TECHNICAL REPORT H-75-12

OUTLET WORKS FOR TAYLORSVILLE LAKE SALT RIVER, KENTUCKY

Hydraulic Model Investigation

by

Mark S. Dortch

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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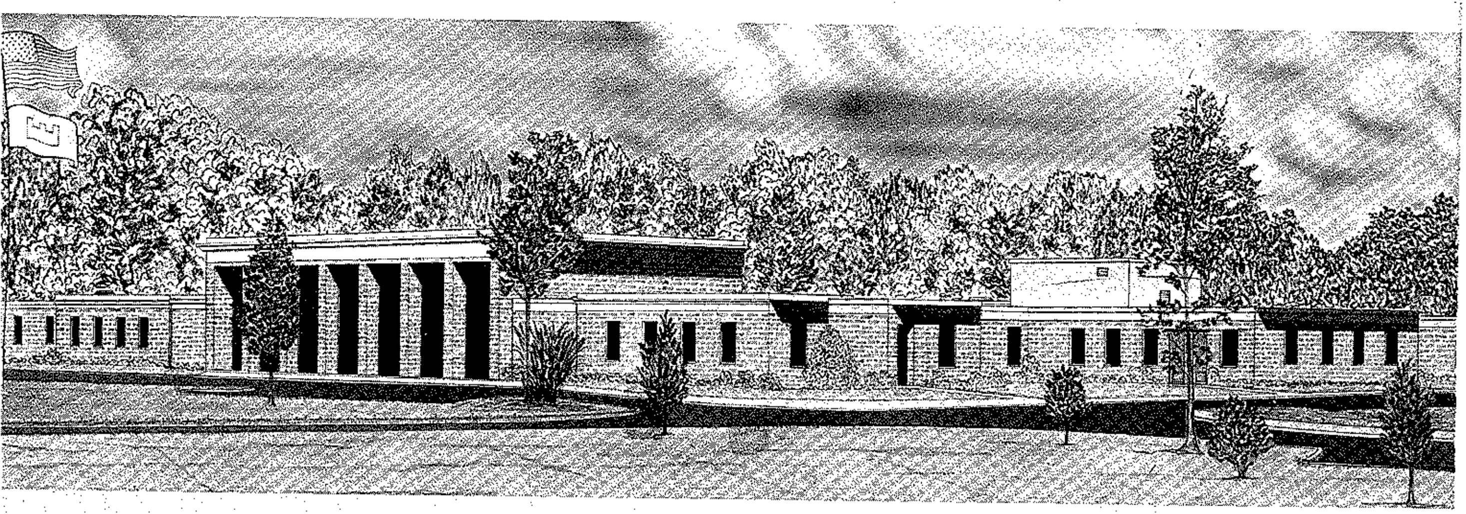
Final Report



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Model investigation of the outlet works for Taylorsville Lake was concerned with verification and improvement of the hydraulic design of the intake structure, conduit, and stilling basin. The study was conducted in a 1:25-scale model of the outlet works which reproduced a portion of the approach area, the intake structure, the outlet conduit, the hydraulic-jump type stilling basin, and approximately 120 ft of exit channel. The proposed intake structure provided effective regulation of both flood-control and

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20. ABSTRACT (Continued).

water-quality releases. Flow and pressure conditions were satisfactory for all expected operating schemes. However, certain extreme operational procedures must be avoided to prevent subatmospheric pressures in the throat section of the water-quality system and flow instabilities in the wet well during selective withdrawal and in the conduit during flood-control flow. Performance of the original design stilling basin was unacceptable as unstable hydraulic action in the basin resulted in poor energy dissipation. Eddy formation throughout the lower range of discharges was a difficult problem to overcome because of the relatively low elevation of the outlet portal invert with respect to the tailwater elevation. A humped trajectory with the central section raised higher than the sides (type 8 basin) diverted more flow to the sidewalls and eliminated eddying. The chute blocks and tapered training walls of the type 8 basin provided stable basin action with good energy dissipation. Single or uneven gate operation produced unbalanced flow in the stilling basin; however, the eddies were not as severe as in the original design. Since single gate operation is rarely necessary and should be avoided, the type 8 basin is considered to be acceptable for prototype construction.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers, U. S. Army, on 8 November 1973, at the request of the U. S. Army Engineer District, Louisville.

The studies were conducted in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) during the period January to October 1974 under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Structures Division, and under the direct supervision of Mr. J. P. Bohan, Chief of the Spillways and Channels Branch. The engineer in immediate charge of the model was Mr. M. S. Dortch, assisted by Mr. B. Perkins. This report was prepared by Mr. Dortch.

During the course of the model investigation, Messrs. D. L. Robey and G. R. Drummond of the U. S. Army Engineer Division, Ohio River, and Messrs. D. A. Beatty, J. J. Skinner, and L. Curry of the Louisville District visited WES to discuss results of the tests and to correlate these results with design studies.

Director of WES during the testing program 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	2.54	centimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
cubic feet per second	0.02831685	cubic metres per second

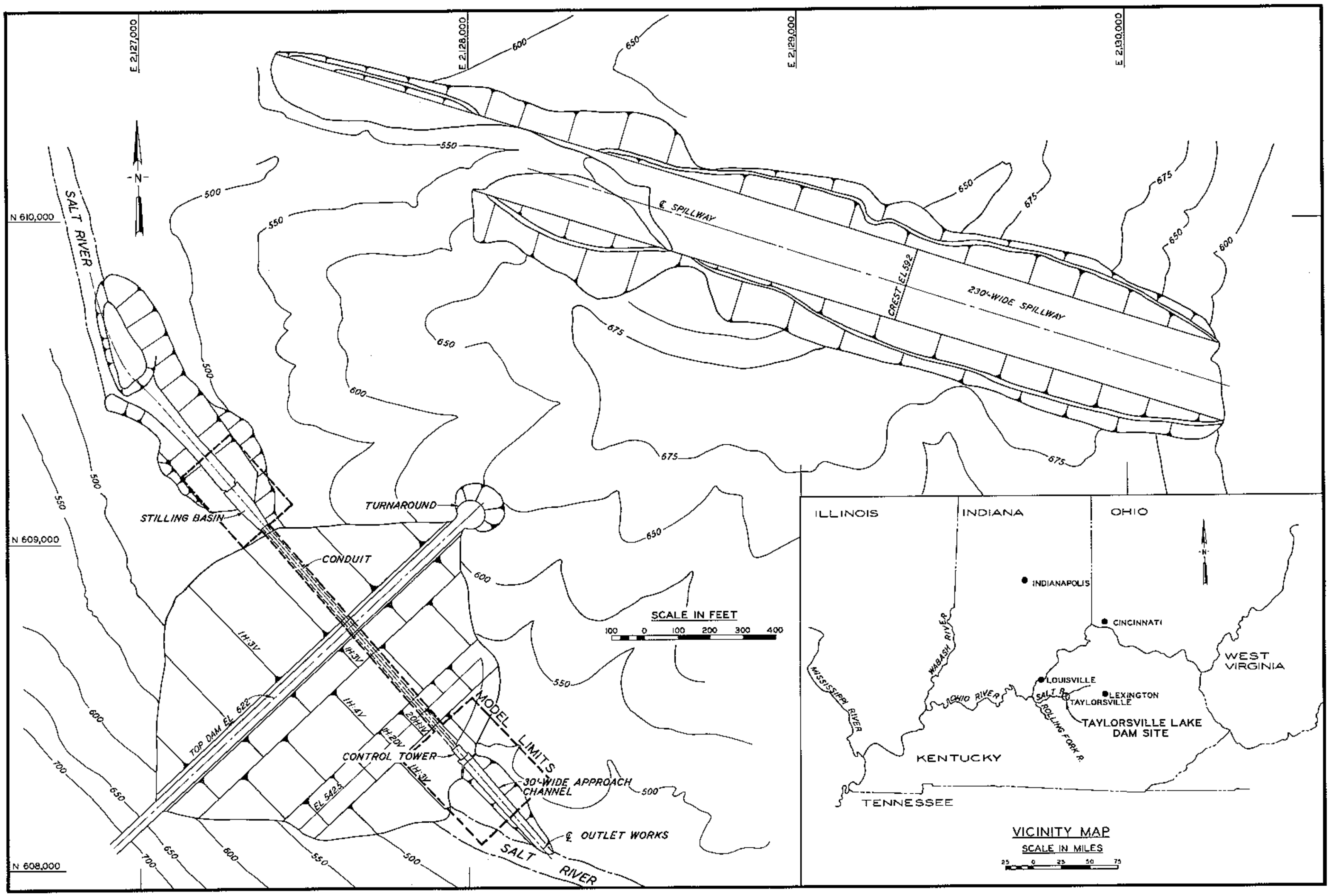

Figure 1. Location map

OUTLET WORKS FOR TAYLORSVILLE LAKE

SALT RIVER, KENTUCKY

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The proposed Taylorsville Lake will be located on the Salt River in north central Kentucky. The damsite is 50 miles* above the confluence with the Ohio River, about 4 miles upstream of Taylorsville, Kentucky, and approximately 26 air miles southeast of Louisville, Kentucky (Figure 1).

2. The plan for the project consists of a rock-filled dam, an open cut uncontrolled spillway in the right abutment, and a controlled outlet works through the right abutment. The top of the dam will be at el 622.0** with the spillway crest at el 592.0 (Figure 1).

3. Reservoir releases will be regulated by a gated intake tower, consisting of two flood-control intakes at the base of the structure (el 474.0) and two wet wells with five 6- by 6-ft water-quality intakes in each wet well at elevations ranging from 503.0 to 534.0. Both flood-control and water-quality flows pass through two separate 5.5- by 14.75-ft rectangular gate passages. The two gate passages transition into a single 11.5- by 14.75-ft oblong conduit. The last 20 ft of the oblong conduit contains a transition to a flat bottom conduit before discharging into an outlet transition and stilling basin. A profile depicting the general plan and original design of the outlet works is shown in Plate 1.

4. During selective withdrawal operation, the emergency gates will be closed and flow will be discharged through the multilevel intakes

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

** All elevations (el) cited herein are in feet referred to mean sea level.

into the wet wells and through an opening located in the roof of the gate passages between the emergency and service gates. The service gates will be used to regulate the selective withdrawal releases. The locations of the ten multilevel intakes (five intakes in each wet well) are shown in Plate 2. An 18-in.-diam pipe bypass around each service gate will be provided to regulate the release of low flows with the service gates closed.

Need for and Purpose of Model Analysis

5. During the design of a multilevel outlet works, many assumptions must be made because of a lack of adequate design guidance. For this reason, engineers at the U. S. Army Engineer District, Louisville, and the U. S. Army Engineer Waterways Experiment Station (WES) considered a model study necessary to determine the overall performance of the structure. The objectives of the model study included determination of the discharge characteristics of both flood-control and water-quality facilities, pressure and flow conditions throughout the structure, and performance of the stilling basin. During the course of the study, it was found that the model was also needed to develop a satisfactory stilling basin design.

PART II: THE MODEL

Description

6. The model (Figure 2) was constructed to an undistorted scale of 1:25 and reproduced a portion of the reservoir approach, the intake

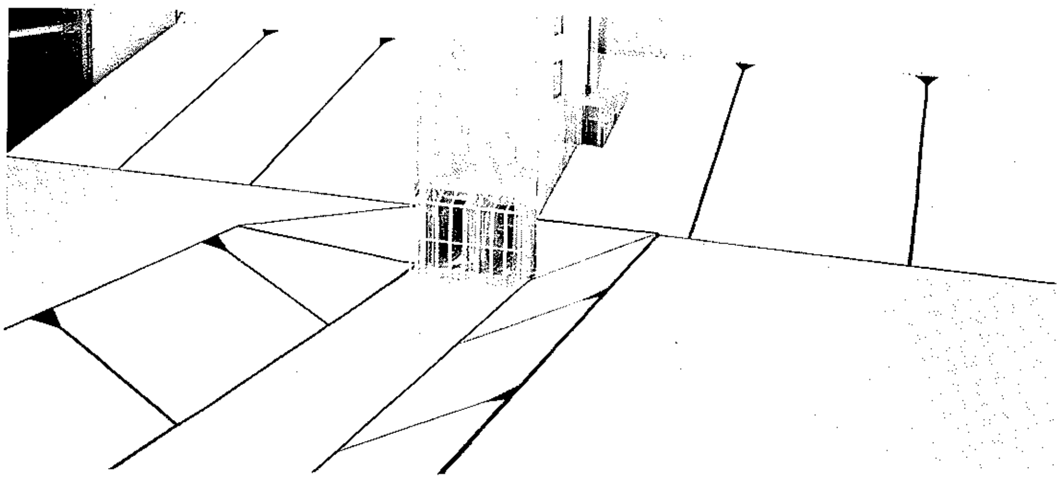


Figure 2. Reservoir area and intake

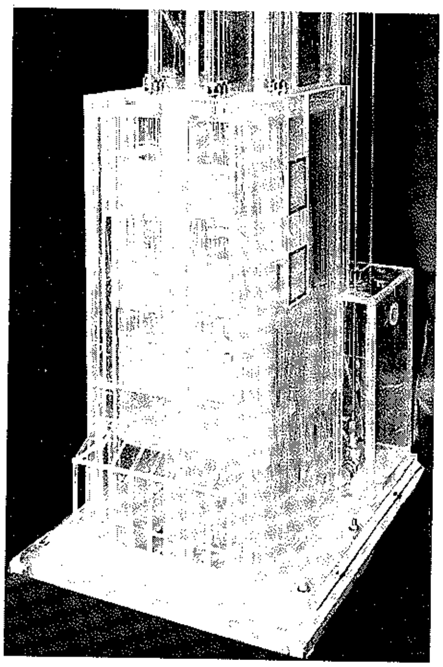


Figure 3. Original design intake structure

structure, the oblong conduit, the outlet transition and stilling basin, and a 120-ft reach of the exit channel. The intake structure and conduit were constructed of transparent plastic (Figure 3). The stilling basin trajectory was fabricated of sheet metal. The sidewalls, basin floor, and basin elements were made of wood, and the exit channel was molded in cement mortar (Figure 4).

7. Water used in the operation of the model was supplied by a recirculating system and discharges were measured by venturi meters. Water-surface elevations were obtained with point gages, and velocities

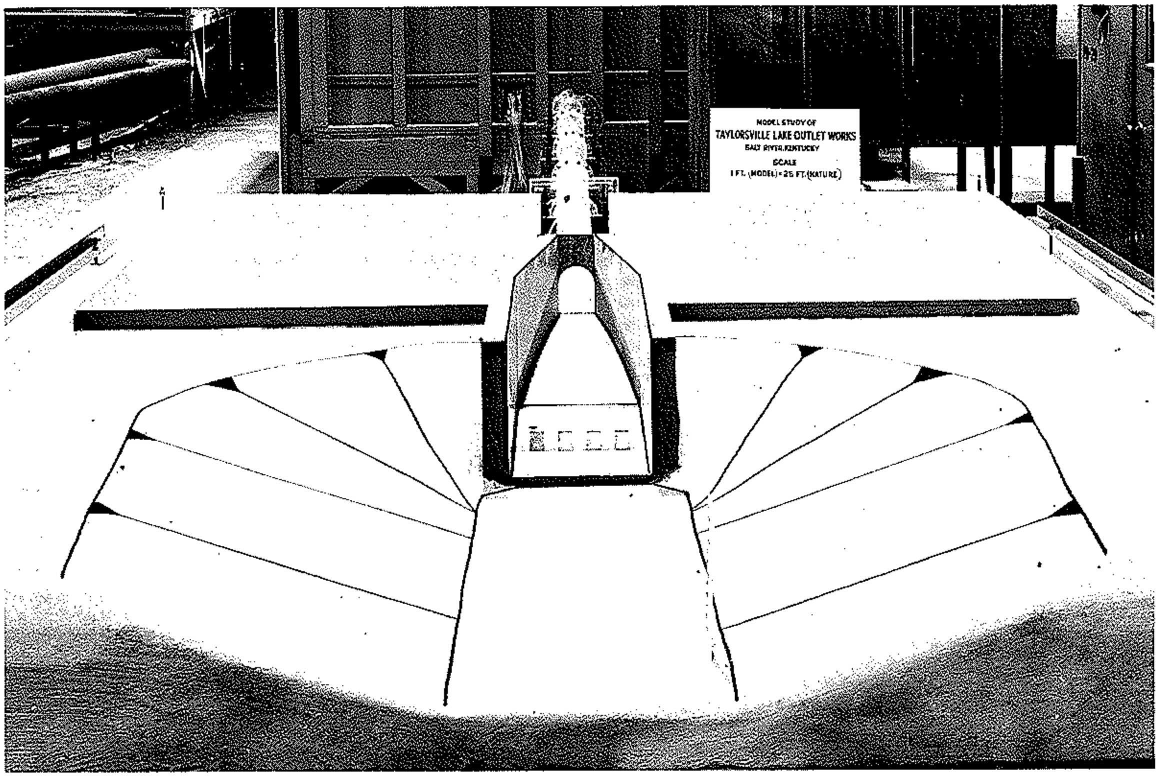


Figure 4. Conduit, stilling basin, and exit channel of original design

were measured with a pitot tube. Piezometers were installed throughout the intake structure and conduit to measure pressures.

Design Considerations

8. In the design of the model, geometric similitude was preserved between model and prototype by means of an undistorted scale ratio. The accepted equations of hydraulic similitude, based on the Froudian relations, were used to express the mathematical relation between the dimensional and hydraulic quantities of the model and the prototype.

9. A valid study of flow conditions in the outlet works required an accurate simulation of the prototype hydraulic grade line in the model. If water is the fluid in the prototype, it is not possible to satisfy the similitude requirements of both the Reynolds and Froude criteria by using water in the model. Since hydraulic similitude

between the model and prototype was based on Froudian relations, the Reynolds number of the design flow (8425 cfs) in the model (6.32×10^5) was lower than that of the prototype (7.9×10^7). This resulted in a larger resistance coefficient in the model ($f = 0.0127$) than that expected in the prototype ($f = 0.0078$). The excess losses in the model conduit were compensated for by constructing only a 19.5-ft (487.5-ft prototype) length of model conduit. This length is based on the relative loss of energy in the model and prototype conduits rather than the scaled length of 32.0 ft (800.0 ft prototype) based on geometry only.

Scale Relations

10. General relations for transfer of the model data to prototype equivalents are presented in the following tabulation:

Dimension	Ratio	Scale Relation
Length	L_r	1:25
Time	$T_r = L_r^{1/2}$	1:5
Velocity	$V_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3125
Pressure	$P_r = L_r$	1:25
Roughness (Manning's n)	$N_r = L_r^{1/6}$	1:1.71

11. Quantitative transfer of model data to prototype equivalents by the scale relations listed above was considered reliable except for pressures in the cavitation range in the prototype. Obviously, it is impossible for negative pressures in the prototype to be less than 1 atm (about -34 ft of water). However, in the model, negative pressures equivalent to prototype pressures less than 1 atm are possible. Thus, negative pressures less than 1 atm recorded in model results indicate zones of certain cavitation in the prototype.

PART III: TESTS AND RESULTS

12. Model tests involved the investigation of the overall performance of the outlet works, including discharge characteristics of both the flood-control and multilevel water-quality facilities, pressure and flow conditions through the structure, and performance of the stilling basin. Test results pertinent to each component of the structure are presented.

Multilevel Intake Structure

Description

13. Details of the multilevel intake structure as tested are shown in Plate 2. It is noted that the fillet radii transition begins at the upstream PC and ends at the downstream PI of the conduit transition. In the original design, the fillet radii transition joined the upstream PI of the conduit transition obliquely and resulted in an abrupt junction. Starting at the upstream PC a fillet radii transition was then developed to provide a tangential intersection with the upstream conduit. Engineers of WES and the Louisville District agreed that this modification to the original plan should provide a smoother flow transition, and so it was incorporated into the model design. Although the need for other structural changes was not indicated based on the tests, certain operational limitations will be required to prevent the occurrence of a flow instability observed in the conduit during flood-control releases. Operational limitations will also be imposed during selective withdrawal releases to prevent severe subatmospheric pressures in the opening provided between the wet well and the gate passage upstream of the service gate.

Discharge characteristics

14. Discharge characteristics of the flood-control facilities with both service gates at full and partial openings are presented in Plate 3. Normal tailwater conditions had no effect on the discharge ratings. The conduit flowed partially full for gate openings less than

75 percent open and flowed full for gate openings greater than 85 percent open. For gate settings between 75 and 85 percent open, an unstable flow was observed in the conduit as it alternated between full and partially full conduit flow. The instability appeared to be created by the periodic transfer of flow control from the conduit to the service gates. Service gate operation in the range indicated should be avoided to prevent such an instability. The average discharge coefficients, computed by the usual form of the orifice equation, are shown in Plate 3 for various partial gate openings.

15. Flood-control discharge ratings for one and both service gates fully open are compared in Plate 4. With a single service gate fully open, the flow remained pressurized to the end of the pier and then transitioned to partially full conduit flow. A capacity of 4300 cfs, indicated by the model with the seasonal pool (el 547.0) and a single gate fully open, compares favorably with the computed capacity of 4450 cfs. The conduit flowed full with pool levels above el 500.0 and both service gates fully open. With both gates fully open and a seasonal pool elevation of 547.0, the model indicated the capacity of the structure to be about 6900 cfs. This is approximately 17 percent greater than the computed capacity of 5900 cfs. The increased efficiency is attributed to the conservative losses used in the theoretical calculations. The equations presented in Plate 4 are empirical and were determined by the best fit of data using the method of least squares. Discharge coefficients for the usual form of the orifice equation are also shown in Plate 4.

16. The discharge ratings of a single partially open service gate with flow through five multilevel intakes in one wet well of the selective withdrawal facilities are presented in Plate 5. For the gate openings shown, flow control was always maintained by the service gate. The plot also describes the boundaries of submerged orifice flow control as governed by a single or double multilevel intake under a 3-ft submergence. The boundary curves were generated by the empirical equation that was determined from the best fit of the submerged orifice data (Plate 6) using the method of least squares. Operating the selective

withdrawal intakes under submerged flow conditions and maintaining flow control with the service gates will reduce turbulence and prevent flow instabilities. For a given pool elevation and service gate opening, there exists a corresponding discharge (Plate 5). If this discharge is less than the discharge that can be passed through a particular scheme of multilevel intakes operating at a 3-ft submergence for the same pool elevation (Plate 5), then control is maintained at the service gate and a submergence of at least 3 ft is provided for each intake that is open. The model indicated that the structure will pass the desired total selective withdrawal capacity of 1500 cfs (750 cfs through each side).

17. Discharge characteristics of a single 6- by 6-ft multilevel intake, acting as a free orifice, submerged orifice, and free weir, are furnished in Plate 6. Free orifice flow was assumed for conditions where the water level in the wet well was equal to or less than the elevation of the top of the multilevel opening. The head on the center of the inlet or orifice was used for determination of the free flow discharge coefficients. Submerged flow was assumed when the water level in the wet well was above the elevation of the top of the intake, and the head differential, ΔH, between the elevation of the pool and the water surface in the wet well was used for computation of the submerged flow discharge coefficients. When the pool elevation was between the top and invert of the intake, the head on the intake invert was used to compute the discharge coefficient for free weir flow. The equations presented in Plate 6 are empirical and were determined by the best fit of data using the method of least squares.

18. The discharge rating curve developed with the model for a single 18-in. low flow bypass is shown in Plate 7. On the average, the discharge capacity indicated by the model was about 15 percent less than the computed capacity. This is attributed to the disproportionally higher losses of the model bypass.

Entrance head loss

19. Entrance loss coefficients applicable to the flood-control facilities of the intake structure were computed from the calibration data by dividing the head loss through the intake structure by the velocity

head within the conduit. The head loss is defined as the difference between the elevations of the upper pool and the energy gradient at the beginning of the conduit. The elevation of the energy gradient was determined by adding the velocity head to the hydraulic gradient measured between piezometers 159 and 165 (area of uniform flow) and extending the gradient upstream to the beginning of the conduit (sta 15+70). Values of the entrance loss coefficient, K_e , obtained are tabulated below.

Discharge, cfs	Intake Structure Loss, H_L , ft	Conduit Velocity Head, $V^2/2g$, ft	$K_e = \frac{H_L}{V^2/2g}$
2000	0.636	3.11	0.205
3000	2.230	7.01	0.318
4000	5.370	12.45	0.431
5000	6.490	19.46	0.334
6000	10.750	28.02	0.384
7000	13.860	38.14	0.363
8000	17.300	49.81	0.347
		Average	0.340

The average entrance loss coefficient of 0.340 is the total accumulation of losses attributed to the trash rack, intake contraction, gate slots, transition contraction, and friction or hydraulic resistance through the intake structure.

Pressures

20. Piezometer locations throughout the structure are shown in Plates 8 and 9. With full conduit flow through the flood-control facilities, all pressures were positive except in the conduit near the outlet portal where the hydraulic grade line was below the roof of the conduit (Table 1). This condition does not pose any cavitation problems. Pressures observed through the flood-control facilities with a single service gate fully open and both service gates opened symmetrically (15 to 75 percent openings) were satisfactory, as shown in Tables 2-4.

21. Pressures observed throughout the water-quality facilities

with a single service gate opening of 25 percent are presented in Table 5. It was also noted that pressures were acceptable for service gate openings not exceeding 55 percent open. For gate openings exceeding 55 percent, however, severe negative pressures were recorded in the throat section upstream of the service gate (piezometer 33, Plate 10). The service gates should not be opened greater than 55 percent during selective withdrawal operations of the water-quality facilities in order to prevent cavitation damage of the opening provided in the crown of the flood-control conduit.

Stilling Basin

Type 1 (original) basin

22. The outlet transition and stilling basin, as originally designed, consisted of a 64-ft-long parabolic trajectory beginning 2 ft downstream of the conduit exit portal that dropped to a horizontal apron 75.5 ft long and 34.9 ft wide. The horizontal apron contained a single row of 3.75- by 3.75-ft baffle piers, a vertical-faced end sill, and parallel basin sidewalls (Plate 11). The sidewalls of the outlet transition were flared linearly in width from 11.5 to 34.9 ft in a length of 64 ft. The invert elevations of the conduit exit portal and the stilling basin apron were located at el 472.3 and 460.3, respectively.

23. Tests with the original design stilling basin indicated need for improvement. Adverse surging and pulsating of the hydraulic jump was experienced for the high discharges, as shown by Photos 1a and 1b. With single gate operation, flow separated from one sidewall and created an eddy in the basin (Photo 1c). Adverse surging and eddy action can cause considerable abrasive damage to the stilling basin. Satisfactory performance was observed with the dual gate operation for release of the lower discharges with normal tailwater conditions (Plate 12), as displayed by Photo 1d. However, further tests indicated the need for a stronger hydraulic jump to suppress eddy tendencies during slightly excessive tailwater conditions.

Types 2 and 3 basins

24. The types 2 and 3 stilling basins (Figures 5 and 6, Plate 13)

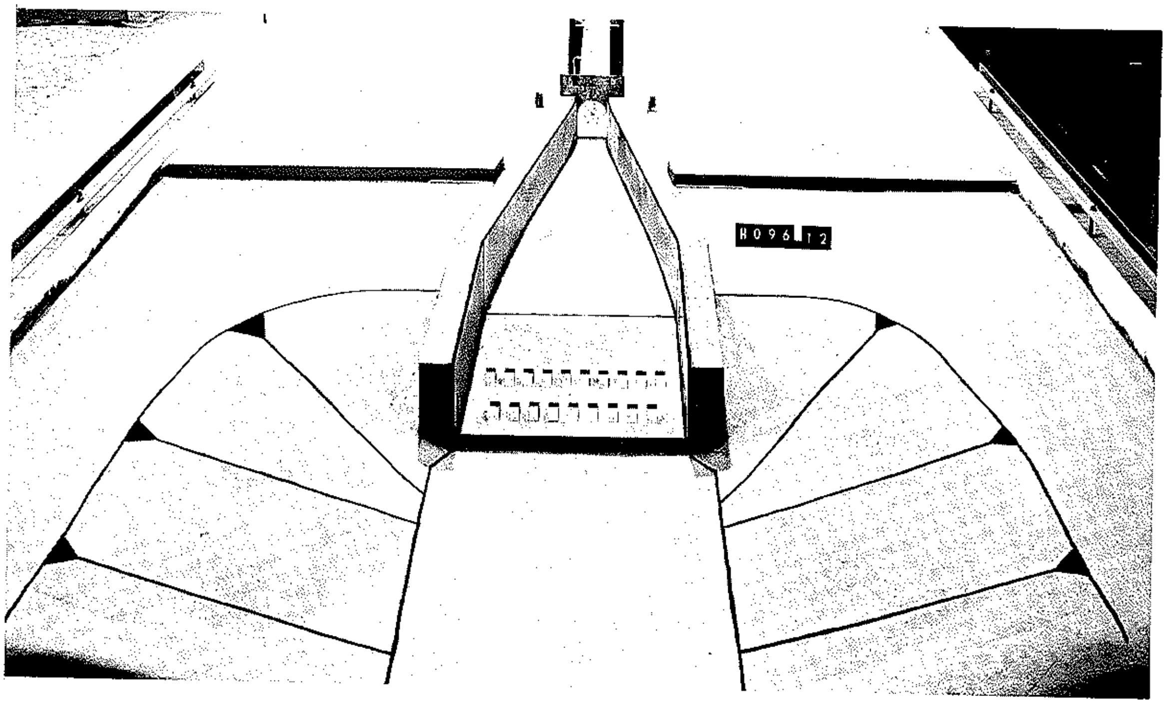


Figure 5. Type 2 stilling basin

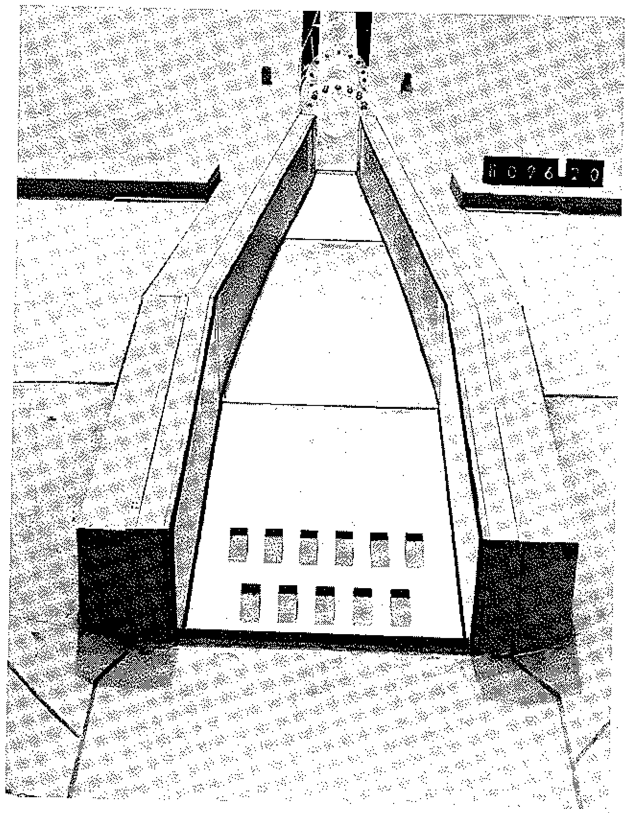


Figure 6. Type 3 stilling basin

consisted of a longer trajectory, which remained horizontal from the outlet portal to the beginning of the parabolic drop. The purpose of the horizontal portion was to spread the flow more uniformly across the parabolic trajectory. The basins were widened and the apron elevations were raised to produce a more stable jump. Two rows of baffle piers were added to help maintain the jump and dissipate the energy.

25. The type 2 stilling basin performed very well for the larger range of discharges (Photo 2a). The improvement was attributed to the wider and shallower basin. However, severe eddying resulted from an oblique standing wave formed by a weak hydraulic jump during low flow operations (Photo 2b).

26. The type 3 stilling basin was made narrower and deeper than the type 2 design in an attempt to improve the low flow performance. This basin also provided satisfactory performance for the larger flows (Photo 3a). For the lower range of flows, eddying was less severe than that observed with the type 2 basin, but the performance was still unacceptable (Photo 3b).

Types 4 and 5 basins

27. A continuous sidewall flare of 1 on 8 was tested with the type 4 basin (Plate 14). The mild taper of the sidewall was unsuccessful in eliminating the eddies present during low flows and caused poor performance with the larger discharges.

28. The type 5 basin (Plate 14) indicated that a sidewall flare of twice the design Froude number at the conduit exit portal (same as the original design flare) with the toe of the trajectory terminated within the sidewall flared section greatly improved the performance for all flow conditions. However, the eddy still occurred with low discharges and appeared to be aggravated by the creation of a stagnant flow area in the basin where the flared walls intersected the parallel walls.

Types 6 and 7 basins

29. Based on the results of the type 5 basin, the decision was made to design the type 6 basin with two different flares of the sidewalls to satisfy both high and low flow conditions (Plate 15). Chute blocks were added to stabilize the hydraulic jump. This basin provided

excellent performance with the larger discharges. Eddying was greatly reduced during the lower flows but was not entirely eliminated. Various arrangements of chute blocks were tested in an unsuccessful attempt to create uniform distribution of flow across the toe of the trajectory in order to prevent the oblique hydraulic jump from forming with low flow conditions.

30. The type 7 basin (Plate 15) provided a humped trajectory in an attempt to force the flow to distribute evenly before entering the basin. A better distribution of flow was achieved, but this did not remedy the eddy problem and the weak hydraulic jump formed at the intersection of the sidewalls.

Type 8 basin

31. The specific energies in the vicinity of the intersection of the flared sidewalls were considerably less than those throughout the outlet transitions provided with the types 1-7 stilling basins. For the lower range of flows, this condition created an oblique hydraulic jump which resulted in an eddy in the stilling basin. The type 8 basin was provided with a trajectory whose central 11.5-ft portion (conduit width) was raised through its entire length (Plate 16). The purpose of the raised central portion of the trajectory was to increase the depth and specific energy of flow along the sidewalls. This provided a more even distribution of specific energy across the trajectory at the toe of the jump. The chute blocks and flared stilling basin walls between the toe of the trajectory and the end sill were effective in stabilizing the hydraulic jump during the larger discharges.

32. The outlet transition sidewall flare of 1 on 5.5 for the type 8 basin was based on twice the Froude number at the outlet portal for the design discharge of 8425 cfs. The basin width of 35 ft at the toe of the trajectory was maintained from the original design because this width provided satisfactory results with the original design basin during the low flow releases. The basin width of 44.6 ft at the end sill was obtained from the equation, $W = 0.3Q/H^{3/2}$, where W was the width of basin, Q was the design discharge (8425 cfs), and H was the height of the outlet portal (14.75 ft). This equation was obtained from WES

report MP H-72-5,* where H , for an oblong conduit, was substituted for D_o , the diameter of a circular conduit. The length of the type 8 stilling basin, 72 ft, was approximately equal to $2.5d_2$, where d_2 was the sequent depth for a discharge of 8425 cfs. The apron elevation was located $0.85d_2$ below the tailwater elevation (487.4) for the design discharge. The height of the chute blocks, baffle piers, and end sill was 3.75 ft, which is greater than d_1 , the depth of flow before the hydraulic jump for design discharge, and approximately equal to $1/8\ d_2$. The first row of baffle piers was located about $0.75d_2$ downstream from the toe of the trajectory. The second row of baffle piers was placed about $0.5d_2$ downstream from the first row.

33. For equal service gate openings, the type 8 basin (Figure 7

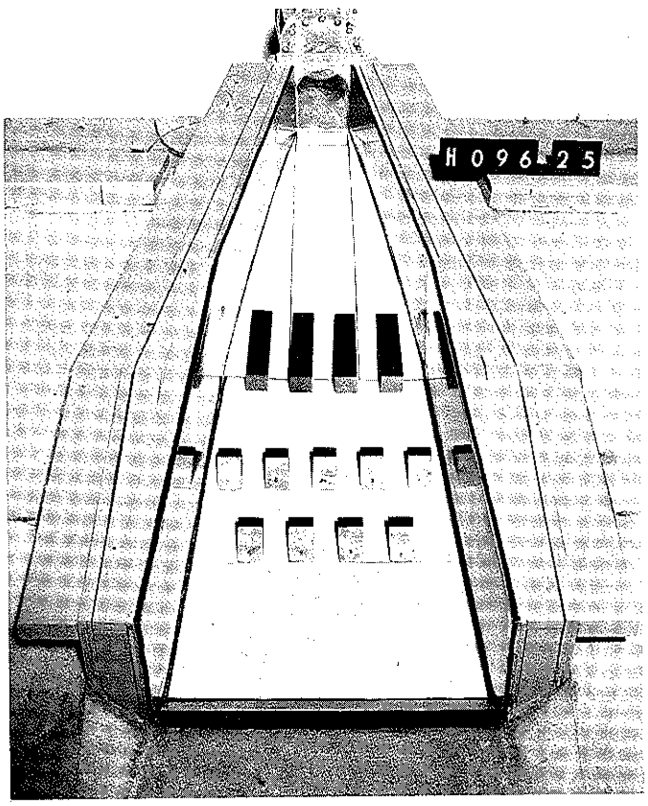


Figure 7. Type 8 stilling basin

* B. P. Fletcher and J. L. Grace, Jr., "Practical Guidance for Estimating and Controlling Erosion at Culvert Outlets," Miscellaneous Paper H-72-5, May 1972, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

and Plate 16) provided sufficient energy dissipation without adverse surging and wave action for the larger discharges (Photo 4a) and adequate flow distribution to prevent eddying during low flow conditions (Photos 4b, c, and d). Eddying was only observed for single service gate openings exceeding 10 percent (Photo 5a) or unequal service gate openings that differ by more than 10 percent. However, the eddying was not as severe as in the type 1 (original) basin and was undetectable, as shown by Photo 5b, for single or unequal service gate settings of 10 percent or less.

PART IV: DISCUSSION OF RESULTS

34. The results of the model investigation of the Taylorsville Lake Outlet Works confirmed the adequacy of certain elements of the structure as designed and the need for modification of other elements. During the design of the model, a revision of the fillet radii transition between the gate chamber and conduit was adopted to provide a less abrupt change in the boundaries of flow. With the exception of this modification, no changes to the intake structure were suggested. The performance of the flood-control and water-quality facilities was acceptable; however, certain operational limitations were suggested to reduce the possibility of cavitation damage and vibration problems caused by flow instabilities.

35. Model tests indicated that flood flows could be passed through the structure without danger of cavitation. The discharge capacity of the outlet works (pool el 592.0) was observed to be about 19 percent greater than the computed capacity. This capacity increase is attributed to entrance losses of the structure and friction losses of the conduit being lower than the values used in theoretical calculations. For both service gates at equal partial openings less than 75 percent and greater than 85 percent, the conduit flowed partially full and full, respectively. Between 75 and 85 percent open, the flow in the conduit alternated between full and partially full. The instability appeared to be caused by a cyclic shift in flow control from the conduit to the service gates. During flood-control operations with both service gates partially open, gate settings exceeding 75 percent should be avoided to prevent this instability which could result in a vibration problem.

36. The model study indicated that the required total selective withdrawal capacity of 1500 cfs (750 cfs through each wet well) can be passed at seasonal pool (el 547.0) without danger of cavitation or any flow instabilities by adhering to the following guidance. Control should always be maintained by the service gate or low flow bypass, with submerged flow through the multilevel intakes, to assure positive operating conditions. The rating curves in Plate 5 and the guidance provided in

paragraph 16 can be used to insure that these conditions are met. Service gate settings should not exceed 55 percent open when using the selective withdrawal facilities. For openings larger than 55 percent, subatmospheric pressures were observed in the throat section connecting the wet well to the gate passage, as shown in Plate 10. If blending between the flood-control intake level and any of the higher multilevel intakes is desired, a wet well and flood-control intake on opposite sides of the intake structure should be used. This is necessary because the emergency gate protrudes into the wet well when the flood-control intake is operating. Releases from the wet well on the same side of the intake structure would have to pass over the emergency gate before entering the throat section in the roof of the gate chamber. This would provide the possibility for an unstable flow condition. It is, therefore, recommended that the flood-control intake and wet well on the same side of the intake structure should not be operated simultaneously.

37. Tests of the original design stilling basin revealed unsatisfactory basin performance for various flow conditions. Adverse surging of the hydraulic jump was observed with the larger flows. For the lower range of discharges, eddying resulted from single gate operation and could be triggered by slightly excessive tailwater during dual gate operation. Development of an adequate stilling basin was complicated by the demand to satisfy a wide range of flow conditions with an outlet works containing a small drop from the conduit exit portal invert to the stilling basin apron. Many designs were tested in an attempt to satisfy both large and low flow requirements.

38. The recommended (type 8) stilling basin (Plate 16), which provided satisfactory performance in the model, contained a raised trajectory, chute blocks, and two rows of baffle piers. Furthermore, this stilling basin was wider and higher than the original design and had flared basin sidewalls. The central 11.5 ft of trajectory was raised to divert more flow to the sidewalls. This redistribution of flow eliminated eddying for all dual gate operating conditions. Chute blocks and tapered training walls were required to stabilize the hydraulic jump for the high range of discharges.

39. With both service gates opened equally, the type 8 stilling basin provided satisfactory performance with sufficient energy dissipation throughout the entire range of expected discharges. However, single or unequal service gate openings exceeding 10 percent or differing by more than 10 percent, respectively, produced eddies in the basin. Although the flow imbalance was not as severe as in the original design stilling basin, this type of operation for long periods of time should be avoided because of the possibility of abrasive damage to the basin.

Table 1

Pressures Throughout Flood-Control Facilities; Original Design, Both Service Gates Open Full

Pool El 567.0, Discharge 8000 cfs, and Tailwater El 486.6

Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water
1	490.00	44.40	48	518.00	49.20	95	488.60	33.20	142	473.96	25.30
2	489.00	35.00	49	521.00	46.20	96	481.40	40.40	143	481.33	19.10
3	488.80	34.20	50	518.00	49.20	97	474.10	48.90	144	488.71	10.75
4	488.75	35.25	51	521.00	46.00	98	474.00	45.20	145	481.33	15.10
5	488.75	37.85	52	521.00	46.00	99	481.40	38.60	146	485.10	17.40
6	488.75	38.55	53	518.00	49.00	100	481.40	34.60	147	473.83	*
7	491.20	35.80	54	524.50	3.00	101	474.00	44.00	148	473.65	19.70
8	493.20	34.60	55	521.00	6.40	102	475.50	39.50	149	473.48	17.80
9	493.70	34.10	56	517.50	9.90	103	481.40	36.40	150	473.30	11.40
10	493.70	34.10	57	493.70	*	104	487.20	29.30	151	473.13	13.00
11	493.70	34.10	58	481.40	51.80	105	488.75	28.25	152	472.95	8.60
12	493.70	34.10	59	481.40	48.80	106	488.75	27.75	153	472.78	6.90
13	498.10	29.70	60	481.40	47.60	107	487.20	29.00	154	472.61	4.05
14	503.00	64.00	61	488.70	39.80	108	481.40	35.80	155	472.43	1.26
15	506.00	61.00	62	484.90	42.60	109	475.50	40.90	156	472.33	7.81
16	506.00	61.00	63	481.40	39.60	110	474.00	43.00	157	472.30	7.53
17	513.10	14.70	64	481.40	41.10	111	481.40	35.60	158	481.20	17.20
18	517.00	35.30	65	488.70	39.60	112	481.40	35.60	159	481.03	12.30
19	529.10	1.10	66	484.90	42.70	113	474.00	33.00	160	480.85	10.90
20	533.00	*	67	481.20	45.70	114	476.40	34.60	161	480.68	6.00
21	544.10	**	68	481.40	45.60	115	481.40	31.60	162	480.50	5.60
22	547.50	**	69	481.40	42.60	116	486.30	25.00	163	480.33	1.40
23	537.50	**	70	481.40	40.80	117	488.75	17.75	164	480.15	-0.70
24	527.50	0.40	71	481.40	40.70	118	488.75	16.75	165	479.98	-3.70
25	522.50	5.30	72	481.40	38.50	119	486.30	25.20	166	479.81	-4.80
26	517.50	10.30	73	481.40	45.60	120	481.40	31.30	167	479.71	-0.40
27	510.50	17.30	74	481.40	44.60	121	476.40	35.10	168	479.68	0.70
28	509.00	19.00	75	481.40	41.60	122	474.00	32.50	169	488.58	9.70
29	515.50	11.70	76	481.40	40.60	123	481.40	25.30	170	488.40	4.55
30	505.50	21.70	77	481.40	40.60	124	481.40	24.60	171	488.23	2.80
31	494.70	33.10	78	481.40	42.40	125	477.70	26.60	172	488.05	-1.10
32	493.20	35.50	79	481.40	39.10	126	474.00	44.00	173	487.88	-2.40
33	491.70	36.30	80	481.40	39.00	127	476.90	38.40	174	487.70	-5.80
34	490.20	35.30	81	474.00	61.50	128	481.40	33.10	175	487.53	-7.50
35	488.75	26.75	82	474.00	56.80	129	485.90	29.60	176	487.36	-11.90
36	488.75	31.75	83	474.00	52.50	130	488.75	27.25	177	487.18	-11.30
37	488.75	31.75	84	474.00	51.50	131	485.90	29.60	178	487.08	-8.20
38	488.75	33.25	85	474.00	50.00	132	481.40	33.60	179	487.05	-3.20
39	494.70	32.90	86	474.00	48.80	133	476.90	38.60	180	479.71	-1.00
40	493.20	34.40	87	474.00	47.20	134	474.00	33.00	181	479.68	0.70
41	492.70	34.90	88	474.00	51.00	135	476.90	30.10	182	474.40	47.60
42	494.70	33.10	89	474.00	47.50	136	481.40	24.60	183	481.40	40.30
43	493.70	33.80	90	474.10	49.70	137	485.90	21.60	184	488.40	33.10
44	493.20	34.30	91	481.40	40.40	138	488.75	17.25	185	474.00	49.50
45	492.70	34.80	92	488.60	34.90	139	485.90	21.10	186	481.40	42.40
46	498.70	29.00	93	488.75	32.75	140	481.40	24.10	187	488.75	34.85
47	498.70	28.60	94	488.75	30.45	141	476.90	28.10			

Note: All elevations are in feet referred to mean sea level.
* Piezometers omitted.
** Piezometers above water surface.

Table 2

Pressures Throughout Flood-Control Facilities; Original Design, Right Service Gate Open Full

Pool El 570.5, Discharge 5000 cfs, and Tailwater El 482.6

Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water
1	490.00	32.50	48	518.00	52.50	95	488.60	**	142	473.96	13.50
2	489.00	15.80	49	521.00	49.50	96	481.40	**	143	481.33	2.90
3	488.80	13.00	50	518.00	52.50	97	474.10	**	144	488.71	**
4	488.75	14.25	51	521.00	49.50	98	474.00	**	145	481.33	2.40
5	488.75	18.35	52	521.00	49.50	99	481.40	16.10	146	485.10	**
6	488.75	19.65	53	518.00	52.50	100	481.40	**	147	473.83	7.10
7	491.20	17.20	54	524.50	**	101	474.00	18.80	148	473.65	9.40
8	493.20	19.60	55	521.00	45.50	102	475.50	13.90	149	473.48	8.40
9	493.70	15.70	56	517.50	32.50	103	481.40	12.60	150	473.30	6.40
10	493.70	15.70	57	493.70	*	104	487.20	5.10	151	473.13	9.50
11	493.70	15.70	58	481.40	35.20	105	488.75	3.85	152	472.95	9.60
12	493.70	15.40	59	481.40	30.90	106	488.75	**	153	472.78	9.90
13	498.10	11.40	60	481.40	28.80	107	487.20	**	154	472.61	10.35
14	503.00	67.50	61	488.70	19.80	108	481.40	**	155	472.43	8.36
15	506.00	64.50	62	484.90	22.90	109	475.50	**	156	472.33	10.51
16	506.00	64.50	63	481.40	17.80	110	474.00	**	157	472.30	8.43
17	513.10	11.40	64	481.40	19.90	111	481.40	11.60	158	481.20	**
18	517.00	32.70	65	488.70	19.70	112	481.40	**	159	481.03	2.00
19	529.10	9.70	66	484.90	23.10	113	474.00	2.50	160	480.85	2.90
20	533.00	*	67	481.20	25.80	114	476.40	2.20	161	480.68	0.50
21	544.10	**	68	481.40	26.10	115	481.40	2.50	162	480.50	3.10
22	547.50	**	69	481.40	27.80	116	486.30	-2.30	163	480.33	2.20
23	537.50	**	70	481.40	19.40	117	488.75	-1.10	164	480.15	2.50
24	527.50	10.30	71	481.40	18.90	118	488.75	**	165	479.98	2.80
25	522.50	10.50	72	481.40	15.60	119	486.30	**	166	479.81	2.10
26	517.50	10.10	73	481.40	85.60	120	481.40	**	167	479.71	2.60
27	510.50	10.90	74	481.40	85.60	121	476.40	**	168	479.68	1.60
28	509.00	11.50	75	481.40	85.60	122	474.00	**	169	488.58	**
29	515.50	**	76	481.40	85.60	123	481.40	0.10	170	488.40	**
30	505.50	8.80	77	481.40	**	124	481.40	**	171	488.23	**
31	494.70	13.60	78	481.40	**	125	477.70	**	172	488.05	**
32	493.20	14.10	79	481.40	**	126	474.00	**	173	487.88	**
33	491.70	19.80	80	481.40	**	127	476.90	1.90	174	487.70	**
34	490.20	17.30	81	474.00	45.50	128	481.40	-0.90	175	487.53	**
35	488.75	0.65	82	474.00	39.20	129	485.90	-1.40	176	487.36	**
36	488.75	9.65	83	474.00	32.80	130	488.75	**	177	487.18	**
37	488.75	9.25	84	474.00	31.50	131	485.90	**	178	487.08	**
38	488.75	11.25	85	474.00	29.50	132	481.40	**	179	487.05	**
39	494.70	13.60	86	474.00	27.60	133	476.90	**	180	479.71	1.30
40	493.20	15.50	87	474.00	25.30	134	474.00	5.60	181	479.68	0.50
41	492.70	15.60	88	474.00	25.20	135	476.90	2.60	182	474.40	25.70
42	494.70	13.40	89	474.00	25.50	136	481.40	-3.10	183	481.40	18.70
43	493.70	14.30	90	474.10	28.20	137	485.90	0.60	184	488.40	12.10
44	493.20	14.30	91	481.40	20.40	138	488.75	**	185	474.00	26.30
45	492.70	14.80	92	488.60	14.90	139	485.90	**	186	481.40	22.10
46	498.70	10.70	93	488.75	10.55	140	481.40	**	187	488.75	14.85
47	498.70	68.10	94	488.75	**	141	476.90	**			

Note: All elevations are in feet referred to mean sea level.
* Piezometers omitted.
** Piezometers above water surface.

Table 3

Pressures Throughout Flood-Control Facilities; Original Design, Both Service Gates Open 75 Percent

Pool El 583.0, Discharge 7500 cfs, and Tailwater El 486.0

Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water
1	490.00	64.00	48	518.00	65.00	95	488.60	**	142	473.96	32.50
2	489.00	65.80	49	521.00	62.00	96	481.40	15.60	143	481.33	27.60
3	486.80	55.20	50	518.00	65.00	97	474.10	29.40	144	488.71	**
4	488.75	56.25	51	521.00	62.00	98	474.00	23.00	145	481.33	**
5	488.75	58.55	52	521.00	65.00	99	481.40	10.60	146	485.10	**
6	488.75	59.45	53	518.00	62.00	100	481.40	14.60	147	473.83	32.10
7	491.20	57.40	54	524.50	**	101	474.00	33.00	148	473.65	27.70
8	493.20	55.80	55	521.00	13.00	102	475.50	28.50	149	473.48	25.80
9	493.70	55.30	56	517.50	13.50	103	481.40	27.60	150	473.30	19.70
10	493.70	55.30	57	493.70	*	104	487.20	23.80	151	473.13	21.00
11	493.70	55.30	58	481.40	71.60	105	488.75	14.25	152	472.95	17.10
12	493.70	55.30	59	481.40	69.00	106	488.75	25.25	153	472.78	13.00
13	498.10	41.40	60	481.40	67.80	107	487.20	31.80	154	472.61	13.15
14	503.00	80.00	61	488.70	60.50	108	481.40	28.60	155	472.43	9.46
15	506.00	77.00	62	484.90	63.10	109	475.50	32.50	156	472.33	13.01
16	506.00	77.00	63	481.40	22.60	110	474.00	35.00	157	472.30	10.03
17	513.10	35.90	64	481.40	12.60	111	481.40	26.60	158	481.20	**
18	517.00	55.80	65	488.70	60.60	112	481.40	28.60	159	481.03	**
19	529.10	9.90	66	484.90	63.30	113	474.00	37.00	160	480.85	**
20	533.00	*	67	481.20	65.60	114	476.40	33.60	161	480.68	**
21	544.10	5.20	68	481.40	65.40	115	481.40	31.60	162	480.50	**
22	547.50	**	69	481.40	61.10	116	486.30	**	163	480.33	**
23	537.50	8.80	70	481.40	53.60	117	488.75	**	164	480.15	**
24	527.50	16.30	71	481.40	24.60	118	488.75	**	165	479.98	**
25	522.50	21.30	72	481.40	9.60	119	486.30	**	166	479.81	3.50
26	517.50	31.80	73	481.40	64.90	120	481.40	30.60	167	479.71	3.60
27	510.50	34.50	74	481.40	63.80	121	476.40	35.10	168	479.68	**
28	509.00	26.40	75	481.40	59.80	122	474.00	37.00	169	488.58	**
29	515.50	25.5	76	481.40	52.90	123	481.40	**	170	488.40	**
30	505.50	35.00	77	481.40	23.60	124	481.40	**	171	488.23	**
31	494.70	54.30	78	481.40	19.60	125	477.70	**	172	488.05	**
32	493.20	55.30	79	481.40	22.60	126	474.00	42.00	173	487.88	**
33	491.70	56.30	80	481.40	15.60	127	476.90	38.10	174	487.70	**
34	490.20	54.80	81	474.00	81.00	128	481.40	33.50	175	487.53	**
35	488.75	51.55	82	474.00	77.00	129	485.90	**	176	487.36	**
36	488.75	57.75	83	474.00	72.00	130	488.75	**	177	487.18	**
37	488.75	**	84	474.00	69.80	131	485.90	**	178	487.08	**
38	488.75	**	85	474.00	65.50	132	481.40	34.60	179	487.05	**
39	494.70	52.30	86	474.00	58.00	133	476.90	38.10	180	479.71	**
40	493.20	55.50	87	474.00	35.00	134	474.00	37.50	181	479.68	2.70
41	492.70	55.60	88	474.00	22.30	135	476.90	34.60	182	474.40	26.60
42	494.70	54.00	89	474.00	24.00	136	481.40	28.60	183	481.40	15.60
43	493.70	55.00	90	474.10	26.90	137	485.90	**	184	488.40	**
44	493.20	55.60	91	481.40	19.60	138	488.75	**	185	474.00	27.00
45	492.70	56.10	92	488.60	**	139	485.90	**	186	481.40	**
46	498.70	45.30	93	488.75	**	140	481.40	29.10	187	488.75	**
47	498.70	48.80	94	488.75	**	141	476.90	34.10			

Note: All elevations are in feet referred to mean sea level.
* Piezometers omitted.
** Piezometers above water surface or air bubbles present.

Table 4

Pressures Throughout Flood-Control Facilities; Original Design, Both Service Gates Open 15 Percent

Pool El 569.0, Discharge 1500 cfs, and Tailwater El 475.8

Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water
1	490.00	78.00	48	518.00	51.00	95	488.60	**	142	473.96	4.30
2	489.00	78.50	49	521.00	48.00	96	481.40	**	143	481.33	**
3	488.80	78.60	50	518.00	51.00	97	474.10	5.20	144	488.71	**
4	488.75	78.75	51	521.00	48.00	98	474.00	2.50	145	481.33	**
5	488.75	78.75	52	521.00	48.00	99	481.40	**	146	485.10	**
6	488.75	78.55	53	518.00	51.00	100	481.40	**	147	473.83	3.60
7	491.20	76.40	54	524.50	42.60	101	474.00	3.50	148	473.65	3.70
8	493.20	74.40	55	521.00	46.10	102	475.50	-2.20	149	473.48	3.30
9	493.70	73.80	56	517.50	50.00	103	481.40	**	150	473.30	1.80
10	493.70	73.80	57	493.70	*	104	487.20	**	151	473.13	3.50
11	493.70	73.80	58	481.40	86.10	105	488.75	**	152	472.95	4.10
12	493.70	73.80	59	481.40	85.90	106	488.75	**	153	472.78	4.00
13	498.10	69.50	60	481.40	85.90	107	487.20	**	154	472.61	4.35
14	503.00	66.00	61	488.70	78.60	108	481.40	**	155	472.43	3.96
15	506.00	63.00	62	484.90	82.40	109	475.50	0.50	156	472.33	4.01
16	506.00	63.00	63	481.40	**	110	474.00	2.50	157	472.30	3.63
17	513.10	53.50	64	481.40	**	111	481.40	**	158	481.20	**
18	517.00	51.10	65	488.70	85.90	112	481.40	**	159	481.03	**
19	529.10	38.50	66	484.90	82.40	113	474.00	1.20	160	480.85	**
20	533.00	*	67	481.20	85.90	114	476.40	0.10	161	480.68	**
21	544.10	23.50	68	481.40	85.70	115	481.40	**	162	480.50	**
22	547.50	20.00	69	481.40	85.60	116	486.30	**	163	480.33	**
23	537.50	30.00	70	481.40	85.20	117	488.75	**	164	480.15	**
24	527.50	40.00	71	481.40	**	118	488.75	**	165	479.98	**
25	522.50	45.00	72	481.40	**	119	486.30	**	166	479.81	**
26	517.50	50.00	73	481.40	85.80	120	481.40	**	167	479.71	**
27	510.50	57.00	74	481.40	85.80	121	476.40	0.10	168	479.68	**
28	509.00	58.50	75	481.40	85.70	122	474.00	1.00	169	488.58	**
29	515.50	52.00	76	481.40	85.60	123	481.40	**	170	488.40	**
30	505.50	62.00	77	481.40	**	124	481.40	**	171	488.23	**
31	494.70	72.80	78	481.40	**	125	477.70	**	172	488.05	**
32	493.20	74.30	79	481.40	**	126	474.00	**	173	487.88	**
33	491.70	78.50	80	481.40	**	127	476.90	0.50	174	487.70	**
34	490.20	77.30	81	474.00	93.40	128	481.40	**	175	487.53	**
35	488.75	78.85	82	474.00	93.20	129	485.90	**	176	487.36	**
36	488.75	78.85	83	474.00	92.90	130	488.75	**	177	487.18	**
37	488.75	**	84	474.00	92.60	131	485.90	**	178	487.08	**
38	488.75	**	85	474.00	91.60	132	481.40	**	179	487.05	**
39	494.70	72.80	86	474.00	92.50	133	476.90	0.20	180	479.71	**
40	493.20	74.30	87	474.00	11.30	134	474.00	5.50	181	479.68	**
41	492.70	74.80	88	474.00	5.00	135	476.90	1.50	182	474.40	3.90
42	494.70	72.80	89	474.00	5.80	136	481.40	**	183	481.40	**
43	493.70	73.80	90	474.10	4.40	137	485.90	**	184	488.40	**
44	493.20	74.30	91	481.40	**	138	488.75	**	185	474.00	4.50
45	492.70	74.80	92	488.60	**	139	485.90	**	186	481.40	**
46	498.70	68.80	93	488.75	**	140	481.40	**	187	488.75	**
47	498.70	68.80	94	488.75	**	141	476.90	0.10			

Note: All elevations are in feet referred to mean sea level.
* Piezometers omitted.
** Piezometers above water surface.

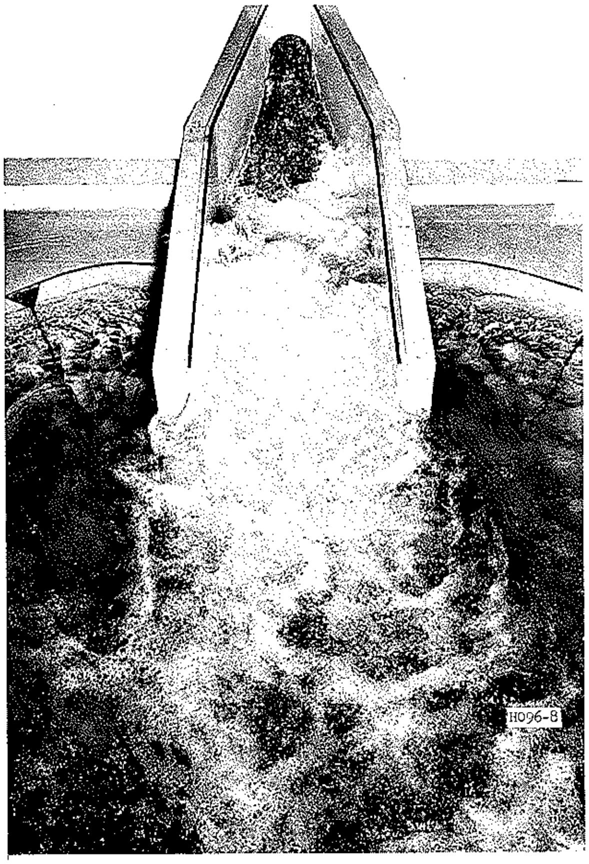
Table 5

Pressures Throughout Water-Quality Facilities; Original Design, Right Service Gate Open 25 Percent

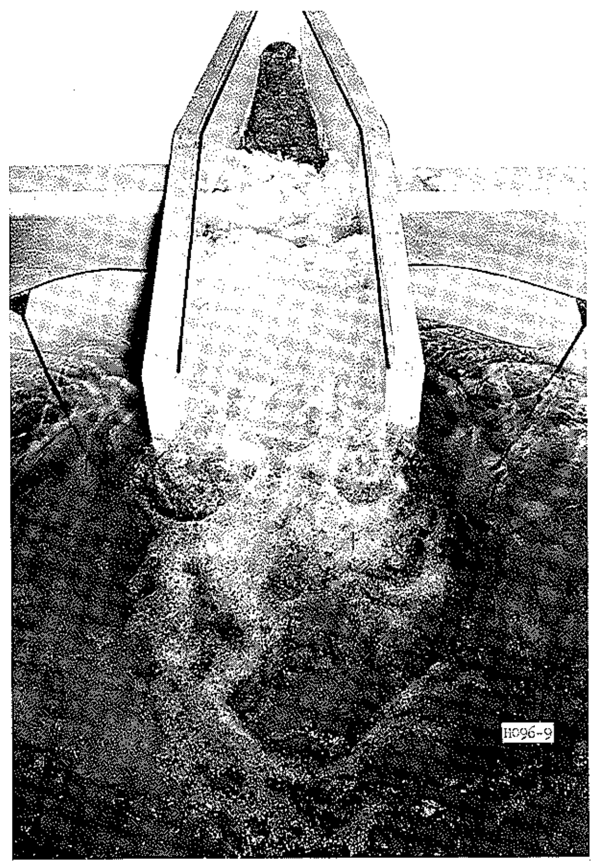
Pool El 590.0, Discharge 1260 cfs, and Tailwater El 475.10

Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water	Piezometer No.	Piezometer El	Pressure ft of Water
1	490.00	94.50	36	488.75	86.25	71	481.40	**	106	487.20	**
2	489.00	95.50	37	488.75	**	72	481.40	**	107	487.20	**
3	488.80	95.70	38	488.75	**	73	481.40	104.10	108	481.40	**
4	488.75	95.75	39	494.70	91.80	74	481.40	104.10	109	475.50	**
5	488.75	95.75	40	493.20	86.80	75	481.40	104.10	110	474.00	**
6	488.75	95.75	41	492.70	85.80	76	481.40	104.10	111	481.40	**
7	491.20	92.10	42	494.70	91.80	77	481.40	**	112	481.40	**
8	493.20	89.8	43	493.70	92.30	78	481.40	**	113	474.00	2.00
9	493.70	93.80	44	493.20	83.80	79	481.40	**	114	476.40	0.40
10	493.70	95.30	45	492.70	85.30	80	481.40	**	115	481.40	**
11	493.70	95.30	46	498.70	88.30	81	474.00	107.50	116	486.30	**
12	493.70	95.30	47	498.70	**	82	474.00	107.50	117	488.75	**
13	498.10	90.40	48	518.00	70.00	83	474.00	104.50	118	488.75	**
14	503.00	86.00	49	521.00	67.00	84	474.00	105.50	119	486.30	**
15	506.00	83.00	50	518.00	70.00	85	474.00	106.00	120	481.40	**
16	506.00	83.00	51	521.00	68.30	86	474.00	96.00	121	476.40	**
17	513.10	75.70	52	518.00	68.30	87	474.00	24.00	122	474.00	**
18	517.00	59.90	53	518.00	71.30	88	474.00	4.00	123	481.40	**
19	529.10	59.90	54	524.50	**	89	474.00	5.00	124	481.40	**
20	533.00	*	55	521.00	**	90	474.00	6.90	125	477.70	**
21	544.10	45.90	56	517.50	**	91	481.40	**	126	474.00	**
22	547.50	42.50	57	493.70	*	92	488.60	**	127	476.90	1.10
23	537.50	52.50	58	481.40	100.60	93	488.75	**	128	481.40	**
24	527.50	62.50	59	481.40	100.60	94	488.75	**	129	485.90	**
25	522.50	67.50	60	481.40	100.60	95	488.60	**	130	488.75	**
26	517.50	72.00	61	488.70	98.80	96	481.40	**	131	485.90	**
27	510.50	77.50	62	484.90	93.60	97	474.10	**	132	481.40	**
28	509.00	77.50	63	481.40	**	98	474.00	**	133	476.90	**
29	515.50	71.00	64	481.40	**	99	481.40	**	134	474.00	4.50
30	505.50	81.00	65	488.70	89.80	100	481.40	**	135	476.90	1.40
31	494.70	88.50	66	484.90	94.10	101	474.00	5.00	136	481.40	**
32	493.20	78.80	67	481.20	97.30	102	475.50	-1.70	137	485.90	**
33	491.70	77.70	68	481.40	97.40	103	481.40	**	138	488.75	**
34	490.20	86.80	69	481.40	95.10	104	487.20	**	139	485.90	**
35	488.75	86.75	70	481.40	94.10	105	488.75	**	140	481.40	**

Note: All elevations are in feet referred to mean sea level. Five intakes are open full.
* Piezometers omitted.
** Piezometers above water surface.



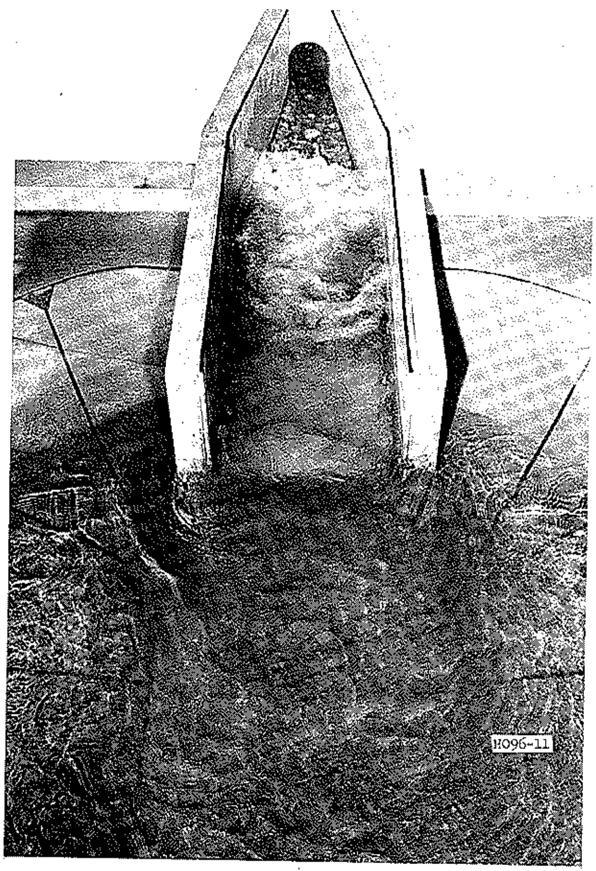
a. Discharge 8425 cfs; tailwater el 487.2; both service gates fully open



b. Discharge 6000 cfs; tailwater el 484.0; both service gates open 75 percent

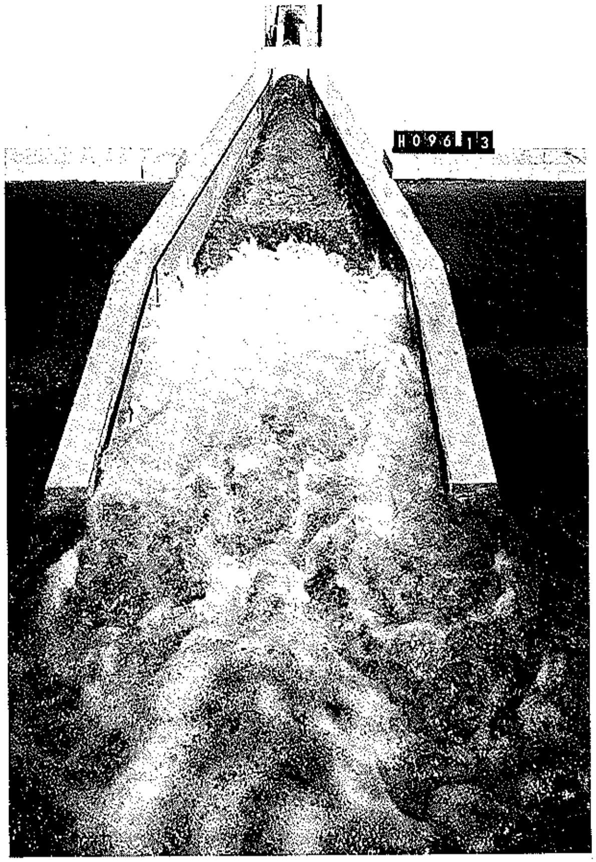
Photo 1. Flow conditions in the type 1 (original design) basin for discharges of 8425, 6000, 1500, and 1320 cfs (sheet 1 of 2)

c. Discharge 1500 cfs; tailwater el 475.7; single service gate open 30 percent

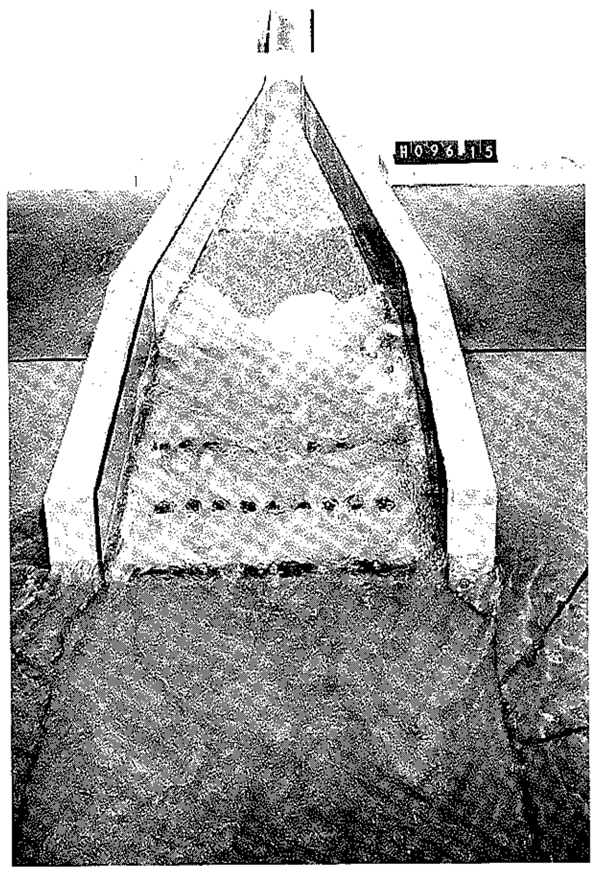


d. Discharge 1320 cfs; tailwater el 475.3; both service gates open 15 percent

Photo 1. (sheet 2 of 2)

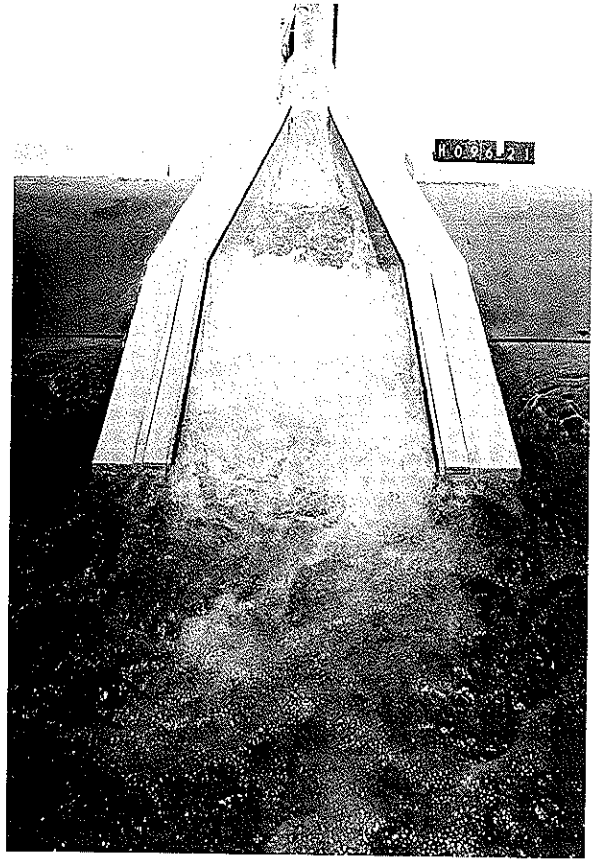


a. Discharge 8425 cfs; tailwater el 487.2; both service gates fully open

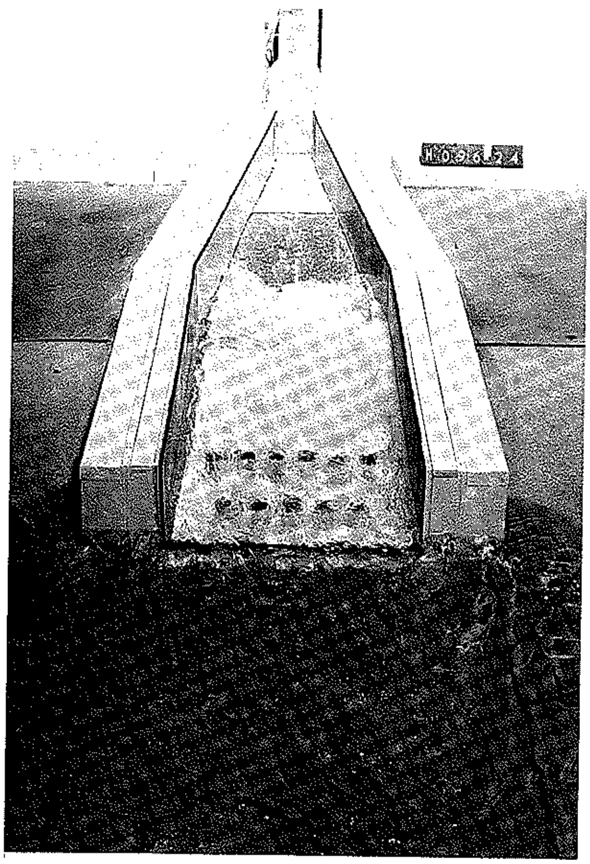


b. Discharge 1320 cfs; tailwater el 475.3; both service gates open 15 percent

Photo 2. Flow conditions in the type 2 basin for discharges of 8425 and 1320 cfs

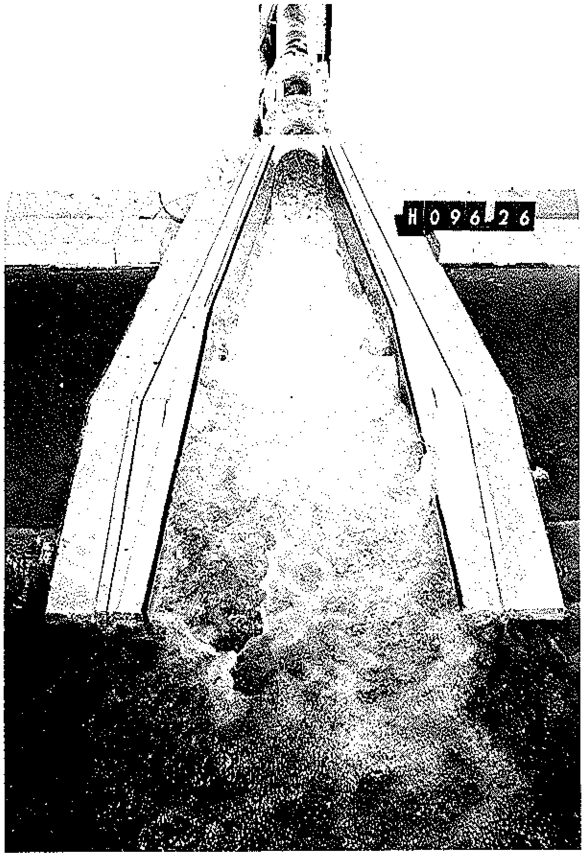


a. Discharge 8425 cfs; tailwater el 487.4; both service gates fully open

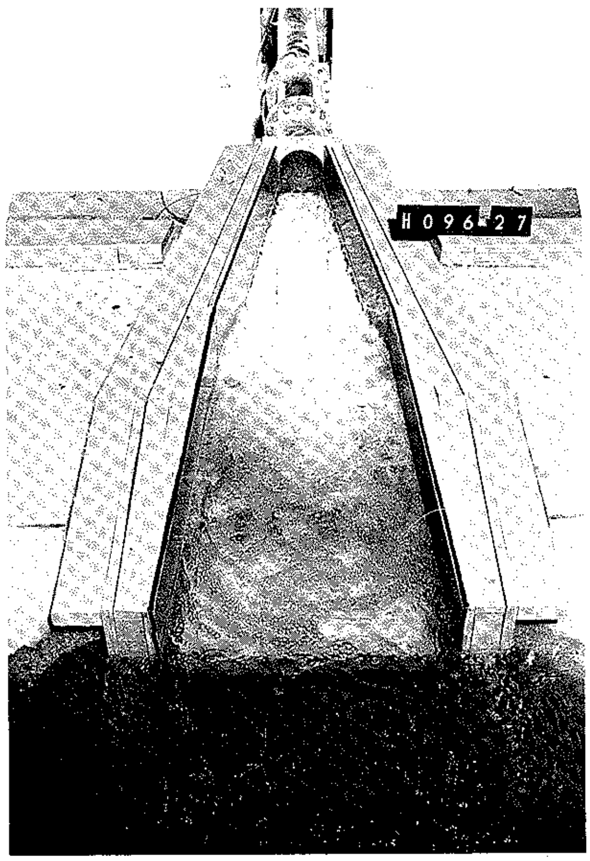


b. Discharge 1000 cfs; tailwater el 474.3; both service gates open 10 percent

Photo 3. Flow conditions in the type 3 basin for discharges of 8425 and 1000 cfs



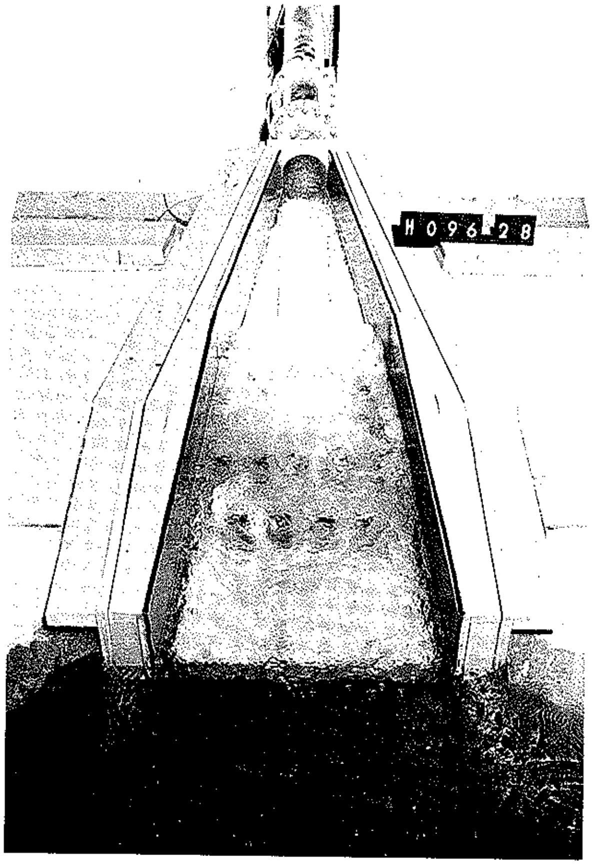
a. Discharge 8425 cfs; tailwater el 487.4; both service gates fully open

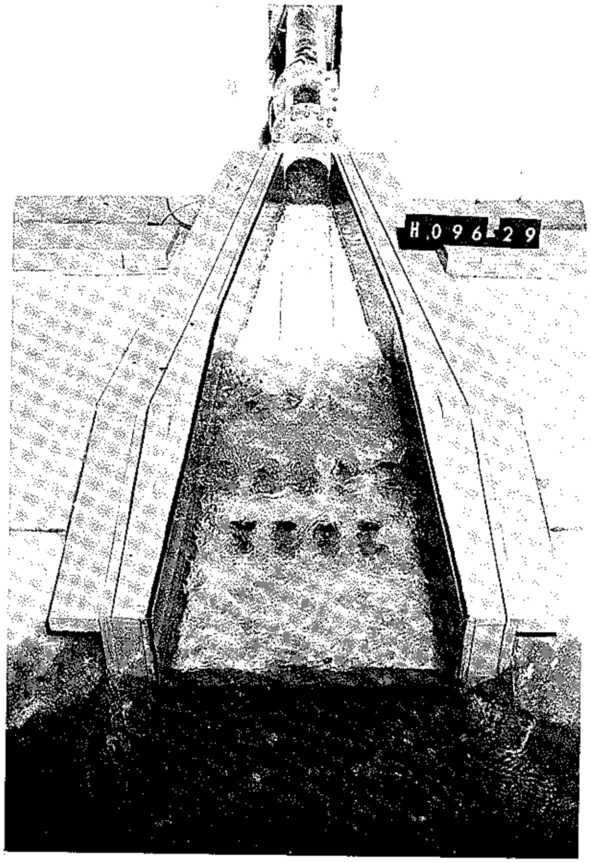


b. Discharge 2200 cfs; tailwater el 477.5; both service gates open 25 percent

Photo 4. Flow conditions in the type 8 basin for discharges of 8425, 2200, 1500, and 1000 cfs (sheet 1 of 2)

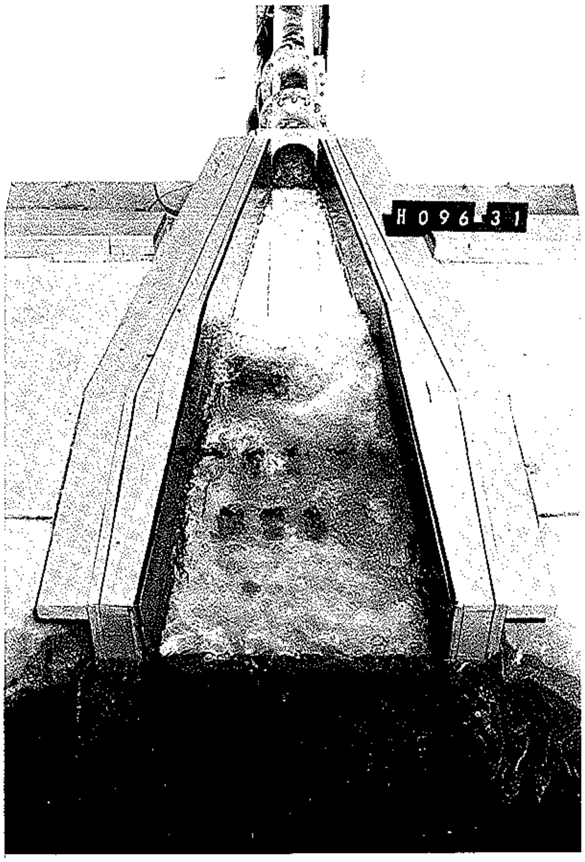
c. Discharge 1500 cfs; tailwater el 475.4; both service gates open 20 percent



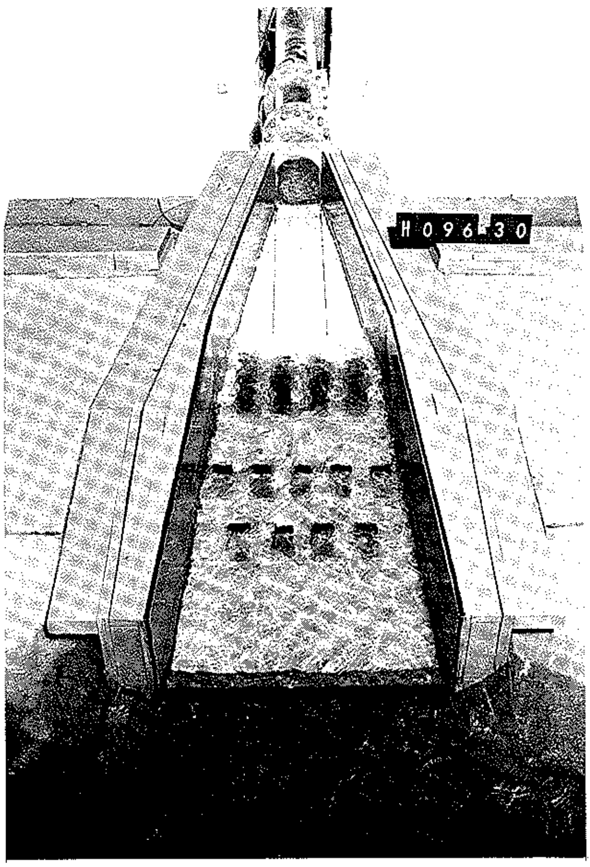


d. Discharge 1000 cfs; tailwater el 474.3; both service gates open 10 percent

Photo 4. (sheet 2 of 2)

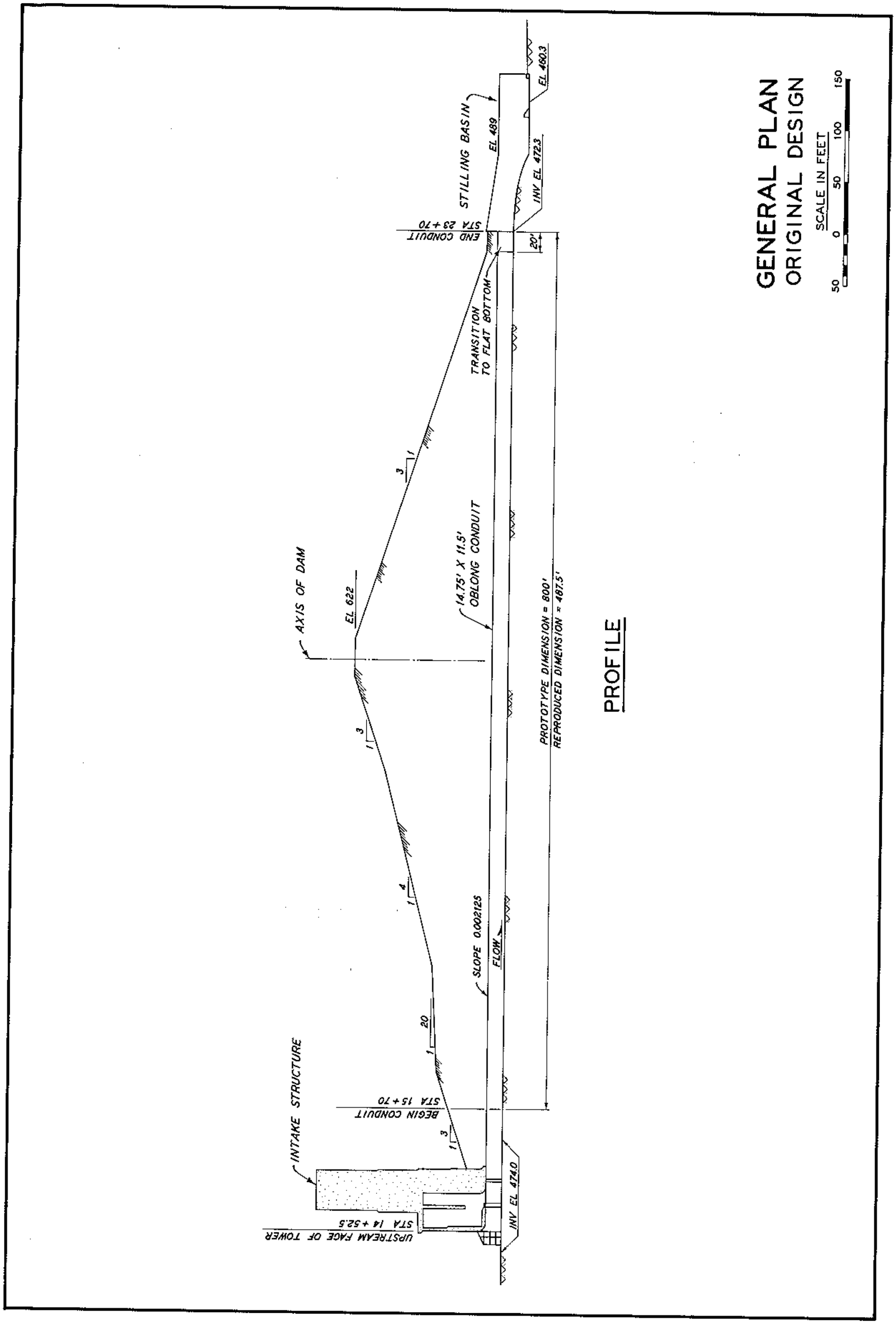


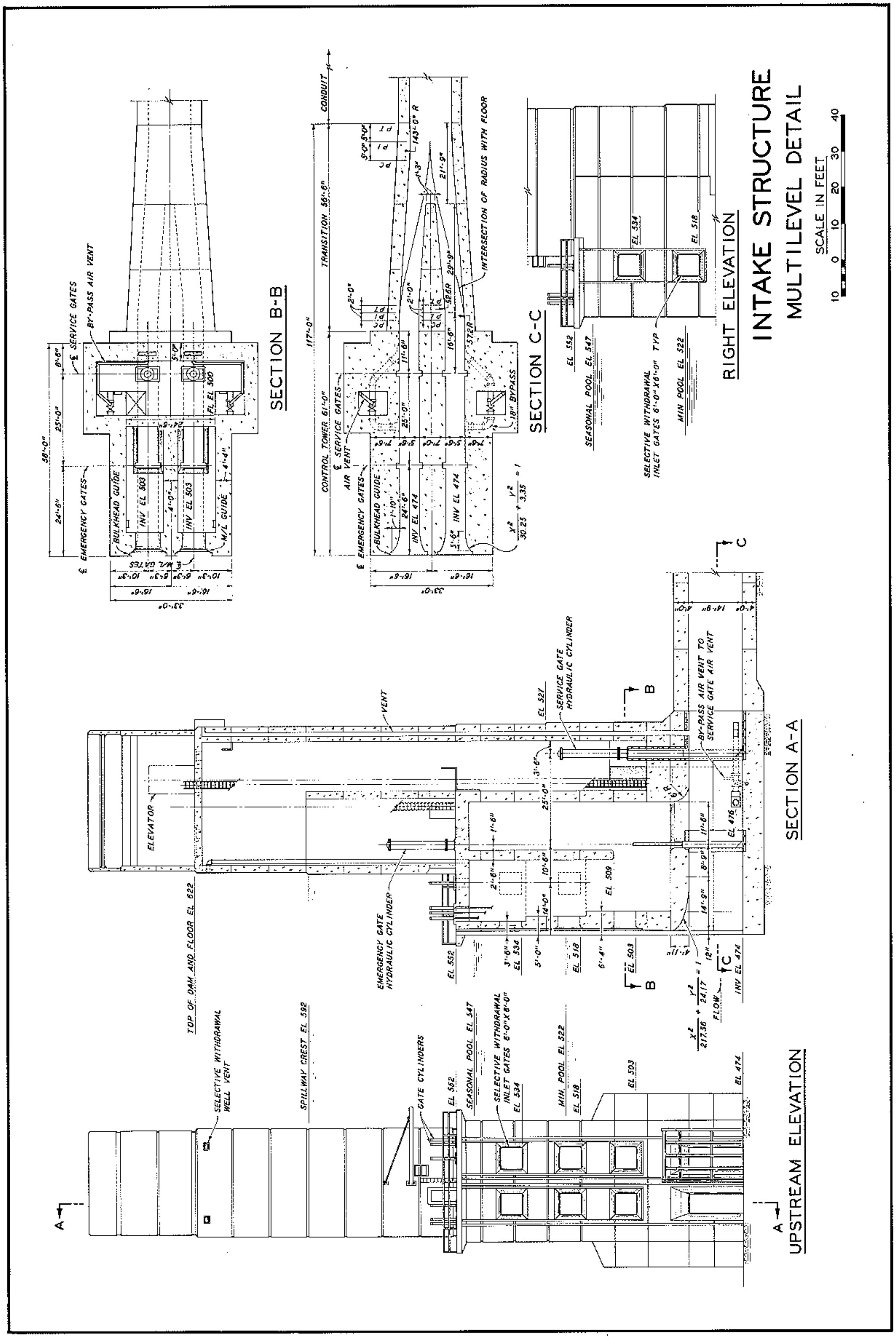
a. Discharge 1200 cfs; tailwater el 475.0; single service gate open 30 percent



b. Discharge 480 cfs; tailwater el 472.3; single service gate open 10 percent

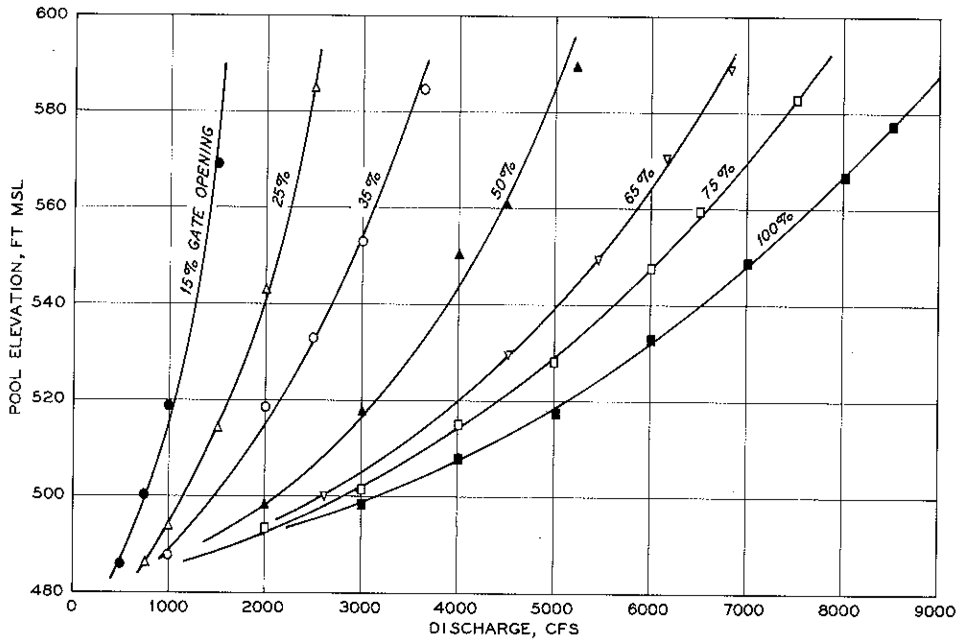
Photo 5. Flow conditions in the type 8 basin for discharges of 1200 and 480 cfs

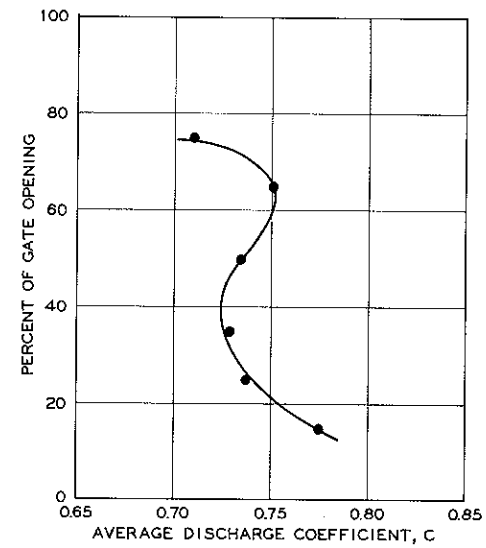

GENERAL PLAN
ORIGINAL DESIGN
SCALE IN FEET
50 0 50 100 150
PROFILE
INTAKE STRUCTURE
UPSTREAM FACE OF TOWER
STA 14 + 52.5
INV EL 474.0
BEGIN CONDUIT
STA 15 + 70
SLOPE 0.002125
FLOW
AXIS OF DAM
EL 622
14.75' X 11.5'
OBLONG CONDUIT
PROTOTYPE DIMENSION = 800'
REPRODUCED DIMENSION = 487.5'
TRANSITION
TO FLAT BOTTOM
END CONDUIT
STA 23 + 70
20'
STILLING BASIN
EL 489
INV EL 472.3
EL 460.3



INTAKE STRUCTURE
MULTILEVEL DETAIL
SCALE IN FEET
10 0 10 20 30 40
SECTION B-B
SECTION C-C
RIGHT ELEVATION
SECTION A-A
UPSTREAM ELEVATION
SERVICE GATES
BY-PASS AIR VENT
EMERGENCY GATES
BULKHEAD GUIDE
M/L GUIDE
INV EL 503
FL EL 500
CONTROL TOWER 61'-0"
TRANSITION 55'-6"
CONDUIT
117'-0"
INTERSECTION OF RADIUS WITH FLOOR
18" BYPASS
AIR VENT
INV EL 474
EL 552
SEASONAL POOL EL 547
SELECTIVE WITHDRAWAL INLET GATES 6'-0"X6'-0" TYP
MIN POOL EL 522
EL 534
EL 518
VENT
EL 527
SERVICE GATE HYDRAULIC CYLINDER
BY-PASS AIR VENT TO SERVICE GATE AIR VENT
ELEVATOR
EMERGENCY GATE HYDRAULIC CYLINDER
TOP OF DAM AND FLOOR EL 622
SPILLWAY CREST EL 592
SELECTIVE WITHDRAWAL WELL VENT
GATE CYLINDERS
EL 509
EL 503
EL 474
FLOW

PLATE 2





NOTE: THE DISCHARGE COEFFICIENTS WERE OBTAINED BY AVERAGING COMPUTED COEFFICIENTS FOR A RANGE OF DISCHARGES.

THE FORMULA USED FOR COMPUTATION: $Q = CA\sqrt{2gH}$

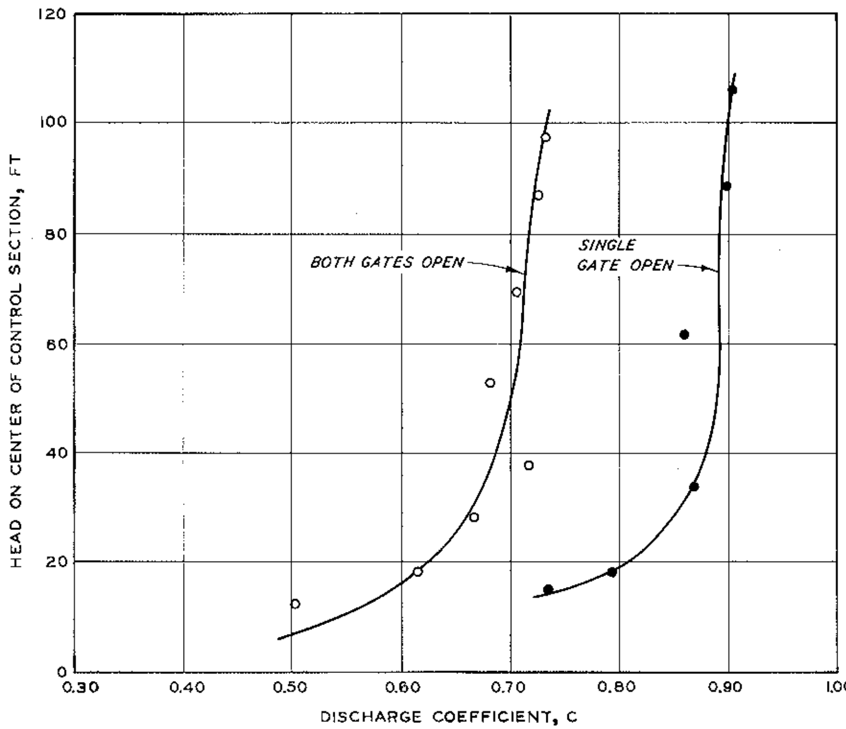
WHERE: A = AREA OF GATE OPENING

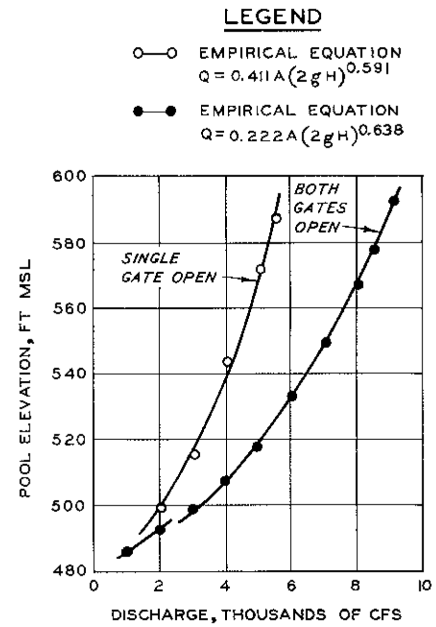
H = HEAD (FROM POOL) TO CENTER OF GATE OPENING

SERVICE GATES ARE 14.75 FT HIGH X 5.5 FT WIDE

INVERT OF GATES AT EL 474.0

DISCHARGE RATING CURVES
FLOOD - CONTROL FLOW
BOTH SERVICE GATES AT FULL AND PARTIAL OPENINGS





NOTE: MODEL DISCHARGE COEFFICIENT DETERMINED FROM EQUATION $Q=CA\sqrt{2gH}$ WHERE:

BOTH GATES OPEN

A - AREA OF CONDUIT
H - HEAD TO CENTER OF OUTLET PORTAL

SINGLE GATE OPEN

A - HALF THE CONDUIT TRANSITION AREA AT THE PIER END
H - HEAD TO THE CENTER OF THE GATE PASSAGE

SERVICE GATES ARE 14 FT 9 IN. HIGH BY 5 FT 6 IN. WIDE

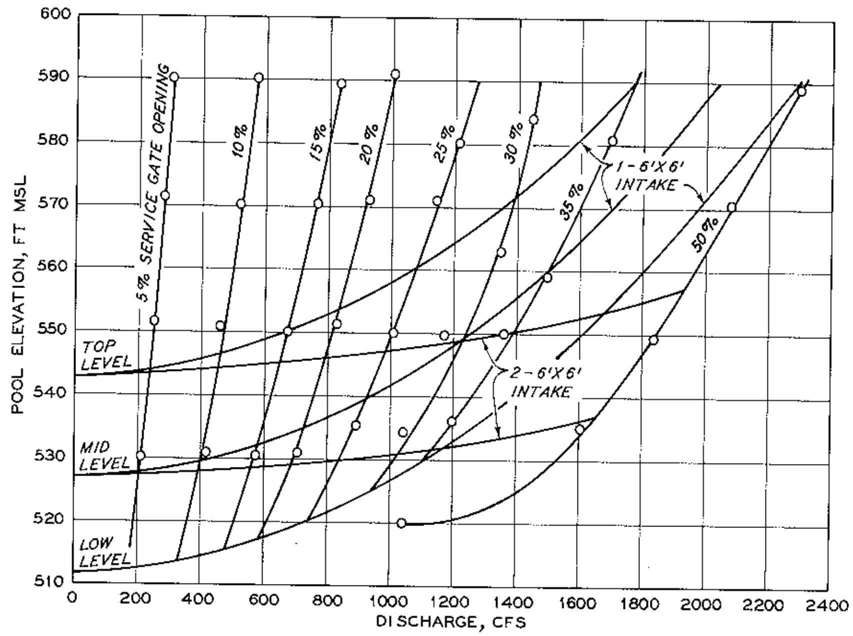
INVERT OF GATES AT EL 474.0

OBLONG CONDUIT IS 14 FT 9 IN. VERTICAL BY 11 FT 6 IN. HORIZONTAL

OUTLET PORTAL INVERT AT EL 472.3

DISCHARGE RATING CURVES
FLOOD-CONTROL FLOW

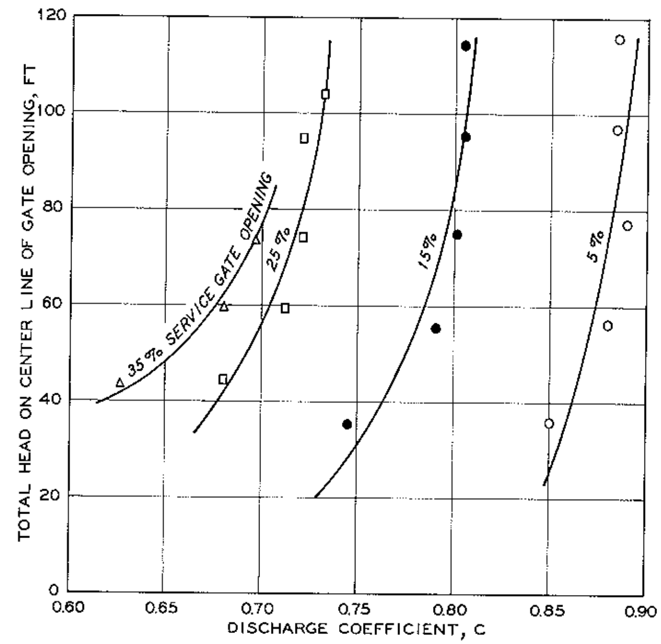
SERVICE GATES FULLY OPEN



NOTE: PARTIAL SERVICE GATE RATINGS WERE OBTAINED FOR FIVE INTAKES OPEN. THE SUBMERGED ORIFICE RATINGS PRESENTED FOR DOUBLE AND SINGLE 6-X 6-FT MULTILEVEL INTAKES WERE OBTAINED FROM THE EMPIRICAL EQUATION: $Q = 0.941\,A\,(2g\Delta H)^{0.494}$

WHERE: A = AREA OF ONE OR TWO 6-X 6-FT INTAKES
ΔH = HEAD DIFFERENTIAL BETWEEN POOL AND WATER LEVEL IN THE WET WELL WHICH WAS HELD CONSTANT AT 3 FT ABOVE THE TOP OF EACH INTAKE

EMERGENCY GATES WERE CLOSED.



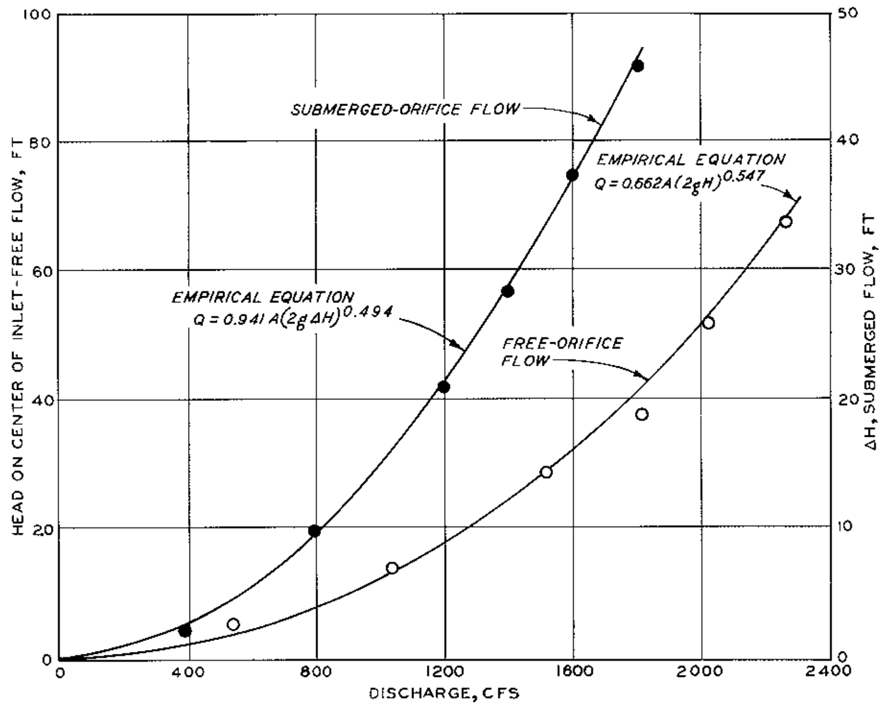
NOTE: MODEL COEFFICIENT DETERMINED FROM EQUATION:

$$Q = CA\sqrt{2gH}$$

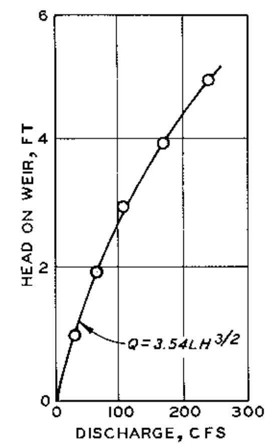
WHERE: A = AREA OF SERVICE GATE OPENING
H = HEAD FROM POOL TO CENTER OF GATE OPENING

DISCHARGE RATING CURVES
WATER-QUALITY FLOW

SINGLE SERVICE GATE PARTIAL OPENINGS WITH BOUNDARIES OF SUBMERGED ORIFICE FLOW CONTROL DESCRIBED FOR A SINGLE OR DOUBLE MULTILEVEL INTAKE



FREE AND SUBMERGED ORIFICE FLOW



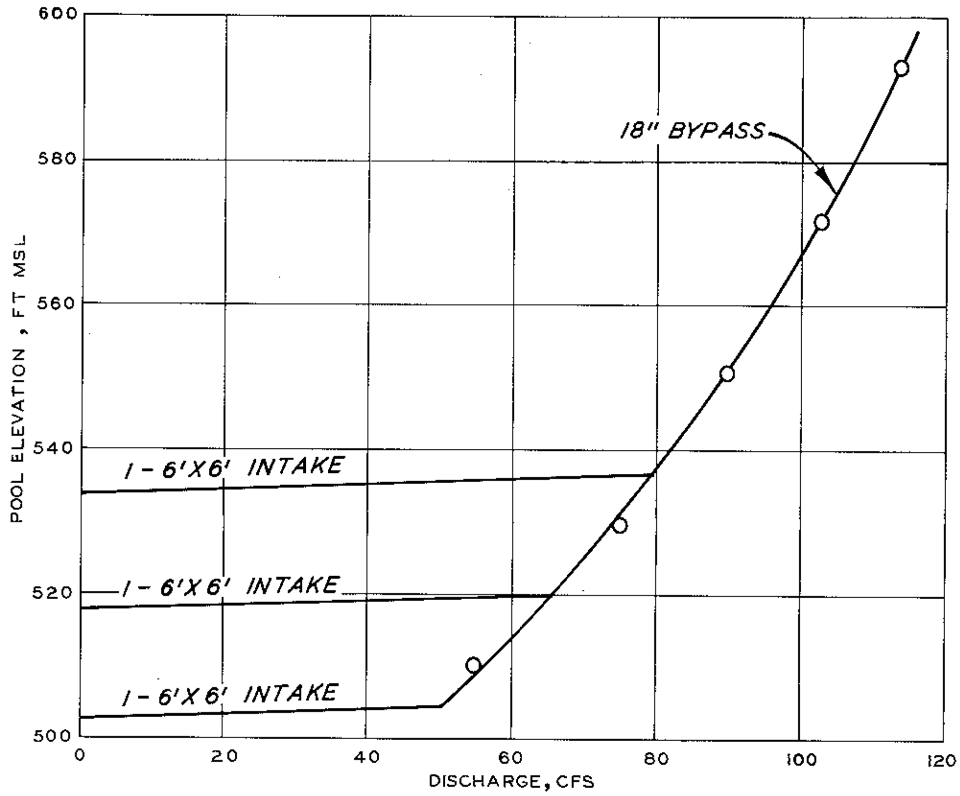
FREE WEIR FLOW

NOTE: FLOW CHARACTERISTICS ARE BASED ON DISCHARGE THROUGH A SINGLE 6-X 6-FT INLET

ΔH IS THE HEAD DIFFERENTIAL BETWEEN THE WATER-SURFACE LEVEL IN THE WET WELL AND THE POOL ELEVATION.

EMPIRICAL EQUATIONS WERE DETERMINED FROM THE BEST FIT OF DATA USING THE METHOD OF LEAST SQUARES.

DISCHARGE RATING CURVES
WATER - QUALITY FLOW
SINGLE MULTILEVEL INTAKE
FLOW CHARACTERISTICS



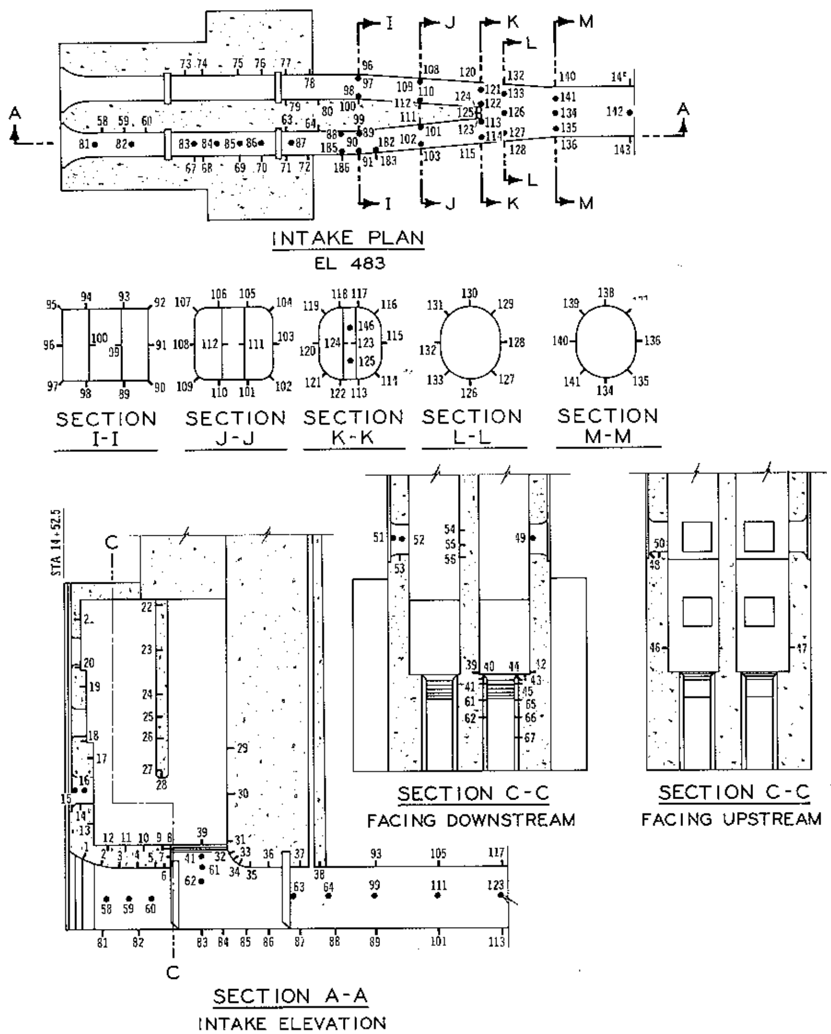
NOTE: BYPASS RATING TAKEN WITH ALL FIVE INTAKES OPEN ON ONE SIDE.

SERVICE GATES WERE CLOSED.

BOUNDARIES OF FREE ORIFICE FLOW CONTROL ARE DESCRIBED FOR A SINGLE INTAKE.

DISCHARGE RATING CURVES WATER-QUALITY FLOW

SINGLE 18-INCH BYPASS PIPE



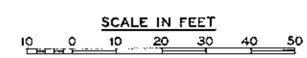
PIEZ NO.	ELEVATION*	STA
1	490.00	14+56.5
2	485.00	14+60.5
3	488.50	14+64.5
4	488.75	14+68.5
5	488.75	14+72.5
6	488.75	14+74.5
7	491.20	14+76.2
8	493.20	14+75.7
9	493.70	14+73.8
10	493.70	14+69.8
11	493.70	14+65.8
12	493.70	14+61.8
13	498.10	14+58.8
14	503.00	14+55.7
15	506.00	14+54.7
16	506.00	14+55.7
17	513.10	14+58.8
18	517.00	14+57.5
19	529.10	14+57.5
20	533.00	14+56.0
21	544.10	14+56.0
22	547.50	14+73.0
23	537.50	14+73.0
24	527.50	14+73.0
25	522.50	14+73.0
26	517.50	14+73.0
27	510.50	14+74.2
28	509.00	14+88.5
29	515.50	14+88.5
30	505.50	14+88.5
31	494.70	14+88.5
32	493.20	14+90.0
33	491.70	14+91.5
34	490.20	14+93.0
35	488.75	14+94.5
36	488.75	14+98.0
37	488.75	15+05.0
38	488.75	15+08.9
39	494.70	14+83.1
40	493.20	14+83.1
41	492.70	14+83.1
42	494.70	14+83.1
43	493.70	14+83.1
44	493.20	14+83.1
45	492.70	14+83.1
46	498.70	14+66.5
47	498.70	14+66.5
48	518.00	14+66.5
49	521.00	14+69.5
50	518.00	14+66.5
51	521.00	14+69.5

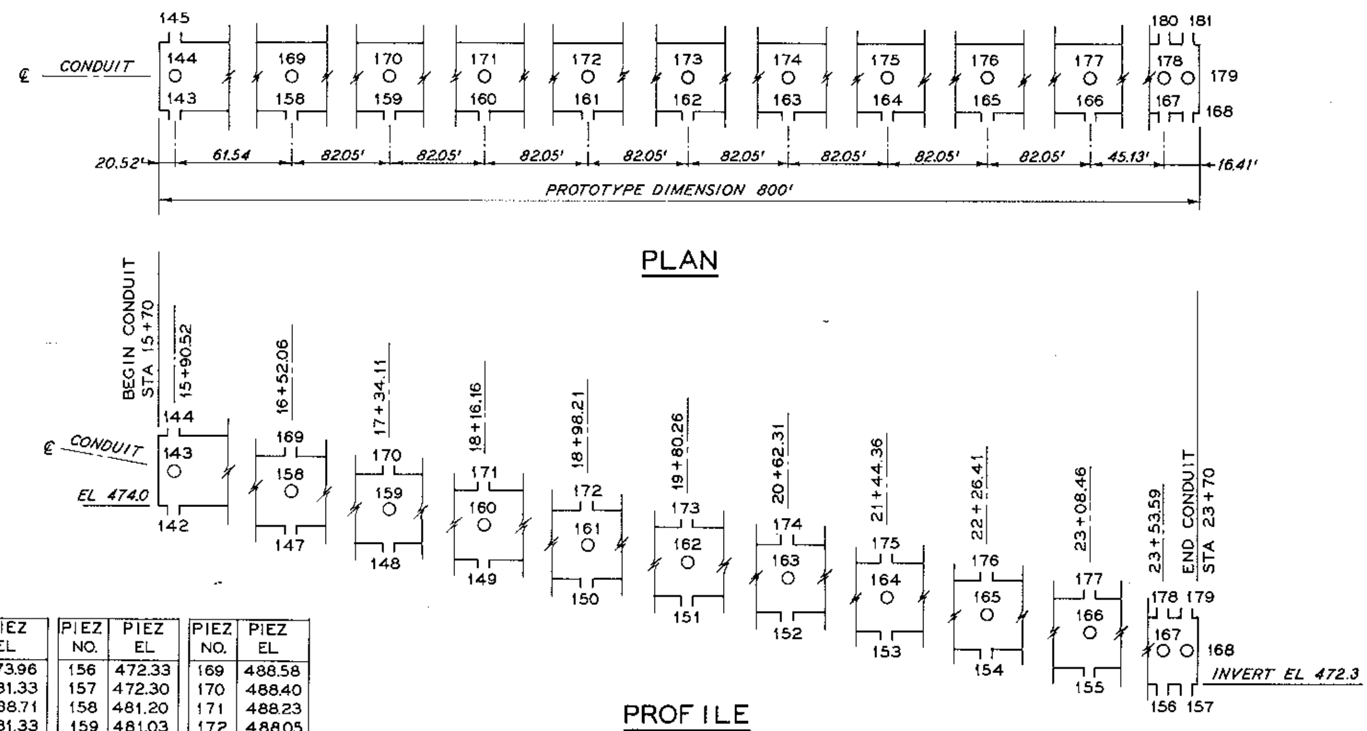
PIEZ NO.	ELEVATION	STA
52	521.00	14+69.5
53	518.00	14+66.5
54	524.50	14+66.5
55	521.00	14+66.5
56	517.50	14+66.5
57	**	**
58	481.40	14+61.5
59	481.40	14+66.5
60	481.40	14+71.5
61	488.70	14+83.1
62	484.90	14+83.1
63	481.40	15+03.5
64	481.40	15+11.5
65	488.70	14+83.1
66	484.90	14+83.1
67	481.20	14+83.1
68	481.40	14+85.1
69	481.40	14+93.1
70	481.40	14+98.1
71	481.40	15+03.5
72	481.40	15+09.0
73	481.40	14+81.0
74	481.40	14+85.0
75	481.40	14+93.0
76	481.40	14+98.0
77	481.40	15+03.5
78	481.40	15+09.0
79	481.40	15+03.5
80	481.40	15+11.5
81	474.00	14+60.5
82	474.00	14+68.5
83	474.00	14+83.0
84	474.00	14+88.0
85	474.00	14+93.0
86	474.00	15+98.0
87	474.00	15+05.0
88	474.00	15+17.5
89	474.00	15+20.5
90	474.10	15+20.5
91	481.40	15+20.5
92	488.60	15+20.5
93	488.75	15+20.5
94	488.75	15+20.5
95	488.60	15+20.5
96	481.40	15+20.5
97	474.10	15+20.5
98	474.00	15+20.5
99	481.40	15+20.5
100	481.40	15+20.5
101	474.00	15+34.4
102	475.50	15+34.4

PIEZ NO.	ELEVATION	STA
103	481.40	15+34.4
104	487.20	15+34.4
105	488.75	15+34.4
106	488.75	15+34.4
107	487.20	15+34.4
108	481.40	15+34.4
109	475.50	15+34.4
110	474.00	15+34.4
111	481.40	15+34.4
112	481.40	15+34.4
113	474.00	15+48.4
114	476.40	15+48.4
115	481.40	15+48.4
116	486.30	15+48.4
117	488.75	15+48.4
118	488.75	15+48.4
119	486.30	15+48.4
120	481.40	15+48.4
121	476.40	15+48.4
122	474.00	15+48.4
123	481.40	15+48.4
124	481.40	15+48.4
125	477.70	15+48.4
126	474.00	15+53.4
127	476.90	15+53.4
128	481.40	15+53.4
129	485.90	15+53.4
130	488.75	15+53.4
131	485.90	15+53.4
132	481.40	15+53.4
133	486.90	15+53.4
134	474.00	15+65.0
135	476.90	15+65.0
136	481.40	15+65.0
137	485.90	15+65.0
138	488.75	15+65.0
139	485.90	15+65.0
140	481.40	15+65.0
141	476.90	15+65.0
142	473.96	15+90.52
143	481.33	15+90.52
144	488.71	15+90.52
145	481.33	15+90.52
146	485.10	15+48.4
182	474.4	15+24.5
183	481.4	15+24.5
184	488.4	15+24.5
185	474.0	15+16.5
186	481.4	15+16.5
187	488.75	15+16.5

* ALL ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.
** PIEZOMETER OMITTED

PIEZOMETER LOCATIONS
INTAKE AND TRANSITION
ORIGINAL DESIGN

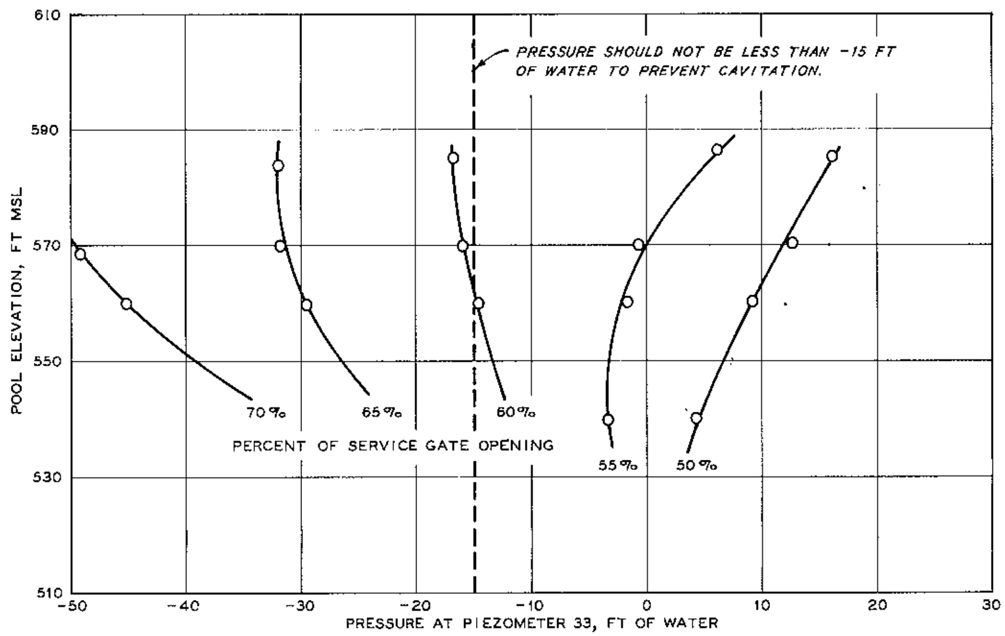




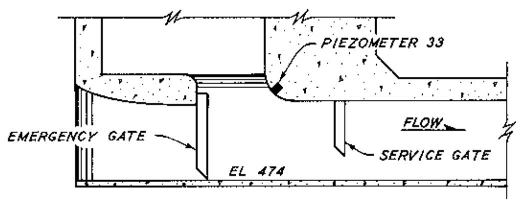
PIEZ NO.	PIEZ EL	PIEZ NO.	PIEZ EL	PIEZ NO.	PIEZ EL
142	473.96	156	472.33	169	488.58
143	481.33	157	472.30	170	488.40
144	488.71	158	481.20	171	488.23
145	481.33	159	481.03	172	488.05
147	473.83	160	480.85	173	487.88
148	473.65	161	480.68	174	487.70
149	473.48	162	480.50	175	487.53
150	473.30	163	480.33	176	487.36
151	473.13	164	480.15	177	487.18
152	472.95	165	479.98	178	487.08
153	472.78	166	479.81	179	487.05
154	472.61	167	479.71	180	479.71
155	472.43	168	479.68	181	479.68

NOTE: ALL ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

PIEZOMETER LOCATIONS IN CONDUIT



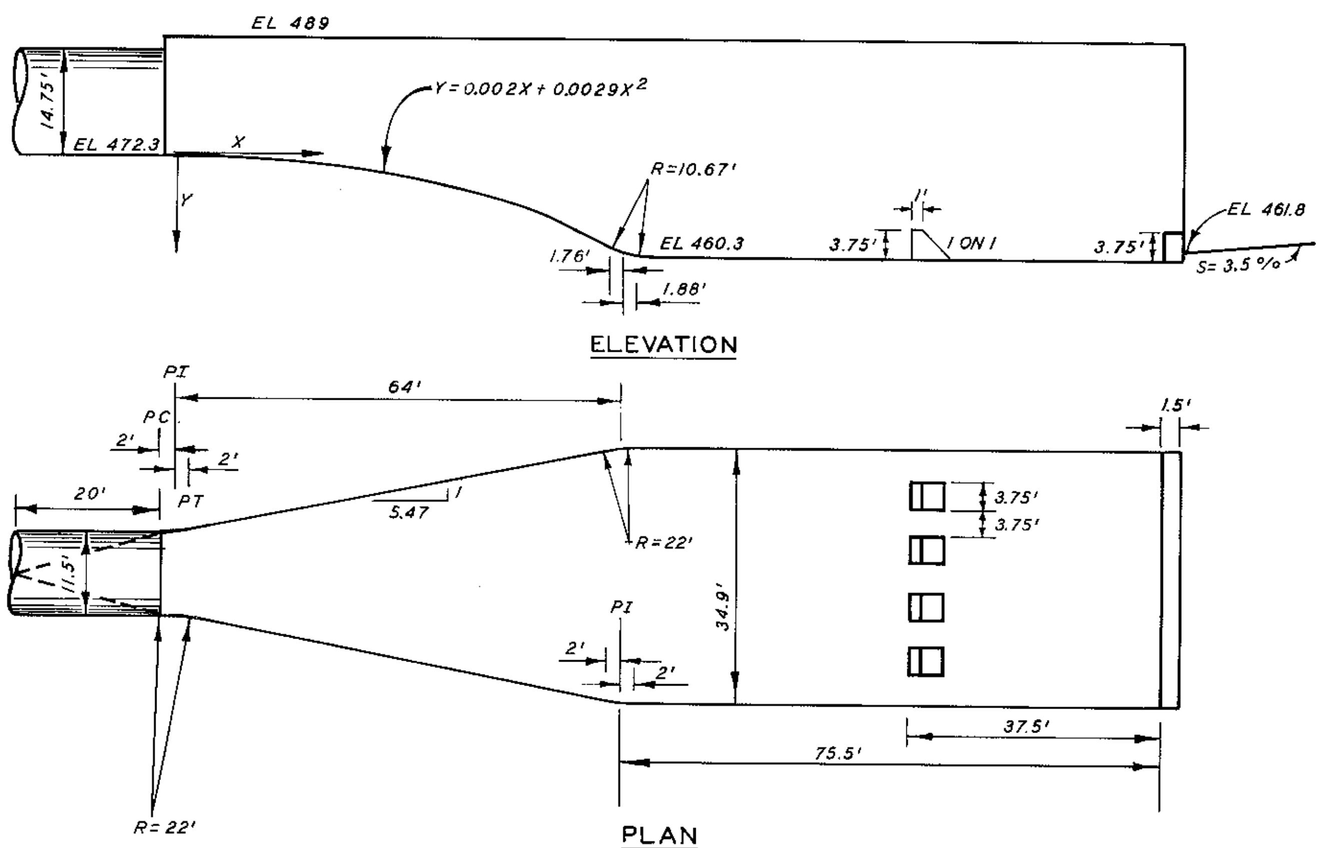
NOTE: FIVE 6-X 6-FT MULTILEVEL INTAKES OPEN FULL AND EMERGENCY GATE CLOSED



MULTILEVEL THROAT SECTION

MINIMUM PRESSURES IN MULTILEVEL THROAT SECTION

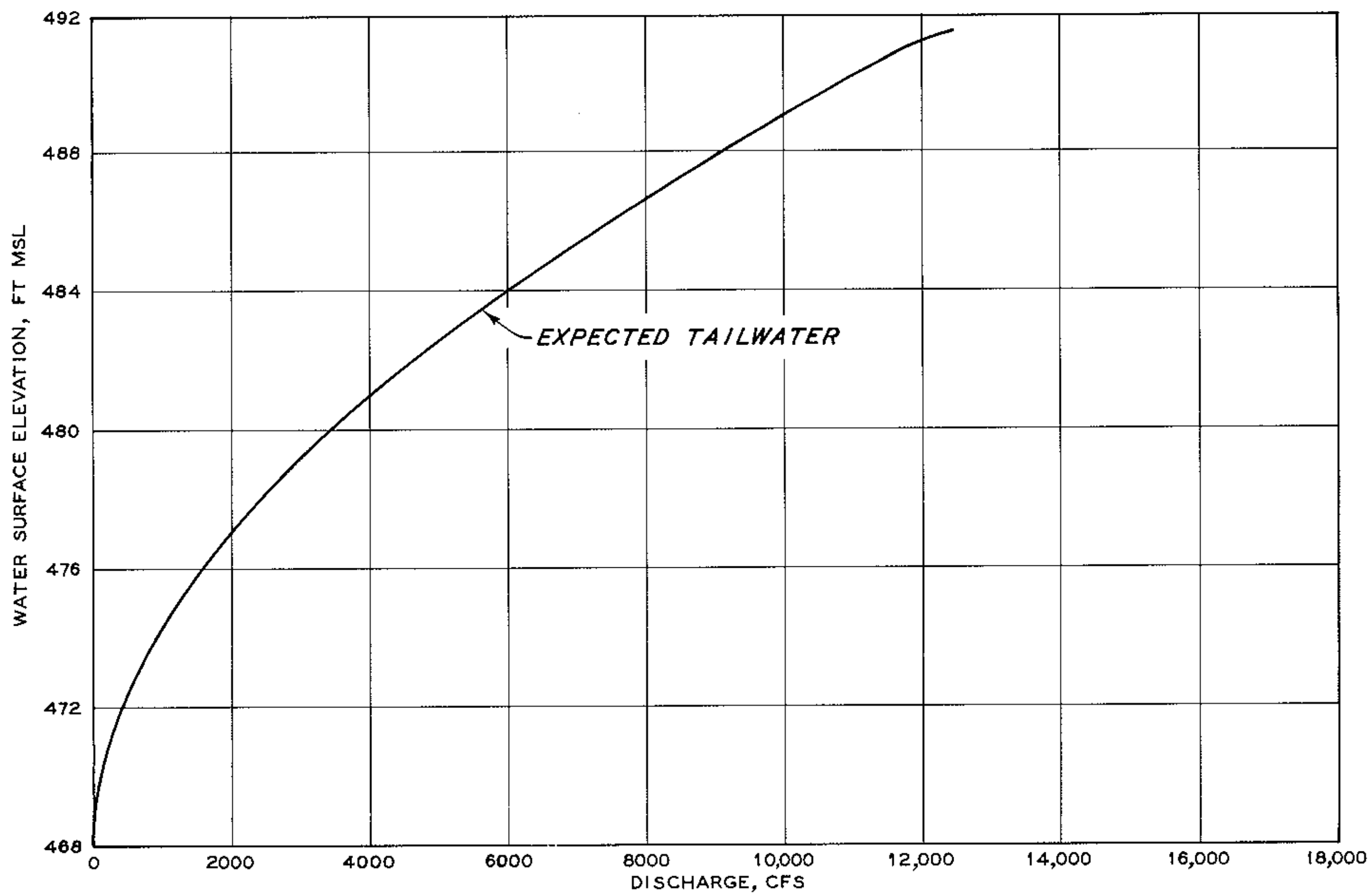
WATER-QUALITY FLOW THROUGH SINGLE WET WELL



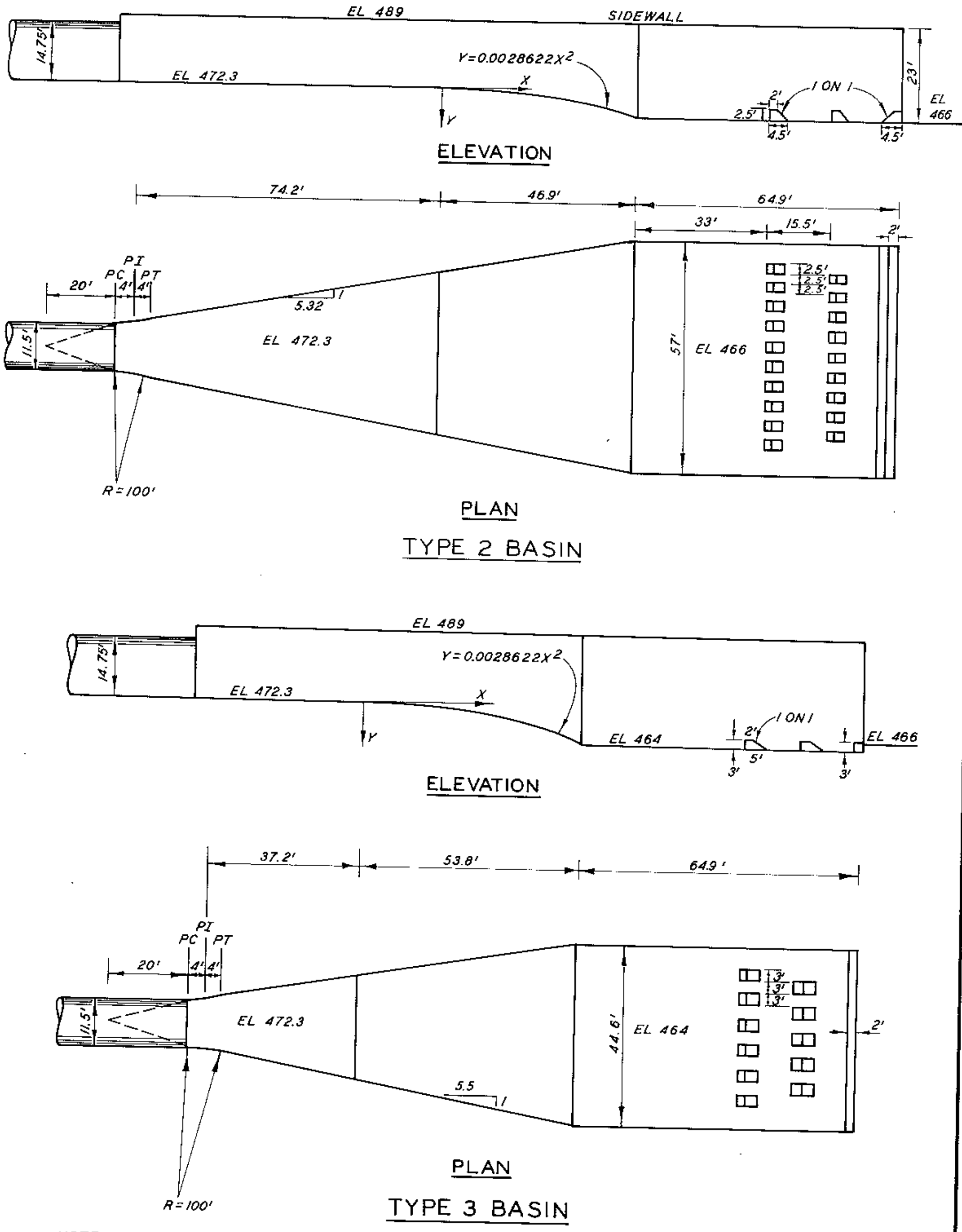
NOTE: ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

DETAILS OF STILLING BASIN

TYPE I (ORIGINAL)

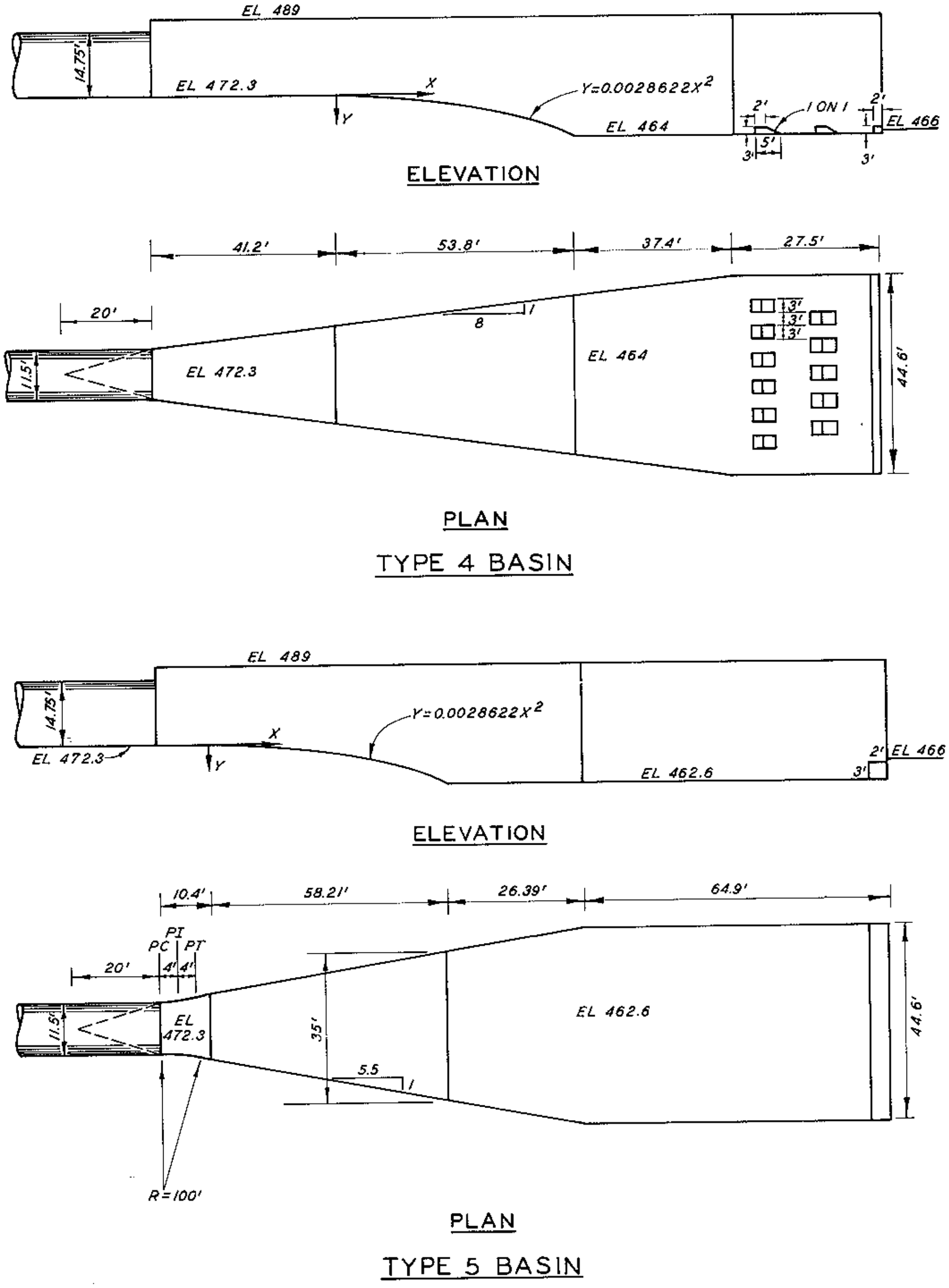


TAILWATER CURVE AT
STILLING BASIN END SILL



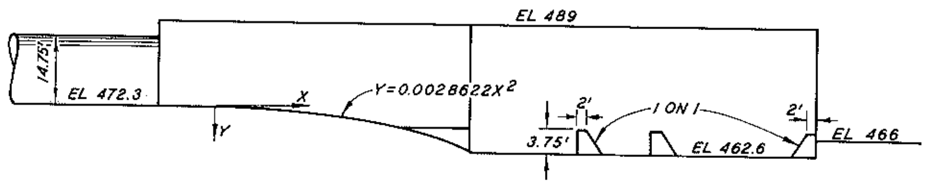
NOTE: ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

DETAILS OF STILLING BASINS
TYPES 2 AND 3

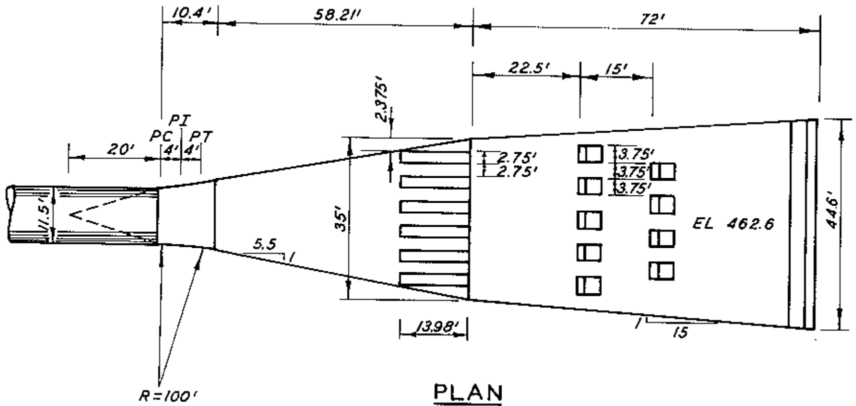


NOTE: ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

DETAILS OF
STILLING BASINS
TYPES 4 AND 5

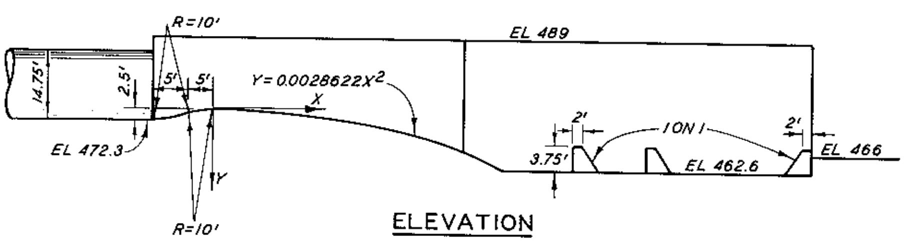


ELEVATION

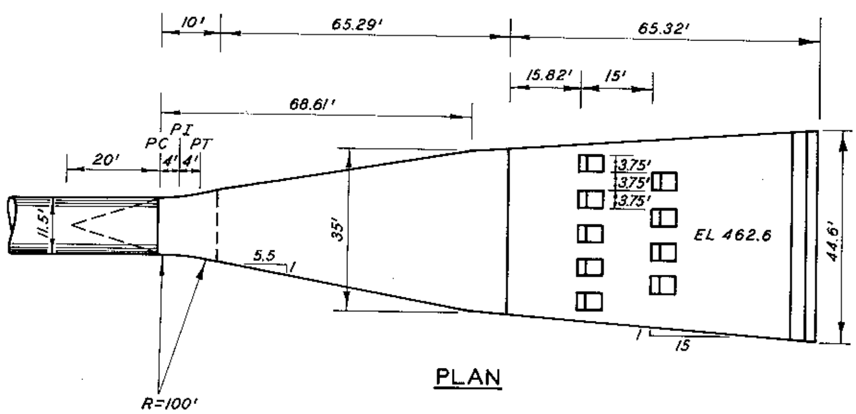


PLAN

TYPE 6 BASIN



ELEVATION



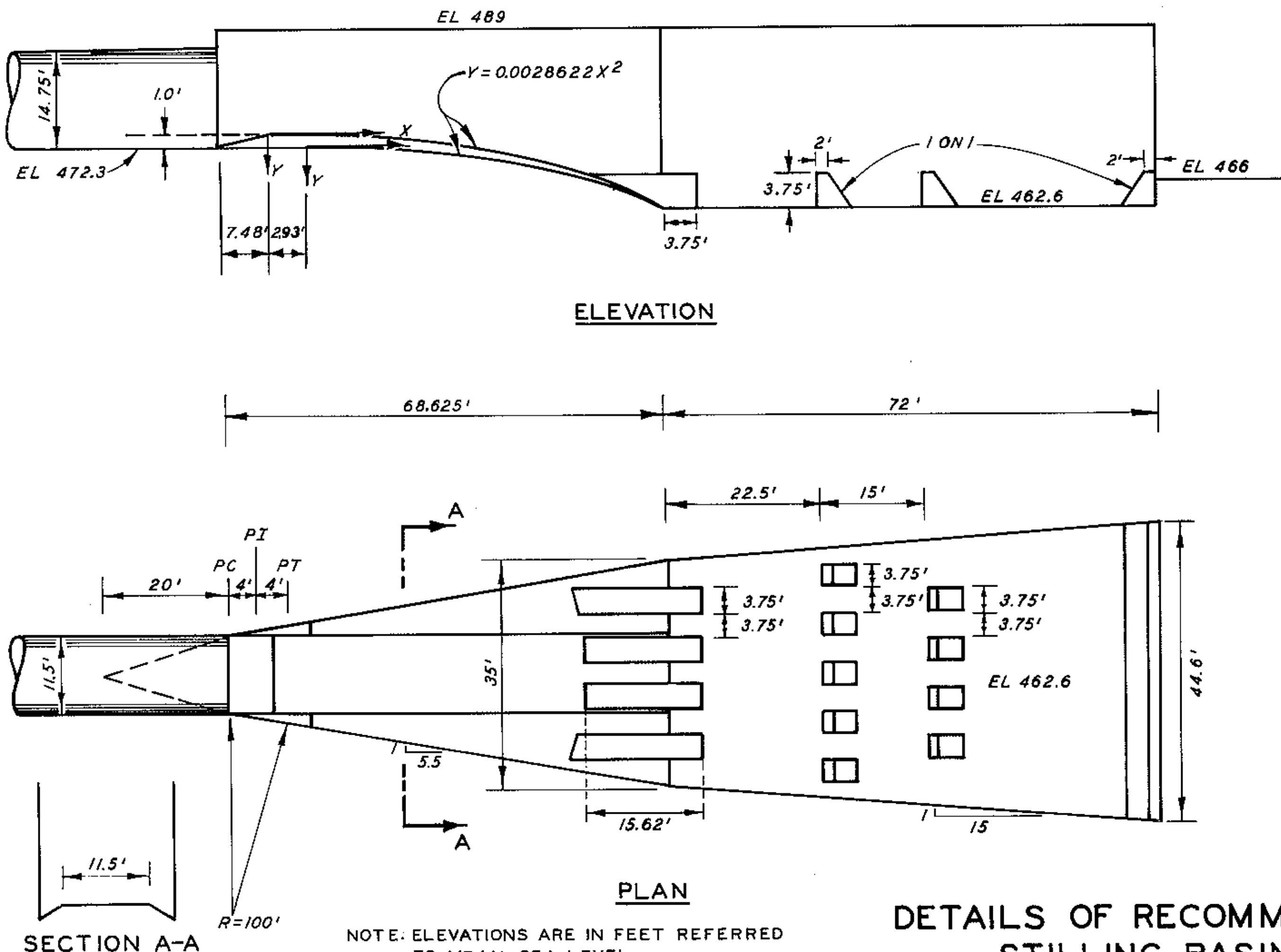
PLAN

TYPE 7 BASIN

NOTE: ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

DETAILS OF STILLING BASINS

TYPES 6 AND 7



NOTE: ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

DETAILS OF RECOMMENDED
STILLING BASIN
TYPE 8

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Dortch, Mark S

Outlet works for Taylorsville Lake, Salt River, Kentucky; hydraulic model investigation, by Mark S. Dortch. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1975.

1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report H-75-12)

Prepared for U. S. Army Engineer District, Louisville, Louisville, Kentucky.

1. Hydraulic models. 2. Outlet works. 3. Stilling basins. 4. Taylorsville Lake. I. U. S. Army Engineer District, Louisville. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report H-75-12)

TA7.W34 no.H-75-12