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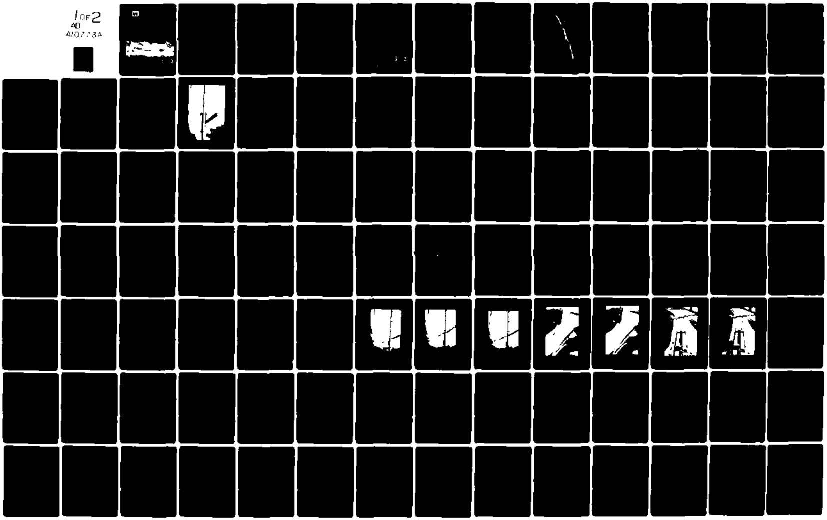

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TECHNICAL REPORT HL-81-7

NAVIGATION CONDITIONS AT MCALPINE LOCKS AND DAM, OHIO RIVER

Hydraulic Model Investigation

by

Louis J. Shows, John J. Franco

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August 1981
Final Report

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Prepared for U. S. Army Engineer District, Louisville
Louisville, Kentucky 40201

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McAlpine Locks and Dam are located on the Ohio River near Louisville, Kentucky, 606.8 miles below Pittsburgh, Pennsylvania. The locks are located in a bypass canal on the left overbank landward of Shippingport Island. A powerhouse is located along the left bank adjacent to the downstream end of Shippingport Island, and a four-gated spillway section is located adjacent to the powerhouse. A fixed-crest weir extends from the four-gated spillway section upstream 6,600 ft generally parallel to the right bank to an upper

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20. ABSTRACT (Continued).

five-gated spillway section which is connected to the right bank with a 1,200-ft-long fixed-crest weir just upstream of the Pennsylvania Railroad bridge. The structures, designed to maintain a minimum upper pool during low flows extending about 75 miles upstream to Markland Locks and Dam near Warsaw, Kentucky, include a navigation lock with clear chambers dimensions of 110 ft wide by 1,200 ft long located at the lower end of a 1.75-mile-long canal along the left bank and two auxiliary locks between the main lock and left bank that are out of service. A fixed-bed model reproduced about 8.5 miles of the Ohio River channel, the lock approach canal, and adjacent overbank areas to an undistorted scale of 1:120.

The model investigation was concerned with improving navigation conditions at the entrance to the lock approach canal; developing modifications required to remove shoaling along the right bank just downstream of the fixed weir at the upper gates; determining the effectiveness of dam modifications on reducing swellhead at the dams; determining the effect of a proposed dike design to reduce scouring along the Indiana bank opposite the lower tainter gates; investigating the effect of an additional 1,200-ft lock on navigation; and investigating the effect of lock filling on surge within the lock approach canal with the proposed additional lock. Results of the investigation revealed that of the plans tested, the greatest improvement in the canal was obtained with a 600-ft-long low dike forming an extension to Shippingport Island. Increasing the number of gate bays and gates to the right of the upper gated spillway or lowering the elevation of the overflow fixed-crest weir would increase the range of controlled flows. Deposition along the right bank downstream of the Pennsylvania Railroad bridge could be reduced with the addition of gates to the right of the existing upper gated spillway or by construction of a training dike to divert flow from the existing upper spillway toward the deposition area. Scouring along the right bank opposite the lower gated spillway could be reduced by construction of a deflector dike between the spillway and the right bank; however, velocities would tend to be increased farther downstream. Velocities impinging on the right bank could also be reduced with flow through the upper gated spillway during lower flows. Surges created by lock filling can vary appreciably, depending on the surge remaining after a previous filling and other factors such as traffic, wind, river discharge, and rate of filling. Proper phasing of the filling of the second lock can reduce the surge produced to heights equal to or less than those produced by filling the first lock. Satisfactory navigation conditions could be developed with two 1,200-ft locks arranged as tested. When emptying the two 1,200-ft locks simultaneously on the riverside of both locks, erosion along Sand Island could be increased to a point that it might have some effect on navigation in the lower approach.

PREFACE

The model investigation described herein was conducted for the U. S. Army Engineer District, Louisville, and authorized by DA Form 2544, Order No. DC-B-73-57, dated 10 October 1972 and DA Form 2544, Order No. DC-B-73-57, Change Order No. 1, dated 7 December 1972, to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. The study was conducted in the Hydraulics Laboratory of WES during the period November 1972 to May 1977.

The model study was conducted under the general supervision of Messrs. H. B. Simmons, and F. A. Herrmann, Jr., Chief and Assistant Chief, respectively, of the Hydraulics Laboratory, and under the direct supervision of Mr. J. E. Glover, Chief of the Waterways Division. The engineer in immediate charge of the model was Mr. L. J. Shows, Chief of the Navigation Branch, assisted by Messrs. R. T. Wooley and T. H. Kyzar. This report was prepared by Messrs. Shows and J. J. Franco.

During the course of the model study, representatives of the U. S. Army Engineer Division, Ohio River, the Louisville District, and other navigation interests visited WES at different times to observe special model tests and to discuss test results. The Louisville District was kept informed of the progress of the study through monthly progress reports and special reports at the end of each test.

Commanders and Directors of WES during the course of this investigation and the preparation and publication of this report were BG E. D. Peixotto, CE, COL G. H. Hilt, CE, COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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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
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
miles (U. S. statute)	1.609344	kilometres

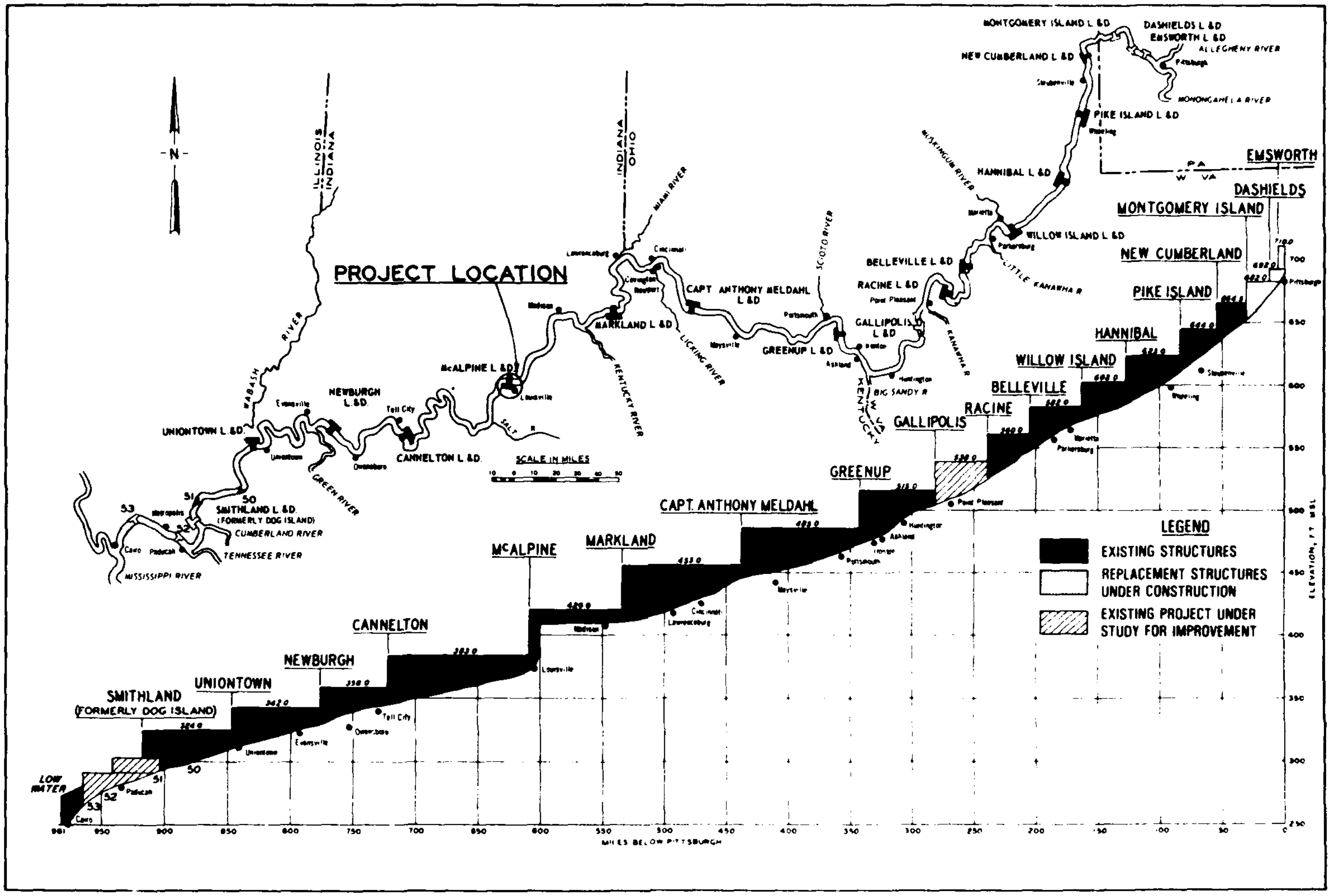

Figure 1. Location map

NAVIGATION CONDITIONS AT McALPINE LOCKS AND DAM

OHIO RIVER

Hydraulic Model Investigation

PART I: INTRODUCTION

Location and Description of Prototype

1. McAlpine Locks and Dam (formerly Locks and Dam 41) are located on the Ohio River at the northwestern end of Louisville, Kentucky (Figure 1), 606.8 miles* below Pittsburgh, Pennsylvania. The structures, including the dam, canal, locks, etc., extend from mile 604.4 to mile 607.4. The upper pool of the dam extends approximately 75 miles upstream to Markland Locks and Dam near Warsaw, Kentucky.

2. Precipitation over the Ohio River basin above Louisville, Kentucky, is generally well distributed throughout the year, but flood-producing rainfall generally occurs in the winter and early spring. Flood stage of el 431.0** at Louisville (upstream of the dam) is reached with an average frequency of once in 15 years. The highest flood of record reached a peak elevation of 460.1 at the dam in January 1937 and had a maximum discharge of 1,110,000 cfs. The second highest flood occurred in March 1945 with a peak elevation of 450.1 and a maximum discharge of 843,000 cfs. Most of the areas adjacent to the project, including Louisville, Kentucky, and New Albany, Clarksville, and Jeffersonville, Indiana, are protected from flooding by means of levees and floodwalls.

History of Navigation Improvements on the Ohio River

3. In its natural state, the Ohio River was obstructed throughout

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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 (msl), Ohio River Datum.

its entire length by snags, rocks, gravel, and sandbars which rendered navigation extremely difficult and hazardous. Controlling depths during low water were 1 to 2 ft from Pittsburgh, Pennsylvania, to the river's mouth at Cairo, Illinois. From about 1824 to 1910, funds were appropriated periodically for navigation improvements, which consisted principally of removal of snags and wreckage from the channel and construction of stone training dikes to contract the channel and increase the scouring action of the river. During this period, the principal Ohio River traffic consisted of downbound coal tows that were assembled in the Pittsburgh harbor area and moved downstream during higher river stages that provided sufficient depth.

4. Initially, coal transport interests opposed the construction of locks and dams. They wanted to use regulatory works to maintain required depths and thus keep a free passage under open-river conditions. This was not possible, however, without constricted channels and excessive velocities that would be hazardous to downstream navigation and would render upstream navigation impossible. Because of these conditions, the need for locks and dams was finally recognized. To eliminate obstacles to downstream traffic, a movable dam was adopted that could be lowered to the bed of the river, thus permitting free passage of downstream tows when natural flows provided sufficient depths. Since loaded upbound traffic was an extremely small part of the total traffic at that time and no material change was foreseen, little consideration was given to upbound traffic.

5. The River and Harbor Act of 25 June 1910 provided for the construction of 54 locks and dams. During construction, certain substitutions and eliminations of structures were made in the plans so that the project consisted of 50 locks and dams when completed in 1929. Since its original completion, the project was further modified so that the system was composed of 46 locks and dams; of these, 42 were movable, 1 was fixed, and 3 were nonnavigable, gate-controlled structures. The dams were designed to maintain a minimum slack-water channel of 9 ft. Pool lifts ranged from 5.6 to 37.0 ft. All dams had at least one

110- by 600-ft lock, and five had an auxiliary lock; four of the auxiliary locks were 56 by 360 ft.

6. The original navigation project, as modified in the 1930's, comprised 46 dam-lock structures and the Louisville and Portland Canal (L&P Canal) at Louisville, Kentucky. A modernization program, initiated in 1954, provides for continuing the 9-ft project depth by the progressive replacement of existing structures by 19 high-lift structures. As of September 1981, all of the high-lift structures between approximately river miles 50 to 920 have been completed except for Gallipolis Locks and Dam which is presently under study and planning for improvement. The modern units consist of nonnavigable, gated dams, a main lock (110 by 1200 ft) and a second lock (110 by 600 ft) except for Smithland which has two 1200-ft locks. McAlpine has a third lock chamber (56 by 360 ft) which is not operable.

Conditions of Existing McAlpine Structures

7. Reconstruction of Locks and Dam 41 (McAlpine Locks and Dam) was part of the general plan of improvement of navigation on the Ohio River. No change would be made to the existing upper pool elevation of 420.0 which will provide navigable depths to Markland Locks and Dam. Modernization of McAlpine Locks and Dam was begun in 1954, and by 1962 a new 110- by 1200-ft lock was in operation. The modernization plan also included reconstruction and widening of the upper lock entrance canal, installation of a surge basin in this canal, and provision for a nonnavigable, gate-controlled dam in place of the Boulé dam and Chanoine wicket dam. The new dam has since been completed and consists of nine tainter gates, four near the powerhouse and five just above the Pennsylvania Railroad bridge, and a fixed weir with a crest at el 422.0 at the four downstream gates, incrementally raised to a crest elevation of 423.0 at the five upstream gates.

Purpose of Model Study

8. The general design of McAlpine Locks and Dam involved the

solution of many problems that would normally not be encountered in structures of this type. The problems were further complicated by the arrangement and alignment of the structures and their relation to the river channel, long approach canal, powerhouse, islands within the channel, and a number of bridges. Because of the many design factors that had to be considered, analytical solution of the hydraulic effects that could reasonably be expected to result from a particular design was both difficult and uncertain. The comprehensive model study was necessary to: (a) develop modifications required to remove the shoaling along the right bank just downstream of the fixed weir at the upper gates; (b) determine effectiveness of various dam modifications on reducing swellhead at the dam; (c) determine effect of a proposed dike designed to reduce scouring along the Indiana bank opposite the tainter gates near the powerhouse; (d) develop modifications that could be used to improve navigation conditions at the entrance to the lock approach canal; (e) investigate the effect of an additional 1200-ft lock on navigation conditions; and (f) investigate the effect of lock filling on surge within the lock approach canal with the proposed additional lock.

9. The model was also used to determine the relative effectiveness of the various improvement plans proposed and to demonstrate for the design engineers and navigation interests the conditions resulting from the proposed design, and to satisfy these interests of the design's acceptability from a navigation standpoint.

PART II: THE MODEL

Description

10. The model was a scale reproduction of approximately 8.5 miles of the Ohio River and adjacent overbank, from mile 599.5 to mile 608.0, with locks and dam structures, canal, hydroplant, bridges, levees, walls, and other structures that affect flow or navigation within the reach (Figure 2). The model was of the fixed-bed type with the channel and overbank areas molded in sand-cement mortar to sheet-metal templates; the locks, dams, hydroplant, and bridges were constructed of sheet metal.

11. The model channel and overbank areas reproduced hydrographic and topographic surveys completed in November 1972 and April 1973, except for a small area immediately downstream of the hydroplant, which was based on a hydrographic survey dated 1955. Overbank areas reproduced extended to the existing levees or floodwalls except along the right and left banks in the upper reach which extended to approximately the el 445.0 and along the right bank opposite the lower gate section of the dam which extended to about el 425.0. Levees, floodwalls, and model limits were constructed to a grade sufficient to confine the 1937 flood (a flow of 1,110,000 cfs). Warehouses, storage tanks, and other buildings located along the overbank that would affect flow were reproduced from Styrofoam.

Scale Relations

12. The model was built to an undistorted linear scale of 1:120, model to prototype, to effect accurate reproduction of velocities, crosscurrents, and eddies that would affect navigation. Other scale ratios resulting from the linear scale ratio were:

Area 1:14,400	Discharge 1:157,743
Velocity 1:10.95	Roughness (Manning's n) 1:2.22
Time 1:10.95	

Measurements of discharges, water-surface elevations, velocities, and

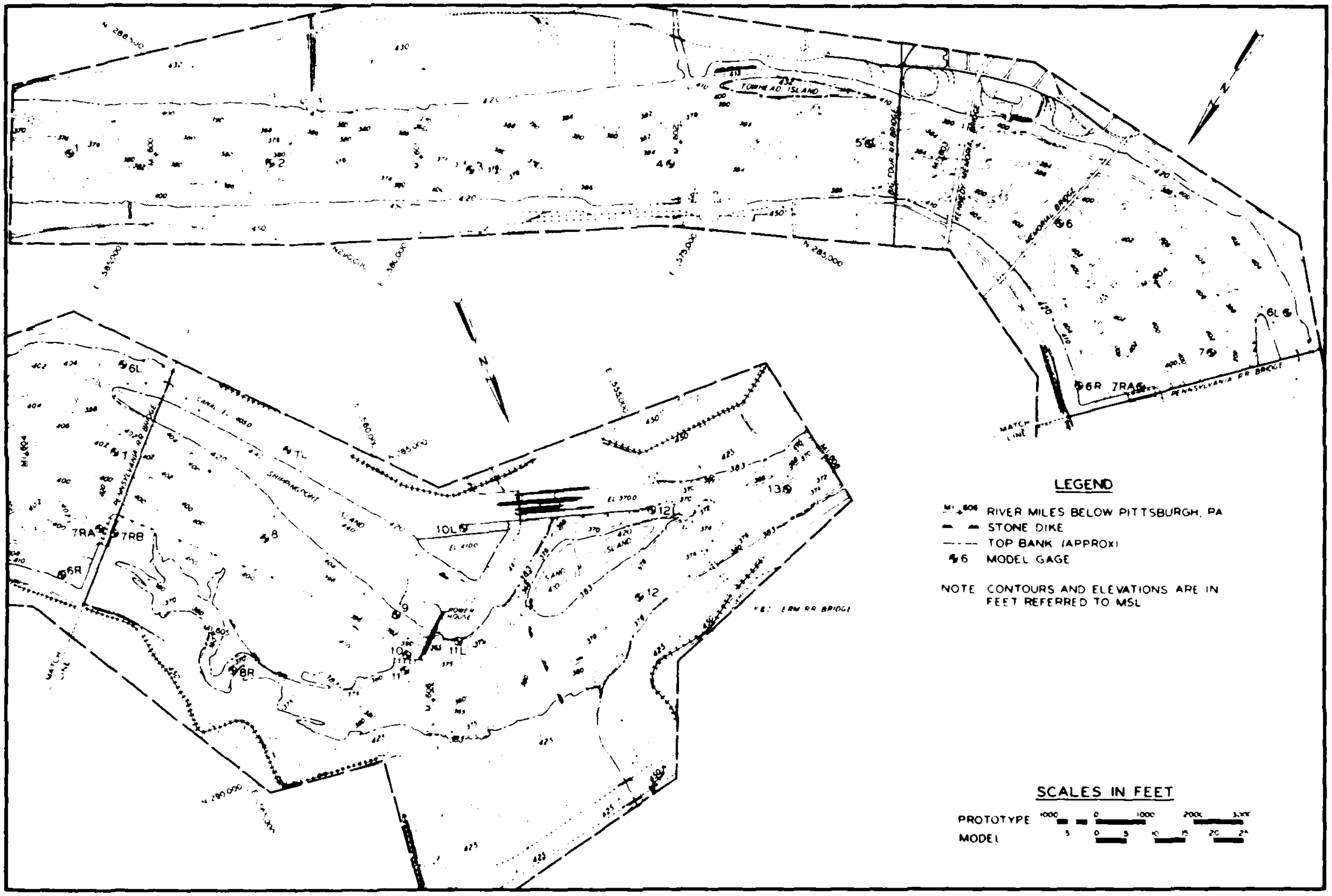

Figure 2. Model layout and gage locations

current directions can be transferred quantitatively from model to prototype equivalents by means of these scale relations.

Appurtenances

13. Water was supplied to the model from a circulating water-supply system. Discharge was controlled by means of a valve and measured at the upper end of the model by means of two venturi meters of different sizes to cover the wide range of flows reproduced. Water-surface elevations were measured by means of 22 piezometer gages located in the model channel and connected to a centrally located gage pit (Figure 2).

14. Velocities and current directions were measured in the model by means of cylindrical wooden floats submerged to the depth of a loaded barge (9 ft prototype) except for special tests, when the floats were submerged to a depth of 3 ft. Confetti was also used to determine surface current directions, and a midget current meter was used to measure spot velocities. A radio-controlled model tow and towboat, equipped with twin screws and powered by two small electric motors operating from batteries located in the tow, were used to study and demonstrate the effects of currents on navigation (Figure 3). The towboat could be run in forward or reverse, at various speeds, and with variable rudder settings. The power of the towboat was adjusted by means of a rheostat to a maximum speed comparable to that of towboats using the Ohio River waterway.

Model Adjustment

15. After construction, the model was adjusted until it reproduced with a reasonable degree of accuracy conditions in the prototype based on the available data. The model surface was constructed of brushed cement mortar to provide a surface roughness (Manning's n) of about 0.0135 which corresponded to a prototype roughness of 0.030. Roughness consisting of folded strips of 8-mesh wire screen was placed along the overbank and downstream of the five upper gates where trees and other

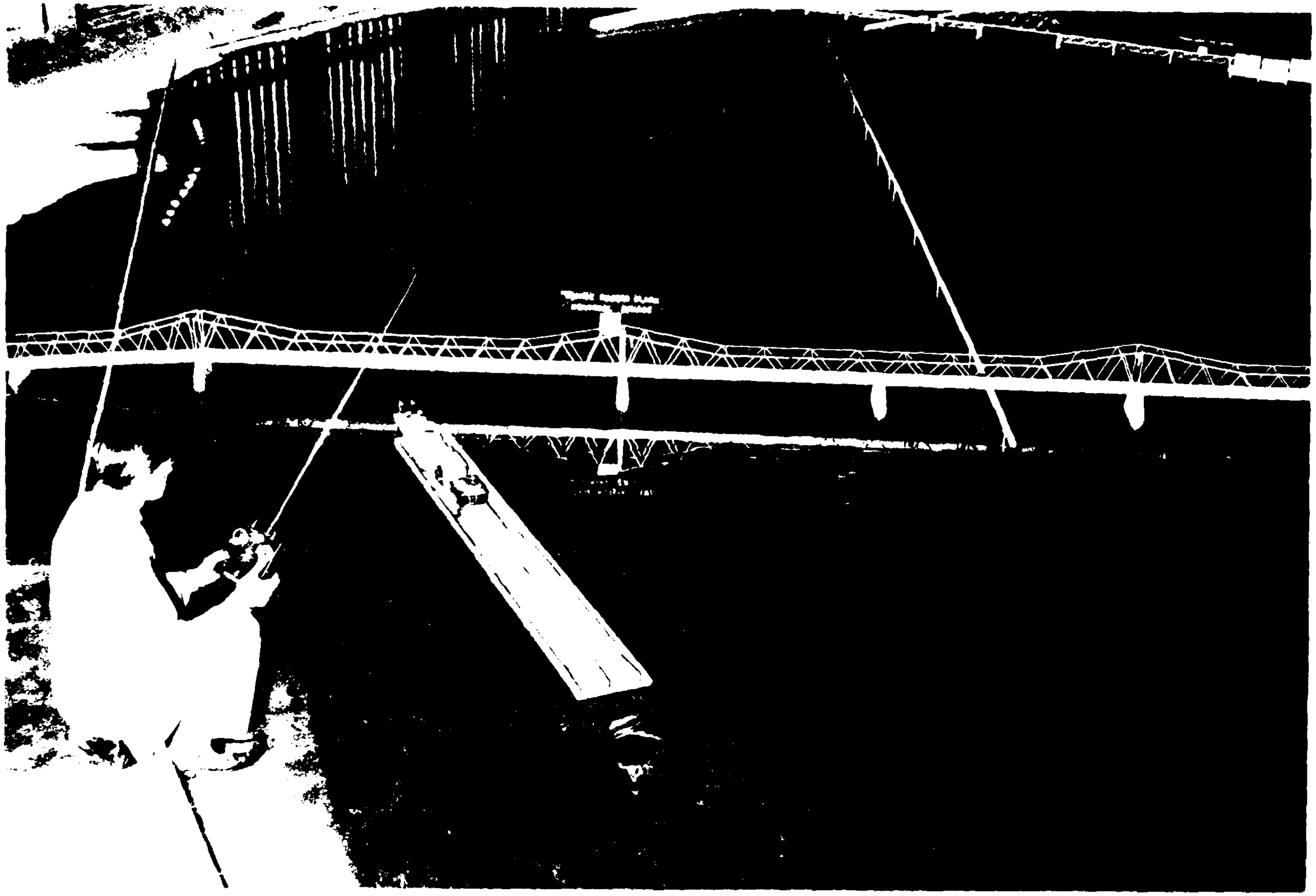

Figure 5. [illegible] towboat [illegible] tow moving upstream past the Memorial bridge

vegetation were indicated. Model roughness was adjusted to reproduce prototype current directions and velocities furnished by the U. S. Army Engineer District, Louisville, and water-surface profiles obtained from a previous model study of the reach* (Plate 1). Although the results of the adjustment indicated that the maximum velocities measured on the model were somewhat lower than those indicated by the prototype data, the alignment of currents and average velocities were sufficiently close and considered adequate for the purpose of the study. Water-surface elevations reproduced those obtained during the previous study to the accuracy necessary for the purpose of this study (Plate 2, Tables 1 and 2).

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* J. J. Franco and C. D. McKellar. 1966 (Nov). "Navigation Conditions at McAlpine Locks and Dam, Ohio River; Hydraulic Model Investigation," Technical Report No. 2-749, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART III: TESTS AND RESULTS

16. Tests were concerned primarily with the study of flow patterns, current velocities in the approach to the L&P Canal, and effects of various modifications for the improvement of navigation conditions for tows approaching and entering the canal. The model towboat was used to observe and demonstrate the effects of the various modifications on the navigability of the reach just upstream of the canal entrance. Tests were also conducted to determine the effects of spillway gate operation, modification of the dam, plans designed to eliminate deposition over the fossil deposit along the right bank downstream of the upper gated spillway and to reduce or eliminate scouring along the right bank opposite the lower spillway, and effect of a new 1200-ft lock on surges in the L&P Canal.

Test Procedures

17. Tests were conducted by reproducing discharges and maintaining the upper pool elevation for controlled riverflows by manipulating the gates in the dam with normal powerhouse releases until the proper pool elevations were obtained. Open riverflows were reproduced with no hydropower releases and all dam gates fully open and controlled by setting the discharge and manipulation of the tailgate until the proper tailwater elevation for the discharge was obtained. Representative flows reproduced during the tests were as follows:

a. Controlled riverflows of 50,000, 77,000, 88,000, 100,000, and 150,000 cfs and normal upper pool el 420.0.

b. Open riverflow of 223,000 cfs with tailwater el 406.0 (maximum pool flow).

c. Open riverflow of 246,000 cfs with tailwater el 408.3.

d. Open riverflow of 270,000 cfs with tailwater el 410.5.

e. Open riverflow of 300,000 cfs with tailwater el 413.0.

f. Open riverflow of 340,000 cfs with tailwater el 416.6.

g. Open riverflow of 400,000 cfs with tailwater el 421.8.

h. Open riverflow of 625,000 cfs with tailwater el 439.1 (maximum navigable flow).

Upper pool elevation was controlled at gage 6R along the right bank just upstream of the fixed weir. The powerhouse discharge for all controlled flows was approximately 32,000 cfs. The tailwater elevation was controlled at gage 12L (located at the end of the lower lock guard wall) for base condition and at gage 13 (located at the downstream end of the model) for tests of plans. The powerhouse was closed during open riverflows. All flows were permitted to stabilize before data were taken.

18. Current directions were determined by plotting the paths of wooden floats (described in paragraph 14) with respect to ranges established for that purpose, and velocities were measured by timing the travel of the floats over measured distances. Surface currents were also indicated by time-exposure photographs recording the movement of paper confetti on the water surface. No data were obtained with the model tows other than observation of their behavior in the lock approaches, approaching and entering the canal, and within the canal during lock filling.

19. Most of the modifications were developed during preliminary tests. Data and results obtained during these tests were sufficient only to assist in the development of plans that appeared to produce some improvement in conditions in the approach to the canal and are not included in this report.

Base Test (Existing Conditions)

Description

20. The base test was conducted with the model reproducing existing conditions as shown in Figures 4 and 5. The purposes of this test were to establish and record the conditions existing in the prototype with the flows selected for testing and to provide a basis for determining the effectiveness of proposed modifications. The principal features of the prototype that were reproduced or simulated in the model for this test included the following:

a. A navigation lock with clear chamber dimensions of 110 ft

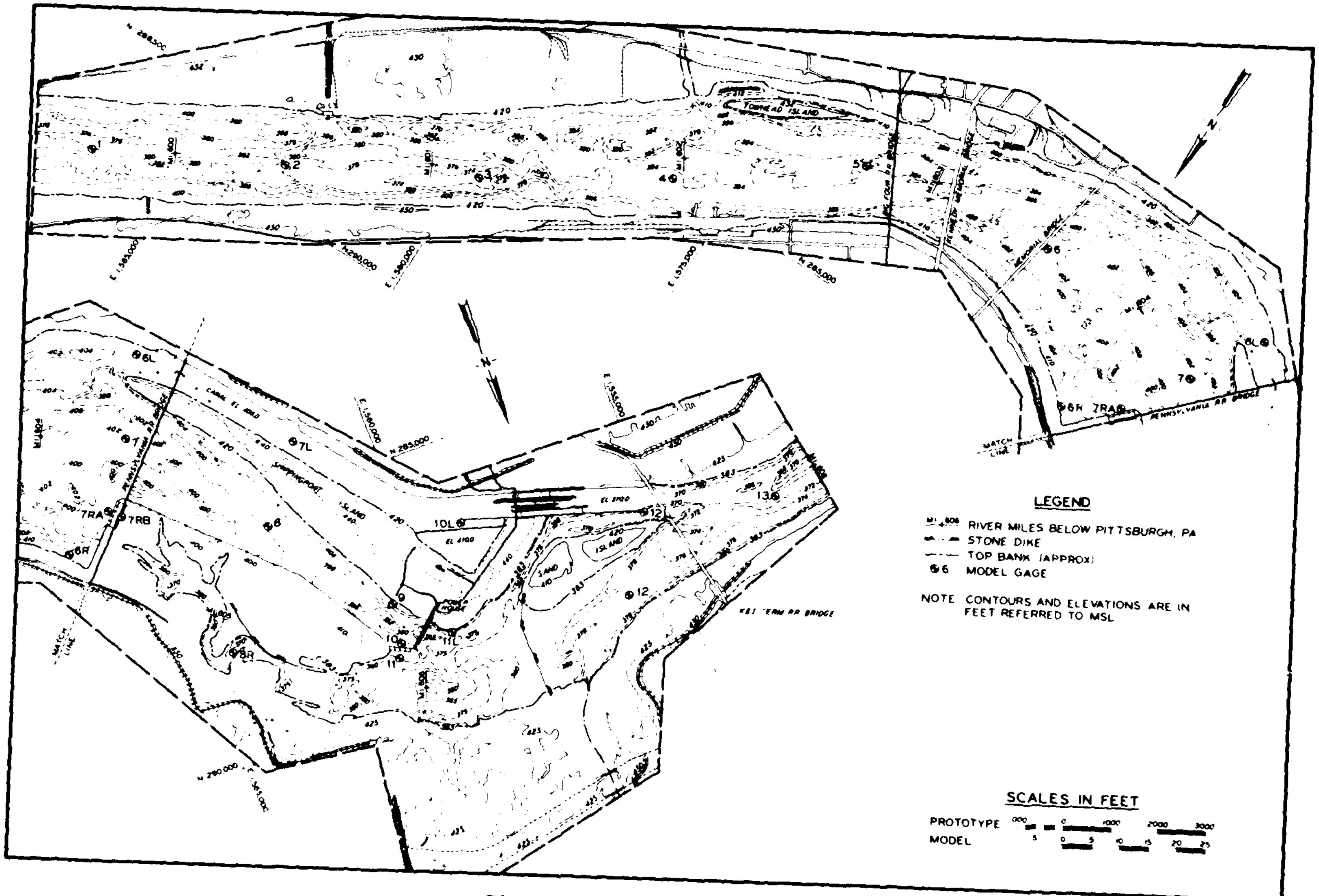


Figure 4. Existing conditions

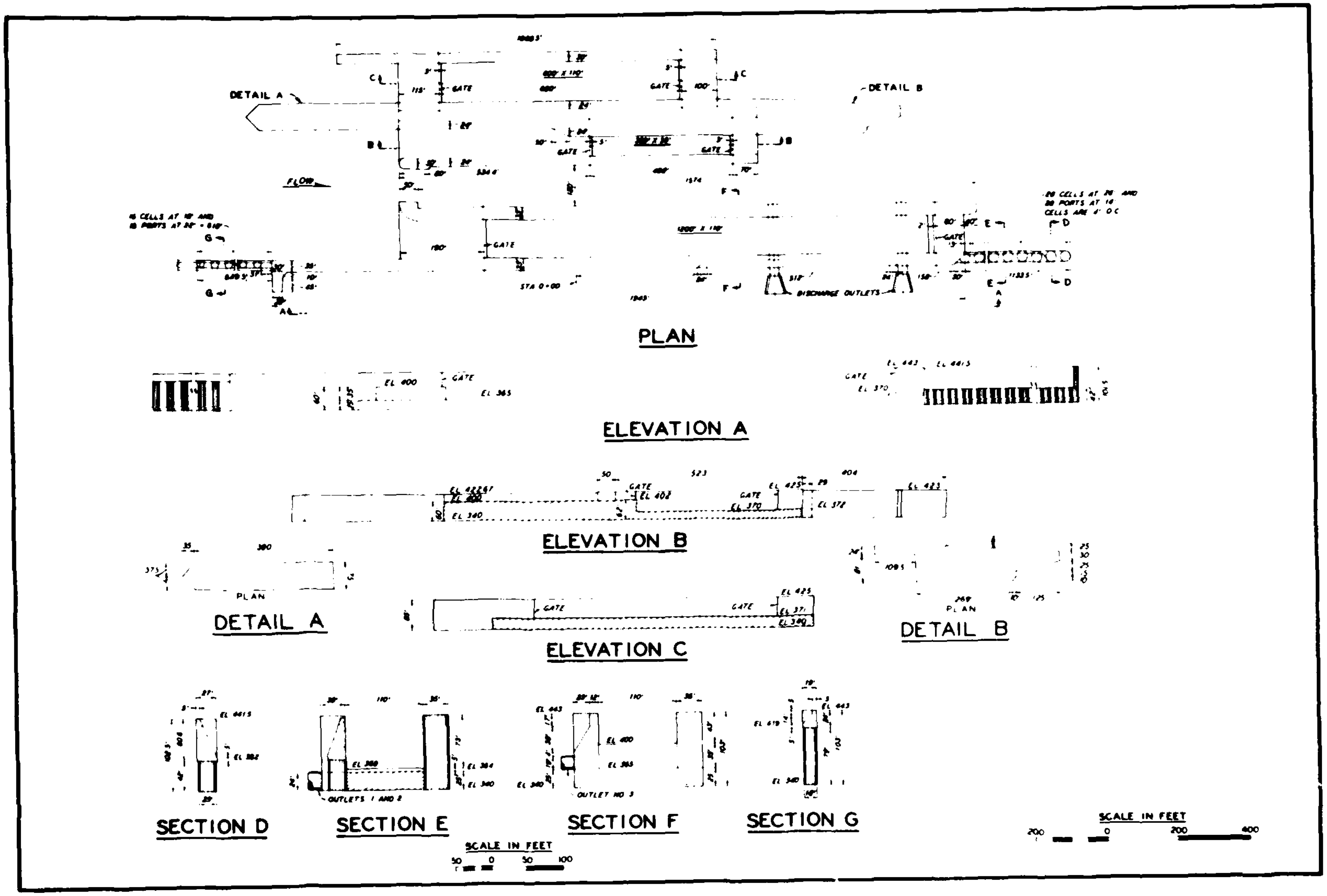


Figure 5. General plan and sections (sheet 1)

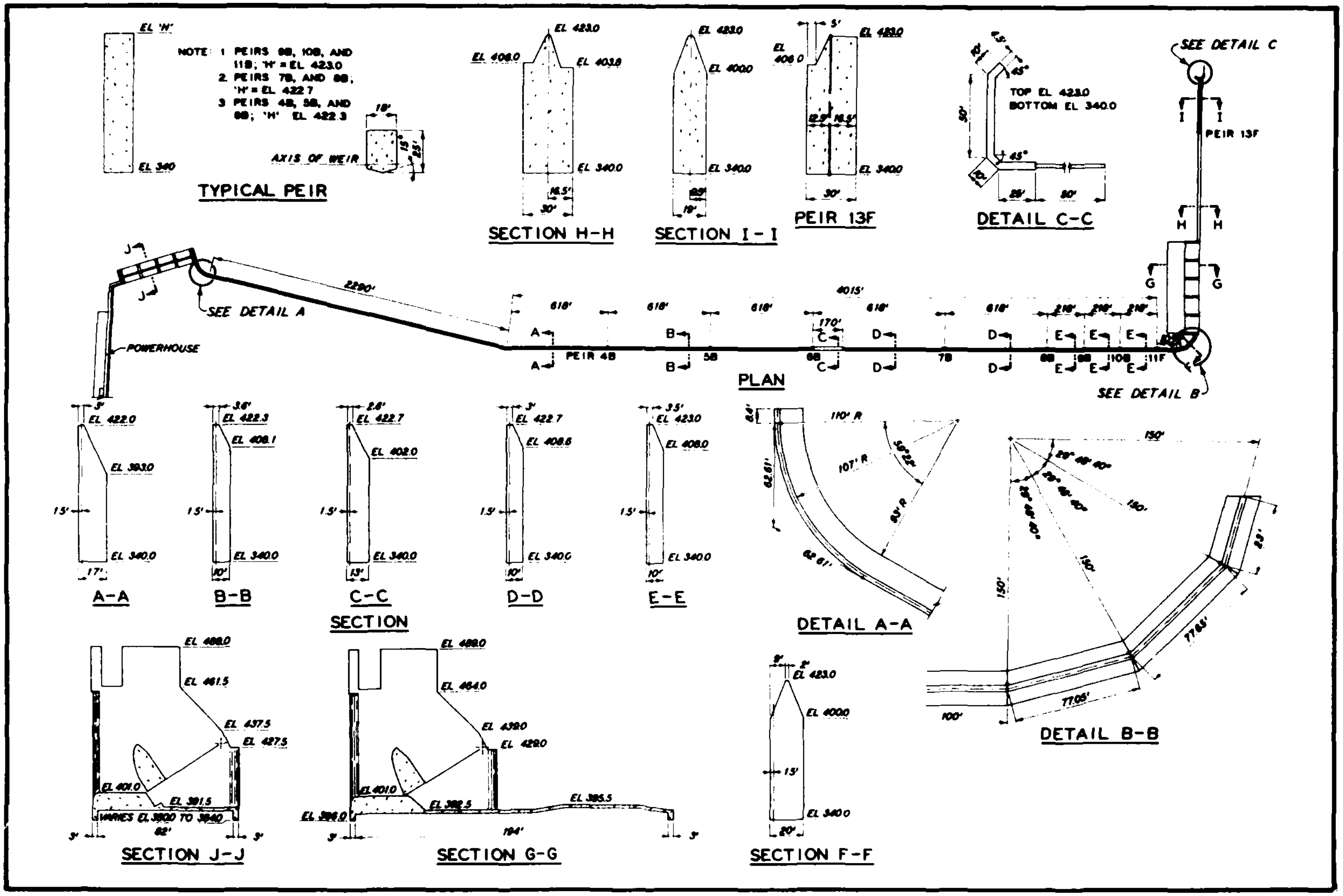


Figure 5. (sheet 2)

wide by 1200 ft long located at the lower end of a 1.75-mile-long canal (bottom width 500 ft) along the left bank and two auxiliary locks between the main lock and left bank that were out of service.

b. A powerhouse located along the left bank adjacent to the downstream end of Shippingport Island; a four-gated spillway section located adjacent to the powerhouse; a 6600-ft-long fixed-crest weir (top elevation varying from 422.0 to 423.0) extending upstream, generally parallel to the right bank; a five-gated upper spillway section; and a 1200-ft-long fixed-crest weir (top el 423.0) connecting the upper five-gated dam to the right bank just upstream of the Pennsylvania Railroad bridge.

c. Three bridges located just upstream of the lock approach canal, one bridge located across the canal downstream of the entrance, and one bridge located just downstream of the locks.

Results

21. Water-surface elevations obtained with existing conditions are shown in Table 2. With open riverflows, the average slope in the model upstream of the head of Shippingport Island (gages 1 to 7) ranged from about 0.2 to 0.3 ft per mile and downstream of the dam (gage 8R to gage 13) ranged from about 0.5 to 0.6 ft per mile. The drop through the gated sections of the dam ranged from about 11.6 to 0.1 ft (gage 7RA to gage 7RB) at the upstream gates to about 11.8 to 0.9 ft (gages 10-11) at the downstream gates (near the powerhouse) with flows ranging from 223,000 to 625,000 cfs.

22. Current directions and velocities obtained with existing conditions are shown in Plates 3-8. The alignments of currents approaching the L&P Canal were generally straight and parallel to the left bank except for crosscurrents near the entrance to the canal. Maximum velocities in the approach to the canal ranged from about 1.6 fps with the 88,800-cfs flow to about 4.9 fps with the 400,000-cfs flow, and somewhat less with the maximum navigable flow. Maximum velocities in the lower approach to the locks ranged from about 3.8 fps with the 88,800-cfs flow to about 5.5 fps with the maximum navigable flow (625,000 cfs).

23. Currents moving along the left bank toward the entrance to the canal have to turn riverward past the head of Shippingport Island,

producing crosscurrents in the approach to the canal with all flows tested. With the higher flows, a slow eddy would develop along the left bank upstream of the entrance, moving the crosscurrents farther riverward. There was some reduction in the intensity of the crosscurrents in the approach to the canal when the upper dam gates were used to control the pool with the 150,000-cfs flow (Plate 4), but the effect on navigation conditions in the approach to the canal was small. With the uncontrolled riverflows, currents would tend to move riverward farther upstream of the entrance to the canal and velocities would be generally higher some distance from the left bank.

24. No serious navigation difficulties were indicated for downbound tows approaching and entering the canal when passing the Memorial Bridge within about 550 ft of the left pier of the navigation span (Photo 1). Tows approaching the canal would have to maintain sufficient power and steerage to overcome the effects of the crosscurrents near the entrance to the canal. Tows passing the Memorial Bridge close to the right pier of the navigation span could experience considerable difficulty in becoming properly aligned for entrance into the canal, particularly during the higher flows. Tows with limited power or tows attempting to stop before entering the canal would tend to be moved riverward by the crosscurrents and would be in danger of hitting the head of Shippingport Island. During high flows, downbound tows can avoid the high-velocity currents by approaching the canal from close along the left bank. Limited depths would prevent tows from moving too close to the left bank just upstream of the entrance during low flows. No difficulties were indicated for upbound tows leaving the canal.

Plan A

Description

25. Plan A was developed to reduce velocities and intensity of the crosscurrents in the approach to the L&P Canal. This plan was the same as existing conditions except that four submerged dikes were placed along the left bank between the Memorial Bridge and the canal entrance

(Figure 6). Tops of the dikes were at el 406.0, 14 ft below normal upper pool.

Results

26. The submerged dikes of Plan A had little or no effect on water-surface elevations (Table 3). With the 246,000- and 300,000-cfs flows, there was a lowering of water surface in the latitude of the dikes of about 0.1 ft. Current directions and velocities shown in Plates 9 and 10 indicate a considerable reduction in velocities with little change in the alignment of currents approaching the entrance to the canal. Maximum velocities in the approach within about 2,000 ft of the entrance ranged from 1.6 to 2.0 fps with the 150,000-cfs flow and operation of the lower gates and about 1.3 fps with operation of the upper gates. Maximum velocities just upstream of the entrance varied from about 2.6 to 3.0 fps. Also, with the higher flow the size and intensity of the eddy along the left bank were considerably less than that with existing conditions.

27. Navigation conditions for downbound tows were considerably better than without the submerged dikes. Tows could approach and enter the canal with somewhat less power. Tows could also approach the canal after passing the Memorial Bridge from any point within the navigation span. However, tows passing the bridge near the right pier of the navigation span might require some maneuvering to become properly aligned for entrance into the canal (Photo 2).

Plan B

Description

28. Plan B involved the placement of a line of cells from the head of Shippingport Island on a line extending toward the riverward pier of the Memorial Bridge navigation span. The plan was designed to reduce the intensity of the crosscurrents near the entrance to the canal and to provide some protection for tows that might be out of control. Eight cells were located on a straight line extending from the existing cell at the head of Shippingport Island toward the pier on the right

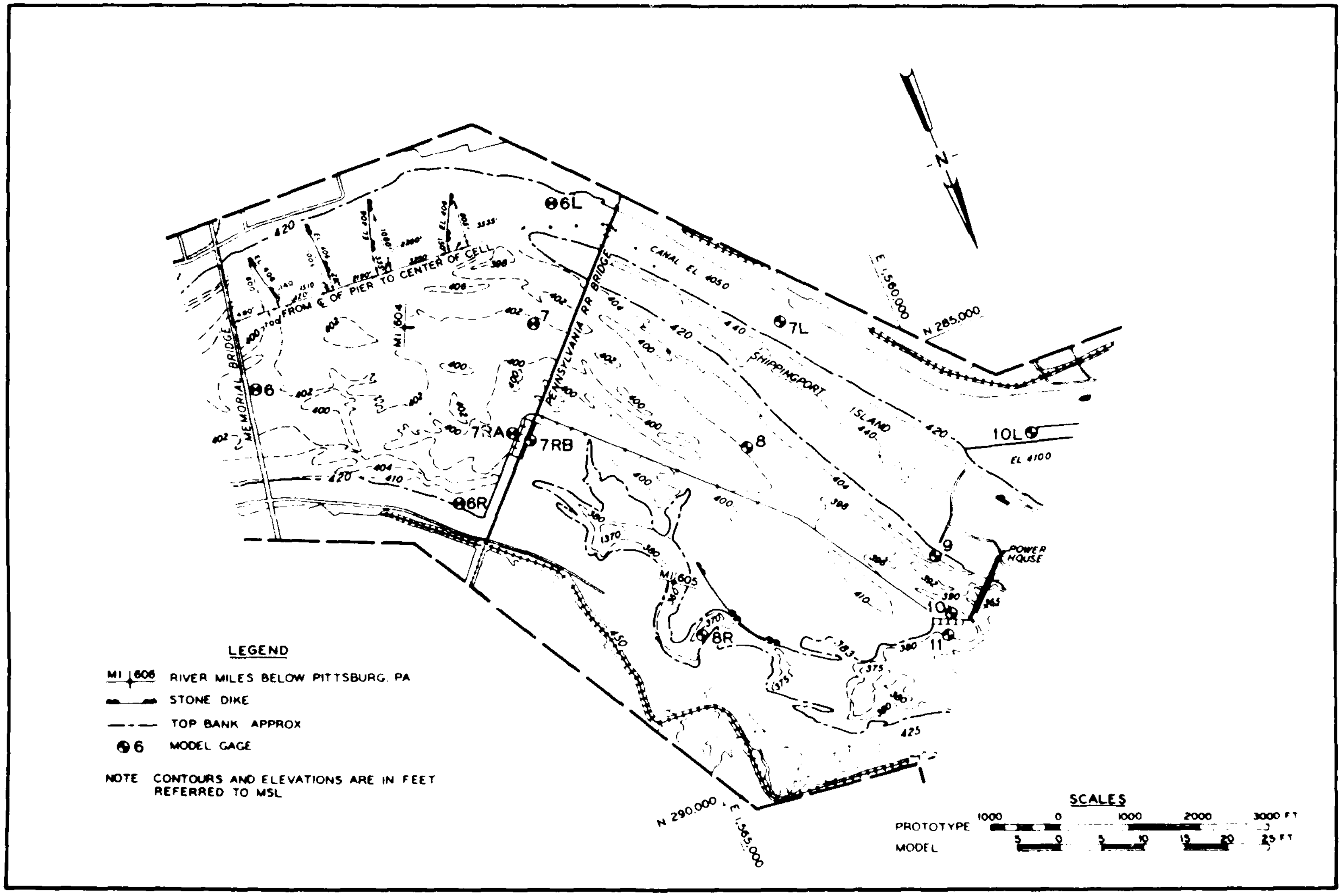


Figure 6. Plan A submerged dikes

side of the Memorial Bridge navigation span (Figure 7). The two end cells were each 30 ft in diameter, and the six intermediate cells were 20 ft in diameter. The new cells were spaced 175 ft center to center, and the space between the existing cell at the head of the island and the first new cell was 375 ft center to center.

Results

29. Results obtained during this test indicate that the cells had little or no effect on water-surface elevations compared with existing conditions. Also, there was little effect on the alignment of currents in the approach to the navigation canal (Plate 11). There was some reduction in the velocity of currents and in the intensity of the crosscurrents near the entrance to the canal.

30. Navigation conditions were only slightly better than those with existing conditions. No serious difficulties were indicated for tows passing the Memorial Bridge within 550 ft of the left pier of the navigation span and maintaining sufficient power to overcome the effects of the crosscurrents. The cells would provide a guide for tows approaching the canal and provide some protection in the event of loss of power and/or control, but would have no effect on upbound tows leaving the canal.

Plan B-Modified

Description

31. Plan B-modified (Figure 8) was the same as Plan B with the addition of the submerged dikes along the left bank in the approach to the canal, the same as in Plan A.

Results

32. Water-surface elevations obtained with Plan B-modified were about the same as those with Plan A (Table 3). Alignment of the currents approaching the entrance to the navigation canal was about the same as that with Plan A (Plate 12). Velocities in the approach to the canal were considerably lower than those with Plan B and only slightly lower than those with Plan A.

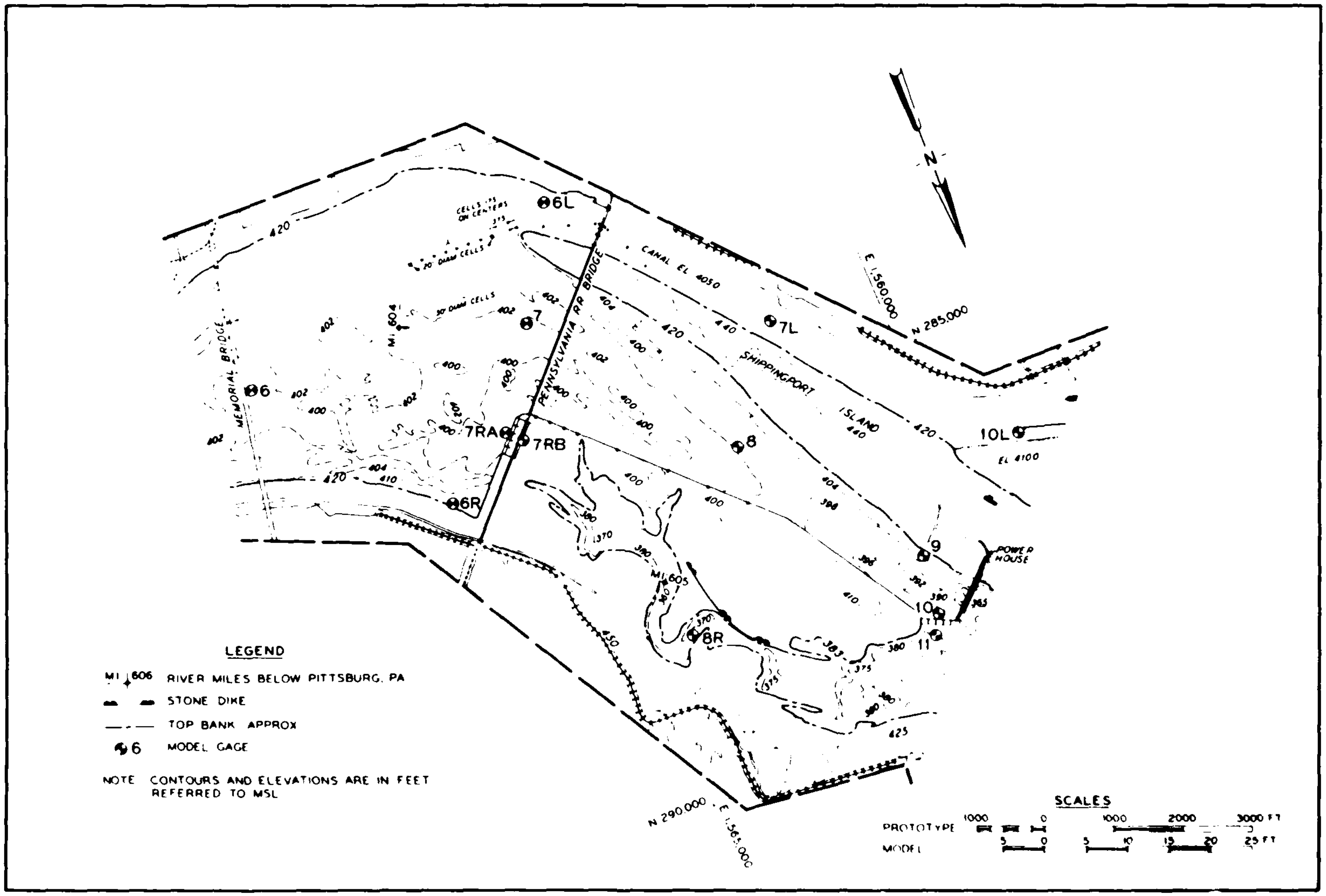


Figure 7. Plan B

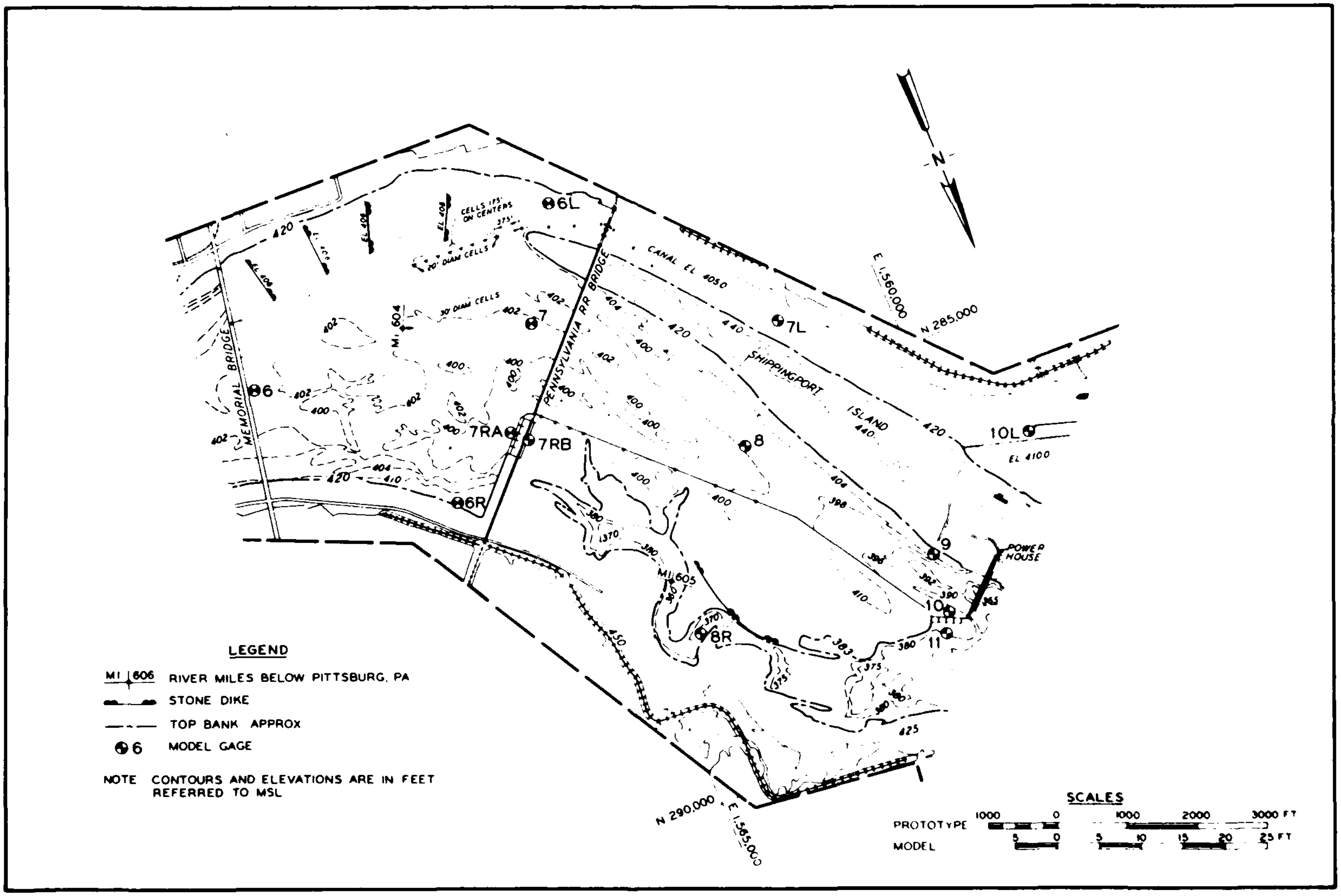


Figure 8. Plan B-modified

33. Navigation conditions with this plan were about the same as those with Plan A. Downbound tows under control could pass through the navigation span close to the right pier and encounter no serious difficulties in approaching and entering the navigation canal (Photo 3). No difficulties were indicated for upbound tows leaving the canal.

Plans C and C-1

Description

34. Plans C and C-1 involved the construction of a canal across Shippingport Island downstream of the Pennsylvania Railroad bridge designed to reduce the intensity of the crosscurrents near the entrance to the navigation canal. Plan C was the same as existing conditions except for a canal located across the island just downstream of the Pennsylvania Railroad bridge (Figure 9). The canal was angled toward the downstream and had a bottom width of 150 ft at el 410.0. Plan C-1 was the same as Plan C except that the canal was located farther downstream (Figure 10).

Results

35. Water-surface elevations obtained during the tests of Plan C and C-1 were about the same as those with existing conditions (Table 2). Current directions and velocities shown in Plate 13 indicate that with Plan C, currents moving close along the left bank would enter the L&P Canal and pass through the proposed canal across the island. Since some of the flow along the left bank entered the navigation canal, less of the flow was diverted riverward, reducing the intensity of the crosscurrents. With the 246,000-cfs flow, currents entering the L&P Canal tended to be concentrated along the right side of the canal. Velocities in the entrance to the canal with the flows tested were about 1.0 to 1.2 fps and somewhat higher along the right side of the canal with the 246,000-cfs flow. Currents approaching the canal were about the same as those with existing conditions.

36. Results with Plan C-1 shown in Plate 14 indicate an increase in the flow entering the navigation canal compared with Plan C, particularly with the 246,000-cfs flow. Velocities approaching the entrance to

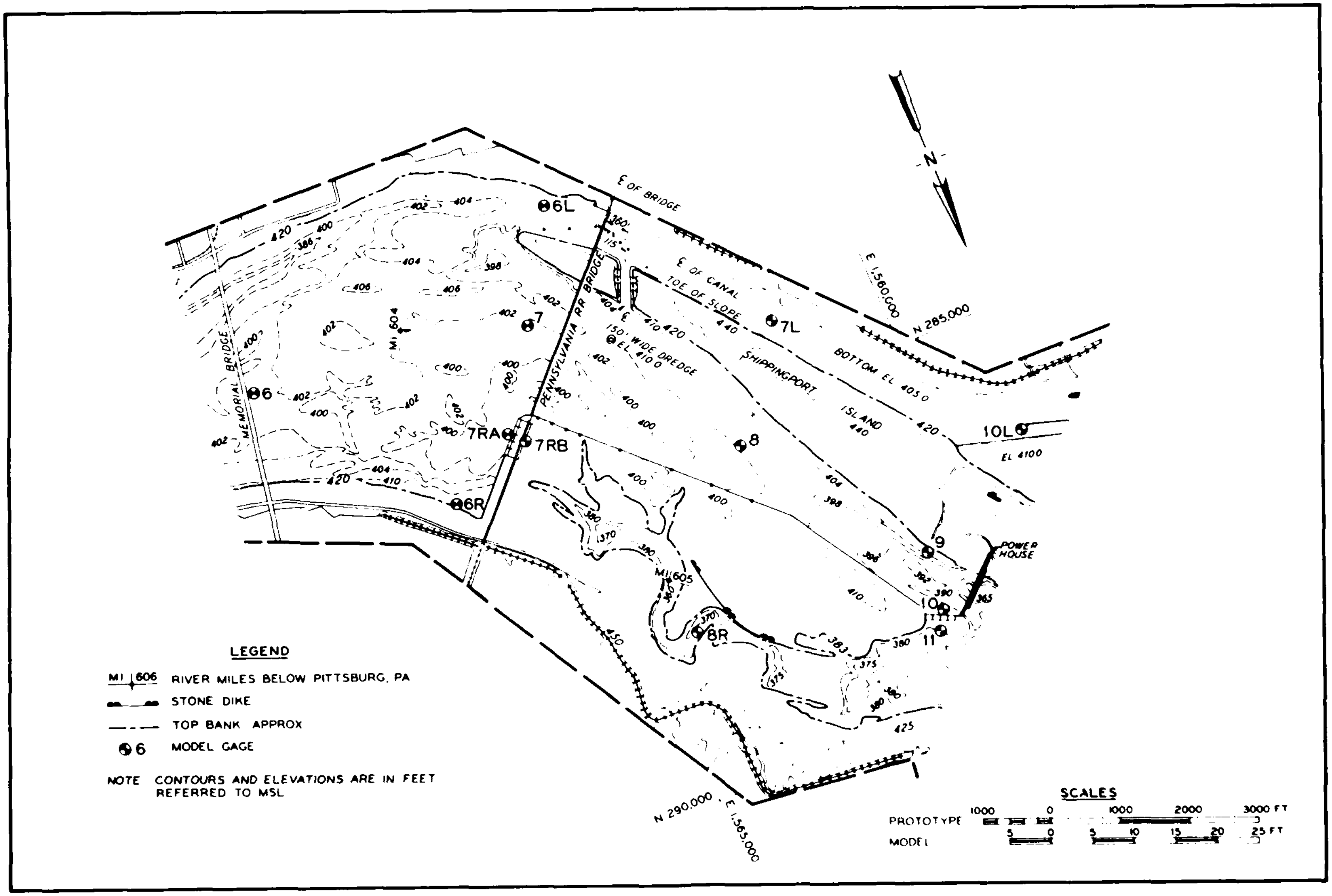


Figure 9. Plan C

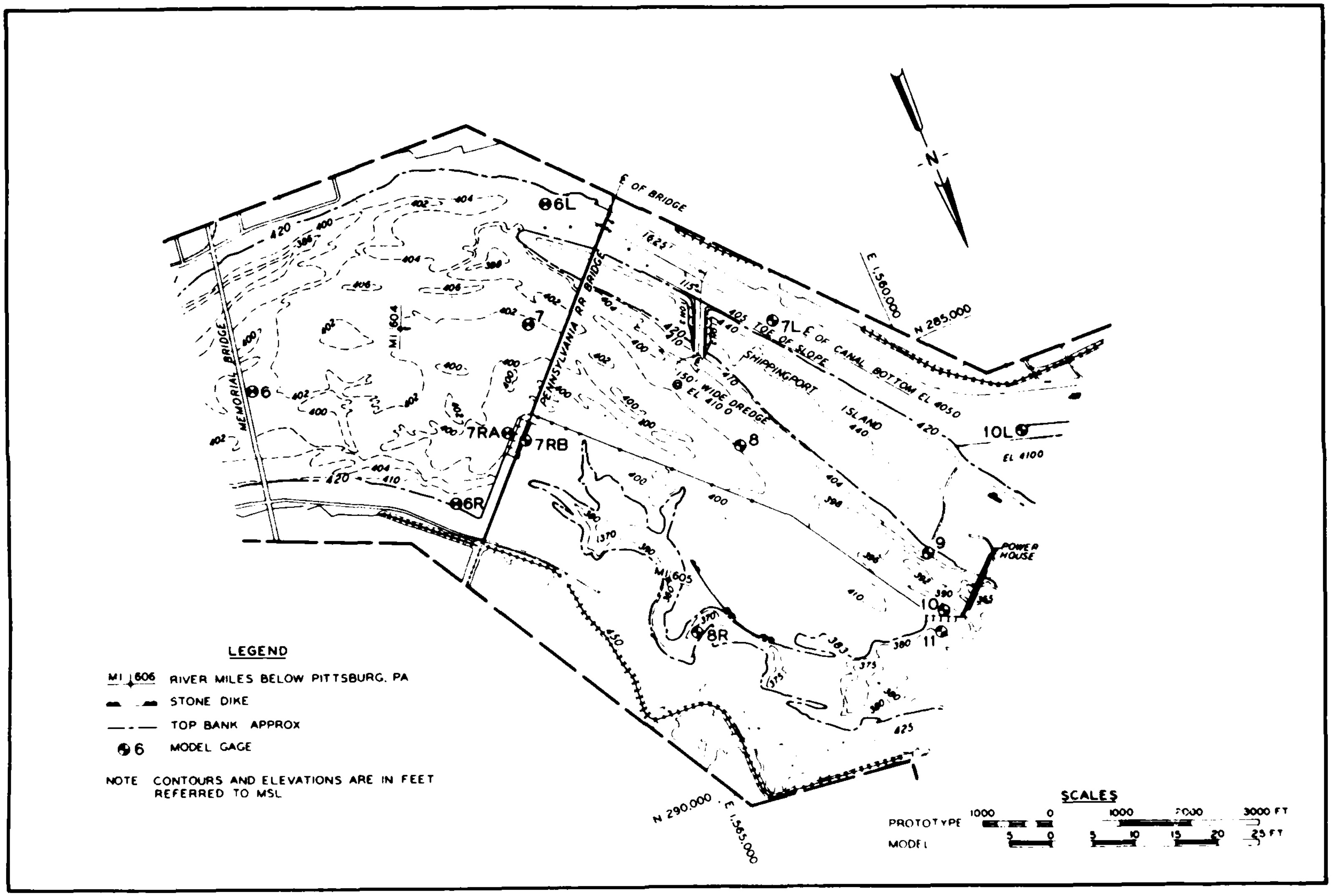


Figure 10. Plan C-1

the canal and within the upper reach of the canal were also higher. Because of the increase in flow into the canal, there was less crosscurrent near the entrance than with Plan C.

37. Because of the reduction in the intensity of the crosscurrents, downbound tows could approach and enter the canal with less difficulty with Plans C and C-1 than with existing conditions. However, because of the currents in the canal, tows would have to maintain power and steerage longer, particularly with Plan C during the lower flows. Tows could also experience some difficulty in stopping, if required, before passing through the Pennsylvania Railroad bridge navigation span. Navigation conditions for tows entering the canal were somewhat better with Plan C-1 than those with Plan C.

Plan D

Description

38. Plan D was the same as existing conditions except for the addition of a 600-ft-long dike extending upstream of the head of Shippingport Island. The lower end of the dike was some 200 ft upstream of the head of the island and formed an extension of the line of cells along the right side of the canal upstream of the Pennsylvania Railroad bridge (Figure 11). The crest of the dike was at el 423.0. The plan was developed during preliminary tests in which the length, location, and elevation of the dike were varied and the most effective plan with reasonable cost was selected for final testing.

Results

39. Results shown in Table 4 indicate that there would be a tendency for some increases in water-surface elevations in the canal, amounting to about 0.1 ft with the 300,000-cfs flow and about 0.3 ft with the 625,000-cfs flow (gages 6L, 7L, and 10L).

40. Current directions and velocities shown in Plate 15 indicate a considerable reduction in velocities on the canal approach side of the dike compared with existing conditions. Most of the crosscurrents, particularly with the 246,000- and 300,000-cfs flows, occurred near

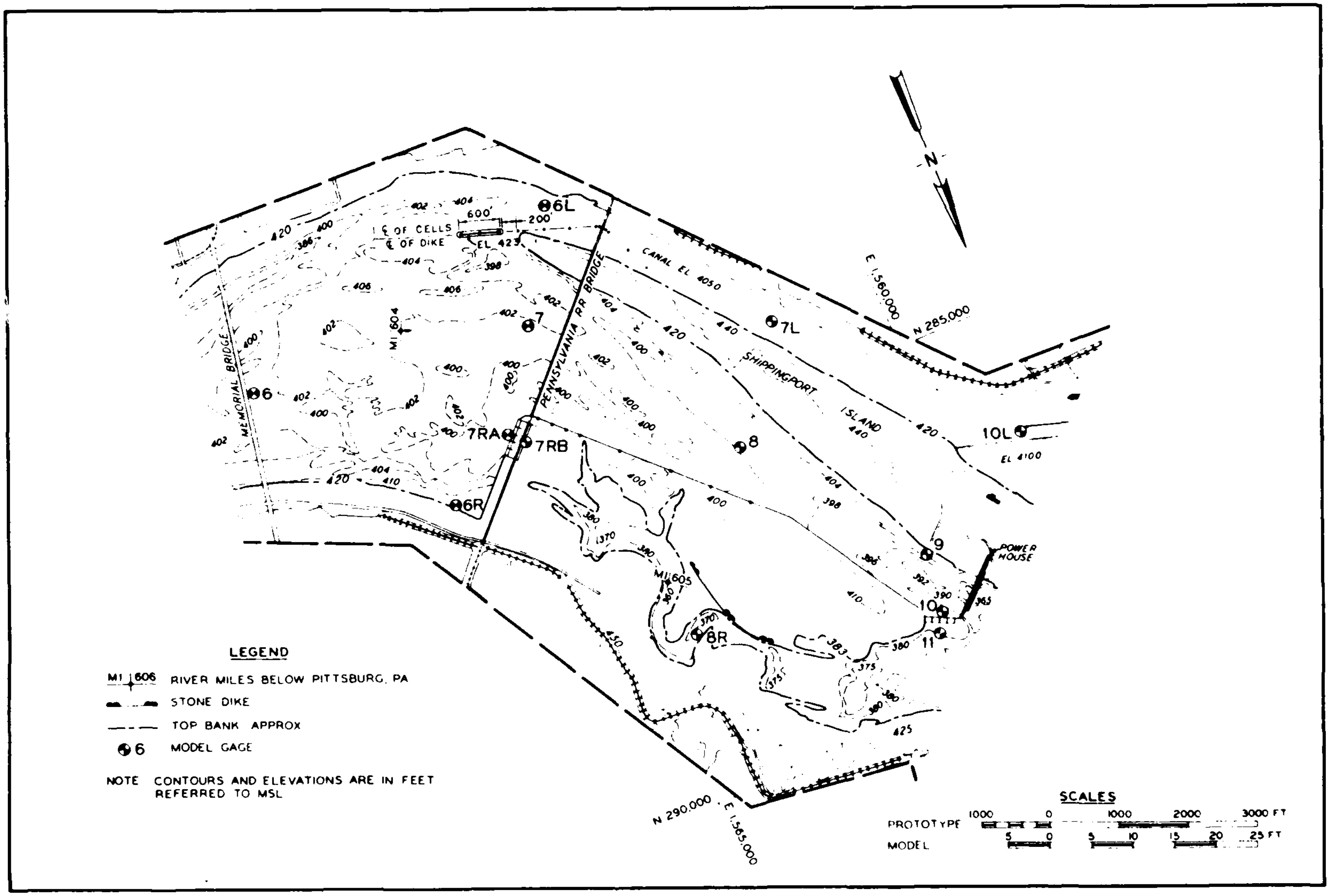


Figure 11. Plan D

the upstream end of the dike. A large slow eddy formed along the left bank upstream of the entrance to the canal with the 625,000-cfs discharge. Although there was considerable flow over the dike with the higher discharge, currents moved toward the dike at a small angle and were only about 1.0 to 2.3 fps.

41. Navigation conditions with Plan D were considerably better than those with existing conditions and better than those with any of the other plans tested. There was little tendency for tows approaching the navigation canal to be moved riverward after passing the upper end of the dike. Downbound tows could even stop before entering the canal with little tendency for the tows to be moved riverward or rotated out of alignment. Tows moving slowly close to the opening between the lower end of the dike and the head of Shippingport Island would tend to be moved toward the opening with the lower flows, but the tendency would be small and could be easily overcome with some power and steerage. Currents in the canal approach with the maximum navigable flow would have little effect on the movement of a downbound tow approaching the entrance to the canal. No difficulties were indicated for upbound tows leaving the canal.

Dam Modification Tests

42. A series of tests were conducted to determine the effects of various dam modifications on swellhead over the range of controlled flows. These modifications involved the addition of more gates to the upper gated spillway section of the dam and changes in the crest of the fixed-weir sections of the dam.

Plans E Through E-5

Description

43. The Plan E series of tests involved the addition of tainter gates or bascule gates to the upper spillway section (Figure 12). Tests were conducted with all tainter gates fully open and bascule gates open

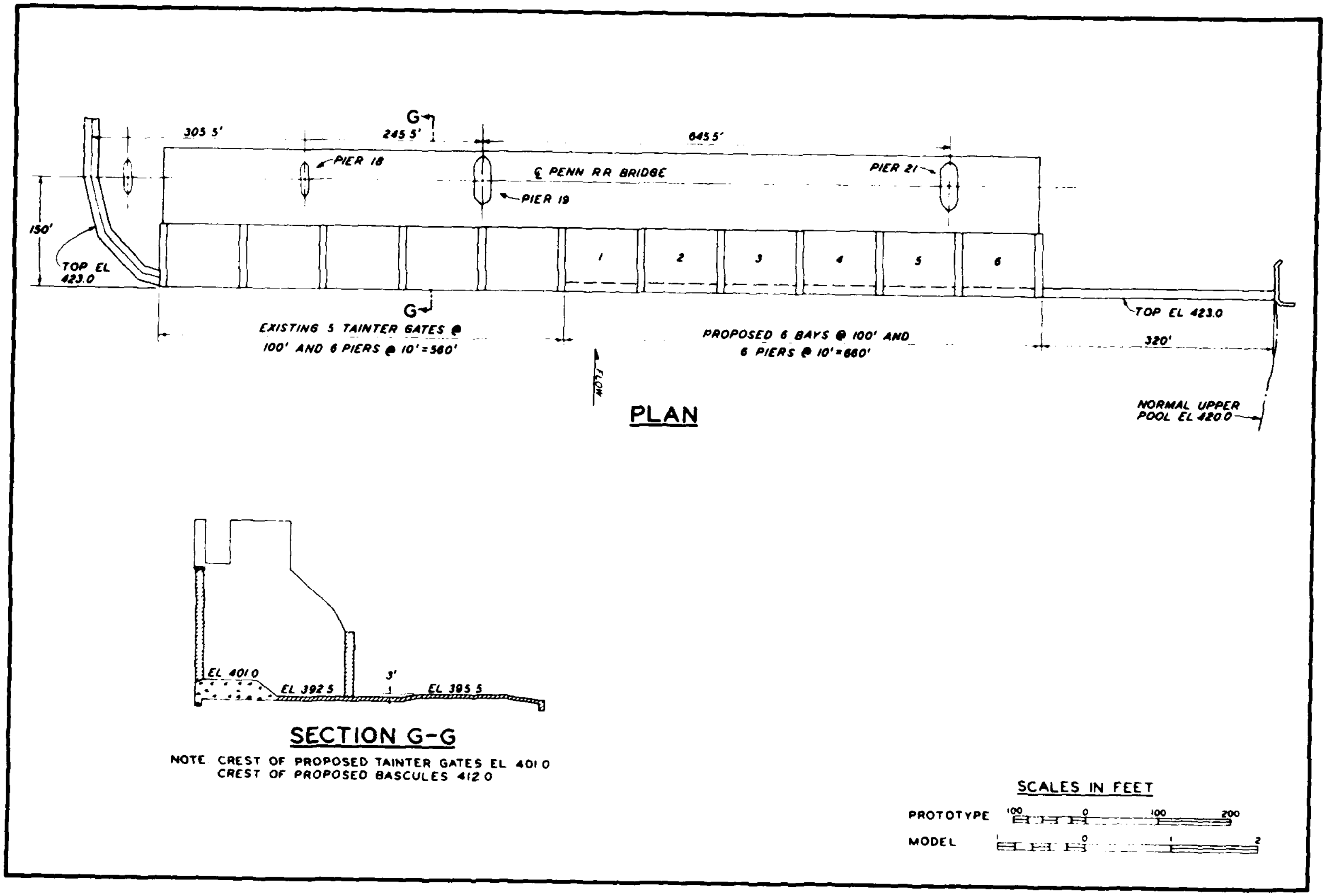


Figure 12. Plan E series, location of proposed additional gate bays

down to el 412.0 (open bascule gates were simulated in the model with a sill having top el 412.0). Modifications for the various plans in the series were as follows:

a. Plan E was the same as existing conditions except for the addition of two gate bays (1 and 2) to the right of the upper gated spillway section (Figure 13). The gate bays were equipped with tainter gates having the same sill elevation as the existing upper gate section.

b. Plan E-1 was the same as Plan E except that four gate bays with tainter gates were added instead of two.

c. Plan E-2 was the same as Plan E except that six gate bays with tainter gates were added instead of two (Figure 13).

d. Plan E-3 was the same as Plan E except that the two gate bays were provided with bascule gates instead of tainter gates.

e. Plan E-4 was the same as Plan E-1 except that the four gate bays were provided with bascule gates instead of tainter gates.

f. Plan E-5 was the same as Plan E-2 except that the six gate bays were provided with bascule gates instead of tainter gates.

Results

44. Effects of the additional gates on water-surface profiles upstream of the Pennsylvania Railroad bridge are shown in Plates 16-19. These results indicate that the amount of lowering of the water-surface elevations upstream of the Pennsylvania Railroad bridge varied with the number and types of gates added and discharge. Typical average lowering of the water-surface elevations with the flows tested are indicated in the following tabulation:

		Average Amount of Lowering, ft Discharge, 1,000 cfs			
Plan	Gates Added	270	300	340	400
E	2 tainter	2.1	1.8	1.3	0.5
E-1	4 tainter	3.7	3.5	2.7	0.9
E-2	6 tainter	4.1	4.0	3.3	1.2
E-3	2 bascule	1.0	0.8	0.5	0.3
E-4	4 bascule	1.8	1.7	1.3	0.5
E-5	6 bascule	2.4	2.4	2.0	0.7

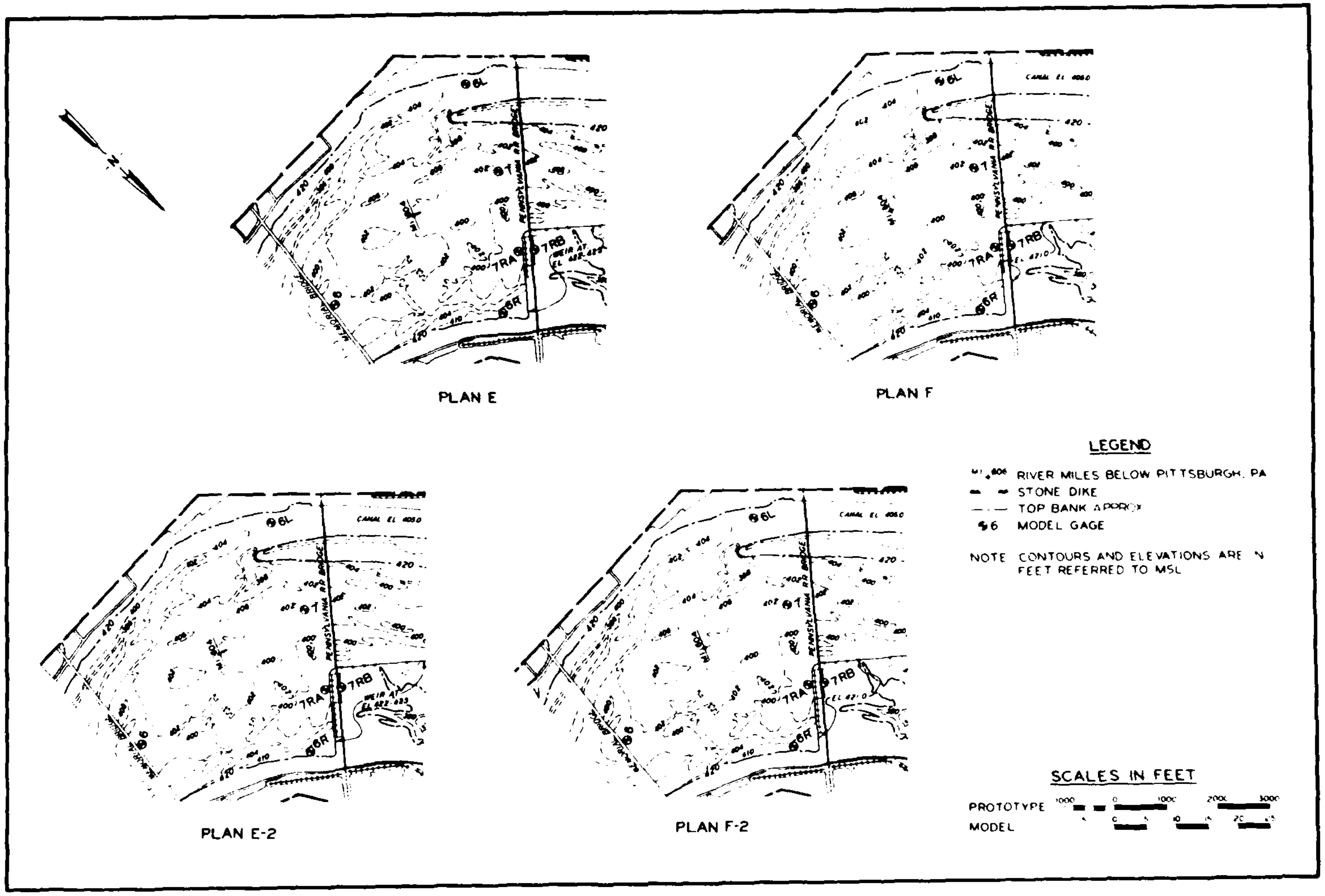


Figure 13. Plans E, F, E-2, and F-2

45. Effects of the added gates on the differences in water-surface elevations between the upper and lower pools are shown by the curves in Plates 20 and 21. The curves, based on actual measurements and interpolation between measurements, indicate that the differences in pool elevations up to the point where the normal upper pool elevation can no longer be maintained would vary about as follows:

Plan	Test Condition	Range of Difference, ft
Base	Existing gates	11.8 to 5.5
E	2 tainter gates added	9.4 to 4.6
E-1	4 tainter gates added	7.2 to 3.6
E-2	6 tainter gates added	6.7 to 2.8
E-3	2 bascule gates added	10.5 to 5.0
E-4	4 bascule gates added	9.6 to 4.4
E-5	6 bascule gates added	8.9 to 4.0

The above data and results shown in Plates 20 and 21 are based on measurements taken along the right bank just upstream of the upper spillway (gage 6R) and at the end of lower lock guard wall (gage 12L).

46. Current directions and velocities obtained with Plans E and E-2 (Plates 22 and 23) indicate some increase in velocities approaching the entrance to the navigation canal compared with existing conditions. The increase in velocities can be attributed mostly to the lowering of the water-surface elevations with the added gates in the upper spillway. There was little difference in the alignment of the currents approaching the canal except that the crosscurrents extended somewhat farther upstream, particularly with the lower flows.

47. Navigation conditions for downbound tows approaching the canal were generally not as good as those with existing conditions because of the high-velocity currents and increase in the intensity of the crosscurrents in the approach.

Plans F Through F-6

Description

48. Plan F series involved the lowering of the fixed overflow

section of the dam to el 421.0 without and with additional gate bays, as shown in Figures 13 and 14. Plan F (base) was the same as existing conditions except for the lowering of the fixed overflow section of the dam. Plans F, F-1, and F-2 included the addition of two, four, and six tainter gates to the upper gated spillway and were the same as Plans E, E-1, and E-2, respectively, except for the lower fixed section of the dam. Plans F-3, F-4, and F-5 included two, four, and six bascule gates instead of the tainter gates and were the same as Plans E-3, E-4, and E-5, respectively, except for the lower fixed section of the dam.

Results

49. Water-surface profiles obtained with the Plan F series, shown in Plates 24-27, indicate average lowering of the water-surface elevation in the upper pool compared with existing conditions about as follows:

Plan	Fixed Weir Lowered and Gates Added	Average Amount of Lowering, ft Discharge, 1,000 cfs			
		270	300	340	400
F (Base)	--	0.2	0.8	1.1	0.8
F	2 tainter	2.1	1.9	1.8	1.2
F-1	4 tainter	3.7	3.5	2.7	1.5
F-2	6 tainter	4.1	4.0	3.3	1.7
F-3	2 bascule	1.0	1.2	1.4	1.0
F-4	4 bascule	1.8	1.9	1.9	1.2
F-5	6 bascule	2.4	2.5	2.3	1.3

The above results indicate that lowering of the fixed weir without modification of the gated spillway (base) would have little effect on the 270,000-cfs flow. Compared with the results of Plan E series, lowering of the fixed weir would have little or no effect on flows up to and including 300,000 cfs and 340,000 cfs with Plans F-1 and F-2. However, with Plans F, F-3, F-4, and F-5 the water-surface elevations were lowered an additional 0.3 to 0.9 ft with the 340,000-cfs flow and 0.5 to 0.7 ft with the 400,000-cfs flow (Plans F through F-5). The lower weir would be more effective in lowering stages with the bascule gates than with the added tainter gates, particularly with the higher flow.

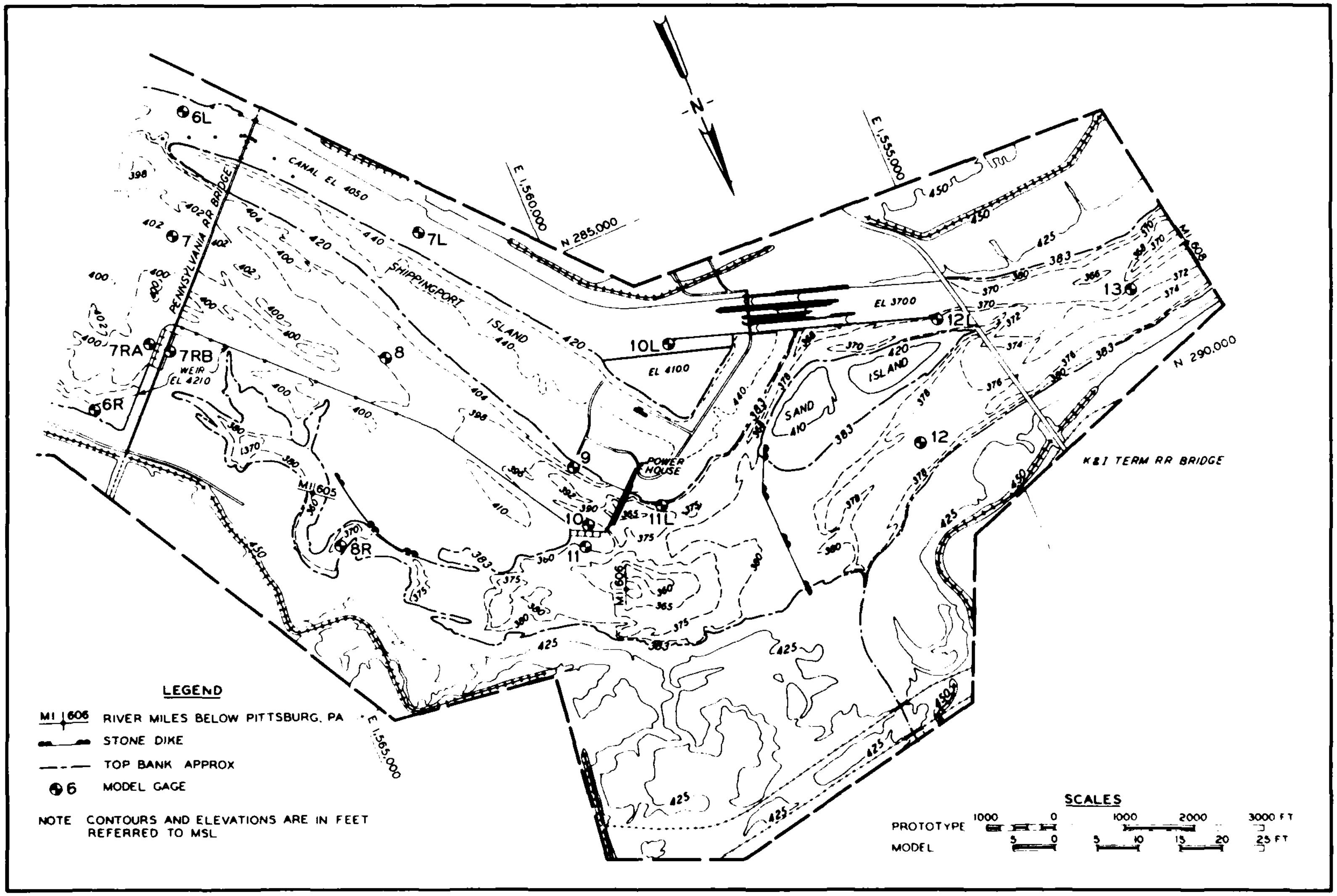


Figure 14. Plan F (base)

50. Effects of the lower fixed weir with and without the added gate bays are illustrated by the curves shown in Plates 28 and 29. The difference in the upper and lower pool elevations with the lower fixed weir and no change in the spillway gates would vary from about 0.2 and 1.1 ft with flows of 270,000 and 400,000 cfs, respectively (compare Plates 20 and 28). Effects of the lower fixed weir with the various numbers and types of gates on the difference in the upper and lower pool elevations (gates 6R and 12L) until upper pool elevations could no longer be maintained would be about as follows:

Plan	Test Condition	Range of Difference, ft
Base	Existing gates	11.6 to 4.0
F	2 tainter gates added	9.2 to 3.7
F-1	4 tainter gates added	7.3 to 3.0
F-2	6 tainter gates added	6.7 to 2.5
F-3	2 bascule gates added	10.5 to 3.8
F-4	4 bascule gates added	9.7 to 3.6
F-5	6 bascule gates added	8.2 to 3.2

Current direction and velocities obtained with only the fixed weir lowered (base) and with two and six tainter gates added to the upper gated spillway are shown in Plates 30-32. These results indicate the same general trends as those obtained with the Plan E series. Velocities in the approach to the entrance to the navigation canal were increased depending on the amount of lowering of the upper pool with a tendency for the crosscurrents to extend farther upstream.

51. Because of the increase in velocities and its effect on crosscurrents, navigation conditions would not be as good with any of these modifications as with existing conditions. The difficulties downbound tows would experience in approaching the canal would tend to increase with the number of gates added and the amount of lowering of the upper pool elevation. In general, downbound tows would have to approach the canal from closer along the left bank than with existing conditions and maintain somewhat more power and steerage to overcome the effects of the crosscurrents. No serious difficulties were indicated for upbound tows leaving the canal.

Sedimentation Tests

52. Tests were conducted to determine the causes of deposition over the fossil coral beds along the right bank downstream of the Pennsylvania Railroad bridge and to determine modifications that could be used to eliminate or prevent such deposition. Tests were conducted with existing conditions except that the existing deposit was removed in the model and replaced with a layer of movable-bed material. Gate operation tests were conducted to determine the effect of controlling the upper pool during low flows by operation of only the five gates in the upper spillway (Test 1) and then by opening the gates in the upper and lower spillway equally (Test 2).

53. Results of current patterns shown in Plate 33 indicate that operation of the gates as mentioned above would have little effect on deposition over the fossil beds. With all flows through the upper spillway, velocities would increase considerably which could increase the length of the area where deposition could occur. Most of the deposition is caused by eddies that form downstream of the fixed weir to the right of the upper gated spillway. The slower moving bottom currents that carry most of the sediment would tend to move to the right into the eddy area and result in deposition of sediment passing through the gated spillway. A typical deposition pattern is shown in Plate 33.

Plans G, G-1, G-2, G-3, and G-4

Description

54. Plans G and G-1 were designed to eliminate the tendency for deposition over the fossil beds by diverting some of the flow through the upper spillway gates to the right over the area where deposition normally occurs. Plan G included a training dike downstream of the Pennsylvania Railroad bridge (pier 19) extending downstream on a straight line with the left pier of the upper spillway gate bay 5 and then turning to the right (Figure 15). Plan G-1 was the same as Plan G except that a second training dike was placed downstream of the Pennsylvania Railroad bridge (pier 18) extending downstream of the pier to the

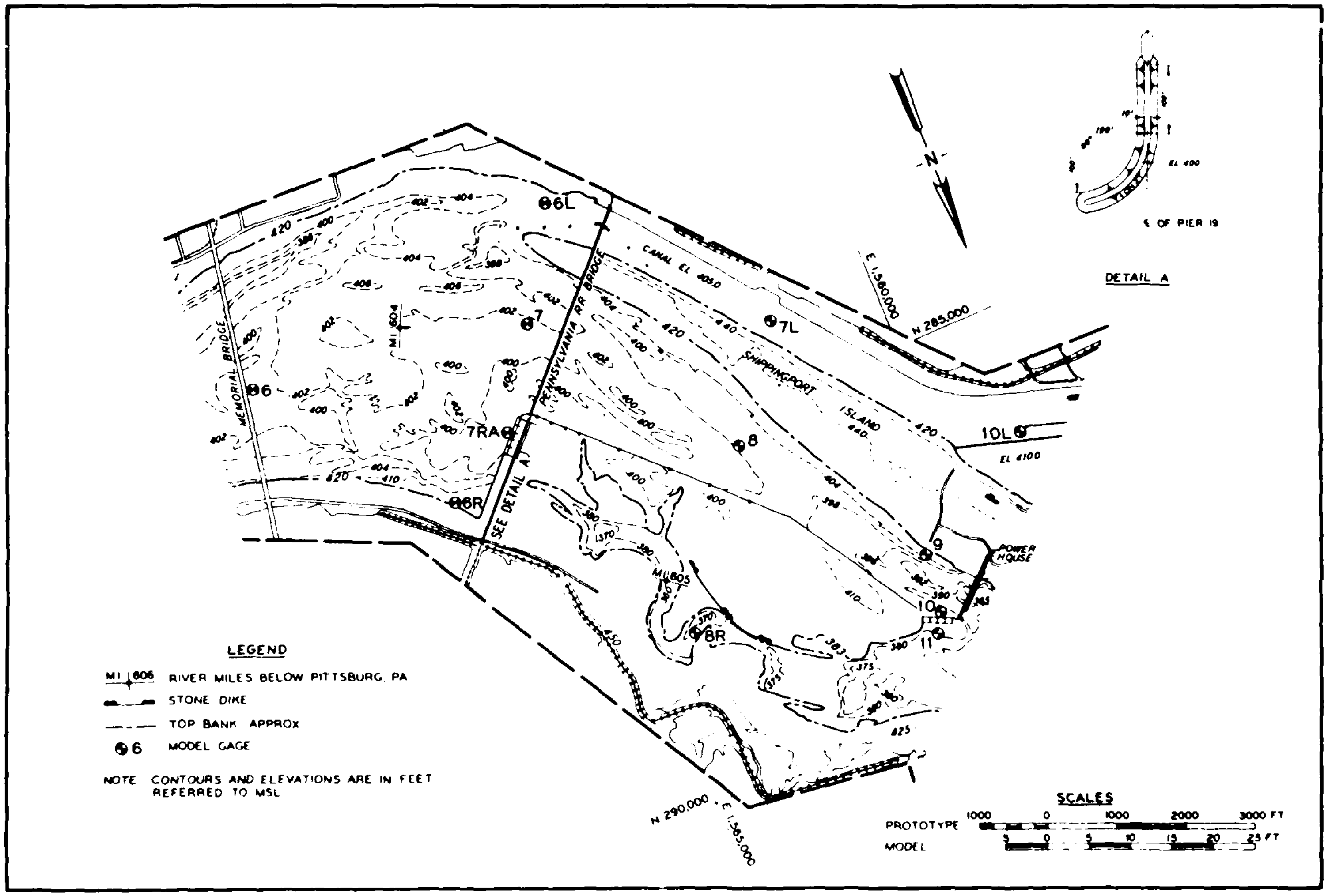


Figure 15. Plan G

right of gate bay 2 and turning to the right farther downstream than the dike of Plan G (Figure 16). The crests of the training dikes were at el 400.0.

55. Plans G-2, G-3, and G-4 involved the addition of one, two, and six gate bays to the right of the upper gated spillway, respectively (Figure 12). Plan G-2 included one additional tainter gate in gate bay 6 of the proposed spillway extension. Plan G-3 included additional tainter gates in gate bays 3 and 6. Plan G-4 included bascule gates in all six gate bays of the proposed spillway extension.

Results

56. Results of the various plans designed to remove or eliminate deposition over the fossil beds are shown in Plates 34-37. These results indicate that the most effective plans were those with the training dikes downstream of the existing upper spillway (Plans G and G-1). There was little difference in the scoured area developed between the two plans. Velocities moving to the right were somewhat higher with the one dike of Plan G than with the two dikes of Plan G-1 and there was less disturbance to fl w from the spillway. The training dikes would not have any effect on deposition a short distance downstream of the railroad bridge and in a narrow strip along the right bank.

57. Installation of additional gate bays produced scour downstream of the additional gates, but scouring was limited to the area covered by the jet downstream of each gate. With the addition of six bascule gates of Plan G-4, scouring occurred over a large area downstream of the gates but flow through the gates had no effect on the deposition over a sizable area along the right bank (Plate 37).

58. Results of these tests are mostly qualitative but should provide a reasonable indication of the area where there will be a tendency for scour. Tests were conducted with the 100,000-cfs flow only and with the existing deposit replaced by a layer of movable material.

Bank Erosion Tests

Effects of gate operation

59. Tests were conducted to determine the effect of gate operation

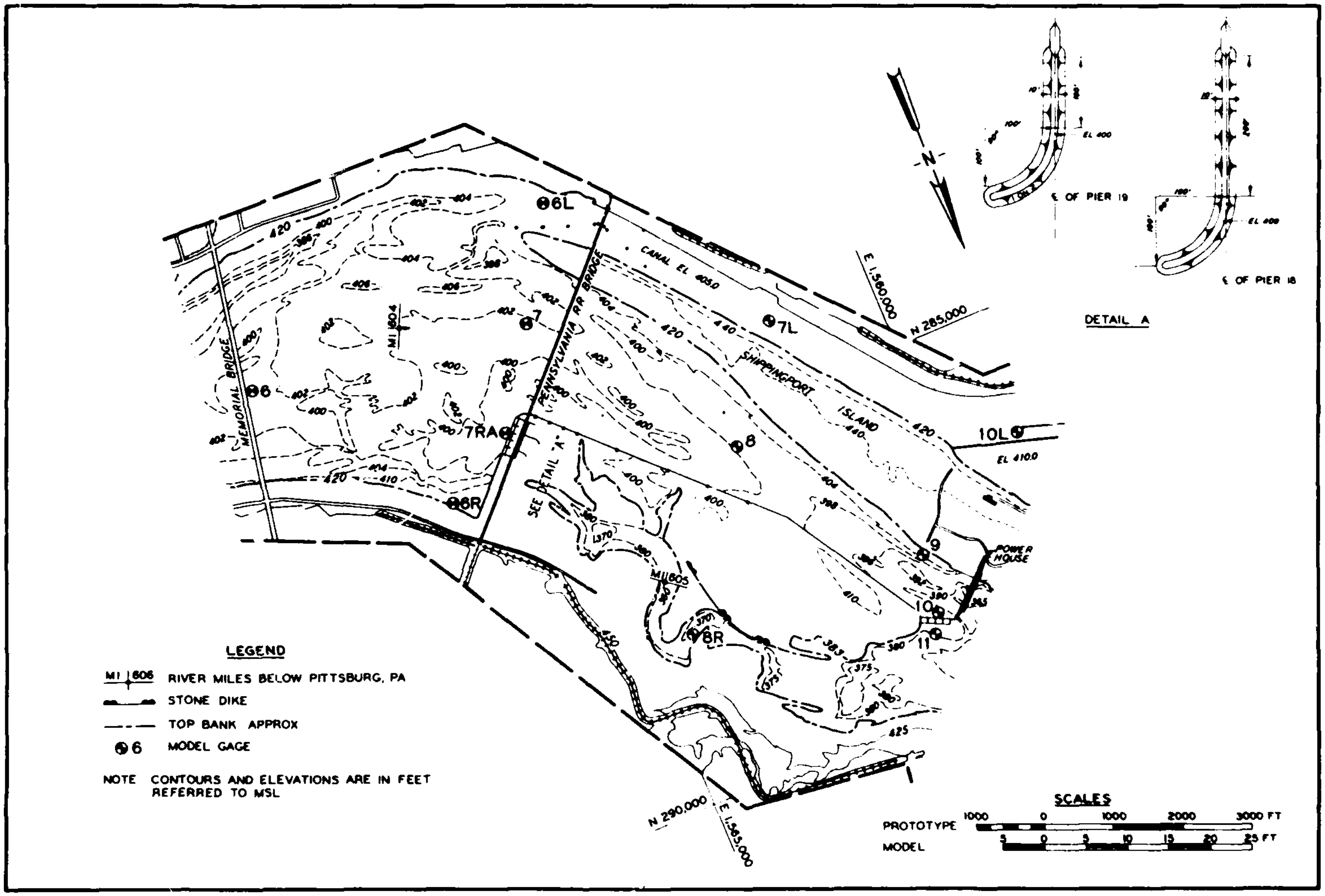


Figure 16. Plan G-1

on currents that could affect the erosion of the right bank opposite the lower spillway gates. During these tests the upper pool elevation was controlled with the lower spillway gates only, with the upper and lower spillway gates opened an equal amount, and with only the upper spillway gates. The flows used were those considered to be within the most critical range (52,000 cfs and 77,000 cfs); it was assumed that the powerhouse would be in operation passing 32,000 cfs of the total.

60. Results of these tests, shown in Plates 38 and 39, indicate that the worst condition would occur with all flow controlled with the gates in the lower spillway. With operation of the lower gates only, maximum velocities moving toward and along the right bank opposite the gates varied from about 7.1 fps with the 52,000-cfs flow to about 11.0 fps with the 77,000-cfs flow. With flow distributed between the upper and lower spillway, maximum velocities along the bank were reduced to less than 4.0 fps with the 52,000-cfs flow and to less than 7.0 fps with the 77,000-cfs flow. Velocities were further reduced when the flows were controlled with the upper spillway gates only.

Deflection dike (Plan H)

61. The only structure tested in an effort to reduce velocities along the right bank opposite the lower spillway consisted of a 920-ft-long dike constructed of 20-ft-diam cells (top el 422.0) located just downstream of the lower spillway (Figure 17).

62. The dike had little or no effect on water-surface elevations with any of the flows tested. Results shown in Plate 40 indicate that the dike reduced velocities considerably along the right bank opposite the spillway and moved the point of attack farther downstream. Effectiveness of the dike decreased with the higher flow when the upper and lower spillway gates were open. Maximum velocities along the right bank with the 400,000-cfs flow were on the order of 7 to 8 fps.

Surge Tests

Description

63. Tests were conducted to determine the effects of a proposed

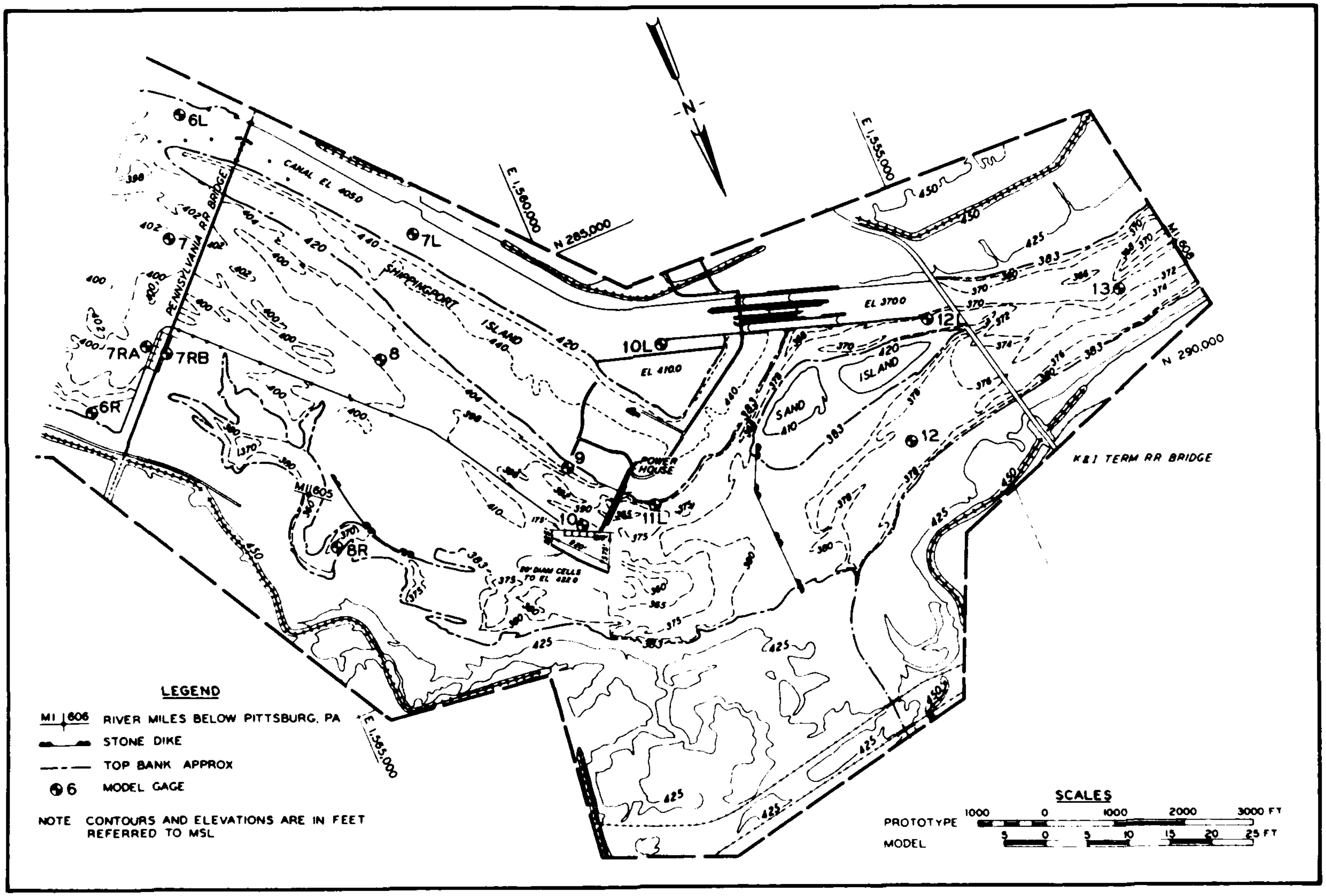


Figure 17. Plan H

second 1200-ft lock on the magnitude of surges in the L&P Canal and navigation conditions in the lock approaches. These tests were based on the proposed future replacement of the existing 600-ft lock with a modern 1200-ft lock (Figures 18 and 19). Tests in the model were conducted with the bottom of the canal at el 405.0 and upper and lower pool elevations of 420.0 and 383.0, respectively.

64. Before tests were undertaken, the model lock filling systems were adjusted until the rate of lock filling was reproduced reasonably close to the curve developed from data furnished by the Louisville District for the existing 1200-ft lock (Plate 41). Comparison of the model and computed prototype filling curves indicates close agreement except at the end of the filling cycle where the rate of filling was somewhat slower in the model. The surge created in the canal by filling of the existing lock was then measured at three ranges located as shown in Figure 18 and compared with prototype measurements and with the surges computed by the Hydrologic Engineering Center unsteady flow computer program. Results of this comparison, also shown in Plate 41, indicate that the magnitude of the first surge in the model at range 1 was about 30 percent lower and occurred later than indicated by the prototype data furnished and agreed more closely with the computed surge. Conditions under which the prototype data were taken are not known and could have been affected by river discharge, depths in the canal, traffic, wind, and remnants of surges resulting from previous lock filling operation and some differences in the rate of lock filling. The computed data were based on cross sections taken in June 1975, which were heavily silted at the time, and later dredged to el 408.0; the bottom of the canal in the model was at el 405.0. Maximum velocities measured in the model during the first surge were about 4.6 fps near the lock (range 1) and about 2.5 fps at ranges 2 and 3. Because of the scale effect, the surge in the model damps faster than in the prototype.

65. Tests with the proposed new lock were then conducted by filling both of the 1200-ft locks simultaneously, 6.6 min apart and 15 min apart; results of these tests are shown in Plates 42-44. It should be noted from these results that the filling of both locks,

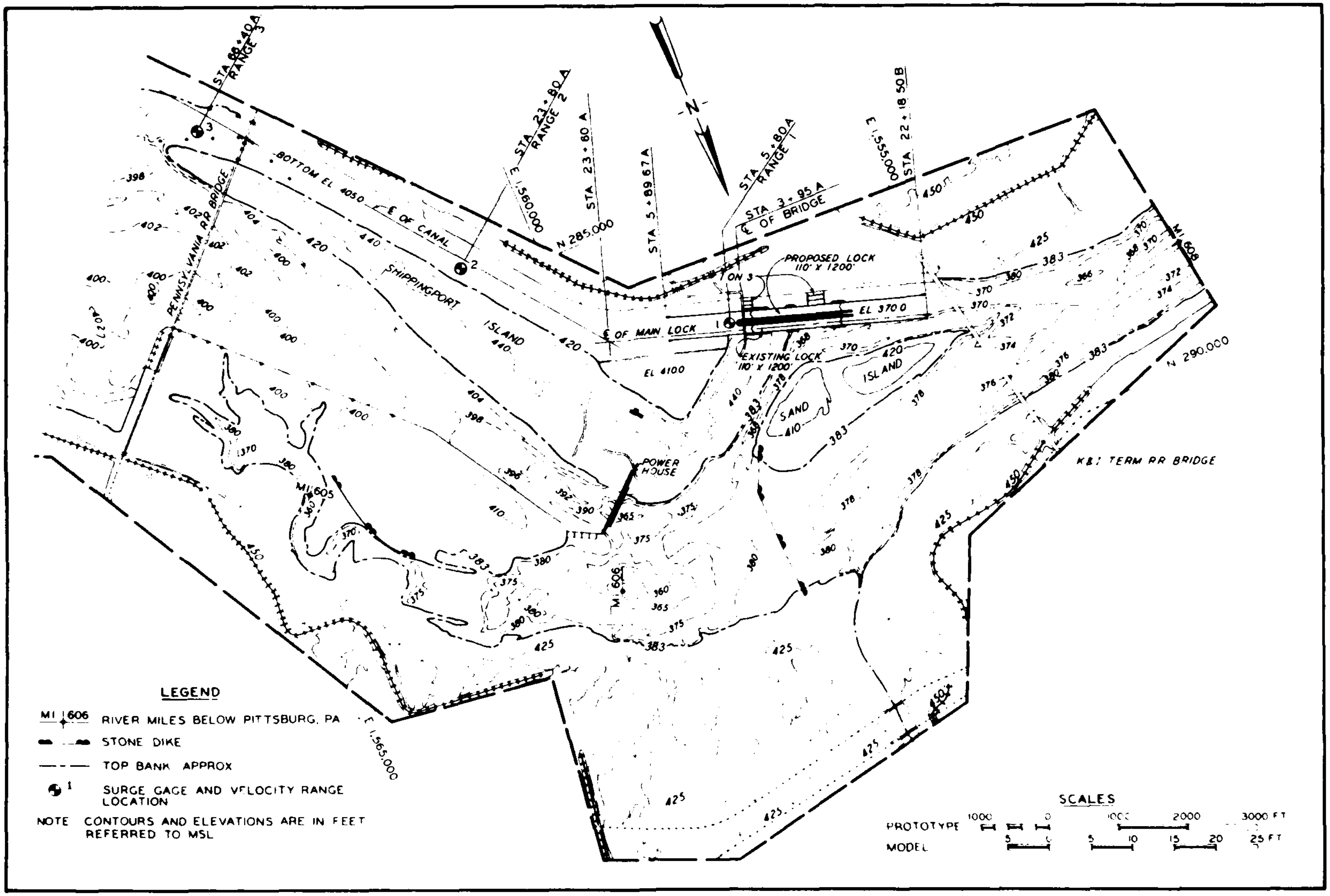


Figure 18. Location of gages and ranges used in surge tests

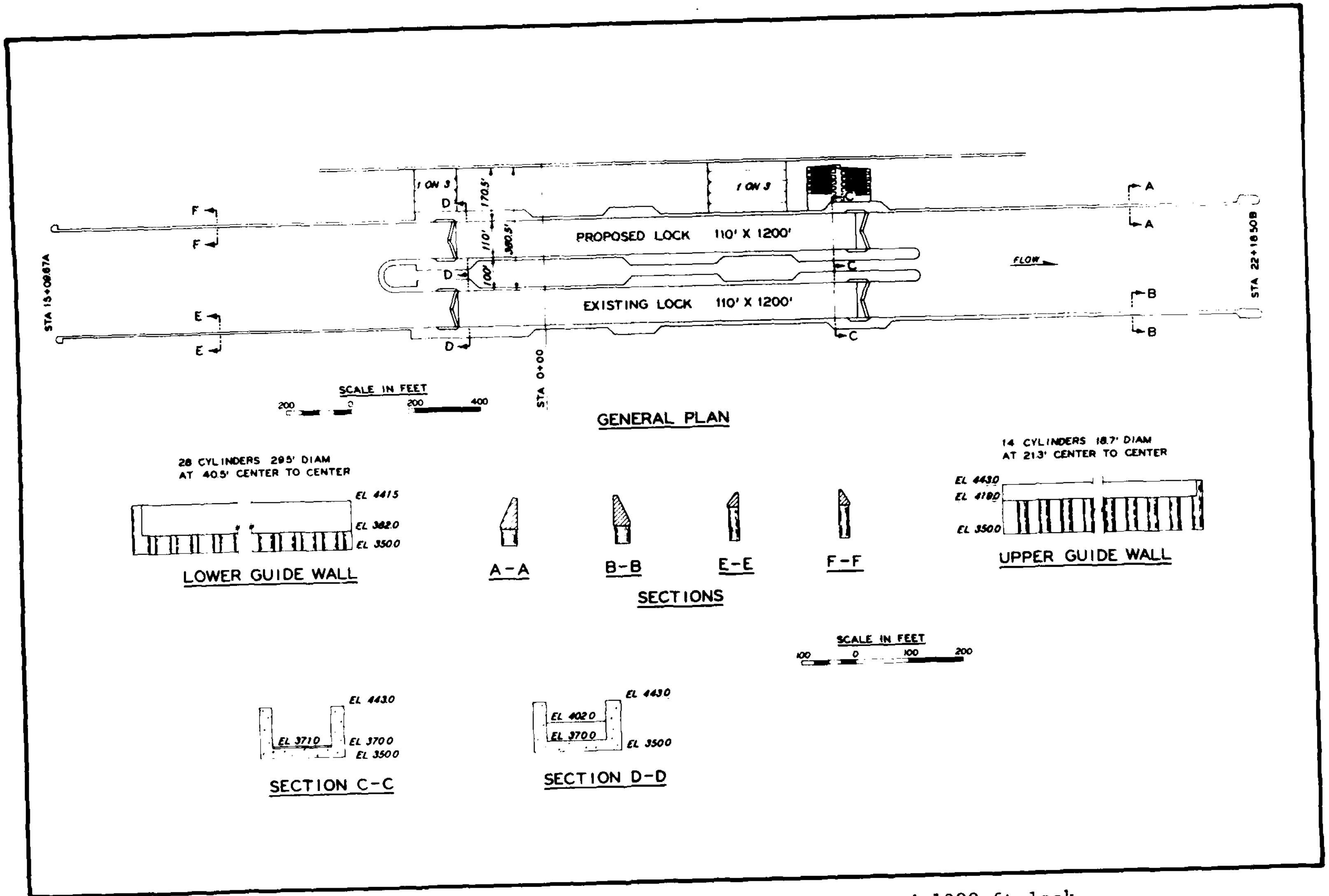


Figure 19. General plan and sections for proposed 1200-ft lock

whether simultaneously or a few minutes apart, had some effect on the rate of filling of both locks, which could be expected. The magnitude of surge with both locks filled simultaneously was about 5.4 ft with a drawdown of about 4.0 ft below normal pool at the locks (range 1) and decreased rapidly at ranges 2 and 3. Filling the two locks 6.6 min and 15 min apart reduced the magnitude of surge near the locks to 2.6 ft and 1.7 ft, respectively. When the locks were filled 6.6 min apart, the magnitude of the surge and maximum velocities near the locks were about the same as with the filling of only the existing lock. When the locks were filled 15 min apart, the surge near the locks was less than when only the existing lock was filled, which would depend on the surge created by the filling of the first lock, but the maximum velocities (4.5 fps) were about the same. Maximum velocities near the locks with both locks filled simultaneously were about 7.2 fps.

Navigation in Lock Approaches

66. Navigation conditions in the lock approaches would be affected by the limited width between the guide walls of the two locks and the maneuvering required for tows to approach and become aligned with the guide walls (Photos 4-7). No serious difficulties were indicated for individual tows approaching and entering either lock under normal conditions. However, it would be necessary for one tow to enter one lock and clear the guide wall of that lock before a second tow could safely approach the guide wall of the other lock. Navigation conditions for downbound tows approaching the locks could be hazardous during lock filling, particularly if the two locks are filled simultaneously. Emptying of both locks simultaneously would tend to increase the erosion of Sand Island and could have some effect on navigation in the lower approach.

PART IV: DISCUSSION OF RESULTS AND CONCLUSIONS

Limitation of Model Results

67. Analysis of the results of this investigation is based mostly on a study of the effects of various plans and modifications on water-surface elevations, current directions and velocities, the effects of the resulting currents on the behavior of the model towboat and tow, and the tendency for deposition over the fossil bed area. In evaluating test results, it should be considered that small changes in current directions and velocities are not necessarily changes produced by a modification in plan since several floats introduced at the same point may follow a different path and move at somewhat different velocities because of pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to a depth of a loaded barge (9 ft prototype) and are more indicative of the currents that would affect the behavior of tows than those indicated by photographs which indicate the movement of confetti on the water surface and could be affected by surface tension.

68. The small scale of the model made it difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water-surface elevations within an accuracy greater than about ± 0.1 ft prototype. Also, current directions and velocities were based on steady flows and would be somewhat different with varying flows. The model was of the fixed-bed type and was not designed to reproduce overall sediment movement that might occur in the prototype; therefore, changes in channel configurations resulting from scouring and deposition could not be developed naturally. However, a layer of lightweight material was placed in the deposition area over the fossil bed to indicate a tendency for bed scour or deposition.

69. Also, because of the small scale of the model, surges tend to damp much faster than would occur in the prototype. Therefore, results of the surge test should be considered qualitative based on the first peak only and used for comparative purposes based on the conditions reproduced in the model. In general, surges in the model were somewhat

lower than those indicated by prototype data and those based on a computer model. With the shallower canal in the prototype and as used in the computer program, surges would be expected to be higher than those indicated by the model results. Also in the prototype, surges resulting from one lock filling operation persist for many hours although decreasing in magnitude with time. A lock filling started with an existing surge in the canal could produce a surge of considerably different magnitude than if the filling is started with no movement in the canal.

Summary of Results and Conclusions

70. The following results and conclusions were developed during the investigation:

a. Navigation conditions in the approach to the existing L&P Canal are affected by the limited depths close along the left bank, crosscurrents in the approach, and alignment of the tows approaching the canal after passing the navigation span of the Memorial Bridge. Downbound tows could approach the canal and make a satisfactory entrance with little difficulty provided that sufficient power and steerage are maintained to offset the effects of the crosscurrents.

b. Navigation conditions for downbound tows approaching the entrance to the L&P Canal could be improved considerably with submerged dikes along the left bank, as in Plan A, which would tend to reduce velocities and crosscurrents in the approach.

c. Placing a line of cells extending from the head of Shippingport Island to the riverward pier of the navigation span of the Memorial Bridge, as in Plan B, would have little effect on currents and navigation conditions in the canal approach. The cells would provide some protection for tows that might be out of control because of loss of power or steerage.

d. Cutting a canal across Shippingport Island downstream of the Pennsylvania Railroad bridge, as in Plans C and C-1, would tend to increase velocities in the canal approach but would reduce the intensity of the crosscurrents. Tows could enter the L&P Canal with less difficulty than with existing conditions, but would have to maintain power and steerage longer because of currents in the canal. Downbound tows could also experience some difficulty in stopping, if required, before passing the Pennsylvania Railroad bridge.

e. Of the plans tested, the greatest improvement in navigation conditions for downbound tows approaching the L&P Canal was obtained with a 600-ft-long low dike forming an extension to Shippingport Island, as in Plan D. With this plan, tows could approach the canal with considerably less power than with existing conditions and with little tendency for the tow to be moved riverward or rotated out of alignment.

f. None of the modifications tested would have any serious effects on upbound tows leaving the canal.

g. Increasing the number of gate bays and gates to the right of the upper spillway or lowering the elevation of the fixed overflow section of the dam would increase the range of controlled flows. The effect would depend on the number and types of gates used. Lowering of the upper pool elevations with the higher flows would tend to increase velocities in the approach to the L&P Canal and the intensity of the crosscurrents during those flows.

h. Deposition over the fossil coral beds along the right bank downstream of the Pennsylvania Railroad bridge could be reduced with the addition of gates to the right of the existing upper gated spillway (Plans G-2, G-3, and G-4) or by the construction of a training dike designed to divert flow from the existing upper spillway toward the deposition area (Plans G and G-1). With additional gates, the area of scour would be limited to a narrow strip covered by the jet from flow through the gate or gates provided.

i. Development of plans for the reduction of scouring along the right bank opposite the lower gated spillway was not fully explored since only one plan involving a deflector dike was tested. The dike would tend to reduce scour opposite the spillway but would tend to increase velocities along the bank farther downstream. Velocities impinging on the right bank could also be reduced with flow through the upper gated spillway during the lower flows.

j. With a proposed second 1200-ft lock, surges in the canal would depend on the phasing of filling of each of the two locks. Filling both locks simultaneously could have some effect on the rate of filling of the locks and could produce a surge with at least twice the magnitude of the surge developed from the filling of only the existing 1200-ft lock. The filling of one lock started about 6.6 min after the start of the filling of the first lock would produce a surge about equal to that produced with the filling of only one lock. When filling of the two locks is started about 15 min apart, the surge could be less than with the filling of one lock but velocities would be about the same. Surges created by lock filling can vary appreciably, depending on the surge remaining after a previous filling and other factors such as traffic, wind, river discharge, and rate of filling.

k. With two 1200-ft locks arranged as tested, no navigation difficulties were indicated for tows approaching either lock. However, because of the limited distance between the two guide walls and the maneuvering required to approach either wall, it would be necessary for a tow using one lock to clear the guide wall before a second tow using the other lock could safely approach the guide wall of that lock.

l. With two 1200-ft locks emptying simultaneously on the riverside of both locks, erosion along Sand Island could be increased to the point that it might have some effect on navigation in the lower approach.

Table 1

Water-Surface Elevations, Adjustment

Gage No.	Water-Surface Elevations, ft msl, at Discharge, cfs 88,800	130,000	264,000	427,000
1	420.3	420.7	422.5	428.8
2	420.3	420.7	422.4	428.6
3	420.2	420.7	422.3	428.4
4	420.2	420.6	422.2	428.3
5	420.2	420.6	422.1	428.0
6	420.2	420.5	421.7	427.5
7	420.2	420.4	421.6	427.5
8	419.7	419.8	421.1	426.9
9	419.0	418.9	420.1	426.5
10	419.0	418.4	419.5	426.1
11	391.4	395.2	407.9	425.1
12	391.9	395.9	407.8	424.2
12-L	391.8*	395.7*	407.7*	424.1*
13	391.6	395.7	407.6	424.1
6R	420.1*	420.4*	421.5	427.4
7RA	420.0	420.4	420.4	426.8
7RB	394.0	399.1	409.5	425.8
8R	394.0	398.6	409.5	425.6
6L	420.2	420.5	421.8	427.8
7L	420.2	420.5	421.8	427.8
10L	420.1	420.5	421.8	427.8
11L	392.5	395.7	407.4	424.2

* Controlled elevation.

Table 2

Water-Surface Elevations, Base Test

Gage	Water-Surface Elevations, ft msl, at Discharge, cfs									
No.	88,800*	150,000**	150,000†	223,000	246,000	270,000	300,000	340,000	400,000	625,000
1	420.3	420.5	420.5	420.8	422.3	423.2	424.7	425.8	427.4	442.5
2	420.3	420.4	420.4	420.7	422.1	423.1	424.6	425.7	427.3	442.3
3	420.2	420.4	420.4	420.6	422.0	423.0	424.5	425.6	427.1	442.2
4	420.2	420.3	420.3	420.6	421.9	422.9	424.4	425.5	427.0	442.1
5	420.2	420.3	420.3	420.4	421.8	422.7	424.3	425.3	426.7	441.9
6	420.2	420.2	420.1	420.1	421.5	422.4	423.8	424.8	426.2	441.5
7	420.2	420.2	420.0	420.0	421.4	422.3	423.7	424.8	426.1	441.6
8	419.7	420.2	419.3	419.6	420.9	421.8	423.2	424.3	425.5	441.2
9	419.0	420.2	418.1	418.7	420.0	420.8	422.2	423.3	424.8	441.0
10	419.0	420.1	417.8	418.0	419.4	420.2	421.5	422.5	424.2	440.7
11	391.4	399.6	399.6	406.2	408.7	411.3	413.9	417.5	422.6	439.8
12	391.9	399.2	399.2	406.1	408.4	410.6	413.1	416.7	421.9	439.2
12-L	391.8††	399.1††	399.1††	406.0††	408.3††	410.5††	413.0††	416.6††	421.8††	439.1††
13	391.6	399.1	399.1	405.9	408.3	410.5	413.0	416.6	421.8	439.1
6R	420.1††	420.1††	420.1††	419.8	421.2	422.1	423.5	424.6	426.1	441.4
7RA	420.0	419.1	419.8	416.9	420.2	421.0	422.5	423.4	425.1	441.3
7RB	394.0	398.2	400.8	407.3	410.6	413.2	415.4	418.4	423.4	441.1
8R	394.0	400.2	401.1	407.8	409.9	412.2	414.8	418.1	423.3	440.8
6L	420.2	420.2	420.1	420.2	421.6	422.5	423.8	425.1	426.5	441.7
7L	420.2	420.2	420.1	420.2	421.6	422.5	423.8	425.1	426.5	441.7
10L	420.1	420.2	420.1	420.2	421.6	422.5	423.8	425.1	426.5	441.7
11L	392.5	399.5	399.0	405.6	408.1	410.4	413.0	416.6	421.7	439.3

* Powerhouse discharge 32,000 cfs, upper gate closed.
** 5 upper dam gates open, 4 lower dam gates closed.
† 1 upper dam gate open, 4 lower dam gates open.
†† Controlled elevation.

Table 3

Water-Surface Elevations, Plan A

Gage No.	Water-Surface Elevations, ft msl, at Discharge, cfs 150,000*	150,000**	246,000	300,000	625,000
1	420.5	420.5	422.3	424.7	442.5
2	420.4	420.4	422.1	424.6	442.3
3	420.4	420.4	422.0	424.5	442.2
4	420.3	420.3	421.9	424.4	442.1
5	420.3	420.3	421.7	424.2	441.9
6	420.2	420.1	421.4	423.7	441.5
7	420.2	420.0	421.3	423.6	441.6
8	420.2	419.3	420.8	423.1	441.2
9	420.2	418.1	419.9	422.1	441.0
10	420.1	417.8	419.3	421.4	440.7
11	399.6	399.6	408.7	413.8	439.8
12	399.2	399.2	408.4	413.1	439.2
12L	399.1	399.1	408.3	413.1	439.1
13	399.1†	399.1†	408.3†	413.0†	439.1†
6R	420.1†	420.1†	421.2	423.4	441.4
7RA	419.1	419.8	420.2	422.4	441.3
7RB	398.2	400.8	410.6	415.3	441.1
8R	400.2	401.1	409.9	414.9	440.8
6L	420.2	420.1	421.5	423.8	441.7
7L	420.2	420.1	421.5	423.8	441.7
10L	420.2	420.1	421.5	423.8	441.7
11L	399.5	399.0	408.1	413.0	439.3

* 5 upper gates open - 4 lower gates closed.
** 1 upper gate open - 4 lower gates open.
† Controlled elevation.

Table 4

Water-Surface Elevations, Plan D

Gage No.	Water-Surface Elevations, ft msl, at Discharge, cfs 246,000	300,000	625,000
1	422.3	424.7	442.5
2	422.1	424.6	442.3
3	422.0	424.5	442.2
4	421.9	424.4	442.1
5	421.8	424.3	441.9
6	421.5	423.8	441.5
7	421.4	423.7	441.6
8	420.9	423.2	441.2
9	420.0	422.2	441.0
10	419.4	421.5	440.7
11	408.7	413.9	439.8
12	408.4	413.1	439.2
12L	408.3	413.0	439.1
13	408.3*	413.0*	439.1*
6R	421.2	423.5	441.4
7RA	420.2	422.5	441.3
7RB	410.6	422.4	441.1
8R	409.9	414.8	440.8
6L	421.6	423.9	442.0
7L	421.6	423.9	442.0
10L	421.6	423.9	442.0
11L	408.1	412.8	439.3

* Controlled elevation.

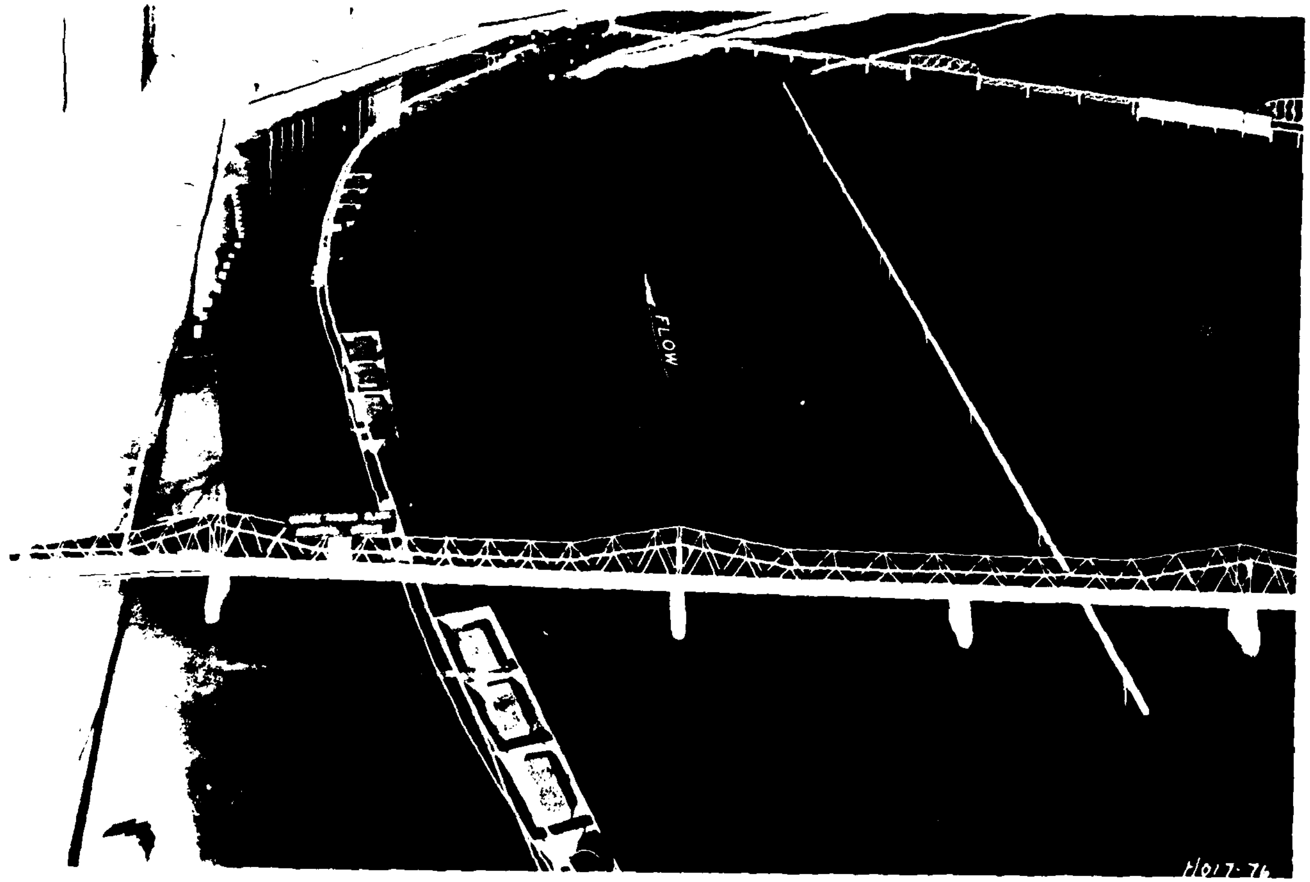


Photo 1. Existing conditions; discharge 246,000 cfs. Typical path of downbound tow approaching canal after passing near center of Memorial Bridge navigation span

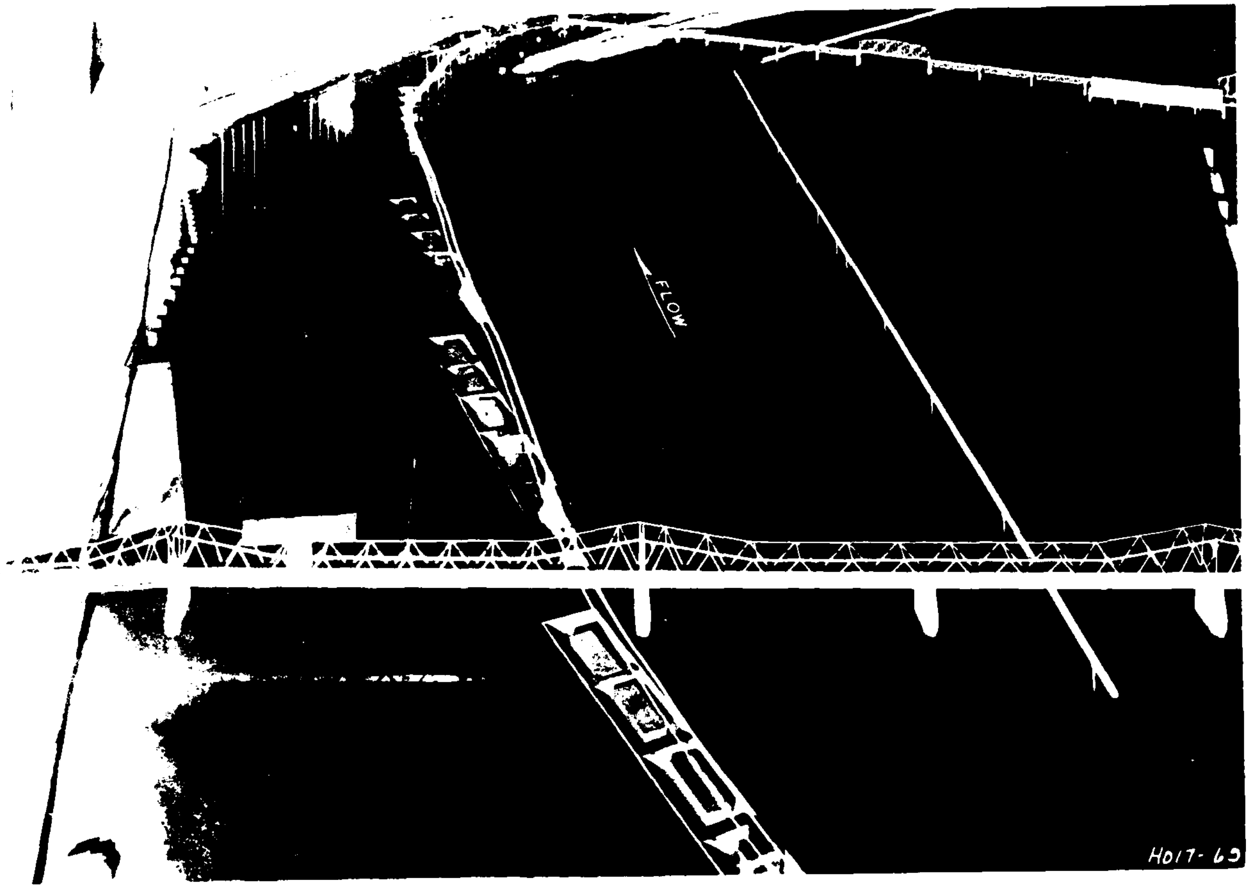


Photo 2. Plan A; discharge 246,000 cfs. Path of downbound tow approaching the canal after passing close to right pier of the Memorial Bridge navigation span. Because of the orientation of the tow in the approach, some maneuvering or flanking might be required to become properly aligned for entrance into the canal

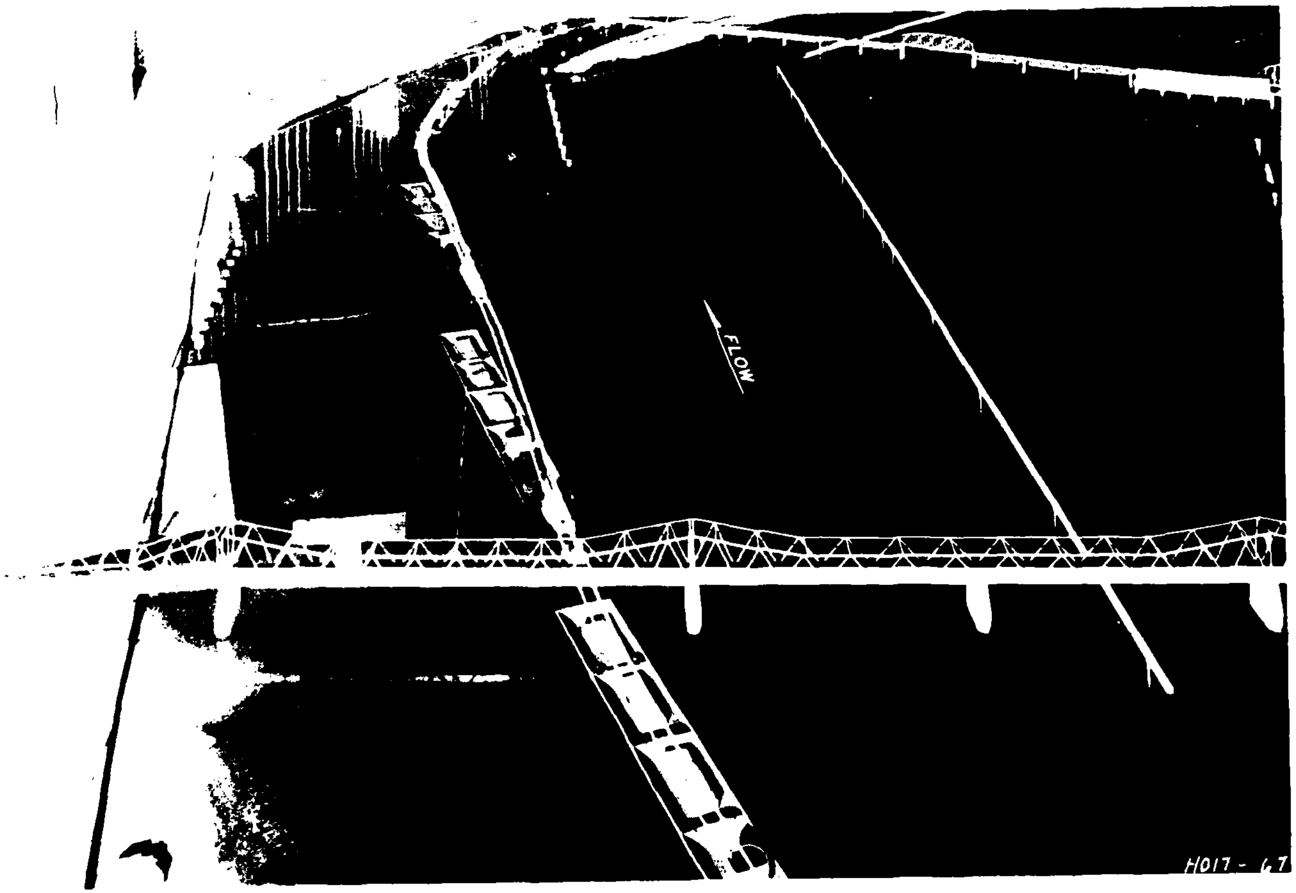


Photo 3. Plan B-modified; discharge 246,000 cfs. Path of downbound tow approaching the canal from right side of Memorial Bridge navigation span with submerged dikes and cells in place. Note similarity of path shown in Photo 2 with Plan A

Photo 4. Paths of downbound tow approaching the proposed new 1200-ft lock and upbound tow leaving existing 1200-ft lock. Note maneuvering required in between the two guide walls with slack water in the canal

Photo 5. Paths of downbound tow approaching the existing 1200-ft lock and upbound tow leaving the proposed new 1200-ft lock. Note maneuvering required for the upbound tow to turn toward the landside of the canal with slack water in the canal

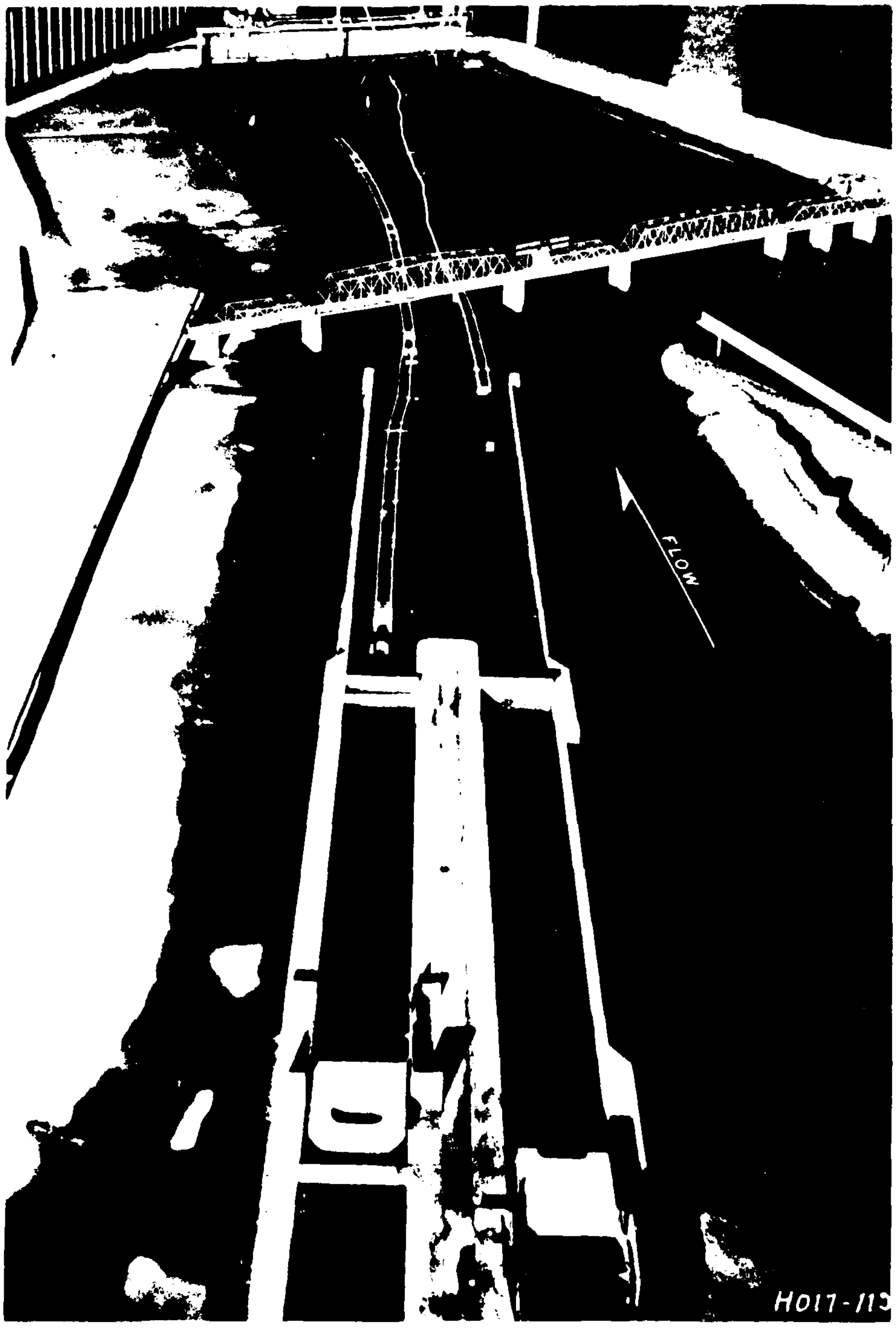


Photo 6. Discharge 246,000 cfs (lower approach). Paths of downbound tow leaving the proposed new 1200-ft lock and upbound tow approaching the existing 1200-ft lock

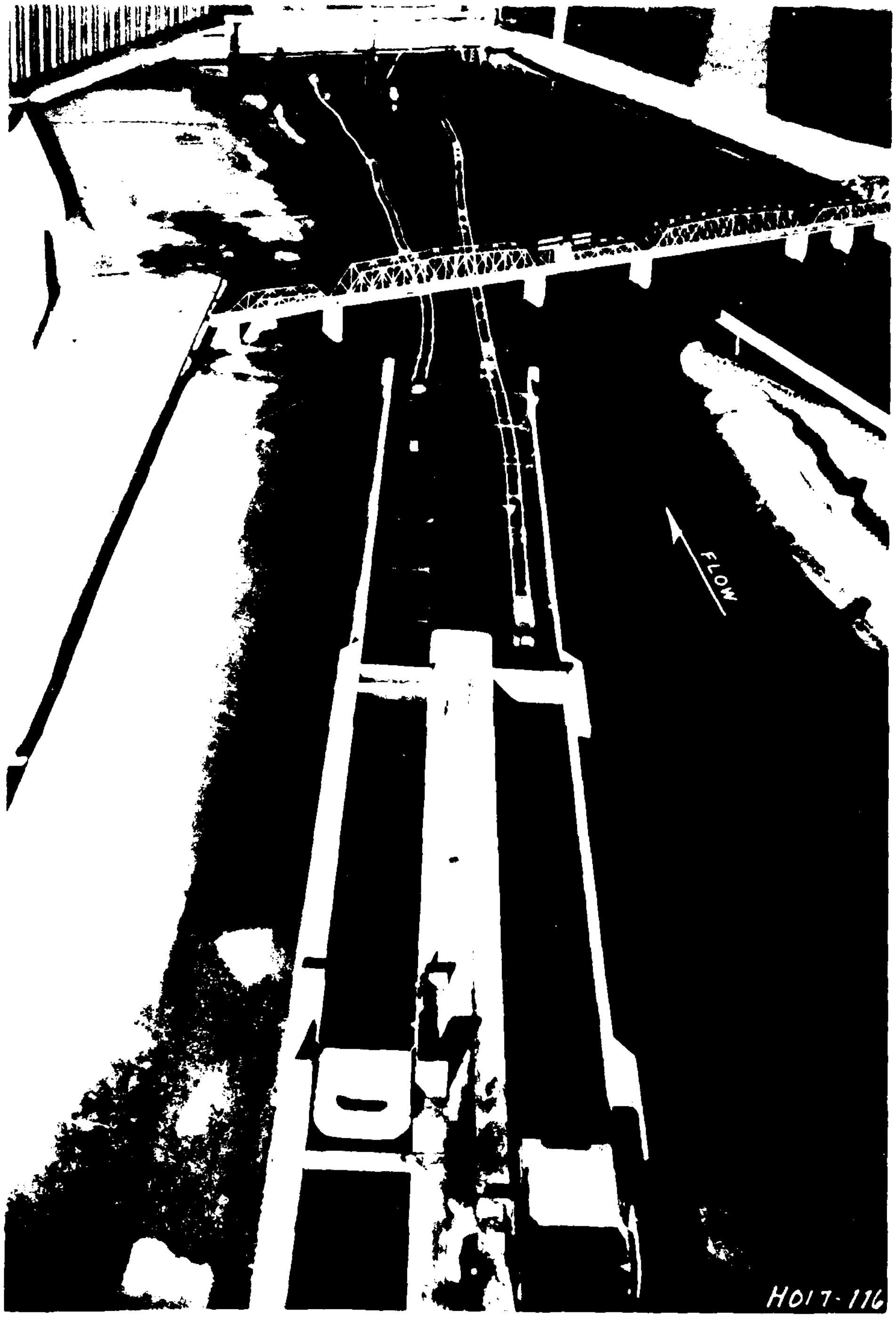
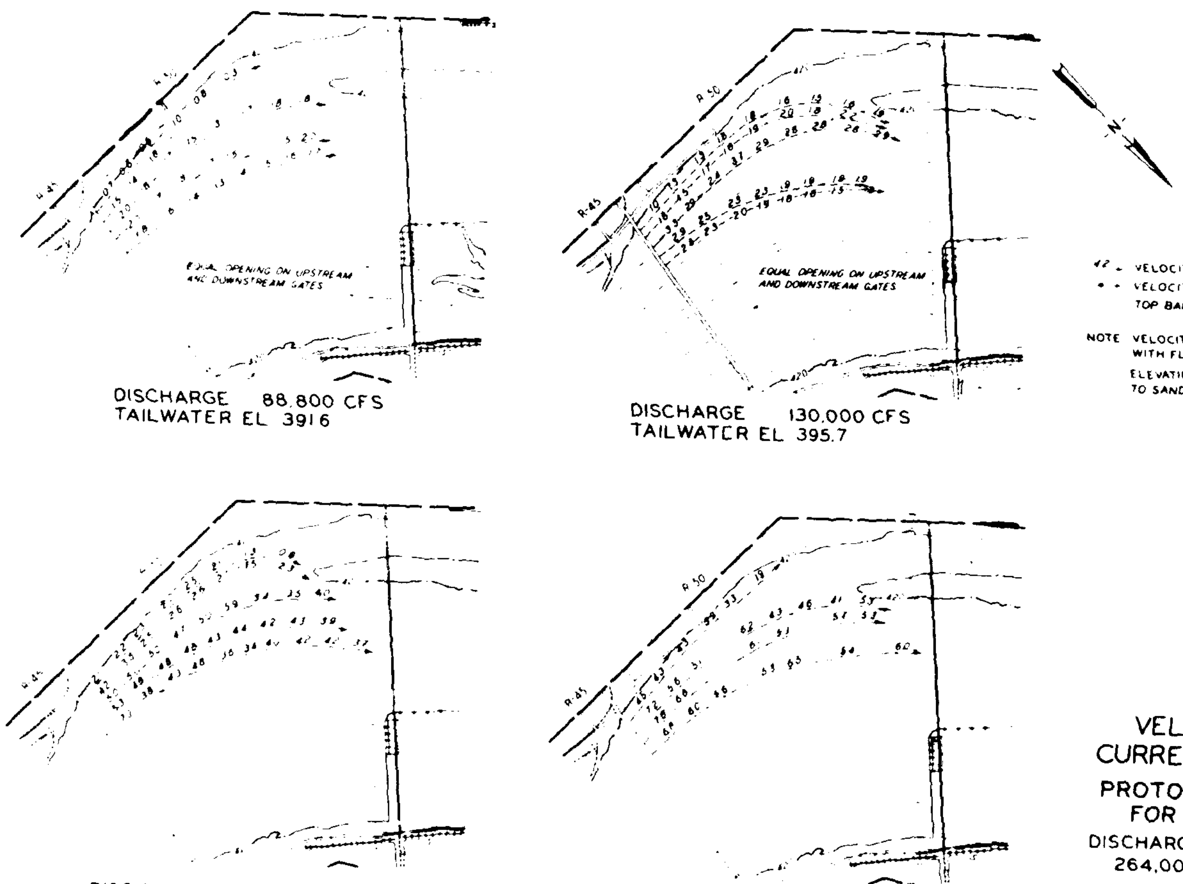


Photo 7. Discharge 246,000 cfs (lower approach). Paths of downbound tow leaving the existing 1200-ft lock and upbound tow approaching the proposed new 1200-ft lock



DISCHARGE 88,800 CFS
TAILWATER EL 391.6

DISCHARGE 130,000 CFS
TAILWATER EL 395.7

DISCHARGE 264,000 CFS
TAILWATER EL 407.6

DISCHARGE 427,000 CFS
TAILWATER EL 424.1

LEGEND

42 ↗ VELOCITY IN FEET PER SECOND

• • VELOCITY LESS THAN 0.5 FEET PER SECOND

TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT

ELEVATION BASED ON MSL FEET REFERRED TO SANDY HOOK DATUM 1882

VELOCITIES AND CURRENT DIRECTIONS

PROTOTYPE DATA USED FOR ADJUSTMENT

DISCHARGES 88,800, 130,000, 264,000, & 427,000 CFS

SCALES IN FEET

PROTOTYPE 100 0 100 200 300

MODEL 5 0 5 10 15 20 25

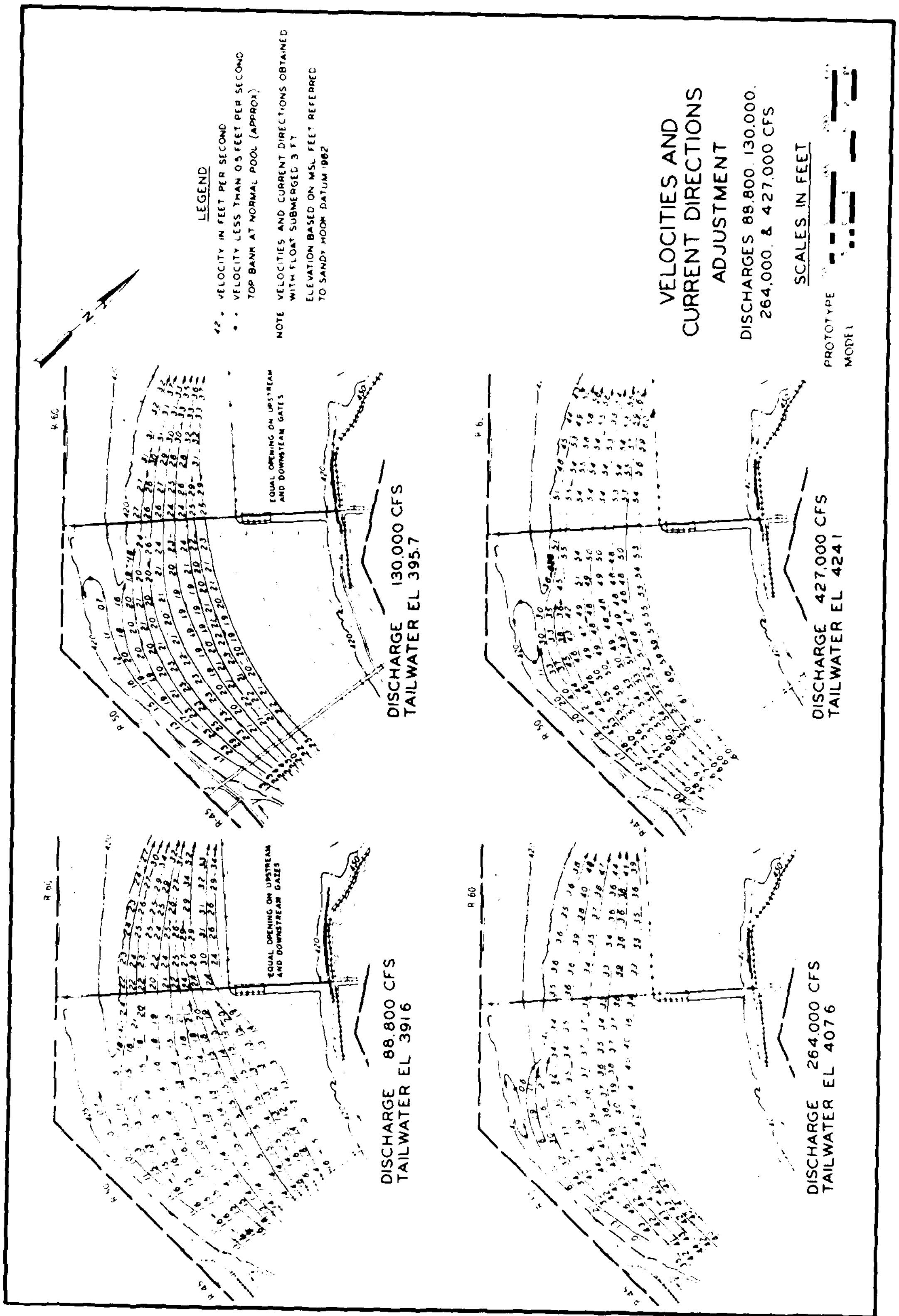
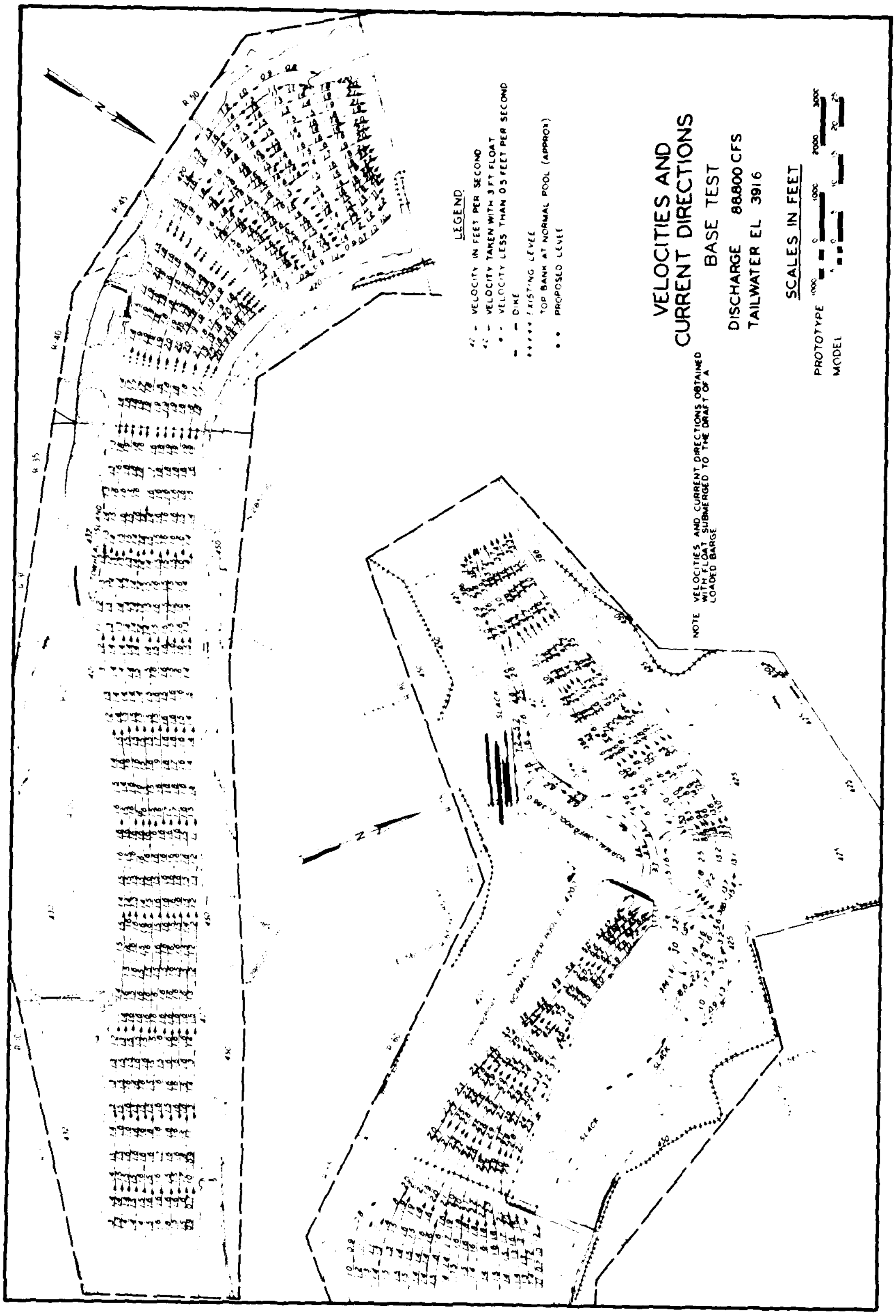
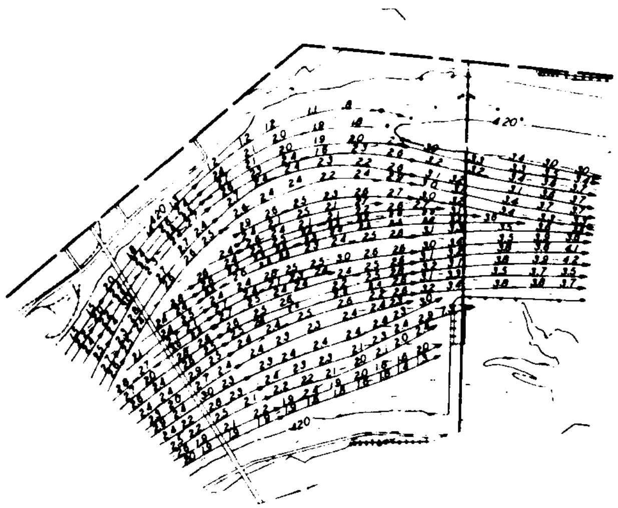

VELOCITIES AND
CURRENT DIRECTIONS
ADJUSTMENT
DISCHARGES 88,800, 130,000,
264,000, & 427,000 CFS
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
TOP BANK AT NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT
ELEVATION BASED ON MSL FEET REFERRED TO SANDY HOOK DATUM 1982
SCALES IN FEET
PROTOTYPE
MODEL
DISCHARGE 88,800 CFS
TAILWATER EL 391.6
DISCHARGE 130,000 CFS
TAILWATER EL 395.7
DISCHARGE 264,000 CFS
TAILWATER EL 407.6
DISCHARGE 427,000 CFS
TAILWATER EL 424.1
EQUAL OPENING ON UPSTREAM AND DOWNSTREAM GATES

PLATE 2

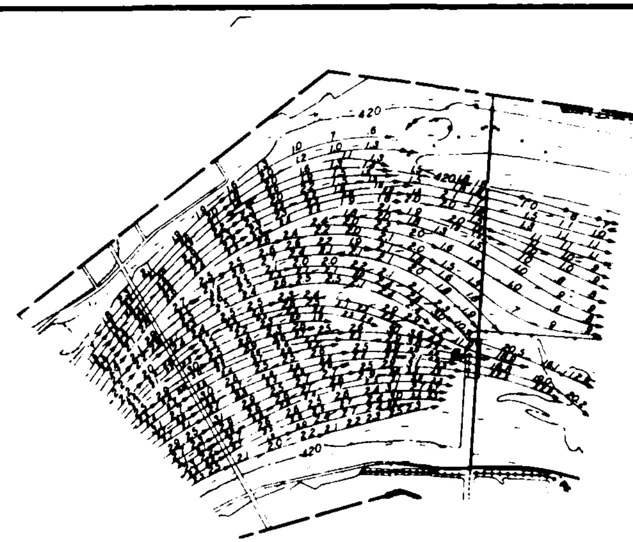


VELOCITIES AND CURRENT DIRECTIONS
BASE TEST
DISCHARGE 88,800 CFS
TAILWATER EL 391.6
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY TAKEN WITH 3 FT FLOAT
VELOCITY LESS THAN 0.5 FEET PER SECOND
DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
PROPOSED LEVEE
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO THE DRAFT OF A LOADED BARGE
SCALES IN FEET
PROTOTYPE
MODEL
SLACK

PLATE 3



DISCHARGE 150,000 CFS
TAILWATER EL 399.1
1 UPPER GATE OPEN
4 LOWER GATES OPEN



DISCHARGE 150,000 CFS
TAILWATER EL 399.1
5 UPPER GATES OPEN
LOWER GATES CLOSED

LEGEND

- 4.2 VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1962

POWERHOUSE DISCHARGE 32,000 CFS (APPROX)

VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE 150,000 CFS
TAILWATER EL 399.1

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

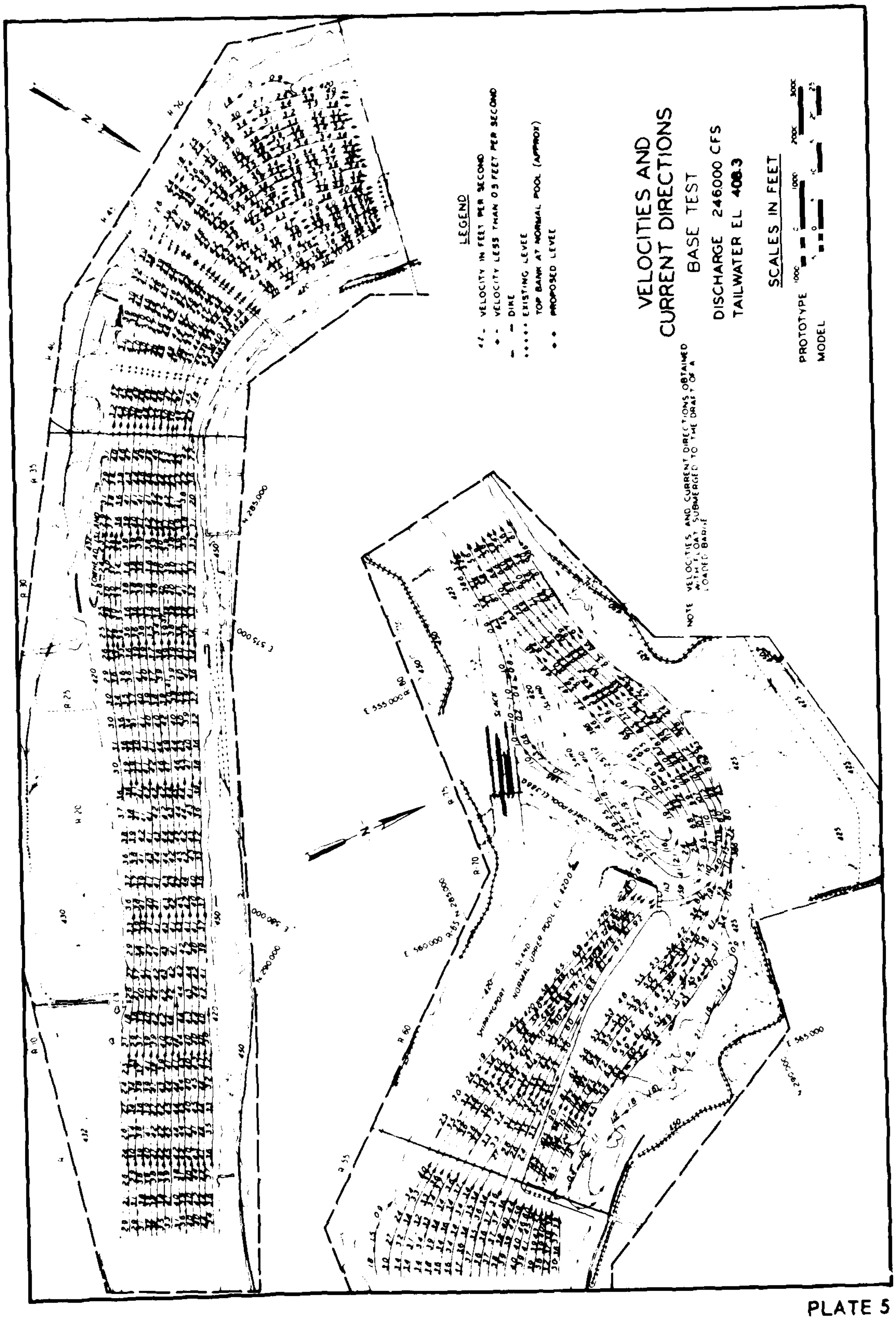
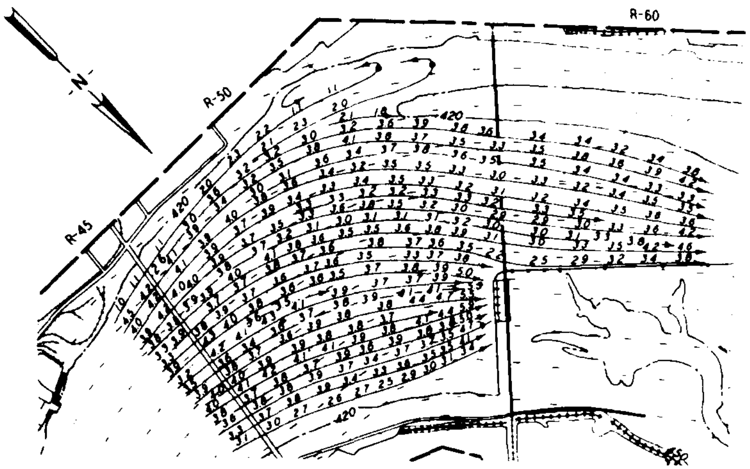
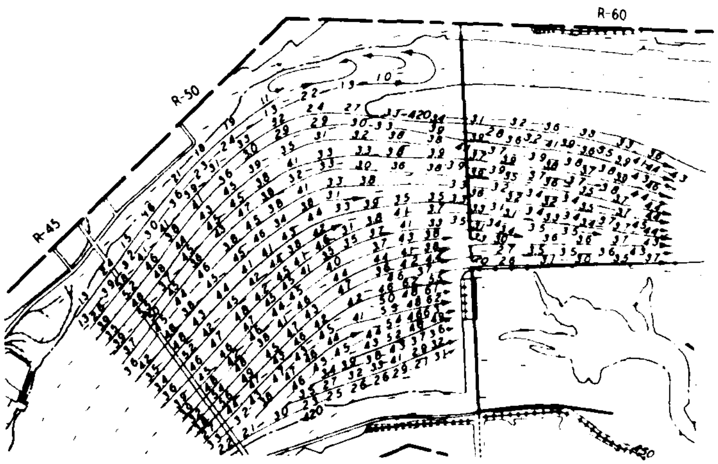

LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
PROPOSED LEVEE
VELOCITIES AND
CURRENT DIRECTIONS
BASE TEST
DISCHARGE 246000 CFS
TAILWATER EL 408.3
SCALES IN FEET
PROTOTYPE
MODEL
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO THE DRAFT OF A LOADED BARGE

PLATE 5



DISCHARGE 223,000 CFS
TAILWATER EL 405.9



DISCHARGE 300,000 CFS
TAILWATER EL 413.0

LEGEND

- 42 VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGES 223,000 & 300,000 CFS

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000

MODEL 5 0 5 10 15 20 25

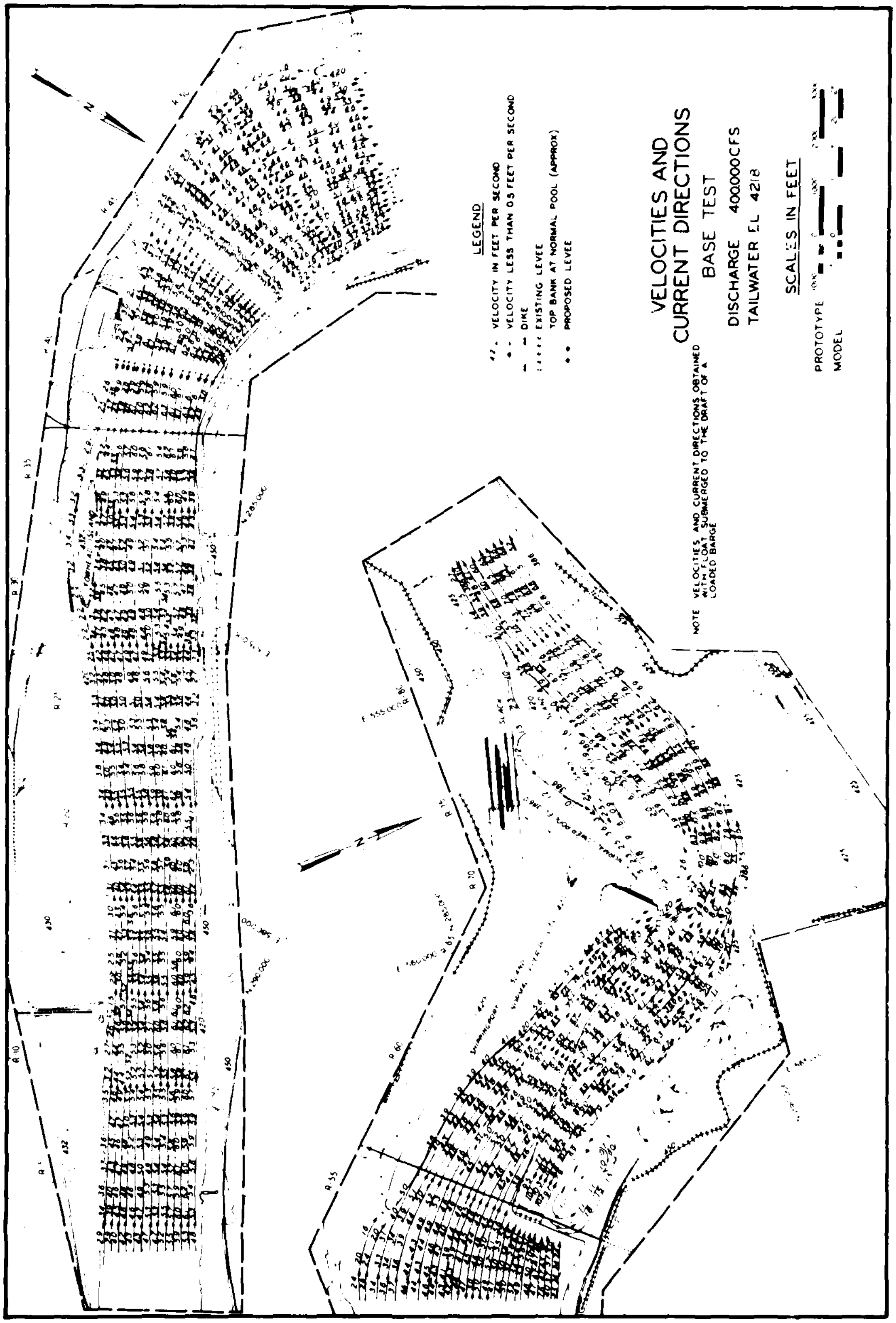

LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
PROPOSED LEVEE
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO THE DRAFT OF A LOADED BARGE
VELOCITIES AND CURRENT DIRECTIONS
BASE TEST
DISCHARGE 400,000 CFS
TAILWATER EL 421.8
SCALES IN FEET
PROTOTYPE
MODEL

PLATE 7

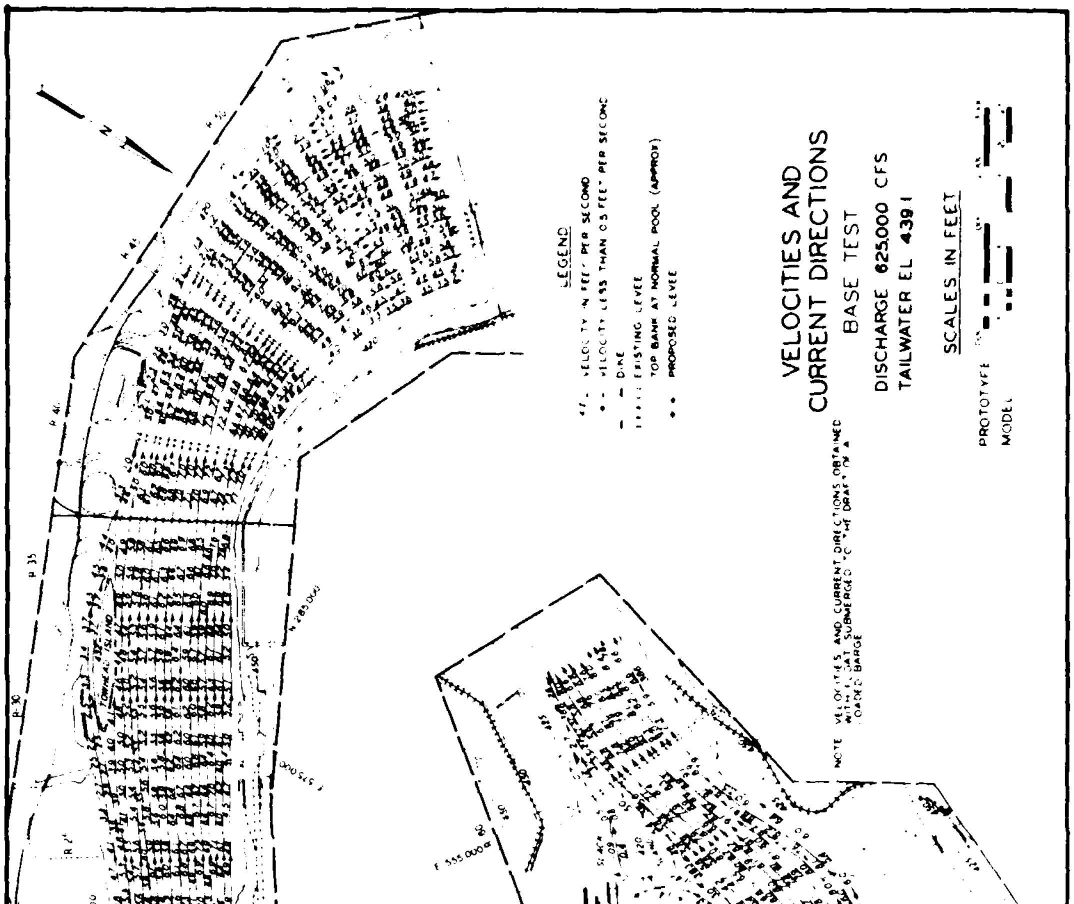
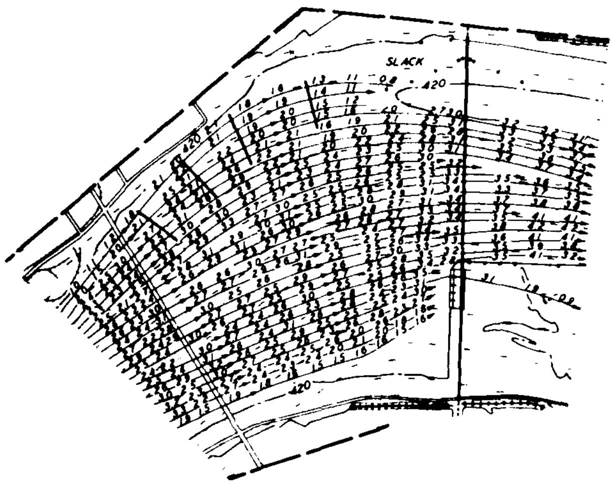
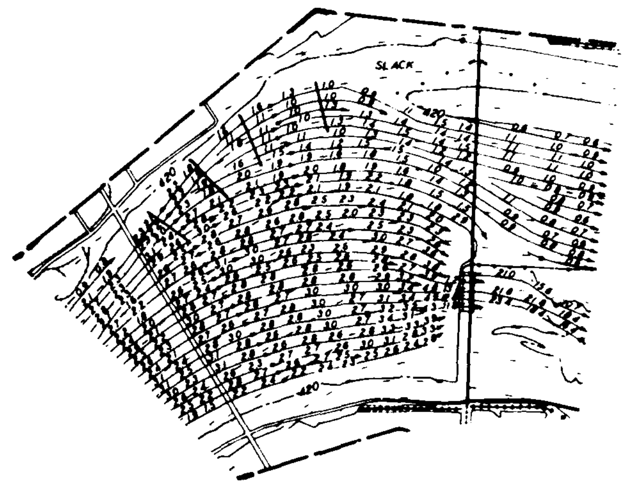

LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
PROPOSED LEVEE
VELOCITIES AND
CURRENT DIRECTIONS
BASE TEST
DISCHARGE 625,000 CFS
TAILWATER EL 439.1
SCALES IN FEET
PROTOTYPE
MODEL
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO THE DRAFT OF A LOADED BARGE
SHREVEPORT ISLAND
NORMAL UPPER POOL EL 420.0

PLATE 8



DISCHARGE 150,000 CFS
TAILWATER EL 399.1
1 UPPER GATE OPEN
4 LOWER GATES OPEN



DISCHARGE 150,000 CFS
TAILWATER EL 399.1
5 UPPER GATES OPEN
LOWER GATES CLOSED

LEGEND

- 4.2 VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)

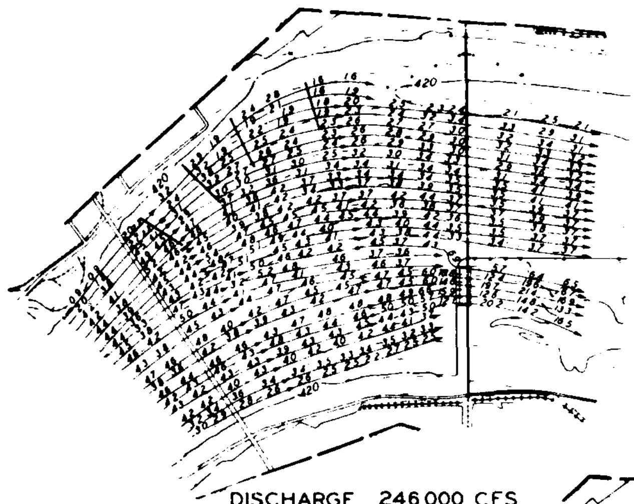
VELOCITIES AND CURRENT DIRECTIONS

PLAN A

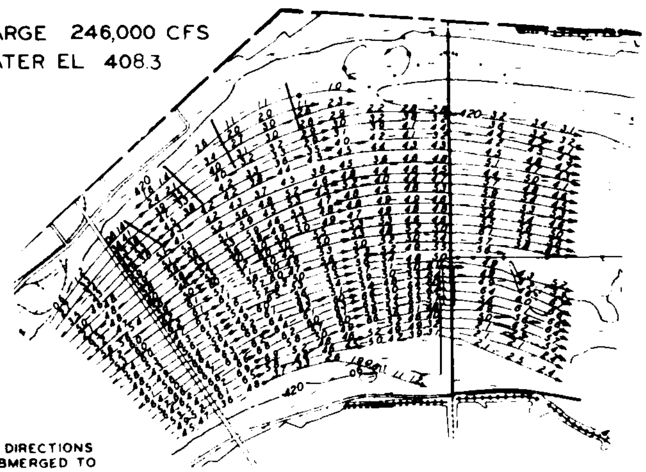
DISCHARGE 150,000 CFS
TAILWATER EL 399.1

SCALES IN FEET

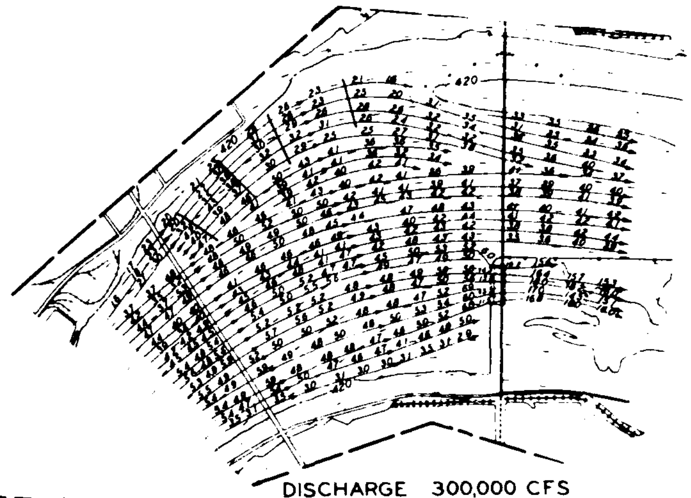
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25



DISCHARGE 246,000 CFS
TAILWATER EL 408.3



DISCHARGE 625,000 CFS
TAILWATER EL 439.1



DISCHARGE 300,000 CFS
TAILWATER EL 413.0

LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- • VELOCITY LESS THAN 0.5 FEET PER SECOND
- — STONE-FILL DIKE
- ++++ EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

VELOCITIES AND CURRENT DIRECTIONS

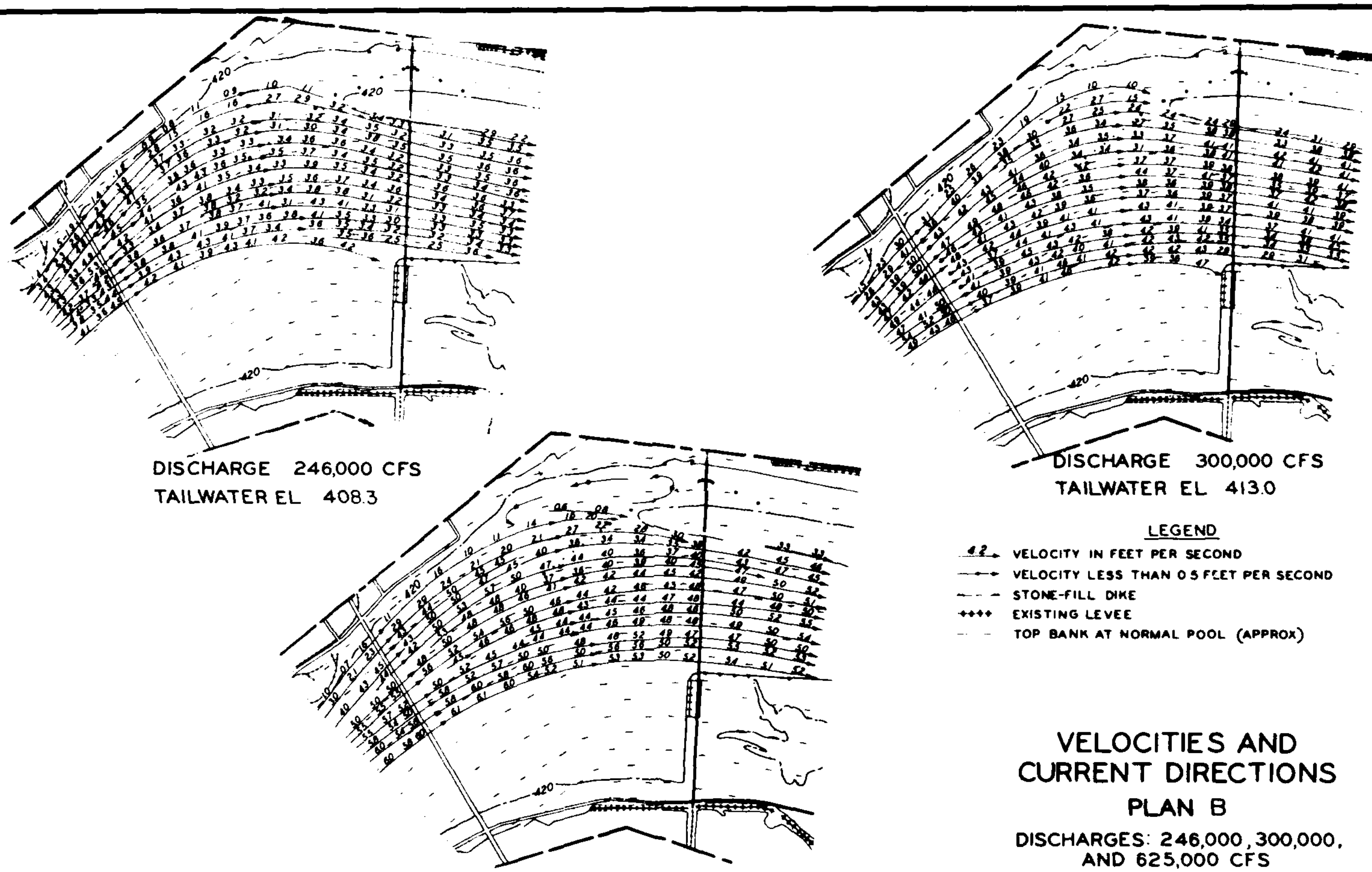
PLAN A

DISCHARGES: 246,000, 300,000, AND 625,000 CFS

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000

MODEL 5 0 5 10 15 20 25



DISCHARGE 246,000 CFS
TAILWATER EL 408.3

DISCHARGE 300,000 CFS
TAILWATER EL 413.0

DISCHARGE 625,000 CFS
TAILWATER EL 639.1

LEGEND

- 4.2 VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

VELOCITIES AND CURRENT DIRECTIONS
PLAN B
DISCHARGES: 246,000, 300,000, AND 625,000 CFS

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

NOTE VELOCITIFS AND CURRENT DIRECTIONS OBTAIN \ITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

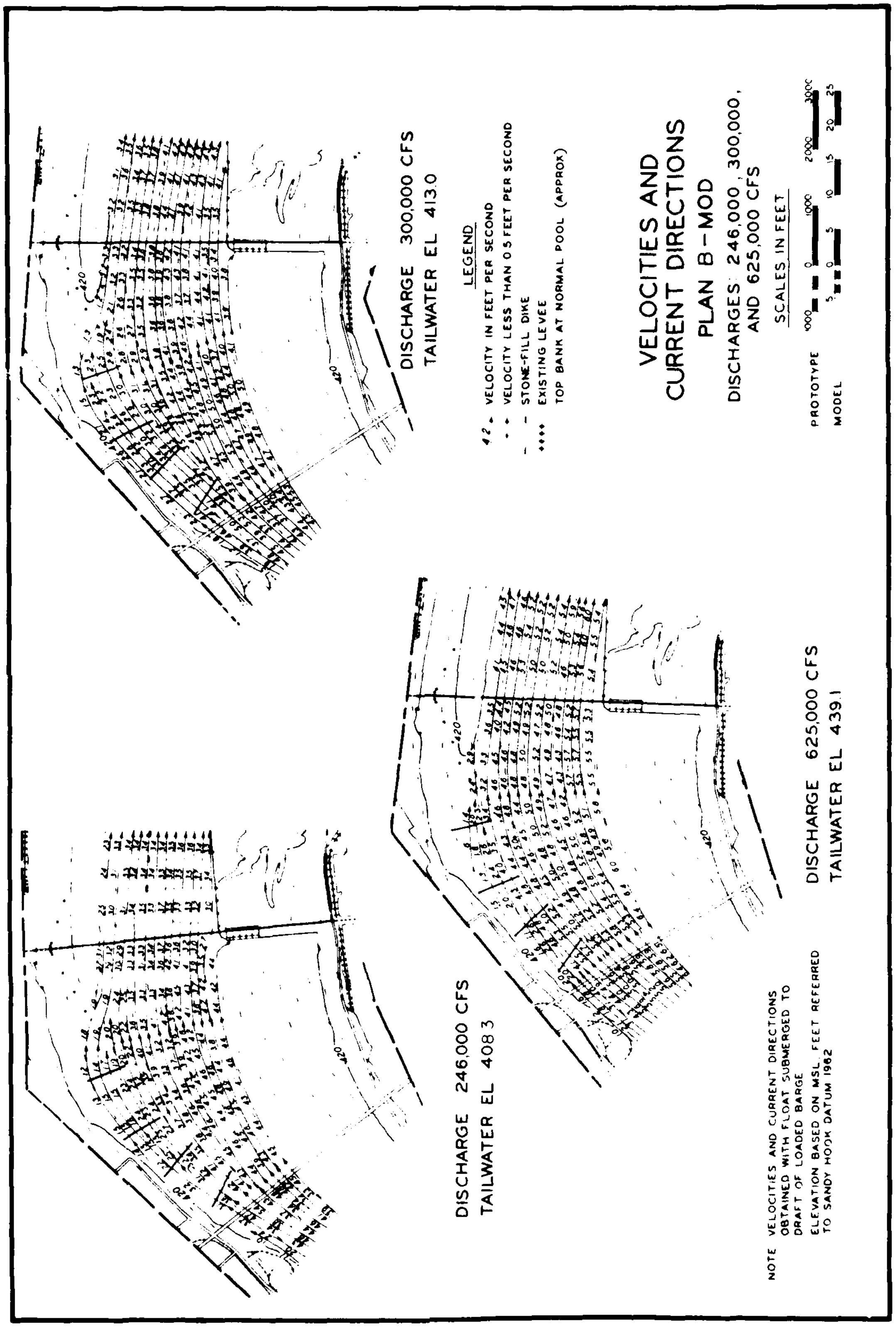
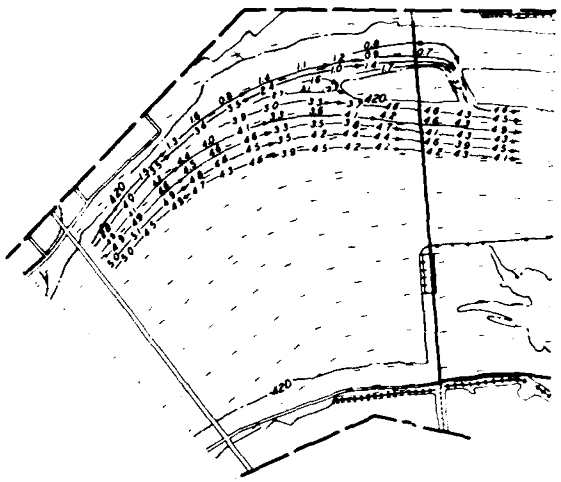
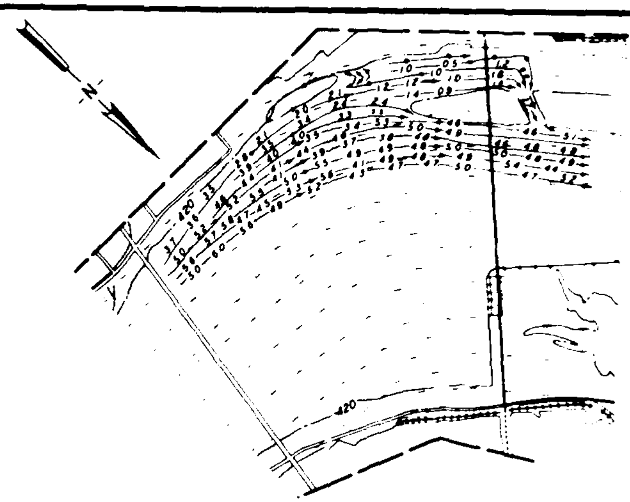

DISCHARGE 300,000 CFS
TAILWATER EL 413.0
LEGEND
4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
VELOCITIES AND CURRENT DIRECTIONS
PLAN B-MOD
DISCHARGES 246,000, 300,000, AND 625,000 CFS
SCALES IN FEET
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25
DISCHARGE 246,000 CFS
TAILWATER EL 408.3
DISCHARGE 625,000 CFS
TAILWATER EL 439.1
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

PLATE 12



DISCHARGE 246,000 CFS
TAILWATER EL 408.3



DISCHARGE 300,000 CFS
TAILWATER EL 413.0

LEGEND

4.2 → VELOCITY IN FEET PER SECOND
→ VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
++++ EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)

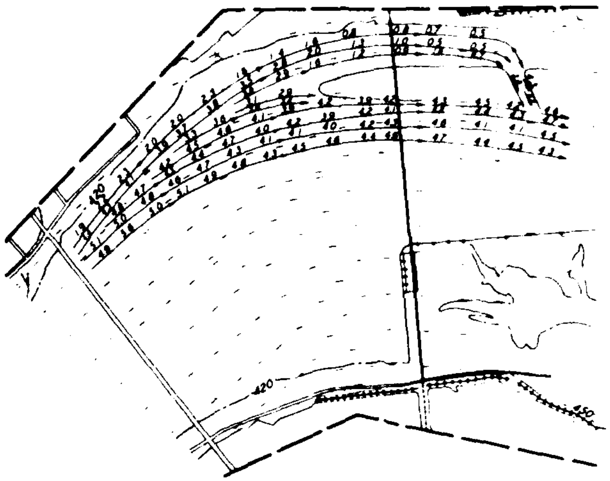
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1962

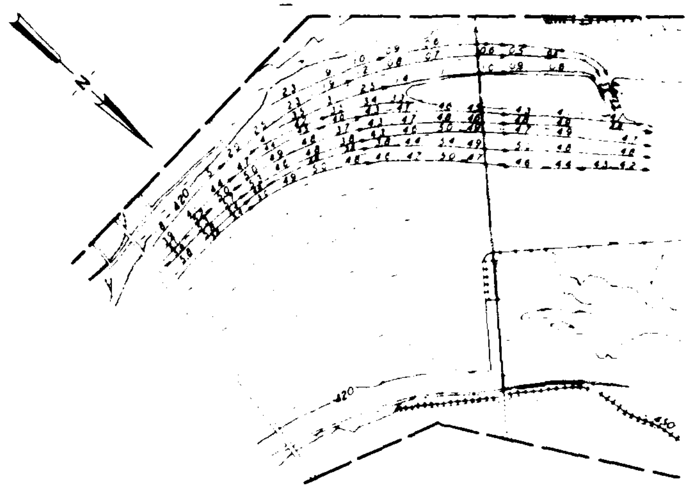
VELOCITIES AND CURRENT DIRECTIONS
PLAN C

SCALES IN FEET

PROTOTYPE	1000	0	1000		2000	3000
MODEL	5	0	5	10	15 20	25



DISCHARGE 246,000 CFS
TAILWATER EL 408.3



DISCHARGE 300,000 CFS
TAILWATER EL 413.0

LEGEND

- 4.2 VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- ++++ EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

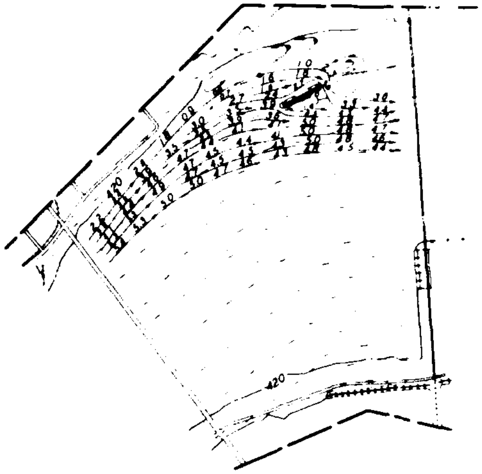
ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1962.

VELOCITIES AND CURRENT DIRECTIONS

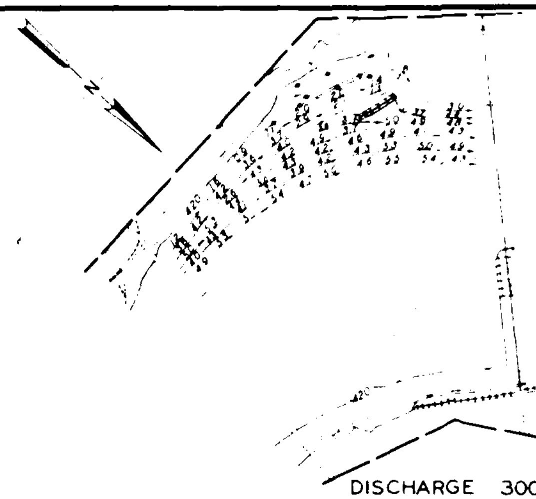
PLAN C-1

SCALES IN FEET

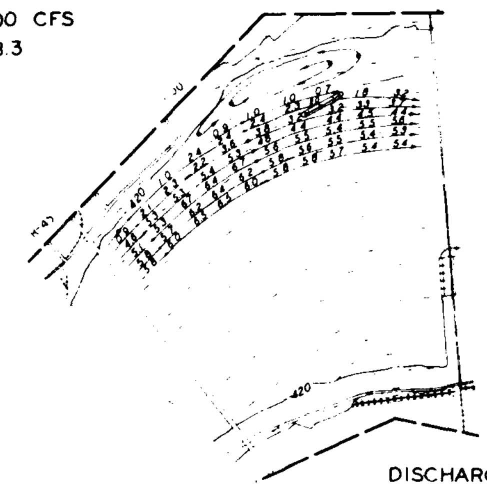
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25



DISCHARGE 246.000 CFS
TAILWATER EL 408.3



DISCHARGE 300.000 CFS
TAILWATER EL 413.0



DISCHARGE 625.000 CFS
TAILWATER EL 439.1

LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- • • VELOCITY LESS THAN 0.5 FEET PER SECOND
- — — STONE-FILL DIKE
- ++++ EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

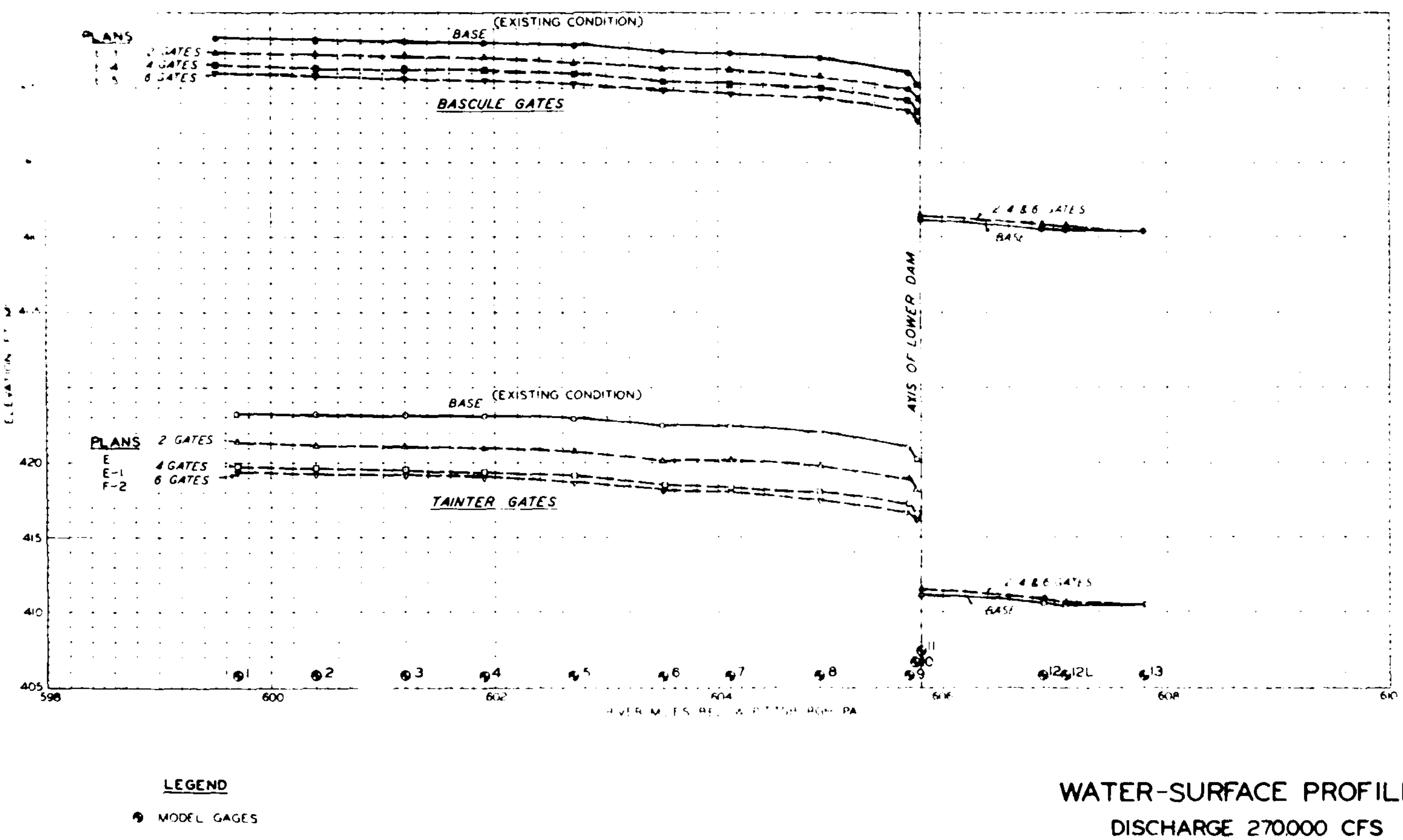
VELOCITIES AND CURRENT DIRECTIONS

PLAN D

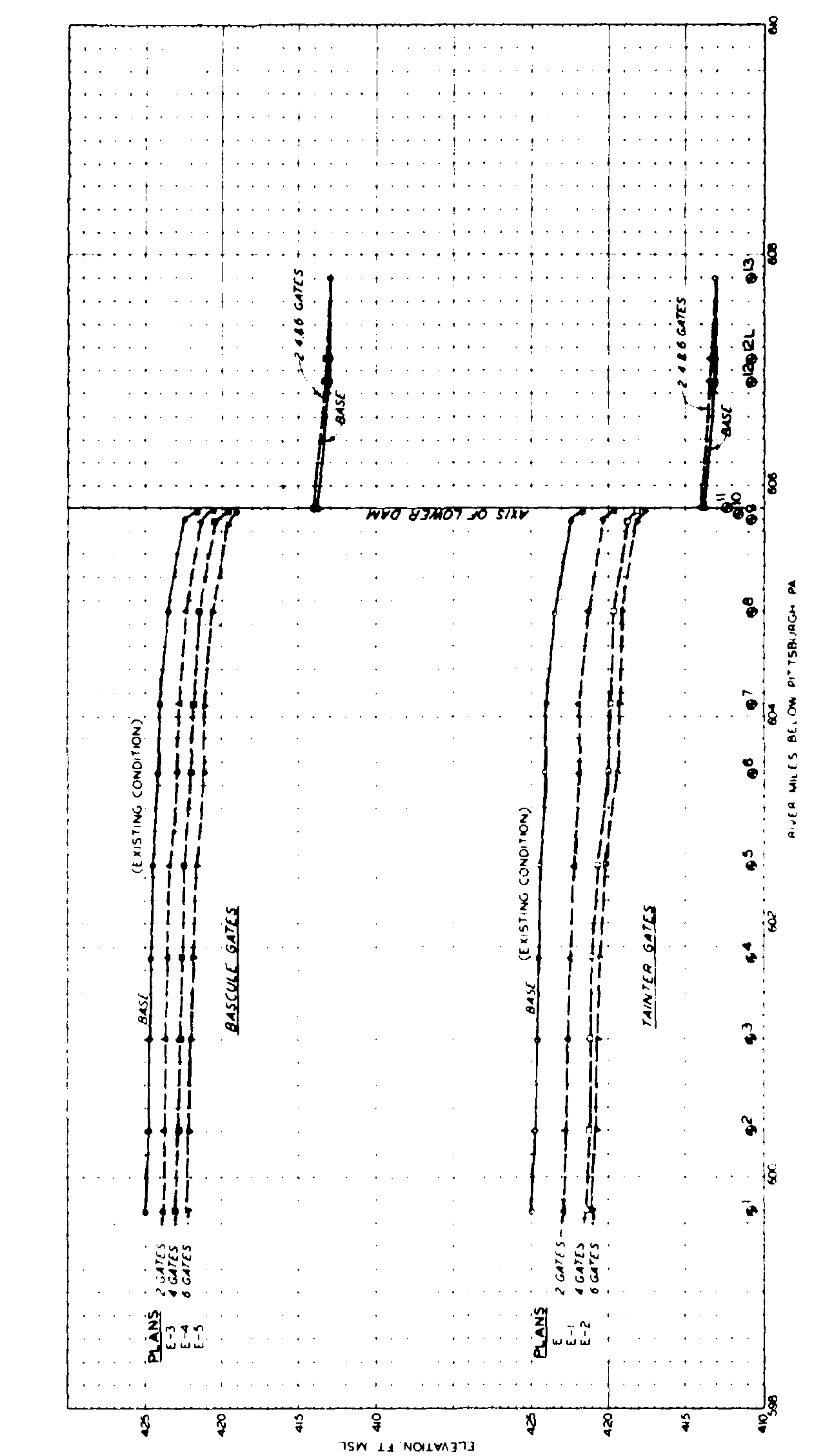
SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000

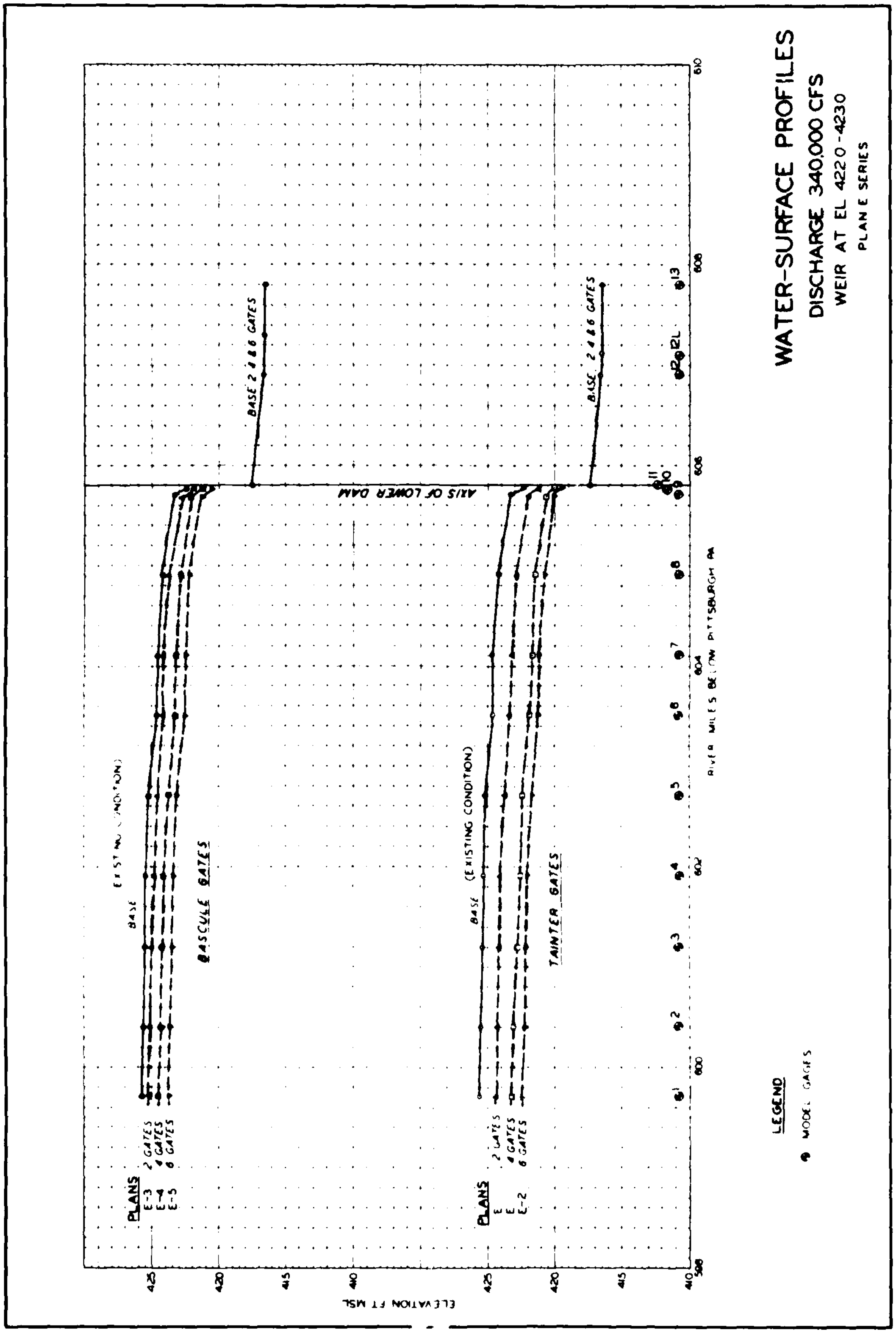
MODEL 5 0 5 10 15 20 25

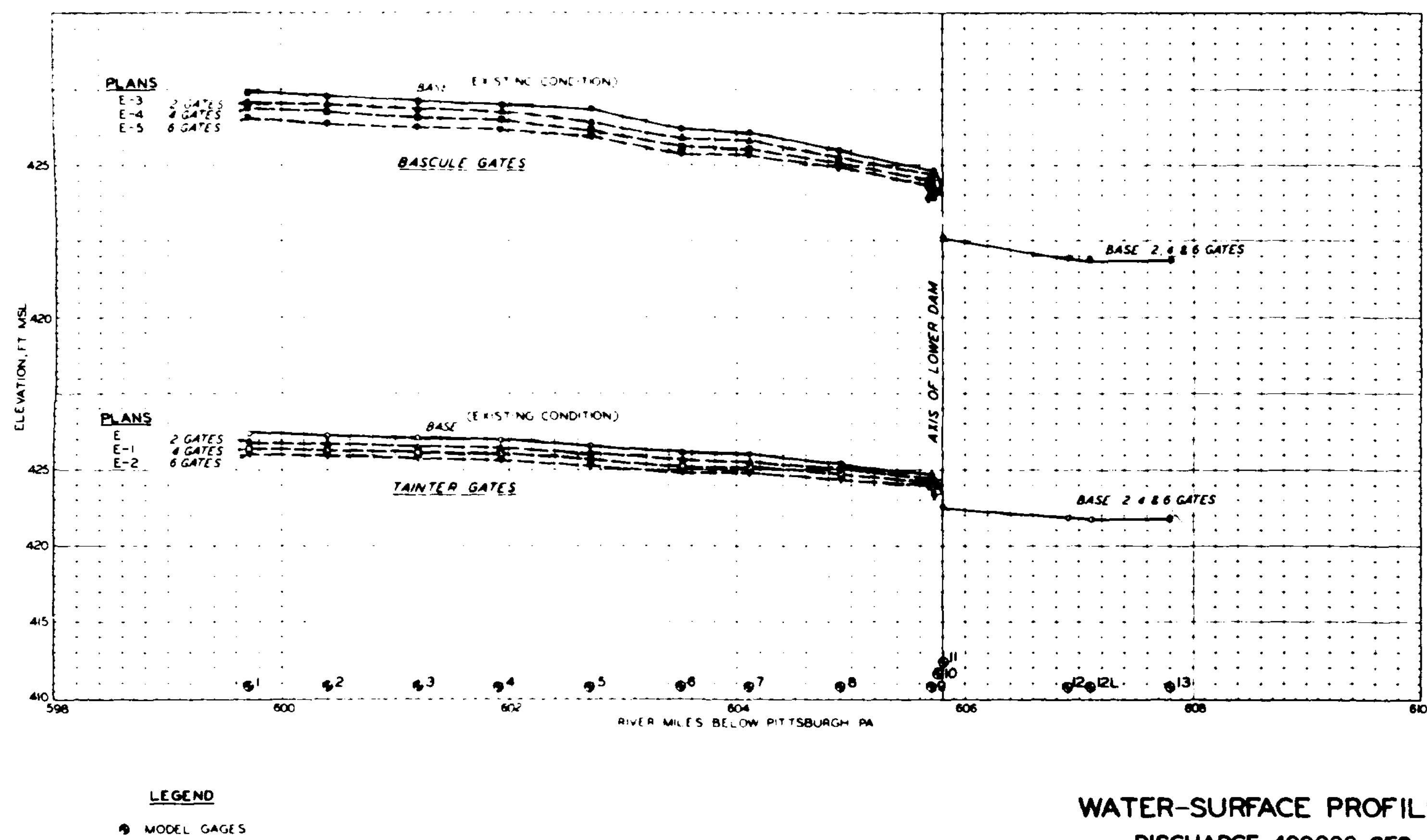


WATER-SURFACE PROFILES
DISCHARGE 270,000 CFS
WEIR AT EL 422.0-423.0
PLAN E SERIES

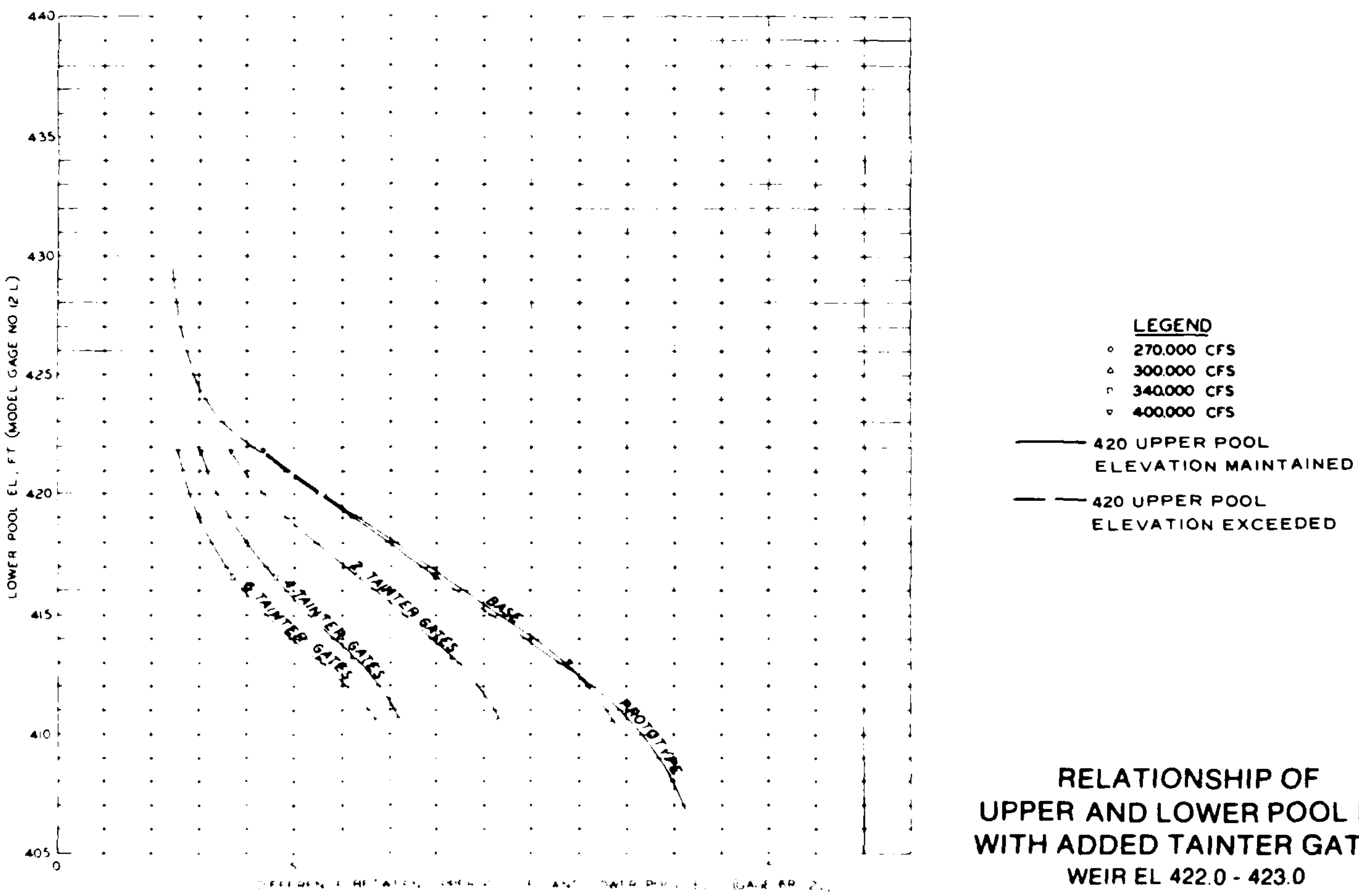


WATER-SURFACE PROFILES
DISCHARGE 300,000 CFS
WEIR AT EL 422.0-423.0
PLAN E SERIES

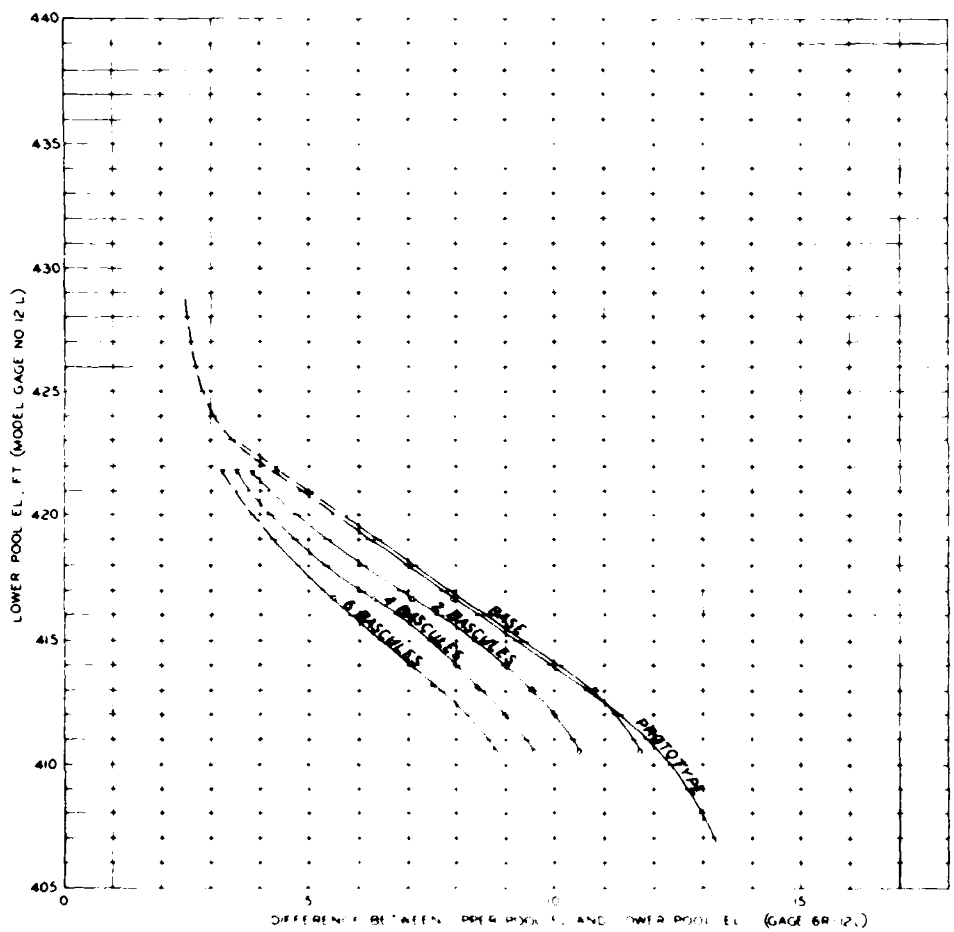

WATER-SURFACE PROFILES
DISCHARGE 340,000 CFS
WEIR AT EL 422.0-423.0
PLAN E SERIES
LEGEND
MODEL GAGES
PLANS
E-3 2 GATES
E-4 4 GATES
E-5 6 GATES
BASE (EXISTING CONDITION)
BASCULE GATES
PLANS
E 2 GATES
E 4 GATES
E-2 6 GATES
TAINTER GATES
AXIS OF LOWER DAM
BASE 2 4 & 6 GATES
BASE 2 4 & 6 GATES
ELEVATION FT MSL
RIVER MILES BELOW PITTSBURGH PA
598
600
602
604
606
608
610
410
415
420
425
410
415
420
425
1
2
3
4
5
6
7
8
10
11
12
12L
13



WATER-SURFACE PROFILES
DISCHARGE 400,000 CFS
WEIR AT EL 422.0-423.0
PLAN E SERIES



RELATIONSHIP OF
UPPER AND LOWER POOL EL
WITH ADDED TAINTER GATES
WEIR EL 422.0 - 423.0
PLANS E, E-1 & E-2



LEGEND
- 270,000 CFS
- 300,000 CFS
- 340,000 CFS
- 400,000 CFS

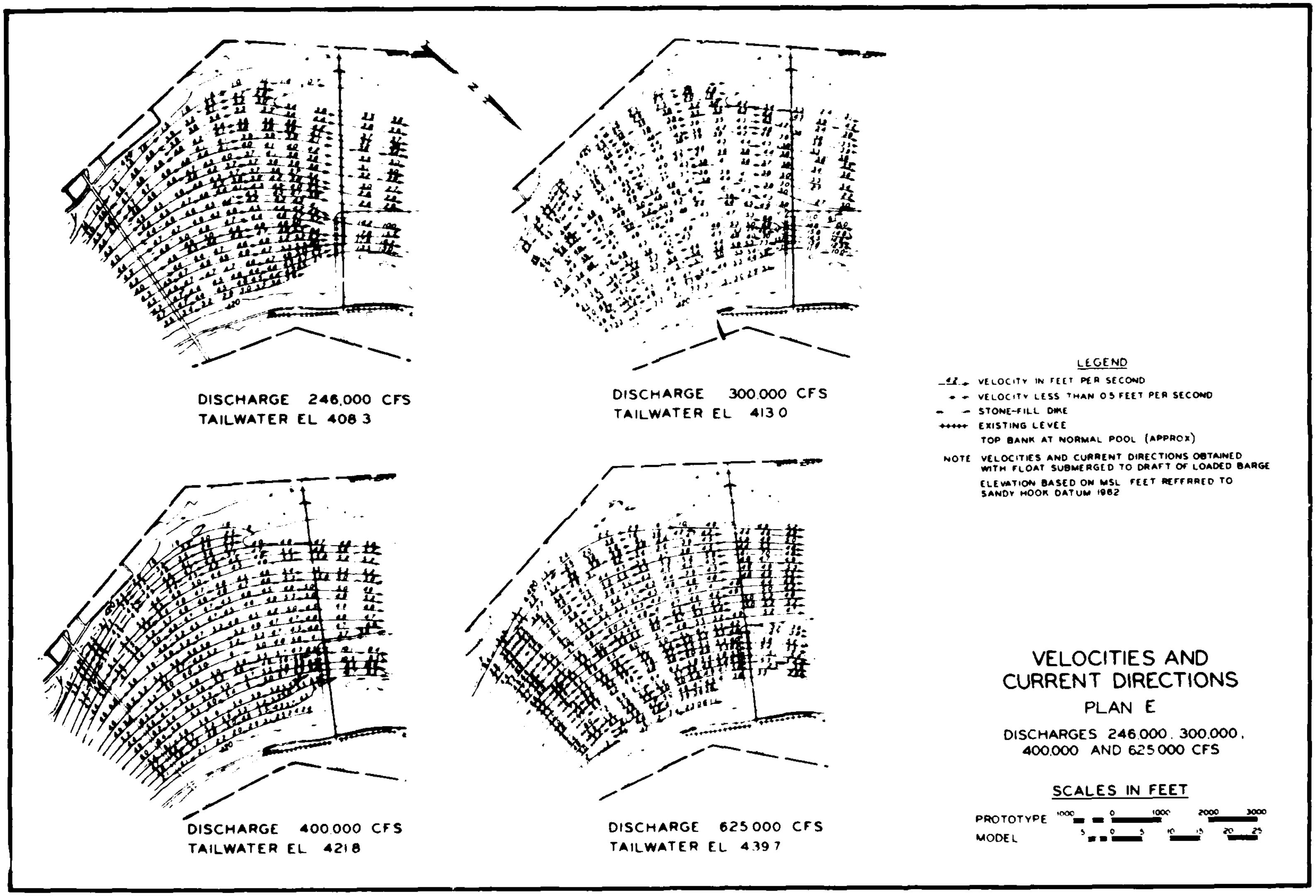
——— 420 UPPER POOL ELEVATION MAINTAINED

— — 420 UPPER POOL ELEVATION EXCEEDED

RELATIONSHIP OF UPPER AND LOWER POOL EL WITH ADDED BASCULE GATES

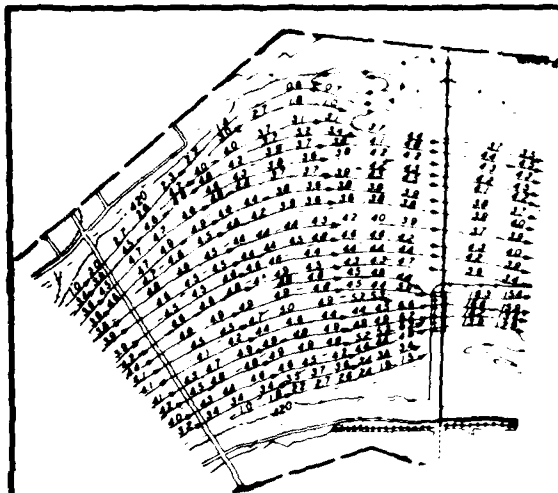
WEIR EL 422.0 - 423.0

PLANS E-3, E-4 & E-5

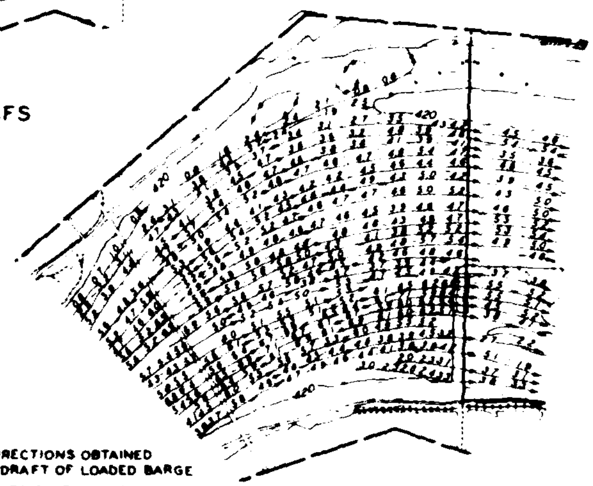


DISCHARGE 246,000 CFS
TAILWATER EL 408.3
DISCHARGE 300,000 CFS
TAILWATER EL 413.0
DISCHARGE 400,000 CFS
TAILWATER EL 421.8
DISCHARGE 625,000 CFS
TAILWATER EL 439.7
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL FEET REFERRED TO SANDY HOOK DATUM 1982
VELOCITIES AND CURRENT DIRECTIONS
PLAN E
DISCHARGES 246,000, 300,000, 400,000 AND 625,000 CFS
SCALES IN FEET
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

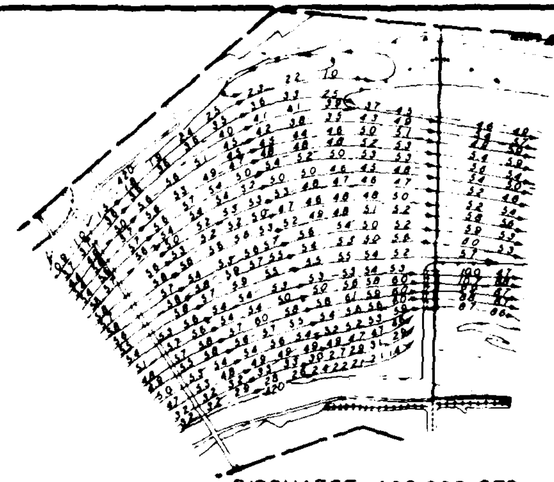
PLATE 22



DISCHARGE 300,000 CFS
TAILWATER EL 413.0



DISCHARGE 625,000 CFS
TAILWATER EL 439.1



DISCHARGE 400,000 CFS
TAILWATER EL 421.8

LEGEND

4.2 ↘ VELOCITY IN FEET PER SECOND
• • VELOCITY LESS THAN 0.5 FEET PER SECOND
— — STONE-FILL DIKE
++++ EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1982

VELOCITIES AND CURRENT DIRECTIONS
PLAN E-2
DISCHARGES: 300,000, 400,000, AND 625,000 CFS

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

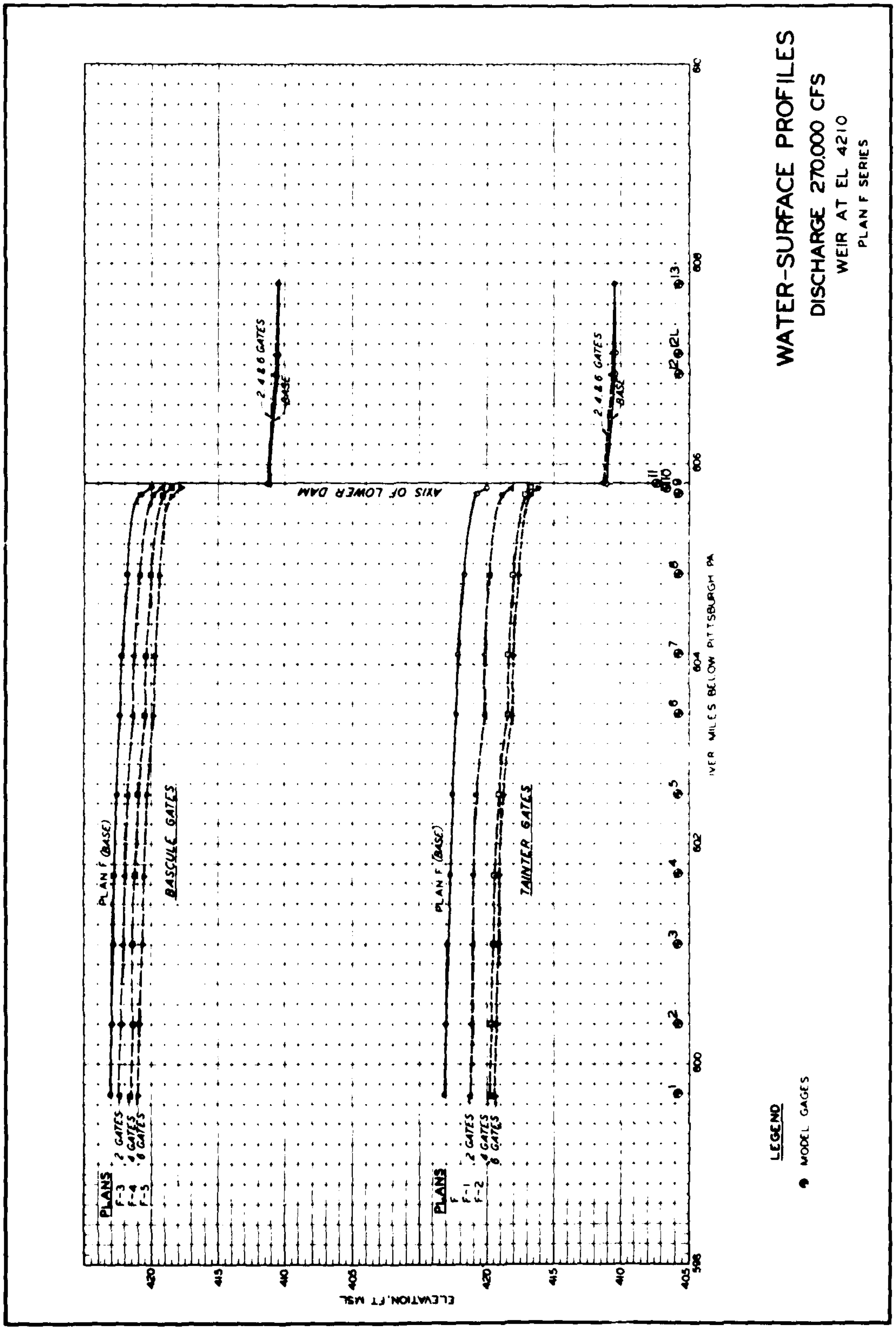
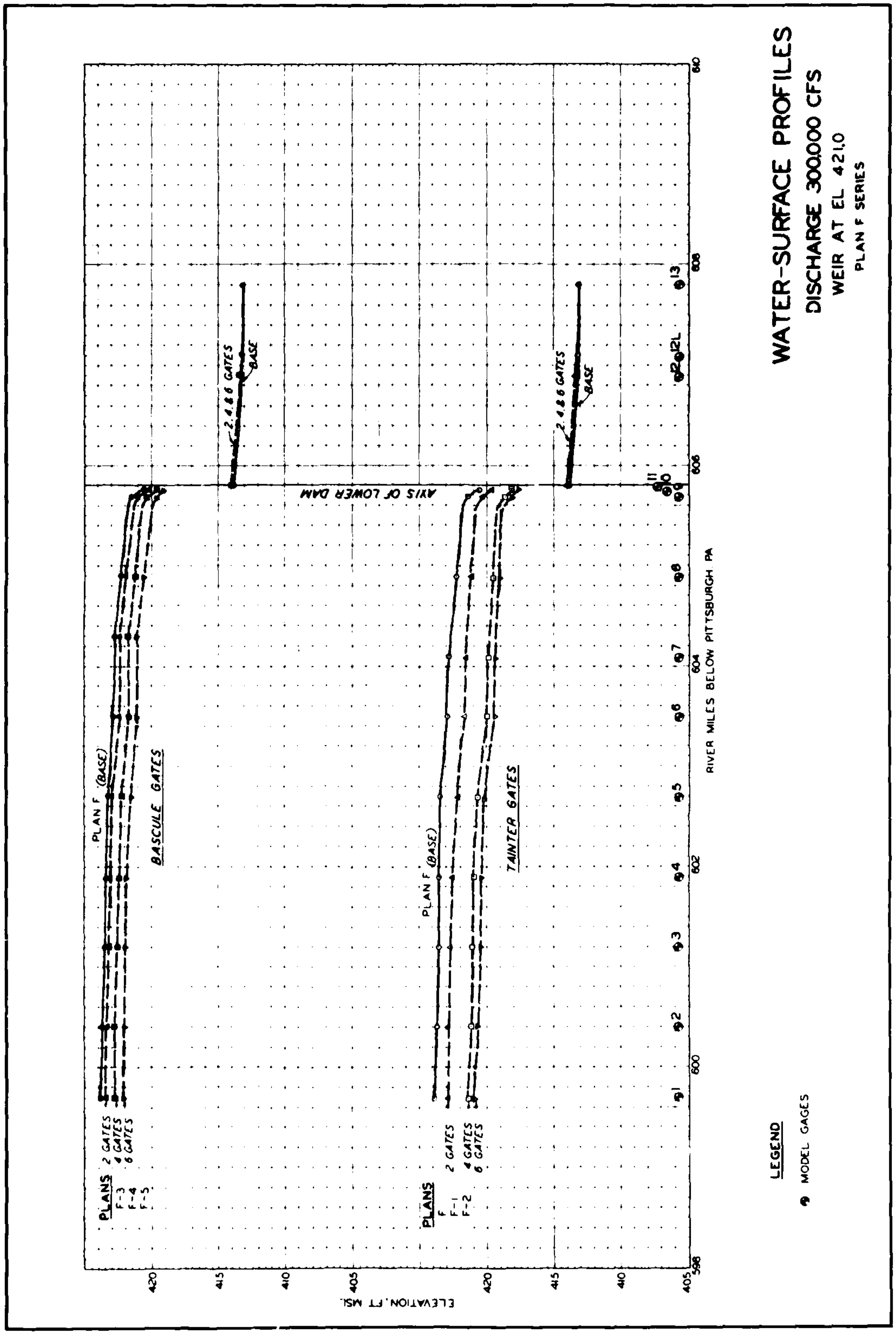
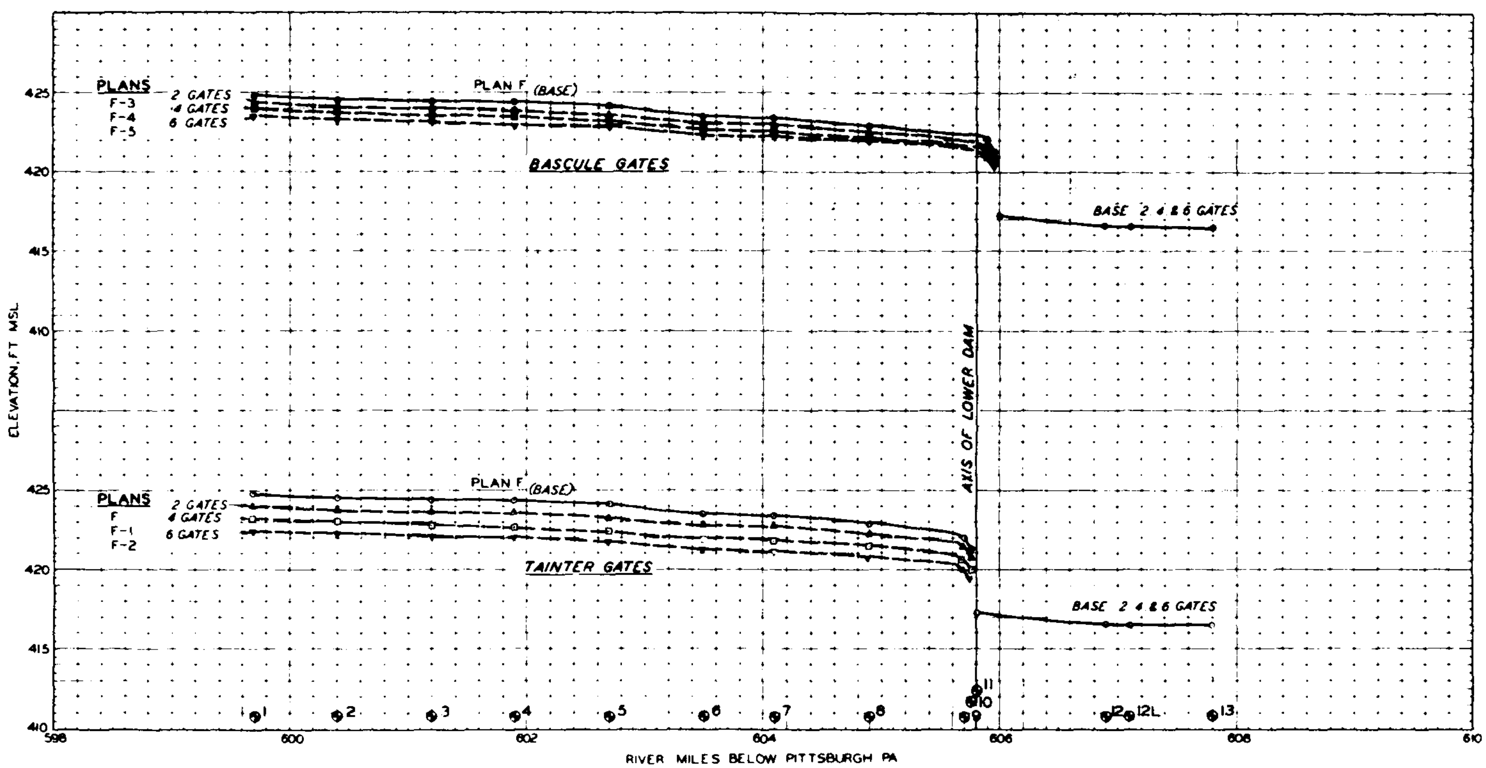

WATER-SURFACE PROFILES
DISCHARGE 270,000 CFS
WEIR AT EL 421.0
PLAN F SERIES
PLANS
F-3 2 GATES
F-4 4 GATES
F-5 6 GATES
PLAN F (BASE)
BASCULE GATES
PLANS
F
F-1 2 GATES
F-2 4 GATES
6 GATES
PLAN F (BASE)
TAINTER GATES
AXIS OF LOWER DAM
2,4 & 6 GATES
BASE
2,4 & 6 GATES
BASE
ELEVATION, FT MSL
IVER MILES BELOW PITTSBURGH PA
LEGEND
MODEL GAGES

PLATE 24


WATER-SURFACE PROFILES
DISCHARGE 300,000 CFS
WEIR AT EL 421.0
PLAN F SERIES
BASCULE GATES
TAINTER GATES
PLAN F (BASE)
PLANS
F-3 2 GATES
F-4 4 GATES
F-5 6 GATES
F 2 GATES
F-1 4 GATES
F-2 6 GATES
2, 4 & 6 GATES
BASE
AXIS OF LOWER DAM
RIVER MILES BELOW PITTSBURGH PA
ELEVATION, FT MSL
LEGEND
MODEL GAGES



LEGEND

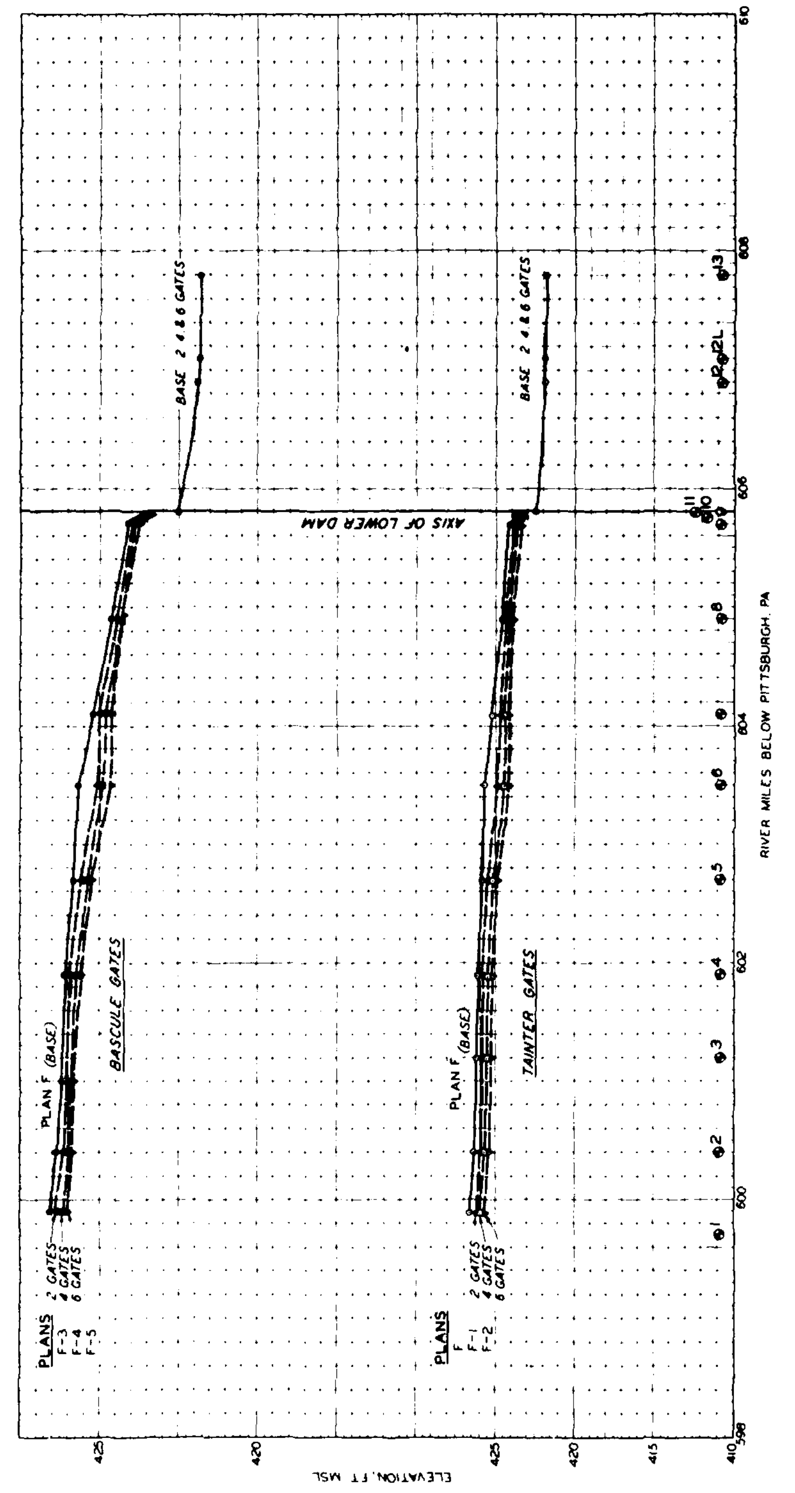
MODEL GAGES

WATER-SURFACE PROFILES

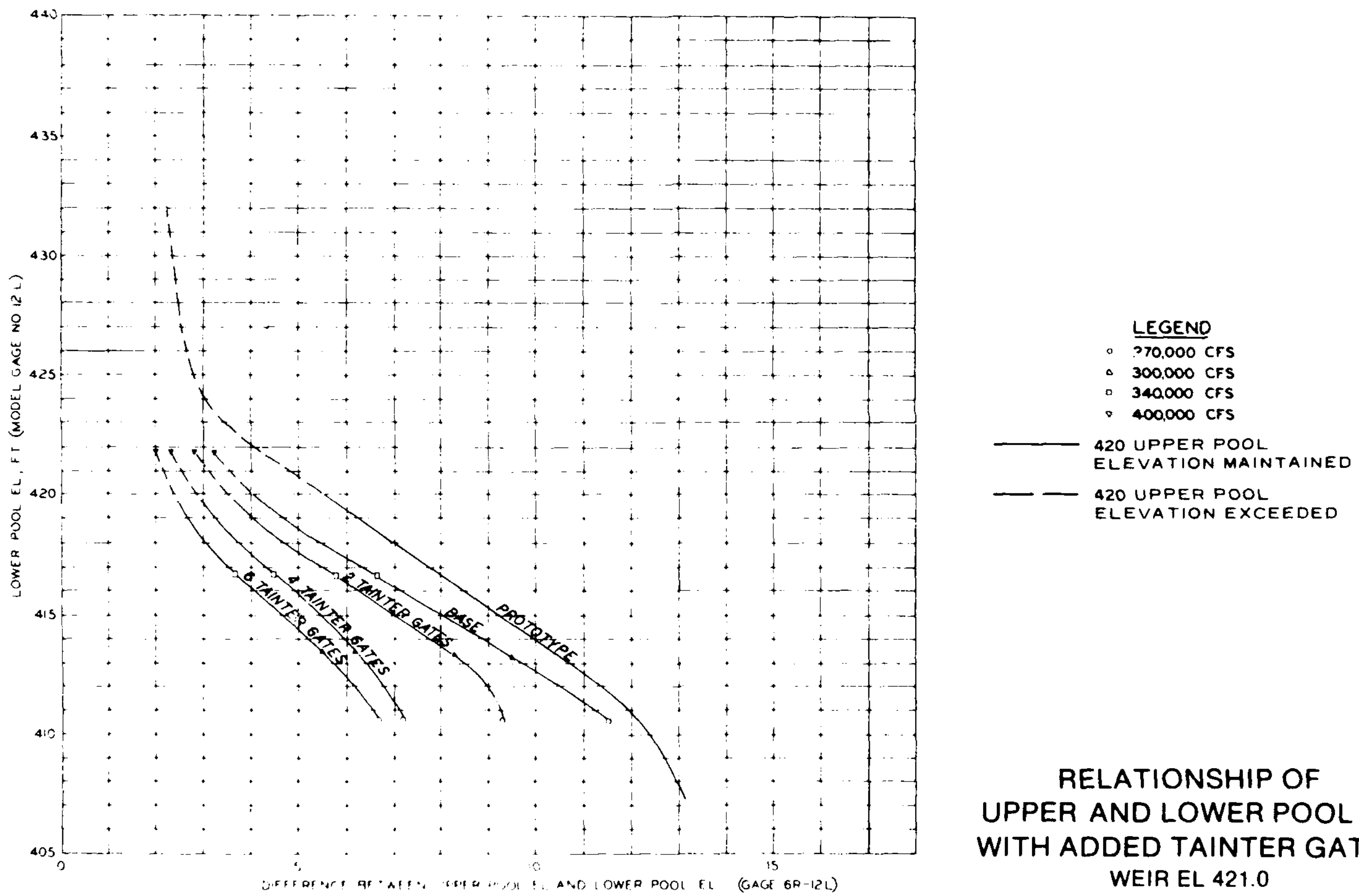
DISCHARGE 340,000 CFS

WEIR AT EL 421.0

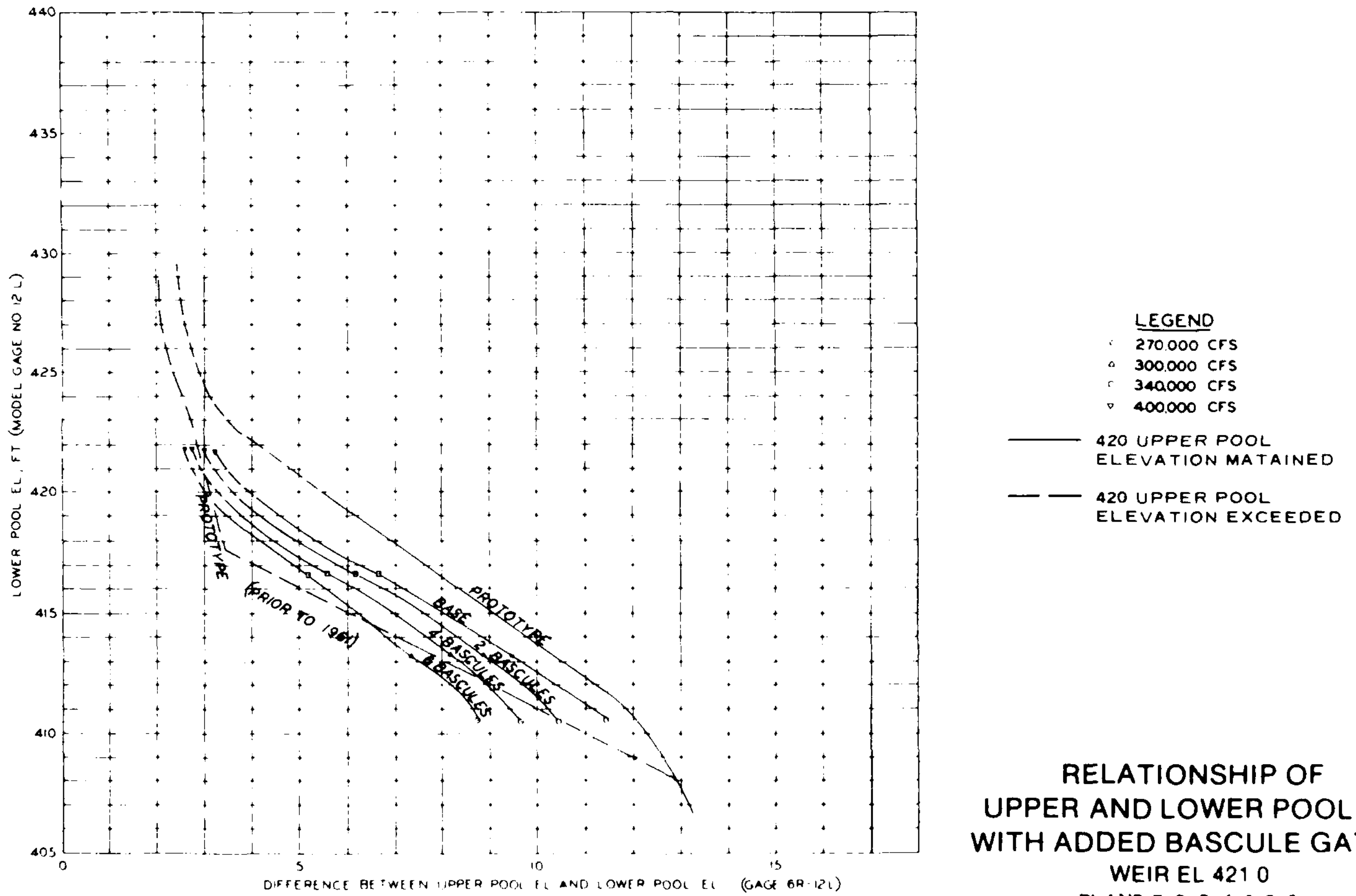
PLAN F SERIES



WATER-SURFACE PROFILES
DISCHARGE 400,000 CFS
WEIR AT EL 421.0
PLAN F SERIES



RELATIONSHIP OF
UPPER AND LOWER POOL EL
WITH ADDED TAINTER GATES
WEIR EL 421.0
PLANS F, F-1 & F-2



RELATIONSHIP OF
UPPER AND LOWER POOL EL
WITH ADDED BASCULE GATES
WEIR EL 421.0
PLANS F-3, F-4 & F-5

AD-A107 734 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/2
NAVIGATION CONDITIONS AT MCALPINE LOCKS AND DAM, OHIO RIVER. HY--ETC(U)
AUG 81 L J SHOWS, J J FRANCO
UNCLASSIFIED WES/TR/HL-81-7 NL

2 OF 2
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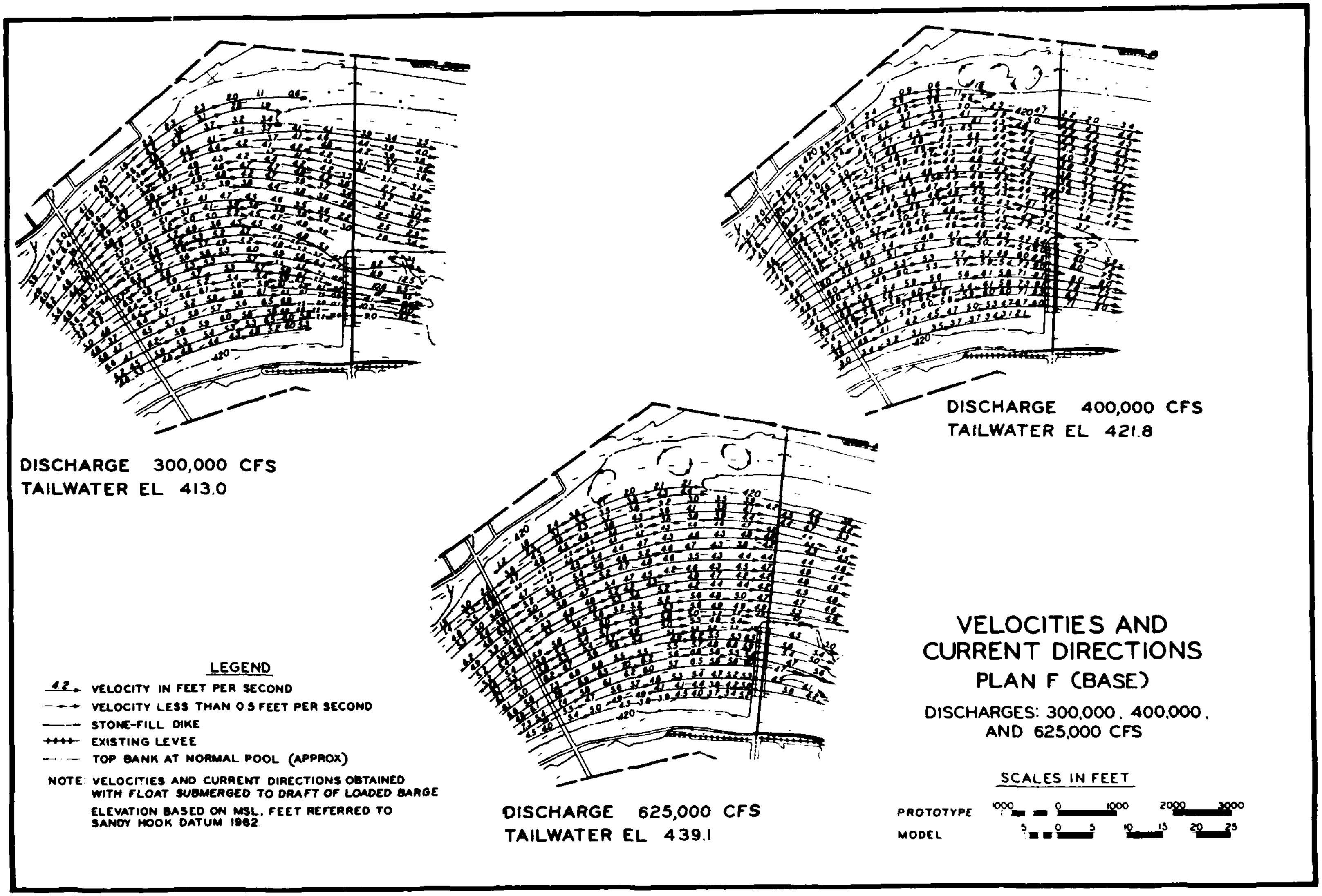
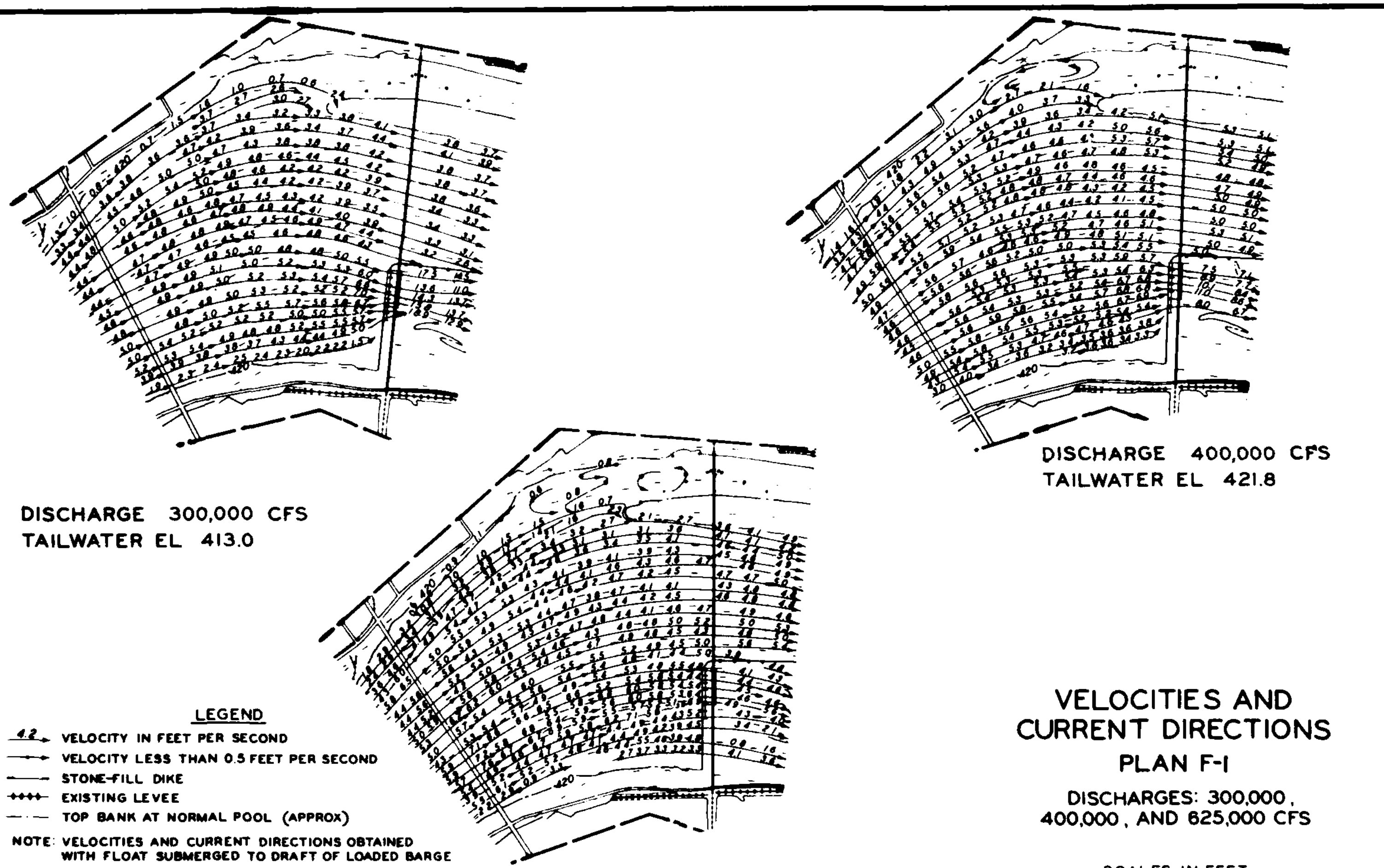

DISCHARGE 300,000 CFS
TAILWATER EL 413.0
DISCHARGE 400,000 CFS
TAILWATER EL 421.8
DISCHARGE 625,000 CFS
TAILWATER EL 439.1
LEGEND
4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962.
VELOCITIES AND CURRENT DIRECTIONS
PLAN F (BASE)
DISCHARGES: 300,000, 400,000, AND 625,000 CFS
SCALES IN FEET
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25



DISCHARGE 300,000 CFS
TAILWATER EL 413.0

DISCHARGE 400,000 CFS
TAILWATER EL 421.8

DISCHARGE 625,000 CFS
TAILWATER EL 439.1

LEGEND

4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)

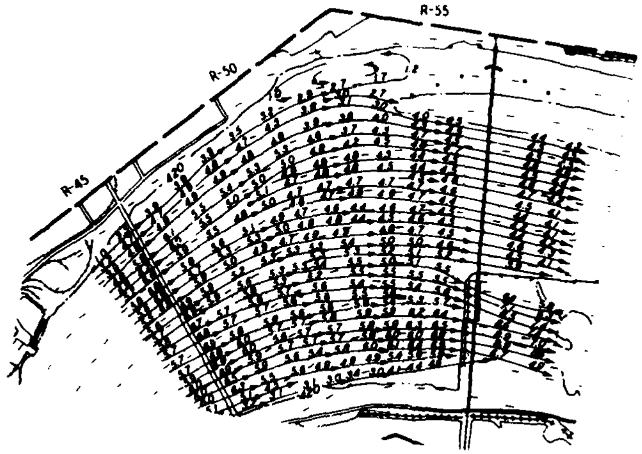
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE

ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

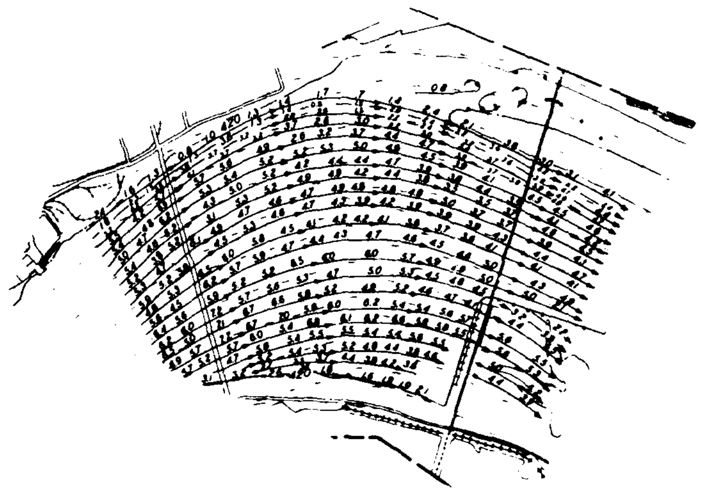
VELOCITIES AND CURRENT DIRECTIONS
PLAN F-1
DISCHARGES: 300,000, 400,000, AND 625,000 CFS

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25



DISCHARGE 400,000 CFS
TAILWATER EL 421.8



DISCHARGE 625,000 CFS
TAILWATER EL 439.1

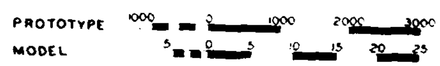
LEGEND

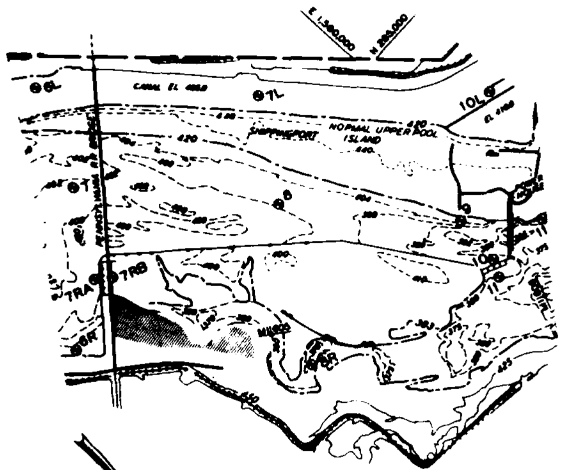
- 4.2 → VELOCITY IN FEET PER SECOND
- → VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962.

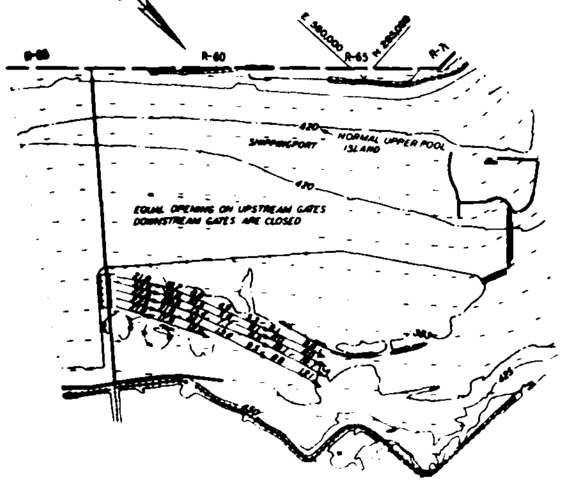
DISCHARGES AND CURRENT DIRECTIONS
PLAN F-2
DISCHARGES: 400,000 AND 625,000 CFS

SCALES IN FEET

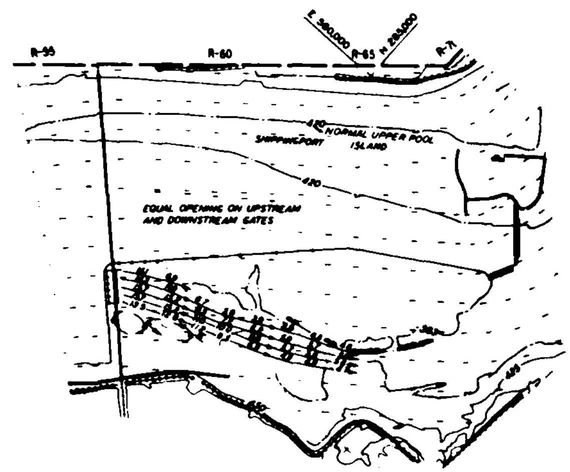




TYPICAL DEPOSITION PATTERN



TEST 1



TEST 2

LEGEND

- VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)
- GAGE LOCATION AND NUMBER
- SCOURED AREA
- DEPOSITION AREA

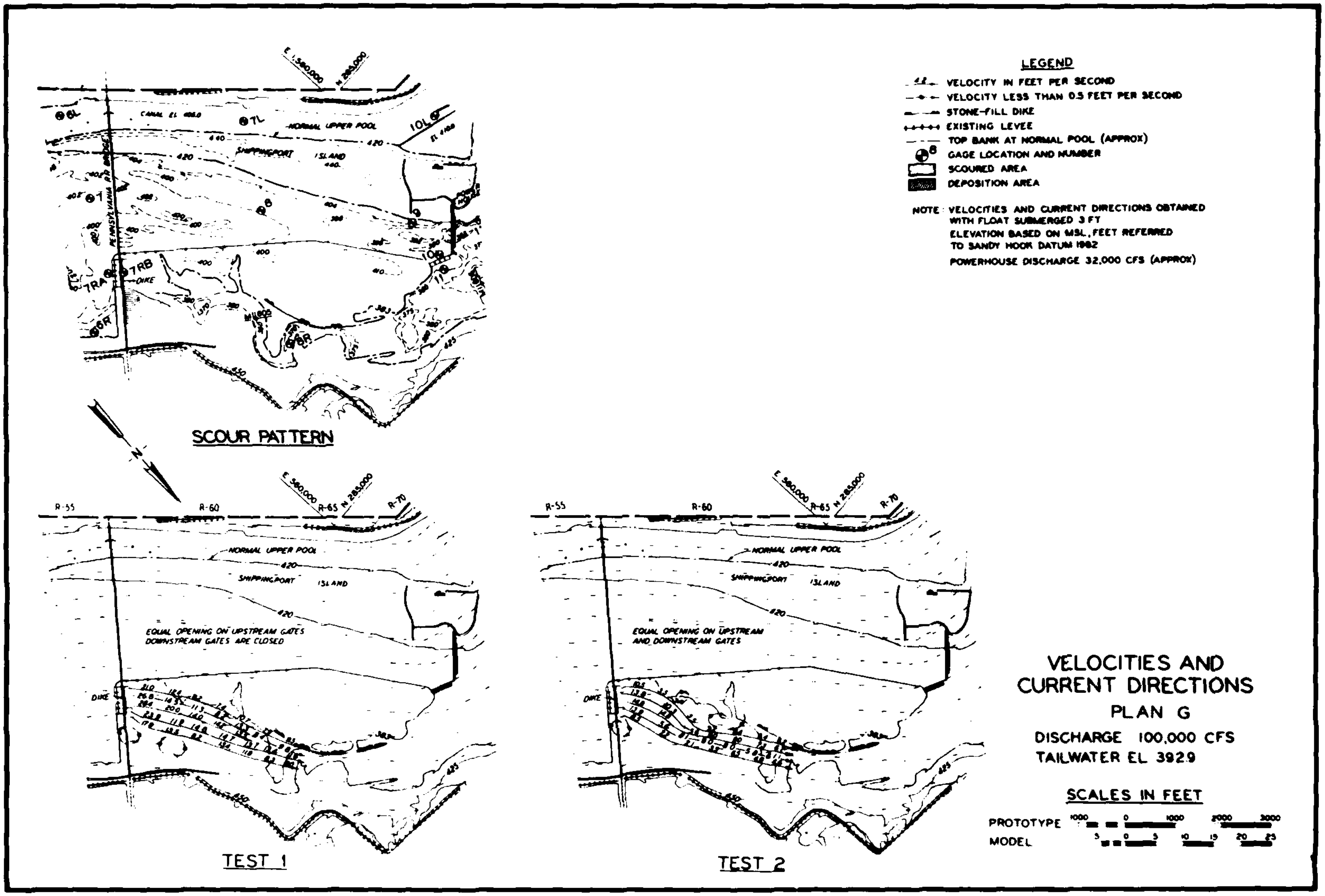
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)

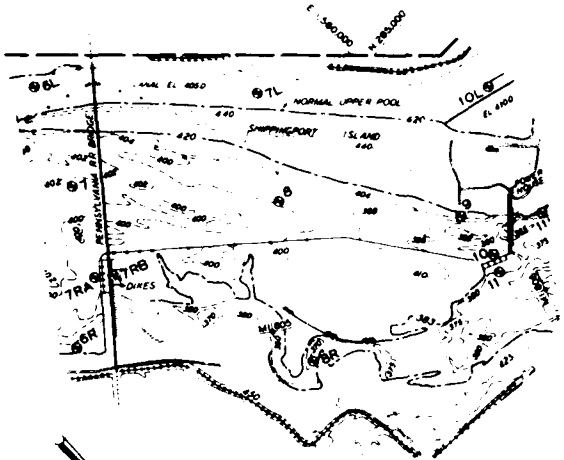
VELOCITIES AND CURRENT DIRECTIONS
BASE TEST

DISCHARGE 100,000 CFS
TAILWATER EL 392.9

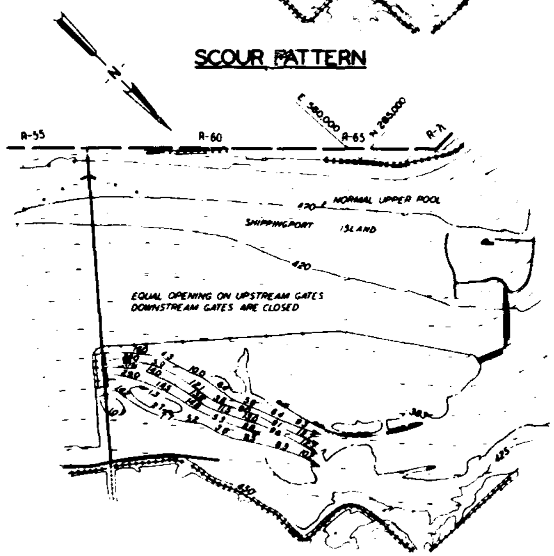
SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

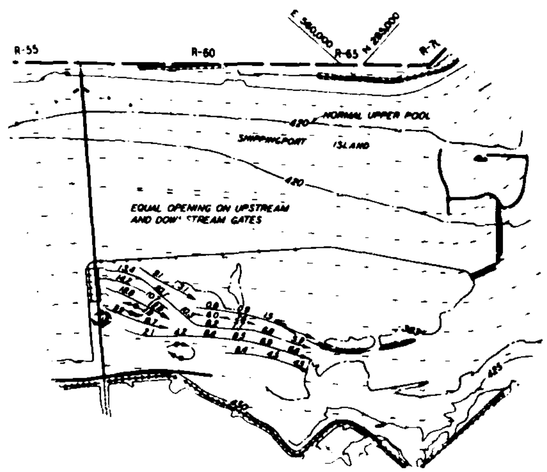

LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
GAGE LOCATION AND NUMBER
SCOURED AREA
DEPOSITION AREA
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1982
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)
SCOUR PATTERN
NORMAL UPPER POOL
SHIPPINGPORT ISLAND
PENNSYLVANIA RR BRIDGE
DIKE
EQUAL OPENING ON UPSTREAM GATES DOWNSTREAM GATES ARE CLOSED
TEST 1
EQUAL OPENING ON UPSTREAM AND DOWNSTREAM GATES
TEST 2
VELOCITIES AND CURRENT DIRECTIONS
PLAN G
DISCHARGE 100,000 CFS
TAILWATER EL 392.9
SCALES IN FEET
PROTOTYPE
MODEL



SCOUR PATTERN



TEST 1



TEST 2

LEGEND

- VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)
- GAGE LOCATION AND NUMBER
- SCOURED AREA
- DEPOSITION AREA

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT.
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)

VELOCITIES AND CURRENT DIRECTIONS
PLAN G-1
DISCHARGE 100,000 CFS
TAILWATER EL 392.9

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

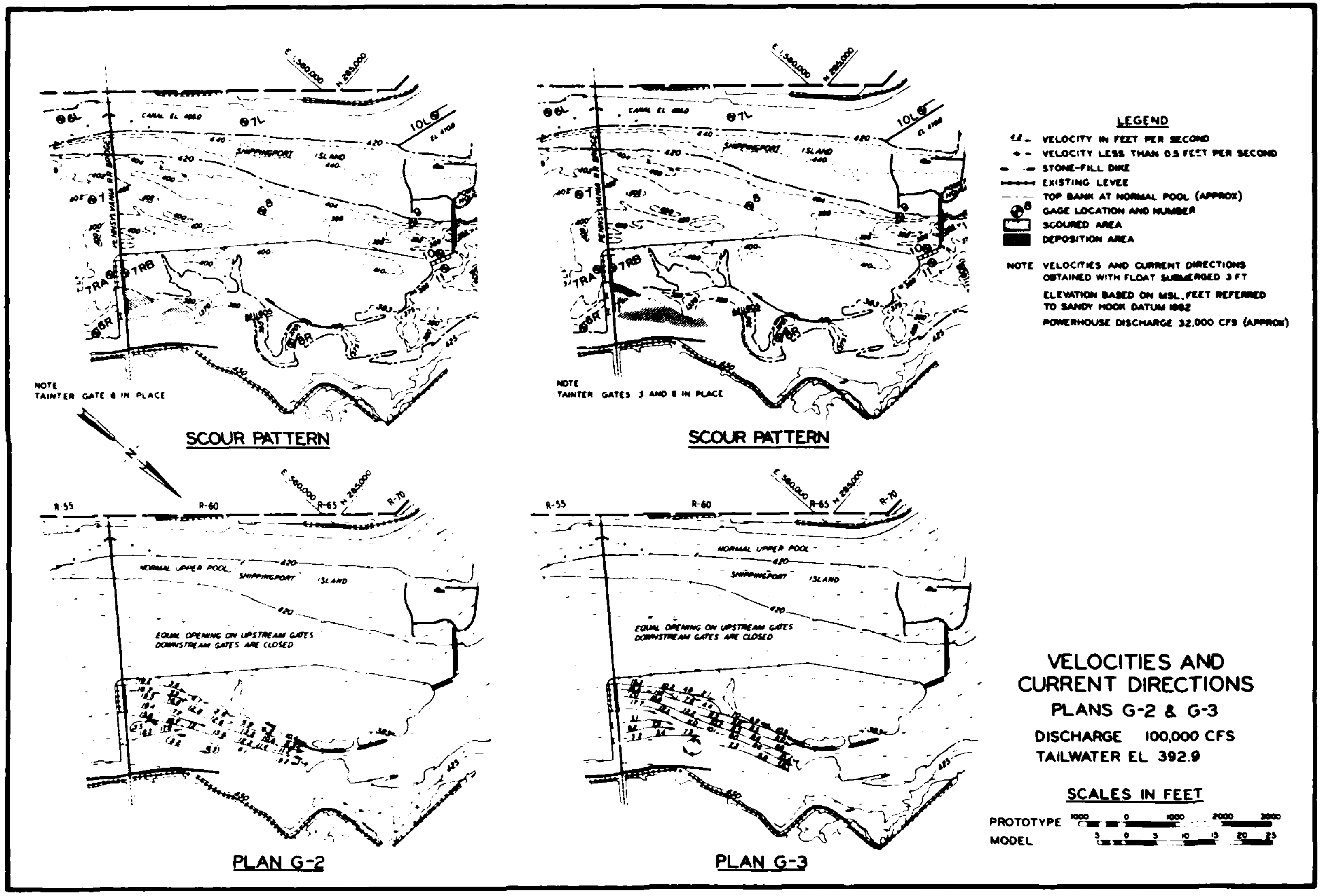
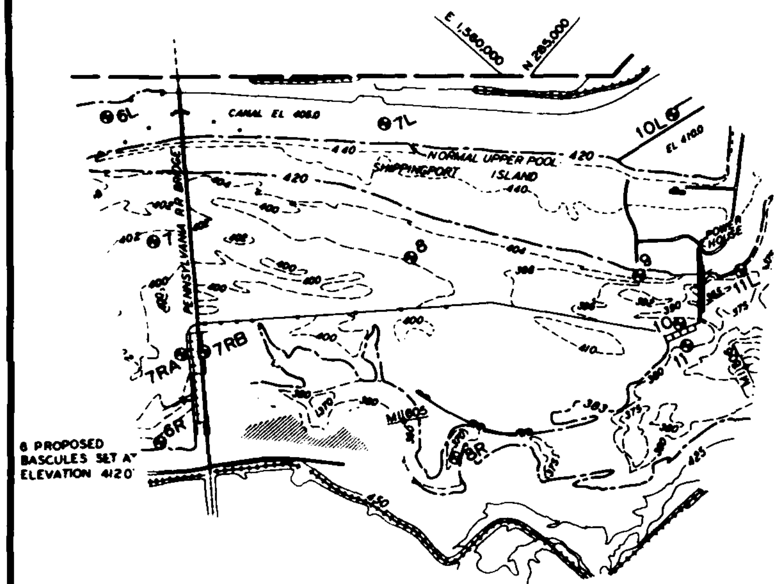

SCOUR PATTERN
NOTE
TAINTER GATE 6 IN PLACE
SCOUR PATTERN
NOTE
TAINTER GATES 3 AND 6 IN PLACE
PLAN G-2
PLAN G-3
SHIPPINGPORT ISLAND
NORMAL UPPER POOL
EQUAL OPENING ON UPSTREAM GATES
DOWNSTREAM GATES ARE CLOSED
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
GAGE LOCATION AND NUMBER
SCOURED AREA
DEPOSITION AREA
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)
VELOCITIES AND
CURRENT DIRECTIONS
PLANS G-2 & G-3
DISCHARGE 100,000 CFS
TAILWATER EL 392.9
SCALES IN FEET
PROTOTYPE
MODEL

PLATE 36

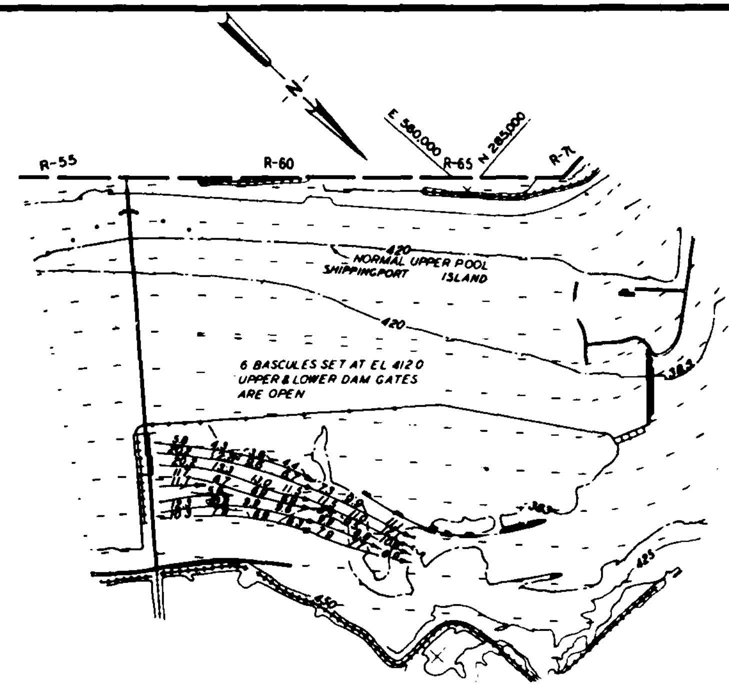


SCOUR PATTERN

LEGEND

- VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)
- GAGE LOCATION AND NUMBER
- SCOURED AREA
- DEPOSITION AREA

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT
ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1982
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)



VELOCITIES AND CURRENT DIRECTIONS

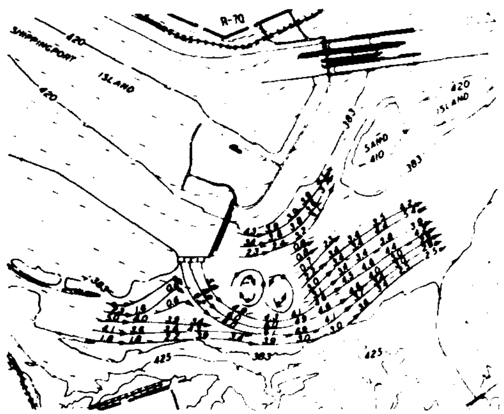
PLAN G-4

DISCHARGE 100,000 CFS
TAILWATER EL 392.9

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

LOWER DAMS OPEN - 4GATES



UPPER AND LOWER DAMS OPEN - 9GATES

UPPER DAMS OPEN - 5GATES

LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- ←→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- — — STONE-FILL DIKE
- +++++ EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED 3 FT
ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)

VELOCITIES AND CURRENT DIRECTIONS

EXISTING CONDITION

DISCHARGE 52,000 CFS
TAILWATER EL 387.4

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25

PLATE 38

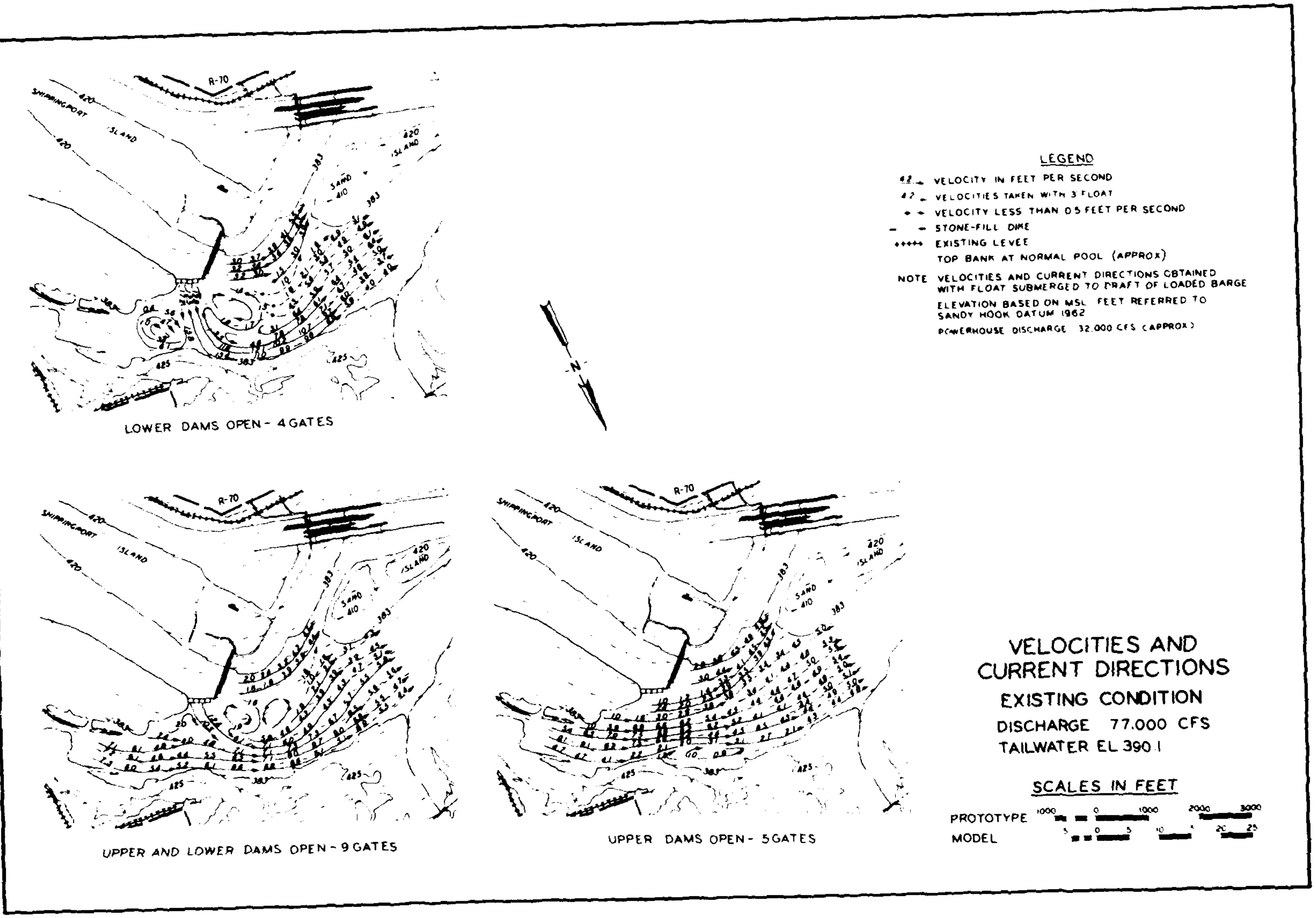
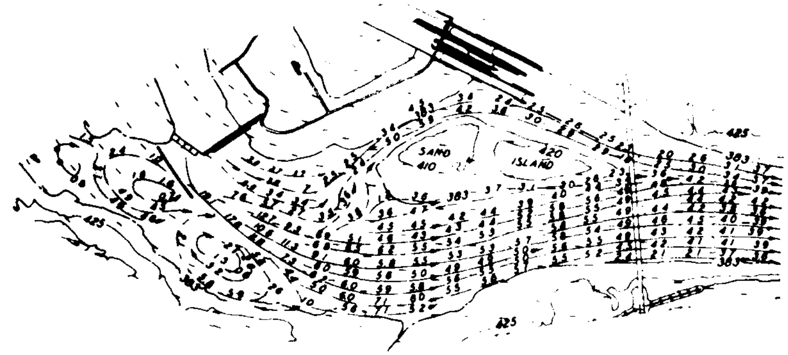
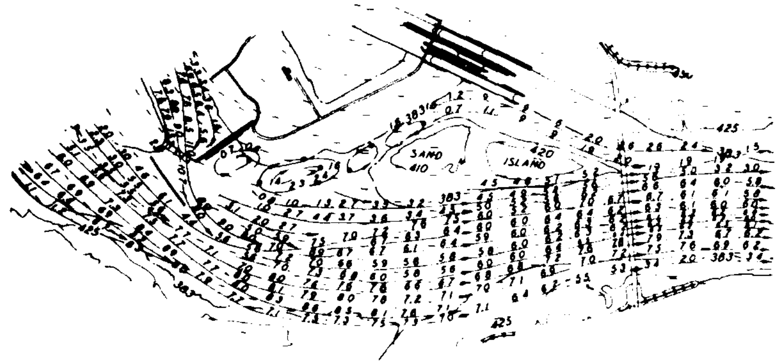

LOWER DAMS OPEN - 4 GATES
UPPER AND LOWER DAMS OPEN - 9 GATES
UPPER DAMS OPEN - 5 GATES
SHIPPINGPORT ISLAND
R-70
SAND
LEGEND
42 VELOCITY IN FEET PER SECOND
42 VELOCITIES TAKEN WITH 3' FLOAT
VELOCITY LESS THAN 0.5 FEET PER SECOND
STONE-FILL DIKE
EXISTING LEVEE
TOP BANK AT NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)
VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITION
DISCHARGE 77,000 CFS
TAILWATER EL 390.1
SCALES IN FEET
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 20 25

PLATE 39



DISCHARGE 88,800 CFS
TAILWATER EL 391.6
UPPER DAM GATES CLOSED



DISCHARGE 400,000 CFS
TAILWATER EL 421.8

LEGEND

- 4.2 VELOCITIES TAKEN WITH 3' FLOAT
- 4.2 VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- STONE-FILL DIKE
- EXISTING LEVEE
- TOP BANK AT NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE
ELEVATION BASED ON MSL. FEET REFERRED TO SANDY HOOK DATUM 1962
POWERHOUSE DISCHARGE 32,000 CFS (APPROX)

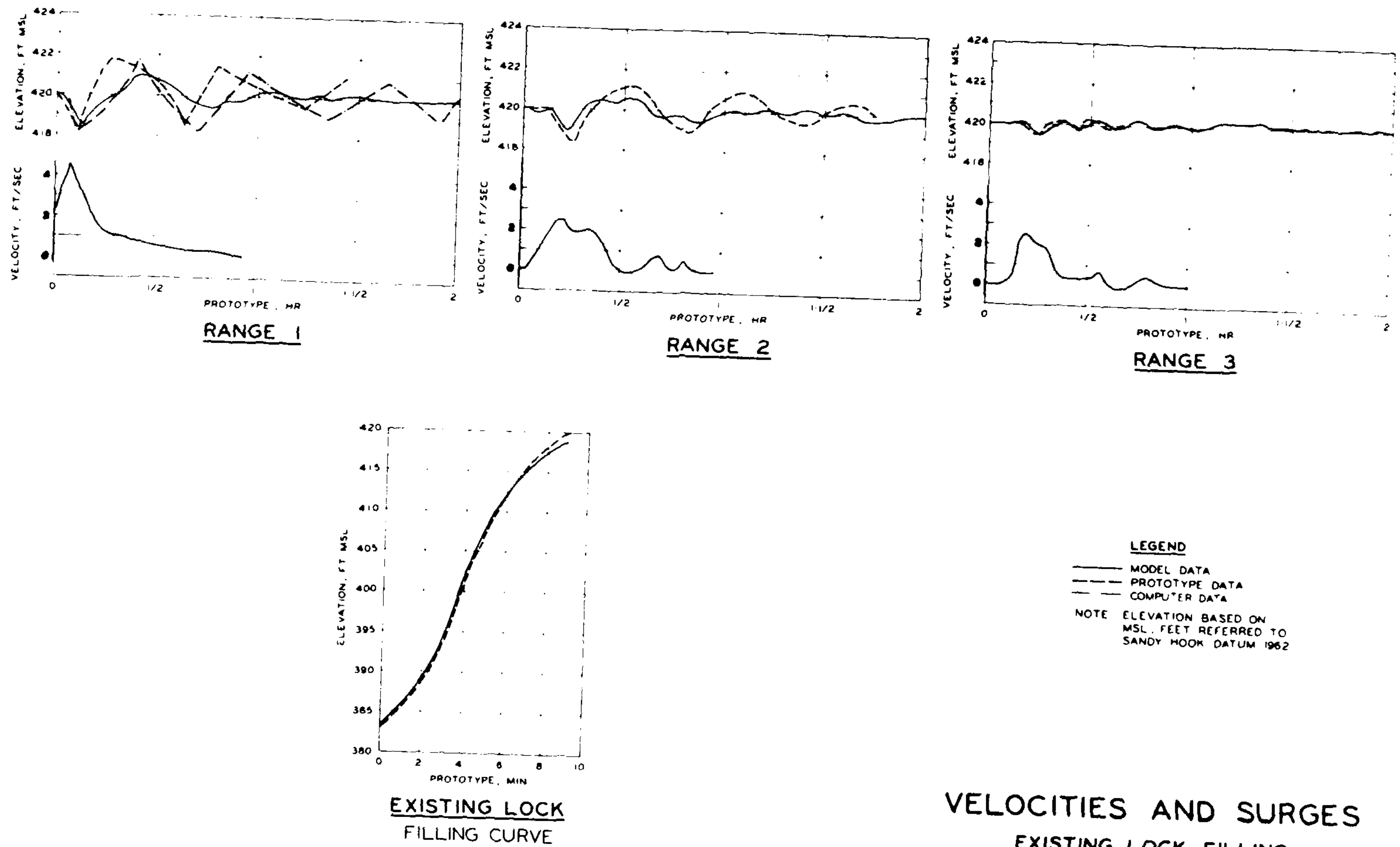
VELOCITIES AND CURRENT DIRECTIONS

PLAN H

DISCHARGES: 88,800 AND 400,000 CFS

SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20 25



VELOCITIES AND SURGES

EXISTING LOCK FILLING
WITH 37-FT HEAD

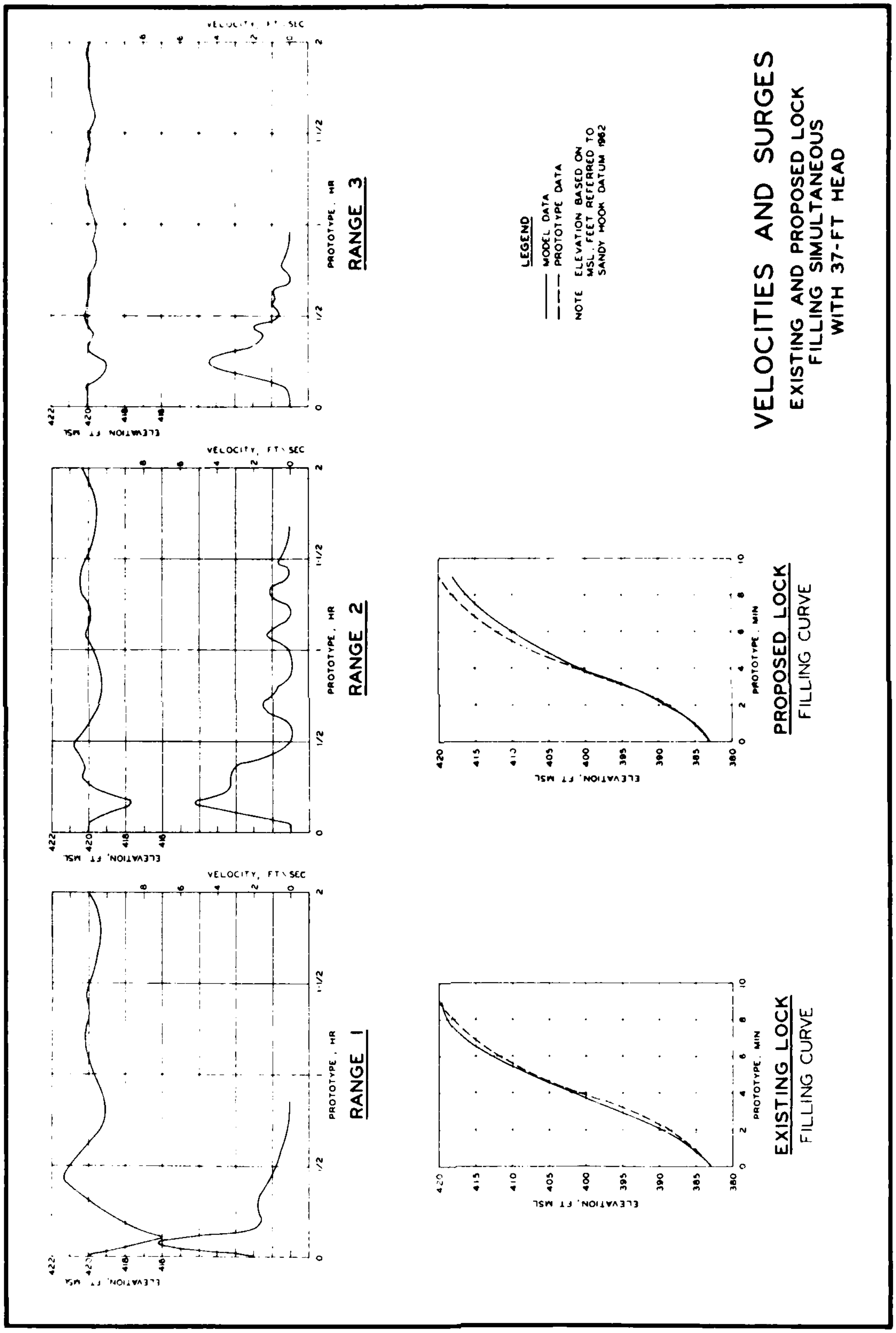
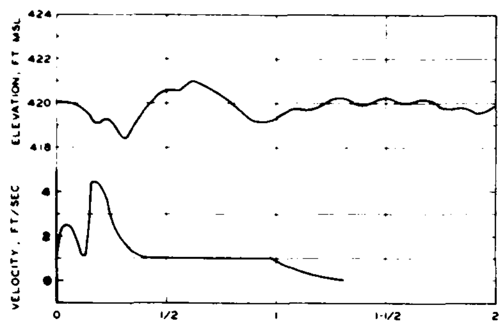
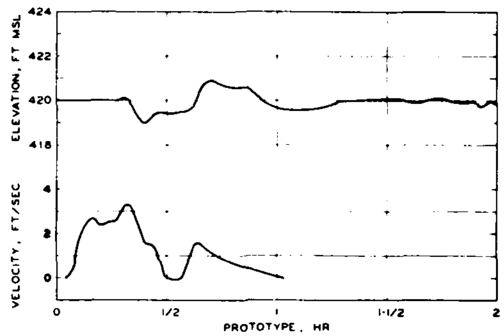

VELOCITIES AND SURGES
EXISTING AND PROPOSED LOCK
FILLING SIMULTANEOUS
WITH 37-FT HEAD
RANGE 1
RANGE 2
RANGE 3
PROTOTYPE, HR
VELOCITY, FT/SEC
ELEVATION, FT MSL
EXISTING LOCK
FILLING CURVE
PROPOSED LOCK
FILLING CURVE
PROTOTYPE, MIN
LEGEND
MODEL DATA
PROTOTYPE DATA
NOTE ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

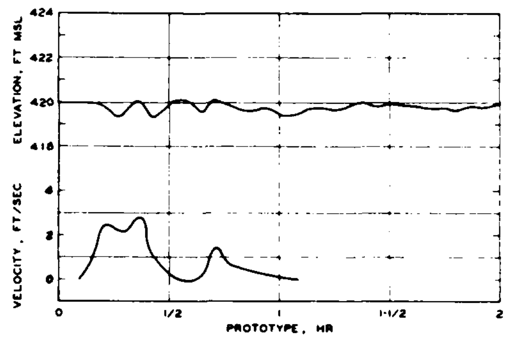
PLATE 42



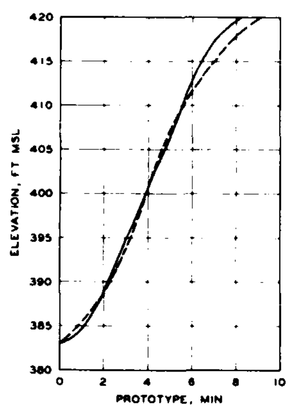
RANGE 1



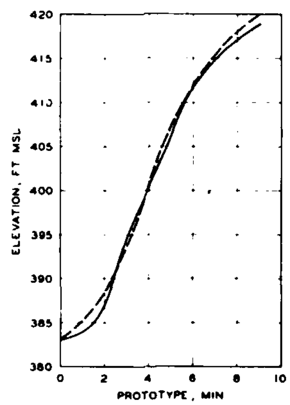
RANGE 2



RANGE 3



EXISTING LOCK
FILLING CURVE



PROPOSED LOCK
FILLING CURVE

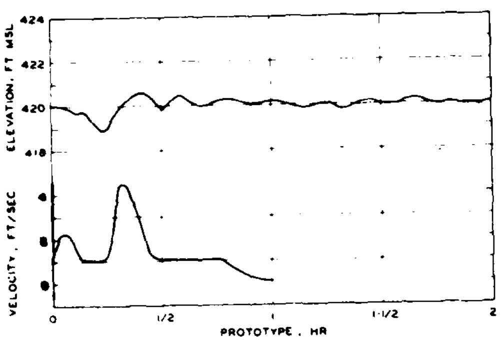
LEGEND

——— MODEL DATA
— — — PROTOTYPE DATA

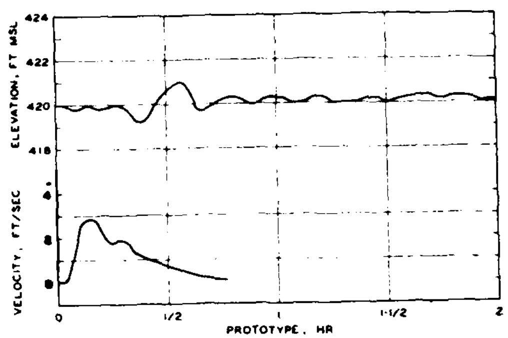
NOTE: ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

VELOCITIES AND SURGES

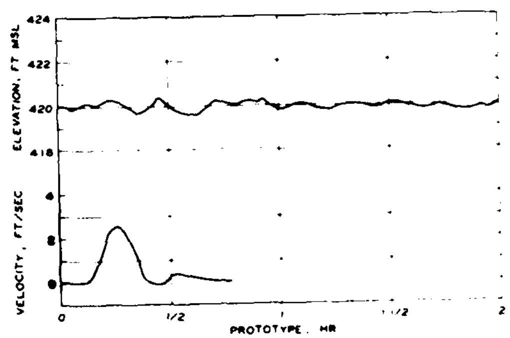
EXISTING AND PROPOSED LOCK
FILLING 6.6 MINUTES APART
WITH 37-FT HEAD



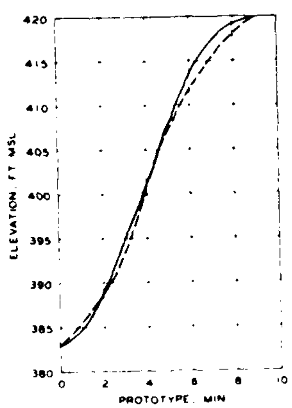
RANGE 1



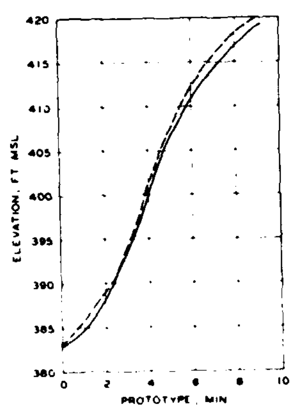
RANGE 2



RANGE 3



EXISTING LOCK
FILLING CURVE



PROPOSED LOCK
FILLING CURVE

LEGEND

——— MODEL DATA
– – – PROTOTYPE DATA

NOTE ELEVATION BASED ON MSL, FEET REFERRED TO SANDY HOOK DATUM 1962

VELOCITIES AND SURGES

EXISTING AND PROPOSED LOCK
FILLING 15 MINUTES APART
WITH 37-FT HEAD

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.

Shows, Louis J.
Navigation conditions at McAlpine Locks and Dam Ohio River : Hydraulic model investigation / by Louis J. Shows, John J. Franco (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.
52, [11] p., 44 p. of plates : ill. ; 27 cm. -- (Technical report / U.S. Army Engineer Waterways Experiment Station ; HL-81-7)
Cover title.
"August 1981."
"Prepared for U.S. Army Engineer District, Louisville."
Final report.

1. Hydraulic models. 2. Locks (Hydraulic engineering). 3. McAlpine Locks and Dam (Kentucky). 4. Ohio River. I. Franco, John J. II. United States. Army. Corps of Engineers. Louisville District. III. U.S. Army Engineer

Shows, Louis J.
Navigation conditions at McAlpine Locks and Dam : ... 1981.
(Card 2)

Waterways Experiment Station. Hydraulics Laboratory. IV. Title V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; HL-81-7.
TA7.W34 no.HL-81-7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