WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

MISSISSIPPI RIVER COMMISSION

MODEL STUDY

OF

PLANS FOR IMPROVEMENT OF NAVIGATION AT THE UPSTREAM ENTRANCE TO ST. MARYS FALLS CANAL, MICHIGAN

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MODEL STUDY OF PLANS FOR IMPROVEMENT OF NAVIGATION AT THE UPSTREAM ENTRANCE TO ST. MARYS FALLS CANAL, MICHIGAN

SYNOPSIS

1. This memorandum constitutes a comprehensive report on the model study of plans for improvement of navigation at the upstream entrance to the St. Marys Falls Canal, Michigan. The study was authorized by the Chief of Engineers, U. S. Army, on 14 May 1943, and was conducted at the U. S. Waterways Experiment Station during the period July 1943 to November 1943.

2. The St. Marys River connects Lake Superior and Lake Huron and is an important link in the Great Lakes navigation system. At Sault Ste. Marie, Michigan, the navigation channel by-passes St. Marys Falls through two canal-and-lock systems, the Canadian Canal and the North and South American Canals. Just above the westerly approach to the South Canal the inlet to the Michigan Northern Power Company Canal opens into the river and creates crosscurrents hazardous to boats which have slowed down to enter the South Canal.

3. It was the purpose of the St. Marys model study to predetermine the effectiveness of various proposed plans for the improvement of navigation velocities through the west approach to the South Canal. These plans can be classified into five general groups: (1) plans of dredging at the upstream entrance to the Michigan Northern Power Canal; (2) plans of 1200-ft extension (solid) of Southwest Pier; (3) plans of 1200-ft extension of Southwest Pier with last 300 ft perforated (50 per cent open); (4) plans of wing dike at end of 1200-ft extension to Southwest Pier; and (5) plans of dredging in main channel at entrance of present Michigan Northern Power Canal west of present Southwest Pier. Supplementary tests were made to determine the effect of decreasing the flow in the Michigan Northern Power Canal and increasing the flow through the U. S. Power Canal by corresponding amounts.

4. In order to determine a basis for comparing the relative effectiveness of the plans listed above, an index was established for each plan by multiplying the average velocity acting perpendicular to a ship passing along an assumed navigation line by the distance over which the velocity was effective. The per cent of reduction in side velocity effected by each plan was then determined by comparing the index for each plan with the index obtained for tests of existing conditions. The principal conclusions drawn from the analyses of the results of the tests of the various plans follow:

a. Dredging of sections A, B, and C at the upstream entrance to the Michigan Northern Power Canal (see plate 8) would reduce the over-all effective side velocity acting on ships entering the South Canal about 20 per cent for both the average and maximum flow. The additional dredging of sections D and E would further reduce effective side velocities only about 3 per cent for each flow.

b. The 1200-ft extension (solid) of Southwest Pier in conjunction with the dredging of sections A, B, and C (see plate 18) would reduce the effective side velocities acting on ships approaching the South Canal about 21 per cent for the average flow and 40 per cent for the maximum. With the pier extended, additional dredging of sections D and E would further reduce side velocities about 10 per cent for the average flow and 8 per cent for the maximum flow.

c. The 1200-ft pier extension with the outer 300 ft perforated would not be as effective as the 1200-ft solid pier extension.

d. Streamlining the alignment of dredging at the entrance to the power canal to improve the efficiency of the intake would be unnecessary.

e. The placement of a 75-ft wing dike at the end of the 1200-ft extension (solid) of Southwest Pier in conjunction with dredging at the upstream entrance to the Michigan Northern Power Canal (Plan X, see plate 73) would reduce effective side velocities in the westerly approach to South Canal about 30 per cent and 51 per cent for the average and maximum flows, respectively.

f. Reducing the flow in the Michigan Northern Power Canal to zero and increasing the flow in the U. S. Power Canal by a corresponding amount (33,000 cfs) would increase the average side-velocity components along the assumed navigation line to Northwest Pier from 0.62 to 0.94 ft per sec for plan A (see plate 8) and from 0.71 to 0.94 ft per sec for plan B (see plate 18).

PART I: AUTHORIZATION

5. The model study of the St. Marys Falls Canal, Michigan, was initiated by the Chief of Engineers in letters to the President, Mississippi River Commission, and Division Engineer, Great Lakes Division, dated 3 May 1943, subject: "Proposed Model Test--St. Marys Falls Canal, Michigan." Authority to undertake the model study was granted by the Chief of Engineers in a teletype dated 14 May 1943. The study was conducted at the U. S. Waterways Experiment Station during the period July 1943 to November 1943.

PART II: THE PROTOTYPE

Location

6. The St. Marys River is 63 miles in length and flows in a southeasterly direction, connecting Lake Superior and Lake Huron. About 14 miles below the head of the river, at Saulte Ste. Marie, Michigan, are located the St. Marys Falls. The vicinity map on plate 1 shows the geographical location of the falls and the extent of the prototype area included in the model.

History and Description

7. The transport of materials past the turbulent St. Marys Falls was a problem of great concern even before the coming of the white man, when Indians were obliged to carry their canoes around the rapids to get from one lake to the other. This tedious portage was continued during the early days of the settlement of the Northwest. However, with the development of fur trading, this expensive portage led the Northwest Fur Company to build a small lock in 1797 which remained in use until it was destroyed by the U. S. Army during the war of 1812.

8. Following the demolition of the Northwest Fur Company's lock no further attempt was made at canal building until 1853, when the State of Michigan constructed the State Lock. In 1881 the Weitzel Lock was completed by the U. S. Engineers, and in 1896 the State Lock was replaced by the Poe Lock. The third and fourth locks, the Davis and the Sabin, were completed in 1914 and 1919, respectively. To accomodate the large deep-draft boats, transporting an ever-increasing amount of iron ore, the old Weitzel Lock was demolished in 1943 and replaced by the MacArthur Lock.

9. The four American-owned locks parallel the rapids on the south side, while one small Canadian-owned lock is located on the north side. Stages above the locks and discharges through the rapids are controlled by a system of gates located directly above the rapids. Three power canals are located adjacent to the rapids to utilize the enormous energy created by the 22-ft drop from the upper end to the lower end of the rapids. The largest of these, and the one of primary concern in the model study, is the Michigan Northern Power Canal, which has its intake directly above the westerly approach to the South Canal.

The Problem

10. The prototype problem with which the model study of the St. Marys Falls Canal was concerned is the hazardous effect of dangerous crosscurrents in the westerly approach to the South Canal on downbound ore carriers. These crosscurrents result from flow into the Michigan

Northern Power Canal which has its intake on the south side of the South Canal at the upstream end of the Southwest Pier. Danger to down-bound ships is magnified by the proximity of the intake to the South-west Pier since ships tying up along this pier must travel at a reduced rate of speed through the troublesome area.

Urgency for Results of Model Tests

11. As stated previously, authority for the model study was granted 14 May 1943 and construction of the model was undertaken immediately thereafter. Since it was evident that the plan adopted must contain provisions for relocating the entrance to the Michigan Northern Power Canal and since it was necessary that the dredging of this new entrance be completed before winter, the District Engineer, Detroit District, submitted specifications for dredging in this area at about the same time construction of the model was undertaken. The specifications (No. N-391, see plate 8) provided for the dredging of three sections, A, B, and C, with an estimated yardage of 485,000 cu yds and optional dredging of two additional sections, D and E, with estimated yardages of 175,000 and 164,000 cu yds, respectively. Contracts for this dredging provided that the contractor be advised not later than 15 October 1943 as to the necessity for dredging sections D and E. Accordingly, it was necessary to conduct the model study as expeditiously as facilities would permit in order to submit the results of tests of the dredging of sections D and E to the District Engineer prior to 15 October 1943.

PART III: THE MODEL

Purpose of Model Study

12. The purpose of the model study was to develop a plan of improvement (dredging, pier construction, or a combination of both) which would effect the greatest reduction in side velocities and provide the most satisfactory navigating conditions in the westerly approach to the MacArthur Lock in South Canal.

General Description of Model

Area reproduced

13. The prototype area reproduced in the model included the entire St. Marys River from Old Vessel Point to a point just below the International Bridge. In order that the distribution of flow be correctly reproduced at the westerly approach to the South Canal and at the end of Northwest Pier it was necessary to simulate in the model the American and Canadian locks, the Regulating Works, the U. S. Power Canal, the Canadian Power Canal, and the Michigan Northern Power Canal. (See plate 1 for vicinity map and photographs 1 and 2 for general views of the model.)

Scale ratios

14. The model was of the fixed-bed type with linear scale ratios, model to prototype, of 1 to 150 horizontally and 1 to 50 vertically, which resulted in a geometric distortion of 3 to 1. Other scale ratios computed directly from these basic linear scales were: discharge, 1 to 53,025; velocity, 1 to 7.07; time, 1 to 21.21.

Model construction

15. The model was constructed to include the latest hydrographic and topographic features of the St. Marys River pertinent to the study. All prototype conditions were transferred as accurately as possible to the model by means of masonite templets located according to established horizontal and vertical controls. Configurations between templets were molded in concrete. A shelter was constructed over the model to prevent wind from affecting current directions.

Model appurtenances

16. Six boxes equipped with 90-degree V-notch weir plates were used to measure the inflow of the St. Marys River and the outflows through the power canals and the Regulating Works. Van Lear weirs were used to measure the flows through the locking systems. Water-surface

elevations at the Southwest Pier gage, the Sluice Gate gage and at two auxiliary gages in the St. Marys River were read by means of hook gages. Velocities were measured by means of pole floats, and flow directions were determined by means of a current-direction indicator.

PART IV: VERIFICATION

Purpose of Model Verification

17. Before undertaking any model tests of proposed plans of improvement it was essential that the required similitude first be established between the model and the prototype. Accordingly, prior to the testing of plans on the St. Marys Falls Canal model, the hydraulic characteristics in the model were adjusted to agree with corresponding prototype phenomena which were known to have occurred. The prototype phenomena used in the verification of the model are described in the following paragraphs.

Prototype Data Available

18. The principal prototype data available for reproduction in the model were current directions and velocities observed by the Detroit District in August 1939 and December 1942. The August 1939 observations were made during a period of very high flow in the St. Marys River, at which time the Regulating Works were discharging 56,000 cfs. This large discharge through the Regulating Works created high velocities around the end of Northwest Pier and provided an excellent opportunity to ascertain the current directions in that area. The current directions were made with staff floats extending 20 ft below the water surface and were made under time control in order that the velocities could be computed. The December 1942 observations were made during a period of very low flow in the St. Marys River. The discharge through the Regulating Works for this low flow was only 500 cfs, whereas the flow in the Michigan Northern Power Canal was 31,500 cfs. This distribution of flow created ideal conditions for observing velocities and current directions in the westerly approach to the South Canal and in the entrance to the Michigan Northern Power Canal. These observations, like those of August 1939, were made with 20-ft staff floats and under time control.

19. Other prototype data available for verification were slope observations in the Michigan Northern Power Canal. These observations were made in the form of daily gage readings over a period of years at the Southwest Pier gage and the Sluice Gate gage. The purpose of these readings was to determine the daily flow in the Michigan Northern Power Canal from slope-discharge curves. Since it was neither feasible nor necessary to reproduce observations covering the entire period, the average slopes for two representative months (July 1942 and March 1943) were selected for verification in the model. These data were supplemented by special slope observations taken at 1-minute intervals by representatives of the Michigan Northern Power Company on 11 July 1939.

Procedure

20. The first step in the verification of the St. Marys Falls Canal model was the adjustment of the slope in the Michigan Northern Power Canal to conform to the average slopes observed during the months of July 1942 and March 1943. The adjustment of the slope was accomplished by setting up in the model the average monthly flow and by varying the roughness in the Power Canal until the corresponding average monthly slope was reproduced. The slope thus obtained was further checked by reproducing the special slope observations made by the Michigan Northern Power Company. The next step in the verification of the model was the adjustment of velocities and current directions in the vicinity of Northwest Pier and in the westerly approach to the South Canal to agree with the prototype observations made in August 1939 and December 1942. As in the adjustment of the slope in the Power Canal, verification of the velocities and current directions was accomplished by controlling stages and discharges to those observed in the prototype at the time the observations were made and then by varying the channel roughness until an agreement with the prototype observations was attained.

21. The observations made in August 1939 and December 1942 have been designated, for use hereinafter, as "High Flow" and "Low Flow," respectively. The stages at Southwest Pier (referred to mean tide at New York) and the distribution of discharge for each flow are shown below:

Location	Low Flow	High Flow
Michigan Northern Power Canal	31,500 cfs	30,000 cfs
U. S. Power Canal	4,000 cfs	10,500 cfs
Regulating Works	500 cfs	56,000 cfs
American Locks:		
North Canal	700 cfs	1,200 cfs
South Canal		800 cfs
Canadian Power Canal	23,417 cfs	22,163 cfs
Southwest Pier Gage	602.75 MT at NY	602.85 MT at NY

22. The method employed in observing the current directions and velocities in the model was similar to that used in the prototype. A small staff float, extending 0.4 ft (20 ft in the prototype) below the water surface, was placed in the model at a point upstream from the problem area. The path of travel of the float was plotted, and the distance for given time intervals was recorded. With the float started at exactly the same location, this procedure was repeated five times, and the average path was determined and plotted with notation of average velocity shown. Other paths of travel were established in this same manner until current directions and velocities covering the entire problem area had been determined.

23. Photographs of current directions for both the low and high flows are shown on photographs 3 and 4, respectively. An unusual technique was employed in making these pictures. The photographs were taken at night from a 27-ft photographic tower. First, the entire model was lighted with photo-flood units, and a picture was taken with a 1-sec exposure at a stop of f 22. After the lens was closed and the photo floods turned out, wooden floats equipped with small flashlight batteries and bulbs were placed in the model. The lens was opened, and the light from the flashlight bulbs recorded on the film the paths of travel of the floats.

Results of Verification

24. The results of the model verification of current directions and velocities for the "Low Flow" and "High Flow" are illustrated on plates 2 and 3, respectively. These plates show that the currents of model and prototype travel along almost identical paths. For the low flow, both current paths are almost parallel to the Vidal Shoals Range line until they become affected by the draw-down from the Power Canal at which time they bear southwardly and enter the Power Canal with an almost uniform distribution. For the high flow, the current paths break rather sharply toward the end of Northwest Pier with some of the paths continuing around the end of the pier and the others striking Northwest Pier and reversing sharply to enter the Power Canal around the end of Southwest Pier.

25. Comparison of the model and prototype velocities shown on plates 2 and 3 reveals that model velocities checked prototype velocities within 0.1 ft per sec in nearly every case and never varied more than 0.5-ft per sec. The accurate reproduction of the high velocities at the end of Northwest Pier for the high flow and at the end of Southwest Pier for the low flow can also be seen by examining these plates.

PART V: TESTS OF PROPOSED IMPROVEMENT PLANS

26. The reproduction of observed prototype velocities and current directions having been attained to a reasonable degree of accuracy in the model, tests of the various plans for improving navigating conditions through the west approach to the South Canal were undertaken. In general, there were five different types of plans, each including dredging at the upstream entrance to the Michigan Northern Power Canal. Variations in the plans were: present Southwest Pier unchanged; 1200-ft extension to Southwest Pier; 300 ft of the outer end of the 1200-ft extension of Southwest Pier perforated (50 per cent open); wing-dike at end of 1200-ft extension to Southwest Pier; additional dredging in the channel off the end of Southwest Pier. Additional tests were made to determine the effect of possible future decrease in the flow in the Michigan Northern Power Canal with corresponding increase in the flow through the U. S. Power Canal.

Testing Procedure

27. The feasibility of the installation of any of the proposed improvement works depends upon the effects of the resulting cross-currents on ships navigating the west approach to the South Canal. Accordingly, three assumed ship courses through the west approach were established on which detailed observations were made. One of the courses, denoted by line A-A' on plate 5, assumed the ships to dock along Northwest Pier; the other two, lines B-B' and C-C', assumed the ships to tie up along Southwest Pier. Current-direction and velocity observations were made at 200-ft intervals along each of these assumed ship courses for each plan tested. Additional observations were made at selected points throughout the problem area. At each point of observation the current direction was obtained by measuring the angle of flow with a current-direction indicator. The velocity at each point was obtained by observing with a stop watch the time required for a staff float 0.4 ft long (20 ft in prototype) to pass through a one-ft range and then converting the observed data to rate of flow in ft per sec.

28. Each plan was tested with both the average and maximum flows of the St. Marys River, the condition for average flow being designated herein as "test 1" and that for maximum flow as "test 2." The distribution of discharge maintained for the two flows are listed below:

	Av. Flow, Test 1	Max. Flow, Test 2
Michigan Northern Power Canal	30,000 cfs	33,000 cfs
U. S. Power Canal	3,600 cfs	12,000 cfs
Regulating Works	5,000 cfs	56,000 cfs
Canadian Power Canal	24,000 cfs	26,000 cfs
Canadian Lock	150 cfs	250 cfs
American Locks: North Canal	700 cfs	1,200 cfs
South Canal	500 cfs	800 cfs
Total Flow	63,950 cfs	129,250 cfs

29. Stages at Southwest Pier gage were maintained at 602.00 and 602.85, mean tide at New York, for the average and maximum flows, respectively.

Method of Analysis

30. In order to determine a basis for comparing the relative effectiveness of the improvement plans, an index was established for each plan by multiplying the average velocity acting perpendicular to a ship passing along the assumed navigation line by the distance over which the velocity was effective. The per cent of reduction in side velocity effected by each plan was then determined by comparing the index for that plan with the index obtained for tests of existing conditions.

Tests of Existing Conditions

31. Prior to conducting tests of the improvement plans, tests were made of the existing prototype conditions. The purpose of these tests was to obtain data which would serve as a basis for comparison of the results of tests of the improvement plans. Current directions and velocities for the tests of existing conditions are shown on plates 4 and 6. Plots of the effective side-velocity components acting on ships passing along the assumed navigation lines are shown on plates 5 and 7.

Tests of Dredging Under Specification No. N-391 Present Southwest Pier Unchanged

Description

32. The elements of plans A, D, and G for dredging at the upstream entrance to the Michigan Northern Power Canal under specification No. N-391 are shown on plates 8, 32, and 44, respectively. Plan A consisted of dredging from the three sections, A, B, and C, an estimated volume of 485,000 cu yds. Plan D included the dredging of an estimated 175,000 cu yds in section D in addition to the dredging for plan A. Plan G consisted of dredging an estimated 164,000 cu yds in section E in addition to the dredging for plan D. The general purpose of these tests was to determine the effect of widening the existing entrance to the Michigan Northern Power Canal on navigating conditions in the westerly approach to the South Canal. The specific purpose was to determine whether the dredging of sections D and E was necessary.

Results

33. The results of the tests of plans A, D, and G are shown on the following plates:

Plan	Test	Description	Plate
A	1	Current directions and velocities	8
A	1	Side-velocity components	9
A	2	Current directions and velocities	10
A	2	Side-velocity components	11
D	1	Current directions and velocities	32
D	1	Side-velocity components	33
D	2	Current directions and velocities	34
D	2	Side-velocity components	35
G	1	Current directions and velocities	44
G	1	Side-velocity components	45
G	2	Current directions and velocities	46
G	2	Side-velocity components	47

A summary of the investigation of side-velocity components perpendicular to the assumed navigation lines is presented in tables 1 and 2.

34. The tests indicated that the dredging of sections A, B, and C would improve navigating conditions along the two assumed navigation lines to the Southwest Pier about 20 per cent for the average flow (test 1) and about 17 per cent for the maximum flow (test 2). Average side-velocity components perpendicular to these lines were reduced from 0.46 to 0.29 ft per sec for the average flow and from 0.50 to 0.40 ft per sec for the maximum flow.

35. This series of tests also indicated that the additional dredging in sections D and E would further improve navigating conditions only about 5 per cent for test 1 and 1 per cent for test 2. The maximum and average side-velocity components were not materially changed.

Tests of Southwest Pier Extended (Solid)

Description

36. The elements of plans B, E, and H, with the Southwest Pier extended (solid), are shown on plates 18, 36, and 48, respectively. The extension of Southwest Pier was designed for the dual purpose of providing additional docking space for ships entering the South Canal and of reducing navigation hazards by moving the high velocities at the end of the existing pier upstream and away from the ship channel. For all three tests in this series the Southwest Pier was extended 1200 ft on an azimuth of 255 degrees. The only variation in the three plans was in the amount of dredging at the upstream entrance to the Michigan Northern Power Canal. The dredging for plans B, E, and H was the same as that described in paragraph 32 for plans A, D, and G, respectively.

Results

37. The results of tests of plans B, E, and H are shown on the following plates:

Plan	Test	Description	Plate
B	1	Current directions and velocities	18
B	1	Side-velocity components	19
B	2	Current directions and velocities	20
B	2	Side-velocity components	21
E	1	Current directions and velocities	36
E	1	Side-velocity components	37
E	2	Current directions and velocities	38
E	2	Side-velocity components	39
H	1	Current directions and velocities	48
H	1	Side-velocity components	49
H	2	Current directions and velocities	50
H	2	Side-velocity components	51

A summary of the investigation of side-velocity components perpendicular to the three assumed navigation lines is presented in tables 3 and 4.

38. The results of tests of plans B, E, and H, when compared to corresponding tests of plans A, D, and G, indicated that the 1200-ft extension of Southwest Pier would further improve navigation through the west approach to Southwest Pier about 4 per cent for the average flow and about 28 per cent for the maximum flow. This represented a total improvement over existing conditions (base test) of 25 per cent and 45 per cent for the average and maximum flows, respectively. A comparison of the results of tests of plan B and plan H showed that the combined dredging of sections D and E would improve navigation an average of 9 per cent for the two flows; this represented an additional 5 per cent improvement over conditions without the pier in place (plan A and plan G).

39. Compared with existing conditions, plan H reduced the average side-velocity components perpendicular to lines B-B' and C-C' from 0.46 to 0.28 ft per sec for the average flow and from 0.50 to 0.27 ft per sec for the maximum flow. Maximum side-velocity components were reduced by like amounts. Average and maximum side-velocity components perpendicular to line A-A' (approach to Northwest Pier) were not materially affected, although slight increases were noted.

Tests of Southwest Pier Extended (Perforated)

Description

40. Plans C, F, and I were made to determine the feasibility of

perforating the last 300 ft of the 1200-ft extension to Southwest Pier, with a view to reducing the high velocities at the end of the pier by distributing the velocity over the 300 ft perforated section. The elements of plans C, F, and I are shown on plates 28, 40, and 52, respectively. The conduct of the tests and the elements of the plans were identical with tests of plans B, E, and H, respectively, except for the perforated section of the pier extension.

Results

41. The results of tests of plans C, F, and I are shown on the following plates:

Plan	Test	Description	Plate
C	1	Current directions and velocities	28
C	1	Side-velocity components	29
C	2	Current directions and velocities	30
C	2	Side-velocity components	31
F	1	Current directions and velocities	40
F	1	Side-velocity components	41
F	2	Current directions and velocities	42
F	2	Side-velocity components	43
I	1	Current directions and velocities	52
I	1	Side-velocity components	53
I	2	Current directions and velocities	54
I	2	Side-velocity components	55

A summary of the investigation of side-velocity components perpendicular to the three assumed navigation lines is presented in tables 5 and 6.

42. The improvement for navigation along lines B-B' and C-C' was reduced about 5 per cent by plans C, F, and I as compared to corresponding tests of plans with the solid pier extension. It was noted that for tests of both the high and low flows the perforated section slightly reduced the maximum side-velocity component but also slightly increased the average side-velocity component.

Tests of Realignment of Dredging

Description

43. Tests were made of three plans involving realigning and streamlining the dredging at the entrance to the Michigan Northern Power Canal, with a view to improving the efficiency of the intake. These plans were designed by Mr. L. H. Davis, Consulting Engineer for the Michigan Northern Power Company. In general, plan R

consisted of dredging sections A, B, C and portions of D and E on a smooth alignment and dredging at the existing entrance to the power canal a section 200 ft north and 100 ft south of the harbor line to a depth of 40 ft. Plan S consisted of dredging sections A, B, and C and dredging a straight alignment through sections D and E. The 1200-ft solid extension of Southwest Pier was in place for tests of plan S. Conditions for plan T were the same as for plan S except the amount of dredging east of the outer end of the pier extension was reduced. Elements of plans R, S, and T are shown on plates 56, 60, and 64, respectively.

Results

44. The results of tests of plans R, S, and T are shown on the following plates:

Plan	Test	Description	Plate
R	1	Current directions and velocities	56
R	1	Side-velocity components	57
R	2	Current directions and velocities	58
R	2	Side-velocity components	59
S	1	Current directions and velocities	60
S	1	Side-velocity components	61
S	2	Current directions and velocities	62
S	2	Side-velocity components	63
T	1	Current directions and velocities	64
T	1	Side-velocity components	65
T	2	Current directions and velocities	66
T	2	Side-velocity components	67

A summary of the investigation of side-velocity components perpendicular to the assumed navigation lines is presented in tables 7 and 8.

45. Compared with tests of existing conditions, the results of tests of plan R indicated that navigation through the approach to Southwest Pier would be improved about 25 per cent for the average flow and 23 per cent for the maximum flow. Comparison of the results of plan R with the results of plans A, D, and G indicates that the additional dredging at the end of the existing Southwest Pier would further improve navigating conditions only about 3 to 5 per cent.

46. The results of tests of plan S indicated that streamlining the alignment of the dredging at the entrance to the power canal would not further improve navigating conditions.

47. The results of tests of plan T showed that the amount of dredging required east of the end of the 1200-ft extension of

Southwest Pier in plan S could be reduced without materially affecting navigation.

Tests of Wing-Dike at End of Southwest Pier Extension

Description

48. The general purpose of these plans was to move the area of high velocities observed at the end of the Southwest Pier extension away from the navigation channel. This was to be accomplished by placing at the end of the pier extension a short wing-dike extending southwesterly into the Michigan Northern Power Canal. The controlling factor in the design of the wing-dike was that the length be such that a head loss would not be created in the power canal. The specific purpose of tests of these plans was to determine the maximum length of wing-dike that could be constructed with different alignments of dredging at the entrance to the power canal. Plans U and X were tested with sections A, B, and C dredged. Plans V and W were tested with sections A, B, and C and the western part of section D dredged. Plans Y and Z were tested with sections A, B, and C and parts of sections D and E dredged with a smooth alignment. The elements of plans W, X, Y, and Z are shown on plates 68, 72, 76, and 80, respectively. The elements and results of tests of plans U and V are not shown since the wing-dikes constructed in these plans created a slight head loss in the Michigan Northern Power Canal.

Results

49. The results of the tests of plans W, X, Y, and Z are shown on the following plates:

Plan	Test	Description	Plate
W	1	Current directions and velocities	68
W	1	Side-velocity components	69
W	2	Current directions and velocities	70
W	2	Side-velocity components	71
X	1	Current directions and velocities	72
X	1	Side-velocity components	73
X	2	Current directions and velocities	74
X	2	Side-velocity components	75
Y	1	Current directions and velocities	76
Y	1	Side-velocity components	77
Y	2	Current directions and velocities	78
Y	2	Side-velocity components	79
Z	1	Current directions and velocities	80
Z	1	Side-velocity components	81
Z	2	Current directions and velocities	82
Z	2	Side-velocity components	83

A summary of the investigation of side-velocity components perpendicular to the assumed navigation lines is presented in tables 9 and 10.

50. In general, plan W and plan Y were found to produce the greatest improvement to navigation through the west approach to the Southwest Pier. Compared to the tests of existing conditions, plan W resulted in an over-all improvement of 37 per cent for tests of the average flow and 58 per cent for tests of the maximum flow. Results of plan Y showed an improvement of 36 per cent and 60 per cent for the two flows. A comparison of the results of plan Y and plan Z showed that, with the dredging provided for in these plans, a 150-ft wing-dike on an azimuth of 210 degrees would be more effective than a wing-dike of the same length on an azimuth of 225 degrees. In comparing the results of plans W and X it was noted that by shortening the wing-dike from 150 ft to 75 ft (azimuth of 210 degrees) and by not dredging the western part of section D the improvement to navigation would be reduced only about 7 per cent.

Tests of Possible Future Redistribution of Flow

Description

51. Four tests were made on each of plans A and B with the flow in the Michigan Northern Power Canal reduced and the flow in the Regulating Works increased by a corresponding amount. The purpose of these tests was to determine the changes which would be effected in the direction and magnitude of currents at the end of Northwest Pier by the possible future redistribution of flow between the Michigan Northern Power Canal and the Regulating Works. The distribution of flow for each of these tests is listed below:

Location	Flow in cfs			
	Test 2	Test 3	Test 4	Test 5
Regulating Works	56,000	56,000	56,000	56,000
Michigan Northern Power Canal	33,000	23,000	8,000	0
U. S. Power Canal	12,000	22,000	37,000	45,000
American Locks:				
North Canal	1,200	1,200	1,200	1,200
South Canal	800	800	800	800
Canadian Locks	250	250	250	250
Canadian Power Canal	26,000	26,000	26,000	26,000

Results

52. The results of the tests of the redistribution of flow on plan A and plan B are shown on the following plates:

Plan	Test	Description	Plate
A	3	Current directions and velocities	12
A	3	Side-velocity components	13
A	4	Current directions and velocities	14
A	4	Side-velocity components	15
A	5	Current directions and velocities	16
A	5	Side-velocity components	17
B	3	Current directions and velocities	22
B	3	Side-velocity components	23
B	4	Current directions and velocities	24
B	4	Side-velocity components	25
B	5	Current directions and velocities	26
B	5	Side-velocity components	27

A summary of the investigation of side-velocity components perpendicular to the assumed navigation lines is presented in tables 11 and 12.

53. In analyzing the results of these tests comparisons were made with the results of test 2 - plan A and test 2 - plan B. Observations along line A-A' revealed that navigation to the Northwest Pier would be impaired about 19, 42, and 52 per cent for tests 3, 4, and 5, respectively, for conditions of plan A, and about 6, 23, and 32 per cent for tests 3, 4, and 5, respectively, for conditions of plan B. The results of these tests also indicated that with zero flow (test 5) in the power canal the maximum side-velocities along line A-A' would be increased from 0.94 to 1.21 ft per sec and from 1.08 to 1.27 ft per sec for plan A and plan B, respectively. Average side-velocity components would be increased from 0.62 to 0.94 ft per sec and from 0.71 to 0.94 ft per sec for plan A and plan B, respectively.

54. In analyzing the results presented in tables 11 and 12 it is apparent that the per cent of change (from test 2) of the index along line A-A' for tests of plan A is somewhat larger than for corresponding tests of plan B. Taking as an example the extreme case, this condition is explained by the fact that with zero flow through the Michigan Northern Power Canal (test 5) the index along line A-A' is the same for both plan A and plan B. This shows that for test 5 the 1200-ft extension of Southwest Pier had no effect on flow conditions along line A-A'. However, with the Michigan Northern Power Canal carrying 33,000 cfs (test 2) the extension of Southwest Pier did create a decided change in current directions along line A-A' which resulted in a higher base index for tests of plan B than for tests of plan A, thereby creating a lower per cent of change from the base index for tests of plan B and, by the same token, a higher per cent of change from the base index for tests of plan A.

PART VI: DISCUSSION OF RESULTS

55. The principal conclusions drawn from an analysis of the results of the tests of the various plans follow:

a. Dredging of sections A, B, and C at the upstream entrance to the Michigan Northern Power Canal (see plate 8) would reduce the over-all effective side velocities acting on ships entering the South Canal about 20 per cent for both the average and maximum flow. The additional dredging of sections D and E would further reduce effective side velocities only about 3 per cent for each flow.

b. The 1200-ft extension (solid) of Southwest Pier in conjunction with the dredging of sections A, B, and C (see plate 18) would reduce the effective side velocities acting on ships approaching the South Canal about 21 per cent for the average flow and 40 per cent for the maximum. With the pier extended, additional dredging of sections D and E would further reduce side velocities about 10 per cent for the average flow and 8 per cent for the maximum flow.

c. The 1200-ft pier extension with the outer 300 ft perforated would not be as effective as the 1200-ft solid pier extension.

d. Streamlining the alignment of dredging at the entrance to the power canal to improve the efficiency of the intake would be unnecessary.

e. The placement of a 75-ft wing-dike at the end of the 1200-ft extension (solid) of Southwest Pier in conjunction with dredging at the upstream entrance to the Michigan Northern Power Canal (plan X, see plate 73) would reduce effective side velocities in the westerly approach to South Canal about 30 per cent and 51 per cent for the average and maximum flows, respectively.

f. Reducing the flow in the Michigan Northern Power Canal to zero and increasing the flow in the U. S. Power Canal by a corresponding amount (33,000 cfs) would increase the average side-velocity components along the assumed navigation line to Northwest Pier from 0.62 to 0.94 ft per sec for plan A (see plate 8) and from 0.71 to 0.94 ft per sec for plan B (see plate 18).

56. An analysis and comparison of the results of all model tests indicate, in the opinion of the Experiment Station, that of all plans

studied plan X would provide the most practicable and effective solution of the prototype problem. This plan consisted of the dredging of sections A, B, and C, the installation of a 1200-ft extension (solid) of the Southwest Pier, and the construction of a 75-ft wing-dike on an azimuth of 210 degrees. This plan reduced the maximum side-velocity components acting along the sailing line to the South Canal from 0.82 ft per sec (under existing conditions) to 0.66 ft per sec for the average flow and from 0.92 to 0.63 ft per sec for the maximum flow. A reduction in the over-all side-velocity components of 30 and 51 per cent (average along lines B-B' and C-C') was effected. The 1200-ft pier extension was included in this plan for the principal purpose of providing additional docking space for downbound navigation, and would not necessarily be the most effective or economical structure for reducing side-velocities in the navigation channel.

57. It is desired to mention that preliminary model tests of a less expensive plan, involving the dredging of sections A, B, and C in combination with a wing-dike extending inwardly at an angle from the end of the existing Southwest Pier, indicated that such a plan would probably be more effective than any of the tested plans in reducing the objectionable side-velocities. However, at the request of the District Engineer, this plan was abandoned since it did not provide for the 1200-ft extension of Southwest Pier which was considered necessary as additional docking space for downbound navigation.

58. It is felt that emphasis should be placed upon the effectiveness of an inwardly-projecting wing-dike in reducing maximum side-velocities in the navigation channel, regardless of what other improvement features are installed. The optimum length and azimuth of such a dike would, of course, be dependent upon the other features of the plan selected. A 75-ft wing-dike on an azimuth of 210 degrees was found to function best in conjunction with the other features of plan X, while a different length and angle would be best in conjunction with some other plan. In the event that the 1200-ft extension is not added to Southwest Pier, a substantial reduction in the objectionable side-velocities in the navigation channel could be effected by the addition of a short wing-dike attached to the existing end of Southwest Pier. A few additional model tests would be required to determine the optimum length and angle of such a dike.

PART VII: LIAISON AND PERSONNEL

Liaison

59. At the direction of the Chief of Engineers, details pertaining to the construction and operation of the model were obtained directly from the District Engineer, Detroit District. Accordingly, close liaison was maintained between the Detroit District Office and the Experiment Station during the course of the model study. An engineer from the Experiment Station inspected the prototype problem area prior to the undertaking of the study, and representatives of the District and Division Offices inspected the model from time to time. Semimonthly progress reports were submitted to the District Engineer during the course of the study, while special reports giving complete analyses of the various phases of the model study were submitted immediately after completion of the model tests involved. Copies of all correspondence were furnished the Chief of Engineers. Conferences were held at the Experiment Station at various times between representatives of the Great Lakes Division, the Detroit District, the Michigan Northern Power Canal, and the Experiment Station.

Personnel

60. The St. Marys River model study was accomplished in the Flood Control and Navigation Section of the Waterways Division of the U. S. Waterways Experiment Station. Mr. G. H. Matthes, Head Engineer, was Director of the Experiment Station and First Lieutenant J. B. Tiffany, Jr., C. E., was Executive Assistant to the Director, during the prosecution of the model study. Chief of the Waterways Division was Captain G. B. Fenwick, C. E., and Chief of the Flood Control and Navigation Section was Mr. E. B. Lipscomb, Associate Engineer. The project engineer in direct charge of the model study was Mr. B. C. Keene, Assistant Engineer. Mr. Keene was assisted in the operation of the model study by Mr. R. I. Bostwick, Senior Engineering Aide, Mr. D. A. Crouse, Engineering Aide, and Mrs. Edna E. Barlow, Junior Engineering Aide.

TABLES

Table 1

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Dredging Under Specification No. N-391, Present S. W. Pier Unchanged

Test 1

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	0.25	0.19	1200	228	
	B-B'	0.62	0.38	1400	532	
	C-C'	1.02	0.55	1400	770	
A	A-A'**	0.29	0.20	1600	320	-40
	B-B'	0.48	0.23	1800	414	22
	C-C'	0.86	0.35	1800	630	18
D	A-A'**	0.29	0.20	1600	320	-40
	B-B'	0.45	0.23	1800	414	22
	C-C'	0.79	0.34	1800	612	21
G	A-A'**	0.37	0.22	1600	352	-54
	B-B'	0.43	0.22	1800	396	26
	C-C'	0.75	0.32	1800	576	25

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 2

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Dredging Under Specification No. N-391, Present S. W. Pier Unchanged

Test 2

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	1.01	0.71	1800	1278	
	B-B'	0.73	0.46	1400	644	
	C-C'	1.11	0.55	1600	880	
A	A-A'**	0.94	0.62	1600	992	22
	B-B'	0.60	0.34	1600	544	16
	C-C'	0.90	0.45	1600	720	18
D	A-A'**	0.84	0.63	1600	1008	21
	B-B'	0.56	0.34	1600	544	16
	C-C'	0.83	0.41	1800	738	16
G	A-A'**	0.86	0.64	1600	1024	20
	B-B'	0.56	0.33	1600	528	18
	C-C'	0.86	0.40	1800	720	18

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

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TABLE 3

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Southwest Pier Extended (Solid)

Test 1

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	0.25	0.19	1200	228	
	B-B'	0.62	0.38	1400	532	
	C-C'	1.02	0.55	1400	770	
B	A-A'**	0.32	0.23	1600	368	-61
	B-B'	0.49	0.26	1600	416	22
	C-C'	0.96	0.39	1600	624	19
E	A-A'**	0.39	0.24	1600	384	-68
	B-B'	0.47	0.25	1600	400	25
	C-C'	0.82	0.36	1600	576	25
H	A-A'**	0.40	0.27	1600	432	-89
	B-B'	0.46	0.23	1600	368	31
	C-C'	0.78	0.33	1600	528	31

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 4

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Southwest Pier Extended (Solid)

Test 2

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	1.01	0.71	1800	1278	
	B-B'	0.73	0.46	1400	644	
	C-C'	1.11	0.55	1600	880	
B	A-A'**	1.08	0.71	1600	1136	11
	B-B'	0.47	0.24	1400	336	48
	C-C'	1.02	0.37	1600	592	33
E	A-A'**	1.02	0.71	1600	1136	11
	B-B'	0.44	0.22	1400	308	52
	C-C'	0.93	0.34	1600	544	38
H	A-A'**	1.10	0.71	1600	1136	11
	B-B'	0.45	0.21	1400	294	54
	C-C'	0.83	0.32	1600	512	42

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 5

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Southwest Pier Extended (Perforated)

Test 1

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	0.25	0.19	1200	228	
	B-B'	0.62	0.38	1400	532	
	C-C'	1.02	0.55	1400	770	
C	A-A'**	0.29	0.23	1600	368	-61
	B-B'	0.54	0.31	1600	496	7
	C-C'	0.86	0.41	1600	656	15
F	A-A'**	0.28	0.21	1600	336	-47
	B-B'	0.46	0.26	1600	416	22
	C-C'	0.75	0.38	1600	608	21
I	A-A'**	0.35	0.24	1600	384	-68
	B-B'	0.39	0.25	1600	400	25
	C-C'	0.70	0.36	1600	576	25

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 6

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Southwest Pier Extended (Perforated)

Test 2

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	1.01	0.71	1800	1278	
	B-B'	0.73	0.46	1400	644	
	C-C'	1.11	0.55	1600	880	
C	A-A'**	0.97	0.68	1600	1088	15
	B-B'	0.52	0.26	1400	364	43
	C-C'	0.82	0.45	1400	630	28
F	A-A'**	0.96	0.68	1600	1088	15
	B-B'	0.49	0.24	1400	336	48
	C-C'	0.77	0.42	1400	588	33
I	A-A'**	0.97	0.66	1600	1056	17
	B-B'	0.41	0.24	1400	336	48
	C-C'	0.76	0.40	1400	560	36

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 7

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Realignment of Dredging

Test 1

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	0.25	0.19	1200	228	
	B-B'	0.62	0.38	1400	532	
	C-C'	1.02	0.55	1400	770	
R	A-A'**	0.26	0.19	1600	304	-33
	B-B'	0.47	0.25	1800	450	15
	C-C'	0.59	0.28	1800	504	35
S	A-A'**	0.43	0.24	1600	384	-68
	B-B'	0.51	0.27	1800	486	9
	C-C'	0.85	0.33	1800	594	23
T	A-A'**	0.37	0.22	1600	352	-54
	B-B'	0.56	0.30	1600	480	10
	C-C'	0.87	0.38	1600	608	21

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 8

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Realignment of Dredging

Test 2

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	1.01	0.71	1800	1278	
	B-B'	0.73	0.46	1400	644	
	C-C'	1.11	0.55	1600	880	
R	A-A'**	0.87	0.64	1600	1024	20
	B-B'	0.57	0.33	1600	528	18
	C-C'	0.73	0.35	1800	630	28
S	A-A'**	0.97	0.68	1600	1088	15
	B-B'	0.52	0.25	1400	350	46
	C-C'	0.86	0.34	1600	544	38
T	A-A'**	1.03	0.71	1600	1136	11
	B-B'	0.49	0.26	1400	364	43
	C-C'	0.84	0.35	1600	560	36

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 9

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Wing-Dike at End of Southwest Pier Extension

Test 1

Plan	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	0.25	0.19	1200	228	
	B-B'	0.62	0.38	1400	532	
	C-C'	1.02	0.55	1400	770	
W	A-A'**	0.36	0.25	1400	350	-54
	B-B'	0.45	0.21	1600	336	37
	C-C'	0.78	0.31	1600	496	36
X	A-A'**	0.35	0.27	1400	378	-66
	B-B'	0.45	0.26	1400	364	32
	C-C'	0.87	0.40	1400	560	27
Y	A-A'**	0.37	0.32	1400	448	-96
	B-B'	0.42	0.26	1400	364	32
	C-C'	0.68	0.33	1400	462	40
Z	A-A'**	0.45	0.31	1400	434	-90
	B-B'	0.54	0.27	1600	432	19
	C-C'	0.75	0.33	1600	528	31

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000
** Curve extends upstream only to line 4400 W

TABLE 10

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Wing-Dike at End of Southwest Pier Extension

Test 2

Plan	Plan	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test of Existing Conditions
Existing Conditions	A-A'**	1.01	0.71	1800	1278	
	B-B'	0.73	0.46	1400	644	
	C-C'	1.11	0.55	1600	880	
W	A-A'**	0.97	0.75	1400	1050	18
	B-B'	0.41	0.22	1000	220	66
	C-C'	0.73	0.37	1200	444	50
X	A-A'**	0.98	0.79	1400	1106	13
	B-B'	0.45	0.25	1000	250	61
	C-C'	0.81	0.37	1400	518	41
Y	A-A'**	1.02	0.79	1400	1106	13
	B-B'	0.36	0.19	1000	190	70
	C-C'	0.77	0.32	1400	448	49
Z	A-A'**	1.01	0.81	1400	1134	11
	B-B'	0.38	0.21	1000	210	67
	C-C'	0.74	0.33	1400	462	48

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 11

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Redistribution of Flow

Plan A

Plan	Test	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test 2 Plan A
A	2	A-A'**	0.94	0.62	1600	992	
		B-B'	0.60	0.34	1600	544	
		C-C'	0.90	0.45	1600	720	
A	3	A-A'**	1.00	0.74	1600	1184	-19
		B-B'	0.53	0.28	1600	448	18
		C-C'	0.78	0.38	1600	608	16
A	4	A-A'**	1.10	0.88	1600	1408	-42
		B-B'	0.43	0.29	800	232	57
		C-C'	0.60	0.31	800	248	66
A	5	A-A'**	1.21	0.94	1600	1504	-52
		B-B'	0.00	0.00	0	0	
		C-C'	0.00	0.00	0	0	

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

TABLE 12

Model Study of the St. Marys River, Mich.
SIDE-VELOCITY COMPONENT INVESTIGATION
Tests of Redistribution of Flow

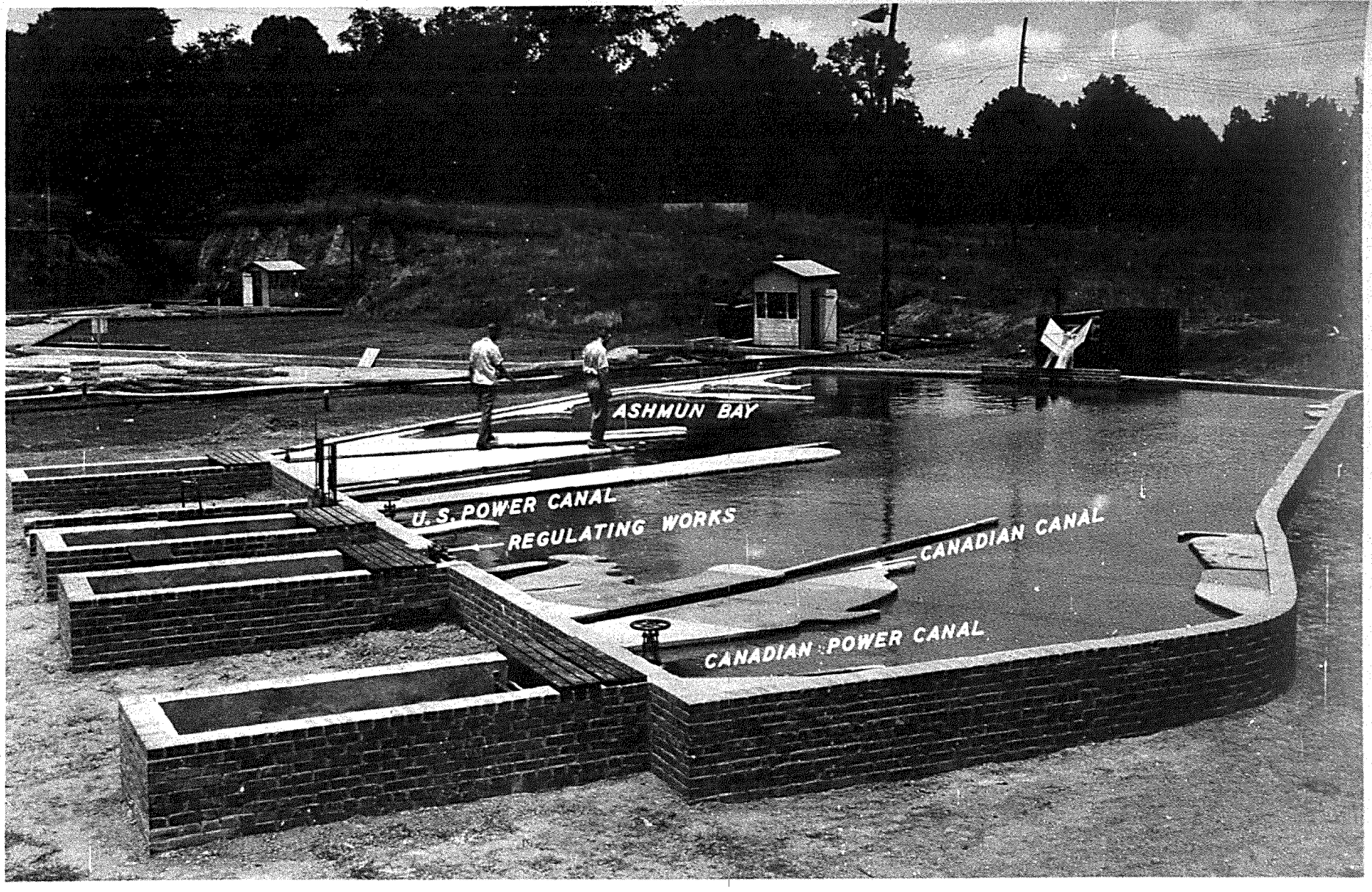
Plan B

Plan	Test	Line	Maximum Side-Velocity Component Perpendicular to Line (ft per sec)	Average Side-Velocity Component Perpendicular to Line (ft per sec)	Distance along Line over which Perpendicular Side-Velocity Component Exists (feet)	Index of Total Side-Velocity Components Perpendicular to Line *	Per Cent Change of Index from Index for Test 2 Plan B
B	2	A-A'**	1.08	0.71	1600	1136	
		B-B'	0.47	0.24	1400	336	
		C-C'	1.02	0.37	1600	592	
B	3	A-A'**	1.03	0.75	1600	1200	- 6
		B-B'	0.42	0.20	800	160	52
		C-C'	0.81	0.36	1000	360	39
B	4	A-A'**	1.13	0.87	1600	1392	-23
		B-B'	0.09	0.04	600	24	93
		C-C'	0.51	0.24	800	192	68
B	5	A-A'**	1.27	0.94	1600	1504	-32
		B-B'	0.00	0.00	0	0	
		C-C'	0.00	0.00	0	0	

* Use as index — side-velocity component perpendicular to line of 1 ft per sec acting over length of 1000 = 1000

** Curve extends upstream only to line 4400 W

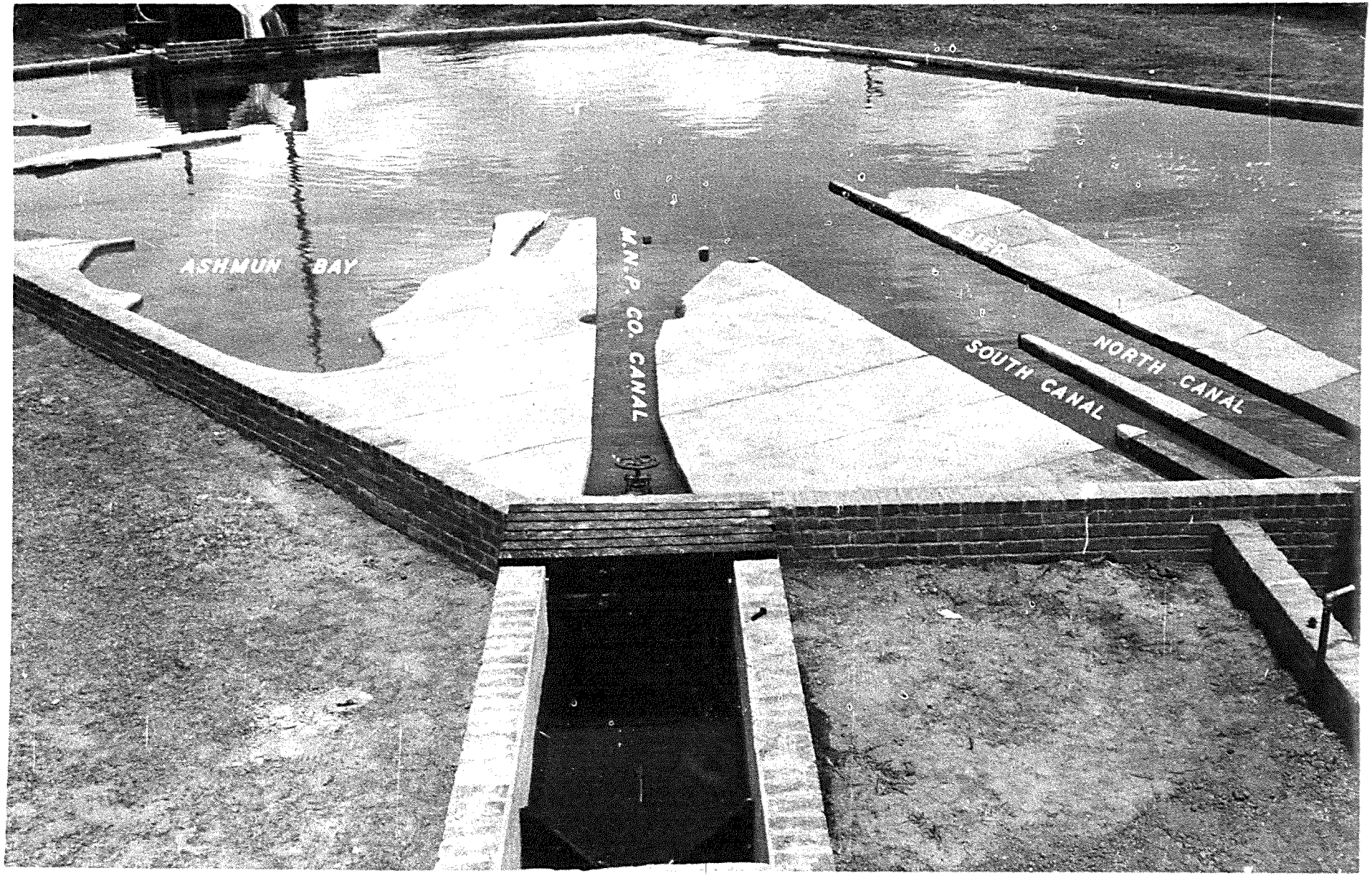
PHOTOGRAPHS



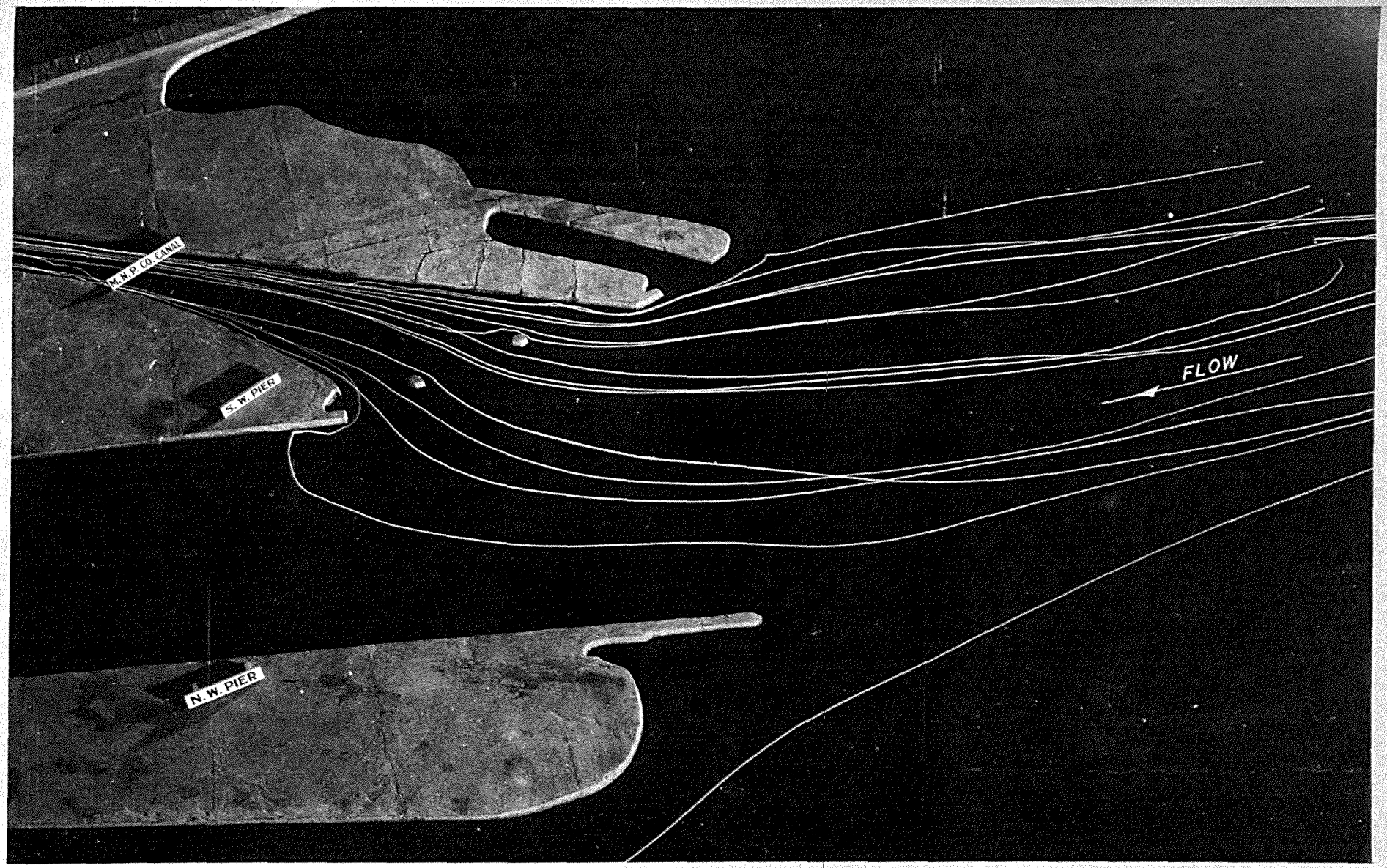
PHOTOGRAPH 1

GENERAL VIEW OF THE MODEL

PHOTOGRAPH 2

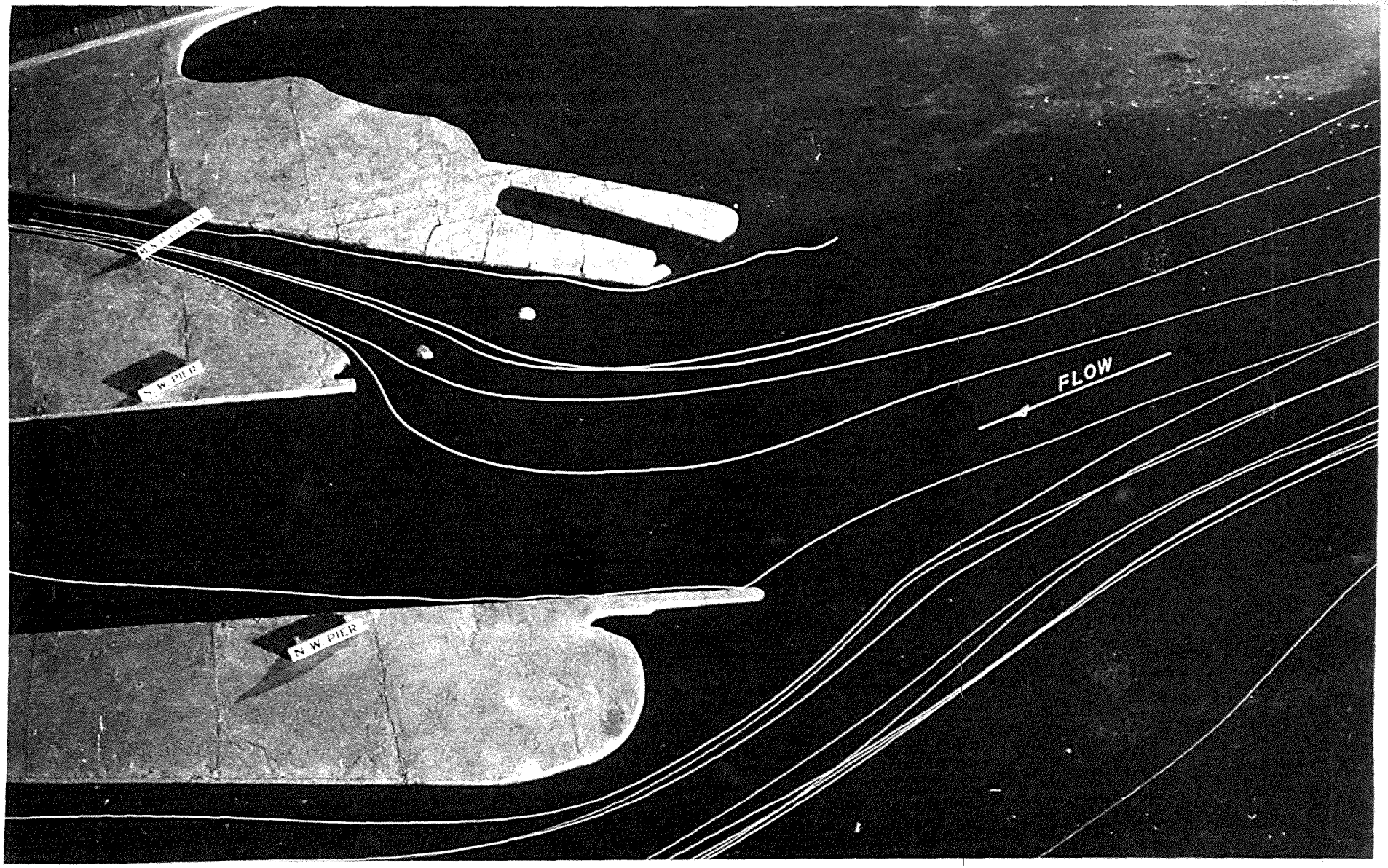


VIEW OF THE PROBLEM AREA



PHOTOGRAPH 3

FLOW PATTERN OF VERIFICATION TEST
DISCHARGE 59,686 C F S WATER-SURFACE ELEV. 602.75



FLOW PATTERN OF VERIFICATION TEST
DISCHARGE 120,663 CFS WATER-SURFACE ELEV. 602.85

PLATES

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

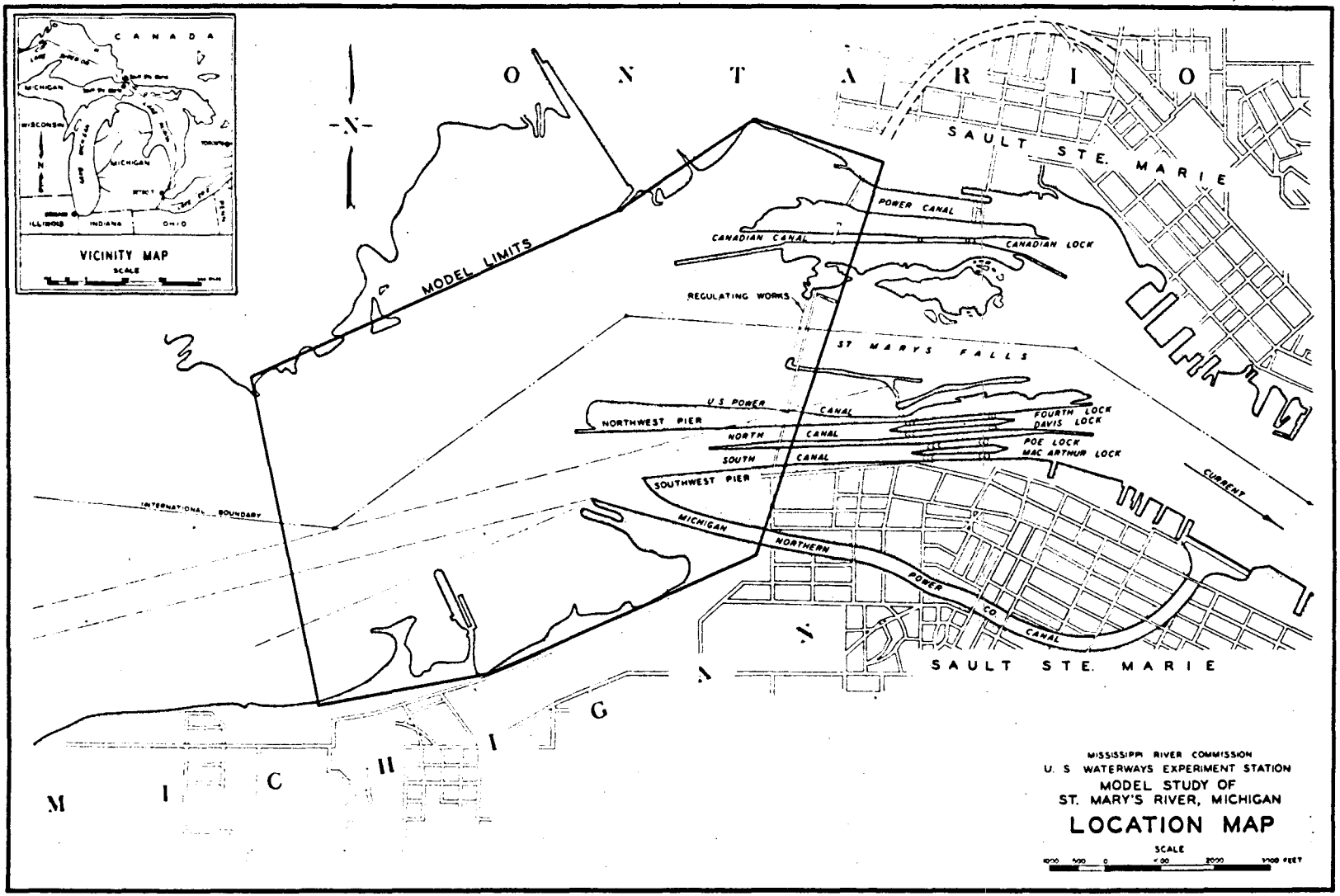
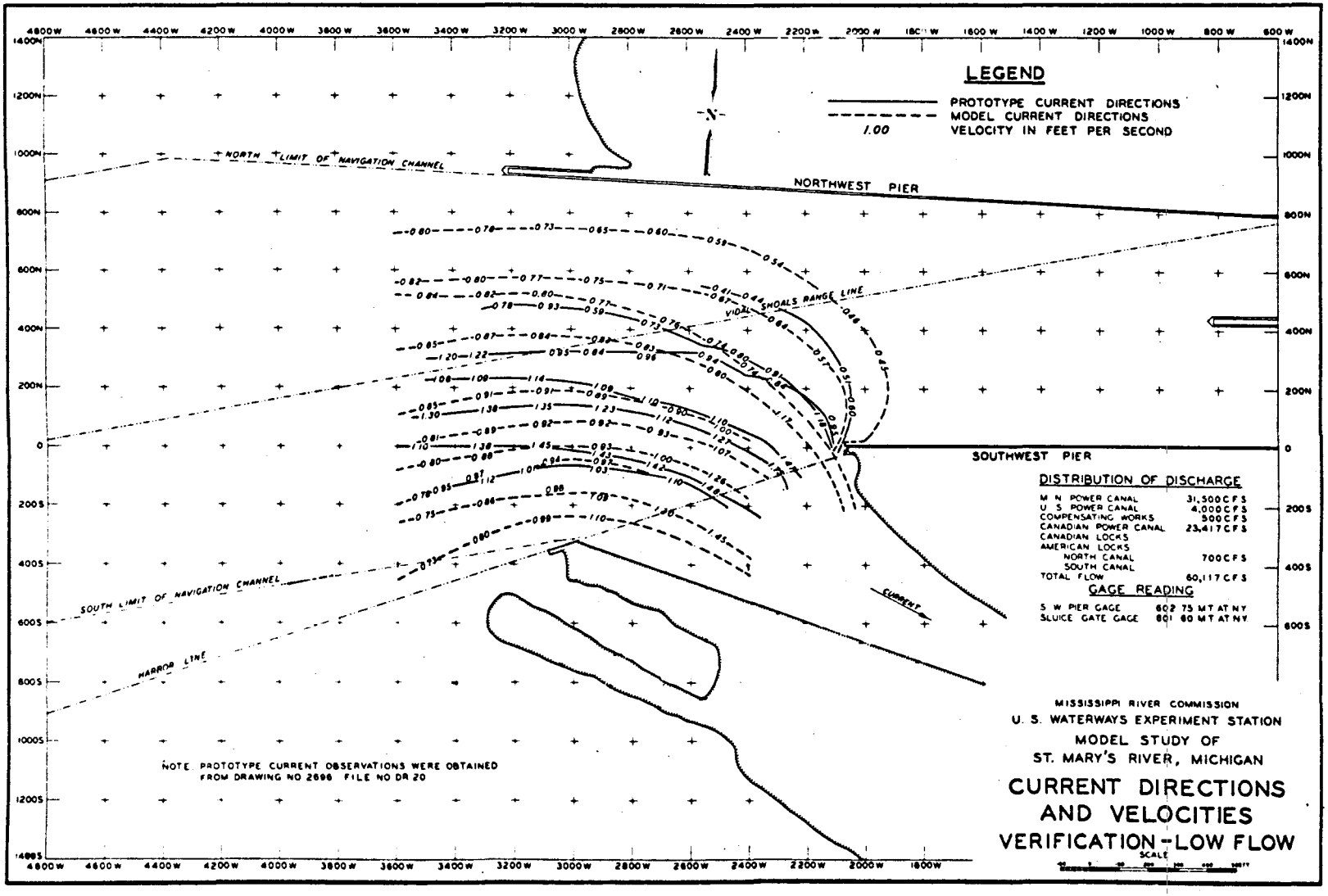


PLATE 1

PLATE 2

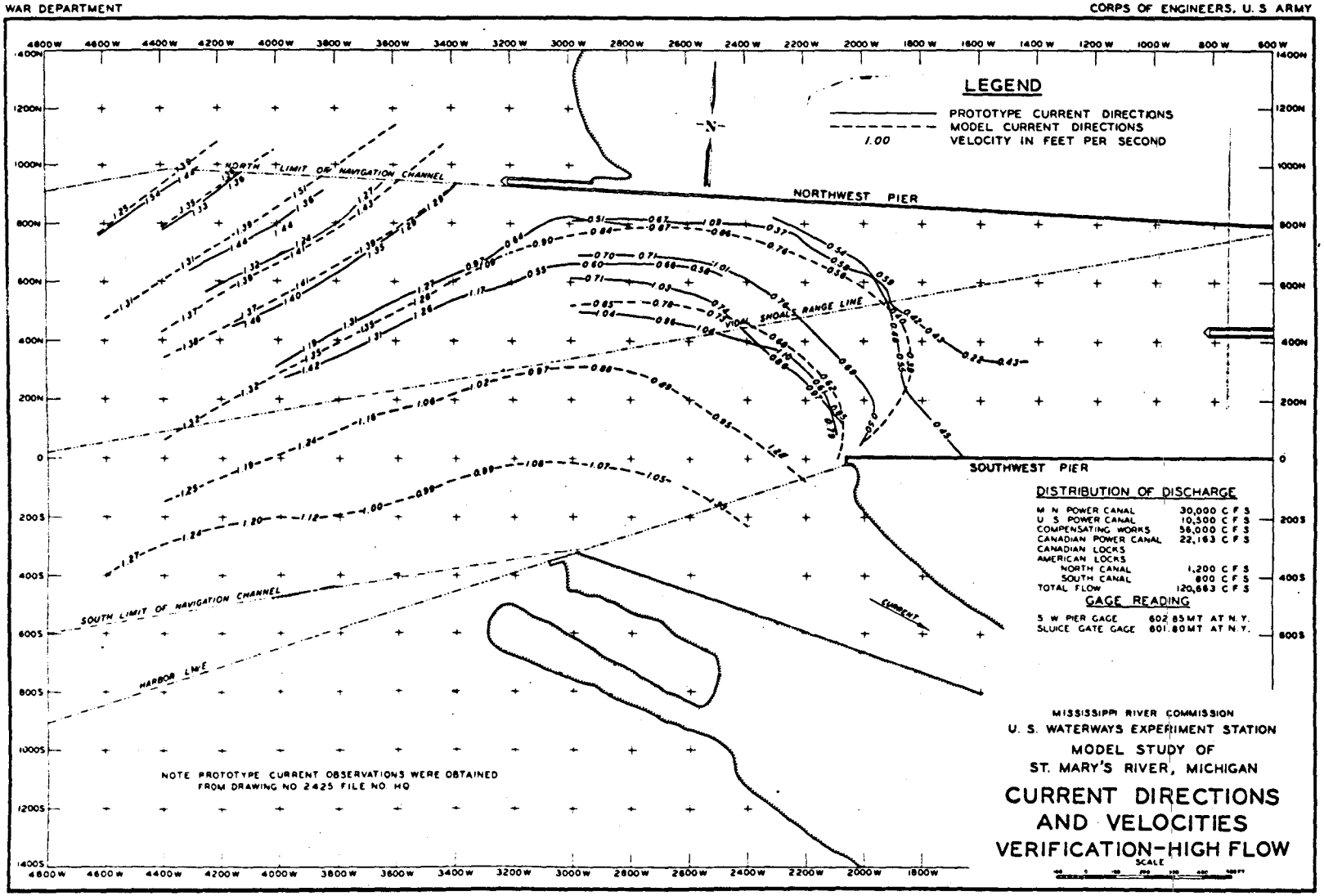
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES VERIFICATION-HIGH FLOW

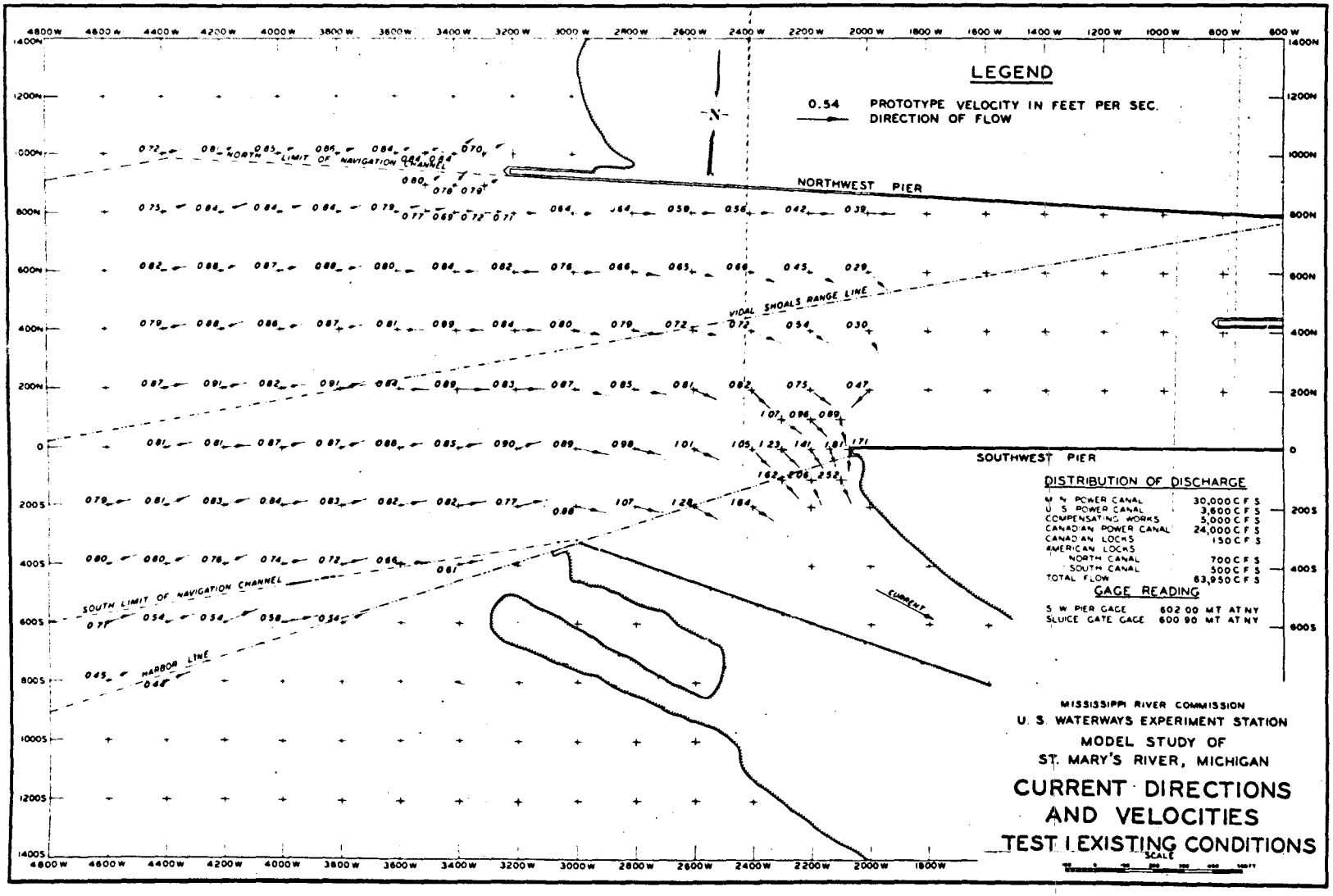
SCALE

PLATE 3

PLATE 4

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

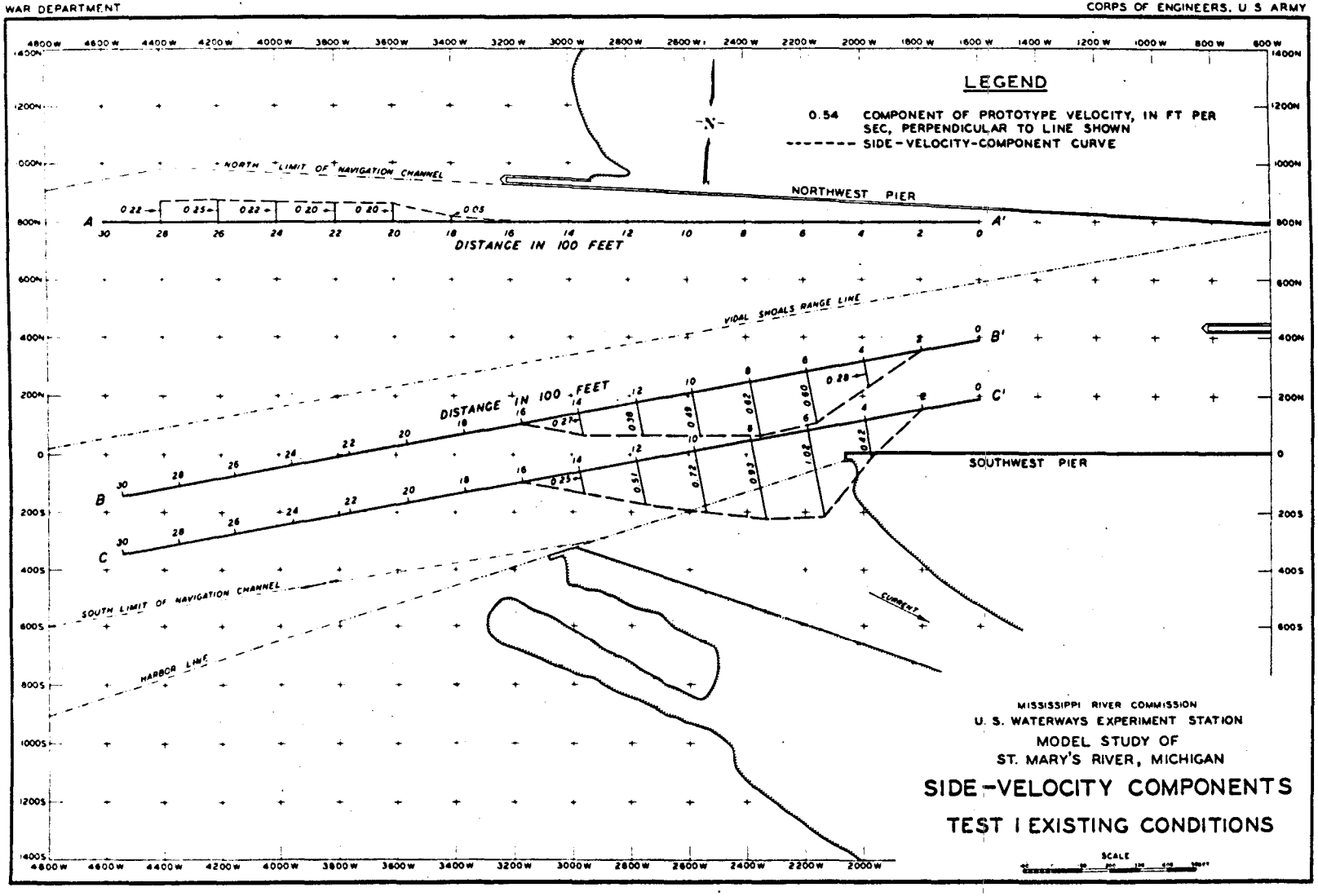
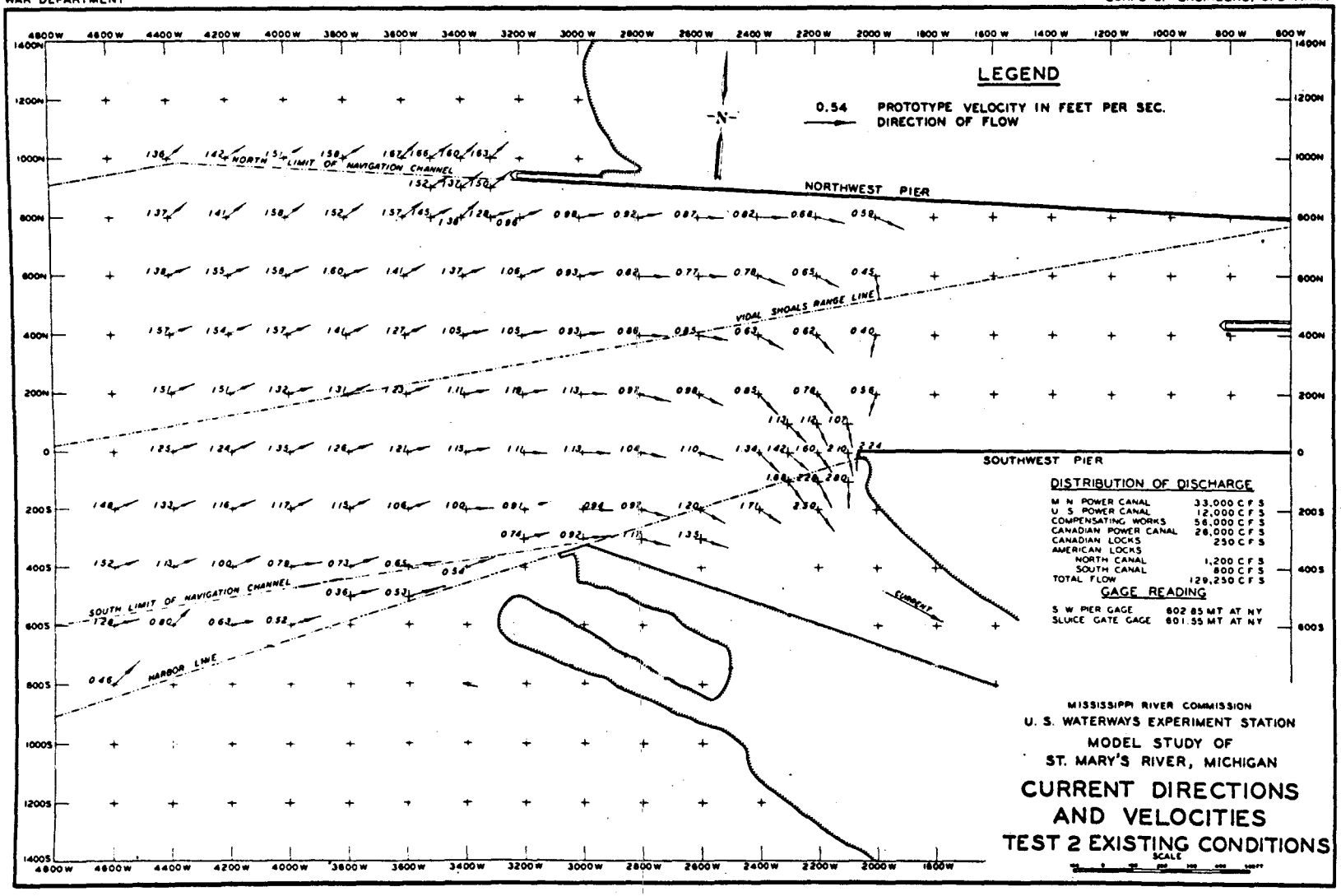


PLATE 5

PLATE 6

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

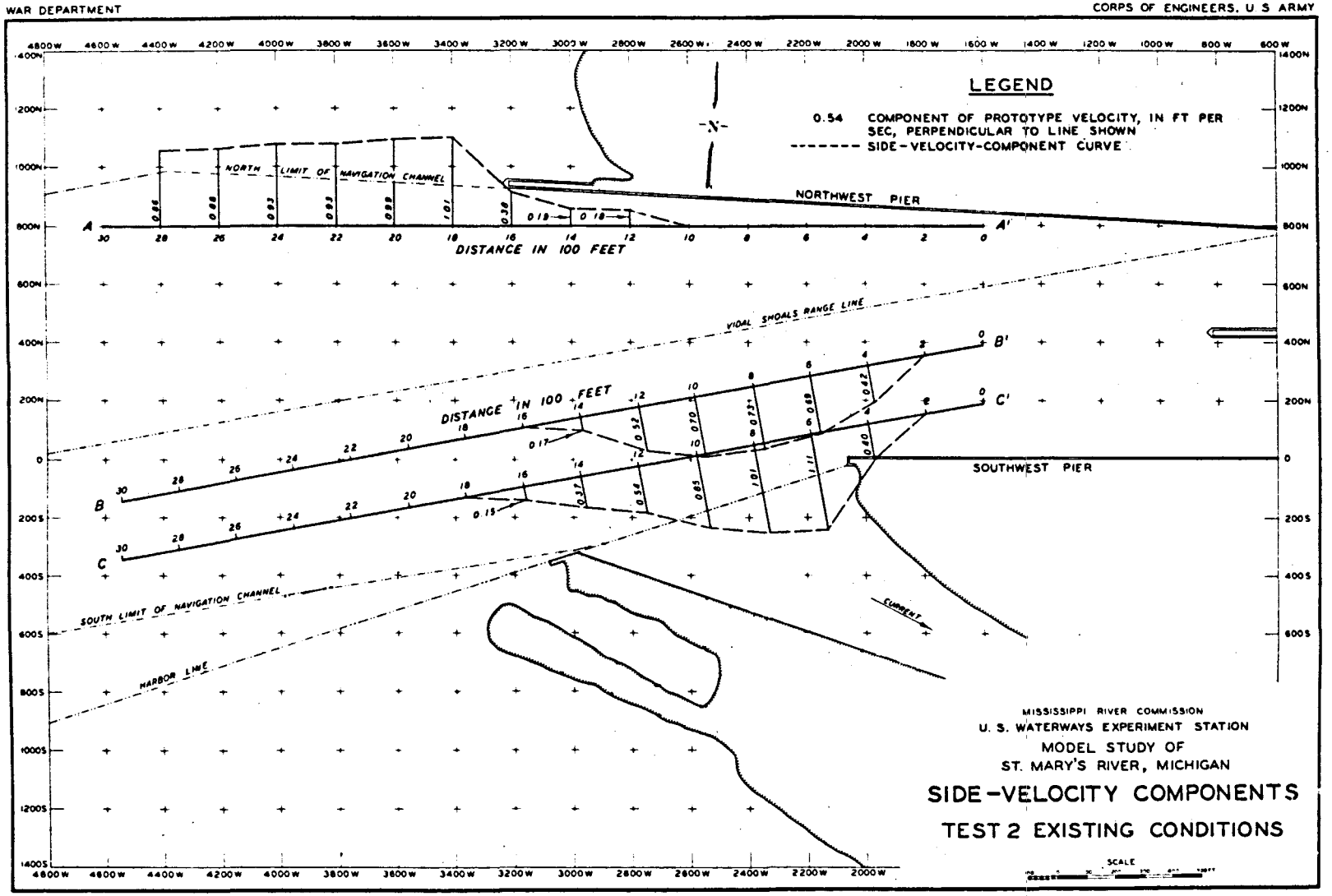
CURRENT DIRECTIONS AND VELOCITIES

TEST 2 EXISTING CONDITIONS

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

SIDE-VELOCITY COMPONENTS

TEST 2 EXISTING CONDITIONS

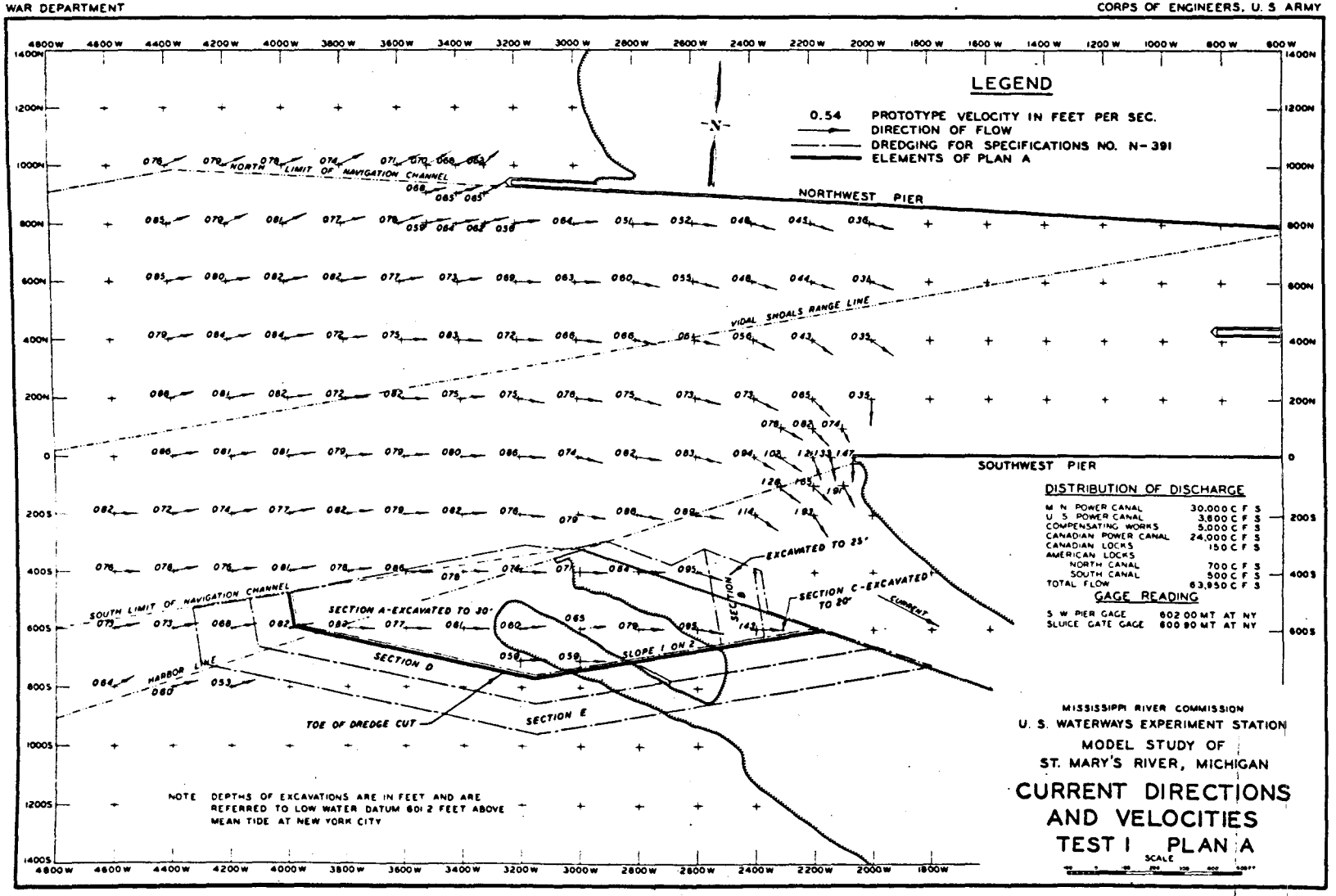
SCALE

PLATE 7

PLATE 8

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

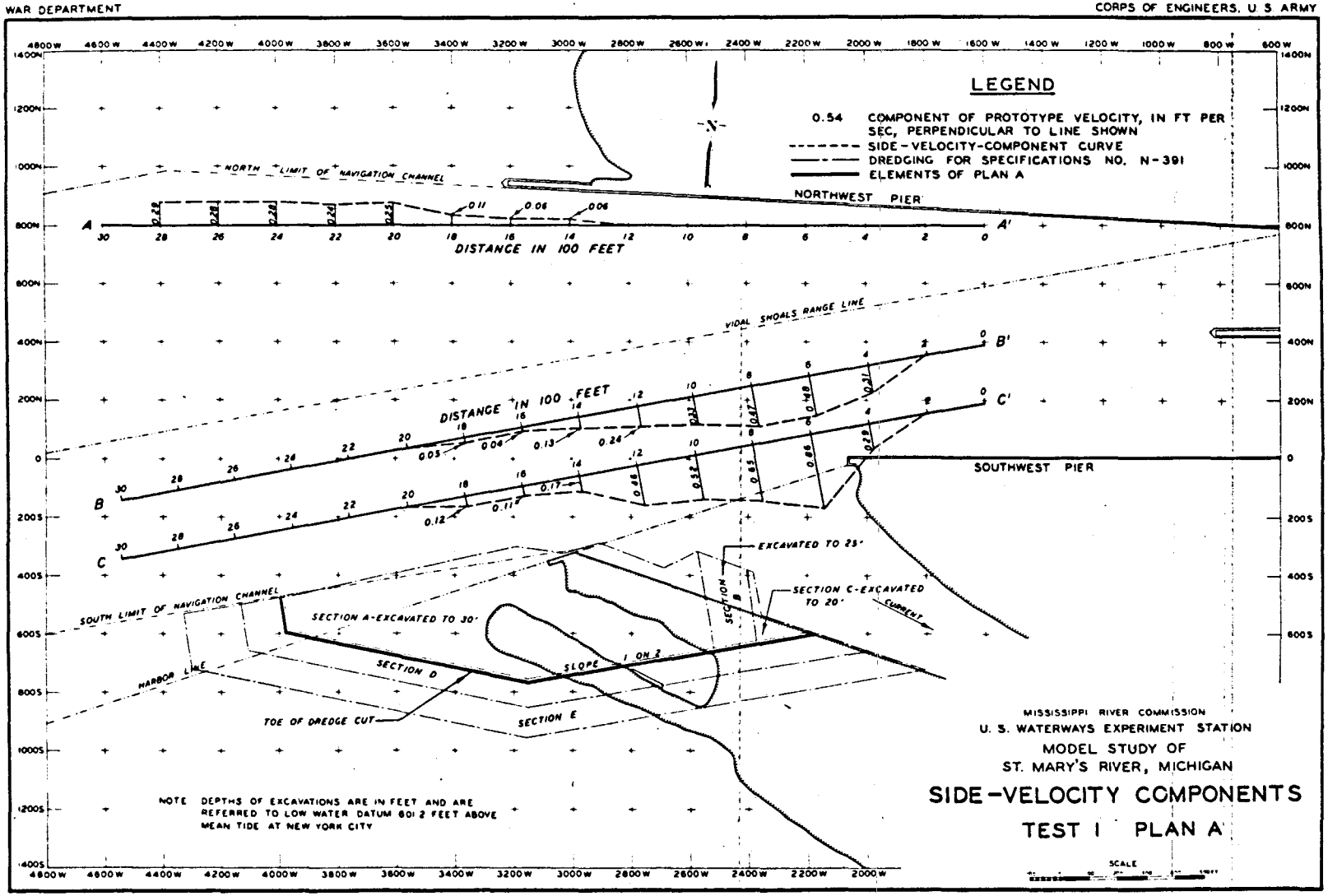
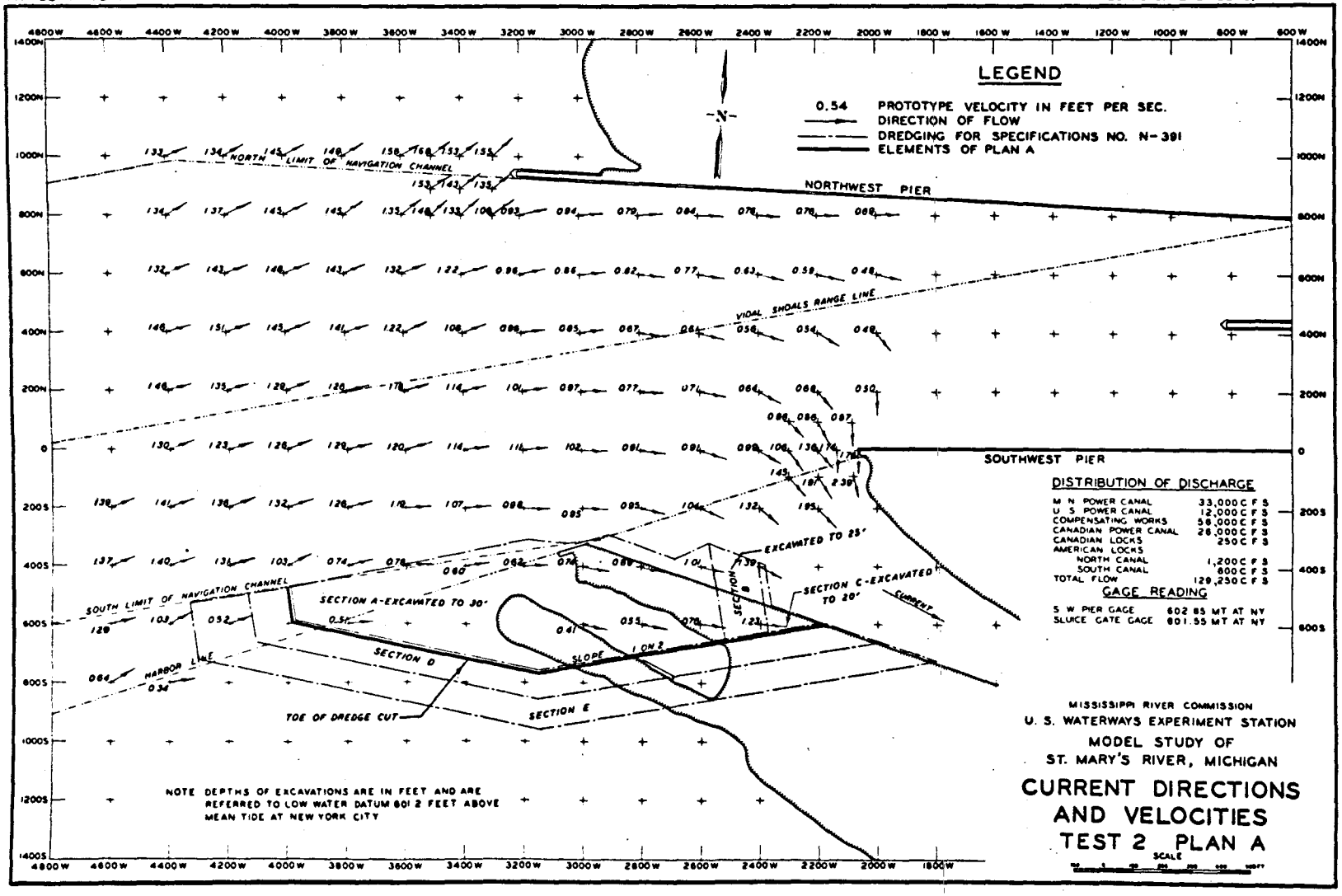


PLATE 9

PLATE 10

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

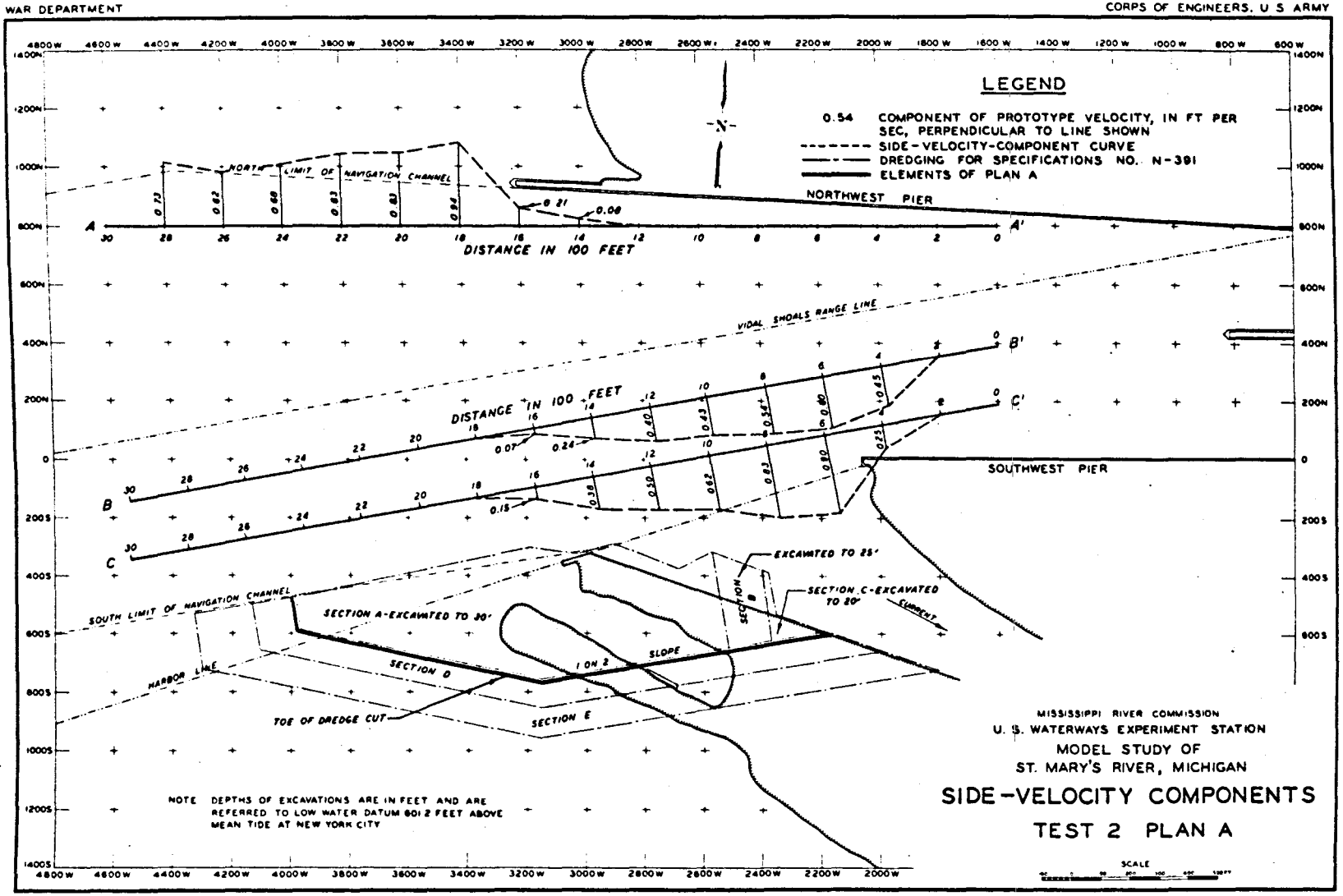
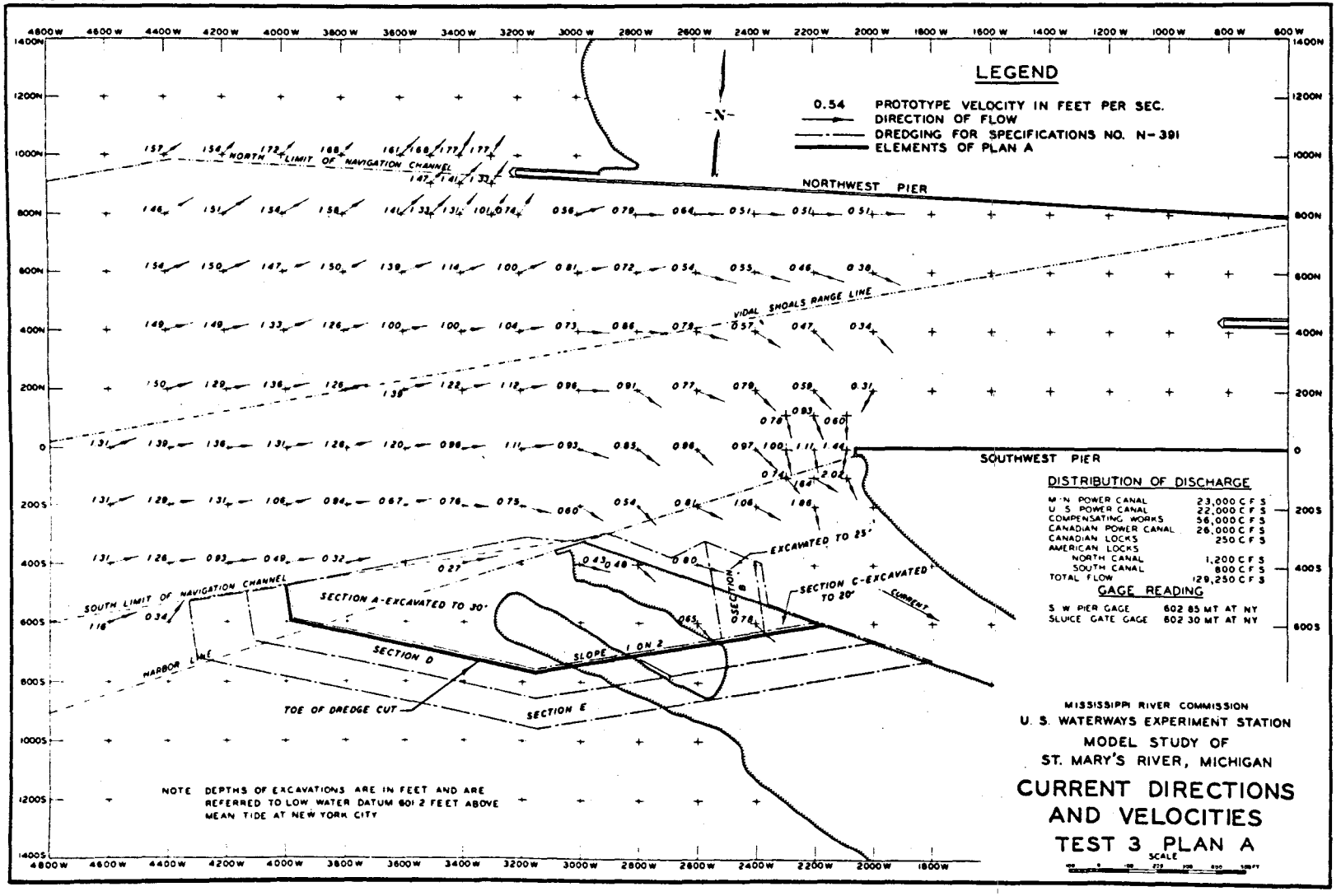


PLATE 11

PLATE 12

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST 3 PLAN A

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

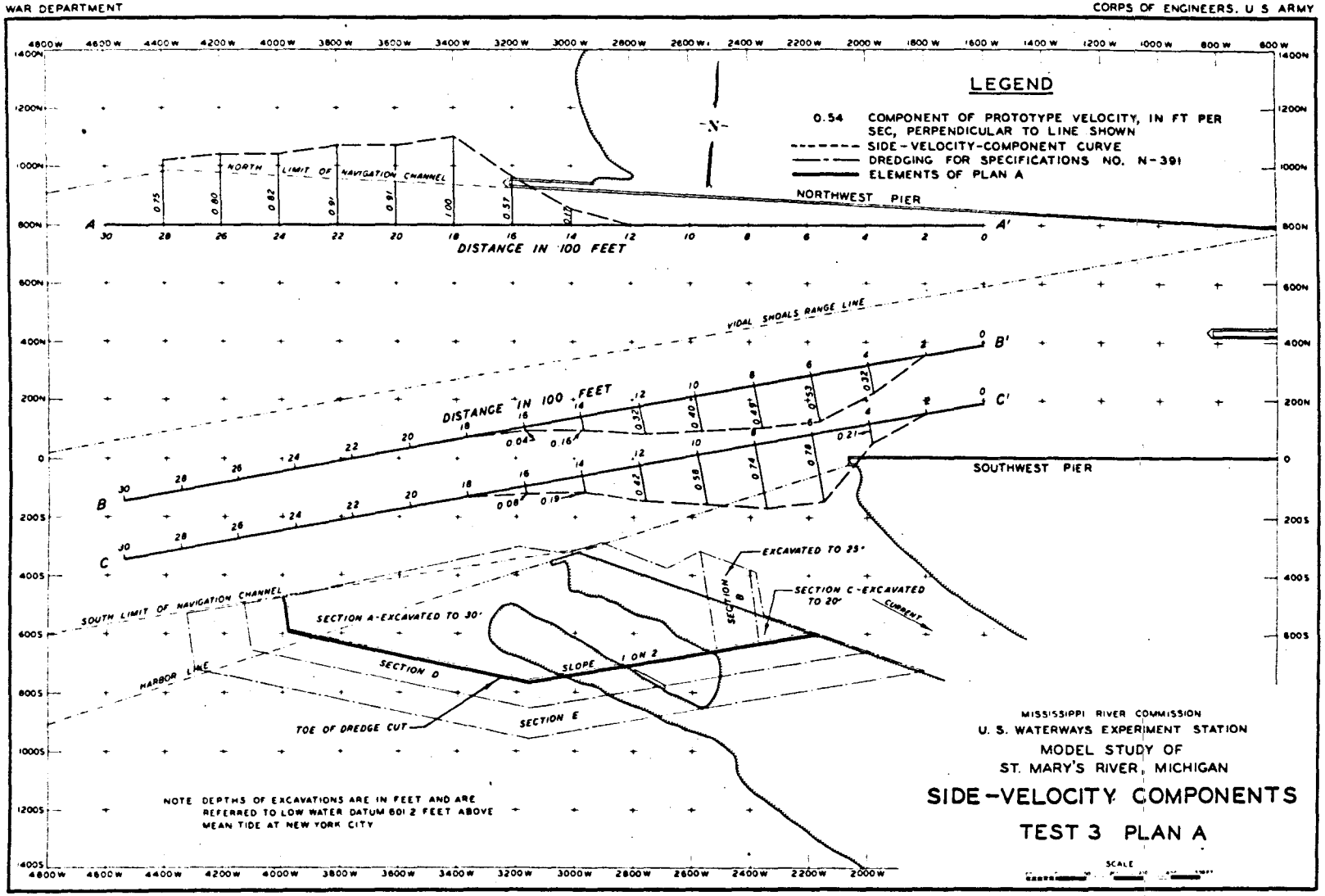
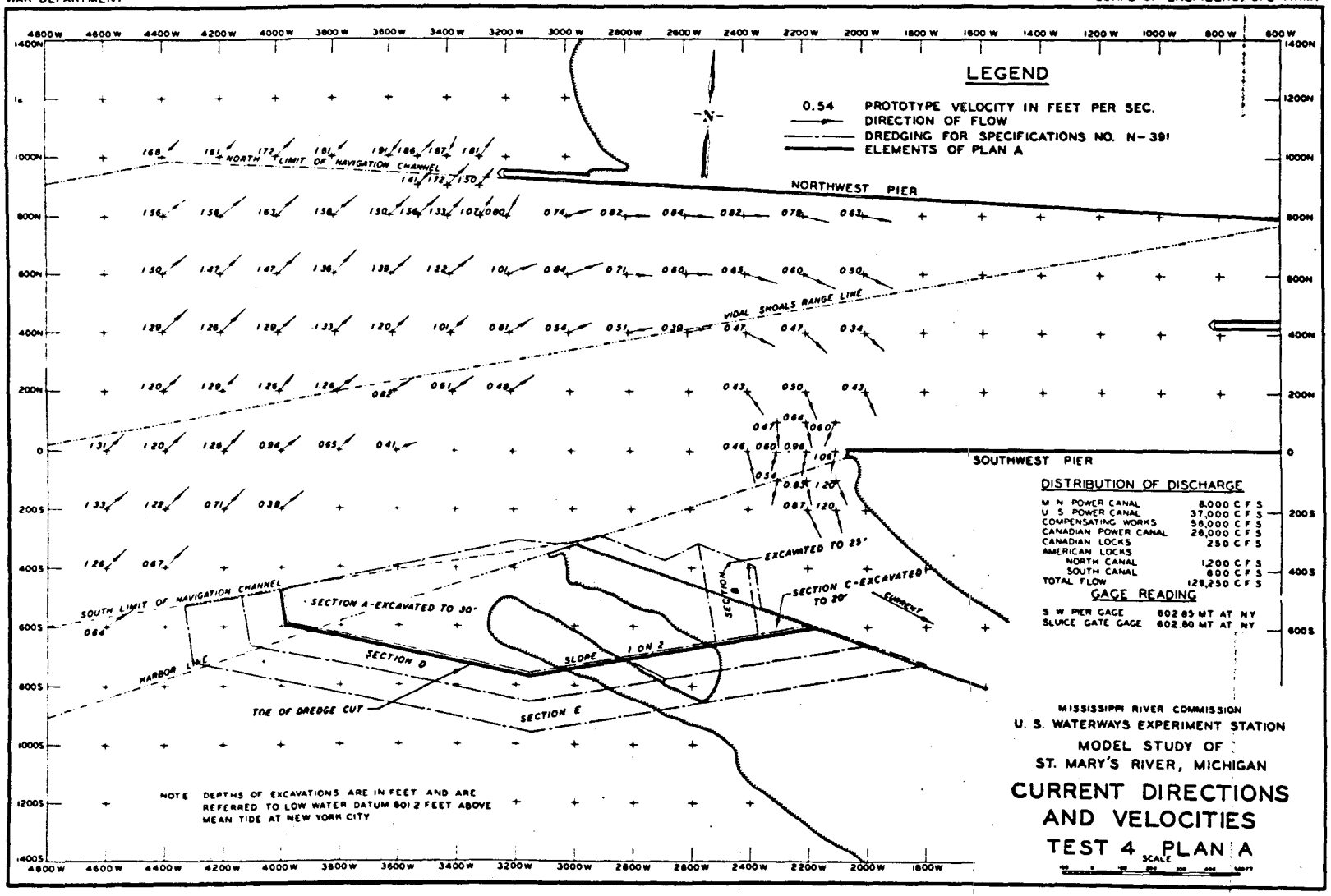


PLATE 13

PLATE 14

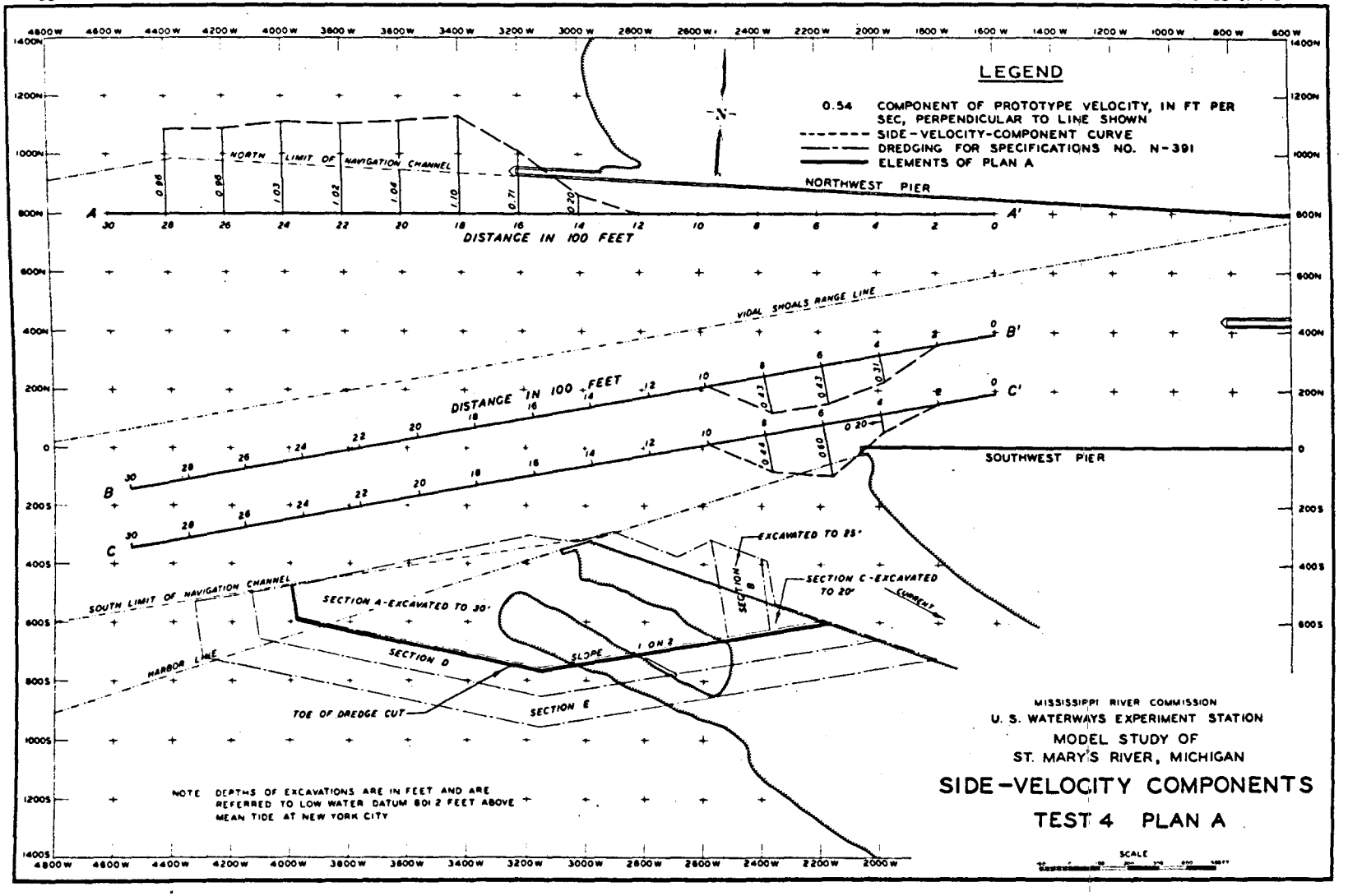
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

SIDE-VELOCITY COMPONENTS

TEST 4 PLAN A

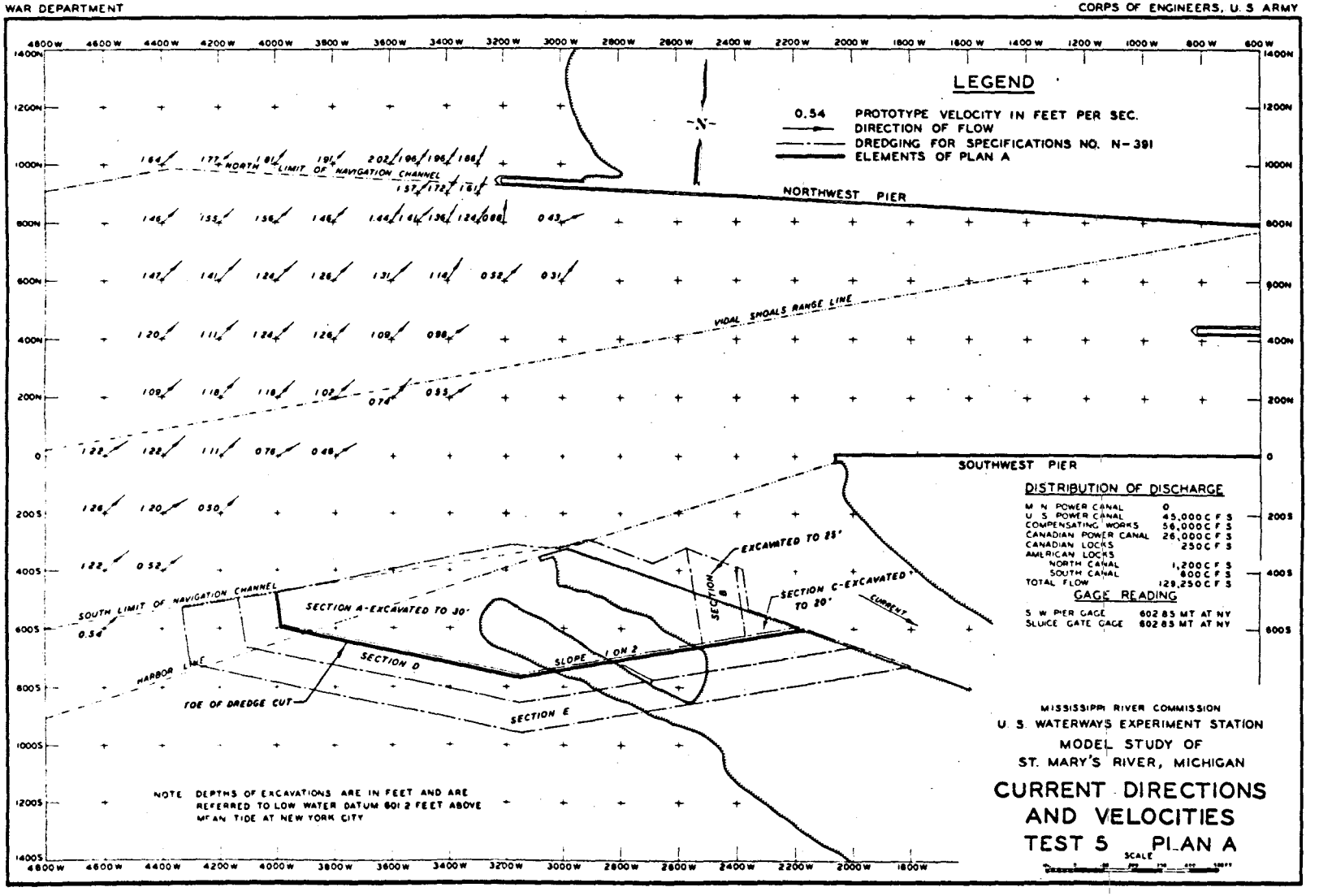
SCALE

PLATE 15

PLATE 16

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST 5 PLAN A

WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

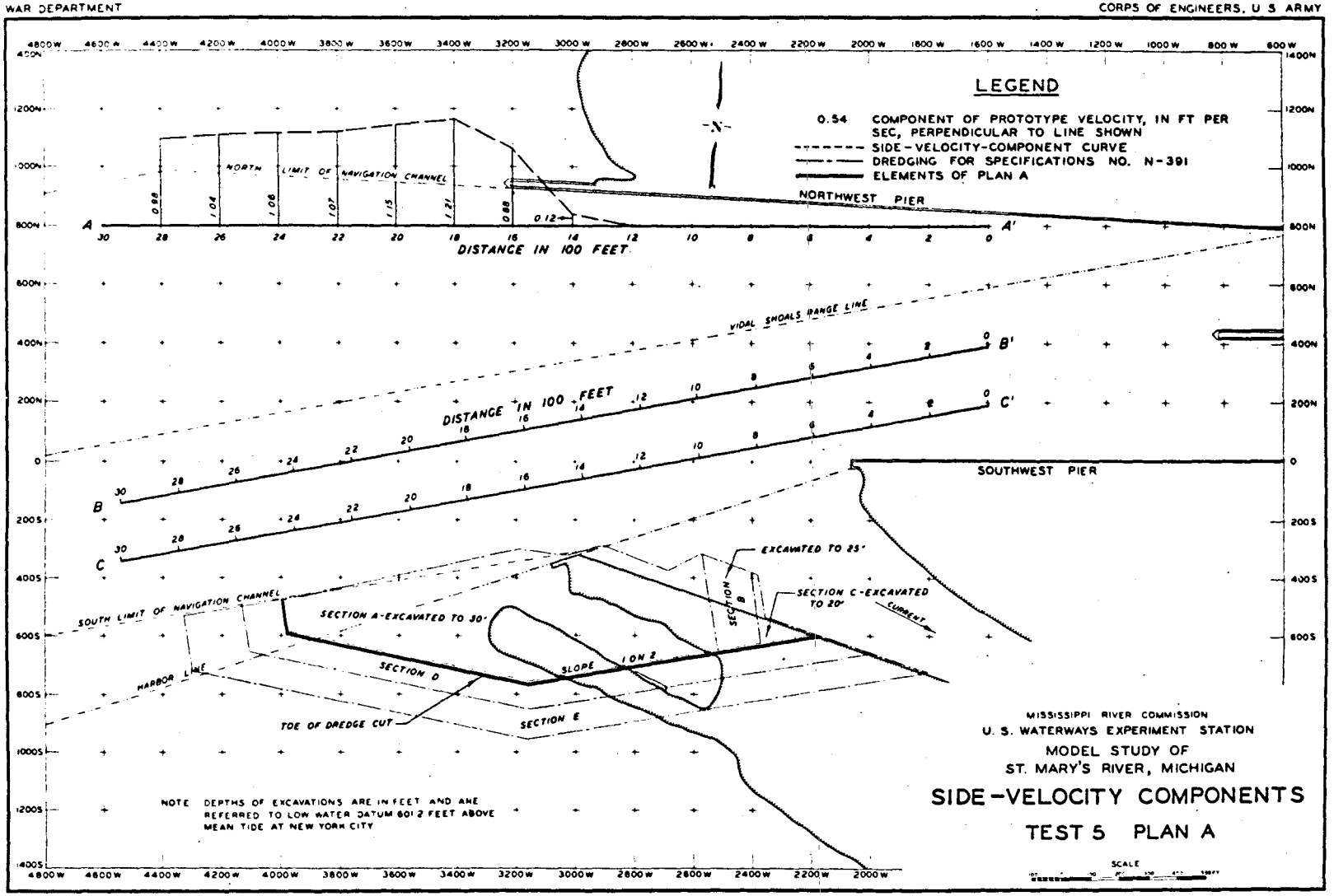
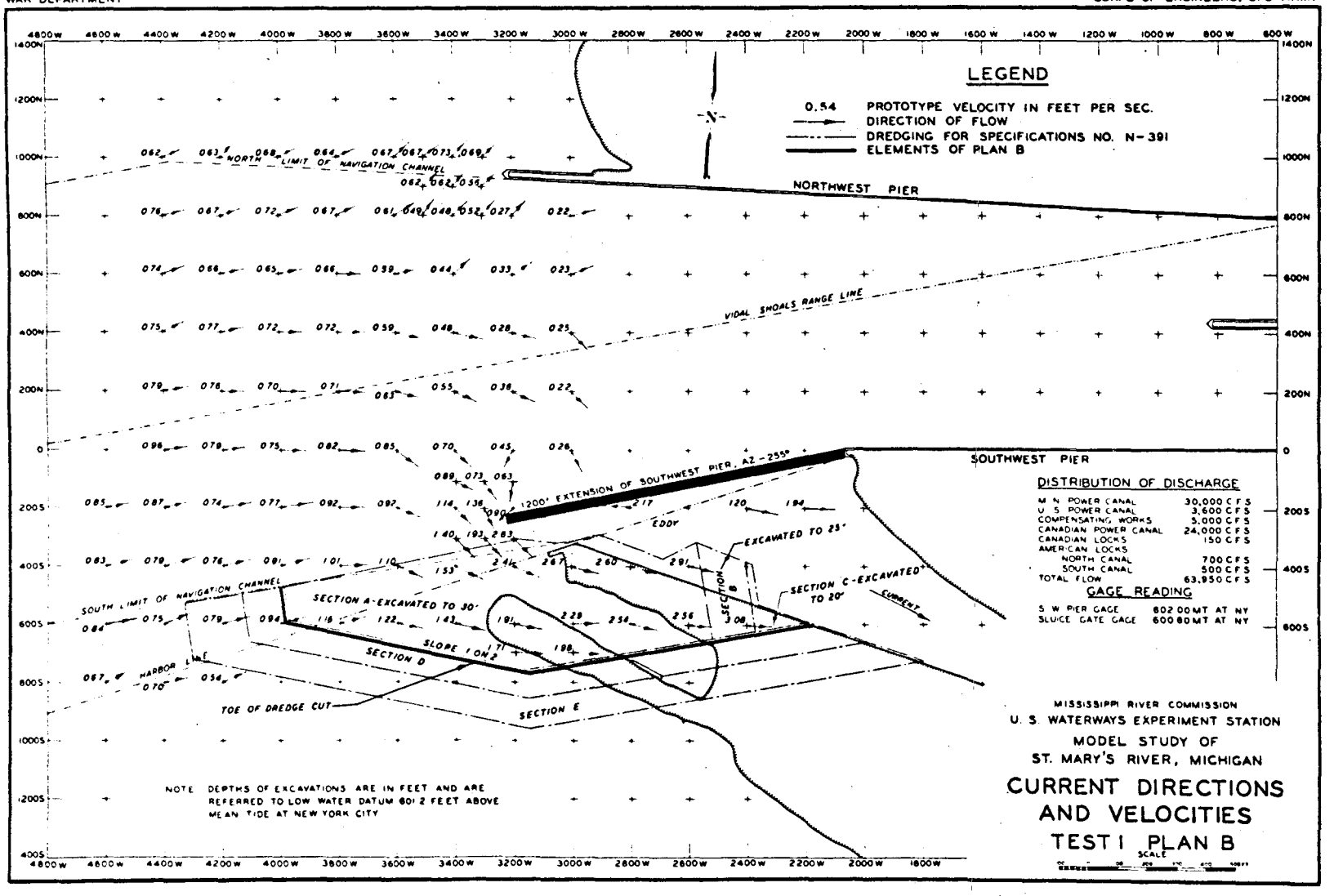


PLATE 17

PLATE 18

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	30,000 C F S
U S POWER CANAL	3,600 C F S
COMPENSATING WORKS	5,000 C F S
CANADIAN POWER CANAL	24,000 C F S
CANADIAN LOCKS	150 C F S
AMERICAN LOCKS	
NORTH CANAL	700 C F S
SOUTH CANAL	500 C F S
TOTAL FLOW	63,950 C F S

GAGE READING

S W PIER GAGE	602.00 M T AT NY
SLUICE GATE GAGE	600.80 M T AT NY

NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES TEST 1 PLAN B

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

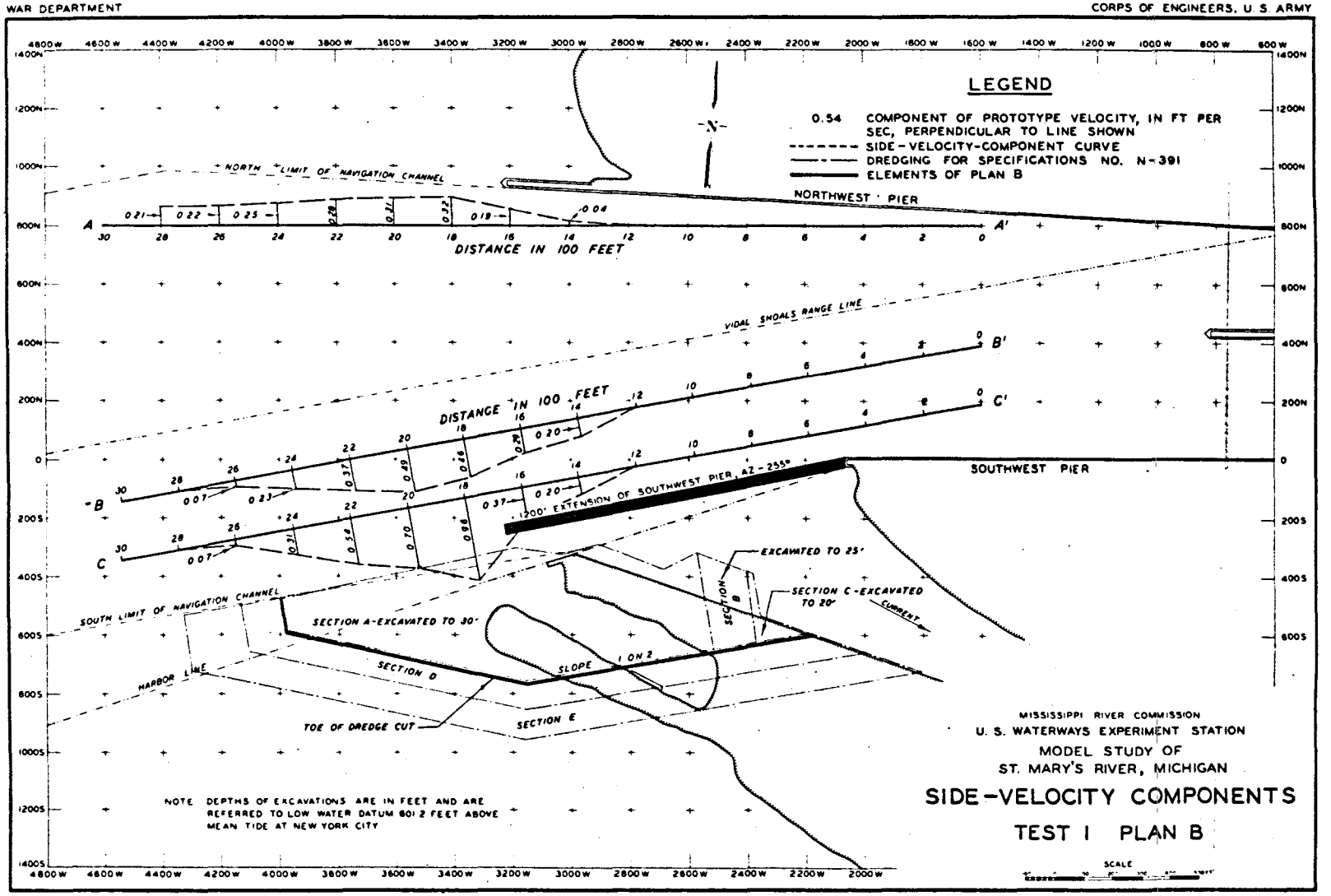
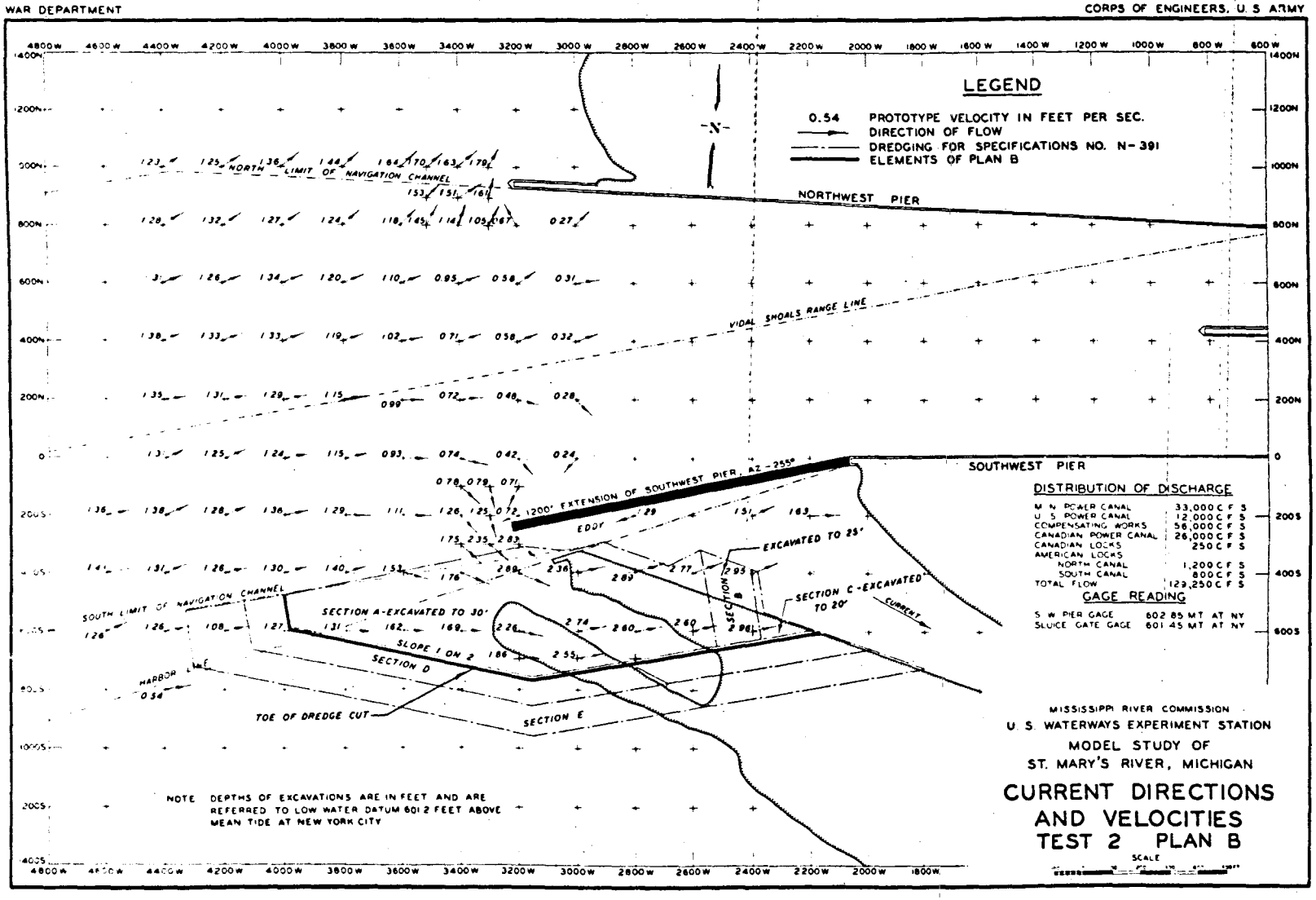


PLATE 19

PLATE 20

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES TEST 2 PLAN B

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

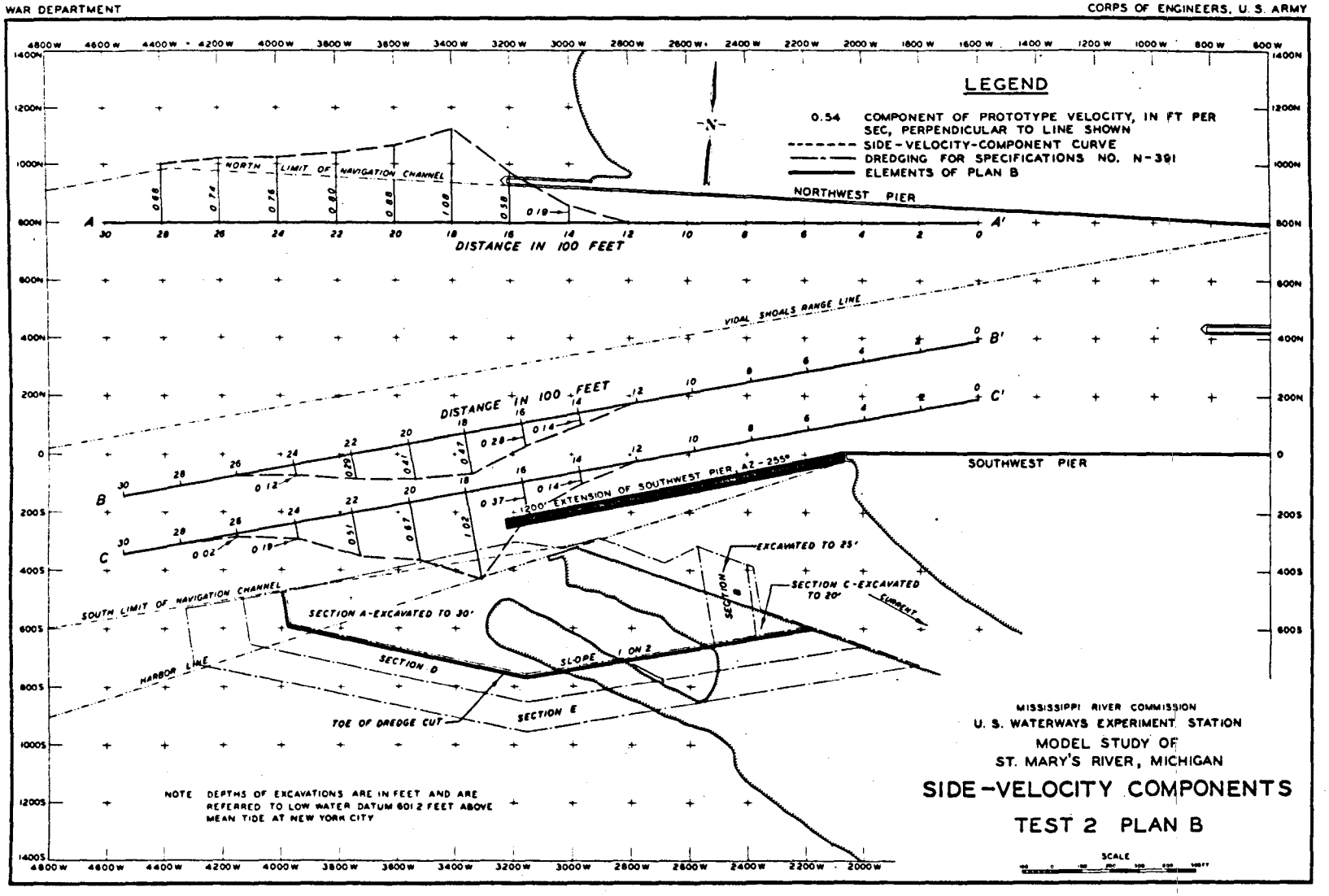
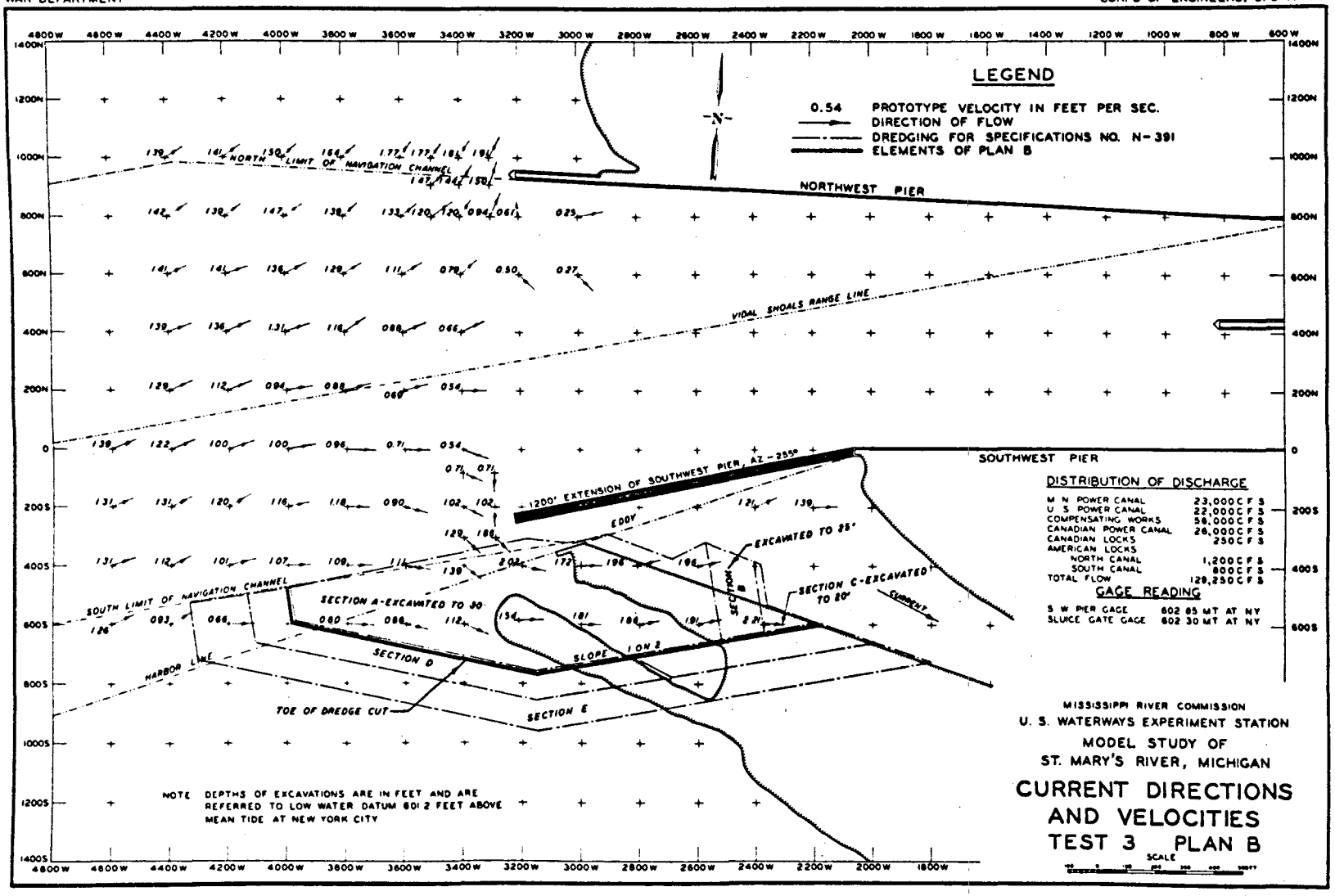


PLATE 21

PLATE 22

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	23,000 C F S
U S POWER CANAL	22,000 C F S
COMPENSATING WORKS	58,000 C F S
CANADIAN POWER CANAL	26,000 C F S
CANADIAN LOCKS	250 C F S
AMERICAN LOCKS	
NORTH CANAL	1,200 C F S
SOUTH CANAL	800 C F S
TOTAL FLOW	129,250 C F S

GAGE READING

S W PIER GAGE	602.65 MT AT NY
SLUICE GATE GAGE	602.30 MT AT NY

NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES TEST 3 PLAN B

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

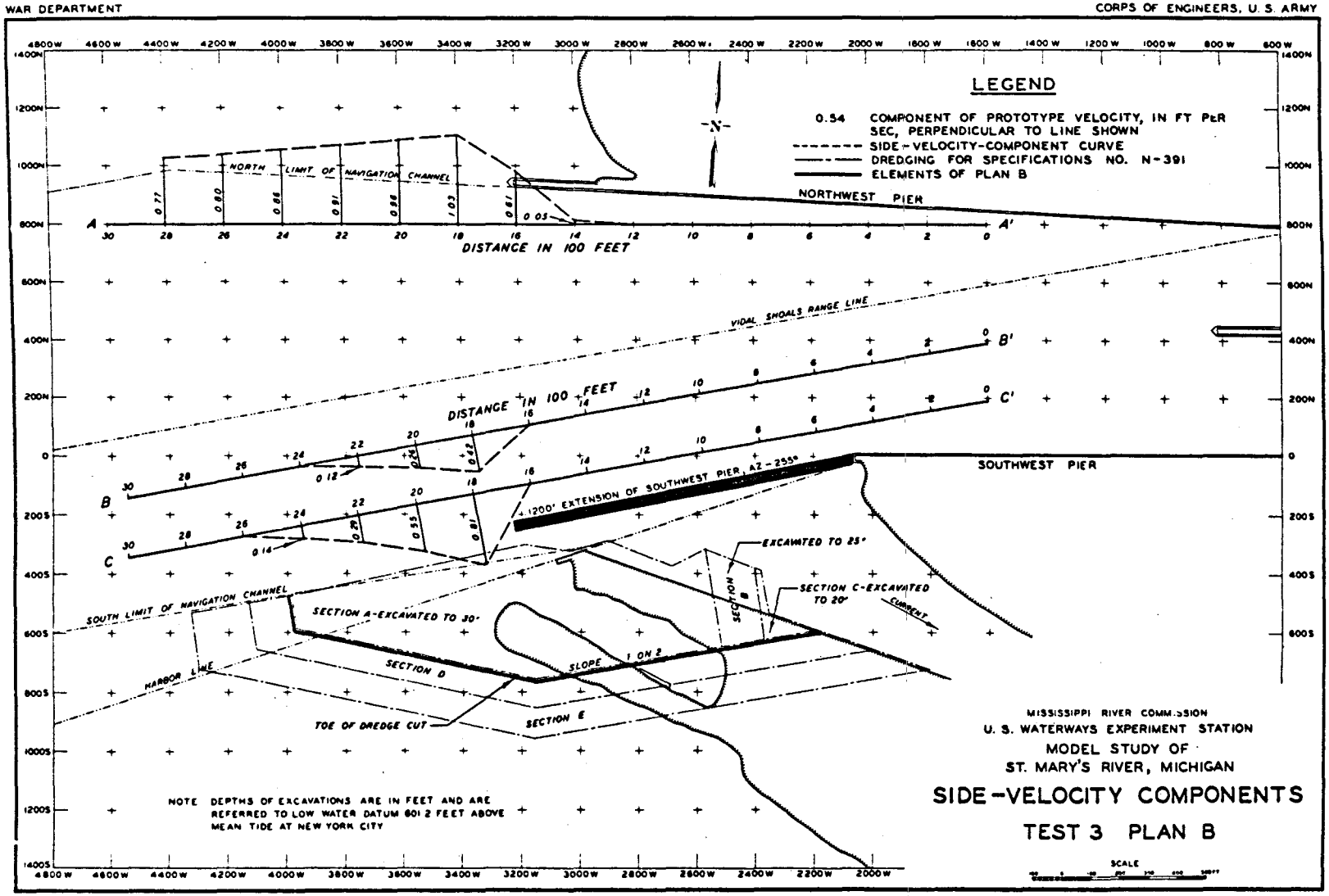
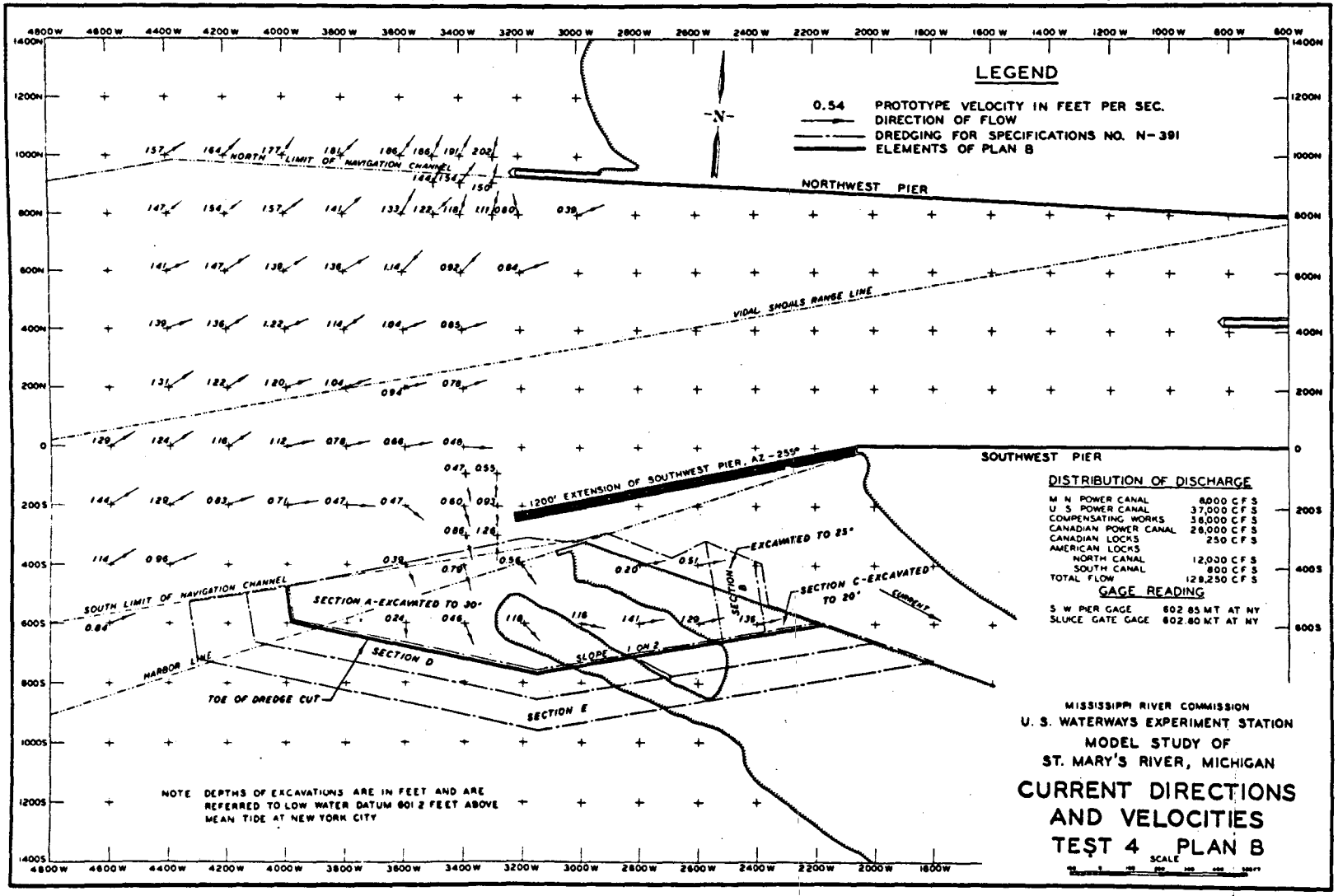


PLATE 23

PLATE 24

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	8,000 C F S
U S POWER CANAL	37,000 C F S
COMPENSATING WORKS	36,000 C F S
CANADIAN POWER CANAL	28,000 C F S
CANADIAN LOCKS	250 C F S
AMERICAN LOCKS	
NORTH CANAL	12,000 C F S
SOUTH CANAL	800 C F S
TOTAL FLOW	129,250 C F S

GAGE READING

S W PIER GAGE	602.85 M T AT NY
SLUICE GATE GAGE	602.80 M T AT NY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

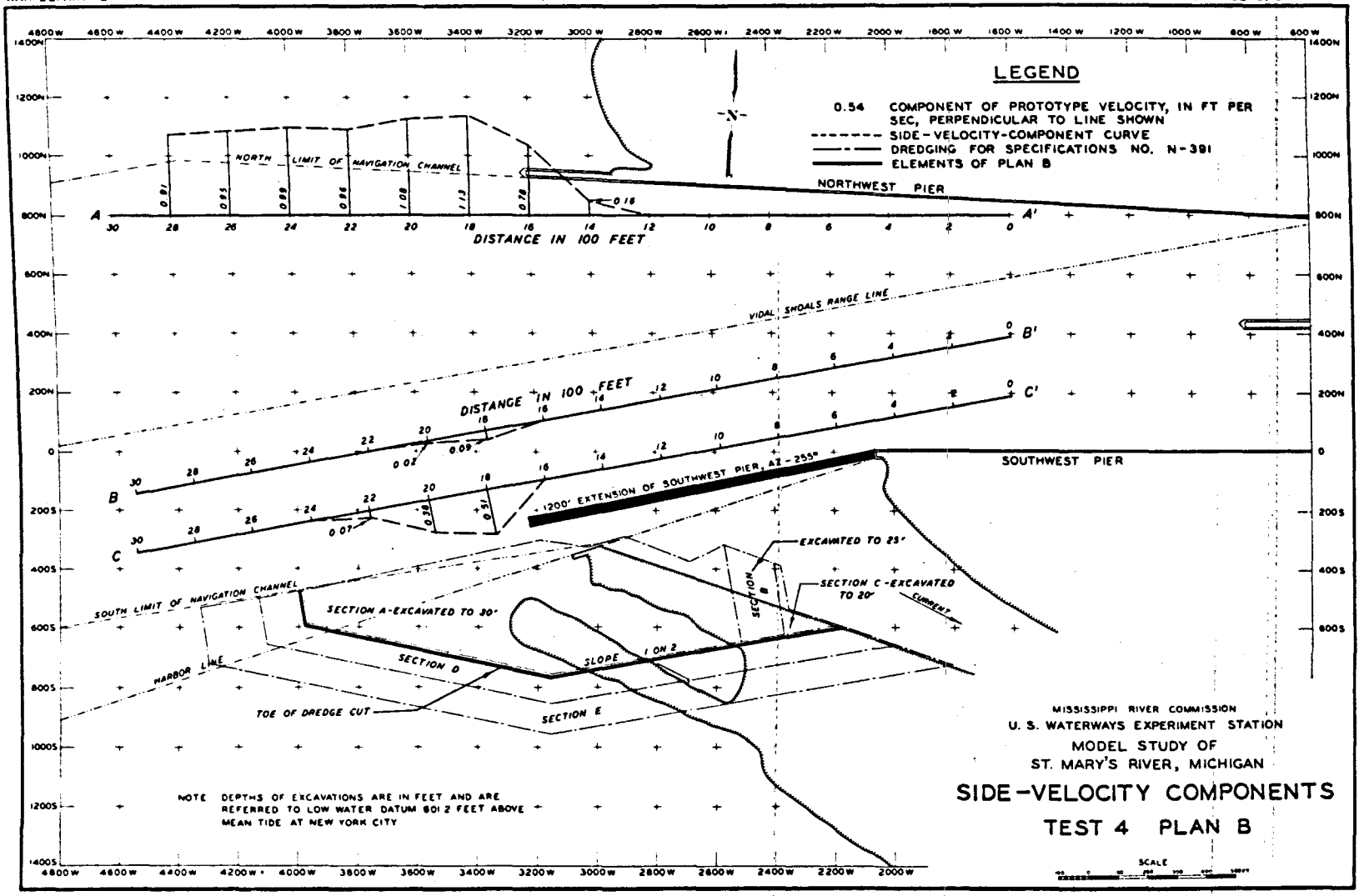
CURRENT DIRECTIONS AND VELOCITIES

TEST 4 PLAN B

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

SIDE-VELOCITY COMPONENTS

TEST 4 PLAN B

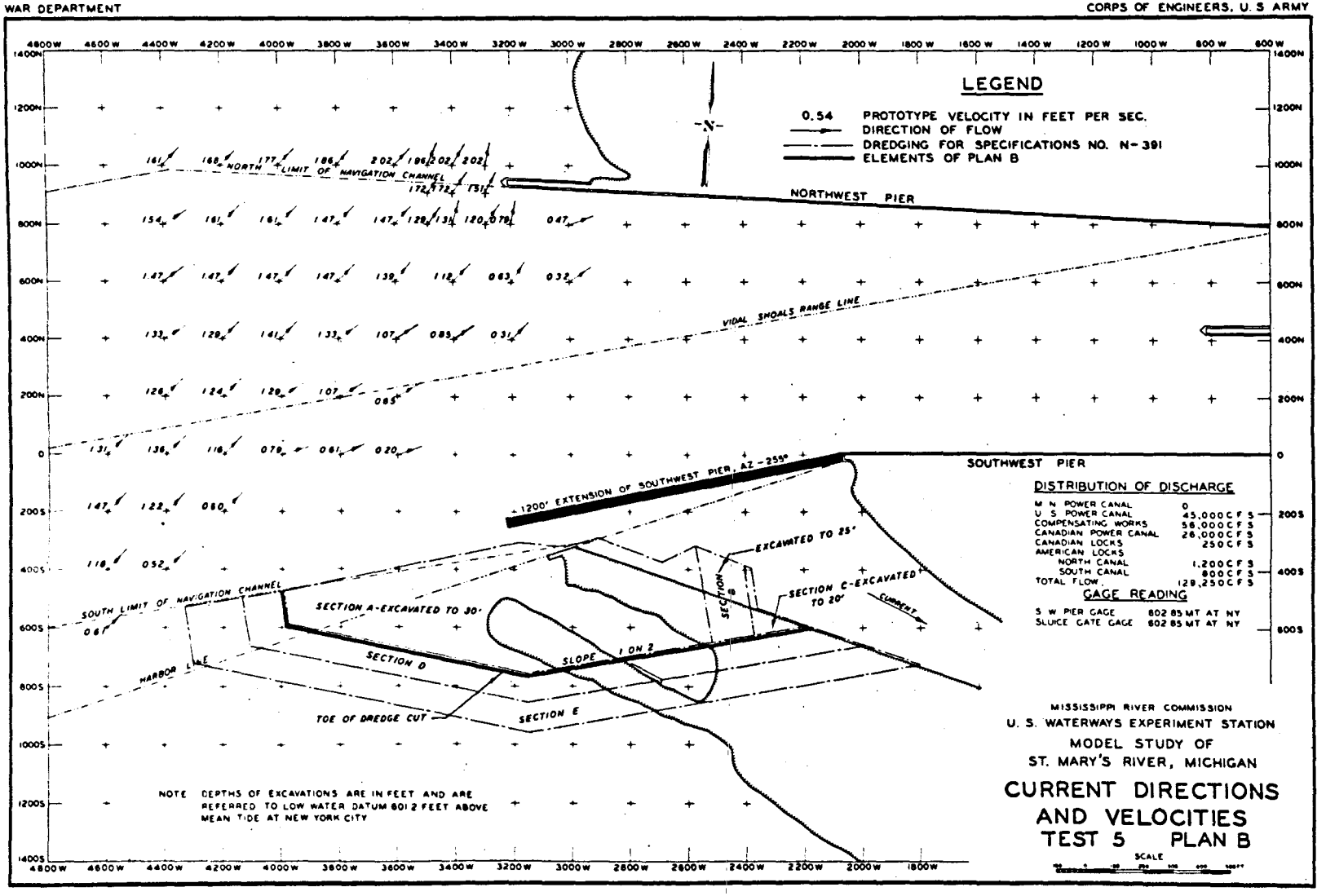
SCALE

PLATE 25

PLATE 26

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

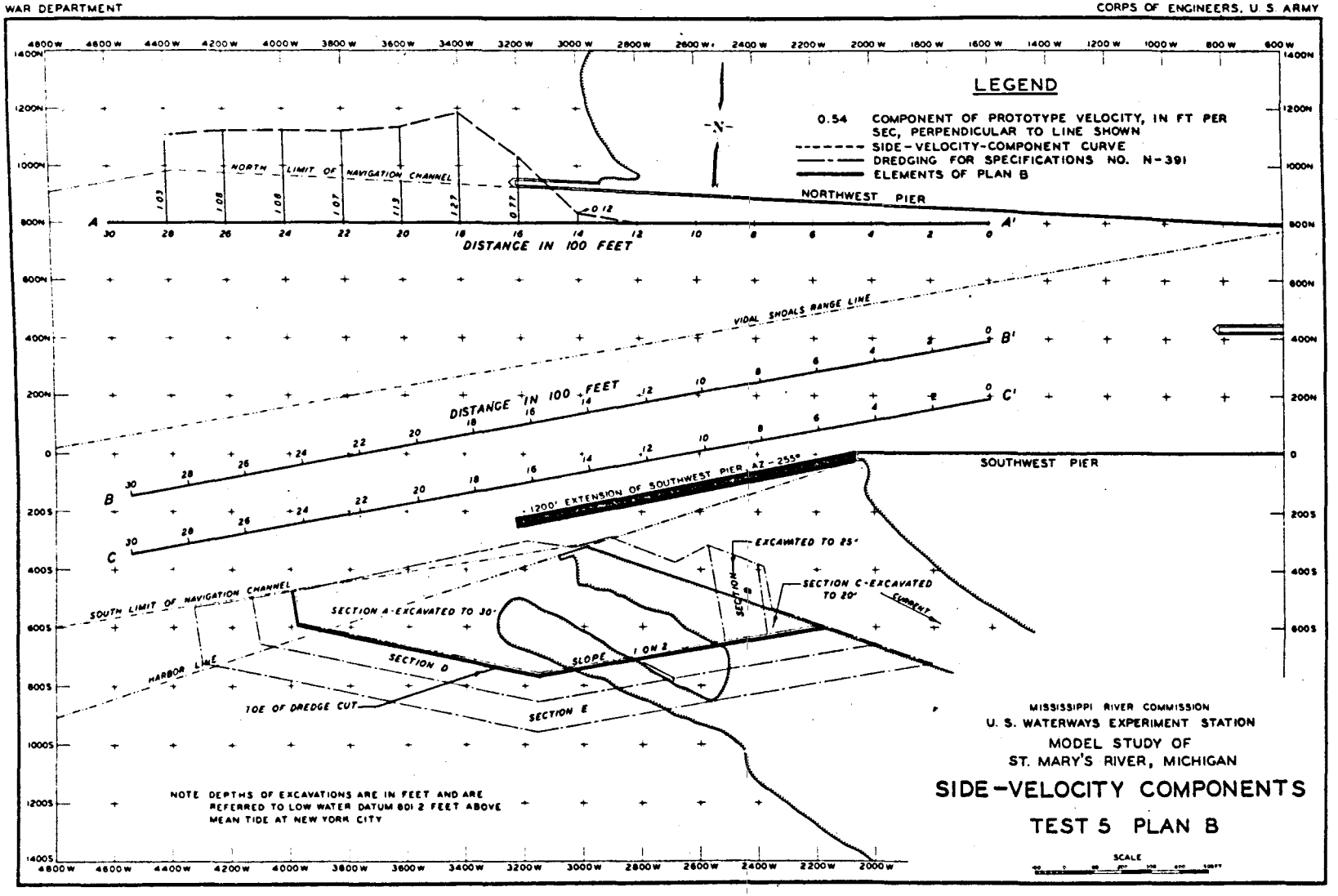
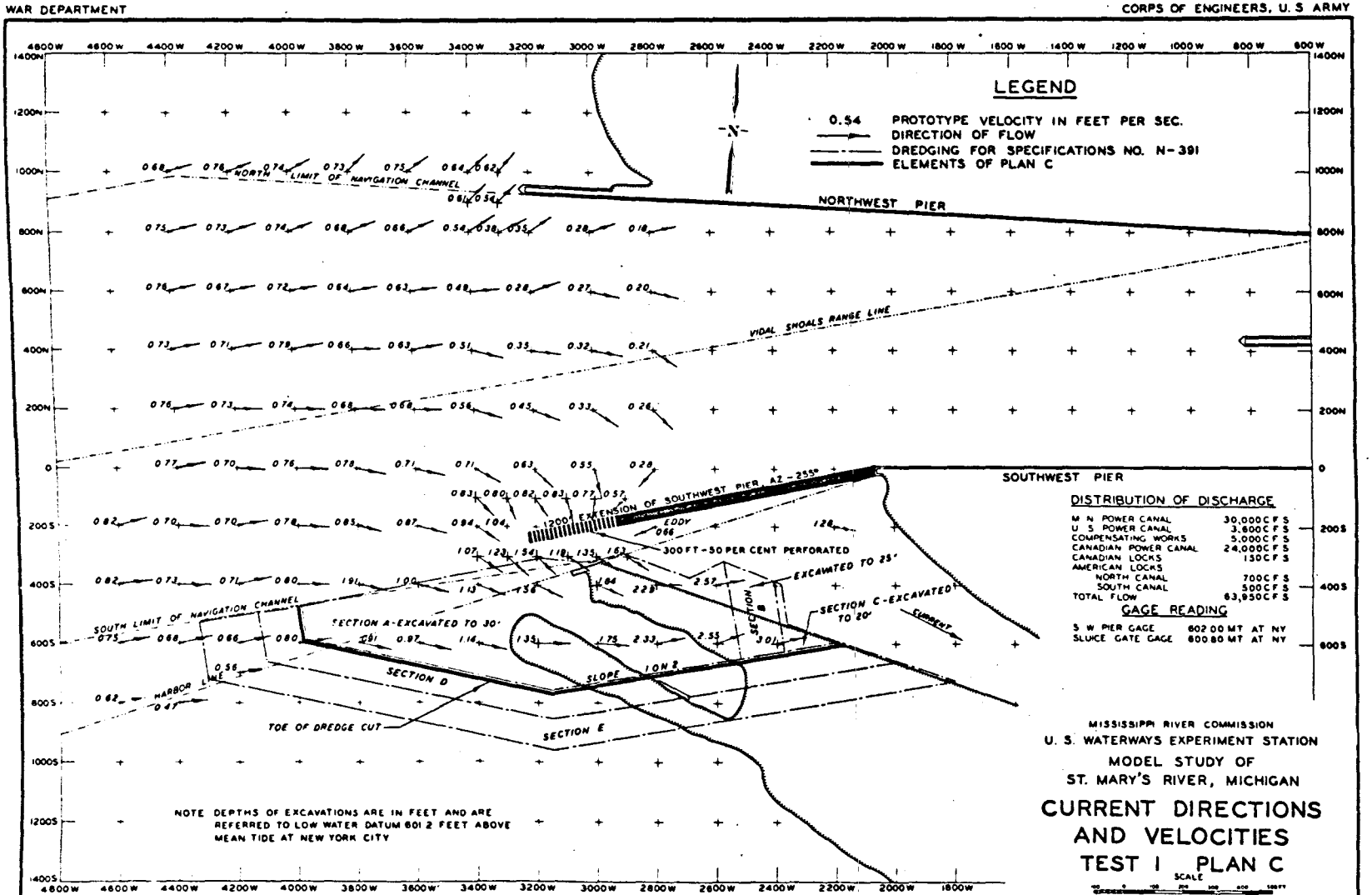


PLATE 27

PLATE 28

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

DISTRIBUTION OF DISCHARGE

M N POWER CANAL	30,000 C F S
U S POWER CANAL	3,600 C F S
COMPENSATING WORKS	5,000 C F S
CANADIAN POWER CANAL	24,000 C F S
CANADIAN LOCKS	150 C F S
AMERICAN LOCKS	
NORTH CANAL	700 C F S
SOUTH CANAL	500 C F S
TOTAL FLOW	63,950 C F S

GAGE READING

S W PIER GAGE	602.00 MT AT NY
SLUICE GATE GAGE	600.80 MT AT NY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN C

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

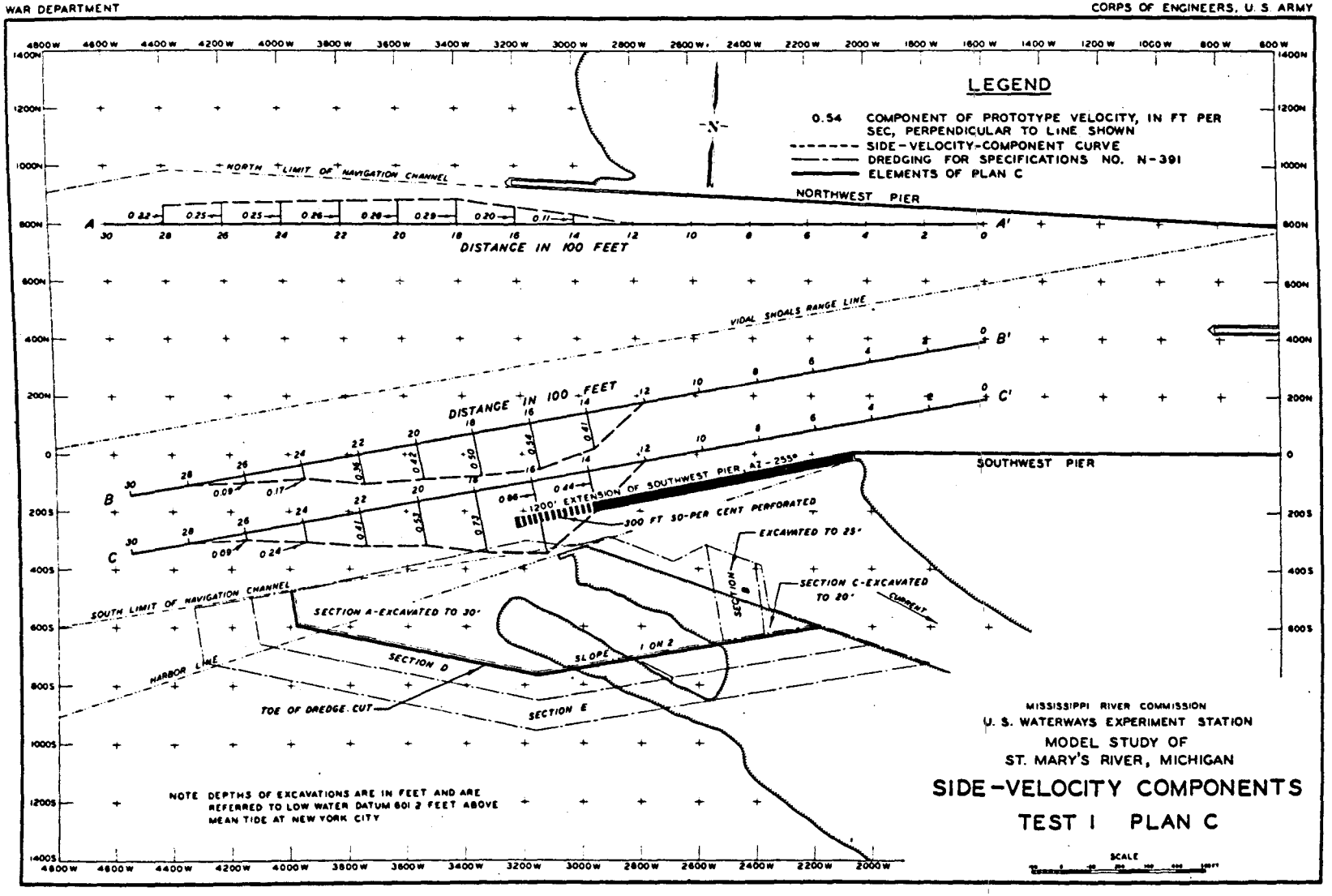
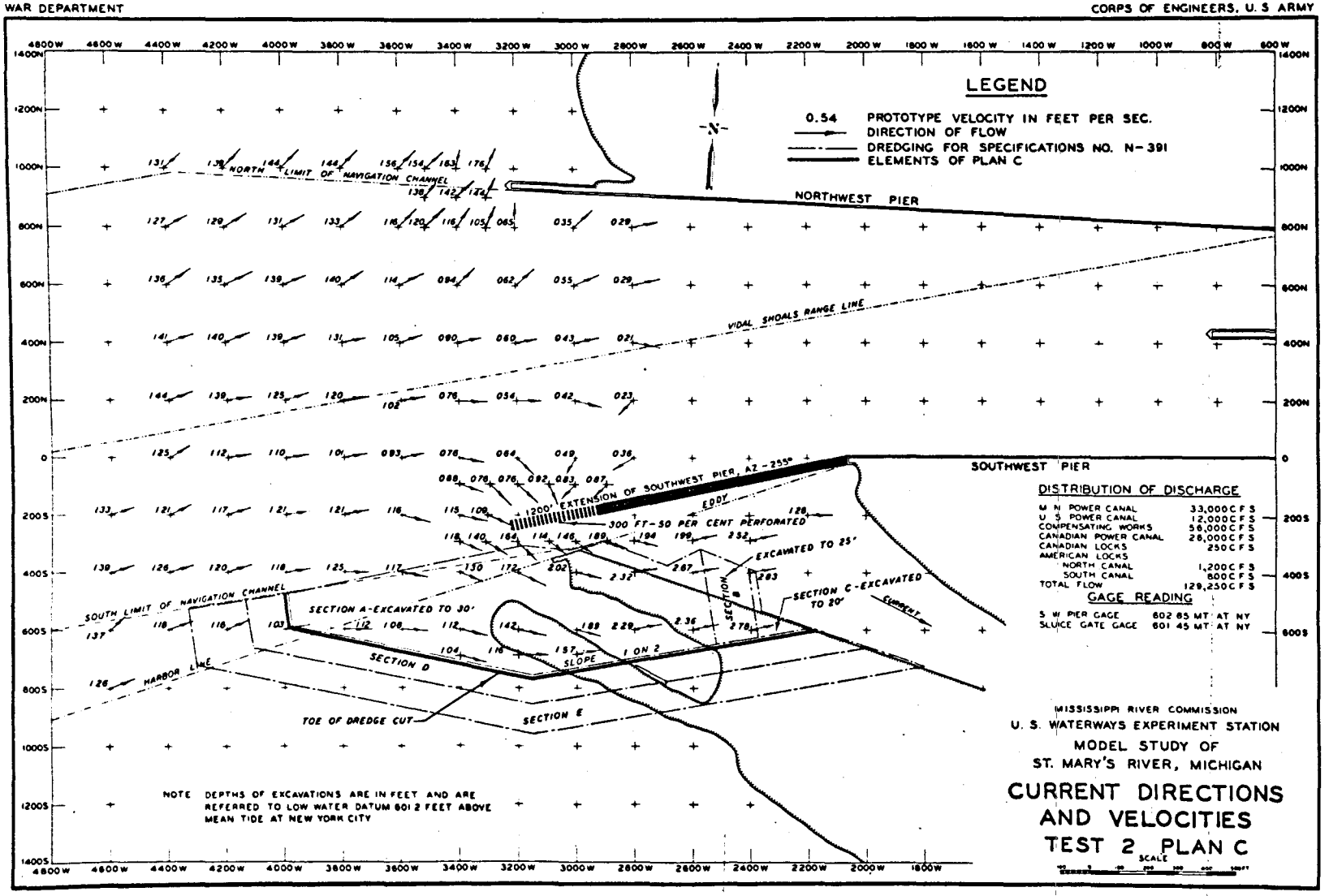


PLATE 29

PLATE 30

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	33,000 C F S
U S POWER CANAL	12,000 C F S
COMPENSATING WORKS	56,000 C F S
CANADIAN POWER CANAL	26,000 C F S
CANADIAN LOCKS	250 C F S
AMERICAN LOCKS	
NORTH CANAL	1,200 C F S
SOUTH CANAL	800 C F S
TOTAL FLOW	129,250 C F S

GAGE READING

S W PIER GAGE	602 85 MT AT NY
SLUICE GATE GAGE	601 45 MT AT NY

NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601 2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

MISSISSIPPI RIVER COMMISSION
U. S. WATERWAYS EXPERIMENT STATION
MODEL STUDY OF
ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES TEST 2 PLAN C

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

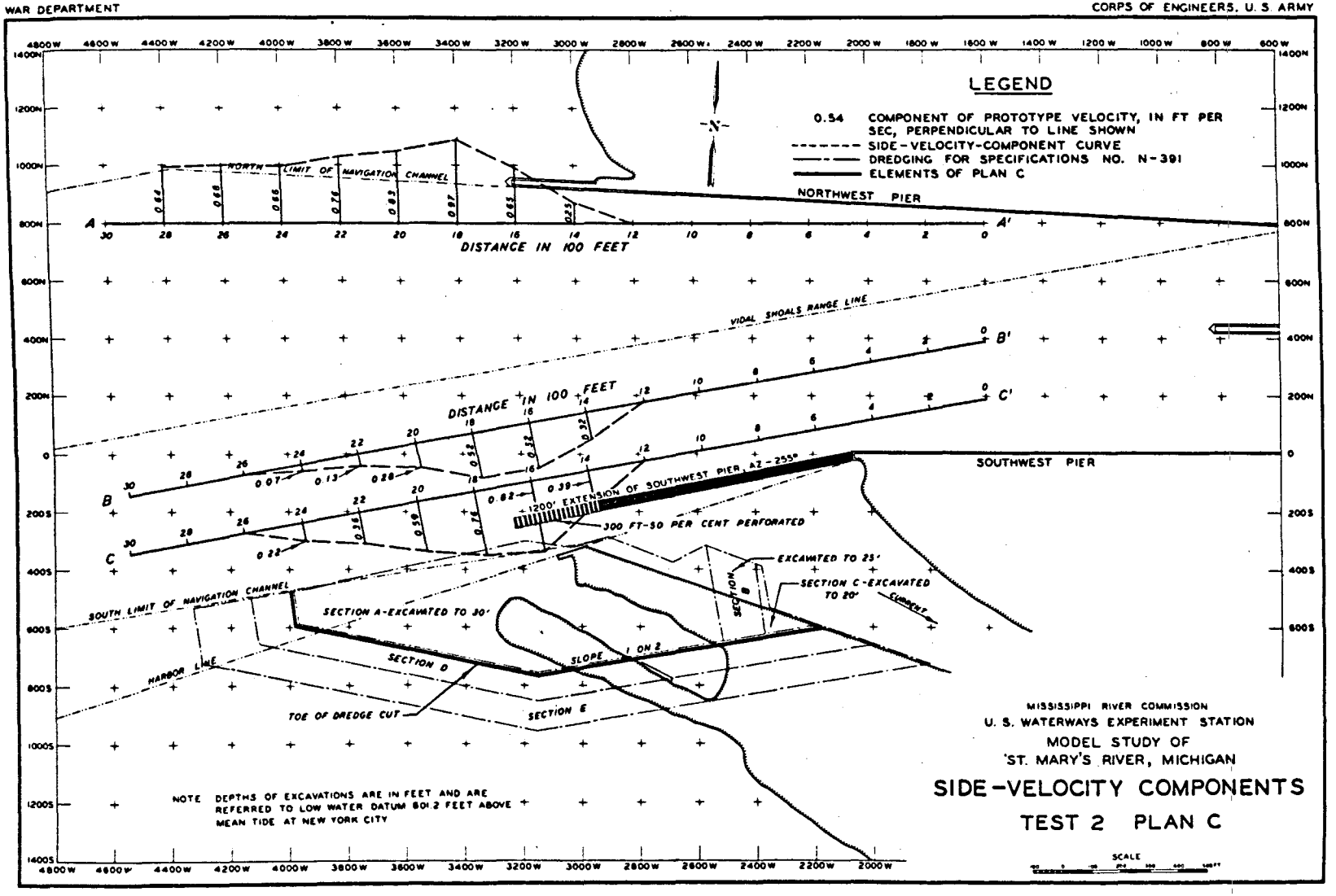
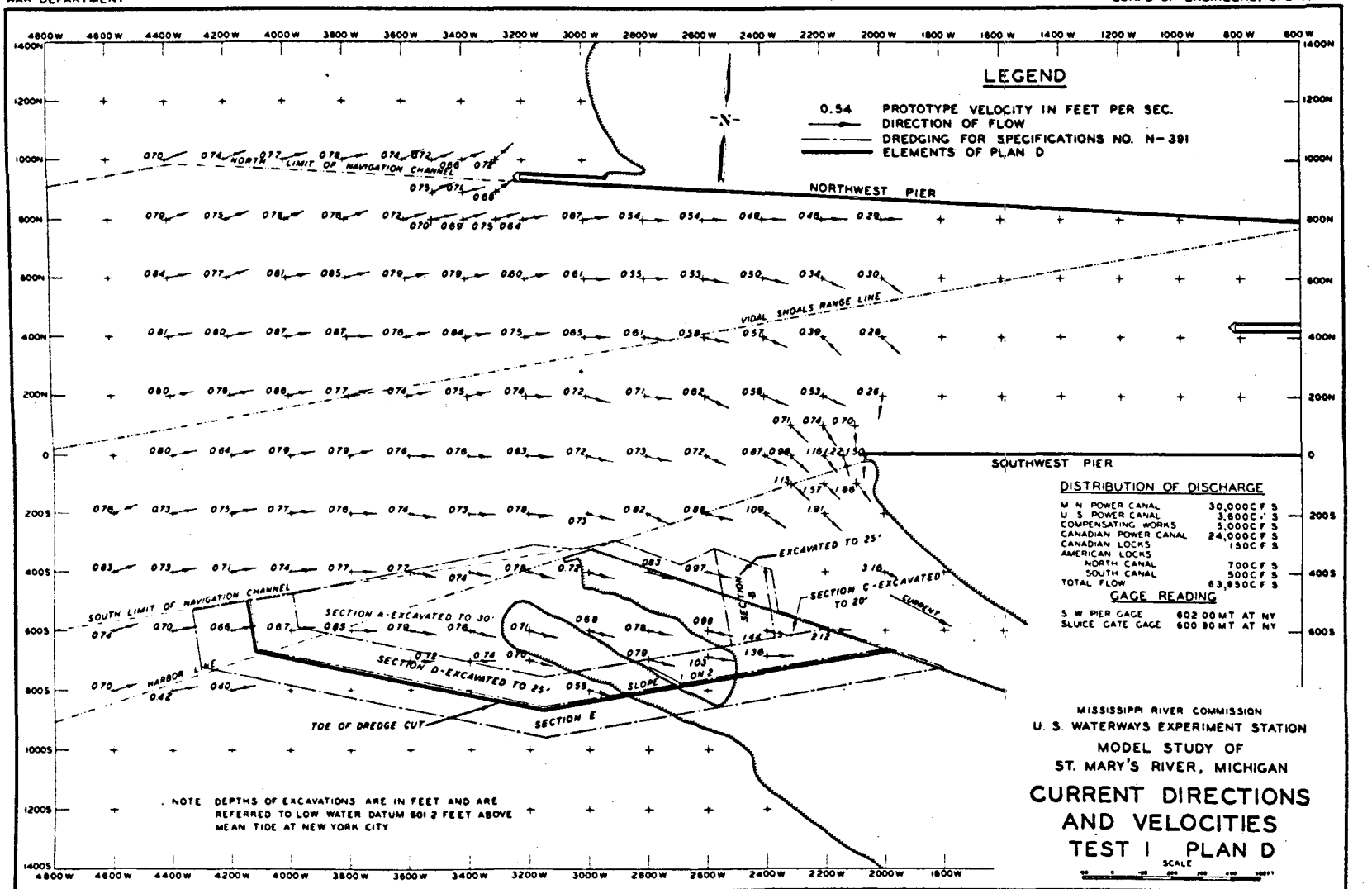


PLATE 31

PLATE 32

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN D

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

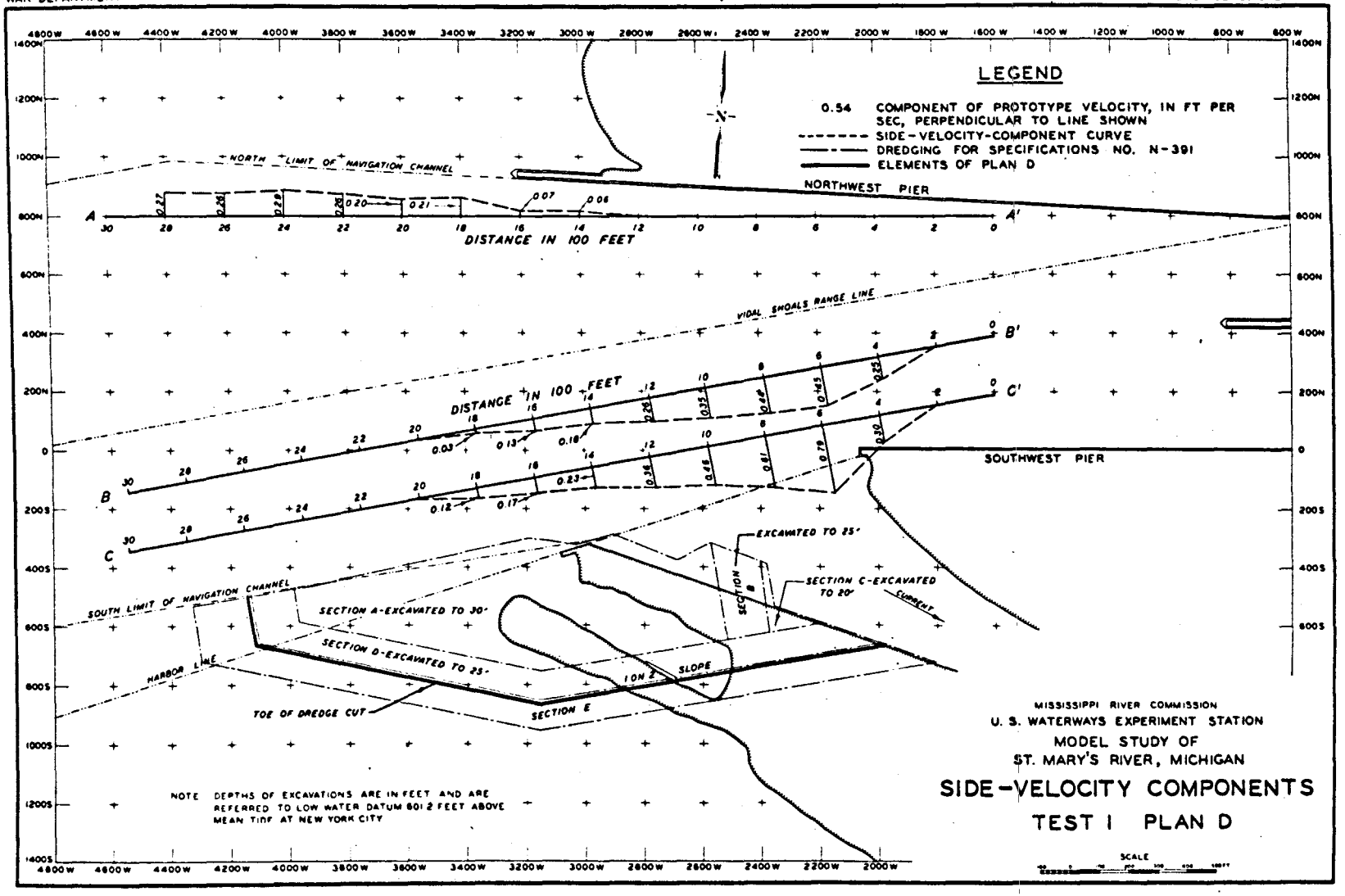
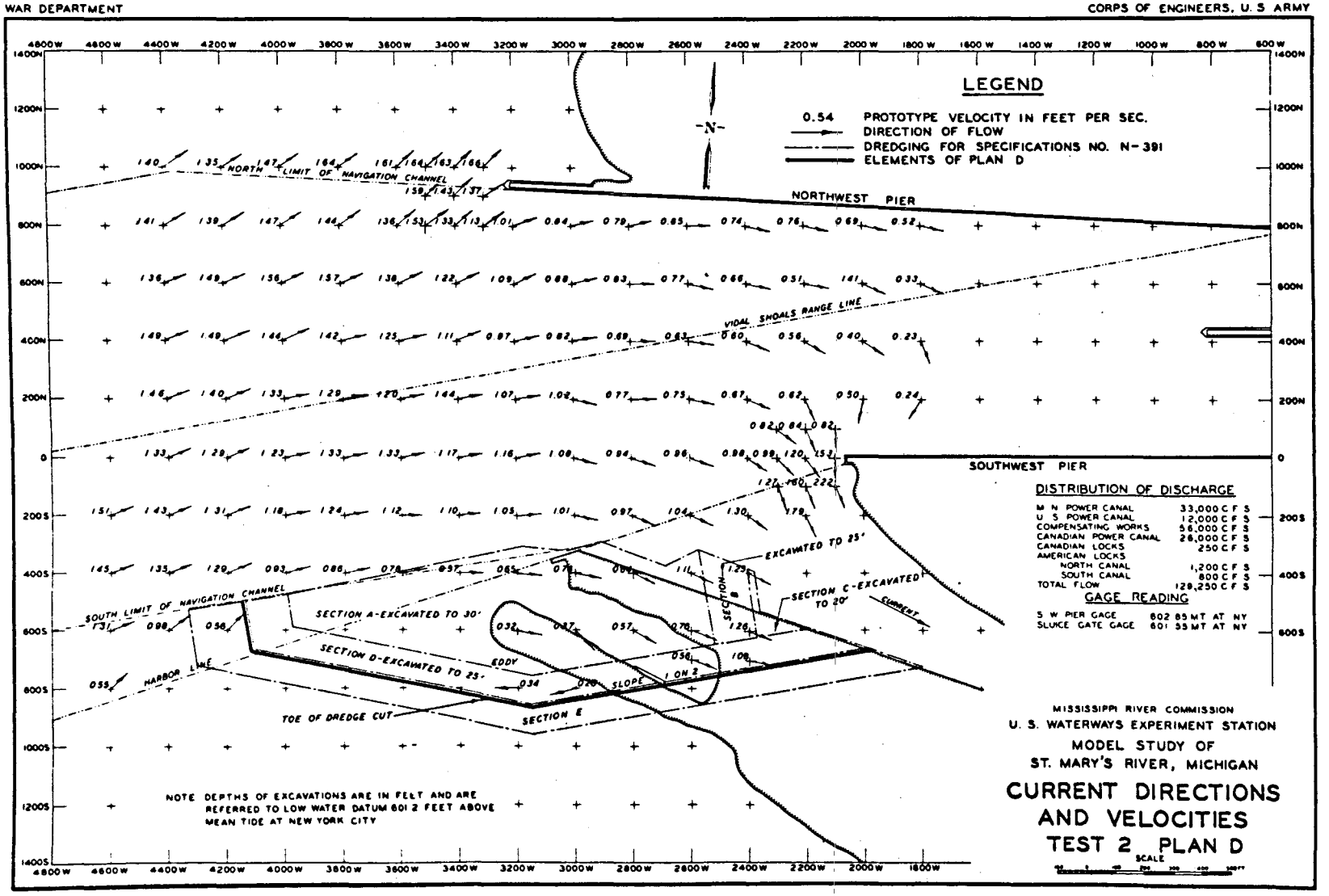


PLATE 33

PLATE 34

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

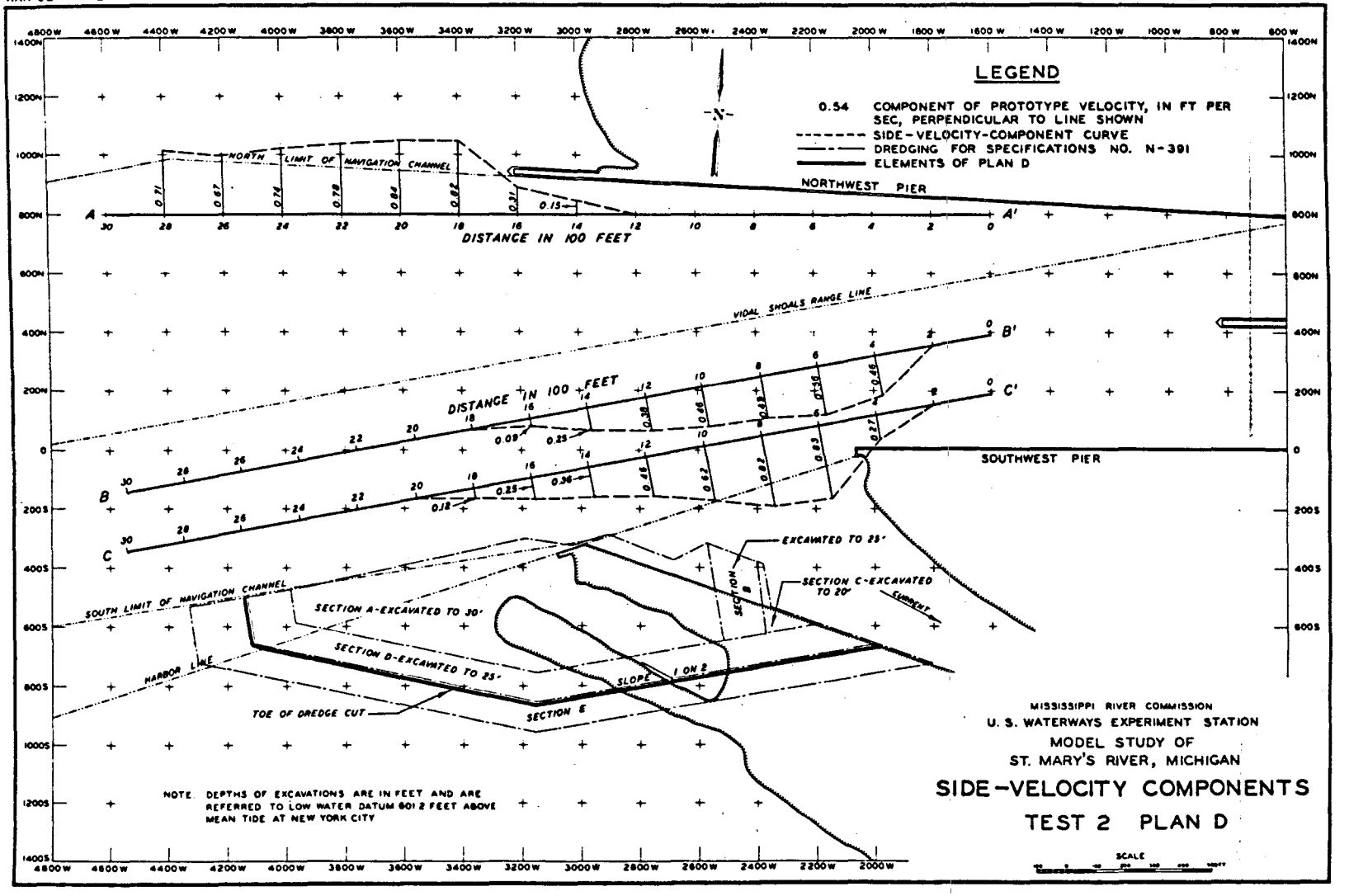
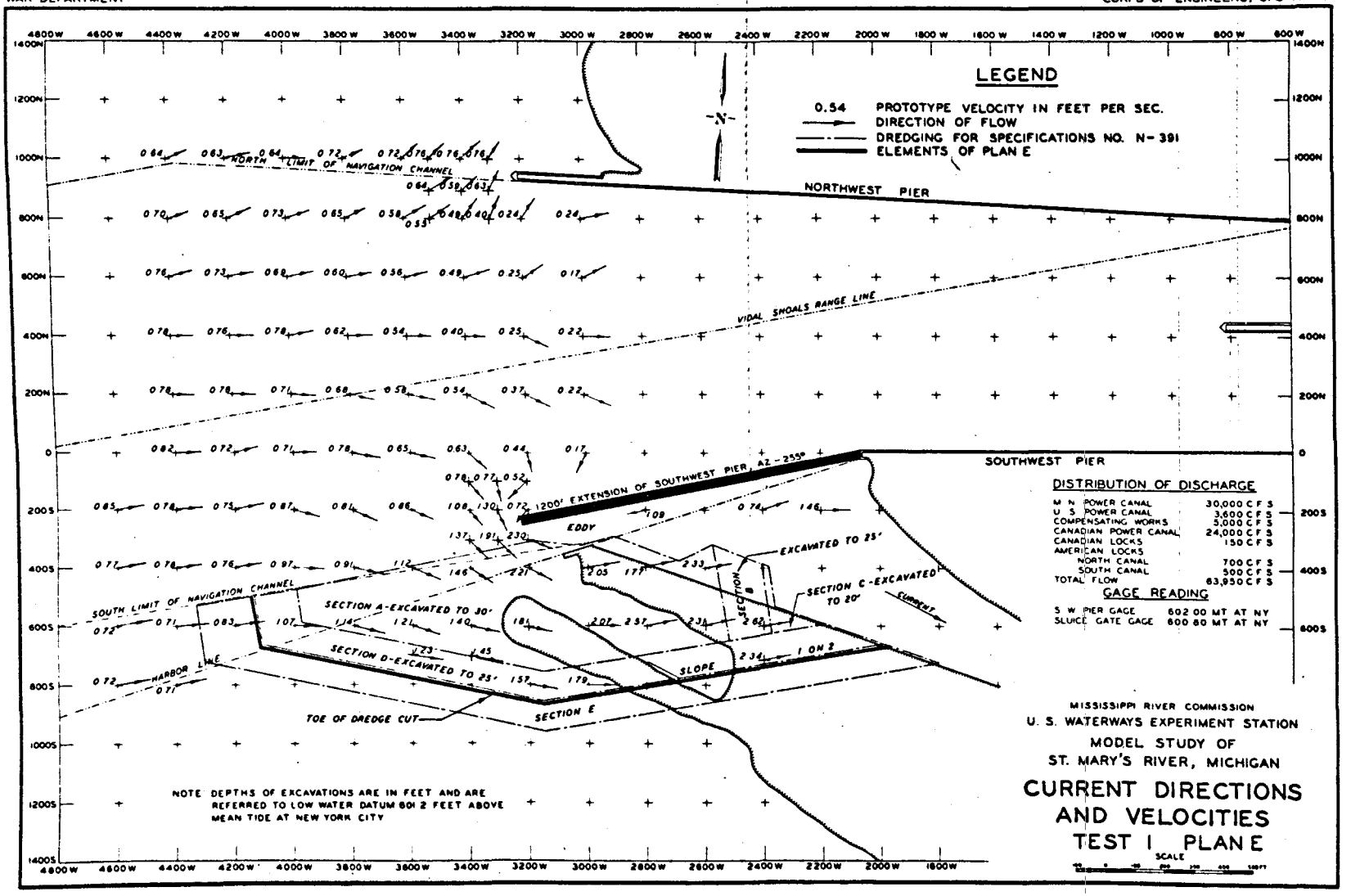


PLATE 35

PLATE 36

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



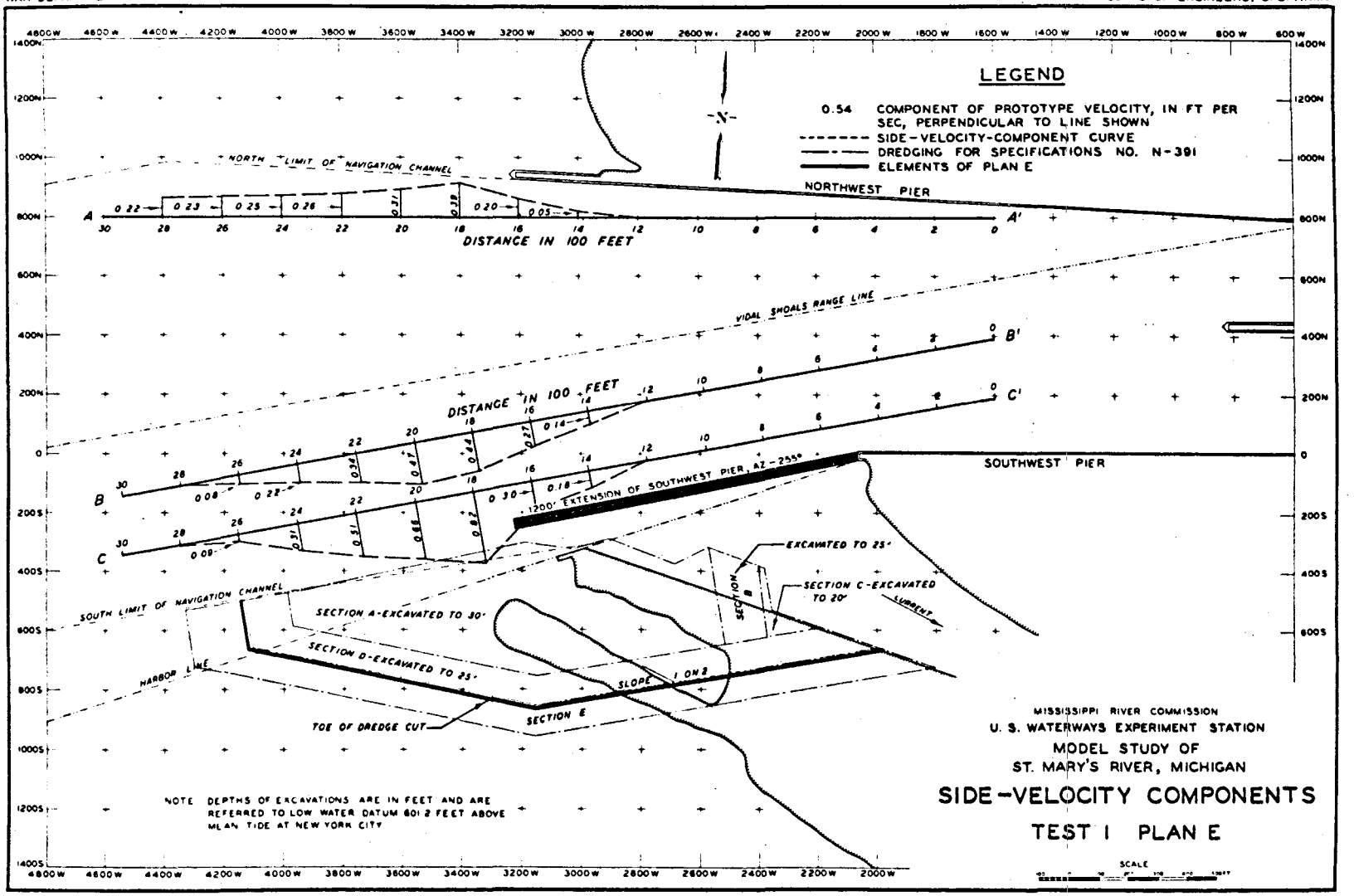
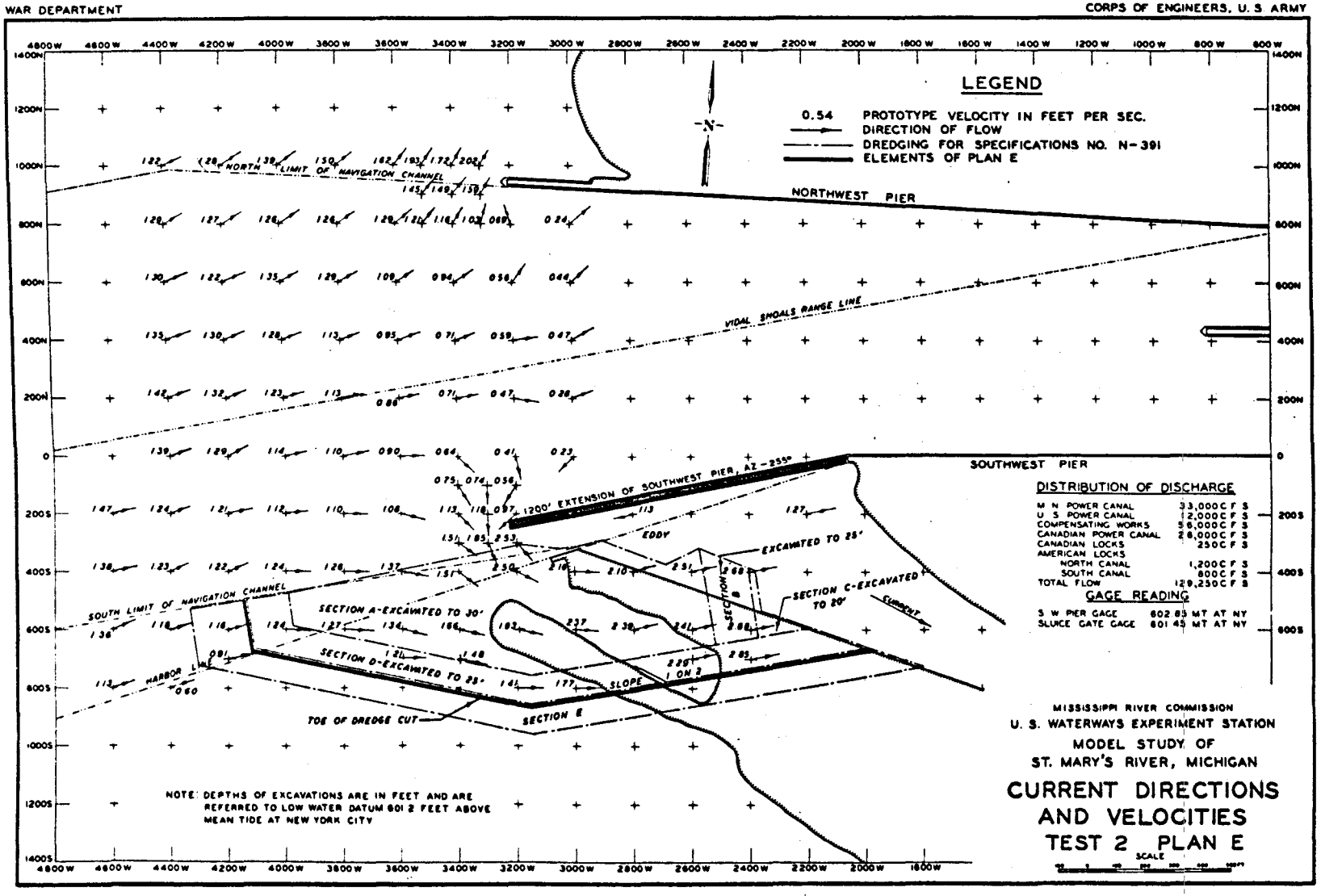

LEGEND
0.54 COMPONENT OF PROTOTYPE VELOCITY, IN FT PER SEC, PERPENDICULAR TO LINE SHOWN
SIDE-VELOCITY-COMPONENT CURVE
DREDGING FOR SPECIFICATIONS NO. N-391
ELEMENTS OF PLAN E
NORTH LIMIT OF NAVIGATION CHANNEL
NORTHWEST PIER
DISTANCE IN 100 FEET
VIDAL SHOALS RANGE LINE
SOUTHWEST PIER
1200' EXTENSION OF SOUTHWEST PIER, AZ - 255°
SOUTH LIMIT OF NAVIGATION CHANNEL
HARBOR LINE
SECTION A-EXCAVATED TO 30'
SECTION B-EXCAVATED TO 25'
SECTION C-EXCAVATED TO 20'
SECTION E
SLOPE 1 ON 3
TOE OF DREDGE CUT
CURRENT
NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY
MISSISSIPPI RIVER COMMISSION
U. S. WATERWAYS EXPERIMENT STATION
MODEL STUDY OF
ST. MARY'S RIVER, MICHIGAN
SIDE-VELOCITY COMPONENTS
TEST 1 PLAN E
SCALE

PLATE 37

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	33,000 C F S
U S POWER CANAL	12,000 C F S
COMPENSATING WORKS	56,000 C F S
CANADIAN POWER CANAL	28,000 C F S
CANADIAN LOCKS	250 C F S
AMERICAN LOCKS	
NORTH CANAL	1,200 C F S
SOUTH CANAL	800 C F S
TOTAL FLOW	129,250 C F S

GAGE READING

S W PIER GAGE	602.83 M T AT NY
SLUICE GATE GAGE	601.45 M T AT NY

NOTE: DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST 2 PLAN E

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

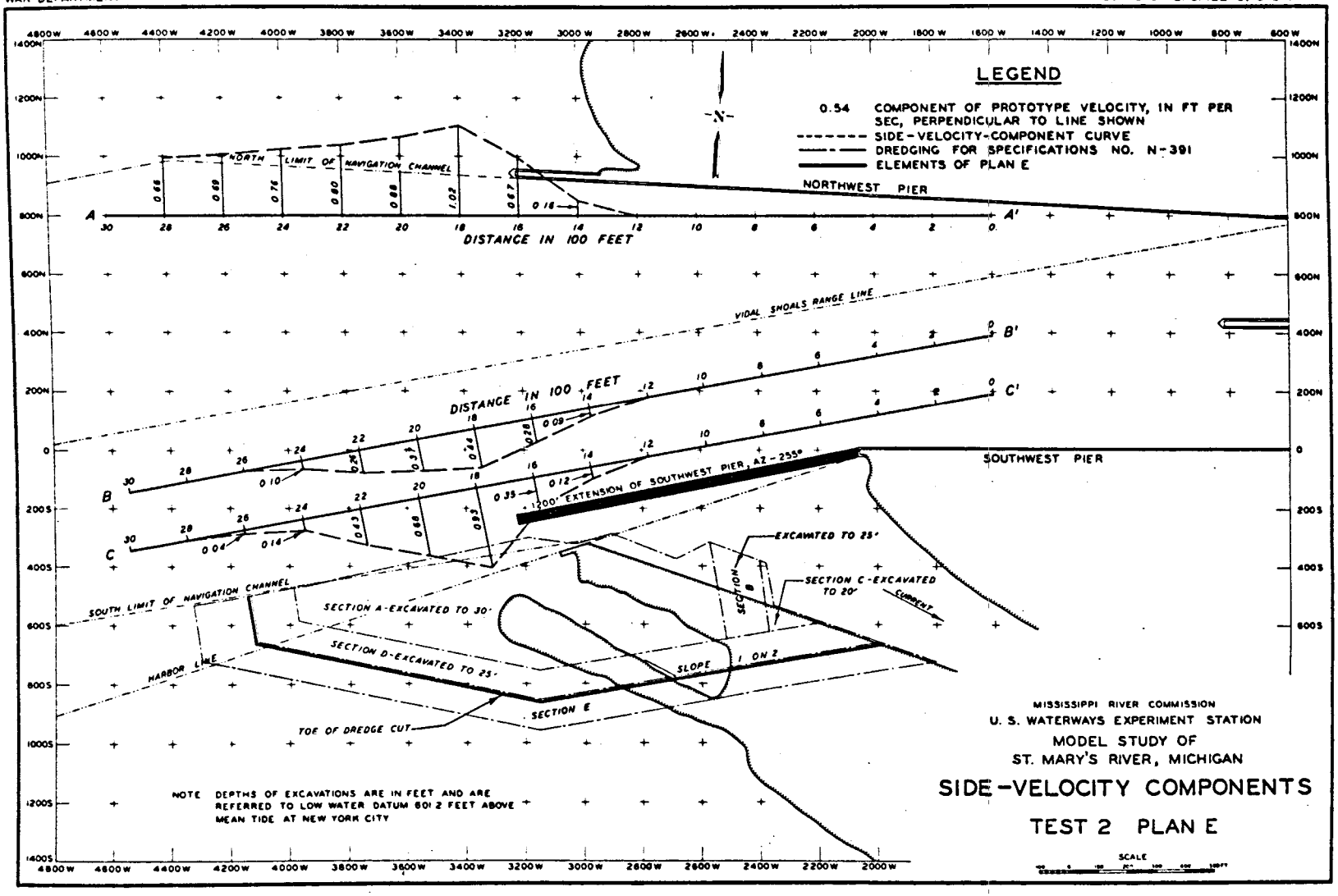
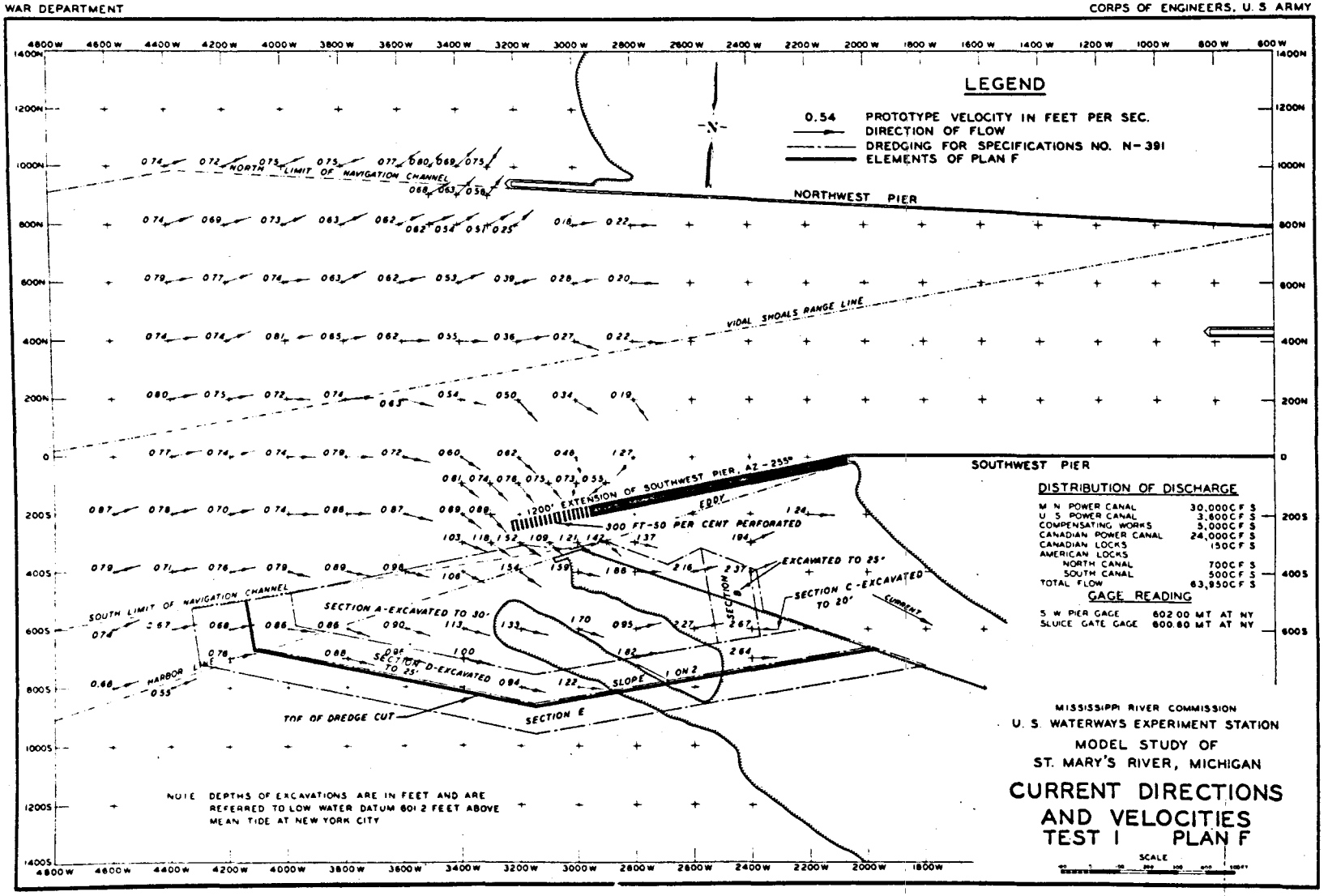


PLATE 39

PLATE 40

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

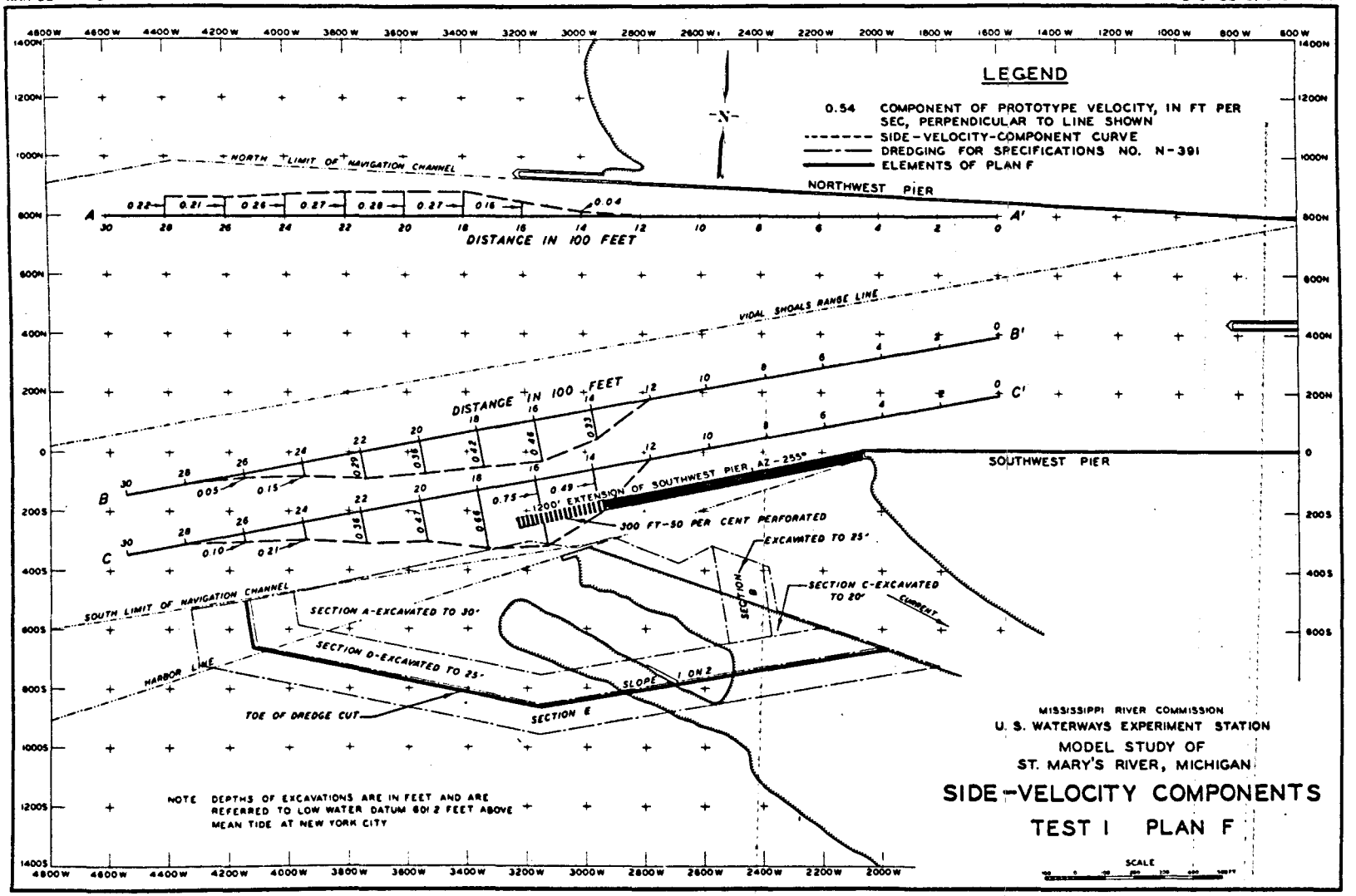
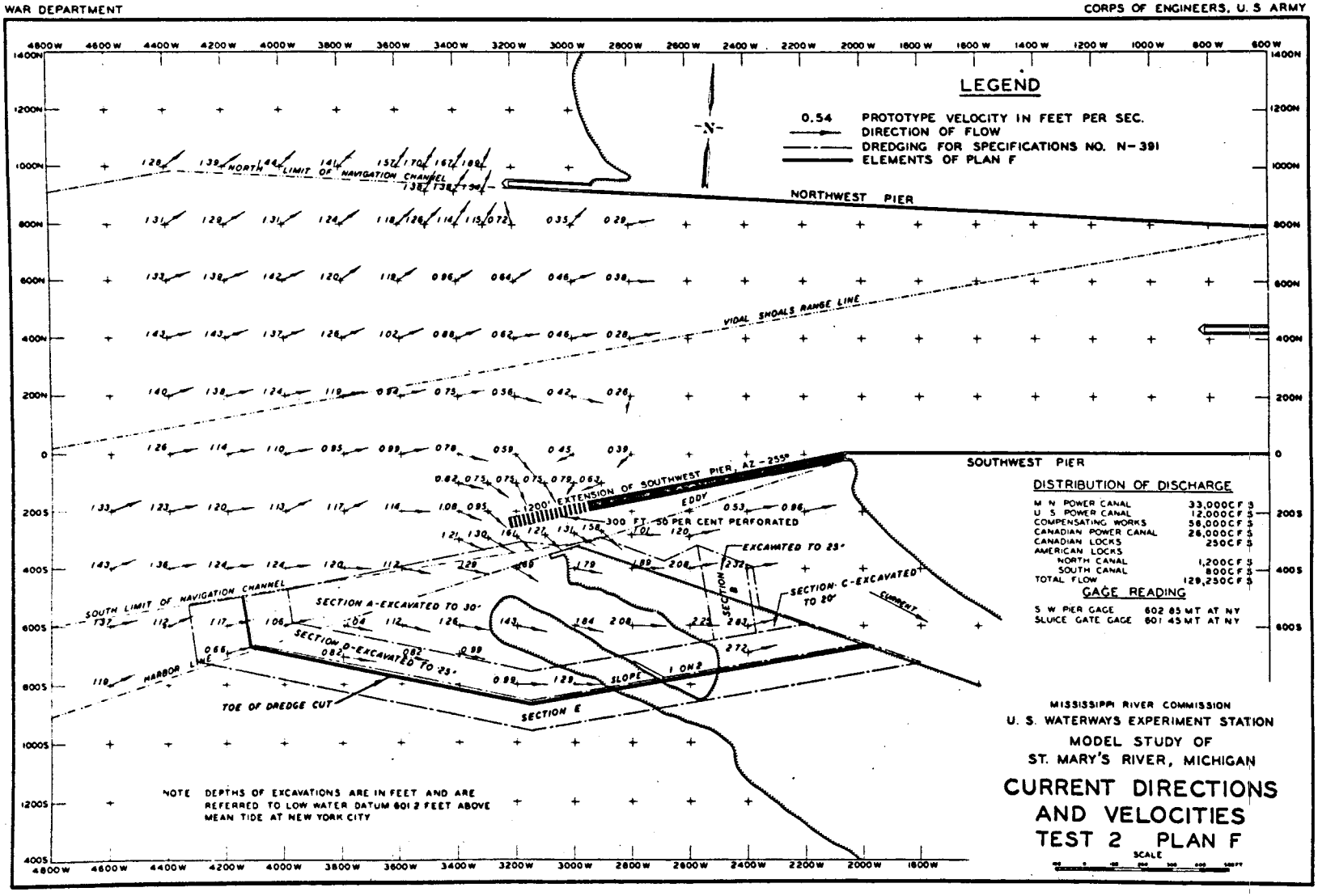


PLATE 41

PLATE 42

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	33,000 C F S
U S POWER CANAL	12,000 C F S
COMPENSATING WORKS	58,000 C F S
CANADIAN POWER CANAL	26,000 C F S
CANADIAN LOCKS	250 C F S
AMERICAN LOCKS	
NORTH CANAL	1,200 C F S
SOUTH CANAL	800 C F S
TOTAL FLOW	129,250 C F S

GAGE READING

S W PIER GAGE 602.85 M T AT NY
SLUICE GATE GAGE 601.45 M T AT NY

NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

MISSISSIPPI RIVER COMMISSION
U. S. WATERWAYS EXPERIMENT STATION
MODEL STUDY OF
ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES TEST 2 PLAN F

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

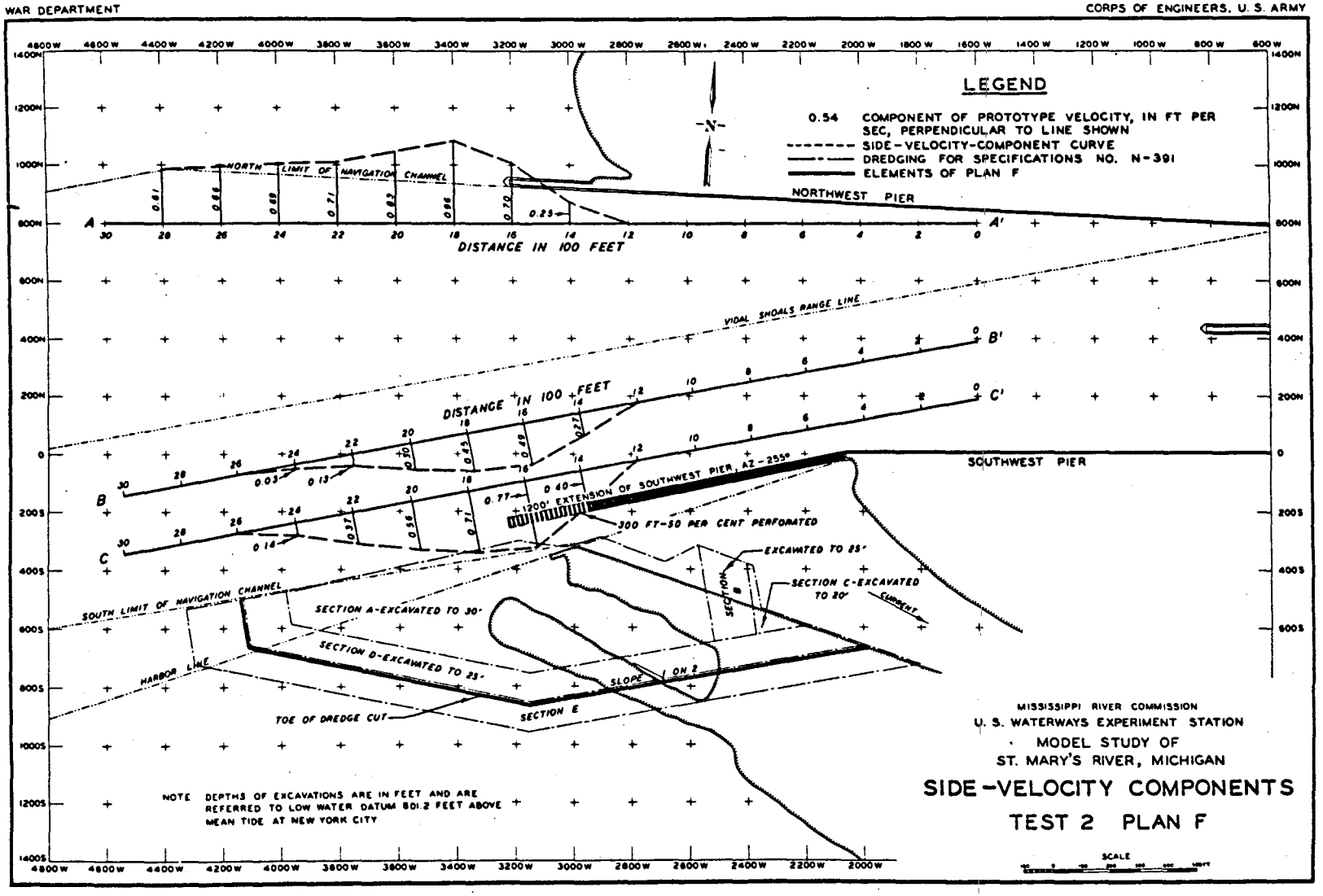
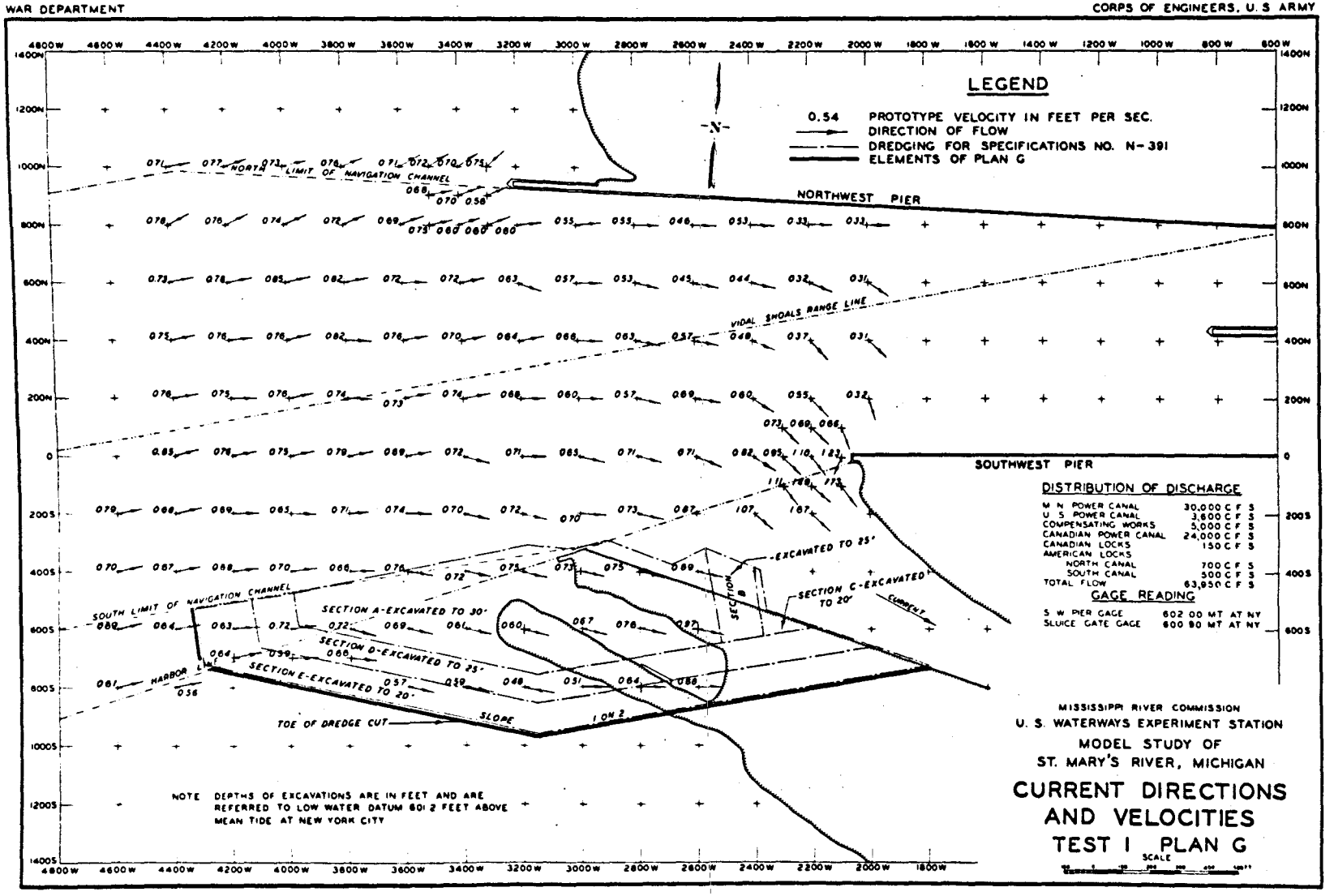


PLATE 43

PLATE 44

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN G

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

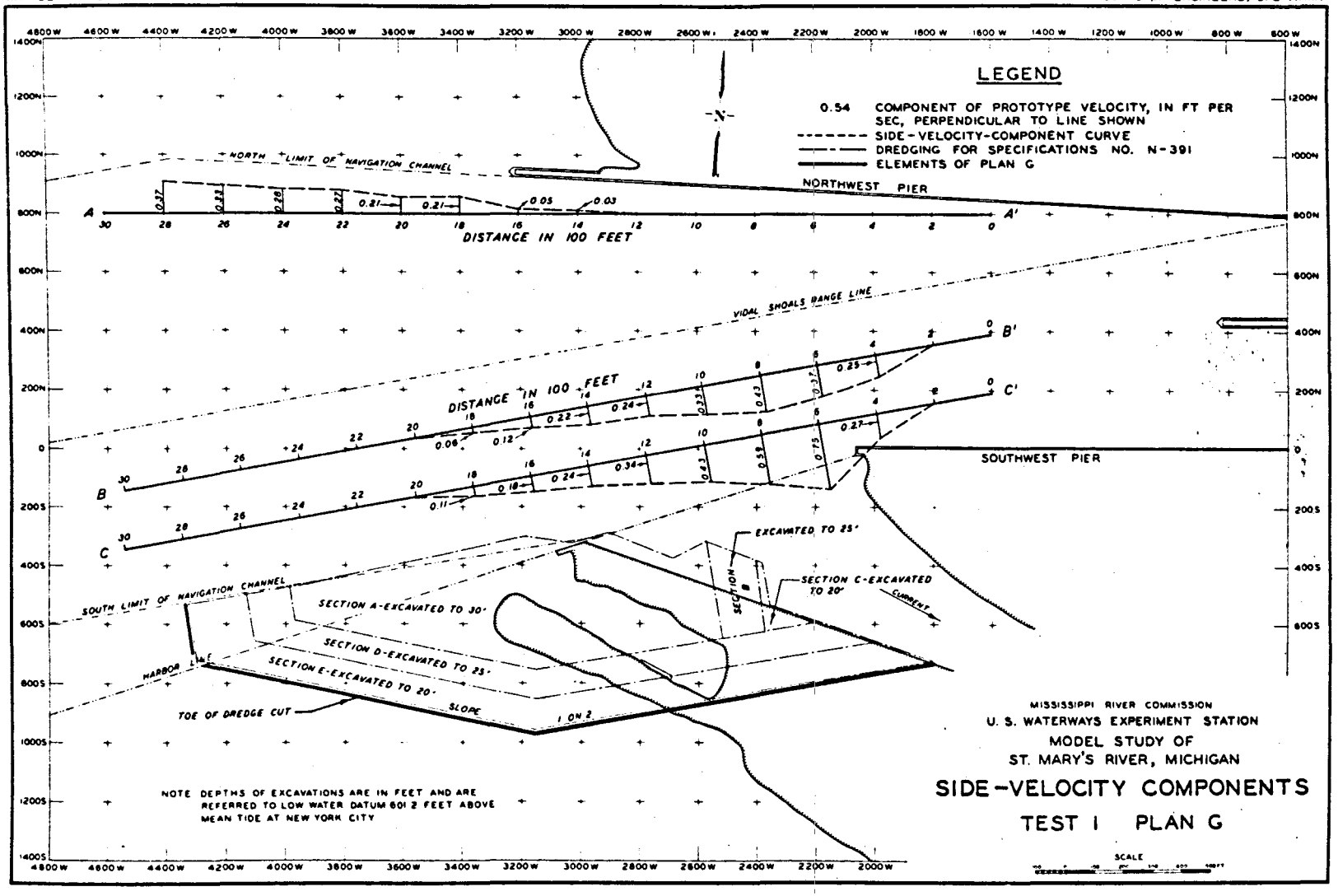
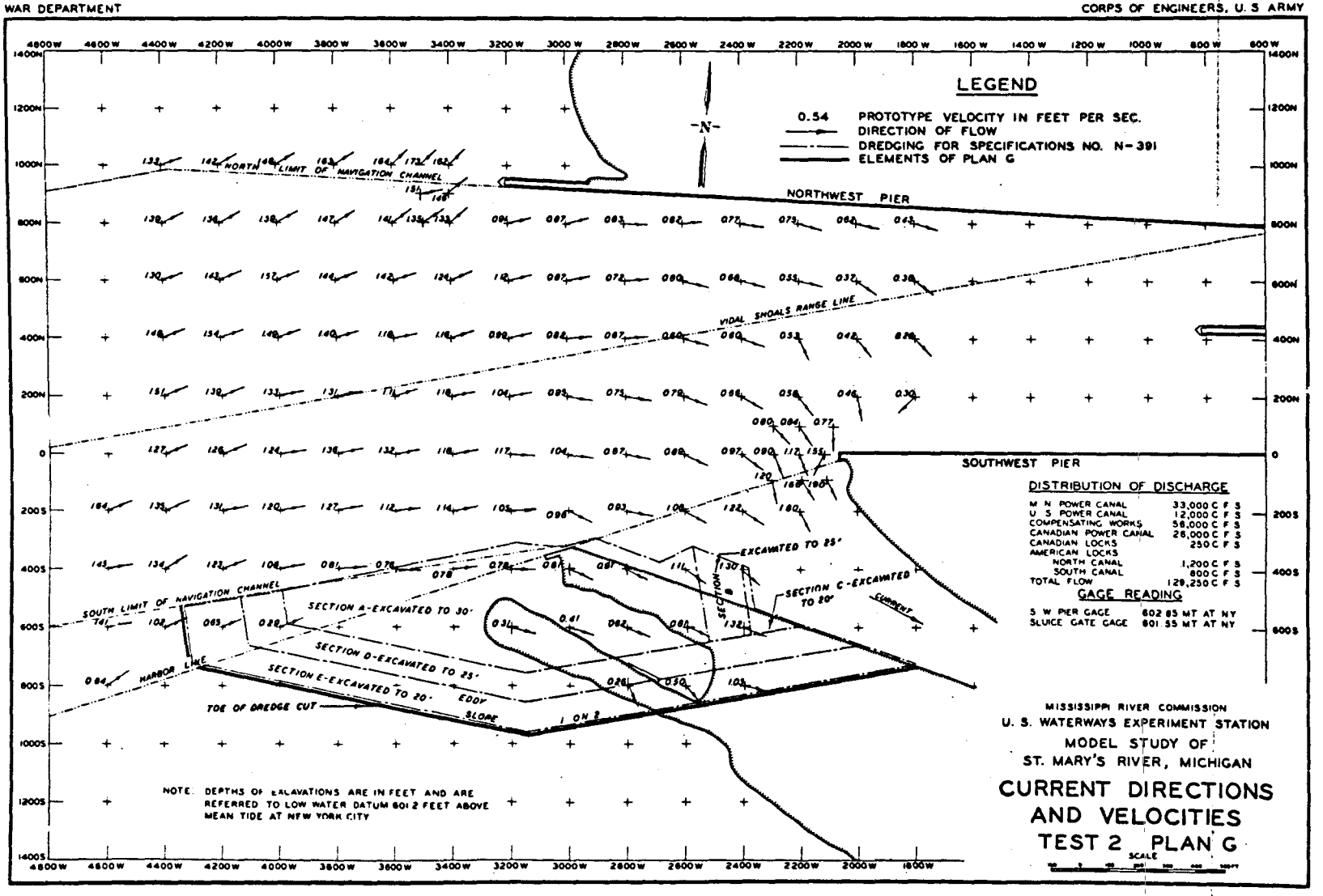


PLATE 45

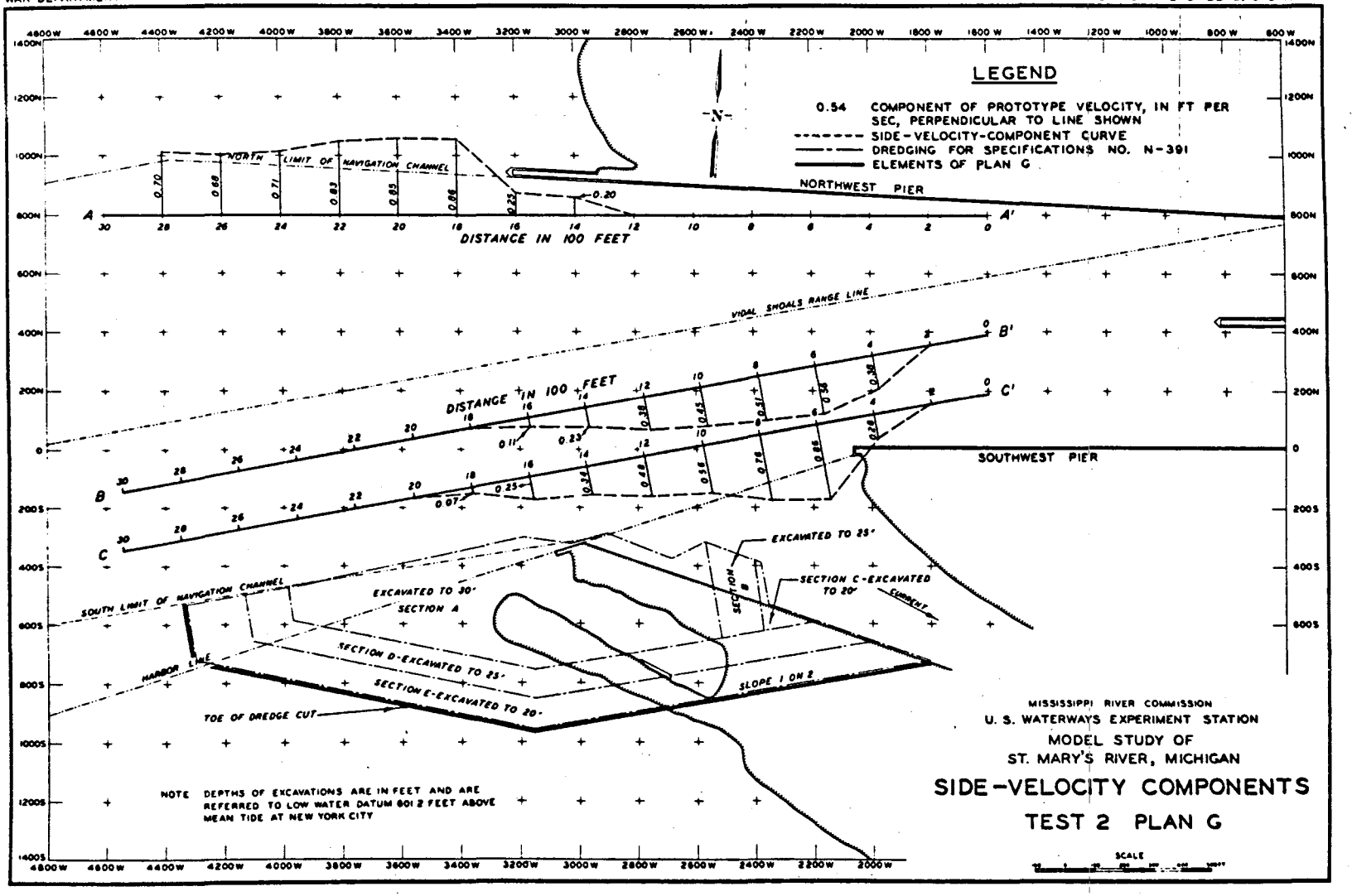
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

SIDE-VELOCITY COMPONENTS

TEST 2 PLAN G

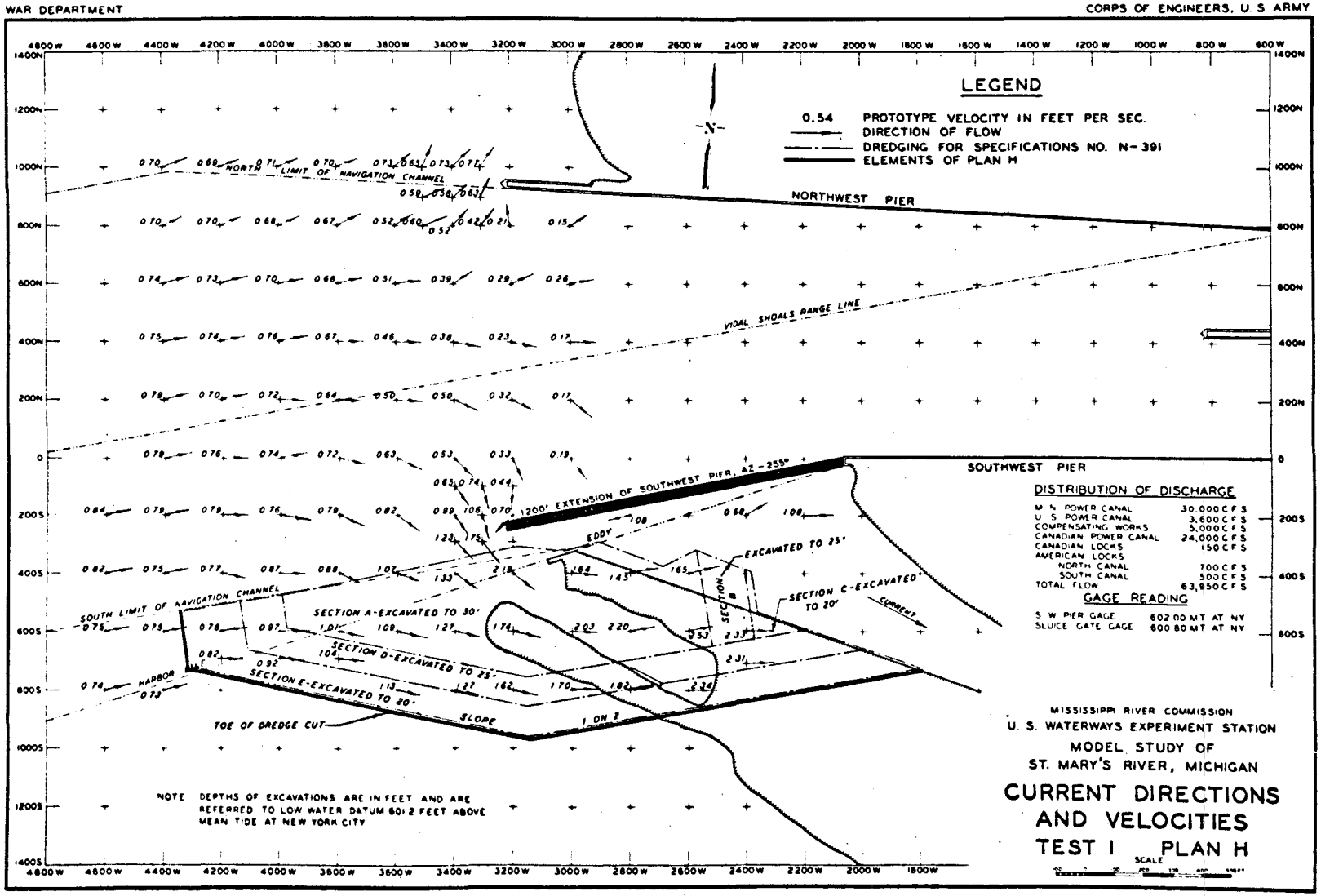
SCALE

PLATE 47

PLATE 48

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

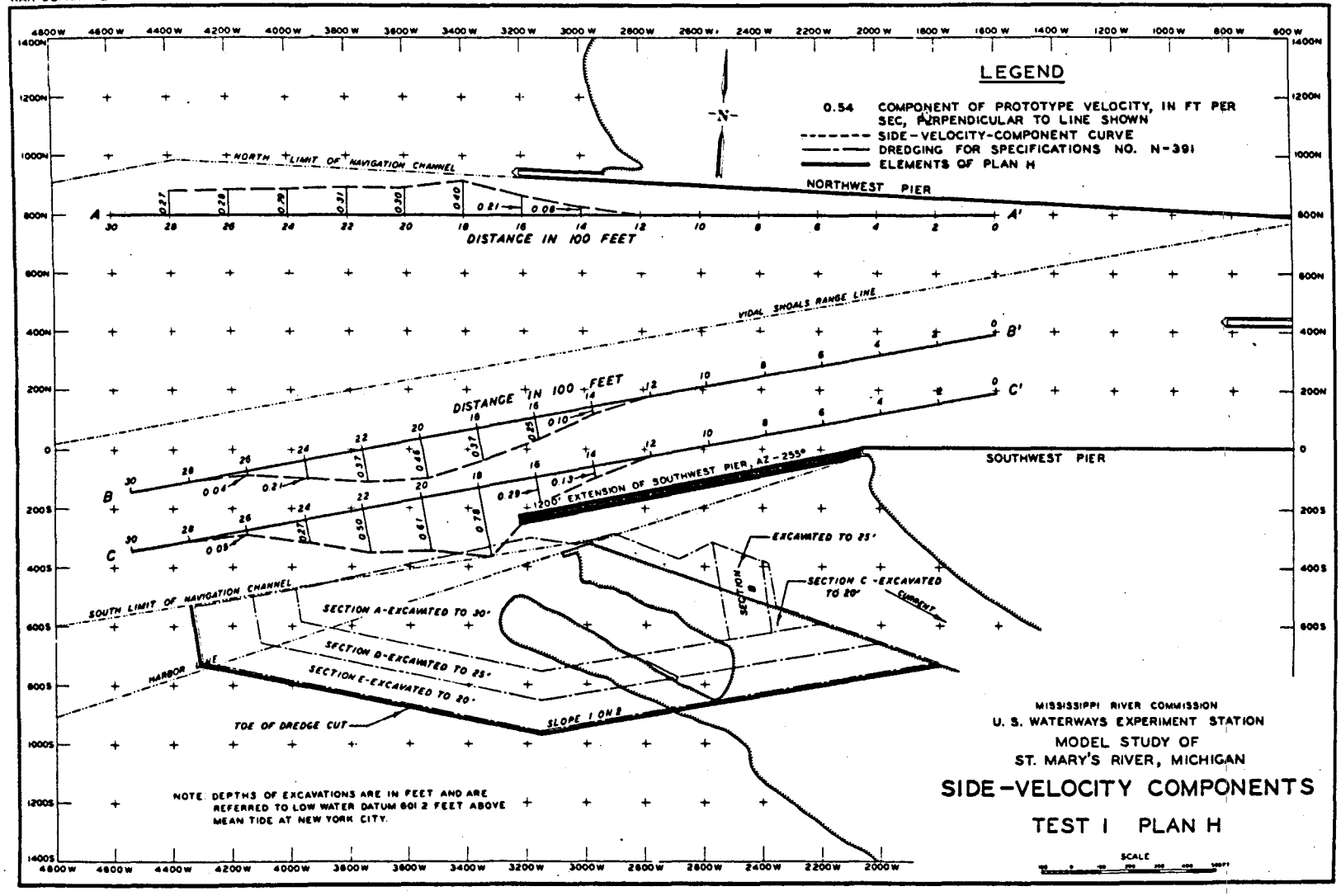
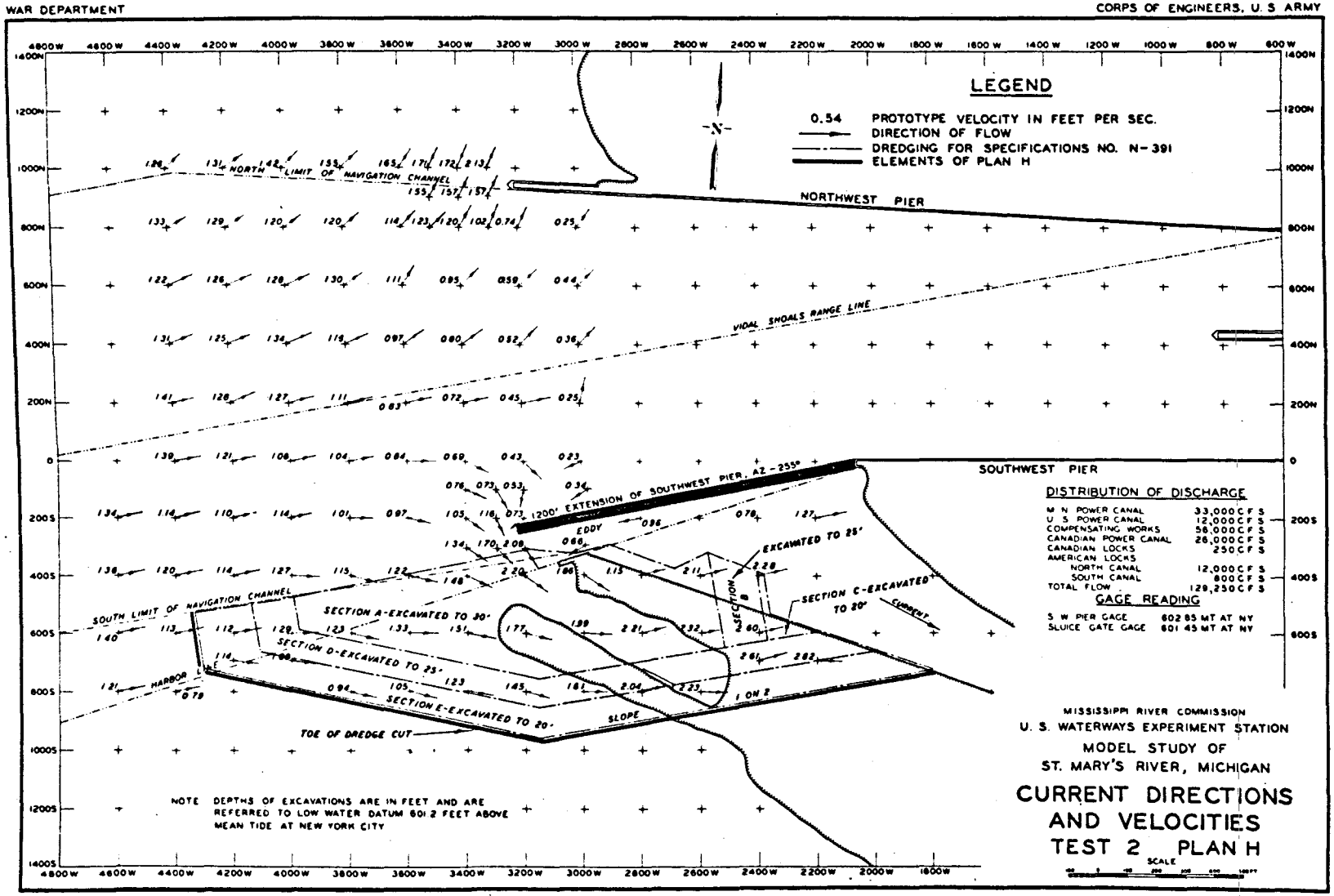


PLATE 49

PLATE 50

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST 2 PLAN H

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

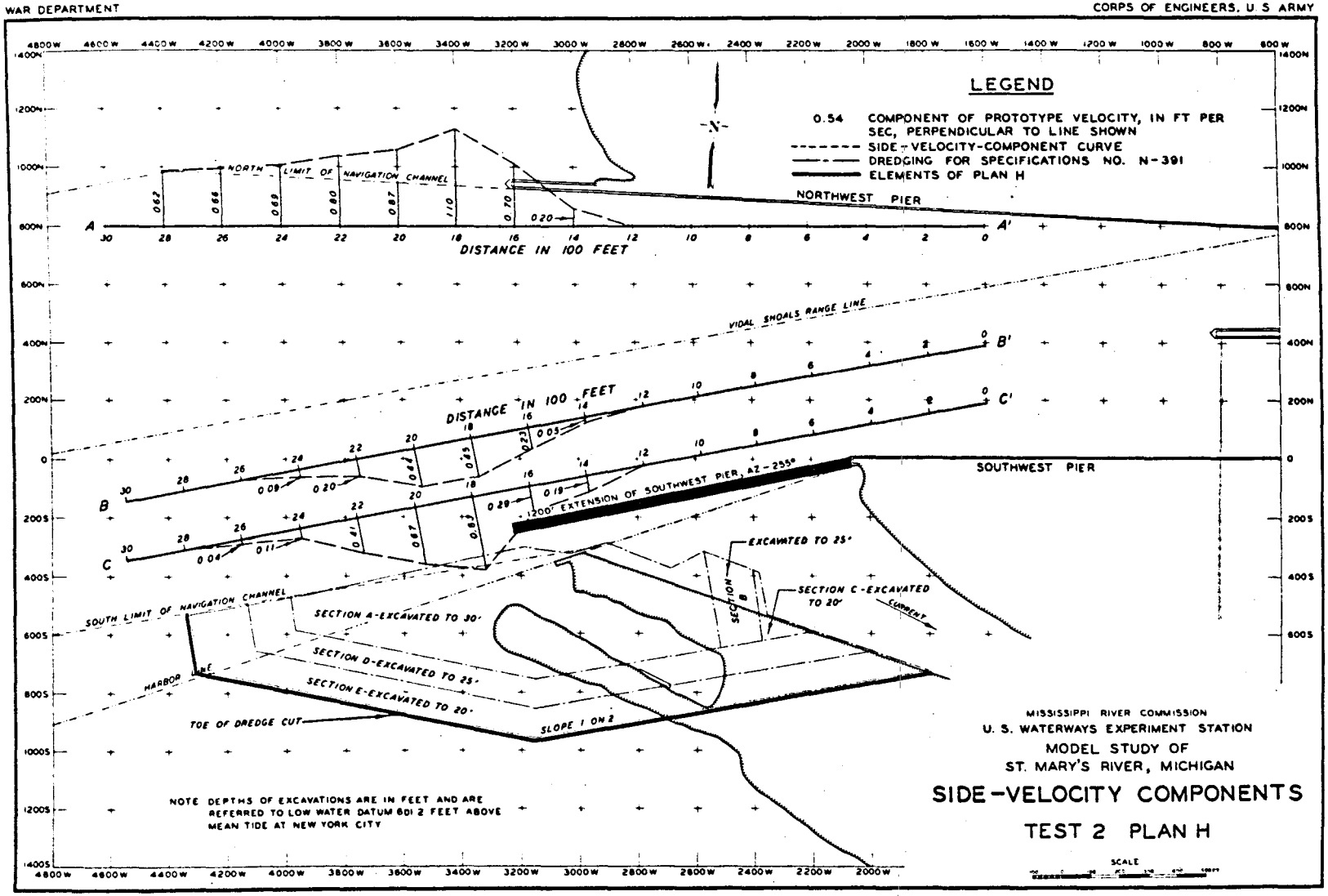
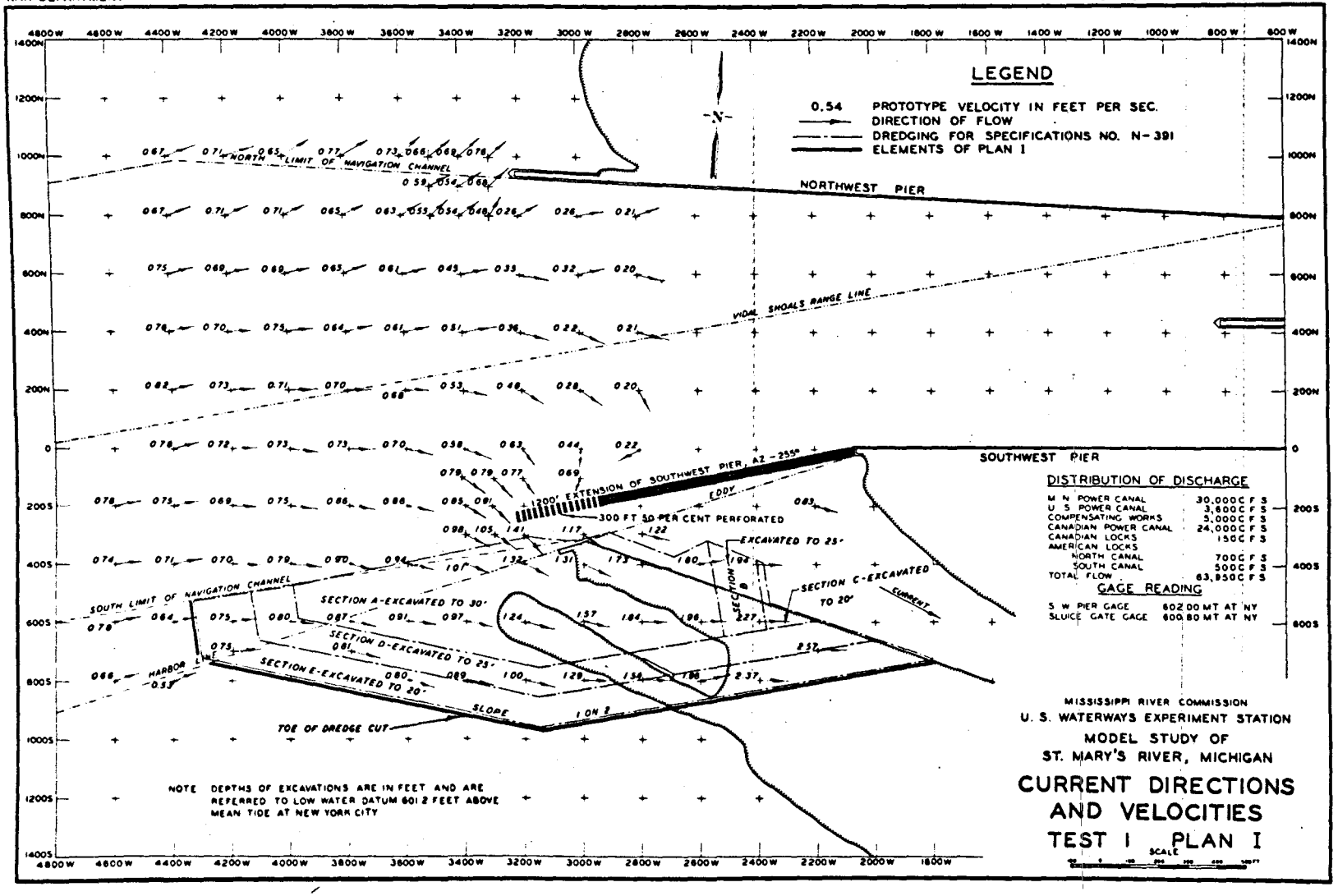


PLATE 51

PLATE 52

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

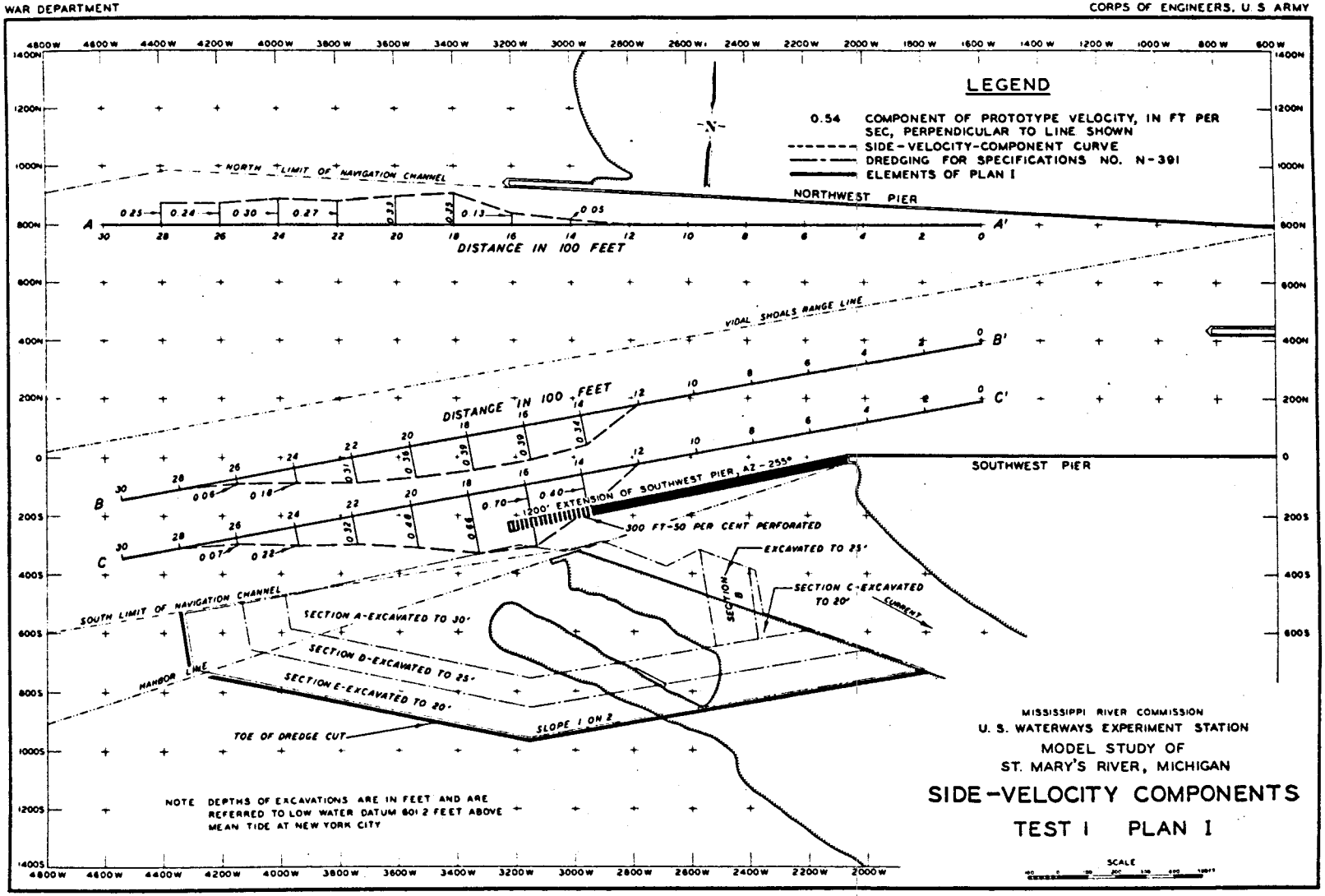
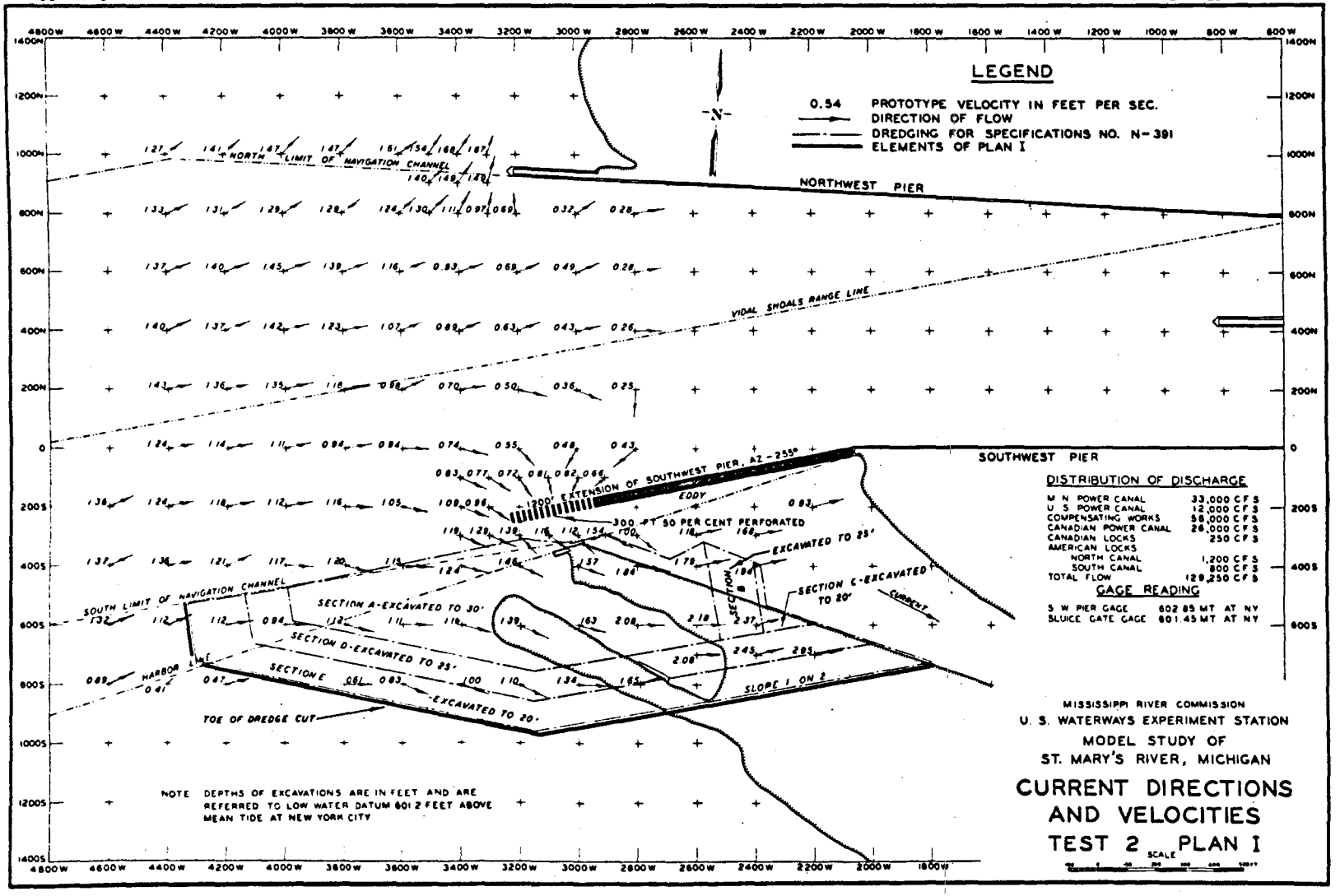


PLATE 53

PLATE 54

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



NOTE DEPTHS OF EXCAVATIONS ARE IN FEET AND ARE REFERRED TO LOW WATER DATUM 601.2 FEET ABOVE MEAN TIDE AT NEW YORK CITY

DISTRIBUTION OF DISCHARGE

M N POWER CANAL	33,000 C F S
U S POWER CANAL	12,000 C F S
COMPENSATING WORKS	58,000 C F S
CANADIAN POWER CANAL	26,000 C F S
CANADIAN LOCKS	250 C F S
AMERICAN LOCKS	
NORTH CANAL	1,200 C F S
SOUTH CANAL	800 C F S
TOTAL FLOW	129,250 C F S

GAGE READING

S W PIER GAGE	602.85 MT AT NY
SLUICE GATE GAGE	601.45 MT AT NY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

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ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST 2 PLAN I

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

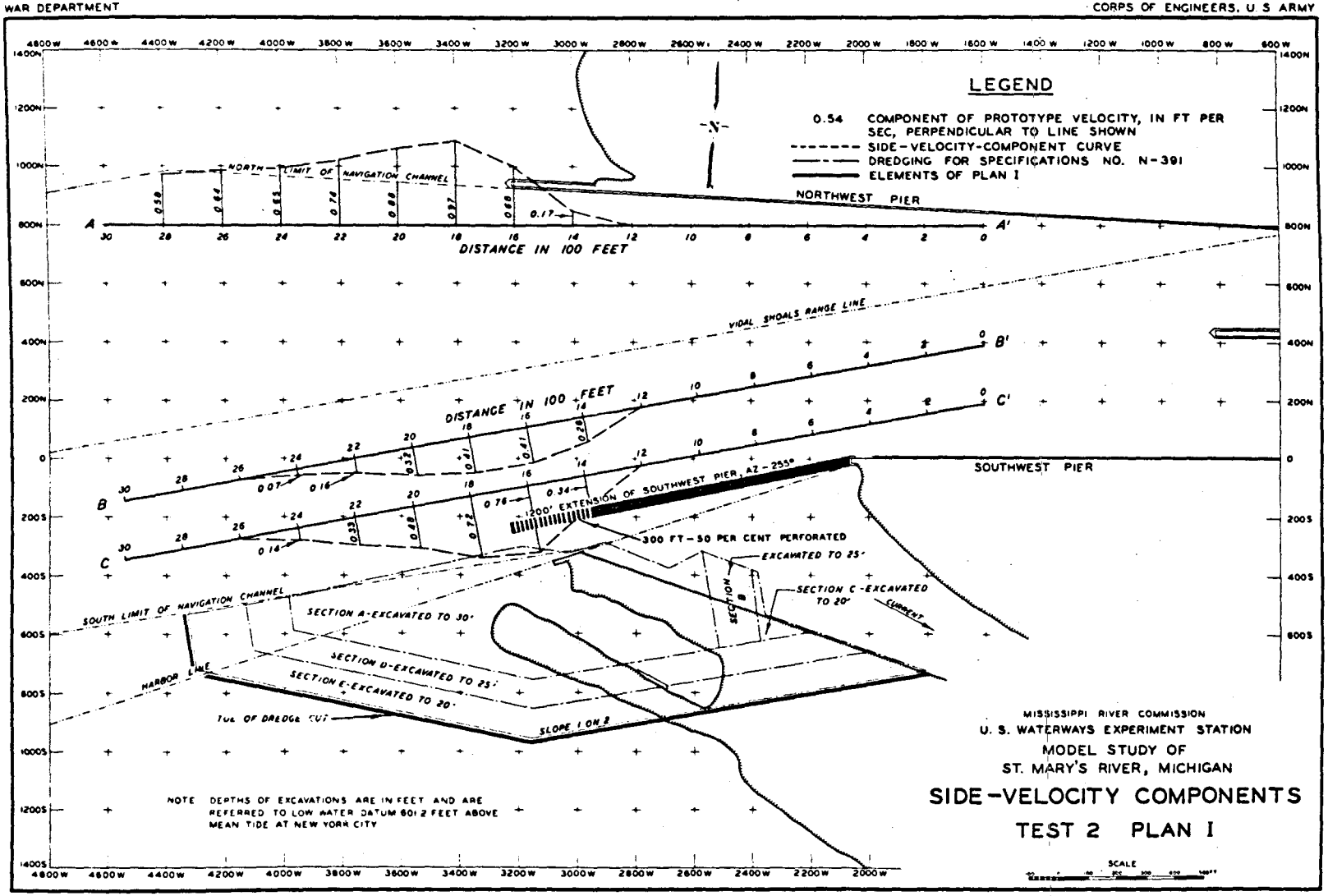
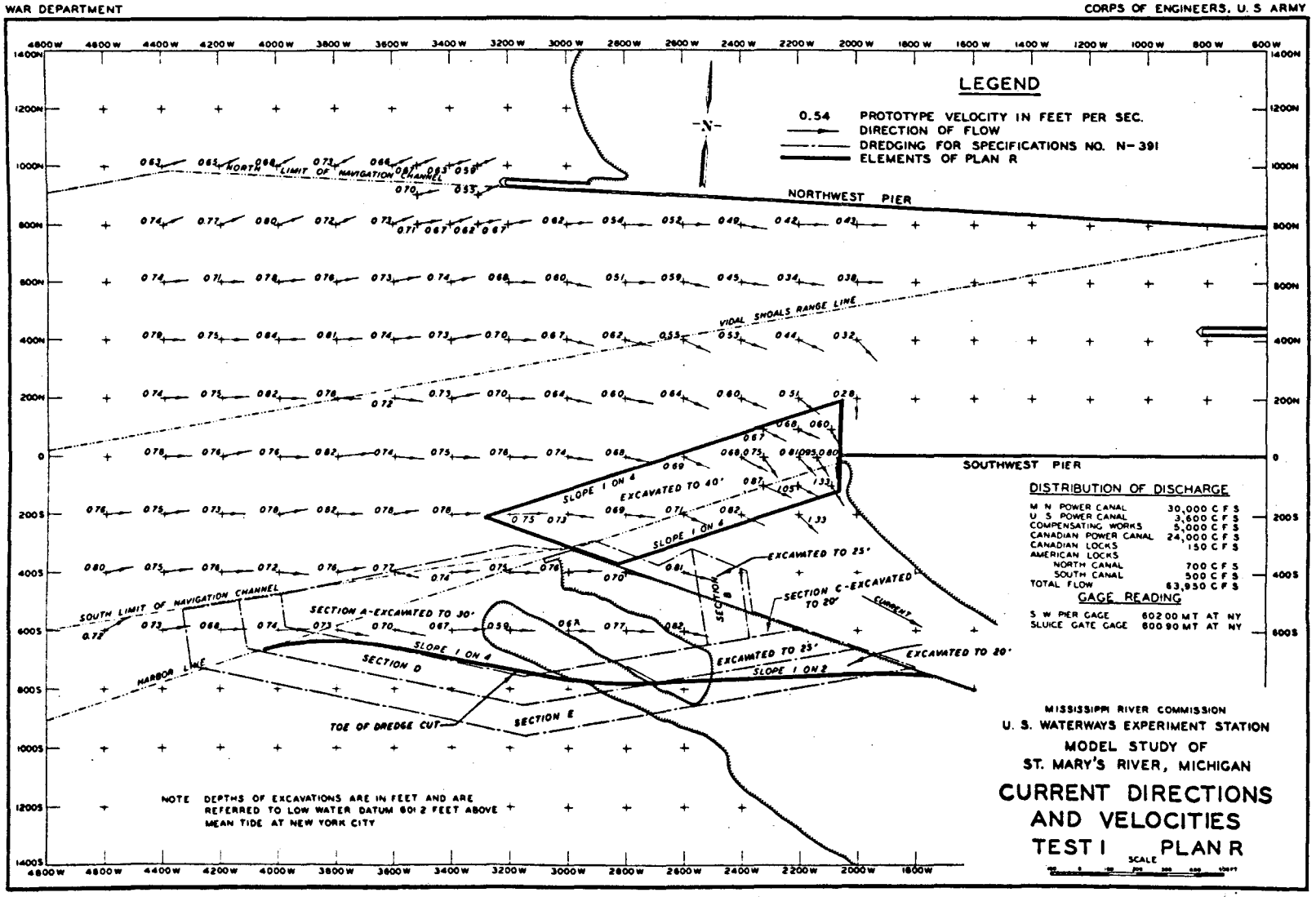


PLATE 55

PLATE 56

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN R

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

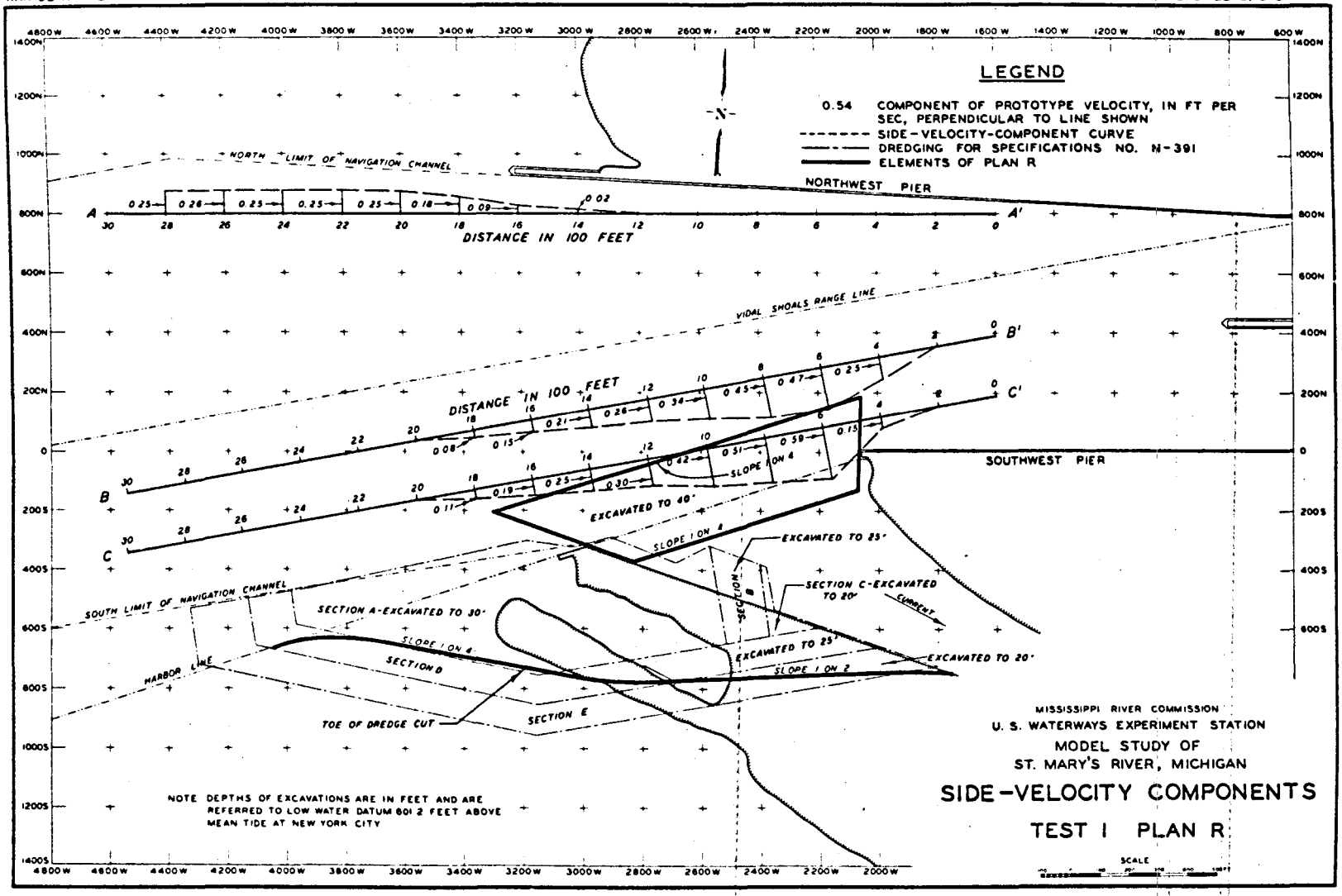
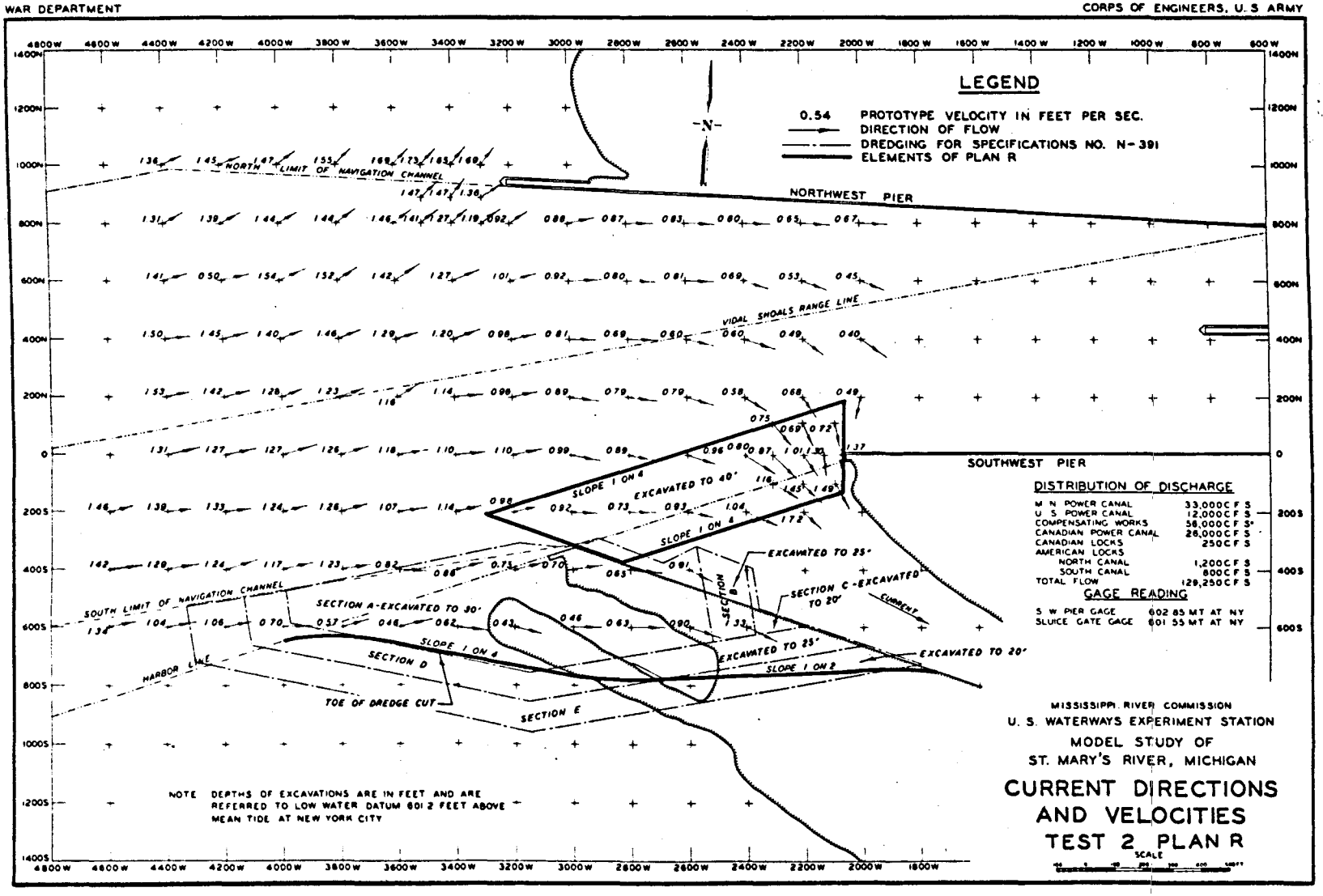


PLATE 57

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

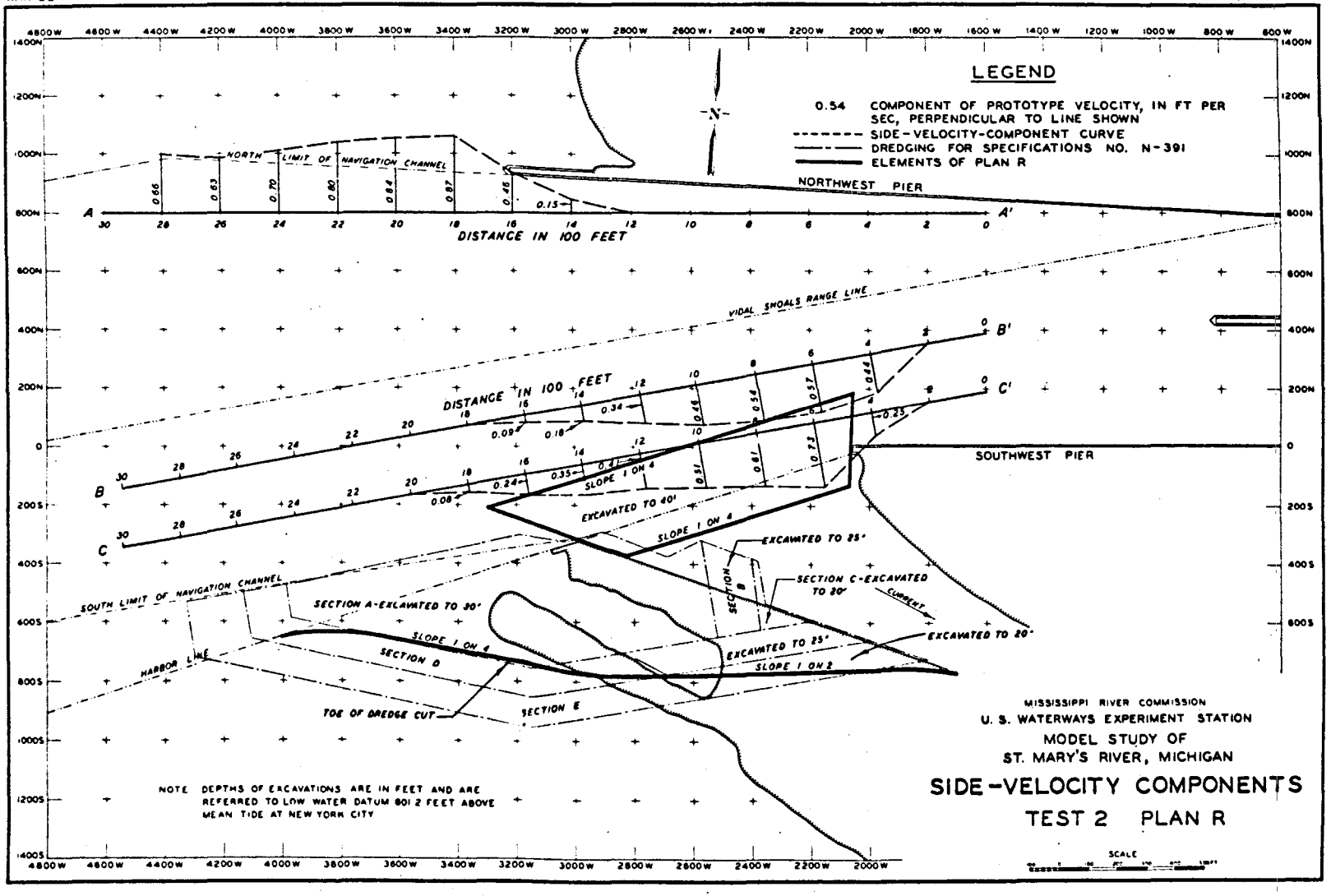
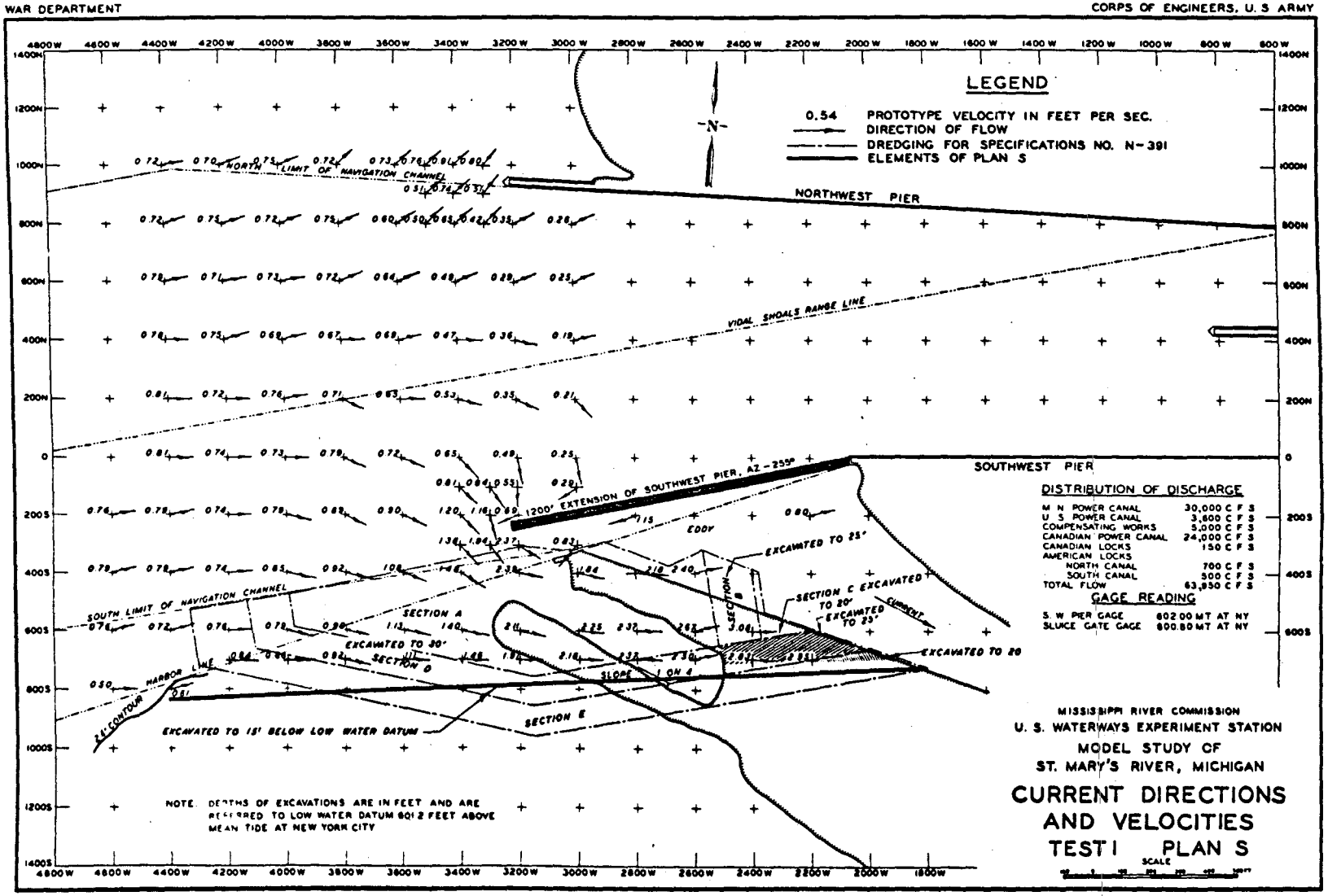


PLATE 59

PLATE 60

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	30,000 C F S
U S POWER CANAL	3,600 C F S
COMPENSATING WORKS	5,000 C F S
CANADIAN POWER CANAL	24,000 C F S
CANADIAN LOCKS	150 C F S
AMERICAN LOCKS	
NORTH CANAL	700 C F S
SOUTH CANAL	500 C F S
TOTAL FLOW	63,950 C F S

GAGE READING

S. W. PIER GAGE	602.00 MT AT NY
SLUICE GATE GAGE	600.80 MT AT NY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN S

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

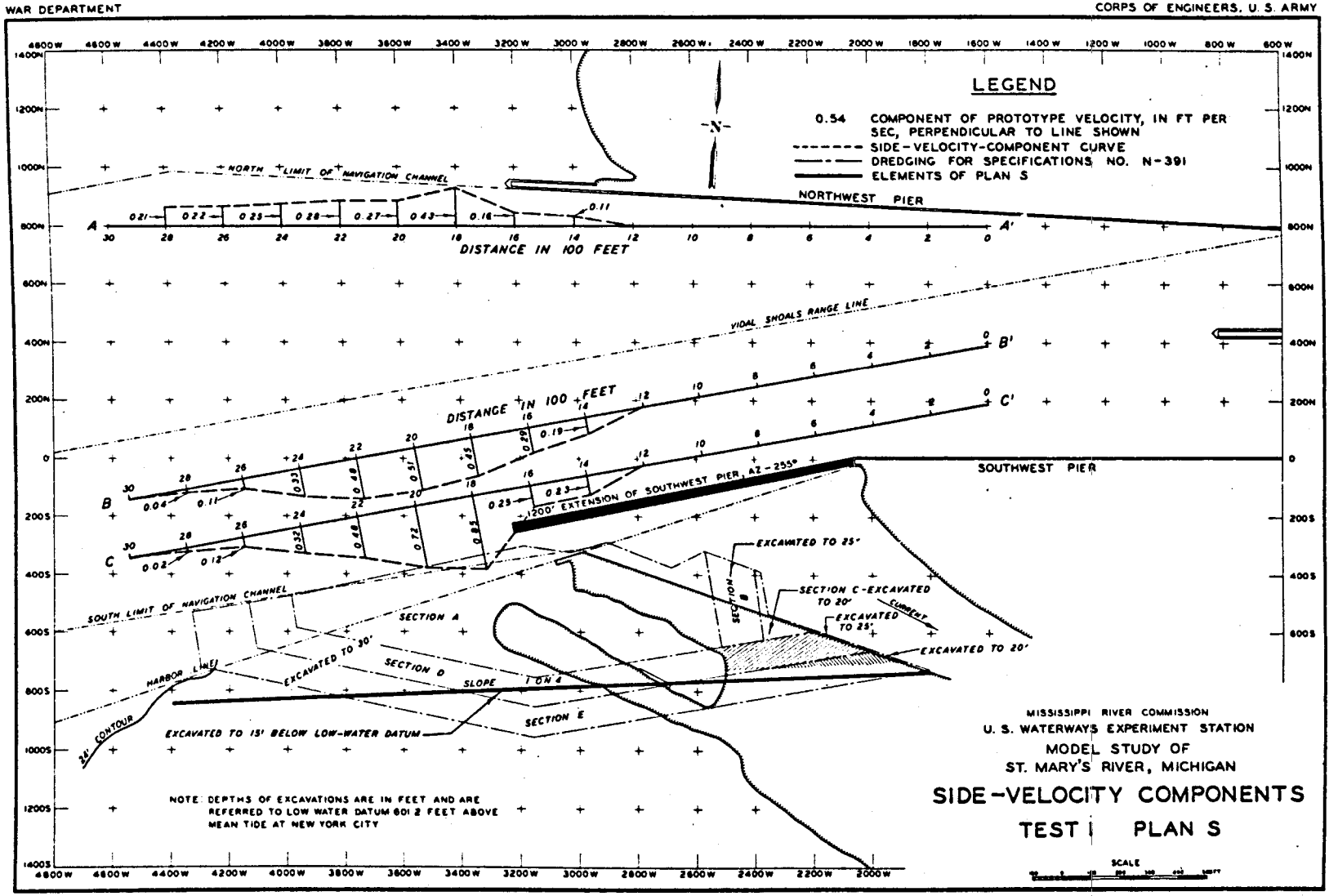
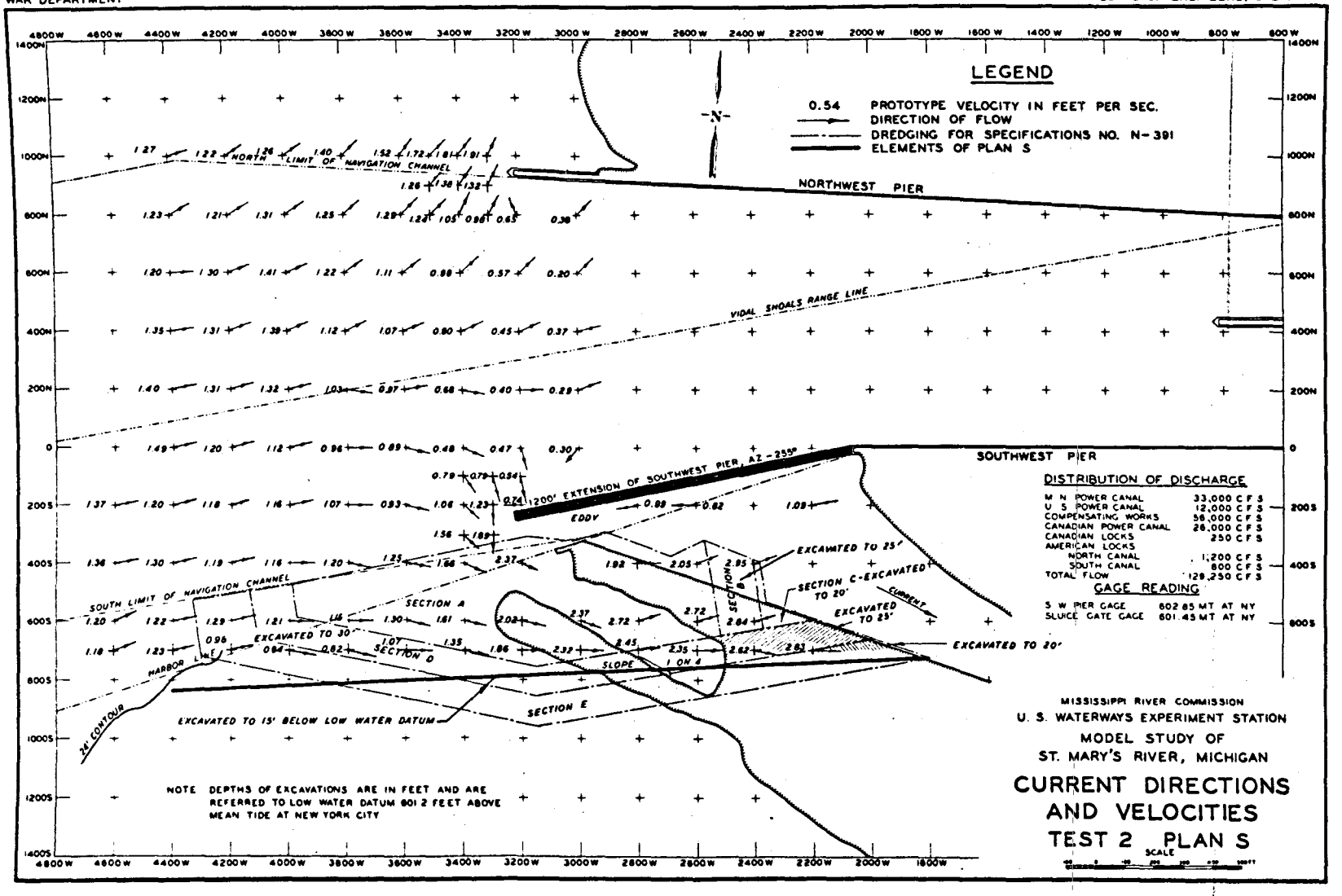


PLATE 61

PLATE 62

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

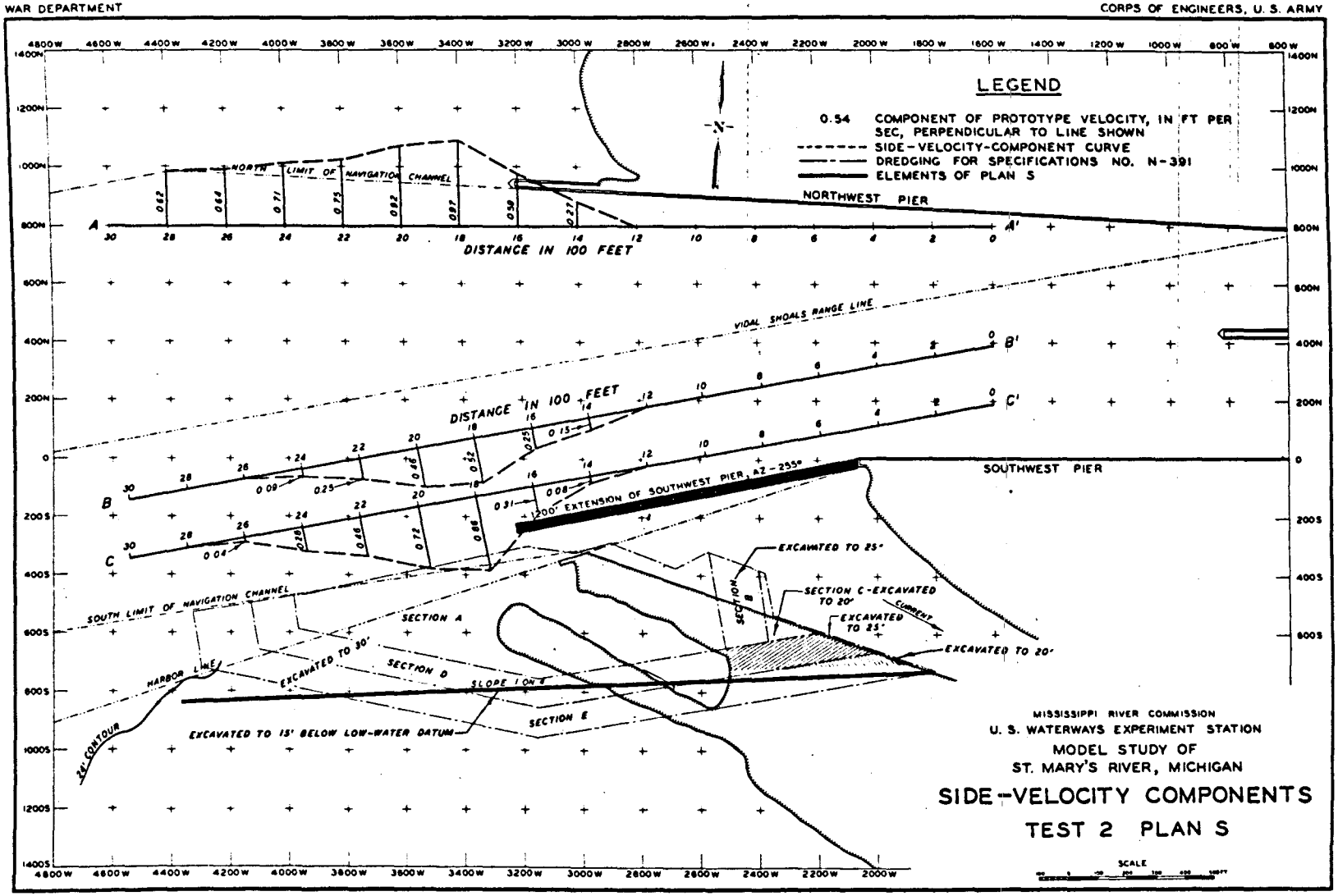
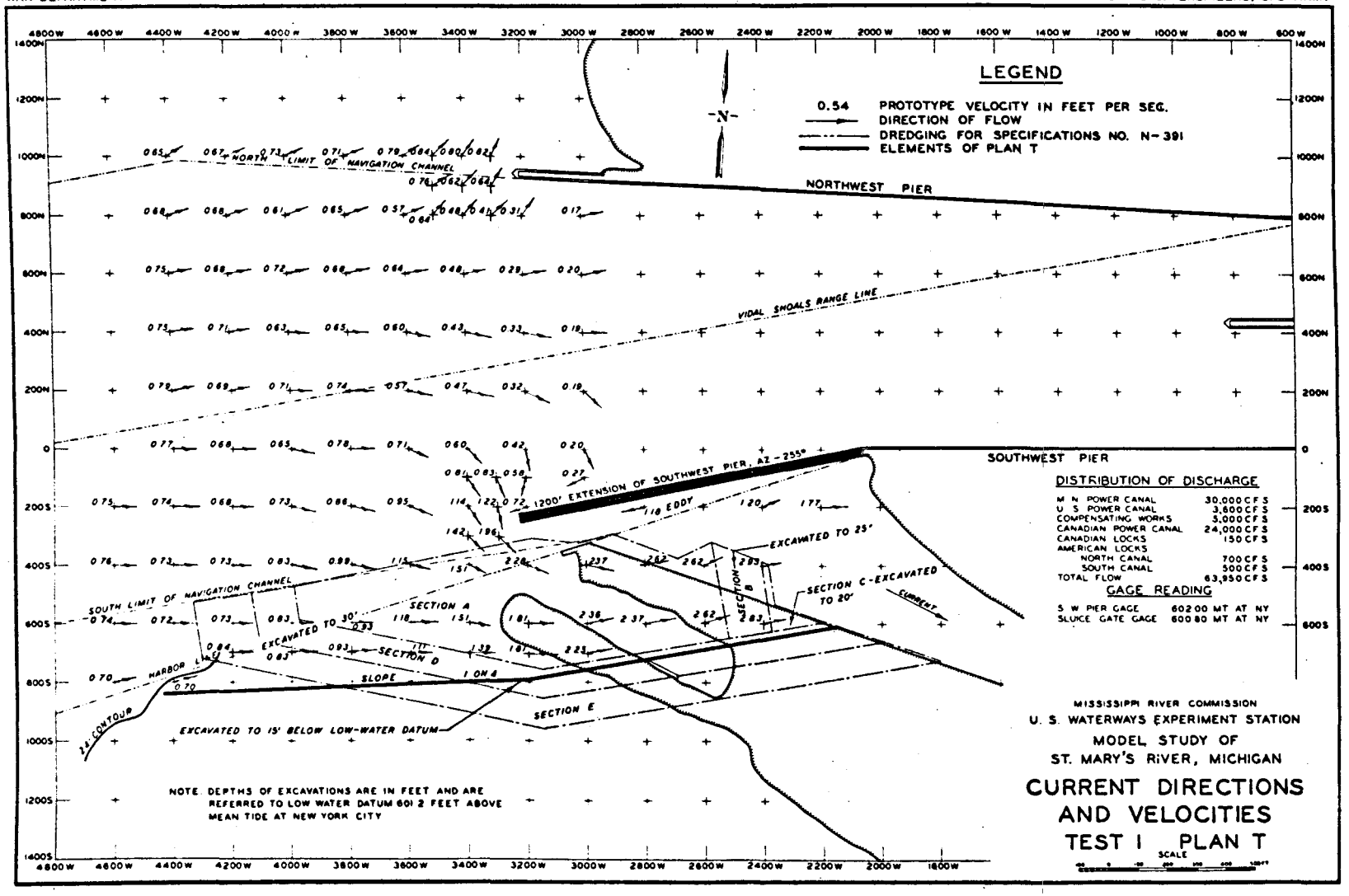


PLATE 63

PLATE 64

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY

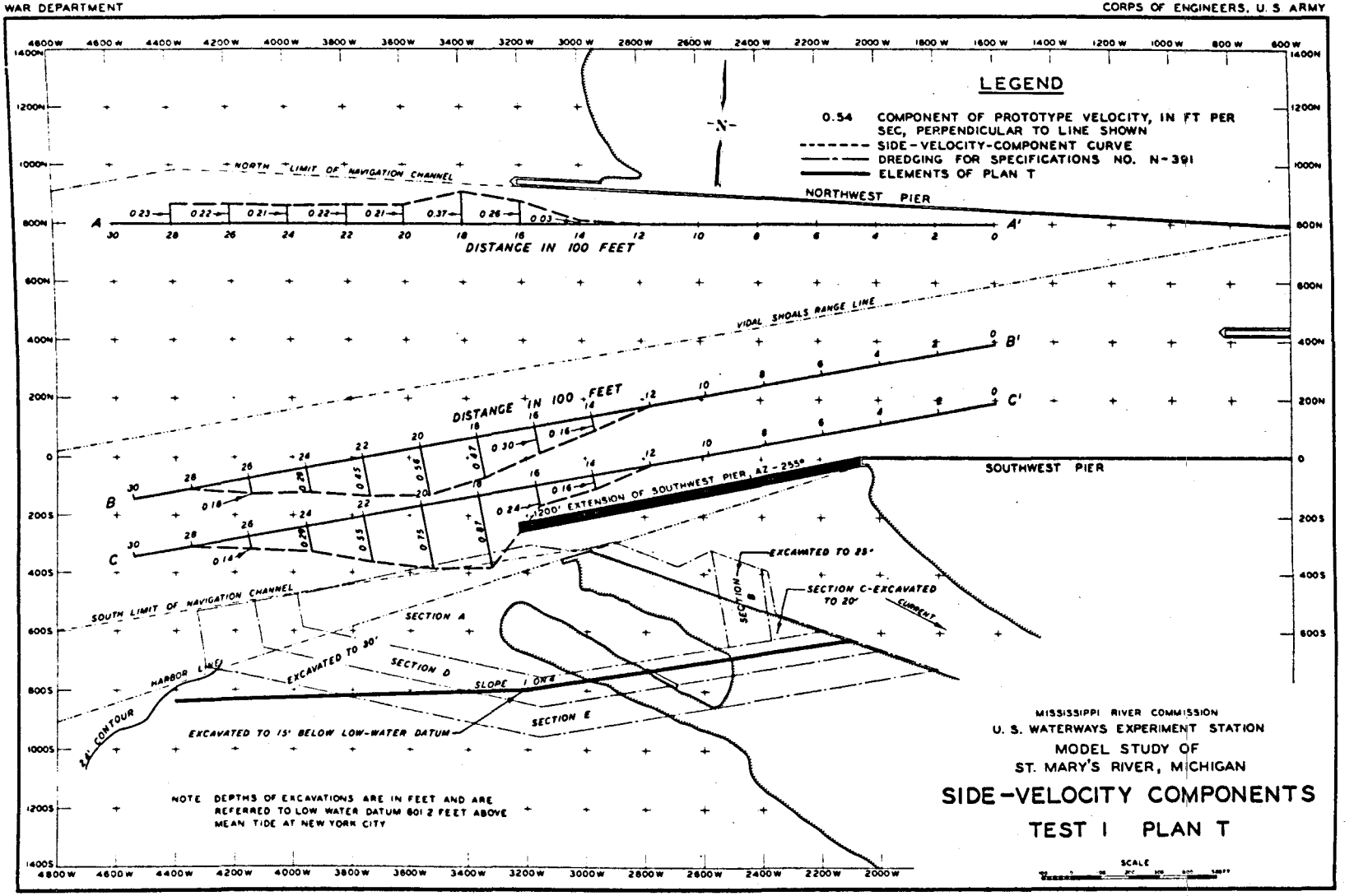
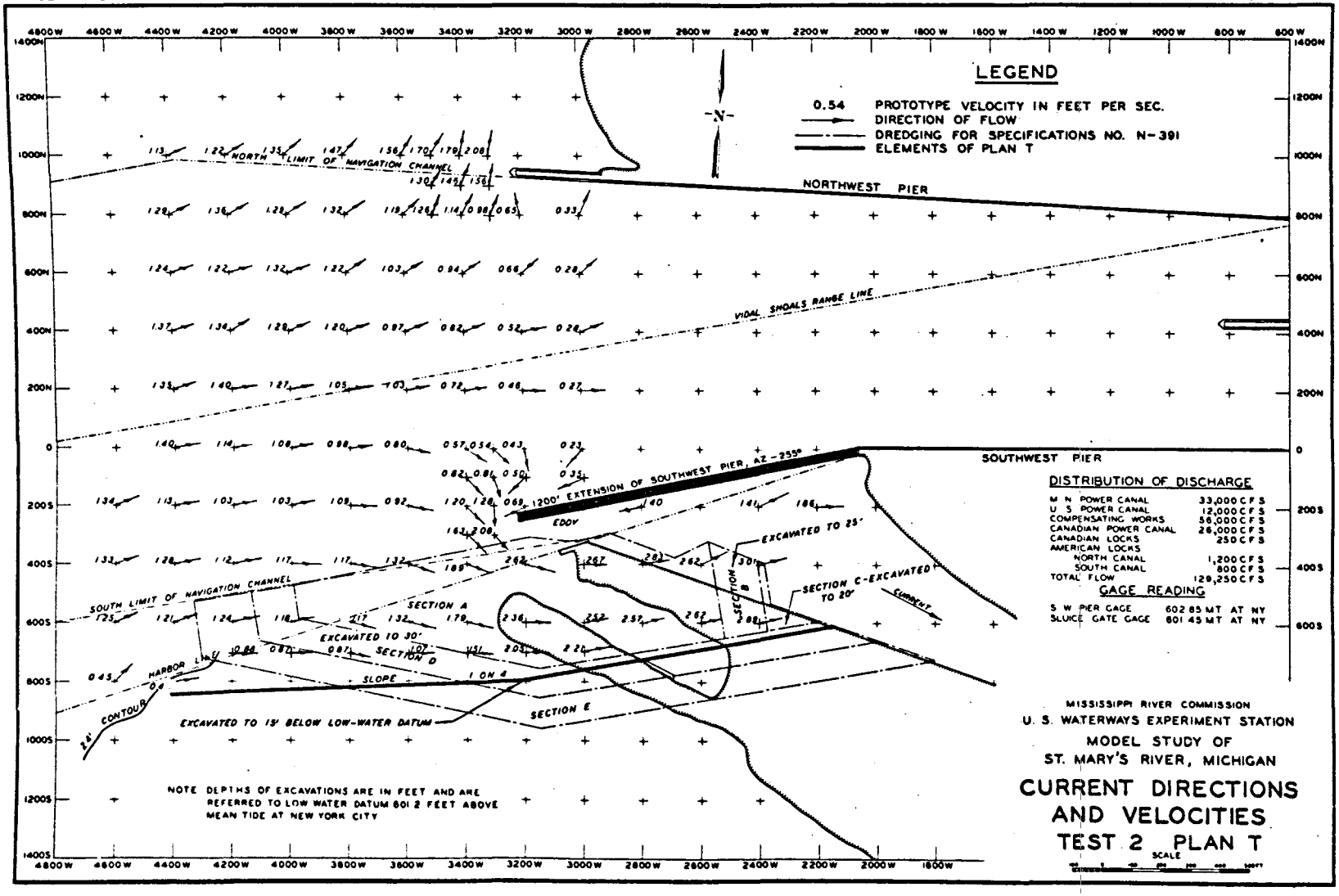


PLATE 65

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

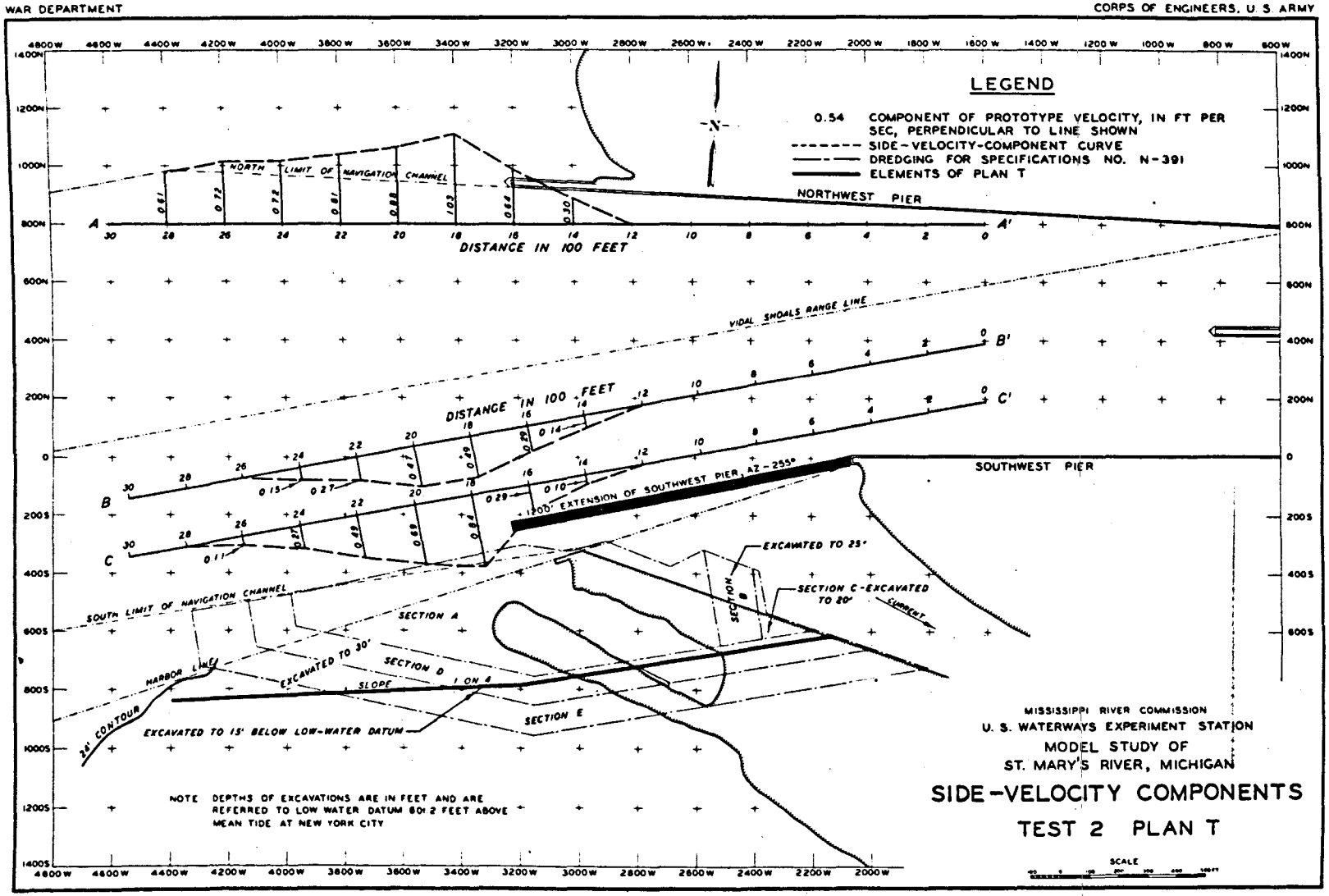
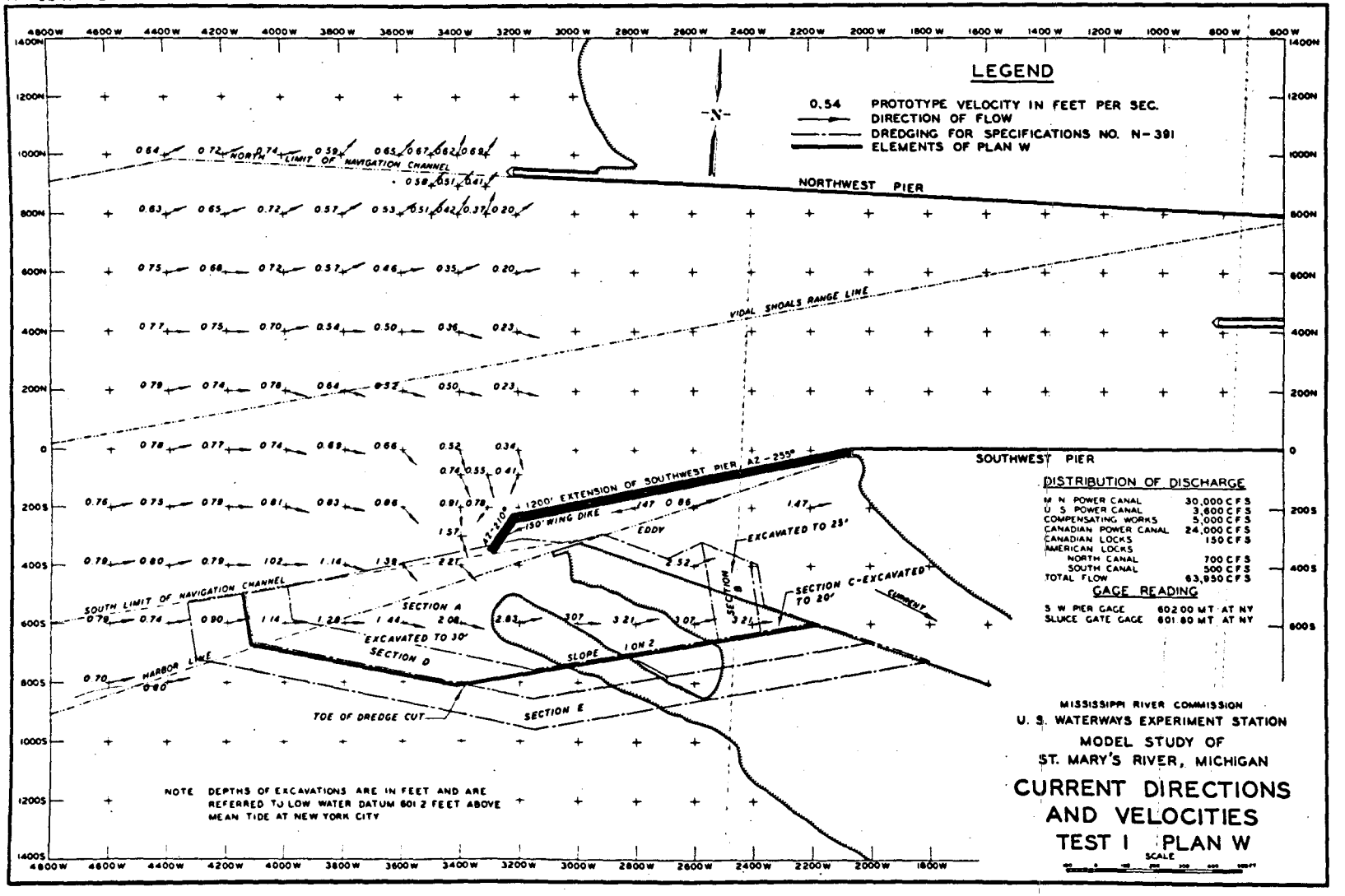


PLATE 67

PLATE 68

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

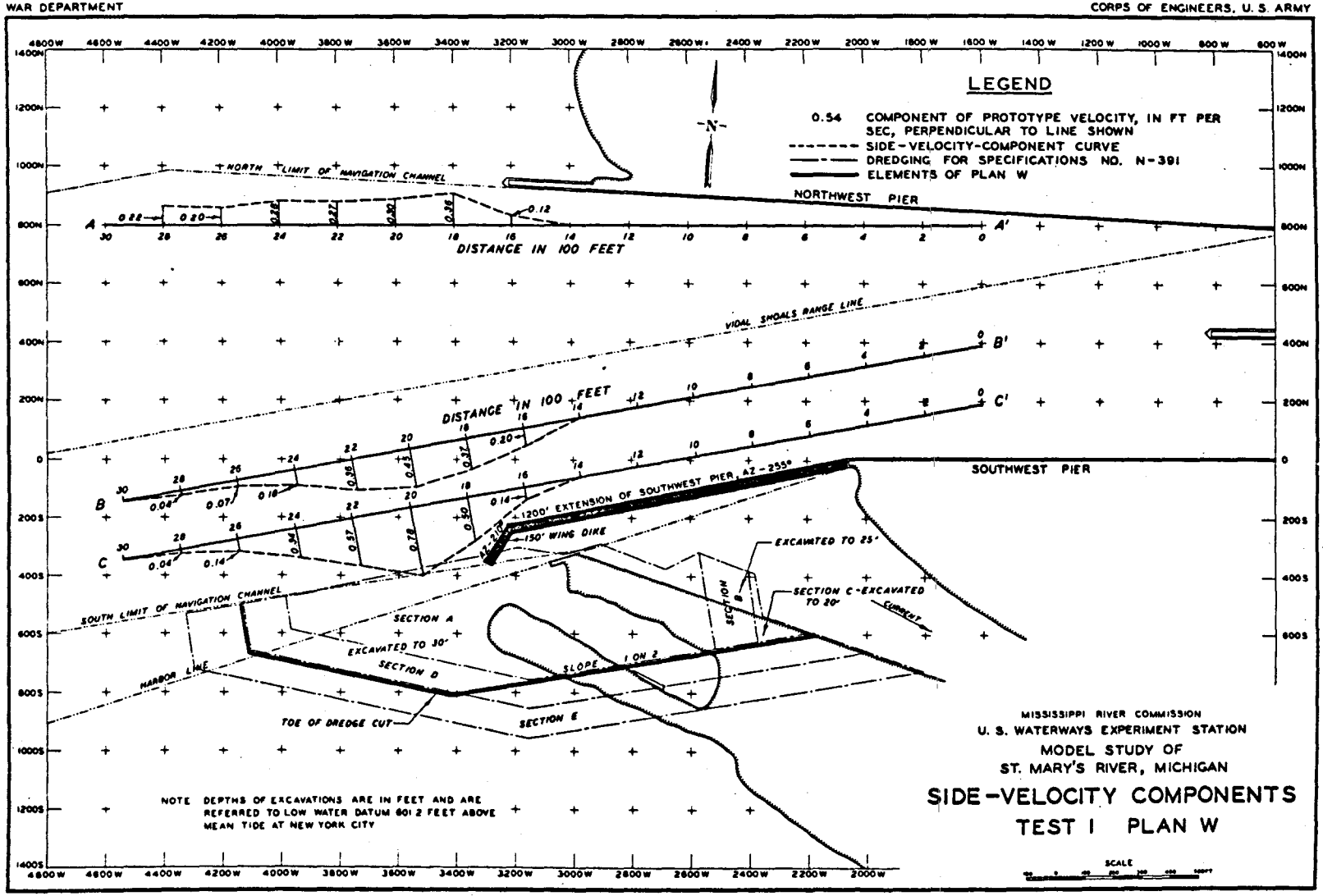
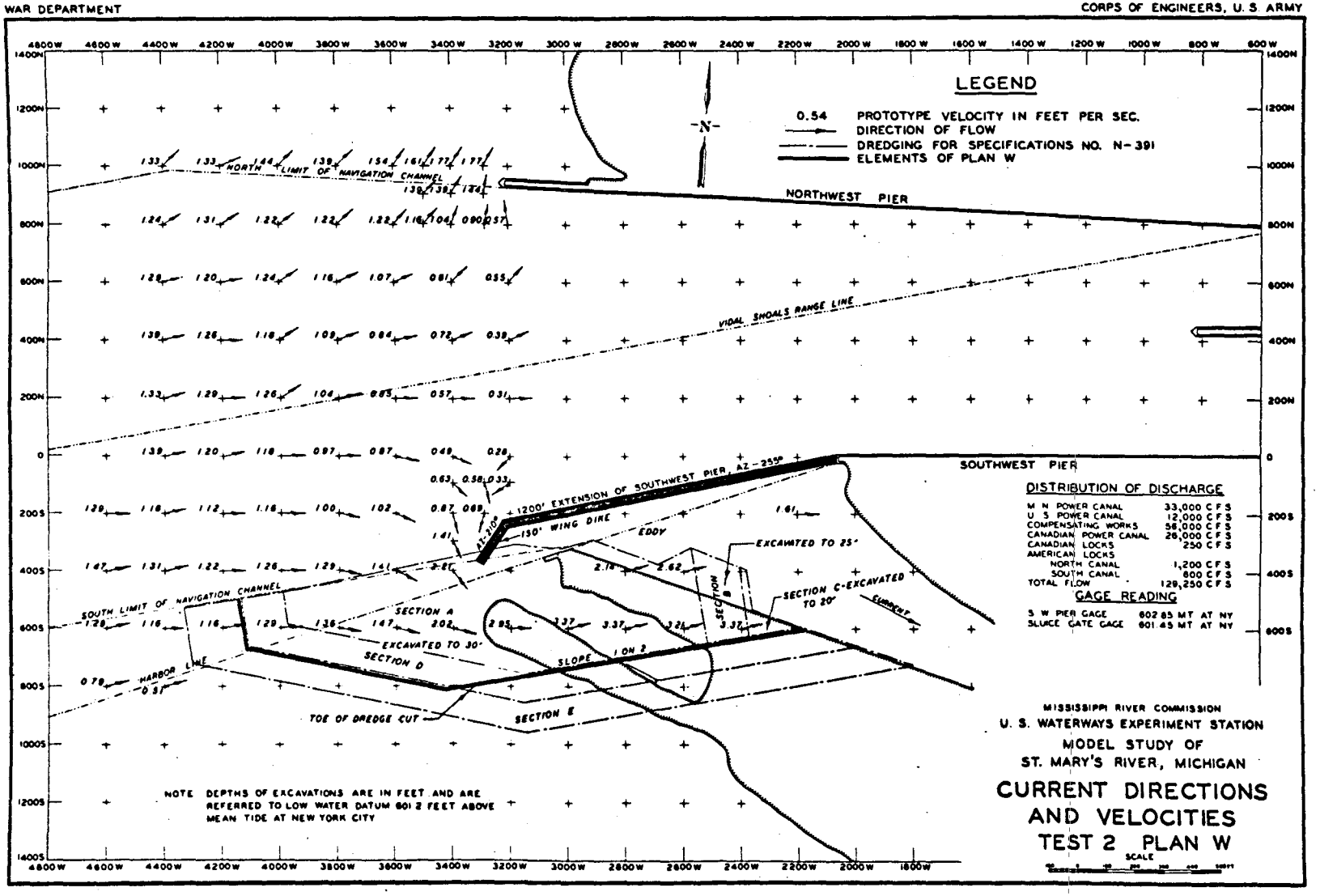


PLATE 69

PLATE 70

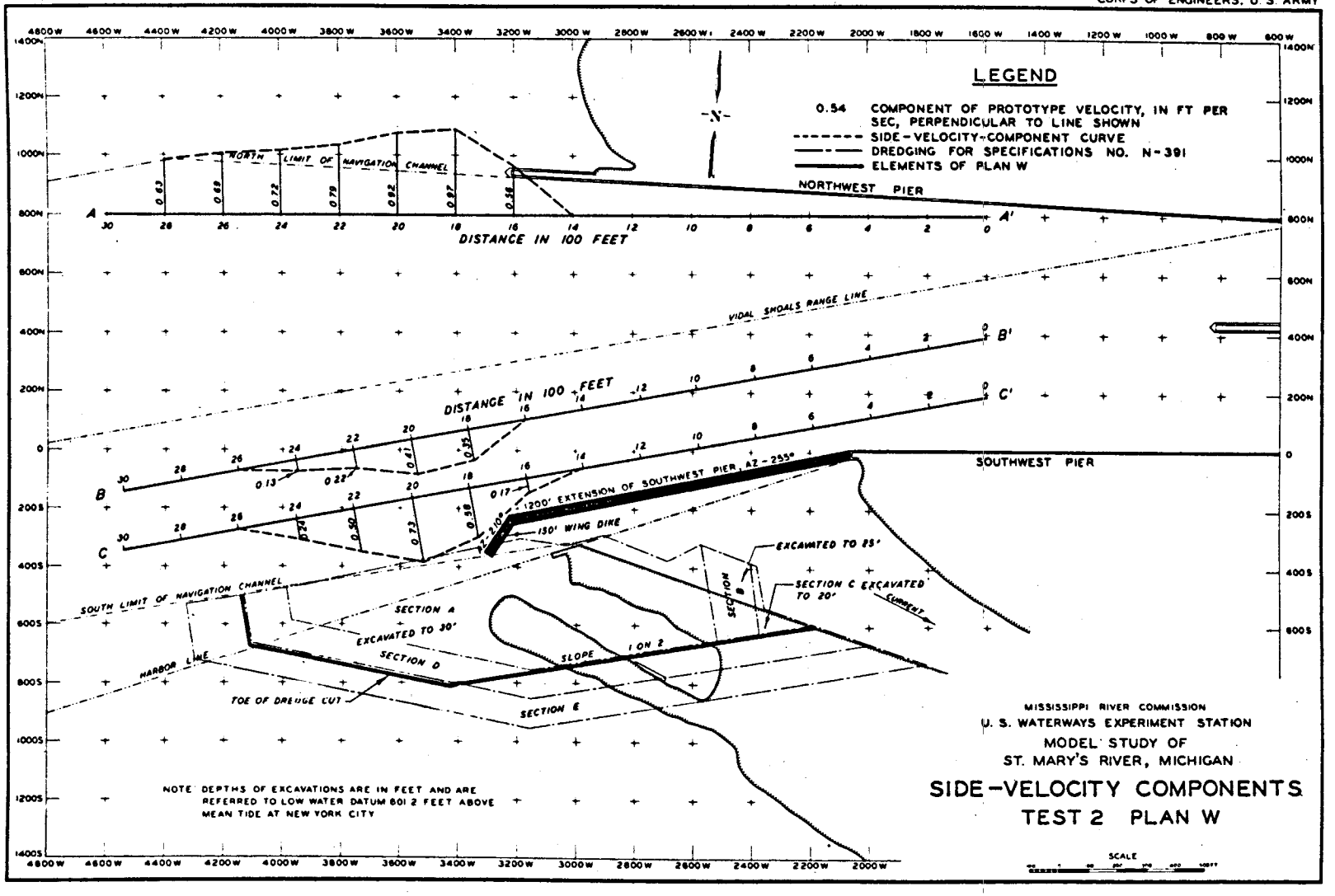
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

SIDE-VELOCITY COMPONENTS

TEST 2 PLAN W

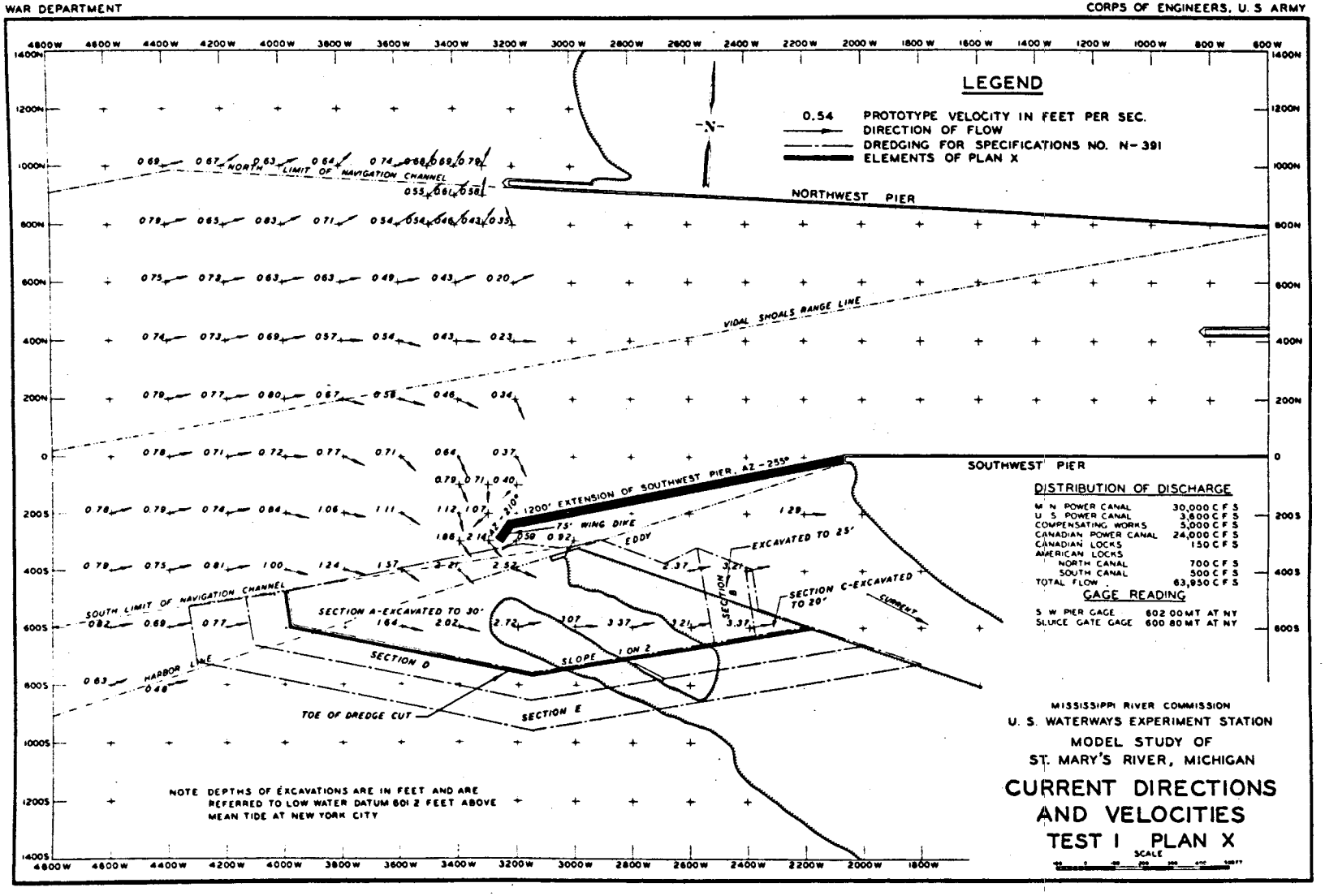
SCALE

PLATE 71

PLATE 72

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN X

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

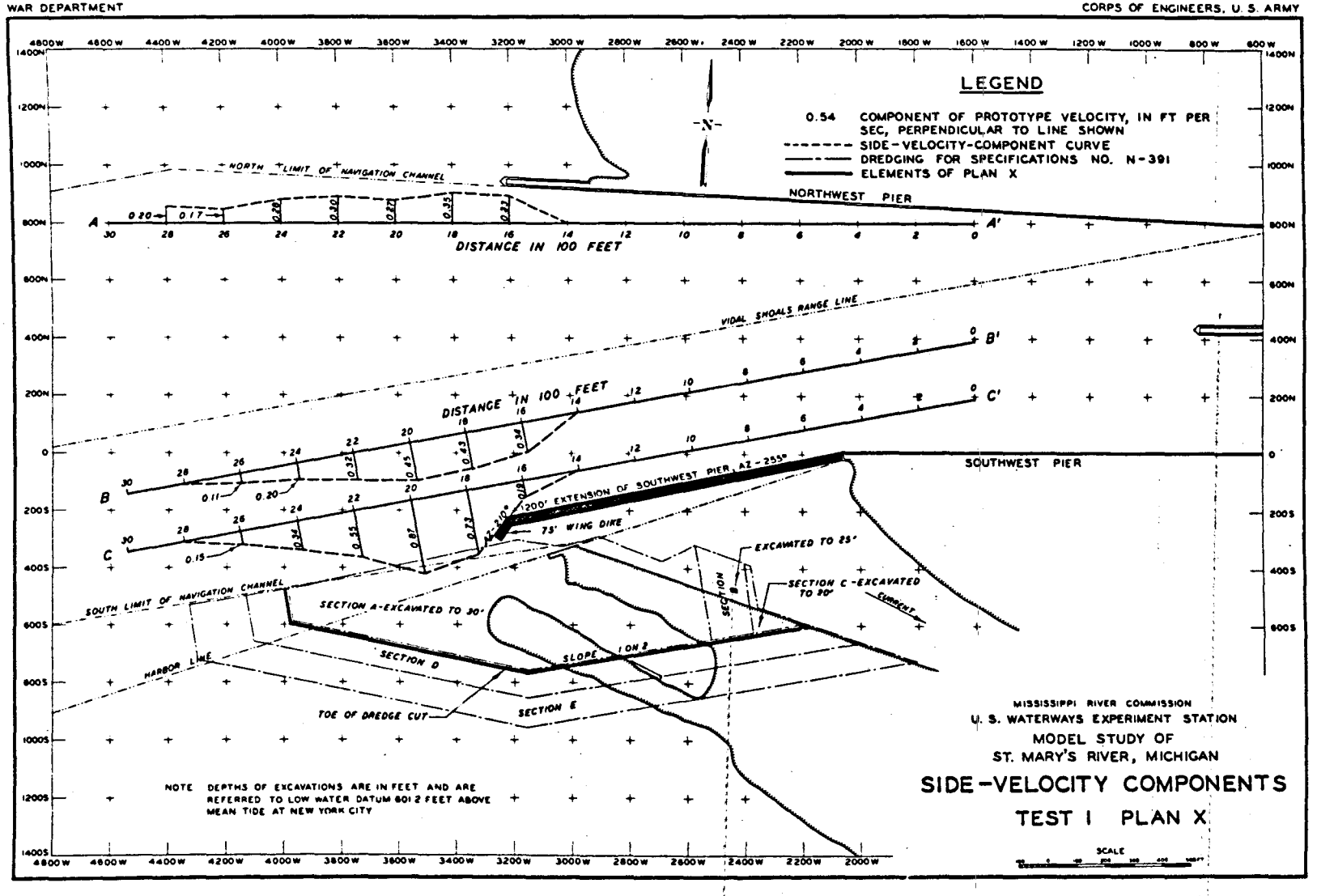
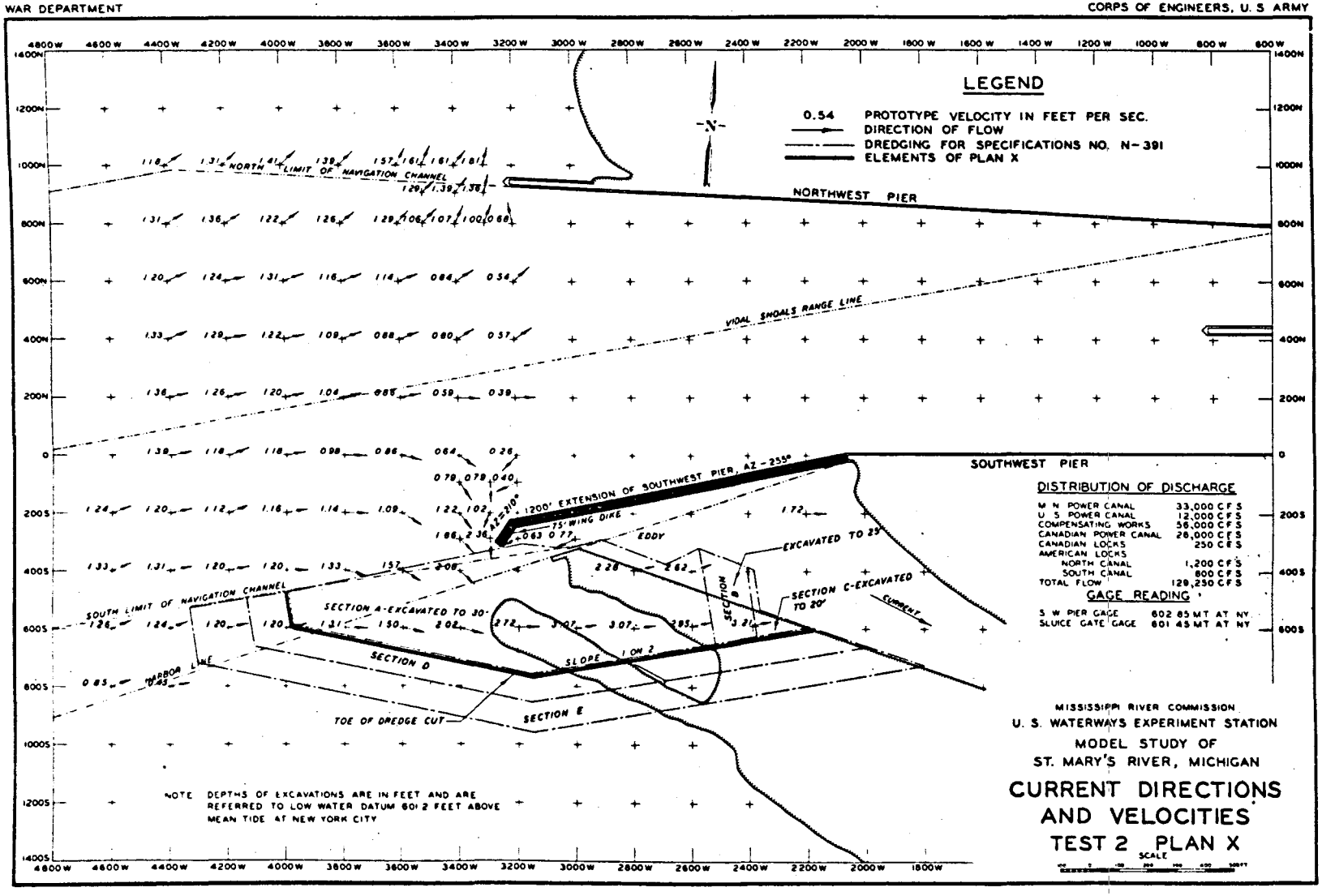


PLATE 73

PLATE 74

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U S ARMY

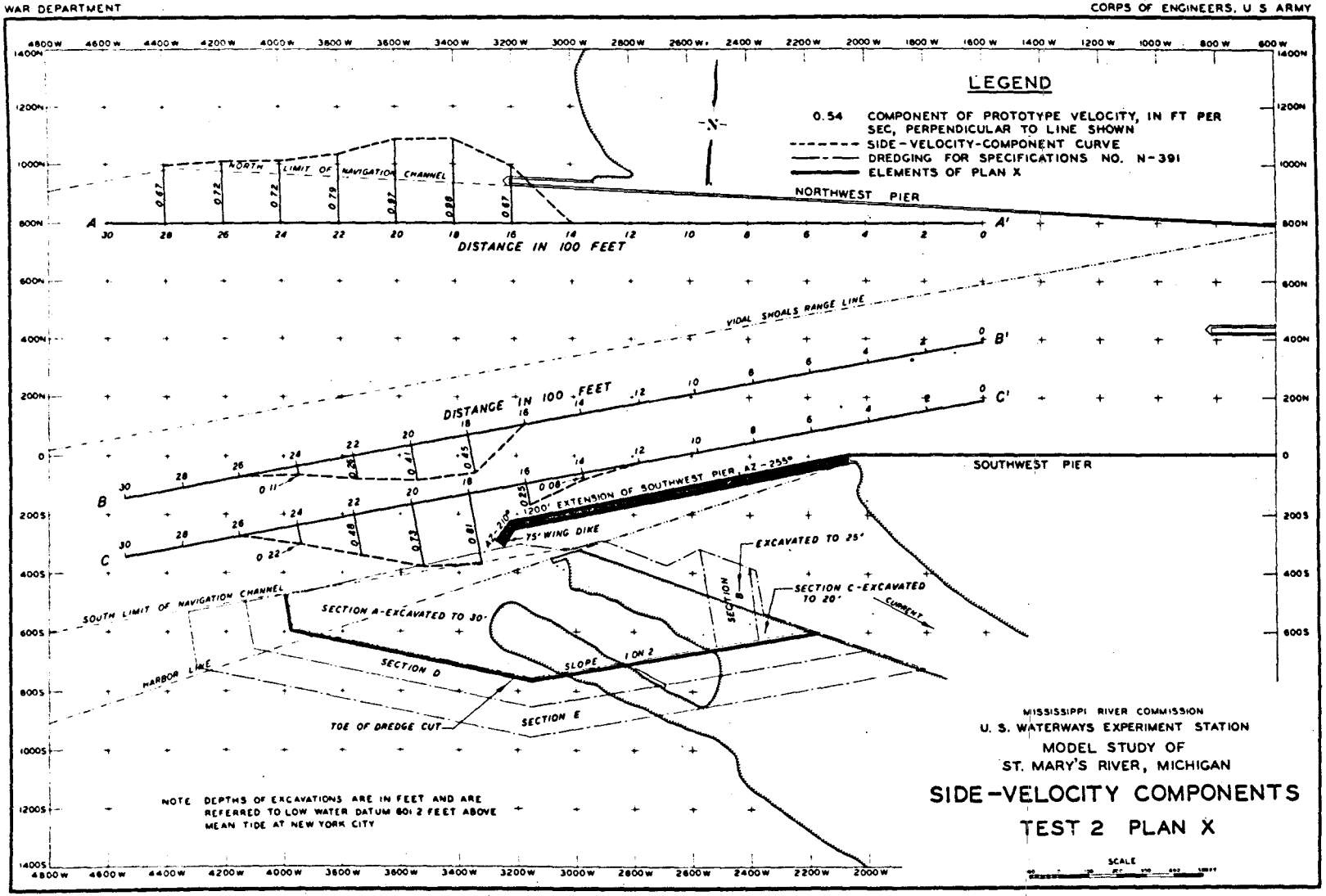
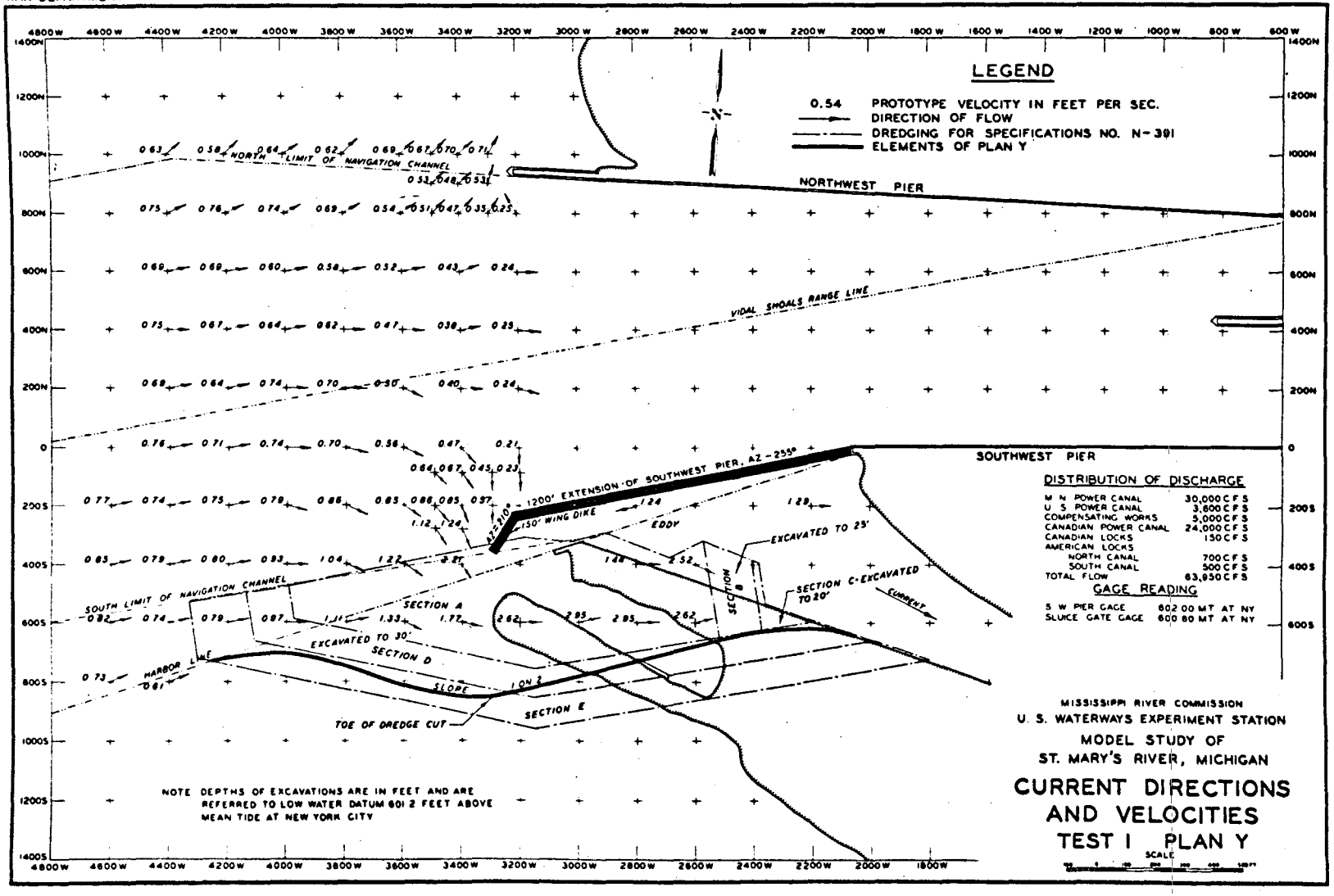


PLATE 75

PLATE 76

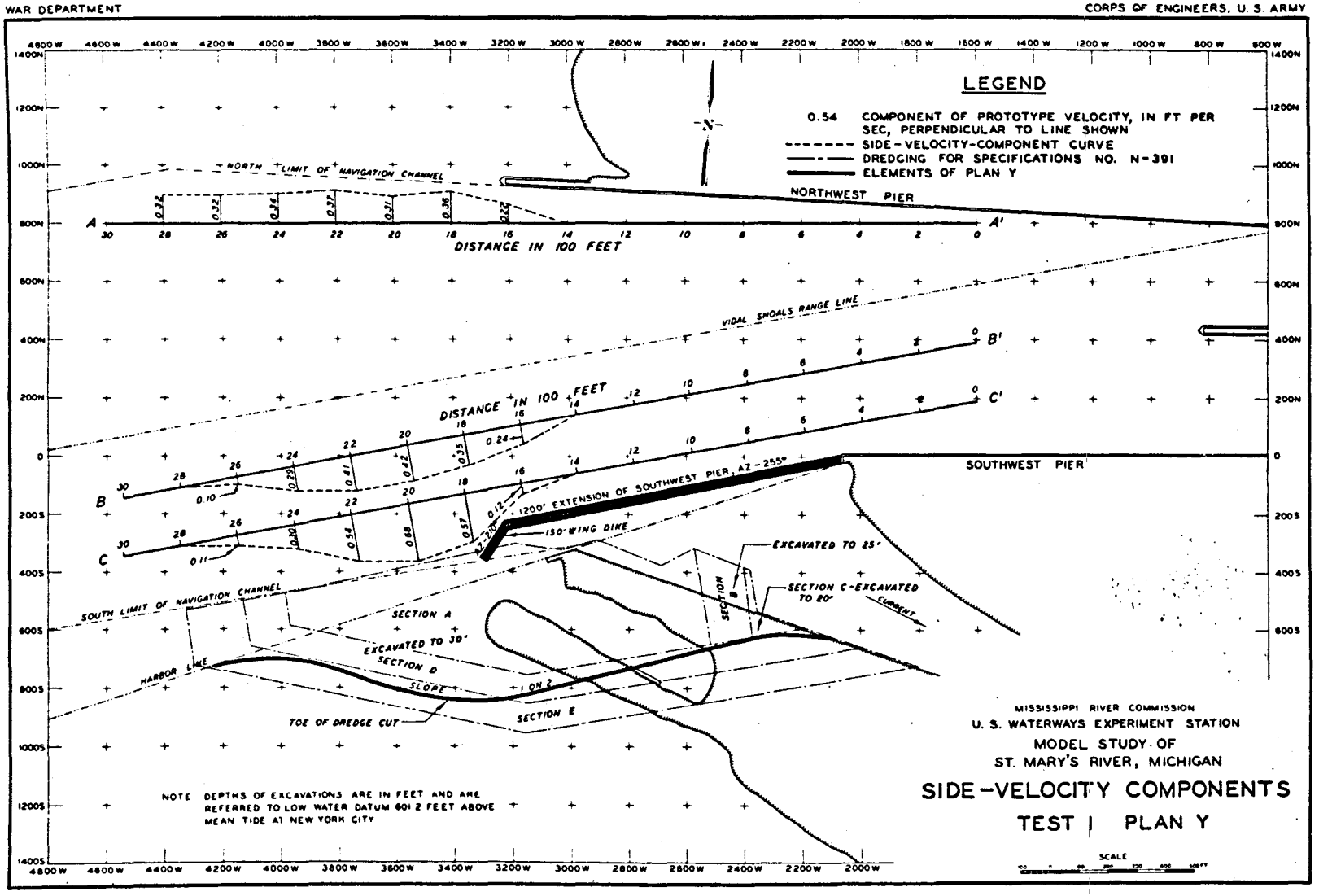
WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

SIDE-VELOCITY COMPONENTS

TEST I PLAN Y

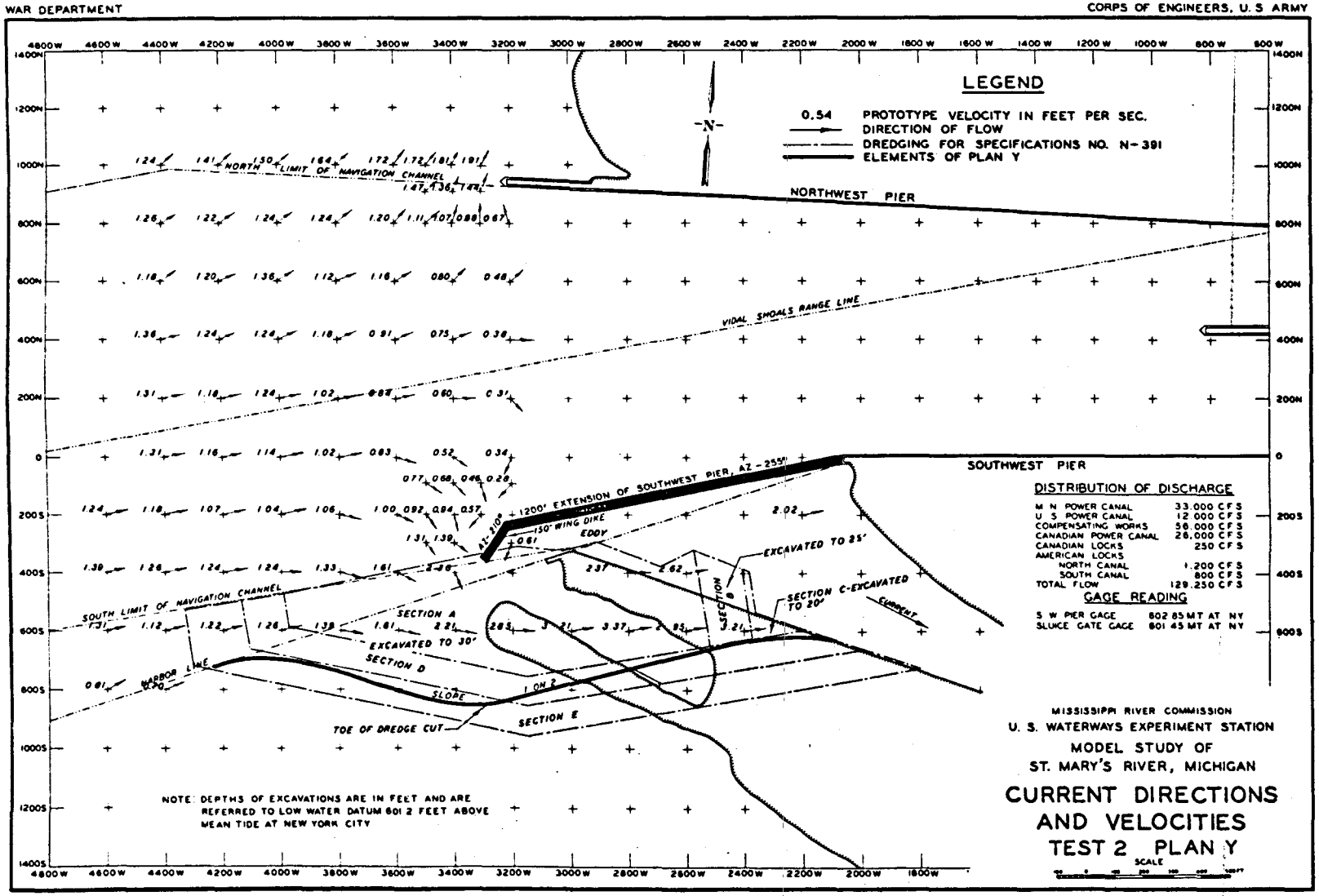
SCALE

PLATE 77

PLATE 78

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

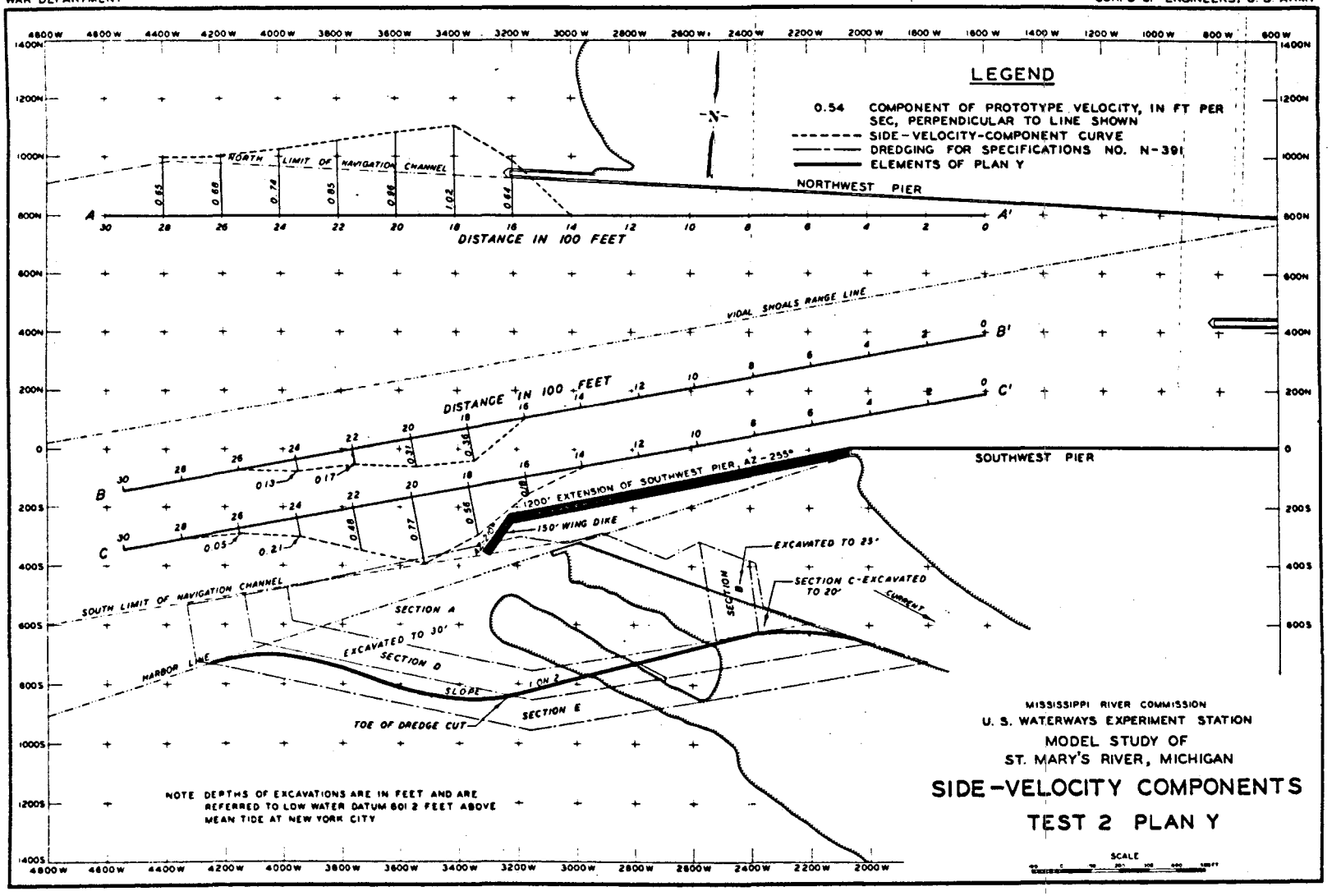
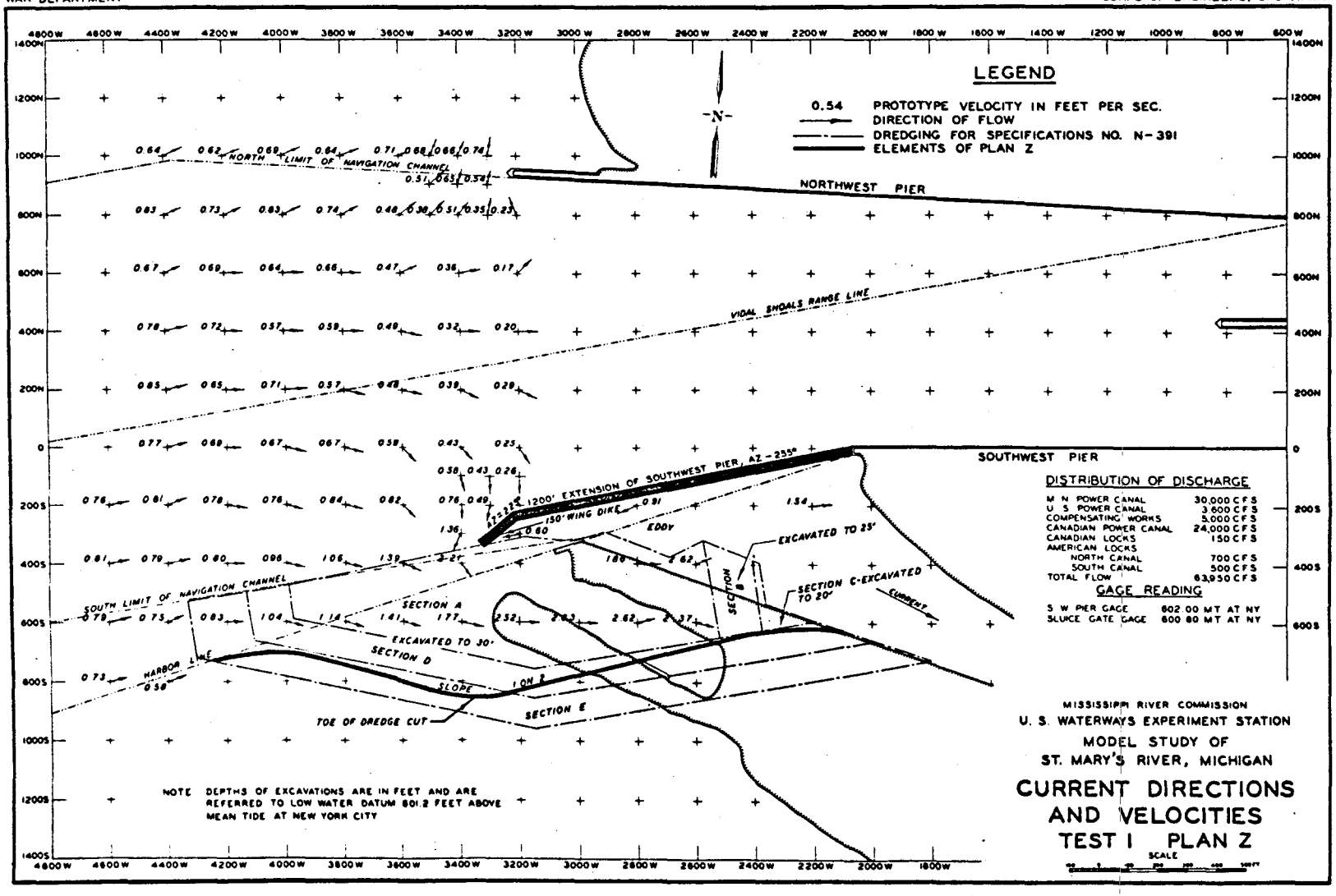


PLATE 79

PLATE 80

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S ARMY



DISTRIBUTION OF DISCHARGE

M N POWER CANAL	30,000 C F S
U S POWER CANAL	3,600 C F S
COMPENSATING WORKS	5,000 C F S
CANADIAN POWER CANAL	24,000 C F S
CANADIAN LOCKS	150 C F S
AMERICAN LOCKS	
NORTH CANAL	700 C F S
SOUTH CANAL	500 C F S
TOTAL FLOW	63,950 C F S

GAGE READING

S W PIER GAGE	602 00 M T AT NY
SLUICE GATE GAGE	600 80 M T AT NY

MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES

TEST I PLAN Z

SCALE

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

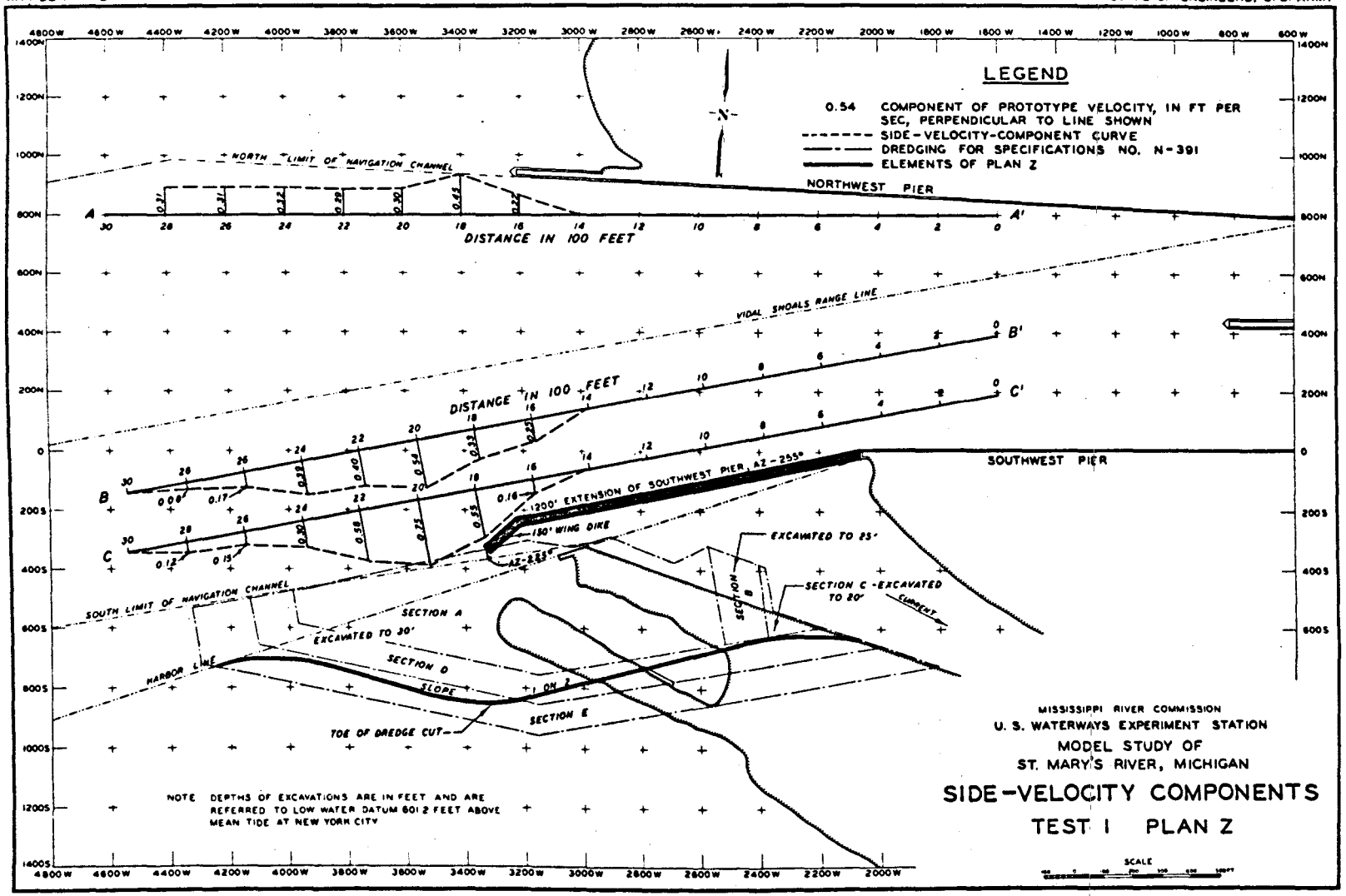
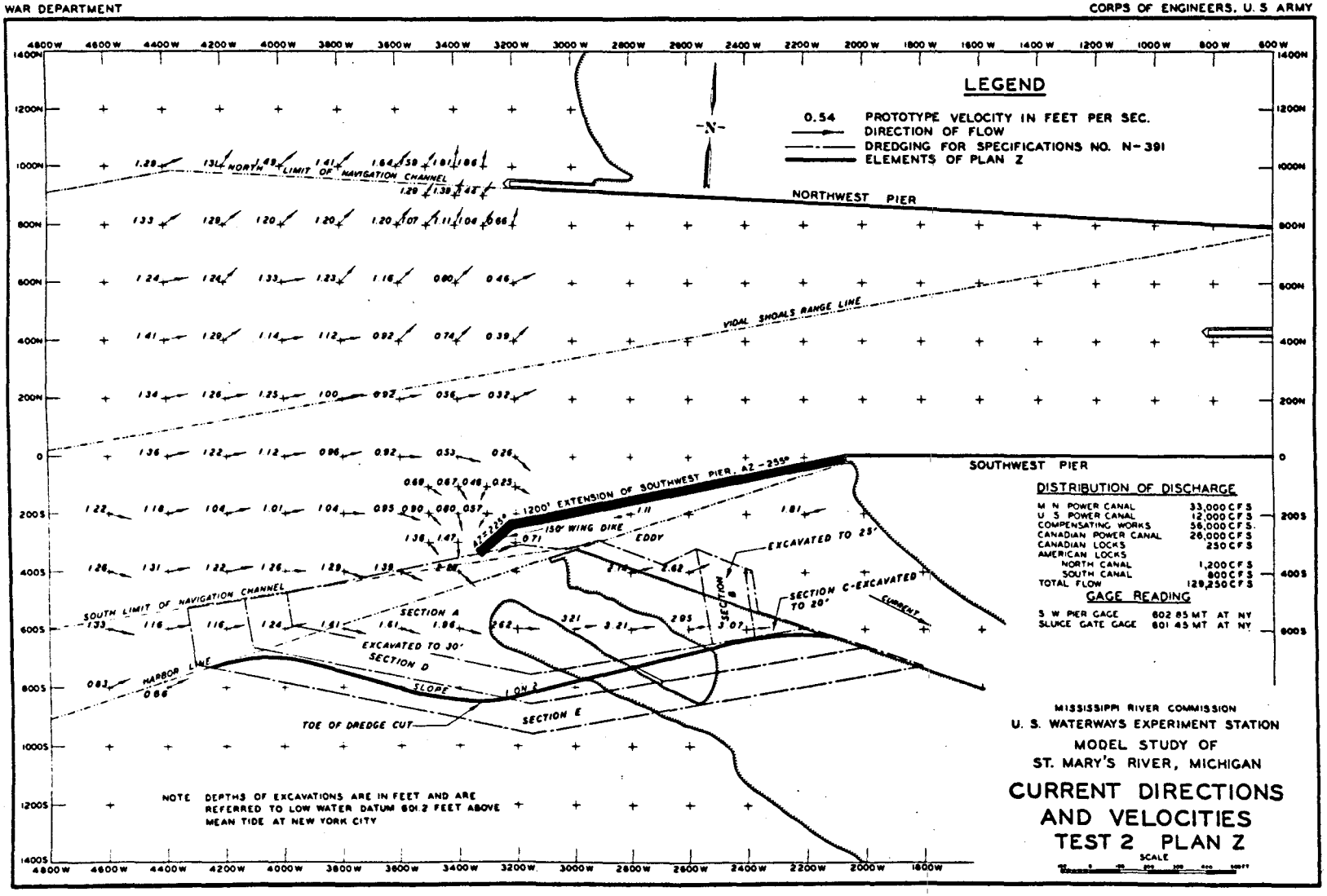


PLATE 81

PLATE 82

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



MISSISSIPPI RIVER COMMISSION

U. S. WATERWAYS EXPERIMENT STATION

MODEL STUDY OF

ST. MARY'S RIVER, MICHIGAN

CURRENT DIRECTIONS AND VELOCITIES TEST 2 PLAN Z

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

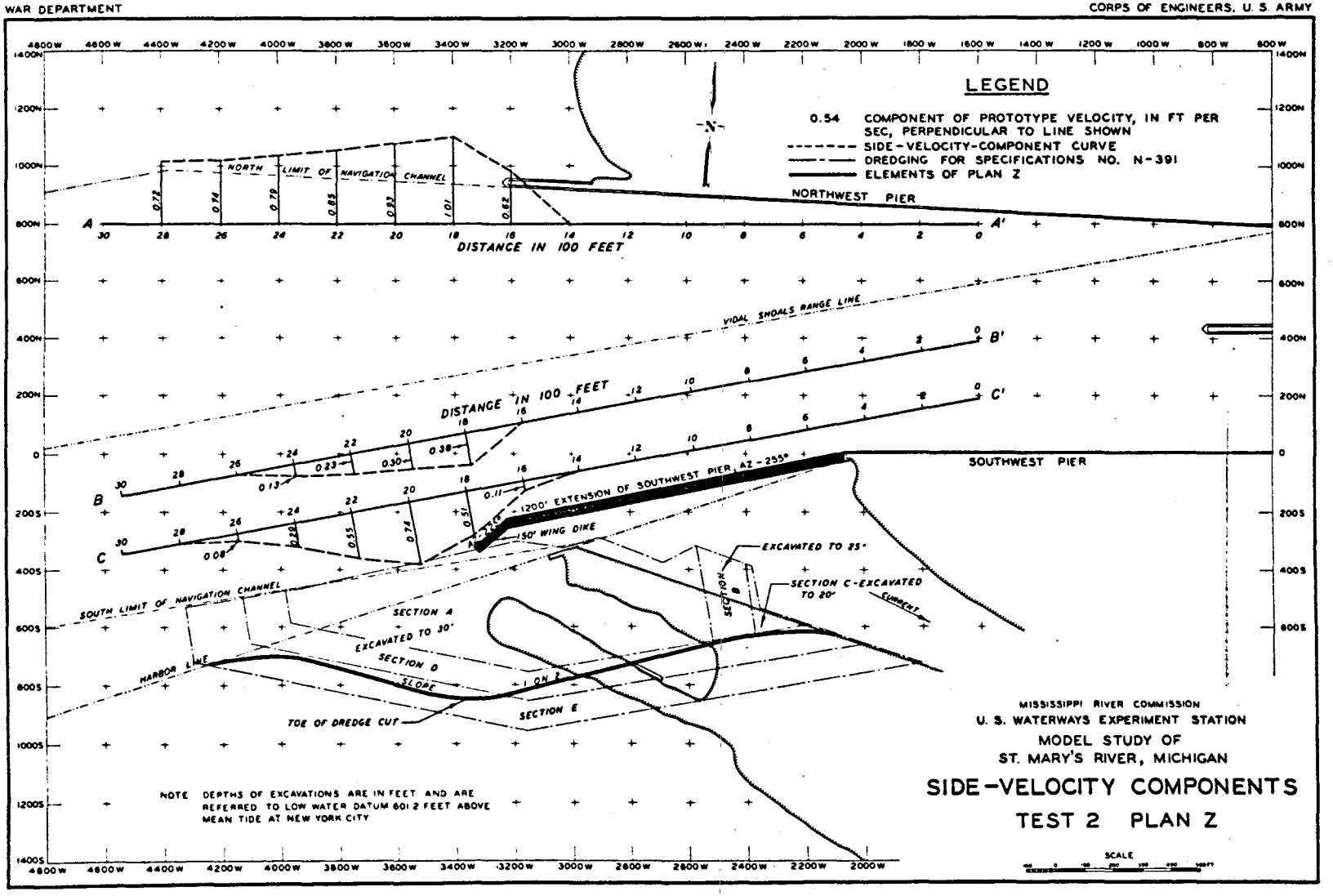


PLATE 83