

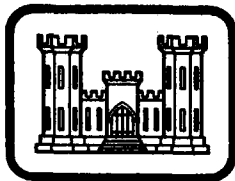
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MODEL STUDY OF HARRY S. TRUMAN SPILLWAY, OSAGE RIVER, MISSOURI--ETC(U)
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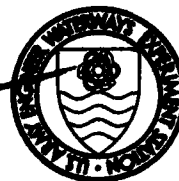
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TECHNICAL REPORT HL-79-20

MODEL STUDY OF HARRY S. TRUMAN SPILLWAY, OSAGE RIVER, MISSOURI

Hydraulic Model Investigation

by

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Hydraulics Laboratory

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November 1979

Final Report

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Prepared for U. S. Army Engineer District, Kansas City
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report HL-79-20 ✓	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 MODEL STUDY OF HARRY S. TRUMAN SPILLWAY, OSAGE RIVER, MISSOURI; Hydraulic Model Investigation.		5. TYPE OF REPORT & PERIOD COVERED Final report, Jan. Feb.
7. AUTHOR(s) 10 Glenn A. Pickering D. Bruce Murray		8. CONTRACT OR GRANT NUMBER(s) 19 WES/TF/HL-79-20
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12 55
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, Kansas City 700 Federal Bldg., 601 E. 12th St. Kansas City, Mo. 64106		12. REPORT DATE Nov 1979
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 51
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Aeration Osage River Gases Spillways Harry S. Truman Dam Supersaturation Hydraulic models		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A fish kill was experienced during the spring of 1978 downstream of the partially completed spillway of the Harry S. Truman Dam which is located on the Osage River in Benton County, Mo. The fish kill was attributed to excessive gas supersaturation in the water downstream of the dam. Flow passing the partially completed spillway became aerated and then plunged to the bottom of the stilling basin where high pressure caused by deep tailwater forced the air into solution. (Continued)		

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20. ABSTRACT (Continued).

A 1:30-scale section model was used to develop a design to prevent gas supersaturation downstream of the spillway for both the partially and fully completed spillway. Immediate relief from the problem was accomplished by removing a 6-ft-deep by 30-ft-long portion of the existing downstream spillway invert. Curves showing tailwater elevations where flow either will or will not plunge into the stilling basin for various discharges and stages of spillway completion were obtained.

A flip lip was developed for the lower portion of the completed spillway to divert lower flows out across the tailwater surface. Higher flows with thicker nappes will pass over this lip into the stilling basin for effective energy dissipation.

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PREFACE

The model investigation reported on herein was authorized by the U. S. Army Engineer District, Kansas City, on 5 June 1978. The model tests were accomplished during the period of June 1978 to February 1979 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and under the direct supervision of Mr. G. A. Pickering, Chief of the Locks and Conduits Branch. The engineer in immediate charge of the model was Mr. D. B. Murray, assisted by Messrs. J. H. Riley and J. C. Patterson. This report was prepared by Messrs. Murray and Pickering.

Messrs. Alfred S. Harrison of the Missouri River Division; Hugh Smith of the North Pacific Division; and Walter M. Linder, Jack Nelson, Byron Bircher, and Tom Wright of the Kansas City District visited WES during the course of the model study to observe model operation and correlate results with design work.

Commanders and Directors of WES during the conduct of the investigation and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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

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

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
atmospheres (normal)	101.325	kilopascals
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms

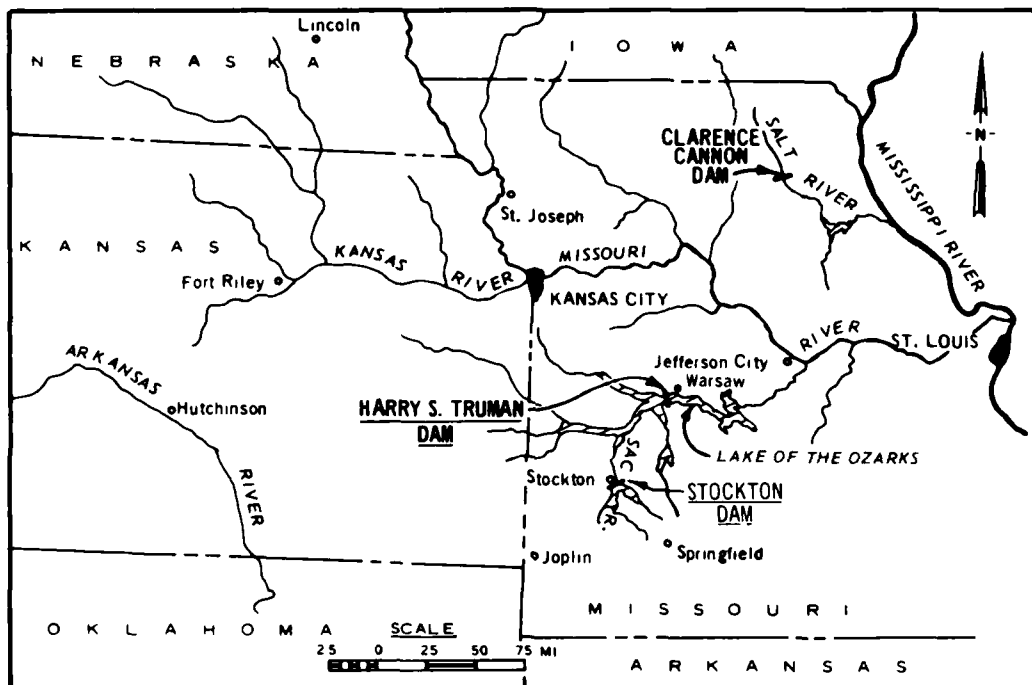


Figure 1. Vicinity map

HARRY S. TRUMAN SPILLWAY
OSAGE RIVER, MISSOURI
Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Harry S. Truman Dam at mile 175 on the Osage River in Benton County, Missouri (Figure 1), 1-1/2 miles* northwest of Warsaw is in the headwater area of the Lake of the Ozarks. Being a multipurpose dam, it will provide recreation, flood control, water conservation, and power-generating facilities. The principal features of the project are an earth-fill embankment, a four-gated overfall spillway, and a power installation. The overall length of the concrete sections and earth embankment will be approximately 5,000 ft, and the height of the dam above the riverbed will be about 126 ft when completed.

2. The ogee weir section with a crest elevation of 692.3** is designed to pass the spillway design discharge of 284,000 cfs at a head of 58.8 ft. Flows over the spillway will be controlled by four 40-ft-wide by 47.3-ft-high tainter gates, supported by 10-ft-wide piers, making the gross length of the weir 190 ft. The weir profile is designed to conform to the lower nappe shape of a weir with a 1V-on-0.5H upstream slope and a design head of 43 ft, which is approximately 75 percent of the 58.8 ft head required to pass the spillway design discharge. That portion of the weir upstream from the crest is formed by radii of 22.79, 9.37, and 2.09 ft, and the downstream portion will follow the curve described by the equation $y = x^{1.825}/43$. A general plan and sections of the portion of the dam investigated in this study are shown in Plate 1.

* 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 (msl).

3. The spillway stilling basin consists of a 206.08-ft-long horizontal apron at el 612.0, surmounted by two staggered rows of 16.5-ft-high baffle piers and a 6-ft-high end sill. The left training wall extends the full length of the basin with its top at el 682.0 and has a 4V-on-1H slope on the inside face. The powerhouse confines the flow on the right side of the basin. A divider wall with its top at el 677.0 separates the powerhouse tailrace and the stilling basin.

4. The four-bay spillway was constructed to el 660.0 (Figure 2, Plate 2) when the last cofferdam of the earth fill was placed to seal



Figure 2. The prototype with spillway completed to el 660.0

off the river and impound water. Construction scheduling provided for raising the partially completed spillway to a final crest elevation of 692.3 by alternately constructing 5- and 6-ft-high concrete lifts in each of the bays.

Problem Description

5. A fish kill was experienced during the spring of 1978 downstream of the partially completed spillway. The cause of the fish kill was attributed to gas embolism due to excessive supersaturation of total dissolved gases in the water downstream of the dam. Flow passing the partially completed spillway (constructed to el 660.0, Figure 3 and Plate 2) became aerated and then plunged to the bottom of the stilling basin. The relatively deep tailwater of approximately 45 ft induced pressures of about 1.3 atmospheres. This pressure forced the air into solution and yielded dissolved gas concentrations equal to about 125 to 130 percent of the saturated level at the surface of the water. These levels were excessive during a period when certain fish were spawning in near surface waters.



Figure 3. 1:30-scale model with spillway completed to el 660.0

Purpose of Model

6. The design of the Harry S. Truman spillway is adequate to pass a design discharge of 284,000 cfs while maintaining satisfactory hydraulic conditions at the weir, in the stilling basin, and in the outlet channel when completed.* However, during the diversion of relatively

* G. A. Pickering, "Spillway for Kaysinger Bluff Dam Osage River, Missouri; Hydraulic Model Investigation," Technical Report No. 2-809, Jan 1968, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

low riverflows through the partially completed spillway, excessive air entrainment in the outlet area produced supersaturation conditions of total dissolved gases which extended throughout the Osage arm of the Lake of the Ozarks and produced substantial adverse environmental effects. A model study was needed to investigate the cause and to develop modifications to prevent gas supersaturation on both the immediate uncompleted spillway and on the future completed spillway. Such modifications developed should operate effectively in the prevention of gas supersaturation during diversions of relatively low riverflows through the spillway, but not interfere with stilling basin performance during release of higher discharges.

PART II: THE MODEL

Description

7. The undistorted, 1:30-scale model (Plate 3, Figure 4), reproduced 313 ft of approach channel topography, a 60-ft-wide section of the partially completed spillway and stilling basin, and 320 ft of exit channel topography. The 40-ft-wide partially completed spillway, 5- and 6-ft-deep concrete lifts, flip lips, and two 10-ft-wide piers were fabricated of sheet metal. The baffle blocks and end sill in the stilling basin were made of wood. Topography in the approach and exit area was reproduced by cement mortar molded to sheet-metal templates.

Appurtenances

8. Water used in operation of the model was supplied by pumps, and discharges were measured by means of venturi meters. Steel rails set to grade along the sides of the flume provided a reference plane for measuring devices. Water-surface elevations were measured by means of a point gage. Tailwater elevations were regulated by a gate at the downstream end of the flume. Wave heights were measured with a capacitance-type water-surface detector that produced a continuous record of the water-surface elevation versus time. A clear plastic window in the flume allowed for observation and photography of the spillway nappe.

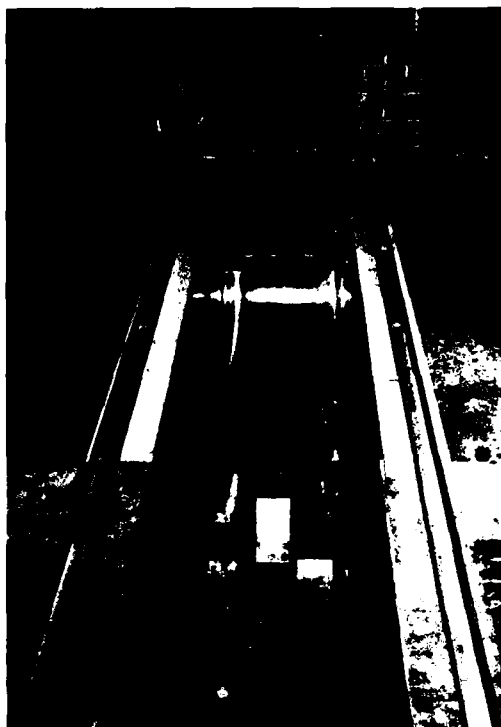


Figure 4. Spillway completed to el 660.0 and end sill

Scale Relations

9. The accepted equations of hydraulic similitude based on the Froudian relations were used to express mathematical relations between dimensions and hydraulic quantities of the model and the prototype. General relations for the transference of model data to prototype equivalents are as follows:

<u>Dimension</u>	<u>Ratio</u>	<u>Scale Relation</u>
Length	L_r	1:30
Area	$A_r = L_r^2$	1:900
Velocity	$V_r = L_r^{1/2}$	1:5.477
Discharge	$Q_r = L_r^{5/2}$	1:4929

PART III: TESTS AND RESULTS

Test Procedure

10. The U. S. Army Engineer District, Kansas City, provided headwater and tailwater rating curves for the completed structure (Plates 4 and 5). For partially completed spillway flow conditions, the headwater elevation was determined from the model for each discharge. These data are shown in Plate 6. To judge the adequacy of various designs, visual observations of the nappe and entrained air bubbles were made. Direct measurement and simulation of gas content were not attempted in the model due to the urgency for determining the cause and evaluating alternative solutions of the problem.

Partially Completed Spillway Crest to El 660.0

11. Initial tests were conducted with the spillway crest partially completed to el 660.0 as shown in Plate 2. Flow passing over the spillway plunged through the tailwater to the stilling basin apron for all discharges with normal tailwater elevations as was experienced in the prototype (Photos 1a-8a). As the tailwater was raised for each of the various discharges, there was an elevation at which flow began to ride the surface. A plot showing this tailwater elevation for various discharges up to 10,000 cfs per bay is shown in Plate 7.

12. Several possible modifications were tested in the model in an effort to produce riding flow along the surface with normal tailwater elevations and thus reduce gas saturation. These modifications included: (a) placing objects under the nappe, (b) placing objects in the stilling basin, and (c) structural changes to the spillway.

Placing objects under nappe

13. It appeared that the easiest and quickest nonpermanent solution in the prototype was to float a net into place with the desired result of intercepting and deflecting the plunging nappe. Testing with several different sizes of net proved ineffective. A bar or beam held

by cables was placed across the spillway invert in an effort to deflect the flow and cause it to ride along or near the tailwater surface. This also proved to be ineffective.

Modification to stilling basin

14. Since the gas supersaturation was caused by the high pressure induced by the deep tailwater to which the plunging nappe was exposed, tests were conducted with the stilling basin apron raised to various levels by means of materials such as automobile bodies and large derrick stone. Initial tests were conducted to determine if flattened automobile bodies would withstand the forces of the jet entering the basin. Each body simulated a prototype size of 20 by 8 by 1.8 ft with a weight of 2,000 lb. Single bodies when placed in the basin near the toe of the spillway were moved downstream and settled around the baffle blocks. Four of the bodies were lashed together (two deep and two abreast); again, the bodies were moved downstream by the jet. Thus, it was concluded that this type of material was not suitable for reducing the depth to which the jet would be allowed to plunge.

15. The stilling basin was filled 20 to 22 ft deep with 4- to 6-ft-diam derrick stone. This rock became unstable at discharges of 8,000 cfs per bay and greater. Violent rock movement and scour hole formation occurred with discharges equal or greater than 12,000 cfs per bay. Instability of fill materials and high estimated costs proved the idea of raising the stilling basin floor to be ineffective.

Flip lip

16. Since none of the temporary type modifications were successful in reducing the gas saturation potential, tests were initiated with more permanent types of modifications. A flip lip on the lower portion of the spillway had been used successfully by the U. S. Army Engineer Division, North Pacific, on structures in the Columbia River. This reinforced concrete lip projects into the nappe causing lower flows to ride along the water surface in the stilling basin, whereas higher flows with thicker nappes will ride over the lip and plunge into the stilling basin. Previous research had indicated that the elevation of the lip relative to the tailwater was very important in causing the jet to ride

along the water surface. Also, the length of the lip (the horizontal projection from the spillway crest) determines the discharge range at which flow begins to ride over the lip into the stilling basin.

17. Initial tests with the flip lip design were conducted on the spillway shape completed to el 660.0 ft (Figure 5). Flip lip lengths of 5.0, 7.0, 15.0, and 17.5 ft were placed and tested at el 650.0 and 655.0. The optimum elevation of the lip appeared to be 655.0 for the expected discharges and tailwater elevations. The smaller lips of 5.0 and 7.0 ft worked well with discharges less than 5,000 cfs per bay. However, with larger discharges, flow rode over the lip and plunged into the basin. Various flows over the partially completed spillway with the 7-ft-long lip at el 655.0 are shown in Photos 1b-8b. The longer lips were successful in diverting larger discharges along the surface. However, concerns for fabricating such large elements in the prototype and their effect on larger flood flows resulted in a search for other methods of diverting flow with the partially completed spillway.

Objects on spillway

18. Another alternative considered was placing objects on the spillway invert in an effort to break up the jet and cause the nappe to ride. Both baffle blocks of various sizes and configurations and 1-, 2-, and 3-ft-high weirs were placed across the flat spillway in an effort to jet the flow out over the tailwater surface. None of these revisions gave satisfactory results.

19. Tests were then conducted with various portions of the next



Figure 5. Spillway completed to el 660.0 with 7-ft flip lip added at el 655.0

6-ft-high concrete lifts in place to determine if this would change the angle of the jet at the downstream side of the spillway. This had little effect on flow conditions and the jet plunged for all discharges tested with normal tailwater elevations. However, when the tailwater was raised 5 to 6 ft, the jet rode the surface with the lower discharges. Thus, it was concluded that if some of the downstream portion of the existing crest could be removed, flow conditions would be improved with normal tailwaters.

Breakouts

20. Tests were conducted with various lengths and depths of the downstream portion of the spillway concrete lifts removed. Lengths ranging from 24 to 67 ft and depths of 4 and 6 ft were tested. Table 1 lists the discharges, breakout areas, and tailwaters tested along with comments about flow conditions. In general, the longer and deeper break-



Figure 6. Spillway completed to el 660.0 with a 6-ft-deep by 30-ft-long breakout of the downstream spillway invert to el 654.0

outs produced riding flow with a larger range of discharges. However, from a practical standpoint of cost and time to modify the prototype structure it was found that breaking out a length of 30 ft for a depth of 6 ft to el 654.0 was optimum. This caused discharges of 12,000 cfs per bay or less to ride the surface with tailwater at or below normal as shown in Photos 9-13. This breakout is shown in Figure 6 and Plate 2. Plate 8 shows tailwater elevations for various discharges where flow began to ride the surface.

Completed Spillway Crest

Flip lip

21. Since it was obvious that low flows would follow the completed crest shape and plunge through the tailwater to the basin apron, tests were conducted with the completed crest to determine the optimum size and elevation of the flip lip. Lip lengths of 5.0, 7.0, and 9.5 ft were tested at el 653.0, 655.0, and 658.0. Curves showing tailwater elevations where flow plunged or rode the tailwater surface for three of the combinations of lengths and elevations are shown in Plates 9, 10, and 11. The 7-ft-long lip at el 655.0 produced the best overall results as shown in Photos 14-20. It diverted the lower flows along the surface of the tailwater and allowed the larger flows to pass into the stilling basin for effective energy dissipation. This design was recommended for the prototype modification and is shown in Plate 12 and in Figure 7.

Wave heights

22. Wave heights were measured approximately 550 ft downstream from the spillway with and without the recommended flip lip in place. Maximum wave heights were about 5.5 ft with the lip in place for a discharge of 10,000 cfs per bay, whereas wave heights without the lip in place and with the same discharge were about 3 ft. With discharges of 16,000 cfs per bay and greater, the lip had little effect on wave heights. It was concluded from these tests that the flip lip would not greatly increase wave heights along the streambanks downstream.



Figure 7. Spillway completed to el 692.3 with 7-ft flip lip at el 655.0 (recommended design)

Intermediate Spillway Elevations

23. Since the spillway crest will be raised in increments by alternately constructing 5- or 6-ft-high concrete lifts in the gate bays, data were needed with the spillway completed to various elevations. Tests to determine flow conditions were conducted with the spillway completed to el 666.0, 671.0, 676.0, 681.0, and 686.0. These tests were conducted with the 7-ft flip lip on the spillway, since the lip will be constructed in the prototype before the spillway is raised. Curves showing tailwater elevations where flow plunged for various discharges with the spillway completed to various elevations are shown in Plates 13-17.

PART IV: SUMMARY AND DISCUSSION

24. The crest of the four-bay spillway at Harry S. Truman Dam will be at el 692.3 when completed. The spillway was constructed to el 660.0 when it became necessary to divert flows over the structure while the earth-fill dam over the natural river was being raised. The spillway will be raised by adding 5- or 6-ft concrete lifts in alternate gate bays as flow allows.

25. During the spring of 1978, flows passing over the partially completed spillway became aerated and plunged to the bottom of the stilling basin causing the water to become supersaturated with gases. An estimated 400,000 fish were killed in the area downstream from the structure and this was attributed to the high level of supersaturated gases in the water. Model studies were needed to determine methods to reduce the gases in the flow with the spillway crest constructed to various elevations, including the completed shape. Since the high gas levels in the water were created by the pressure due to the relatively deep tailwater to which the plunging nappe was exposed in the stilling basin, it was concluded that modifications to the structure were needed that would cause low flows to ride along the surface of the tailwater rather than plunge to the basin apron. However, any modification to the completed spillway should not interfere with energy dissipation for the higher discharges.

26. Several modifications were tested with the spillway partially completed to el 660.0. These included placing objects such as nets under the jet, placing objects in the stilling basin to reduce the level to which the jet could plunge, adding baffles and sills to the spillway crest, adding the flip lip on the spillway, and removing part of the constructed spillway crest. With the exception of adding a flip lip, none of the modifications other than removing the downstream part of the highest spillway concrete lift was successful in eliminating the problem. Breaking out the downstream portion of the existing spillway monolith to lower elevations allowed flow to ride along the surface for the range of discharges expected with the partially completed spillway.

The optimum breakout was found to be 30 ft long and 6 ft deep and this modification was immediately recommended for the prototype.

27. A flip lip was developed for the completed spillway that caused lower flows to ride along the surface, but allowed high flows to pass into the stilling basin for effective energy dissipation. The recommended lip was 7 ft long and was placed at el 655.0. The flip lip did not greatly increase wave heights downstream from the structure except for a very limited range of discharges.

28. Since the spillway crest will be raised in increments of 5 or 6 ft, data were obtained to determine flow conditions with the spillway completed to el 666.0, 671.0, 676.0, 681.0, and 686.0.

Table 1
Tests on Breaking Out Spillway Invert

Discharge per Bay cfs	Head- water	Invert Breakout Distance		Tail- water El	Comments
		U.S. ft	Down to El, ft		
8,000	678.5	52	654	659.0	Flow rides surface
8,000	676.1	67		659.0	
12,000	682.7	67		663.0	
12,000	684.2	52		663.0	
10,000	682.0	27		661.5	1/2-in. hardwood cloth simu- lates roughness of broken out area, 5-ft rooster tail--flow rides
10,000		30			Flow rides surface
10,000		33			Flow rides surface
10,000		41			+7-ft rooster tail--flow rides
10,000		37			Flow rides surface
10,000		23			Almost plunging
10,000		20			Plunging
10,000		24			Flow rides--roughly
10,000	681.6	30	656	662.0	Flow rides surface but a lot of turbulence reaches the bottom, +6-ft rooster tail
10,000	681.4	24			Flow rides some then appears to plunge upstream of baffle blocks--lots of bubbles on bottom and flow plunges eventually
10,000	682.1	33			Flow rides surface then plunges into baffle blocks-- a lot of turbulence. Fair conditions only
10,000	681.8	36			Flow is turbulent but rides the surface fairly well. A lot of bubbles reach the floor

(Continued)

Table 1 (Concluded)

Discharge per Bay cfs	Head- water	Invert Breakout Distance		Tail- water El	Comments
		U.S. ft	Down to El, ft		
10,000		39	656	662.0	Flow rides the surface well; some turbulence reaches the bottom but looks pretty good
2,000	670.4	30	654	658.0	Tailwater rides surface nicely
2,000	670.4			646.4	Plunges but will ride back out onto surface. No good
2,000	670.4			652.1	Tailwater still rides surface but turbulence stays free of bottom
4,000	676.4			658.5	Tailwater rides surface
4,000				651.8	Permits reverse roller on surface
4,000				657.0	Tailwater rides satisfac- torily. Note: Tailwater will ride from 652.5 on, but not very satisfactorily
8,000	678.5			660.0	Rides surface nicely
8,000	676.5			656.7	Borderline between plunging and riding the surface when raising tailwater from plunging condition
8,000	678.5			657.2	Borderline when lowering tail- water from riding surface
10,000	681.4			661.0	Flow rides okay
10,000	681.4			658.9	Borderline, just between plunging when lowering tail- water from riding surface
10,000	681.4			657.7	Borderline, from plunging to riding the surface
12,000	684.4			662.0	Flow rides
12,000	684.4			659.8	Transition from riding to plunging conditions. Note: Fully plunging at tailwater el 658.7
12,000	684.4			660.1	Transition from plunging to riding the surface



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 1. Spillway completed to el 660.0; discharge 2,000 cfs
per bay, tailwater el 657.0



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 2. Spillway completed to el 660.0; discharge 4,000 cfs
per bay, tailwater el 658.0



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 3. Spillway completed to el 660.0; discharge 5,000 cfs
per bay, tailwater el 658.5



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 4. Spillway completed to el 660.0; discharge 6,000 cfs
per bay, tailwater el 658.5



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 5. Spillway completed to el 660.0; discharge 8,000 cfs
per bay, tailwater el 659.0



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 6. Spillway completed to el 660.0; discharge 10,000 cfs
per bay, tailwater el 661.5



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 7. Spillway completed to el 660.0; discharge 12,000 cfs
per bay, tailwater el 663.0



a. Without flip lip



b. With 7-ft flip lip at el 655.0

Photo 8. Spillway completed to el 660.0; discharge 16,900 cfs
per bay, tailwater el 669.0



Photo 9. Spillway completed to el 660.0; 6- × 30-ft invert breakout, discharge 2,000 cfs per bay



Photo 10. Spillway completed to el 660.0; 6- × 30-ft invert breakout, discharge 4,000 cfs per bay



Photo 11. Spillway completed to el 660.0; 6- × 30-ft invert breakout, discharge 8,000 cfs per bay



Photo 12. Spillway completed to el 660.0; 6- × 30-ft invert breakout, discharge 10,000 cfs per bay

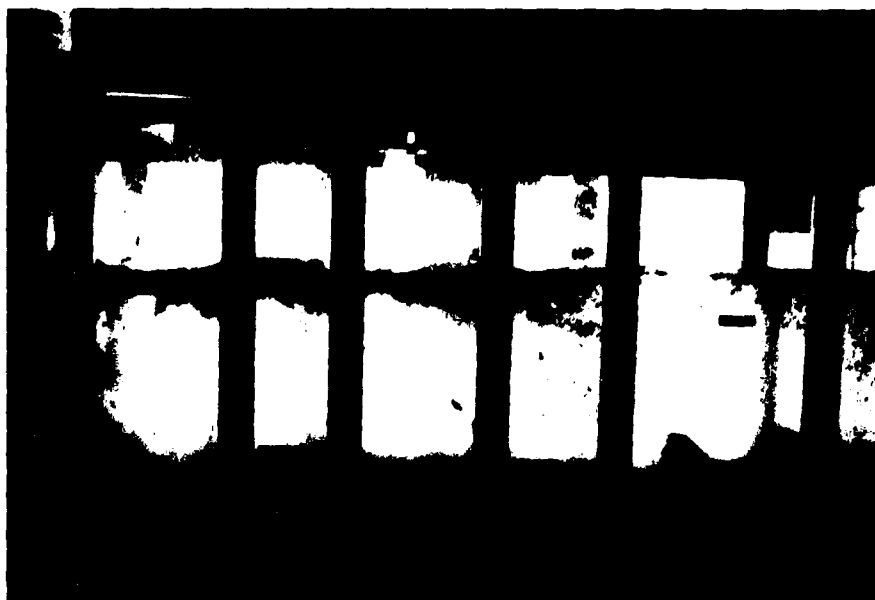


Photo 13. Spillway completed to el 660.0; 6- × 30-ft invert breakout, discharge 12,000 cfs per bay



Photo 14. Completed spillway crest with 7-ft flip lip at el 655.0; discharge 2,000 cfs per bay, headwater 717.0, tailwater el 652.0



Photo 15. Completed spillway crest with 7-ft flip lip at
el 655.0; discharge 2,000 cfs per bay, headwater 735.5,
tailwater el 660.0



Photo 16. Completed spillway crest with 7-ft flip lip at
el 655.0; discharge 6,000 cfs per bay, headwater 735.5,
tailwater el 665.0



Photo 17. Completed spillway crest with 7-ft flip lip at
el 655.0; discharge 7,000 cfs per bay, headwater 735.5,
tailwater el 660.0



Photo 18. Completed spillway crest with 7-ft flip lip at
el 655.0; discharge 8,000 cfs per bay, headwater 735.5,
tailwater el 660.0



Photo 19. Completed spillway crest with 7-ft flip lip at
el 655.0; discharge 12,000 cfs per bay, headwater 740.0,
tailwater el 663.0



Photo 20. Completed crest shape with 7-ft flip lip at
el 655.0; discharge 16,900 cfs per bay, headwater 740.0,
tailwater el 669.0

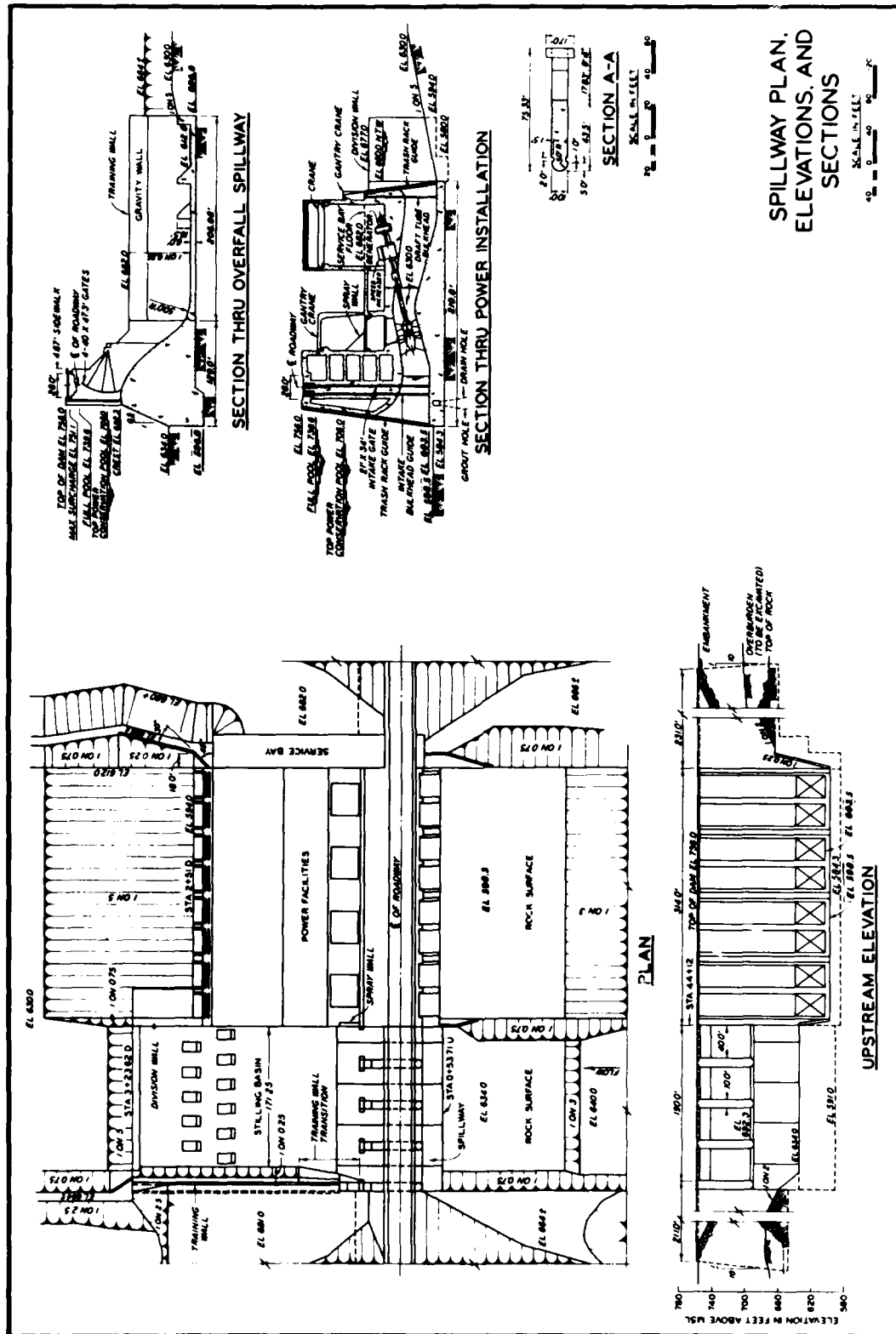
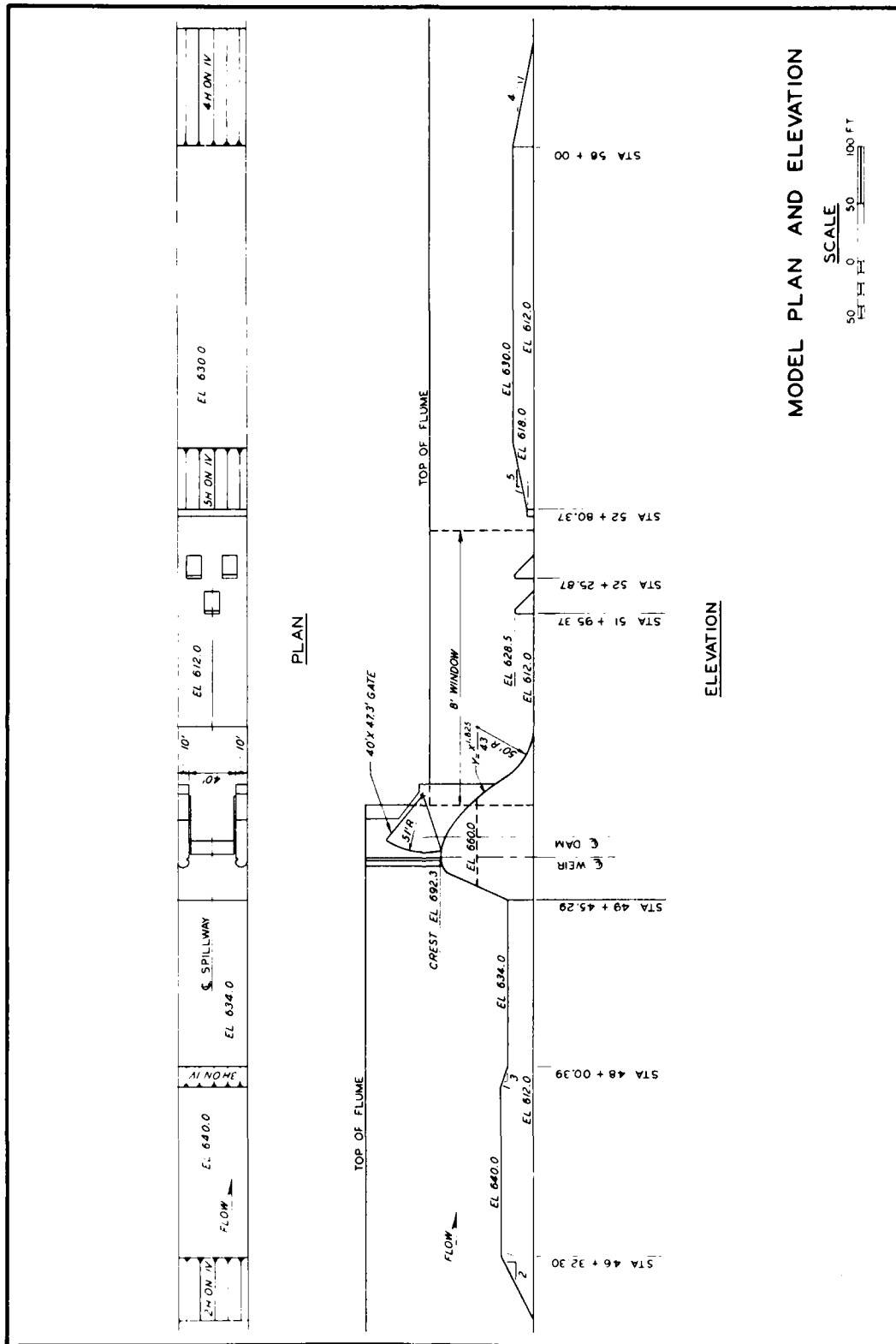
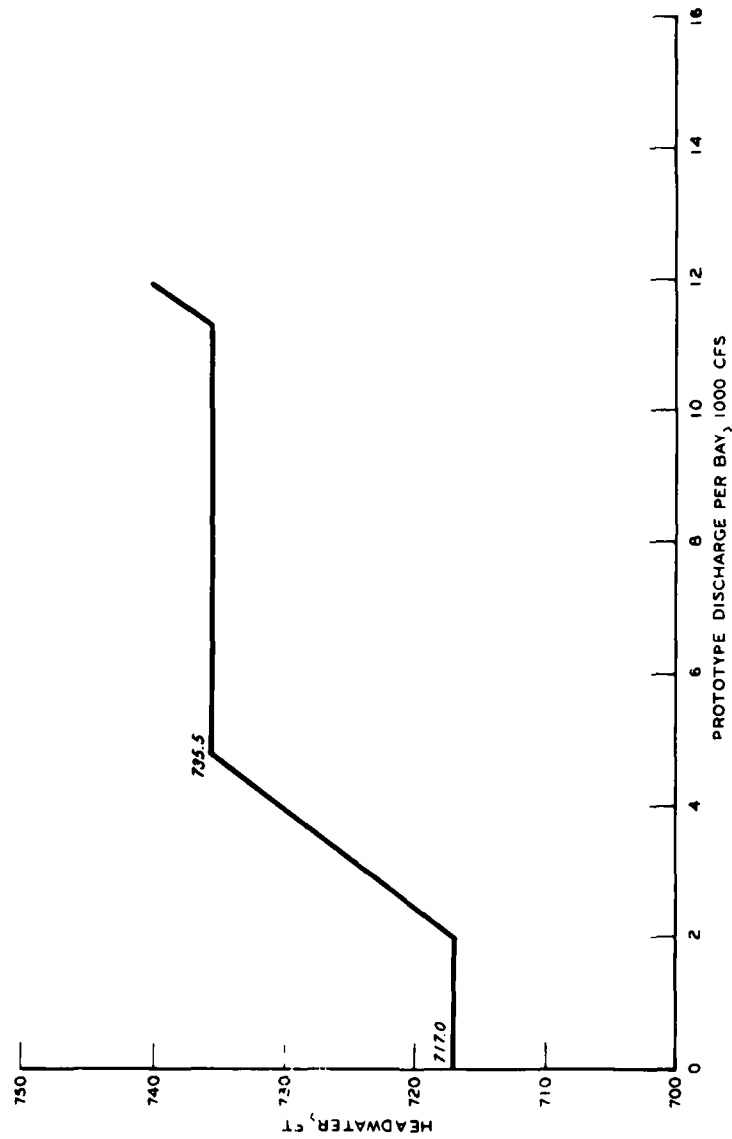


PLATE 1

SCALE







NOTE: INFORMATION SUPPLIED
BY K.C. DISTRICT.

SPILLWAY DISCHARGE VS HEADWATER
FOR SPILLWAY COMPLETED TO EL 692.3

PLATE 4

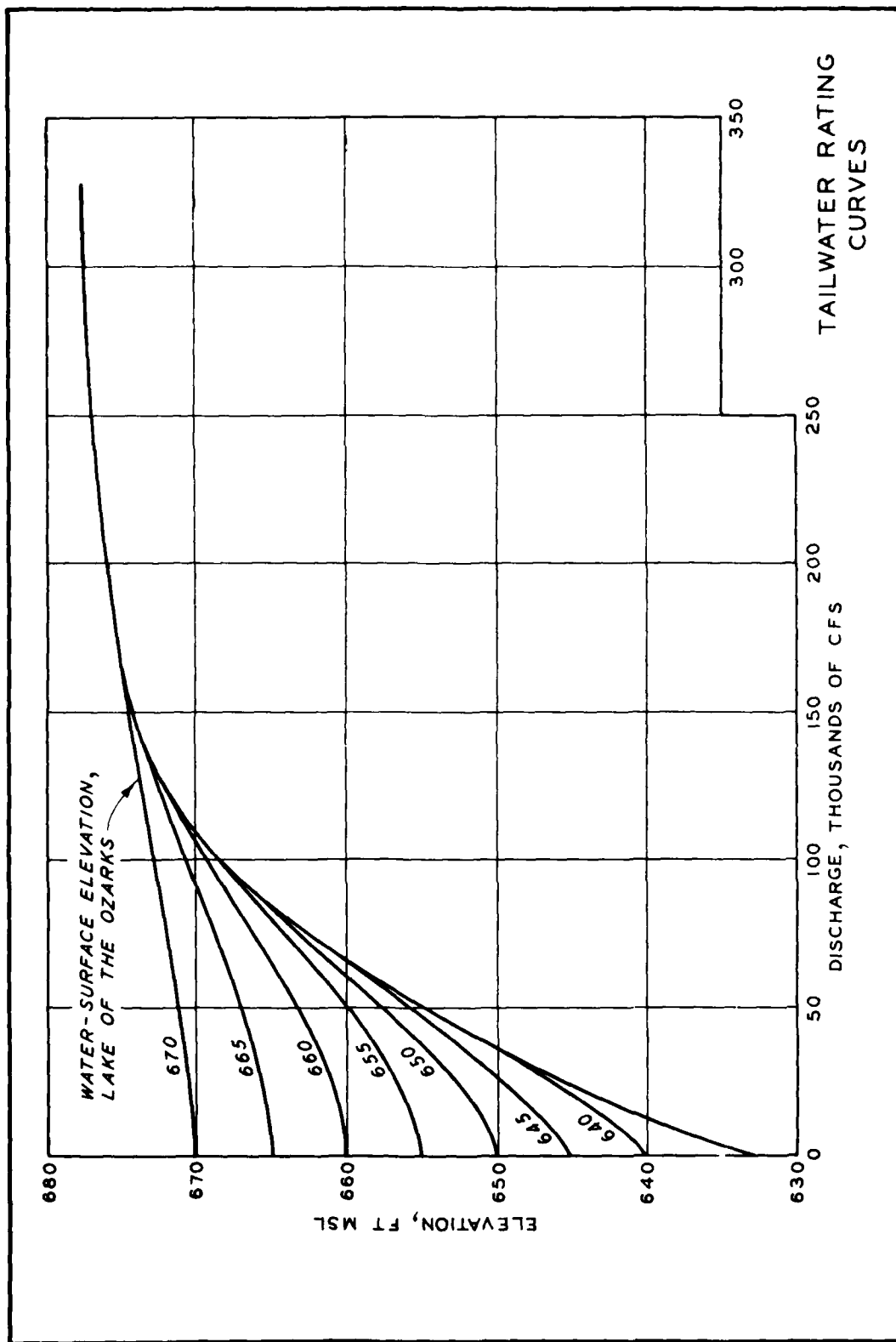
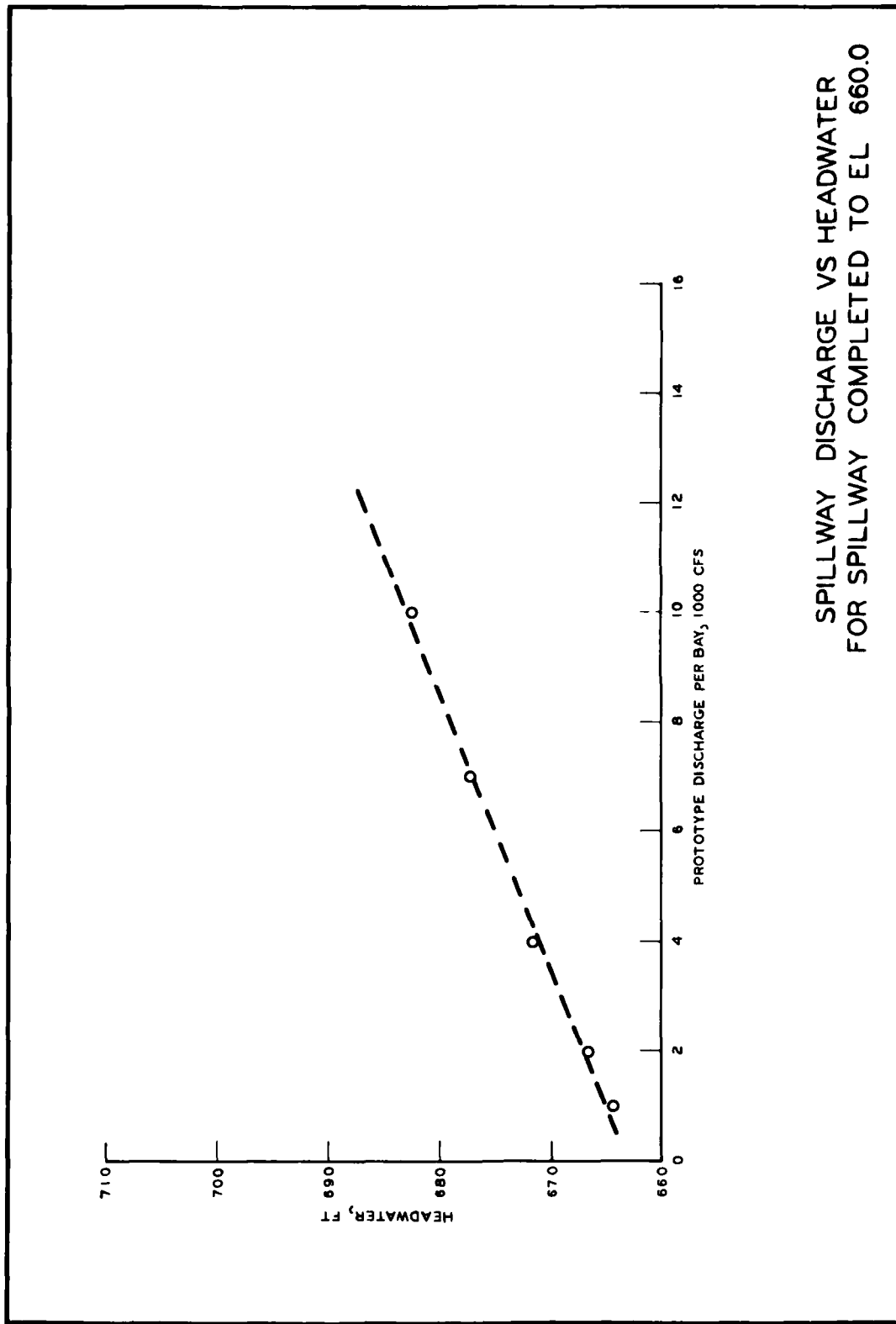
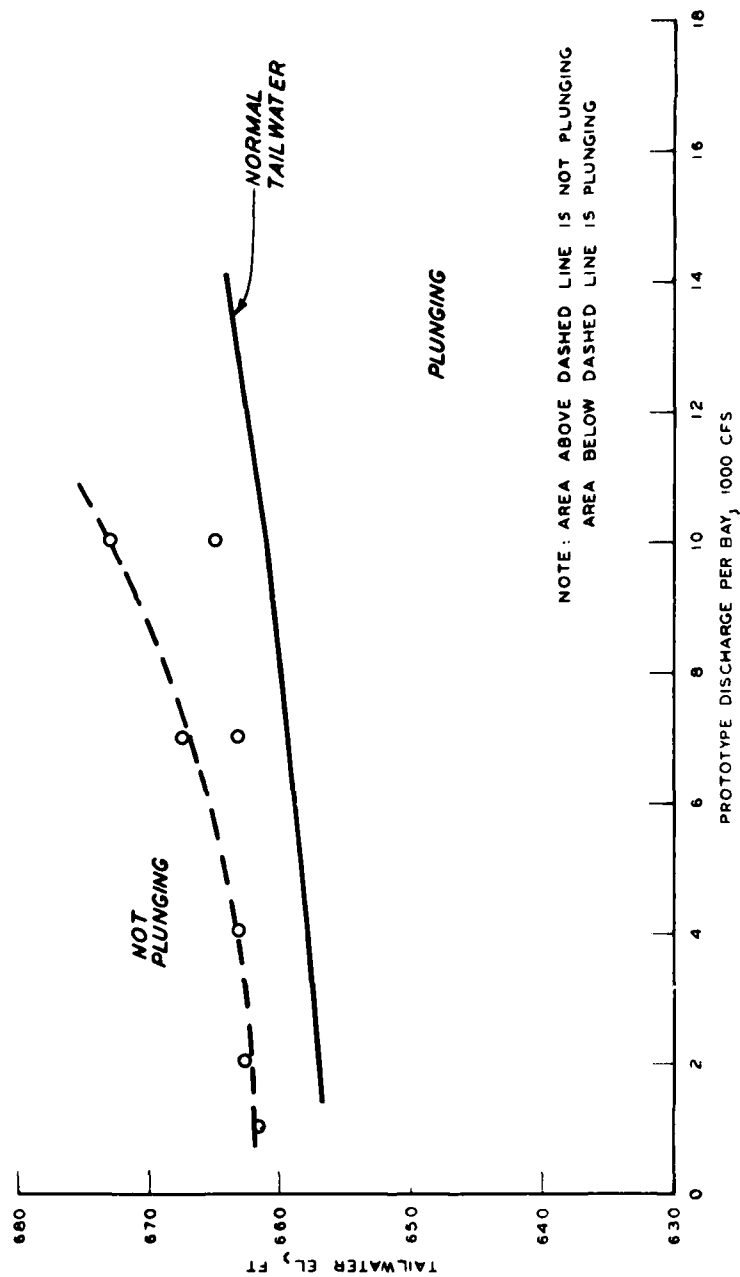


PLATE 5



SPILLWAY DISCHARGE VS HEADWATER
FOR SPILLWAY COMPLETED TO EL 660.0



NOTE: AREA ABOVE DASHED LINE IS NOT PLUNGING
AREA BELOW DASHED LINE IS PLUNGING

ORIGINAL DESIGN-SPILLWAY INVERT
COMPLETED TO EL 660.0

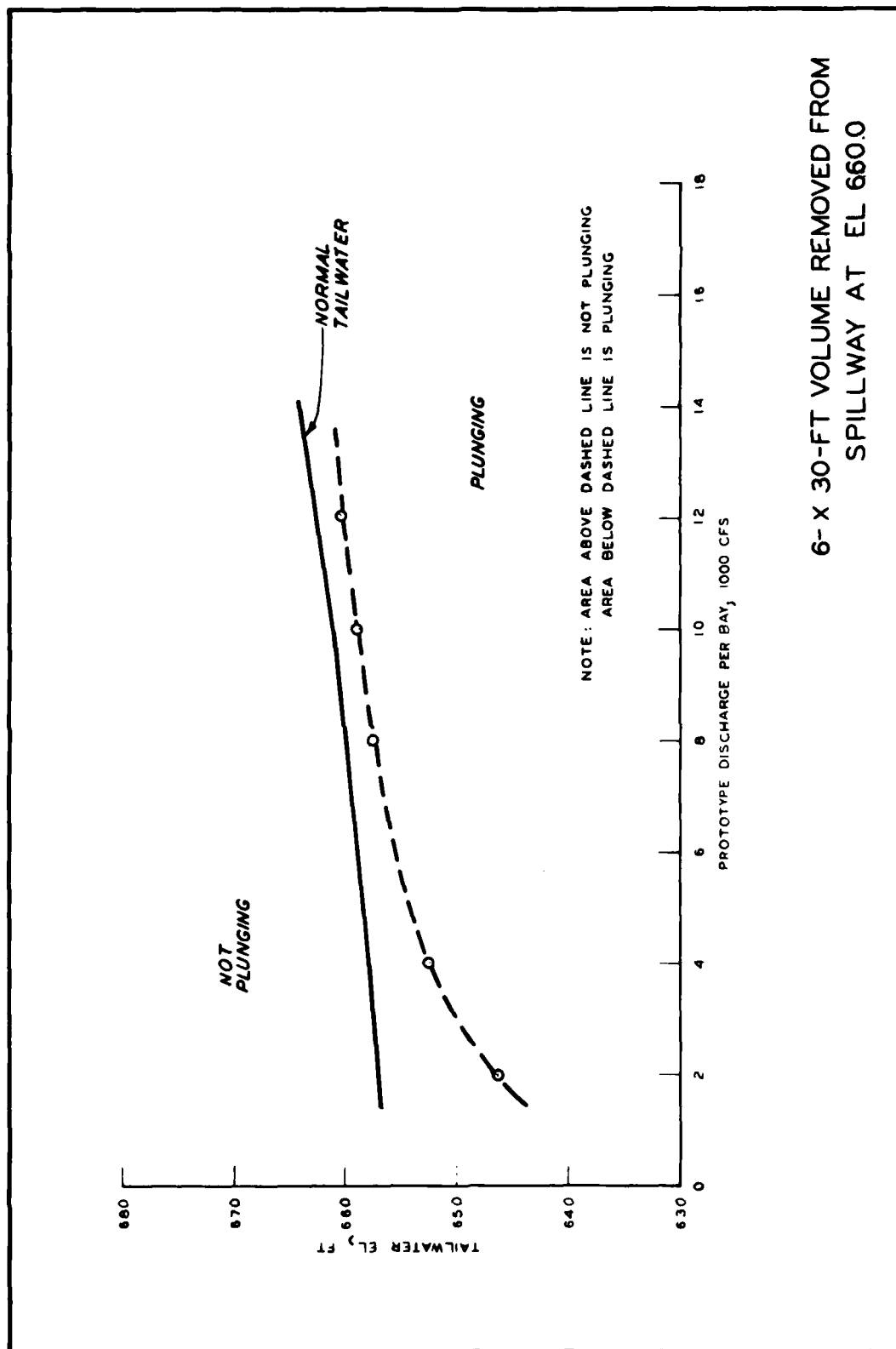
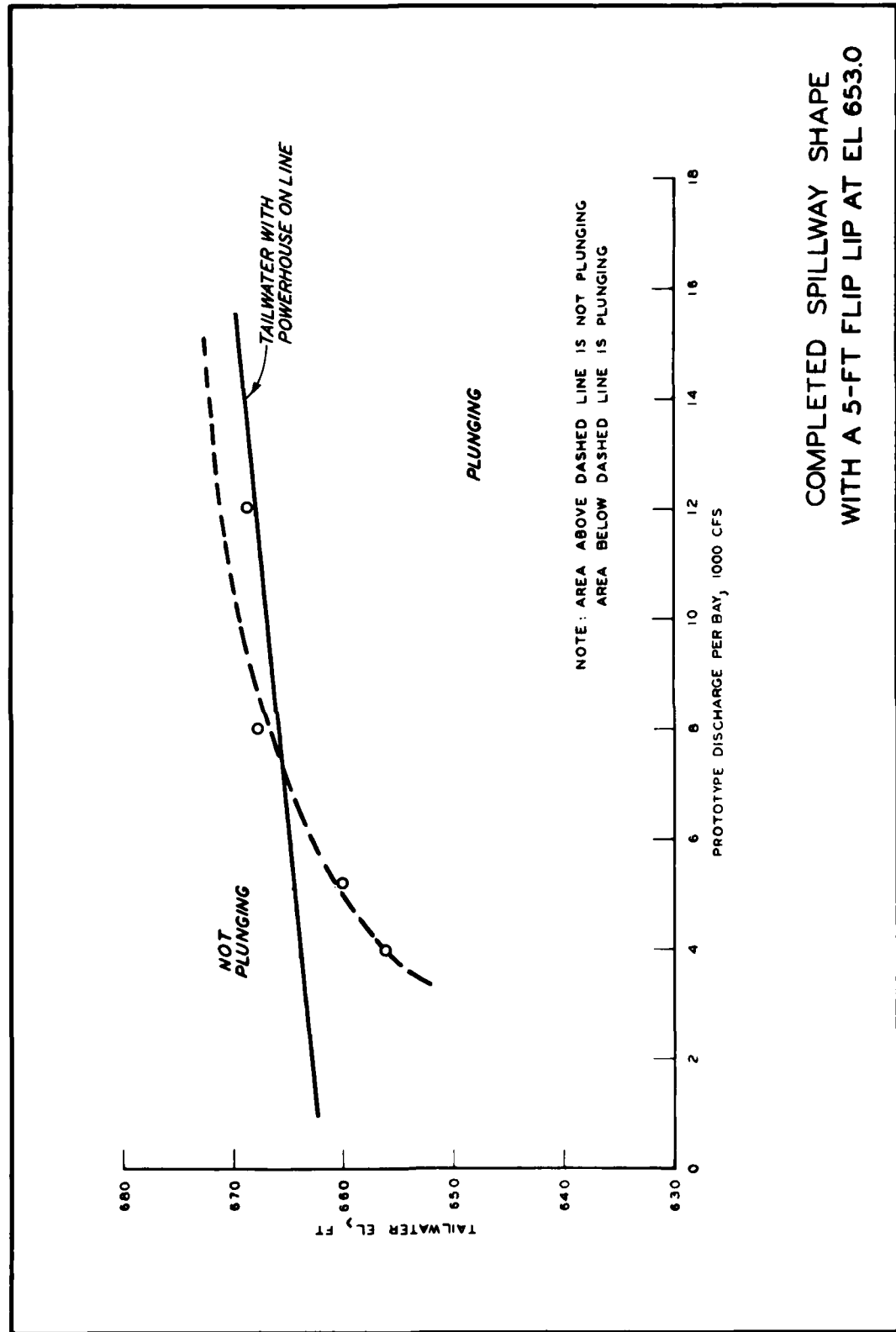
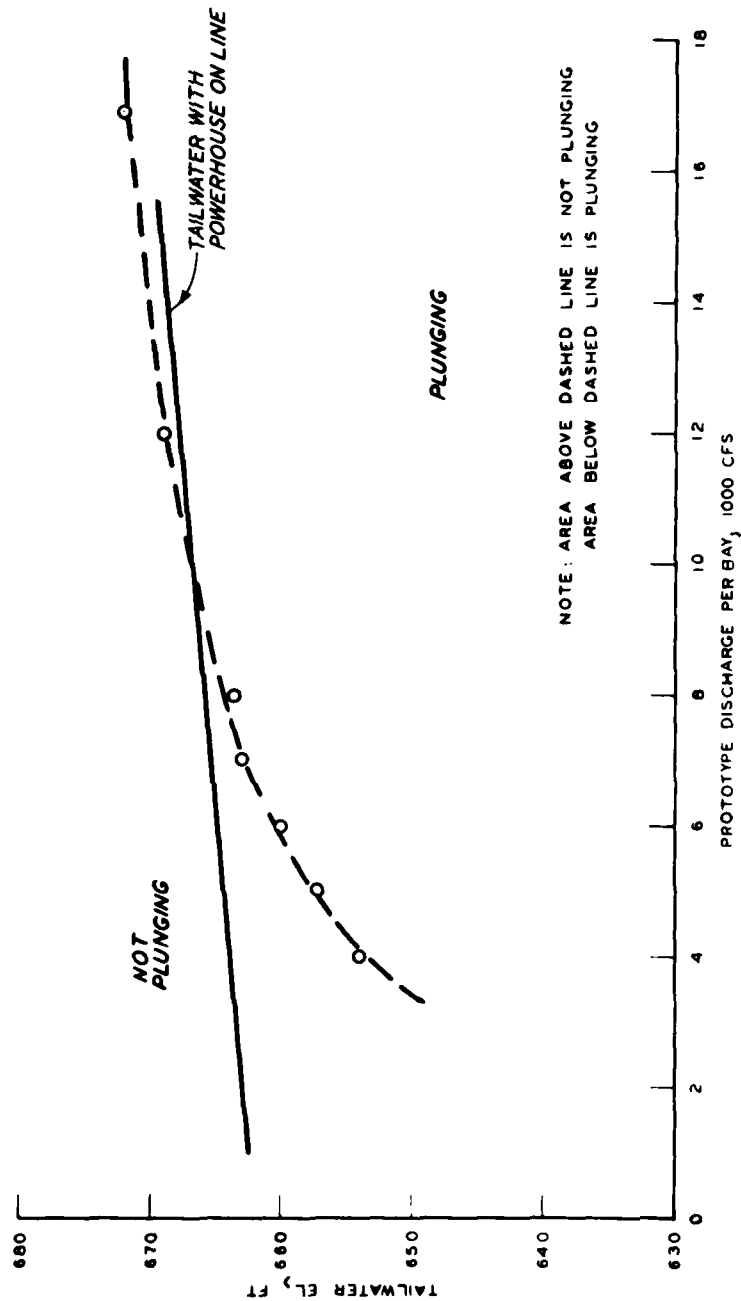


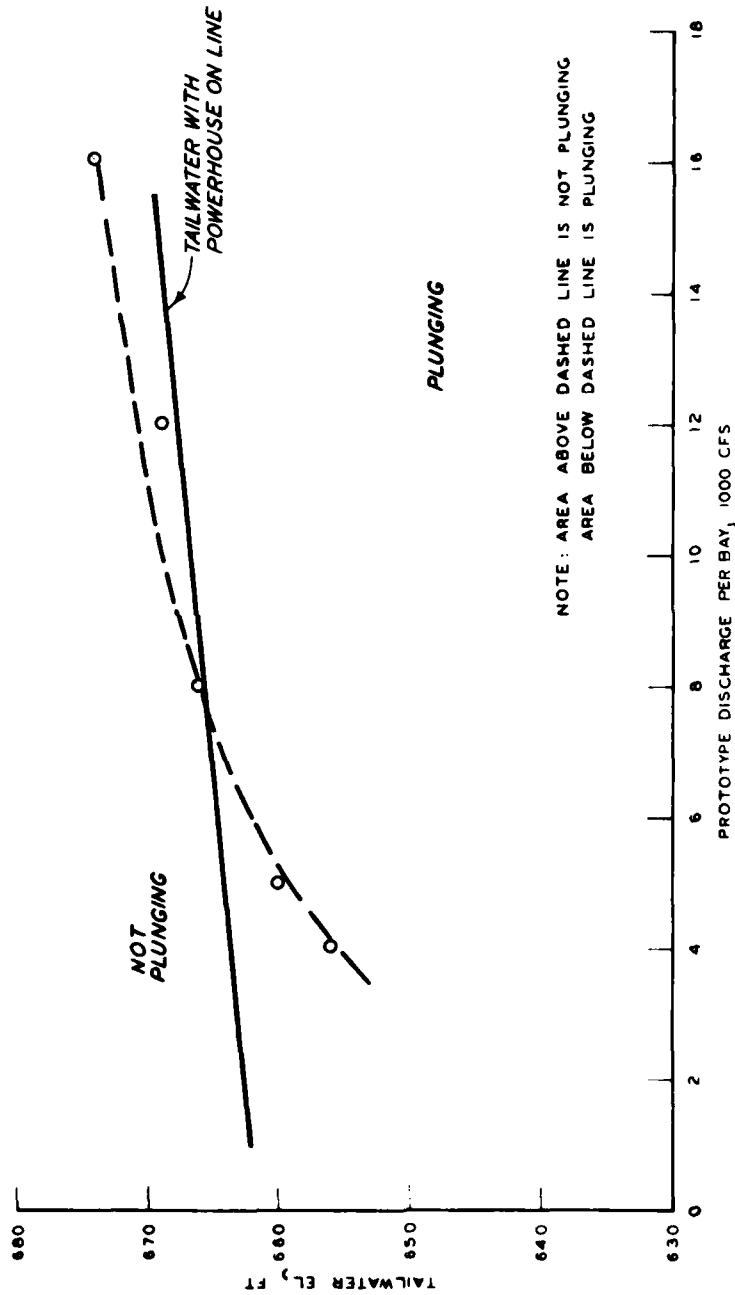
PLATE 8



COMPLETED SPILLWAY SHAPE
WITH A 5-FT FLIP LIP AT EL 653.0



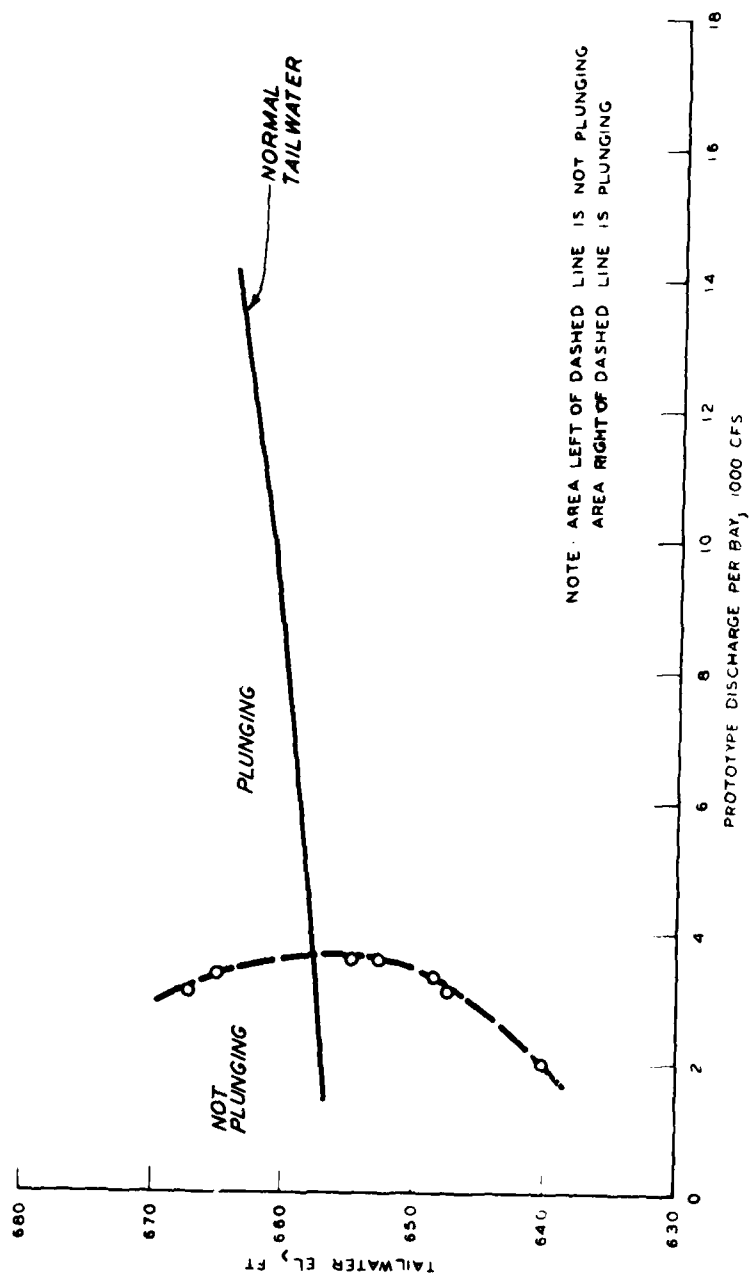
COMPLETED SPILLWAY SHAPE
WITH A 7-FT FLIP LIP AT EL 655.0



NOTE: AREA ABOVE DASHED LINE IS NOT PLUNGING
AREA BELOW DASHED LINE IS PLUNGING

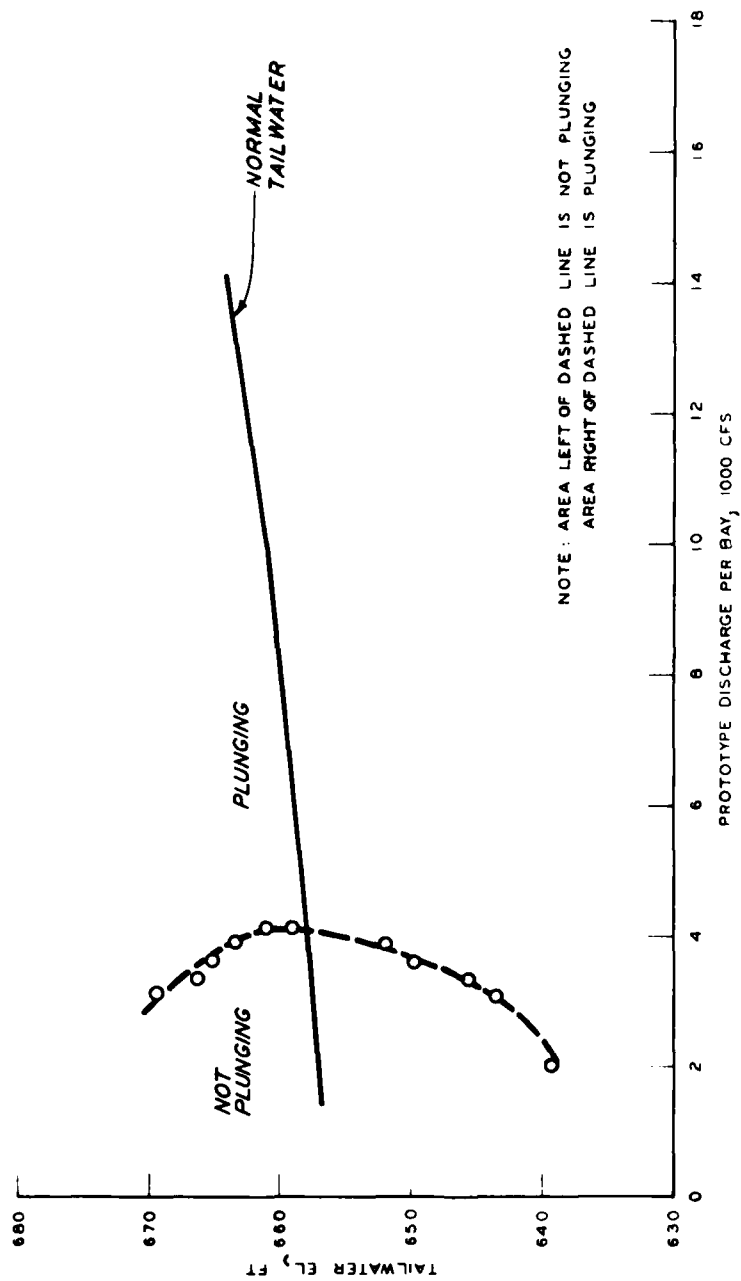
COMPLETED SPILLWAY SHAPE
WITH A 9.5-FT FLIP LIP EL 658.0





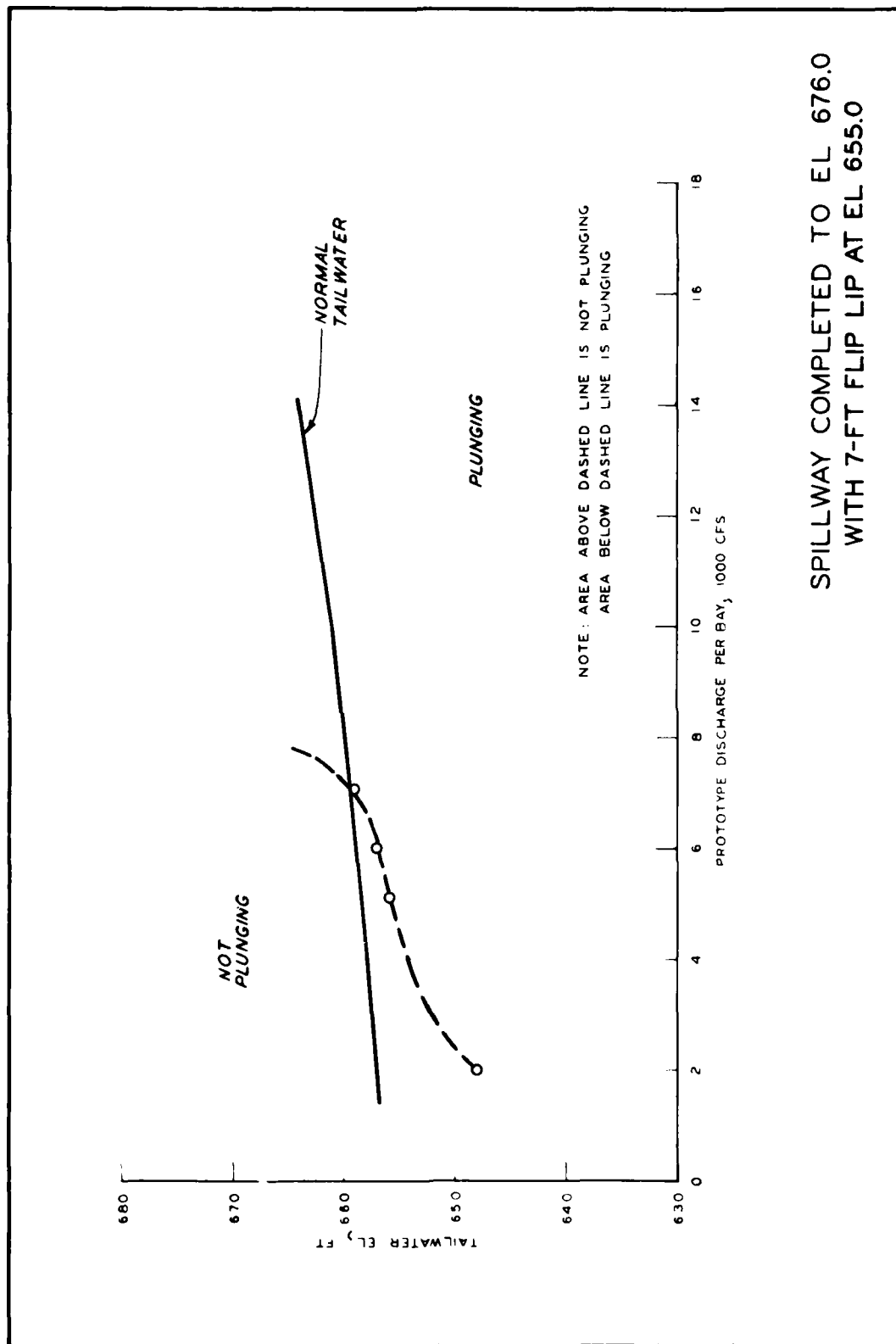
NOTE: AREA LEFT OF DASHED LINE IS NOT PLUNGING
 AREA RIGHT OF DASHED LINE IS PLUNGING

SPILLWAY COMPLETED TO EL 666.0
 WITH 7-FT FLIP LIP AT EL 655.0



SPILLWAY COMPLETED TO EL 671.0
WITH 7-FT FLIP LIP AT EL 655.0

PLATE 14



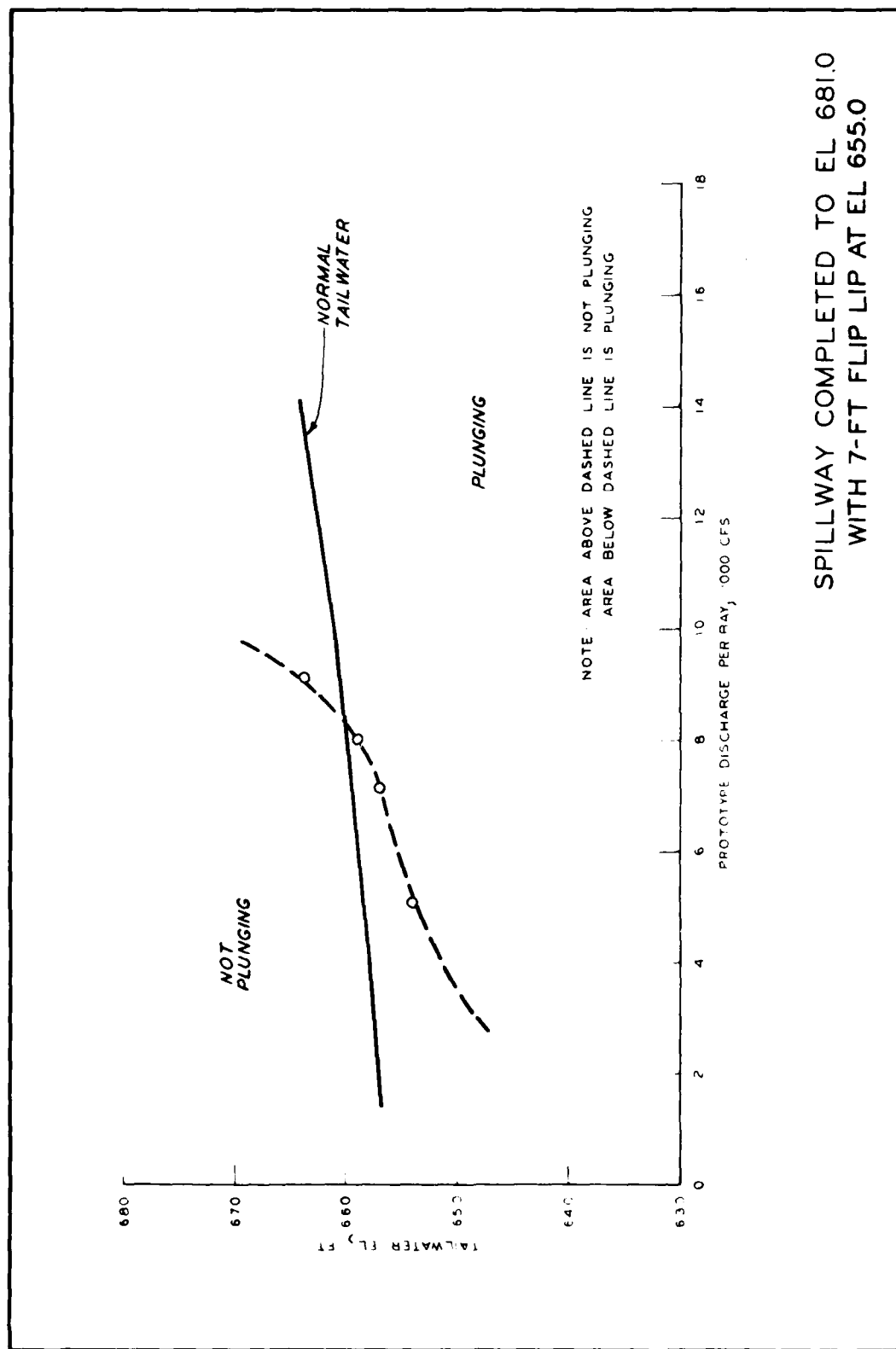
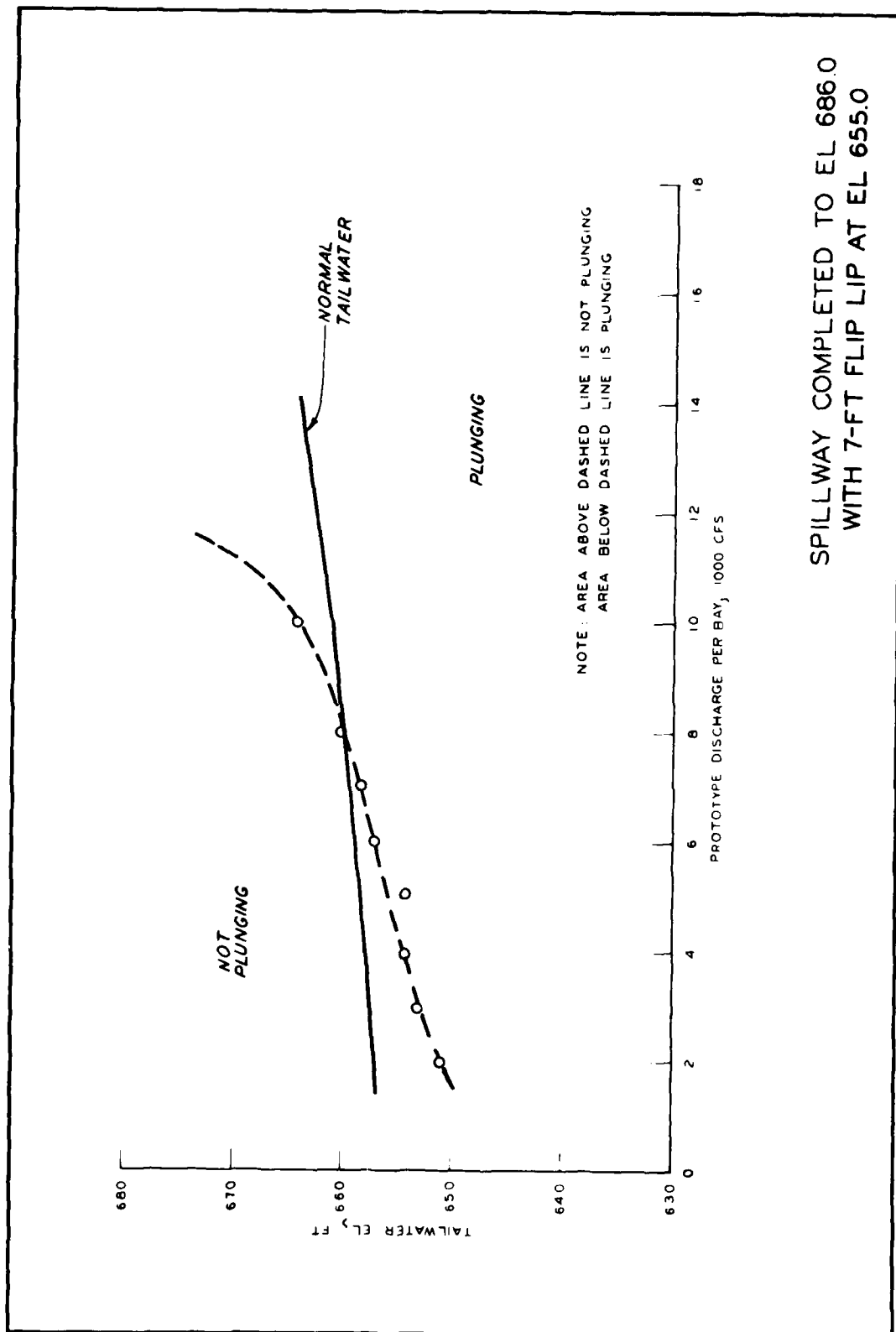


PLATE 16



SPILLWAY COMPLETED TO EL 686.0
WITH 7-FT FLIP LIP AT EL 655.0

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Pickering, Glenn A

Model study of Harry S. Truman spillway, Osage River, Missouri; hydraulic model investigation / by Glenn A. Pickering, D. Bruce Murray. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.

18, [16] p., 17 leaves of plates : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; HL-79-20)

Prepared for U. S. Army Engineer District, Kansas City, Kansas City, Missouri.

1. Aeration. 2. Gases. 3. Harry S. Truman Dam. 4. Hydraulic models. 5. Osage River. 6. Spillways. 7. Supersaturation. I. Murray, D. Bruce, joint author. II. United States. Army. Corps of Engineers. Kansas City. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; HL-79-20.
TA7.W34 no.HL-79-20