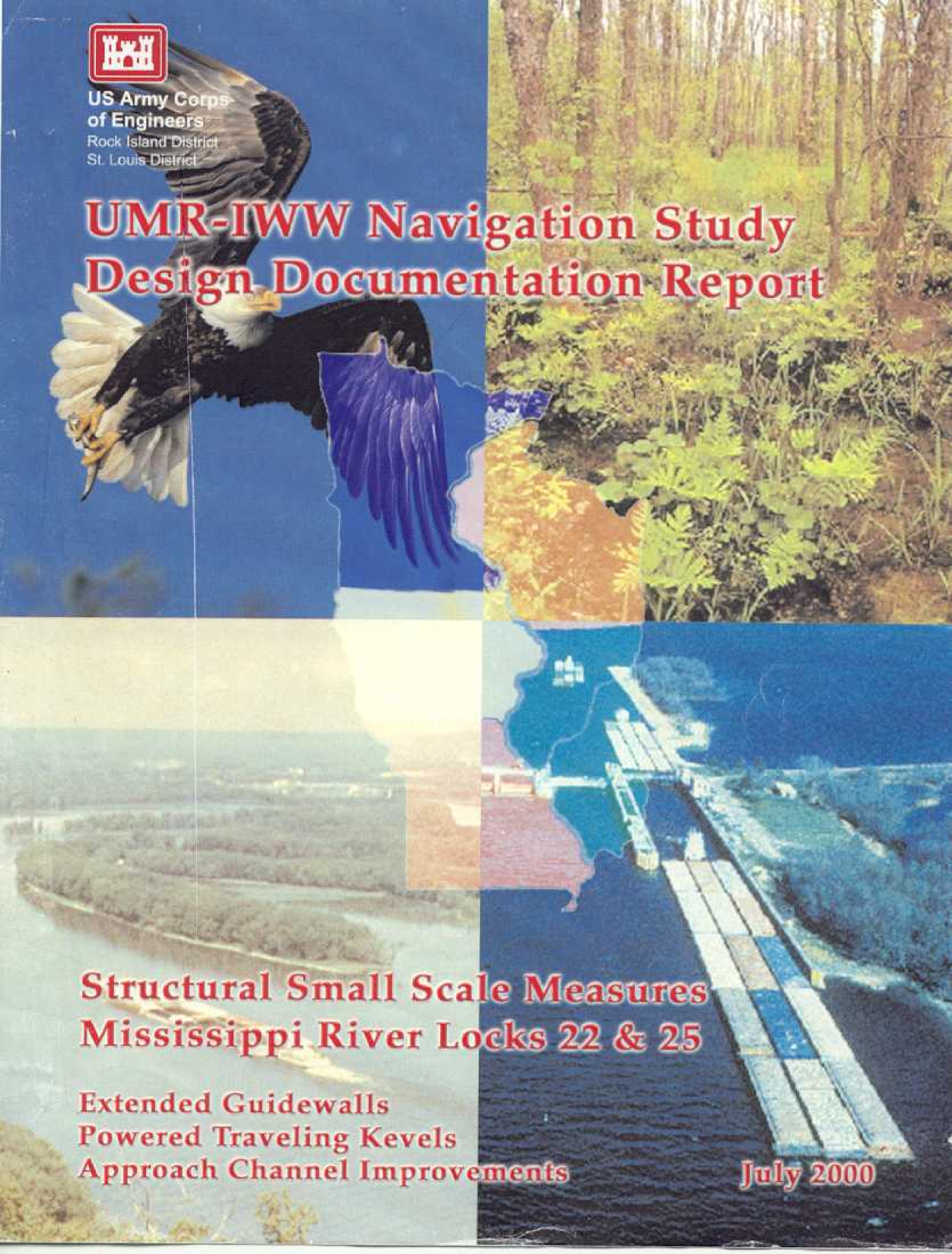


US Army Corps
of Engineers
Rock Island District
St. Louis District

UMR-IWW Navigation Study
Design Documentation Report

Structural Small Scale Measures
Mississippi River Locks 22 & 25

Extended Guidewalls
Powered Traveling Kevels
Approach Channel Improvements

July 2000

DESIGN DOCUMENTATION REPORT
STRUCTURAL SMALL SCALE MEASURES
LOCKS 22 AND 25
MISSISSIPPI RIVER

TABLE OF CONTENTS

4. **Appendices**

A. Structural Analysis
B. Powered Traveling Kevel Analysis
C. Hydraulics Analysis
D. Geotechnical
E. General Site Considerations
F. Value Engineering Study, March 1999
G. Regulation 33 CFR 207.300 and Navigation Notice #1
H. Glossary

SUMMARY

This report includes discussions and recommendations for structural small scale improvements at Locks 22 and 25 on the Mississippi River. This Design Documentation Report is a small subset of the Upper Mississippi River/Illinois Waterway System Navigation Study. Small scale improvements are defined as lower cost alterations which provide benefits by reducing barge traffic delays. The specific improvements covered herein are extended guidewalls, powered traveling kevels, and approach channel improvements.

Locks 22 and 25 were chosen for two main reasons. The first is that one lock is rock founded (Lock 22) and the other sand founded (Lock 25). All analysis and decisions concerning these foundations will be easily transferred to other similar locks. The other reason is that Lock 22 is within the Rock Island District and Lock 25 within the St. Louis District. Since both Districts are heavily involved in the Navigation Study, it was beneficial to gather information and input at locks from each District. Also, both locks are located at the southern end of the Upper Mississippi and therefore receive heavy industrial traffic.

Each of the structural small scale measures are discussed in three categories; existing condition, considered alternatives, and conclusions and recommendations. Detailed analyses of the three measures are included as appendices. Other appendices include; geotechnical information, civil/site issues, a VE Study conducted in March 1999, applicable regulations, and a glossary of terms.

1. Introduction

1.1 **Navigation Study Overview.** The Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study is a feasibility study addressing navigation improvements planning for the years 2000 to 2050. The study will assess the need for navigation improvements at 29 locks on the UMR and 8 locks on the IWW and the impacts of providing these improvements. More specifically, the principal problem being addressed is the potential for significant traffic delays on the system within the 50-year planning horizon, resulting in economic losses to the nation. The study is to determine whether navigation improvements are justified, and the appropriate navigation improvements, sites, and sequencing for the 50-year planning horizon. The feasibility study also includes the preparation of a system Environmental Impact Statement (EIS). The final product of the System Navigation Study is a feasibility report which will be the Decision Document for Congressional approval.

1.2 **Authority.** Authority for the UMR-IWW System Navigation Study is contained in Section 216 of the Flood Control Act of 1970 (Public Law 91-611) which allows for the review of completed Corps of Engineers projects when found advisable due to significantly changed physical or economic conditions.

1.3 **Purpose.** This Design Documentation Report will provide the technical basis for plans and specifications. It will serve mainly as a summary of the final recommended design for future use and reference. This report documents the basic criteria and decisions made for extension of guidewalls, powered traveling kevels, and channel improvements at a rock founded site (Lock and Dam 22) and at a sand founded site (Lock and Dam 25).

1.4 **Scope.** This report represents continued analysis of the structural small-scale improvements as part of the UMR-IWW System Navigation Study. These structural small scale measures represent items that significantly reduce existing and expected traffic delays at the system locks but involve considerably less cost than the construction of new lock facilities or the extension of existing lock chambers. Locks 22 and 25 were chosen for this report because these locks have the greatest potential for navigation improvements. Locks 22 and 25 are at the lower end of the UMR-IWW and experience significant navigation delays. Lock 22 is a rock founded site and thus the preliminary work done in this report will be applicable to other rock founded sites on the UMR-IWW. Lock 25 is a sand founded site and thus the preliminary work done in this report will be applicable to other sand founded sites on the UMR-IWW.

1.5 **Report Format and Content.** This report focuses on the aforementioned structural small scale improvements at Lock and Dam 22 and Lock and Dam 25. Section 1 provides information on the study purpose and scope, discusses the background of the study, and lists a summary of pertinent data. Section 2 describes and recommends the preferred alternatives for the structural small scale measures studied in this report, which are; extended guidewalls, powered traveling kevels, and approach channel improvements. These improvements are interdependent, that is, performing only one of these improvements would not provide nearly the benefits as performing all three. Section 3 contains an investigation of the different contracting methods and documents the recommended contracting method for the improvements contained in this report. Section 4 lists the appendices. The appendices provide in-depth detail of the guidewall extension, powered traveling kevel, approach channel improvements, geotechnical, site considerations, and value engineering used to compile this report.

This report provides a detailed overview of the design of each of the recommended small scale measures for two particular sites, Lock and Dam No. 22, a rock founded site, and Lock and Dam No. 25 a sand founded site. Design decisions, assumptions, methods, and summaries of important calculation results are described in detail for each of the proposed measures at both sites.

1.5.1 Lock 22 Description – Rock Founded

Location and History. Lock and Dam 22 is located at Saverton, Missouri, 301.2 miles above the confluence of the Ohio and Mississippi rivers. Pool 22 extends from Saverton in a northwesterly direction 23.7 river miles to Lock and Dam No. 21 at Quincy, Illinois. Construction of Lock and Dam 22 began in December of 1933 and was completed in July 1938. Between 1987 and 1990, the Rock Island District rehabilitated Lock and Dam 22 for the purpose of extending its useful life. Rehabilitation work on the lock included the mechanical/electrical systems, replacing deteriorated concrete, and rehabilitating the miter gates and tainter valves. Work on the dam included rehabilitating the roller and tainter gates, and replacement of the electrical systems. The lock and dam facility is currently in good condition with no significant structural deficiencies noted.

Lock. The main lock has a clear length of 600 feet and a width of 110 feet, with a maximum lift of 10.5 feet. The lock structure consists of three walls: a land wall, an intermediate wall, and a river wall. The land wall of the lock is 1,940 feet long, which includes the upper guidewall of 517 feet, the main lock wall of 923 feet, and the lower guidewall of 500 feet. The intermediate lock wall is 897.5 feet. The river wall, which is the partially complete left sidewall of the auxiliary lock chamber, is 278.5 feet long. The lock has three miter gates, two in the main chamber, one upstream and one downstream, and one in the auxiliary chamber, an upstream gate. All of these are vertically framed steel gates. With the exception of the guidewalls, all the walls that comprise the lock structure rest on solid limestone rock foundation and are keyed directly into the rock. Timber cribs that are placed on a shale layer, which is approximately 5 feet thick and rests directly on the limestone, support the upstream and downstream guidewalls. The filling and emptying of the lock chamber is by gravity flow through culverts within the land and intermediate walls.

Dam. The dam has a total length of 3,084 feet, consisting of 1,024 feet of gated section, 460 feet of a non-overflow earth dike section, and 1,600 feet of an overflow earth dam section. The gated section adjoins Lock 22 and is located across the main channel. The gated section has

3 roller gates and 10 tainter gates, together with appurtenant piers, sills, aprons, service bridge, operating machinery, and control houses. Three of the tainter gates, located adjacent to the lock, are separated from the remainder of the tainter gates by the three roller gates, which are situated at approximately mid-channel. A portion of the non-overflow section is formed by a storage yard 200 feet long. The dam also has a rock foundation.

1.5.2 Lock 25 Description – Sand Founded

Location and History. Lock and Dam 25 is located approximately 3 miles east of Winfield, Missouri, along the east shore of Bradley Island, 61.5 river miles upstream from St. Louis and 241.5 river miles above the mouth of the Ohio River. Bradley Island is separated from the Missouri shore by Sandy Slough, which is approximately 900 feet wide at the project site. Lock and Dam 25 may be accessed from Missouri State Highway 79 at Winfield, Missouri via county road east to the project access road. Pool 25 extends from Winfield in a northerly direction 32 river miles to Lock and Dam 24 at Clarksville, Missouri. The dam and the 600-feet main lock were authorized by the Rivers and Harbors Act, 3 July 1930, Rivers and Harbors Commission, Document No. 12, 70th Congress, First Session. Lock and Dam 25 was authorized as part of the navigation system to provide a 9-feet deep by 400-feet minimum width channel on the upper Mississippi River between the mouth of the Missouri River and Minneapolis, Minnesota. The project was designed and constructed to operate in conjunction with similar structures upstream and downstream to provide continuous navigation on the upper Mississippi River.

Lock. The main lock has a clear length of 600 feet and a width of 110 feet, with a maximum lift of 15 feet. The lock structure consists of three walls: a land wall, an intermediate wall and a river wall. The land wall is 1,992.5 feet in length, which includes an upstream guidewall of 570 feet, a main lock wall of 920.5 feet and a downstream guidewall of 502 feet. The intermediate lock wall is 907 feet in length. The river wall (the partially completed left sidewall of the upstream auxiliary lock bay) is 269 feet in length. The lock has three miter gates; one at each end of the main chamber and one in the auxiliary lock bay. All of these miter gates are vertically framed steel gates. All the walls that comprise the lock structure are founded on timber pile with the predominant sized pile being a 12-inch diameter pile at the head and an 8-inch diameter at the tip. In addition to the timber piles the downstream guidewall monoliths are also founded on rock-filled timber cribbing. The filling and emptying of the lock chamber is by gravity flow through culverts within both the land wall and the intermediate wall.

Dam. The dam has a total length of 4,078 feet, consisting of 1,296 feet of gated section, followed by 216 feet of a non-overflow compacted earth fill storage yard section and finishing with a 2,566 feet overflow dike section which ends at the Illinois bluffs. The overflow dike is constructed of compacted earth fill protected with stone and gravel on the side slopes. The gated section adjoins Lock 25 and is located across the main channel. The gated section has 3 roller gates accompanied by 14 tainter gates together with appurtenant piers, sills, aprons, service bridge operating machinery houses and storage houses. Nine of the tainter gates are located adjacent to the lock and are separated from the other 5 tainter gates by the 3 roller gates. The roller gates are situated at approximately mid-channel. The dam piers are founded on vertical wood piles accompanied by upstream and downstream steel sheetpile cutoff walls.

1.6 **Coordination.** An Engineering Work Group (EWG) was formed to help facilitate coordination for this report. The EWG consists of representatives from two Corps of Engineers districts, the Rock Island District and the St. Louis District. Lock and Dam 22 is within the Rock Island District, Lock and Dam 25 is within the St. Louis District. The EWG met on a regular basis to review and discuss progress and to make any required adjustments to satisfactorily address all the engineering objectives. Because the EWG consists of personnel from two Corps of Engineers districts, the telephone, email, and ftp Internet sites were utilized on a regular basis to ensure proper coordination. The EWG also met and coordinated with Corps of Engineers representatives from Operations Division, Construction Division, Planning Division, and Real Estate Division, as well as other Corps of Engineers Districts with navigation missions.

Coordination additionally occurred with the general public, the navigation industry, and various state, local and federal government agencies. Study oversight was provided by the Mississippi Valley Division and Headquarters of the Army Corps of Engineers.

2. Structural Small Scale Measures

Description. Structural small scale measures are defined as lower cost measures requiring construction that can reduce traffic delays and congestion at the system locks without the major construction and expense involved with extending the existing lock chamber or building new locks. The structural small scale measures that are a part of this report were carried forward from the screening of the *Detailed Assessment of Small Scale Measures* report. The *Detailed Assessment of Small Scale Measures* report focused on quantifying the benefits and costs of implementing small scale measures. It additionally examined the small scale measures and their relationship with other considerations such as a reduction in approach time, reduction in extraction time of the first cut, reduction in chambering time of double lockage tows outside of the chamber, and the reconfiguration of setover and knockout singles.

A Value Engineering Study was performed in the St. Louis District in March 1999 to review extended guidewalls and powered traveling kevels. Members included personnel from several Corps Districts as well as private industry. A copy of this report is included in Appendix F.

This section contains a description of three structural small scale measures; extended guidewalls, powered traveling kevels, and approach channel improvements.

2.1. Extended Guidewalls.

2.1.1 Existing Conditions. On the UMR and IWW, the existing guidewalls are located on the land side of the approach channel and are typically 600 feet long. These walls are used to align the tows with the lock and to guide the tows into the lock chamber. Typically, vessels tie up against the guidewall while waiting their turn into the lock. Guidewalls are also used to tie off unpowered cuts which remain tied off until the powered cut is finished locking through and the two halves are then recoupled. Since the unpowered cut and guidewall are each approximately 600 feet long, the powered cut remains inside the lock chamber while the two cuts are recoupled. Therefore the lock cannot be used for other vessels until the powered and unpowered cuts are recoupled, and moved out of the lock area.

Extending the existing guidewalls would allow the powered cut of a double lockage to recouple with the unpowered cut completely outside of a normal 600 foot lock chamber. The lock would then be free to be turned back for the next vessel traveling in the same direction. This extended guidewall results in a major time savings benefit when combined with a powered traveling kevel that would move the unpowered cut to the end of the extended guidewall. The powered traveling kevel is further described in Section 2.2.

There are many different methods to achieve an extended guidewall. In the paragraphs that follow, a brief review is given of the design proposals considered, the screening criteria used, and the screening results.

2.1.2 Alternatives Considered. Mississippi Locks 22 and 25 have guidewalls that are approximately 500 ft to 600 ft in length. The main design objective of this measure is to extend the guidewalls from their present 500 feet to 1200 ft. The increased length will make it possible for a full tow to remake entirely outside of the main lock chamber. Below is a list of the design alternatives that the Corps considered for the guidewall extensions accompanied by a brief explanation of the work involved for each proposal.

Proposal 1 – Float in Walls. Hollow concrete wall sections are pre-cast and floated on the river to the desired location. Once in position, the sections are flooded and brought to rest on an already prepared foundation. Finally the flooded compartments of the wall section are filled with concrete. After completion, the float in wall is essentially a mass concrete structure.

Proposal 2 –Tied Parallel Sheet Pile Wall. Two parallel sheet pile walls are driven, approximately thirty feet apart. The sheet pile walls are connected by steel tie rods and filled with sand. The entire structure is then covered with a concrete cap to create the guidewall.

Proposal 3 – Incorporate Cofferdam into Permanent Structure. Sheet piles are driven to create a cofferdam for the work area where the guidewall is to be placed. The sheet pile cofferdam is filled with concrete to create the guidewall. After completion of the concrete placement, the sheet pile remains in place, serving as outer armor for the entire guidewall.

Proposal 4 – Floating Walls. Several hollow concrete tubular beams form the wall. These beams, which are light enough to float, rest between concrete piers that act as guides. The piers keep the walls in alignment and provide stability against overturning. The wall is free to rise and fall with the changing elevation of the pool in which it rests.

Proposal 5 – Pre-cast Beams on Drilled Shafts. Pre-cast concrete beams are fixed on the concrete caps of widely spaced groups of drilled shafts. The shafts carry the dead load of the beams and provide stability against overturning. The beams act as the guidewall and are capable of withstanding barge impacts.

Proposal 6 – Pre-cast Beams on Sheet Pile Cells. This proposal is very similar to the preceding one, except concrete filled sheet pile cells are used in lieu of drilled shafts for the purpose of carrying the dead load of the concrete beams and providing stability against overturning.

Proposal 7 – Pre-cast Beams on Modular Steel Cans. This proposal is identical to proposals 5 and 6 except in the method of supporting the beams. A concrete filled prefabricated steel can will be used instead of drilled shafts or sheet pile cells.

Proposal 8 – Float-In Pre-cast Beam. Several hollow concrete tubular beams form the walls. These sections are pre-cast, floated into place, and then securely fastened to widely spaced sheet pile cells. Unlike the arrangement in proposal 4, these beams will not rise and fall with fluctuations in pool elevation; they will remain fixed to the cells. As a result of this fixity, the dead load exerted on the supporting cells by the beams varies depending on the pool elevation. Piles are placed at regular intervals along the length of the beams to support some of their dead load under low water conditions. (CEMVR-ED-DS conducted a preliminary investigation into this design concept before it was screened out in favor of a different proposal. See Appendix # for a summary of this study.)

Screening Results. The Corps design team screened each of these proposals on the basis of the following criteria: (1) operability, (2) impacts to navigation, and (3) cost. Through this screening process it was possible to arrive at the most suitable design concept for the proposed guidewall extension. Given below, grouped by determining criteria, are the reasons for the elimination of various proposals. The reasons described do not provide an exhaustive list of all the objections or problems for each proposal. The discussion is limited to the difficulties that carried the greatest weight in the decision to screen out any particular proposal.

Operability. Proposal 4 was the only proposal found to be incompatible with the operational requirements of the lock and dams, and was screened out on this basis. The kevel rail, which is used to guide the first cut of a double lockage out of the lock chamber, must extend over nearly the entire length of a guidewall. The existing guidewalls at all the Mississippi River lock sites have top horizontal surfaces with fixed elevations. The top horizontal surface of a guidewall extension made from floating concrete segments, as described in proposal 4, will vary in elevation depending on the level of the pool in which it rests. If such floating guidewall extensions were built at the Mississippi Lock sites under consideration, the completed guidewall would consist of one fixed segment, the original guidewall, and one floating segment, the new extension. A kevel rail cannot be installed on this type of hybrid wall. In order to provide the rail with a continuously level horizontal surface, the wall must either be all fixed or all floating.

Impacts to Navigation. Several proposals were rejected because their construction would either require or pose a considerable risk of causing an extended interruption of navigation outside of the winter season. During the winter, very little cargo is moved on the Upper Mississippi System, therefore, at that time, a complete navigation shutdown of the lock can take place with little or no impact to industry. If, however, outside of the winter season, navigation is prevented from moving through the locks for an extended period of time, i.e., several days or more, the cost to industry becomes very substantial. This cost typically far exceeds any potential savings that a particular construction technique might yield.

Proposals 3 and 5 were screened out because their construction is believed to be extremely difficult, if possible at all, without a shutdown of navigation through certain phases of construction. Proposal 3 would require the construction of a sheet pile cofferdam to create a work area. This cofferdam would be left in place, without being filled with concrete, through at least part of one navigation season. If tows were passing by, it would not be possible to allow anyone to work in the cofferdam. A barge impact to the cofferdam could cause a breach, imperiling the life of anyone inside. If proposal 5 were pursued, the drilled shafts would be set in place first. Until a concrete cap is placed on a group of drilled shafts, they will not act as a unit, but only as a number of individual shafts. The ability of these shafts to resist the applied load from a barge impact would be no greater than the strength of a single shaft. Before the placement of a concrete cap, navigation would pose a significant threat to the placed drilled shafts. Without a shutdown of navigation until concrete caps had been placed on all drilled shafts, something that could not easily be completed in a winter closure, the government would assume a considerable risk for any costs incurred if an impact did occur. For proposals 6 and 7, which are identical to proposal 5 but would use sheet pile cells or modular steel cans respectively in place of drilled shafts, navigation during construction is not a serious concern. The sheet pile cells or cans could be constructed during a winter closure, and are quite capable of withstanding a barge impact.

Proposal 2 has the advantage of being a traditional form of construction that many contractors are familiar with. This would undoubtedly reduce construction costs, but the nature of this construction procedure poses a problem. A tied parallel sheet pile wall requires linear construction, or, in other words, it can not be broken down into phases easily completed during a winter shutdown. Although the construction work could continue into the navigation season safely, the ongoing work would very likely interfere with navigation. On the basis of this probable impact to navigation, proposal 2 was screened out.

Finally, proposals 1 and 8 were also screened out, in part, because of their potential for creating significant navigation delays. Theoretically, float in walls or beams could be placed with no, or at least insignificant, impacts to navigation. Yet the newness of these techniques makes it unlikely that they can be used without some complications. It is possible that these impacts would not be great, but lack of experience with these float in procedures makes it difficult to determine the extent of the risk involved.

Cost. As stated above, proposals 1 and 8 were screened out, in part, because of their potential impact to navigation. They were also screened out, in part, because of their potential cost relative to other available construction alternatives. As was the case with construction impacts to navigation for these proposals, the exact cost of construction is difficult to determine, in this instance because of the number and magnitude of variables involved. It is possible that float in construction techniques will be cost effective, yet they may be much more expensive than other alternatives; this would be difficult to determine in advance of construction. Two important examples of the unknowns involved are the location and the method of casting the floating sections. Because of their tremendous weight (sections would weigh more than 1000 tons each,) the casting would need to be done in a facility from which the sections could be floated on to the river. The cost of such an operation would vary greatly depending on its location relative to the work site and the method of casting used. Therefore, proposals 1 and 8 were screened out because of both the uncertainties surrounding their impacts to navigation and their construction cost. Cost estimate summary sheets are included in the appendix.

2.1.3 **Conclusions and Recommendations.** As a result of the screening process, proposals 6 and 7 were found to be the most suitable designs for the guide wall extensions. Both proposals are similar, the modular steel can simply being an alternative method of constructing what is essentially a concrete filled sheet pile cell. Due to past performance and construction ease and speed, proposal 7 is recommended over proposal 6. The design is fully compatible with the operational requirements of the lock and is suitable for both sand and rock founded sites. Construction can be done in phases that pose little risk of interfering with navigation. The modular steel can could be placed during several winter shutdowns, and, as stated earlier, would be fully capable of withstanding any barge impacts that may occur during regular lock operations. The cost of this design is quite reasonable in comparison with the other proposals. Therefore, Proposal 7, pre-cast beams on modular steel cans will be used at both Locks 22 and 25. Structural analyses covering both locks is presented in Appendix A Structural Analysis, of this report.

2.2 **Powered Traveling Kevels.** A kevel is a heavy metal deck fitting having horn-shaped arms around which lines are secured for towing or mooring a vessel. A powered traveling kevel is rail-mounted and provides power to extract the unpowered barge cut from the lock.

2.2.1 **Existing Conditions.** Currently locks extract the unpowered barge cut with a winch system known as a tow haulage unit. The current tow haulage units were not designed for efficient handling of todays unpowered barge cuts. The existing system consists of two single line winches, one located just above the upstream miter gates and one just below the downstream miter gates. Once the first (unpowered) cut of the tow has been brought to the proper pool level, the cable from the winch is secured near the stern of the first barge or the bow of the second barge. The slack is then taken out of the line and the unpowered barges are extracted at a normal speed of 50 feet per minute. Once the cabled connection passes the winch, the winch can no longer exert a pulling force on the barge. So in effect, the barge drifts out of the chamber. Normally, the momentum of the cut of barges is sufficient to completely exit the chamber. However, if the barge slows to a stop, then a new connection from the winch to the barge must be established, and the process repeated. Obviously, if this occurs, the time to lock through is significantly increased. When the barge is moved upstream, existing non powered traveling kevels help to hold the barge against the guide wall to counter outdraft currents.

2.2.2 **Alternatives Considered.** The alternatives listed below are named for the hundreds of feet they cover. For example, 12-6-12, means that the first set of kevels cover 1200 feet, the next set 600 feet, and the last set 1200 feet.

12-6-12. This system requires three powered kevels and two unpowered kevels. There would be a powered and unpowered kevel for each of the downstream and upstream guidewalls, and one powered kevel inside the chamber.

12-18. This configuration would have an unpowered and powered kevel for the downstream guidewall on a common rail, and an unpowered and powered kevel for the chamber and the upper guidewall. The common kevel for the upper guidewall and the chamber would have to cross the upstream miter gate.

30. This configuration would have a total of only two kevels, one powered and one unpowered. The kevels would travel the entire lengths of both guidewalls and the chamber. The main disadvantage would be crossing both miter gates. Obviously, this system requires that the lower guidewall be the same height as the chamber walls and the upper guidewalls, which is not always the case.

12-N-12. For this system, the existing tow haulage units are utilized. It would require two kevels, (one powered and one unpowered) for each guidewall.

2.2.3 **Conclusions and Recommendations.** Based on the *Detailed Assessment of Small Scale Measures, Improved Tow Haulage Equipment*, the VE Study, site visits, and interviews with Industry and Lock personnel; the following configuration is recommended for Locks 22 and 25. The recommended alternative is similar to the 12-N-12 configuration, but would include three kevels, (two powered and one unpowered) for each guidewall. The existing tow haulage unit would be utilized within the chamber, with the units moved completely inside the miter gates. The powered lead kevel is mainly for towing the unpowered barge cut to the end of the guidewall, the unpowered kevel is for safety and providing an extra tie to the barge, and the trailing kevel functions as a braking device.

A detailed discussion and analysis is presented in Appendix B, Powered Traveling Kevel. A cost estimate summary sheet is also included.

2.3 **Approach Channel Improvements.** This section covers approach and exiting problems which currently exist at Locks 22 and 25. The locks are over 50 years old and were not designed to handle the size of the present days tows. Additional transit time has been added to the locking process as tows maneuver excessively to align with the lock chamber. Many different measures or combinations of measures, are possible which would increase safety and decrease barge approach time. Improvements under consideration include, channel widening, channel realignment, and alignment dikes.

Downbound tows normally have greater approach difficulties than upbound tows. This is due to the outdraft common at most locks. An outdraft is a current that flows from the upstream shoreline across the lock approach to the dam gates. This is a serious problem and has caused barges to break apart and be carried to the dam in the past. Helper boats are widely used by the navigation industry to reduce this risk.

Existing conditions, alternative measures, and recommendations are described for both locks in the paragraphs below. Much of this information is also contained in Appendix C, Hydraulics Analysis, and must be referenced to understand the different alternatives. The appendix also contains a description of how the micro, physical, and numerical models were utilized to examine the different alternatives and help determine the recommended alternative.

2.3.1 **Existing Conditions.**

Lock 22. Strong outdraft currents are experienced by downstream tows approximately 0.8 miles upstream of the lock. This condition is worsened by at higher river flows. Upbound tows have the problem of shallow water, which requires recurring dredging of the downstream channel. However, dredging effectiveness is limited by underwater rock outcroppings.

Lock 25. Downstream approaches are extremely difficult due to strong outdrafts coupled with a meandering channel. A dike was built along the right bank to correct the outdraft, however helper boats are still a common necessity. Downbound tows exiting the lock are forced to make a sharp left turn to stay within the channel.

2.3.2 **Alternatives Considered**

Lock 22.

Alternative A Raise existing elevations of dikes RM 302.2R and RM 302.4R from 456.6 ft to 461.5 ft (2 ft above flat pool).

Alternative B Same as Alt. A, but add L-Head dike at elevation 461.5 ft (2 ft above flat pool). L-Head extends 600 ft from the bankline at RM 301.9R and is tied into the existing mooring cell, then extends 400 ft towards the lock

Alternative C Same as Alt. B, but adds L-Head dike off the tip of the island at RM 303.6. The L-Head dike directs currents towards the dam and reduces cross-currents off of the island. The crest elevation of the L-Head dike is at 461.5 ft

Alternative D Same as Alt. C, but adds spur dike at RM 302.8, angled slightly upstream. Spur dike provides gradual transition of flow towards the main channel. The crest elevation of the spur dike is at 456.5 ft

Alternative E Raise existing elevations of dikes RM 302.2R and RM 302.4R from 456.6 ft to 461.5 ft (2 ft above flat pool).
Extend these two dikes 300 ft and 200 ft, respectively.
Add L-Head dike at RM 301.9R, 700 ft from bank and 500 ft towards the lock, with a crest elevation of 461.5 ft.

Alternative F Raise existing elevations of dikes RM 302.2R and RM 302.4R from 456.6 ft to 461.5 ft (2 ft above flat pool).
Extend dike at RM 302.4 by 200 ft.

Lock 25.

Alternative 1 Removed trail from L-Dike 242.1R and lengthened dike 450 feet.

Alternative 2 Added an L-Dike at mile 242.3R with a dike length of 700 feet and trail length of 700 feet.

Alternative 3 Lengthened Trail on L-Dike 242.1R 1200 feet to the downstream bankline.

Alternative 4 Rebuilt Dike 242.8R to a length of 900 feet and at an elevation of 444 feet or +14 feet referenced to minimum pool.

Alternative 5 Added 1250 foot dike at mile 243.0R.

Alternative 6 Added structures from Alternatives 2 and 5 together.

Alternative 7 Removed dikes 244.0R, 243.8R, 243.5R, 242.9R, and 242.8R. Added 5 chevron structures in mid channel at an elevation of +2 feet minimum pool at river miles 243.9, 243.7, 243.4, 243.2, and 242.9.

Alternative 8 Same as Alternative 4, but added a 1300 foot dike on the Illinois bankline at mile 243.4L.

Alternative 9 Same as Alternative 4, but added 4 chevron structures in mid channel at miles 243.9, 243.7, 243.4, and 243.2.

Alternative 10 Removed half of the submerged island located upstream of the Dam and towards the Missouri bankline.

Alternative 11 Removed the entire submerged island located upstream of the Dam.

2.3.3 **Conclusions and Recommendations.**

Lock 22.

The alternatives and model results were presented to barge industry representatives, District operations personnel, District biologists, and the US Fish and Wildlife Service. Based on this presentation and subsequent discussion, a modified plan was developed. After thorough testing of thirteen variations, the following alternative was recommended. Place a 550 foot emergent wingdam from the right back and RM 301.9R to the mooring cell and extended beyond an additional 100 feet. In addition, the spur dike at RM 301.7R would be removed, and the lengths of the three left-bank wingdams in the pool (RM 302.2, 301.9, and 301.6) would be reduced by 100, 200, and 300 feet, respectively.

The model results showed that bed response would be in localized areas, mainly consisting of scour off the ends of the wingdams. The recommended plan eliminates the hazardous outdraft currents in the upstream approach by dramatically decreasing the velocities behind the wingdam. The area of calm water created behind the wingdam can be used as a staging area for barges as they wait for lockage, which may provide additional time savings. The Rock Island District is currently addressing the potential environmental impacts of the recommended plan. Mussel surveys will be performed to identify potential impacts to threatened or endangered species as a result of the project.

Lock 25.

After team meetings, design alternative 4 was selected as most effective at improving navigation conditions in an environmentally friendly manner. In this design, a 900-foot long dike was added near mile 242.8R at an elevation of +14 feet referenced to minimum pool. An old submerged pile dike currently exists in this naturally depositional area. The model showed that the design had minimal effect on the bed response and bathymetry as compared to the base test. Flow visualization images showed vast improvement to the flow patterns near the lock chamber. The base test images revealed high currents near the lock chamber are directed away from the lock and toward the dam. The dike design created a downstream "shadow" of slow velocity currents near the lock chamber. An area of slack water between the dike and the lock chamber will greatly improve the safety of downbound tows entering the lock chamber.

3.0 **Contract Methods.** Contracting will be required for both design and construction. Although design may be performed with in-house forces, its likely that a design effort of this magnitude would require, or be supplanted with, private sector contracting.

3.1 **Design contracts.** Two major types of A/E contracts could be utilized. Where a significant portion of design can be separated, and adequate time is available, firm fixed price contracts are preferred. These type of contracts are solicited based on a known scope of work. Therefore it is much easier to write a specific solicitation intended to draw from a smaller pool of qualified A/E firms that possess the required experience. These contracts do not have time or dollar limitations. However, it can take up to nine months or longer to progress from CBD solicitation to contract award.

When time is critical, and the design fee is expected to be less than $1Million, Indefinite Delivery Contracts may be used. These contracts offer significant increase in speed of execution as the contract is already in place. The Scope of Work must fit within the requirements of the basic contract. These contracts do have time and dollar limitations. The typical Indefinite Delivery Design contract is for one year, with two option years, and the dollar limit is up to $1Million per year.

The recommended contract type is Firm-fixed price contracts. As shown above, proper planning is required to advertise, select, negotiate, and award this type of contract.

3.2 **Construction Contracts.** The normal method of construction contracts has been the low bid method. This type of contract requires the prospective bidders to familiarize themselves with the project through plans, specifications, and site visits. As the title indicates, the low bidder is awarded the contract based solely on cost. There is basically no flexibility in this type of contract. Normally the low bid can not be over the Independent Government estimate by more than 25%.

Another type of contract gaining in popularity, is Best Value Contracts. The Contractors are required to submit their proposal based on time, construction approach and cost. The Government is not obligated to choose the low bidder, but rather the Contractor that best demonstrates their ability to successfully complete the project. This type of contract gives the Government the flexibility to choose the best contractor for the job.

Although there are several other types of contracts, such as Cost-Plus-Fixed Fee, Cost-Plus-Incentives, and Cost Reimbursement, it is doubtful that any of these would be utilized. These contracts put very little risk on the contractor.

The recommended construction contract type is Best Value, for the reasons stated above. Obtaining the best contractor for navigation projects is paramount to avoiding delays to industry.

4. References.

4.1 *Detailed Assessment of Small Scale Measures*, December 1998. Prepared by Rock Island, St. Louis, and St. Paul Districts. Discusses non-structural and structural small scale measures.

4.2 *Improved Tow Haulage Equipment*, September 1995. Prepared by Rock Island, St. Louis, and St. Paul Districts. Discusses technical feasibility of various tow haulage improvements and their resulting impacts to transit times in the locking process.

Guidewall Extension - Structural Analysis

Appendix A

APPENDIX A
STRUCTURAL ANALYSIS
EXTENDED GUIDEWALLS

Table of Contents

Tables and Figures

APPENDIX A
STRUCTURAL ANALYSIS
EXTENDED GUIDEWALLS

Plates/Drawings. The list of plates included in this appendix is shown below.

Drawing #	Drawing Title
1	L&D 22, site plan and vicinity map
2	L&D 22, proposed guidewall extension
3	L&D 25, site plan and vicinity map
4	L&D 25, proposed guidewall extension
5	L&D's 22 & 25, guidewall extension general layout
6	L&D's 22 & 25, typical sections
7	L&D 22 & 25, starting cell
8	L&D 22 & 25, starting cell steel can
9	L&D 22 & 25, intermediate cell
10	L&D 22 & 25, intermediate cell steel can
11	L&D 22 & 25, end cell
12	L&D 22 & 25, end cell steel can
13	L&D's 22 & 25, guidewall extension top detail
14	L&D's 22 & 25, guidewall extension precast beam plan
15	L&D's 22 & 25, guidewall extension precast beam section

APPENDIX A
STRUCTURAL ANALYSIS
EXTENDED GUIDEWALLS

1 Description of Measure

In order to provide guidewalls of at least 1200 feet in length at each end of the lock chambers at Lock Nos. 22 and 25, the upstream and the downstream guidewalls at both sites will be extended by approximately 700 feet. The extensions will consist of stacked pre-cast concrete beams that span between modular steel can cells filled with concrete (see Plates 1-5). For the upstream guidewall extensions the beams shall be stacked two high and on the downstream guidewall extension the beams shall be stacked three high due to the lower water elevations (see Plate 6). The pre-cast concrete beams shall be post-tensioned box beams measuring 9 feet high and 8.5 feet wide. The walls of the beams shall vary in thickness from 1.25 feet to 2.5 feet (see Plate 15). Each beam shall be 132.67 feet in length and weigh in the neighborhood of 350 tons. Standard reinforcing bars and high strength post-tensioning tendons shall provide the beams with the necessary tensile strength and compression force to withstand all possible load combinations. The modular steel can cells supporting the pre-cast, post-tensioned concrete beams shall be predominantly circular in shape and approximately 40 feet and 44 feet in height at Locks Nos. 22 and 25 respectively. The intermediate cells shall have a diameter of 35 feet and the end cells, due to the greater potential for a more direct barge impact load, shall have a diameter of at least 50 feet.

2 Design Considerations and Calculations

The development of the design for the guidewall extensions involved numerous engineering considerations with regard to component design and layout. Given below is a detailed description of the design decisions, assumptions, and methods used to address the following areas of engineering concern: the optimization of cell shape, the design of pre-cast beams, the design of intermediate wall and end cells, development of connection detail of beam to cell, hydraulic considerations, and details for appurtenances.

2.1 Optimization of Cell Shape

The modular steel can cells, which will support the box beams, are massive structures that, once filled with concrete, will each weigh more than 2,800 tons. Because these large cells make up a significant portion of the cost of the proposed guidewall extensions, consideration was given to optimizing their shape (i.e. determining the smallest adequate cross sectional area) and thus limiting their expense. As a result of the geometry of the guidewall extension system, the cells must resist much larger lateral loads than longitudinal ones. Barge impact loads, hawser pulls, and other loads related to the locking process have longitudinal components, but a much larger percentage of these loads are exerted laterally against the wall. The non-homogeneous nature of cell loading makes the use of a non-axisymmetric shape, such as an oval, rectangle, dumbbell, etc., an attractive option for optimization.

Despite the cost savings that a non-axisymmetric shape might provide during the construction phase of the project, the Corps design team believes that a circular shape is the best design for the support cells of the guidewall extension. During the construction process, the modular steel can cells will stand without the box beams installed through at least one navigation season. If a barge strikes a cell in this stand-alone situation, the cell must be able to withstand the impact without overturning. With no beams in place to restrict the magnitude of the longitudinal component of an impact load, a non-axisymmetric cell could easily be overwhelmed by a longitudinal strike. The circular shape, which is equally capable of resisting overturning whatever the angle of impact, is not vulnerable in this stand-alone case. Given the construction delays, additional costs, and impacts to navigation, that could be produced by the failure of a cell, the security provided by a circular shape justifies its use. In addition, the circular cell design, unlike possible non-axisymmetric designs, is one that has been implemented in the St. Louis district before. At the Melvin Price Locks and Dam project, a guidewall using circular cells to support pre-cast concrete beams was used and has performed well in the field. Also, other Corps districts have constructed guidewalls similar in design to the proposed guidewall extension presented here.

2.2 Design of Pre-Cast Concrete Beams

The most important aspects of the design process for the pre-cast concrete beams include the selection of beam type, the determination of design loads, and the analysis methodology. In the paragraphs that follow, these aspects of the design are described in detail, followed by a brief summary of the results and the final beam design.

2.2.1 Selection of Beam Type

The Corps design team chose to design the pre-cast concrete beams as post-tensioned box beams. This type of beam was superior to other, more traditional possibilities, for several reasons, the most significant being its lightweight. The designers wished to space the modular steel can support cells as widely as possible, in order to limit any potential construction impacts to navigation and to lower the overall cost of the project. The weight of the concrete beams is the limiting factor for the length of cell spacing. Beyond a certain weight limit, lifting of the beams during construction becomes impractical. Clearly, to maximize beam length the lightest possible beam cross section should be used. A traditional reinforced concrete beam with a solid cross section weighs at least twice as much as a post-tensioned box beam with the same load carrying capacity. Considering the importance of maximizing cell spacing, the post-tensioned box beam is clearly more suitable for this design.

2.2.2 Design Loads

The loads considered for the design of the pre-cast concrete beam are the self weight of the beam, barge impact, uplift, uniform ice load, ice expansion load, live load, hawser pull, wind load, and earthquake load. The magnitudes of these loads were determined from assumed material properties, conditions at the lock and dam site, relevant design standards, recent Corps studies, and Corps experience from previous design work on navigation structures (all design standards used are listed in the References at the end of this report.) What follows is a description of how the magnitude of each load was determined for design. Two items will be noted here that apply to all the design loads considered below. First, of the beams stacked together to form the guidewall, the top beam is subjected to the most severe loads and therefore it alone is analyzed for the purpose of design. Second, many of the loads considered, both horizontal and vertical, do not act through the centroid of the beam. However, to simplify the analysis these eccentricities are ignored and all loads are treated as acting through the centroid. This approach neglects torsional effects, but is considered adequate for the type of preliminary design presented in this report (see note on analysis methodology provided on pg. A-9 of this report.)

2.2.2.1 Self-Weight of Beam

The post-tensioned concrete box beam will be constructed with lightweight concrete weighing 120 pcf. The hollow center of the box beam will be filled with a styrofoam assumed to weigh 2 pcf. In order to account for permanent fixtures such as handrails and light posts, an additional dead weight of 75 plf was also assumed to act over the span of the beam. Until the exact dimensions of the box beam were determined by running several design iterations, the self-weight of the beam had to be approximated. Plate 15 shows the final dimensions assumed for the box beam. With these dimensions the beam has a self-weight of 6310 plf. This value for the self-weight includes the weight of the styrofoam and the assumed weight of permanent fixtures.

2.2.2.2 Barge Impact

Three levels of barge impact were considered for design of the concrete beam, usual, unusual, and extreme. The Louisville District conducted a study to determine the magnitude of the loads for these three levels of impacts. River current has a considerable influence on the magnitude of impacts, therefore the Louisville study produced separate values for the upper and lower guidewall extensions. The loads determined by that study and used for design are given in Table A1.1.

Barge Impact Loads	
Design Condition	**Glancing Blow – Beam (mid-span)**
Upper Guidewall	
Usual	330 kips
Unusual	500 kips
Extreme	700 kips
Lower Guidewall	
Usual	165 kips
Unusual	250 kips
Extreme	350 kips

Table A1.1 – Barge Impact Loads from Louisville Study

The upper guidewall values, which are substantially larger than those for the lower guidewall, were used for preliminary design of the beams. The impact loads are assumed to act at the mid-span of the beam as this creates the most severe loading condition.

2.2.2.3 Uplift

The uplift force or buoyancy, which is an upward force, tends to alleviate stress caused in the beam by its own self-weight. The top beam of the guidewall is typically only partially submerged. For design it is assumed that 3 feet of the beam is submerged. To be conservative, it is assumed that the interior of the box beam is partially flooded, somewhat reducing the alleviating uplift force. From calculations the uplift force was found to be 1140 plf.

2.2.2.4 Uniform Ice Load

Through discussions with lock personnel, it was decided to use a 3ft by 3ft section of ice accumulation attached to the rubbing face of the beam just above normal pool elevation to approximate a severe ice condition. This ice accumulation is assumed to extend along the entire length of the beam. To calculate the magnitude of this force, 56 pcf is taken as the unit weight of ice. From calculations ice accumulation is found to result in a 504 plf downward force.

2.2.2.5 Ice Expansion Load

The ice expansion load, which is a horizontal force, is assumed to be the result of a 1ft thick sheet of ice forming on the surface of the water behind, or landward of, the guidewall extension. The ice is assumed to exert a pressure of 5,000 psf, or 5,000 plf for the 1ft thick sheet; this is the maximum design pressure recommended in EM 1110-2-2602, "Planning and Design of Navigation Locks."

2.2.2.6 Live Load

A live load equal to 100 psf is applied to the top horizontal surface of the beam. The placement of the railing, the traveling kevel, and the appurtenances limit the live load to the middle of the wall. The pressure starts 2.5 ft from the rubbing surface and extends 5.5 ft towards the back of the wall. The load extends over the full length of the beam.

2.2.2.7 Hawser Pull

Guidance found in EM 1110-2-2602 was followed for the determination of hawser pull direction and intensity. A 160,000 lb pull is used with an angle of application of 30° with the wall. The resulting component perpendicular to the wall is 80,000 lb. The longitudinal component of this load is neglected for analysis.

2.2.2.8 Wind Load

A wind pressure of 27 psf was calculated according to the Uniform Building Code. This pressure is applied to the to the back of the wall, from the surface of normal pool to the top of the wall, for the full length of the wall.

2.2.2.9 Earthquake Load

The seismic load, which is assumed to act horizontally, was estimated using the equivalent static load procedure presented in division I-A, paragraph 4.5 of AASHTO, Standard Specification for Highway Bridges. Lock and Dams No.22 and 25 are situated in a category A region for seismic performance and are estimated to have an acceleration coefficient, E_H, of .05. From calculations, the equivalent static earthquake load is found to be 6,210 plf. This load is applied to the riverface of the beam over its entire length.

2.2.3 Analysis Methodology

The analysis methodology used to arrive at a preliminary design of the post-tensioned box beam consists of six distinct steps, the entire sequence of which is repeated several times until achieving a satisfactory solution. The steps are as follows: *(1)* choose a reasonable cross section for the beam, *(2)* based on concrete stress limits, estimate the post-tensioning force, *(3)* arrange post-tensioned reinforcement in the section and determine the eccentricity of the steel centroid, *(4)* establish critical load combination cases, *(5)* determine stresses generated in the beam by the post-tensioning force combined with each of the critical load combinations, and *(6)* if stresses exceed allowable limits or seem conservatively low pick a more reasonable cross section and repeat steps 1-6, otherwise design is complete. A more detailed discussion of each step is provided in the paragraphs below. For design, a span length of 140 feet from center to center of support cells was chosen.

(1). The designer assumes overall dimensions and wall thickness for the box beam that are consistent with construction weight limits and the operational requirements of the guidewall extension.

(2). To estimate the post-tensioning force, the permissible stress levels in the concrete are established. Table A1.2 provides a list of the permissible stress levels used for design. These values are taken from paragraph 18.4.1 of ACI 318-99. The phrase "after transfer" used in the table refers to the period immediately after the post-tensioning force has been applied to the beam. It is assumed that at the time of transfer the concrete has only attained 75% of its ultimate strength, f'_c. The compressive strength of the concrete at the time of transfer is represented with the symbol f'_{ci}.

Allowable Stresses in Concrete		
Symbol	**Title**	**Value**
f_{ci}	In Compression Immediately After Transfer	$0.60 f'_{ci}$
f_{ti}	In Tension Immediately After Transfer	$3(f'_{ci})^{1/2}$

Table A1.2 – Allowable Stresses in Concrete

For this analysis f'_c is taken to be 6000 psi.

Using the permissible stress levels in concrete, the assumed eccentricity of the prestressing strands, and the geometry of the cross section selected in step 1, the post-tensioning force, P, is estimated. P is then divided by the ultimate strength of the prestressing strands to approximate the area of prestressing reinforcement required. The area and number of prestressing strands needed will vary depending on type of prestressing strand used. For this design, ½"ϕ seven wire strands, grade 270, with an ultimate strength of 270,000 psi, were selected.

(3). The prestressing strands are arranged in the most suitable manner to resist stresses induced in the beam by service loads. The majority of the service loads applied to the beam act in the downward direction or horizontally from right to left (the riverward side of the beam is designated as the right side for this analysis.) These loading conditions are reflected in the arrangement of the reinforcing tendons. (See Figure A1.1) The eccentricity of the prestressing strands with regard to the concrete centroid of the cross section induces stresses in the beam that must be considered when evaluating the adequacy of the beam design. To calculate these stresses the centroid of the steel prestressing tendons is found. The values e_x and e_y in the analysis represent the difference between the concrete and steel centroids in the x direction and y direction respectively.

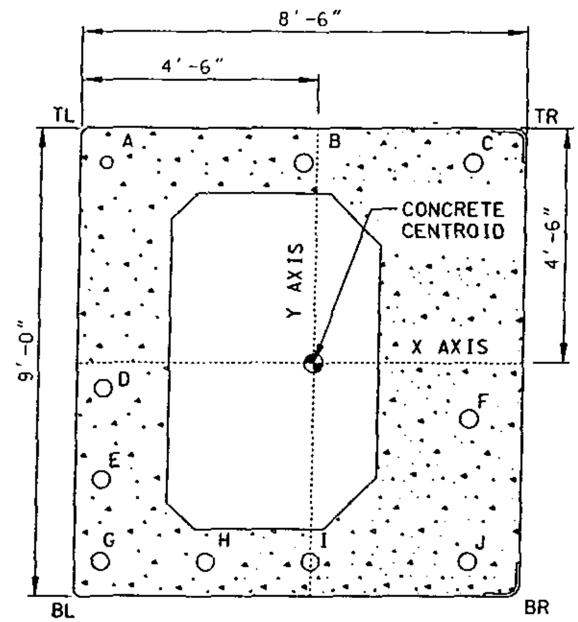


Figure A1.1 – Beam Cross Section

(4). A modification of the working stress method is employed to check the capacity of the prestressed beam chosen in steps 1-3 to carry the service loads. Typically when the working stress method is used, the critical service load combinations are applied to the beam without modification, that is, there are no load factors. To insure there is an adequate factor of safety, the ultimate compression and tensile strengths of the concrete are reduced by some reasonable factor to obtain allowable stresses. If the service stresses do not exceed the allowable stresses the beam is adequate. For this design, the allowable stresses for prestressed concrete recommended by ACI 318-99, 18.4.1, were adopted. (See Table A1.2) To simplify the analysis, these values for allowable stress are used regardless of the severity or likelihood of the service loads being considered.

To evaluate the beam design a number of load combination cases must be considered in order to determine the most adverse load condition. Consulting EM 1110-2-2602, "Planning and Design of Navigation Locks," EM 1110-2-2104, "Strength Design for Reinforced Concrete Hydraulic Structures" and drawing on previous Corps experience with the design of navigation structures, the design team developed six critical load combination cases. Although the same values for allowable stress in the concrete are used for each of the critical load combination cases, some consideration is given to the severity and frequency of the loads by employing load factors. Using the recommended allowable stresses for normal, severe, and extreme load conditions suggested in EM 1110-2-2101, "Working Stresses for Structural Design," and ACI 318-99 as guidance, load factors were determined for each load case. The notations used to designate the various design loads are listed in Table A1.3 and all load combinations, multiplied by the appropriate load factors, are listed in Table A1.4.

Design Load Notations	
DL	Self Weight of Beam
BC330	Usual Barge Impact Load
BC500	Unusual Barge Impact Load
BC700	Extreme Barge Impact Load
WA	Uplift
IL	Uniform Ice Load
IEL	Ice Expansion Load
LL	Live Load
HL	Hawser Pull
WL	Wind Load
EL	Earthquake Load

Table A1.3 – Design Load Notations

Design Load Combinations		
1	Normal	1.00[DL + LL + WA + HL]
2	Barge Impact	1.00[DL + LL + WA + BC330]
3	Unusual Barge Impact	0.75[DL + LL + WA + BC500]
4	Earthquake	0.75[DL + LL + WA + 1.25EL]
5	Extreme Barge Impact	0.50[DL + LL + WA + BC700]
6	Winter Conditions	0.50[DL + LL + WA + WL + HL + IL + IEL]

Table A1.4 – Design Load Combinations

(5). To determine the stresses generated in the beam, the cross section is divided into four quadrants, the top left (TL,) the top right (TR,) the bottom left (BL,) and the bottom right (BR.) (See Figure A1.1) The resultant stresses in each quadrant are the combination of the axial stresses created by the post-tensioning force, the bending stresses generated by the eccentricity of the prestressing reinforcement, and the bending stresses generated by the service loads. The equations used for evaluating each of these components of the resultant stress are given in Table A1.5.

Beam Stress Formulas	
Description	**Formula**
Post-tensioning force, axial stress	P / A_g
Prestressing Reinforcement – eccentricity in y-direction, bending stress	$P\ e_y / S_{xi}$
Prestressing Reinforcement – eccentricity in x-direction, bending stress	$P\ e_x / S_{yi}$
Service Loads – loading perpendicular to the x-axis, bending stress	M_x / S_{xi}
Service Loads – loading perpendicular to the y-axis, bending stress	M_y / S_{yi}
Value Definitions	
P = post-tensioning force A_g = total cross sectional area of concrete $e_{x,\ y}$ = difference between concrete and steel centroids in x and y direction respectively $S_{xi,\ yi}$ = section modulus about x and y axis respectively for the *ith* quadrant $M_{x,\ y}$ = moments generated by loads perpendicular to the x and y axis respectively	

Table A1.5 – Formulas For Resultant Beam Stress

The post-tensioning force induces a compressive axial stress in all of the quadrants. The moments created by the eccentricity of the prestressing reinforcement generates either tension or compressive stresses in a quadrant, depending on the location of the quadrant with regard to the steel centroid, i.e., the centroid of the prestressing reinforcement. If the steel centroid falls within a quadrant, compressive stresses are generated; otherwise stresses are tensile. For example, if the steel centroid were located below the concrete centroid, then the eccentricity of the steel centroid in the y-direction would create compressive stresses in the bottom quadrants of the cross section and tensile stresses in the top quadrants. Similarly, service moments generate either tension of compressive stresses in a quadrant, depending on the location of the quadrant with regard to the applied service load. If a quadrant were on the same side of the neutral axis as an applied load, then the bending stresses generated in that quadrant by that applied load would be compressive. Otherwise the stresses would be tensile. For each critical load combination case the formulas in Table A1.5 are evaluated for all four quadrants of the beam cross-section. If, for all quadrants, the sum of the resultants of these formulas is less than the stress limits set out in Table A1.2, then the beam, if not excessively conservative, is acceptable.

(6). If stresses exceed the allowable limits or the chosen cross section is too conservative, then return to step 1. Otherwise, analysis is complete.

Note on Analysis Methodology: The design team believes that flexural stresses will determine the overall dimensions of the concrete beam, and therefore chose to use the analysis methodology described above. However, this methodology ignores the effects of shear and torsional stresses, and does not consider any weakening of the concrete from long term losses such as post-tensioning relaxation, creep, or shrinkage. Such factors must be considered when the preliminary design presented in this report is prepared for plans and specifications.

2.2.4 Conclusions

After completion of the analysis, a preliminary design of the post-tensioned concrete box beams had been reached. This design has beams that are 9.0 feet tall by 8.5 feet wide with wall thicknesses as shown on Plate 15. The prestressing reinforcement is ½"ϕ seven wire strands, grade 270, with a total area of reinforcement of approximately 42 in^2. 29 reinforcing stands are placed in each conduit, with the exception of conduit A, which has only 15 strands. The beams are 132.67 feet in length and weigh approximately 350 tons. This is the recommended preliminary beam design for both Locks Nos. 22 and 25.

2.3 Design of Intermediate and End Cells

2.3.1 Introduction

The following narrative describes both the design of the rock founded cells for the guidewall extensions at Locks No. 22 and the pile- supported cells for the guidewall extensions at Locks No. 25. These cells, together with the guidewall beams they support, make up the guidewall extensions at each lock respectively. Four cell structures were designed for each foundation condition: lower intermediate cells, a lower end cell, upper intermediate cells, and an upper end cell.

Lock No. 22, Rock Foundation
The design of the rock founded cells was accomplished with the assistance of the Corps program "Three-Dimensional Stability Analysis/Design Program" (3DSAD.) The design considered sliding, overturning, and bearing of the cells. The only unknown in the design was the cell diameter. All other cell and beam geometry had previously been determined. Because of the complexity in manually analyzing the stability of the cells when less than 100% of their base is in compression, 3DSAD was used to analyze the stability of each cell.

Lock No. 25, Sand Foundation
The design of the sand founded cells was based on the Corps program, "Pile Group Analysis" (CPGA) which is a computer program for the analysis of a pile group using the stiffness method for the soil-founded cells. The manually calculated applied loads, pile and soil properties, pile location and the pile allowable loads are input data into the program. CPGA uses the pile and load information to determine the axial load, lateral load and bending moments in every pile. The program then uses these loads to determine the deflections of the structure. These loads and deflections are checked to insure the pile design can pass three separate failure modes: (1) the cells are designed to keep axial loads below the allowable capacity of the soil/pile interface, (2) the piles have to be strong enough to withstand stresses from the combined effects of axial load and bending and (3) deflections must be within tolerable limits. All piles will be non-concrete filled 36-inch diameter steel pipe piles driven vertically with possibly two exceptions. The

piles at the two cells (one upper and one lower) that will be placed adjacent to existing pile founded structures. A pile load test will be performed to study the effects of driving 36-inch diameter steel pipe piles at adjacent existing pile founded structures. The results of this study may preclude this type of pile being used at these particular locations. Either a smaller diameter driven pile in a larger quantity or an alternate type of foundation installation, may be required. Whichever of these options would be used (if required), they would increase the foundation cost on these particular cells. The only unknowns in this design were the cell diameters. All other cell and beam geometry had previously been determined. However, based on past experience from a similar type guidewall that was installed at the Melvin Price Locks & Dam project as stated above, it was assumed that a 35ft diameter intermediate cell and a 57ft diameter end cell would be adequate for this work. Therefore, the design was based on these cell diameters. If a further reduction in cell size (cost) was pursued, it is conceivable these cells could be somewhat reduced.

2.3.2 Geometry

2.3.2.1 Lock No. 22, Rock Foundation

The bases of the cells are located approximately at elevation 431.5 ft, which will also be referred to as elevation 0 ft. The top elevation of the cells is 471.5 ft (40 ft). All cells are cylindrical with a notch towards the navigation lanes for placement of the wall beams. All notches, or beam seats, are 8.0 ft deep, and the wall beams are 8.5ft wide. Beams, therefore, overhang their seats by 0.5 ft. The lower cells require three wall beams, each nine feet high, which places the beam seats at elevation 444.5(13 ft). The upper cells only require two nine foot high wall beams, which places the upper cell beam seats at elevation 453.5 ft(22 ft). Figures A2.1 and A2.2 show typical plan views of the intermediate and end cells with key coordinates for 3DSAD input.

2.3.2.1.1 Intermediate Cells

All intermediate cells are 35 ft in diameter. From the beam seat elevation upward, all intermediate cells have the same horizontal cross-section. The lower intermediate cells' notches are larger in height to accommodate 3 wall beams, rather than the 2 wall beams the upper intermediate cells support. All intermediate cells have 2.5 ft of removal from the edge facing navigation. This removal creates a vertical plane approximately 18 ft wide below beam seats. Beyond this 2.5 ft removal, the 8 ft deep notch is taken for beam placement. The 2.5 ft frontal removal continues for the full height of the lower intermediate cell. The 2.5 ft removal only continues 10 ft below the beam seat of the upper intermediate cell, at which point, it returns to the full circular section towards the base.

2.3.2.1.2 End Cells

Both the upper and lower end cells are identical with the exception to their notches for wall beam placement. The lower end cell notch is larger in height to accommodate 3 wall beams, rather than the 2 wall beams the upper end cell supports. The end cells have 50 ft diameters and are cylindrical.

The bases of the cells are located approximately at elevation 400.0 ft (which also will be referred to as elevation 0 ft up from the base of the cell). The top elevation of the cells is 444.0 ft (44 ft). All cells are cylindrical with a notch towards the navigation lanes for placement of the guidewall beams. All notches (beam seats) are 8.0 ft in depth and the guidewall beams are 8.5 ft wide. Beams, therefore, overhang their beam seats by 0.5 ft. The lower cells require three guidewall beams, each nine feet high, which places the beam seats at elevation 417.0 ft (17 ft). The upper cells require only two nine foot high guidewall beams, which places the upper cell beam seats at elevation 426.0 ft (26 ft). Figures A2.1 and A2.2 show typical plan views of the intermediate and end cells.

2.3.2.2 Lock No. 25, Sand Foundation

2.3.2.2.1 Intermediate Cells

The intermediate cells are 35 ft in diameter. From the beam seat (elevation 426.0 ft, upper and elevation 417.0 ft, lower) upwards, all intermediate cells have the same horizontal cross-section with a notch to accept the guidewall beams. The lower intermediate cells' notches are larger in height to accommodate 3 guidewall beams versus the 2 guidewall beams the upper intermediate cells will support. Starting at the beam seat elevation and extending downward, the intermediate cells also have 2.5 ft of removal from the edge facing navigation. The reason for the removal is so the cell face will line-up in the same vertical plane as the guidewall beam face. This removal creates a vertical plane that is approximately 18 ft wide below the beam seats. On the lower intermediate cells, the 2.5 ft removal continues to the base of the cell. On the upper intermediate cells, the 2.5 ft removal continues down only to elevation 417.0 ft. It next begins to transition outward until the removal dissipates at elevation 414.5 ft. At this point, it becomes a full circular section. It remains a full circular section all the way to the base of the cell.

2.3.2.2.2 End Cells

Both the upper and lower end cells are identical with the exception of the notch height for the guidewall beam placement. The lower end cell notch is larger in height to accommodate 3 guidewall beams whereby the upper end cell accommodates 2 guidewall beams. The end cells are 57 ft in diameter and are cylindrical in shape from the beam seat elevations to the base of the cells.

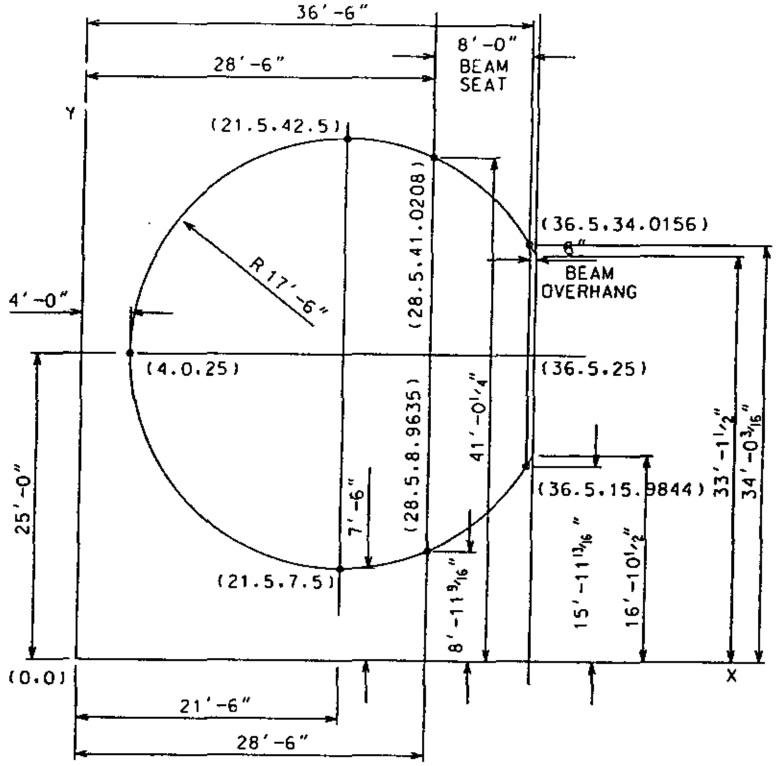


Figure A2.1 –Typical Plan View of Intermediate Cells for Lock No. 22

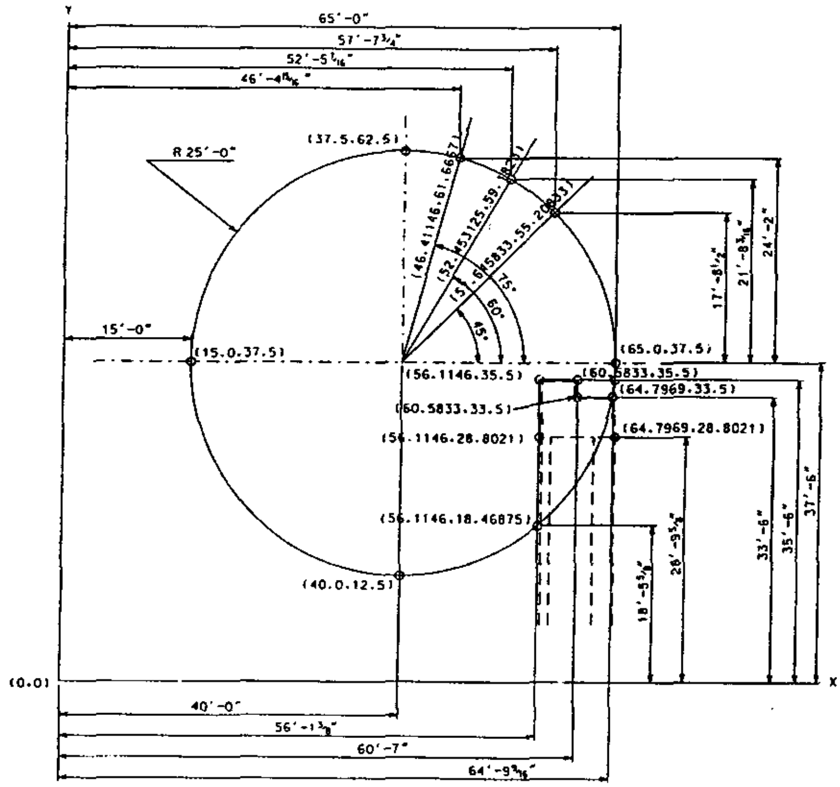
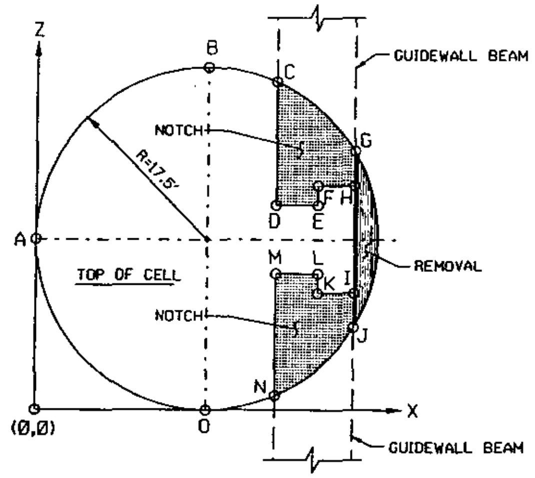


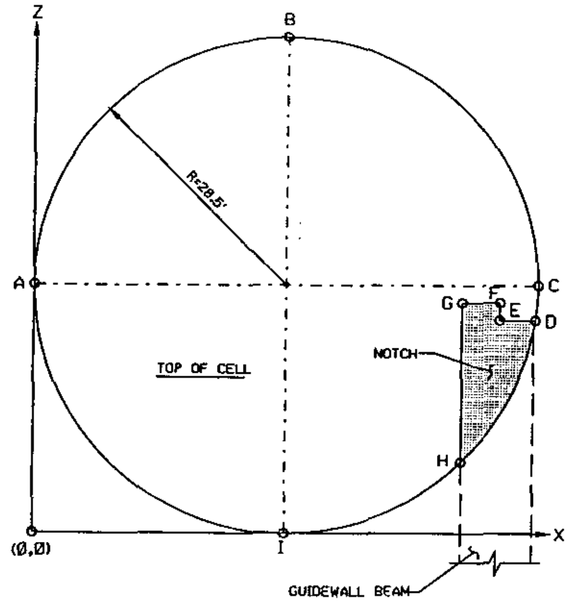
Figure A2.2 – Typical Plan View of End Cells for Lock No. 22



TOP OF CELL = ELEV. 444.0
BOTTOM OF CELL = ELEV. 400.0
NOTCH (BEAM SEAT) = ELEV. 426.0 (UPPER)
= ELEV. 417.0 (LOWER)

AXIS	DIMENSIONS (IN FEET)														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
X	0	17.5	24.5	24.5	28.75	28.75	32.5	32.5	32.5	32.5	28.75	28.75	24.5	24.5	17.5
Z	17.5	35.0	33.52	21.0	21.0	23.0	26.52	23.0	12.0	8.48	12.0	14.0	14.0	1.48	0

Figure A2.3 – Typical Plan View of Intermediate Cells for Lock No. 25



TOP OF CELL = ELEV. 444.0
BOTTOM OF CELL = ELEV. 400.0
NOTCH (BEAM SEAT) = ELEV. 426.0 (UPPER)
= ELEV. 417.0 (LOWER)

AXIS	DIMENSIONS (IN FEET)								
	A	B	C	D	E	F	G	H	I
X	0	28.5	57.0	56.75	52.75	52.75	48.5	48.5	28.5
Z	28.5	57.0	28.5	24.5	24.5	26.5	26.5	8.20	0

Figure A2.4 – Typical Plan View of End Cells for Lock No. 25

2.3.3 Design Loads

Several loads were considered for the design of the cells. The loads are the structure's self weight, barge impact, uplift, ice, live load, dead load, hawser pull, wave load, and wind load. The intensity and location of each load is described below. Figures A2.5 and A2.6 show the majority of the loads applied to the cells and guidewall beams for Lock 22. Figures A2.7 and A2.8 show the majority of the loads applied to the cells and guidewall beams for Lock 25. Note that because the barge impact loads used for these designs are much larger than any likely seismic loads(see discussion of seismic loads in section 2.2.2.9 of this report,) the design team chose to ignore seismic loads for the preliminary design of these cells.

(SEE TYPICAL SECTIONS ON NEXT TWO PAGES)

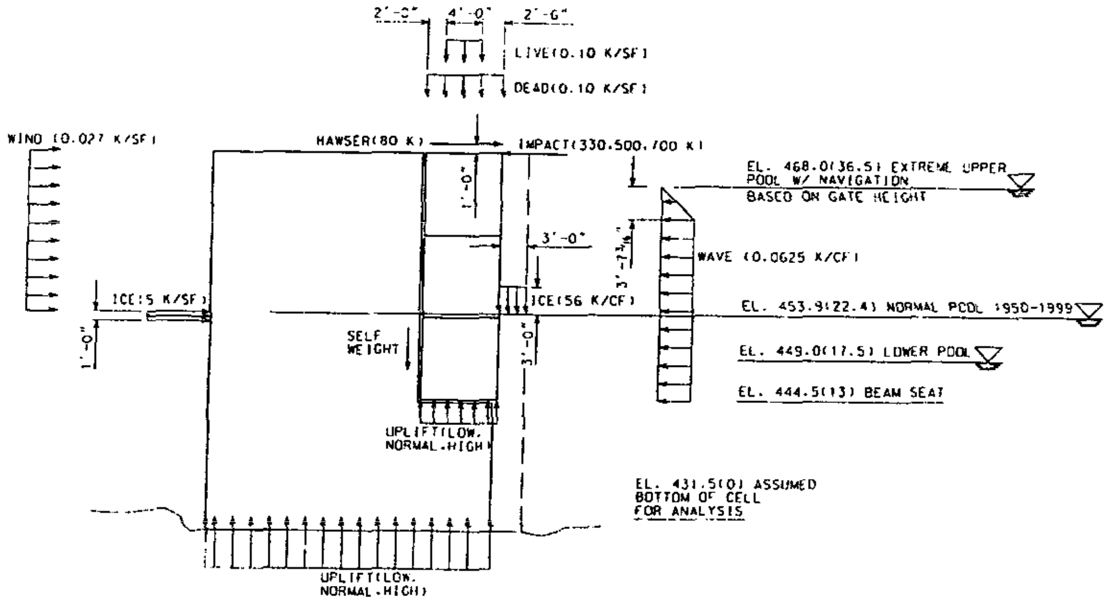


Figure A2.5 – Typical Section Through Lower Guide Wall Extension for Lock No. 22 with Loads and Water Elevations

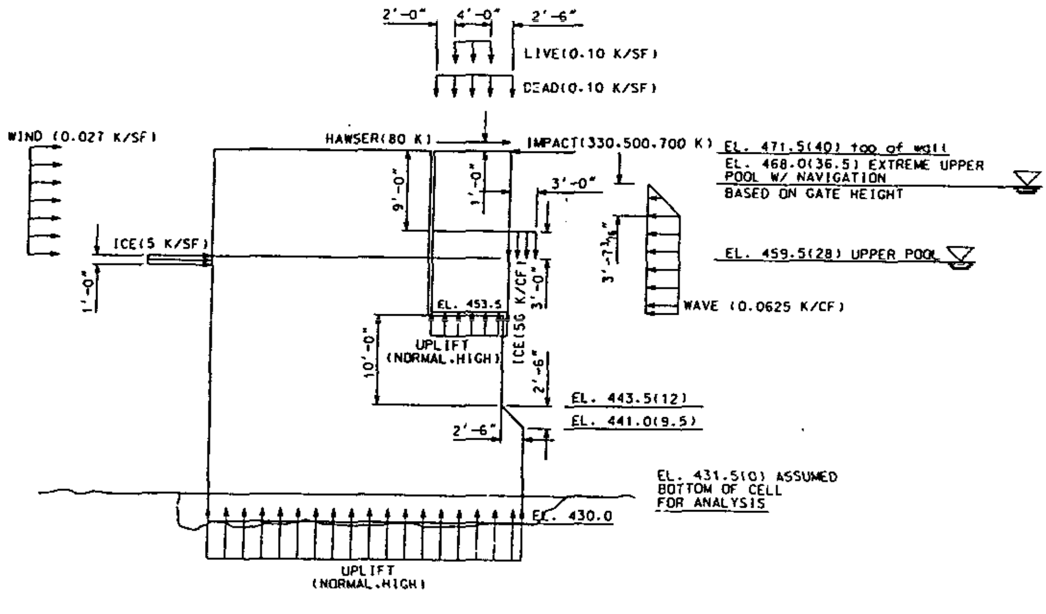


Figure A2.6 – Typical Section Through Upper Guide Wall Extension for Lock No.22 With Loads and Water Elevations

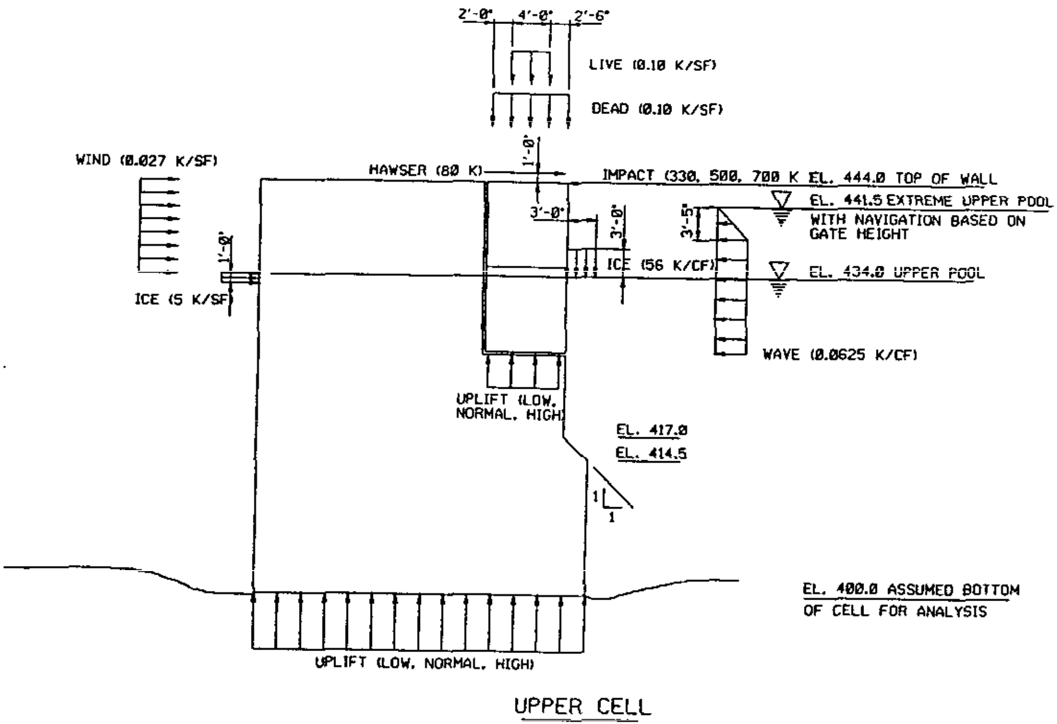


Figure A2.7 – Typical Section Through Upper Guidewall Extension for Lock No. 25 With Loads and Water Elevation

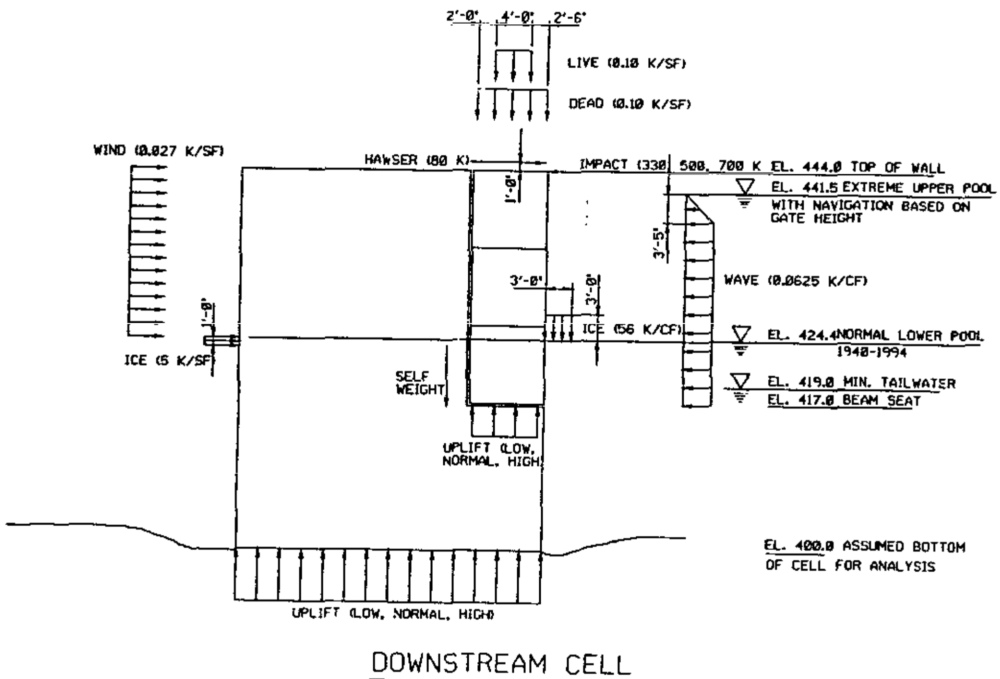


Figure A2.8 – Typical Section Through Lower Guidewall Extension for Lock No. 25 With Loads and Water Elevations

2.3.3.1 Self Weight

A concrete unit weight of 145 pcf was used for all cells, which assumes normal unreinforced concrete. Light weight concrete, 120 pcf, will be used for the guidewall beams.

2.3.3.1.1 Lower Intermediate Cells

The cells were divided into the lower section below the guidewall beam seat, the section above the beam seat and an area that includes the guidewall beam slots and the solid end portions of the beams, also above the beam seats. Three sections of beams were placed on either side of the cells. The beam sections extended to midspan of the 140 ft spans on both sides of the cells.

2.3.3.1.2 Upper Intermediate Cells

The cells were divided into two lower sections below the guidewall beam seat, the section above the beam seat and an area that includes the guidewall beam slots and the solid end portions of the beams, also above the beam seats. Two sections of beams were placed on either side of the cells. The beam sections extended to midspan of the 140ft spans on both sides of the cells.

2.3.3.1.3 End Cells

The cells were divided into a lower section below the guidewall beam seat, an upper section above the beam seat and an area that includes the guidewall beam slot and the solid end portions of the beams, also above the beam seats. Because the weight of the beams are asymmetric on the end cells, a reaction equal to one-half the beam weight was also included.

2.3.3.2 Barge Impact

The same barge impacts are applied to both the lower and upper cells. For the preliminary design, the impact loads on the end cells are higher than those on the intermediate cells.

2.3.3.2.1 Intermediate Cells

Three levels of impact were applied to the cells: usual at 330 kips, unusual at 500 kips, extreme at 700 kips. These impacts were considered glancing blows and were applied perpendicular to the guidewall beams at the top of the cells.

2.3.3.2.2 End Cells

Two levels of impact were applied to the cells, unusual(1,400 kips) and extreme(1,950 kips). These impacts were direct blows and were applied at four different angles at the top of the cells resulting in four applications of impact loads. The first impact load was applied at the far end of the upper or lower end cell with the force pushing on the cell and parallel to the river's flow. Each additional applied load rotates an additional 15 degrees towards the navigation side of the end cell until the load has been applied at all four angles. The load was oriented such that it always passes through the center of the cell. It was not believed likely for a barge to approach the end cells at any angle outside those mentioned and still be considered a direct blow.

2.3.3.3 Uplift (Buoyancy)

Full uplift as described in EM 1110-2-2200, "Gravity Dam Design" was applied to the base of all cells and at the bottom of the lowest guidewall beam in each stack. A unit weight of water equal to 62.5 pcf was used for the stability calculations.

2.3.3.3.1 Intermediate Cells, Lock No. 22

The lower cells were analyzed under three water elevations, which resulted in three different uplift pressures. The three water elevations considered are 468.0 ft(36.5 ft), 453.9 ft(22.4 ft), and 449.0 ft(17.5 ft). Elevation 468.0 ft(36.5 ft) was determined to be an extreme upper pool in which lock operation would cease. This was based on the water's height against the miter gates, or its closeness to the top girder. Elevation 453.9 ft(22.4ft) is the statistical mean lower pool elevation from a compilation of gage readings between the years 1950 and 1999, and will be called the normal lower pool elevation. Elevation 449.0 ft(17.5 ft) is flat pool and is assumed to be the lowest elevation of lower pool.

2.3.3.3.2 End Cells, Lock No. 22

The upper cells were analyzed under two water elevations, which resulted in two different uplift pressures. The two water elevations considered are 468.0 ft(36.5 ft) and 459.5 ft(28.0 ft). Elevation 468.0 ft(36.5 ft) was determined to be an extreme upper pool in which lock operation would cease. This was based on the water's height against the miter gates, or its closeness to the top girder. It is attempted to maintain upper pool at 459.5 ft(28.0 ft), the other elevation for which the upper cells were analyzed.

2.3.3.3.3 Intermediate Cells, Lock No. 25

The lower cells were analyzed under three water elevations, which resulted in three different uplift pressures. The three water elevations considered were El 441.5 ft (41.5 ft), El 424.4 ft (24.4 ft) and El 419.0 ft (19.0 ft). El 441.5 ft was determined to be an extreme upper pool in which lock operation would cease. This was based on the water's height against the miter gates or its closeness to the top girder. El 424.4 ft is the statistical mean lower pool elevation from a compilation of gage readings between the years 1940 and 1994 and will be called the normal lower pool elevation. El 419.0 ft is minimum tailwater and is assumed to be the lowest elevation of lower pool. The base of the lower cells was considered to be El 400.0 ft (0 ft).

2.3.3.3.4 End Cells, Lock No. 25

The upper cells were analyzed under two water elevations, which resulted in two different uplift pressures. The two water elevations considered are El 441.5 ft (41.5 ft) and El 434.0 ft (34.0 ft). El 441.5 ft was determined to be an extreme upper pool in which lock operation would cease. This was based on the water's height against the miter gates or its closeness to the top girder. It is attempted to maintain upper pool at El 434.0 ft, the other elevation for which the upper cells were analyzed. The base of the upper cells was considered to be El 400.0 ft (0 ft).

2.3.3.4 Ice Load

Both a vertical ice accumulation and a horizontal ice expansive force were considered. It was decided to use a 3 ft by 3 ft section of ice accumulation attached to the rubbing face of the guidewall beams just above normal pool elevation. The ice accumulation extends along the entire length of the beam. A unit weight of 56 pcf was used for the ice accumulation in the stability calculations. A horizontal ice force was also considered to act on the cells. This force was assumed to be the result of a 1ft thick sheet of ice forming on the surface of the water behind, or landward of, the guidewall extension. The ice was assumed to exert a pressure of 5,000 psf, or 5,000 plf for the 1ft thick sheet. This maximum pressure is recommended in EM 1110-2-2602.

2.3.3.5 Live Load

A live load equal to 100 psf was applied to the top of the upper guidewall beam in the stack of beams. The placement of the railing, the traveling kevel and appurtenances limited the live load to the middle portion of the top face of the upper beam. The pressure starts 2.5 ft from the rubbing face and extends 5.5 ft towards the back of the beam. The load extends the full length of the beam.

2.3.3.6 Dead Load

A dead load equal to 100 psf was applied at the top of the top guidewall beam in the stack of beams. The pressure acts over the entire face, 8.5ft, of the beam and for the beam's entire length.

2.3.3.7 Hawser Pull

Guidance found in EM 1110-2-2602 was followed for the determination of hawser pull direction and intensity. A 160,000 lb pull was used with an angle of application of 30° with the top guidewall beam. The resulting component perpendicular to the beam is 80,000 lb and is applied 1ft above the beam. The longitudinal component was not considered.

2.3.3.8 Wave Pressure

Table 6-7 of the United States Department of the Interior, Bureau of Reclamation, "Design of Small Dams" was used to determine the design wave height. To determine the design wave height from the table cited above, the wind velocity and fetch for the site must be known. The basic sustained maximum wind speed for the area is 40 mph. Based on the geography at the site, the fetch is less than 1 mile. Therefore, to be somewhat on the conservative side a fetch distance of 1 mile was used. This wind speed and fetch resulted in a wave height of 2.6 ft, which should be a conservative approximation and should not have to be re-evaluated unless this wave height results in the critical load case. The wave pressure was applied to the entire length of the riverward side of the guidewall.

2.3.3.9 Wind Pressure

A wind pressure of 27 psf was calculated according to the Uniform Building Code. This pressure was applied to the back of the guidewall, from the surface of normal pool to the top of the wall, for the full length of the wall. Because wind and ice loads are considered in the same load combination case, placing wind on the back of the wall is the most conservative assumption.

2.3.4 Analysis of Cell on Rock Foundation, Lock No. 22

2.3.4.1 Foundation Properties

2.3.4.1.1 Internal Angle of Friction

A typically published coefficient of friction between clean rock and concrete is 0.7, which corresponds to an internal angle of friction equal to 35°. This angle was used for the 3DSAD input.

2.3.4.1.2 Cohesion and Shear Angle

The cohesion of the foundation material was assumed equal to 0.0 psf. All resistance to sliding was credited to friction between the cell concrete and the underlying foundation material. The 3DSAD program was allowed to determine the shear angle; it was set to default.

2.3.4.2 Load Cases

EM 1110-2-2602, EC 1110-2-291, "Stability Analysis of Concrete Structures," and the "Design Memorandum for Upstream Guard Wall, Kanawha River – Marmet, West Virginia" were used along with engineering judgement to determine load case combinations. The following four tables show the combinations of loads that were applied to the guide wall extensions. All load cases include the weight of the beams and cells, the live load, the dead load, and some level of uplift.

(SEE LOAD COMBINATIONS TABLES NEXT TWO PAGES)

LOWER GUIDEWALL INTERMEDIATE CELLS		LOAD COMBINATIONS FOR STABILITY CALCS CASE NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	3DSAD FORCE NAMES
SELF WEIGHT																BAS1,UPR,BM1A,BM2A,BM3A,SLOT,BM1B,BM2B,BM3B
IMPACT	USUAL															IMPN
	UNUSUAL															IMPU
	EXTREME															IMPE
UPLIFT	LOW															BYA1,BYB1,CBY1
	HIGH															BYA2,BYB2,CBY2
	NORMAL															BYA3,BYB3,CBY3
ICE	HORIZ.															HICE
	VERT.															VICE
LIVE LOAD																LIVE
DEAD LOAD																DEAD
HAWSER PULL																HAWS
WAVE																WAVE
WIND																WIND

Table A2.1 - Load Combinations and 3DSAD Variable Names for Lower Guide Wall Intermediate Cells.

UPPER GUIDEWALL INTERMEDIATE CELLS		LOAD COMBINATIONS FOR STABILITY CALCS CASE NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	3DSAD FORCE NAMES
SELF WEIGHT																BAS1,BAS2,UPR,BM1A,BM2A,SLOT,BM1B,BM2B
IMPACT	USUAL															IMPN
	UNUSUAL															IMPU
	EXTREME															IMPE
UPLIFT	NORMAL															BYA1,BYB1,CBY1
	HIGH															BYA2,BYB2,CBY2
ICE	HORIZ.															HICE
	VERT.															VICE
LIVE LOAD																LIVE
DEAD LOAD																DEAD
HAWSER PULL																HAWS
WAVE																WAVE
WIND																WIND

Table A2.2 - Load Combinations and 3DSAD Variable Names for Upper Guide Wall Intermediate Cells.

LOWER GUIDEWALL END CELLS		LOAD COMBINATIONS FOR STABILITY CALCS — CASE NUMBER																							3DSAD FORCE NAMES
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
SELF WEIGHT																									BAS1,UPR,BM1,BM2,BEND,RBM
IMPACT	UNUSUAL 90																								IU90
	UNUSUAL 75																								IU75
	UNUSUAL 60																								IU60
	UNUSUAL 45																								IU45
	EXTREME 90																								IE90
	EXTREME 75																								IE75
	EXTREME 60																								IE60
	EXTREME 45																								IE45
UPLIFT	LOW																								BY1,RBY1,CBY1
	HIGH																								BY2,RBY2,CBY2
	NORMAL																								BY3,RBY3,CBY3
ICE	HORIZ.																								HICE,RHIC
	VERT.																								VICE,RVIC
LIVE LOAD																									LIVE,RLIV
DEAD LOAD																									DEAD,RDEA
HAWSER PULL																									HAWS
WAVE																									WAVE,RWAV
WIND																									WIND,RWIN

Table A2.3 - Load Combinations and 3DSAD Variable Names for Lower Guide Wall End Cells.

UPPER GUIDEWALL END CELLS		LOAD COMBINATIONS FOR STABILITY CALCS — CASE NUMBER																							3DSAD FORCE NAMES
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
SELF WEIGHT																									BAS1,UPR,BM1,BM2,BEND,RBM
IMPACT	UNUSUAL 90																								IU90
	UNUSUAL 75																								IU75
	UNUSUAL 60																								IU60
	UNUSUAL 45																								IU45
	EXTREME 90																								IE90
	EXTREME 75																								IE75
	EXTREME 60																								IE60
	EXTREME 45																								IE45
UPLIFT	NORMAL																								BY1,RBY1,CBY1
	HIGH																								BY2,RBY2,CBY2
ICE	HORIZ.																								HICE,RHIC
	VERT.																								VICE,RVIC
LIVE LOAD																									LIVE,RLIV
DEAD LOAD																									DEAD,RDEA
HAWSER PULL																									HAWS
WAVE																									WAVE,RWAV
WIND																									WIND,RWIN

Table A2.4 - Load Combinations and 3DSAD Variable Names for Upper Guide Wall End Cells.

Three highly improbable load cases (load cases 11, 12, and 13) were applied only to the intermediate cells. These load cases included barge impacts with wave pressures acting simultaneously. Although possible, none of the references cited above included a loading with both these forces acting together, most likely because of their low probability of simultaneous occurrence. Regardless of these facts, the author decided to run the load cases for a "feel good" check. These three improbable cases were not considered for design and are not referred to in the summary of results discussion.

2.3.4.3 Summary of Results

Select Results from 3DSAD Output					
		Sliding	% Base in	Base Pressure(ksf)	
Description	Case No.	F.S.	Compression	Minimum	Maximum
Lower Intermediate Cells					
	1	12.59	100.0	4.782	7.832
	2	7.80	100.0	2.168	5.897
	3	8.31	100.0	6.218	6.545
	4	5.15	100.0	7.660	0.557
	5	5.94	100.0	4.322	8.619
	6	3.68	87.5	0.000	9.969
	7	3.48	100.0	0.950	7.229
	8	4.95	83.9	0.000	14.580
	9	51.94	100.0	0.510	11.737
	10	32.18	100.0	1.625	6.076
	11	2.41	78.5	0.000	11.360
	12	2.08	60.4	0.000	15.223
	13	1.79	39.5	0.000	23.897
Upper Intermediate Cells					
	1	6.70	100.0	2.456	4.118
	2	4.53	100.0	0.000	4.440
	3	4.42	100.0	0.838	5.736
	4	2.99	76.0	0.000	6.600
	5	3.16	91.5	0.000	7.750
	6	2.13	40.7	0.000	13.008
	7	3.73	100.0	0.437	4.002
	8	3.03	54.6	0.000	14.415
	9	27.65	100.0	0.195	6.379
	10	18.67	100.0	0.518	3.921
	11	2.05	55.7	0.000	9.317
	12	1.66	26.9	0.000	19.946
	13	1.36	2.3	0.000	241.496
Lower End Cell					
	1	5.00	99.7	0.000	10.325
	2	3.55	88.0	0.000	8.946
	3	5.00	100.0	0.144	10.012
	4	3.55	89.0	0.000	8.819
	5	5.00	100.0	0.490	9.667
	6	3.55	90.2	0.000	8.656
	7	5.00	100.0	0.852	9.304
	8	3.55	91.7	0.000	8.473
	9	3.59	89.6	0.000	12.310
	10	2.55	68.3	0.000	12.086
	11	3.59	91.9	0.000	11.900
	12	2.55	69.4	0.000	11.868
	13	3.59	94.2	0.000	11.478
	14	2.55	70.9	0.000	11.599
	15	3.59	96.4	0.000	11.068
	16	2.55	72.6	0.000	11.291
	17	6.07	100.0	2.228	4.978
	18	7.73	100.0	2.042	7.353
	19	87.47	100.0	3.436	6.720
	20	62.06	100.0	2.780	4.426
Upper End Cell					
	1	4.20	96.6	0.000	9.265
	2	3.55	90.0	0.000	8.701
	3	4.20	97.8	0.000	9.056
	4	3.55	90.9	0.000	8.583
	5	4.20	99.0	0.000	8.834
	6	3.55	92.0	0.000	8.447
	7	4.20	99.9	0.000	8.617
	8	3.55	93.1	0.000	8.301
	9	3.02	82.0	0.000	11.584
	10	2.55	70.6	0.000	11.667
	11	3.02	83.8	0.000	11.283
	12	2.55	71.6	0.000	11.472
	13	3.02	85.7	0.000	10.969
	14	2.55	72.9	0.000	11.250
	15	3.02	87.6	0.000	10.668
	16	2.55	74.3	0.000	11.005
	17	10.39	100.0	2.746	4.470
	18	7.02	100.0	1.615	6.921
	19	73.52	100.0	3.183	5.353
	20	62.15	100.0	2.904	4.313

Table A2.5 - Sliding Factor of Safety, Percent Base In Compression, Minimum Base Pressure, and Maximum Base Pressure For Cells.

The above Table A2.5 is a compilation of select 3DSAD output. For each load case applied to the four cells are the sliding factor of safety, the amount of base in compression, and the minimum and maximum pressures exerted between the cell base and foundation.

To simplify the review of results, the worst values have been extracted from Table A2.5 and presented below for each cell type. No distinction among loading conditions (usual, unusual, or extreme) were made for this exercise. The values were not necessarily taken from the same load case.

2.3.4.3.1 Lower Intermediate Cells

The lowest factor of safety against sliding is 3.48, which occurs under the unusual load case 7. This case includes water at the highest pool elevation combined with wave pressures. The worst overturning conditions results under the extreme load case 8 that represents severe winter conditions. This case includes ice accumulation on the front of the cell and the expansive ice force on the back of the wall. Case 8 results in an 83.9% base in compression. The maximum base pressure, 14.580 ksf, is also caused by load case 8.

2.3.4.3.2 Upper Intermediate Cells

The highest level of instability occurs for load case 6, which includes an extreme barge impact during high water conditions. For this case, both the safety factor against sliding and the percent base in compression are the lowest. The sliding safety factor is 2.13 and the percent base in compression is 40.7. The extreme winter load case 8 creates the largest base compressive pressure, 14.415 ksf.

2.3.4.3.3 Lower End Cell

The lowest sliding safety factor, 2.55, is a result of all load cases that include an extreme impact and high water. These cases are 10, 12, 14, and 16. The lowest percent of base in compression, 68.3, results from load case 10, that has an extreme barge impact on the very end of the wall directed parallel to the beams. The largest base pressure, 12.310 ksf, is produced by load case 9.

2.3.4.3.4 Upper End Cell

The lowest sliding safety factor, 2.55, is a result of all load cases that include an extreme impact and high water. These cases are 10, 12, 14, and 16. The lowest percent of base in compression, 70.6, and the largest base pressure, 11.667 ksf, result from load case 10, that has an extreme barge impact on the very end of the wall directed parallel to the beams.

Table A2.6 shows a comparison between the 3DSAD results and allowables stated in EC 1110-2-291 for critical structures with ordinary site information. Forty percent of the concrete compressive strength multiplied by the appropriate factor from the EC is used for the allowable bearing pressure since the foundation strength is higher than that of the concrete. The concrete compressive strength is assumed equal to 4 ksi. The worst values that were extracted from Table A2.5 and discussed above have been highlighted in Table A2.6.

(SEE TABLE A2.6 NEXT PAGE)

Comparison of Select Results from 3DSAD Output To Allowables							
Description	Case No.	Allowable Sliding F.S.	Sliding F.S.	Allowable % Base in Compression	% Base in Compression	Base Pressure(ksf) Allowable	Base Pressure(ksf) Maximum
Lower Intermediate Cells							
	1	≥2.00	12.59	100.00	100.0	≥230	7.832
	2	≥2.00	7.80	100.00	100.0	≥230	5.897
	3	≥1.75	8.31	≥75.0	100.0	≥263	6.545
	4	≥1.75	5.15	≥75.0	100.0	≥263	0.557
	5	≥1.33	5.94	>0.0	100.0	≥346	8.619
	6	≥1.33	3.68	>0.0	87.5	≥346	9.969
	7	≥1.75	3.48	≥75.0	100.0	≥263	7.229
	8	≥1.33	4.95	>0.0	83.9	≥346	14.580
	9	≥2.00	51.94	100.00	100.0	≥230	11.737
	10	≥1.75	32.18	≥75.0	100.0	≥263	6.076
Upper Intermediate Cells							
	1	≥2.00	6.70	100.00	100.0	≥230	4.118
	2	≥2.00	4.53	100.00	100.0	≥230	4.440
	3	≥1.75	4.42	≥75.0	100.0	≥263	5.736
	4	≥1.75	2.99	≥75.0	76.0	≥263	6.600
	5	≥1.33	3.16	>0.0	91.5	≥346	7.750
	6	≥1.33	2.13	>0.0	40.7	≥346	13.008
	7	≥1.75	3.73	≥75.0	100.0	≥263	4.002
	8	≥1.33	3.03	>0.0	54.6	≥346	14.415
	9	≥2.00	27.65	100.00	100.0	≥230	6.379
	10	≥1.75	18.67	≥75.0	100.0	≥263	3.921
Lower End Cell							
	1	≥1.75	5.00	≥75.0	99.7	≥263	10.325
	2	≥1.75	3.55	≥75.0	88.0	≥263	8.946
	3	≥1.75	5.00	≥75.0	100.0	≥263	10.012
	4	≥1.75	3.55	≥75.0	89.0	≥263	8.819
	5	≥1.75	5.00	≥75.0	100.0	≥263	9.667
	6	≥1.75	3.55	≥75.0	90.2	≥263	8.656
	7	≥1.75	5.00	≥75.0	100.0	≥263	9.304
	8	≥1.75	3.55	≥75.0	91.7	≥263	8.473
	9	≥1.33	3.59	>0.0	89.6	≥346	12.310
	10	≥1.33	2.55	>0.0	68.3	≥346	12.086
	11	≥1.33	3.59	>0.0	91.9	≥346	11.900
	12	≥1.33	2.55	>0.0	69.4	≥346	11.888
	13	≥1.33	3.59	>0.0	94.2	≥346	11.478
	14	≥1.33	2.55	>0.0	70.9	≥346	11.599
	15	≥1.33	3.59	>0.0	96.4	≥346	11.068
	16	≥1.33	2.55	>0.0	72.6	≥346	11.291
	17	≥1.75	6.07	≥75.0	100.0	≥263	4.978
	18	≥1.33	7.73	>0.0	100.0	≥346	7.353
	19	≥2.00	87.47	100.00	100.0	≥230	6.720
	20	≥1.75	62.06	≥75.0	100.0	≥263	4.426
Upper End Cell							
	1	≥1.75	4.20	≥75.0	96.6	≥263	9.265
	2	≥1.75	3.55	≥75.0	90.0	≥263	8.701
	3	≥1.75	4.20	≥75.0	97.8	≥263	9.056
	4	≥1.75	3.55	≥75.0	90.9	≥263	8.583
	5	≥1.75	4.20	≥75.0	99.0	≥263	8.834
	6	≥1.75	3.55	≥75.0	92.0	≥263	8.447
	7	≥1.75	4.20	≥75.0	99.9	≥263	8.617
	8	≥1.75	3.55	≥75.0	93.1	≥263	8.301
	9	≥1.33	3.02	>0.0	82.0	≥346	11.584
	10	≥1.33	2.55	>0.0	70.0	≥346	11.667
	11	≥1.33	3.02	>0.0	83.8	≥346	11.283
	12	≥1.33	2.55	>0.0	71.6	≥346	11.472
	13	≥1.33	3.02	>0.0	85.7	≥346	10.969
	14	≥1.33	2.55	>0.0	72.9	≥346	11.250
	15	≥1.33	3.02	>0.0	87.6	≥346	10.668
	16	≥1.33	2.55	>0.0	74.3	≥346	11.005
	17	≥1.75	10.39	≥75.0	100.0	≥263	4.470
	18	≥1.33	7.02	>0.0	100.0	≥346	6.921
	19	≥2.00	73.52	100.00	100.0	≥230	5.353
	20	≥1.75	62.15	≥75.0	100.0	≥263	4.313

Table A2.6 - Comparison of Select Results to Allowables.

2.3.5 Analysis of Cell on Sand Foundation, Lock No. 25

2.3.5.1 Foundation Properties

Subsurface characterization was based on borings performed at the project and in particular twelve borings taken in the location of the guidewall extensions. These borings along with a plan showing boring locations and a discussion of foundation properties is included in the Geotechnical Appendix, Appendix D. Six of these borings were taken upstream of the existing guidewall and six borings were taken in the location of the lower guidewall extension. The existing soil surface elevation is approximately El 400 ft, which is the proposed base elevation of the extended guidewalls. The materials are mostly sands and gravels extending down to the bedrock surface at approximately El 325 ft.

2.3.5.1.1 Internal Angle of Friction

Based on in-situ SPT tests performed on this granular material, a saturated unit weight of 130 pcf and a friction angle of 35 degrees were used in the design.

2.3.5.1.2 Cohesion

The cohesion of the granular materials existing at the site is zero.

2.3.5.2 Load Cases

EM 1110-2-2602, EC 1110-2-291, "Stability Analysis of Concrete Structure," and the "Design Memorandum for Upstream Guard Wall, Kanawha River – Marmet, West Virginia" were used along with engineering judgement to determine load case combinations. The following four tables (Tables A2.7 thru A2.10) show the combinations of loads that were applied to the guide wall extensions. All load cases include the weight of the beams and cells, the live load, the dead load and some level of uplift.

(SEE LOAD COMBINATIONS TABLES NEXT TWO PAGES)

LOWER GUIDEWALL INTERMEDIATE CELLS		LOAD COMBINATIONS FOR STABILITY CASE NUMBER													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
SELF WEIGHT															
IMPACT	USUAL														
	UNUSUAL														
	EXTREME														
UPLIFT	LOW														
	HIGH														
	NORMAL														
ICE	HORIZONTAL														
	VERTICAL														
LIVE LOAD															
DEAD LOAD															
HAWSER PULL															
WAVE															
WIND															

Table A2.7 - Load Combinations for Intermediate Cells
LOWER GUIDEWALL

UPPER GUIDEWALL INTERMEDIATE CELLS		LOAD COMBINATIONS FOR STABILITY CASE NUMBER													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
SELF WEIGHT															
IMPACT	USUAL														
	UNUSUAL														
	EXTREME														
UPLIFT	NORMAL														
	HIGH														
ICE	HORIZONTAL														
	VERTICAL														
LIVE LOAD															
DEAD LOAD															
HAWSER PULL															
WAVE															
WIND															

Table A2.8 - Load Combinations for Intermediate Cells
UPPER GUIDEWALL

LOWER GUIDEWALL END CELLS		LOAD COMBINATIONS FOR STABILITY — CASE NUMBER																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SELF WEIGHT		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
IMPACT	UNUSUAL 90	■	■																		
	UNUSUAL 75			■	■																
	UNUSUAL 60					■	■														
	UNUSUAL 45							■	■												
	EXTREME 90									■	■										
	EXTREME 75											■	■								
	EXTREME 60													■	■						
	EXTREME 45															■	■				
UPLIFT	LOW	■		■		■		■		■		■		■		■					
	HIGH		■		■		■		■		■		■		■		■	■			■
	NORMAL																		■		
ICE	HORIZONTAL																		■		
	VERTICAL																		■		
LIVE LOAD		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
DEAD LOAD		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HAWSER PULL																				■	■
WAVE																		■			
WIND																			■		

Table A2.9 - Load Combinations for End Cells
LOWER GUIDEWALL

UPPER GUIDEWALL END CELLS		LOAD COMBINATIONS FOR STABILITY — CASE NUMBER																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SELF WEIGHT		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
IMPACT	UNUSUAL 90	■	■																		
	UNUSUAL 75			■	■																
	UNUSUAL 60					■	■														
	UNUSUAL 45							■	■												
	EXTREME 90									■	■										
	EXTREME 75											■	■								
	EXTREME 60													■	■						
	EXTREME 45															■	■				
UPLIFT	NORMAL	■		■		■		■		■		■		■		■			■	■	
	HIGH		■		■		■		■		■		■		■		■	■			■
ICE	HORIZONTAL																		■		
	VERTICAL																		■		
LIVE LOAD		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
DEAD LOAD		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
HAWSER PULL																				■	■
WAVE																		■			
WIND																			■		

Table A2.10 - Load Combinations for End Cells
UPPER GUIDEWALL

2.3.5.3 Pipe Piles

36-inch diameter pipe piles with one-inch steel wall thickness were analyzed for axial compression, axial tension, and lateral capacity. These pipe piles are used to found both the intermediate and the end cells. Ten (10) piles are used in the design for the intermediate cells. Sixteen (16) piles are used in the design for the end cells. All piles will be installed vertically.

2.3.5.3.1 Axial Tension Capacity

A study was made of the foundation material existing beneath the lock to determine the depth to which piles could be driven. All tension capacities were based on the minimum tip penetration. It is likely that many piles will be driven deeper than the minimum tip elevation, however, the tension capacity of the piles must be based on this minimum elevation in the event that they are not. Axial tension capacity was computed assuming a pile embedment of 70 feet. The ultimate axial tension capacity is 332 kips and will have to be reduced by the factors of safety listed in 2.3.5.3.3 to determine the allowable service loads. The ultimate tension capacities were calculated with the static pile formula using the following equations:

$$Q_{ult} = K_t \gamma' D A_s \tan\delta$$

$$D_c = 15B$$

Where:

Q_{ult} = pile ultimate tension capacity
K_t = coefficient of lateral earth pressure for piles in tension
γ' = effective unit weight
D = depth of pile penetration
A_s = area of pile shaft
d = angle of friction between pile and soil
D_c = critical depth below which the unit side resistance is constant
B = width of pile

In calculating the ultimate tension capacities the following values were used:

Kt = 0.5
$\phi = 35°$
$\delta = 26°$
γ' = 68.6 pcf

2.3.5.3.2 Axial Compression Capacity

In order to develop full axial capacity, piles must be driven to refusal, preferably seated on bedrock. The piles will be driven to refusal on rock with driving shoes giving an allowable stress of 14.5 ksi according to EM 1110-2-2906. This allowable stress requires verification from a pile load test and results in an allowable compression capacity of 1594 kips. An overstress of 33 percent is allowed for unusual loading conditions and 75 percent is allowed for extreme loading conditions.

Skin friction is determined using the same methodology used to determine tension capacity, however, the lateral earth pressure coefficient for piles in compression, K_c, is used in lieu of K_t. K_c=1.5 for a steel pile in sand. Assuming a minimum embedment of 70 feet, the ultimate skin friction of the pile would be 996 kips. This capacity is not included in the allowable compression capacity used in design, but does relieve load transferred to bedrock. Borings attached in Appendix E show some zones of less desirable shale were encountered in the exploration program in addition to the more competent limestone.

2.3.5.3.3 Allowable Axial Design Loads

The following allowable axial pile capacities were used to design the intermediate and end cells for the guidewall extensions:

	Allowable Loads	
Loading Condition	Tension Capacity	Compression Capacity
Usual	111 kips	1594 kips
Unusual	148 kips	2120 kips
Extreme	195 kips	2790 kips

2.3.5.3.4 Combined Bending and Axial Compression

The upper regions of the pile may be subject to the effects of bending and buckling as well as axial load. According to EM 1110-2-2906, the allowable axial and bending stress for A36 steel is 18 kips for usual loading conditions. Again, the allowable stress is higher for the unusual and extreme loading conditions; 24 and 31 ksi respectively. For the circular pipe pile cross section, the maximum bending moment can be determined from the following equation;

$$M_{\max} = \sqrt{M_x^{\,2} + M_y^{\,2}}$$

Where M_{max} is the maximum bending moment in the pile
M_x is the bending moment about the x axis
M_y is the bending moment about the y axis

The stress caused by this bending moment is combined with the axial stress. The highest combined stress for each loading condition is included in Table 3.X.

2.3.5.4 Soil Pile Stiffness

Pile group design is accomplished by use of the Pile Group Analysis Computer Program (CPGA) based on an elastic stiffness method. CPGA is a three dimensional analysis, that incorporates both a global three-dimensional coordinate system and local three-dimensional coordinate systems for each pile. Input to the computer program consists of applied loads, pile properties, pile locations and the soil-pile stiffness. Lateral, axial, and torsional stiffness of each pile resists movement and determines how forces and moments are transferred between piles. Pile stiffness coefficients are defined as follows, where 1, 2 and 3 refer to the local pile coordinate system axes and 4, 5 and 6 are rotations about those axes:

b_{11} Force required to displace the pile head a unit distance along the local 1 axis

b_{22} Force required to displace the pile head a unit distance along the local 2 axis

b_{33} Force required to displace the pile head a unit distance along the local 3 axis

b_{44} Moment required to displace the pile head a unit rotation about the local 1 axis

b_{55} Moment required to displace the pile head a unit rotation about the local 2 axis

b_{66} Moment required to displace the pile head a unit rotation about the local 3 axis

b_{15} Force required along the local 1 axis to resist lateral movement during a unit rotation of the pile head around the local 2 axis

b_{24} Force required along the local 2 axis to resist lateral movement during a unit rotation of the pile head around the local 1 axis

b_{51} Moment required around the local 2 axis to resist rotation caused by a unit displacement of the pile head along the local 1 axis

b_{42} Moment required around the local 1 axis to resist rotation caused by a unit displacement of the pile head along the local 2 axis

Although the program determines load distributions and pile displacements using these ten stiffnesses, only two stiffness coefficients are needed as input for each pile, a component of axial stiffness (C_{33}) and a component of lateral stiffness (n_h). These two components are used in combination with pile parameters and connection fixity to determine the ten appropriate pile stiffnesses. In addition, the component of lateral stiffness must be reduced to take into account group effects. A torsional modifier can be used to determine the torsional behavior of a single pile, but this modifier is not used for pile groups.

2.3.5.4.1 Axial Stiffness

Axial load in a compression pile is transferred to the soil by a combination of tip bearing and skin friction. The axial stiffness of a pile is calculated by the equation:

$$b_{33} = C_{33}(AE/L)$$

Where b_{33} = axial pile stiffness
A = pile cross-sectional area
E = modulus of elasticity
L = length of pile

The AE/L term is the stiffness of the pile acting as a column with no soil present. The axial stiffness parameter needed in the CGPA program, C33, is referred to as the axial stiffness modifier. The term C_{33} was determined for the pipe pile with the subsurface conditions at Lock and Dam No. 25 using the computer program CAXPILE. The program is used to calculate pile deflections under a range of loads, and the value of C_{33} can be calculated using the following equation:

$$C_{33} = \frac{\Delta}{\delta}.$$

Where $\Delta = PL/AE$
δ = axial movement of the pile head due to axial load P
P = axial load on the pile

Values of C_{33} were determined for both compression and tension piles in sand for one-eighth and one-quarter inch axial movement. Based on this analysis and verified with results from numerous pile load tests performed in sand for the Lock and Dam No. 26 replacement, the following values of C_{33} were used in design of the guidewall extensions:

(1) For pipe piles in compression driven to refusal, $C_{33} = 0.9$.

(2) C_{33} for tension piles is one-half the value used for compression piles.

2.3.5.4.2 Lateral Stiffness

The lateral stiffness parameter needed in the CPGA program, n_h, is referred to at the constant of horizontal subgrade reaction. The value of n_h used in the design of the guidewall extensions was determined by calculating lateral deflections for a range of loads using the computer program COM624. Values for n_h were calculated using the following equation:

$$n_h = \frac{C\left(\frac{P_t}{Y_t}\right)^{1.67}}{(EI)^{0.67}}$$

Where:

C = 0.89 for a fixed-head pile
P_t = lateral load applied at the top of the pile at the ground surface.
Y_t = lateral deflection of the top of the pile at the ground surface.

The value of n_h = 20 pci was determined to be appropriate for deflections less than ½ inch, this value was verified with results from lateral load tests performed in sand for the Lock and Dam No. 26 replacement. This value of n_h has been reduced for group effects and is valid for center to center pile group spacings of 9 feet. The lateral stiffness of a pile in CPGA is then calculated by the equations:

$$b_{11} = b_{22} = C_o\,(EI/T^3)$$

$$T = (EI/n_h)^{1/5}$$

Where:

E and I are pile properties
C_o determines the degree of fixity between the pile and the pile cap, in this instance C_o = 1.075
n_h = constant of horizontal subgrade reaction

The above formula assumes a linearly increasing horizontal subgrade modulus (E_s) with depth (x) where $E_s = n_h x$.

2.3.5.4.3 Torsional Stiffness

The torsional stiffness coefficient needed in the CPGA program is b66. Since no rotation of individual piles about their vertical axis exists for either the intermediate or the end cells, this stiffness is not needed. The remaining coefficients (b44, b55, b15, b24, b51, and b42) are calculated by CPGA using pile parameters and pile-soil information already required to determine lateral stiffness, using the following equations:

$$b_{44} = b_{55} = C_o \, (EI/T)$$

Where Co = 1.5, and T is the same as for b_{11} and b_{22}

$$b_{15} = b_{51} = C_o \, (EI/T^2)$$

$$b_{24} = b_{42} = -C_o \, (EI/T^2)$$

Where Co = 1.0, and T is the same as for b_{11} and b_{22}

2.3.5.5 Summary of Results

Tables A2.11 and A2.12 are a compilation of select results determined from CPGA. Maximum pile loads in tension and compression, maximum pile combined axial and bending stress, horizontal displacements at the base of the cell and at the top of the cell and vertical displacements are given for each load case applied to the four types of cells. Horizontal displacements are positive if they are toward the riverside and negative in the landside direction.

Axial pile loads and combined stresses in the piles were within allowable limits for all piles for the numerous load cases considered. Horizontal deflections and settlements were less than one inch in all cases considered for design.

(SEE CPGA RESULTS TABLES NEXT TWO PAGES)

Select Results Determined from CPGA Output							
Description (notes)	Load Case No.	Maximum Pile Load Comp.	Maximum Pile Load Tension	Combined Pile Stress (ksi)	Horizontal δ Base of Cell (inches)	Horizontal δ Top of Cell (inches)	Vertical δ (inches)
Lower Guidewall – Intermediate Cells							
	1	747	0	10.3	-0.12	-0.21	0.23
	2	679	0	8.8	-0.16	-0.44	0.23
	3	893	0	13.0	-0.21	-0.43	0.29
	4	825	6	11.5	-0.25	-0.66	0.29
	5	1065	0	16.2	-0.31	-0.69	0.36
	6	997	156	14.7	-0.35	-0.92	0.35
	7	873	48	14.6	-0.33	-0.79	0.31
	8	1063	0	15.5	0.33	0.83	0.37
	9	877	0	8.2	0.08	0.32	0.29
	10	432	0	4.6	0.04	0.09	0.14
Lower Guidewall – End Cells							
	1	1461	0	22.0	-0.36 **	-0.72 **	0.45
	2	1171	0	19.5	-0.35 **	-0.69 **	0.40
	3	1471	0	22.2	-0.35 **	-0.70 **	0.50
	4	1181	0	19.6	-0.34 **	-0.66 **	0.44
	5	1442	0	22.1	-0.31 **	-0.63 **	0.53
	6	1152	0	19.3	-0.30 **	-0.60 **	0.47
	7	1377	0	21.6	-0.26 **	-0.52 **	0.54
	8	1086	0	18.8	-0.25 **	-0.49 **	0.48
	9	1682	0	27.5	-0.50 **	-0.99 **	0.60
	10	1391	180	25.0	-0.49 **	-0.96 **	0.49
	11	1696	0	27.7	-0.48 **	-0.96 **	0.60
	12	1405	188	25.1	-0.47 **	-0.92 **	0.55
	13	1655	0	27.5	-0.43 **	-0.86 **	0.64
	14	1365	147	24.8	-0.42 **	-0.83 **	0.59
	15	1563	0	26.7	-0.35 **	-0.71 **	0.66
	16	1273	56	23.9	-0.35 **	-0.68 **	0.60
	17	705	0	8.9	-0.09	-0.14	0.22
	18	828	0	9.5	0.10	0.22	0.28
	19	894	0	8.3	0.04	0.14	0.30
	20	616	0	6.1	0.02	0.05	0.19

** note: marked horizontal deflections are in the upstream (-)/downstream (+) direction, all other deflections are landward (-) or riverward (+).

Table A2.11 – Pile Factors of Safety and Displacements for Cells.

Select Results Determined from CPGA Output							
Description	Load Case No.	Maximum Pile Load Comp. (kips)	Maximum Pile Load Tension (kips)	Combined Pile Stress (ksi)	Horizontal δ Base of Cell (inches)	Horizontal δ Top of Cell (inches)	Vertical δ (inches)
Upper Guidewall – Intermediate Cells							
	1	708	0	9.3	-0.15	-0.36	0.23
	2	687	0	8.8	-0.17	-0.43	0.23
	3	854	0	12.0	-0.24	-0.61	0.29
	4	834	15	11.5	-0.25	-0.67	0.29
	5	1026	12	15.2	-0.33	-0.86	0.36
	6	1006	165	14.7	-0.35	-0.93	0.36
	7	762	0	11.2	-0.24	-0.61	0.26
	8	931	39	14.0	0.31	0.79	0.33
	9	576	0	5.7	0.05	0.16	0.18
	10	423	0	4.6	0.04	0.09	0.13
Upper Guidewall - End Cells							
	1	1259	0	20.3	0.35 **	0.69 **	0.43
	2	1162	0	19.4	0.35 **	0.68 **	0.40
	3	1268	0	20.4	0.34 **	0.67 **	0.46
	4	1172	0	19.5	0.34 **	0.66 **	0.45
	5	1240	0	24.1	0.54 **	0.83 **	0.49
	6	1143	0	19.2	0.30 **	0.59 **	0.48
	7	1174	0	19.6	0.25 **	0.49 **	0.50
	8	1080	0	18.7	0.25 **	0.48 **	0.49
	9	1479	112	25.7	0.49 **	0.96 **	0.52
	10	1382	177	24.9	0.49 **	0.95 **	0.48
	11	1493	110	25.9	0.47 **	0.93 **	0.57
	12	1396	190	25.0	0.47 **	0.92 **	0.55
	13	1452	69	25.6	0.43 **	0.83 **	0.61
	14	1356	150	24.7	0.42 **	0.82 **	0.59
	15	1361	0	24.8	0.35 **	0.68 **	0.62
	16	1267	58	23.9	0.35 **	0.67 **	0.61
	17	687	0	7.9	-0.06	-0.11	0.21
	18	714	0	8.5	0.09	0.18	0.23
	19	697	0	6.7	0.03	0.07	0.22
	20	611	0	6.1	0.02	0.04	0.18

** note: marked horizontal deflections are in the upstream (-)/downstream (+) direction, all other deflections are landward (-) or riverward (+).

Table A2.12 – Pile Factors of Safety and Displacements for Cells.

To simplify the review of results, the worst values have been extracted from Table A2.11 and Table A2.12 and presented below (Table A2.13) for each cell type. The results of usual, unusual and extreme loading conditions for each cell type are compared to allowable capacities and stresses in the Table.

Comparison of Select Results Determined from CPGA Output to Allowables								
Desc.	Compression Load (kips)		Tension Load (kips)		Combined Stress (ksi)		Horiz. δ Top (in.)	Settlemnt (in.)
	Max.	Allow.	Max.	Allow.	Max.	Allow.		
Lower Guidewall – Intermediate Cells								
Usual	877	1594	0	111	10.3	18	-0.44	0.29
Unusual	893	2120	48	148	14.6	24	-0.79	0.31
Extreme	1065	2790	156	195	16.2	31	-0.92	0.37
Lower Guidewall - End Cell								
Usual	894	1594	0	111	8.3	18	0.22	0.30
Unusual	1471	2120	0	148	22.2	24	-0.72	0.54
Extreme	1696	2790	188	195	27.7	31	-0.99	0.66
Upper Guidewall – Intermediate Cells								
Usual	708	1594	0	111	9.3	18	-0.43	0.23
Unusual	854	2120	15	148	12.0	24	-0.67	0.29
Extreme	1026	2790	165	195	15.2	31	-0.93	0.36
Upper Guidewall - End Cell								
Usual	697	1594	0	111	6.7	18	0.18	0.22
Unusual	1259	2120	0	148	24.1	24	0.83	0.50
Extreme	1493	2790	190	195	25.9	31	0.96	0.62

Table A2.13 – Comparison of Select Results to Allowables

2.3.5.5.1 Lower Guidewall – Intermediate Cells

Load case 6 is an extreme loading condition and resulted in a tensile load of 156 kips in one of the piles. This tensile load is below the allowable load of 195 kips for extreme loading conditions.

2.3.5.5.2 Lower Guidewall – End Cell

Load case 12 is an extreme loading condition and resulted in a tensile load of 188 kips in one of the piles. This tensile load is below the allowable load of 195 kips for extreme loading conditions. The combined stresses for unusual loading cases 1, 3, 5, and 7 are 22 ksi, which is below the allowable stress of 24 ksi. The combined stresses for extreme loading cases 9, 11, 13, and 15 are 27 ksi, which is below the allowable stress of 31 ksi.

2.3.5.5.3 Upper Guidewall – Intermediate Cells

Load case 6 is an extreme loading condition and resulted in a tensile load of 165 kips in one of the piles. This tensile load is below the allowable load of 195 kips for extreme loading conditions.

2.3.5.5.4 Upper Guidewall – End Cell

Load case 5 is an unusual loading case where the combined pile stresses are 24 ksi, which is the threshold for an allowable pile stress. Load case 12 is an extreme loading condition and resulted in a tensile load of 190 kips in one of the piles. This tensile load is below the allowable load of 195 kips for extreme loading conditions. The combined stresses for unusual loading cases 1, 3, 5, and 7 are 22 ksi, which is below the allowable stress of 24 ksi. The combined stresses for extreme loading cases 9, 11, 13, and 15 are 27 ksi, which is below the allowable stress of 31 ksi.

2.3.6 Conclusions

Lock No. 22, Rock Foundation
Intermediate cells should have a 35 ft diameter, and the end cells should have a 50 ft diameter. Cells of this size are adequate to meet all stability requirements for the anticipated loadings.

Lock No. 25, Sand Foundation
The intermediate cells should have a 35 ft diameter with 10 pipe piles, and the end cells should have a 57 ft diameter with 16 pipe piles. Cells of this size with the number of piles indicated are adequate to meet all stability requirements for the anticipated loadings.

GOVERNMENT ESTIMATE WORKSHEET Sheet 1 of 1

Project: ***UPPER MISSISSIPPI NAVIGATIONAL STUDY***
PED Closedown for Upstream and
Downstream Guidewall Extensions @ L&D 25

DATE: 26 JULY 2000

ITEM NO.	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT
05	LOCKS				
05.60	Guidewalls (Upstream and Downstream)				
	Intermediate & End Cells				
	Tremie Concrete	18,345.0	CY	$190.00	$3,485,550.00
	Reinforcement	10,200.0	LBS	$0.75	$7,650.00
	Structural Steel Cylinder	2,656,400.0	LBS	$3.50	$9,297,400.00
	Pipe Piles (36" diameter)	10,560.0	LF	$450.00	$4,752,000.00
	Underwater Excavation	11,320.0	CY	$20.00	$226,400.00
	"C" Stone	17,575.0	TONS	$20.00	$351,500.00
	Check Posts	10.0	EA	$1,000.00	$10,000.00
	Line Hooks	25.0	EA	$1,000.00	$25,000.00
	Ladders	225.0	LF	$100.00	$22,500.00
	Precast/Prestressed Concrete Beam				
	Concrete	5,584.0	CY	$850.00	$4,746,400.00
	Reinforcement	1,959,390.0	LBS	$0.50	$979,695.00
	1/2" Low Relaxation Strands	360,470.0	LBS	$2.50	$901,175.00
	Gap Filler Material	1,620.0	SF	$3.40	$5,508.00
	Epoxy Adhesive	1,620.0	SF	$1.70	$2,754.00
	Elastomeric Bearing Pads (Bearing)	100.0	EA	$450.00	$45,000.00
	Elastomeric Bearing Pads (Impact)	50.0	EA	$450.00	$22,500.00
	Elastomeric Bearing Pads (Rebound)	50.0	EA	$250.00	$12,500.00
	Elastomeric Bearing Pads (Longitudinal)	50.0	EA	$250.00	$12,500.00
	Steel Armor Protection	681,672.5	LBS	$1.80	$1,227,010.50
	Polystyrene Filler	114,412.5	CF	$2.40	$274,590.00
	Post-Tensioning Threadbars/Plates	25,000.0	LBS	$3.00	$75,000.00
	Expansion Joint Material	1,125.0	LF	$120.00	$135,000.00
	Remove Existing Guide Cell				
	Concrete Demolition	1,500.0	CY	$50.00	$75,000.00
	Removal of 6" Minus Rockfill	1,570.0	CY	$22.50	$35,325.00
	Sheet Pile Removal, PS32, length = 72'/each, 30' embedded,	86.0	EA	$450.00	$38,700.00
	Miscellaneous				
	Handrail, 2" diameter standard steel pipe	3,925.0	LF	$30.00	$117,750.00
	Electrical Work	1.0	LS	——	$204,675.00
	Clearing 24' diameter trees	5.0	EA	$200.00	$1,000.00
	Seeding	1.0	ACR	$1,500.00	$1,500.00
	Stripping	828.0	CY	$1.50	$1,242.00
	Embankment	7,100.0	CY	$5.00	$35,500.00
	12" Crushed Stone	160.0	TONS	$20.00	$3,200.00
	PZ27 Sheetpile Cut-off Wall	39,000.0	LF	$45.00	$1,755,000.00
	PROJECT SUBTOTAL:				$28,886,524.50
	Contingency - 25%				7,221,631.13
	SUBTOTAL W/CONTINGENCIES:				$36,108,000.00
30	PLANNING, ENGINEERING, & DESIGN - 15%				5,416,200.00
31	CONSTRUCTION MANAGEMENT - 10%				3,610,800.00
	TOTAL PROJECT COST				$45,135,000.00

References

EM 1110-1-2101
Working Stresses for Structural Design (Jan 72)

EM 1110-2-2104
Strength Design for Reinforced Concrete Hydraulic Structures (Jun 92)

EM 1110-2-2200
Gravity Dam Design (Jun 95)

EM 1110-2-2602
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EM 1110-2-2906
Design of Pile Foundations (Jun 91)

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Stability Analysis of Concrete Structures (Oct 97)

MEMORANDUM CELRL-ED-DS (Sep 99)
UMR&IWW Navigation Study, Barge Impact Analysis, Memorandum from CELRL-ED-DS to CEMVR-ED-DM, dated 17 September 1999

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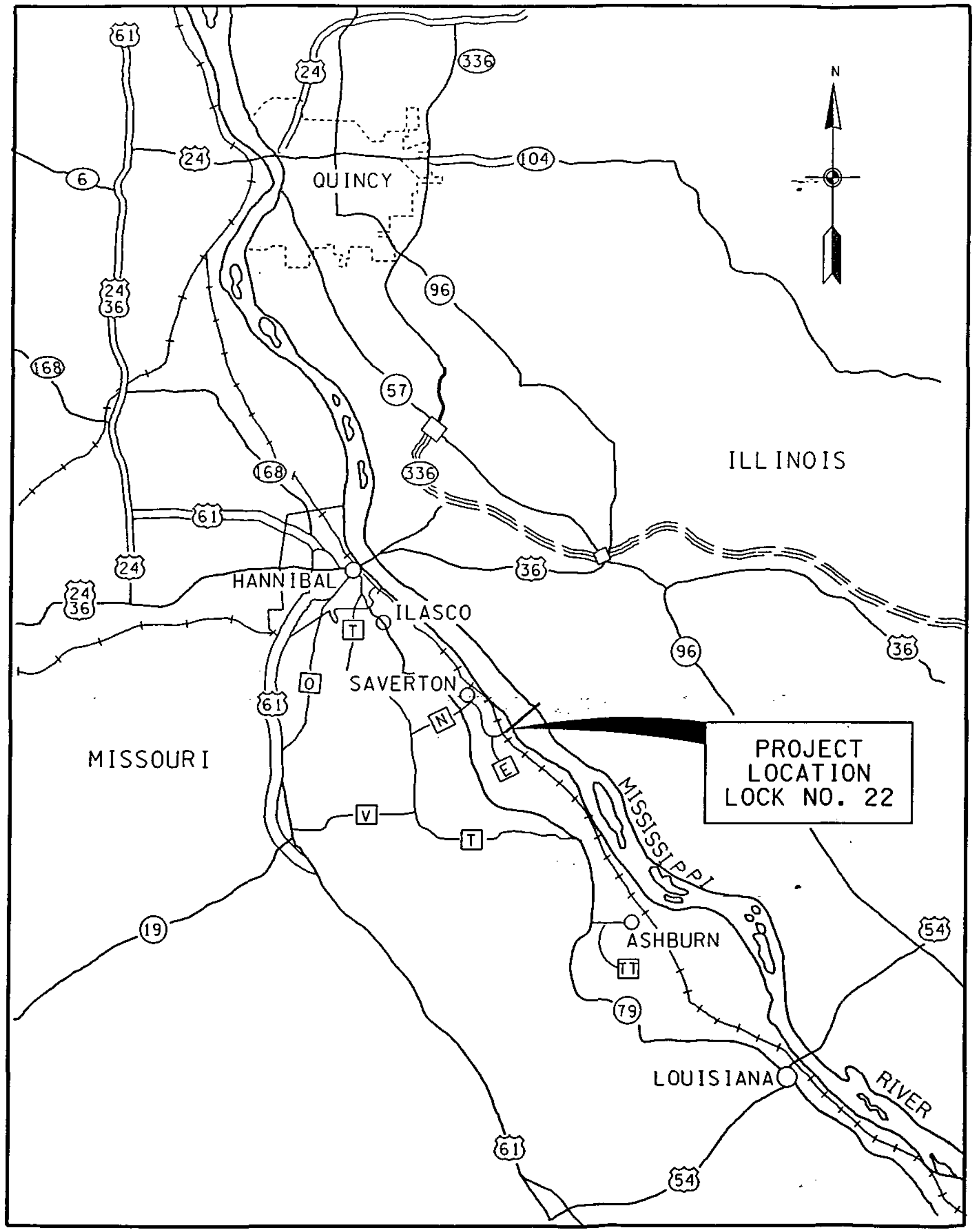
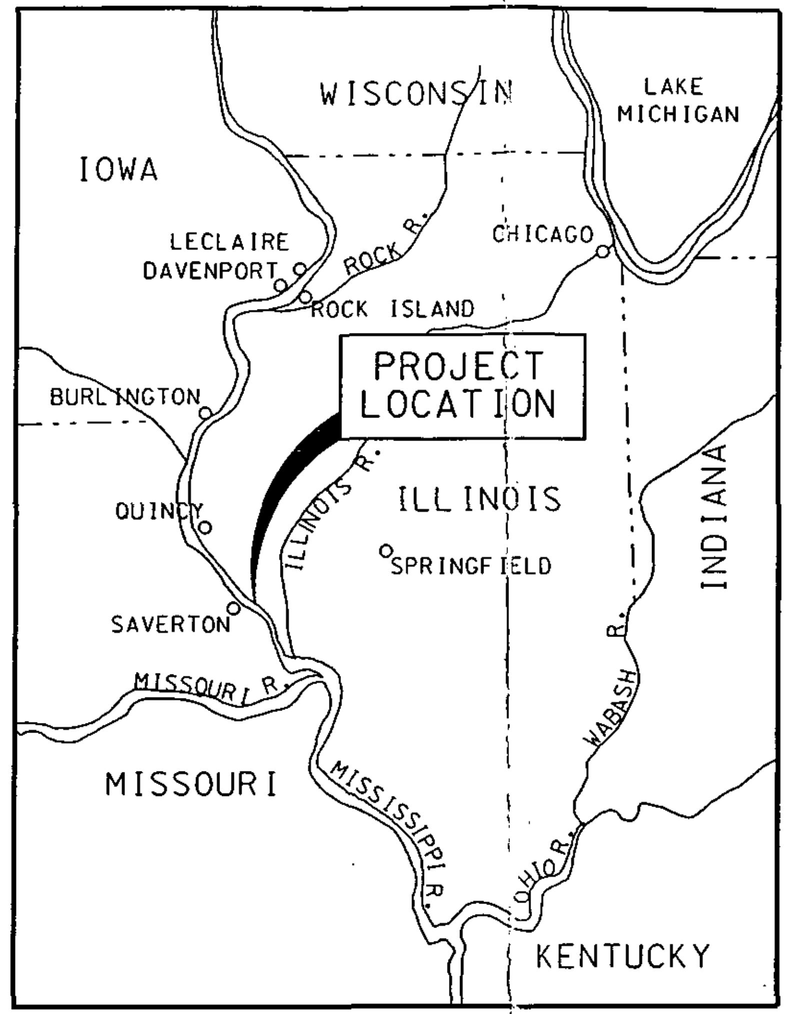


LOCK 22 - PROJECT LOCATION

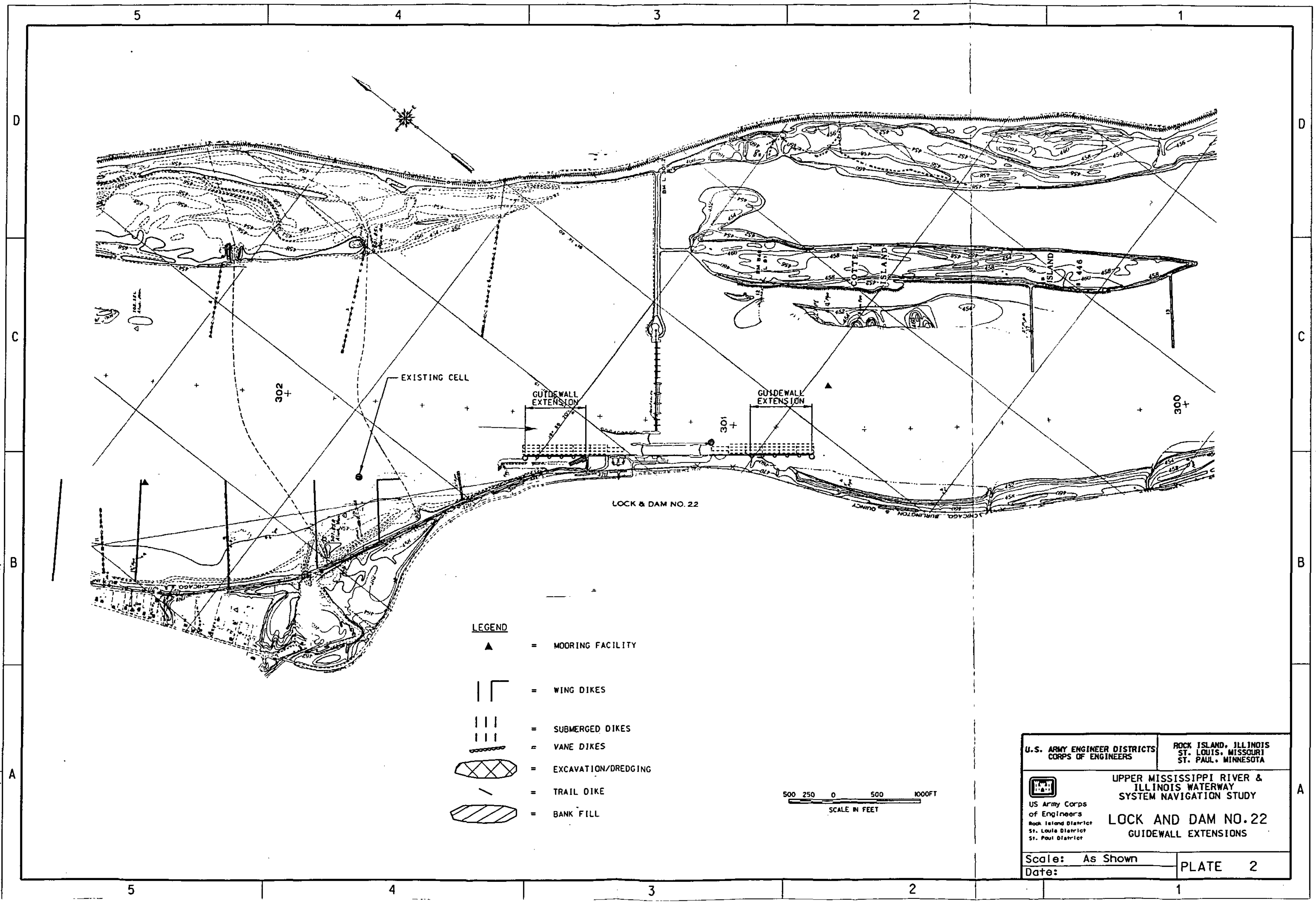
5 0 5 10 15
SCALE IN MILES



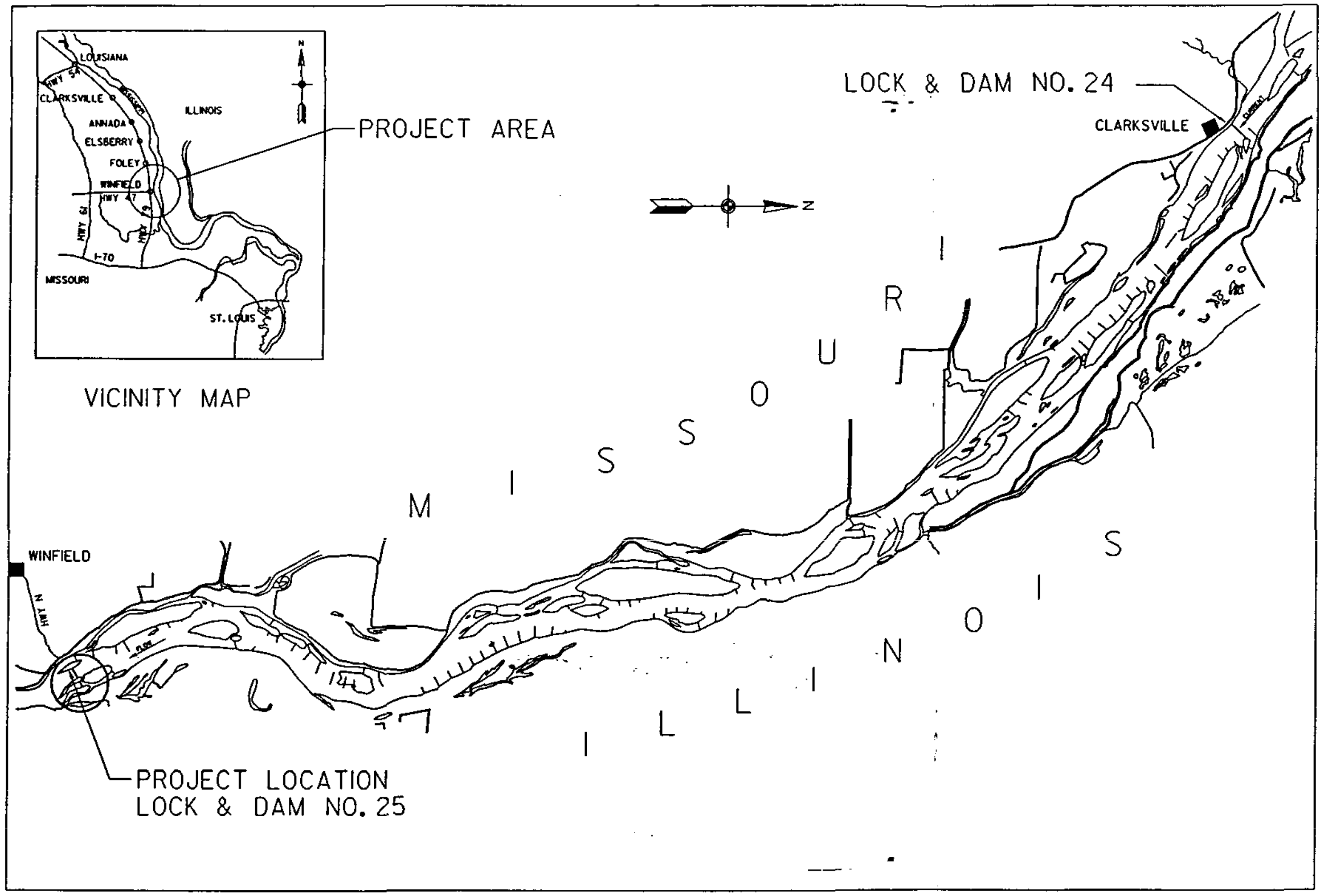
VICINITY MAP

25 0 25 50 75
SCALE IN MILES

U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA
US Army Corps of Engineers Rock Island District St. Louis District St. Paul District	UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY **LOCATION AND VICINITY MAPS**
Scale: As Shown Date:	PLATE 1



EXISTING CELL
GUIDEWALL EXTENSION
GUIDEWALL EXTENSION
COTTELL ISLAND
LOCK & DAM NO. 22
302
301
300
LEGEND
= MOORING FACILITY
= WING DIKES
= SUBMERGED DIKES
= VANE DIKES
= EXCAVATION/DREDGING
= TRAIL DIKE
= BANK FILL
500 250 0 500 1000FT
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS
ST. LOUIS, MISSOURI
ST. PAUL, MINNESOTA
UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY
US Army Corps of Engineers
Rock Island District
St. Louis District
St. Paul District
LOCK AND DAM NO.22
GUIDEWALL EXTENSIONS
Scale: As Shown
Date:
PLATE 2



US Army Corps of Engineers
ST. LOUIS DISTRICT

Symbol	Description	Date	Appr.
	Revisions		

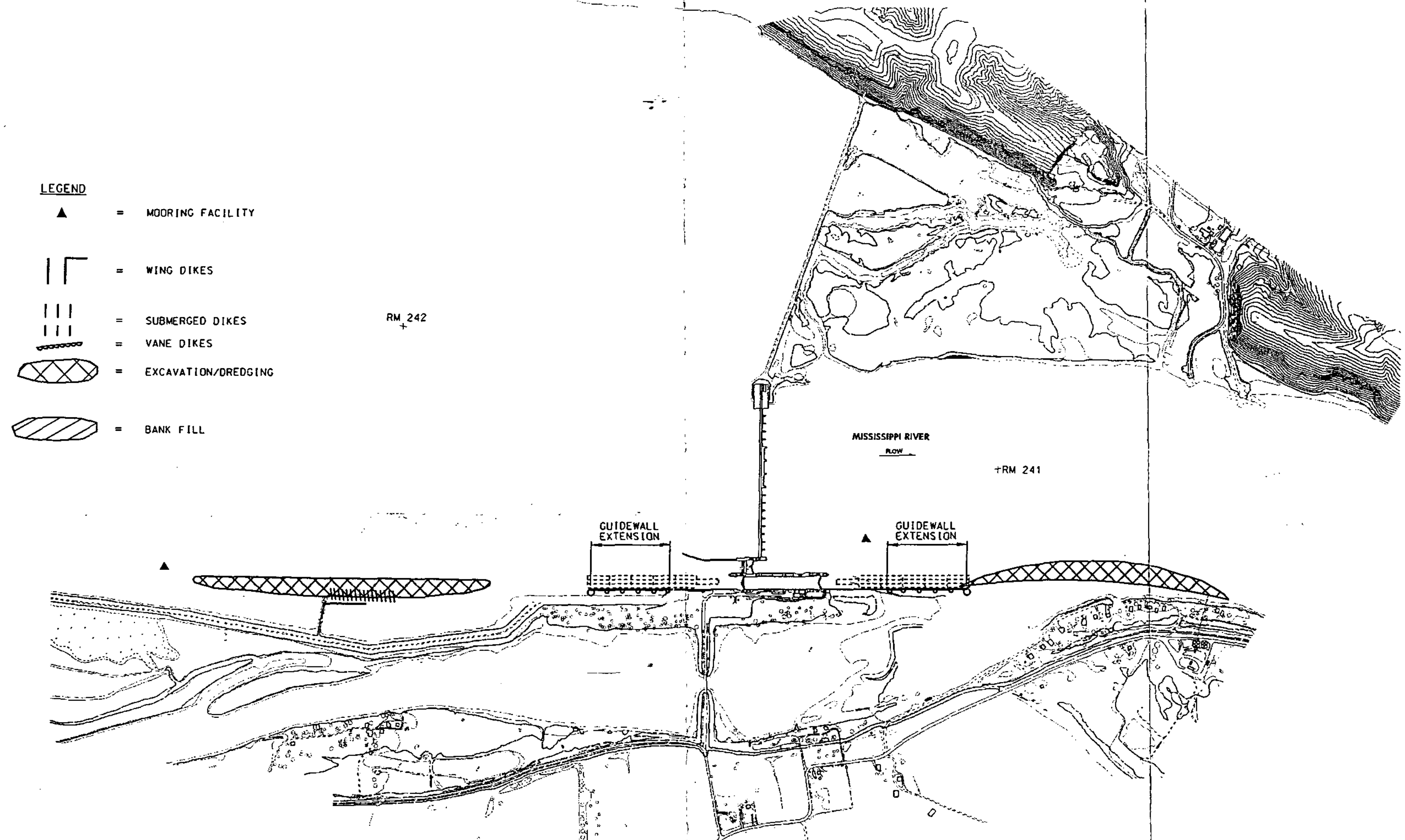
U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

Designed by:
Drawn by: Ckd by:
Reviewed by:
x
APPROVED:
BOBBY HUCHEY, P.E.
Chief, Design Branch

Date:
SUBMITTED:
MICHAEL R. RECTOR, P.E.
Chief, Civil / Specs. Section
File name:

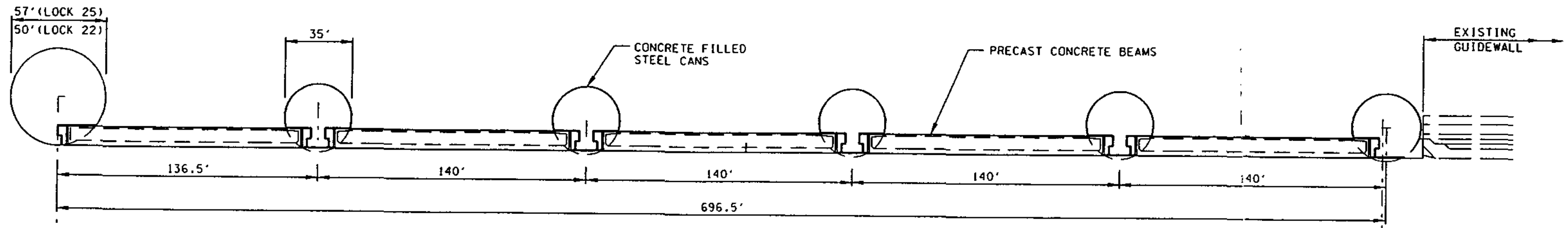
MISSISSIPPI RIVER
LOCK AND DAM NO. 25
GUIDEWALL EXTENSION
GENERAL
VICINITY MAP

PLATE 3
DRAWING NUMBER

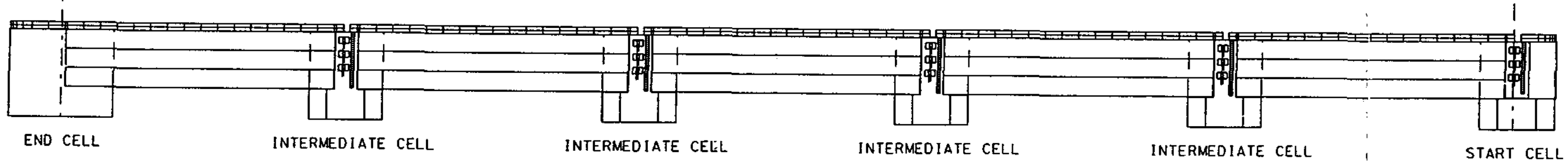


PLAN - LOCK AND DAM 25

U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA
US Army Corps of Engineers Rock Island District St. Louis District St. Paul District	UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY LOCK AND DAM NO. 25 GUIDEWALL EXTENSIONS
Scale: As Shown Date:	PLATE 4



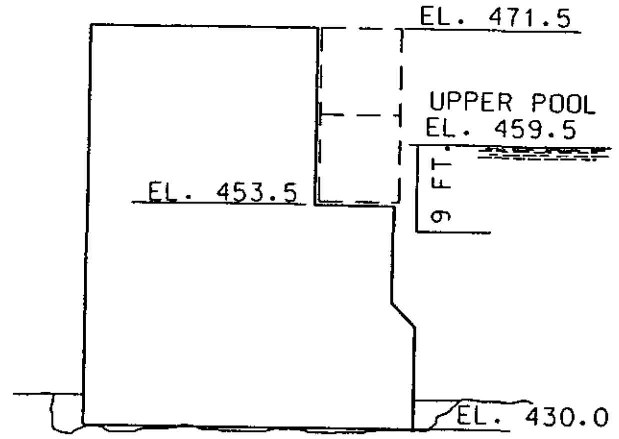
PLAN



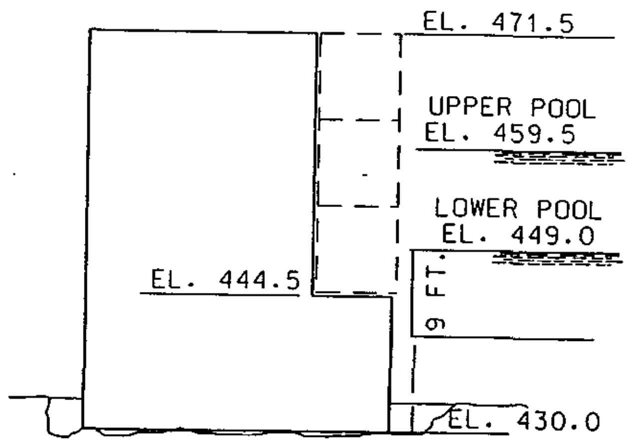
ELEVATION

DOWNSTREAM GUIDEWALL SHOWN

U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA
US Army Corps of Engineers Rock Island District St. Louis District St. Paul District	UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY **LOCK AND DAM 22 & 25 GUILDEWALL EXTENSION GENERAL LAYOUT**
Scale: As Shown Date:	PLATE 5



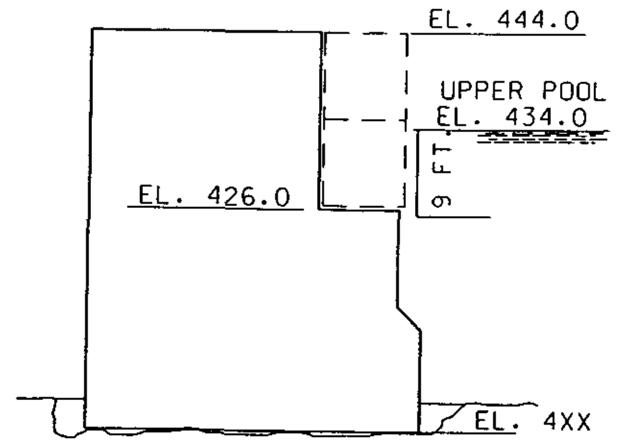
UPSTREAM



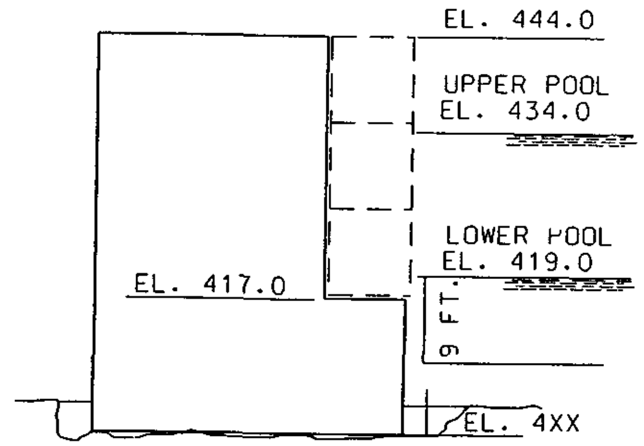
DOWNSTREAM

LOCK & DAM 22

ROCK



UPSTREAM



DOWNSTREAM

LOCK & DAM 25

PILES

U.S. ARMY ENGINEER DISTRICTS
CORPS OF ENGINEERS

ROCK ISLAND, ILLINOIS
ST. LOUIS, MISSOURI
ST. PAUL, MINNESOTA

US Army Corps
of Engineers
Rock Island District
St. Louis District
St. Paul District

UPPER MISSISSIPPI RIVER &
ILLINOIS WATERWAY
SYSTEM NAVIGATION STUDY

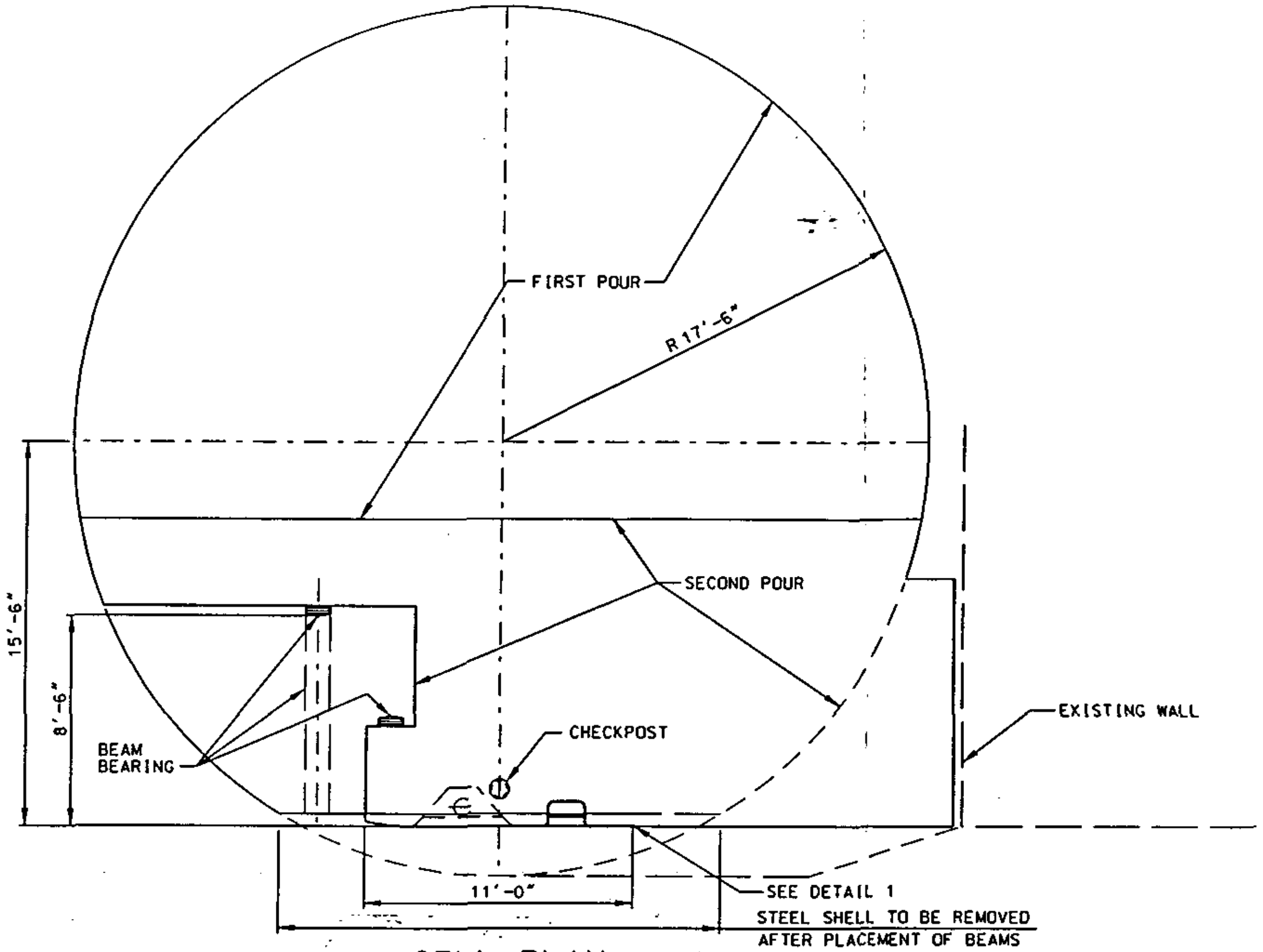
MISSISSIPPI RIVER
GUIDEWALL EXTENSION
TYPICAL SECTIONS

Scale: As Shown
Date:

PLATE 6

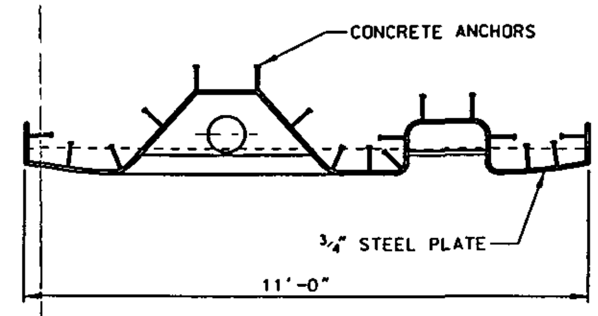
02-AUG-2000 14:54

ELEVATIONS (FEET)					
LOCK NO.	20	21	22	24	25
TOP OF U.S. GUIDEWALL	488.0	483.5	471.5	457.0	444.0
UPPER POOL	480.0	470.0	459.5	449.0	434.0
BOTTOM OF U.S. BEAM	470.0	465.5	453.5	439.0	426.0
TOP OF D.S. GUIDEWALL	486.0	483.5	471.5	455.0	444.0
LOWER POOL	470.0	459.5	449.0	434.0	419.0
BOTTOM OF D.S. BEAM	459.0	456.5	444.5	428.0	417.0

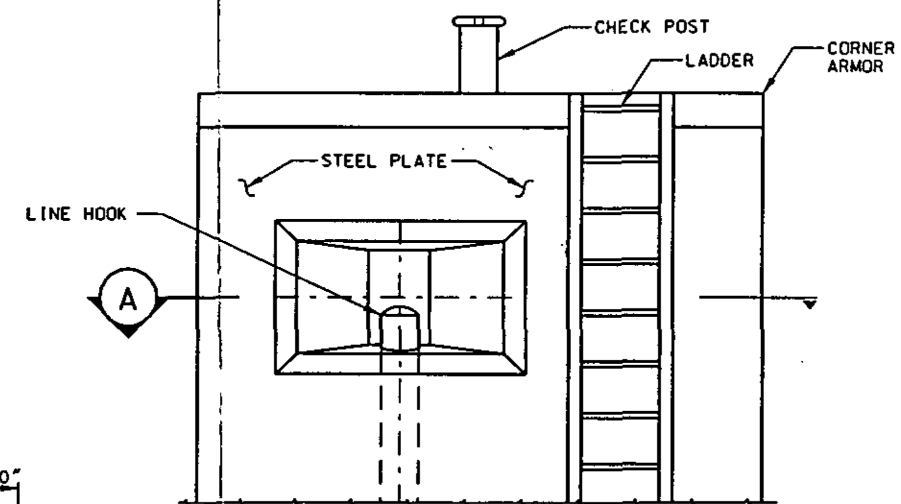


CELL PLAN

NO SCALE

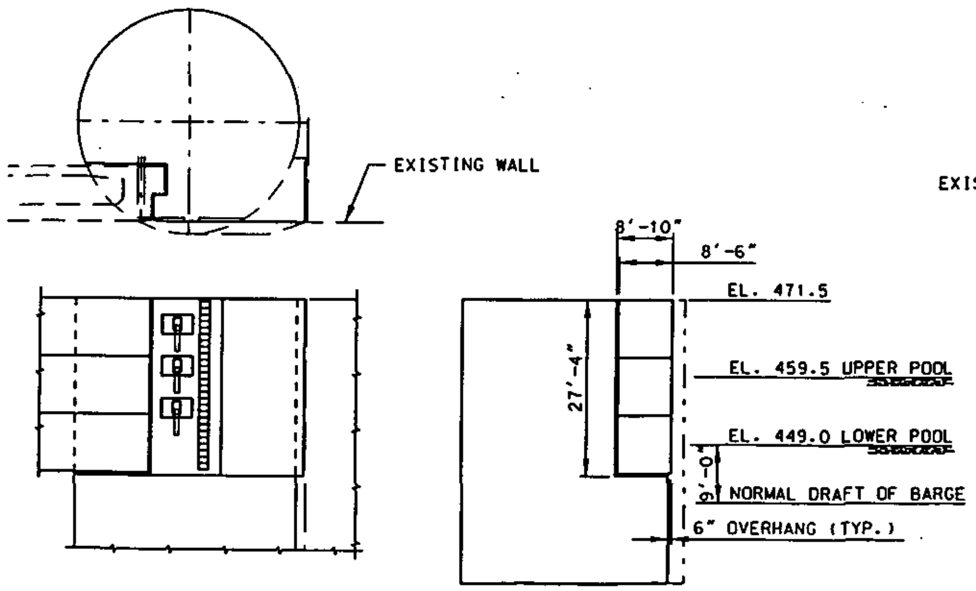


SECTION (A)



DETAIL 1

NO SCALE

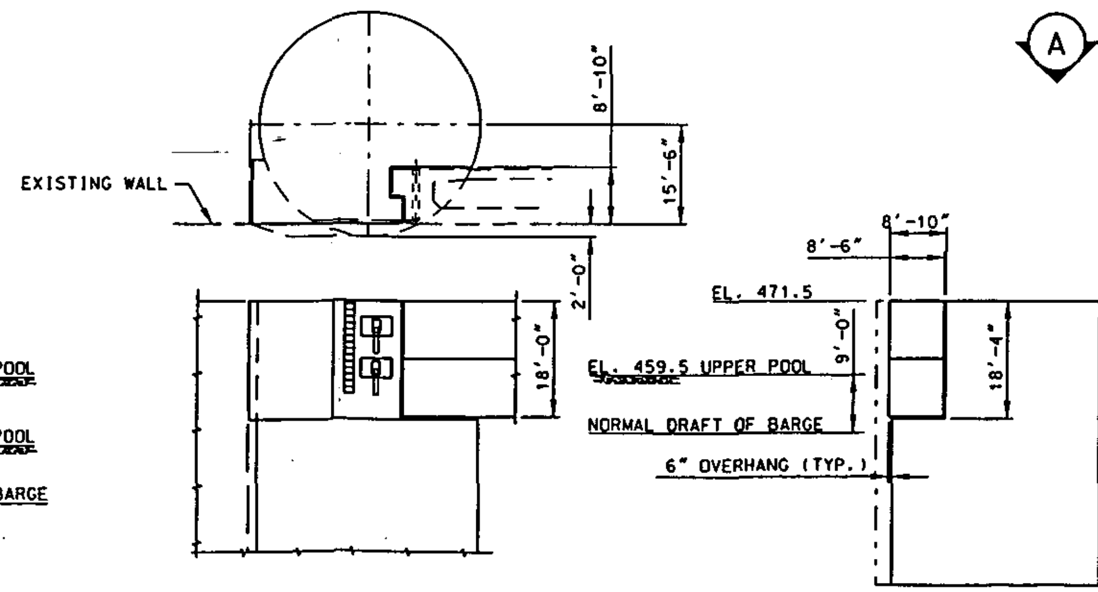


DOWNSTREAM GUIDEWALL

LOCK 22 SHOWN

30 0 30 60'

SCALE IN FEET



UPSTREAM GUIDEWALL

LOCK 22 SHOWN

30 0 30 60'

SCALE IN FEET

U.S. ARMY ENGINEER DISTRICTS
CORPS OF ENGINEERS

ROCK ISLAND, ILLINOIS
ST. LOUIS, MISSOURI
ST. PAUL, MINNESOTA

US Army Corps of Engineers
Rock Island District
St. Louis District
St. Paul District

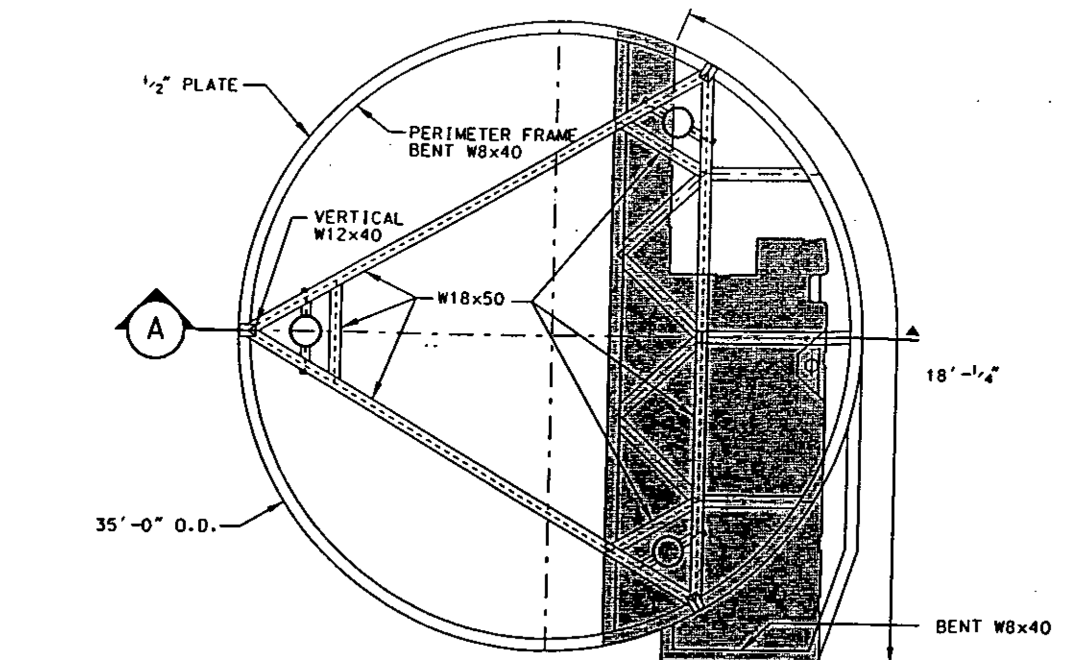
UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK & DAM 22 & 25
START CELL

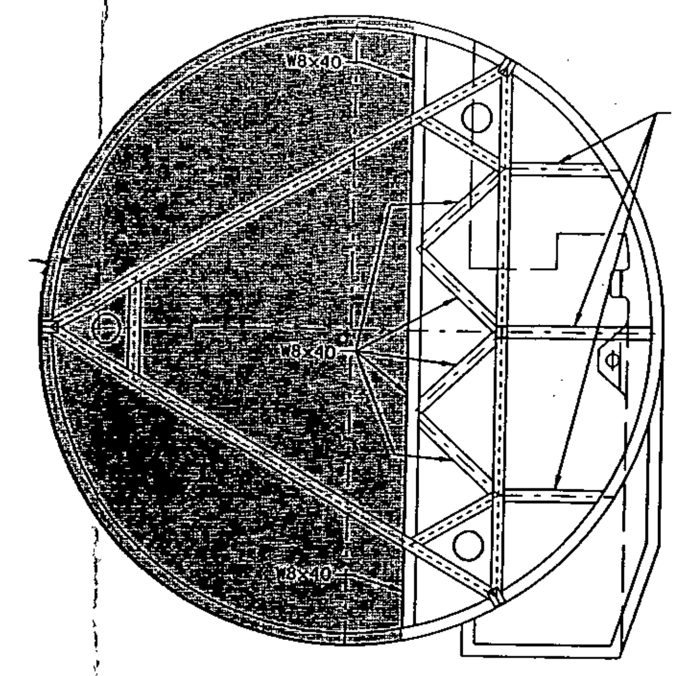
Scale: As Shown

Date:

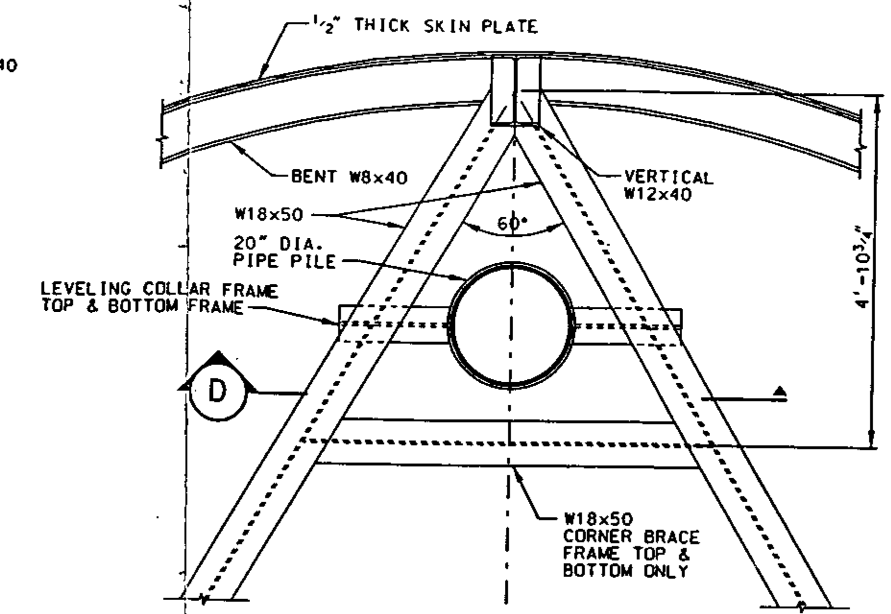
PLATE 7



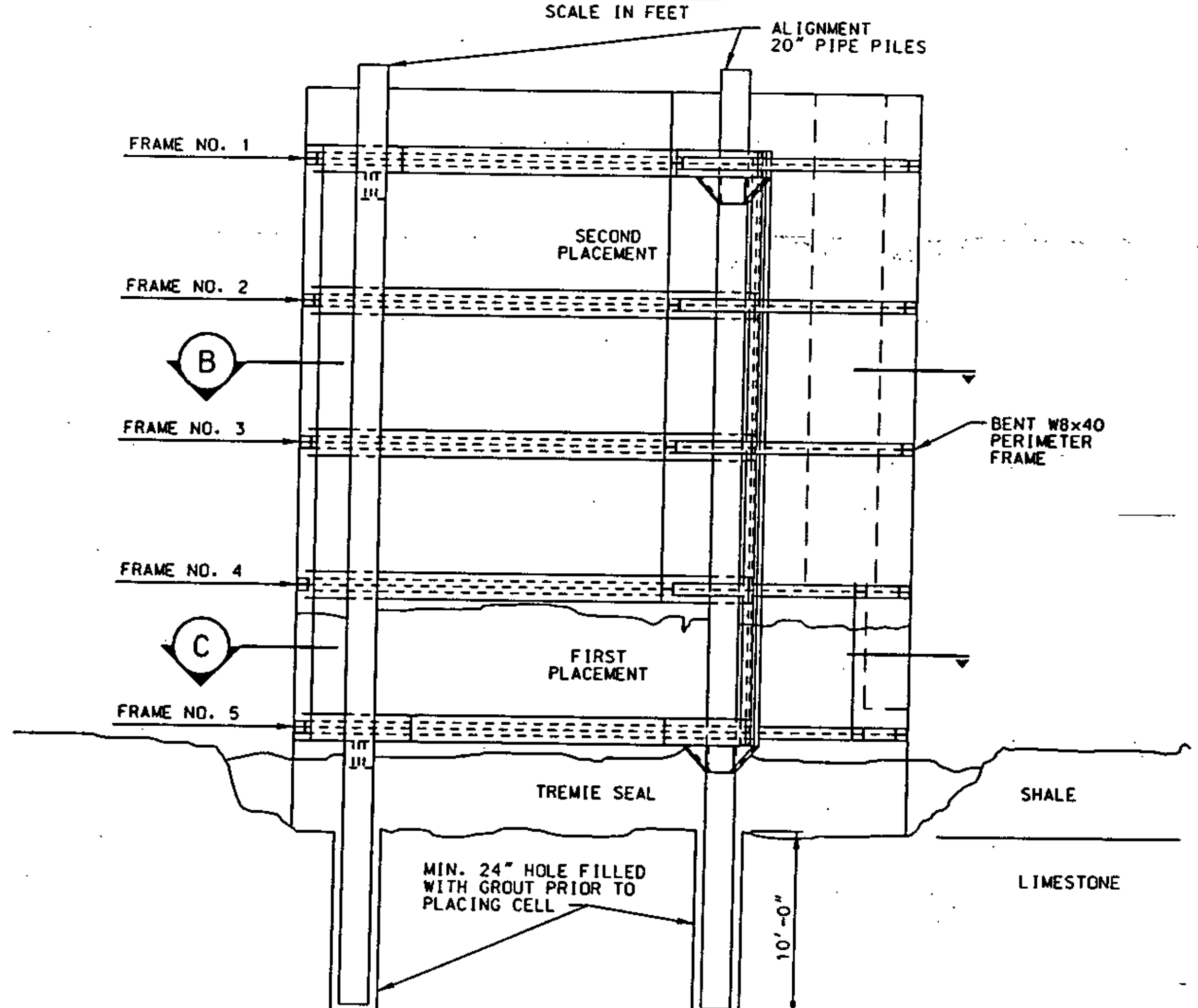
DEWATERED PLAN
FINAL PLACEMENT
4 0 4 8'
SCALE IN FEET



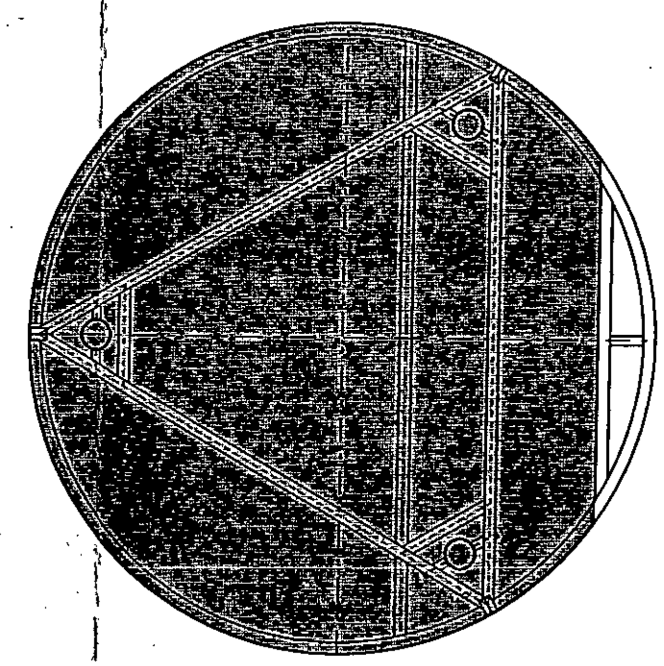
IN THE WET
SECTION B
SECOND PLACEMENT
4 0 4 8'
SCALE IN FEET



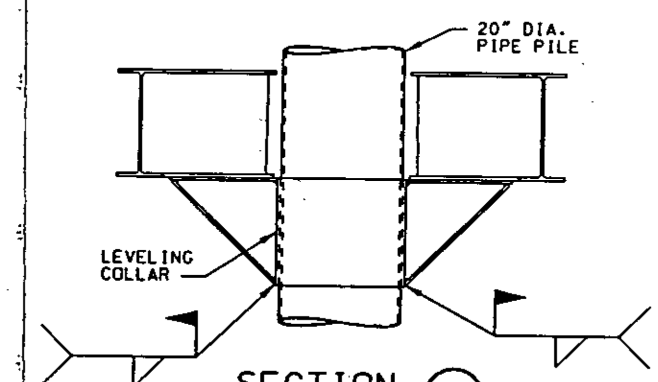
CORNER BRACE DETAIL
2 0 2 4'
SCALE IN FEET



SECTION A
4 0 4 8'
SCALE IN FEET



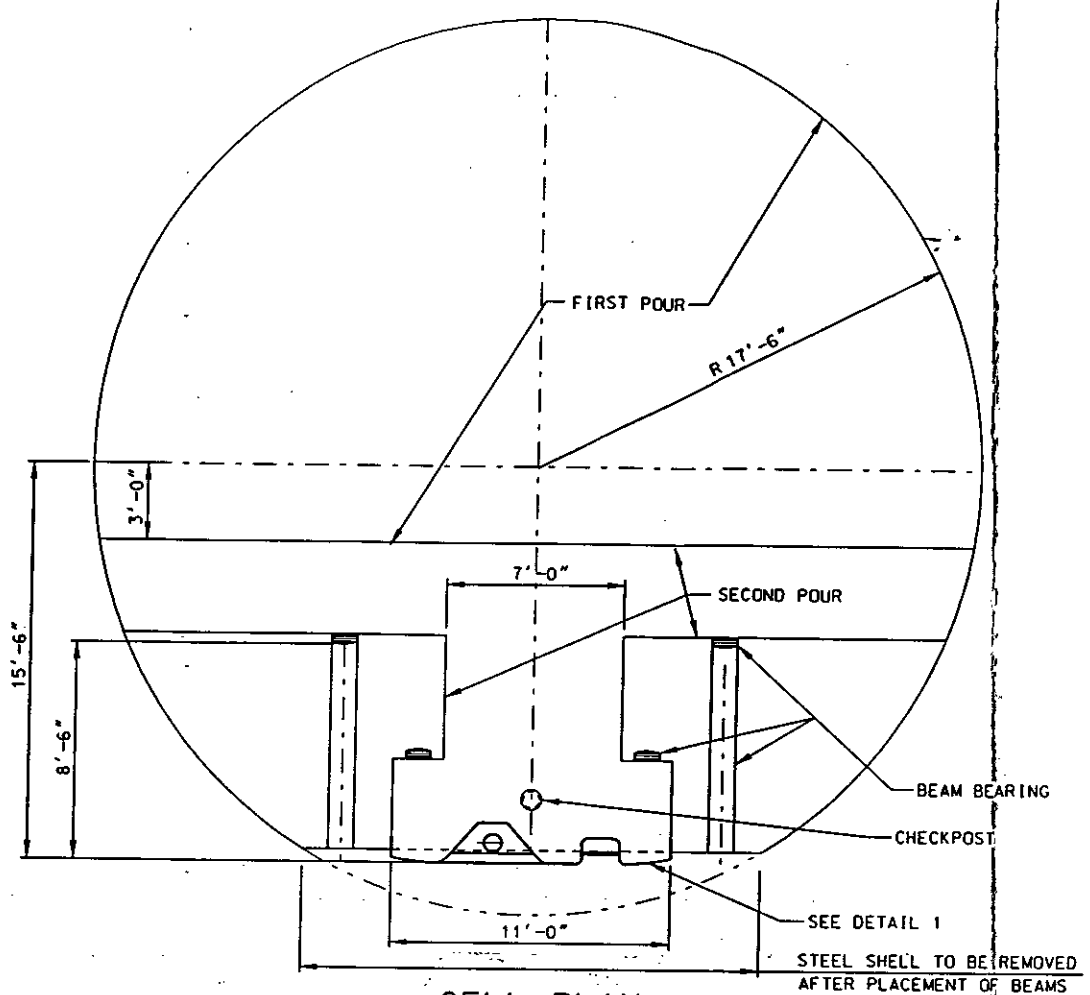
IN THE WET
SECTION C
FIRST PLACEMENT
4 0 4 8'
SCALE IN FEET



SECTION D

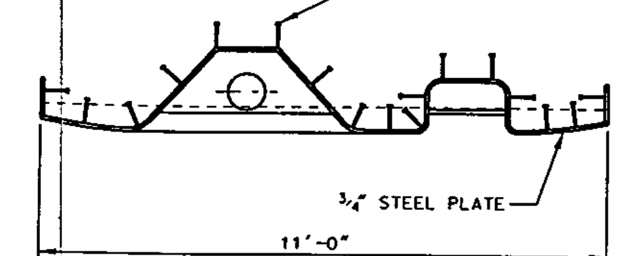
U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA
US Army Corps of Engineers Rock Island District St. Louis District St. Paul District	UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY **LOCK AND DAM NO. 22 & 25 START CELL STEEL CAN**
Scale: As Shown Date:	PLATE 8

ELEVATIONS (FEET)					
LOCK NO.	20	21	22	24	25
TOP OF U.S. GUIDEWALL	488.0	483.5	471.5	457.0	444.0
UPPER POOL	480.0	470.0	459.5	449.0	434.0
BOTTOM OF U.S. BEAM	470.0	465.5	453.5	439.0	426.0
TOP OF D.S. GUIDEWALL	486.0	483.5	471.5	455.0	444.0
LOWER POOL	470.0	459.5	449.0	434.0	419.0
BOTTOM OF D.S. BEAM	459.0	456.5	444.5	428.0	417.0

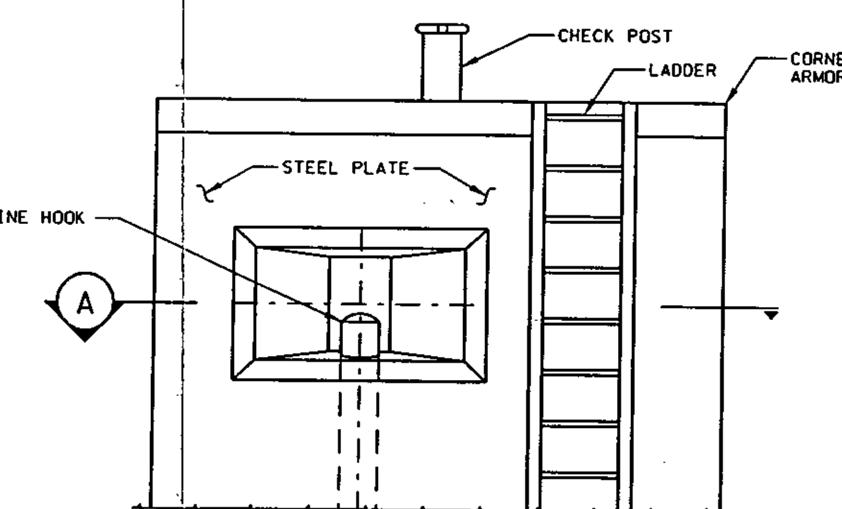


CELL PLAN

NO SCALE

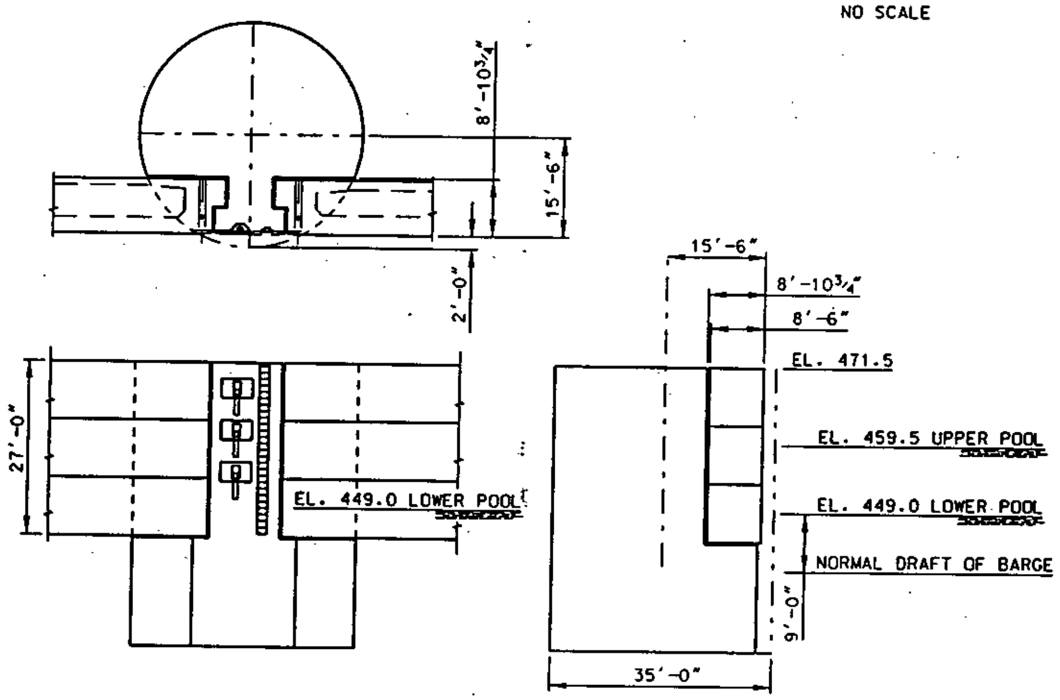


SECTION (A)



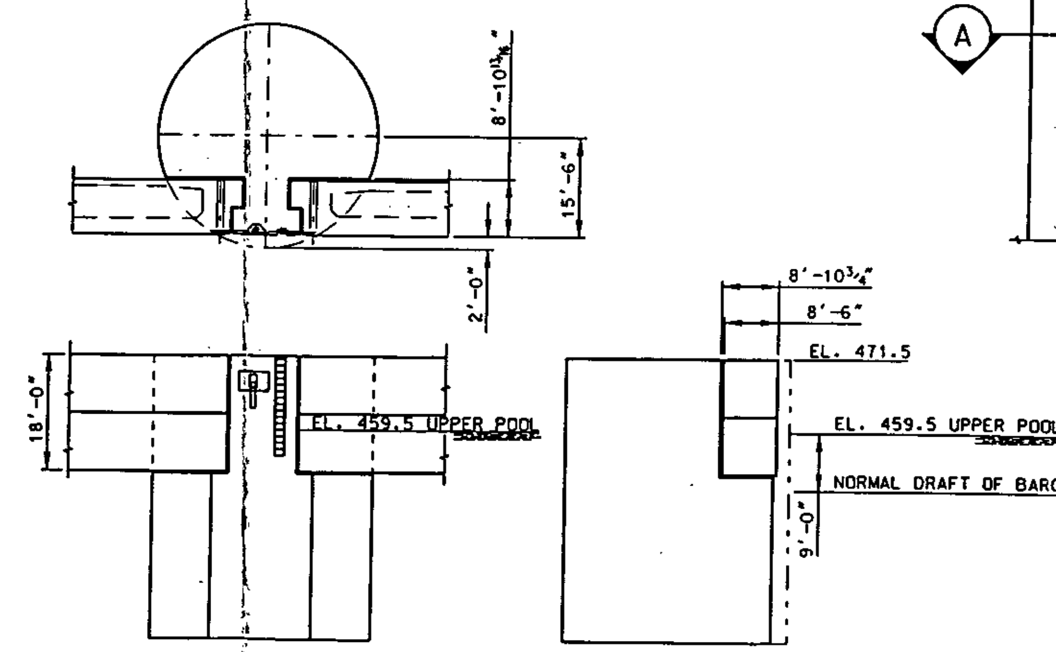
DETAIL 1

NO SCALE



DOWNSTREAM GUIDEWALL

30 0 30 60'
SCALE IN FEET



UPSTREAM GUIDEWALL

30 0 30 60'
SCALE IN FEET

U.S. ARMY ENGINEER DISTRICTS
CORPS OF ENGINEERS

ROCK ISLAND, ILLINOIS
ST. LOUIS, MISSOURI
ST. PAUL, MINNESOTA

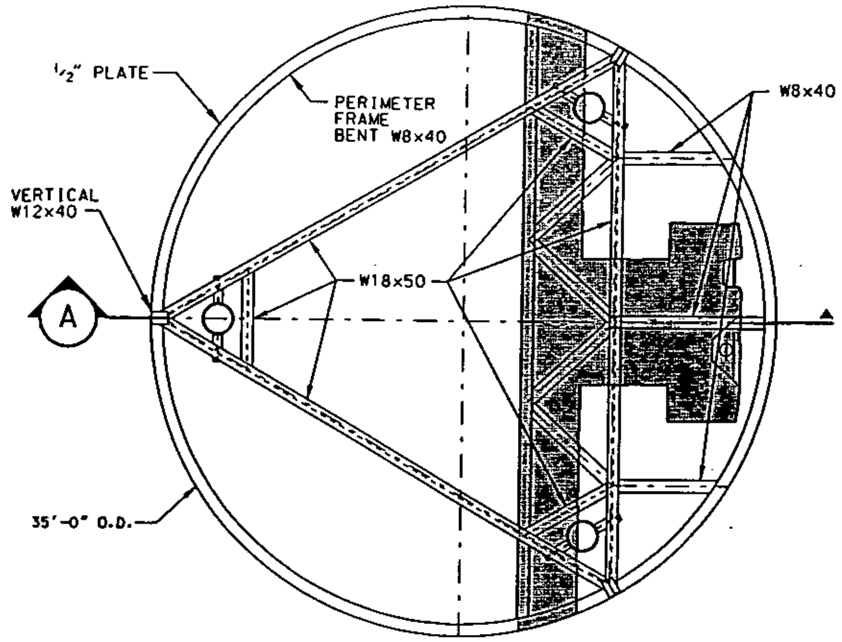
US Army Corps of Engineers
Rock Island District
St. Louis District
St. Paul District

UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK & DAM 22 & 25
INTERMEDIATE CELL

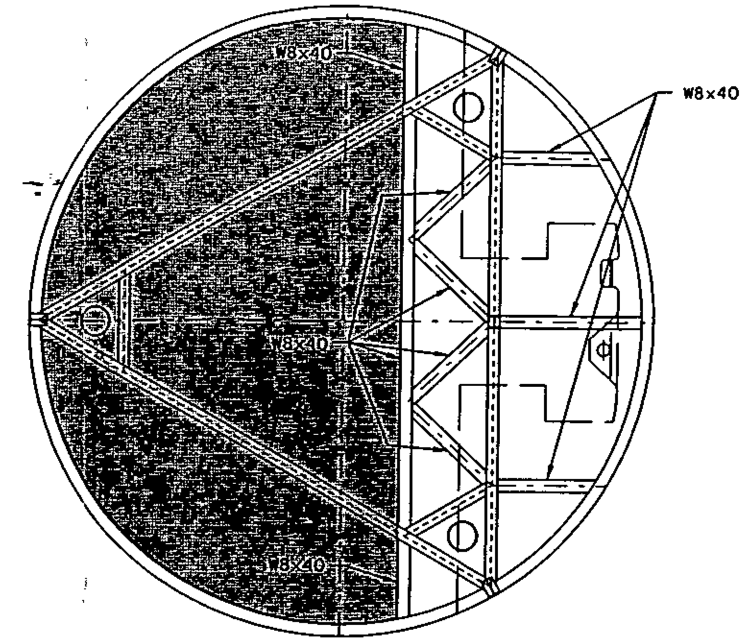
Scale: As Shown
Date:

PLATE 9



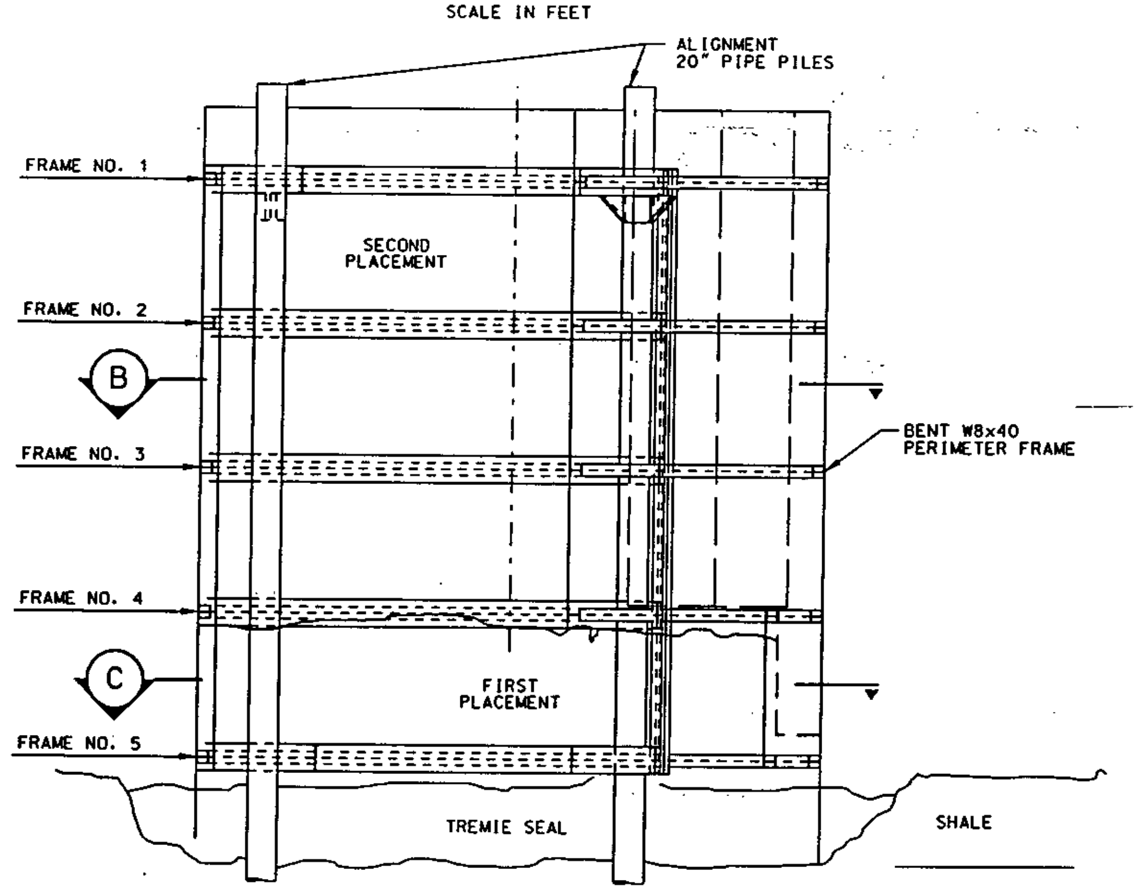
DEWATERED
PLAN
FINAL PLACEMENT

4 0 4 8'
SCALE IN FEET



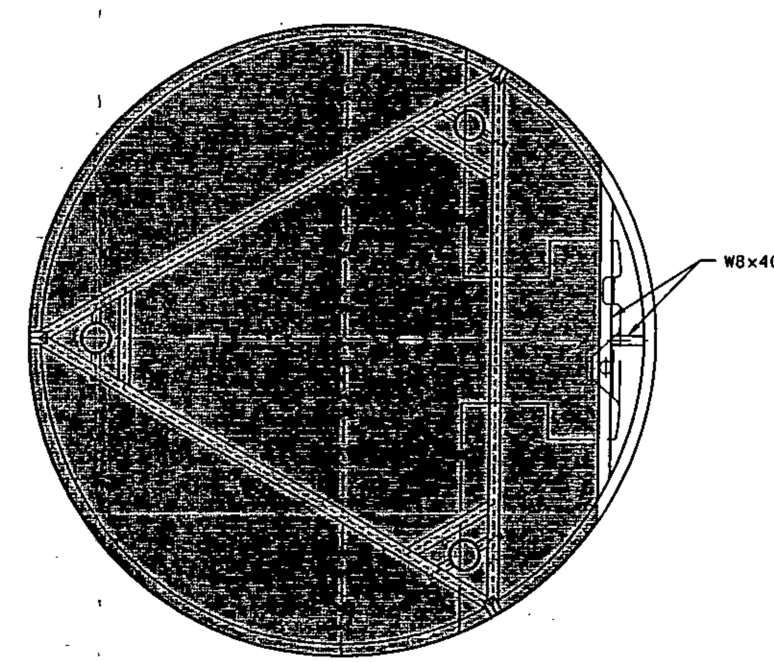
IN THE WET
SECTION (B)
SECOND PLACEMENT

4 0 4 8'
SCALE IN FEET



SECTION (A)

4 0 4 8'
SCALE IN FEET



IN THE WET
SECTION (C)
FIRST PLACEMENT

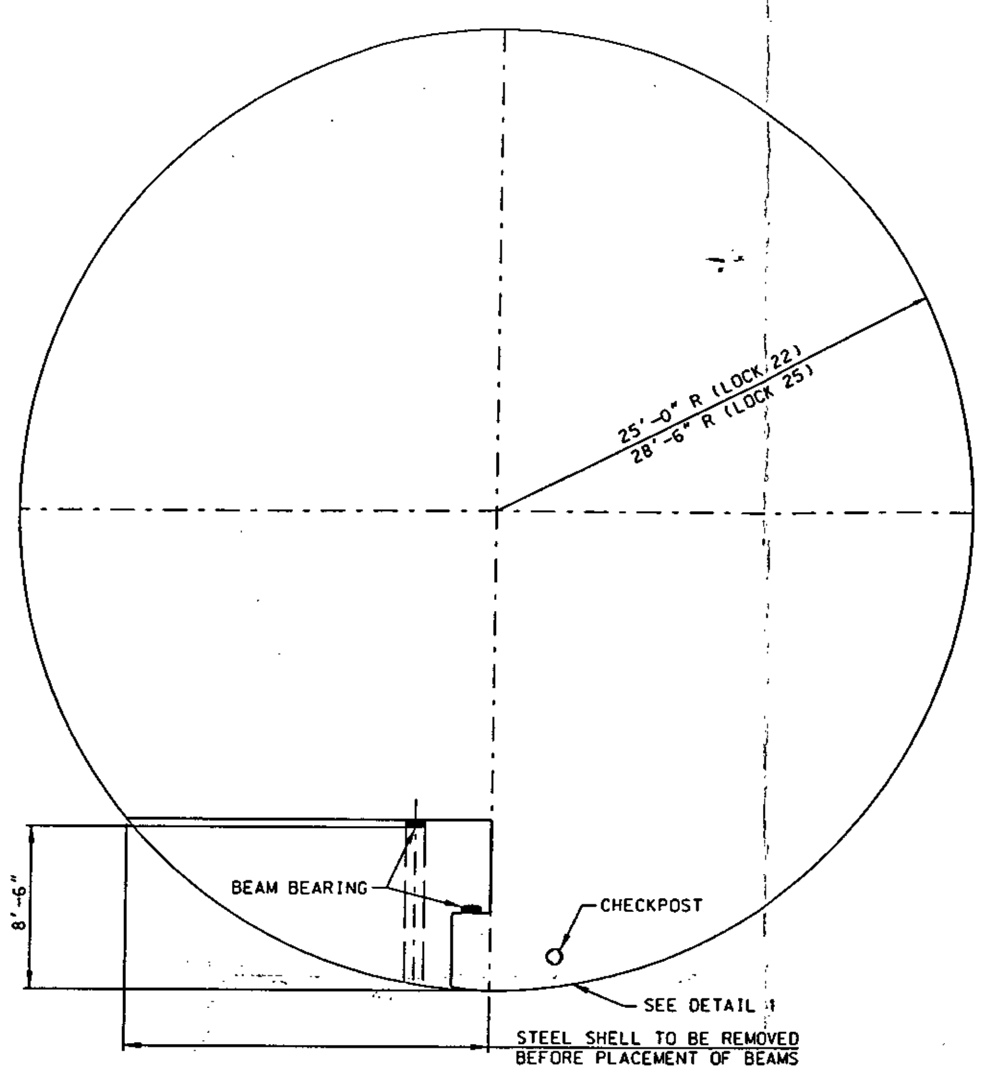
4 0 4 8'
SCALE IN FEET

6 0 6 12'
SCALE IN FEET

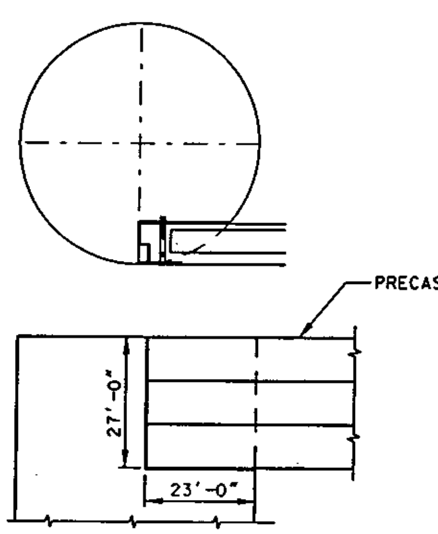
U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA
US Army Corps of Engineers Rock Island District St. Louis District St. Paul District	UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY **LOCK AND DAM NO. 22 & 25 INTERMEDIATE CELL STEEL CAN**
Scale: As Shown Date:	PLATE 10

27-JUL-2000 13:23

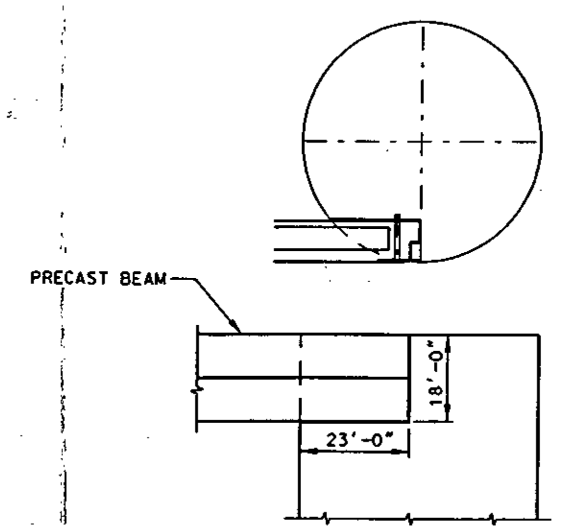
ELEVATIONS (FEET)					
LOCK NO.	20	21	22	24	25
TOP OF U.S. GUIDEWALL	488.0	483.5	471.5	457.0	444.0
UPPER POOL	480.0	470.0	459.5	449.0	434.0
BOTTOM OF U.S. BEAM	470.0	465.5	453.5	439.0	426.0
TOP OF D.S. GUIDEWALL	486.0	483.5	471.5	455.0	444.0
LOWER POOL	470.0	459.5	449.0	434.0	419.0
BOTTOM OF D.S. BEAM	459.0	456.5	444.5	428.0	417.0



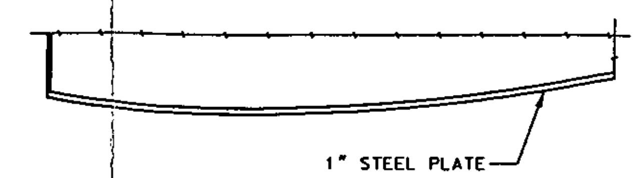
CELL PLAN
NO SCALE



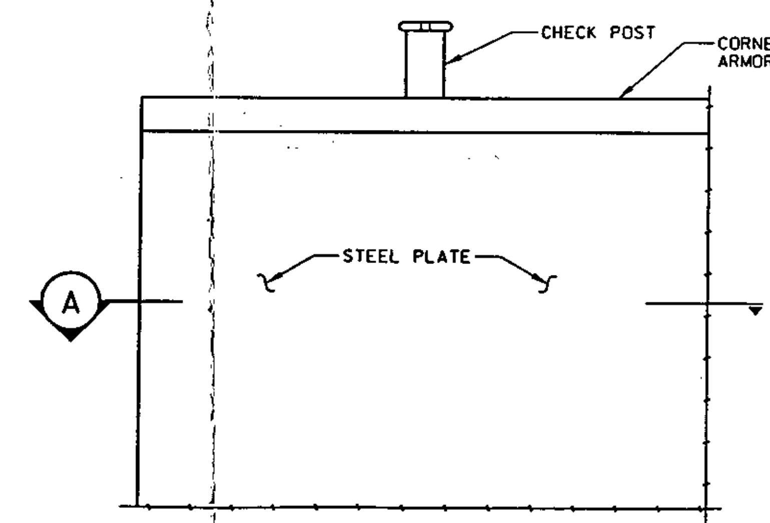
DOWNSTREAM GUIDEWALL



UPSTREAM GUIDEWALL



SECTION (A)



DETAIL 1
NO SCALE

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ST. LOUIS, MISSOURI
ST. PAUL, MINNESOTA

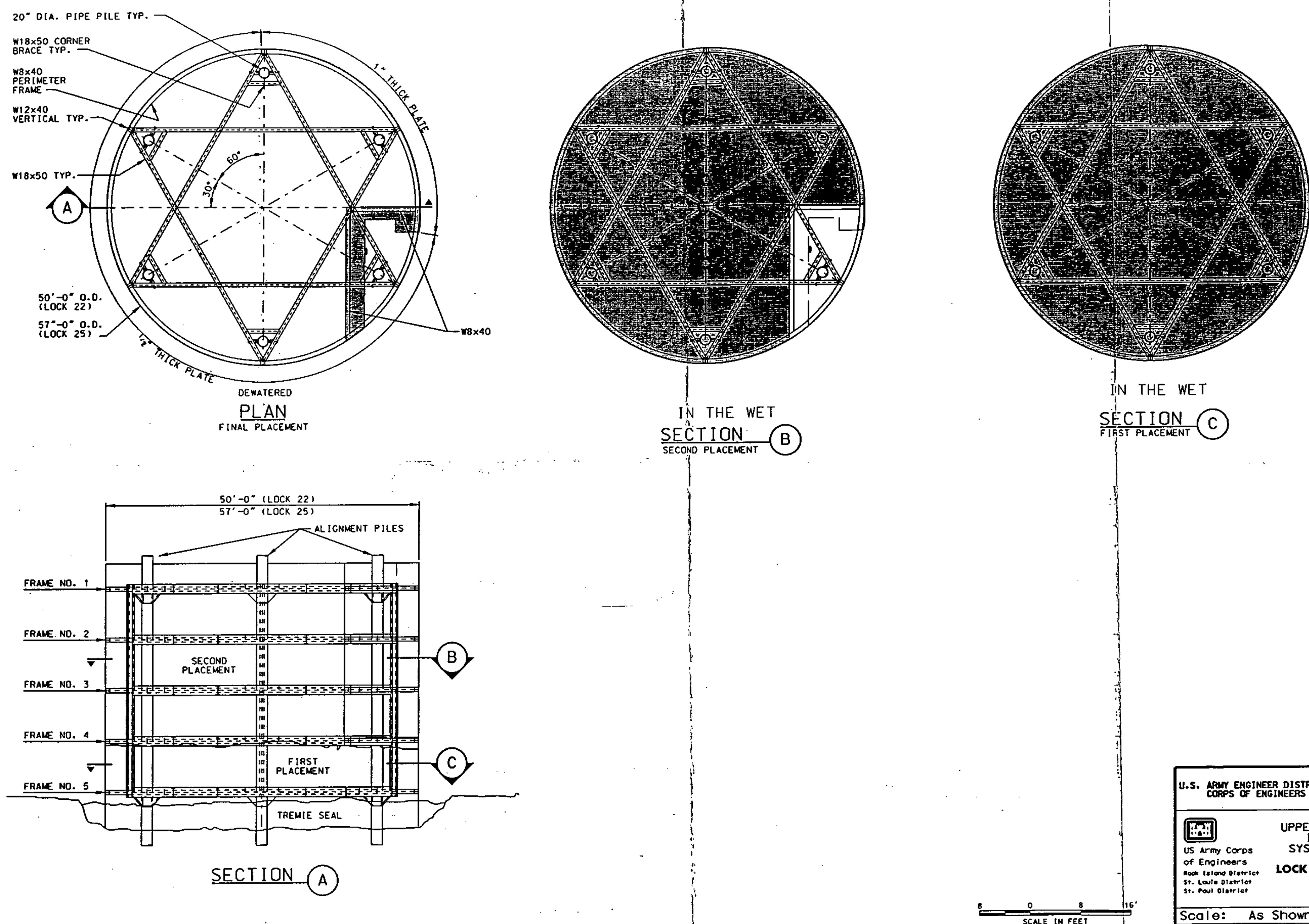
US Army Corps of Engineers
Rock Island District
St. Louis District
St. Paul District

UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 22 & 25
END CELL

Scale: As Shown
Date:

PLATE 11



U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA

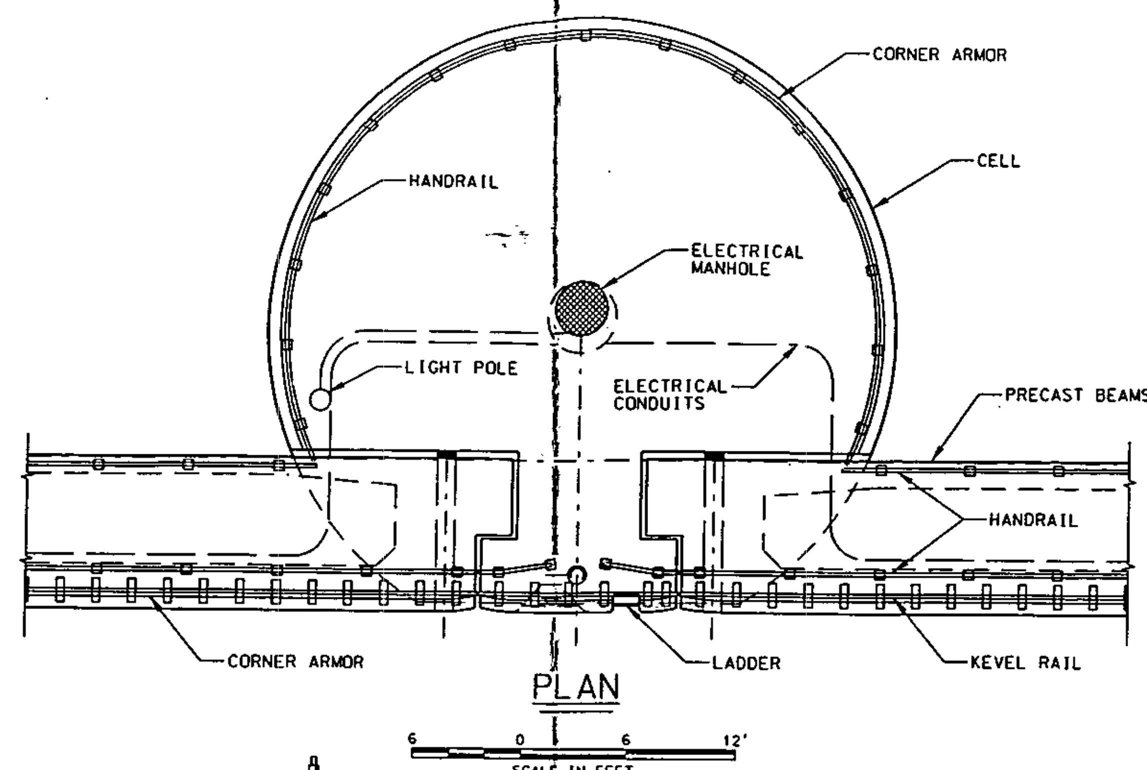
US Army Corps of Engineers
Rock Island District
St. Louis District
St. Paul District

UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

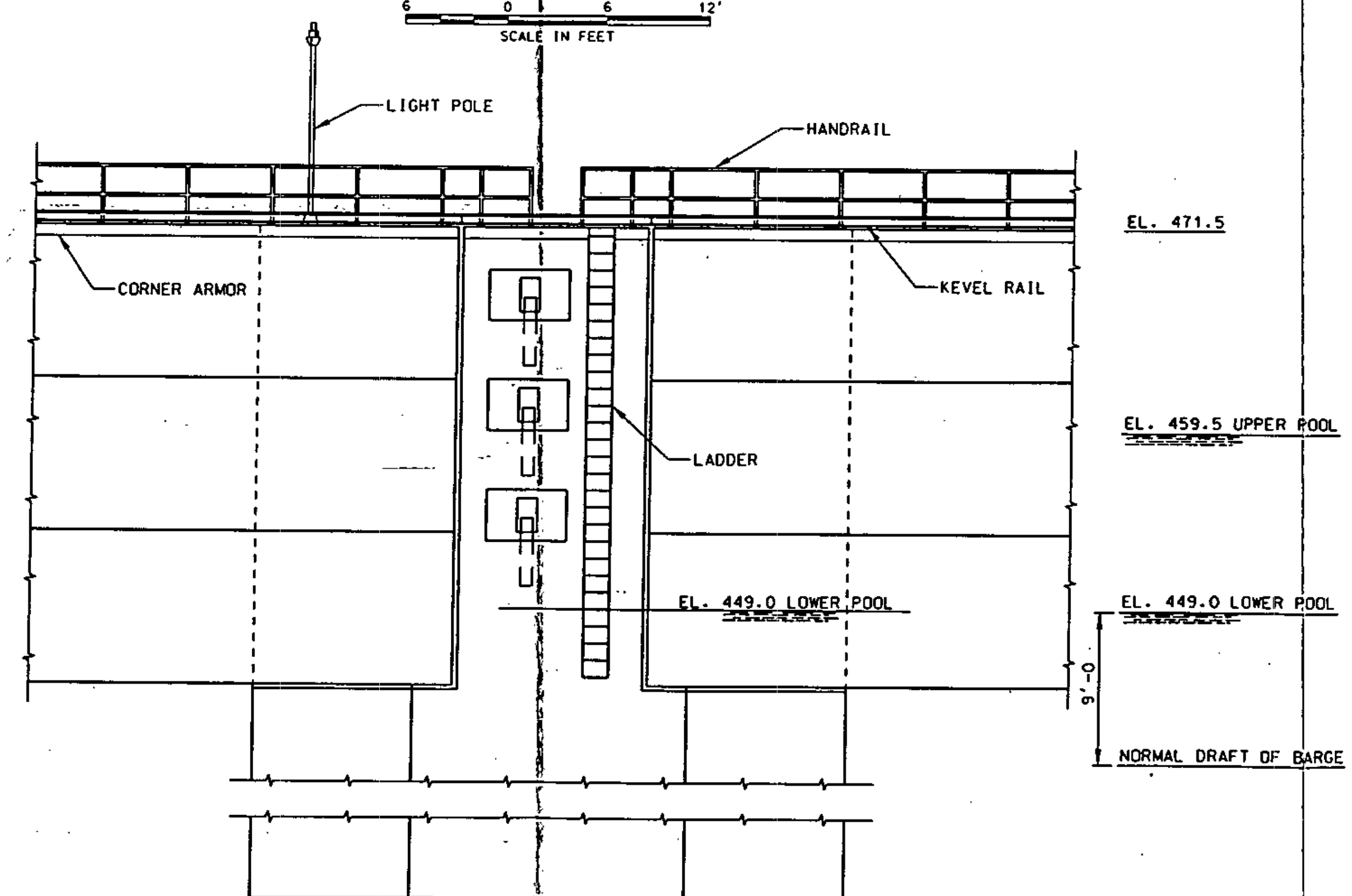
LOCK AND DAM NO. 22 & 25
END CELL
STEEL CAN

Scale: As Shown
Date:

PLATE 12



PLAN



ELEVATION

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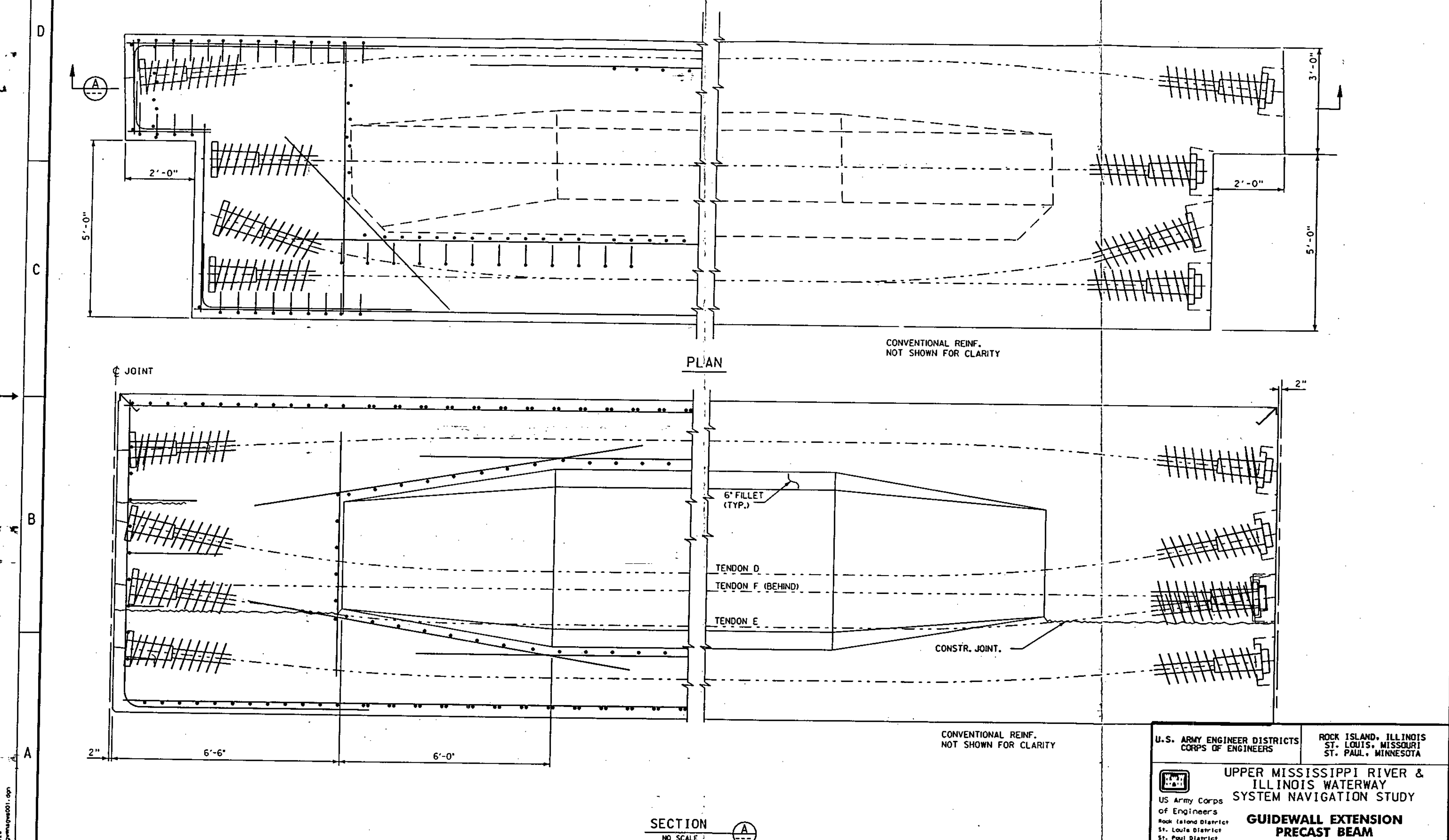
UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM 22 & 25 GUIDEWALL EXTENSION TOP DETAIL

Scale: As Shown
Date:

PLATE 13

27-JUL-2000 14:24



U.S. ARMY ENGINEER DISTRICTS CORPS OF ENGINEERS	ROCK ISLAND, ILLINOIS ST. LOUIS, MISSOURI ST. PAUL, MINNESOTA

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Rock Island District
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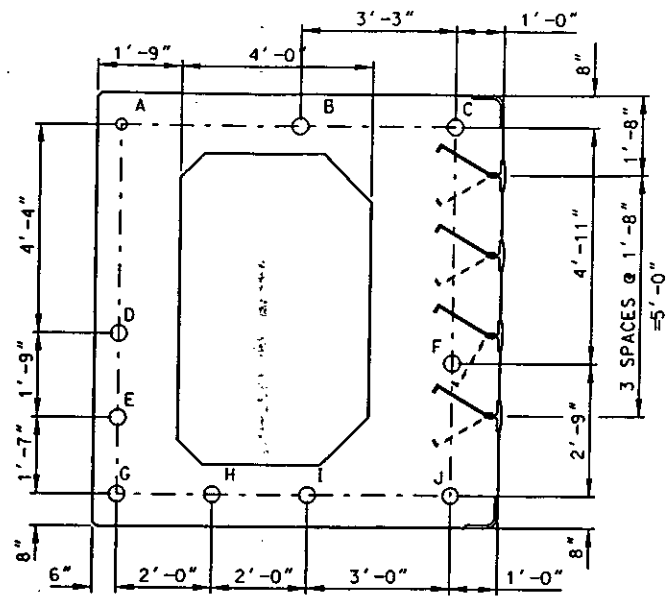
UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

GUIDEWALL EXTENSION PRECAST BEAM

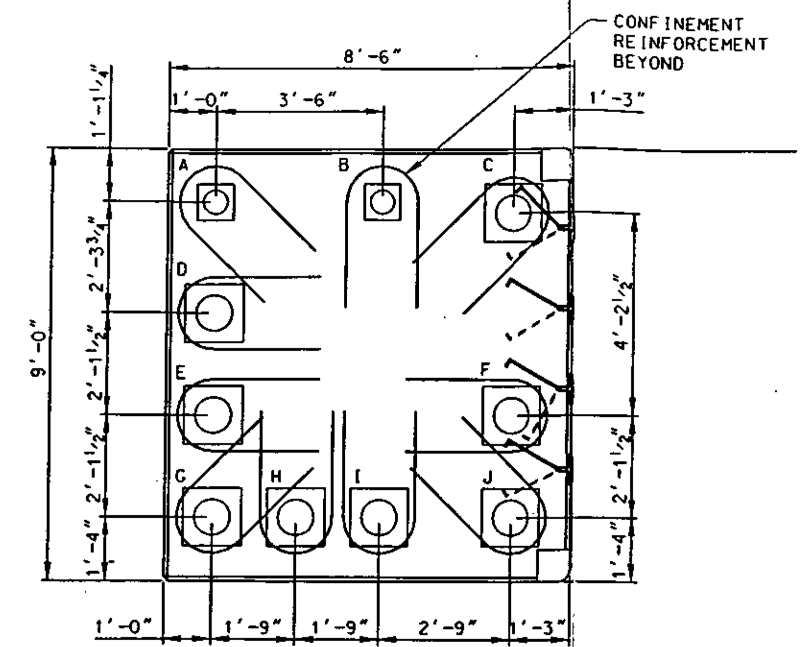
Scale: As Shown
Date:

PLATE 14



TYPICAL SECTION - POSTTENSIONING

NO SCALE



TYPICAL ENDWALL ELEVATION & POSTTENSIONING ANCHORAGE

NO SCALE

POSTTENSIONING TENDONS	
TENDON	No. OF STRANDS
A	12
B	12
C	24
D	31
E	31
F	24
G	31
H	31
I	31
J	31

NOTES

1. ALL STRANDS IN TENDONS SHALL BE ½" DIAMETER (7 WIRE STRANDS). 270 KSI LOW RELAXATION STEEL.

2. CONCRETE COMPRESSIVE STRENGTH:
   f'c = 5000 PSI @ 28 DAYS
   f'ci = 4000 PSI @ TIME OF STRESSING

3. REINFORCEMENT NOT SHOWN FOR CLARITY

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UPPER MISSISSIPPI RIVER &
ILLINOIS WATERWAY
SYSTEM NAVIGATION STUDY

GUIDEWALL EXTENSION
PRECAST BEAM
SECTIONS

Scale: As Shown
Date:

PLATE 15

27-JUL-2000 14:28

Powered Traveling Kevel Analysis

Appendix B

Appendix B

Powered Traveling Kevel - First Cut Extraction System

Introduction. The UMR-IWW System Feasibility Study proposed a powered traveling kevel (PTK) system operating on an extended guidewall to reduce the time it takes for double cut tow lockages to transit a lock. Such a system has undergone additional study and requires operational revisions. A recommended PTK system is explained herein. Baseline lockage timings and improved lockage timings are provided in graphical form to assist the reader.

UMR – IWW System Feasibility Study Proposal. The UMR-IWW System Feasibility Study proposed a powered traveling kevel system that is feasible and, with two added staff (per shift); saved lockage time for double cuts could be approximately 20 minutes upbound and 23 minutes downbound. Currently two lockmen and three deckhands lock a tow. The additional staff would allow two deckhands with both cuts when they are under movement and have a dedicated PTK system operator. The annual cost would be about $3.3 million for the PTK system, the guidewall upon which it rides, and the added staff.

Variation from System Study Proposal. The System Study proposal met with some resistance because hiring additional staff is very unlikely considering the typical hiring practices of the Federal Government and/or towing industry. A PTK system had to be developed that would require no additional staff to operate than the existing two lock operators and three deckhands. The system described and recommended herein uses no additional staff, but timesavings benefits were reduced to 17 minutes upbound and 20 minutes downbound. Annual costs were reduced to $2.8 million (based on subtracting the personnel costs used in the System Study). The tradeoff of cost and performance was developed considering typical operation policy and general acceptance by lock operators.

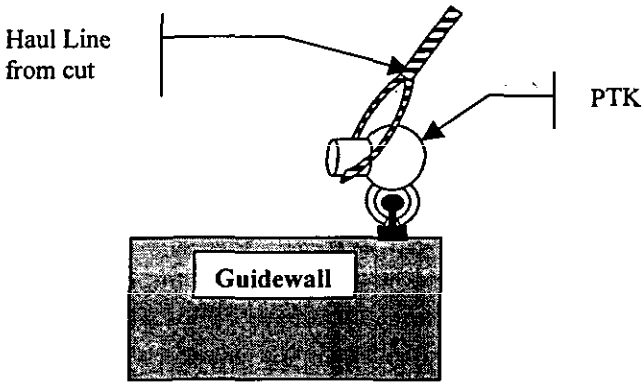
Definitions:

Kevel - A kevel is a heavy metal deck fitting having two horn-shaped arms projecting outward around which lines may be secured for towing or mooring a vessel

Powered Traveling Kevel (PTK) - This device is actually a system of kevels mounted on a common rail in which the first kevel can pull the head of the first cut and a trailing kevel can slow and stop the cut by connecting to the stern. The kevels are connected with wire rope to hydraulic or electric-driven winches located at the ends of travel of the kevels. The kevels could feature an auto trip device that casts-off the line at predesignated locations.

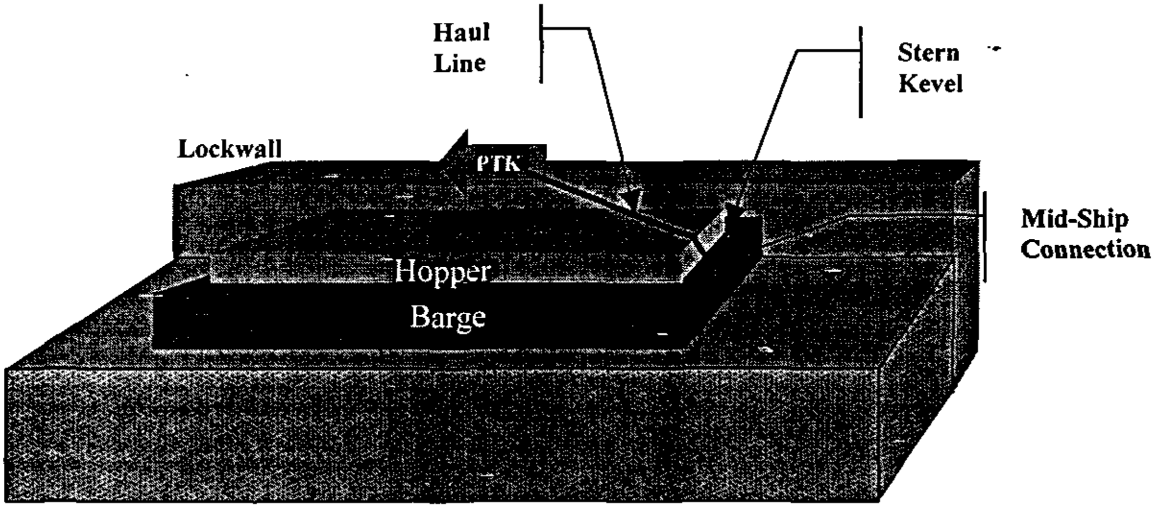
Extended Guidewalls – Extended guidewalls are permanent structural improvements at a lock that extend the existing guidewalls. The guidewalls serve to identify the lock approach, aid in aligning approaching vessels, moor vessels, and, in this case, support a PTK system. Approximately 700 feet of guidewall will be added totaling about 1300 feet of wall. The extra length places the tow boat farther form the miter gates allowing pressure from the tows propellers to dissipate before hitting the miter gates.

General Description of Recommended PTK System. The kevels used in this application somewhat resemble a typical barge deck fitting. These have two horn-shaped arms to receive haul lines, but the PTK will also have a pin with an auto-trip lever to castoff the haul line. A PTK is a rail-mounted kevel attached by cables to powered winches. The PTK system operates along the existing guidewall (some will have to be raised to a higher elevation) and its extension. The kevel system will pull first cuts to the end of the extended guidewall and stop them where the cut will await remake with the powered cut. Remaking of the tow would be done completely outside of the lock chamber allowing it to be turned back more quickly to process the next tow. The process of extracting the unpowered cut starts with the existing tow haulage unit extracting the cut to full stop just outside the miter gates as it is presently done. The unit will be relocated just inboard of the culvert valve pits to permit pulling out the tow cable before the miter gates are recessed saving about two minutes in the lockage process. From there, a leading PTK pulls the head of the cut, a second line to another kevel safeguards the head, and a trailing PTK controls the stern and stops the cut. The deckhand can back up stopping of the cut by checking to pins in and on top of the wall. The cut movement is controlled by one lock operator on the lockwall and one deckhand tending the cut. The other lock operator and two deckhands lock the powered cut. This process reduces the time to lock a 1200-ft tow through a 600-ft lock by approximately 17 minutes upbound and 20 minutes downbound. A more detailed description is provided later in the report. For the time being, a graphic of a kevel is provided below. The horns of the kevel can't be seen in this view; however, a side pin is shown that will more readily secure lines from empty barges that ride above the top of the lockwall.



Alternative Post Location

PTK Development Background. A significant amount of research, study, and site visits were made to develop the recommended PTK system. Site visits were made to Pickwick Locks, Kentucky Lock, Barkley Lock, Allegheny Locks 4, 5, and 7, Wilson Locks, and Wheeler Locks. These sites have tow haulage systems that use a kevel that travels only within the lock chamber (except Pickwick). The UMR recommendation adapts the system for tow haulage use along an extended guidewall. In addition, techniques involved in switchboat operations and industry self-help were observed at Locks 25 and 27 to understand the physical movement of tows. The upbound cut extraction system at Pickwick Locks serves as the closest precedent for the recommended PTK system. A typical PTK acting as a tow haulage unit similar to Kentucky Lock is shown below.



Typical PTK's Used as Tow Haulages Today.

Operational Policy, Procedure, and Operator's General Input. The UMR-IWW System Feasibility Study proposed a PTK system that would increase the speed that cuts are extracted from 50 fpm to 100 fpm rate. Lock operators agreed in subsequent interviews that cuts could be extracted slightly faster since the tow haulage units had the capacity to do so, but it would be advised only during certain conditions. Pulling cuts twice as fast in any event was not advised. Since the recommended PTK system stops the cut as it is currently done, lock operators would not advise extracting first cut any faster. There will be no timesavings related to faster extraction of the first cut.

The UMR-IWS Navigation Study proposed a PTK system that requires the hiring of additional staff. This conflicts with the constraints of the existing O&M budget as well as current hiring practices. The recommended PTK system operates with no additional staff members to satisfy this constraint.

Navigation Notice #1 requires that two deckhands be with the first cut as it travels through the miter gate area during which time two deckhands tend bumpers to minimize damage to the gates and generally ensure the safe egress of the first cut. Currently, after the cut stops, only one deckhand tends it as it awaits remake. From this position, the recommended PTK system would haul the first cut to the end of the extended guidewall with assistance from one lock operator and only one deckhand stationed at the stern. Navigation Notice #1 does not specifically address this system because it doesn't exist. Lock operators were against not having a deckhand on the head of the cut while it was in motion, but a safety kevel (second line) was added to safeguard the head and reduce concern. **For the recommended system to**

work, policy must be written to accept one deckhand on the first cut performing duties that are explained herein.

The older lock at Pickwick Locks features a PTK that traveled across the miter gate and was used to extract first cuts; however, the kevel would travel the gate while not pulling on the cut. At one time, it was anticipated that such a system could continue along the guidewall and its extension. Evaluation by Engineering and Operations ruled this out due to safety problems with cable and operational shortcomings. It appears that a reason for the PTK's cable and rail to cross the gate was to provide for a more convenient location to install the winch and drum. No new systems have used the crossing-over-the-gate concept.

During interviews with lock operators, there seemed to be occasional resistance to the PTK concept. Some of this was blamed on the predominance of inexperienced deckhands and their perceived inability to operate the seemingly complicated recommended PTK. Perhaps some of the opposition may be general resistance to change, which can be relieved by a planned operational procedure. The following plan is only a guide to help ease into the PTK implementation. Many of the line items may not yet be familiar to the reader, but can be found herein.

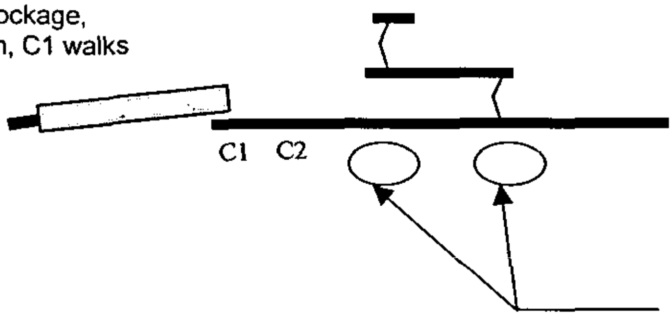
1. Implement approach channel improvements.
2. Construct the lower guidewall extension with PTK's
3. Pull downbound cuts as we do now and hook head to both kevels and leave the cut there. [Downbound extraction would be used as a prototype because it will not be adversely influenced by outdraft like upbound extraction.]
4. After locking, the powered cut would face up to stern of the first cut. The two outside wires would be made (or a multi-part line midship) and the partially reassembled tow would push out onto the wall for full remake. The lead kevels would restrain the head. This process would save some time and therefore generate some of the navigation benefits.
5. After this is comfortable to users, let the PTK haul the first cut to the end of the wall with two deckhands on the cut and one on the wall. At the end of travel. Lines from the cut could be made to fixed pins on the guidewall. When lines are made to the wall, two deckhands would walk back to the powered cut. The walk time would negate any timesavings offered by the added feature. The lockmen could drive the deckhands back in new, larger electric carts to save time in the lock process. In either case, the measure would serve to examine the process for possible flaws/improvements.
6. After this is worked out, the next step would be for the PTK system to haul the cut down the wall with only one deckhand aboard tending the stern.
7. After the downbound operation is solidified, start phasing in the use of the upbound extractions. Certainly, step 4 would work for upbounders. Outdraft would restrict use.

<u>Baseline double-cut lockage process:</u> The baseline double lockage procedure has been established and adjusted over many years of locking double cuts through 600 ft locks. The tow haulage units are a critical part of the process. The graphical representation on the next three pages shows a downbound lockage with elapsed time during the start or end of activities for which timing data was available. There are other activities during the process, but they either are not on the critical path or there was not timing data available. In a double lockage the lockage begins as the full tow approaches and enters the chamber. Due to the tow's length, the first cut (the unpowered section of tow or "unpowered cut") must be uncoupled from the rest of the tow and locked separately. The towboat and remaining barges (the "powered cut") then back away and allow the first cut to lock through. At this point, the lock gates are closed and the chamber emptied. Once the first cut is at the proper pool elevation, the miter gates are opened and the tow haulage equipment is used to pull the first cut from the chamber (Step #5). When the first cut is clear of the miter gates, the gates are closed and the chamber is turned back. That is, the chamber goes through the gate operations and filling needed to get the chamber back to the upper pool elevation for the powered cut. As soon as the upstream miter gates are opened, the powered cut can enter the chamber and be locked through (Step #11). The powered cut must then abut the unpowered cut and the wires are remade that connect the two cuts. At sites with 600-foot or shorter guidewalls, the baseline condition, the powered cut remains partially in the chamber while the first cut is along the guidewall. Step 12 shows the blocking of the chamber that delays the ability to use the chamber to lock other tows.

BASELINE DOUBLE LOCKAGE ELEMENTS, DOWNBOUND

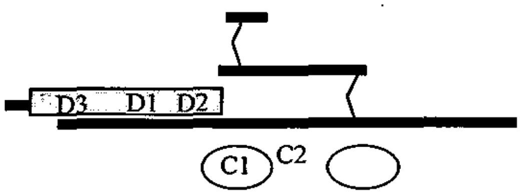
file: R:\\...Gwall Ext\2. Doc\Rpt\ENGR APP\Genl Txt\PTK/GWE with PTK

STEP #1
t= 0 min, Start Lockage, upper gates open, C1 walks head in



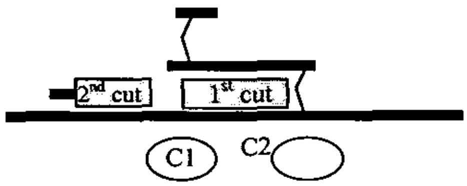
Lock controls locations

STEP #2
t= 22 min, Complete Approach, Start Entry

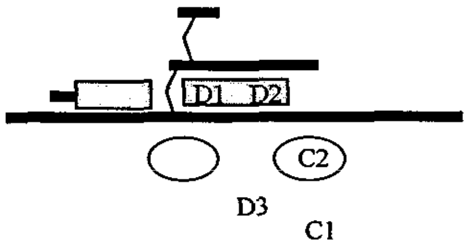


ABBREVIATIONS
D1 - Deckhand #1
D2 - Deckhand #2
D3 - Deckhand #3
C1 - Corps #1
C2 - Corps #2

STEP #3
t= 36 min, Complete Entry

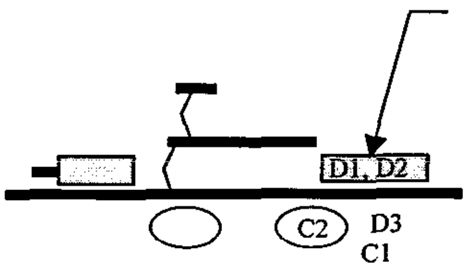


STEP #4
t= 38 min, Upper gates closed
t= 44 min, Chamber emptied, C1 moves from upper gates to lower tow haulage unit
t= 46 min, Lower gates opened. C1 and C2 extract tow haulage cable



STEP #5
t= 48 min, tow haulage unit initiates movement of first cut
t= 50 min, D2 on the cut and D3 on the wall check the head
t= 61 min, Cut clears gate, D1 checks stern to full stop, C1 may escort head, C2 closes lower gates

First cut checked to full stop at **t= 61 min.**



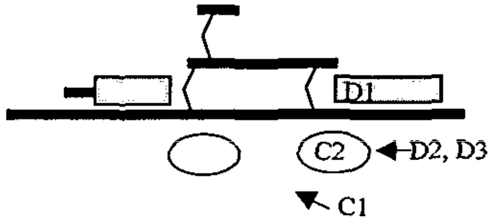
BASELINE DOUBLE LOCKAGE ELEMENTS, DOWNBOUND

file: R:\\...Gwall Ext\2. Doc\Rpt\ENGR APP\Genl Txt\PTK/GWE with PTK

STEP #6

t= 62.5 min, D2 leaves 1st cut & walks w/D3 to second cut

t= 63 min, Lower miter gates closed. C2 starts to fill chamber. C1 goes to upper lock control booth.

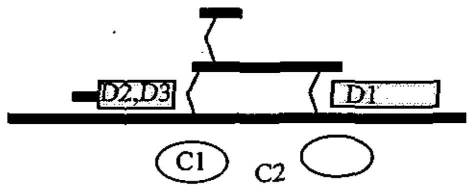


STEP #7

t= 64.5 min C1 arrives at upper booth.

t=68 min, D2 and D3 board second cut. .

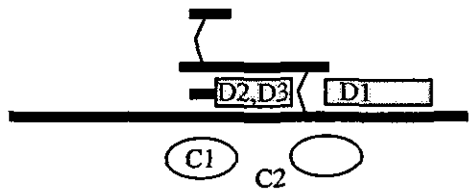
t= 69 min, chamber is full



STEP #8

t= 71 min, upper gates recessed, C2 walks head in/observes entry

t=77 min, 2nd cut completes entry, C1 closes upper gates



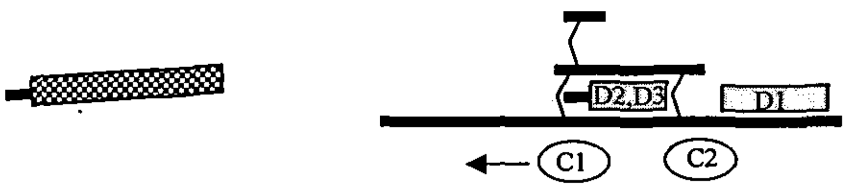
ABBREVIATIONS

D1 - Deckhand #1
D2 - Deckhand #2
D3 - Deckhand #3
C1 - Corps #1
C2 - Corps #2

STEP #9

t= 79 min, upper gates closed, C1 starts chamber empty , C2 moves to lower control booth

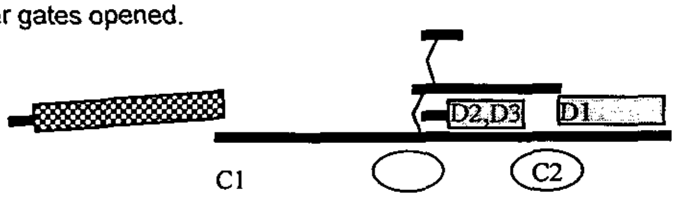
t= 80 min, C1 moving to assist approach of next downbound tow.



file: R:\\...Gwall Ext\2. Doc\Rpt\ENGR APP\Genl Txt\PTK/GWE with PTK

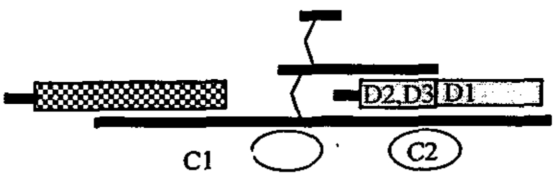
STEP #10
t= 81 min, C2 moves to lower control booth.
t= 82 min, C1 arrives to help downbound tow.

STEP #11
t= 83 min, C1 assists next tow, C2 arrives at lower lock control booth
t= 85 min, chamber emptied, C2 opens lower gate
t=87 min, lower gates opened.

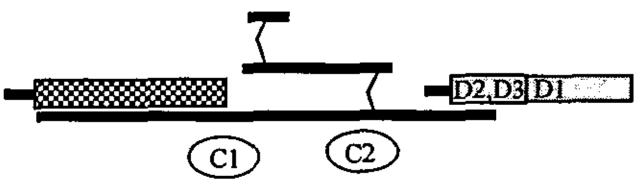


ABBREVIATIONS
D1 - Deckhand #1
D2 - Deckhand #2
D3 - Deckhand #3
C1 - Corps #1
C2 - Corps #2

STEP #12
t= 101 min, Tow remade



STEP #13
t= 106 min, stern clears gates
t= 108 min, lower miter gates closed.
t= 114 min, chamber raised, C1 opens upper miter gates
t= 116 min, upper gates open, C1 walks head in



Revised Double Cut Lockage Process Using the Recommended PTK System. The revised double cut lockage process is a result of adding extended guidewalls with PTK's at a project and relocating the tow haulage units. The lockage process is similar to the baseline process until Step #5 as shown on the graphical depictions to follow. About 2 minutes into Step #5, the head of the tow will come abreast of and connected to the PTK system on the guidewall. A deckhand on the cut and one on the wall connect a single line to the lead, powered kevel and a second line to a backup, unpowered kevel. The cut is stopped in the current manner by checking a stern line against a mooring pin on the lockwall (Step #5). A deckhand on the wall would transfer this single line to the trailing kevel, which provides a braking force later in the haulage process. At this time, the first cut is secured to the PTK system with two lines on the head and one on the stern. Two of the three deckhands leave the first cut to tend the powered cut's lockage. The third deckhand rides the stern of the first cut while the Corps lockman operates the winches on the lockwalls that provide the pulling and braking forces to the first cut. The lockman can operate both pulling and braking kevels from a central control stand. The extraction speed is variable, but expected to be about 50 fpm. The PTK system will brake the first cut to a stop at the end of the extended guidewall where it will await the arrival of the powered cut to start the recoupling process (Step #10). Step #12 shows the egress of the powered cut and indicates that the lock chamber can be turned back to service the next tow. (Note that the guidewall is approximately 1300 feet long to allow the powered cut to move further away from the miter gates so they can be closed with less effect from the tow's propeller wash.) Herein lie the timesavings by decreasing the downtime of the chamber. Step #13 shows the abutting of the two cuts, which initiates the recoupling process. Step #13 also shows the lock's availability to receive the next tow because the upper miter gates are open.

Automatic Tripping of Lines. Two lines connect the head of the first cut to two kevels, one powered and the second unpowered. After the tow is remade, it will proceed along its way as soon as possible. Both kevels could be designed to have the lines cast-off by a mechanism that engages a tripping lever on the kevels. Waiting for deckhands to perform this function could cause delays. This function can be as simple as that of Kentucky Lock's device where a second rail engages a pin that physically pushes a collar that slips the rope off the mooring pin. For the recommended PTK system, two kevels require lines to be tripped. Both kevels would have to be dragged over a second rail. Alternatively, a more active system composed of small hydraulic cylinders strategically located to engage the trip levers at the lockman's command/action.

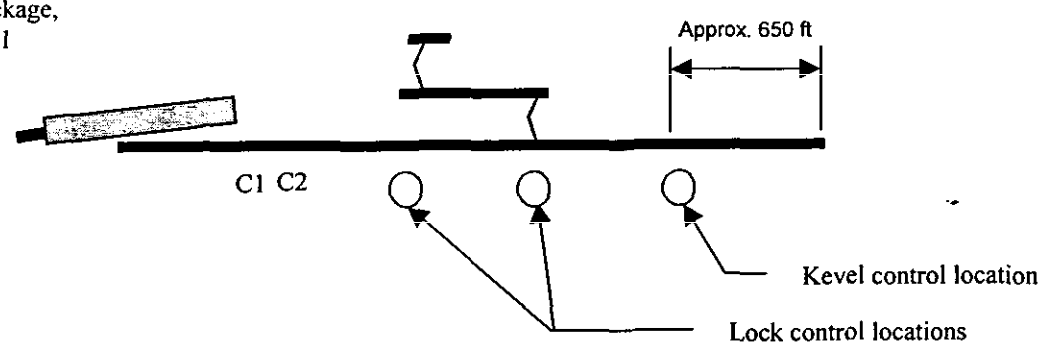
Lock operator's duties. The general duties of the lock operators can be obtained from the graphics and the above paragraphs. The specific controls movements and manual operations are not depicted here. In summary, one operator will operate most functions of the locking process. The other operator will mostly be operating the tow haulage unit(s), escorting the unpowered cut to full stop, and ensuring that it is securely moored when its stern is about 700 feet from the lock. To ensure safe, reliable, and efficient operation, control stations will have to be added for the operation of the PTK system. They will probably be located near where the stern of the first would come to rest and at the existing lock control houses on the lockwall. Wireless remote controls may also be necessary to maximize the efficiency of the operation.

GUIDEWALL EXTENSIONS WITH RECOMMENDED PTK SYSTEM

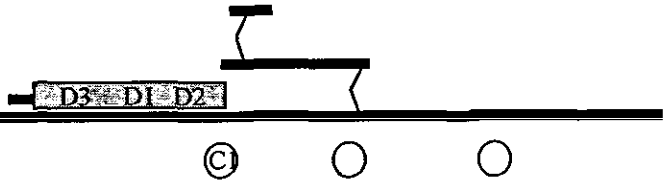
DOWNBOUND DOUBLE LOCKAGE ELEMENTS Page 1 of 3.

file: R:\\...Gwall Ext\2. Doc\Rpt\ENGR APP\Genl Txt\PTK/GWE with PTK

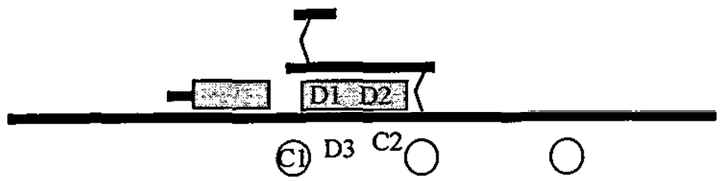
STEP #1
t= 0 min, Start Lockage, upper gates open, *C1* walks head in



STEP #2
t= 22 min, Complete Approach, Start Entry

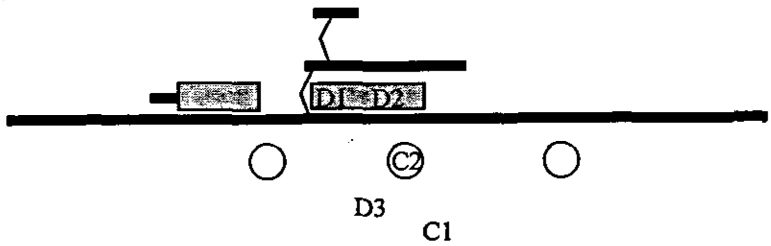


STEP #3
t= 36 min, Complete Entry, uncouple, complete back out

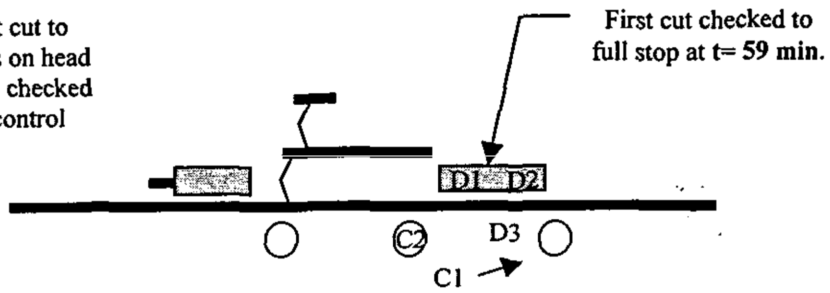


ABBREVIATIONS
D1 - Deckhand #1
D2 - Deckhand #2
D3 - Deckhand #3
C1 - Corps #1
C2 - Corps #2

STEP #4
t= 38 min, Upper gates closed
t= 43 min, extract tow cable (tow haulage unit is relocated)
t= 44 min, Chamber emptied
t= 45 min, towing cable connected
t= 46 min, Lower gates opened. Towing initiated.



STEP #5
t= 48 min, D2 and D3 connect cut to lead and backup (safety) kevels on head
t= 59 min, Cut clears gate and checked to full stop, C1 starts for PTK control pedestal, C2 closes lower gates



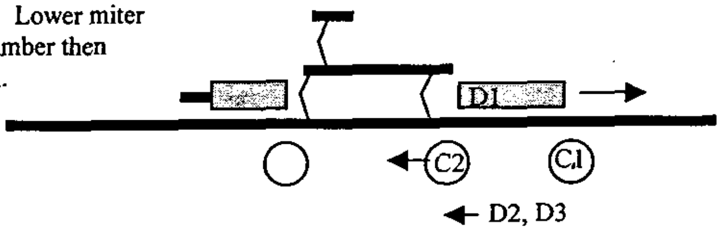
GUIDEWALL EXTENSIONS WITH RECOMMENDED PTK SYSTEM

DOWNBOUND DOUBLE LOCKAGE ELEMENTS Page 2 of 3.

file: R:\\...Gwall Ext\2. Doc\Rpt\ENGR APP\Genl Txt\PTK/GWE with PTK

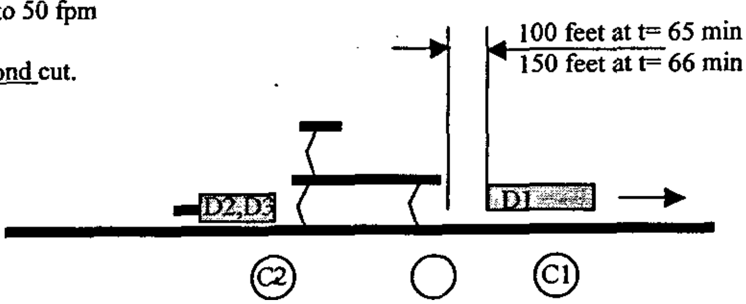
STEP #6

t= 60 min, D3 transfers checking line to trailing (braking) kevel
t= 60.5 min, C1 arrives @ PTK pedestal, D2 leaves 1st cut & goes w/D3 to powered cut
t= 61 min, C1 restarts first cut. Lower miter gates closed. C2 starts to fill chamber then goes to upper lock control booth.



STEP #7

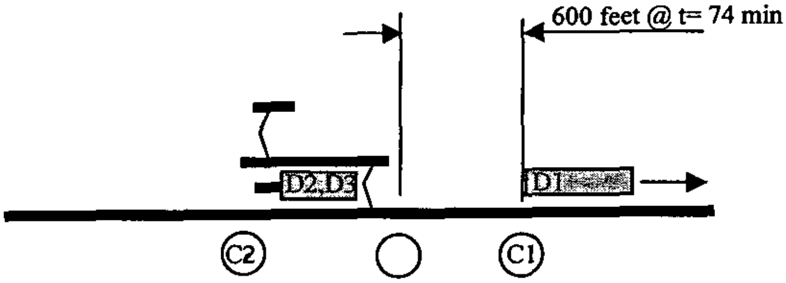
t= 62.5 min, C2 arrives at upper booth.
t= 65 min, First cut accelerated to 50 fpm over 100 feet by lead kevel.
t=66 min, D2 and D3 board second cut. First cut keeps speed at 50 fpm.
t= 67 min, chamber is full



ABBREVIATIONS
D1 - Deckhand #1
D2 - Deckhand #2
D3 - Deckhand #3
C1 - Corps #1
C2 - Corps #2

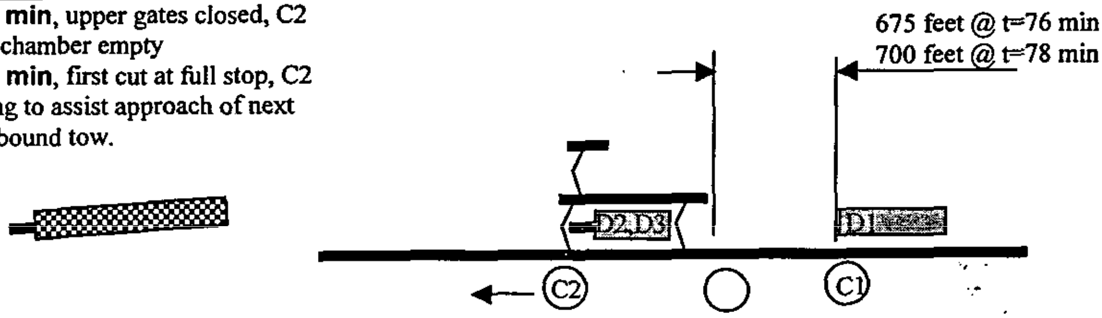
STEP #8

t= 69 min, upper gates recessed
t= 74 min, trailing kevel starts deceleration of first cut.
t= 75 min, 2nd cut completes entry, C2 closes upper gates



STEP #9

t= 77 min, upper gates closed, C2 starts chamber empty
t= 78 min, first cut at full stop, C2 moving to assist approach of next downbound tow.



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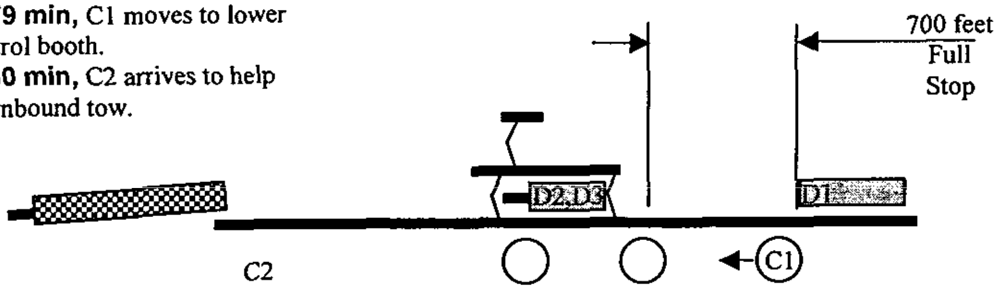
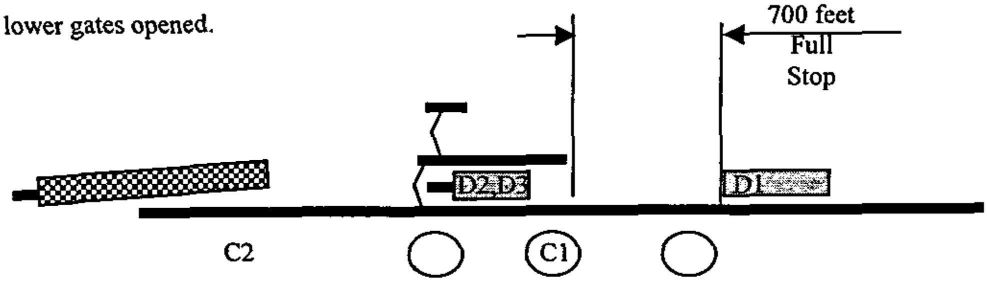
STEP #10
t= 79 min, C1 moves to lower control booth.
t= 80 min, C2 arrives to help downbound tow.

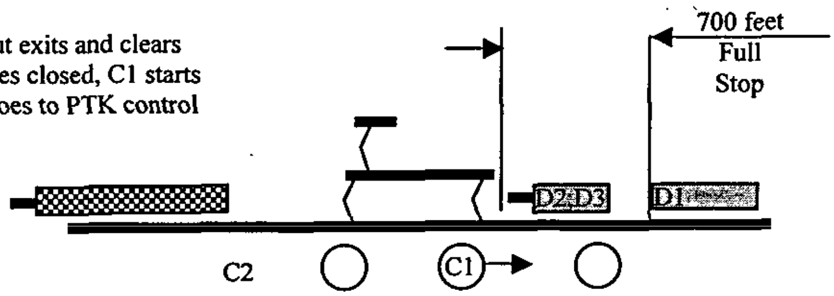


ABBREVIATIONS
D1 - Deckhand #1
D2 - Deckhand #2
D3 - Deckhand #3
C1 - Corps #1
C2 - Corps #2

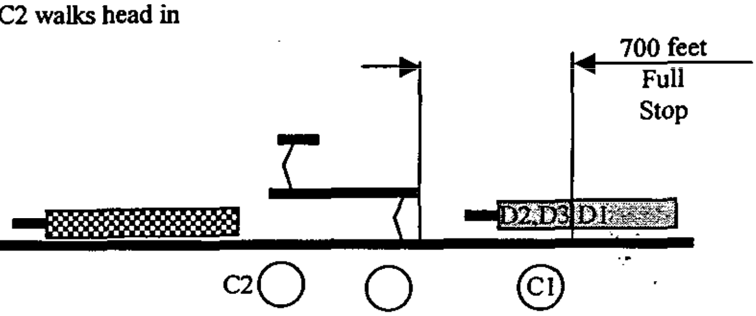
STEP #11
t= 81 min, C2 assists next tow, C1 arrives at lower lock control booth
t= 83 min, chamber emptied, C1 opens lower gate
t=85 min, lower gates opened.



STEP #12
t= 89 min, second cut exits and clears
t= 91 min, lower gates closed, C1 starts to fill chamber then goes to PTK control pedestal

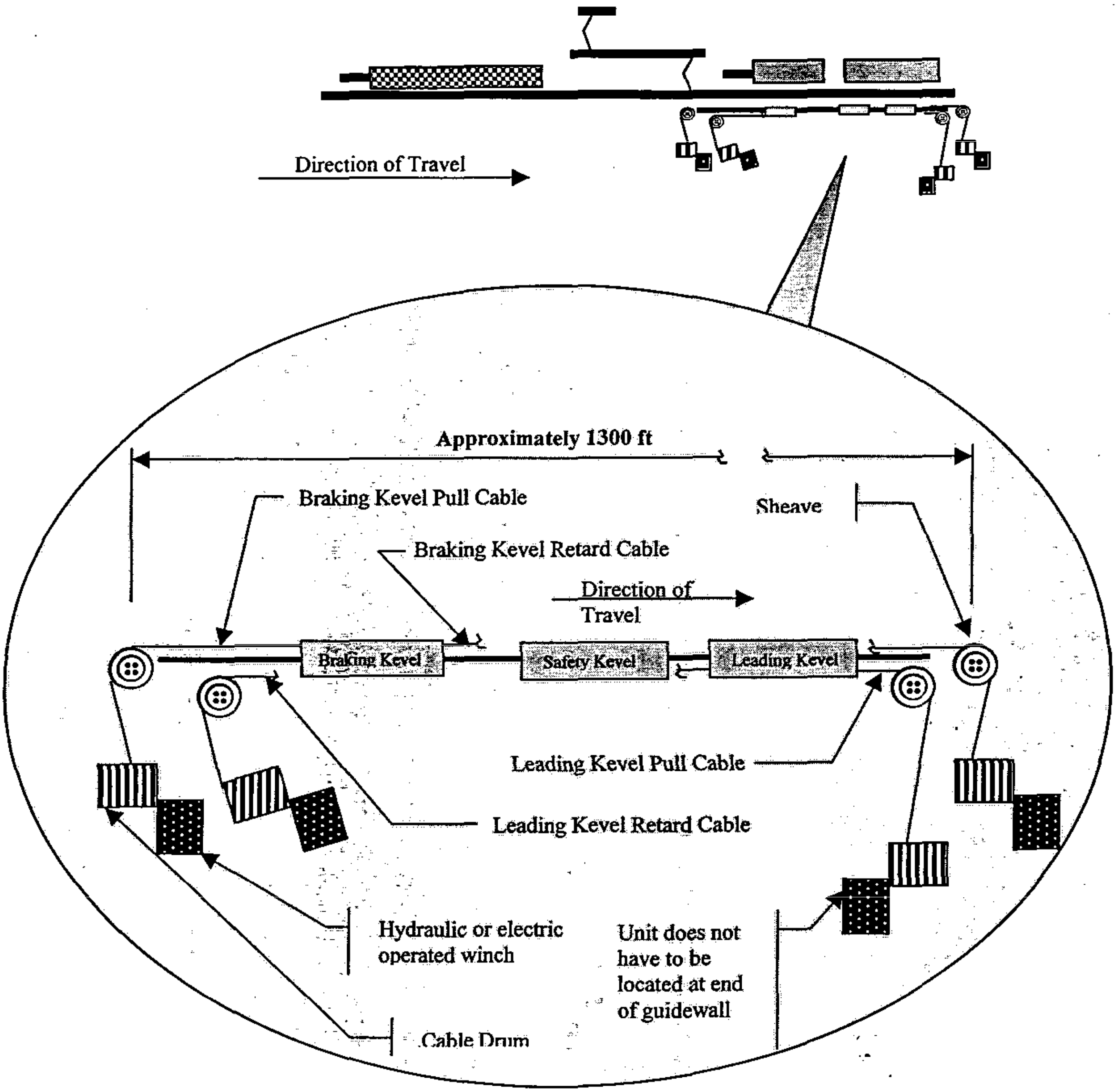


STEP #13
t= 92 min, Cuts faced up
t= 93 min, C1 arrives @ PTK control pedestal.
t= 97 min, chamber raised, C2 opens upper gates
t= 99 min, upper gates open, C2 walks head in
t= 108 min, tow is remade



Machinery Layout and Function for Pull – Retard PTK Recommended System. The double lockage procedure in the previous graphics uses pull-retard winches as depicted below. The same system is used on both guidewalls. The machinery layout for the lower guidewall is shown in the graphic below. The machinery below performs the following functions:

1. Leading kevel – provides force to pull the cut along the extended guidewall. The machinery will retrieve the leading kevel and the safety kevel for use by the next tow. The machinery will also apply a retarding force that keeps the cables tight.
2. Braking (trailing) Kevel – provides force to slow and stop the cut along the extended guidewall. The machinery will retrieve the braking kevel for use by the next tow. The machinery will also apply a retarding force that keeps the cables tight.



<u>PTK Control Unit from Allegheny Lock 7:</u> This graphic is based on the PTK control units for Allegheny Lock #7. It is used to control a PTK acting as a tow haulage unit with in the confines of the lock chamber.

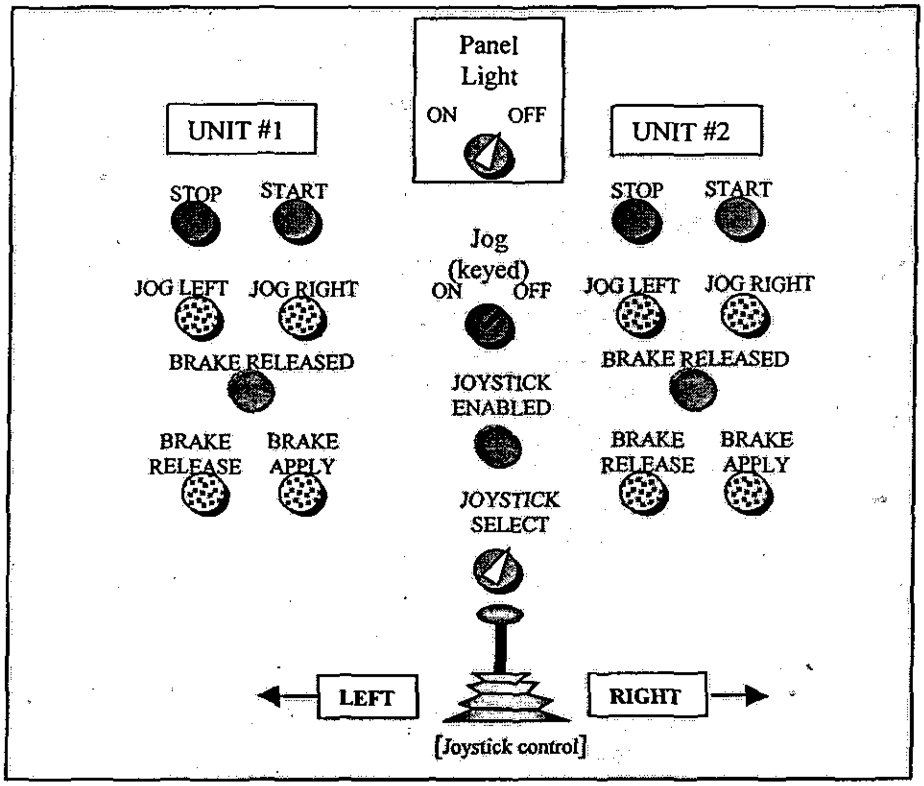


Figure: PTK Control Panel

A powered traveling kevel is typically controlled by two machines. The primary winch pulls the kevel toward the end of the guidewall, while the secondary winch provides a retarding force to keep the wire ropes on both winches tight. For the lead kevel, the above controls would operate as follows: movement to the right (see previous lockage graphics) would be caused by leading kevel pull wire rope exerting about 15,000 pounds force to the right, while the leading kevel retard wire rope exerts a restraining force of about 1000 pounds to the left. This will pull the first cut along the guidewall. The trailing (braking) kevel will have an identical set of controls, which can be operated in the reverse direction to control the rear end of the tow cut. The operator can initiate braking at anytime that it is required, even while pulling the cut. This combined operation of the leading and braking kevels can serve to pull the cut towards the guidewall if necessary. It may be necessary to combine the controls of the two sets of kevels into one panel to ease operations.

The winches will be similar to the standard electrical or hydraulic tow haulage winches now in service at various locations. Forty horsepower electric motors drive many of the current systems on the Mississippi River. It may be possible to use smaller capacity winches for retard service, since full load capacity is not required in both directions of kevel travel. It is anticipated that each winch will need about 1,300 to 1,500 feet of 5/8-inch steel wire rope mounted on the drum. The wire rope will be connected to the traveling kevel with swaged swivel fittings to prevent twisting of the wire rope in service. Large diameter sheaves will be used to extend the normal 15-20 year service life of the wire rope. Kevels will be designed with sufficient wheels, with shafts and bushings, to transmit all uplift and side loads properly to the rail. New rail, designed and anchored for the existing loadings, shall be provided to mate with the traveling kevels.

The control system shall be an electronic system, which coordinates the leading (braking) pull winch with the leading (braking) retard winch to maintain wire rope tension. The control system will use a joystick to vary the pulling speed and maximum line tension on the wire rope, while controlling the retard winch tension and speed in a regenerative mode. The control system will also allow retrieval of the traveling kevels at a fast speed with relatively little load.

Operational Options for Recommended PTK System: The recommended PTK extraction system requires the first cut to be stopped so that one deckhand can get off the first cut to assist with the powered cut's lockage. Some options have been considered, but discarded because they violate current operating policy.

Option #1 – One deckhand would be on the first cut from its initial extraction until the subsequent face up of the powered cut. This would free the other **two deckhands** to lock the powered cut through with two deckhands per Nav. Notice #1. This options achieves a larger time savings since the first cut can be pulled out faster since it would not have to stop where it currently does. Timesavings would be about 22 minutes upbound and 25 minutes downbound. This requires the deckhand on the first cut to secure two head lines and walk back to the stern to secure the checking line to the braking kevel. This would be in violation of Navigation Notice #1's minimum staff requirements for the first cut. For this option to be successful, Navigation Notice #1 would have to be changed. With only one deckhand on the first cut, fenders couldn't be tended on port and starboard sides as the cut is pulled past the miter gates. Also, there is a chance that the deckhand could get delayed from returning to the stern of the cut to fasten the stern line to the braking kevel.

Option #2 – Two deckhands would be on the first cut from initial extraction until the subsequent face up of the powered cut. This options achieves a larger time savings since the first cut can be pulled out faster because it would not have to stop where it currently does. Timesavings would be about 22 minutes upbound and 25 minutes downbound. The powered cut would lock through with only one deckhand. This options does not allow the powered cut to moor both head and stern (if required at the specific lock) inside the lock chamber. This would be in violation of Navigation Notice #1 minimum staff requirements for the second cut and lines for lockage. With only one deckhand on the first cut, fenders couldn't be tended on port and starboard sides as the cut as it is pulled past the miter gates.

Additional Considerations for PTK Implementation:

1. One lockman will have to do most of the lock operation while the other escorts the unpowered cut. Neither lockmen will be able to stop to enter OMNI data (data such as lock process times, vessel information, weather, etc). Either computers will have to be put on the wall or an automated data collection system is required. The later is the preferred by operators.
2. Lock operation from either end may be required. This would necessitate automated controls in the booths on the wall and cameras. Locks 24 and 25 have this capability.
3. Some operators have suggested that two floating mooring bitts (FMB's) be added for deckhands to attach their stern lines without assistance from the lockman. They may be too busy to assist or efficiency could suffer. Some locks have insufficient depth to feature FMB's. Also, there is some disagreement on the need for FMB's. FMB's are not been featured in this report.
4. Upstream channel improvements are necessary to safely and reliably extract first cuts upbound. The adverse effects of outdraft on unpowered cuts was a fear of many operators.
5. The PTK system as recommended is not a proven technology. It may require numerous cycles of operation to perfect. Additional funding may be required to perfect the system.
6. At Lock 24 downbound cuts are sometimes difficult to stop because of the flow from the dam tends to push along the exposed length of the cut dragging it out of the chamber. The amount of force on the cut is difficult to know, but it undoubtedly exists. The deckhands on the head work together going from checkpost to checkpost to keep the head along the wall (checking it) which can also slow the cut down if done correctly. This slowing of the cut reduces the force of the checking operation that brings the cut to full stop. The stern is checked to a checkpost on top of the wall stopping the cut over a distance of about 20 feet. The faster the cut is going, the larger the stopping force at the stern. Inexperienced deckhands (more prevalent in the springtime) complicate the matter because they may not be checking the head as required to get the cut's speed slowed. Or, they may not be able to handle stopping the cut at all. This occurrence may not be as much of a problem at some locks.
If the same occurrence would happen with extended guidewalls, the consequences could be that the cut would continue to drift downstream. It is not known whether this will happen more or less than now, however, the new stopping system can apply a gradual braking force over a longer distance to lessens the total load in the line. The load would be about 15,000 pounds making it unlikely that that a break of any line in decent condition would happen.
Below is a caption from an output file of a numerical hydraulic model. The arrows show the direction of flow and their length shows the relative magnitude of the velocity. Although the clarity of the graphic is average, the reader can see that a component of the encircled vectors would tend to drag along the cuts adding to the required stopping force.

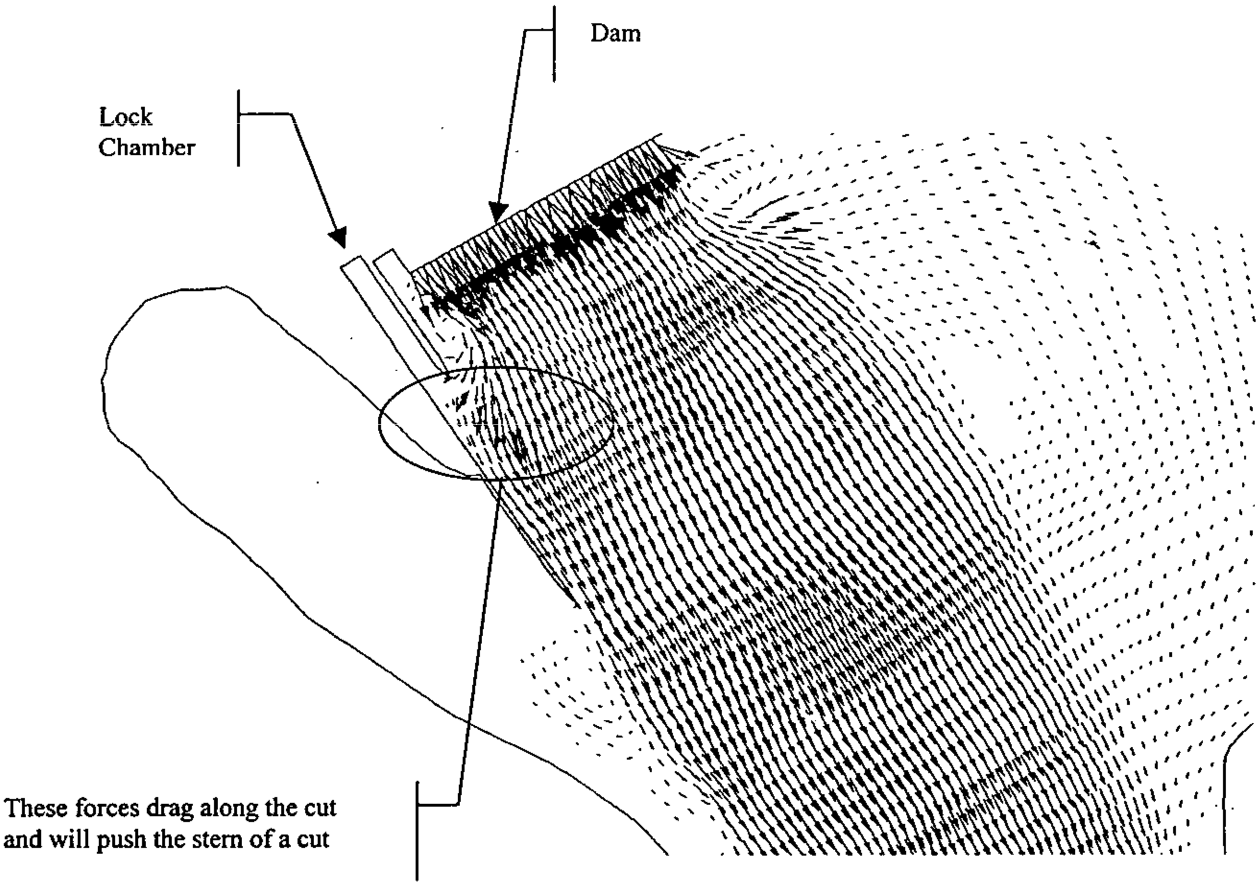


Figure: Direction of Current Below the Dam

7. An individual tow may not realize any timesavings during its lockage. In fact, it may take longer to remake along the guidewall because it may take longer to square-up the cuts. However, a tow will be processed through the waiting line faster. The lock has less idle time.
8. It is possible to have the cut stopped by a deckhand checking to the wall. This would make his job very similar to what it is now. This is done on the Arkansas and Tennessee Rivers.
9. It is desirable to have the lead kevels outfitted with auto-trip features to cast-off the line when necessary. This can be done by a mechanism that is remotely controlled. A lock operator will actually have to push a button for this to happen. Many operators have stated that they would not like the only line on the head to be one that could slip off the horn of a kevel. They want a positive connection and an action by an operator to engage the mechanism that casts-off the line.
10. Navigation Notice #1 prohibits stopping cuts by checking to ¼ kevels. This is probably because it places the deckhand between the guidewall and the wall of a hopper barge. He could be knocked into the water by any one of a number of mishaps. He could be crushed between the guidewall and barge.

11. Lines will be connected to the kevel while it is moving. This necessitates personnel being next to the moving kevel. The design details must include protecting the individual from the moving cable.
12. A VE Study was done in early March 1999. Many ideas were exchanged. The Study results were not screened to those that would be acceptable. Recommendations mostly consisted of variations of powered traveling kevels. This proves that powered traveling kevels are viable and that there are alternative solutions to extract tows along extended guidewalls.
13. A spare rope will by available at the lock for emergencies. One would be located at the point where the stern of the first cut will come to rest and possibly at other locations.
14. At the location where the stern will come to final rest on the guidewall, at least two and possibly three sets of mooring pins should be featured. This allows the deckhand alternate locations to catch a stern line backup if the trailing kevel does not brake the tow to a full stop. Pins can be placed on top of the upper beam at regular intervals, but they add to congestion in the heavily reinforced beams. Stacks of mooring pins are more easily outfitted to a cell rather than a beam. Three pins would probably not fit easily into a cell making two pins the preferable choice. The ladder at that location would probably be eliminated to make room for the second stack of mooring pins.
15. A line will usually be made to the deck fitting in a towing or backing lead configuration. This configuration must be kept or a line could foul. In other words, a kevel pulling in one direction should not reverse its pull direction unless the deckhand remakes the line on the deck fitting.
16. Lines can be fastened to deck fittings that are midship rather than on port or starboard sides. This arrangement will allow for a larger component of force perpendicular to the guidewall keeping the cut pinned to the wall. This can be attempted on a trial and error basis by operators and may only be needed on occasion. Midship connections have been observed at Kentucky Lock and Wheeler Lock.
17. For any type of kevel system there are consequences should a line part during operation:
   a) Upbound
      i) Head line failures – the likely time for this to part would be during pulling the cut if the head line does the pulling. It could happen any time during the extraction, but is more likely to happen when the line is initially tensioned. Initial tension will check the adequacy of the connections and rope itself.
      After the cut is stopped, it could have a tendency to move with the flow, toward the lock. The kevel must remain upstream of the tie to the barge in order to keep the line from fouling. This is a possible, but unlikely time of failure. Any other instances of failure are unlikely.

      ii) Head line consequences of failure:
         (1) Failure on initial Pull - if the headline breaks shortly after it becomes abreast of the leading, head kevel, the cut will still be partially within the chamber. The deckhands and the lockman should be able to tie-up the cut.
         (2) Failure when cut is fully extracted – if the headline breaks when the cut is resting at the end of the wall, the head will topple around and place a large load on the line at the stern. If the stern line breaks, the cut will be sent towards the dam. It might get caught within the guardwall. If not, barges would impact the dam. In any case, some barges would most likely be sent towards the dam. In

any event, the safety kevel connection must also fail for there to be any adverse consequences.

iii) Stern line failures – A stern line would likely fail when it is being used to stop a cut. When stopping the cut, a deckhand and lockman will be present. In the event of line failure, an emergency line would be supplied by the lock to control the cut. This response will be immediate and probably effective.

iv) Stern Line consequences of failure - If the operators failed their mission, the stern would probably drift around a bit, but should remain connected at the head. If the head line (and safety line) were to break, the cut would drift back towards the lock and have a chance of ending up in the dam.

b) Downbound:
   i) Head line failures – the likely time for this line to part would be during pulling the cut if the head line does the pulling. It could happen any time during the extraction, but is more likely to happen when the line is initially tensioned. Initial tension will check the adequacy of the connections and rope itself.
   After the cut is stopped, it could have a tendency to move with the flow, away the lock. The kevel must remain downstream of the tie to the barge in order to keep the line from fouling. This is a possible, but unlikely time of failure. Any other instances of failure are unlikely.

   ii) Head line consequences of failure:
      (1) Failure on initial Pull - if the headline breaks shortly after it becomes abreast of the leading kevel, the cut will still be partially within the chamber. The deckhands and the lockman should be able to check and tie-up the cut.
      (2) Failure when cut is fully extracted – if the headline breaks when the cut is resting at the end of the wall, the head may drift from the wall and change the angle of load on the line at the stern. If the stern line breaks, the cut will be sent downstream until it is rescued or runs aground. Most likely the stern line will hold the cut. In any event, the safety kevel connection must also fail for there to be any adverse consequences.

   iii) Stern line failures –A stern line would likely fail when it is being used to stop a cut. When stopping the cut, a deckhand and lockman will be present. In the event of line failure, an emergency line would be supplied by the lock to control the cut. This response will be immediate and probably effective. Note: this would seem like the most likely line to fail. The operators will be reluctant to pull cuts fast because of a tendency for them to be hard to slow down when they get about half the cut exposed to flow. It would be good to have a braking system that could apply braking forces anytime after the stern is connected to the kevel.
   iv) Stern Line consequences of failure - If the operators failed their mission, the stern would probably drift away from the wall and downstream. The lines at the head would change from a towing line to a backing line and probably foul at the deck fitting. The cut would probably drift downstream if the operators failed their mission.

Options Considered During the Development of the Recommended PTK Concept. Many options were considered during the development of the PTK system. Some were considered to establish an array of feasible options and to possibly generate more ideas. The table on the following page summarizes the alternatives.

Haul Alt.	Lead Kevel (LK)			Trailing Kevel (TK)			Method of Stopping cut	Faster Initial Extract	Deckhands on first cut*	Additional Number of Winches per Guidewall	Special Features	Advantages	Disadvantages
	Power	Function	Connection to cut	Power	Function	Connection to cut							
1	Cable, Pull-retard	Pull cut, hold head	2-part line pulling bow of first barge	Cable, Pull-retard	Braking, Hold stern	2-part line behind stern of last barge	Full Stop by Powered TK	yes	1	2 on LK 2 on TK	Winches do all pulling and stopping. Offers most control of all alternatives.	Pull cut US and/or DS anywhere along guidewall. Good option to pull and hold stern & head in	Lots of machinery to maintain. Controls more complicated that other alternatives
2	Cable, Pull-retard	do	do	None	Hold stern	2-part line behind ¾ kevel of last barge	Full Stop by Deckhand Checking stern on wall	yes	1	2 on LK	Stopping of cut done by deckhand using a third, 2-part line to pin in face of or on top of wall. There are 3 lines from cut to guidewall.	Deckhand does stopping as he does now. Powered LK can pull head against guidewall.	May require working ¾ kevel when cut is moving placing deckhand between cut and wall – safety. Deckhand must successfully engage pin to stop cut. Unpowered TK cannot pull stern against guidewall.
2A	do	do	do	TK outfitted with brakes to stop the cut gradually		2-part line pulled by stern or ¾ kevel of last barge	TK with self-contained brake system. Backup by deckhand on stern.	yes	1	2 on LK	Brakes on TK could be electric/hydraulic. Stern kevel is for deckhand backup checking.	Brakes on TK allow stopping anywhere along rail.	Nav. Notice #1 prohibits stopping cuts with quarter kevel (probably because deckhand might be between cut and wall – safety) Unpowered TK cannot pull stern against guidewall.
2B	do	do	do	Wall outfitted with brakes to engage TK and stop the cut gradually		2-part line pulled by stern or ¾ kevel of last barge	TK slows and stops cut with brakes on the guidewall. Backup by deckhand on stern.	yes	1	2 on LK	Brakes on wall could be electric/hydraulic. Brakes on wall would not require powered TK. Stern kevel is for deckhand checking.	TK is unpowered.	Nav. Notice #1 prohibits stopping cuts with quarter kevel (probably because deckhand might be between cut and wall – safety) Unpowered TK cannot pull stern against guidewall. Brakes on wall will have a fixed location, which limits stopping location of first cut.
2C	do	do	do	TK outfitted to engage a check post to stop the cut		2-part line pulled by stern of last barge	Full Stop by Deckhand Checking stern to anchored TK	yes	1	2 on LK	TK automatically engages check post on wall or lockman engages manually. Deckhand checks to anchored TK.	Stopping of cut is done by deckhand similar to as it is currently done.	Mechanism to engage checkpost would have to be developed. Unpowered TK cannot pull stern against guidewall.
3	None	Hold head	2-part line pulled by bow of first barge	Cable, Pull-retard	1. Pull cut, Hold stern 2. Stop cut, hold stern	2-part line pulling stern of last barge then remade to 2-part braking line to stern of last barge.	Full Stop by one line to Powered TK	yes	1	2 on TK	Deckhand must remake line to TK from leading to backing line while cut is moving. Bow must stay ahead of LK for line not to foul.	Braking is done at stern where deckhand and lockman are stationed.	Unpowered LK can't pull head against guidewall. Bow could back up behind LK especially for upbound tows. This could foul the line.
4	None	do	do	None	Hold Stern	2-part line pulled by stern of last barge	1st stop: 2-part line to existing check post 2nd stop: second cut thru multi-part line	no	2	0	First cut stops just outside miter gates. Second cut must push cut to end of guidewall. Small winches are required to retrieve kevels.	This method is somewhat proven by a similar action that is currently done during icy conditions. No new machinery.	No benefits from faster extraction. Added time for second cut to clear sill
4A	None	do	do	None	do	2-part line pulled by ¾ kevel of last barge	Full Stop by Deckhand Checking stern on wall	yes	1	1 for new tow haulage	A second ("tandem") tow haulage unit on the guidewall will provide additional pull on first cut as needed. Small winches are required to retrieve kevels.	Simplified machinery.	Additional handling of second tow haulage system by lock staff. Unpowered TK cannot pull stern against guidewall.
5	Cable, Pull-retard	Pull cut, hold head, braking	Line #1. 2-part braking line behind bow of first barge Line #2. pulling wire ahead of ¼ kevel on first barge	None	do	2-part line pulled by stern of last barge	Full Stop by Line #1 on LK, backup by deckhand on stern	yes	1	2 on LK	LK will have a bit for each line. Pulling wire slips off as ¼ kevel passes LK when tow is underway.	One kevel pulling and braking simplifies the controls. Powered LK can pull head against guidewall.	Since the lockman and the deckhand are probably at the stern, they will be separated from the braking operation of the LK. Unpowered TK cannot pull stern against guidewall. Pull wire has to be looped onto ¼ kevel by Lockman. Wire must be maintained by the Corps.
5A	Cable, Pull-retard	Pull cut, hold head, braking	2-part line first pulling bow of first barge, then same line trails bow to brake.	None	do	2-part line pulled by ¾ kevel of last barge	Full Stop by powered LK, backup by deckhand on stern	yes	1	2 on LK	Line to LK from first barge is required to both pull and brake the cut.	Same as #5. Only one line to attach to LK.	*Line to LK could foul when going from pulling to backing lead. Feasibility of this alternative is dependent on this connection.* Unpowered TK cannot pull stern against guidewall.

Common features for all Alternatives:

- The existing tow haulage units are used for initial extraction.
- An extra line will be required at the stern for the deckhand to make to pins in the guidewall prior to disconnecting from the TK.
- For systems that pull with the **LK**, the existing tow haulage system will have to pull the **bow** of the cut past the miter gates and **abreast of the LK.**
- For systems that pull with the **TK**, the existing tow haulage system will have to pull the **stern** of the cut past the miter gates and **abreast of the TK.**
- In all but Alternative #4A the deckhand on the first cut makes the line(s) to the LK then walks back to the stern to make a line(s) there. He remains with the stern in all cases. Only one deckhand is detailed to the first cut in order to allow the other two deckhands to tend the powered cut so as not to cause delays to locking.
- Autotrip devices can be featured on the kevels to throw-off lines.

Relocated Tow Haulage Units in Combination with the Recommended PTK System.
Shown below is the relocated upstream (downstream should be similar) tow haulage system for initial cut extraction from the lock. It is important to notice that the location of the existing unit required that the miter gates be recessed in order that the tow cable be extracted. The recommended new location does not require this. The cable can be extracted and hooked to the cut readying it to be pulled as soon as the miter gates are fully recessed. This process saves about 2 minutes.
On rare occasions, northbound extractions of first cuts don't completely clear the chamber causing them to have to be pulled again. Contrary to the existing tow haulage location, the new location can't accomplish this if the stern of the cut passes the tow haulage unit. For this case, another tow haulage unit has to be placed near the location of the existing unit. [Alternatively, the existing could remain and a new unit purchased for the relocation.] Tow haulage units are about $100,000 each. For southbounders, the second unit is not required. Cuts that do not clear the chamber can be safely moved by slightly opening the upstream culvert valves to create flow in the chamber that will flush the cut out.

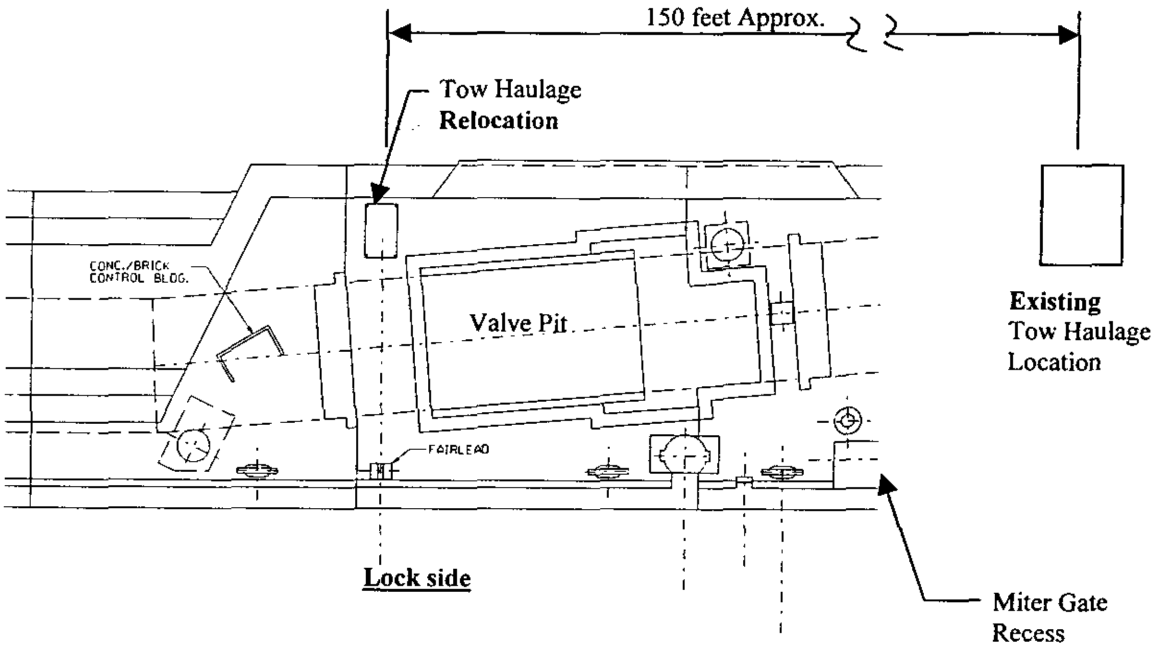


Figure: Tow haulage relocation and relationship to the existing location and the miter gate recess

COST ESTIMATE FOR
POWERED TRAVELING KEVEL CUT EXTRACTION SYSTEM
TWO POWERED KEVELS AND ONE UNPOWERED KEVEL
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
22-Jul-00

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	40 HP Winch (w/power unit &power panel)	8	EA	$150,000	$1,200,000
2	1" Dia Wire Rope	6,800	LF	$5	$34,000
3	36" Dia Sheaves w/Assembly	16	EA	$5,000	$80,000
4	140# Rail (w/[plates, clips & anchors)	2,600	LF	$60	$156,000
5	Tow Haulage Bitts	6	EA	$3,000	$18,000
6	Rigid Steel Conduit	3,400	LF	$10	$34,000
7	Power/Control Cables	10,200	LF	$10	$102,000
8	Control/MCC Modifications & Additions	2	EA	$10,000	$20,000
9	Removal of Checkposts	20	EA	$250	$5,000
10	Install New Checkposts	20	EA	$3,500	$70,000
11	Removal & Relocation of Handrail	1,100	LF	$20	$22,000
12	Misc. Structural Mods. (ladders,trenches)	1	EA	$10,000	$10,000
13	Remote Control	2	EA	$2,000	$4,000
14	Testing/Start-Up Services	1	EA	$15,000	$15,000
15	Training	1	EA	$5,000	$5,000
16	Move Existing Tow haulage units	2	EA	$10,000	$20,000
		SUBTOTAL			$1,795,000
		CONTINGENCIES (25%)			$449,000
		SUBTOTAL			$2,244,000
		P.,E., & D (15%)			$337,000
		C.M. (10%)			$224,000
		TOTAL			$2,805,000

Hydraulics Analysis

Appendix C

Appendix C
Hydraulics Analysis

Upper Mississippi River – Illinois Waterway System Feasibility Study

Engineering Appendix of Site Specific Feasibility Report:

Guidewall Extensions with Powered Traveling Kevels,

and Approach Improvements to Lock 22 and Lock 25

Hydraulics Appendix

Preface

A hybrid modeling approach, utilizing prototype data collection, numerical models, and micro models, was performed for Locks & Dams 22 and 25 to analyze navigation conditions in the upstream and downstream lock approaches and to make recommendations of measures to improve the efficiency and safety of the lock approaches. This modeling effort was performed by personnel of the Rock Island and St. Louis Districts of the Corps of Engineers.

DESIGN DOCUMENTATION REPORT
FOR
GUIDEWALL EXTENSIONS with POWERED TRAVELING KEVELS, and APPROACH IMPROVEMENTS to LOCK 22 and LOCK 25

HYDRAULICS APPENDIX

TABLE OF CONTENTS

Subject

LIST OF FIGURES

Title

DESIGN DOCUMENTATION REPORT
FOR
GUIDEWALL EXTENSIONS with POWERED TRAVELING KEVELS,
APPROACH IMPROVEMENTS TO
LOCKS & DAMS 22 AND 25
MISSISSIPPI RIVER

HYDRAULIC APPENDIX

SECTION 1 – PURPOSE AND SCOPE OF INVESTIGATION

DESCRIPTION OF MEASURE

Approach channel improvements could consist of many different measures or combinations of measures designed to improve the efficiency and safety of navigation conditions experienced by tows approaching and exiting a lock. In addition, reduction of outdraft currents will lessen the hydraulic forces affecting the first cut of barges pulled to the end of an extended guidewall. The correct set of improvements is highly site-specific and depends on the hydraulic and bathymetric conditions at a given site. Examples of approach channel improvements include: widening or realignment of the approach channel; installation of dikes or other channel training structures; and bank realignment.

DESIGN CONSIDERATIONS

1. Upper Lock Approach

Hazardous conditions that can affect downbound tows include high current velocities, crosscurrents, uneven channel depths in the lock approach, and overbank flow in the immediate lock approach. The most prevalent approach problem on the Upper Mississippi River System is that of outdraft. Outdraft is the detrimental crosscurrents produced as flow crosses over from the bankline to the dam gates, immediately upstream of the lock. If a tow becomes caught in these dangerous currents, the pilot must quickly adjust the tow or risk the tow breaking up and being carried into the dam. This scenario could severely damage the structure, result in the loss of the navigation pool, and endanger the lives of the crew and lock personnel. Helper boats are widely used by tows throughout the system to reduce this risk. The helper boat guides the head of the tow into the lock chamber as the tow pilot maneuvers the stern near the guidewall. Outdraft problems are present at most locks and dams on the Upper Mississippi River. The degree and severity of outdraft varies between lock sites depending on the river alignment. Solutions to outdraft, and other approach problems, are highly site specific. Typically, outdraft does not impair (and at some locations even assists) an upbound tow leaving the lock chamber.

An upper ported guardwall can be used to eliminate or reduce crosscurrents near the end of the wall by permitting all or a major portion of the flow intercepted by the wall to pass through submerged ports in the wall. The flow through the submerged ports will tend to move a tow toward the wall, helping the tow to align with the lock chamber while requiring minimal maneuvering on the part of the pilot. Physical model results have shown that the use of an upstream, ported guardwall eliminates the need for a helper towboat, provided that an acceptable navigation channel is provided above the lock. A ported guardwall length of 1200' is recommended to provide protection from crosscurrents over the entire length of the tow. As part of the UMR/IWW System Navigation Study, ported guardwalls were eliminated from consideration due to the high first cost and impacts to navigation that would result during construction. Other potential measures that have the ability to reduce crosscurrents in the upper approach include channel training structures (dikes) designed to reduce and realign channel velocities in the immediate lock approach.

Variable depths in the approach channel can affect the movement of tows in the approach, particularly if the tow is moving at reduced speeds from deep to shallow water. Tows moving along a bank and passing from deep to shallow water block a portion of the flow in the shallow channel. This causes a higher water level to develop between the tow and the adjacent bank that could move the head of the tow riverward. The effects of changes in depths can be minimized or eliminated with submerged dikes located some distance upstream of the lock walls. The submerged dikes could also be used to reduce velocities in the approach. It is desirable to improve the lock approach such as to provide sufficient depths to allow a tow to align with the guide- or guardwall a minimum of two tow lengths upstream of the upper end of the wall.

Overbank flow moving toward the river from the adjacent bank or from the river toward the adjacent bank can produce serious crosscurrents. Typically, this is not a major problem on the UMR due to the presence of levees and railroad embankments.

2. Lower Lock Approach

Currents affecting navigation in the lower lock approach depend on channel alignment, discharges from the gated spillway, and lock discharges during the emptying cycle. Eddies forming in the lower lock approach and flow moving from the gated spillway toward the guidewall produce currents that could be objectionable to navigation, and may result in greater impact loads as the tow lands on the lower guidewall. A straight channel extending downstream of the lock will generally provide the most favorable conditions for upbound tows approaching the lock.

3. Channel Maintenance

At many of the Locks & Dams on the UMR, significant dredging is required in the immediate, downstream lock approach. The efforts described herein did not look directly at the reason for, or the solutions to, these channel maintenance problems. However, channel maintenance requirements were considered in evaluating project alternatives in terms of the potential to increase dredging requirements in known problem areas and the potential to create new problem dredging areas.

4. Environmental Considerations

Construction of approach channel improvements has the potential to negatively impact terrestrial and aquatic resources. Potential impacts include changes in the flow regime in areas containing mussel beds, loss or reduction in quality of available habitat for fish, loss of bottomland hardwood forests, and potential impacts to threatened or endangered species. In order to identify potential impacts, alternatives considered and model output were provided to district biologists for evaluation. District biologists and a representative from the U.S. Fish & Wildlife Service also participated in the coordination meetings.

SECTION 2 – CURRENT APPROACH CONDITIONS

LOCK & DAM 22

1. *Upstream Approach*

Downbound tows approaching Lock 22 experience strong outdraft currents 0.8 miles upstream of the lock. The outdraft current pushes the front of the barge away from the guidewall and towards the dam. To counteract this crosscurrent, approaching tows sweep out towards the Illinois bankline and cut back across the channel to the lock guidewall. At higher river flows, outdraft conditions become worse. Experienced tow pilots have stated that maximum outdraft conditions occur when the dam first goes out of operation (at a flow of 162,000 cfs). Under these conditions the tow uses a flanking maneuver toward the Missouri bankline or they use a helper boat to assist them into the lock chamber. According to industry, approximately 80% of approaches require the use of the helper boat due to hazardous outdraft conditions in the pool.

Wingdam rehabilitation in pool 22 was conducted in 1995 to reduce the need for dredging in problem areas of the pool. After these improvements were made, scour developed in the pool leading to localized dredging in the tailwater. A mooring cell, located approximately 0.7 miles upstream of the lock, has been partially undermined due to scour and is presently leaning. The cell foundation has been re-grouted to stabilize the structure, yet tow operators are still cautious about using the cell. If the cell is not used, barges must wait for lockage on the Missouri shore near RM 303, approximately 2.5 miles upstream of the lock.

2. Downstream Approach

Upbound tows approaching Lock 22 navigate along the Missouri bankline. In recent years, shallow depths and dredging operations have been a concern to industry. An underwater rock outcropping exists that limits the depth at which this area can be dredged. The frequent dredging in the downstream lock approach may be related to the increased scour in the pool following the 1995 wingdam rehabilitation. A new bathymetric survey was completed in February 2000 that indicated the riverbed is stabilizing and future dredging requirements in the area will likely decrease.

LOCK & DAM 25

1. Upstream Approach

Dam 25 creates a wide, shallow pool upstream of the dam with numerous islands and backwater areas ranging from less than a foot to several feet deep. The navigation channel meanders through the pool making numerous crossings. The channel favors the left descending bank approximately 8,000 ft upstream of the dam, makes a crossing toward the right bank between 6,000 and 4,000 ft upstream of the dam, and approaches the lock along the right bank. The crossing is created and maintained by a large underwater stump field. The stump field is a pre-impoundment island that acts as a structure that forces flow away from the Illinois bankline and into the lock approach along the Missouri bank.

Flow from along the right bank moves across the upper approach toward the dam, creating a serious outdraft near the upstream end of the guard wall. Due to the alignment of the channel and crosscurrents, navigation conditions for downbound tows approaching the lock are extremely difficult. An L-head dike was constructed along the right bank, approximately 0.6 miles upstream of the lock, to improve navigation conditions. Although the dike may have improved navigation conditions, a helper boat is still used most of the time to overcome the outdraft currents and to align the tow with the guide wall. Maximum outdraft conditions occur when the dam is out of operation (at flows greater than 135,000 cfs). Under these conditions, velocities in the lock approach are greatest.

2. Downstream Approach

The right bank immediately downstream of the lock juts riverward and forces downbound tows to make a hard left turn as they exit the lock to enter the main river channel. Upbound tows navigate along the left bank to a point about 3,000 ft downstream of the dam, and then cross to the lock.

SECTION 3 - SITE EVALUATION PROCEDURE

DESCRIPTION

A hybrid modeling approach utilizing prototype data collection, numerical models, and micro models was used to evaluate approach conditions at Locks & Dams 22 and 25. While physical models are best suited for studying navigation conditions, they have a high cost and do not have the flexibility of numerical and micro models for making quick changes in bank alignment, bathymetry, and implementing project alternatives. The hybrid modeling approach was designed to take advantage of the strengths of each modeling tool.

Numerical models are relatively inexpensive tools that provide a good, quantitative estimate of channel velocities and depths that can be used to assess and compare alternatives. In addition, the numerical models yield output that has proven useful in evaluating the environmental effects of project alternatives using a habitat unit based approach. However, the numerical model used in this investigation is a fixed bed model that does not account for scour or deposition resulting from a given set of improvements.

Micro models are extremely small-scale, movable bed, physical models. Also relatively inexpensive (compared to large-scale physical models), the micro model provides an estimate of bed response and allows for flow visualization of a given alternative. Micro models are also good communication tools for discussing ideas with navigation industry and natural resource agency representatives. However, due to the scale used in the models, quantitative estimates of channel velocities are not possible.

Once final alternatives were chosen, large-scale physical models should be used to verify the performance of the recommended measures utilizing a model towboat.

The hybrid modeling approach allowed for feedback between the models providing a measure of consistency between results. A more detailed description of each modeling tool and the prototype data collection effort follows.

PROTOTYPE DATA COLLECTION

Prototype velocity and depth measurements were taken using an Acoustic Doppler Current Profiler (ADCP) and sounding equipment at selected river cross-sections. The ADCP measures water velocities at varying depths in the water column along a river transect. The field data were reduced to depth-averaged velocities for comparison to the numerical model results.

1. Lock & Dam 22

The bathymetric survey for Lock & Dam 22 was taken on July 20, 1998. Due to dredging operations in the tailwater before and after this time and the need for more detailed information, an additional tailwater survey was conducted on Feb 23, 2000. Hydrographic survey ranges were spaced approximately 200 ft apart. ADCP velocity measurements were taken on Dec 9-10, 1998, at ten main channel transects, at two side channel transects, and around seven wingdams.

2. Lock & Dam 25

Current and historical bathymetric information were used to evaluate the bed response of the Lock and Dam 25 models. Hydrographic surveys from 1947, 1977, 1982, 1986, 1993, 1995, and 1997 were used along with historical aerial photography to assess the general hydrologic and sediment transport characteristics that have existed in the upper and lower approaches to Lock & Dam 25. ADCP velocity measurements were conducted on Oct. 28-29, 1998 in the vicinity of the dam to mile 243.5. Detailed measurements were recorded near the area of concern.

NUMERICAL MODELS

The numerical model used for this effort was RMA2 (RMA – River Management Associates). RMA2 is a numerical model that solves the two-dimensional, vertically averaged Reynolds form of the Navier-Stokes equations for free surface flow. The model computes the water surface elevations and flow velocities at nodal points of a finite element mesh representing the river. The Surface-Water Modeling System (SMS) was used to develop the finite element mesh and to display model results.

The RMA2 model is capable of modeling secondary flow conditions such as outdraft and eddies, however, the model's ability to represent three-dimensional flow conditions such as that occurring through the submerged ports of a guard wall or in the immediate vicinity of the dam gates (when the dam is in operation) is limited.

At each of the lock and dam sites, finite element meshes were constructed which described the bathymetry (bottom surface geometry) and adjacent topography of the sections of river being modeled. The goal of the modeling effort was to reproduce a minimum of two miles of the river both upstream and downstream of the dam; however, the actual extent of the models was based on available bathymetric information, program constraints, and the presence of side channels. Two models were constructed for each lock and dam, one for the headwater and one for the tailwater. This is necessary as the flow through the dam structure could not be accurately represented within the numerical mesh, and therefore was modeled as a known boundary condition. Hydrographic survey data in the form of XYZ coordinates were input into SMS as the basis for construction of the finite element meshes. Figure 1 shows the headwater finite element mesh constructed for Lock & Dam 22.

Model boundary conditions are typically entered as an incoming (upstream) flow rate and a downstream water surface elevation. Also specified are roughness (Manning's n) and turbulent exchange parameters for each element of the model.

1. Description of Lock & Dam 22 Numerical Model

The Lock & Dam 22 numerical model investigated navigation conditions between RM 299.6 and 304.4. This represents an area from 3.2 miles upstream of the dam to 1.6 mile downstream of the dam. The geographic extent of the Lock & Dam 22 numerical

Lock & Dam 22
Headwater Numerical Model

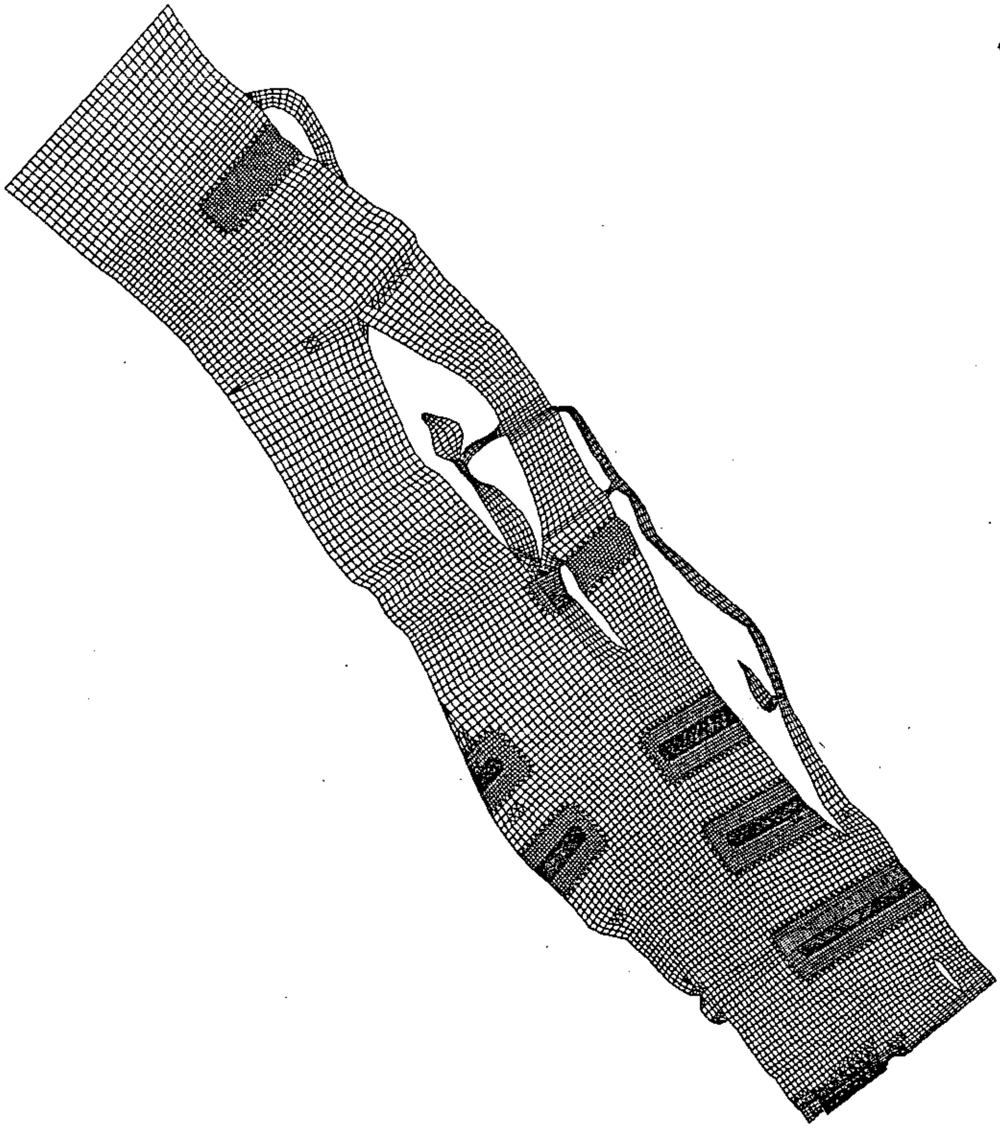


Figure 1

model is shown in Figure 2. The baseline headwater model consisted of 2,666 elements and 7,493 nodes; the tailwater model consisted of 2,803 elements and 7,541 nodes.

Bathymetric information, used to create the model grid, was obtained from the Rock Island District, and was based on 1998 soundings. Additional bathymetric information for areas around the wingdams was collected at the same time the prototype velocity measurements were taken. Topographic information was obtained from 1:24000 USGS Quad Maps. Existing bathymetric conditions above Lock & Dam 22 are shown in Figure 3.

Calibration of the numerical models was accomplished through comparison with prototype measurements of velocities and water surface profiles. Computed water surface slopes were compared to historical water surface slopes (for known flow rates) between the Lock & Dam 22 pool gage and the nearest upstream gage at Hannibal, MO (RM 309.0). The tailwater model was calibrated to a flow of 92,000 cfs, and the pool model was calibrated to a flow of 90,000 cfs. These flow rates correspond to the river discharge at the time of the ADCP survey.

The final selected Manning's n values for the selected material types were: 0.022 for the open channel, 0.030 for the side channels, 0.060 over the submerged wingdams, and 0.080 for the wooded terrestrial areas. Turbulent exchange parameters (eddy viscosities) were automatically computed and assigned by the hydraulic model using a Peclet number of 20.

River conditions ranging from a typical overwintering flow (median flow for December through February) to the 5-year event were simulated to examine navigation conditions over a wide range of flows. Modeled flows and boundary conditions are summarized in Table 1, below.

TABLE 1: Lock & Dam 22 Model Flows and Boundary Conditions

Flow (cfs)	Significance of Flow	Headwater Elevation	Tailwater Elevation	Elevation at Lower Model Extent
52,000	Typical Overwintering Flow	459.5 ft msl	451.4	451.2
80,000	50% Duration for Navigation Season	459.5	453.3	453.0
92,000	Tail Calibration Flow (90,000 Pool)	459.5	454.3	453.9
162,000	Maximum Flow Prior to Spillway Use	459.5	459.1	458.1
245,000	20% Annual Exceedence (5-year Event)	463.7	464.4	463.9

2. Description of Lock & Dam 25 Numerical Model

The Lock & Dam 25 numerical model investigated navigation conditions between RM 238.9 and 246.7. This represents an area from 5.2 miles upstream of the dam to 2.6 miles downstream of the dam. The geographic extent of the Lock & Dam 25 numerical model is shown in Figure 4. The baseline headwater model consisted of 9,550 elements and 27,521 nodes. The tailwater model consisted of 8,206 elements and 24,158 nodes.

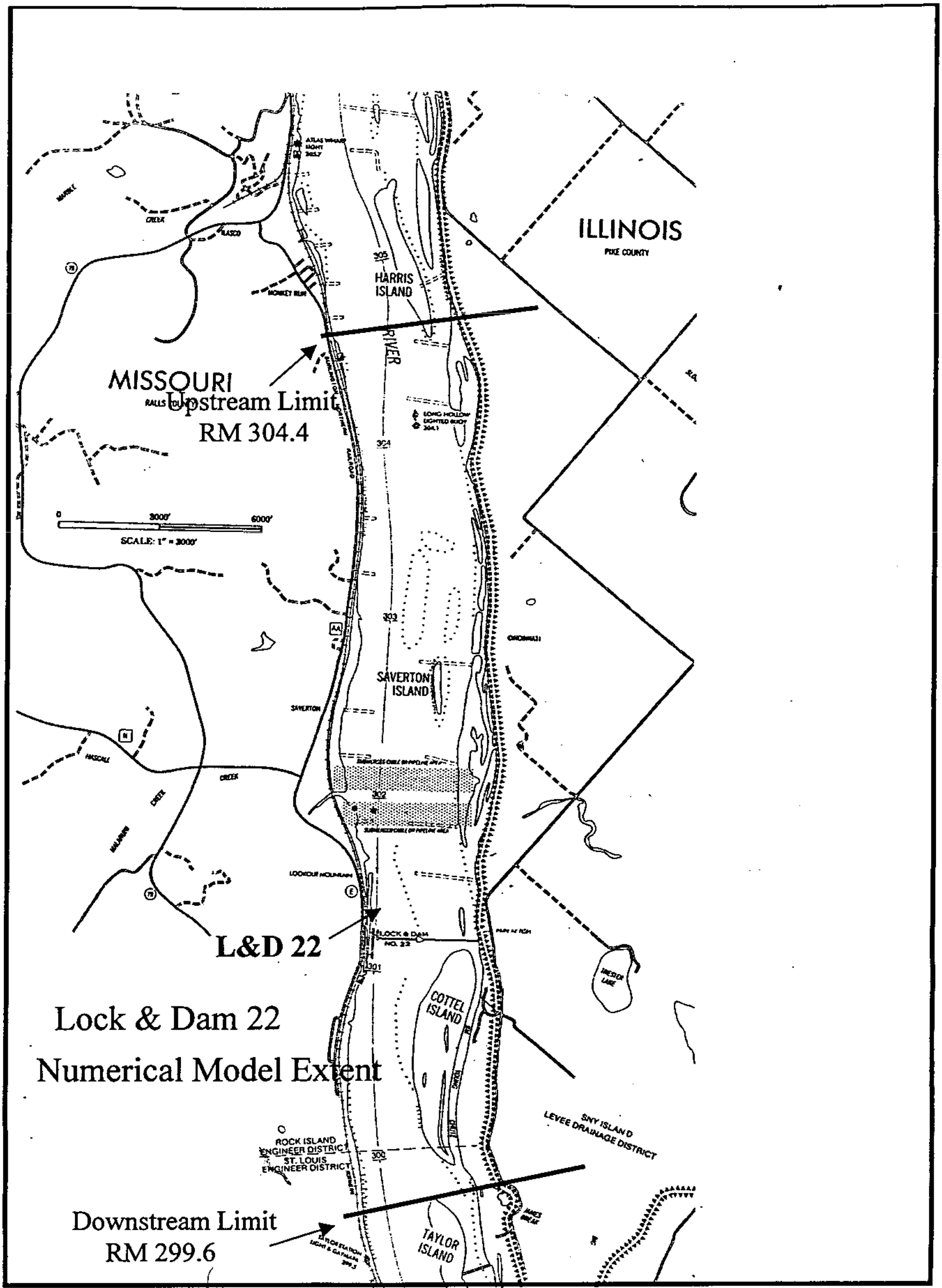

ILLINOIS
PIKE COUNTY
HARRIS ISLAND
RIVER
MISSOURI
Upstream Limit
RM 304.4
SCALE: 1" = 3000'
SAVERTON ISLAND
SAVERTON
LOOKOUT MOUNTAIN
LOCK & DAM NO. 22
L&D 22
COTTEL ISLAND
Lock & Dam 22
Numerical Model Extent
SNY ISLAND LEVEE DRAINAGE DISTRICT
ROCK ISLAND ENGINEER DISTRICT
ST. LOUIS ENGINEER DISTRICT
Downstream Limit
RM 299.6
TAYLOR ISLAND

Figure 2

Lock & Dam 22
Headwater Numerical Model
Existing Bathymetry

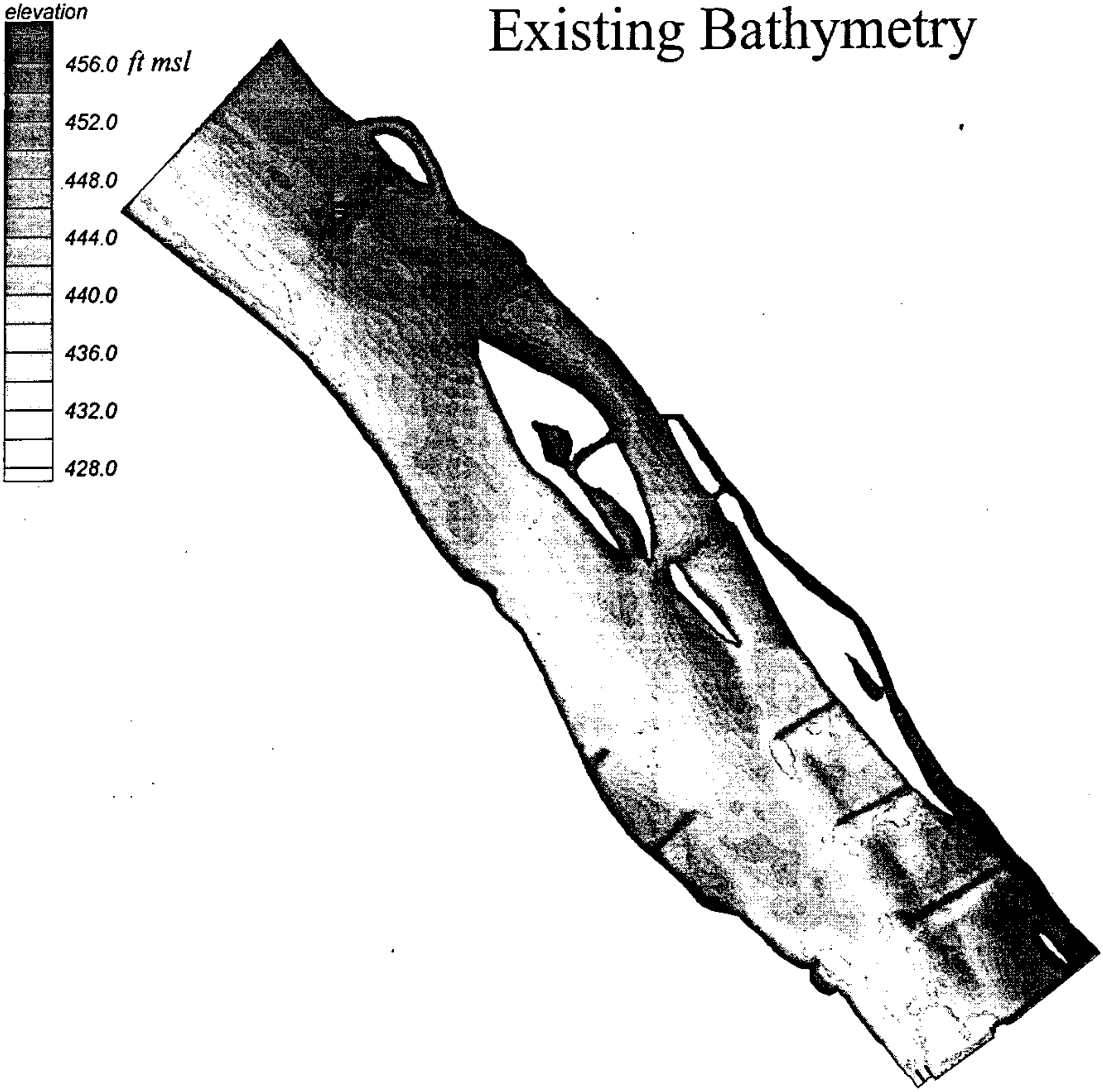


Figure 3

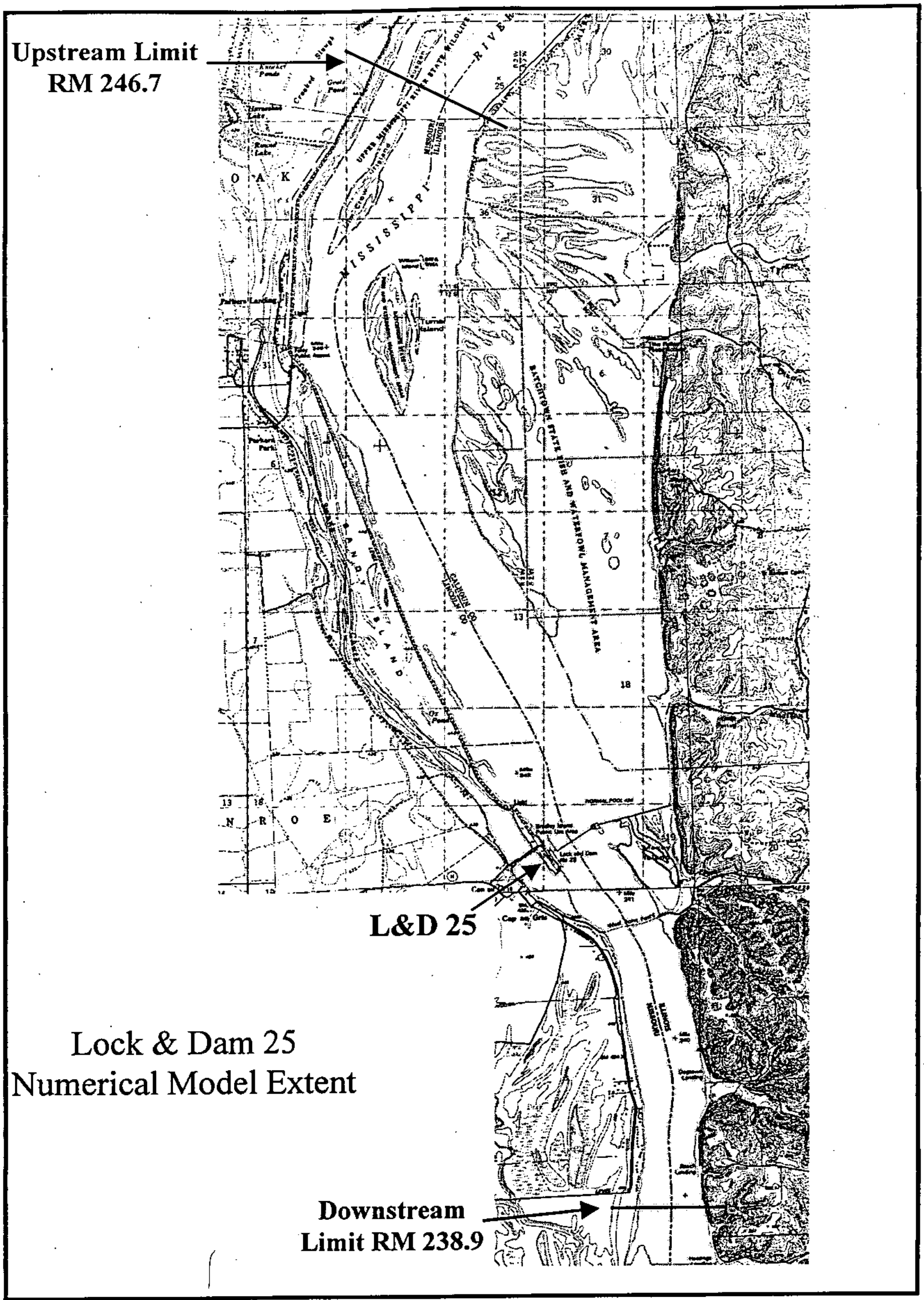

Upstream Limit
RM 246.7
L&D 25
Lock & Dam 25
Numerical Model Extent
Downstream
Limit RM 238.9
MISSISSIPPI
RIVER

Figure 4

Bathymetric information was obtained from the St. Louis District, and was based on 1997 soundings. Additional bathymetric information for the backwater area near the outlet of Sandy Chute was obtained from the Upper Midwest Environmental Sciences Center (formerly the Environmental Management Technical Center). Topographic information was obtained from 1:24000 USGS Quad Maps. Existing bathymetric conditions above Lock & Dam 25 are shown in Figure 5.

Three different material types were used in the model: open channel, aquatic and terrestrial grasses, and wooded terrestrial. Land Use/Land Cover information (developed using 1989 aerial photography by the Upper Midwest Environmental Sciences Center) was used to delineate wooded areas and the extent of aquatic plant beds.

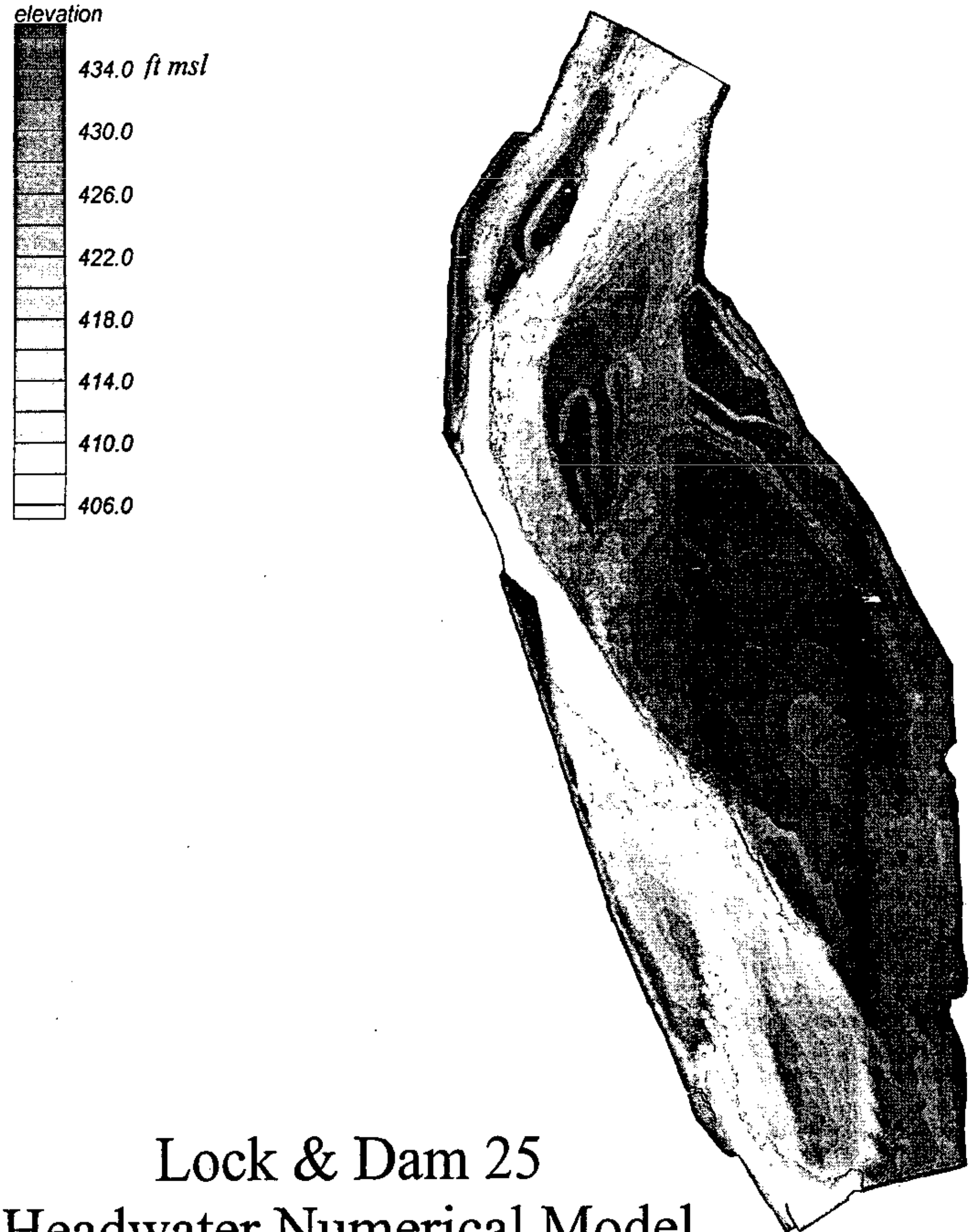
Calibration of the numerical models was accomplished through comparison with prototype measurements of velocities and water surface profiles. Computed water surface slopes were compared to historical water surface slopes (for known flow rates) between the Lock & Dam 25 pool gage and Mosier Landing (next upstream gage, RM 260.3) for the headwater model, and the Lock & Dam 25 tailwater gage and Dixon Landing (next downstream gage, RM 228.3) for the tailwater model. Results of these comparisons indicated that the numerical model satisfactorily reproduced conditions in the prototype based on the available data.

The final, selected Manning's n values for the three material types were: 0.025 for the open channel, 0.040 for aquatic and terrestrial grasses, and 0.095 for the wooded terrestrial areas. Turbulent exchange parameters (eddy viscosities) were automatically computed and assigned by the hydraulic model using a Peclet number of 20.

River conditions ranging from a typical overwintering flow (median flow for December through February) to the 5-year event were simulated to examine navigation conditions over a wide range of flows. Table 2, below, summarizes the modeled flows and boundary conditions.

TABLE 2: Lock & Dam 25 Model Flows and Boundary Conditions

Flow (cfs)	Significance of Flow	Headwater Elevation	Tailwater Elevation	Elevation at Lower Model Extent
55,000	Typical Overwintering Flow	433.0 ft msl	422.5	422.0
80,000	50% Duration for Navigation Season	431.5	423.6	423.0
138,000	Maximum Drawdown	429.5	429.0	428.0
202,000	Maximum Flow Prior to Spillway Use	434.0	433.5	432.4
252,000	5-year Event (20% Annual Exceedance)	437.1	436.6	435.5



Lock & Dam 25
Headwater Numerical Model
Existing Bathymetry

Figure 5

MICRO MODELS

Micro models are small-scale physical models capable of sediment transport and showing bedform trends. The model is constructed from dense foam using aerial photographs and is inserted into a standard micro model flume (tabletop sized). Figure 6 is a photograph of the Lock & Dam 25 Micro Model. The bed material used in the model has five grain sizes of a granular plastic urea, Type II, with a specific gravity of 1.23. A computer interfaced electronic control valve and submersible pump regulates flow into the model. The pump re-circulates sediment within the model to maintain sediment equilibrium. After bedforms have stabilized, the flow is turned off, the model is slowly drained, and the bedforms are digitized. Stages and wingdam crests are checked with a three-dimensional point digitizer, and the overall bed bathymetry is measured and recorded with a three-dimensional laser digitizer. Surface current patterns are captured using time exposure photography of floating particles carried by the currents. The Rock Island District completed the micro model for L&D 22, and the St. Louis District completed the micro model for L&D 25. The micro models simulated only open-river conditions (dam out of operation), since this is when the outdraft currents are the most severe. Project alternatives were tested under steady state flow conditions.

1. Description of the Lock & Dam 22 Micro Model

The L&D 22 micro model reproduced the reach of the Mississippi River from RM 298.3 to RM 309.6. The horizontal scale of the model was 1 inch = 800 feet, or 1:9600, and the vertical scale was 1 inch = 50 ft, or 1:600, for a 16 to 1 distortion ratio. The upper 4.5 miles served as an entrance condition to stabilize the bedforms and the flow of the model. Model parameters (water discharge, sediment load, floodplain slope, entrance conditions, and screen material at the dam) were adjusted until the model trends matched the bathymetry of the 1998 hydrographic survey. At this point the model was considered calibrated and changes were made to investigate various alternatives.

2. Description of the Lock & Dam 25 Micro Model

The Lock and Dam 25 Micro Model reproduced a 10-mile reach of the Mississippi River between River Miles 239 and 249. The horizontal scale of the model was 1 inch = 700 feet, or 1:8400, and the vertical scale was 1 inch = 50 feet, or 1:600, for a 14 to 1 distortion ratio. The model was constructed from dense foam using 1994 aerial photography and was inserted into a standard micro model flume. Both current and historical hydrographic survey data were used to assess the general hydrologic and sediment transport characteristics that have existed in this reach of river. This data was used to calibrate the model according to the current bed geometry of the river. Calibration involved adjustment of water discharge, sediment load, floodplain slope, and entrance conditions. These parameters were refined until the measured bed response of the model was similar to that of the prototype. Once a favorable comparison of the model surveys was made with prototype surveys, the model was considered calibrated. The resultant bathymetry of this bed response served as both the verification and the base test of the micro model. The effectiveness of each design alternative was evaluated by comparing the resultant bed configuration and flow patterns to that of the base condition.

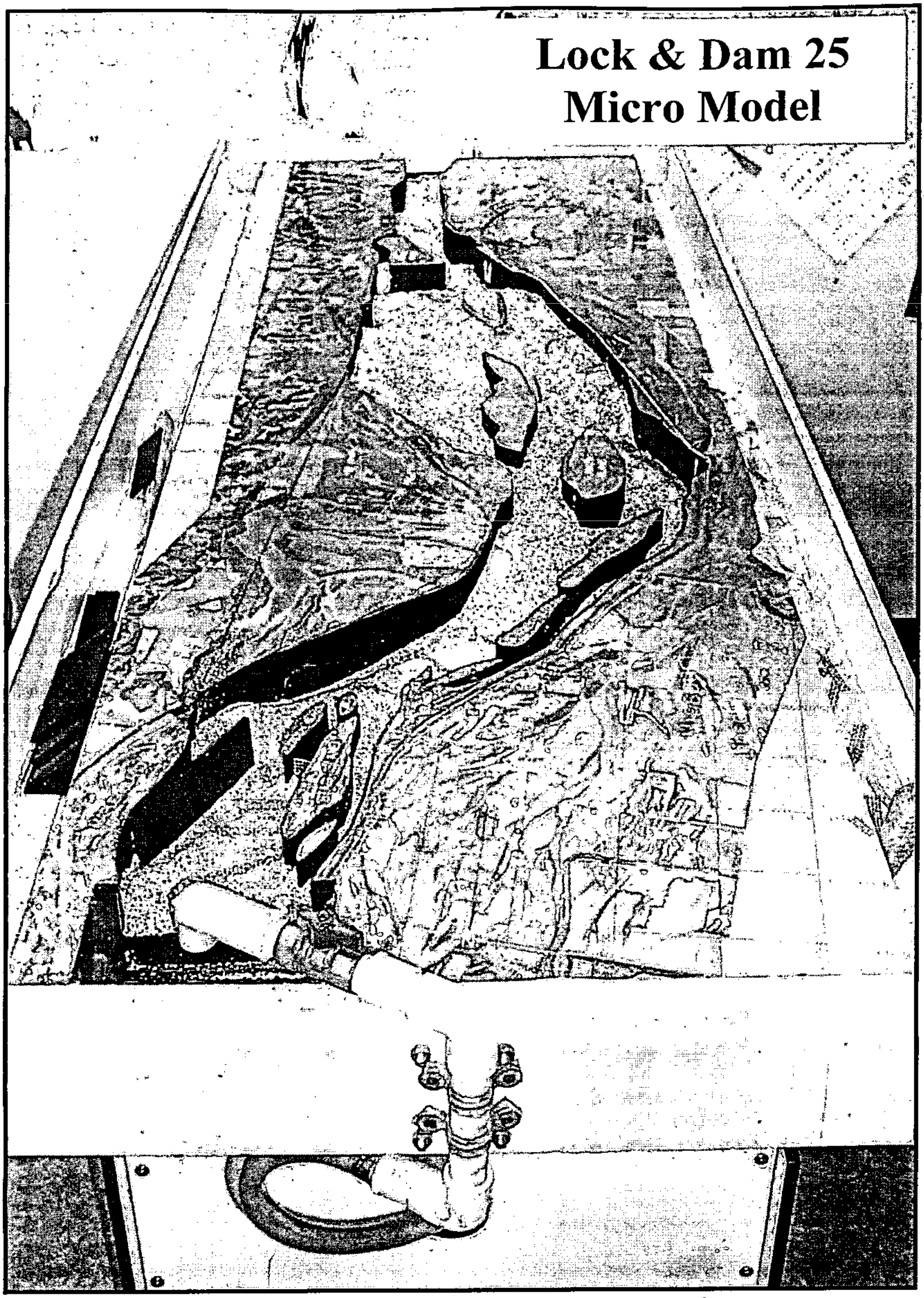


Figure 6

LARGE-SCALE PHYSICAL MODELS

Large-Scale physical models were previously constructed and tested, for Locks & Dams 22 and 25, as part of an evaluation of approach conditions for various alternative lock locations under investigation as part of the Upper Mississippi River – Illinois Waterway System Navigation Study. Physical models are hydraulically scaled down replications of a river that preserve the flow characteristics of the river. The L&D 22 and 25 models were of fixed-bed type with the overbank areas and the channels molded of sand-cement mortar to sheet metal templates set to the proper grade. The model was built to an undistorted linear scale of 1:120, model to prototype. This scale allows accurate reproduction of velocities, eddies, and crosscurrents that affect navigation.

Velocities and current directions are 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 radio-controlled model towboat and 15-barges is used to evaluate and demonstrate the effects of currents on tows approaching and exiting the lock. The speed and rudders of the tow are remote-controlled, and the towboat can be operated in forward and reverse at scale speeds comparable to those used by towboats on the Upper Mississippi River. The video tracking system is also used to track the path of the model tow.

The Lock & Dam 22 physical model reproduced about 3.5 miles of the Upper Mississippi River and adjacent overbank areas from about 10,700 feet upstream to about 7,700 feet downstream of the dam. The channel portion of the model was molded to conform to hydrographic survey information collected in October 1993.

The Lock & Dam 25 physical model reproduced about 3.7 miles of the Upper Mississippi River and adjacent overbank areas from about 9,800 feet upstream to about 9,600 feet downstream of the dam. The channel portion of the model was molded to conform to hydrographic survey information collected in 1994.

Prior to implementation of the approach improvement plans described herein, large-scale physical modeling should be performed to verify the performance of the recommended measures.

SECTION 4 – ALTERNATIVES CONSIDERED

LOCK & DAM 22

The micro model was used in conjunction with the numerical models to evaluate six dikefield alternatives at the upstream approach to lock 22. The micro model provided flow patterns and bedform changes, and the numerical models produced velocity changes resulting from each alternative. A summary of the six alternatives is shown on Table 3 below. Figure 7 shows the location of the existing wingdams.

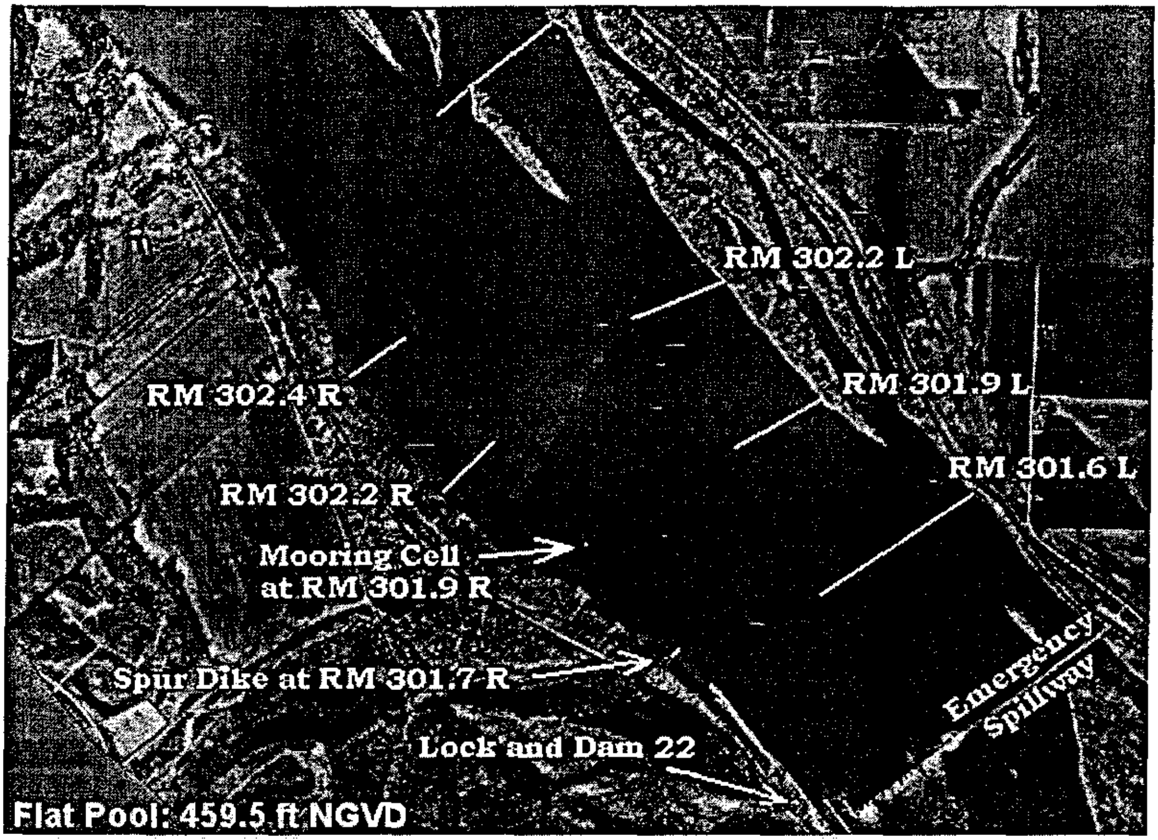


Figure 7. Existing conditions, Lock & Dam 22

TABLE 3: Summary of Initial Dikefield Alternatives for L&D 22

Alternative A	Raise existing elevations of dikes RM 302.2R and RM 302.4R from 456.6 ft to 461.5 ft (2 ft above flat pool).
Alternative B	Same as Alt. A, but add L-Head dike at elevation 461.5 ft (2 ft above flat pool). L-Head extends 600 ft from the bankline at RM 301.9R and is tied into the existing mooring cell, then extends 400 ft towards the lock
Alternative C	Same as Alt. B, but adds L-Head dike off the tip of the island at RM 303.6. The L-Head dike directs currents towards the dam and reduces cross-currents off of the island. The crest elevation of the L-Head dike is at 461.5 ft
Alternative D	Same as Alt. C, but adds spur dike at RM 302.8, angled slightly upstream. Spur dike provides gradual transition of flow towards the main channel. The crest elevation of the spur dike is at 456.5 ft
Alternative E	*Raise existing elevations of dikes RM 302.2R and RM 302.4R* from 456.6 ft to 461.5 ft (2 ft above flat pool). Extend these two dikes 300 ft and 200 ft, respectively. Add L-Head dike at RM 301.9R, 700 ft from bank and 500 ft towards the lock, *with a crest elevation of* 461.5 ft.

Alternative F Raise existing elevations of dikes RM 302.2R and RM 302.4R from 456.6 ft to 461.5 ft (2 ft above flat pool). Extend dike at RM 302.4 by 200 ft.

Model results were presented to barge industry representatives (RIAC), district operations personnel, district biologists, and a representative from the U.S. Fish & Wildlife Service at a meeting on Feb 9, 2000. The outdraft problem at the upstream approach to the lock was discussed as well as dredging concerns in the tailwater. Based on discussions of the alternative plans presented, a modified plan was developed and tested. The final plan was chosen after evaluating thirteen variations of the modified plan with the numerical model. A summary of the numerical model tests is shown in Table 4, below. Wingdam locations are shown in Figure 7, above. Details of the recommended plan are given in Section 5 (Recommended Alternative) of this Appendix.

TABLE 4: Numerical Model Final Design Summary for L&D 22 approach

	OPTIONS TO DESIGN ALTERNATIVES			
MAIN FEATURE OF DESIGN ALTERNATIVE	**Shorten Left-Bank Dikes**			**V-Notch in Emergent Dike**
	RM 301.6	RM 301.9	RM 302.2	
Remove Stub Dike at RM 301.7 R (note: all alternatives remove this dike)	**100 ft**	-	-	-
Add Submerged Wingdam (3 ft below flat pool) from bankline at RM 301.9 R to the mooring cell	**100 ft**	-	-	-
Add Emergent Wingdam (2 ft above flat pool) from bankline at RM 301.9 R to the mooring cell	**100 ft**	-	-	-
	200 ft	**100 ft**	-	-
	300 ft	**200 ft**	**100 ft**	-
	100 ft	-	-	**60 ft notch, 6 ft deep**
Add Emergent L-Head Dike (2 ft above flat pool) from bankline at RM 301.9 R to the mooring cell, then 400 ft towards the lock	**100 ft**	-	-	-
Add Emergent Wingdam (2 ft above flat pool) from bankline at RM 301.9 R extending 100 ft beyond the mooring cell	**100 ft**	-	-	-
	300 ft	**200 ft**	**100 ft**	-
	300 ft	**200 ft**	**100 ft**	**60 ft notch, 6 ft deep**
	300 ft	**200 ft**	**100 ft**	**25 ft notch, 6 ft deep**
Add Emergent Wingdam (2 ft above flat pool) from bankline at RM 301.9 R extending 200 ft beyond the mooring cell	**100 ft**	-	-	-
	300 ft	**200 ft**	**100 ft**	-

LOCK & DAM 25

After the model was calibrated, the effectiveness of eleven remedial design solutions was tested in the model. The overall effectiveness of each design was qualitatively determined by analyzing the resultant bathymetry and flow patterns and by comparing it with those of the base test. The process also involved an evaluation of the economic feasibility and environmental ramifications of each alternative, as well as coordination with lock and dam personnel, river industry tow pilots, and other engineers during an August 8, 1999 meeting meetings held at the St. Louis District's Applied River Engineering Center. Figure 8 shows the location of the existing wingdams. A summary of the eleven alternatives is shown in Table 5, below:

TABLE 5: Summary of Design Alternatives for L&D 25

Alternative 1	Removed trail from L-Dike 242.1R and lengthened dike 450 feet.
Alternative 2	Added an L-Dike at mile 242.3R with a dike length of 700 feet and trail length of 700 feet.
Alternative 3	Lengthened Trail on L-Dike 242.1R 1200 feet to the downstream bankline.
Alternative 4	Rebuilt Dike 242.8R to a length of 900 feet and at an elevation of 444 feet or +14 feet referenced to minimum pool.
Alternative 5	Added 1250 foot dike at mile 243.0R.
Alternative 6	Added structures from Alternatives 2 and 5 together.
Alternative 7	Removed dikes 244.0R, 243.8R, 243.5R, 242.9R, and 242.8R. Added 5 chevron structures in mid channel at an elevation of +2 feet minimum pool at river miles 243.9, 243.7, 243.4, 243.2, and 242.9.
Alternative 8	Same as Alternative 4, but added a 1300 foot dike on the Illinois bankline at mile 243.4L.
Alternative 9	Same as Alternative 4, but added 4 chevron structures in mid channel at miles 243.9, 243.7, 243.4, and 243.2.
Alternative 10	Removed half of the submerged island located upstream of the Dam and towards the Missouri bankline.
Alternative 11	Removed the entire submerged island located upstream of the Dam.

SECTION 5 – RECOMMENDED ALTERNATIVE

LOCK & DAM 22

After the meeting with industry and the review of subsequent design alternatives, a final recommended plan was chosen. In this design, a 550 ft emergent wingdam would be added from the right bank at RM 301.9R to the mooring cell and extended 100 ft beyond it. In addition, the spur dike at RM 301.7 R would be removed, and the lengths of the three left-bank wingdams in the pool (RM 302.2, 301.9, and 301.6) would be reduced by 100, 200, and 300 ft, respectively. Figure 9 shows the location of the recommended measures.

Figure 8

Figure 9. Recommended Plan: Lock & Dam 22

The model results showed that bed response would be in localized areas, mainly consisting of scour off the ends of the wingdams. The recommended plan eliminates the hazardous outdraft currents in the upstream approach by dramatically decreasing the velocities behind the wingdam. The area of calm water created behind the wingdam can be used as a staging area for barges as they wait for lockage, which may provide additional time savings. The Rock Island District is currently addressing the potential environmental impacts of the recommended plan. Mussel surveys will be performed to identify potential impacts to threatened or endangered species as a result of the project.

LOCK & DAM 25

After team meetings, design alternative 4 was selected as most effective at improving navigation conditions in an environmentally friendly manner. In this design, a 900-foot long dike was added near mile 242.8R at an elevation of +14 feet referenced to minimum pool. An old submerged pile dike currently exists in this naturally depositional area. Figure 10 shows the location of the recommended measures. The model showed that the design had minimal effect on the bed response and bathymetry as compared to the base test. Flow visualization images showed vast improvement to the flow patterns near the lock chamber. The base test images revealed high currents near the lock chamber are directed away from the lock and toward the dam. The dike design created a downstream "shadow" of slow velocity currents near the lock chamber. An area of slack water between the dike and the lock chamber will greatly improve the safety of downbound tows entering the lock chamber.

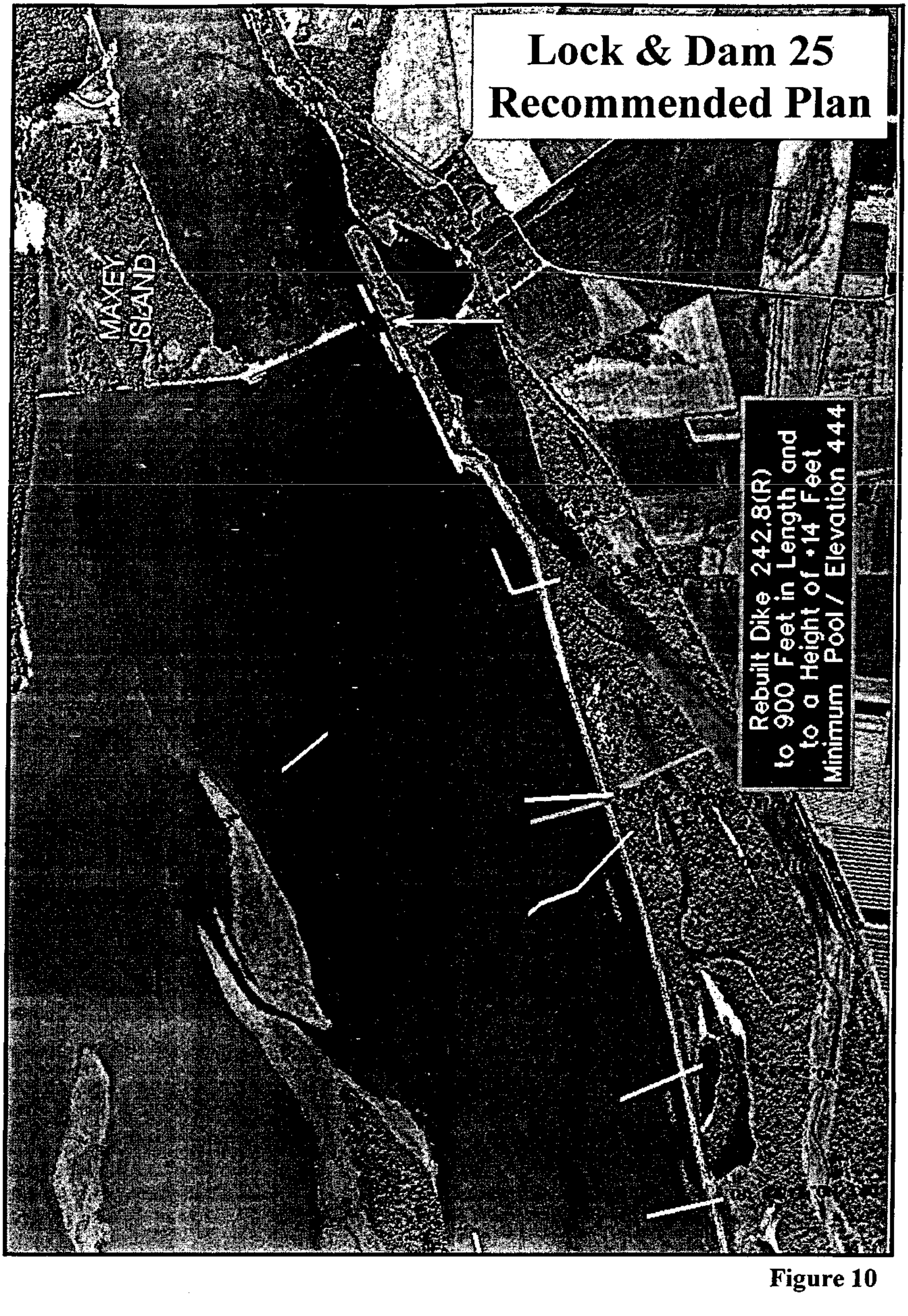

Lock & Dam 25
Recommended Plan
MAXEY ISLAND
Rebuilt Dike 242.8(R)
to 900 Feet in Length and
to a Height of +14 Feet
Minimum Pool / Elevation 444

Figure 10

REFERENCES

Wooley, Ronald T. 1997. Navigation Conditions at Lock and Dam 25, Mississippi River: Hydraulic Model Investigation. Prepared for U.S. Army Engineer District, Rock Island by Waterways Experiment Station, Vicksburg, MS. 106 pp.

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Appendix D

Geotechnical

Appendix D
Geotechnical

Upper Mississippi River – Illinois Waterway
System Feasibility Study

Engineering Appendix of Site Specific Feasibility Report:

Guidewall Extensions with Powered Traveling Kevels,

Approach Improvements,

Lock 22

Mississippi River

DESIGN DOCUMENTATION REPORT
FOR
GUIDEWALL EXTENSIONS with POWERED TRAVELING KEVELS
APPROACH IMPROVEMENTS

LOCK 22
MISSISSIPPI RIVER
GEOTECHNICAL APPENDIX

TABLE OF CONTENTS

LIST OF PLATES

DESIGN DOCUMENTATION REPORT
FOR
GUIDEWALL EXTENSIONS with POWERED TRAVELING KEVELS
APPROACH IMPROVEMENTS

LOCK 22
MISSISSIPPI RIVER
GEOTECHNICAL APPENDIX
SECTION 1 - PURPOSE AND SCOPE

PURPOSE

The purpose of this appendix is to illustrate and define the foundation conditions for the installation of upstream and downstream guidewall extensions with powered traveling kevels. These are approach improvements to Lock 22 on the Mississippi River.

SCOPE

The scope of the study included a comprehensive review of published data especially portions of the hydropower feasibility report, reference 1., dam stability computations periodic inspection reports, analysis of recent and dated boring logs, and conferences with associated personnel.

SECTION 2 – LOCATION AND GEOLOGY OF STUDY AREA

LOCATION

Lock and Dam 22 is located on the Mississippi River about 9 miles downstream from Hannibal, Missouri, and 301.1 miles upstream from the mouth of the Ohio River. The lock and dam was constructed during the period of December 1933 to July 1938. Plate A-1 shows the site location.

GEOLOGY

The project lies within the Till Plain Section of the Central Lowlands Province of the Interior Plains.

The floodplain of the Mississippi River along this reach was built on the glaciofluvial filling of a much deeper valley. Bedrock elevation varies from 433 MSL at the lock to elevation 420 MSL at the East End of the dam. The bottom of this preglacial valley lies at depths of up to 100 feet or more below the present riverbed. The floodplain is towered on either side by bluffs of 150 to 200 feet above the valley. Mississippian age limestone outcrop in the bluffs and in the valleys of tributaries to the Sny River in this vicinity. Outliers of such rocks occur in the area between the headwaters of these streams and the Mississippi River bluffs. The uplands are covered with deposits of the Pre-Illinoian glacial stage. These glacial tills are covered with varying thicknesses of loess.

SECTION 3 –CONSTRUCTION HISTORY

GENERAL

Lock and Dam 22 was constructed under two separate contracts. Work commenced on the lock on 28 December 1933 and was completed on 21 May 1935. Construction of the dam, consisting of 3 roller gates, 10 tainter gates, a 200 foot –long storage yard, and approximately 1,600 feet of submersible earth dike, was started on 21 September 1936 and was accepted by the Government on 25 July 1938.

FOUNDATIONS

All construction at the damsite was founded on bedrock. Very little overburden, most of which consisted of sand, was present near the lock, the amount increasing as the Illinois bank of the river was approached. The rock is limestone of the Kimmswick and Plattin Formations. The Kimmswick is believed to be quite thin at this location, and where the depth to limestone is the greatest, the surface bedrock is probably the Plattin Formation. During construction, some shale seams were encountered. These seams varied in thickness, with a maximum thickness of 12 inches. Construction records indicated that these seams were cleaned out and grouted successfully.

The rock encountered during construction of the lock was described as dense grey limestone of excellent quality for foundation purposes. Segregations of calcite crystals and areas of iron oxide discoloration were found at intervals throughout the deposit. No evidence of tilting of the deposit was apparent, the bedding planes, in general, were horizontal and divided the deposits into laminations varying in thickness from a few inches to 3 feet. Some minor faults were encountered, but these were, for the most part, healed with calcite.

SECTION 4 – FOUNDATION EXPLORATIONS

Original construction borings for the lock and dam design were obtained prior to 1933. Plate A-2 shows these original borings in plan and section. With the exception of a few clay layers in some of these original borings, the lithology is, for the most part, repeated in the new, 1998, borings. In general, all borings show some fine to medium sands with occasional gravels underlain by either a thin clay layer or more likely a medium to hard shale, which varies in thickness from seams to a few feet. In nearly all cases, this is underlain by a hard medium to massive bedded limestone of competent character. Plate A-1 shows the 1998 borings in plan and Plates A-3 through A-6 show the logs and geologic sections. The engineering characteristics of both the unconsolidated materials and bedrock are described in Section 5 below.

The exploratory boring program for 1998 was accomplished from an offshore floating plant. Drilling was accomplished through a door in the loading ramp at the front of the barge. Drilling equipment consisted of a B57 Mobile truck mounted rotary drill. Four and ¼ -inch ID hollow stem (HS) augers were used to case drill holes from the surface to bedrock. Overburden samples were obtained using a 2-inch diameter split spoon sampler driven by a Mobile Auto Hammer. Blow counts were recorded for standard penetration, N value determination. Rock Samples were obtained with a Christensen Mining Products NX wireline system producing 1 and 7/8-inch core runs of up to 5 feet. All drilling depths were measured from the barge deck surface (top of hole), which was two feet above water surface. River pool and tail gage readings were recorded daily. Top of hole elevations were based on these and are referenced to MSL 1912 fourth gage adjusted Datum.

SECTION 5 – ENGINEERING PROPERTIES OF THE FOUNDATION

UNCONSOLIDATED DEPOSITS

As described in the geology section, the unconsolidated materials consist of glaciofuvial materials which contain sands of fine to medium grain size, some gravels, and to a lesser extent a few clays. Laboratory tests were performed on these materials and gradations are shown on Plates A-7 through A-12.

PERMEABILITY

Glaciofuvial materials generally have a greater horizontal than vertical permeability. Overall they transmit water quite readily with coefficients ranging from 2 to 0.002 feet per minute, see recommendations below. A cutoff to the bedrock was used during the original dam construction. Dewatering was accomplished using 10 and 12-inch vertical pumps with very little problems maintaining the dewatered condition.

BEDROCK

For design purposes it is logical to use the most competent rock lying at the highest elevation, barring the need for excavation. At this location this would be the massive limestone found at an approximate elevation of +/- 430 MSL. Assuming then that the unconsolidated materials and thinner bedded shales above the limestone would not be used for engineering purposes, the engineering characteristics of the limestone will be addressed: Previous studies i.e. references 1 through 7 should be reviewed in conjunction with the examination of this report. Essential results from these earlier studies have been re-examined and are presented herewith:

The bedrock at Lock 22 is a hard limestone, thick bedded with horizontal parting at bedding planes or stylolites. Some solutioning and recrystallation of the limestone are evident from calcite filled vugs .The quality of the rock as determined from the Rock Quality Designation (RQD) technique, is good with values ranging from 58 to 100 percent. The lowest designation, 58 percent in boring LD 22-98-8 may be attributed to drilling equipment difficulties. Based on typical test results of this type of limestone, the following values may be considered for use in a design analysis: For a medium grained limestone, Wood, reference 2., gives a shear strength value as a cohesion of 5,300 psi, and internal angle of friction ϕ of 35 degrees (tan 0.7). The Lock and Dam 22 Stability Analysis, reference 3, used an assumed value for ϕ of 30 degrees (tan 0.6). Based on the intact nature of the foundation limestone, the higher friction angle is judged to be reasonable. The high cohesion value of 5,300 psi is probably due to the interlocking grain structure of the limestone. This can be used as peak cross-bed shear strength of the intact limestone. Other test values, Goodman, reference 4, indicates a ϕ of 42 degrees and WES, reference 5, used a ϕ of 56 degrees with a compressive strength of 4,870 psi. Previous studies by NCR, reference 6,recommended a ϕ of 42 degrees with 0 assumed cohesion, and reference 7, ETL 1110-2-184, lists a ϕ of 56 degrees with a compressive strength of 6,000 psi for a similar type rock.

SECTION 6 – RECOMMENDATIONS

Based on the laboratory gradations of the alluvial materials, and typical expected permeabilities, the construction of any cutoff walls, cofferdams, or connecting dike embankments should be founded on bedrock or with sheet pile cutoffs to bedrock.
A founding elevation of +/- 430 MSL is recommended for the uppermost level of any permanent structure. Lower elevations of 3 to 4 feet could be possible in areas of questionable quality bedrock. It is recommended that the shale be excavated and the cells founded on competent limestone.

Prior to issuance of plans and specifications and final site selection, it is recommended that 4-inch core samples be taken and tested to verify bedrock values

The following strength parameters are taken, in part, from the stability analysis and reflect findings of recent borings and correlation with results of the cited references.

Material	Failure Plane	Tan ϕ	Dry Unit Wt.(γ).	Cohesion (psi)	Remarks
Limestone	Cross-bed	0.7	160 (pcf)	5,300	Peak Strength
Limestone	Stylolite/ Beddg. Plane	0.7	150 "	0	
Dol. L.S.*	Beddg. Plane	0.9	165 "	6,000	Compress. Strength
Dol. L.S.*	Intact./ Direct Shear	1.4	165 "	4,870	Compress. Strength
Sand		0.6	115 "	0	

* Dol. L.S. = Dolomitic Limestone

REFERENCES

1. U.S. Army Corps of Engineers, Rock Island District, Lock and Dam No. 22, Feasibility Report for Hydropower, Technical Appendix Volume II of II Geotechnical Considerations, August 1984.
2. Wood, L. C. Physical Properties of Rocks, From Table 1 in American Geological Institute Data Sheets, 1979
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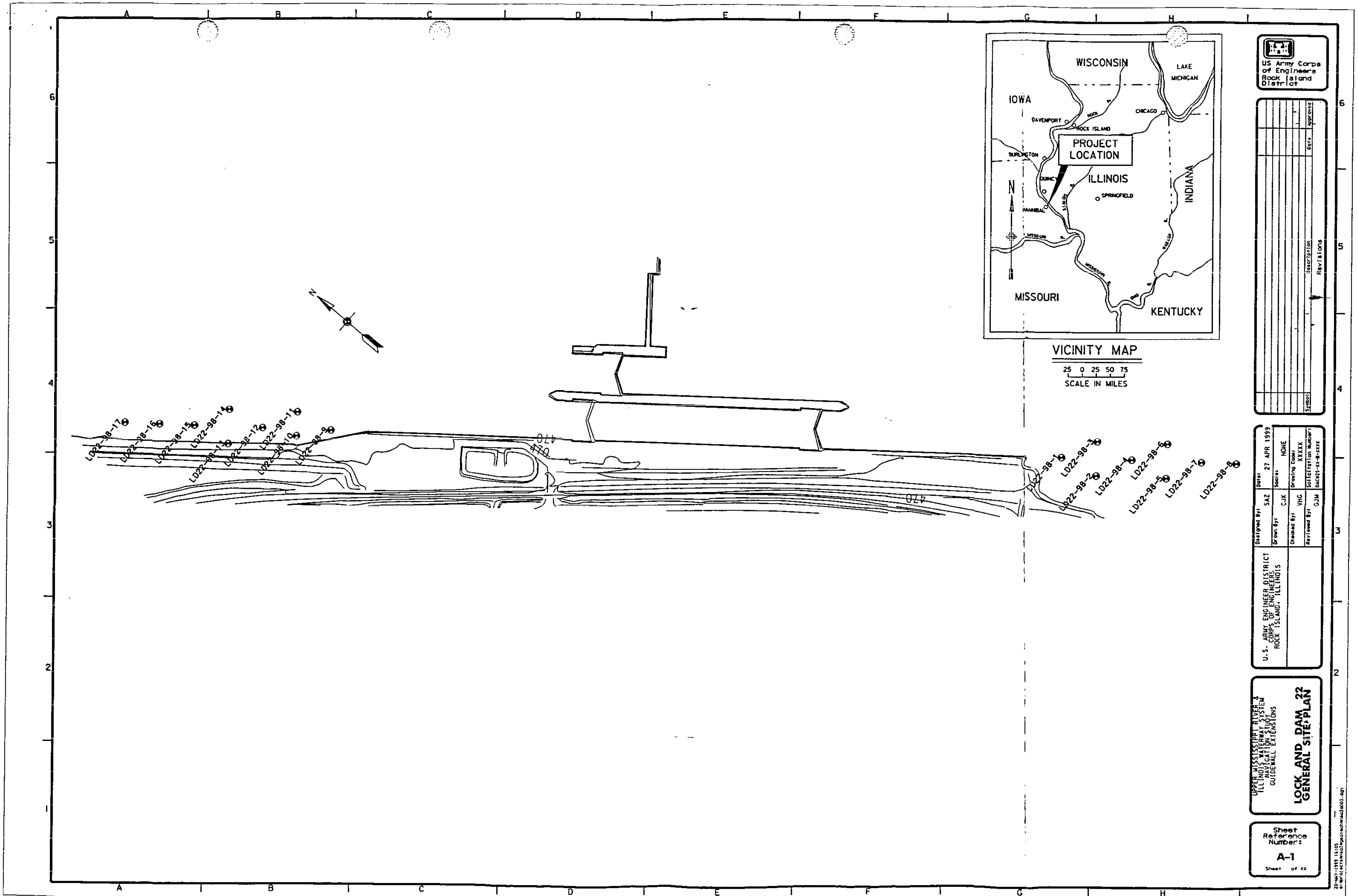
5. U.S. Army Corps of Engineers, Waterways Experiment Station, Phase I Rehabilitation Investigation and Duplicate Lock Studies, 1988
6. U.S. Army Corps of Engineers Rock Island District Dresden Island Lock and Dam Project STS Hydropower Project No. 1039 September, 1992.
7. Department Of The Army, DAEN-CWE-D ETL 1110-2-184 Gravity Dam Design Stability, 1974.

LIST OF PLATES



WISCONSIN
LAKE MICHIGAN
IOWA
DAVENPORT
ROCK ISLAND
CHICAGO
BURLINGTON
PROJECT LOCATION
QUINCY
ILLINOIS
SPRINGFIELD
INDIANA
HANNIBAL
MISSOURI
KENTUCKY
VICINITY MAP
25 0 25 50 75
SCALE IN MILES
LD22-98-1
LD22-98-2
LD22-98-3
LD22-98-4
LD22-98-5
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LD22-98-16
LD22-98-17
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Drawn By: CJK
Checked By: VHG
Reviewed By: GJM
Date: 27 APR 1999
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LOCK AND DAM 22 GENERAL SITE PLAN
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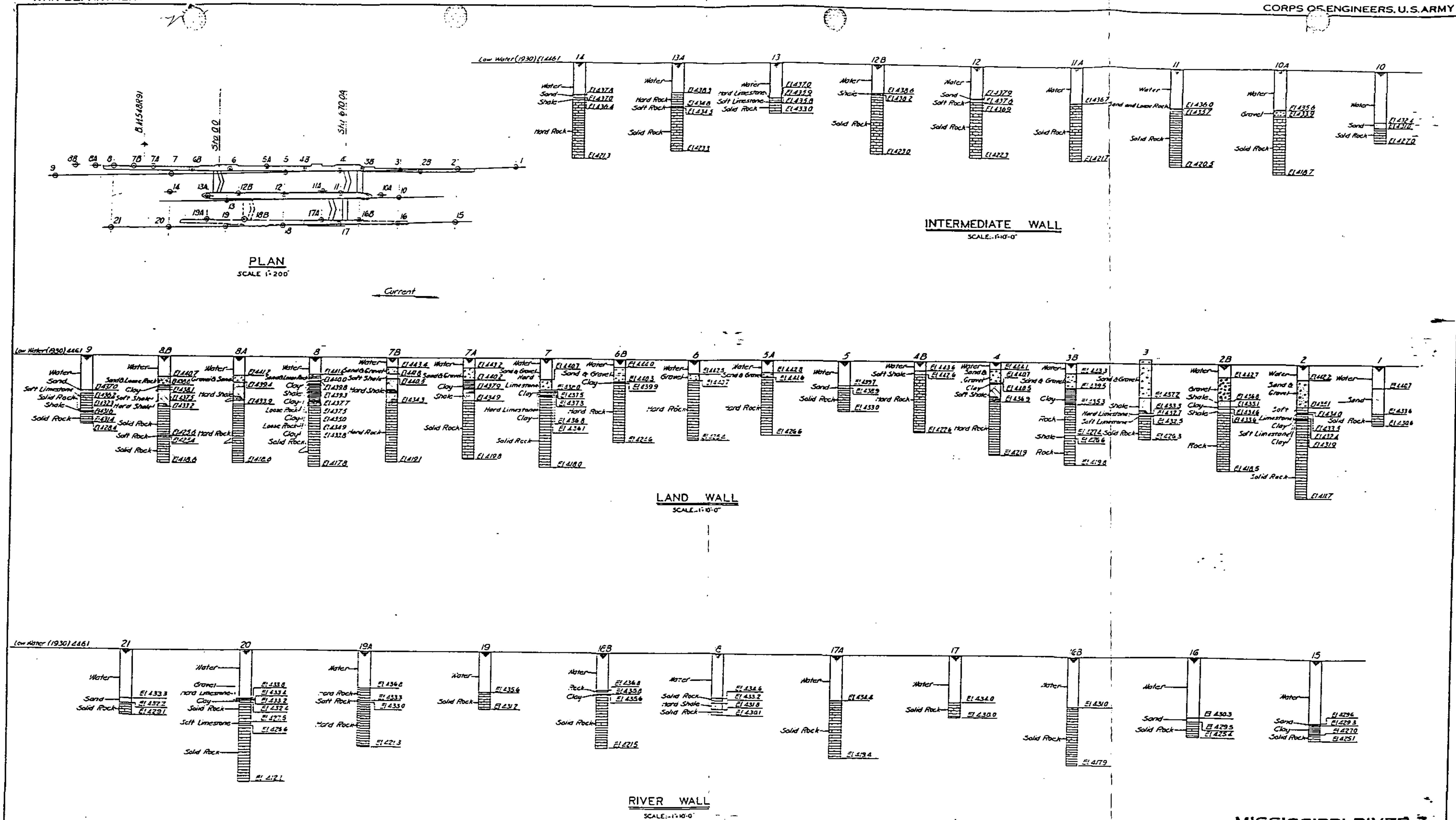


MISSISSIPPI RIVER
LOCK & DAM NO. 22
LOCK
BORINGS

SCALE:-AS SHOWN

DATE	REVISION
12-16-33	REDRAWN - ADDITIONAL BORINGS

U. S. ENGINEER OFFICE
ROCK ISLAND, ILLINOIS

ROCK ISLAND DISTRICT
DECEMBER, 1933

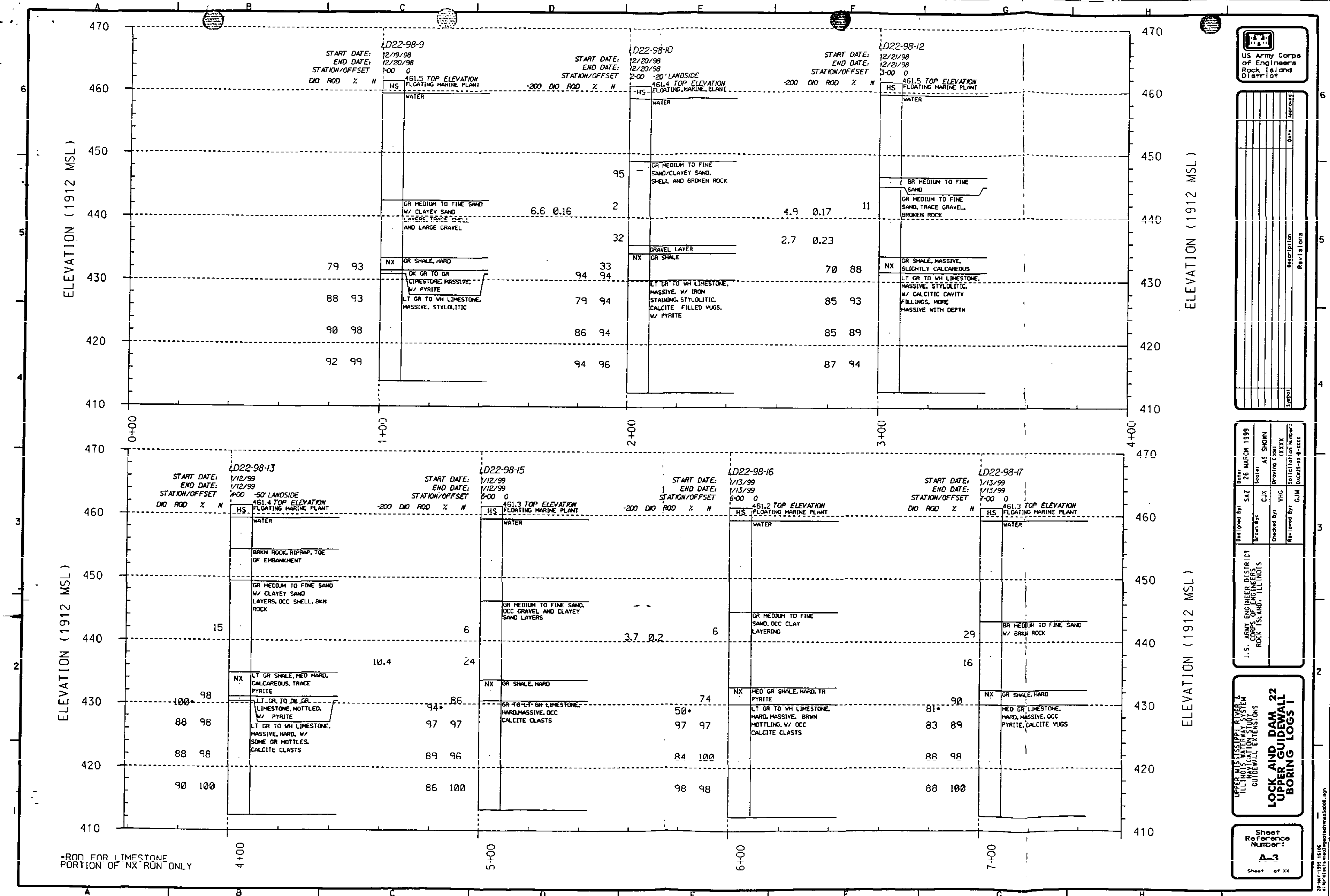
SUBMITTED:

APPROVED:

THIS SHEET SUPERCEDES SHEET 9/3

ML22 10/3A

PLATE A-2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END DATE: 12/20/98
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461.5 TOP ELEVATION
FLOATING MARINE PLANT
DIO ROD % N
HS
WATER
GR MEDIUM TO FINE SAND W/ CLAYEY SAND LAYERS, TRACE SHELL AND LARGE GRAVEL
NX
GR SHALE, HARD
DK GR TO GR LIMESTONE, MASSIVE, W/ PYRITE
LT GR TO WH LIMESTONE, MASSIVE, STYLOLITIC
LD22-98-10
START DATE: 12/20/98
END DATE: 12/20/98
STATION/OFFSET 2+00 -20' LANDSIDE
461.4 TOP ELEVATION
FLOATING MARINE PLANT
GR MEDIUM TO FINE SAND/CLAYEY SAND, SHELL AND BROKEN ROCK
GRAVEL LAYER
GR SHALE
LT GR TO WH LIMESTONE, MASSIVE, W/ IRON STAINING, STYLOLITIC, CALCITE FILLED VUGS, W/ PYRITE
LD22-98-12
START DATE: 12/21/98
END DATE: 12/21/98
STATION/OFFSET 3+00 0
461.5 TOP ELEVATION
FLOATING MARINE PLANT
GR MEDIUM TO FINE SAND
GR MEDIUM TO FINE SAND, TRACE GRAVEL, BROKEN ROCK
GR SHALE, MASSIVE, SLIGHTLY CALCAREOUS
LT GR TO WH LIMESTONE, MASSIVE, STYLOLITIC, W/ CALCITIC CAVITY FILLINGS, MORE MASSIVE WITH DEPTH
LD22-98-13
START DATE: 1/12/99
END DATE: 1/12/99
STATION/OFFSET 4+00 -50' LANDSIDE
461.4 TOP ELEVATION
FLOATING MARINE PLANT
BRKN ROCK, RIPRAP, TOE OF EMBANKMENT
GR MEDIUM TO FINE SAND W/ CLAYEY SAND LAYERS, OCC SHELL, BKN ROCK
LT GR SHALE, MED HARD, CALCAREOUS, TRACE PYRITE
LT GR TO DK GR LIMESTONE, MOTTLED, W/ PYRITE
LT GR TO WH LIMESTONE, MASSIVE, HARD, W/ SOME GR MOTTLES, CALCITE CLASTS
LD22-98-15
START DATE: 1/12/99
END DATE: 1/12/99
STATION/OFFSET 5+00 0
461.3 TOP ELEVATION
FLOATING MARINE PLANT
GR MEDIUM TO FINE SAND, OCC GRAVEL AND CLAYEY SAND LAYERS
GR SHALE, HARD
GR TO LT GR LIMESTONE, HARD, MASSIVE, OCC CALCITE CLASTS
LD22-98-16
START DATE: 1/13/99
END DATE: 1/13/99
STATION/OFFSET 6+00 0
461.2 TOP ELEVATION
FLOATING MARINE PLANT
GR MEDIUM TO FINE SAND, OCC CLAY LAYERING
MED GR SHALE, HARD, TR PYRITE
LT GR TO WH LIMESTONE, HARD, MASSIVE, BRWN MOTTLING, W/ OCC CALCITE CLASTS
LD22-98-17
START DATE: 1/13/99
END DATE: 1/13/99
STATION/OFFSET 7+00 0
461.3 TOP ELEVATION
FLOATING MARINE PLANT
GR MEDIUM TO FINE SAND W/ BRKN ROCK
GR SHALE, HARD
MED GR LIMESTONE, HARD, MASSIVE, OCC PYRITE, CALCITE VUGS
•ROD FOR LIMESTONE PORTION OF NX RUN ONLY
US Army Corps of Engineers Rock Island District
Description
Revisions
Designed By: SAZ
Drawn By: CJK
Checked By: VHG
Reviewed By: GJM
Date: 26 MARCH 1999
Scale: AS SHOWN
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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY GUIDEWALL EXTENSIONS
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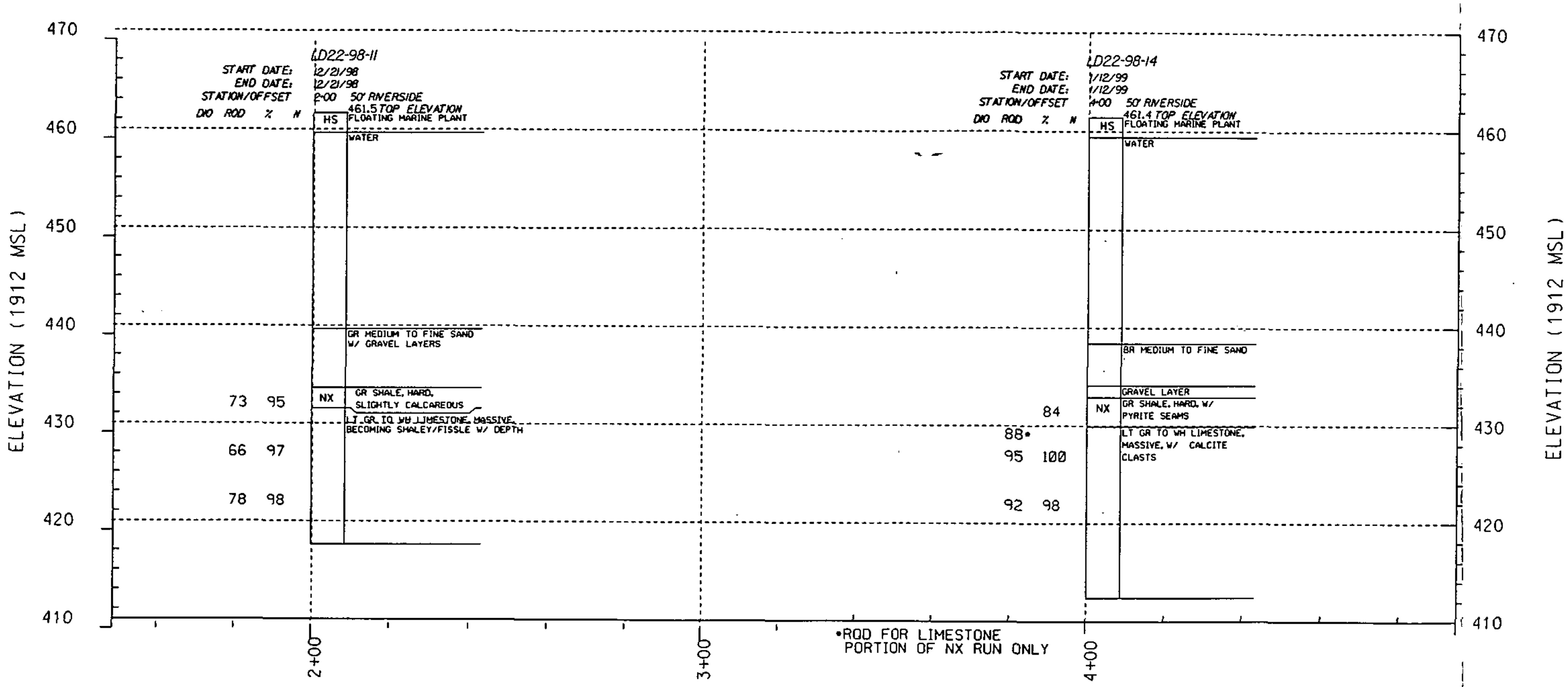

US Army Corps of Engineers
Rock Island District

Symbol	Description	Date	Approved

Revisions

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Drawn By: CJK	Scale: AS SHOWN
Checked By: VHG	Drawing Code: XXXXX
Reviewed By: GJM	Solicitation Number: DACW25-XX-B-XXXX

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM
NAVIGATION STUDY
GUIDEWALL EXTENSIONS

LOCK AND DAM 22
UPPER GUIDEWALL
BORING LOGS II

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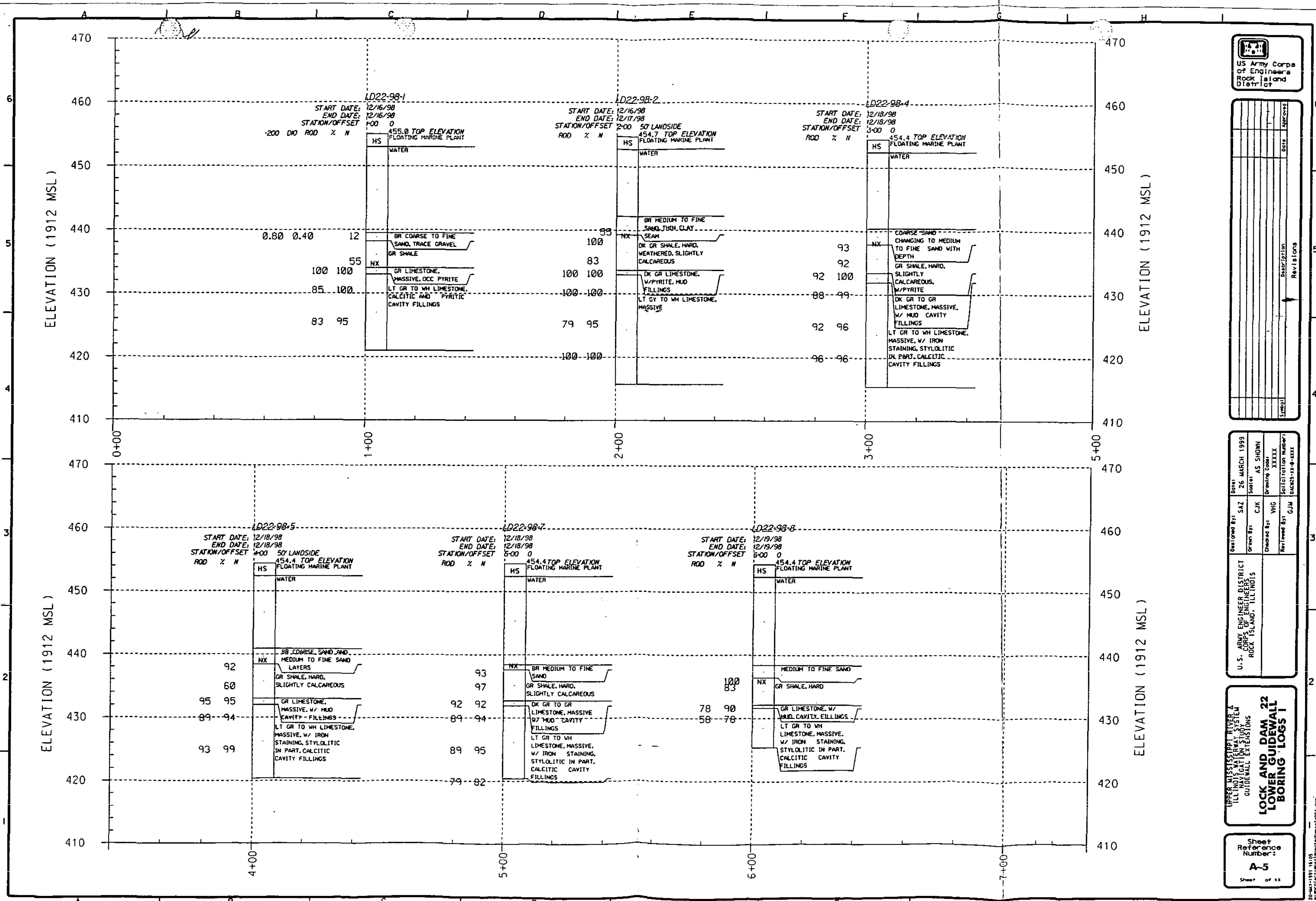
Sheet of XX



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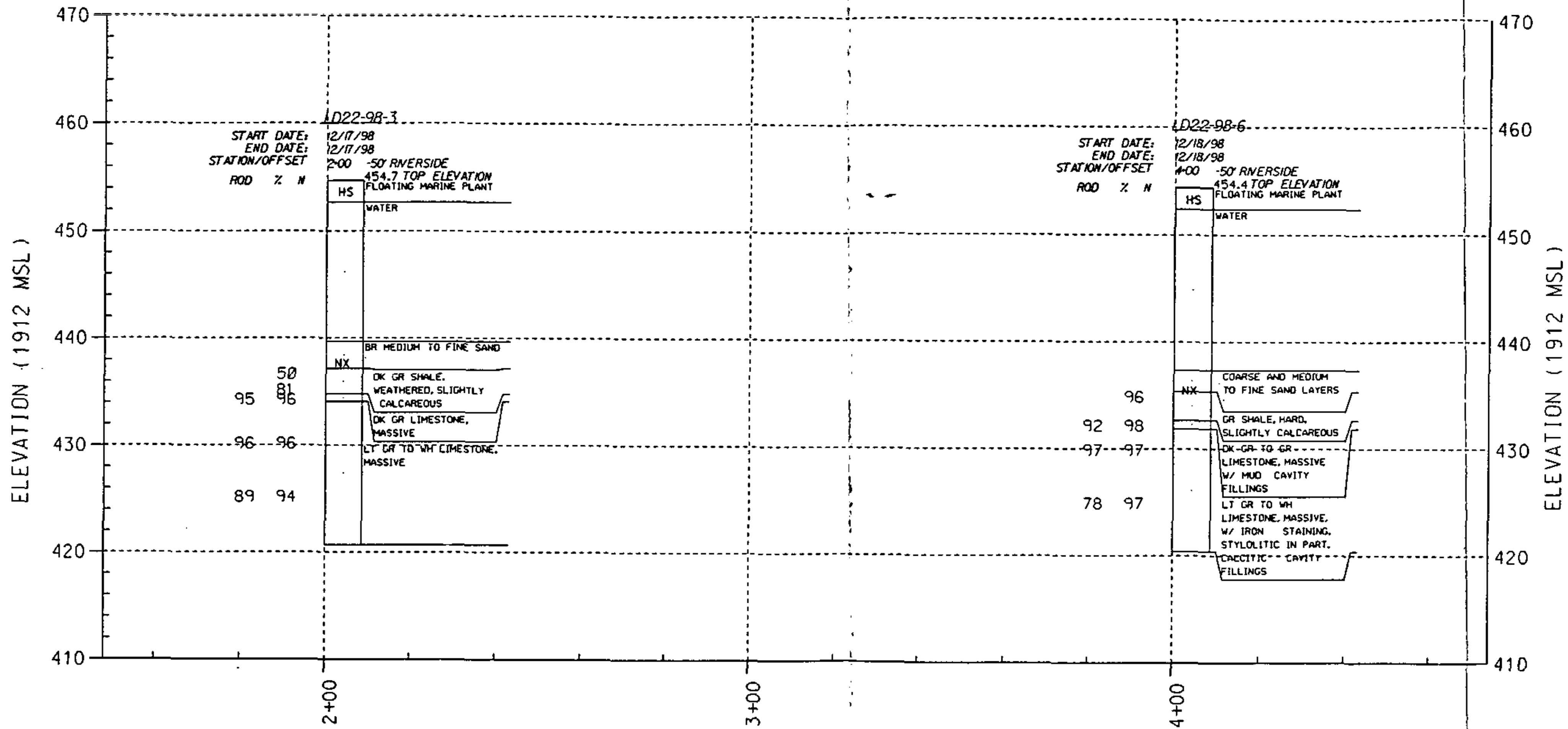
LD22-98-1
START DATE: 12/16/98
END DATE: 12/16/98
STATION/OFFSET 1+00 0
455.0 TOP ELEVATION
FLOATING MARINE PLANT
WATER
BR COARSE TO FINE SAND, TRACE GRAVEL
GR SHALE
GR LIMESTONE, MASSIVE, OCC PYRITE
LT GR TO WH LIMESTONE, CALCITIC AND PYRITIC CAVITY FILLINGS
LD22-98-2
START DATE: 12/16/98
END DATE: 12/17/98
STATION/OFFSET 2+00 50' LANDSIDE
454.7 TOP ELEVATION
FLOATING MARINE PLANT
WATER
BR MEDIUM TO FINE SAND, THIN CLAY SEAM
DK GR SHALE, HARD, WEATHERED, SLIGHTLY CALCAREOUS
DK GR LIMESTONE, W/PYRITE, MUD FILLINGS
LT GY TO WH LIMESTONE, MASSIVE
LD22-98-4
START DATE: 12/18/98
END DATE: 12/18/98
STATION/OFFSET 3+00 0
454.4 TOP ELEVATION
FLOATING MARINE PLANT
WATER
COARSE SAND CHANGING TO MEDIUM TO FINE SAND WITH DEPTH
GR SHALE, HARD, SLIGHTLY CALCAREOUS, W/PYRITE
DK GR TO GR LIMESTONE, MASSIVE, W/ MUD CAVITY FILLINGS
LT GR TO WH LIMESTONE, MASSIVE, W/ IRON STAINING, STYLOLITIC IN PART, CALCITIC CAVITY FILLINGS
LD22-98-5
START DATE: 12/18/98
END DATE: 12/18/98
STATION/OFFSET 4+00 50' LANDSIDE
454.4 TOP ELEVATION
FLOATING MARINE PLANT
WATER
BR COARSE SAND AND MEDIUM TO FINE SAND LAYERS
GR SHALE, HARD, SLIGHTLY CALCAREOUS
GR LIMESTONE, MASSIVE, W/ MUD CAVITY FILLINGS
LT GR TO WH LIMESTONE, MASSIVE, W/ IRON STAINING, STYLOLITIC IN PART, CALCITIC CAVITY FILLINGS
LD22-98-7
START DATE: 12/18/98
END DATE: 12/18/98
STATION/OFFSET 5+00 0
454.4 TOP ELEVATION
FLOATING MARINE PLANT
WATER
BR MEDIUM TO FINE SAND
GR SHALE, HARD, SLIGHTLY CALCAREOUS
DK GR TO GR LIMESTONE, MASSIVE W/ MUD CAVITY FILLINGS
LT GR TO WH LIMESTONE, MASSIVE, W/ IRON STAINING, STYLOLITIC IN PART, CALCITIC CAVITY FILLINGS
LD22-98-8
START DATE: 12/19/98
END DATE: 12/19/98
STATION/OFFSET 6+00 0
454.4 TOP ELEVATION
FLOATING MARINE PLANT
WATER
MEDIUM TO FINE SAND
GR SHALE, HARD
GR LIMESTONE, W/ MUD CAVITY FILLINGS
LT GR TO WH LIMESTONE, MASSIVE, W/ IRON STAINING, STYLOLITIC IN PART, CALCITIC CAVITY FILLINGS
US Army Corps of Engineers Rock Island District
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ROCK ISLAND, ILLINOIS
Date: 26 MARCH 1999
Scale: AS SHOWN
UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY GUIDEWALL EXTENSIONS
LOCK AND DAM 22 LOWER GUIDEWALL BORING LOGS I
Sheet Reference Number: A-5



US Army Corps of Engineers
Rock Island District

Symbol | Description | Date | Approved

Revisions

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ROCK ISLAND, ILLINOIS

Designed By:	SAZ	Date:	26 MARCH 1999
Drawn By:	CJK	Scale:	AS SHOWN
Checked By:	TEW	Drawing Code:	XXXXX
Reviewed By:	GJW	Solicitation Number:	DACW25-XX-B-XXXX

UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY GUIDEWALL EXTENSIONS

LOCK AND DAM 22 LOWER GUIDEWALL BORING LOGS II

Sheet Reference Number:

A-6

Sheet of XX

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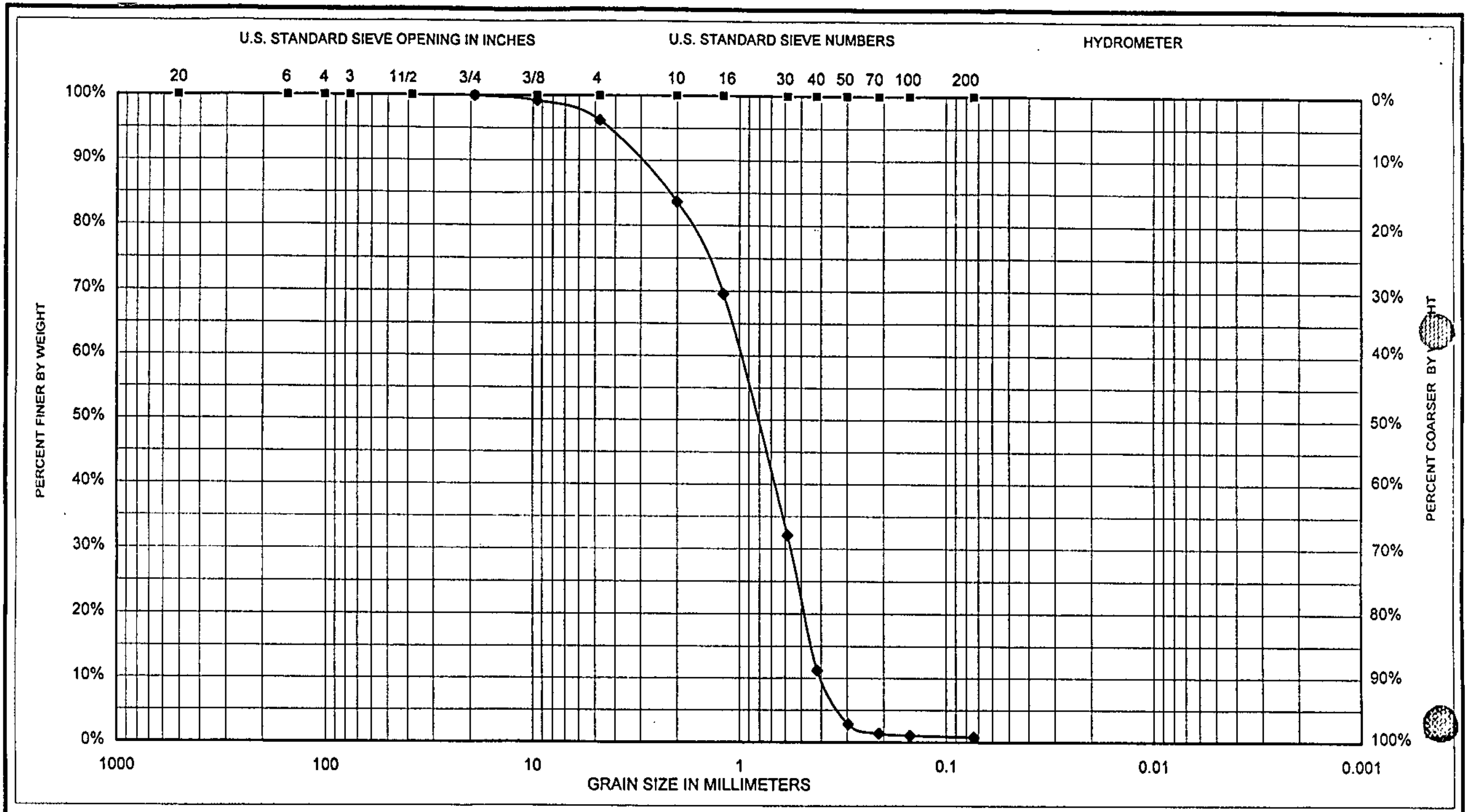

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<tr><td>COARSE</td><td>FINE</td><td>COARSE</td><td>MEDIUM</td><td>FINE</td></tr>
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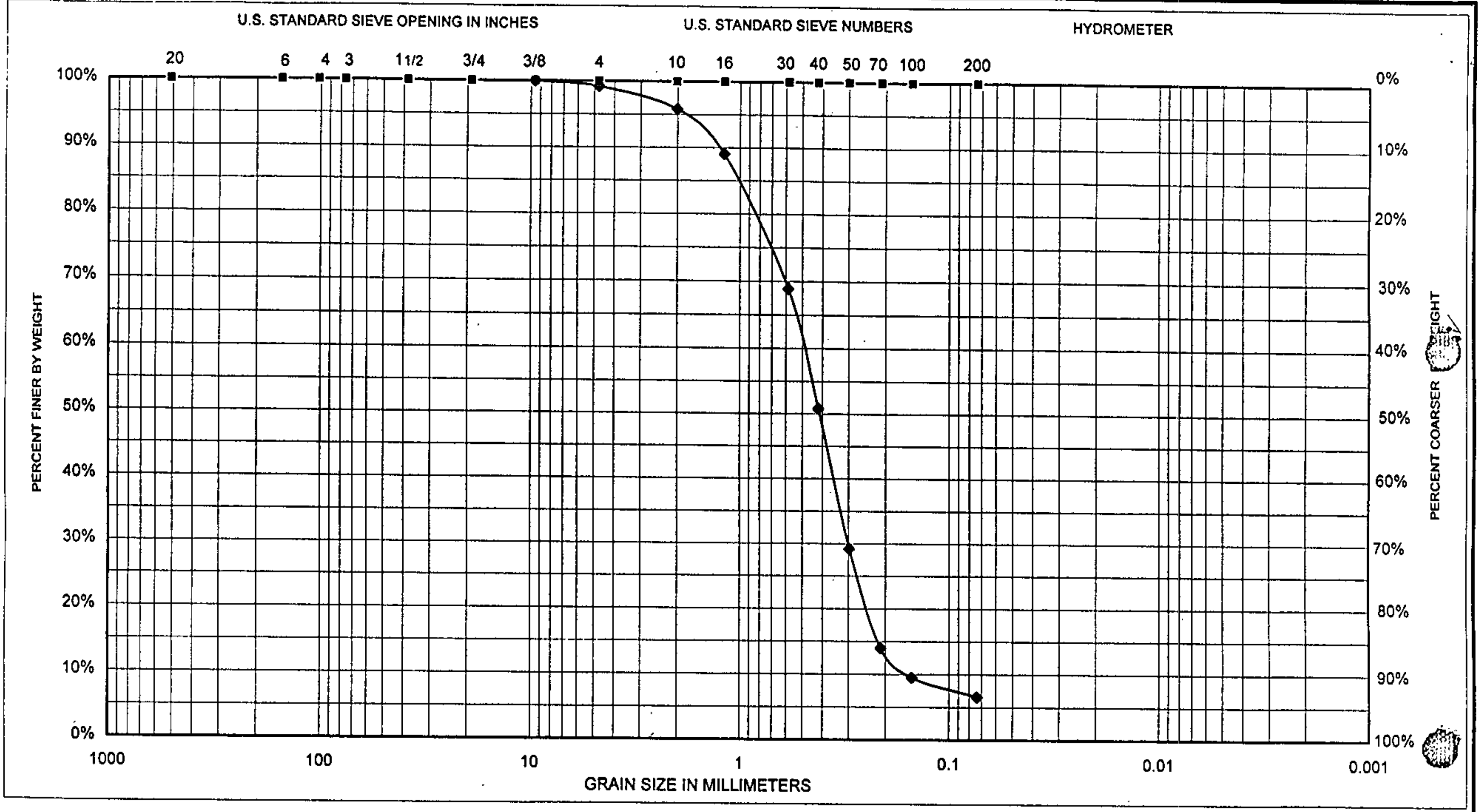
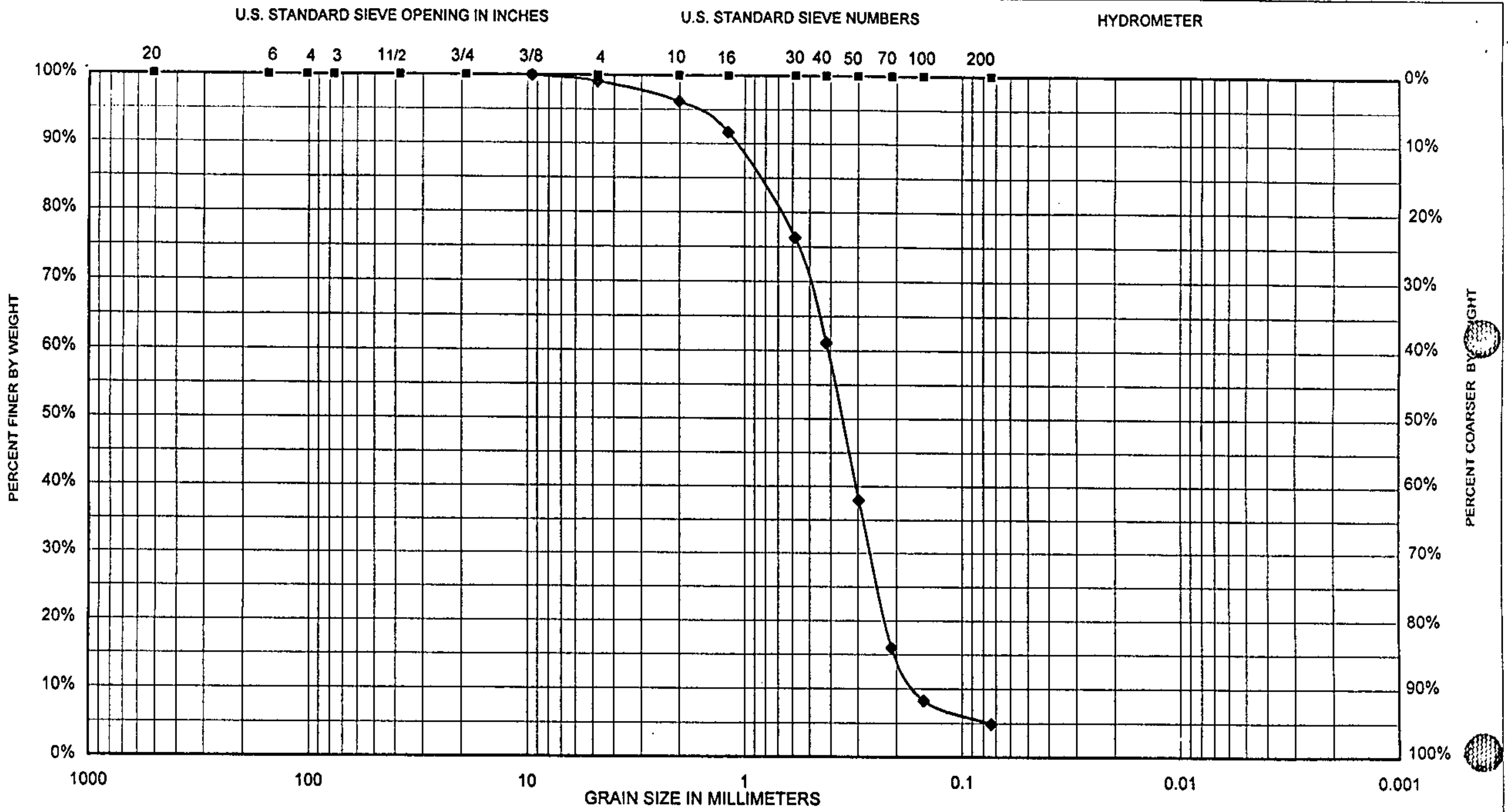
Sample No.	Elev or Depth	Classification	Color	D_{10}	-#200	Project: Lock and Dam 22 Navigation Study
1	16.0-17.0	SP, COARSE TO FINE SAND, TRACE GRAVEL	BR	0.40	0.8%	
						Area: Lower Guidewall
						Boring No.: LD22-98-1
						Date: 16-Dec-98



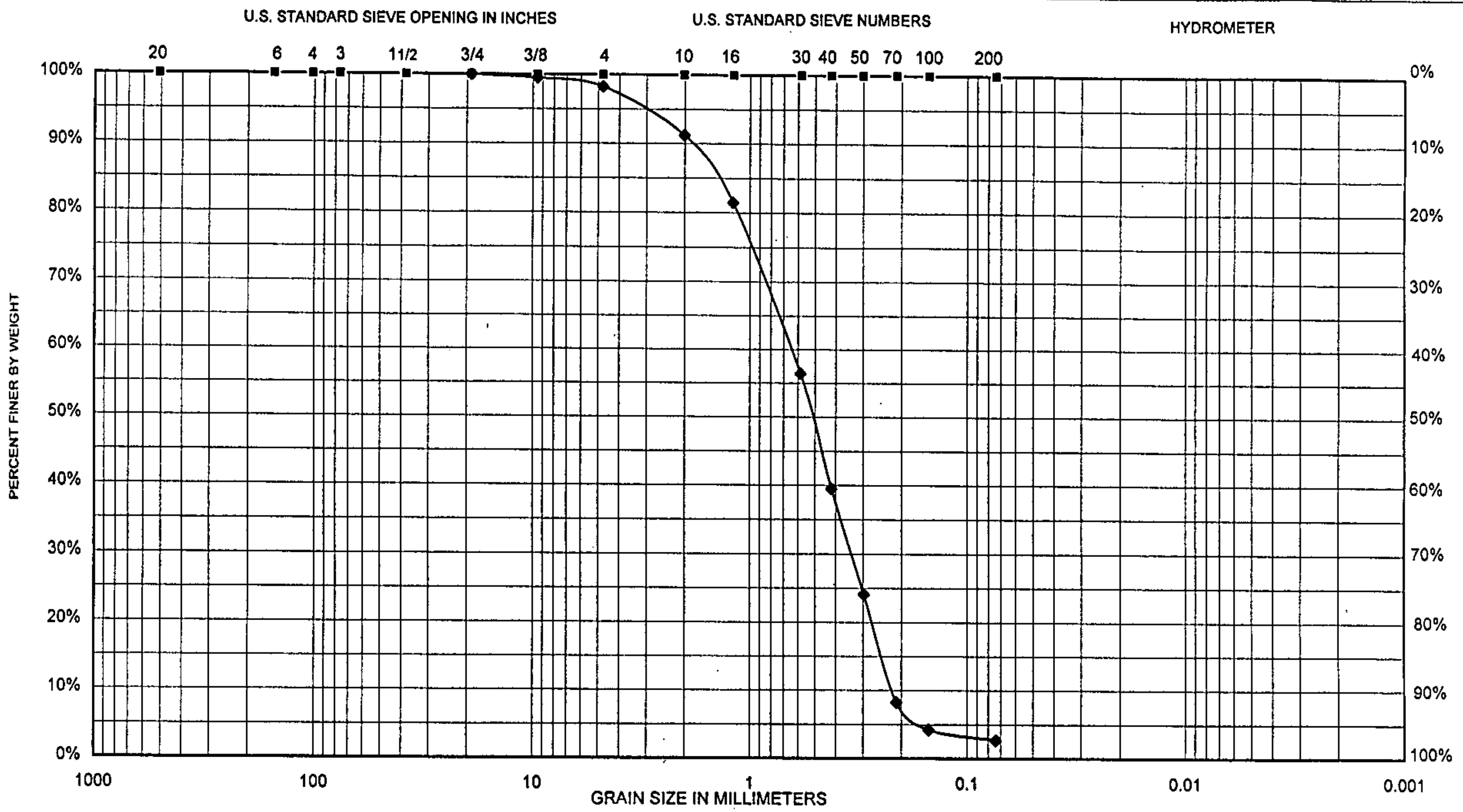
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Color	D_{10}	-#200	Project: Lock and Dam 22 Navigation Study
2	19.0-20.0	SP-SC, CLAYEY MEDIUM TO FINE SAND	BR	0.16	6.6%	Area: Upper Guidewall
						Boring No.: LD22-98-10
						Date: 20-Dec-98



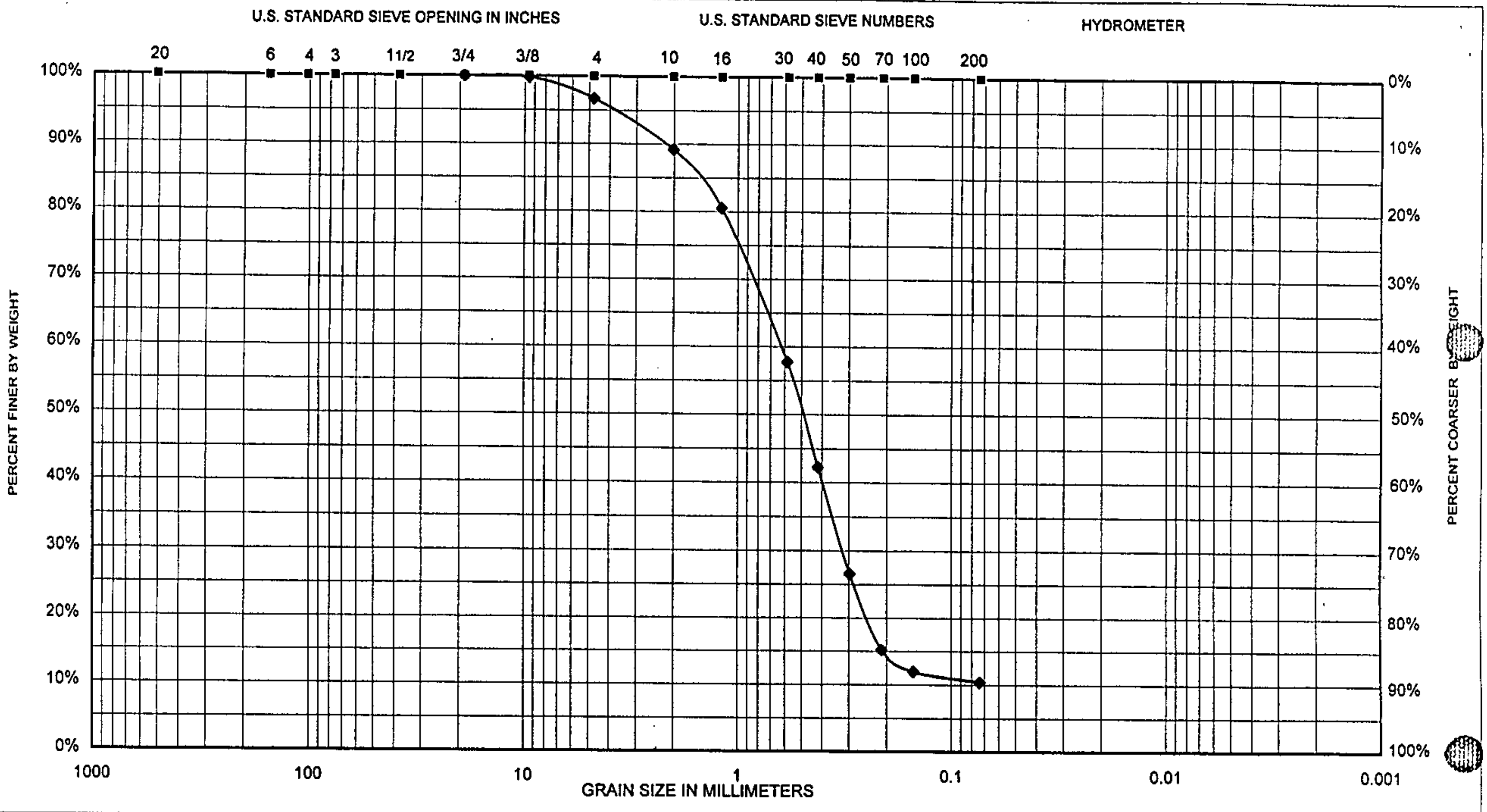
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Color	D_{10}	-#200	Project: Lock and Dam 22 Navigation Study
1	19.5-20.5	SP, MEDIUM TO FINE SAND	BR	0.17	4.9%	
						Area: Upper Guidewall
						Boring No.: LD22-98-12
						Date: 21-Dec-98



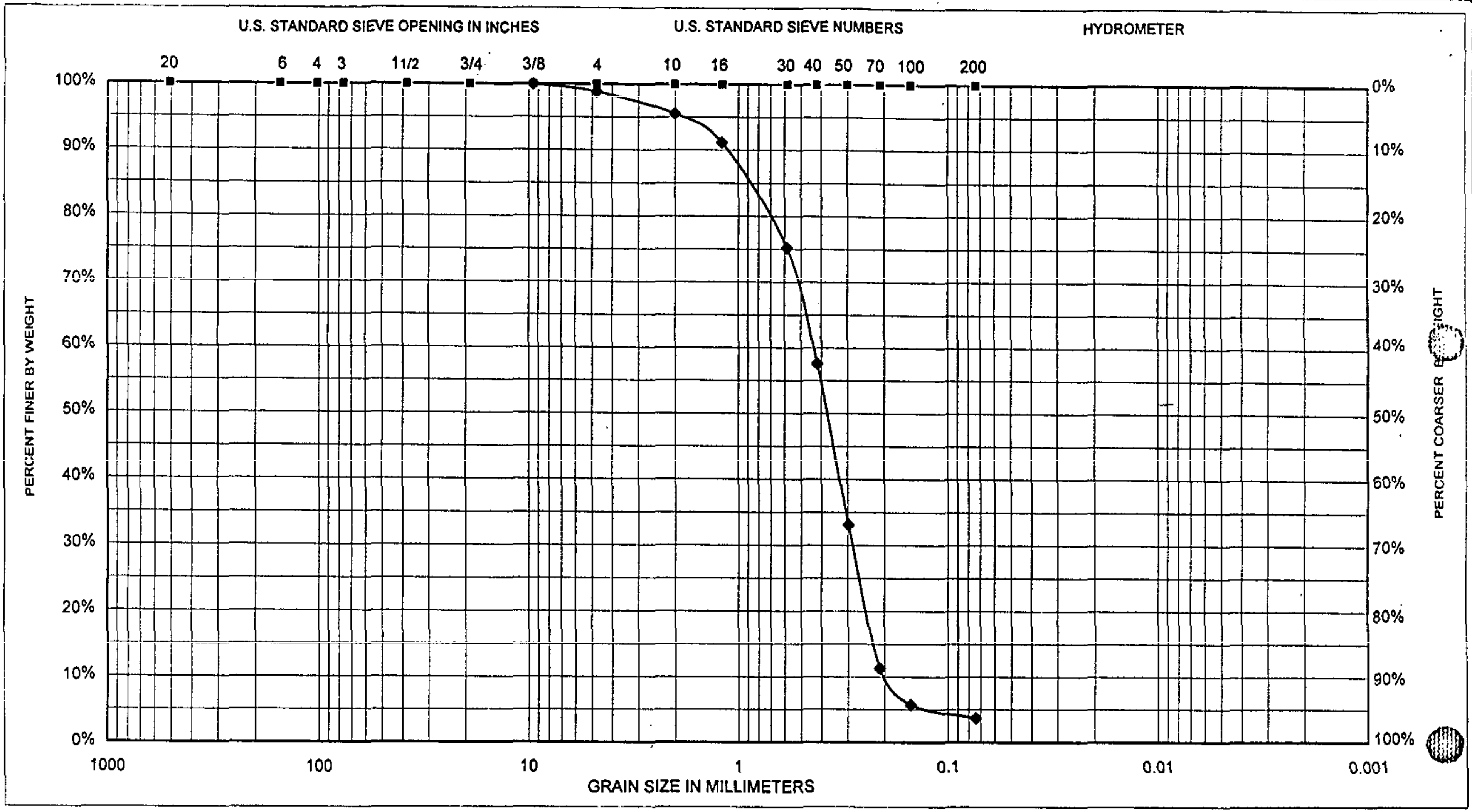
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Color	D_{10}	#200	Project: Lock and Dam 22 Navigation Study
2	24.0-25.0	SP, MEDIUM TO FINE SAND	BR	0.23	2.7%	
						Area: Upper Guidewall
						Boring No.: LD22-98-12
						Date: 21-Dec-98



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Color	D_{10}	-#200	Project: Lock and Dam 22 Navigation Study
2	24.5-25.5	SP-SC, CLAYEY MEDIUM TO FINE SAND, TRACE GRAVEL	BR		10.4%	
						Area: Upper Guidewall
						Boring No.: LD22-98-15
						Date: 12-Jan-99



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Elev or Depth	Classification	Color	D_{10}	-#200	Project: Lock and Dam 22 Navigation Study
1	19.5-20.5	SP, MEDIUM TO FINE SAND	BR	0.20	3.7%	
						Area: Upper Guidewall
						Boring No.: LD22-98-16
						Date: 13-Jan-99

General Site Considerations

Appendix E

Appendix E
General Site Conditions

Each site will have specific physical characteristics that must be addressed. The following paragraphs are intended to be general in their application with the understanding that the coordination and descriptions are more rule-of-thumb guidance rather than site specific.

(a). Assess Existing Site Conditions. At each site, specific physical characteristics must be evaluated on land and over water, location and availability of utilities, drainage, elevation above a minimum flood frequency level established by the by Engineering Work Group (EWG) and accessibility. An up-to-date survey should be made of the lock site. This will be especially important when determining additional real estate and utility needs as well as for use in designing necessary site work for staging, construction, fleeting, fabrication, outfitting of guidewall extension materials and components as determined by EWG.

(b). Real Estate Issues. It is likely that many aspects of this construction will require a combination of temporary and permanent relocation and acquisition of real estate interests in non-government owned land. These will be required for lands needed for staging, construction, access via land and water, borrow and disposal of earthen materials fleeting, fabrication, outfitting of guidewall beams, cells and related components as determined by Engineering Work Group. A Real Estate Design Memorandum and Gross Appraisal is required for any acquisitions. Project scheduling must allow time for the coordination of the relocation and acquisition process of real estate interests. A construction project cannot be awarded if the proper real estate interests are not in place.

(c). Staging Areas. The area required for staging will consider beam size, number of beams required to have staged on site and the appurtenances needed on site for outfitting and installation of guidewall components. Allowances must be made for the possibility for float-in and trucking of these components. If the site is physically limited in available area and accessibility, the EWG will prioritize construction features and sequencing to allow for potential staging/assembly nearest the lock. Office trailers and parking may be in the more remote site to allow for closer staging of materials for project features.

(d). Fleeting Areas. Assess the needs of the floating plant. At most sites, guidewall beam placement will require the use of barge mounted cranes. These cranes will pick the final assembled beams from barges and place for the guidewall extension. Identify type of vessels, barges, loading and offloading characteristics and maximum draft requirements. Use these considerations to define limits of the over-water work area and any dredging needs for floating plant access. Coordinate and document NEPA, HTRW Phase I . Floating plant must also have spill control plan and hazard analysis as part of its standard operating plan.

(e). Disposal Areas. A site may require dredging or excavation as part of the site work. Disposal areas for excavated material must be coordinated and documented for NEPA and HTRW Phase I. Promote beneficial use instead of disposal if appropriate.

(f). Borrow Areas. Site work may require additional borrow. Borrow areas must be coordinated with geotechnical engineer for borings and determine suitability and documented for NEPA compliance. An HTRW Phase I investigation must also be completed.

(g). Hazardous, Toxic and Radioactive Waste. An HTRW site investigation must be performed for each site in which the government acquires a real estate interest. This investigation can be as simple as a site visit and record search resulting in documentation referred to as a "Phase I" report. Preliminary research could then lead to a "Phase II" investigation requiring sampling and testing of the site which in turn could potentially reveal contamination of the site. From the point of identifying a site and requesting a minimum Phase I assessment HTRW investigation, typically is a 3 month process.

(h). Permit Requirements. The shoreline of a body of water is generally defined by the ordinary high water mark. This mark on the shore or stream bank is established by water level fluctuation. The Corps of Engineers has regulatory jurisdiction below this mark which may extend into tributaries. Construction of guidewall extensions will involve placement of structures within the navigable Through specific congressional authorization, this work may be exempted from the waters of the United States. permitting requirements of Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403). Under this law a permit is needed from the Corps of Engineers for any structure or work that takes place in, under or over a navigable water or wetland adjacent to navigable waters of the United States.

Guidewall extension work will also require dredging and fill into waters of the United States. Federal Section 404 of the Clean Water Act (CWA) (33 U.S.C. 1344) states that a permit is needed to excavate in or discharge dredged or fill material into a water of the United States. This includes wetlands. Wetland are areas inundated or saturated by surface or ground water at a frequency or duration sufficient to support and, under normal circumstances, support a prevalence of vegetation adapted for life in saturated soil conditions. Size is not a limitation. Areas smaller than an acre are regulated and any disturbances must be mitigated.

While the Corps of Engineers regulates only those activities resulting in a discharge of dredge or fill material into a wetland, individual states set water quality standards within their own boundaries. Section 401 of the CWA requires all permits or licenses issued by the federal government for activities affecting waters of the United States be certified by the state in which the discharge is to occur that the activity will comply with the water quality standards of that state. For example, in the case of Illinois, the Illinois

Environmental Protection Agency (IEPA) has the authority to certify such federal permits and licenses and to regulate activities resulting in a discharge of any pollutant into a wetland. This authority is limited, however, to only those activities requiring a federal permit or license. These water quality standards must be equal to or more stringent than those established in Section 303 of the CWA.

A storm water pollution control construction and operating permit is required from the state in which the activity is to take place if five or more acres of land are disturbed, or the project is listed as an industrial activity with storm water concerns. (Illinois Section 402 (NPDES) Storm Water Runoff)

In the case of Illinois, construction in the floodway or floodplain requires hydraulic analysis to show 0.01 foot or less induced flooding or, in essence a zero increase in flood height before the Illinois Department of Natural Resources Office of Water Resources (IDNR-OWR) will issue a permit.

Value Engineering Study, March 1999

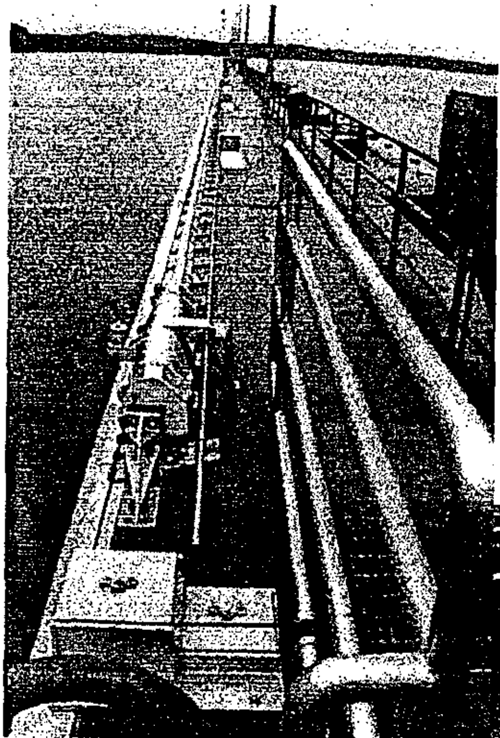
Appendix F

Value Engineering Study

Extended Lock Guidewalls with Powered Traveling Kevels

Upper Mississippi River - Illinois Waterway System Navigation Study

March 1999



Improving Lockage Efficiency Through Value Analysis to Serve the Waterways User

A Team Effort to Produce Results

U.S. Army Corps of Engineers
- **St. Louis District**
- **Rock Island District**
- **Nashville District**

U.S. Maritime Administration

Brown Water Towing

American River Transportation

US Army Corps of Engineers
St. Louis District

Executive Summary

Value Engineering Proposals Developed and Evaluated

1. Use Tandem Tow Haulage Units to Extract First Cuts
   ($1 million savings x 5 locks = $5 million)

2. Faster Extraction of First Cuts with Existing Haulage

3. Use Motorized Mule (capable of crossing Miter Gate) to Extract First Cuts

4. Use a Tow Haulage System Consisting of a Continuous Cable with Two Dependent Powered Kevels and One Unpowered Kevel to Extract First Cuts
   ($735,000 savings x 5 locks = $3.675 million)

5. Use a Simplified System Consisting of Unpowered Kevels, with Powered Cut Moving First Cut to End of Guidewall
   ($1.43 million x 5 locks = $7.15 million)

6. Use a Tow Haulage System Entitled the "1200-300-1200 Powered Kevel Option." (The numeric values represent the kevel haul distances on the guidewall, within the lock, and on the other guidewall, respectively) (not recommended for further consideration)

7. Use a Guidewall Substructure Featuring a "Pile Cap on Sand – Place Cell Later" Method (This oversized pile cap allows installation of more piles and a minimum-sized pier stem)

8. Use a Slender Substructure with Rock Anchors to Lessen the Size of the Substructure Units
   ($333,000 savings/guidewall cell x 12 cells/lock x 2 applicable locks = $8.0 million)

9. Investigate Alternative-shaped Cells to Economize on the Amount of Structure Required

10. Use Smaller Guidewall Beam Configurations/Weights to Reduce Lifting Demands and Reduce Costs

11. Study the Use of Protection Cells Above and Below the I-wall to Control Lateral Tow Movement Upon Extraction

12. Investigate Concrete Cribs Substructure with Rock Fill to Lessen Guidewall Costs

13. Focus Hydraulic Models on Cut Extraction Forces

14. Use High Density Polymer Bumpers to Reduce Impact Loads on Guidewalls (not recommended)

15. Slope the Top of Guidewall Cells to Reduce Concrete Placements

16. Investigate the Feasibility of a Floating Guidewall (not recommended)

17. Issue Request for Proposal (RFP) for Long-term Contract for Extracting the First Cut and Placing the Cut on the Upstream Structure

Value Engineering Study Team

Extended Lock Guidewalls with Powered Traveling Kevels

Upper Mississippi River-Illinois Waterway System Navigation Study

March 1-5, 1999
St. Louis, Missouri

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Bob Aldrich	Brown Water Towing	(314) 992-0195
Forrest Wade Phillips	Brown Water Towing	(618) 975-7065
Randy Johnson	ARTCO	(314) 481-8828
Walter Wagner	CEMVS-ED-DM	(314) 331-8272
Bill Bennett	Nashville District CO-T-L	(615) 736-5971
Steve McCann	CEMVR Lockmaster L/D 22	(573) 221-0294
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Ed Demsky	CEMVS-ED-GE	(314) 331-8420
Ron Burkhard	CEMVD-VE	(601) 634-5930
Marv Martens	CEMVR-ED-HH	(309) 794-5222
Richard Bielenberg	CEMVR-CD-C	(319) 386-0572
Billy Arthur	CEMVS-ED-H	(314) 331-8333
Bob Hughey	CEMVS-ED-D	(314) 331-8300
Brad Thompson	CEMVR-PM-M	(309) 794-5256
Fred Joers	CEMVR-ED-DS	(309) 794-5248
Greg Dyn	CEMVS-ED-CE	(314) 331-8319
Tom Mack	CEMVR-ED-G	(309) 794-5459
Jeff Stamper	CEMVS-ED-DA	(314) 331-8226
Gene Degenhardt	CEMVS-ED(VE) Team Leader	(314) 331-8305

Bold lettering denotes individuals who comprised the "core" team which prepared the individual VE proposals during the Development Phase of the VE Job Plan.

Value Engineering Study

Extended Lock Guidewalls with Powered Traveling Kevels

Upper Mississippi River-Illinois Waterway System Navigation Study

March 1999

Purpose and Format of Value Engineering Study

The Value Engineering (VE) study was conducted 1-4 March 1999 for the purpose of evaluating the preliminary design concept for constructing and operating extended guidewalls with powered traveling kevels at Upper Mississippi River (UMR) Locks 20-25. While focused on specific locks, the results will be applicable to other lock sites on the UMR and Illinois Waterway.

The VE study was performed during the site-specific feasibility level of design to take advantage of the broadest level of thinking before subsequent design changes would become too costly in terms of time or resources. The VE study team members comprised a carefully selected group of professionals from the Rock Island, St. Louis, and Nashville Corps Districts, Mississippi Valley Division-level VE representation, towing industry representatives, towboat pilots, deckhands and lockmasters.

The initial phase of the VE study involved the entire group for the first two days as they collected information through numerous discussions, brainstormed alternative solutions, and performed evaluative screenings. A smaller core group stayed for the remainder of the VE study to further analyze the alternatives and develop individual proposals from a technical and cost effectiveness basis.

Bob Hughey, Chief, Design Branch, St. Louis District, welcomed the VE study team participants and set the stage for the VE study effort by providing a brief overview of the UMR-IWW System Navigation Study. The Upper Mississippi River-Illinois Waterway System Navigation Study (Navigation Study) is a feasibility study addressing navigation improvement planning for the Upper Mississippi River and Illinois Waterway (UMR-IWW) system for the years 2000-2050. This study assesses the need for navigation improvements at 29 locks on the Upper Mississippi River and 8 locks on the Illinois Waterway and the impacts of providing these improvements. More specifically, the principal problem being addressed is the potential for significant traffic delays on the system within the 50-year planning horizon, resulting in economic losses to the nation. The study is to determine whether navigation improvements are justified, and, if so, the appropriate navigation improvements, sites, and sequencing for the 50-year planning horizon.

This VE study can best be considered as an sub-effort within this large feasibility study. As part of the overall feasibility study, large scale measures such as new locks and extensions to existing locks are being considered. However, this VE effort is focused on just guidewall extensions with powered kevels, one of the most promising of the small scale measures.

Why Perform a VE Study in the Early Design Stage?

This report documents the Value Engineering Study of proposed powered traveling kevels to operate on extended lock guidewalls to extract the first cuts of tows that require a double lockage. The kevel and guidewall are structural improvements that act as a system to reduce lockage times by expediting the extraction of the first cut. The bottom line benefit is that the VE process revealed that improved operational methods and reduced costs are possible when compared to the original kevel and guidewall system.

Contrary to traditional practice, this VE Study was performed prior to starting the detailed design phase of the above mentioned project features. Traditionally, a VE Study would be undertaken when the design would be nearly complete, thus making significant changes costly, difficult to incorporate and still meet the schedule. VE Studies performed very early in the design process can take advantage of a broader group of ideas prior to detailed design; however, less than completed documents must be used. A conceptual design (with some adaptation) from the Upper Mississippi River – Illinois Waterway System Feasibility Study was used as the original design (for the guidewall and powered traveling kevels) for this VE Study. The VE Study team was presented background information which was used to generate approximately 92 ideas to be evaluated against established criteria. Of the 92 ideas, 17 survived screening and 14 were recommended for post -VE Study design efforts. Where possible, potential savings for some of the proposals were computed, based on available information and are regarded as preliminary at this time. The individual savings items should not be construed to be cumulative.

It is important to note that the VE study proposed alternatives for improved and simplified designs, improved operations, in addition to cost savings. Although initial cost savings are reported, their actual value was considered secondary to the fact that future [larger] cost savings will definitely be achievable as the design process continues. Early implementation of the Value Engineering Study process generated valuable proposals for operational improvements and efficiencies that should be carefully considered in the forthcoming detailed design effort.

Finally, performing a value analysis of these project features in the post-formulation/pre-design stage allowed the flexibility of "brainstorming" on the primary objectives of "reducing lockage times" and "increasing operational efficiency," rather than being confined to speculate on just a "concrete `n steel" design item. As can be seen from the VE team member listing, a broad spectrum of government and private expertise comprised the study group, thus enabling a wide range of ideas to be surfaced for analysis and development.

Value Engineering Study Process

Gene Degenhardt, St. Louis District VE Officer, served as the team leader/facilitator for the study. He provided a brief overview of the VE process. Value Engineering is an organized study of function requirements to satisfy the user's needs and obtain the maximum value through applied creativity resulting in win-win outcomes. It is a short-term process focused on developing a new way of thinking about things. It is not a cost cutting or a cheapening technique. Instead, it is focused on looking at what other options will accomplish the required functions.

The VE study was conducted using the following five phase VE Job Plan:

- **Information** – The entire study team reviewed the current double lockage process and the guidewall extensions with the powered kevel option. As part of this process, existing and potential problems were identified with the guidewall extension/powered kevel option. A very useful tool was the utilization of a hand-made micro-scale model (1 inch = 20 feet) of Lock & Dam No. 22.1/ Prior to proceeding to the Speculation Phase, the VE study team developed a listing of problems related to the lockage process, both real and perceived, as expressed by the diverse group of individuals.

- **Speculation** – The team then conducted a brainstorming session and generated 92 ideas for alternative guidewall and kevel designs and operational scenarios. Critical analysis of the ideas was discouraged during this phase so as to obtain the maximum number of ideas.

- **Analysis** – Evaluation, testing, and critical analysis of all ideas generated during the Speculation Phase was then preformed during a preliminary screening to determine applicability of ideas to a given set of criteria that was develop by the entire group. Ideas not surviving the criteria were eliminated from further consideration. The entire team was then divided into two groups, guidewalls and kevels, to perform a second screening and then develop preliminary VE proposals for the smaller core group to consider during the remainder of the VE study.

- **Development** – Beginning on the third day of the VE study, the smaller core group undertook an intensive technical development session to evaluate and further develop the preliminary list of VE proposals. Proposal descriptions, technical support documentation, and cost estimates, where appropriate and possible, were prepared to support the VE recommendations as presented in this report.

- **Presentation** – The information contained in the VE study report will undergo several reviews and presentations. First, a draft VE Study Report was distributed for review by all VE study team members and their respective agencies. This final report has been distributed to project supporters and decision-makers. Formal, oral presentations of the VE Study Proposals will be offered, if desired.

1/ Simulation of the lockage and cut extraction process was utilized to develop alternatives and identify shortcomings in the new process.

Information Phase

As mentioned previously, Bob Hughey initiated the Information Phase of the VE Job Plan by describing the purpose and scope of the VE study. This was followed by Jeff Stamper, a Structural Engineer with the St. Louis District, who reviewed the double lockage process and timing (see handout in Appendix) to ensure a common understanding of the current lockage process being preformed at the locks on the UMR-IWWS (Upper Mississippi River-Illinois Waterway System). He then described the extended guidewall with powered kevel option as currently developed (see team read-ahead package in Appendix). Jeff stated that the major function of the improvements is to allow the tow to remake outside of the lock chamber. During this presentation, Jeff highlighted the specific steps, timing, and location of lock staff, deckhands, and cuts of the tow. He also covered the proposed construction process to build guidewalls and stated that the study team is looking at potential approach channel improvements, which could reduce outdraft flows.

Jeff Stamper also explained that a kevel is a heavy metal deck fitting having two horn-shaped arms projecting outward around which lines may be made fast for towing or mooring a vessel. A powered traveling (rail mounted) kevel provides power to extract the unpowered-first cut from the lock. The current winch system and length of cable would remain and be supplemented by kevels added on both upstream and downstream walls. The guidewall can be lengthened and the unpowered cut of barges pulled a greater distance from the lock chamber with a powered traveling kevel on the guidewall. The powered unit for the kevel system is a pull/retard system. The system will be able to pull and stop cuts along with restraining lateral movement of the head and stern.

Powered traveling kevels provide time savings based on their ability to extract the cuts along an extended guidewall allowing the recoupling (remake) to occur outside of the chamber. The next tow traveling in the same direction is therefore allowed to use the lock. For tows traveling downstream, moving the unpowered cut further down the guidewall allows faster chamber emptying at some sites, since the danger of breaking lines would be reduced.

Jeff Stamper emphasized that this concept is being proposed for both upstream and downstream guidewalls. The desire is for an option that is useable in all types of weather and flow conditions, and if there are limitations when it can't be used, they should be documented. To the extent possible, the options should not require additional staff on the tows or at the lock. Success is dependent on reliable machinery in combination with knowledgeable users. However, it is anticipated that as with any change, new procedures will involve some learning curve.

Other information included a video of the tow haulage system for Pickwick Locks. Bill Bennett provided photographs of Pickwick and other locks utilizing powered traveling kevels.

Identification of Problems and Concerns

During the Information Phase, the following potential problems were identified by the team members. The contribution by each person was not questioned by others since a diverse group of individuals can each perceive problems differently.

- Lockage Times – lockages too slow
- Need extended chambers
- Think system-wide
- Insufficient staffing on tows and locks
- Reduce manpower/reduce costs
- Not enough space on guidewall and miter gates for equipment
- Need ability to remove equipment during floods
- Safety of use
- Complexity of operation/excessive line handling
- Need training on new operations
- Maintenance costs
- River conditions/adverse flow conditions
- Expensive temporary solution
- Personal injury exposure
- Extraction is too slow
- Communication between lock personnel and tows (captain/deckhands)
- Damage to environment – fuel use during long lockage process
- Satisfy customer – reduce lock time
- Inability to cross miter gate bay with kevel rail
- Approach alignment
- Getting deck crew up/down lock walls
- Placement of trailing kevel – attachment to location on barge
- Equipment maintenance
- Single rail is not good enough
- Retrofitting 60-year old structures
- Angle of haul line through low and high water
- Update barge equipment

Brainstorming Session

An integral component of the Value Engineering methodology is the use of the function analysis concept where an item is dissected into discrete function components and described in a verb-noun format. For example, a pencil is described as a device whose intended function is to "transfer-information" [brain to paper], with possible secondary functions such as stir-paint, dig-hole, etc. Once this concept was presented to the VE study team, they were asked to speculate on the required function(s) of the guidewall/kevel features, namely, guide-tow, move-[barge] cut, reduce [lockage] time, etc. The subsequent speculation process produced the following listings which were categorized into three areas; guidewalls, kevels and technology transfer. The number beside each item pertains to the reason why that idea was not carried forward for further consideration and is explained in the Analysis Phase section of this report. During the brainstorming session, however, participants were encouraged to "think out of the box" and offer any idea that came to mind. No evaluations were permitted at that time. The brainstorming ideas are presented in an "as recorded" unedited format to preserve the intent of the suggestors comment.

Brainstorming Results - Guidewall Speculation Items

3-Cells only, no walls (cells at spaces).
Floating guidewall.
1-Moving guidewall.
3-No guidewall.
Triangular-shaped cells.
5-Mooring facilities.
Rectangular cells.
Move the cells landward (save material).
Change attachment.
Beam configuration (narrower, with wider walkway.
High density polyethylene bumpers (look at sliding impacts).
3-Delong piers.
Series of horizontal steel rails mounted on cells/steel frames for two to slide along.
1-Shore-based hydraulic arm to replace wall segments.
5-Lift-in construction for guidewall.
4-Two guidewalls.
3-Replace guidewall with a rock dike.
Submersible lock gates/lift gates.
3-Timber guidewall (also #4).
Concrete beam cribs with rock fill.
Alternate forms for sub-structure (plastic rock cribs – fabric fill, slip forms).
3-Debris fill.
3-Fill cells with CCH (chalk-like material – leftovers from fertilizer production).
3-Sink derelict ships/barges.
5-Pre-cast concrete boxes filled with sand or rock.
3-Design only part of wall for impact.
5-Is tow load figured accurately?
3-More flexible wall (idea "out" if used with rail).
1-Wall made out of ultra dense polystyrene material.
1-Grow a guidewall.
1-Zebra mussel guidewall.
Put walls on riverside.
Slender substructure with rock anchors (post tensioning).

Brainstorming Results - Guidewall Speculation Items (Continued)

Issue RFP (Long-term contract for extracting the first cut).
Sloping top on cells.
Focus hydraulic models on cut.

Brainstorming Results - Kevel Speculation Items

3- Big pulley (no guidewall).
Kevel crosses the gated cable system with wall (cable pulling/cable restraining).
5- Switchboat/Helper/Haulage boats.
5- Self help.
Cableless kevel.
Cog rail system.
Motorized kevel.
1- Kevel underwater (off guidewall).
Two rail kevel.
Automated kevel.
Release/trip mechanism.
Cable tram system (with guidewall).
3- Perpendicular steel rails on cells.
3- Rails on face of wall in recess.
3- Propulsion device mounted on barges (connecting to rail on wall) (also #4).
6- Flush out cuts (operational –not new).
Mules (Panama Canal-like, land-based locomotive to haul/stop).
1- Electro-magnetic connections.
1- Suction cup (electric haul rail).
4- Submersible lift gates.
3- Alternate location for brake line.
Brakes on kevel (calipers&pads).
One kevel does stop and start.
Single loop for both kevels.
Cog rail system that actually positively attaches to barge for absolute control (arm).
1- Steam.
Bow thrusters at lock.
1- Propelled motor – big outboard motor.
1- Put kevel on incline.
Test program (power existing kevel to haul cuts).

Brainstorming Results - Technology Transfer Speculation Items

1- Electrified rail.
1- Pushing kevel with compressed air.
6- Push with water (flush cuts).
Same principle as an elevator turned sideways.
1- Hydraulic system in wall.
Ski-slopes (J hook).
Nashville District (look at their system of kevels cross gates).
Panama Canal mule system.
1- Overhead crane technology.
1- Portland District approaches to recreation lockages.
1- Steam.

Brainstorming Results - Technology Transfer speculation Items (Continued)

1- Aircraft carriers – catapult – starting and stopping.
1- Pitching machine/Jugs Machine (wheels on side).
1- Roller on bottom.
   Auto plant technology (conveyors).
1- Same type of rail as moves across dam for crane to set gates.
   DC motors (e.g., big trucks in quarries).
1- Worm drive.
   Chain drive.
   Electro-hydraulic motor.
1- Roller coaster.
   Kevel turns to work towards mechanical advantage.
4- Derrick crane with rails on each side of chamber.
1- Stored energy.

Analysis Phase

Initial Screening: As mentioned previously, a two-phase screening process was used to evaluate the potential options identified during the brainstorming session. The following list of evaluative criteria was developed by the VE study team and utilized during the initial screening by the entire group. These numbers are shown next to the speculation listing(s) as presented on the preceding pages. Ideas without a number were carried forward to the second screening level. This listing is shown below.

Criteria Number	Description
1	Not technically feasible, unworkable, not practical
2	Beyond scope of VE effort and/or Navigation Study
3	Acceptability – measure presents unacceptable risks, requirements, or operations
4	Economic – Too costly
5	Still under consideration – under context of the overall Feasibility Study
6	Currently being done

Items Remaining after Initial Screening - Guidewall

- Floating guidewall
- Triangular-shaped cells
- Rectangular cells
- Move the cells landward – save material, change attachment
- Beam configuration – narrower, with wider walk way
- High density polyethylene bumpers – (look at sliding impacts)
- Series of horizontal steel rails mounted on cells/steel frames for tow to slide along
- Protection cells above and below I-wall
- Submersible lock gates/lift gates
- Concrete beam cribs with rock fill
- Alternate Forms for Sub-Structure (Plastic rock cribs – fabric fill, slip forms)
- Put walls on river side
- Slender substructure with rock anchors (post tensioning)
- RFP - long term contract for extracting the first cut
- Sloping top on cells
- Focus hydraulic models on cut extraction forces

Items Remaining after Initial Screening - Kevel

- Kevel crosses the gated
- Cable system with wall – cable pulling/cable restraining
- Cableless kevel
- Cog rail system
- Motorized kevel
- Two rail kevel
- Automated kevel
- Release Mechanism/Trip
- Cable Tram system – with guidewall
- Mules (Panama Canal-like land based locomotive – haul/stop)
- Electric Haul Rail
- Brakes on kevel (calipers&pads)
- One kevel does stop and start
- Single loop for both kevels
- Cog rail system that actually positively attaches to barge – absolute control (arm)
- Bow thrusters at lock
- Test program – Power Existing Kevel to Haul Cuts

Items Remaining After Initial Screening - Technology Transfer

- Same principle as an elevator turned sideways
- Ski-slopes – J hook
- Nashville District – look at their system kevels cross gates
- Panama Canal - mule
- Auto plant tech (conveyors)
- Chain drive
- Electro-hydraulic motor
- Kevel turns to work towards mechanical advantage

<u>Second Screening</u>: To proceed to the second screening, the VE study team was then divided into two groups, guidewalls and kevels, according to their expertise and interest. Each group was instructed to consider the following evaluative criteria, as a minimum: cost, time savings, technical feasibility, constructability, acceptability and impacts to navigation. Those ideas, which survived this second screening, were then presented to the core group of individuals for their detailed evaluation and analysis in the Development Phase of the VE Job Plan.

The guidewall VE study group took the time to categorize the alternatives to summarize their efforts and created the following list:

Guidewall Items recommended for further analysis

<u>High Priority</u>

- Build slender sub-structure with rock anchors
- Alternate-shaped cells (i.e., triangular vs. round)
- Beam configuration analysis
- Protection cells above and below I-wall

<u>Maybe Consider</u>

- Concrete cribs with rock fill
- Focus on hydraulic models
- High density polyethylene bumpers
- Issue RFP for long-term contract for extracting first cut

<u>Drop From Consideration</u>

- Sloping top on cells
- Floating guidewall
- Move cells landward
- Series of horizontal steel rails mounted on cells
- Put walls on river side

The traveling kevel VE study group spent considerable time utilizing the micro-scale model to arrive at lockage alternatives. Those alternatives with most merit are described in the individual VE proposals which follow.

Development Phase

Upon completion of the Information, Speculation and Analysis phases of the VE Job Plan, the attendees who participated for just the first part of the VE study were thanked for their contribution and informed that they would be receiving a draft copy of the VE report for their review. The remaining core group of individuals, denoted by an asterisk on the Participation Roster, then proceeded to further analyze each proposal in detail. The results of their efforts are shown on the following pages as individual VE proposals. As can be noted, a number of them were dropped from further consideration for the reasons noted.

While carried forward for evaluation as possible VE proposals, additional consideration during the Development Phase screened out the following guidewall items:

Description	Reason for Elimination
Move cells landward.	Not technically advantageous. Minor benefits.
Steel structure to replace concrete beam	Workgroup felt that alternative offers no advantage over concrete beams.
Walls on riverside.	More structure to construct. Would have to remove existing guidewall. Operations are conducted from landwall, therefore, retrofit would be complicated. Impacts to navigation during construction would be very costly.

The reader may find a lack of narrative in the individual "justifications" and "cost savings" of the proposals. For all of the proposals, a general explanation about their adoption into design may help. Many proposals were made and all of them were compared against the baseline by mostly subjective criteria. Generally, a comparison of cost was performed, but detailed cost estimates were not available for the baseline condition since the VE Study was conducted early in the design phase. This makes it extremely difficult to report accurate cost savings, but nevertheless, it is obvious that cost savings were achievable. On the other hand, the timing of the study was advantageous in that all the proposals could be considered during design either in part or in their entirety.

Value Engineering Proposals Developed and Evaluated

1. Use Tandem Tow Haulage Units to Extract First Cuts
   ($1 million savings x 5 locks = $5 million)

2. Faster Extraction of First Cuts with Existing Haulage

3. Use Motorized Mule (capable of crossing Miter Gate) to Extract First Cuts

4. Use a Tow Haulage System Consisting of a Continuous Cable with Two Dependent Powered Kevels and One Unpowered Kevel to Extract First Cuts
   ($735,000 savings x 5 locks = $3.675 million)

5. Use a Simplified System Consisting of Unpowered Kevels, with Powered Cut Moving First Cut to End of Guidewall
   ($1.43 million x 5 locks = $7.15 million)

6. Use a Tow Haulage System Entitled the "1200-300-1200 Powered Kevel Option." (The numeric values represent the kevel haul distances on the guidewall, within the lock, and on the other guidewall, respectively) (not recommended for further consideration)

7. Use a Guidewall Substructure Featuring a "Pile Cap on Sand – Place Cell Later" Method (This oversized pile cap allows installation of more piles and a minimum-sized pier stem)

8. Use a Slender Substructure with Rock Anchors to Lessen the Size of the Substructure Units
   ($333,000 savings/guidewall cell x 12 cells/lock x 2 applicable locks = $8.0 million)

9. Investigate Alternative-shaped Cells to Economize on the Amount of Structure Required

10. Use Smaller Guidewall Beam Configurations/Weights to Reduce Lifting Demands and Reduce Costs

11. Study the Use of Protection Cells Above and Below the I-wall to Control Lateral Tow Movement Upon Extraction

12. Investigate Concrete Cribs Substructure with Rock Fill to Lessen Guidewall Costs

13. Focus Hydraulic Models on Cut Extraction Forces

14. Use High Density Polymer Bumpers to Reduce Impact Loads on Guidewalls (not recommended)

15. Slope the Top of Guidewall Cells to Reduce Concrete Placements

16. Investigate the Feasibility of a Floating Guidewall (not recommended)

17. Issue Request for Proposal (RFP) for Long-term Contract for Extracting the First Cut and Placing the Cut on the Upstream Structure

VALUE ENGINEERING PROPOSAL

Proposal No. 1

DESCRIPTION: Use Tandem Tow Haulage Units to Extract First Cuts

ORIGINAL DESIGN: The original design has two kevels that are powered independently by a set of pull/retard winches. These powered kevels and rails do not cross the miter gates. This option uses the existing tow haulage to extract the cut from the chamber. The unpowered cut is then stopped in the current position, just outside the gates, and attached to the two powered kevels. During this process 2 to 3 deckhands move with the cut, and only leave for the powered cut when the cut is stopped and tied off to the kevels. One deckhand remains on the stern of the cut. The cut is then pulled to the end of the wall using the leading kevel for power. The trailing kevel provides a restraining force and the deckhand checks the tow if needed. Since both units are powered, utilizing a pull-retard cable system, 4 winches are needed (2 for each kevel) on each guidewall, 8 total per lock.

PROPOSED DESIGN: This option replaces the powered kevels with two unpowered units and adds an additional tow haulage unit to the wall to complete movement of the cut to end of the guidewalls. Again the initial extraction is provided using the existing tow haulage. However, in this instance only one deckhand stays on the cut during extraction. The cut is not stopped immediately above the lock, but is instead attached to two unpowered kevels on the move and allowed to continue to coast up the guidewall. If the cut is able to move to the end of the guidewall it is allowed to do so. However, if the cut slows or stops prior to this point. The new tow haulage winch, located somewhere out on the guidewall, is attached to the trailing kevel (or barge) by a cable and used to provide the additional force necessary to again move the cut to the end of the wall. The stopping force is provided by checking the cut as is currently done.

Will continue to look into options to use the new winch to apply some restraining force by pulling on the trailing kevel.

ADVANTAGES:

- Less machinery and cable (only 1 new winch is required per wall vs. 4 per wall under original design).
- Lower first cost
- Equal Time Savings – upbound (similar downbound)
- Less maintenance (considerably fewer winches and cables to maintain).
- Relies primarily on existing technology (may need to add remote control)
- Uses proven technology, reduces risk

DESCRIPTION: Use Tandem Tow Haulage to Extract First Cuts

DISADVANTAGES:

- No braking ability in kevels
- Additional operation required by lockperson if second pull is needed
- One lockperson needs to stay with the unpowered cut and tow haulage
- Safety concerns in stopping the downbound cuts.
- Lead kevel does not have ability to fully control the head of unpowered cut (greater concern on downbound).

JUSTIFICATION:

To be determined during further design efforts.

COST SAVINGS:

The first-cost savings is estimated at roughly $1.0 million per lock (just for reductions in winches) as calculated from taking the difference between the two cost estimates. Annual costs would also be reduced due to reduced operations and maintenance needs (cable replacements, winch repair, replacements, etc.).

NOTE: The cost estimate for the 12-N-12 alternative (Baseline/Original) is considered the baseline estimate for comparison with the other alternatives that had a cost estimate.

UMRIWS VALUE ENGINEERING STUDY

COST ESTIMATE FOR
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
ALTERNATIVE 12-N-12 (Baseline/Original)

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	40 HP Winch (w/power unit &power panel)	8	EA	$80,000	$640,000
2	1" Dia Wire Rope	6,800	LF	$5	$34,000
3	36" Dia Sheaves w/Assembly	16	EA	$5,000	$80,000
4	140# Rail (w/[lates, clips & anchors)	2,600	LF	$60	$156,000
5	Tow Haulage Bitts	4	EA	$3,000	$12,000
6	Rigid Steel Conduit	3,400	LF	$10	$34,000
7	Power/Control Cables	10,200	LF	$10	$102,000
8	Control/MCC Modifications & Additions	2	EA	$10,000	$20,000
9	Removal of Checkposts	20	EA	$250	$5,000
10	Install New Checkposts	20	EA	$3,500	$70,000
11	Removal & Relocation of Handrail	1,100	LF	$20	$22,000
12	Misc. Structural Mods. (ladders,trenches)	1	EA	$10,000	$10,000
13	Remote Control	2	EA	$2,000	$4,000
14	Testing/Start-Up Services	1	EA	$15,000	$15,000
15	Training	1	EA	$5,000	$5,000
		SUBTOTAL			$1,209,000
		CONTINGENCIES (25%)			$302,000
		SUBTOTAL			$1,511,000
		P.,E., & D (15%)			$227,000
		C.M. (10%)			$151,000
		TOTAL			$1,889,000

UMRIWS VALUE ENGINEERING STUDY

COST ESTIMATE FOR
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
ALTERNATIVE for TANDEM TOW HAULAGE UNITS

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	40 HP Winch (w/power unit &power panel)	2	EA	$80,000	$160,000
2	1" Dia Wire Rope (2@200')	400	LF	$5	$2,000
3	36" Dia Sheaves w/Assembly	6	EA	$5,000	$30,000
4	140# Rail (w/[lates, clips & anchors)	2,600	LF	$60	$156,000
5	Tow Haulage Bitts	4	EA	$3,000	$12,000
6	Rigid Steel Conduit	1,800	LF	$10	$18,000
7	Power/Control Cables	4,800	LF	$10	$48,000
8	Control/MCC Modifications & Additions	1	EA	$10,000	$10,000
9	Removal of Checkposts	20	EA	$250	$5,000
10	Install New Checkposts	20	EA	$3,500	$70,000
11	Removal & Relocation of Handrail	1,100	LF	$20	$22,000
12	Misc. Structural Mods. (ladders,trenches)	1	EA	$10,000	$10,000
13	Remote Control	2	EA	$2,000	$4,000
14	Testing/Start-Up Services	1	EA	$15,000	$15,000
15	Training	1	EA	$5,000	$5,000
		SUBTOTAL			$567,000
		CONTINGENCIES (25%)			$142,000
		SUBTOTAL			$709,000
		P.,E., & D (15%)			$106,000
		C.M. (10%)			$71,000
		TOTAL			$886,000

VALUE ENGINEERING PROPOSAL

Proposal No. 2

DESCRIPTION: Faster Extraction of First Cuts with Existing Haulage

ORIGINAL DESIGN: Extraction uses the existing tow haulage to extract the cut from the chamber at existing speed of roughly 50 fpm.

PROPOSED DESIGN: Again the initial extraction is provided using the existing tow haulage, but the tow haulage is sped up to a faster extraction speed of approximately 75 fpm. However, in this instance, only one deckhand would ride the first cut out of the chamber and attachment to the kevels would be made without stopping the cut immediately above the lock. The faster extraction is possible since there is additional guidewall to slow and stop along. The potential for predictable performance of this action is unknown.

ADVANTAGES:

- Additional time savings on cut extraction (roughly 4 min faster).
- Same cost

DISADVANTAGES:

- Safety concerns in stopping cuts (especially downbound cuts).
- Requires making to the stern kevel on the move.

JUSTIFICATION:
Feasibility and safety issues need to be further assessed.

COST SAVINGS:
Anticipated to provide considerable economic benefits at no additional cost

VALUE ENGINEERING PROPOSAL

Proposal No. 3

DESCRIPTION: Use Motorized Mule (capable of crossing Miter Gate) to Extract First Cuts

ORIGINAL DESIGN: The original design has two kevels that are powered independently by a set of pull/retard winches. These powered kevels and rails do not cross the miter gates. This option uses the existing tow haulage to extract the cut from the chamber. The unpowered cut is then stopped in the current position, just outside the gates, and attached to the two powered kevels. During this process 2 to 3 deckhands move with the cut, and only leave for the powered cut when the cut is stopped and tied off to the kevels. One deckhand remains on the stern of the cut. The cut is then pulled to the end of the wall using the leading kevel for power. The trailing kevel provides a restraining force and the deckhand checks the tow if needed. Since both units are powered, utilizing a pull-retard cable system, 4 winches are needed (2 for each kevel) on each guidewall, 8 total per lock.

PROPOSED DESIGN: A self powered kevel travels along a kevel rail that crosses the miter gate and enters roughly 100 feet into the chamber. This simplifies line handling, since the crew only makes one connection to the tow haulage, and the bow is attached before the tow starts moving. The kevel can then extract the cut the entire distance to the end of the wall. Start up forces occur in the chamber, but the kevel does not apply pulling force while crossing the miter gate. In this instance only one deckhand stays on the cut during extraction, attaching the unpowered trailing kevel on the move. The stopping force is provided by the powered kevel and checking the cut if necessary.

Further refinement of the design options could evaluate two guide rails, bus bar power system, cog traction, diesel power, battery power, or oil hydraulic. Diesel power would appear to provide the most straight forward design at this time.

ADVANTAGES:

- Simple operation – crews only make one connection to tow haulage equipment.
- Potential for faster extraction
- Safety advantage of less line handling and less cables
- One machine vs. numerous winches
- Can be automated/semi-automated
- Only one machine needed to extract and stop the cuts
- A properly designed mule could perform the function in a dependable manner

DISADVANTAGES:

- Need modification to miter gate and lockwall
- Needs traction system (new technology to lock operations)
- Maintenance (refueling and/or other maintenance)
- Would require significant research and design development effort

VALUE ENGINEERING PROPOSAL

Proposal No. 3 (Continued)

DESCRIPTION: Use Motorized Mule (capable of crossing Miter Gate) to Extract First Cuts

DISADVANTAGES (Continued):

- To apply extraction and stopping force with one powered kevel need 2 lines to tow, one will be a longer line
- Likely need two rails

JUSTIFICATION:
Could be determined during further design efforts.

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 4

DESCRIPTION: Use a Tow Haulage System Consisting of a Continuous Cable with Two Dependent Powered Kevels and One Unpowered Kevel to Extract First Cuts

ORIGINAL DESIGN: The original design has two kevels that are powered independently by a set of pull/retard winches. These powered kevels and rails do not cross the miter gates. This option uses the existing tow haulage to extract the cut from the chamber. The unpowered cut is then stopped in the current position, just outside the gates, and attached to the two powered kevels. During this process 2 to 3 deckhands move with the cut, and only leave for the powered cut when the cut is stopped and tied off to the kevels. One deckhand remains on the stern of the cut. The cut is then pulled to the end of the wall using the leading kevel for power. The trailing kevel provides a restraining force and the deckhand checks the tow if needed. Since both units are powered, utilizing a pull-retard cable system, 4 winches are needed (2 for each kevel) on each guidewall, 8 total per lock.

PROPOSED DESIGN: Kevel design involves two dependent powered kevels set a fixed distance apart (roughly 150 feet) attached to a single continuous loop cable system. A separate unpowered kevel is provided to hold the stern along the wall. This proposal allows for less machinery and extracting and stopping force to be provided by one machine, with a single controller. Again the initial extraction is provided using the existing tow haulage. However, in this instance only one deckhand stays on the cut during extraction. The cut is not stopped immediately above the lock, but is instead attached to the first of two dependent powered kevels on the move and allowed to continue to move up the guidewall. This first kevel will serve as the braking kevel. Next the deckhand on the cut walks back to the end of the first barge and attaches a line to the second dependent powered kevel, which will provide additional extracting force to take the cut to the end of the wall. Finally the deckhand attaches a line from the stern to the unpowerd kevel. The stopping force is provided by the first or braking kevel and checking of the head as is currently done.

The development of the cable system could benefit from a study of ski lift technologies.

ADVANTAGES:

- Less machinery
- Lower cost
- Additional safety associated with one additional connection between unpowered cut and wall
- Only one machine needed to extract and stop the cuts - simplifying the lock person's operations
- Appears to be a dependable system

DESCRIPTION: Use a Tow Haulage System Consisting of a Continuous Cable with Two Dependent Powered Kevels and One Unpowered Kevel to Extract First Cuts

DISADVANTAGES:

- During maintenance both powered kevels are out of operation
- Likely to require additional time to conduct maintenance to system.
- Need to make one additional connection to tow
- Requires one very large/long cable for each guidewall

JUSTIFICATION:

To be determined during further design efforts.

COST SAVINGS: The cost savings (approximately $753,000) for this system are mostly in the reduced machinery requirements.

UMRIWS VALUE ENGINEERING STUDY

COST ESTIMATE FOR
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
ALTERNATIVE for CONTINOUS CABLE SYSTEM
(two dependent & one independent kevels)

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	40 HP Winch (w/power unit &power panel) (w/power unit, power panel & larger drum)	2	EA	$10,000	$20,000
2	1" Dia Wire Rope (2@2800')	5,600	LF	$5	$28,000
3	36" Dia Sheaves w/Assembly	8	EA	$5,000	$40,000
4	140# Rail (w/[lates, clips & anchors)	2,600	LF	$60	$156,000
5	Tow Haulage Bitts	6	EA	$3,000	$18,000
6	Tensioning Device	2	EA	$10,000	$20,000
7	Concrete Cable Trench w/Steel Cover Plat	2,600	LF	$100	$260,000
8	Concrete Foundation for Winches	2	EA	$10,000	$20,000
9	Rigid Steel Conduit	800	LF	$10	$8,000
10	Power/Control Cables	1,600	LF	$10	$16,000
11	Control/MCC Modifications & Additions	1	EA	$10,000	$10,000
12	Removal of Checkposts	20	EA	$250	$5,000
13	Install New Checkposts	20	EA	$3,500	$70,000
14	Removal & Relocation of Handrail	1,100	LF	$20	$22,000
15	Misc. Structural Mods. (ladders,trenches)	1	EA	$10,000	$10,000
16	Remote Control	2	EA	$2,000	$4,000
17	Testing/Start-Up Services	1	EA	$15,000	$15,000
18	Training	1	EA	$5,000	$5,000
		SUBTOTAL			$727,000
		CONTINGENCIES (25%)			$182,000
		SUBTOTAL			$909,000
		P.,E., & D (15%)			$136,000
		C.M. (10%)			$91,000
		TOTAL			$1,136,000

VALUE ENGINEERING PROPOSAL

Proposal No. 5

DESCRIPTION: Use a Simplified System Consisting of Unpowered Kevels, with Powered Cut Moving First Cut to End of Guidewall

ORIGINAL DESIGN: The original design has two kevels that are powered independently by a set of pull/retard winches. These powered kevels and rails do not cross the miter gates. This option uses the existing tow haulage to extract the cut from the chamber. The unpowered cut is then stopped in the current position, just outside the gates, and attached to the two powered kevels. During this process 2 to 3 deckhands move with the cut, and only leave for the powered cut when the cut is stopped and tied off to the kevels. One deckhand remains on the stern of the cut. The cut is then pulled to the end of the wall using the leading kevel for power. The trailing kevel provides a restraining force and the deckhand checks the tow if needed. Since both units are powered, utilizing a pull-retard cable system, 4 winches are needed (2 for each kevel) on each guidewall, 8 total per lock.

PROPOSED DESIGN: The cut is attached to two unpowered kevels and, shorten the lockage cycle, the powered cut provides force to move the unpowered cut to the end of the extended guidewall. As in the current process, the initial extraction is provided using the existing tow haulage. The crew movements and the location for stopping the cut immediately above the lock, remain the same. However, under this approach the cut is tied off to the two unpowered kevels. The stopping force is provided by checking the cut as is currently done.

The cut then waits just outside the lock until the powered cut has locked through. The gates then open and the powered cut faces up to the unpowered cut and a 4 to 8 part line is attached in less than a minute between the center deck fittings. The tow then pushes the cut to the end of the guidewall, with the unpowered kevels holding the first cut along the wall and the tow providing the pushing and restraining forces. Once clear of the gates a line is attached from the unpowered cut to the wall and remake proceeds.

ADVANTAGES:

- Avoids need for powered kevels (less machines and cables)
- Cost reductions
- Less maintenance
- Safety - no checking required outside of the bullnose
- Is currently used on occasion during ice lockages and is a proven procedure – reduces risk

DESCRIPTION: Use a Simplified System Consisting of Unpowered Kevels, with Powered Cut Moving First Cut to End of Guidewall

DISADVANTAGES:

- Reduces time savings by 2-4 minutes (tow must slow in chamber during face up & attachment of single line).
- Pilot required to judge stopping distance.

JUSTIFICATION:

Recommended for continued consideration as a phase-in step in the initiation of any powered-kevel option. However, concern is that the cost savings is not worth the loss in time savings.

COST SAVINGS:

Difference between the two estimates is $1.43 million in potential savings.

UMRIWS VALUE ENGINEERING STUDY

COST ESTIMATE FOR
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
ALTERNATIVE for Simplified System w/ Unpowered Kevels

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	140# Rail (w/[lates, clips & anchors)	2,600	LF	$60	$156,000
2	Tow Haulage Bitts	4	EA	$3,000	$12,000
3	Removal of Checkposts	20	EA	$250	$5,000
4	Install New Checkposts	20	EA	$3,500	$70,000
5	Removal & Relocation of Handrail	1,100	LF	$20	$22,000
6	Misc. Structural Mods. (ladders,trenches)	1	EA	$10,000	$10,000
7	Testing/Start-Up Services	1	EA	$15,000	$15,000
8	Training	1	EA	$5,000	$5,000
		SUBTOTAL			$295,000
		CONTINGENCIES (25%)			$74,000
		SUBTOTAL			$369,000
		P.,E., & D (15%)			$55,000
		C.M. (10%)			$37,000
		TOTAL			$461,000

VALUE ENGINEERING PROPOSAL

Proposal No. 6

DESCRIPTION: Use a Tow Haulage System Entitled the "1200-300-1200 Powered Kevel Option." (The numeric values represent the kevel haul distances on the guidewall, within the lock, and on the other guidewall, respectively

ORIGINAL DESIGN: The original design has two kevels that are powered independently by a set of pull/retard winches. These powered kevels and rails do not cross the miter gates. This option uses the existing tow haulage to extract the cut from the chamber. The unpowered cut is then stopped in the current position, just outside the gates, and attached to the two powered kevels. During this process 2 to 3 deckhands move with the cut, and only leave for the powered cut when the cut is stopped and tied off to the kevels. One deckhand remains on the stern of the cut. The cut is then pulled to the end of the wall using the leading kevel for power. The trailing kevel provides a restraining force and the deckhand checks the tow if needed. Since both units are powered, utilizing a pull-retard cable system, 4 winches are needed (2 for each kevel) on each guidewall, 8 total per lock.

PROPOSED DESIGN: Only difference from original design is that the chamber extraction force is provided by a powered kevel on a 300 foot rail along the lock chamber guidewall.

ADVANTAGES:
- All haulage is provided by powered kevels.
- Appears to be a dependable system.

DISADVANTAGES:
- Added cost – additional kevel and rail in chamber adds cost.
- Doesn't save any more time than original design.

JUSTIFICATION:
Eliminated this proposal since it provides no additional time savings and increases cost.

COST SAVINGS:
Increased cost related to additional kevel and rail in chamber.

VALUE ENGINEERING PROPOSAL

Proposal No. 7

DESCRIPTION: Use a Guidewall Substructure Featuring a "Pile Cap on Sand – Place Cell Later" Method (This oversized pile cap allows installation of more piles and a minimum-sized pier stem)

ORIGINAL DESIGN: Can extended over piles

PROPOSED DESIGN: Piling is driven into sand using a template. The oversized pile cap is constructed with tremie concrete. After the pile cap has gained strength, the steel can is place onto the pile cap. The can is then filled with concrete and the superstructure is constructed as originally proposed.

ADVANTAGES:

- Facilitates easy placement of can
- Pile cap form could serve as pile driving template
- Allow placement of piles prior to can.
- Allows smaller cell to have a larger foundation.

DISADVANTAGES:

- Different structure underwater
- Pile cap and pile pier are separate structures, therefore probably lengthening construction time

JUSTIFICATION:
Need to consider during design

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 8

DESCRIPTION: Use a Slender Sub-structure with Rock Anchors to Lessen the Size of the Substructure Units

ORIGINAL DESIGN: Larger cells.

PROPOSED DESIGN: Instead of the cells acting as pure gravity structures (where the weight of the structure provides the downward force required for stability), post-tensioned rock anchors will supply portions of the downward force. Rock anchors facilitate the use of smaller cells without compromising stability.

ADVANTAGES:

- Smaller cell size
- Cost savings
- Smaller steel can to fabricate, ship, handle (allows use of smaller crane)
- Less concrete – faster filling
- Less impacts to navigation during construction smaller items easier to construct
- Rock anchor may be installed during navigation after construction of the cell
- Anchor could help with flexural and shear capacity of cell

DISADVANTAGES:

- Smaller cell may require stronger material/more reinforced design (getting away from strength inherent to massive concrete structures)
- Primarily applicable to rock founded structures - may not work on sand

JUSTIFICATION:
Stability analysis is required.
Regulation EC-291 allows use of tension anchors.

COST SAVINGS:
$333,000

OTHER CONSIDERATIONS:
Bond/unbonded
Maintenance of anchors (monitoring)
No prestressed anchor (pipe pile)

UMRIWS VALUE ENGINEERING STUDY

COST ESTIMATE FOR
GUIDEWALL SUBSTRUCTURE
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
35' DIA CELL (baseline/original)

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	Helper Boat	1	LS		$150,000
2	Underwater Excavation	1	LS		$50,000
3	Pipe Piles	1	LS		$100,000
4	Instrumentation	1	LS		$5,000
5	Concrete	1	LS		$440,000
6	Structural Steel	1	LS		$525,000
7	Cell Lighting	1	LS		$20,000
		SUBTOTAL			$1,290,000
		CONTINGENCIES (25%)			$323,000
		SUBTOTAL			$1,613,000
		P.,E., & D (15%)			$242,000
		C.M. (10%)			$161,000
		TOTAL			$2,016,000

UMRIWS VALUE ENGINEERING STUDY

COST ESTIMATE FOR
GUIDEWALL SUBSTRUCTURE
UPPER MISSISSIPPI RIVER LOCKS AND DAMS
25' DIA CELL WITH ROCK ANCHORS

Item No.	Item Description	Quantity	Unit	Unit Price	Estimated Amount
1	Helper Boat	1	LS		$150,000
2	Underwater Excavation	1	LS		$25,000
3	Pipe Piles	1	LS		$100,000
4	Instrumentation	1	LS		$5,000
5	Concrete	1	LS		$360,000
6	Structural Steel	1	LS		$345,000
7	Cell Lighting	1	LS		$20,000
8	Rock Anchors (13 strand)	6	EA	$12,000	$72,000
		SUBTOTAL			$1,077,000
		CONTINGENCIES (25%)			$269,000
		SUBTOTAL			$1,346,000
		P.,E., & D (15%)			$202,000
		C.M. (10%)			$135,000
		TOTAL			$1,683,000

VALUE ENGINEERING PROPOSAL

Proposal No. 9

DESCRIPTION: Investigate Alternative-Shaped Cells to Economize on the Amount of Structure Required

ORIGINAL DESIGN: Round cells

PROPOSED DESIGN: The use of prefabricated steel allow the use other shapes other than round cells. Other shapes may transfer service loads to the foundation material in a more efficient manner. Shapes to consider include, but not limited to are: elliptical, tear drop, triangular, dog bone, and cone. Cells with cross section varying with height may also be considered.

ADVANTAGES:

- Easier for boats to land on a flat surface
- Easier for deckhand to work from
- Flat is easier to fabricate than circular
- Shape can be configured to efficiently resist applied loads
- Alternative shapes may allow more similarity between pile and rock founded structures

DISADVANTAGES:

- Circular doesn't deform while filling with concrete, while non-circular shapes may deflect/deform from pressure during concrete placement.
- Extra strength required in shell in order to reduce occurrence in above disadvantage. Internal bracing may cause interference.
- Circular cells tend to deflect tow hits

JUSTIFICATION:

Requires additional analysis to determine shape
Stability analysis will be required for each alternate shape
Other cell shapes will be investigated as part of the design process

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 10

DESCRIPTION: Use Smaller Guidewall Beam Confirgurations/Weights to Reduce Lifting Demands and Reduce Costs

ORIGINAL DESIGN: Box beam

PROPOSED DESIGN: Use smaller and lighter beams. Investigate alternative shapes and smaller beams with wide walkways. Shapes to consider may be trapezoidal, T-Sections, etc.

ADVANTAGES:
- Cheaper
- Easier to handle/placement

DISADVANTAGES:
- Weaker

JUSTIFICATION:
Requires analysis to determine feasibility. This is being done as part of existing design efforts.

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 11

DESCRIPTION: Study the Use of Protection Cells Above and Below the I-wall to Control Lateral Tow Movement Upon Extraction

ORIGINAL DESIGN: None

PROPOSED DESIGN: Add cells upstream and/or downstream of I-wall. Currently the unpowered cuts are held partially in alignment by the intermediate wall. Placing a cell 100-300 feet upstream from the intermediate wall would assist in keeping the stern of the unpowered cut near the guidewall during extraction. Also the proposed guide cell would keep the head of the powered cut aligned when it exits the chamber.

ADVANTAGES:
- Tow will be able to get parallel with wall and stay there
- Helps hold unpowered cut to the wall
- Can help hold powered cut to wall and assist in alignment with unpowered cut
- Protects gates from impact due to misaligned tows making their approach to the lock

DISADVANTAGES:
- Shortens effective length of guidewalls (more adverse during downbound approaches)

JUSTIFICATION:
Need to carefully evaluate advantages and disadvantages. Site specific analysis and industry comments needed.

COST SAVINGS:
Not easily determined.

VALUE ENGINEERING PROPOSAL

Proposal No. 12

DESCRIPTION: Investigate Concrete Cribs Substructure with Rock Fill to Lessen Guidewall Costs

ORIGINAL DESIGN: Steel Cans filled with concrete

PROPOSED DESIGN: Construction using rock filled concrete cribs to create substructure of the guidewall. Several existing guidewalls on the UMR, have timber cribs on the submerged portion of the guidewall. Cribs are basically boxes that are open on the tops and bottoms. The existing cribs are filled with rock as the substructure for the existing wall. The proposed design is similar. Cribs would be constructed of precast concrete, placed on the bottom, and filled with rock. Then the super-structure would be built on the crib/rock substructure.

ADVANTAGES:

- Cost – replaces round cells with concrete fill.
- Reduces size, cost and complexity of superstructure by reducing/eliminating beam span
- Beams would not have to be prestressed.

DISADVANTAGES:

- Potential additional difficulties in leveling cribs and/or completed substructures
- Many items to place could extend construction duration
- Uncertainty in achieving required construction tolerances
- More units required to complete substructure

JUSTIFICATION:
Cost savings possible, but not likely

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 13

DESCRIPTION: Focus Hydraulic Models on Cut Extraction Forces

ORIGINAL DESIGN: None

PROPOSED DESIGN: Recommend prototype measurements and possible numeric or micro model analysis.

ADVANTAGES:

- Economics – may show ability to reduce or eliminate tow haulage units on downstream end

DISADVANTAGES:

- Additional analysis required
- Could have some risk of relying on the consistency of natural forces to aid extractions

JUSTIFICATION:
Should do prototype measurements. The feasibility of fulfilling this proposal will be considered by the Hydraulic Engineers in site-specific feasibility.

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 14

DESCRIPTION: Use High-Density Polymer Bumpers to Reduce Impact Loads on Guidewalls

ORIGINAL DESIGN: Steel T-Armor

PROPOSED DESIGN: Use high-density polymer bumpers.

ADVANTAGES:

- Dampens impact loads, absorbs shock.

DISADVANTAGES:

- Wears out-will need replacement
- Costs as much as steel
- Less durable than steel
- Anchorage difficulties
- Great uncertainty as to the possibility of success of this proposal

JUSTIFICATION:

No advantages over steel – Not carried forward.

COST SAVINGS:

VALUE ENGINEERING PROPOSAL

Proposal No. 15

DESCRIPTION: Slope the Top of Guidewall Cells to Reduce Concrete Placements

ORIGINAL DESIGN: Flat

PROPOSED DESIGN: Slope top of cells.

ADVANTAGES:
- Lower quantities of concrete

DISADVANTAGES:
- Additional cost in formwork for the sloped concrete may cost more than the saving in material cost.

JUSTIFICATION:
Savings minimal if any.

COST SAVINGS:
Negligible

VALUE ENGINEERING PROPOSAL

Proposal No. 16

DESCRIPTION: Investigate the Feasibility of a Floating Guidewall

ORIGINAL DESIGN: Cells on Beams

PROPOSED DESIGN: Floating guidewall

ADVANTAGES:

- Reusable for guidwalls at other sites

DISADVANTAGES:

- Can not be used with kevel rail.
- Could be a high risk venture. Favorable long-term performance on Mississippi River is suspect.

JUSTIFICATION:
Not carried forward.

COST SAVINGS:
N/A

VALUE ENGINEERING PROPOSAL

Proposal 17

DESCRIPTION: Issue Request for Proposal (RFP) for Long-term Contract for Extracting the First Cut and Placing the Cut on the Upstream Structure

ORIGINAL DESIGN: New guidewall wall designed by the Corps based on commonly available materials, equipment and structure.

PROPOSED DESIGN: Let a long term contract for a company to provide equipment and structures that provide the same functions as extended upper guidewall and additional extraction equipment.

ADVANTAGES:

- Might cost less
- Easy to design
- Allows someone other than the COE to utilize their expertise and equipment.

DISADVANTAGES:

- Cannot evaluate until proposal is submitted.
- Expertise or equipment may not be available.
- Great uncertainty as to the long-term performance.

JUSTIFICATION:

This option may fall under two options that were considered as part of the original study. This option may, in part or in a general sense, be considered under the privatization of lock operations and/or switchboat operations. Privatization was dropped from consideration during earlier portions of the study. Switchboat operations are still being considered as an option in the study.

COST SAVINGS:

unknown

Appendices

1. Photos of VE Workshop Activities

2. Handout by Jeff Stamper explaining the double lockage process and timing
    - Existing method of extraction of unpowered cuts
    - Proposed method to extract unpowered cuts along extended guidewalls
    - Preliminary information on construction of the extended guidewalls

2. Value Engineering study team read-ahead package describing the extended guidewall with traveling kevel option

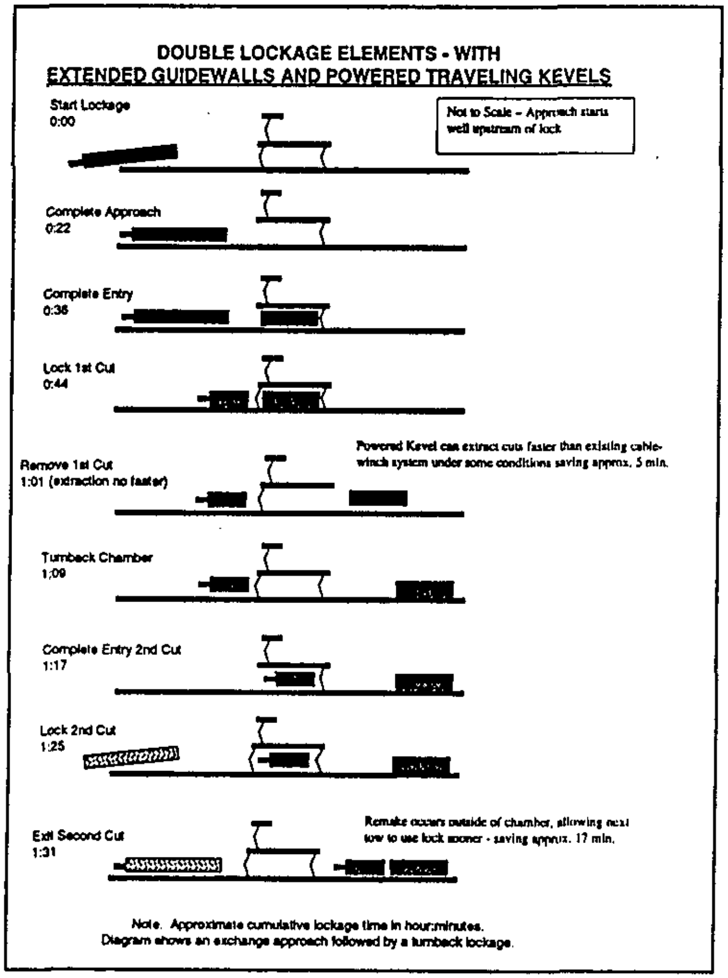
VE Workshop Activities

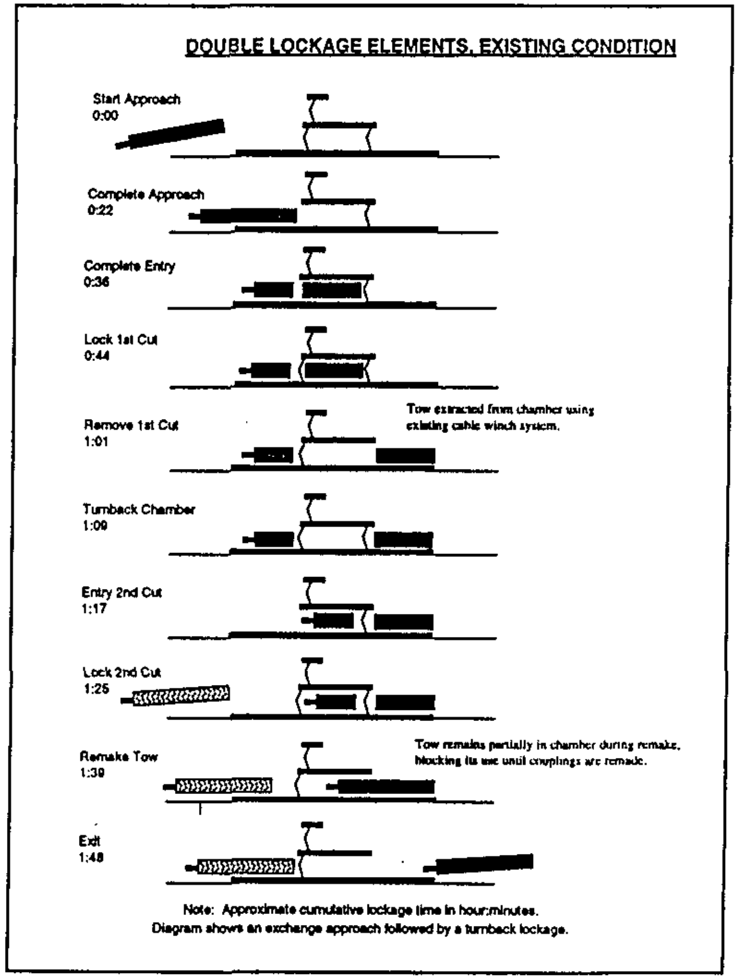
Upper Mississippi River-Illinois Waterway System Navigation Study.

Value Engineering Study: Extended Guidewalls with Powered Traveling Kevels

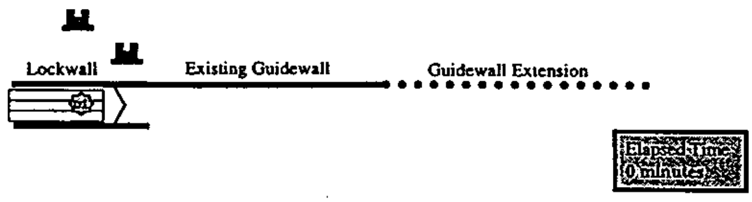
The Following are Presentations of the:

1. Existing method of extraction of unpowered cuts
2. Proposed method to extract unpowered cuts along extended guidewalls
3. Preliminary information on construction of the extended guidewalls


DOUBLE LOCKAGE ELEMENTS - WITH
EXTENDED GUIDEWALLS AND POWERED TRAVELING KEVELS
Not to Scale - Approach starts well upstream of lock
Start Lockage
0:00
Complete Approach
0:22
Complete Entry
0:36
Lock 1st Cut
0:44
Remove 1st Cut
1:01 (extraction no faster)
Powered Kevel can extract cuts faster than existing cable-winch system under some conditions saving approx. 5 min.
Turnback Chamber
1:09
Complete Entry 2nd Cut
1:17
Lock 2nd Cut
1:25
Exit Second Cut
1:31
Remake occurs outside of chamber, allowing next tow to use lock sooner - saving approx. 17 min.
Note. Approximate cumulative lockage time in hour:minutes.
Diagram shows an exchange approach followed by a turnback lockage.


DOUBLE LOCKAGE ELEMENTS, EXISTING CONDITION
Start Approach
0:00
Complete Approach
0:22
Complete Entry
0:36
Lock 1st Cut
0:44
Remove 1st Cut
1:01
Tow extracted from chamber using existing cable winch system.
Turnback Chamber
1:09
Entry 2nd Cut
1:17
Lock 2nd Cut
1:25
Remake Tow
1:39
Tow remains partially in chamber during remake, blocking its use until couplings are remade.
Exit
1:48
Note: Approximate cumulative lockage time in hour:minutes.
Diagram shows an exchange approach followed by a turnback lockage.

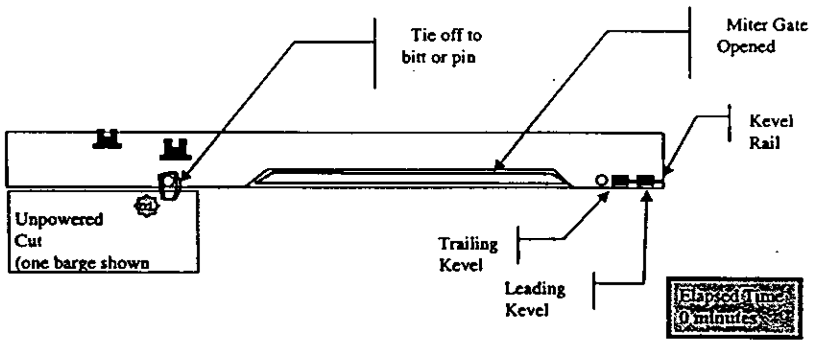
<u>Details of Improved Lockage Times</u>



1. Introduction Slide.

- Modified Upper Guidewall with Upbound Tow shown in Chamber.
- Unpowered cut in lock chamber awaiting extraction along extended guidewall by existing tow haulage unit.

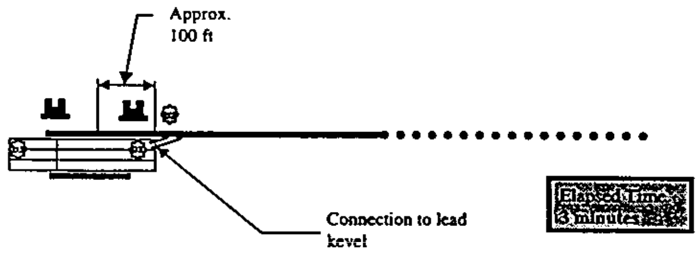
<u>Details of Improved Lockage Times</u>



1. <u>Close-up view</u>.

- **Line from head of unpowered cut to pin or floating mooring bitt on lockwall.**
- **Miter gates Open.**
- **Existing tow haulage hooked up (not shown).**

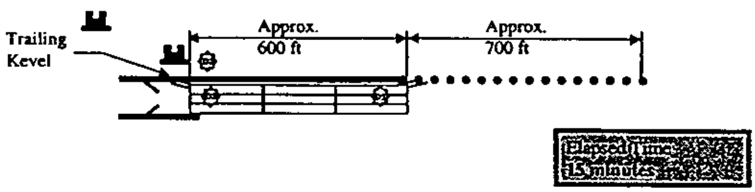
Details of Improved Lockage Times



2. Connect to Lead Kevel.

- At t = 3 minutes cut has an average speed of 50 feet/minute.
- At about 100 feet out, Deckhand #1 and Corps #2 make 2 part line (4 part is possible) to head. Connection takes 2 minutes and is made on the move.
- Cut can then be pulled by lead kevel.
- Corps #1 retrieves tow haulage cable.

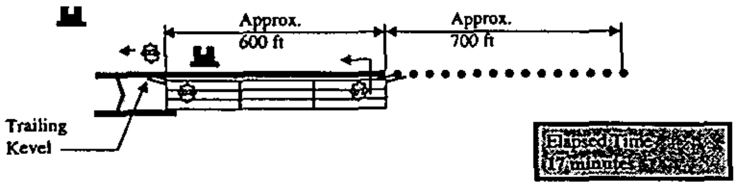
Details of Improved Lockage Times



3. Extract cut to existing Checking point.

- Head is kept checked by lead kevel.
- Stern of cut is checked at existing check post.
- Corps #1 has has closed gates.
- Corps #2 places checking line on check post. Monitors lead kevel.
- Deckhand #3 checks cut.
- Cut is at full Stop at t=15 minutes.

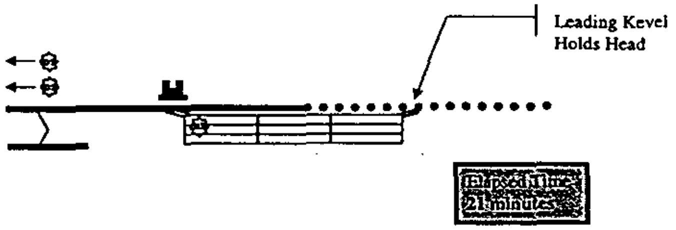
Details of Improved Lockage Times



4. Make Line to Trailing Kevel.

- Corps #1 has started emptying of chamber then moves to lower end of lock to operate miter gates.
- Deckhand #3, Corps #2, and Deckhand #2 complete two-part line to trailing kevel at t=17 minutes.
- Corps #2 maneuvers trailing kevel to assist remake.
- Deckhands #1 and #2 start walk to return to powered cut.
- Cut is still at full Stop

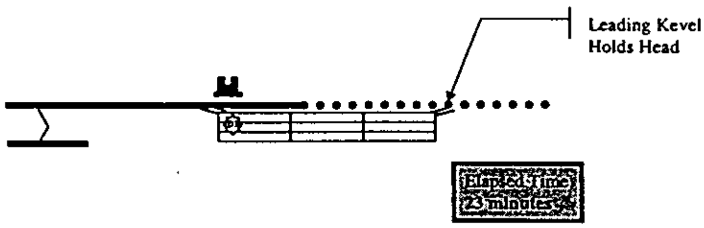
Details of Improved Lockage Times



5. Cut is hauled about 200 ft more at 50 fpm.

- Leading kevel can probably reduce pulling force.
- Corps #2 monitors kevels and adds braking/pulling when required.
- Deckhands #1 and #2 nearing ladders to climb down to powered cut.
- Chamber is empty and Corps #1 starts opening of lower gates at t = 22 minutes.

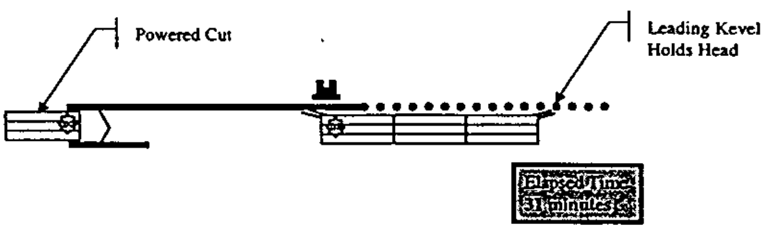
Details of Improved Lockage Times



6. Cut is hauled about 100 ft. more

- Within 1000 ft speed of cut will be slowed to average 25 fpm at t= 25 minutes.
- Lower miter gates are opened. Powered cut starts entry at t= 24 minutes
- Corps #2 monitors kevels and adds braking/pulling when required.
- Corps #1 leaves for upper end to ensure head line of powered cut gets attached.

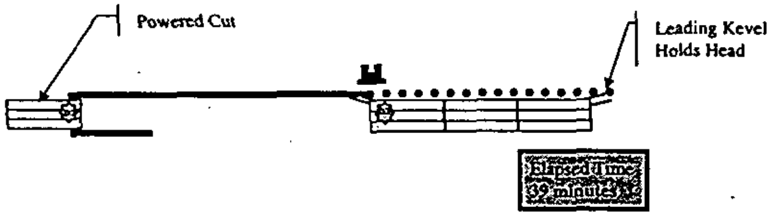
Details of Improved Lockage Times



7. Cut is hauled about 600 ft.

- Unpowered cut is in last 100 feet of travel. Speed of cut is very slow - say 12.5 fpm at t= 31 minutes.
- Powered Cut has completed entry.
- Corps #1 has ensured head line, assisted stern line, and closed lower miter gates
- Corps #2 monitors kevels and adds braking/pulling when required.

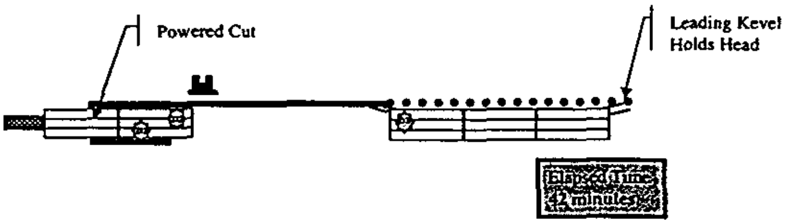
Details of Improved Lockage Times



8. Cut is hauled 100 ft more to full stop at end of wall.

- Powered Cut is ready to start exit at t = 39 minutes.
- Cut is stopped by a combination of slowed speed by the trailing kevel and deckhand #3 checking to a pin in the wall. (t=41 minutes)
- Deckhand #3 completes shortened line to pin in wall. (t=41 minutes)
- Corps #2 releases stern line to trailing kevel. (t=40 minutes)
- Corps #2 and trailing kevel start back to meet powered cut which is already moving

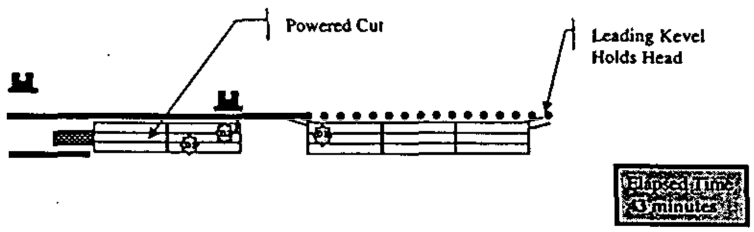
Details of Improved Lockage Times



9. Powered Cut Pushes out. At 200 feet...

- After about 200 feet of travel, trailing kevel, Corps #2 and head of powered cut meet.
- Head is 50 feet beyond bullnose
- Deckhand #2 and Corps #2 initiate attaching head line to kevel at t=42 minutes.

Details of Improved Lockage Times

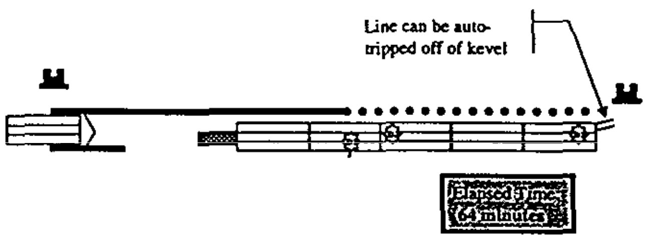


10. Line to Kevel is made.

- **After about 300 - 400 feet out, Deckhand #2 and Corps #2 complete attaching head line to kevel.**
- **At t=45 minutes, Corps #1 starts to close miter gates.**
- **At t=47 minutes, miter gates are closed and chamber turnback starts.**
- **At t=50 minutes, cuts bump together.**

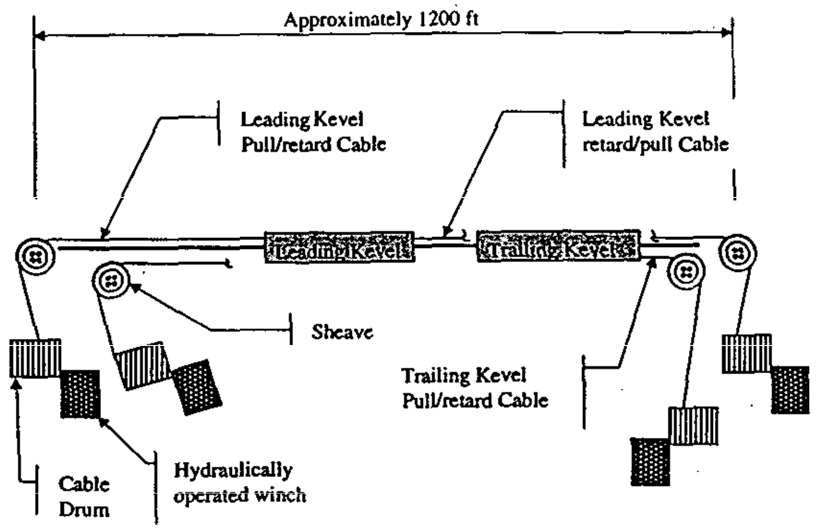
This number would be used to compare the time savings. For the existing method, the elapsed time would be 64 minutes, therefore 17 minutes are saved.

Details of Improved Lockage Times



11. Tow is remade.

- **At t=64 minutes tow is remade.**
- **Corps #2 trips headline at t=64 minutes.**
- **At t=70 minutes, Corps #2, trailing kevel, and lead kevel back for next cut**
- **At t=79 minutes, upper miter gates are opened and next cut ready to exit**



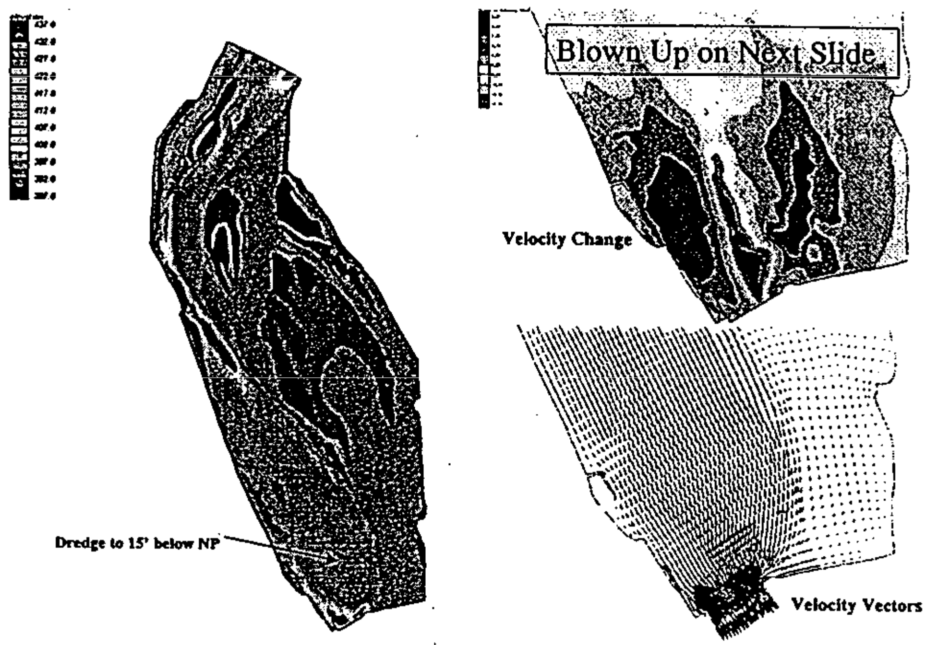
Kevel Machinery Layout

LD 25 Approach Improvements

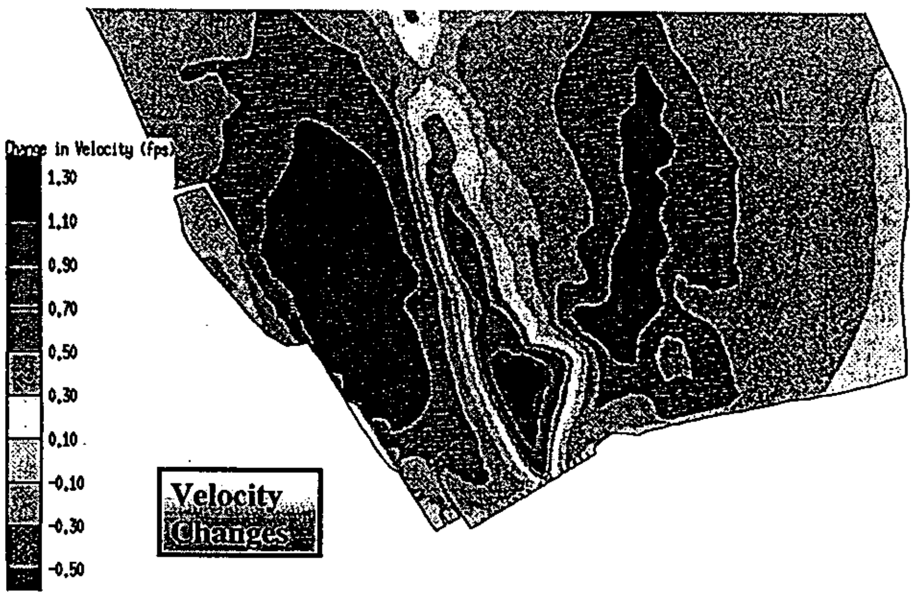
LD 25 Pool Model

All Models Run at 202,000 cfs;
Maximum Flow Before Spillway In Use

Note: Normal Pool (NP) Elevation is 434.0 ft NGVD



GWE, Removal of Submerged Upstream Island to a depth of 15' below NP



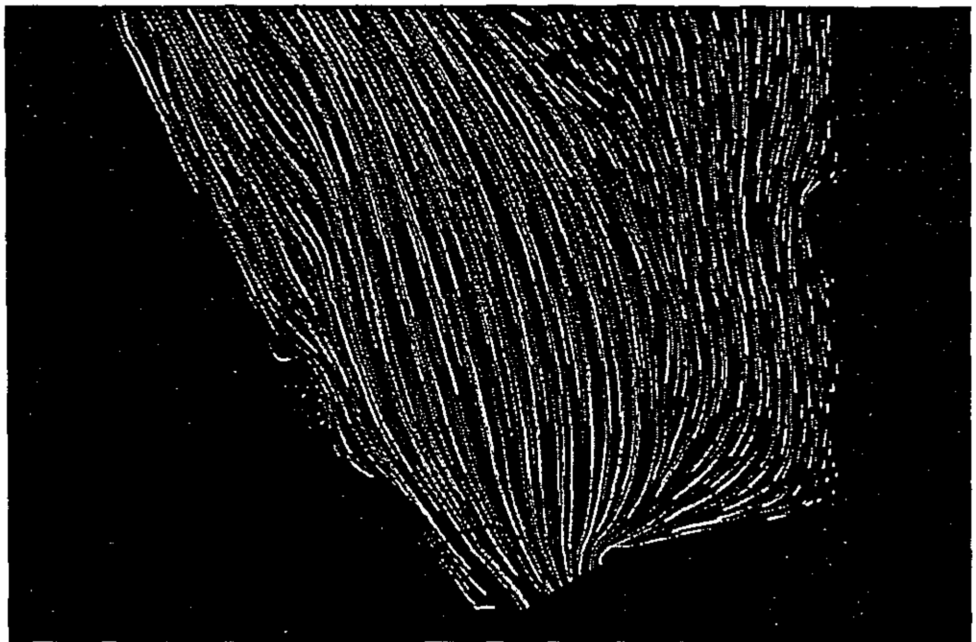
GWE, Removal of Submerged Upstream Island to a depth of 15' below NP

Comparison of Island Removal Alternatives

Alternative	Flow 1 (cfs)	Flow 2 (cfs)	Flow 3 (cfs)
CWE	50,090	17,730	27,090
12' Depth	45,650 (8.9 % reduction)	29,790 (68.0 % increase)	25,200 (7.0 % reduction)
15' Depth	41,510 (17.1 % reduction)	37,470 (111.% increase)	23,220 (14.3 % reduction)

Locations:

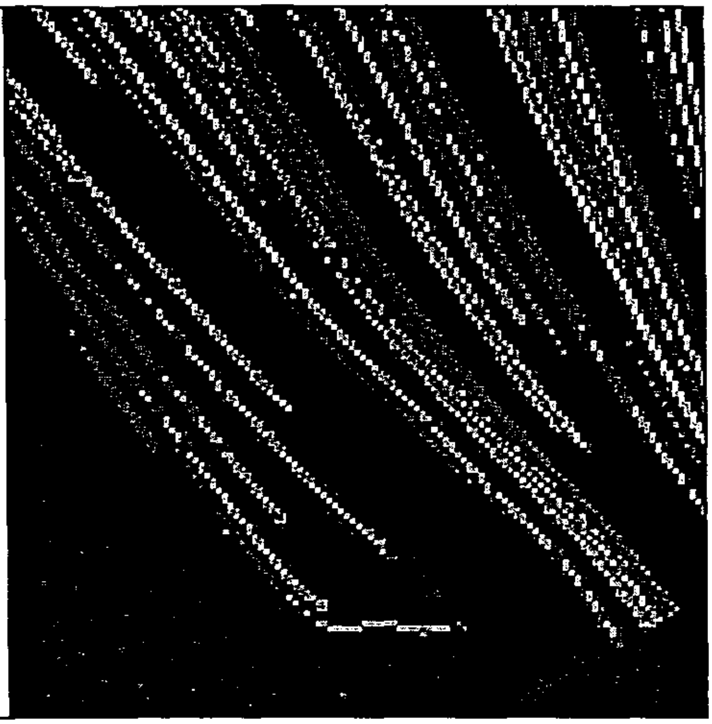
1 - Flow in Channel Approach
2 - Flow Over Submerged Island
3 - Flow around East side of Submerged Island



Flow Trace of Pool 25 Upper - Guidewall Extension & Removal of Upstream Island to 15' Depth

Flow Trace of Pool 25

Upper - Guidewall Extension & Removal of Upstream Island to 15' Depth



Guidewall Extension Conceptual Design

1. In the Wet Construction
2. Prefabricated, Lift-in elements
   - Steel Cans weighing approx 80 tons
   - Precast Box Beams approx 400 tons
3. Winter Construction over two winters
4. Substantial Cell Exposed after First Winter.

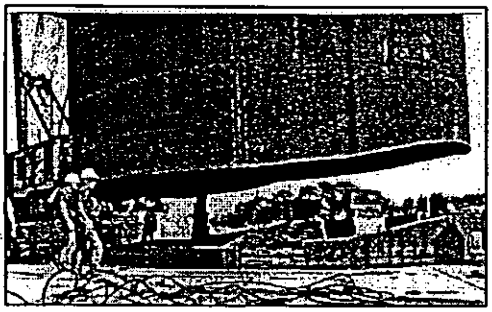
Cutting Bottom and Placing of Cell

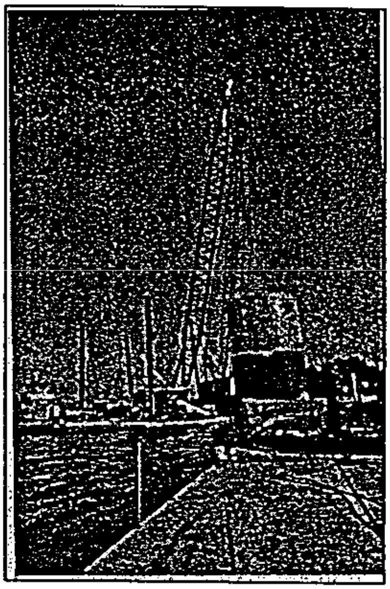
* Bottom of cell was cut to contour of bedrock
* Cell (80 tons) was placed by two cranes on floating plant *(insufficient floating plant for one crane)*
* Cell was positioned over guide piles by

pushboat and some booming of cranes

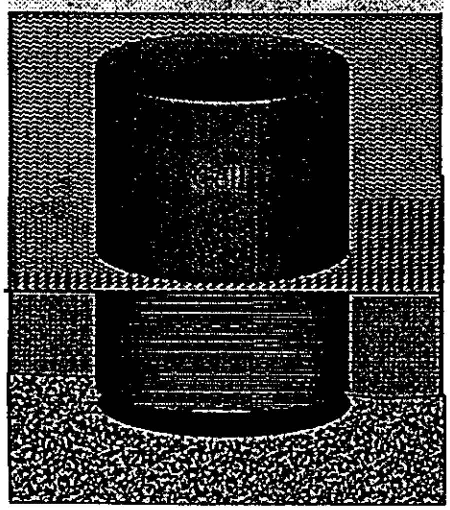
(Actually two cranes easily manipulated cell)

* floating plant blocked river currents





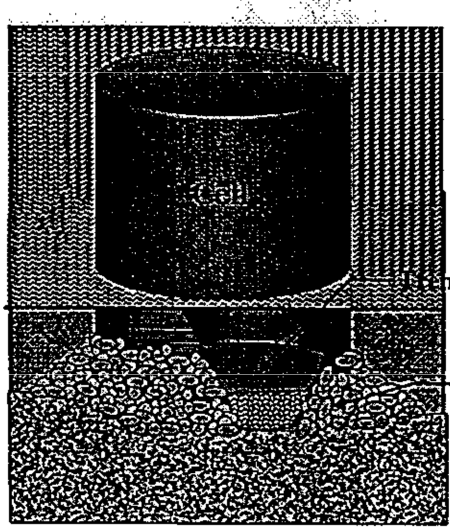
Leveling of Can



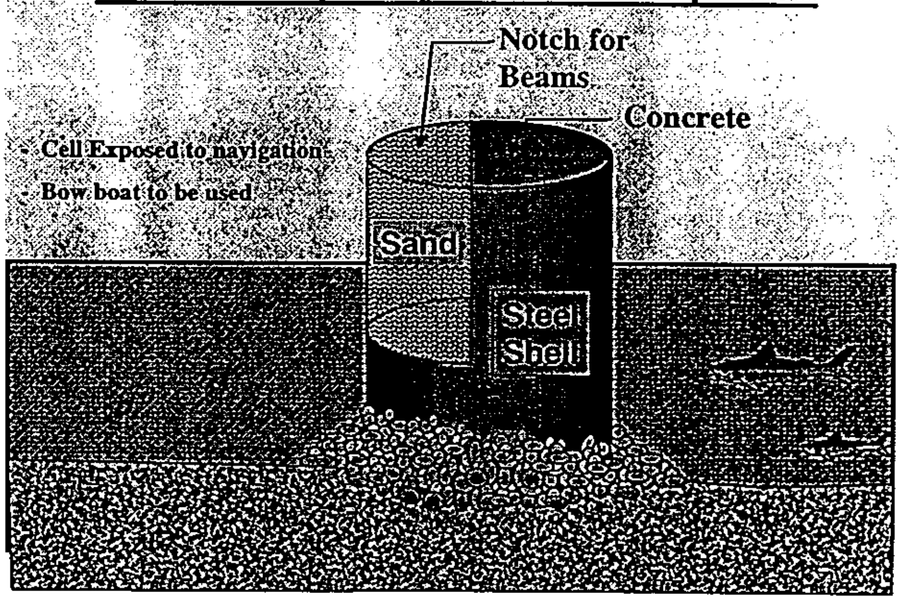
* Underwater Excavation
* Hollow, Bottomless cylinder lowered into water
* Cylinder sets on bedrock
* Leveled with pin piles, flat jacks, hydraulic pistons, etc
* Could use catamaran barge for setting

Tremie Seal Concrete

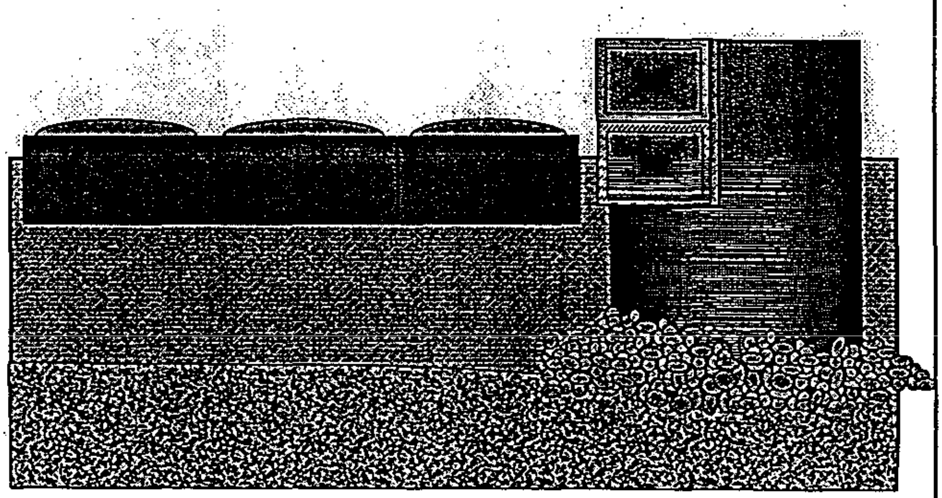
* Stone Seal around exterior perimeter
* Diver checked stone seal
* Diver added several palettes of sandbags to seal
* Cell cleaned out by airlift
* Tremie concrete seal layer placed



Cell in Temporary State of Completion



Precast Beams in Place



Summary and Pertinent Information

Summary:

Guidewall extensions approximately 700 feet long with powered traveling kevels are being studied for Locks 20 - 25.

Pertinent Information:

- Proposed for upstream and downstream
- Useable in all types of weather conditions
- Has limitations when it can't be used
- No additional staff for tow or lock
- Anything new will have a learning curve
- Success is dependent on machinery reliability in combination with knowledgeable users.

Read Ahead Package for Value Engineering Study Participants

Upper Mississippi River – Illinois Waterway System Navigation Study

Value Engineering Study

of

Extended Lock Guidewalls with Powered Traveling Kevels

Purpose of UMR&IW Navigation Study. The Upper Mississippi River & Illinois Waterway System Navigation Study ("Navigation Study") is a feasibility study addressing navigation improvement (small and large scale) planning for the Upper Mississippi River and Illinois Waterway (UMR&IW) system for the years 2000-2050. This study will assess the need for navigation improvements at 29 locks on the Upper Mississippi River and 8 locks on the Illinois Waterway and the impacts of providing these improvements. More specifically, the principal problem to be addressed is congestion of commercial traffic at locks in the UMR&IW system due to limited lockage capacity and increasing traffic. The study will determine the location and appropriate sequencing of improvements on the UMR&IW, prioritizing navigation improvements for the 50-year planning horizon. Site-Specific investigations will also be conducted. The feasibility study will also include preparation of a system Environmental Impact Statement (EIS) and mitigation costs of environmental impacts.

Small-Scale Improvements. Small Scale navigation measures are improvements targeted to reduce congestion at the locks and are less costly than new lock construction. As a part of rigorous investigations, 92 possible measures were generated, screened, and analyzed by the Corps along with private industry, State resource and transportation agencies, U.S. Fish and Wildlife Service, U.S. Coast Guard and the U.S. Environmental Protection Agency. The alternative plans remaining are: (1) guidewall extensions with powered traveling kevels; (2) switchboats with guidewall extensions; (3) congestion tolls/lockage time charges: (4) mooring facilities; and (5) approach channel improvements.

Extended Guidewalls with Powered Traveling Kevels. This improvement is the subject of the Value Engineering Study to determine that the proposal is a cost effective and efficient solution.

Value Engineering Study. A multi-disciplined team of experts will assemble in the St. Louis District March 1 –5, 1999 to perform a Value Engineering (VE) study of extended guidewalls with powered traveling kevels.

Previous efforts by the Engineering Work Group (EWG) of the Navigation Study resulted in the identification of 92 small-scale measures to reduce delays at navigation locks. Further studies of these measures highlighted Extended Lock Guidewalls outfitted with Powered Traveling Kevels as an item for immediate study to reduce lock congestion. This VE study will be site specific since it will use Mississippi River Locks 20 through 25 as a study focus.

The VE study will be performed during the site-specific feasibility level of design to take advantage of the broadest level of thinking before subsequent design changes would become too costly. The VE study team members comprise a carefully selected group of professionals from several Corps Districts, towing industry representatives, towboat pilots, deckhands and lockmasters. The first phase of the VE study will involve the entire group as they collect information and brainstorm alternative solutions from an operational perspective. Next, a smaller segment of the group will analyze and develop individual VE proposals on a technical and cost effectiveness basis.

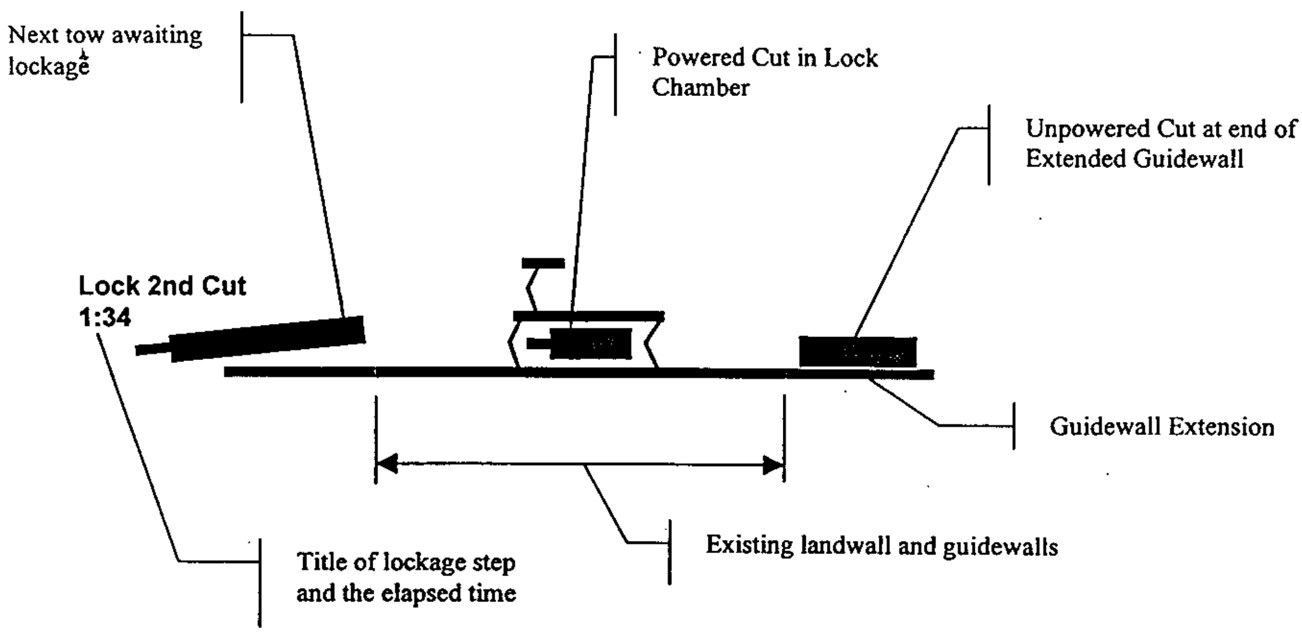
The Corps Value Engineering program began in 1967 and has reaped over $4 billion in savings to date. In addition to reducing costs, the VE study will also focus on operational improvements as attested to by the participation of working-level users on the study team.

GRAPHICAL PRESENTATION OF THE STEPS IN A LOCKAGE.

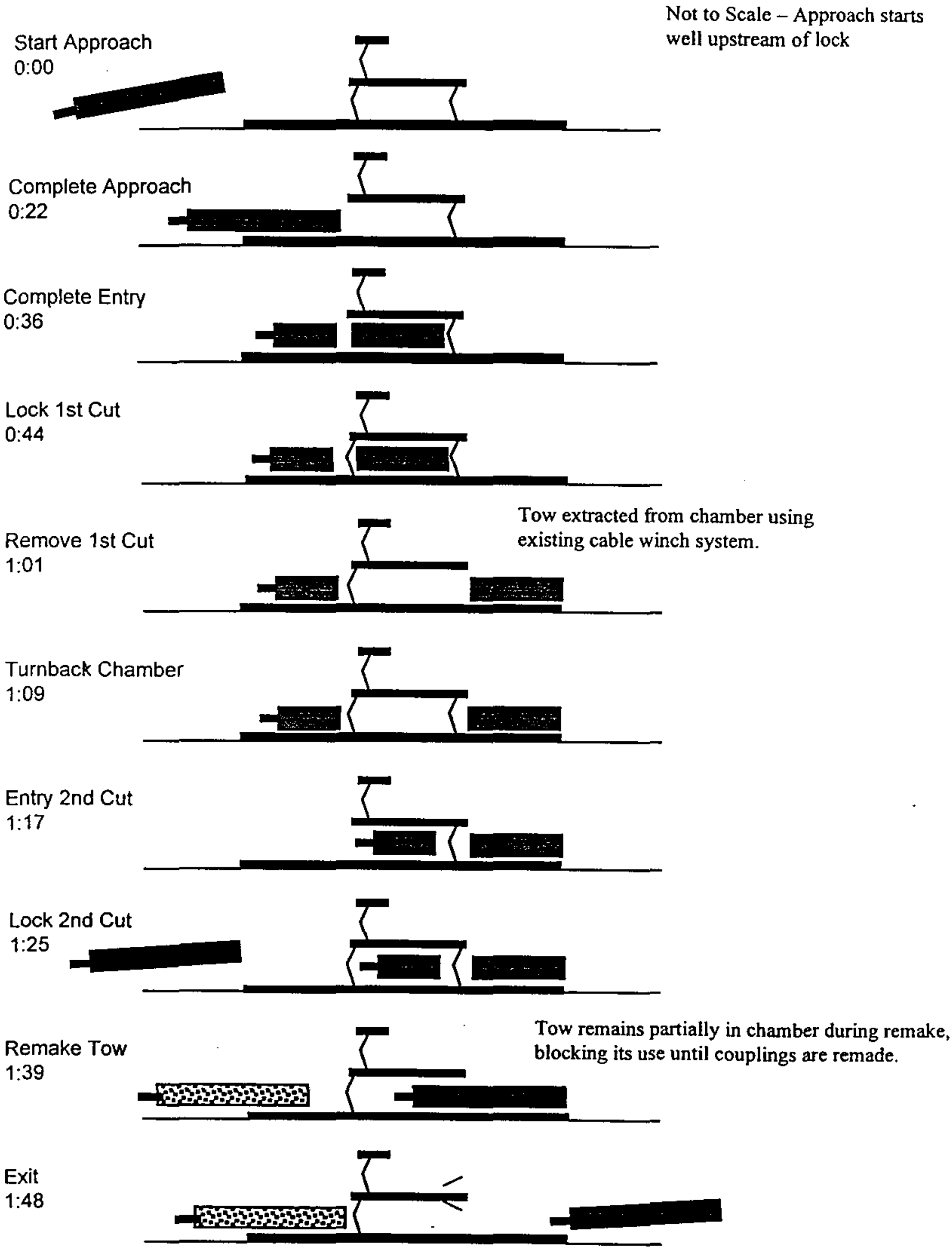
On the following two pages, the existing double-cut lockage steps with elapsed times are shown in graphical form for information. Also provided are the steps and the elapsed times of a double cut lockage they would be improved by extended guidewalls with powered traveling kevels. (Times are averages and rounded to the nearest minute for clarity of presentation.) The reader can reference the graphics in conjunction with the text below.

The existing locks under study for the subject improvement are 600ft long and most lockages involve tows that are approximately 1200ft long. This requires that the tows break apart and use two cycles of locking in order to pass the lock. There are many steps required during this method of operation and guidewall extensions mostly address one of them. Although guidewall extensions will not reduce the need to break tows, they will facilitate the remake of the tow outside of the lock chamber. This occurrence allows the lock to be turned back to service the next tow awaiting to travel in the same direction. The segment of time that is saved combined with the cost to implement show good economic promise.

The following graphic is used repeatedly on the following pages. Its basic components are identified here.

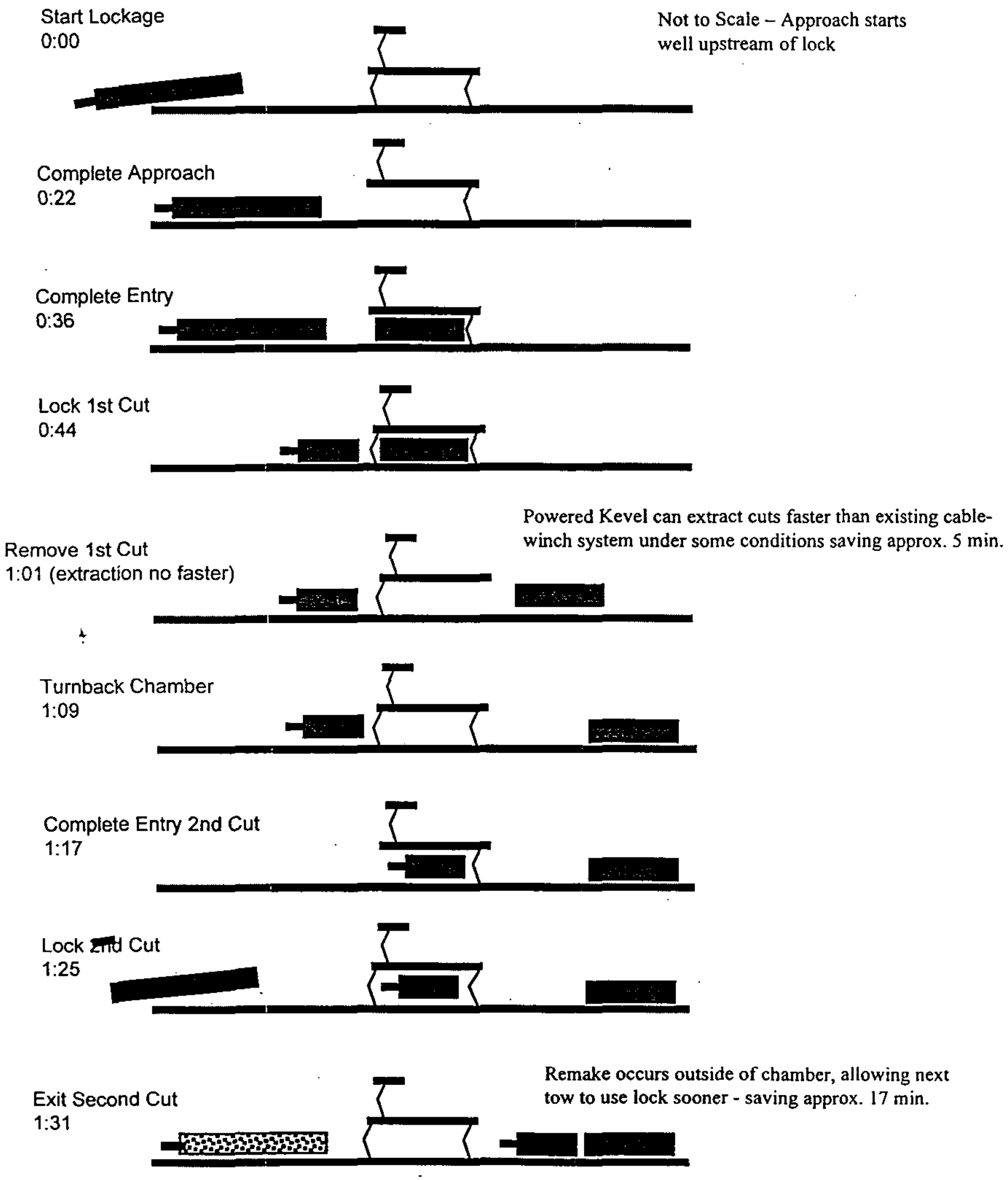


DOUBLE LOCKAGE ELEMENTS, EXISTING CONDITION



Note: Approximate cumulative lockage time in hour:minutes.
Diagram shows an exchange approach followed by a turnback lockage.

DOUBLE LOCKAGE ELEMENTS - WITH EXTENDED GUIDEWALLS AND POWERED TRAVELING KEVELS



Note: Approximate cumulative lockage time in hour:minutes.
Diagram shows an exchange approach followed by a turnback lockage.

Upper Mississippi River – Illinois Waterway System Navigation Study

Value Engineering Study
of
Extended Lock Guidewalls with Powered Traveling Kevels

Meeting Location: **St. Louis District Office**
1222 Spruce Street (RAY Federal Building)
Room 7.207
St. Louis, MO

Agenda:

3/01/99
12:30 Welcome
1:00 Information phase of VE Study
4:00 Adjourn

3/02/99
8:00 Review/revisit
9:00 Speculation phase of VE Study
1:00 Evaluation phase of VE Study
4:00 Adjourn

(Entire Group: 3/01/99 – 3/02/99)

3/03/99
7:30 - 4:30 Further evaluate and quantify alternatives. Subjective screening. Fill out VE forms.

3/04/99
7:30 – 4:30 Further evaluate and quantify and cost estimate alternatives. Write VE Report, identify and assign tasks to complete report.

3/05/99
7:30 – 12:00 As needed to complete documentation of the VE.

(Segment of Group: 3/03/99 – 3/05/99)

<u>Upper Mississippi River – Illinois Waterway System Navigation Study</u>

Agenda: Value Engineering Study
of
Extended Lock Guidewalls with Powered Traveling Kevels

<u>3/01/99</u> , **Monday**

12:30 Welcome and Introduction, Review Agenda — **Bob Hughey**
- *General Intention of UMR-IWS Navigation Study*
- *Specific Intention of this Meeting,*
  - *G.Wall Ext. with PTK*
  - *Locks 20-25*

1:00 The Value Engineering Process — **Gene Degenhardt**

1:15 The Double Cut Lockage Process and Timing — **Jeff Stamper**
- *Existing Condition, Video*
- *Improved Condition with Ext. Guidewalls and PTK, Video*
  - *Upbound and Downbound use, Dependability, Limitations*

1:45 Guidewall Construction Proposal — **Jeff Stamper**
- *Lift-in Modular, In-the-wet Construction*
  - *Prefabricated steel shell, substructures*
  - *Precast concrete beams, superstructures*
- *Winter time construction, Intermittent Closures during Navigation Season*

2:15 Brainstorming Session — **Gene Degenhardt**
- *Warm-up Exercise*
- *Generate Ideas, NO CRITICISM*

4:00 Adjourn

<u>3/02/99</u> , **Tuesday**

8:00 Review/revisit
- *Additional Ideas*
- *Clarification of Ideas*

9:00 Continue Brainstorming

10:00 First Level of Evaluation of Ideas
- *Establish Criteria for Evaluation, Cost, Time Savings, Technical Feasibility, Constructiblity, Impacts to Navigation, Operational Ease, Previously Investigated*
- *Combine Similar Ideas*
- *Subjective Screening*
- *Evaluate against Established Criteria*

11:30 Lunch

12:30 Continue Evaluation
- *Look for Additional Ideas*
- *General Critique*
- *Quantify Elements/Components of Viable Alternatives*

4:00 Adjourn

Regulations, Navigation Notice #1

Appendix G

BLUE BOOK

33 CFR 207.300

"Regulations Prescribed by the Secretary of the Army for Ohio River, Mississippi River above Cairo, Ill and their Tributaries. Use Administration and Navigation."

REGULATIONS PRESCRIBED BY THE SECRETARY OF THE ARMY FOR OHIO RIVER, MISSISSIPPI RIVER ABOVE CAIRO, ILL., AND THEIR TRIBUTARIES; USE, ADMINISTRATION AND NAVIGATION

THE LAW

Section 7 of the River and Harbor Act of August 8, 1917, provides as follows:

"That it shall be the duty of the Secretary of War to prescribe such regulations for the use, administration, and navigation of the navigable waters of the United States as in his judgment the public necessity may require for the protection of life and property, or of operations of the United States in channel improvement, covering all matters not specifically delegated by law to some other executive department. Such regulations shall be posted, in conspicuous and appropriate places, for the information of the public; and every person and every corporation which shall violate such regulations shall be deemed guilty of a misdemeanor and, on conviction thereof in any district court of the United States within whose territorial jurisdiction such offense may have been committed, shall be punished by a fine not exceeding $500, or by imprisonment (in the case of a natural person) not exceeding six months, in the discretion of the court."

In pursuance of the law above quoted, the following regulations were prescribed to govern the use, administration, and navigation of the Ohio River, the Mississippi River above Cairo, Ill., and their tributaries.

207.300 Ohio River, Mississippi River above Cairo, Ill., and their tributaries; use, administration, and navigation.

(a) Authority of Lockmasters. The lockmaster shall be charged with the immediate control and management of the lock, and of the area set aside as the lock area, including the lock approach channels. He shall see that all laws, rules, and regulations for the use of the lock and area are duly complied with, to which end he is authorized to give all necessary orders and directions in accordance there with, both to employees of the Government and to any and every person within the limits of the lock or lock area, whether navigating the lock or not. No one shall cause any movement of any vessel, boat, or other floating thing in the lock or approaches except by or under the direction of the lockmaster or his assistants. In the event of an emergency, the lockmaster may depart from these regulations as he deems necessary. The lockmasters shall also be charged with the control and management of Federally constructed mooring facilities.

(b) Safety Rules for Vessels Using Navigation Locks. The following safety rules are hereby prescribed for vessels in the locking process, including the act of approaching or departing a lock:

(1) Tows with Flammable or Hazardous Cargo Barges, Loaded or Empty.

(i) Stripping barges or transferring cargo is prohibited.

(ii) All hatches on barges used to transport flammable or hazardous materials shall be closed and latched, except those barges carrying a gas-free certificate.

(iii) Spark-proof protective rubbing fenders ("possums") shall be used.

(2) All Vessels.

(i) Leaking vessels may be excluded from locks until they have been repaired to the satisfaction of the lockmaster.

(ii) Smoking, open flames, and chipping or other spark-producing activities are prohibited on deck during the locking cycle.

(iii) Painting will not be permitted in the lock chamber during the locking cycle.

(iv) Tow speeds shall be reduced to a rate of travel such that the tow can be stopped by checking should mechanical difficulties develop. Pilots should check with the individual lockmasters concerning prevailing conditions. It is also recommended that pilots check their ability to reverse their energies prior to beginning an approach. Engines shall not be turned off in the lock until the tow has stopped and been made fast.

(v) U.S. Coast Guard Regulations require all vessels to have on board life saving devices for prevention of drowning. All crew members of vessels required to carry work vests (life jackets) shall wear them during a lockage, except those persons in an area enclosed with a handrail or other device which would reasonably preclude the possibility of failing overboard. All deckhands handling lines during locking procedures shall wear a life jacket. Vessels not required by Coast Guard Regulations to have work vests aboard shall have at least the prescribed life saving devices, located for ready access and use if needed. The lockmaster may refuse lockage to any vessel which fails to conform to the above.

(c) Reporting of Navigation Incidents. In furtherance of increased safety on waterways the following safety rules are hereby prescribed for all navigation interests:

(1) Any incident resulting in uncontrolled barges shall immediately be reported to the nearest lock. The report shall include information as to the number of loose barges, their cargo, and the time and location where they broke loose. The lockmaster or locks shall be kept informed of the progress being made in bringing the barges under control so that he can initiate whatever actions may be warranted.

(2) Whenever barges are temporarily moored at other than commercial terminals or established fleeting areas, and their breaking away could endanger a lock, the nearest lock shall be so notified, preferably the downstream lock.

(3) Sunken or sinking barges shall be reported to the nearest lock both downstream and upstream of the location in order that other traffic passing these points may be advised of the hazards.

(4) In the event of an oil spill, notify the nearest lock downstream, specifying the time and location of the incident, type of oil, amount of spill, and what recovery or controlling measures are being employed.

(5) Any other activity on the waterways that could conceivably endanger navigation or a navigation structure shall be reported to the nearest lock.

(6) Whenever it is necessary to report an incident involving uncontrolled, sunken or sinking barges, the cargo in the barges shall be accurately identified.

(d) Precedence at Locks.

(1) The vessel arriving first at a lock shall normally be first to lock through, but precedence shall be given to vessels belonging to the United States. Licensed commercial passenger vessels operating on a published schedule or regularly operating in the "for hire" trade shall have precedence over cargo tows and like craft. Commercial cargo tows shall have precedence over recreational craft, except as described in paragraph (f).

(2) Arrival posts or markers may be established above and/or below the locks. Vessels arriving at or opposite such posts or markers will be considered as having arrived at the locks within the meaning of this paragraph. Precedence may be established visually or by radio communication. The lockmaster may prescribe such departure from the normal order of precedence as in his judgment is warranted to achieve best lock utilization.

(e) Unnecessary Delay at Locks. Masters and pilots must use every precaution to prevent unnecessary delay in entering or leaving locks. Vessels failing to enter locks with reasonable promptness when signaled to do so shall lose their turn. Rearranging or switching of barges in the locks or in approaches is prohibited unless approved or directed by the lockmaster. This is not meant to curtail "jackknifing" or set-overs where normally practiced.

(f) Lockage of Recreation Craft.

In order to fully utilize the capacity of the lock, the lockage of recreational craft shall be expedited by locking them through with commercial craft, provided that both parties agree to joint use of the chamber. When recreational craft are locked simultaneously with commercial tows, the lockmaster will direct, whenever practicable, that the recreational craft enter the lock and depart while the tow is secured in the lock. Recreational craft will not be locked through with vessels carrying volatile cargoes or other substances likely to emit toxic or explosive vapors. If the lockage of recreational craft can not be accomplished within the time required for three other lockages, a separate lockage of recreational craft shall he made. Recreational craft operators are advised that many locks have a pull chain located at each end of the lock which signals the lockmaster that lockage is desired. Furthermore, many Mississippi River locks utilize a strobe light at the lock to signal recreational type vessels that the lock is ready for entry. Such lights are used exclusively to signal recreational craft.

(g) Simultaneous Lockage of Tows with Dangerous Cargoes.

Simultaneous lockage of other tows with tows carrying dangerous cargoes or containing flammable vapors normally will only be permitted when there is agreement between the lockmaster and both vessel masters that the simultaneous lockage can be executed safely. The lockmaster shall make a separate decision each time such action seems safe and appropriate, provided:

(1) The first vessel or tow in and the last vessel or tow out are secured before the other enters or leaves.

(2) Any vessel or tow carrying dangerous cargoes is not leaking.

(3) All masters involved have agreed to the joint use of the lock chamber.

(h) Stations While Awaiting Lockage. Vessels awaiting their turn to lock shall remain sufficiently clear of the structure to allow unobstructed departure for the vessel leaving the lock. However, to the extent practicable under the prevailing conditions, vessels and tows shall position themselves so as to minimize approach time when signaled to do so.

(i) Stations While Awaiting Access Through Navigable Pass. When navigable dams are up or are in the process of being raised or lowered, vessels desiring to use the pass shall wait outside the limits of the approach points unless authorized otherwise by the lockmaster.

(j) Signals. Signals from vessels shall ordinarily be by whistle; signals from locks to vessels shall be by whistle, another sound device, or visual means. When a whistle is used, long blasts of the whistle shall not exceed 10 seconds and short blasts of the whistle shall not exceed 3 seconds. Where a lock is not provided with a sound or visual signal installation, the lockmaster will indicate by voice or by the wave of a hand when the vessel may enter or leave the lock. Vessels must approach the locks with caution and shall not enter nor leave the lock until signaled to do so by the lockmaster. The following lockage signals are prescribed:

(1) Sound Signals by Means of a Whistle. These signals apply at either a single lock or twin locks.

(i) Vessels desiring lockage shall on approaching a lock give the following signals at a distance of not more than one mile from the lock:

(a) If a single lockage only is required: One long blast of the whistle followed by one short blast.

(b) If a double lockage is required: One long blast of the whistle followed by two short blasts.

(ii) When the lock is ready for entrance, the lock will give the following signals:

(a) One long blast of the whistle indicates permission to enter the lock chamber in the case of a single lock or to enter the landward chamber in the case of twin locks.

(b) Two long blasts of the whistle indicates permission to enter the riverward chamber
in the case of twin locks.

(iii) Permission to leave the locks will be indicated by the following signals given by the lock:

(a) One short blast of the whistle indicates permission to leave the lock chamber in the case of a single lock or to leave the landward chamber in the case of twin locks.

(b) Two short blasts of the whistle indicates permission to leave the riverward chamber in the case of twin locks.

(iv) Four or more short blasts of the lock whistle delivered in rapid succession will be used as a means of attracting attention, to indicate caution, and to signal danger. This signal will be used to attract the attention of the captain and crews of vessels using or approaching the lock or navigating in its vicinity and to indicate that something unusual involving danger or requiring special caution is happening or is about to take place. When this signal is given by the lock, the captains and crews of vessels in the vicinity shall immediately become on the alert to determine the reason for the signal and shall take the necessary steps to cope with the situation.

(2) Lock Signal Lights. At locks where density of traffic or other local conditions make it advisable, the sound signals from the lock will be supplemented by signal lights. Flashing lights (showing a one-second flash followed by a two-second eclipse) will be located on or near each end of the land wall to control use of a single lock or of the landward lock of double locks. In addition, at double locks, interrupted flashing lights (showing a one-second flash, a one- second eclipse and a one- second flash, followed by a three-second eclipse) will be located on or near each end of the intermediate wall to control use of the riverward lock. Navigation will be governed as follows:

Red Light. Lock cannot be made ready immediately. Vessel shall stand clear.

Amber Light. Lock is being made ready. Vessel may approach but under full control.

Green Light. Lock is ready for entrance.

Green and Amber. Lock is ready for entrance but gates cannot be recessed completely. Vessel may enter under full control and with extreme caution.

(3) Radio Communications. VHF-FM radios, operating in the FCC authorized Maritime Band, have been installed at all operational locks (except those on the Kentucky River and Lock 3. Green River). Radio contact may he made by any vessel desiring passage. Commercial tows are especially requested to make contact at least one half hour before arrival in order that the pilot may be informed of current river and traffic conditions that may affect the safe passage of his tow.

All locks monitor 156.8 MHz (Ch. 16) and 156.65 MHz (Ch. 13) and can work 156.65 MHz (Ch. 13) and 156.7 MHz (Ch. 14) Ch. 16 is the authorized call, reply and distress frequency, and locks are not permitted to work on this frequency except in an emergency involving the risk of immediate loss of life or property. Vessels may call and work Ch. 13, without switching, but are cautioned that vessel to lock traffic must not interrupt or delay Bridge to Bridge traffic which has priority at all times.

(k) Rafts. Rafts to be locked through shall be moored in such manner as not to obstruct the entrance of the lock, and if to be locked in sections, shall be brought to the lock as directed by the lockmaster. After passing the lock the sections shall be reassembled at such distance beyond the lock as not to interfere with other vessels.

(1) Entrance to and Exit from Locks. In case two or more boats or tows are to enter for the same lockage. their order of entry shall be determined by the lockmaster. Except as directed by the lockmaster, no boat shall pass another in the lock. In no case will boats he permitted to enter or leave the locks until directed to do so by the lockmaster. The sides of all craft passing through any lock shall be free from projections of any kind which might injure the lock walls. All vessels shall be provided with suitable fenders, and shall be used to protect the lock and guide walls until is has cleared the lock and guide walls.

(m) Mooring.

(1) At Locks.

(i) All vessels when in the locks shall be moored as directed by the lockmaster. Vessels shall be moored with bow and stern lines leading in opposite directions to prevent the vessel from "running" in the lock. All vessels will have one additional line available on the head of the tow for emergency use. The pilothouse shall be attended by qualified personnel during the entire locking procedure. When the vessel is securely moored, the pilot shall not cause movement of the propellers except in emergency or unless directed by the lockmaster. Tying to lock ladders is strictly prohibited.

(ii) Mooring of unattended or nonpropelled vessels or small craft at the upper or lower channel approaches will not be permitted within 1200 feet of the lock.

(2) Outside of Locks.

(i) No vessel or other craft shall regularly or permanently moor in any reach of a navigation channel. The approximate centerline of such channels are marked as the sailing line on Corps of Engineers' navigation charts. Nor shall any floating craft, except in an emergency, moor in any narrow or hazardous section of the waterway. Furthermore, all vessels or other craft are prohibited from regularly or permanently mooring in any section of navigable waterways which are congested with commercial facilities or traffic unless it is moored at facilities approved by the Secretary of the Army or his authorized representative. The limits of the congested areas shall be marked on Corps of Engineers' navigation charts. However, the District Engineer may authorize in writing exceptions to any of the above if, in his judgment, such mooring would not adversely affect navigation and anchorage.

(ii) No vessel or other craft shall be moored to railroad tracks, to riverbanks in the vicinity of railroad tracks when such mooring threatens the safety of equipment using such tracks, to telephone poles or power poles, or to bridges or similar structures used by the public.

(iii) Except in case of great emergency, no vessel or craft shall anchor over revetted banks of the river, and no floating plant other than launches and similar small craft shall land against banks protected by revetment except at regular commercial landings. In all cases, every precaution to avoid damage to the revetment works shall be exercised. The construction of log rafts along mattressed or paved banks or the tying up and landing of log rafts against such banks shall be performed in such a manner as to cause no damage to the mattress work or bank paving. Generally, mattress work extends out into the river 600' from the low water line.

(iv) Any vessel utilizing a federally constructed mooring facility (e.g., cells, buoys, anchor rings) at the points designated on the current issue of the Corps' navigation charts shall advise the lockmaster at the nearest lock that from point by the most expeditious means.

(n) Draft of Vessels. No vessel shall attempt to enter a lock unless its draft is at least three inches less than the least depth of water over the guard sills, or over the gate sills if there be no guard sills. Information concerning controlling depth over sills can be obtained from the lockmaster at each lock or by inquiry at the office of the district engineer of the district in which the lock is located.

(o) Handling Machinery. No one but employees of the United States shall move any lock machinery except as directed by the lockmaster. Tampering or meddling with the machinery or other parts of the lock is strictly forbidden.

(p) Refuse in Locks. Placing or discharging refuse of any description into the lock, on lock walls or esplanade, canal or canal bank is prohibited.

(q) Damage to Locks or Other Work. To avoid damage to plant and structures connected with the construction or repair of locks and dams, vessels passing structures in the process of construction or repair shall reduce their speed and navigate with special caution while in the vicinity of such work. The restrictions and admonitions contained in these regulations shall not affect the liability of the owners and operators of floating craft for any damage to locks or other structures caused by the operation of such craft.

(r) Trespass on Lock Property. Trespass on locks or dams or other United States property pertaining to the locks or dams is strictly prohibited except in those areas specifically permitted. Parties committing any injury to the locks or dams or to any part thereof will be responsible therefor. Any person committing a willful injury to any United States property will be prosecuted. No fishing will be permitted from lock walls, guide walls, or guard walls of any lock or from any dam, except in areas designated and posted by the responsible District Engineer as fishing areas. Personnel from commercial and recreational craft will be allowed on the lock structure for legitimate business reasons; e.g., crew changes. emergency phone calls, etc.

(s) Restricted Areas at Locks and Dams. All waters immediately above and below each dam, as posted by the respective District Engineers, are hereby designated as restricted areas. No vessel or other floating craft shall enter any such restricted area at any time. The limits of the restricted areas at each dam will he determined by the responsible District Engineer and marked by signs and/or flashing red lights installed in conspicuous and appropriate places.

(t) Statistical Information.

(1) Masters of vessels shall furnish to the lockmaster such statistics of passengers or cargo as may be requested.

(2) The owners or masters of vessels sunk in the navigable waters of the United States shall provide the appropriate District Engineer with a copy of the sunken vessel report furnished to the U.S. Coast Guard Marine Inspection Office in accordance with Code of Federal Regulations Title 33 Subpart 64.10-1.

(u) Operations during High Water and Floods in Designated Vulnerable Areas. Vessels operating on these waters during periods when river stages exceed the level of "ordinary high water," as designated on Corps of Engineers' navigation charts, shall exercise reasonable care to minimize the effects of their bow waves and propeller washes on river banks; submerged or partially submerged structures or habitations', terrestrial growth such as trees and bushes; and man-made amenities that may be present. Vessels shall operate carefully when passing close to levees and other flood protection works, and shall observe minimum distances from banks which may be prescribed from time to time in Notices to Navigation Interests. Pilots should exercise particular care not to direct propeller wash at river banks, levees, revetments, structures or other appurtenances subject to damage from wave action.

(v) Navigation Lights for Use at All Locks and Dams except on the Kentucky River and Lock 3, Green River.

(1) At locks at all fixed dams and at locks at all movable dams when the dams are up so that there is no navigable pass through the dam, the following navigation lights will be displayed during hours of darkness.

(a) Three green lights visible through an arc of 360 arranged in a vertical line on the upstream end of the river (guard) wall unless the intermediate wall extends farther upstream. In the latter case, the lights will be placed on the upstream end of the intermediate wall.

(b) Two green lights visible through an arc of 360 arranged in a vertical line on the downstream end of the river (guard) wall unless the intermediate wall extends farther downstream. In the latter case, the lights will be placed on the downstream end of the intermediate wall.

(c) A single red light, visible through an arc of 360 on each end (upstream and downstream) of the land (guide) wall.

(2) At movable dams when the dam has been lowered or partly lowered so that there is an unobstructed navigable pass through the dam, the navigation lights indicated in the following paragraphs will be displayed during hours of darkness until lock walls and weir piers are awash.

(a) Three redlights visible through an arc of 360 arranged in a vertical line on the upstream end of the river (guard) wall.

(b) Two red lights visible through an arc of 360 arranged in a vertical line on the downstream end of the river (guard) wall.

(c) A single red light visible through an arc of 360 on each end (upstream and downstream) of the land (guide) wall.

(3) After lock walls and weir piers are awash they will be marked as prescribed in paragraph (x) below.

(4) If one or more beartraps or weirs are open or partially open, and may cause a set in current conditions at the upper approach to the locks, this fact will be indicated by displaying a white circular disk 5 feet in diameter, on or near the light support on the upstream end of the land (guide) wall during the hours of daylight, and will be indicated during hours of darkness by displaying a white (amber) light vertically under and 5 feet below the red light on the upstream end of the land (guide) wall.

(5) At Locks No, 1 and 2. Green River, when the locks are not in operation because of high river stages, a single red light visible through an arc of 360 will be displayed on each end (upstream and downstream) of the lock river (guard) wall at which time the lights referred to above will not be visible.

(w) Navigation Lights for Use at Locks and Dams on the Kentucky River and Lock 3 Green River. A single red light visible through an arc of 360 shall be displayed during hours of darkness at each end of the river wall or extending guard structures until these structures are awash.

(x) Buoys at Movable Dams.

(1) Whenever the river (guard) wall of the lock and any portion of the dam are awash, and until covered by a depth of water equal to the project depth, the limits of the navigable pass through the dam will be marked by buoys located at the upstream and downstream ends of the river (guard) wall, and by a single buoy over the end or ends of the portion or portions of the dam adjacent to the navigable pass over which project depth is not available. A red nun-type buoy will be used for such structures located on the left-hand side (facing downstream) of the river and a black can-type buoy for such structures located on the right-hand side. Buoys will be lighted, if practicable.

(2) Where powerhouses or other substantial structures projecting considerably above the level of the lock wall are located on the river (guard) wall, a single red light located on top of one of these structures may be used instead of riverwall buoys prescribed above until these structures are awash, after which they will be marked by a buoy of appropriate type and color (red nun or black can buoy) until covered by a depth of water equal to the project depth. Buoys will be lighted, if practicable.

(y) Vessels to Carry Regulations. A copy of these regulations shall be kept at all times on board each vessel regularly engaged in navigating the rivers to which these regulations apply. Copies may be obtained from any lock office or District Engineer's office on request. Masters of such vessels are encouraged to have on board copies of the current edition of appropriate navigation charts.

NOTE: These regulations are those in effect 31 July 1975.

NOTES

1. Muskingum River Lock & Dam 1 has been removed. Ohio River slackwater provides navigable channel for recreational craft to Lock 2 near Devola, Ohio. Muskingum River Locks 2 thru 11 inclusive have been transferred to the State of Ohio and are operated during the recreational boating season by the Ohio Department of National Resources. Inquiries regarding Muskingum River channel conditions and lock availability should be directed to the aforementioned Department.

2. Little Kanawha River Lock and Dam 1 has been removed, thus permitting recreational craft to navigate up to Lock 2 near Slate, W. Va. Operation of Locks 2 thru 5 on the Little Kanawha River has been discontinued.

3. Big Sandy River: Lock 1 has been removed, thus permitting recreational craft to navigate to Lock 2, near Buchanan, Ky. Operation of Lock 2 and Lock 3 near Fort Gay, W. Va. has been discontinued. Operation of Lock and Dam 1 on Levisa Fork near

Gallup. Ky. and Lock and Dam 1 on Tug Fork near Chapman, Ky. has been discontinued.

4. Operation of the following Green River Locks has been discontinued: Lock 4 near Woodbury, Ky., Lock 5 near Glenmore, Ky., and Lock 6 near Brownsville, Ky.

5. Operation of Barren River Lock and Dam No. 1 near Richardsville, Ky. has been discontinued.

6. Operation of Rough River Lock and Dam No. 1 near Hartford, Ky. has been discontinued.

7. Operation of Osage River Lock and Dam 1 near Osage City. Mo., has been discontinued.

8. Operation of the 34 locks in the Illinois and Mississippi (Hennepin) Canal, including the feeder section. has been discontinued.

9. Operation of the Illinois and Michigan Canal has been discontinued.

APPENDIX D IS NOT INCLUDED. IT IS AVAILABLE IN PRINTED FORM. CONTACT DISTRICT OFFICES FOR LOCK CLOSURE INFORMATION.

Received by [handwritten initials] 5/6/

American Commercial Barge Line Company

730 E. Davis Street, St. Louis, Missouri 63111
Area Code (314) 544-7224
FAX (314) 544-7277

April 26, 1991

To: Jim Blanchar
Monty Hines
Ray Horton

From: Thomas M. Seals, Chairman of RIAC

Re: Self-help Program

Please find attached a copy of the revised self-help program. Please acknowledge your acceptance of these procedures and let me know when we can expect to have these implemented.

Thanks,

Tommy M. Seals

Thomas M. Seals
Chairman, RIAC

caa

March 11, 1991

Attn: Monty Hines/Ray Horton

As a result of our discussion concerning our self-help programs, we feel that there are some things that all parties in their respective areas can do that will enable us to do a better job with these self help programs. They are listed below.

A: It was the consensus of the group that we definitely need tie off buoys at all of the locks. Realizing that this will be a long drawn out process, we feel just the locks being discussed today should be addressed.

B: It must be a standard practice that all boats waiting turn at these locks keep alert. They should monitor their radios at all times and make every effort to move up as close to the locks as often as need be so that no delays can occur because of their inattention.

C: Lockmasters should keep boats advised as to their locking position and the importance of a boat staying close by to prevent delays.

D: Pleasure boats should be grouped together and locked between every third boat locking. However, this will be handled and directed by the Lockmaster.

E: Lockmen on the lock walls should be ready and willing to help deck crews double their lines when asked. However, Lockmasters prefer two part lines as much as possible.

F: Every towboat captain should make every effort to have experienced deck crews working aboard his vessel. Realizing that all companies carry green deck hands at times, the captain should be willing to get an experienced mate from the opposite watch to work over and assist in these types of situations.

G: Single tow lockages should be utilized to our advantage to speed up turn around times at the different locks.

H: Lockmasters should work closely with other locks on either side of his location to ensure that they are aware of boats either coming to them or going away from them, so that the lockmaster at the next location will know how to plan for these boats on arrival relative to cue lists and locking conditions.

I: Lock and Dam #14 should consider putting a tie off cable back on the revetted shore above the lock, so that a boat will have a place to tie off, so that he is prepared to make the lock as soon as a northbound boat has cleared. This wire is necessary to prevent the head of the tow from swinging out into the path of the up-bound vessel leaving the lock. There were also some suggestions made that the Corps consider placing two (2) tie off cells below lock #14 in the middle of the crossing so that northbound tows will have a place to tie off and assist at the locks.

J: Taking into consideration the fact that most companies carry hip barges, certain locks should allow heel lines to be used for exiting the locks; especially Lock #21 and Lock #14.

K: It should be a standard practice that all locks go to a (three-up; three-down) locking ratio when four or more boats back up at a lock, depending on future cue list arrivals. When the locks have enough boats to go to a (three-up; three-down) situation , the self help programs will automatically be implemented by the lockmaster or whoever is in charge at the locks. The (three-up; three-down) combination should work fine until a back log of six or more boats occurs on either of the downstream or upstream side of the lock. When this happens, then the lock man should contact chairmen of RIAC for help. The chairman or co-chairman of RIAC will at that time help to implement a more productive self help program.

Next, we decided that the self help program for each lock should work as follows: In the (three-up; three-down) scenario, the #1 tow will be used to remake couplings on. Either the #2 or #3 boat will pull cuts while the other one holds tows. This should work in most of the situations described below.

Lock #25: All southbound cuts will be pulled down to the last pin on the wall. These cuts should not be taken away from the wall because there is no likely areas for remaking cuts near the lock. The boat that is pulling the cuts should stand by the cuts until his crew has helped remake the coupling, and he has assisted these southbound tows away from the lock. He will then repeat this same procedure for each cut that he pulls.

Each northbound cut will be away from the lock up along side the_dike and tied off on the side of #1 southbound tow who will be waiting there. Once he has secured the cut, he will proceed back to the lock and be ready to pull the next cut. The crew on the #1 southbound tow should go out and assist in making up along side of him.

The last northbound cut that is pulled will be left on the upper wall. The boat that is pulling the cuts will have its crew assist in remaking the couplings and then he will proceed back to his tow and prepare to lock.

Lock #24: Southbound tows will be pulled down to the last pin on the wall. These cuts should not be taken away from the wall because there is no likely areas for remaking cuts near the lock. The boat that is pulling the cuts should stand by the cuts until his crew has helped remake the coupling, and he has assisted these southbound tows away from the lock, He will then repeat this same procedure for each cut that he pulls.

Northbound cuts will be pulled up the wall by either a cable or an assist boat. These northbound cuts will not be taken away from the lock unless the cue is large enough that different measures should be taken.

Lock #22: All southbound cuts will be pulled down to the last pin on the wall. These cuts should not be taken away cuts near the lock. The boat that is pulling the cuts should stand by the cuts until his crew has helped remake the coupling, and he has assisted these southbound tows away from the lock. He will then repeat this same procedure for each cut that he pulls.

Northbound cuts will be pulled up the wall by either a cable or an assist boat. These northbound cuts will not be taken away from the lock unless the cue is large enough that different measures should be taken.

In addition to this pattern, a southbound boat should always be positioned on the cells located just above Lock #22. By doing this, the boat will be ready to approach the lock as soon as the last northbound boat clears.

Lock #21: All southbound cuts will be pulled down to the last pin on the wall. These cuts should not be taken away from the wall because there is no likely areas for remaking cuts near the lock. The boat that is pulling the cuts should stand by the cuts until his crew has helped remake the coupling, and he has assisted these southbound tows away from the lock. He will then repeat this same procedure for each cut that he pulls.

Northbound cuts need to be pulled away from the lock and put back together alongside the tow that will be tied off in the pocket below the dike. The last northbound boat will make his coupling on the wall.

Note: Industry feels that the Corps of Engineers should put some sort of float and deadman underneath the dike located just above the lock. This will enable the boat holding up in the pocket to tie off in a secure fashion. This should have top priority.

Lock #20: All southbound cuts will be pulled down to the last pin on the wall. These cuts should not be taken away from the wall because there is no likely areas for remaking cuts near the lock. The boat that is pulling the cuts should stand by the cuts until his crew has helped remake the coupling, and he has assisted these southbound tows away from the lock. He will then repeat this same procedure for each cut that he pulls.

Northbound cuts need to be pulled away from the lock and put back together alongside the tow that will be tied off in the pocket. The last northbound boat will make his coupling on the wall.

We will also need a tie off buoy located just above Lock #20. That will enable us to operate in the safest manner. This should have top priority.

Lagrange Lock: Southbound cuts should be pulled away from the lock and put back together alongside of the #1 northbound boat waiting turn. All three cuts should be pulled away from the lock. This will enable Lagrange to lock singies or pleasure boats while the last tow is being put back together down below. Northbound cuts should be pulled away from the lock and put back together alongside of the #1 southbound tow. The last cut that is pulled at Lagrange northbound should be pulled away from the lock and put back together alongside of the second and third tow waiting turn. This would allow the #1 southbound tow to begin his approach to the lock as soon as possible.

Peoria Lock: Southbound cuts should be pulled away from the lock and made back up alongside of the #1 northbound boat. Northbound cuts will be pulled out and tied off on the upper wall. We will continue this process until six or more tows have cued. When we have a cue of six or more, we will pull these cuts away from the lock and put them back together alongside of the #2 southbound tow which will be back in below Killers drydock. This will enable the #1 southbound boat to start his approach as soon as possible after the last cut has been pulled.

NAVIGATION NOTICE NO. 1-1998

Mississippi Valley Division

Great Lakes and Ohio River Division

Rev.97A
April 1998

INTRODUCTION:

1. As a result of partnering efforts with navigation interests, a consolidated Notice to Navigation Interests has been prepared for the Upper Mississippi River, the Great Lakes and Ohio River Systems. The intent is to provide consistency by replacing current district and division regulations with a joint notice which will be updated annually. The notice is applicable to the St. Paul, Rock Island, St. Louis, Pittsburgh, Huntington, Louisville, and Nashville Districts.

2. The basic document includes policies that are applicable to all rivers, while the appendices cite policies applicable to certain rivers or projects. Also included as appendices are: District maintenance schedules, and the Code of Federal Regulations containing the "Blue Book" of navigation regulations prescribed by the Secretary of the Army.

3. Comments on how we may improve this notice may be sent to the U.S. Army Corps of Engineers, Rock Island District, Clock Tower Building, P.O. Box 2004, Rock Island, IL 61204-2004, ATTN: CEMVR-OD-B (LaVeta B. Bear) or by telephone at 309/794/5366.

GENERAL:

1. Reference revised Regulation, 33 CFR 207.300, Ohio River, Mississippi River above Cairo, IL, and their tributaries; use, administration, and navigation, effective 31 July 1975. This regulation contains information essential to the navigation of those waters and may be found at Appendix E. Copies of the above regulation may also be obtained from lock operators without charge.

2. The following information is furnished in addition to the above-referenced regulation to provide guidance about the procedures, control, and management of the locks on the Mississippi River, Illinois Waterway and Ohio River System. Suggested towboat operations are also included that will enhance safety and reduce damage to Government structures, commercial vessels, and recreational craft.

SAFETY:

1. Commercial and recreational craft shall use the locks at all times except for navigable pass dams, and authorized fixed weir passages.

2. Vessels shall not pass under gates in the dam when they are out of the water and the river is flowing freely through the gate opening.

3. Lockage of leaking or listing vessels may be refused. Leaking or listing vessels shall be moored in a location outside of the channel and outside of the Arrival Point so as not
to interfere with passing navigation.

4. All craft and tows approaching a lock, within a distance of 200 feet of the upper or lower lock gate, shall proceed at a speed not greater than two miles per hour (rate of a slow walk).

5. All tows entering the lock shall be properly aligned with the guide or lock wall. Tows may be required to stop prior to entering certain locks at which unusual conditions exist.

6. When an amber flashing light is displayed and approval is given by lock personnel, a descending or ascending vessel may approach and moor with a backing line to the guide wall; however, the head of the tow shall be no closer than 100 feet from the near end of the lock gate recess.

7. Burning fenders shall be dropped overboard immediately rather than being placed on the deck of a barge or towboat. Fenders shall not be secured to cleats or timberhead and left unattended.

8. When tows are underway in the lock approaches or lock chamber and there is a potential for damage to the structure a minimum of two deckhands with fenders shall be stationed at the head end of every tow 100 feet or greater in width. One deckhand with a fender shall be required at the head end of tows less than 100 feet in width. Additional personnel shall be required at the aft end if the lock operator determines that it is necessary to protect the lock and guide walls from damage.

9. It is the responsibility of the vessel operator to provide adequate mooring lines. The lock operator may require mooring lines to be replaced with satisfactory lines before lockage is made if the lines appear to be of such quality, size, or condition that would make safe lockage questionable.

10. Mates and deckhands, when preparing to moor within the lock chambers, shall not throw heavy mooring lines onto the walls, but shall wait for a heaving line.

11. All towboat crews, while locking or moving a tow into or out of a lock chamber, must station themselves to preclude the possibility of being injured by the parting of a cable or line under strain. Single part lines only will be used to check a moving tow. During inclement weather conditions (snow and ice) the working area of the tow where lines

are used shall be free of snow and ice to prevent injury to towing industry personnel. Working lines shall be kept dry and in working condition (not frozen) to allow lines to be worked properly and to prevent injury to personnel.

12. Towboat crew members shall not jump between moving tows and lock or guide walls while preparing for lockage, locking, or departing lock. Use of lockwall ladder ways is permitted only after tows are securely moored and the chamber is at upper pool.

13. Tabulated below are the minimum numbers of vessel personnel required for handling lines during lockages. The captain/pilot can not act as a deckhand.

TYPE OF VESSEL OR TOW	MINIMUM NUMBER OF PERSONNEL	MINIMUM NUMBER OF LINES USED	MINIMUM NUMBER OF EMERGENCY USE LINES
Vessels less than 65 feet	1	1	1
Towboats	1	1	1
All other vessels requiring single lockage	2	*2 (see paragraph 7, page 4)	1
Tows requiring double lockage (one deckhand to remain with first cut)	3	2	1
Set-over tows	3	2	1
Knock-out tows	2	2	1

14. All vessels, when in the locks, shall be moored and/or moved as directed by the lock operator.

15. Commercial towing companies shall ensure that vessel operators and boat crew members have received orientation and training in all aspects of deck work and lockage procedures to ensure the safety of personnel, floating plant, and structures.

16. All cylinders or containers holding gases or liquids under pressure or any other chemical or substance shall be securely fastened to the hull of the vessel to prevent their rolling overboard into the lock chamber.

17. All containers holding paint, gasoline, or other volatile materials shall be securely fastened with tight fitting covers.

OPERATIONAL ASPECTS

1. Commercial fishing craft are included in the classification "recreational craft" when considering the precedent at the locks.

2. Personal watercraft of the "sit-down" variety, (those you sit on and ride), will be accepted for lockage. The "stand-up" variety, (those that require the vessel to be moving for the operator to be out of the water), will not be accepted for lockage unless the craft is tied off to and locked through with an approved vessel, and the operator of the "stand-up" craft boards the approved vessel. Operators of personal watercraft and their passengers are required to wear Coast Guard approved PFD=s during lockage.

3. The sides of all vessels passing through the locks shall be free from projections that may damage lock structures. Suitable fenders shall be used with all commercial tows passing through the locks to prevent damage to the lock walls and structures. Fenders shall be cylindrical in shape and no less than 6 inches in diameter. The fenders shall be used on guide walls and lock chambers to protect the structures. The fenders shall be manufactured or fabricated for the purpose of fendering, using woven rope; laminated, molded reinforced, natural, or synthetic rubber, or other suitable material. Single, double, or triple strands of mooring line, with or without knots, and old tires will not be considered as suitable fenders. Lock operators may refuse lockage to all commercial tows not conforming to the above.

4. The Corps of Engineers endorses the towing industry initiative toward voluntary "self help," such as pulling unpowered cuts at locks where significant delays are being experienced because of high lockage demand, lock repairs, or some other reason.

5. During severe winter navigation conditions, the length and width of the tows may be restricted to facilitate passage of the tow into the lock chamber and to minimize lock structural damage.

6. Rake to box ice couplings the entire width of the tow at break points of the tow will be required at all locks when ice conditions so dictate. Double tripping and use of industry provided helper boats during ice conditions will be required if proper couplings are not accomplished prior to arrival at the lock. (Required by 1 November on Upper Mississippi and Illinois River). Failure to have the tow configured properly may result in loss of lock turn.

7. A single towboat requires only 1 line. If the length of a tow or section of a tow permits, the tow or section of a tow in the lock will use a minimum of two lines. The navigator will provide an additional line or lines at the lock operator's request when, in the lock operator's opinion, conditions indicate that such added precautions are necessary for safe lockage. All vessels will have one additional line, at least equal in length to the lock lines, on the head (working side) of the tow for emergency use.

8. Tows using locks equipped with floating mooring bitts shall use at least one line on each of two floating bitts if the tow length permits. Floating mooring bitts shall not be used to check a tow.

9. In a knock-out lockage, the towboat shall be placed in the hole alongside the rear barges and should be located sufficiently forward to allow for ample clearance between its stern and the mitering gates. While exiting from any lockage, the towboat shall proceed slowly to reduce backwash action and possible damage to lock gates.

10. Radio communications between a lock and an approaching tow are required at all times. All tows shall have a positive two-way voice communication between the pilot and the head of the tow to facilitate proper and safe approach to the lock guide wall and subsequent entrance into the lock chamber. All tows that decide to switch to another channel during the locking process for communication with their deckhands will be required to inform the lock personnel as to what channel they are changing to.

11. Lock personnel will monitor the frequencies indicated below. However, the District Engineers are authorized to require that the initial contact to any lock be made on other frequencies where circumstances indicate necessity.

Initial contact with locks are as follows:

UPPER MISSISSIPPI RIVER	
Locks 1-24 and Melvin Price Lock	156.7 MHz (Channel 14)
Locks 25 and 27	156.6 MHz (Channel 12)
ILLINOIS WATERWAY	
All Locks and Chicago Harbor Lock	156.8 MHz (Channel 16)
OHIO RIVER	
Louisville, Nashville, Huntington, and Pittsburgh District Locks	156.65 MHz (Channels 13)
Louisville and Nashville District Locks also monitor	156.8 MHz (Channel 16)

All tows awaiting lockage shall monitor the appropriate lock channel at all times. This will allow the lock personnel the capability of calling tows in the case of needing pull boats, broadcasting general announcements, call for preparation for lockage, etc.

12. Under normal conditions, tows that can be arranged to avoid a double lockage shall be rearranged prior to approaching the lock. Non-compliance will result in not being assigned a lock turn, until tow has been rearranged to comply or until no other vessel awaits lockage.

13. Where additional mooring facilities are provided, tows that must be rearranged in the approach area; i.e., set-overs, jackknives, etc., shall rearrange at these moorings, prior to entering the lock, if they must wait for entry. Lock operators should be

contacted prior to arrival and will render a decision whether the tow should be rearranged at the moorings or in the lock.

14. Towboats, when entering a lock, must remain fully attached to the barges until the tow has been stopped and properly moored. Barges within the tow configuration must be properly cabled. Lockage may be refused if lock operator considers barge couplings inadequate.

15. When moving or making up tows prior to leaving the lock in up bound movement, towboat operators are required to keep all barges secured to the lock or guide wall. At the locks where traveling mooring bitts are used, the line shall not be released until the regulator mooring line is secured at the bow. Generally, the deckhand will not release snubbing and holding lines from the lock or guide walls until the towboat is properly secured to the tow. For a single lockage, with a towboat only set over, deviating from this procedure will be allowed if the immediate situation will permit safe departure under power and a lock operator walks a line out with the tow until the towboat is again adequately secured to the tow. Lock operators will assist by moving barges with tow-haulage equipment. However, when moving barges from the lock chamber, it is the responsibility of the vessel master to assure that adequate lines and personnel are available for safe exit handling and mooring of the tow or sections to the lock or guide walls. Sufficient personnel shall remain with the other sections to assure its security.

16. When leaving the lock in down bound movement, rearrangement of tows in motion will be permitted while passing out of the lock at the discretion of the lockmaster. If there is a floating plant, bridges, or other structure located immediately downstream from the lock, these procedures shall not be used.

17. Lockage lengths in excess of 595 feet, but not more than 600 feet, will be permitted with the following conditions:

a. The vessel operator shall inform the lock operator by radio, prior to arrival, as to the
precise overall length of an integrated tow (single lockage) or the cut lengths of a multiple lockage the number of barges in the tow, cargo type, and tonnage. Failure to provide all information may result in refusal of lockage.

b. A tow may be required to have a total of four lines, two each leading fore and aft, at the discretion of the lock operator. The lines shall be in good condition.

c. The pilot shall be in the pilothouse and be in constant radio contact with lock personnel during the entire lockage procedure.

d. Experienced deck personnel shall be stationed at each end of the tow to monitor movement.

18. Lockage of tows wider than 108 feet for a 110-foot chamber, 82 feet for an 84-foot chamber, and 54 feet for a 56-foot chamber will be refused.

19. During the high water season, strong out drafts occur at the upstream approach to some navigation locks. On the Upper Mississippi River and the Illinois Waterway the out draft signals are displayed on the upper end of the land guide walls, (river wall bullnose at Lockport Lock), and may be orange or amber. At some locks, similar signs are also displayed on the downstream end of the lower guide wall for the information of upbound tows. Lock personnel on duty will advise navigators when dangerous out draft conditions prevail. All vessel operators are directed to exercise extreme caution when approaching locks for a downbound lockage or when leaving locks upbound, where out draft conditions exist. Double trips may be required if doubt exists as to the ability of the tow to enter or leave the lock safely.

20. When requested, the pilot of the towboat shall provide an accurate description of the contents of any covered or tank barge in their tow. Transiting of the locks with unknown cargos will not be permitted.

21. All deck barges loaded with rock, scrap materiel, construction equipment and other material shall be loaded to allows for safe passage of crew members along the edge of the barges. A minimum of 2 feet of clear space shall be maintained along the edge of all of the barges. The barges shall be loaded such that the material does not move or fall into the 2-foot wide clear space while moving or transporting the barges. Additionally, material shall be loaded on barges such that it will not become dislodged or moved during the locking process, possibly falling off the barge into the lock chamber or coming to rest protruding off the edge of the barge. Lock operators may refuse lockage to all commercial tows not conforming to the above.

Phillip R. Anderson
Major General, Corps of Engineers
Division Engineer
Mississippi Valley Division

Hans A. Van Winkle
Brigadier General, Corps of Engineers
Division Engineer
Great Lakes and Ohio River Division

APPENDIX A

Upper Mississippi River

A. St. Paul District

B. Rock Island District

1. The practice of heeling off the lockwall (using lockwall for leverage) will not be tolerated while departing the locks, unless the tow has significant forward movement and it is absolutely necessary. (The purpose for this restriction is to reduce the very costly damage to the scour protection along the guide walls and beneath the lower and upper sills). Use of heeling line from barge to a pin on lockwall may be used in the Rock Island District to assist in swinging head of tow away from lockwall.

2. A minimum 8-foot lead will be required and wheel wash will be directed out towards the river and not against the guide wall.

3. At Lock 19, Keokuk, Iowa, due to very strong currents pulling along the short upper guide wall during the filling operation of the lock, all downbound commercial vessels shall not enter the forebay until the upper gates are submerged and the lockmaster has given the vessel permission to proceed.

4. Due to strong currents near intakes and extreme turbulence within the lock chamber, all personal watercraft, i.e. wet bikes, jet bikes, jet skis, wave runners, wave jumpers, etc. will not be locked through while under their own power at Lock 19. Personal watercraft will be locked through while being towed into and out of the lock by a conventional pleasure craft, i.e. bass boat, ski boat, runabout, day cruiser, houseboat, etc. While the personal watercraft is being towed into, locked through and towed out of the lock approach, they shall not be ridden or operated. The operator of the personal watercraft will be required to board the vessel performing the towing of the personal watercraft. Boarding and unboarding will not delay traffic in any way.

C. St. Louis District

APPENDIX B

Illinois Waterway

A. Chicago District

The Chicago Harbor Lock is at the upper end of the Illinois Waterway which is a tributary of the Mississippi River. All rules and regulations defined in 33 CFR 207.300, Ohio River, Mississippi River above Cairo, Illinois, and their tributaries; use, administration and navigation shall apply except where they conflict with 33 CFR 207.420, Chicago River, IL, Chicago Harbor Lock and Controlling Works; use, administration and navigation of the lock at the mouth of the river.

B. Rock Island District

1. Only vessels awaiting lockage turn at Marseilles Lock will be allowed to moor in Marseilles Canal. Mooring of tows or barges for other reasons is prohibited.

2. Lockage of all doubles through Lockport Lock, Illinois Waterway, shall be restricted to a length of no more than 595 feet for the first cut.

3. Due strong currents near intakes and extreme turbulence within the lock chamber, all personal watercraft, i.e. wet bikes, jet bikes, jet skis, wave runners, wave jumpers, etc, will not be locked through while under their own power at Lockport Lock, Brandon Road Lock, Dresden Island Lock, Marseilles Lock, and Starved Rock Lock. Personal watercraft will be locked through while being towed into and out of the lock by a conventional pleasure craft, i.e. bass boat, ski boat, runabout, day cruiser, houseboat, etc. While the personal watercraft are being towed into, locked through and towed out of the lock approach, the shall not be ridden or operated. The operator of the personal watercraft will be required to board the vessel performing the towing of the personal watercraft. Boarding and unboarding will not delay traffic in any way.

C. St. Louis District

APPENDIX C

Ohio River and Tributaries

A. Pittsburgh District

1. At Emsworth, Dashields, Montgomery, and lock 2, Monongahela set overs lockages will not be done. Tows in this configuration will be locked as a double lockage.

2. At Emsworth a third line (breast line) is required for upbound lockages due to the heavy turbulence created during the lock chambers filling.

B. Huntington District

1. The towing industry and barge owners operating on the Kanawha River with the concurrence of the Corps of Engineers have agreed to implement the Switch Boat Program for downbound lockages through the land chamber. Details of billing procedures can be obtained by contacting one of the committee members as follow:

David Reed	Crounse Corporation	(606)654-6843
Vernon Smith	Ingram Barge Co.	(412)469-8705
John Reynolds	American Electric Power	(304)675-6300
Ray Thornton	The Ohio River Company	(304)523-6461

2. Out draft conditions for a downbound approach when the total dam opening is five feet or more at London or Marmet, require lock personnel to meet all downbound tows at the end of the wall when requested by vessel operators.

3. Deckhands must stand clear of haul-out cables during all pull-out operations.

C. Louisville District

1. The U.S. Coast Guard, Marine Safety Office, Louisville will place its Vessel Traffic Service (VTS) into operation when the upper gage at McAlpine Locks and Dam reaches 13.0. All upbound vessels should contact "Louisville Traffic" on Channel 13 upon arrival at McAlpine Locks and Dam. All downbound vessels should contact "Louisville Traffic" on Channel 13 upon arrival at Twelve Mile Island.

2. It is occasionally necessary to flush drift or ice from the upper lock approaches at Markland and Cannelton Locks and Dams. During these periods, flow is passed over a partially submerged emergency gate and through the auxiliary (600-foot) lock chamber. The auxiliary chamber will be closed during these flushing procedures and all traffic will be passed through the main (1200-foot) lock. Navigators should observe extreme caution and carefully follow the instructions of lock operators regarding the flushing operations.

3. In the Louisville District, the following radio procedures shall be observed:

a. Vessel operators should monitor Marine Channels 13 and 16 while awaiting lockage.

b. Vessel operators should continuously monitor Channel 16 during lockages. Lock operators will use that channel to contact vessels.

c. Vessel operators should contact lock personnel on Channel 13 during lockages
and switch to Channel 14 when requested.

4. McAlpine locks and Dam Radio Contact Location. Due to traffic in the Louisville and Portland Canal, downbound vessels, are permitted to announce their presence for lockage when they reach Six Mile Island (Mile 597.1).

5. Markland Locks and Dam. During periods of high drift, lock operators may instruct tows to stop closer than 100 feet from the upper miter gates of the main chamber top prevent excessive build up of drift between the head of the tow and the miter gates.

D. Nashville District

1. No vessel shall attempt to enter Kentucky Lock with less than 12 inches clearance over the miter sill.

2. Reference Notice to Navigation Interests CEORN-CO-W 93- 22 dated May 5, 1993.

SUBJECT: Procedures For Locking Fast Doubles at Pickwick Locks, Tennessee River Mile 206.7.

For the past few years most fifteen barge tows have been locked through Pickwick as a fast double using both locks, and the procedure has reflected a considerable reduction in locking time. The Nashville District Corps of Engineers, in cooperation with the Navigation Industry, plans to continue the fast double procedure for the purpose of enhancing safety and expediting lockages. The following guidelines will be used for the fast double lockages at Pickwick locks.

a. Downbound fast double lockages will not be conducted when the total discharge exceeds 100,000 cfs unless specifically requested by the operator of the vessel to be locked. When discharge exceeds 100,000 cfs a request to be locked as a fast double will be honored if, in the lock operator's opinion, it is safe to do so, based on such factors as water levels, actual amount of discharge, wind, etc.

b. A downbound fast double lockage will be accomplished by locking the fifteen barges in the 1,000 ft. main lock and the towboat in the 600 ft. auxiliary lock. Once locked down, the towboat will move to the main lock and prepare to receive the barges as they are pulled from the chamber with the lock's haulage unit equipment. Upon request by the towboat operator, the towboat may face up to the tow and pull the barge from the chamber in lieu of using the lock's haulage unit. In either event, a crew member should be stationed on the upstream end of the tow and inform the towboat operator when the stern of the tow sufficiently clears the short wall to provide clearance for the boat to move in and make up to the stern of the tow. Proper protective devices must be used to protect concrete and wall armor during the pull out operation.

c. Upbound fast double lockages will not be conducted when there is discharge through the spillways, regardless of the amount, or when total discharge exceeds 100,000 cfs. When either of the above conditions exist fifteen barge upbound tows will be locked as straight doubles.

d. During an upbound fast double lockage the towboat should pull the tow out of the lock chamber a distance that will permit the towboat to safely remake to it's tow. The lock's haulage unit equipment will not normally be used to pull an upbound fast double cut from the chamber because it would still be necessary for the towboat to continue the pull out until a sufficient clearance is achieved.

e. With the exception of paragraphs 3 and 4 above all other aspects of locking and upbound fast double are the same as stated above for downbound lockages.

f. If, for any reason, a vessel operator desires to lock a fifteen barge tow as a straight double and conditions are such to allow for a fast double lockage, he will be locked as a straight double if determined by the lock operator that it will not create any additional delay to any other vessel(s). If the lock operator determines additional; delay will be created and the vessel operator still desires a straight double lockage, his position in queue will be reestablished until such time additional delay to other traffic does not result. Tows considered in making such determination do not necessarily have to be at the arrival point.

g. The lock operator may require that a fifteen barge tow be locked as a straight double through either lock, rather than as a fast double, due to various factors such as flow, wind, mechanical problems, approach obstruction, or any time when it will result in the most efficient utilization of the lock.

h. Prior to beginning each lockage, procedural aspects of the lockage will be coordinated between the lock and vessel operators in an effort to insure a mutual and thorough understanding of the locking procedure.

3. Due to the draw in the upstream lock approach when filling the chamber on Pickwick main lock all cuts of tows must be at the 600 ft. marker or greater on the upper approach wall and have a minimum of 2 lines, four to six part each under normal conditions. During abnormal conditions/adverse weather conditions, tows may tie above the upper gates with additional lines provided the lock operator approves.

E. <u>General</u>

1. The lockage of oversize tows is not permitted on the Ohio River and tributaries. An oversize tow being defined as a tow that can not be locked through a 1200-foot lock in one lockage.

Glossary

Appendix H

GLOSSARY

These definitions apply to the terms as they are used in this document, except when the context conveys an obviously different meaning.

approach - *see lock approach*

barge - a large steel cargo-carrying vessel, connected to a towboat (and usually connected to other barges) to form a "tow"

bow - the front end of a vessel or barge

buoy - a hollow metal object that floats in the river to mark the limits of a channel, obstruction, or other important waterway feature

CEMVP - St. Paul District Office of the U.S. Army Corps of Engineers in St. Paul, Minnesota, of the Mississippi Valley Division

CEMVR - Rock Island District Office of the U.S. Army Corps of Engineers in Rock Island, Illinois, of the Mississippi Valley Division

CEMVS - St. Louis District Office of the U.S. Army Corps of Engineers in St. Louis, Missouri, of the Mississippi Valley Division

chamber - *see lock chamber*

check post (sometimes informally called a "button") - a metal pipe with a welded cap securely anchored to a lockwall or guidewall used to put hawser lines around from a tow (or cut of a tow) to hold the tow (or cut) onto the wall, keeping it from drifting away; also used to slow a moving cut

congestion - a condition of high traffic levels causing delay to vessels using the navigation system as they wait for lockage availability while other vessels are locking through

Corps - U.S. Army Corps of Engineers; the engineering branch of the United States Army with responsibility for the operation and maintenance of the Inland Waterway Navigation System of the United States

coupling - joining two barges or a barge and a vessel together

current - the movement of water, typically measured by velocity and direction

cut - a group of barges that is only a portion of the towboat's full load; the unpowered cut is the section of barges that is locked through without the towboat attached, typically the first cut of a double lockage; the powered cut is that section of barges that still has the towboat attached, typically the second cut of a double lockage

deckhand - a person who works as a crew member on a towboat charged with the handling of lines and lashings

delay - the time a tow must wait after arrival at a lock to the start of its lockage

DeLong Pier - a temporary pier made up of a barge that is anchored to the bottom with "spuds," or piling, that is driven into the riverbed

dike - a wall (generally trapezoidal) of material, usually rock, used to train or align the flow of water in a particular direction; a dike may be submerged or exposed above the water surface

double lockage - the process of locking a tow that is too large to fit into the lock chamber as a single lockage, but rather involves breaking the tow into two parts that are locked through individually

downbound - traveling in the direction of the flow of the river

exchange lockage - when the vessel entering the lock passes a vessel traveling in the opposite direction departing the lock (one vessel is making an "exchange exit" and the other is making an "exchange entry")

expert elicitation - convening experts in a field to solicit their estimates of parameters with uncertainty, especially when there is a lack of relevant data

fender - a device made of rubber, plastic, or wood, used to dissipate the energy of a vessel striking it or guide a vessel past a vulnerable structure

flanking - a maneuver tows often use in making a lock approach or exit made difficult by cross currents and/or restricted navigable area. In flanking, a tow must slow to stop, or even reverse directions, and then slowly bring the bow of the tow to the desired alignment before proceeding.

fly lockage - when a vessel enters a lock that is already prepared to receive it; the vessel does not have to wait for another vessel to lock through, nor does it pass a vessel that has just exited the lock; it can proceed directly into the lock (making a "fly entry") and depart the lock with no obstruction from other vessels (a "fly exit")

forebay - the area just upstream of the upper miter (or lift) gates of the lock chamber guardwall - a wall extending upstream or downstream from a lock chamber, located on the riverside of the lock, that serves to protect vessels from the force of river currents entering or discharging from the dam

guide cell - a large, round structure, 20 feet or larger in diameter, consisting of a sheetpile cell filled with earth or concrete; the cell is strategically placed to allow tows to pivot on it or otherwise get or stay properly aligned with a lock

guidewall - a long wall extending upstream or downstream of a lock approach, located on the landside of the approach channel, used to guide towboats into the lock chamber and temporarily moor tows or cuts of tows while they wait for the next step in a lockage process

head - the energy of elevated water

head differential - a difference in water levels; sometimes loosely called just "head"

helper boat - a low-power towboat used to assist tows in entering or exiting a lock chamber

Illinois Waterway - the commercial water route including the Illinois River, the Calumet-Sag Channel, the Chicago Sanitary and Ship Canal, and a portion of the Des Plaines and Chicago Rivers

intakes - the entrance to the filling/emptying culvert

intermediate lockwall - the common wall between two adjacent locks

IWW - Illinois Waterway

kevel - a heavy, metal deck fitting having two horn-shaped arms projecting outward around which lines may be made fast for towing or mooring a vessel

knockout tow - a tow configuration whereby the towboat uncouples from its traveling position and moves into an empty space in the barge configuration

L2 - Location 2 - place for the construction of a river guidewall, upstream extension of the river wall (intermediate wall) of the existing chamber

L3 - Location 3 - place for the construction of a river guidewall, upstream extension of the river wall of the auxiliary lock/miter gate bay

landwall - the landside wall of a lock chamber (except for the landward wall of the riverward lock of two adjacent locks which is generally referred to as the intermediate wall) life-cycle costs - all costs that a project will incur throughout its project life

lift - the difference in water surface elevations from the upper pool to the lower pool; head differential

lift gates - steel gates that can be placed at either end of a lock (but more commonly used upstream) to maintain desired water levels in the lock and raised or lowered vertically to allow the passage of vessels; they can be used for passage of ice and debris as well

line - natural fiber, synthetic rope or wire cable used in the maritime industry

line haul boats - towboats used for moving barges on the system, typically higher powered (>2,500 hp)

lock - the lock chamber, guidewalls and/or guardwalls, as applicable, and appurtenances

lock approach - the area through which tows must pass to reach the lock chamber

lock chamber - the area of a lock between the upstream and downstream miter or lift gates that is emptied and filled to lower or raise vessels

lock location - an alternative placement of a new lock at an existing lock and dam site

lock person – a person who works at a lock and dam facility

lock transit time - lockage time plus delay time

lockage - the process of passing floating objects (vessels, ice, debris) from one pool water level to the next through a type of gravity-operated "water elevator"

lockage process - the sequence of steps involved in a lockage

lockage time - the time a tow requires from the start of its lock approach to the completion of its exit (including all intermediate lockage steps)

Lockmaster - the person locally in charge of a single lock and dam facility

lockwall - the landside or riverside wall of a lock chamber

lower pool - the water at the downstream side of a lock; tailwater

LPMS - Lock Performance Monitoring System; used by the Corps of Engineers to track elements of lock operations marginal traffic movements - Those shipments with the smallest rate differential between some other mode or use. If increases in rates on one mode occur, these are the first shipments to seek another mode or use.

mate - a member of the towboat crew who typically has responsibility for deck operations during lockage; the mate is usually in direct communications contact with the tow captain

miter gate - a steel gate used at each end of a lock chamber that opens to allow tows in or out of the lock chamber and closes to allow a change in water level within the lock chamber

mooring cell - typically a sheet pile cell 20 feet or more in diameter and filled with soil, rock, or concrete. Towboats tie off to them while awaiting lockage.

navigation - water travel

Navigation Notice - a communication from the Corps of Engineers to all concerned with river navigation, to provide guidance about the procedures, control, and management of Corps locks and to communicate safety and practices that will reduce damage to Government structures, commercial vessels, and recreational craft

navigation system - the series of navigable channels, channel training works, locks and dams, and other elements necessary for navigation

N-up/N-down - a locking policy whereby a certain number of vessels are consecutively locked through in one direction before a number are consecutively locked through in the other direction; for example, a 3-up/4-down policy would require three consecutive vessels to be locked upbound before locking four consecutive vessels downbound; such a procedure would then be repeated until another locking policy was implemented

open pass - a condition which occurs at navigable dams (such as wicket dams) when the wickets (or other navigable gate type) are lowered during higher flow conditions, allowing navigation over the dam, bypassing the lock, similar to open channel conditions

outdraft - the current along the upstream guidewall that tends to pull a towboat away from the guidewall and towards the dam; the current depends upon a number of factors such as total river flow, channel alignment, channel depth, placement of structures, etc.

pelican hook - a quick release mechanism used in barge couplings performance - the lock's capability to perform its basic function of locking boats. A high performance lock is efficient and consistent. A low performance lock operates more slowly and less consistently.

pike pole - a long pole with a metal spike on the end; used by lock operators to move trash and ice in the lock chamber and approaches

pilot - a licensed mariner who directs the operations of a towboat

powered cut - the set of barges connected to the towboat after uncoupling for a double lockage

present worth - the value (sum) of all costs (first costs, maintenance, replacement, etc.), discounted from the projected time of expenditure to the current time at a given discount (interest) rate; or, the amount that, if invested now at the discount rate, would be sufficient to pay all life-cycle costs as they are incurred

propwash - the turbulence produced by a vessel's propeller

rake - the flared end of a barge

recess - the indentation that the miter gates move into in order to become flush with the lock walls, or that house other appurtenances that must not protrude from the lock wall into the lock chamber clear width

recoupling - joining a powered cut of a tow with the unpowered during a double lockage after initially uncoupling to lock the tow in two parts; coupling

reliability - the probability that a structure, or some significant component of it, will perform satisfactorily at a certain time given that it has performed satisfactorily up to that time. The inverse of reliability is the probability that the structure will perform unsatisfactorily over a given time interval.

reliability analysis - a computational analysis to determine feature reliabilities

RIAC - River Industry Action Committee; a maritime industry organization

riverwall - the riverside wall of a lock chamber (except for the riverside wall of the landward lock of two adjacent locks which is generally referred to as the intermediate wall)RM - River Mile - on the Upper Mississippi River, indicates the distance in miles from the confluence of the Ohio River with the Mississippi River at Cairo, IL, following the main channel

rubbing armor - steel embedded into concrete lockwalls and guidewalls to protect the walls from abrasion setover tow - a tow configuration whereby a towboat pushes barges into the chamber, then uncouples itself and a portion of its barges, and moves into a configuration that fits into the lock chamber all at once

sheet piling - long vertical interlocking metal pieces that, when fitted together, can form a wall; often driven down into the bottom and placed in a circular shape to form a guide or mooring cell

shoaling - the river's natural process of creating shallow areas by moving riverbed material

sill - the fixed concrete against which the miter gates seal

sill depth - the depth from a defined minimum water surface elevation to the top of the sill (adequate clearance is needed for safe entry and exit of tows)

single lockage - the process of locking a tow that fits entirely into the lock chamber without being separated into multiple parts

site - any of the existing lock and dam sites included in the Navigation Study, e.g., Lock and Dam 20, Lock and Dam 24, Peoria Lock and Dam, etc.

spool - the drum that holds the wire rope on a tow haulage unit

steamboat ratchet - a device used to take up the slack in a coupling

stern - the rear of a barge, tow, or other vessel

straight single - a tow configuration that requires no reconfiguration prior to lockage

submergence - the difference between the lower pool and the lock chamber floor

switchboat - a large horsepower towboat that can remove unpowered cuts from a chamber and take them to an area where the towboat can recouple the cuts

systems models - economics models, including a simulation approach and equilibrium approach, which will be used by the study team in evaluating the various improvement measures

tainter gate - a steel dam gate that uses a curved face of a pie-shaped wedge to control the flow of water

timber head - a metal fixture on towboats, barges, or on the top of a lock wall used to secure a line to; it has two large round metal cylinderstow - a commercial river vessel consisting of a towboat and one or more barges tow haulage equipment - a land-based powered cable system that removes unpowered cuts from lock chambers

towboat - the part of a tow that provides the power and steerage for the tow, that pushes the barges and houses the pilot and crew

traveling kevel - a kevel that is mounted on a rail on the top of the guidewall and is used to hold the bow of an unpowered cut close to the upper guidewall while it is being extracted from the chamber

turnback - the process of locking through one vessel and then taking the steps to prepare the empty lock to receive another vessel traveling in the same direction

turnback lockage - a lockage in which a tow locks through in the same direction as the previous tow; the tow can make its approach but must wait for chamber turnback to continue its lockage

UMR - Upper Mississippi River

uncoupling - disconnecting the barges of the unpowered cut from the barges (or towboat itself) of the powered cut

unpowered cut - the set of barges not connected to the towboat after uncoupling for a double lockage

upbound - traveling in the opposite direction of the flow of the river

Upper Mississippi River - that part of the Mississippi River from Cairo, IL (about 185 miles south of St. Louis, MO) to the rivers headwaters in Minnesota

upper pool - the water at the upstream side of a lock and/or dam; headwater

verification - check of the behavior of an adjusted model against a set of prototype conditions

wicket dam - dam consisting of wooden wickets which can be lowered during higher flows, allowing navigation passage without a lockage

winch - a hand or power-driven machine having one or more drums or barrels on which to wind a chain or rope and used for hoisting or hauling

wing dams - rock "walls" that extend from the shoreline into the river and are used to maintain a deep channel for vessel traffic; rock dikes may be either exposed or submerged