TECHNICAL REPORT HL-81-1

VIRDEN CREEK PUMPING STATION AND GRAVITY-FLOW OUTLET STRUCTURE WATERLOO, IOWA

Hydraulic Model Investigation

by

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

The model study was conducted to evaluate the characteristics of the pumped and gravity flows through the proposed structures from Virden Creek into the Cedar River and to develop practical modification if required to improve the hydraulic performance of the structures.

Hydraulic performance of the original design four-conduit gravity-flow structure was inadequate with unsymmetrical flow. This was attributed to the

(Continued)

20. ABSTRACT (Continued).

existing structures and the indirect approach to the gravity structure. This unsymmetrical flow through the original four-conduit gravity-flow structure was improved by a three-conduit structure which enhanced the hydraulic and structural adequacy of the gravity-flow outlet structure.

Hydraulic performance of the original converging-sidewall, low-submergence pump sump indicated that air-entraining surface vortices would occur intermittently in the vicinity of the pump intakes. A modified pump sump with rounded approach pier noses and a horizontal baffle wall prevented the adverse vortices and resulted in good hydraulic performance.

Sediment deposition expected during gravity-flow operations was simulated with results indicating that normal sand and gravel deposits should not affect performance of the pumping station with the gates to the pump sump closed during gravity-flow conditions.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), U. S. Army, on 2 November 1976, at the request of the U. S. Army Engineer District, Rock Island.

The study was conducted during the period January 1977 to December 1977 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and under the general supervision of Messrs. J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and N. R. Oswalt, Chief of the Spillways and Channels Branch. Project Engineer for the model study was Mr. P. E. Saunders, assisted by Messrs. F. L. Hebron, E. Jefferson, and R. L. Bryant. This report was prepared by Mr. E. D. Rothwell.

During the course of the investigation, Messrs. J. S. Robertson and S. B. Powell of OCE; J. D'Aniello, L. Coffill, and J. F. Ordonez of the U. S. Army Engineer Division, North Central; S. Doak, B. Snowden, and D. Logsdon of the U. S. Army Engineer District, Rock Island; and J. Biron of Midwestern Equipment Company visited WES to discuss the program and results of model tests, observe the model in operation, and correlate these results with design studies.

Commanders and Directors of WES during the conduct of the study 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.

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
acres	4046.856	square metres
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
gallons per minute	3.785412	cubic decimetres per minute
inches	25.1	millimetres
miles (U. S. statute)	1.609344	kilometres
square miles (U. S. statute)	2.589988	square kilometres

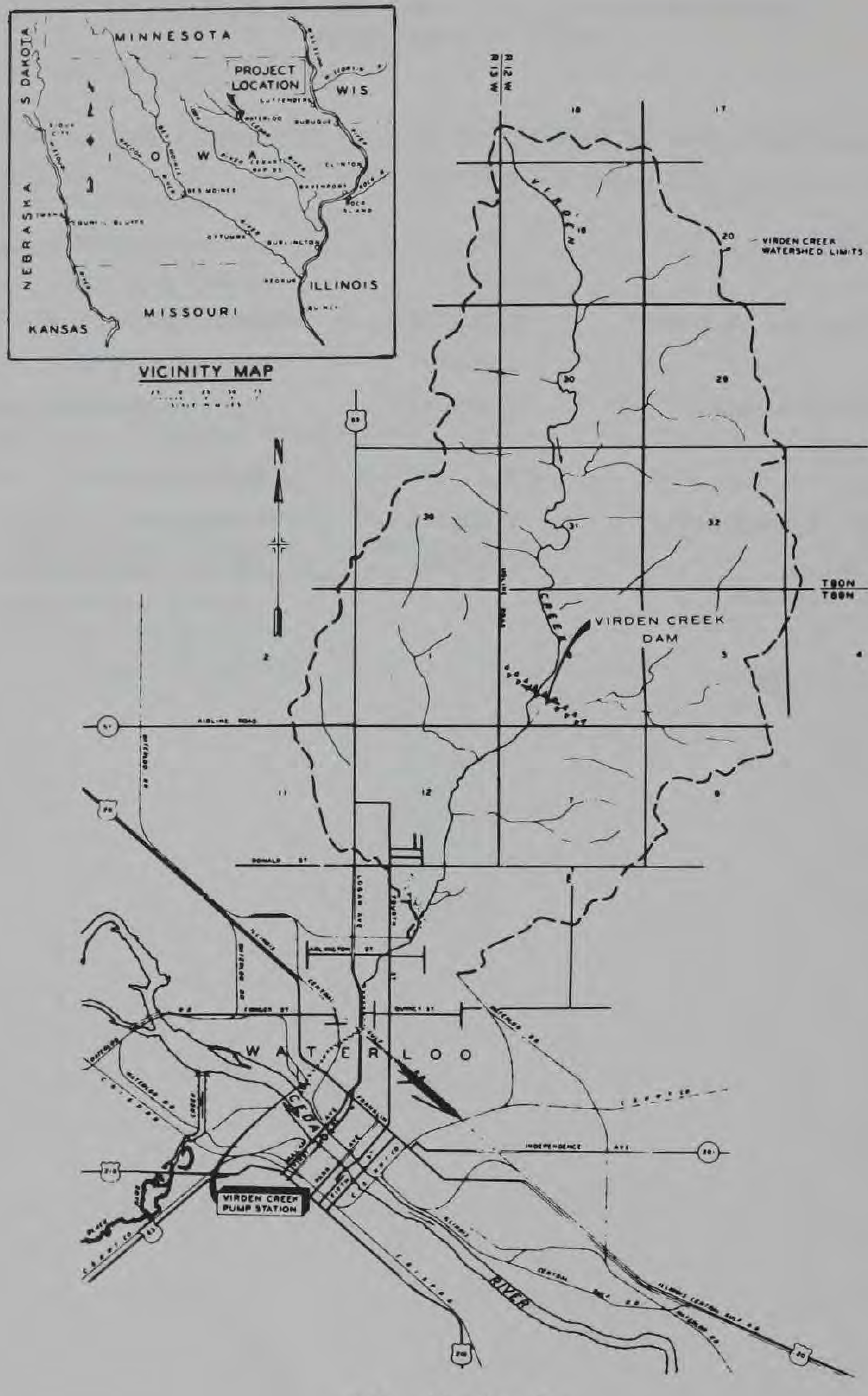

Figure 1. Location map

VIRDEN CREEK PUMPING STATION AND GRAVITY-FLOW OUTLET STRUCTURE, WATERLOO, IOWA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The proposed Virden Creek pumping station and gravity-flow outlet structure will be located in the channel of Virden Creek at its confluence with the Cedar River in Waterloo, Black Hawk County, Iowa (Figure 1 and Plates 1-3). Virden Creek enters the Cedar River from the left bank at Cedar River mile* 200.0. The drainage basin consists of an area of 15 square miles (9,625 acres) of which the drainage from the upper 8.5 square miles will be controlled by the Virden Creek Dam. The proposed pumping station and gravity-flow outlet structure will control runoff from the 6.5 square miles immediately upstream from the structures. The length of the watershed basin is 8.3 miles with a total change in elevation of 165 ft.

2. The existing improvements to the Virden Creek drainage system start at a distance 250 ft upstream from the mouth. Twin-box culverts, ranging from twin 16- by 8-ft to twin 12- by 8-ft culverts, extend upstream for a distance of 4,500 ft. The channel has been straightened and concrete-lined for another 1,800 ft. At the upstream end of the lined open channel are twin 12- by 8-ft concrete box culverts under the intersection of East Fourth Street and Arlington Street; above this point, Virden Creek is unimproved.

3. The proposed dumping station will be of the wet-pit (sump) type and will employ three vertical shaft pumps to provide a pumping capacity of 134,650 gpm (300 cfs). Trashracks will be provided for protection of the pump intakes from debris. The sump floor elevation for

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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 sump bays is 834 ft.* The pumps will discharge through three 42-in. (I.D.) discharge pipes into Cedar River (Plate 4).

4. The proposed gravity-flow outlet structure consisted of four gated bays, numbered 1 to 4 from left to right looking downstream, separated by piers (Plate 4). The gate bays will be fitted with 8- by 8-ft vertical motor-operated slide gates. The discharge will be released directly into the Cedar River at water-surface elevations equal to or less than 843.5.

Purpose of Model Study

5. The model study was conducted to evaluate the characteristics of pumped and gravity flows in the original design pumping station and to develop modifications required for improving the distribution of flow to the pump intakes and gravity-flow outlets.

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* All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

PART II: THE MODEL

Description

6. The model of Virden Creek pumping station and gravity-flow outlet structure (Figure 2), constructed to an undistorted linear scale ratio of 1:9, reproduced approximately 265 ft of the approach channel, including the geometry and alignment of existing bridge piers, the proposed pumping station, and gravity-flow outlet structure (Plates 2 and 3). The approach channel and existing piers were fabricated of plastic-coated plywood and treated with a waterproofing compound to prevent expansion. The pumping station and gravity-flow outlet structure were fabricated of transparent plastic to permit visual observation of flow approaching and entering the pump intakes and gravity-flow outlet structure. Trashracks were simulated with metal strips forming a mesh screen.

7. Water used in the operation of the gravity-flow outlet portions of the model was supplied by pumps. Flow through the pumping station intakes was provided by individual suction pumps that permitted simulation of various flow rates through one or more pump intakes. Discharges were measured with turbine flowmeters and venturi meters; water-surface elevations were measured with staff and point gages; and velocities were measured with a turbine current meter and a pitot tube. Current patterns were determined by dye injected into the water and by confetti sprinkled on the water surface. Rotation of flow entering the pumps was measured by vortimeters (free rotating propellers with zero pitch blades) located inside each pump intake at the approximate position of the prototype pump propeller. Location of the vortimeter is shown in Figure 3.

Model to Prototype Similitude

8. The predominant forces affecting flows in the approach channel and pump chambers are inertia and gravity. Under these conditions, hydraulic similarity between model and prototype requires that the ratio of inertial to gravitational forces, defined as the Froude number of flow,

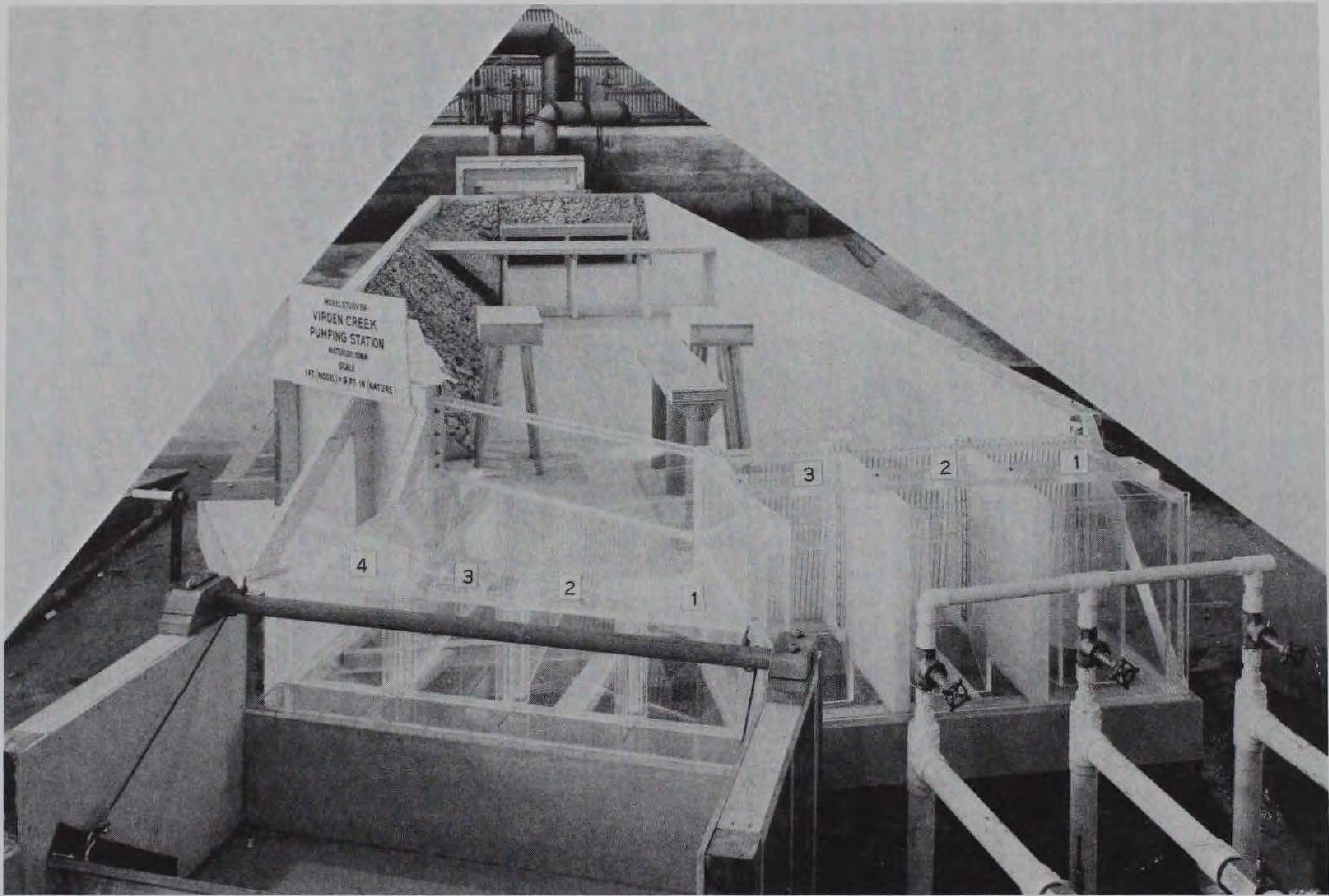


Figure 2. Overall view of the 1:9-scale model (original design)

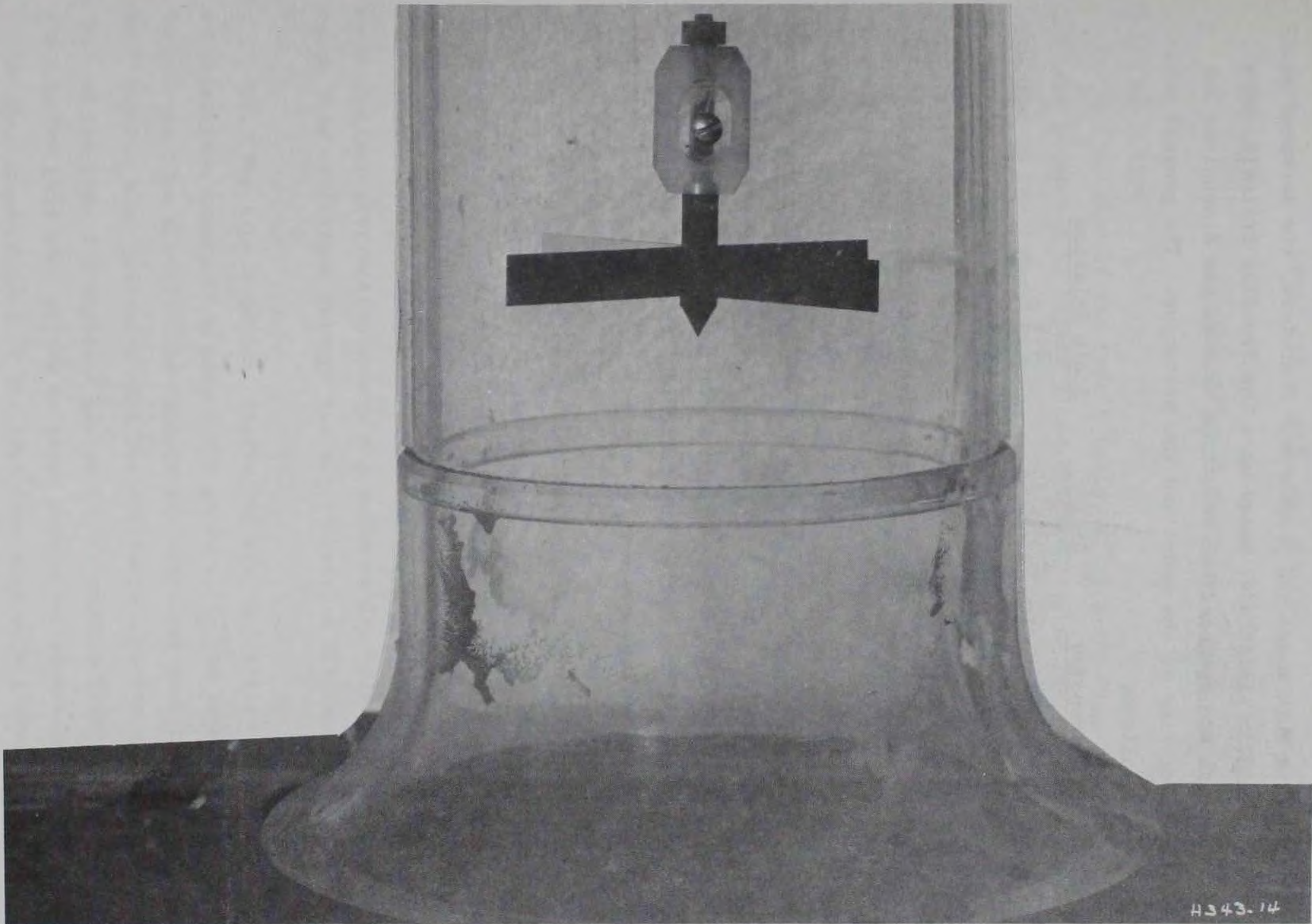


Figure 3. Model vortimeter

be identical in both model and prototype. Therefore, the accepted equations of hydraulic similitude, based upon the Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. The general relations are as follows:

Dimension	Ratio	Scale Relation
Length	L_r	1:9
Area	$A_r = L_r^2$	1:81
Velocity	$V_r = L_r^{1/2}$	1:3
Discharge	$Q_r = L_r^{5/2}$	1:243
Time	$T_r = L_r^{1/2}$	1:3
Frequency	$f_r = \frac{1}{L_r^{1/2}}$	1:0.333

Measurement of discharge, water-surface elevations, heads, velocities, and frequency can be transferred quantitatively from the model to prototype equivalents by these scale relations.

PART III: TESTS AND RESULTS

Gravity-Flow Performance

Original design

9. Details of the type 1 (original) gravity-flow outlet structure are presented in Figure 2 and Plates 2 and 4. Initial tests were conducted in the 1:9-scale model to evaluate the hydraulic performance of the gravity-flow section. Visual observation of the model for the anticipated range of flow conditions indicated uneven distribution of flow exiting the four gravity-flow bays (Figure 4). However, despite these adverse flow conditions, the original gravity-flow section did provide the required capacity to pass the design discharge of 2,450 cfs with a Cedar River tailwater elevation of 843.5.

10. Results of these tests indicated that modifications could be made to provide more uniform distribution of flow through the gravity-flow section and reduce the water-surface contraction around the guide walls.

Alternate gravity-flow designs

11. The gravity-flow section guide walls were modified as shown in Figure 5 and Photo 1. An analysis of the results with the type 2 design (Figure 5a) indicates that the discharge capacity decreased at low-flow rates and increased at high-flow rates. The type 2 design also revealed only a slight improvement in flow distribution and water-surface contraction around the guide walls. Figure 6 shows adverse flow conditions through the section with a discharge of 1,800 cfs.

12. The type 3 design (Figure 5b) was ineffective in reducing the water-surface contraction around the guide walls and in eliminating the nonuniform flow distribution through the three-bay gravity-flow section. Test results also indicated that the discharge capacity was less than that of the type 1 (original) design for discharges less than 1,100 cfs and greater than that of the original design for discharges greater than 1,300 cfs. A comparison of the free-flow discharge characteristics of

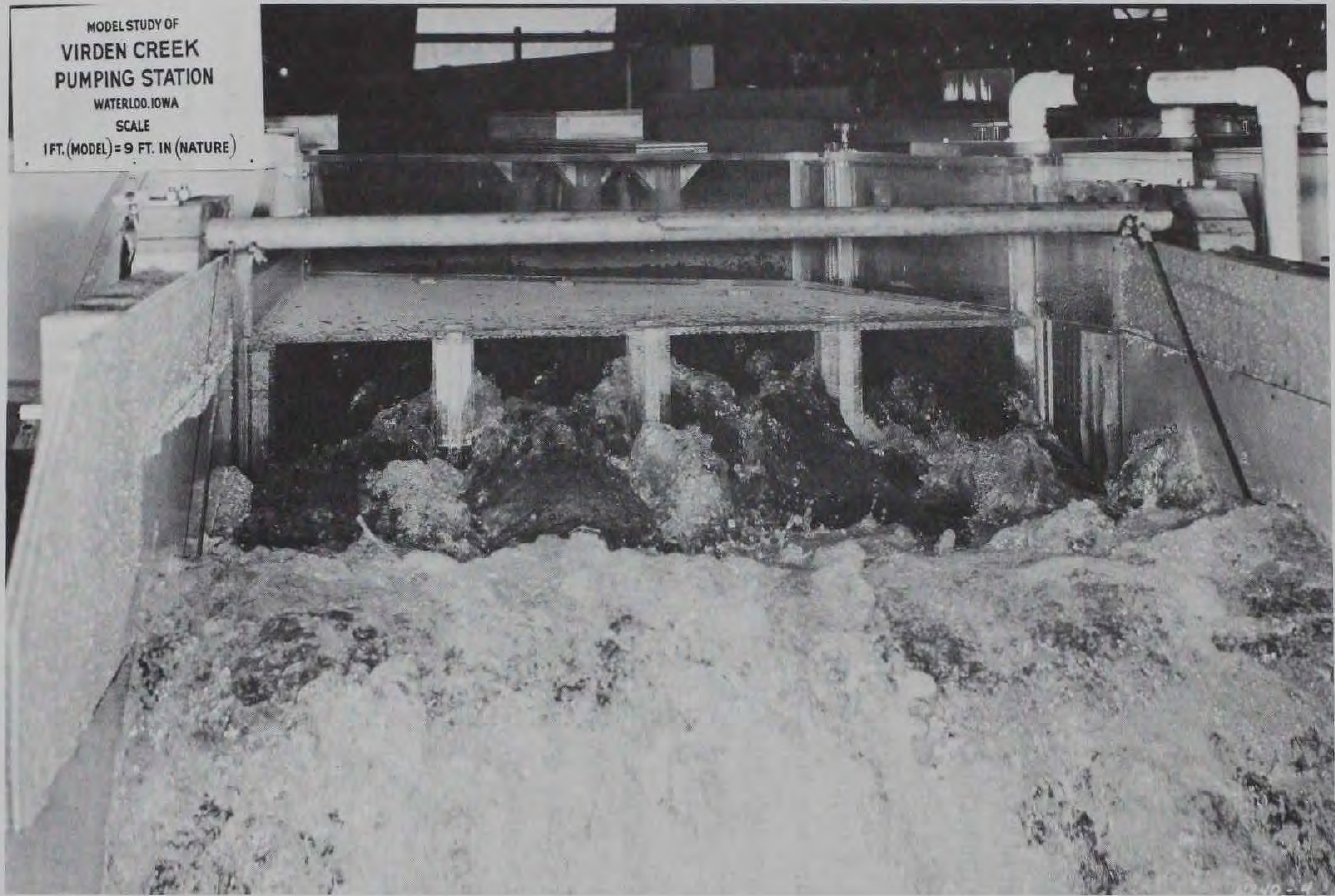
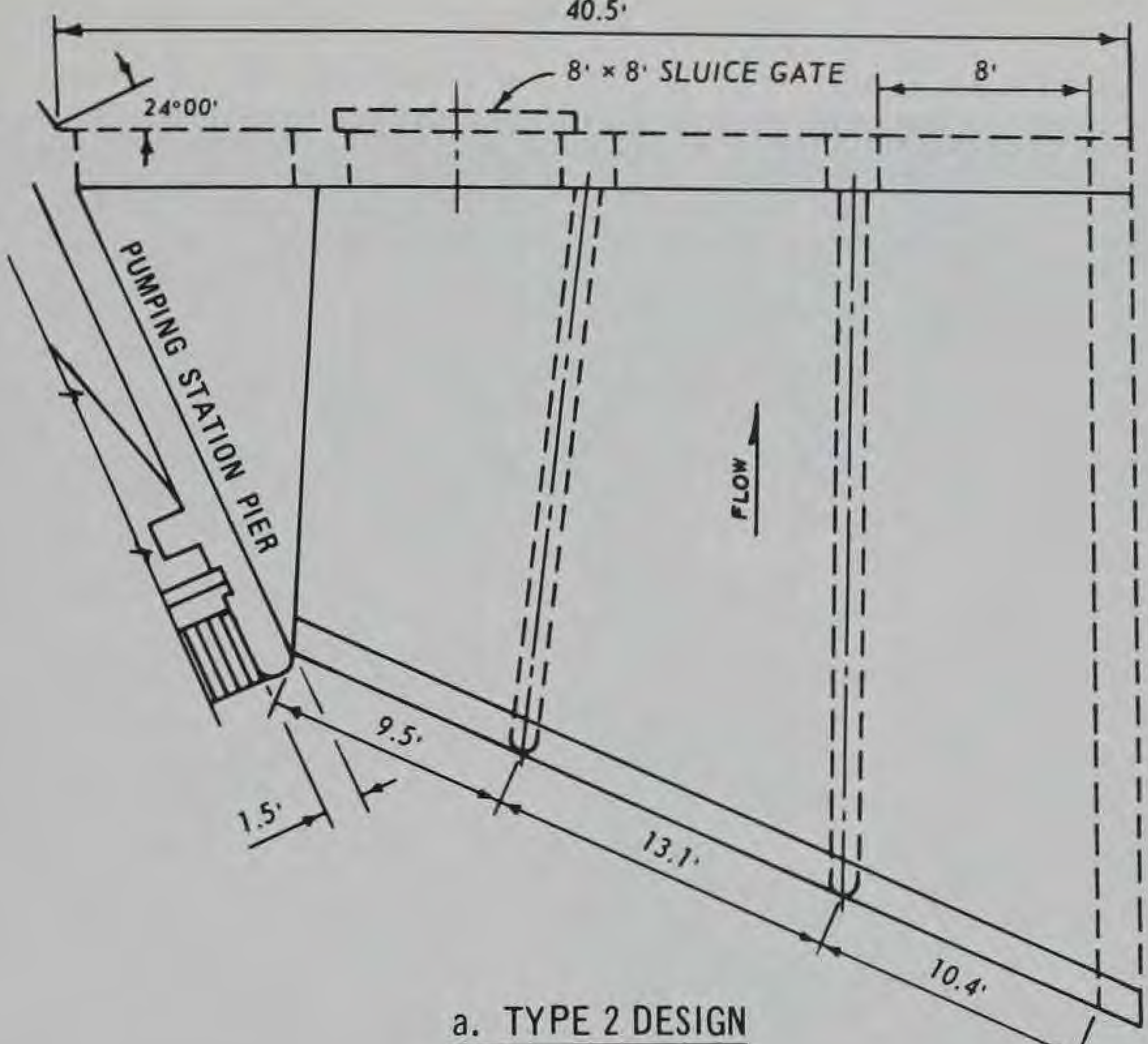
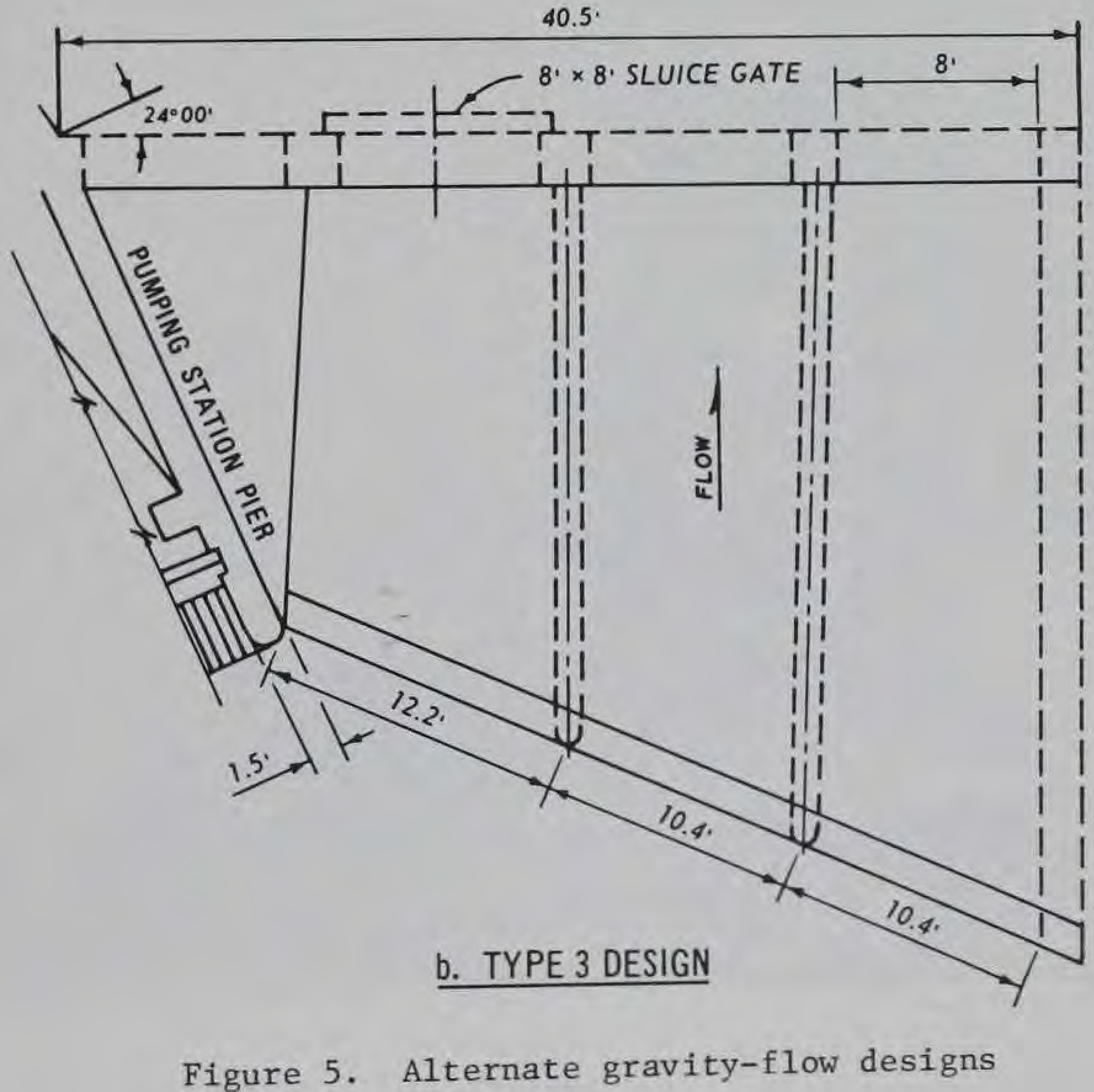


Figure 4. Flow conditions through gravity-flow section type 1 (original) design; discharge 1800 cfs, tailwater el 832



a. TYPE 2 DESIGN



b. TYPE 3 DESIGN

Figure 5. Alternate gravity-flow designs

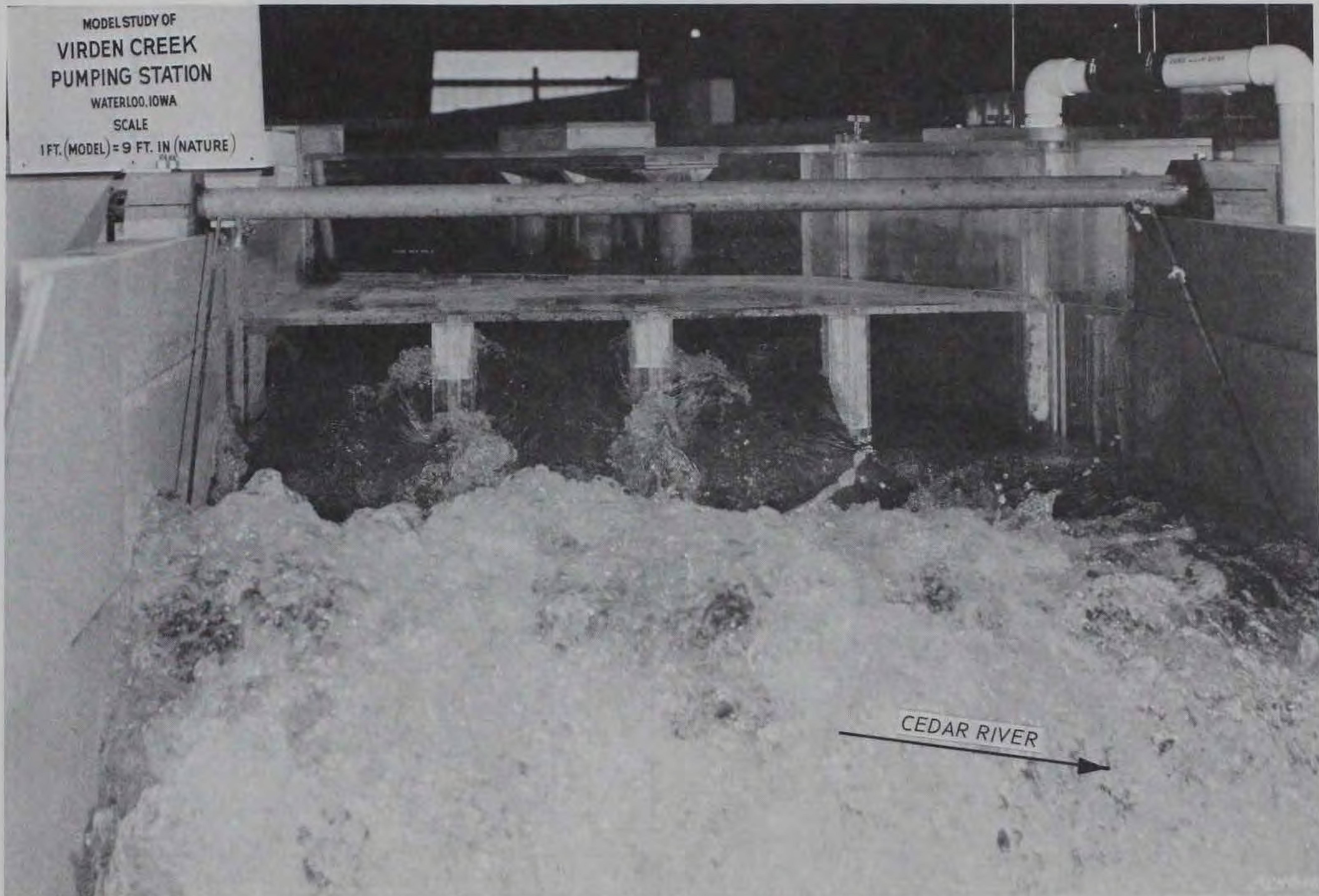


Figure 6. Flow conditions through gravity-flow section; type 2 design, discharge 1800 cfs, tailwater el 832

the three designs studied is presented in Plate 5.

13. Results of limited tests to improve the flow distribution and hydraulic performance of the gravity-flow section indicated that the original (type 1) design would provide the required capacity to pass the design discharge of 2,450 cfs with a tailwater elevation of 843.5; however, poor flow patterns and inefficiencies of flow indicated that improvement might be economical. The several modifications tested provided only limited improvement as discussed in paragraphs 11 and 12. Reducing the original four-bay gravity-flow structure to a three-bay gravity-flow structure to provide a more uniform distribution of flow was the most significant improvement to the gravity-flow structure. This resulted in considerable cost savings, which more than offset the cost of the entire model study. Plates 6 and 7 show the final gravity-flow structure and the pumping station as designed and constructed by the U. S. Army Engineer District, Rock Island. The final design of the gravity-flow section included the improved three-bay structure developed in limited model tests. Due to the sponsor's time constraints the exact final design was not simulated in the model.

Gravity-Flow Discharge Characteristics

14. The basic uncontrolled-flow calibration data (Plate 8) show the elevation of energy in the approach channel corresponding to a particular discharge and tailwater established in the model. Data for each of the various discharges shown in Plate 8 illustrate the following:

- a. The relation between the elevation of energy of the flow in the approach channel for various discharges and tailwater elevations in the exit channel.
- b. The range of tailwater elevations at which the energy of the approach flow is constant, i.e., the range of free uncontrolled flow.
- c. The range of tailwater elevations that affect the energy of the approach flow due to the submergence effects of the tailwater, i.e., the range of submerged uncontrolled flow.

Pumping Station Performance

Original design

15. The 1:9-scale reproduction of the original design of the pump sump including the three 42-in.-diam pumps is shown in Figure 2 and design details are given in Plate 4. The pumps were numbered as indicated in Figure 2. The invert of each sump will be at el 834 and the base of each pump suction bell at el 836.5. Pumps will operate within the range of a minimum sump elevation of 838.5 and the maximum sump elevation of 843.5 for a total capacity of 134,650 gpm (300 cfs). Hydraulic performance of the pump sump was evaluated by visual observations of flow conditions and flow distributions, and rotation of flow (swirl) at the approximate position where each propeller will be located in the prototype.

16. The original sump to be tested was an extremely close-wall converging sump. The design departs significantly from sump dimensions recommended in current Corps manuals and by the Hydraulic Institute. The proposed low submergence over the suction bell also departs from the recommendations contained in pump manufacturers standard literature for prevention of surface vortices. Evaluation of this concept of sump design, currently in use in Rock Island District for a number of smaller pumping stations, was the primary reason for the hydraulic model investigation described herein. Various suction-pipe-induced flow conditions (actual pumps were not reproduced in the model) illustrated that small air-entraining vortices would occur intermittently in the vicinity of the pump intakes at the low range of water-surface elevations. Various flow conditions in the model illustrated that an air-entraining vortex would occur intermittently in the vicinity of the pump intakes for the anticipated range of water-surface elevations. The location and strength of vortex action in the model appeared to be directly related to the distribution of flow entering the individual sumps and the submergence of the pump intakes. Rotational flow tendencies (expressed as revolutions per minute in the prototype intakes) and vortex observations are presented in Table 1.

Alternate designs

17. Several designs were investigated to develop uniformly distributed flow to the pump intakes and suppress or eliminate the formation of vortices. Flow separation at the pier noses was reduced by adding 1.5-ft radii to the noses of the piers (type 2 design) as shown in Plate 9. The type 2 design did not significantly improve flow distribution or eliminate the vortex action in the vicinity of the pump intakes. Rotational flow tendencies and vortex observations are presented in Table 2.

18. The type 3 design with the rounded pier noses and a lowered breast wall (Plate 10) was installed in the model. This modification increased the tendency for adverse flow conditions in the vicinity of the pump intakes; results are presented in Table 3.

19. Investigation of several types of vortex suppressors were conducted to develop a device that would eliminate the vortex and provide uniform flow distribution to the pump intakes. The type 4 design which consisted of rounded pier noses and a horizontal baffle wall in front of the pump intakes (Plate 11) eliminated the surface vortex formation and reduced the average rotational flow tendencies. Rotational flow tendencies measured with a vortimeter are presented in Table 4. While the average values indicate a significant reduction in magnitude, the maximum vortimeter reading remains higher than the maximum value obtained with the original design (Table 1).

20. Additional modifications were investigated in an attempt to improve flow distribution to the pump intakes. The type 5 design, which included only a horizontal baffle wall in front of the pump intakes, and several other baffle designs (types 6 and 7), which included investigating the effects of extending the length of the piers upstream, were considered unsatisfactory. Rotational flow tendencies and vortex observations for the types 5, 6, and 7 designs are presented as Tables 5, 6, and 7.

21. Further tests with the original converging sidewalls removed (type 8 design) and replaced with a curved wall behind the pump intake (type 9 design) indicated no improvement in hydraulic performance over that obtained with the converging walls and the type 4 design. Removal

of the original converging walls and/or the curved wall behind the pump intakes increased the surface vortexing at the low-water operation conditions. The pump station has been constructed and the pumps have been installed and tested. Rock Island District reports water was obtained for the pump testing by recirculating Cedar River water through the open gravity outlet to the pumps forebay. This resulted in very adverse flow conditions at the approach to the pump intakes. Under these conditions, the pumps operated satisfactorily without excessive noise and met the specified vibration limitations at pool level el 839. The recommended minimum submergence by the manufacturer was 6.7 ft over the bell of the pump and the test was made with the water level at 2.5 ft over the bell.

Recommended Design

22. The type 4 (recommended) design pumping station (Figure 7) included rounded pier noses, a horizontal baffle wall, and converging

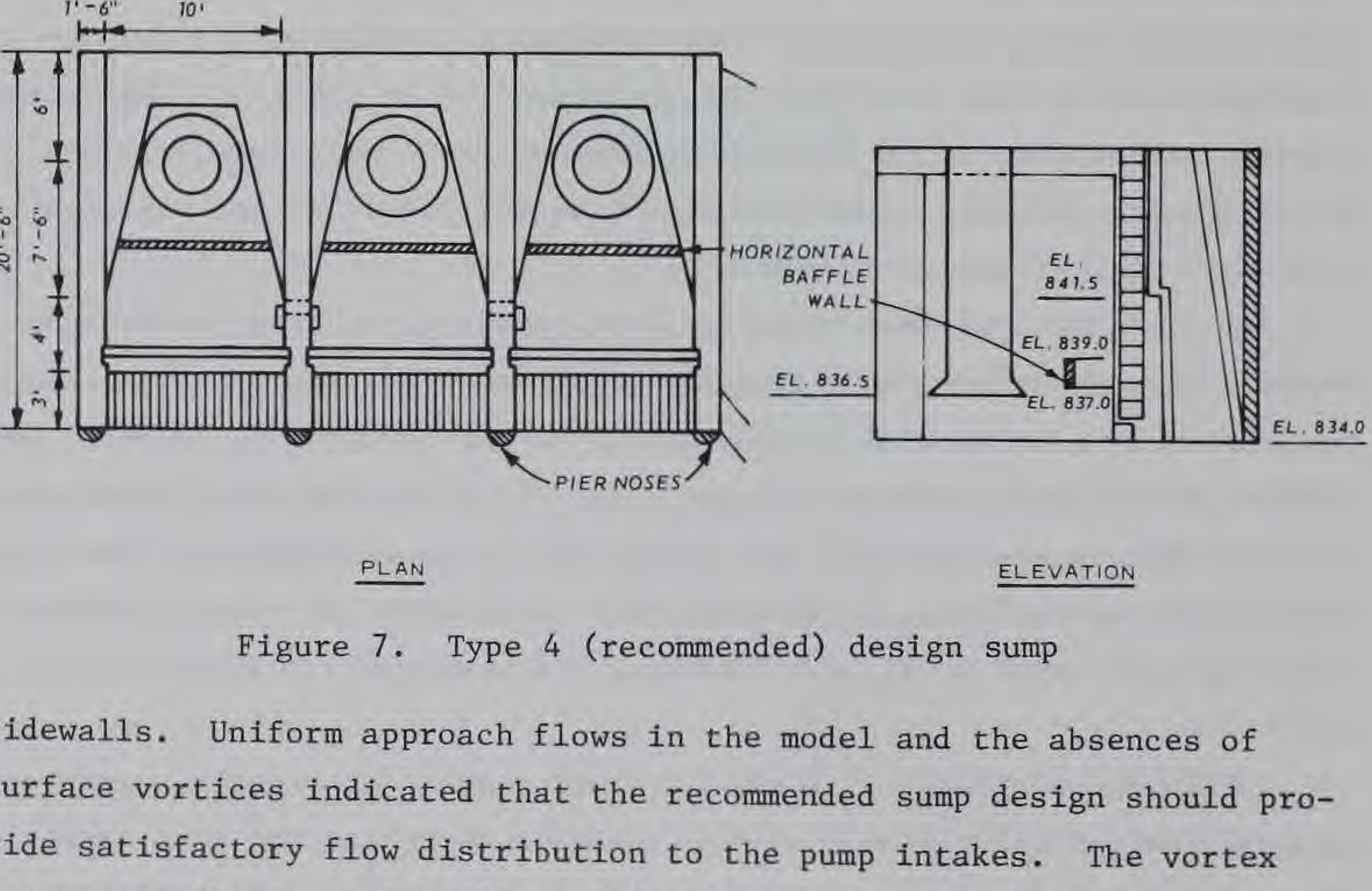


Figure 7. Type 4 (recommended) design sump

sidewalls. Uniform approach flows in the model and the absences of surface vortices indicated that the recommended sump design should provide satisfactory flow distribution to the pump intakes. The vortex suppressor (horizontal baffle wall) eliminated any tendency for surface vortices to form. Although all vortimeter readings (Tables 1-7) were relatively low, the average rotation of flow (swirl) for the recommended design was only 1.1 rpm. There may still be a tendency for horizontal axis vortices (sidewall) to form. While these are nonsurface vortices and thus nonair-entraining, the influence on noise and vibration that these may have on this prototype remains unknown.

Sediment Deposition

23. Tests were conducted with sand introduced into the model during simulation of a 6-hr duration hydrograph to determine the relative sediment deposition pattern to be expected during gravity-flow operations. Photos 2-4 taken after the sediment tests show the pattern of deposition developed in the approach channel. Test results indicate deposits of sediment within 15 ft of the right pump bay looking downstream and within 35 ft of the left bay (Photo 4). These simulated test results indicated that normal deposits from gravity-flow operations with the gates to the pump sump closed should not affect performance of the pumping station.

PART IV: SUMMARY OF RESULTS

24. Tests of the original gravity-flow outlet indicated the existence of poor flow patterns through the outlet flow arrangement. Flow through the outlet conduit nearest the pumping station was only about one tenth of the total flow. This unsymmetrical flow through the original four gravity-flow conduits was improved by a three-conduit structure which enhanced the hydraulic and structural adequacy of the gravity-flow outlet structure. The Rock Island District developed the final gravity-flow design (Plate 6) based upon these model tests.

25. Hydraulic performance of the original pump sump indicated that air-entraining vortices would occur intermittently in the vicinity of the pump intakes. Several alternate designs were unsuccessful. Satisfactory sump performance was provided with the type 4 (recommended) design sump which included rounded pier noses, a horizontal baffle wall, and converging sidewalls. Thus, the model study indicated that the design concept used by the Rock Island District to provide close and converging sidewalls in a low submergence sump required only relatively simple and easy modifications (with respect to standard designs) to achieve satisfactory hydraulic performance.

26. Sand introduced into the model during a simulated 6-hr duration storm hydrograph to determine the relative sediment deposition pattern to be expected during gravity-flow operations indicated that normal deposits should not affect performance of the pumping station with the gates to the pump sump closed during gravity-flow conditions.

Table 1

Sump Performance, Original Design

Pool El ft	Vortimeter Readings, rpm, for Pump No.		
	1	2	3
838.5	-1.0*	X	X
838.5	X	X	+4.3*
838.5	+1.1	+0.5	X
839	+1.1	0.0	X
838.5	+1.6*	X	-2.7*
838.5	X	+2.1*	-2.9*
839	X	+0.2	-4.0*
841	X	0.0	-2.8
838.5	+1.2*	+0.9*	-4.0*
839	+1.6*	+0.6*	-4.0*

Percentage of tested conditions with vortex present	60
Average vortimeter reading, rpm	1.8
Maximum vortimeter reading, rpm	4.3

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
- = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

Table 2

Sump Performance, Type 2 Design

Pool El ft	Vortimeter Readings, rpm, for Pump No. 1	2	3
838.5	+0.2*	X	X
838.5	X	X	+2.7*
838.5	+0.9*	+0.07*	X
839	+0.8*	0.0*	X
838.5	+2.2*	X	-1.1*
838.5	X	+3.8	-1.3*
839	X	+0.9*	-4.8*
841	X	0.0	-2.3
838.5	+2.7*	+1.3*	-4.2*
839	+0.7*	+1.3*	-3.8*

Percentage of tested conditions with vortex present	85
Average vortimeter reading, rpm	1.7
Maximum vortimeter reading, rpm	4.8

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
- = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

Table 3

Sump Performance, Type 3 Design

Pool El ft	Vortimeter Readings, rpm, for Pump No.		
	1	2	3
838.5	+0.4*	X	X
838.5	X	X	+7.3*
838.5	+0.6*	-5.0*	X
839	+6.0*	-4.0*	X
838.5	+0.6*	X	+3.7*
838.5	X	+4.0	-2.1*
839	X	+2.2*	+3.3
841	X	+4.0	-6.0
838.5	+1.9*	+1.2*	-5.7*
839	-1.2*	-0.8*	-4.7*

Percentage of tested conditions with vortex present	80
Average vortimeter reading, rpm	3.2
Maximum vortimeter reading, rpm	7.3

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
- = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

Table 4

Sump Performance, Type 4 Design

Pool El ft	Vortimeter Readings, rpm, for Pump No.		
	1	2	3
838.5	0.0	X	X
838.5	X	X	+2.1
838.5	+0.4	+0.4	X
839	+0.4	+0.3	X
838.5	-0.9	X	-0.8
838.5	X	+5.0	-0.7
839	X	+0.1	-0.3
841	X	+0.2	-3.7
838.5	+2.0	+0.2	-0.7
839	+0.6	0.0	-0.4

Percentage of tested conditions with vortex present	0
Average vortimeter reading, rpm	1.1
Maximum vortimeter reading, rpm	5.0

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
− = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

Table 5

Sump Performance, Type 5 Design

Pool El ft	Vortimeter Readings, rpm, for Pump No. 1	2	3
838.5	-1.1*	X	X
838.5	X	X	-3.1*
838.5	+0.2*	+0.6*	X
839	0.0	+2.5	X
838.5	-2.7*	X	-0.4*
838.5	X	+4.3*	-0.3*
839	X	+2.3	-0.3
841	X	+0.2	-3.6
838.5	+0.4*	+0.4*	-0.4*
839	+0.1	+0.3	-0.2

Percentage of tested conditions with vortex present	45
Average vortimeter reading, rpm	1.2
Maximum vortimeter reading, rpm	4.3

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
- = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

Table 6

Sump Performance, Type 6 Design

Pool El ft	Vortimeter Readings, rpm, for Pump No.		
	1	2	3
838.5	0.0*	X	X
838.5	X	X	-0.8*
838.5	+4.0*	+0.7*	X
839	+3.8	+0.9	X
838.5	+2.0	X	-0.6
838.5	X	+3.7	-0.2
839	X	+0.9	-0.4*
841	X	+1.0	-4.3
838.5	+4.3*	0.0*	+0.07*
839	+3.3	+0.1	-0.3

Percentage of tested conditions with vortex present	40
Average vortimeter reading, rpm	1.6
Maximum vortimeter reading, rpm	4.3

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
- = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

Table 7

Sump Performance, Type 7 Design

Pool El ft	Vortimeter Readings, rpm, for Pump No.		
	1	2	3
838.5	0.0*	X	X
838.5	X	X	-0.3*
838.5	+1.0*	+0.4*	X
839	+0.4*	0.0*	X
838.5	+2.4*	X	-3.7*
838.5	X	+1.8*	-2.7*
839	X	+1.1*	-3.7*
841	X	+0.1	-3.2
838.5	+2.7*	+1.3*	-5.3*
839	+1.0*	+1.2*	-3.5

Percentage of tested conditions with vortex present	85
Average vortimeter reading, rpm	1.8
Maximum vortimeter reading, rpm	5.3

Note: All magnitudes are expressed in terms of prototype equivalents.
Discharge per pump = 100 cfs or 44,883 gpm
+ = clockwise rotation
- = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
* = vortex observed

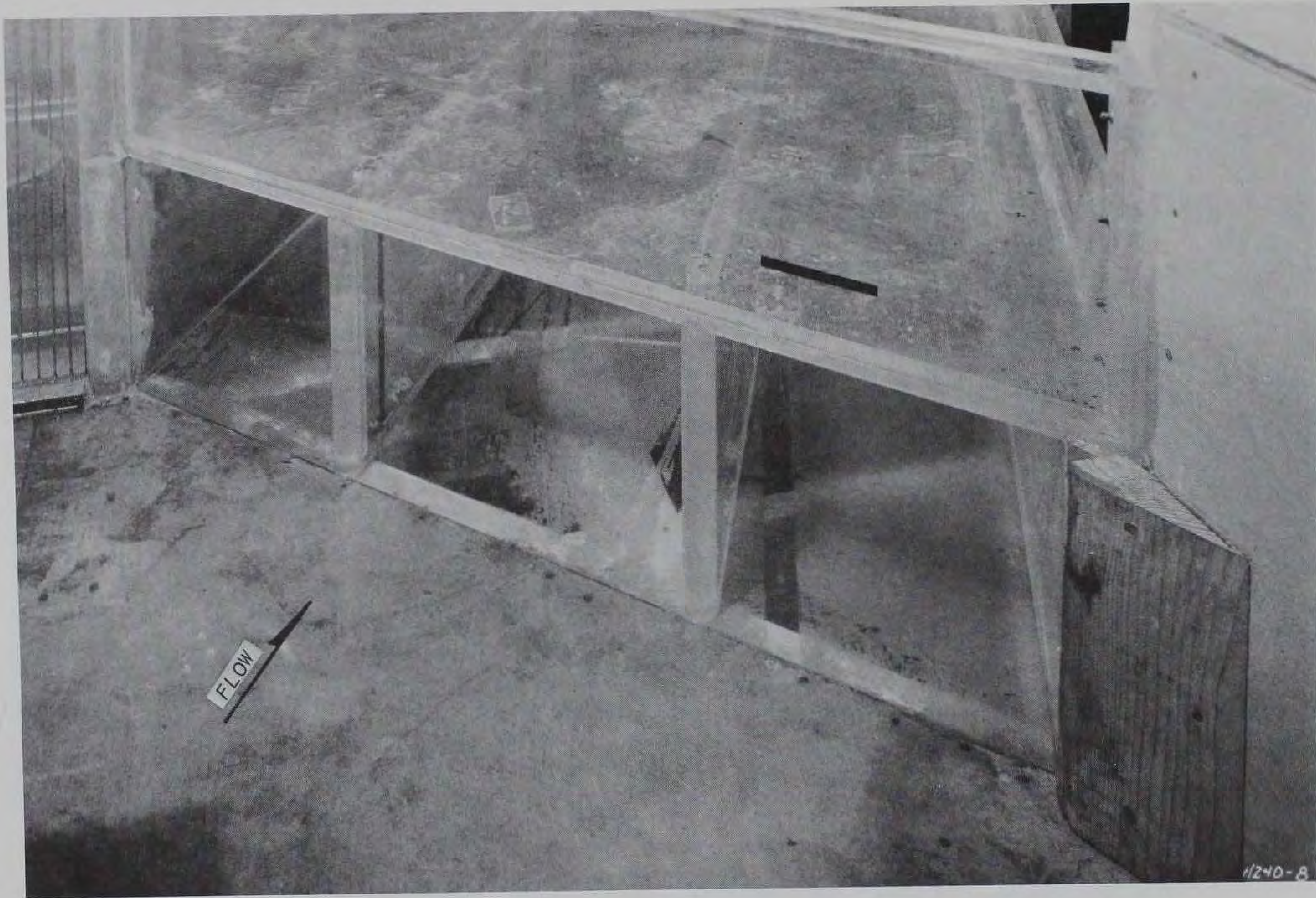


Photo 1. Type 2 design gravity-flow section

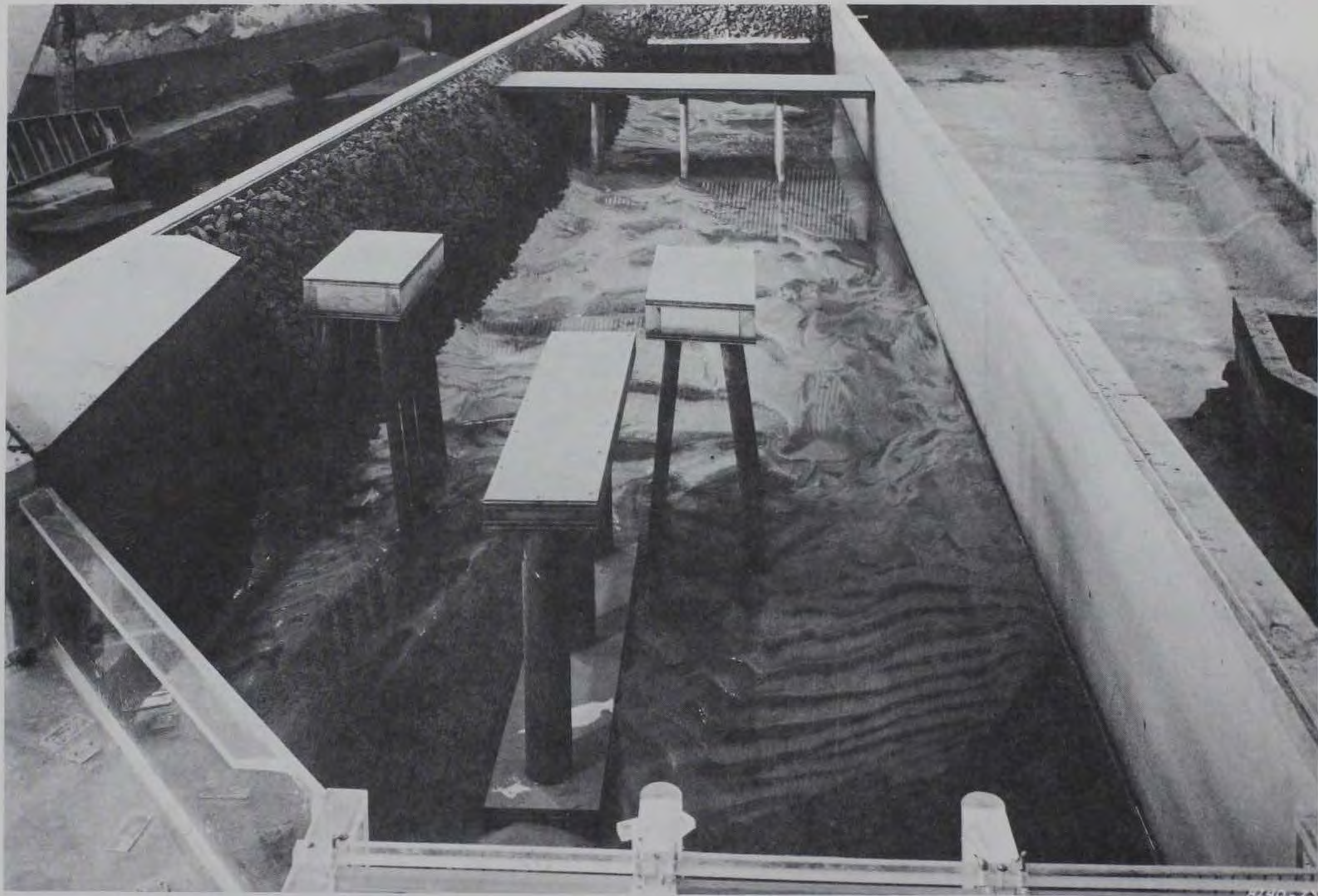


Photo 2. Looking upstream, after simulating 6-hr hydrograph

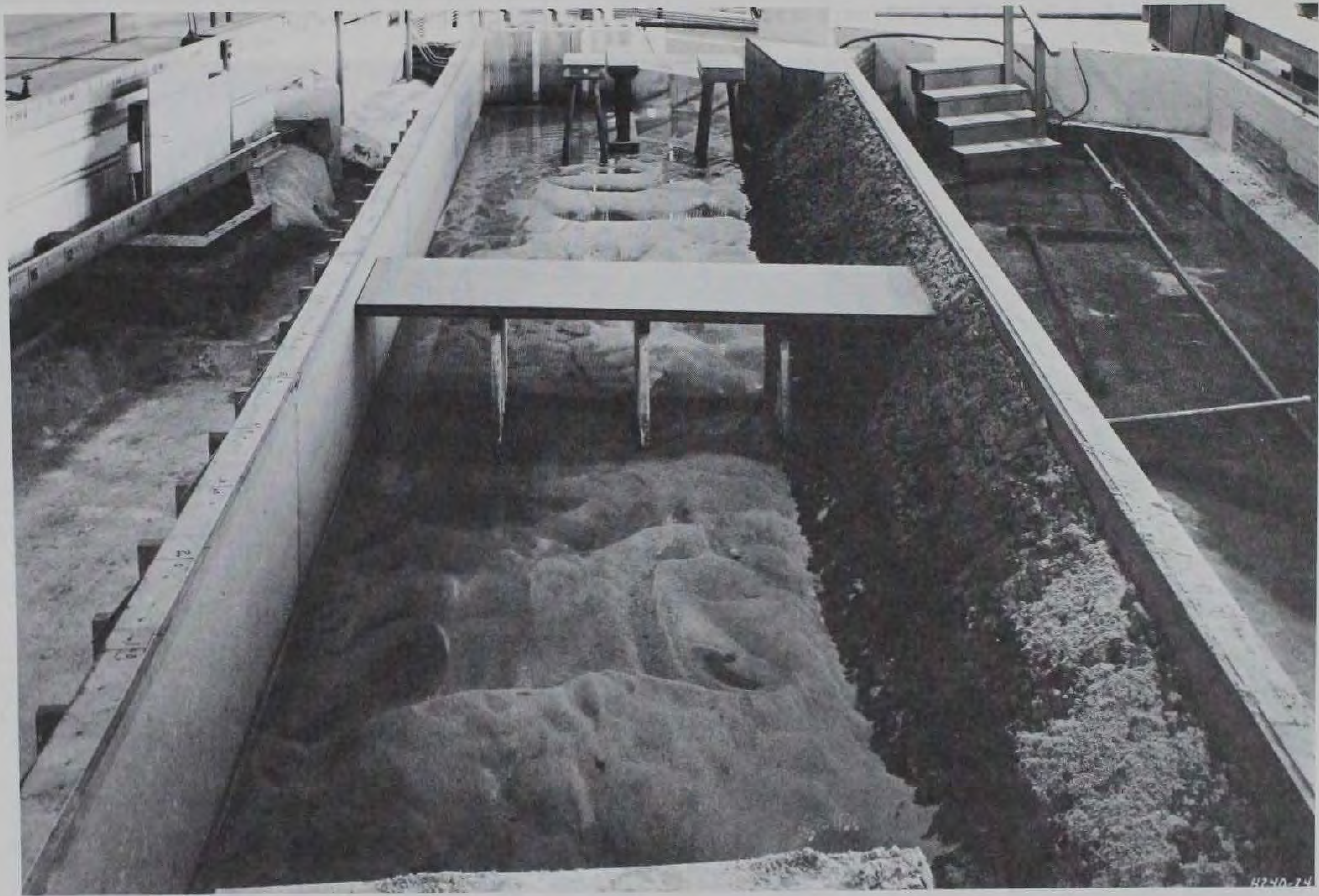


Photo 3. Looking downstream, after simulating 6-hr hydrograph

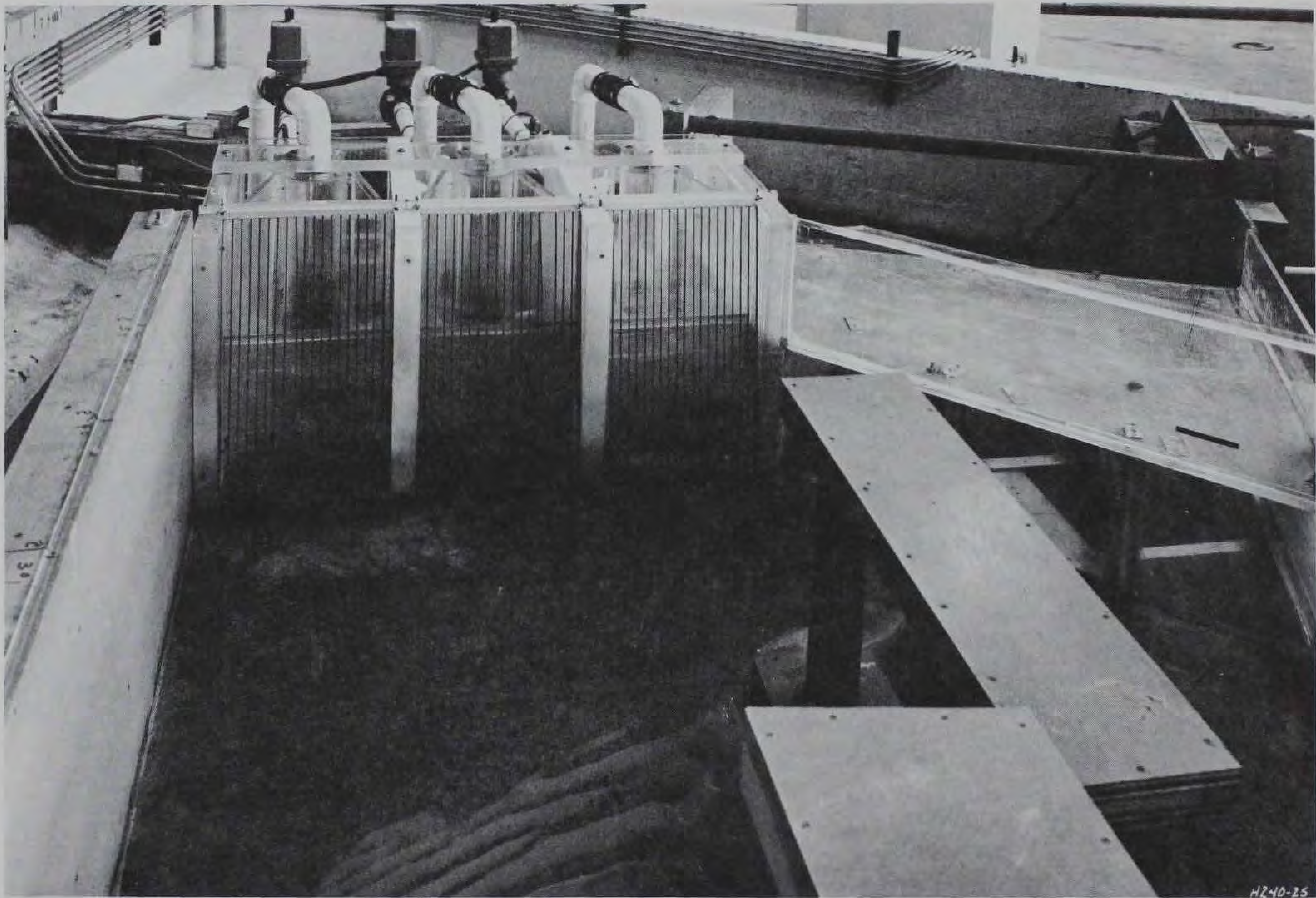
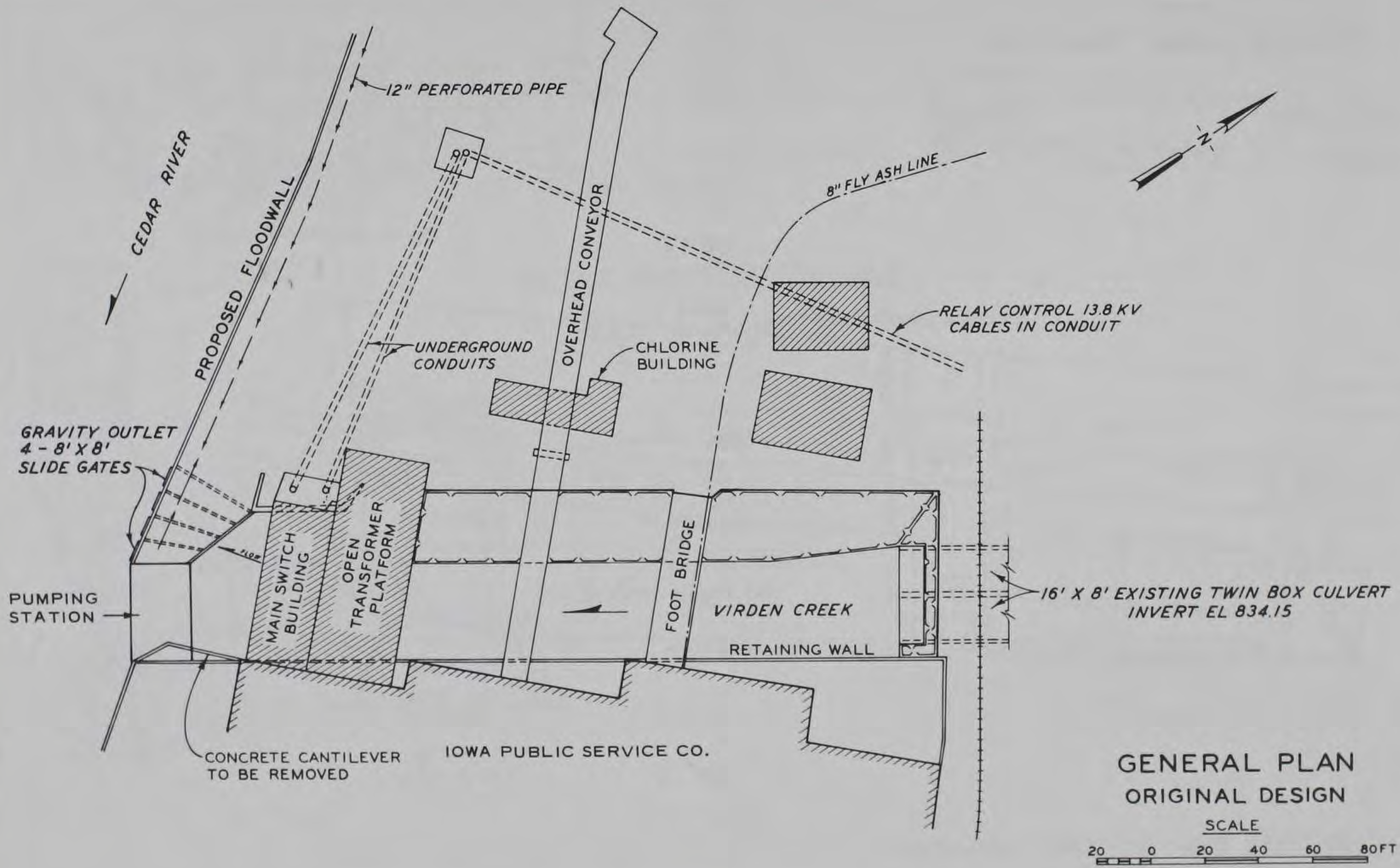


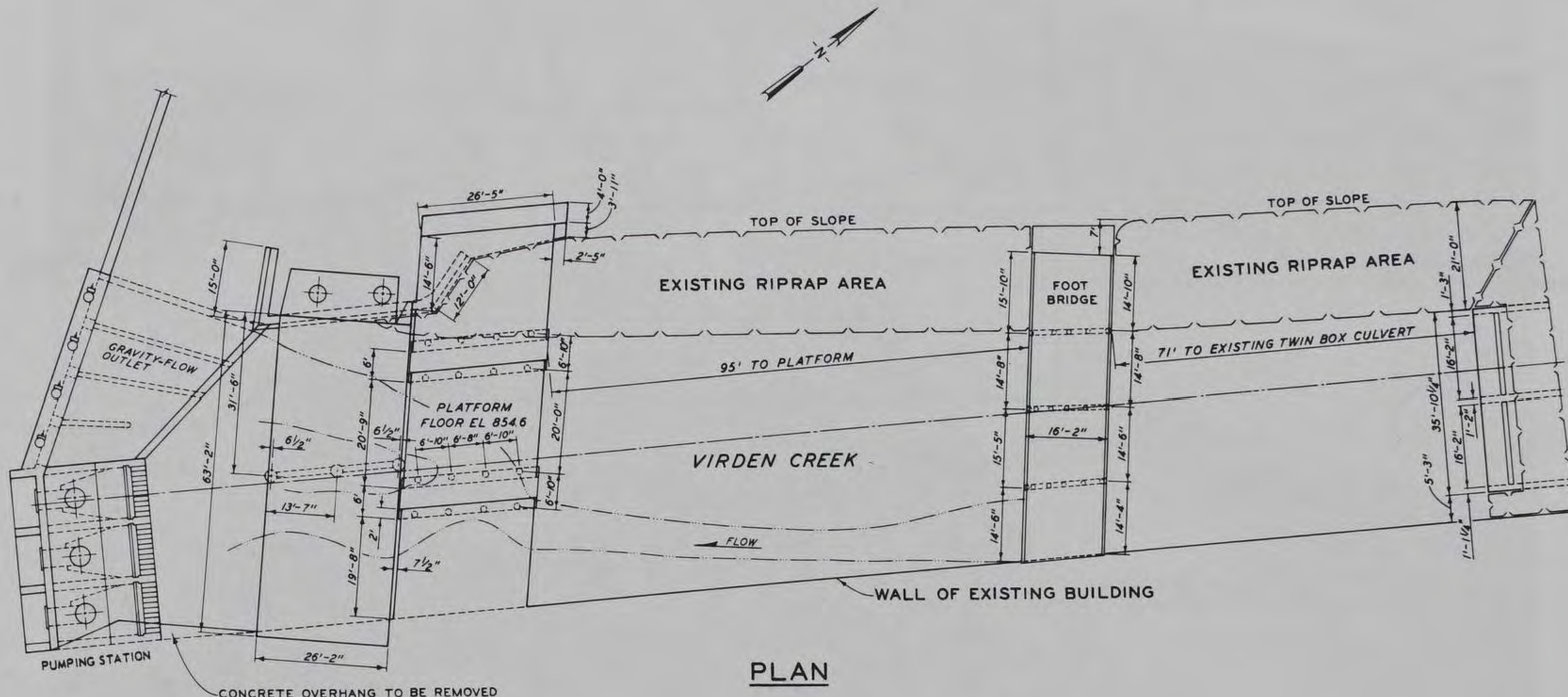
Photo 4. Closeup view of pumping station, after simulating 6-hr hydrograph



GENERAL PLAN
ORIGINAL DESIGN

PLATE 1

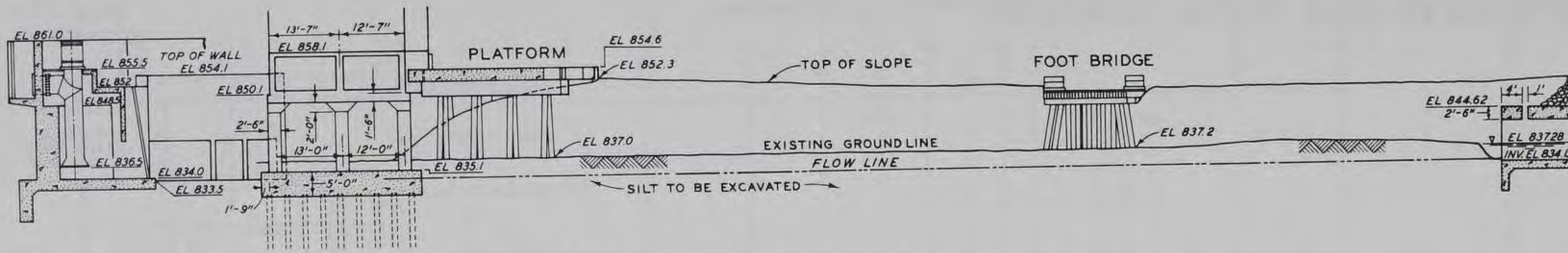
PLATE 2



ORIGINAL PLAN DETAILS

SCALE

10 0 10 20 30 40 FT



PROFILE ALONG CENTER LINE

SCALE

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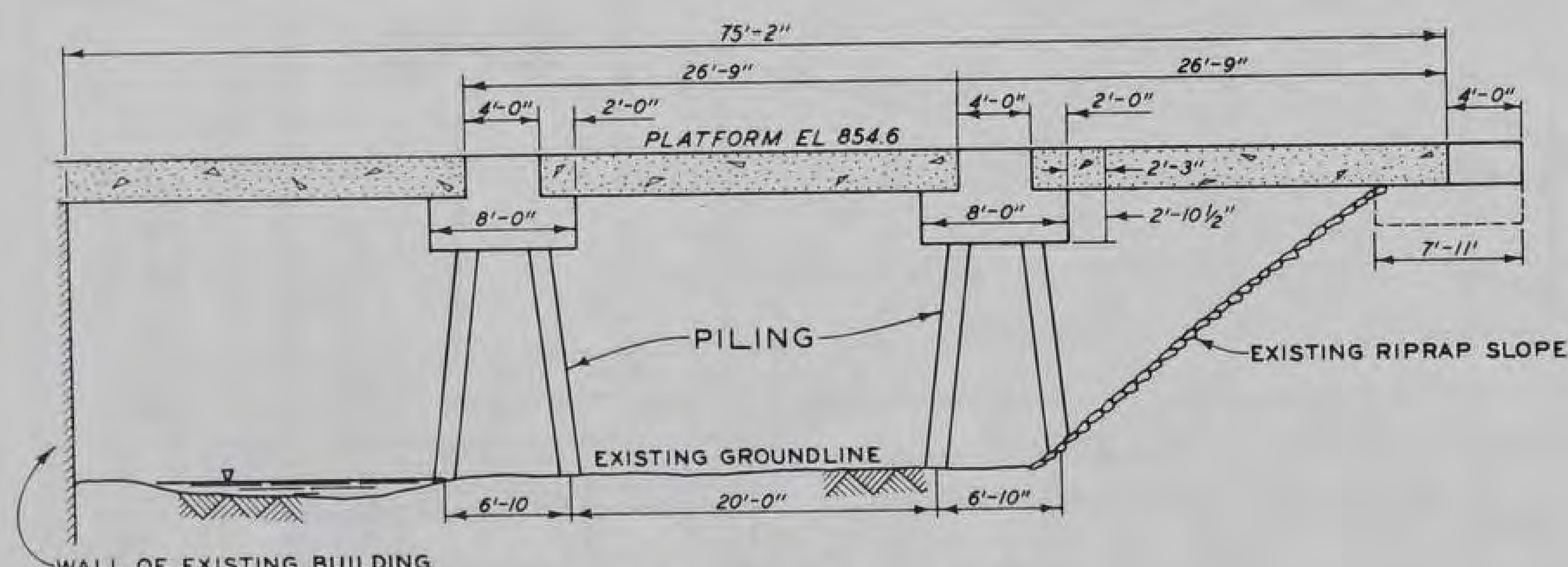
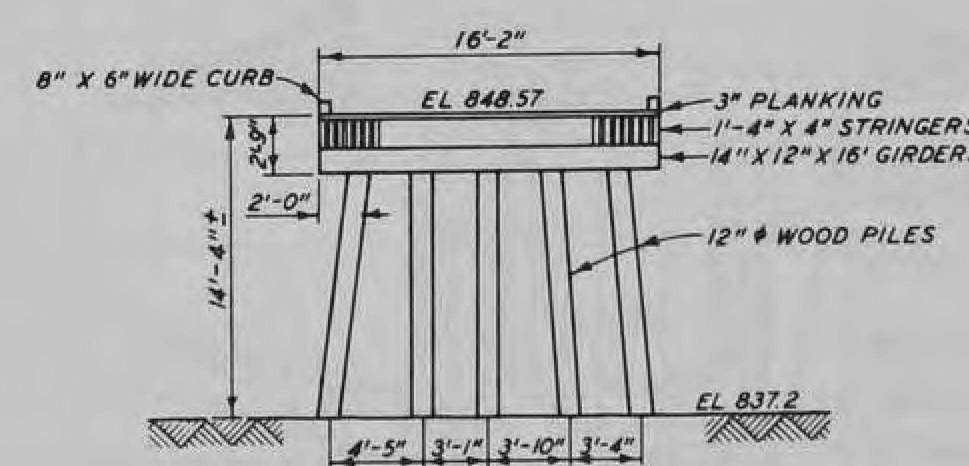


PLATFORM SECTION

(UPSTREAM)

SCALE

5 0 5 10 FT



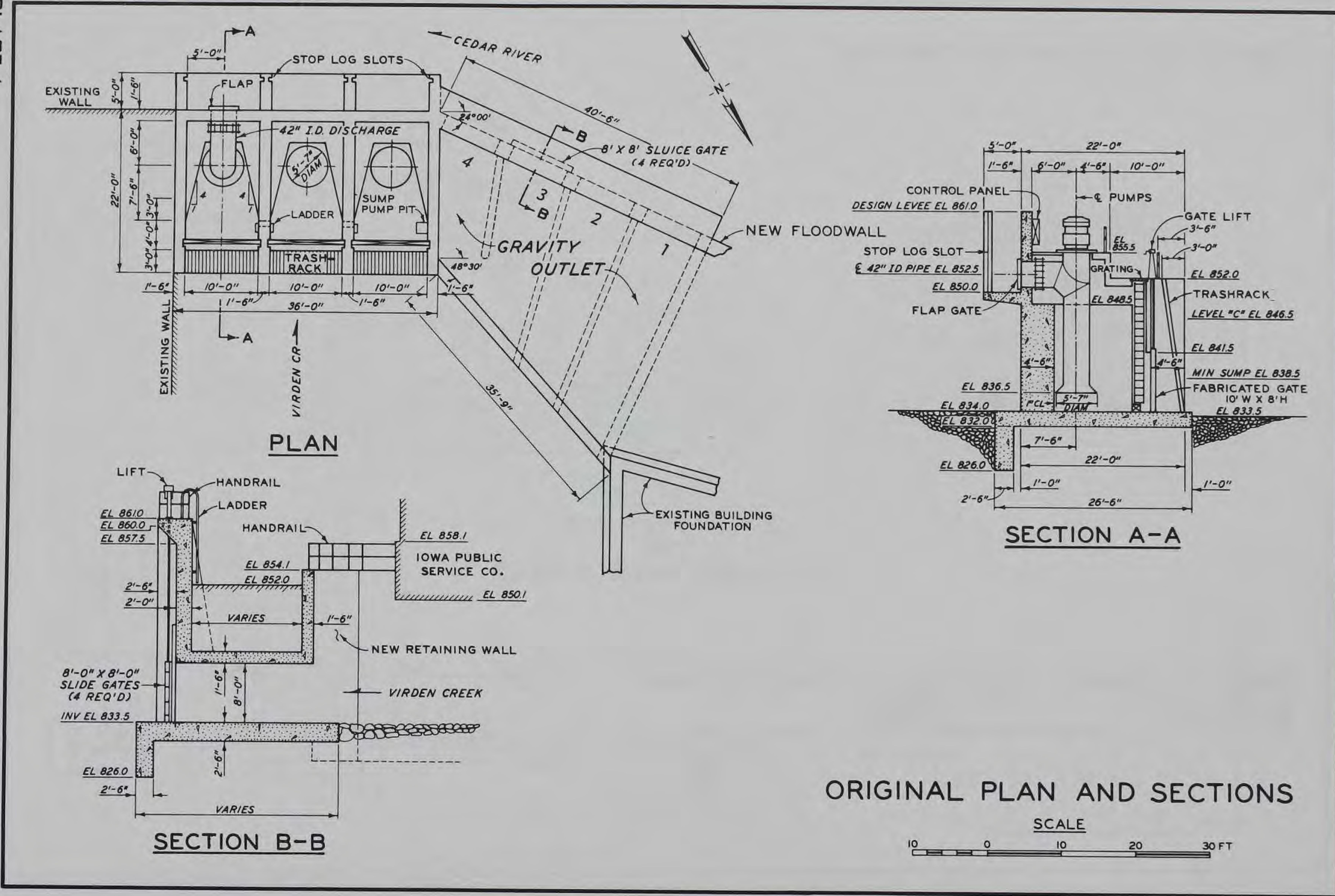
FOOT BRIDGE SECTION

(NORTH SET OF PILING)

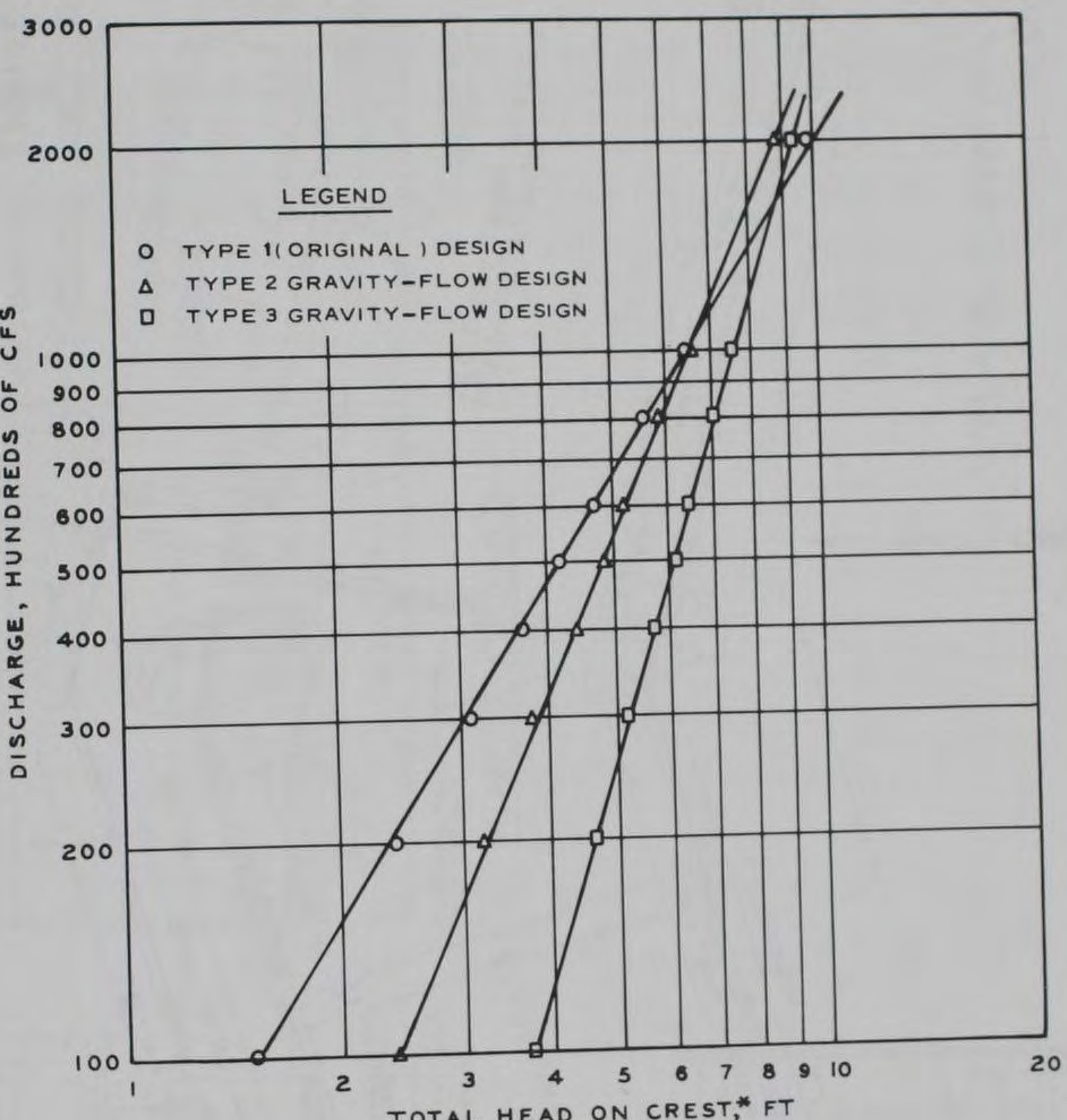
SCALE

5 0 5 10 FT

ORIGINAL PROFILE AND SECTIONS



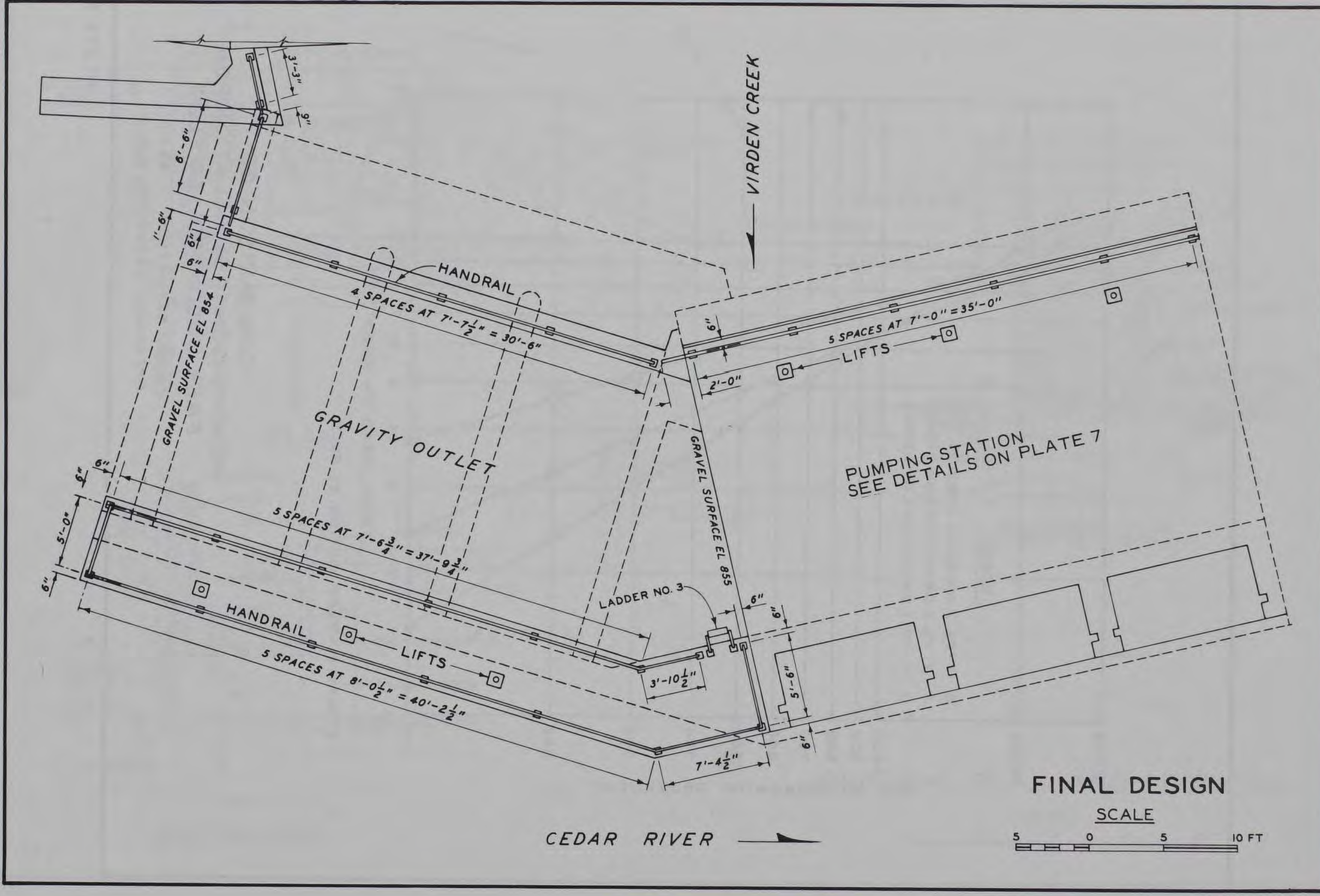
ORIGINAL PLAN AND SECTIONS



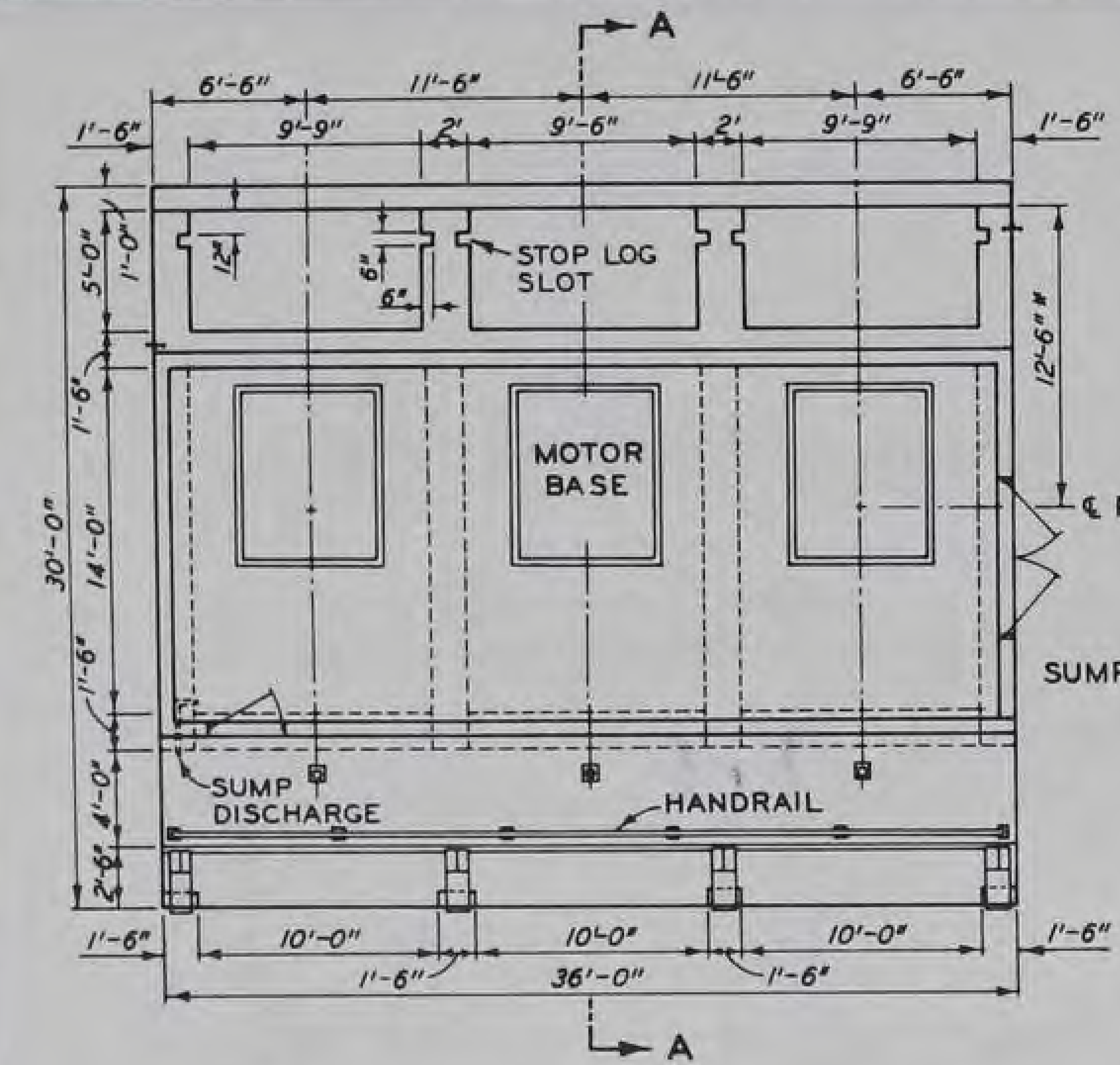
* GRAVITY-FLOW SECTION, EL 833.5

COMPARISON OF
HEAD-DISCHARGE RELATION FOR
FREE UNCONTROLLED FLOW

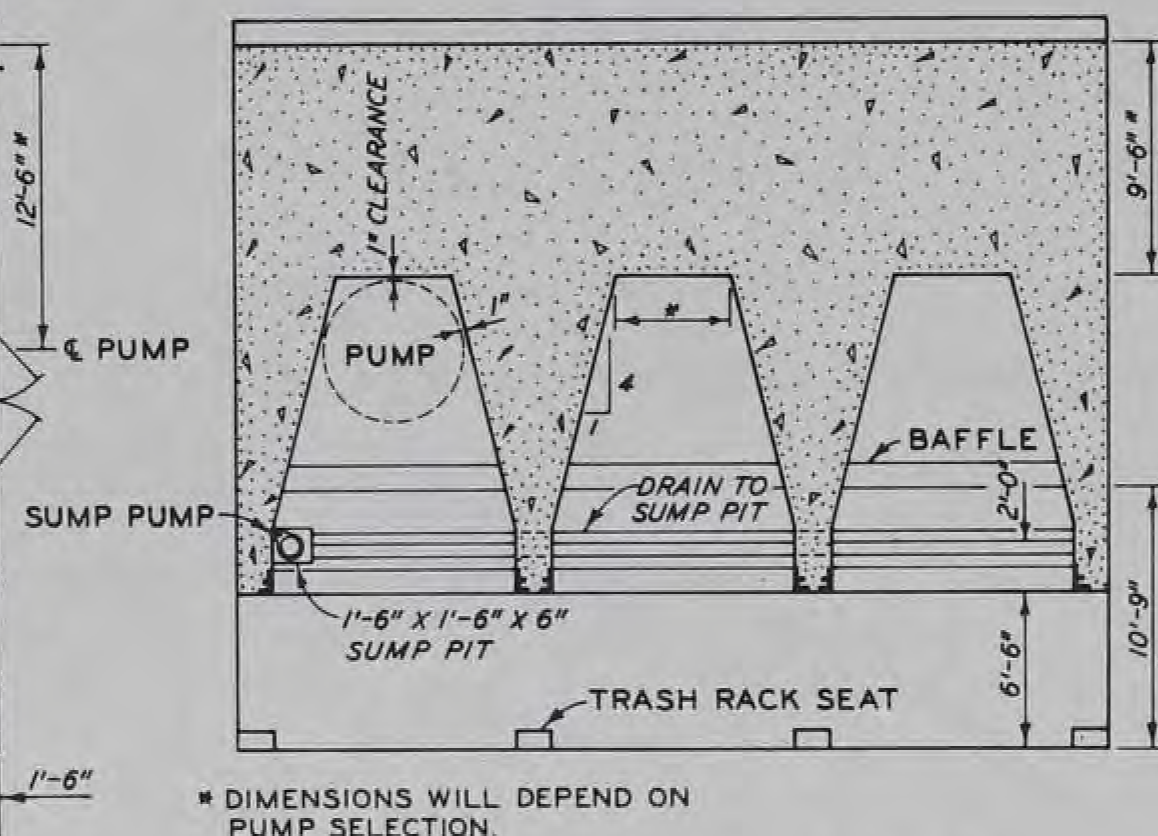
CREST ELEVATION 833.5
APPROACH ELEVATION 833.5



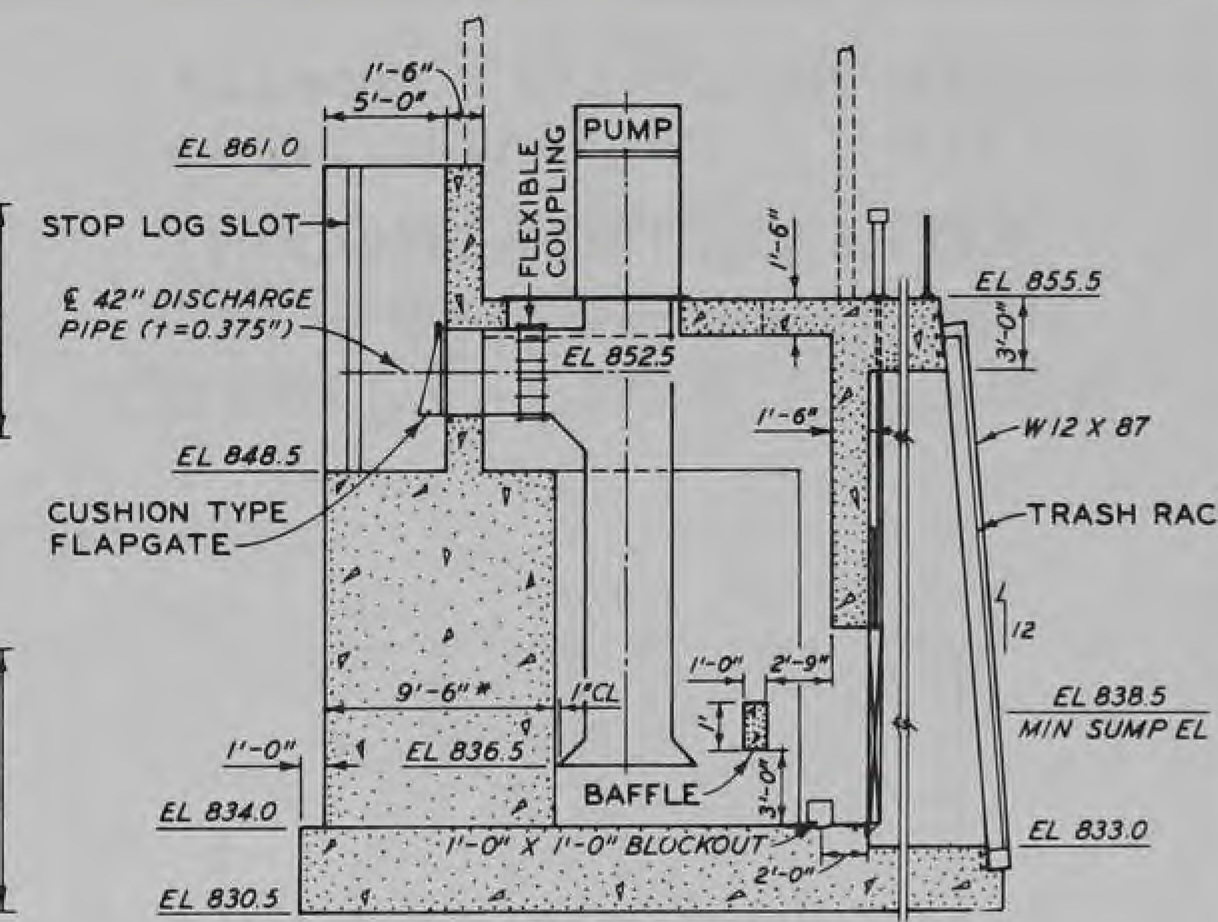
FINAL DESIGN



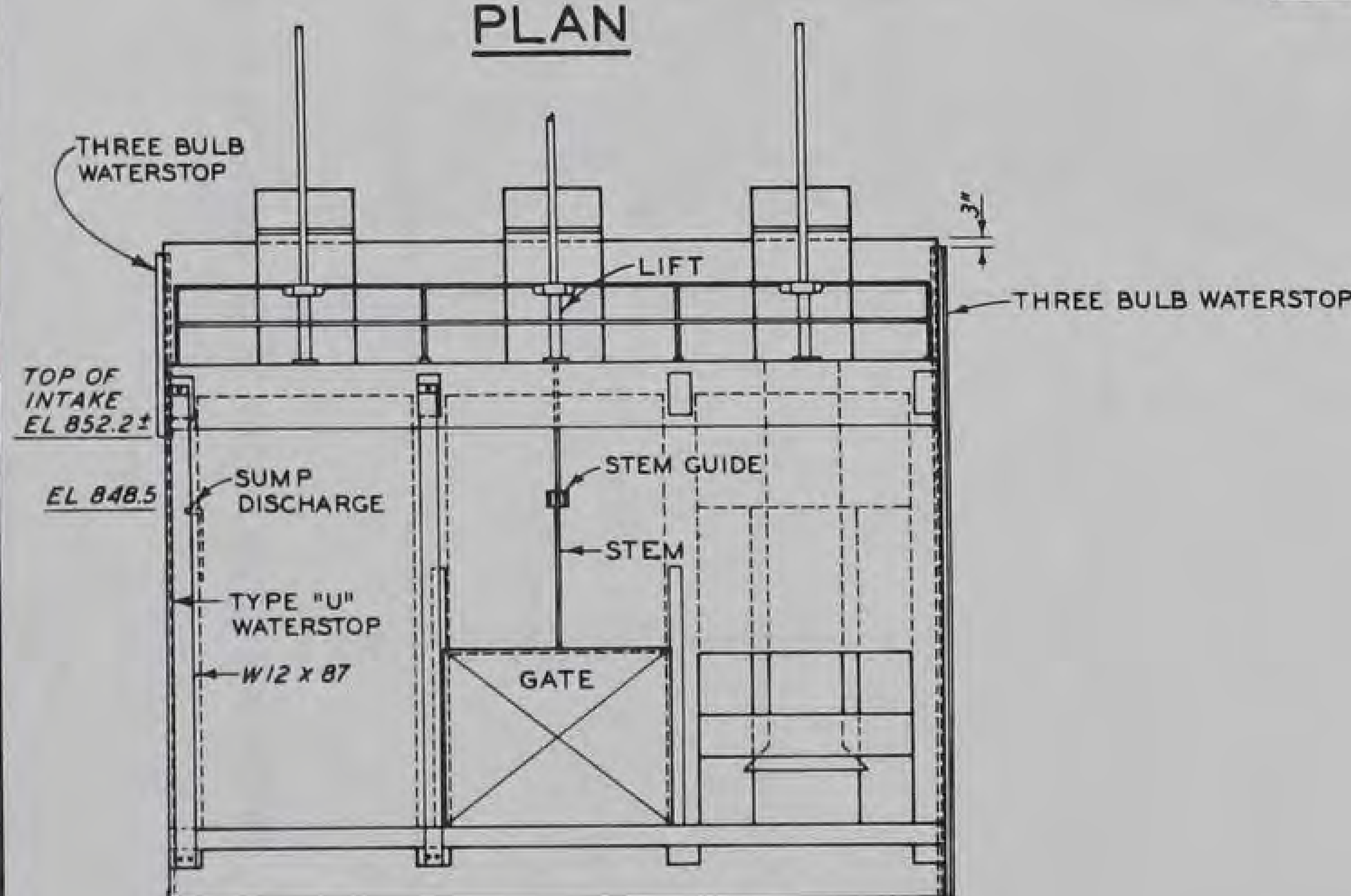
PLAN



PLAN AT EL 840.0



SECTION A–A



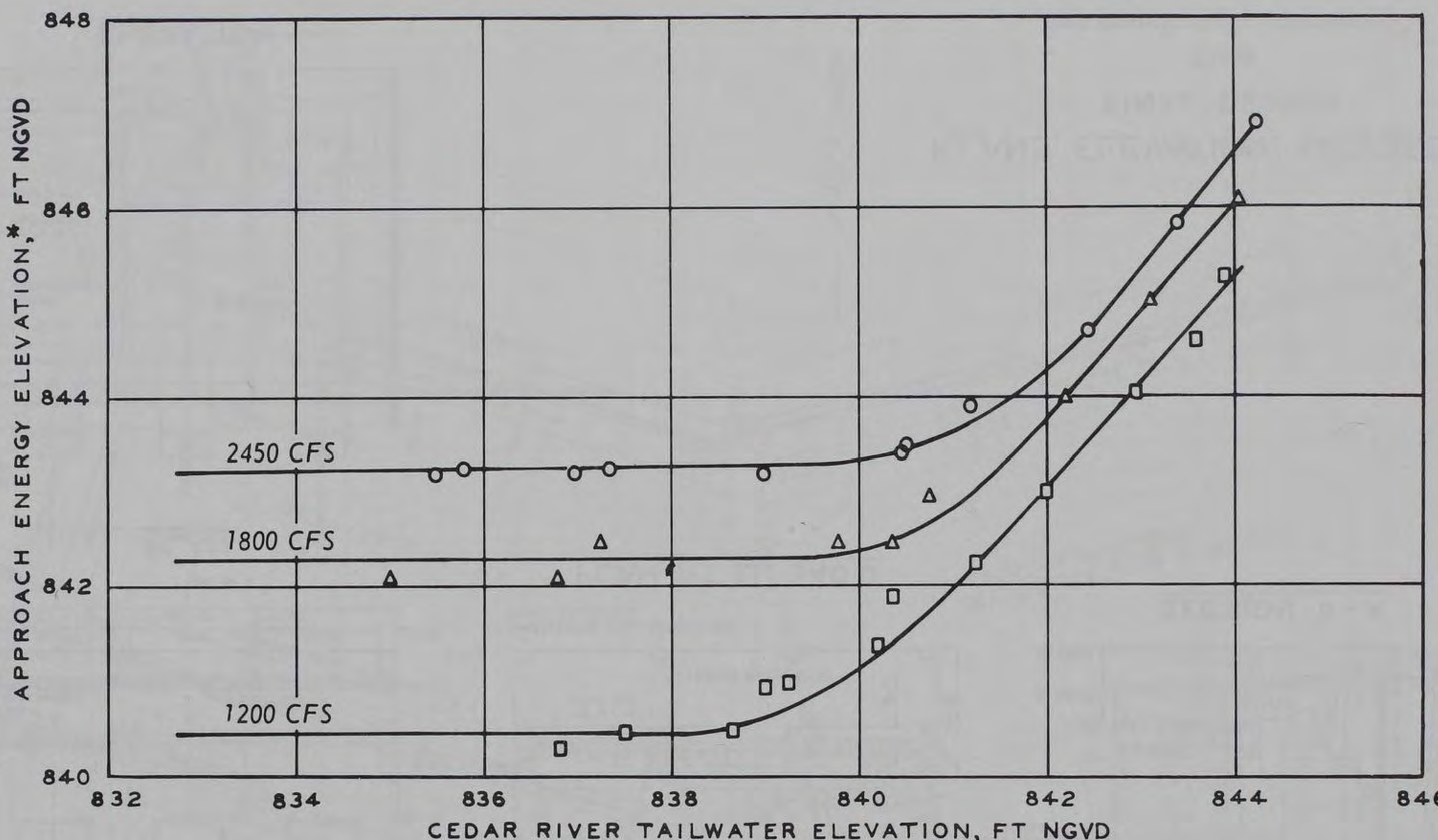
ELEVATION

PLANS, ELEVATION, AND SECTION

FINAL DESIGN

SCALE

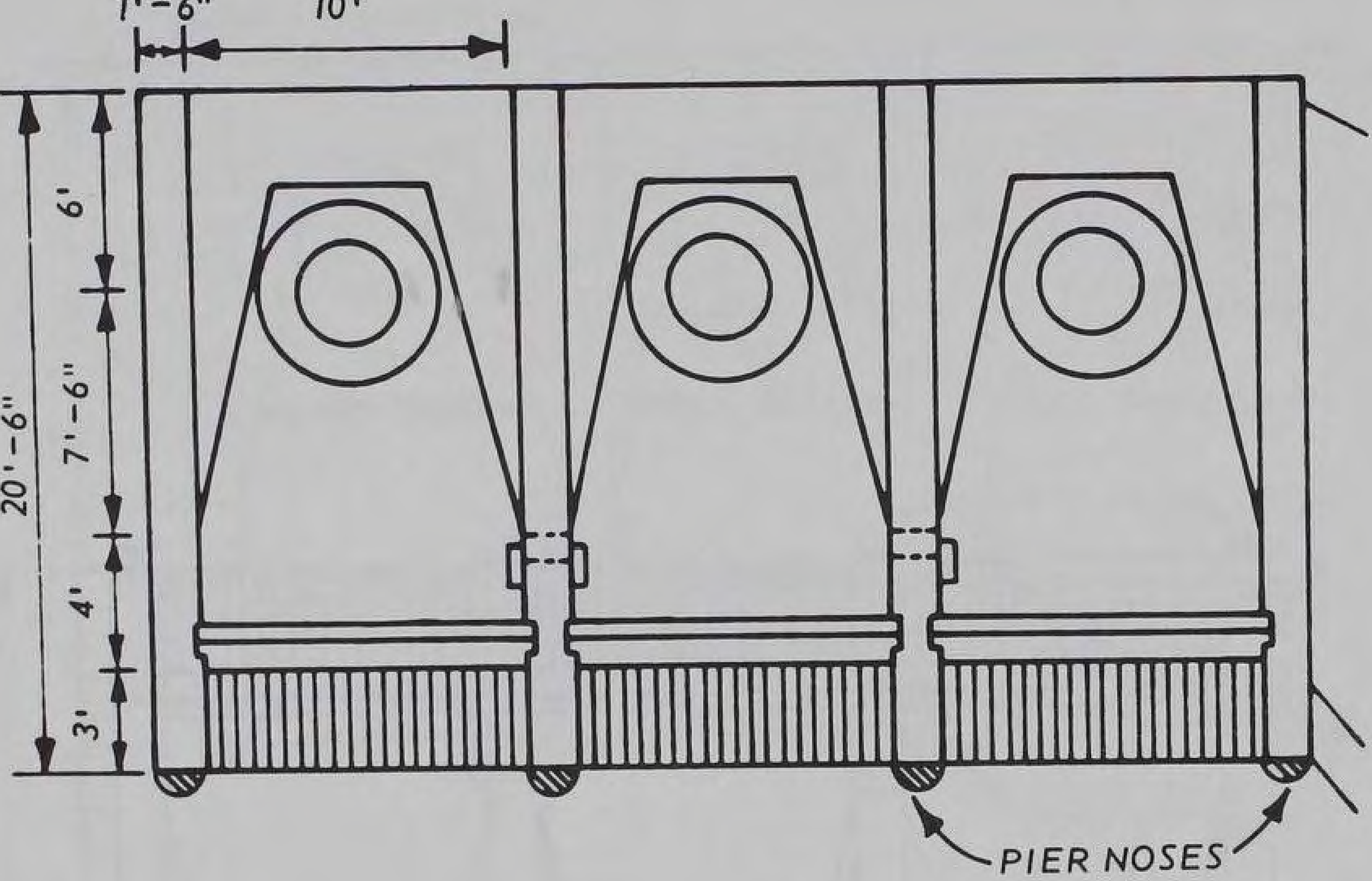
10 0 10 20 FT



* ELEVATION UPSTREAM OF TRANSFORMER PLATFORM

GRAVITY - FLOW SECTION
CALIBRATION DATA FOR
UNCONTROLLED FLOW

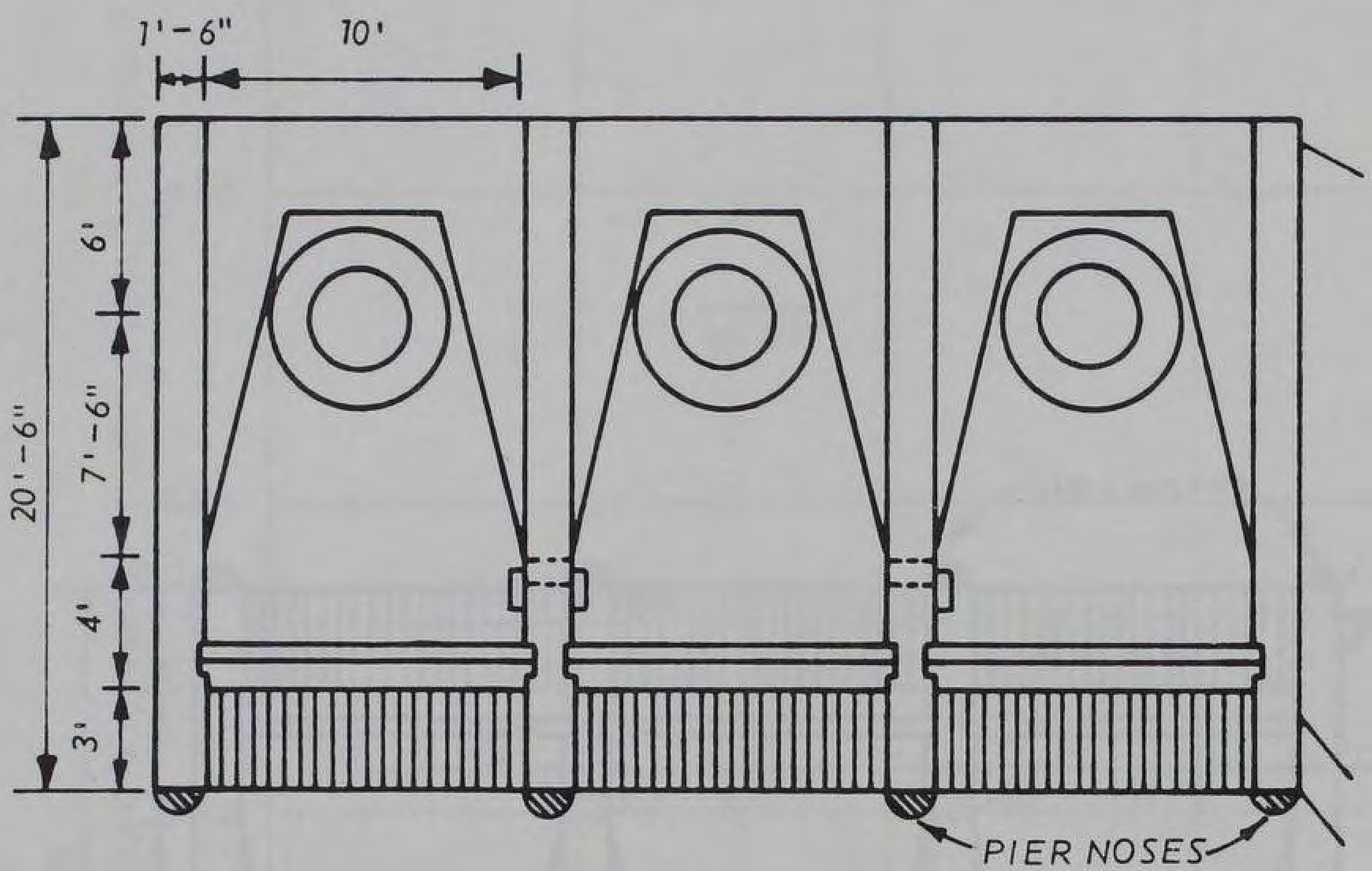
CREST ELEVATION 833.5
APPROACH ELEVATION 833.5



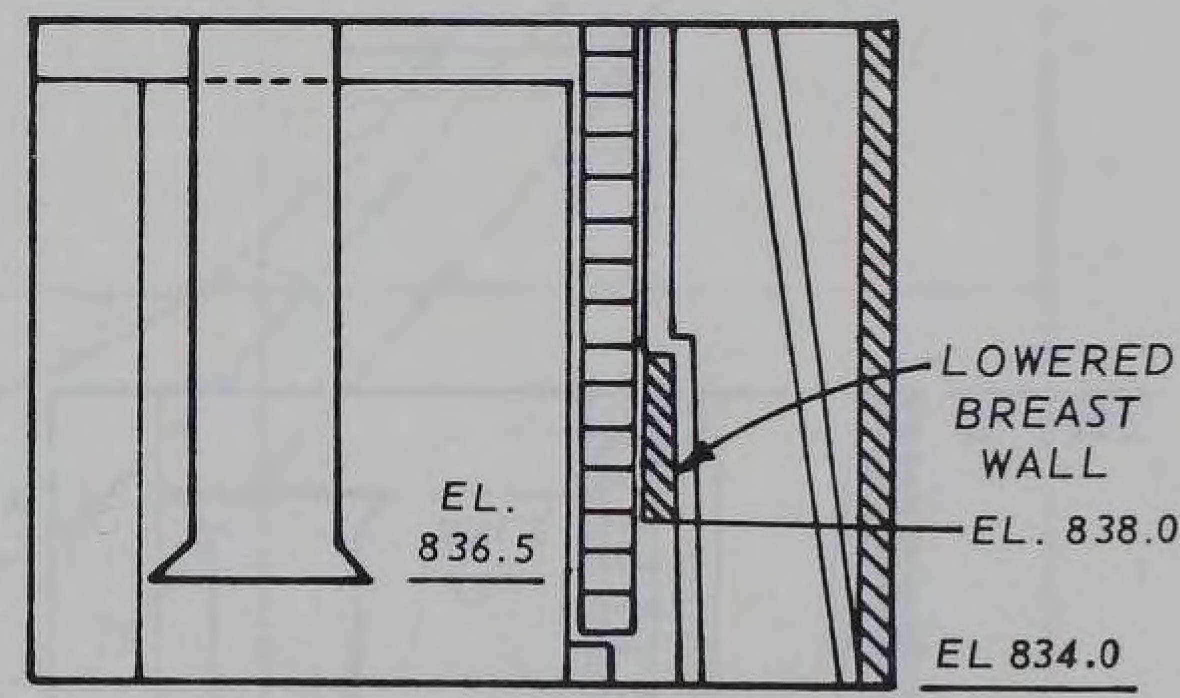
PLAN

ELEVATION

PUMP SUMP
TYPE 2 DESIGN



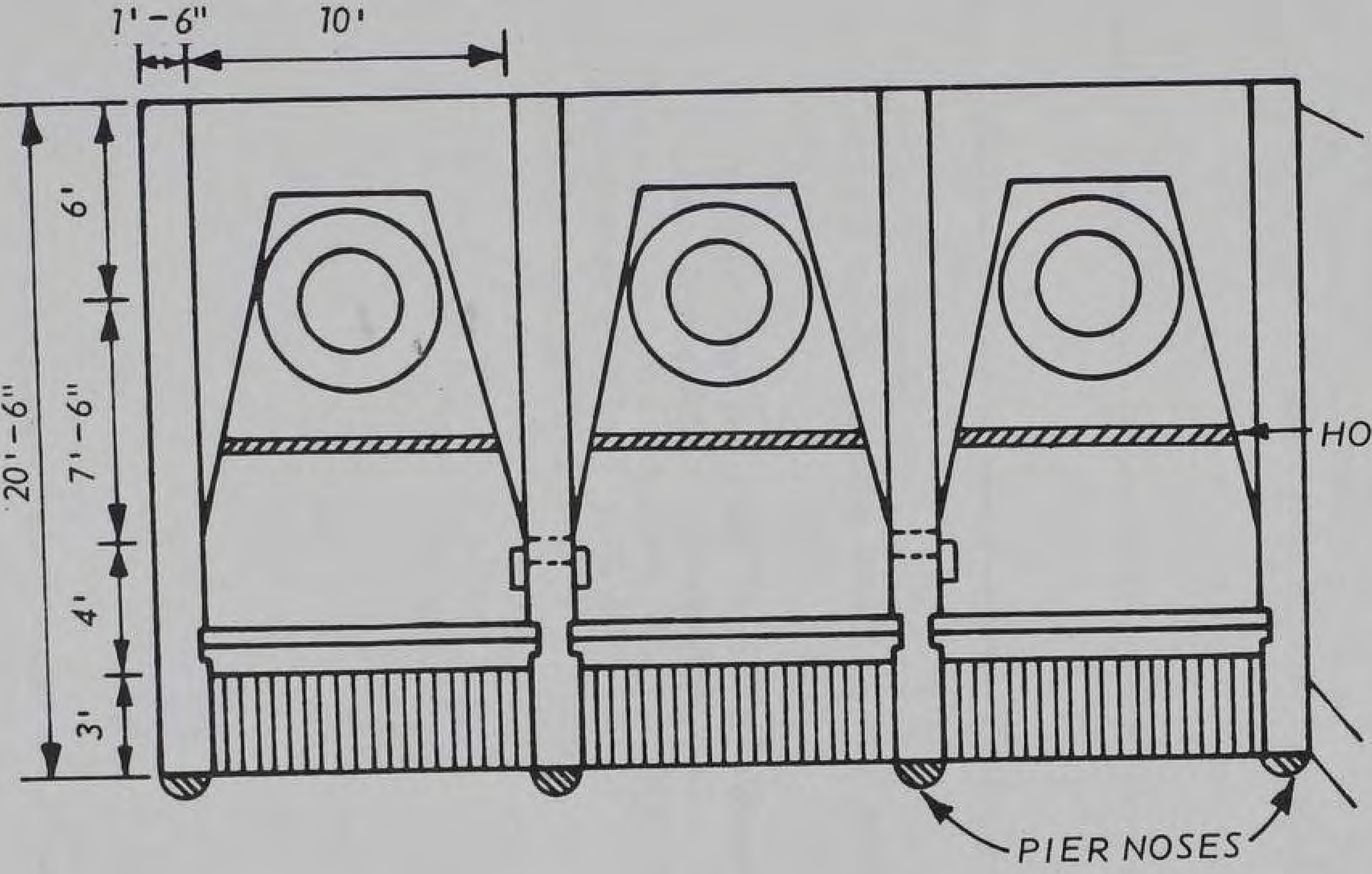
PLAN



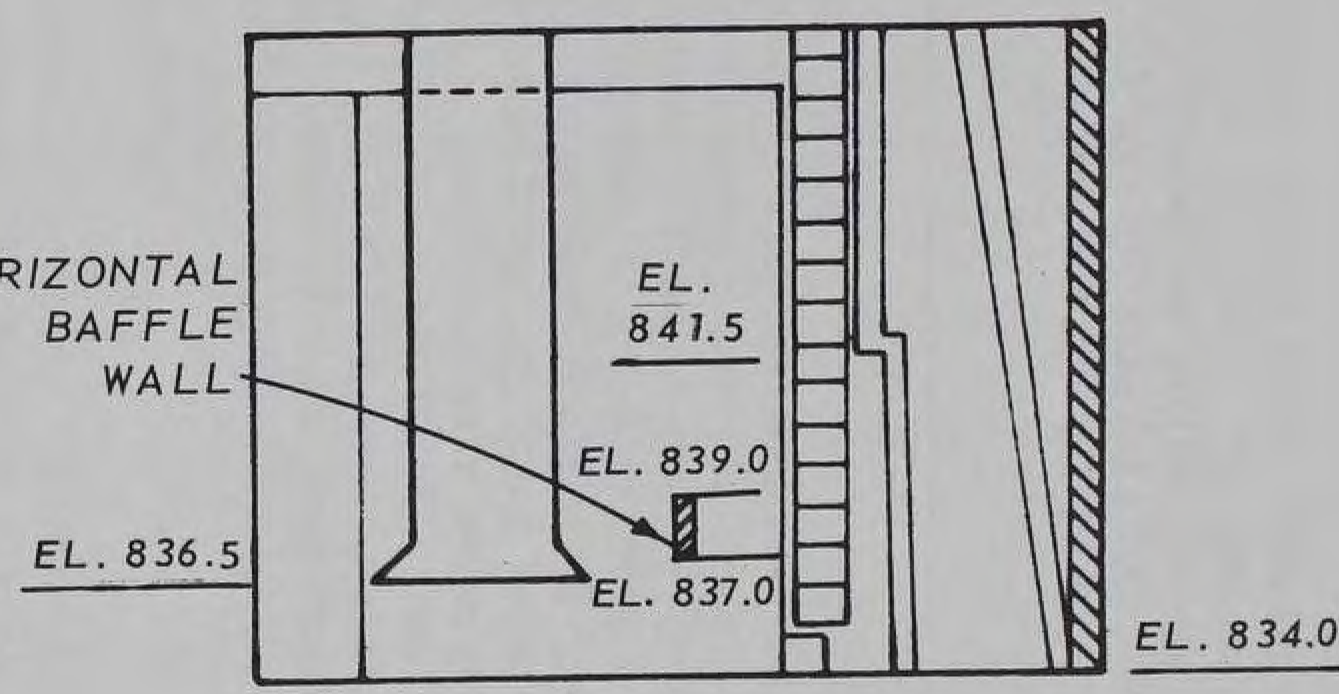
ELEVATION

PUMP SUMP

TYPE 3 DESIGN



PLAN



ELEVATION

PUMP SUMP

TYPE 4 (RECOMMENDED) DESIGN