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Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

J. T. Myers Landside Lock Outlet Diffuser Study, Ohio River

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Final report

Prepared for U.S. Army Engineer District, Louisville
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Abstract: Navigation improvements are planned at J. T. Myers Locks and Dam on the Ohio River main stem. The existing project consists of a navigation dam, a 1,200-ft-long by 110-ft-wide main lock chamber adjacent to a 600-ft-long by 110-ft-wide auxiliary lock chamber. One of the improvements includes developing a 1,200-ft long lock chamber from the existing 600-ft-long lock chamber. The outlet design originally proposed for the filling and emptying system in the extended lock section was a manifold type diffuser located within the landside guide wall monolith and discharging toward the right (looking downstream) bank. A landside diffuser would help minimize closure of the main lock during construction of the lock extension. A 1:25-scale model was used to evaluate the originally proposed outlet design (Hite 2004). Since the publication of that report, the lock design changed and a new outlet design was necessary. This report provides the results of the model investigation for the new outlet design. The performance of the outlet design was based on scour tendencies in the vicinity of the outlet and hawser forces experienced by a tow moored at various locations in the lower lock approach. Two different guide wall designs were tested during the study

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Preface

The model investigation reported herein was authorized by the Headquarters, U.S. Army Corps of Engineers at the request of the U.S. Army Engineer District, Louisville (LRL) in July 2008. The model experiments were performed during the period January to March 2009 by personnel of the Coastal and Hydraulics Laboratory (CHL) of the U.S. Army Engineer Research and Development Center, ERDC, under the general supervision of Dr. W. D. Martin, Director of the CHL; Dr. R. M. Kress, Acting Deputy Director of the CHL; D. W. Webb, Chief of the Navigation Branch, CHL, and J. Lillycrop and Dr. J. Davis, Technical Directors, CHL.

The experimental program was led by Messrs. D. M. Marshall and J. R. Bull under the supervision of Dr. J. E. Hite, Jr., Leader, Locks Group. Model construction was completed by Messrs. H. F. Acuff III, Z. S. Smith, J. E. Gullet, J. A. Lyons, C. Burr and K. K. Raner of the Model Shop, Department of Public Works (DPW), ERDC, under the supervision of M. A. Simmons (retired) Chief of the Model Shop, DPW. Data acquisition and remote-control equipment were installed and maintained by T. E. Nisley, Information Technology Laboratory (ITL), ERDC. Data acquisition software was developed by T. W. Warren, ITL. The report was written by Dr. Hite. M. T. Sanchez performed a peer review of the report.

During the course of the model study, Messrs. James A. (Andy) Lowe and Adam M. Connelly and Ms. Kathleen B. Feger of U.S. Army Engineer District Louisville (LRL) visited ERDC to observe model operation, review experiment results, and discuss model results.

COL Gary E. Johnston was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Executive Summary

Navigation improvements are planned at J. T. Myers Locks and Dam on the Ohio River main stem. The existing project consists of a navigation dam, a 1,200-ft-long by 110-ft-wide main lock chamber adjacent to a 600-ft-long by 110-ft-wide auxiliary lock chamber. One of the improvements includes developing a 1,200-ft long lock chamber from the existing 600-ft-long lock chamber. The outlet design originally proposed for the filling and emptying system in the extended lock section was a manifold type diffuser located within the landside guide wall monolith and discharging toward the right (looking downstream) bank. A landside diffuser would help minimize closure of the main lock during construction of the lock extension. A 1:25-scale model was used to evaluate the originally proposed outlet design (Hite 2004). The location of that outlet had to be moved due to changes in the design of the lock. Discussions between the Louisville District (LRL) and the Engineer Research and Development Center (ERDC) led to the selection of an outlet diffuser similar to the one used in the new McAlpine Lock (Hite 2000) as the replacement for the outlet manifold. The McAlpine Navigation Project has a maximum lift of 37 ft and is located on the Kentucky side of the Ohio River at Louisville Kentucky. This report provides the results of the model investigation for the new outlet design. The performance of the outlet design was based on scour tendencies in the vicinity of the outlet and hawser forces experienced by a tow moored at various locations in the lower lock approach. A solid and ported lower guide wall designs were tested during the study. The outlet diffuser design performed well. There were no significant scour issues and hawser forces measured on a tow moored at different locations in the lower approach were low. The design should perform well for the J. T. Myers lock extension project.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meter
knots	0.5144444	meters per second
miles (U.S. statute)	1,609.347	meters
pounds (mass)	0.45359237	kilograms
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms

1 Introduction

Background

The U.S. Army Engineer District, Louisville (LRL), is planning navigation improvements at J. T. Myers Locks and Dam on the Ohio River. These improvements include extending the existing 600-ft-long by 110-ft-wide[1] landside chamber to accommodate a tow consisting of barges 3 wide by 5 long (each barge 35 ft wide by 195 ft long) and towboat and also modifying the approach walls for better tow entry and exit. Hite and Crutchfield (2004) performed a model study to evaluate the lock filling and emptying system for the lock extension. During this study, evaluation of the lock outlet was initiated but was halted, so that Huntington District could use the lock filling and emptying facility to study the filling and emptying system for the Greenup Navigation project. The outlet study was continued in another flume and this report provides the results of that investigation.

Prototype

The existing J. T. Myers Locks and Dam project is located on the Ohio River approximately 846 miles below its head at Pittsburgh, PA, and about 3.5 miles downstream from Uniontown, KY (Figure 1). The locks are on the Indiana side of the river. The current lock system consists of a 110-ft wide by 1,200-ft long lock chamber adjacent to a 110-ft wide by 600-ft long lock chamber. The filling and emptying system for the 600-ft chamber is the single-culvert bottom-lateral design with 6 laterals. A view of the existing J. T. Myers locks and dam on the Ohio River is shown in Figure 2, along with a schematic of a proposed lock expansion. The proposed outlet diffuser for the landside of the lock is shown in Figure 3.

Purpose and scope

The purpose of the investigation was to assist the Louisville District in verifying the performance of the landside outlet design, since it was changed from the one evaluated in Hite (2004), and make modifications to the design if necessary to achieve acceptable performance. The landside outlet is preferable over a riverside outlet for lock extension projects since

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

closure of the main lock chamber will be minimized during construction of the outlet. The outlet was evaluated based on flow patterns in the lower approach, tendencies for scour in the vicinity of the outlet, and hawser forces on a tow moored in the lower approach.

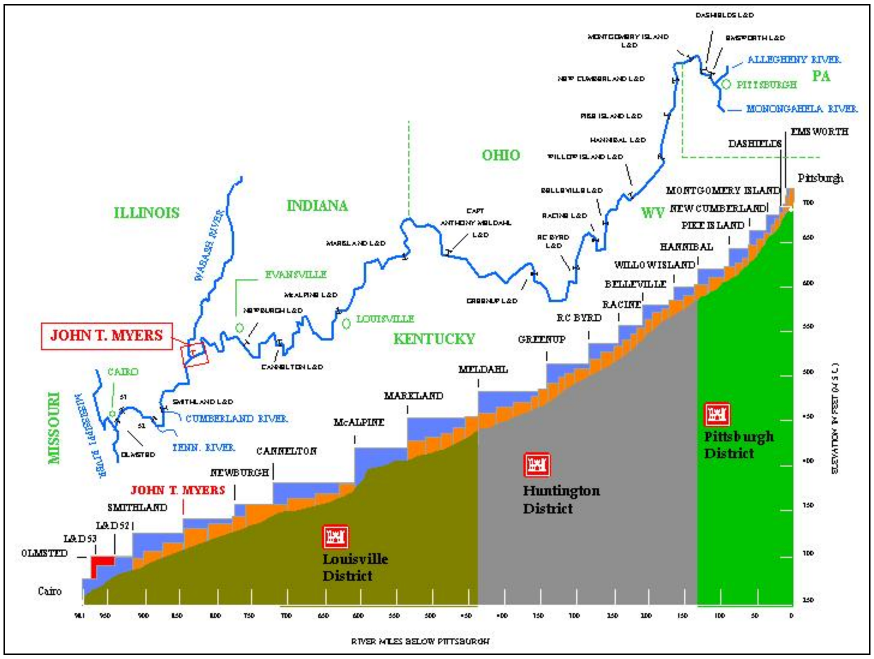

Figure 1. Location map.

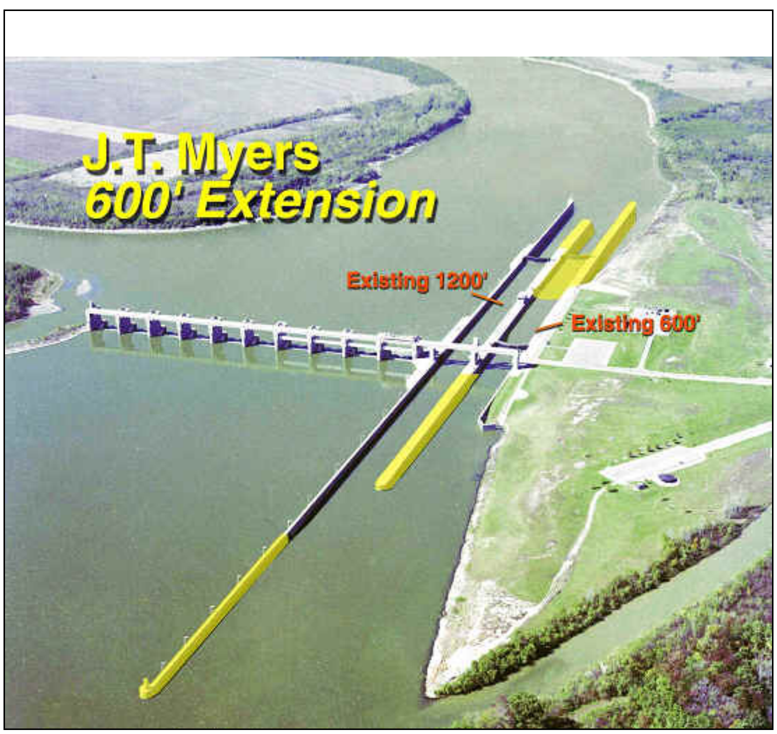

Figure 2. J. T. Myers proposed lock extension looking downstream.

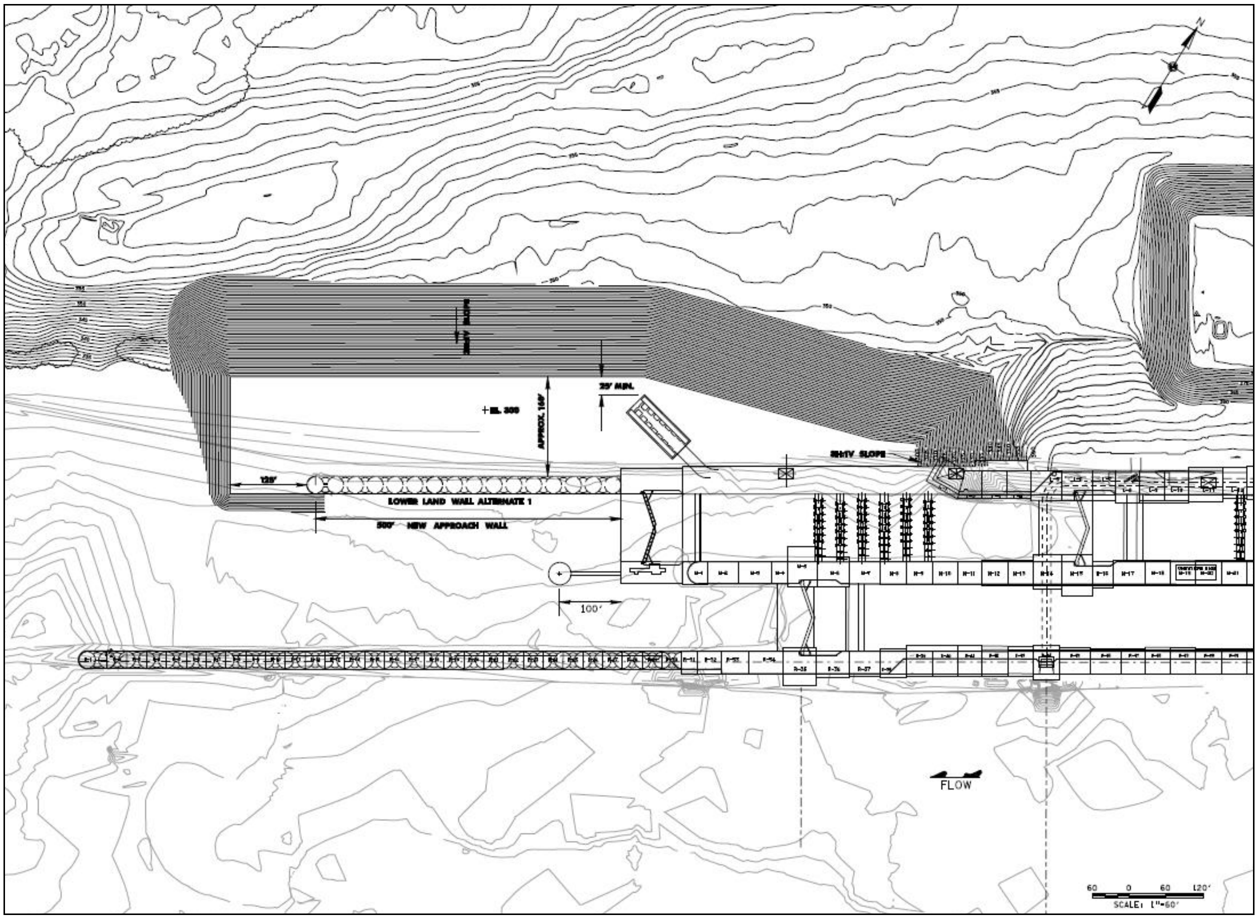

Figure 3. Lower approach with outlet diffuser on landside of lock.

2 Physical Model

Description

The 1:25-scale model reproduced the landside culvert and emptying valve and the landside topography beginning 215 ft upstream from the lower emptying valve. The lower approach to the landside and riverside locks was reproduced for a distance of 1,400 ft downstream from the landside lock pintle. The left wall (looking downstream) of the model flume represented the lower guard wall for the riverside lock. The model included the reverse tainter valve for emptying, the lock culvert between the emptying valve and outlet, the landside outlet diffuser and portions of the lower approach topography. The model layout for this study is shown in Figure 4. The dark blue lines in Figure 4 represent the model cut off walls, which separate the upper and lower pools. Photographs of the outlet model are shown in Figures 5 and 6.

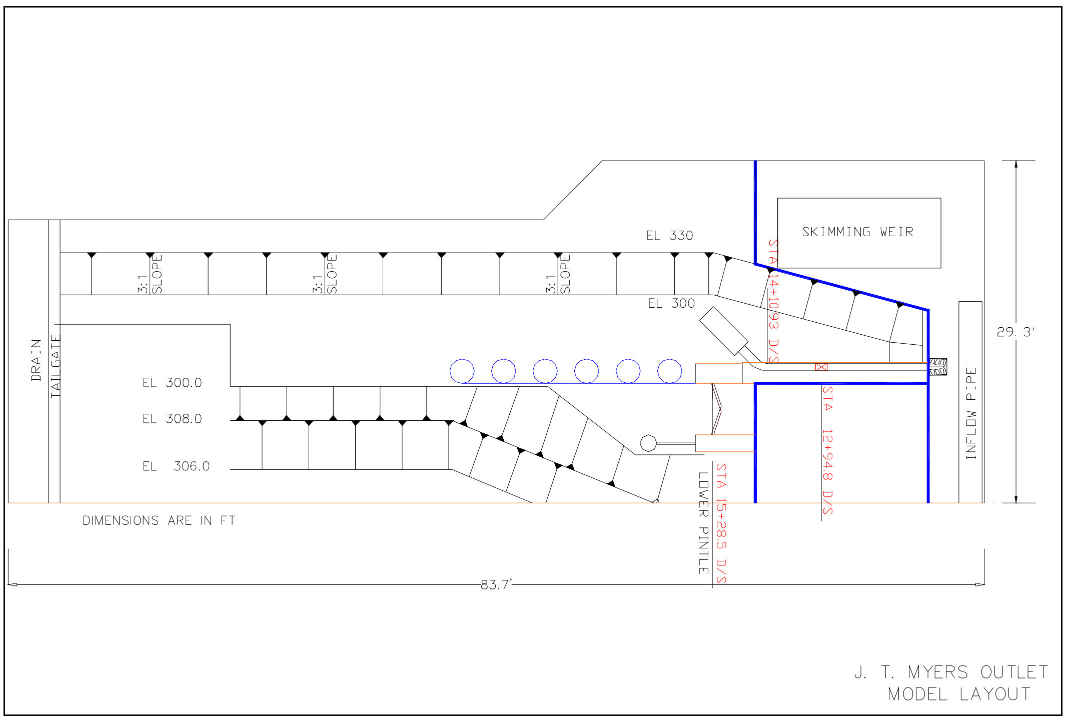

Figure 4. Model layout for landside outlet diffuser

Figure 5. View of 1:25-scale J. T. Myers outlet model looking upstream

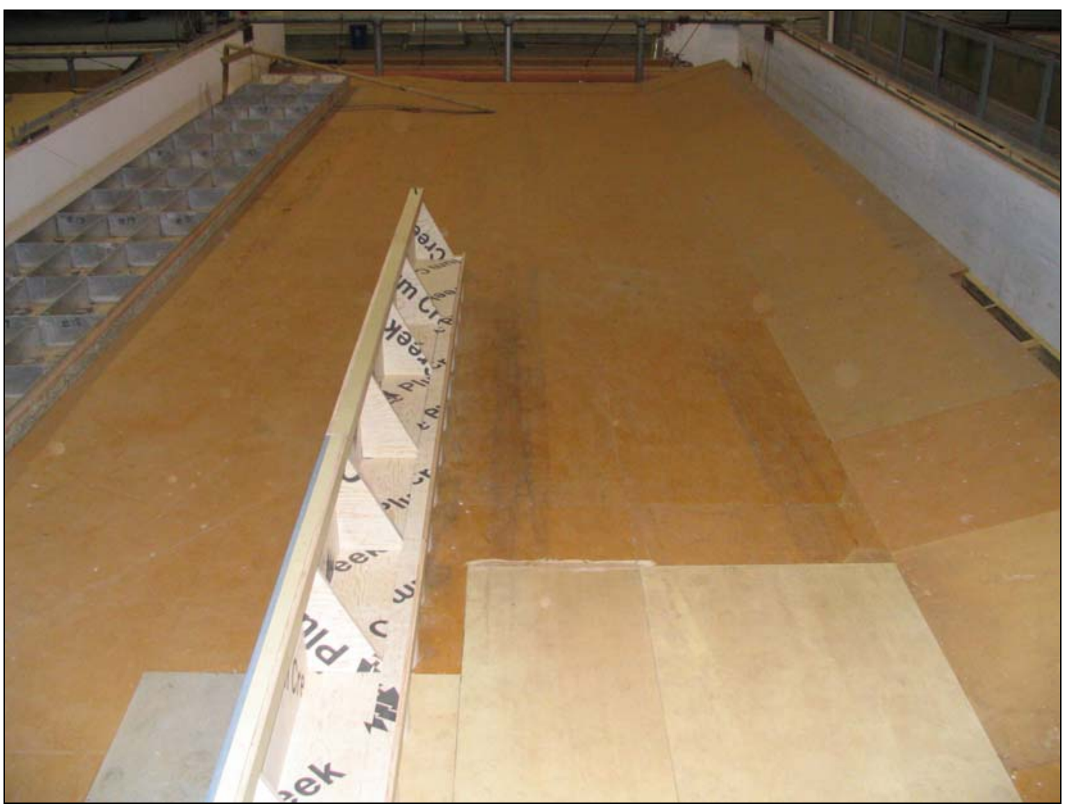

Figure 6. View of 1:25-scale J. T. Myers outlet model looking downstream

Appurtenances and instrumentation

Water was supplied to the model through a circulating system. The lower pool was maintained at near constant elevations during the emptying operations using a long horizontal weir at the end of the flume. A constant head skimming weir was used upstream from the outlet diffuser to provide a discharge source. A paddle-wheel type flow meter was calibrated in a separate facility to insure proper working condition. The meter was then installed in the culvert upstream from the emptying valve and the relationship between culvert discharge and gate opening was established. Knowing this relationship, the correct emptying hydrographs could be reproduced using the emptying valve. Water-surface elevations inside the lower approach model were determined using point gages. Dye and confetti were used to study subsurface and surface current directions.

An automated data acquisition and control program was used to control the valve operation and collect strain gauge data for the hawser force measurements. Four data channels were used, one for control of the emptying valve and three for collecting strain gauge information. The data were usually collected at a sampling rate of 10 hz.

A hawser-pull (force links) device used for measuring the longitudinal and transverse forces acting on a tow in the lock chamber during filling and emptying operations is shown in Figure 7. Three such devices were used: one measured longitudinal forces and the other two measured transverse forces on the downstream and upstream ends of the tow, respectively. These links were machined from aluminum and had SR-4 strain gauges cemented to the inner and outer edges. When the device was mounted on the tow, one end of the link was pin-connected to the tow while the other end was engaged to a fixed vertical rod. While connected to the tow, the link was free to move up and down with changes in the water-surface in the lock. Any horizontal motion of the tow caused the links to deform and vary the signal, which was recorded with a personal computer using an analog-to-digital converter. The links were calibrated by inducing deflecttion with known weights. Instantaneous pressure and strain gauge data were recorded digitally with a personal computer.

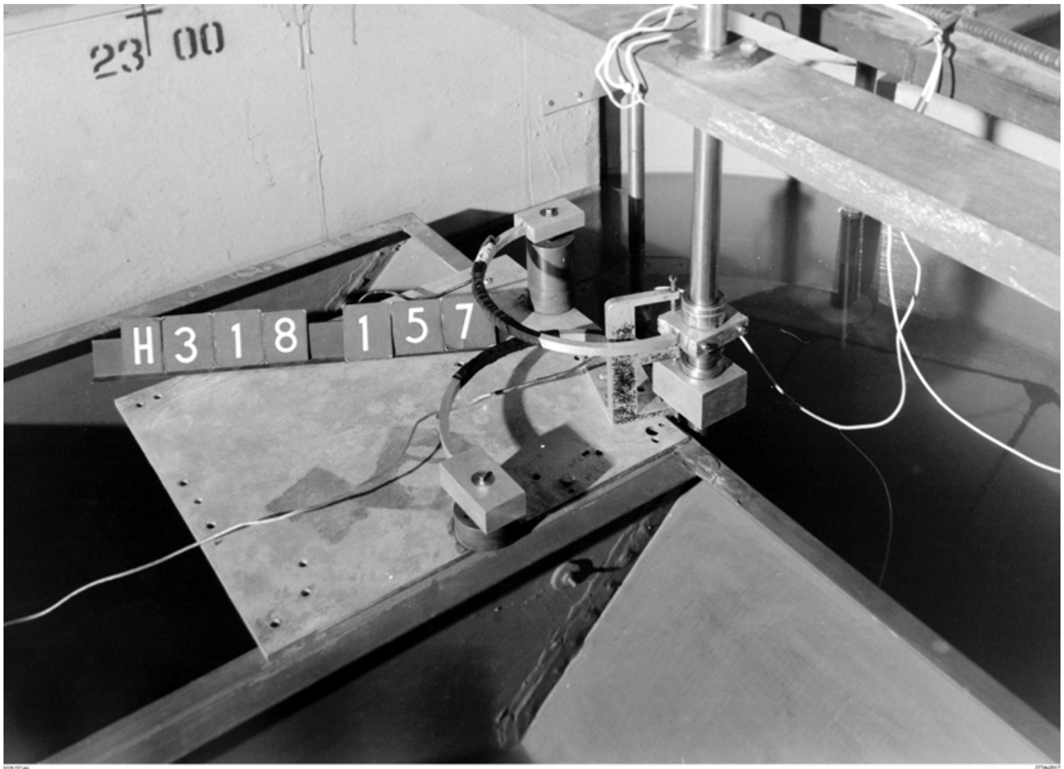

Figure 7. Hawser pull (force-links) measuring device.

Similitude considerations

Kinematic similitude

Kinematic similarity can be used for modeling free-surface flows in which the viscous stresses are negligible. Kinematic similitude requires that the ratio of inertial forces ($\rho V^2 L^2$) to gravitational forces ($\rho g L^3$) in the model is equal to those of the prototype. Here, ρ is the fluid density, V is the fluid velocity, L is a characteristic length, and g is the acceleration due to gravity. This ratio is generally expressed as the Froude number, N_F.

$$N_F = \frac{V}{\sqrt{gL}} \tag{1}$$

where L is usually taken as the flow depth in open-channel flow.

The Froude number can be viewed in terms of the flow characteristics. Because a surface disturbance travels at celerity of a gravity wave, $(gh)^{1/2}$, where h is the flow depth, it is seen that the Froude number describes the ratio of advection speed to the gravity wave celerity. Evaluation of the flow conditions in the lower lock approach included measuring hawser forces on moored barges during emptying operations. These hawser forces are generated primarily by slopes in the water-surface.

Dynamic similitude

Modeling of forces is a significant purpose of the laboratory investigation. Appropriate scaling of viscous forces requires the model to be dynamically similar to the prototype. Dynamic similarity is accomplished when the ratios of the inertia forces to viscous forces ($\propto VL$) of the model and prototype are equal. Here, $\propto$ is the fluid viscosity. This ratio of inertia to viscous forces is usually expressed as the Reynolds number

$$N_R = \frac{VL}{V} \tag{2}$$

where V is the kinematic viscosity of the fluid ($V = \propto / p$) and the pipe diameter is usually chosen as the characteristics length, L, in pressure flow analysis.

Similitude for models

Modeling of lock filling and emptying systems is not entirely quantitative. The system is composed of pressure flow conduits and open-channel components. Further complicating matters, the flow is unsteady. Discharges (therefore N_F and N_R) vary from no flow at the beginning of an operation to peak flows within a few minutes and then return to no flow at the end of the cycle. Fortunately though, engineers now have about 50 years of experience in conducting large-scale models and subsequently studying the corresponding prototype performance. This study used a 1:25-scale Froudian model in which the viscous differences were small and could be estimated based on previous model-to-prototype comparisons. Setting the model and prototype Froude numbers equal results shown in Table 1 between the dimensions and hydraulic quantities:

Table 1. Results between the dimensions and hydraulic quantities for Froude numbers.

Characteristic	Dimension[1]	Scale Relation Model :Prototype
Length	$L_r = L$	1:25
Pressure	$P_r = L_r$	1:25
Area	$A_r = L_r^{2}$	1:625
Velocity	$V_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3,125
Time	$T_r = L_r^{1/2}$	1:5
Force	$F_r = L_r^{3}$	1:15,625

[1]Dimensions are in terms of length.

These relations were used to transfer model data to prototype equivalents and vice versa.

Experimental procedures

Evaluation of the lock outlet was based on observation of flow conditions in the vicinity of the outlet, sediment deposition tendencies, energy dissipation achieved by the outlet basin, and hawser forces experienced by tows moored in the lower approach. Experiments were conducted to investigate these conditions and obtain velocity and hawser forces measurements.

3 Model Experiments and Results

Type 13 outlet diffuser

The outlet diffuser design is shown in Figures 8 and 9. The diffuser consisted of 16 ports (8 on each side of the diffuser) 3 ft 1 in. wide by 8 ft high and spaced 9 ft 9 in. apart. The width of the outlet decreases in the downstream direction to provide a uniform discharge among the ports. The ports discharge into a channel with a concrete wall located 7 ft 9 in. from the outer port face. The invert of the channel is el 288.5[1] and the top of the channel wall is at el 308. The outlet was designated the type 13 outlet diffuser since 12 designs had been evaluated previously (see Hite 2004).

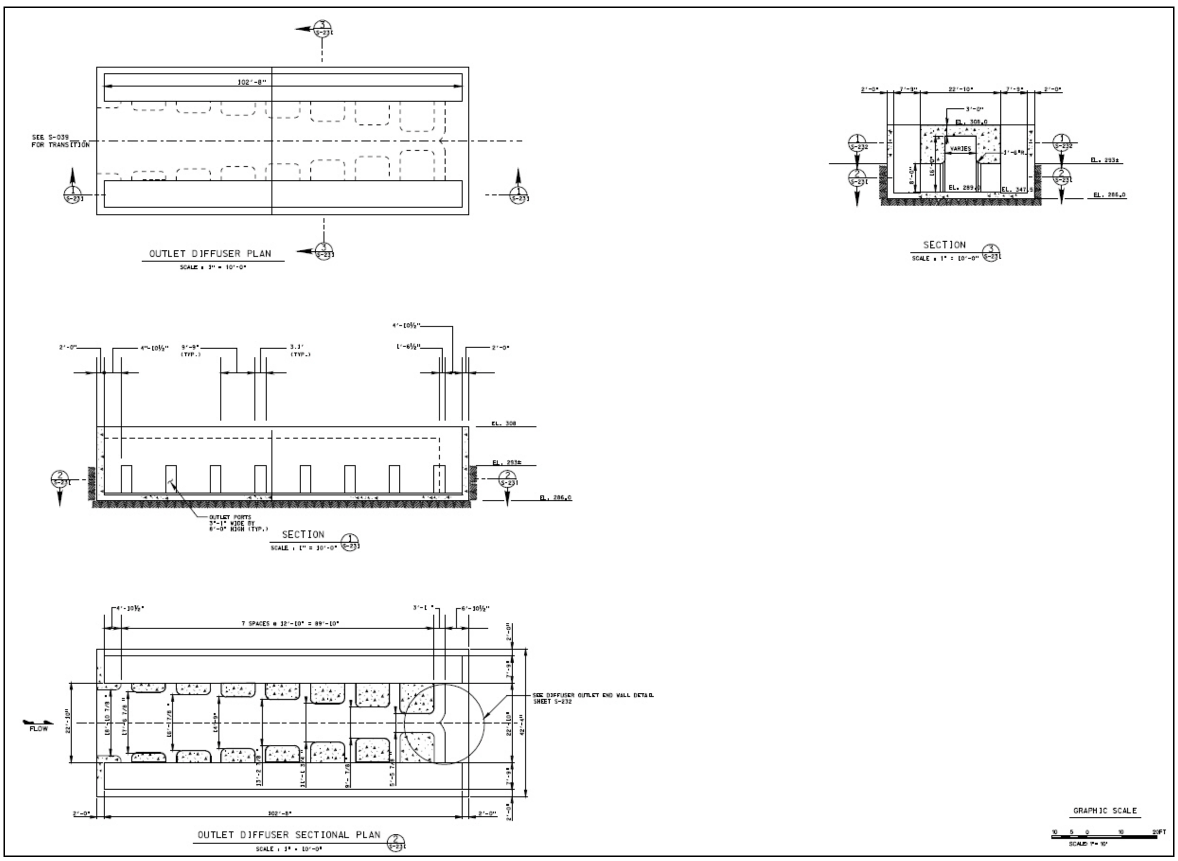

Figure 8. Details of the outlet diffuser.

[1] All elevations (el) cited herein are in feet referenced to the National Geodetic Vertical Datum. To convert feet to meters, multiply number by 0.3048.

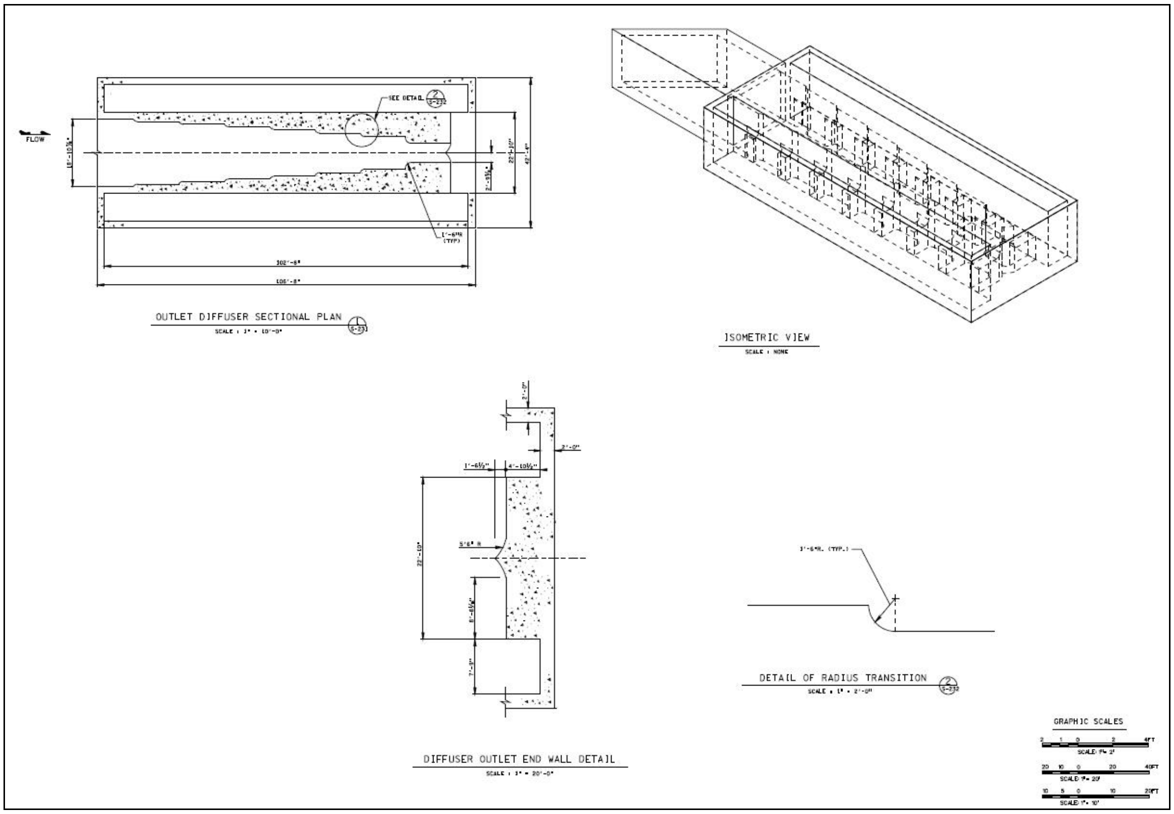

Figure 9. Isometric view and more details of outlet diffuser.

Alternative 1 guide wall

The alternative 1 guide wall was placed in the model for the initial model tests. This guide wall design is shown in Figures 10 and 11. The solid wall design consists of a concrete gravity wall placed on top of circular sheet pile cells, as shown in Figure 11. The top of the cells is el 322. The wall is 500 ft long and starts at sta 15+65. Figure 12 shows the alternative 1 guide wall in the model. The landside sloping portion of the gravity wall was not reproduced in the model since the tailwater was el 324. This el was below this portion of the wall and therefore the flow conditions in the lower approach were not affected.

Model valve operation

The operation of the model differs from a typical lock operation since the model does not include the lock chamber. The model emptying valve is operated to simulate the outlet discharge during a selected valve operation. In an actual lock emptying operation, the valve would be fully opened in a desired time and remain open until the lock chamber emptied. For a typical lock emptying operation, the outlet discharge would increase as the valve began to open, reach a peak after the valve was fully open, and then begin to decrease due to the falling head in the lock chamber. These discharge hydrographs for various valve operations were obtained from the data collected in the previous model study of the J. T. Myers filling and emptying system (Hite and Crutchfield 2004). The discharge hydrographs for the 1-, 2-, and 5-min valve operations are shown in Figure 13. A flow meter was installed in the culvert upstream from the emptying valve. The culvert was then removed from the model and installed in a calibration facility to obtain a calibration curve for meter reading versus discharge. The culvert was then placed back in the model and a relationship between valve opening and discharge was determined for a constant head condition. Knowing this relationship, the valve could then be operated to simulate the discharge hydrographs shown in Figure 13.

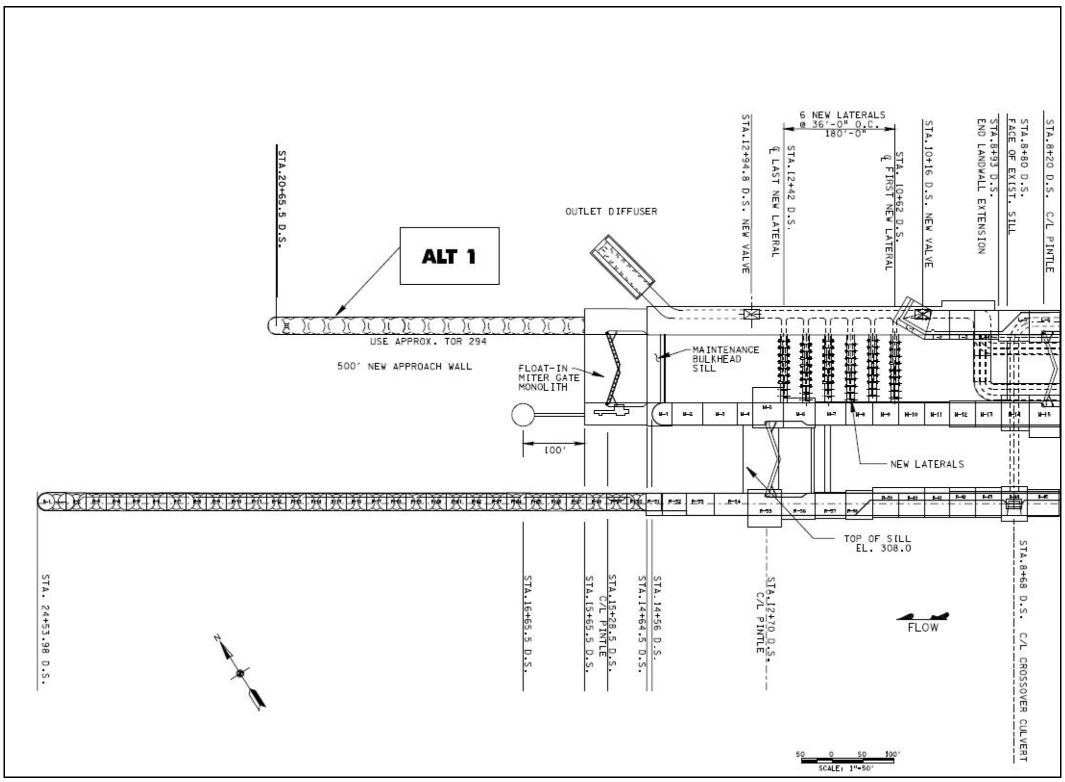

Figure 10. Plan view of Alternative 1 lower guide wall.

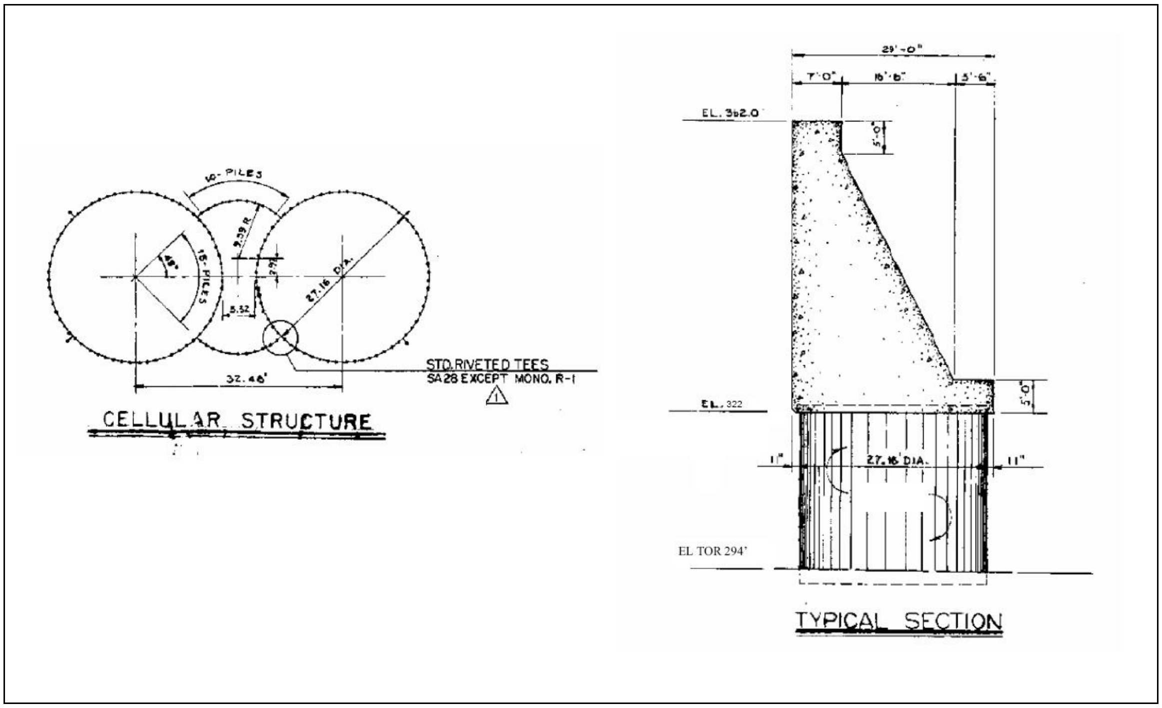

Figure 11. Partial plan and section views of Alternative 1 lower guide wall.

Figure 12. Landside view of Alternative 1 lower guide wall in model looking upstream.

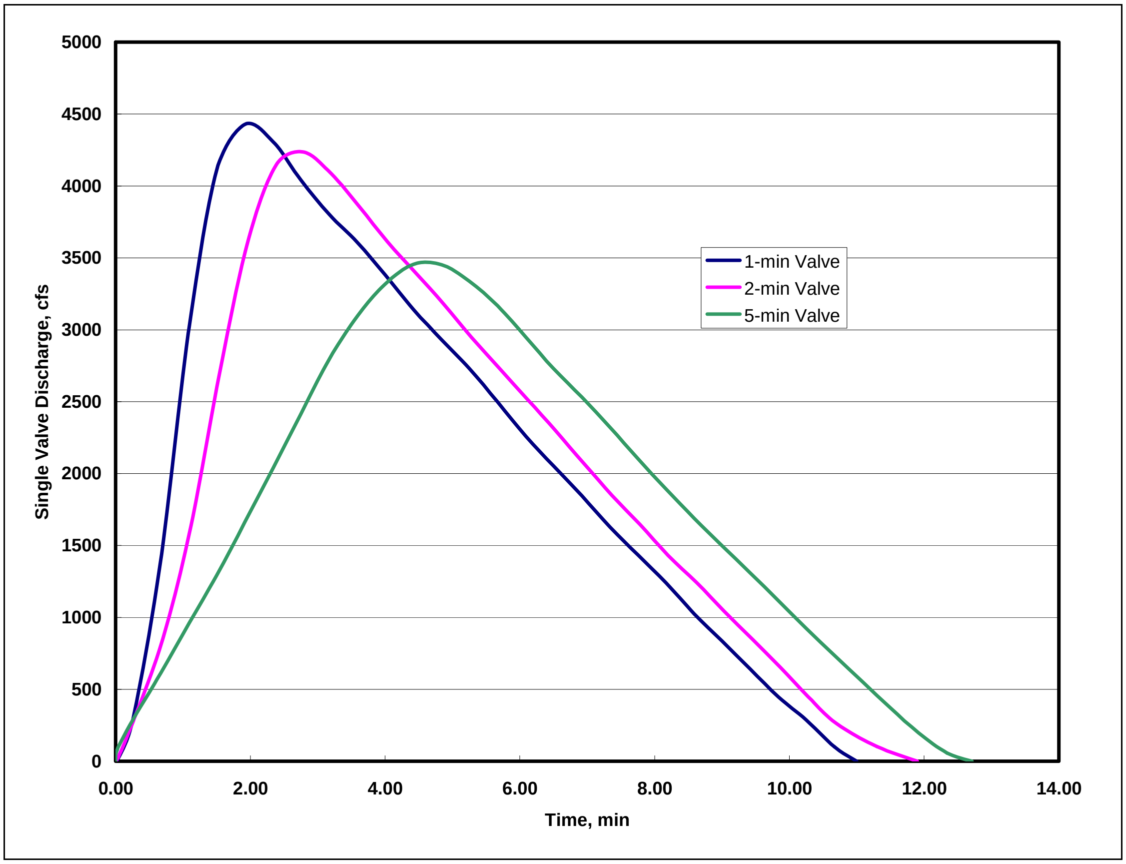

Figure 13. Discharge hydrographs for 1-, 2-, and 5-min valve operations.

Scour tests with type 13 outlet diffuser

Sand was placed around the outlet, as shown in Figures 14 and 15, to help evaluate the tendency for scour around the outlet for selected valve operations. The top of the sand was placed at the same el as the surrounding topography (el 300). A 5-min valve operation was performed to simulate an upper pool el of 342 and a lower pool el of 324. No noticeable scour was observed around the outlet and velocities in the outlet channel were very low. A 2-min valve operation was then performed with similar observations. A 1-min valve operation was then performed and again there was no noticeable scour and velocities in the outlet channel were low. The valve was then fully opened and left in this position for 15 minutes model time (1 hr 15 min equivalent prototype time). No significant scour was observed during this operation. The scour of the sand in the vicinity of the outlet after these experiments were conducted is shown in Figures 16 and 17. Slight movement of the sand can be seen in Figure 17 at the downstream end of the outlet, but this was not considered significant. These experiments indicated the type 13 outlet diffuser was a very good energy dissipater and minimal size riprap would be needed to protect the area around the outlet. The type 1 riprap design recommend in the previous study of the outlet would perform fine with this new outlet. This will be discussed in a subsequent paragraph.

Figure 14. Looking upstream at sand placed around type 13 outlet design.

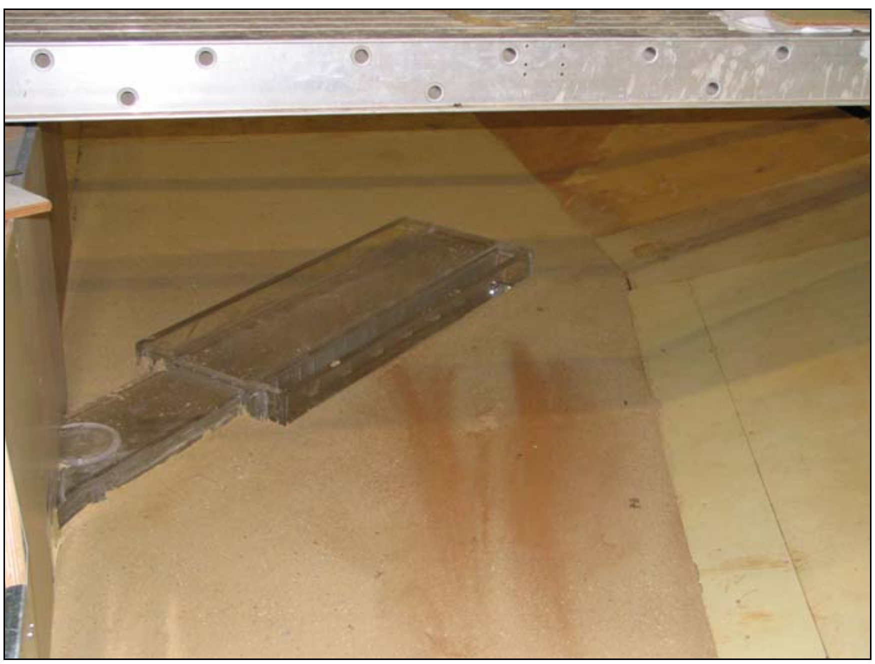

Figure 15. Looking downstream at sand placed around type 13 outlet design.

Figure 16. Looking upstream at sand after scour test.

Figure 17. Looking downstream at sand after scout test.

Hawser force measurements, valve operations and barge location

Hawser force measurements were obtained for the 1-, 2-, and 5-min valve operation with the barges located as shown in Figure 18. Location 1 had the head of a 3-wide by 5-long barge train moored 100 ft downstream from the lower pintle of the landside lock. The tow was moved then moved laterally from location 1 to a similar position in the lower approach to the riverside lock for location 2. The barge train was moved 1 tow length (195 ft) downstream from location 1 and this position was designated location 3.

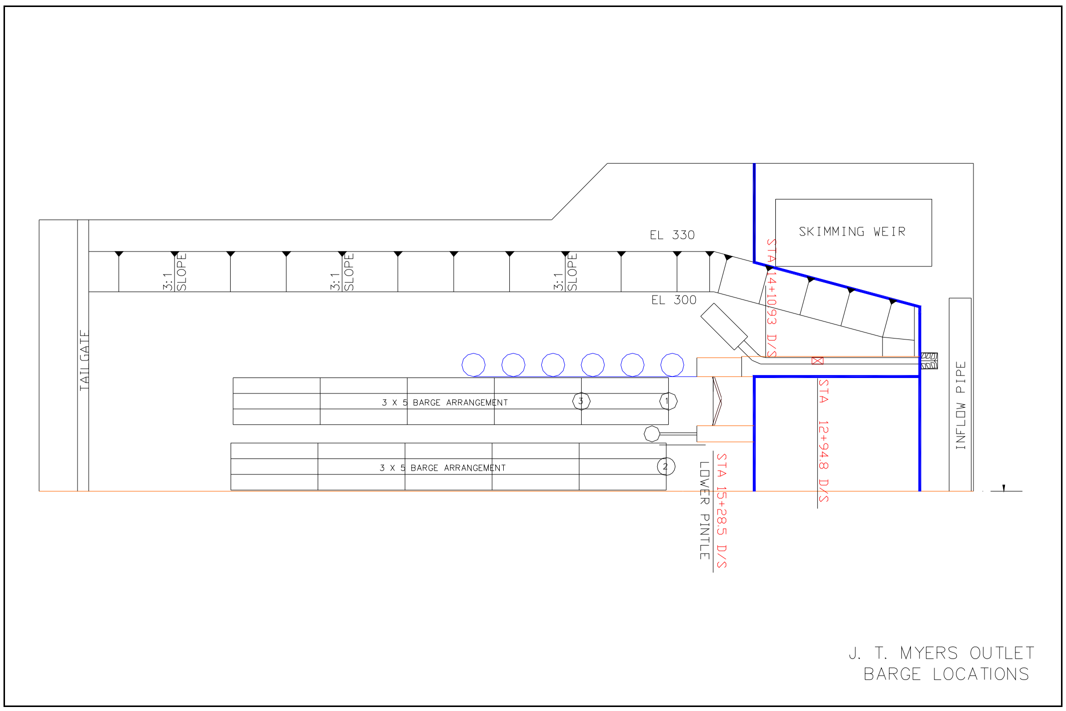

Figure 18. Barge locations for hawser force measurements.

Hawser force measurements, alternative 1 guide wall, barge head at location 1

Typical time histories of the hawser forces measured for the 1-, 2-, and 5-min valve operations with the alternative 1 guide wall are shown in Figure 19. Multiple tests were conducted to insure repeatability of the data. The upper three time histories were measured with the 1-min valve. The top time history is the longitudinal (upstream-downstream) hawser force and below that is the upstream transverse (side to side) hawser force with the downstream transverse hawser forces below the upstream transverse. Longitudinal hawser forces above zero are in the upstream direction and forces below zero are in the downstream direction. Transverse hawser forces above zero indicate movement to the right side of the lower approach (looking downstream) and forces below zero indicate movement to the left side of the lower approach. The longitudinal hawser force shows that for the first 45 secs there is practically no force. A downstream force occurs for the next 1.5 min and then the force returns to zero for the remainder of the test. The maximum downstream hawser force measured was 2.5 tons and occurred at 1 min 36 secs into the emptying operation. This force is considered very small. The upstream and downstream hawser forces show a movement to the left side of the lower approach during the same time period as the longitudinal hawser force was in the downstream direction. These forces were also very small.

Hawser force measurements with the 2-min valve operation showed similar trends to the 1-min valve operation. The longitudinal hawser forces occurred in the downstream direction and the transverse hawser forces indicated movement of the barge train to the left side of the lower approach. These forces were also considered very small. The hawser force measurements made during the 5-min valve operation showed very small forces and no noticeable changes in direction.

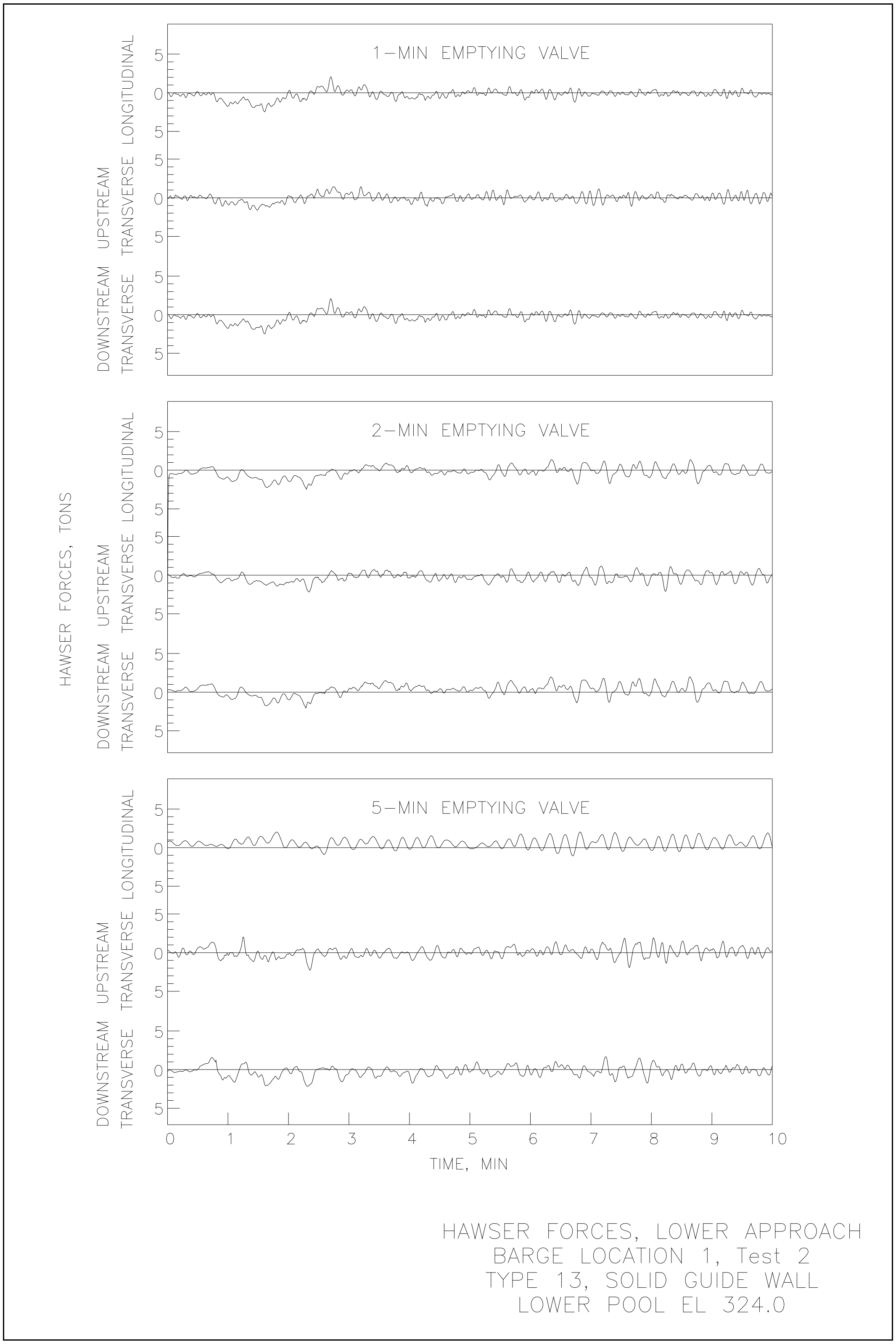

Figure 19. Time histories of hawser forces with alternative 1 lower guide wall at location 1.

Hawser force measurements, alternative 1 guide wall, barge head at location 2

Typical time histories of the hawser forces measured with the alternative 1 guide wall and the head of the barges placed at location 2 are shown in Figure 20. A slight downstream hawser force was observed between 2 and 3.5 min into the emptying operation with the 1-min valve, but these were less than observed at location 1. Hawser forces measured with the 2- and 5-min valve were also very small.

Hawser force measurements, alternative 1 guide wall, barge head at location 3

Typical time histories of the hawser forces measured with the alternative 1 guide wall and the head of the barges placed at location 2 are shown in Figure 21. Downstream longitudinal hawser forces occurred with the 1-min valve operation for about 2 min beginning 1 min 40 secs into the emptying operation. These hawser forces were small. The transverse hawser forces indicated movement of the barge train to the left side of the lower approach, beginning about 45 secs into the emptying operation and lasting for about 2 min and 15 secs. These forces were also considered small and not a problem. The hawser forces measured with the 2- and 5-min valve operations were very small. A slight movement to the left side of the lower approach was observed for the transverse hawser forces with the 2-min valve operation and again, this would not cause any mooring problems.

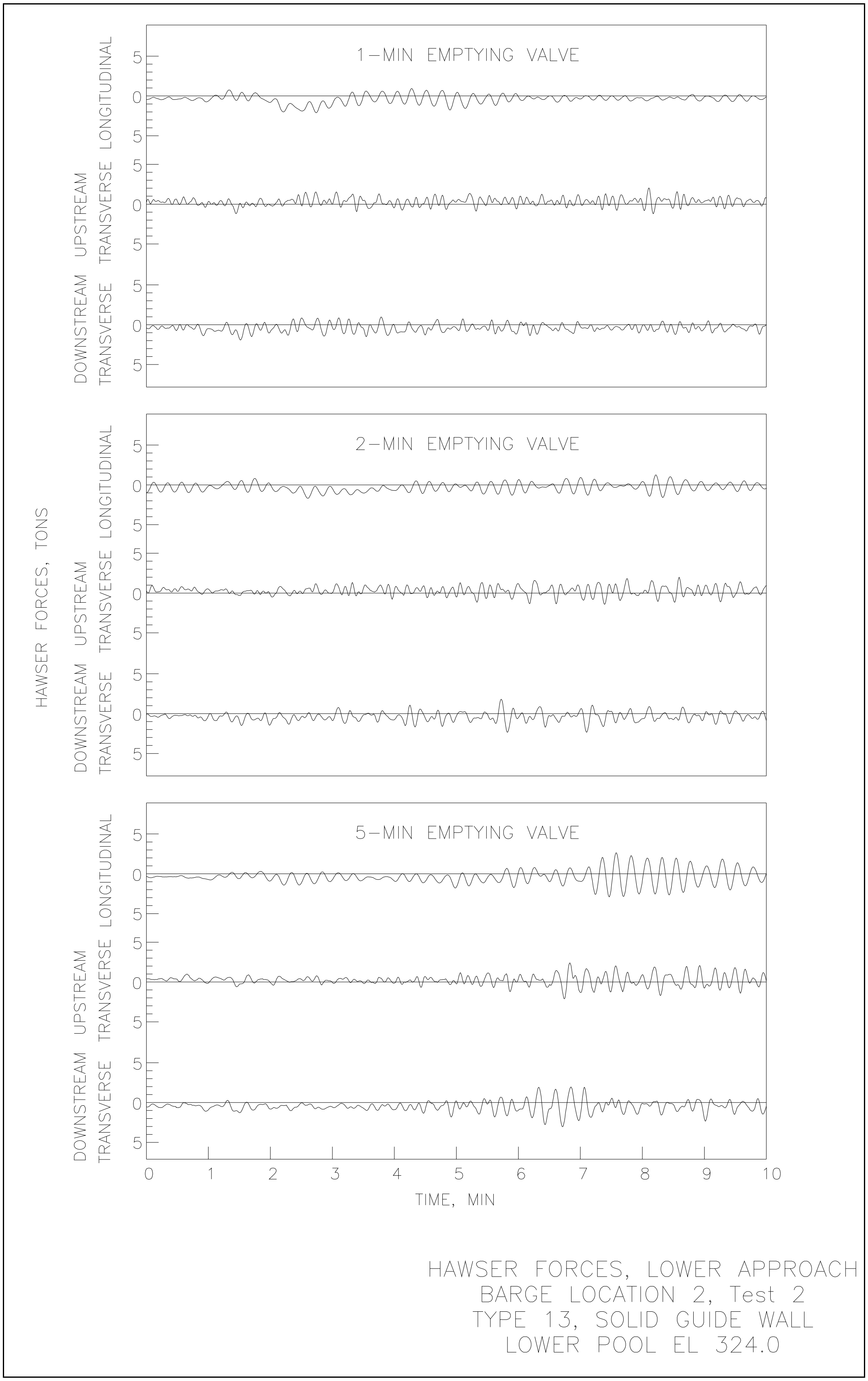

Figure 20. Time histories of hawser forces with alternative 1 lower guide wall at location 2.

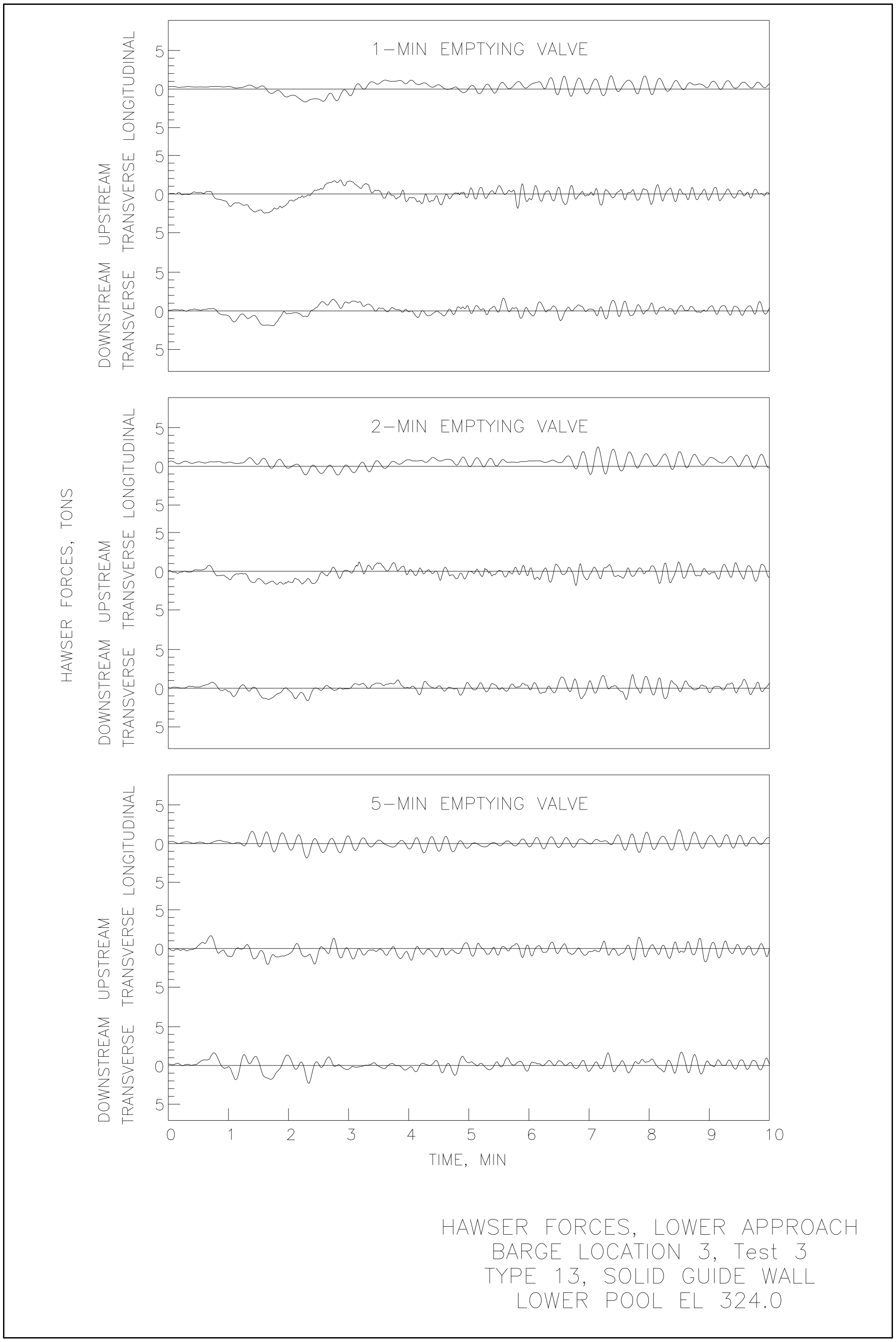

Figure 21. Time histories of hawser forces with alternative 1 lower guide wall at location 3.

Alternative 2 Guide Wall

The alternative 1 guide wall was removed from the model and the alternative 2 guide wall was placed in the model. The alternative 2 guide wall, shown in Figures 22 and 23, was 500 ft long and consisted of a six 52-ft 2.75-in. diameter cells spaced on 89-ft centers with the top of the cells at el 328. Precast concrete box beams were notched into the riverside face of the cells down to el 322. Figure 24 shows the alternative 2 guide wall in the model.

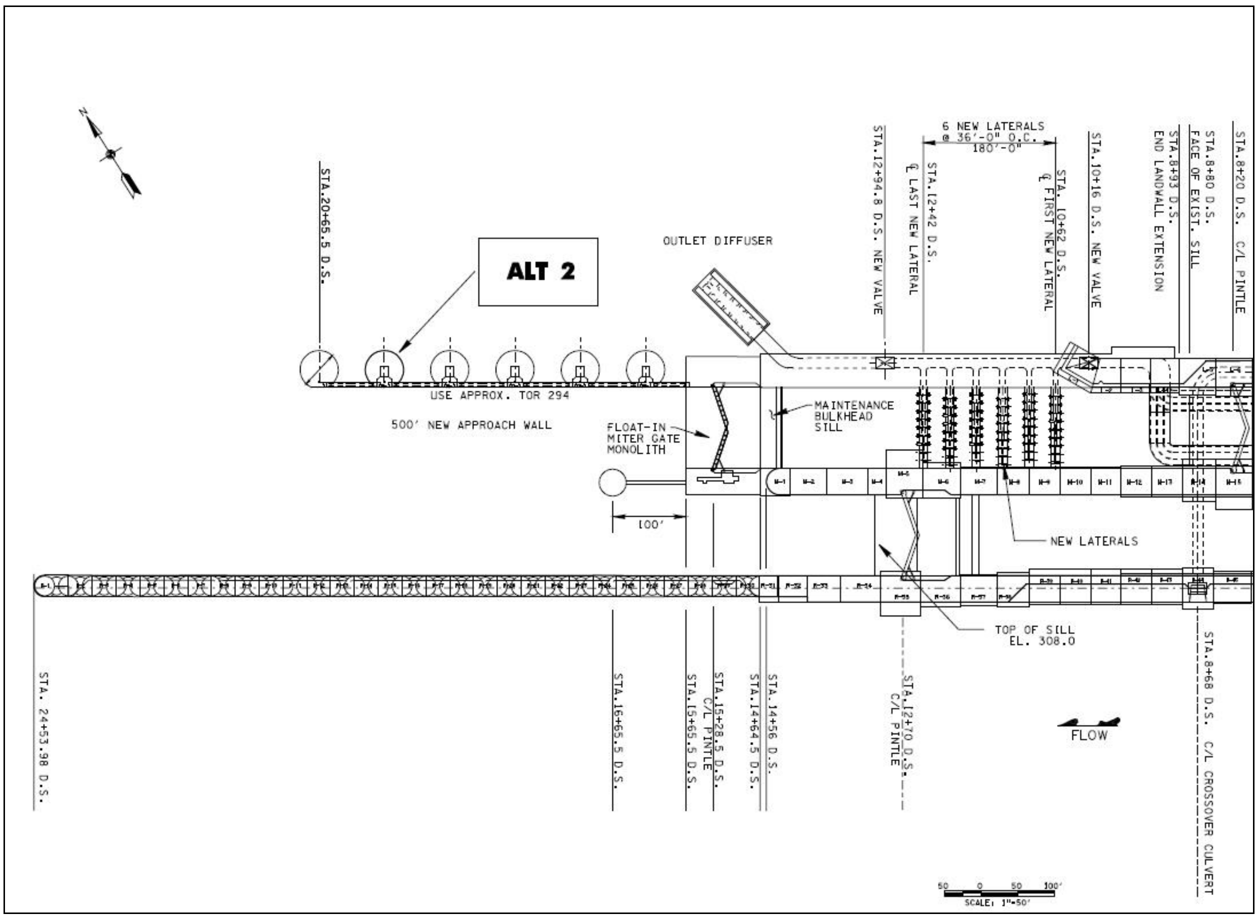

Figure 22. Plan view of alternative 2 lower guide wall.

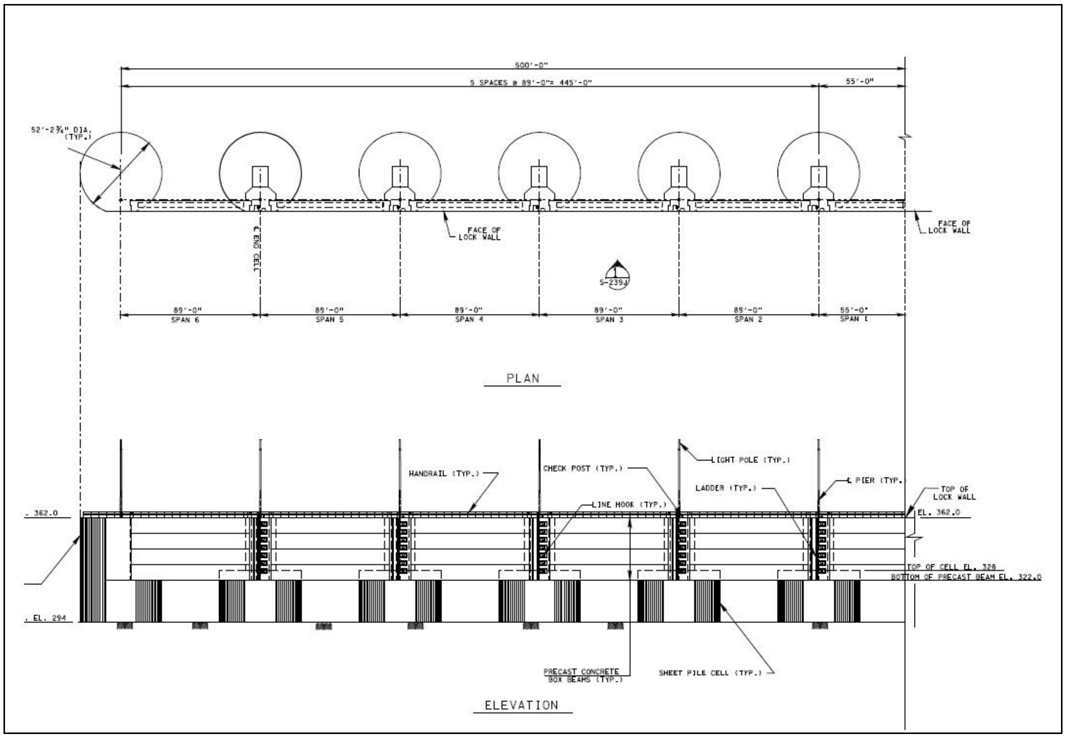

Figure 23. Partial plan and section views of alternative 2 lower guide wall.


Figure 24. View of alternative 2 lower guide wall looking upstream.

Hawser force measurements, alternative 2 lower guide wall, barge head at location 1

Typical time histories of the hawser forces with 1-, 2-, and 5-min valve operations and the head of the barges placed at location 1 are shown in Figure 25. The longitudinal hawser force shows that for the first 3 min 30 secs, a downstream force occurred with a maximum hawser force of 4.7 tons at 2 min 40 secs. After 3 min 30 secs, a slight upstream longitudinal force was observed for 1 min 20 secs and then the hawser forces were essentially zero. The upstream and downstream transverse hawser forces indicate the barge train would move to the left side of the lower approach if not moored. The transverse hawser forces were less than 2 tons during the 1-min valve operation. Similar hawser forces were observed with the 2-min valve operation although the maximum longitudinal hawser force was 4 tons in the downstream direction and occurred at 3 min 15 secs. The transverse forces with the 2-min valve operation also showed slight movement to the left side of the lower approach. The hawser forces with the 5-min valve operation were small. The maximum longitudinal hawser force was 1.8 tons and occurred at 4 min 30 secs into the emptying operation. The longitudinal hawser forces with the alternative 2 guide wall at location 1 were higher than those observed with the alternative 1 guide wall, but were still considered small forces.

Hawser force measurements, alternative 2 guide wall, barge head at location 2

Typical time histories of the hawser forces measured with the alternative 2 guide wall and the head of the barges placed at location 2 are shown in Figure 26. The hawser forces and tendencies were very similar to those measured with the head of the barges at location 1. With the 1-min valve, a maximum downstream longitudinal hawser force of 4.2 tons was measured at 2 min 45 secs into the emptying operation. The upstream transverse hawser forces with the 1-min valve showed hawser forces in the left direction for 2 min and 50 secs with the maximum force around 2 tons. The downstream transverse hawser forces were essentially zero for the 1-, 2-, and 5-min valve operations. The maximum longitudinal hawser force with the 2-valve operation was 4 tons and with the 5-min valve operation, 2.2 tons.

Hawser force measurements, alternative 2 guide wall, barge head at location 3

Typical time histories of the hawser forces measured with the alternative 2 guide wall and the head of the barges placed at location 3 are shown in Figure 27. The hawser forces were very similar to those measured with the head of the barges at location 1. With the 1-min valve, a maximum downstream longitudinal hawser force of 4.8 tons was measured at 2 min 50 secs into the emptying operation. Both the upstream and downstream transverse hawser forces with the 1-, 2-, and 5-min valve were all close to zero. The maximum longitudinal hawser force with the 2-min valve operation was 3.2 tons and with the 5-min valve operation, 1.8 tons.

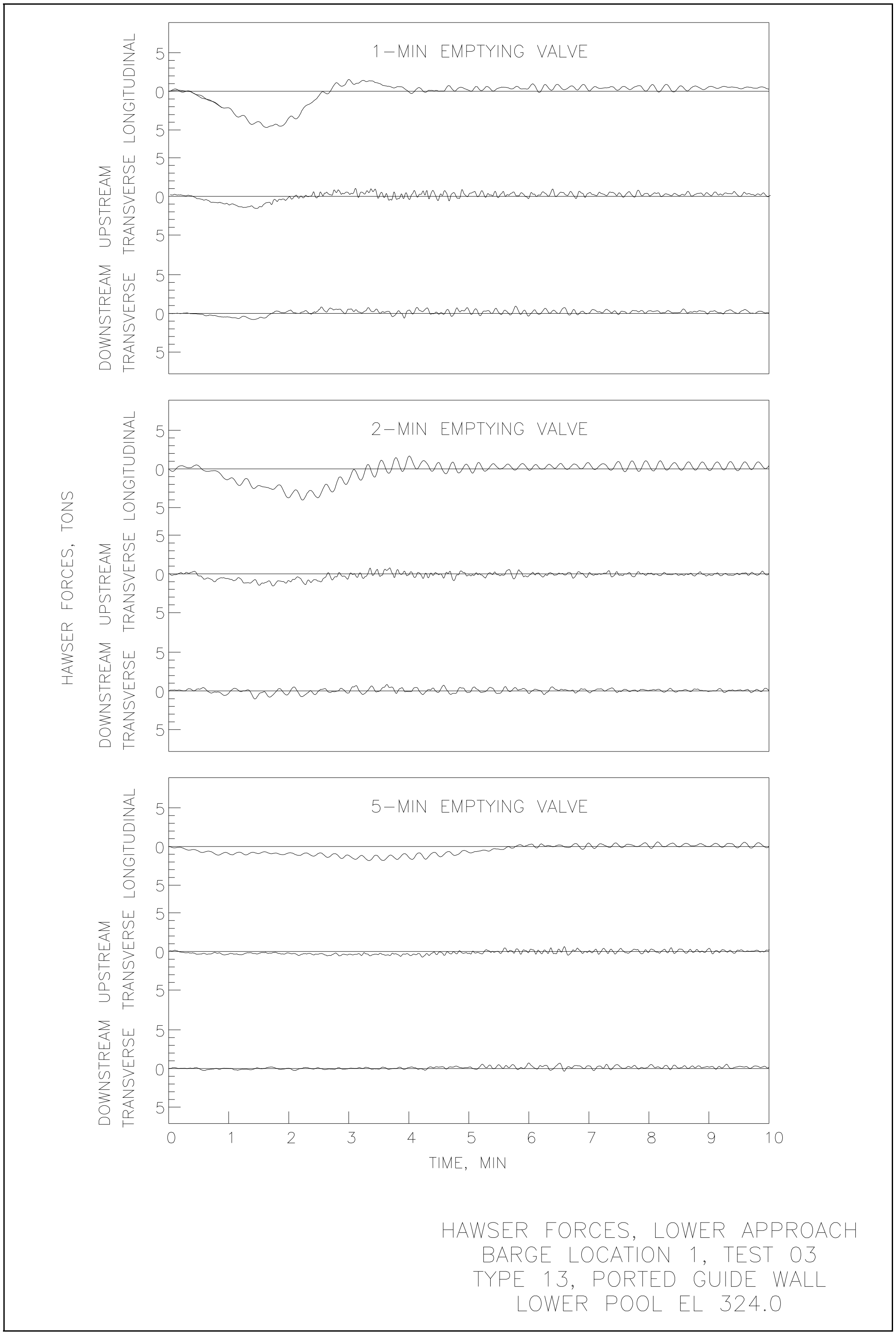

Figure 25. Time histories of hawser forces with alternative 2 lower guide wall at location 1.

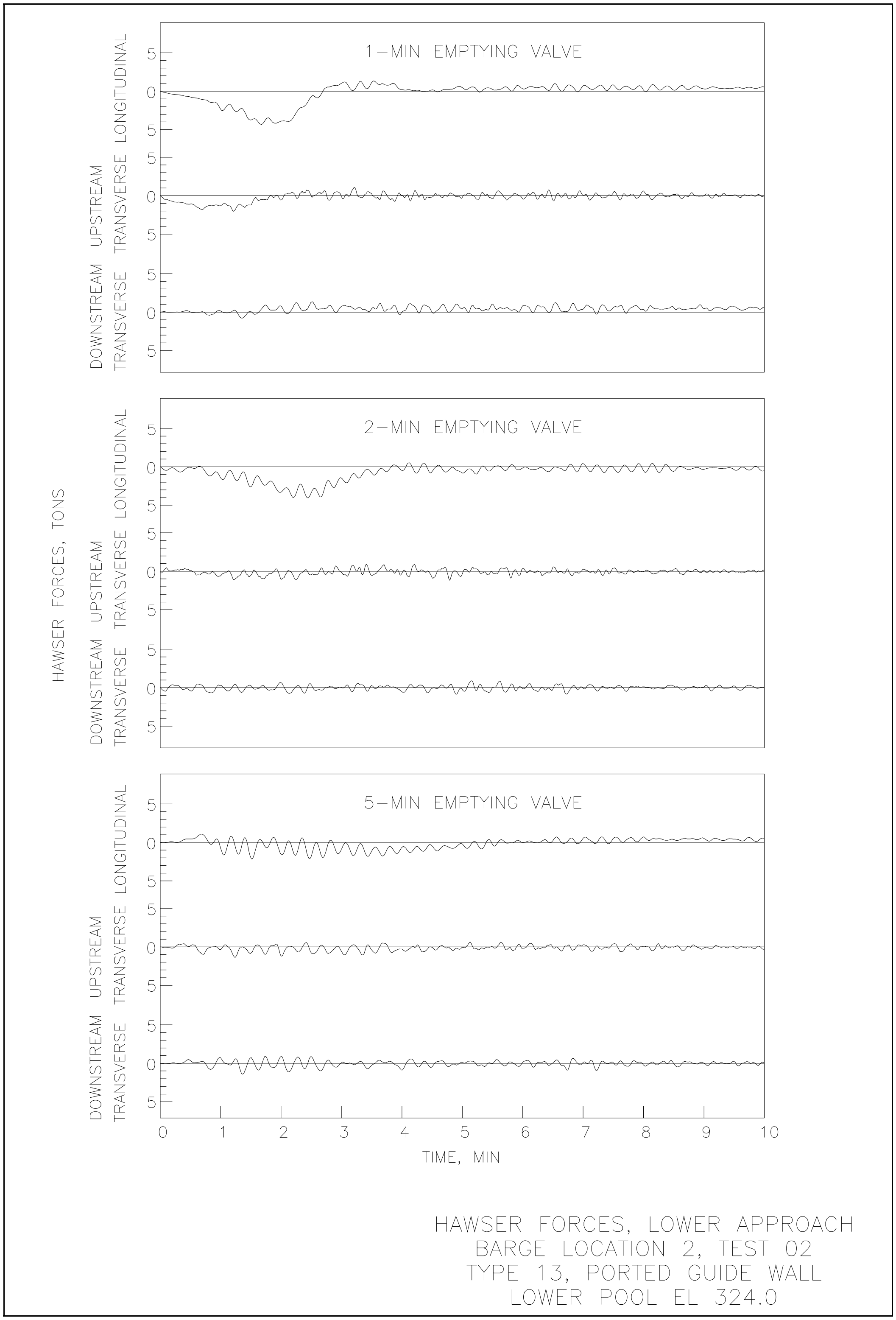

Figure 26. Time histories of hawser forces with alternative 2 lower guide wall at location 2.

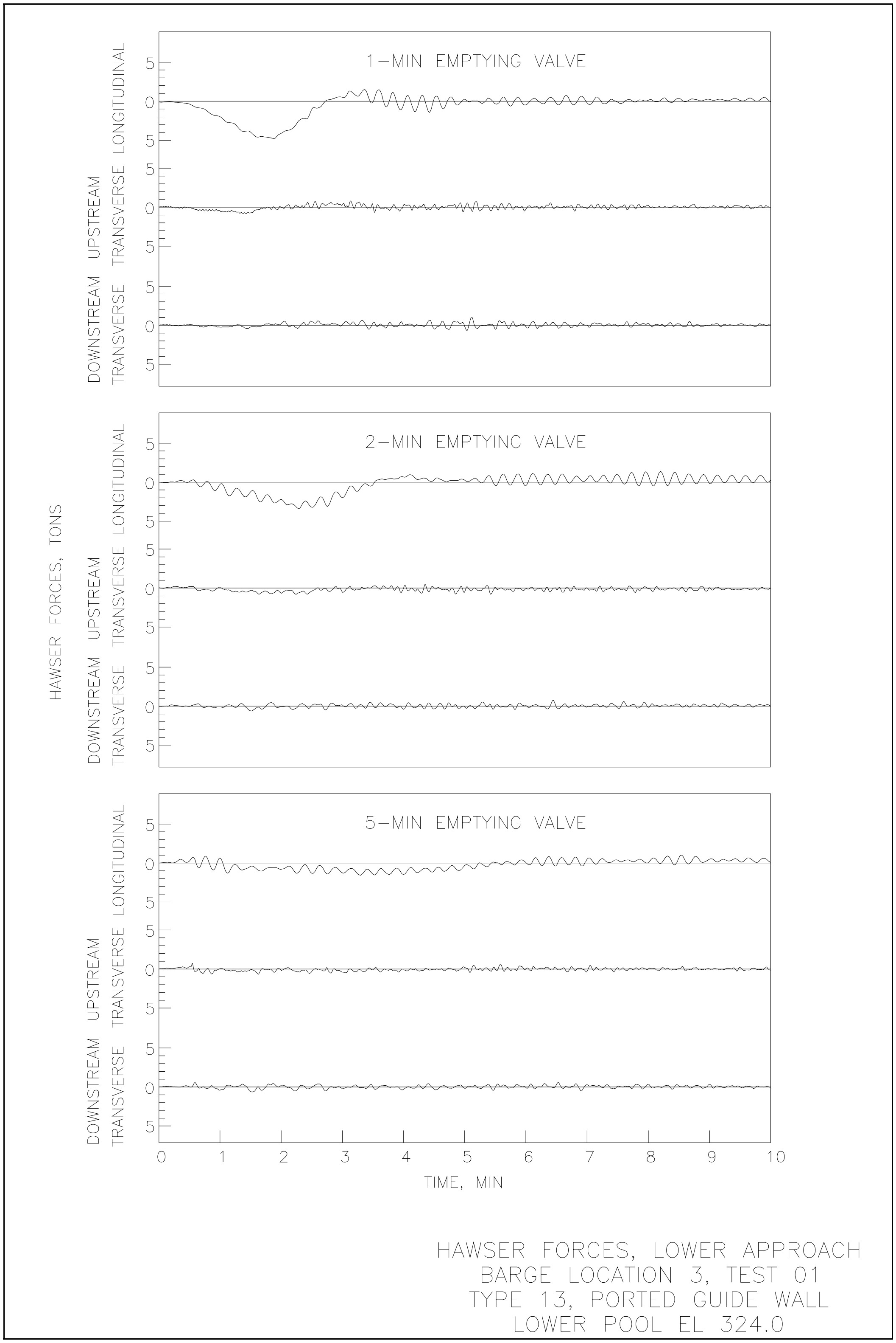

Figure 27. Time histories of hawser forces with alternative 2 lower guide wall at location 3.

4 Summary and Recommendations

Riprap Requirements

The results of the scour tests indicated that the discharge from the type 13 outlet design during emptying operations did not cause any significant scour in the vicinity of the outlet. The flow along the bank in the downstream direction was slow and no strong eddies were present around the outlet. The type 1 riprap design evaluated in the previous outlet study (Hite 2004) would be adequate to protect the bottom and channel banks from the discharge from lock emptying operations. This design was based on an average velocity of 6 ft/sec and the HDC criteria (HQUSACE 1988) for riprap placed in the dry for highly turbulent flow. The design consists of a d50 size stone of 6 in with a blanket thickness of 18 in. The limits of the riprap gradation from Engineer Manual 1110-2-1605 (HQUSACE 1987) and the gradation used in the model are shown in Figure 8. The extent of the riprap required in the vicinity of the outlet diffuser indicated by scour tendencies observed in the model is minimal. It is recommended that at least 20 ft of riprap be placed around the outlet with the top el of the riprap no higher than el 300. This will help prevent any scour adjacent to the outlet. The riprap recommendations are based solely on discharge from the outlet. If high spillway flows or any known unusual spillway conditions cause flow behind the landside lock wall, the riprap should also be designed to protect against scour from these conditions.

Hawser forces on barges moored in the lower approach

The hawser force measurements indicated that the forces on a tow moored in the lower approach caused from the landside lock emptying with the type 13 outlet design and the alternative 1 lower guide wall were low. The direction of the forces were downstream and toward the left side of the lower approach. No forces larger than 5 tons were measured at any of the three locations observed in the lower approach. The 5-ton hawser force criteria have been adopted for use in evaluating lock filling and emptying systems. A filling and emptying system that does not cause hawser forces on a tow moored inside the chamber greater than 5 tons for a desired lock operation time is considered to be an acceptable system. At present, there is no hawser force guidance or criteria for tows moored in the lower approach. The forces measured with the type 13 outlet design and the alternative 1 lower guide wall would not cause any adverse mooring problems in the lower approach.

The forces measured with the type 13 outlet design and the alternative 2 lower guide wall were slightly higher than those measured with the alternative 1 lower guide wall, but were not considered excessive. Longitudinal hawser forces measured for the 1-min emptying operation were close to 5 tons in the downstream direction with the barges moored at location 1. The longitudinal hawser forces measured with the 1-min emptying valve and the barges moored a locations 2 and 3 were less than 5 tons. There was slight movement of the barges toward the left side of the lower approach, as was also observed with the alternative 1 lower approach wall. Since the forces with the alternative 2 lower guide wall were also small, the selection of the guide wall can be based upon factors other than the hydraulic performance of the outlet during lock emptying.

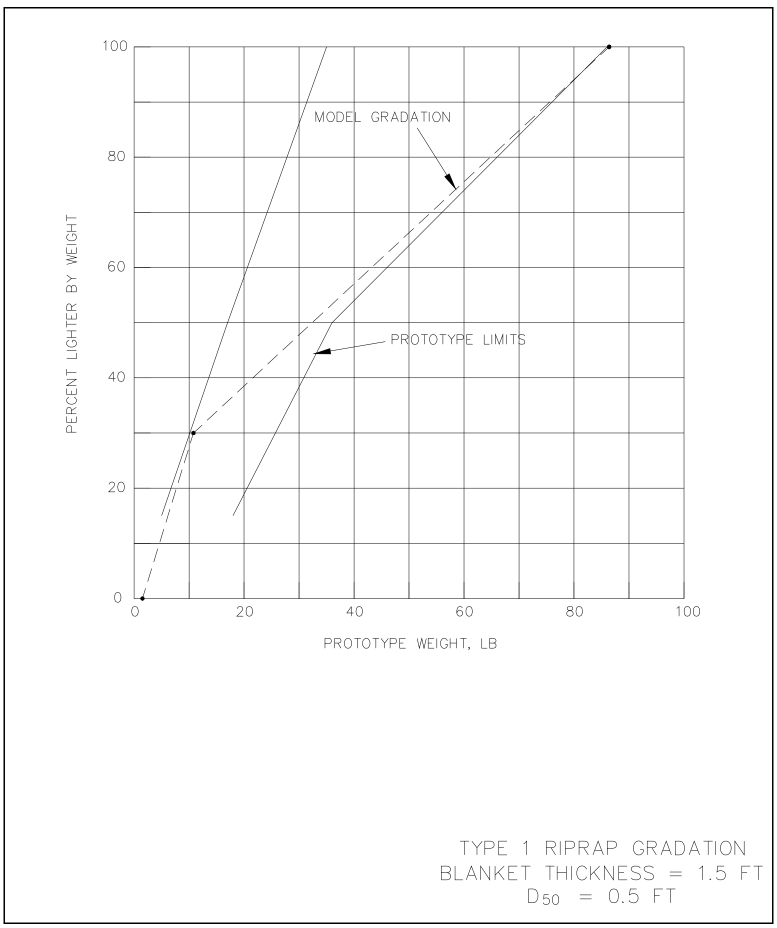

Figure 28. Type 1 riprap design from Hite 2004.

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14. ABSTRACT
Navigation improvements are planned at J. T. Myers Locks and Dam on the Ohio River main stem. The existing project consists of a navigation dam, a 1,200-ft-long by 110-ft-wide main lock chamber adjacent to a 600-ft-long by 110-ft-wide auxiliary lock chamber. One of the improvements includes developing a 1,200-ft long lock chamber from the existing 600-ft-long lock chamber. The outlet design originally proposed for the filling and emptying system in the extended lock section was a manifold type diffuser located within the landside guide wall monolith and discharging toward the right (looking downstream) bank. A landside diffuser would help minimize closure of the main lock during construction of the lock extension. A 1:25-scale model was used to evaluate the originally proposed outlet design (Hite 2004). Since the publication of that report, the lock design changed and a new outlet design was necessary. This report provides the results of the model investiga-tion for the new outlet design. The performance of the outlet design was based on scour tendencies in the vicinity of the outlet and hawser forces experienced by a tow moored at various locations in the lower lock approach. Two different guide wall designs were tested during the study.

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