that energy dissipation in the stilling basin was satisfactory with the deflectors at elevation 336 during the standard project flood of 420,000 cfs and the project design discharge of 850,000 cfs.

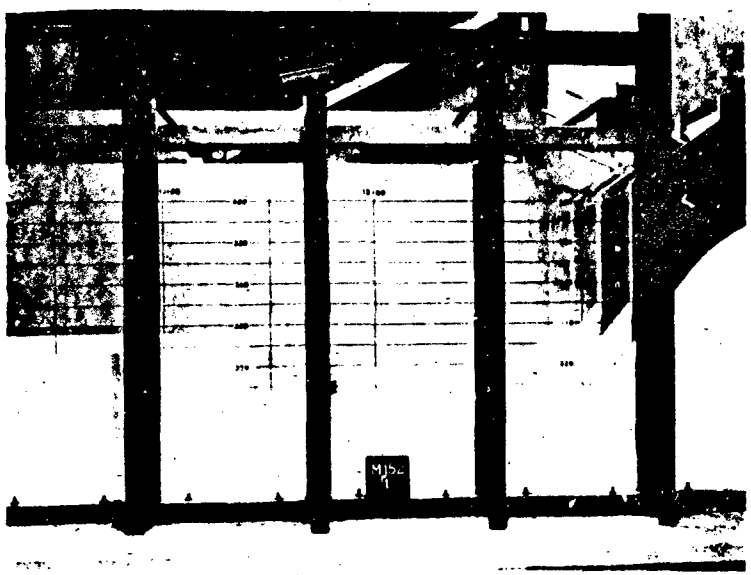
42. The 12.5-foot deflector at elevation 336 was tested with 9- and 10-bay operation and the surging (unstable) zones of operation (plate 57) and depth and quantity of air penetration in the basin did not significantly change from those with eight-bay operation. Flow conditions with the deflector length increased to 20 feet and located at elevation 335 were similar to those occurring with the 12.5-foot deflector.

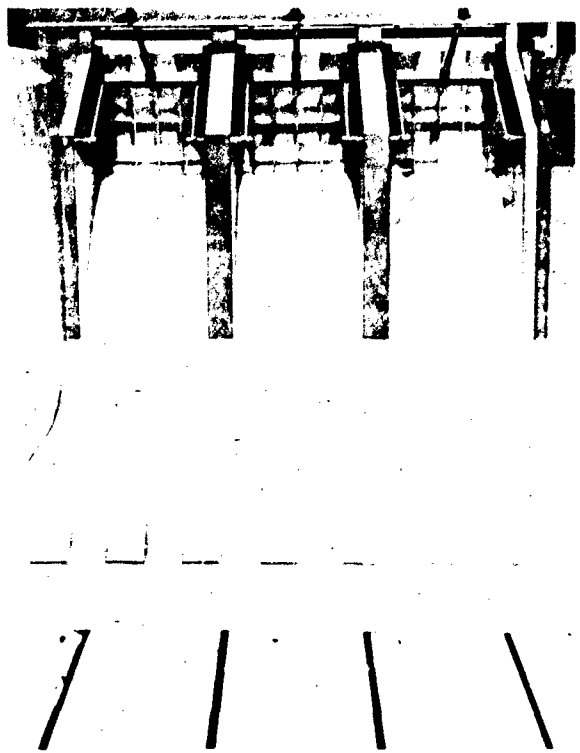
Other Designs

43. Two arrangements of dentates were tested with the 12.5-foot deflectors at elevation 336 (plate 53). The depth and quantity of aeration in the stilling basin for dentate Plan A (two rows) and Plan B (three rows) are shown in photographs 47 and 48, respectively. Both plans reduced aeration during the 2-year flood; however, little improvement occurred during the 5-year flood and the dentates were not beneficial at the 10-year discharge. Since the ability of dentates to withstand cavitation damage and debris impact is questionable and their effect on fish passing downstream over the spillway was unknown, they were not recommended for use.

44. Slotted bulkheads designed to dissipate energy by jet diffusion were tested with the 20-foot deflectors (plate 53). The bulkheads, located in the stoplog slot upstream from the spillway gates, were intended to pass up to 18,500 cfs per bay. Tests in the model indicated that a discharge of 12,500 cfs per bay at a spillway gate opening of 15 feet was the approximate minimum discharge for effective use of the bulkheads. At lower flows, the gate controlled flow and the water surface between the gate and bulkhead approximated that in the forebay. Considerable nappe fluctuation occurred at the gate lips and vibration of the model was evident. A deflector length of 20 feet was required to intercept the nappes from flows through the bulkheads with the spillway gates clear of the jets exiting from the bulkhead

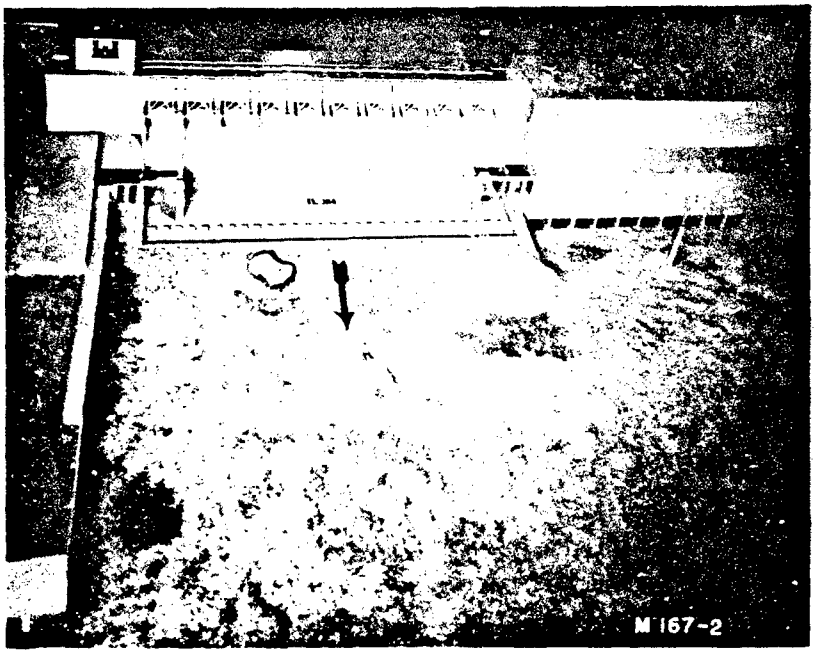
slots. The depth and quantity of aeration in the stilling basin were not reduced by the slotted bulkheads; therefore, use of slotted bulkheads in conjunction with deflectors was not considered to be practical.

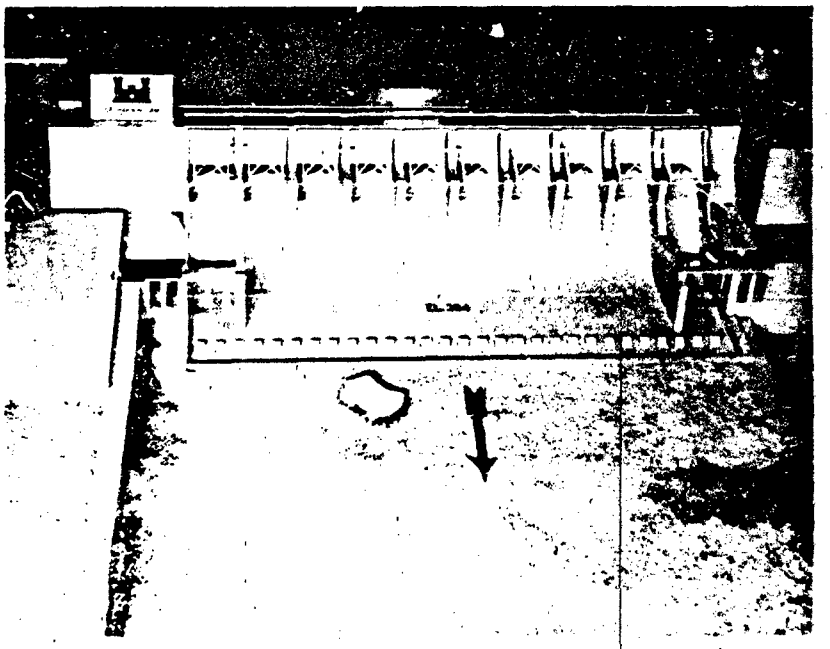




Ice Harbor Dam

Photograph 42. Existing spillway and stilling basin in 1:40-scale sectional model.

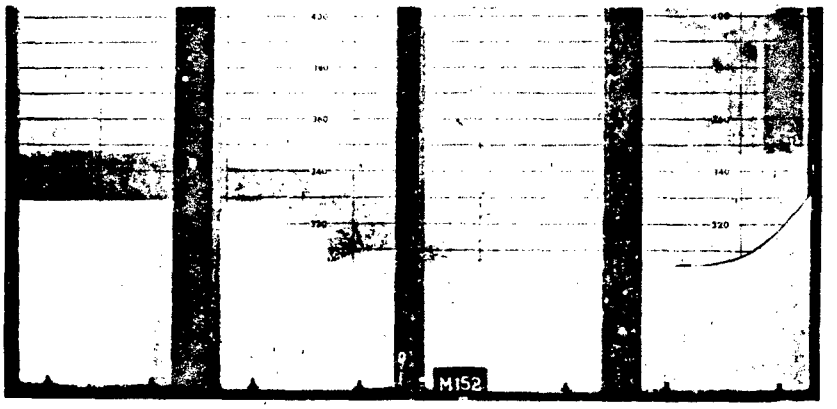




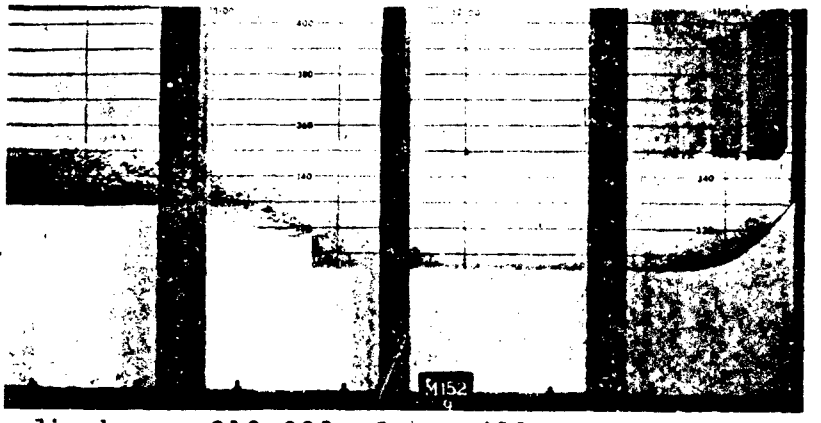
Deflectors in bays 3 to 8.

Ice Harbor Dam

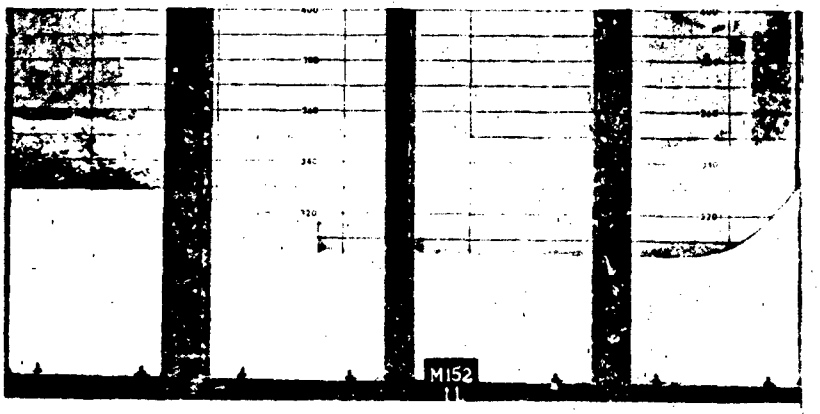
Photograph 43. The 1:50 scale comprehensive model.



River discharge 160,000 cfs, spillway flow 6,500 cfs per bay, tailwater elevation 350.0, 8-bay operation.



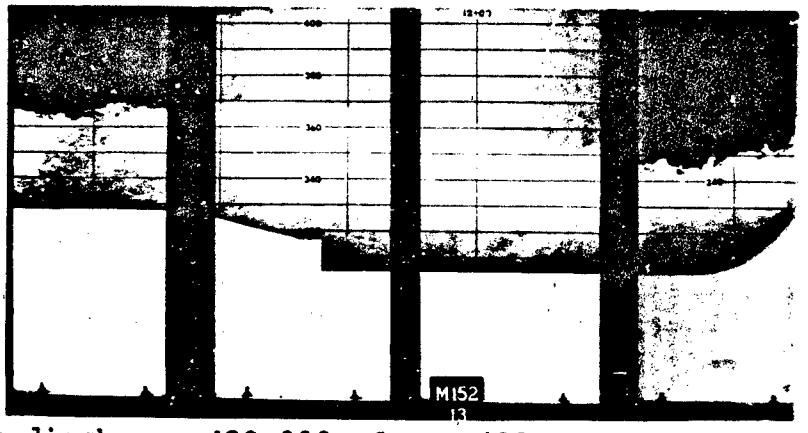
River discharge 210,000 cfs, spillway flow 12,500 cfs per bay, tailwater elevation 352.6, 8-bay operation.



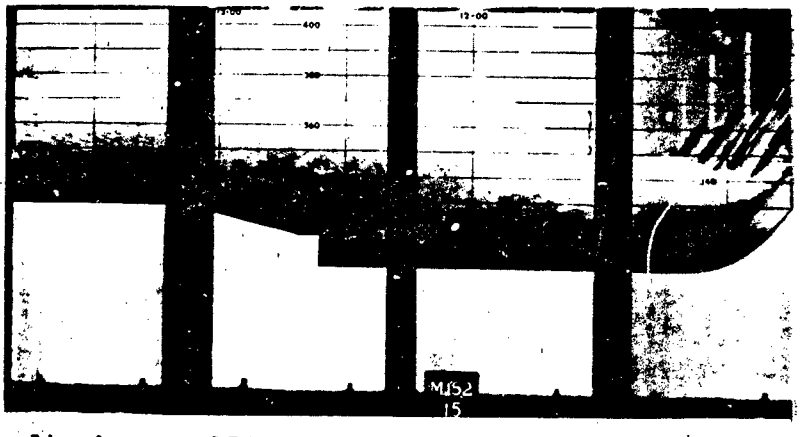
River discharge 250,000 cfs, spillway flow 17,500 cfs per bay, tailwater elevation 354.6, 8-bay operation.

Ice Harbor Dam

Photograph 44. Flow conditions in existing stilling basin (no deflectors).



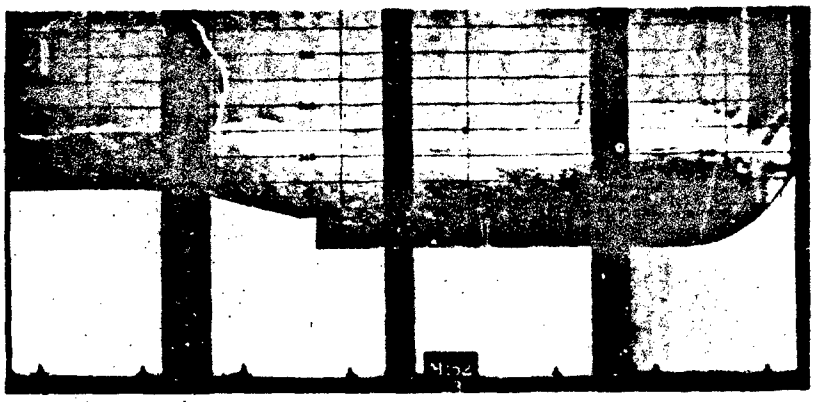
River discharge 420,000 cfs, spillway flow 39,000 cfs per bay, tailwater elevation 363.0, 8-bay operation.



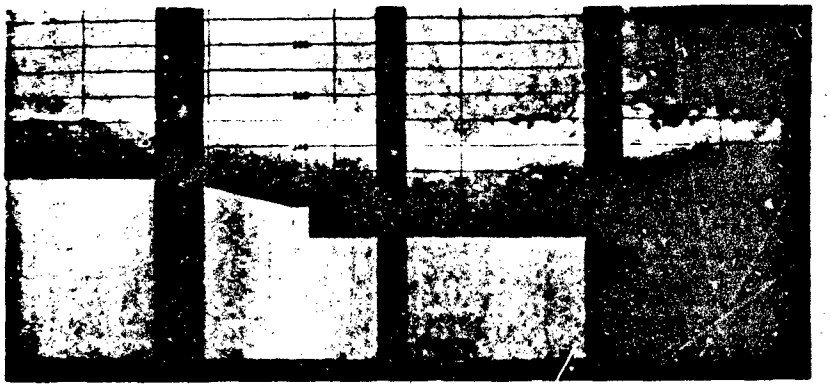
River discharge 850,000 cfs, spillway flow 85,000 cfs per bay, tailwater elevation 373.8, 10-bay operation.

Ice Harbor Dam

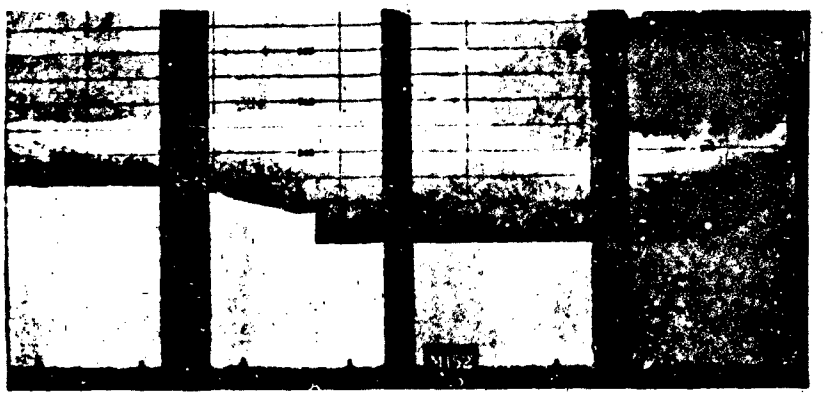
Photograph 44. Continued.



River discharge 160,000 cfs, spillway flow 6,500 cfs per bay, tailwater elevation 350.0, 8-bay operation.



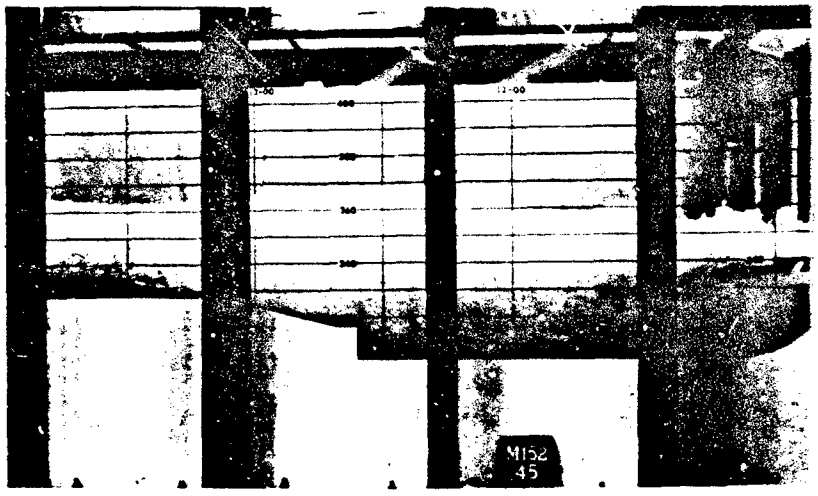
River discharge 210,000 cfs, spillway flow 12,500 cfs per bay, tailwater elevation 352.6, 8-bay operation.



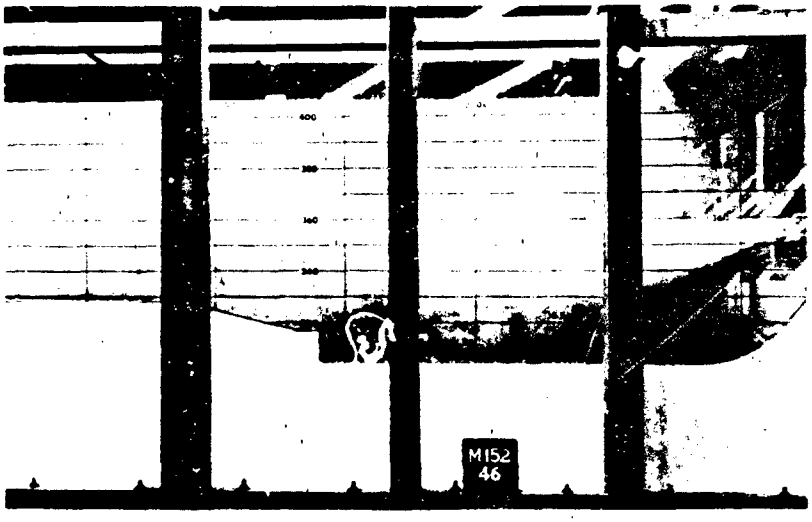
River discharge 250,000 cfs, spillway flow 17,500 cfs per bay, tailwater elevation 354.6, 8-bay operation.

Ice Harbor Dam

Photograph 45. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 336.0.



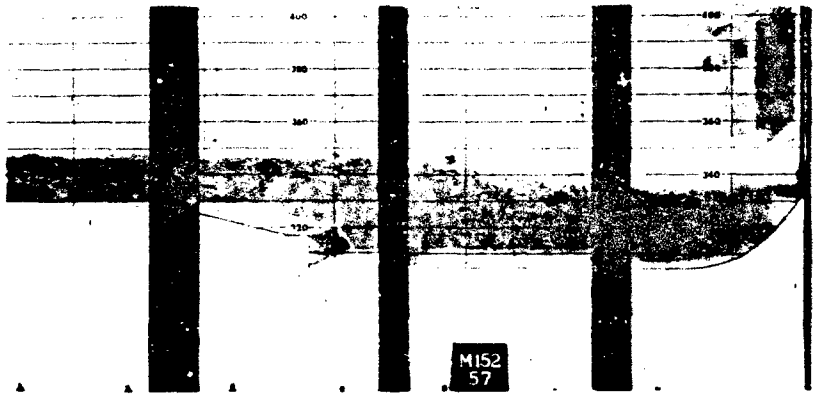
River discharge 420,000 cfs, spillway flow 39,000 cfs per bay, tailwater elevation 363.0, 8-bay operation.



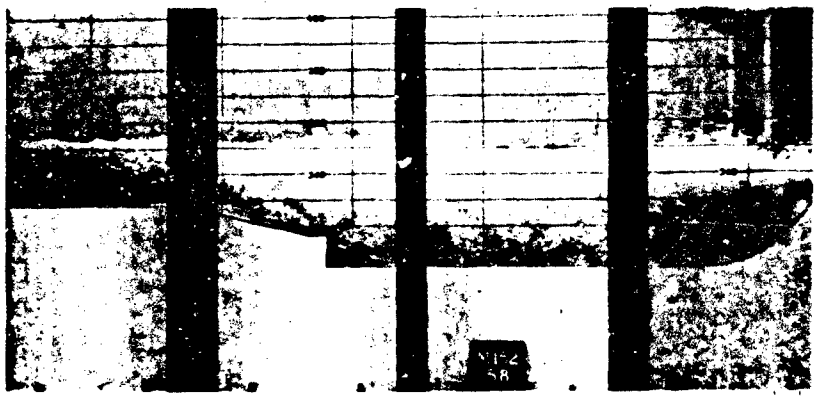
River discharge 850,000 cfs, spillway flow 85,000 cfs per bay, tailwater elevation 373.8, 10-bay operation.

Ice Harbor Dam

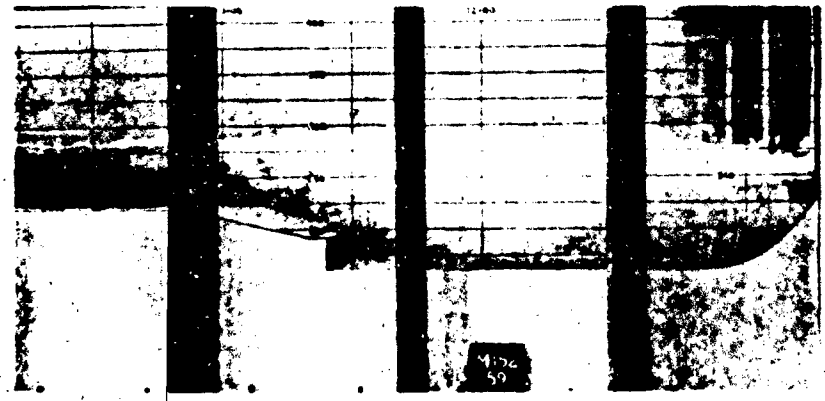
Photograph 46. Flow conditions in stilling basin with 12.5-foot deflector at elevation 336.0.



River discharge 160,000 cfs, spillway flow 6,500 cfs per bay, tailwater elevation 350.0.



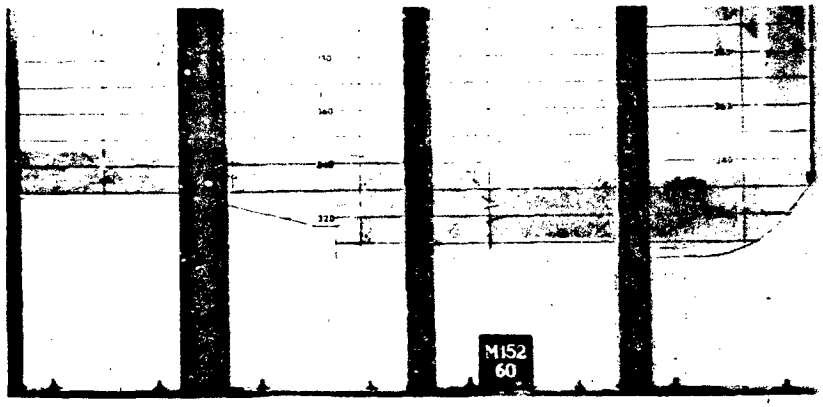
River discharge 210,000 cfs, spillway flow 12,500 cfs per bay, tailwater elevation 352.6.



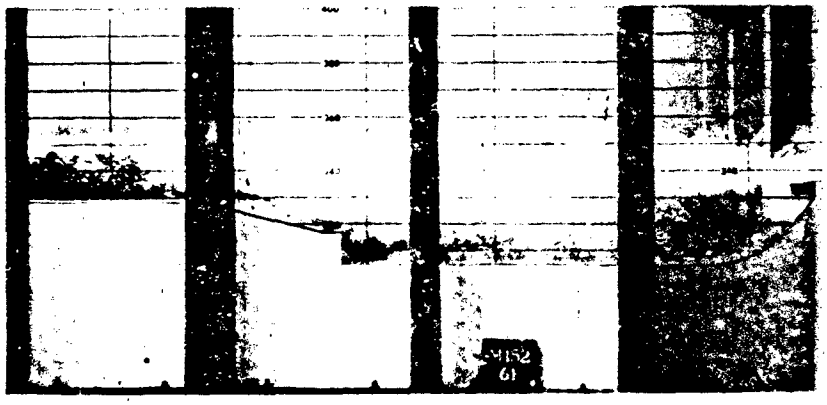
River discharge 250,000 cfs, spillway flow 17,500 cfs per bay, tailwater elevation 354.6.

Ice Harbor Dam

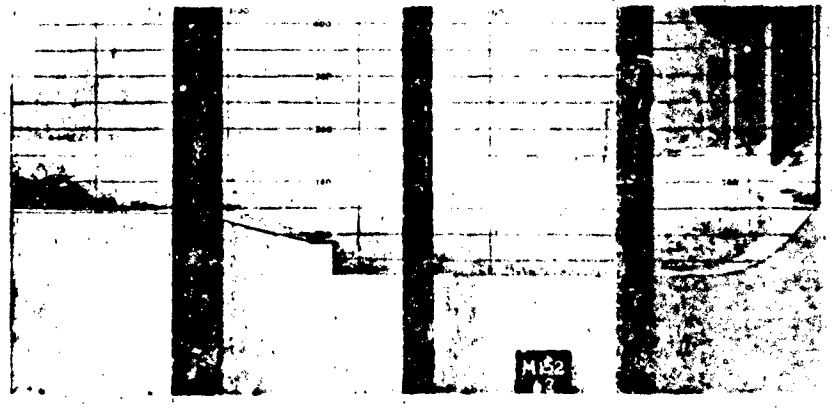
Photograph 47. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 336.0, plan A dentates, and 8-bay operation.



River discharge 160,000 cfs, spillway flow 6,500 cfs per bay, tailwater elevation 350.0.



River discharge 210,000 cfs, spillway flow 12,500 cfs per bay, tailwater elevation 352.6.



River discharge 250,000 cfs, spillway flow 17,500 cfs per bay, tailwater elevation 354.6.

Ice Harbor Dam

Photograph 48. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 336.0, plan B dentates, and 8-bay operation.

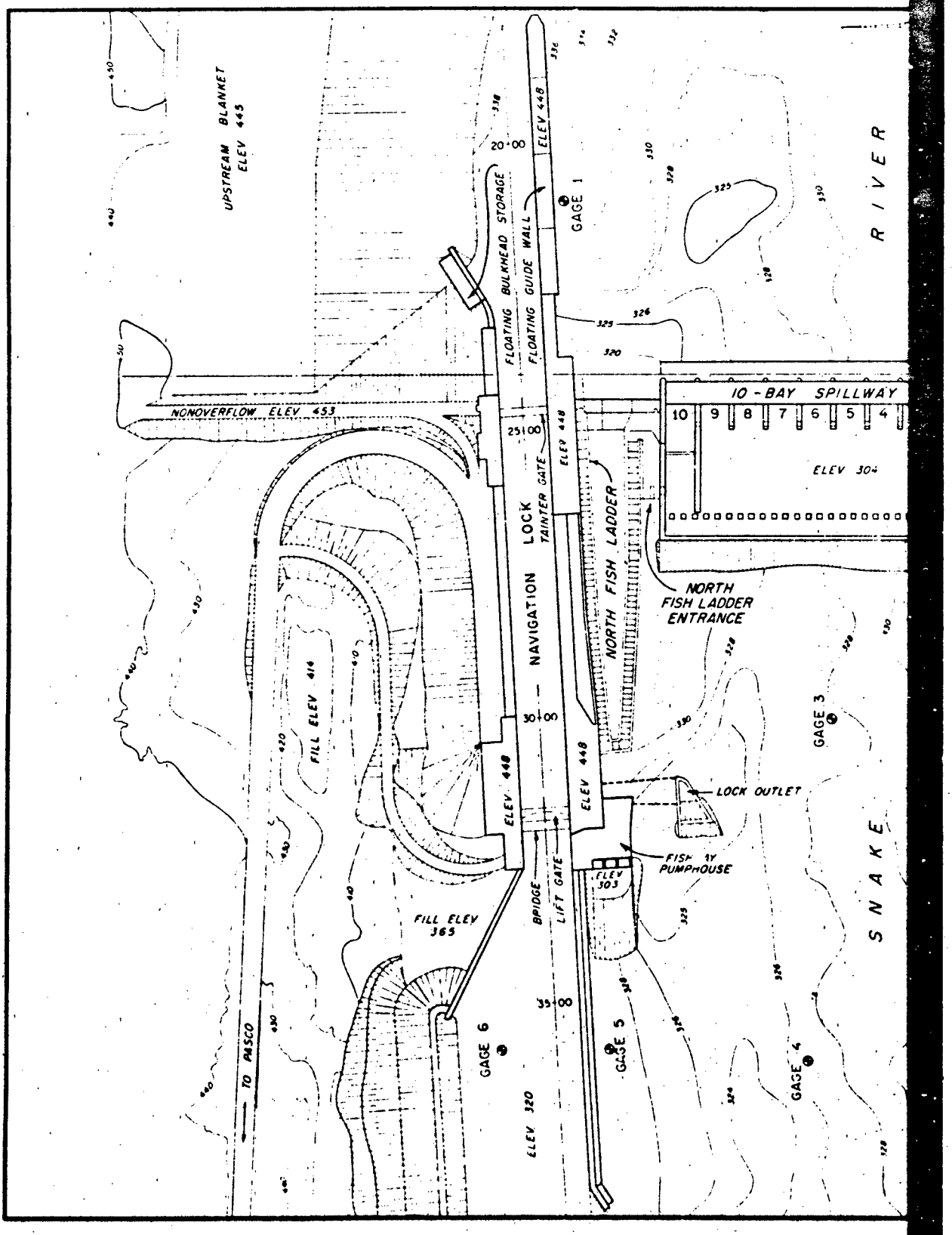


Plate 50

1 of 2

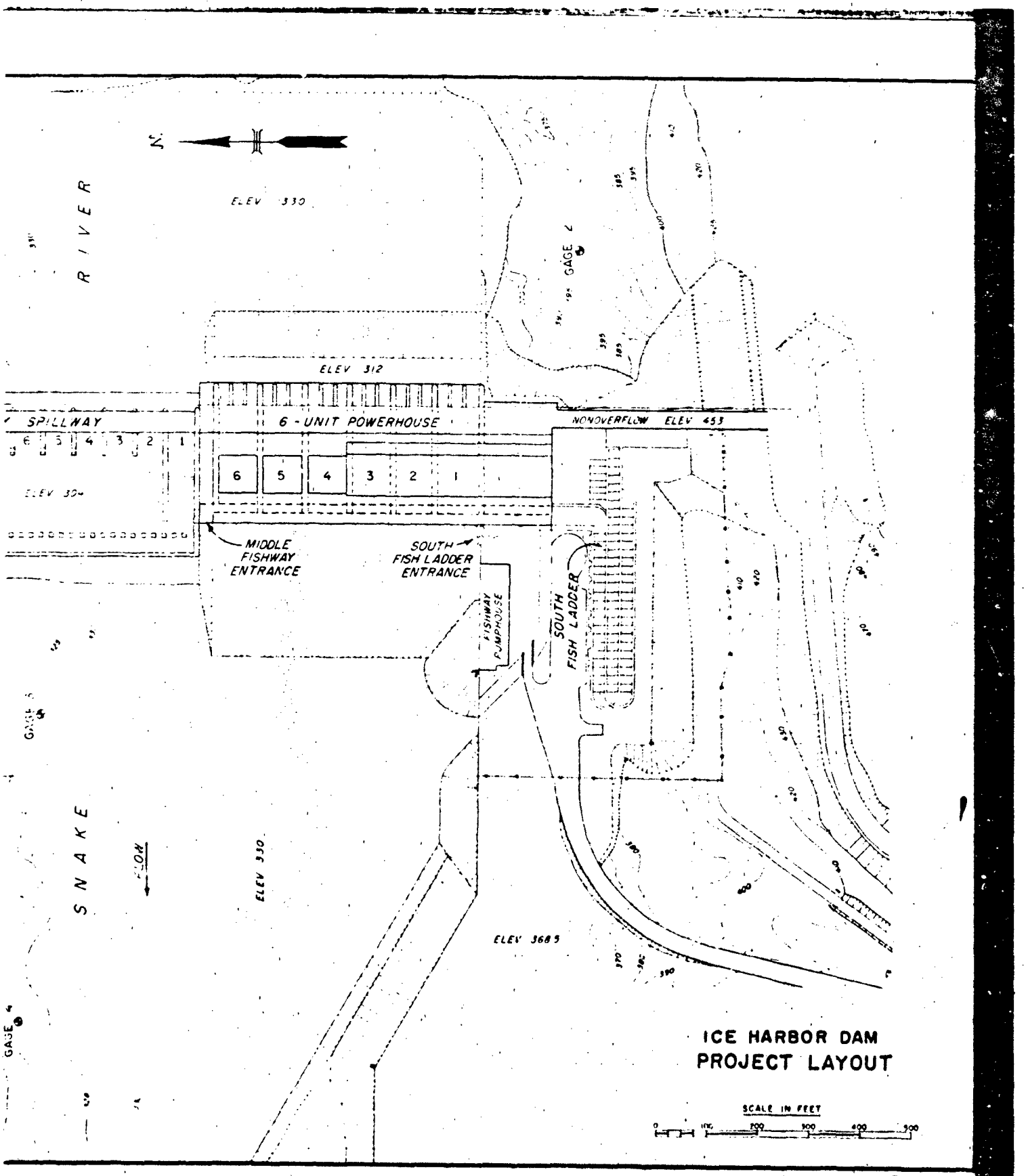


PLATE 50

2 of 2

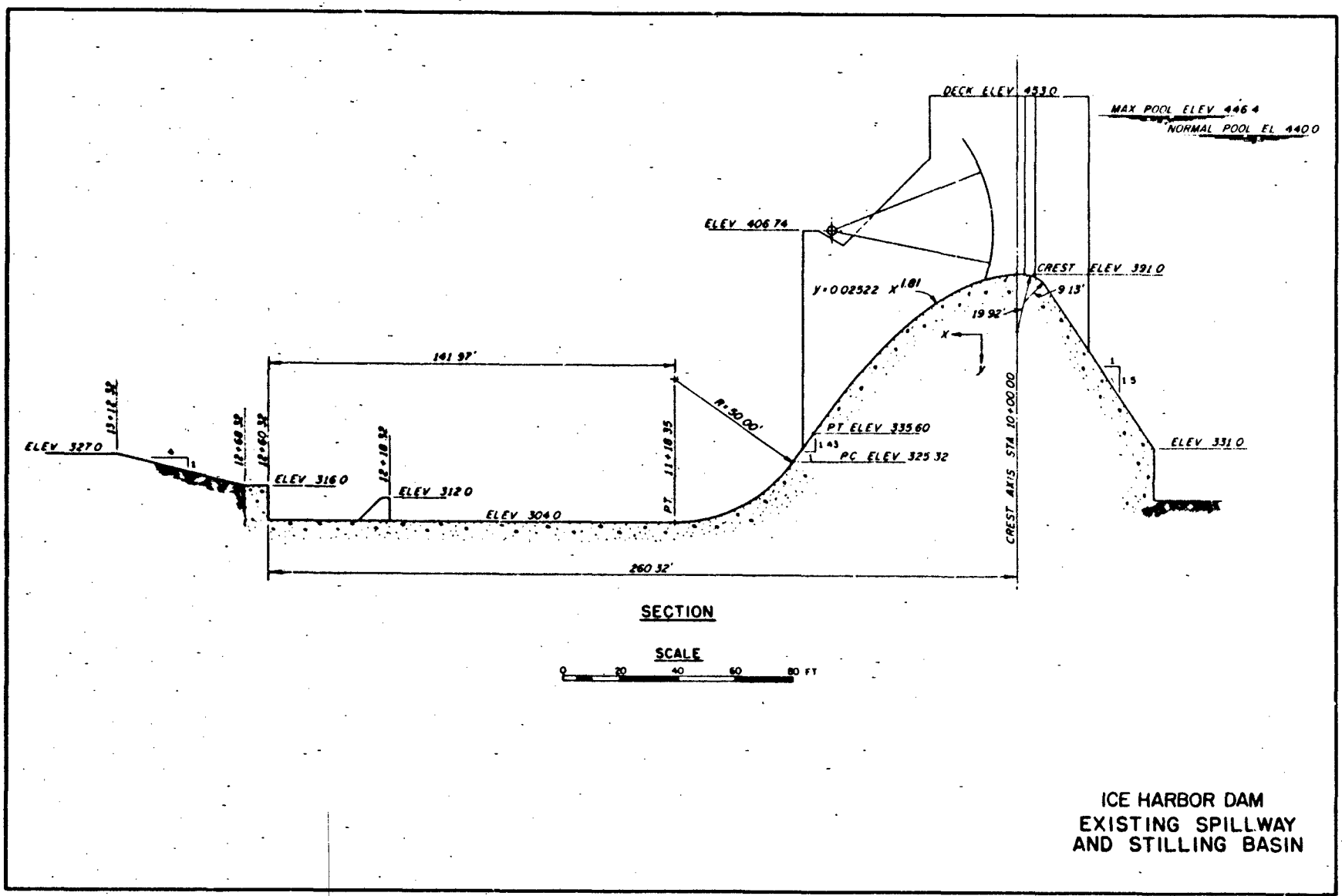
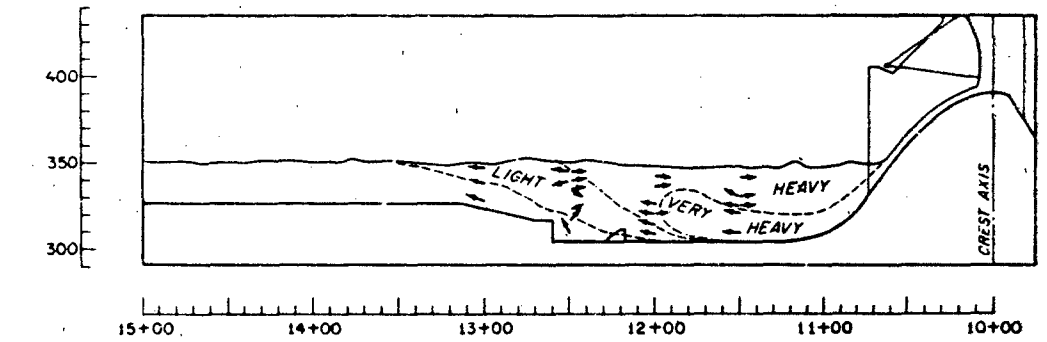


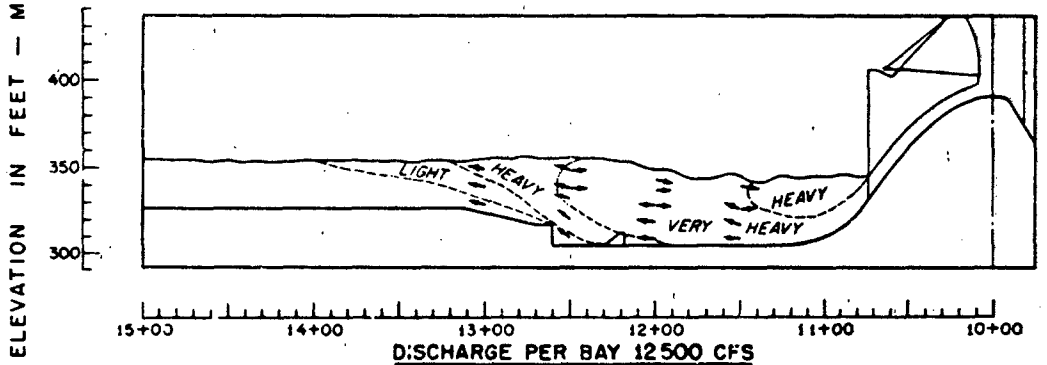
PLATE 51

ICE HARBOR DAM
EXISTING SPILLWAY
AND STILLING BASIN

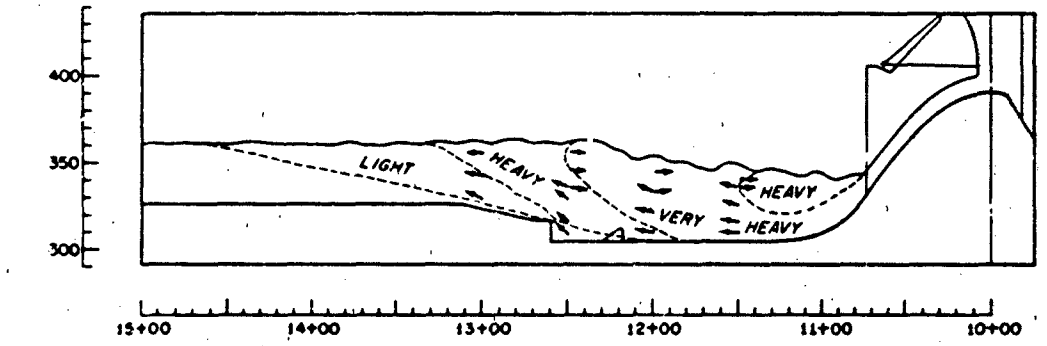


DISCHARGE PER BAY 6 500 CFS
TAILWATER ELEV 350.0

ELEVATION IN FEET — MSL



DISCHARGE PER BAY 12500 CFS
TAILWATER ELEV 352.6



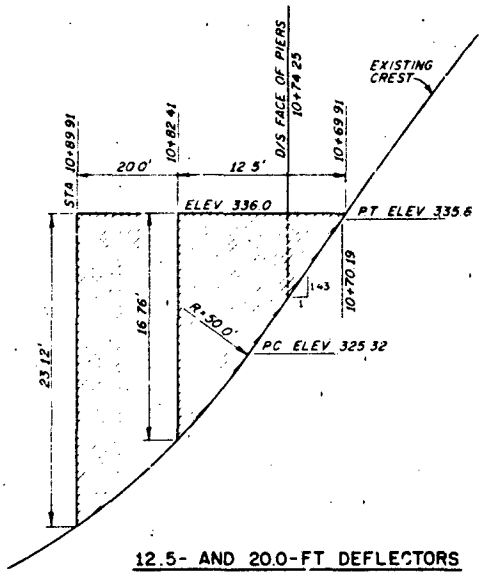
STATIONS NORMAL TO CREST AXIS
DISCHARGE PER BAY 17500 CFS
TAILWATER ELEV 354.6

LEGEND

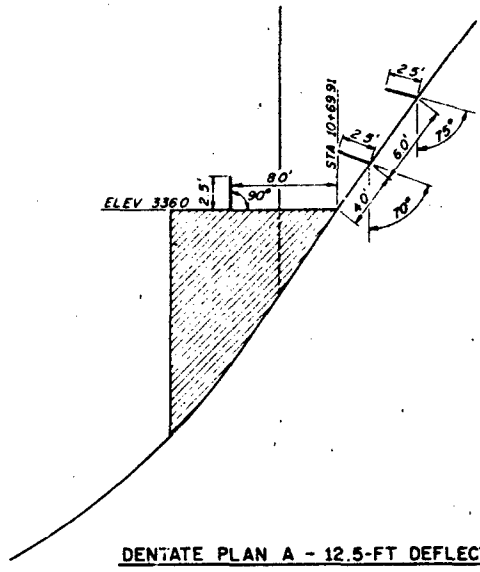
---------- ZONES OF AERATION

ICE HARBOR DAM
AERATION AND FLOW DIRECTIONS
NO DEFLECTORS
8-BAY OPERATION

PLATE 52

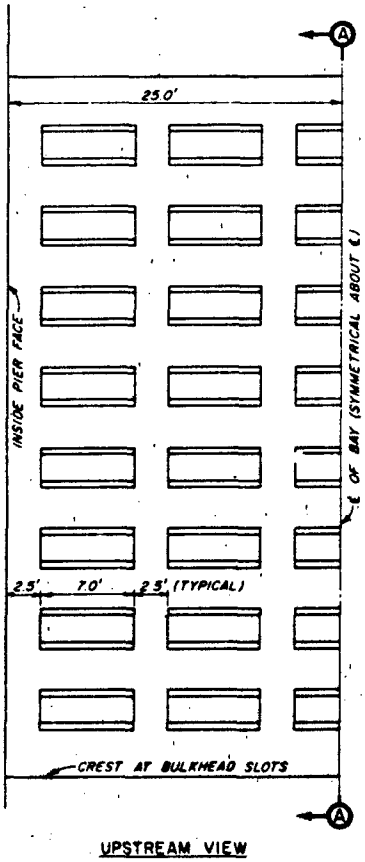


12.5- AND 20.0-FT DEFLECTORS

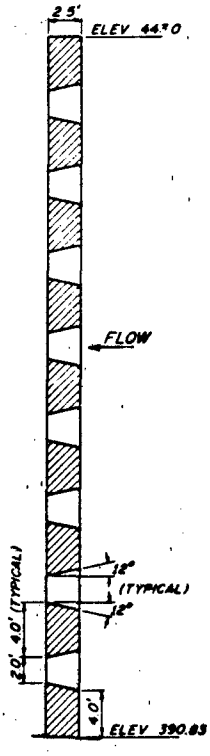


DENTATE PLAN A - 12.5-FT DEFLECTOR
(SHOWN)

DENTATE PLAN B - 12.5-FT DEFLECTOR
(ROW ON DEFLECTOR OMITTED)

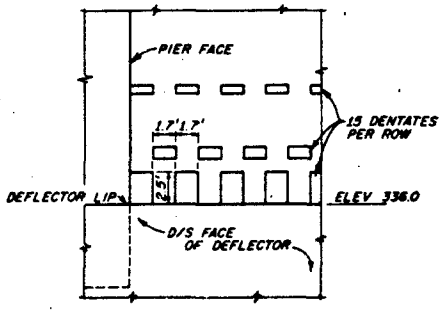


UPSTREAM VIEW



SECTION A-A

SLOTTED BULKHEAD



U/S VIEW OF DENTATES

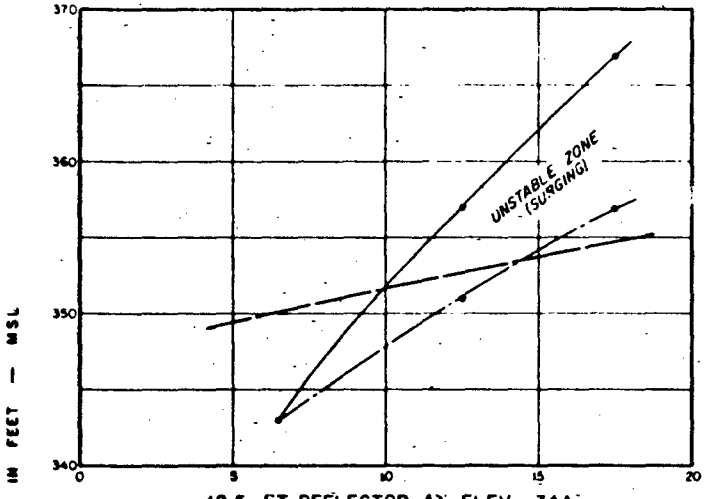
ICE HARBOR DAM

SPILLWAY DEFLECTORS AND SLOTTED BULKHEAD

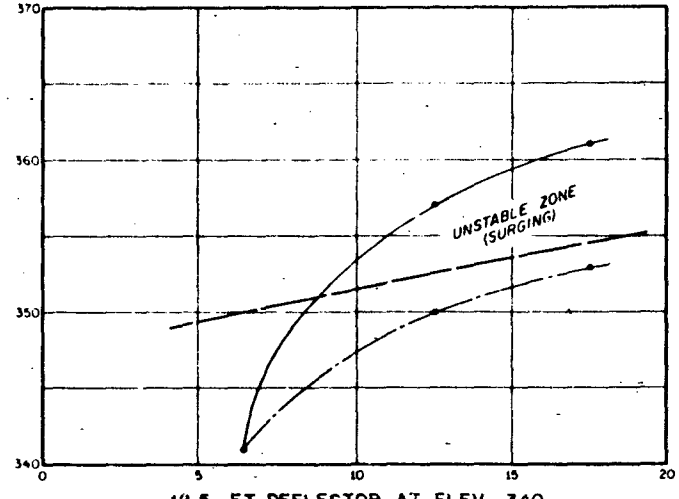
12.5- AND 20.0-FT DEFLECTOR LENGTHS
DENTATE PLANS A AND B

PLATE 53

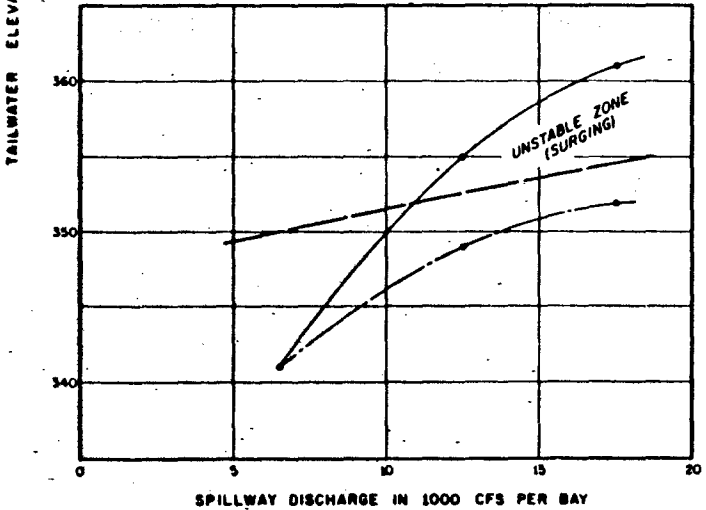
PLATE 54



12.5-FT DEFLECTOR AT ELEV 344



12.5-FT DEFLECTOR AT ELEV 340



TAILWATER ELEVATION IN FEET — MSL

SPILLWAY DISCHARGE IN 1000 CFS PER BAY

12.5-FT DEFLECTOR AT ELEV 338

LEGEND

- NORMAL TAILWATER
- MIN TW FOR STABLE SKIMMING FLOW
- MAX TW FOR STABLE PLUNGING FLOW

NOTES

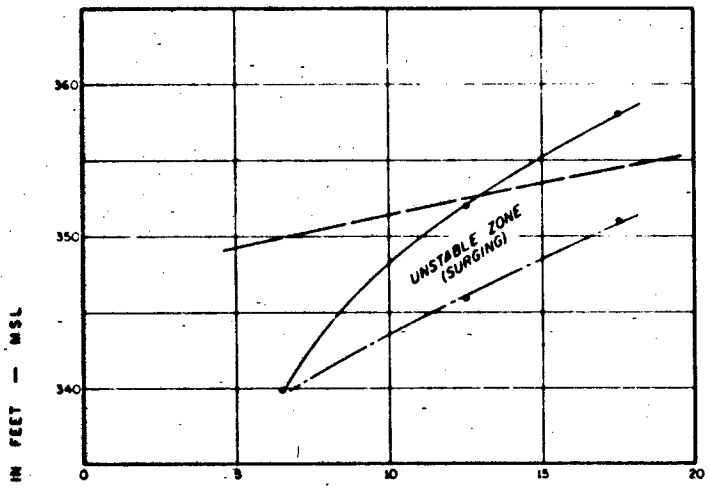
1. TAILWATER INCLUDES POWERHOUSE FLOW FROM 6 OPERATING UNITS
2. NO BUCKET ON DEFLECTORS.

ICE HARBOR DAM

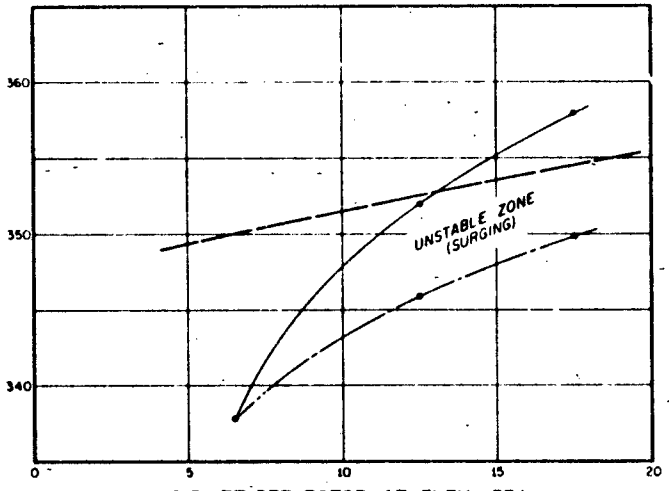
FLOW CONDITIONS IN STILLING BASIN

12.5-FT DEFLECTORS, ELEVATIONS 344, 340, AND 338

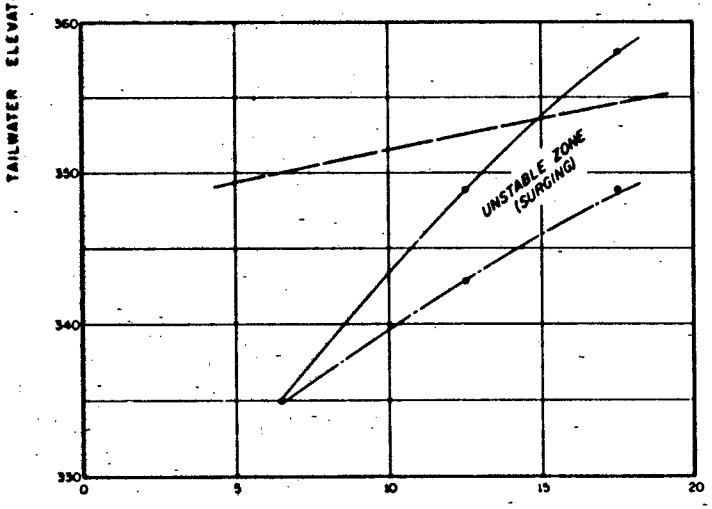
8-BAY OPERATION



12.5-FT DEFLECTOR AT ELEV 336



12.5-FT DEFLECTOR AT ELEV 334



12.5-FT DEFLECTOR AT ELEV 332

LEGEND

- NORMAL TAILWATER
- MIN T.W. FOR STABLE SKIMMING FLOW
- MAX T.W. FOR STABLE PLUNGING FLOW

NOTES

1. TAILWATER INCLUDES POWERHOUSE FLOW FROM 6 OPERATING UNITS
2. NO BUCKET ON DEFLECTORS

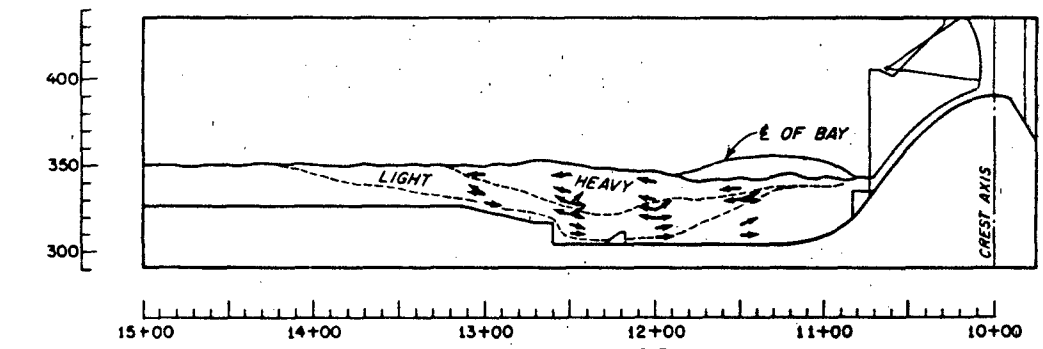
ICE HARBOR DAM

FLOW CONDITIONS IN STILLING BASIN

12.5-FT DEFLECTORS, ELEVATIONS 336, 334, AND 332

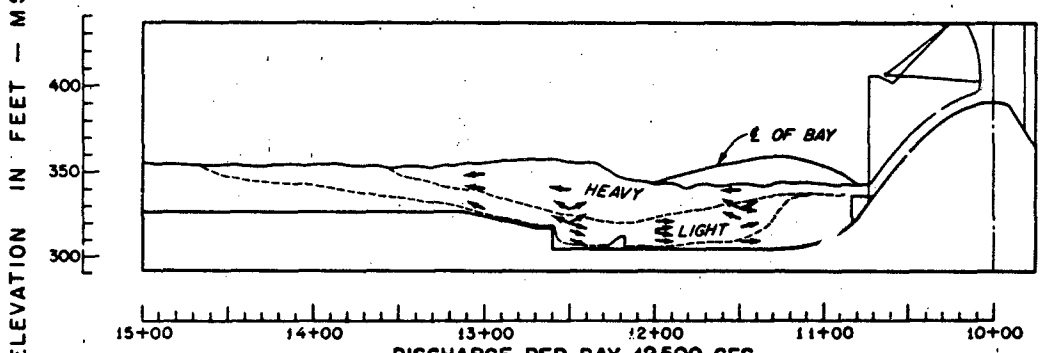
8-BAY OPERATION

PLATE 55

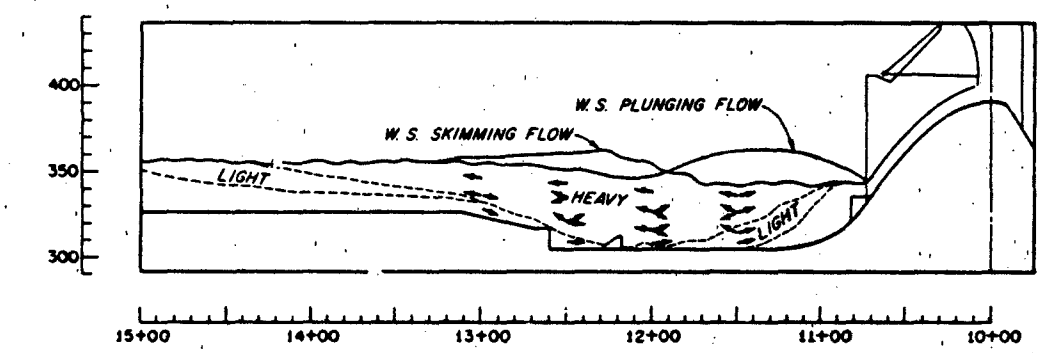


DISCHARGE PER BAY 6 500 CFS
TAILWATER ELEV 350.0

ELEVATION IN FEET — MSL



DISCHARGE PER BAY 12500 CFS
TAILWATER ELEV 352.6



STATIONS NORMAL TO CREST AXIS
DISCHARGE PER BAY 17500 CFS
TAILWATER ELEV 354.6

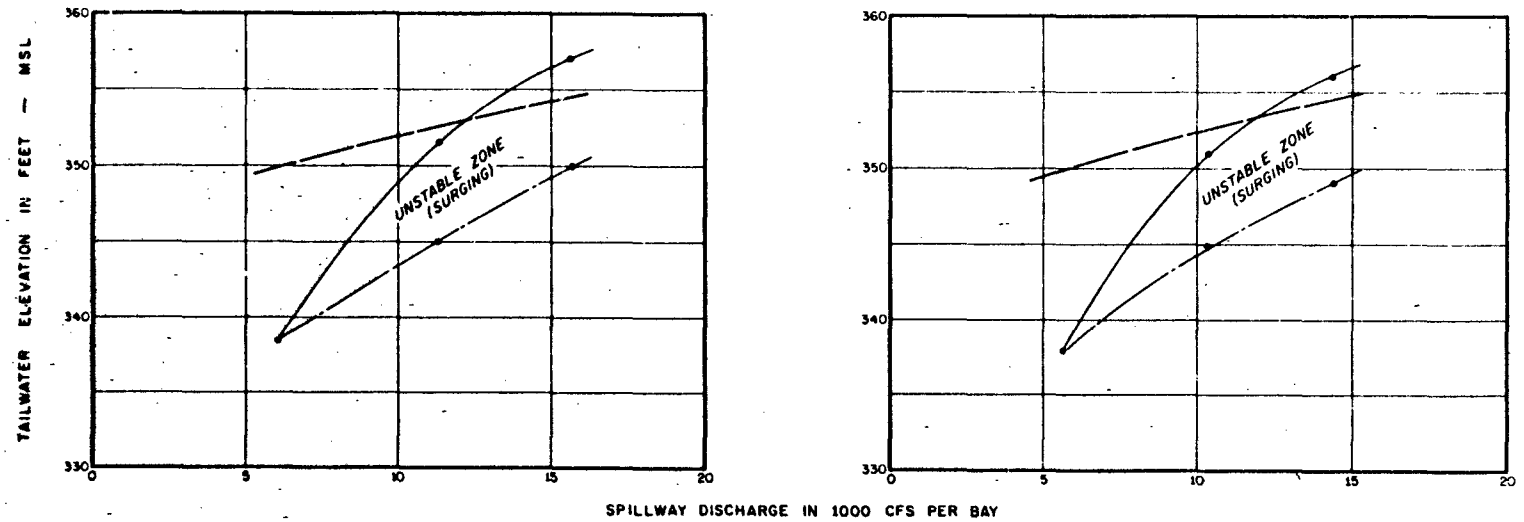
LEGEND

--------- ZONES OF AERATION

ICE HARBOR DAM

AREATION AND FLOW DIRECTIONS
12.5-FT DEFLECTORS AT ELEV 336
8-BAY OPERATION

PLATE 56



9-BAY OPERATION

10-BAY OPERATION

LEGEND

- NORMAL TAILWATER
- MIN T.W. FOR STABLE SKIMMING FLOW
- MAX T.W. FOR STABLE PLUNGING FLOW

NOTES

1. TAILWATER INCLUDES POWERHOUSE FLOW FROM 6 OPERATING UNITS.
2. NO BUCKET ON DEFLECTORS.

ICE HARBOR DAM
FLOW CONDITIONS IN STILLING BASIN
12.5-FT DEFLECTORS AT ELEVATION 336
9- AND 10-BAY OPERATION

PLATE 57

PART VI

LOWER MONUMENTAL DAM

PART VI: LOWER MONUMENTAL DAM TESTS AND RESULTS

The Prototype

45. The Lower Monumental project includes an eight-bay spillway, a six-unit powerhouse, a single-lift navigation lock, and a fish ladder on each side of the river (plate 58). The spillway is designed to pass 850,000 cfs at pool elevation 548 and is controlled by 50-foot-wide by 61-foot-high tainter gates. The stilling basin is 198 feet long and terminates in a sloping (1 vertical : 1 horizontal), 13-foot-high end sill. A section through the spillway and basin is shown on plate 59.

The Models

46. A 1:42.47-scale model (photograph 49 and plate 60) was used to develop the deflector design. The model was a reproduction of a three-bay section of the spillway with approximately 1,000 feet of upstream approach, the stilling basin, and 1,400 feet of the downstream channel at elevation 418. The spillway crest, piers, gates, and bucket were constructed of acrylic plastic, while the stilling basin and upstream and downstream channels were constructed of wood. The pool elevation was controlled by the spillway gates, and the computed tailwater elevations (plate 61) were controlled by a vaned tailgate.

47. A 1:50-scale comprehensive model (photograph 50 and plate 62) was used to determine the number of deflectors to be installed and to establish operating procedures which would provide optimum fish-passage conditions at adjacent fishway entrances. The model included the spillway, both fishway entrances, fish ladder, powerhouse, navigation lock wall, bank lines, and 1,600 feet of downstream topography. The majority of the model was constructed of waterproofed wood. The spillway gates, fishway systems, and deflectors were constructed of

acrylic plastic, while the downstream topography was molded of concrete between sheetmetal templates to conform to field surveys and design plans. The tailwater was controlled by a hinged tailgate and measured at gage 14A, 865 feet downstream from the powerhouse construction baseline.

Tests

48. Spillway flows of 5,175, 10,060, and 15,000 cfs per bay--which correspond to river discharges of 172,000, 212,000 and 251,000 cfs, respectively,--were observed with the existing (without deflectors) spillway for comparison with conditions after the deflectors were installed. The air-bubble pattern in the basin (plate 63 and photograph 51) indicated that aerated water penetrated to the basin floor and then was distributed throughout the basin and carried downstream.

49. Three different deflector lengths--10.0, 12.5, and 15.0 feet--were tested with river discharges ranging from 85,000 to 850,000 cfs. The deflectors (photograph 52 and plate 64) were tested at elevations ranging between 426 and 438. With all plans tested, low discharges produced a stable, skimming surface flow which prevented the aerated spillway flow from being carried deep into the basin. However, as discharge increased, an unstable surging condition developed in the basin causing violent mixing of the aerated water.

50. Varying the deflector length from 15.0 to 12.5 feet had little effect on its ability to produce skimming flow and reduce the amount of air drawn to the basin floor. Photographs 53 through 56 and photographs 57 through 59 show flow conditions in the stilling basin with 15.0- and 12.5-foot-long deflectors, respectively, for various discharges and deflector locations. The extent of aeration was very similar with the two deflector lengths; however, conditions with the 12.5-foot-long deflector were slightly better at the higher (15,000 cfs per bay) discharge. Both deflector lengths were ineffective with

riverflows of 420,000 and 850,000 cfs (photograph 60). The 10-foot-long deflector was ineffective with discharges greater than 10,060 cfs per bay as it did not intercept the nappe at those conditions. The limits of skimming, unstable, and plunging flow conditions with the various deflector lengths and elevations are shown on plate 65. Deflector elevations below 434 created standing waves in the basin which drew air into the flow. With the deflector at or above elevation 438, the nappe lacked sufficient submergence and plunged near the center of the basin causing air entrainment.

51. Based upon the tests discussed, the 12.5-foot-long deflector at elevation 434 was selected as the optimum design to provide stable, skimming flow for river discharges up to 251,000 cfs (15,000 cfs per bay). Aeration zones and flow directions with the recommended design are shown on plate 66. Pressure at four locations on the deflector (plate 67) were positive (table C). The highest pressures occurred in the radius bucket of the deflector, while the lowest pressures generally existed on the downstream face of the deflector. The pressures ranged from +2 (minimum measured) to +82 (maximum measured) feet of water.

52. In an attempt to increase the allowable discharge per bay to produce stable, skimming flow conditions in the stilling basin, various arrangements of dentates were located on the spillway above the 12.5-foot-long deflector. The most satisfactory arrangement--Plan H--consisted of three horizontal rows of 1.8-foot-wide by 2.6-foot-high dentates spaced 1.8 feet apart in each row (plate 67 and photograph 61). With the dentates, zones of aeration and flow directions in the basin (plate 68 and photograph 62) were noticeably improved over conditions existing with only the deflector. Pressures on and near the dentates were well within the cavitation range (table D). Minimum pressures of -30 and -32 feet of water were measured at piezometer D-2 (plate 67) with discharges of 212,000 and 251,000 cfs, respectively, and -18 feet of water (piezometer D-6) with a discharge of 420,000 cfs.

53. The recommended 12.5-foot deflector and the Plan H dentates were installed in bay 2 of the prototype structure and subjected to one season of operation. Extensive cavitation damage on the spillway around the dentates resulted (photograph 63), and the decision was made to remove the dentates and install the remaining deflectors without dentates. At that time the 15-foot radius on the upstream edge of the deflector was also eliminated.

54. Once the detailed design of the deflectors was verified by the studies in the sectional model, the 1:50-scale model was used to determine the total number of deflectors to be installed and to evaluate flow conditions near the fishway entrances. Tests were accomplished with river discharges of 100,000, 200,000, and 420,000 cfs with either three or six units operating for the following conditions: existing spillway, deflectors in spillway bays 2 through 7, deflectors in spillway bays 1 through 8, and deflectors in spillway bays 2 and 4 through 7.

55. Flow conditions with the existing spillway and river discharges of 100,000, 200,000 and 420,000 cfs are shown on plates 69 through 76 and photographs 64 through 66. With discharges of 100,000 and 200,000 cfs, high velocities existed near the bottom of the basin over the end sill with relatively uniform (top to bottom) velocities farther downstream of the basin. Fish-attraction conditions at the south fishway entrance (left end of spillway) were very good. A small eddy formed behind and under the fish ladder but did not disrupt the entrance flow pattern. The flow patterns near the powerhouse unit 6 fishway entrance were not as well defined and were less effective for fish passage. With units 1 through 3 operating, a large eddy formed near the entrance; while with all six units operating upwelling caused upstream flow near the entrance. Both conditions interfered with flow from the fishway entrance.

Deflectors in Bays 2 Through 7

56. Flow conditions with a river discharge of 100,000 cfs are shown on plates 77 and 78 and photograph 67. Stable, skimming flow existed in the stilling basin with high downstream surface velocities and low upstream velocities over the end sill at mid-depth and along the bottom. The plunging flow in bays 1 and 8 produced upstream surface flow along each training wall. Velocities and flow intensity increased with a riverflow of 200,000 cfs (photograph 68). The greater spills--132,050 cfs with three units operating (plate 79) and 63,050 cfs with six units operating (plate 81)--produced larger areas of upwelling below bays 1 and 8 with upstream flow over much of the stilling basin floor. Flow conditions in and just downstream from the stilling basin were satisfactory with stable, skimming flow from bays 2 through 7.

57. Attraction conditions at the fishway entrances were acceptable at all flows. The upwelling along each training wall created flow conditions at the end of each training wall which would allow fish to swim into the stilling basin at bays 1 and 8 (plates 80 and 82). An eddy along the navigation lock wall created upstream flow near the south fishway entrance, but a good path of downstream flow existed between the eddy and the spillway flow. Flow conditions at the entrance near unit 6 were less favorable as current tended to flow across the entrance with three units operating and flow was upstream towards the entrance with six units operating.

58. Flow conditions with a river discharge of 420,000 cfs (highest observed in the model) are shown on plates 83 and 84 and photograph 69. The same flow patterns as those existing at the lower discharges prevailed with the increased spill. Maximum velocities of 24 fps existed in the channel downstream from the end sill. A spill per bay of 43,790 cfs (with units 1 through 3 operating) caused deep plunging flow along the full length of the basin. With six units

operating, the spill was reduced to 35,140 cfs per bay which produced skimming flow near the center of the spillway and wide areas of plunging flow at each end of the spillway.

Deflectors in Bays 1 Through 8

59. Flow conditions with deflectors in all eight spillway bays are shown on plates 85 through 90 and photographs 70 through 72. Stable, skimming flow existed at discharges of 100,000 and 200,000 cfs. The eddy existing along the navigation lock wall was slightly stronger than that existing without end bay deflectors due to the higher velocities along the water surface. The fishway entrance near unit 6 was subjected to conditions influenced primarily by powerhouse flow and did not change with the addition of deflectors in the end bays. Although a better high-velocity fish block existed near the water surface at the end of the training walls, velocities adequate to block fish did not exist at mid-depth or near the bottom of the wall.

60. With the maximum flow tested--420,000 cfs--the flow again overrode the deflectors and produced the same type of plunging flow in the stilling basin as that which occurred with the six-deflector plan. Attraction flow from the south fishway entrance was confined closer to the wall of the navigation lock wall but was adequate for migrating fish.

Deflectors in Bays 2 and 4 Through 7

61. This configuration was tested to evaluate its adequacy in the event that construction time would not be long enough to complete installation of the deflectors in bays 2 through 7 of the prototype prior to the spring runoff. Brief studies indicated that poor attraction conditions existed with uniform spillway operation and this configuration. Adjusting the spillway gates to provide greater than

normal flow in the end bays improved attraction conditions but caused upstream and/or plunging flow below bay 3; this operating condition was not considered to be satisfactory.

TABLE C

Table C

LOWER MONUMENTAL DAM

PRESSURES

12.5-Ft Deflectors at Elevation 434.0

Piezometer			River flow 85,000 cfs, spwy 2,560 cfs per bay. Tailwater elev 441.2			River flow 172,000 cfs, spwy 5,175 cfs per bay. Tailwater elev 445.1			River flow 212,000 cfs, spwy 10,060 cfs per bay. Tailwater elev 447.2			River flow 251,000 cfs, spwy 15,000 cfs per bay. Tailwater elev 449.0		
No.	Station	Elevation	Pressure in Feet of Water											
			Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
D-2	10+65.80	441.4	3	2	3	4	2	4	8	3	6	13	9	11
D-4	10+74.46	434.8	6	5	5	23	14	16	38	33	35	46	45	45
D-6	10+83.93	434.0	6	5	6	7	6	6	10	8	9	15	13	14
D-7	10+85.67	433.6	8	7	8	10	8	9	8	5	6	7	4	6
			River flow 344,000 cfs, spwy 26,875 cfs per bay. Tailwater elev 453.2			River flow 420,000 cfs, spwy 36,590 cfs per bay. Tailwater elev 456.2			River flow 490,000 cfs, spwy 45,625 cfs per bay. Tailwater elev 459.2			River flow 850,000 cfs, spwy 106,250 cfs per bay. Tailwater elev 465.1		
D-2	10+65.80	441.4	29	27	28	38	35	37	45	43	44	63	61	62
D-4	10+74.46	434.8	63	59	60	67	64	65	72	69	70	82	80	80
D-6	10+83.93	434.0	28	23	26	32	29	31	34	39	38	59	53	56
D-7	10+85.67	433.6	6	2	4	11	2	5	13	2	6	24	18	21

NOTE: Piezometer locations shown on plate 69.

Table D

LOWER MONUMENTAL DAM

PRESSURES

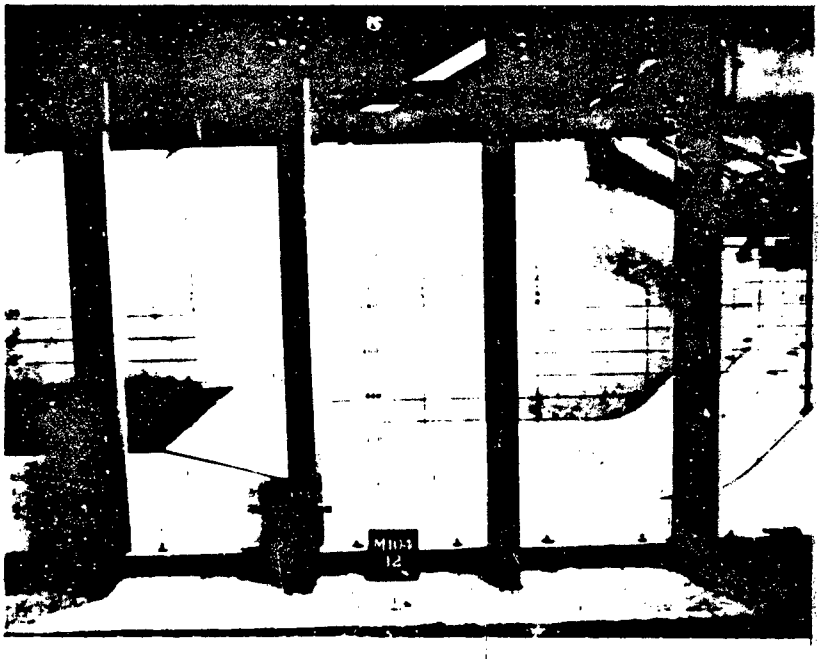
12.5-Ft Deflectors at Elevation 434.0

Piezometer			River flow 212,000 cfs Spwy 10,060 cfs per bay Tailwater elev 447.2			River flow 251,000 cfs Spwy 15,000 cfs per bay Tailwater Elev 449.0			River flow 344,000 cfs Spwy 26,875 cfs per bay Tailwater elev 453.2		
No.	Station	Elevation	Pressures in Feet of Water								
			Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
D-1	10+66.44	442.3	71	48	68	73	71	72	76	72	75
D-2	10+65.80	441.4	- 3	-32	-28	-24	-30	-27	- 3	-13	- 8
D-3	10+74.14	436.4	44	42	43	54	50	51	68	64	66
D-4	10+74.46	434.8	*	*	*	14	11	12	24	22	23
D-5	10+83.04	435.3	*	*	*	54	50	51	60	48	52
D-6	10+83.93	434.0	- 4	- 6	- 5	- 9	-12	-11	-13	-16	-16
D-7	10+85.67	433.6	10	5	7	16	12	14	26	23	24
			River flow 420,000 cfs Spwy 36,590 cfs per bay Tailwater elev 456.2			River flow 490,000 cfs Spwy 45,625 cfs per bay Tailwater elev 459.2			River flow 850,000 cfs Spwy 106,250 cfs per bay Tailwater elev 465.1		
D-1	10+66.44	442.3	77	72	75	79	73	76	82	76	78
D-2	10+65.80	441.4	10	- 1	3	14	7	11	41	36	38
D-3	10+74.14	436.4	69	64	67	71	66	69	71	70	70
D-4	10+74.46	434.8	31	29	30	37	35	36	57	54	56
D-5	10+83.04	435.3	60	55	58	69	63	66	89	83	85
D-6	10+83.93	434.0	-11	-18	-13	- 7	-13	-10	6	1	4
D-7	10+85.67	433.6	38	30	31	39	36	37	57	54	55

* Piezometer exposed to air

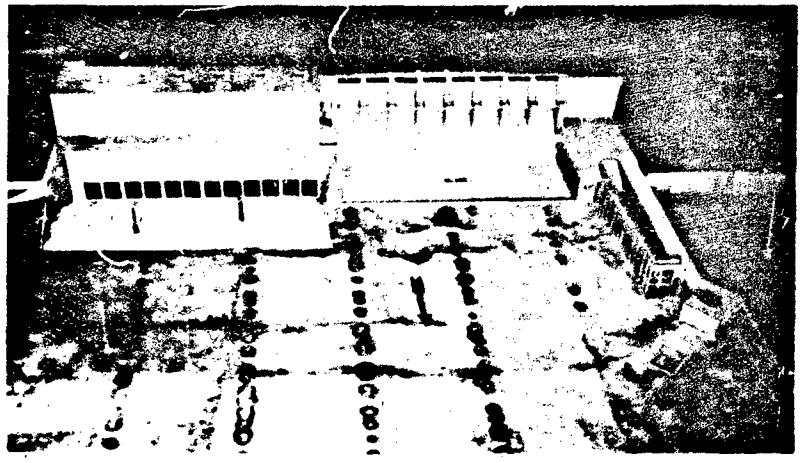
NOTE: Piezometer locations shown on plate 69.

TABLE D



Lower Monumental Dam

Photograph 49. Existing spillway and stilling basin in 1:42.47-scale model.



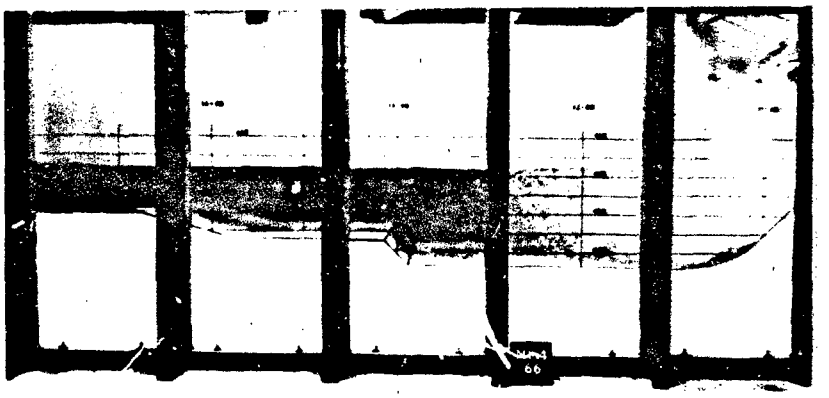
Looking upstream.

Unit 6 fishway entrance.

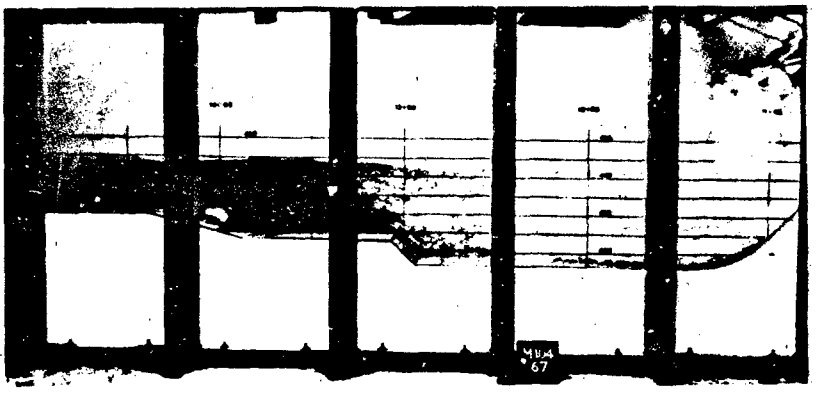
South fishway entrance.

Lower Monumental Dam

Photograph 50. 1:50-scale comprehensive model.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.

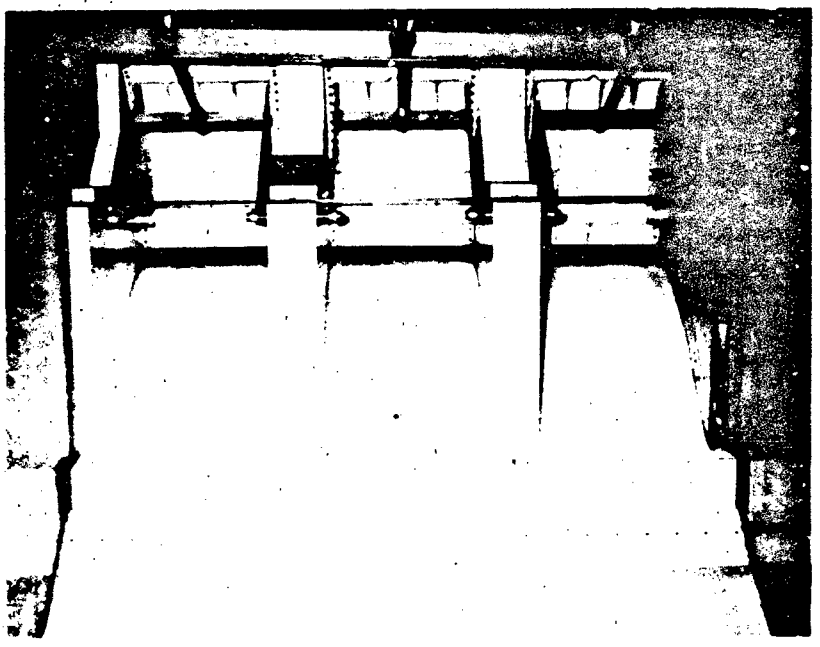


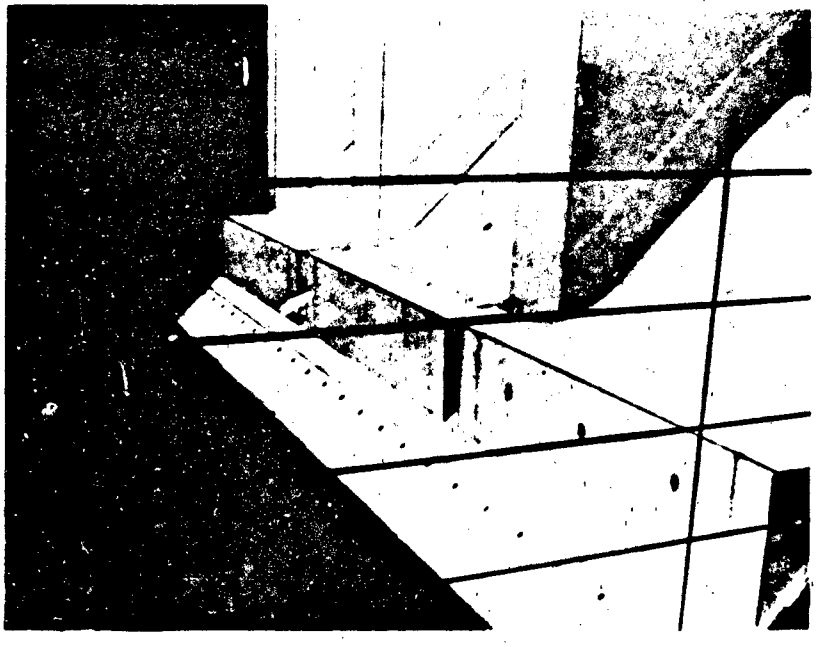
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.

River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

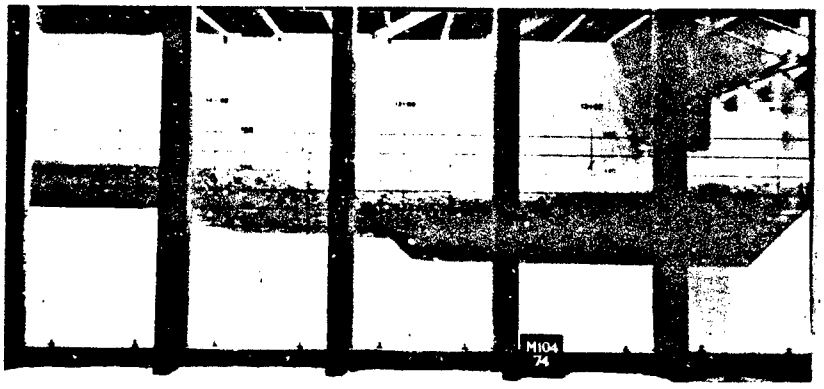
Photograph 51. Flow conditions in existing stilling basin.



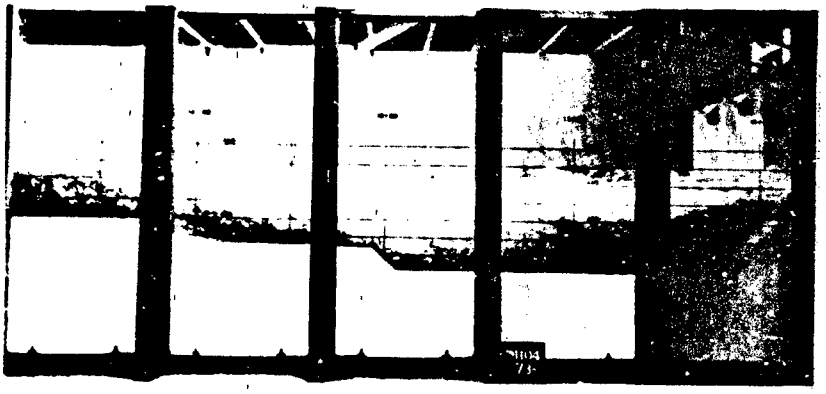


Lower Monumental Dam

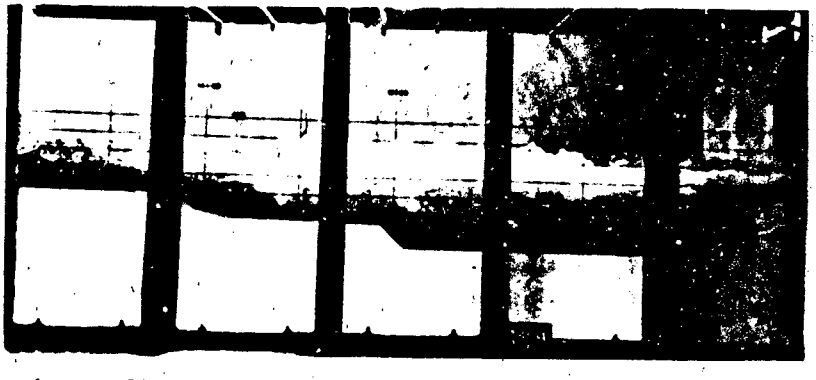
Photograph 52. Typical deflector.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



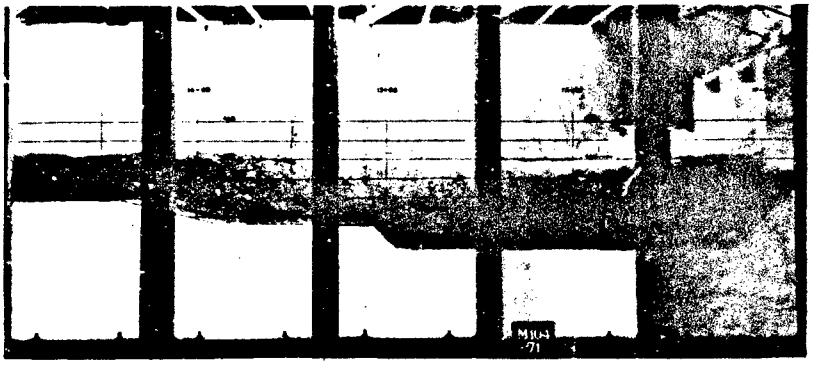
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



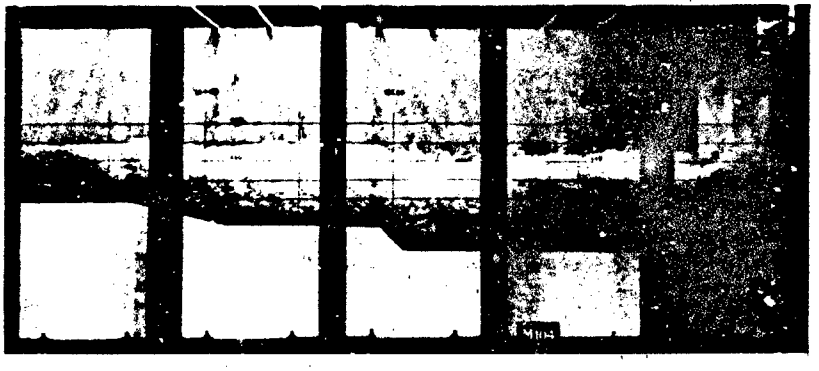
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

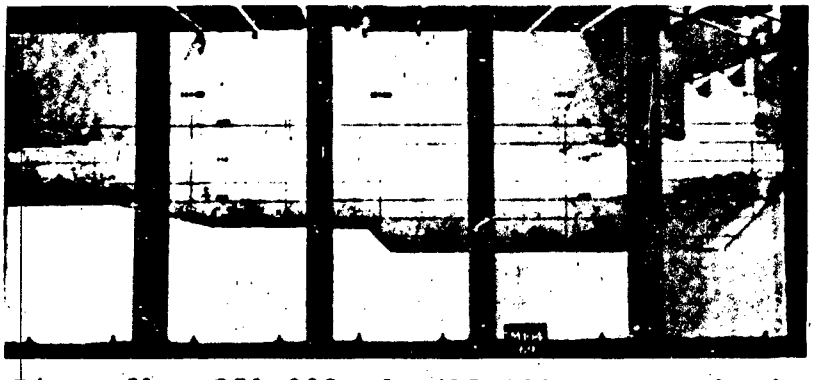
Photograph 53. Flow conditions in stilling basin with 15-foot deflectors at elevation 438.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



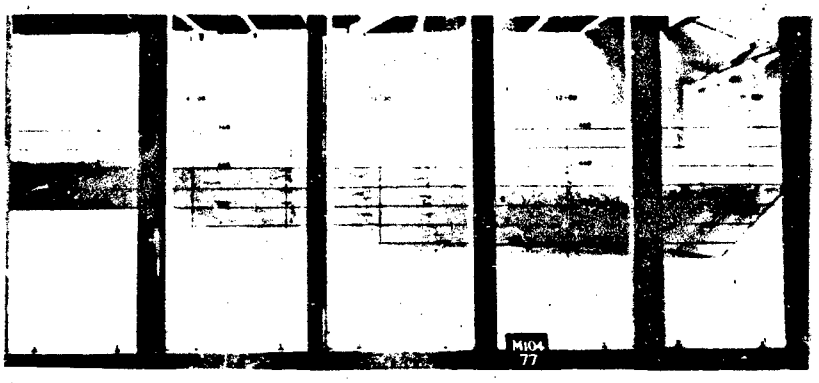
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



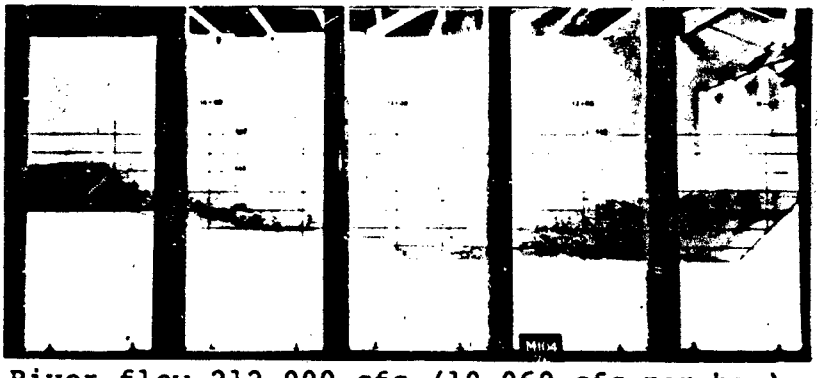
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

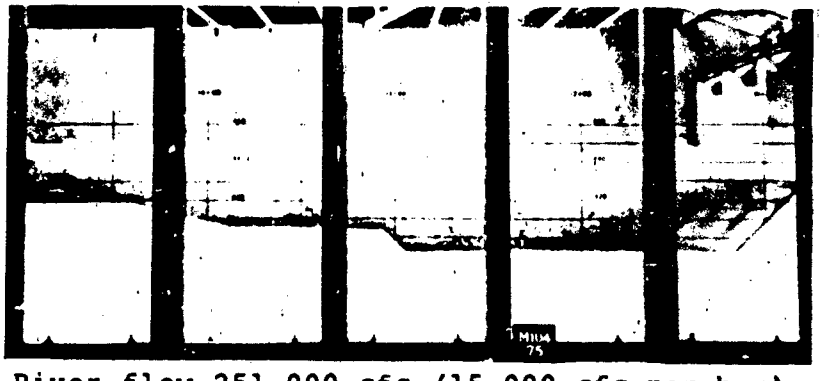
Photograph 54. Flow conditions in stilling basin with 15-foot deflectors at elevation 434.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



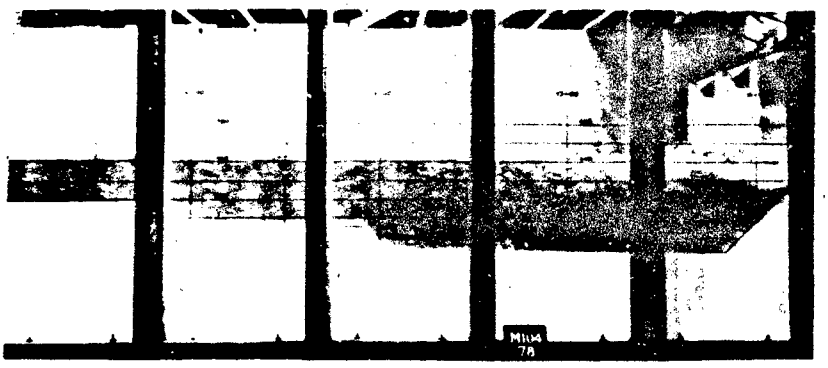
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



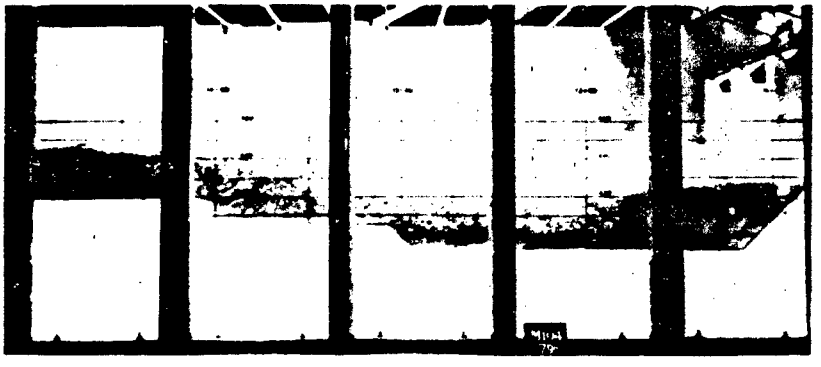
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

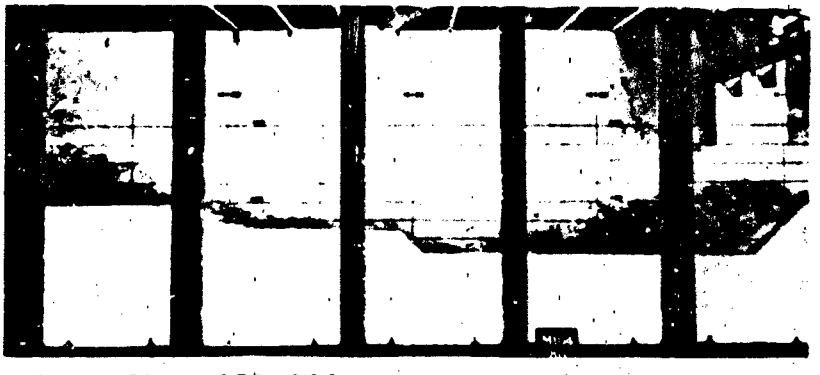
Photograph 55. Flow conditions in stilling basin with 15-foot deflectors at elevation 430.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



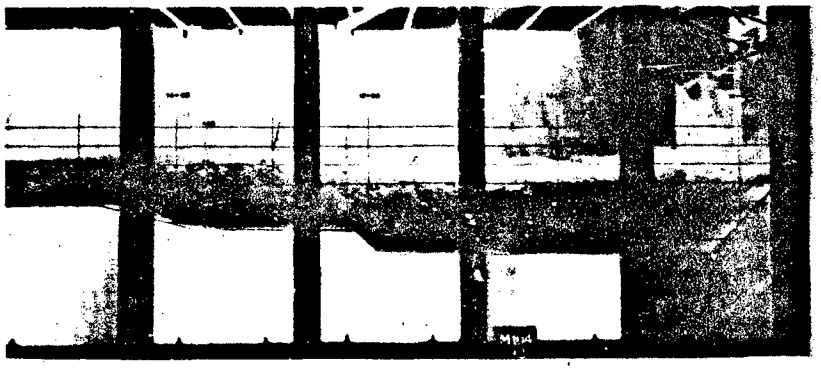
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



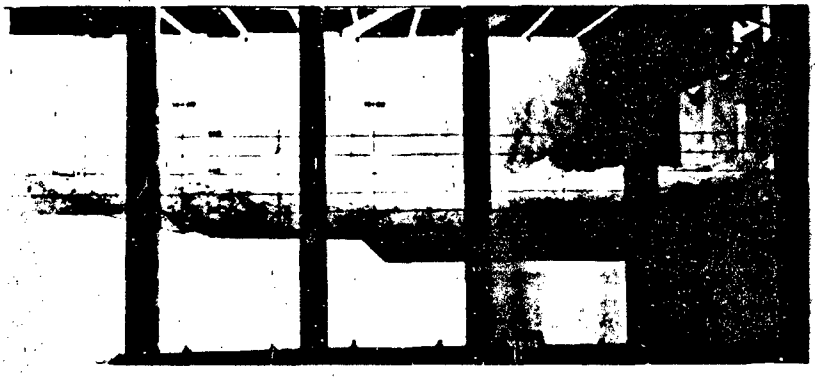
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

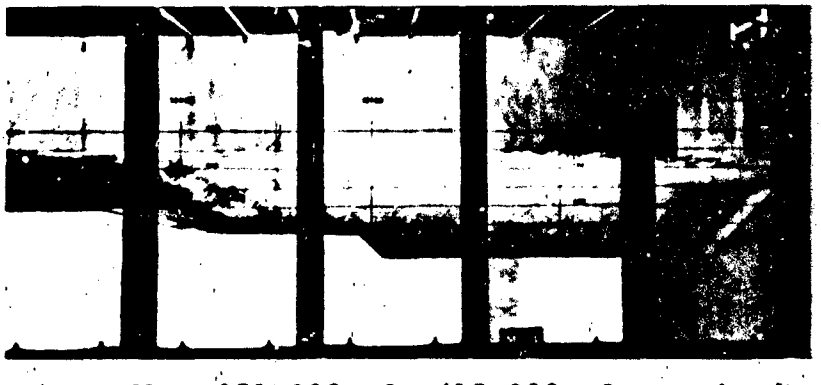
Photograph 56. Flow conditions in stilling basin with 15-foot deflectors at elevation 426.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



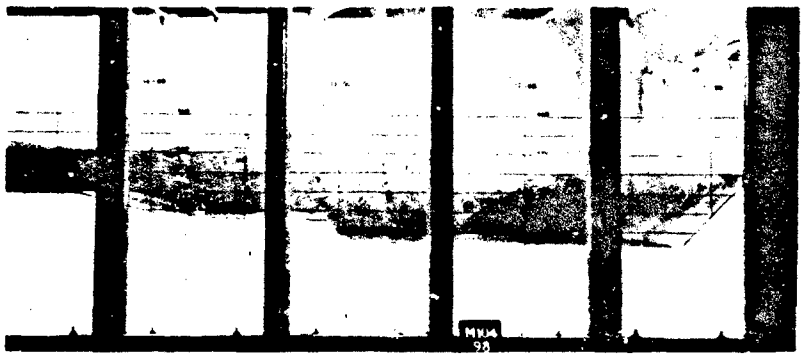
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



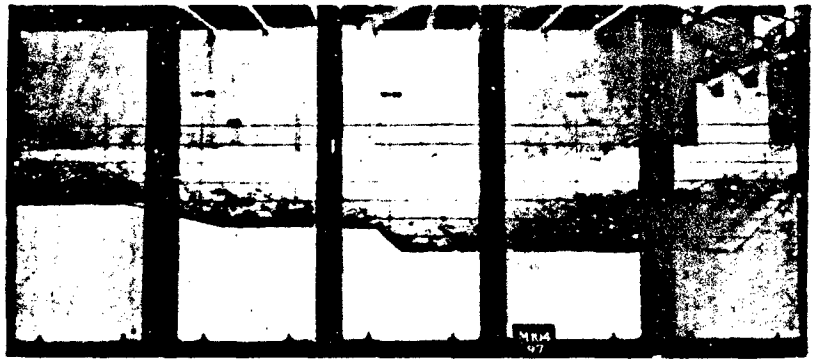
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

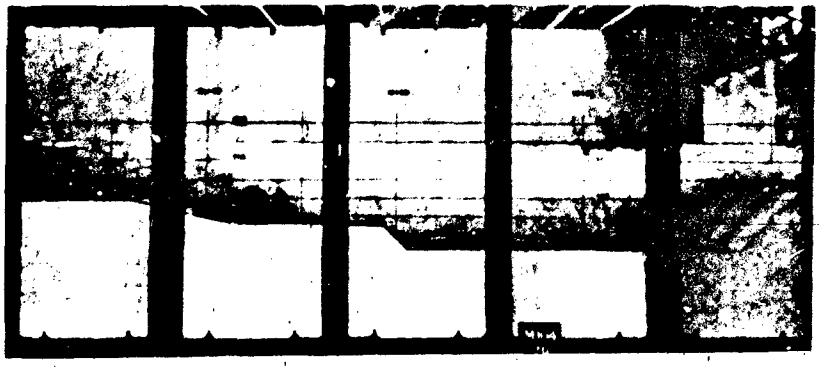
Photograph 57. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 438.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



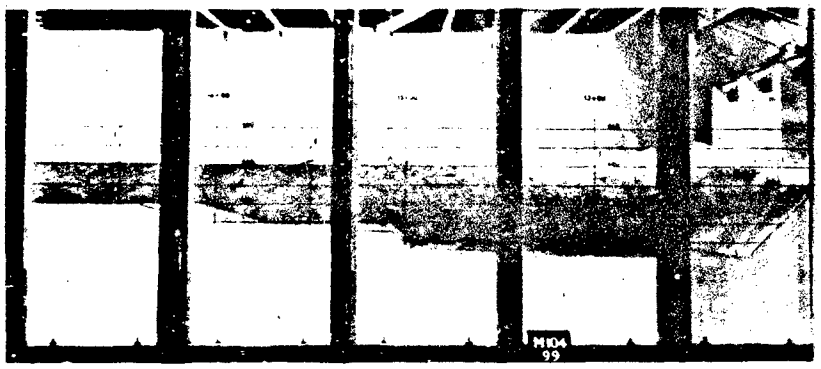
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



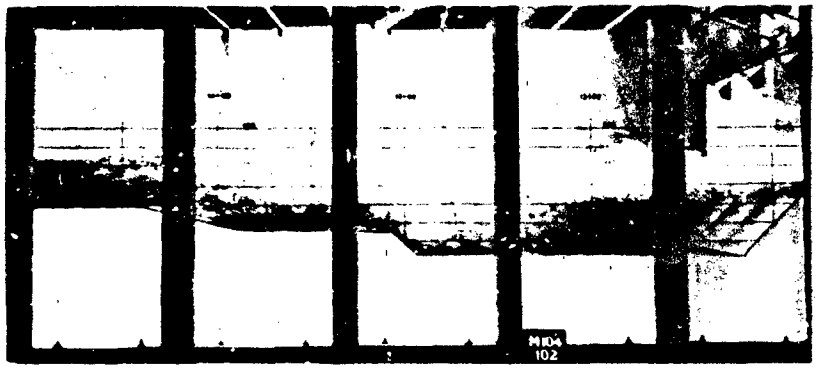
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

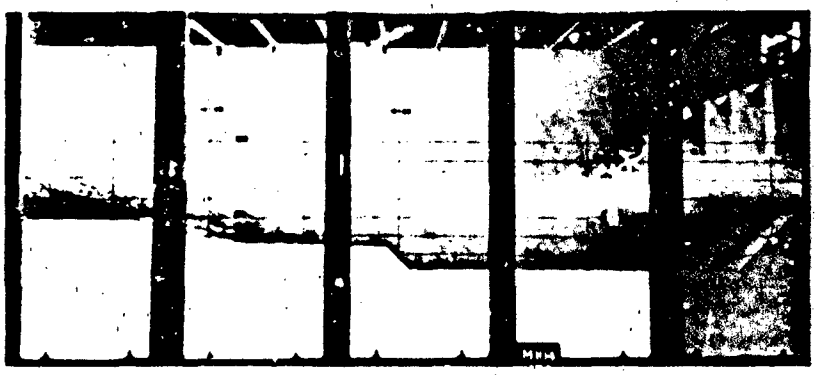
Photograph 58. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 434.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



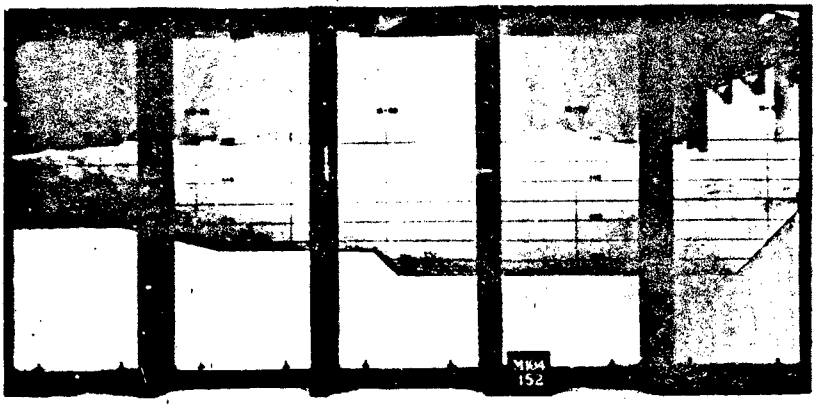
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



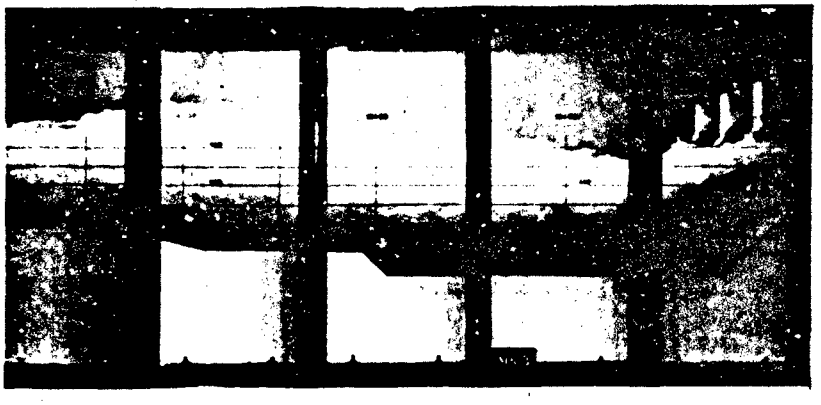
River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

Lower Monumental Dam

Photograph 59. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 432.0.



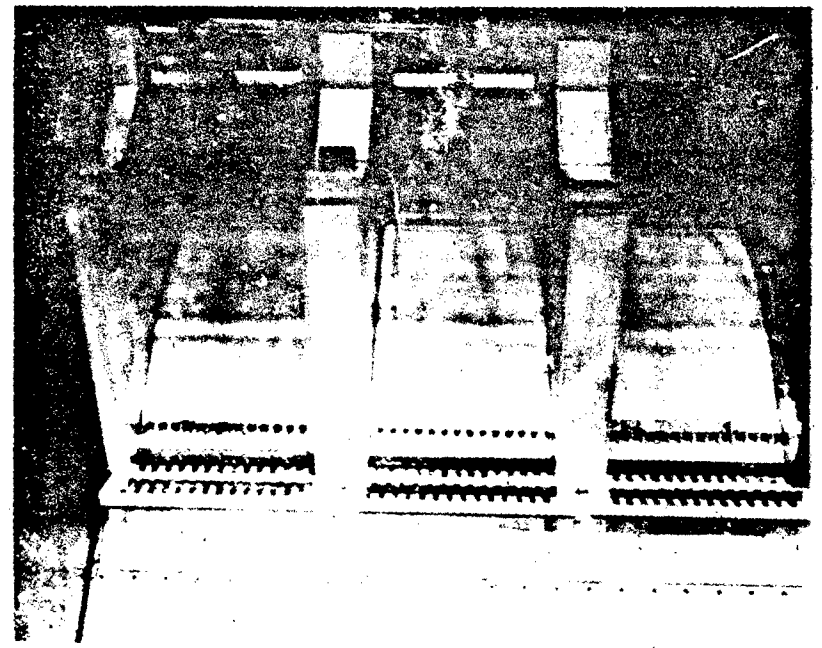
River flow 420,000 cfs (36,590 cfs per bay), tailwater elevation 456.2.

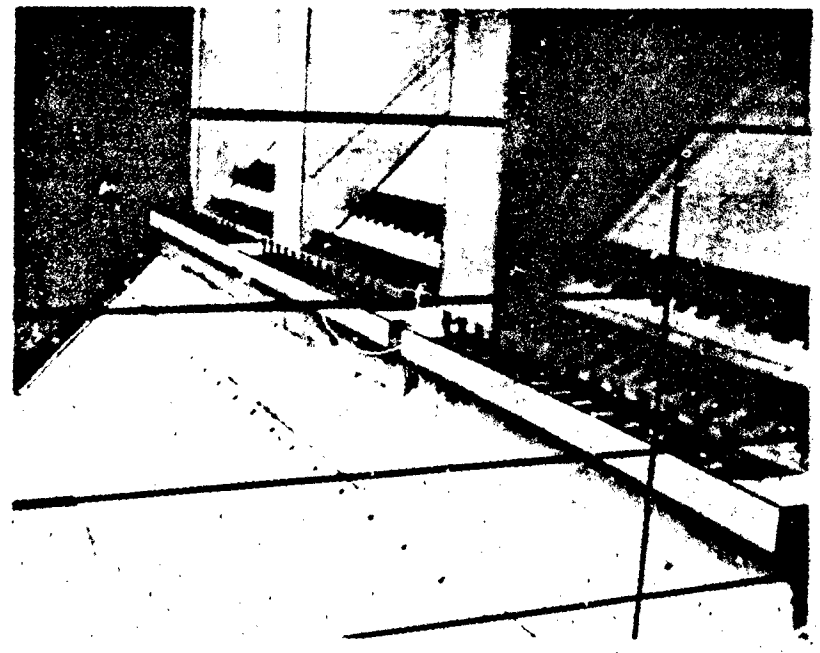


River flow 850,000 cfs (106,250 cfs per bay), tailwater elevation 465.1.

Lower Monumental Dam

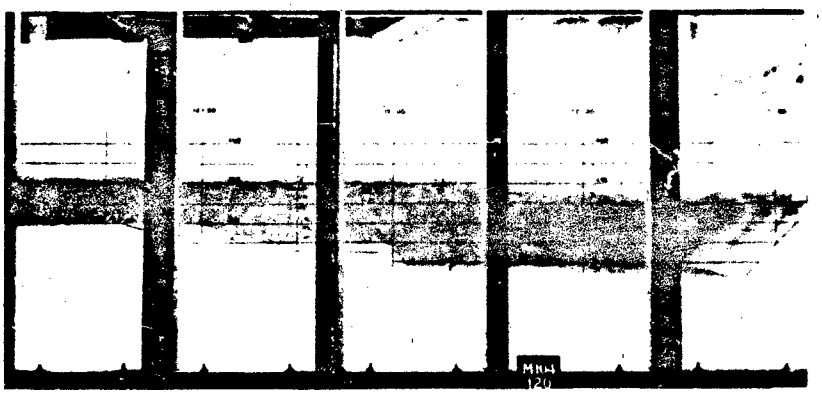
Photograph 60. Flow conditions in stilling basin with 12.5-foot deflectors at elevation 434.0.



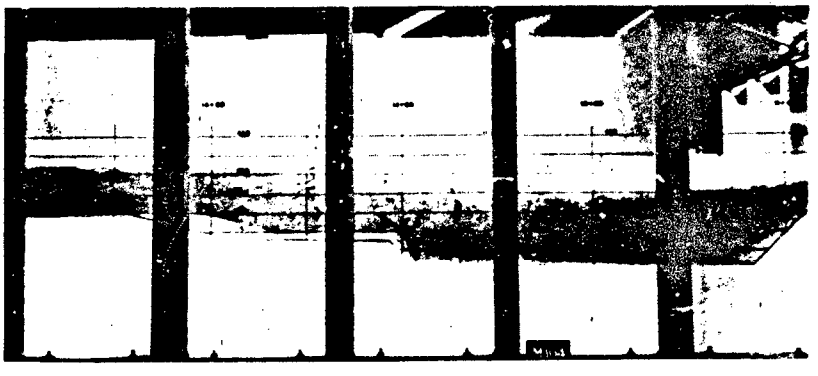


Lower Monumental Dam

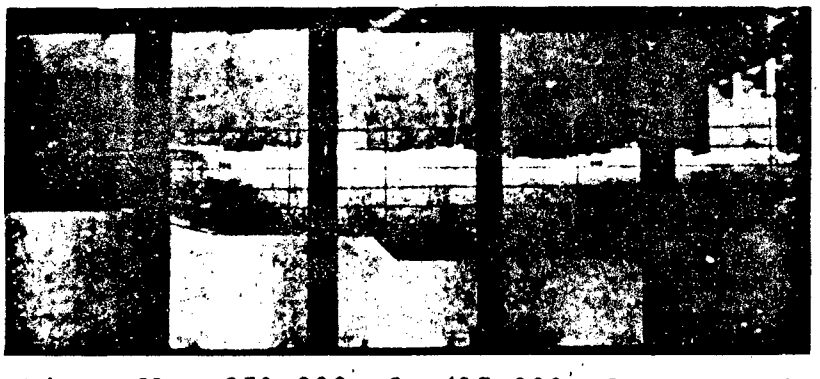
Photograph 61. Plan H dentates and 12.5-foot deflector at elevation 434.0.



River flow 172,000 cfs (5,175 cfs per bay), tailwater elevation 445.1.



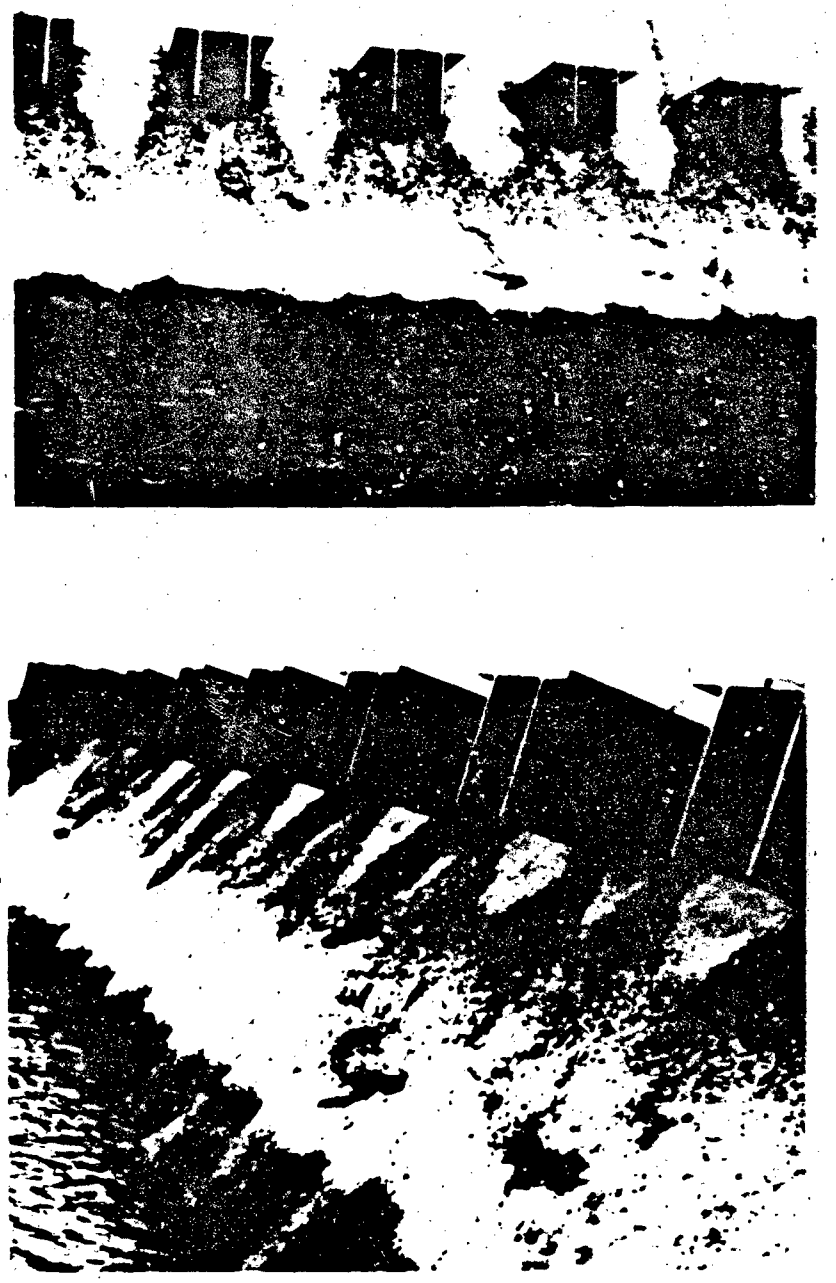
River flow 212,000 cfs (10,060 cfs per bay), tailwater elevation 447.2.



River flow 251,000 cfs (15,000 cfs per bay), tailwater elevation 449.0.

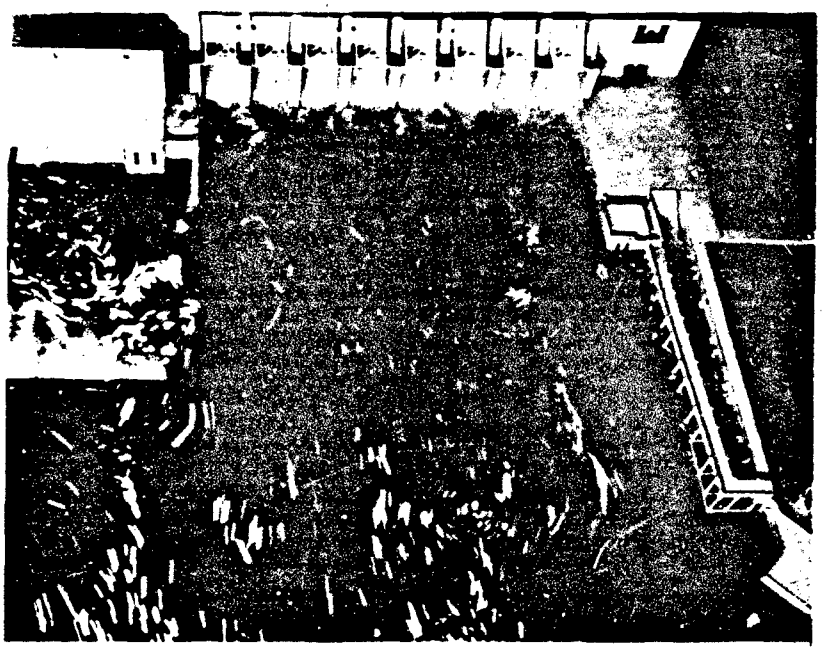
Lower Monumental Dam

Photograph 62. Flow conditions in stilling basin with plan H dentates and 12.5-foot deflector at elevation 434.0.



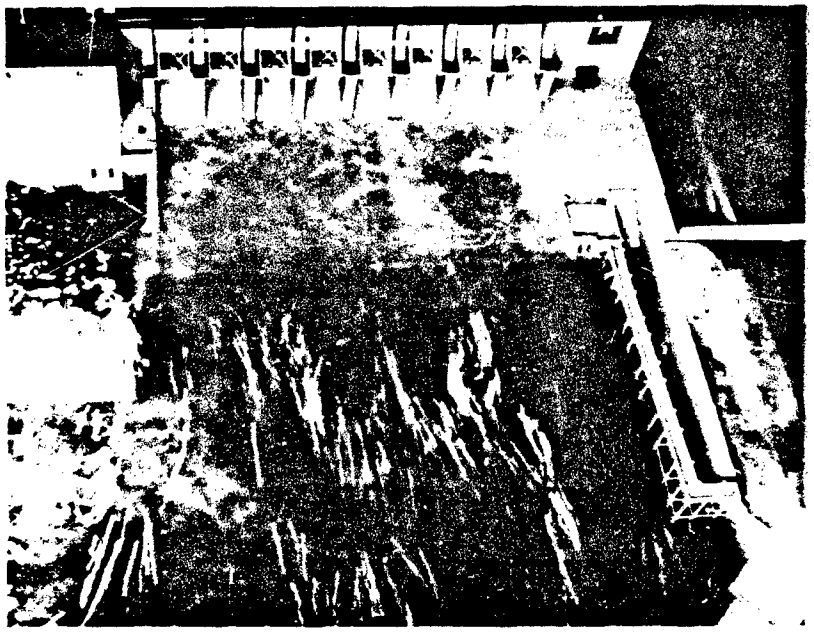
Lower Monumental Dam

Photograph 63. Erosion of concrete below dentates in bay 2 of Lower Monumental spillway.



Lower Monumental Dam

Photograph 64. Flow patterns without spillway deflectors; river discharge 100,000 cfs; powerhouse units 1 to 3 operating, uniform spillway operation, spillway discharge 35,200 cfs.

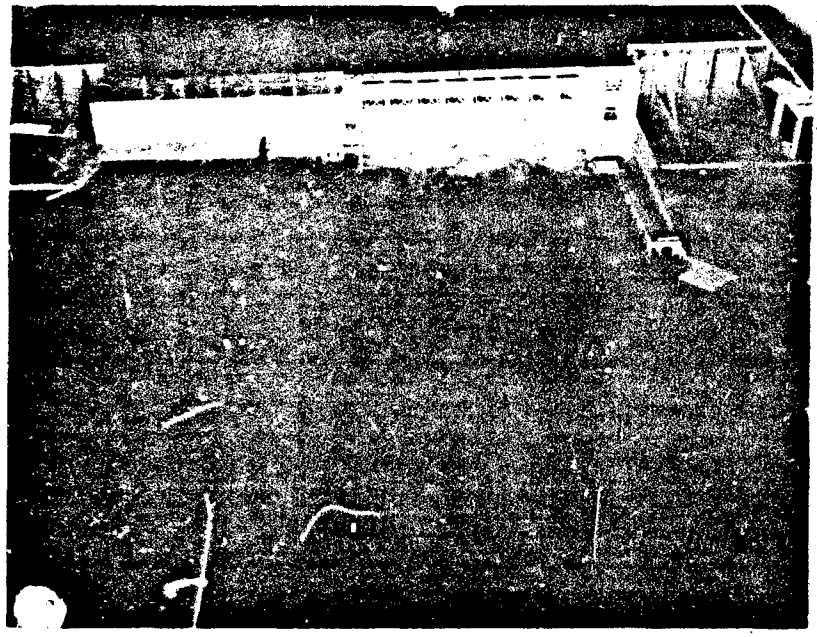


Powerhouse units 1 to 3 operating,
spillway discharge 132,050 cfs.

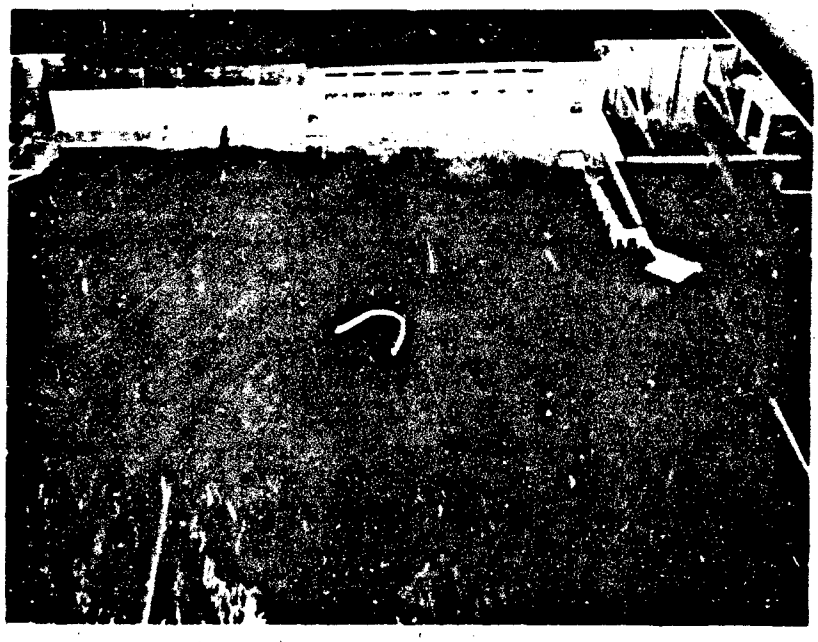
Powerhouse units 1 to 6 operating,
spillway discharge 63,050 cfs.

Lower Monumental Dam

Photograph 65. Flow patterns without spillway deflectors; river discharge 200,000 cfs; uniform spillway operation.



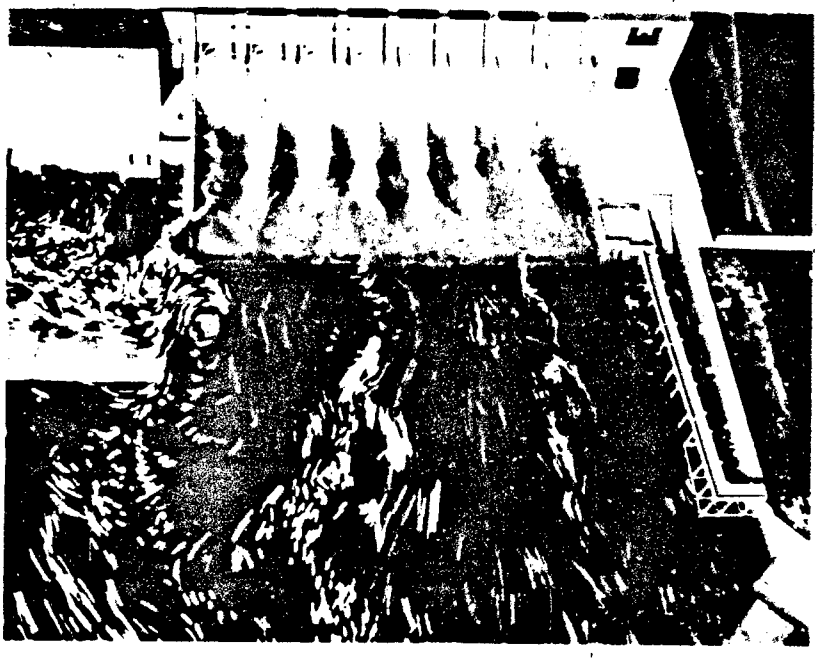
Powerhouse units 1 to 3 operating,
spillway discharge 350,340 cfs.



Powerhouse units 1 to 6 operating,
spillway discharge 281,130 cfs.

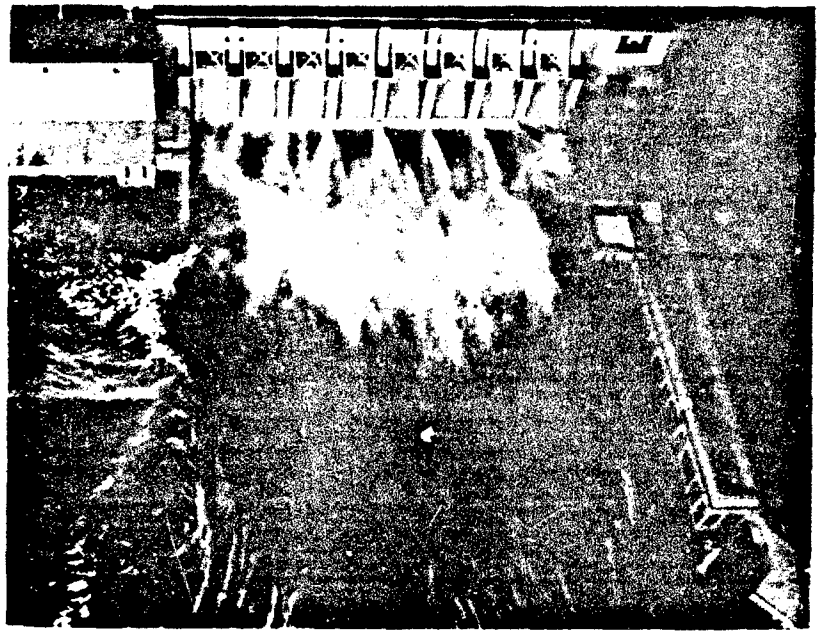
Lower Monumental Dam

Photograph 66. Flow patterns without spillway deflectors; river discharge 420,000 cfs; uniform spillway operation.

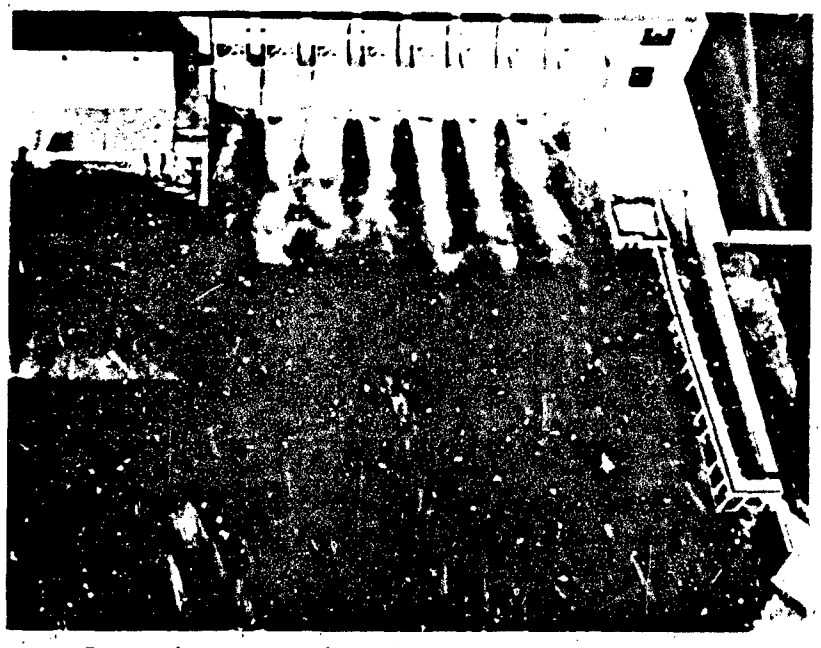


Lower Monumental Dam

Photograph 67. Flow patterns with 12.5-foot deflectors in spillway bays 2 to 7. Powerhouse units 1 to 3 operating, river discharge 100,000 cfs, spillway discharge 35,200 cfs, uniform spillway operation.



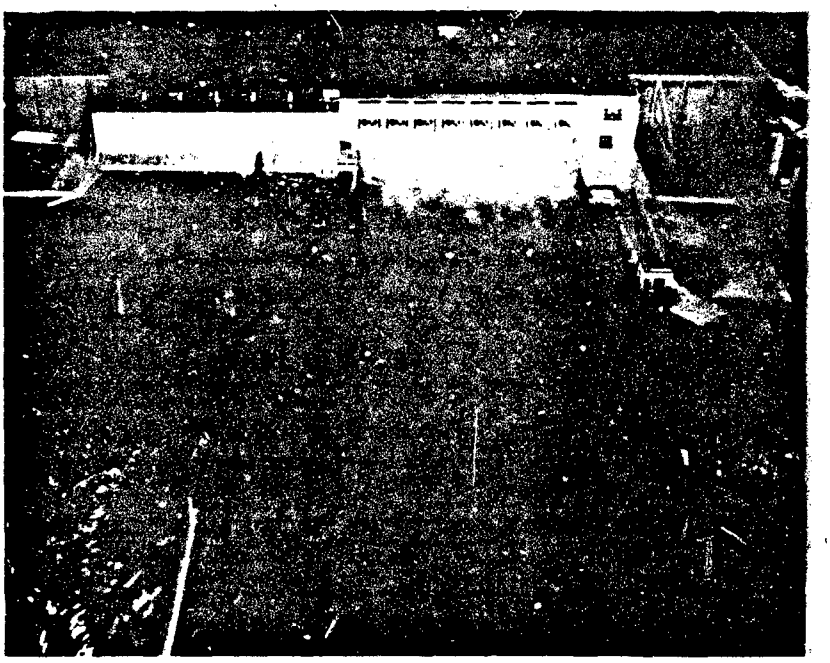
Powerhouse units 1 to 3 operating,
spillway discharge 132,050 cfs.



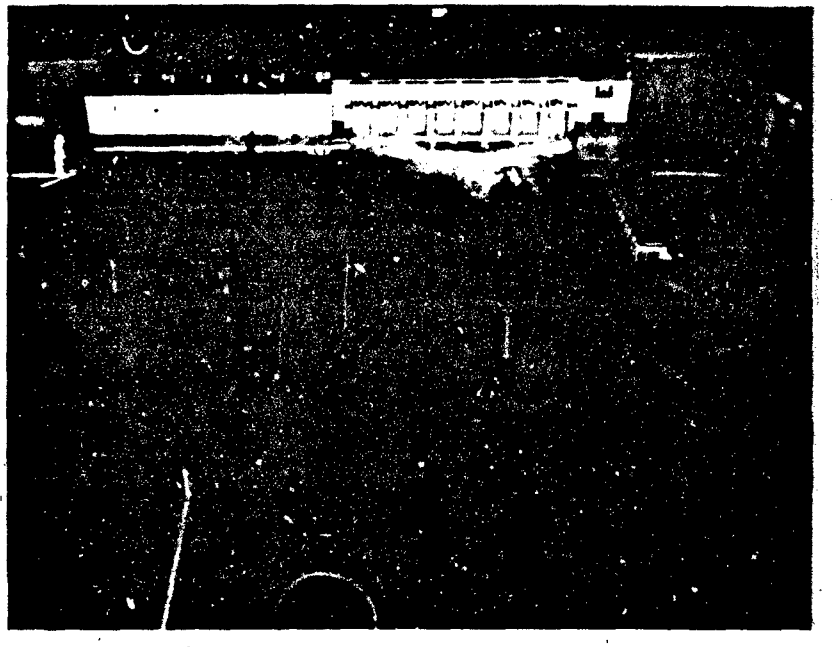
Powerhouse units 1 to 6 operating,
spillway discharge 63,050 cfs.

Lower Monumental Dam

Photograph 68. Flow patterns with 12.5-foot deflectors in spillway bays 2 to 7; river discharge 200,000 cfs; uniform spillway operation.



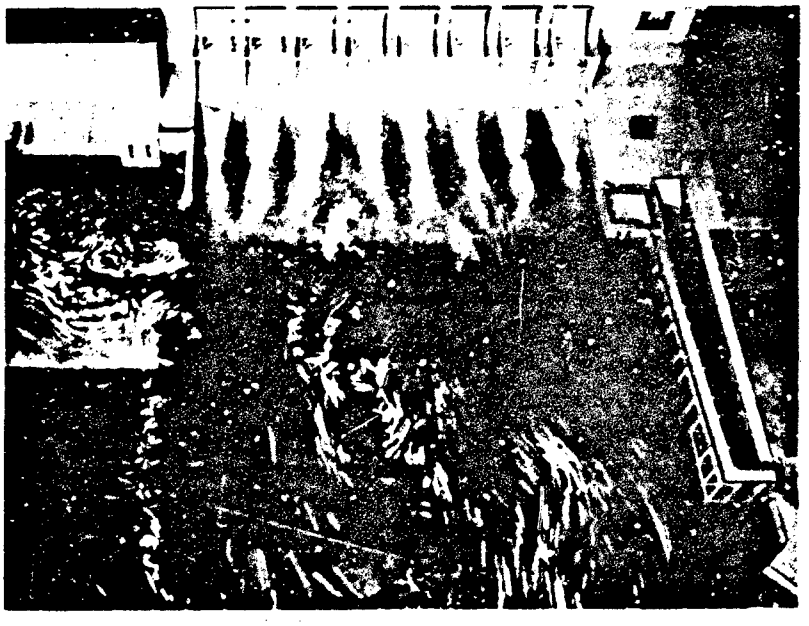
Powerhouse units 1 to 3 operating,
spillway discharge 350,340 cfs.



Powerhouse units 1 to 6 operating,
spillway discharge 281,130 cfs.

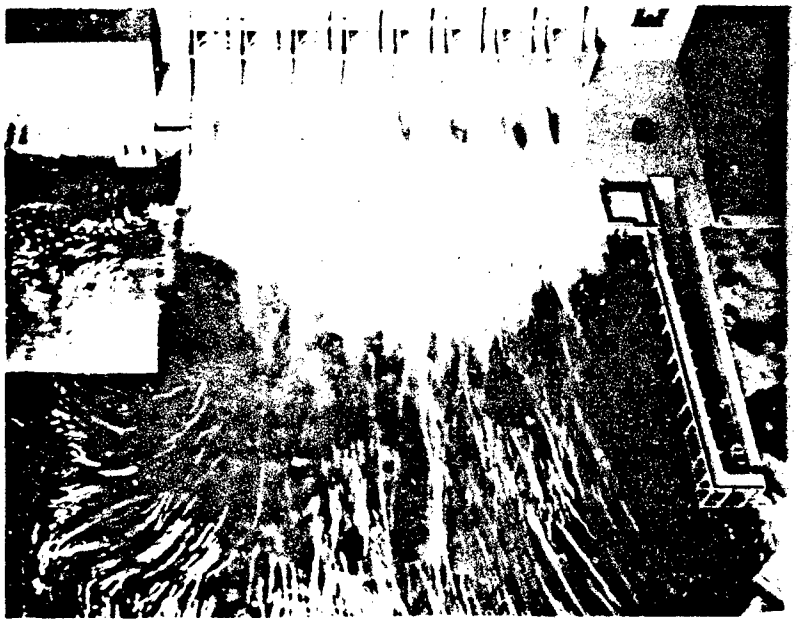
Lower Monumental Dam

Photograph 69. Flow patterns with 12.5-foot deflectors in spillway bays 2 to 7; river discharge 420,000 cfs; uniform spillway operation.

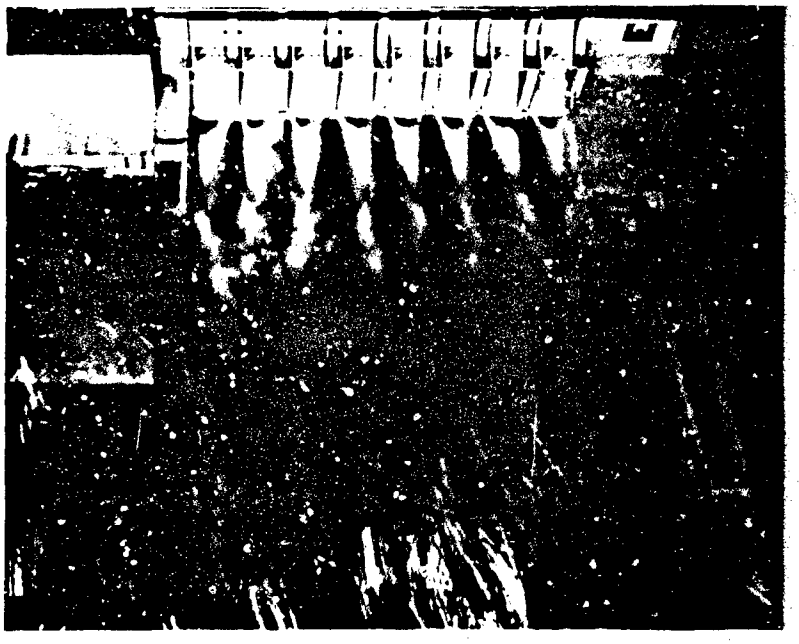


Lower Monumental Dam

Photograph 70. Flow patterns with 12.5-foot deflectors in spillway bays 1 to 8. Powerhouse units 1 to 3 operating, river discharge 100,000 cfs, spillway discharge 35,200 cfs, uniform spillway operation.



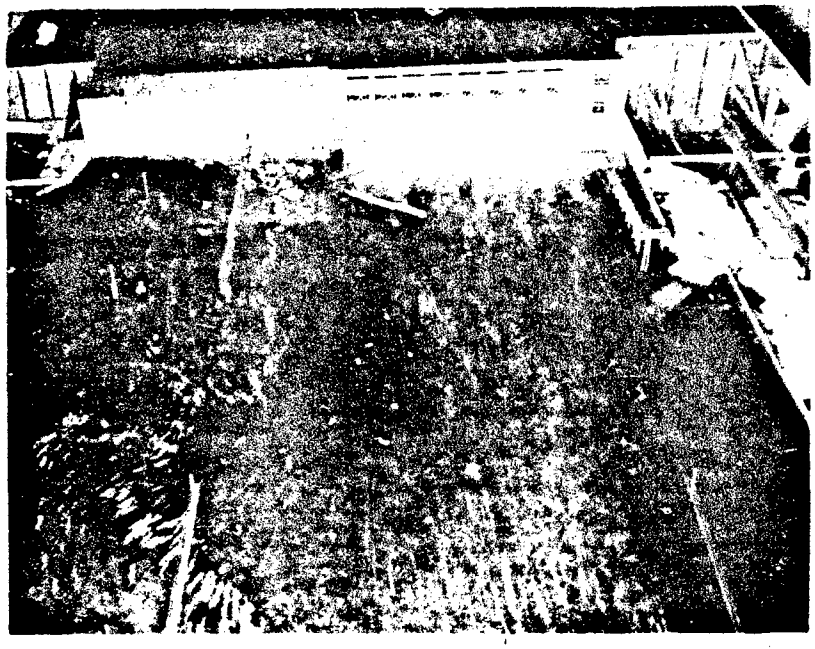
Powerhouse units 1 to 3 operating,
spillway discharge 132,050 cfs.



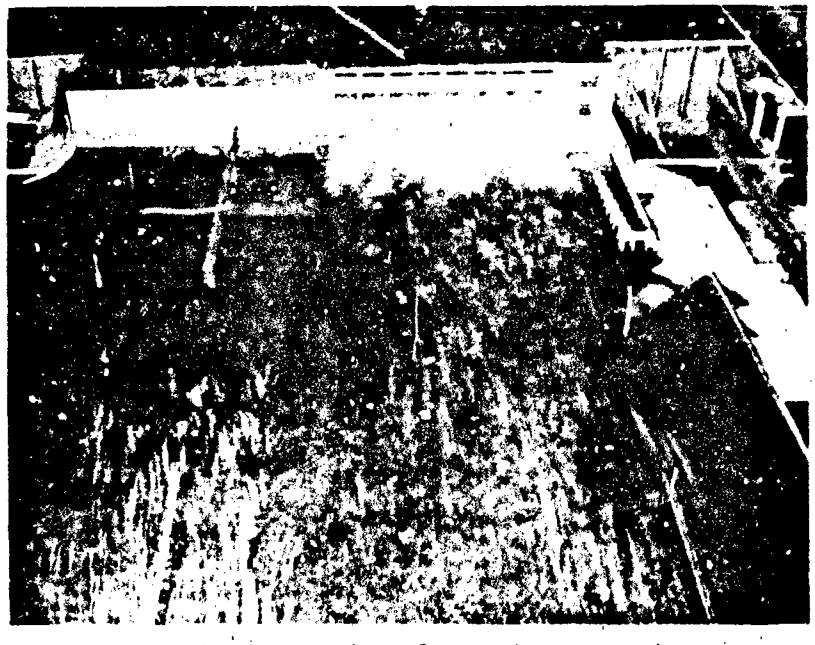
Powerhouse units 1 to 6 operating,
spillway discharge 63,050 cfs.

Lower Monumental Dam

Photograph 71. Flow patterns with 12.5-foot deflectors in spillway bays 1 to 8; discharge 200,000 cfs; uniform spillway operation.



Powerhouse units 1 to 3 operating,
spillway discharge 350,340 cfs.



Powerhouse units 1 to 6 operating,
spillway discharge 281,130 cfs.

Lower Monumental Dam

Photograph 72. Flow patterns with 12.5-foot deflectors in spillway bays 1 to 8; river discharge 420,000 cfs; uniform spillway operation.

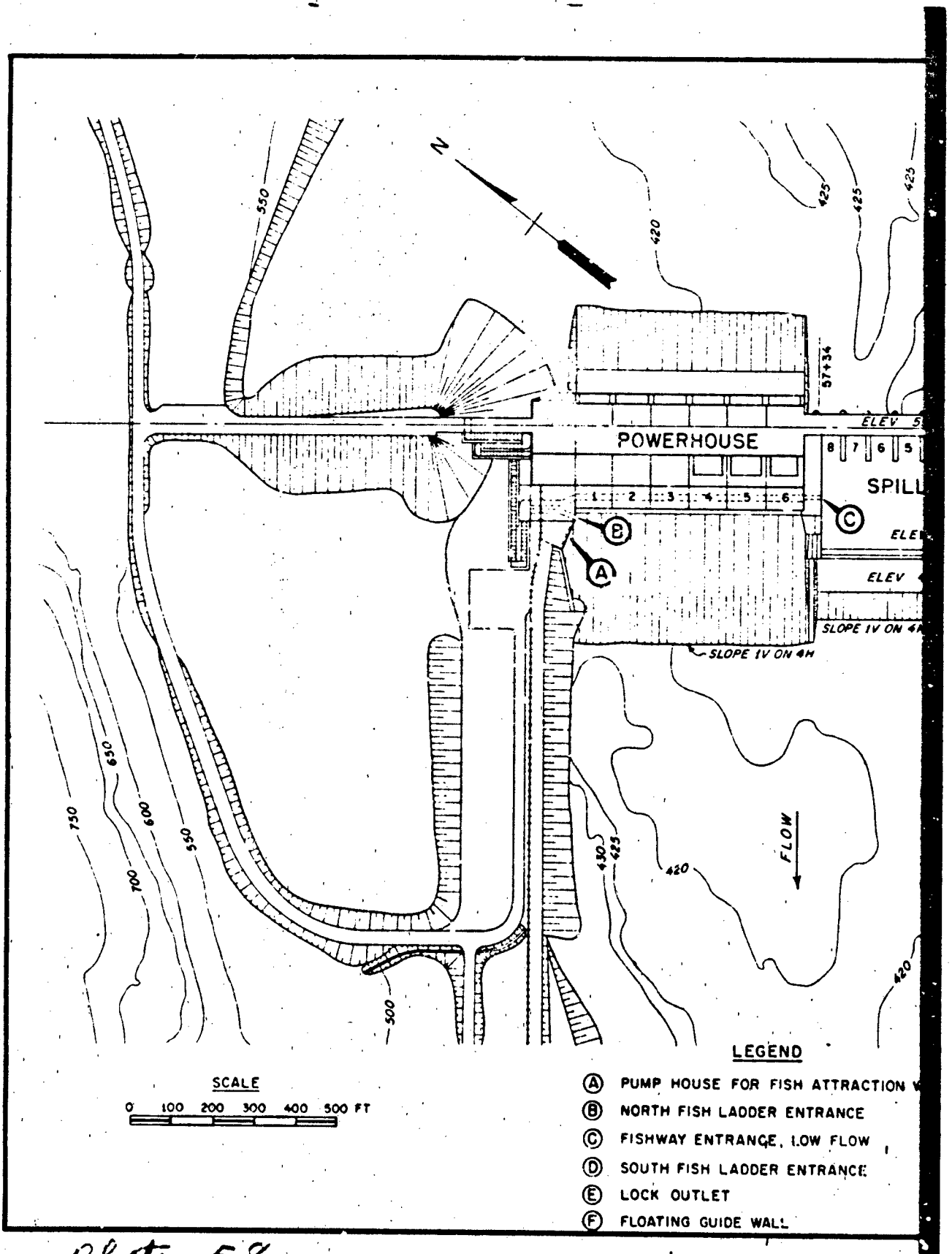
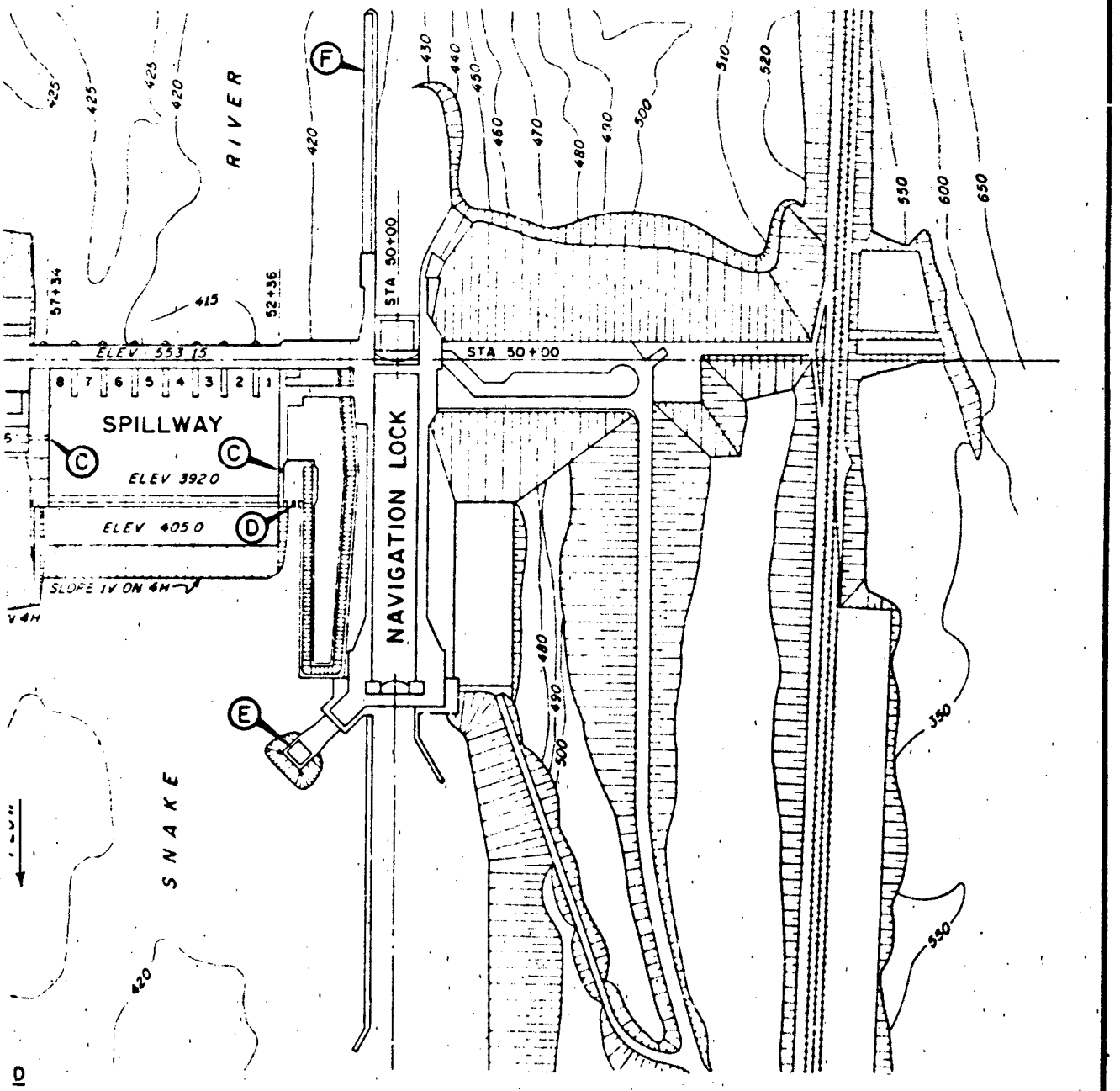


plate 58

1 of 2



D

H ATTRACTION WATER

NTRANCE

LOW FLOW

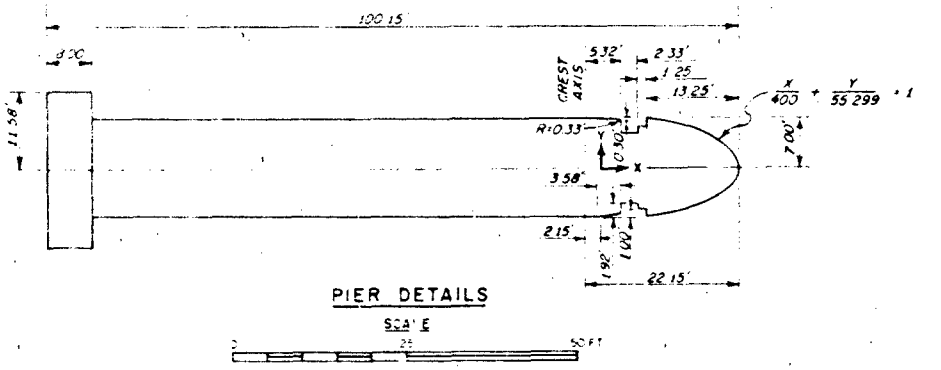
NTRANCE

LOWER MONUMENTAL DAM

PROJECT LAYOUT

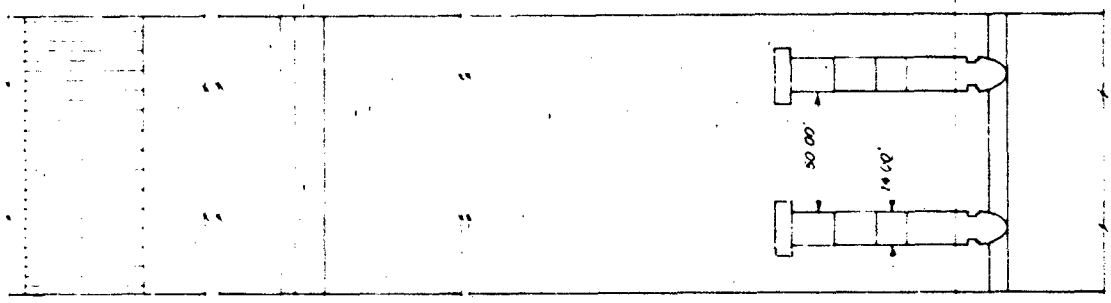
PLATE 58

2 of 2

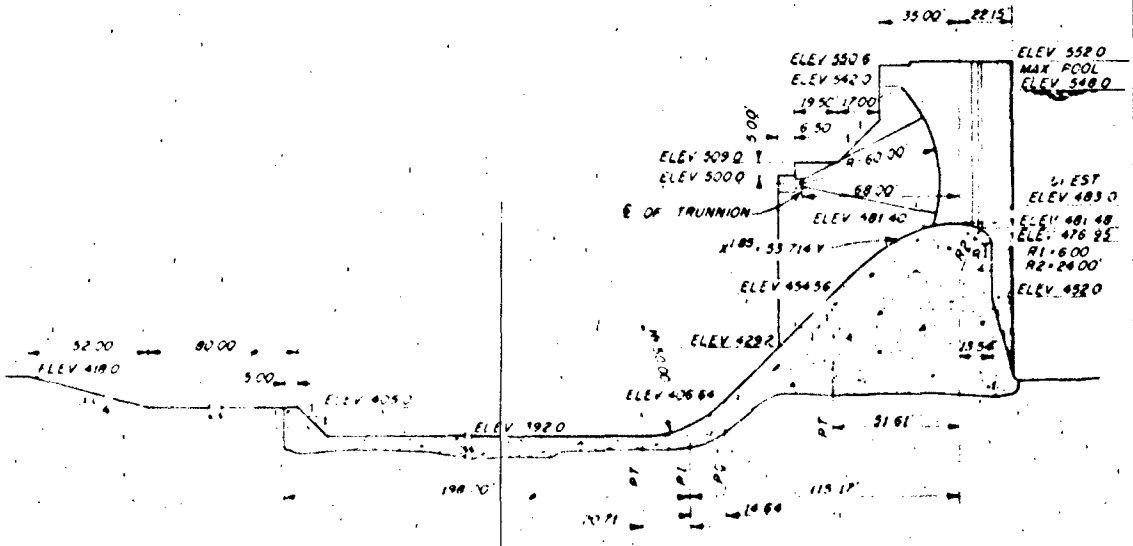


PIER DETAILS

SCALE



PLAN



SECTION THROUGH SPILLWAY

SCALE

LOWER MONUMENTAL DAM
SPILLWAY DETAILS
EXISTING DESIGN

PLATE 59

REPRODUCED AT GOVERNMENT EXPENSE

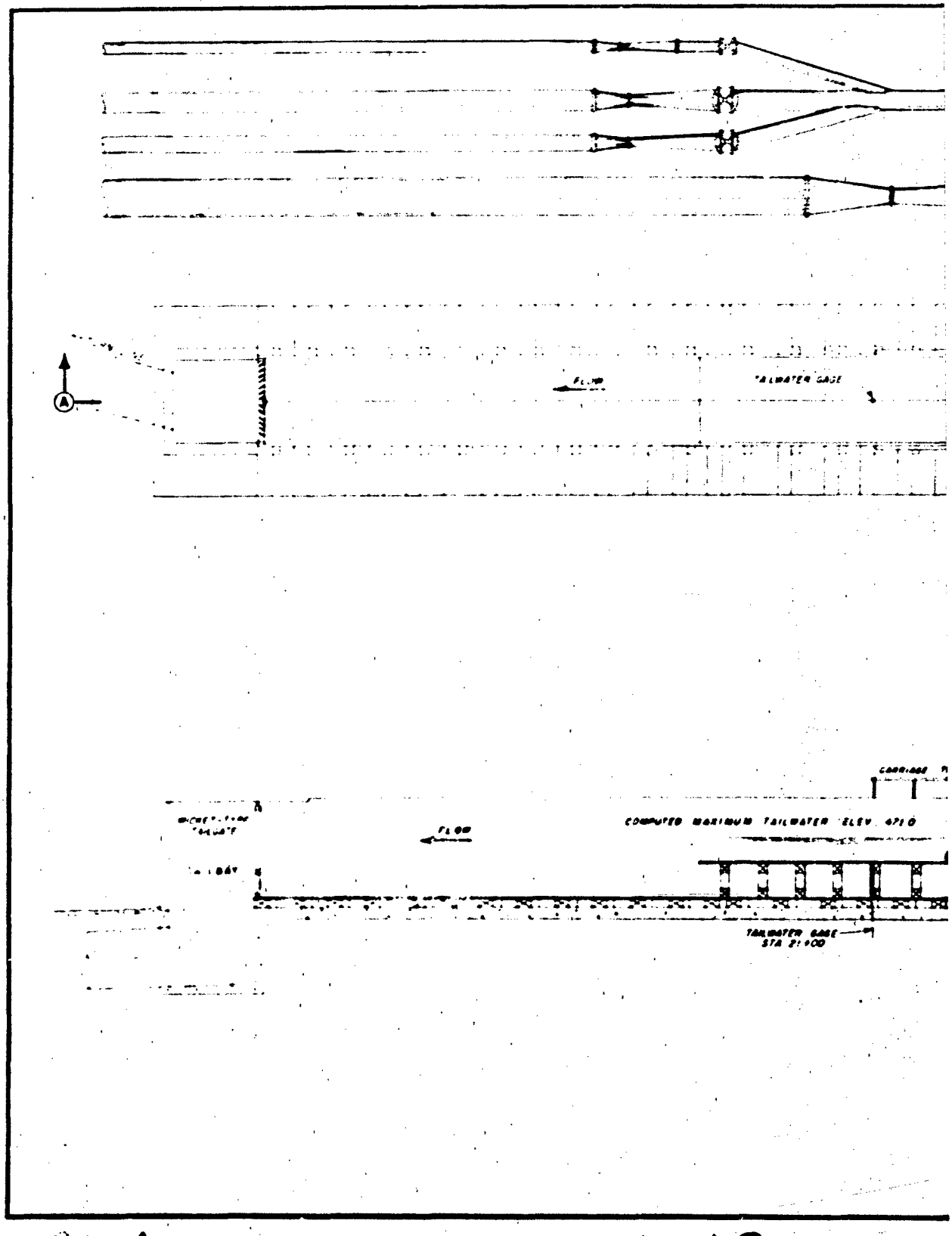
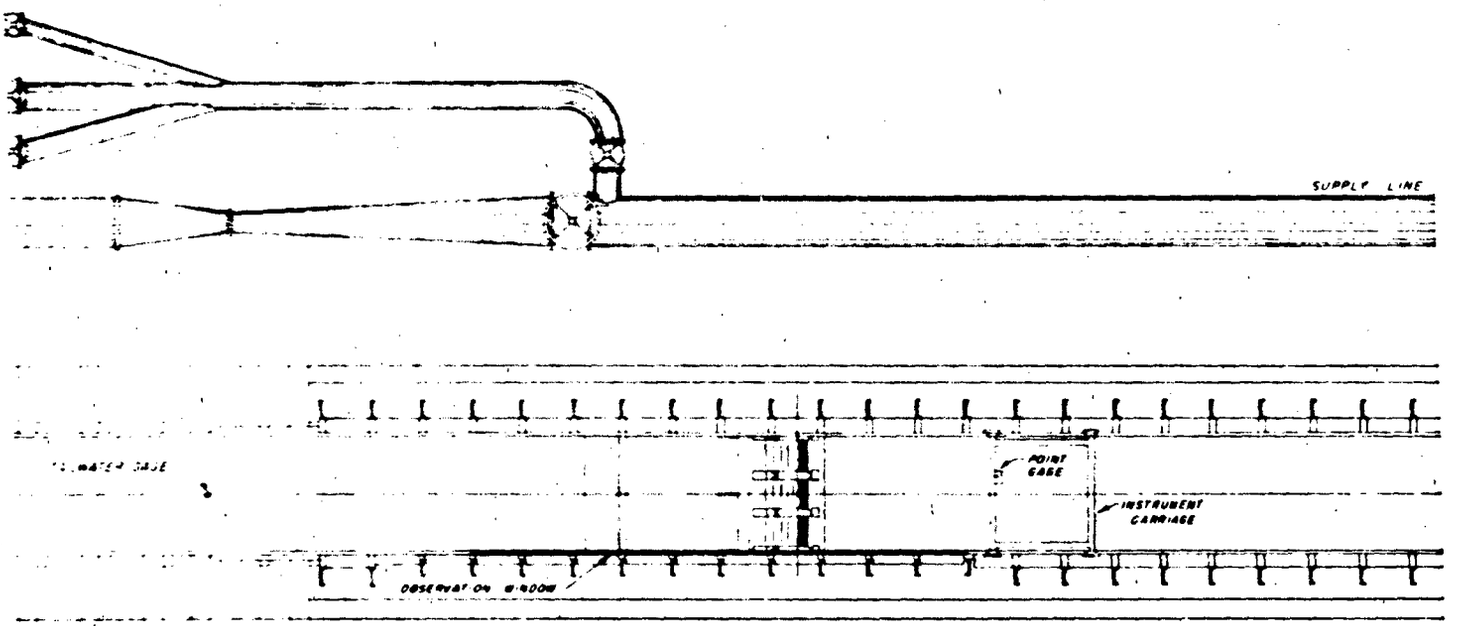


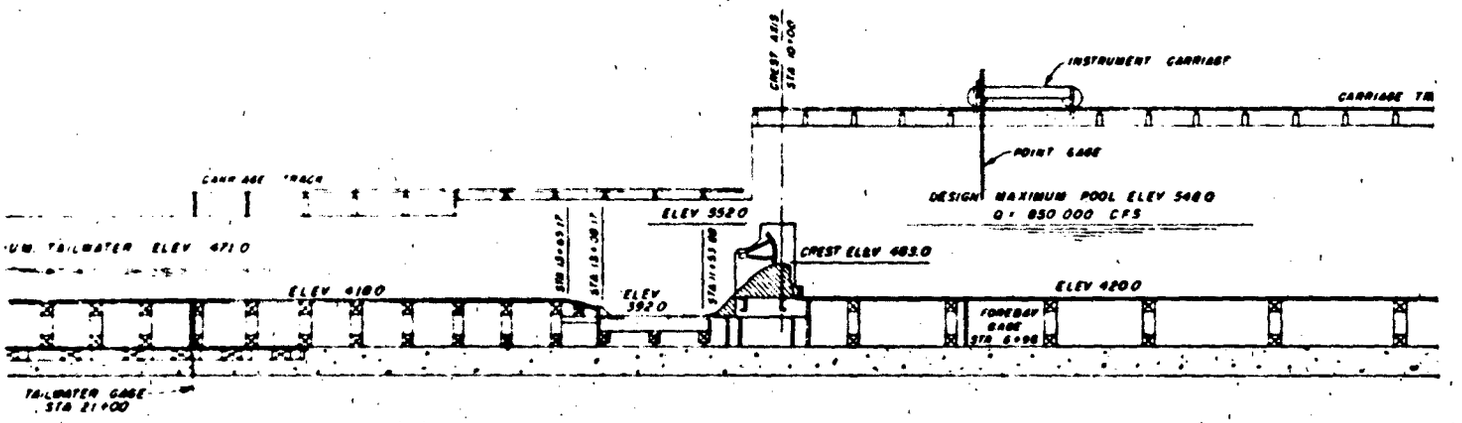
Plate 60

1 of 3

REPRODUCED AT GOVERNMENT EXPENSE

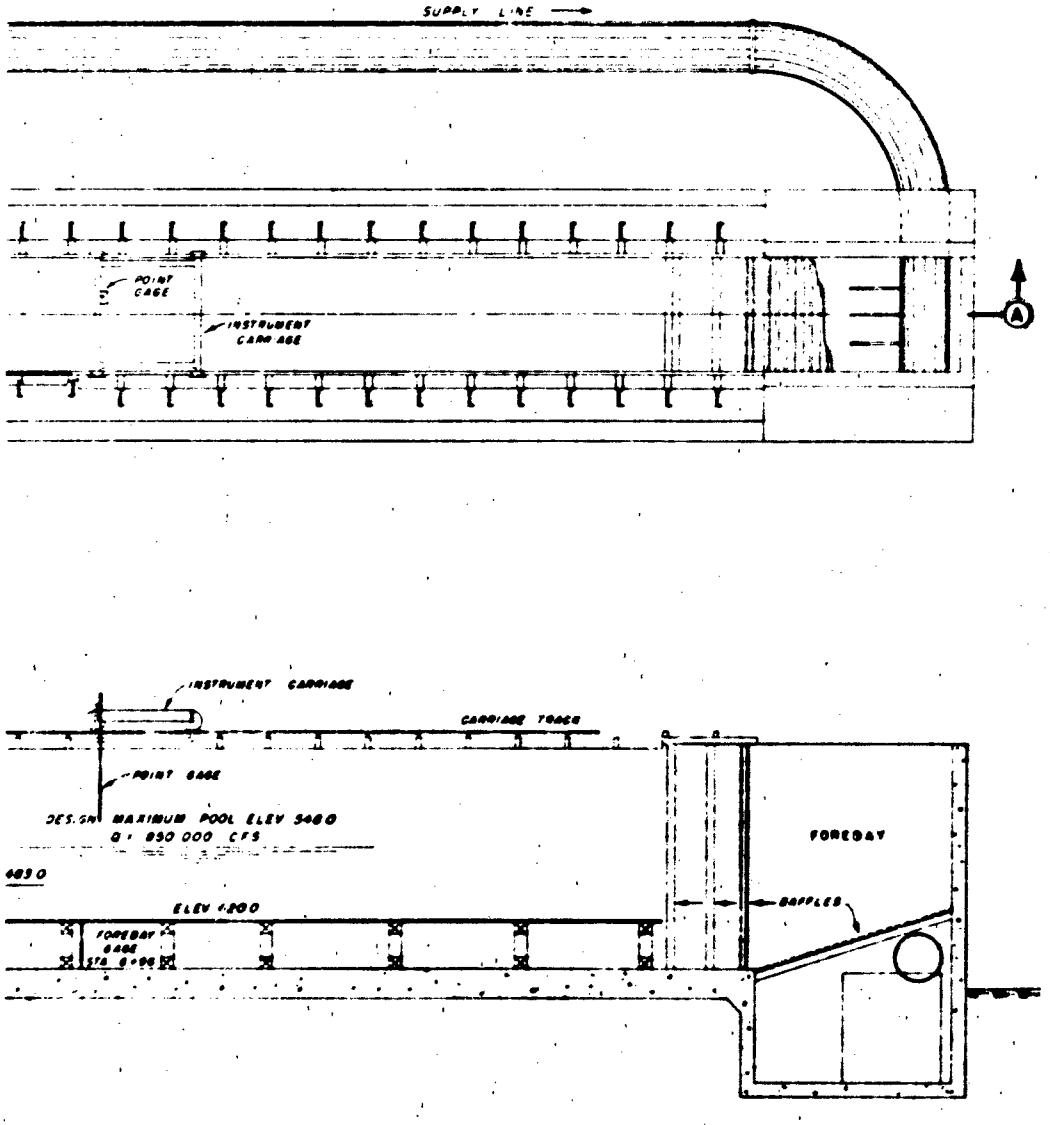


PLAN



SECTION A-A

REPRODUCED AT GOVERNMENT EXPENSE



LOWER MONUMENTAL DAM
1:42.47-SCALE MODEL LAYOUT
EXISTING DESIGN

PLATE 60

3 of 3

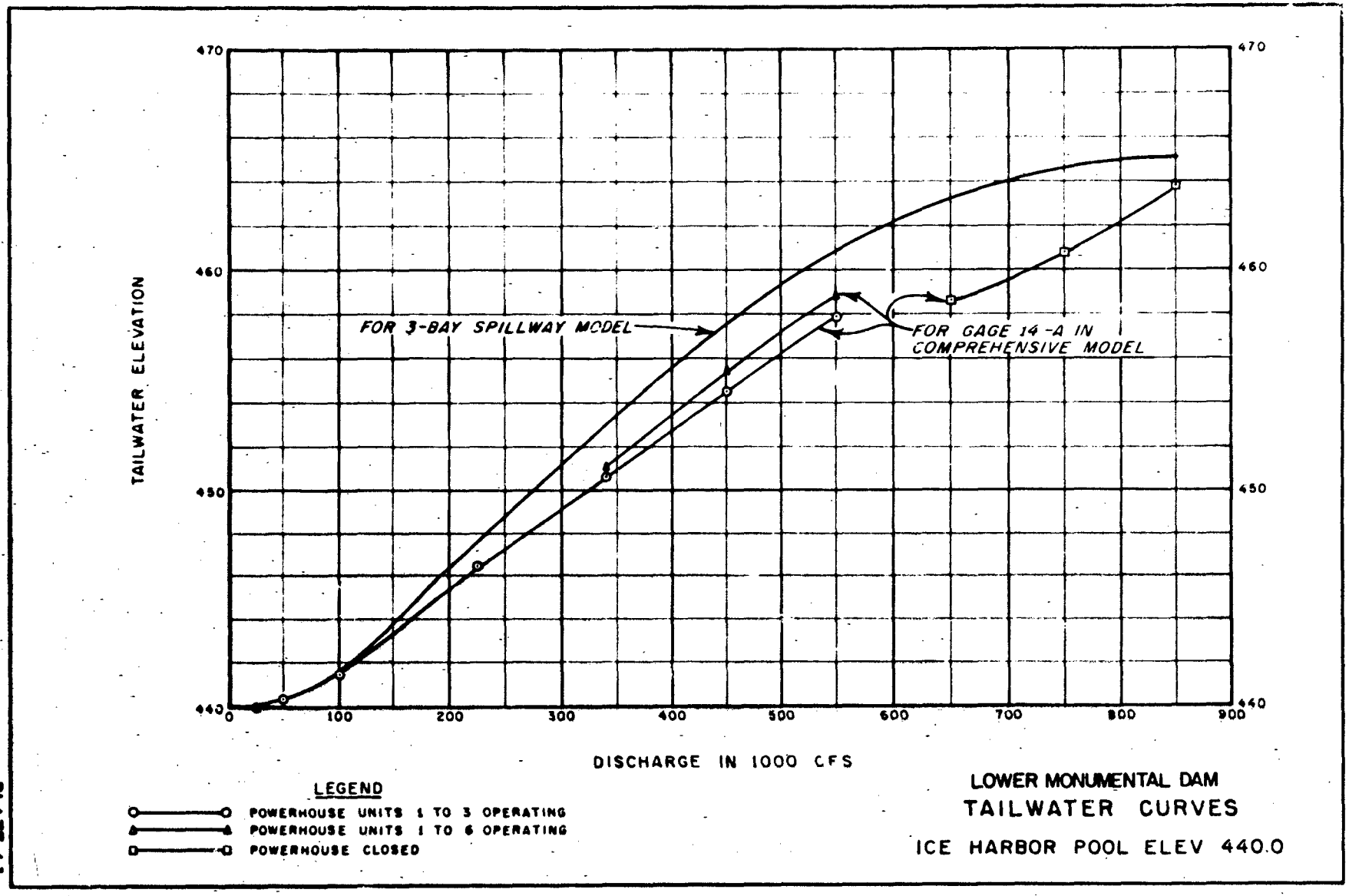


PLATE 61

LOWER MONUMENTAL DAM
TAILWATER CURVES
ICE HARBOR POOL ELEV 440.0

REPRODUCED AT GOVERNMENT EXPENSE

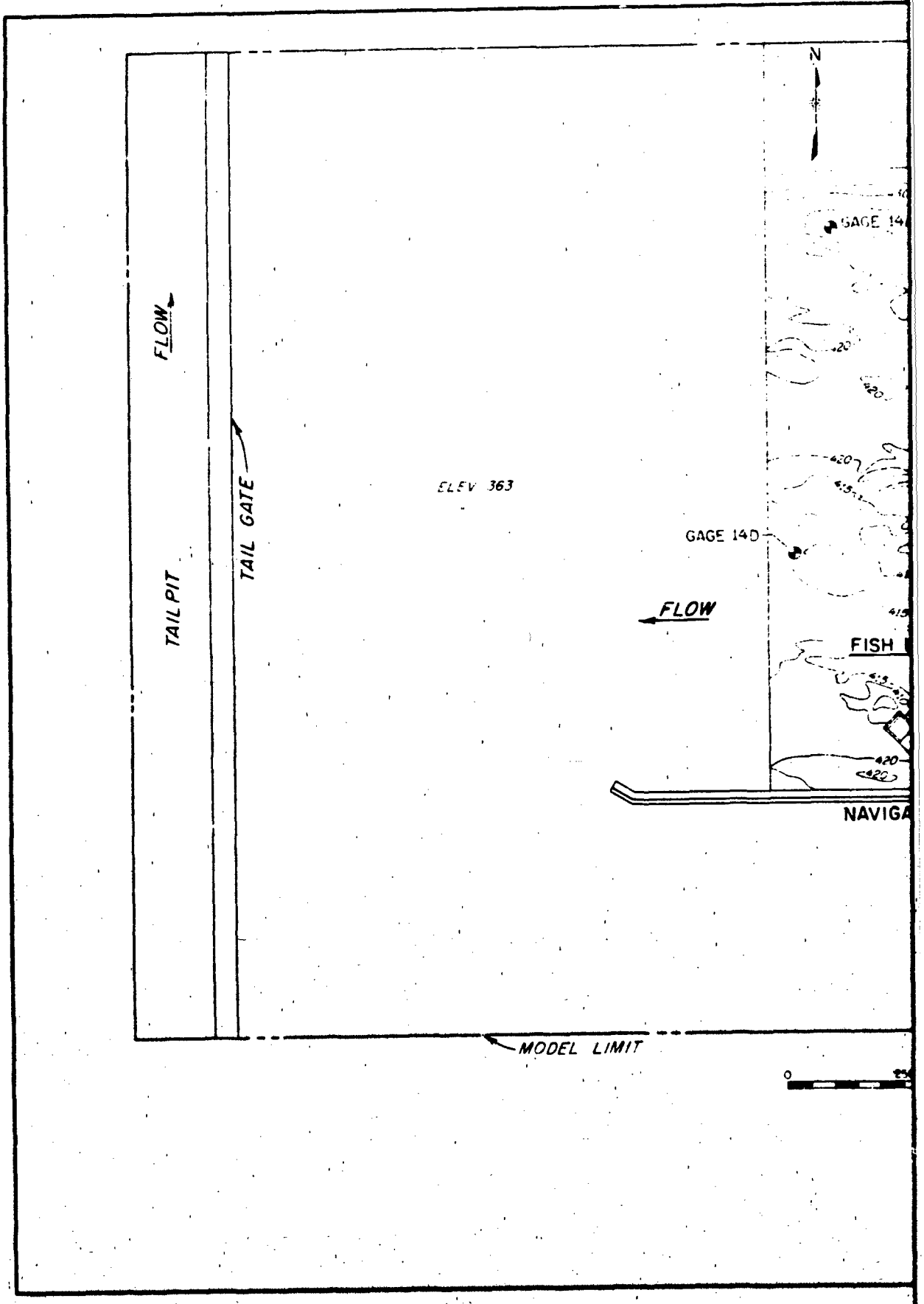
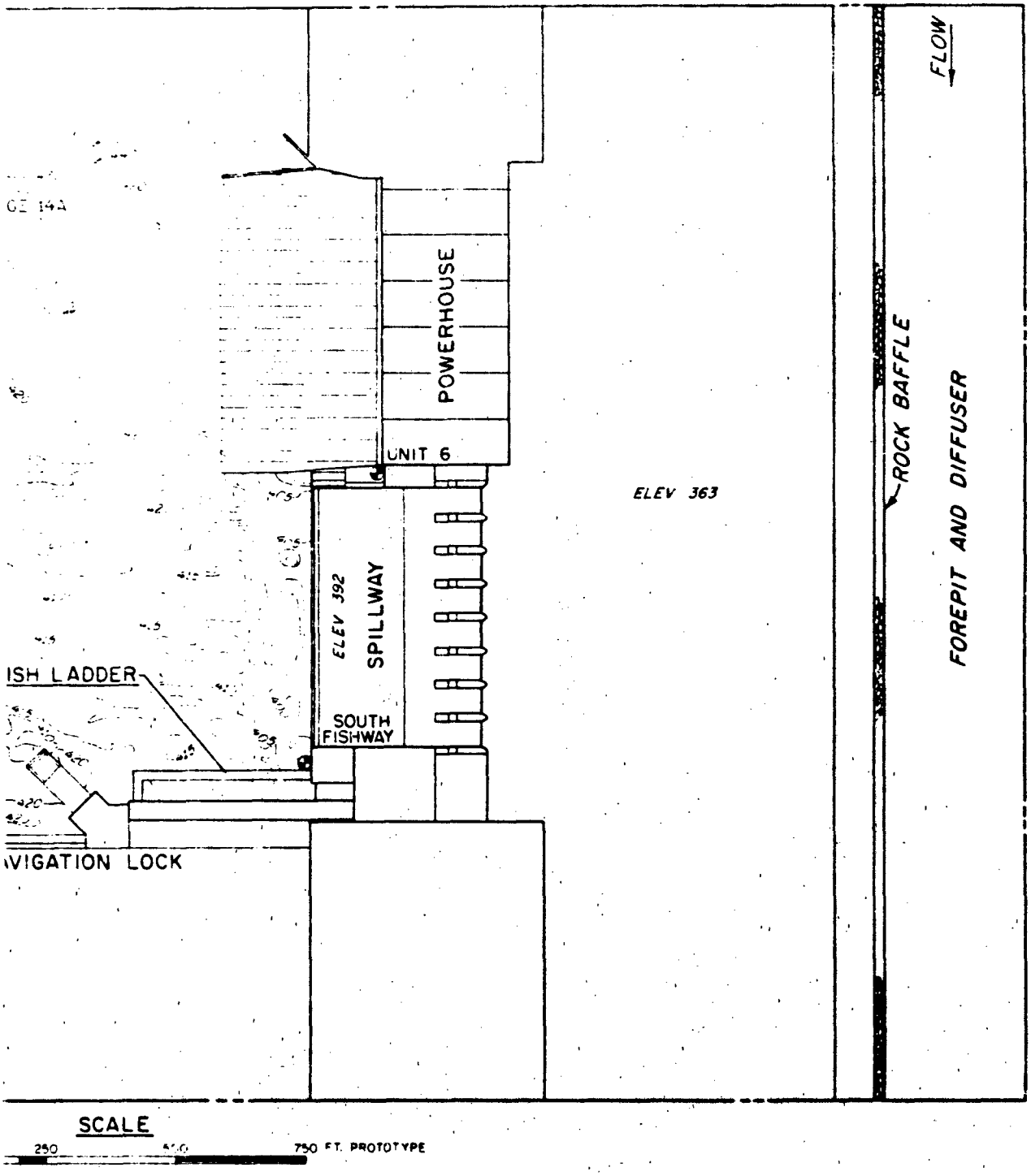


Plate 62

14 (2)

REPRODUCED AT GOVERNMENT EXPENSE

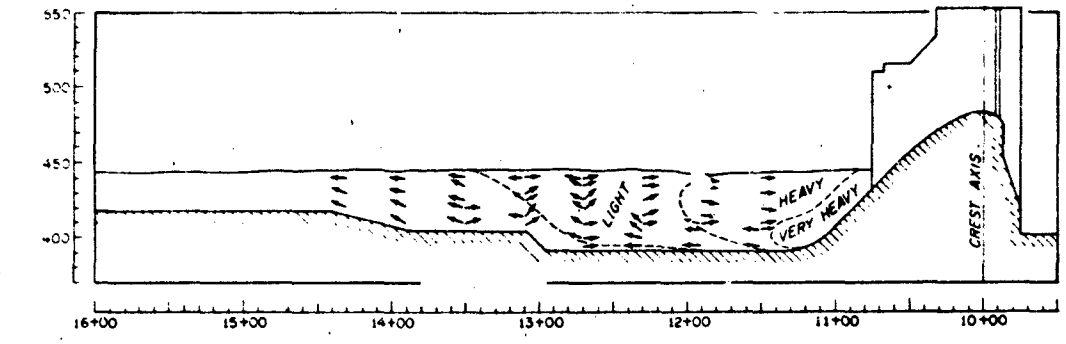


LOWER MONUMENTAL DAM

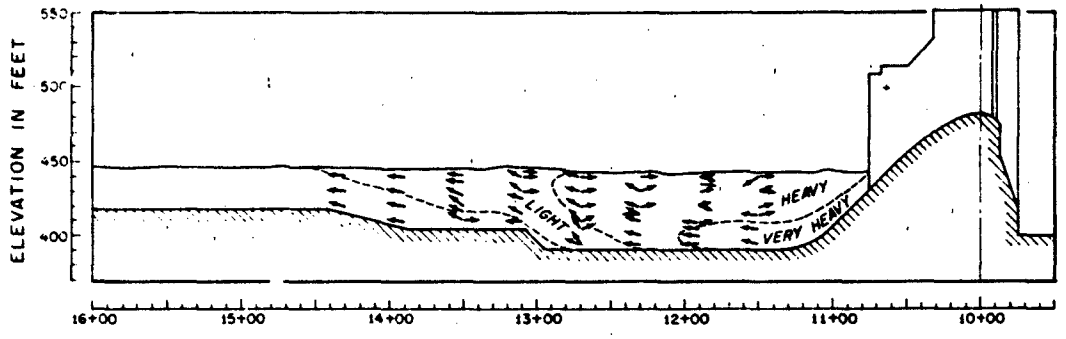
1:50 SCALE COMPREHENSIVE MODEL

PLATE 62

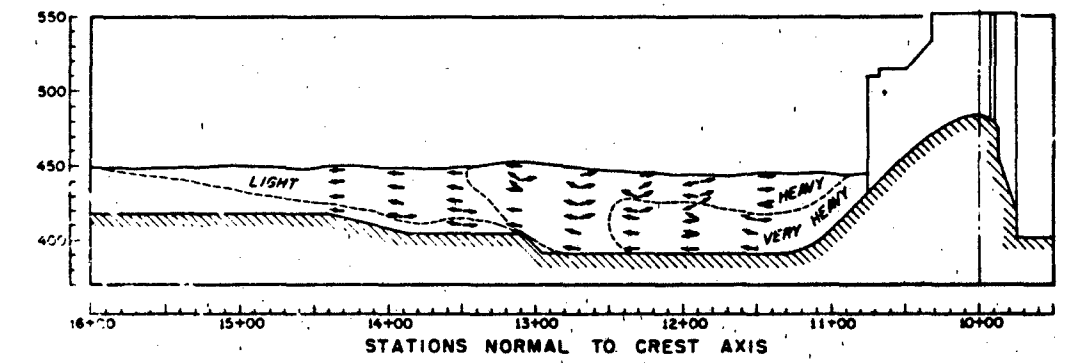
Def 2



DISCHARGE PER BAY 5 175 CFS



DISCHARGE PER BAY 10 060 CFS



DISCHARGE PER BAY 15 000 CFS

LEGEND

--------- ZONES OF AERATION

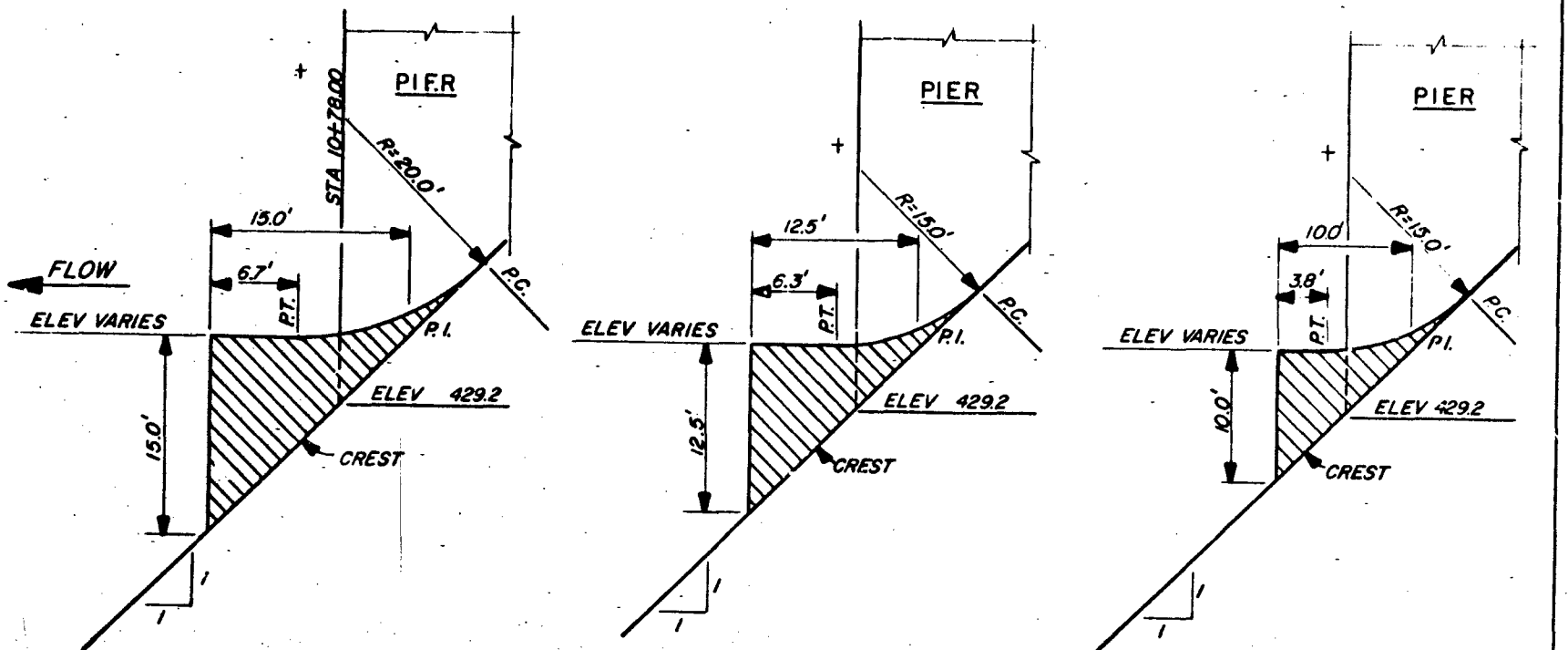
NOTE

SPILLWAY DETAILS SHOWN ON PLATE 59.

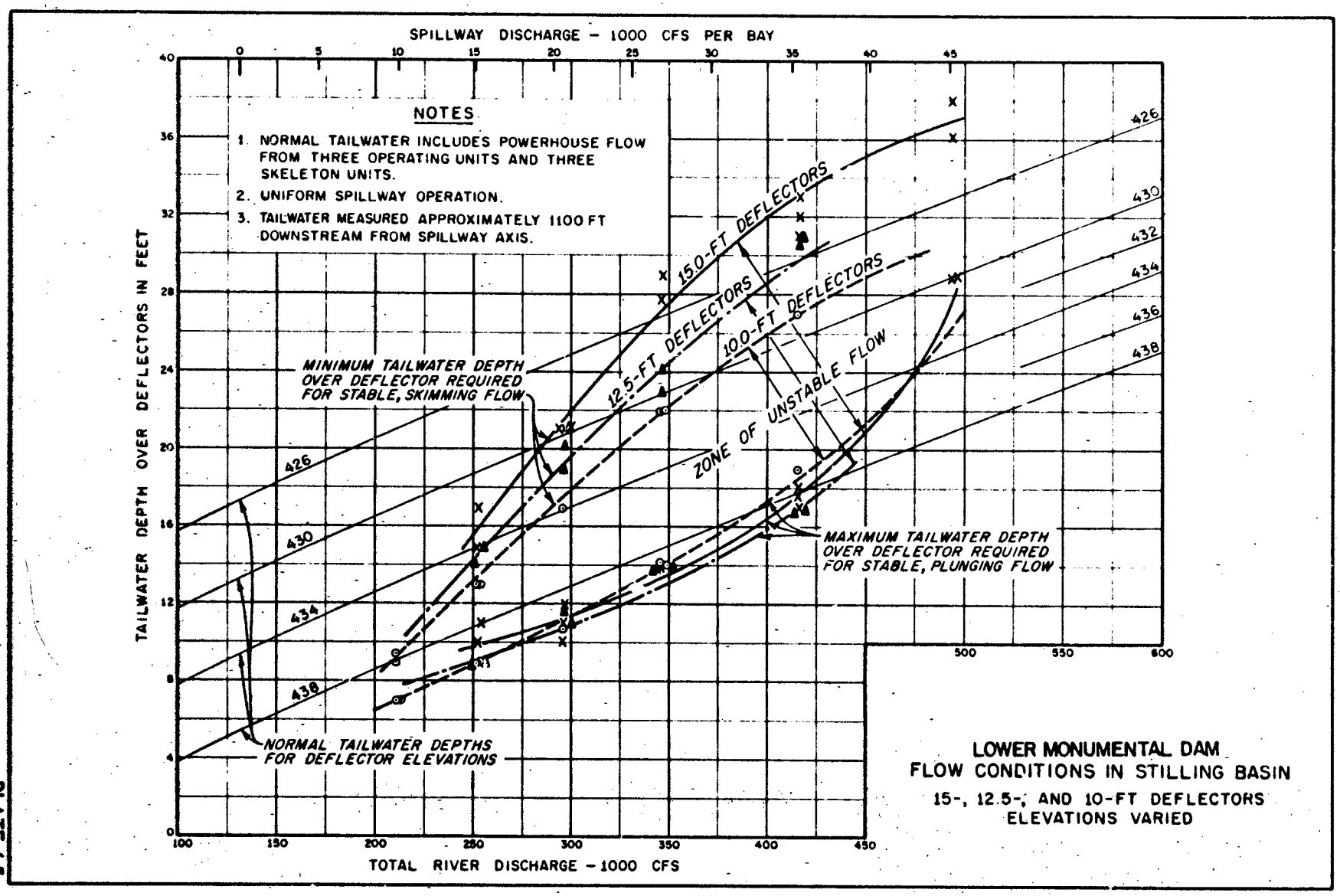
LOWER MONUMENTAL DAM
AERATION AND FLOW DIRECTIONS
IN EXISTING STILLING BASIN

PLATE 63

PLATE 64

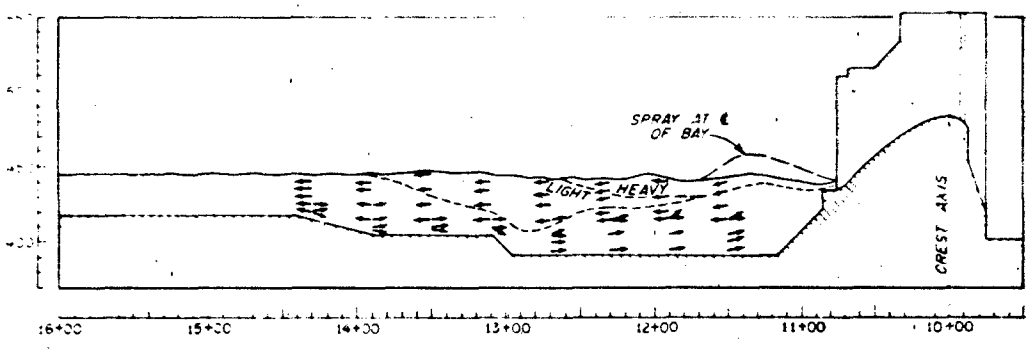


LOWER MONUMENTAL DAM
SPILLWAY DEFLECTORS
15-, 12.5-, AND 10-FT LENGTHS

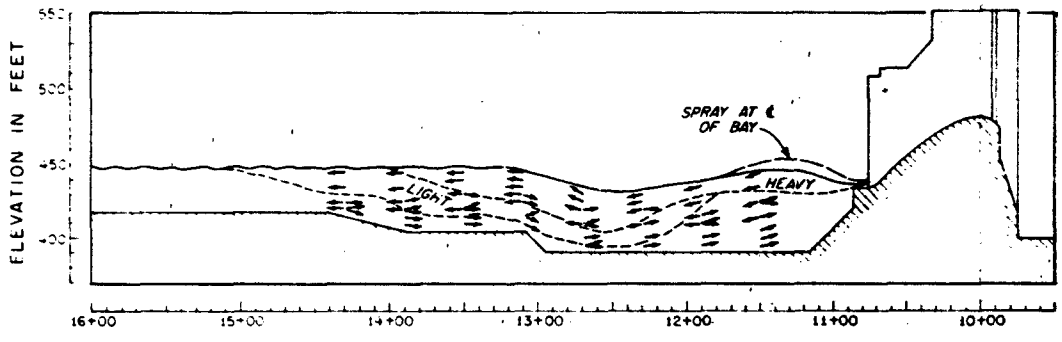


LOWER MONUMENTAL DAM
FLOW CONDITIONS IN STILLING BASIN
15-, 12.5-, AND 10-FT DEFLECTORS
ELEVATIONS VARIED

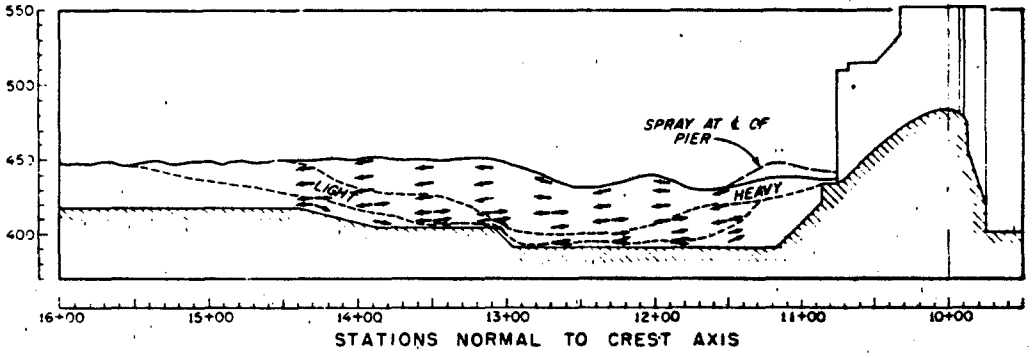
PLATE 65



DISCHARGE PER BAY 5175 CFS



DISCHARGE PER BAY 10060 CFS



DISCHARGE PER BAY 15000 CFS

LEGEND

---------- ZONES OF AERATION

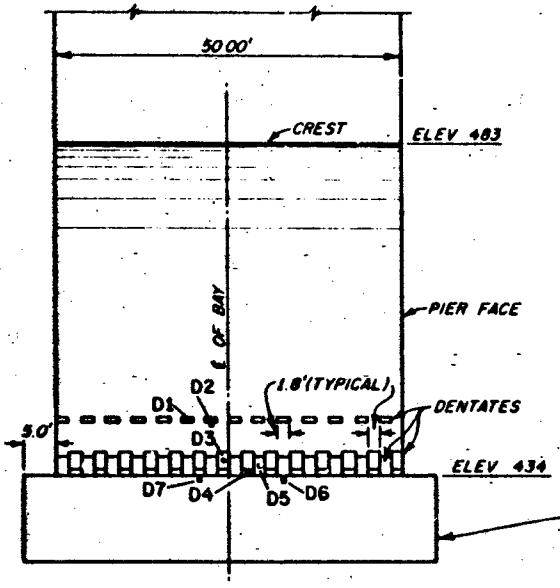
NOTE

DETAILS OF DEFLECTORS SHOWN ON PLATE 3.

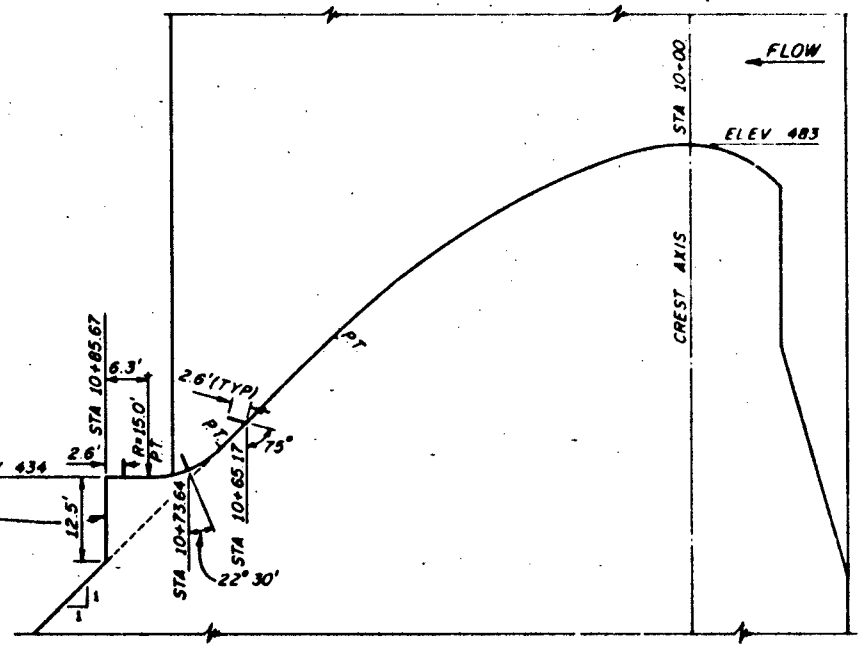
LOWER MONUMENTAL DAM
AERATION AND FLOW DIRECTIONS IN STILLING BASIN

±2.5-FT DEFLECTORS AT ELEV 434

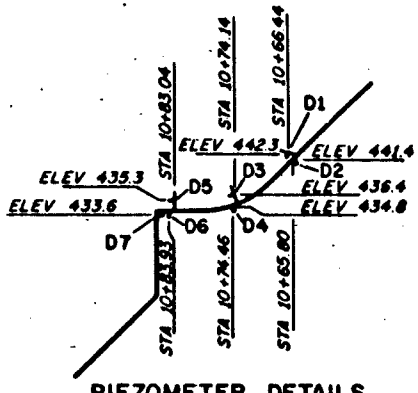
PLATE 66



DOWNSTREAM ELEVATION



SIDE ELEVATION

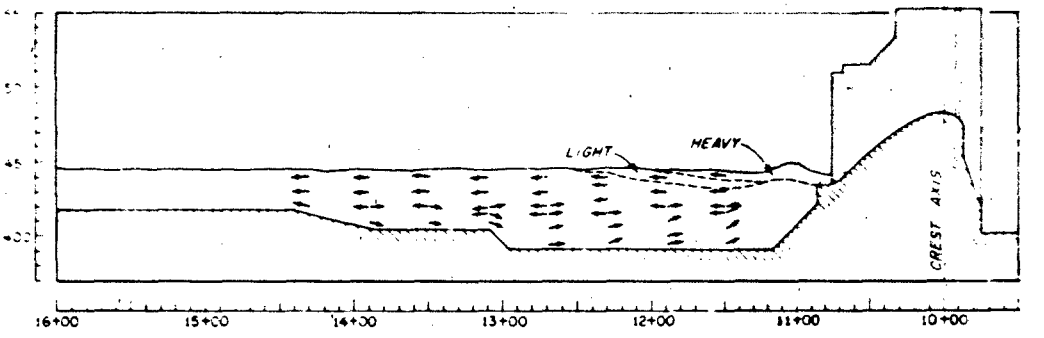


PIEZOMETER DETAILS

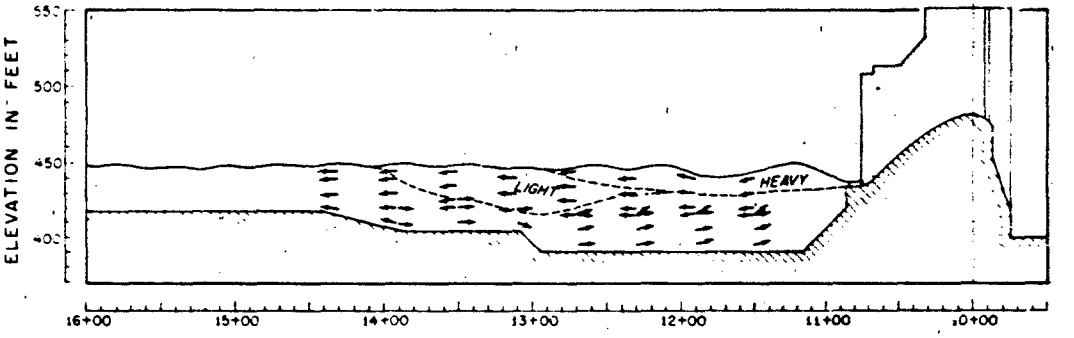
LOWER MONUMENTAL DAM
DETAILS AND PIEZOMETER LOCATIONS

12.5-FT DEFLECTORS AT ELEV 434
PLAN H DENTATES

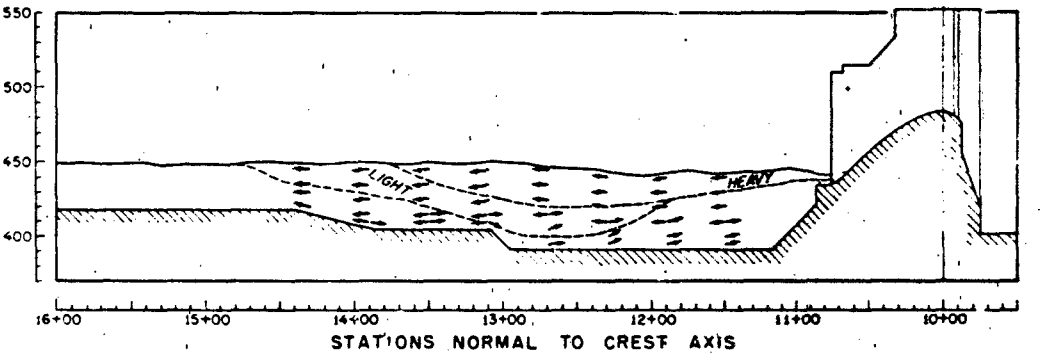
PLATE 67



DISCHARGE PER BAY 5 175 CFS



DISCHARGE PER BAY 10 060 CFS



DISCHARGE PER BAY 15 000 CFS

LEGEND

---------- ZONES OF AERATION

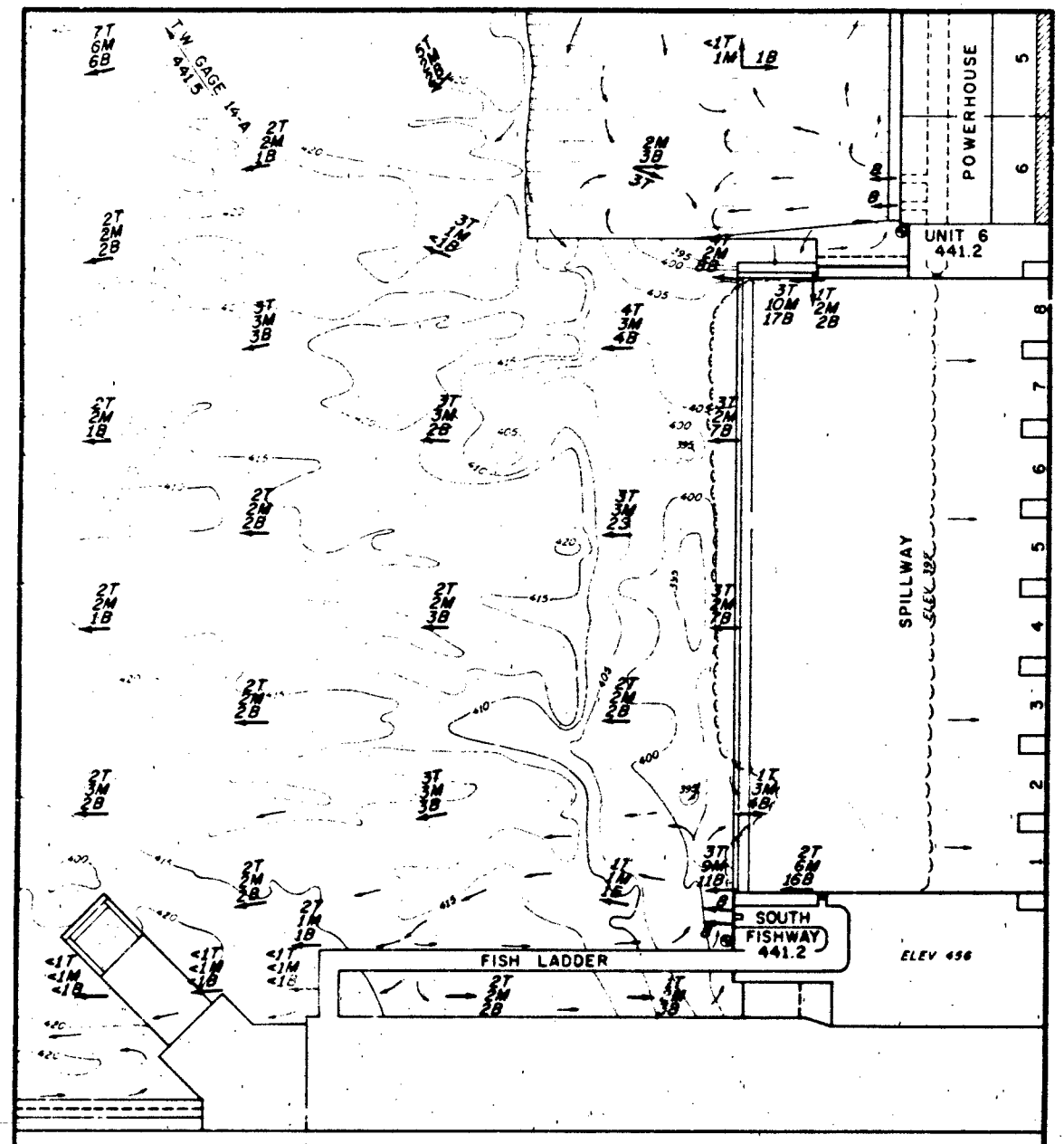
NOTE

DETAILS OF DENTATE PLAN H SHOWN ON PLATE 9

LOWER MONUMENTAL DAM
AERATION AND FLOW DIRECTIONS IN STILLING BASIN

12.5-FT DEFLECTORS AT ELEV 434
PLAN H DENTATES

PLATE 68



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 200 FT

UNIFORM SPILLWAY OPERATION

WITHOUT DEFLECTORS

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	64 650 CFS
SPILLWAY BAYS 1 TO 8	35 200 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	654 CFS

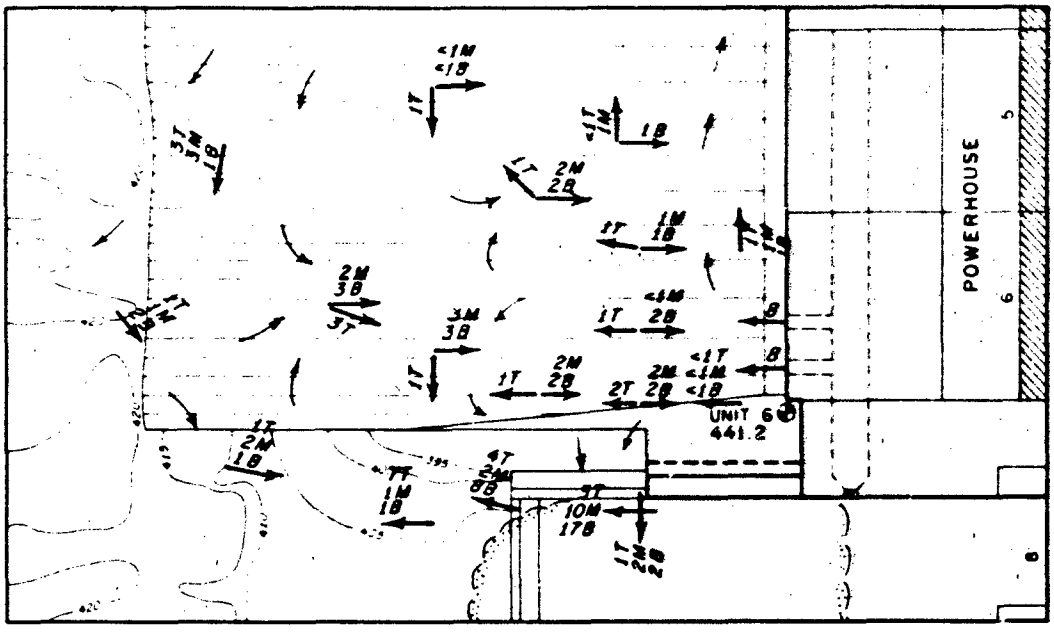
LOWER MONUMENTAL DAM

FLOW CONDITIONS

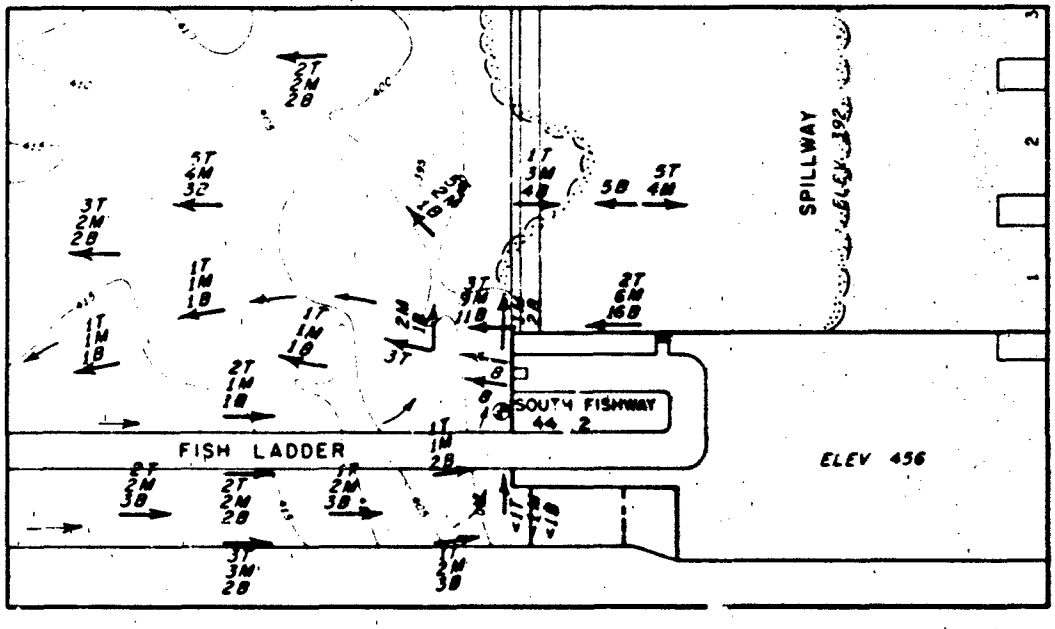
RIVER DISCHARGE 100 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 69



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- 4 VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 FT

LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
WITHOUT DEFLECTORS

FLOW CONDITIONS
AT FISHWAY ENTRANCES

RIVER DISCHARGE 100 000 CFS
POWERHOUSE UNITS 1 TO 3

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	64 650 CFS
SPILLWAY BAYS 1 TO 8	35 200 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	654 CFS

PLATE 70

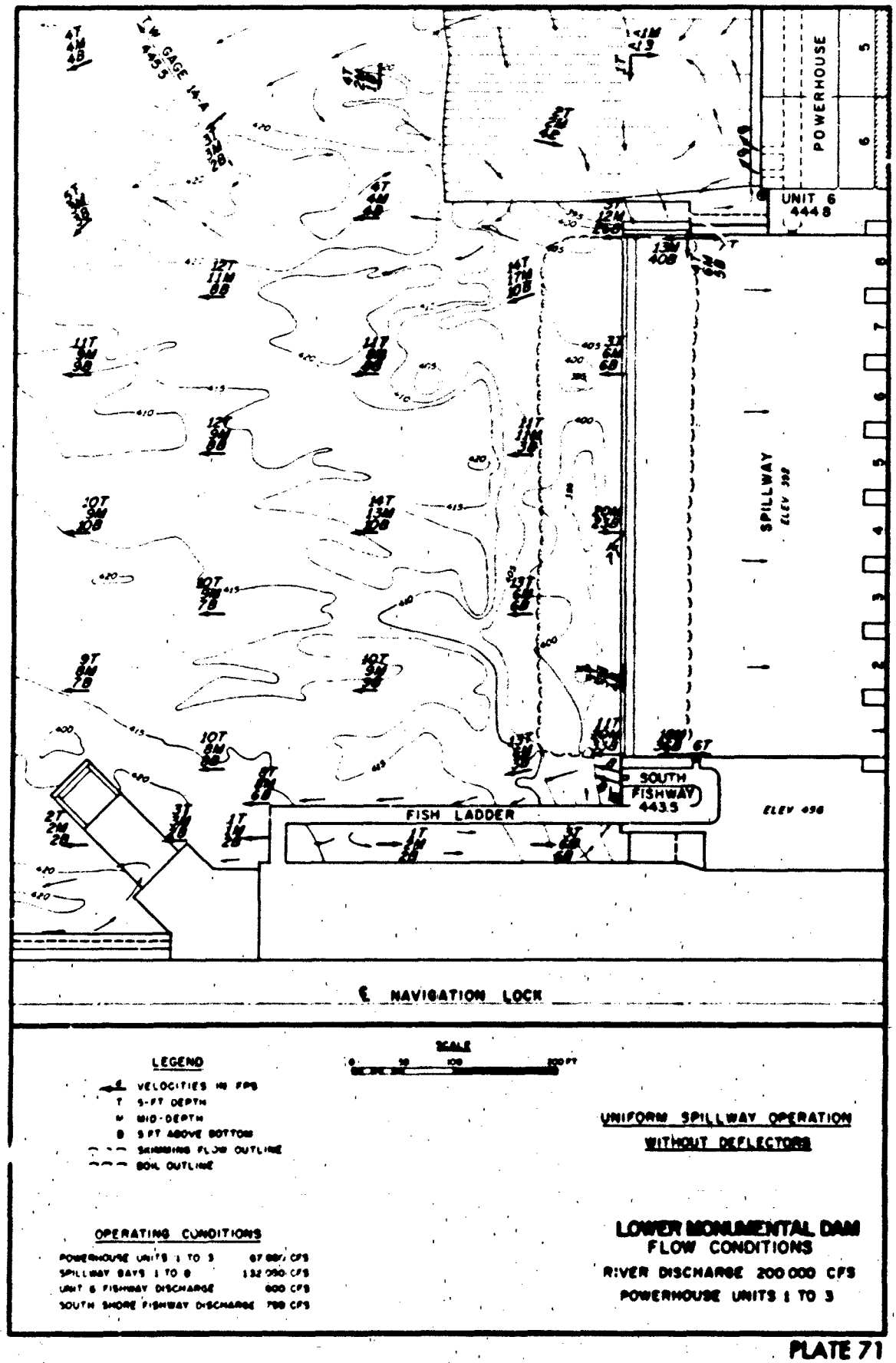
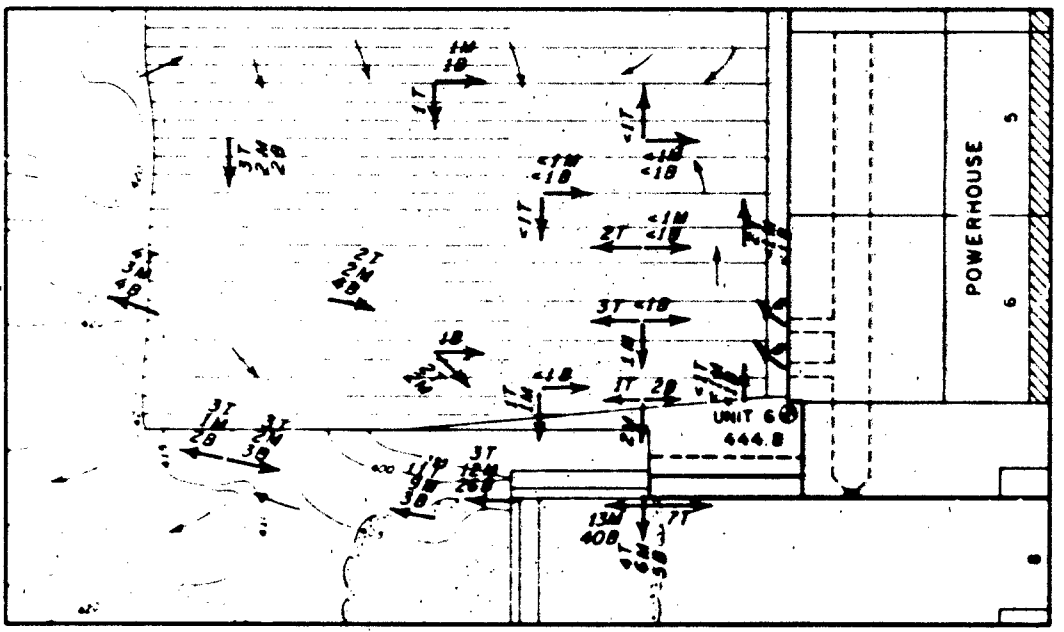
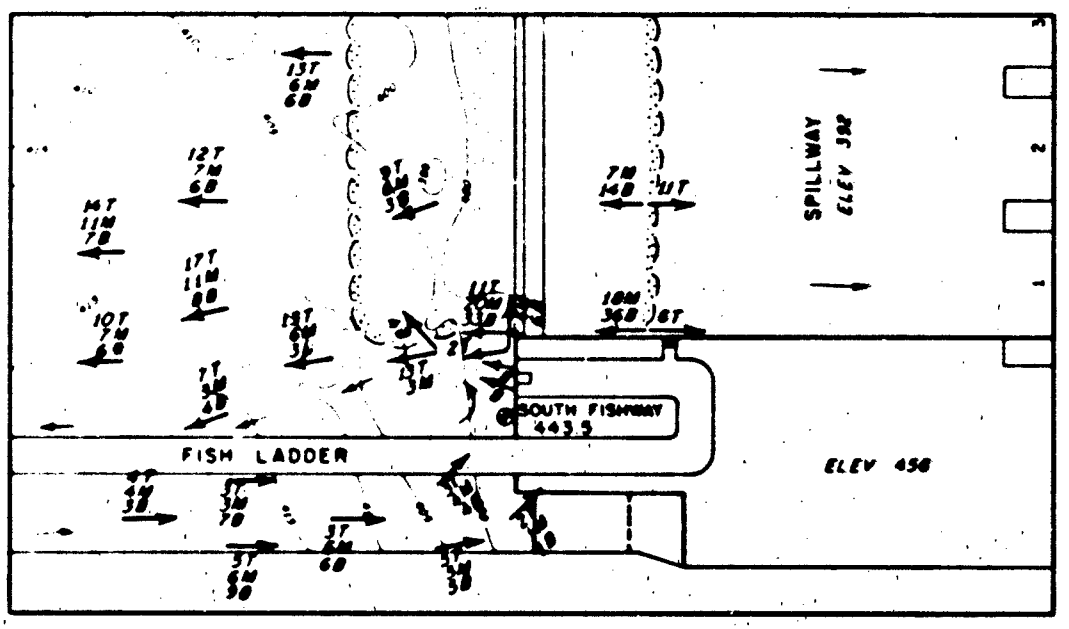

POWERHOUSE
UNIT 6
444.8
SPILLWAY
ELEV 392
SOUTH
FISHWAY
443.5
FISH LADDER
ELEV 496
℄ NAVIGATION LOCK
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
SKIMMING FLOW OUTLINE
BOIL OUTLINE
SCALE
0 50 100 200 FT
UNIFORM SPILLWAY OPERATION
WITHOUT DEFLECTORS
OPERATING CONDITIONS
POWERHOUSE UNITS 1 TO 3 87 000 CFS
SPILLWAY BAYS 1 TO 8 132 000 CFS
UNIT 6 FISHWAY DISCHARGE 600 CFS
SOUTH SHORE FISHWAY DISCHARGE 700 CFS
LOWER MONUMENTAL DAM
FLOW CONDITIONS
RIVER DISCHARGE 200 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 71



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- S FT DEPTH
- M MID DEPTH
- B 5 FT OFF BOTTOM
- SWIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	67 800 CFS
SPILLWAY BAYS 1 TO 8	132 090 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

SCALE

0 50 100 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

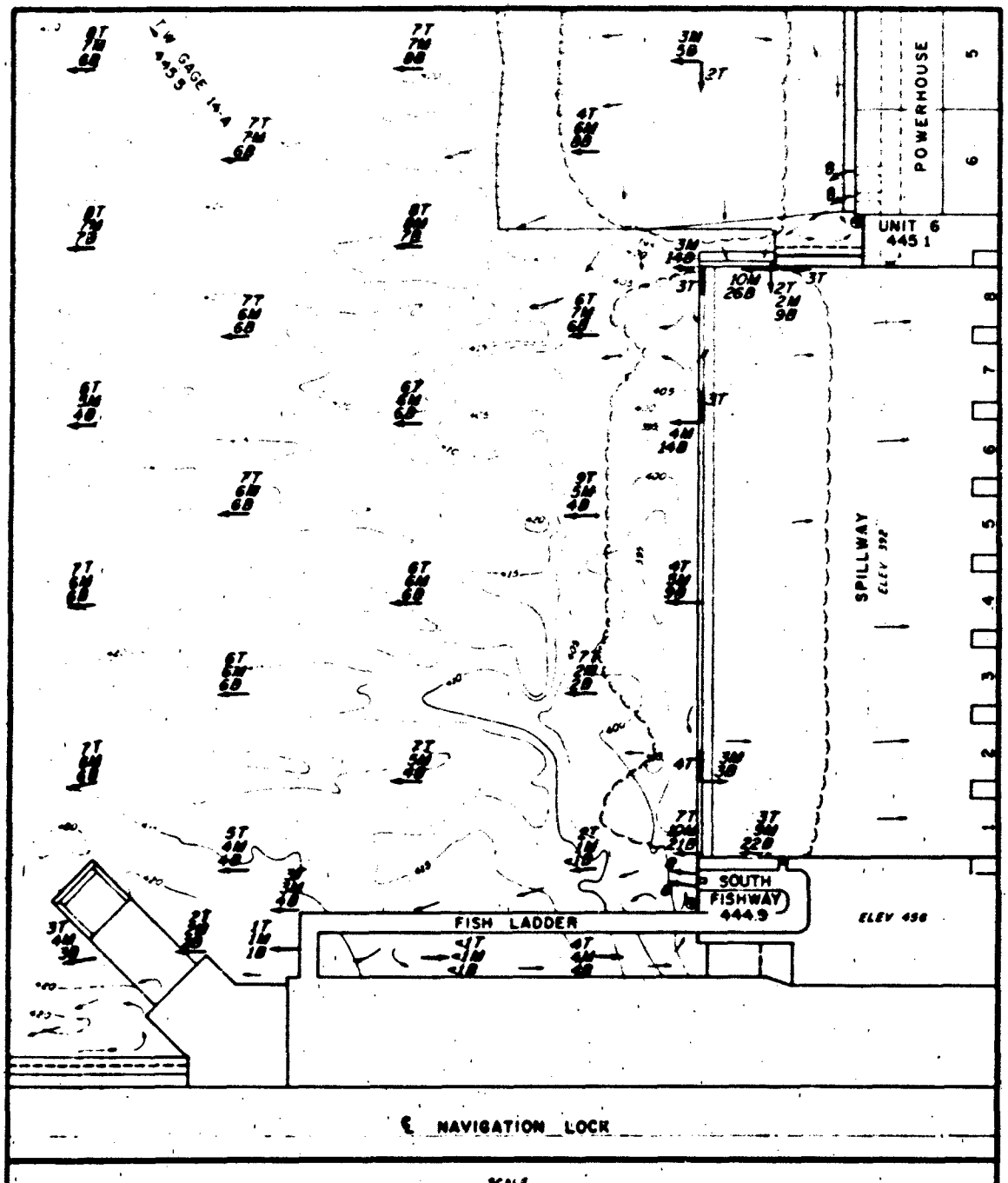
WITHOUT DEFLECTORS

FLOW CONDITIONS AT FISHWAY ENTRANCES

RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 72



SCALE
0 50 100 200 FT

LEGEND

- VELOCITIES IN FPS
- T 5 FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SHIMMERING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 800 CFS
SPILLWAY BAYS 1 TO 8	63 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	700 CFS

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

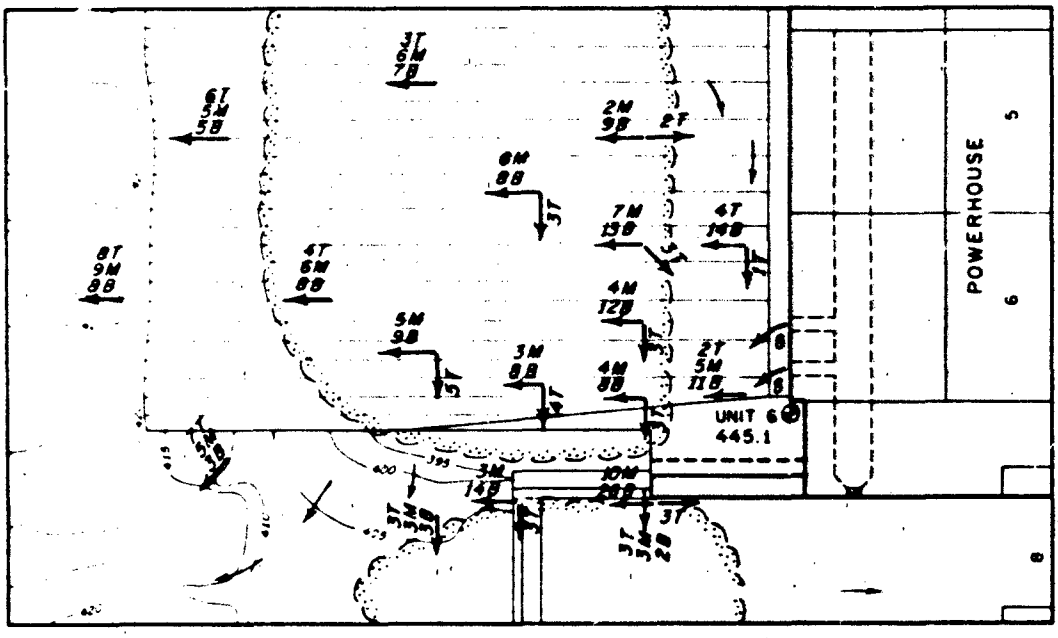
WITHOUT DEFLECTORS

FLOW CONDITIONS

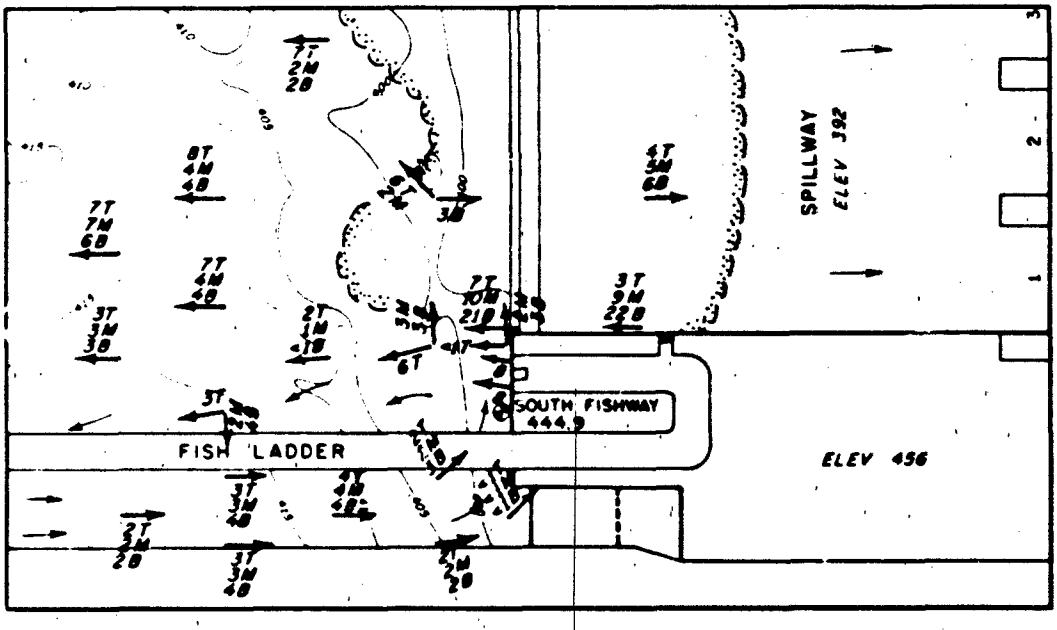
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 6

PLATE 73



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- 4 — VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE 0 50 100 FT

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 800 CFS
SPILLWAY BAYS 1 TO 9	63 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
WITHOUT DEFLECTORS

FLOW CONDITIONS
AT FISHWAY ENTRANCES

RIVER DISCHARGE 200 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 74

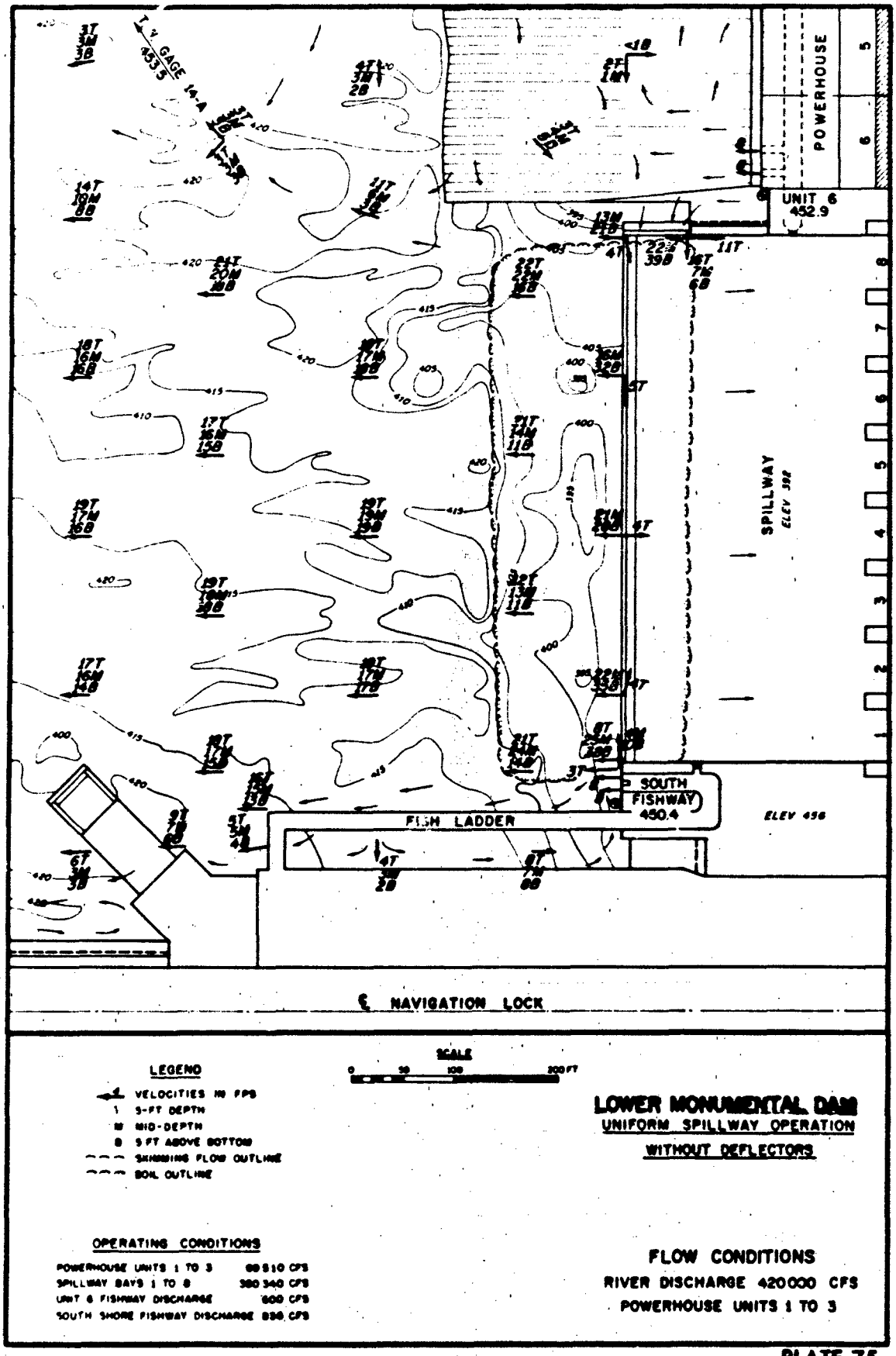

POWERHOUSE
UNIT 6
452.9
SPILLWAY
ELEV 396
SOUTH
FISHWAY
450.4
ELEV 456
FISH LADDER
T.V. GAGE 14-A
453.5
℄ NAVIGATION LOCK
LEGEND
VELOCITIES IN FPS
5-FT DEPTH
MID-DEPTH
5 FT ABOVE BOTTOM
SKIMMING FLOW OUTLINE
BOIL OUTLINE
SCALE
0 50 100 200 FT
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
WITHOUT DEFLECTORS
OPERATING CONDITIONS
POWERHOUSE UNITS 1 TO 3 69 510 CFS
SPILLWAY BAYS 1 TO 8 350 340 CFS
UNIT 6 FISHWAY DISCHARGE 600 CFS
SOUTH SHORE FISHWAY DISCHARGE 850 CFS
FLOW CONDITIONS
RIVER DISCHARGE 420000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 75

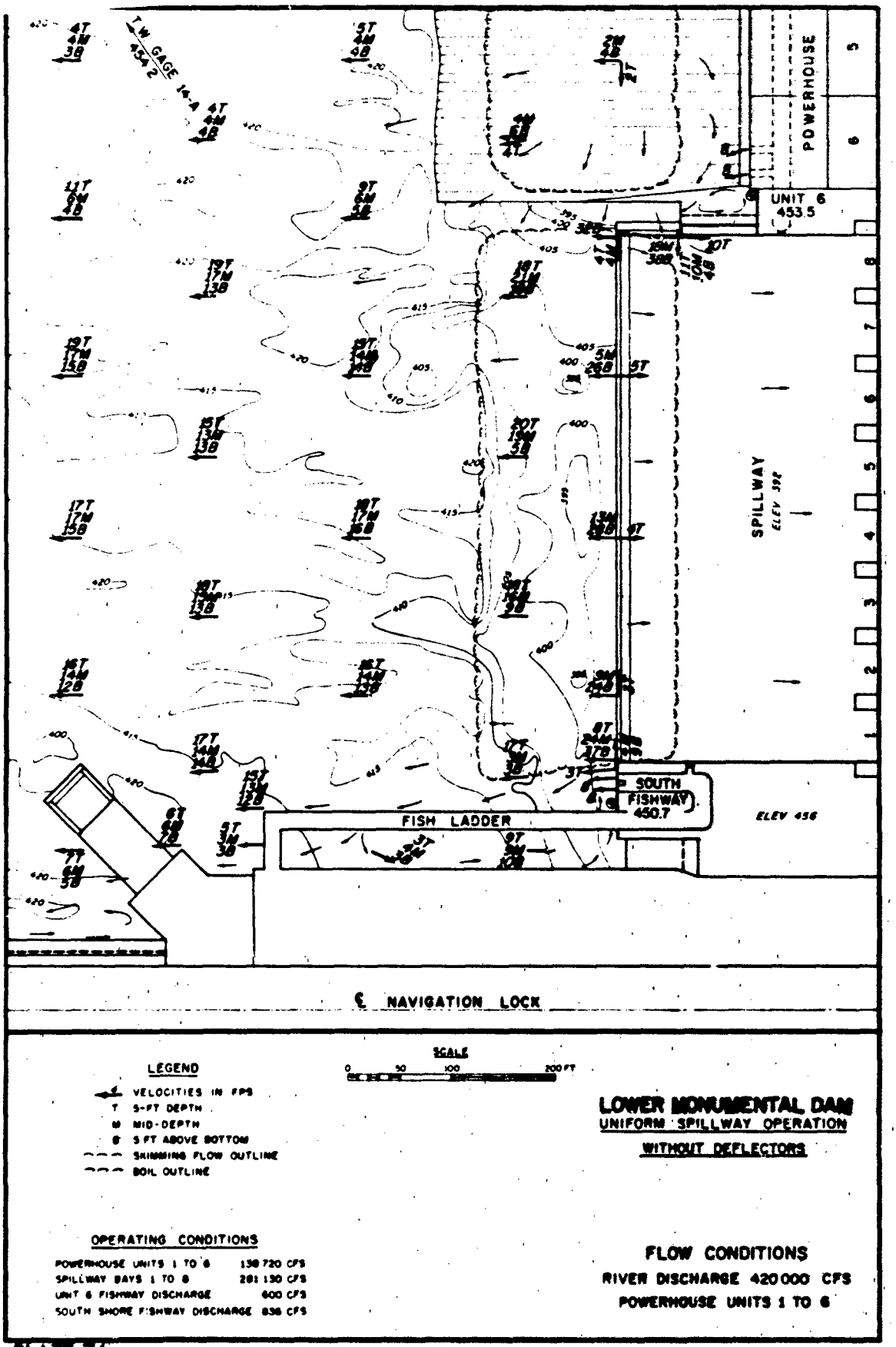
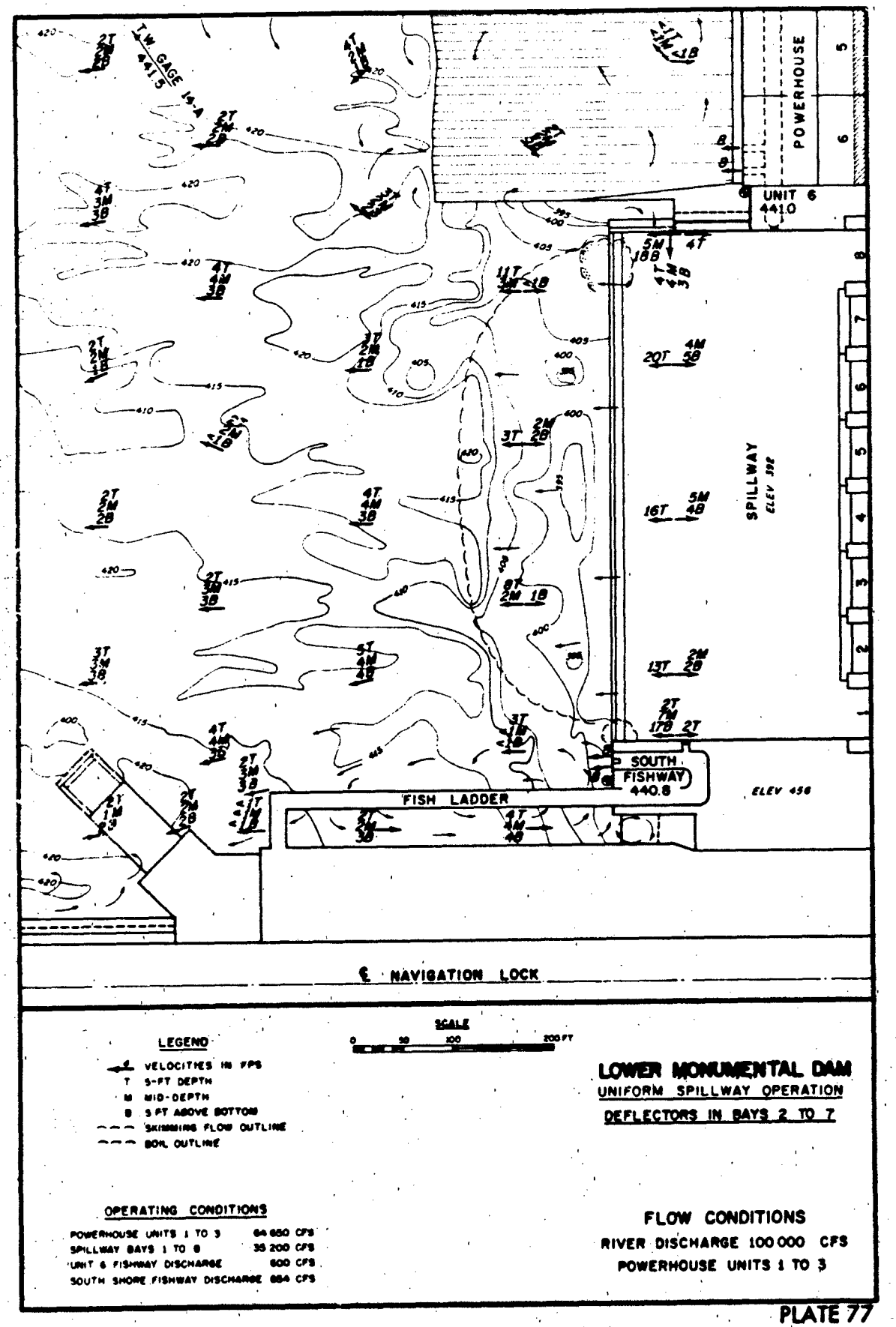

TW GAGE 14-A
454.2
POWERHOUSE
UNIT 6
453.5
SPILLWAY
ELEV 392
SOUTH
FISHWAY
450.7
FISH LADDER
ELEV 456
℄ NAVIGATION LOCK
SCALE
0 50 100 200 FT
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
SKIMMING FLOW OUTLINE
BOHL OUTLINE
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
WITHOUT DEFLECTORS
OPERATING CONDITIONS
POWERHOUSE UNITS 1 TO 6 138 720 CFS
SPILLWAY BAYS 1 TO 8 281 130 CFS
UNIT 6 FISHWAY DISCHARGE 600 CFS
SOUTH SHORE FISHWAY DISCHARGE 838 CFS
FLOW CONDITIONS
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 76



SCALE
0 50 100 200 FT

LEGEND
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

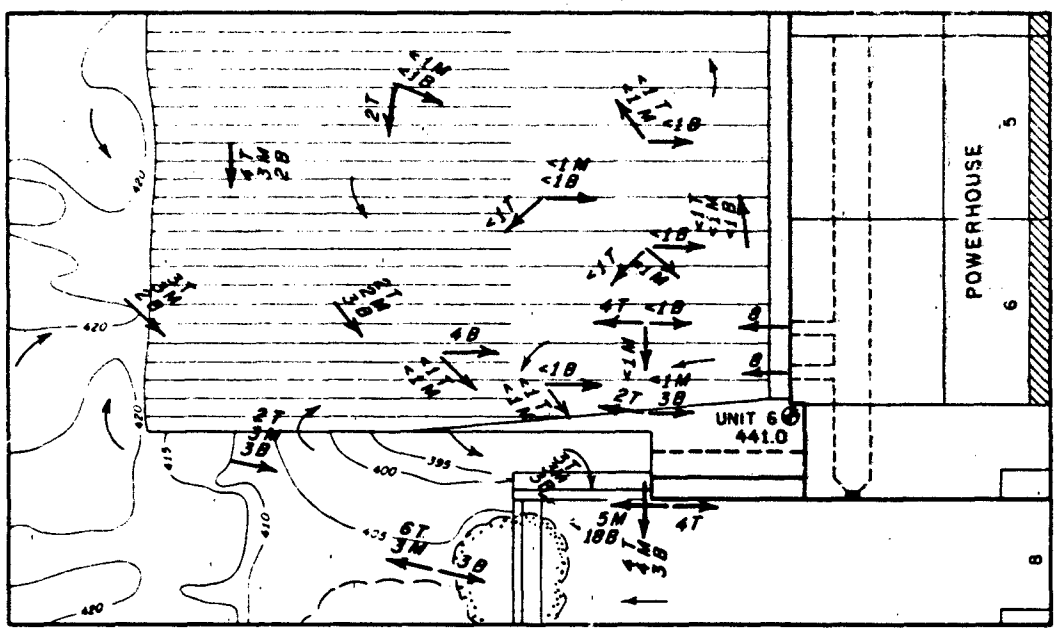
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 2 TO 7

OPERATING CONDITIONS

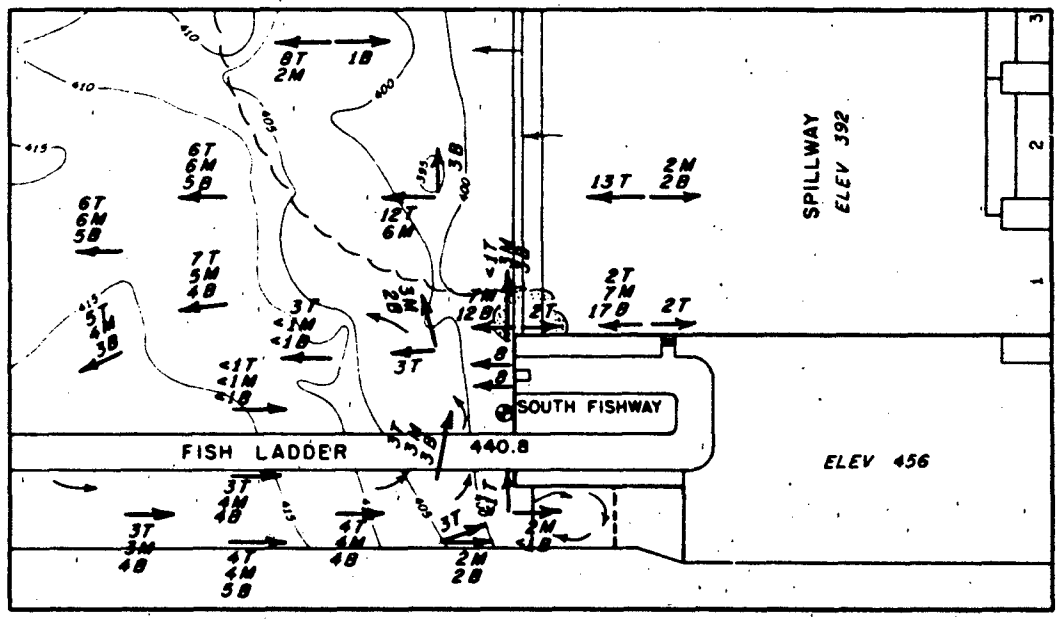
POWERHOUSE UNITS 1 TO 3	64 650 CFS
SPILLWAY BAYS 1 TO 8	35 200 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	664 CFS

FLOW CONDITIONS
RIVER DISCHARGE 100 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 77



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- 4 ← VELOCITIES IN FPS
- T 5-FT. DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE 0 50 100 FT

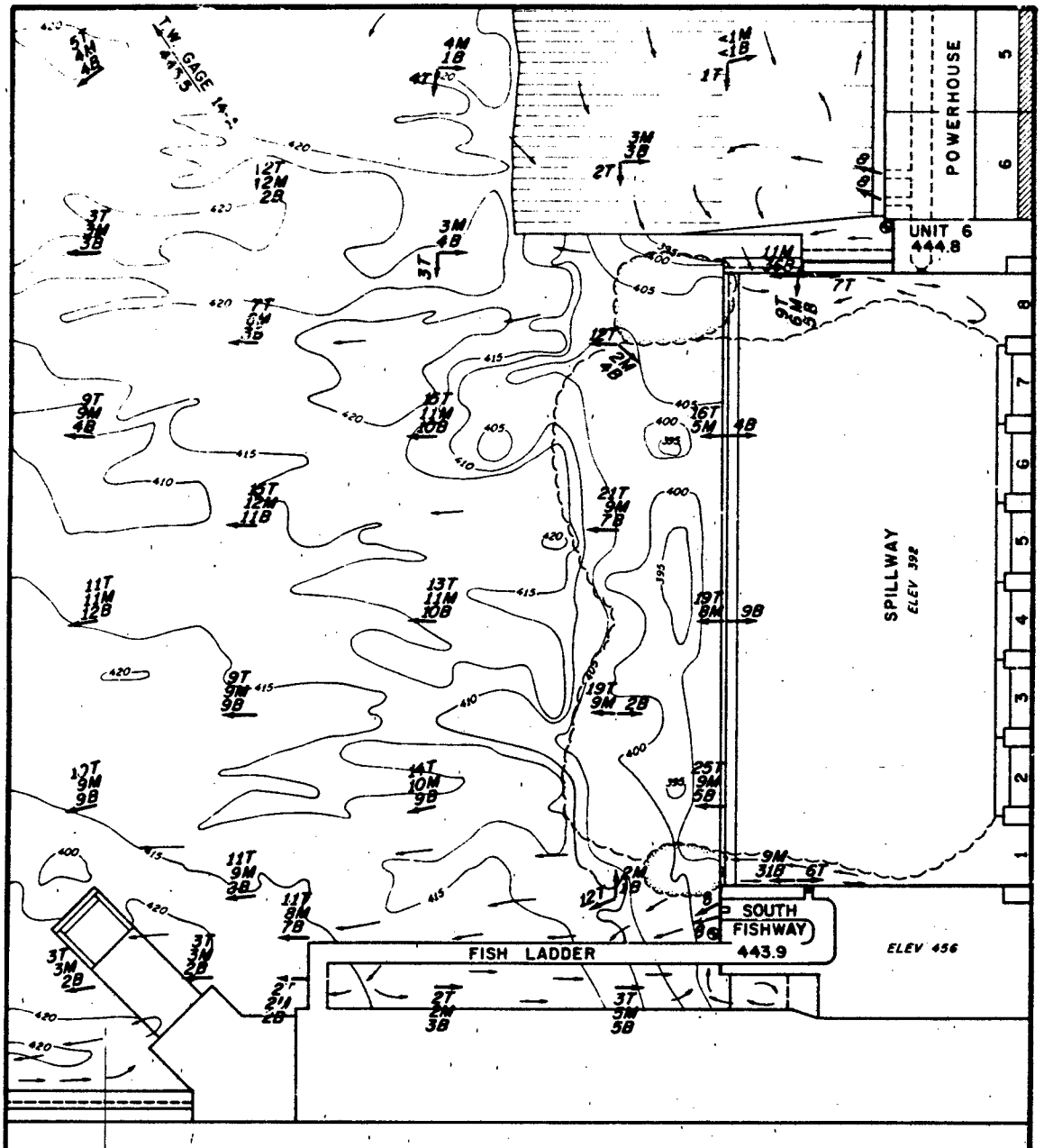
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 2 TO 7

FLOW CONDITIONS
AT FISHWAY ENTRANCES
RIVER DISCHARGE 100 000 CFS
POWERHOUSE UNITS 1 TO 3

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	64 650 CFS
SPILLWAY BAYS 1 TO 8	35 200 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	654 CFS

PLATE 78



SCALE
0 50 100 200 FT

LEGEND
- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

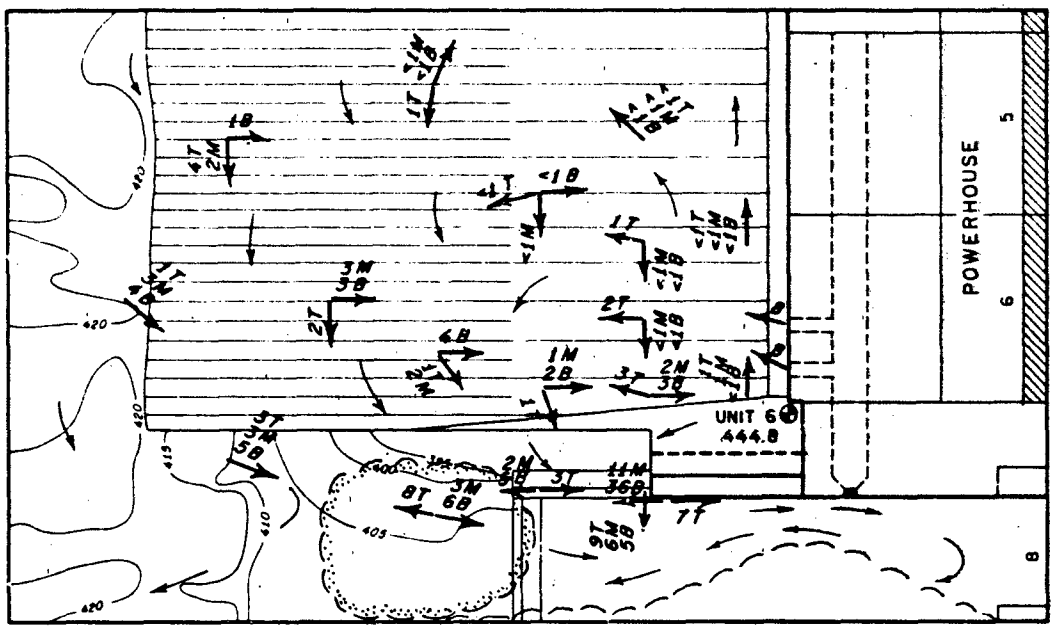
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 2 TO 7

OPERATING CONDITIONS

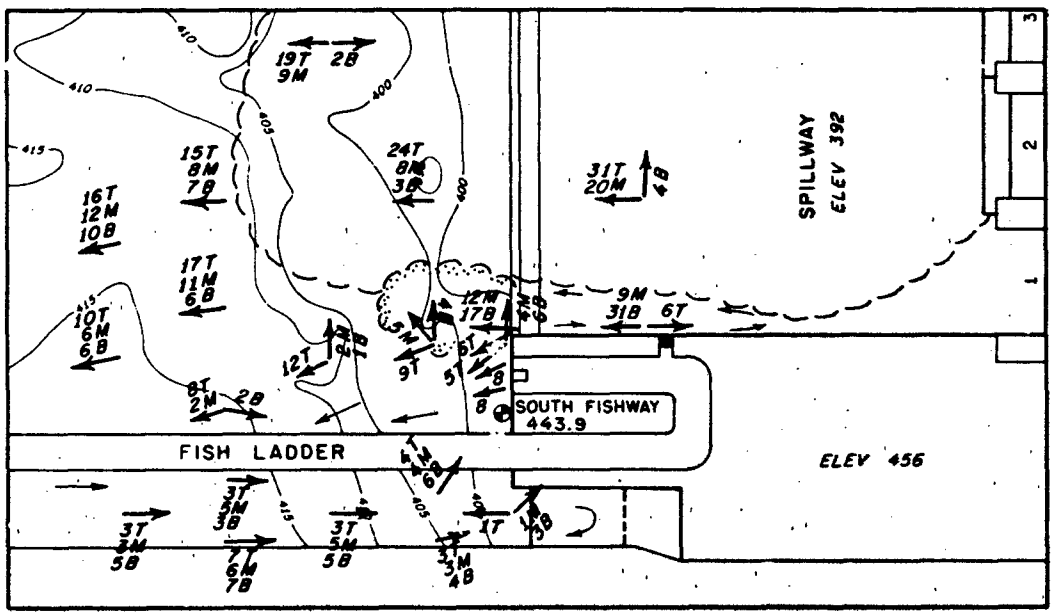
POWERHOUSE, UNITS 1 TO 3	67 800 CFS
SPILLWAY BAYS 1 TO 8	132 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

FLOW CONDITIONS
RIVER DISCHARGE 200 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 79



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- 4 VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE 0 50 100 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 2 TO 7

FLOW CONDITIONS AT FISHWAY ENTRANCES

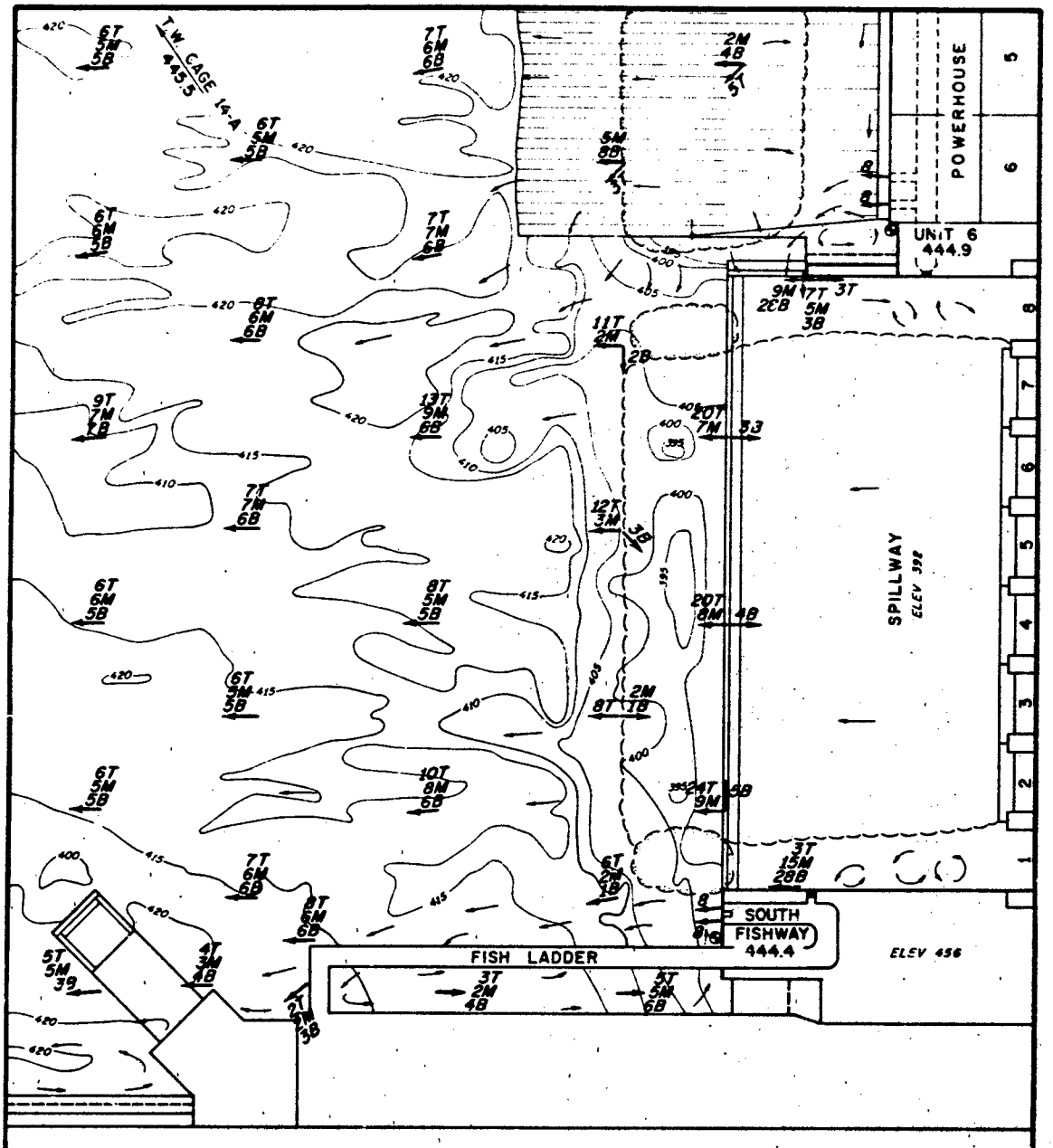
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 3

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	67 800 CFS
SPILLWAY BAYS 1 TO 8	132 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

PLATE 80



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 200 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 2 TO 7

OPERATING CONDITIONS

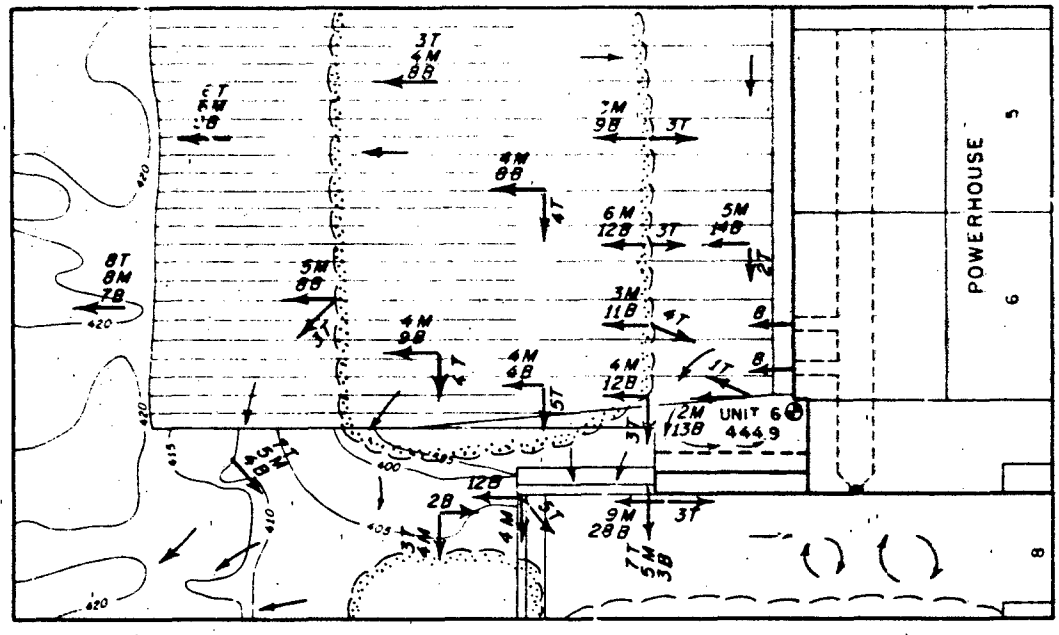
POWERHOUSE UNITS 1 TO 6	136 800 CFS
SPILLWAY BAYS 1 TO 8	63 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

FLOW CONDITIONS

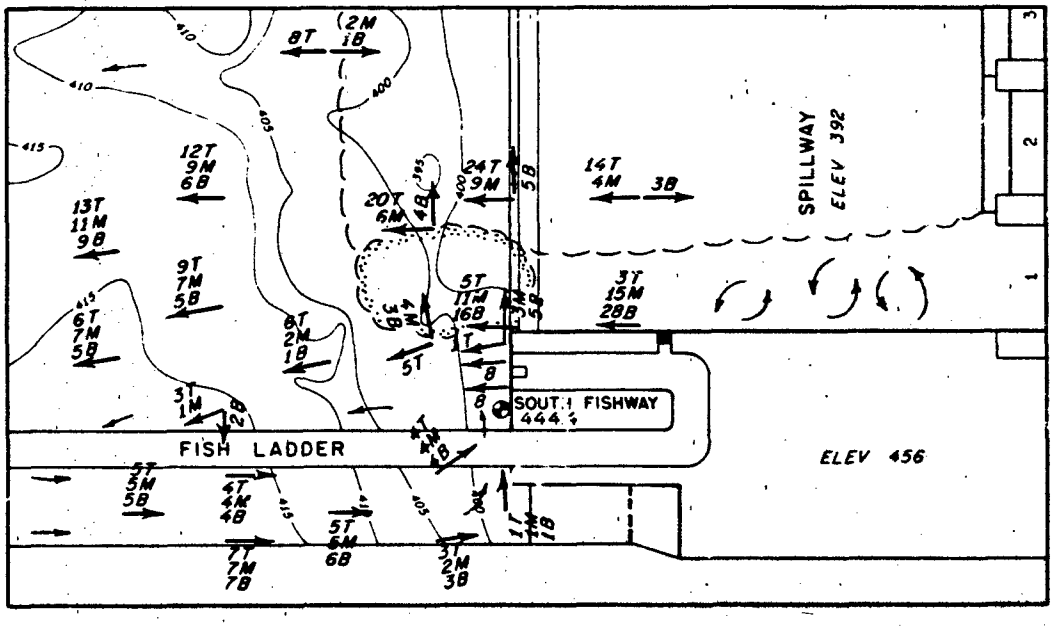
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 6

PLATE 81



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- 4 ← VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 2 TO 7

FLOW CONDITIONS AT FISHWAY ENTRANCES

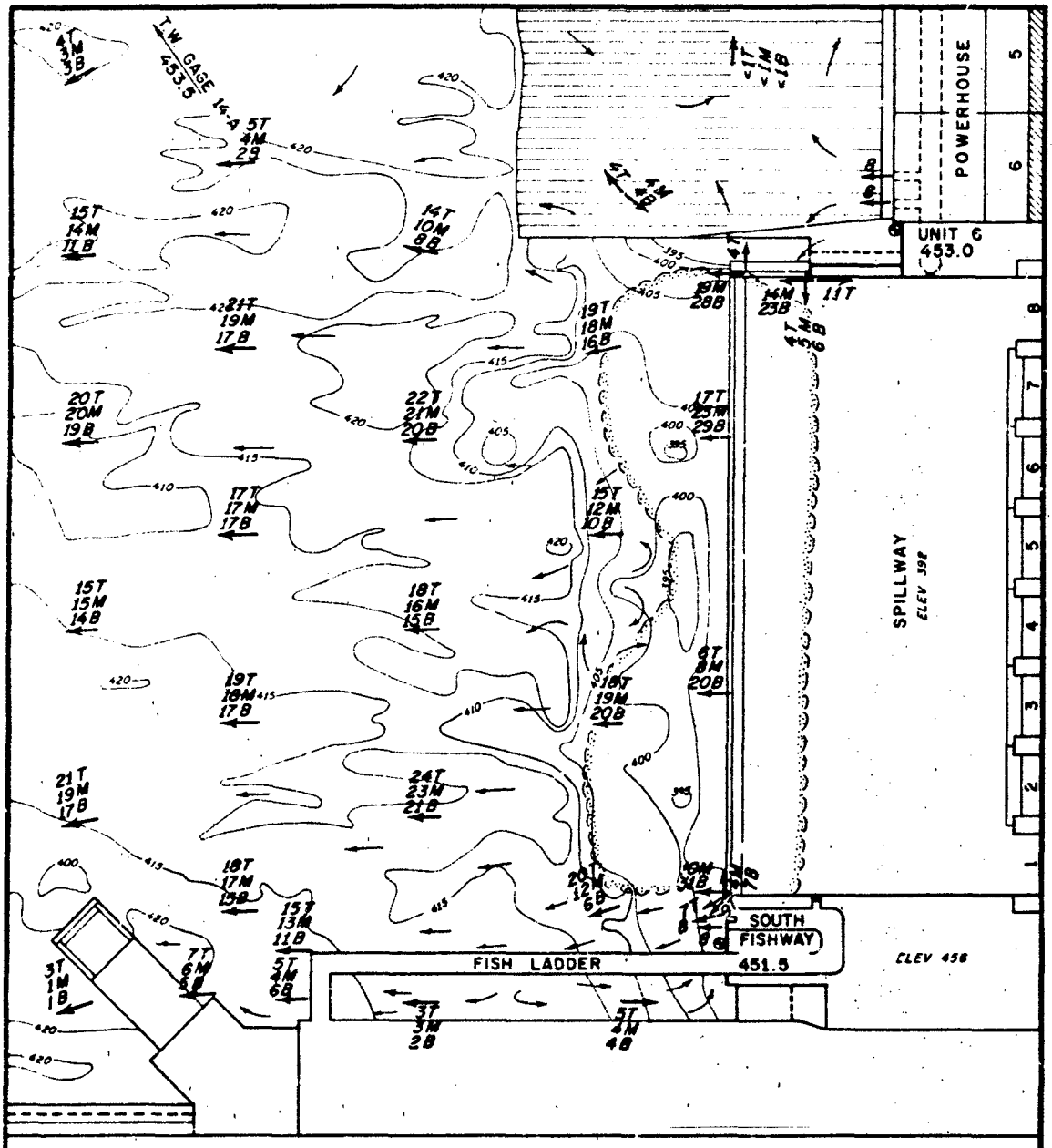
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 6

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 800 CFS
SPILLWAY BAYS 1 TO 8	63 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

PLATE 82



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE 0 50 100 200 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 2 TO 7

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	69 510 CFS
SPILLWAY BAYS 1 TO 8	350 340 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	850 CFS

FLOW CONDITIONS

RIVER DISCHARGE 420 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 83

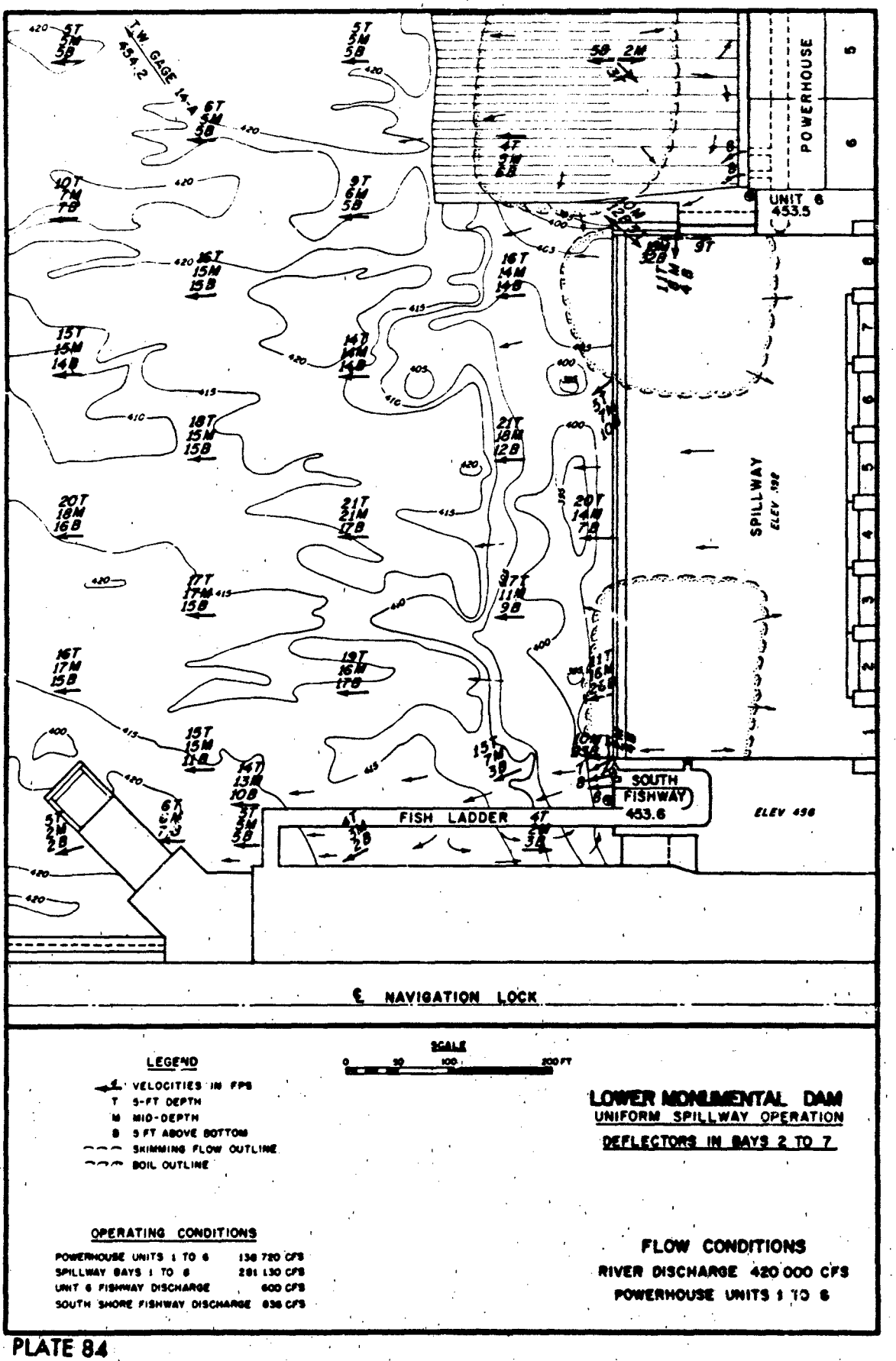
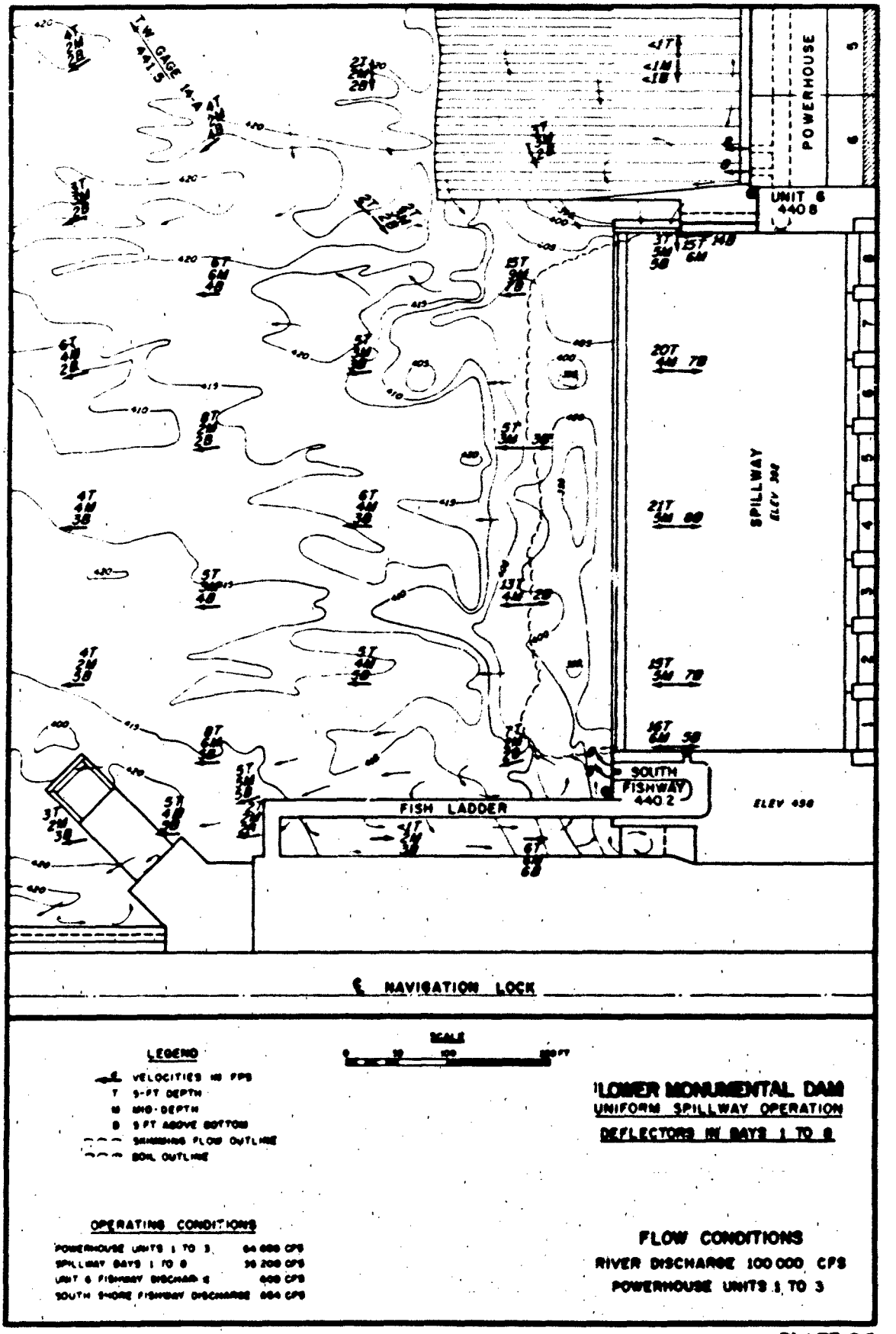

T.W. GAGE 14-4
454.2
POWERHOUSE
UNIT 6
453.5
SPILLWAY
ELEV 198
SOUTH
FISHWAY
453.6
FISH LADDER
ELEV 498
℄ NAVIGATION LOCK
SCALE
0 50 100 200 FT
LEGEND
VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
SKIMMING FLOW OUTLINE
BOIL OUTLINE
OPERATING CONDITIONS
POWERHOUSE UNITS 1 TO 6 136 720 CFS
SPILLWAY BAYS 1 TO 8 281 130 CFS
UNIT 6 FISHWAY DISCHARGE 600 CFS
SOUTH SHORE FISHWAY DISCHARGE 636 CFS
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 2 TO 7
FLOW CONDITIONS
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 84



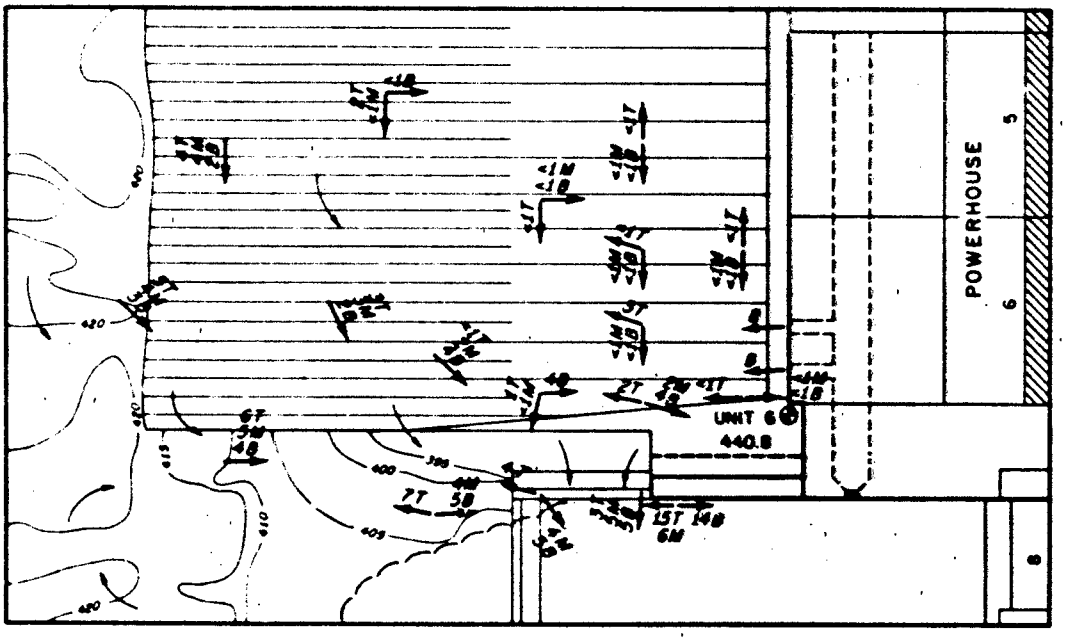
LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 1 TO 8

OPERATING CONDITIONS

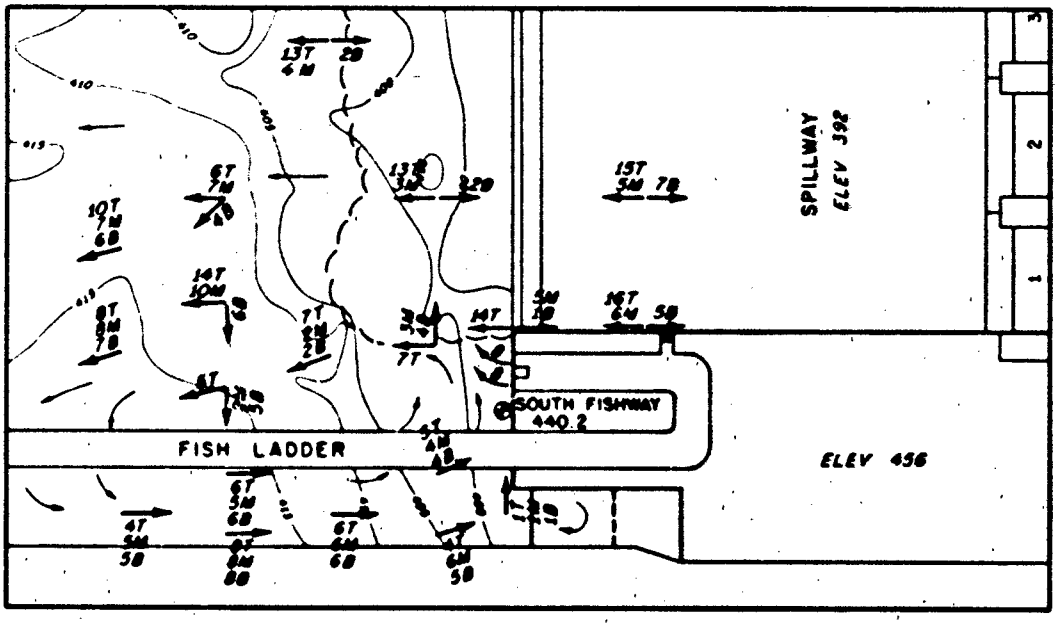
POWERHOUSE UNITS 1 TO 3	84 600 CFS
SPILLWAY BAYS 1 TO 8	15 200 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	650 CFS

FLOW CONDITIONS
RIVER DISCHARGE 100 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 85



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 9-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

OPERATING CONDITIONS

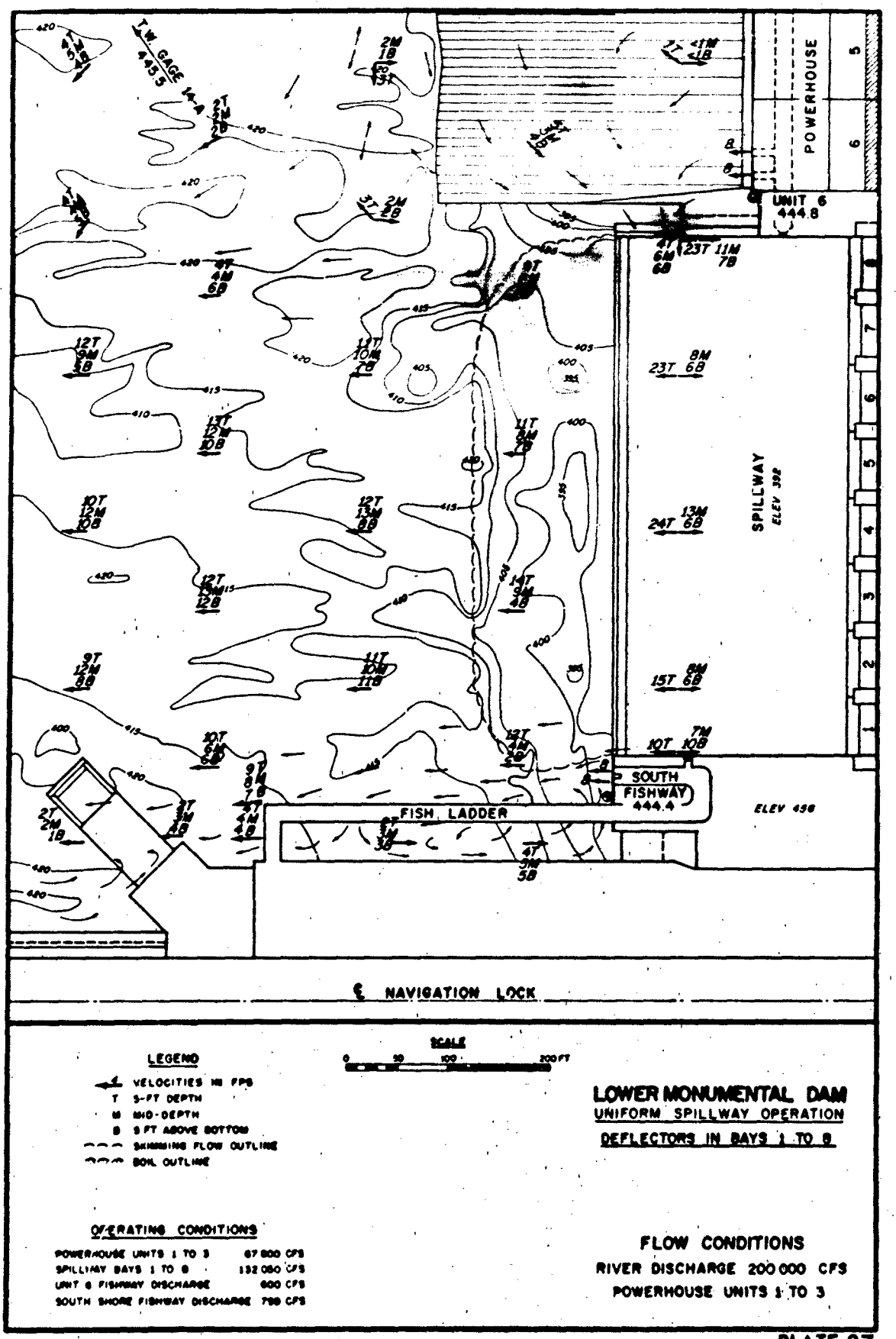
POWERHOUSE UNITS 1 TO 3	64 650 CFS
SPILLWAY BAYS 1 TO 8	35 200 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	664 CFS

LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 1 TO 8

FLOW CONDITIONS
AT FISHWAY ENTRANCES

RIVER DISCHARGE 100 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 86



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 200 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 1 TO 8

OPERATING CONDITIONS

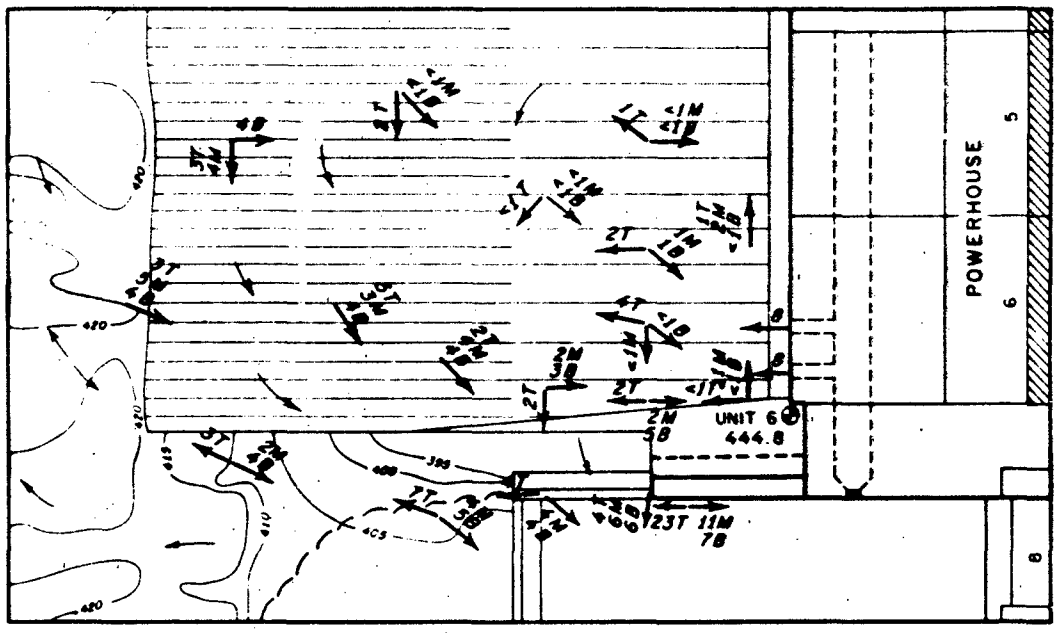
POWERHOUSE UNITS 1 TO 3	67 800 CFS
SPILLWAY BAYS 1 TO 8	132 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	750 CFS

FLOW CONDITIONS

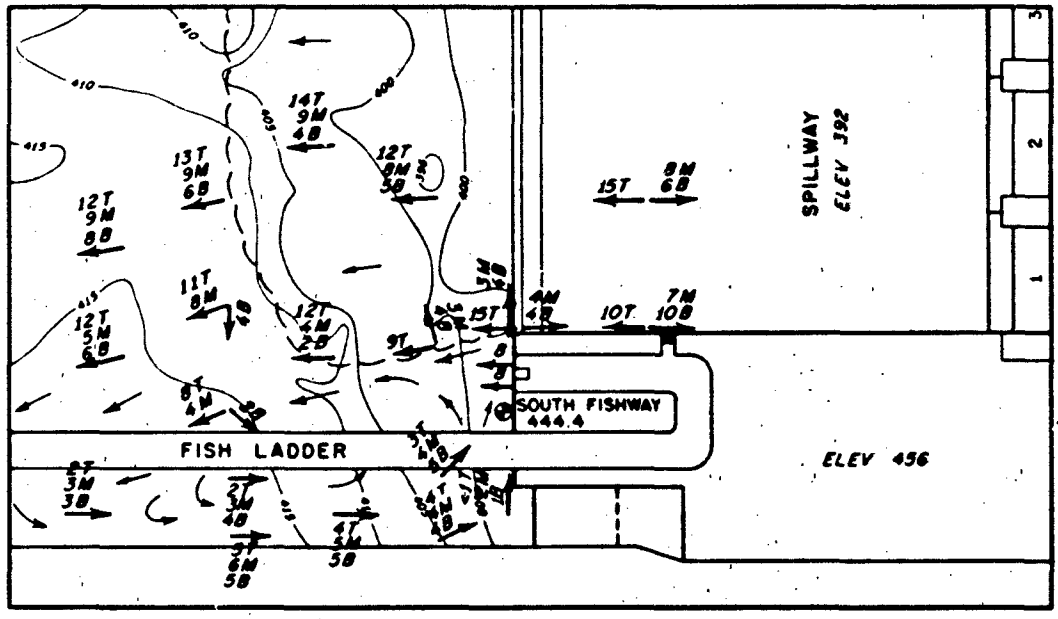
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 87



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 FT

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 1 TO 8

FLOW CONDITIONS AT FISHWAY ENTRANCES

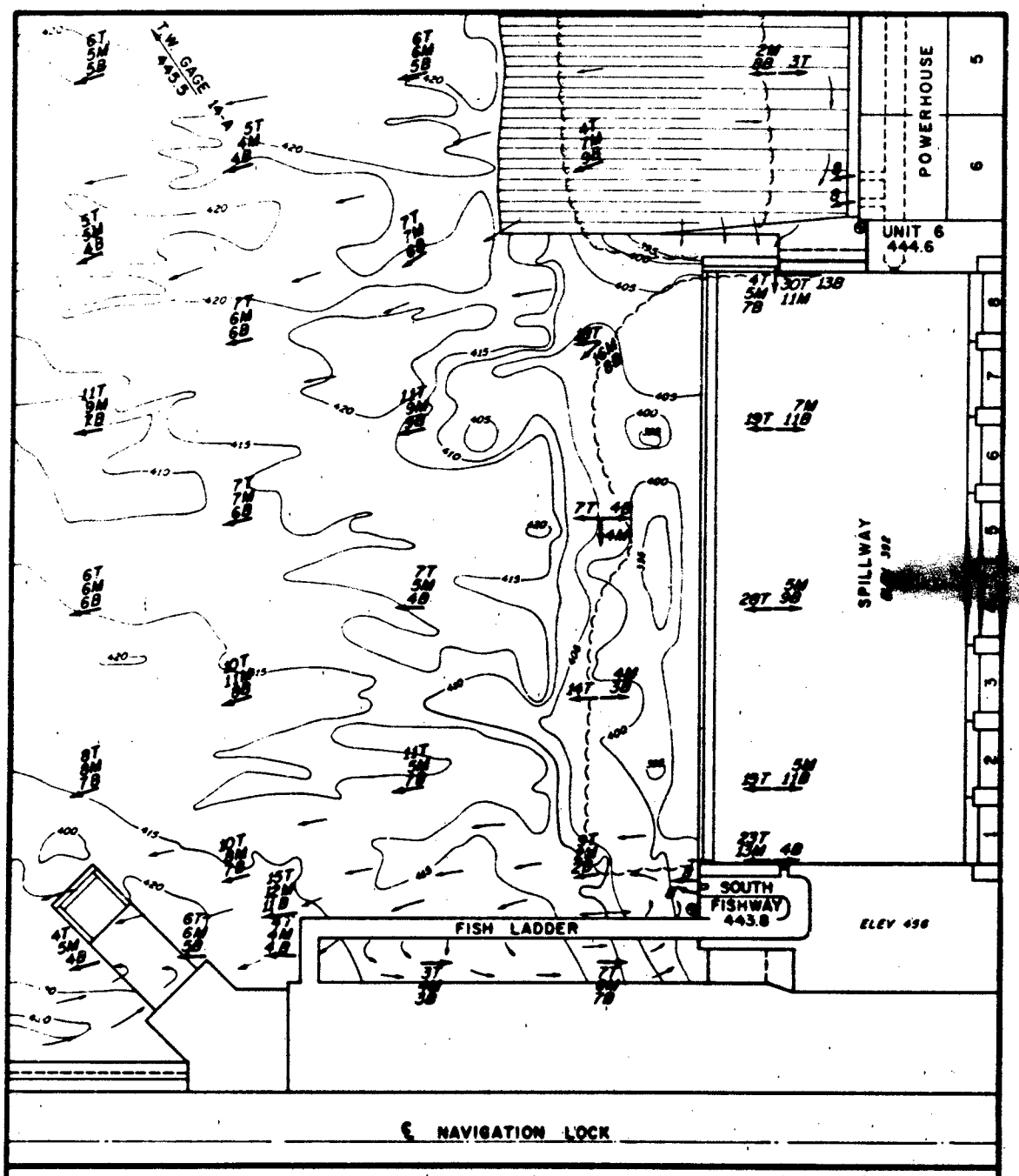
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 3

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	67 800 CFS
SPILLWAY BAYS 1 TO 8	132 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

PLATE 88



SCALE
0 50 100 200 FT.

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

LOWER MONUMENTAL DAM

UNIFORM SPILLWAY OPERATION

DEFLECTORS IN BAYS 1 TO 8

OPERATING CONDITIONS

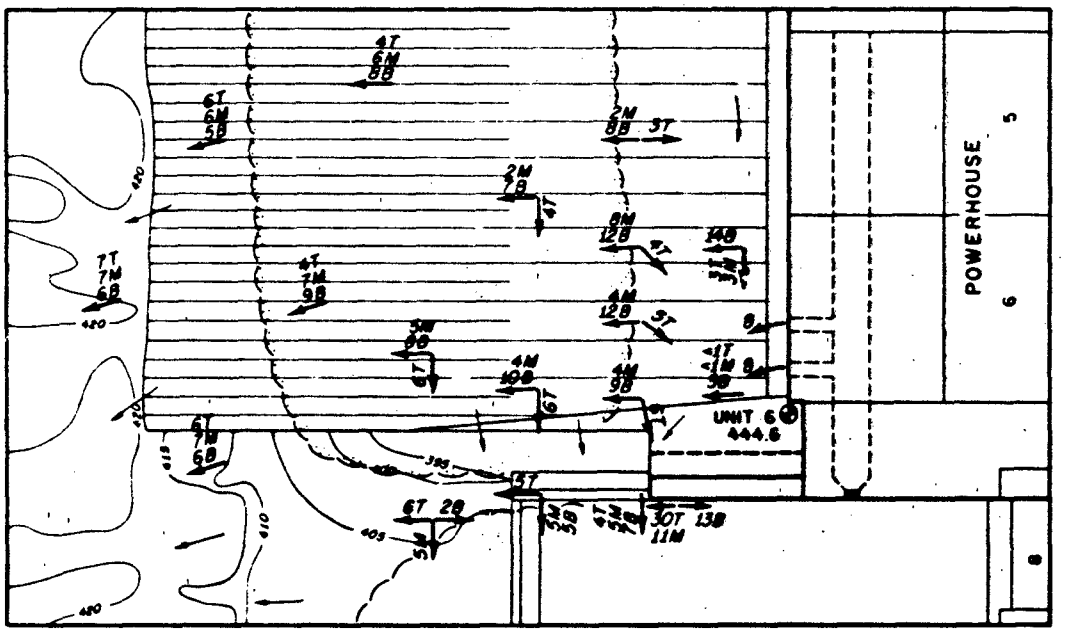
POWERHOUSE UNITS 1 TO 6	138 800 CFS
SPILLWAY BAYS 1 TO 8	63 000 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	700 CFS

FLOW CONDITIONS

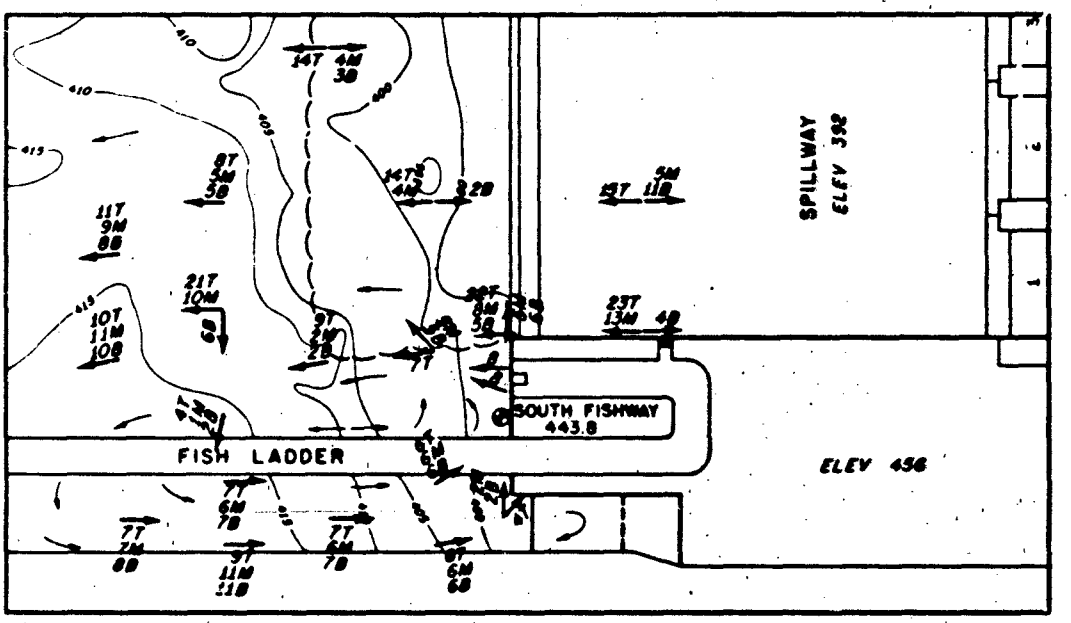
RIVER DISCHARGE 200 000 CFS

POWERHOUSE UNITS 1 TO 6

PLATE 89



UNIT 6 FISHWAY ENTRANCE



SOUTH SHORE FISHWAY ENTRANCE

LEGEND

- 4 — VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

SCALE

0 50 100 FT

LOWER MONUMENTAL DAM
UNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 1 TO 8

FLOW CONDITIONS
AT FISHWAY ENTRANCES
RIVER DISCHARGE 200 000 CFS
POWERHOUSE UNITS 1 TO 6

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 800 CFS
SPILLWAY BAYS 1 TO 8	63 050 CFS
UNIT 6 FISHWAY DISCHARGE	600 CFS
SOUTH SHORE FISHWAY DISCHARGE	799 CFS

PLATE 90

PART VII

LITTLE GOOSE DAM

PART VII: LITTLE GOOSE DAM TESTS AND RESULTS

The Prototype

62. The Little Goose project includes an eight-bay spillway, a six-unit powerhouse, a navigation lock, and facilities for migratory fish (plate 91). The spillway is designed to pass 850,000 cfs at a pool elevation 646.4 and is controlled by 50-foot-wide by 60-foot-high tainter gates. The spillway terminates in a dentated 50-foot-radius roller bucket followed by a 20-foot-long, 20-degree sloping apron (plate 92).

The Models

63. A 1:42.47-scale model (photograph 73) simulating a three-bay section of the approach spillway, roller bucket, and exit channel was used to develop the optimum design of the deflector. The spillway crest, piers, and gates were constructed of acrylic plastic; the roller bucket, dentates, and runout were made of waterproofed wood and plywood; and the upstream and downstream riverbed was of heavy planking. The tailwater was controlled by a variable tailgate.

64. A 1:50-scale model (photograph 74) was used to evaluate the effects of the recommended deflector on flow conditions and to establish spillway operation schedules for optimum fish passage. The model structures were constructed of plastic, waterproofed wood, and plywood. The exit channel was contoured in crushed rock and drypack cement to conform with a 1973 hydrographic survey. The tailwater was controlled by a hinged tailgate and was measured at a gage located 1,000 feet downstream from the crest axis.

Tests

65. Tests were accomplished in both models for conditions both with and without deflectors. River discharges between 160,000 and 850,000 cfs (4,700 and 106,250 cfs per bay) were tested in the sectional model, and discharges between 100,000 and 506,400 cfs were tested in the comprehensive model. Without the deflectors, large volumes of aerated water were carried to the bottom of the bucket with all discharges tested. Such conditions would create nitrogen supersaturation in the water downstream of the project. Flow conditions without the deflector are shown on plates 93 and 94 and photographs 75 through 77. Velocities measured just downstream of the bucket apron are listed in table E.

66. Four different deflector lengths--8.0, 10.0, 12.5 and 17.5 feet—were initially tested in the sectional model (plate 95). The two longer deflectors were unacceptable since flow at high discharges overshot the dentates and impacted directly on the unpaved tailwater channel downstream of the roller bucket. The optimum deflector elevation was determined by varying the 10-foot-long deflector between elevations 528 and 532. The deflector located at elevation 532 produced the greatest range of stable, skimming flow—the most desirable condition for preventing supersaturation (plate 96). The 8.0-foot-long deflector was tested at elevation 532 and provided more stability at the higher discharges and was therefore selected as the final design. Flow conditions with the final-design deflector are shown on plates 97 and 98 and photographs 78 through 80. Velocities at the end of the roller bucket runout are listed on table E.

67. Data from the existing structures (without deflectors) were obtained in the 1:50-scale comprehensive model for use as a basis of comparison with later tests with deflectors installed. The purpose of the tests was to determine the effects of deflectors on flow conditions for fish passage and to establish spillway operation patterns for optimum fish passage conditions with the modified spillway. Initial tests were made with spillway gate openings (1-foot increments) as near to

uniform for all eight bays as the total spill would allow. Later tests were made with non-uniform spill to improve fish passage conditions. Flow from the north shore fishway was carried into the spillway flow rather quickly with the lower discharges; but as the spillway flow increased, the attraction flow was carried farther downstream. The expanding spillway flow caused the eddy along the fill to become tighter with higher velocities at the 420,000-cfs flow. Conditions around the fishway entrance at unit 6 were satisfactory at all flows. The energy dissipation created with uniform spill was well distributed across the spillway and provided good downstream flow conditions along both banks. Flow conditions existing without the deflectors are shown on plates 100 through 107 and in photographs 81 through 85.

Deflectors in Bays 1 Through 8

68. The 8-foot-long deflector developed in the sectional model was installed in all eight bays of the spillway at elevation 532. The same series of discharges tested without the deflector were tested with the deflector installed in all eight bays. Uniform spillway operation was maintained for tests with all eight deflectors installed with the exception of the 420,000 cfs discharge. With that flow, conditions were very poor at the north fishway until spillway flow through bays 7 and 8 was reduced. The size and intensity of the eddy along the north shore fill was also dependent upon the quantity of spill from bays 7 and 8. Although further improvement in flow conditions could have been made by non-uniform operation of spillway gates, uniform gate operation was tested to provide a true comparison with base data. Under all conditions tested, attraction flow from the entrance near unit 6 moved downstream approximately 100 feet before being drawn into the spillway flow. Flow conditions are shown on plates 108 through 116 and in photographs 86 through 90.

Deflectors in Bays 1 Through 7

69. Flow conditions near the north fishway entrance appeared to be improved if there was no deflector in bay 8. The same series of discharges was tested with deflectors in bays 1 through 7 as in the previous tests. With flows of 212,000 cfs and below, the eddy along the north shore fill was generally larger with much slower velocities upstream along the bank than that which existed with deflectors in all eight bays. The difference in flow conditions from those with the eight-deflectors was not significant at 420,000 cfs and above. Flow from the north fishway entrance moved downstream a short distance before being drawn into the spillway flow with all conditions tested. Uniform gate settings provided fair attraction conditions and quiet water at the north entrance but could be further improved with non-uniform spillway operation. Entrance conditions at the unit 6 entrance were good with units 1 through 3 operating; however, the attraction flow was crowded against the powerhouse side of the left training wall with six units operating.

Deflectors in Bays 2 Through 7

70. Tests in the model indicated acceptable flow conditions could also be obtained with deflectors in only the six interior bays of the spillway. Concern over fish acceptance of flow conditions with deflectors in end bays adjacent to fishway entrances led to the decision to install deflectors in only the six interior bays under the initial contract and observe fish conditions on this and similar dams for a year prior to installing additional deflectors. Riverflows pertinent to fish passage—212,000 cfs and less—were tested with non-uniform spill to obtain optimum attraction conditions at both fishway entrances. General flow conditions existing downstream from the spillway are shown on plates 117 through 121 and photographs 91 through 95. Generally, higher than normal discharges were used in the end bays to provide good approach conditions with strong downstream flow near the entrances on each end of the spillway. With the lower river discharges

tested, additional flow was passed through bays 2 and 7 to reinforce the flow in the end bays. With the flow of 212,000 cfs, and with units 1 through 3 operating, discharge through bays 1 and 8 was reduced to maintain acceptable levels of turbulence and wave action near the entrances. Flow conditions at the unit 6 entrance remained satisfactory since adjacent flow patterns were affected more by powerhouse flow than by spillway conditions.

North Shore Fill

71. The north shore fill, a finger dike adjacent to the north fishway entrance (photograph 96), was designed to improve flow conditions with the original spillway. The existing prototype fill has partially eroded at the downstream end and will eventually reach stability. Tests were made in the model to determine the effectiveness of the fill on flow conditions with deflectors installed on the spillway. With the installation of eight deflectors, the fill became less effective and caused an eddy to partially block flow from the fishway entrance (photographs 97 through 99). With the fill removed, the eddy did not exist and a very slow flow moved across the entrance (plate 122 and photographs 100 through 102).

72. Flow conditions at the north fishway entrance were improved slightly both with or without the fill by the addition of a tapered nose extension to the adjacent training wall. The tapered extension allowed fishway flow to enter the spillway flow across a 1-foot nose, instead of the square end of the 14-foot-wide training wall. The tight eddy and excessive drawdown that occurred with the broad nose of the wall were eliminated, but the large eddy remained in front of the entrance when the north shore fill was in place (photographs 103 and 104).

Heads on Fishway System

73. A difference in water surface at each entrance was required for operation of the gravity-flow fishway system. Water surfaces at the north fishway entrance had to be lower than at unit 6 to provide an operating head. With the existing spillway and the north shore fill, heads varied favorably from +0.1 to +0.6 foot with discharges up to 212,000 cfs—the design discharge for fish passage (table F). When all eight deflectors were installed, the increased surface velocities changed the flow patterns and lowered the water surface elevations at both entrances with resulting heads of 0.0 to +0.5 foot—less than existed originally but still satisfactory (table F). With the deflector removed from bay 8, velocities and drawdown were less and the head reversed to -0.4 foot at 212,000 cfs with units 1 through 3 operating. Heads at lower flows ranged from 0.0 to +0.3 foot. With deflectors in bays 2 through 7, further reduction of head was attained at a discharge of 212,000 cfs with units 1 through 3 operating by utilizing a non-uniform spillway operation. With flow through bay 8 decreased to improve attraction conditions, the head dropped to -0.7 foot. At discharges less than 212,000 cfs, flow through bay 8 was either equal to or higher than flow through the remaining bays and heads ranged from +0.2 to +0.5 foot (table F). Removal of the north shore fill reduced the velocities by allowing the spillway flow to expand, causing an increase in water surface elevation and loss of head (+0.5 foot dropped to -0.4 foot at 212,000 cfs with units 1 through 3 operating).

Transmission Tower Fill

74. A land fill protrudes from the left bank into the powerhouse flow approximately 1,000 feet downstream from the structures (plate 91). The fill serves two purposes: diverting flow away from the navigation lock approach and serving as a base for a transmission tower. Flow conditions existing around the fill without deflectors installed on the spillway are shown on plate 123. The effect of deflectors on flow conditions around the fill is shown on plates 124 and 125. The

direction and intensity of flow and area of impact on the fill did not vary appreciably when deflectors were added. Flow conditions were acceptable for upstream movement of fish with or without deflectors installed on the spillway.

Waves and Rideup

75. The high-velocity surface flow produced by the spillway deflectors increased waves and rideup along the banks at the lower flows. With 212,000 and 420,000 cfs and units 1 through 3 operating, waves and rideup were reduced when deflectors were added. Table G lists these conditions at the transmission tower fill, the north shore fill, the right training wall, and along the face of the powerhouse both with and without deflectors. Prototype conditions would vary from the recorded data due to wind affect, bulking of air in the stilling basin, and bank roughness.

Table E

LITTLE GOOSE DAM

VELOCITIES AT STATION 14+00

Existing Spillway and 8-Ft Deflector at Elevation 532

River Discharge cfs	Spillway Discharge cfs per bay	Tailwater Elevation	Velocity, fps		
			Depth	No Deflector	8-ft Deflector elev 532
172,000	4,700	542.4	T	4 - 5	3 - 4
			M	2 - 4	3 - 4
			B	1 - 2	U 6 - 8
160,000	11,650	541.9	T	7 - 8	8 - 13
			M	5 - 8	5 - 6
			B	2 - 3	U 2 - 4
212,000	18,000	543.2	T	10 - 14	18 - 19
			M	7 - 9	10 - 11
			B	3 - 4	U 3 - 4
251,000	22,700	544.0	T	14 - 17	16 - 18
			M	8 - 10	9 - 11
			B	5 - 8	5 - 6
344,000	34,200	546.4	T	12 - 14	16 - 17
			M	14 - 15	12 - 15
			B	13 - 14	10 - 12
420,000	43,750	548.5	T	12 - 15	14 - 17
			M	16 - 19	13 - 15
			B	18 - 23	13 - 18
680,000	85,000	555.5	T	13 - 14	15 - 17
			M	24 - 28	21 - 22
			B	37 - 42	33 - 38
850,000	106,250	560.6	T	14 - 15	14 - 17
			M	29 - 33	26 - 31
			B	48 - 50	45 - 50

NOTES: 1. Flow is downstream, except as noted U.
2. Data taken on center line of bays; average of 3 bays.
3. Velocities at 5-ft depth T, 0.5-depth M, and 5 ft above bottom B.

Table F

LITTLE GOOSE DAM

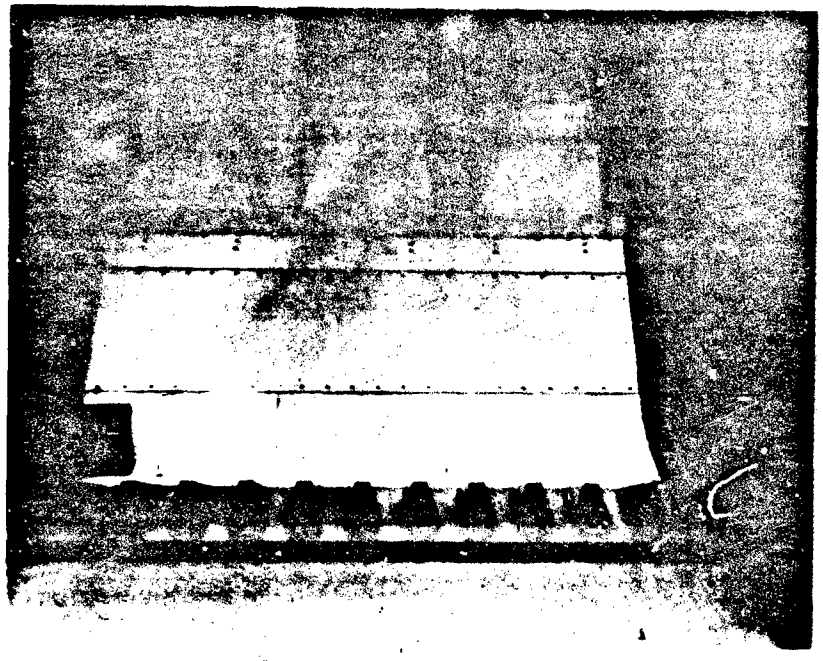
WAVES AND RIDEUP

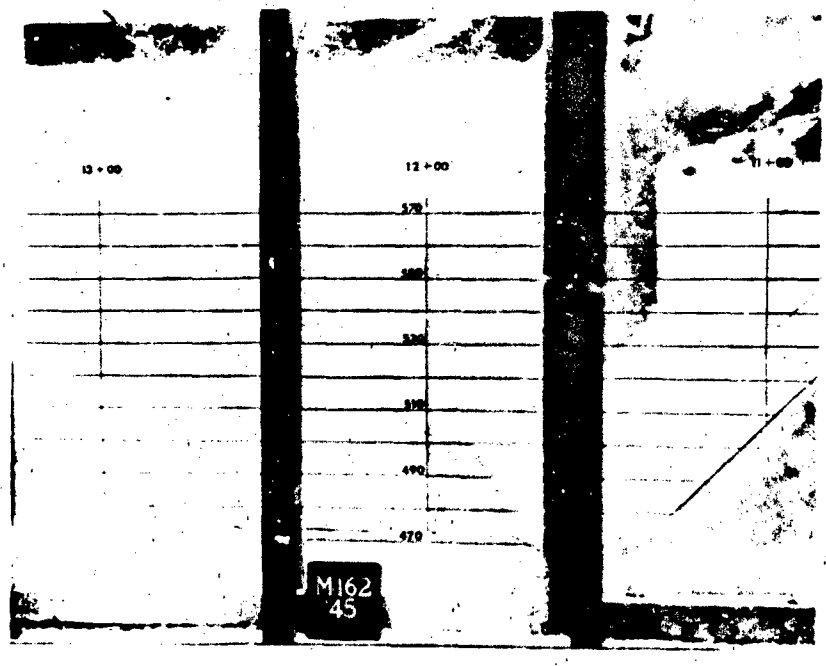
River Discharge in CFS	Pwhs Units Opr	Deflectors in Bays	Waves in feet (or elev)					Rideup in ft	
			North Shore Fill	Right Training Wall	Unit 3	Unit 1	Trans Tower Fill	North Shore Fill	Trans Tower Fill
100,000	1-3	1 to 8	1	539-542	1	1	0.5	4	3
		1 to 7	1	539-541	0.5	0.5	0.5	4	3
		0	0.5	539-541	0.5	0.5	0.5	2	1
160,000	1-3	1 to 8	4	538-544	1	1	1	8	5
		to 7	3	540-543	1.5	1	1	6	6
160,000	1-6	1 to 8	1	540-543	0.5	0	0	6	1
		1 to 7	0.5	541-543	0	0	0.5	2	2
212,000	1-3	1 to 8	5.5	538-547	1.5	1.5	1	15	8
		1 to 7	2.5	539-546	1.5	1	1	12	7
		0	5	543-553*	2	1.5	2	20	10
212,000	1-6	1 to 8	2.5	540-548	0	0.5	1	10	5
		1 to 7	1.5	541-546	0.5	0.5	1	8	5
		0	1.5	543-545	0.5	0.5	0.5	6	4
420,000	1-3	1 to 8	6	545-553*	2	2	2*	20	14*
		1 to 7	4	545-553*	2	1.5	2*	17	15*
		0	10*	5.5-553*	3	3	3*	30*	16*
420,000	1-6	1 to 8	7*	545-553*	2.5	2	3*	19*	13*
		1 to 7	5.5*	546-551	3	3	2.5*	18*	14*
		0	6*	550-553*	3	2.5	2.5*	20*	12*
506,400	0	1 to 8	10*	554-553*	7.5	4.5	3*	-*	-*
		1 to 7	7*	544-553*	5	2.5	4*	14*	5*
		0	7*	545-553*	4	3	3*	25*	-*

* Indicates overtopping of wall or fill.

NOTES: 1. No long term wave (surge) was observed along powerhouse or at transmission tower fill.

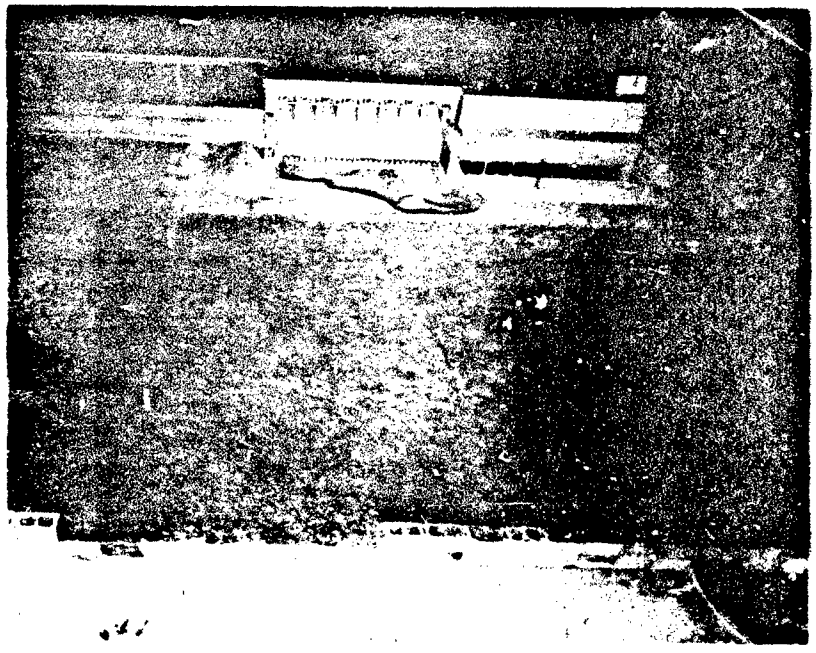
2. Waves and rideup measured from lowest trough to highest peak.

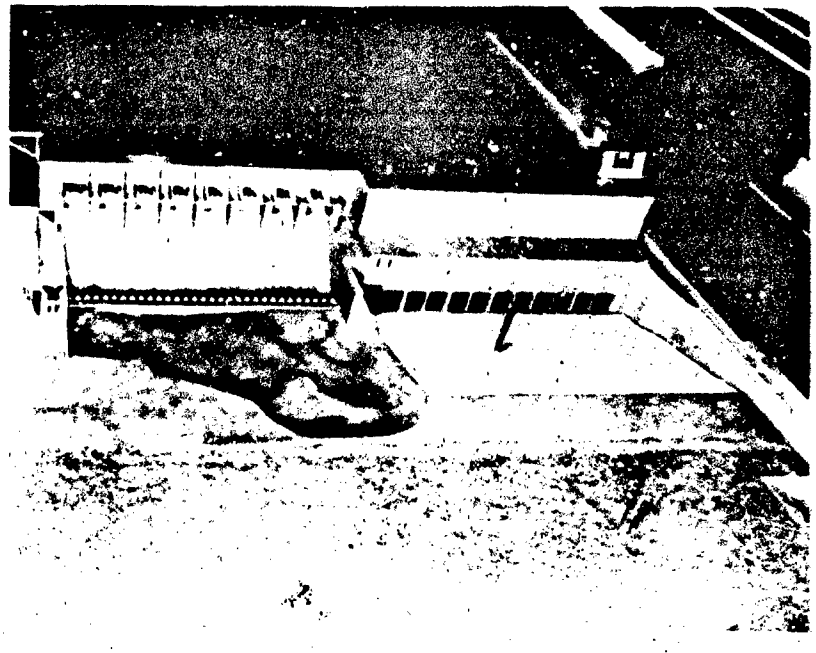




Little Goose Dam

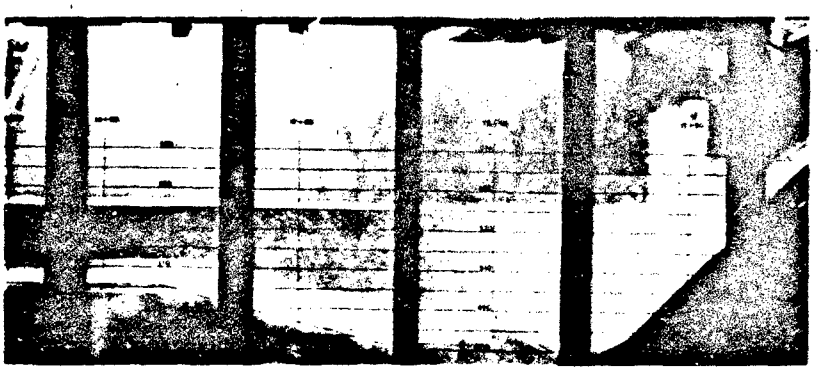
Photograph 73. Dry bed of 1:42.47-scale model.



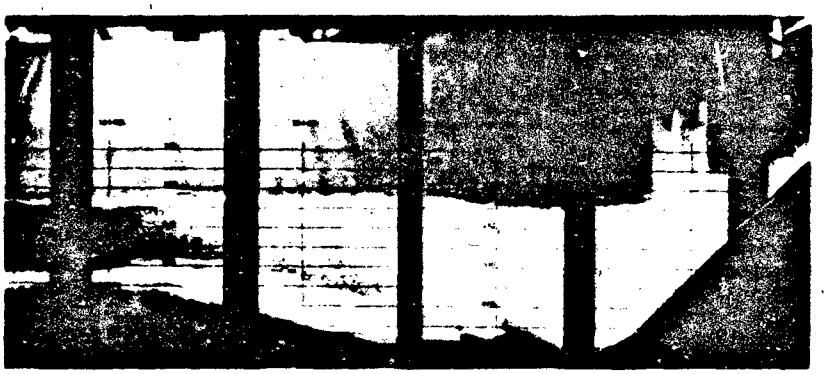


Little Goose Dam

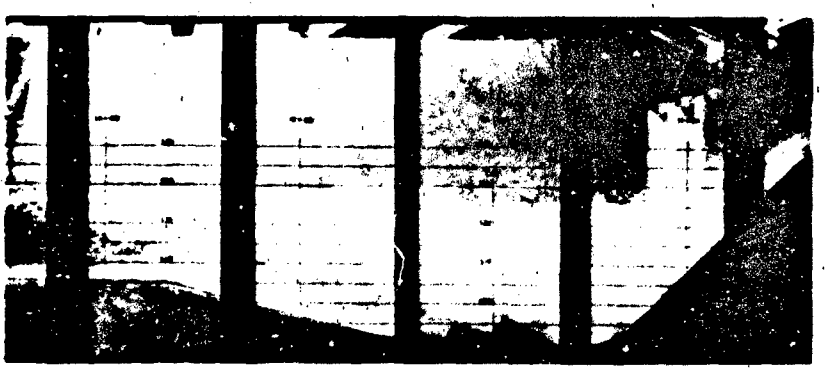
Photograph 74. Existing spillway and powerhouse with tailbay erosion of Aug 1973 in 1:50-scale comprehensive model.



River flow 172,000 cfs (4,700 cfs per bay), tailwater elevation 542.4.



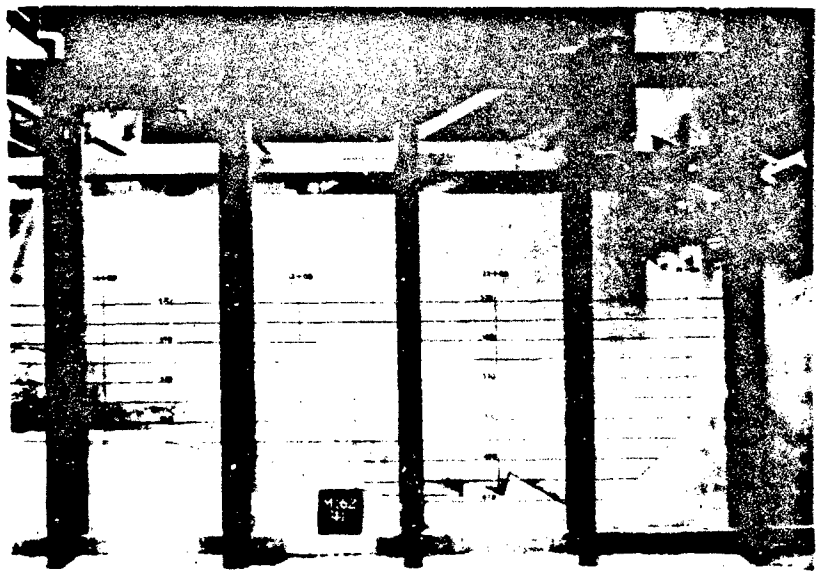
River flow 160,000 cfs (11,650 cfs per bay), tailwater elevation 541.9.



River flow 212,000 cfs (18,000 cfs per bay), tailwater elevation 543.2.

Little Goose Dam

Photograph 75. Flow conditions with existing spillway and roller bucket (no deflector).

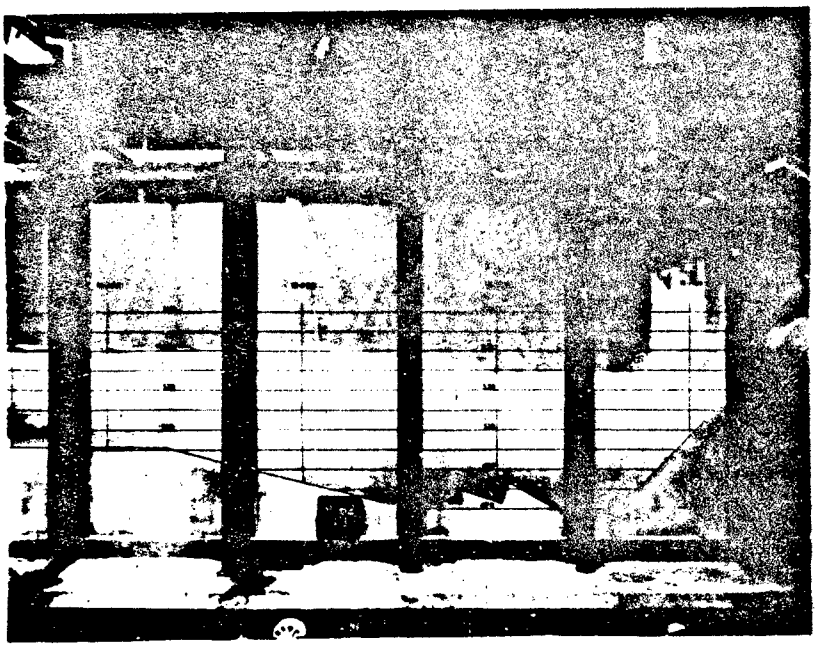


Discharge 22,700 cfs per bay. River flow 251,000 cfs. Tailwater elevation 544.0.

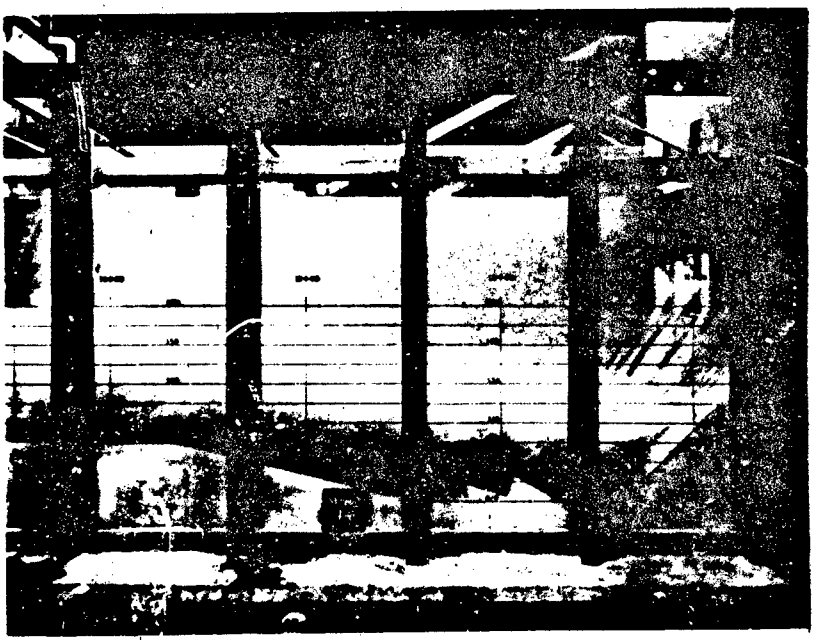
Discharge 34,200 cfs per bay. River flow 344,000 cfs. Tailwater elevation 546.4.

Little Goose Dam

Photograph 76. Flow conditions with existing spillway and roller bucket (no deflector).



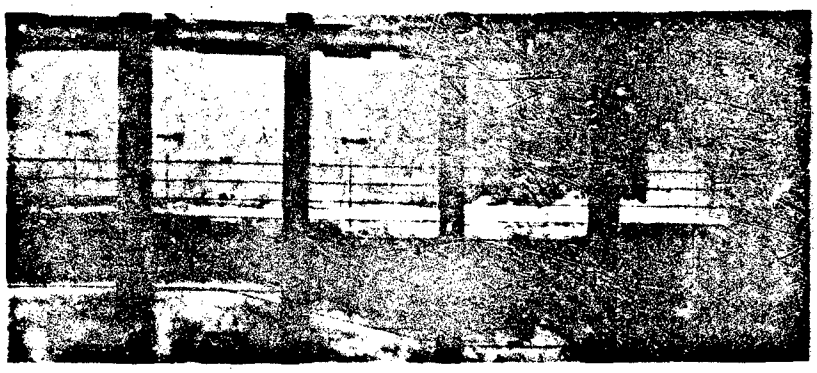
Discharge 43,750 cfs per bay. River flow 420,000 cfs.
Tailwater elevation 548.5.



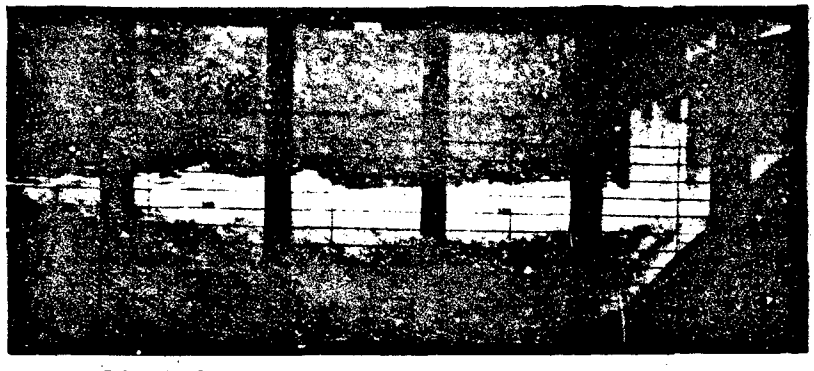
Discharge 106,250 cfs per bay. River flow 850,000 cfs.
Tailwater elevation 560.6.

Little Goose Dam

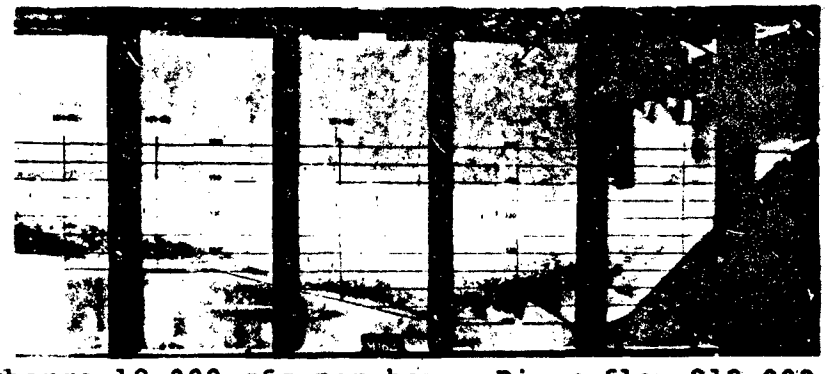
Photograph 77. Flow conditions with existing spillway and roller bucket (no deflector).



Discharge 4,700 cfs per bay. River flow 172,000 cfs.
Tailwater elevation 542.4.



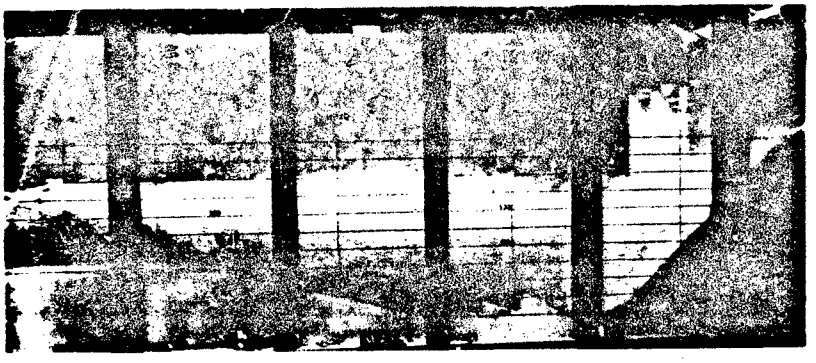
Discharge 11,650 cfs per bay. River flow 160,000 cfs.
Tailwater elevation 541.9.



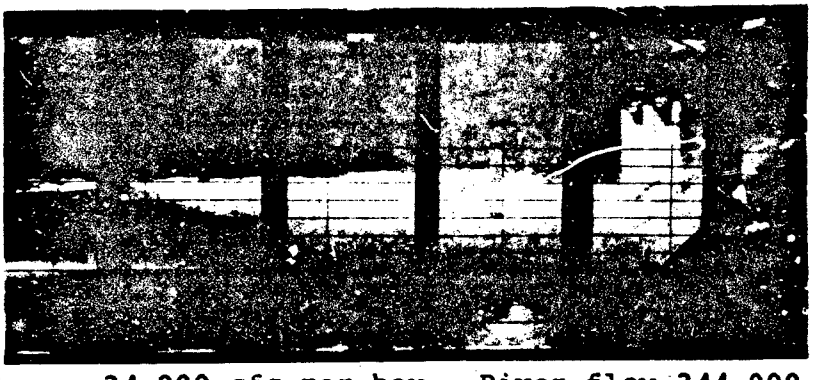
Discharge 18,000 cfs per bay. River flow 212,000 cfs.
Tailwater elevation 543.2.

Little Goose Dam

Photograph 78. Flow conditions with 8-foot deflector at elevation 532 (final design).



Discharge 22,700 cfs per bay. River flow 251,000 cfs.
Tailwater elevation 544.0.

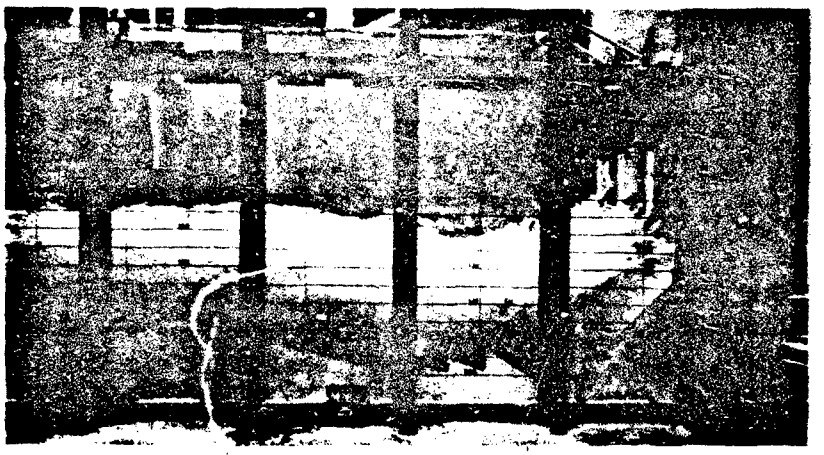


Discharge 34,200 cfs per bay. River flow 344,000 cfs.
Tailwater elevation 546.4.

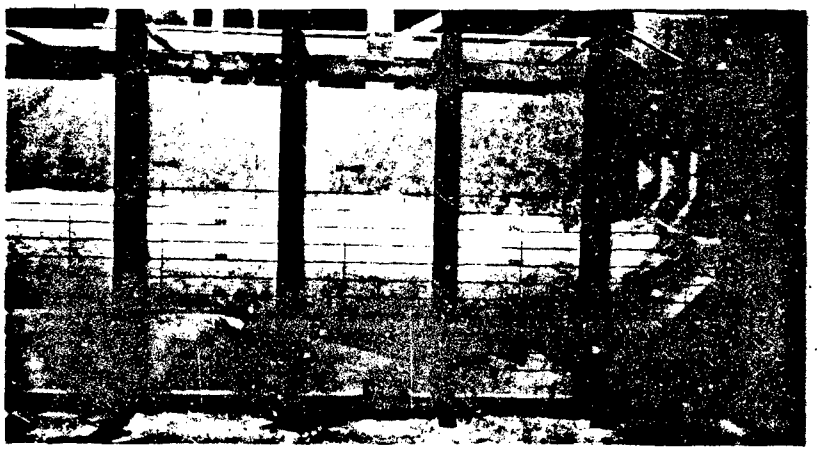
Discharge 43,750 cfs per bay. River flow 420,000 cfs.
Tailwater elevation 548.5.

Little Goose Dam

Photograph 79. Flow conditions with 8-foot deflector at elevation 532 (final design).



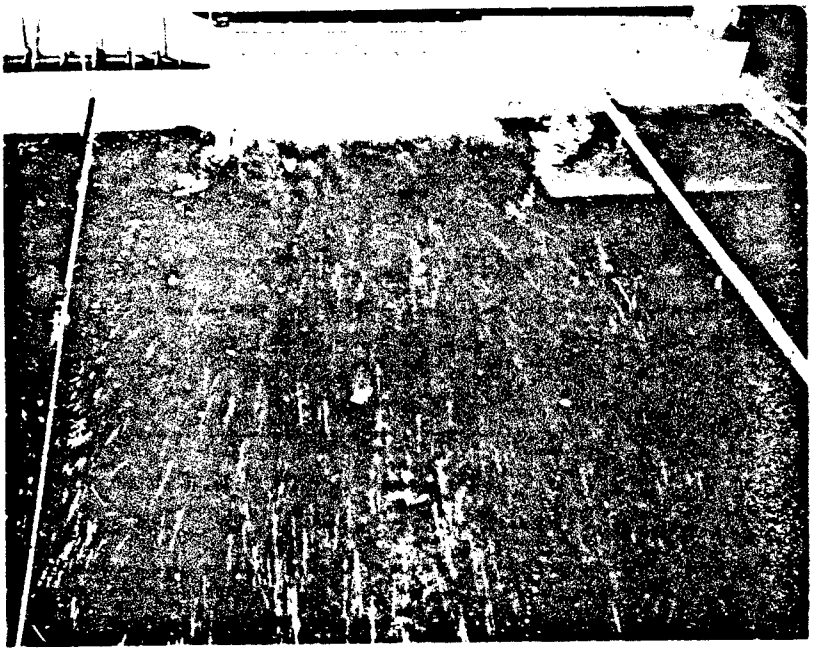
Discharge 85,000 cfs per bay. River flow 680,000 cfs.
Tailwater elevation 555.5.

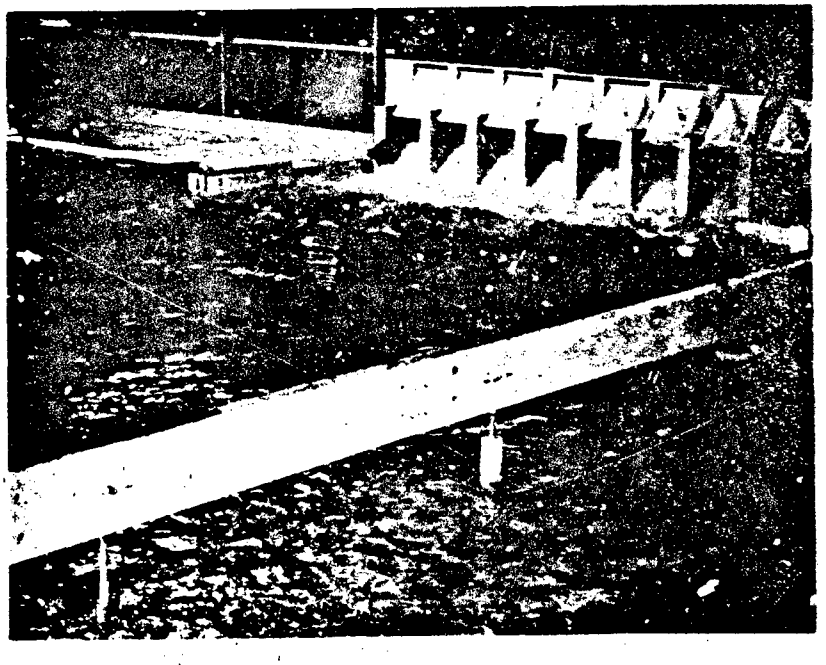


Discharge 106,250 cfs per bay. River flow 850,000 cfs.
Tailwater elevation 560.6.

Little Goose Dam

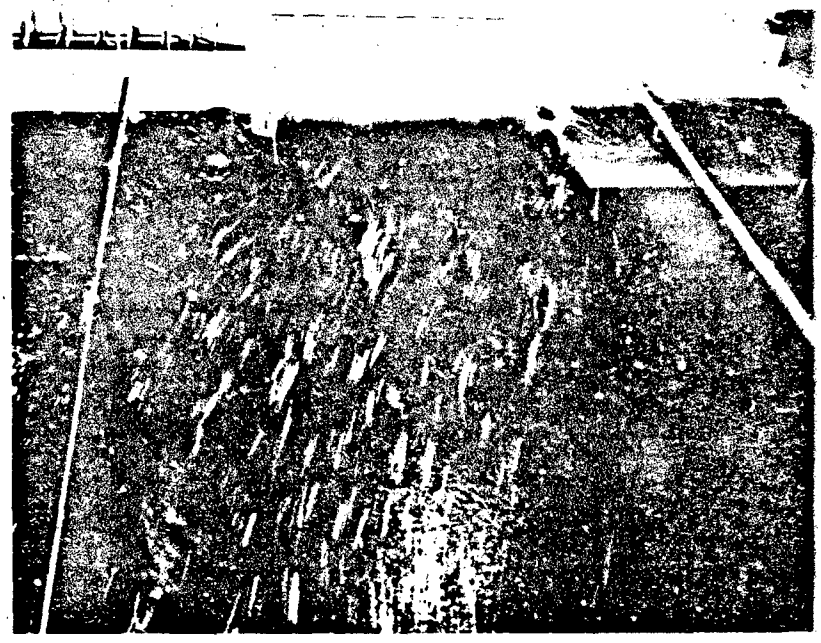
Photograph 80. Flow conditions with 8-foot deflector at elevation 532 (final design).

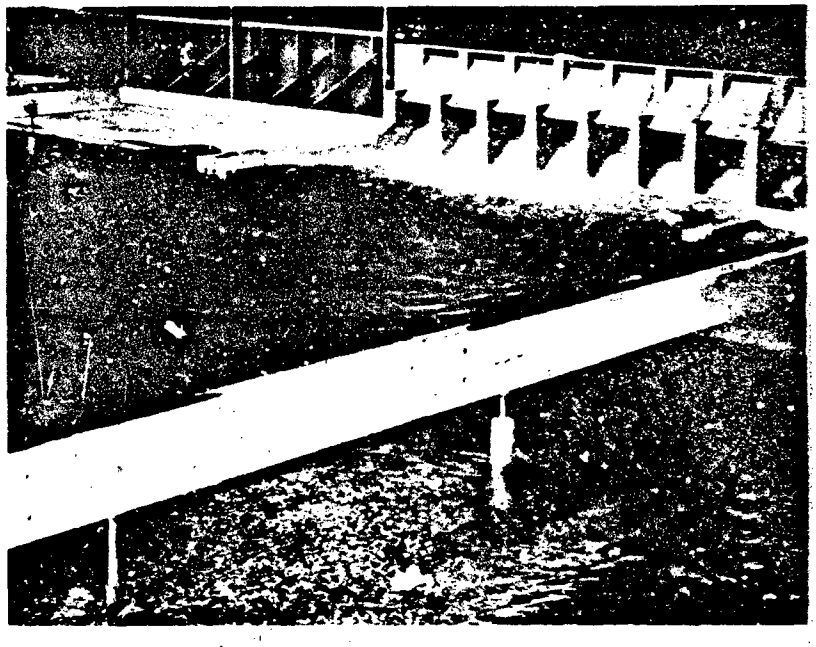




Little Goose Dam

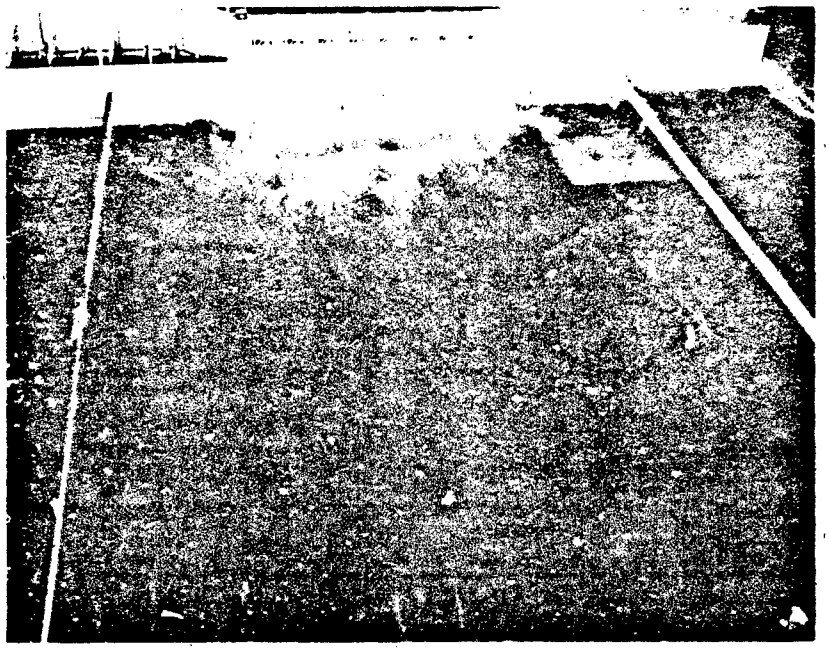
Photograph 81. Flow conditions without deflectors. River discharge 212,000 cfs; powerhouse units 1 to 3 operating.

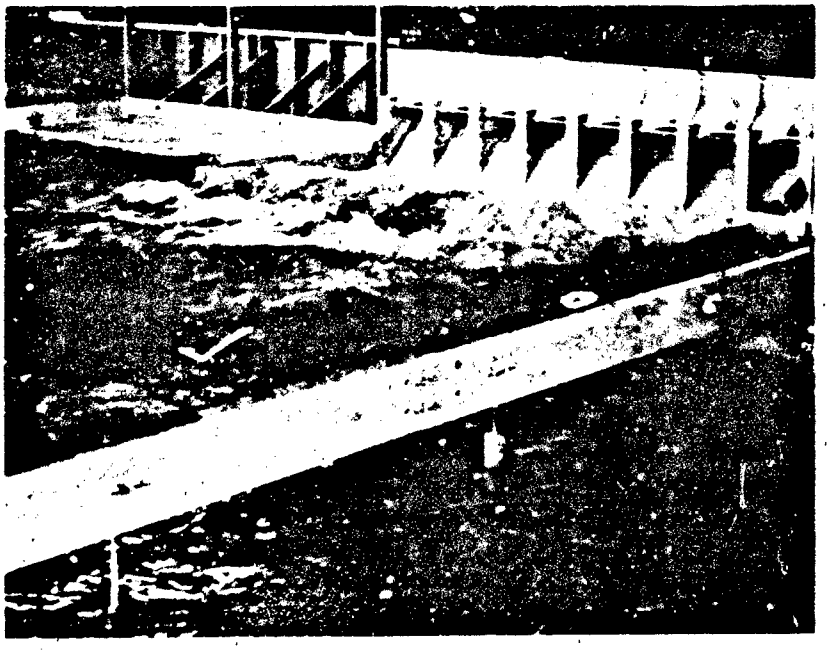




Little Goose Dam

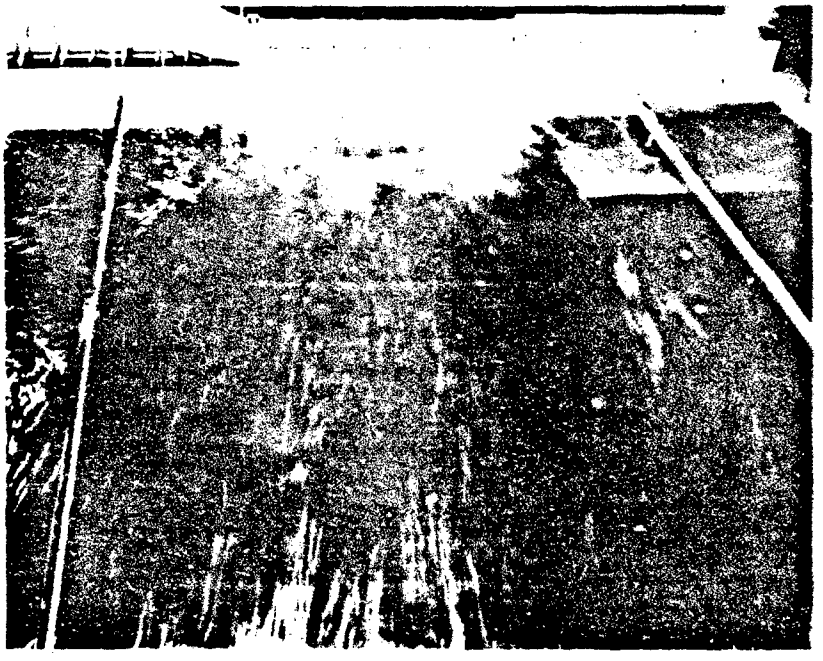
Photograph 82. Flow conditions without deflectors. River discharge 212,000 cfs; powerhouse units 1 to 6 operating.

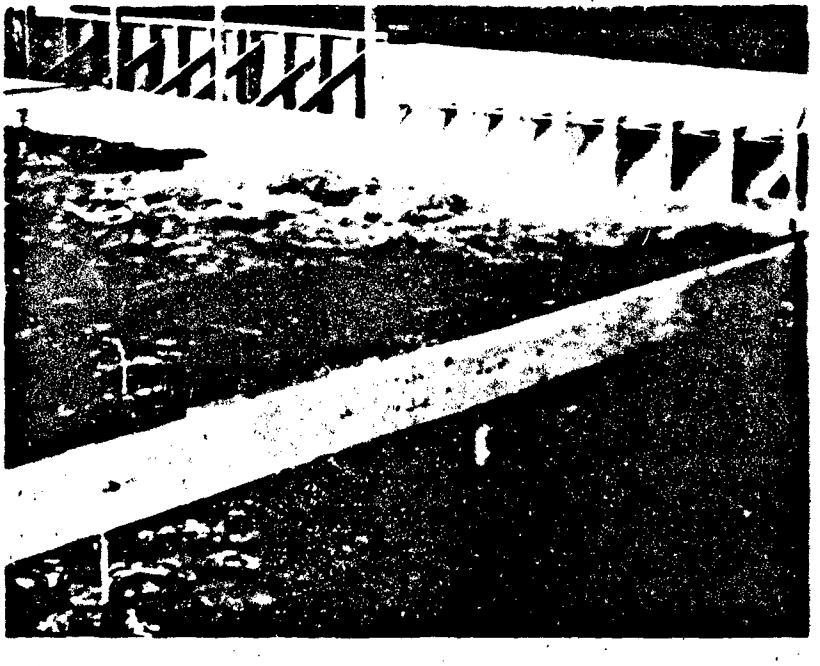




Little Goose Dam

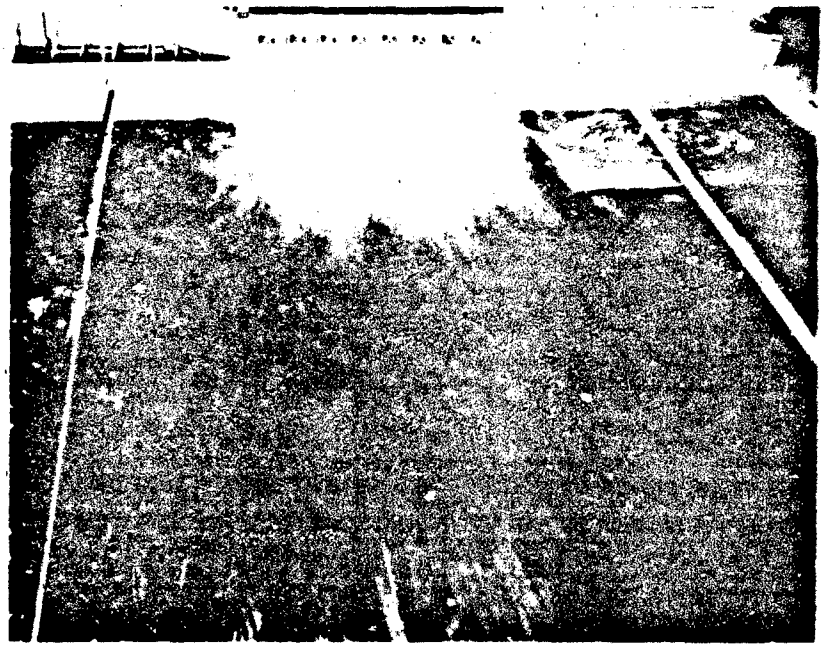
Photograph 83. Flow conditions without deflectors. Spillway discharge 420,000 cfs; powerhouse units 1 to 3 operating.

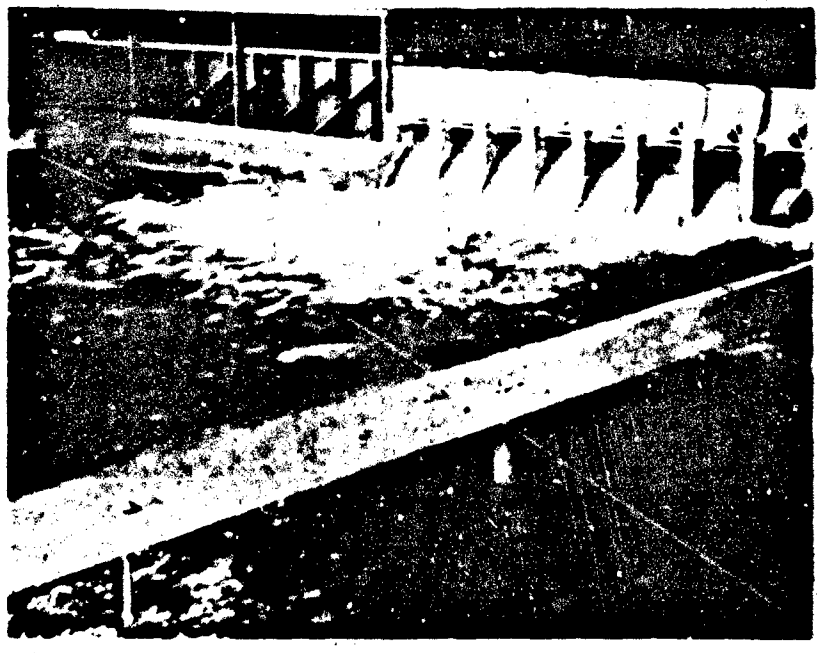




Little Goose Dam

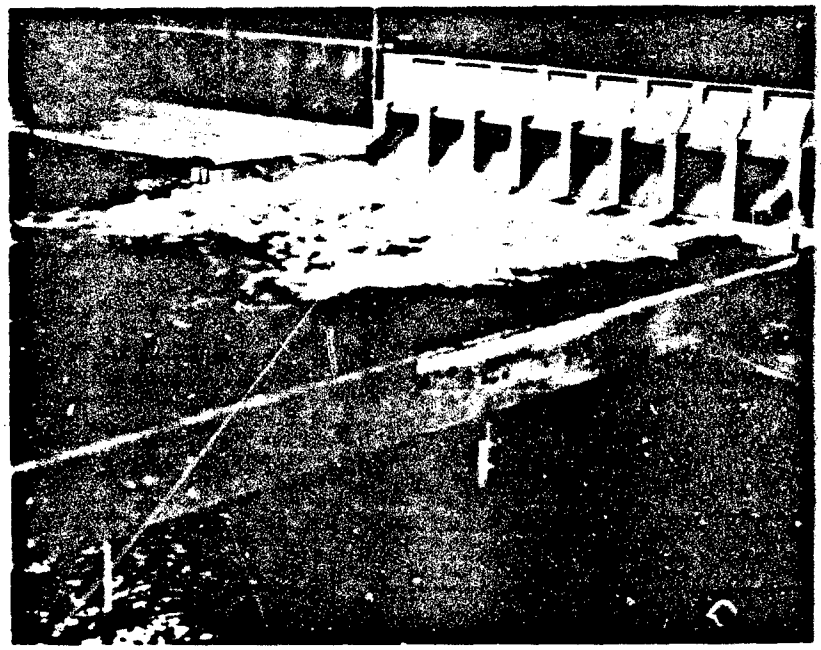
Photograph 84. Flow conditions without deflectors. River discharge 420,000 cfs; powerhouse units 1 to 6 operating.

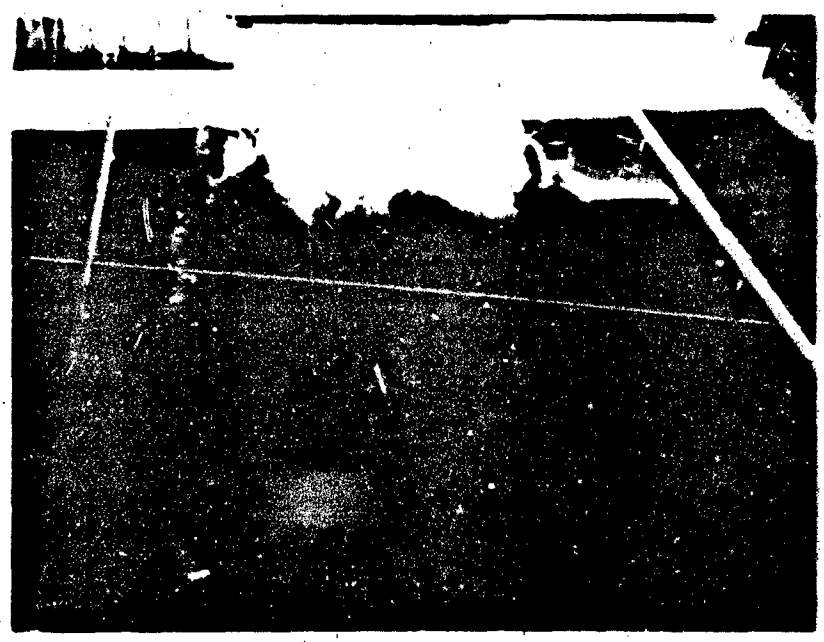




Little Goose Dam

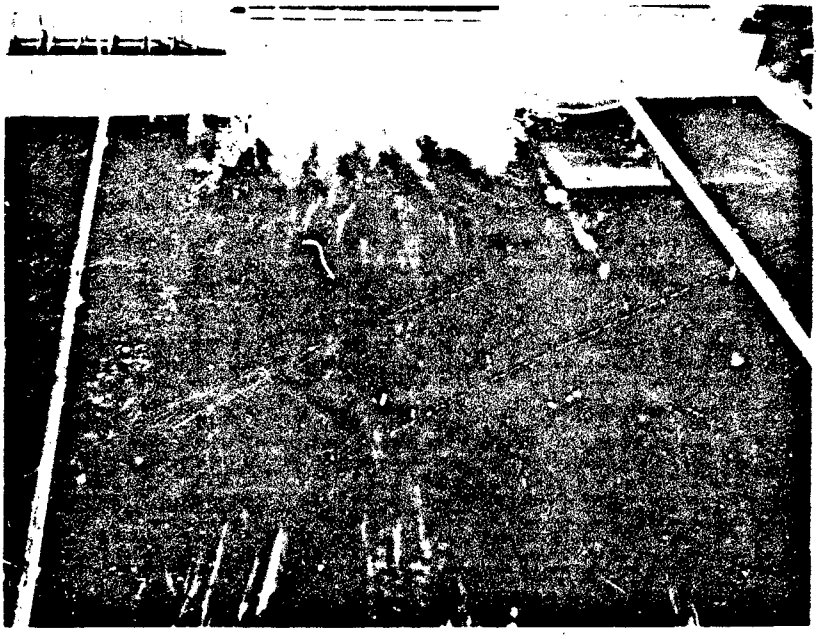
Photograph 85. Flow conditions without deflectors. River discharge 506,400 cfs; powerhouse not operating.

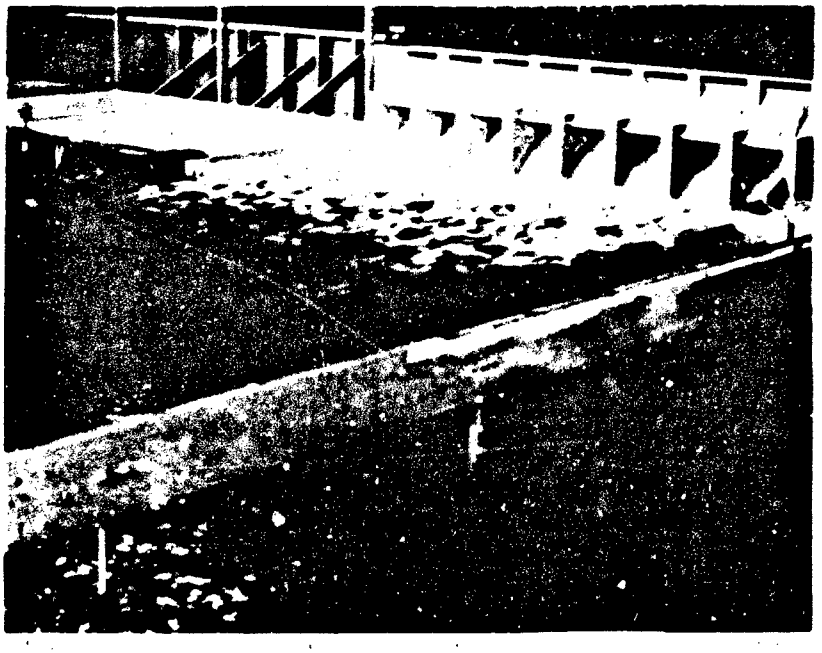




Little Goose Dam

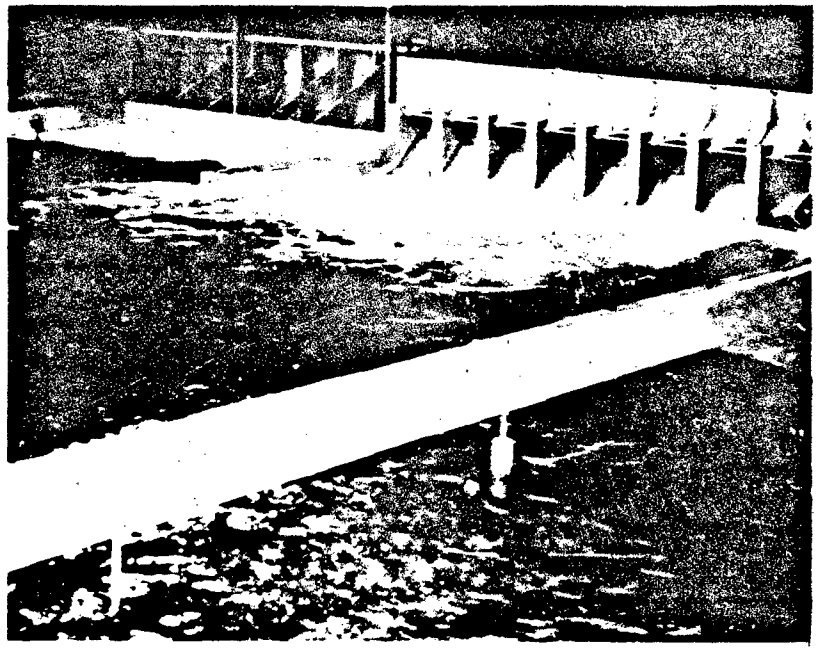
Photograph 86. Flow conditions with deflectors in spillway bays 1 to 8. River discharge 212,000 cfs; powerhouse units 1 to 3 operating.

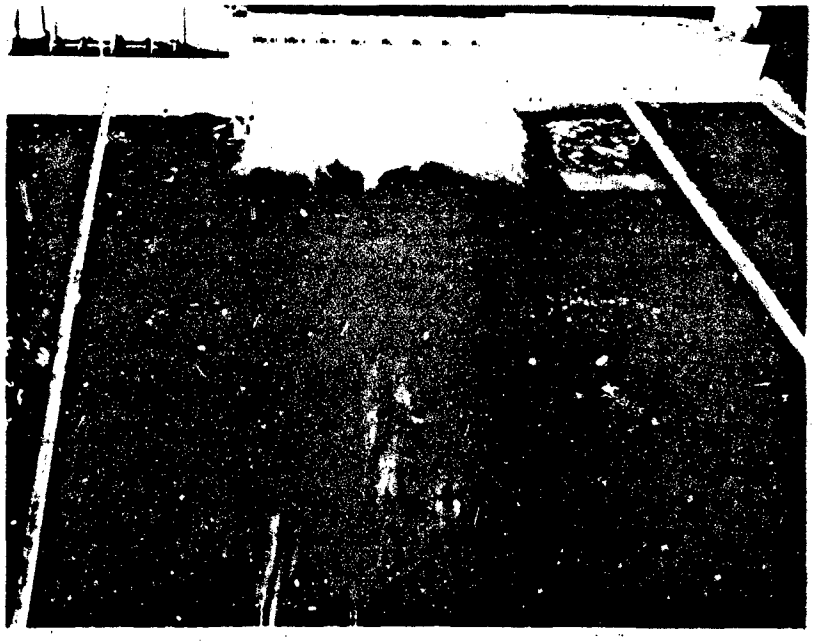




Little Goose Dam

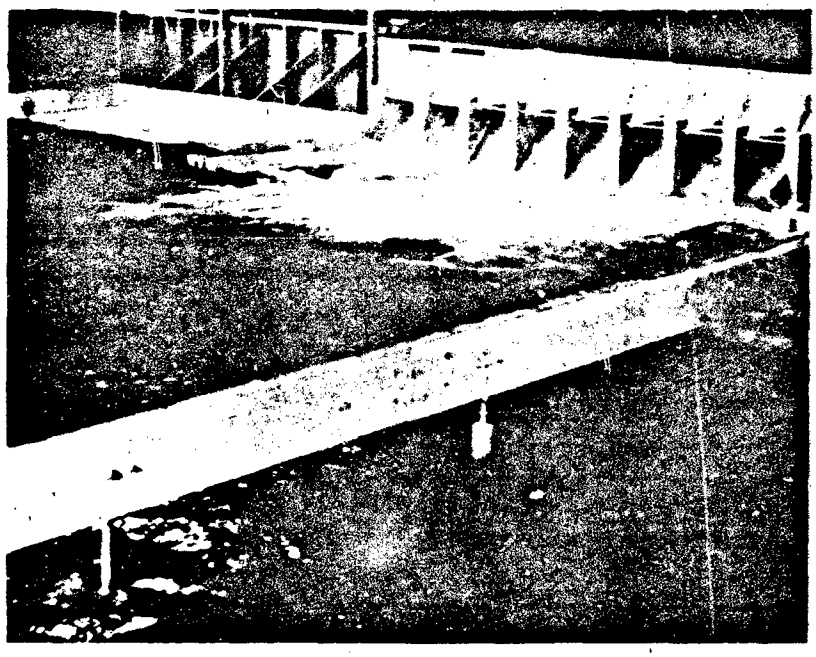
Photograph 87. Flow conditions with deflectors in spillway bays 1 to 8. River discharge 212,000 cfs; powerhouse units 1 to 6 operating.

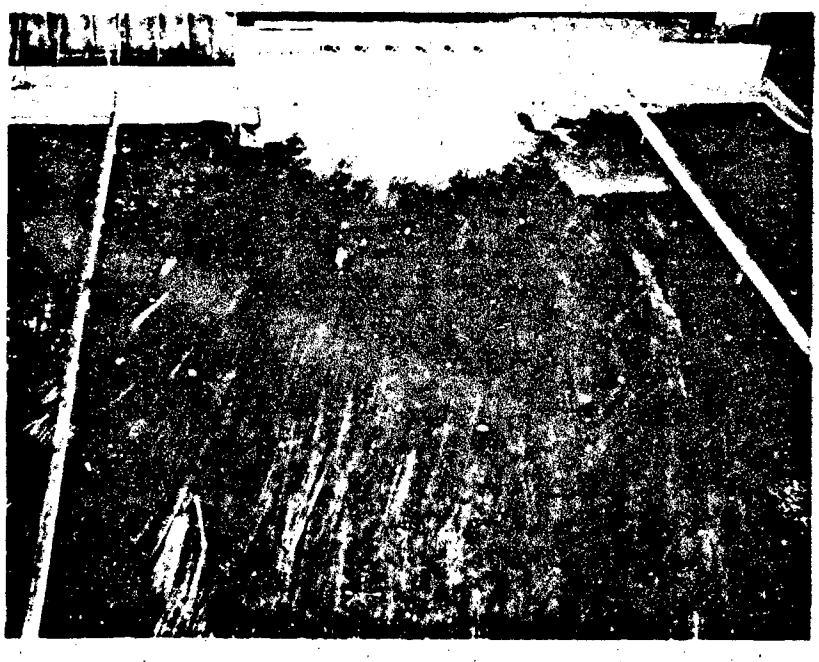




Little Goose Dam

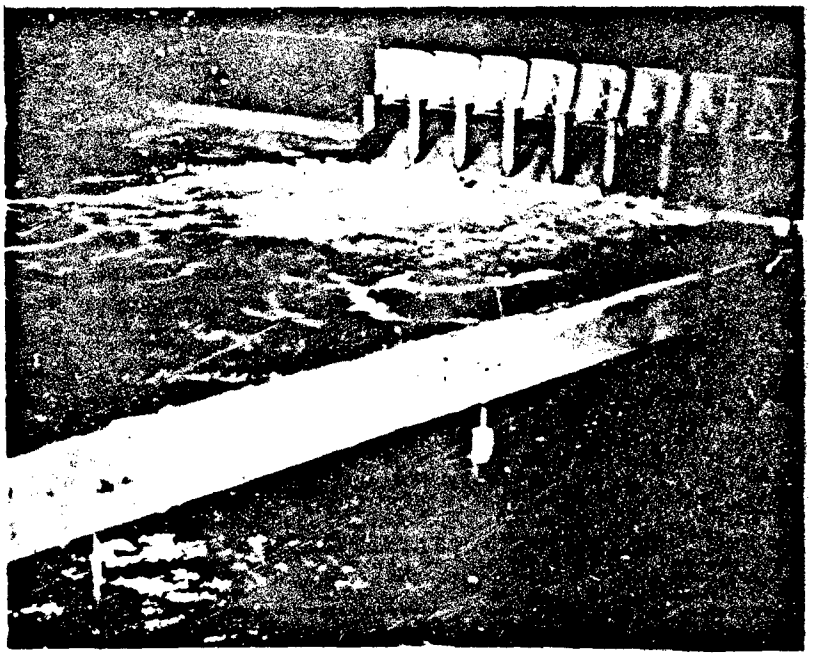
Photograph 88. Flow conditions with deflectors in spillway bays 1 to 8. River discharge 420,000 cfs; powerhouse units 1 to 3 operating.

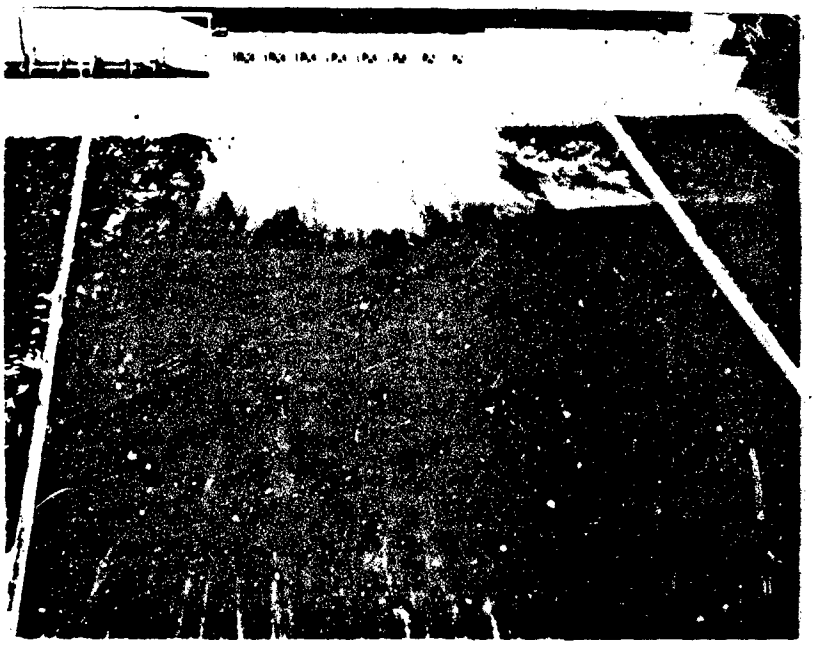




Little Goose Dam

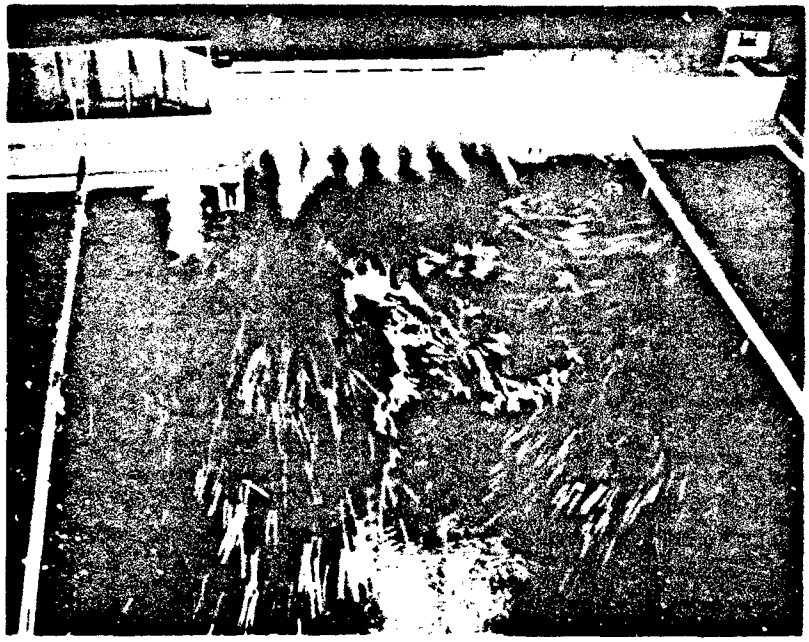
Photograph 89. Flow conditions with deflectors in spillway bays 1 to 8. River discharge 420,000 cfs; powerhouse units 1 to 6 operating.

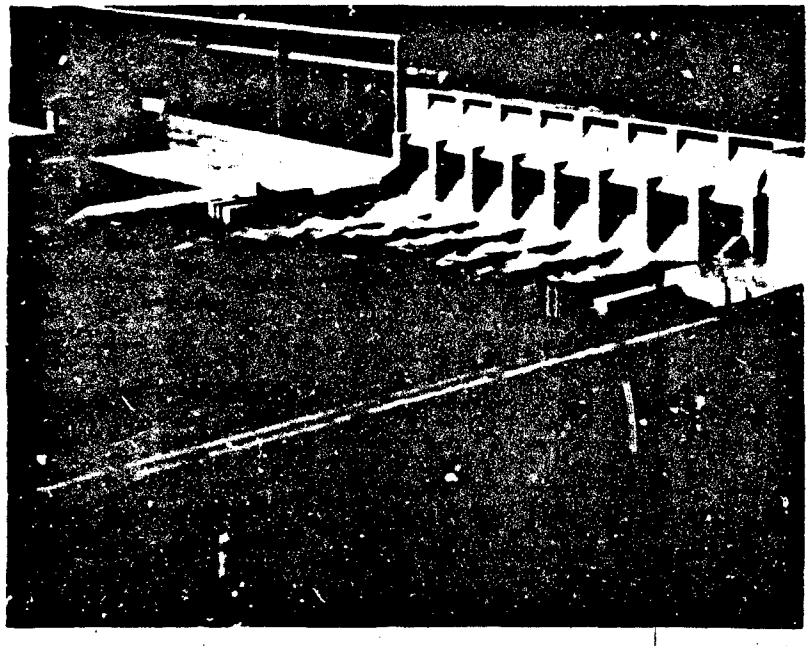




Little Goose Dam

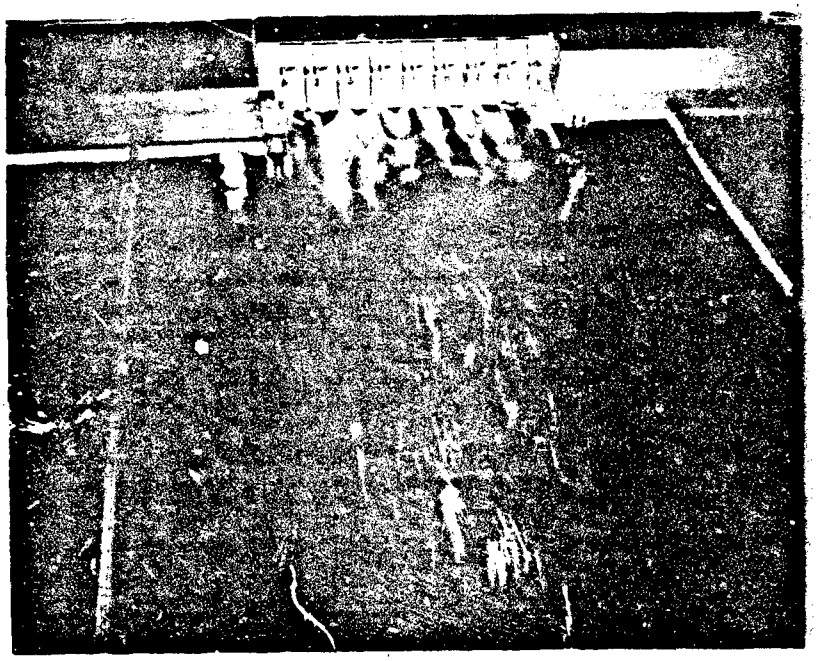
Photograph 90. Flow conditions with deflectors in spillway bays 1 to 8. River discharge 506,400 cfs; powerhouse not operating.

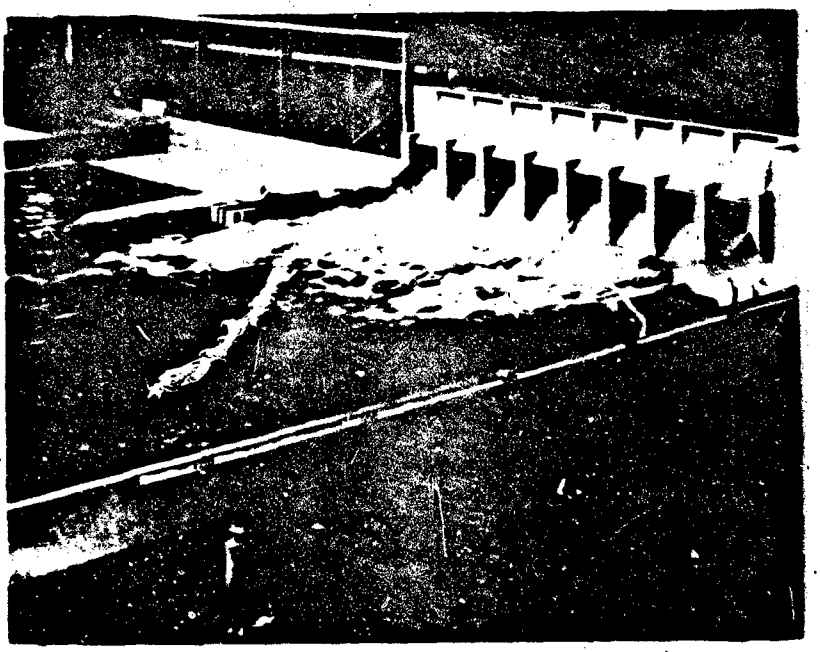




Little Goose Dam

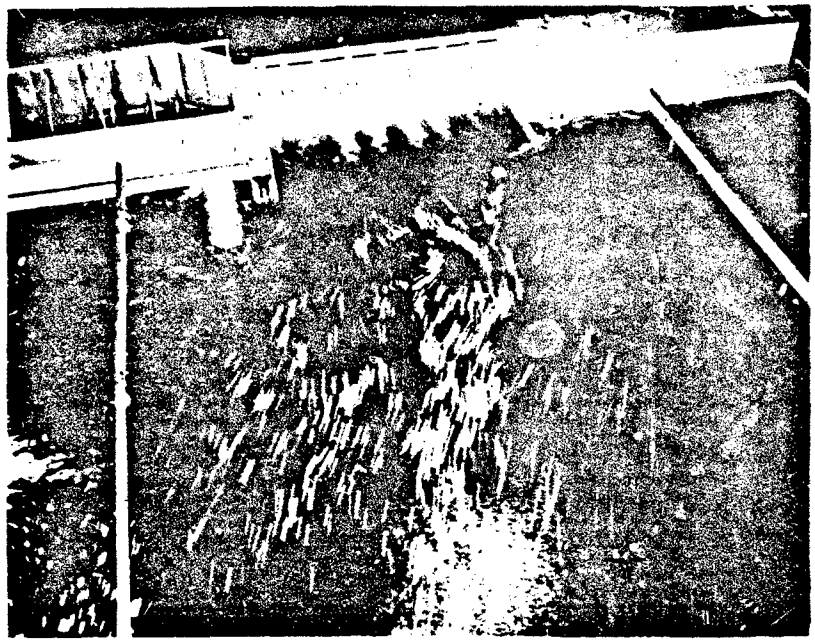
Photograph 91. Flow conditions with deflectors in spillway bays 2 to 7. River discharge 100,000 cfs; powerhouse units 1 to 3 operating.

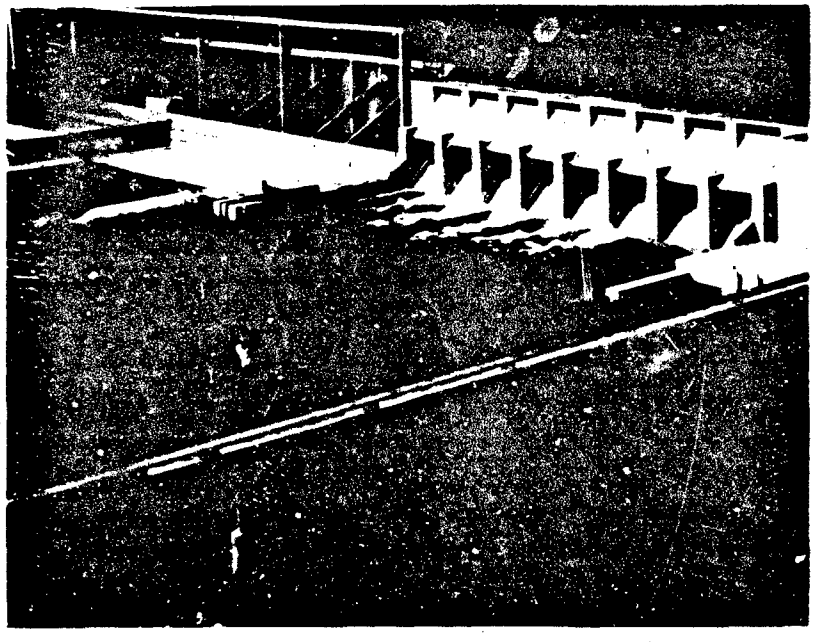




Little Goose Dam

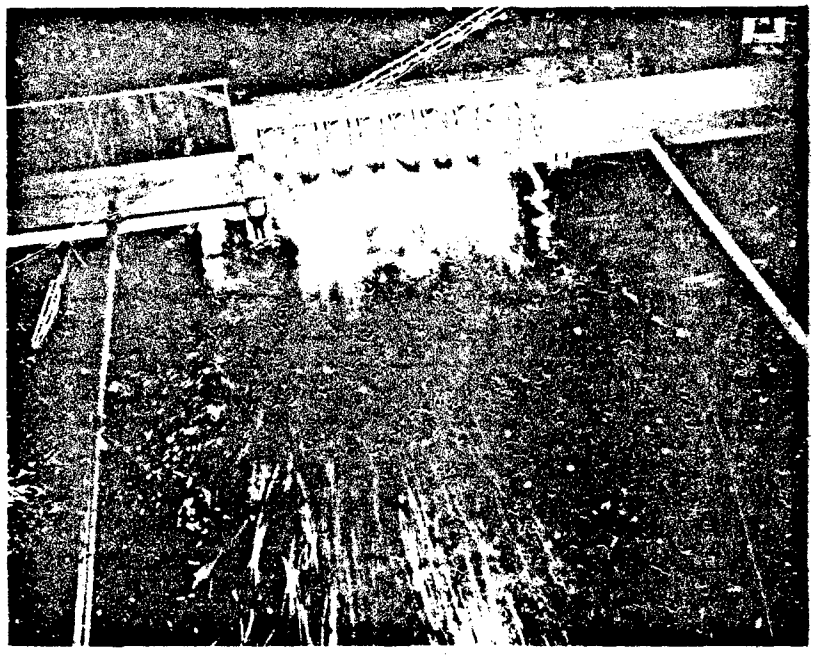
Photograph 92. Flow conditions with deflectors in spillway bays 2 to 7. River discharge 160,000 cfs; powerhouse units 1 to 3 operating.

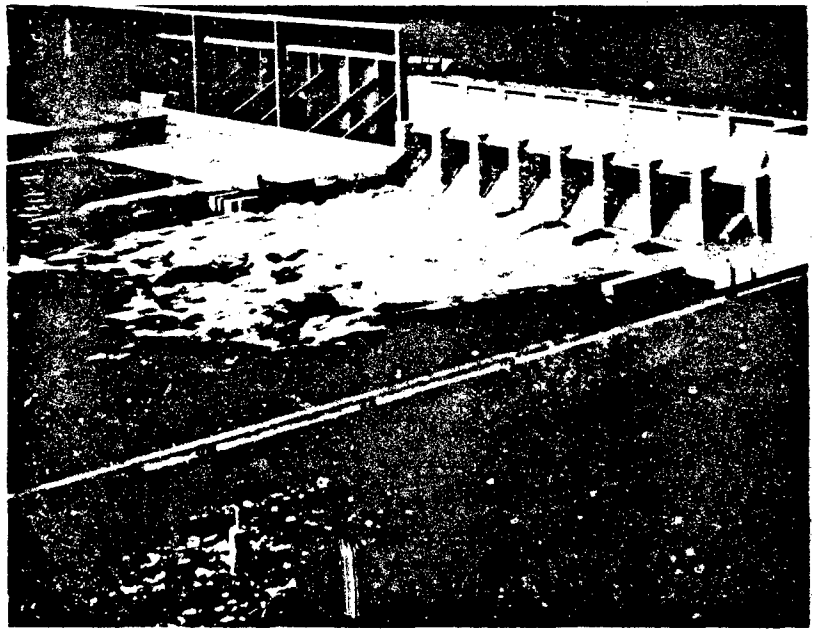




Little Goose Dam

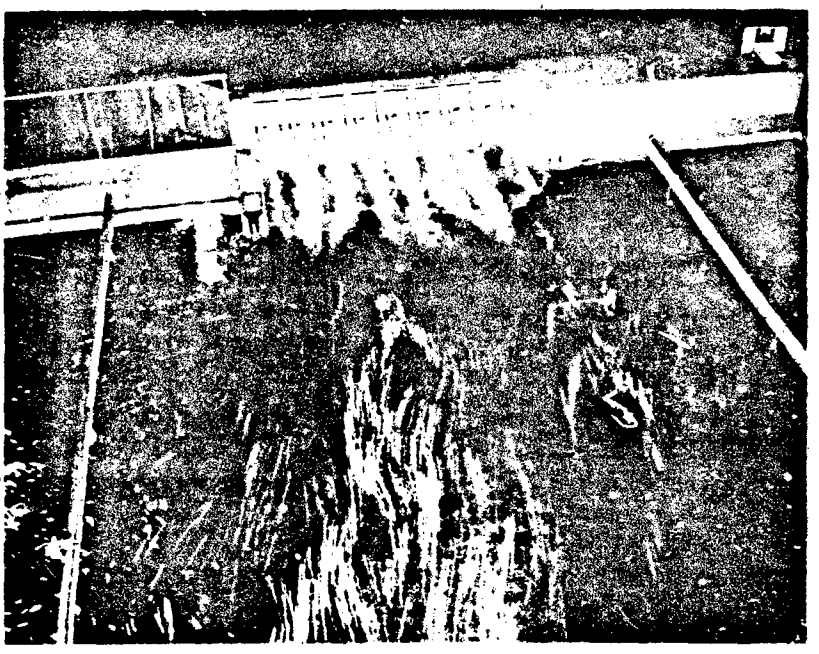
Photograph 93. Flow conditions with deflectors in spillway bays 2 to 7. River discharge 160,000 cfs; powerhouse units 1 to 6 operating.

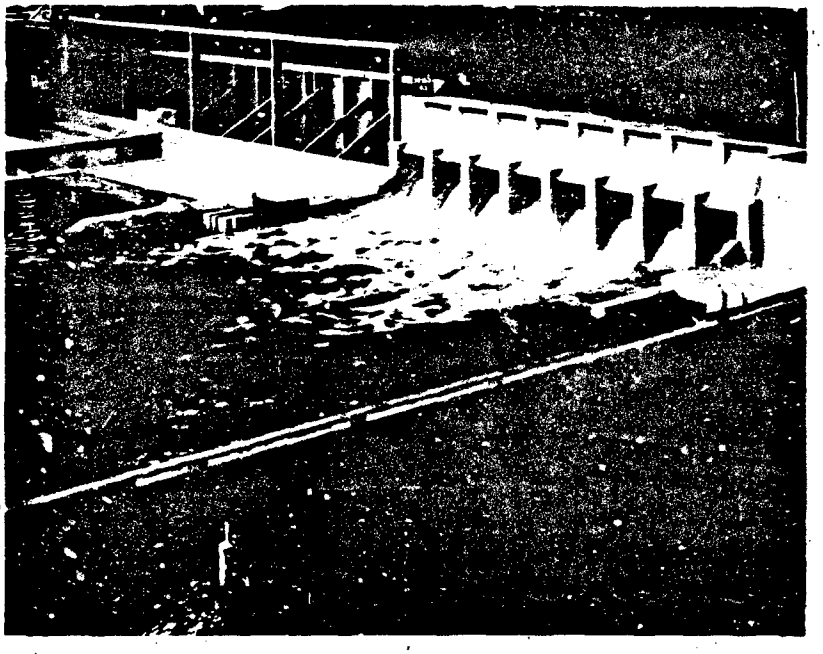




Little Goose Dam

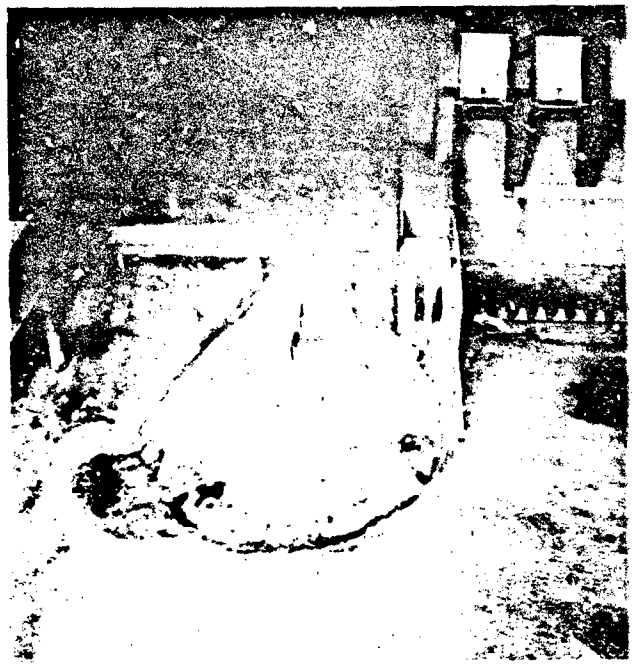
Photograph 94. Flow conditions with deflectors in spillway bays 2 to 7. River discharge 212,000 cfs; powerhouse units 1 to 3 operating.



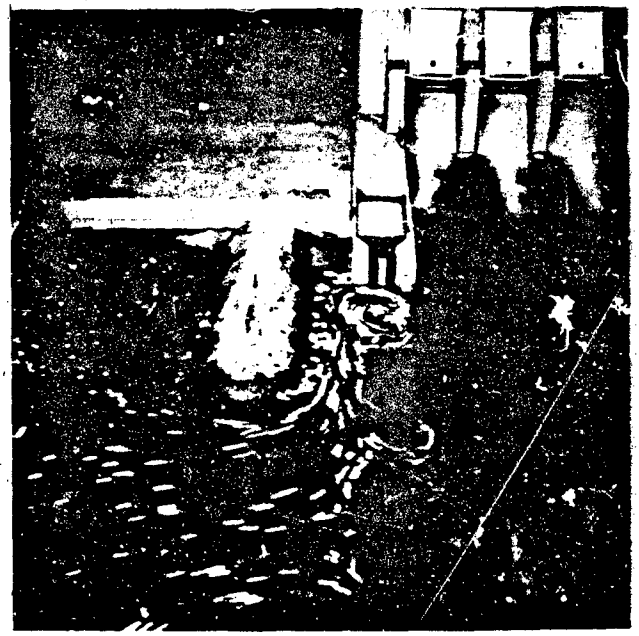


Little Goose Dam

Photograph 95. Flow conditions with deflectors in spillway bays 2 to 7. River discharge 212,000 cfs; powerhouse units 1 to 6 operating.

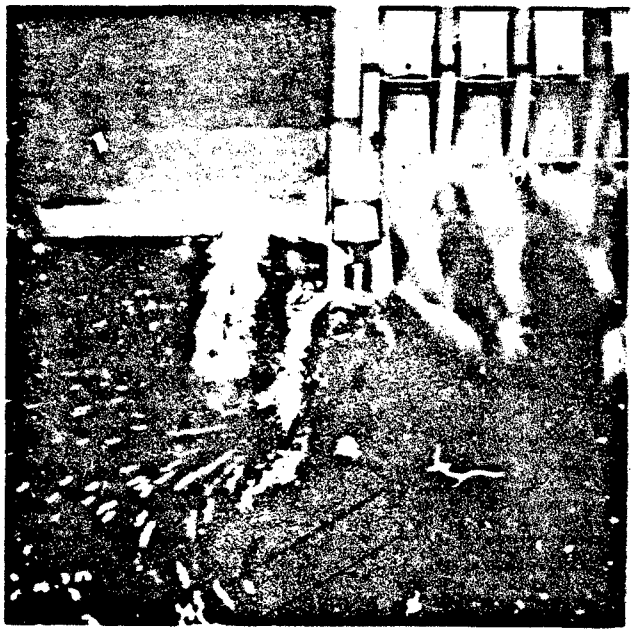


Photograph 96. Dry bed.



Photograph 97. Flow conditions with deflectors in bays 1 to 8. River discharge 100,000 cfs; powerhouse units 1 to 3 operating.

Little Goose Dam - Finger dike fill near north fishway entrance

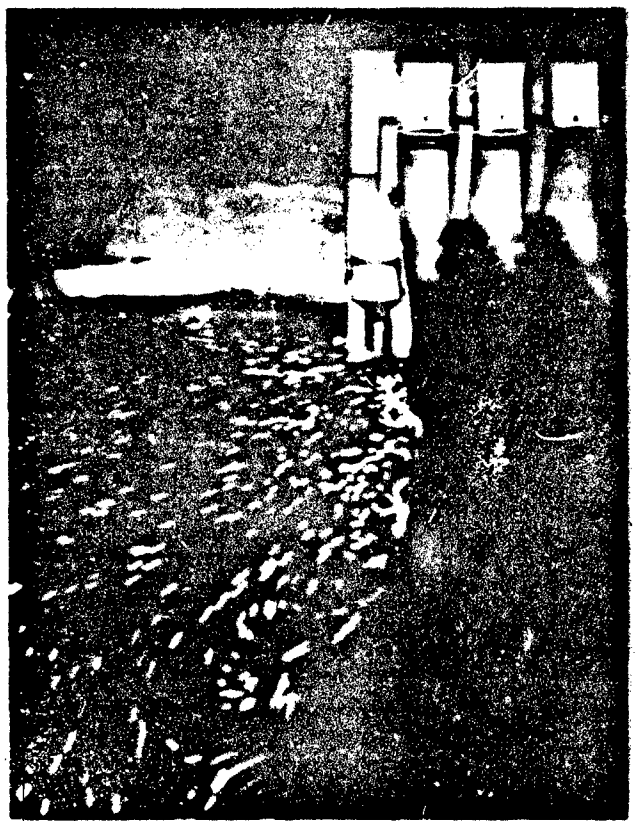


Photograph 98. Powerhouse units 1 to 3 operating.

Photograph 99. Powerhouse units 1 to 6 operating.

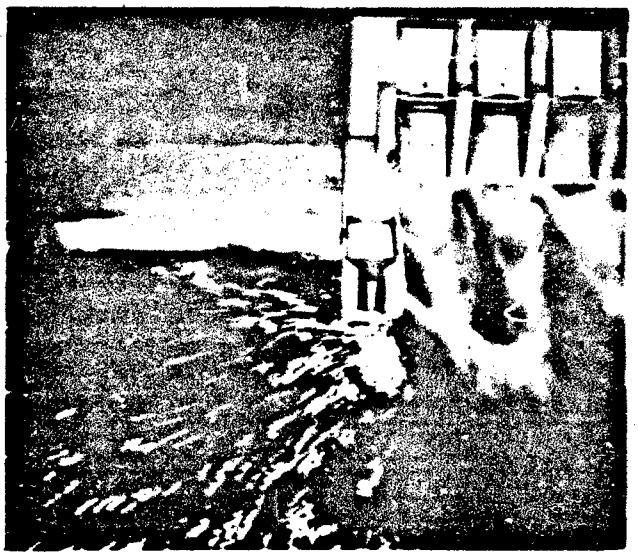
Little Goose Dam

Flow conditions with deflectors in bays 1 to 8 and finger dike fill near north fishway entrance in place. River discharge 160,000 cfs.

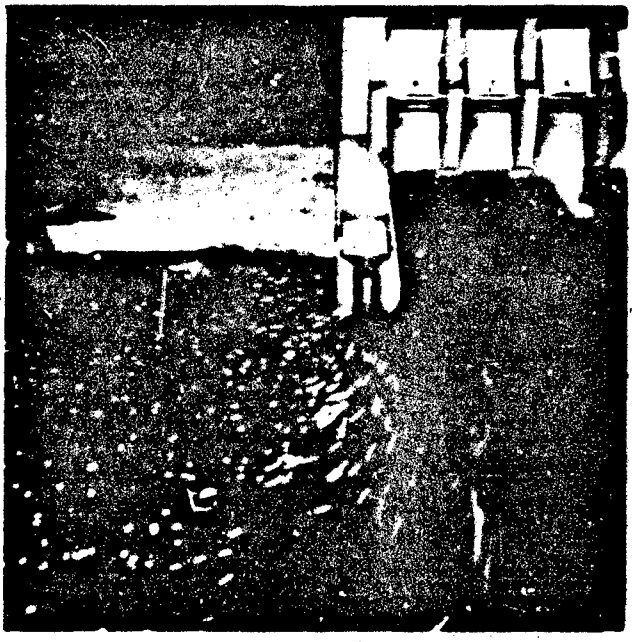


Little Goose Dam

Photograph 100. Flow conditions with deflectors in spillway bays 1 to 8 and finger dike fill near north fishway entrance removed. River discharge 100,000 cfs; powerhouse units 1 to 3 operating.



Photograph 101. Powerhouse units 1 to 3 operating.



Photograph 102. Powerhouse units 1 to 6 operating.

Little Goose Dam

Flow conditions with deflectors in spillway bays 1 to 8 and finger dike fill near north fishway entrance removed. River discharge 160,000 cfs.

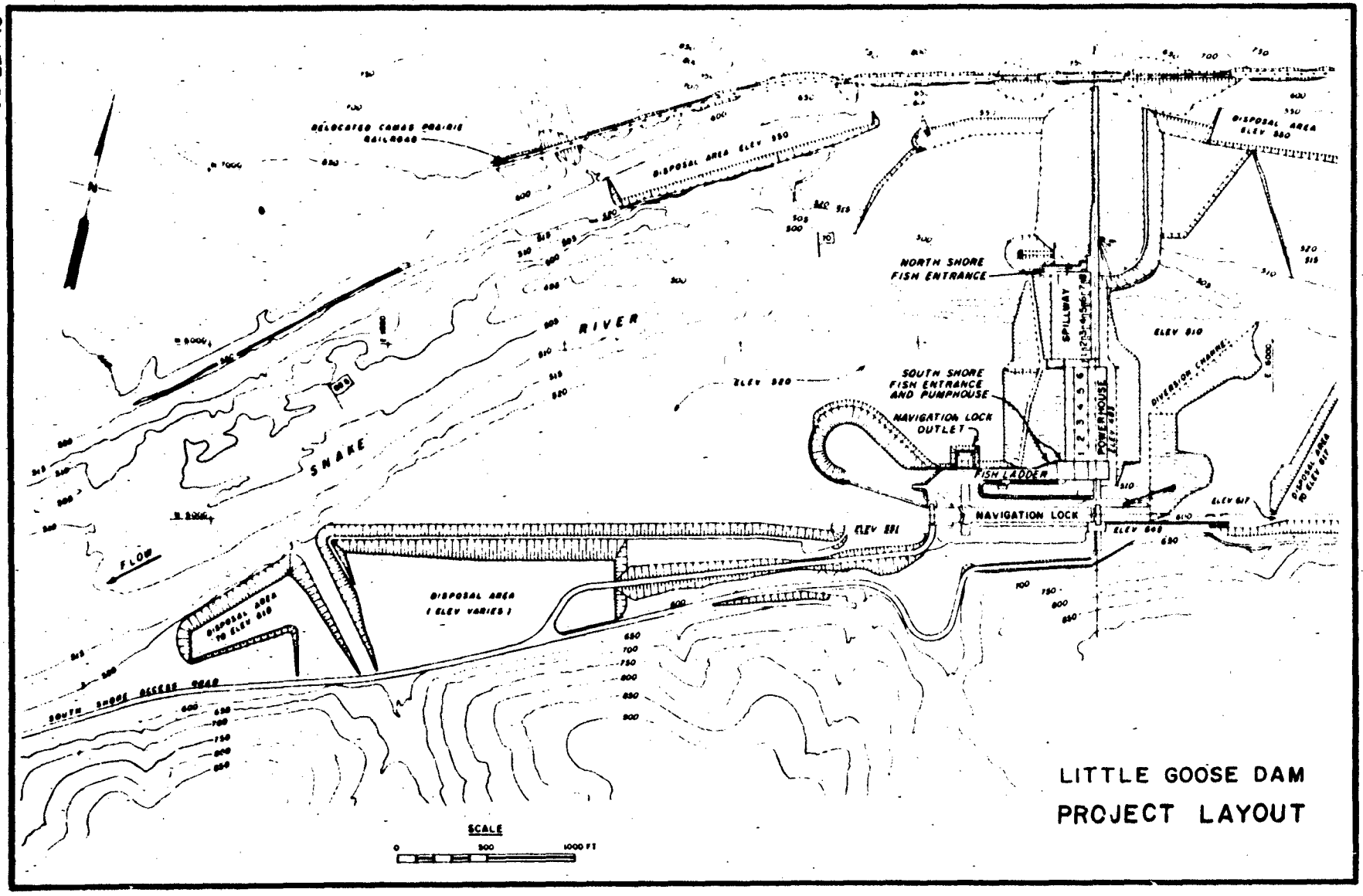
Photograph 103. Deflectors in spillway bays 1 to 8.

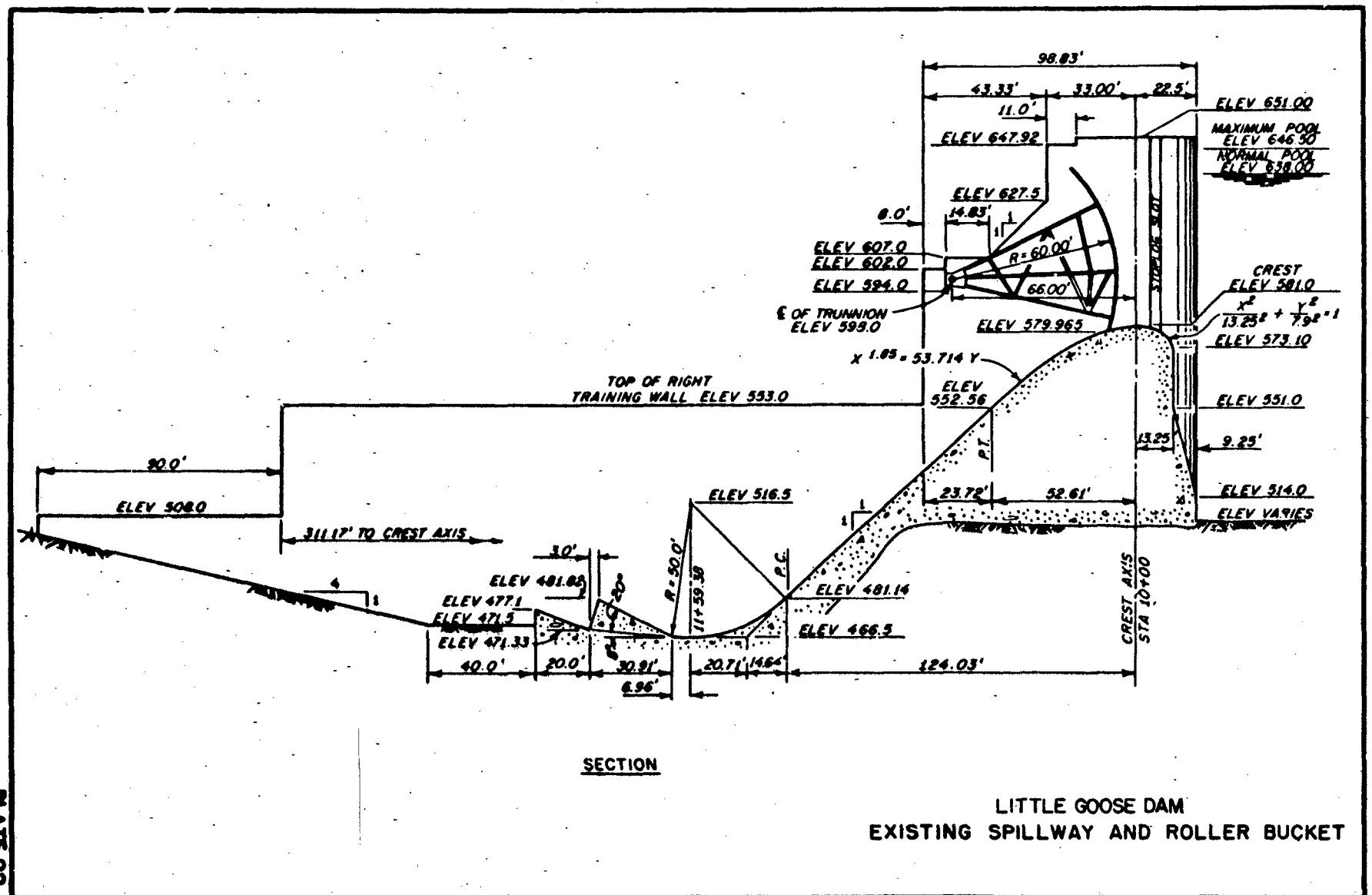
Photograph 104. Deflectors in spillway bays 1 to 7.

Little Goose Dam

Flow conditions with finger dike fill near north fishway entrance in place and 15-foot tapered nose on right training wall. Powerhouse units 1 to 3 operating; river discharge 212,000 cfs.

PLATE 91

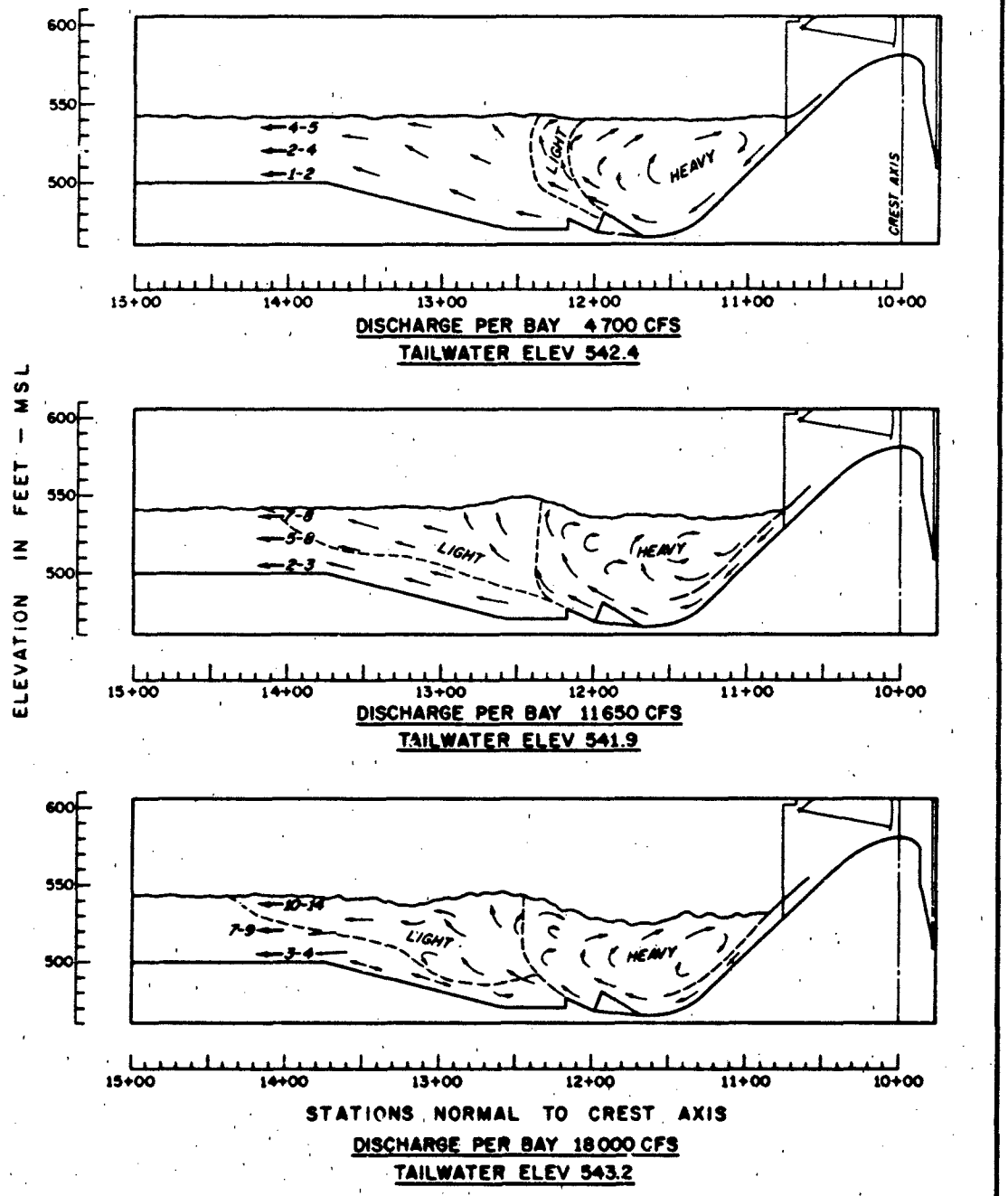

RELOCATED CAMAS PRAIRIE RAILROAD
DISPOSAL AREA ELEV 880
DISPOSAL AREA ELEV 880
NORTH SHORE FISH ENTRANCE
SPILLWAY
POWERHOUSE
ELEV 810
SOUTH SHORE FISH ENTRANCE AND PUMPHOUSE
NAVIGATION LOCK OUTLET
DIVERSION CHANNEL
FISH LADDER
NAVIGATION LOCK
ELEV 881
ELEV 880
ELEV 617
DISPOSAL AREA TO ELEV 617
SNAKE RIVER
FLOW
DISPOSAL AREA TO ELEV 810
DISPOSAL AREA (ELEV VARIES)
SOUTH SHORE ACCESS ROAD
SCALE
0
500
1000 FT
LITTLE GOOSE DAM
PROJECT LAYOUT



SECTION

LITTLE GOOSE DAM
EXISTING SPILLWAY AND ROLLER BUCKET

PLATE 92



LEGEND

– – – – – – – – ZONES OF AERATION

←10-14 VELOCITY RANGE IN FPS

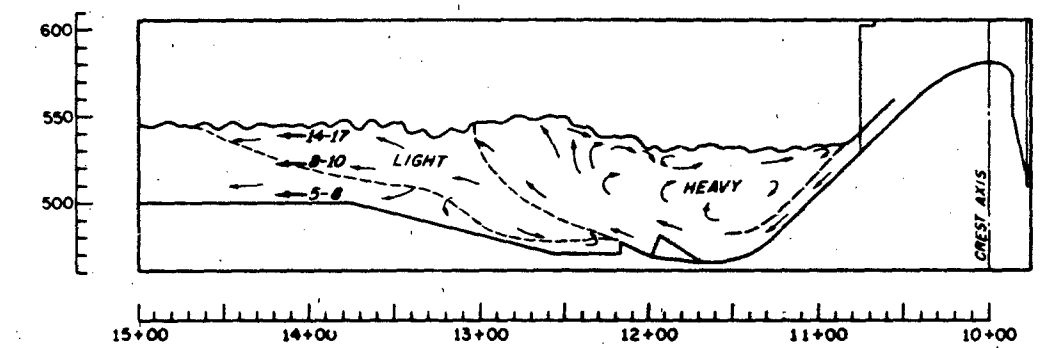
LITTLE GOOSE DAM

AERATION, FLOW DIRECTIONS AND VELOCITIES

NO DEFLECTOR

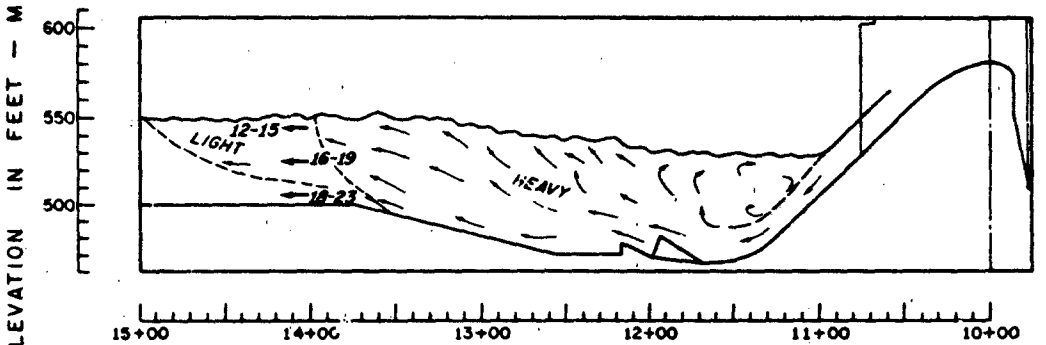
DISCHARGES 4700, 11650, 18000 CFS PER BAY

PLATE 93

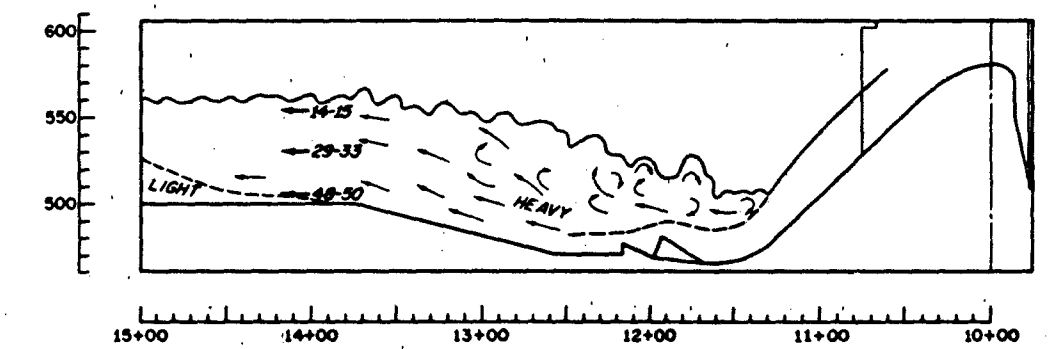


DISCHARGE PER BAY 22700 CFS
TAILWATER ELEV 544.0

ELEVATION IN FEET – MSL



DISCHARGE PER BAY 43750 CFS
TAILWATER ELEV 548.5



STATIONS NORMAL TO CREST AXIS
DISCHARGE PER BAY 106250 CFS
TAILWATER ELEV 560.6

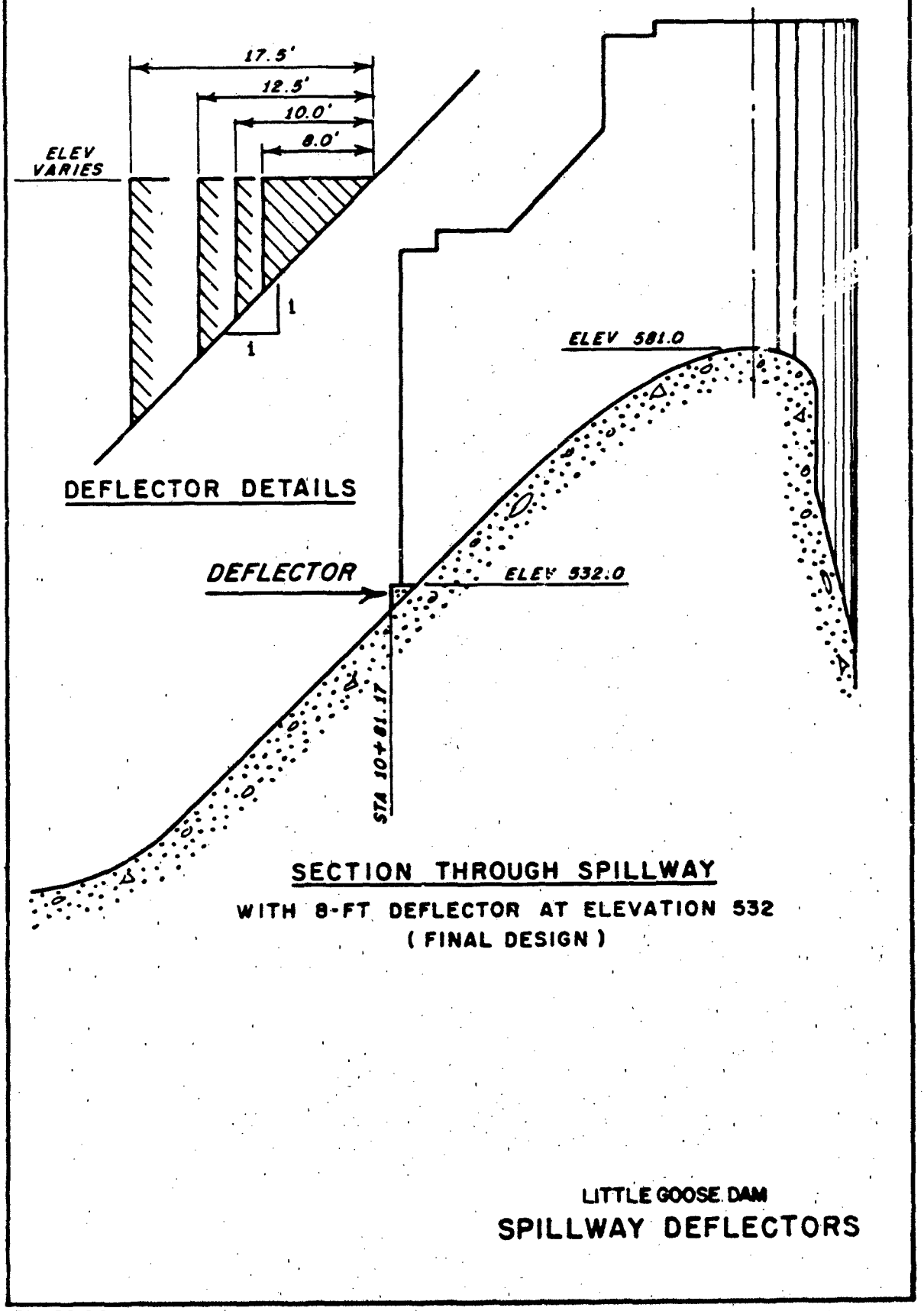
LEGEND

--------- ZONES OF AERATION

←14-17 VELOCITY RANGE IN FPS

LITTLE GOOSE DAM
AERATION, FLOW DIRECTIONS AND VELOCITIES
NO DEFLECTOR
DISCHARGES 22700, 43750, 106250 CFS PER BAY

PLATE 94



SECTION THROUGH SPILLWAY

WITH 8-FT DEFLECTOR AT ELEVATION 532

(FINAL DESIGN)

LITTLE GOOSE DAM

SPILLWAY DEFLECTORS

PLATE 95

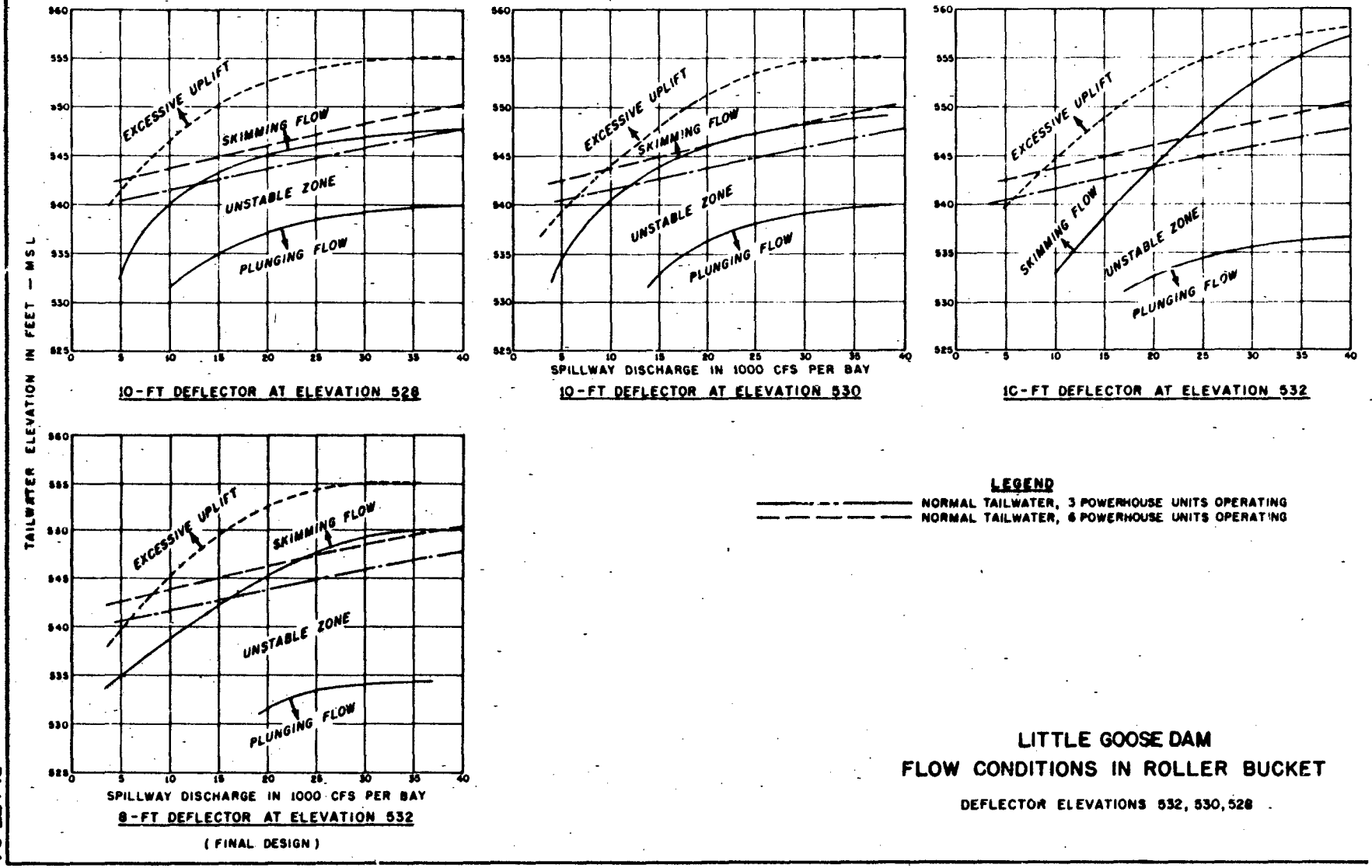
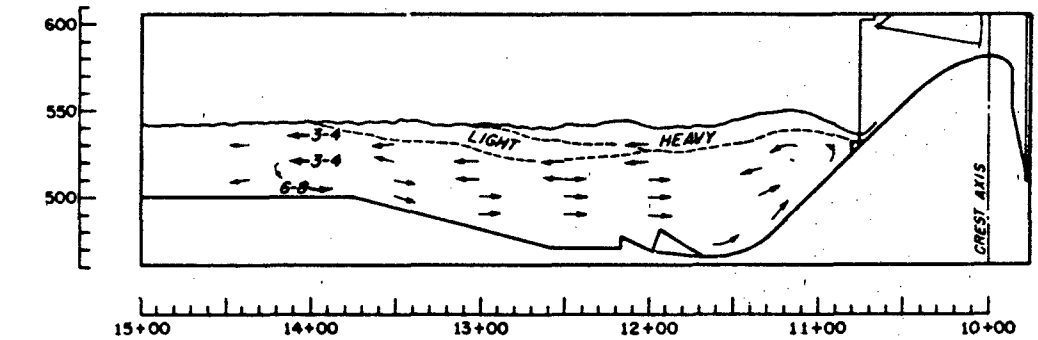


PLATE 96

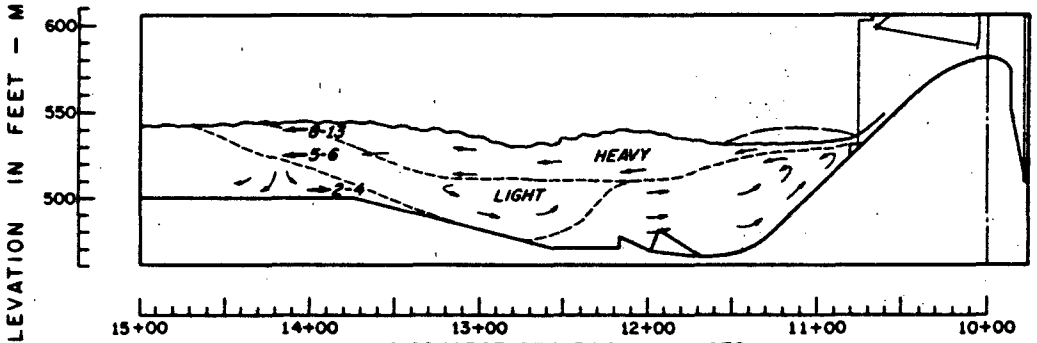
LITTLE GOOSE DAM
FLOW CONDITIONS IN ROLLER BUCKET

DEFLECTOR ELEVATIONS 532, 530, 528

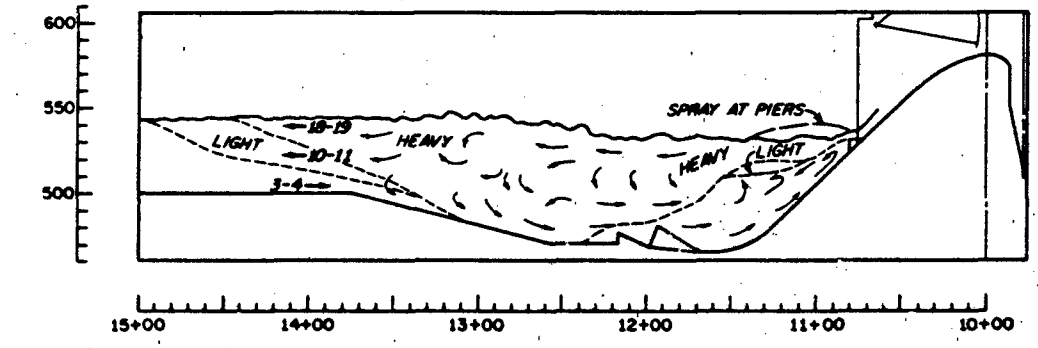


DISCHARGE PER BAY 4700 CFS
TAILWATER ELEV 542.4

ELEVATION IN FEET – MSL



DISCHARGE PER BAY 11650 CFS
TAILWATER ELEV 541.9



STATIONS NORMAL TO CREST AXIS
DISCHARGE PER BAY 18000 CFS
TAILWATER ELEV 543.2

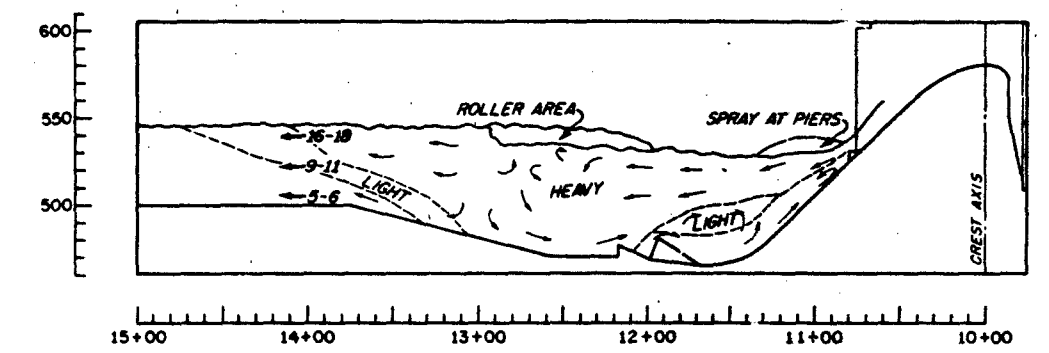
LEGEND

– – – – – – – – ZONES OF AERATION

←10-11 VELOCITY RANGE IN FPS

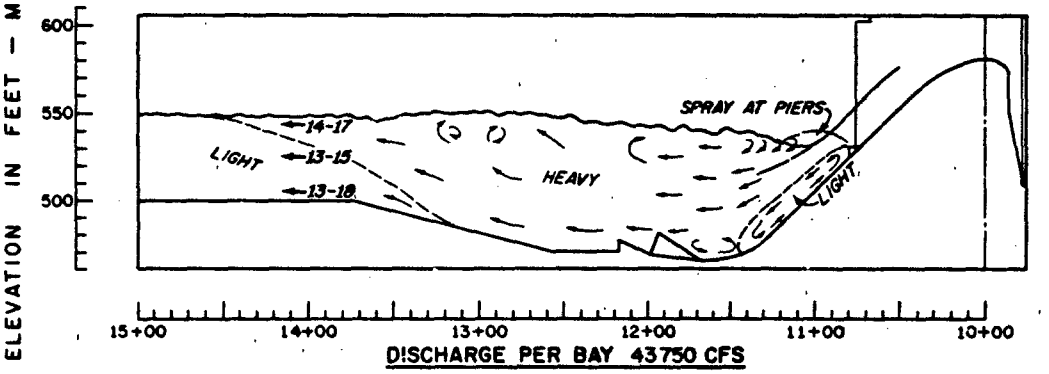
LITTLE GOOSE DAM
AERATION, FLOW DIRECTIONS AND VELOCITIES
8-FT DEFLECTOR AT ELEV 532
DISCHARGES 4700, 11650, 18000 CFS PER BAY

PLATE 97

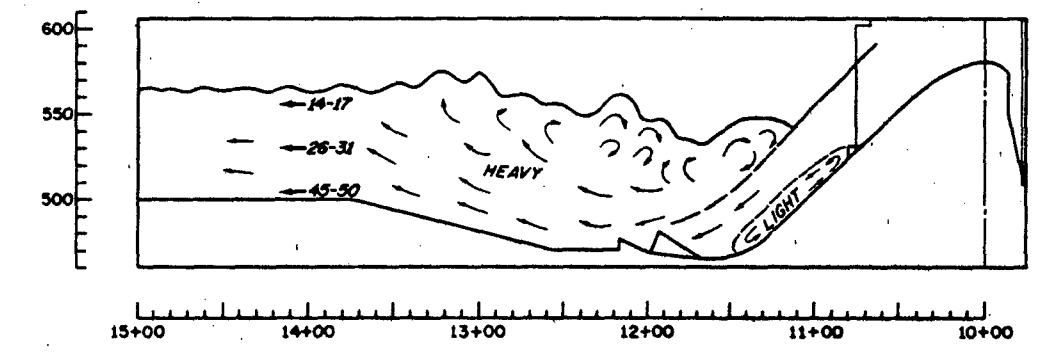


DISCHARGE PER BAY 22700 CFS
TAILWATER ELEV 544.0

ELEVATION IN FEET – MSL



DISCHARGE PER BAY 43750 CFS
TAILWATER ELEV 548.5



STATIONS NORMAL TO CREST AXIS
DISCHARGE PER BAY 106250 CFS
TAILWATER ELEV 560.6

LEGEND

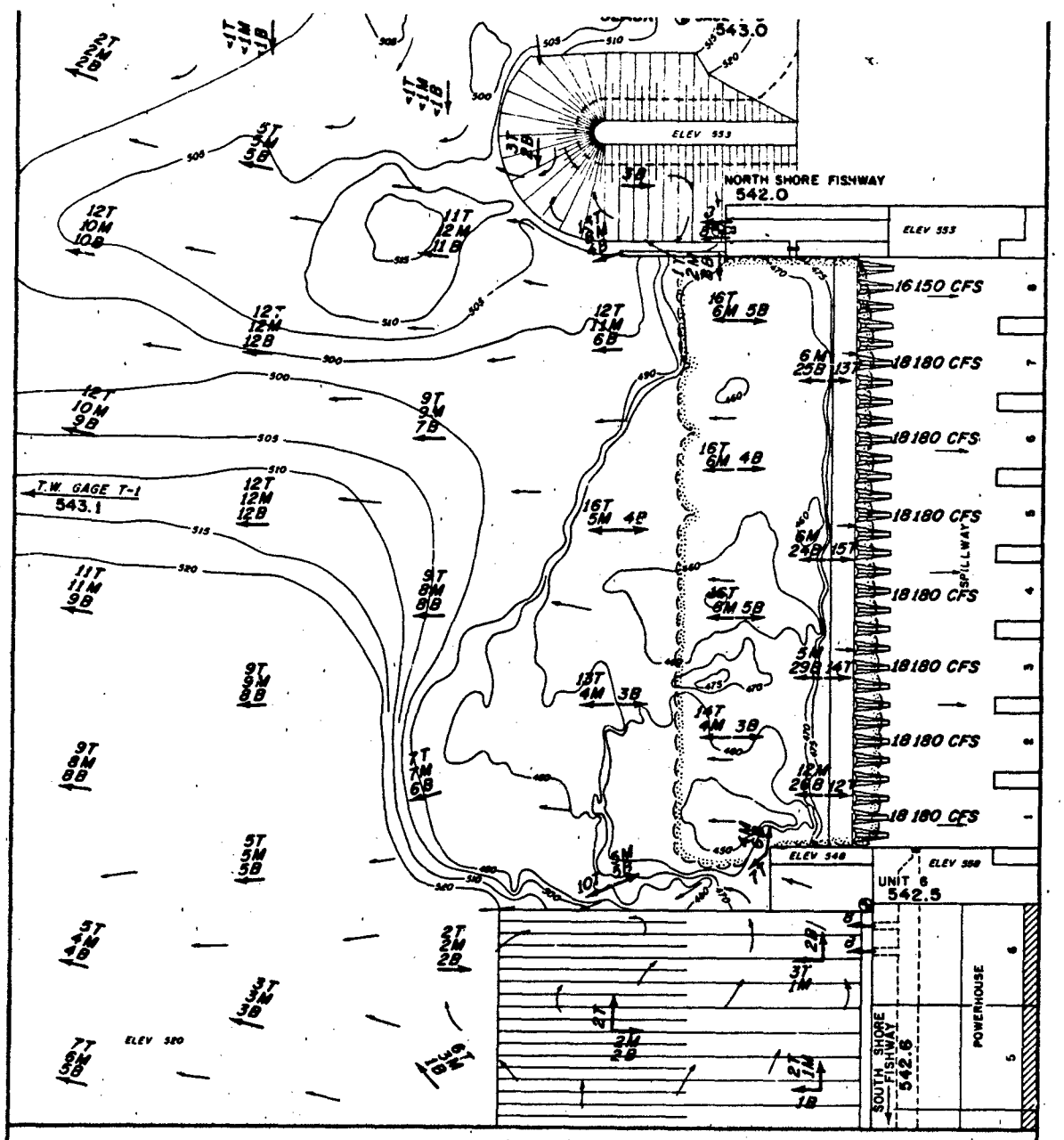
---------- ZONES OF AERATION

←14-17 VELOCITY RANGE IN FPS

LITTLE GOOSE DAM

AERATION, FLOW DIRECTIONS AND VELOCITIES
8-FT DEFLECTOR AT ELEV 532
DISCHARGES 22700, 43750, 106250 CFS PER BAY

PLATE 98



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SOIL OUTLINE

OPERATING CONDITIONS

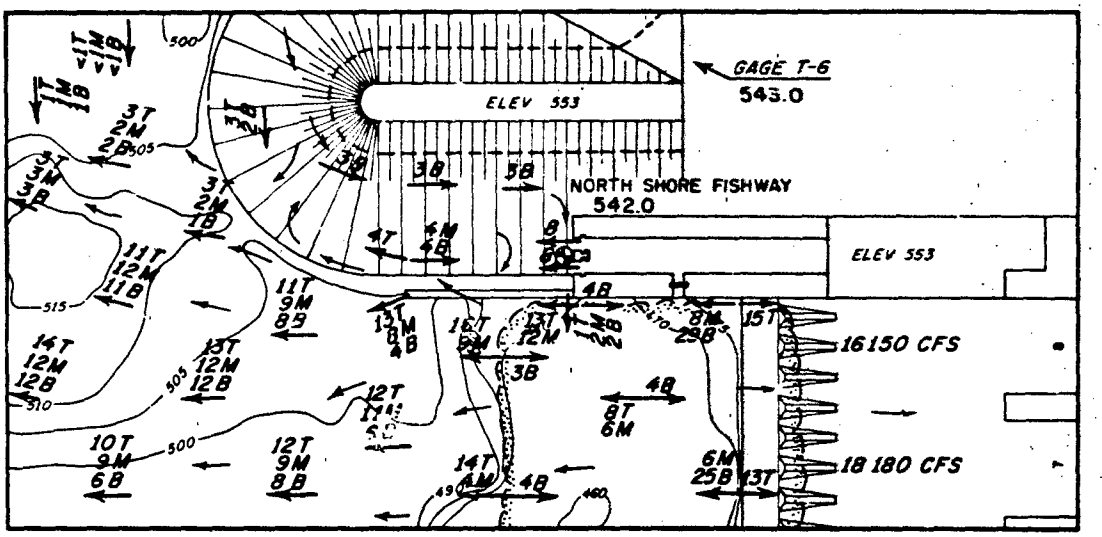
POWERHOUSE UNITS 1 TO 3	66 250 CFS
SPILLWAY BAYS 1 TO 8	143 675 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

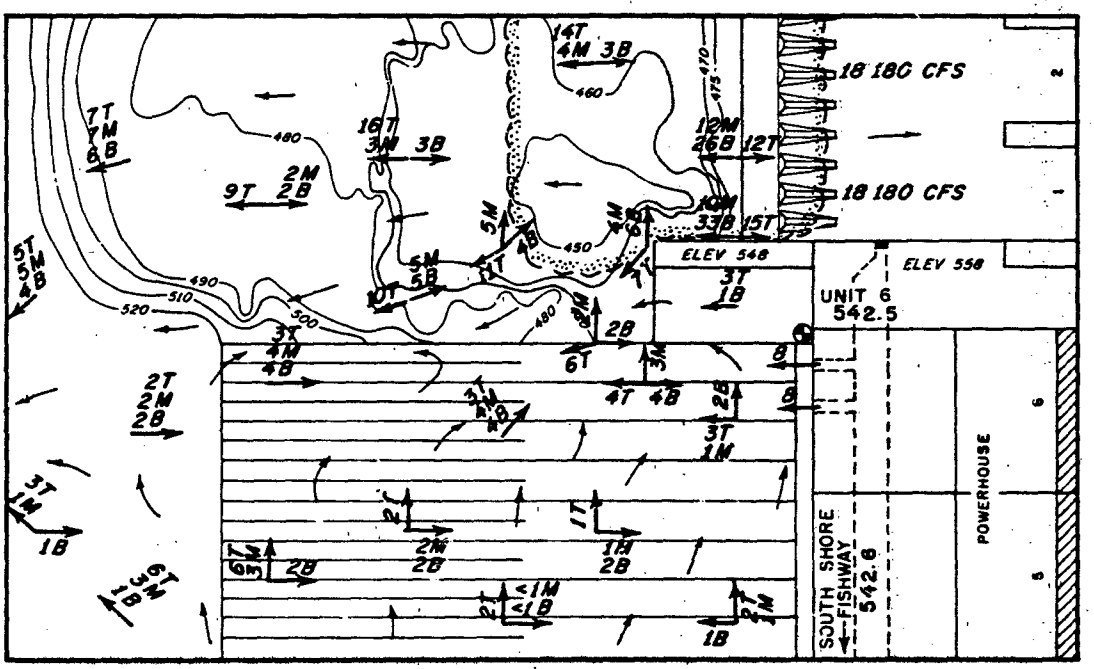
LITTLE GOOSE DAM
WITHOUT DEFLECTOR

FLOW CONDITIONS
RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 99



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	68 250 CFS
SPILLWAY BAYS 1 TO 8	143 675 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

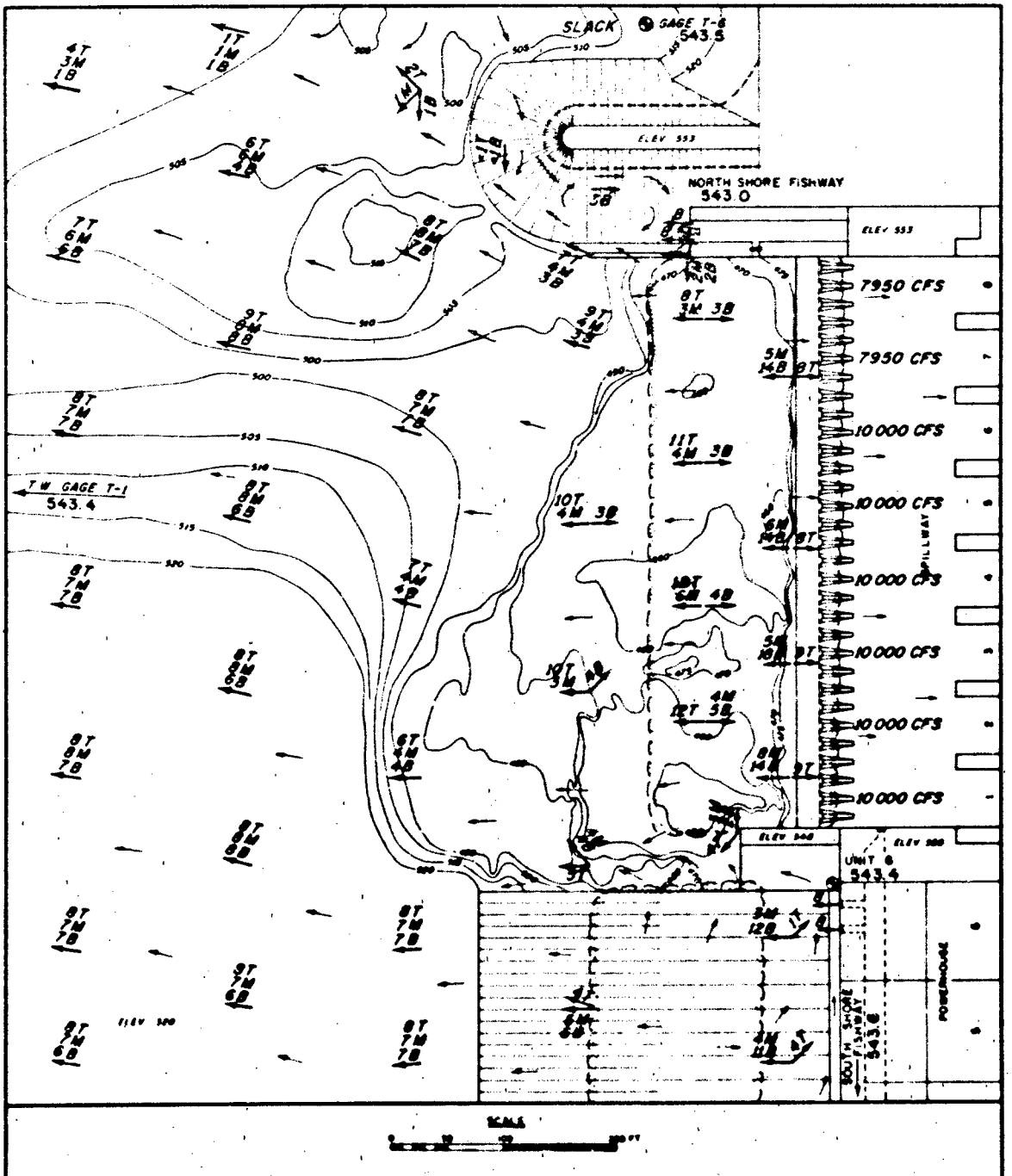
* PUMPED FROM TAILWATER

WITHOUT DEFLECTOR

LITTLE GOOSE DAM

FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 100



LITTLE GOOSE DAM

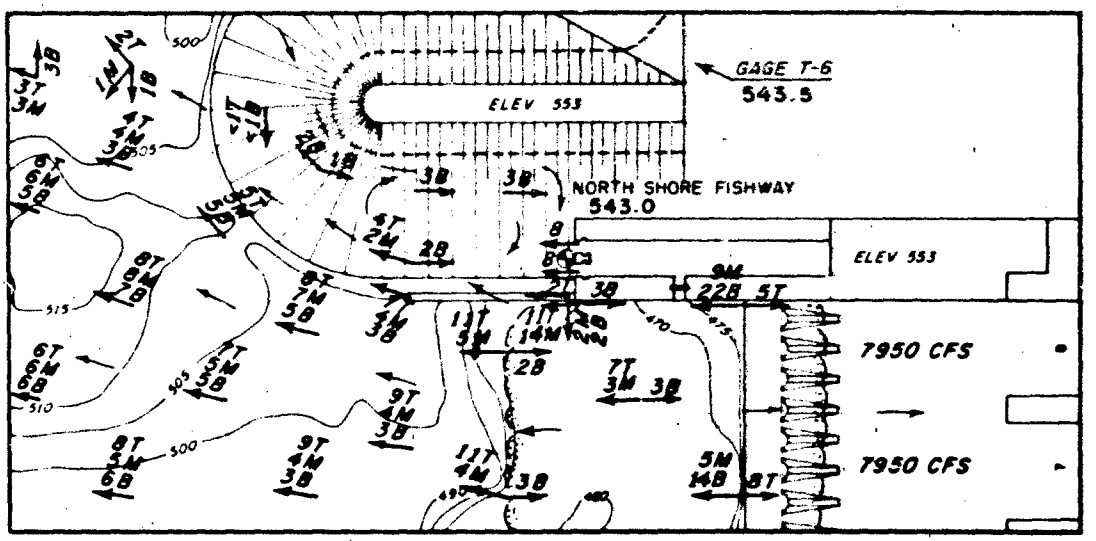
WITHOUT DEFLECTOR

FLOW CONDITIONS

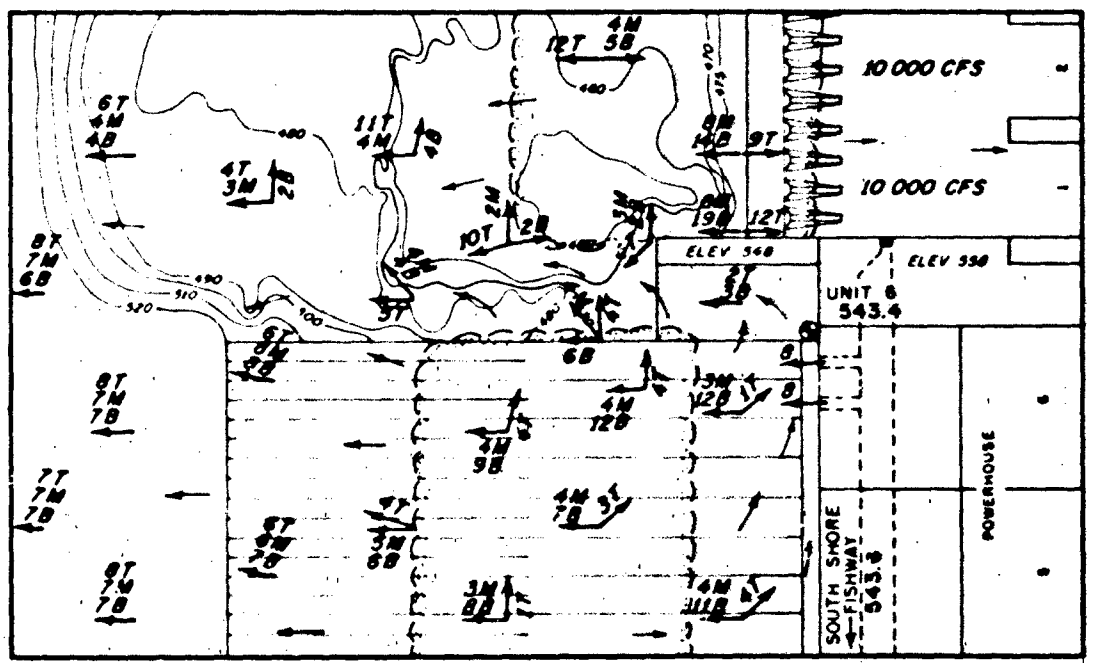
RIVER DISCHARGE 212 000 CFS

POWERHOUSE UNITS 1 TO 6

PLATE 101



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT OFF BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 500 CFS
SPILLWAY BAYS 1 TO 8	75 425 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	800 CFS
NORTH SHORE FISHWAY *	750 CFS

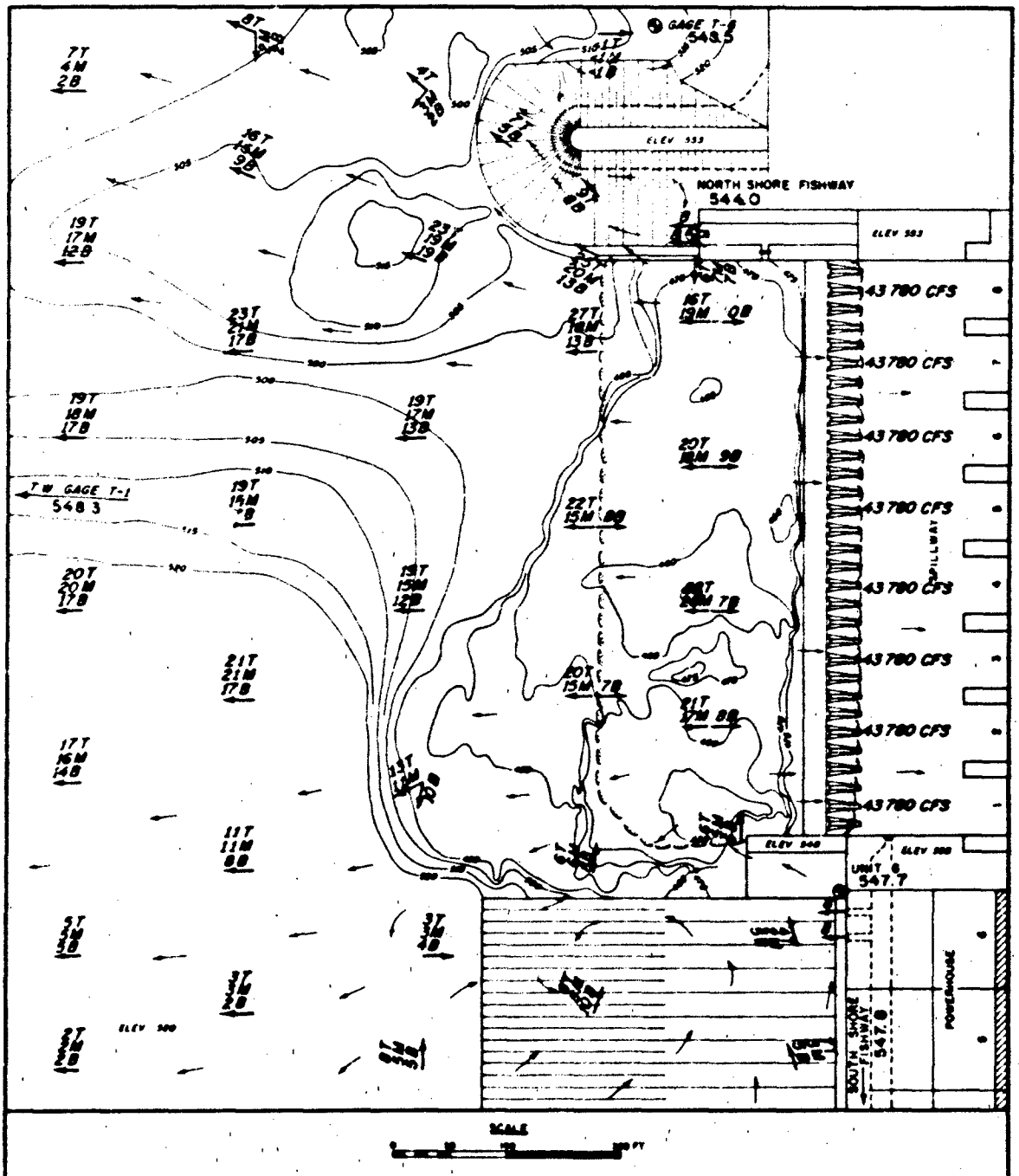
* PUMPED FROM TAILWATER

WITHOUT DEFLECTOR

LITTLE GOOSE DAM

FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 102



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	69 900 CFS
SPILLWAY BAYS 1 TO 8	350 025 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	780 CFS

* PUMPED FROM TAILWATER

LITTLE GOOSE DAM

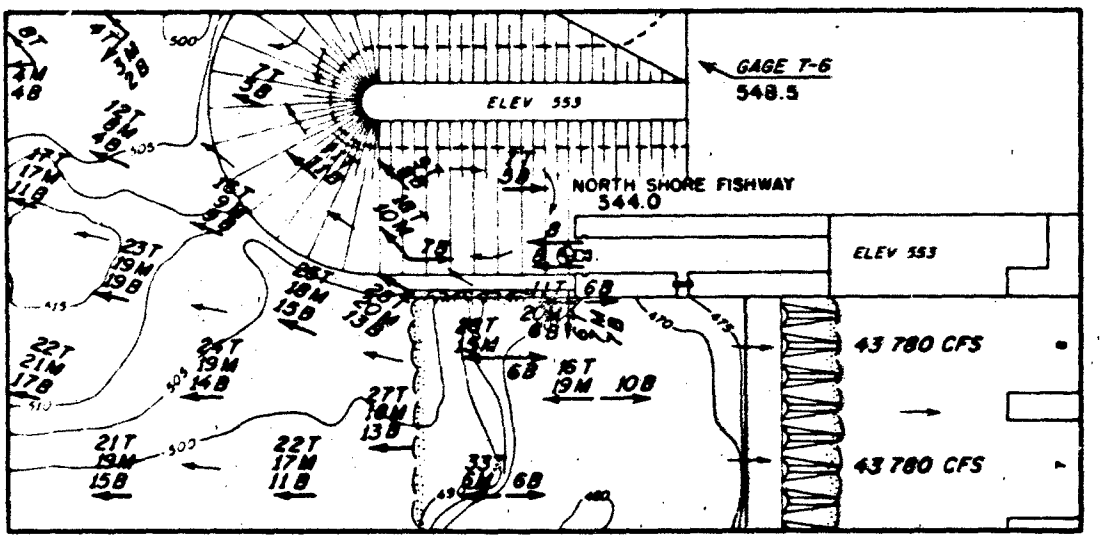
WITHOUT DEFLECTOR

FLOW CONDITIONS

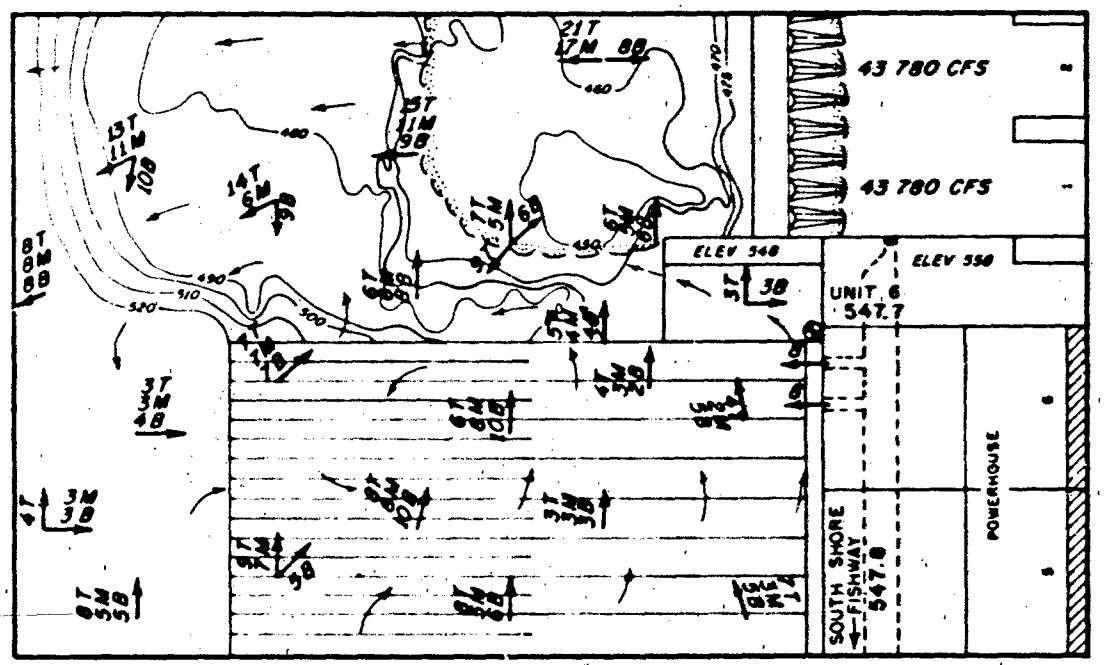
RIVER DISCHARGE 420 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 103



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

WITHOUT DEFLECTOR

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	69 900 CFS
SPILLWAY BAYS 1 TO 8	350 025 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

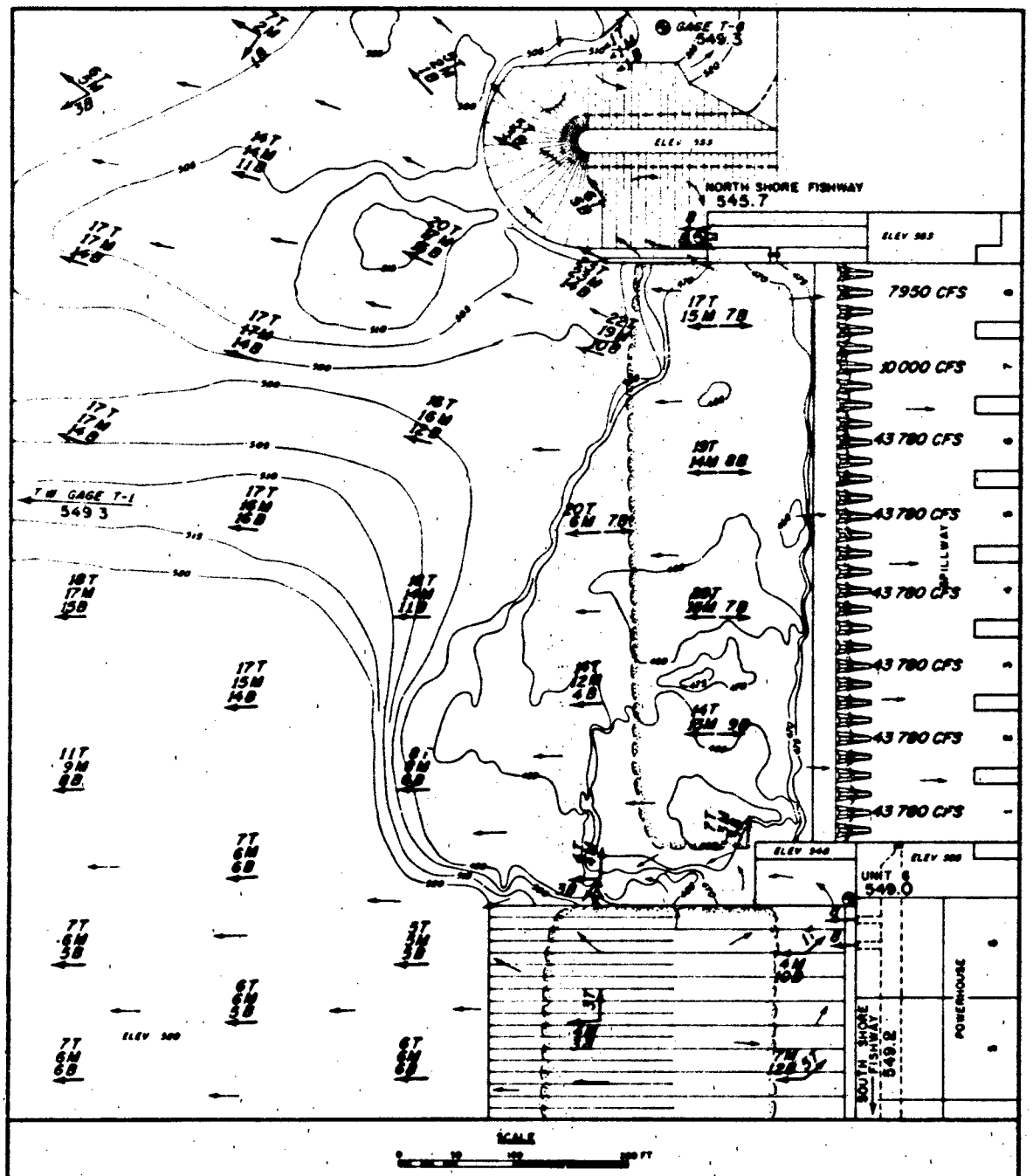
LITTLE GOOSE DAM

FLOW CONDITIONS FISHWAY ENTRANCES

RIVER DISCHARGE 420 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 104



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	139 800 CFS
SPILLWAY BAYS 1 TO 8	280 125 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

LITTLE GOOSE DAM

NONUNIFORM SPILLWAY OPERATION

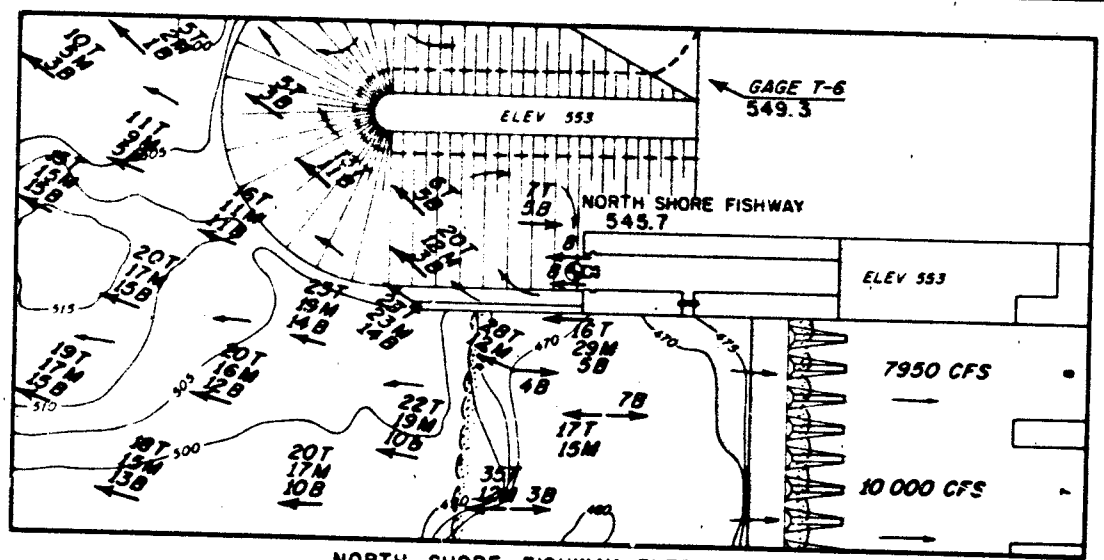
WITHOUT DEFLECTOR

FLOW CONDITIONS

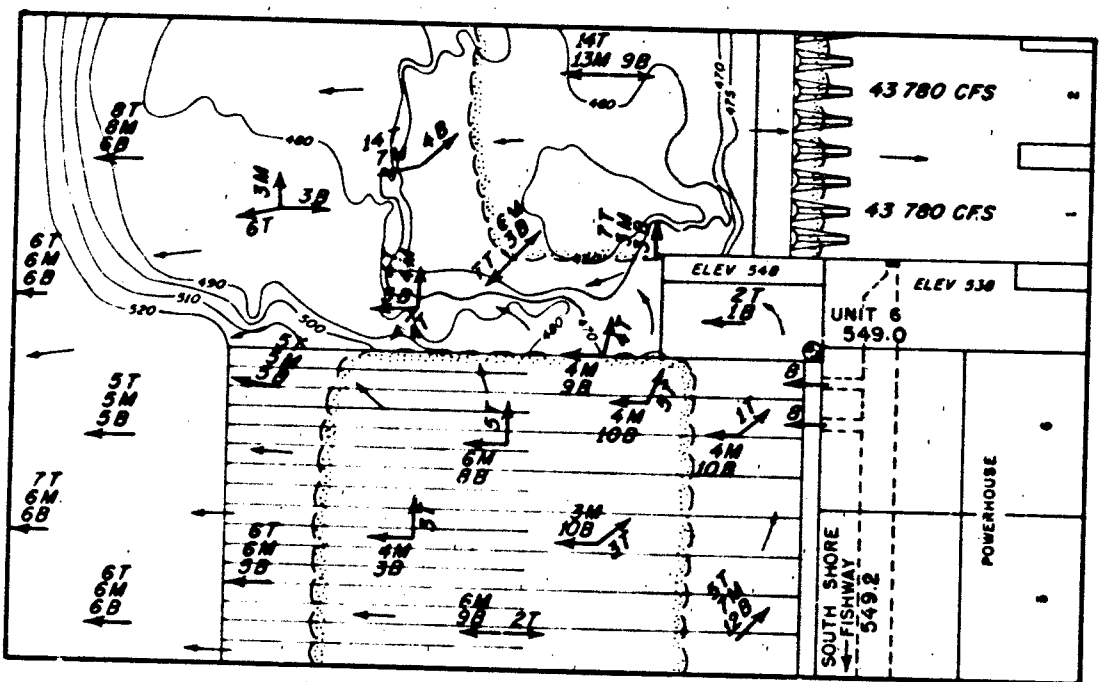
RIVER DISCHARGE 420 000 CFS

POWERHOUSE UNITS 1 TO 6

PLATE 105



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

4 VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM

BOIL OUTLINE

SCALE

0 50 100 200 FT

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	139 800 CFS
SPILLWAY BAYS 1 TO 8	280 125 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

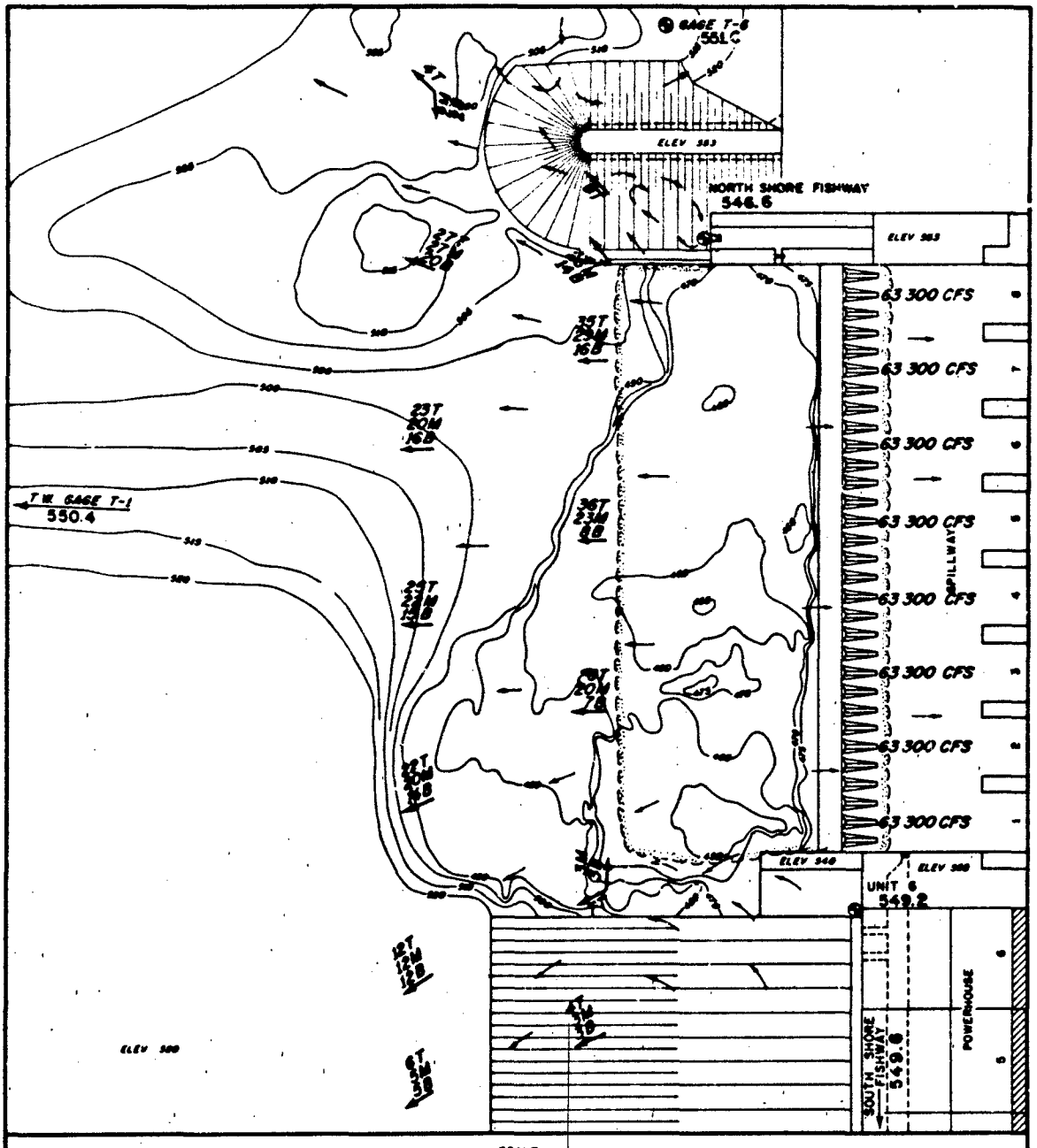
* PUMPED FROM TAILWATER

NONUNIFORM SPILLWAY OPERATION
WITHOUT DEFLECTOR

LITTLE GOOSE DAM

FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 106



SCALE

0 50 100 200 FT

LEGEND

VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM

BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE CLOSED	0 CFS
SPILLWAY BAYS 1 TO 8	506400 CFS

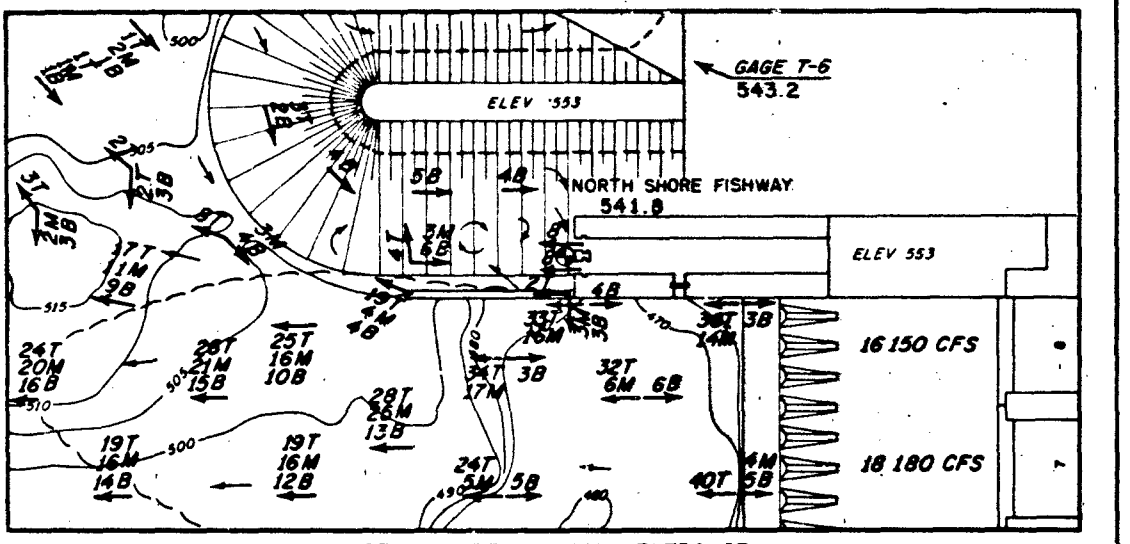
LITTLE GOOSE DAM

WITHOUT DEFLECTOR

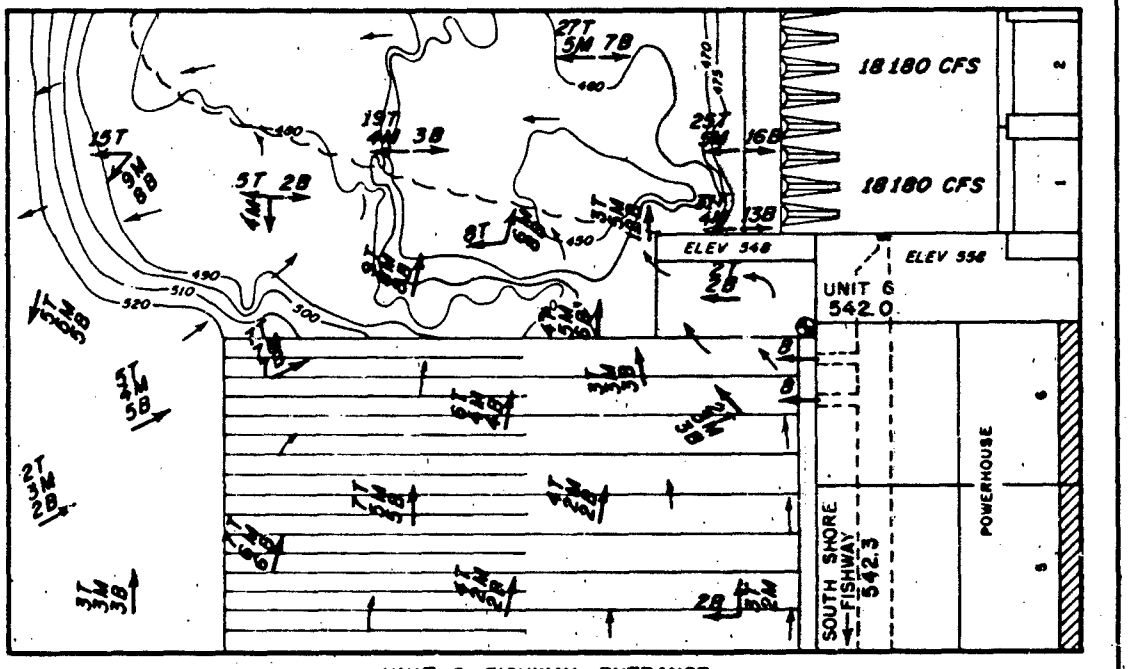
FLOW CONDITIONS

RIVER DISCHARGE 506 400 CFS
POWERHOUSE CLOSED

PLATE 107



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

DEFLECTORS IN BAYS 1 TO 8

LITTLE GOOSE DAM

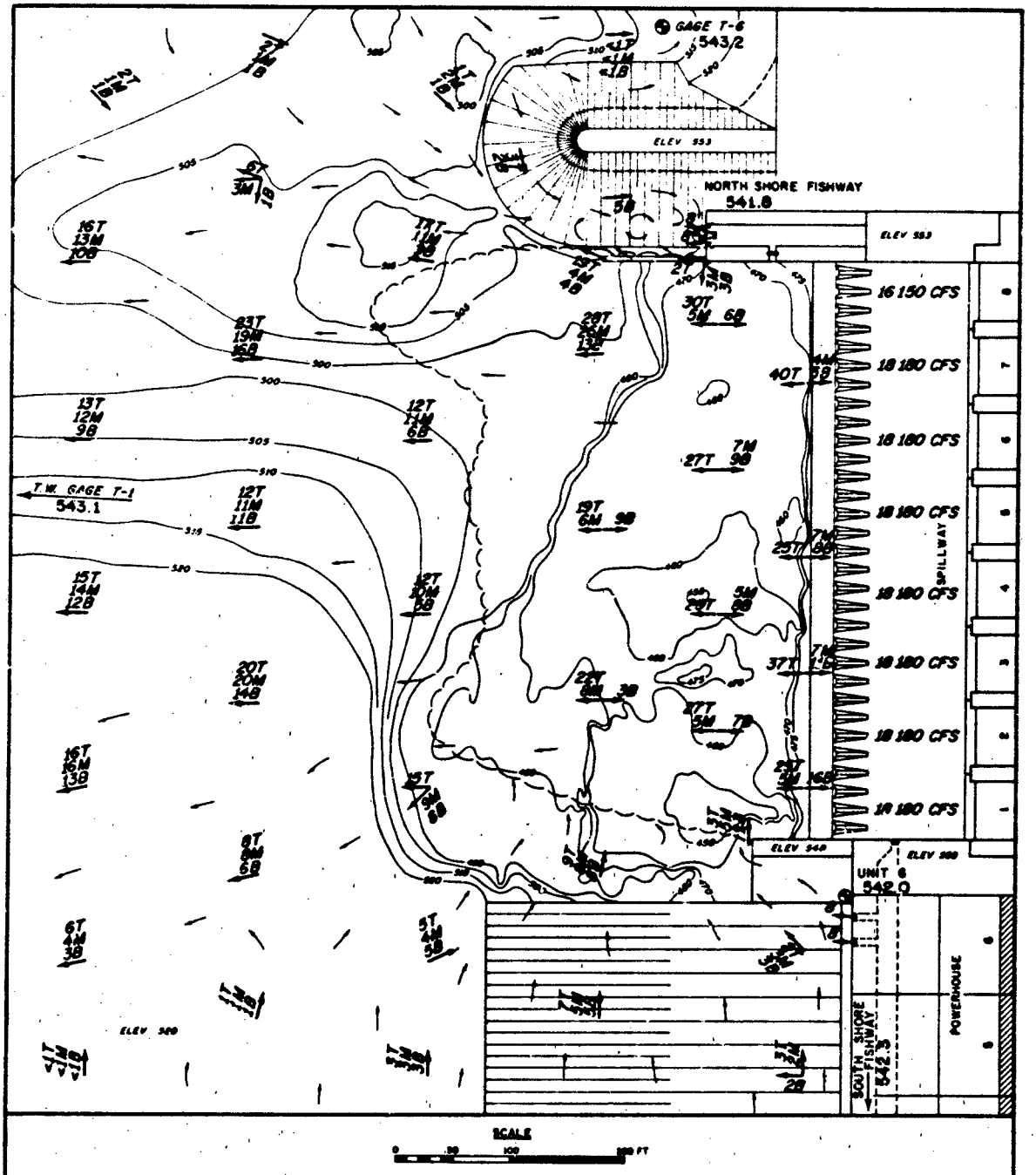
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 3

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	68 250 CFS
SPILLWAY BAYS 1 TO 8	143 675 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

PLATE 108



SCALE

0 50 100 200 FT

LEGEND

- 4 ← VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 250 CFS
SPILLWAY BAYS 1 TO 8	143 675 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

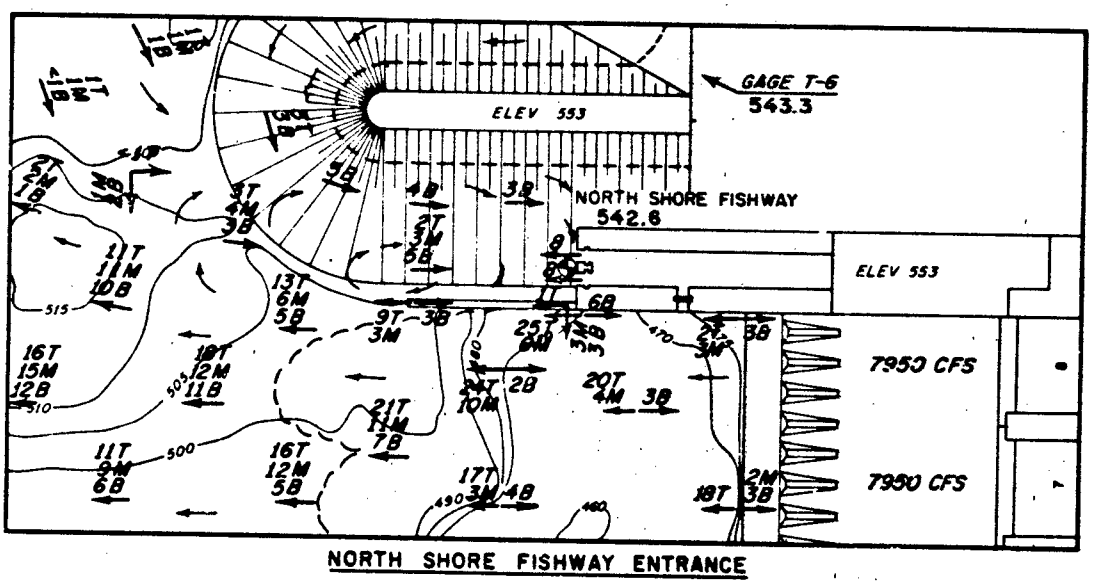
LITTLE GOOSE DAM

DEFLECTORS IN BAYS 1 TO 8

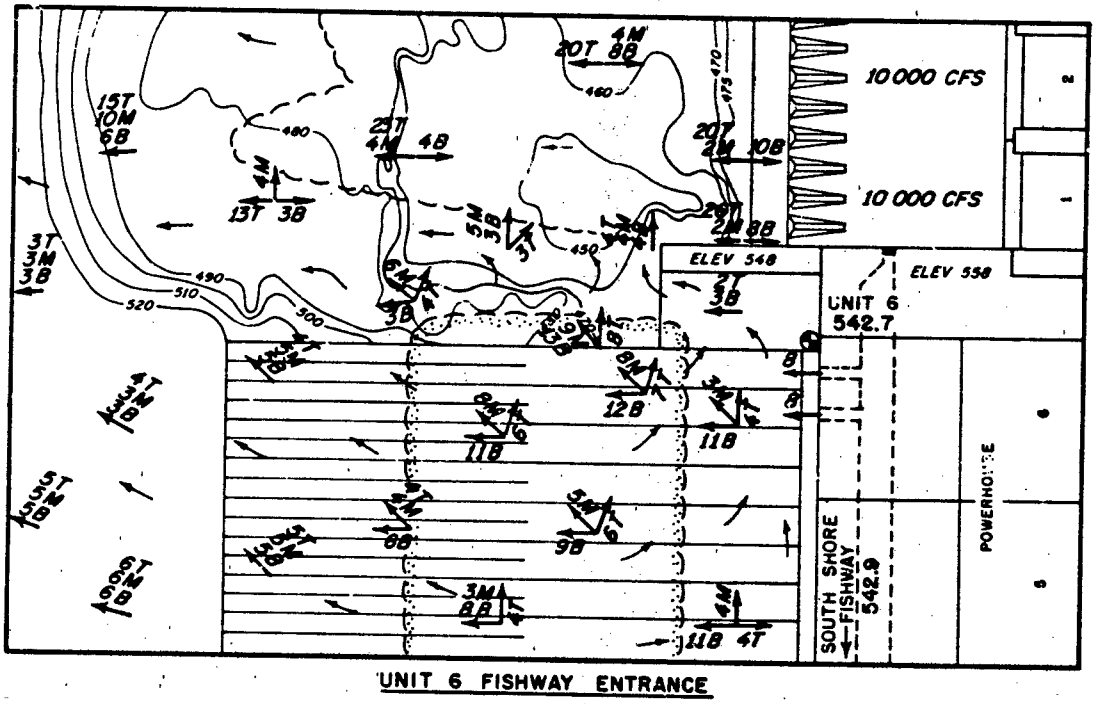
FLOW CONDITIONS

RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 109



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 500 CFS
SPILLWAY BAYS 1 TO 8	75 425 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

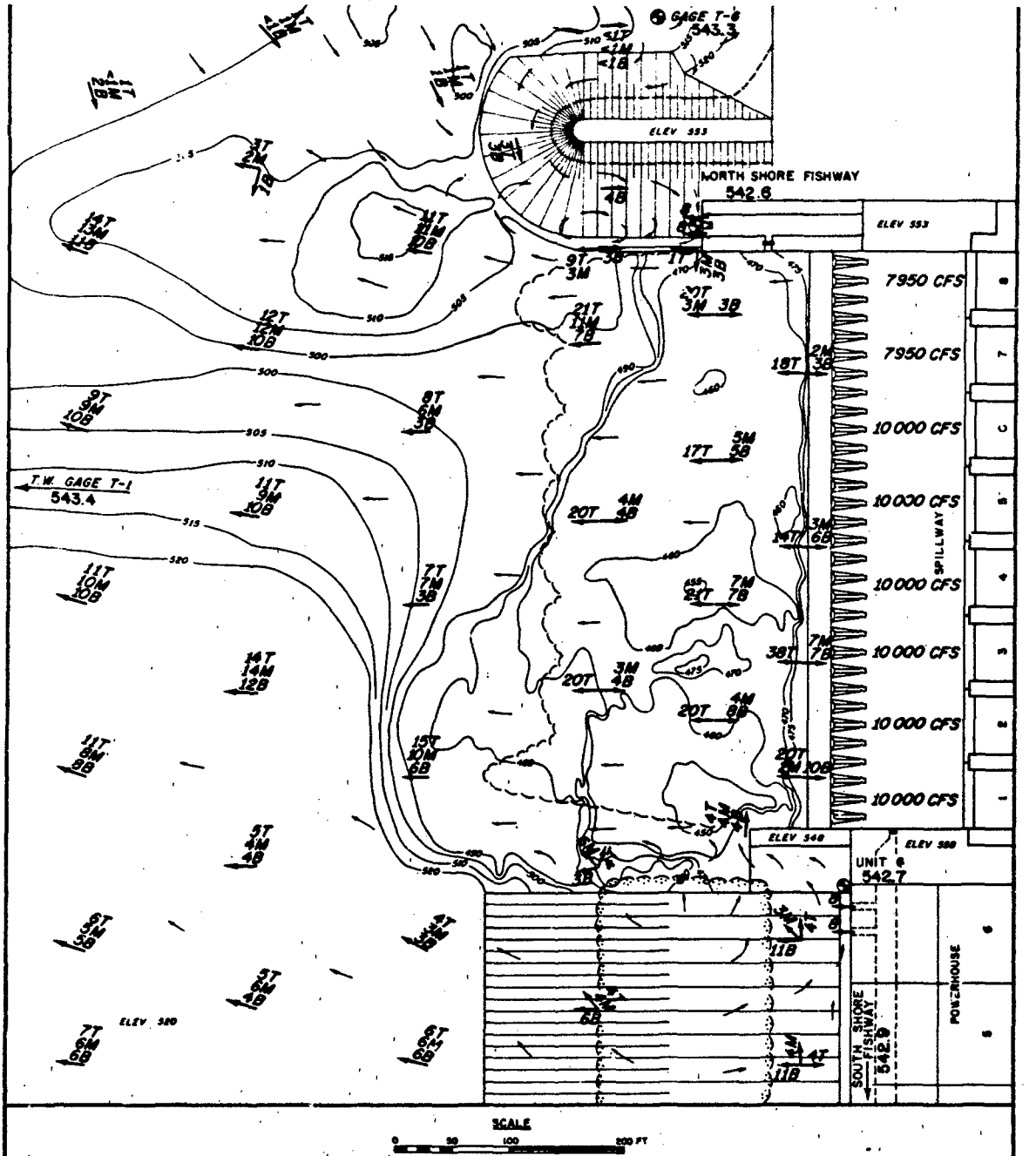
DEFLECTORS IN BAYS 1 TO 8

LITTLE GOOSE DAM

FLOW CONDITIONS FISHWAY ENTRANCES

RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 110



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136500 CFS
SPILLWAY BAYS 1 TO 8	75425 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

LITTLE GOOSE DAM

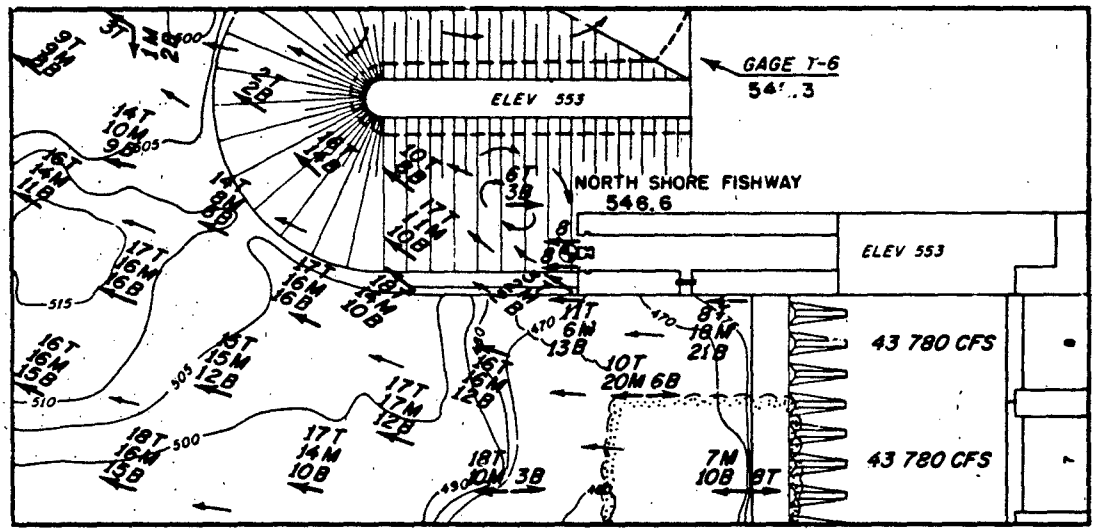
DEFLECTORS IN BAYS 1 TO 8

FLOW CONDITIONS

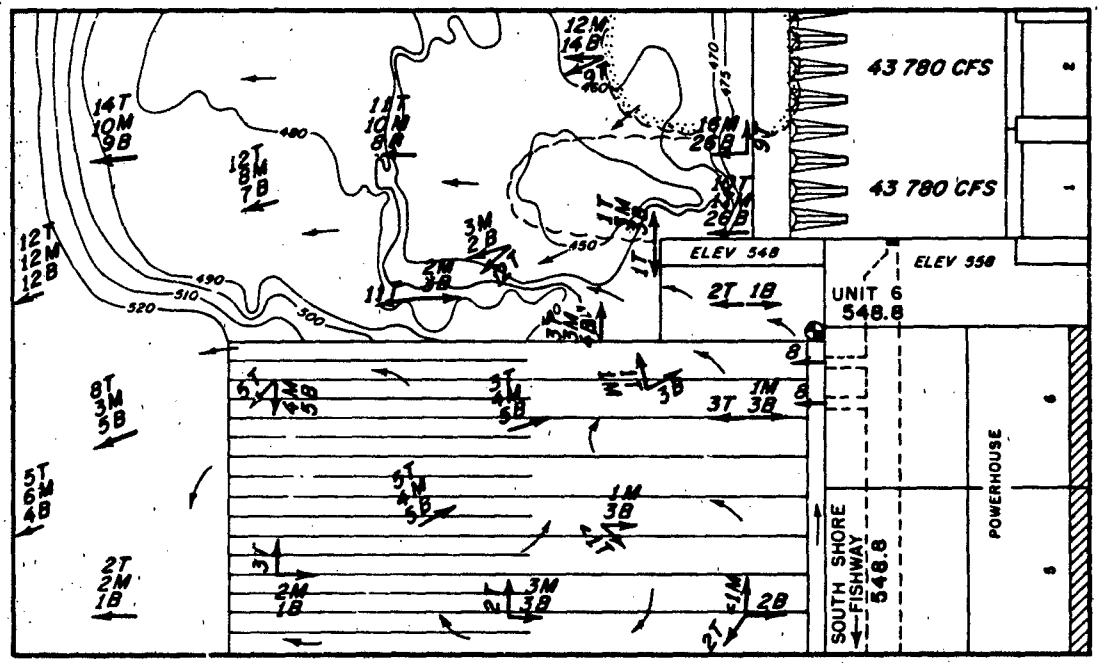
RIVER DISCHARGE 212 000 CFS

POWERHOUSE UNITS 1 TO 6

PLATE 111



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

DEFLECTORS IN BAYS 1 TO 8

LITTLE GOOSE DAM

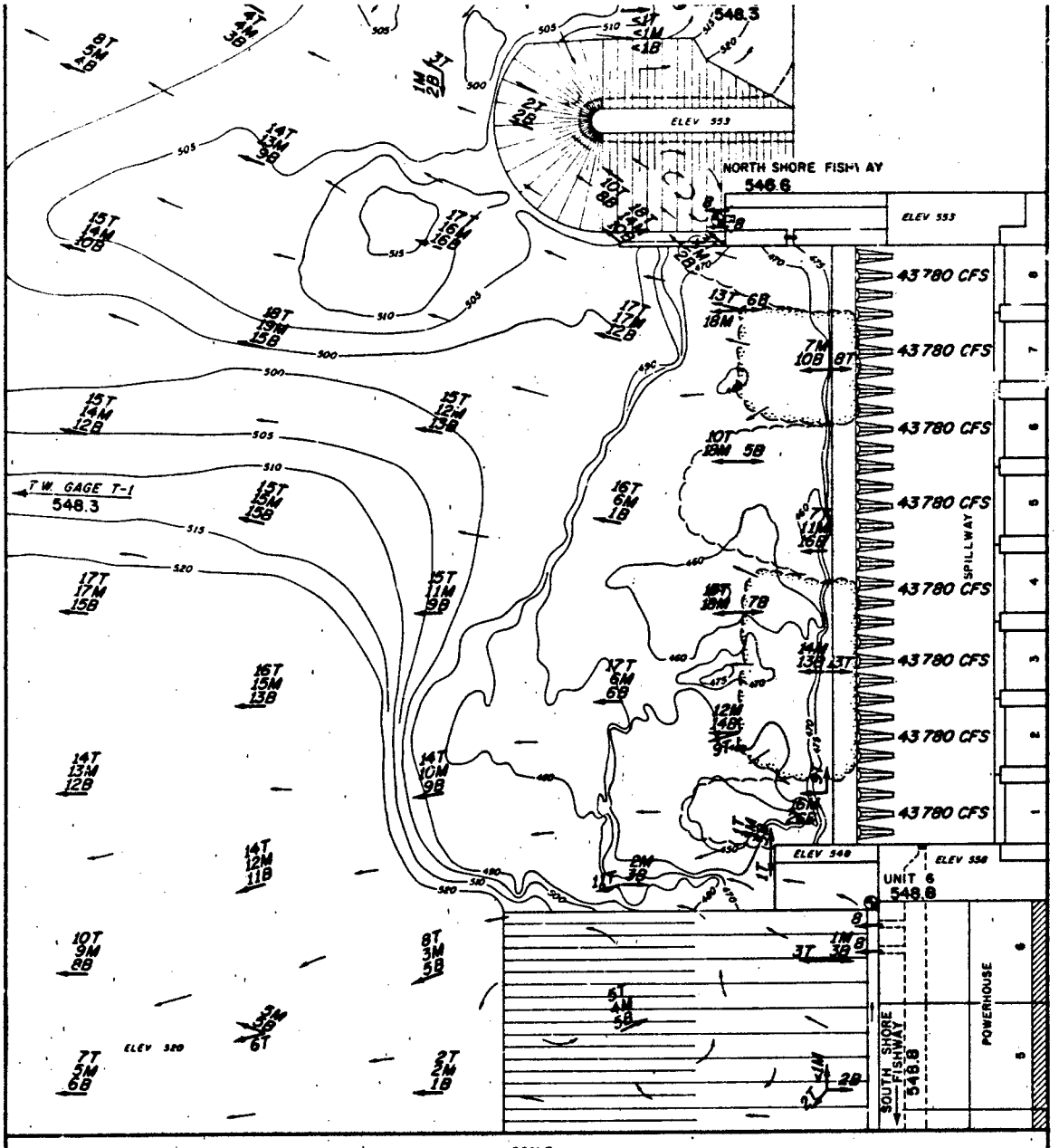
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 3

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	69 900 CFS
SPILLWAY BAYS 1 TO 8	350 025 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

PLATE 112



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	69900 CFS
SPILLWAY BAYS 1 TO 8	350025 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

LITTLE GOOSE DAM

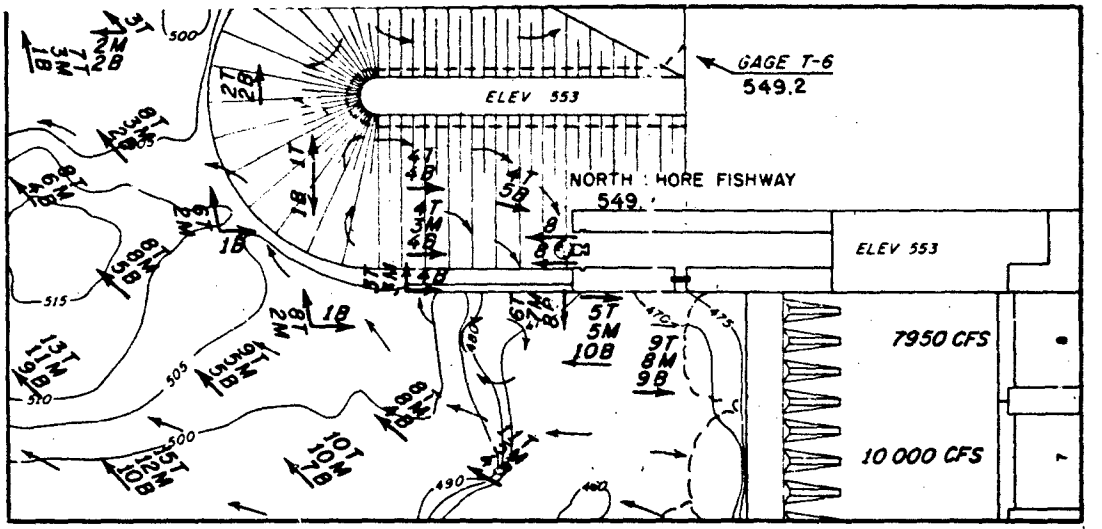
DEFLECTORS IN BAYS 1 TO 8

FLOW CONDITIONS

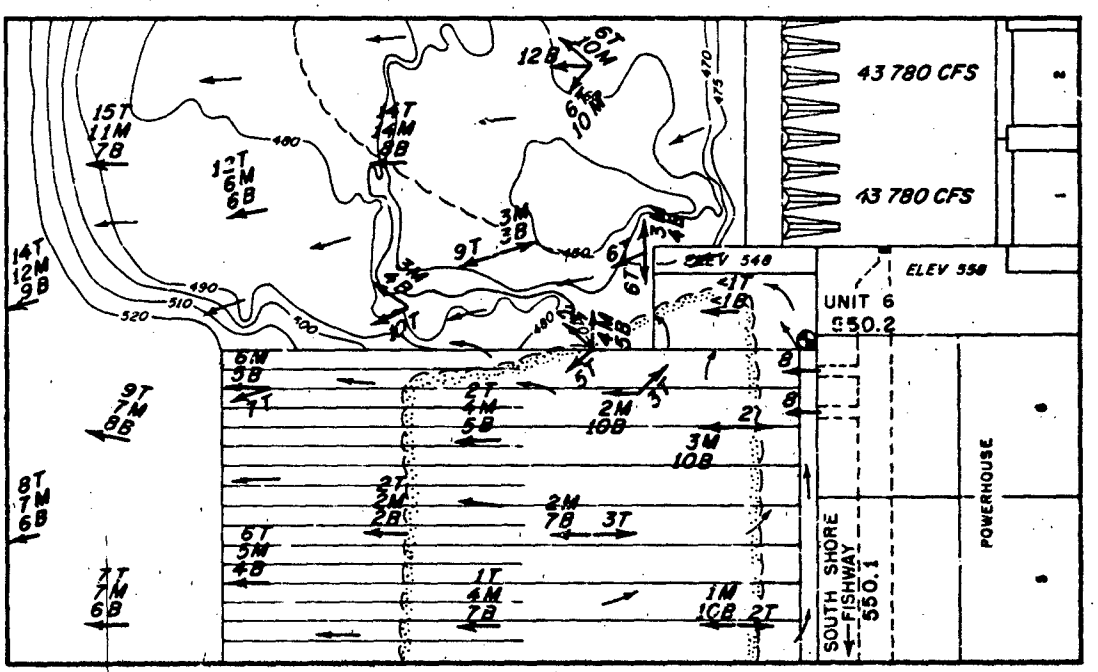
RIVER DISCHARGE 420 000 CFS

POWERHOUSE UNITS 1 TO 3

PLATE 113



NORTH SHORE FISHWAY ENTRANCE



UNIT 6 FISHWAY ENTRANCE

LEGEND

- 4 VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

SCALE

0 50 100 200 FT

NONUNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 1 TO 8

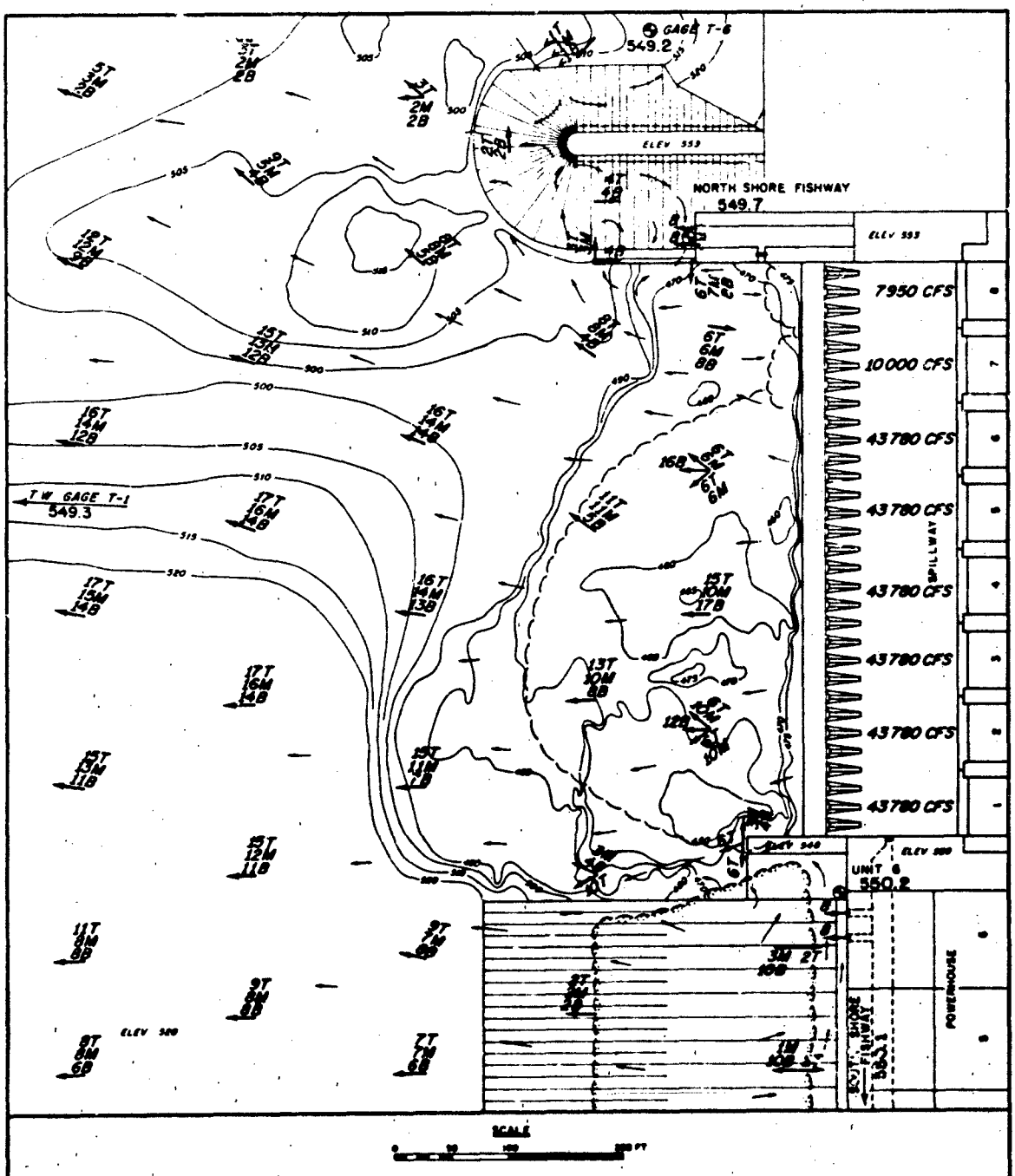
OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	139 800 CFS
SPILLWAY BAYS 1 TO 8	280 125 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

LITTLE GOOSE DAM
FLOW CONDITIONS
FISHWAY ENTRANCES
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 114



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136800 CFS
SPILLWAY BAYS 1 TO 8	280125 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

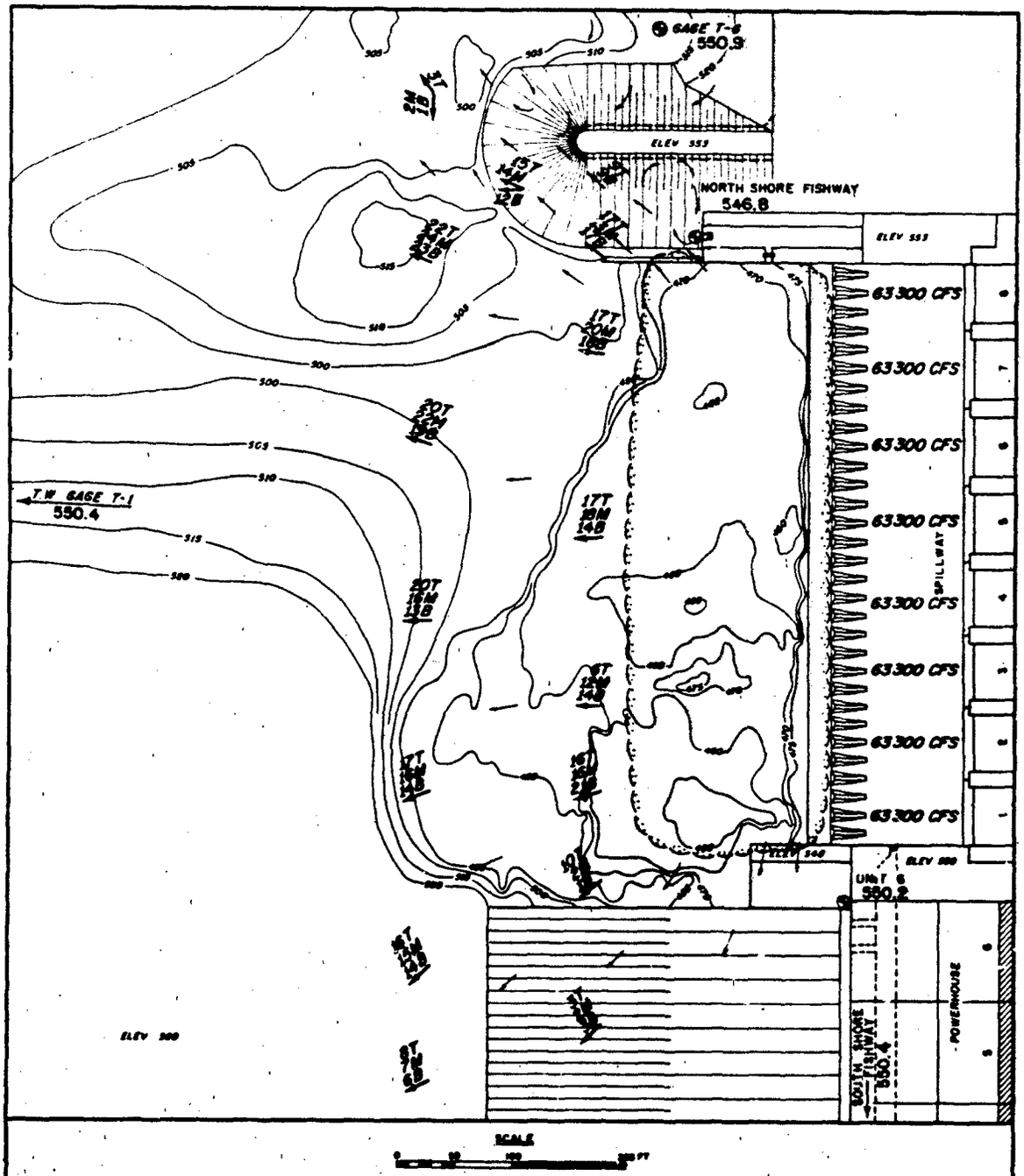
* PUMPED FROM TAILWATER

NONUNIFORM SPILLWAY OPERATION
DEFLECTORS IN BAYS 1 TO 8

LITTLE GOOSE DAM
FLOW CONDITIONS

RIVER DISCHARGE 420000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 115



LEGEND

- VELOCITIES IN FPS
- T 9-FT DEPTH
- M MID-DEPTH
- B 9 FT ABOVE BOTTOM
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE CLOSED	0 CFS
SPILLWAY BAYS 1 TO 8	506400 CFS

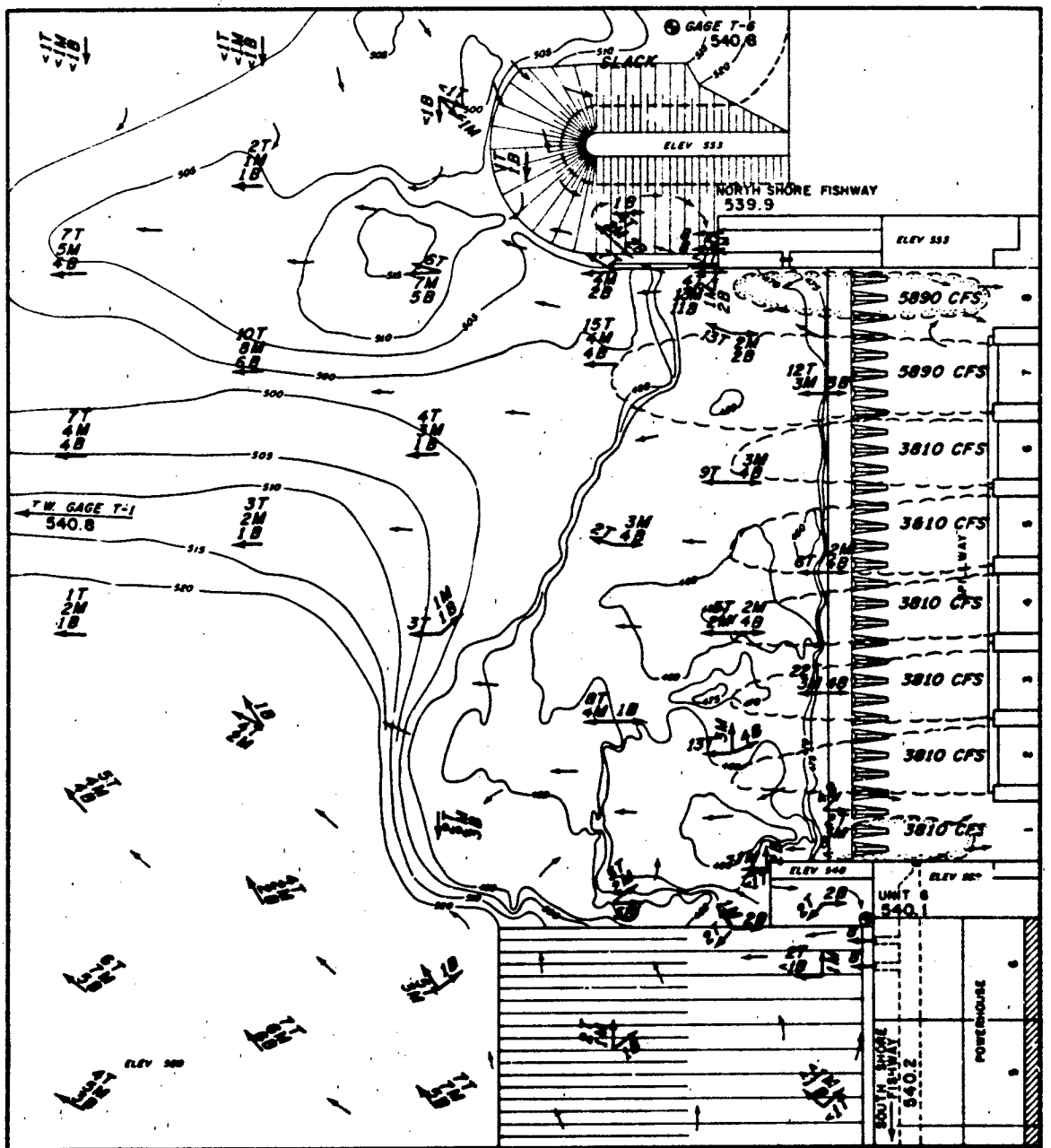
LITTLE GOOSE DAM

DEFLECTORS IN BAYS 1 TO 8

FLOW CONDITIONS

RIVER DISCHARGE 506 400 CFS
POWERHOUSE CLOSED

PLATE 116



LEGEND

- VELOCITIES IN FPS
- T 9-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	65 550 CFS
SPILLWAY BAYS 1 TO 8	34 375 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	500 CFS
NORTH SHORE FISHWAY *	600 CFS

* PUMPED FROM TAILWATER

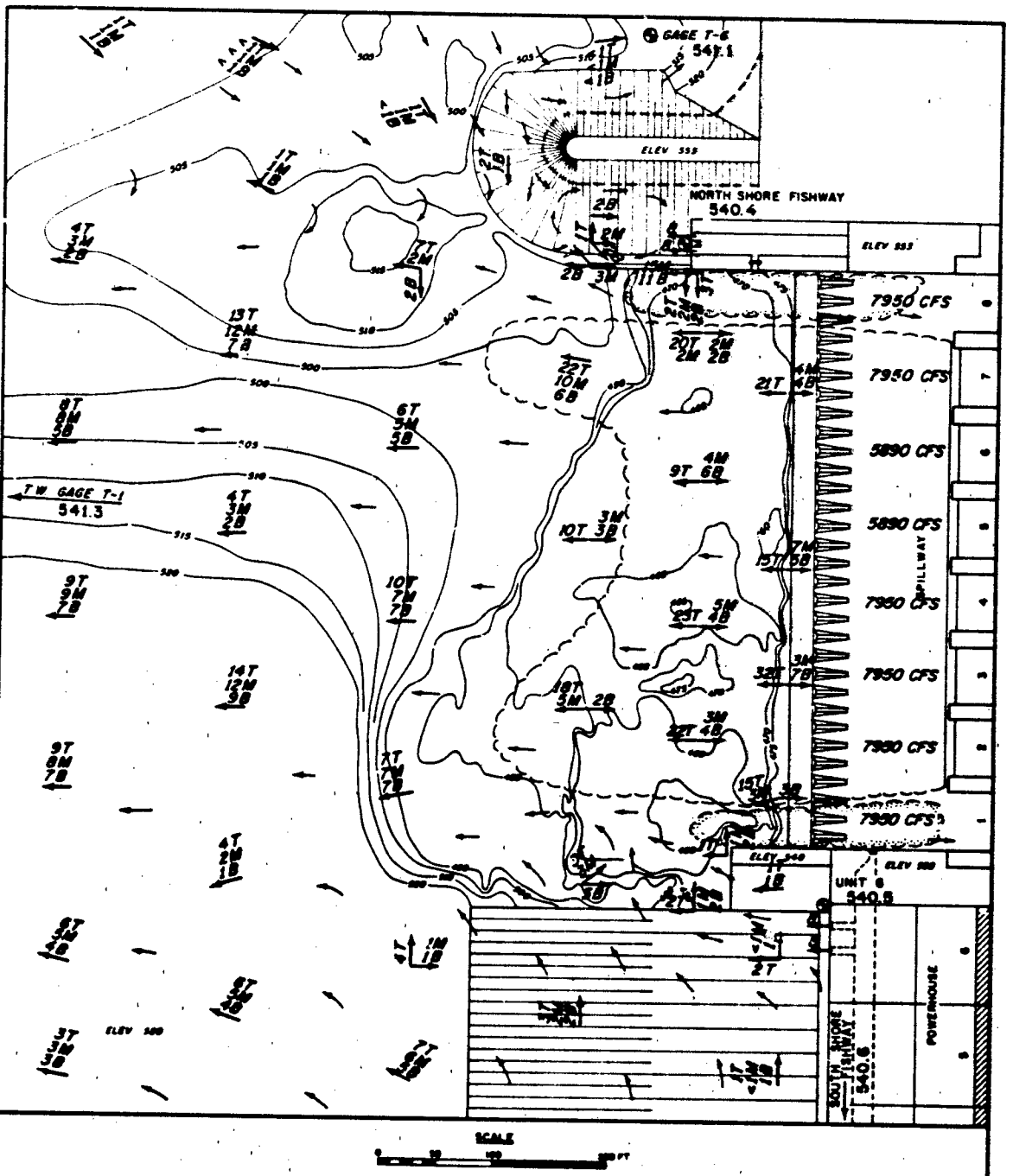
LITTLE GOOSE DAM

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION
DEFLECTORS IN BAYS 2 TO 7

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 117



LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SKIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	66 000 CFS
SPILLWAY BAYS 1 TO 8	59 925 CFS
FISH LADDER	75 CFS
UNIT 8 FISHWAY *	500 CFS
NORTH SHORE FISHWAY *	600 CFS

* PUMPED FROM TAILWATER

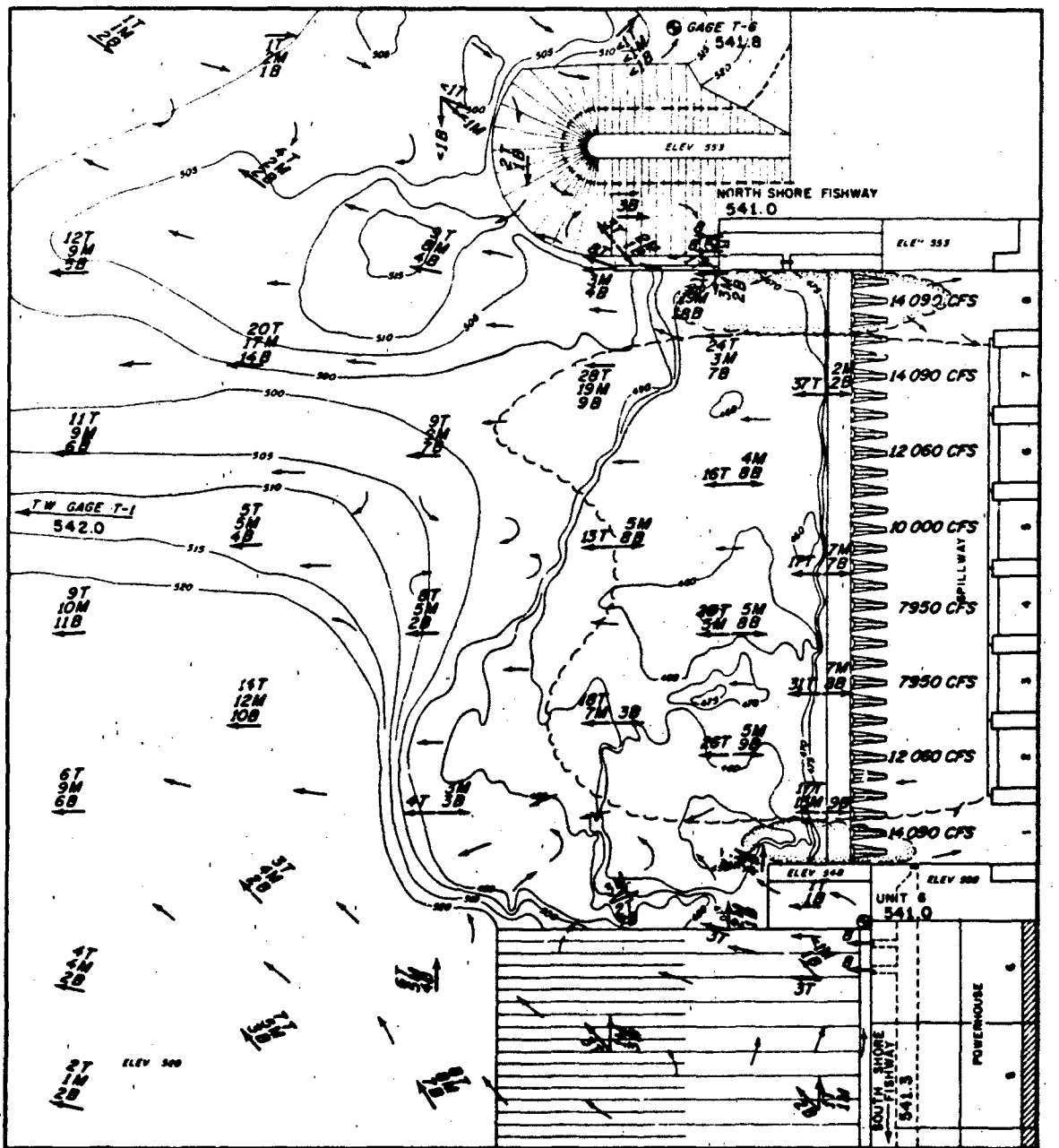
LITTLE GOOSE DAM

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION
DEFLECTORS IN BAYS 2 TO 7

FLOW CONDITIONS

RIVER DISCHARGE 128 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 118



SCALE

LEGEND

- VELOCITIES IN FPS
- T 5-FT DEPTH
- M MID-DEPTH
- B 5 FT ABOVE BOTTOM
- SWIMMING FLOW OUTLINE
- BOIL OUTLINE

LITTLE GOOSE DAM

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION
DEFLECTORS IN BAYS 2 TO 7

OPERATING CONDITIONS

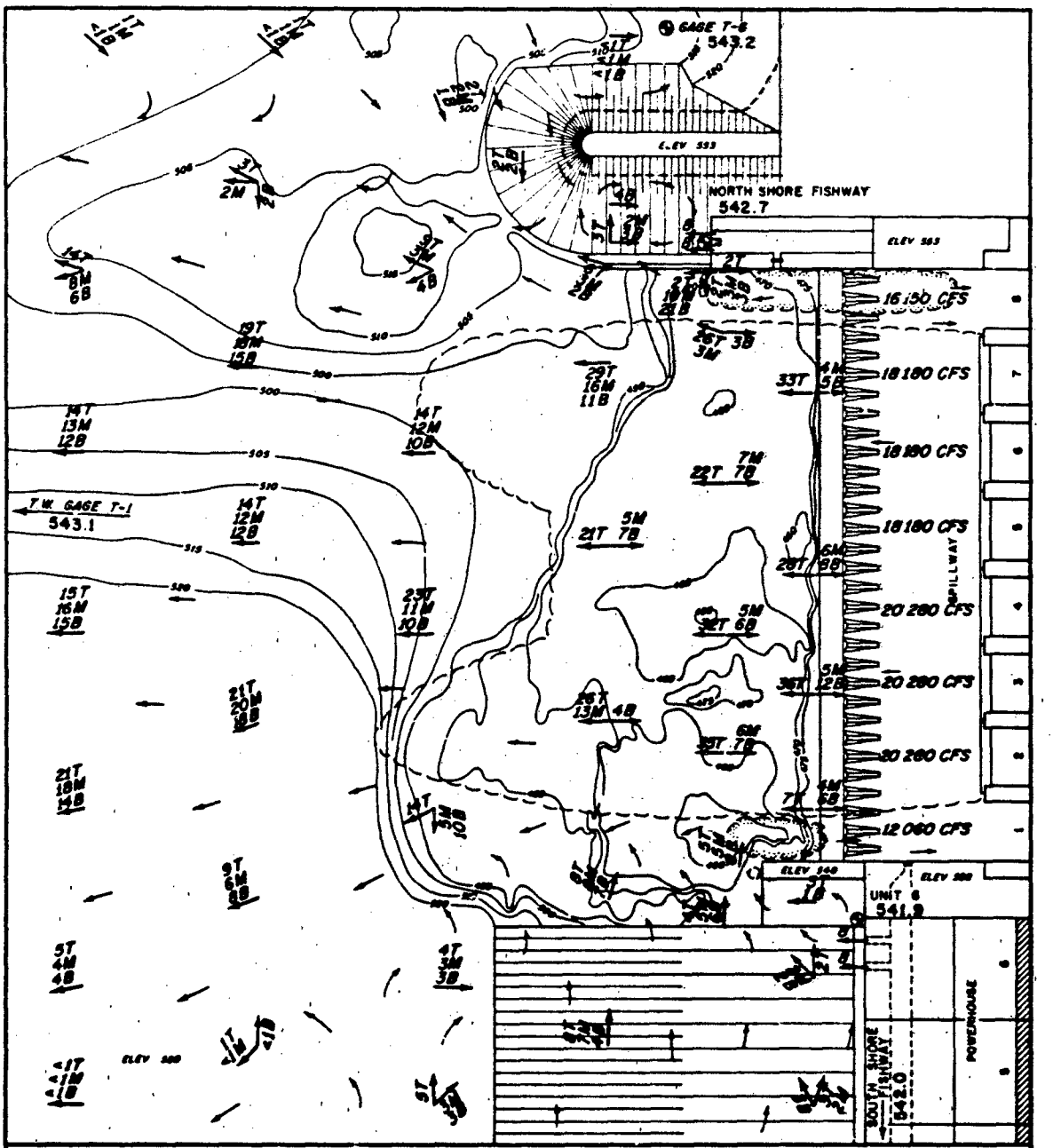
POWERHOUSE UNITS 1 TO 3	66 900 CFS
SPILLWAY BAYS 1 TO 8	93 025 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

FLOW CONDITIONS

RIVER DISCHARGE 160 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 119



LEGEND

- VELOCITIES IN FPS
- T 3-FT DEPTH
- M MID-DEPTH
- B 3 FT ABOVE BOTTOM
- SWIMMING FLOW OUTLINE
- SOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 3	68 250 CFS
SPILLWAY BAYS 1 TO 8	143 675 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

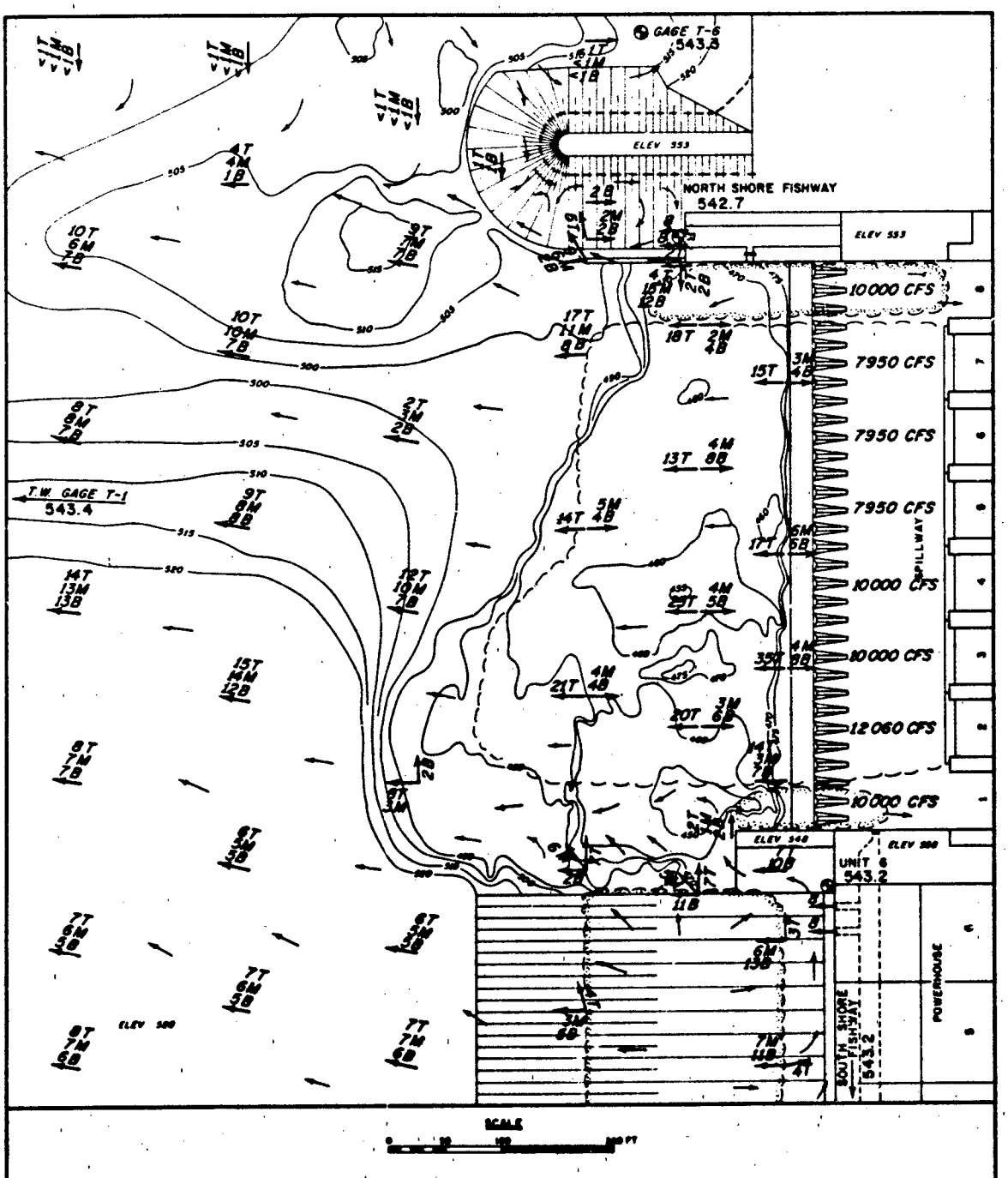
LITTLE GOOSE DAM

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION
DEFLECTORS IN BAYS 2 TO 7

FLOW CONDITIONS

RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 3

PLATE 120



LEGEND

- 4 — VELOCITIES IN FPS
- T — 5-FT DEPTH
- M — MID-DEPTH
- B — 5 FT ABOVE BOTTOM
- SWIMMING FLOW OUTLINE
- BOIL OUTLINE

OPERATING CONDITIONS

POWERHOUSE UNITS 1 TO 6	136 900 CFS
SPILLWAY BAYS 1 TO 8	75 425 CFS
FISH LADDER	75 CFS
UNIT 6 FISHWAY *	600 CFS
NORTH SHORE FISHWAY *	750 CFS

* PUMPED FROM TAILWATER

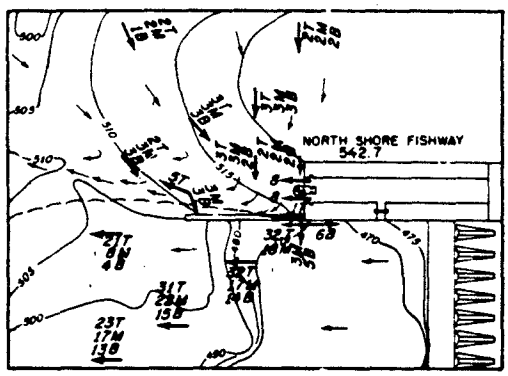
LITTLE GOOSE DAM

SPILLWAY ADJUSTED FOR FISHWAY ATTRACTION
DEFLECTORS IN BAYS 2 TO 7

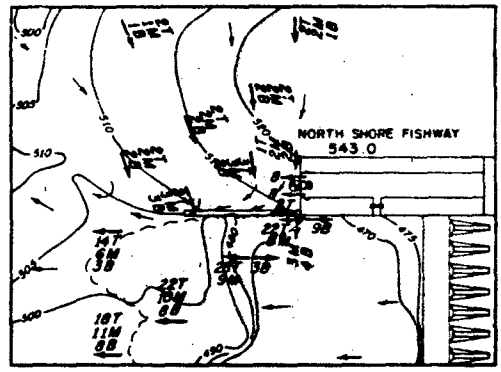
FLOW CONDITIONS

RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 6

PLATE 121

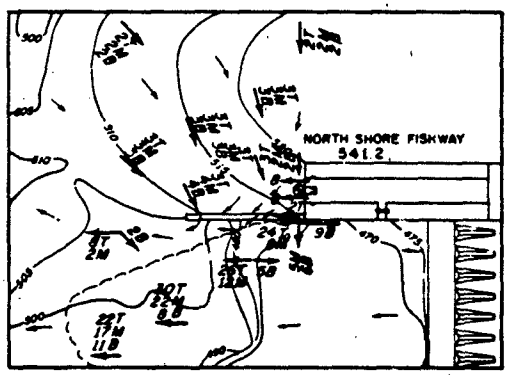


POWERHOUSE UNITS 1 TO 3 OPERATING
SPILLWAY DISCHARGE 143 675 CFS

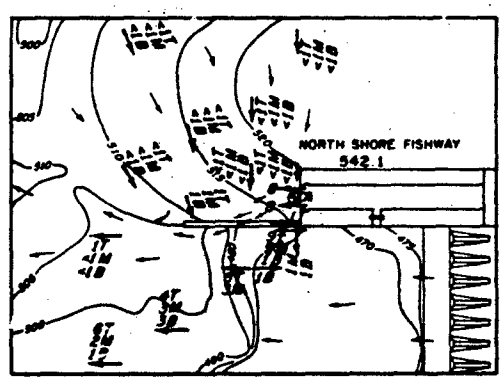


POWERHOUSE UNITS 1 TO 6 OPERATING
SPILLWAY DISCHARGE 75 425 CFS

RIVER DISCHARGE 212 000 CFS

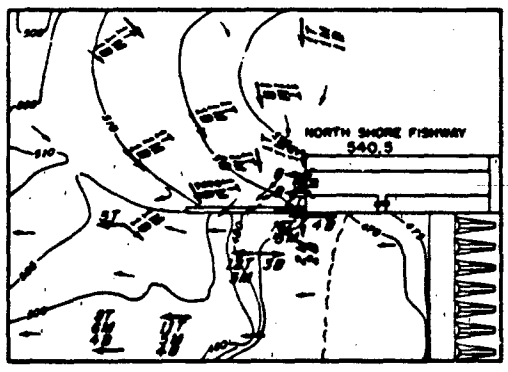


POWERHOUSE UNITS 1 TO 3 OPERATING
SPILLWAY DISCHARGE 93 025 CFS



POWERHOUSE UNITS 1 TO 6 OPERATING
SPILLWAY DISCHARGE 26 125 CFS

RIVER DISCHARGE 160 000 CFS



POWERHOUSE UNITS 1 TO 3 OPERATING
SPILLWAY DISCHARGE 34 375 CFS

RIVER DISCHARGE 100 000 CFS

LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
M MID-DEPTH
B 5 FT ABOVE BOTTOM
SKIMMING FLOW OUTLINE

LITTLE GOOSE DAM
FLOW CONDITIONS
NORTH SHORE FILL REMOVED
DEFLECTORS IN BAYS 1 TO 8

PLATE 122

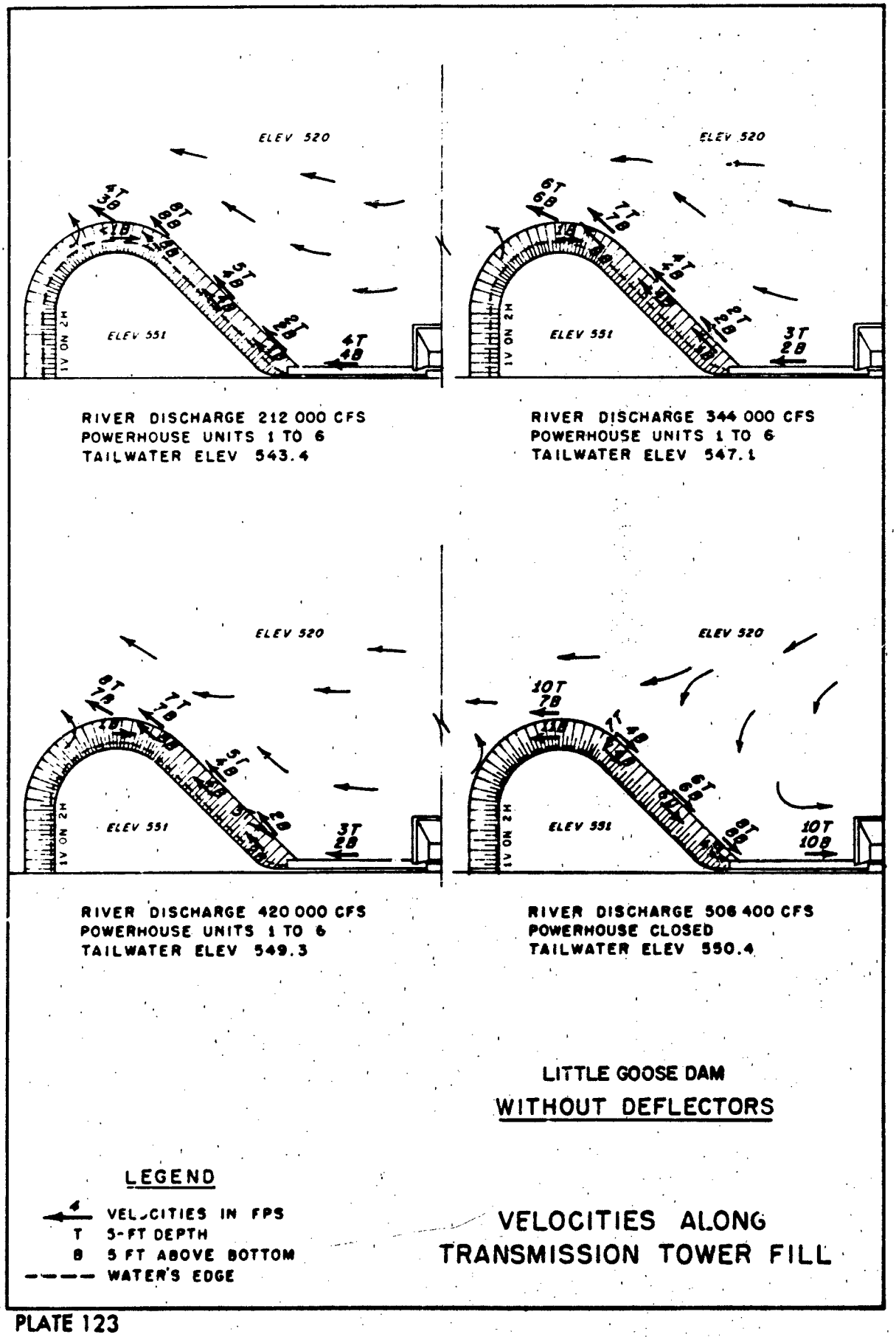
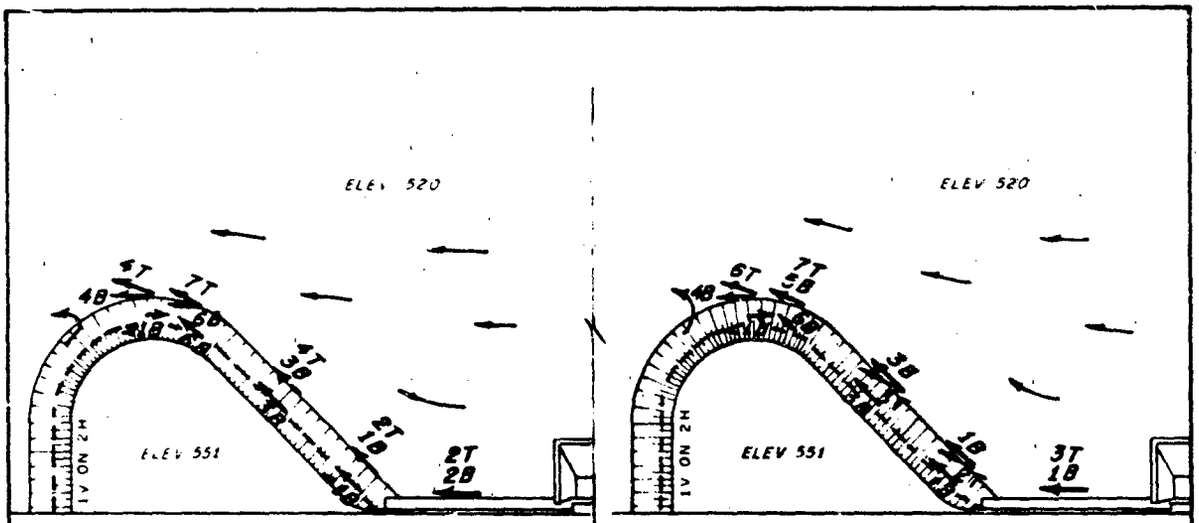
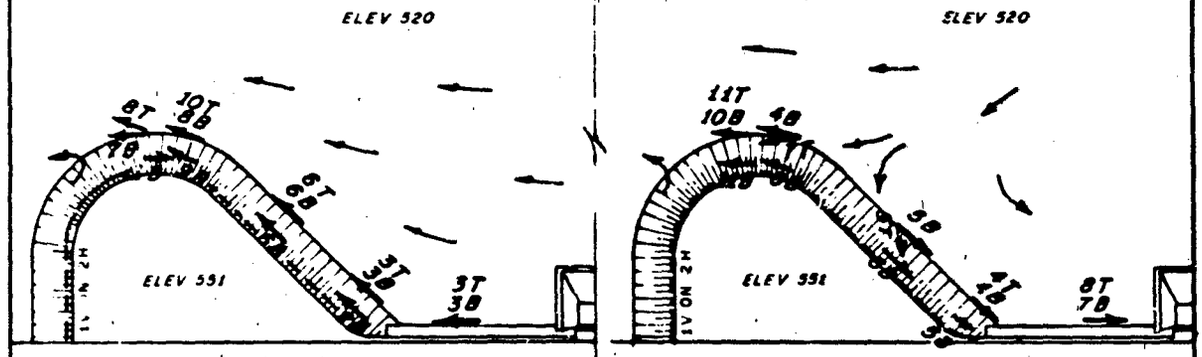

ELEV 520
ELEV 551
1V ON 2H
4T 3B
6T 6B
5T 4B
2T 2B
4T 4B
RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 543.4
ELEV 520
ELEV 551
1V ON 2H
6T 6B
7T 7B
4T 4B
2T 2B
3T 2B
RIVER DISCHARGE 344 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 547.1
ELEV 520
ELEV 551
1V ON 2H
6T 7B
7T 7B
5T 4B
2B
3T 2B
RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 549.3
ELEV 520
ELEV 551
1V ON 2H
10T 7B
1T 4B
6T 6B
8T 8B
10T 10B
RIVER DISCHARGE 506 400 CFS
POWERHOUSE CLOSED
TAILWATER ELEV 550.4
LITTLE GOOSE DAM
WITHOUT DEFLECTORS
LEGEND
4 VELOCITIES IN FPS
T 3-FT DEPTH
B 5 FT ABOVE BOTTOM
WATER'S EDGE
VELOCITIES ALONG
TRANSMISSION TOWER FILL

PLATE 123



RIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 543.4

RIVER DISCHARGE 344 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 547.1



RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 549.3

RIVER DISCHARGE 506 400 CFS
POWERHOUSE CLOSED
TAILWATER ELEV 550.4

LITTLE GOOSE DAM

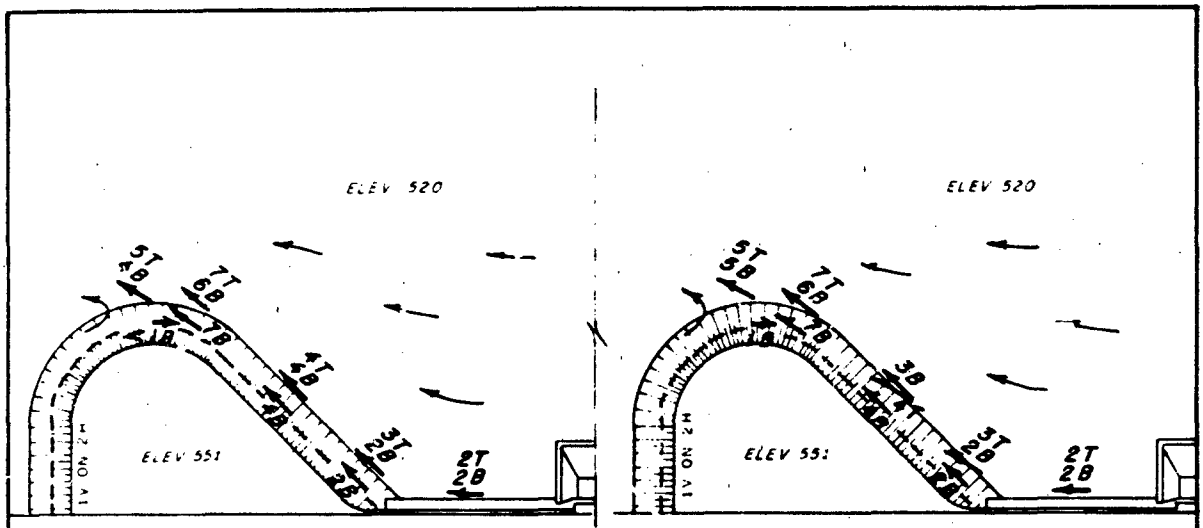
DEFLECTORS IN BAYS 1 TO 8

LEGEND

4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM
WATER'S EDGE

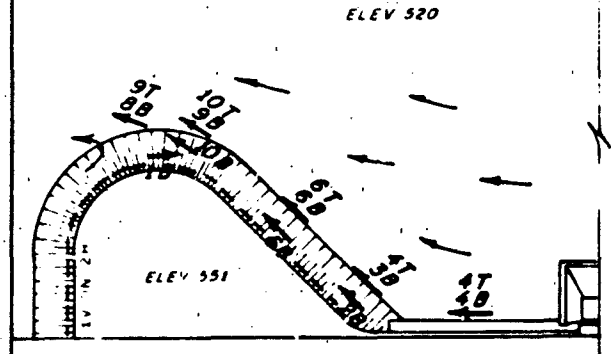
VELOCITIES ALONG TRANSMISSION TOWER FILL

PLATE 124

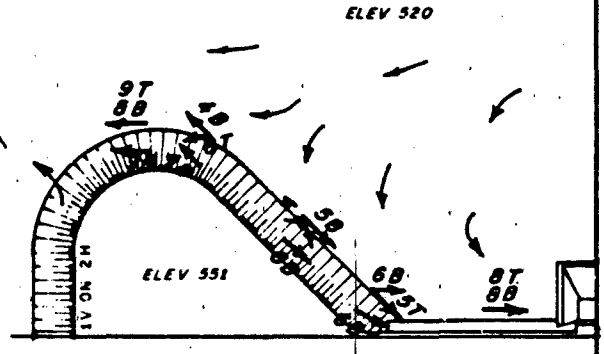


PIVER DISCHARGE 212 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 543.4

RIVER DISCHARGE 344 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 547.1



RIVER DISCHARGE 420 000 CFS
POWERHOUSE UNITS 1 TO 6
TAILWATER ELEV 549.3



RIVER DISCHARGE 506 400 CFS
POWERHOUSE CLOSED
TAILWATER ELEV 550.4

LITTLE GOOSE DAM

DEFLECTORS IN BAYS 2 TO 7

LEGEND

- 4 ← VELOCITIES IN FPS
- T 3-FT DEPTH
- B 5 FT ABOVE BOTTOM
- ---- WATER'S EDGE

VELOCITIES ALONG TRANSMISSION TOWER FILL

PLATE 125

PART VIII

SUMMARY

VIII: SUMMARY

76. Hydraulic model studies were conducted to develop the design of the flow deflectors for installation at seven projects located on the Columbia and Snake Rivers. Tests accomplished for six of those projects are presented in this report. Development of deflectors for the seventh project, Lower Granite Dam on the Snake River, are reported in Technical Report 121-1, Lower Granite Dam, Snake River, Washington, Hydraulic Model Investigation dated August 1984. The deflectors were investigated as a method to remedy the nitrogen supersaturation problem resulting from highly aerated spillway discharges plunging deep into a stilling basin or roller bucket. With the exception of John Day Dam, separate sectional spillway and comprehensive models were used for each project. The larger scale sectional models were used to develop the design details of the deflectors, while the smaller scale comprehensive models were used to determine the effects of the deflectors on flow conditions downstream of the spillway and to establish spillway operation schedules for optimum fish-passage conditions.

Bonneville Dam

77. Model tests indicated that a 12-foot-long deflector located at elevation 14 on all 18 spillway bays would be the optimum design. With this design, stable, skimming stilling basin flow conditions existed with river discharges as low as 325,000 cfs (11,500 cfs per bay). Adequate attraction conditions at the fishway entrance could be attained by adjusting spillway gate operations. The deflectors were ultimately installed on 12 of the 18 spillway bays in the prototype (bays 4 through 15).

John Day Dam

78. The 12.5-foot-long deflector located at elevation 149 provided the best overall results based on flow stability, quantity and depth of air penetration in the stilling basin, and energy dissipation. With the tailwater created by The Dalles project at reservoir

elevation 160, skimming flow occurred with spillway discharges up to 16,000 cfs per bay when at least five power units were operating. With all 16 power units operating, skimming flow existed in the basin with virtually all spillway discharges. The deflectors were not installed in the prototype.

McNary Dam

79. The studies indicated that 12.5-foot-long deflectors located at elevation 256 in bays 3 through 20 was the optimum configuration for spill patterns that created good flow conditions at the fishway entrances. Although reduction in nitrogen supersaturation would be best with deflectors in all 22 bays, those in the 4 end bays would have very limited value. That is, the deflectors in the four end bays would only be of value if spill were great enough to create plunging flow for river discharges equal to or greater than 450,000 cfs (5-year flood). With these conditions, 40 to 33 percent of the total spill would not utilize the deflectors to reduce nitrogen supersaturation. With 18 deflectors, flow through split gates in the 4 end bays could be as little as 24 percent of the total spill.

80. Two combinations of spillway settings were developed to create good conditions for fish attraction. It is recognized that other combinations of powerhouse and spillway flows, different tailwater conditions, and different evaluations of factors that result in good fish attraction would result in acceptable attraction conditions with different spill patterns. The spill patterns developed through the model studies will provide a basis for operation of the prototype spillway.

81. Deflectors were installed in bays 4 through 19 of the 22-bay prototype spillway.

Ice Harbor Dam

82. The best overall reduction in depth and quantity of air penetration in the stilling basin was obtained with a 12.5-foot-long deflector located at elevation 336. The best fishway attraction flows were obtained with deflectors located in bays 3 through 8. The model indicated that flow instability can be expected to occur with discharges of approximately 13,000 to 25,000 cfs per bay.

83. Slotted bulkheads in the spillway bays were tested but did not decrease aeration of the flow and were therefore not recommended. The addition of dentates to the deflectors lessened air penetration in the stilling basin but were not recommended due to potential cavitation damage and fish mortality.

84. The deflectors were not installed in the prototype structure.

Lower Monumental Dam

85. The optimum design developed in the model was a 12.5-foot-long deflector located at elevation 434. Fish-attraction conditions were acceptable with deflectors located either in all eight bays or in bays 2 through 7 only.

86. Dentates located on the spillway above the deflectors improved flow conditions and zones of aeration in the stilling basin, but pressures on and near the dentates were within the range of cavitation. A deflector with dentates was installed in one bay of the prototype and subjected to one season of operation. Extensive cavitation damage resulted, and the decision was made to install the remaining deflectors without dentates in bays 2 through 7 of the prototype.

Li''le Goose Dam

87. The optimum design developed in the model was an 8-foot-long deflector located at elevation 532. The deflectors were installed in bays 2 through 7 of the prototype. Non-uniform spillway operation developed in cooperation with members of the Columbia River Fisheries Technical Advisory Committee and tested in the model improved the observed fish passage conditions.

Prototype Performance

88. Upon completion of installation of the deflectors on the prototype structures, a monitoring program was initiated to measure the nitrogen levels downstream from the structures during spill periods. In general, the deflectors have resulted in lowering of the nitrogen levels during average water years from the 130-140 percent range experienced prior to installation to a range of about 115-120 percent. During high water years the reduction is generally from the approximate range of 140-150 percent to about 120-125 percent. More specific data on the actual nitrogen levels may be obtained from the NPD Water Quality Section, telephone (503) 221-3764.

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