Technical Report CHL-98-3
January 1998

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Waterways Experiment Station

Navigation Conditions at Lock and Dam 19, Mississippi River

Hydraulic Model Investigation

by Howard Park

WES

Prepared for U.S. Army Engineer District, Rock Island

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U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

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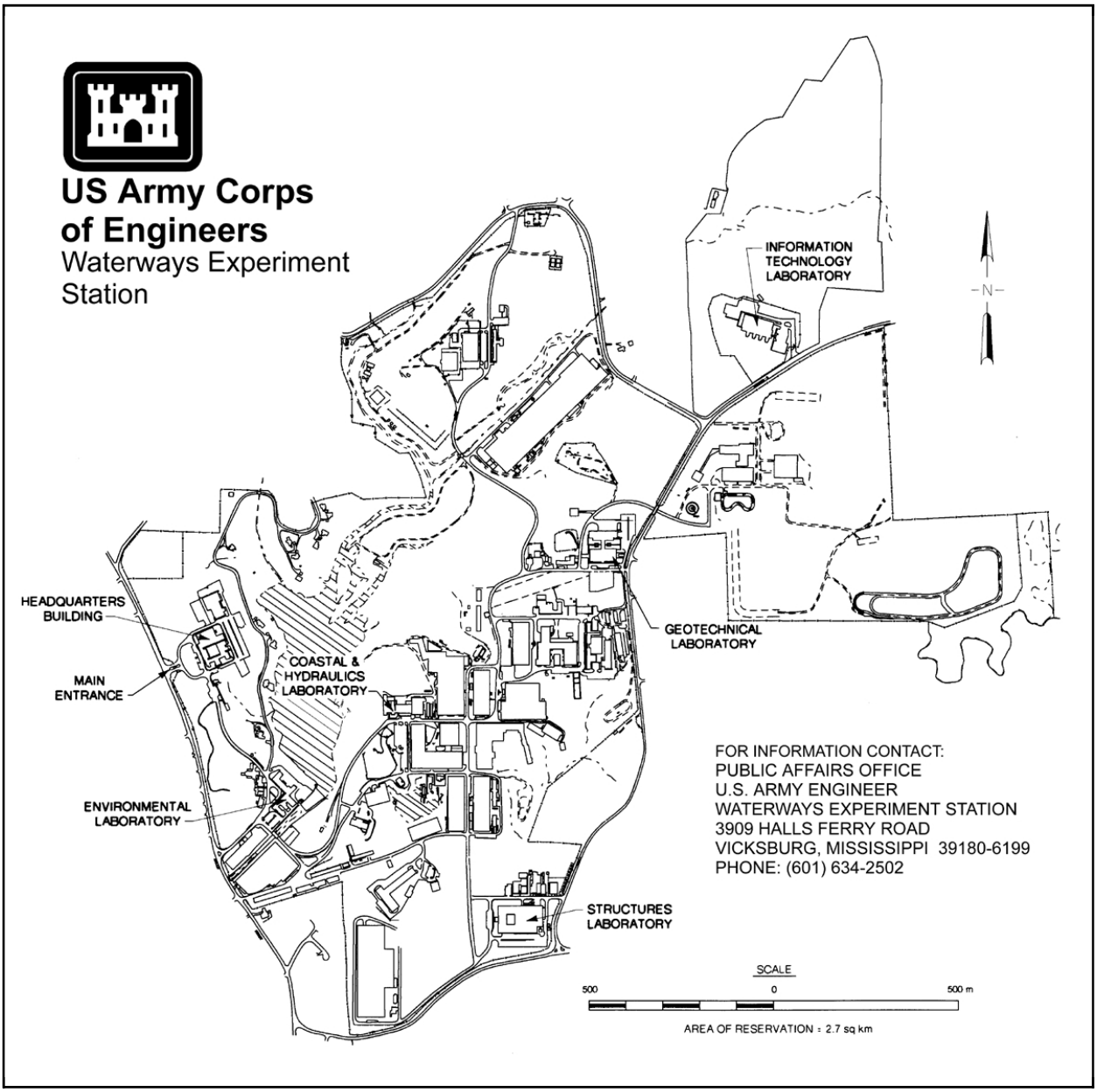

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Preface

This model investigation was conducted for the U.S .Army Engineer District, Rock Island, by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The study was conducted in the Hydraulics Laboratory of WES from November 1988 to November 1990.

In October 1996, the WES Hydraulics Laboratory merged with the WES Coastal Engineering Research Center to form the coastal and Hydraulics Laboratory (CHL). Dr. James R. Houston is the Director of the CHL and Messrs. Richard A. Sager and Charles C. Calhoun, Jr., are Assistant Directors.

During the course of the model study, representatives of the Rock Island District; the North Central Division, Headquarters, U.S. Army Corps of Engineers; and other navigation interests visited WES at different times to observe the model and discuss test results. The Rock Island District was informed of the study's progress by monthly progress reports and by evaluation reports at the end of each test.

The model study was conducted under the general supervision of Messrs. F. A. Herrmann, Jr., and R. A. Sager, CHL, and under the direct supervision of Mr. M. B. Boyd and Dr. L. L. Daggett, CHL. The principal investigators in immediate charge of the model were Mr. H. E. Park and Mr. R. T. Wooley, assisted by Messrs. E. Johnson, J. Sullivan, and M. Caldwell, and Mses. D. P. George and P. Birchett, all of CHL. This report was prepared by Mr. Park.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Robin R. Cababa, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers
square miles	2.58998	square kilometers

1 Introduction

Location and Description of Prototype

Lock and Dam No. 19 is located on the right descending bank of the Mississippi River approximately 364.3 river miles[1] above the mouth of the Ohio River at Keokuk, Iowa (Figure 1). The normal operating pool at Lock and Dam No. 19 is at elevation (el) 518.2 and extends 46.2 miles up the Mississippi River to Lock and Dam No. 18. The principal existing structures are a 110-ft by 1,200-ft-long lock, a closure dam that connects the 1,200-ft lock to the powerhouse, the Union Electric Powerhouse with 16 power generating units, a gated dam, consisting of 119 gate bays with crest elevation of 507.2, that extends from the Union Electric Powerhouse to the left bank, and a radial ice fender that extends upstream of the dam about 1,300 ft.

History of Project

In 1905, the Mississippi River Power Company was authorized to construct a hydroelectric plant with a lock, dam, powerhouse, and a dry dock at Keokuk, Iowa. Upon project completion in 1913, the lock and dry dock were turned over to the U.S. Government. By the Rivers and Harbor Act of 1935, Congress authorized a system of locks and dams that would provide a channel 9 ft in depth and of sufficient width for long-haul commercial carrier service from St. Louis, Missouri, to Minneapolis, Minnesota. The existing 110-ft by 360-ft lock and dam at Keokuk were integrated into this project and became known as Lock and Dam No. 19.

In general, the locks and dams on the Upper Mississippi were constructed by the Federal Government during the 1930's. The design size of the locks was to be 110 ft by 600 ft (usable chamber). Development of the waterway and more powerful pushers significantly increased traffic on the waterway. After World War II, this development showed that the 110-ft by 600-ft locks were too small

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page vi.

Figure 1. Location map

to handle future carrier demands; therefore, the maximum capacity of these locks would be reached in the near future.

After about 30 years of wear and tear on the existing lock, the increases in shipping demands, and because the existing lock was a severe bottleneck in the navigation system, the present day 110-ft by 1,200-ft (usable chamber) was constructed in the 1950's. This lock is located between the dry docks and the Iowa shore.

Purpose of Model Study

Although the design of the proposed improvements for the upper lock approach to Lock and Dam No. 19 was based on sound theoretical design practice and experience for the time it was built, conditions in the upper lock approach were found to be extremely complex. This could be attributed to the crosscurrents in the upper lock approach, irregular channel configurations, and limited approach channel. Navigation conditions vary with location and flow conditions upstream of the structure, and an analytical study to determine the hydraulic effects expected to result from a particular design is both difficult and inconclusive. Therefore, the comprehensive model study was considered necessary to:

a. Determine the effects of the proposed alternatives on navigation in the upper lock approach.

b. Develop modifications that could improve navigation conditions.

c. Evaluate navigation conditions for tows entering and leaving the upper lock approach.

The model also demonstrated the conditions resulting from the various alternatives tested and satisfied design engineers and navigation interests of the design's acceptability.

2 The Model

Description

The model reproduced about 2.4 miles of the Mississippi River and the adjacent overbank area that contains riverflows to at least el 518.2. The model duplicated about 1.9 miles of river channel above the dam and about 0.5 mile of river channel below the dam. The model was a fixed-bed type with the overbank area and the channel molded of sand cement mortar to sheet metal templates set to the proper grade. The lock, powerhouse, gated spillway, and the radial ice fender were constructed of sheet metal and plexiglass and set to the proper grade. The channel and overbank were molded to conform to a 1943 hydrographic-topographic survey.

Scale Relations

The model was built to an undistorted linear scale of 1:120, model to prototype. This scale allows accurate reproduction of velocities, eddies, and cross-currents that affect navigation. Other scale relations resulting from the linear scale ratio are as follows:

Characteristic	Units of Length	Scale Relation Model: Prototype
Area	$A = L_r^2$	1:14,400
Velocity	$V = L_r^{1/2}$	1:10.95
Time	$T = L_r^{1/2}$	1:10.95
Discharge	$D = L_r^{5/2}$	1:157,743
Roughness (Manning's n)	Manning's n = $L_r^{1/6}$	1:2.22

Measurements of current velocities, discharge, and water-surface elevations can be transferred quantitatively from model to prototype by means of these scale relations.

Appurtenances

Water was supplied to the model by a 10-cfs pump operating in a circulating system. A venturi meter and a valve were used to control and measure the discharge. Water-surface elevations were measured with piezometer gauges in the model channel and were connected to a centrally located gauge pit. A tailgate, at the lower end of the model, was used to control the tailwater elevation for the discharge tested.

Velocities and current directions were measured in the model by a video tracking system which tracks a light source attached to floats submerged to the depth of a loaded barge (9.0 ft). A video tracking system measured the path and velocity of the float and confetti determined surface current patterns. A radio-controlled model towboat and 15-barge tow with 9.0-ft draft were used to determine and demonstrate the effects of currents on tows entering and leaving the upper lock approach of the project. The towboat was equipped with twin screws and was propelled with two small electric motors operating with the battery in the tow. The speed and rudders of the tow were remote-controlled, and the towboat could be operated in forward and reverse at scale speeds comparable to those used by towboats on the Mississippi River.

Model Adjustments

The model was constructed of brushed cement mortar to provide a roughness (Manning's n) of about 0.012, which corresponds to a roughness in the prototype of about 0.026. With the existing structures in place, the powerhouse was calibrated for a maximum discharge of 62,000 cfs. With riverflows exceeding maximum powerhouse discharge, the additional flow was passed through the gated spillway. The model was checked against the available prototype data. The spillway gates were operated according to rules used by Corps operators. The results indicated that the model reproduced with a reasonable degree of accuracy the conditions in the prototype based on the available data.

3 Tests and Results

The primary concern of the tests was to study the flow patterns, measurement of velocities and water-surface elevation, and the effects of currents on the movement of the model tow entering and leaving the upper lock approach. These conditions were studied with several alternatives.

Test Procedures

The following representative selection of flows was used for testing based on information furnished by the U.S. Army Engineer District, Rock Island:

Riverflow (cfs)	Upper Pool (el)	Tailwater (el)
29,000	518.2	480.9
62,000	518.2	482.4
122,000	518.2	487.4
177,000	518.2	491.4
249,000	518.2	495.1

All plans were evaluated with maximum powerhouse discharge (62,000 cfs).

Riverflows were reproduced by introducing the proper discharge and maintaining the upper pool elevation of 518.2 with the powerhouse and the dam gates. The tailgate was manipulated to maintain the proper tailwater elevation. During the base test, the upper pool elevation was controlled at gauge 7 (Figure 2). For subsequent tests the upper pool elevation was controlled at gauge 5 to the elevations obtained during the base test.

Current direction was determined by plotting the path of floats with respect to ranges established for that purpose, and velocities were measured by timing the travel of floats over measured distances. In the interest of clarity, only the main trends are shown on plots of currents in turbulent areas or where crosscurrents or eddies existed. Navigation conditions for tows moving through the study reach were evaluated and demonstrated using the model tow with a 15-barge tow

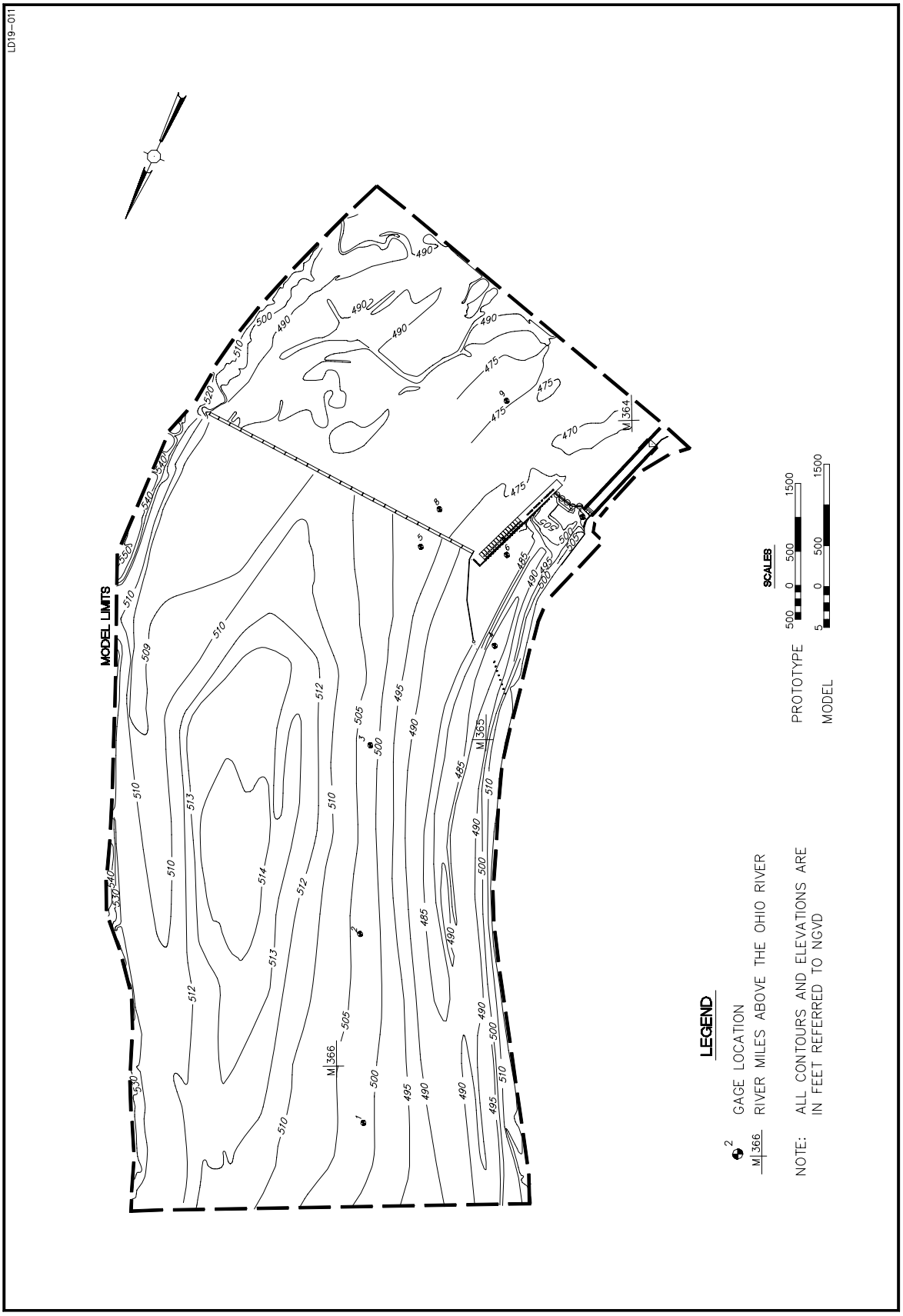


Figure 2. Base conditions, gauge 2

drafting 9.0 ft. The path of the model tow was recorded with a video tracking system and, in some instances, with multiple-exposure photography.

Base Tests

Description

Base tests, as shown in Figures 2 and 3 and Photo 1, were conducted with the model reproducing existing conditions. These tests verified that the model reproduced prototype conditions and provided information and data that could evaluate the effects of the proposed alternatives on current direction and velocities, water-surface elevations, and navigation conditions. Existing conditions consisted of the following principal features:

a. An existing 110-ft by 1,200-ft lock located on the Iowa shore.

b. The Union Electric Powerhouse with 15 power-generating units with a maximum capacity of 4,000 cfs per unit and 1 smaller unit with a maximum capacity of 2,000 cfs used to generate power for the powerhouse.

c. A cellular sheetpile closure dam that connects the 1,200-ft lock to the powerhouse.

d. The remaining portion of the 525-ft-long ice fender located on the right descending bank just upstream of the lock approach. The only remaining portion of the ice fender are the piers below elevation 504.2.

e. A radial ice fender that extends about 1,300 ft upstream of the gated dam and a 38-ft-diam cell adjacent to the end of the radial ice fender.

f. A gated dam extends from the Union Electric Powerhouse to the left bank and has 119 gate bays with the crest at el 507.2.

Results

Current directions and velocities. Current direction and velocity data, as shown in Plates 1-10, indicated that the maximum velocity of the currents between the end of the radial ice fender and the right bank ranged in magnitude from 1.0 fps with a 29,000-cfs riverflow to 5.3 fps with a 249,000-cfs riverflow. The maximum velocity of the currents recorded in the forebays of the powerhouse and the lock ranged in magnitude from 1.1 to 4.8 fps with 29,000 and 249,000-cfs riverflows, respectively. A large clockwise eddy, as shown in Photo 2, formed in the upper lock forebay with all flows tested. The maximum upstream velocity of the upstream currents ranged from less than 0.5 to 0.7 fps.

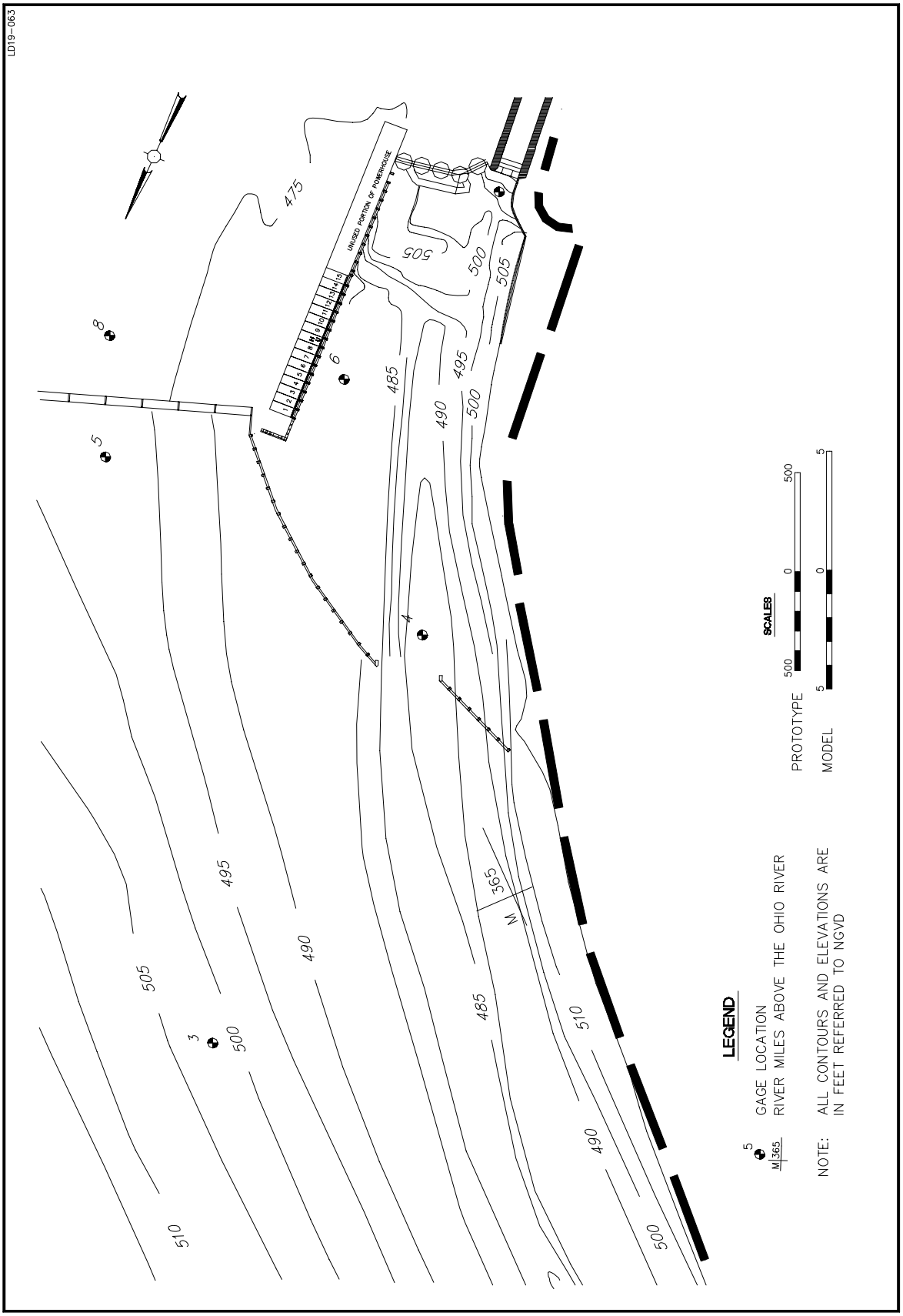


Figure 3. Base conditions, gauge 5

Water-surface elevations. Water-surface elevations, for the base tests, shown in Table 1, indicate the slope in the water surface (model gauges 1-7) ranged from less than 0.1 ft/mile with a 29,000-cfs riverflow to 0.2 ft/mile with a 249,000-cfs riverflow.

Navigation conditions. The model test, conducted with a 105-ft-wide by 975-ft-long barge flotilla with a 150-ft pusher, indicated that navigation conditions for downbound tows were very difficult and would require a considerable amount of maneuvering for tows to enter the lock due to the current alignment in the lock approach with all flows tested. With the 62,000-cfs and 122,000-cfs riverflows, downbound tows approaching close along the right descending bank and maintaining proper alignment could align with and enter the lock with a minimum amount of maneuvering (Photos 3 and 4). However, if the tow moves away from the right bank and intercepts the currents moving across the lock approach toward the powerhouse, the tow could lose control and be pushed into the powerhouse (Photo 5). With the 249,000-cfs riverflow, considerable maneuvering and possibly some type of assistance would be required for downbound tows to align with and enter the lock chamber (Photo 6). There was a strong tendency for the tow to be moved into the powerhouse. If tows maintained control, then navigation conditions for upbound tows leaving the lock were satisfactory with all flows tested (Photos 7 - 9).

Pre-existing Conditions

Description

Pre-existing conditions, as shown in Figure 4, are the same as the base test with one exception: a ported ice fender some 525 ft long extending into the river channel from the right descending bank.

Results

Current direction and velocities. Current direction and velocity data, as shown in Plates 11-15, indicate that maximum velocities through the 300-ft opening between the ice fenders ranged in magnitude from 1.0 fps with a 29,000-cfs riverflow to 4.7 fps with a 249,000-cfs riverflow. The maximum velocities recorded in the forebay of the powerhouse ranged in magnitude from 1.1 fps with a 29,000-cfs riverflow to 4.7 fps with a 249,000-cfs riverflow. A large clockwise eddy was observed with all flows tested. The maximum upstream velocities recorded ranged in magnitude from less than 0.5 to 0.7 fps.

Water-surface elevations. Water-surface elevations for pre-existing conditions are shown in Table 2. The slope in water surface (model gauges 1-7) ranged from less than 0.1 ft/mile with a 29,000-cfs riverflow to 0.3 ft/mile with a 249,000-cfs riverflow.

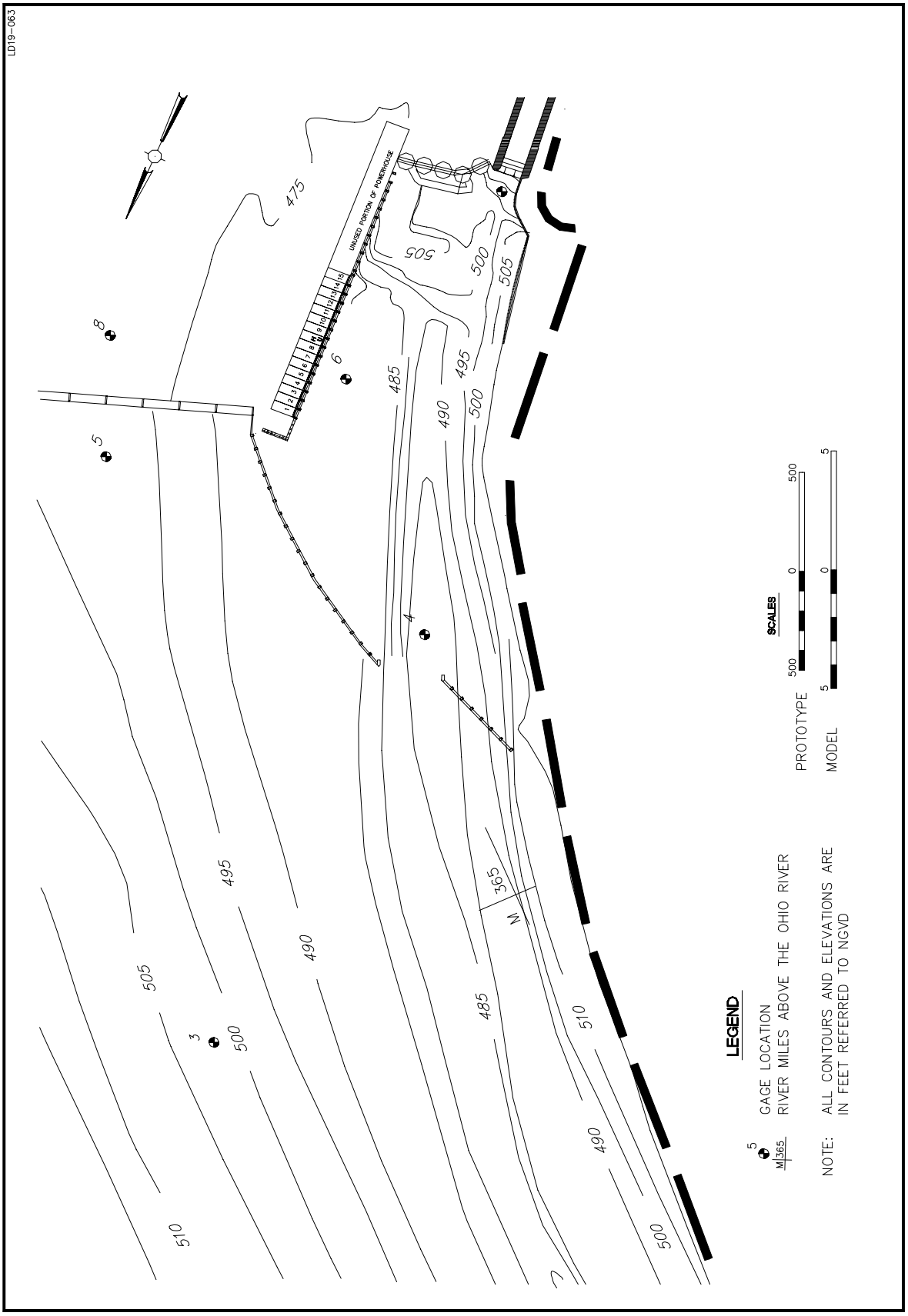


Figure 4. Pre-existing conditions

Navigation conditions. Navigation conditions ranged from very difficult to dangerous for downbound tows navigating the 300-ft opening in the ice fenders and entering the lock approach with all flows tested. With a 62,000-cfs riverflow and below, downbound tows could drive the 300-ft opening at the ice fenders, as shown in Plates 16 and 17, but there was a tendency to slide toward the end of the radial ice fender. By driving the 300-ft opening, downbound tows approach the structures (i.e., the powerhouse or the closure dam between the lock and the powerhouse) at a high rate of speed. Therefore, to avoid hitting any structures in the lock approach and to provide a reasonable margin of safety, a flanking maneuver was necessary. With riverflows above 62,000 cfs, to avoid sliding or being pushed into the end of the radial ice fender or one of the structures in the lock approach a flanking maneuver was considered necessary to navigate through the 300-ft opening at the ice fenders. Once the ice fender was cleared, it was found that downbound tows required a considerable amount of maneuvering or some type of assistance to enter the lock (Plates 18-20). It should be noted that downbound tows driving the opening in the ice fenders experienced a strong tendency to slide toward or into the end of the radial ice fender (Plates 21-23). Navigation conditions were satisfactory for upbound tows leaving the lock for all flows tested (Plates 24-29). However, with a 249,000-cfs riverflow, there was a tendency for upbound tows navigating the 300-ft opening in the ice fenders to slide toward the end of the radial ice fender (Plate 30).

Plan A

Description

Plan A, shown in Figure 5, is the same as the base test, with the following exceptions:

a. The cell at the upstream end of the radial ice fender was removed.

b. The radial ice fender was shortened 140 ft and its piers were removed to el 504.2. The remaining radial ice fender extended upstream of the gated dam about 1,160 ft.

c. A cellular guard wall extended upstream about 2,400 ft from the riverside lock wall to its intersection with the radial ice fender at sta 37+72.66. The downstream 825 ft of the guard wall was ported. The ports were 50 ft wide with the top of ports at el 507.2 and were located between cells 1 and 2, 3 and 4, 5 and 6, and 7 and 8. The remaining 1,576.16 ft of the guard wall is unported.

Results

Current directions and velocities. Current direction and velocity data, shown in Plates 31-35, indicate a significant change in the current patterns

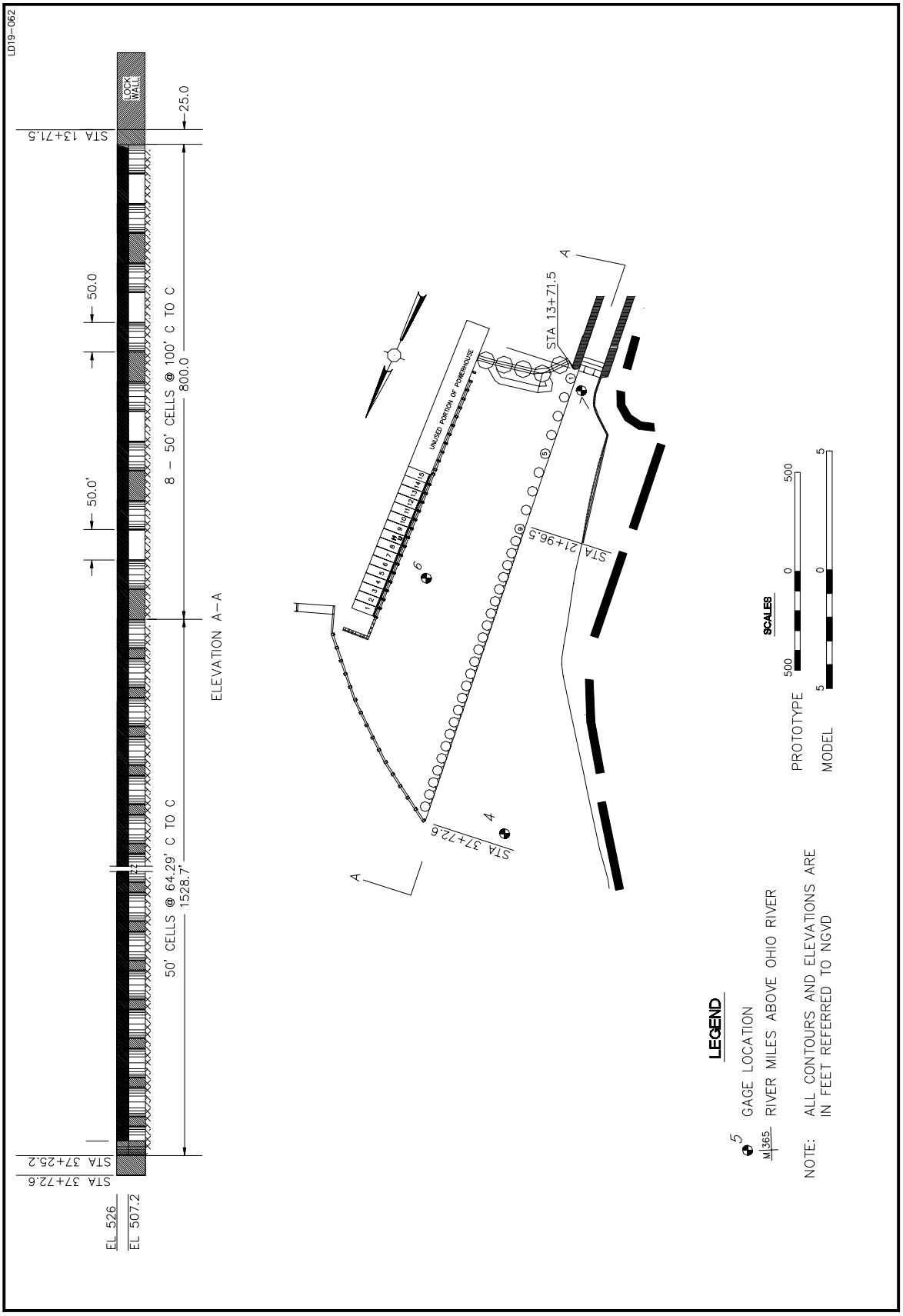


Figure 5. Plan A

immediately upstream of the lock forebay and the radial ice fender. With the 29,000- and 62,000-cfs riverflows, when all flow was passing through the powerhouse, the current was generally parallel with the right descending bank line to a point about 1,500 ft upstream of the ice fender and then angled across the lock approach toward the ice fender. A large, low-velocity eddy formed in the lock forebay along the right bank opposite the upstream end of the guard wall. With the 62,000-cfs riverflow and above, flow moved along the guard wall and exited the lock forebay through the downstream ports. As the riverflow increased and flow was passed through the dam, the amount of flow entering the lock forebay increased, the angle of the currents moving across the lock forebay decreased, and the flow moving along the guard wall and through the downstream ports increased. The maximum velocity of the currents moving across the approach to the lock near the upstream end of the guard wall varied from about 1.0 to 4.5 fps with the 29,000- and 249,000-cfs riverflows, respectively. The maximum velocity of the currents along the guard wall varied from less than 0.5 to 2.7 fps with the 29,000- and 249,000-cfs riverflows, respectively. The velocities of the current in the forebay of the powerhouse also increased compared to base tests due to the flow being concentrated through the ice fender. The maximum velocity of about 5.3 fps was recorded with 249,000-cfs riverflow.

Water-surface elevations. Water-surface elevations for Plan A are shown in Tables 3 and 4 and gauge locations are shown in Figure 6. The slope in water surface from model gauges 1 and 5 ranged from less than 0.1 ft/mile with a 29,000-cfs riverflow to about 0.3 ft/mile with a 249,000-cfs riverflow. The water-surface elevations increased at model gauge 4 and decreased at model gauge 6 when compared to the base test (Table 1). The maximum increase in stage at gauge 4 was about 0.2 ft and the maximum decrease in stage at gauge 6 was about 0.5 ft with a 249,000-cfs riverflow. The head loss across the guard wall, as shown in Table 4, ranged from 0.1 to 0.7 ft with riverflows of 29,000 and 249,000 cfs, respectively. The head loss across the radial ice fender ranged from 0.1 to 0.5 ft with 29,000 cfs- and 249,000-cfs riverflows, respectively.

Navigation conditions. Navigation conditions were satisfactory for tows entering and exiting the upper lock approach with all flows tested. With riverflows through 122,000 cfs, downbound tows could drive into the protection of the guard wall, reverse engines to reduce speed when the head of the tow was about 2,500 ft upstream of the lock, and land on the guard wall to align with the lock chamber without major difficulties (Plates 36 and 37). As the riverflow increased to 177,000 cfs and above, downbound tows were required to flank along the right descending bank to a point immediately upstream of the ice fender and then drive into the lock forebay (Plates 38 and 39). This maneuver was necessary to avoid entering the lock forebay at a high rate of speed. Some maneuvering was required for upbound tows to exit the lock forebay. Upbound tows could rotate the head of the tow off the guard wall and exit the lock forebay along the right descending bank without major difficulties (Plates 40-43). However, tows driving upstream along the guard wall experienced a strong tendency to be pinned against or rotated around the upstream end of the guard wall.

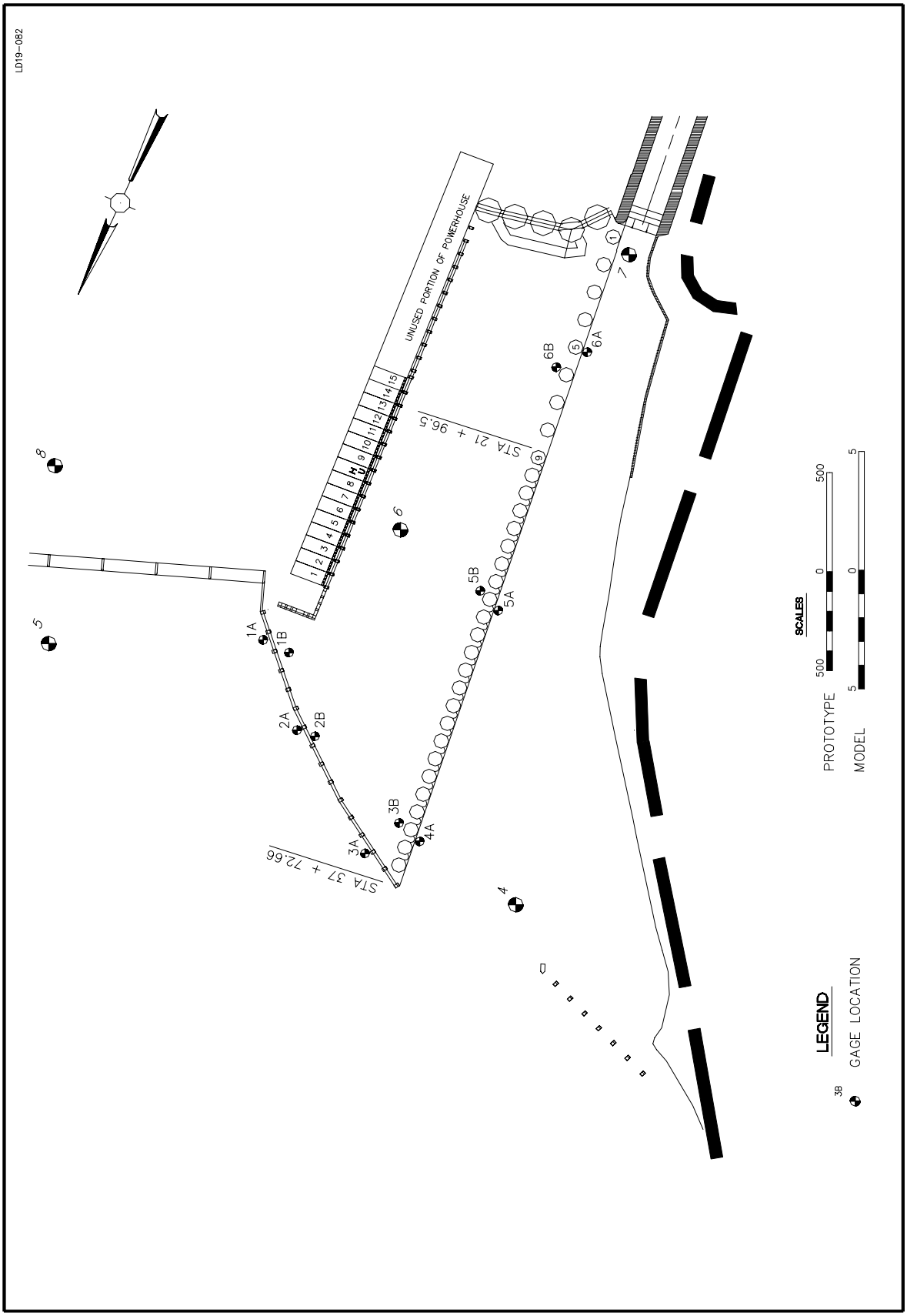


Figure 6. Plan A gauge locations

Plan A-Modified

Description

Plan A-Modified, shown in Figure 7, is the same as Plan A, with the following exceptions:

a. The guard wall was shortened about 560 ft to sta 32 + 10.9.

b. The downstream 825-ft portion of the guard wall was ported to pass flow. There were eight 50-ft-wide ports between cells 1 and 8 and one 25-ft port between the lock and cell 1. The top of all ports was el 507.2. The remaining 1,014.4 ft of the guard wall was non-ported.

Results

Current direction and velocities. Current direction and velocity data, shown in Plates 44-48, indicate shortening the guard wall reduced the angle of the currents moving across the lock forebay while the velocities of the current remained about the same as with Plan A. The currents were generally parallel with the right bank to a point about 500 ft upstream of the ice fender and then angled across the forebay toward the powerhouse. With 122,000-cfs riverflows and above, a large low-velocity eddy formed along the right bank opposite the upstream end of the guard wall. As the riverflow increased, the size and intensity of the eddy increased. With riverflows of 62,000 cfs and above, flow moved along the guard wall and exited through the downstream guard wall ports. The maximum velocity of the currents moving across the approach to the lock near the upstream end of the guard wall varied from about 1.0 to 4.1 fps with the 29,000- and 249,000-cfs riverflows, respectively. The maximum velocity of the currents along the guard wall varied from less than 0.5 fps to about 1.8 fps with the 29,000- and 249,000-cfs riverflows, respectively. Shortening the guard wall reduced the flow through the ice fender with all riverflows and concentrated the flow through the area between the upstream end of the guard wall and the ice fender. A maximum current velocity of about 5.2 fps was recorded in the forebay of the powerhouse with a 249,000-cfs riverflow.

Water-surface elevations. Water-surface elevations for Plan A-Modified are shown in Table 5. The slope in water surface (model gauges 1 and 5) ranged from less than 0.1 to about 0.3 ft/mile with 29,000- and 249,000-cfs riverflows, respectively. Water-surface elevations at model gauge 4 decreased by about 0.1 ft and the stages at model gauge 6 increased by about 0.3 ft with a riverflow of 249,000 cfs when compared with Plan A.

Navigation conditions. Navigation conditions were satisfactory for tows entering and exiting the upper lock approach with all riverflows tested (Plates 49-54). Shortening the guard wall reduced the angle and intensity of the currents moving across the lock approach and improved navigation conditions

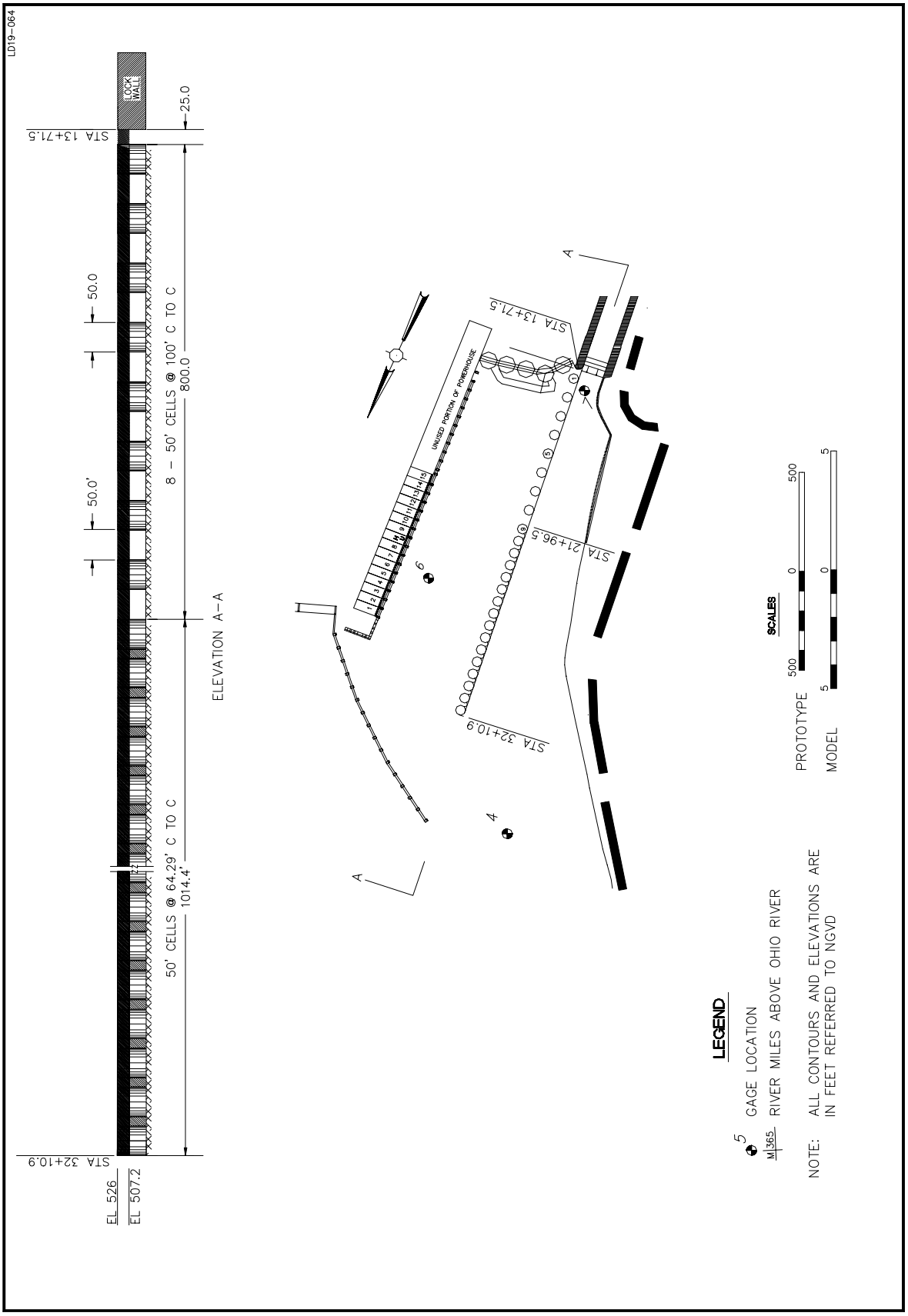


Figure 7. Plan A-Modified

when compared to Plan A. With riverflows through 177,000 cfs, downbound tows could drive into the protection of the guard wall, reverse engines to reduce speed when the head of the tow was about 2,500 ft upstream of the lock, and land on the guard wall to align with the lock chamber without any major difficulties. Downbound tows driving close along the right bank could approach the lock at a slow speed. As the riverflow increased to 249,000 cfs, a flanking maneuver was required for downbound tows to maintain alignment and an acceptable speed as they entered the lock forebay and approached the guard wall. A downbound tow could flank along the right bank to a point just upstream of the ice fender, then drive into the lock forebay, reversing the engines to approach the guard wall and align with the lock chamber. This maneuver was necessary to avoid entering the upper lock approach at high speed. Some maneuvering was required for upbound tows to exit the lock forebay. Upbound tows could rotate the head of the tow off the guard wall and exit the lock forebay along the right bank without any difficulties. However, tows driving upstream along the guard wall experienced a strong tendency to be pinned against or forced around the upstream end of the guard wall.

Plan B

Description

Plan B, shown in Figure 8, is the same as the base test with one exception: an 80-ft-diam “pivot”cell was placed 500 ft upstream of the lock at sta 18 + 71.5 in alignment with the inside face of the riverside lock wall.

Results

Current directions and velocities. Observation of the model indicated only very localized changes in current patterns around the pivot cell when compared to the base test; therefore, current direction and velocity data were not collected with this plan.

Water-surface elevations. Observation of the model indicated only very localized changes in water-surface elevation; therefore, water-surface elevation data were not collected with this plan.

Navigation conditions. Navigation conditions were generally the same as with the base test. Properly aligned downbound tows approaching close to and along the right bank could enter the lock forebay and use the pivot cell to align with the lock chamber. However, when the tow was aligned with the lock to enter the chamber about 600 ft of the tow would extend upstream of the cell and be exposed to the currents moving toward the powerhouse. There was a tendency for the tow to be rotated around the pivot cell with the higher riverflows. Downbound tows that are not properly aligned entering the lock forebay have a strong tendency to move toward or into the pivot cell (Plates 55-57). The

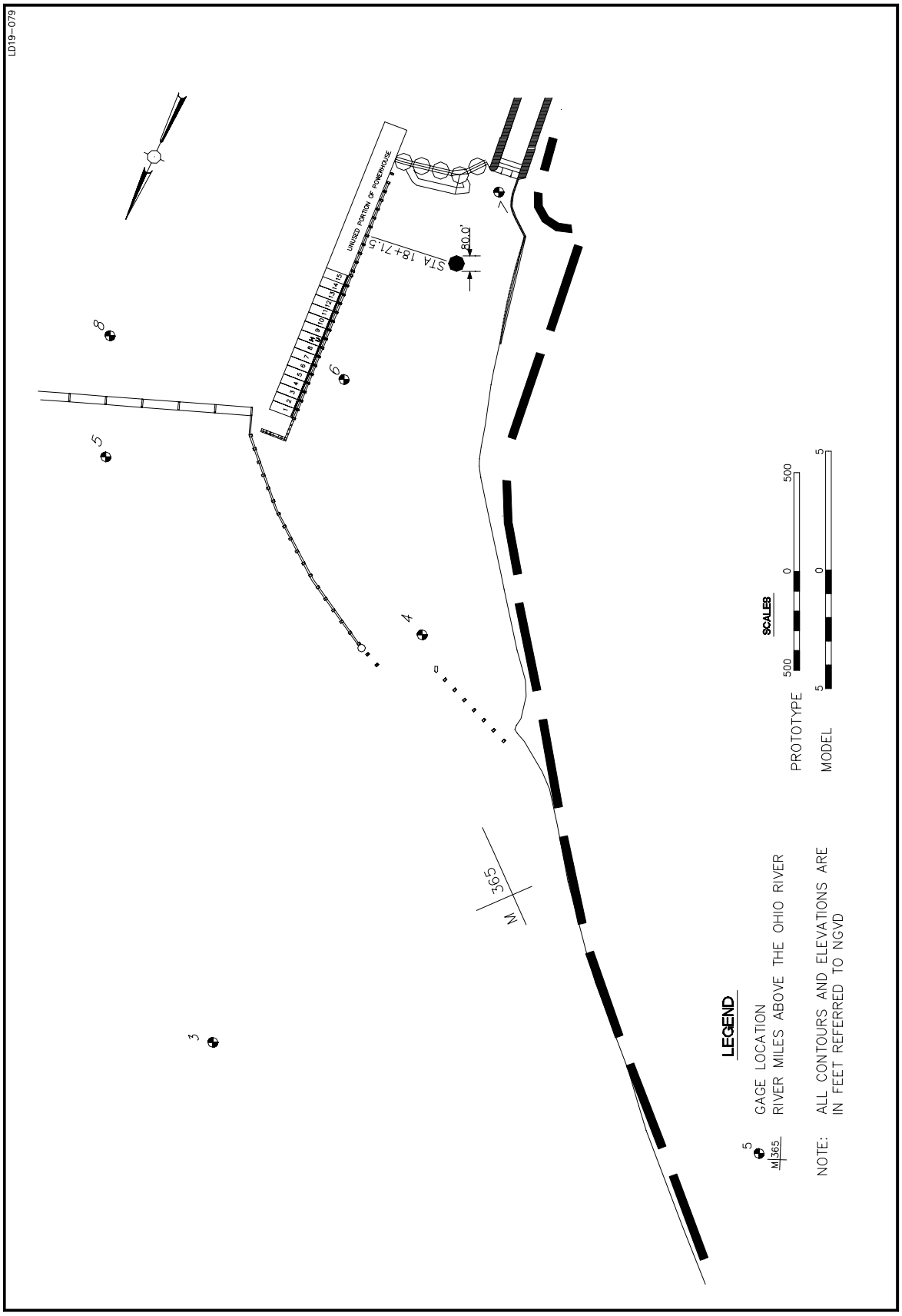


Figure 8. Plan B

placement of the cell in the lock forebay restricted the maneuvering area for upbound tows. Upbound tows could not swing the stern of the tow until it cleared the cell; therefore, there was a tendency for the tow to move into the radial ice fender (Plates 58-60). As the riverflow increased, the danger of an upbound tow rotating around the pivot cell or moving into the radial ice fender increased.

Plan B-1

Description

Plan B-1, shown in Figure 9, is the same as Plan B, with one exception: the pivot cell was relocated 1,000 ft upstream of the lock at sta 23 + 71.5.

Results

Current direction and velocities. Observation of the model indicated no significant changes in current patterns when compared to the base test. Therefore, current direction and velocity data were not recorded.

Water-surface elevations. Observation of the model indicated no significant changes in water-surface elevation; therefore, water-surface elevation data were not recorded.

Navigation conditions. Navigation conditions for downbound tows were slightly improved when compared to Plan B (Plates 61-63). Properly aligned downbound tows approaching close along the right bank could enter the lock forebay and use the pivot cell to align with the lock chamber (Plate 61). Downbound tows entering the lock forebay misaligned with the lock could land on the pivot cell, but could be rotated around the cell if the stern is exposed to the currents moving toward the powerhouse, especially with the higher riverflows (Plate 62). There was a strong tendency for downbound tows entering the lock forebay to move toward or into the pivot cell with the higher riverflows (Plate 63). The placement of the cell in the lock forebay restricted the maneuvering area for upbound tows far more than Plan B. Upbound tows could not swing the stern of the tow until it cleared the cell; therefore, there was a strong tendency for the tow to be moved into the radial ice fender (Plates 64-66). As the riverflow increased, the danger of an upbound tow rotating around the pivot cell or moving into the radial ice fender increased.

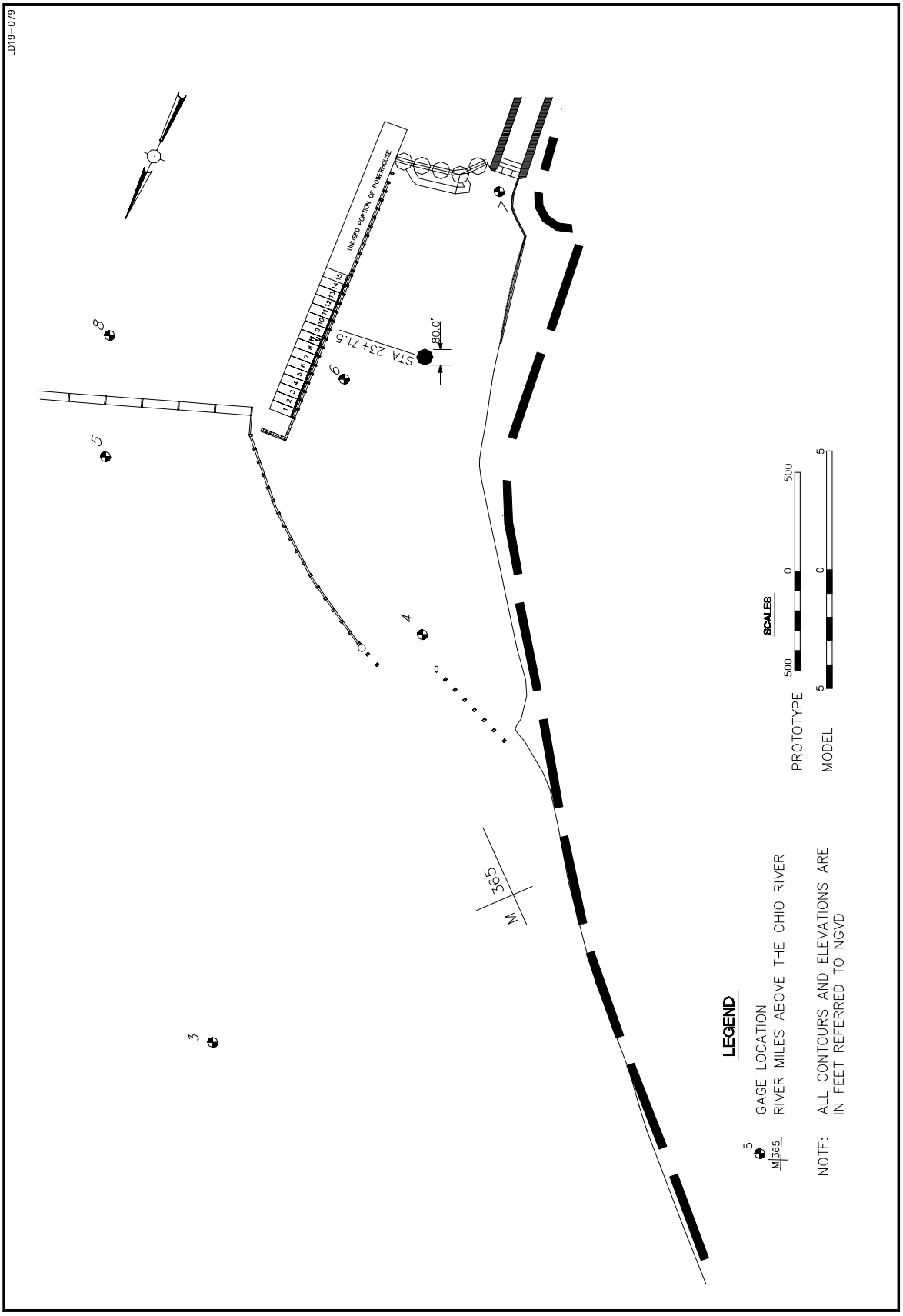


Figure 9. Plan B-1

Plan C

Description

Plan C, shown in Figure 10, is the same as the base test, with the following exceptions:

a. A non-ported diaphragm closure wall was placed 155 ft riverward and parallel to the center line of the lock. The wall consists of 60-ft-diam cells with arched diaphragm closures and extends upstream from about sta 20 + 61.5 to sta 30 + 21.5. The closure wall was 960 ft long with the top of cells at el 522.2.

b. An earthen dike with top elevation 522.2 and 1V : 6H side slopes extended from the unused portion of the powerhouse structure at about sta 17 + 65 to the most downstream cell of the closure wall at about sta 20 + 70.

Results

Current direction and velocities. Current direction and velocity data, shown in Plates 67-71, indicated that the current patterns were generally the same as with Plan A-Modified except there was no flow entering the lock forebay. The currents were generally parallel with the right bank to a point about 500 ft upstream of the ice fender and then angled across the lock forebay toward the powerhouse. The outdraft at the upstream end of the closure wall was slightly stronger than with Plan A-Modified. A low-velocity eddy formed in the lock forebay at the upstream end of the closure wall with riverflows of 62,000 cfs and above. The maximum velocity of the currents moving across the approach to the lock near the upstream end of the closure wall varied from 1.3 to 4.5 fps with 29,000- and 249,000-cfs riverflows, respectively. A large clockwise eddy formed in the powerhouse forebay with all flows tested. The maximum upstream current velocities recorded ranged from 1.2 to 2.5 fps with 29,000- and 249,000-cfs riverflows, respectively. The maximum current velocity of about 6.1 fps was recorded in the powerhouse forebay with a 249,000-cfs riverflow.

Point velocities. A directional miniature velocity meter recorded the direction and velocities of the currents approaching the powerhouse. These measurements determined the changes in currents due to the closure wall. Point velocities were taken at 60 percent of the water depth with the base test and Plan C. Velocity data for Plan C (Plates 72 and 73) indicated that velocities in the powerhouse forebay increased significantly when compared to the base test (Plates 74 and 75) due to reduction of the flow area by the closure wall. The maximum approach velocity recorded with Plan C was 7.1 fps with a 249,000-cfs riverflow. The maximum approach velocity recorded with the base test was 3.7 fps with a 249,000-cfs riverflow.

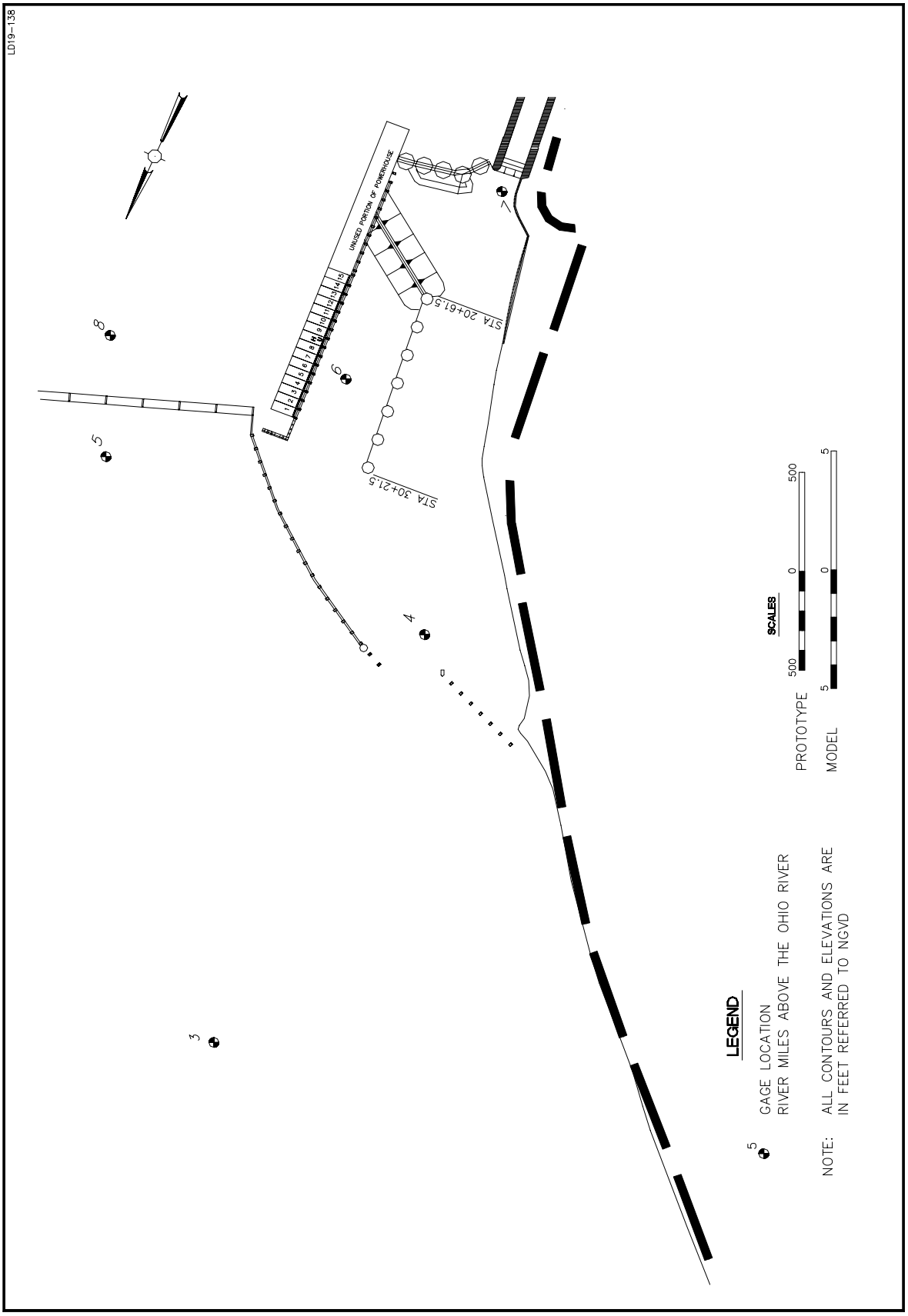


Figure 10. Plan C

Water-surface elevations. Water-surface elevations for Plan C are shown in Tables 6 and 7 and gauge locations are shown in Figure 11. The slope in water surface from model gauges 1 and 5 ranged from less than 0.1 to about 0.4 ft/mile with 29,000- and 249,000-cfs riverflows, respectively. With a 249,000-cfs riverflow, the water-surface elevation at model gauge 6 dropped by about 0.5 ft when compared to the base test. The maximum head loss recorded across the ice fender was 0.1 ft with a 249,000-cfs riverflow. And the maximum head loss across the closure wall was 0.7 ft with a 249,000-cfs riverflow.

Navigation conditions. Navigation conditions were satisfactory for tows entering and exiting the upper lock approach with all riverflows tested (Plates 76-82). Although this plan did not provide a guide wall for downbound tows, tows would maneuver in slack water to align with the lock. With riverflows through 122,000 cfs, downbound tows could drive into the protection of the closure wall, reverse engines when the head of the tow was about 1,500 ft upstream of the lock, and align with the lock chamber without major difficulties. Downbound tows driving close along the right bank could approach the lock at a slower speed (Plate 77). With a 249,000-cfs riverflow, a flanking maneuver was required for downbound tows to maintain an acceptable speed entering the lock forebay. Downbound tows that were not properly aligned when entering the lock forebay exposed the stern of the tow to the outdraft near the upstream end of the closure wall and could be rotated out of alignment (Plate 78). Downbound tows moving close along the right bank and maintaining proper alignment entering the lock forebay could reverse engines about 1,200 ft upstream of the lock and align with the lock chamber without major difficulties, as shown in Plate 79. Navigation conditions were satisfactory for upbound tows. Upbound tows could push out of the lock chamber into the slack water canal, let the stern of the tow clear the lock, rotate the head of the tow toward the right bank and push out of the lock canal into the river channel, as shown in Plates 80-82. However, tows exiting the slack water canal parallel with the closure wall experienced a strong tendency to be pushed into the closure wall or the ice fender.

Plan C-1

Description

Plan C-1, shown in Figure 12, is the same as Plan C, with one exception: four submerged dikes, spaced 500 ft apart, with top elevation 498.2 ft, were placed along the right bank upstream of the ice fender. The dike locations are given in Table 8.

Results

Current direction and velocities. Current direction and velocity data, shown in Plates 83 - 87, indicated the current patterns were generally the same as with Plan C except there was a separation of flow near the riverward end of the

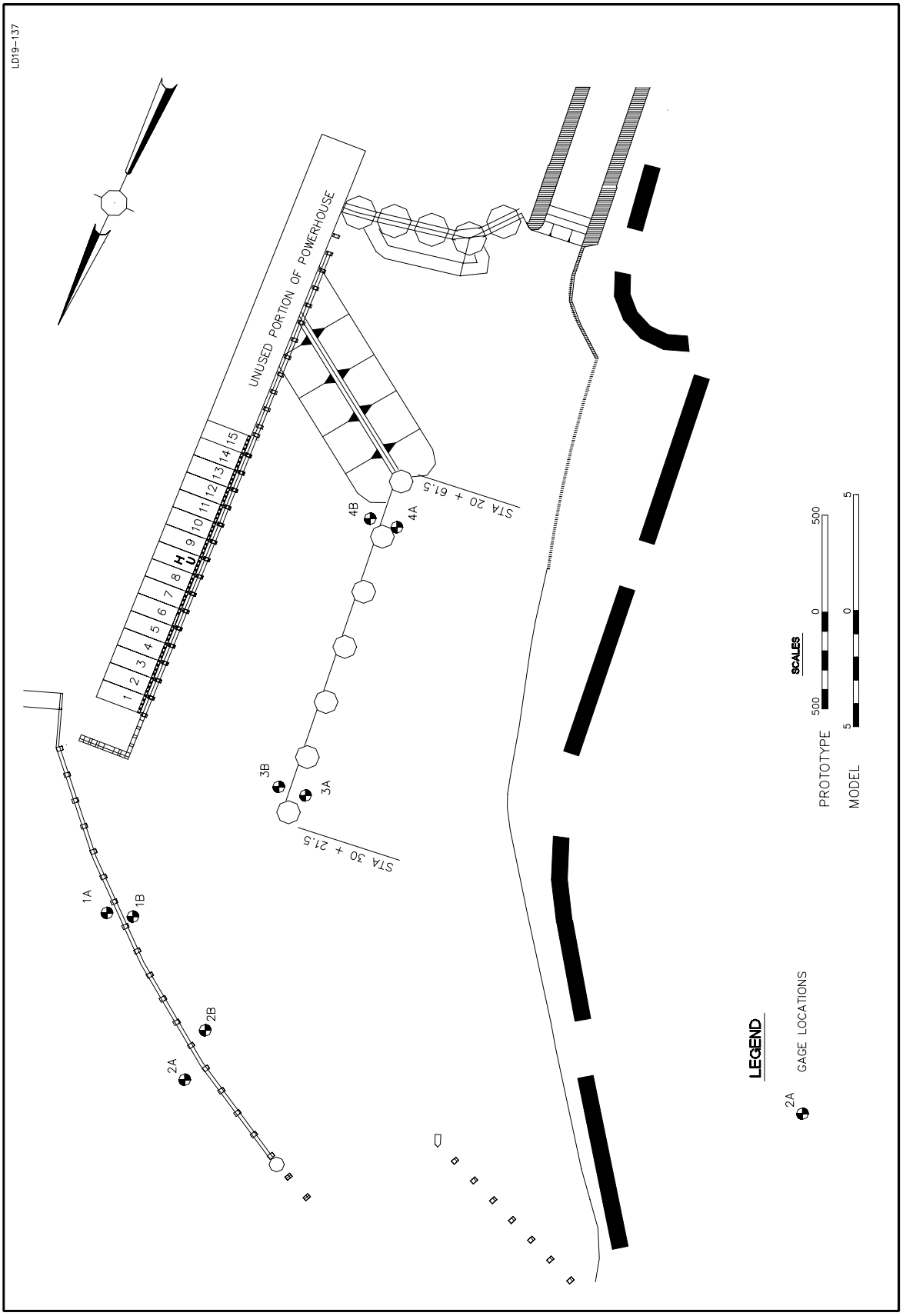


Figure 11. Plan C gauge locations

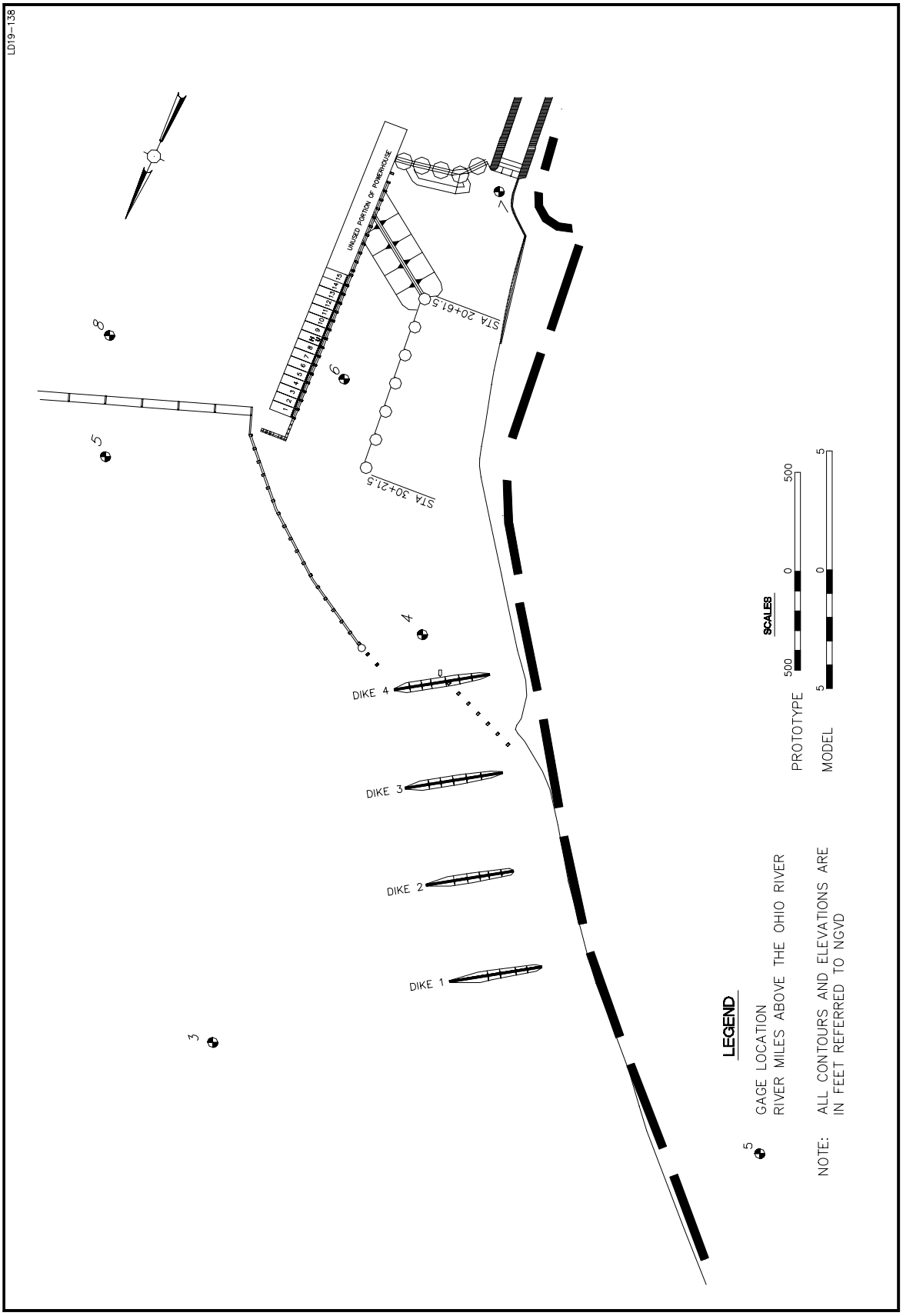


Figure 12. Plan C-1

dikes. The dike field moved flow out of the upper approach to the lock toward and through the ice fender. There was a decrease in velocities in the vicinity of the dikes and near the upstream end of the closure wall when compared to Plan C. The maximum velocity near the upstream end of the closure wall varied from about 0.5 to 3.0 fps with 29,000 and 249,0000-cfs riverflows, respectively. A large eddy formed in the powerhouse forebay with all flows tested. The maximum upstream velocities of the eddy varied from 0.9 to 2.6 fps with 29,000- and 249,000-cfs riverflows, respectively. The maximum velocity recorded in the powerhouse forebay was 5.6 fps with a 249,000-cfs riverflow.

Point velocities. Meter velocity data (Plates 88 and 89) indicated a slight change in velocities in the powerhouse forebay and a change in the direction of the current approaching the powerhouse. The current was almost parallel to the powerhouse face. The maximum velocity recorded was 6.7 fps with a 249,000-cfs riverflow compared to 7.1 fps for Plan C.

Water-surface elevations. Water-surface elevations for Plan C-1 are shown in Tables 9 and 10 and gauge locations are shown in Figure 13. The slope in water surface ranged from less than 0.1 to about 0.4 ft/mile with 29,000- and 249,000-cfs riverflows, respectively. There was no significant change in water-surface elevations in the powerhouse forebay (gauge 6) when compared to Plan C. The maximum head loss across the ice fender was 0.1 ft with a 249,000-cfs riverflow. The maximum drop across the closure wall was 0.8 ft with a 249,000-cfs riverflow.

Navigation conditions. Navigation conditions were improved for tows entering and exiting the lock forebay with all riverflows tested (Plates 90 - 95). Downbound tows could enter the lock forebay with less speed and maneuvering due to the decrease in outdraft and current velocities when compared with Plan C. With riverflows through 122,000 cfs, downbound tows could drive into the protection of the closure wall, reverse engines when the head of the tow was about 1,500 ft upstream of the lock, and align with the lock chamber without major difficulties. With a 249,000-cfs riverflow, downbound tows could flank along the right bank to a point about 500 ft upstream of the ice fender, align the head of the tow with the right bank, and drive into the protection of the closure wall (Plate 92). Upbound tows could push out of the lock chamber into the slack water canal, let the stern of the tow clear the lock, rotate the head of the tow toward the right bank and push out of the lock canal into the river channel without major difficulties (Plates 93-95). However, tows exiting the slack water canal parallel with the closure wall experienced a strong tendency to be pushed into the closure wall or the ice fender.

Plan D

Description

Plan D, shown in Figure 14, is the same as the base test, with one exception: the riverside wall of the lock was extended upstream 200 ft to sta 15 + 71.5.

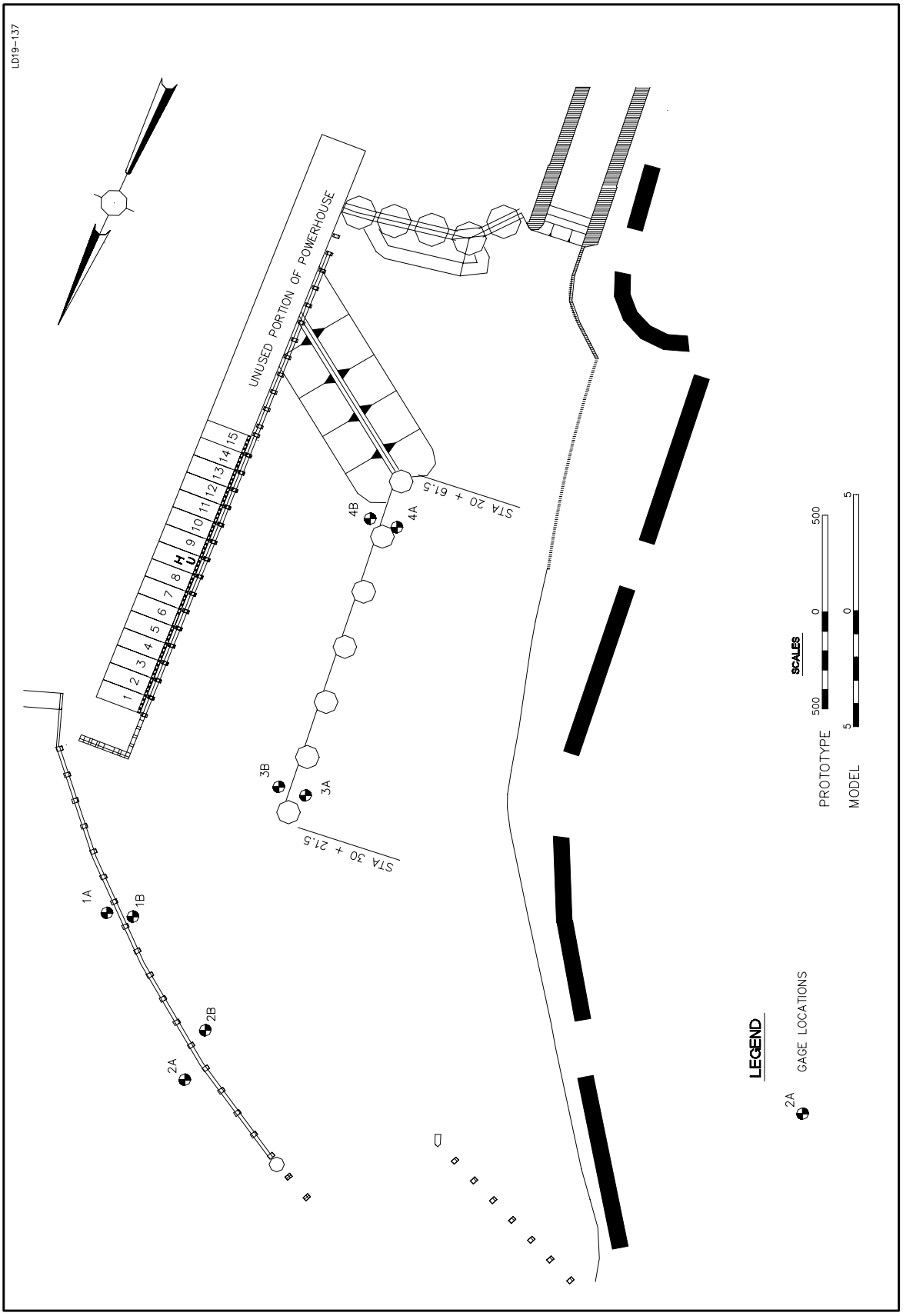


Figure 13. Plan C-1 gauge locations

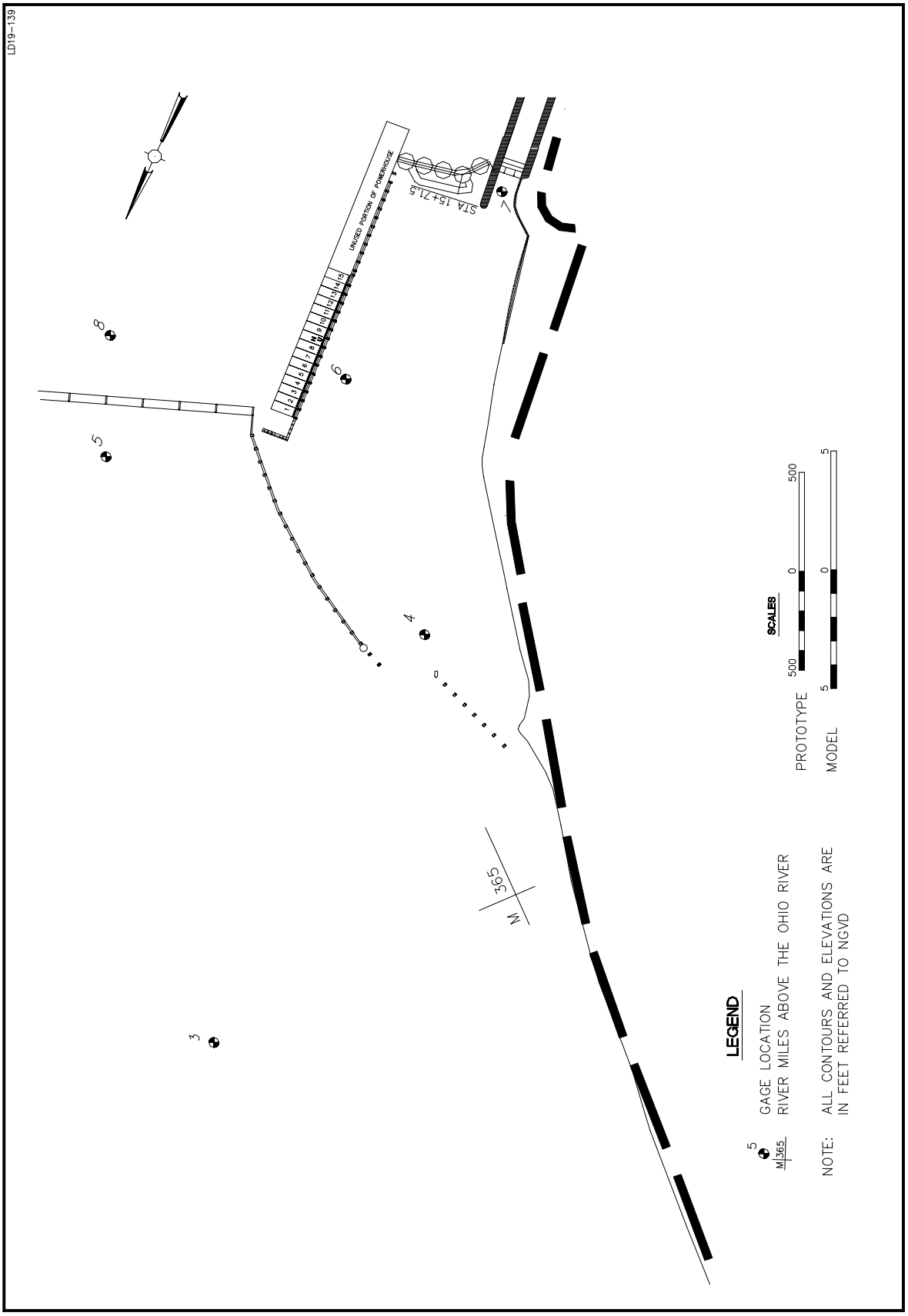


Figure 14. Plan D

Results

Current direction and velocities. Observation of the model indicated no major changes in current patterns when compared with the base test. Therefore, current direction and velocity data were not recorded.

Water-surface elevations. Water-surface elevations for Plan D, shown in Table 11, indicated no significant changes when compared with the base test.

Navigation conditions. Generally, navigation conditions for tows entering and exiting the lock forebay were the same as with the base test (Plates 96-101). Downbound tows were required to approach the lock close along the right bank to align with and enter the lock, the same as with the base test (Plates 96-98). The extension of the riverside wall was considered an aid for downbound traffic approaching the lock. The extension of the riverside wall allowed the head of the tow to be placed on the extension, move the stern of the towboat toward the powerhouse, align with the lock, and push into the lock chamber. Upbound tows could push out of the lock chamber, clear the extension, and swing the head of the tow toward the right bank without major difficulties. Although the extension required upbound tows to push out of the lock chamber an additional 200 ft before maneuvering to move upstream along the right descending bank, it did not appear to adversely impact navigation conditions for upbound traffic (Plates 99-101). It should be noted that although no observations of an upbound tow dragging a “hip” barge were made, a tow configuration of this type could cause an upbound tow to encroach on the powerhouse more so than a standard configured tow (5 ft long by 3 ft wide).

Plan D-1

Description

Plan D-1 shown in Figure 15 and Photo 10, is the same as Plan D, with one exception: four submerged dikes spaced 500 ft apart with a 498.2-ft top elevation, were placed along the right bank upstream of the ice fender.

Results

Current direction and velocities. Current direction and velocity data, shown in Plates 102 - 106, indicated a change in the current pattern and velocity in the upper lock approach when compared to the base tests; i.e., existing conditions. The dike field reduced current velocities near mid-channel in the upper lock approach; however, velocities increased along the right bank. The dike field redistributed the flow in the upper lock approach and reduced slightly the flow entering the approach. The current velocities near mid-channel at the upstream end of the ice fender were reduced about 0.4 and 2.0 fps with 62,000- and 249,000-cfs riverflows, respectively, when compared to the base test.

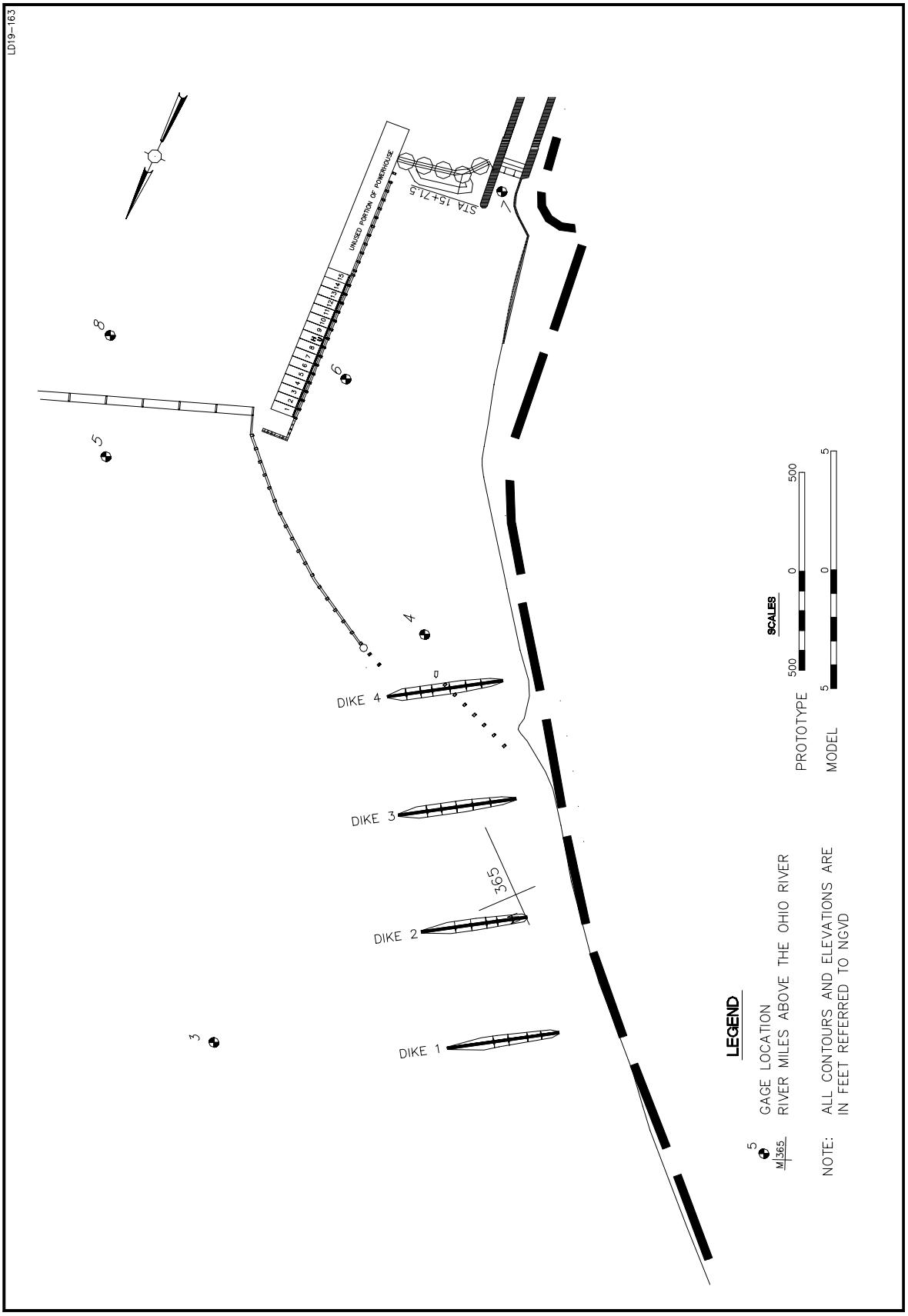


Figure 15. Plan D-1

However, current velocities increased along the right bank at the upstream end of the ice fender. The increase in velocities along the right bank ranged from about 0.5 fps with a 62,000-cfs riverflow to about 2.5 fps with a 249,000-cfs riverflow. Current velocities along the right bank ranged from about 1.2 to 3.2 fps with 62,000 and 249,000-cfs riverflows, respectively. The clockwise eddy in the lock forebay was reduced in size when compared to the base test. The change in the eddy was most notable with a 249,000-cfs riverflow.

Water-surface elevations. Water-surface elevations are shown in Table 12. There was no significant change in water-surface elevations when compared to the base test. Water-surface elevations increased about 0.1 ft at model gauges 1-3 with riverflows above 122,000 cfs and model gauge 6 generally decreased by 0.1 ft.

Navigation conditions. Navigation conditions for downbound tows entering the upper lock approach, shown in Plates 107-110 and Photos 11-13, did not significantly change when compared to the base test with existing conditions or Plan D. Downbound tows were required to approach the lock close to the right bank in the same manner as with the base test and Plan D. There was a tendency for the currents generated by the powerhouse to move the tow out of alignment with the lock and more maneuvering was required when downbound tows did not approach the lock close to the right bank (Plate 108 and Photos 11-12). The dike field redistributed the flow in the approach and the velocities along the right bank were increased. This could adversely impact a downbound tow approaching the lock, especially with the higher riverflows (Plate 110 and Photo 13). This is particularly important when making the final turning maneuver to align with and enter the lock chamber (Plates 108-110 and Photos 11-13). Navigation conditions for upbound tows, shown in Plates 111-113 and Photos 14 -16, were nearly the same as the base test and Plan D. Upbound tows could push out of the lock chamber, clear the extension, and swing the head of the tow toward the right bank without major difficulties. With the higher riverflows, upbound tows exiting the upper lock approach may tend to encroach on the powerhouse more than in tests with existing conditions or tests with Plan D conditions (Plate 113 and Photo 16).

4 Results and Conclusions

Limitations of Model Results

Analysis of the results of this investigation is based on a study of the effects of the various alternatives on current directions and velocities, water-surface elevations, and the effects of the resulting currents on the behavior of the model towboat and tow. In evaluating test results, it should be remembered that small changes in current direction and velocities are not necessarily changes produced by a particular modification because several floats introduced at the same point may follow a different path and move at a slightly different velocity due to eddies and pulsating currents. The current directions and velocities shown in the plates were taken with floats submerged to the draft of a loaded barge (9-ft prototype) and are indicative of the currents that affect tow behaviors.

As this was a small model scale, it was difficult to accurately reproduce the hydraulic characteristics of the prototype structures or to measure water-surface elevations within a prototype accuracy greater than about 0.1 ft. Since the model data were based on steady flow conditions but the flow varied in the prototype, prototype current directions and velocities could be somewhat different from model current directions and velocities. The model was of the fixed-bed type and was not designed to reproduce overall sediment movement that might occur in the prototype with the various alternatives tested. Thus, changes in the channel configuration resulting from scouring and deposition and any resulting changes in current directions and velocities were not evaluated.

Summary of Results and Conclusions

The following results and conclusions were developed during the study:

a. *Base tests, downbound tows*. Navigation conditions were very difficult entering the upper lock approach and required a considerable amount of maneuvering for downbound tows to enter the lock chamber. With the higher riverflows, some type of assistance may be required for tows entering the upper lock approach.

b. *Base tests, upbound tows*. Navigation conditions were satisfactory leaving the upper lock approach, provided tows maintained control.

c. *Pre-existing conditions, downbound tows*. Navigation conditions were very difficult and dangerous entering the upper lock approach.

d. *Pre-existing conditions, upbound tows*. Navigation conditions were satisfactory leaving the upper lock approach. With the higher riverflows, there was a tendency for upbound tows to slide toward the radial ice fender.

e. *Plan A, downbound tows*. Navigation conditions approaching the lock improved when compared to the base test. The maneuvering required for tows to align with and enter the lock chamber was reduced. However, a strong outdraft developed near the upstream end of the ice fender that could adversely affect navigation with the higher riverflows.

f. *Plan A, upbound tows*. Navigation conditions were satisfactory leaving the upper lock approach.

g. *Plan A-Modified, downbound tows*. Navigation conditions were better approaching the lock when compared to Plan A. The outdraft near the upstream end of the ice fender was reduced.

h. *Plans B and B-1*. Cells placed in the lock forebay did not significantly improve navigation conditions for downbound tows when compared to the base test.

i. *Plans B and B-1*. Cells placed in the lock forebay would restrict the maneuvering of upbound tows and adversely affect navigation conditions.

j. *Plan C*. This plan provided some protection for tows maneuvering to enter or exit the lock forebay. Downbound tows could drive into the slack water behind the closure wall and maneuver to align with and enter the lock chamber.

k. *Plan C*. Navigation conditions were satisfactory for upbound tows leaving the upper lock approach.

l. *Plan C-1*. The four submerged dikes placed upstream of the lock forebay reduced the flow along the right descending bank, and improved navigation conditions for downbound tows approaching the lock when compared to Plan C.

m. *Plan C-1, upbound tows*. Navigation conditions were satisfactory.

n. *Plan D, downbound tows*. Extending the riverside lock wall upstream 200 ft provided some aid to downbound tows aligning with the lock chamber. However, the navigation conditions approaching the lock would be the same as with the base tests.

o. *Plan D, upbound tows*. It did not restrict the maneuverability of a 15-barge tow enough to create any major difficulties. However, the

maneuverability of a 16-barge tow with a starboard hip barge may be restricted enough to create some difficulties.

p. *Plan D-1*. The placement of the dike field upstream of the ice fender did not significantly improve navigation conditions for tows entering and leaving the upper lock approach when compared to base tests with existing conditions or Plan D.

q. *Plan D-1*. It is likely that navigation conditions for both downbound and upbound tows could be more difficult due to the increase in velocity along the right bank.

Table 1
Water-Surface Elevations, ft (NGVD), Base Tests

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1	518.2	518.2	518.3	518.4	518.6
2	518.2	518.2	518.3	518.3	518.4
3	518.2	518.2	518.3	518.2	518.2
4	518.1	518.2	518.2	518.2	518.2
5	518.2	518.2	518.2	518.2	518.2
6	518.2	518.1	518.2	518.2	518.2
7	518.2[1]	518.2[1]	518.2[1]	518.2[1]	518.2[1]

[1] Controlled elevations.

Table 2
Water-Surface Elevations, ft (NGVD), Pre-Existing Conditions

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1	518.2	518.2	518.3	518.4	518.7
2	518.2	518.2	518.3	518.3	518.5
3	518.2	518.2	518.2	518.3	518.3
4	518.2	518.2	518.2	518.2	518.2
5	518.2[1]	518.2[1]	518.2[1]	518.2[1]	518.2[1]
6	518.2	518.1	518.1	518.2	518.2
7	518.2	518.2	518.2	518.2	518.2

[1] Controlled elevations.

Table 3
Water-Surface Elevations, ft (NGVD), Plan A, Gauges 1-7

	Discharge in 1,000 cfs				
Gauge No.	**29**	**62**	**122**	**177**	**249**
1	518.3	518.2	518.4	518.6	518.7
2	518.3	518.2	518.3	518.4	518.6
3	518.3	518.2	518.3	518.3	518.4
4	518.2	518.2	518.3	518.3	518.4
5	518.2[1]	518.2[1]	518.2[1]	518.2[1]	518.2[1]
6	518.2	518.0	518.0	517.9	517.7
7	518.3	518.2	518.3	518.3	518.3

[1] Controlled elevations.

Table 4
Water-Surface Elevations, ft (NGVD), Plan A, Gauges 1A-6B

	Discharge in 1,000 cfs				
Gauge No.	**29**	**62**	**122**	**177**	**249**
1A	518.2	518.2	518.2	518.2	518.1
1B	518.1	517.9	518.0	518.0	517.9
2A	518.2	518.2	518.2	518.2	518.1
2B	518.1	517.9	517.9	517.8	517.6
3A	518.2	518.1	518.0	517.9	517.8
3B	518.2	517.9	517.9	517.9	517.5
4A	518.2	518.2	518.3	518.4	517.8
5A	518.2	518.1	518.2	518.3	518.4
5B	518.1	517.9	517.9	518.0	517.7
6A	518.1	518.0	518.1	518.2	518.2
6B	518.1	517.9	517.9	518.0	517.8

Note: Water-surface elevations recorded to measure head loss across the radial ice fender and the guard wall.

Table 5
Water-Surface Elevations, ft (NGVD), Plan A-Modified

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1	518.2	518.2	518.2	518.5	518.7
2	518.2	518.2	518.2	518.4	518.6
3	518.2	518.2	518.2	518.4	518.4
4	518.2	518.2	518.2	518.3	518.3
5	518.2[1]	518.2[1]	518.2[1]	518.2[1]	518.2[1]
6	518.2	517.9	518.1	517.9	518.0
7	518.2	518.2	518.2	518.2	518.2

[1] Controlled elevations.

Table 6
Water-Surface Elevations, ft (NGVD), Plan C, Gauges 1-7

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1	518.2	518.2	518.4	518.5	518.8
2	518.2	518.2	518.3	518.4	518.6
3	518.2	518.2	518.3	518.3	518.4
4	518.2	518.2	518.2	518.3	518.3
5[1]	518.2	518.2	518.2	518.2	518.2
6	518.1	517.7	517.7	517.7	517.7
7	518.2	518.2	518.3	518.3	518.4

[1] Controlled elevations.

Table 7
Water-Surface Elevations, ft (NGVD), Plan C, Gauges 1A-4B

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1A	518.2	518.2	518.3	518.3	518.4
1B	518.2	518.2	518.2	518.2	518.3
2A	518.2	518.2	518.3	518.3	518.4
2B	518.2	518.2	518.3	518.3	518.3
3A	518.3	518.3	518.4	517.4	518.4
3B	518.0	517.7	517.7	517.7	517.7
4A	518.2	518.2	518.3	518.3	517.3
4B	518.0	517.7	517.7	517.7	517.7

Note: Water-surface elevations recorded to measure head loss across the radial ice fender and the closure wall.

Table 8
Dike Locations, Plan C-1

Dike No.	State Plane Coordinates Iowa - South Zone Riverward End	Azimuth Toward Right Bank	Length, ft
1	N 155,652.24 E 2,592,311.80	260-42-48	460.38
2	N 155,164.38 E 2,592,426.65	260-42-48	436.21
3	N 154,674.58 E 2,592,529.61	260-42-48	485.30
4	N 154,176.80 E 2,592,583.81	260-42-48	475.76

Table 9
Water-Surface Elevations, ft (NGVD), Plan C-1, Gauges 1-7

	Discharge in 1,000 cfs				
Gauge No.	**29**	**62**	**122**	**177**	**249**
1	518.2	518.2	518.4	518.5	518.9
2	518.2	518.2	518.4	518.4	518.7
3	518.2	518.2	518.3	518.3	518.4
4	518.2	518.2	518.3	518.2	518.3
5[1]	518.2	518.2	518.2	518.2	518.2
6	518.1	517.7	517.7	517.7	517.6
7	518.2	518.2	518.3	518.3	518.4

[1] Controlled elevations.

Table 10
Water-Surface Elevations, ft (NGVD), Plan C-1, Gauges 1A-4B

	Discharge in 1,000 cfs				
Gauge No.	**29**	**62**	**122**	**177**	**249**
1A	518.2	518.2	518.3	518.2	518.2
1B	518.2	518.1	518.2	518.1	518.2
2A	518.2	518.2	518.3	518.2	518.3
2B	518.2	518.1	518.2	518.2	518.3
3A	518.2	518.3	518.3	517.3	518.4
3B	518.1	517.7	517.8	517.7	517.6
4A	518.2	518.2	518.3	518.3	517.3
4B	518.1	517.8	517.8	517.7	517.7

Note: Water-surface elevations recorded to measure head loss across the radial ice fender and the closure wall.

Table 11
Water-Surface Elevations, ft (NGVD), Plan D

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1	----------	518.2	518.3	518.4	518.6
2	----------	518.2	518.3	518.3	518.4
3	----------	518.2	518.3	518.2	518.2
4	----------	518.2	518.2	518.2	518.2
5	----------	518.2[1]	518.2[1]	518.2[1]	518.2[1]
6	----------	518.1	518.2	518.2	518.2
7	----------	518.2	518.2	518.2	518.2

[1] Controlled elevations.

Table 12
Water-Surface Elevations, ft (NGVD), Plan D-1

Gauge No.	Discharge in 1,000 cfs				
	29	**62**	**122**	**177**	**249**
1	518.2	518.2	518.3	518.5	518.8
2	518.2	518.2	518.3	518.4	518.5
3	518.2	518.2	518.2	518.3	518.3
4	518.2	518.2	518.2	518.2	518.3
5	518.2[1]	518.2[1]	518.2[1]	518.2[1]	518.2[1]
6	518.1	518.1	518.1	518.1	518.1
7	518.2	518.2	518.2	518.2	518.2

[1] Controlled elevations.

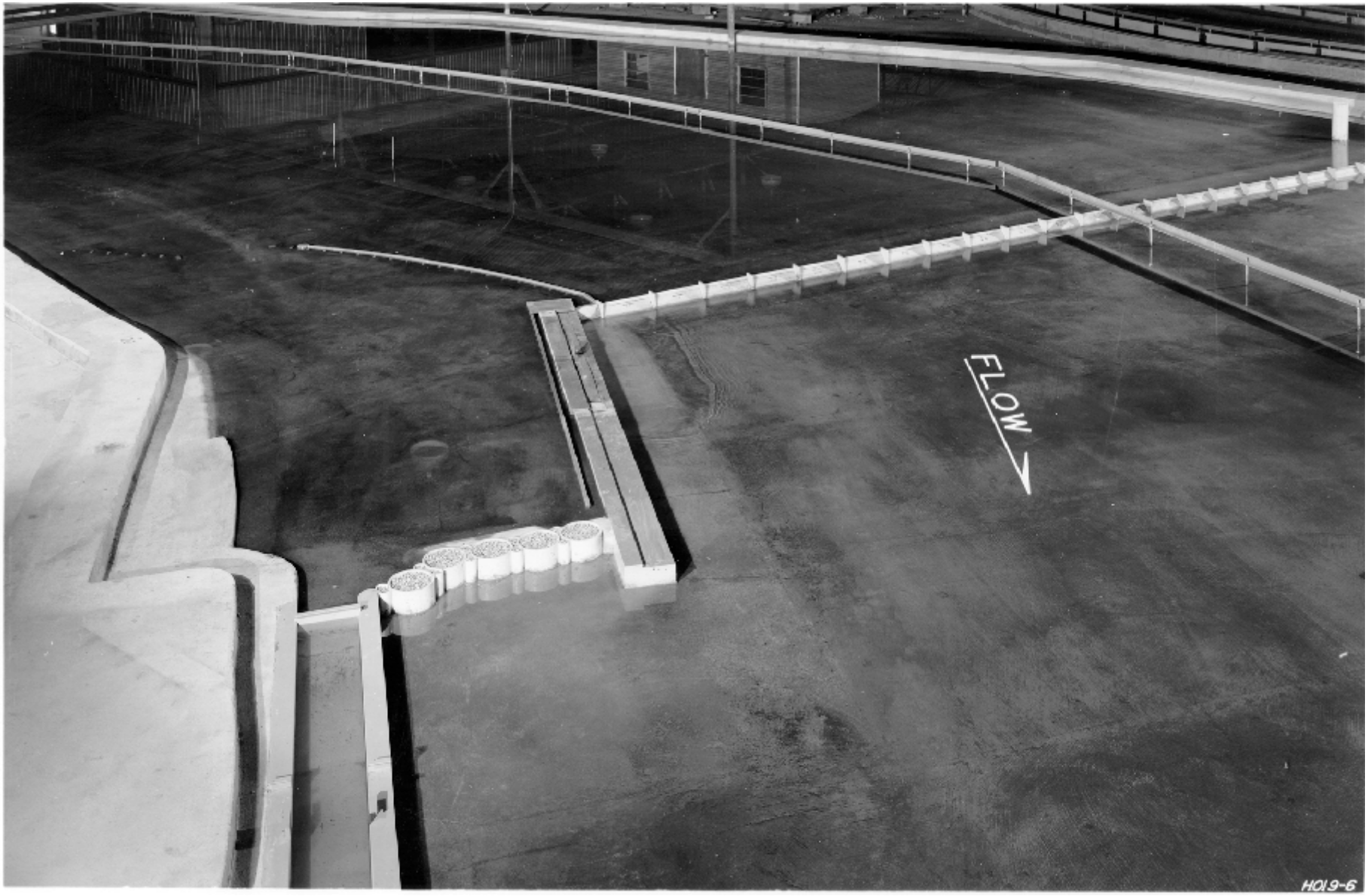


Photo 1. Base Test, looking upstream, showing the approach and forebay to the lock

Photo 2. Base Test, total riverflow = 62,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, confetti showing surface current patterns

Photo 3. Base Test, total riverflow = 62,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching and entering the lock (note maneuvering required to enter lock)

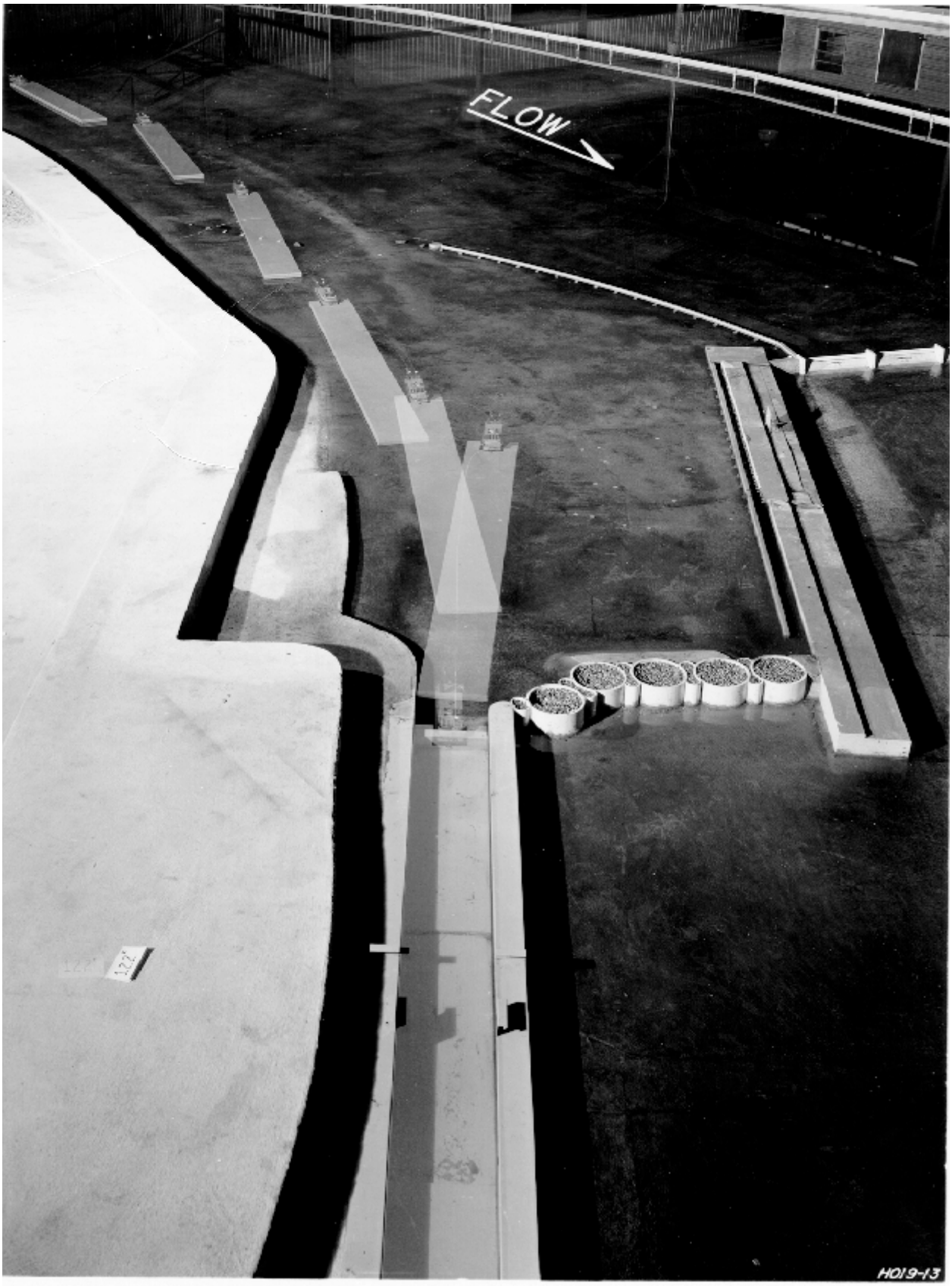


Photo 4. Base Test, total riverflow = 122,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching and entering the lock (note maneuvering required to enter lock)

Photo 5. Base Test, total riverflow = 122,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching lock (note tendency for currents to move tow toward powerhouse)

Photo 6. Base Test, total riverflow = 249,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching and entering the lock (note maneuvering required to enter lock)

Photo 7. Base Test, total riverflow = 62,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of upbound leaving lock

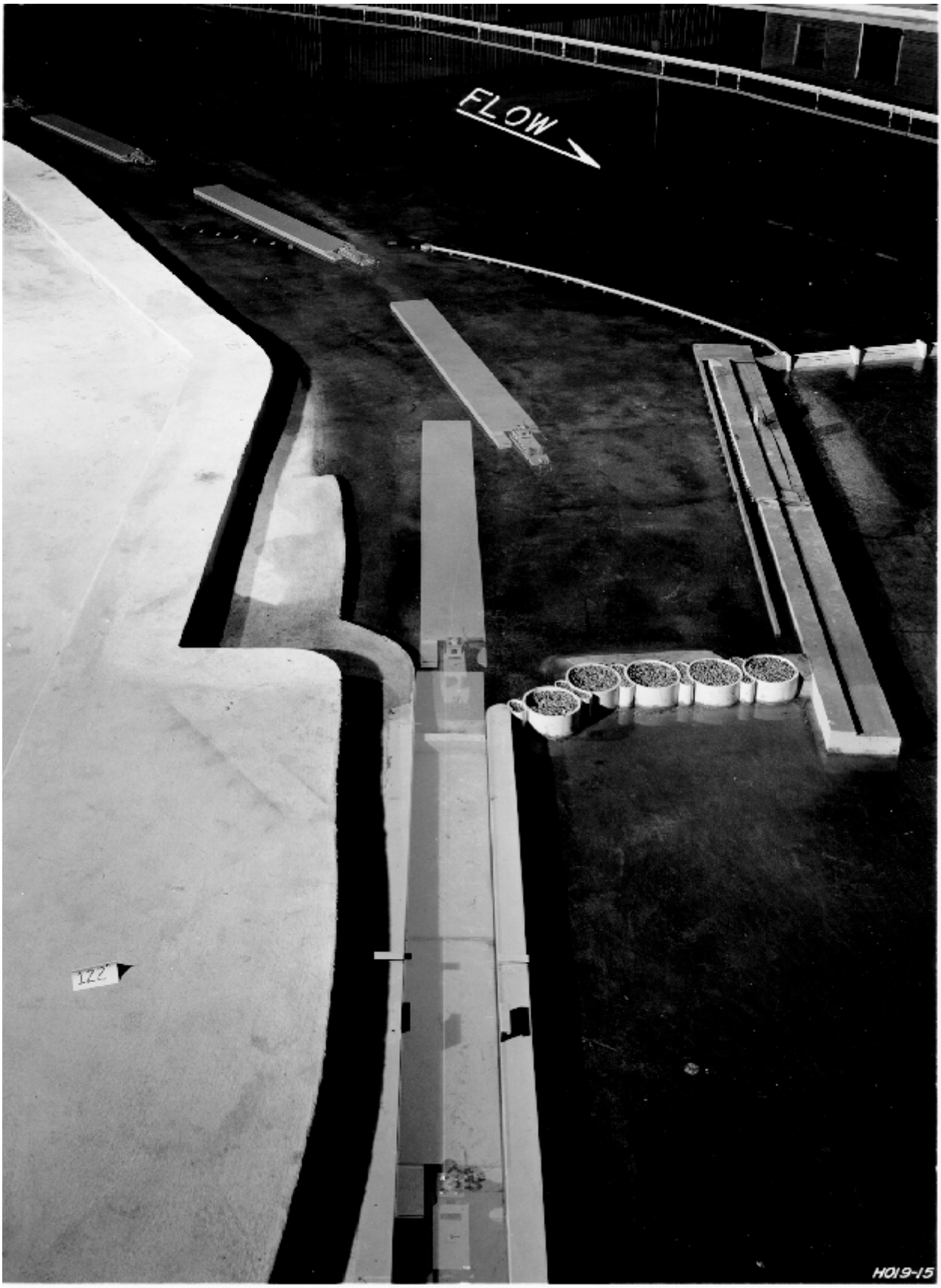


Photo 8. Base Test, total riverflow = 122,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of upbound tow leaving lock

Photo 9. Base Test, total riverflow = 249,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of upbound tow leaving lock

Photo 10. Plan D-1, looking upstream, showing the structures

Photo 11. Plan D-1, total riverflow = 62,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching and entering the lock (note tendency for stern of tow to move toward powerhouse)

Photo 12. Plan D-1, total riverflow = 122,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching and entering the lock (note maneuvering required for tow to enter lock)

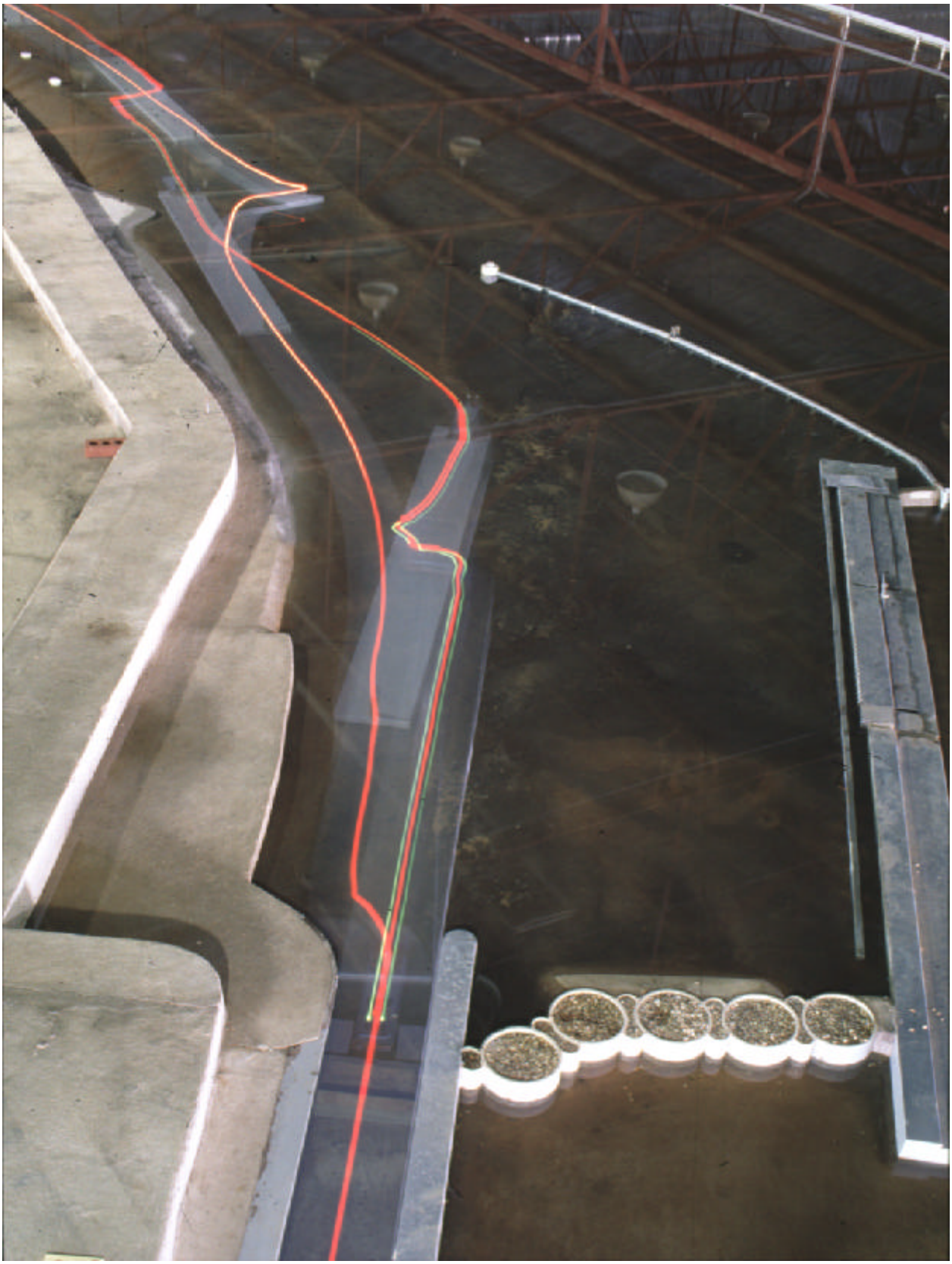


Photo 13. Plan D-1, total riverflow = 249,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of downbound tow approaching and entering the lock (note tendency for stern of tow to move toward powerhouse and maneuvering required to enter lock)

Photo 14. Plan D-1, total riverflow = 62,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of upbound tow leaving lock

Photo 15. Plan D-1, total riverflow = 122,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of upbound tow leaving lock

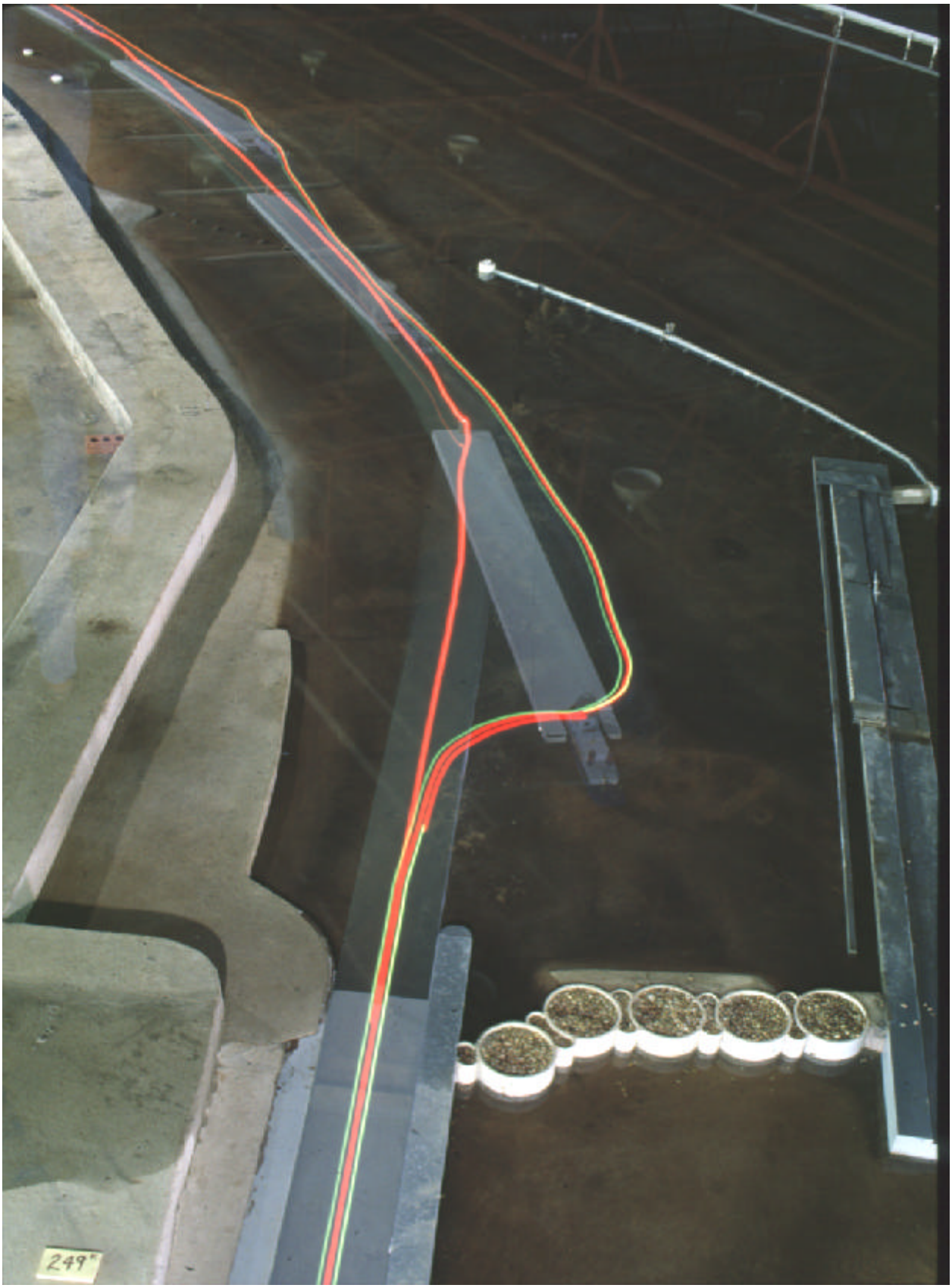


Photo 16. Plan D-1, total riverflow = 249,000 cfs, powerhouse discharge = 62,000 cfs. Looking upstream, showing the path of upbound tow leaving lock (note clearance between stern of tow and powerhouse)

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500 1500

MODEL 5 0 500 1500

VELOCITIES AND CURRENT DIRECTIONS

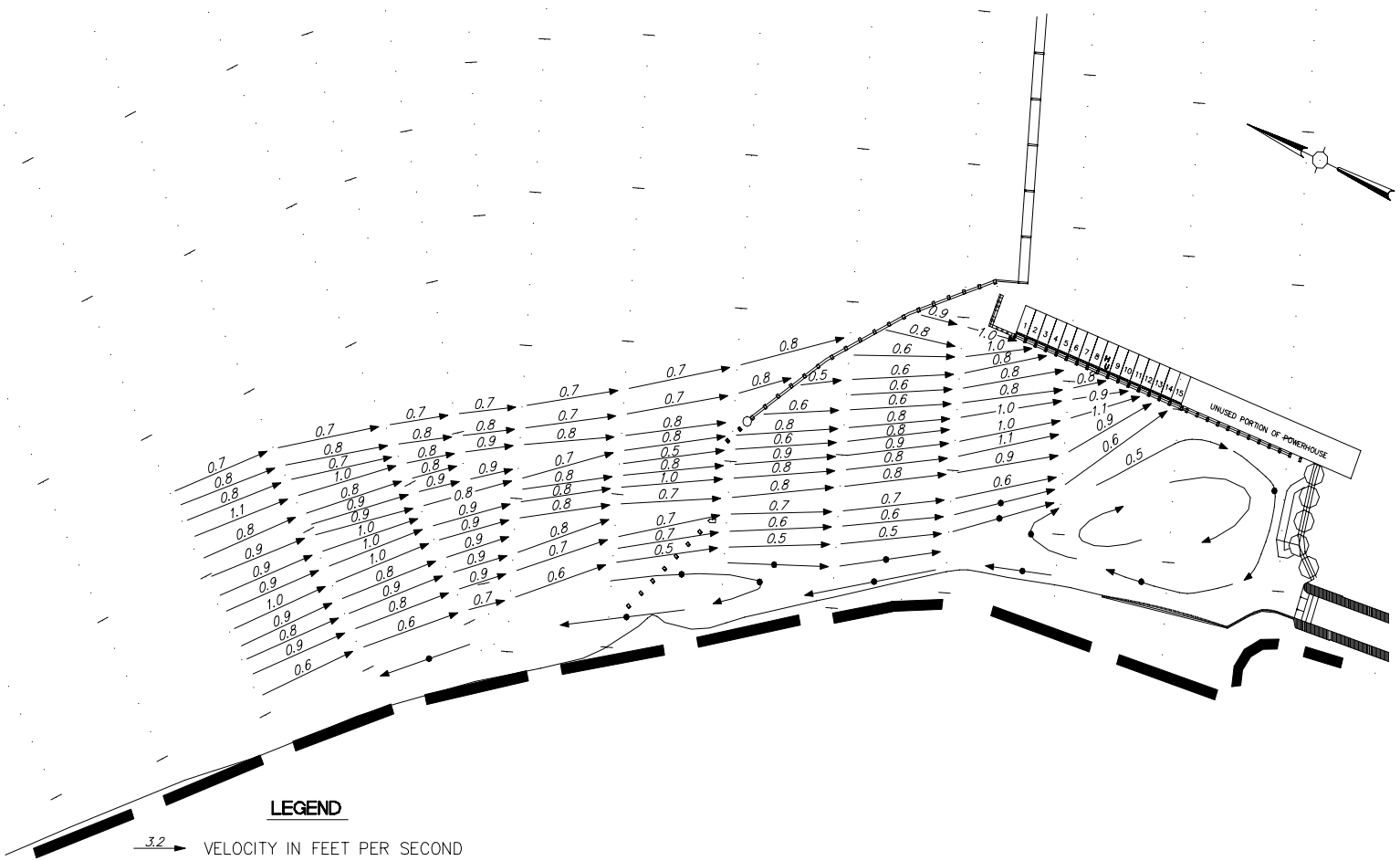
BASE TEST

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

Plate 2

LD19-026



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

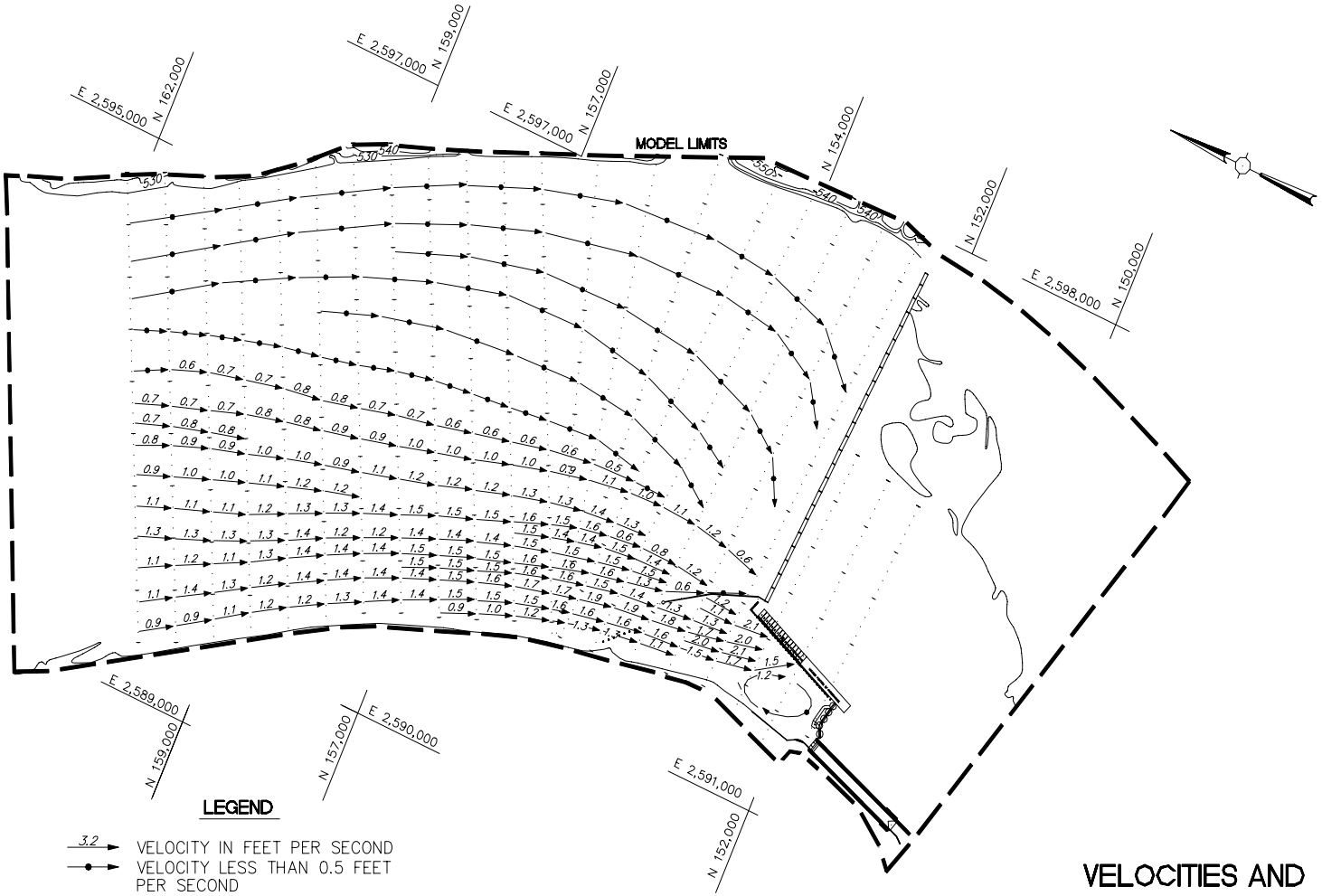
VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-023



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500 1500

MODEL 5 0 500 1500

VELOCITIES AND CURRENT DIRECTIONS

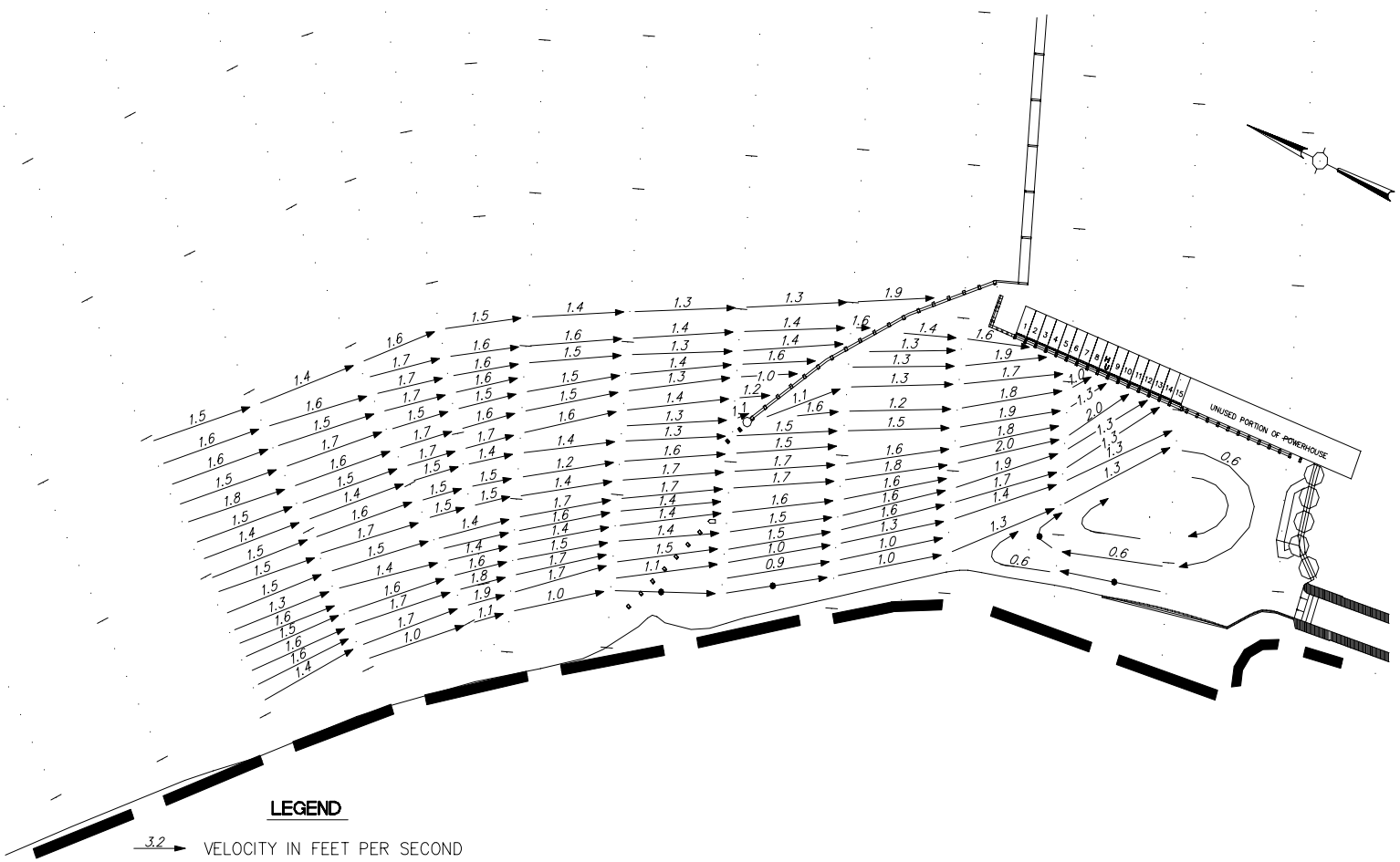
BASE TEST

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

Plate 4

LD19-027



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

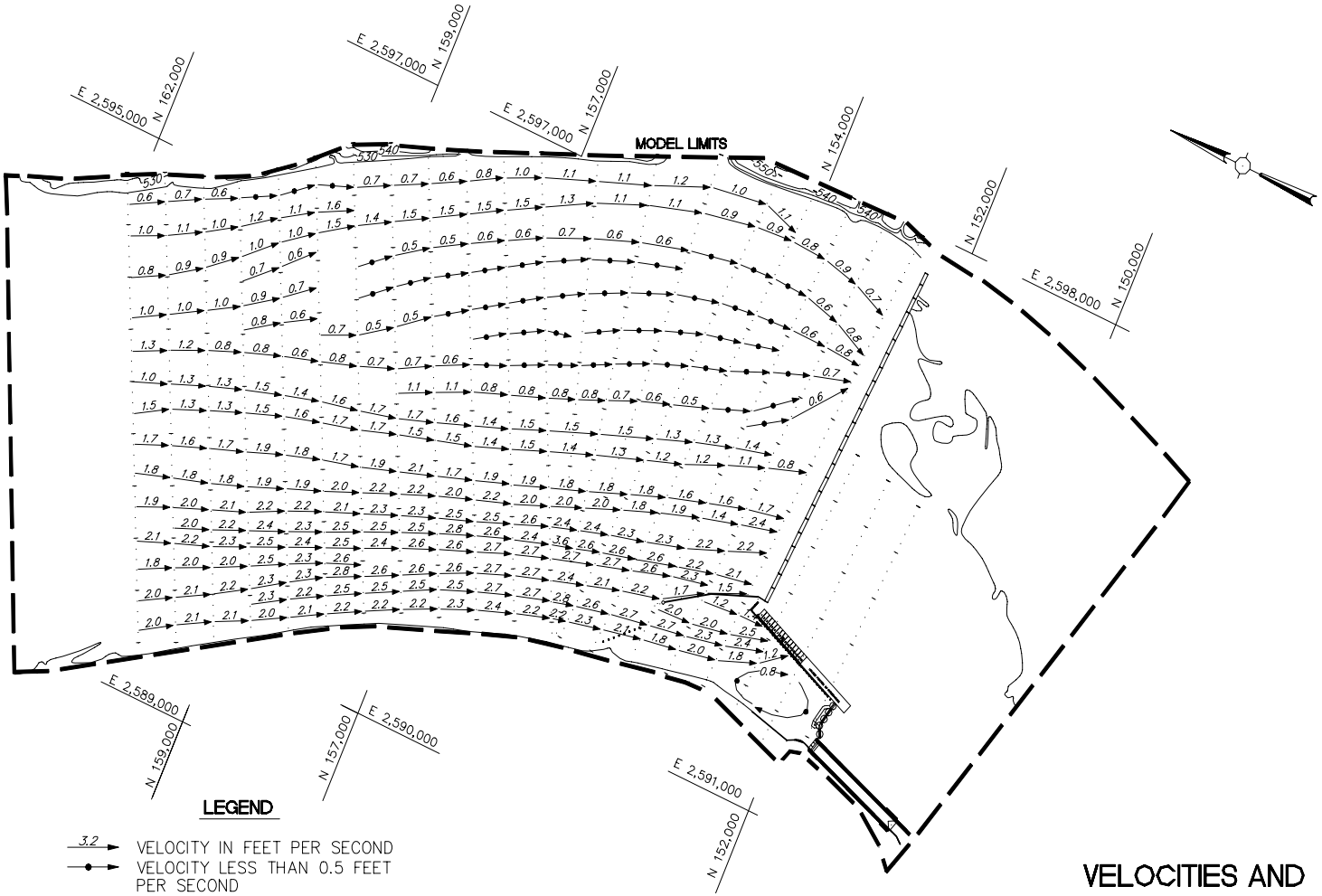
VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19–024



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500 1500

MODEL 5 0 500 1500

VELOCITIES AND CURRENT DIRECTIONS

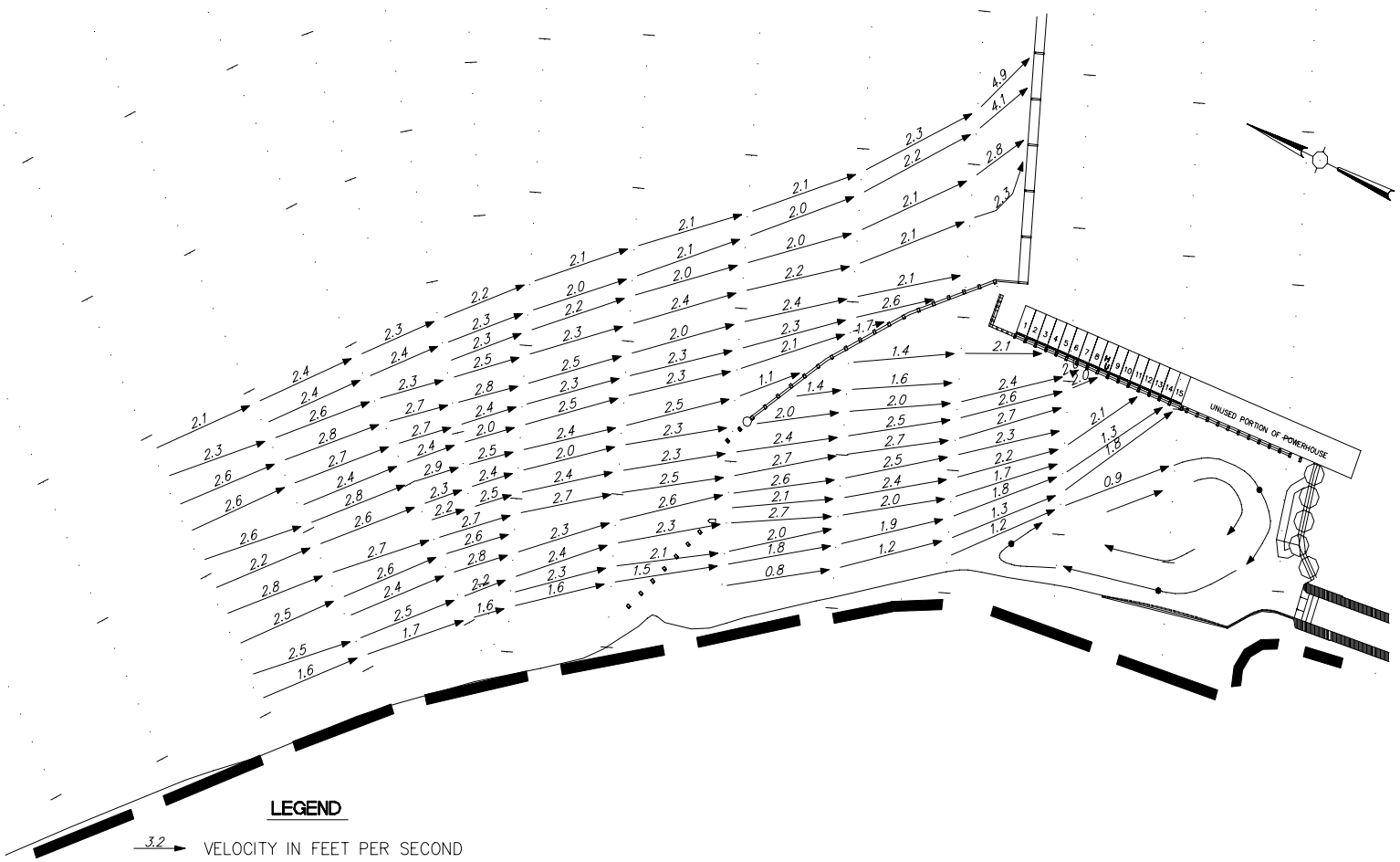
BASE TEST

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

Plate 6

LD19-028



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

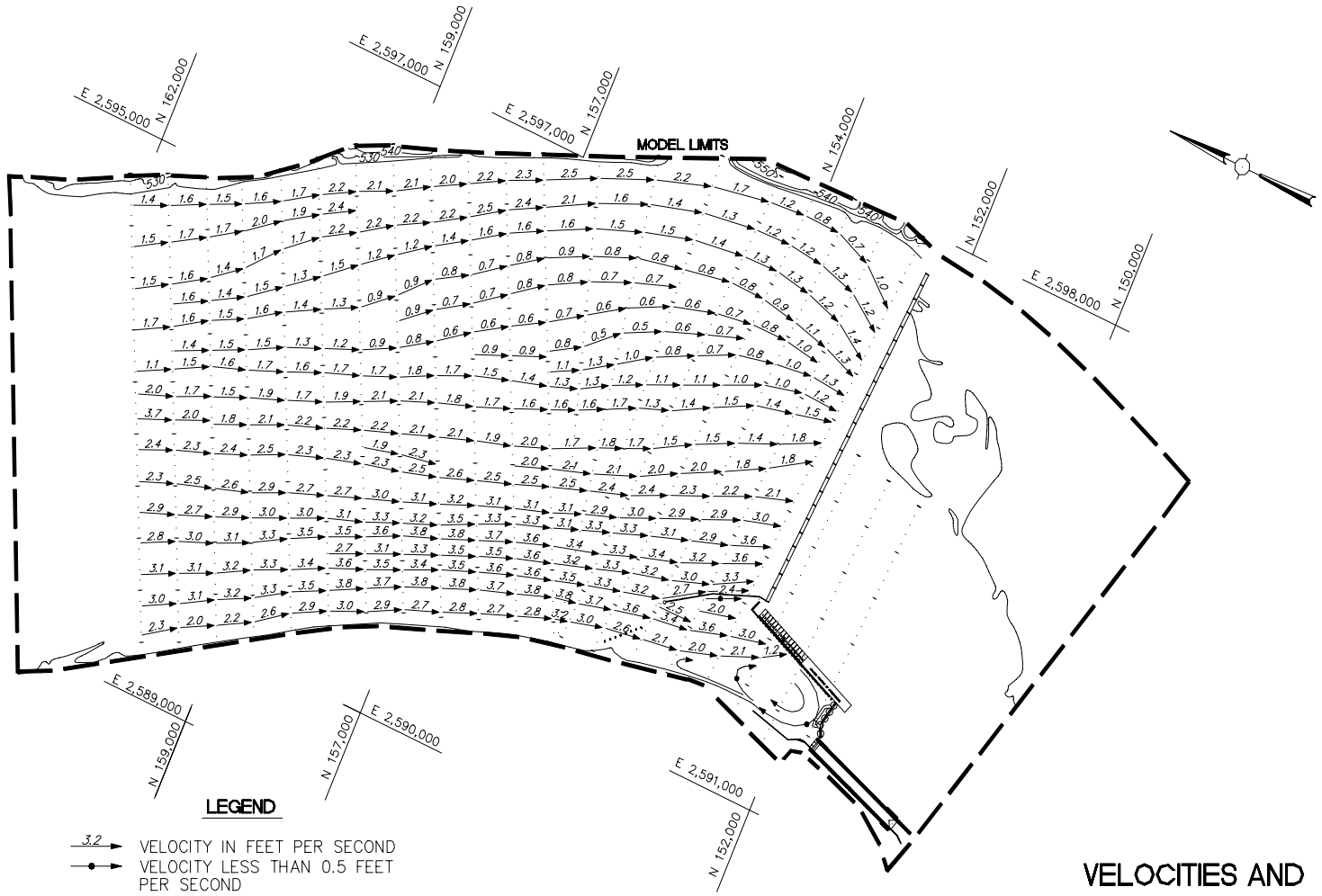
VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-020



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

→● VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500 1500

MODEL 5 0 500 1500

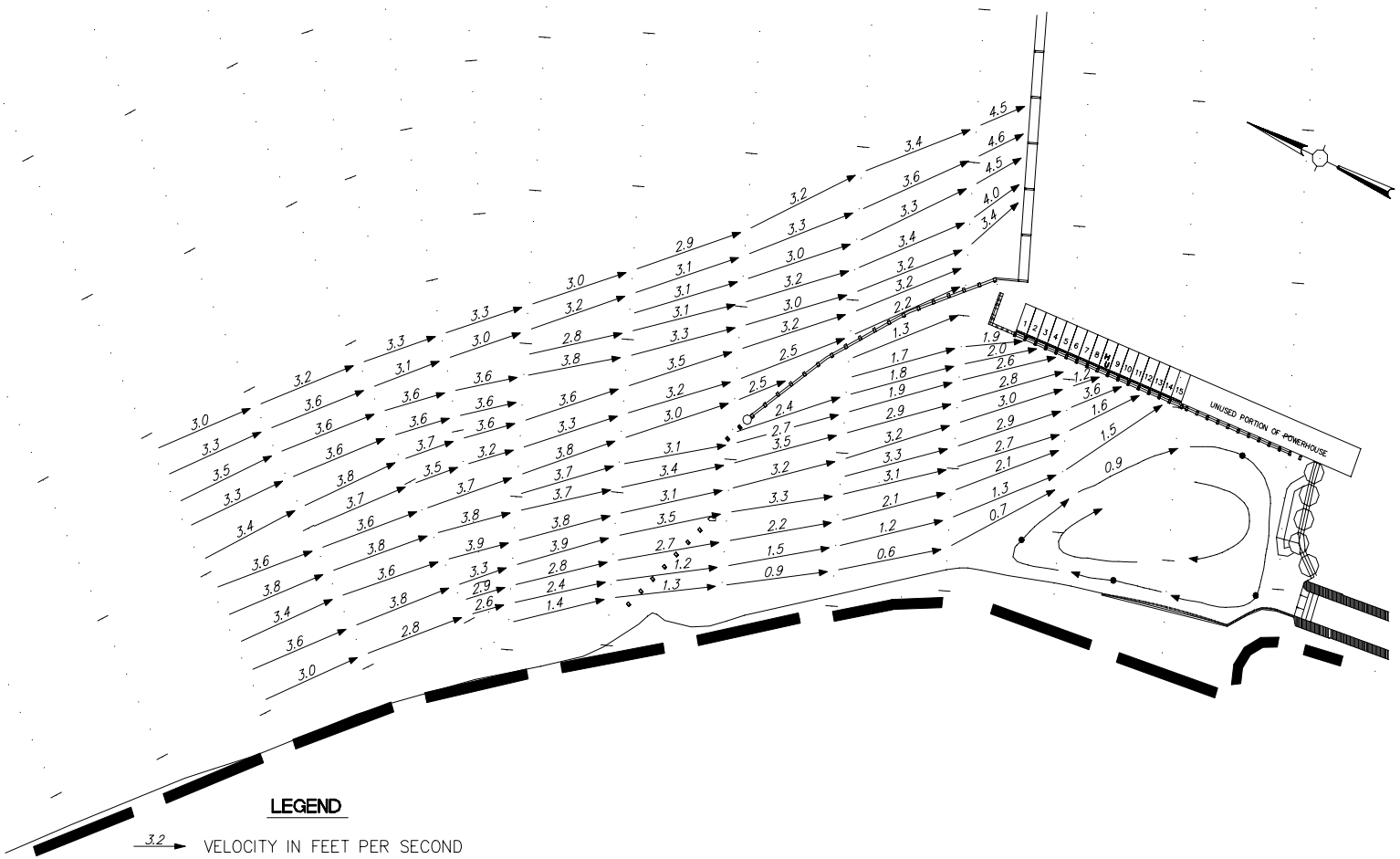
VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

LD19-029



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

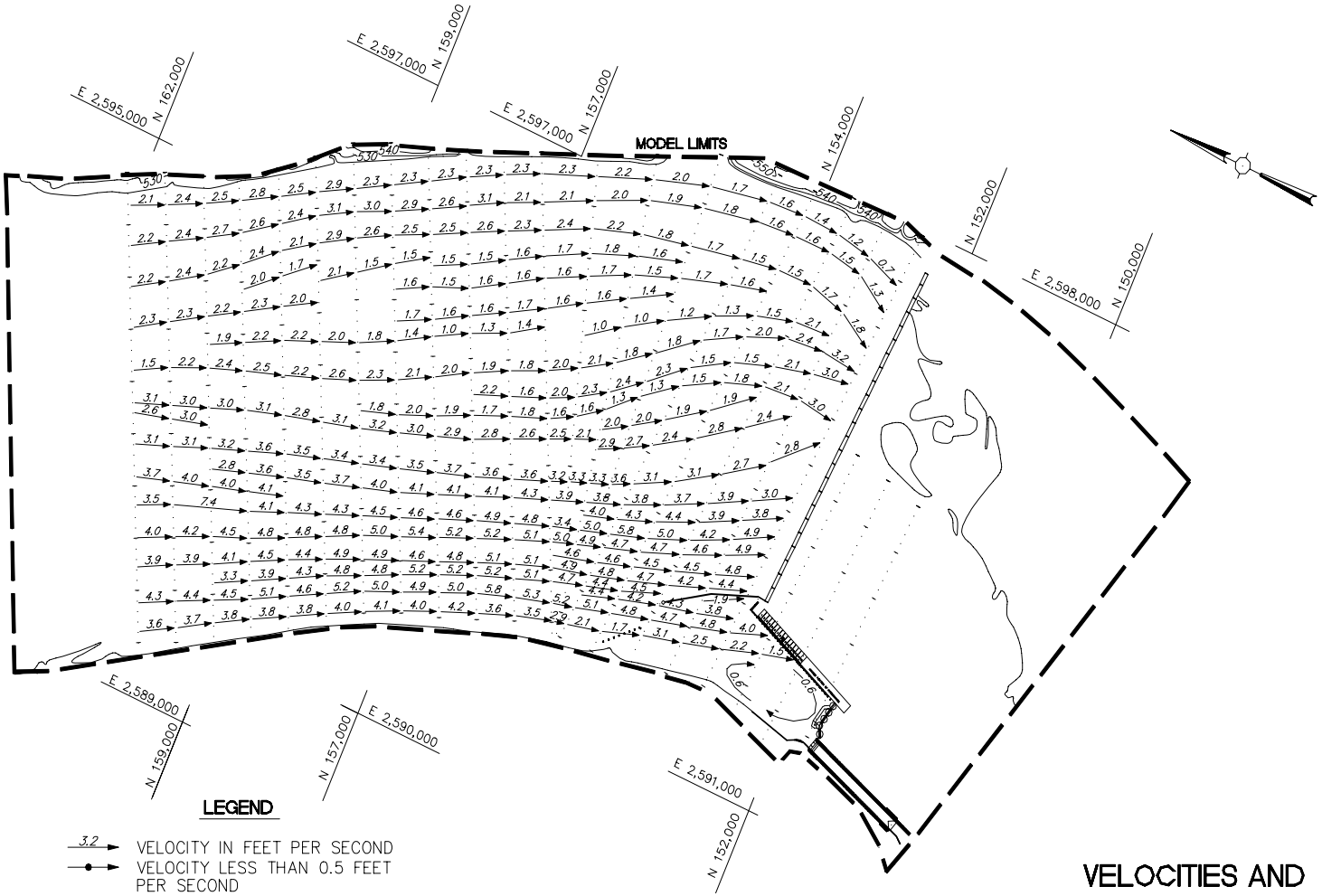
MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500 1500

MODEL 5 0 500 1500

VELOCITIES AND CURRENT DIRECTIONS

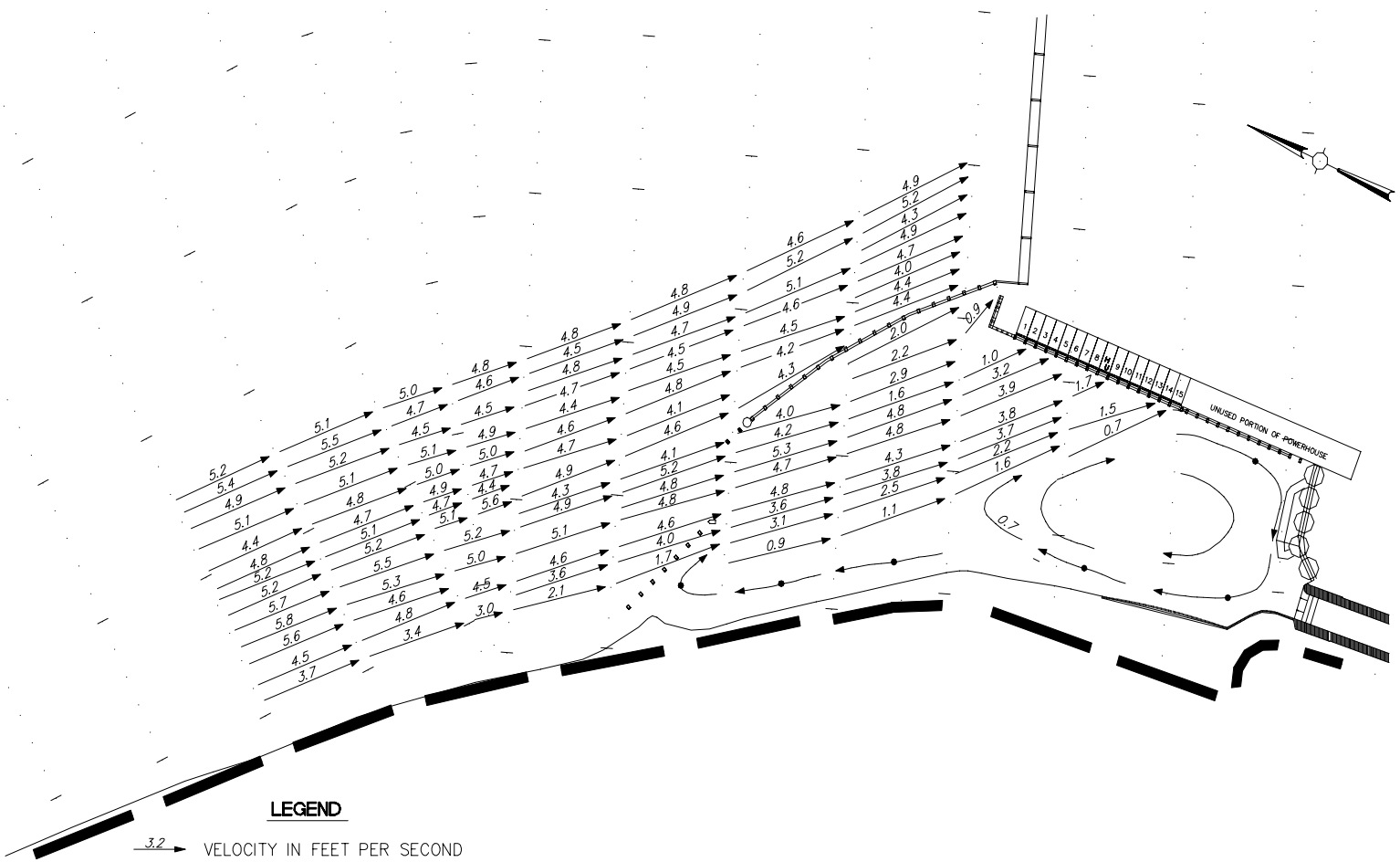
BASE TEST

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

Plate 10

LD19-030



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

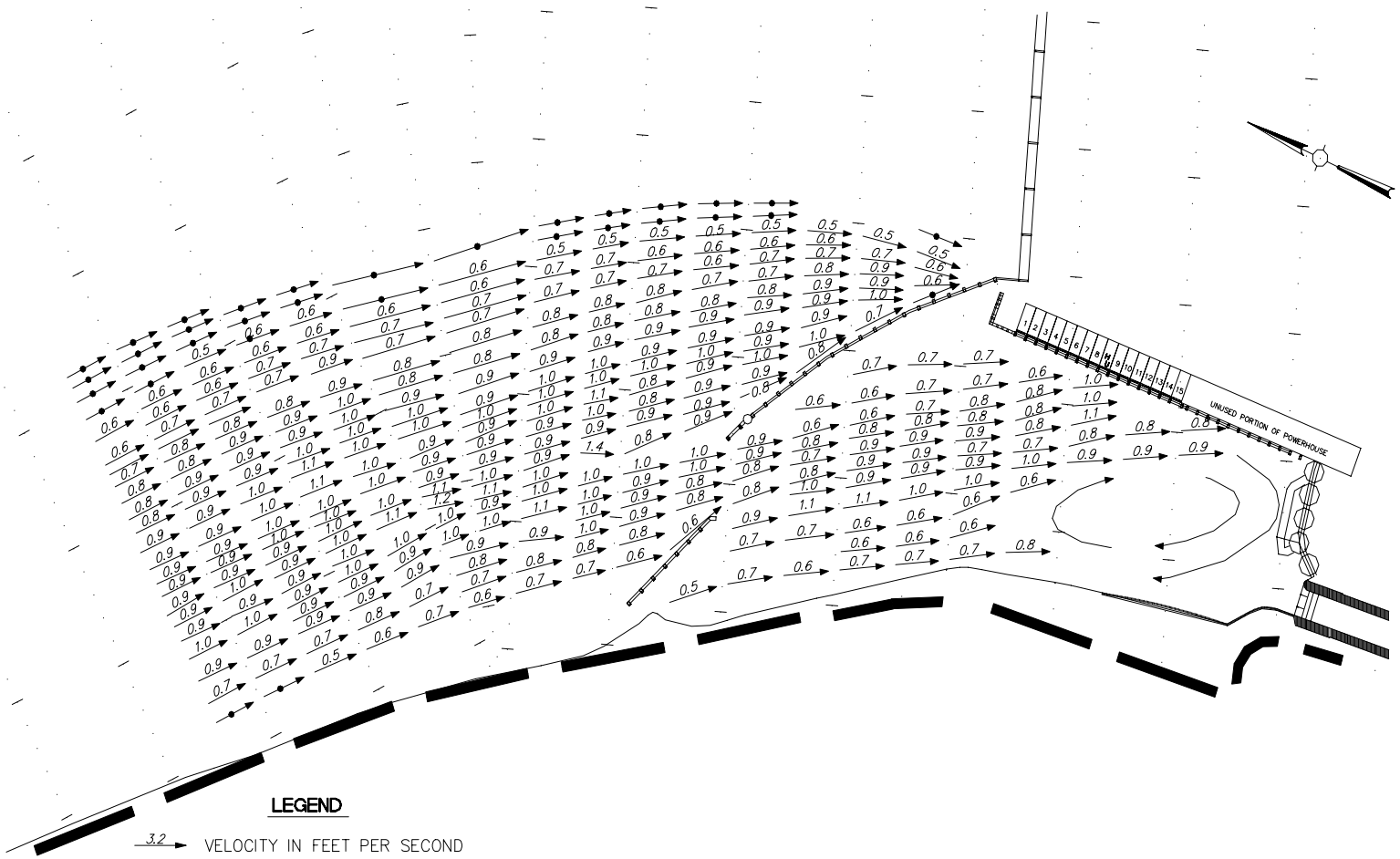
VELOCITIES AND CURRENT DIRECTIONS

BASE TEST

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19-037



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

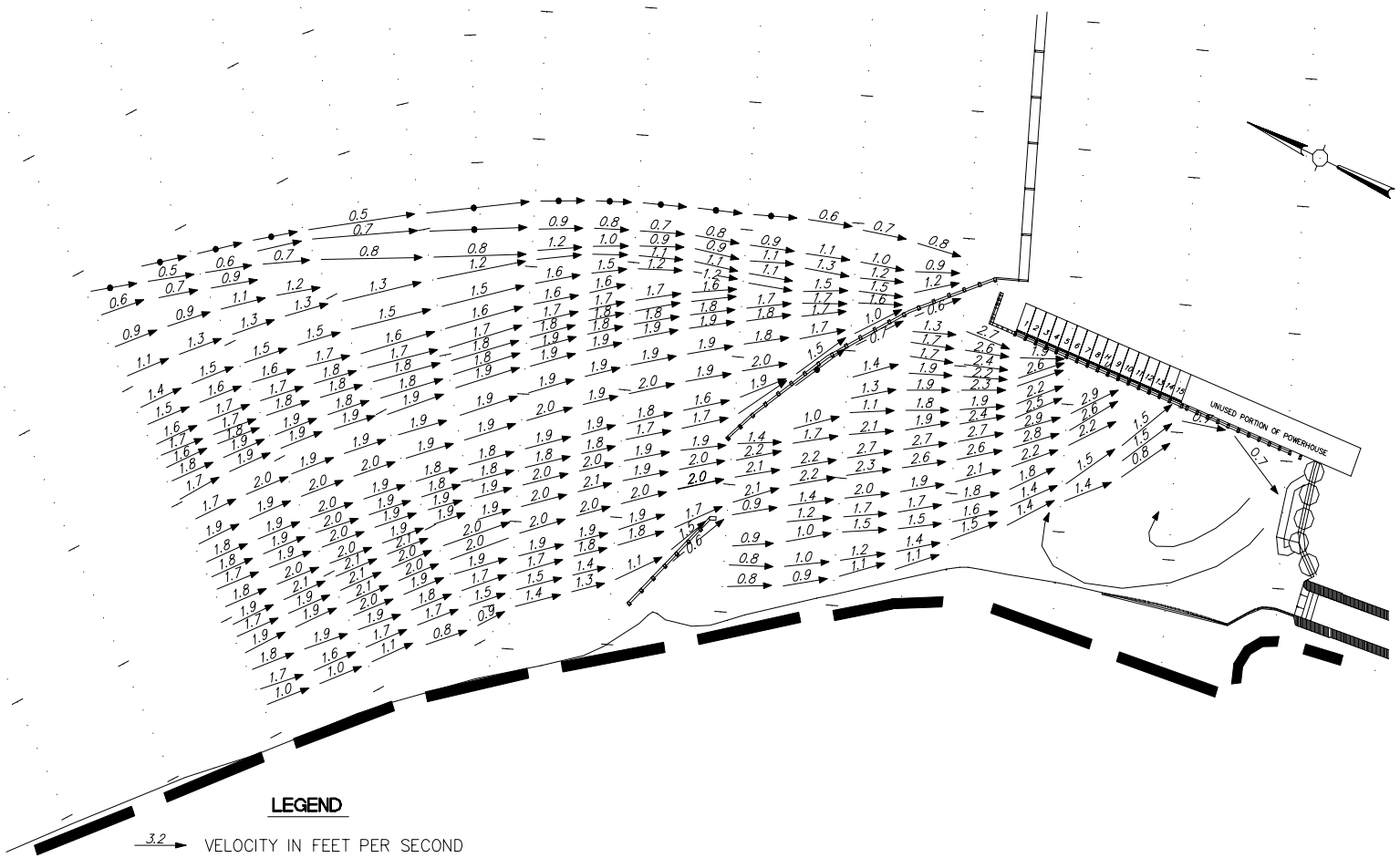
VELOCITIES AND CURRENT DIRECTIONS

EXISTING CONDITIONS

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-034



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

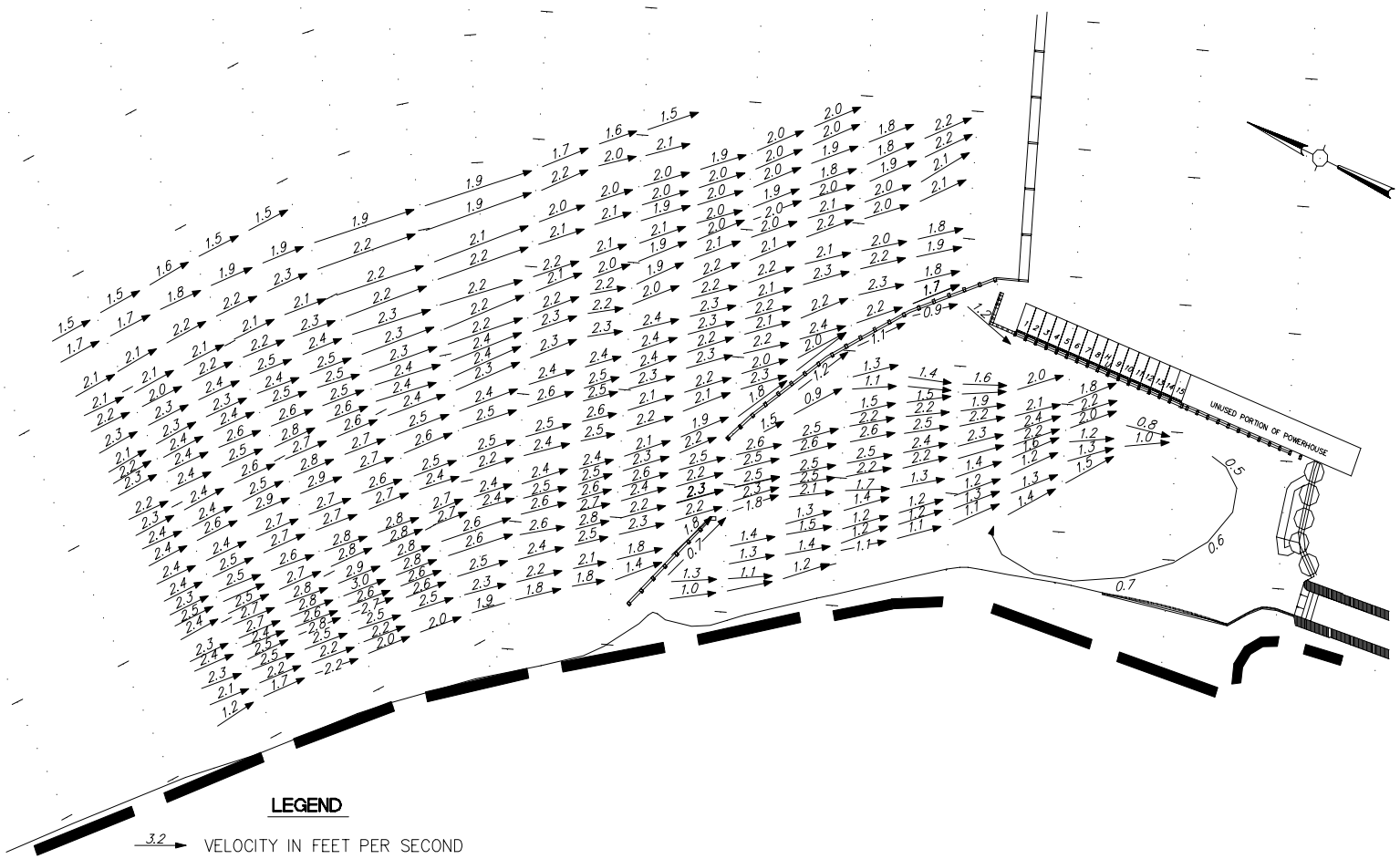
VELOCITIES AND CURRENT DIRECTIONS

PRE-EXISTING CONDITIONS

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19-035



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

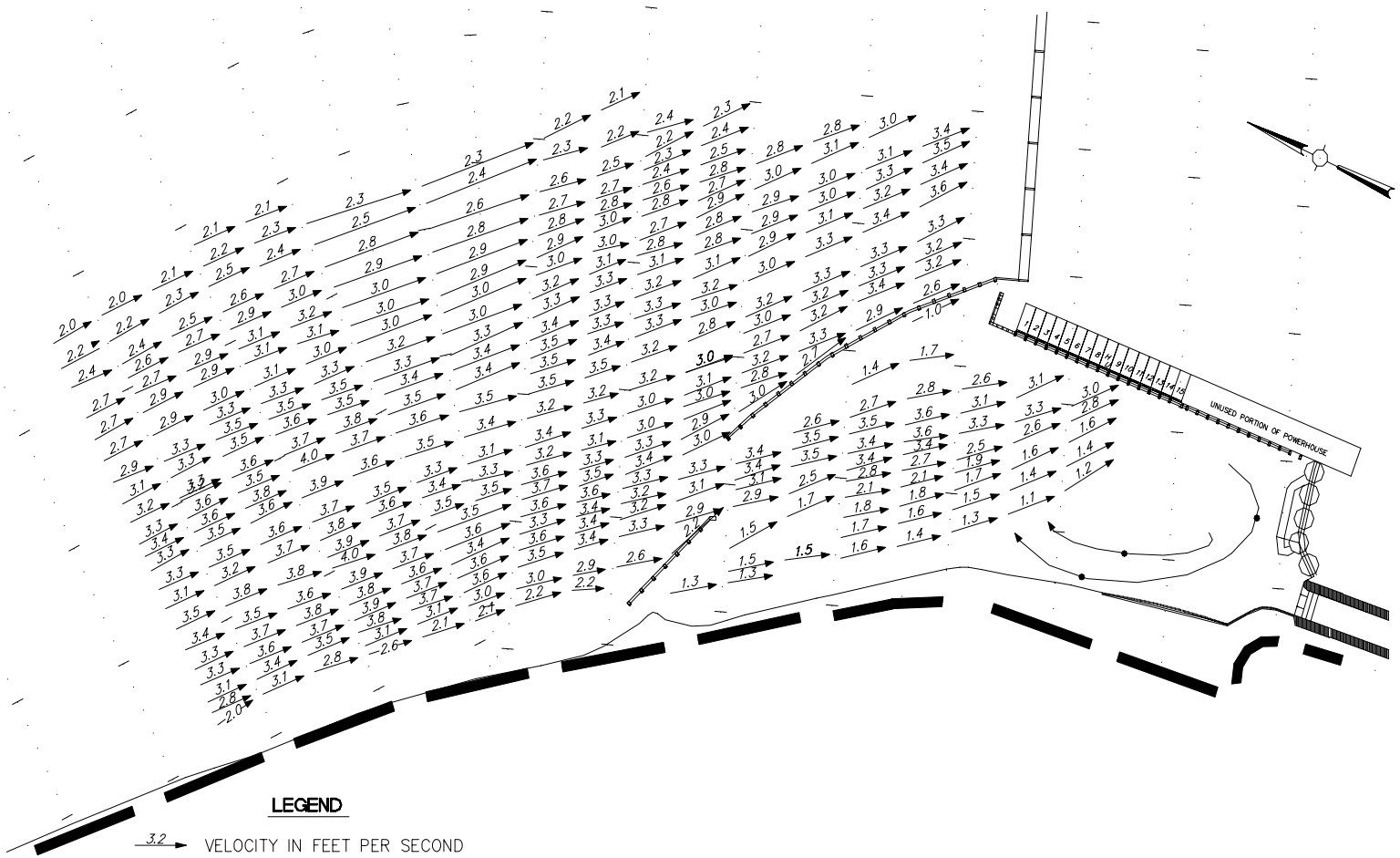
VELOCITIES AND CURRENT DIRECTIONS

PRE-EXISTING CONDITIONS

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-036



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PRE-EXISTING CONDITIONS

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

LD19-033

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PRE-EXISTING CONDITIONS

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

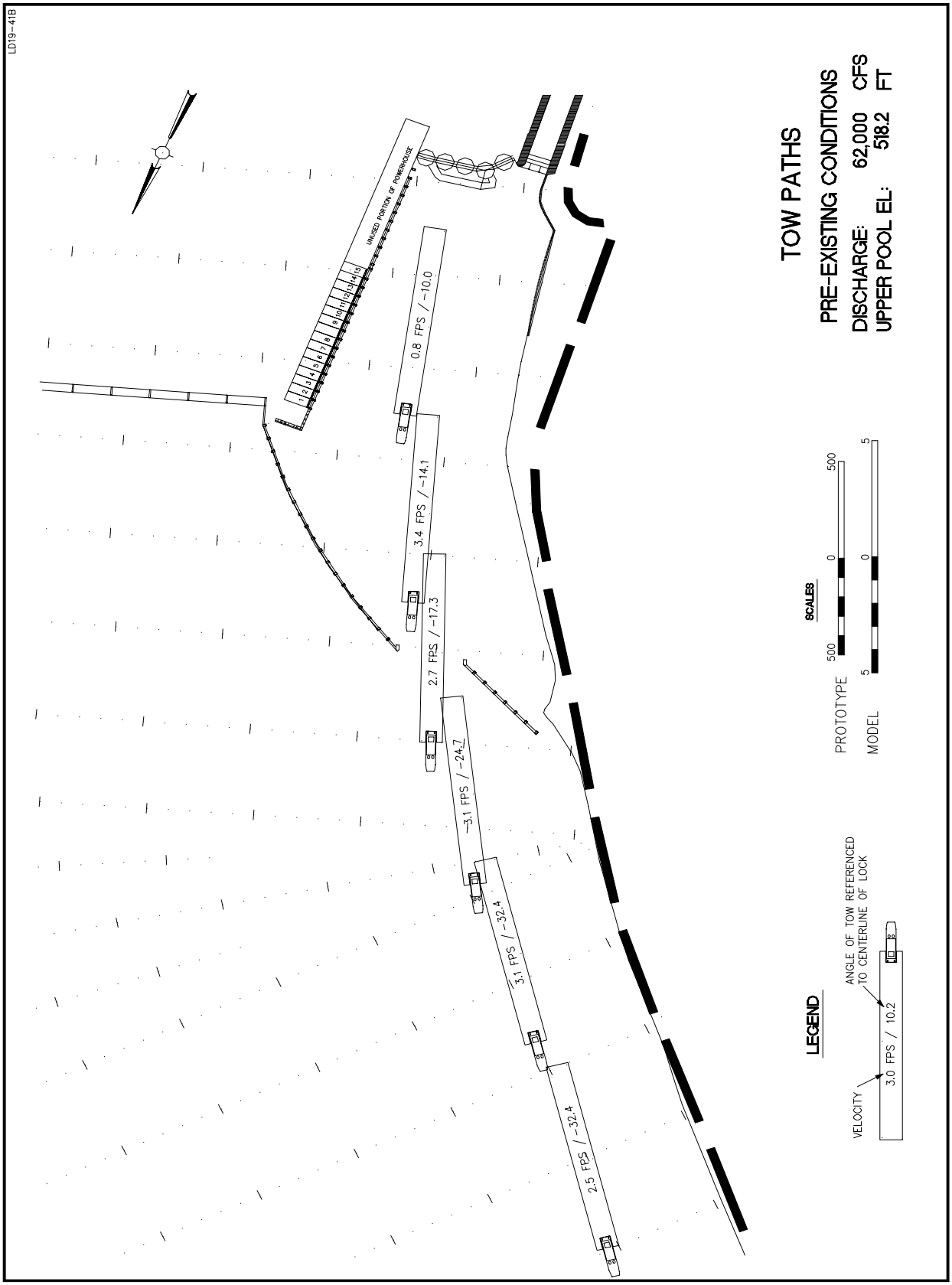
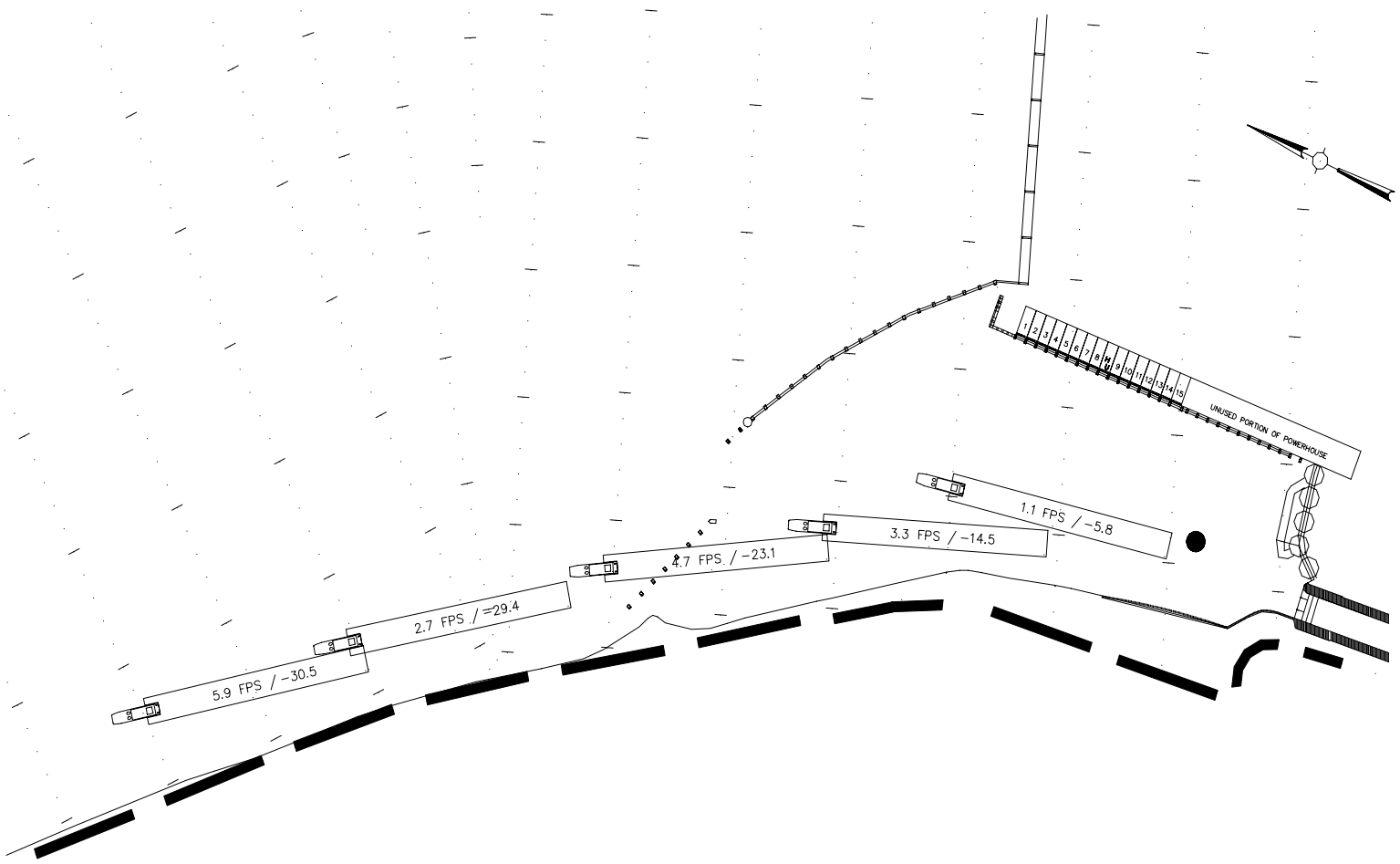
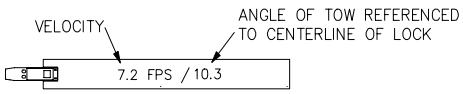

LD19-41B
TOW PATHS
PRE-EXISTING CONDITIONS
DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0.8 FPS / -10.0
3.4 FPS / -14.1
2.7 FPS / -17.3
-3.1 FPS / -24.7
3.1 FPS / -32.4
2.5 FPS / -32.4
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
3.0 FPS / 10.2

Plate 16



LEGEND



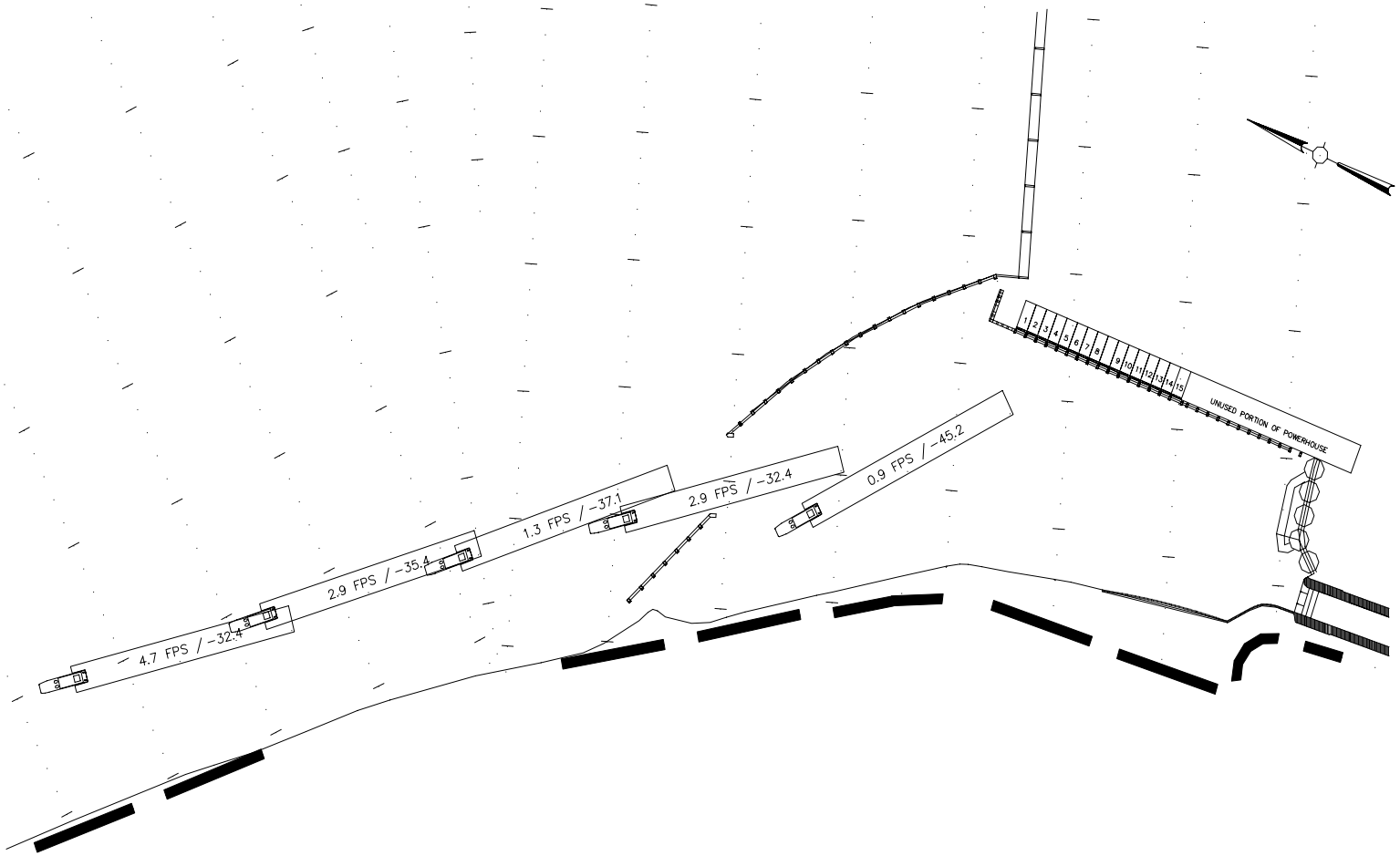
SCALES

TOW PATHS

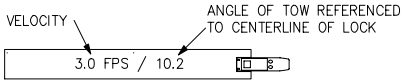
PLAN B

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

LD19-39E



LEGEND

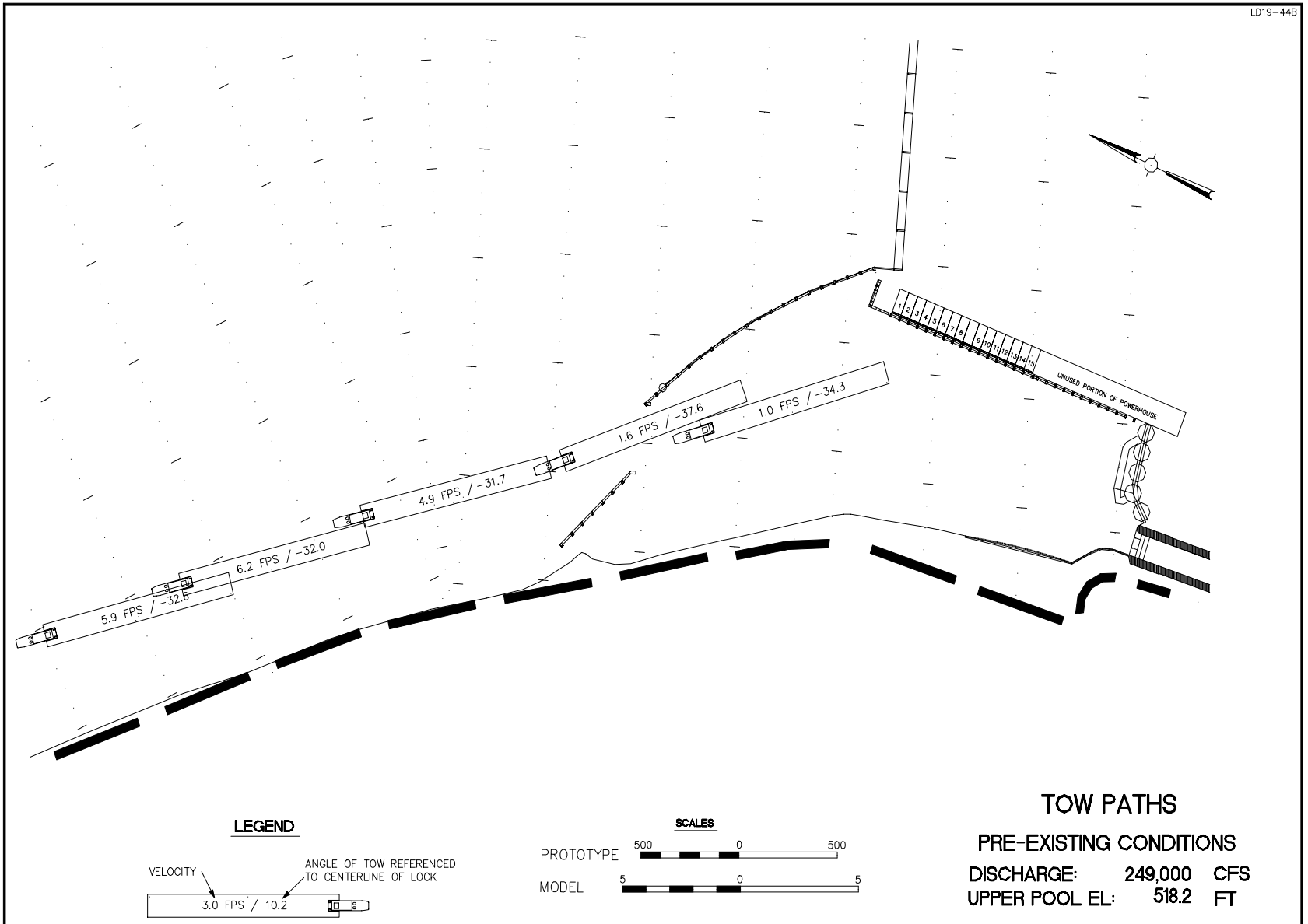


SCALES

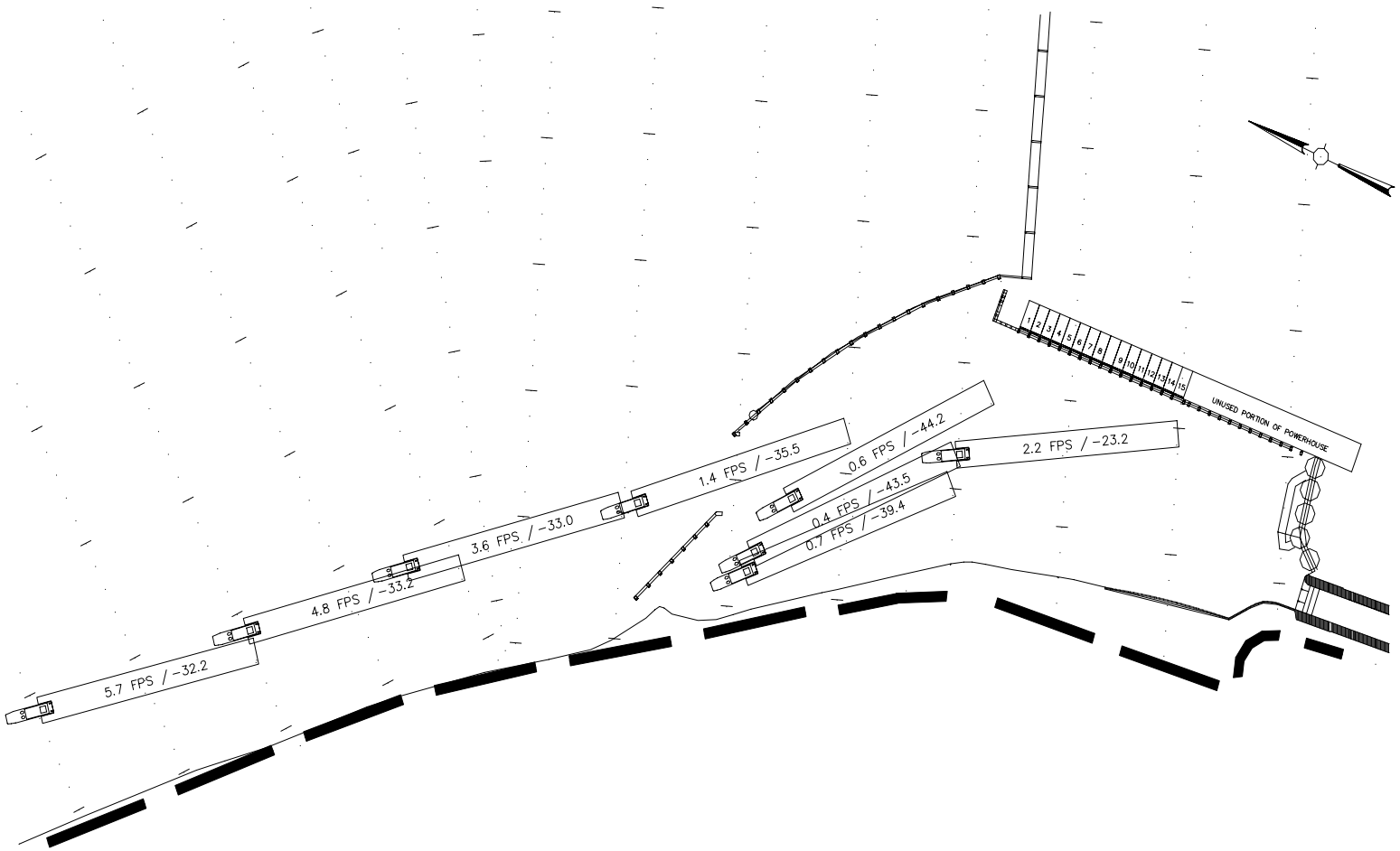
TOW PATHS

PRE-EXISTING CONDITIONS

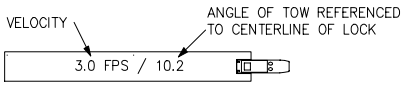
DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT


LD19-44B
5.9 FPS / -32.6
6.2 FPS / -32.0
4.9 FPS / -31.7
1.6 FPS / -37.6
1.0 FPS / -34.3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
UNUSED PORTION OF POWERHOUSE
LEGEND
VELOCITY
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
3.0 FPS / 10.2
SCALES
PROTOTYPE
500 0 500
MODEL
5 0 5
TOW PATHS
PRE-EXISTING CONDITIONS
DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

LD19-44D



LEGEND

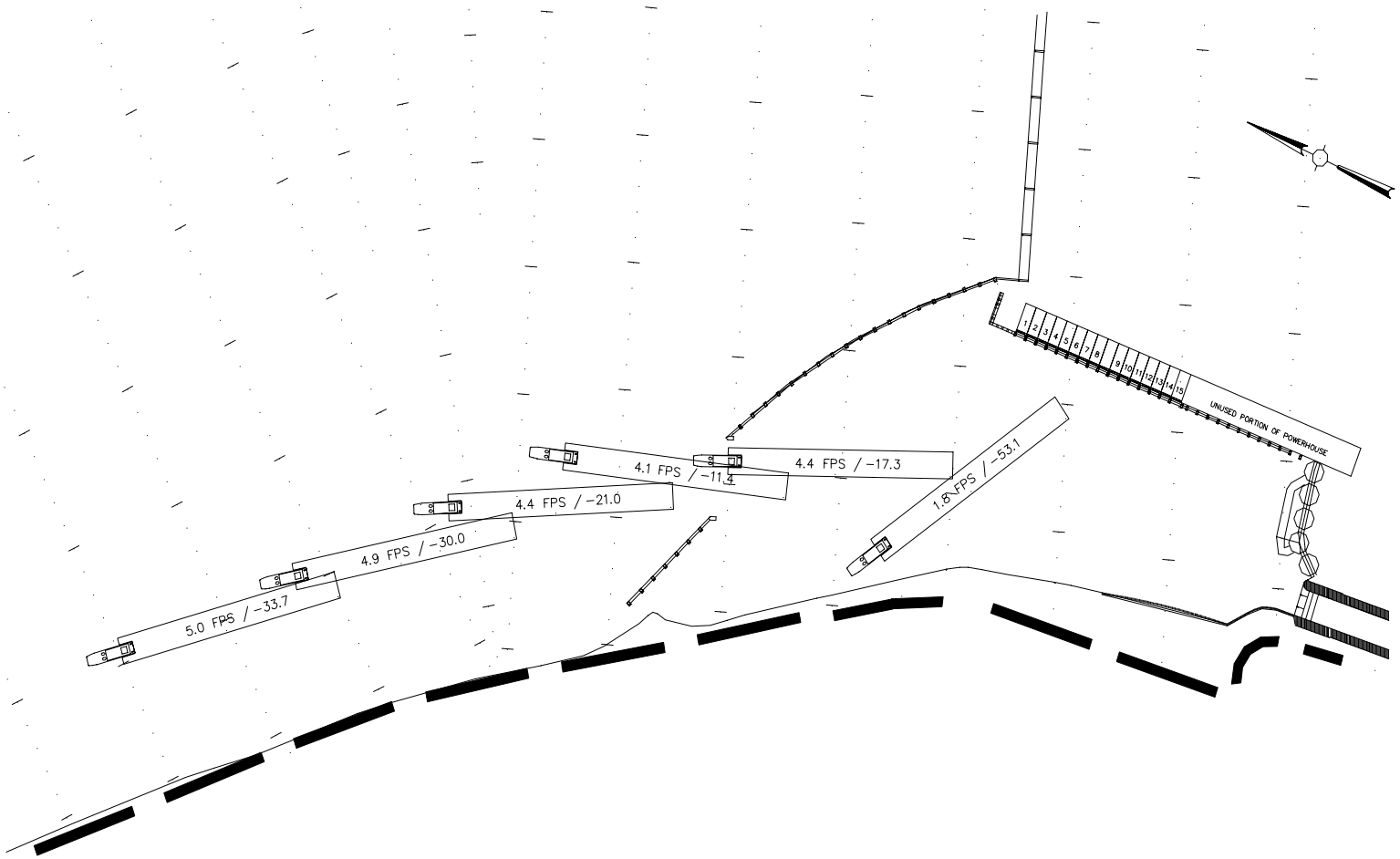


SCALES

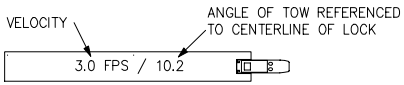
TOW PATHS

PRE-EXISTING CONDITIONS

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND



SCALES

TOW PATHS

PRE-EXISTING CONDITIONS

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

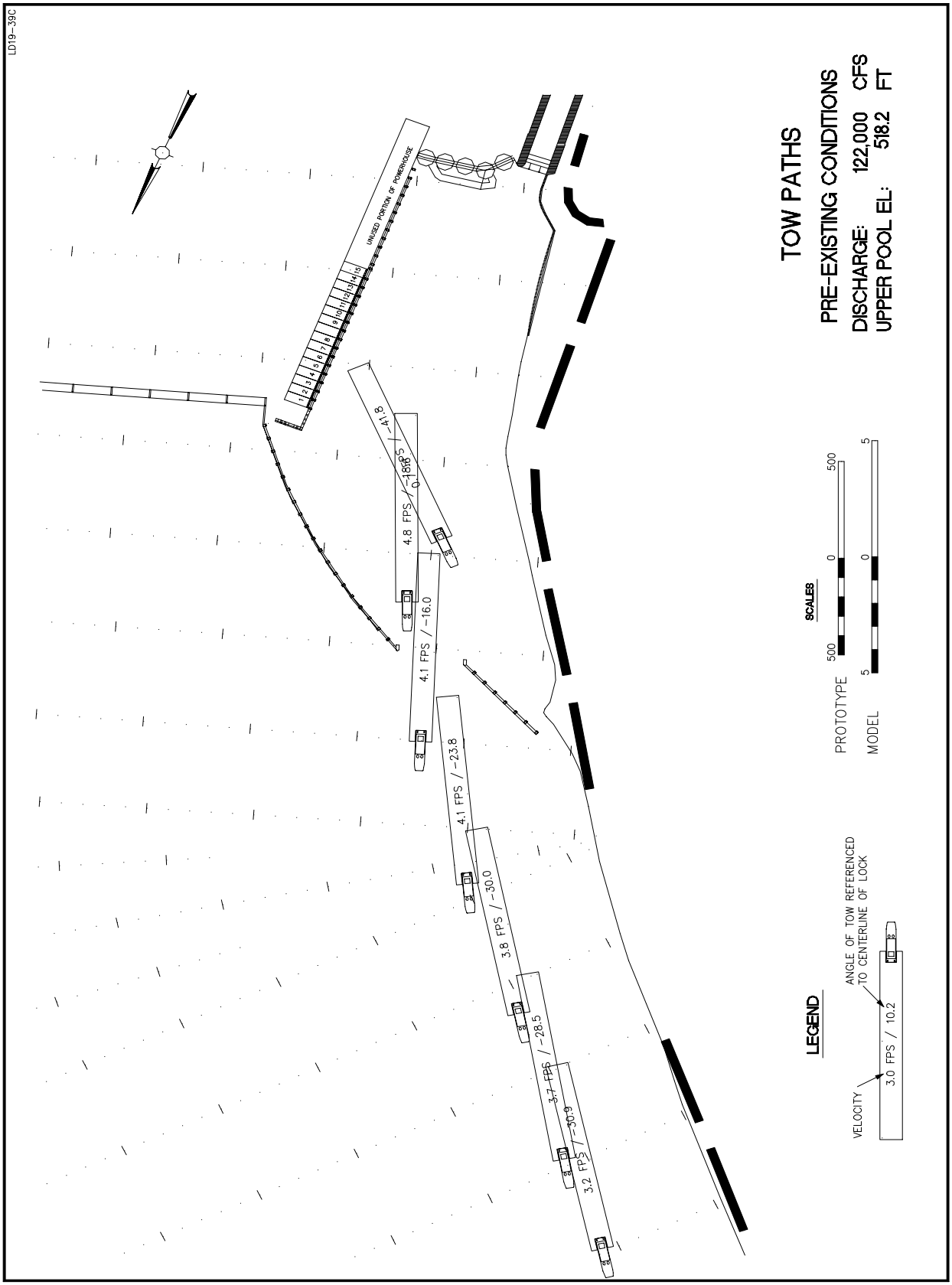
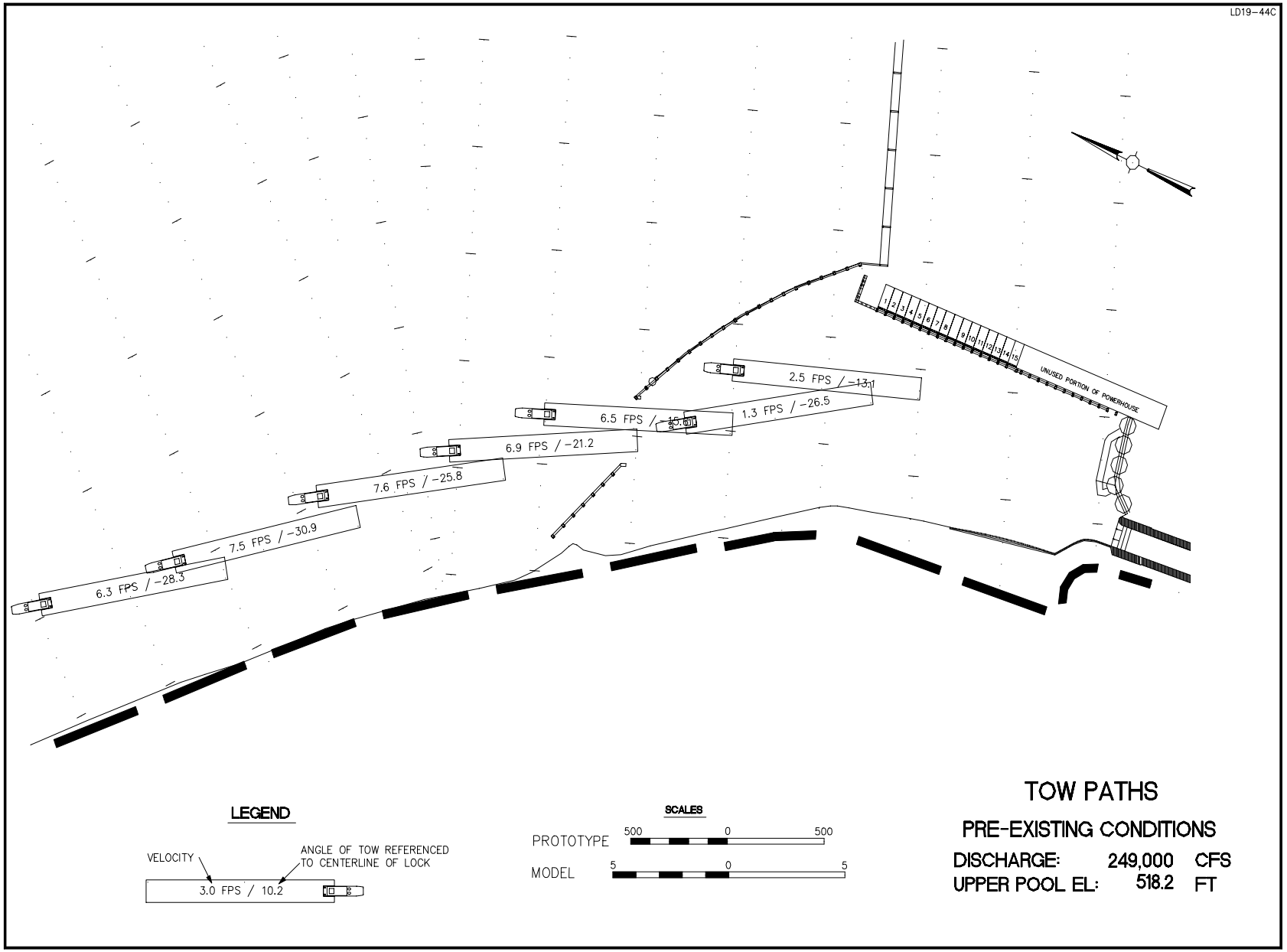

LD19-39C
TOW PATHS
PRE-EXISTING CONDITIONS
DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
4.8 FPS / -41.8
0.1 CFS / -180.5
4.1 FPS / -16.0
4.1 FPS / -23.8
3.8 FPS / -30.0
3.7 FPS / -28.5
3.2 FPS / -30.9
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
3.0 FPS / 10.2

Plate 22


LD19-44C
2.5 FPS / -13.1
1.3 FPS / -26.5
6.5 FPS / -15.0
6.9 FPS / -21.2
7.6 FPS / -25.8
7.5 FPS / -30.9
6.3 FPS / -28.3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
UNUSED PORTION OF POWERHOUSE
LEGEND
VELOCITY
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
3.0 FPS / 10.2
SCALES
PROTOTYPE
500 0 500
MODEL
5 0 5
TOW PATHS
PRE-EXISTING CONDITIONS
DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

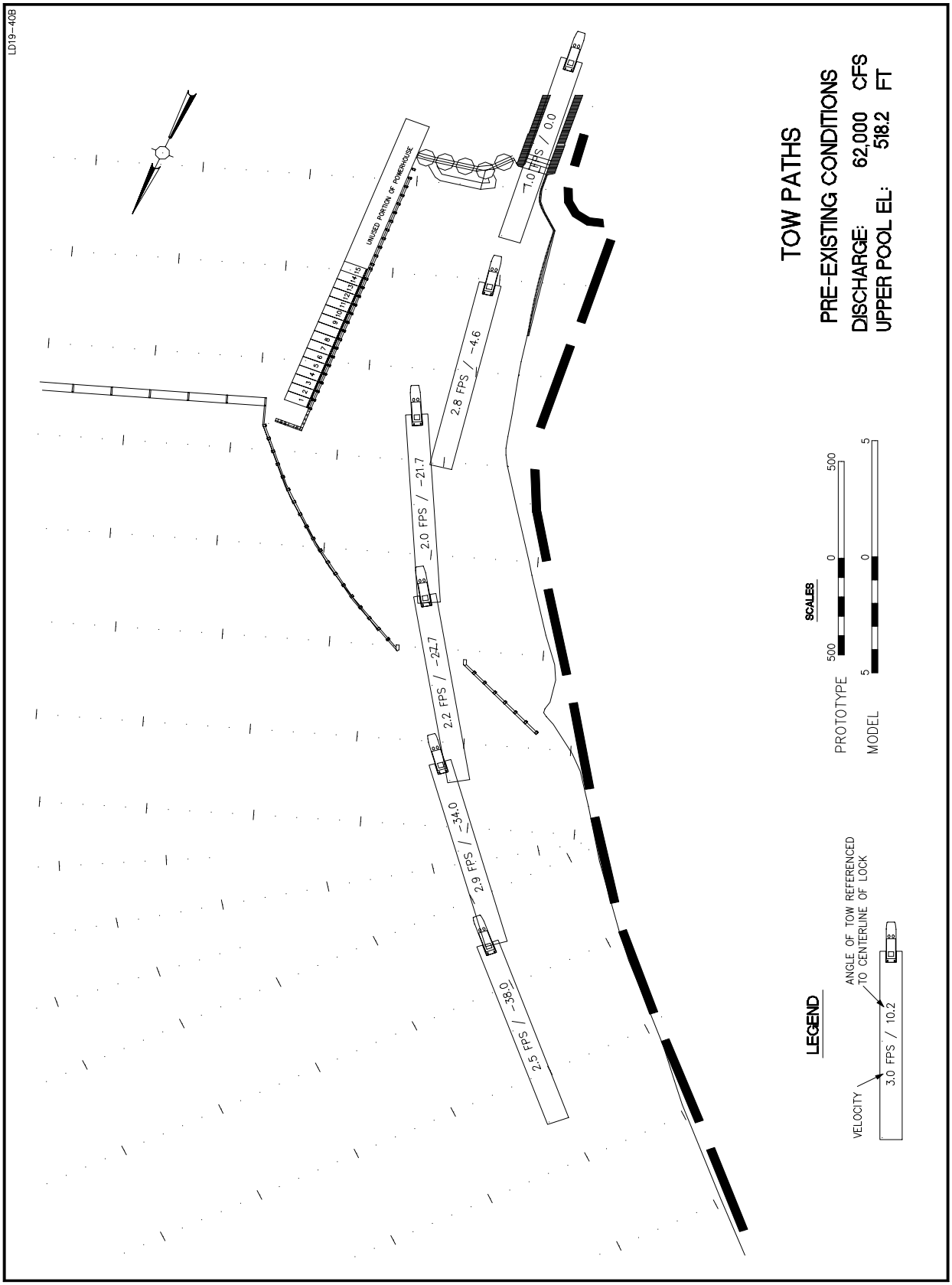
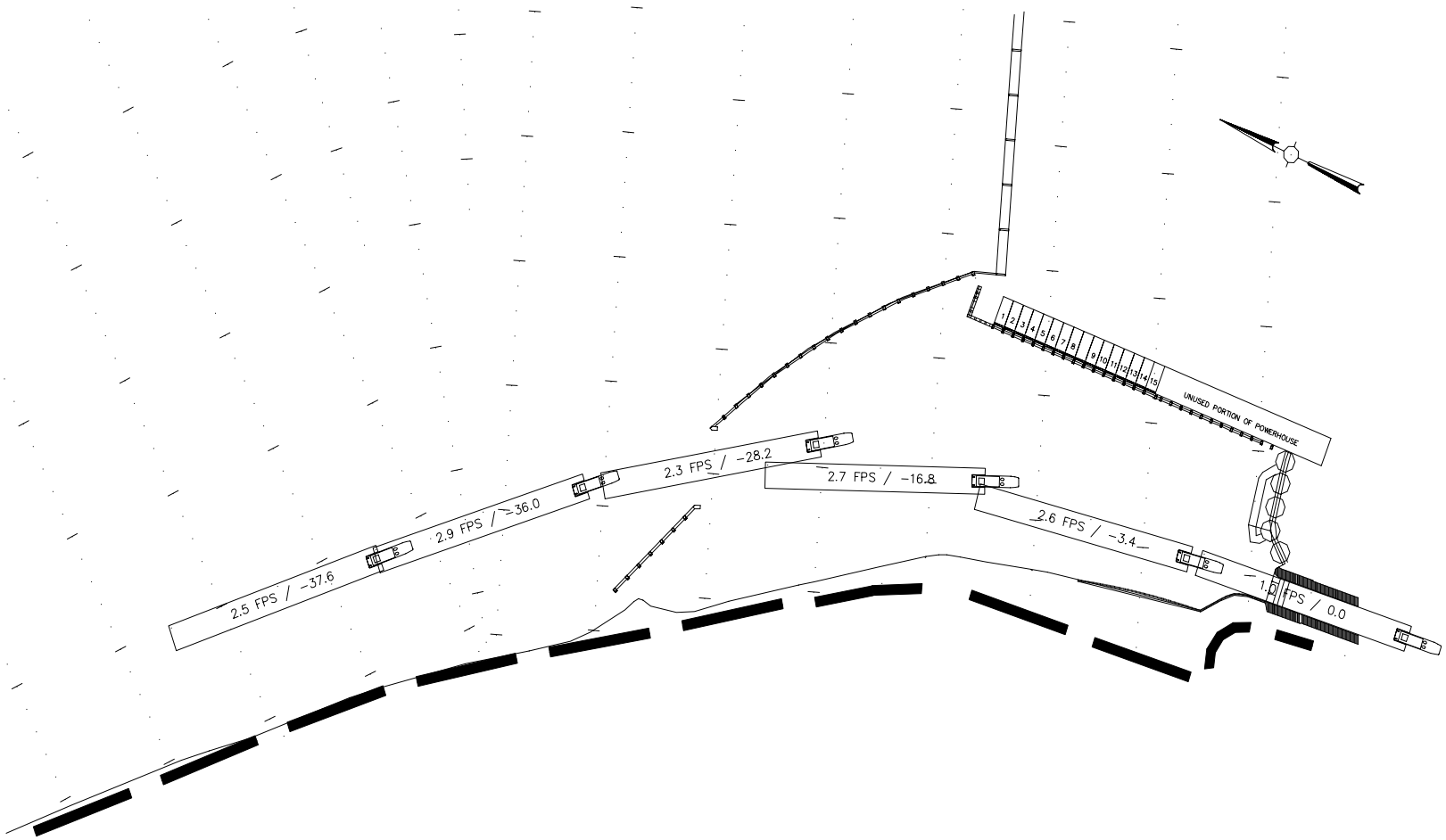
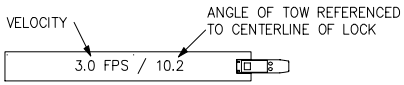

LD19-40B
TOW PATHS
PRE-EXISTING CONDITIONS
DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
7.0 FPS / 0.0
2.8 FPS / -4.6
2.0 FPS / -21.7
2.2 FPS / -27.7
2.9 FPS / -34.0
2.5 FPS / -38.0
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
3.0 FPS / 10.2

Plate 24



LEGEND



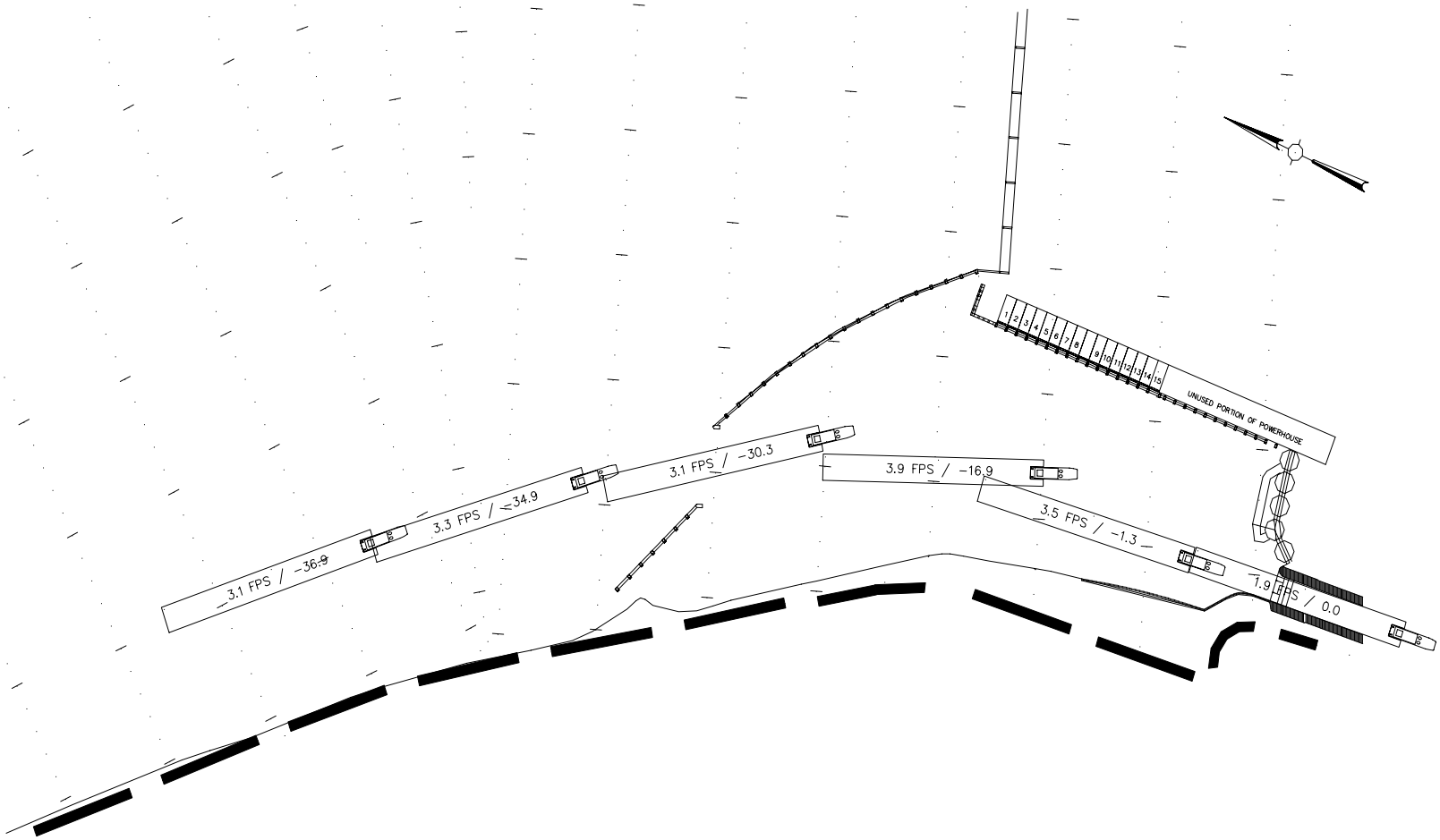
SCALES

TOW PATHS

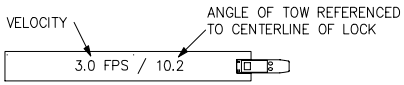
PRE-EXISTING CONDITIONS

DISCHARGE: 62,000 CFS
TAILWATER EL: 482.4 FT

LD19-38A



LEGEND

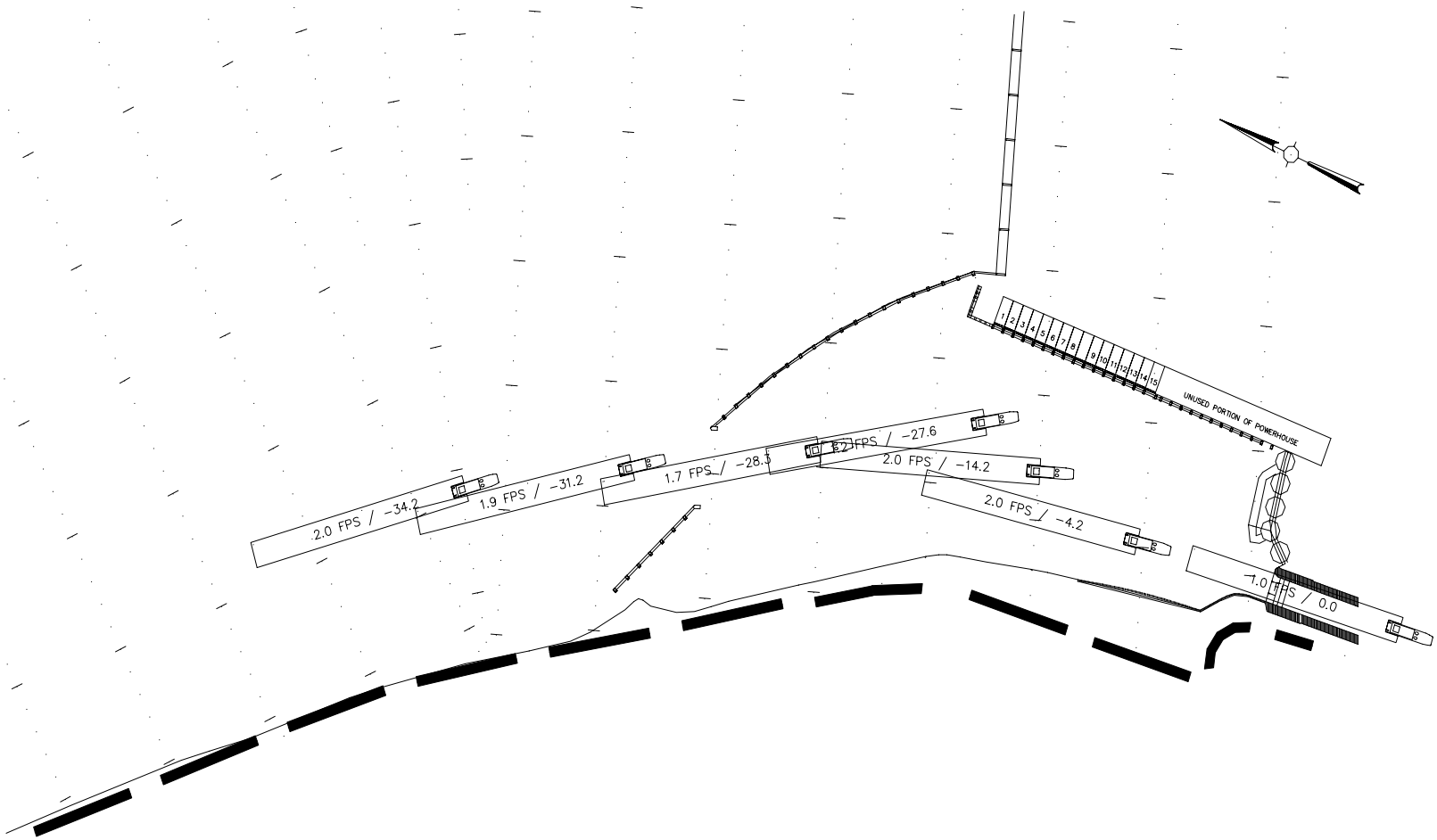


SCALES

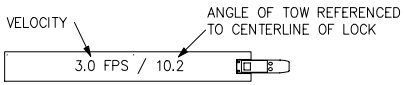
TOW PATHS

PRE-EXISTING CONDITIONS

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND



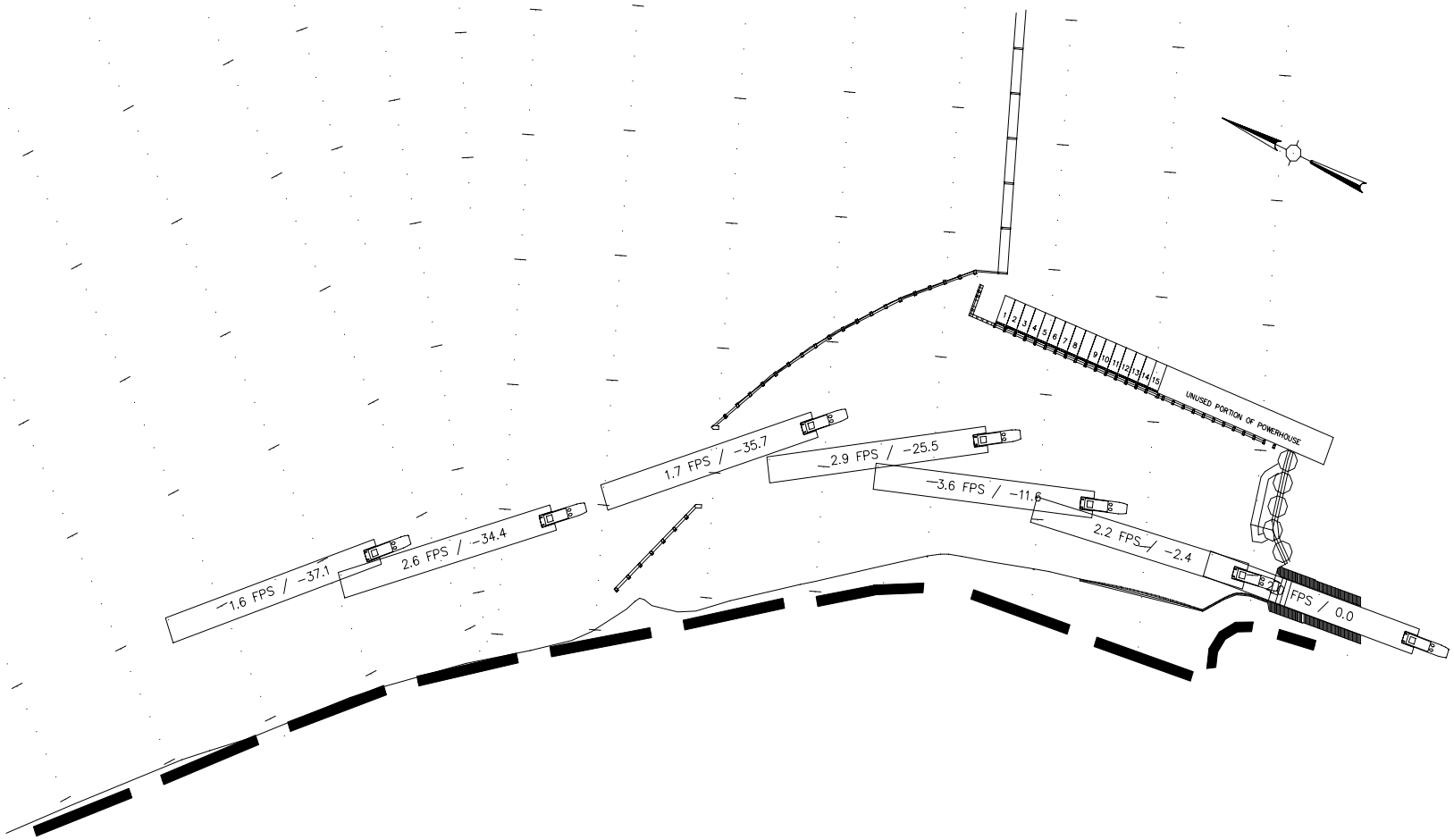
SCALES

TOW PATHS

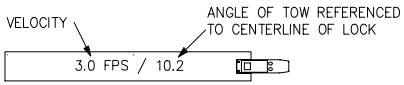
PRE-EXISTING CONDITIONS

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

LD19-43E



LEGEND

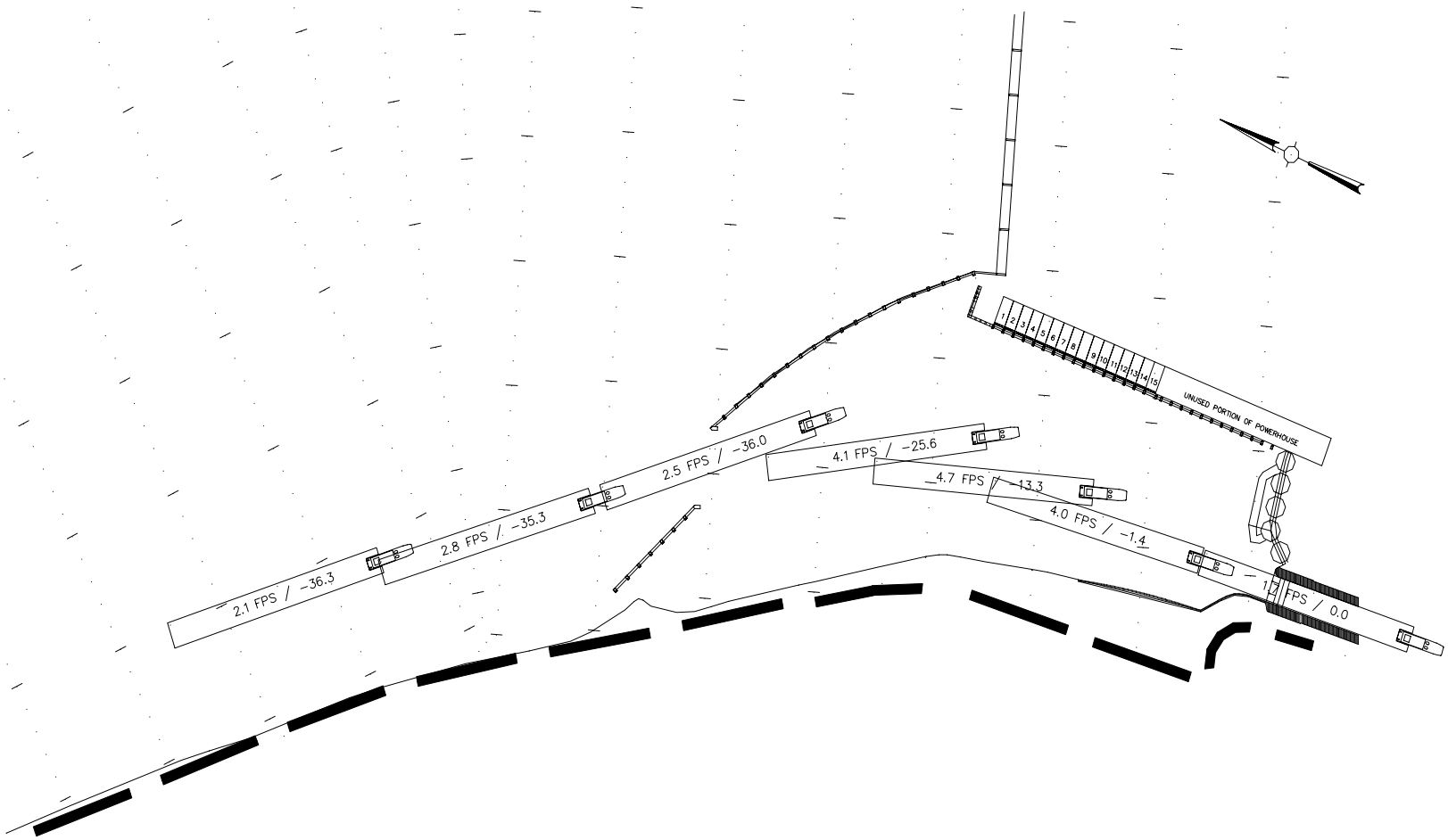


SCALES

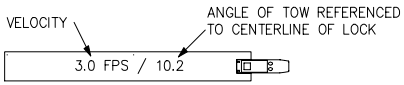
TOW PATHS

PRE-EXISTING CONDITIONS

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND



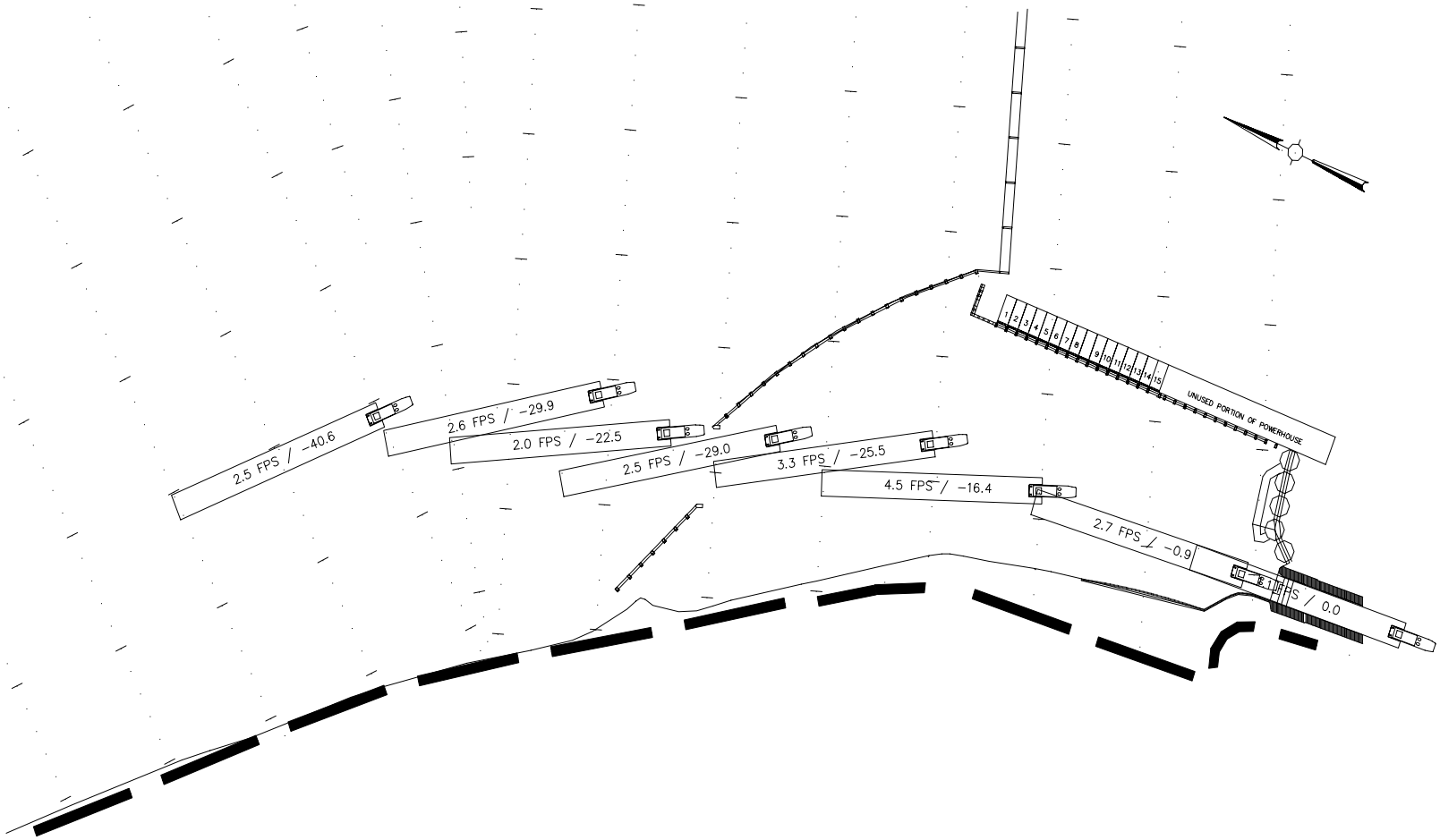
SCALES

TOW PATHS

PRE-EXISTING CONDITIONS

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

LD19-43A



LEGEND

VELOCITY

ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK

3.0 FPS / 10.2

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

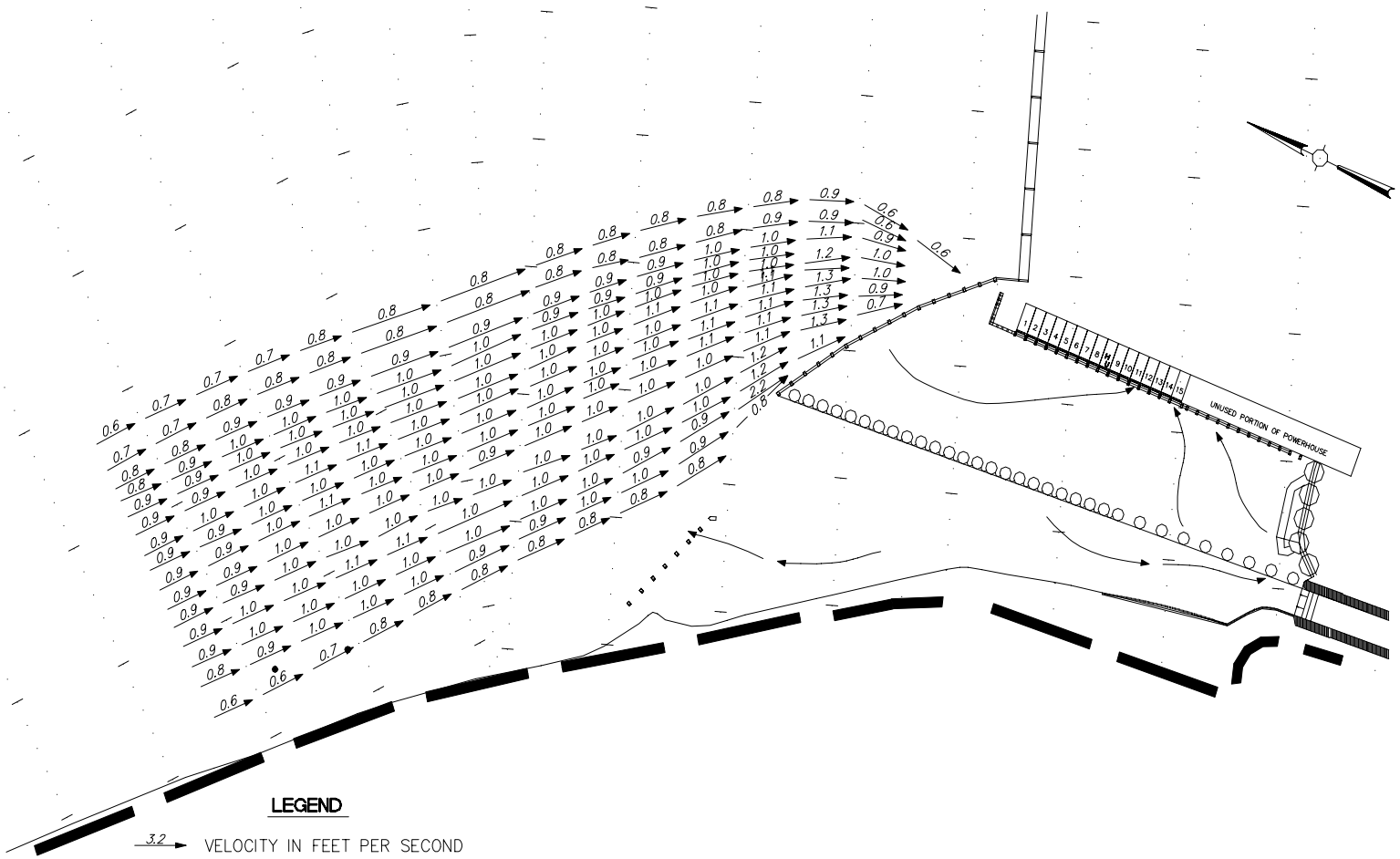
TOW PATHS

PRE-EXISTING CONDITIONS

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19-059



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

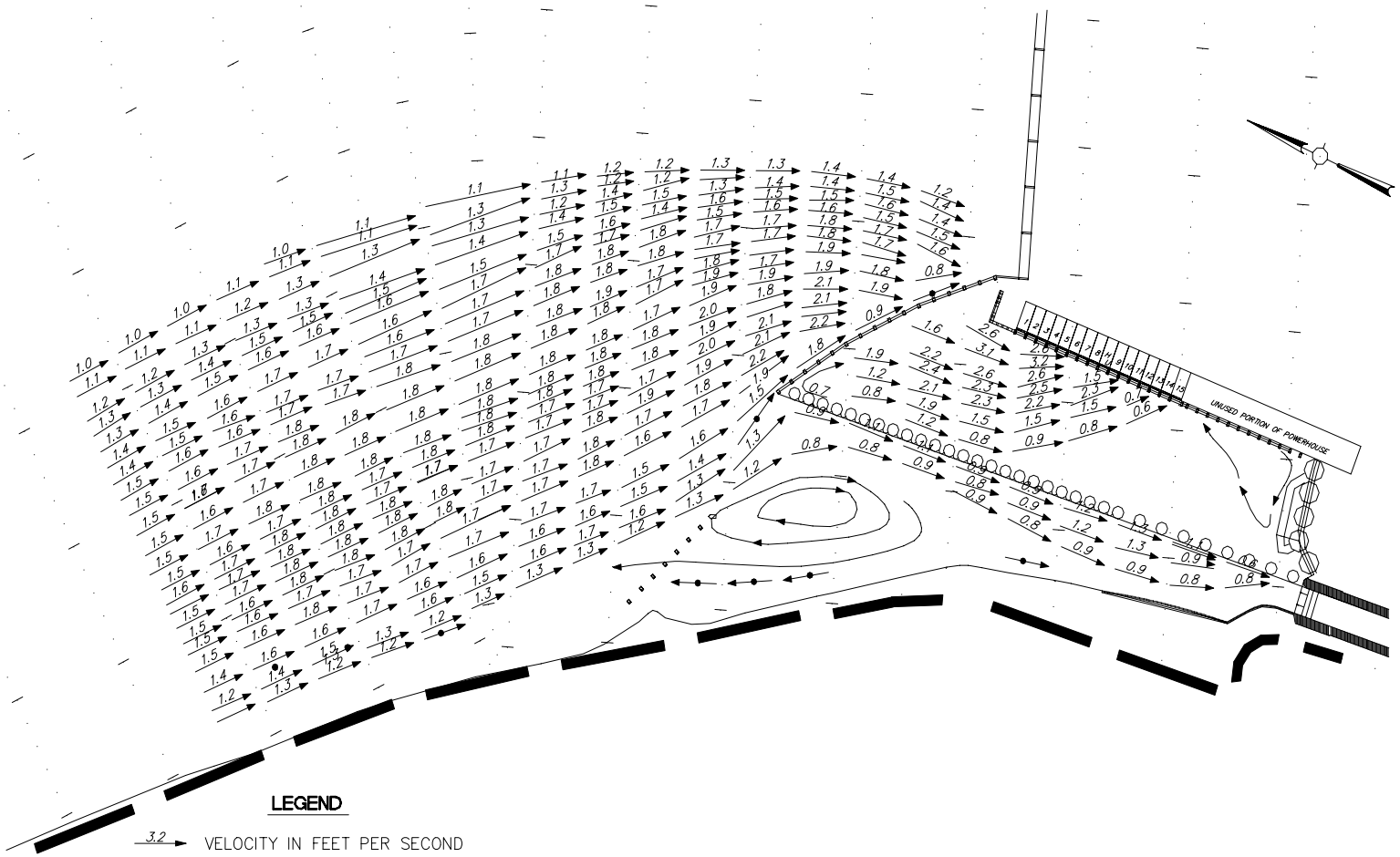
VELOCITIES AND CURRENT DIRECTIONS

PLAN A

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-058



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PLAN A

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19-048

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PLAN A

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-047

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

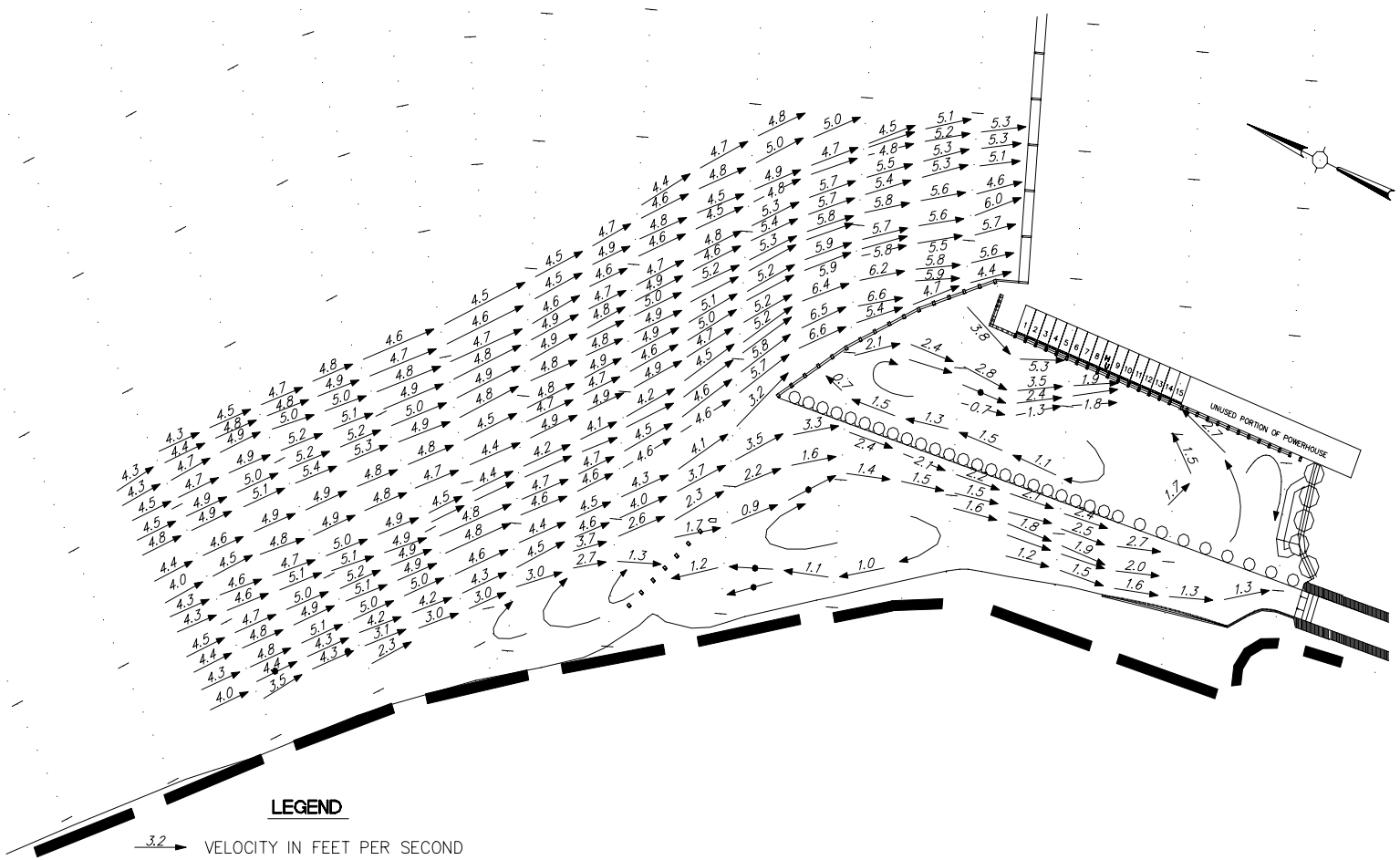
VELOCITIES AND CURRENT DIRECTIONS

PLAN A

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

LD19-046



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

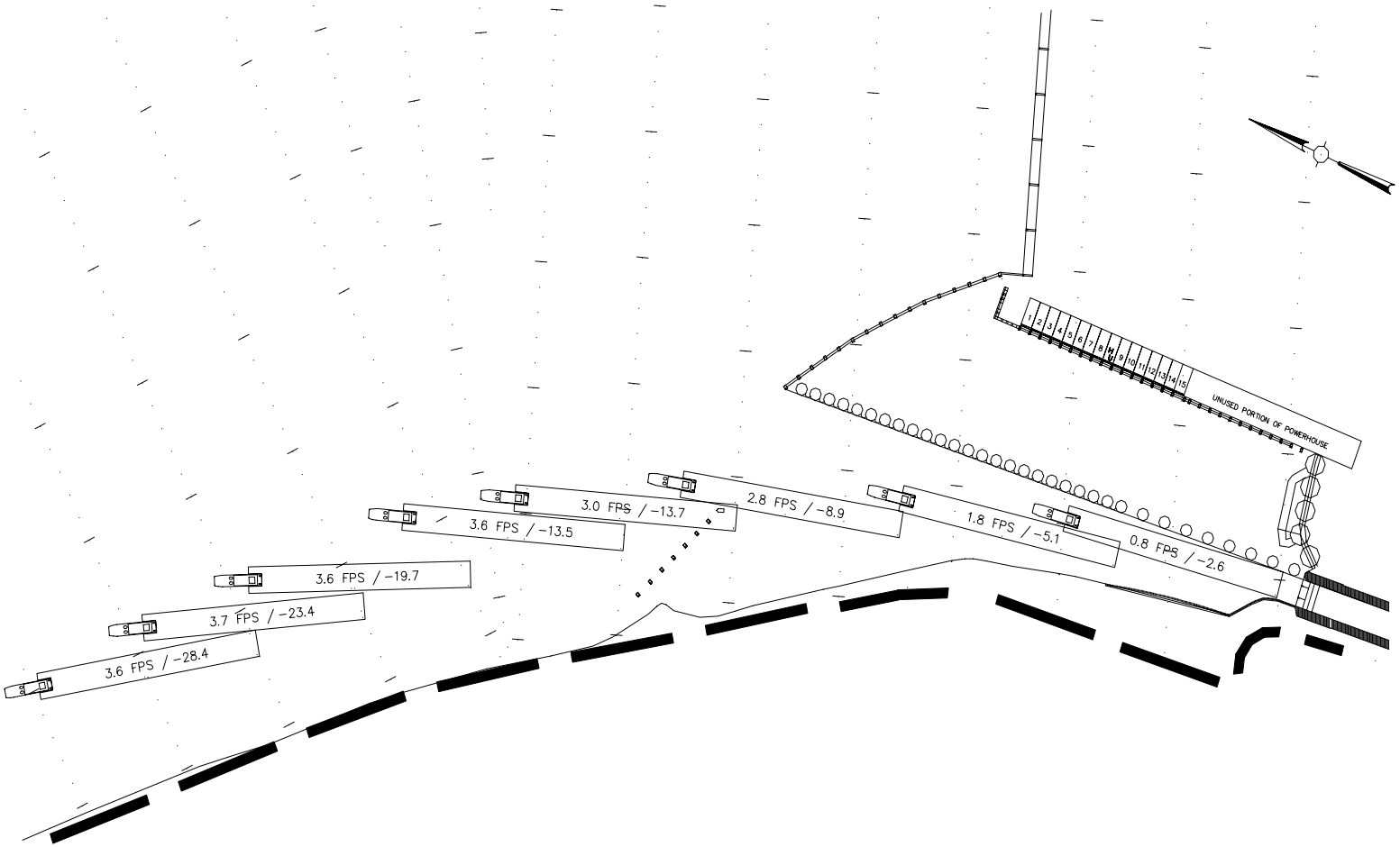
VELOCITIES AND CURRENT DIRECTIONS

PLAN A

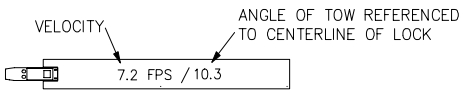
DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19051A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

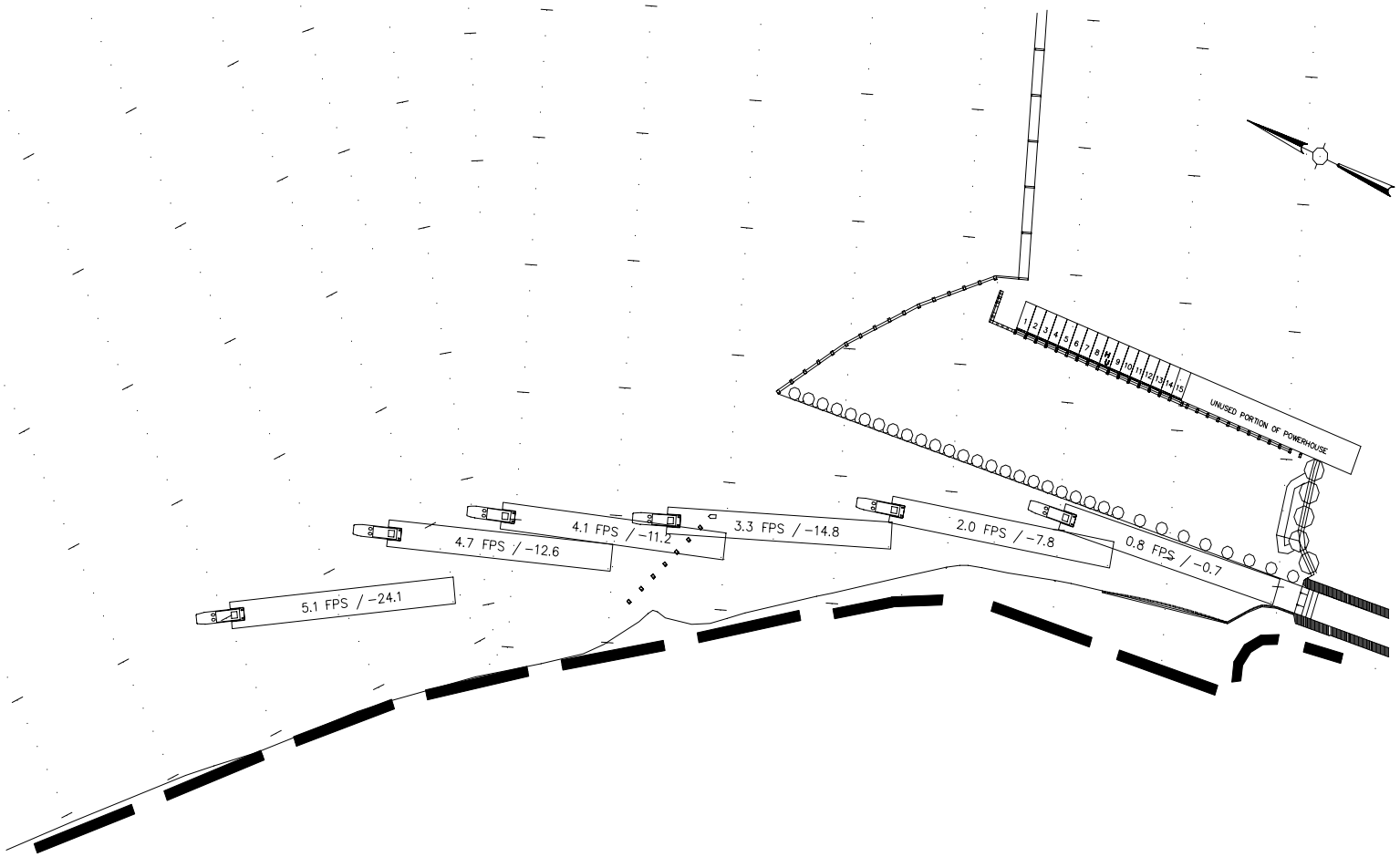
TOW PATHS

PLAN A

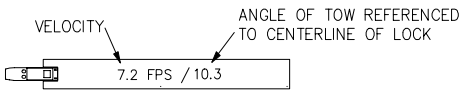
DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19052A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

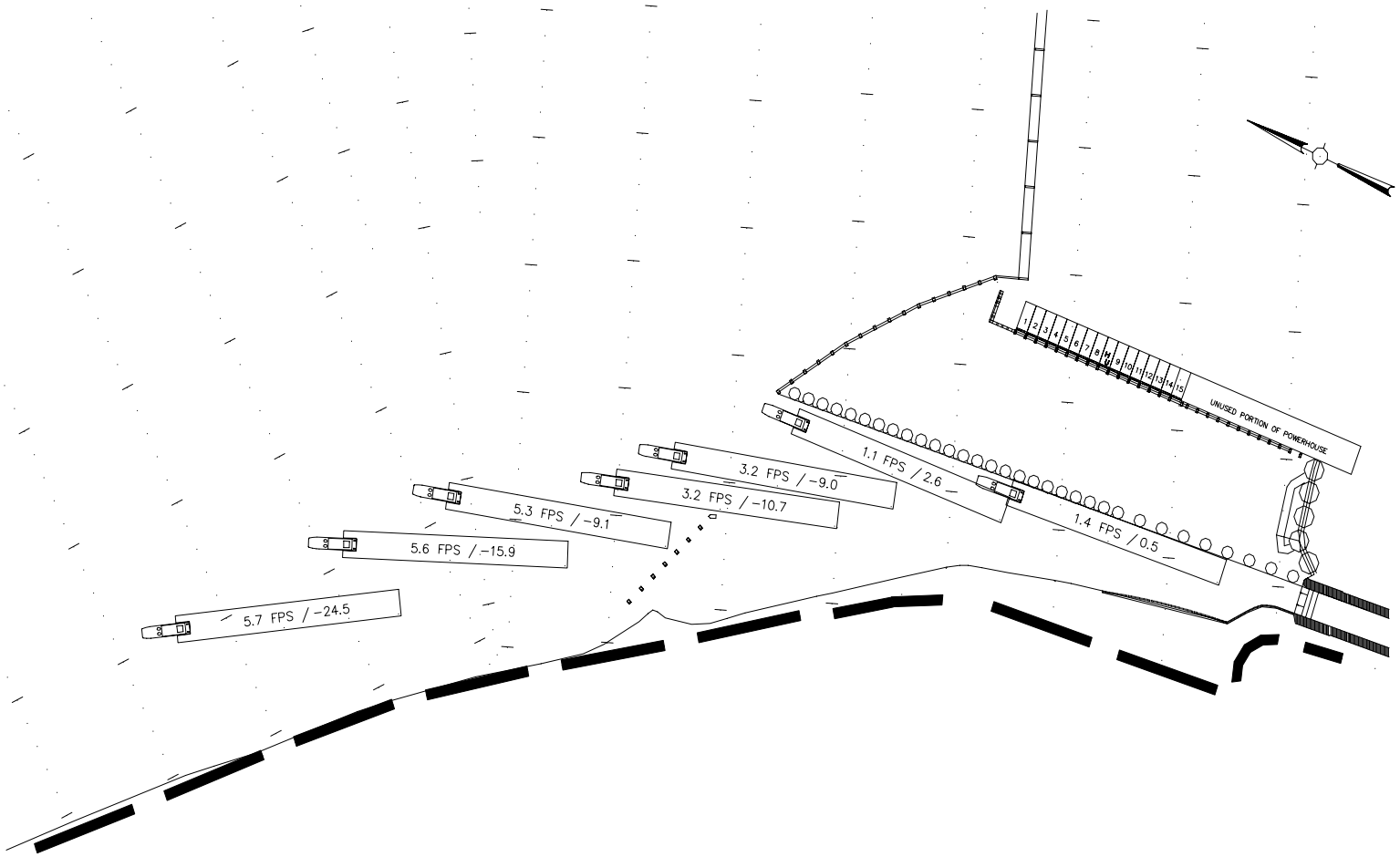
TOW PATHS

PLAN A

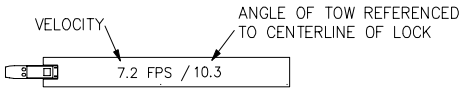
DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-55A



LEGEND

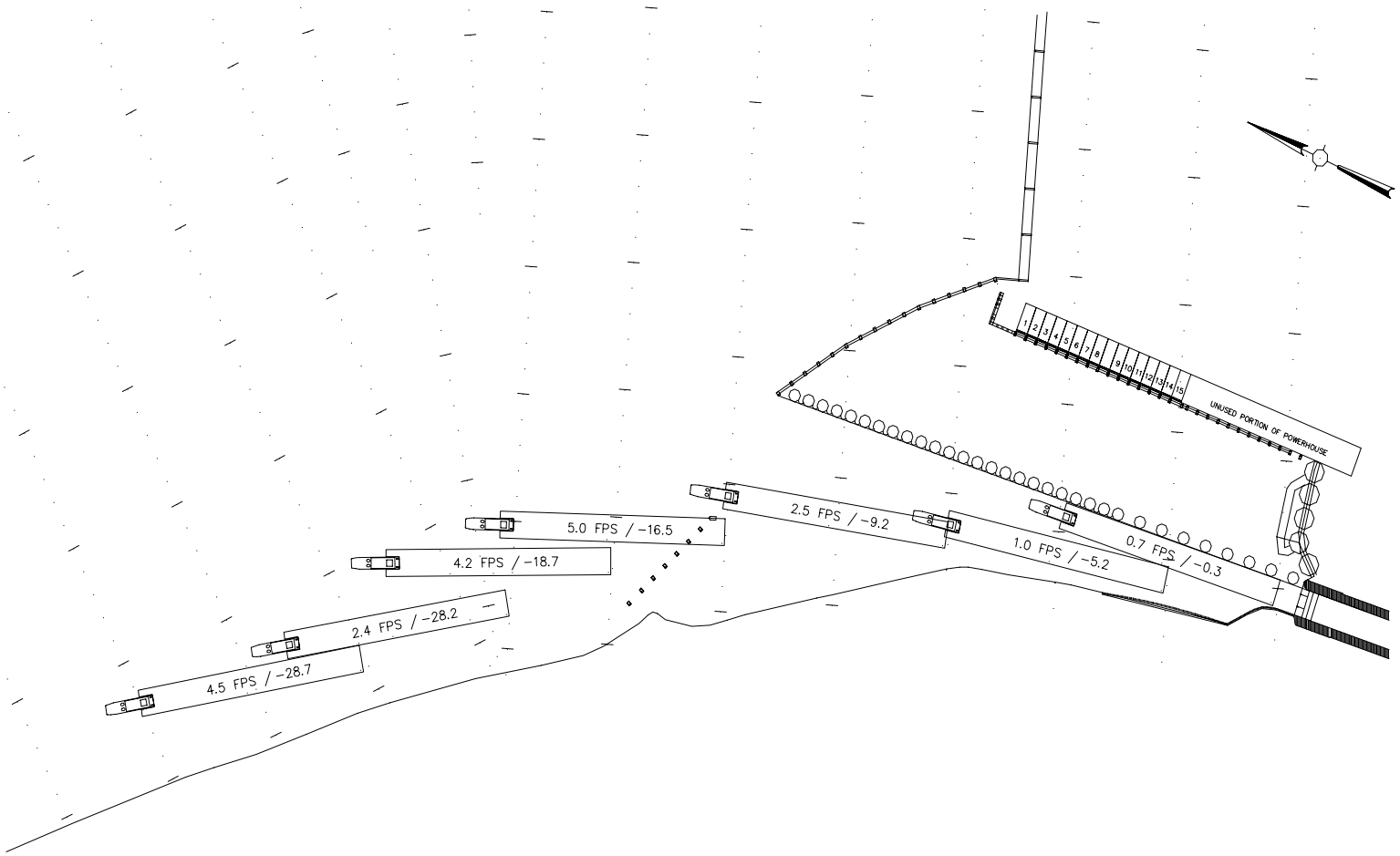


SCALES

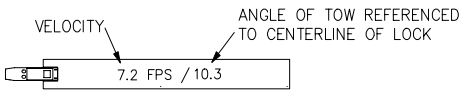
TOW PATHS

PLAN A

DISCHARGE: 177,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND



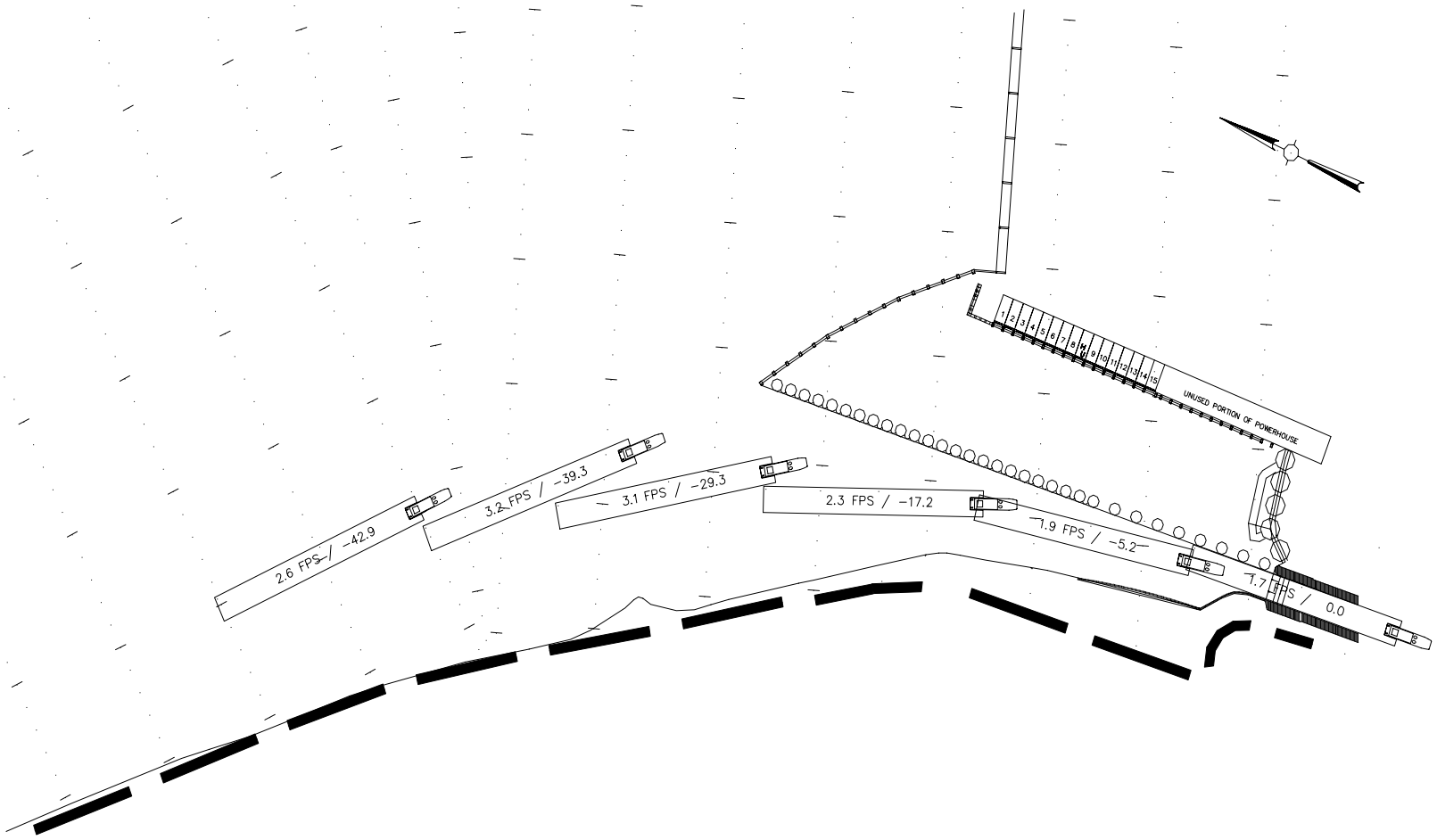
SCALES

TOW PATHS

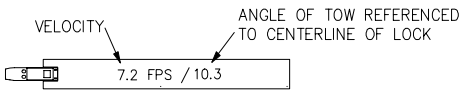
PLAN A

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

LD19049A



LEGEND

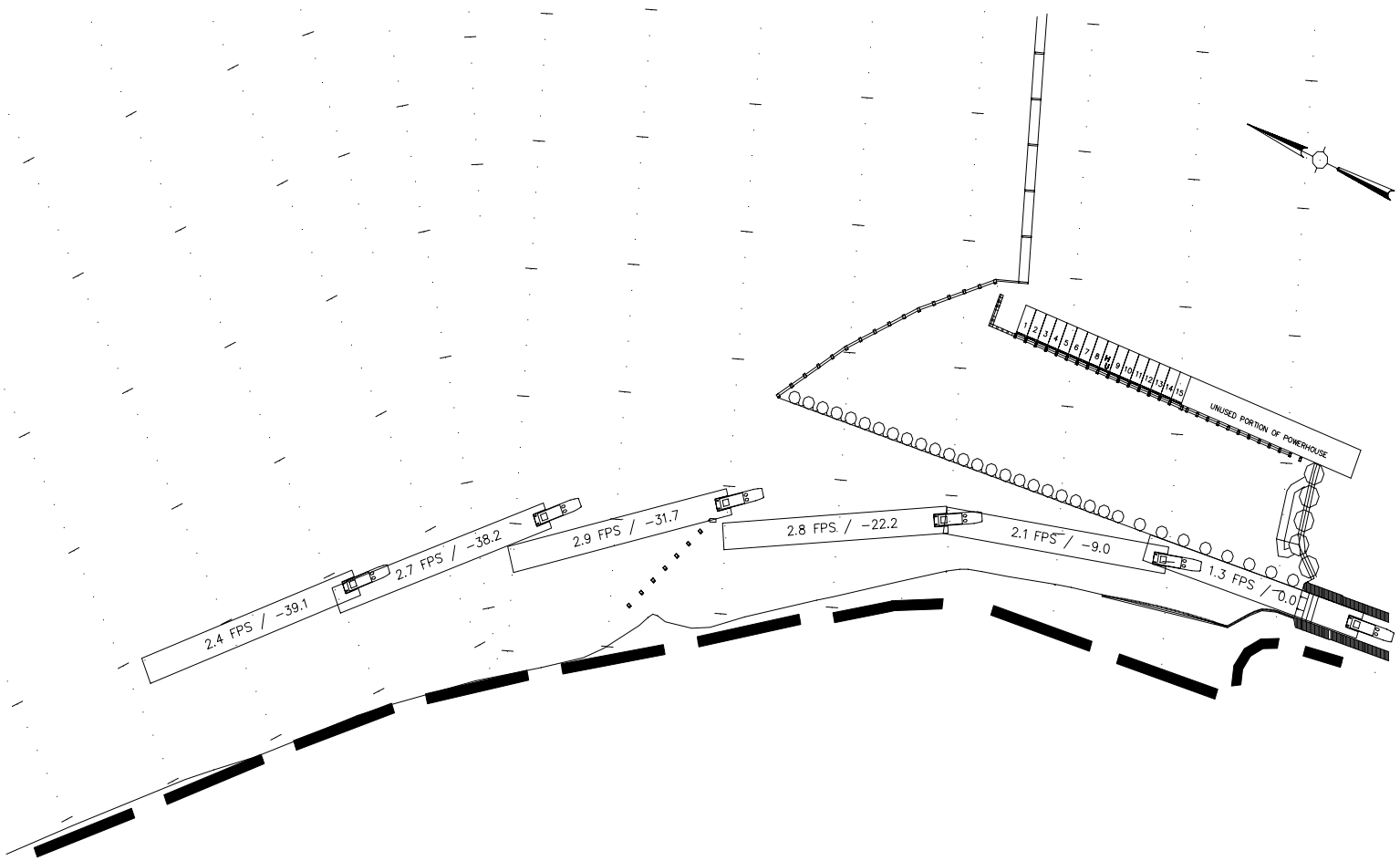


SCALES

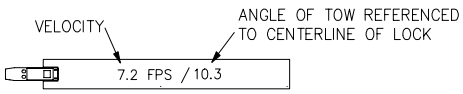
TOW PATHS

PLAN A

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND



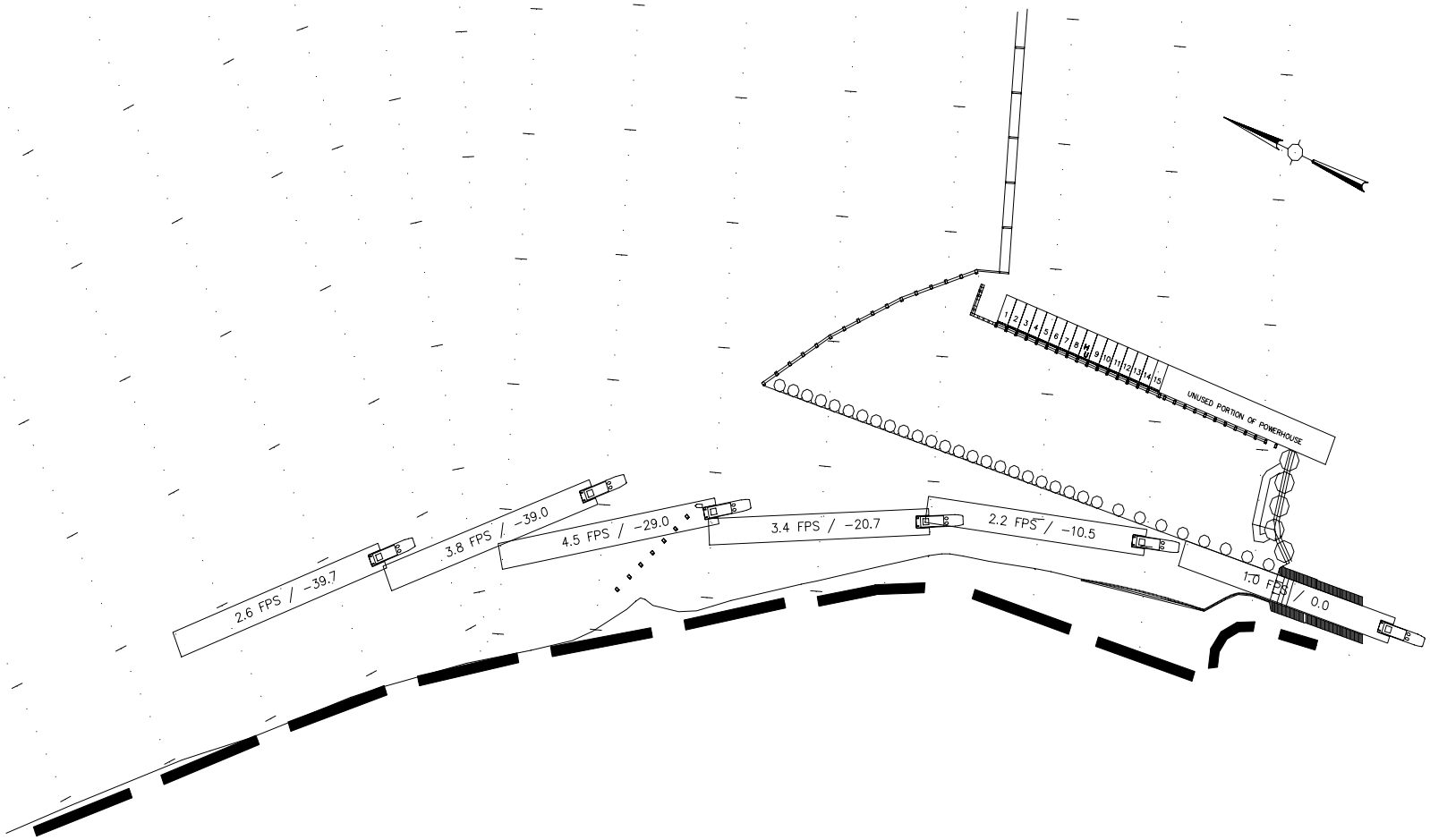
SCALES

TOW PATHS

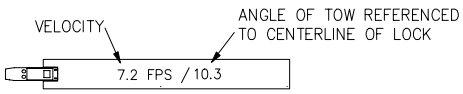
PLAN A

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

LD19-54A



LEGEND



SCALES

PROTOTYPE 500 0 500

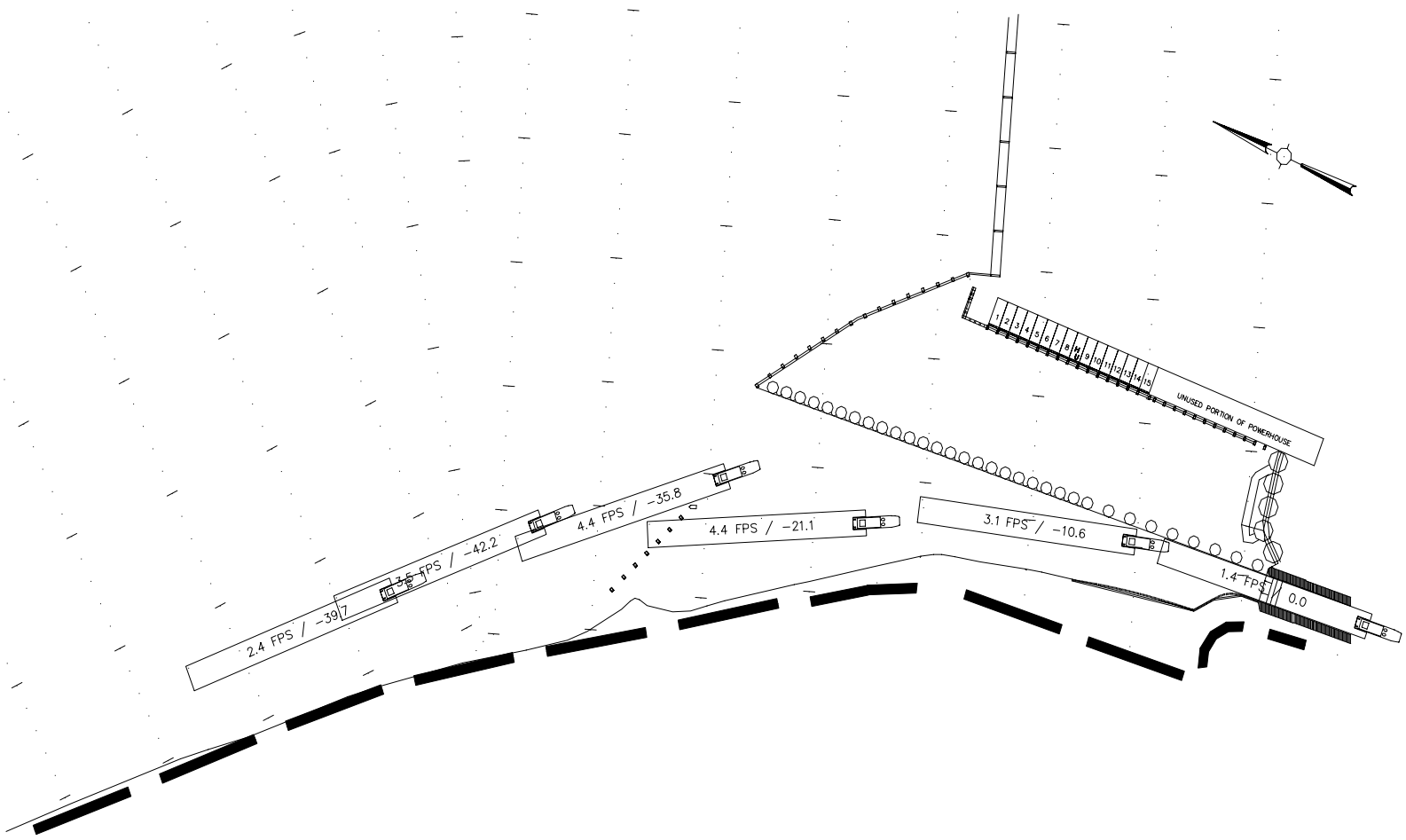
MODEL 5 0 5

TOW PATHS

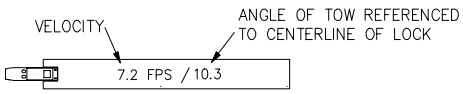
PLAN A

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND



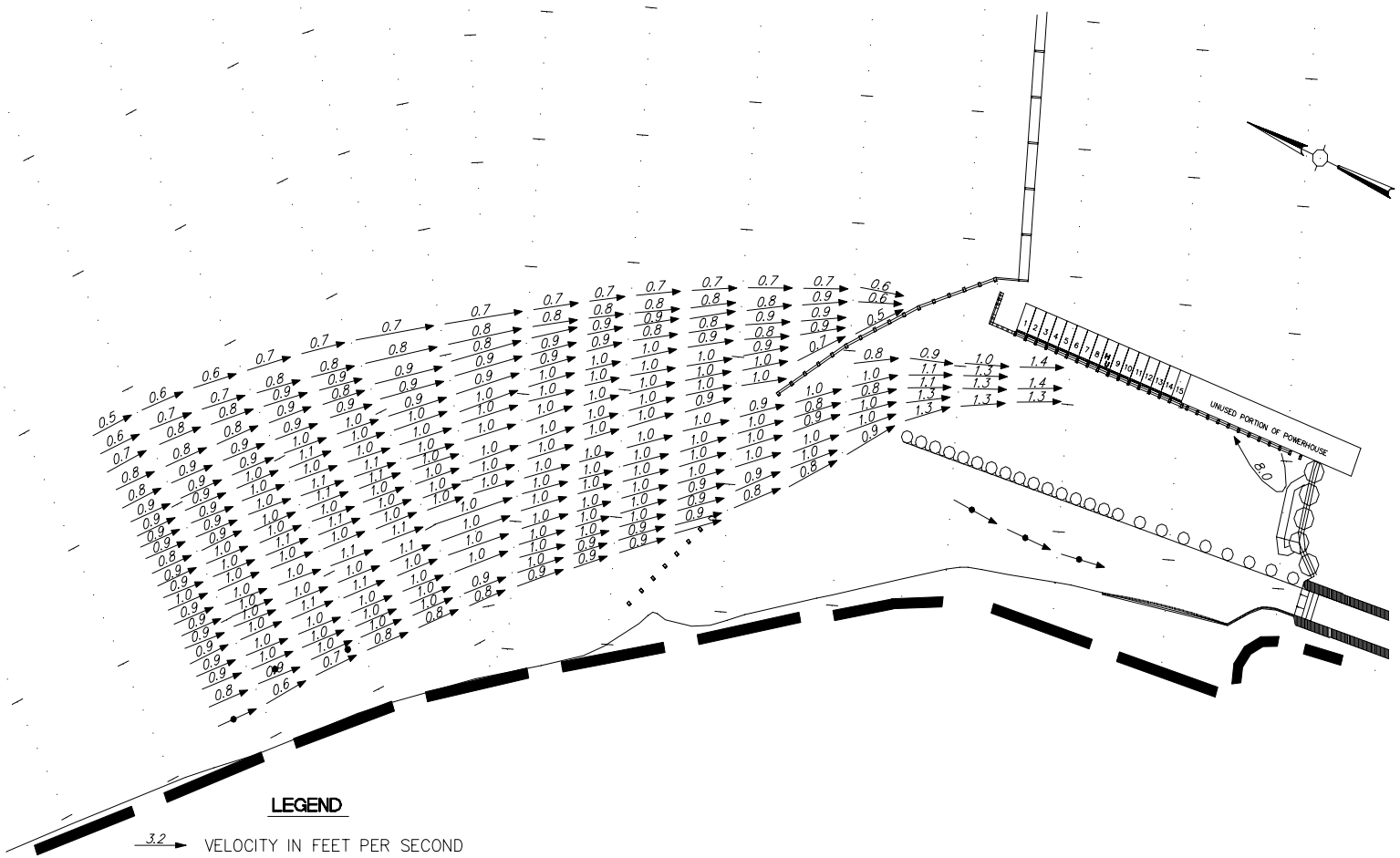
SCALES

TOW PATHS

PLAN A

DISCHARGE: 249,000 CFS
TAILWATER EL: 518.2 FT

LD19-070



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

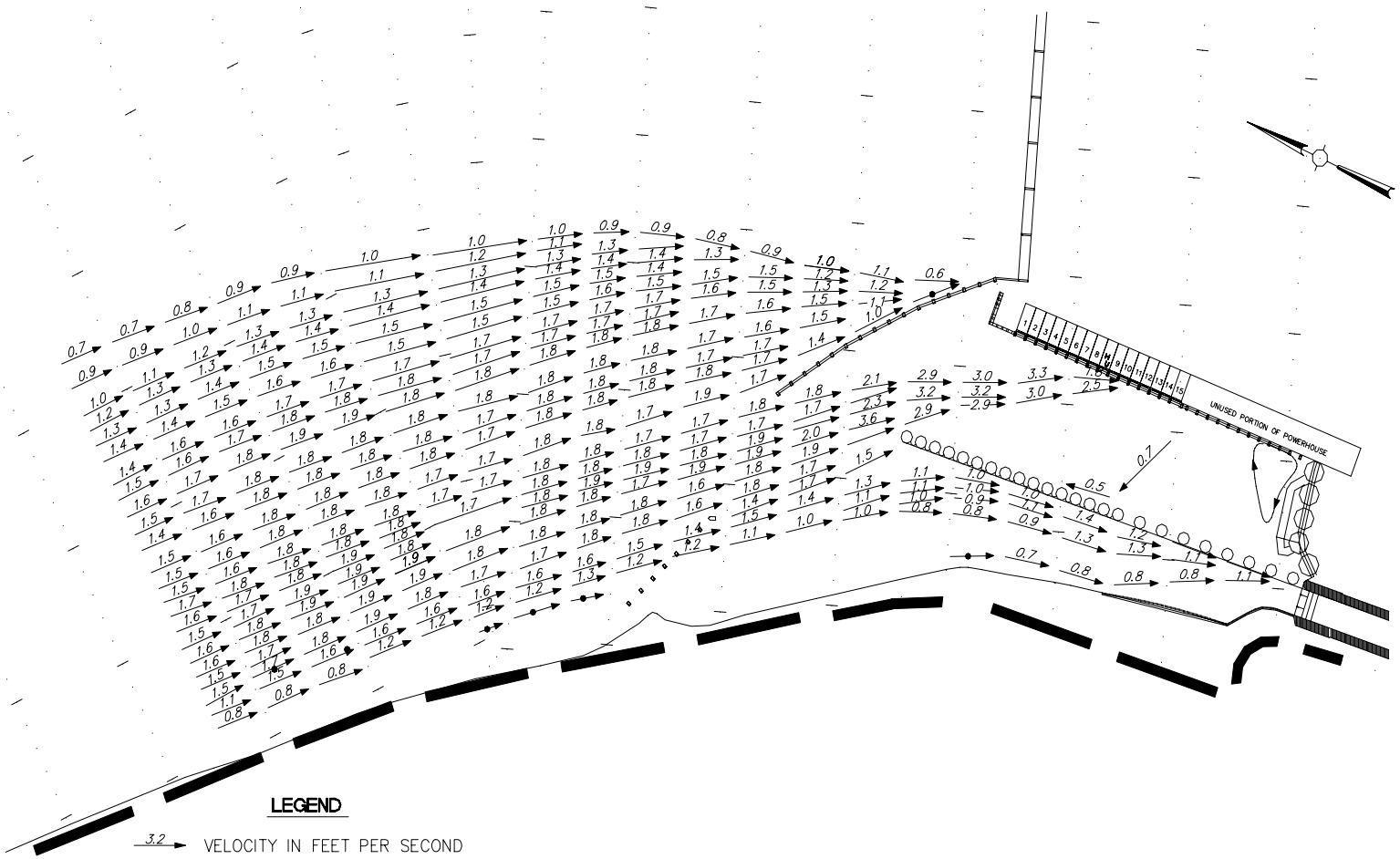
VELOCITIES AND CURRENT DIRECTIONS

PLAN A-MODIFIED

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-066



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

→● VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

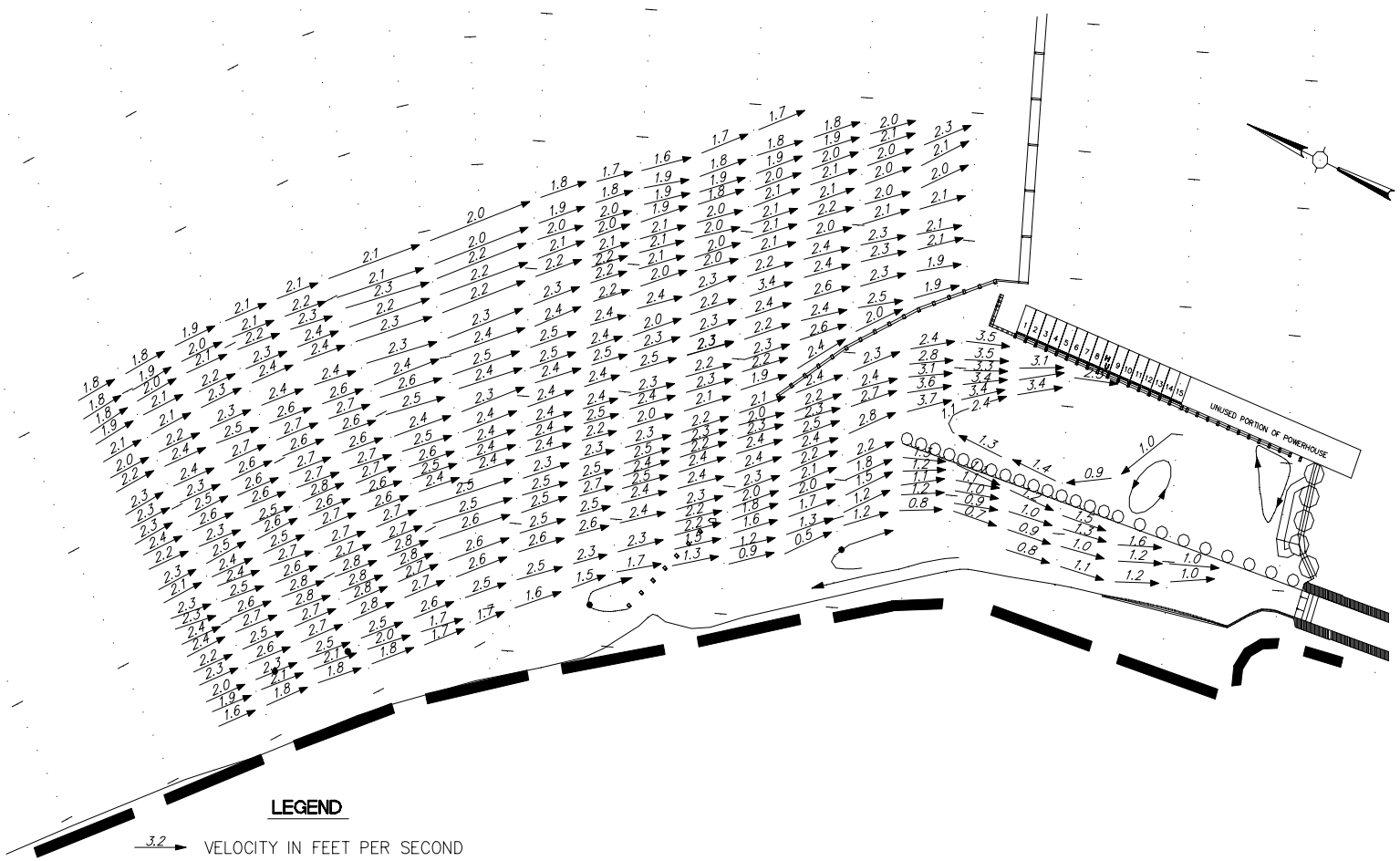
VELOCITIES AND CURRENT DIRECTIONS

PLAN A-MODIFIED

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19-067



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PLAN A-MODIFIED

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-068

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

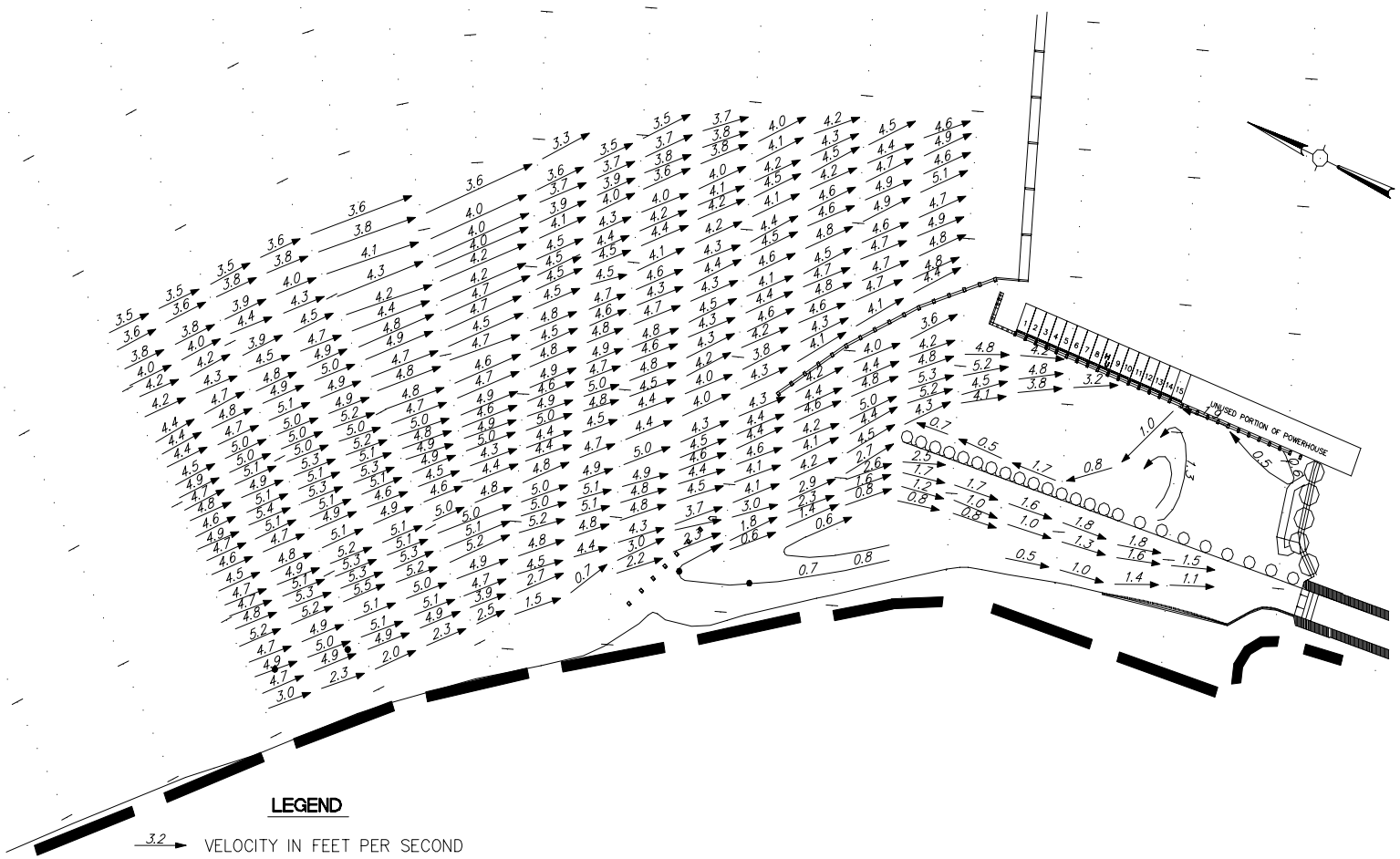
VELOCITIES AND CURRENT DIRECTIONS

PLAN A-MODIFIED

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

LD19-069



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

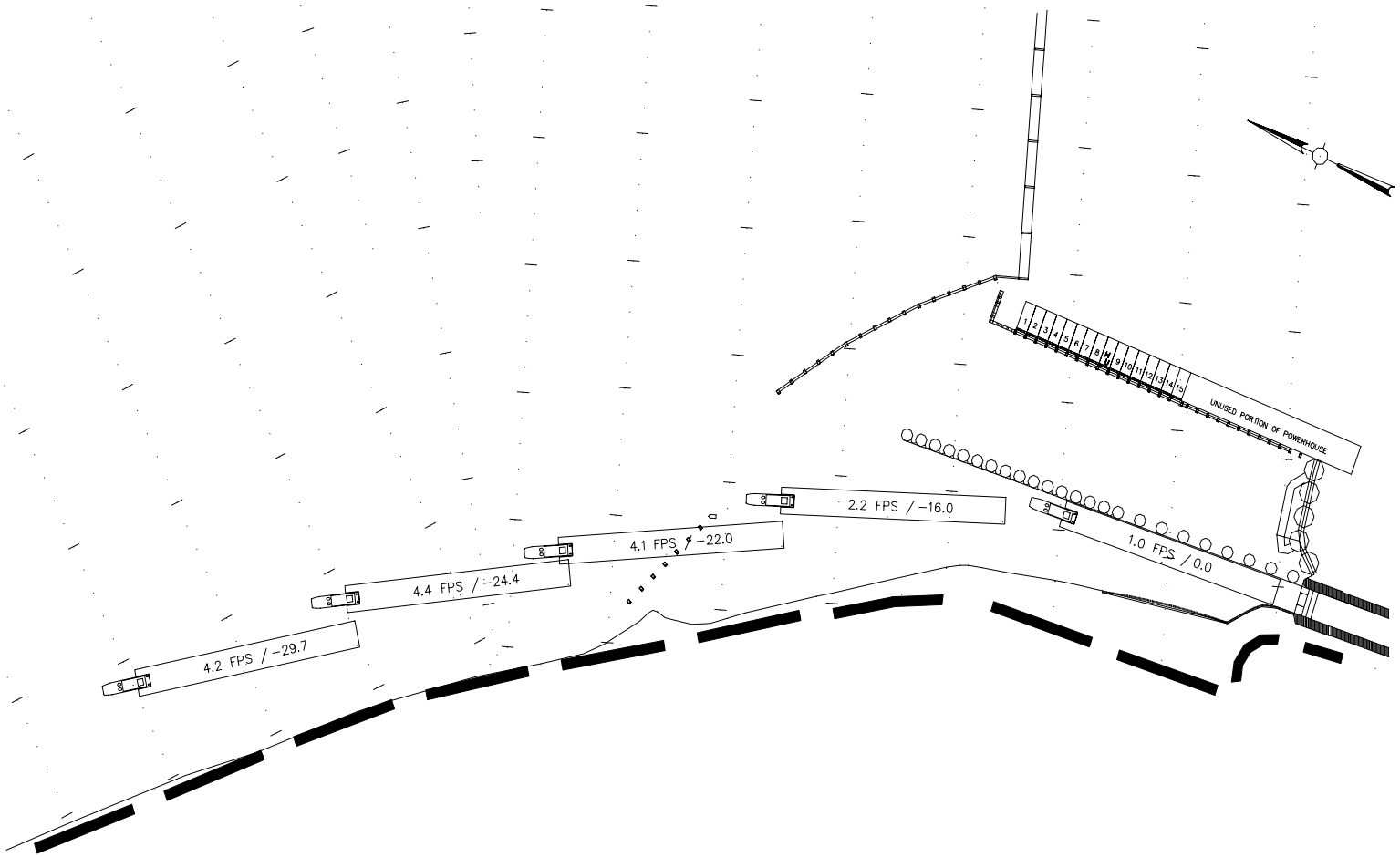
VELOCITIES AND CURRENT DIRECTIONS

PLAN A-MODIFIED

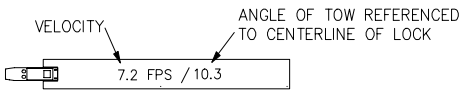
DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19072A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

TOW PATHS

PLAN A-MODIFIED

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

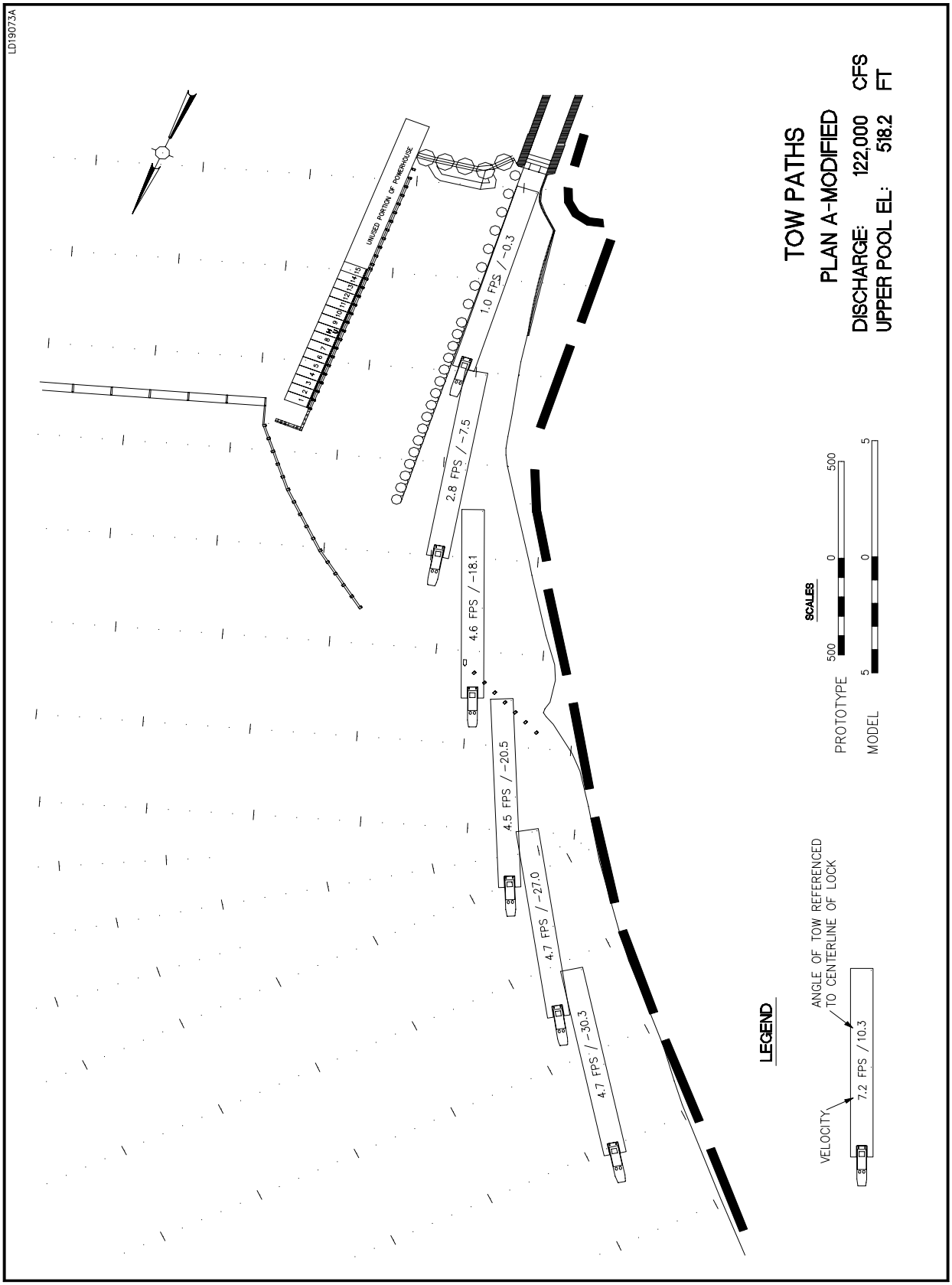
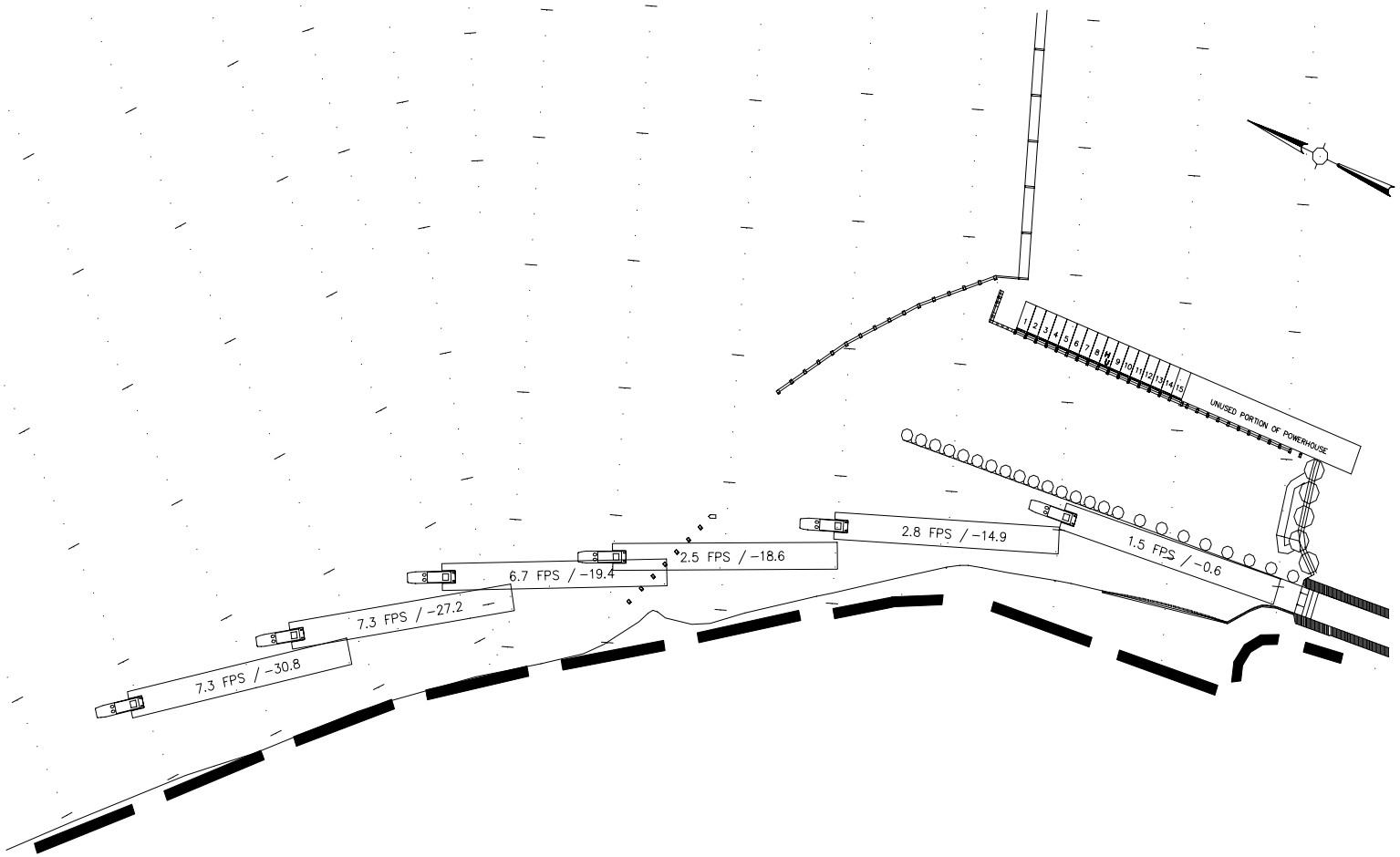
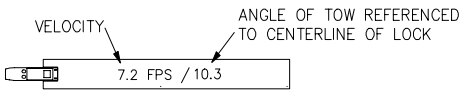

LD19073A
TOW PATHS
PLAN A-MODIFIED
DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1.0 FPS / -0.3
2.8 FPS / -7.5
4.6 FPS / -18.1
4.5 FPS / -20.5
4.7 FPS / -27.0
4.7 FPS / -30.3
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
7.2 FPS / 10.3

Plate 50

LD19074A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

TOW PATHS

PLAN A-MODIFIED

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

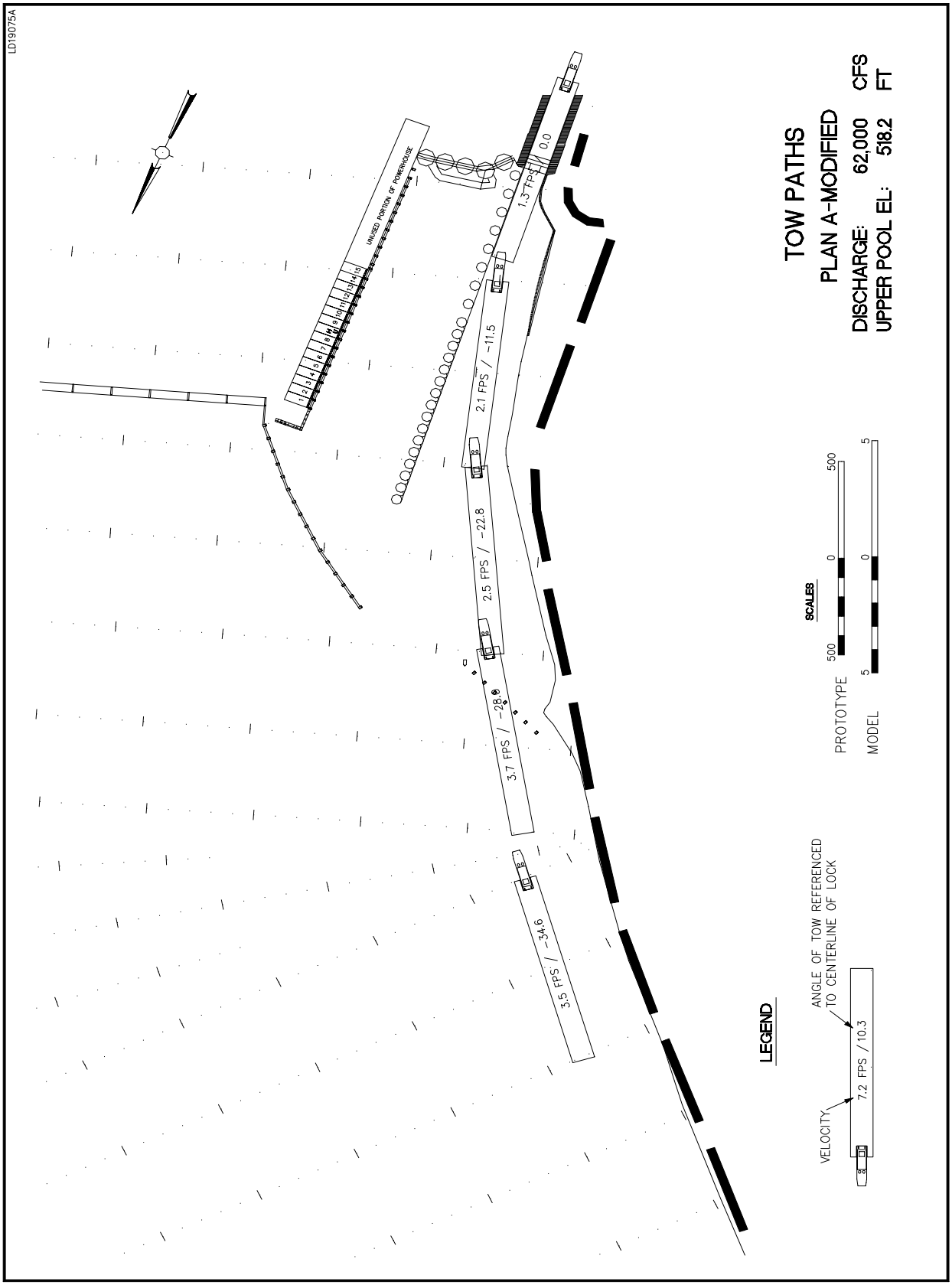
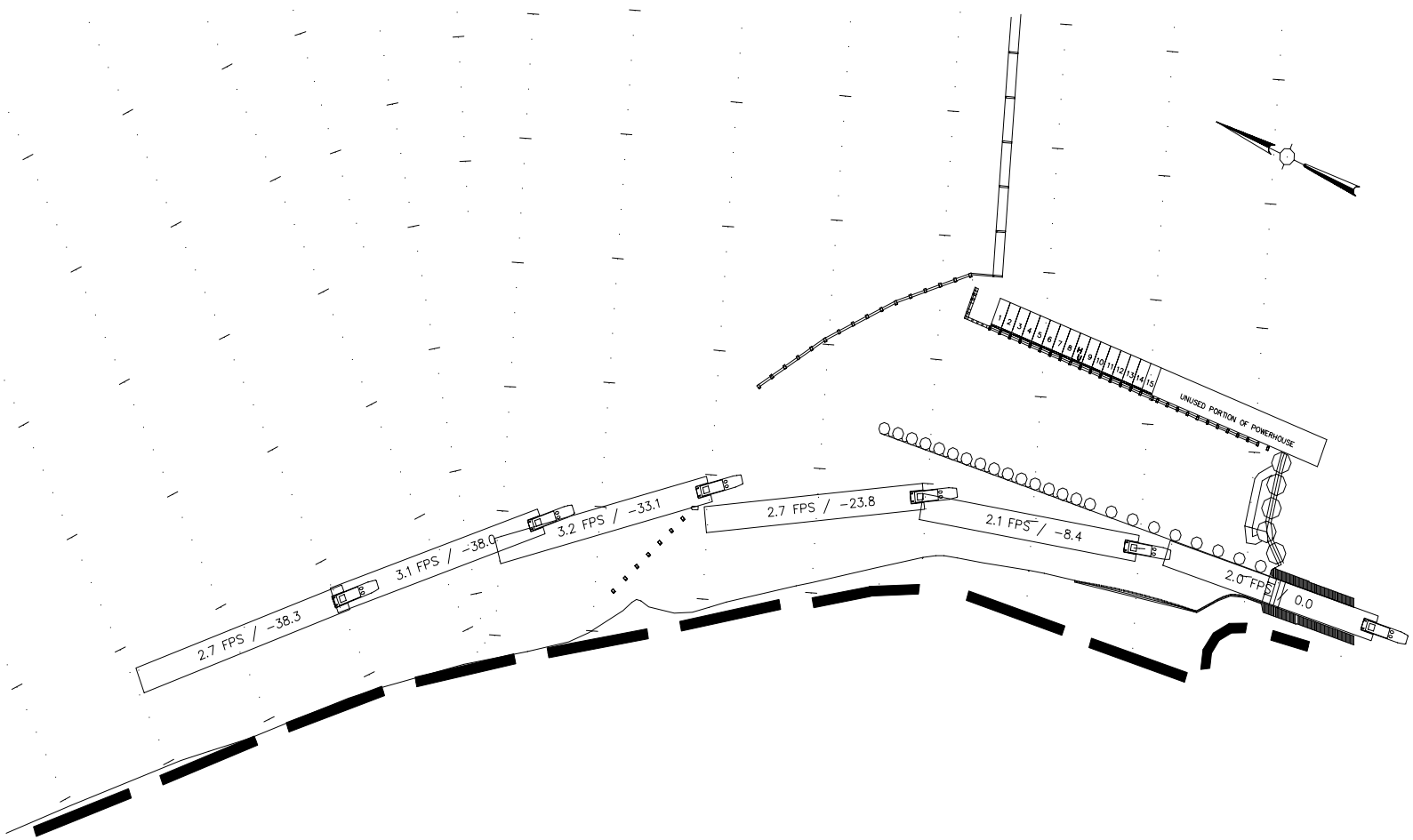
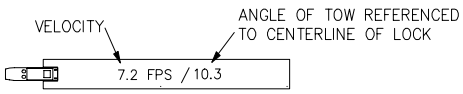

LD19075A
TOW PATHS
PLAN A-MODIFIED
DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1.3 FPS / 0.0
2.1 FPS / -11.5
2.5 FPS / -22.8
3.7 FPS / -28.0
3.5 FPS / -34.6
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
7.2 FPS / 10.3

Plate 52



LEGEND



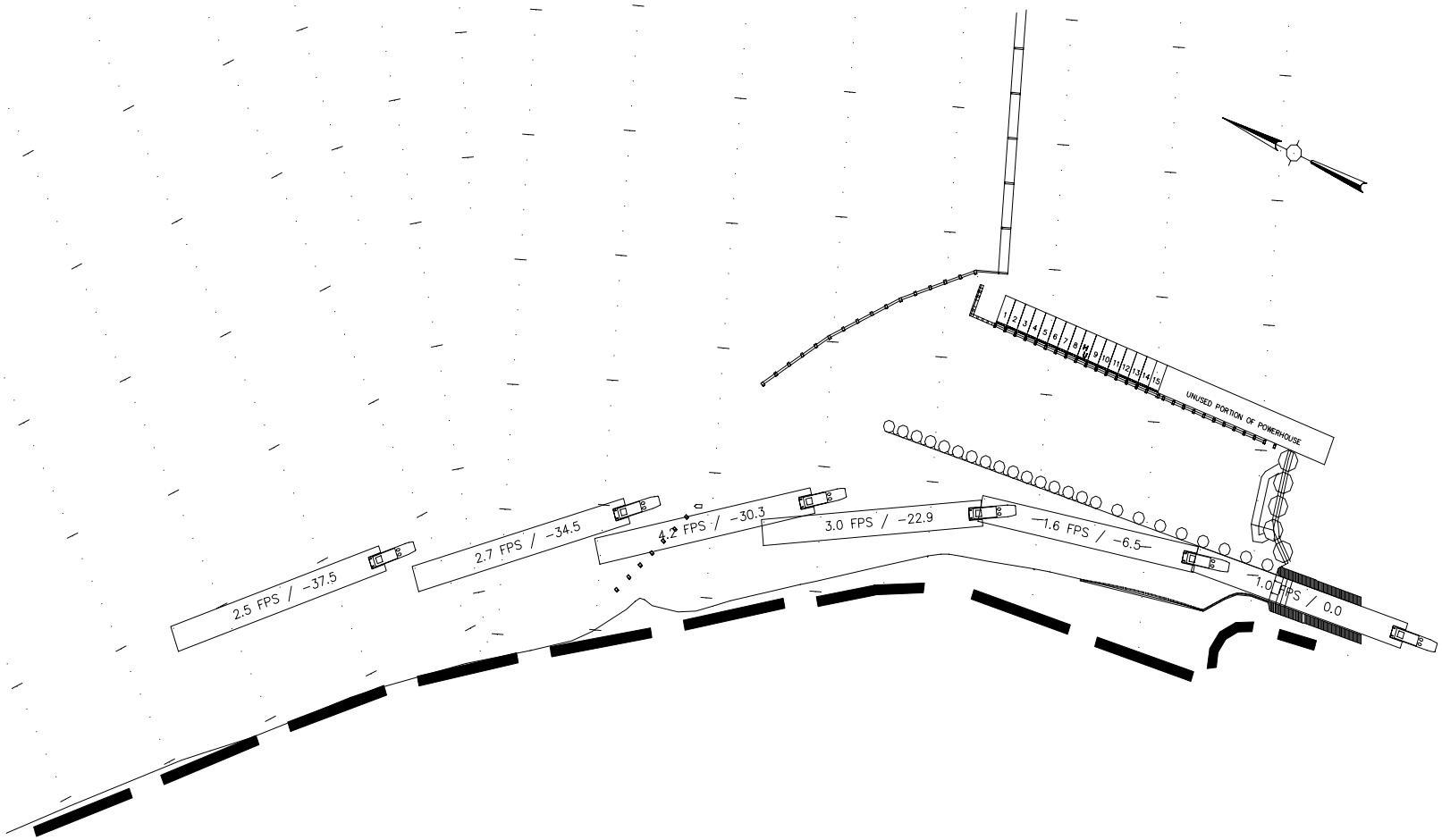
SCALES

TOW PATHS

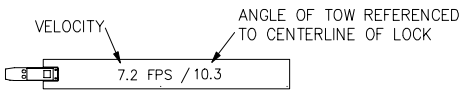
PLAN A-MODIFIED

DISCHARGE: 122,000 CFS
TAILWATER EL: 518.2 FT

LD19-78A



LEGEND



SCALES

PROTOTYPE 500 0 500

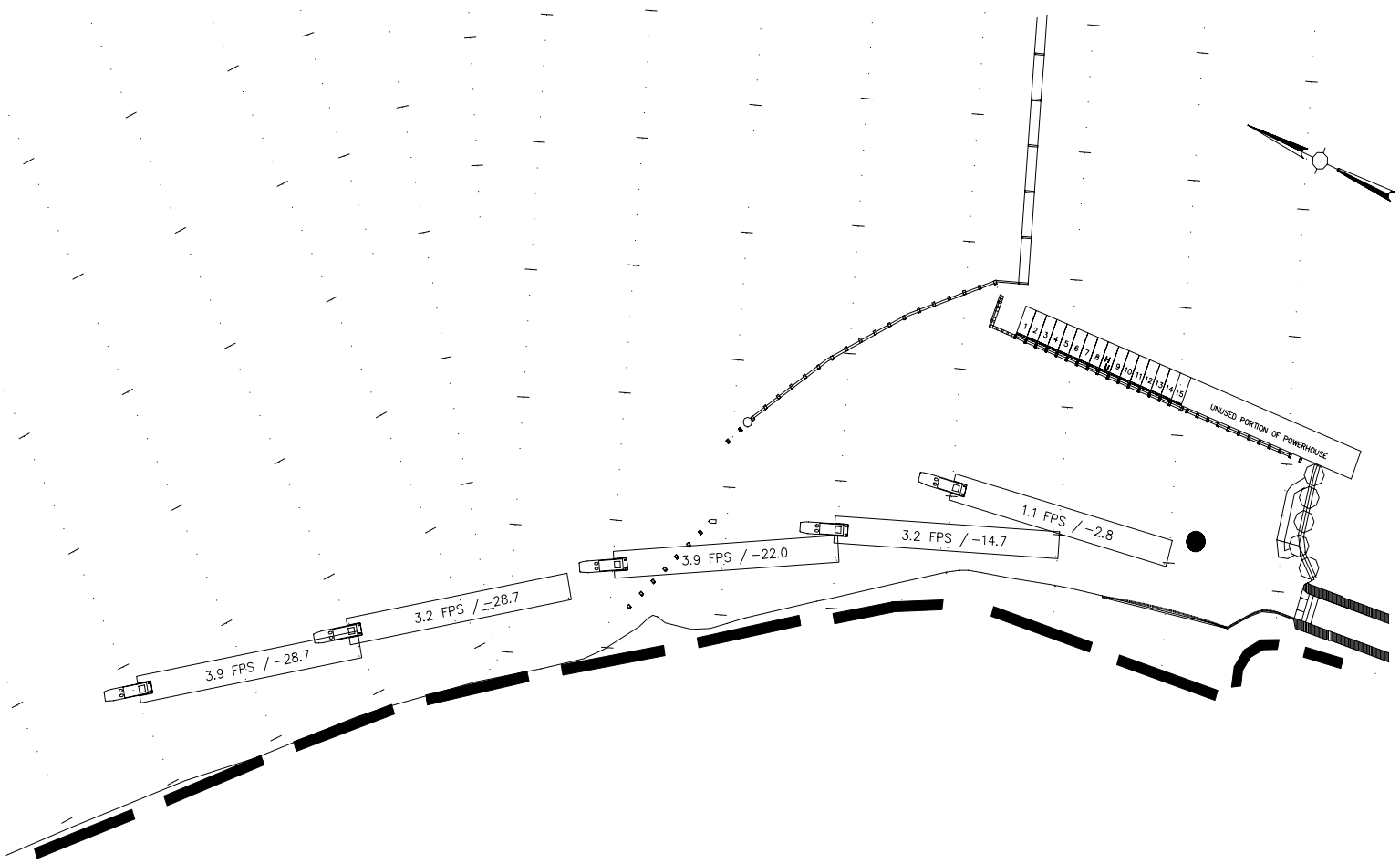
MODEL 5 0 5

TOW PATHS

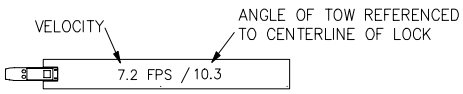
PLAN A-MODIFIED

DISCHARGE: 249,000 CFS

TAILWATER EL: 518.2 FT



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

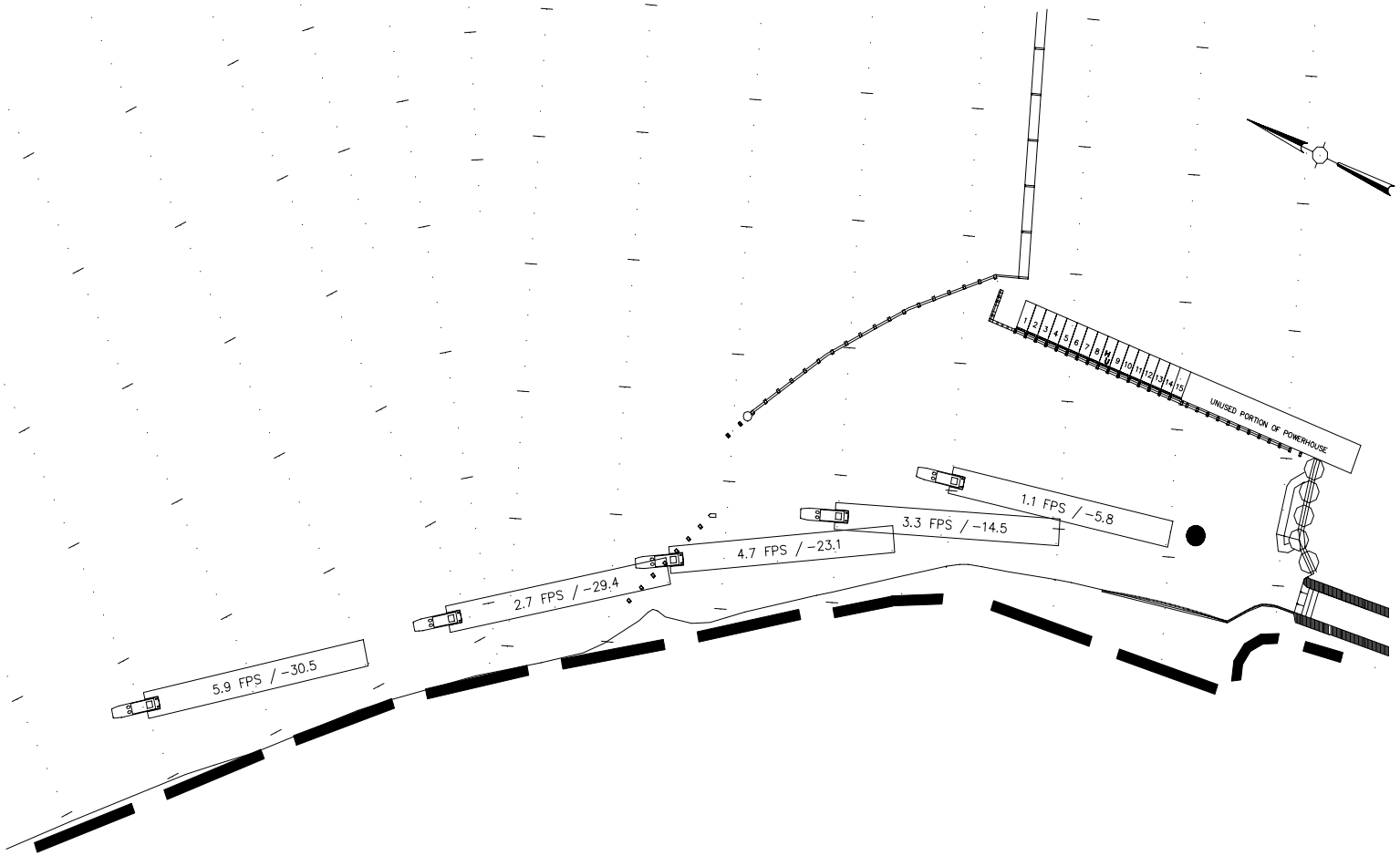
TOW PATHS

PLAN B

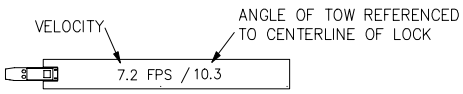
DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19-86A



LEGEND



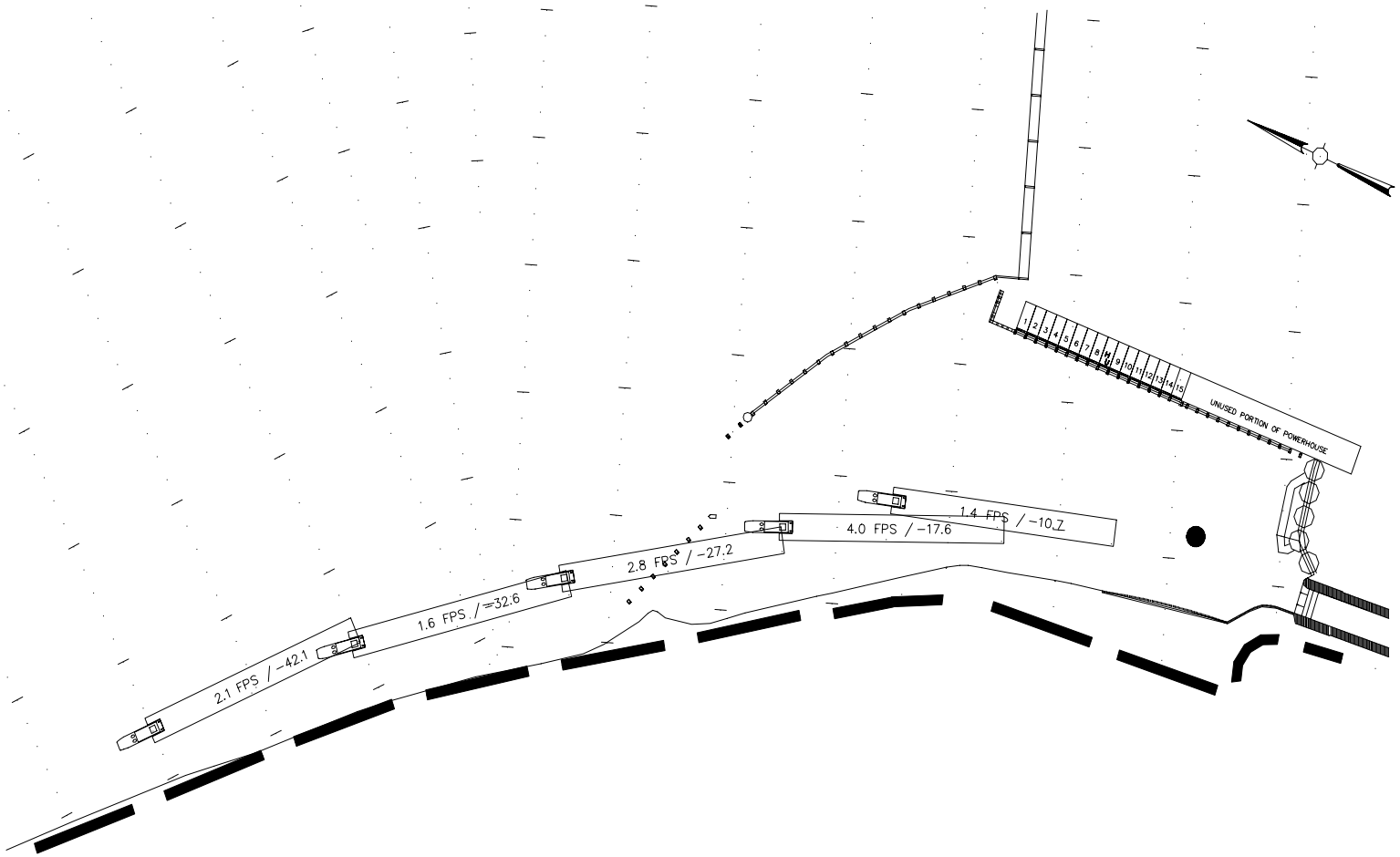
SCALES

TOW PATHS

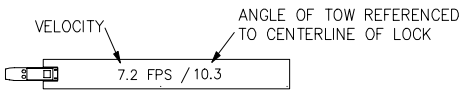
PLAN B

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

LD19-85A



LEGEND



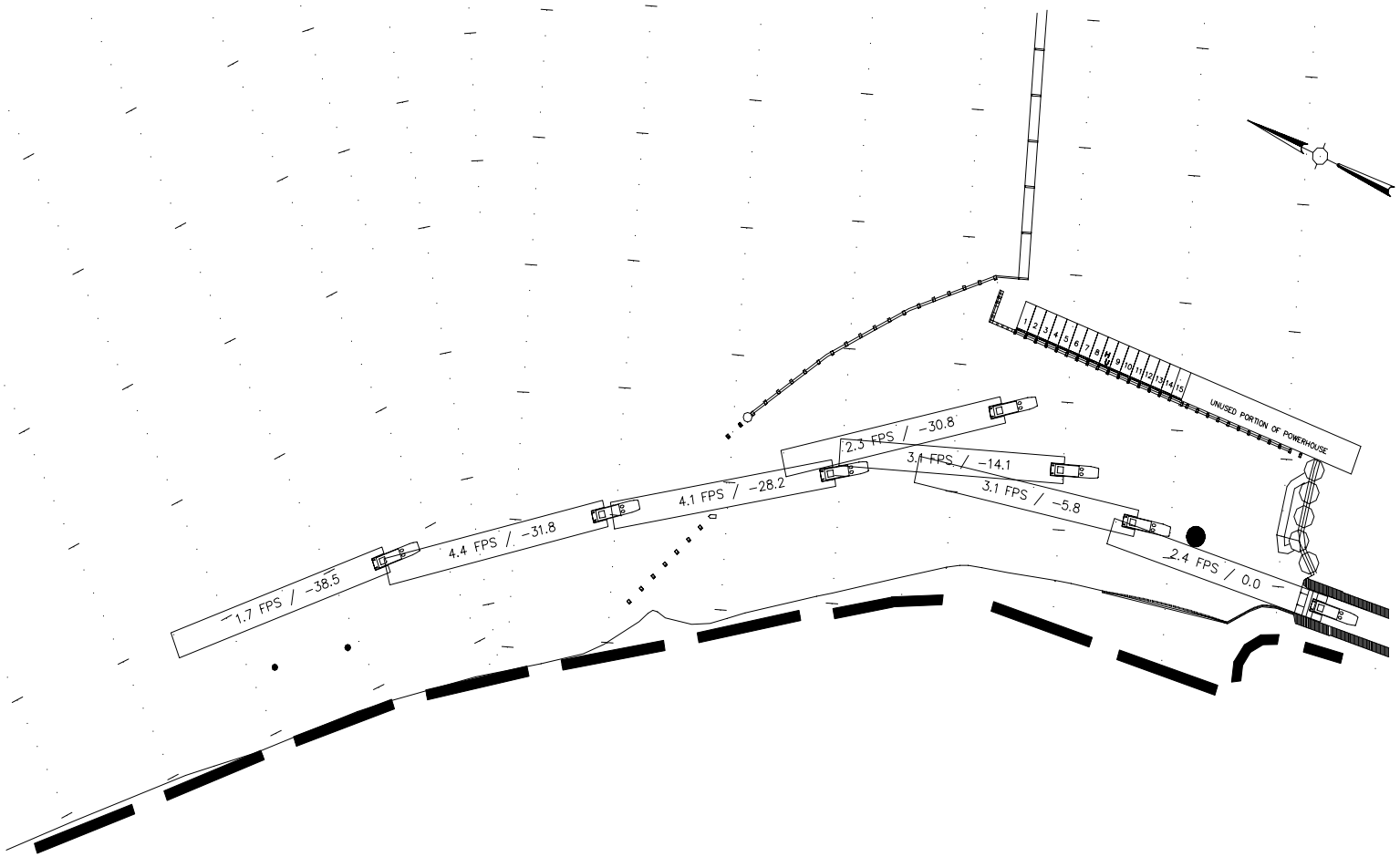
SCALES

TOW PATHS

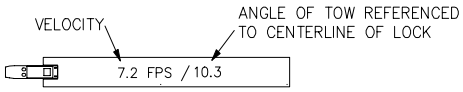
PLAN B

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

LD19-84A



LEGEND



SCALES

PROTOTYPE 500 0 500

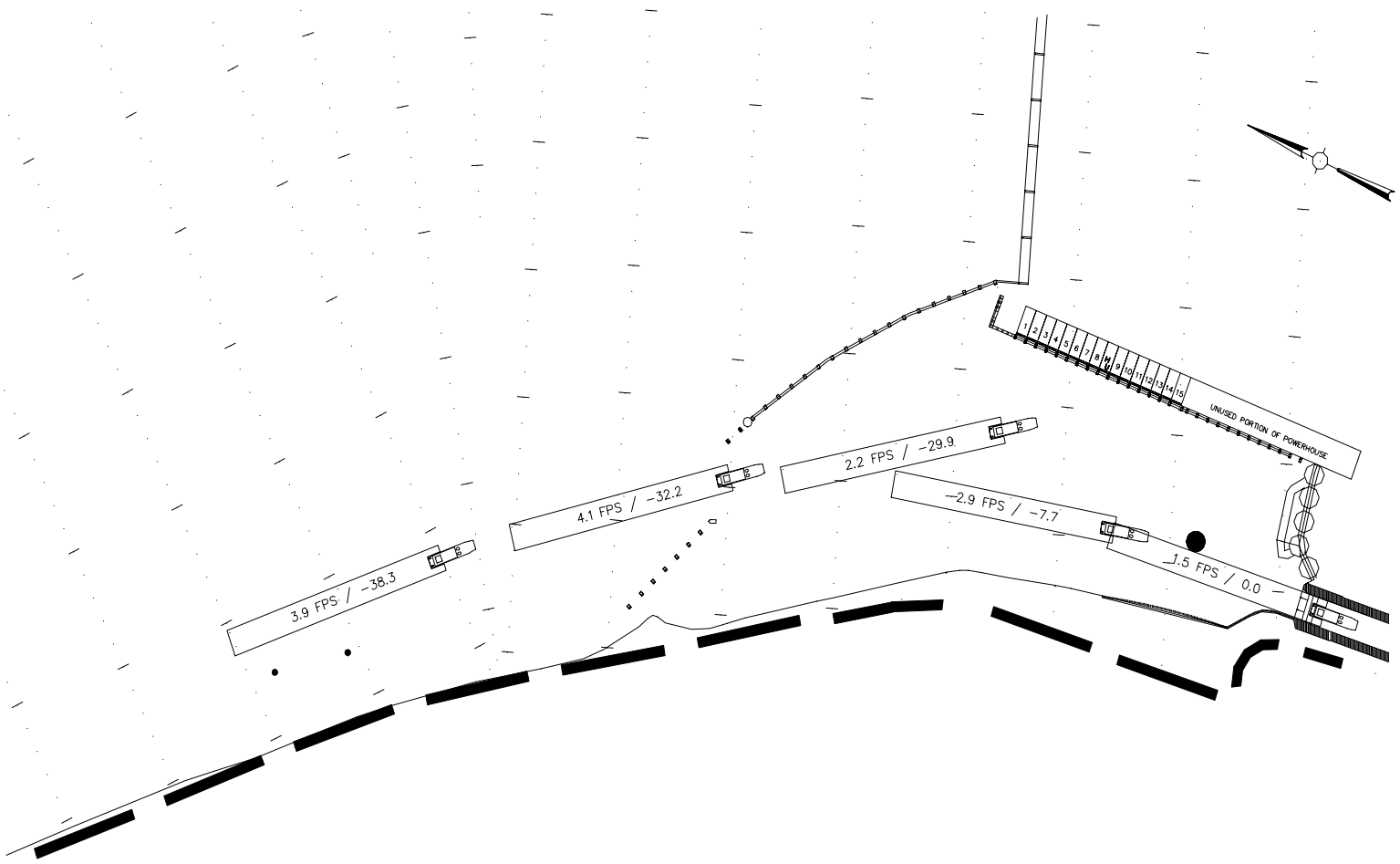
MODEL 5 0 5

TOW PATHS

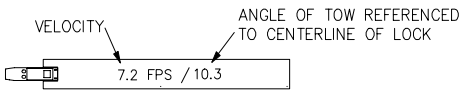
PLAN B

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND



SCALES

TOW PATHS

PLAN B

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

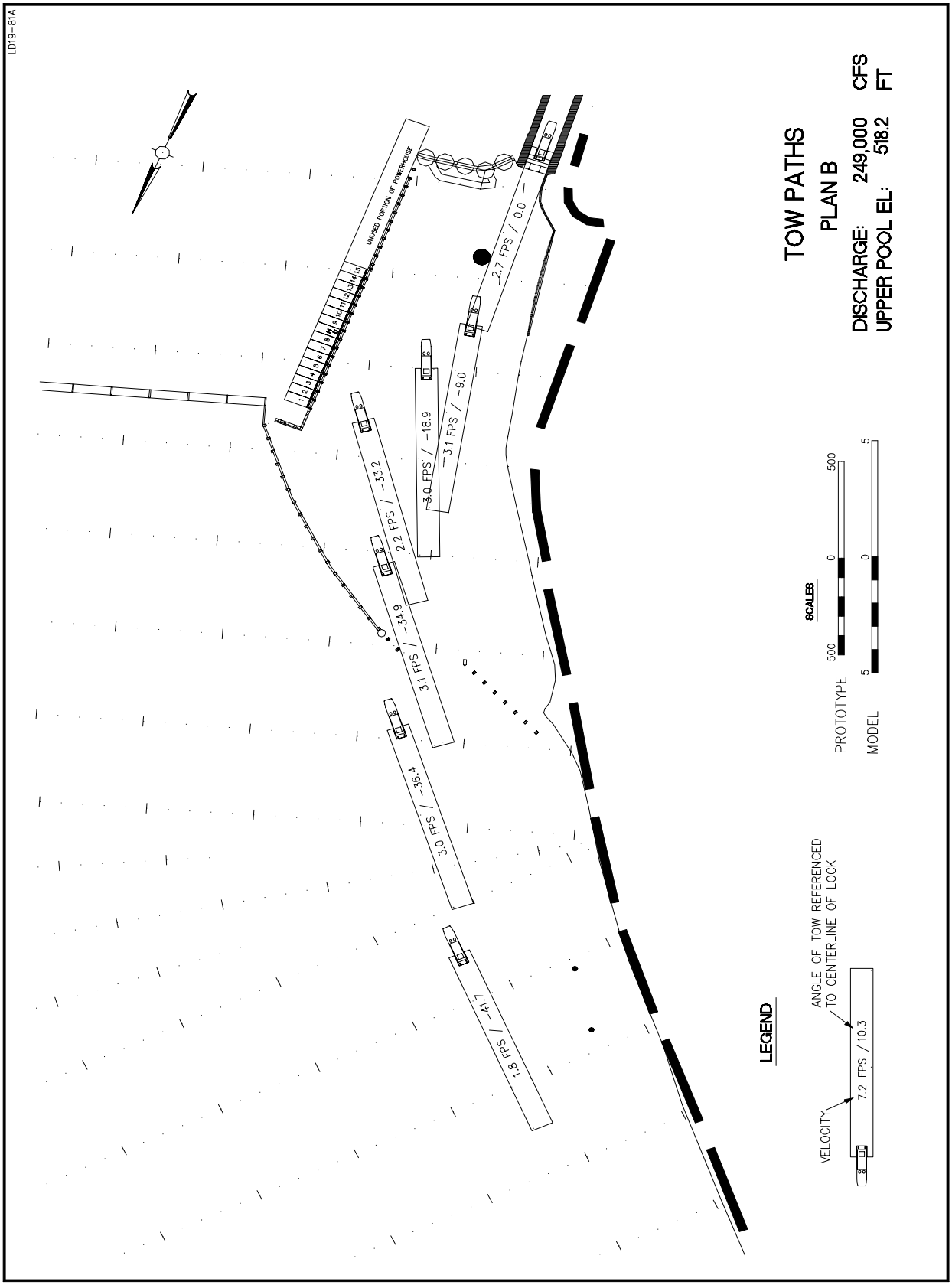
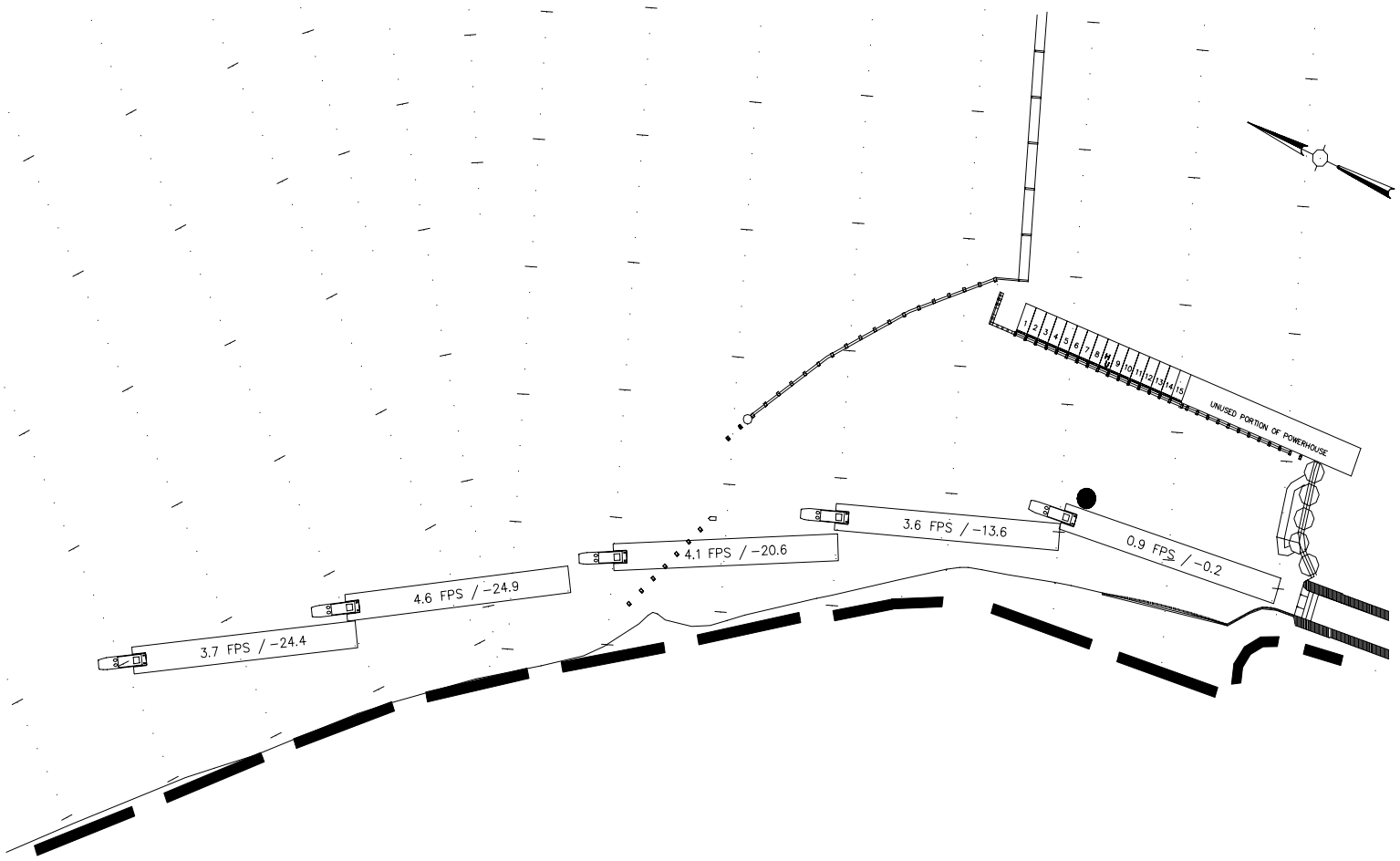
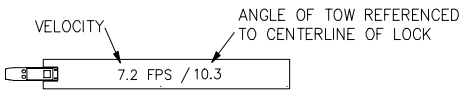

LD19-81A
TOW PATHS
PLAN B
DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
2.7 FPS / 0.0
3.1 FPS / -9.0
3.0 FPS / -18.9
2.2 FPS / -33.2
3.1 FPS / -34.9
3.0 FPS / -36.4
1.8 FPS / -41.7
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
7.2 FPS / 10.3

Plate 60



LEGEND



SCALES

TOW PATHS
PLAN B-1

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

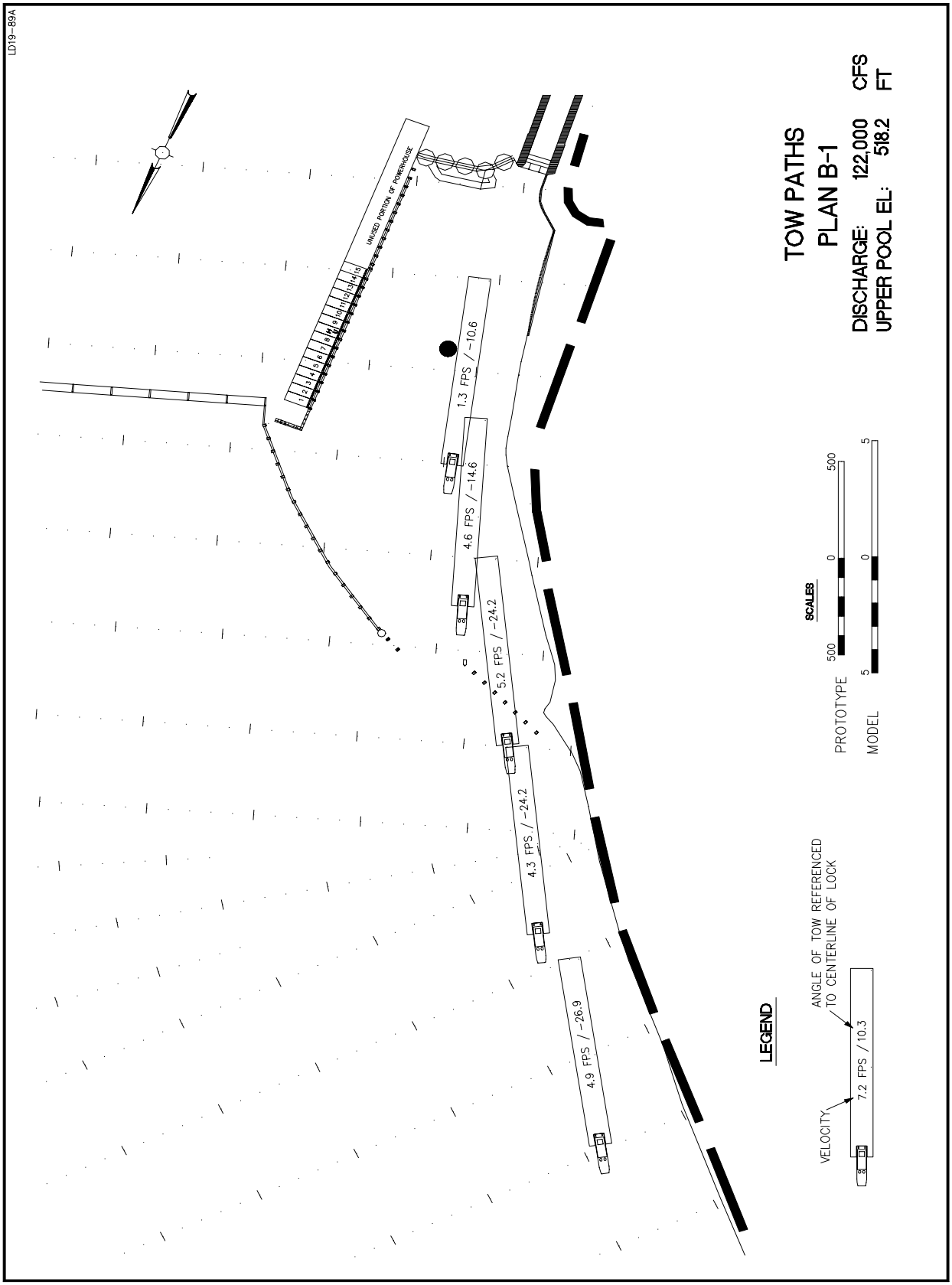
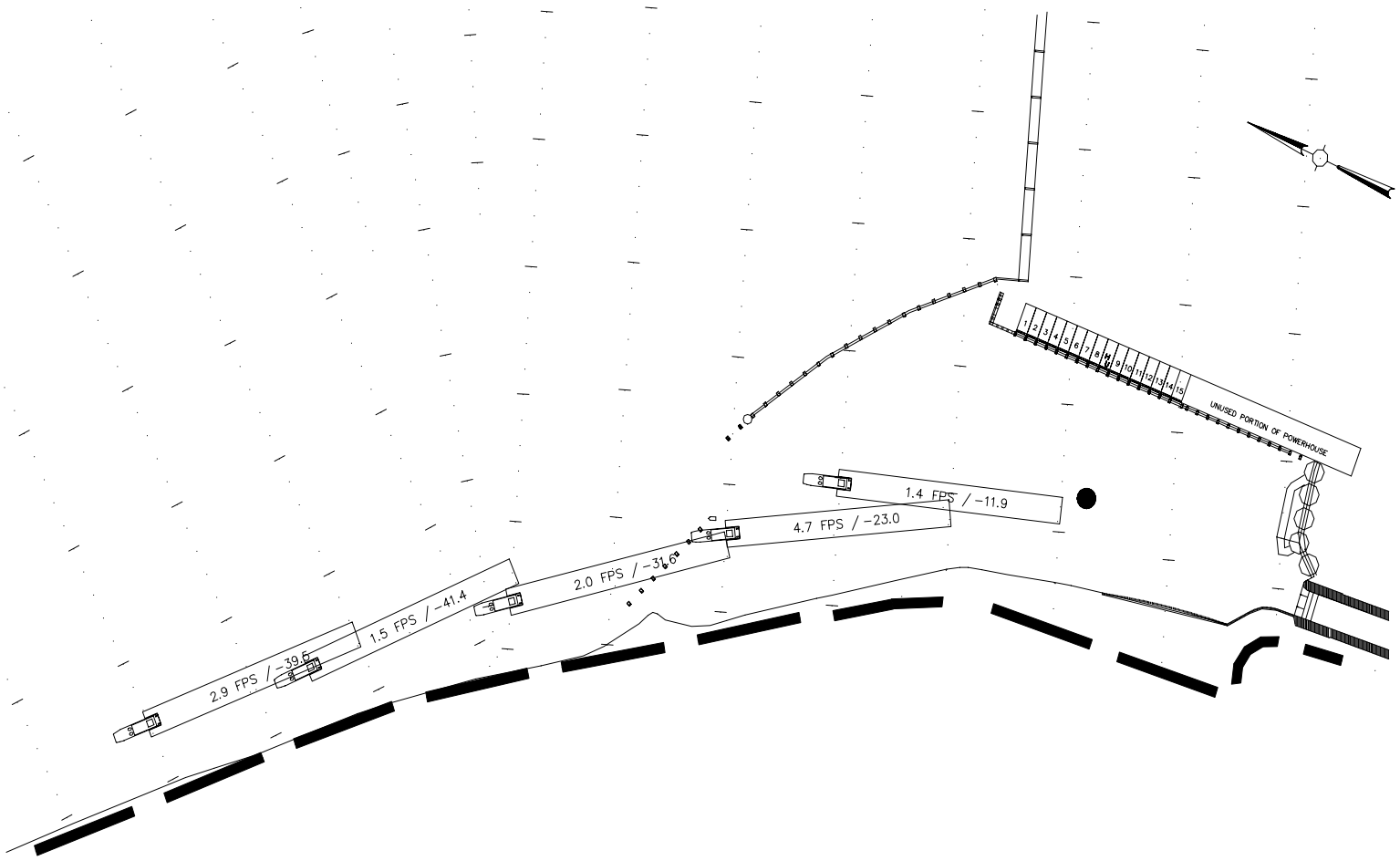
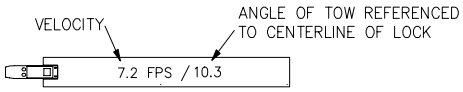

LD19-89A
TOW PATHS
PLAN B-1
DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1.3 FPS / -10.6
4.6 FPS / -14.6
5.2 FPS / -24.2
4.3 FPS / -24.2
4.9 FPS / -26.9
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
7.2 FPS / 10.3

Plate 62



LEGEND

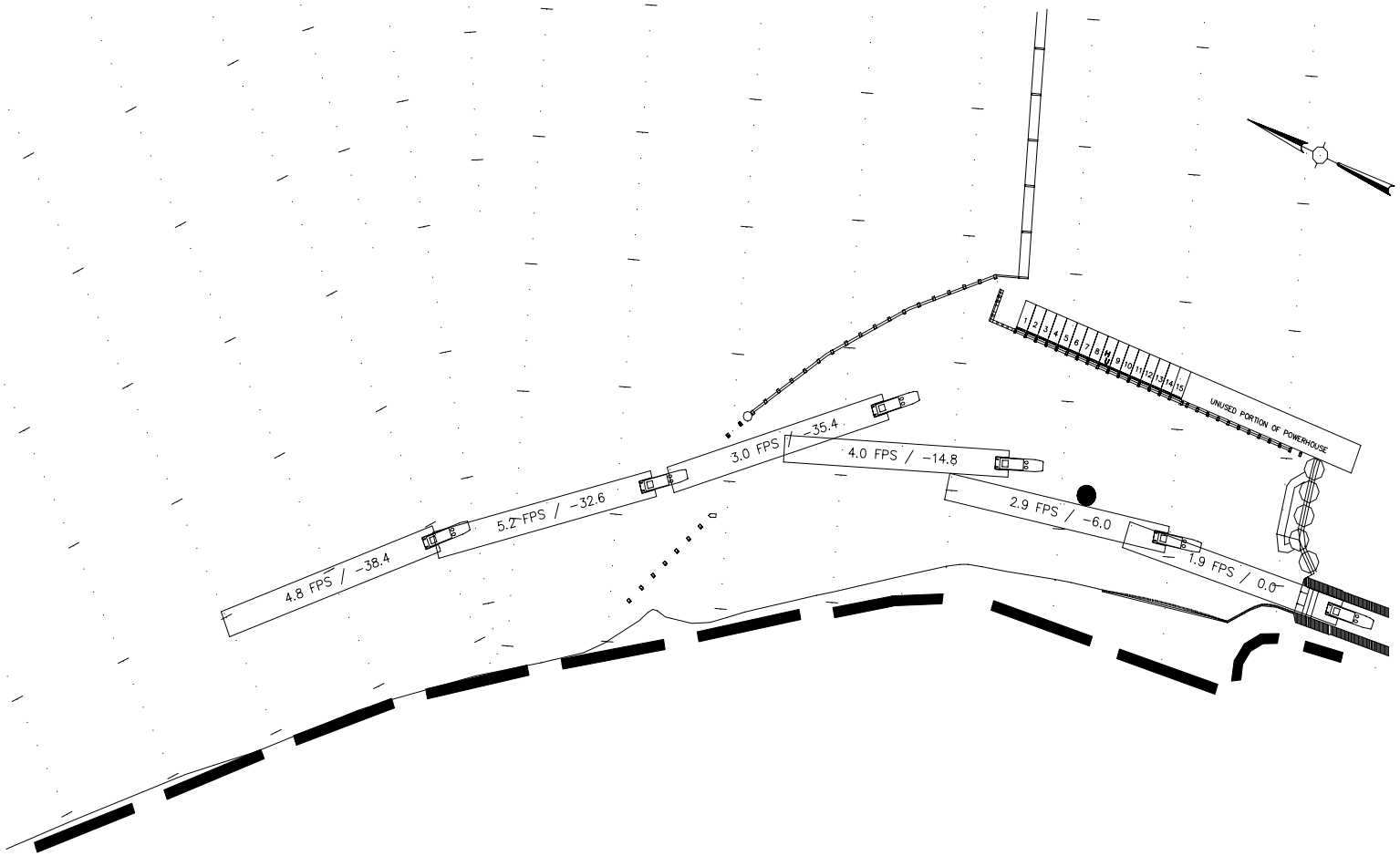


SCALES

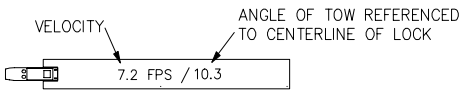
TOW PATHS
PLAN B-1

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

LD19-91A



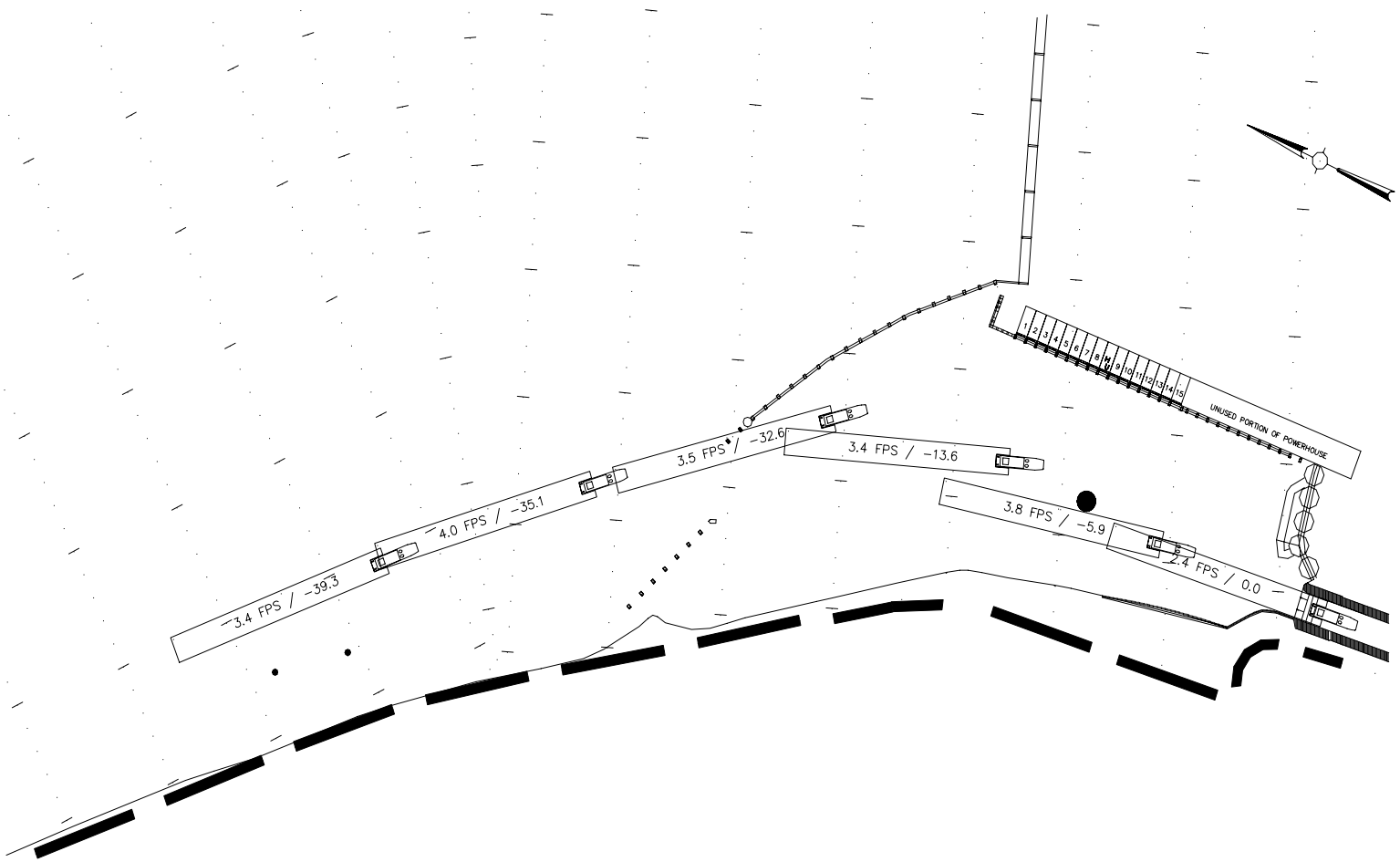
LEGEND



SCALES

TOW PATHS
PLAN B-1

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND

VELOCITY — ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK

7.2 FPS / 10.3

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

TOW PATHS
PLAN B-1

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

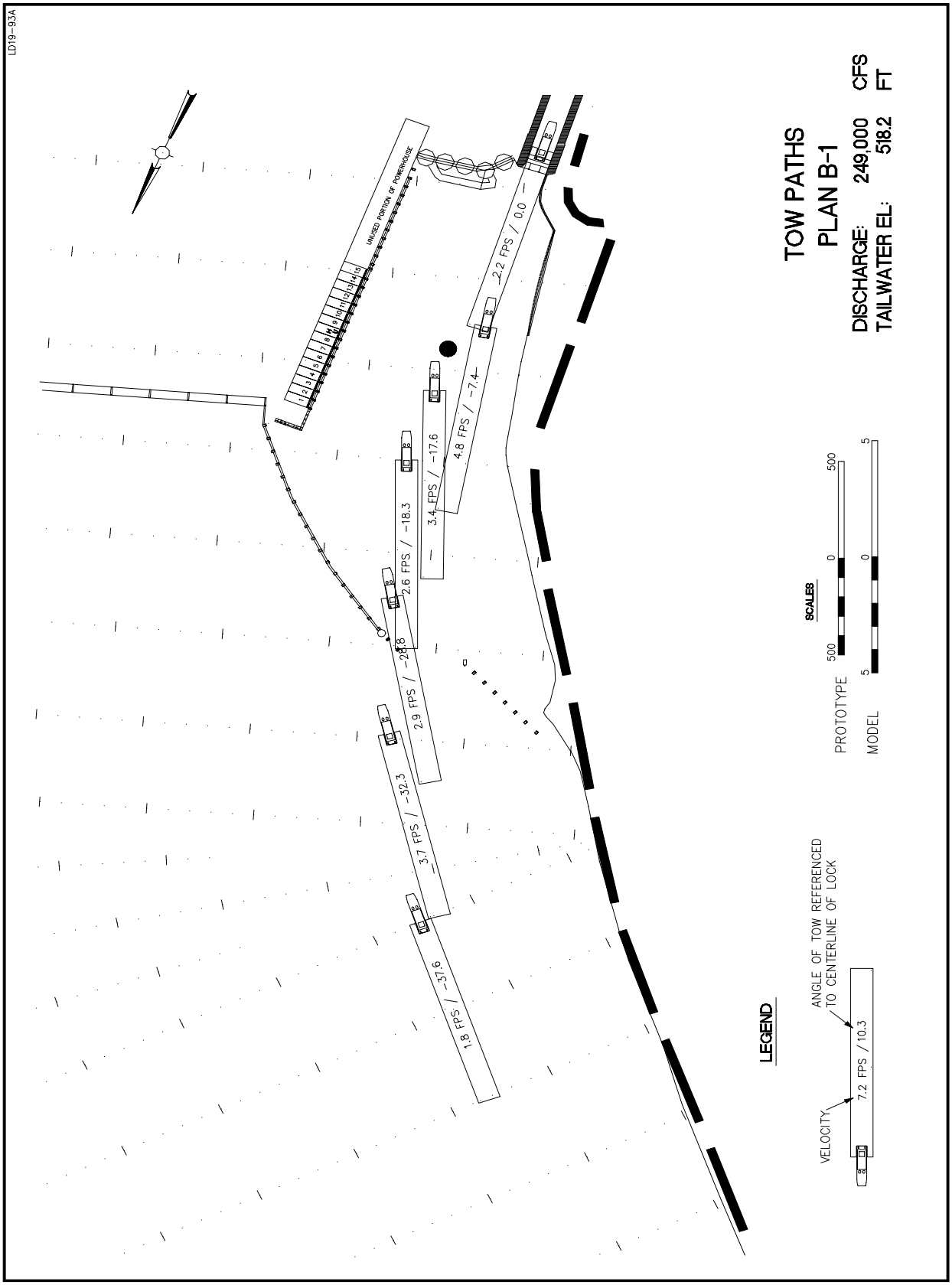
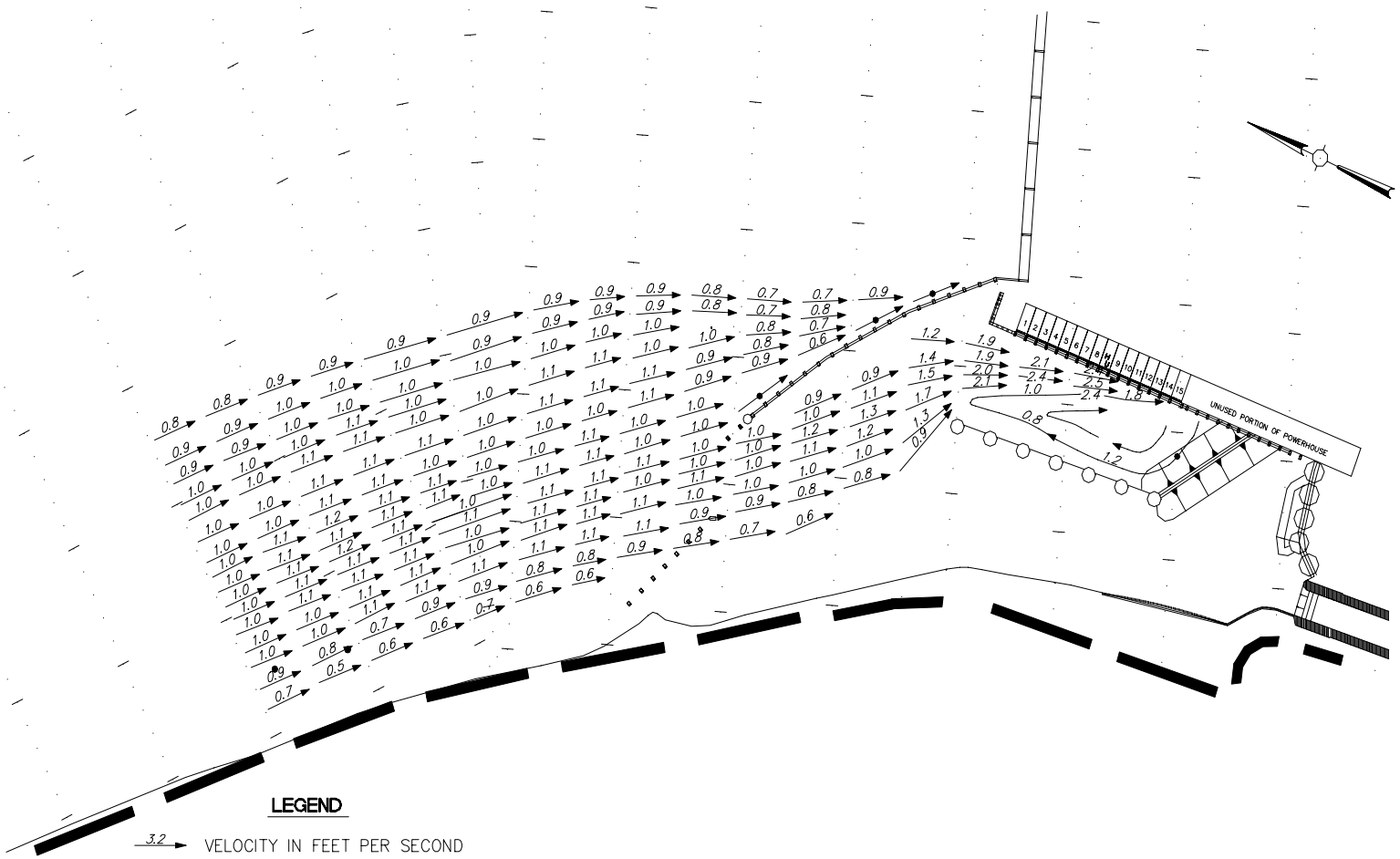

LD19-93A
UNUSED PORTION OF POWERHOUSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1.8 FPS / -37.6
3.7 FPS / -32.3
2.9 FPS / -28.8
2.6 FPS / -18.3
3.4 FPS / -17.6
4.8 FPS / -7.4
2.2 FPS / 0.0
TOW PATHS
PLAN B-1
DISCHARGE: 249,000 CFS
TAILWATER EL: 518.2 FT
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
7.2 FPS / 10.3

Plate 66



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

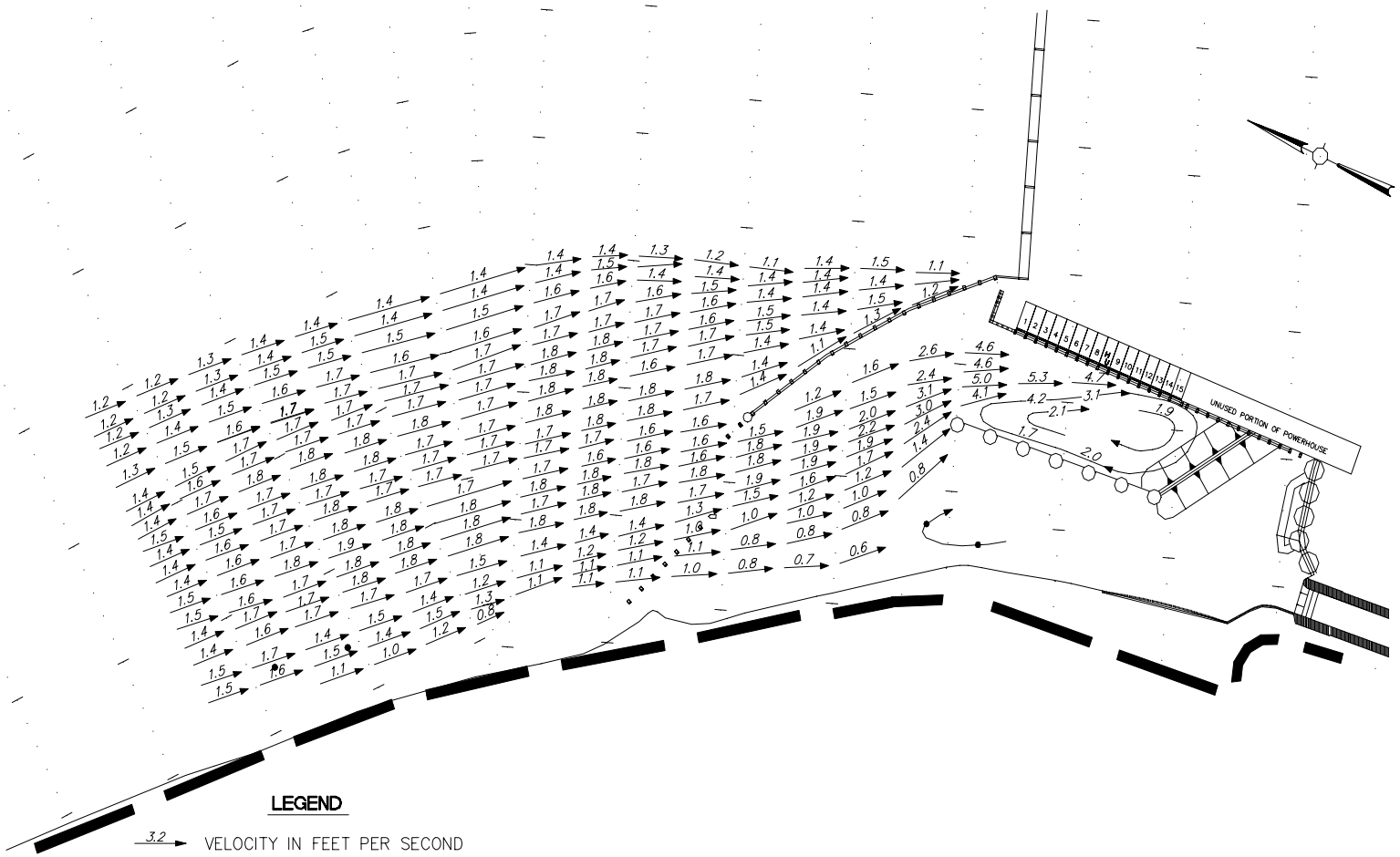
VELOCITIES AND CURRENT DIRECTIONS

PLAN C

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-102



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

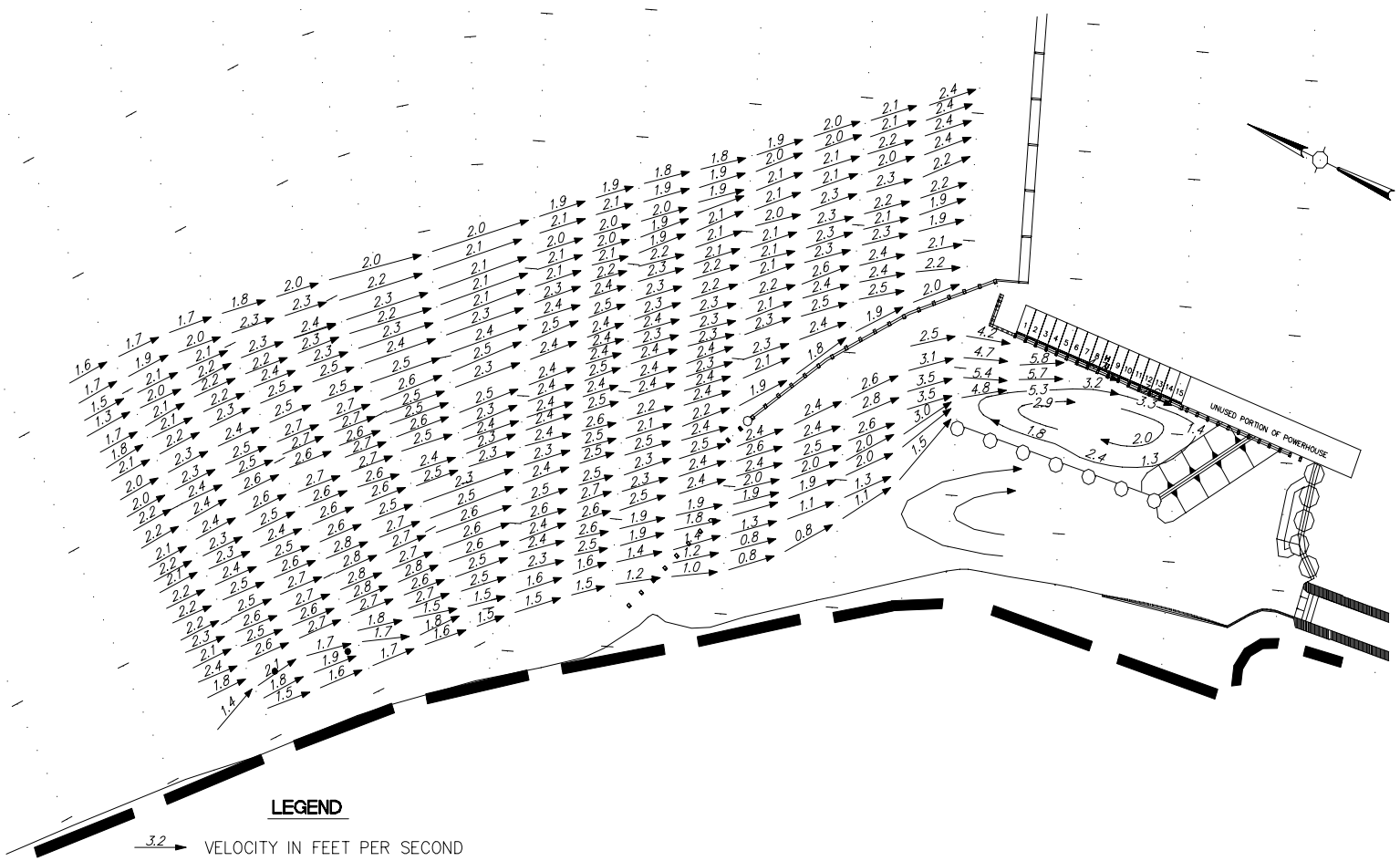
MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PLAN C

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

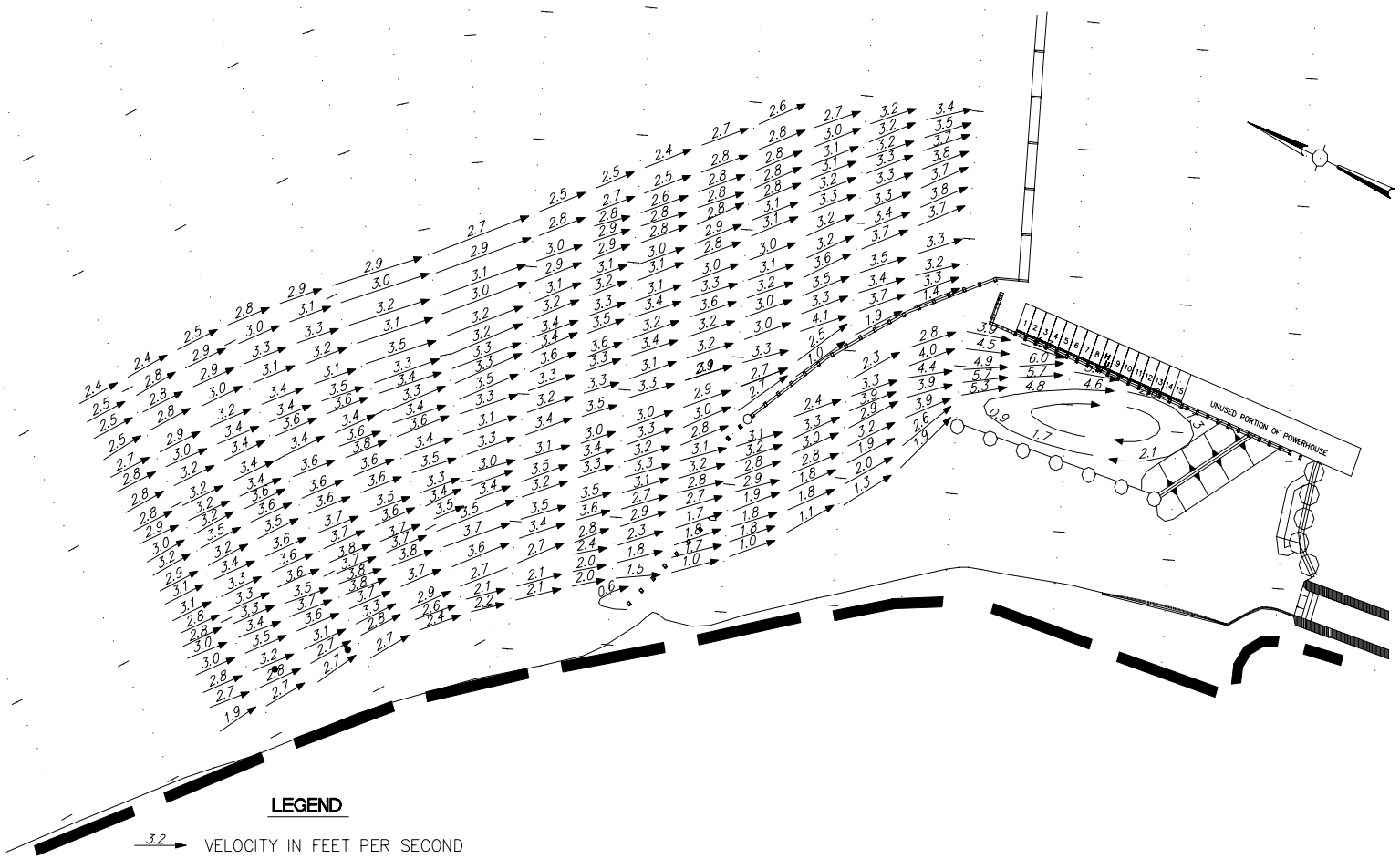
VELOCITIES AND CURRENT DIRECTIONS

PLAN C

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-100



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

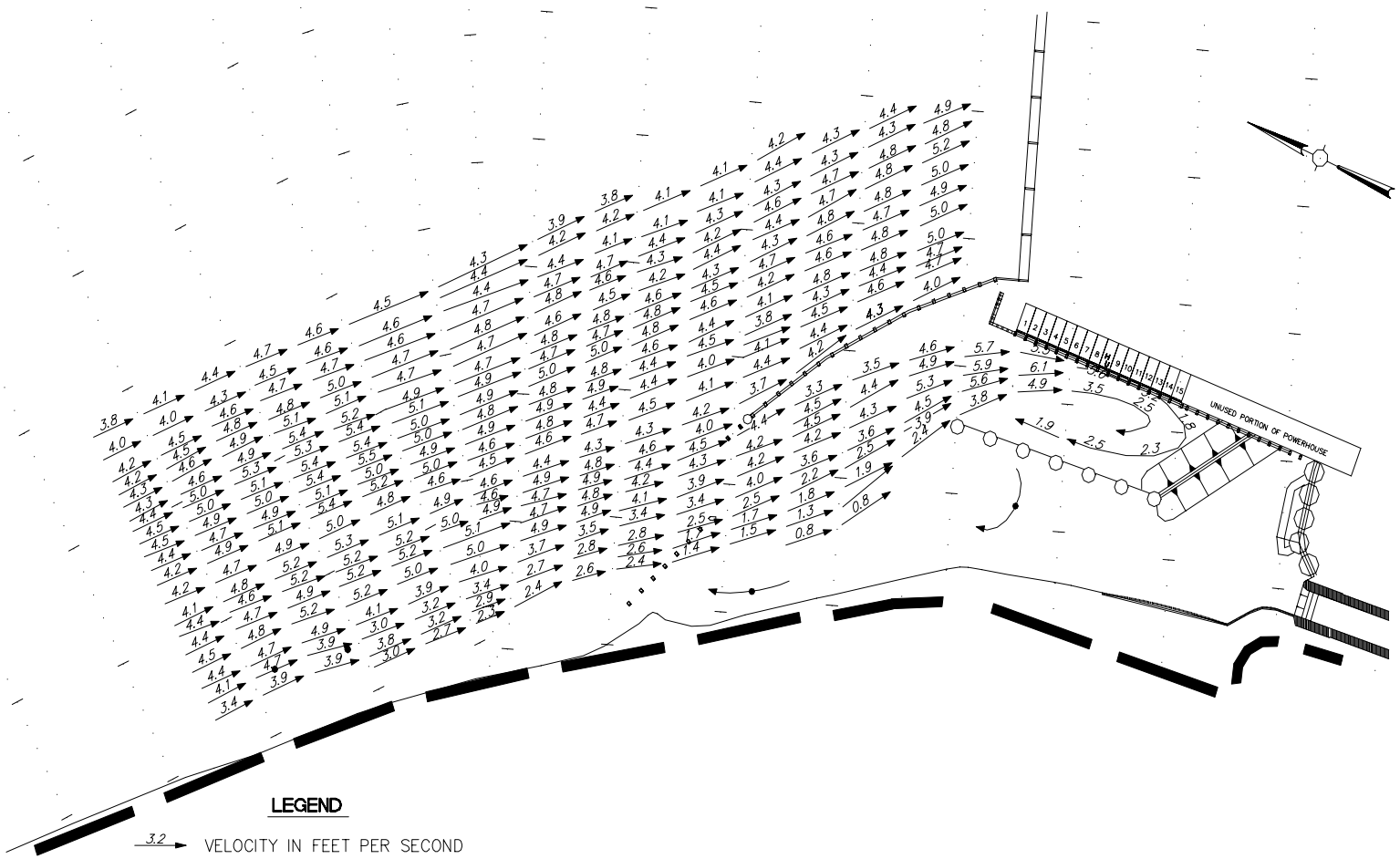
VELOCITIES AND CURRENT DIRECTIONS

PLAN C

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

LD19-099



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

→● VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

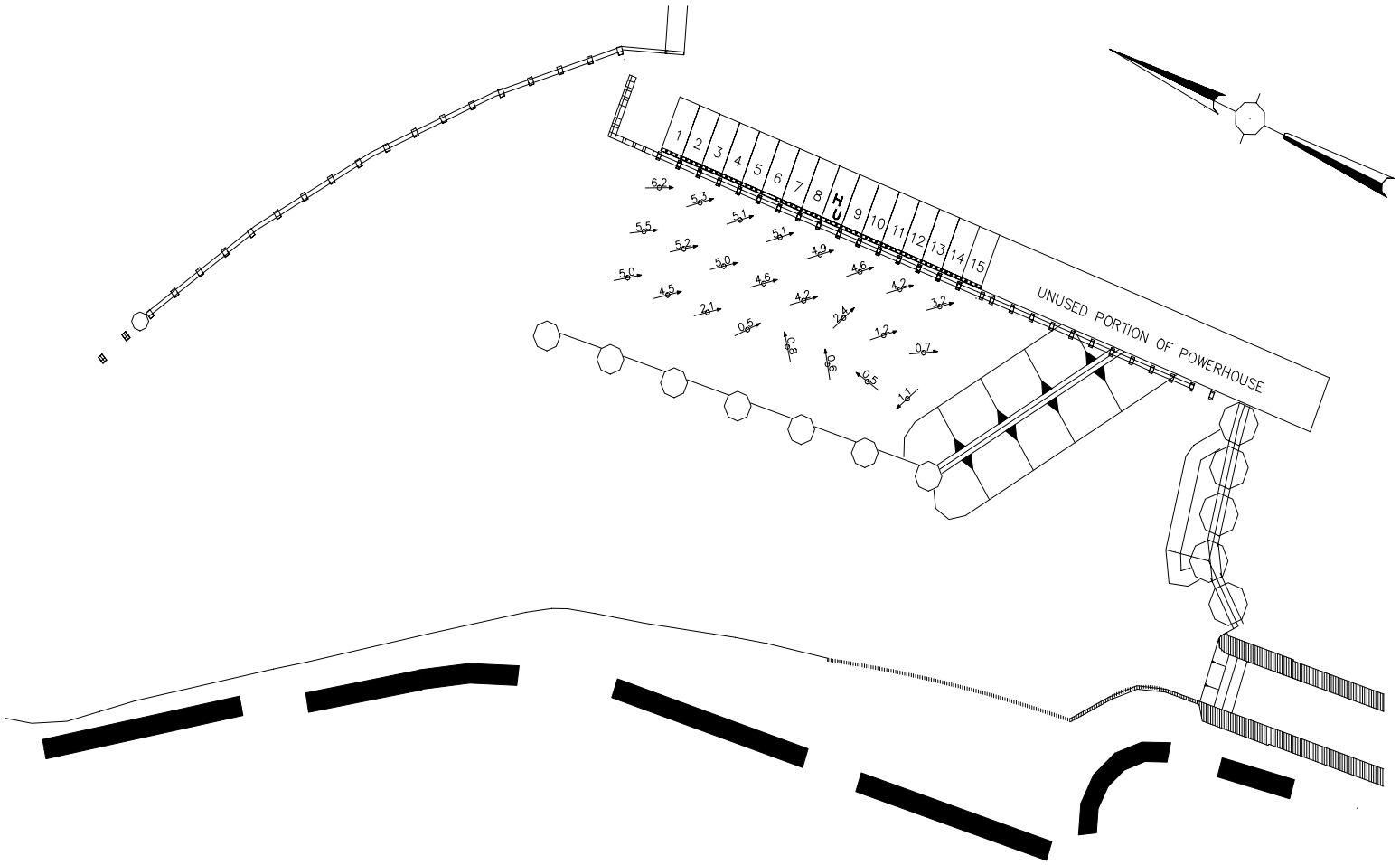
VELOCITIES AND CURRENT DIRECTIONS

PLAN C

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19-106



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

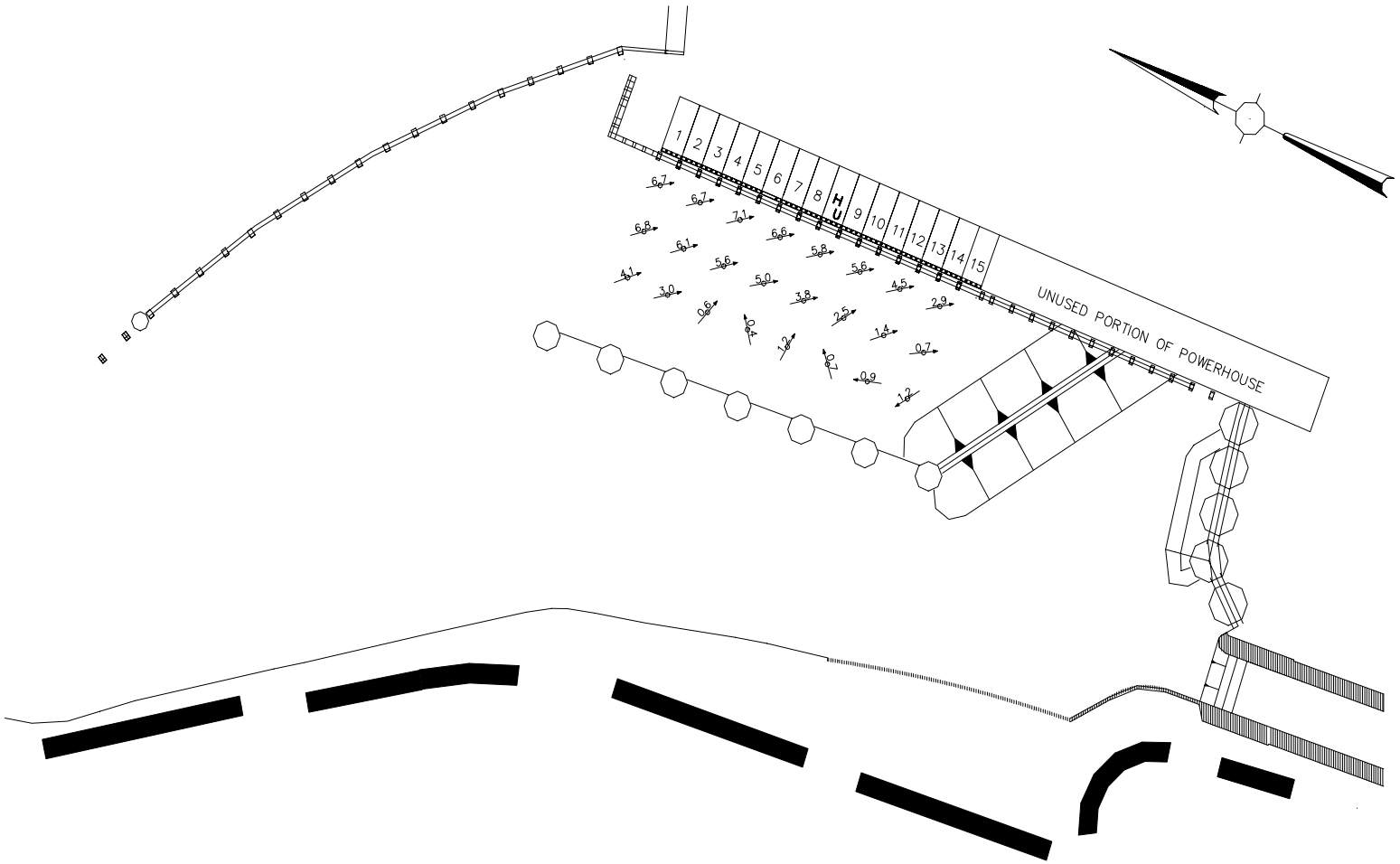
MODEL 5 0 5

METER VELOCITIES

PLAN C

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

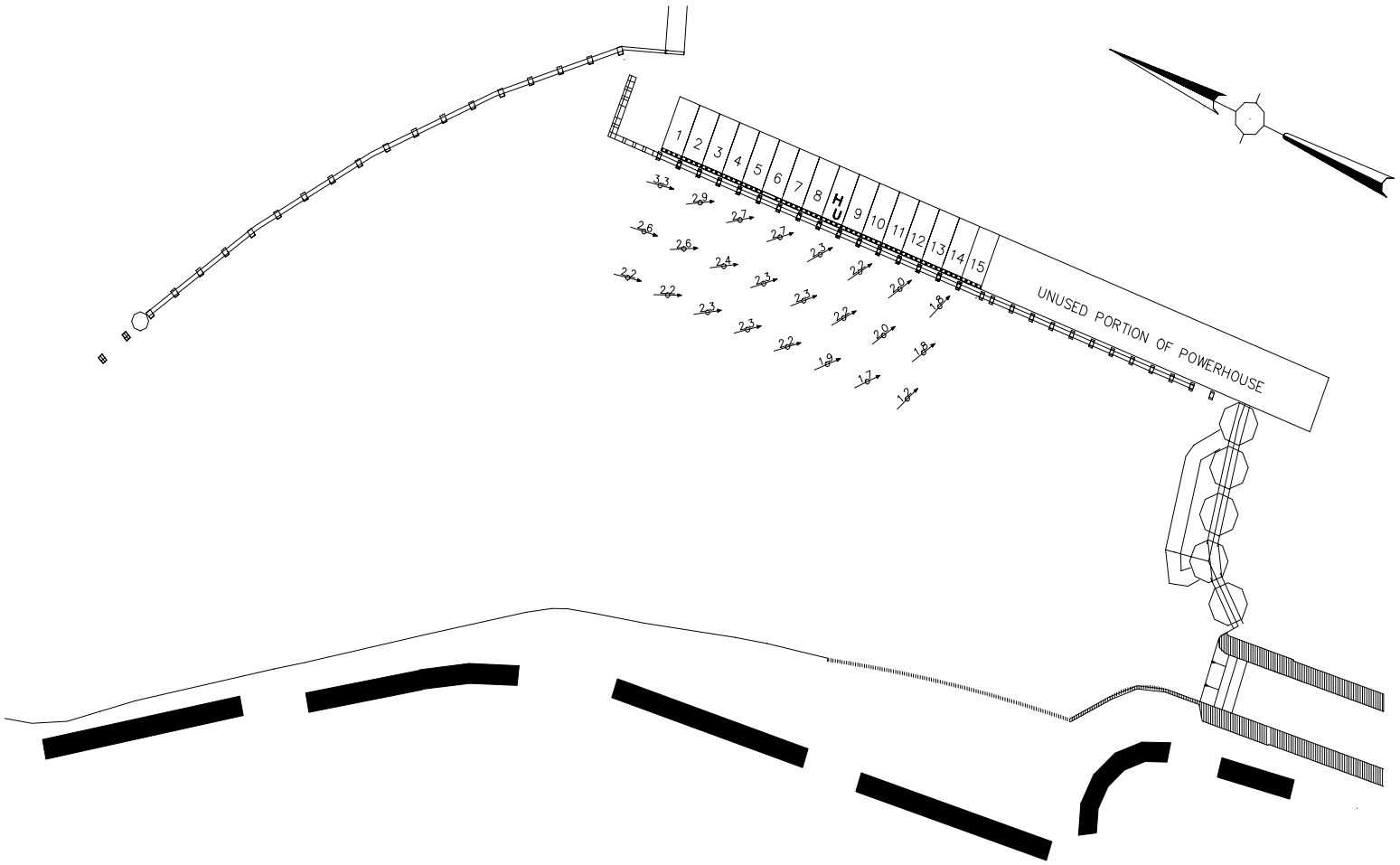
MODEL 5 0 5

METER VELOCITIES

PLAN C

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

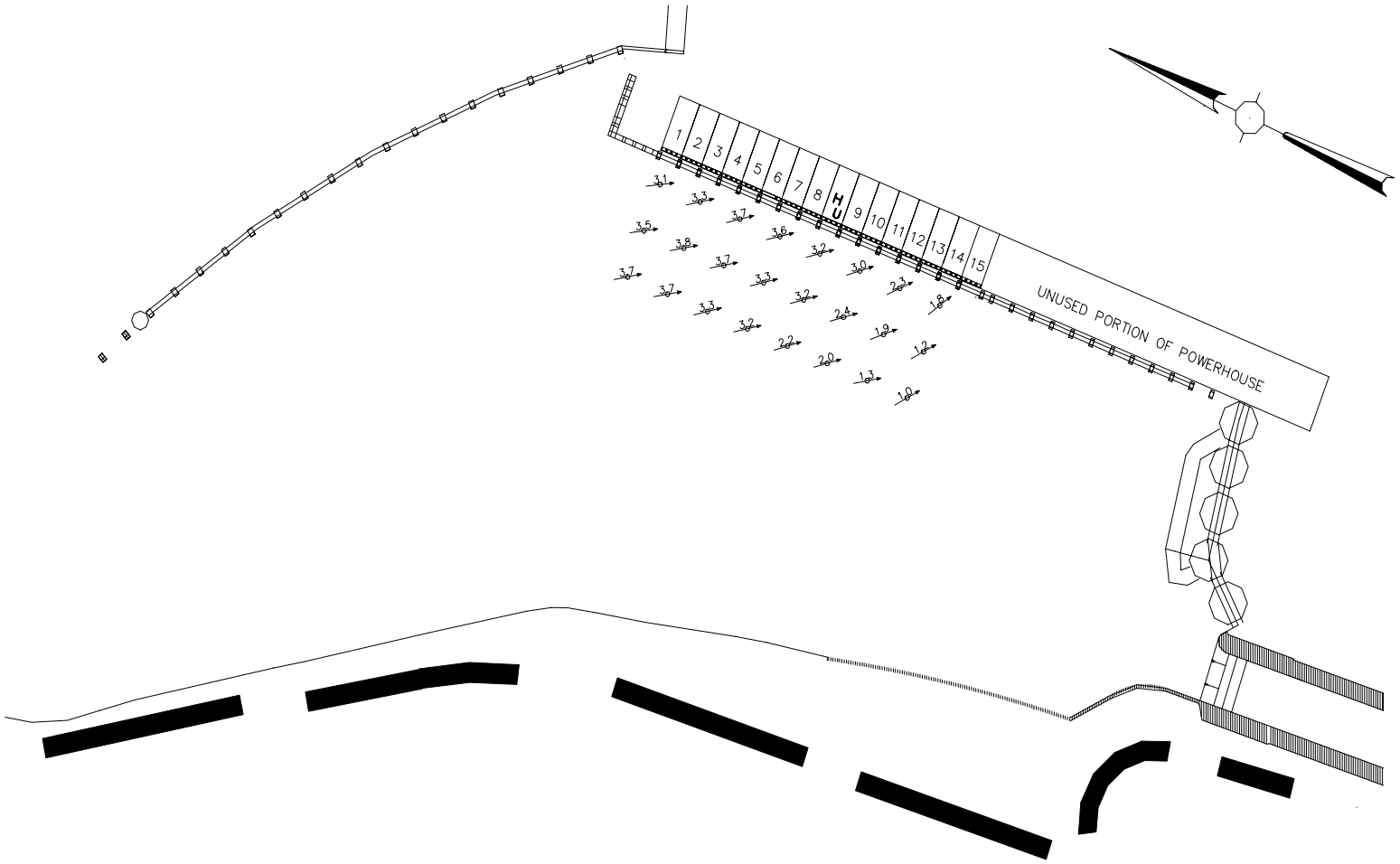
METER VELOCITIES

BASE TEST

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19-095



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

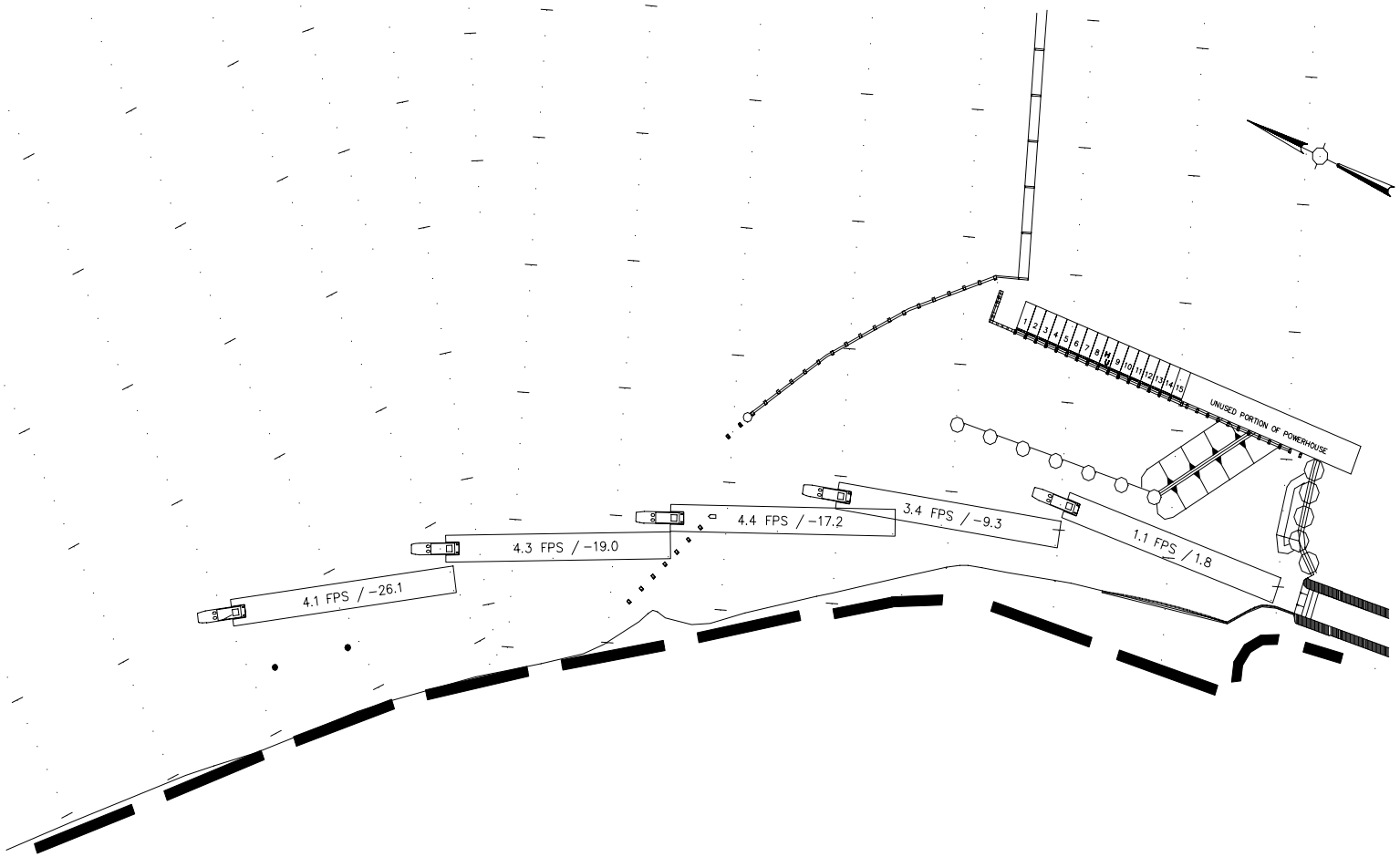
METER VELOCITIES

BASE TEST

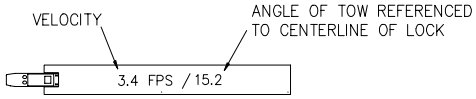
DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

19–118A



LEGEND



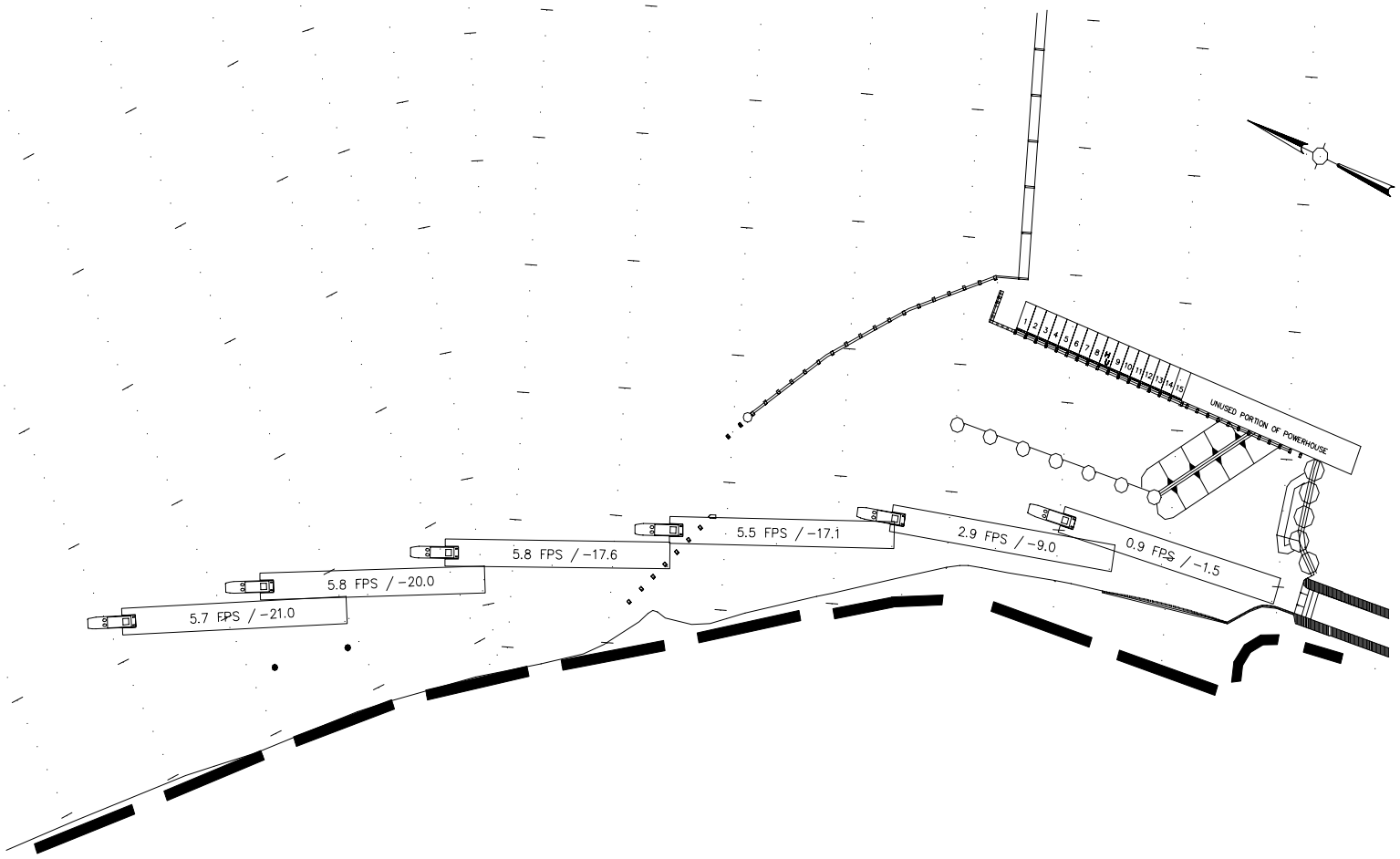
SCALES

TOW PATHS

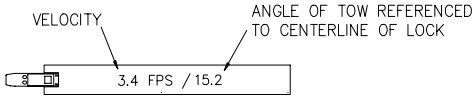
PLAN C

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

19-117A



LEGEND



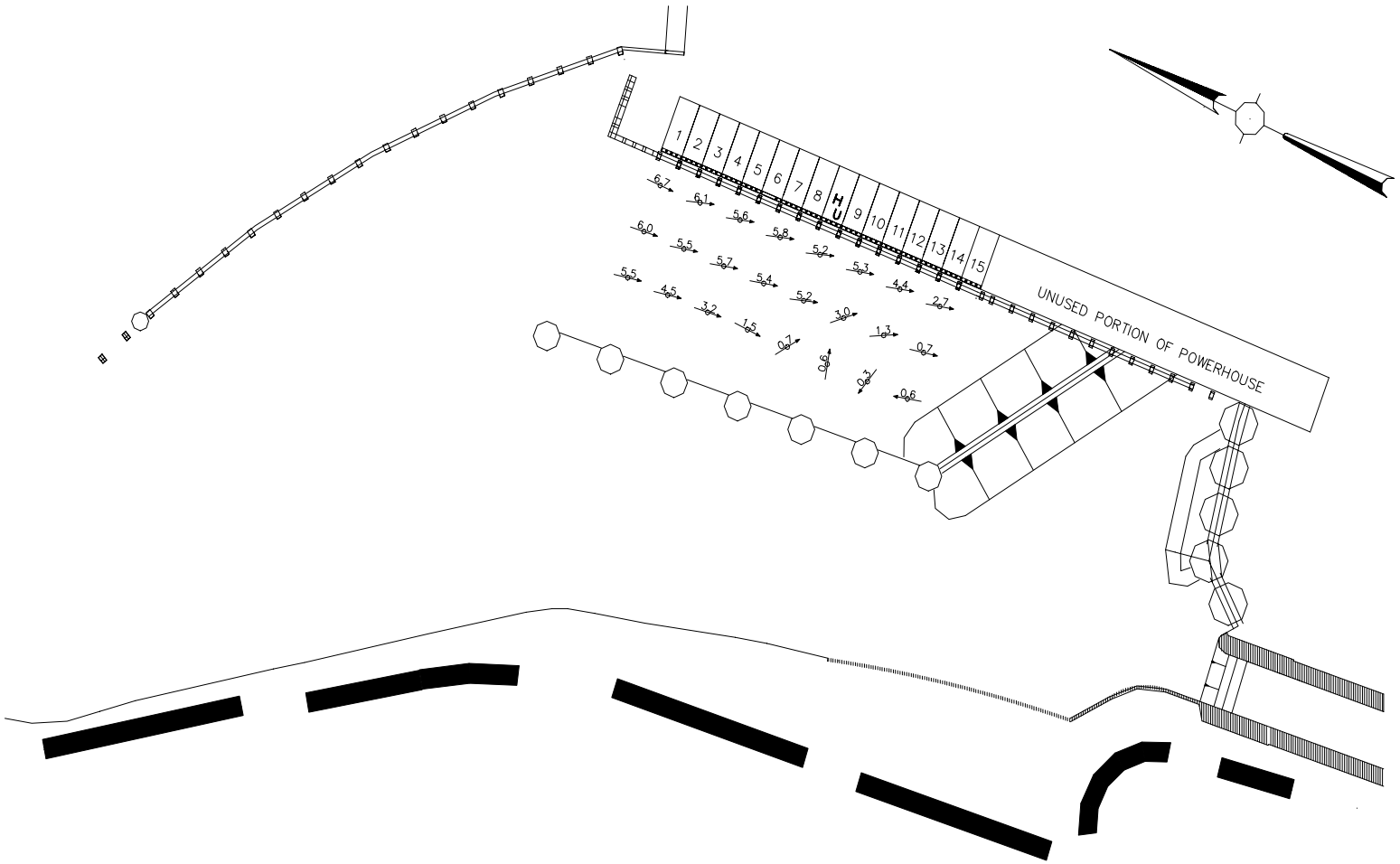
SCALES

TOW PATHS

PLAN C

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

LD19-108



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

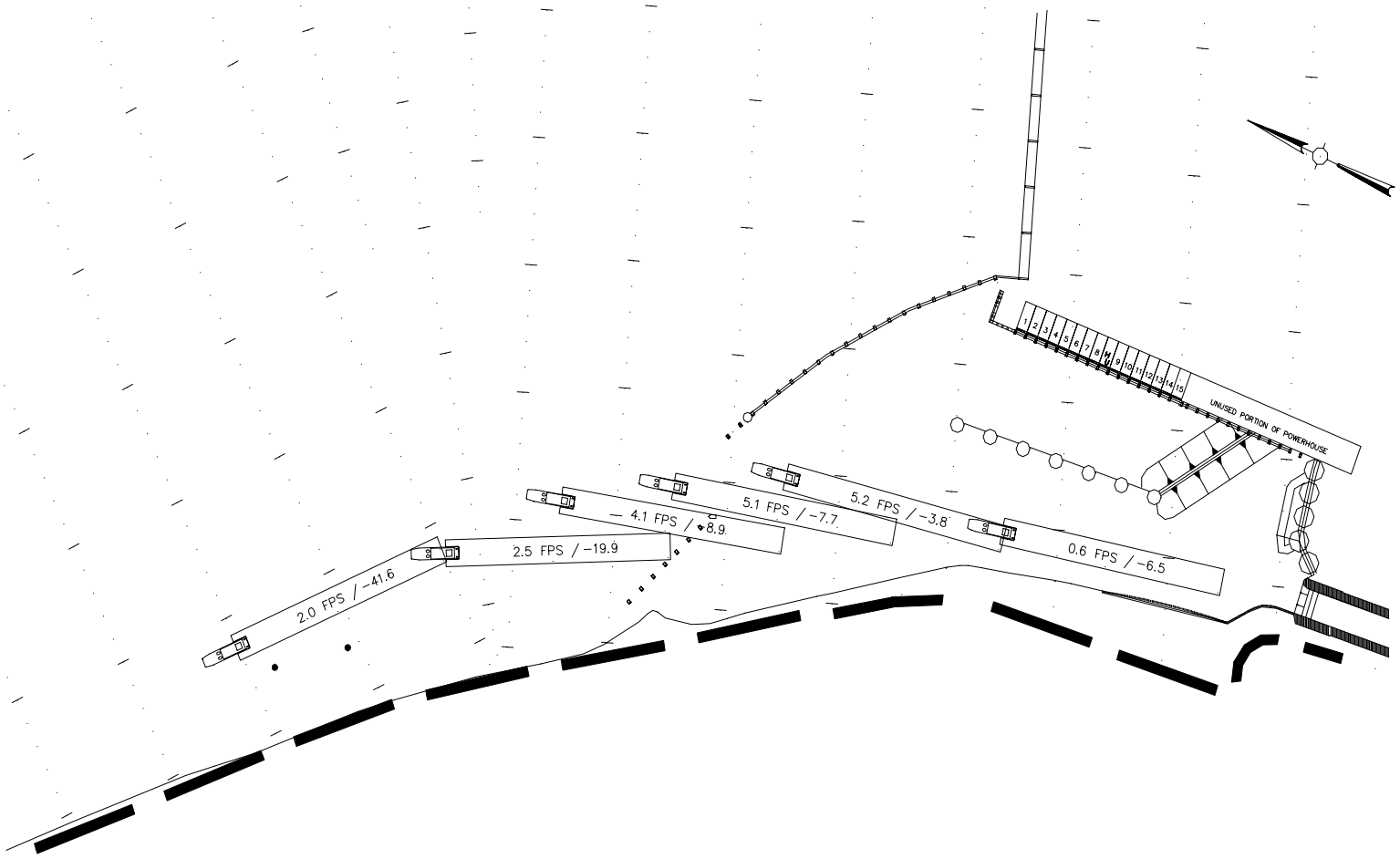
METER VELOCITIES

PLAN C-1

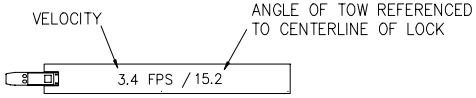
DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

19-116A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

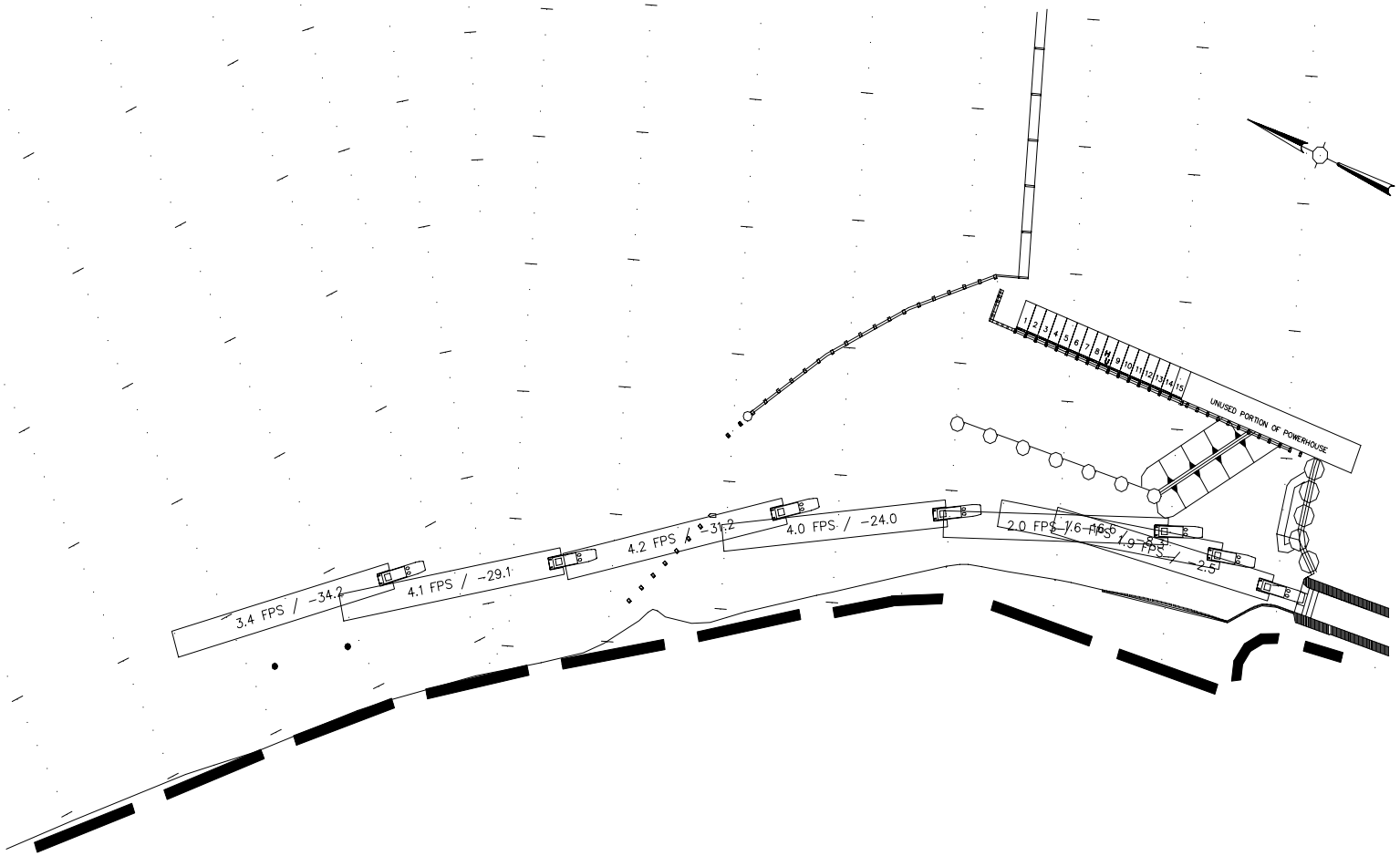
TOW PATHS

PLAN C

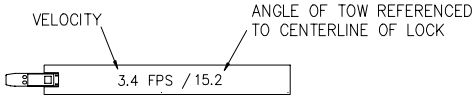
DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

19-119A



LEGEND



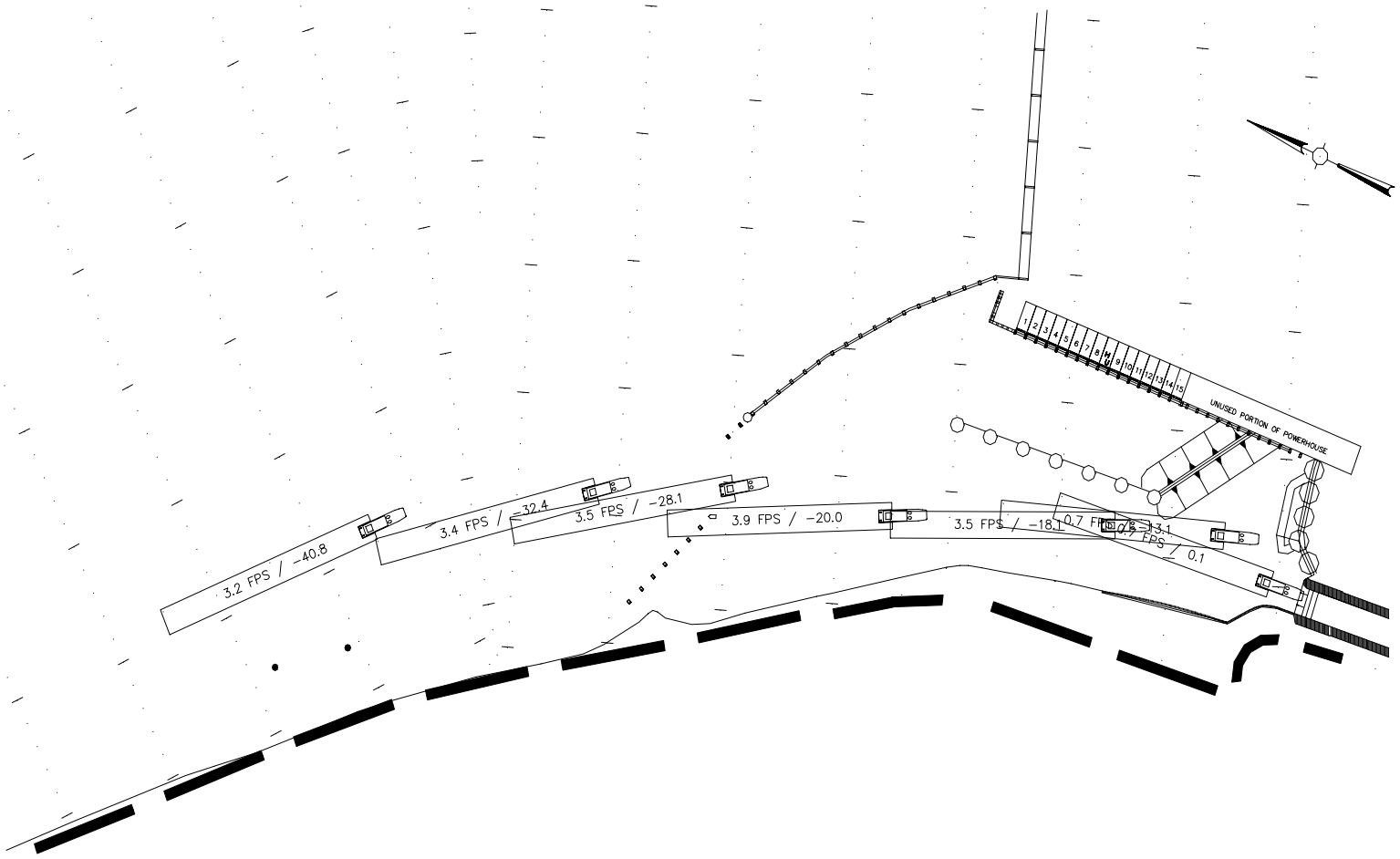
SCALES

TOW PATHS

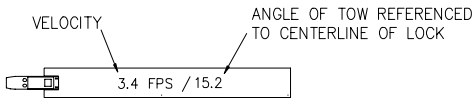
PLAN C

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

19–120A



LEGEND



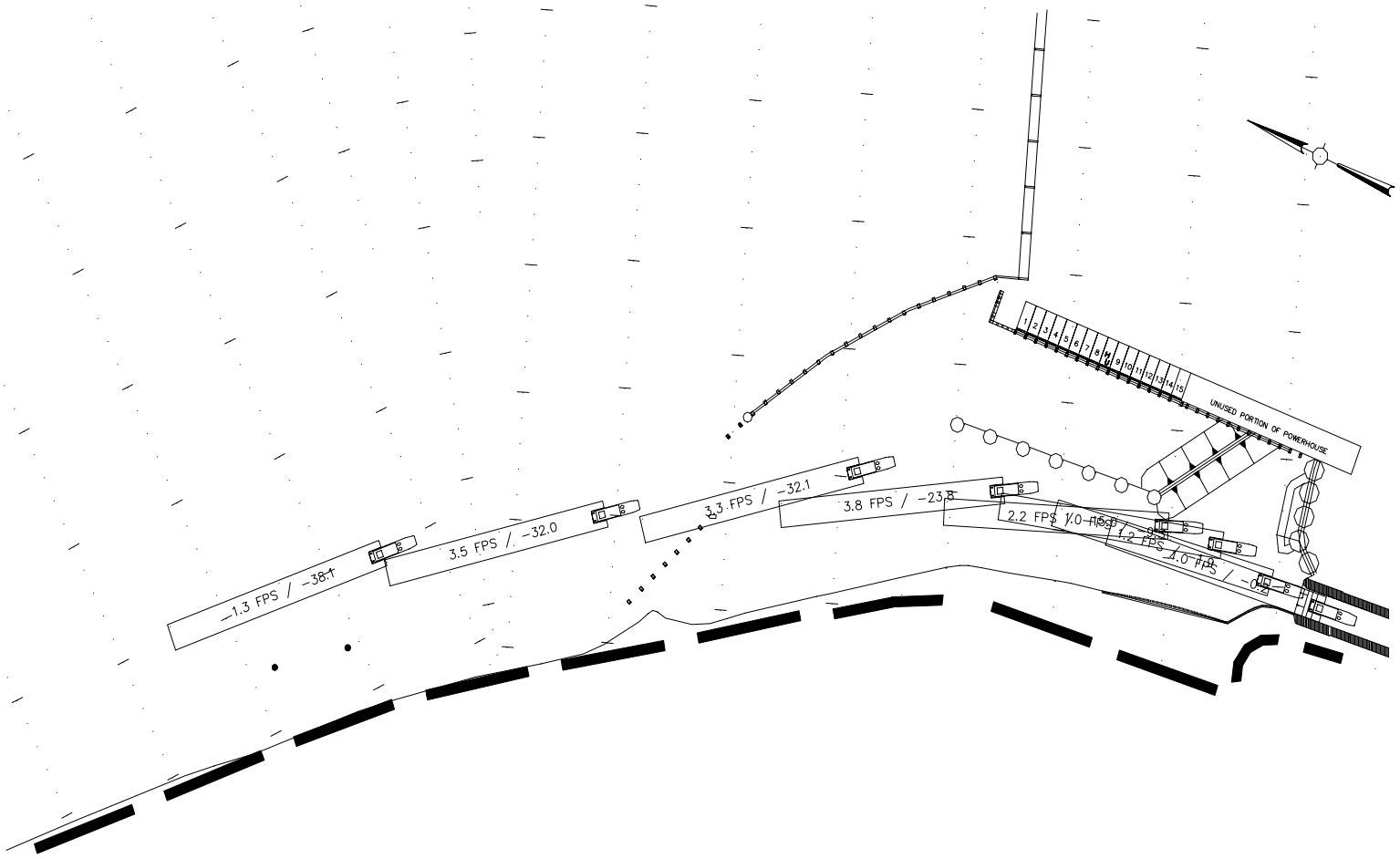
SCALES

TOW PATHS

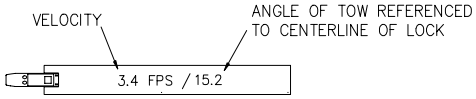
PLAN C

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

19-121A



LEGEND



SCALES

TOW PATHS

PLAN C

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT

LD19-114

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

→● VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

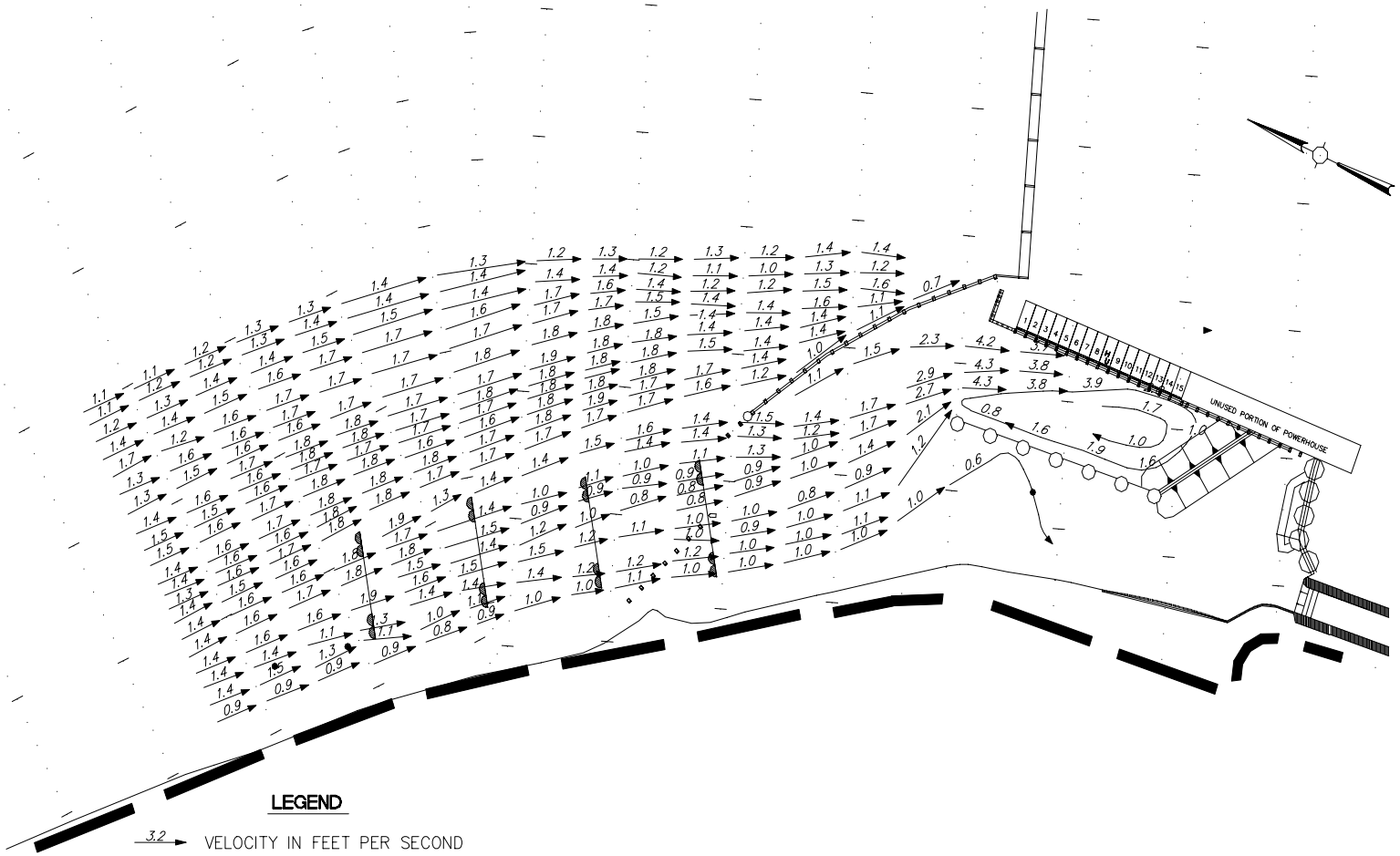
VELOCITIES AND CURRENT DIRECTIONS

PLAN C-1

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-113



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

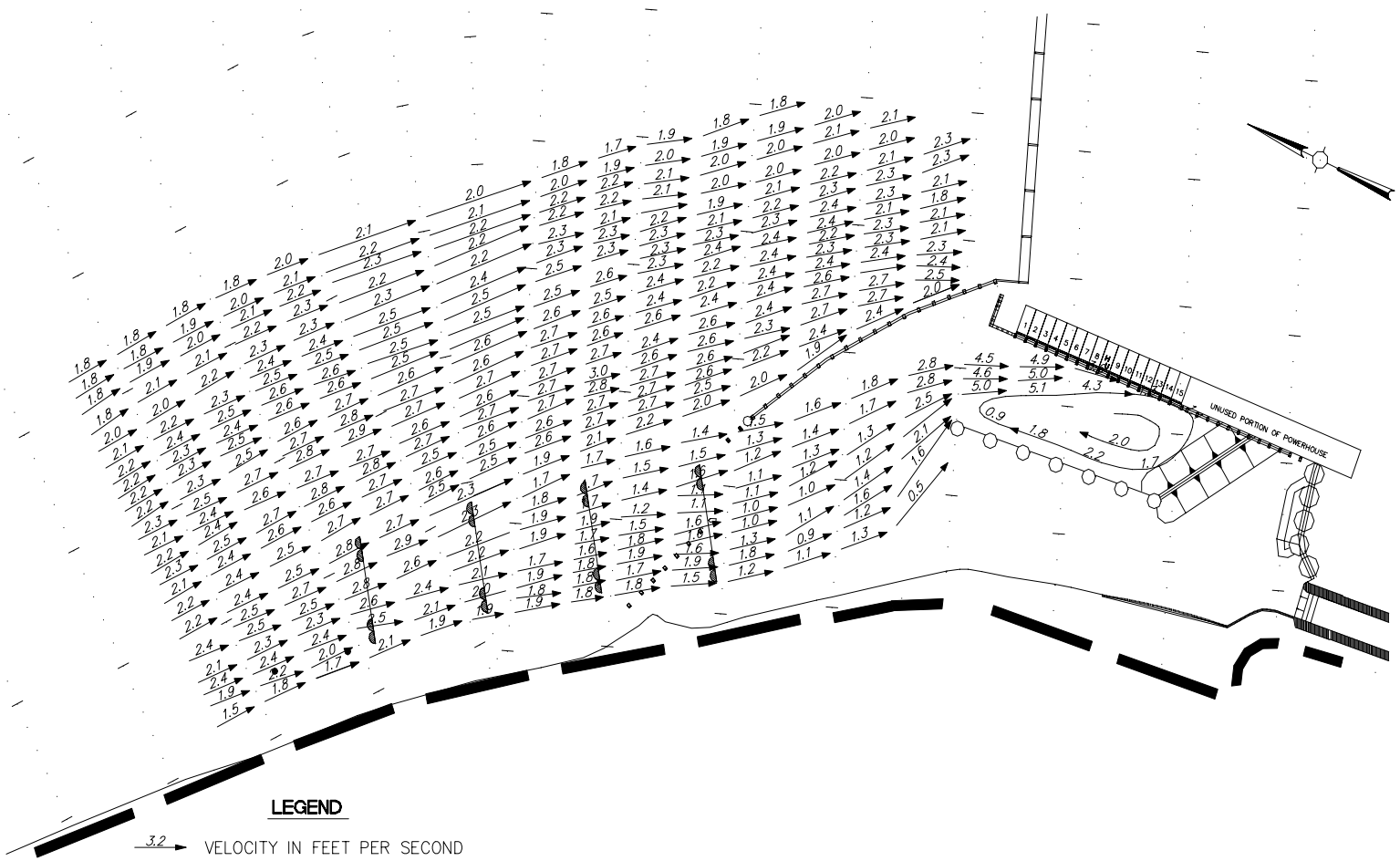
MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PLAN C-1

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

→● VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

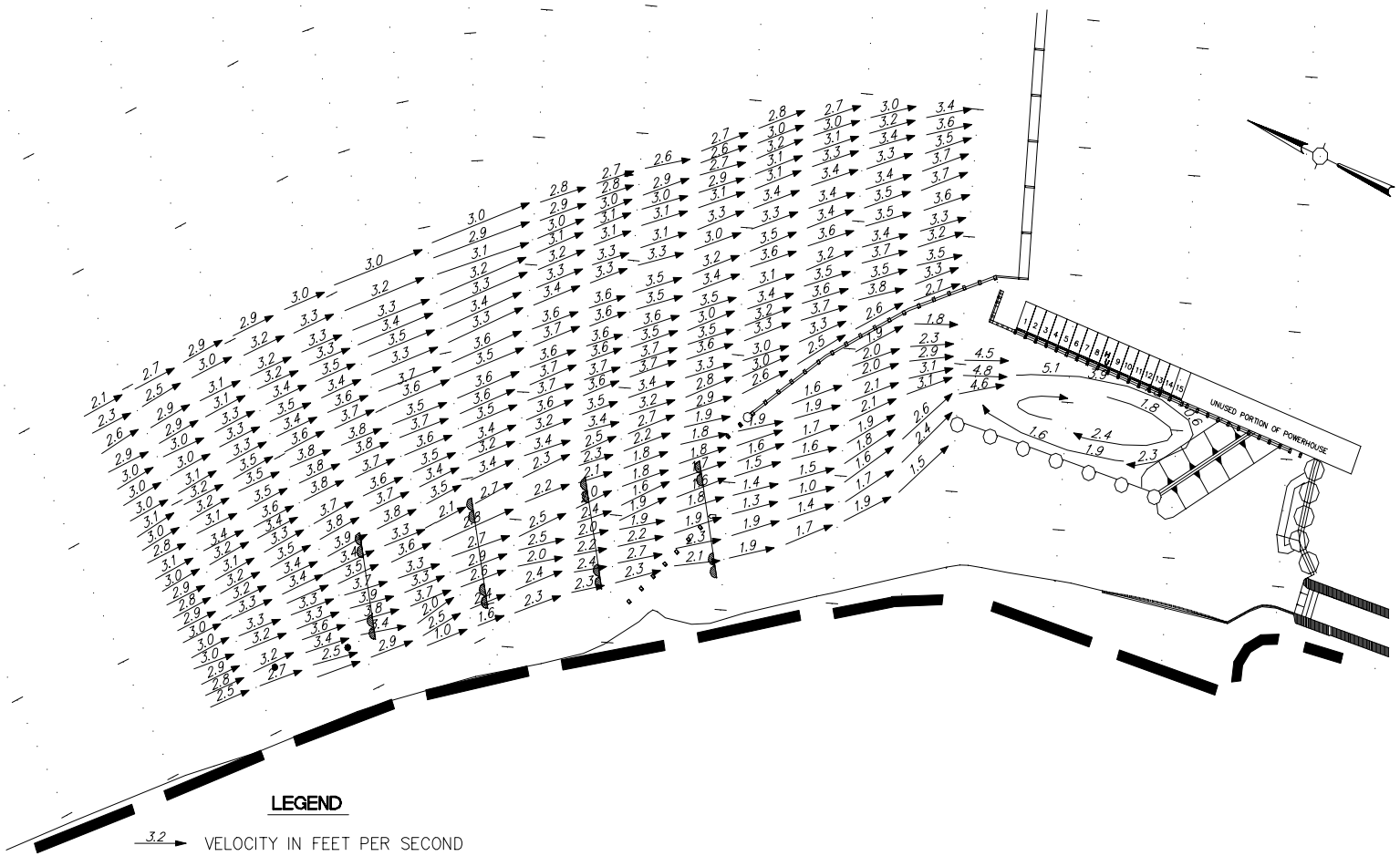
VELOCITIES AND CURRENT DIRECTIONS

PLAN C-1

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-111



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

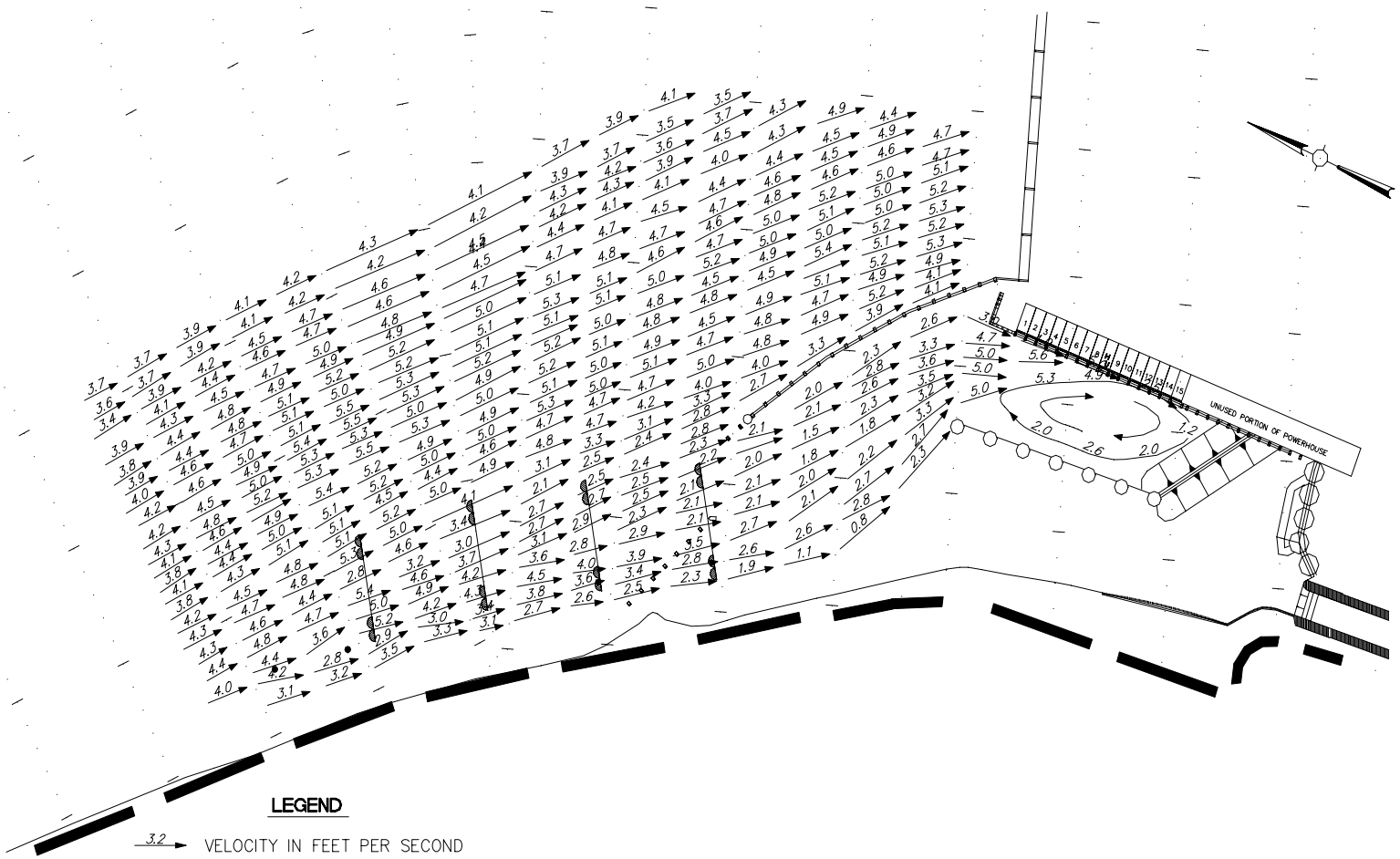
VELOCITIES AND CURRENT DIRECTIONS

PLAN C-1

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

ld19-110



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

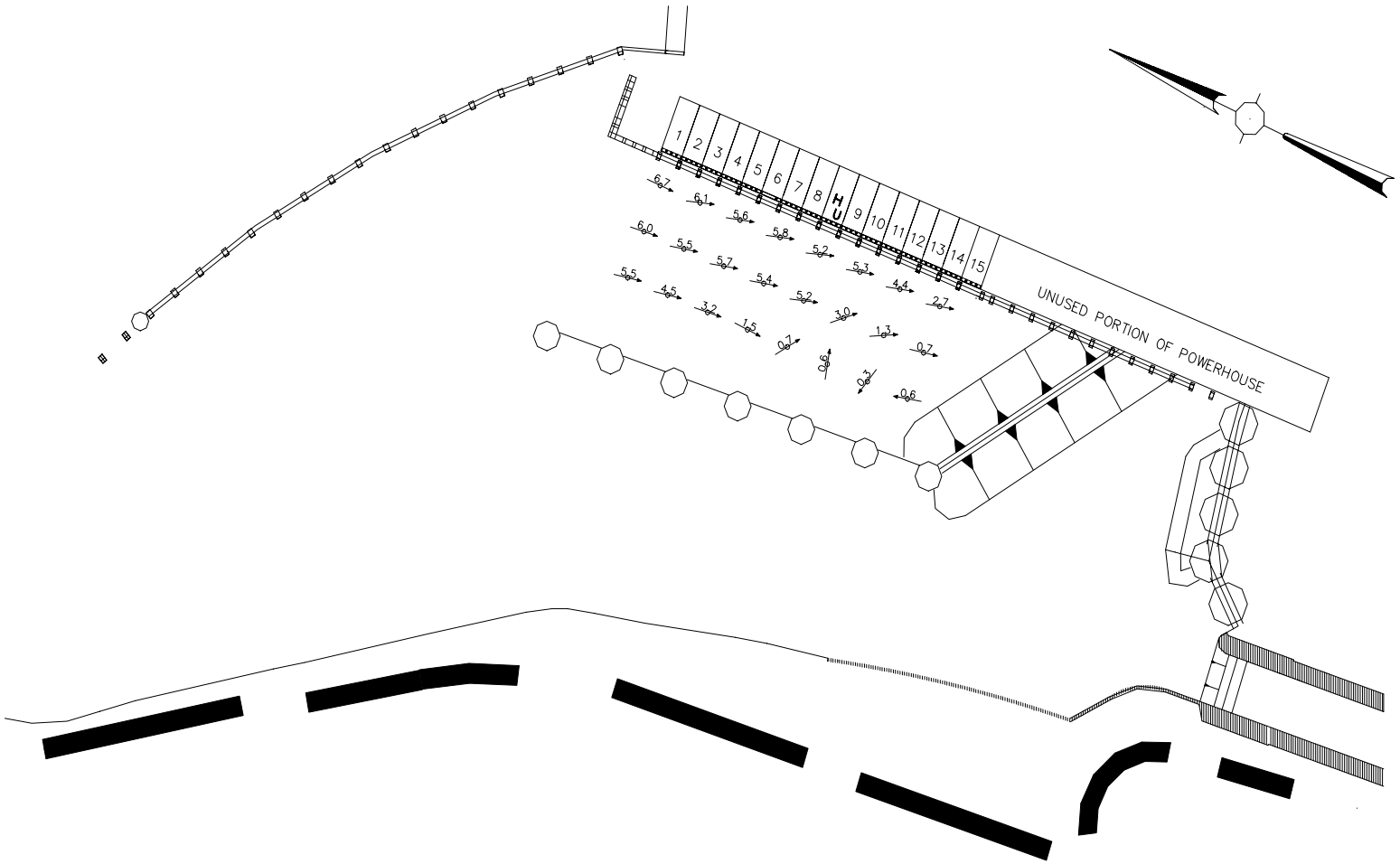
VELOCITIES AND CURRENT DIRECTIONS

PLAN C-1

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19-108



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

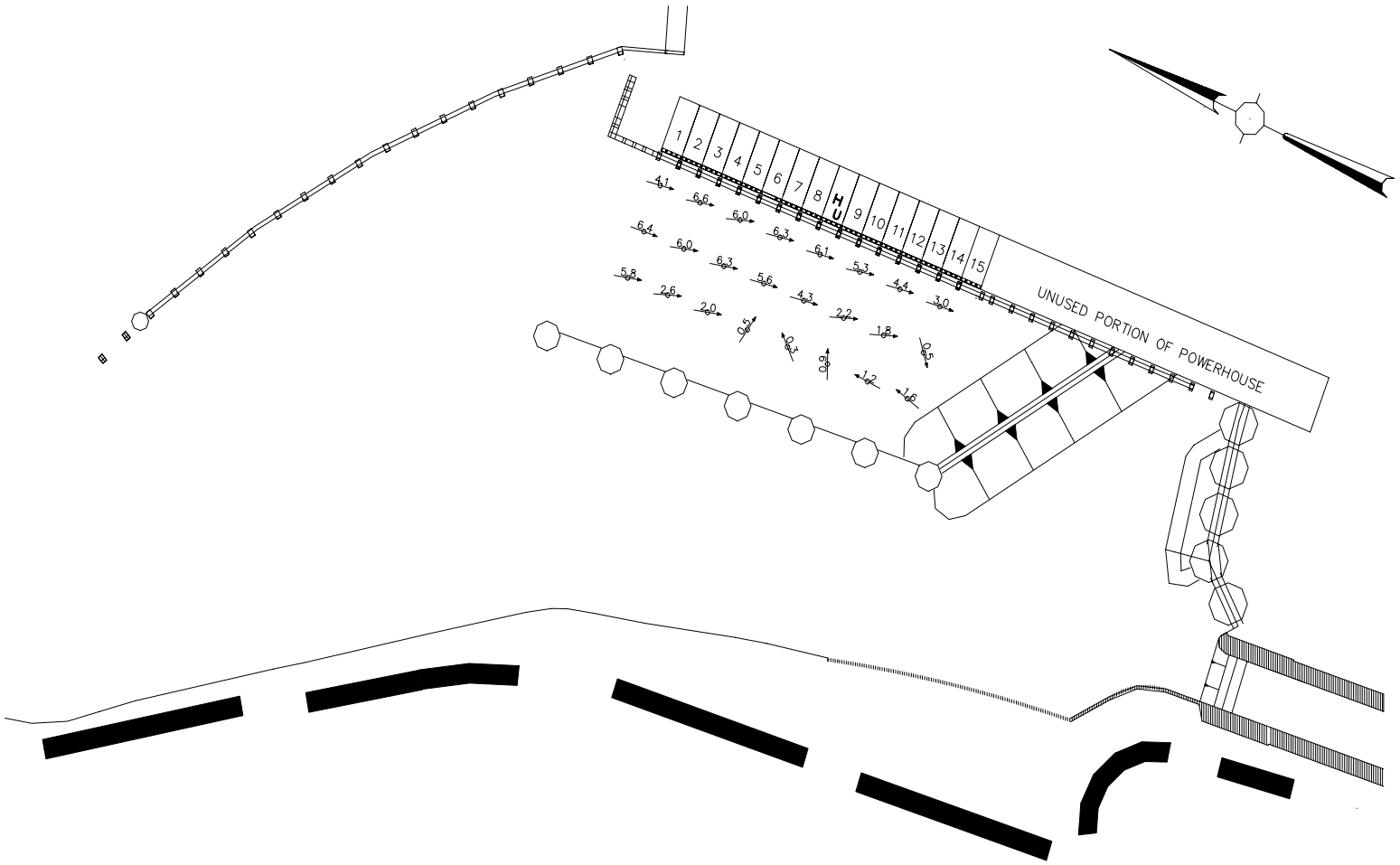
MODEL 5 0 5

METER VELOCITIES

PLAN C-1

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND

NOTE: METER VELOCITIES RECORDED AT SIXTY PERCENT OF THE DEPTH

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

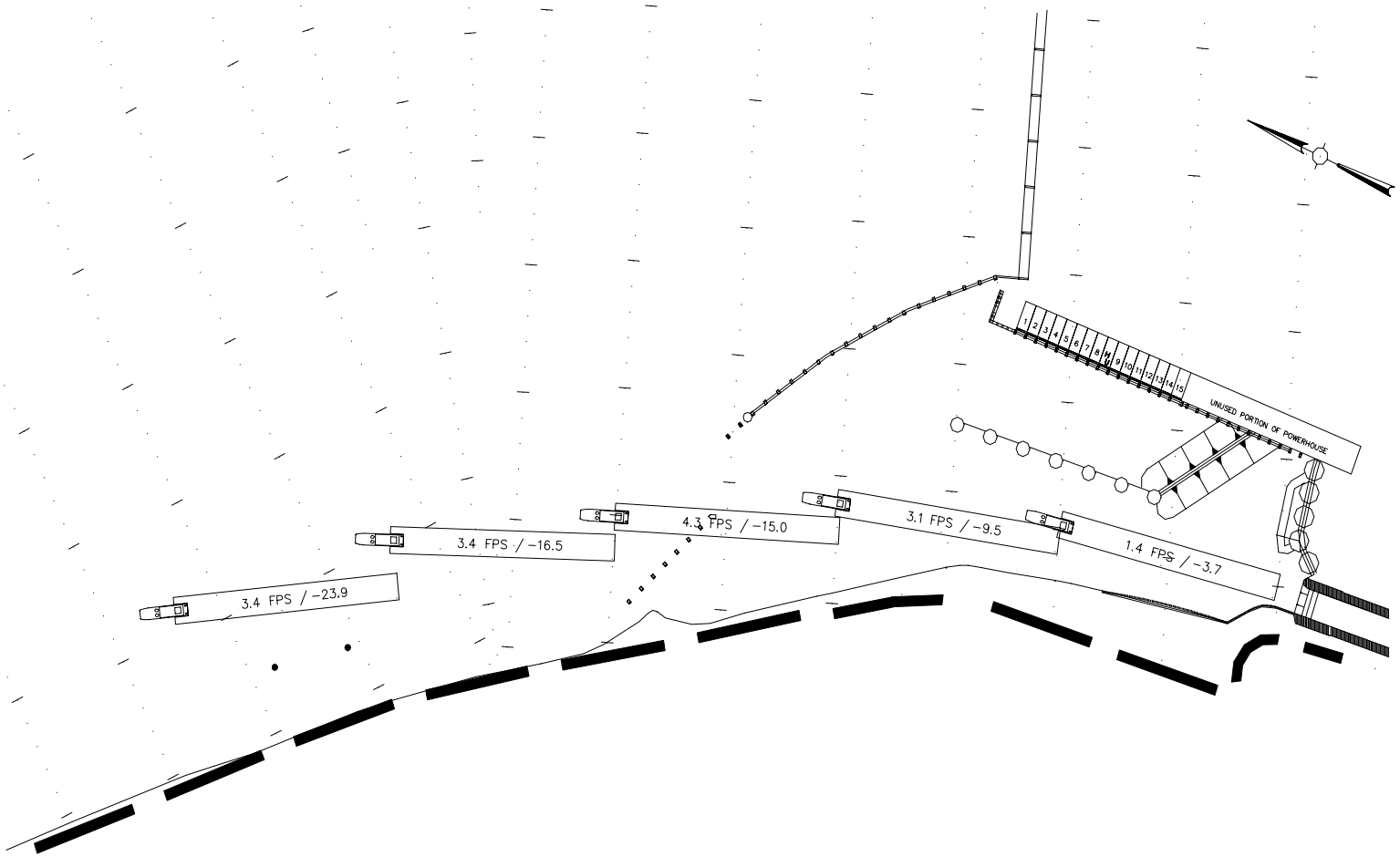
METER VELOCITIES

PLAN C-1

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

19-126A



LEGEND

VELOCITY

ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK

3.4 FPS / 15.2

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

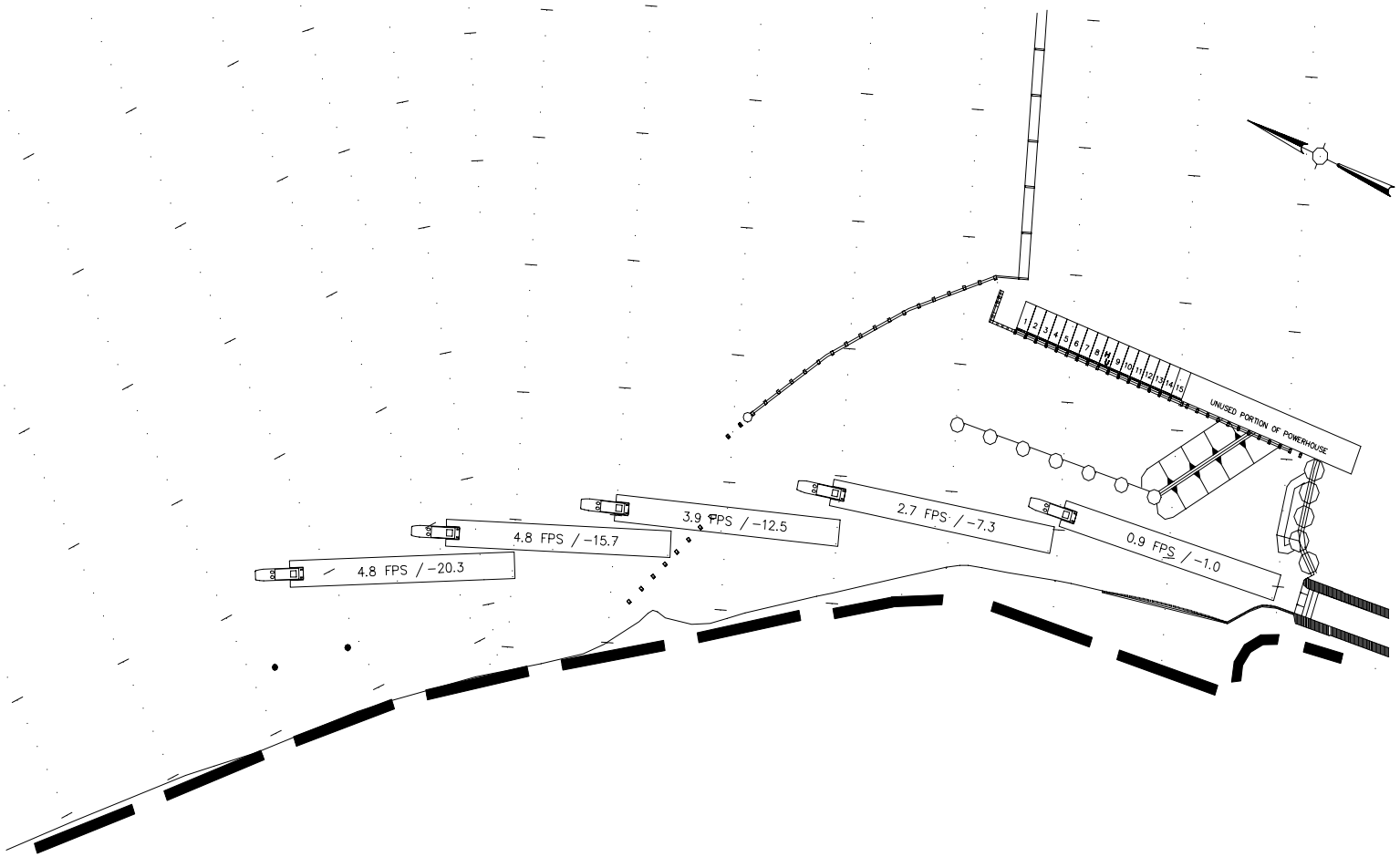
TOW PATHS

PLAN C-1

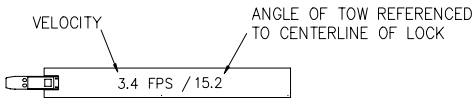
DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

19-127A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

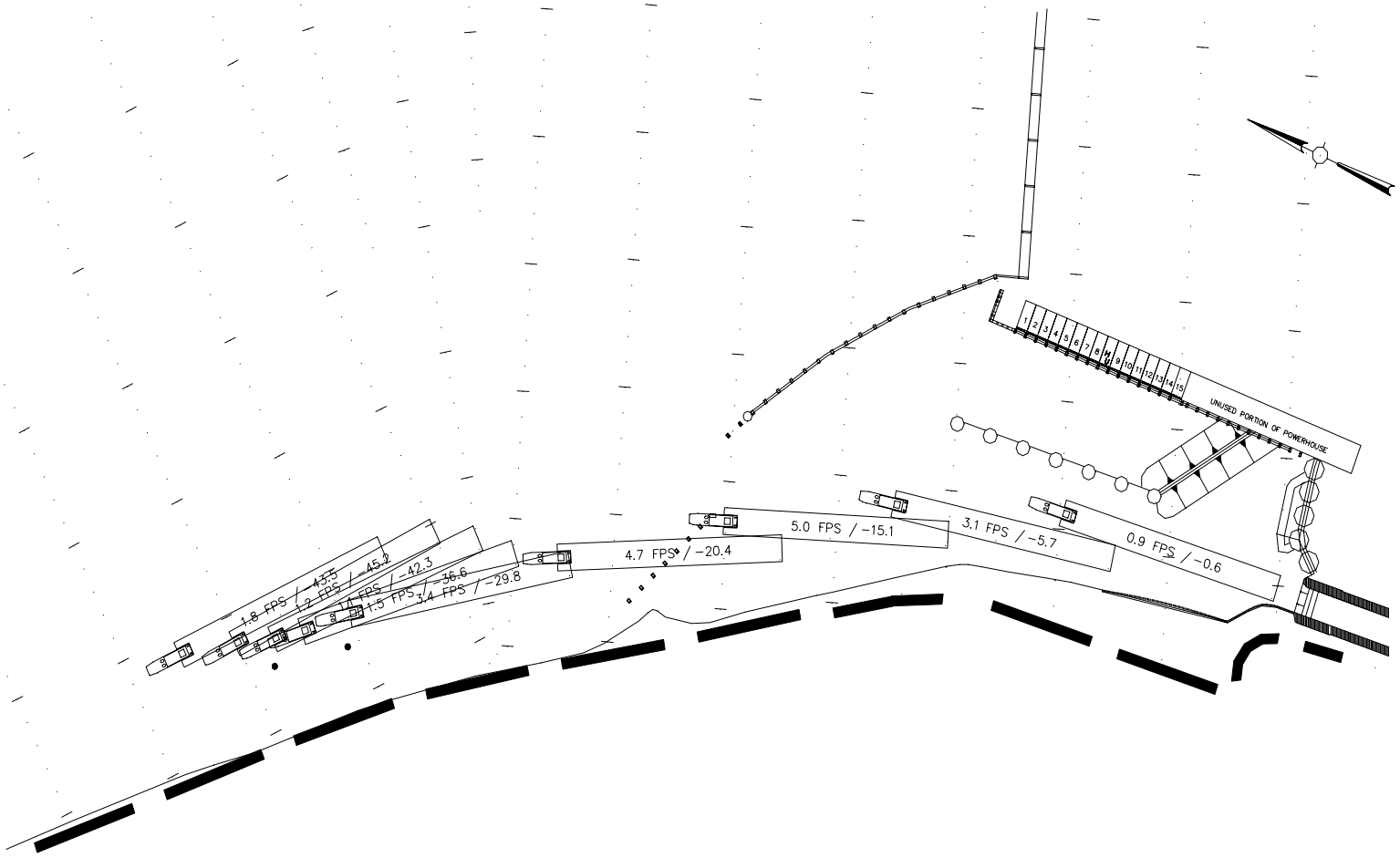
TOW PATHS

PLAN C-1

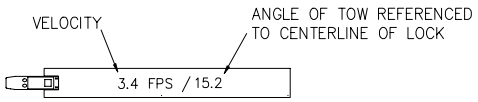
DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

19-128A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

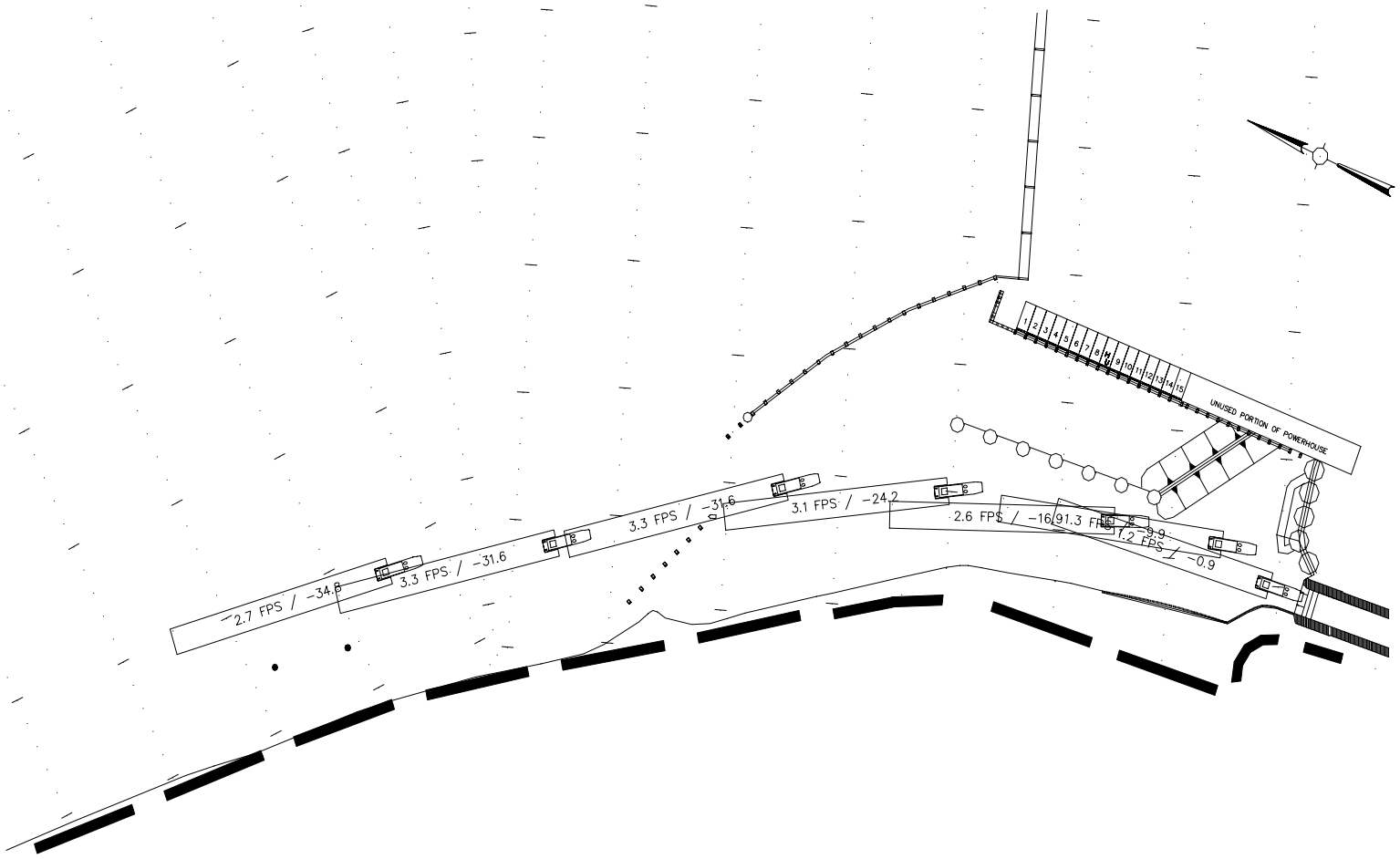
TOW PATHS

PLAN C-1

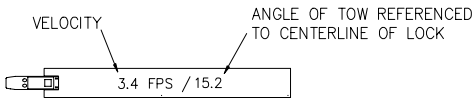
DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

19-123A



LEGEND



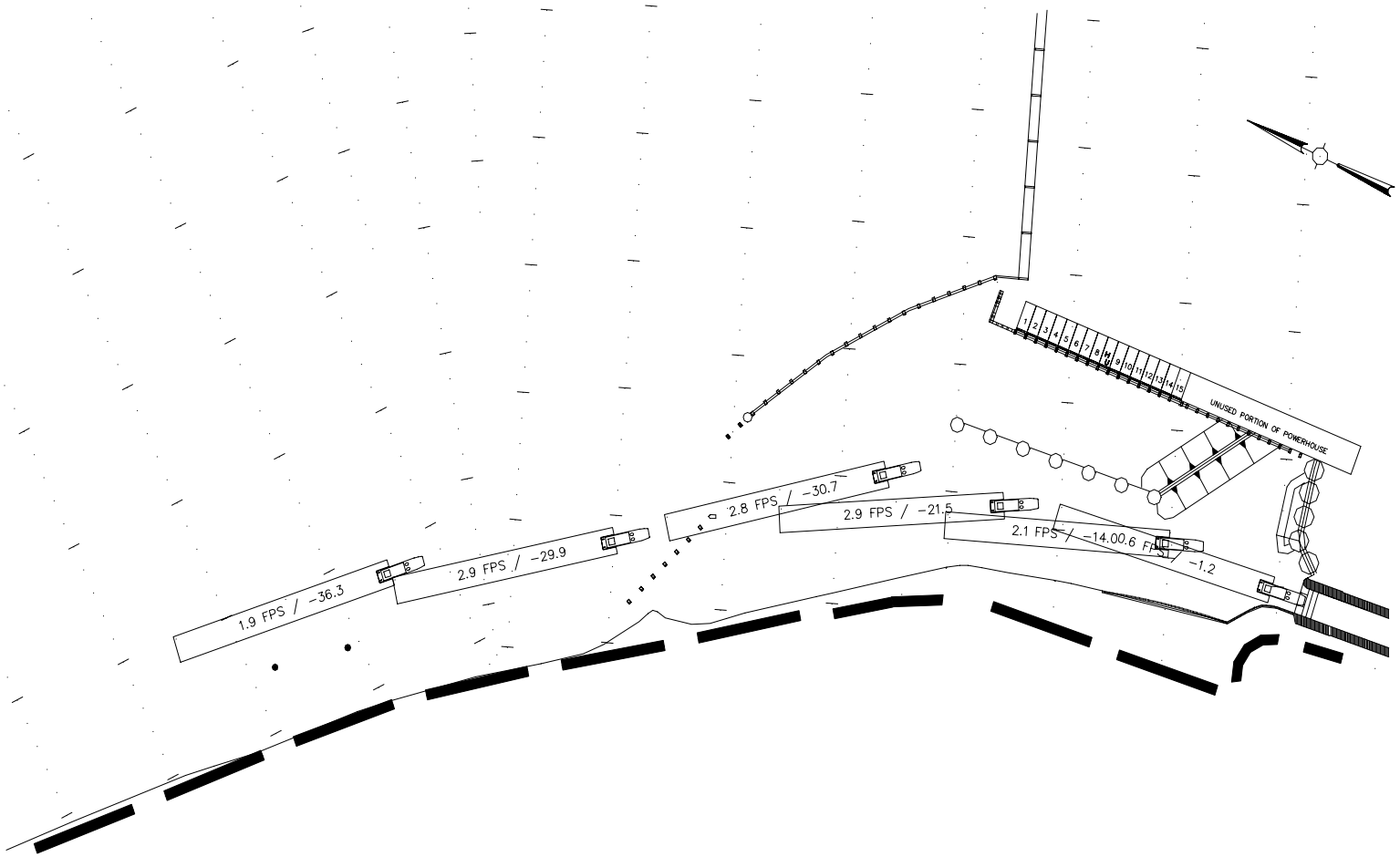
SCALES

TOW PATHS

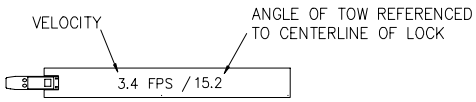
PLAN C-1

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

19-124A



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

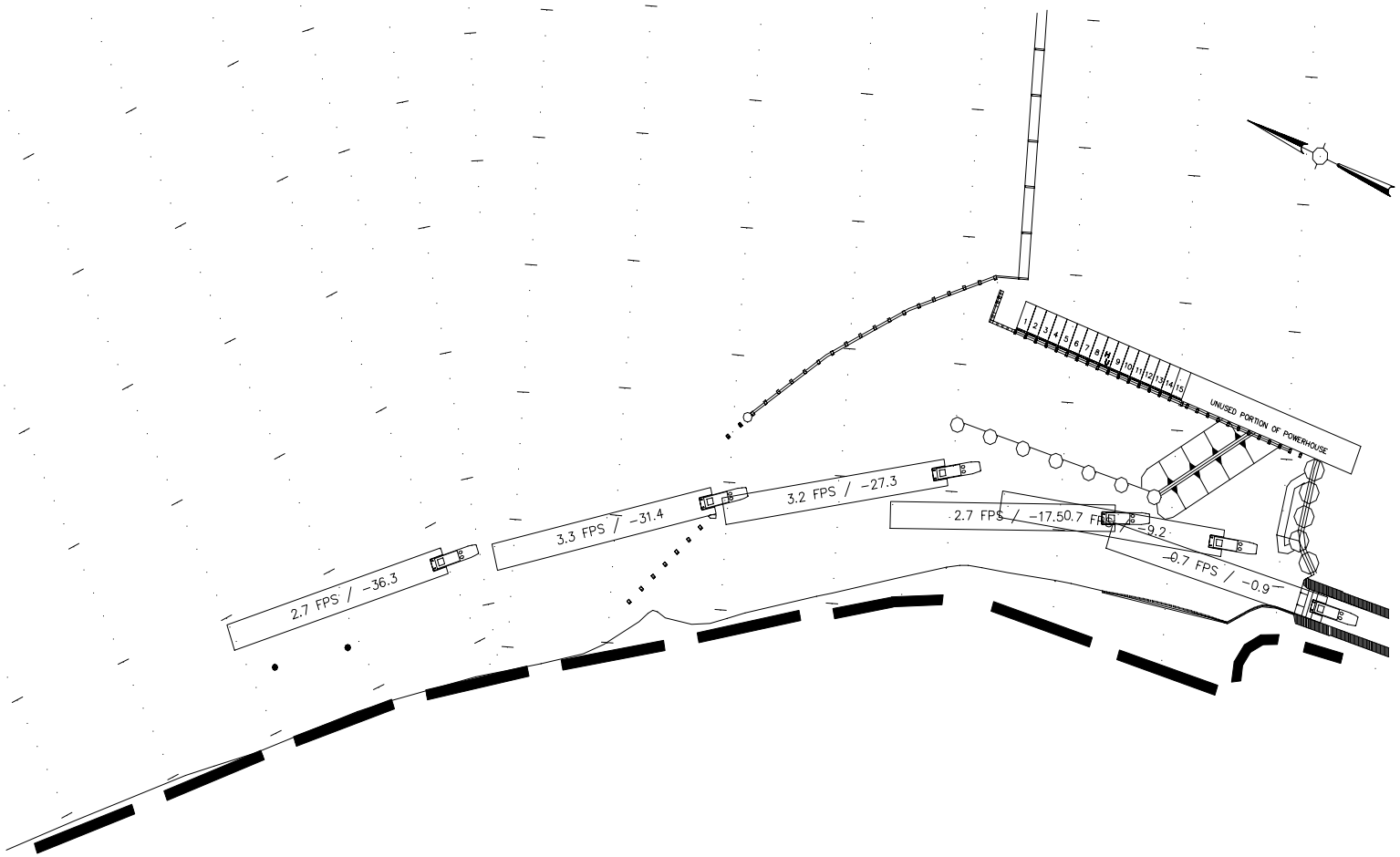
TOW PATHS

PLAN C-1

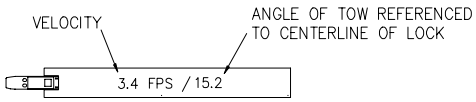
DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

19-125A



LEGEND

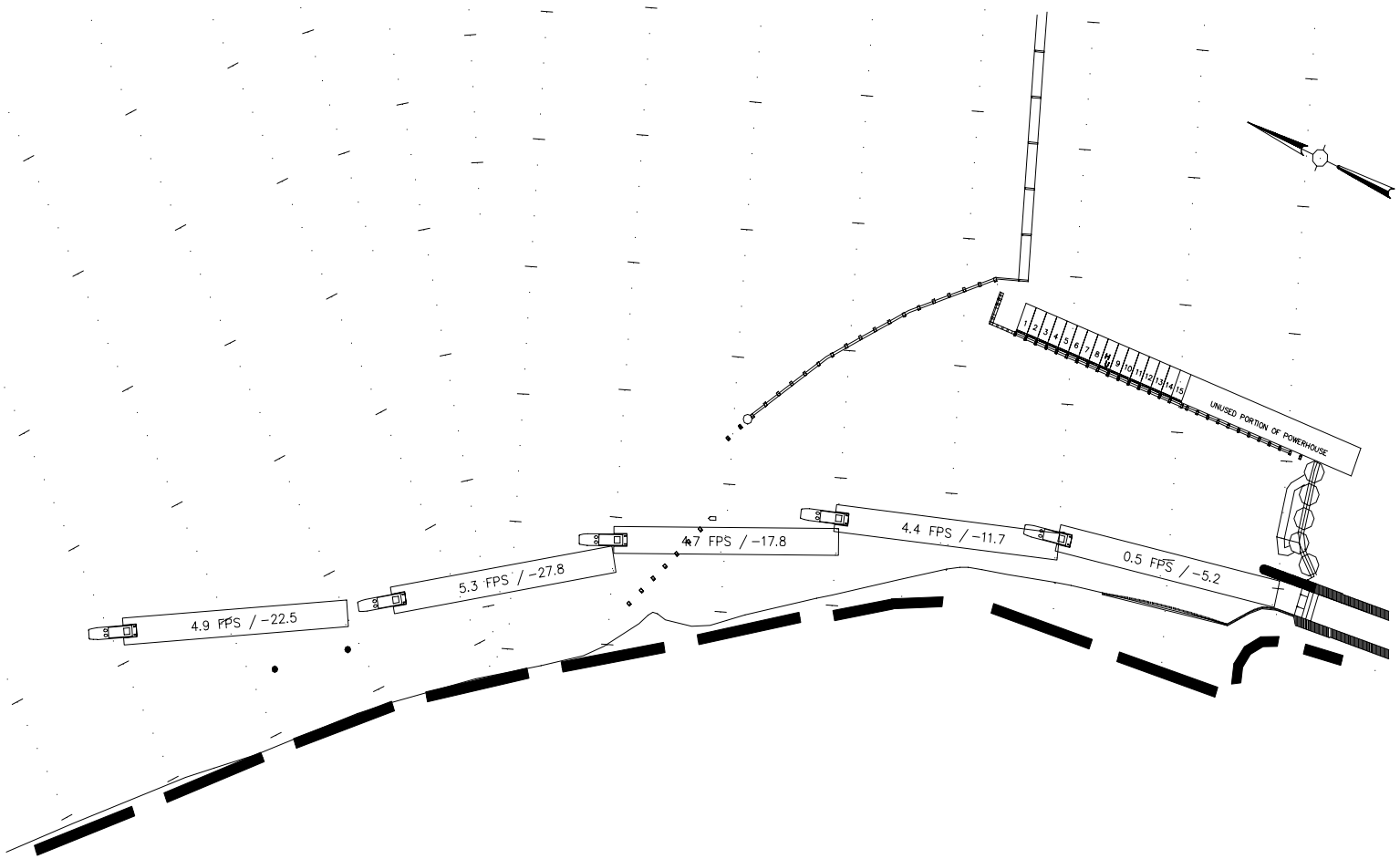


SCALES

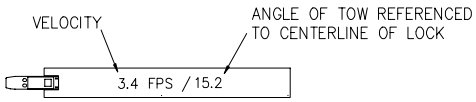
TOW PATHS

PLAN C-1

DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND

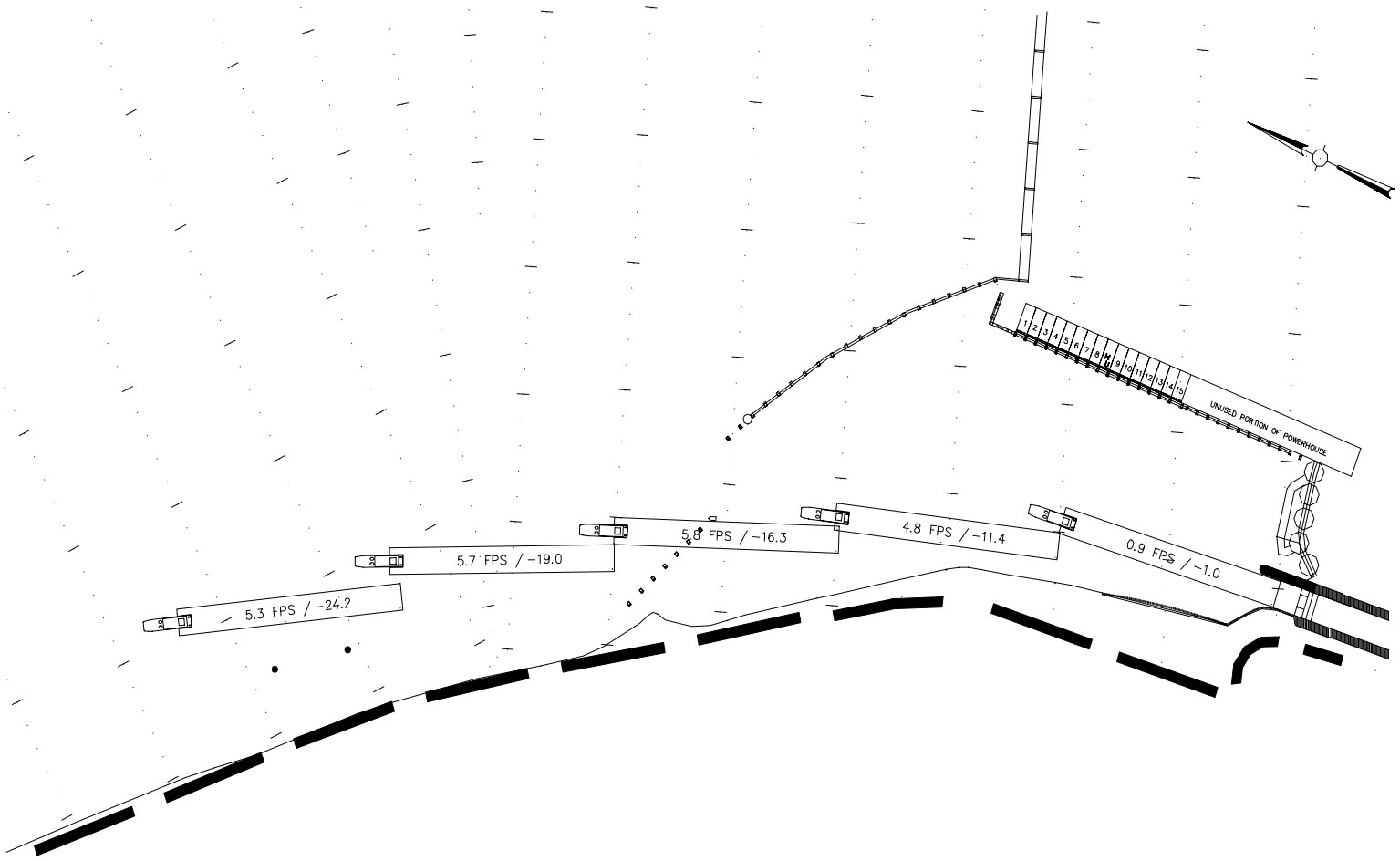


SCALES

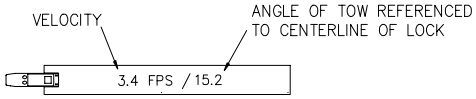
TOW PATHS

PLAN D

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT



LEGEND



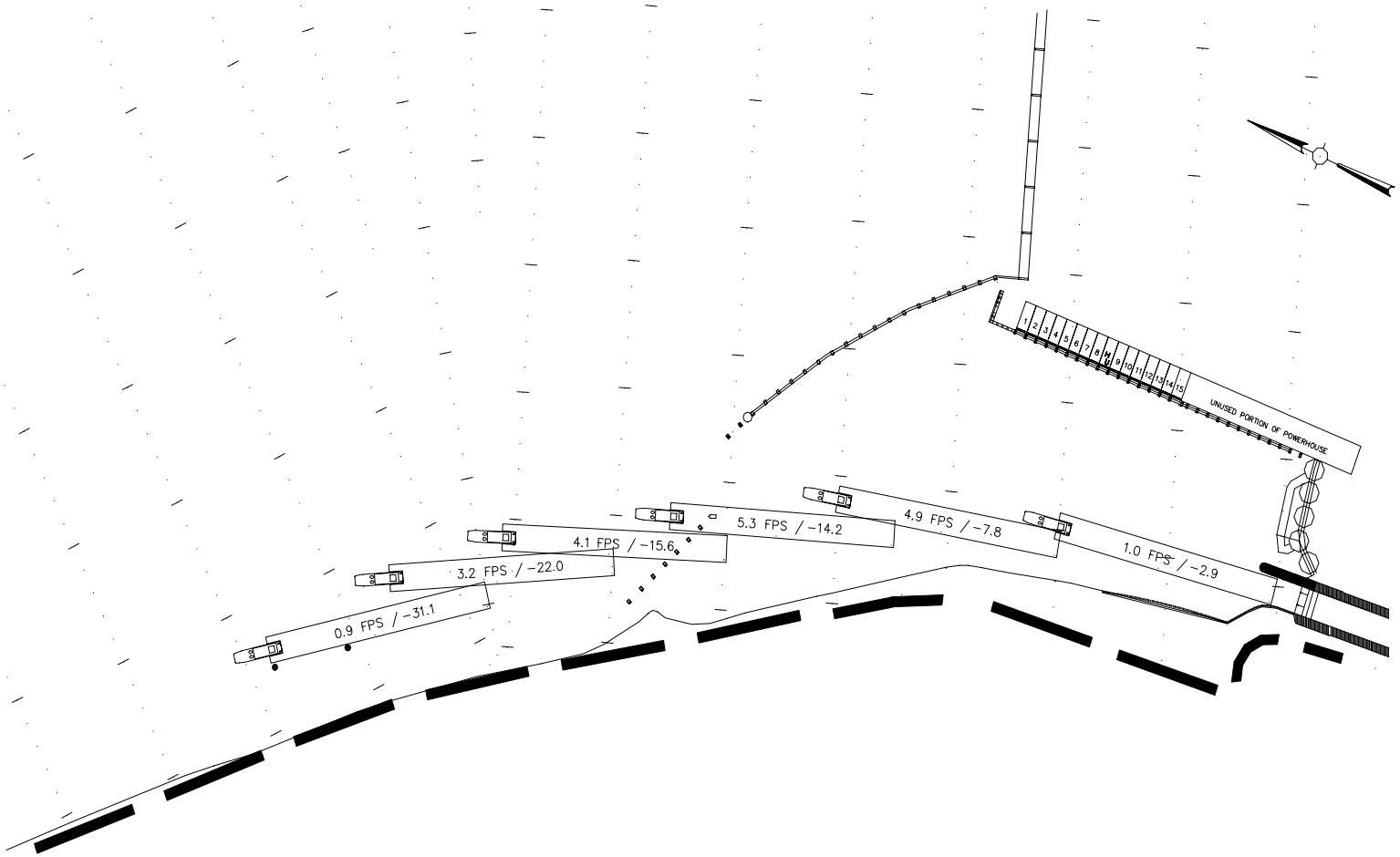
SCALES

TOW PATHS

PLAN D

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

LD19-132



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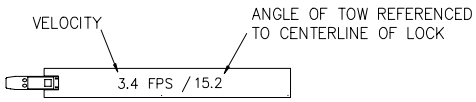


SCALES

PROTOTYPE 500 0 500

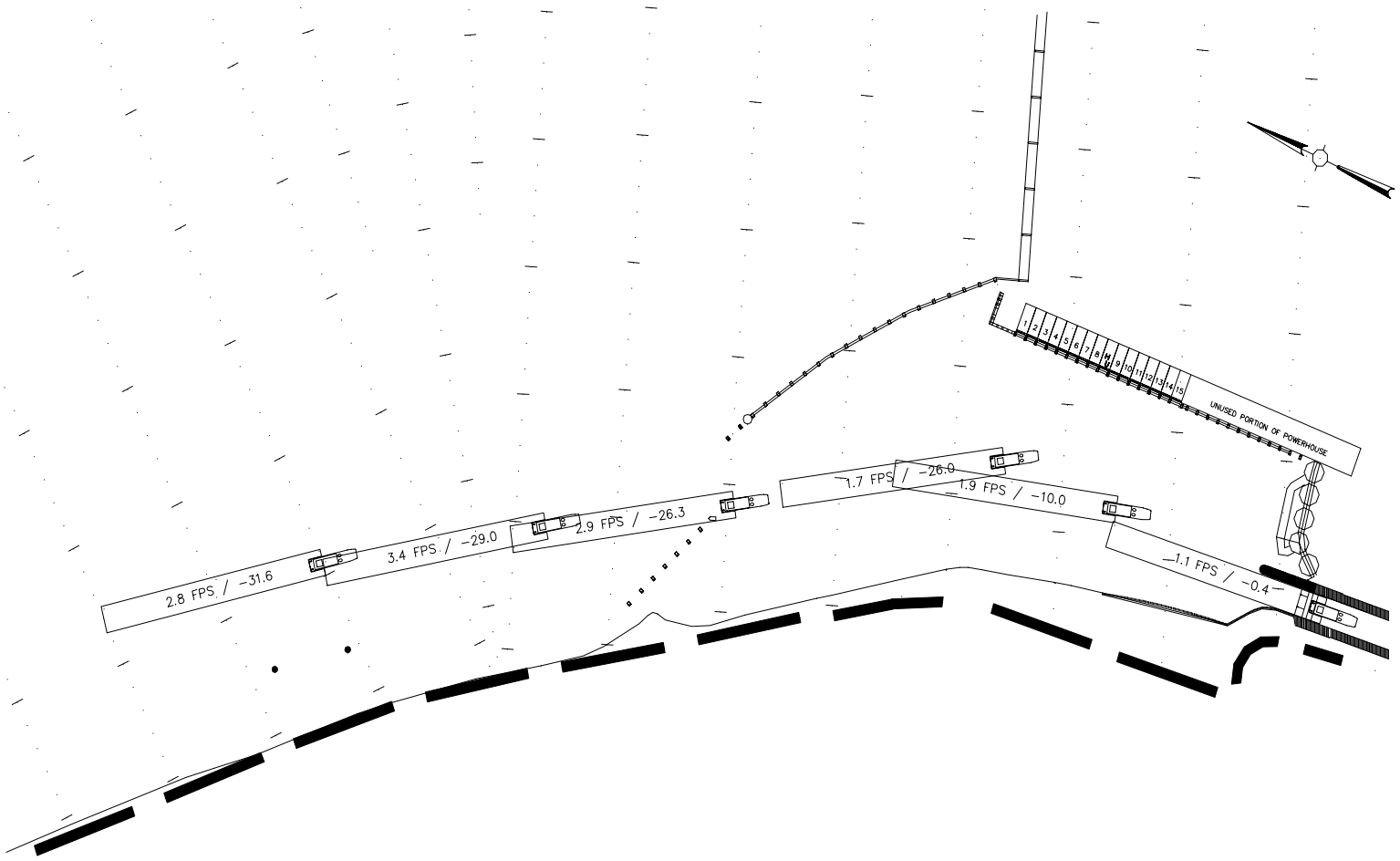
MODEL 5 0 5

TOW PATHS

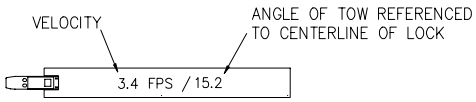
PLAN D

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT



LEGEND



SCALES

TOW PATHS

PLAN D

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

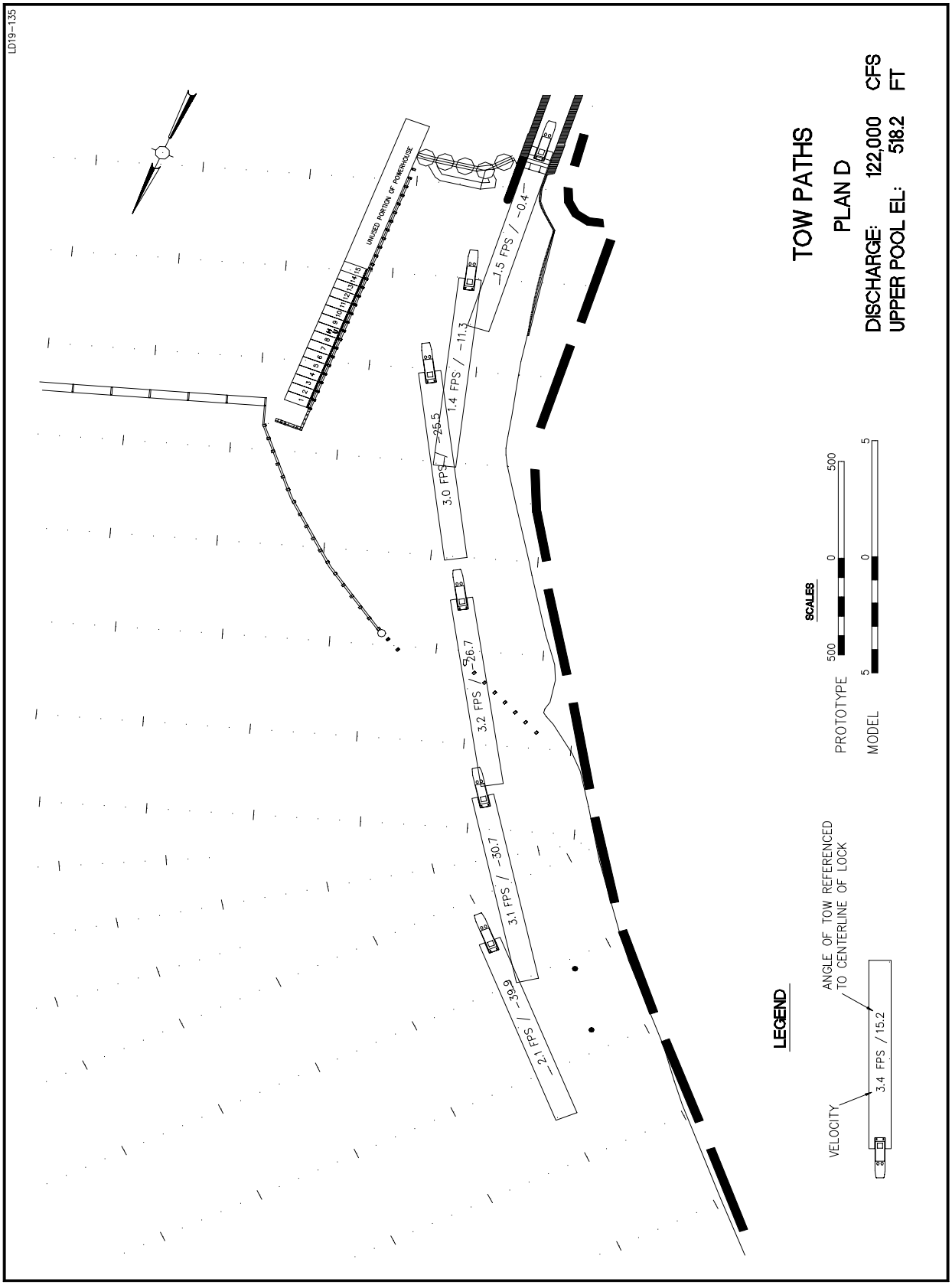
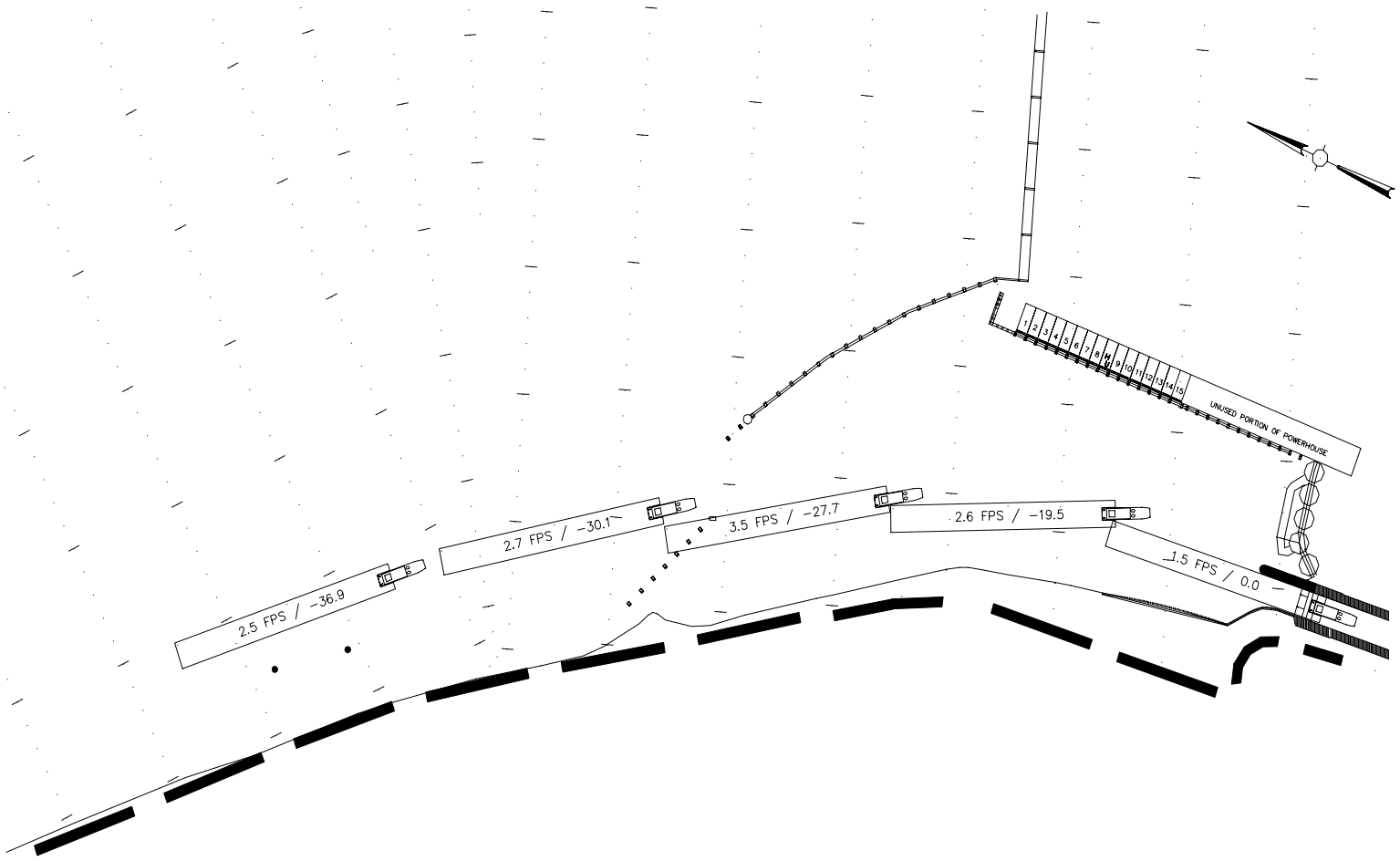

LD19-135
TOW PATHS
PLAN D
DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT
UNUSED PORTION OF POWERHOUSE
1.5 FPS / -0.4
1.4 FPS / -11.3
3.0 FPS / -25.5
3.2 FPS / -26.7
3.1 FPS / -30.7
2.1 FPS / -39.9
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
3.4 FPS / 15.2

Plate 100



LEGEND

VELOCITY

ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK

3.4 FPS / 15.2

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

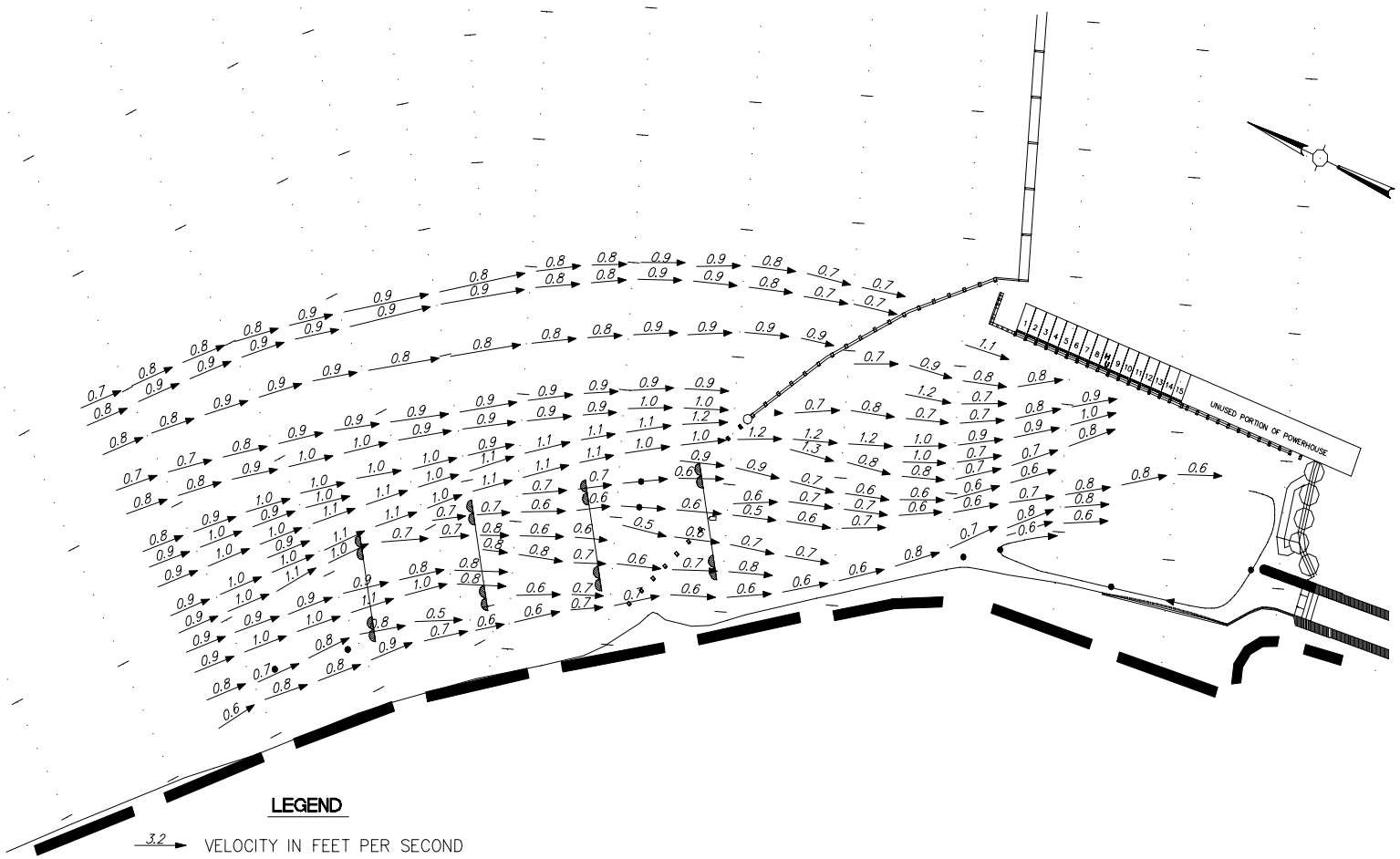
TOW PATHS

PLAN D

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19-153



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

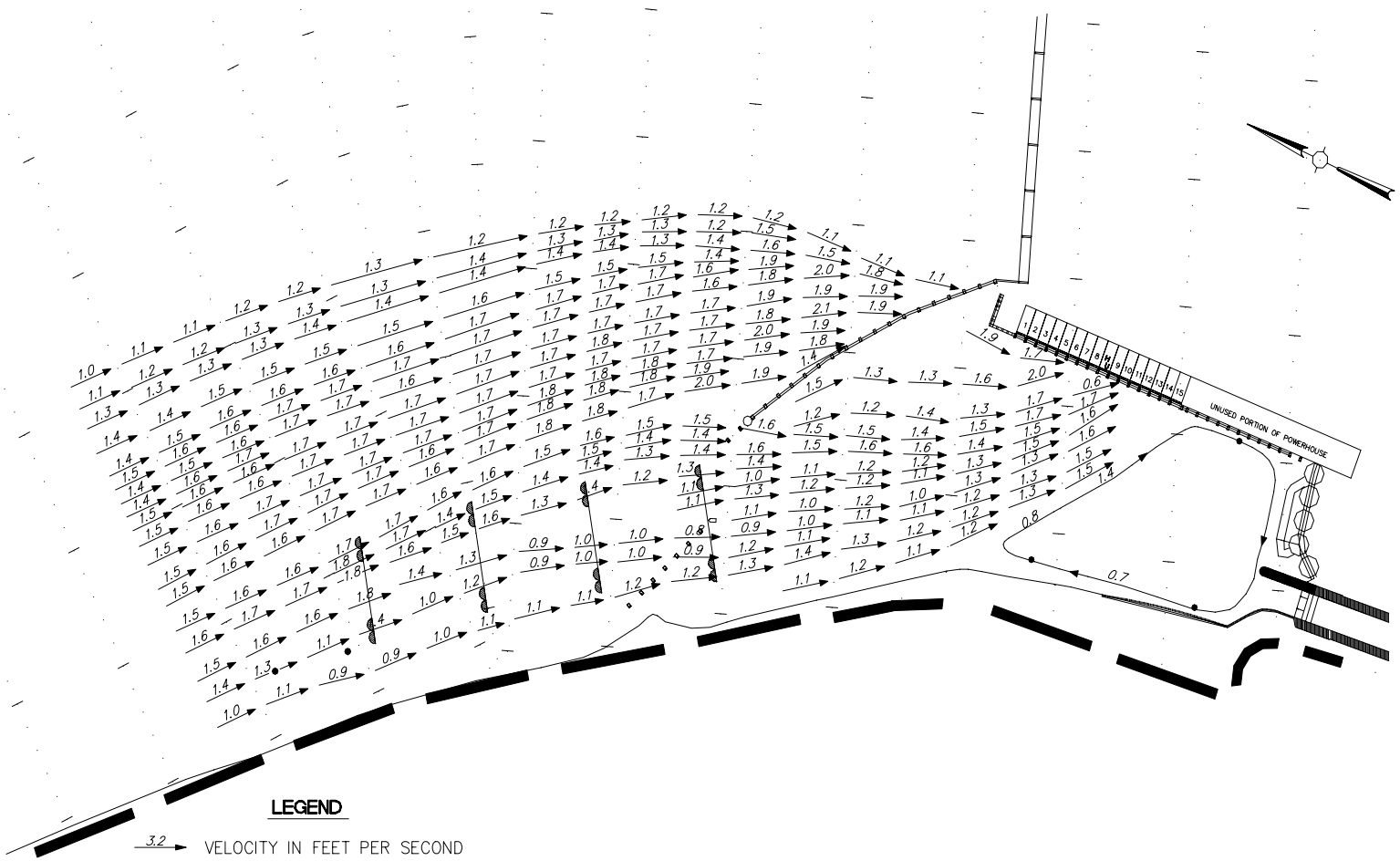
VELOCITIES AND CURRENT DIRECTIONS

PLAN D-1

DISCHARGE: 29,000 CFS

UPPER POOL EL: 518.2 FT

LD19-152



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

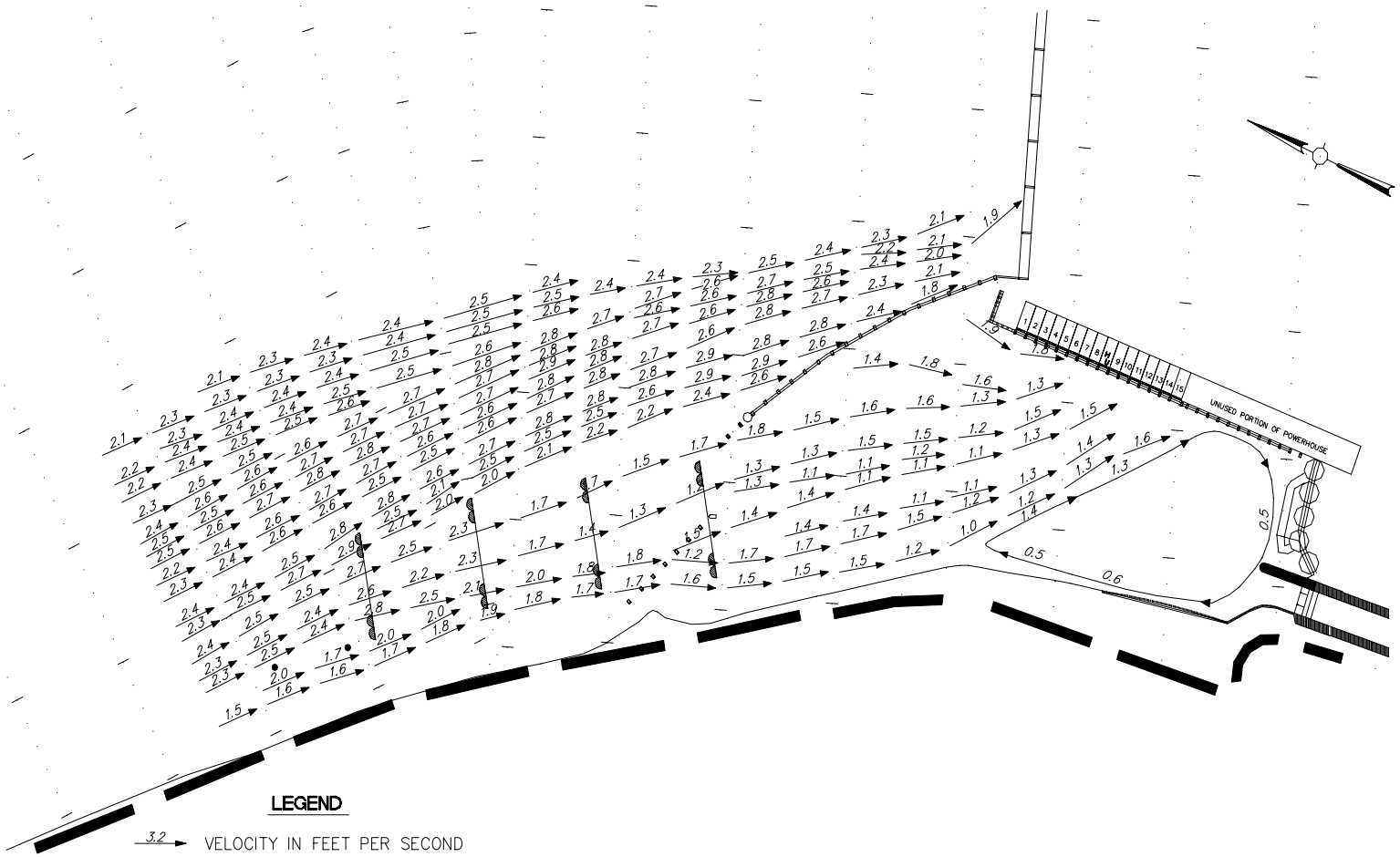
VELOCITIES AND CURRENT DIRECTIONS

PLAN D-1

DISCHARGE: 62,000 CFS

UPPER POOL EL: 518.2 FT

LD19-151



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

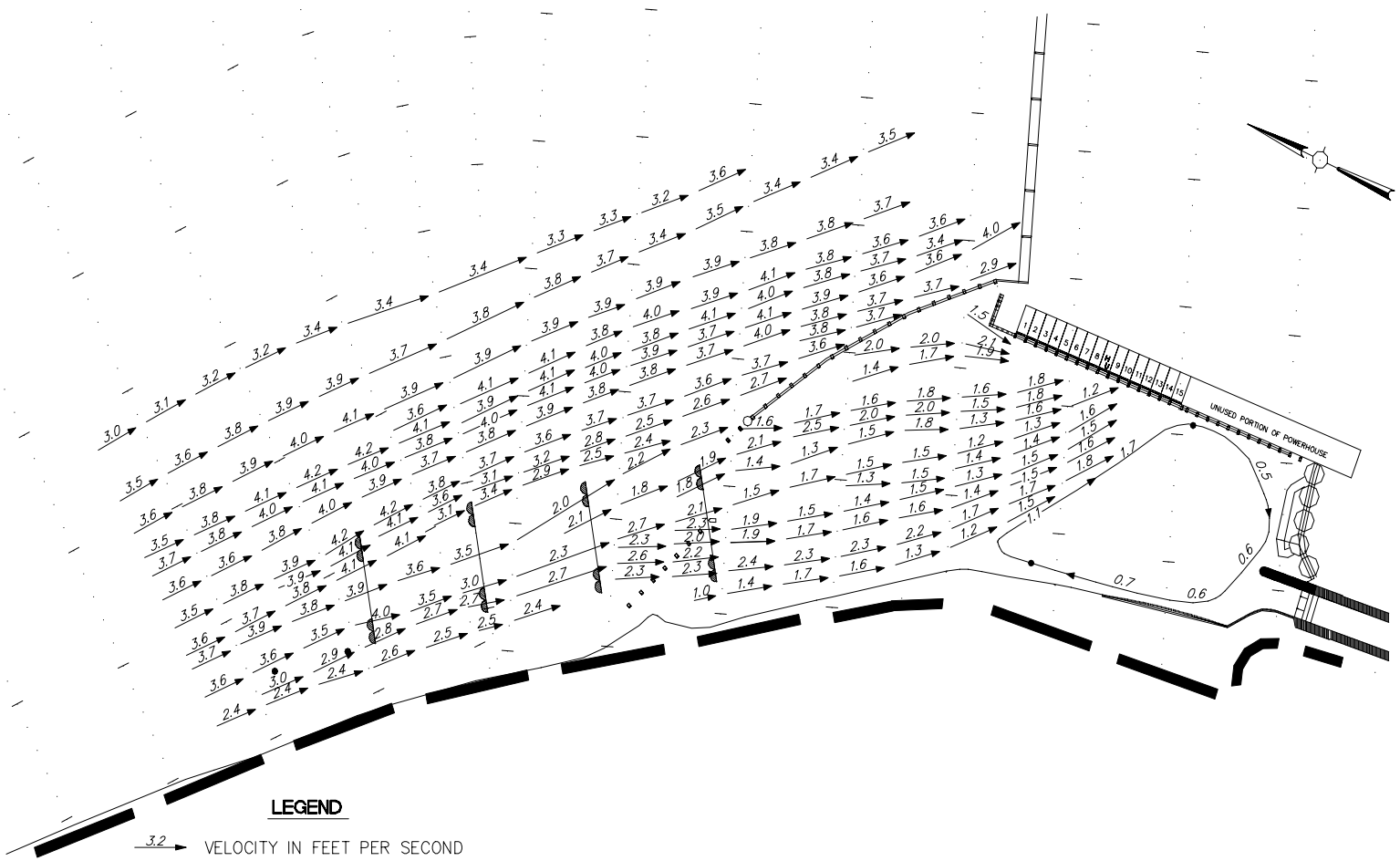
VELOCITIES AND CURRENT DIRECTIONS

PLAN D-1

DISCHARGE: 122,000 CFS

UPPER POOL EL: 518.2 FT

LD19-150



LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

VELOCITIES AND CURRENT DIRECTIONS

PLAN D-1

DISCHARGE: 177,000 CFS

UPPER POOL EL: 518.2 FT

LD19-149

LEGEND

3.2 → VELOCITY IN FEET PER SECOND

—●→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE. (9.0FT)

ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO NGVD

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

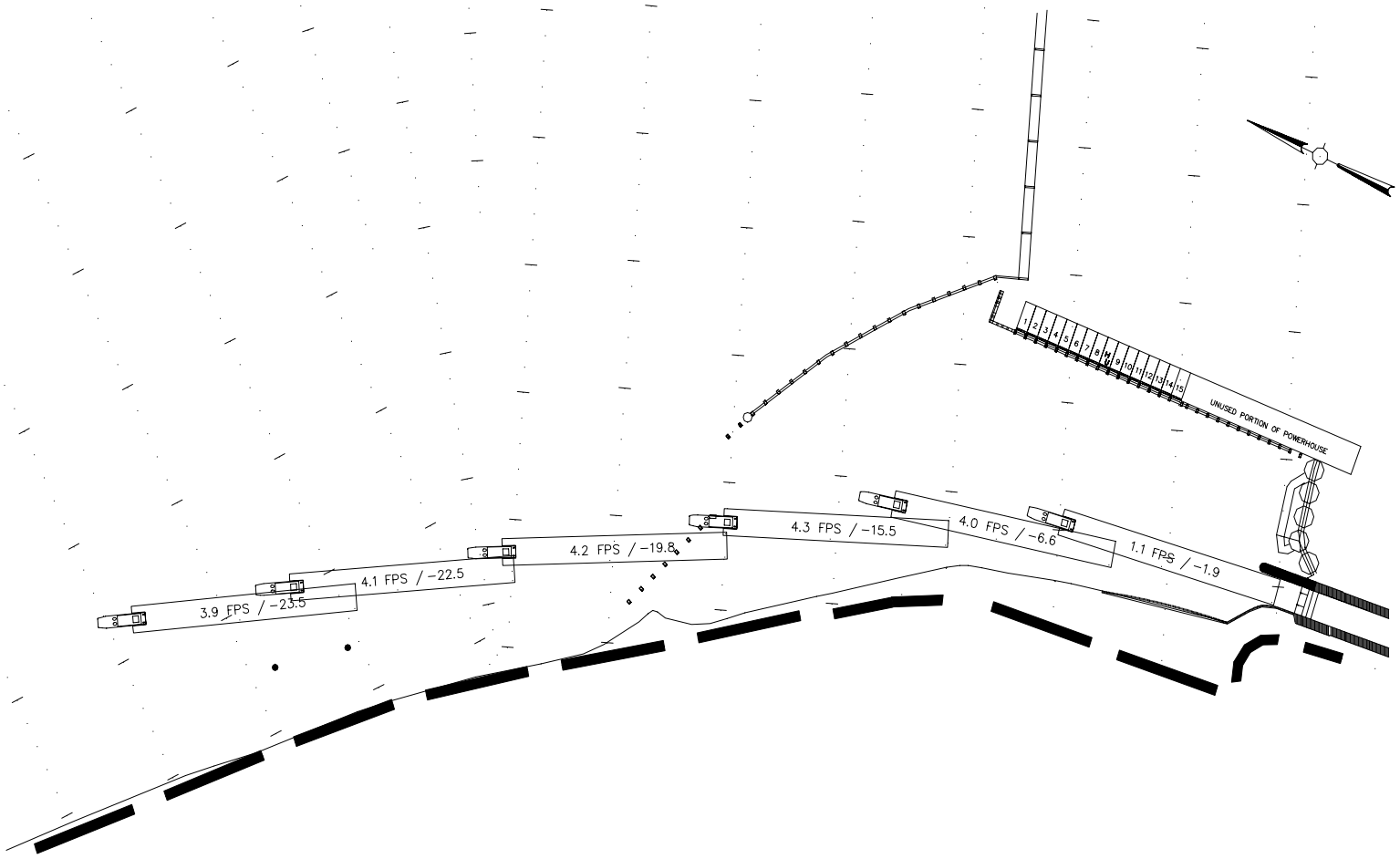
VELOCITIES AND CURRENT DIRECTIONS

PLAN D-1

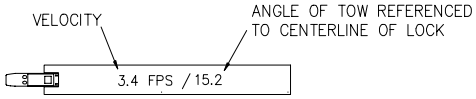
DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

LD19-143



LEGEND



SCALES

PROTOTYPE 500 0 500

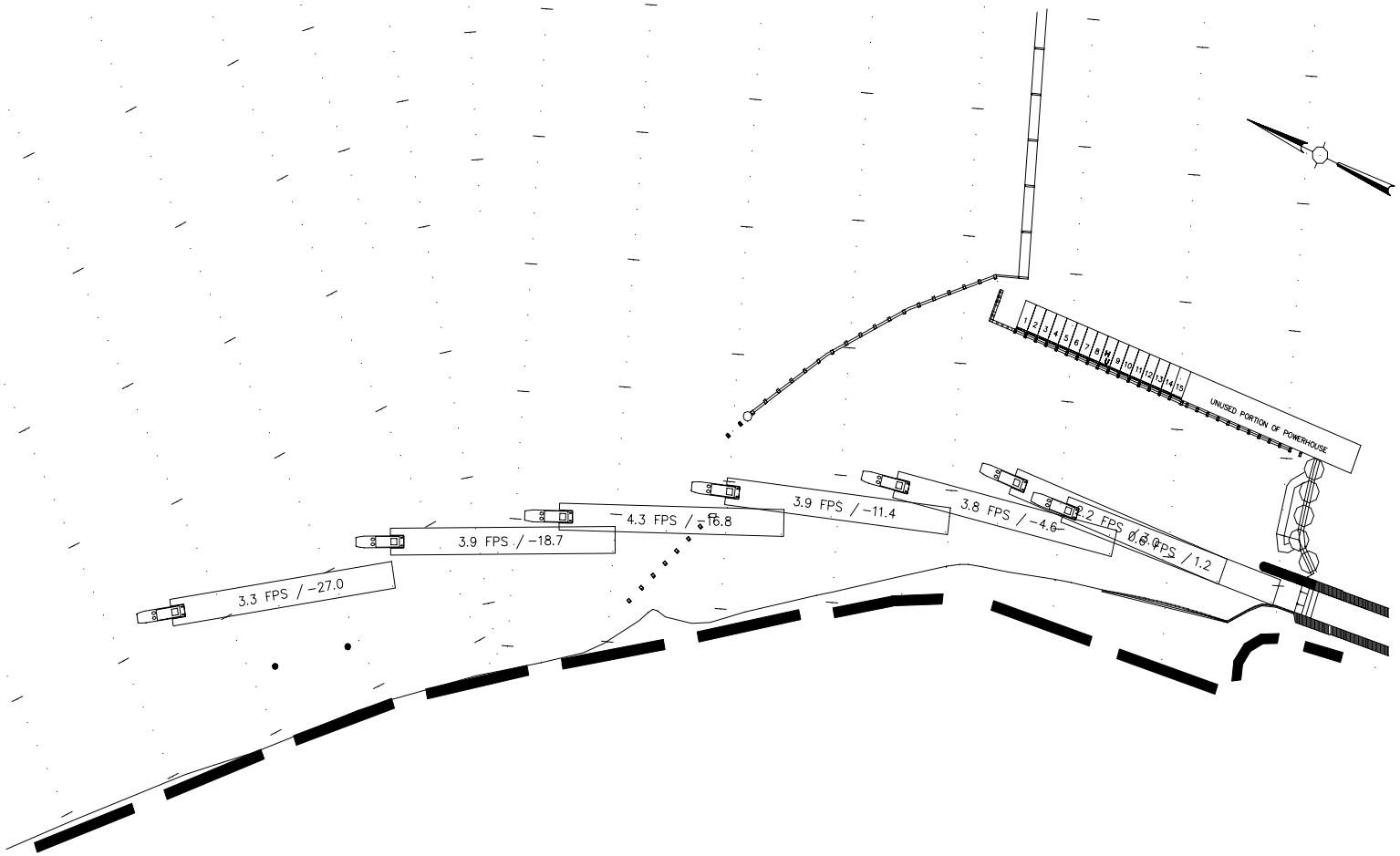
MODEL 5 0 5

TOW PATHS

PLAN D-1

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

LD19-143



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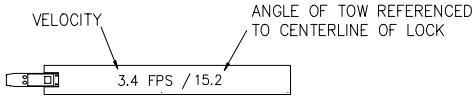


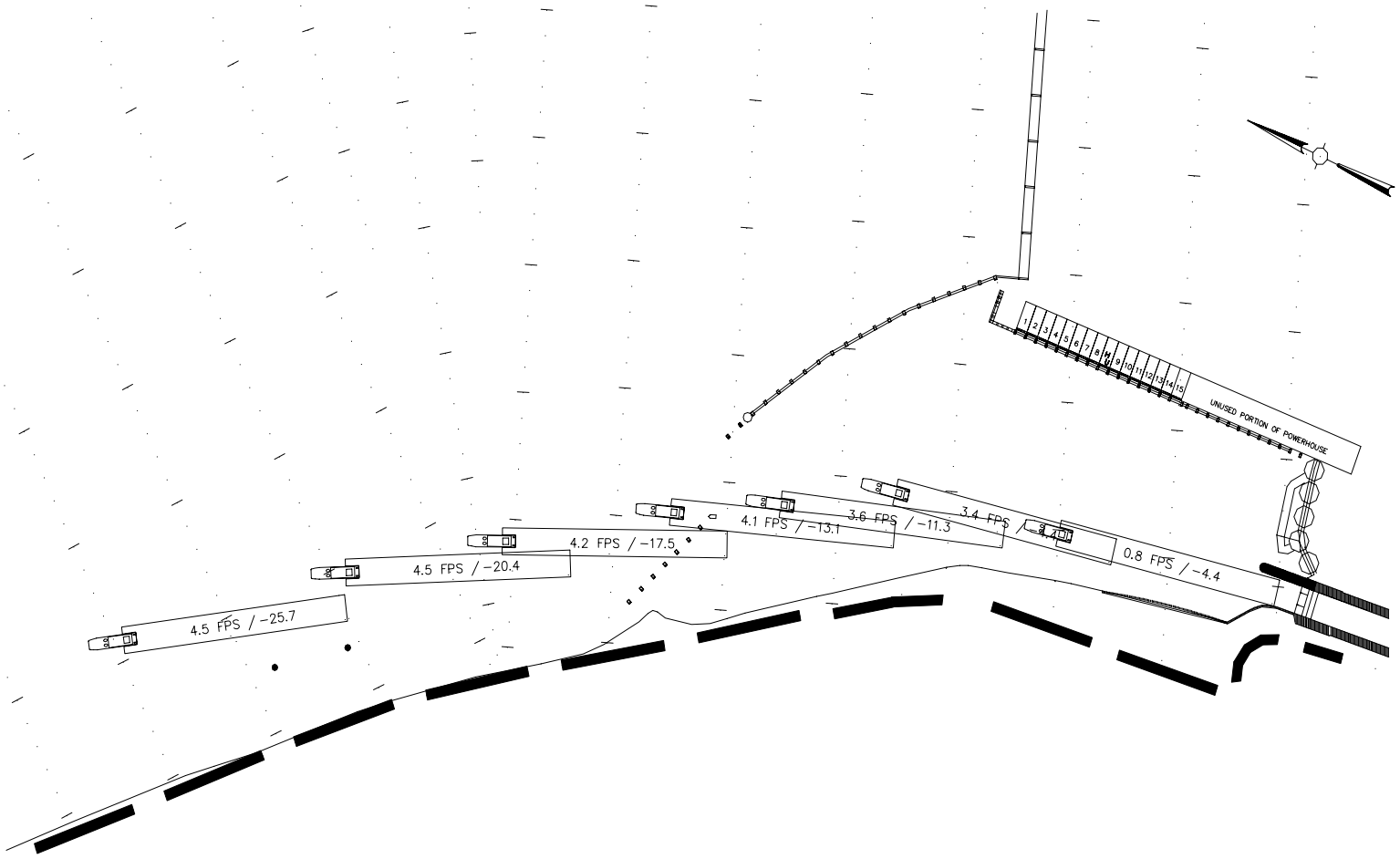
SCALES

TOW PATHS

PLAN D-1

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

LD19-144



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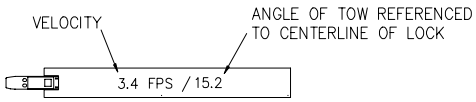


SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

TOW PATHS

PLAN D-1

DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT

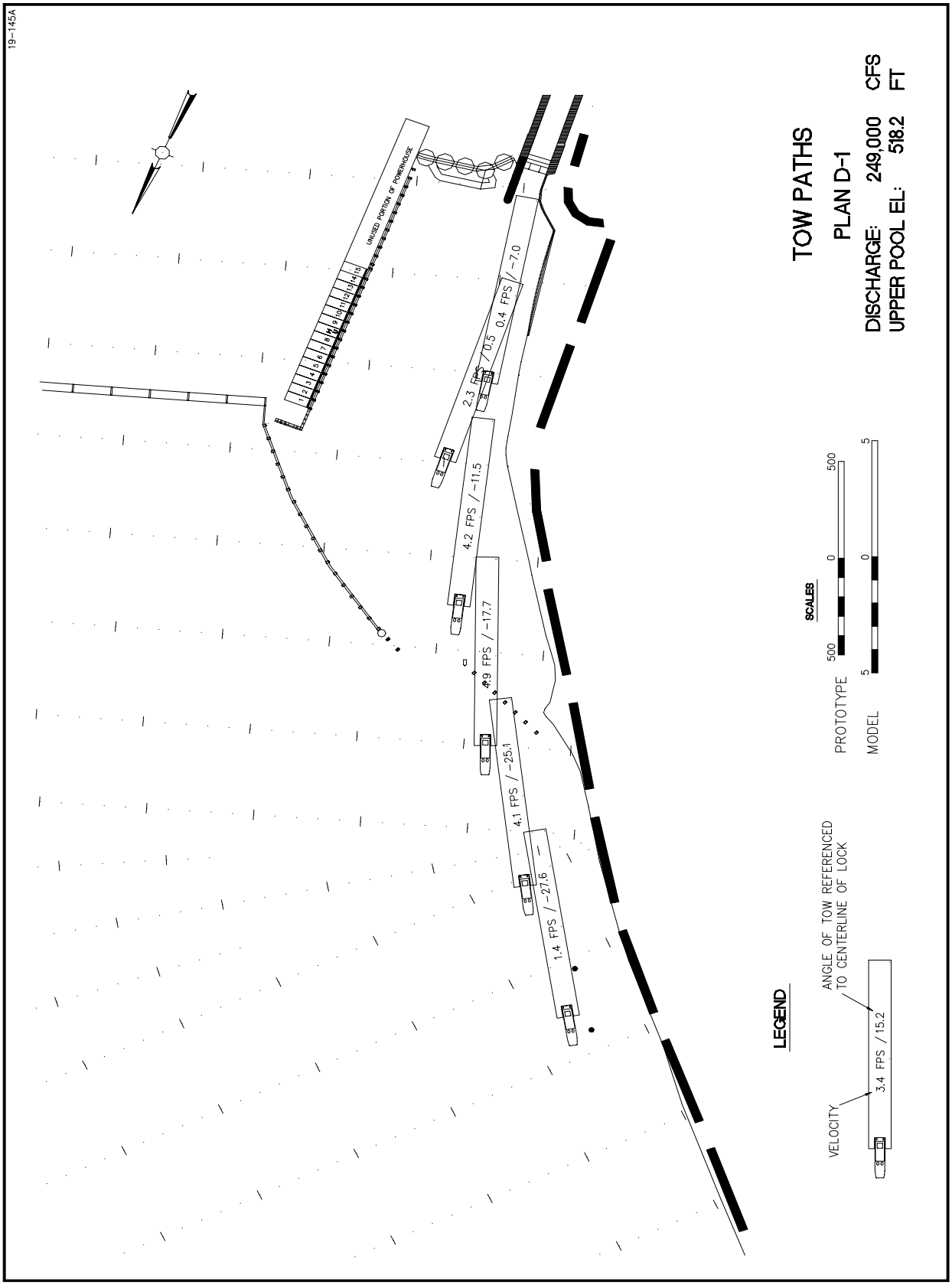
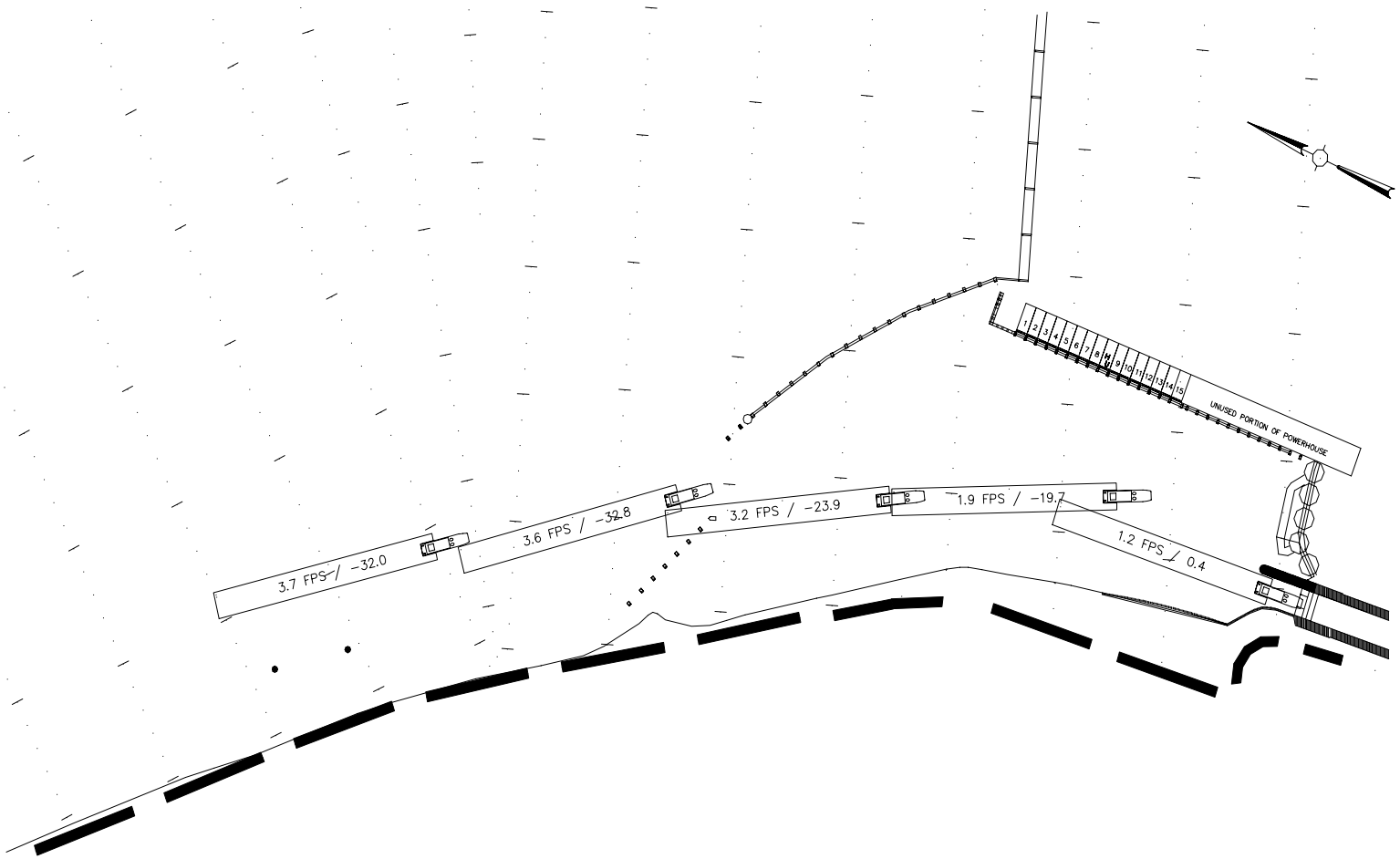
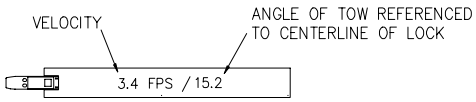

19-145A
UNUSED PORTION OF POWERHOUSE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
2.3 FPS / 0.5
0.4 FPS / -7.0
4.2 FPS / -11.5
4.9 FPS / -17.7
4.1 FPS / -25.1
1.4 FPS / -27.6
TOW PATHS
PLAN D-1
DISCHARGE: 249,000 CFS
UPPER POOL EL: 518.2 FT
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
3.4 FPS / 15.2

Plate 110



LEGEND



SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

TOW PATHS

PLAN D-1

DISCHARGE: 62,000 CFS
UPPER POOL EL: 518.2 FT

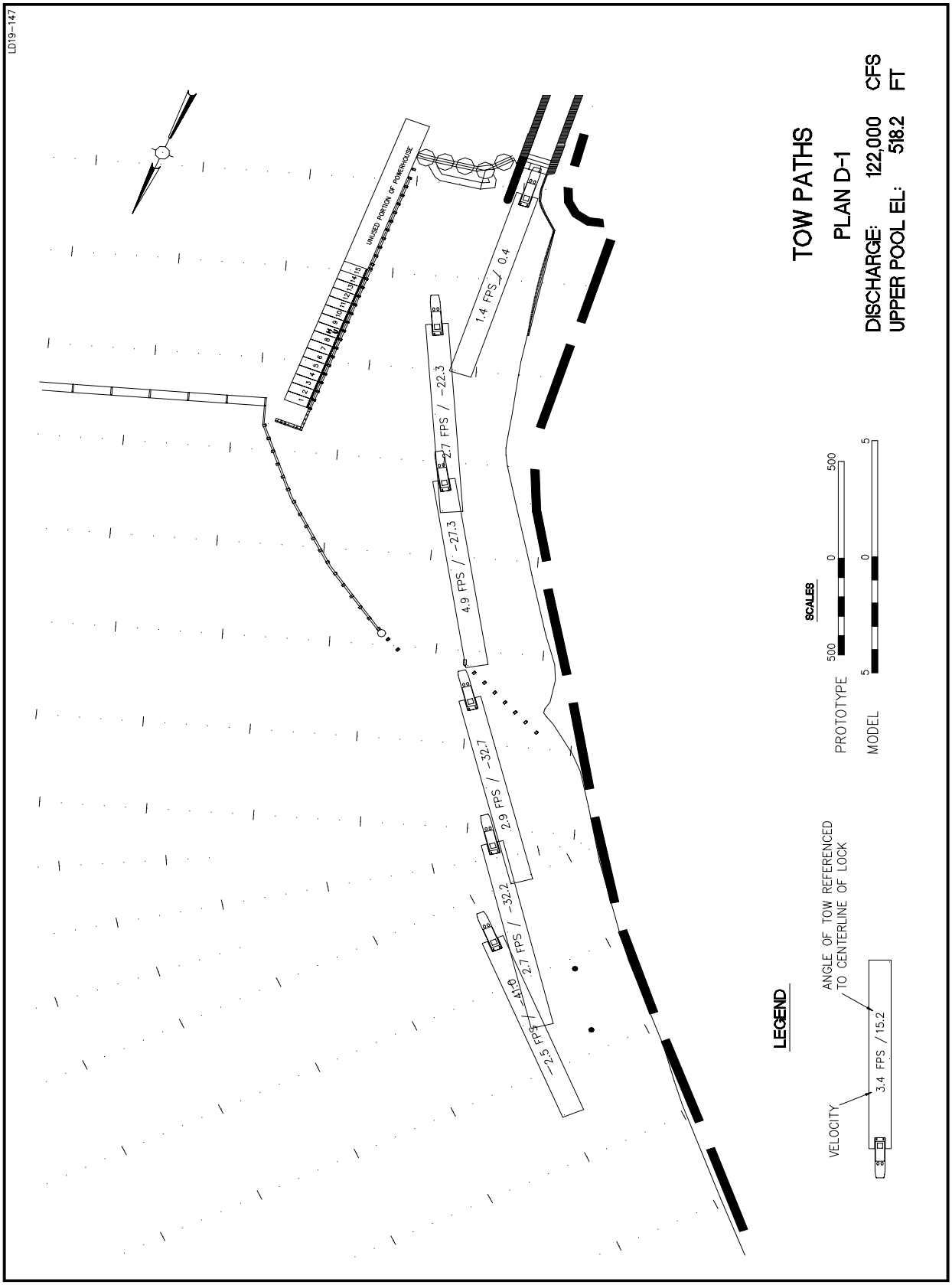
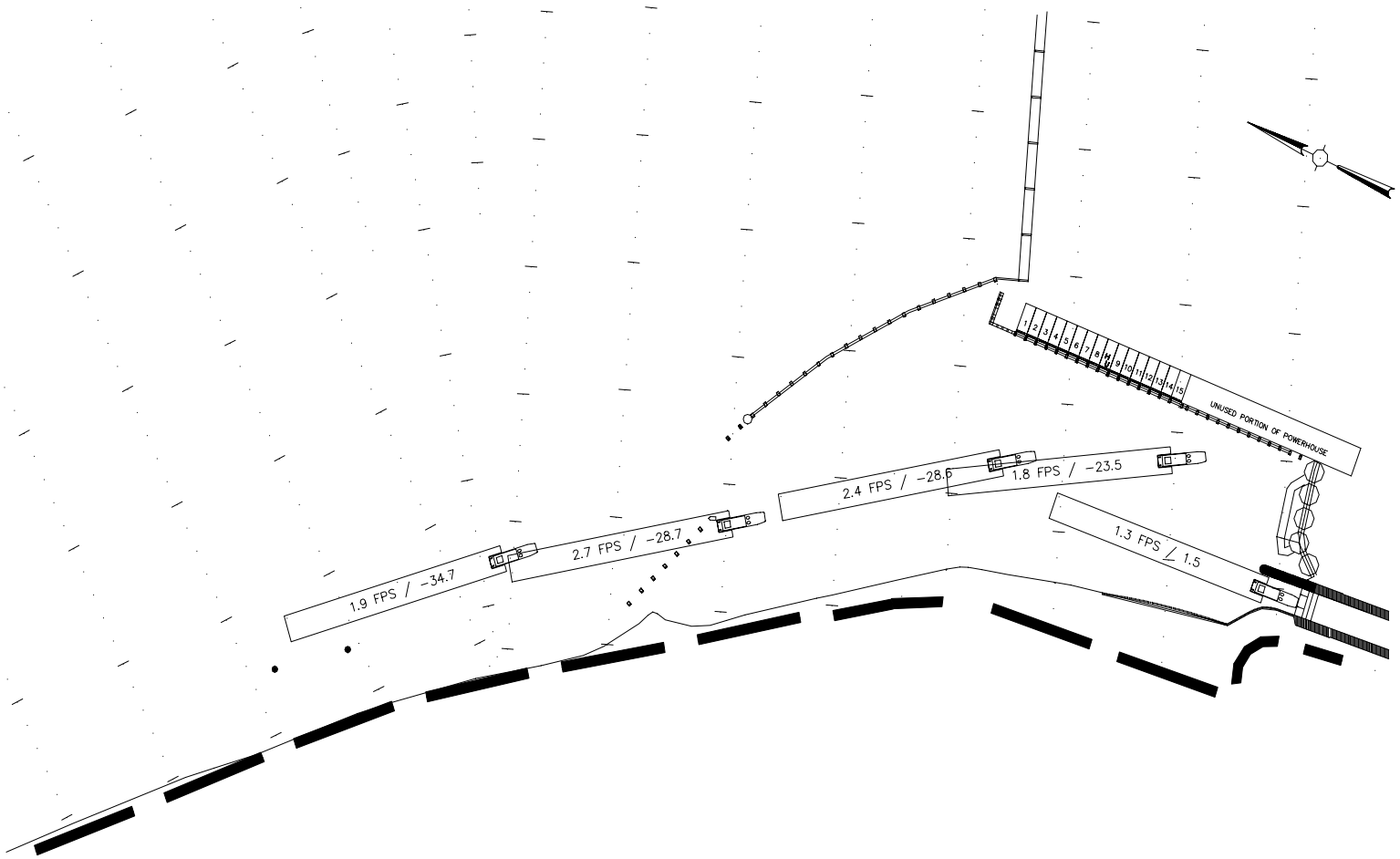

LD19-147
UNUSED PORTION OF POWERHOUSE
1.4 FPS / 0.4
2.7 FPS / -22.3
4.9 FPS / -27.3
2.9 FPS / -32.7
2.7 FPS / -32.2
-2.5 FPS / -41.8
TOW PATHS
PLAN D-1
DISCHARGE: 122,000 CFS
UPPER POOL EL: 518.2 FT
SCALES
PROTOTYPE 500 0 500
MODEL 5 0 5
LEGEND
ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK
VELOCITY
3.4 FPS / 15.2

Plate 112



LEGEND

VELOCITY — ANGLE OF TOW REFERENCED TO CENTERLINE OF LOCK

3.4 FPS / 15.2

SCALES

PROTOTYPE 500 0 500

MODEL 5 0 5

TOW PATHS

PLAN D-1

DISCHARGE: 249,000 CFS

UPPER POOL EL: 518.2 FT

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13. ABSTRACT *(Maximum 200 words)*

Lock and Dam 19, Mississippi River is located on the right descending bank of the Mississippi River approximately 364.3 rivermiles above the mouth of the Ohio River at Keokuk, Iowa. A comprehensive model study was conducted for Lock and Dam 19 in order to accomplish the following:

a. Determine the effects of proposed alternatives on navigation in the upper lock approach.
b. Develop modifications that could improve navigation conditions.
c. Evaluate navigation conditions for tows entering and leaving the upper lock approach.

The model was a fixed-bed type with the overbank area and the channel molded of sand cement mortar to sheet metal templates set to the proper grade. The lock, power house, gated spillway, and the radial ice fender were constructed of sheet metal and plexiglass and set to the proper grade. The model demonstrated conditions resulting from various alternatives tested and satisfied design engineers and navigation interests of the design's acceptability. Based on the available data, the model reproduced with a reasonable degree of accuracy the conditions in the prototype. Flow patterns were studied, velocities and water-surface elevations were measured, and the effects of currents on the movement of a model tow entering and leaving the upper lock approach were monitored.

14. SUBJECT TERMS
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Mississippi River
Navigation conditions

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