TECHNICAL REPORT H-76-5

TIOGA OUTLET WORKS, TIOGA AND HAMMOND LAKES, SUSQUEHANNA RIVER BASIN, PENNSYLVANIA

Hydraulic Model Investigation

by

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A 1:25-scale model of the Tioga outlet works was used to determine the adequacy of the stilling basin to perform as desired for discharges up to 15,860 cfs, to study flow conditions in the exit channel, and to determine minimum riprap requirements for the exit channel. A schematic of the intake tower, the outlet conduit, the stilling basin, and about 600 ft of the exit channel were reproduced in the model.

The original design stilling basin performed satisfactorily for discharges ranging from 2,000 to 14,000 cfs; however, flow separation and adverse vortex action occurred with lesser flows and a pulsating jump that

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20. ABSTRACT (Continued):

overtopped the basin walls occurred with greater flows. Performance with low release rates was determined for both single- and double-gate operations. Recommended changes to the original design stilling basin included widening the basin from 55.5 to 72 ft, decreasing the flare of the outlet transition from 1 on 4.683 to 1 on 6, raising the basin apron 4.5 ft from el 1005.5 to 1010.0, raising the elevation of the sidewalls from 1043.0 to 1048.0, and lengthening the basin approximately 30 ft to the 38.64-ft-long horizontal floor at the outlet portal. The minimum size riprap required for stability in the exit channel was determined with the design discharge of 15,860 cfs.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), U. S. Army, on 14 November 1973, at the request of the U. S. Army Engineer District, Baltimore. The study was conducted in the Hydraulics Laboratory (HL) of the U. S. Army Engineer Waterways Experiment Station (WES), during the period March to June 1974, under the direction of Messrs. H. B. Simmons, Chief of HL, and J. L. Grace, Jr., Chief of the Structures Division, HL. The tests were conducted by Messrs. N. R. Oswalt, H. H. Allen, and W. A. Walker under the supervision of Mr. G. A. Pickering, Chief of the Locks and Conduits Branch. This report was prepared by Mr. Oswalt.

During the investigation, LTC G. J. Norton, CE, Deputy District Engineer of the Baltimore District; Messrs. Earl Eiker, T. L. Johnson, Ron Spath, Hugh Tamassia, Ed Marcinski, and Dick Strong also from the Baltimore District; Mr. William D. Stockman of the North Atlantic Division; and Mr. Sam Powell of OCE visited WES to observe model tests, discuss test results, and correlate these results with the design work being conducted concurrently at the Baltimore District.

Director of WES during the study and the preparation and publication of this report was COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

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

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

Multiply	By	To Obtain
inches	0.0254	metres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.02831685	cubic metres per second

TIOGA OUTLET WORKS, TIOGA AND HAMMOND LAKES, SUSQUEHANNA RIVER BASIN, PENNSYLVANIA

HYDRAULIC MODEL INVESTIGATION

PART I: INTRODUCTION

LOCATION

1. The Tioga outlet works is located on the Tioga River at the Tioga-Hammond Lakes project in Tioga County, Pennsylvania, approximately 8 miles* south of the Pennsylvania-New York State boundary (Figure 1). The general location of the project is about 20 miles southwest of Elmira, New York.

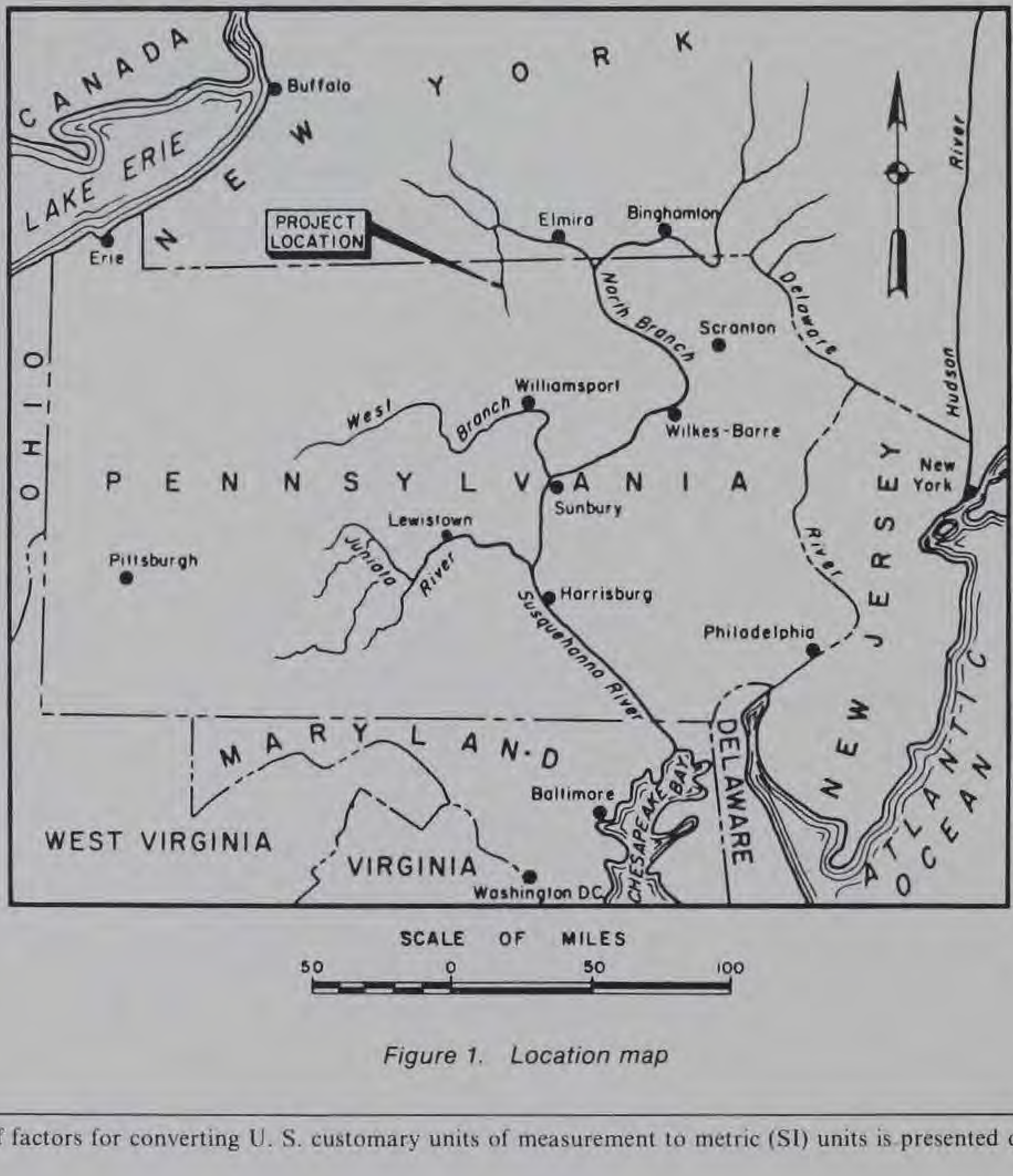


Figure 1. Location map

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

PROJECT FEATURES

2. The Tioga outlet works consist of a gated intake structure, transition conduit, stilling basin, and an exit channel. The gate structure will contain two 7-ft-wide by 21-ft-high hydraulically operated fixed wheel-type service gates designed to pass a maximum discharge of 15,860 cfs.

3. Low-flow releases will be made through four ports located on the upstream face of the raking platform. Two ports will be located to the right of the trashracks and two to the left. Each port will contain a 3- by 6-ft hydraulically operated slide gate. Each combination of two right ports and two left ports will discharge into a common wet well before discharging through a 2- by 5-ft hydraulically operated slide gate. The flow through the slide gates will discharge downstream of the service gates. Discharge through either the fixed wheel-type service gates or the low-flow slide gates will pass through a 52-ft-long transition and a cut-and-cover oblong conduit, 525 ft long, 21 ft high with 14.5-ft-diam top and bottom semicircles and vertical sides. Discharge energy at the end of the conduit will be dissipated in a stilling basin. The exit channel will lead from the stilling basin to the Tioga River. A plan and profile of Tioga outlet works are shown in Plate 1.

PURPOSE OF MODEL INVESTIGATION

4. The Tioga outlet works is intended to pass a controlled flow of water through Tioga Dam in order to maintain Tioga Lake at a preset elevation during normal conditions and to control water storage in both Tioga and Hammond Lakes during periods of high flow. The purpose of the model study included:

a. Determination of flow characteristics throughout the outlet works for both separate and combined flow operations.

b. Verification and/or refinement of the stilling basin design.

c. Study of flow conditions in the exit channel.

d. Determination of the minimum riprap requirements for the exit channel.

5. Special consideration was given to the stilling basin to assure adequate performance for the complete range of discharges up to 15,860 cfs.

PART II: THE MODEL

DESCRIPTION

6. The study was conducted using a 1:25-scale model which reproduced a schematic intake structure, the 21-ft-high by 14.5-ft-wide oblong conduit, the stilling basin, and 600 ft (prototype) of downstream channel topography (Figure 2). The model layout is provided in Plate 2. All flows were regulated by the two 7- by 21-ft service gates in the plastic intake structure. The headbay and stilling basin were fabricated of wood, the conduit of sheetmetal, and the downstream channel shaped in sand and molded with cement mortar. Crushed limestone (riprap) on filter cloth over the sand replaced the cement mortar before testing to determine the minimum downstream riprap requirements.

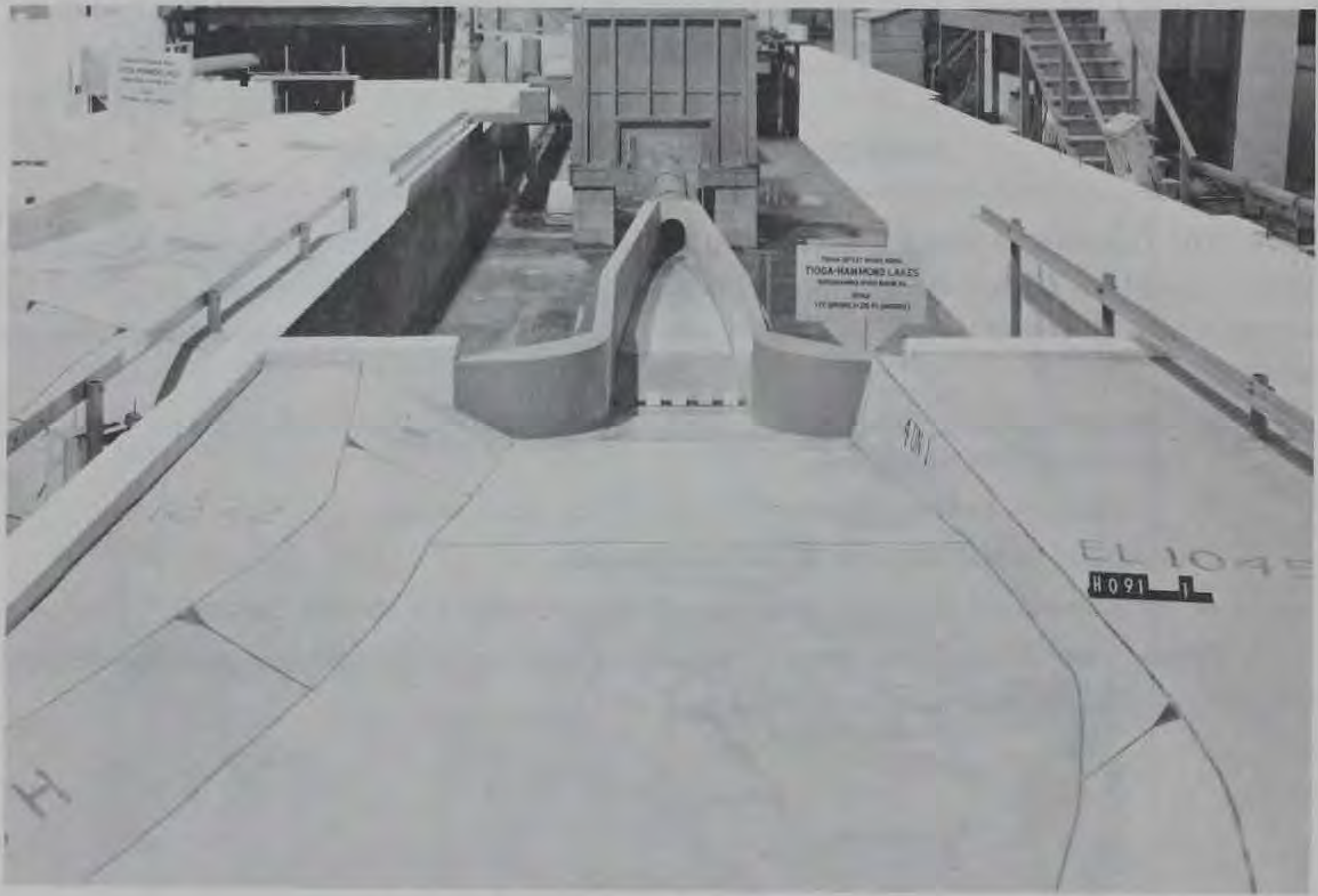


Figure 2. Overall view of model, original design

APPURTENANCES

7. Discharge was measured with precalibrated venturi meters and the headbay elevation was controlled by the two main service gates located in the intake tower. The tailwater elevation, and subsequently the basin water surface, were regulated by a vertical tailgate located at the downstream end of the model. Water-surface elevations and velocities were measured with point gages and a pitot tube, respectively. Performance of the stilling basin was based on both visual observations and velocities

measured just downstream of the basin. Steel rails set to grade along each side of the basin and downstream channel provided a reference plane for measuring devices and for horizontal stationing of the channel.

SCALE RELATIONS

8. The accepted equations of hydraulic similitude, based on the Froudian criteria, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for the transference of model data to prototype equivalents are presented below:

Dimensions	Ratio	Scale Relations
Length	L_r	1:25
Area	$A_r = L_r^2$	1:625
Velocity	$V_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3,125
Volume	$\forall_r = L_r^3$	1:15,625
Time	$T_r = L_r^{1/2}$	1:5

Model measurements of discharge, water-surface elevation, and velocities can be transferred quantitatively to prototype equivalents by means of the scale relations. Experimental data also indicate that the prototype-to-model scale ratio is valid for scaling riprap in the sizes used in this investigation.

MODEL ADJUSTMENT

9. In design of the model, geometric similitude was preserved between model and prototype by means of an undistorted scale ratio. Making a valid study of flow conditions in the outlet works required that the hydraulic grade line be simulated accurately in the model. It is not possible to satisfy the requirements of both the Froudian and the Reynolds criteria for complete similitude by using water in the model. Since water is also the fluid in the prototype and hydraulic similitude between the model and prototype was based on Froudian relations, the Reynolds number with the design flow in the model was lower than that in the prototype. Therefore, the resistance coefficient of the model was higher than that of the prototype, and the excess losses in the model were compensated for by shortening the length of model conduit by 37 percent.

PART III: TESTS AND RESULTS

CALIBRATION TESTS

10. Since the intake structure was only schematically reproduced in the model, calibration tests were conducted to verify the accuracy of the model discharge-pool relationship. This calibration indicated adequate correlation between the model and the computed discharge-pool relationship. Pertinent capabilities of the Tioga outlet works as given in the project design memorandum are as follows:

a. Capacity to pass a 10-yr construction season flood with a maximum reservoir pool elevation (Tioga Reservoir) of 1069.5 ft.* The maximum depth of the diversion flood pool would be 34.5 ft. Peak discharge through the outlet works would be 7440 cfs.

b. Discharge capacity of the service gates at given reservoir pool elevations with ports closed:

Tioga Reservoir Pool Elevation, ft	Rising Pool Discharge, cfs	
	One Gate Open	Two Gates Open
1060 - Winter pool	2,240	4,150
1081 - Summer pool	6,900	9,430†
1131 - Spillway crest	11,100‡	15,000

† Normal discharge restricted to 8,300 cfs.

‡ Use of only one service gate with pool elevation above summer pool not recommended. It is preferable to distribute flow equally between two gates, or restrict one-gate flow to 8,300 cfs.

c. Discharge capacity of the low-flow control system:

Tioga Reservoir Pool Elevation, ft	Maximum Discharge cfs
1060 - Winter pool	500
1081 - Summer pool	780

ORIGINAL DESIGN STILLING BASIN

11. The stilling basin as originally designed (Plate 3) consisted of a horizontal apron 108 ft long and 55.5 ft wide with one row of 3.67-ft-high baffle piers and a 3.67-ft-high end sill. A 96-ft-long transition with sidewalls flared 1 on 4.683 connected the outlet portal to the basin. A curved trajectory was provided between the invert of the outlet portal (el 1031.5) and the stilling basin apron (el 1005.5). Circular wing walls with a radius of 40 ft were provided downstream of the parallel basin walls.

12. The original design stilling basin was subjected to the full expected range of discharges up to 15,860 cfs with the related tailwaters shown in Plate 4. Flows between 500 and 1,500 cfs allowed flow separation from one of the stilling basin sidewalls, and adverse eddies formed in the basin as shown in Photo 1. Medium flows of 2,000 to 14,000 cfs were adequately dissipated by the hydraulic jump in the

* Elevations (el) cited herein are in feet referred to mean sea level (msl).

original stilling basin, Photo 2. Single-gated flows of 2,000 to 8,000 cfs also produced stable hydraulic jumps. With flows above 14,000 cfs, the high-velocity jet exiting the conduit outlet was concentrated in the center rather than uniformly distributed across the full width of the transition section (Figure 3). This produced an unstable hydraulic jump and pulsating stilling basin action that caused flow to overtop the original basin sidewalls and generated excessive wave action downstream (Photo 3). The original stilling design was adequate only for flows between 2,000 and 14,000 cfs; therefore, modifications were necessary to improve energy dissipation for the flows above and below these limits.

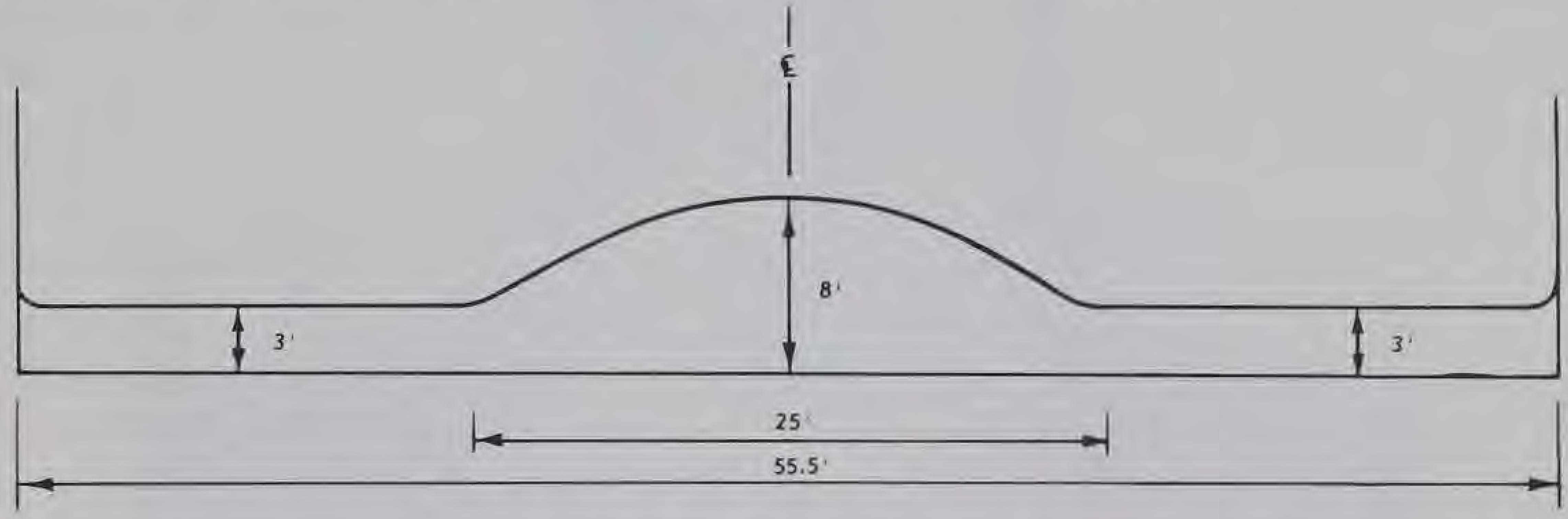


Figure 3. Cross section of depth of flow at toe of trajectory, Q = 15,860 cfs (design flow)

MAJOR BASIN DESIGN MODIFICATIONS

13. Several modifications to the original stilling basin were made in attempts to eliminate the low-flow eddies by improving flow distribution at the outlet portal and down the trajectory, and also improve the energy dissipation at maximum flows. Only the most significant modifications are documented herein, several of which produced limited benefit.

Raised Walls

14. The high degree of turbulence in the original basin required an 8-ft increase in wall height (Figure 4) to contain the oversplash. An 8-ft higher wall was not considered a feasible solution since it had no effect on the flow eddies, and model efforts were directed toward modifying the transition and basin dimensions and other possible transitional improvements.

Transition Flare

15. The flare of the transition between the outlet portal and the basin was reduced from 1 on 4.683 to 1 on 6 and then to 1 on 8 in efforts to improve stilling action. The 1-on-6 flare had little effect on stilling basin performance with the original 55.5-ft-wide basin. The 1-on-8 flare improved low-flow performance but the design discharge caused excessive velocities along the basin center line near the water surface at the downstream end of the basin. This created undesirable surface wave action in the downstream channel. In later tests with the width of the basin increased, it was found that the 1-on-6 flare was optimum to accommodate all expected flows.

Outlet Portal Fillets

16. Various modifications to the fillets in the transition downstream from the outlet portal were

Figure 4. Original basin with walls raised 8 ft to el 1051

tested in attempts to improve the flow distribution at sta 17+74.25. Shorter fillets (29 ft long) were installed to check their effectiveness in uniformly distributing flow with the original 1 on 4.683 flared walls and with walls flared 1 on 6. No measurable improvement was detected with the 29-ft-long fillets. However, they were as effective as the original 60-ft-long fillets. It was obvious that the fillets did not produce the imbalanced flow described in paragraph 12 because their removal or alteration did not significantly change the undesirable flow distribution.

Outlet Portal Transition

17. A transition from the original oblong conduit to a rectangular cross section, 18 ft high by 14.5 ft wide, at the outlet portal within the last 25-ft closed portion of the conduit was tested in an effort to obtain better distribution of flow in the stilling basin. The invert at the outlet portal remained at el 1031.5. Flow conditions in the basin with this design and discharges from 200 to 15,860 cfs are shown in Photo 4. Some improvements were noted with this design but a mild eddy was still present during the discharge of 1,000 cfs (Photo 4c) and excessive overtopping of the basin walls (Photo 4f) occurred during discharges above 14,000 cfs. Therefore, the original oblong conduit was retained to the outlet portal.

Elevated Center Line

18. For design 6, the invert along the center line of the transition trajectory was elevated as shown in Plate 5. This modification was effective in eliminating the eddies during low flows when both intake gates were open an equal amount (Photo 5a) and also improved flow distribution with higher discharges (Photo 5b-d). However, discharges above 14,000 cfs continued to cause periodic overtopping of the basin walls. With only one intake gate open, a mild eddy occurred with discharges from 1,000 to 1,500 cfs as shown in Photo 6. The elevated center line was tested with both the original and the rectangular outlet, and little difference in flow conditions could be detected with either of the designs. A basin without the elevated center line was selected for the final design. However, the invert immediately downstream from the outlet was extended horizontally for a distance of 38.64 ft to stabilize and spread flow before it reached the curved trajectory.

Basin Width

19. After testing the several modifications to the transition and basin discussed above, it became apparent that the basin width would have to be increased to reduce the extreme turbulence encountered with the higher discharges. Thus, the basin width was increased to 72 ft, the maximum desirable width according to the sponsor. Details of this basin are shown in Plate 6 as the type 11 design. The eddies that formed with low flows with previous designs were practically eliminated, and the hydraulic jump was more stable with higher flows. However, flow still splashed over the walls with the design discharge, and the basin walls would have to be raised 2 ft to retain all flow within the basin.

Basin Apron Elevation

20. Although the type 11 basin performed satisfactorily, especially with flows up to 10,000 cfs, tests were conducted with the basin apron at higher elevations in an effort to stabilize the jump with higher flows. With the basin floor raised 9.5 ft to el 1015, a jump could not be maintained in the basin with minimum tailwater and the apron was lowered to el 1010. Satisfactory performance was obtained with the apron at this elevation; therefore, it was adopted for the recommended design.

Transition Curve

21. The radius of the curve connecting the outlet portal and the flared walls of the transition was reduced from 227.3 to 50 ft at the request of the sponsor. With discharges above 10,000 cfs, flow separated from the flared walls downstream from the 50-ft-radius curve, causing flow to build up along each wall. Velocities along the parallel sidewalls of the basin were about 2 fps higher than those in the center; therefore, tests were conducted with an 80-ft radius. There was a slight buildup of flow along each wall with this curve but this did not cause severe unequal distribution of flow in the basin as shown by the velocity measurements in Plate 7.

Baffle Block Modifications

22. Several baffle block heights and locations were studied in an effort to stabilize the hydraulic jump and reduce the overtopping that occurred with the original basin; however, little improvement was realized with most modifications. One row of 4.5-ft-high baffles (1.23 d_1) placed 60 ft (1.7 d_2) downstream from the trajectory toe appeared best with the original basin el 1005.5 and 55.5-ft width.

23. Several single and double rows of 3.5- to 4.5-ft-high baffles (3.5 to 7.0 ft wide) located from 35 to 75 ft downstream from the toe of trajectory were tested with the 72-ft-wide basin. The optimum baffle

arrangement consisted of two rows of 3.5-ft-high (0.95 d_1) by 3.5-ft-wide baffles located 45 ft (1.27 d_2) and 65 ft (1.85 d_2) downstream from the toe of the trajectory as shown on the recommended stilling basin design (design 15) in Plate 8.

Stilling Basin Wing Walls

24. The 40-ft-radius circular quadrant wing walls (Figure 2) were replaced with parallel abrupt walls extending to sta 20+23.25 in an effort to reduce wave actions against the downstream banks. Only minor wave reduction was realized initially with this change because adverse surging in the basin continued until major basin improvements were established. However, the parallel sidewalls were beneficial in maintaining wave heights below 18 in. with the proposed design. These tests confirm other results at the U. S. Army Engineer Waterways Experiment Station indicating the abrupt end wing walls are more desirable for minimizing downstream wave action. The potential side roller behind the abrupt wall is neutralized on the left by the 4V on 1H slope cut in natural rock and on the right by the 1V on 2.5H riprap slope (Figure 5).

Figure 5. Abrupt walls with satisfactory wave action at design flow

RECOMMENDED DESIGN STILLING BASIN

25. Design of the stilling basin recommended to accommodate the full range of expected flows up to 15,860 cfs was based on the previously described tests and provided better energy dissipation throughout the range of operation than did the original design. Changes to the original design included:

- *a.* Widening the basin from 55.5 to 72 ft.
- *b.* Decreasing the flare of the transition walls from 1 on 4.683 to 1 on 6.
- *c.* Decreasing the radius of the curve connecting the outlet portal with the flared walls from 227.3 to 80 ft.
- *d.* Lengthening the basin approximately 30 ft to include the 38.64-ft-long horizontal floor at the outlet portal.
- *e.* Raising the basin apron 4.5 ft to el 1010.
- *f.* Raising the elevation of the top of the sidewalls from 1043 to 1048.
- *g.* Replacing the 40-ft-radius circular quadrant wing walls at the end of the basin with parallel walls.

The recommended basin is shown in Figure 6 and details are shown in Plate 8. Flow conditions with various discharges are shown in Photo 7.

DOWNSTREAM RIPRAP REQUIREMENTS

26. Tests to determine the minimum riprap requirements in the downstream channel were conducted with the recommended stilling basin. The recommended protection plan is shown in Plate 9 and Figure 7. The left bank slope just downstream of the basin is natural rock and therefore requires no added protection. Riprap smaller than that shown was unstable for the design discharge, where the highest velocities and wave action occurred. Wave action along the left bank near sta 27+00 caused movement of the 12-in. riprap during a discharge of 15,860 cfs (Photo 8). The 12-in. riprap in the area of riprap movement was replaced with 24-in. riprap as shown in Figure 7. Several 5-hr tests were conducted with the recommended riprap plan installed and discharges from 500 to 15,860 cfs without movement of the riprap.

27. Although the downstream model limits terminate where the bottom width expands to 175 ft near sta 29+00, the wave action will probably extend to the confluence of Tioga River near sta 42+50; it is therefore recommended that the side slopes be protected with 12-in. riprap between sta 29+00 and 42+50.

Figure 6. Recommended stilling basin, design 15

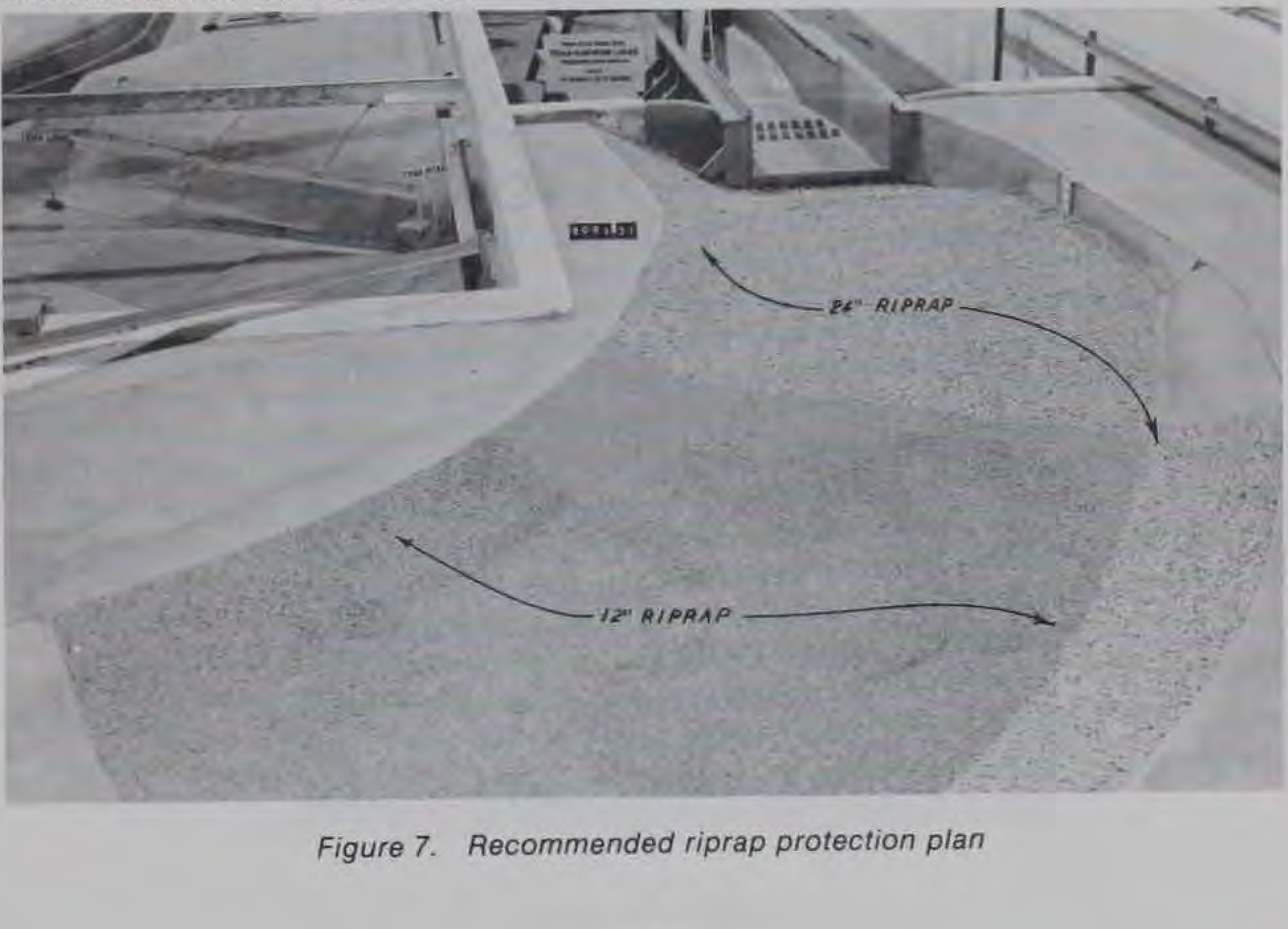


Figure 7. Recommended riprap protection plan

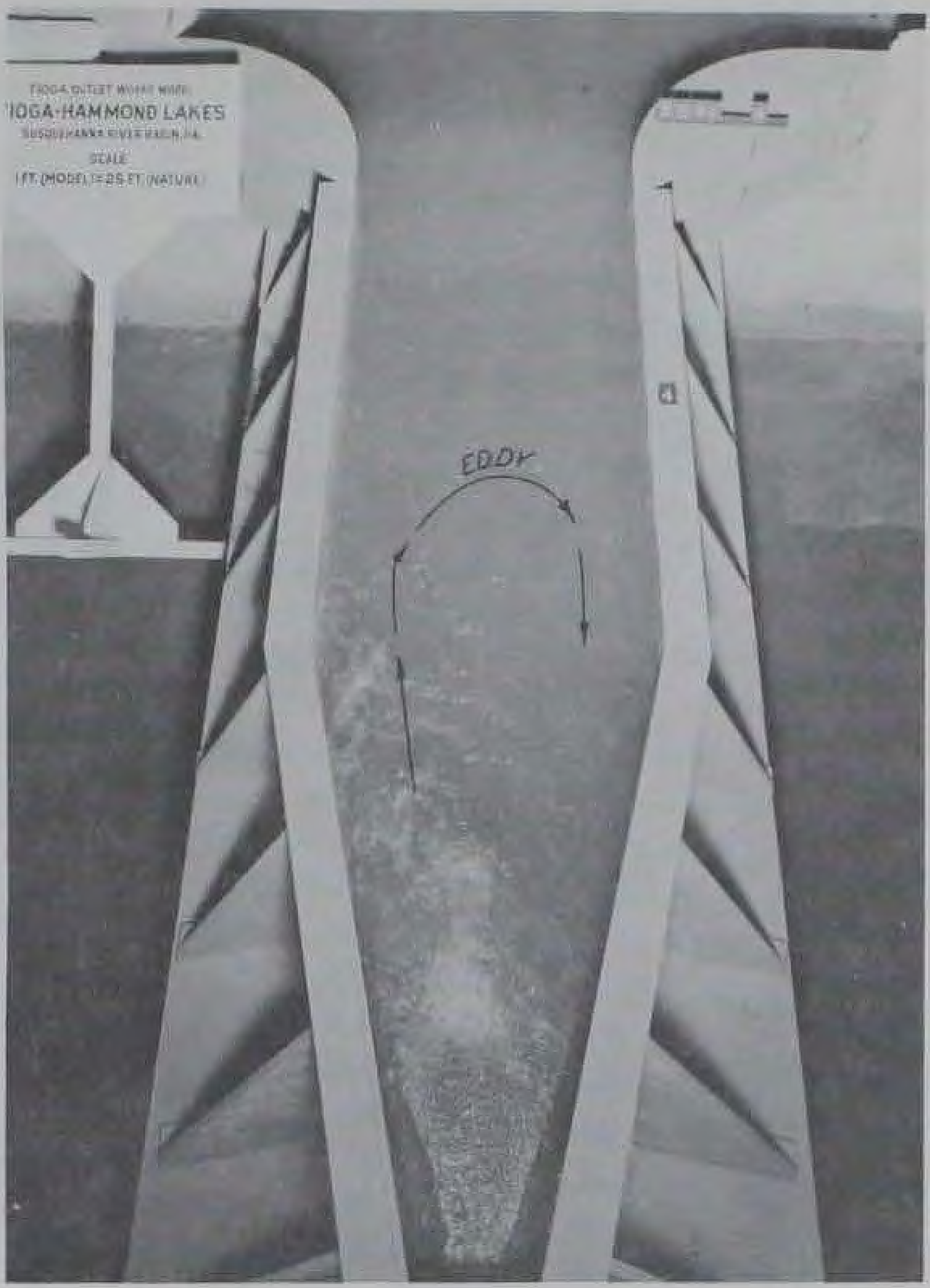
PART IV: DISCUSSION OF RESULTS

28. The original design stilling basin for the Tioga outlet works performed satisfactorily for flow releases of 2,000 to 14,000 cfs; however, unsatisfactory stilling basin performance occurred at higher and lower discharges. An unstable (pulsating) hydraulic jump occurred in the original basin at discharges above 14,000 cfs, causing flow to overtop the basin sidewalls at el 1043.0, and generated excessive wave action downstream. With discharges between 500 and 1,500 cfs, flow separated from both sidewalls and formed adverse eddies in the original basin.

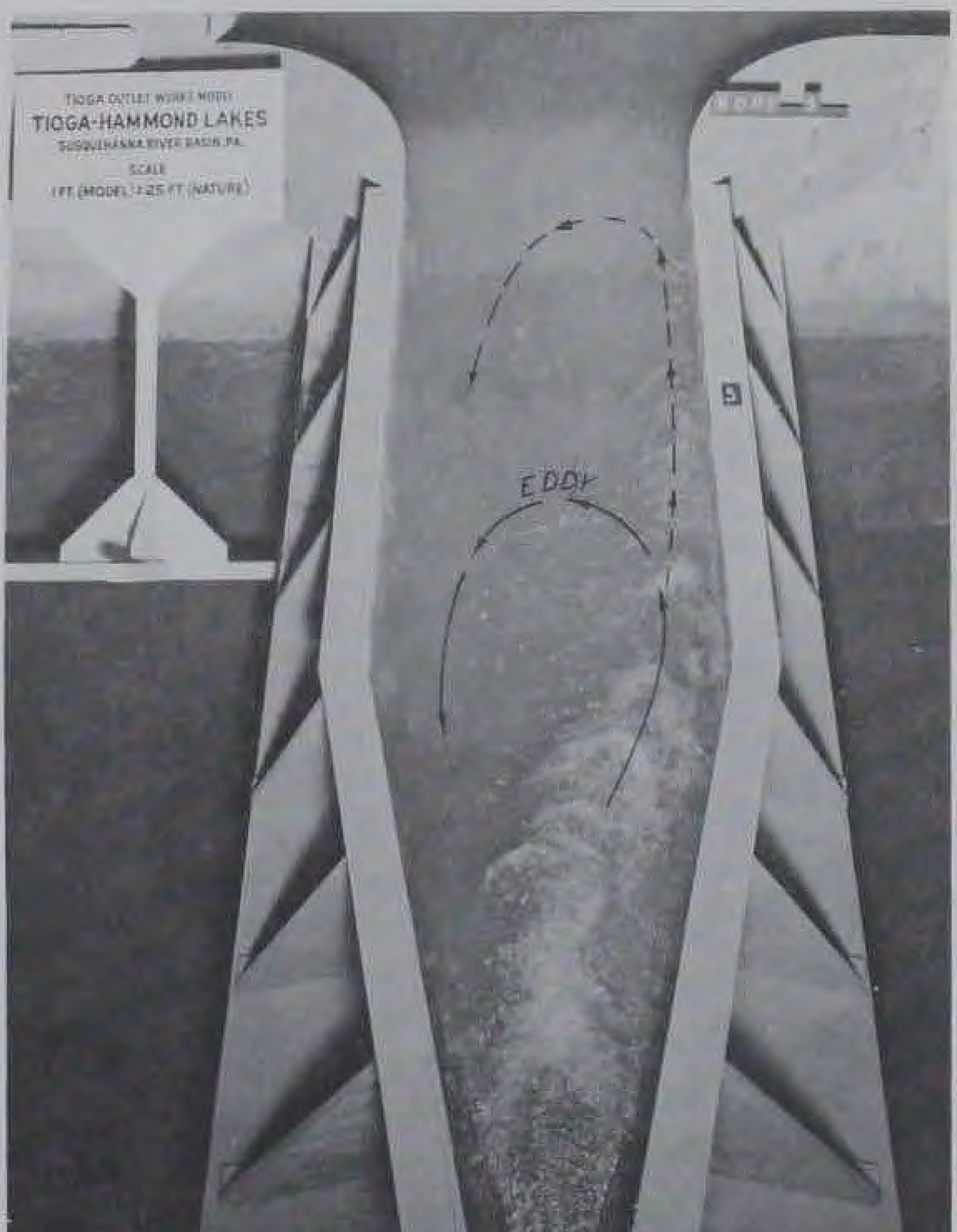
29. Various modifications to the original design basin and the outlet portal were tested with some success in solving either the unstable high flows or the low-flow eddying; however, only after all of the modifications were incorporated into the recommended design were both the high- and low-flow problems eliminated. Modifications to the original design basin included widening the basin from 55.5 to 72 ft, decreasing the flare of the transition walls from 1 on 4.683 to 1 on 6, raising the basin apron 4.5 ft from el 1005.5 to 1010.0, raising the elevation of the sidewalls from 1043.0 to 1048.0, and lengthening the basin approximately 30 ft to include the 38.64-ft-long horizontal floor at the outlet portal.

30. The recommended design contains the essential basin elements required to produce the optimum performance throughout the expected range of discharges and tailwaters. Eddies that formed in the basin during low flows with previous designs were eliminated and the hydraulic jump was more stable with the higher flows. Only minor splash and spray at the top of the basin walls were observed with the design discharge. The 80-ft radius of the sidewalls immediately downstream from the outlet portal allowed flow to spread along the 1-on-6 flared walls with a slight buildup of flow along each wall. However, this did not cause severe unequal distribution of flow in the basin.

31. A satisfactory riprap plan was developed for the exit channel to the Tioga River. The minimum riprap protection requirements established were adequate for the full range of discharges and tailwaters.

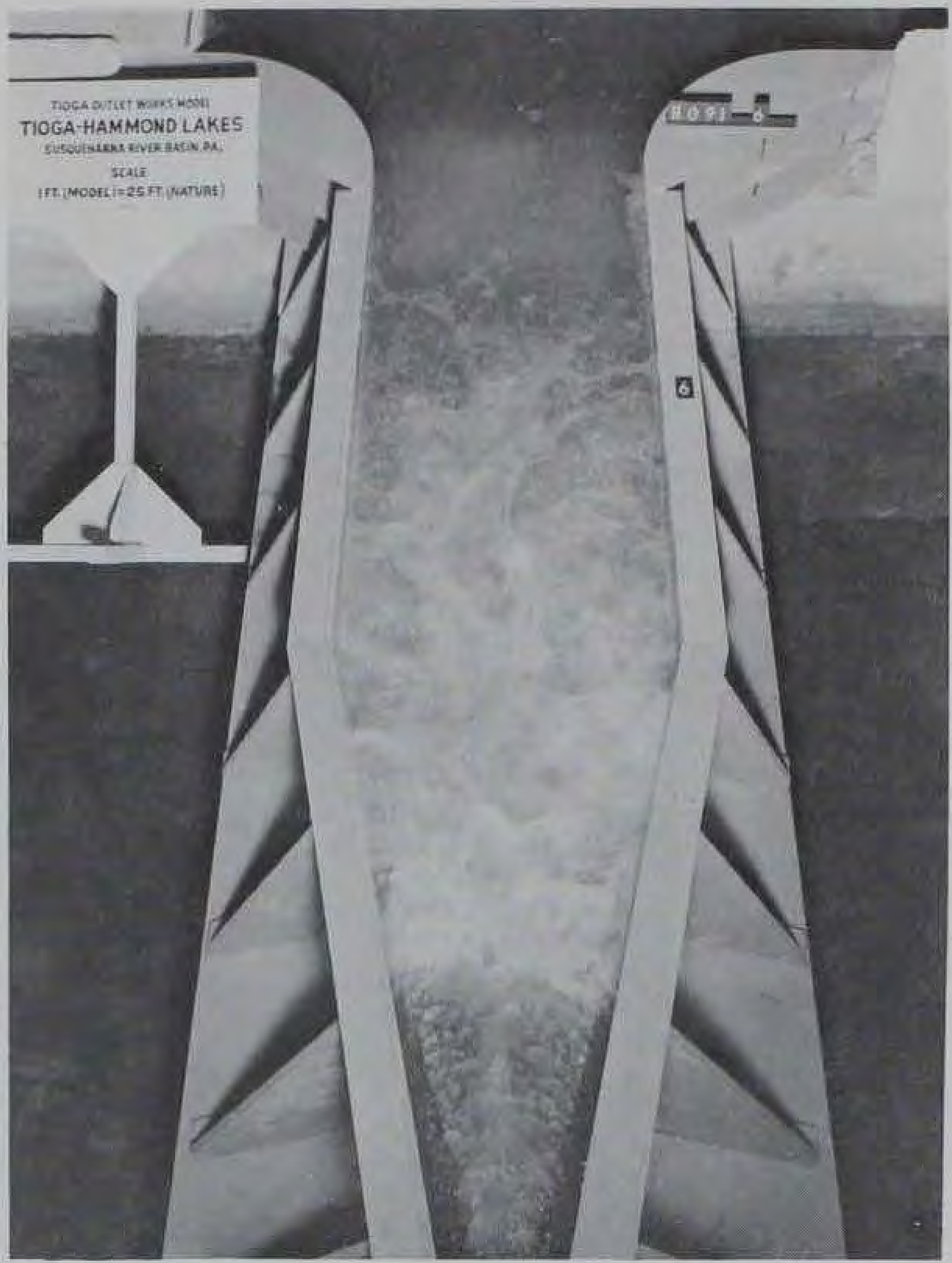


a. Q = 500 cfs

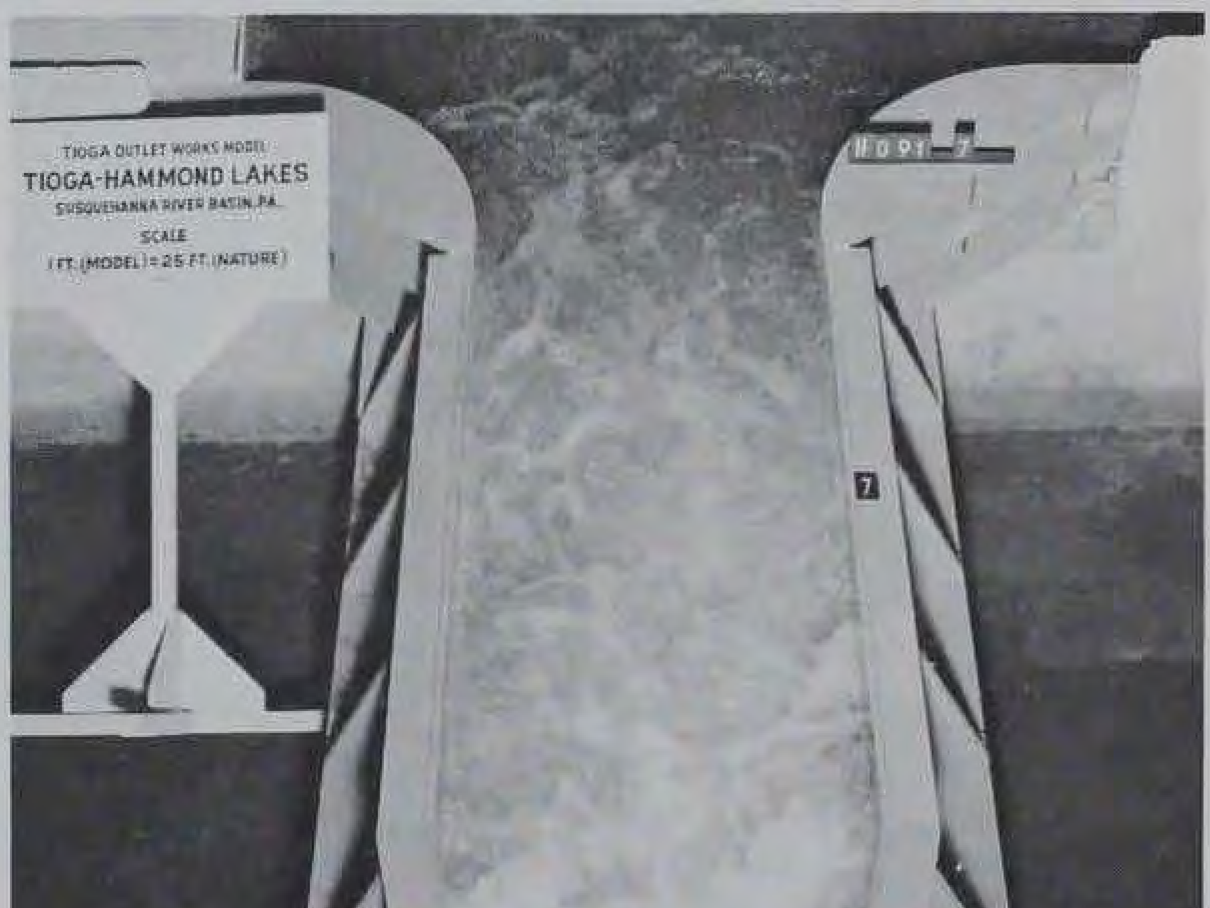


b. Q = 1000 cfs

Photo 1. Original design, adverse eddies

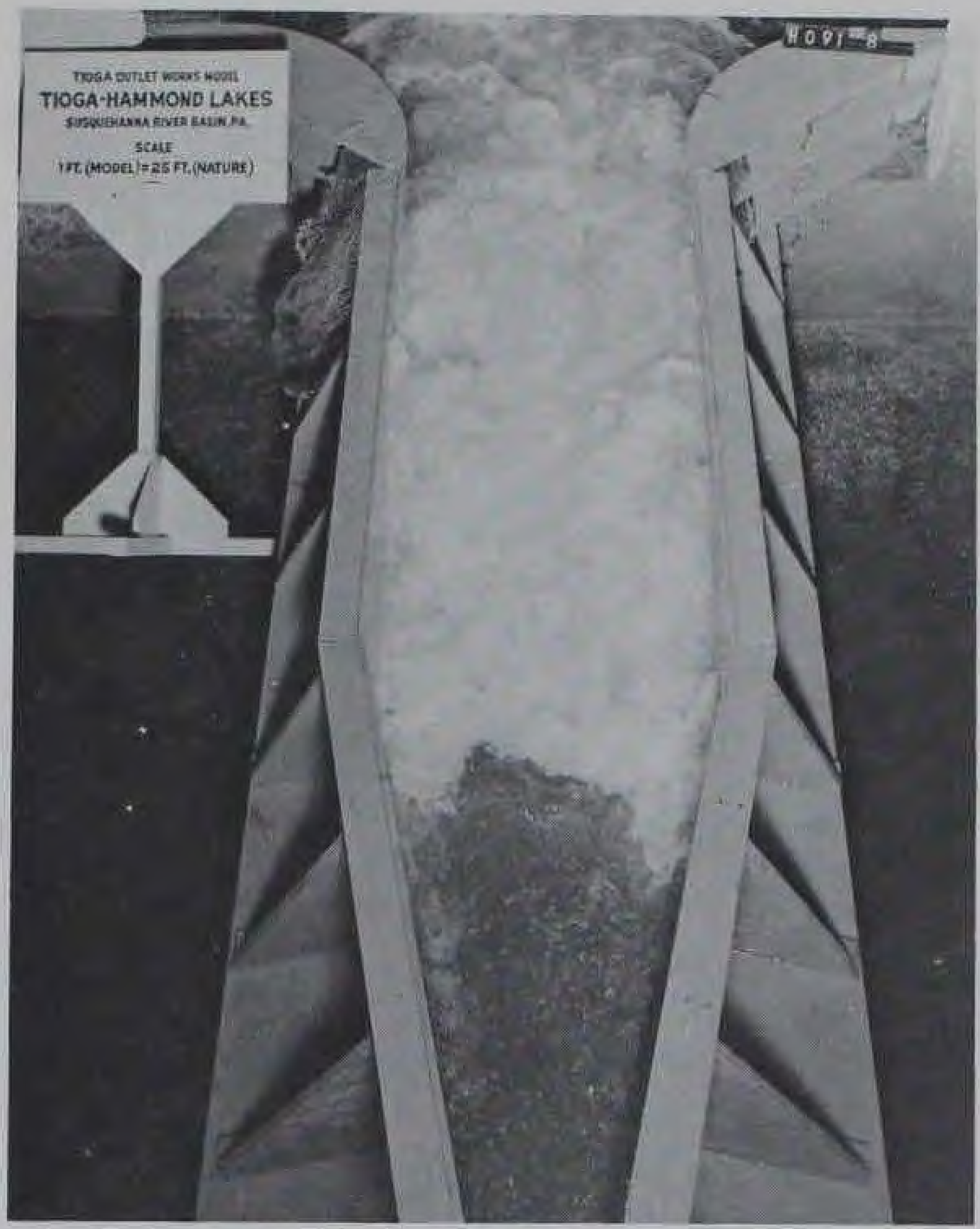


a. Q = 5000 cfs



b. Q = 10,000 cfs

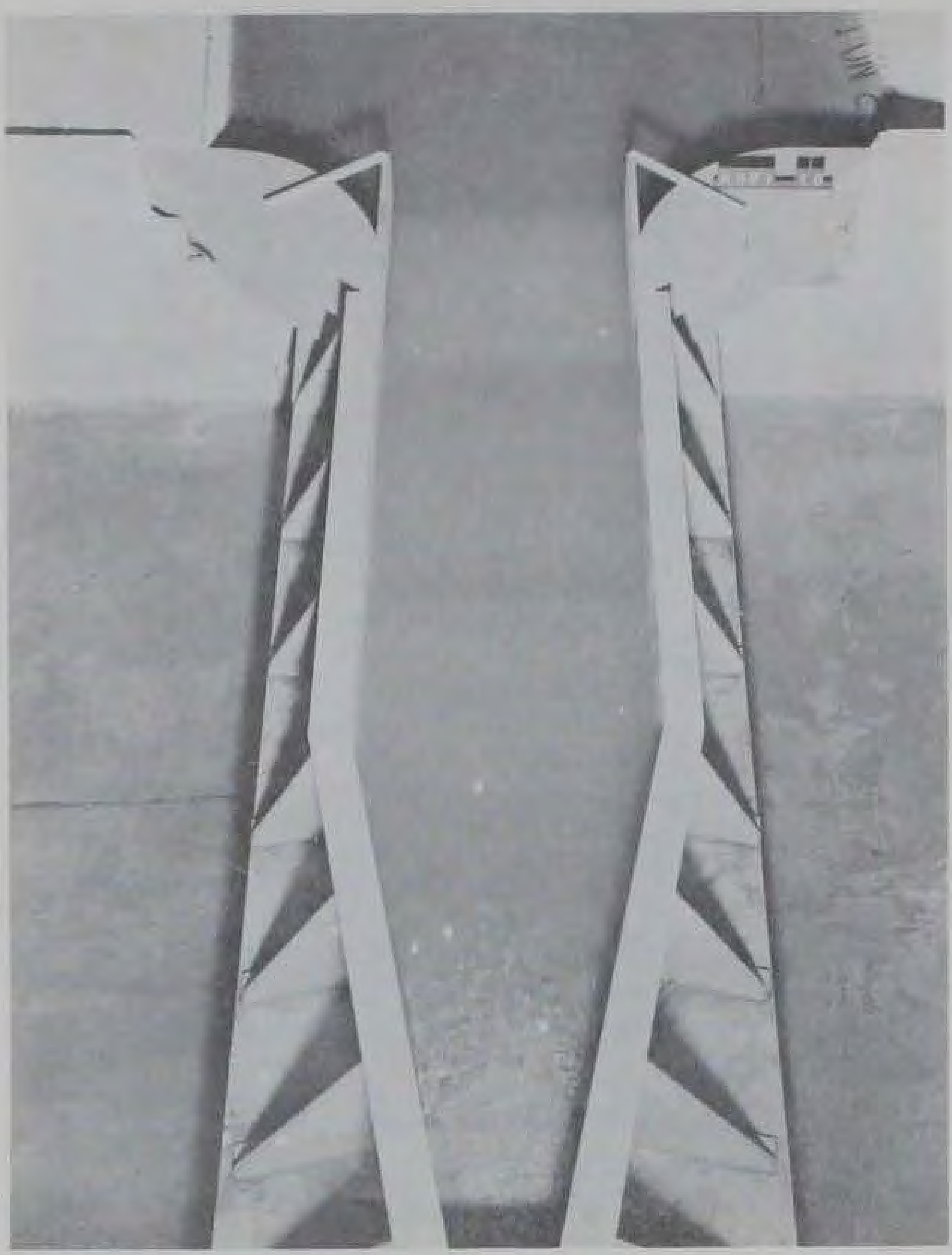
Photo 2. Original design, good stilling action



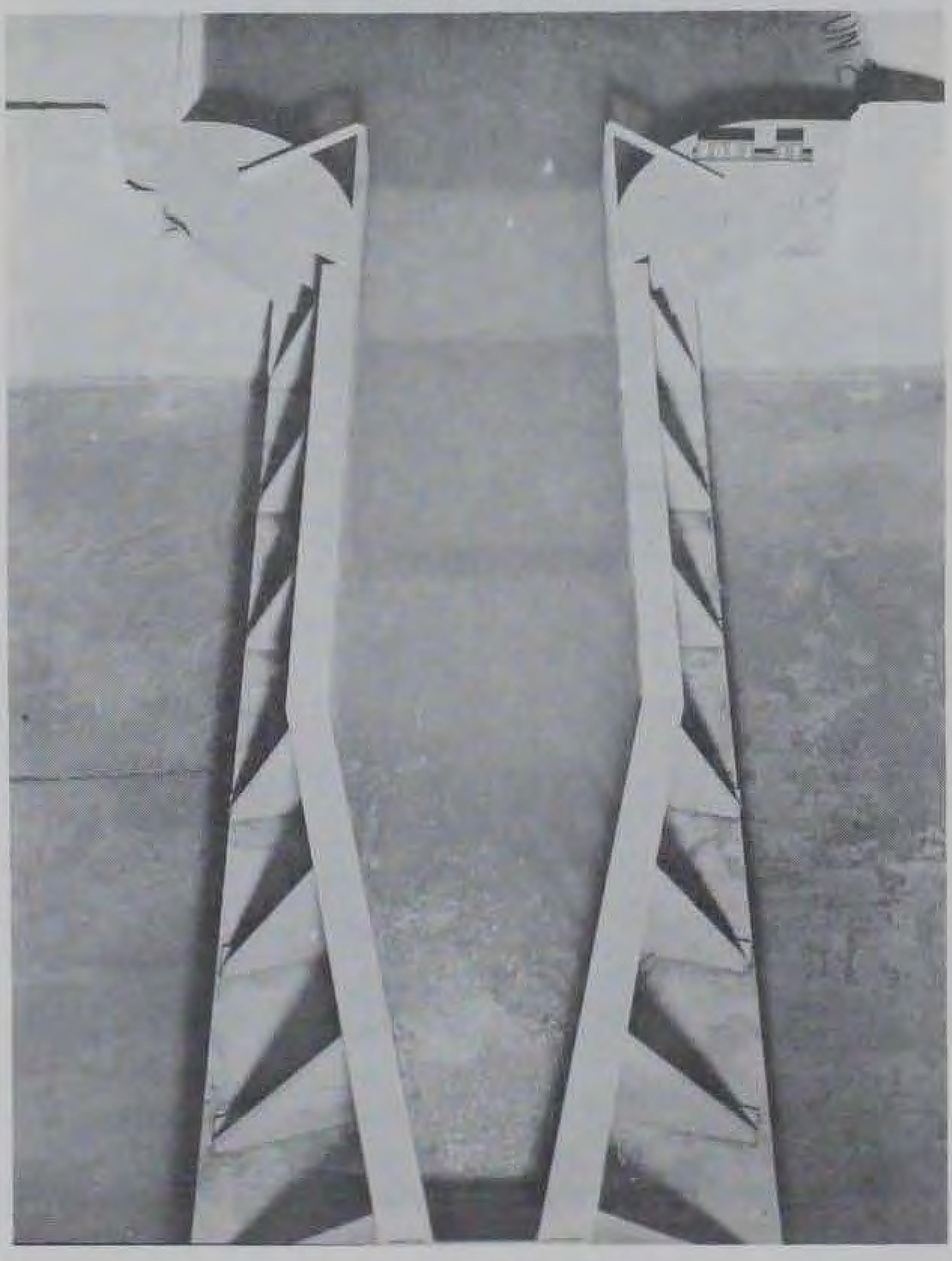
a. Q = 15,000 cfs

b. Q = 15,860 cfs

Photo 3. Original design, flow overtopping walls and excessive wave action downstream

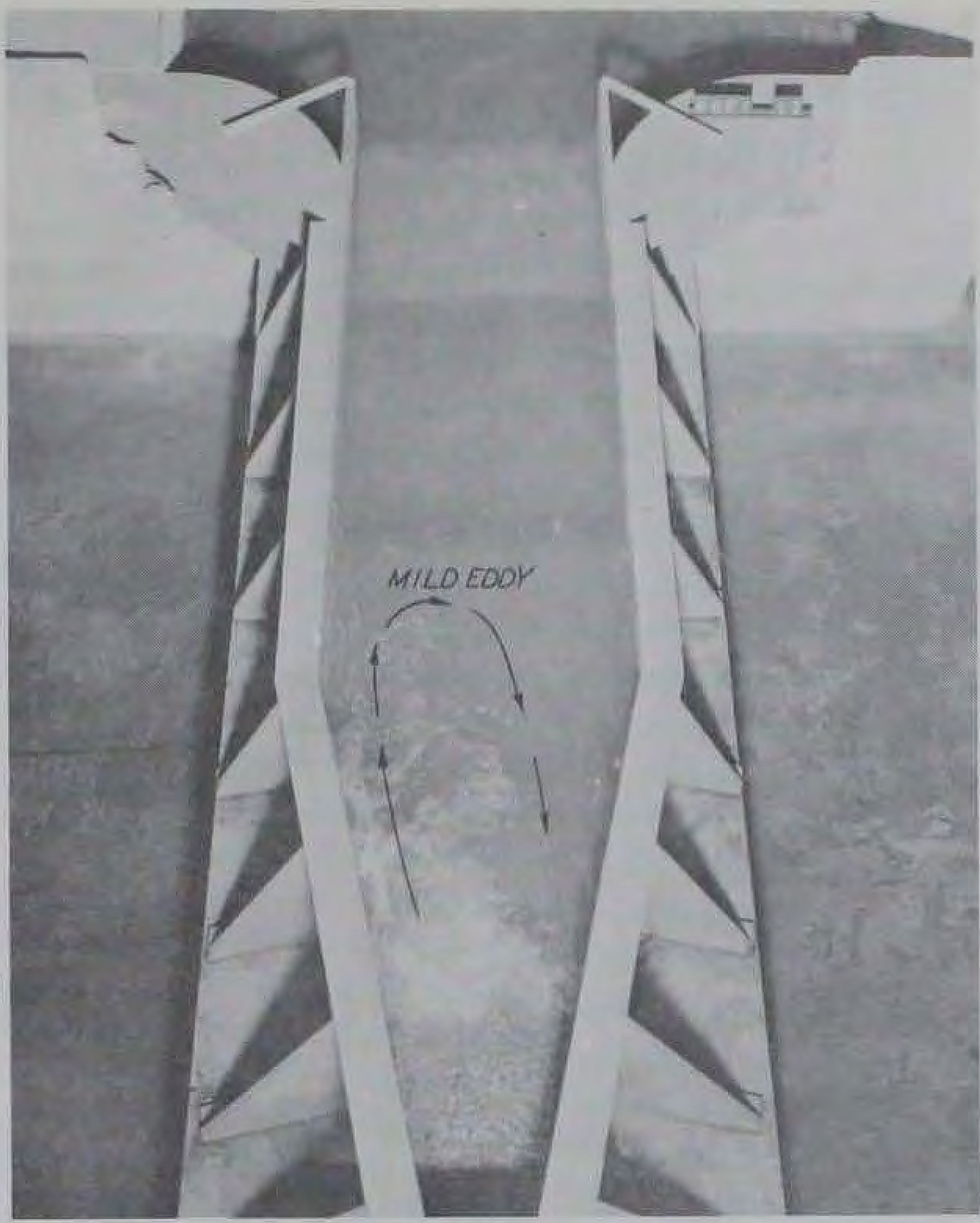


a. Q = 200 cfs

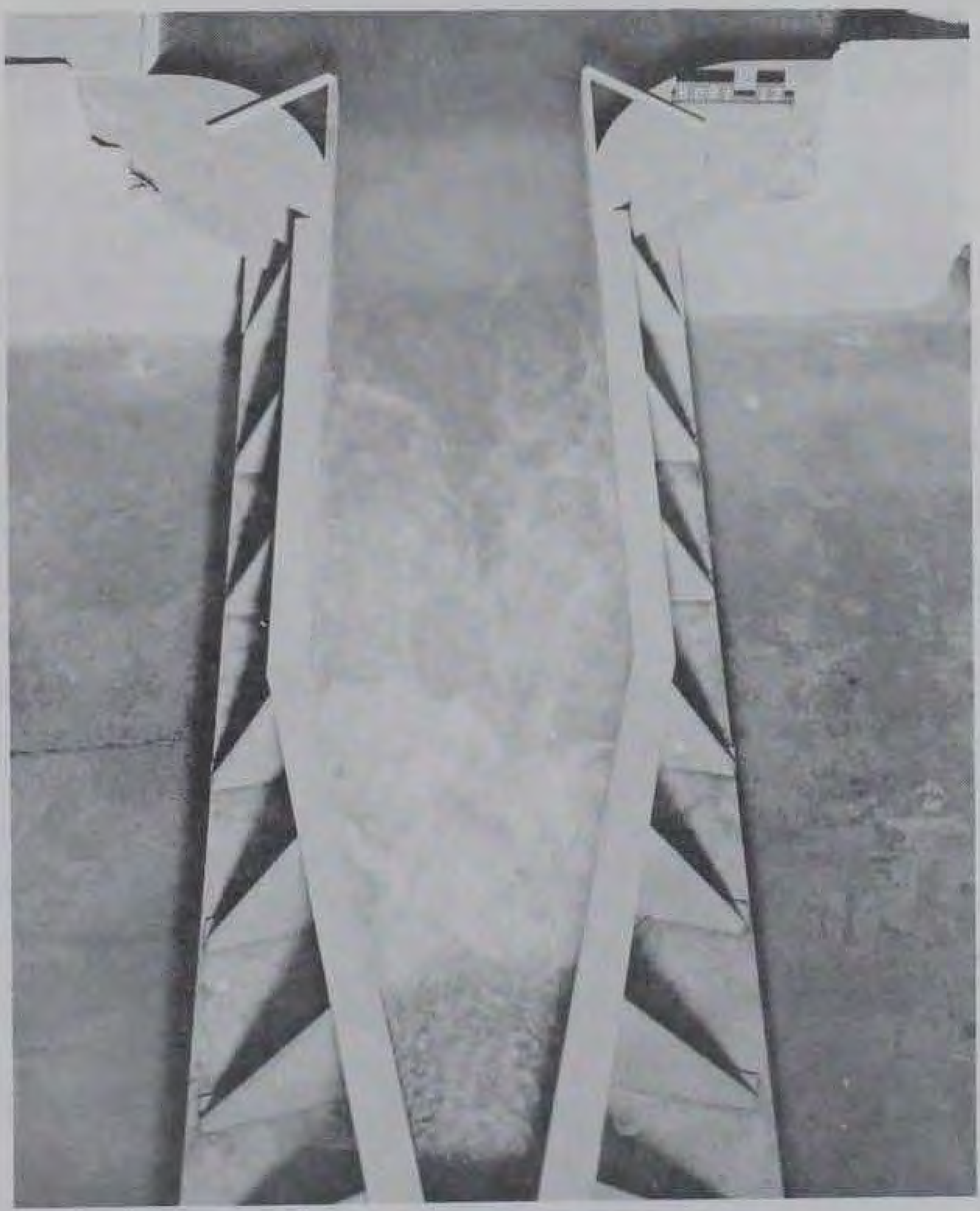


b. Q = 500 cfs

Photo 4. Rectangular outlet portal, 18 by 14.5 ft (sheet 1 of 3)

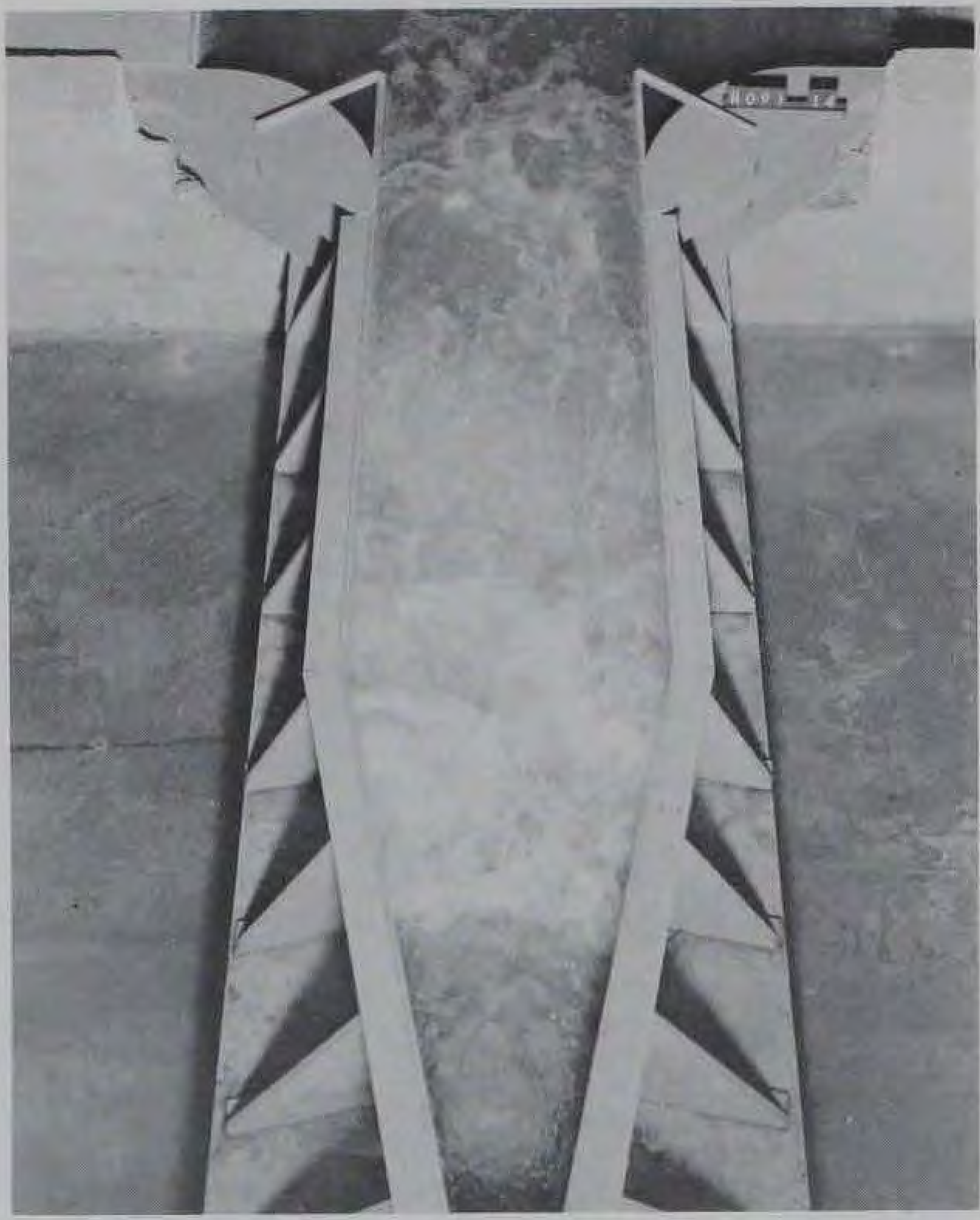


c. Q = 1000 cfs



d. Q = 5000 cfs

Photo 4. (sheet 2 of 3)

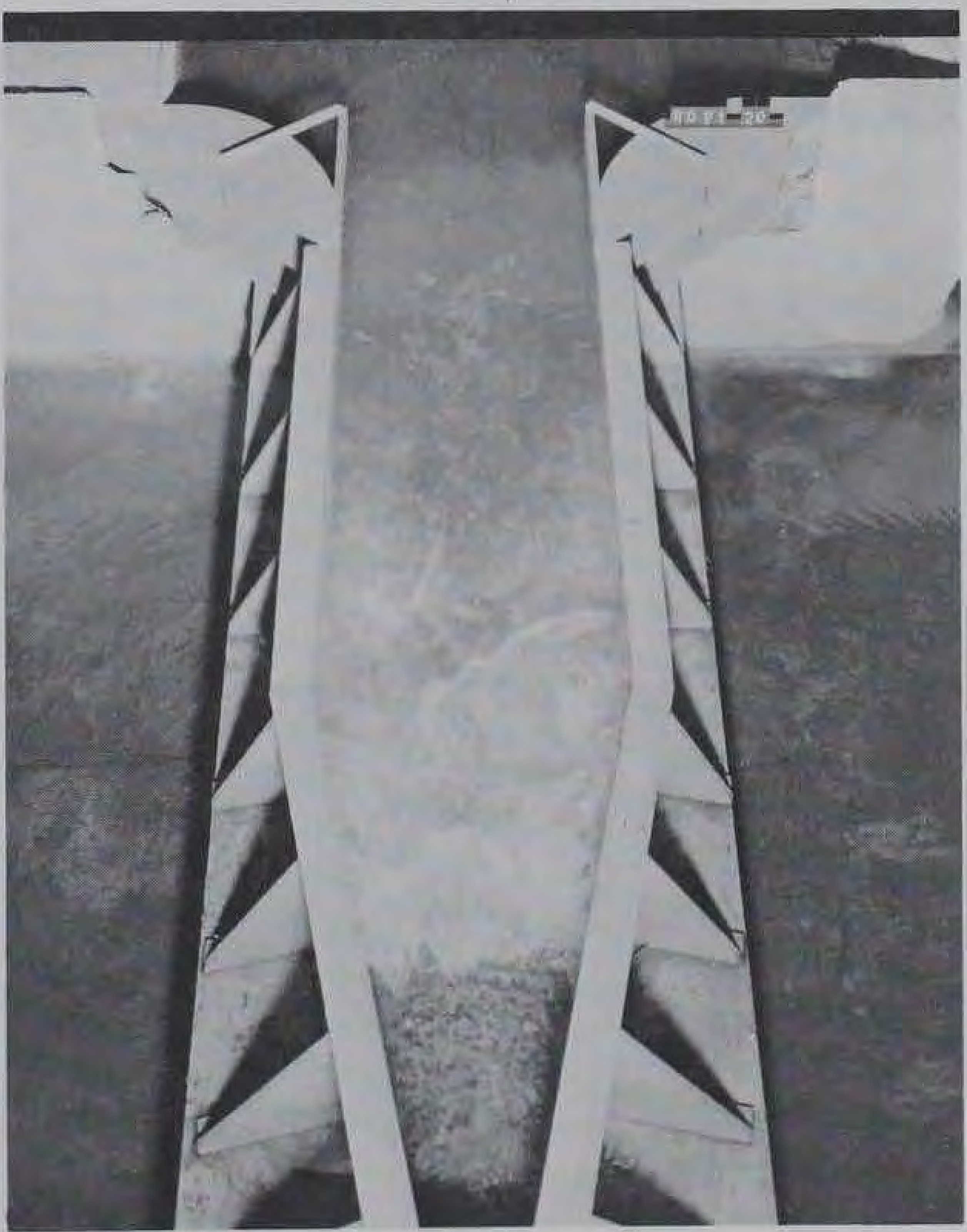


e. Q = 10,000 cfs

f. Q = 15,860 cfs

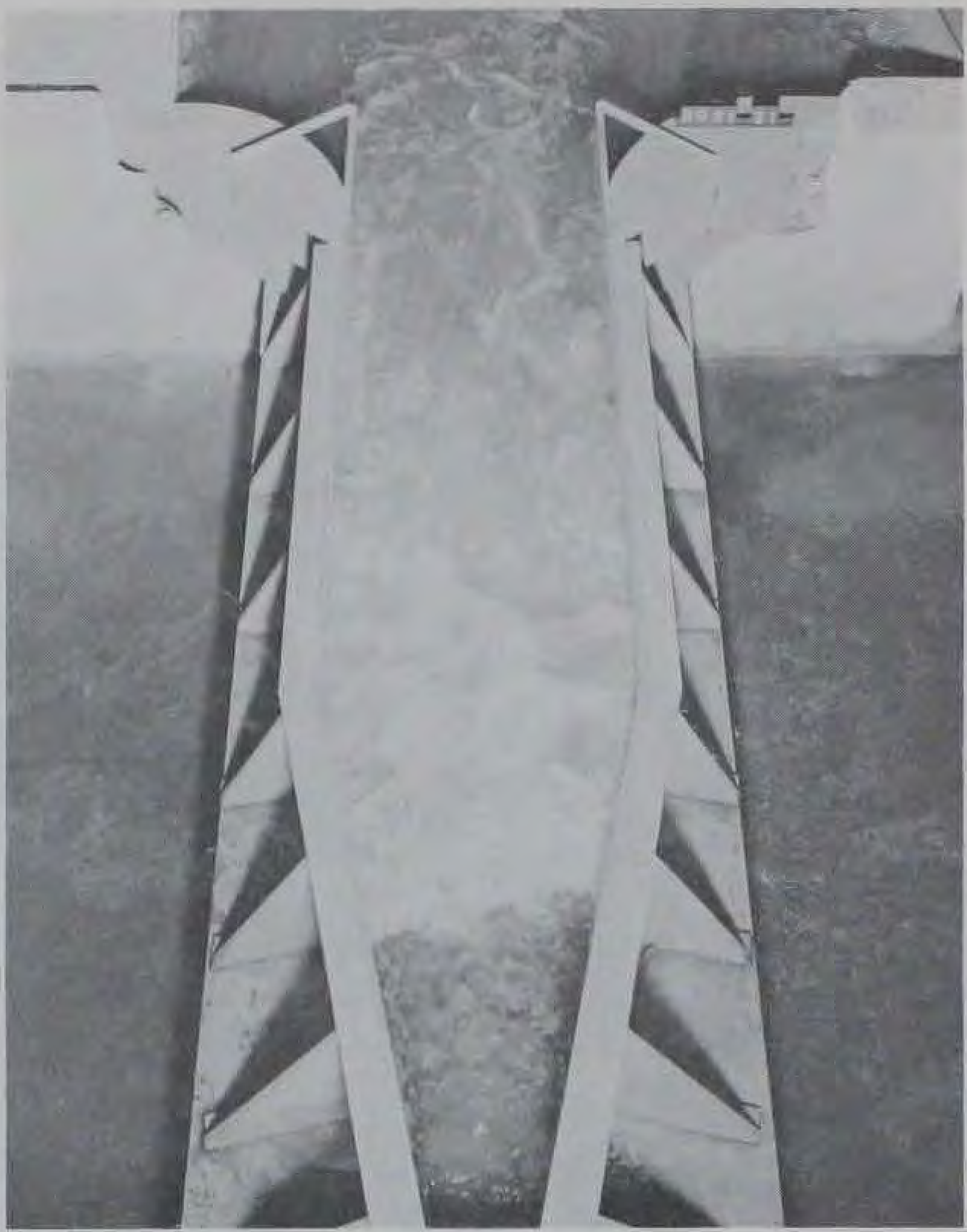
Photo 4. (sheet 3 of 3)

a. Q = 500 cfs (no eddies)

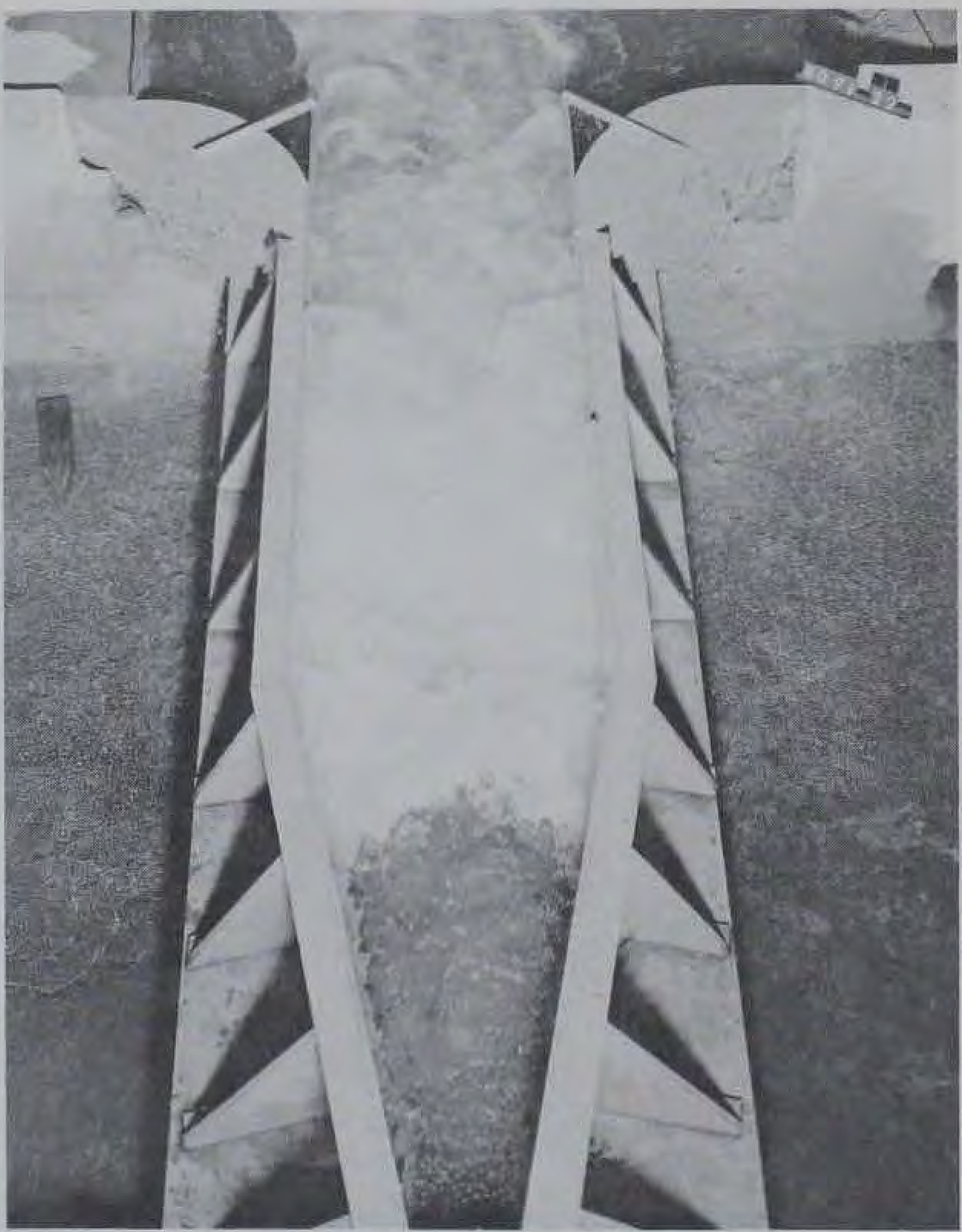


b. Q = 5000 cfs (good stilling action)

Photo 5. Rectangular outlet portal elevated center line (sheet 1 of 2)



c. Q = 10,000 cfs (good stilling action)



d. Q = 15,860 cfs (flow overtopping walls)

Photo 5. (sheet 2 of 2)

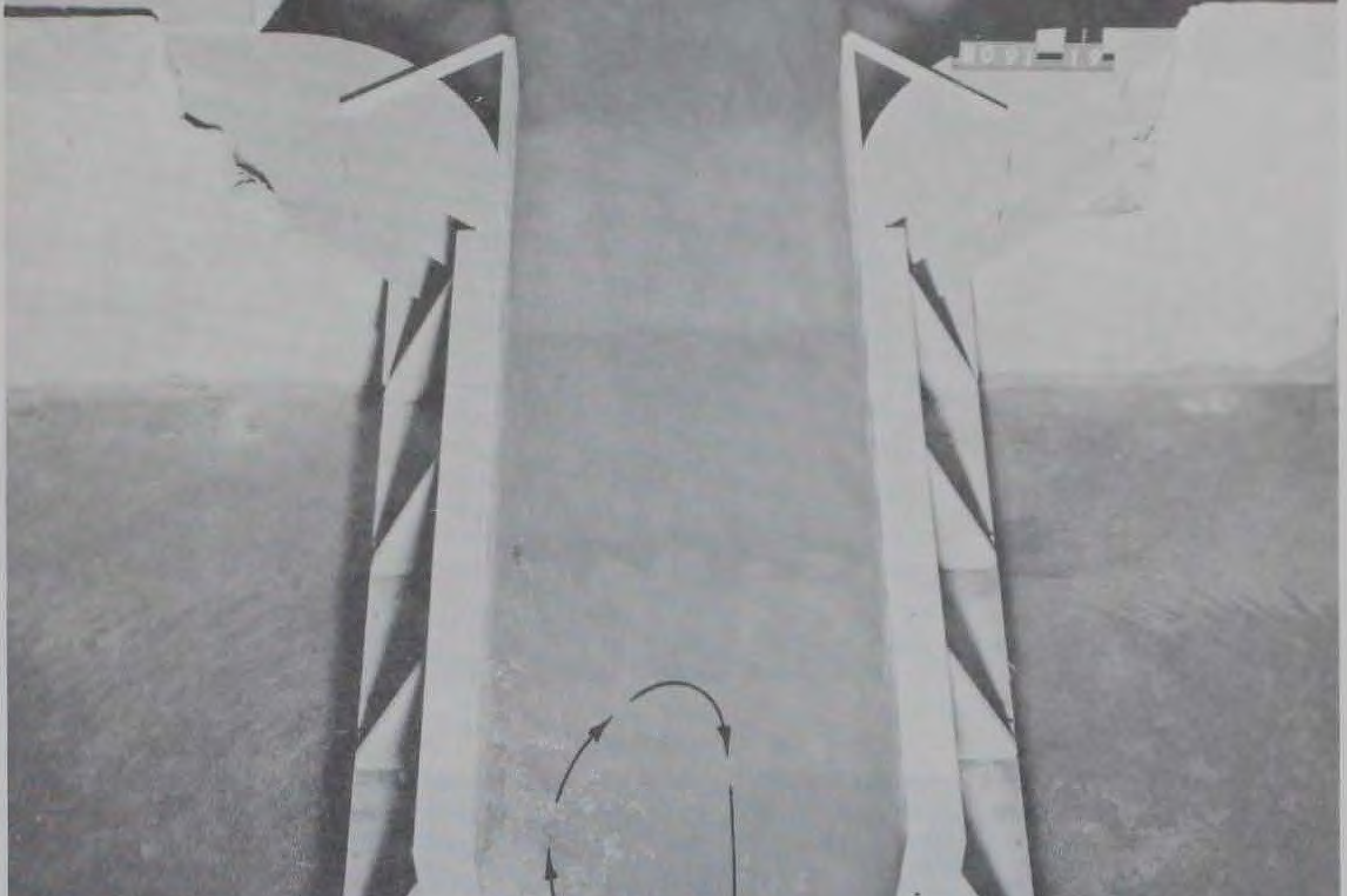
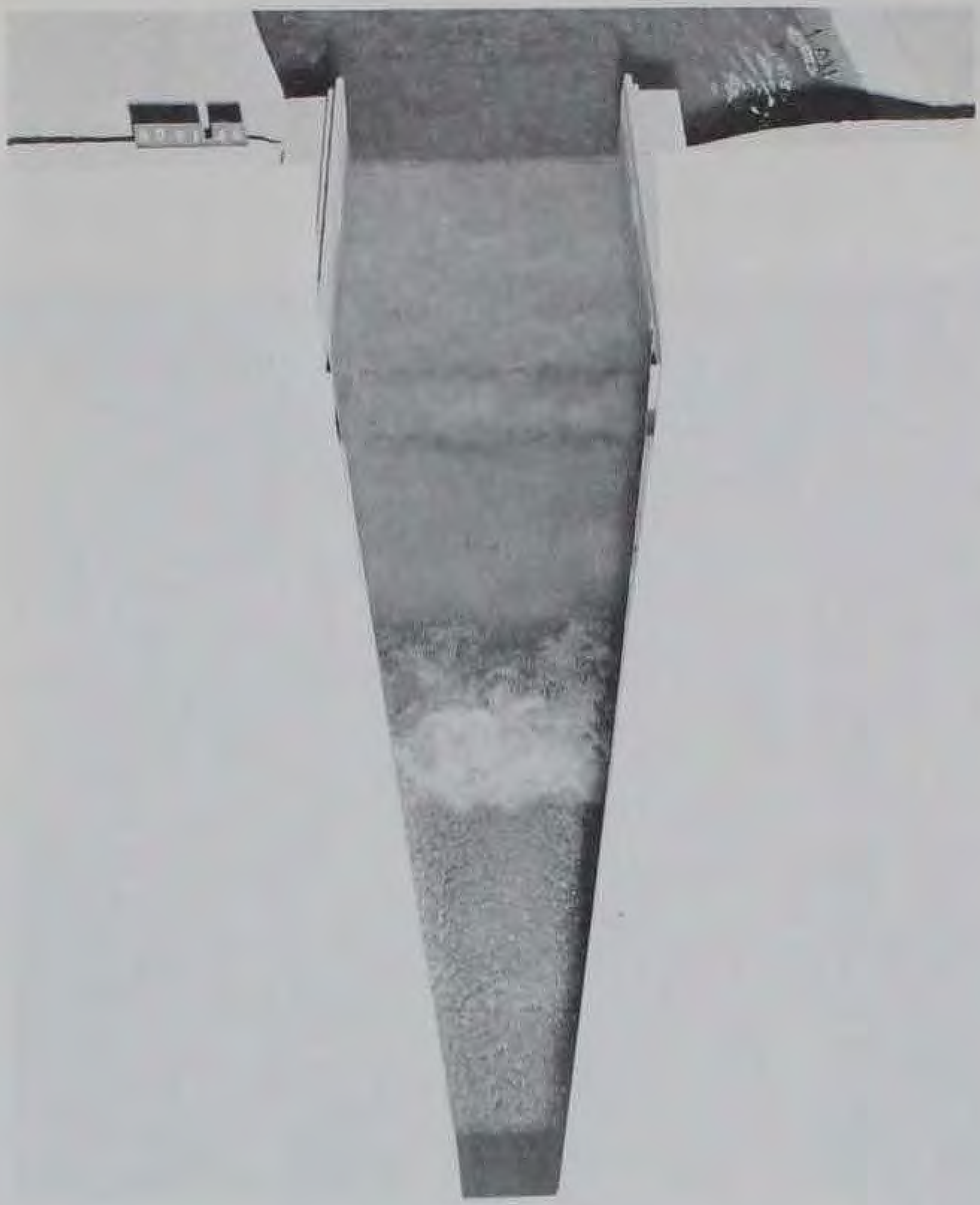
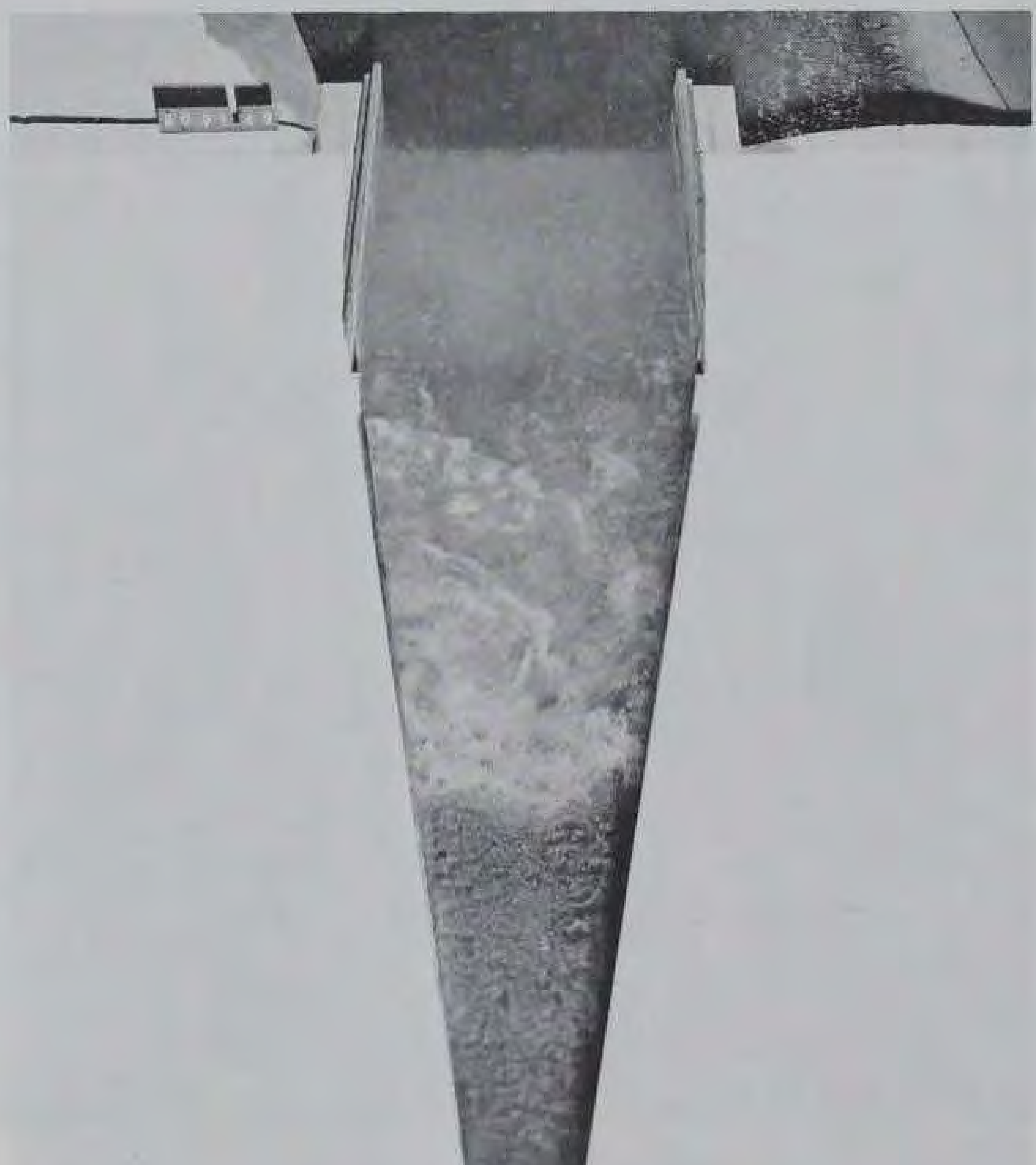


Photo 6. Elevated center line; one service gate operating, Q = 1000 cfs (mild eddy)

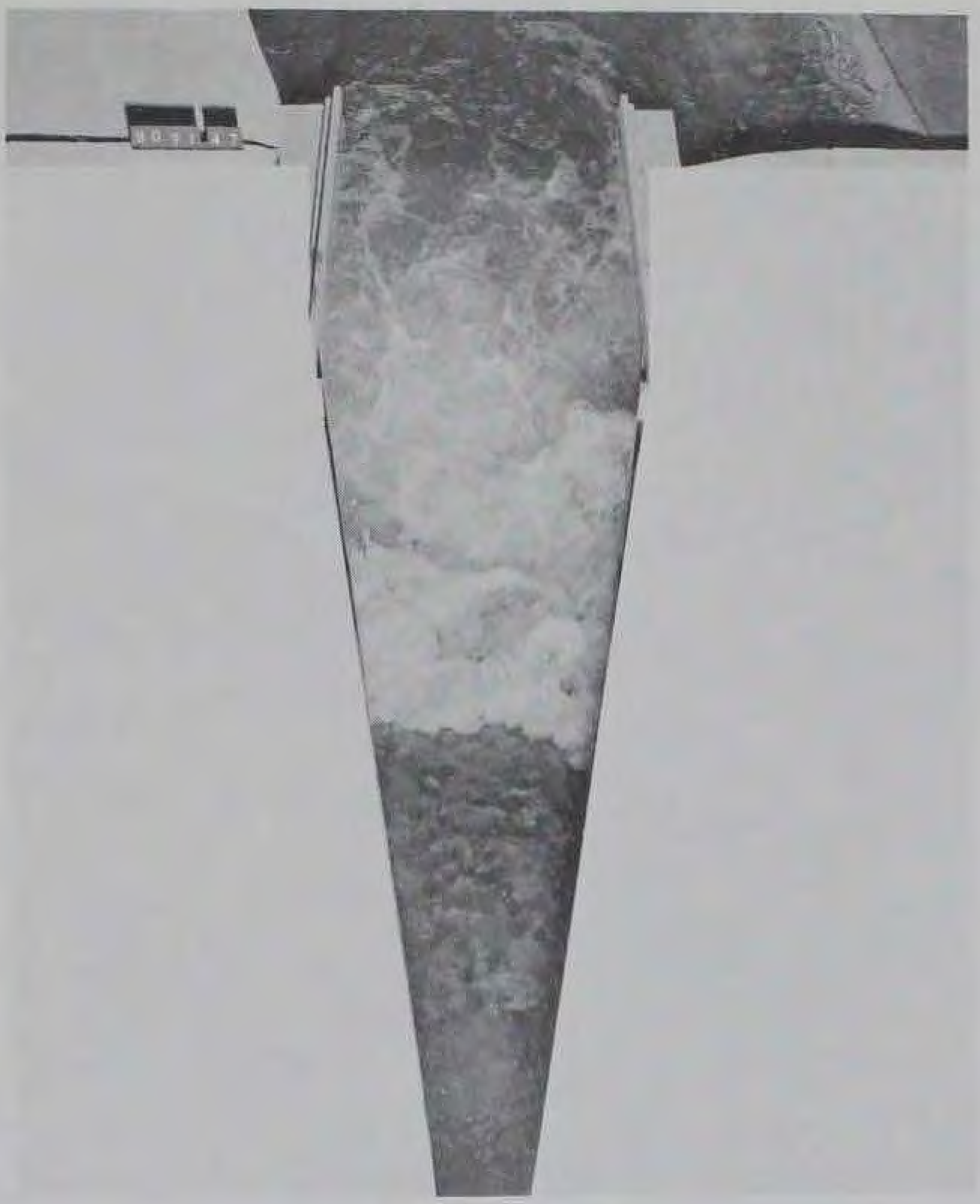


a. Q = 1000 cfs

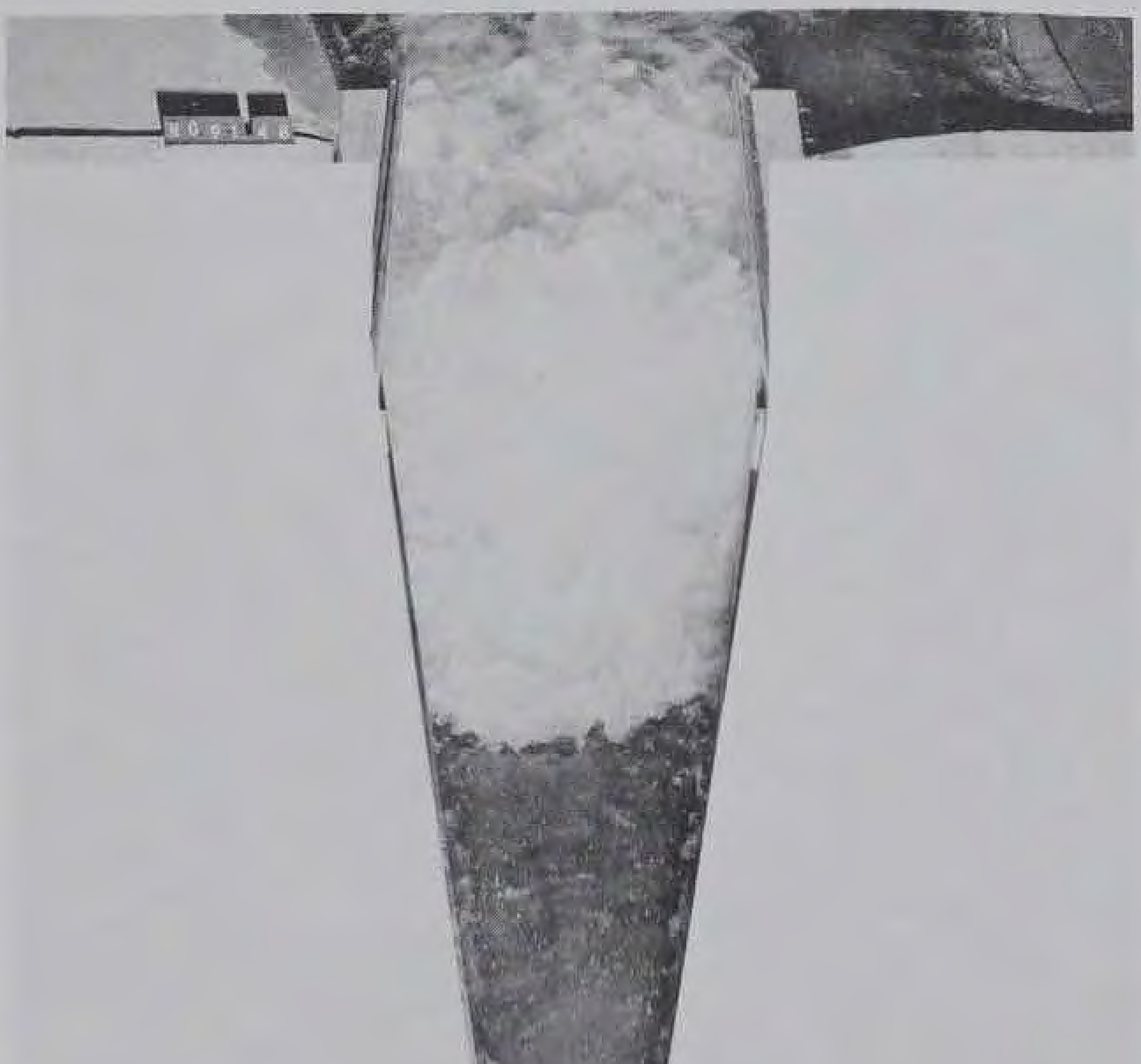


b. Q = 5000 cfs

Photo 7. Recommended design stilling basin (sheet 1 of 2)

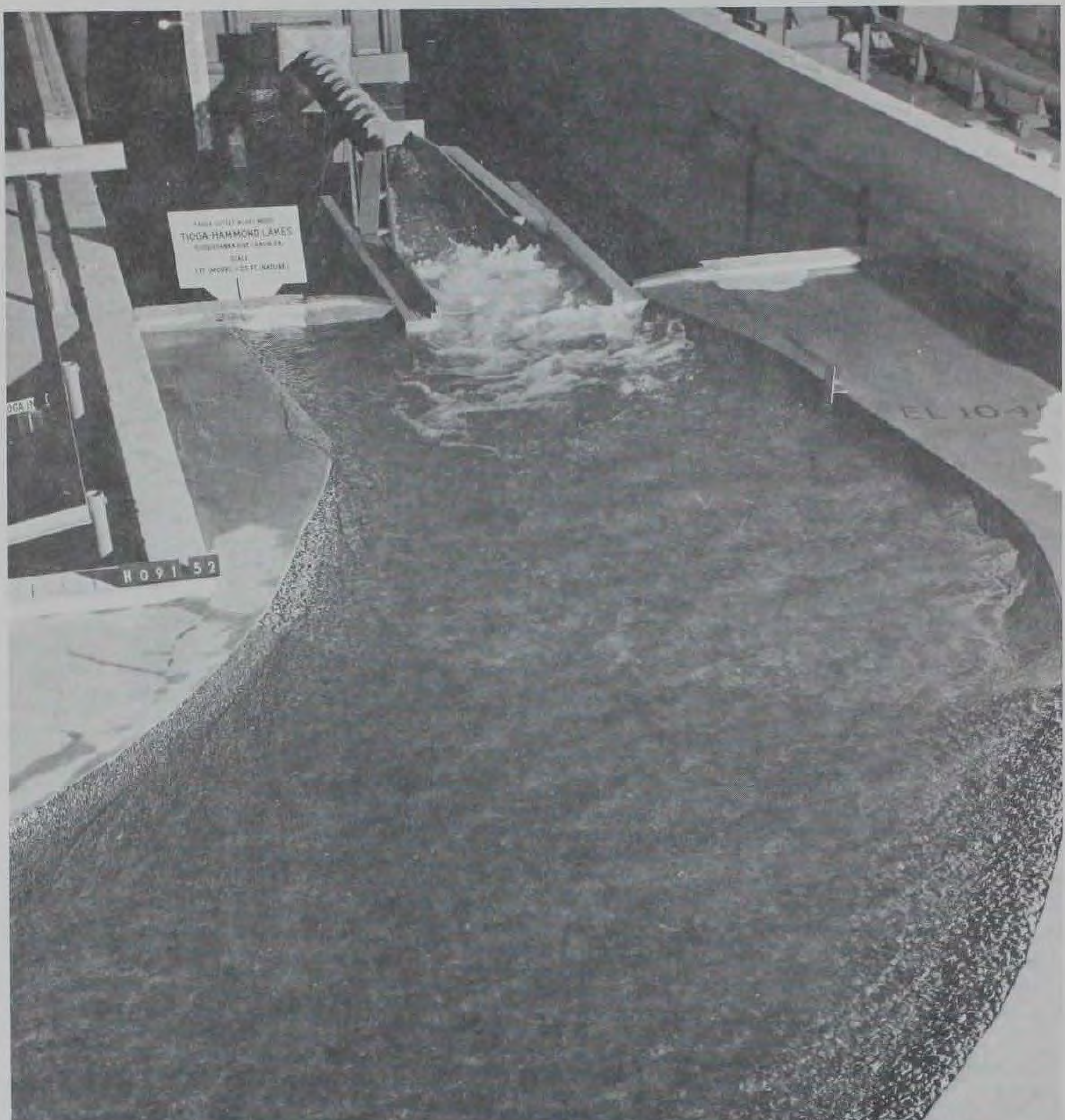


c. Q = 10,000 cfs



d. Q = 15,860 cfs

Photo 7. (sheet 2 of 2)

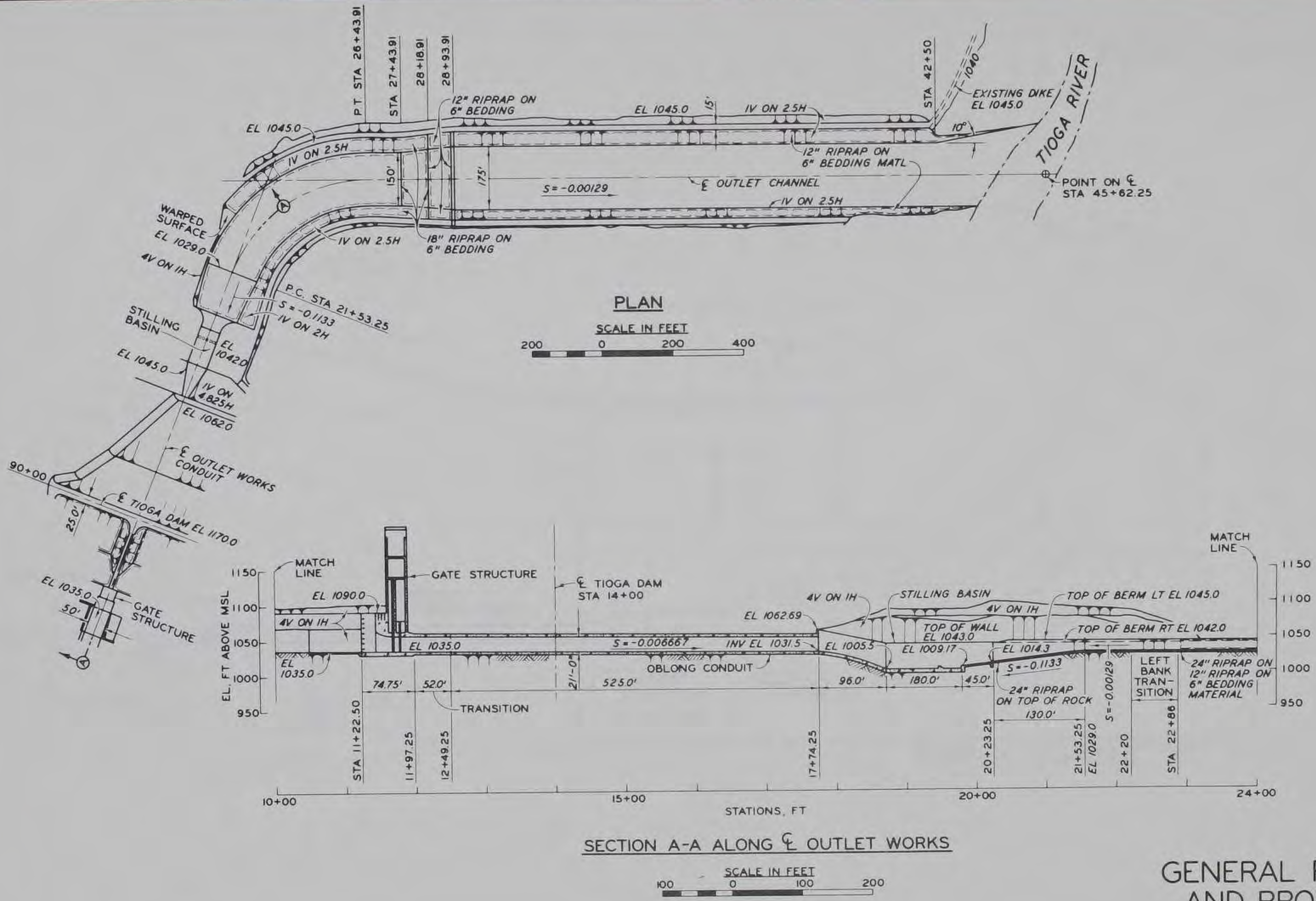


a. During flow

Photo 8. Damage to 12-in. riprap with flow of 15,860 cfs (sheet 1 of 2)

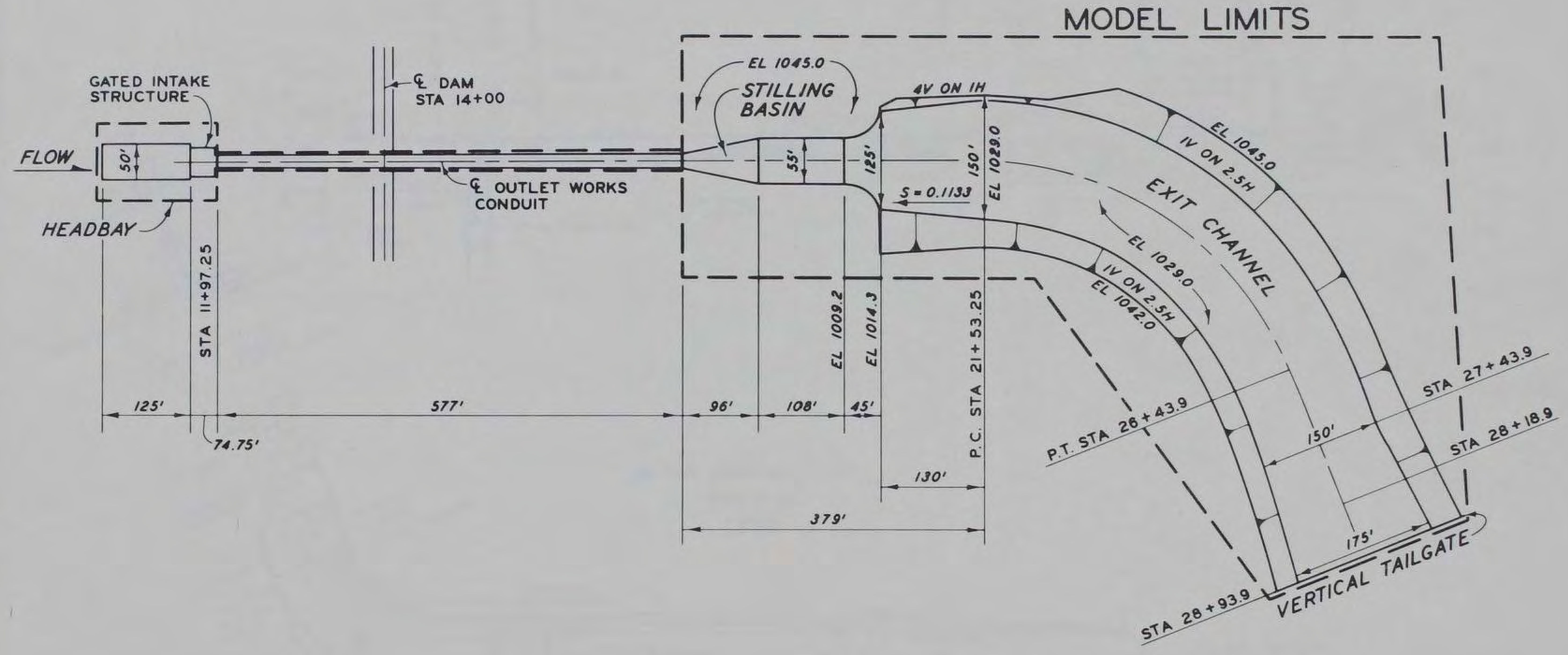
b. After 5 hr of operation (failure)

Photo 8. (sheet 2 of 2)

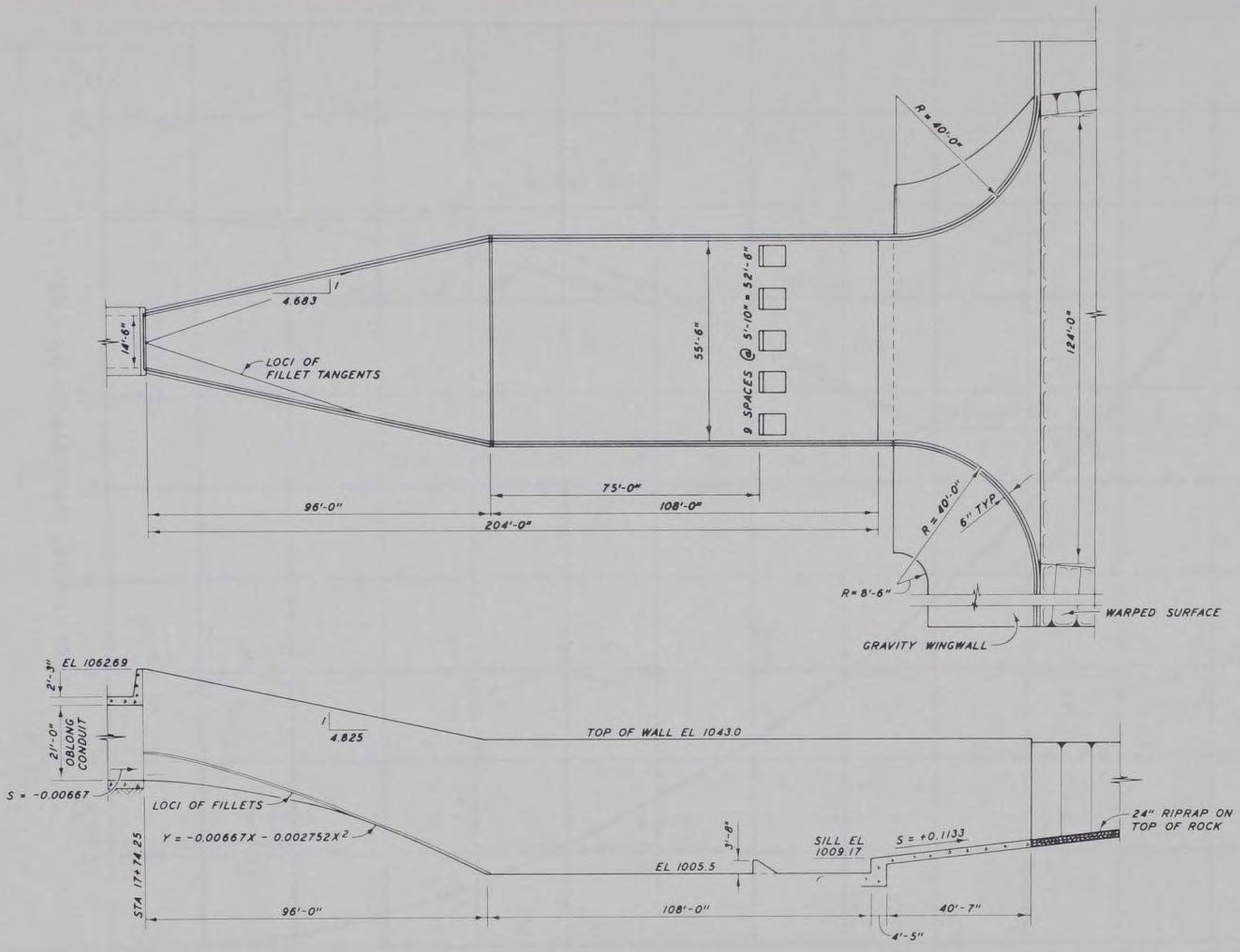


GENERAL PLAN AND PROFILE ORIGINAL DESIGN

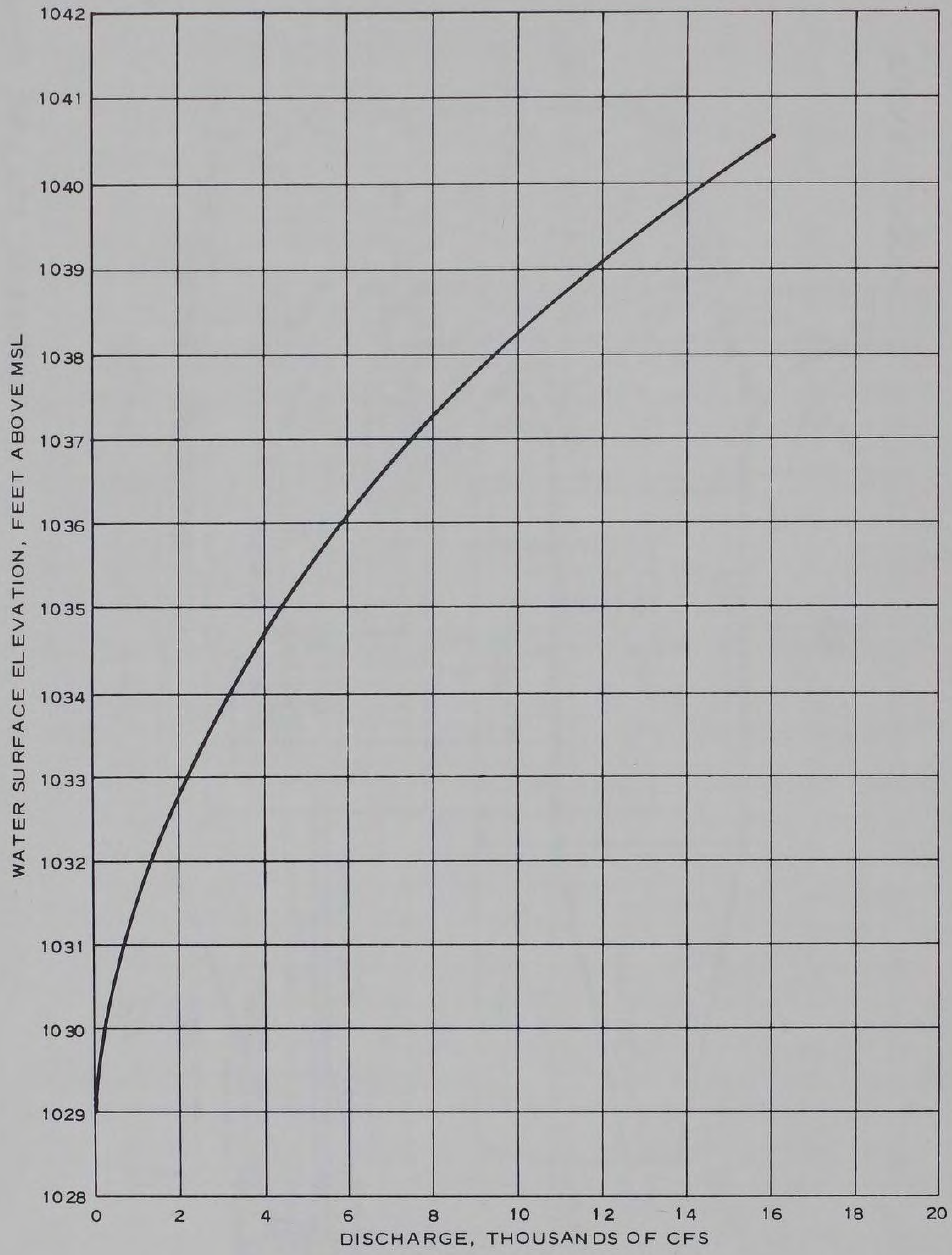
PLATE 1



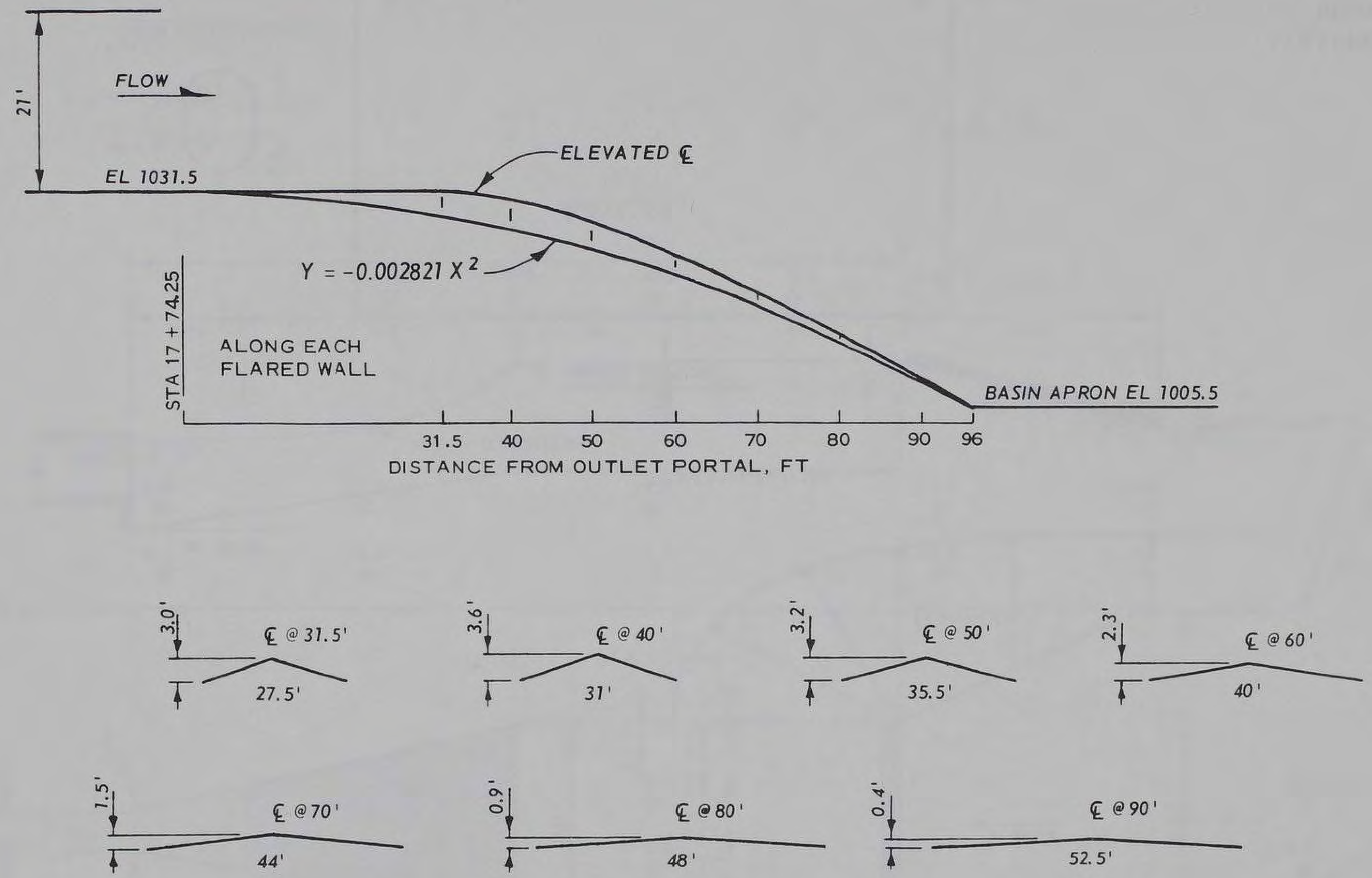
MODEL LAYOUT



ORIGINAL STILLING BASIN

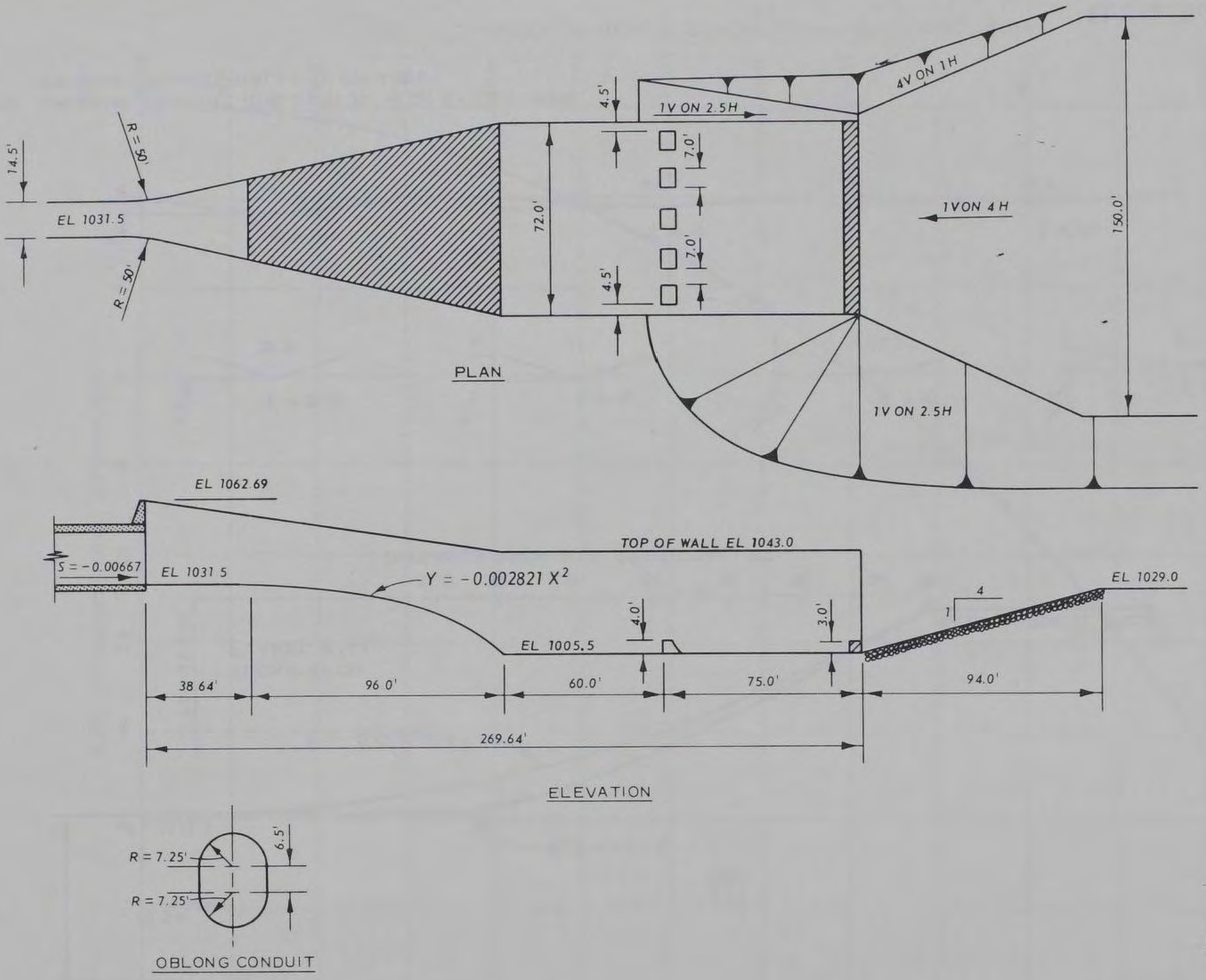


TAILWATER RATING CURVE

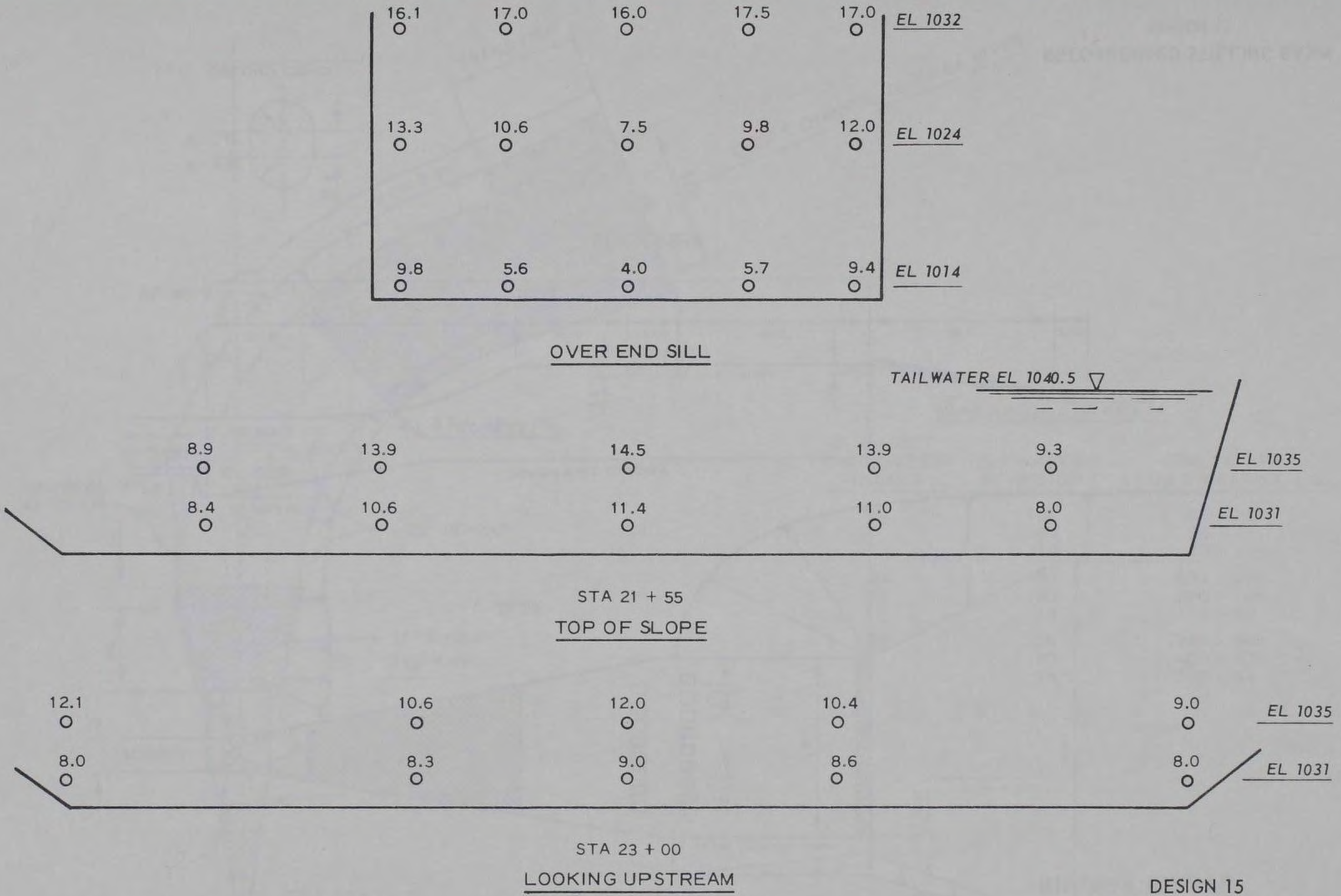


NOTE: ORIGINAL CONDUIT (OBLONG) 21' HIGH BY 14.5' WIDE
ORIGINAL FLARED WALLS 1V ON 4.683H

ELEVATED CENTER LINE

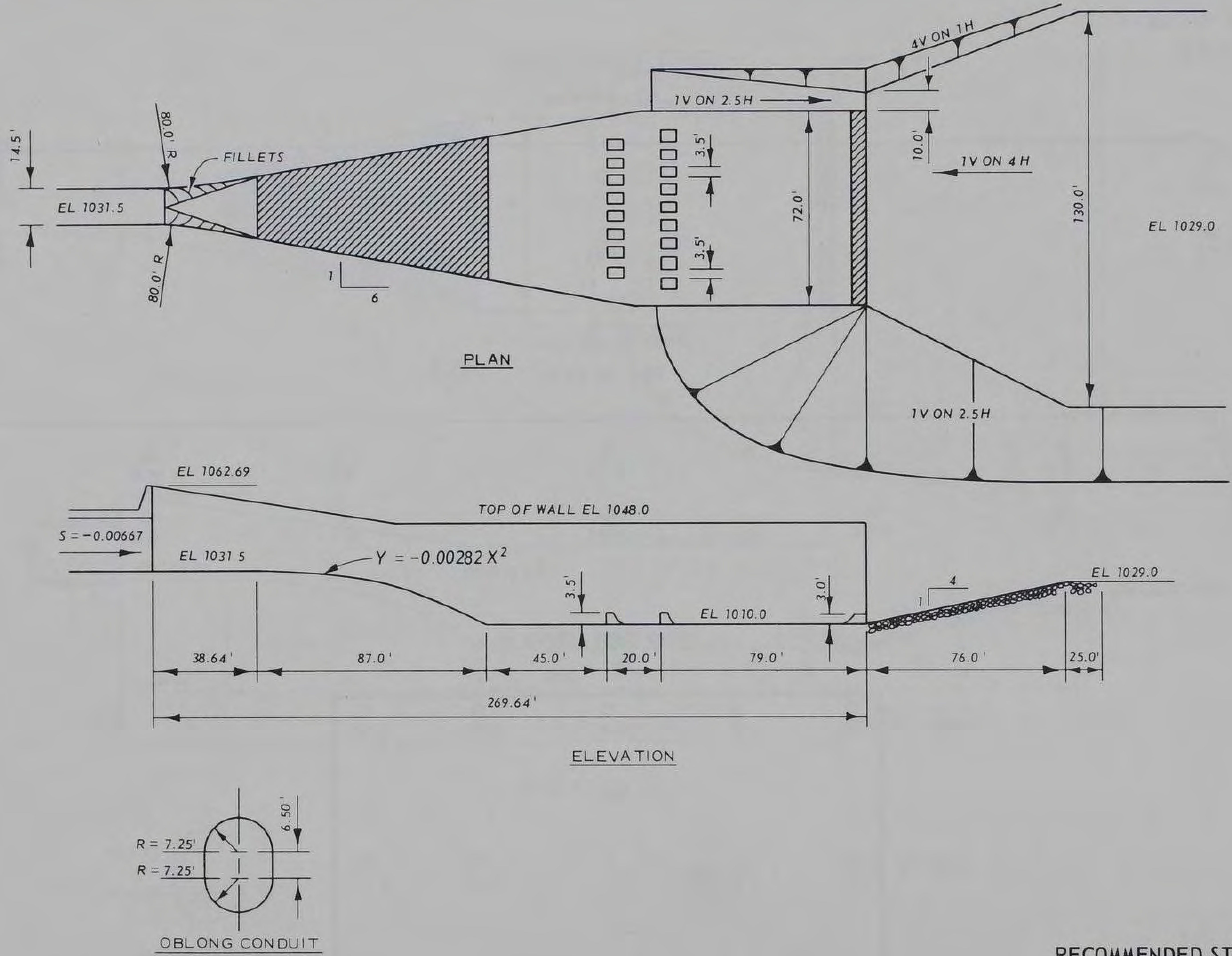


STILLING BASIN
DESIGN 11



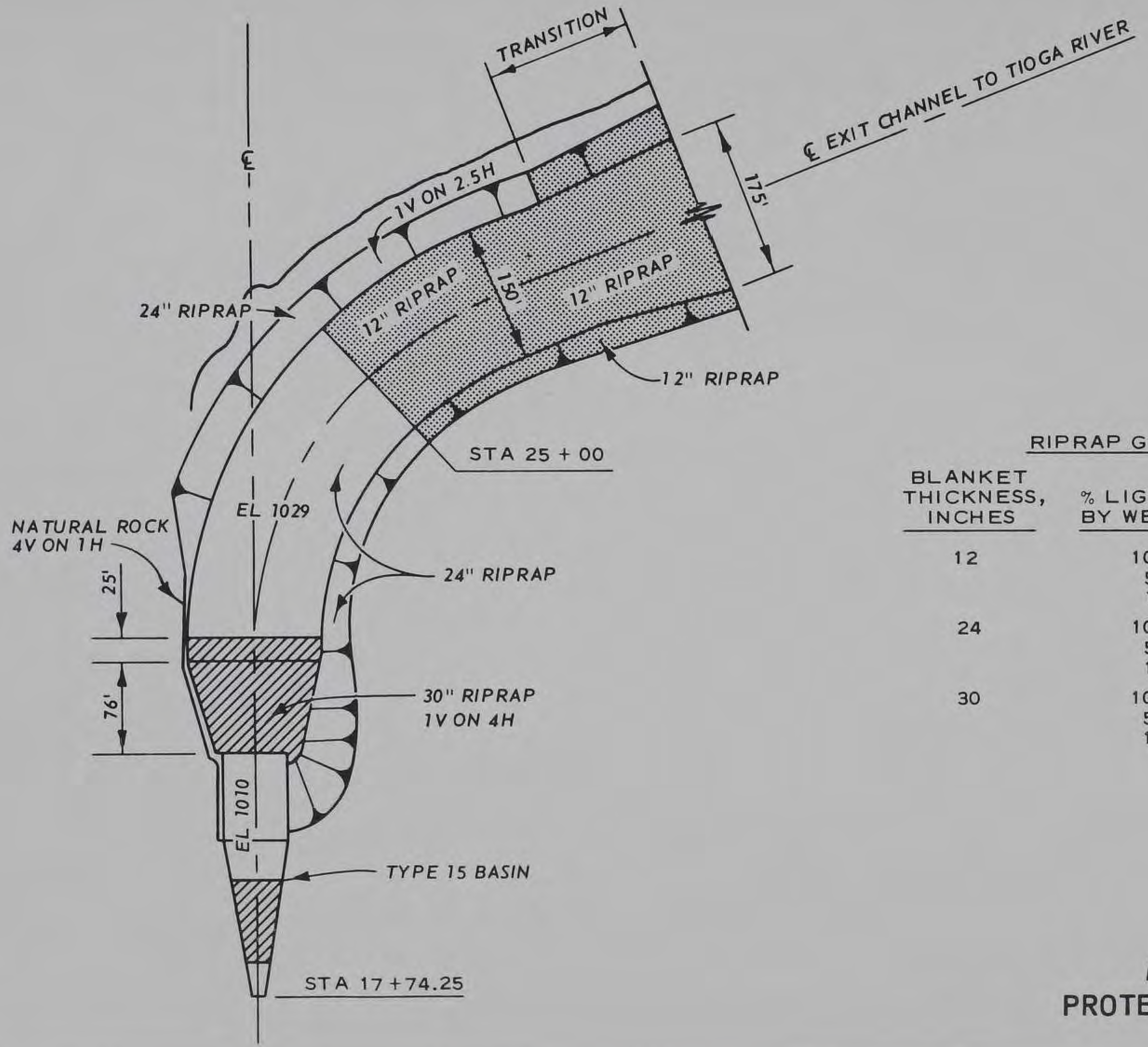
DESIGN 15
MAXIMUM VELOCITIES
Q = 15,860 CFS

PLATE 8



RECOMMENDED STILLING BASIN

DESIGN 15



RIPRAP GRADATIONS

BLANKET THICKNESS, INCHES	% LIGHTER BY WEIGHT	LIMITS OF STONE WEIGHT, LB
12	100	86 - 35
	50	26 - 17
	15	13 - 5
24	100	691 - 276
	50	205 - 138
	15	102 - 43
30	100	1350 - 540
	50	400 - 270
	15	200 - 84

MINIMUM RIPRAP PROTECTION REQUIREMENTS