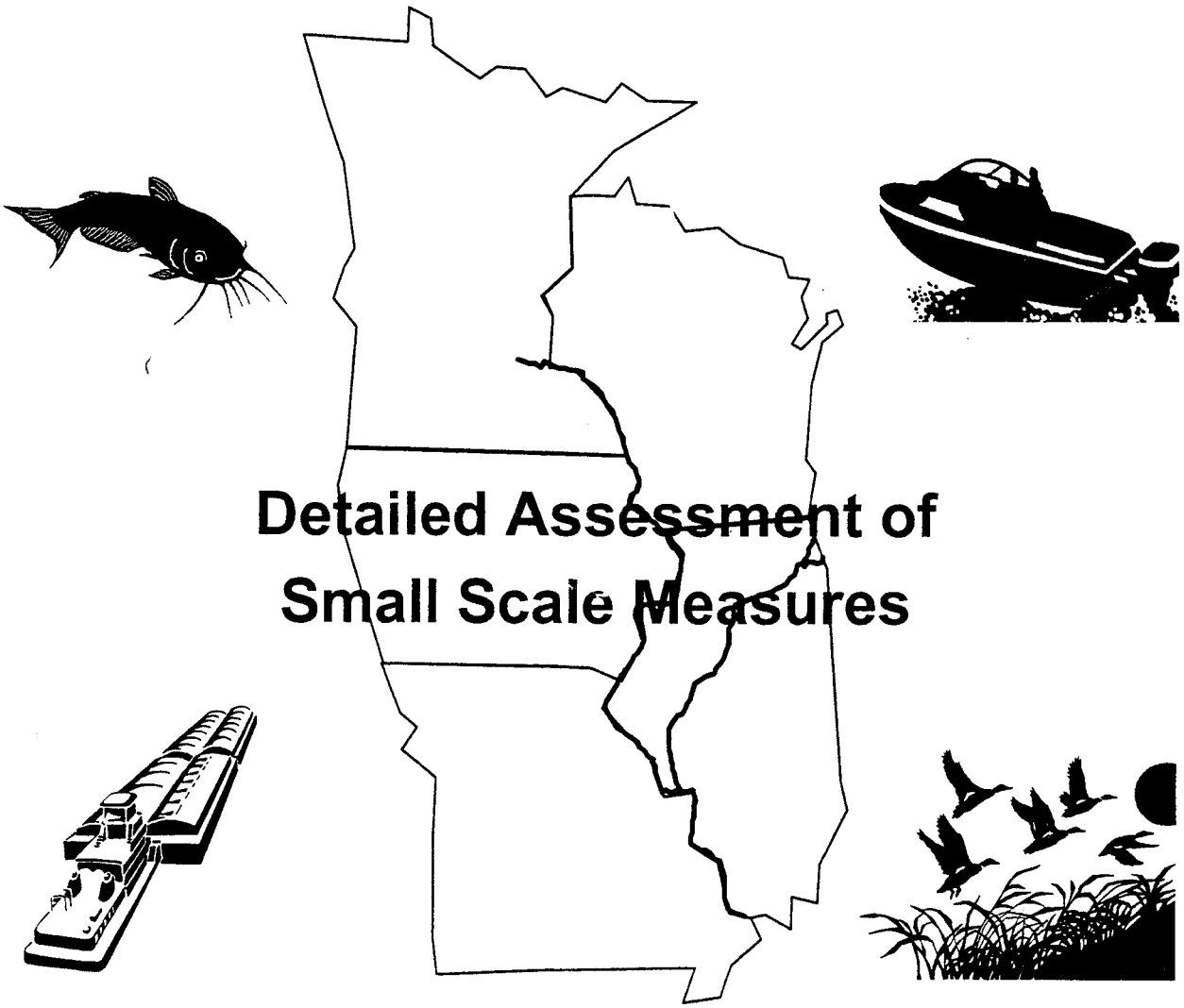
Upper Mississippi River - Illinois Waterway System Navigation Study



Detailed Assessment of Small Scale Measures

INTERIM REPORT

December 1998

US Army Corps of Engineers

Rock Island District
St. Louis District
St. Paul District

SUMMARY

This interim report contains a detailed assessment of the small scale measures under consideration as part of the Upper Mississippi River - Illinois Waterway System Navigation Study. The information generated for this effort will be considered as part of the plan formulation process for the System Navigation Study.

Small scale measures are defined as lower cost measures 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 a new lock. The goal of this evaluation is to further define and analyze these small scale measures using quantitative and some qualitative information. The evaluation focuses particularly on quantifying the benefits (ability of the measure to reduce delays at the lock facilities) and costs of implementing the measure and identifying other relevant considerations.

The small scale analysis process began in 1994 with the identification of the range of possible structural and non-structural small scale alternatives. A total of 92 measures originally were identified and qualitatively assessed as part of the *General Assessment of Small Scale Measures* interim product report completed in June 1995. The general assessment narrowed the list to 16 measures, which were recommended for further detailed assessment and quantitative study.

This report assesses in detail the 16 measures carried forward from the screening in the initial *General Assessment* report, in addition to some other measures resulting from further analysis and information. The unpowered traveling kevels measure was added as an outgrowth of discussions on extended guidewalls and tow haulage equipment measures. The permanent deck winches and additional personnel measures evolved from the analysis of similar crew element measures. The powered ratchets measure was initially considered infeasible due to unavailability. However, the recent manufacture of a commercially available powered ratchet, which has been put into limited use by the navigation industry, demonstrates the need to evaluate its use. The approach channel improvements measure was initially thought to have limited value. Later hydraulic model studies indicated that, on a site-specific basis, channel improvements may offer significant time savings.

These measures were divided into two broad categories—structural and non-structural—primarily to distinguish between the items requiring construction and those which could be implemented with little or no construction. However, combinations of measures, such as towboat power with guidewall extensions or remote moorings, reduce these distinctions to some extent. Under these categories, the measures have been grouped with other similar measures as listed below.

Non-Structural Measures

Towboat Power
- Helper Boats
- Switchboats
- Industry Self Help

Tolls and Reports
- Congestion Tolls
- Excessive Lockage Time Charges
- Lockage Time Charges
- Publish Lockage Times

Recreational Vessels
- Scheduling of Recreational Vessel Usage
- Recreational Craft Landing Above and Below Lock

Optimizing Decisions
- Scheduling Program

Structural Measures

Extended Guidewalls
Tow Haulage Equipment
- Powered Traveling Kevel
- Endless Cable
- Unpowered Kevels *

Adjacent Mooring Facilities
Crew Elements
- Universal Couplers/Hand Winches
- Standard Training for Crews
- Permanent Deck Winches *
- Additional Personnel *
- Powered Operated Ratchets *

Approach Channel Improvements *

* Measures added after the initial screening.

Based on the analysis of both the quantitative and qualitative information collected as part of this study effort, it appears that several small scale measures used separately or in combination have the potential to provide significant time savings at the locks. The cost and performance information in this report will be used by the study team to further screen the measures, assisting in identifying the most complete, effective, efficient, and acceptable small scale measures for consideration in the detailed plan formulation phase of the study. The final product of the System Navigation Study is a feasibility report that is the decision document for processing to Congress.

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SECTION 1 - INTRODUCTION

This report is organized into four general sections. Section 1 provides the background information on the study purpose and scope, lockage process, background and methodology. Section 2 summarizes the findings of the analysis of each measure, and Section 3 discusses how each of the measures applies to the particular lock sites under consideration in the study—Upper Mississippi River (UMR) Locks 11-27 and Illinois Waterway (IWW) Locks from Lockport to La Grange. Finally, Section 4 provides a more in-depth look at the technical information analyzed and development of the cost and time savings data.

PURPOSE

The Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study is a feasibility study addressing navigation improvements planning for the UMR and IWW System for the years 2000-2050. 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. (Figure 1-1 is a plan view of the UMR-IWW System). This assessment focuses particularly on the lower sites on the system—Locks 11-27 on the UMR and Lockport to La Grange Lock on the IWW. This area of focus was selected to evaluate the principal problem, which is the potential for significant traffic delays on the system within the 50-year planning horizon, resulting in economic losses to the nation.

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.

SCOPE OF THIS REPORT

This assessment represents continued analysis of the small scale measures under consideration as part of the UMR-IWW System Navigation Study. The measures being considered fall under the study's definition of small scale measures, which are items that reduce traffic delays at the system locks but involve considerably less cost than the construction of new lock facilities (i.e., new 600-foot or 1,200-foot locks) or extension of the existing lock chambers.

The engineering cost and performance data summarized in this report will assist in identifying the most complete, effective, efficient, and acceptable small scale measures for consideration in the detailed plan formulation phase of the study. However, whether the measures fall in the with- or without-project condition and the details of how the measures would be implemented and whether they would result in policy changes, new requirements, and who would pay, were not thoroughly evaluated as part of this assessment. Rather, the focus was on identifying and quantifying the time savings potential and associated costs. Additional concerns will be subsequently addressed should implementation be pursued based on the system analysis.

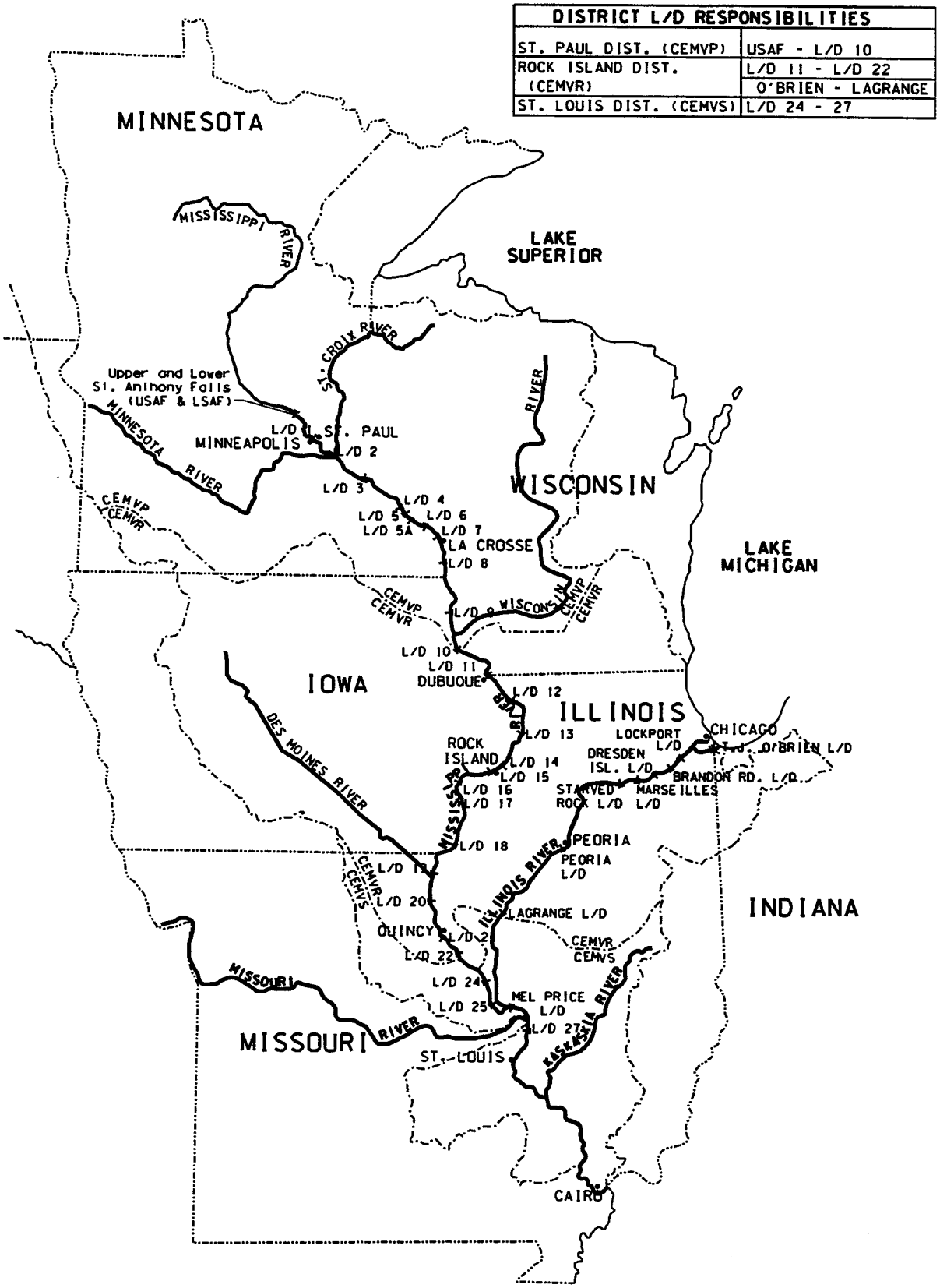


FIGURE 1-1: Upper Mississippi River - Illinois Waterway Navigation System

Unlike large scale measures which eliminate steps in the lockage process, small scale measures primarily decrease delay time for tows by reducing the time required for certain steps in the lockage process. Thus, more tows could be locked in a given time period, and delays to tows using the lock could be reduced or eliminated. Most small scale measures provide their full benefits under heavy congestion. However, with large queues and higher traffic levels, the remaining delays may be sufficient to warrant the additional expenditure on large scale improvements.

The small scale analysis process began with the identification of the range of possible structural and non-structural small scale alternatives. Originally, 92 measures were identified and qualitatively assessed as part of the *General Assessment of Small Scale Measures* interim product report completed in June 1995. The general assessment narrowed the list to 16 measures, which were recommended for further detailed assessment and quantitative study. See Appendix A for the original list of 92 measures. The initial screening process eliminated those measures which:

(1) have no potential to reduce delays at locks,
(2) are not technically feasible,
(3) are not safe,
(4) are not environmentally acceptable,
(5) are economically inefficient,
(6) are not cost effective,
(7) should be pursued through industry cooperation rather than Corps of Engineers requirements, or
(8) are addressed through the Corps of Engineers Operations and Maintenance Program.

This report focuses on conducting a detailed assessment of the 16 measures carried forward from the screening in the initial *General Assessment* report, plus some additional measures resulting from further analysis and information. The unpowered traveling kevels measure was added as an outgrowth of discussions on extended guidewalls and tow haulage equipment measures. The permanent deck winches and additional personnel measures evolved from the analysis of similar crew element measures. The powered ratchets measure was initially considered infeasible due to unavailability. However, the recent manufacture of a commercially available powered ratchet, which has been put into limited use by the navigation industry, demonstrates the need to evaluate its use. The approach channel improvements measure was initially thought to have limited value. Later hydraulic model studies indicated that, on a site-specific basis, channel improvements may offer significant time savings.

These measures can be divided into the two broad categories of structural and non-structural. While some measures overlap to some extent, the categories provide a simple way to distinguish between the structural items requiring construction and non-structural items that could be implemented with changes in public policy, management practice, regulatory policy, or pricing policy. Under these categories, the measures have been grouped with other similar measures:

Non-Structural Measures

Towboat Power
- Helper Boats
- Switchboats
- Self Help

Tolls and Reports
- Congestion Tolls
- Excessive Lockage Time Charges
- Lockage Time Charges
- Publish Lockage Times

Recreational Vessels
- Scheduling of Recreational Vessel Usage
- Recreational Craft Landing Above and Below Lock

Optimizing Decisions
- Scheduling Program

Structural Measures

Extended Guidewalls

Tow Haulage Equipment
- Powered Traveling Kevel
- Endless Cable
- Unpowered Kevels*

Mooring Facilities (Adjacent to Lock Approach)

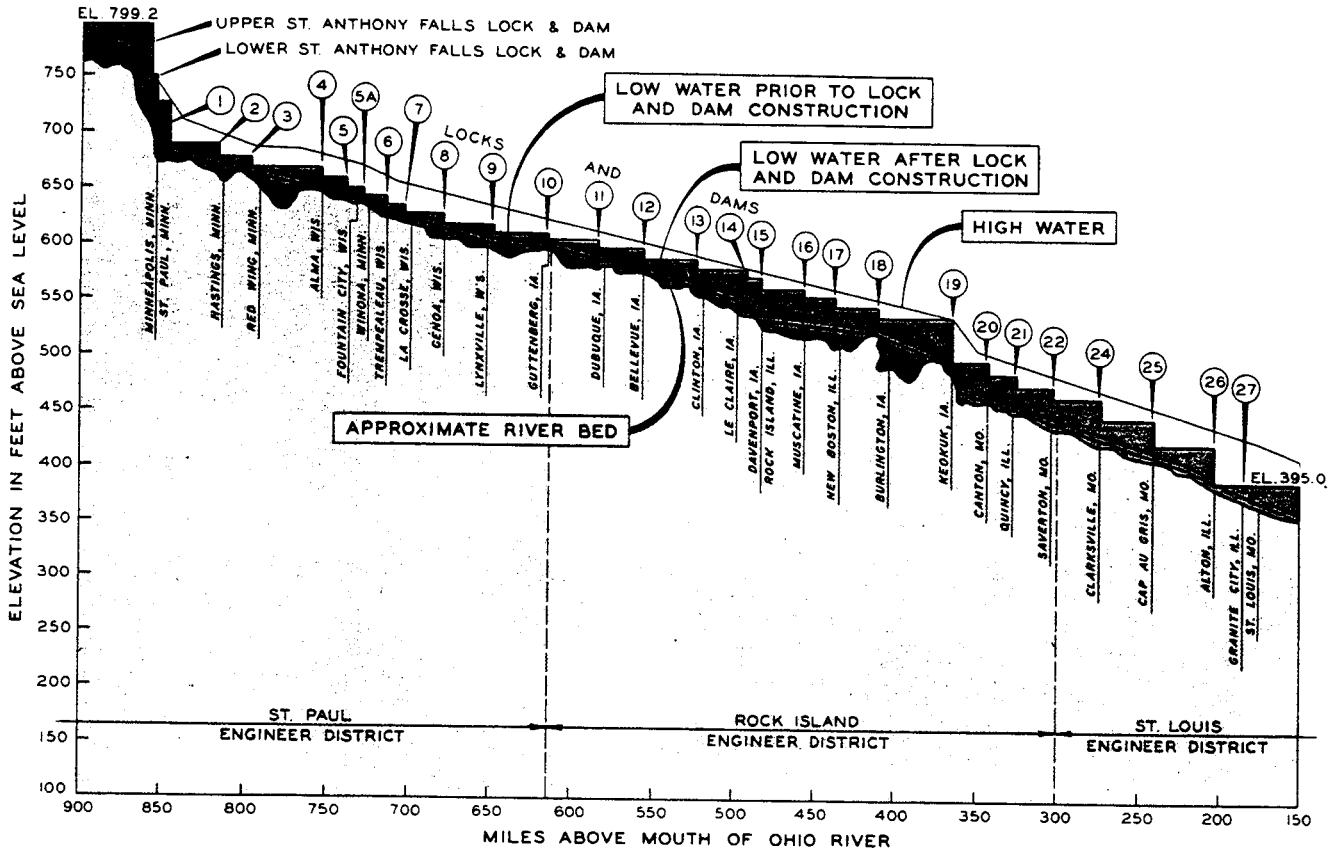
Crew Elements
- Universal Couplers/Hand Winches
- Standard Training for Crews
- Permanent Deck Winches*
- Additional Personnel*
- Powered Ratchets*

Approach Channel Improvements*

* Measures added after the initial screening.

BACKGROUND

The 9-Foot Channel Navigation Project, primarily constructed in the 1930s, created most of the lock and dam system that serves as a form of river stairway. The dams create the pools of water which ensure reliable navigation depths, while the locks provide the means for vessels to be lifted or lowered to the next pool. Figures 1-2 and 1-3 show the river profiles for the UMR and IWW, respectively. The 29 lock and dam structures on the UMR and 8 locks and dams on the IWW operate on the same principles, although some vary slightly in their actual configuration and ancillary equipment. The following section provides some background on the physical facilities, elements of a lockage, priority of locking vessels, and factors affecting lockage time.



Stairway of Water
Makes navigation possible between Minneapolis, Minnesota and St. Louis, Missouri.

FIGURE 1-2: UMR Profile, Minneapolis, Minnesota, to St. Louis, Missouri

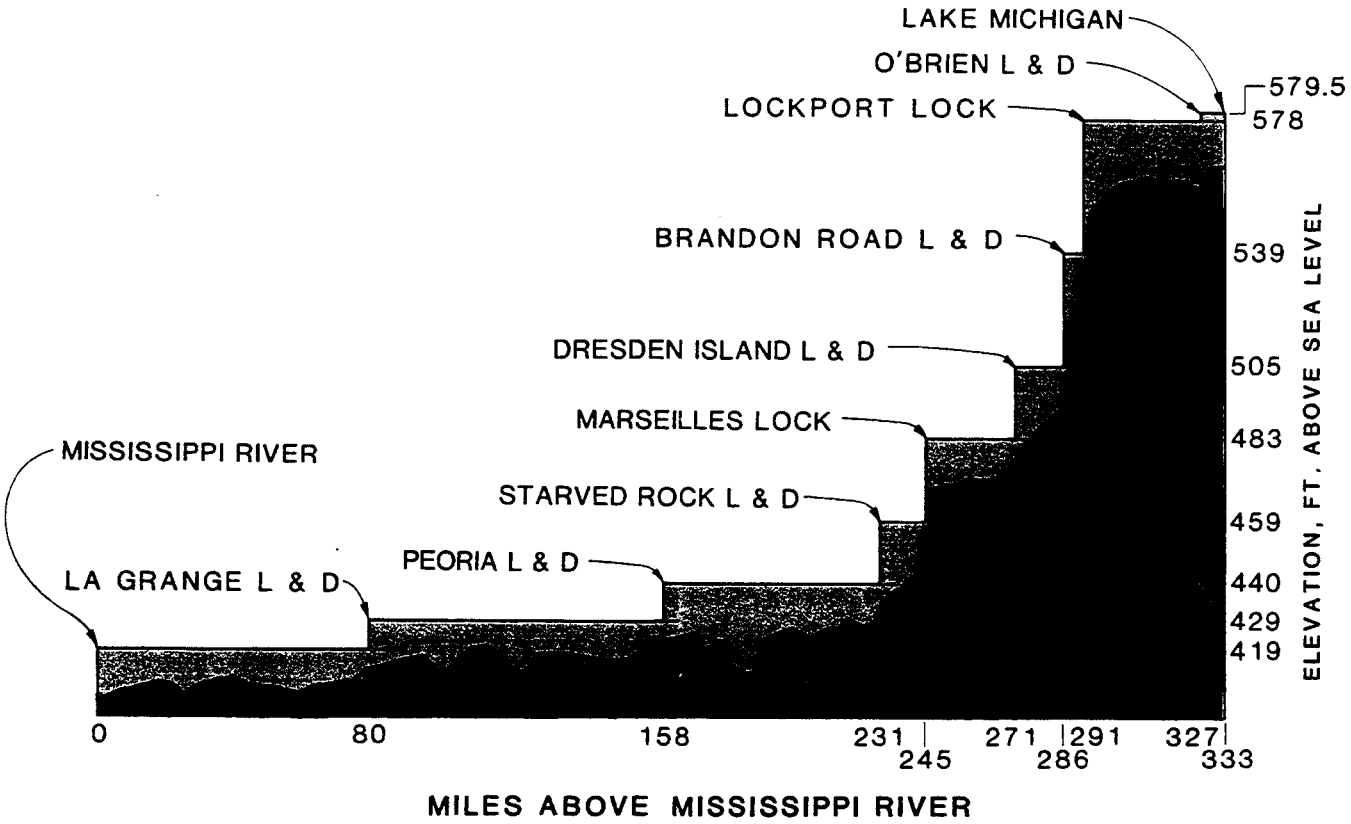


FIGURE 1-3: Illinois Waterway Profile

Physical Facilities

Figure 1-4 shows a typical lock site, including the upstream and downstream approaches, the main lock chamber, and upstream and downstream lock gates (the doors to the chamber). The approaches are those areas where the vessels prepare and position themselves for entry into the lock chamber or ready themselves for departure from the area. The upstream approach consists of the approach channel, guidewall, and bullnose. Some locks also have guardwalls or approach cells. The approach channel, a cleared area, provides a path for tows to approach and align with the lock chamber. Flow control structures may be found in the approach channel and are used to control the flow of water to assist in aligning vessels for a proper approach.

The lock chamber, made up of a series of concrete structures, is generally 110 feet wide and 600 feet long (the main chambers at Locks 19, Mel Price, and 27 are 1,200 feet long). The lock chamber is the basin in which the vessel is raised or lowered from one pool to the next. The upstream and downstream ends of the chamber consist of structures that include miter gates or lift gates, intake and discharge ports, and valves. The filling and emptying system is used to control and direct the flow of water into and out of the main lock chamber.

The guidewall is generally a concrete wall extending upstream and downstream in line with the lock chamber. On the UMR and IWW, the guidewalls are generally on the land side of the approach channel. They are typically 600 feet in length each, to match the length of the chamber, but may be as long as 1,200 feet for those locks with a 1,200-foot chamber.

These guidewalls are used by the towboats to physically guide their tow into the lock chamber. If the tow is not properly aligned, it may not fit into the chamber. Approaching vessels align against the wall in preparation for entry into the lock. Sometimes vessels are required to tie up against the guidewall while waiting their turn into the lock. Guidewalls are also used to tie off unpowered cuts. An unpowered cut is a section of barges (usually 9) that is taken from the front end of longer tows that require double lockages. The guidewalls often have armor plating to protect them from the constant rubbing of the barges.

The bullnose is the mass concrete element on the riverside of the approach and acts as protection for the lock structure and gives the tow some room to get aligned on the guidewall without being constrained by two walls.

A guardwall is similar to a guidewall, but is located on the riverside of the approach to the lock. This location helps to keep errant barges from being pulled into the dam. Guardwalls are constructed with openings below the waterline. These openings allow water to flow into the channel and then pass out through the openings under the walls, or between the cells. This flow will tend to pull the vessel against the wall, aligning the vessel for entry into the lock chamber.

Cells, whether they are guide cells or mooring cells, are typically made up of sheetpiling that has been driven in a circular configuration and then filled with stone or concrete. They form a sort of "column" up from the riverbed. Guide cells are typically placed just above the bullnose, on the upstream end, and provide the same distance of opening to the guidewall as does the bullnose. Towboats traveling downstream use them as a guide. Unpowered cuts traveling upstream and that have been pulled out of the chamber use them as insurance against the effects of outdraft. Cells located farther away from the lock provide moorings for tows waiting to use the lock.

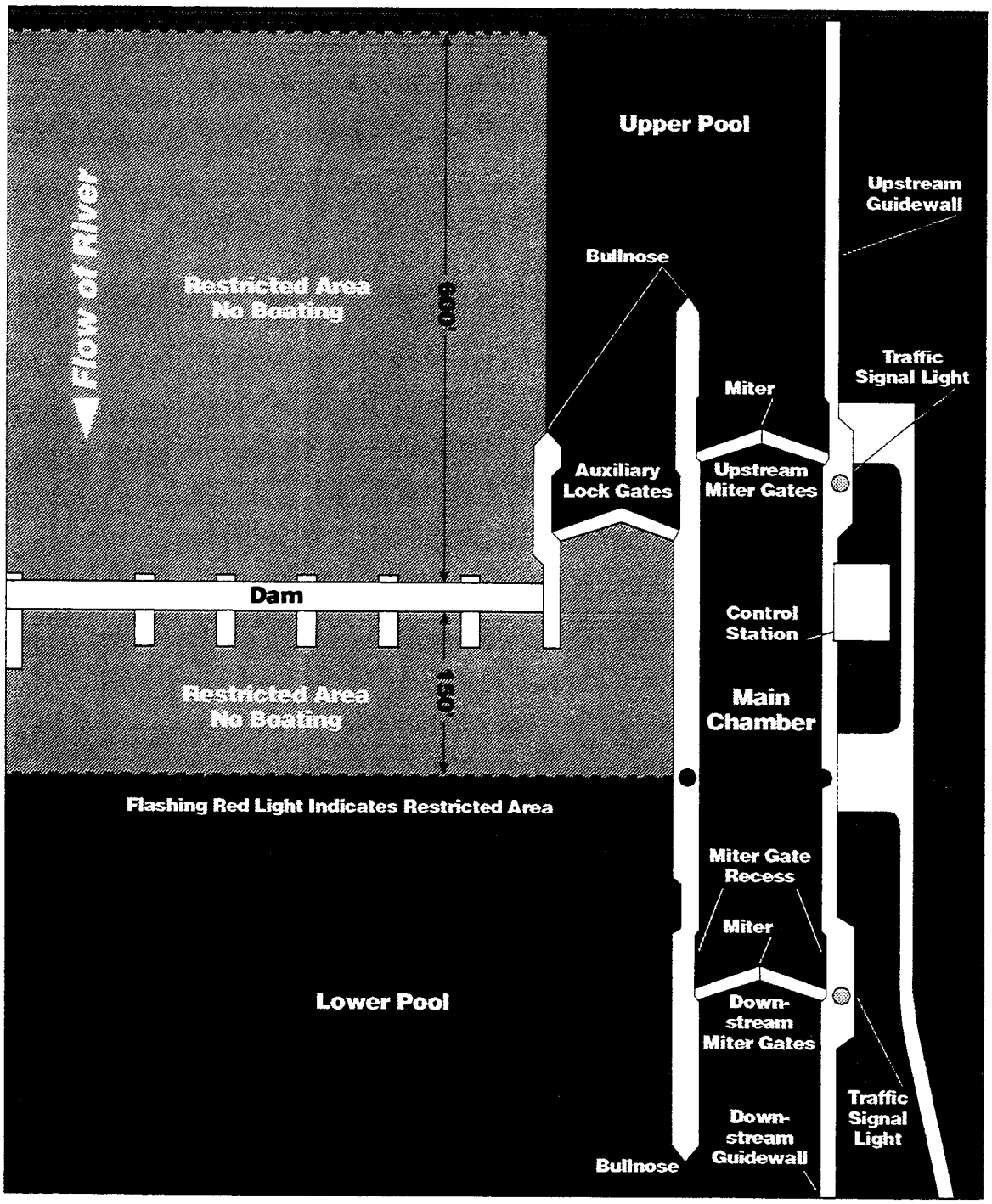


FIGURE 1-4: Typical Lock Configuration, Upper Mississippi River

Elements of a Lockage

Lock performance has been defined as the lock's ability to lock tows efficiently. The lower the lock's transit time for tows, the higher the efficiency. The focus of the small scale measures is on improving overall lock efficiency by reducing the time associated with various steps in the lockage process.

Many steps in the lockage process are of relatively short duration or are not easily alterable with small scale measures, such as entering the chamber, gate operations, and chamber filling and emptying. In general, the small scale measures in this report seek to reduce the longer time elements, including the approach, extracting the first cut, remaking or reconfiguring the tows, and exiting the lock.

Locks are operated through a system of valves, culverts, gates, intake, and discharge ports. The locks utilize gravity filling and emptying systems. The culverts and valves guide and control the movement of the water into and out of the lock chamber. No pumping is required. Figure 1-5 shows how the filling and emptying system works.

Most Mississippi River and Illinois Waterway locks are 600 feet long by 110 feet wide. Tows that are this size or smaller are able to lock through as a single lockage or in one piece. Larger tows, such as the prevailing 15-barge tow size, which is about 1,200 feet long by 105 feet wide, must lock through as a double lockage or in two pieces. The double lockage adds several steps to the lockage process as well as considerable time. The major elements of a single and double lockage, the two most common types of lockage, are summarized below. For these lockages, the total lockage time equals the sum of the durations of the lockage steps. Figure 1-6 compares a typical double lockage timeline and a single lockage timeline, while Figures 1-7 and 1-8 provide plan views of the various single and double lockage steps.

<u>Single Lockage Steps</u>: Only possible when lock chamber is at least as large as the tow.

(1) Approach
(2) Entering the chamber
(3) Gate operation
(4) Filling or emptying of the lock chamber
(5) Gate operation
(6) Exit

Vessels first approach the lock. The approach process includes the time for the tow to approach the lock, align with the guidewall, and place its bow (front of boat) over the sill of the chamber. The vessel entry time extends from the time when the tow gets its bow over the sill until the tow is fully in the chamber and the gate can be closed. For a vessel traveling downstream (a downbound vessel), the lock chamber is first filled, if it is not already at the upper pool level, by closing the lower lock gates and the downstream valves and opening the upstream or filling valves. The level of water in the chamber rises to the upstream level, as the water from the upper pool flows through the culverts and into the lock chamber. The upper gates then open and the vessel enters into the chamber by pushing along the guidewall.

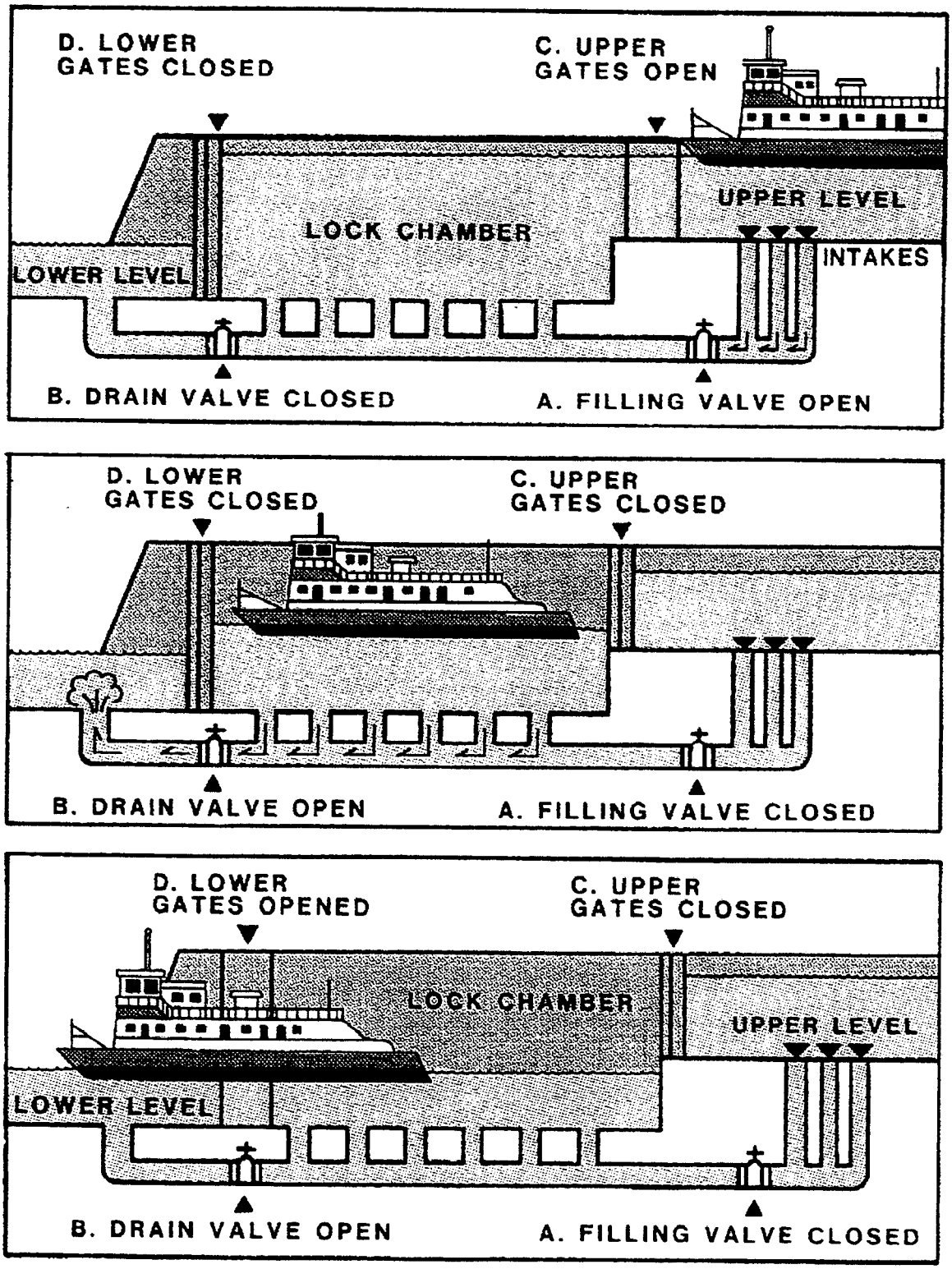


FIGURE 1-5: Lock Filling and Emptying Procedure

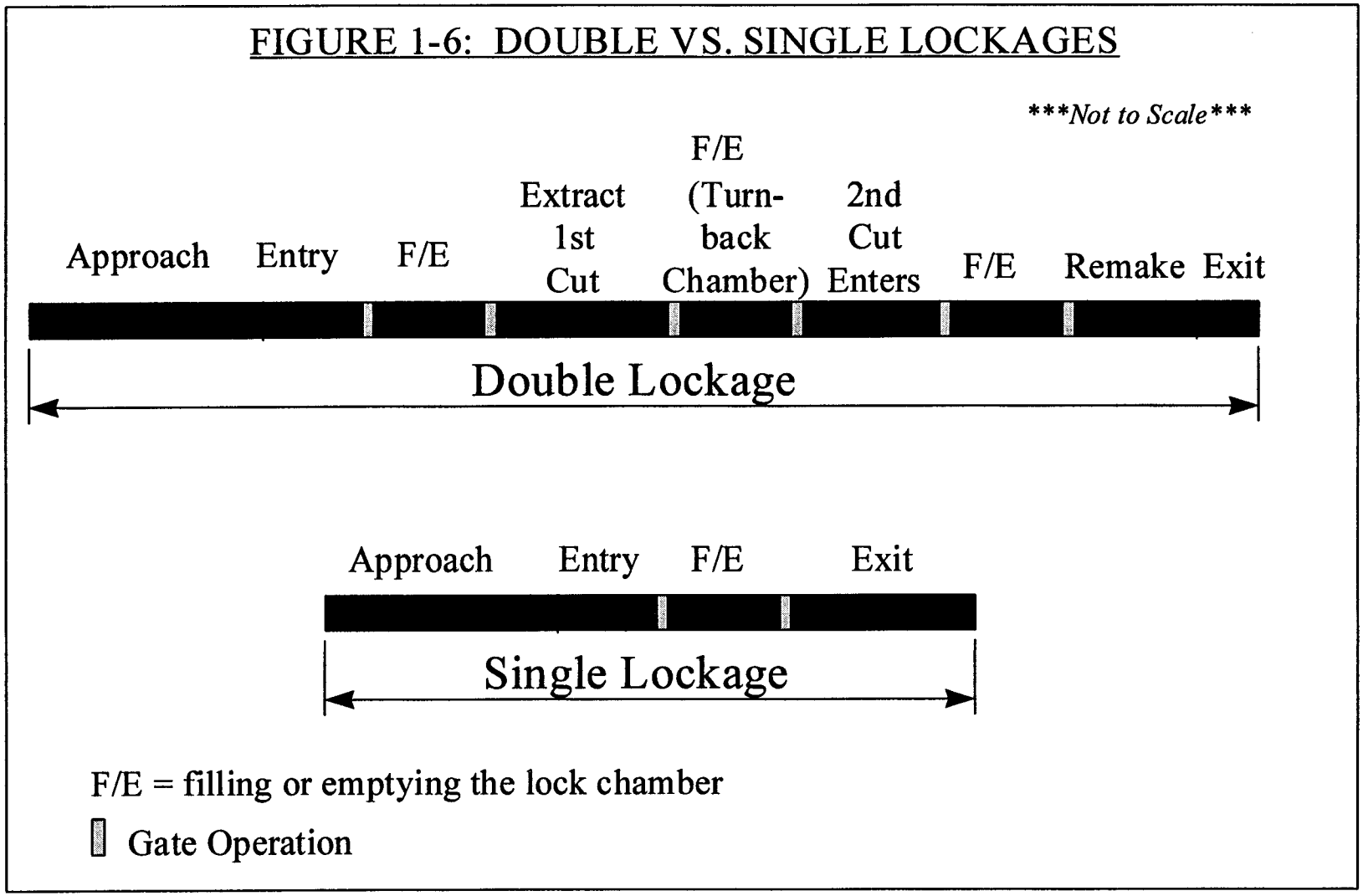
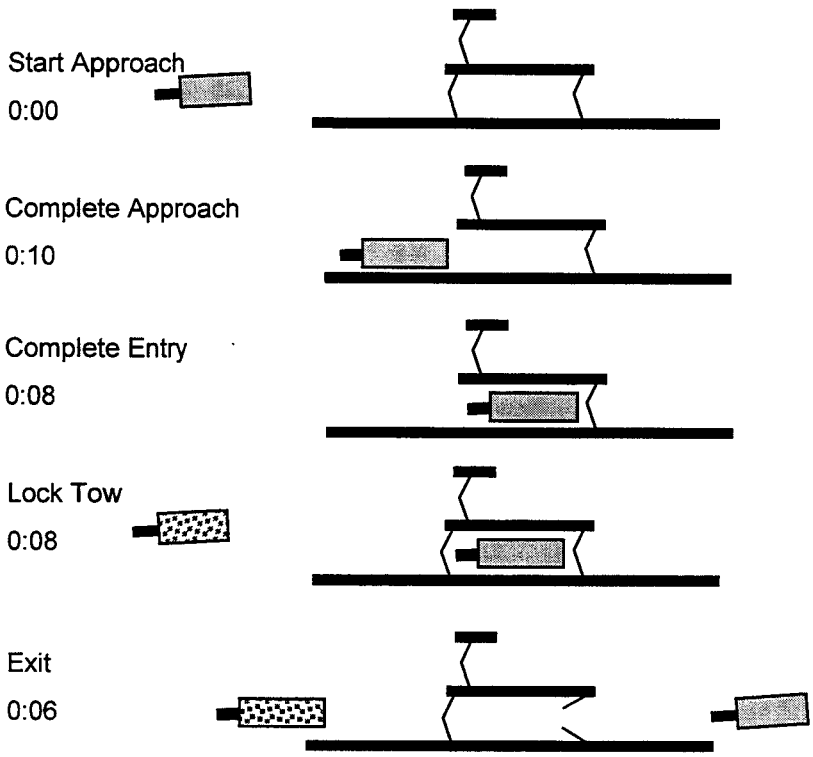


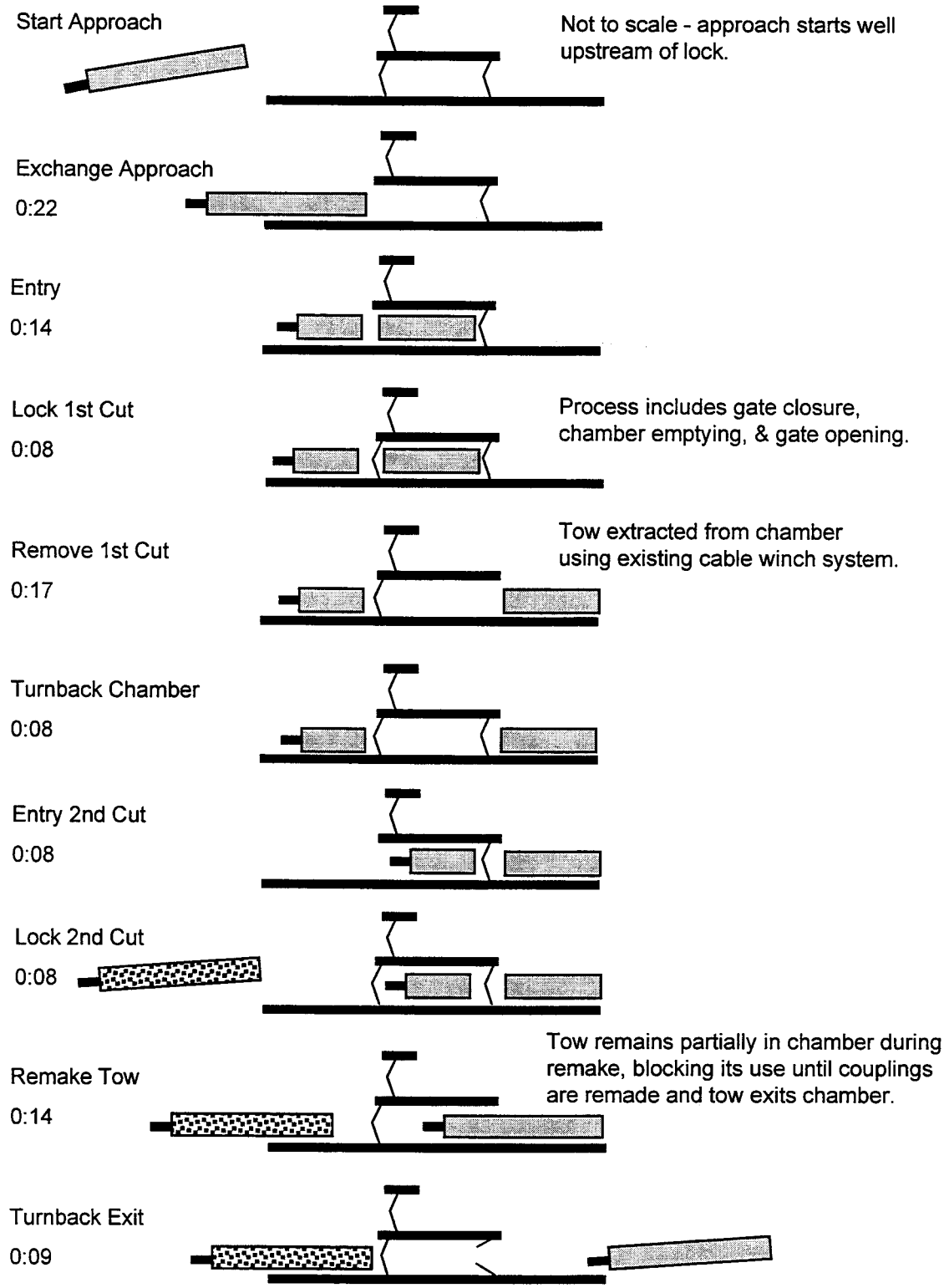
FIGURE 1-6: Double vs. Single Lockages



Total Lockage Time 0:34

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

FIGURE 1-7: Single Lockage Elements - Downbound at Existing 600-Foot Lock



Total Lockage Time 1:48

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

FIGURE 1-8: Double Lockage Elements - Downbound at Existing 600-Foot Lock

Once the vessel is secured inside the lock chamber, the upstream gates are closed. The vessel is then lowered by closing the filling valves and opening the downstream, or emptying, valves. The water in the chamber flows back into the culvert and then out into the lower pool, lowering the water level within the chamber until it is equal to the water level downstream of the lock. When the water level in the lock chamber is even with the lower pool, the lower gates are opened and the vessel exits the lock. The process is reversed for vessels going upstream (upbound vessels).

Double Lockage Steps - Double lockages, the most common type of commercial lockage, are required when total tow length exceeds the chamber length.

(1) Approach
(2) Entering the chamber
(3) Uncoupling the tow and backing the second cut out of chamber*
(4) Gate operation
(5) Filling or emptying of the lock chamber
(6) Gate operation
(7) First cut exiting the lock chamber*
(8) Gate operation*
(9) Filling or emptying of the lock chamber {opposite direction of step (4)}*
(10) Gate operation*
(11) Second cut enters the lock chamber*
(12) Gate operation*
(13) Filling or emptying {same as step (4)}*
(14) Gate operation*
(15) Recoupling the tow*
(16) Exit

*These steps are only involved with double lockages when the size of the tow exceeds the size of the lock chamber. The most common example of this in the current navigation system is with 1,200-foot-long tows transiting through 600-foot-long locks.

Double lockages require several additional steps. The full tow approaches and enters the chamber just as a single lockage tow does. However, due to the tow's length, a first cut (unpowered section of tow) must be uncoupled from the front end of the tow and locked separately. These cuts, generally consisting of 9 barges, fill the whole lock. The towboat and remaining barges then back away and allow the first cut to lock through. For downbound tows, once the first cut is at the lower pool elevation, the gates are opened and some form of assistance (a tow haulage winch or a switchboat) must pull, or extract, the first cut from the chamber. The cut is typically pulled out along the guidewall and tied off to wait for the second cut. When the first cut is clear of the gates, the chamber is turned back, goes through the gate operations and filling to get the chamber back up to the elevation of the second, or powered, cut. As soon as the gate is opened, the second cut can enter the chamber and be locked through as a single. The one remaining difference is that before the tow can exit the lock facility it must move forward to the first cut and remake its couplings. At sites with 600 feet or shorter guidewalls, the second cut usually remains partially inside the chamber while the first cut is along the guidewall, eliminating the ability to use the chamber to lock other tows. This is one element of delay that will be addressed in this report.

Lockage Priority of Vessels

The use of locks is conducted in accordance with published regulations (33 CFR 207.300) and policy notices (see Appendix B). These regulations set lockage priorities based on the classification of the requesting vessel. In general, the vessel arriving first at the lock has the preference to be the first to be locked through. However, precedence is first given to vessels of the United States. Licensed commercial vessels operating on a published schedule or in regular "for hire" service are given precedence over cargo tows and like craft. Cargo vessels are given precedence over recreational craft. However, the current navigation regulations state that the lockage of recreational craft shall be expedited by locking them through with commercial craft provided both parties agree. If the lockage of recreational craft(s) can not be accomplished within the time required for three other lockages, a separate lockage of recreational craft(s) shall be made.

Factors Affecting Lockage Time

A number of factors affect the overall lockage time. These items, which are discussed briefly in this section, include tow configuration, type of lockage, site conditions, direction of travel, towboat and equipment, and skill of crew.

- **Tow Configuration**

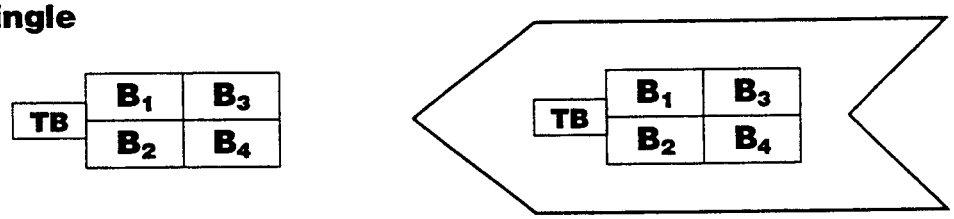
There are several different types of tow configurations for lockage. Most of the locks on the UMR and IWW are 110-foot by 600-foot locks. Only three locks on the Mississippi River (19, Melvin Price, and 27) have 110-foot by 1,200-foot chambers. In addition, ice accumulation on the lock walls in the winter tends to narrow the available space for tows in the chambers. Because of the size limitations of the locks, many of the tows must be reconfigured before and after locking in order to fit in the chamber. Figure 1-9 provides a general indication of the appearance of these configurations.

Straight Single. In this configuration, a tow's length and width does not exceed the size of the lock chamber it is preparing to enter. It therefore does not require reconfiguration and can transit the lock in an expeditious manner.

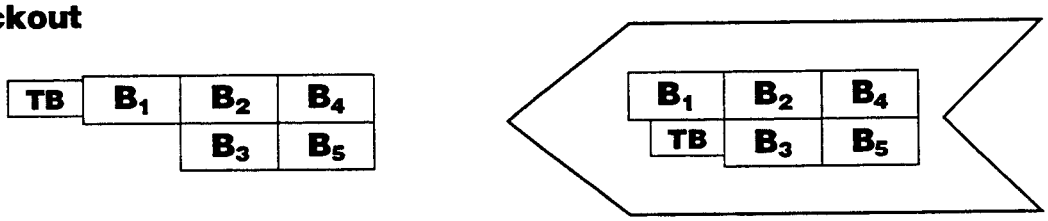
Knockout Single. In a knockout configuration, the combined length of barges and towboat is too long for the lock. A knockout can meet the length and width requirements of a lock by moving the towboat off the end of the barges and into a "notch," or hole, in the barge configuration. Only the towboat is required to move in a knockout configuration.

Setover Single. In a setover tow, the towboat and one or more of its barges are separated as a unit from the remaining barges to be "set over" to one side in order to fit the lock.

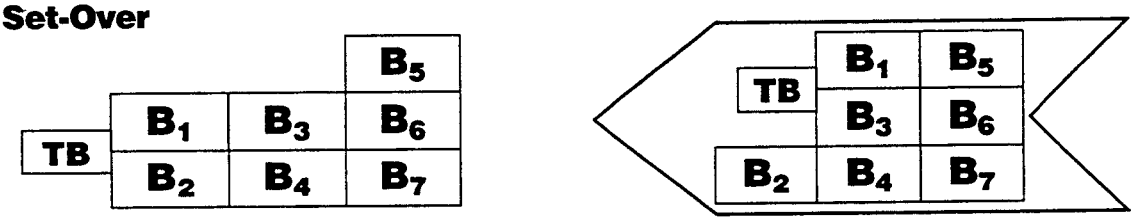
❶ Straight Single



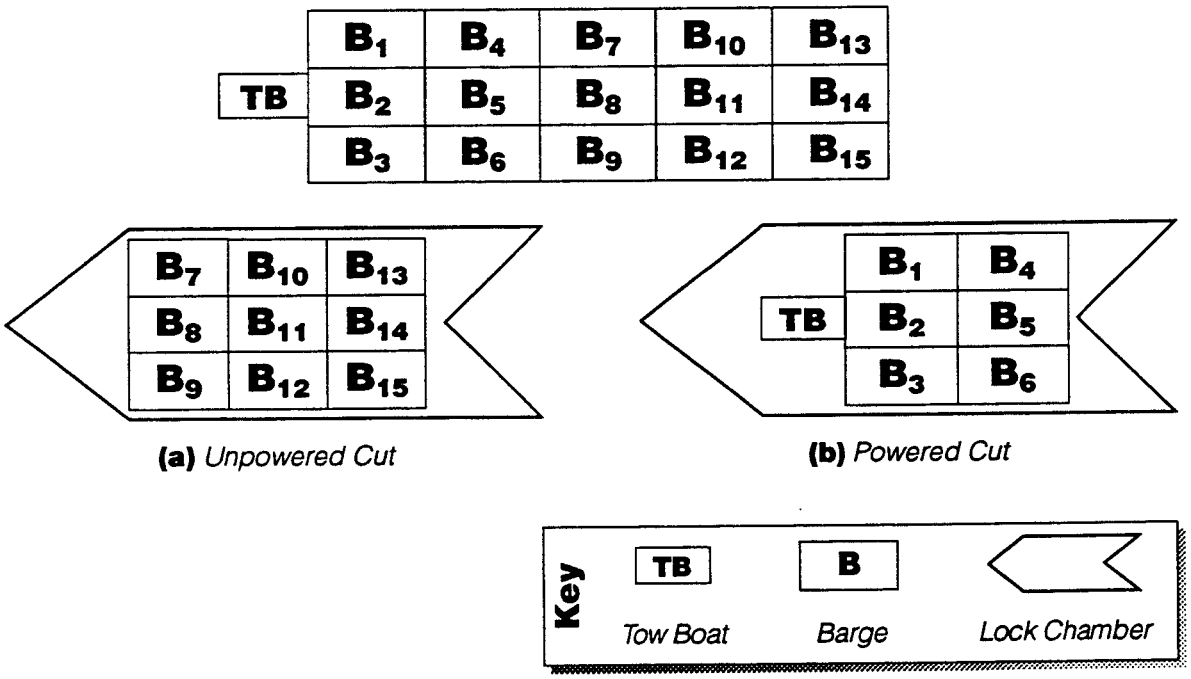
❷ Knockout



❸ Set-Over



❹ Double



(a) *Unpowered Cut* **(b)** *Powered Cut*

FIGURE 1-9: Tow Configurations at a 600-Foot Lock

Double (or Multiple). In a double lockage, the length and/or width of the tow exceed the limits of the lock and the tow is usually locked through in two or more segments. The most common form of double lockage is used to move 15-barge tows through 600-foot locks. The first 9 barges (3 wide and 3 long) are locked through as the first or unpowered cut. The first cut is secured to the guidewall after lockage while the second, or powered, cut (the towboat and remaining 6 barges) locks through.

While all locks receive some of each configuration, the most common configuration on the UMR and lower IWW is the double. However, singles and knockouts dominate the lockage types at sites farther up the IWW. Table 1-1 provides some information on the relative percentage of each type of tow configuration operating on the system in 1990.

TABLE 1-1: PERCENTAGE OF TOW CONFIGURATION IN 1990

Lock	Tows Processed	Percent Singles	Percent Knockout Singles	Percent Setover Singles	Percent Doubles
UMR Locks					
3	1,625	17.7%	7.4%	2.0%	67.6%
9	1,609	11.4%	6.0%	2.6%	77.1%
11	1,965	18.4%	4.9%	2.7%	73.5%
15	3,093	20.3%	4.5%	1.6%	72.4%
18	3,298	13.6%	4.4%	1.6%	78.3%
22	3,614	13.4%	5.0%	1.4%	78.4%
25	3,776	13.1%	7.2%	1.4%	76.7%
IWW Locks					
Lockport	3,433	36.2%	36.1%	2.8%	16.9%
Brandon Rd	3,397	36.9%	35.4%	2.6%	17.8%
Dresden Is	2,998	33.2%	28.2%	4.5%	31.1%
Marseilles	2,911	32.2%	18.5%	5.2%	40.5%
Starved Rock	3,097	31.8%	17.7%	4.8%	43.5%
Peoria	1,137 Lkgs	25.4%	9.9%	5.0%	56.6%
La Grange	1,282 Lkgs	18.0%	9.1%	4.3%	67.6%

Note: Peoria and La Grange totals do not include tows passing facility during open pass conditions.

▪ Type of Lockage

A vessel can make three types of entries/exits at the lock—fly, exchange, or turnback.

Fly. A fly entry occurs when the tow approaches an idle lock that is already at the proper pool level to receive it. A fly exit is when the lock will be idle following the vessel's departure.

Exchange. An exchange entry or exit occurs when a vessel outbound from the lock passes a vessel inbound to the lock. The outbound vessel is in an exchange exit and the inbound vessel is in an exchange entry.

Turnback. A turnback entry occurs when the lock must be turned back, empty of any vessels, from a previous lockage to accept the next vessel which is traveling in the same direction as the first. A turnback exit is when the lock must again be turned back, empty, to receive the next vessel. For example, vessel A is proceeding upstream followed by vessel B. After vessel A is raised to the upper pool, the lock is emptied or "turned back" in order to be ready to receive vessel B. Also, tows that are too large to fit in the chamber are typically broken down so that the first group of barges, the "unpowered cut," can be locked through, followed by a turnback to lock through the powered cut.

All these types of approaches and exits occur. However, as the traffic level and lock utilization rate increase the percentage of fly lockages decreases. Under more severe congestion when several same direction lockages are scheduled before taking tows from the other direction, the percentage of turnbacks can increase dramatically. Table 1-2 summarizes the percentage of fly, exchange, and turnback exits of double tows present in 1990. While these numbers vary slightly from the percentages for all commercial tows, they indicate the types of approaches and exits occurring on the system.

TABLE 1-2: PERCENTAGE OF TOW EXIT TYPES IN 1990

Lock	Percent Fly Exit of Double Lockage	Percent Exchange Exit of Double Lockage	Percent Turnback Exit of Double Lockages	Percent Turnback Exit of All Commercial Lockages
UMR Locks				
3	31.8%	48.7%	19.6%	13.2%
9	38.9%	37.6%	23.5%	18.1%
11	26.7%	45.2%	28.1%	20.7%
15	17.1%	38.9%	44.0%	39.0%
18	16.5%	47.4%	36.1%	28.2%
22	10.2%	44.0%	45.9%	36.0%
25	13.1%	43.2%	43.7%	42.6%
IWW Locks				
Lockport	28.7%	50.9%	20.4%	3.4%
Brandon Rd	22.0%	50.3%	27.6%	4.9%
Dresden Is	31.7%	42.6%	25.8%	8.0%
Marseilles	26.2%	47.6%	26.2%	10.6%
Starved Rock	35.8%	40.2%	24.0%	10.4%
Peoria	20.5%	39.0%	40.4%	22.9%
La Grange	23.1%	30.5%	46.4%	31.4%

Note: Peoria and La Grange totals do not include tows passing facility during open pass conditions.

▪ Site Conditions

A number of variable site conditions can affect the amount of time required for a lockage. Many of the conditions listed in this section vary in time and from site to site. For example, the location of a particular lock may increase the maneuvering required to approach the lock or the site may have particularly strong outdraft currents due to site conditions. Strong winds can also impact lock transit time.

River Currents. River currents in the UMR and the IWW are affected by the configuration of the river basin, the flow of tributaries into the river, the amount of rainfall in the contributing drainage basins, releases from hydropower plants and dams, and lock operation. Currents play a major role in the maneuvering of vessels, particularly when the vessel is approaching a lock. An example is the outdraft currents upstream of the locks and dams, prevalent during high water flow conditions, that tend to pull a towboat away from the guidewall and toward the dam.

Weather Conditions. The weather plays an important role in the operation of vessels on the rivers. Rainfall not only affects currents and water levels, but it can also restrict visibility and make work on steel decks slippery. Snow and sleet have similar effects, and ice conditions can completely shut down traffic flow on the rivers. Locks filled with ice may require both gate and valve machinery to be heated. Decks and ladders become slippery, and ice may accumulate on the rake end of the barge, increasing the danger of damage to the sill. Wind can significantly increase the difficulty in maneuvering tows, especially empty barges. Fog, haze, and smoke may also impair visibility, thereby slowing approaches to and exits from the lock.

Water Level Differential Between Pools. The water level differential between the upper and lower pools affects the amount of time it takes to fill or empty the lock chamber. The water level for all pools above Lock 27 is controlled by spillway releases from the dams. Locks in the study area are typically low to intermediate lift locks with maximum lifts ranging from 8.0 (Lock and Dam 17) to 42 feet (Lockport Lock).

Time of Day. The time of day also affects the speed of the locking process. Nighttime approaches to lock facilities are much more difficult than daytime approaches and, as a result, they tend to be slower.

▪ Direction of Travel

An additional factor affecting lockage times is the tow's direction of travel. Tows traveling against the river's current (upbound) often travel at slower speeds out in the channel than tows traveling with the river's current (downbound). At the lock sites, downbound tows typically require longer times due to the difficulty in making the approach. This is especially true in outdraft conditions were the river currents pull the tow away from the approach and towards the dam. In addition to outdraft, as the downbound vessel slows it loses maneuverability because the relative speed of the water flowing past the rudder approaches zero. In contrast, upbound approaches maintain greater maneuverability because even at slow speeds the water flowing past the vessel's rudders allows for steering.

- **Towboat and Equipment**

A variety of towboats are on the rivers today with different characteristics that affect the speed at which they can accomplish an approach, exit, or reconfiguration. These vessels' characteristics include, but are not limited to: horsepower; screw and rudder configuration; the availability of a bow thruster (or bow boat); and the length, draft, beam and hull shape of the towboat.

A fully laden fleet of barges has less freeboard, greater draft, and a lower center of gravity than a fleet of empty barges. These factors greatly affect vessel maneuverability and thus vessel speed on approach to the lock. A lower freeboard means the vessel is less susceptible to the forces of the wind, but the greater draft makes the vessel more susceptible to river currents, eddies, outdrafts, and tailwater currents. The increased draft also increases the turning radius of the vessel as the amount of water beneath the vessel decreases, particularly upon approach to the lock.

Towboats pushing a mixture of laden and unladen barges or an asymmetrical configuration must also account for the changes in vessel handling characteristics resulting from a horizontal shift of the center of gravity. A vessel hauling dangerous materials may also be subject to additional precautions and slower transits due to the nature of its cargo.

The mechanical means by which the barges and towboats are fastened to each other affects the speed of reconfiguration. Modern equipment can decrease the time it takes to break up and make up the setover, knockout, and double tow configurations.

- **Skill of Crew**

The actions of those people on the tows and at the locks play a significant role in lock processing time. The master, or pilot, of a vessel must align the tow with the guidewall to enter the lock. The deckhands must uncouple any barges for reconfiguration and secure them to the guidewall or lock wall. The lock personnel may assist with the mooring lines of the tow and its barges. Once the vessel is secure, lock personnel must close the gates, empty or fill the chamber, and then open the gates at the opposite end. If extraction of an unpowered cut is required, tow haulage equipment must be attached and operated as well. Deckhands will tend lines during exit and reconfiguration with assistance from lock personnel if required. The skill of those involved in this process can have a substantial impact on the time that it takes to accomplish.

METHODOLOGY

The goal of this evaluation is to further define and analyze the remaining small scale measures using qualitative and quantitative analysis. The evaluation focuses specifically on quantifying the performance or benefits of the measure (i.e., ability to reduce delays at the lock facilities), its cost, and to identify other relevant considerations (e.g., safety, implementability, etc.). The following items were identified for each measure, with a brief description of this information for each measure included in Section 2 and greater detail and specifics included in Section 4:

(a) Description of Measure - What the measure involves and how it has been and could be implemented.
(b) Time Savings Estimates - What problem does it solve, and if possible quantification of the time savings (e.g., minutes per lockage) including a summary of results of past application and study.
(c) Conditions Affecting Implementation - Are the benefits limited by any factors; will it benefit the entire UMR-IWW System, a particular lock, or certain areas; what (if any) changes would be required to implement; and any disadvantages of implementing an item.
(d) Costs - Estimated costs including both the first costs and ongoing operations and maintenance.
(e) Relationship to Other Measures - Is the measure complementary with other small scale measures; does it conflict with any.
(f) Conclusion - Comments on general implications of data gathered for each measure.

Since significant differences do exist between some sites on the system, the study team attempted to maximize the use of site-specific information. The study team decided that where detailed distributional site data exist, such as the Lock Performance Monitoring System (LPMS) data, its use would be preferred to opinions from interviews. Such distributional data also provide a means to incorporate risk and uncertainty into the analysis. The type of data allows subsequent study efforts to take into account the distributional aspects, as well as the mean times, for various elements. Other information, such as the results of a timing study or model study at a single site, was used to assist in developing and verifying the site-specific data.

The general approach used for this study was to first review available data sources including past Corps of Engineers reports, contractor reports, and LPMS data. Following this initial fact finding, information was gathered through site visits, interviewing lockmasters, workshops, and finally through an Expert Elicitation process. This section highlights some of the sources utilized. However, the methodology is further explained in Section 4 for each of the measures on how data were collected, analyzed, and applied in evaluating that item.

One of the first sources of information identified was LPMS data. This data base contains detailed information on each lockage occurring on the UMR System. The lock personnel record these data at the time of the lockage. The information includes the type of lockage, direction, number of barges, tonnage, and various time elements (delay, approach, entry, chambering, exits, etc.). The study team selected LPMS data from 1990 for the analysis since it was the last year that the St. Paul District collected all the detailed lockage elements. Further review of the average lockage times for commercial tows over the past 15 years and flow information for 1990 indicate that it is a generally representative year. The exception to the use of 1990 data was Mel Price Lock. This facility was not in operation in 1990, so data from an initial year of its operation were used. Data from 1992 were used for the 1,200-foot main chamber and 1995 data for the 600-foot auxiliary chamber. At most lock sites, over 3,000 commercial lockages occurred in 1990, which provides an adequate sample to determine the distributional characteristics of the various lockage time elements. The LPMS data summarized in this report focus on UMR Locks 11-27 and IWW locks from Lockport to La Grange. In most cases, data were evaluated separately for each river due to differences in water levels and flow conditions. If initial plan formulation efforts demonstrate a need for detailed data for the sites above Lock 11, the data for the evaluated sites can be extrapolated or site-specific information can be assembled.

Lock site visits were initially conducted at UMR Locks 11-25 and Peoria and La Grange Locks on the IWW in August and September of 1994. Following an initial review of existing reports and some preliminary analysis of the LPMS data, the study team determined that additional site visits and follow-up calls to the lockmasters were needed. In August 1996, members of the Engineering Work Group met at Lock 27 to discuss issues related to Lock 27 and Mel Price. Site visits to the other IWW locks, including Starved Rock, Marseilles, Dresden Island,

Brandon Road, and Lockport, were conducted in November 1996. Participants at these site visits varied, but included State resource agency representatives, U.S. Fish and Wildlife Service personnel, and navigation industry interests. In addition to the site visits, follow-up calls to lockmasters were made to clarify results and gather additional information on site-specific applications of the various measures to the particular lock sites.

Due to uncertainties in quantifying potential time savings, on January 22, 1997, the study team held a Lock Approach Assessment Workshop in Rock Island, Illinois, to assess potential approach improvements to locks under the system study and to approximate their time savings potential when compared to existing approach conditions. Participants included Corps of Engineers staff from various offices, including the Waterways Experiment Station. Field data, physical and numerical model results, and the experience of the team members were provided as a basis for approximating the approach time savings for various small scale improvements at each of the UMR locks and dams. Alternative small scale improvements discussed included: extended guidewalls, ported guard walls, channel realignment, and channel training structures.

Despite the efforts of the study team to gather existing information to define and evaluate the various measures, some information was simply unavailable or contained a large amount of uncertainty. To address these issues, the Engineering Work Group hosted an Expert Elicitation Meeting on February 4 and 5, 1997. This meeting provided valuable information and validation to the study methodology. Participants at the meeting included navigation industry; construction industry; and Corps of Engineers operations, engineering, and construction personnel. The purpose of the expert elicitation process was to obtain estimates and identify uncertainties in time savings, costs, and the feasibility of various measures. Four small scale questions were asked which provided information where a historical record was not available. In such situations, expert elicitation is a recognized methodology for obtaining useful estimates of the uncertain factors.

Finally, information was obtained from a review of draft data by The American Waterways Operators; Maritime Administration; River Industry Action Committee (RIAC); MARC 2000; a number of private companies; and Corps Operations Division personnel. This process resulted in considerable comments, discussions, and additional data gathering and analysis. This process started with the sharing of draft information on January 30, 1998, and concluded with a Lockmaster Expert Panel Process on July 30, 1998. The major specific comments centered on the safety, horsepower, and cost issues associated with regular use of helper boats, switchboats, and industry self help. Based on these comments and subsequent reanalysis, the horsepower requirements and associated facilities of most towboat power measures were modified.

ENVIRONMENTAL CONSIDERATIONS

Environmental impacts from small scale measures have not been assessed in detail. Some of the measures—adjacent mooring facilities, guidewall extensions, and approach channel improvements—are structural in nature and have the potential for impacts. Where these measures are proposed, the results from Habitat Evaluation Procedures (HEP) evaluations of large scale measures could be applied to estimate environmental impacts and costs.

Small scale measures are discussed briefly within *Environmental Report 7, Site Specific Habitat Assessment*, May 1998. It has been agreed to in agency coordination that any recommended small scale measures would be coordinated and evaluated in detail as part of detailed site-specific evaluation efforts prior to implementation.

NEXT STEPS

This report quantifies and presents the available engineering cost and performance data on the remaining small scale measures. The Navigation Study Team will use the data in this report in plan formulation efforts to further screen the list of potential measures to those measures most likely for implementation. Some refinement of the cost and performance data may occur as the data are further analyzed. The data will then be used, along with the environmental information, in the development of alternative plans.

SECTION 2 - MEASURES UNDER CONSIDERATION

This section provides a general overview of the study findings regarding the performance (time savings potential) and cost of each of the measures under consideration. Those readers interested in the specifics of how these measures apply to each of the lock sites under consideration should see Section 3. Finally, Section 4 provides additional detail on supporting information, methods, and data used in analyzing the measures, as well as additional cost information and the considerations and limitations in applying the data for the systems analysis.

NON-STRUCTURAL MEASURES

The first half of this section presents information on the non-structural measures under consideration as part of the study. In general, these measures primarily could be implemented through procedural or policy changes with little or no construction.

Towboat Power

Three separate measures related to the use of an assist boat were carried forward for further analysis. These measures include the use of helper boats, the use of switchboats, and the expanded use of industry self help. Assist boats can provide additional towboat power to direct tows into the chamber, speed the extraction of the unpowered cuts (portion of a double lockage tow that does not include the towboat), move the unpowered cut away from the lock facility for remake, and provide additional assistance as needed.

For this report, the three measures were classified by the horsepower rating of the boats. Helper boats have the least amount of power, less than 1,200 horsepower, while switchboats typically range from 1,200 to 2,500 horsepower. Industry line haul boats generally have greater than 2,500 horsepower. The amount of horsepower and size influence the type and effectiveness of various types of assistance.

Based on the analysis conducted as part of this study, the study team determined that while additional helper boat assistance on approaches may provide some increased benefits at some sites, most benefits are already being captured. The majority of incremental towboat power benefits are associated with the larger switchboats and line haul boats, which can extract cuts. Switchboats can be implemented in one of two ways in combination with extended guidewalls or with remote mooring areas. Providing guidewall extensions and mooring areas in combination with industry self help allows for a safer and more efficient application of this existing measure.

- **Helper Boats**

Description of Measure. Helper boats are the smallest of the towboats being considered in this analysis, averaging approximately 800 horsepower with a range from roughly 300 to 1,200 horsepower. Helper boats can reduce delays associated with approaching the lock and in some cases exiting the lock. They are currently used and are particularly effective when assisting downbound tows that must make their approaches or exits under adverse conditions (e.g., outdraft, wind, ice, etc.) or with inexperienced crews (see Figure 2-1). This assistance reduces overall lockage times by countering the effects of outdraft on the approach, thereby allowing a more

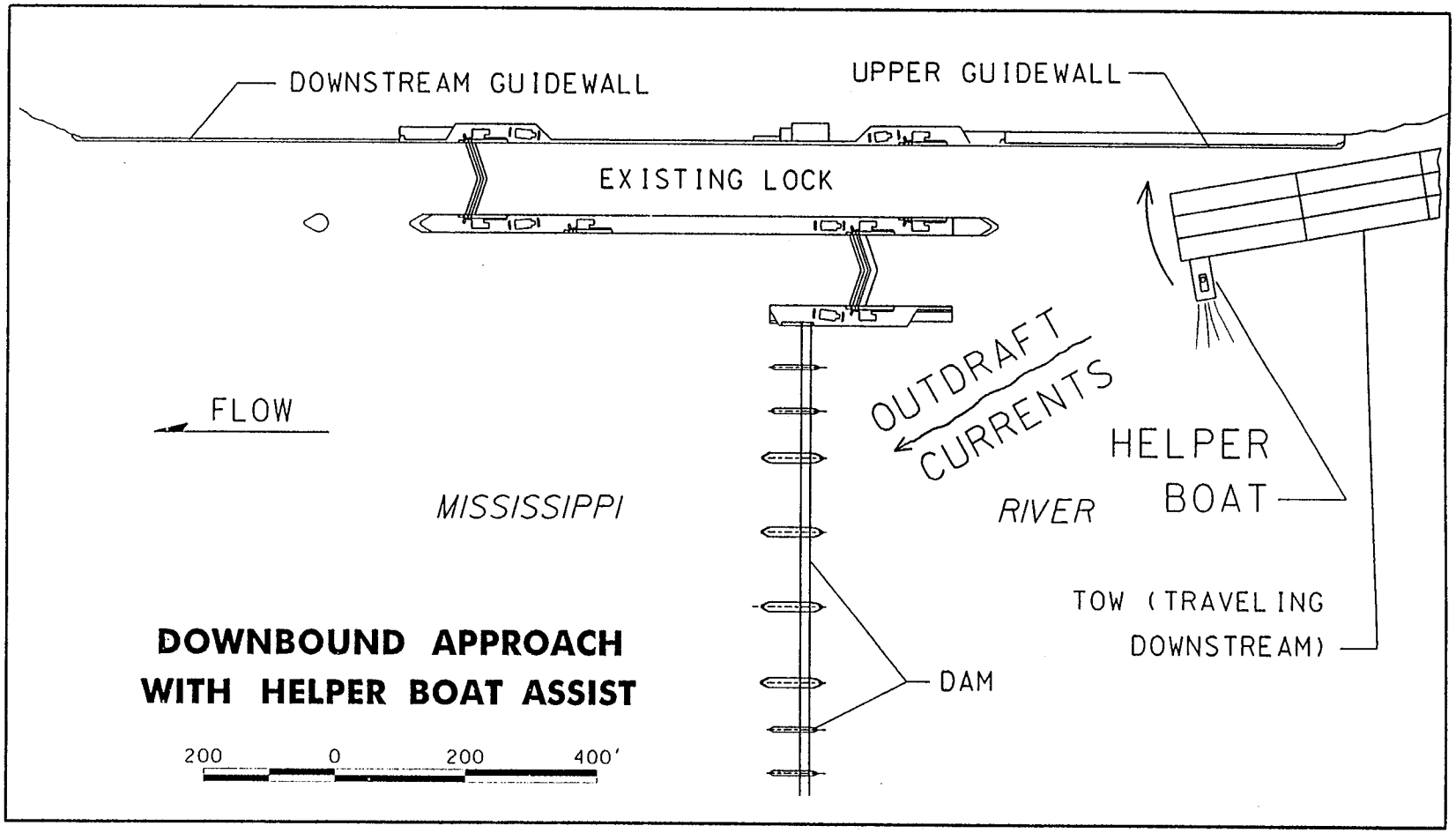


FIGURE 2-1: Switchboat Assistance

controlled, efficient, and safe entry into the chamber. They also can move ice and debris. Since some use of helper boats is already occurring, this study analysis focused on identifying what incremental benefits are available if use were to increase. Using helper boats to pull cuts along extended guidewalls was also evaluated, but it was determined that these boats have inadequate horsepower to safely conduct this operation under all conditions.

In addition to improving approach efficiency, a major benefit of helper boats is increased safety related to the reduction in the potential for a major accident or substantial delay related to a tow which is unable to successfully maneuver a lock without assistance. Currently, helper boats are regularly available at a number of locks, and the majority of other lock sites can have helper boats available on relatively short notice. Under current Corps policy, the use of helper boats is not required, but their use is strongly recommended during outdraft conditions. In general, most companies follow these recommendations in their own interest to increase safety and reduce delays.

Time Savings Estimates. Potential time savings in the lockage process was only identified for downbound lock approaches. Improving other steps in the process, such as pulling the first cut of double lockages, were not considered to be safe operations with this size of boat.

Approach. Since most downbound tows currently use helper boat assistance under outdraft conditions, there is essentially no additional "with-project" benefit to be gained in these conditions. Therefore, time savings was only assessed for assistance to downbound tow approaches under normal flows where there is potential for additional time savings. The time savings estimates for the Upper Mississippi River (UMR) are tabulated in Table 2-1. Based on information from the Expert Elicitation meeting, the time savings of using a helper boat under normal flows for downbound fly and exchange lockages was estimated at 6 minutes for singles with a range of 3 to 10 minutes. Double lockage tows were estimated to save 11 minutes with a range of 6 to 17 minutes. These ranges exclude the most extreme values possible. The time savings for setovers and knockouts was estimated to be between the approach time savings for singles and doubles. There are many site-specific differences regarding the achievable improvements with the use of helper boats. See Sections 3 and 4 for more information. On average, much smaller time savings would be possible for turnback lockages, since many of these tows are already able to get on the guidewall during the locking of the previous tow.

Significant time savings was not anticipated at Illinois Waterway (IWW) locks under normal flows, except at Lockport, which has stronger outdraft currents.

TABLE 2-1: ESTIMATED APPROACH TIME SAVINGS (MINUTES) OF HELPER BOAT ASSISTANCE UNDER NORMAL FLOWS AT UMR LOCKS FOR DOWNBOUND FLY AND EXCHANGE LOCKAGES

Delay Reduction	Straight Single			Knockout and Setover*			Straight Double		
	Expected	Max	Min	Expected	Max	Min	Expected	Max	Min
Downbound Approaches	6	10	3	8	14	5	11	17	6

* Note: Setover and knockout single time savings were estimated from singles and doubles.

Source: Expert Elicitation meeting estimates from February 4, 1997.

Total Time Savings. In total, it appears that only limited additional benefits would be gained by increasing the use of helper boats. In addition, the savings are even more limited in situations where a queue exists, since only fly and exchange lockages benefit significantly. However, it appears that a few sites could benefit from increased helper boat availability.

Conditions Affecting Implementation. The focus of this analysis was on determining the benefits to those tows not currently receiving assistance. However, there is a large amount of variability involved with the time savings potential for a particular measure. Many tows already receive assistance from helper boats, or there may be situations where a helper boat is unable to provide assistance. Some of the tows not currently requesting assistance are the most skilled at navigating the locks and could actually be slowed in making their approaches if helper boat assistance is required. Some additional factors influencing the potential time savings include the experience of the crew and performance of equipment (e.g., age of boat, experience of the pilot, etc.). These factors can contribute to significant differences in overall time savings.

The use of helper boats already occurs on a regular basis and likely will continue and expand whether or not a project is completed. This is currently occurring, since use has increased in recent years and is likely to continue to expand as traffic levels and safety awareness continue to grow.

Costs. The annual capital and operating costs of helper boats range from $430,000 to $785,000 per boat for use during the 270-day navigation season. At many sites, some of this cost is already being incurred due to the existing use of the boats, and the incremental cost to implement the measure would be lower.

At most sites, only one boat would be required to provide assistance for downbound approaches. However, there may be some sites and conditions where a boat could be used downstream as well to assist tows in upstream approaches and in leaving the guidewall.

Relationship to Other Measures. The use of helper boats is compatible with most measures. The scheduling program measure, approach improvements, and switchboats all can address approach time issues to some extent and, as a result, have reduced joint benefits if combined with a helper boat option.

Conclusion. The use of helper boats to assist approaches is currently occurring in the without project, especially at the most congested sites. Additional helper boat assistance may reduce approach times at some sites for some tows, but the majority of benefits are already being captured and the incremental savings is highly variable and uncertain.

▪ Switchboats with Guidewall Extensions

Description of Measure. Using switchboats in combination with extended guidewalls was one of two primary ways identified to implement switchboat use. Switchboats in the 1,800 to 2,000 horsepower range were determined to be able to safely extract the unpowered first cut of double lockages out along an extended guidewall. This process represents the major additional time savings, since it provides a faster extraction than the existing tow haulage and allows the next waiting tow (traveling in the same direction) to use the lock while the first tow remakes its couplings. Switchboats, like helper boats, can also assist tows in approaching the locks in adverse conditions and by moving ice and debris from around the chamber.

To fully implement this measure, the guidewalls must be extended approximately 600 feet, using either cellular sheet pile construction with precast concrete panels or DeLong Pier/spud barges. This provides space for the powered cut to fully exit the chamber for remake, allowing the next tow heading in the same direction to use the lock, while the first tow recouples.

Time Savings Estimates. The four time savings categories are discussed separately below.

Approach. In general, switchboats can provide the same approach time savings benefits as helper boats. However, the fact that at many sites tows already use assistance under normal flows limits the potential incremental savings. There is also a wide range of potential factors affecting the potential savings, including variability of flow, site-specific differences, the pilot and crew skill levels, weather, etc. These factors make it very difficult to accurately predict what, if any, additional approach time savings is possible. In addition, when a queue is present and the lock operates with multiple turnback lockages, these benefits are even more limited since only fly and exchange lockages typically experience the full benefits of approach assistance. As a result, while some potential savings is possible, no specific per lockage benefit was identified.

Pulling First Cut of Double Lockages. The use of switchboats to pull the unpowered cuts of doubles was also evaluated. Assistance with this portion of the lockage primarily results in the ability to extract cuts faster than the existing tow haulage systems, take the cut farther along the guidewall, and hold the cut.

The average resulting time savings upstream for UMR locks is 7 minutes for upbound and 9 minutes for downbound lockages. The variation from site to site is provided in Section 4. This is only the time associated with clearing the lock gates, allowing the chamber to be turned back for the next cut, not the entire time to move the cut and tie it off.

Remake of Double Lockages. Additional time savings can be obtained by pulling cuts far enough along an extended guidewall so that the tow can remake without blocking the chamber. While this benefits tows waiting in queue, it does not reduce the remake time for the actual locking tow. It simply moves the remake process out of the lock chamber. To achieve this time savings with a switchboat, a guidewall extension providing a total of 1,200 feet of surface would be required. This time savings would result from alleviating the existing condition at locks with 600-foot guidewalls where a second cut of a tow is unable to clear the chamber until it has remade its couplings with the first cut, thus keeping the chamber from servicing other tows. The potential time savings is only for turnback lockages, where the next tow locks in the same direction. If the next lockage is an exchange (going in the opposite direction), no additional time is saved since the first tow is still blocking the approach during its remake.

Resultant time savings are 15 minutes upbound and 18 minutes downbound for the UMR locks, and 19 and 20 minutes for the same estimates for the IWW locks.

Reduced Chambering Time - Faster Emptying on Downbound Cuts. Typically, the rate of emptying the chamber is reduced when an unpowered cut is waiting in the downstream approach for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is pulled 600 feet down an extended guidewall for remaking. The time savings is highly dependent on the water level elevation (head) difference between pools and location of discharge. At lower flows when head differences are the greatest, the time savings would be greater. At higher flows, there would be little or no savings. An average savings of 0 to 2 minutes is possible at UMR locks. Larger time savings of 1 to 7 minutes would be possible at the upper IWW locks where head differences are greater.

Total Time Savings. Table 2-2 shows the potential time savings associated with the use of a switchboat and extended guidewalls at UMR locks. Similar time savings is possible at IWW locks, but approach time reductions would be smaller. Total time savings benefits to tows waiting in queue are estimated at 22 minutes per double lockage for an upbound (upstream) tow; 27 minutes for a tow heading downstream at UMR locks 11-25. The remake time savings only applies to turnback lockages where the next tow is heading in the same direction. The remake

benefits also do not accrue to the actual tow using the lock, since even if the chamber is available it still must remake. This lowers the savings to 7 and 9 minutes, respectively. These time savings are dependent on an extended guidewall and the opportunity to remake double lockage tows outside of the chamber. A study of the effect of helper boats at the former Lock and Dam 26 site to extract unpowered cuts along an extended guidewall and allow remake outside of the chamber identified similar time savings of 23 minutes for double lockage tows.

The actual time savings for a queue depends on the lockage type, the number of tows requiring double lockages, how the extraction is handled, and the number of switchboats.

TABLE 2-2: ESTIMATED AVERAGE TIME SAVINGS FOR SWITCHBOAT WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25

Delay Reduction	Double Lockages Benefits to Tows Waiting in Queue	Double Lockages Benefits to the Locking Tow
Pulling the unpowered cut	7 min. upbound 9 min. downbound	7 min. upbound 9 min. downbound
Remaking the tow (with extended guidewalls – turnback lockages only)	15 min. upbound 18 min. downbound	Tow still remakes, location is moved to end of the guidewall
Reduced chambering time	0-2 min. downbound	0-2 min. downbound
Total time savings potential*	22 min. upbound * 27 min. downbound *	7 min. upbound 9 min. downbound

* Total benefit to waiting tows assuming the next lockage is a turnback. Otherwise, benefits are limited to 7 minutes upbound and 9 minutes downbound.

There are also some potential benefits to setover and knockout single lockages associated with permanent guidewall extensions (see Section 4).

Conditions Affecting Implementation. As stated under the helper boat option, there is considerable uncertainty in the ability to provide increased approach time savings. As a result, this analysis focused on the benefits of switchboats to assist other steps in the lockage process.

One limitation of using switchboats to pull cuts along extended guidewalls is that they only realize remake time savings if the next tow is traveling in the same direction (turnback lockages). They also require extended, preferably 1,200-foot, guidewalls. Even with extended upper guidewalls, pulling cuts under outdraft conditions does present some safety risks under high flows.

Comments from Navigation Industry question the safety and reliability of using DeLong Pier/Spud Barge guidewall extensions. The expressed concerns regarding the safety of using 1,800 horsepower boats if flow moves underneath the walls, impaired ability to approach the lock, potential for the wall and tows to be damaged, and increased downtime. Industry does not believe DeLong Pier/spud barge guidewalls are an acceptable alternative, and they instead strongly recommend using permanent guidewall extensions.

Costs. The annual cost of a 1,800 to 2,000 horsepower switchboats is approximately $1,129,000 per boat for 270 days of use. At sites lacking an auxiliary lock (currently most sites), two switchboats and upstream and downstream guidewall extensions would be required to provide maximum benefits. In addition, the placement of cellular sheetpile construction or DeLong Pier guidewall extensions, and their associated costs, would be required. A 600-foot DeLong Pier guidewall consisting of three 200-foot piers, has a first cost of approximately $3.2 million per wall. In addition, a few sites would require some minor bank excavation or other site prep work. The estimated first cost of permanent guidewall extensions averaged $23.5 million for the upstream walls and $12.9 million for downstream guidewalls at UMR sites. The cost for permanent guidewalls at IWW sites is estimated to be much higher, $60 to $80 million per wall,

due to impacts to navigation during construction. There are also considerable differences in annual cost and expected life.

Relationship to Other Measures. The use of switchboats is compatible with most measures. In particular, traditional or DeLong Pier guidewall extensions are required to fully implement using switchboats to extract cuts. The use of scheduling to increase the number of turnback lockages also increases the potential benefits of this measure.

The scheduling program measure and approach improvements can also address approach time issues to some extent and, as a result, have reduced joint benefits if combined with a switchboat option. Regarding pulling cuts, the tow haulage equipment, switchboats with remote remake, and industry self-help measures provide similar assistance and would likely not be jointly selected.

Conclusion. Use of switchboats, in combination with extended guidewalls, could provide significant time savings and should be considered at sites experiencing significant delays.

- **Switchboats with Remote Remake Areas**

Description of Measure. In contrast to the previous measure, larger boats in the 2,200 to 2,400 horsepower range were determined to be necessary to safely extract the unpowered first cut and push it to a remote mooring under all flow conditions. The additional size allows them to remove an unpowered cut from the chamber and move it to a remote mooring facility, as shown in Figure 2-2. Due to safety concern, switchboats would not be used to back cuts upriver, above the dam. Instead a short guidewall extension, roughly 300 feet, would be provided allowing the switchboat to extract the cut, tie it off, uncouple from the cut, move to the downstream end, recouple, and then push upstream to the remote mooring. Remote remake increases the flexibility over scheduling or the use of switchboats with guidewall extensions, since exchange lockage tows can also remake out of the approach path. Switchboats can also assist tows in approaching the locks in adverse conditions and by moving ice and debris from around the chamber. Using switchboats in combination with remote remake areas can also reduce chambering times by allowing faster releases of water from the chamber.

At most sites, the placement of upstream and downstream mooring facilities is required. If extended guidewalls were available at the locks, tows could remake along them and only the last tow of the N-up/N-down series would need to be taken to a mooring facility for remaking to open the approach for tows headed in the opposite direction.

Time Savings Estimates. The four time savings categories are discussed separately below.

Approach. As stated under the previous section, switchboats can provide the same approach time savings benefits as helper boats. However, potential incremental savings are limited by the existing use of helperboats and a number of other factors and conditions. As a result, while some potential savings is possible, no specific per lockage benefit was identified.

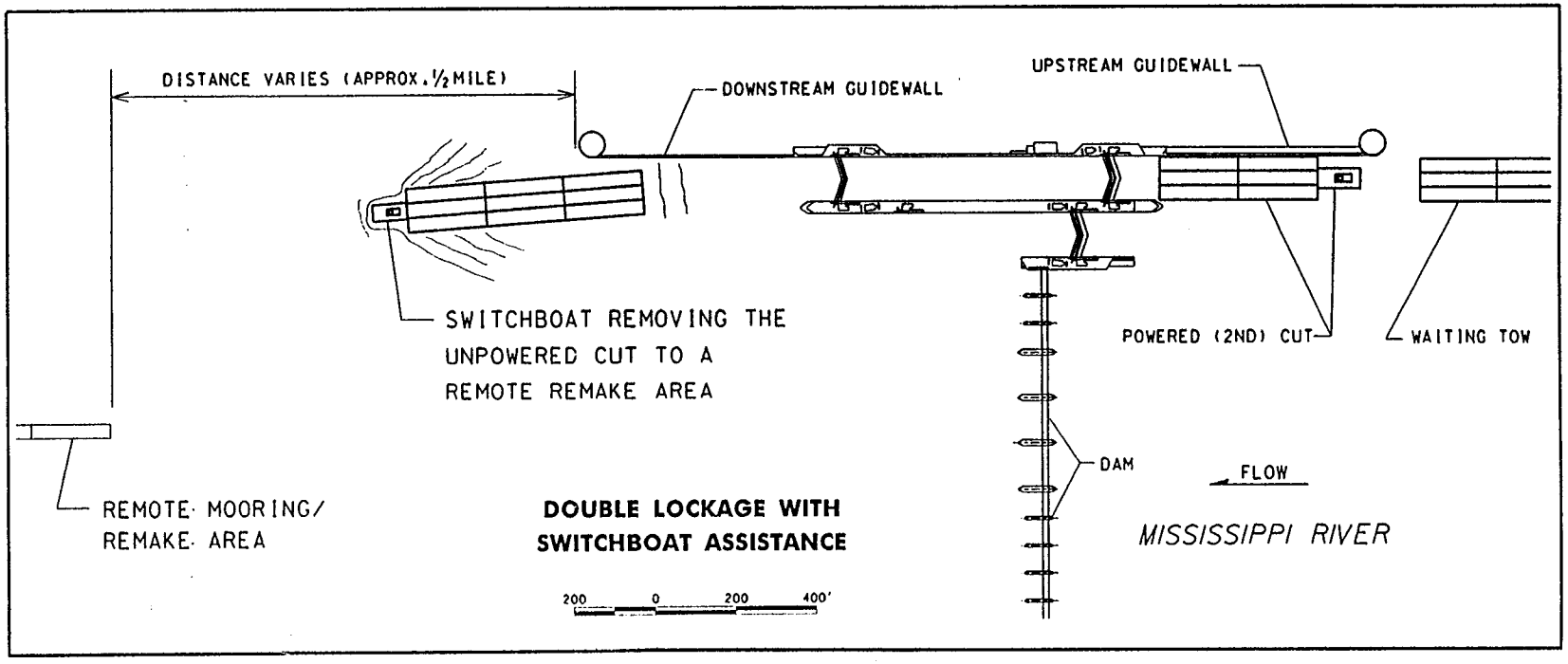


FIGURE 2-2: Switchboat in Action

Pulling the First Cut. Assistance with this portion of the lockage primarily results in the ability to extract cuts faster than the existing tow haulage, taking the unpowered cut along the guidewall or to a remote mooring. Using LPMS data to analyze extraction times, a time savings of 7 minutes was estimated for upbound lockages and 9 minutes for downbound lockages at UMR Locks 11-25. Upbound times were reduced from approximately 14 minutes using the existing tow haulage to 7 minutes with switchboat assistance. Downbound lockages were reduced from 17 to 8 minutes. This is only the time associated with clearing the lock gates allowing the chamber to be turned back for the next cut, not the entire time to move the cut and tie it off.

Remake of Double Lockages (Exit and Clear Second Cut). An additional time savings can be obtained by pulling cuts far enough so that the tow can remake without blocking the chamber. This alleviates the existing condition at locks with 600-foot guidewalls where a double lockage tow is unable to exit the chamber until it has remade its couplings, thus keeping the chamber from servicing other tows. Unlike the previous switchboat option using guidewall extensions, this benefits both exchange and turnback lockages, since remake occurs clear of the lock chamber, guidewall, and approach path. While this process allows the next tow to use the lock earlier, it does not reduce the actual remake time for a particular tow, it just occurs at a facility where it does not cause delay to tows in the queue. If the time is included to move both cuts to the remote mooring, align them, recouple, and then leave the mooring area, it is likely that the process will actually take as long or longer than the existing process.

The general sites under consideration for remake areas are shown in Figure 2-3. The estimated time savings at UMR locks are 15 minutes for upbound tows and 18 minutes for downbound tows. This savings represents a reduction in the existing tow exit and clear time of the second cuts from approximately 20 and 24 minutes to 5 and 6 minutes, respectively, for downbound and upbound tows. At IWW locks, time savings of 19 and 20 minutes are estimated for upbound and downbound tows, respectively. Again, there are site-specific differences in the time savings (see Sections 3 and 4 for more information).

While in general the proposed operations would work as a way to reduce times, without significantly reducing the benefits identified for faster extraction and remote remake. However, there is a high likelihood of some events occurring where the overall benefits are reduced, due to a given tow or group of tows taking longer on one or a number of steps. This is especially likely at sites with faster chambering times, more distant remote remake areas, or during periods of adverse conditions. This could lead to delays in the switchboat returning to the lock to pull the next cut and delays at the mooring facility while the previous tow completes its remake. The delays in getting the switchboat back to the lock can be addressed by moving the other assist boat to the same pool to alternate pulling cuts.

Reduced Chambering Time - Faster Emptying on Downbound Cuts. Typically the rate of emptying the chamber is reduced when an unpowered cut is waiting in the downstream approach for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is removed and taken to a mooring facility for remaking. The time savings is highly dependent on the head difference and location of discharge. At lower flows when head differences are the greatest, the time savings would be greater. At higher flows, there would be little or no savings. An average savings of 0 to 2 minutes is possible at UMR locks. Larger time savings of 1 to 7 minutes would be possible at the upper IWW locks where head differences are greater.

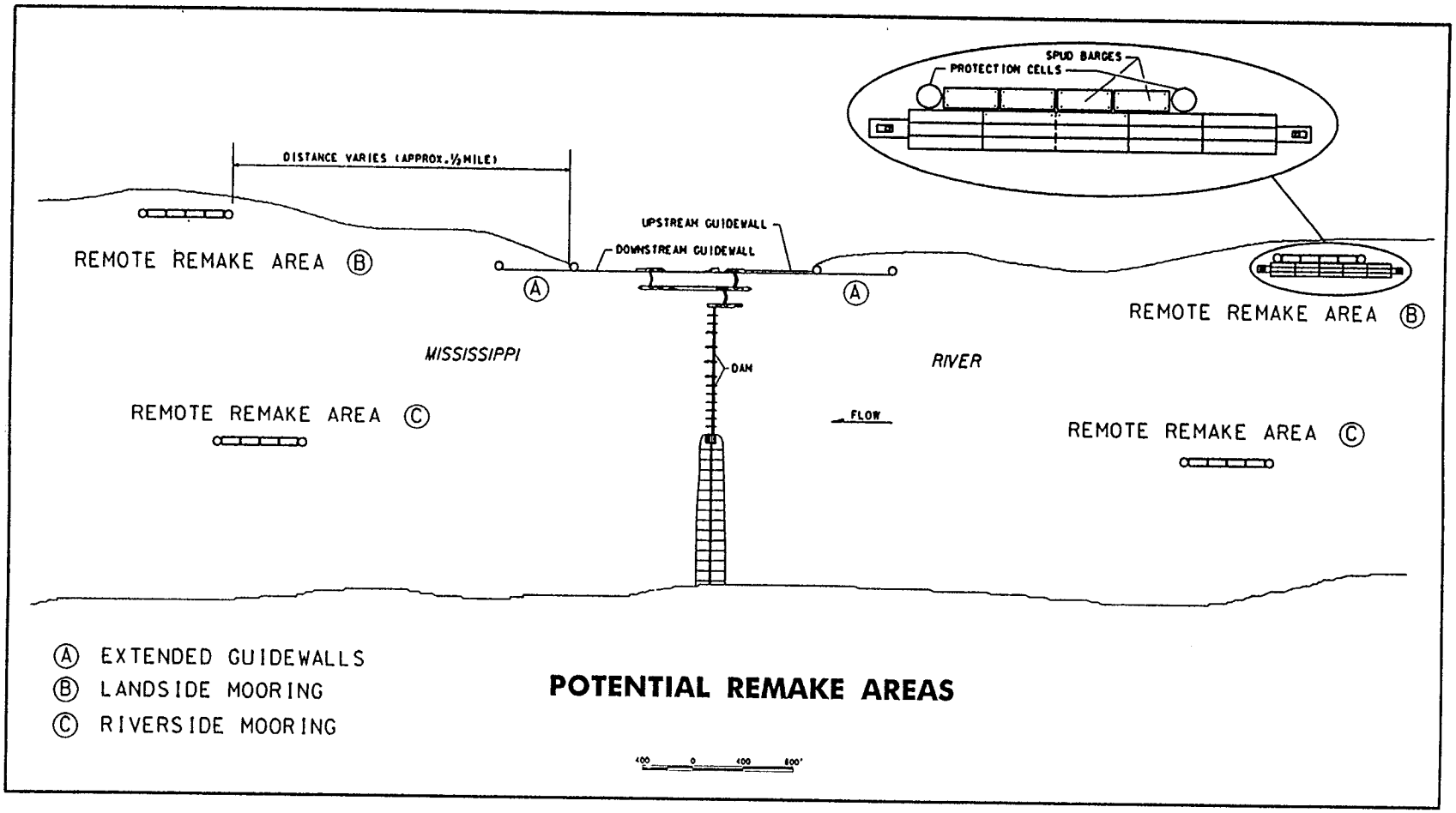


FIGURE 2-3: Potential Remake Areas

Total Time Savings. As Table 2-3 indicates, a variety of time savings appears possible with the use of a switchboat and remote remake areas at UMR locks. Similar time savings is possible at IWW locks. In total, it appears possible to reduce lockage times by 20 to 30 minutes.

While the tows waiting in queue generally can benefit from the full 22- to 27-minute reduction in lockage time, the actual tow being assisted is likely to require more time to use the lock and remake area than before. Estimates show that an upbound tow is likely to spend from 5 to 25 minutes more in the lockage process than it would currently. This is primarily due to the additional time required to move both cuts to a remote site, approach the mooring, face up, and then remake. Downbound tows, which are not required to turn around, will have more limited increases in overall processing time. However, since some of this additional time (roughly 7.5 to 15 minutes) is associated with moving to the mooring, which also moves the tow closer to its eventual destination, only the additional approach and maneuvering time represents an added inefficiency. This results in a more limited additional time of approximately 5 minutes, associated with the need for an additional approach at the mooring area.

TABLE 2-3: ESTIMATED SAVINGS FOR SWITCHBOAT USE WITH REMOTE REMAKE AREAS AT UMR LOCKS 11-25

Delay Reduction	Double Lockages Benefits to Tows Waiting in Queue	Double Lockages Benefits to the Locking Tow
Pulling the Unpowered Cut	7 min. upbound 9 min. downbound	7 min. upbound 9 min. downbound
Remaking the tow (applies to both turnback and exchange lockages)	15 min. upbound 18 min. downbound	Tow still remakes, location is moved to end of the guidewall
Reduced chambering time	0-2 min. downbound	0-2 min. downbound
Additional time required to approach & align with cut at remote site	NA [2]	Delay 5 min. upbound Delay 5 min. downbound
Total time savings potential [1]	22 min. upbound * 27 min. downbound *	2 min. upbound 4 min. downbound

[1] Total does not include approach assistance, but assumes 300-foot upstream guidewall extension and remote mooring.
[2] The additional time to approach and align at the remote site does not impact other waiting tows.

Conditions Affecting Implementation. A key requirement for the implementation is the existence of moorings located out of the approach path. The placement of the mooring facilities is a site-specific consideration; however, an average distance to the mooring sites is roughly ½ to 1 mile from a lock. The length of the mooring facilities (farthest tie-up points) should be 600 feet or greater to be effective. For pushing tows upstream, it is estimated that the switchboats should have a minimum of approximately 2,250 horsepower to overcome the outdraft currents.

The use of remote remake area, especially above the lock, increases risk and presents some safety concerns. More maneuvering and handling of barges is required. The increased handling of the barges upstream of the dam increases the chance of damage to the dam and barges. In addition, the pattern of flow and position of moorings affect the ability to use this measure. The increased numbers of operations required by remote remake also increase variability and the risk that the full time savings will not be achieved on any particular lockage.

Costs. Implementing a switchboat measure involves three primary costs—switchboats, remote moorings, and 300-foot upstream guidewall extension. The annual cost to operate a 2,200 to 2,400 horsepower switchboat for 270 days per year is estimated at $1.3 million per boat. To provide maximum benefits, two switchboats would be required at sites lacking an auxiliary lock.

However, with full implementation of switchboats, the existing use of helper boats could be eliminated at most sites, reducing the incremental cost to implement the measure.

Some significant additional costs would be associated with providing mooring facilities at locations where they are not available. One option would be the use of a combination of cells and spud barges, flat deck barge with four spuds, or pilings which can be driven into the river bottom to anchor the barge in place. This alternative is estimated to cost $3.7 million per mooring, including maintenance. Most sites in the study area would require placing a remote remake area both above and below the lock for a total first cost of over $7.4 million per site. In addition, a cost of approximately $40,000 per barge per year would be expected for barge placement, maintenance, and repair. Major repairs would be required every 5 years at a cost of $200,000 per barge.

The first cost of a 300-foot upstream guidewall extension ranges from $2.1 million for a DeLong Pier wall to $11.7 million for cellular sheet pile construction. The costs for IWW sites are estimated to be $30 to $40 million higher per wall due to impacts to navigation during construction. This is due to the fact that there is not a winter closure period that allows for non-conflicting construction.

Relationship to Other Measures. The use of switchboats increases savings when combined with most measures. In particular, remote mooring facilities or extended guidewalls for remaking cuts out of the chamber are required for efficient use of switchboats to extract cuts. Scheduling both commercial and recreational vessels also assists in maximizing the benefits of using switchboats.

When switchboats are available, they fill the same role in most instances as helper boats, tow haulage equipment, and industry self-help policy. While these measures are not mutually exclusive, a number of the benefits overlap, therefore the benefits are reduced when an additional measure is used when others are in place. If the switchboats remove the unpowered cuts to mooring facilities away from the locks for remaking, the benefits of crew elements are reduced since the recoupling would be done out of the queue and the lock could be used by other tows.

Conclusion. Switchboats in combination with remote mooring facilities provide time savings greater than those provided by industry self help and allow for remake assistance of exchange lockages which switchboats with just guidewall extensions can not assist. However, this measure includes more operations and variability than using switchboats with guidewall extensions.

- **Industry Self Help**

Description of Measure. Self help requires the towing industry to extract unpowered cuts without the assistance of lock personnel or equipment. In most cases, these line haul towboats have 2,500 to 6,000 horsepower, substantially more than either helper boats or switchboats. When self help is implemented, a waiting tow ties off its barges and begins assisting other tows. The assisting boat acts as a switchboat, removing the unpowered cut from the lock and pulling it along the guidewall or to a remote mooring area. See Section 4 for a description of the process and a figure showing the process. Under the existing procedure, a tow waiting to lock in the opposite direction is often used as a mooring. The powered cut is then able to simply lock through and proceed away from the chamber. One advantage of a self-help policy is that with little or no additional investment it can serve as a temporary measure and be implemented as needed.

Implementing self help requires significant coordination and cooperation among the various towboat companies. This direct involvement of industry allows for a large amount of flexibility to address location- and queue-specific issues. Some use of this measure will likely continue into the future regardless of any actions taken by the navigation study. However, as part of adapting this measure for use as a standard procedure, various facilities could be provided to improve efficiency, safety, and reduce environmental impacts. Specifically providing 600-foot guidewall extensions would allow tows to safely remake at the lock site and eliminate the need for tows to

regularly back cuts to remake areas. In addition, mooring cells could be added to the site to provide moorings for assisting tows to tie off their cuts to, as well as two cells for a waiting tow to tie off to when serving as the remote remake facility. This results in three potential ways to implement self help: without additional facilities, with remote moorings, or with guidewall extensions.

Time Savings Estimates. Self help primarily provides assistance in reducing lockage times for double lockage tows in the same ways as switchboats do. In addition, the total remaking time can be reduced in some cases since the crew of the assisting tow helps with the recoupling. If the towboats assist with lock approaches like helper boats, they can also reduce delays associated with approach times, but they are less maneuverable and efficient in providing approach assistance and do not typically provide this type of assistance.

Pulling the First Cut of Double Lockages. As part of self help, industry tows pull cuts from the lock chamber. They typically are able to extract cuts somewhat faster than the existing tow haulage and take the unpowered cut along the guidewall or remove the unpowered cut to a remote site. However, due to the larger lines and reduced maneuverability of line haul boats, smaller time savings are expected than those estimated from the use of helper boats or switchboats. Using industry boats under the self-help policy to pull cuts is expected to yield time savings of 1 and 3 minutes for upbound and downbound lockages, respectively. The resulting time savings vary from site to site as indicated in Sections 3 and 4.

Remake of Double Lockages. An additional time savings can be obtained by pulling cuts far enough so that the tow can remake without blocking the chamber. Functioning like switchboats, line haul boats can pull cuts to the end of extended guidewalls or to remote moorings, thereby benefiting both exchange and turnback lockages. The estimated time savings is 15 minutes for upbound tows and 18 minutes for downbound tows at UMR Locks 11-25. The same time savings would be possible using the self help in combination with extended guidewalls, but would only apply to turnback lockages. However, if only the existing guidewalls are available and cuts are pulled to the last check post (last pin), the time savings would drop to 13 minutes for upbound tows and 15 minutes for downbound tows because the tows have to exit slower and face up to their cuts prior to the start of gate closure. However, not all tows will benefit from the remake time savings. Tows would not back cuts upstream for remote remake during strong outdraft conditions. In addition, not all tows can use the existing guidewalls, since some of the larger towboats could not fit in the space between the last check post and the lock gates.

Reduced Chambering Time - Faster Emptying on Downbound Cuts. As stated for the switchboat options, the concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is removed and taken to a mooring facility for remaking or sufficiently far enough down an extended guidewall. This results in an average savings of 0 to 2 minutes at UMR locks. Larger time savings of 1 to 7 minutes would be possible at the upper IWW locks where head differences are greater.

Total Time Savings. Table 2-4 generally indicates the amount of time savings associated with the use of industry self help at UMR locks. The primary difference between the use of industry line haul boats and helper boats and switchboats is that generally line haul boats do not provide approach assistance and their slower face-up reduces the savings associated with the exit and clear of the first cut. In total, however, it appears possible to reduce double lockage times by 15 to 20 minutes. The actual time savings for a queue depends on the scheduling approach, number of tows requiring double lockages, where the tows remake (guidewall, mooring, or waiting tow), and the number and experience of the assisting boats.

While tows in queue can benefit from the entire time savings, the actual tow locking through may actually spend more time in the lockage process if remote remake is used. This is similar to the times associated with using switchboats and remote remake discussed previously. The additional time required to approach a remote mooring is an additional time requirement, reducing any time savings gained by the faster extraction. Remake times from the perspective of the locking tow remain virtually the same regardless of the location.

TABLE 2-4: ESTIMATED SAVINGS OF INDUSTRY SELF HELP WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25

Delay Reduction	Double Lockages Benefits to Tows Waiting in Queue	Double Lockages Benefits to the Locking Tow
Pulling the unpowered cut	1 min. upbound 3 min. downbound	1 min. upbound 3 min. downbound
Remaking the tow (with extended guidewalls – turnback lockages only)	15 min. upbound 18 min. downbound	Tow still remakes, just location is moved out of chamber
Reduced chambering time	0-2 min. downbound	0-2 min. downbound
Total time savings potential*	16 min. upbound * 21 min. downbound *	1 min. upbound 3 min. downbound

* Time savings would be virtually the same if tows were pulled to the last pin on the existing guidewall. However, the remake/exit of the second cut would take an additional 2 to 3 minutes, reducing time savings, and a smaller portion of tows would benefit.

The numbers shown in the preceding table apply to the use of industry boats with 1,200-foot lock guidewalls. In instances where the cut is pulled to the last pin on the existing 600-foot guidewall, the benefits are reduced. In these instances, the time savings is reduced because the second cut will exit more slowly, reducing the savings identified by 2 to 3 minutes. In addition, the existing guidewall does not have adequate length to allow the largest tows on the system, most 5,000 and 6,000 horsepower boats, to remake without blocking the chamber.

The use of self help, especially without the addition of facilities, may not be implementable under some conditions. The benefits shown would likely be unattainable for upbound tows during outdraft conditions. Benefits would not accrue when smaller queues are present and during periods of lower economic incentive. There may also be unacceptable impacts associated with routine use of remote remake if facilities are not provided.

Conditions Affecting Implementation. The key elements to implementing industry self help are cooperation of the various industry groups and an adequate queue of 10 or more tows. The potential for this coordination has been established by RIAC; however, additional discussion regarding each site on the system would likely be required to develop a negotiated agreement for each site. In addition, the willingness of various tow companies to handle each other's tows on a more regular basis must be addressed, in contrast with existing practice which is typically associated with unusual events such as emergency closures, accidents, and ice conditions. Productive implementation of self help requires the presence of a relatively large queue. In situations with more moderate congestion and delay (e.g., six waiting tows or less), self help would likely provide relatively little time savings since the helping towboat would require time to return and recouple with its barges before locking.

The willingness of industry to participate in the long term is also based on the potential for increased risks, which could lead to higher accident rates and increased insurance rates. If higher accident rates are experienced resulting in higher costs, the use of these types of operations and facility requirements would be re-evaluated. The additional use of equipment and lines could also affect maintenance costs and equipment life.

There is also a need to determine whether designated mooring areas are required at each site. The assisting tow can leave its barges with another waiting tow while it provides assistance and the locking tow can remake along a waiting tow. However, the presence of moorings in these areas can provide safety and environmental improvements. Designated mooring areas would allow tows to idle at slower rates as well as avoid the need to push into the bank or tie off to trees. There are a number of options for mooring facilities (e.g., cells, spud barges, bank anchors, etc.).

Some of the benefits may be more variable than under a switchboat or helper boat option. Industry self help relies on participation and coordination. The overall level of effectiveness also varies based on the assisting captain, crew, and power and maneuverability of assisting towboats. The crew of a line haul boat would not know a particular lock site's conditions as well as a switchboat or helper boat crew assigned to that lock. The crew of designated assist tows (helper boats or switchboats) would also become highly efficient through repetition and specialization at one lock site in pulling and backing cuts to the designated remakes.

Costs. In contrast to the other towboat power options, it is difficult to determine the cost of using industry self help. The actual cost of industry self help would be any added variable costs (primarily fuel use at approximately $50 hour, risk, and wear on its equipment), estimated at roughly $324,000 per boat per year. This cost covers fuel expense for one tow, 24 hours a day, during the 270-day navigation season. It is anticipated that this overstates the need for assistance, especially in the early years of the analysis period. However, in identifying costs, only the cost of additional fuel was quantifiable given available data. Some expense related to increased insurance rates and increased wear on equipment would be expected, but the magnitude is unknown.

There also would be some significant costs associated with additional mooring cells, remote remake areas, or guidewall extensions where they are required. These costs are similar to those discussed previously for facilities with switchboats. For more information on these costs, see Sections 3 and 4.

Relationship to Other Measures. The use of industry self help adds additional savings when combined with most measures. In particular, mooring facilities or extended guidewalls for remaking cuts along greatly improves the efficiency of using self help to extract cuts and would be required at most sites to fully implement the measure. Scheduling both commercial and recreational vessels can also assist in maximizing the benefits of self help. However, the flexibility currently used in implementing N-up/N-down as part of the self-help policy diminishes the potential for future benefits associated with better scheduling.

The implementation of a self-help policy typically provides similar benefits as helper boats, switchboats, and improved tow haulage equipment. While these measures are not mutually exclusive, self help can provide a significant portion of the benefits at a lower incremental cost to industry. If the towboats remove the unpowered cuts to mooring facilities away from the locks for remaking, then the benefits of crew elements are reduced since the recoupling would be done away from the lock while other tows are using the lock facility.

Conclusion. Self help provides industry an option to obtain a portion of the towboat power assistance benefits at little additional out-of-pocket expense. As a result of expected performance improvements (time savings) which are near the level of helper boats and switchboats and lower incremental cost, this measure is recommended to be carried forward for more in-depth consideration.

Tolls and Reports

The toll collecting and reporting measures are forms of demand management that seek to reduce delays through creating incentives to reduce overall lockage times and shift demand away from congested locks. Federal law currently prohibits the charging of tolls for watercraft passing through locks (33 U.S.C. 5). If a fee measure is ultimately selected for implementation, the recommendation to change the current Federal law which prohibits charging tolls would go forward with the final feasibility report. While the issue of how the money collected would be used does not affect the study analysis, it is assumed that it would be designated for use in defraying navigation-related costs on the system (navigation improvements, operations and maintenance, etc.) or placed in the Inland Waterways Trust Fund.

This section addresses four measures: congestion tolls, excess lockage time charges, lockage time charges, and publishing lockage times. Of these measures, congestion tolls would have the greatest direct cost to industry. In contrast to the other measures in this section, which primarily focus on creating incentives for vessels to lock faster, congestion tolls are primarily directed at addressing overall demand for the locks. While primarily intended for commercial lockages, tolls and lockage charges could also be collected from recreational users.

▪ Congestion Tolls

Description of Measure. Tolls would be collected from tows and possibly recreational craft that are using congested locks. While congestion tolls are typically charged during a particular peak period of demand, analysis has demonstrated that there is little regular variability in commercial waterway traffic except as influenced by seasonal weather (e.g., winter closures, spring flooding). As a result, it would appear that a more effective use of the congestion toll is to charge a fee at all locks experiencing a significant delay, or a licensing fee to operate on the system. The tolls would be developed to shift the potential traffic away from these congested locks to alternative modes of transportation or other inland waterway systems.

Applying congestion tolls would not increase system throughput, but rather would provide a mechanism to ration the resource and provide an incentive to coordinate and schedule transit to avoid congestion. However, the issues of how tolls would affect the demand for lockages, the behavior of the barge operators, and the potential creation of an incentive to change tow configurations need to be evaluated. To provide a reasonable incentive to the towing industry, tolls could be charged based on lockage time and set at the expected delay cost of tows waiting in queue. This would create a mechanism for tows to internalize the delay cost they impose on other tows. A more simple approach administratively would be to charge a licensing fee to operate on the system. The fee could be set at a level to reduce overall demand for the system or, if necessary, the number of licenses could be limited.

Time Savings Estimates. The collection of a congestion toll would be targeted at reducing the overall traffic at congested locks. This measure, when properly implemented, can provide significant delay reduction by reducing traffic and shifting marginal traffic movements to other modes or areas.

A systems evaluation is needed in order to appropriately set the level of tolls and adequately evaluate the impacts. This measure should be carried forward for analysis using the systems models being developed to analyze the UMR-IWW System as part of this study.

Conditions Affecting Implementation. A number of factors are likely to influence the ultimate implementation of this measure. One key concern is the response of the navigation industry which has historically opposed congestion tolls and other fee options. Depending on how the tolls are

structured, users may not know if congestion tolls will be in effect until radioing or reaching the lock. In this instance, additional information on real-time traffic flow may be needed to assist industry in avoiding peak periods of delay. If tolls were extended to recreational users, these users' responses also would likely be negative. Congestion tolls as a form of a user charge also raise issues surrounding the efficiency and fairness aspects of the charges.

In addition, rationing systems traffic could result in negative regional economic impacts and changes in water-compelled rate impacts on other modes. The tolls also have the potential to negatively impact the profitability of various towboat companies.

A low-cost and unburdened method of toll collection would need to be developed, both from staffing and budget perspectives. One potential for billing would be an adaptation of the existing LPMS data base. As lockage data are collected, the program could be developed to record the company name and lockage time for consolidation and billing on a periodic basis.

Cost. The primary costs associated with this measure include developing a congestion toll policy and structure and collecting the tolls. The estimated cost of this measure is $465,000 for a study to develop an approach, set toll levels, and establish a billing and bookkeeping system. There would also be an annual cost of about $235,000 for bookkeeping and fee collection for the entire system. Despite these costs, this measure is estimated to produce revenue in excess of costs. Tolls on recreational craft would need to be set at a lower level than commercial traffic, but would still be highest at those locks with the greatest delay and lowest at locks with less traffic and delay. Two potential major economic costs to the nation and region are increased shipping costs on remaining modes because of reduced transportation options, and negative impacts on recreation, a significant economic activity in the study region.

Relationship to Other Measures. Other time reduction measures could be implemented along with congestion tolls. However, congestion tolls, focused on eliminating significant delays by reducing traffic at the most congested lock sites, could potentially reduce traffic to levels low enough to eliminate the need for other measures. In addition, due to the complexity of a multiple fee structure and goals of congestion tolls, combining them with other fee collection measures is not recommended.

Conclusion. Additional analysis to determine the feasibility of congestion tolls requires using the UMR-IWW System Navigation Study systems models to determine the actual ability to address congestion and whether there are sites and periods of congestion that tolls could address.

- **Excess Lockage Time Charges**

Description of Measure. This measure would charge a fee to users who have an "excessive" lockage time at a particular lock. The fee creates an incentive specifically designed to modify the operations and behavior of the companies and crews with the slowest lockage times. To implement the measure, what constitutes an "excess" lockage time would be defined for each lock, and users exceeding that time would be assessed a fee. The level of the exceedance that triggers the charge would be based on a statistical analysis of the distribution of historic lockage times at a particular site. While the specifics of the measure would be determined at a later date in coordination with the navigation industry, the times would be determined on a site-specific basis in consideration of weather, river, and lock conditions.

While this measure involves the collection of a fee, it varies considerably from a congestion toll. In this case, the fee is set at a much lower level so that the incentive is to improve lockage efficiency rather than limit use of the system. In addition, the charge is only applied to the tows with the longest lockage times rather than all of the tows in a queue. However, the charging of any fee does have the potential to eliminate some traffic movements.

Time Savings Estimates. Fee collection for excessive lockage times creates an economic incentive for especially the slowest crews and companies to improve their practices and avoid the time charge. This could sometimes result in significant time savings for other tows, since a slow tow in a queue can considerably delay all other waiting tows. It may also create further incentives for industry to pursue time savings measures such as increased use of approach assistance, additional crew training, development of better couplers, or other equipment improvements to reduce lockage times and avoid charges. There are many uncertainties in estimating the efficacy of this measure.

Conditions Affecting Implementation. It would be very difficult to arrive at an acceptable criterion to define an excess lockage time by site and by lockage type that would be agreeable to the Corps, navigation industry, and recreational users. This is due to the problems associated with attempting to take into account variable site, weather, and river conditions.

As with congestion tolls, the response of the navigation industry is of primary interest. One of the primary concerns with this measure is the potential to create incentives to reduce safety practices in an effort to lock faster and avoid charges. In addition, a suitable method of collection would need to be developed.

This type of measure could present equity concerns among those locking. By design, the charges only apply to a portion of the total traffic using a lock in an attempt to create an incentive for tows to beat some time standard. This leads to some inequity around the point where the fee is implemented. Tows locking just a few minutes faster may not pay any fee, while other tows taking just a little longer would pay the time charge. However, both tows in this example would cause nearly equal delays in the queue. The charges may also disproportionately impact small operators and others less able to update equipment and provide additional personnel.

Costs. The costs of implementing this measure would be essentially the same as those for developing a congestion toll. These costs for the entire system include:

- Determining the sites where the measure should apply, developing a fee structure, and coordinating with the public and navigation industry (total of $465,000).
- Administration of measure (bookkeeping and fee collection) ($235,000/year).

Relationship to Other Measures. The collection of excessive lockage time charges would provide benefits in combination with other time reduction measures. Since the relative lockage time of the particular crew determines if a fee is collected, the incentive to eliminate slow lockages would remain even if other measures are in effect and average lockage times reduced. However, it is recommended that this measure not be implemented with other fee collection structures due to the complexity of tracking and collecting multiple fees.

Conclusion. Determining what constitutes an excess lockage time presents some problems based on variability in conditions. Additional analysis is required to determine the actual ability to address delays and whether there are sites and significant numbers of lockages that could be improved through the use of excess lockage time charges.

▪ Lockage Time Charges

Description of Measure. This measure would charge all vessels based on the length of time the lock is in use. By charging the tow on a per unit time basis, all vessels will be charged. As a result, all tows, not just the slowest, will have an incentive to improve their locking efficiency in order to reduce the charge they receive. However, these charges would only apply to the lockage

elements where the vessel and its staff can affect the time. This would eliminate such times as gate opening and closing and chamber filling and emptying which are operations performed by the lock staff.

As with the excessive lockage time charge measure, this measure varies from a congestion toll. The fee, set at a lower level, would provide an incentive to improve lockage efficiency rather than to limit use of the system. However, collecting a fee does have the potential to eliminate some traffic, especially with this measure since all tows would be charged some fee.

Time Savings Estimates. The collection of a fee based on lockage times creates an economic incentive for all operators, especially the slowest crews and companies, to improve their practices to reduce their charge. This could result in significant time savings, since all tows in a queue would have an incentive to improve their times by whatever means.

However, determining the actual delay reduction would be based on assumptions of industry's response to the incentive. It also assumes that additional cost-effective time savings are available to industry, beyond what they currently have an incentive to implement.

Conditions Affecting Implementation. As with the earlier toll measures, the response of the navigation industry is of primary interest. Time charges again have the potential to create incentives to reduce safety in an effort to lock faster and avoid charges. This may be especially true of this measure since the longer the lockage takes, the greater the charge.

There would also be some difficulty in arriving at a level for the charges that is acceptable to the Corps, the navigation industry, and the recreational users. Variable weather and river conditions also should be taken into account. In addition, a suitable method of collection must be developed.

Costs. The costs of implementing this measure would be essentially the same as those for developing a congestion toll or excess lockage time charge ($465,000 initially plus $235,000 annually for the entire system).

Relationship to Other Measures. The collection of lockage time charges would provide benefits in combination with other time reduction measures. However, as the average lockage time is reduced due to the implementation of delay reduction measures, the economic incentives to improve locking efficiency associated with lockage time charges would be reduced. This measure should not be implemented with other fee collection measures due to the complexity of tracking and collecting multiple fees.

Conclusion. As with the other fee measures, additional analysis is required using the Navigation Study systems models to determine the actual ability to address delay and whether there are sites and periods of congestion where lockage time charges could reduce overall delays.

- **Publish Lockage Times**

Description of Measure. This measure would identify those towboats and towboat companies whose crews have the fastest and slowest lockage times. Although this measure does not involve a direct economic incentive or charge to reduce time, it informs the particular companies and the entire navigation industry of the performance of particular tows. Since it is in the best interest of all parties to reduce lockage times, this measure should assist companies and the industry in identifying which tows perform the best and which tows may need additional crew training, crew members, or equipment.

The lockage times for a particular tow, currently collected as part of the Lock Performance Monitoring System, would simply need to be formatted and published on the Corps of Engineers

Internet home page and in river industry periodicals (e.g., the *Waterways Journal, River Transportation News*, or others). In order to reduce the amount of reporting, just those tows locking fastest and slowest could be included as positive and negative incentives, respectively.

The publishing of information on performance has been carried out by the airline industry, city and county governments attempting to collect property taxes, and even agencies attempting to collect child support. In many cases, these efforts have been successful in raising awareness of both the involved parties and the public and in bringing about improvements.

Time Savings Estimates. The publishing of lockage times highlights performance and creates a peer incentive for crews and companies to be listed as the best performers or to improve their practices to avoid being identified by the industry, their customers, and others as contributing significantly to delays. This could result in improvements in the lockage times of some companies. It may also create further incentives for industry to pursue additional time savings measures.

The Corps currently meets regularly with industry groups and shares information on companies or tows that create unnecessary delays. A significant amount of industry peer pressure also exists to reduce delays, and often just sharing information with the navigation industry has brought substantial improvements in performance.

Due to the unknown response of industry to the incentives created by this measure, its benefits can not be forecasted to any reasonable degree of accuracy.

Conditions Affecting Implementation. The major condition affecting implementation is to determine how to disseminate the information for review by the navigation industry. In addition, the industry response to this information is difficult to accurately predict.

Costs. Since the data are currently collected and only need formatting and publishing, the cost of implementing this measure would be relatively low. However, the actual cost would be based on the format in which the data are published, the frequency of publishing, and whether a publication would include the information at no charge. The cost associated with compiling/sorting the data and publishing it in at least one publication is estimated at $65,000 per year. There may be additional incidental costs associated with this measure.

Relationship to Other Measures. Publishing lockage times can be used in combination with all other small scale measures, including the fee collection measures, since the peer incentive would exist whether other measures are implemented or not. However, if other measures significantly reduce delays, the pressure on slower tows to improve their performance could be substantially reduced.

Conclusions. Despite the relatively low cost of the measure, it is not likely to significantly decrease system delays. In addition, ongoing communications with industry are addressing many of these issues to some extent.

Recreational Vessels

Two separate measures addressing conflicts between commercial and recreational vessels at locks are being considered to address delays at locks. Increasing recreational and commercial usage of the UMR and IWW places commercial and recreational craft in competition for use of the locks at certain times. This section addresses the scheduling of recreational vessel usage and construction of recreational craft landings above and below the locks as ways to reduce these conflicts.

▪ Scheduling of Recreational Vessel Usage

Description of Measure. This measure would involve limiting recreational craft lockages to certain times of the day in order to minimize locking conflicts with commercial traffic. For example, recreational craft lockages would be offered at a set number of times during the day (e.g., morning, noon, evening). The purpose of scheduling is to maximize the number of recreational craft per lockage while reducing or eliminating recreational lockages at other times. Although scheduling would reduce the flexibility of providing lockages whenever recreational craft are present, it would provide increased predictability as to when recreational craft would be able to utilize the lock chamber. It could also reduce safety hazards by minimizing the times when both commercial and recreational crafts are approaching a lock at the same time.

Existing navigation regulations (33 CFR 207.300) state that the lockage of recreational crafts shall be expedited by locking them through with commercial craft provided both parties agree. If the lockage of recreational craft cannot be accomplished within the time required for three commercial lockages, a separate lockage of recreational craft(s) is to be made. This regulation would need to be changed to allow a scheduling option to be implemented.

Time Savings Estimates. This method has been tested at various locks on the UMR System in the 1970s and early 1980s. Three to four half-hour time periods were designated each day for recreational lockages at selected locks. Frequently, tows would be forced to wait and no recreational craft would arrive for the designated time, especially in poor weather. While some recreational boat operators took advantage of the dedicated times, the majority appeared to ignore the special scheduling. The conclusion of the test, while not strictly enforced for recreational craft, was that the dedicated periods did not seem to significantly benefit recreational craft and did cause additional delays to commercial traffic.

In addition to these tests of recreational scheduling measures, some information has been collected on the recreational boaters' usage of the locks and river and their perceptions of lock conflicts. For the system as a whole, an average of only two to three recreational boats are in the chamber during each recreational lockage. This is an under-utilization of a 600-foot lock's capacity which is estimated at over 50 recreational boats. A key finding was that while the length of delay was not a major source of frustration for boaters (as long as it remained under 60 minutes), not knowing when delays would occur was viewed as a major problem. This highlights the possibility that predictable times for recreational lockages may be valued by recreational users as the system becomes more congested.

To get an idea of the potential time savings, the lockage time required to implement a recreational scheduling program versus what is actually occurring was examined. The amount of time was calculated that recreational vessels would have the chamber designated to their use under a strictly enforced scheduling program (see Section 4 for details). These calculations indicate that at sites that currently have low to moderate levels of recreational traffic, such as the lower UMR sites, having designated recreational lockage times every day of the week may actually increase overall delays to commercial traffic. However, at sites with the highest recreational craft use, some delay reduction would be possible. There would also be a significant decrease in overall flexibility, in contrast to the current situation where recreational craft are often locked during the turning back of the chamber for tows heading in the same direction. This current process allows for recreational lockages while generally minimizing impacts on overall delay.

Conditions Affecting Implementation. The major concern in implementing recreational scheduling is the potential for negative impacts and reactions from the commercial industry and negative responses from recreational users. The more strictly the policy is enforced (e.g., allowing recreational craft only during designated times and not allowing tows during designated times) the

greater the potential for a negative response from members of either affected user group. In addition, strictly enforcing the policy results in the loss of flexibility to lock recreational craft, possibly creating significant delays for recreational craft that are traveling longer stretches of the river, requiring several lockages. A strict application of the policy has not been attempted in the past.

Several factors are likely to play a major role in the effectiveness of any implementation of this measure. Public involvement and education of the recreational boating community and navigation industry would need to be a very high priority, both in regards to setting the times and in clearly communicating why they are needed and how they will be enforced.

Costs. Implementing recreational craft scheduling could be done for about $520,000. The major costs of the measure would be associated with developing the schedule (especially if it is coordinated with user groups and possible collection of survey data) and then notifying the public of any changes. In addition, developing adequate signage and publicizing any new schedule would involve some expense. An additional annual cost of $35,000 is necessary to monitor and re-evaluate the scheduling and to add or replace signs.

In addition to the potential for losses related to delays to commercial navigation, there may be the potential for significant negative economic impacts if changes in the recreational craft's ability to use the locks leads to reductions in recreational use of the system. Recreational use of the UMR-IWW System contributes direct and secondary expenditures of over $1.2 billion, significantly benefiting the economy of the five study area states.

Relationship to Other Measures. The scheduling of recreational craft would be compatible with the other small scale measures under consideration. However, if both scheduling of recreational craft and a scheduling program for commercial tows were implemented, additional coordination would be required to ensure that the measures work together.

Conclusion. Implementing recreational scheduling does not appear to have an ability to reduce delays at the most congested locks on the system. There would be some time savings potential at the upper locks, but currently there are not significant delays to commercial traffic in these areas. In addition, there are significant concerns with the acceptability of a strictly enforced program to both commercial navigation and recreational interests.

- **Recreational Craft Landing Above and Below Lock**

Description of Measure. This measure calls for ensuring that adequate boat ramp facilities are available at either end of a pool near the lock in order to minimize the need for recreational craft to lock between pools due to a lack of access in one pool. This measure addresses the problem that in some locations the only available landing for several miles is located either just above or below a lock. At these locations, a large number of users may launch their boats in a pool on the opposite side of the lock from their desired pool, and then have to lock through. During periods of higher traffic, these additional recreational lockages increase overall lock delays, especially in consideration of the existing policy which requires that, at a minimum, recreational craft are locked after every third commercial lockage. In addition, providing additional landings could increase safety by reducing commercial and recreational boats simultaneously waiting to use a lock.

Time Savings Estimates. This measure has the potential to reduce delays to commercial craft by reducing the number of recreational craft lockages. However, additional recreational craft landings are not likely to provide measurable or significant system benefits in reducing lockage times. The actual delay reduction is limited by the inevitability of some recreational lockages

(e.g., local traffic that simply enjoys locking, marina based craft, and through-system travelers). In addition, the willingness of recreational users to wait for the lock will greatly influence the response of recreational craft users to increasing delays.

The study team conducted a two-step analysis in determining the potential time savings related to additional boat landings. The first step was to identify sites where a lack of recreational facilities exists which could be contributing to delays. The second step was to look at various recreational studies and LPMS data to determine the likely response of boaters and potential time savings. The following is a summary of the more detailed reporting of findings in Section 4.

From this investigation, it was determined that the some sites could benefit from an additional landing facility. However, as a whole, the studies of recreational craft movements indicate that additional boat landings within the pool are likely to have little impact on the lock usage. In order to actually produce a time savings, the number of recreational craft *lockages* and not just recreational craft using the locks need to be reduced. Currently an average of two to three recreational craft are in the chamber for each recreational lockage. If traffic is reduced based on constructing new landings, there is no delay reduction unless the number of lockages is reduced. Also, as noted above, many of the boats using the locks are marina based, and the presence or absence of landings is unlikely to affect their use of the locks.

An additional concern is the potential to further increase the number of recreational users in the areas around the lock by locating ramps close to the lock, possibly negatively impacting safety. A factor that may limit recreational lockages is the apparent delay sensitivity of many recreational boaters. Studies have indicated that many boaters may simply not use the locks if there are long delays that are occurring with increasing commercial traffic.

Conditions Affecting Implementation. The reaction of the recreational boating community is a major factor that will affect the overall impact of constructing additional landings. As some of the information summarized above indicates, recreational craft use the locks for a variety of reasons, many of which would not be changed by the addition of boat ramps.

The development of new recreational facilities at formerly unused sites could lead to significant site-specific adverse environmental impacts. However, the presence and extent of any impacts would not be known until an actual site and plan are selected.

Costs. Table 2-5 summarizes the expected costs associated with the development of a new boat landing at a currently undeveloped site. The estimates are based on recent Corps construction activities. The cost does not include the land costs for the boat landing site or environmental costs. These costs were not included because the specific sites where a new landing would be constructed were not identified as part of this analysis. An additional annual expense of approximately $12,500 would be incurred for operation and maintenance.

TABLE 2-5: COSTS OF DEVELOPING A BOAT RAMP, PARKING, AND ACCESS

Item	Cost
Site location (Identify & purchase if required)	Varies Based on Site
Construction Contingency 25%	$180,000 $ 45,000
Subtotal	$225,000
Planning, Engineering, and Design (15% of project costs + 5% inspection)	$45,000
Total First Costs (not including site acquisition)	$270,000

Relationship to Other Measures. This measure can be combined with virtually all other measures. The possible exception could be the placement of a new landing in an area that would conflict with the placement of mooring cells or tie-off areas for commercial barges waiting for lockages or engaging in remote remake.

Conclusions. The primary benefits of the construction of additional boat landings would be at a limited number of sites where there is currently an absence of adequate facilities that is resulting in additional lockages. Existing data do not strongly support the concept that additional landings will provide significant benefits in reducing the number of recreational lockages.

▪ Scheduling Program

General Description. The use of a scheduling program could achieve time savings by optimizing the sequence of the particular vessels present at a lock or series of locks. It would be computer-based and would develop a scheduling sequence for tows in a queue, based on mathematical modeling of the various types and configurations of queues expected. While the potential delay reduction varies considerably based on the type of queue present, two different approaches can be taken.

Under the first approach, the primary benefit of scheduling would be minimizing approach and reconfiguration times. For example, scheduling could result in a higher percentage of turnback lockages which generally take significantly less time than exchange lockages. Additional time savings could be achieved by locking recreational craft together and placing tows requiring only a single cut at the beginning and end of an N-up/N-down series. This type of program would provide flexible and responsive scheduling that would assist in maximizing throughput and reducing delays. A second approach would be to schedule tows to reduce delay per tow, delay per barge, or delay per loaded barge. Under this approach, the throughput remains relatively unchanged, but delay as defined by the criteria can be reduced.

The current scheduling policy for the navigation system is first come, first served for commercial tows. However, the lockmasters may depart from this procedure when warranted, and often do to obtain greater efficiency. The current regulations also state that recreational craft will not be required to wait for more than three commercial lockages before being locked through. In many cases, recreational craft are locked between every commercial lockage. While recreational craft lockages typically take a relatively short amount of time (approximately 15 minutes at UMR sites and 20 minutes at IWW sites) and they can use the chamber when it is being turned back for the next tow, they do impact the overall scheduling.

Consideration was given to a program that would schedule a specific lockage time for each tow at each lock as a form of system trip planning. However, this approach is not practical due to the variability in traveling the river and the potential for unforeseen events that would result in the need to continually modify the schedule for all tows on the system. However, a program could be developed to optimize a group of locks systemically. This type of scheduling would allow for closer coordination between locks so that tows are processed through the system and not just from one queue to the next.

Time Savings Estimates. Several sources of data were evaluated to provide information on the potential time savings available for implementing a scheduling program. These are referenced in Section 4 of this report.

The following section summarizes the potential time savings associated with the first approach of better N-up/N-down type scheduling (to minimize approach and reconfiguration times) by evaluating approach and exit times using 1990 LPMS data. The time savings of replacing an exchange lockage with a turnback lockage is approximately 10 minutes on single lockages and 17 minutes on doubles. This does not account for the extra time associated with

turning back the chamber (averaging 11 minutes), which reduces the time savings. Not all tows realize this lockage time savings because scheduling only increases the percentage of turnback lockages. Some exchange lockages still must occur. In addition, some of the time savings is already being captured by existing turnbacks and the use of an N-up/N-down policy. Due to the number of variables involved, the system's models would be required to make the final estimation of benefits (reduced delays) expected from saving time in certain lockage sequences through scheduling.

Under the second approach where the processing order is altered to minimize delay times based on a certain criterion, no significant increase or decrease in lockage time is expected. However, some time savings for the selected criterion can be expected (i.e., minimize delay per barge).

Costs. The costs of implementing a scheduling program are relatively low, estimated at slightly more than $550,000. This cost includes studying the various option, then designing, testing, and running the program. In addition, an annual cost of approximately $35,000 would be incurred to continue training lock staff and supporting and updating the program. The actual cost, however, would be influenced by how the final program is scoped, implemented, and maintained. Some similar types of scheduling programs have been developed (WES and University of Maryland) and could serve as a starting point. However, even if a developed model is used it would still require additional efforts to adapt it for use on the UMR-IWW navigation system.

Conditions Affecting Implementation. In present practice, lockmasters frequently vary scheduling from first come, first served to various N-up/N-down procedures when the conditions and queue dictate. In situations where these alterations are already made, it reduces the potential incremental benefits associated with the use of further scheduling. The current policy on locking recreational craft after every third commercial lockage also impacts the lockmasters' ability to optimize scheduling.

The use of a computer-based scheduling program has some potential disadvantages. It would likely require additional timely and accurate data collection and coordination. A model designed to address site-specific optimization may be too narrow in scope to adequately address whole river issues. In addition, the use of a scheduling program could impact equity by requiring individual tows to wait longer than under present practices (first come, first served) for the good of the majority of tows.

Relationship to Other Measures. The use of a scheduling program would be compatible with virtually all other measures and in many cases additional time reductions could be obtained through joint implementation.

Conclusion. Most of the benefits of a scheduling program are already being obtained by the use of a flexible N-up/N-down policy. However, scheduling does provide benefits to the system and should continue in some form.

STRUCTURAL MEASURES

The remainder of this section presents the structural small scale measures. In general, these measures would primarily be implemented through the construction of additional navigation facilities or modification of the river channel and approach.

- ***Extended Guidewalls***

Description of Measure. 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. Sometimes vessels tie up against the guidewall while awaiting 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 recoupled. Since the unpowered cut and guidewall are each 600 feet long, the powered cut remains partially inside the lock chamber while the two cuts are recoupled. This means that the lock cannot be used for other vessels until the two cuts are secured to each other and the recoupled tow moves out of the lock area.

Extending the existing 600-foot guidewalls to 1,200 feet would allow the powered cut of a double lockage to make up with the unpowered cut completely outside of a 600-foot lock chamber. The lock would therefore be free to be turned back for the next vessel traveling in the same direction. This is the major time savings benefit from this measure that works best when combined with other small scale measures such as tow haulage, switchboats, or industry self help that would move the unpowered cut to the end of the extended guidewall.

The following text describes the benefits of extended guidewalls. Immediately following this section, the joint benefits of combining guidewall extensions with the tow haulage option (powered and unpowered kevels) are discussed. The benefits in combination with the towboat power option were discussed previously.

Time Savings Components. The actual total time savings associated with extended guidewalls can be broken down into four components: reduced approach time, reduced extraction time for the first cut, reduced chambering time downbound from faster emptying of the chamber (the first cut is removed from the lock discharge area), and remake of the double cuts occurring outside the chamber along the extended guidewall. These components are discussed in turn below. There is also some potential benefit to setover and knockout single lockages (see Section 4).

Reduction in Approach Time. The lengthening of the guidewall provides two elements of time savings in the approach. First, the longer wall gives a larger "landing surface" for the tow to steer for (safety is also enhanced if the tow is able to get on the guidewall sooner). Second, a waiting tow will be able to stage itself just outside the lock chamber for a turnback lockage because it can fit on the entire wall (and not have any part of the tow "hanging off" the wall). When the lock is turned back, the tow will be able to move immediately into the lock instead of leaving a bank or mooring structure to make its approach. This part of the time savings associated with extended guidewalls is site specific and is included in the later discussion of the small scale measure titled "Approach Channel Improvements."

Reduction in Extraction Time of the First Cut. The potential for reduction in the extraction time of the first cut is directly attributable to other small scale measures in conjunction with extended guidewalls. Powered traveling kevels depend on extended guidewalls, and the potential time savings is discussed next under "Tow Haulage Equipment." Switchboats and self help are other small scale measures discussed in this report which can be used in combination with extended guidewalls to extract the unpowered cut faster from the lock chamber. The guidewall extension cost reported here has to be included with each of these measures if they assume the presence of 1,200-foot guidewalls.

Reduction in Chambering Time (Faster Emptying for Downbound Lockages). Typically, the rate of emptying the chamber is reduced when an unpowered cut is waiting below the lower

lock gates for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is pulled to the end of the extended guidewall by helper boat or tow haulage for remake. The time savings is dependent on the head differential and location of discharge. At lower flows, when the head differentials are greatest, the time savings would be greatest. At higher flows, there would be little or no savings. On average, a savings of 0-2 minutes would be likely at most UMR locks. Larger time savings is possible at some of the IWW locks where head differences are greater. The average savings for both the UMR and IWW locks is 1 minute.

Remake of Double Lockage Tows (Outside of Chamber). A significant time savings can be achieved by allowing the two cuts of a double lockage to remake along the extended guidewall outside the limits of the lock chamber and thus allow the lock to be turned back for the next tow traveling in the same direction sooner (see Figure 2-4). The reduction in service time and the cost for extending guidewalls is addressed herein.

A turnback lockage occurs when the lock chamber is emptied or filled and the miter gates are opened to receive the next waiting tow traveling in the same direction as the first. The two tows must be traveling in the same direction so that the reconnection of the two cuts from the previous lockage can be completed along the guidewall while the second tow is locking its first, unpowered, cut through. A tow tied up to the guidewall during remake is an obstruction to a tow traveling in the opposite direction. Consequently, the time savings is more fully realized in conjunction with the N-up/N-down locking procedure discussed under the "Scheduling Program" measure. Even with the current locking policy, a significant opportunity exists to reduce delays at the locks by providing extended guidewalls due to a currently high percentage of turnback lockages (see Tables 1-1 and 1-2). This information shows the increase in percentage of turnback lockages paralleling the increase in commercial traffic from the upper river to the lower end of the study area on the Mississippi River. These trends are the same for the IWW locks. As traffic continues to increase, a greater number of turnback lockages will result.

Time Savings Estimate for Remake of Double Lockage. Section 4 shows the computation, using LPMS data, of the expected time savings of moving the remake out of the chamber. It was estimated that the average time savings for double lockage tows would be 16 minutes for upbound tows and 18 minutes for downbound tows. This savings represents a reduction in the existing tow remake and exit time for the second cuts of 22 and 24 minutes to about 6 minutes for both upbound and downbound tows after implementation of the extended guidewall measure. The potential benefits to setover and knockout singles locking tows are described in Section 4.

Conditions Affecting Implementation. Complete guidewall extensions are applicable to the UMR lock sites except Locks 15 and 19 because of the channel alignment and navigational safety concerns. Even if 1,200-foot guidewalls were possible at Lock 19, a 1,200-foot lock, no remake time savings could be realized since tows pass as a single lockage. Melvin Price Locks have 1,200-foot guidewalls. Complete guidewall extensions are implementable only at Peoria and La Grange Locks on the IWW. The other IWW locks have restrictions (some minor) to construction of guidewall extensions either upstream or downstream due to various site conditions. Section 4 details these restrictions. The only sites on the IWW where guidewall extensions are not recommended are Lockport and the lower guidewall at Dresden Island. Guidewall extensions at these locations restrict the flow area and are potential hazards to navigation.

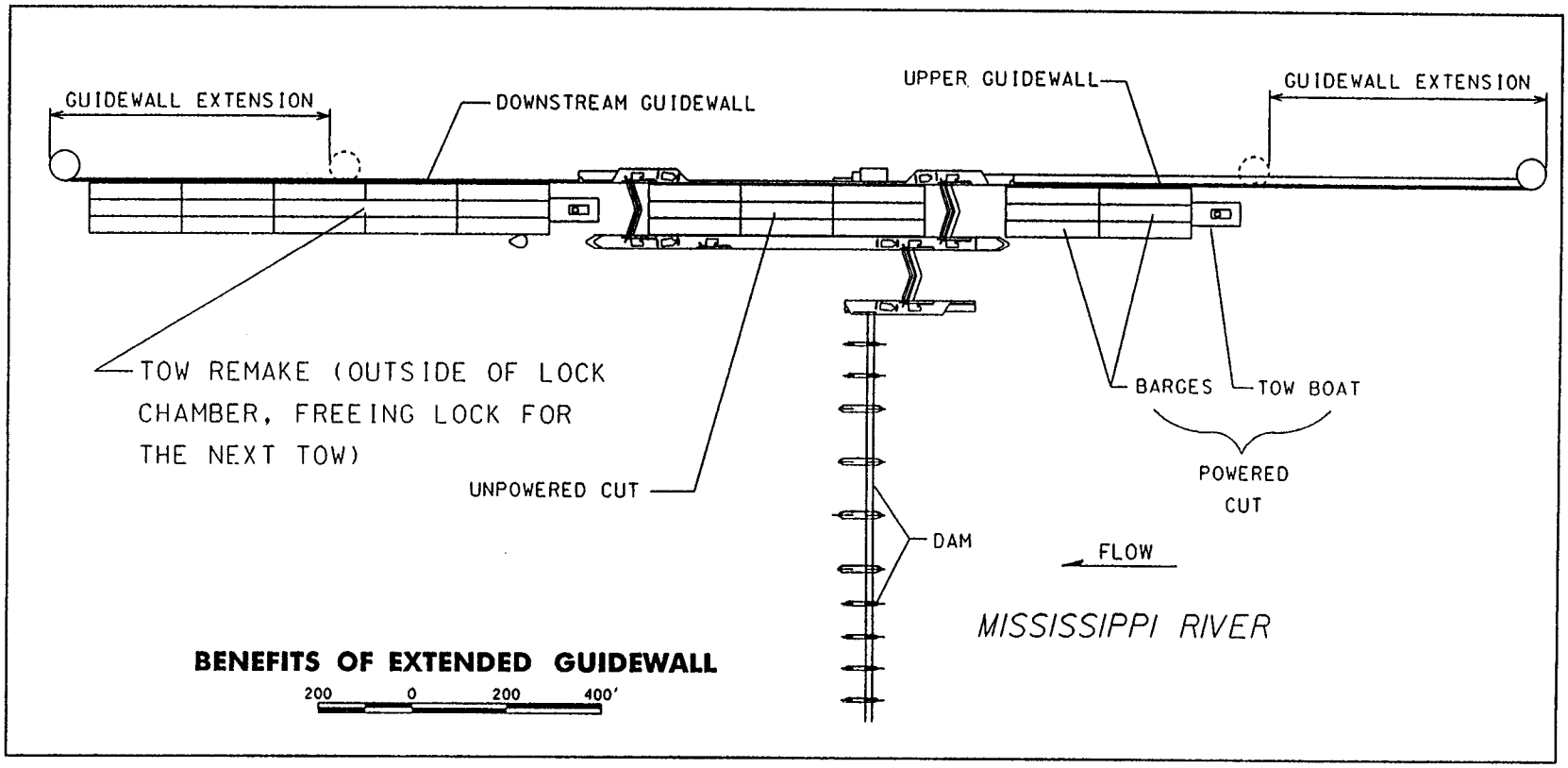


FIGURE 2-4: Benefits of Extended Guidewall

Cost of Extended Guidewalls. The descriptions of the guidewalls are included in the 1996 Conceptual Lock Designs report. The design is for precast concrete beams spanning sheetpile cells. Larger cells with greater span lengths are being considered for the upper guidewall extensions at the UMR lock sites. This allows for staged construction during several winter lock closures and eliminates impacts to the navigation industry during construction. The average cost for the permanent guidewall extensions (both upstream and downstream together) for a pile-founded guidewall at a UMR site is about $37 million. The average cost for a rock foundation (both upstream and downstream together) at a UMR site is about $33 million. The average cost for both guidewall extensions for the applicable IWW sites is $23 million. In addition, there are environmental impacts. Also, relatively high economic impacts to the navigation industry are expected during construction at the IWW lock sites. Year-round navigation on the IWW does not allow for staged construction during winter closure periods as is the case for the UMR lock sites. For more information on these impacts, see Section 4 of this report. In addition, annual costs of $30,000 per wall or $60,000 per lock were estimated.

Extending guidewalls with DeLong Piers is a lower cost alternative ($3.2 million per wall) than constructing permanent guidewall extensions. DeLong Pier wall extensions can be used in conjunction with switchboat assistance (see earlier discussion of switchboat measure). However, DeLong Pier guidewall extensions have inadequate stability for installation of tow haulage equipment, and outdraft flows under the upstream piers impact approaching or adjacent tows.

Relationship to Other Measures. Tow haulage or switchboats are needed in conjunction with permanent guidewall extensions to extract the first cut to the end of the extended guidewall. These combinations will allow for faster emptying of the chamber on downbound cuts and for the tow remake outside the lock chamber. Extended guidewalls enhance the N-up/N-down and self-help policies in minimizing lock transit time.

Conclusions. Extended guidewalls, when combined with other small scale measures such as tow haulage or switchboats, appear to be one of the most effective small scale measures for saving lockage time by reducing approach time and extraction time, allowing faster chamber emptying on downbound cuts, and remaking tows outside of the lock chamber.

Tow Haulage Equipment

Tow haulage equipment is the name given to any of a number of mechanical devices used to pull unpowered cuts of barges from the lock chamber. A form of tow haulage equipment is already in use at most of the lock sites in the study area. For this improvement measure, however, extended guidewalls are required plus new tow haulage equipment of one of several alternative designs to pull the first cut to the end of the extended guidewall. The tow haulage equipment transfers force from some land-based power source to the unpowered barges through a mechanical connection. The most common of these devices is a single-line cable winch, which is presently used at the UMR-IWW lock sites to extract cuts from the lock chamber. Two measures for improving the current tow haulage operation were carried forward for further analysis. These two measures, "Powered Traveling Kevel" and "Endless Cable," are briefly discussed below. More detailed information is available in Section 4. A related measure involving unpowered traveling kevels was added as an outgrowth of evaluating powered kevels.

▪ Powered Traveling 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. A powered traveling kevel is a rail-

mounted kevel which provides power to extract the unpowered cut of barges from the lock. The current winch system and length of cable are eliminated. A powered traveling kevel would have greater benefit if combined with a guidewall extension. Extending the existing 600-foot guidewalls to 1,200 feet would allow the powered cut to make up with the unpowered cut completely outside of a 600-foot lock chamber (freeing the chamber for the next tow in a turnback situation). An unpowered kevel ahead of and riding the same rail as the powered kevel would hold the head of the unpowered cut along the extended guidewall as the cut moved down the wall.

- **Endless Cable**

Endless cable systems extract unpowered cuts from the lock chamber by attaching the unpowered cut of barges to a fitting on the cable. This continuous cable is already in place and is powered to remove the cut. Endless cable systems eliminate the need to haul the cable off the drum in the current tow haulage systems. The unpowered cut is therefore removed more efficiently. An endless cable system would have greater benefit if combined with a guidewall extension to allow the powered cut to remake with the unpowered cut outside of the lock chamber.

Time Savings Estimates. The time savings associated with the improved tow haulage units is from the reduction in extraction time of the first cut. Since improved tow haulage assumes the presence of permanent extended guidewalls to maximize benefits, the additional cost and benefits of the guidewall extensions must be included in the final analysis of improved tow haulage.

The existing "unpowered" kevel/rail systems in the study area cannot provide any braking of the first cut. However, a tow haulage system that can travel the full length of the lock approach wall and can both pull the barges as well as provide braking to slow and stop the barge once out of the chamber, can improve the efficiency of the first cut removal process.

The 1990 LPMS data show the time for extracting all first cuts with the existing tow haulage system to average 14 minutes upstream and 17 minutes downstream for Locks 11 through 25 on the Mississippi River and 13 minutes upstream and 13 minutes downstream for Lockport Lock through La Grange Lock on the IWW.[1] With improved tow haulage, the estimated average extraction time savings are 5 minutes for UMR locks and 3 minutes for IWW locks. The average time savings for the UMR and IWW locks combined is 4 minutes in both directions. However, as noted below, the time savings for this lockage element would not likely be realized in the *total* lockage time, unless additional personnel are provided.

Conditions Affecting Implementation of Measure. Corps of Engineers Navigation Notice 1-1998 requires a minimum of three personnel for handling lines during double lockages. Generally, two deckhands ride the first cut of a double lockage as it is extracted from the lock chamber, moves down the guidewall and is tied off to await remake with the second (powered) cut. A third deckhand walks the guidewall with the first cut. Two of the deckhands must walk back to the powered cut to accompany it into the lock chamber (one deckhand stays with the first cut). With first cuts hauled to the end of guidewalls extended to 1,200 feet long, it is estimated that the powered cuts would have to wait for the deckhands about 14 minutes, negating the 3- to 5-minute savings (4 minutes combined average) in extraction time noted above. However, the provision of two additional deckhands/lock workers to travel with the cut would eliminate the 14-minute delay. See "Tow Haulage Equipment" discussion in Section 4 of this report for more information.

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[1] The LPMS data show higher mean extraction times for downbound cuts than upbound cuts at Mississippi River locks (and Peoria and La Grange Locks on the Illinois Waterway). This is because for these locks more downbound tows than upbound tows are loaded. The extraction times are typically higher for downbound cuts because there is more mass to move with a loaded cut and there is more water resistance when cuts are loaded to a deeper draft. It is reasonable to assume a similar time differential with improved tow haulage systems.

Cost of Improved Tow Haulage Equipment. Cost estimates are developed in Section 4. The costs of providing new tow haulage equipment on both the upstream and downstream guidewalls (extended to 1,200 feet long) ranges from about $1,025,000 to $1,110,000. These costs are based upon a pull/retard power mechanism for a traveling kevel. One winch pulls against the other at a reduced torque to maintain a constant tension in the line and prevent slack cable from occurring in the system. If the 600-foot-long existing tow haulage adjacent to the lock is also replaced, the total cost ranges from $1,440,000 to $1,520,000. These costs include 25 percent contingencies, 10 percent engineering and design, and 10 percent construction management. For the "system," an average cost of $750,000 is used for new tow haulage (pull/retard system) per guidewall extension. An estimated first cost of $100,000, along with $518,000 annually, would cover the expense of additional employees.

Relationship to Other Small Scale Measures. Improved tow haulage assumes the construction of permanent extended guidewalls, thus the cost of the guidewall extensions must be included in the evaluation of the tow haulage. Besides additional costs, however, guidewall extensions, as previously discussed, provide additional time savings as a separate improvement measure. In addition, the provision of additional personnel is highly recommended.

Conclusion. In summary, extracting the first cut faster with new tow haulage along extended guidewalls will not have a negative impact on the total lock transit time unless additional personnel are provided. However, as shown in Tables 2-6A and B, this measure, combined with reduced chambering time (faster emptying) on downbound cuts and remaking the tow along the extended guidewall, benefits turnback lockages by reducing the lock service time an average of 6 minutes for upbound tows and 9 minutes for downbound tows without additional personnel and 20 minutes for upbound and 23 minutes for downbound with additional personnel.

TABLE 2-6A: ESTIMATED AVERAGE TIME SAVINGS FOR POWERED TRAVELING KEVELS WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25

Delay Reduction	Double Lockages Benefits to Tows Waiting in Queue	Double Lockages Benefits to the Locking Tow
Pulling the unpowered cut	5 min both directions	5 min both directions
Entry second cut delayed waiting for crew	-14 min both directions	-14 min both directions
Remaking the tow (with extended guidewalls - turnback lockages only)	15 min upbound 18 min downbound	Tow still remakes, location is moved to end of the guidewall
Reduced chambering time	0-2 min downbound	0-2 min downbound
Total time savings potential	6 min upbound 9 min downbound	-9 min upbound -9 min downbound

TABLE 2-6B: ESTIMATED AVERAGE TIME SAVINGS FOR POWERED TRAVELING KEVELS WITH GUIDEWALL EXTENSIONS AND ADDITIONAL PERSONNEL AT UMR LOCKS 11-25		
Delay Reduction	**Double Lockages Benefits to Tows Waiting in Queue**	**Double Lockages Benefits to the Locking Tow**
Pulling the unpowered cut	5 min both directions	5 min both directions
Entry second cut delayed waiting for crew	No delay	No delay
Remaking the tow (with extended guidewalls - turnback lockages only)	15 min upbound 18 min downbound	Tow still remakes, location is moved to end of guidewall
Reduced chambering time	0-2 min downbound	0-2 min downbound
Total time savings potential	20 min upbound 23 min downbound	5 min upbound 5 min downbound

- **Unpowered Traveling Kevels**

Description of Measure. This measure was added as an outgrowth of discussions on the Extended Guidewalls and Tow Haulage Equipment measures. The use of unpowered traveling kevels is another measure that utilizes an extended guidewall to allow remake of tows outside of the lock chamber. This measure provides two rail-mounted kevels along both extended upstream and downstream guidewalls. These kevels are free-rolling and not attached to any cable/winch power system. With this alternative, the first cut of a double lockage is extracted from the lock chamber as is presently done with the existing tow haulage system (a single winch and cable system). In the extraction, the bow (front) of the cut is secured to the first kevel. The stern (back) of the first cut is attached to the second kevel after the first cut clears the miter gate recess and comes to rest, being tied off to a checkpost. Two of the three deckhands then walk back a maximum of 1,200 feet, as they do now, to accompany the powered second cut into the chamber. After the lock gates are opened, the powered cut faces up to the first cut. At this point, instead of completely remaking the cuts, as is presently done (with the powered cut occupying part of the lock chamber), only the two outside couplings are remade. The powered cut then pushes the first cut to the end of the 1,200-foot guidewall with the two kevels riding the rail, helping to keep the first cut along the guidewall (see Figure 2-5). In this scenario, the powered cut provides the power to move the first and second cuts clear of the lock chamber. Control of the first cut is ensured with bow and stern lines to the kevels and connection to the powered cut with the two outside couplings. When the stern of the powered cut clears the gate recess, the chamber can be turned back to receive the next tow traveling in the same direction, while the exiting tow completes its remake along the extended guidewall.

Time Savings Estimates. The time savings of this measure is a result of allowing the remake of the two cuts to be made outside of the lock chamber, thus freeing the chamber for service to the next tow. This savings is only realized for turnback lockages where the next tow to be locked through is going in the same direction. The time savings is maximized when used in conjunction with the N-up/N-down policy where a certain number (N) tows are locked through in one direction before N tows are locked through in the opposite direction. The time savings is the difference in the activity that takes place while occupying the lock; that is, it is the difference in the remake coupling time for remaking five wires versus the time for remaking only the two outside wires.

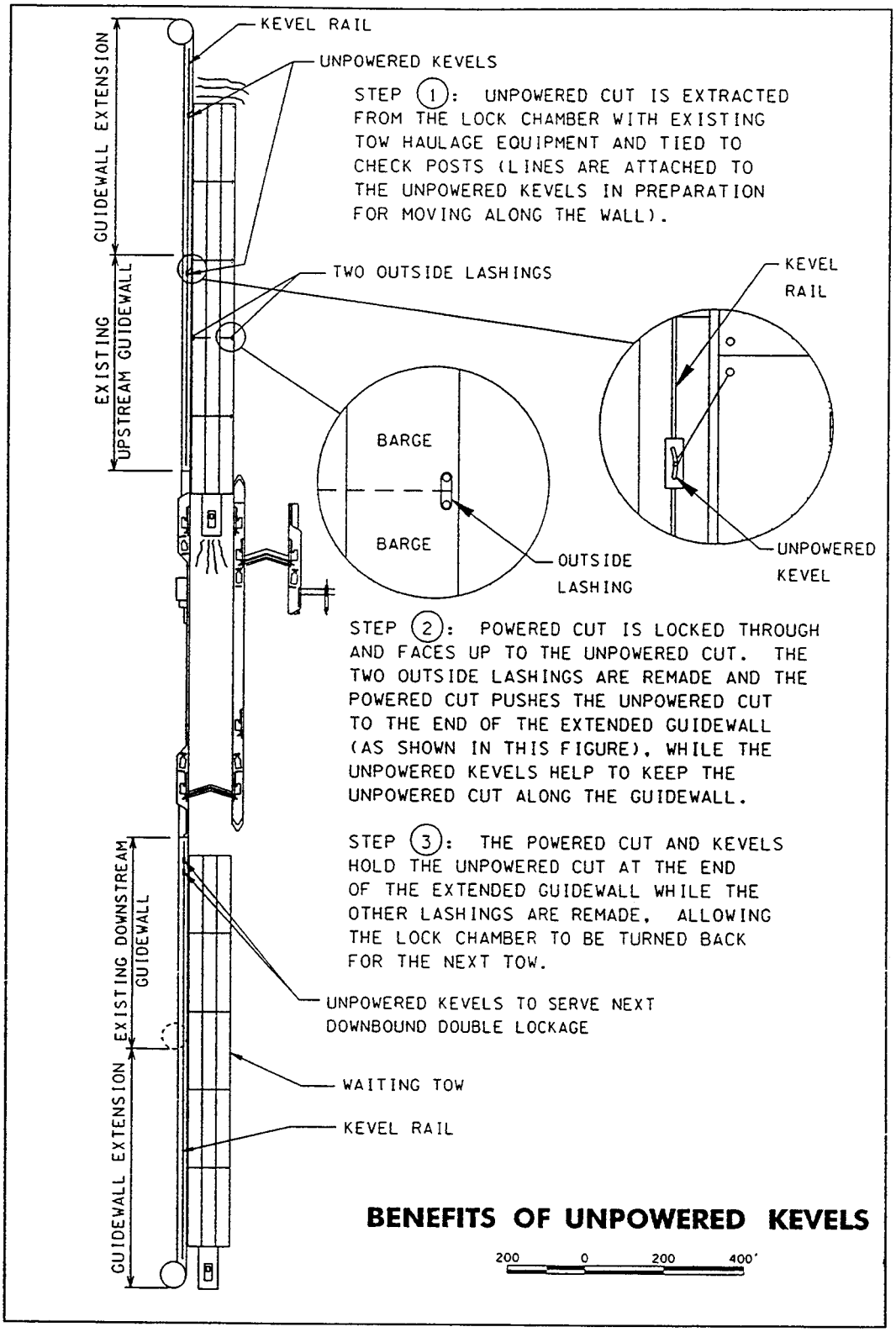

FIGURE 2-5: Benefits of Unpowered Kevels

A baseline estimate of 12 minutes for remaking five wires was determined earlier by a limited number of timed observations with a typical crew of three people. Each wire requires 6 minutes to remake, but with a crew of three, overlapping activities allow 5 wires to be completed in 12 minutes. With the use of the unpowered kevels, the two deckhands who walk back to accompany the powered cut through the lockage remake the two outside wires. The deckhands work simultaneously, each on one wire, requiring 6 minutes in total. Thus, the total time savings is the difference in the average estimated remake time of 12 minutes (for all five wires) and 6 minutes (the remake time for the two outside wires). This equates to a total average time savings of 6 minutes, which is assumed to be applicable to all turnback double lockages at all lock sites under study. Greater time savings, as discussed in Section 4, can be achieved for lockages with setover and knockout tows, 26 minutes and 7 minutes, respectively.

Using the 6-minute time savings and 1990 LPMS data, the average new exit time of the second cut for the UMR locks in the downbound direction goes from 23 minutes to 17 minutes and in the upbound direction goes from 20 minutes to 14 minutes. For the IWW locks, the average new lock exit time of the second cut in the downbound direction goes from 26 minutes to 20 minutes and in the upbound direction from 24 minutes to 18 minutes.

Conditions Affecting Implementation. Unpowered kevels are applicable at all lock sites where extended guidewalls are implemented. The existing kevel rail on the existing upstream guidewalls at locks within the study area can remain in place to reduce the implementation cost. Upstream kevel rails are present at all locks on the UMR except for the 600-foot auxiliary locks at Melvin Price Lock and Locks 27 and at Lock 19 which is a single 1,200-foot lock. Upstream kevel rails are also present at all locks on the IWW except for Lockport, Brandon Road, and Marseilles. Dresden Island Lock has kevel rails on both existing upstream and downstream guidewalls.

Costs. The estimated first cost for installing two unpowered kevels and a rail at a typical site is $240,000 for the upstream guidewall and $360,000 for the downstream guidewalls. In addition to the first cost, annual maintenance is estimated at $2,000 per unpowered kevel or $4,000 per lock. These estimates do not include the guidewall extension cost or the impacts to industry during the construction of the guidewall extensions at the IWW locks. Those additional costs are discussed in Section 4.

Relationship to Other Measures. Extended guidewalls with unpowered kevels eliminate the need for tow haulage or towboat power assistance to pull the first cut of double lockages for remake along an extended guidewall. The unpowered kevel measure would enhance the N-up/N-down policy to minimize lock transit time. All other small scale measures could be implemented in conjunction with unpowered kevels. DeLong Piers, which can be used as a temporary extension of a guidewall, can not be used as a foundation for tow haulage including unpowered kevels. Continual straight alignment of the kevel rail is needed for proper operation of the kevels, and this is difficult to maintain with a segmented DeLong Pier foundation.

Conclusion. Implementation of the unpowered kevels measure has an expected time savings for double lockages of about 6 minutes. While the percentage of setover and knockout lockages is low at most lock sites, the turnback exit time savings is substantial for these lockages. With a relatively low implementation cost and moderate time savings potential, this measure should be considered further for comparison with the other surviving measures.

Adjacent Mooring Facilities

Adjacent mooring facilities are structures that provide vessels a place to tie off while waiting for their turn to lock through. Without such facilities, the towboats may be forced to wait a considerable distance from the locks and must either push into the riverbank, which can cause erosion and damage to shoreline vegetation, or wait out in the currents of the river, which wastes fuel. Both options can cause scour of the bank by a vessel's propwash. The three basic types of mooring facilities are: mooring buoys, land-based moorings (or bank anchors), and mooring cells, each of which is described below. An additional form of mooring, made from spud barges, is discussed as part of the switchboat measure.

▪ Mooring Buoys

Description of Measure. Mooring buoy assemblies consist of two anchors connected to a concrete sinker which is connected to a large floating buoy with a heavy anchor/riser chain. The buoy is typically 12 feet in diameter, 3.5 feet high, and filled with polyurethane foam for buoyancy. The buoy is fitted with a mooring ring or other point to which a tow can attach a mooring line. A mooring buoy can be used in trial locations to determine the best location for a mooring cell which is immobile and more costly. A new buoy design (noncylindrical) is under development to make buoys more usable and accessible to waiting tows.

▪ Land-Based Moorings

Description of Measure. Land-based moorings consist of an anchor and chain located on land adjacent to the lock approaches. The anchor is buried in the nearby bank, leaving the chain and mooring ring available for use by the tows.

▪ Mooring Cells

Description of Measure. Mooring cells are constructed of sheet pile and are filled with earthen material and/or concrete. Mooring cells are preferred by industry because of their stability and ease of use. However, proper location of the cell is critical to its being used by tow operators. Achieving the proper location that suits all pilots, all river conditions, and all maneuvering techniques is very difficult. The cells are typically 30 to 40 feet in diameter and are fitted with a mooring ring or check posts for a point of attachment. Cells are preferred by industry, especially upstream of a lock because they provide a more positive tie-off for barges when a line boat is needed to assist with an emergency at the lock or is needed to pull other cuts from the lock chamber during an N-up/N-down or self-help scenario at the lock.

Existing Mooring Facilities and Alternative Improvements. Most lock sites in the study area do not have existing mooring facilities either above or below the lock or have limited facilities which could be augmented or improved. Sections 3 and 4 show the existing mooring facilities at the UMR and IWW locks as well as locations of new additional moorings closest to the locks. These locations were determined based on discussions with lockmasters and industry representatives (towboat captains/pilots) and review of prior reports.

Time Savings Estimates. Installation of adjacent mooring facilities benefits lock transit time if they are placed to enable tows to moor closer to the lock while waiting their turn to lock through. This reduces the approach time to the lock after a moored tow starts its approach as shown in Table 2-7. However, the total benefits are nearly double for exchange lockages since moving the mooring closer not only shortens the approach, but it also shortens exit times by a comparable

amount. Under present conditions, tows generally wait as close as they can to a lock. Installation of moorings where tows presently wait does not shorten the approach time, but having a dedicated mooring makes for safer operating conditions and moves tows off the riverbank, preserving shoreline vegetation. Also, fuel can be conserved if tows do not have to idle their engines to hold position (estimate 15 gal/hr to hold, 4 to 5 gal/hr idling out of gear).

Table 2-7 identifies lock sites where additional moorings will bring tows closer to the lock and save time on their approach following an exchange lockage.

TABLE 2-7: COST AND TIME SAVINGS OF NEW MOORING FACILITIES

Lock	RM (Lock Gate)	Dir.	Wait at RM Exist	Wait at RM New	Cost ($1,000's)	Miles Closer	Time Savings Doubles (min)[1/]
Upper Mississippi River							
12	556.6	UB	555.0LC	556.0LC	50	1.0	13
14	493.3	DB	494.6RC	493.7RB	500	0.9	12
14	493.3	UB	489.7LC	492.5LC	500	2.8	37 (35% of the time)
16	457.2	UB	455.5LC	456.2LC	50	0.7	(*)
18	410.5	UB	409.0RB	409.7RB	50	0.7	9
20	343.2	DB	346.0LB	345.0LB	500	1.0	(*)
20	343.2	UB	342.0LC	342.8LC	50	0.8	11
22	301.2	DB	303.6RB	302.3RC	500	1.3	(*)
22	301.2	UB	300.3RB	300.8LC	50	0.5	7
24	273.4	DB	274.5RB	274.0RB	500	0.5	7
25	241.5	UB	240.6RB	241.3LC	50	0.7	9
Melvin Price	201.6	UB	199.6LB	200.6LB	50	1.0	13
Illinois Waterway							
La Grange	80.2	DB	80.9RB	80.4RB	500	0.5	7

UB = upbound, DB = downbound, LB = Left Bank, RB = Right Bank, LC = Left Channel, RC = Right Channel
(*) = Next mooring location (not closest to lock)
[1/] Approach time savings shown are for exchanges of double lockage tows. Similar savings for exchange exits are anticipated. Savings of roughly one-half this amount are anticipated for single lockage tows.

Conditions Affecting Implementation. There are few conditions affecting implementation of mooring facilities at locations shown in Table 2-7. All locations can be accessed without dredging or other channel excavation.

Cost. The estimated first cost for mooring buoys and land-based moorings is $50,000 each. This is based on historical costs for placement of these types of moorings. The first cost of a mooring cell is estimated at $500,000. In addition, annual costs of $5,000 per buoy and $20,000 per cell are anticipated. These costs are considered to be fairly consistent for mooring placements at any of the above lock sites.

Relationship to Other Measures. Adjacent moorings are complementary to most other measures. Channel improvements can impact the location of mooring facilities.

Conclusion. For those sites that presently do not have a mooring facility placed as close as is practical, adding a properly placed mooring facility would result in time savings for exchange lockages. In addition, mooring facilities can have environmental benefits from preservation of bank vegetation and reduced fuel consumption. For turnback lockages, the environmental benefits may be applicable; however, no significant lockage time savings is expected. As with most measures, the actual benefits depend upon the specific conditions at a given site.

Crew Elements

Crew elements refer to the feasibility of improving the process of breaking and remaking tows involved in double lockages. Crew elements are identified here as a small scale structural measure because of its implied relationship to any structural modification in the existing barge coupling mechanism. Two measures were recommended for detailed analysis in the "General Assessment of Small Scale Measures" interim report dated June 1995. The first measure is the use of universal couplers and hand winches. The development of a simple, quick-operating, and universally adaptable coupler for joining barges could save considerable time in breaking and remaking tows. The second measure is to require a minimum crew size with crew training. A well-trained crew that is large enough to handle a lockage can save time in the breaking and remaking of tows. Typically, the recoupling of barges takes more time than the uncoupling; therefore, the focus of this effort was on identifying an improvement in the recoupling time.

In addition to universal couplers and hand winches and minimum crew size with crew training, other measures with potential to reduce the remake time of double lockages were identified in the September 1995 *Universal Couplers and Crew Training* interim report of the Navigation Study. These additional measures include permanent deck winches, additional personnel, and power operated ratchets. Unlike the "minimum crew size" measure which would ensure a minimum staff traveling with a tow, the "additional personnel" measure would assign personnel to a lock site to attend to all tows, not travel with a tow. Each is described below with estimated cost and approximate time savings, after the following discussion of the current recoupling times.

Current Recoupling Times. The typical deck crew that handles the coupling and uncoupling of barges usually consists of three people—the mate and two deckhands. These three are responsible for remaking the two cuts after a double lockage. This coupling typically consists of 5 wires, each wrapped 3 to 4 times across the gap between barges. From the time when the cuts bump together until the tow leaves the wall, the major activity is remaking the 5 wires. Based on timing data collected, this process takes an average of 12 minutes with considerable variability (during the timing data collection the observed times varied from 7 minutes to about 18 minutes). The elements of this process include approximately 3 minutes to lay the wire and 3 minutes to tighten it. Since each of the two deckhands has to work on two wires, this 6 minutes per wire becomes 12 minutes for the total recoupling.

This remake time causes significant delays at many locks in the study area during peak operation times. A reduction in the remake time is applicable to all double lockages and benefits all tows in the queue.

▪ Universal Coupler and Hand Winches

Description of Measure. Industry continues to pursue improvements to the barge coupling system for time savings and increased worker safety. The aim of these efforts is toward a new coupling mechanism for use at all points in the tow, not just the couplings that are worked during a double lockage. Since the development of new hardware and coupling procedures will benefit the towing industry as a whole, the industry will continue its interest and support of the development of such improvements.

The September 1995 *Universal Couplers and Crew Training* report concluded that a universal coupler could be operated quickly, resulting in time savings. However, the lack of existing technology for this application, combined with the investment cost to develop such a device, makes the recommendation of this alternative untenable.

▪ Minimum Crew Size with Training

Description of Measure. This measure provides an experienced crew that is large enough to handle a lockage and save time in the breaking and remaking of tows. Training could reduce the variability involved in the make-up process.

Industry currently provides the required crew size of 3 people (the captain/pilot can not act as a deckhand) to handle lines during a double lockage as required by the Corps of Engineers' Navigation Notice 1-1998.

Crew training is commonly handled as on-the-job training, though formal training programs are provided by some of the larger barge lines. The Coast Guard is responsible for policing the waterways and ensuring their safety. However, the Coast Guard does not require testing or licensing requirements for deckhands on the inland waterways. One way crew skill is reflected is in the time consumed in the coupling process. However, there is no clear indication that one form of training produces crews with greater skill levels than another form of training. As reported in the 1995 *Universal Couplers and Crew Training* report, the majority of the towing companies have responsible staffing and equipment standards, adequate to satisfy any reasonable regulation. Thus, "standardization" of training for crews is not recommended at this time as a method of reducing tow remake time.

▪ Permanent Deck Winches

Description of Measure. Some barge lines keep their equipment dedicated to their own fleets and have chosen to mount deck winches on the forward decks of all their barges. The deck winches are used in lieu of the steamboat ratchet to tighten the primary fore/aft couplings. Each winch is permanently welded to the deck of the barge and an ample length of wire rope is spooled on the drum of the winch. The speed of the uncoupling, although not a significant element of total lockage time, could be substantially reduced. A deckhand must tighten the wheel of the winch slightly to permit the removal of the locking paw, releasing the wheel. This simple step puts sufficient slack in the line to permit its removal from all the timberheads and kevels.

Once the two halves of a tow are faced up, the recoupling can be done, tightening the lines by cranking a wheel on the winch. Tightening a single line with a winch will take only a few minutes; the operation is much cleaner than the procedure currently used by the majority of tows.

Time Savings Estimate. Recoupling with the use of deck winches is estimated to require 8 minutes, a savings of 4 minutes over the present method of recoupling. The total time of 8 minutes is broken down as 2 minutes per wire to lay times 2 wires per person plus 2 minutes per wire to tighten times 2 wires per person. In the LPMS data base, recoupling times are included in the "exit" times. With this measure, exit times would be expected to be lowered by about 4 minutes.[2]

Conditions Affecting Implementation. It is reasonable to ask why all towing companies have not equipped their barges with deck winches. The answers from industry are three-fold. First, the deck winches are expensive. Second, the fleet is essentially interchangeable and a barge owned by one company may frequently be found in the tow of another company. Therefore, the assumed benefit would not necessarily be accrued by the company that made the investment. Third, for the system to work, it would require a costly mandate that all barges (at least those to be used for double lockages) be retrofitted with deck winches or that new barge construction provide for permanent deck winches.

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[2] LPMS data for 1990 show the exit time for all double lockages to be from 20 to 27 minutes on the Upper Mississippi River and from 26 to 35 minutes on the Illinois Waterway.

Costs. The current practice of most companies is to exchange barges on a regular basis for economic reasons. It was therefore assumed that each barge in operation would need to be retrofitted with deck winches. Without this provision, the benefits would be lost in reconfiguring tows to match up barges equipped with deck winches.

The cost of a single deck winch was estimated to be $1,000 for equipment and installation. Based on an industry fleet of 13,000 barges and 4 winches per barge, the initial capital cost would be $52 million. Maintenance costs are expected to be comparable to those costs for the existing barge coupling system. In addition, annual maintenance costs of $400 per barge would also be required.

Relationship to Other Measures. Permanent deck winches are complementary to other small scale measures, but crew element measures themselves seem to be mutually exclusive. However, the combination of permanent deck winches and additional personnel could be considered.

- **Additional Personnel**

Description of Measure. There are five wires to connect the first and second cuts of a tow, but only three deck personnel on duty to make the connections. Therefore, each of the deck personnel have to take responsibility for one or two of the connections. If two additional personnel were available at the lock, each one could be responsible for just one of the connections. Since all five connections would be made concurrently, the total remake process time could be reduced by one-half. When the coupling process is completed, the two additional deckhands would return to the top of the guidewalls and await the next tow.

Time Savings Estimate. Recoupling with the use of additional personnel is estimated to require 9 minutes, a savings of 3 minutes over the present recoupling operation. The total time of 9 minutes is broken down as 3 minutes to lay the wires, 4 minutes to tighten them, and 2 minutes for the extra personnel to exit the tow (leaving the recoupling points and climbing up the ladder).

Conditions Affecting Implementation. This proposed efficiency measure would assign experienced deckhands to each of the locks in the congestion area. It is estimated that there is a sufficient pool of experienced deckhands that would fill these positions. One issue to be resolved is who would be the employer of these workers. The following are three alternative resolutions to this issue:

- They could be government employees;
- They could be employees of a local harbor service or switching company that would be under contract to the government; or
- They could be employees of a local harbor service or switching company whose services would be billed to the towing industry for each use.

Utilization would be required during periods as directed by the lockmaster (communicated through a Corps of Engineers Navigation Notice) in the same way that helper boats are currently required for specific river conditions.

Costs. There are no capital expenditures to implement this measure. The costs would be the annual cost of the part-time or contract-hire personnel. Assuming that the additional personnel are required to be at the locks in the congested area 24 hours a day during the peak traffic periods, the cost is estimated at $1,200/day/lock (2 employees x 24 hours/day x $25/hr). The $25 per hour cost

assumes a multiple of 2.5 times the average wage for this type of work to include the anticipated indirect administrative and operational costs.

Relationship to Other Measures. Additional personnel is complementary to other small scale measures, but crew element measures themselves seem to be mutually exclusive. However, the combination of permanent deck winches and additional personnel could be considered.

- **Power Operated Ratchet**

Description of Measure. A power operated ratchet is a compact device using a 4-horsepower gas engine to power a hydraulic drive system which operates a specially designed wrench head to engage the steamboat ratchet. The device is portable and can be stationed on the center barge at the break couplings. The device allows one deckhand to follow behind the other two deckhands who are laying wires and to tighten each wire in turn in 30 seconds to less than a minute per wire. The unit improves safety by eliminating the use of cheater pipes and requiring less physical labor. However, the unit is heavy (32 lbs.) and could lead to injury if mishandled.

Time Savings Estimate. Recoupling with the use of power operated ratchets is estimated to require 7 minutes, a savings of 5 minutes over the present method of recoupling. The total time of 7 minutes is broken down as 3 minutes to lay the wires plus 4 minutes to tighten them.

Conditions Affecting Implementation. Recently the towing industry has started testing the power operated ratchet with somewhat mixed opinion. There is no known condition adversely impacting implementation of this measure other than safety from mishandling.

Costs. Each power operated ratchet costs about $7,500. Each double lockage tow would need one unit. The learning curve to operate the ratchet is reportedly short, requiring about three or four lockages of on-the-job training to be efficient. An option would be a lock provided power ratchet instead of tow provided. This would necessitate the placement of a ratchet with a hoist at both the upper and lower guidewalls at the point where the couplings are remade. A lock person would lower the ratchet after the first cut is tied off along the guidewall. After the second cut faces up to the first cut, the ratchet is available for tightening the wires. The lock person would then raise the ratchet after five of the six couplings were remade. The tow line would then be released from the wall and the sixth wire remade using the present procedure (cheater pipe) for tightening the wire.

The first cost is estimated at $172,500. This includes $22,500 for the three ratchets (one standby) and $75,000 for installation of a hoist mechanism at each guidewall. An additional lock person would be needed to operate the hoist on a 24-hour basis. This would be an added annual cost of $259,000.

Relationship to Other Measures. The power operated ratchet is complementary to other small scale measures, but excludes the other two crew element measures: Permanent Deck Winches and Additional Personnel.

- **Conclusion**

Table 2-8 summarizes the advantages and disadvantages of the three crew element measures discussed above.

TABLE 2-8: SUMMARY OF CREW ELEMENT MEASURES

Measure	Advantages	Disadvantages
Deck Winch Time Savings: 4 min First Cost: $4,000/barge, system cost	Saves time Eliminates steamboat ratchet Safer to operate Secondary time/cost benefits Proven use (petroleum barges)	Major capital expenditure Operational benefit not always realized by investor Used by many companies Stays with barge, not towboat Requires higher maintenance
Additional Personnel Time Savings: 3 min Cost: $1,200/day/lock	Saves time Seasonal flexibility No permanent modifications No capital investment costs Minimal training required	Availability when needed Organizational/pay arrangement Some non-productive time Reduced safety to board and depart the tows
Power Operated Ratchet Time Savings: 5 min First Cost: $7,500/unit/tow provided; $172,500/lock provided, plus $259,000 additional annual cost	Saves time Can be safer to operate than cheater pipes No permanent modifications Proven use (by few towing companies) Portable Cost	Short-term history of operation Heavy and could lead to injury if mishandled

As summarized in the above table, all measures provide a time savings. The relative low first cost, highest time savings, and the reported successful testing of the tow provided power operated ratchet make it appear to be the best of these crew element measures. However, injury from mishandling is a concern, and usage of the tool would be at the discretion of towing companies. As a result of these concerns, further review of these measures, as well as verification of whether these measures fall in the with- or without-project condition, is needed.

Approach Channel Improvements

Approach channel improvements can consist of many different measures or combinations of these measures to increase safety and reduce the approach time to a lock. Approach channel improvements are usually made within a 1.5-mile travel distance from the lock. The 1995 *General Assessment of Small Scale Measures* report listed several potential measures under the category heading of "Improvements to Approach Channels." These included:

Approach Channel Widening/Realignment
Adjacent Mooring Facilities
Funnel-Shaped Guidewalls
Wind Deflectors
Extended Guidewalls
Add Guide Cells
Reconfigure Bullnose
Radar Reflectors
Electronic Guidance System

The *General Assessment* report screened most of the above from further consideration because they were not expected to reduce delays (congestion) at locks or be economically inefficient. Approach channel widening/realignment was not recommended because it was

deemed to be not cost effective. Adjacent mooring facilities and extended guidewalls were recommended for further analysis (and were addressed previously in this section).

Navigation model testing of Locks 22 and 25 was later conducted at the Corps of Engineers Waterways Experiment Station (WES). From the model studies it became apparent that the addition of approach channel improvements could improve the path that the downbound tow travels when approaching a lock and provide significant savings in approach times. In addition, the cost of the channel improvements, relative to the time savings achieved, appeared to be a good value. Therefore, it was decided to revisit the cost and performance of approach channel improvements as a small scale measure of reducing traffic congestion. The following paragraphs summarize the findings of the further investigation into approach channel improvements.

Improvements Evaluated. Approach improvements included not only approach channel improvements but structural improvements or additions to the lock facility as well as extended guidewalls or new 1,200-foot guardwalls which alone provide incremental time savings benefits to the lock approach at some locks. The evaluated improvements are listed below, generally in order of increasing magnitude of time savings.

- Extended guidewalls
- Channel improvements
- Extended guidewalls plus channel improvements
- Location 3 guardwall alone (auxiliary lock guardwall)
- Location 2 guardwall alone (existing lock guardwall)
- Channel improvements plus a location 3 guardwall
- Extended guidewalls plus channel improvements plus a location 3 guardwall
- Channel improvements plus a location 2 guardwall

Without site-specific model studies, there is a limited basis for estimating the time savings that would be achieved by these measures at each site. Due to the uncertainties in quantifying potential time savings, the study team held a lock approach assessment workshop to collectively assess the potential approach improvements and associated time savings. Participants included Corps of Engineers staff from various offices, including the WES. Field data, physical and numerical model results, and the experience of the team members were the basis for approximating the approach time savings. A rating system was developed for the approach improvements and was applied at each of the UMR lock and dam study sites. The benchmark for this rating system is the maximum improvement obtained in the Lock and Dam 22 physical model testing. This site currently has the longest fly approach times (i.e., approaches that are not influenced by other tow movements). Therefore, the best improvement at Lock and Dam 22 is thought to be the upper limit of improvement at other sites.

In the Lock and Dam 22 physical model, maximum improvement achieved for the typical (50% duration) flow was a 35 percent reduction in the downbound approach time for Lock and Dam 22. Each of the above improvements was rated on a 0 to 10 scale representing the relative level of improvement. With this scale, a rating of 10 equals 35 percent improvement and a rating of 0 is no improvement. In general, the percent time savings equals the rating divided by 10, times 35 (e.g., a rating of 1 is estimated to yield 1/10 x 35 = 3.5 percent improvement). The estimated percent savings was then multiplied by the known approach times from the LPMS timing data and that value (savings in minutes) was subtracted from the approach time to give the new approach time.

Improvements to existing upbound approaches and their potential time saving, although less significant than downbound approach improvements, were also evaluated on the same 0 to 10 scale. Upbound approach improvements include extension of the lower guidewall, channel improvements, and combinations of these.

Table 2-9 shows the 0 to 10 scale rating for each of the approach improvements by lock site from which the percent savings was computed. The write-ups and summary tables in Section 4 show the conversion to minutes saved by lock. The hydraulic conditions of the IWW are different than those of the UMR. The IWW is narrower and the outdraft above the locks is not as severe as on the UMR. Therefore, the above scale based upon Lock 22 model study results was not considered applicable to the locks on the IWW since approach channel improvements are aimed primarily at reducing the effects of outdraft on the lock approach times. The 0 to 10 scale shown for the IWW lock sites in Table 2-9 is used only to identify the relative magnitude of potential improvements. The IWW improvements generally provide a safer lock approach.

With the exception of improving the downbound approach canal to Marseilles Lock, the reduction in lock approach time on the IWW is considered negligible. Additional navigation model studies of the IWW may identify potential approach time savings from these measures, including a realignment of the upper approach channel at La Grange Lock.

Each of the eight approach channel improvements (or combinations of improvements) are described below. Cost and time savings estimates for the eight improvements are also discussed.

▪ Extended Guidewalls

Description of Measure. Under this measure, the existing upstream and downstream 600-foot-long landside guidewalls are extended to 1,200 feet long (see Figure 2-4).

Time Savings Components. As previously discussed, the actual total time savings associated with extended guidewalls can be broken down into four components: the reduction in approach time; the reduction in the extraction time of the first cut of a double lockage (when used with tow haulage or additional towboat power); the reduction in chambering time from faster emptying of the chamber on downbound cuts; and the time saving of allowing the remake of the double cut to occur outside the lock chamber along the extended guidewall. The latter three were previously discussed. The reduction in approach time is addressed here.

Upstream guidewall extensions allow tows to be in a more controlled state farther up the approach, lessening the impacts from dam outdraft on their downbound approach to a lock. The upper extension provides a larger target for tows to steer for and easier maneuvering of their stern to the guidewall for securing a line to the wall and working the head of the tow to the wall for proper alignment and entry into the lock chamber. Downstream guidewall extensions also provide a larger landing surface for upbound tows, but these tows are typically not subjected to outdraft.

Site-Specific Limitations. Complete guidewall extensions are applicable to the UMR and IWW lock sites, except as noted on page 2-27. At some sites, guidewall extensions benefit the remake time, but do not improve the approach time.

Cost. Construction costs by lock site are in presented in Section 4 of this report. The first costs range from about $30 to $40 million per site for both the upstream and downstream walls at UMR Locks 11-25. Annual maintenance costs average $30,000 per wall extension. The environmental impacts also must be added. Guidewall extension costs are less for the IWW locks, but impacts to navigation are high since there is year-round navigation on the IWW. IWW locks are not closed during the winter months.

TABLE 2-9: RELATIVE IMPROVEMENT OF INDIVIDUAL AND COMBINATIONS OF "CHANNEL" IMPROVEMENTS

UPPER MISSISSIPPI RIVER LOCKS

	UPPER LOCK APPROACH								LOWER LOCK APPROACH		
LOCK. NO	1 EXTENDED GUIDEWALL	2 CHANNEL IMPROVEMENT	3 1+2	4 LOC 3 GRD WALL	5 LOC 2 GRD WALL	6 2+4	7 1+2+4	8 2+5	1 EXTENDED GUIDEWALL	2 CHANNEL IMPROVEMENT	3 1+2
25	0 to 1	2 to 3	2 to 4	3 to 4	NR	5 to 6	6 to 7	9 to 10	0 to 1	3 to 4	4 to 5
24	0 to 1	3 to 4	3 to 5	3 to 4	2 to 3	5 to 6	6 to 7	9 to 10	1 to 2	2 to 3	3 to 4
22	0 to 1	3 to 4	3 to 5	3 to 4	NR	5 to 6	6 to 7	9 to 10	0 to 1	NR	NA
21	0 to 1	3 to 4	3 to 5	NR	NR	5 to 6	6 to 7	8 to 9	1 to 2	NR	NA
20	0 to 1	3 to 4	3 to 5	NR	NR	5 to 6	5 to 7	9 to 10*	0 to 1	3 to 4	3 to 5
19	NA	NR	NA	NA	4 to 6	NA	NA	3 to 4 MOD GRWL	1 to 2	2 to 3	4 to 5
18	2 to 3	1 to 2	3 to 5	NR	NR	NR	NR	NR	2 to 3	NR	NA
17	0 to 1	3 to 4	4 to 5	4 to 5	9 to 10	5 to 6	6 to 7	NR	NR	3 to 4	4 to 5
16	0 to 1	5 to 6	5 to 6	NR	NR	6 to 7	6 to 8	9 to 10	2 to 3	2 to 3	2 to 4
15	NR	5 to 6	NA	NR	NR	6 to 7	NR	8 to 10	0 to 2	2 to 4	3 to 5
14	0 to 1	3 to 5	3 to 5	NA	NR	NA	NA	8 to 10*	2 to 3	0 to 1	3 to 4
13	0 to 1	NR	NA	NR	NR	NA	NA	NA	0 to 1	NR	NA
12	0 to 1	NR	NA	5 to 7	9 to 10	NA	6 to 8	NA	0 to 1	1 to 3	3 to 5
11	NR	3 to 5	3 to 5	3 to 4	NR	5 to 6	5 to 7	8 to 10	0 to 2	NR	NA

Col 8 (2+5) includes removal of the existing guide wall and bank shaping

Example of estimated time saving for Lock 25 channel improvements

0.2 x 0.35 x 23.8 = 1.7min. (minimum potential saving); 0.3 x 0.35 x 23.8 = 2.5 min. (maximum potential savings)

0.2 = 20% of total potential savings

0.35 = 35% total potential saving based on field and model data for L/D 22

23.8 = mean approach time from lock timing data (1990 double lockages-downstream direction-fly approach)

ILLINOIS WATERWAY LOCKS

	UPPER LOCK APPROACH					LOWER LOCK APPROACH		
LOCK	1 EXTENDED GUIDEWALL	2 CHANNEL IMPROVEMENT	3 1+ 2	4 LOC 3 GRD WALL	5 LOC 2 GRD WALL	1 EXTENDED GUIDEWALL	2 CHANNEL IMPROVEMENT	3 1+2
LA GRANGE	0 to 2	1 to 3	2 to 4	NA	8 to 10*	0 to 1	1 to 2	1 to 3
PEORIA	2 to 4	1 to 3	3 to 5	NA	NR	0 to 1	NR	NA
STARVED RK	NR	NR	NA	NA	NR	0 to 3	7 to 10	7 to 10
MARSEILLES	NR	0 TO 5; 10	NA	NA	NA	1 to 3	NR	NA
DRESDEN IS	1 to 3	NR	NA	7 to 9	8 to 10	NR	3 to 7	NA
BRANDON RD	NR	0 to 3	NA	NA	NR	NR	1 to 3	NA
LOCKPORT	NR	NR	NA	NA	NR	NR	NR	NA

NR = Not recommended, NA = Not Applicable

* Requires extensive channel excavation for an existing lock guardwall (loc2).

Approach Time Savings Estimates. Except for Lock 18, whose downbound approach times would be expected to improve (i.e., decrease) 2 to 3 minutes, the other UMR lock sites are expected to improve by 1 minute or less. The upbound approach improves by an average of 1 minute. The site-specific approach time improvements are tabulated in Table 4-46. The improved approach times were determined using the average relative improvement ratings from column 1 of Table 2-9. Approach times are not expected to decrease for the IWW locks.

Conclusions/Summary. Extending the existing lock guidewalls allows for a safer lock approach and slightly reduces the lock approach time. Guidewall extensions provide yet a greater reduction to the overall lock transit time when combined with other small scale measures to extract the first cut of a double lockage faster from the lock chamber and to allow for tow remake outside the chamber along the extended guidewall.

- **Channel Improvements**

Description of Measure. Channel Improvements can be one or several additions to the approach channel to better align the tow with the lock before the bow of the tow gets to the lock approach wall. A safe and efficient lock approach is important in the overall locking process. The locks, built 50 to 60 years ago, and their lock approaches were not designed to handle the size (length) of today's tows. Additional transit time is added to the locking process when tows maneuver excessively to align with the lock chamber. This can be due in large part to unfavorable cross currents or an inadequately aligned approach channel or a combination of both and other factors requiring tow captains/pilots in some cases to bring the tow to a stop, back up a distance, and then proceed forward to the lock (a "**flanking**" maneuver).

Downbound tows have greater approach difficulties than upbound tows. This is because of the outdraft which is common at most UMR locks. An outdraft is a current that flows from the upstream shoreline across the lock approach to the dam gates. This current requires tows to flank their approach for some distance above the lock, maneuvering their **stern** to the shoreline as they approach the lock guidewall. Outdraft is especially severe during higher than normal river flows when currents are swifter. For upbound tows, the flow, which spreads out below the dam toward the shoreline, helps push the tow to the lower landside guidewall, thus making for an easier upbound approach most of the time. Sometimes this current pins a tow along the lower guidewall, making downbound exits from the wall difficult.

In general, a straight approach of three tow lengths or 3,600 feet from the end of the approach wall (a 1,200-foot guidewall or a 1,200-foot guardwall) is desirable for the downbound approach. Two tow lengths or 2,400 feet is considered a minimum for the downbound approach. This criteria can be relaxed for the upbound approach on a site-specific basis since tows are not subjected to a severe outdraft.

Outdraft is not as severe a problem at locks on the IWW, especially at locks above Peoria Lock. Peoria and La Grange Locks both have wicket gate dams which allow open pass travel (bypass the lock) when the wickets are lowered during high river flows. The two-tow length criteria can be relaxed for the downbound approach as well as the upbound approach.

Sample Measures. Figure 2-6 shows a sample of the various measures being considered to provide a better approach channel. A brief description of each measure is provided below.

Submerged Dikes (groins) are placed above the lock to reduce the magnitude of the outdraft. They are constructed of rock and their top elevation is a minimum of 15 feet below pool elevation. If the water is deep enough, 20 feet is preferred.

Dike Fields are placed upstream of the lock to reduce the outdraft. They are constructed of rock and their top elevation is usually 2 feet above pool elevation. They are placed perpendicular or at a slight angle to the shoreline. The distance between the dikes varies, but commonly they are placed about 1,000 feet apart.

Vane Dikes are placed parallel to the channel to reduce the current to the dam from the shoreline (outdraft). They can be used when the distance from the riverbank to the channel's edge is too far, making placement of dikes from the shoreline uneconomical. These dikes are constructed of rock with the crest 2 feet above normal pool elevation. They are set back from the channel and have gaps between them to allow some passage of flow.

Dredging/Bank Excavation is recommended if the channel needs to be shifted to better align with the lock, especially for the downbound approach, where a straight alignment is desired for two tow lengths (2,400 feet) above the lock approach wall. Dredging/bank excavation can be recommended downstream to make the approach/exit more efficient near the approach wall.

Trail Dikes are angled off the downstream end of the riverward lockwall to keep flow from pinning downbound tows on the lower approach wall, making their exit difficult. These dikes are 50 to 100 feet long and are constructed of rock. A short concrete wall can be a better solution.

Applicability to Lock Sites. Section 4 contains a description of the alternative measures that are being considered for each site.

Cost and Performance. The estimated costs and performance (i.e., improved approach times) for channel improvement measures are summarized in Table 4-47. At sites where channel improvements are applicable, the first costs vary from about $200,000 to about $5 million. At Lock 16, the cost is as high as $14 million if the upper channel is relocated. In addition, annual maintenance costs ranging from $8,000 to $680,000 per approach also are required. These costs do not include environmental impacts which must be added. There are no impacts to navigation during placement of channel improvements. Downbound approach times decrease by an average of 3 minutes (range 1 to 6 minutes) at the applicable lock sites. Marseilles Lock is an exception where savings of approximately 60 minutes or more are possible on roughly 25 percent of exchange lockages (30 minutes savings in upbound exits/30 minutes savings in downbound approaches). Likewise, upbound approach times decrease by about 2 minutes at applicable sites. The improved approach times were determined using the average relative improvement ratings from column 2 of Table 2-9.

Conclusions/Summary. The estimated savings in lock approach time at some locks is significant with channel improvements. Physical model testing should be considered to determine and verify the improvements needed to provide the most efficient navigation approach.

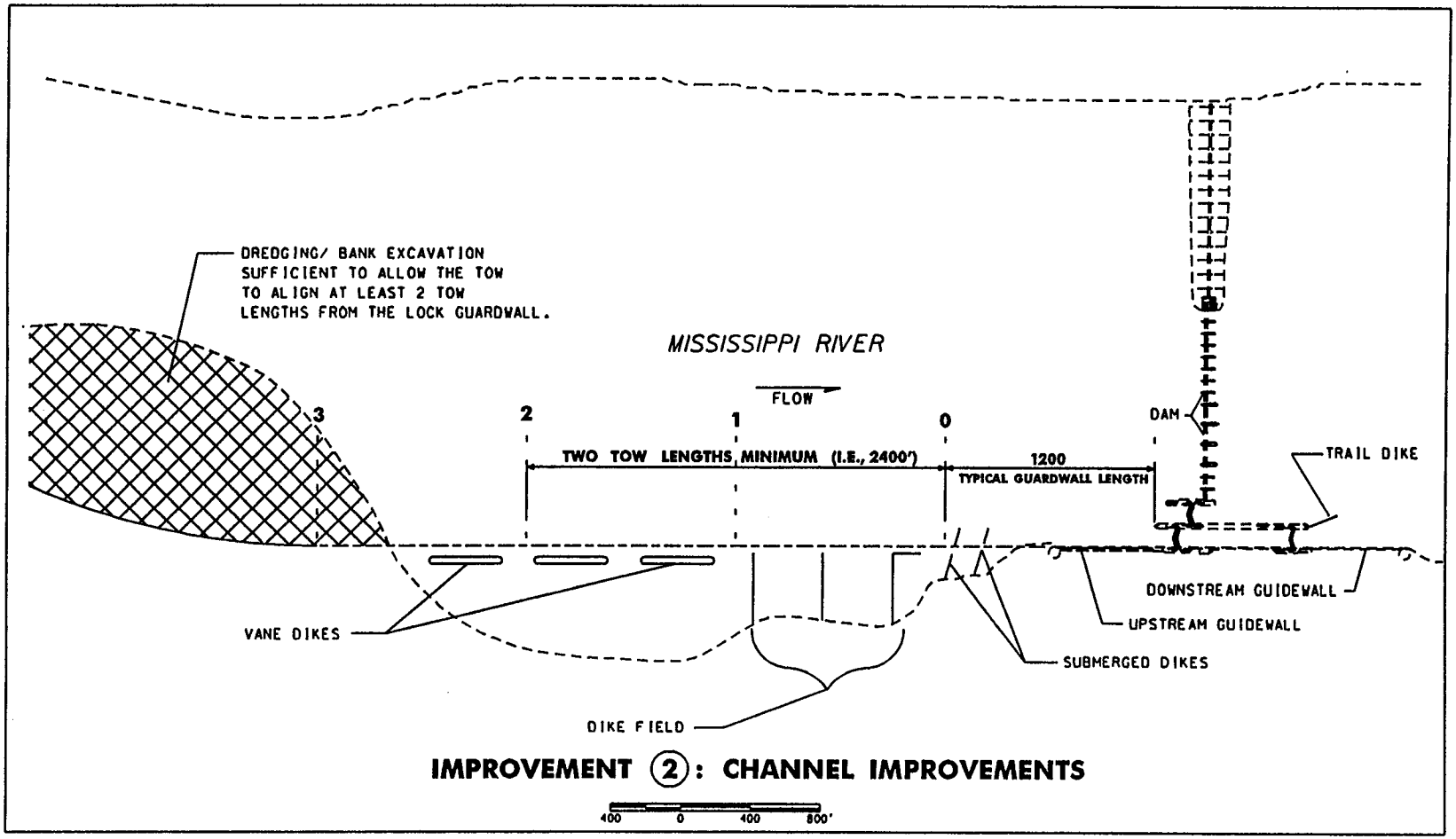

FIGURE 2-6: Channel Improvements

▪ Extended Guidewalls Plus Channel Improvements

Description of Measure. This measure combines the two previously discussed measures, extending the guidewalls plus channel improvements. An example is shown in Figure 2-7 for a generic lock site.

Cost and Performance. The first cost and new approach time savings for the fly and exchange approaches are given in Table 4-48. In addition to the first cost, annual maintenance costs averaging over $200,000 upstream and over $90,000 downstream would be required. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 3 of Table 2-9. The average improvement in the downbound fly approach is about 4 minutes with a maximum of about 7 minutes. The average improvement in the downbound exchange approach is about 3 minutes with a maximum of about 5 minutes. The upbound improvement in both the fly and exchange approaches is about 3 minutes.

Conclusions/Summary. The combination of extended guidewalls and channel improvements gives a greater reduction in lock approach times than the individual measures do separately. Channel improvements generally provide a greater incremental approach time savings at less cost than guidewall extensions and, after confirmation by site-specific model studies, should be considered further as a betterment to lock transit time.

▪ Auxiliary Lock Guardwall

Description of Measure. An auxiliary lock guardwall (L3) is constructed as a 1,200-foot upstream extension of the river wall (Figure 2-8). Upstream guardwalls are constructed with openings below the waterline that allow water to flow from the approach channel to the dam gates. This flow tends to pull a tow toward the guardwall. If the guardwall is located as an extension of the riverside lockwall, this helps to align the tow for entry into the lock chamber. In this case with the wall located riverward of the lock chamber, there is some reduction in the magnitude of the outdraft, but the tow must still use the existing 600-foot guidewall to align itself for entry into the lock chamber. The 1,200-foot guardwall provides some added safety in preventing tows or breakaway barges from being drawn into the dam gates, potentially causing damage to the dam and the barges as well as their cargo.

Applicability to Lock Sites. The placement of an auxiliary lock guardwall alone without any other upstream channel improvement is applicable at only a few lock sites where the existing riverbank above the lock goes landward, providing room for a tow (1,200 feet long) to approach the lock. Construction of an auxiliary lock guardwall is possible at Mississippi River Locks 11, 12, 17, 22, 24, and 25. On the IWW, an auxiliary lock guardwall placement is possible only at Dresden Island.

Cost. The cost of this measure ranges from $16 to $23 million for those sites where an auxiliary lock guardwall alone without any other approach improvement is applicable. Annual maintenance costs are estimated at $10,000 per lock. Environmental impacts must be added as well as impacts to navigation during construction of the guardwall. See Section 4 for more discussion of costs and impacts and Table 4-49 for site-specific cost and the additional cost from navigation impacts.

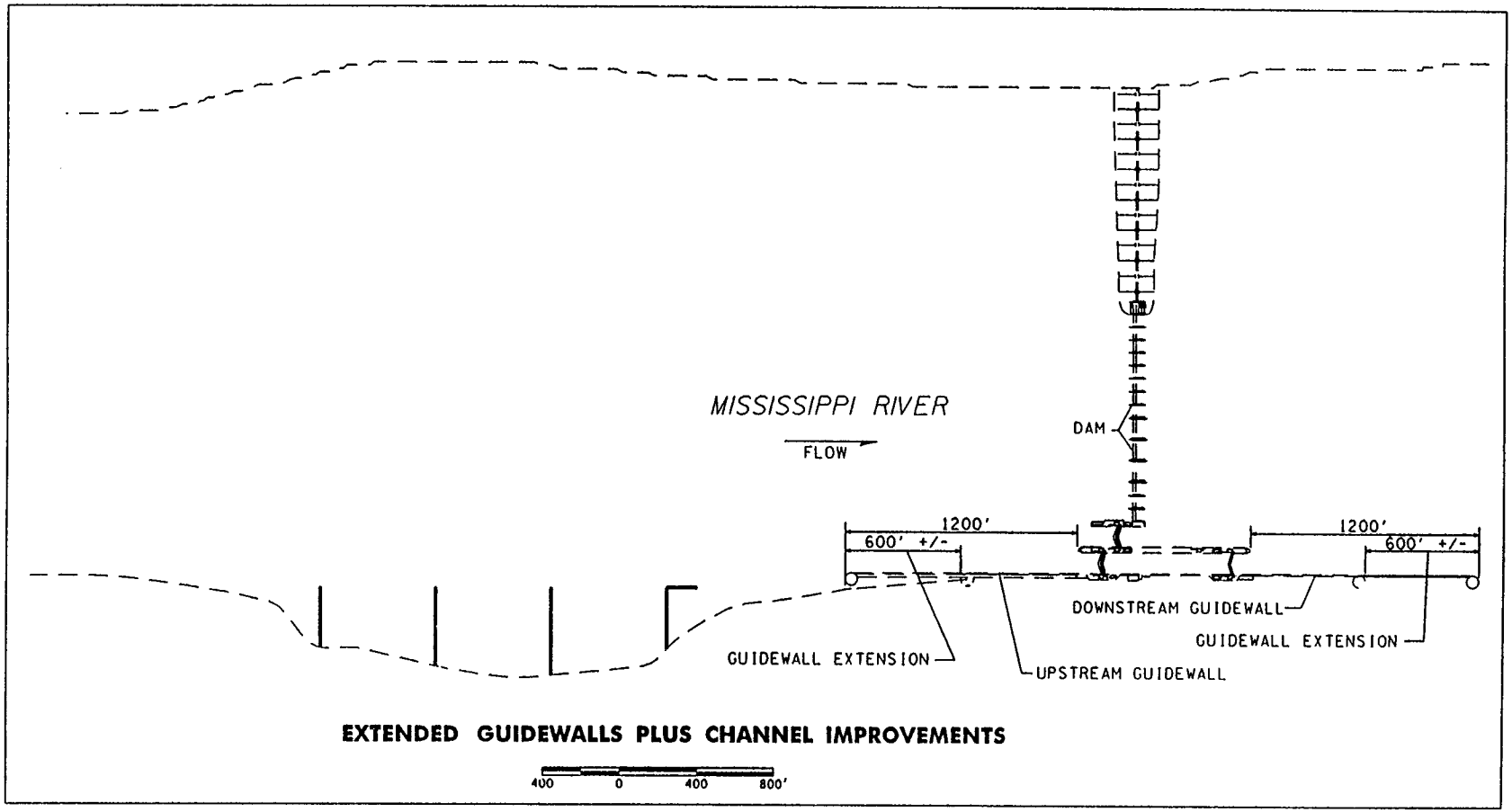

FIGURE 2-7: Extended Guidewalls Plus Channel Improvements

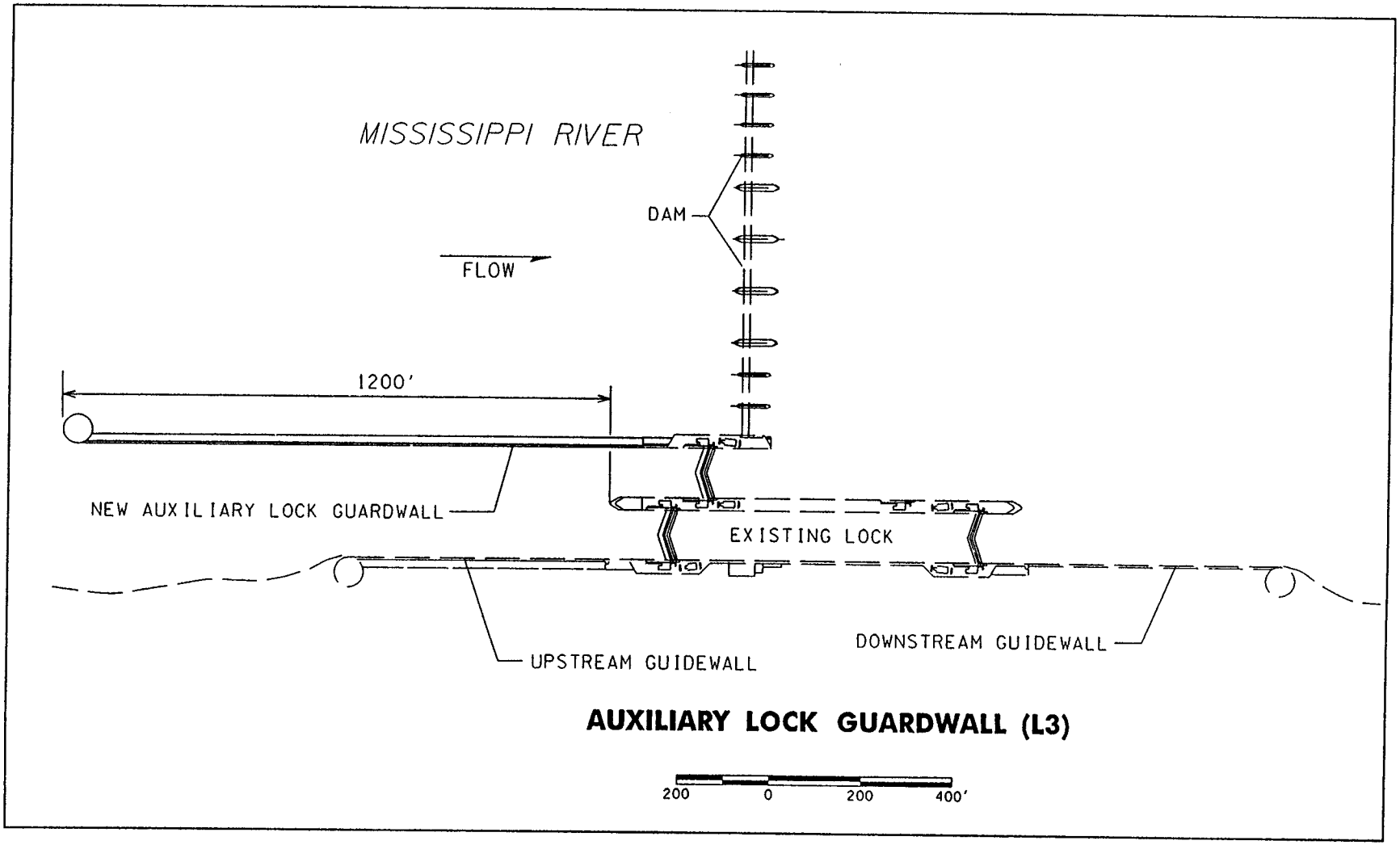

FIGURE 2-8: Auxiliary Lock Guardwall (L3)

Time Savings Estimates. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 4 of Table 2-9. An average time savings of 3 to 4 minutes is estimated with a maximum saving of 6 minutes for the fly approach at Locks 17 and 22. Table 4-49 shows the improved approach times by lock sites.

Conclusions/Summary. It is estimated that a location 3 guardwall alone provides a similar reduction in lock approach time as extended guidewalls with channel improvements. A location 3 guardwall alone does not provide any other reduction in lock transit time.

- **Existing Lock Guardwall**

Description of Measure. An existing lock guardwall (L2) is constructed as a 1,200-foot upstream extension of the intermediate lockwall (the wall between the existing lock and the auxiliary lock) (Figure 2-9). At this location, the guardwall provides more benefits to downbound tows than an auxiliary lock guardwall if outdraft is not severe. If outdraft is severe and no other approach improvements are made to reduce the outdraft, an existing lock guardwall is more of a hindrance to approaching tows than a guardwall at the auxiliary lock location. The existing lock guardwall would be constructed of the same design as the auxiliary lock guardwall. The existing guidewall would not be used and would likely be a hazard. The guidewall would be removed and the bankline tapered to provide a 200-foot-wide opening for the tow as the tow approaches the guardwall. The existing lock guardwall would also provide the safety benefit of helping to prevent tows or breakaway barges from being drawn into the dam.

Applicability to Lock Sites. The placement of an existing lock guardwall alone without any other upstream channel improvement is applicable at fewer lock sites than those lock sites where an auxiliary lock guardwall is applicable. This is because inadequate room for a 1,200-foot-long tow would be available to approach the lock with an existing lock guardwall. An existing lock guardwall placement without channel work is possible at Mississippi River Locks 12, 17, 19, and 24, although at Lock 24 outdraft during high flows would impede tows approaching the guardwall. On the IWW, an existing lock guardwall placement is possible at Dresden Island.

Cost Estimate. The cost of an existing lock guardwall ranges from $14 to $21 million for those sites where placement is applicable. Additionally, annual maintenance costs are estimated at $30,000 per lock. Environmental impacts must be added, as well as the high cost impacts to navigation during construction of the guardwall. See Section 4 for more discussion of costs and impacts and Table 4-50 for site-specific costs.

Time Savings Estimates. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 5 of Table 2-9. These improvement ratings indicate an average 11- to 14-minute saving for Lock 17, and more moderate improvements (2 to 6 minutes) for the other sites where this measure is applicable (Table 4-50).

Conclusions/Summary. Of the four sites on the UMR where a location 2 guardwall (alone) is applicable, only at Locks 12 and 17 is there an apparent additional reduction in downbound approach time over what a location 3 guardwall provides.

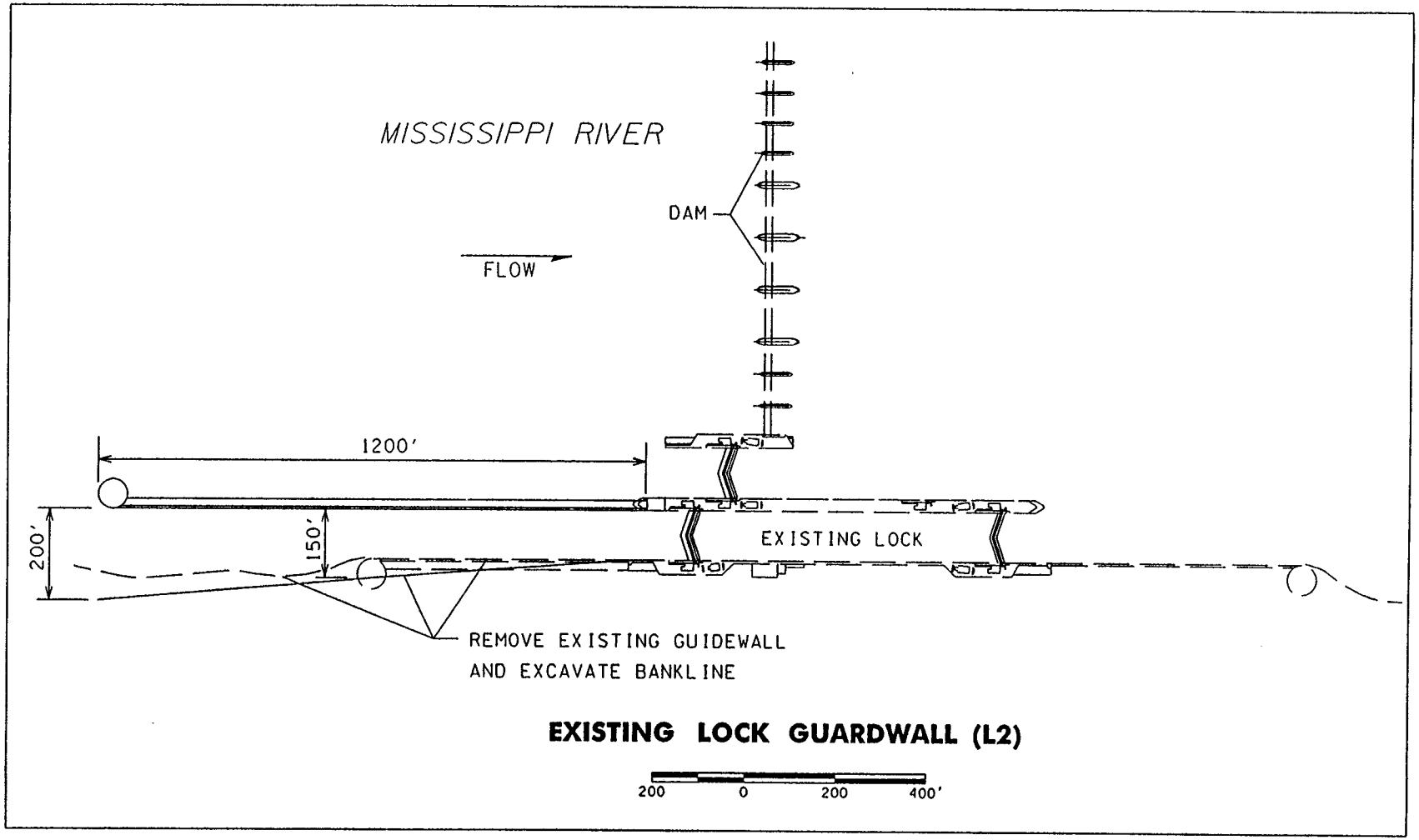

FIGURE 2-9: Existing Lock Guardwall (L2)

- **Channel Improvements Plus an Auxiliary Lock Guardwall**

Description of Measure. This measure combines the two previous measures of the same names. Together this combination provides some incremental benefit over placement of each of the two measures separately.

Applicability to Lock Sites. Channel improvements plus an auxiliary lock guardwall is applicable to all the UMR lock sites except Locks 12, 13, 14, 18, 19, Melvin Price, and Locks 27. Channel improvements plus an auxiliary lock guardwall is not, however, applicable to any of the lock sites on the IWW because these locks do not have an auxiliary gate bay (in the case of Dresden Island there are no identified upstream channel improvements even though it has an auxiliary gate bay).

Cost and Performance. The first cost and new approach time savings for the fly and exchange approaches are given in Table 4-51 (Section 4) for the applicable lock sites. In addition to the first cost, annual maintenance costs averaging approximately $250,000 per lock are anticipated. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 6 of Table 2-9. Average savings in approach times are estimated at 5 to 6 minutes.

Conclusions/Summary. Channel improvements plus a location 3 guardwall provide an incremental savings in the downbound approach time over what these measures provide independently. As with any of the approach channel improvements discussed in this section, physical model testing should be considered during site-specific lock studies to verify the most efficient approach improvements.

- **Extended Guidewalls Plus Channel Improvements Plus an Auxiliary Lock Guardwall**

Description of Measure. This measure combines the three measures of the same names. This combination provides a slight incremental saving to the approach time over what the combination of channel improvements plus an auxiliary lock guardwall provides. In addition to lessening the delays due to outdraft, which channel improvements and an auxiliary lock guardwall do, the tow has the benefit of an extended 1,200-foot guidewall on which to land and align with the lock chamber.

Applicability to Lock Sites. Extended guidewalls plus channel improvements plus a location 3 guardwall is applicable to all the UMR lock sites except Locks 13, 14, 15, 18, 19, Melvin Price Locks and Locks 27. This combination is not applicable to any of the lock sites on the IWW because these locks, other than Dresden Island, do not have an auxiliary miter gate bay. This combination is not applicable at Dresden Island either since there are no identified upstream channel improvements for Dresden Island.

Cost and Performance. The first cost ranges from $38 to $54 million for this combination of measures, plus the economic impact to navigation during construction. Table 4-52 (Section 4) shows site-specific costs and impacts. Annual maintenance costs are estimated at $300,000 per lock site (range from $91,000 to $720,000). Environmental impact costs have not been identified to date. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 7 of Table 2-9. The downbound exchange approach times decrease by an average of 5 minutes.

Conclusions/Summary. The basic cost for this improvement is higher than the more efficient improvement which is discussed next: Channel Improvement Plus an Existing Lock (Location 2) Guardwall. However, the impacts to navigation are much less during construction of the extended guidewall and auxiliary lock guardwall than during construction of an existing lock guardwall that is in closer proximity to the navigation channel.

- **Channel Improvements Plus a Guardwall Addition to the Existing Lock**

Description of Measure. This measure combines the two measures of the same names. This improvement includes removing the existing landside guidewall and tapering the bankline to provide a 200-foot navigable opening at the upper end of the guardwall. This combination generally provides the most significant time savings over existing conditions.

Applicability to Lock Sites. Channel improvements plus an existing lock guardwall is applicable to all the UMR lock sites except Locks 12, 13, 17, 18, Melvin Price Locks and Locks 27. For Locks 13 and 18, no time savings is anticipated from placement of an existing lock guardwall. However, future site-specific model studies may contradict this assumption. At Locks 12 and 17, placement of an existing lock guardwall *without* any channel improvements already improves the approach as much as can be expected.

Some lock sites require more extensive channel widening/shifting to accommodate an existing lock guardwall. Excavation into the Old Le Claire Canal at Lock 14 is needed to provide just one-half tow length of straight approach above an existing lock guardwall.

For the IWW, channel improvements plus an existing lock guardwall is applicable only at La Grange Lock. Extensive channel excavation is needed above the lock to provide one tow length of straight approach above the guardwall. A model study would help identify any approach time savings.

Cost and Performance. The first cost ($11 to $33 million) and improved times for the fly and exchange approaches are given in Table 4-53. Annual maintenance costs are estimated at $250,000 annually per lock. The high cost impacts to navigation during construction are discussed in Section 4. Environmental impact costs have not been included. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 8 of Table 2-9. The average improvement in the downbound approach times for the applicable lock sites is 6 to 9 minutes.

Conclusions/Summary. Channel improvements with an existing lock (location 2) guardwall generally provides the most efficient downbound lock approach where outdraft is a major concern such as at the UMR locks. At some locks, the desired minimum straight approach of two tow lengths (2,400 feet) above the guardwall is not attainable without additional major channel widening and/or relocation.

SECTION 3 - SITE APPLICATION OF MEASURES

The following section provides information collected on the application of the small scale measures to each lock site. The information was complied by the study team during lock site visits in August and September of 1994 to UMR Locks 11 to 25 and Peoria and La Grange Locks on the IWW. In August 1996, members of the Engineering Work Group met at Lock 27 to discuss issues related to Locks 27 and Mel Price. Site visits to other IWW locks, including Starved Rock, Marseilles, Dresden Island, Brandon Road, and Lockport, were conducted in November 1996. Participants at these meetings varied, but included State resource agency representatives, U.S. Fish and Wildlife Service personnel, and navigation interests. In addition to the site visits, follow-up calls were made to lockmasters to clarify results and gather information on site-specific applications of the various measures to the particular lock sites.

Approach improvement information was provided from modeling studies at the Corps of Engineers Waterways Experiment Station and a follow-up meeting with the principal investigator. A June 1993 report by the Rock Island District entitled, *Mississippi River Locks and Dams 11-22 Approach Improvements: Rehabilitation Evaluation Report,* also provided valuable information.

A significant amount of information was collected from each site and is summarized where applicable in the following report sections. Information is presented first for UMR locks, followed by IWW locks. Categories of information collected for each site include:

- Description: Summary of site location
- Approach Conditions/Locations: Information on site conditions and Fly and Exchange Lockage Approach Points
- Measures Under Consideration: Time savings and cost estimates and listing of measures not applicable to a particular site
- Adjacent Moorings: Both current and potential sites for new adjacent moorings
- Approach Improvements and Guidewall/Guardwall Extensions
- Remote Remake Areas: Potential sites
- Other Site Information: Use of helper boats, scheduling, self help, etc.

UPPER MISSISSIPPI RIVER LOCKS

Lock 11, Dubuque, Iowa

- **Description**

Lock 11 is located at River Mile (RM) 583.0 with the lock located on the Iowa shore near Dubuque, Iowa. This lock marks the upper limit of the sites being specifically evaluated as part of this detailed assessment. Completed in 1937, the lock has a usable chamber measuring 110 feet wide and 600 feet long. The upstream guidewall is 510.5 feet, with a 626-foot skewed wall extending upriver. The lower guidewall is 500 feet long. The lift is 11.0 feet. Plate 1 in Appendix C shows the site and potential improvements that are described below.

▪ Approach Conditions/Locations

Outdraft is a problem at this site, as reported during the initial screening site visit. Strong outdraft currents, significantly impacting approaches, occur during approximately 25 percent of the navigation season. Downbound tows usually wait about 200 feet from the upstream end of the skewed section of the upper guidewall. Upbound tows are able to pass downbound tows at this location. Currently some downbound tows tie off on the dogleg or skewed wall, sometimes causing a 10- to 15-minute delay. Departing northbound tows must maneuver around the bow of the southbound tow. The marina downstream of the lock does not interfere with lock conditions. It is located approximately 1 mile downstream. There is ample room for northbound tows to wait along the Iowa bank below the lock. The endangered Higgins' eye *(Lampsilis higginsi)* mussel is present along the left descending riverbank below the storage yard, and this area is a popular fishery. A large scour hole below the dam gates, approximately 60 feet to 80 feet deep, extends across the entire gated section of the dam. Small scale measures should consider mooring cells where tows currently wait. A properly placed mooring cell downstream of the lock, possibly out in the channel, would improve the dangerous situation with recreation traffic in the area.

The following approach locations are the typical river miles were a fly approach (tow approaching an available lock) and an exchange approach (tow approaching a lock being exited by a tow going the opposite direction) are considered to start. In most cases, the fly approach point is where the tow comes into view of the lock crew. The typical exchange point location is where the stern of the exiting tow passes the stern of the approaching tow. While exchange points can take place in the channel, they most often occur in areas where the tow waiting to lock can tie off or push into the bank. However, approach locations and times vary considerably due to changing site, weather, and river conditions and widely variable capabilities of the crews and tows operating on the system.

Upper Approach/Downbound: Fly and exchange lockages approach points are at RM 583.6.

Lower Approach/Upbound: Fly and exchange lockages approach points are at RM 582.5.

▪ Measures Under Consideration

At Lock 11, most small scale measures are currently under consideration. The following table summarizes the expected cost and time savings by measure for this site. However, the time savings for some measures, including tolls and reports, recreational measures, and scheduling, could not be determined without additional analysis. The information in this table, while providing a general indication of the cost and time savings, has been greatly simplified and does not equally summarize the cost and performance factors of each measure. As a result, this table's value is somewhat limited in comparing the measures. Section 4 provides additional information on the cost and performance of each measure.

TABLE 3-1: COST AND TIME SAVINGS OF MEASURES AT LOCK 11

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted. Likely to happen without project.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.2 to 22.3 mil initial/gw ext	US: 22 min. TRBK DBL DS: 23 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. Requires removal of dogleg guidewall.
Switchboat w/Remote Remake & 300' US Guidewall	$1.33 mil/boat/year $3.7 mil initially/moor $2.1 to 11.2 mil initial/gw ext [3]	US: 22 min. all DBL DS: 23 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 16 min. all DBL DS: 17 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings		N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $22.8 mil initially DS: $13.9 mil initially	US: 7 min. TRBK DBL DS: 7 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $22.9 mil initially DS: $13.9 mil initially Plus $518,000 annually per lock	US: 21 min. TRBK DBL DS: 21 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels w/Ext Guidewalls	US: $22.3 mil initially	6 min. TRBK DBL 21 min. TRBK SETOVER 9 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.5 mil initially	6 min. TRBK DBL 14 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$4.6 to 26.7 mil initially***	Less than 1 min. to 4 min.	Individual options detailed in Section 4**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot walls.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

Currently both the upstream and downstream approaches lack formal mooring areas (mooring cells, bank anchors, etc.). However, some downbound tows are able to approach up to the end of the skewed guidewall at RM 583.3. Potential locations for adjacent moorings include:

Upper Approach/Downbound: Could use a mooring cell at RM 583.8 on the right descending bank. A closer mooring at RM 583.5 would be possible if approach channel improvements are not made.

Lower Approach/Upbound: Could use a mooring cell at RM 582.5 on the left descending bank.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Based on the presence of outdraft conditions upstream of the lock, the potential for approach time savings exists if approach improvements are implemented. The three upstream locations under consideration for guidewall and guardwall extensions mirror the options at most of the other sites. The first option is extending the existing landside guidewall to 1,200 feet. Guidewall extensions are under consideration as a measure both above and below the lock. The second option or location 2 (L2) involves construction of a 1,200-foot guardwall (riverside structure) extending upstream from the intermediate wall or riverside lockwall. The final option is the construction of a 1,200-foot guardwall extending upstream at location 3 (L3) from the riverward wall of the auxiliary gate in the auxiliary lock if one is present.

Upper Lock Approach: The potential channel improvements include reconstructing the wing dike located about 1,900 feet above the lock with an L-head, adding another wing dike about 1,000 feet above it, constructing a series of vane dikes for 2,000 feet above the dikes, and shifting the navigation channel about 500 feet east along and above the vane dikes. Soundings show adequate water depths in the area of the channel shift, thereby eliminating any initial channel dredging. These channel improvements have an estimated betterment of 3 to 4 on the 10 scale described in Section 4. Extending the guidewall without the channel improvements could have a negative impact on the approach. An L3 guardwall alone has an improvement potential of 3 to 4 and improves, when implemented in combination with other measures. An L2 guardwall alone is not recommended but, in combination with the channel improvements to include removal of the existing guidewall and the dog-legged extension, gives the best improvement potential of 8 to 10. Ice collection with either the L2 or L3 guardwall is a concern and has to be model studied prior to any implementation.

Lower Lock Approach: No channel improvements are recommended for the lower approach. Extending the guidewall has an estimated betterment of 0 to 2 on the 10 scale.

▪ Remote Remake Areas

The same locations mentioned for adjacent mooring facilities could be remake areas. The primary difference would be the use of spud barges and cells to create a flat surface rather than a single cell or other mooring. Additional sites are currently available upstream; however, if the vane dikes are constructed, the potential to use the off-channel area around RM 584 would be eliminated. Ideally, another site than the nearest adjacent mooring cell would be found to allow exchange lockages to occur without slowing the first tow approaching from the opposite direction.

Upper Approach/Upbound: Could use a remake area at RM 583.5 on the right descending bank. If channel improvements are not made, a site from RM 583.7 to RM 584.5 would be available.

Lower Approach/Downbound: Could use a mooring at RM 582.5 on the left descending bank. Use of this location could require shortening of the wing dams. The other potential option at this site would be at RM 582.5 on the right descending bank, below the lock. However, the site would need to be placed carefully to avoid conflicts with the marina.

- **Other Site Information**

As a result of moderate traffic levels at the site, scheduling and self help are not typically used. However, helper boats are used for approach assistance when stronger outdraft currents are present.

L&D 12, Bellevue, Iowa

- **Description**

Lock 12 is located on the Bellevue, Iowa, riverfront at RM 556.7. The lock has a usable chamber of 110 feet wide and 600 feet long. The site includes a 517-foot-long upstream guidewall and a 500-foot-long lower guidewall. The lift at flat pool is 9.0 feet. Plate 2 in Appendix C shows the site and potential improvements described below.

- **Approach Condition/Locations**

As reported during the initial screening site visit, outdraft (occurring during approximately 45 percent of the navigation season) is a problem at this site. In addition, there is a poor exit condition going downstream. Tows leaving the lock have to "flank out" to get away from the wall and avoid a wing dam just below Mill Creek. Some interference with recreation traffic occurs downstream as there is a city dock just downstream of the lock. Lock personnel thought the upstream outdraft problem could be solved with a 1,000-foot solid extension of the landside guidewall. A large scour hole below the dam gates, approximately 90 feet deep, extends across the entire gated section of the dam. The existing mooring cell upstream of the lock at RM 557.4 is well placed for the existing lock usage.

Upper Approach/Downbound: Fly lockages approach point is at RM 558.0. Exchange lockages point is at RM 557.4 on the existing cell.

Lower Approach/Upbound: Fly lockages approach point is at RM 556.0. Exchange lockages point is at RM 555.0 where tows wait along the bank.

▪ Measures Under Consideration

At Lock 12, all measures are currently under consideration. Table 3-2 summarizes the expected cost and time savings by measure for this site. However, the time savings for some measures, including tolls and reports, recreational measures, and scheduling, could not be determined without additional analysis. The information in this table, while providing a general indication of the cost and time savings, has been greatly simplified and does not equally summarize the cost and performance factors of each measure. As a result, this table has limited value in comparing the measures. Section 4 provides additional information on the cost and performance of each measure.

▪ Adjacent Moorings

While an existing cell at RM 557.4 assists downbound tows, the lower approach lacks a formal mooring area (mooring cells, bank anchors, etc.). The addition of a mooring around RM 556.0 would provide considerable benefits to the site by allowing tows to exchange nearly one mile closer to the lock than what is normally occurring due to the relatively narrow channel. A significant time savings of over 20 minutes and up to 40-45 minutes was estimated due to reduced travel time for the exiting tow to reach the exchanging tow, and reduced time and distance for the approaching tow to reach the lock.

Upper Approach/Downbound: Could use an additional mooring at RM 558.0 on the right descending bank. However, this may conflict with houses located near shore.

Lower Approach/Upbound: Could use a mooring at RM 556.0 on the left descending bank. Use of this location would likely require shortening of the wing dams.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Based on the presence of outdraft conditions upstream of the lock due to the narrow dam, some potential for approach time savings exists if approach improvements are implemented. The optimum approach improvements should be verified by a model study before any implementation of the improvements.

Upper Lock Approach: Some straightening/filling of the bankline above the lock may help reduce the outdraft to a limited extent. Extending the guidewall has a potential improvement of 0 to 1. An L3 guardwall with guidewall extension has a potential improvement of 6 to 8. An L2 guardwall with removal of the existing guidewall has an estimated improvement of 9 to 10. The model study could show the incremental benefits of a guide cell above the riverward lockwall. The need for unpowered or powered kevels in combination with the guidewall extension will also be explored.

Lower Lock Approach: Channel improvements include shortening the wing dikes along the left descending bank, a trail dike off the lower end of the riverside lockwall, and some dredging along the channel right edge to allow for a better downbound exit from the guidewall. These channel improvements have an estimated betterment of 1 to 3 on the 10 scale. The guidewall extension has a potential improvement of 0 to 1. Together the channel improvements and guidewall extension have a potential improvement of 3 to 5.

TABLE 3-2: COST AND TIME SAVINGS OF MEASURES AT LOCK 12

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted. Likely to happen without project.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.2 to $27.6 mil initial/gw ext	US: 18 min. TRBK DBL DS: 24 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.1 to $13.8 mil initial/gw ext [3]	US: 18 min. all DBL DS: 24 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 12 min. all DBL DS: 18 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	N/A	Currently no landing available for over 15 mi below lock on left bank
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $28.1 mil initially DS: $13.6 mil initially	2 min. TRBK DBL 5 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: 28.1 mil initially DS: 13.7 mil initially Plus $518,000 annually per lock	US: 16 min. TRBK DBL DS: 19 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels w/Ext Guidewalls	US: $27.6 mil initially	6 min. TRBK DBL 20 min. TRBK DBL 8 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.2 mil initially	6 min. TRBK DBL 20 min. TRBK DBL 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
DS Mooring RM 556.0	$50,000 initially	13 min. UB EXCH APRCH	Left channel
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$810,000 to $27.9 [4] mil initially***	Less than 1 min. to 4 min	Individual options detailed in Section 4**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot walls.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

- **Remote Remake Areas**

The same locations described for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of spud barges and cells to create a flat surface for use with switchboats or just a couple cells with self help.

Upper Approach/Upbound: Could use a mooring at approximately RM 557.5 in the channel. A suitable site on the right descending bank at or around RM 557.4 would be preferred; however, a number of houses are present. Another option would be along the right descending bank at RM 557.9.

Lower Approach/Downbound: Could use a mooring at RM 556.1 on the left descending side of the channel. Use of this location could require shortening of the wing dams.

- **Other Site Information**

Currently nearly 50 percent of tows use helper boat assistance throughout the year due to site conditions that result in outdraft being present approximately 45 percent of the year. Typically one of two different assist boats is available, with either 450 or 800 horsepower. While the time savings provided by the helper boats varies widely, they provide an estimated average approach time savings of 25 plus minutes under outdraft conditions and 15 to 20 minutes under lower, non-outdraft flows.

A switchboat should be able to pull cuts under all flows.

Don't regularly use scheduling or industry self help due to limited queues.

Could use an additional boat landing below the lock on the Illinois side. Currently the closest site is nearly 20 miles away.

L&D 13, Fulton, Illinois

- **Description**

Lock 13 is located on the Illinois shore at RM 522.5 just upstream of Fulton, Illinois, and Clinton, Iowa. The lock has a usable chamber of 110 feet wide and 600 feet long. The site includes a 500-foot-long upstream guidewall and a 517-foot-long lower guidewall. The lift at flat pool is 11.0 feet. Plate 3 in Appendix C shows the site and location of proposed measures.

- **Approach Condition/Locations**

Outdraft is not a problem at this site. However, the pool is very wide and tows can have a problem navigating against the wind, especially when pushing empty barges. The prevailing westerly winds can help downbound tows approach the lock by pushing them against the upper guidewall, but these winds also cause ice accumulation around the upper lock gates. The lock is easily approached, and the mooring cell upstream of the lock is in a good location. Lock personnel feel that approach conditions for southbound traffic could be improved by placing a guide cell 300 feet

above the intermediate wall. However, the cell could be a problem for northbound traffic passing tows waiting along the upper dike. A model study would verify optimum approach conditions.

Upper Approach/Downbound: Fly lockages approach point is at RM 523.7.
Exchange lockages approach point is typically at RM 523.5, with tows often waiting on the existing cell.

Lower Approach/Upbound: Fly lockages approach point is at RM 521.0.
Exchange lockages approach point is at RM 521.6 where tows wait along the bank on either side of the river.

▪ Measures Under Consideration

At Lock 13, all small scale measures are currently under consideration, except additional recreational craft landings. The following table summarizes the expected cost and time savings by name for this site.

TABLE 3-3: COST AND TIME SAVINGS OF MEASURES AT LOCK 13

Measure	Cost [1/]	Time Savings to Waiting Tows [2/]	Comments
Helper Boat	$640,000/boat/year	Limited	One of best approaches on system, virtually no savings possible.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.3 to $23.0 mil initial/gw ext	US: 19 min. TRBK DBL DS: 26 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. Higher US guidewall costs are for bank excavation.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.2 to $11.5 mil initial/gw ext [3/]	US: 19 min. all DBL DS: 26 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same as above	US: 13 min. all DBL DS: 20 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $23.5 mil initially DS: $13.9 mil initially	US: 3 min. TRBK DBL DS: 7 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $23.5 mil initially DS: $13.9 mil initially Plus $518,000 annually per lock	US: 17 min. TRBK DBL DS: 21 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels w/Ext Guidewalls	US: $22.9 mil initially	6 min. TRBK DBL 17 min. TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.5 mil initially	6 min. TRBK DBL 18 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially

TABLE 3-3 (Continued)

Measure	Cost [1/]	Time Savings to Waiting Tows [2/]	Comments
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Imprvmnts:			
Ext Guidewalls	See costs above	Less than 1 min.	Existing approaches are good

[1/] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2/] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3/] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot walls.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

The existing cell at RM 523.5 allows downbound tows waiting for a lockage to tie off as close as possible. The lower approach lacks formal mooring areas (mooring cells, bank anchors, etc.). The addition of a mooring around RM 522.0 would bring tows closer to the lock.

Upper Approach/Downbound: Could use an additional mooring at RM 525.3 on the left descending bank or lock side.

Lower Approach/Upbound: A mooring at RM 522.0 would bring tows 0.4 mile closer to the lock. However, the lockmaster suggests that a formalized mooring is not needed. Another option is to formalize the existing waiting area at RM 521.6 on the left descending bank by placing a mooring in that area.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Upper Lock Approach: The existing approach at Lock 13 is one of the most efficient upper approaches on the UMR. No improvements were identified other than extending the guidewall, which has an improvement potential of 0 to 1. Guardwalls are not necessary or preferred due to the limited amount of outdraft at the site.

Lower Lock Approach: The existing approach is efficient. No improvements were identified other than extending the guidewall which has an improvement potential of 0 to 1 on the 10 scale. A trail dike off the end of the riverside lockwall may help downbound tows exit the guidewall.

▪ Remote Remake Areas

The same locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface. Potential sites include either side of the channel, due to adequate channel width and depth.

Upper Approach/Upbound: Could use a mooring at approximately RM 523.5 on the left descending or right descending bank.

Lower Approach/Downbound: Could use a mooring located from RM 522.0 to 521.7 on the left descending bank. A second option would be for a mooring on the right descending bank along Stamps Island at RM 521.6.

- **Other Site Information**

Helper boats are not typically available at the site, and approach conditions rarely necessitate their use. They are expected to provide little or no approach time savings under normal flow conditions. However, they could assist tows affected by wind, which can reduce the tow's ability to leave the guidewall.

A switchboat should be able to pull cuts under all flows to the moorings identified earlier.

Don't regularly use scheduling or industry self help due to limited queues.

Adequate boat landings are available both above and below the lock. Currently recreational conflicts are not of concern. In most cases, a recreational lockage is provided after every second commercial lockage.

L&D 14, Le Claire, Iowa

- **Description**

Lock 14 is located on the Iowa shore at RM 493.3 downstream of Le Claire, Iowa, and upstream of Hampton, Illinois. The lock has a usable chamber of 110 feet wide and 600 feet long. The site includes a 517-foot-long upstream guidewall and a 500-foot-long lower guidewall. The lift at flat pool is 11.0 feet. In addition, an auxiliary lock 320 feet long by 78 feet wide is located west of the main lock. Plates 4 and 5, located in Appendix C, show the site and potential improvements.

- **Approach Conditions/Locations**

The lock location and flow condition require tows to maneuver to reach the lock. Downbound tows leave the main channel with its stronger current and angle into the slower moving water above the lock. Then they stop, pull the stern eastward to line up with the lock, and continue downstream. Upbound tows cross the main channel with its stronger current as they approach the lock. Once they cross the main channel, a secondary current pushes them west toward the downstream guidewall. This aligns the tow for the lockage. This same current requires downbound tows to start turning east after they exit the lock to avoid being pushed aground downstream of the lock. There are no waiting areas near the lock for upbound or downbound tows. During the site visit, it was mentioned that a mooring cell downstream in the "wide spot" just upstream of the Campbell's Light and Day Mark should be a No. 1 priority. Downbound tows would benefit with cells at RM 493.5 and 494.5. The 80-foot by 320-foot auxiliary lock landward of the main lock is used mainly on weekends for recreation traffic. This smaller lock outlets the environmentally and historically sensitive Old Le Claire Canal which is about 5.5 feet deep.

Upper Approach/Downbound: Fly lockages approach point is at RM 495.0. Exchange lockages typically occur at RM 494.6 out in the channel. Some tows are able to wait in the pocket at RM 493.7, but reduced depth and width from sedimentation requires most tows to wait along the Le Claire, Iowa, riverfront at RM 496.7.

Lower Approach/Upbound: Fly lockages approach point is at RM 492.5. Exchange lockages normally occur at RM 492.5, but at times when conditions or situations dictate, they occur at RM 489.7 along Dynamite Island.

▪ Measures Under Consideration

At Lock 14, all measures are currently under consideration, except recreational craft landings. The following table summarizes the expected cost and time savings by name for this site.

TABLE 3-4: COST AND TIME SAVINGS OF MEASURES AT LOCK 14

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.3 to $22.3 mil initial/gw ext	US: 24 min. TRBK DBL DS: 26 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.8 mil initially/moor $2.2 to $11.2 mil initial/gw ext [3]	US: 24 min. all DBL DS: 26 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 18 min. all DBL DS: 20 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $22.9 mil initially DS: $11.9 mil initially	US: 8 min. TRBK DBL DS: 10 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $22.9 mil initially DS: $12.0 mil initially Plus $518,000 annually per lock	US: 22 min. TRBK DBL DS: 24 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $22.3 mil initially	6 min. TRBK DBL 25 min. TRBK SETOVER 10 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $11.5 mil initially	6 min. TRBK DBL 19 min. TRBK SETOVER 10 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially

TABLE 3-4 (Continued)

Measure	Cost [1/]	Time Savings to Waiting Tows [2/]	Comments
US Mooring RM 493.7	$500,000 initially	12 min. DB EXCH APRCH	Right bank
DS Mooring RM 492.5	$500,000 initially	37 min. UB EXCH APRCH (35% of the time)	Left channel
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$985,000 to $23.1 mil initially***	Less than 1 min. to 3 min.	Individual options detailed in Section 4**

[1/] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2/] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3/] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot walls.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

Site conditions both above and below the lock provide the opportunity for significant time savings on exchange lockages with the addition of adjacent moorings. Upstream of the lock, an adjacent mooring cell in the pocket at RM 493.7 would reduce exchange lockages from 1 to 1.7 miles and save 30 to 45 minutes. However, in addition to the cell, considerable dredging would be required. Another option would be a site out in the channel around RM 494.5.

The lower approach would be greatly improved through the addition of a mooring at RM 492.5. The lower approach is generally narrow with a rock shelf running along the border of the navigation channel. Tows typically begin their approach from Dynamite Island at RM 489.7 once the entire approach is clear. The addition of the mooring would reduce the exchange distance by over 3 miles for the exiting and approaching tow, combined with the potential for savings of over 1 hour. A customer survey of the navigation industry highlighted that the two most needed/ desired improvements were construction of mooring cells below the lock at RM 492.5 and dredging to open up the pocket upstream of the lock.

Upper Approach/Downbound: Could use an additional mooring at RM 493.7 on the right descending bank. Second option would be a mooring in the channel around RM 494.5.

Lower Approach/Upbound: A mooring cell at RM 492.5 on the left descending side of the channel in the wide spot in the channel would provide significant benefits.

▪ Approach Improvements and Guidewall/Guardwall Extensions

The bend in the river at Lock 14 reduces the ability of tows to easily approach the lock.

Upper Lock Approach: The channel improvement is the dredging of the area above the lock shown on plate 4, including the silted-in pocket area above the lock from the guidewall extended to the rock breakwater and riverward of the breakwater. Tows used to wait in this pocket above the lock before it was silted in, but now tows must wait near the I-80 Bridge. This channel work alone has an estimated time savings potential of 3 to 5 on the 10 scale. The guidewall extension has an estimated time savings potential of 0 to 1.

Plate 5 includes an expanded channel excavation and realignment above the lock to encompass an expanded cross-hatched area. This alignment extends into the Le Claire Canal, causing severe impacts to this sensitive area. The purpose in identifying this improved channel is to estimate the incremental attendant time savings to navigation. As the table shows, with this expanded channel relocation, the estimated improvement potential goes from 3 to 5 for dredging the pocket area, to 4 to 6 for the expanded realignment. With an L2 guardwall and removal of the existing guidewall, the improvement factor goes from 8 to 10 with the expanded realignment. However, significant additional impacts are associated with this measure.

Lower Lock Approach: The channel improvement is a trail dike from the end of the riverward lockwall and some dredging below the extended guidewall for access to the auxiliary (recreation traffic) lock. These improvements have an estimated time improvement factor of 0 to 1. The extended guidewall has an estimated improvement factor of 2 to 3. Together these improvements have an improvement factor of 3 to 4. An additional benefit of an extended guidewall is that it could provide a secure fleeting area for the Corps fleet.

▪ Remote Remake Areas

The same locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of spud barges and cells to create a flat surface.

Upper Approach/Upbound: Could use a remake area at RM 493.7 on the right descending bank. A second option would be a remake area at RM 494.5 on the right descending bank. A site out in the channel at RM 494.5 could also be considered, but has greater safety concerns.

Lower Approach/Downbound: Potential remake area at RM 492.5 on the left descending side of the channel in the wide spot in the channel.

▪ Other Site Information

Outdraft conditions are present approximately 30 percent of the navigation season, but helper boats are not typically available at the site. However, they could provide an estimated time savings of 5 to 30 minutes on downbound approaches, depending on the conditions. They could also provide significant benefits to downbound tows that often experience difficulty in getting the head of the tow off the lower wall due to currents, eddies, and wind which can pin them to the wall. Assistance in exiting the wall could save 5 to 15 minutes on average and over 30 minutes in more extreme conditions.

The lockmaster estimated that a 1,500-horsepower switchboat should be able to take cuts to remote moorings under virtually all flows. However, an industry line haul boat would be preferred. Subsequent discussions with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin for safety.

A 3-up/3-down scheduling policy is used regularly at the site and is activated by the presence of 5 or more tows waiting to lock. However, queues rarely require the use of industry self help.

The auxiliary recreation lock at the site virtually eliminates recreational conflicts. Although the lock does not remain open at all times, it is available from 4:00 p.m. to midnight on Fridays and 8:00 a.m. to midnight on Saturdays and Sundays from Memorial Day to Labor Day. This schedule allows for the processing of the majority of recreational traffic. However, if significant recreational traffic growth were to occur, expanded hours could be implemented.

L&D 15, Rock Island, Illinois

▪ Description

Lock 15 is located along Arsenal Island on the Illinois shore at RM 482.9 between Rock Island, Illinois, and Davenport, Iowa. The lock has a usable chamber of 110 feet wide and 600 feet long. The site includes a 533.5-foot upstream guidewall and a 718-foot lower guidewall. The maximum lift is 16.0 feet. A 110-foot wide by 360-foot-long auxiliary lock sits adjacent to the main chamber. Plate 6, located in Appendix C, shows the site and potential improvements.

▪ Approach Conditions/Locations

From the initial screening site visit it was found that outdraft can be severe at this site. The reach of river from Lock 15 to Lock 14 can be one of the most congested areas on the Upper Mississippi River. Outdraft conditions are present approximately 20 percent of the navigation season. Presently, tows are pushed away from the downstream guidewall by eddy currents and Sylvan Slough currents. Options for proposed new mooring facilities and remake areas are limited by the existing urban development in the area and site geography.

Upper Approach/Downbound: Fly and exchange lockage approach points are at RM 483.4 at the Lock 15 Daymark.

Lower Approach/Upbound: Fly and exchange lockage approach points are at RM 482.3 near the Casino Rock Island. However, tows wait at RM 480.5.

Switchboats are not usable below the lock since no potential remake areas exist. Adequate boat landings are already available.

▪ Measures Under Consideration

At Lock 15, most measures are currently under consideration. While an upstream guidewall extension is not recommended, there would be opportunities to use a combination of cells and DeLong Piers to allow helper boats to extract cuts. Table 3-5 summarizes the expected cost and time savings for this site related to the following measures:

TABLE 3-5: COST AND TIME SAVINGS OF MEASURES AT LOCK 15

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.3 to $23.4 mil initial/gw ext	US: 21 min. TRBK DBL DS: 25 min. TRBK DBL	May be difficult to extend US wall, impacts to harbor.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.8 mil initially/moor $2.2 to $11.7 mil initial/gw ext [3]	US: 21 min. all DBL DS: 25 min. TRBK DBL	No remote mooring site DS, so remake time savings for DS on Turnback Doubles only. May be difficult to extend US wall, impacts to harbor.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 15 min. all DBL DS: 19 min. TRBK DBL	No remote mooring site DS, so remake time savings for DS on Turnback Doubles only, unable to back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	DS: $8.5 mil initially	DS: 11 min. TRBK DBL	Cost of powered kevels is $750,000 initially
Powered Kevels w/Ext Guidewalls & Addl Personnel	DS: $8.5 mil initially Plus $518,000 annually per lock	DS: 25 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	DS: $8.1 mil initially	6 min. TRBK DBL 26 min.TRBK SETOVER 9 min. TRBK KNOCKOUT	Cost of extending kevel is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$742,000 to $29.2 [4] mil initially***	1 min. to 7 min.	Individual options detailed in Section 4**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

Currently tows are able to wait at various sites upstream of the lock along Arsenal Island and the Iowa shore. The construction of new mooring cells or bank anchors would not be able to bring tows significantly closer than the areas where they currently wait; however, it would provide formal mooring locations which are currently lacking. Below the lock, the only available location is at the outlet of the Sylvan Slough where some tows currently wait. Additional benefits could be gained with the addition of another mooring, but river uses along the Rock Island and Davenport riverfronts limit options.

Upper Approach/Downbound: Could use mooring cells at RM 483.8 on the left descending bank. A second option would be a mooring on the right descending bank along the Iowa shore at RM 484.7.

Lower Approach/Upbound: Could use a cell at RM 482.6 on the left descending bank. Otherwise, no site closer than RM 480.5 was identified, but this site could also use a mooring cell.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Upper Lock Approach: The channel improvement is the addition of five submerged dikes above the lock to reduce the outdraft. This alone provides an improvement of 5 to 6 on the 10 scale and may eliminate the need for helper boat assistance. The submerged dikes should also reduce ice interference with the approach. At this site, there are concerns with guidewall or guardwall extensions blocking access to the bay area. The guidewall extension could be a combination of the wall extended short of 1,200 feet, along with a pivot cell above the shortened extension or 2 pivot cells, as shown on plate 6. This would maintain water access to the harbor area landward of the lock. An L2 or L3 guardwall alone are not recommended. Again, as common to most sites, the best improvement is a combination of channel improvement and an L2 guardwall. An additional improvement would be to take the corner off the island above the lock, which would allow for a straight approach and less outdraft impacts.

Lower Lock Approach: The channel improvement is the addition of a deflection dike at the outlet of Sylvan Slough and a trail dike off the end of the auxiliary lock riverwall. This should reduce Sylvan Slough high outflows impacting both upbound and downbound traffic and dam flows pinning exit tows on the guidewall. A combination of guidewall extension and these channel improvements gives an estimated improvement of 3 to 5 on the 10 scale. Currently the site has a 718-foot lower guidewall.

▪ Remote Remake Areas

The same general locations mentioned for adjacent mooring facilities above the lock could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface. However, since multiple sites are available upstream, a site that would not impact the closest approach mooring facility would be preferred. This would allow downbound tows to wait near the lock and make exchange lockages even if an upbound tow were using the remake area.

Upper Approach/Upbound: Could use a remake area located at approximately RM 484.0 on the left descending bank. A second option would be a mooring on the right descending bank along the Iowa shore at approximately RM 484.7.

Lower Approach/Downbound: No remote remake area was identified; however, the existing 718-foot guidewall or an extended guidewall could be used for remakes.

- **Other Site Information**

Helper boats are typically available at the site; however, their greatest use occurs during high water periods in the spring and fall. They are currently used by 20 to 25 percent of tows.

At this site, scheduling and industry self help are not regularly used.

The 360-foot auxiliary lock next to the main chamber eliminates recreational conflicts. Unlike the auxiliary lock at Lock 14, this auxiliary lock is open at all times.

L&D 16, Muscatine, Iowa

- **Description**

Lock 16 is located along the Illinois shore at RM 457.2 near Muscatine, Iowa. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 517-foot upstream guidewall and a 500-foot lower guidewall. The maximum pool lift is 9.0 feet. Plate 7, located in Appendix C, shows the site and potential improvements described below.

- **Approach Conditions/Locations**

Due to required maneuvering, downbound traffic can take an hour or so longer to get to the lock than it takes to lock through. The traffic crosses the current and heads to the upper lock gate. Then tows stop, back up toward the wing dike above the lock at RM 457.7 to align better with the lock, and then enter the lock. The wing dike reduces the current and makes it easier to enter the lock. When leaving the lock, some downbound tows start turning before they clear the lock and have damaged the lower miter gate by brushing them. This may occur because tows must cross toward the Iowa side of the river to align with the channel span of the Muscatine highway bridge about a mile downstream. During recent rehabilitation work, it was noted that closing the first two tainter gates caused an eddy current which pulled tows off the guidewall. Outdraft conditions are present at the site approximately 25 percent of the time.

Channel realignment provides significant benefits upstream of the lock by improving the locking efficiency at this site. This pertains to most small scale improvements.

Upper Approach/Downbound: Fly lockages approach point is at RM 458.6.
Exchange lockages typically occur at RM 457.5 with most tows waiting in the pocket. Otherwise, exchange occurs in the channel around RM 458.0.

Lower Approach/Upbound: Fly lockages approach point is at RM 455.9. Exchange lockages vary based on conditions. Higher flows and poor conditions force exchange lockages to occur below the bridge at RM 455.5. Otherwise, they can exchange with the approaching tow while waiting along the bank at RM 456.8.

- **Measures Under Consideration**

At Lock 16, all measures are currently under consideration. Table 3-6 summarizes the expected cost and time savings by measure for this site.

TABLE 3-6: COST AND TIME SAVINGS OF MEASURES AT LOCK 16

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted. Likely to happen without project.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.2 to $21.6 mil initial/gw ext	US: 21 min. TRBK DBL DS: 25 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.1 to $10.8 mil initial/gw ext [3]	US: 21 min. all DBL DS: 25 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 15 min. all DBL DS: 19 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Only considering developing site upstream of the lock on IL side
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $22.1 mil initially DS: $13.5 mil initially	US: 5 min. TRBK DBL DS: 7 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevel w/Ext Guidewalls & Addl Personnel	US: $22.1 mil initially DS: $13.6 mil initially Plus $518,000 annually per lock	US: 19 min. TRBK DBL DS: 21 min. TRBKI DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $21.6 mil initially	6 min. TRBK DBL 21 min. TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.1 mil initially	6 min. TRBK DBL 31 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$12.8 mil to 42.5 [4] mil initially***	Less than 1 min. to 7 min.	Channel shift with individual options detailed in Section 4**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

- **Adjacent Moorings**

The addition of upstream adjacent moorings is not likely to allow tows to approach any closer to the lock. However, the sites currently being used by tows lack formal moorings. Along the lower approach, a cell at RM 456.8 could allow some additional tows to approach closer to the locks.

Upper Approach/Downbound: Tows can wait in the pocket at RM 457.9 on the left descending bank. Second option would be a mooring on the right descending bank at RM 458.6.

Lower Approach/Upbound: Could provide a mooring at RM 456.8. While used on occasion, this site currently lacks a mooring cell. A mooring at RM 456.2 would bring the next waiting location 0.7 mile closer to the lock.

- **Approach Improvements**

Upper Lock Approach: The maximum channel improvement is a potential realignment of the channel above the lock to accommodate a guardwall at L2. This is shown on plate 7 in Appendix C. It was noted that a further shift in this alignment to the Illinois side of the river (Drury Slough) could be a lesser cost realignment since this would put the relocated channel in alignment with an earlier channel. A guardwall is not recommended without the channel realignment.

Lower Lock Approach: The channel improvement is a trail dike off the end of the riverward lockwall to help direct flow from the lower guidewall. This should help downbound tows with the starboard exit they make to approach the channel span of the highway bridge about a half mile below the lock. The combination of the guidewall extended with the trail dike has a potential improvement of 3 to 4 on the 10 scale.

- **Remote Remake Areas**

The same locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface. However, approach channel improvements are likely to eliminate the ability of tows to wait in the pocket or remake.

Upper Approach/Upbound: Tows can wait in the pocket at RM 457.7 on the left descending bank. Second option would be a mooring on the right descending bank at RM 457.9.

Lower Approach/Downbound: Could provide a remake area at RM 456.7; preferred location would be at RM 456.3 to allow for an adjacent mooring near the lock in addition to the remake area.

- **Other Site Information**

A harbor service located in Muscatine provides helper boats (750-850 horsepower) on an on-call basis. Helper boat assistance is provided for downbound approaches primarily under more severe outdraft conditions. Approximately 20 percent of tows utilize helper boat assistance on approaches, saving an estimated 15 to 30 minutes for larger, double lockage tows.

Scheduling is used on a limited basis, two to three times per year, typically to clear a queue formed following lock maintenance or breakdown. Industry self help has not been regularly used. The lockmaster was only aware of three uses in the past 9 years.

The lockmaster estimated that a 1,500- to 1,800-horsepower switchboat should be able to take cuts under virtually all conditions to identified remake areas. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Would like a cell 50 to 100 feet above the extended intermediate wall.

Recreational traffic is not causing significant delays, and adequate recreational facilities are present. One potential site for an additional recreational facility would be above the lock on the Illinois side, where currently the nearest site is approximately 10 river miles upstream. The placement of a cell above the upper bullnose would improve alignment for downbound tows. This would also provide protection for the upper gates.

Placing riprap along the bank in the pocket area at RM 457.9 would help stabilize this riverbank where tows wait.

L&D 17, New Boston, Illinois

▪ Description

Lock 17 is located at RM 437.1 on the Illinois shore approximately 4 miles upstream of New Boston, Illinois. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 517-foot upstream guidewall and a 500-foot lower guidewall. The maximum pool lift is 8.0 feet.

▪ Approach Conditions/Locations

During the initial site screening visit, it was reported that usually there is an outdraft requiring downbound traffic to flank their approach to the lock. More major outdraft occurs when the tailwater reaches 7 or 8 feet, which occurs approximately 35 percent of the navigation season.

Upper Approach/Downbound:	Fly lockages approach point is at RM 438.7. Exchange lockages typically occur at RM 437.4, with most tows waiting along the bank.
Lower Approach/Upbound:	Fly lockages approach point is at RM 436.0. Exchange lockages typically occur around RM 436.5. Although no mooring cell is available, tows wait along both banks.

▪ Measures Under Consideration

At Lock 17, all measures are currently under consideration. The following table summarizes the expected cost and time savings by measure for this site.

TABLE 3-7: COST AND TIME SAVINGS OF MEASURES AT LOCK 17

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted. Most tows are currently unassisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.3 to $23.8 mil initial/gw ext	US: 21 min. TRBK DBL DS: 28 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. Higher US guidewall costs are for bank excavation.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.2 to $11.9 mil initial/gw ext [3]	US: 21 min. all DBL DS: 28 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 15 min. all DBL DS: 22 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Only considering developing site upstream of the lock on IL side
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $24.3 mil initially DS: $17.5 mil initially	US: 6 min. TRBK DBL DS: 8 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $24.4 mil initially DS: $17.6 mil initially Plus $518,000 annually per lock	US: 20 min. TRBK DBL DS: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $23.8 mil initially	6 min. TRBK DBL 20 min. TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $17.1 initially	6 min. TRBK DBL 27 min.TRBK SETOVER 6 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$3 mil to $30.9 [4] mil initially***	1 min. to 8 min.	Individual options detailed in Section 4**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.
* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

- **Adjacent Moorings**

Currently tows wait at RM 437.4 along the left descending bank. The addition of adjacent moorings is not likely to allow tows to approach any closer to the lock. However, the other sites currently being used by tows lack formal moorings. In particular, a series of two or three cells in the pocket above the lock would provide tows formal areas to wait and reduce the potential for damage to the levee. These cells could also be used for remaking tows during periods of self help.

Upper Approach/Downbound: Could place multiple mooring cells along the left descending bank from RM 437.4-437.8.

Lower Approach/Upbound: A preferred mooring location would be at RM 436.5 on the right descending side, but other options are available immediately downstream on either bank.

- **Approach Improvements**

Potential for approach channel improvements to impact mooring/remake areas immediately above the lock, but some area would remain.

Upper Lock Approach: Channel improvements include the addition of five wing dikes above the lock and shortening of two dikes on the right descending bank to open up the flow area. The improvement potential with the dikes in place and the guidewall extended is 4 to 5 as discussed in Section 4. An L3 guardwall without channel improvement is estimated at a 4 to 5 improvement. The most effective improvement, estimated at a 9 to 10, is an L2 guardwall with removal of the existing guidewall and no dike field above the lock.

Lower Lock Approach: The recommended channel improvement is the excavation of the riverbank below the lock for a better exit/entrance to the lock chamber. This alone is an improvement, and with the guidewall extended is estimated at a 4 to 5 betterment on the 0 to 10 scale.

- **Remote Remake Areas**

The same general locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface. Since multiple sites are available both upstream and downstream for mooring areas and remake sites, a remake area not impacting the approach of exchange lockages or the closest waiting area would be preferred. As a result, sites just beyond the closest adjacent mooring site would be recommended to maximize efficiency. The addition of remake areas would also provide additional protection for the levee by keeping tows away from the bank.

Upper Approach/Upbound: Remake areas could be located upstream of the lock along the left descending bank at RM 437.8.

Lower Approach/Downbound: Remake areas could be located downstream of the lock on either bank from RM 436.5 to 436.0.

- **Other Site Information**

A helper boat is rarely available at Lock 17. On the average, only about 1 percent of downbound approaches use assistance. However, time savings and increased safety would be possible at other times if a helper boat were available.

Winds greater than 10 mph can also cause problems for tows exiting the locks with empty barges.

Scheduling is used on occasion, while industry self help is rarely used. However, industry self help can provide significant benefits during periods of traffic congestion.

The lockmaster estimated that a 1,000-horsepower or larger switchboat should be able to pull cuts under virtually all conditions to identified remake areas. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Currently there are no significant conflicts with recreational craft. However, an additional site above the lock on the Illinois side may provide some benefit, with the nearest available site approximately 10 river miles upstream.

This is typically one of the first locks to go out of operation in the Rock Island District due to flooding.

L&D 18, Gladstone, Illinois

- **Description**

Lock 18 is located at RM 410.5 on the Illinois shore near Gladstone, Illinois, approximately 6.5 miles upstream of Burlington, Iowa. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 517-foot upstream guidewall and a 500-foot lower guidewall. The maximum pool lift is 9.8 feet. Plate 9, located in Appendix C, shows the site and location of proposed measures.

- **Approach Conditions/Locations**

An initial site visit to Lock and Dam 18 revealed that approach conditions to the existing lock are good. Tows make a zigzag approach/exit upstream of the lock, but the maneuvering required could be considered relatively insignificant compared to other sites. Outdraft conditions, which are present approximately 25 percent of the year, are not a problem at this site, although wind affects tows in their upstream approach to the lock.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 411.5. Exchange lockages vary from RM 411.0 to RM 411.7 to 418.2 depending on the timing of the tows exchanging. While waiting areas are available near the lock, tows are unable to pass from RM 412 to 416.

Lower Approach/Upbound: Fly lockages approach point is at RM 409.6. Exchange lockages typically occur around RM 409.0. Although no mooring is available, two to three tows can wait along Otter Island.

▪ Measures Under Consideration

At Lock 18, most measures are currently under consideration. However, no additional recreational landings are needed. The following table summarizes the expected cost and time savings for this site related to the following measures.

TABLE 3-8: COST AND TIME SAVINGS OF MEASURES AT LOCK 18

Measure	Cost [1/]	Time Savings to Waiting Tows [2/]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted. Likely to happen without project.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.2 to $22.5 mil initial/gw ext	US: 21 min. TRBK DBL DS: 28 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.1 to $11.2 mil initial/gw ext [3/]	US: 21 min. all DBL DS: 28 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 15 min. all DBL DS: 22 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $23.0 mil initially DS: $14.0 mil initially	US: 5 min. TRBK DBL DS: 8 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $23.0 mil initially DS: $14.1 mil initially Plus $518,000 annually per lock	US: 19 min. TRBK DBL DS: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $22.4 mil initially	6 min. TRBK DBL 20 min. TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.7 mil initially	6 min. TRBK DBL 22 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
DS Mooring RM 409.7	$50,000 initially	9 min. UB EXCH APRCH	Right channel
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow

TABLE 3-8 (Continued)

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Approach Improvements: Ext Guidewalls and Dredging	$200,000 to $22.4 mil initially**	1 min. to 5 min.	Details in Section 4

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

On the upper approach, the addition of a mooring is not likely to allow tows to get any closer to the lock. However, the floating mooring buoy located at RM 411.6 often flips over and is unavailable for use by tows waiting to lock.

Developing a mooring in the channel around RM 409.7 would allow tows to approach closer to the lock and reduce exchange lockage times.

Upper Approach/Downbound: Could replace the existing floating mooring buoy with a cell on the left descending bank at RM 411.6, and a cell or bank anchor could be added for tows waiting in the pocket at RM 411.0 on the left descending bank.

Lower Approach/Upbound: A preferred mooring location would be in the channel at RM 409.7.

▪ Approach Improvements

Upper Lock Approach: It was noted that the stretch of channel above the lock is one of the most dredged areas in the Rock Island District. Since 1990, there has been ongoing work on existing dikes and new dikes added. In 1990, a common waiting spot for tows was at Oquawka, Illinois. Dredging is needed between Oquawka and the upper approach to restore the channel width and increase traffic efficiency through this area. Plate 9 in Appendix C shows a sufficient width of deep water with only a little dredging needed just above the lock to shift the sailing line east and allow a straighter approach to the lock. The potential improvement is estimated at 1 to 2 on the 10 scale. The guidewall extension alone is 2 to 3. Together the improvement is estimated at 3 to 5. A guardwall is not considered applicable at this site as a time saver. A model study will identify the optimum approach improvements and may, in fact, identify a time savings with a lock guardwall.

Lower Lock Approach: There are no identified channel improvements for the lower approach. The extended guidewall is estimated at a 2 to 3 improvement.

- **Remote Remake Areas**

The same general locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface.

Upper Approach/Upbound: Remake areas could replace the floating mooring buoy on the left descending bank at RM 411.6 or use an adjacent site closer to the lock at RM 411.3.

Lower Approach/Downbound: Remake areas could be located in the channel at RM 409.7; the next potential site would be on the right descending bank at RM 409.0 along Otter Island.

- **Other Site Information**

Currently a helper boat is available at Lock 18. On the average, only about 80 percent of downbound approaches use assistance during high waters. During these times, they are saving an estimated 20 to 30 minutes per assistance. However, under normal/lower flows, a time savings of approximately 15 minutes would be possible if a helper boat were used.

Scheduling is used on occasion, while industry self help is only used about 1 to 2 times per year.

If switchboats were used to pull cuts at the site, approximately a 2,000-horsepower boat would be needed above the lock and a 1,000-horsepower boat below. However, the lockmaster would not recommend backing cuts during higher flows that are present approximately 25 percent of the year on average. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Some conflicts with recreational craft are occurring. However, recreational boat landings are available immediately downstream of the lock and within approximately 5 miles upstream.

L&D 19, Keokuk, Iowa

- **Description**

Lock 19 is located at RM 364.2 along the Iowa shore at Keokuk, Iowa. The lock has a usable chamber 110 feet wide by 1,200 feet long. No usable upper or lower approach wall of significant length is available, but the lower wall extends 480 feet at a skew. The maximum lift at the site is 38.2 feet. The dam is owned and operated by the Union Electric Company and contains a hydropower facility adjacent to the upper lock approach. Plates 10 and 11 in Appendix C highlight the existing site's potential improvements.

- **Approach Conditions**

There is an existing 1,200-foot lock at this site. Outdraft conditions significantly affecting approaches occur during approximately 25 percent of the navigation season. The intake structure for the hydropower facility is located near the upper lockwalls and constrains the type of options to be considered. WES previously completed a model study addressing potential small scale improvements for the approach area above the 1,200-foot lock.

Upper Approach/Downbound: Fly lockages approach point is generally at RM 367 when tows call in. Exchange lockages point typically occurs at RM 365.0, with the waiting tow tied off to the existing cells.

Lower Approach/Upbound: Fly lockages approach point is at RM 361.5. Exchange lockages point typically occurs at RM 363.0, otherwise tows wait at RM 361.7 to 362.0 but have cells at 363.6. Many tows do not like to wait in this location.

▪ Measures Under Consideration

At Lock 19, only a few measures are currently under consideration. The presence of a 1,200-foot chamber precludes the need to look at remake options such as switchboats and self help. In addition, adequate boat landings are available near the lock facility. Table 3-9 summarizes the expected cost and time savings by measure for this site.

TABLE 3-9: COST AND TIME SAVINGS OF MEASURES AT LOCK 19

Measure	Cost [1/]	Time Savings to Waiting Tows [2/]	Comments
Helper Boat	$640,000/boat/year	Some incremental approach time savings possible	Approach time savings is limited to those tows not currently being assisted. Likely to happen without project.
Switchboat	N/A	N/A	Tows able to lock as singles
Industry Self Help	N/A	N/A	Tows able to lock as singles
Tolls and Time Charges	$465,000* initially $235,000* annually	No significant reduction likely at this site	Not likely to be needed at this site in early years of study period
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Approach Improvements Various Options:	$4.1 mil to $13.7 mil initially***	1 min. to 5 min.	Individual options detailed in Section 4**

[1/] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2/] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

While a couple cells are currently available for downbound tows to wait along RM 365.0, additional cells at RM 365.5 would provide additional waiting areas, which are currently lacking. However, no additional time savings is estimated to occur.

At one time, there were three cells downstream of the lock around RM 363.5; now there are two cells. Building a new cell above the two cells that are at RM 363.5 would make RM 363.5 a more desirable site for waiting tows. However, many tows do not like to wait this close due to the

channel width and approach conditions. A preferred site would be RM 361.7. Many tows are now waiting at RM 361.7 to 362.0 just above the mouth of the Des Moines River on the right descending bank; however, no formal mooring is available.

Upper Approach/Downbound: Add two mooring cells at RM 365.5 to provide a location for additional tows to wait above the lock.

Lower Approach/Upbound: Additional cells could be provided for tows at RM 361.7.

- **Approach Improvements and Guidewall/Guardwall Extensions**

Upper Lock Approach: For small scale improvements, the March 1996 draft report by WES was referenced: *Navigation Conditions at Lock and Dam 19, Mississippi River.* Plan C-1 from this report with the non-standard guardwall and the four submerged dikes above the lock forebay to improve the downbound fly and exchange approach gives a potential improvement of 3 to 4 on the referenced scale of 0 to 10 (see plate 10 in Appendix C). This reduces the number of missed approaches and improves the average approach time. Implementing the channel improvements only (4 submerged dikes) is a small improvement, 0 to 1, and is not recommended. With only the non-standard guardwall, the improvement is 2 to 3. The Plan A-Modified option from the WES report (plate 11 in Appendix C) with the shortened guardwall at L2 has a potential improvement of 4 to 6. Guidewall or guardwall extensions are at the top of the list for improvements at the site. However, any work upstream will need to be coordinated with the power company. A 100-foot extension of the riverside lockwall or a 500-foot extension angled landward from the landside lockwall would assist tows into the lock.

Lower Lock Approach: Channel improvement is the widening of the channel, shown as the cross-hatched area on plates 10 and 11 in Appendix C, which is rock excavation and has a potential improvement of 2 to 3. Excavation may also be needed near the existing cells at RM 363.6 to prevent loaded tows from grounding out during low water conditions. This would provide a wider turn for upbound tows and a potentially closer exchange point (many tows now wait at RM 362 near the mouth of the Des Moines River). A 600-foot solid extension of the riverward guidewall would help downbound and upbound tows and is a potential 1 to 2 improvement. The channel excavation and extended riverward guidewall together is a potential 4 to 5 improvement.

- **Remote Remake Areas**

Remote remake areas are unnecessary at the site due to the 1,200-foot chamber length that allows all tows transiting the system to lock as singles.

- **Other Site Information**

A helper boat now is rarely available at the site. However, the expanded use of helper boats could provide some benefits to downbound tows in making their approaches. Its use could save an average of approximately 10 minutes on downbound approaches.

The presence of a 1,200-foot chamber eliminates the need for industry self help and switchboats.

Scheduling currently is not used at the site because its use could easily create very large queues for the upstream and downstream locks.

Adequate recreational landings are available above and below the lock, and recreation usage of the lock has not been a problem.

L&D 20, Canton, Missouri

▪ Description

Lock 20 is located on the Missouri shore at RM 343.2 at the town of Canton, Missouri. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 517-foot upstream guidewall and a 500-foot lower guidewall. The maximum pool lift is 10 feet. Plate 12, located in Appendix C, shows the site and potential improvements.

▪ Approach Conditions/Locations

Discussions with the lockmaster and tow pilots during an initial site visit revealed that the downbound approach to the lock requires flanking during the approach. Tows have a tendency to be drawn into the riverbank. The site has relatively moderate outdraft, with strong outdraft occurring during 30 percent of the navigation season. During high flows when the dam gates are out of the water, a helper boat is needed to assist tows making their final approach to the lock from upstream. This can occur frequently since the dam is one of the first to go out of operation during high water. The upbound approach to the lock can take as long as 45 minutes after a downbound lockage due to the distance that downstream tows must wait before making the approach.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 345.0. Exchange lockages vary from RM 343.5 to RM 345.0 depending on the timing of the tows exchanging.

Lower Approach/Upbound: Fly lockages approach point is at RM 340.7. Exchange lockage approach points vary. Tows wait along bank below 342.8 down to near 342.0.

▪ Measures Under Consideration

At Lock 20, all measures are currently under consideration. The following table summarizes the expected cost and time savings by measure for this site.

TABLE 3-10: COST AND TIME SAVINGS OF MEASURES AT LOCK 20

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Additional approach time savings is limited. Approx. 80% of tows already assisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.2 to $23.3 mil initial/gw ext	US: 23 min. TRBK DBL DS: 30 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. DS additional cost with bank excavation and addressing Buck Run.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.1 to $11.7 mil initial/gw ext [3]	US: 23 min. all DBL DS: 30 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 17 min. all DBL DS: 24 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Considering developing site upstream of the lock on both sides
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $23.8 mil initially DS: $11.7 mil initially	US: 6 min. TRBK DBL DS: 10 min. TRBK DBL	Kevels need redesign because of the low elevation of the lock guidewalls. During high water, barges ride too high, negating the use of the "typical" kevel design.
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $23.8 mil initially DS: $11.7 mil initially Plus $518,000 annually per lock	US: 20 min. TRBK DBL DS: 25 min. TRBK DBL	Same concern over redesign. Annual cost increase associated with additional personnel.
Unpowered Kevels W/Ext Guidewalls	US: $23.3 mil initially	6 min. TRBK DBL 26 min. TRBK SETOVER 6 min. TRBK KNOCKOUT	Kevels need redesign because of the low elevation of the lock guidewalls. During high water, barges ride too high, negating the use of the "typical" kevel design.
	DS: $11.3 mil initially	6 min. TRBK DBL 27 min. TRBK SETOVER 7 min. TRBK KNOCKOUT	Same concerns as above for redesign
DS Mooring RM 342.8	$50,000 initially	11 min. UB EXCH APRCH	Left channel
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$1.3 mil to 43.1 [4] mil initially***	Less than 1 min. to 6 min.	Individual options detailed in Section 4**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

On the upper approach, the addition of a mooring is not likely to allow tows to get any closer to the lock. They currently are able to wait in the pocket at RM 343.5. However, the site lacks a mooring cell, bank anchor, or other structure, and the water depth is limited to approximately 9 feet and may require dredging in the near future to remain open. The next available site is at

RM 345 on the left descending bank and then tows must wait along Nelson and Polly Islands upstream of RM 346.0. Mooring at RM 345 brings tows 1 mile closer to lock.

Developing a mooring in the channel around RM 342.8 would allow tows to approach closer to the lock and reduce exchange lockage times. Other cells farther downstream either above or below the Ayers Oil Company docks at RM 342.6 would allow tows to moor without pushing into the bank. Currently during periods of low flow, 15-barge tows must either wait in the channel or at Howards Crossing Light and Day Mark at RM 337.5. While exchange times vary, they can take up to 1 hour when a tow must wait this far from the lock.

Upper Approach/Downbound: A mooring or bank anchor could be added for tows waiting in the pocket at 343.5 or at 344.0.

Lower Approach/Upbound: A preferred mooring location would be a cell on the left descending side out in the channel at RM 342.8. Other cells downstream would provide alternative locations to assist in keeping tows from using the Canton riverfront.

- **Approach Improvements**

Upper Lock Approach: The channel improvements include extensive excavation above the lock to widen the channel and allow tows to drive to the lock. This excavation is to the landside and follows a straight extension of the landside guidewall. Improvements also include filling/straightening of the riverbank immediately above the guidewall and placement of three submerged dikes above the lock to reduce outdraft. Outdraft can be somewhat controlled at this site with operation of the gates toward the Illinois side of the dam. Extending the guidewall alone does little to improve the approach without the channel widening. An L3 or L2 guardwall alone are not recommended. Section 4 shows the relative merits of the improvements. The fly approach benefits from the channel improvements if using 1990 timing data. It was noted that in 1990 (reference year for timing data) the exchange point was the pocket about 1,500 feet above the guidewall. Now, because of siltation in the pocket area, the exchange point is more common at RM 345.0, which is considered to be the arrival point for a fly approach. Channel dredging could bring the exchange point back near the pocket area.

Lower Lock Approach: The Buck Run Creek outlet will have to be relocated farther downstream if the guidewall is extended. Extending the guidewall gives some improvement to the approach. With some dredging below the extended guidewall, the approach has a potential improvement of 3 to 5 on the reference scale.

- **Remote Remake Areas**

The same general locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface.

Upper Approach/Upbound: Remake areas could be located either just upstream of the pocket at approximately RM 343.9 on the Missouri shore or possibly out in the channel around RM 344.0.

Lower Approach/Downbound: Remake areas could be located in the channel at RM 342.7. The next potential site would be on the right descending bank either immediately above or below the Ayers Oil Company docks at RM 342.6.

▪ Other Site Information

Currently a helper boat is regularly available at Lock 20. An average of 80 percent of downbound approaches use assistance. The time savings for this assistance is estimated at more than 20 minutes during higher flows and 10 minutes during lower flows.

Scheduling is used fairly regularly when queues develop. Industry self help is implemented when a queue of 6 or more boats develops, which occurs less than 5 percent of the time.

The lockmaster estimated that, if switchboats were used to pull cuts at the site, about a 1,200-horsepower boat would be needed above the lock and a 800- to 1,000-horsepower boat below. With adequate horsepower, the switchboats should be able to pull cuts under all conditions at this site. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Currently there are not significant lock usage conflicts between commercial and recreational users. However, above the lock no landing is available on the Illinois side for approximately 15 miles.

L&D 21, Quincy, Illinois

▪ Description

Lock 21 is located on the Illinois shore at RM 324.9 at the city of Quincy, Illinois. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 517-foot upstream guidewall and a 500-foot lower guidewall. The maximum pool lift is 10.5 feet. Plate 13 in Appendix C shows the site and potential improvements.

▪ Approach Conditions/Locations

Downbound tows use a flanking approach to the lock and fight an outdraft off the end of the intermediate lockwall. Outdraft conditions significantly impacting approaches occur during approximately 55 percent of the navigation season. High tailwaters approaching flood stage require use of a helper boat to assist tows approaching the lock.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 327.0. Exchange lockages typically occur at RM 325.3 to RM 325.7 with the downbound tow waiting along the bank either just above or just below the wing dam.

Lower Approach/Upbound: Fly lockages approach point is at RM 323.7. Exchange lockage approach points vary, but 324.5 is typical. However, tows wait along Orton Island on the right descending bank around RM 323.0.

▪ Measures Under Consideration

At Lock 21, the following measures are currently under consideration. Recreational craft landings are not required due to adequate existing facilities. The following table summarizes the expected cost and time savings by measure for this site.

TABLE 3-11: COST AND TIME SAVINGS OF MEASURES AT LOCK 21

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Additional approach time savings is limited. Approx. 80% of tows already assisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.3 to $23.2 mil initial/gw ext	US: 25 min. TRBK DBL DS: 31 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. US & DS walls require bank excavation.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.2 to $11.6 mil initial/gw ext [3]	US: 25 min. all DBL DS: 31 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 19 min. all DBL DS: 25 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $23.6 mil initially DS: $14.4 mil initially	US: 7 min. TRBK DBL DS: 10 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $23.7 mil initially DS: $14.5 mil initially Plus $518,000 annually per lock	US: 21 min. TRBK DBL DS: 24 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $23.1 mil initially	6 min. TRBK DBL 27 min. TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $14.1 mil initially	6 min. TRBK DBL 30 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$2.3 mil to 32.3 [4] mil initially***	Less than 1 min. to 6min.	Individual options detailed in Section 4.**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

- **Adjacent Moorings**

On the upper approach, the addition of a mooring is not likely to allow tows to get any closer to the lock. They currently are able to wait in the pocket at RM 325.3. However, the site lacks a mooring cell, bank anchor, or other structure and the width is limited, requiring some exiting tows to take extra time to move out of the chamber. The next available site is at RM 325.7 on the left descending bank, but docks in the area and ongoing development along the Quincy riverfront limit the number of available waiting areas.

Developing a mooring in the channel around RM 324.5 would allow tows to wait over 1 mile closer to the lock and reduce exchange lockage times. Other cells farther downstream along Orton Island would allow tows to moor without pushing into the bank.

Upper Approach/Downbound: A mooring cell or bank anchor could be added for tows waiting in the pocket at RM 325.3.

Lower Approach/Upbound: A preferred mooring location would be a cell in the channel at RM 324.5. Other cells on downstream would provide alternative locations to moor without pushing into the bank along Orton Island.

- **Approach Improvements and Guidewall/Guardwall Extensions**

Guidewall extensions are under consideration as a measure both above and below the lock.

Upper Lock Approach: Channel improvements include excavating along the bankline above the lock, filling/straightening the bankline immediately above the lock, removing the wing dam located about 3,200 feet above the lock, and placing five submerged dikes above the lock to reduce outdraft. The top of the dikes is 15 feet below normal pool, which is the minimum acceptable. These improvements should allow for a straighter approach to the lock and reduce the maneuvering now needed to enter the lock. An L3 or L2 guardwall alone are not recommended.

Lower Lock Approach: There are no identified improvements for the lower approach. An extension of the guidewall gives some added benefit to the approach.

- **Remote Remake Areas**

Any remake area above the lock should be located above the pocket at RM 325.3; otherwise, it would likely block the approach. Below the lock, a remake area could be located at RM 324.3 just downstream of the boat landing along the Illinois shore.

Upper Approach/Upbound: Remake areas could be located either just upstream of the pocket at approximately RM 325.7 on the Illinois shore or possibly farther upstream along the Quincy riverfront.

Lower Approach/Downbound: Remake areas could be located along the Illinois shore at RM 324.3. Other potential sites would be out in the channel or along Orton Island.

- **Other Site Information**

An approximately 800-horsepower helper boat is regularly available at Lock 21. On average, about 75 to 80 percent of downbound approaches currently use helper boat assistance. This assistance can cut approach times by approximately 50 percent.

The lockmaster regularly implements 3-up/3-down scheduling. Industry self help, while utilized less often, is commonly used at the site.

The lockmaster estimated that, if switchboats were used to pull cuts at the site, approximately a 1,200- to 1,600-horsepower boat would be needed above the lock. With adequate horsepower, the switchboats should be able to pull cuts under all conditions at this site. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Currently there are not significant lock usage conflicts between commercial and recreational users, and adequate recreational facilities are available above and below the lock.

A guide cell added 100 feet above the upper guidewall and below the lower guidewall would assist tows and provide some increased protection for the lock gates.

L&D 22, Saverton, Missouri

- **Description**

Lock 22 is located on the Missouri shore at RM 301.2 near the town of Saverton, Missouri. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 517-foot upstream guidewall and a 500-foot lower guidewall. The maximum pool lift is 10.5 feet. Plate 14 in Appendix C shows the site and potential improvements.

- **Approach Conditions/Locations**

This site has the some of the most severe outdraft conditions on the Upper Mississippi River system. Strong outdraft currents are present approximately 40 percent of the navigation season. As downbound vessels reduce speed to make the approach to the lock, they must fight a strong outdraft. Helper boats are required to assist at tailwater stages above 8 feet. The channel upstream of the lock is narrow. A mooring cell located 3,500 feet upstream of the lock is rarely used because it is hard to access. Therefore, downbound traffic waits approximately 3 miles upstream to allow upbound traffic to pass.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 303.7 Exchange lockages typically wait either at RM 301.9 on the existing cell or at RM 303.6.

Lower Approach/Upbound: Fly lockages approach point is at RM 300.3. Exchange lockage tows typically wait along the Missouri bank at RM 300.3.

- **Measures Under Consideration**

At Lock 22, all measures are currently under consideration. The following table summarizes the expected cost and time savings by measure for this site.

TABLE 3-12: COST AND TIME SAVINGS OF MEASURES AT LOCK 22

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Additional approach time savings is limited. Approx. 80% of tows already assisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.2 to $24.3 mil initial/gw ext	US: 24 min. TRBK DBL DS: 29 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. US wall requires bank excavation.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.2 to $12.2 mil initial/gw ext. [3] An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.	US: 24 min. all DBL DS: 29 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 18 min. all DBL DS: 23 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Considering site upstream of the lock on Mo side, downstream on IL side
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $24.8 mil initially DS: $13.0 mil initially	US: 8 min. TRBK DBL DS: 10 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $24.8 mil initially DS: $13.0 mil initially Plus $518,000 annually per lock	US: 22 min. TRBK DBL DS: 24 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $24.2 mil initially	6 min. TRBK DBL 29 min. TRBK SETOVER 6 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $12.6 mil initially	6 min. TRBK DBL 33 min.TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
DS Mooring RM 300.8	$50,000 initially	7 min. UB EXCH APRCH	Left channel
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$4.8 mil to 34.7 [4] mil initially	Less than 1 min. to 10 min.	Individual options detailed in Section 4.**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

On the upper approach, the addition of a mooring could allow tows to get closer to the lock. While a cell has been constructed at RM 301.8, it has been damaged. As a result, many tows are not using the mooring cell and instead are waiting 2 miles farther upstream of RM 304. Recommendations for the site would include repairing the existing mooring cell and possibly adding additional mooring cells farther upstream to provide formal mooring areas for waiting tows.

Developing a mooring along the Missouri shore at RM 300.3, while not allowing tows to approach any closer to the lock, would provide a formal waiting area and help tows stay off the riverbanks. Another option would be a mooring located out in the river channel near RM 300.8.

Upper Approach/Downbound: Repair or replace mooring cell at RM 301.8. Additional mooring at RM 302.3 or upstream to RM 304.0 would allow other tows to wait close to the lock.

Lower Approach/Upbound: A preferred mooring location would be a cell or buoy in the channel at RM 300.8 on the left descending side. A second option would be a cell along the right descending bank at RM 300.3.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Upper Lock Approach: Channel improvement refers to the added dike system above the lock as described in the model study. This improvement (5 dikes) aligns the currents along the right bank and reduces the outdraft. Section 4 shows the potential approach improvement relative to the various improvement measures and combinations thereof. Both the fly and exchange approaches benefit from the channel improvement.

Lower Lock Approach: Channel improvement is the continuation of maintenance dredging which is done now on an as-needed basis. This, in combination with the guidewall extension, gives the maximum expected improvement (1 to 3).

▪ Remote Remake Areas

The same general locations mentioned for adjacent mooring facilities could work for remote remake areas. However, upstream it would be preferable to position a remake area upstream of the existing cell. Downstream of the lock, both locations ideally would be developed—one as an adjacent mooring and the other as a remake area. This would allow for maximum efficiency in processing exchange lockages.

Upper Approach/Upbound: Remake areas could be located on the Missouri bank at RM 302.3 just upstream of the existing cell.

Lower Approach/Downbound: Preferred remake areas correspond to the preferred adjacent mooring locations, along the Missouri bank at RM 300.6 or in the channel at RM 300.8. Ideally, both areas could be developed and one used as a remake and the other as a mooring area.

- **Other Site Information**

Currently a helper boat is regularly available at Lock 22. On average, about 80 percent of downbound approaches use assistance. The time savings for this assistance is estimated at more than 30 minutes during higher flows and 15 to 20 minutes during lower flows.

Helper boats could also be used to pull cuts along an extended guidewall, but barges may need to be attached to a traveling kevel to keep the cut along the wall.

Scheduling is used approximately 10 percent of the year and is implemented when queues develop. Both 3-up/3-down scheduling and different variations are used based on the type of queue. Industry self help is implemented when a longer queue develops, which occurs approximately 2 percent of the time.

The lockmaster estimated that, if switchboats were used to pull cuts at the site, approximately a 2,000-horsepower boat would be needed above the lock and a 1,500- to 1,800-horsepower boat below. With adequate horsepower, switchboats should be able to back cuts away upstream from the lock approximately 60 percent of the time, except during outdraft conditions. During these outdraft periods, moving the switchboat to the downstream end would be required, so the tow could be pushed upstream. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety. These larger boats should allow assistance to occur under virtually all flow conditions.

Faster emptying times would be possible if the first cut of a downbound double were taken along an extended guidewall or to a remote remake facility. However, the time savings depend on the head difference between the upper and lower pools (head is greatest during low-flow periods). At this site, the average head difference is 5.1 feet. When the head is in the 4- to 5-foot range, the valves are opened one-third to one-half of the way until the lines are tightened, and then the valves are fully opened. This leaves little potential for additional savings. In contrast, when the head difference is 10 feet, the valves are opened one-third of the way until the lines are tightened. They are then opened to two-thirds until the chamber is half empty, at which time the valves are fully opened.

Currently there is not a significant lock usage conflict between commercial and recreational users. However, above the lock there are no landings available for approximately 8 miles.

L&D 24, Clarksville, Missouri

- **Description**

Lock 24 is located on the Missouri shore at RM 273.4 at the town of Clarksville, Missouri. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 518-foot upstream guidewall and a 516-foot lower guidewall. The lift is 15 feet. Plate 15 in Appendix C shows the existing site and potential improvements.

- **Approach Conditions/Locations**

Severe outdraft conditions in the upstream approach to the lock give Lock and Dam No. 24 the distinction of being one of the most dangerous locks to approach in the lower reach of the Upper Mississippi River. Some level of outdraft conditions is present roughly 90 percent of the

navigation season, with major outdraft present over 40 percent of the time. While construction of a spur dike in the upstream approach has improved the situation, a helper boat is still needed much of the time to aid tows in their approach to the lock.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 275.4. Exchange lockages vary, but tows typically wait along refuge at RM 274.5 on the right descending bank.

Lower Approach/Upbound: Fly lockages approach point is at RM 272.0. Exchange lockage approach points vary, with tows wait along bank from approximately RM 273.0 to 272.0.

- **Measures Under Consideration**

At Lock 24, all measures are currently under consideration. Table 3-13 summarizes the expected cost and time savings by measure for this site.

- **Adjacent Moorings**

Smaller tows (9 barges or less) can wait in the pocket at RM 274.0, but the site lacks a mooring cell, bank anchor, or other structure and is limited to use by smaller tows. However, by moving the dike upstream, larger tows could use the pocket at RM 274.0, bringing tows one-half mile closer to the lock. Moving upstream, the next available sites are the two cells at Dundee Cement at RM 274.3 on the right descending bank, but most tows tie off to one of the three bank anchors along the Clarksville State Game Refuge from approximately RM 274.7 to 275.4.

Tows currently are able to wait near the lock along both sides of the river by pushing into the bank. The site also has an anchor buoy at RM 272.0, but then there is not adequate depth closer to the lock. As a result, tows need assistance in staying off the city's riverfront and dredging could be required for sites close to the lock. Several mooring cells or bank anchors could be added from RM 272.0 to 273.0 on the Missouri bank and from RM 272.0 to 272.7 along Clarksville Island.

Upper Approach/Downbound: A mooring cell or bank anchor could be added for tows waiting above the pocket at RM 274.0. Farther upstream, adequate moorings are available.

Lower Approach/Upbound: Mooring cells or bank anchors could be added from RM 273.0 to 272.0 on the Missouri bank and from RM 272.6 to 272.0 in the channel along Clarksville Island.

- **Approach Improvements and Guidewall/Guardwall Extensions**

Upper Lock Approach: The channel work consists of a dike field above the lock starting with the rework of the existing dike 2,700 feet above the dam to add an L-head and then the addition of two more dikes above it spaced at 1,000 feet for a total of three dikes above the lock. The top elevation is at 2 feet above normal pool. A guidewall extension gives the lowest level of improvement to navigation (0 to 1). The next order of improvement is the dike field above the lock, which by itself gives an estimated improvement of 3 to 4 on the 0 to 10 scale. An L3 guardwall with the dike field and extension of the existing guidewall gives an estimated improvement of 6 to 7. The most improvement (9 to 10) is achieved with an L2 guardwall, channel work and removal of the existing guidewall, and reshaping of the bankline to give the 200-foot opening at the upper end of the guardwall. Other improvements and combinations thereof are discussed in Section 4. Both the fly and exchange approaches benefit from the channel improvement.

TABLE 3-13: COST AND TIME SAVINGS OF MEASURES AT LOCK 24

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Additional approach time savings is limited, regularly assists tows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.2 to $20.5 mil initial/gw ext	US: 22 min. TRBK DBL DS: 30 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. US wall requires bank excavation.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.2 to $10.3 mil initial/gw ext [3]	US: 22 min. all DBL DS: 30 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 16 min. all DBL DS: 24 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Only considering developing site downstream of the lock on IL side
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $21.0 mil initially DS: $11.4 mil initially	US: 6 min. TRBK DBL DS: 8 min. TRBK DBL	Cost of unpowered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $21.0 mil initially DS: $11.4 mil initially Plus $518,000 annually per lock	US: 20 min. TRBK DBL DS: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $20.4 mil initially	6 min. TRBK DBL 27 min. TRBK SETOVER 6 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $11.0 mil initially	6 min. TRBK DBL 21 min.TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
US Mooring RM 274.0	$500,000 initially	7 min. DB EXCH APRCH	Right bank
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$1.6 mil to 31.7 [4] mil initially***	Less than 1 min. to 4 min.	Individual options detailed in Section 4.**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.
*** An additional cost of $450,000 is anticipated for a model study to verify the site-specific optimum approach improvements.

Lower Lock Approach: Channel improvement is the addition of a trail dike off the end of the riverward lockwall to help deflect flows from the wall. This, in combination with the guidewall extension, gives the maximum anticipated improvement. Like all lock sites, a model study is needed to verify the optimum approach improvements and in this case to identify the effectiveness of the trail dike in allowing downbound tows to exit the guidewall more efficiently.

- **Remote Remake Areas**

Above the lock, a potential site at RM 274.0 is along a rock shelf on the Missouri bank. The next available site would be upstream along the state game refuge at RM 274.5.

Below the lock, the same general locations mentioned for adjacent mooring facilities should work for remote remake areas. The primary difference would be the use of spud barges or a combination of cells and spud barges to create a flat surface.

Upper Approach/Upbound: Remake areas could be located either just upstream of the pocket at approximately RM 274.0 or upstream along the Missouri shore at RM 274.5.

Lower Approach/Downbound: A remake area could be located any where from RM 272.0 to 273.0 on the Missouri Bank and from RM 272.0 to 272.7 along Clarksville Island, but closer sites are preferred.

- **Other Site Information**

Currently a helper boat is regularly available at Lock 24. The time savings for this assistance is estimated at 10 to 15 minutes during non-outdraft flows.

Scheduling is used fairly regularly when a queue of five or more tows develops. Industry self help is implemented on a more limited basis following closures or backups of larger numbers of tows.

The lockmaster estimated that, if switchboats were used to pull cuts at the site, approximately a 1,200- to 1,400-horsepower boat would be needed above the lock and a 1,200-horsepower boat below. With adequate horsepower, the switchboats should be able to pull cuts upstream approximately 60 percent of the time, excluding severe outdraft conditions. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety. These larger boats should also allow assistance to occur under virtually all flow conditions.

Currently there are not significant lock usage conflicts between commercial and recreational users. However, below the lock no landing is available on the Illinois side for approximately 8 miles.

A micro-model is being used to address outdraft at this lock. An initial plan calls for the extension of the deflection dike above the lock as well as four bendway weirs along Middleton Island. Potential implementation is FY 98.

L&D 25, Cap au Gris, Missouri

- **Description**

Lock 25 is located on the Missouri shore at RM 241.5 near the town of Cap au Gris, Missouri. The lock has a usable chamber 110 feet wide and 600 feet long. The site includes a 512-foot upstream guidewall and a 516-foot lower guidewall. The lift is 15 feet.

- **Approach Conditions/Locations**

Minor outdraft conditions are present 85 percent of the navigation season, but more severe outdraft conditions are present approximately 35 percent of the time. Severe outdraft conditions hamper downbound tows approaching the lock. While construction of a spur dike in the upstream

approach has improved the situation, a helper boat is still needed much of the time to aid tows in their approach to the lock. The ported guardwall creates some interference with the helper boat. Additionally, the trash removal opening in the ported guardwall has proven to be ineffective as trees become pinned across the opening, which in turn encourages the collection of smaller debris. As debris continues to accumulate over time, the opening becomes plugged. This results in more flow being forced through the series of timber piles upstream. Because the timber piles are on 5-foot centers, debris accumulates quickly. As plugging of the openings increases, the outdraft near the nose cell, due to flow crossing over to the dam, becomes more severe, aggravating scour of the bed riverward of the upstream cells as well as hampering navigation.

Upper Approach/Downbound: Fly lockages approach point is at RM 241.9. Exchange lockages typically occur at RM 242.1 with the approaching tow waiting on the L head dike or at the Sandy Creek Light Daymark at RM 245.3.

Lower Approach/Upbound: Fly and exchange lockages approach points occur at RM 240.6. Exchange lockages typically occur at RM 240.6.

- **Measures Under Consideration**

At Lock 25, all measures are currently under consideration. Table 3-14 summarizes the expected cost and time savings by measure for this site.

- **Adjacent Moorings**

On the upper approach, the addition of a mooring would not allow tows to get any closer to the lock. They currently are able to moor to the bank anchor on the L-head dike above the lock at RM 242.1 on the right descending bank. However, an additional mooring site at RM 242.4 would allow the next (second) tow to approach 0.8 mile closer to the lock, from RM 245.3.

A mooring at RM 240.6 would formalize the existing waiting area as well as protect the bank. Another option would be to develop a mooring in the channel around RM 241.3 that would also allow tows to approach closer to the lock and reduce exchange lockage times.

Upper Approach/Downbound: A mooring cell or bank anchor could be added above the pocket at RM 242.4.

Lower Approach/Upbound: The preferred site is a mooring in the channel at RM 241.3 on the left descending side of the channel. A second option would be a cell or bank anchor at the existing waiting area on the Missouri bank at RM 240.6.

- **Approach Improvements and Guidewall/Guardwall Extensions**

Upper Lock Approach: Channel work includes shortening the L-head dike located about 3,900 feet above the dam and channel realignment to about 5,000 feet above the dam. A guardwall at either Location 3 (L3) or Location 2 (L2) would be beneficial. A guardwall at either L3 or L2 should eliminate the need for a helper boat that is commonly used at this site. The L3 guardwall would be used with the existing guidewall in place. The L2 guardwall would be used with the existing guidewall removed and bank shaped to provide a 200-foot opening at the upper end of the guardwall. An L2 guardwall by itself is not recommended. Combinations of these improvements are valued in Section 4.

TABLE 3-14: COST AND TIME SAVINGS OF MEASURES AT LOCK 25

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Additional approach time savings is limited. Approx. 80% of tows already assisted.
Switchboat w/Guidewall Extension	$1.13 mil/boat/year $3.3 to $27.3 mil initial/gw ext	US: 24 min. TRBK DBL DS: 31 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. US & DS walls require bank excavation.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/year $3.7 mil initially/moor $2.2 to $13.7 mil initial/gw ext [3]	US: 24 min. all DBL DS: 31 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 18 min. all DBL DS: 25 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Only considering developing site US of the lock on MO side
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $27.8 mil initially DS: $15.1 mil initially	US: 6 min. TRBK DBL DS: 8 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $27.8 mil initially DS: $15.1 mil initially Plus $518,000 annually per lock	US: 20 min. TRBK DBL DS: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $27.2 mil initially	6 min. TRBK DBL 27 min. TRBK SETOVER 6 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $14.7 mil initially	6 min. TRBK DBL 23 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of powered kevels is $360,000 initially
DS Mooring RM 241.3	$50,000 initially	9 min. UB EXCH APRCH	Left channel
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$1.0 mil to 34.1 [4] mil initially	Less than 1 min. to 5 min.	Individual options detailed in Section 4.**

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by ½ cost of 600-foot US wall.
[4] Includes impacts to navigation during construction.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.
** Some options provide potentially greater time savings but at a high cost to the navigation industry due to delays and closures during construction.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

Lower Lock Approach: The guidewall extension provides very little improvement. The extended wall would make for a better upbound approach but could make the downbound exit worse if the tow has to hug the wall before it can swing its stern to make the leeward exit as it now does. Channel excavation, including the right descending bank at RM 240.8, would provide a straighter approach/exit and together with the guidewall extended would provide the greatest potential improvement (4 to 5 on the referenced scale). It was noted that there are environmental concerns along the right descending bank.

- **Remote Remake Areas**

The same locations mentioned for adjacent mooring facilities could work for remote remake areas. The primary difference would be the use of a combination of cells and spud barges to create a flat surface.

Upper Approach/Upbound: A remake area could be added above the pocket at RM 242.4 on either the right descending bank or left descending channel.

Lower Approach/Downbound: A remake area could be located along the Missouri bank at RM 240.6; the second option would be a cell out in the channel at RM 240.8.

- **Other Site Information**

Currently a helper boat is regularly available at Lock 25, but often the towing company must be notified to get a crew on site to operate the boat. On average, approximately 80 percent of downbound approaches use assistance. The time savings for this assistance is estimated at up to 45 minutes during outdraft and 10 to 15 minutes during normal flows. However, nearly all tows are currently using assistance during outdraft conditions.

Scheduling is used on average nearly 10 percent of the year. It is implemented when a queue of five or more tows develops. Industry self help is implemented only when the queue dictates larger N-up/N-down procedures, such as 6-up/6-down.

The lockmaster estimated that, if switchboats were used to pull cuts at the site, approximately a 2,000-horsepower boat would be needed above the lock and a 1,200-horsepower boat below. With adequate horsepower, the switchboats should be able to back cuts to remote remake areas under non-outdraft conditions 60 to 70 percent of the time. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Recreational traffic has been growing and increasingly conflicting with commercial users. Below the lock, no landings are available on the Illinois side for approximately 18 miles. The St. Louis District did try recreational scheduling at the site in 1980, with no noticeable benefit. See the recreational scheduling writeup in Section 4 for details.

Melvin Price Locks & Dam, Alton, Illinois

- **Description**

Mel Price has two lock chambers located near the Illinois bank and in the channel at RM 200.8 near the town of Alton, Illinois. The main lock has a usable chamber 110 feet wide and 1,200 feet long. An auxiliary lock, 110 feet wide and 600 feet long, is also available at the site. The

auxiliary lock has upper and lower guidewalls of approximately 1,200 feet. The lift at the site is 16 feet. Plate 17 in Appendix C shows the site and potential measures.

- **Approach Conditions/Locations**

Mel Price is the newest lock on the Upper Mississippi River System. The placement of the main chamber out in the channel with gates on both sides allows the lock staff to control outdraft under most conditions. As a result, approach assistance is almost never required.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 202.5. Exchange lockages points vary, but tows typically pass in the channel at RM 202.0 out in the channel.

Lower Approach/Upbound: Fly and exchange lockages approach points are at approximate RM 199.6.

- **Measures Under Consideration**

At Mel Price Locks, only a few improvement measures are currently under consideration. Due to the presence of a 1,200-foot chamber and 1,200-foot guidewalls at the 600-foot lock, switchboats with remote remake were considered unnecessary. In addition, no approach improvements or guidewall extensions are required. The Table 3-15 summarizes the expected cost and time savings for this site related to the following measures.

- **Adjacent Moorings**

Currently downbound tows do not have a formal mooring, and development and fleeting in the area above the locks reduces potential mooring areas. Some bank anchors at approximately RM 204.0 would provide tows with an area to wait during periods of congestion.

The addition of a dedicated mooring in the channel or along the bank at RM 200.6 on the left descending side has the potential to bring tows approximately 1 mile closer to the lock.

Upper Approach/Downbound: A bank anchor or series of bank anchors could be provided for tows along the left descending bank at RM 204.0.

Lower Approach/Upbound: Mooring or bank anchors could be added at RM 200.6 along the left descending side.

- **Approach Improvements and Guidewall/Guardwall Extensions**

No approach improvements were identified for Mel Price Lock.

- **Remote Remake Areas**

Not applicable to site.

TABLE 3-15: COST AND TIME SAVINGS OF MEASURES AT MEL PRICE LOCK (AUX. LOCK)

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/yr	N/A	Good approach, limited additional savings possible.
Switchboat	$1.13-$1.33 mil/boat/yr	N/A	Switchboats, while not currently used, only needed during main lock closure.
Industry Self Help	$50/hour for fuel $500k initially/cell	N/A	Self help or switchboats currently required during main lock closure.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Only considering a site below the lock
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels	US: $750,000 initially	TBD	Helper boat used now when main lock is closed. Existing guidewall is 1,200 ft.
	DS: $750,000 initially	TBD	Helper boat used now when main lock is closed. Existing guidewall is 1,200 ft.
Unpowered Kevels	US: $360,000 initially	TBD	Helper boat used now when main lock is closed. Existing guidewall is 1,200 ft.
	DS: $360,000 initially	TBD	Helper boat used now when main lock is closed. Existing guidewall is 1,200 ft.
DS Mooring RM 200.6	$50,000 initially	13 min. UB EXCH APRCH	Left bank
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements: None Identified			

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification

[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Other Site Information

Helper boats are rarely used at this site and only provide approach assistance to 1 to 2 percent of tows using the facility.

Scheduling is not typically required, and self help is only implemented in situations were the main lock chamber is closed and all tows must use the 600-foot chamber.

Recreational traffic above the lock is relatively heavy, and several marinas and landings are available. While a recreational boat landing is available immediately below the lock on the right descending bank, the condition of the facility and site make it difficult to use. There is some potential that an additional landing below the lock would allow some craft wanting to use the lower pool or Missouri River to avoid locking through.

Locks & Dam 27, Granite City, Illinois

▪ Description

Locks and Dam 27 is located in the Chain of Rocks Canal at RM 185.5 near the town of Granite City, Illinois. The site has two chambers. The main chamber is 110 feet wide and 1,200 feet long, while a second chamber is 110 feet wide by 600 feet long. The intermediate wall extends upstream approximately 600 feet, providing a guidewall for tows approaching either lock to use. Below the locks a 600-foot guidewall located along the left descending bank is available for the main lock chamber. However, the lower 600 feet of the main lockwall can be used as a guidewall in approaching the 600-foot lock. The lift at the site is approximately 10 feet, but varies considerably based on the discharge of the Upper Mississippi River, Illinois Waterway, and Missouri River.

▪ Approach Conditions/Locations

Due to the location of the locks in the canal, no outdraft conditions are present; however, at times wind can cause some problems.

Upper Approach/Downbound: Fly lockages approach point is generally recorded at RM 186.5. Exchange lockages vary, but typically occur considerably closer.

Lower Approach/Upbound: Fly lockages approach point is at RM 183.0 in St. Louis harbor. Exchange lockage approach points vary, but tows can wait along the right descending bank near the lower end of the canal at RM 184.3 to 185.0.

▪ Measures Under Consideration

At this site, all measures are not currently under consideration. The following table summarizes the expected cost and time savings by measure for this site.

▪ Adjacent Moorings

Above the locks, several old bank anchors are available along the canal. While in need of replacement, they continue to provide some formal moorings. Below the lock and in many areas above, tows simply push into the bank while awaiting lockage.

Upper Approach/Downbound: Some replacement of damaged bank anchors could be conducted.

Lower Approach/Upbound: Could provide bank anchors along right descending bank near the lower end of the canal at RM 184.3 to 185.0.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Upper Lock Approach: The approach in the canal is generally good; however, extending the existing guidewall an additional 600 feet or at a minimum adding an additional cell 400 feet above the existing cell upstream of the intermediate wall would provide some benefits.

Lower Lock Approach: No specific improvement was identified, other than when the main chamber is down, spud barges could be added to extend the lower wall, allowing tows to remake outside of the chamber along the extended lower wall.

- **Remote Remake Areas**

Several areas above the lock on either side of the channel could be explored as remake areas.

Below the lock, tows could be remade along waiting tows or some flat surface placed along the right descending bank. However, remaking tows in this area is likely to limit the ability of upbound tows to get through and approach the lock due to the bend in the canal and relatively narrow channel widths.

TABLE 3-16: COST AND TIME SAVINGS OF MEASURES AT LOCK 27 (AUX. LOCK)

Measure	Cost [1/]	Time Savings to Waiting Tows [2/]	Comments
Helper Boat	$640,000/boat/yr	N/A	Good approach, limited additional savings possible.
Switchboat	$1.13 to $1.33 mil/boat/yr	N/A	Switchboats, while not currently used, only needed during main lock closure
Industry Self Help	$50/hour for fuel $500k initially/cell	N/A	Self help or switchboats currently required during main lock closure
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Will be evaluated using system models
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	TBD	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	TBD	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $14.3 mil initially DS: Not recommended	TBD	Cost of powered kevel is $750,000/wall Tow haulage design must accommodate higher than "normal" guidewall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $14.3 mil initially DS: Not recommended Plus $518,000 annually per lock	TBD	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $13.9 mil initially DS: Not recommended	TBD	Cost of extending unpowered kevels is $240,000 initially Guidewall is too high for "normal" kevel/rail design
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements:	N/A	N/A	None identified; outdraft not a problem

[1/] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification
[2/] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

- **Other Site Information**

Currently helper boats are very rarely available at the lock, and conditions seldom require their use due to the absence of outdraft in the canal.

Scheduling (4-up/4-down) is used fairly regularly, and at times the lock may go to 6-up/6-down or 12-up/12-down in coordination with Mel Price. Industry self help is typically only required when the main 1,200-foot lock goes down.

Currently there are not significant lock usage conflicts between commercial and recreational users due to the present high level of commercial traffic and lack of desirable recreational use areas. The majority of the recreational traffic utilizing the site is larger craft moving long distances in the spring and fall.

ILLINOIS WATERWAY LOCKS

La Grange Lock, Versailles, Illinois

- **Description**

La Grange lock is located at Illinois RM 80.2 on the right descending bank near the town of Versailles, Illinois. The lock has a usable chamber 110 feet wide and 600 feet long with a lift of 10 feet. The site includes a 625-foot upstream guidewall and a 550-foot lower guidewall. The dam is constructed of wicket gates that can be lowered during higher flows, providing an open pass condition, where tows can transit the area without locking through the chamber. Plate 27 in Appendix C shows the site and potential improvements.

- **Approach Conditions/Locations**

The dam consists of an 80-foot-wide tainter gate and 109 wicket gates 4 feet wide. Open pass exists about 40 to 50 percent of the time. The tainter gate has helped to lessen the magnitude of the outdraft. Lower flow velocities (1-2 fps) allow easier maneuvering for tows on their downbound approach as they tuck into the pocket of water above the lock. The lock is located on the outside of a bend in the river and the natural flow "pins" tows to the right descending bank.

The following approach locations are the typical river miles were the fly and exchange approaches are considered to start.

Upper Approach/Downbound: Fly lockages approach point is recorded at RM 81.0; during open pass the fly is recorded at the end of the bullnose.
Exchange lockages typically wait at RM 81.2.

Lower Approach/Upbound: Fly lockages approach point is at RM 78.8.
Exchange lockages typically occur at RM 79.7.

- **Measures Under Consideration**

At La Grange Lock, the following measures are currently under consideration:

TABLE 3-17: COST AND TIME SAVINGS OF MEASURES AT LA GRANGE LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Outdraft not a problem under most flows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.2 to $12.0 mil initial/gw ext	US: 21 min. TRBK DBL DS: 29 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.1 to $5.8 mil initial/gw ext [3]	US: 21 min. all DBL DS: 29 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 17 min. all DBL DS: 25 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Additional sites above and below lock under consideration
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $12.1 [4] mil initially DS: $12.4 [4] mil initially	US: 7 min. TRBK DBL DS: 11 min. TRBK DBL	Does not include ext guidewall costs Does not include ext guidewall costs
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $12.2 [4] mil initially DS: $12.4 [4] mil initially Plus $518,000 annually per lock	US: 21 min. TRBK DBL DS: 25 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $11.6 [4] mil initially	6 min. TRBK DBL 22 min. TRBK SETOVER 5 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $12.0 [4] mil initially	6 min. TRBK DBL 22 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
US Mooring RM 80.4	$500,000 initially	7 min. DB EXCH APRCH	Right bank
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements Various Options:	$150,000 to $22.9 [4] mil. initially	TBD	Model study to confirm

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Impacts to navigation during construction are significant. See Section 4.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

On the upper approach, the addition of a mooring would allow tows to wait closer to the lock. An anchor at RM 80.9 formerly provided a mooring but it is no longer usable. Improving this area would allow for tows to exchange approximately 0.3 mile closer to the lock or 0.5 mile closer from RM 80.9 if the channel were widened above the lock.

Below the lock, several tows are able to wait near the lock starting at RM 79.7 on the right descending bank. However, these sites lack formal moorings which, if available, could assist in protecting the bank.

Upper Approach/Downbound: A mooring could be added above the lock at RM 80.9 or RM 80.4.

Lower Approach/Upbound: Could formalize current waiting areas by placing several moorings from RM 79.7 downstream along the right descending bank.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Upper Lock Approach: With open pass conditions present 40 to 50 percent of the time, the lock is used when flows are typically lower and currents not as fast as those on the Upper Mississippi River. In general, tows can maneuver more easily on their approach to the lock. The criteria of providing a straight approach for two tow lengths (2,400 feet) above an extended guidewall or 1,200-foot guardwall may be relaxed because of the lower flow velocities. Channel improvements include excavating and widening the channel and adding five wing dikes along the left descending bank. These channel measures give some improvement to the approach and in combination with the guidewall extended give added safety to the approach. A lock guardwall requires additional channel widening, along with the five dikes and removal of the existing guidewall. The lock guardwall with channel improvements provides a safer lock approach. A reduction in approach time is questionable; however, since during higher river flows when outdraft impacts the approach to the lock, tows use open pass and bypass the lock. With a new 1,200-foot guardwall, there is less than one tow length of straight approach above the guardwall.

Lower Lock Approach: The guidewall extended along with a trail dike off the end of the riverward lockwall has a relative improvement potential for downbound tows exiting the guidewall. The extended guidewall offers some approach improvement potential for upbound tows.

▪ Remote Remake Areas

Due to the limited channel width and large variability in flows, remote remake areas are not as attractive at this site compared to the Upper Mississippi River. However, locations are available.

Upper Approach/Upbound: A remake area could be added on the right descending bank at RM 81.2.

Lower Approach/Downbound: A remake area could be added on the right descending bank at RM 79.5.

▪ Other Site Information

Helper boats are not regularly available at La Grange lock and must travel approximately 8 miles to reach the site. The boats that are typically available range from 800 to 1,100 horsepower. They provide assistance to an average of 50 to 60 percent of downbound approaches. The time savings for this assistance is estimated at well over 15 to 30 minutes during outdraft conditions, but time savings is minimal during normal flows.

Scheduling is used most regularly during winter navigation from November to February when it is used approximately 20 percent of the time. Industry self help implementation typically occurs when scheduling is required. The majority of the time, the industry boat simply pulls the cut out along the wall. This does not result in moving the remake operation out of the chamber. On a much more limited basis, cuts are pulled from the lock chamber and put back together along the number one tow waiting to lock in the opposite direction or along the existing guidewall by pulling the cut to the last pin on the wall. Construction of moorings for tows to tie off would improve safety in the operation of self-help.

The lockmaster estimated that, if switchboats were used to pull cuts at the site, approximately a 1,500- to 2,000-horsepower boat would be needed above the lock and a 1,200-horsepower boat below. With adequate horsepower, the switchboats should be able to pull cuts under all conditions. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Recreational traffic remains at relatively low levels and currently is not resulting in major conflicts at the lock sites. However, the nearest recreational landings are 8 to 9 miles upstream and downstream.

Peoria Lock, Peoria, Illinois

▪ Description

Peoria Lock is located at RM 157.7 on the left descending bank near the city of Peoria, Illinois. The lock has a usable chamber 110 feet wide and 600 feet long with a lift of 11 feet. The site includes a 500-foot upstream guidewall and a 500-foot lower guidewall. The dam is constructed of wicket gates that can be lowered during higher flows, allowing tows to transit the area without locking through the chamber. Plate 26 in Appendix C shows the site and potential improvements.

▪ Approach Conditions/Locations

The dam consists of an 80-foot-wide tainter gate and 108 wicket gates 4 feet wide. Open pass exists about 40 percent of the time. Lower flow velocities are typical when the lock is in use, allowing easier maneuvering by tows above the lock on their downbound approach.

Upper Approach/Downbound: Fly lockages approach point is at RM 158.5. Exchange lockages typically occur at RM 158.0, just above the I-474 bridge. The next exchange site is at RM 160.5.

Lower Approach/Upbound: Fly lockages approach point is located at RM 156.5. Exchange lockages typically occur at RM 156.8, but can vary from RM 157.5 to 156.0 depending on flows.

▪ Measures Under Consideration

At Peoria Lock, the following measures are currently under consideration:

TABLE 3-18: COST AND TIME SAVINGS OF MEASURES AT PEORIA LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Outdraft not a problem under most flows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.2 to $13.4 mil initial/gw ext	US: 23 min. TRBK DBL DS: 28 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. DS bank excavation required.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.1 to $6.3 mil initial/gw ext [3]	US: 23 min. all DBL (no site) DS: 28 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 19 min. all DBL (no site) DS: 24 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $13.2 [4] mil initially DS: $13.8 [4] mil initially	US: 8 min. TRBK DBL DS: 12 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $13.2 [4] mil initially DS: $13.8 [4] mil initially Plus $518,000 annually per lock	US: 22 min. TRBK DBL DS: 26 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $12.7 [4] mil initially	6 min. TRBK DBL 28 min. TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.4 [4] mil initially	6 min. TRBK DBL 28 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements	$350,000	Limited	Upstream vane dikes

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Impacts to navigation during construction are significant. See Section 4.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

On the upper approach, the addition of a mooring would not allow tows to get closer to the lock. If the waiting area at RM 158.0 is eliminated, tows will be forced to move 2.5 miles upriver to RM 160.5 to wait, increasing total exchange times up to 40 to 60 minutes. As a result, a formal mooring near RM 158.0 should be pursued and developed.

Below the lock, tows are able to wait near the lock starting from RM 157.5 to 156.0 on the left descending bank. However, these sites lack formal moorings that could protect the shore.

Upper Approach/Downbound: A mooring could be added above the lock at RM 158.0.

Lower Approach/Upbound: Could formalize current waiting areas by placing several moorings from RM 157.5 on down along the left descending bank.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Upper Lock Approach: Open pass exists at this lock about 40 percent of the time. Channel improvement includes the addition of wing dikes or vane dikes above the guidewall, extended to 400 feet upstream of and encasing the I-474 Bridge piers, to align currents with the lock and increase safety approaching the bridge piers. The commercial docks along the left descending bank above the I-474 Bridge may limit the placement of control dikes. A lock guardwall is not recommended at this site because of its proximity to the I-474 Bridge piers and resultant width restriction at the guardwall entrance. The upper approach area has become more congested with the increased fleeting activities just above the lock along the right descending bank.

Lower Lock Approach: No channel improvements are recommended.

▪ Remote Remake Areas

Finding a suitable site for a remake area above the lock may present some difficulties. Sites are limited due to the presence of a bridge, fleeting areas, docks, and other adjacent uses. If the use of switchboats appears to provide significant benefits following further analysis, a specific site could be identified.

Below the lock a number of potential sites are available, but a site on the opposite bank below RM 157.0 would be preferred.

Upper Approach/Upbound: Identifying a suitable remake area would require additional analysis.

Lower Approach/Downbound: A remake area could be added on the right descending bank below RM 157.0.

▪ Other Site Information

Helper boats are regularly available at Peoria Lock. They provide assistance to an average of 30 percent of downbound approaches, but approximately 80 percent use assistance during outdraft or ice conditions. If an extended guidewall were present at the site, helper boats should be able to pull cuts along the wall in all conditions, except during heavy ice conditions when a switchboat or line haul boat would be required. Subsequent discussion with the U.S. Coast Guard and

navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Scheduling is used most regularly during winter navigation from November to February when it is used well over 50 percent of the time. Industry self help implementation typically occurs when scheduling is required. As part of the implementing self help, cuts are typically pulled from the lock chamber out along the existing guidewall, but remake time savings is not realized. On a more limited basis, the cuts are pulled out for remote remake and put back together along a tow waiting to lock in the opposite direction.

Recreational traffic is significant at the site with larger marina-based boats constituting a high percentage of the total traffic. Recreational landings are available near the lock site.

Starved Rock Lock, Ottawa, Illinois

▪ Description

Starved Rock Lock is located at RM 231.0 along the right descending bank near Ottawa, Illinois. The lock has a chamber 110 feet wide (with 108 feet of usable width). The chamber is 600 feet long with a lift of about 18 feet. The site includes a 598-foot upstream guidewall and a 594-foot lower guidewall. The site has a number of mooring cells upstream of the lock. Plate 25 in Appendix C shows the site and location of proposed measures.

▪ Approach Conditions/Locations

No major difficulties exist with the downbound lock approach. The channel is wide enough to provide good passing areas above the lock. The upbound approach is through a much narrower channel along Plum Island where siltation is a chronic problem. Tows normally wait along Plum Island, but two tows typically cannot both be under power when passing along Plum Island because of the narrow channel. Tows waiting downstream near the railroad bridge take an extra 20 minutes to an hour for the approach. Closer to the lock, outdraft from the dam at Leopold Island pushes tows into the right bank. Tows have hit the end of the lower guidewall because of this, yet tows must stay close to the guidewall because of shallow water just riverward of the guidewall.

Upper Approach/Downbound: Fly lockages approach point is the Starved Rock Marina at RM 233.3. Exchange point is at the mooring cells at RM 231.5. During high flows (gate opening above 18 feet), tows cannot wait at these cells because they can not get off them due to outdraft. The next waiting spot is at the Delbridge Island Light and Daymark (L&D) at RM 233.0.

Lower Approach/Upbound: Fly lockages are generally recorded at the red buoy along the left descending riverbank at RM 230.6.
Exchange point is along Plum Island at about RM 230.4.

▪ Measures Under Consideration

At Starved Rock Lock, the following measures are currently under consideration:

TABLE 3-19: COST AND TIME SAVINGS OF MEASURES AT STARVED ROCK LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Outdraft not a problem under most flows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.2 to $11.1 [4] mil initial/gw ext	US: 23 min. TRBK DBL DS: 25 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. DS bank excavation required.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.1 to $4.8 [4] mil initial/gw ext [3]	US: 23 min. all DBL DS: 25 min. all DBL	Remake time savings possible all flows with adequate horsepower.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 19 min. all DBL DS: 21 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $10.1 [4] mil initially DS: $11.3 [4] mil initially	US: 6 min. TRBK DBL DS: 8 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $10.2 [4] mil initially DS: $11.3 [4] mil initially Plus $518,000 annually per lock	US: 20 min. TRBK DBL DS: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $9.6 [4] mil initially	6 min. TRBK DBL 30 min. TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $10.9 [4] mil initially	6 min. TRBK DBL 27 min.TRBK SETOVER 8 min. TRBK KNOCKOUT	Cost of upowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements	$500,000	Limited	DS, vane dikes to control sedimentation

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Impacts to navigation during construction are significant. See Section 4.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

Mooring facilities at the waiting areas listed above would reduce riverbank damage, but their use below the lock is contingent on controlling the siltation problem since the channel is too narrow and tows may not access facilities if they become silted in. Placement of facilities would not bring tows closer to the lock.

Below the lock, tows presently push into the bank along Plum Island with attendant resource damage. Tow waiting areas, in addition to the exchange point on the left descending bank at RM 230.4, include the right bank at RM 230 (because of the shallow area along Plum Island) and the area below the highway bridge at RM 229.3. Additional mooring cells below the highway bridge would help.

The lockmaster indicated that three cells placed along the right descending bank at RM 231.6 could be used to secure barges while the towboat pulls cuts at the lock, and these cells could shorten exchange times during high water when tows normally wait at RM 233.3.

Upper Approach/Downbound: Mooring cells are available above the lock at RM 231.5, but a mooring could be provided for tows waiting at RM 233.3.

Lower Approach/Upbound: Could formalize current waiting areas by placing moorings at RM 230.4 on the left bank, near RM 230.0 on the right bank, and RM 229.3 on the left bank.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Industry does not believe there is a large approach time savings with either an upper or lower guidewall extension. It is more important to maintain/improve the lower channel. Concern is for safety. The first cut pulled an additional 600 feet along a lower guidewall extension would be exposed to outdraft. In lieu of extended guidewalls, could use two cells at the 200- and 400-foot mark from the end of the existing guidewalls with tow makeup still on the existing guidewall flat surface.

Upper Lock Approach: No extreme difficulties were noted for the downbound approach during a December 1996 site visit with the lockmaster and navigation industry representative. An upper guidewall extension adds little improvement to the approach time.

Lower Lock Approach: Channel improvements include the addition of a closure structure, comprised of 100-foot-long vane dikes with 50-foot openings to control the outflow from the dam into the navigation channel and possibly lessen the siltation. This should be studied as part of any detailed improvement plan.

Two alignment cells could be added at the end of the existing lower left short wall to help upbound tows flatten out as suggested during the site visit in lieu of a guidewall extension. A solid guidewall extension provides little added improvement to the upbound approach.

▪ Remote Remake Areas

The use of switchboats is highly questionable, since there are no remote remake areas near the lock that do not block exchange lockages. One potential option for remaking out of the chamber would be to pull cuts to the last checkpost on the existing wall, dredge the remake area, or take the cuts below the highway bridge for remake.

Upper Approach/Upbound: Identifying a suitable remake area would require additional analysis.

Lower Approach/Downbound: Identifying a suitable remake area would require additional analysis.

▪ Other Site Information

Currently there is not enough demand to keep a helper boat at the site. Begin to use at 15.5 feet of gate opening. Boats are available at Ottawa (approximately 45 minutes of travel time, 6-9 RM upstream). Most boats are in the 800 horsepower range. Cost for their assistance is $150 per hour (charged for travel time as well, making total cost approximately $300 per assistance). Helper boats with 800 horsepower could be used to pull cuts along the existing guidewall or the last pin on the guidewall and hold the cut during remake without blocking the chamber. Additional cells off the end of the upper guidewall at 200, 400, and 600 feet would assist in holding cuts for remake. Helper boats are used to move ice and are also needed during windy conditions.

Scheduling is not typically required. Scheduling is used perhaps a couple of times a year during high flows, ice conditions, or extreme traffic.

Self help has potential at this site. Self help is presently used during heavy ice periods. The navigation industry representative indicated that additional mooring cells would make tow operators more willing to leave their unpowered barges and assist in pulling cuts.

Some recreational craft conflicts exist and they are increasing. There are adequate recreational craft landings at this site. Most boaters use the State Park access and the 66 river miles to the Peoria Lock and Dam. A major problem is that not all recreational craft have radios or they use different channels. This makes it difficult for lock personnel to get all recreational boats effectively into the chamber for an efficient multiple recreational craft lockage. Education and proper usage of the radio around the lock are key issues.

During year-round navigation, ice problems greatly impact lock operations. Bubblers at the remake area may improve lockage efficiency.

The lockmaster would like improved lighting in the remake areas. The current 400 watt lights are not comparable to the newer lock sites with 2,000 watt floodlights. This would improve safety and efficiency in remaking couplings at night.

The lockmaster would also like to see two additional floating timber heads on the landside of the lock and an additional ladder on the lower guidewall to assist the crew in accessing the powered cut.

Marseilles Lock, Marseilles, Illinois

▪ Description

Marseilles Lock is located at RM 244.6 at the downstream end of the Marseilles Canal. The lock has a usable chamber 110 feet wide and 600 feet long with a lift of 24.3 feet. The site includes a 600-foot upstream guidewall and a 597-foot lower guidewall. This site is identified as the major bottleneck on the Illinois Waterway because of the 2.5-mile approach canal above the lock which is shallow and narrow and prevents tows from passing. Plates 22 through 24 in Appendix C show the site and potential improvements.

▪ Approach Conditions/Locations

Channel soundings taken in March-May 1996 show the 2.5-mile downbound approach channel varies from 100 to 200 feet wide and not much more than 10 to 11 feet deep below flat pool in isolated areas. Since tows cannot pass, a downbound tow must wait above the highway bridge at Marseilles for an exchange with an upbound tow. It takes an upbound tow about 45 to 50 minutes to travel to this point from the lock, and the downbound tow another 45 to 50 minutes to reach the lock. Depending on its arrival time, a downbound tow can sometimes (60 to 75 percent of the time) get to the mooring piers just above the lock for an exchange there. The turnback approach can also be just above the lock at the existing mooring piers. The narrow, shallow channel also causes a problem when the lock is filling, using water from the canal. Tows must reverse engines and use caution on their approach as the water level above the lock can drop 8 to 12 inches during the filling process. Compared to improvements at other Illinois Waterway locks, it is estimated that channel improvements to include channel widening to 300 feet with a minimum depth of 11 feet would be a 10+ on a 1 to 10 scale of all other potential improvements on the Illinois Waterway. Dredging selected areas along the 2.5-mile canal to provide passing zones would benefit also and is estimated at a 5 on the 1 to 10 improvement scale. A passing area is best placed about halfway down the canal. Any proposed dredging is faced with the difficulty of identifying dredged material placement sites.

The bridge upstream at Marseilles was thought to be a restriction at the canal entrance but the bridge is being replaced. New bridge pier locations provide some added channel span width but not a 300-foot passing width.

Below the lock, approach and exit tows have difficulty navigating past the existing cells along the left descending riverbank at 20 to 25 feet of gate opening at the dam due to currents coming around the island from the dam. The cells are considered to be a hazard to navigation. If tows do manage to get to these cells, they are in the way of downbound tows. A shoaling area on the right side below the lock at RM 244.2 prevents tows from bearing right as they leave the lock. A barge at the chemical dock at RM 244 also presents some hindrance to navigation but on a limited scale. The lockmaster commented that during high water the lower guidewall becomes submerged and the lock implements a 70-foot-width restriction to avoid potential damage to the railing and light posts along the wall. However, these conditions only occur about 2 percent of the time.

Upper Approach/Downbound: Fly lockages arrival point is the Canal Light and Daymark RM 245.6, about 1 mile above the lock; however, tows call in their approach at Ballard's Island at RM 248.0.
Exchange lockage point is either at Ballard's Island or just above the lock on mooring piers at RM 244.7.

Lower Approach/Upbound: Fly and exchange lockages approach points both generally occur at the Marseilles Lock Daymark at RM 243.3.

▪ Measures Under Consideration

At Marseilles Lock, the measures shown in Table 3-20 are currently under consideration.

▪ Adjacent Moorings

Mooring facilities at the waiting areas at Ballard's Island and below the lock at RM 242.0 and 243.3 would not bring traffic closer to the lock but would lessen resource damage to the riverbank. It takes about 45 to 50 minutes to reach the lock from Ballard's Island. If a tow is exiting the lock upstream, it can take 1 hour and 30 minutes or more for an exchange (45 to 50 minutes for the exiting tow to reach Ballard's Island and another 45 to 50 minutes for the downbound approach), during which time the lock is not being used. However, if the downbound tow can get to the mooring cells above the lock before the upbound exit, the exchange time is greatly reduced. There is only room for one tow to wait on the piers above the lock. However, adjacent moorings in combination with channel widening in the canal could provide intermediate exchange locations and reduce the number of times tows must wait at Ballard's Island.

Below the lock, upbound tows wait at the Daymark on the left bank RM 243.3 or at RM 242.0 on the left bank. There are no mooring facilities at either location; tows push into the riverbank. Generally, the four cells below the lock are not used by the larger tows but do get occasional use by smaller tows and recreational traffic.

In addition, the industry representative stated that the removal of the existing four cells above the lock and the four cells below the lock would constitute a site improvement, since these cells are thought to be a hindrance to navigation.

Upper Approach/Downbound: A mooring cell is available above the lock at RM 244.7, but additional mooring could be provided in conjunction with channel widening on the left bank at RM 245 and 245.6-246.0.

Lower Approach/Upbound: Could formalize current waiting areas by placing moorings at RM 243.3 and 242.0 on the left bank.

▪ Approach Improvements Guidewall/Guardwall Extensions

The addition of extended guidewalls should provide some benefits at the site. The existing upstream guidewall is on the right and the downstream guidewall is on the left descending bank. The lock has very little freeboard. A cell below the bullnose in the tailwater would help the approach and keep the second cut of an upbound tow from being pulled off the guidewall by eddy currents from chamber emptying.

Upper Lock Approach: Widening the 2.5-mile approach canal has been studied in the past. The original design width of the canal is a constant 200 feet from the lock upstream to the dam. The canal was needed to bypass existing rock rapids. Construction started in 1928 by the State of Illinois and was finished in 1933 by the Corps of Engineers. Although the project lands are owned by the State, the Corps has jurisdiction, control, maintenance, and operation responsibilities. The Corps' Chicago District estimated the cost to widen the canal to 300 feet (width needed for tows to pass) to be $10.6 million in 1974.

TABLE 3-20: COST AND TIME SAVINGS OF MEASURES AT MARSEILLES LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Outdraft not a problem under most flows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.3 to $12.2 [4] mil initial/gw ext	US: 24 min. TRBK DBL DS: 23 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. US & DS bank excavation required.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.2 to $5.4 [4] mil initial/gw ext [3]	US: 24 min. all DBL DS: 23 min. all DBL	US requires dredging remake areas DS unable to use during high flows
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 20 min. all DBL DS: 19 min. all DBL	Remake time savings possible all flows with adequate horsepower, except would not back cuts US during outdraft without wall ext.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	N/A	N/A	Adequate sites available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $11.1 [4] mil initially DS: $12.4 [4] mil initially	US: 7 min. TRBK DBL DS: 8 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $11.2 [4] mil initially DS: 12.4 [4] mil initially Plus $518,000 annually per lock	US: 21 min. TRBK DBL DS: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $10.7 [4] mil initially	6 min. TRBK DBL 27 min. TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $12.0 [4] mil initially	6 min. TRBK DBL 33 min.TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements:	$2.0 to $4.0 mil. initially	60 min. on 25% of exchange lockages	One or two upstream passing areas; considered major bottleneck on the IWW

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Impacts to navigation during construction are significant. See Section 4.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

Soundings taken in May 1996 show that the navigation channel within the canal has the following widths for a 10-foot draft condition. The first 2,000 feet upstream of the lock averages 200 feet in width and widens to a maximum of 250 feet. The next 2,000 feet upstream of the lock averages close to 200 feet in width with a minimum of about 180 feet. The remainder of the channel averages only around 150 feet wide with a stretch approximately 1,000 feet long averaging just over 100 feet in width. This 1,000-foot stretch is located between 8,000 and 9,000 feet upstream of the lock (or approximately 2,000 to 3000 feet downstream of the dam). Based on this information, the channel has not been maintained to a constant 200-foot width. Substantial excavation, including some rock excavation, is required to provide a 300-foot-wide passing channel.

Two passing areas along the canal are identified for consideration in lieu of complete channel widening to 300 feet for the 2.5-mile canal. The first passing area is immediately upstream of the lock from RM 244.7 to 245.4. The second passing area is about halfway along the canal from RM 245.6 to 246.0. Both areas require dredging for an additional 100-foot width, approximately 6 to 8 feet deep. Rock excavation is not anticipated at either location. Total construction cost for each location is $2 million. This cost, per location, includes dredging 80,000 cubic yards of material, two mooring/guide cells, and riprap protection along the riverbank. A dredged material placement site has recently been approved on Bell's Island located immediately upstream of the lock. Although this site was approved for maintenance dredging, the opportunity exists for using this site for potential channel widening. The time savings in providing these improvements is estimated to be roughly proportional to the distance reduced or 60 minutes or more per exchange lockage (30 minutes on exit and 30 minutes on approach).

The entrance to the canal at the bridge may be improved with vane dikes (100 feet long with 50-foot gaps and a top elevation 2 feet above pool) to reduce outdraft. This is secondary to providing passing areas. Protection cells are there now. There was also some discussion on reviewing the chamber filling/emptying rates to see if some improvement could be realized from an improved rate/system. The average lift based on the 50 percent duration flow is 24 feet, and the existing filling/emptying rates may be kept low because of flow impacts to approaching and exiting tows and their first cuts.

Lower Lock Approach: Channel improvement, again secondary to the upper passing areas, is the addition of vane dikes to direct the flow at RM 244.15 away from passing tow traffic. For safety, it was recommended during the December 1996 lock visit that the cells below the lock along the left descending riverbank be removed due to difficulties in navigating past them. The cells are considered a hazard to navigation.

- **Remote Remake Areas**

Switchboats are not considered to be a feasible alternative as there are no logical remake areas away from the guidewall that do not block exchange lockages. There is some possibility to place a spud barge or other remake facility below the lock, but currents coming from around the island at RM 244.1 would likely make backing a cut nearly impossible without some channel work. There is some potential that a remake area could be located at the first passing area under consideration above the lock.

Upper Approach/Upbound: Identifying a suitable remake area would require additional analysis. Some possibility that channel widening in the canal could provide a feasible remake area.

Lower Approach/Downbound: Identifying a suitable remake area would require additional analysis.

- **Other Site Information**

No anticipated need for additional manpower to operate tow haulage on opposite guidewalls since lock personnel do it now under the present arrangement.

Helper boats are not typically at the site due to a limited demand. However, there are boats available if needed at Ottawa (approximately 30 minutes of travel time by river). Most available boats are in the 800 horsepower range. Cost for their assistance is $150 per hour (likely charged for travel time as well, making total cost approximately $300 per assistance). Helper boats are used to move ice in the winter. They can also be used to pull cuts along the guidewall or to the last pin on the guidewall and hold the cuts for remake without blocking the chamber; 800 horsepower is adequate. The estimated time savings from LPMS data was verified for accuracy. The lockmaster prefers industry self help over helper boats.

Self help is used fairly regularly depending on the type of queue and the willingness and ability of a tow to leave its barges and provide assistance. The tow operators would be more willing to leave their barges and assist if additional well placed mooring facilities were provided. The lockmaster reported that Marseilles has processed 20 tows in 24 hours with industry towboats pulling cuts. The current practice is to pull cuts to the last pin on the guidewall and to hold the cut with the towboat until the couplings are remade.

Adequate recreational craft landings are available above and below the lock.

Scheduling 3-up/3-down is fairly common due to creation of queues at this lock site. This is a fairly effective method of eliminating congestion.

Dresden Island Lock, Morris, Illinois

- **Description**

Dresden Island Lock is located on the left descending bank at RM 271.5. The lock has a usable chamber 110 feet wide and 600 feet long. The lift is usually 20.5 feet with a maximum lift of 21.5 feet. The site includes a 578-foot upstream guidewall and a 594-foot lower guidewall. The site has a number of mooring cells upstream of the lock.

- **Approach Conditions/Locations**

There are no major downbound approach problems. Outdraft can be controlled by passing flow through the far side dam gates. Tows use the mooring/guide cells above the guidewall. The upbound approach is made difficult by the narrow channel span of the railroad bridge. An upbound tow moored at the four cells below the lock on an exchange lockage does not start its approach to the lock until the downbound tow passes the railroad bridge. The downbound tow uses the moored tow to align with the bridge channel span. Flow from the dam can force an upbound tow into the left descending riverbank.

Upper Approach/Downbound: Fly lockages approach point is the Kankakee River Light and Daymark RM 272.4. The exchange point is at the mooring cells at RM 272; smaller tows can use the two cells above the auxiliary gate.

Lower Approach/Upbound: Fly lockages point is the railroad bridge at RM 270.6. The exchange point is at the four cells below the lock on the left bank at RM 270.9.

- **Measures Under Consideration**

At Dresden Island Lock, the following measures are currently under consideration:

TABLE 3-21: COST AND TIME SAVINGS OF MEASURES AT DRESDEN ISLAND LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Outdraft not a problem under most flows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.2 to $9.9 mil initial/gw ext	US: 26 min. TRBK DBL DS: 5 min. TRBK DBL	Remake time savings listed assume ext. guidewalls not implemented DS
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.1 to $4.9 mil initial/gw ext [3]	US: 26 min. all DBL DS: 27 min. all DBL	Remake time savings depends on finding suitable remake sites.
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 22 min. all DBL DS: 25 min. all DBL	Remake time savings depends on finding suitable remake sites.
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	NA	N/A	Adequate site available
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $10.4 [4] mil initially	US: 8 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $10.5 [4] mil initially Plus $518,000 annually per lock	US: 22 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $9.9 [4] mil initially	6 min. TRBK DBL 28 min. TRBK SETOVER 7 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements	$400,000 initially	Limited	Vane dikes lower pool

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Impacts to navigation during construction are significant. See Section 4.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
DS - Downstream
TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

Providing adjacent moorings would not allow tows to approach closer to the lock, but they would assist in reducing the potential for resource damage to the riverbank, especially above the lock. Two cells are needed at the Kankakee River Light and Daymark at RM 272.4. Tows presently push into the bank near the I&M Canal preserve lands. Two cells placed here would provide a positive tie-off. The water is deep along the bankline, allowing placement of the cells close to the shoreline.

Below the lock, normally only one tow waits above the railroad bridge along the four cells with most tows tying to the lower two cells. The next waiting spot is at RM 270.2 on the left bank. Tows push into the riverbank as there are no dedicated mooring facilities there other than cells at the chemical dock. The railroad bridge is a big impediment to navigation. Mooring facilities below the lock at RM 270.2 would provide a formal waiting area for tows

Additional mooring facilities help during ice conditions when self help is implemented by providing the helping towboat a tie-off for its barges.

Upper Approach/Downbound: Could formalize current waiting areas by placing moorings at RM 272.4 at the Kankakee River Light.

Lower Approach/Upbound: Could formalize current waiting areas by placing moorings at RM 270.2 below the EJ&E railroad bridge.

▪ Approach Improvements

Upper Lock Approach: No channel improvements were identified. Extending the upper guidewall slightly benefits the approach but negates the present use of the cells above the existing guidewall. Adding an auxiliary gate guardwall or a lock guardwall improves the downbound approach, but only slightly, as outdraft is really not a problem.

Lower Lock Approach: A system of vane dikes was suggested to keep the dam outflow parallel with Little Dresden Island and the approach to the narrow channel span of the Elgin, Joliet & Eastern Railway bridge. This is more of a safety consideration than it is to reduce the upbound approach time. Extension of the guidewall is not recommended because such an extension may impact a downbound tow's exit turn and approach to the EJ&E railroad bridge. The railroad bridge below the lock is the major impediment, and its future disposition is beyond the small scale scope of the this study. However, any final resolve by the U.S. Coast Guard to remove the bridge will benefit the downstream tow approach/exit.

When a waiting upbound tow is butted up to the lower four cells, the downbound tow can pass and use the waiting tow as a guide to the opening at the railroad bridge which is only 113 feet wide. Going through the narrow bridge span is like trying to make a lock approach. A waiting upbound tow cannot start its approach to the lock until the downbound tow passes the waiting tow. Maintenance of the cells and dredging around them are mandatory to have an efficient operation. There is a bad outdraft below the lock (at 15 feet of gate opening) which pushes tows to the left bank and then farther down comes back across the channel toward the right bank. The placement of a guide cell 100 feet below the bullnose on the right descending side would help tows align with the chamber and provide some benefits in entering the chamber.

▪ Remote Remake Areas

As at the other Illinois Waterway sites, channel constraints severely limit the number of potential locations for remake areas.

Upper Approach/Upbound: A potential remake area would be along the right descending bank at RM 272.4.

Lower Approach/Downbound: Identifying a suitable remake area would require additional analysis. There is some potential to use the existing mooring area at RM 270.9 for remaking in some situations.

▪ Guidewall/Guardwall Extensions

Extending the upper guidewall is possible but may not be a good idea since the mooring cells above the lock would have to be moved and these cells are currently used. While an extended upper wall may help tows overcome winds from the south and outdraft conditions, it may actually slow approaches under normal conditions. The downstream extension is not recommended because an extension would impact a downbound tow's exit and turn toward the railroad bridge. Full benefit from extended guidewalls, even if possible, may not be realized at this site because remakes along extended guidewalls primarily only benefit turnback lockages and current operations rarely call for locking more than 2 up/2 down. Adding cells above and below the short wall bullnose may be of more benefit to the approaches and to hold the first cut on the existing guidewalls. Plate 21 in Appendix C shows the site and location of proposed measures.

▪ Other Site Information

There is not enough demand to keep a helper boat at the site. Outdraft becomes a problem at a 15-foot gate opening for which helper boats could provide tow assist. Boats are available at Morris and Channahon, each about an hour travel time. Most boats are in the 600 horsepower range. Cost for their assistance is $150 per hour (charged for travel time as well, making total cost approximately $450 per assistance). Helper boats could be used to pull cuts along the existing guidewall or to the last pin on the guidewall and hold the cut during remake without blocking the chamber. Helper boats are used to move ice and to assist downbound empties that are affected by winds of 10-15 mph from the south at this site. However, wind effects are not as great at this site as they are at the Brandon Road Lock.

Pulling cuts with switchboats does not appear to be viable at this site. The only possible remote make up area appears to be near the Kankakee River Light and Daymark RM 272.4R. The navigation industry representative estimated that it might take up to 30 minutes to back a cut to this area with an 800-horsepower boat. A larger boat, possibly 1,200 horsepower, would be required. Currents from the Kankakee River also cross this area. Pulling cuts downstream may be possible with the addition of spud barges between the existing cells; however, congestion is a problem in this area. Subsequent discussion with the U.S. Coast Guard and navigation industry lead to increasing the size of switchboats to 1,800 to 2,400 horsepower to allow a greater margin of safety.

Scheduling is not used very often. Normally there is not a traffic backlog and 1 up/1 down works fine. If there is heavy traffic on both ends, the operation goes to 2 up/2 down.

Self help is rarely used at this site (backlog is normally not greater than 2 up/2 down), but when implemented is usually used only during severe winter weather (ice). This site needs additional tie-off facilities for barges: two cells at RM 272.4 R and a couple of cells below the railroad bridge spaced about 400 feet apart. The navigation industry representative stated that pulling cuts under self help seems to be the most viable towboat power option at this site and that additional mooring facilities would benefit self help.

There are sufficient recreational craft landings in the area. Much of the recreation traffic through the lock is marine based. Scheduling of recreation traffic was suggested, but its practicality was questioned. A lockage charge for recreation traffic was thought to be a better idea. Many boaters lock through and then shortly after come back and want to lock through again. Recreation traffic seems to be on the increase at this site.

Brandon Road Lock, Joliet, Illinois

▪ Description

Brandon Road Lock is located on the right descending bank at RM 286.0 near Joliet, Illinois. The lock has a usable chamber 110 feet wide and 600 feet long with a lift of 34 feet. The site includes a 598-foot upstream guidewall and a 594-foot lower guidewall.

▪ Approach Conditions/Locations

Wind is the biggest problem in the upper pool. Outdraft is not a problem. When it is windy, downbound tows usually wait at the I-80 Bridge for upbounders to pass rather than moor in the open area above the lock since south winds of only 7-8 mph can have an impact on upbound tows above the lock. The upbound approach is through a narrow channel below the lock, which is a hard push for the larger, loaded tows.

Upper Approach/Downbound: Fly lockage arrival point is between the I-80 Bridge and McDonough Street at about RM 287.2. The exchange point is the I-80 Bridge. Tows wait on the right bank piers or along the riverwall below the I-80 Bridge.

Lower Approach/Upbound: Fly lockage arrival point is the conveyor across the river at RM 284.8. Exchange point is at the Commonwealth Edison Co. (CEC) dock on the left descending bank at RM 285.1.

▪ Measures Under Consideration

At Brandon Road Lock, the following measures are currently under consideration:

TABLE 3-22: COST AND TIME SAVINGS OF MEASURES AT BRANDON ROAD LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Limited	Outdraft not a problem under most flows.
Switchboat w/Guidewall Extension	$1.13 mil/boat/yr $3.2 to $13.6 [4] mil initial/gw ext	US: 26 min. TRBK DBL DS: 29 min. TRBK DBL	Remake time savings possible all flows with adequate horsepower. DS bank excavation required.
Switchboat w/Remote Remake & 300' US Guidewalls	$1.33 mil/boat/yr $3.7 mil initially/moor $2.1 to $5.6 [4] mil initial/gw ext [3]	US: 26 min. all DBL DS: 29 min. all DBL	Time savings depends on identifying remake area at site
Industry Self Help w/Moorings or Guidewall Ext.	$50/hour for fuel $500k initially/cell GW costs same above	US: 22 min. all DBL DS: 25 min. all DBL	May be able to use existing guidewall or proposed cells in area
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Downstream sites under consideration
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Powered Kevels w/Ext Guidewalls	US: $11.7 mil initially DS: $13.8 mil initially	US: 11 min. TRBK DBL DS: 14 min. TRBK DBL	Cost of powered kevel is $750,000/wall
Powered Kevels w/Ext Guidewalls & Addl Personnel	US: $11.8 [4] mil initially DS: $13.9 [4] mil initially Plus $518,000 annually per lock	US: 25 min. TRBK DBL DS: 28 min. TRBK DBL	Annual cost increase associated with additional personnel
Unpowered Kevels W/Ext Guidewalls	US: $11.3 [4] mil initially	6 min. TRBK DBL 25 min. TRBK SETOVER 5 min. TRBK KNOCKOUT	Cost of extending unpowered kevels is $240,000 initially
	DS: $13.4 [4] mil initially	6 min. TRBK DBL 36 min.TRBK SETOVER 6 min. TRBK KNOCKOUT	Cost of unpowered kevels is $360,000 initially
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements: Wind Cell, US	$500,000	Limited	Safer approach

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
[3] Costs of 300-foot wall extensions approximated by one-half cost of 600-foot US wall.
[4] Impacts to navigation during construction are significant. See Section 4.

* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
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TBD - To Be Determined
TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

Above the lock there is no place to get tows closer. However, this is one of the worst locks for wind. Safety would be improved for these tows by a cell on the right side about 50 to 100 feet above the existing cell above the lock to catch tows from the wind. The cell should be offset 5 feet or so from the existing cell to avoid binding problems.

Below the lock, there are no dedicated mooring facilities and tows sometimes use the CEC docking area RM 285.1. The next waiting area is RM 284.5L, which also lacks a mooring facility. The two cells at RM 285.3, which are in the dam outdraft area, are not used and are considered a hazard to navigation. Two cells on the right descending bank at RM 285 near the "long pond" would be helpful. There is no room below the lock to get tows closer to the lock.

Upper Approach/Downbound: While tows can not be brought close, an additional cell 50 to 100 feet upstream of the existing cell above the guidewall could improve efficiency in wind conditions.

Lower Approach/Upbound: Two additional cells at RM 285 would provide an official mooring area near the lock.

▪ Approach Improvements and Guidewall/Guardwall Extensions

Extending the downstream guidewall would make entrance conditions worse unless the narrow channel is widened. Extending the upstream guidewall may require widening the existing guidewall that is only 4 feet wide, especially if tow haulage is added. It is doubtful if extended guidewalls would increase approach efficiency, but they will allow for tow remake outside the lock chamber. However, system remake time savings is limited by the few number of 15-barge tows in this reach of the Illinois Waterway.

Upper Lock Approach: The recommended approach improvement, as suggested during the lock site visit in December 1996, is an additional cell offset slightly with the existing cell above the lock to help negate the northeast and southeast wind impacts on downbound tows and to increase safety.

Lower Lock Approach: The canal below the lock has a shallow rock bottom, maybe 11 feet and in some areas only 10 feet deep, and is narrow. The upbound entrance into the lock is a "hard push" and very slow going as there is little space around the tow for the displaced water to go. Likewise, it sometimes takes two or three tries with tow haulage and up to 45 minutes to exit the first cut (loaded) downstream because of the shallow, narrow canal. It takes 15 minutes for downbounders to pass the downstream exchange point and then another 30 minutes for upbounders to reach the lock and another 15 minutes to push into the lock. However, the tow haulage is being relocated to the far downstream end of the guidewall to make the exit more efficient. A review of December 1996 soundings shows a relatively shallow and narrow channel. It was suggested that the sill depth may be a contributor to the piston like approach/entrance to the lock which could be addressed during site-specific studies. There is a potential improvement to navigation if the channel can be improved. Widening and/or deepening the rock bottom canal below the lock could make the lock approach and first cut exit more efficient, but again benefits mainly the larger tows which are relatively few in this area. Vane dikes at RM 285.4 could help align the dam outflow and reduce the existing cross currents in this area.

- **Remote Remake Areas**

In general, using switchboats and remote remake areas is not practical at this site. The bigger boats and tows do not come up in this reach of the river. In addition, site conditions make using remote remake areas fairly questionable at this site. Above the lock, a site could likely be identified if necessary. Below the lock, the narrow channel and cross current flows would present greater challenges.

- **Other Site Information**

The existing upstream guidewall, which is 4 feet wide, may need to be widened if tow haulage is improved/added with the guidewall extended. Unpowered kevels should not require additional width.

It was estimated that a helper boat pulling cuts out would save 10 minutes upstream and significant time downstream. Would pull along the existing guidewalls and hold for remake. Available remote makeup areas are non-existent downstream. Remote makeup may be possible upstream. Helper boats are available at Illinois Marine.

Self help is almost never required or used at this site.

The River Club boat landing is just above the lock. Nothing much below the lock for 8 miles or so. There is not a lot of recreational traffic in this area. Recreational traffic is concentrated at the beginning and end of the season.

Although there is little recreation traffic in the area, the lockmaster indicated that scheduling of recreational traffic may be a good idea during the season's busier beginning and ending periods.

The operation at Brandon Road Lock is very dependent on the traffic at the Lockport Lock; i.e., how fast Lockport is locking upbound traffic the traffic that is coming down to Brandon Road. River travel time between the two locks is 50 minutes for a full tow and 30 minutes for setovers.

Tows sometimes use commercial docks/moorings when waiting below the lock. There is some concern that if these properties were sold, the new owners may not allow other tows the luxury of waiting at these sites. As discussed above, additional cells at RM 285R would alleviate this concern.

Primarily only smaller towboats move barges in this area, so the larger towboats do not have to contend with the congestion in the Brandon Road-Lockport area.

Lockport Lock, Lockport, Illinois

- **Description**

Lockport Lock is located at RM 291.1 on the left descending bank at Lockport, Illinois. The lock has a usable chamber 110 feet wide and 600 feet long with a lift of 39 feet. There is a curved 1,000-foot upper guidewall and a slightly curved 444-foot lower guidewall. Plate 19 in Appendix C shows the site and potential improvements.

▪ Approach Conditions/Locations

Downbound approach conditions are difficult at this lock because of the curvature of the approach wall and the inconvenience of the canal width restriction above the lock requiring larger tows to reconfigure during their approach. Reconstructing the high earthen/rock embankments forming the high elevation Chicago Sanitary & Ship Canal (over 20 feet higher than the adjacent Des Plaines River) to widen the canal is not practical. There are no major upbound approach difficulties.

Upper Approach/Downbound: Fly lockage arrival point is 16th Street, RM 292.2. Exchange point is 9th Street at RM 292.7 unless both tows together are less than 150 feet wide, in which case they can pass below the 16th Street Bridge. Tows can moor at pins along the left descending wall above the lock.

Lower Approach/Upbound: Fly lockage arrival point is the EJ&E railroad bridge at RM 290. Exchange point is just downstream of the lock at RM 290.5L where tows lay on the bank as there are no mooring facilities there.

▪ Measures Under Consideration

At Lockport Lock, the following measures are currently under consideration:

TABLE 3-23: COST AND TIME SAVINGS OF MEASURES AT LOCKPORT LOCK

Measure	Cost [1]	Time Savings to Waiting Tows [2]	Comments
Helper Boat	$640,000/boat/year	Some approach time savings possible	Approach time savings is limited to those tows not currently being assisted.
Switchboat	$1.13 mil/boat/yr	N/A	Guidewall Ext not possible
Switchboat w/Remote Remake &	$1.33 mil/boat/yr $3.7 mil initially/moor	US: 28 min. all DBL DS: 32 min. all DBL	If able to place remote mooring cells above and below lock
Industry Self Help w/Moorings	$50/hour for fuel $500k initially/cell	US: 24 min. all DBL DS: 27 min. all DBL	If able to place cells above and below lock
Tolls and Time Charges	$465,000* initially $235,000* annually	TBD	Roughly same cost for all fee measures - includes coordination, setting charge, implementation.
Publish Lockage Times	$65,000* annually	Limited	Very difficult to estimate time savings
Recreational Craft Scheduling	$520,000* initially $35,000* annually	Limited	Cost includes public meetings, signage, and public awareness
Rec Boat Landings	$270,000 initially $12,500 annually	Limited	Upstream sites under consideration, but sites and rec opportunities limited
Scheduling Program	$550,000* initially $35,000* annually	Limited	Time savings/delay reduction depends on method used
Permanent Deck Winches	$4,000/barge initially	4 min. all DBL	System cost TBD
Additional Personnel	$1,200/day/lock	3 min. all DBL	Implement during lock congestion periods
Powered Ratchet Wrench	$7,500/unit initially	5 min. all DBL	One unit per DBL tow
Approach Improvements	$2 mil. initially	Limited	Four mooring cells at RM 290.5 left bank. Safer remake conditions below high lift lock.

[1] Costs listed in this table provide an indication of the total cost for the measure; however, Section 4 provides additional detail and clarification.
[2] Time savings in tables are not additive, since many of the measures address the same elements. However, several combinations are possible. Time savings shown are for tows waiting in queue. The actual tow may experience smaller savings, since in some cases the same operations are performed, only the location is moved.
* Denotes systems costs that includes the total cost for all sites under consideration and not just this particular lock.

US - Upstream
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TRBK - Turnback Lockages Only
DBL - Double Lockages

▪ Adjacent Moorings

It is not possible to bring tows closer to the lock with new mooring facilities. No remote makeup areas are possible above the lock.

A priority is for cells below the lock on the left bank above the railroad bridge for tie-off and for remake when a helper boat is pulling cuts. Below the lock, the water is deep in this area all the way to the left bank at RM 290.5. Two sets of cells 400 feet apart at this location could be placed on the bank to help tows fight the dump from the lock and to help with tow remake if cuts are pulled from the lock.

Upper Approach/Downbound: None

Lower Approach/Upbound: Two sets of cells above the railroad bridge near RM 290.5 would assist approaching tows and allow for remake.

▪ Approach Improvements and Guidewall/Guardwall Extensions

A slightly curved downstream guidewall extension is limited by the outflow from Deep Run Creek along the left bank. An upstream guidewall extension is not practical because of the existing curved wall. Tows presently make up on a flat section of wall just above the upper lock gate. Straight guidewall extensions are not recommended above or below the lock. Extensions would restrict the flow widths and are hazards to navigation.

Upper Lock Approach: No recommendations were made for improving the approach. It was noted from the December 1996 site visit Memorandum for Record that there are not many 15-barge tows in this area due to difficulties in navigating this reach of the waterway, including a 70-foot tow width restriction (canal is 160 feet wide) from 9th Street upstream for about 8 miles to Lemont, Illinois. This causes the larger tows to break at Lemont and leave barges there for another tug to bring down to 9th Street where tows are remade before moving on to the lock.

Lower Lock Approach: Two sets of mooring cells along/in the left descending bank at RM 290.5L to help with tow remake if cuts are pulled from the lock and to provide a tie-off for barges during self help.

▪ Remote Remake Areas

In general, using switchboats and remote remake areas is not practical at this site. The bigger boats and tows do not come up in this reach of the river. However, there may be some potential for a remake area below the lock above the railroad bridge from RM 290 and 290.5 on the left bank.

▪ Other Site Information

There are few 15-barge tows in this reach of the waterway, and the tow operators abide by the lock policy to make tows into a single for lockage whenever possible.

Helper boats are used for the downbound approach at a flow of 6,000-7,000 cfs and to pull cuts for remake on the guidewalls. Traffic stops at 9,000-10,000 cfs. This is a discretionary action by the towing companies due to the problem of navigating through the many bridges in the Joliet Harbor area, RM 289 - 287.5 downbound.

Could remake below the lock if cells were placed along the left bank above the railroad bridge. Normal time savings pulling cuts is 10-15 minutes. Could save 20 minutes for next turnback approach from 9th Street. Several 700-800 horsepower helper boats are available in the area. It takes 45 minutes for helper boats to get to the lock and they normally charge $150 per hour.

Most recreation through-traffic is larger craft going to the lake. There is a boat landing (rock ramp) below the lock at RM 288.7.

The No. 1 recommendation for small scale improvements at Lockport is the addition of two sets of cells below the lock at RM 290.5L.

SECTION 4 - TECHNICAL INFORMATION ON DETERMINING PERFORMANCE AND COST

This section expands upon the information provided in Section 2 by providing more detail on the supporting information, analysis methods, and data used in estimating the time savings and cost. This section follows the same format as Section 2, first providing a discussion of the non-structural measures before covering the structural measures.

NON-STRUCTURAL SMALL SCALE MEASURES

Towboat Power

Towboat power measures employ the use of an assist boat to reduce lockage times. Three separate measures related to additional towboat power were carried forward for further analysis: helper boats, switchboats, and expanded use of industry self help. These measures can assist tows into the chamber, speed the extraction of the unpowered cuts, move the unpowered cut away from the lock facility for remake, and provide additional assistance as needed. Towboat power measures generally provide greater time savings to tows requiring double lockages or reconfiguration.

For the purpose of this report, the horsepower of the assisting vessel defines the vessel category. Helper boats have the least amount of power, less than 1,200-horsepower , while switchboats typically range from 1,200 to 2,500 horsepower. Industry line haul boats, used for self help, generally have greater than 2,500 horsepower. The boat's horsepower and size influence the type of assistance that can be provided and it effectiveness.

Based on the analysis conducted as part of this study, the study team determined that while additional helper boat assistance on approaches may provide some increased benefits at some sites most benefits are already being captured. The majority of incremental towboat power benefits are associated with the larger switchboats and line haul boats that can extract cuts. Switchboats can be implemented in one of two ways—in combination with extended guidewalls or with remote mooring areas. Providing guidewall extensions and mooring areas in combination with industry self help allows for a safer and more efficient application of this existing measure.

- **Helper Boats**

Description of Measure. Helper boats are the smallest of the towboats being considered in this analysis, averaging approximately 800 horsepower with a range from roughly 300 to 1,200 horsepower. Helper boats can reduce delays associated with approaching the lock and in some cases exiting the lock. They are currently used and are particularly effective when assisting downbound tows that must make their approaches or exits under adverse conditions (e.g., outdraft, wind, ice, etc.) or with inexperienced crews. This assistance reduces overall lockage times by countering the effects of outdraft on the approach, thereby allowing a more controlled, efficient, and safe entry into the chamber. Figure 4-1 shows a tow receiving approach assistance. The primary approach benefit is in reducing delays associated with inability to align the tow along the guidewall that, if unsuccessful, requires the tow to back up, maneuver, and retry its approach. Since some use of helper boats is already occurring, this study analysis focused on identifying what incremental benefits are available with increased use. Using helper boats to pull unpowered

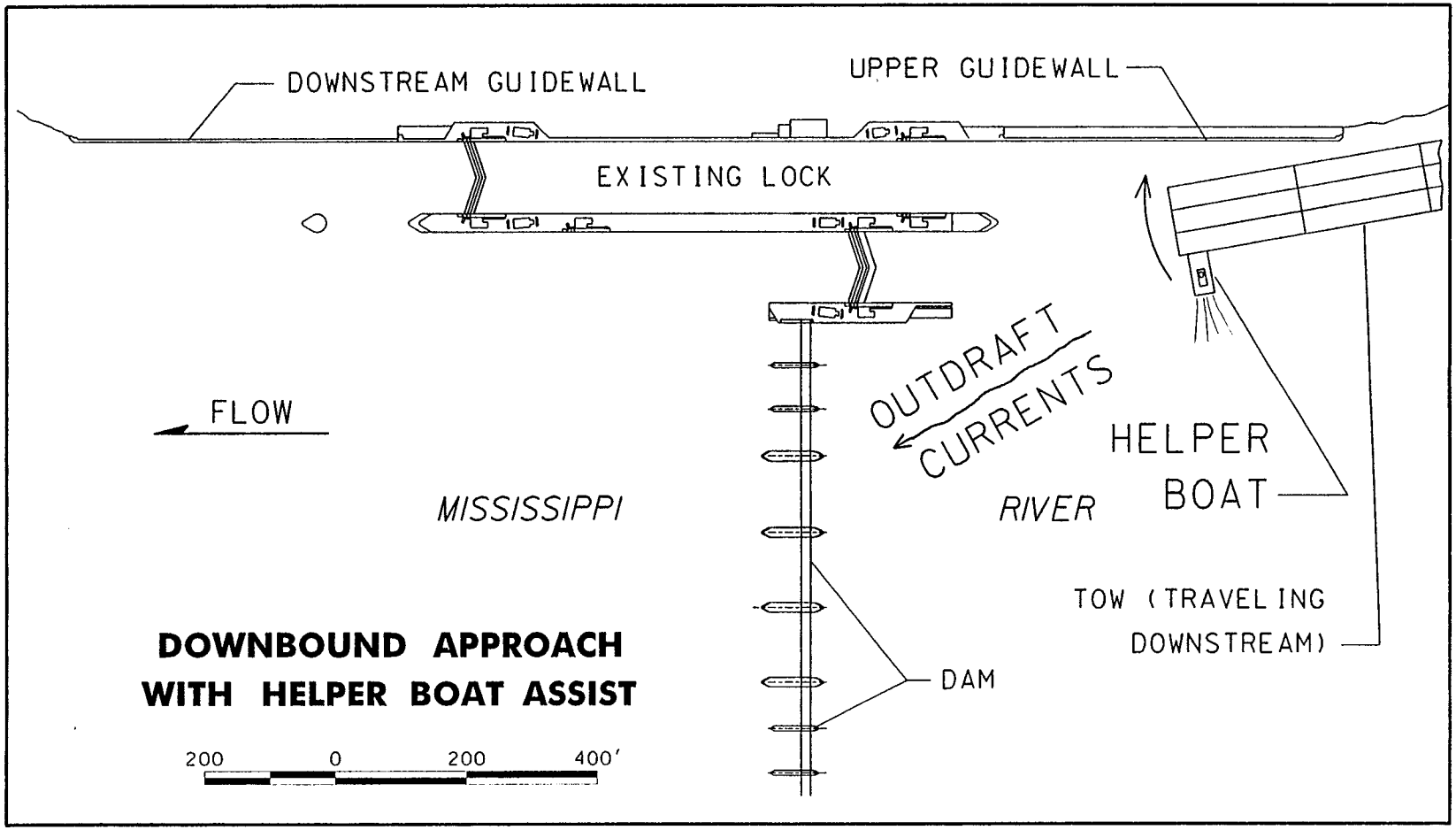


FIGURE 4-1: Helper Boat Assistance on Approach

cuts along extended guidewalls was also evaluated, but it was determined that they have inadequate horsepower to safely conduct this operation under all conditions.

In addition to improving approach efficiency, a major benefit of helper boats is increased safety related to the reduction in the potential for a major accident or substantial delay related to a tow which is unable to successfully maneuver a lock without assistance.

Currently helper boats are regularly available at Locks 3, 10, 12, 15, 20, 21, 22, 24, and Peoria. Often these boats are provided by a harbor service that leaves a boat at the lock facility and then provides staff on an as-needed basis. Full-time assistance is provided when required during periods of congestion or outdraft. The majority of other lock sites can have helper boats available on relatively short notice. These helper boats primarily provide assistance to tows in approaching the locks, but they also move ice and debris. Under current Corps policy, the use of helper boats is not required, but their use is strongly recommended during outdraft conditions. In general, most companies follow these recommendations in their own interest to increase safety and reduce delays.

Delay Reductions Methodology/Time Savings Estimates. Potential time savings in the lockage process were only identified for downbound lock approaches (upbound tows typically do not require assistance). Improving other steps in the process, such as pulling the first cut of double lockages, were not considered to be safe operations with this size of boat. The estimated savings, along with the approach used to determine the savings, is summarized below.

Several sources of data were evaluated to provide information on the potential time savings available for implementing helper boats. These sources include the 1990 Lock Performance Monitoring System (LPMS) data; responses from the February 4-5, 1997, Expert Elicitation meeting with navigation industry; and interviews and site visits with lockmasters and navigation industry. This section summarizes the results of these efforts.

Approaching the Lock. Determining the actual time savings benefits per lockage using LPMS data is difficult, since the level of benefits varies based on approach type, site conditions, weather, equipment, crew, and when and how the helper boats are used. Despite these difficulties, LPMS data on lockages were evaluated as part of the study investigation. The study team analyzed the approach times for tows that received assistance versus the approach times for tows that did not receive assistance. However, the results were inconclusive because the approach point can vary considerably from one lockage to the next depending on the type of approach (e.g., fly, turnback, exchange). In addition, major differences occur in site conditions and crew experience. The data are also biased by the fact that higher levels of helper boat assistance are provided during outdraft conditions, in poor weather, and to less experienced crews.

As a result of these complicating factors, the approximate approach time savings was estimated based on information from the expert elicitation process, as well as interviews and site visits with lockmasters and navigation industry. As part of the expert elicitation, towboat captains, lockmasters, and others present were asked to estimate the time savings of using a helper boat or switchboat to assist with downbound approaches under both outdraft and normal flow conditions for both single and double lockage tows. Only downbound exchange and fly approaches were evaluated. Upbound approaches rarely need assistance due to the absence of outdraft and since the water flow allows for better control and steering. Approach assistance is less critical with turnback lockages because the tow waiting a lockage can often get on the guidewall prior to the end of the preceding lockage. However, some turnback lockage tows during high water will not approach until the gates are open unless assisted by a helper boat or extended guidewall. By providing this assistance, some additional number of turnback lockages would be able to improve their approach times.

After some discussion, the participants felt that it would not be necessary to evaluate time savings during outdraft conditions, since most tows currently use assistance under those

circumstances. The result of the weighted time savings was that for the UMR under normal flows, the average time savings of using a helper boat for single lockage tows was estimated at 6 minutes with a range of 3 to 10 minutes. Double lockage tows were estimated to save 11 minutes with a range of 6 to 17 minutes. These ranges, which exclude extreme values, approximate the range rather than provide an absolute maximum and minimum. As part of the discussion at the Expert elicitation meeting, those present felt that the time savings for setovers and knockouts could be estimated by averaging the approach time savings for singles and doubles. This assumption allows for the extension of the approach time savings data to these categories and an estimated savings of 8 minutes.

Significant time savings was not anticipated for IWW locks under normal flows, except at Lockport, which has stronger outdraft currents.

TABLE 4-1: ESTIMATED APPROACH TIME SAVINGS (MINUTES) OF HELPER BOAT ASSISTANCE UNDER NORMAL FLOWS AT UMR LOCKS FOR DOWNBOUND FLY AND EXCHANGE LOCKAGES

Delay Reduction	Straight Single			Knockout and Setovers*			Straight Double		
	Expected	Min	Max	Expected	Min	Max	Expected	Min	Max
Downbound Approaches	6	3	10	8	5	14	11	6	17

* Note: Setover & Knockout Single time savings estimated from singles and doubles.

Source: Expert elicitation meeting, February 4, 1997.

Individual interviews with lockmasters provided information consistent with the elicitation. At locks with moderate to severe outdraft conditions, such as the lower locks on the UMR, lockmasters estimated a time savings of 5 to 15 minutes for helper boat assistance on downbound double approaches under normal flows. As outdraft flows increase, the benefits of helper boat assistance steadily rise, with time savings of 20 minutes or more likely up to the point where at certain flows navigation is not possible without helper boat assistance on downbound approaches.

The lockmasters at sites on the Illinois (La Grange to Lockport) generally reported smaller time savings. These lockmasters estimated time savings of 0 to 10 minutes under normal flow conditions due to the limited amount of outdraft. However, many of these sites benefit from helper boats under higher flow conditions, with savings of 10 minutes or more possible. Currently, helper boats are not typically used on exits. The primary situations where they provide assistance on exits is when wind pushes a tow into the guidewall and reduces or eliminates the tow's ability to leave the lock. A summary of the lockmasters' estimates of current helper boat use and approach time savings for their particular lock is included in Table 4-2. Note that of the percentage currently unassisted, that only roughly 60 percent are fly and exchange lockages able to benefit from approach assistance and that the percentage will decrease over time as more turnback lockages occur.

TABLE 4-2: APPROACH TIME SAVINGS OF HELPER BOATS ON FLY/EXCHANGE LOCKAGES									
Lock Site and Direction		% of Season Out-Draft	Time Savings (min.) Approach of Fly and Exch Downbound Double Lockages	Time Savings (min.) Expert Elicitation - Exchange Lockages Normal Flows Double Lockages			Percent Tows Already Receiving	Potential Savings for Currently	Additional Percent of Tows Capable of
		Occurs	Lockmaster Estimates	Min	Max	Avg	Assist	Unassisted	Savings [1]
11	US	25	10 min. normal flow	6	17	11	In Outdraft	11	75
12	US	45	15-20 normal flow, 25+ outdraft	6	17	11	50	11	50
13	US	25	very limited				Low	Limited	Limited
14	US	30	5-30 depending on flows	6	17	11	Low	11	80
15	US	20	5-30 depending on flows	6	17	11	20-25	11	75
16	US	25	15-30 on average	6	17	11	20	11	80
17	US	35	rarely a helper boat available	6	17	11	1	11	Over 90
18	US	25	15 normal flw 20-30 higher flw	6	17	11	20	11	80
19	US	25	10 on average	6	17	11	Rarely	11	80
20	US	30	10 normal flw, 20+ higher flow	6	17	11	80	11	20
21	US	55	10 normal flow	6	17	11	80	11	20
22	US	40	15-20 normal flow, 30+ outdraft	6	17	11	80	11	20
24	US	40	10-15 avg flow	6	17	11	Regularly	11	20
25	US	35	15 avg flow, 30-45 min. outdraft	6	17	11	80	11	10
MEL PRICE	US	NA	NA	NA	NA	NA	1 to 2	Limited	Limited
27	US	NA	NA	NA	NA	NA		Limited	Limited
LOCKPORT	US		10-15 normal, 20 + outdraft	NA	NA	NA		11	50
BRANDON	US		Assist tows overcome wind	NA	NA	NA	Limited	Limited	Limited
DRESDEN	US	25	fairly limited	NA	NA	NA	Limited	Limited	Limited
MAR-SEILLES-	US	30	0-5 normal, higher in outdraft	NA	NA	NA	Limited	Limited	Limited
STARVED ROCK	US	15	0-5 normal, higher in outdraft	NA	NA	NA	<15	Limited	Limited
PEORIA	US	30	minimal lower flw, 15-30 higher	NA	NA	NA	30	Limited	Limited
LA GRANGE	US	20	minimal lower flw, 15-30 higher	NA	NA	NA	50-60	Limited	Limited
Average UMR 11-25	US	28.7	5-20 min. under lower flows	6	17	11	NA	NA	NA
Average Illinois	US	24.0	Limited under lower flows	NA	NA	NA	NA	NA	NA

[1] Note that of the percentage currently unassisted, only roughly 60% are fly and exchange lockages able to benefit from approach assistance and that the percentage will decrease over time as more turnback lockages occur.
US = upstream, DS = downstream, NA = not applicable, NR = not recommended

Total Time Savings. In total, it appears that only limited additional benefits would be gained by increasing the use of helper boats. In addition, the savings are even more limited in situations where a queue exists, since only fly and exchange lockages benefit significantly. However, it appears that a few sites, Locks 14, 17 and 19, could benefit from increased helper boat availability.

Conditions Affecting Implementation. The focus of this analysis was on determining the benefits to those tows not currently receiving assistance. However, there is a large amount of variability involved with the time savings potential for a particular measure. Many tows already receive assistance from helper boats, or there may be situations where a helper boat is unable to provide assistance. Some additional factors influencing the potential time savings include the experience of the crew and performance of equipment (e.g., age of boat, experience of the pilot, etc.). These factors can contribute to significant differences in overall time savings.

As part of the expert elicitation, the participants estimated that most tows currently receive approach assistance during severe outdraft conditions, which are present approximately 20 to 40 percent of the time depending on the lock site. In addition, 40 to 50 percent of tows under normal flow conditions already receive helper boat assistance on approaches. Only assistance to the other tows not currently receiving assistance under normal flows would result in additional savings. Some of the tows not currently requesting assistance are the most skilled at navigating the locks and could actually be slowed in making their approaches if helper boat assistance is required.

The use of helper boats already occurs on a regular basis and likely will continue and expand whether or not a project is completed. According to the site visits, this is currently occurring, since use has increased in recent years and is likely to continue to expand as traffic levels and safety awareness grow.

Costs. The Corps of Engineers' *Draft Economic Planning Guidance for Shallow Draft Vessel Costs* estimates that helper boat replacement costs range from approximately $550,000 to $1.3 million depending on size and horsepower. However, the actual total daily, yearly, and hourly costs in 1996 dollars for operating a helper boat of various size categories have been summarized in Table 4-3. The helper boats currently available at most locks are privately owned by harbor services and towing companies and simply provide assistance on an as-needed basis or assistance during periods of outdraft. Many operators have older boats and use small crews (a pilot and deckhand) that are on call and only at the site while providing assistance.

Three possible scenarios exist regarding how these boats could be supplied: (1) the government could purchase boats and provide assistance, (2) harbor services and tow companies with switchboats could provide assistance under government contract, or (3) the existing approach used for helper boats could be expanded to switchboats (a harbor service or tow company provides assistance and then bills the assisted vessel directly).

At most sites, only one boat would be required to provide assistance for downbound approaches. However, there may be some sites and conditions where a boat could be used downstream as well to assist tows in leaving the wall.

TABLE 4-3: DAILY COSTS TO OPERATE A HELPER BOAT

Cost	400-600 hp	800-1000 hp	1200 hp
Capital Costs (cost recovery - 7.75% over 20 yrs)	$ 155	$ 270	$ 355
Operating Costs			
• Crew of 5.26 (Approx. 3 on duty at all times)	650	880	1,020
• Boat Costs (Maintenance, Supplies, Insurance, Taxes)	330	445	510
• Administration	125	165	190
• Fuel Cost (Average Power) *	140	325	490
• Profit (13.5%)	190	280	345
Total Daily Cost	$ 1,590	$ 2,365	$ 2,910
Total Annual Cost (Daily * 270 days)	$429,300	$638,550	$785,700
Hourly Cost (Daily Cost/24 hrs)	$ 66	$ 99	$ 121

*Note: Fuel cost is approximately $250 - $500 higher per day if under high power most of the time.
Source: FY97 Planning Guidance Shallow Draft Vessel Costs.

On the UMR-IWW System, most tows are currently charged a fee of approximately $250 per assistance or $150 per hour for the use of a helper boat. The cost varies by site, depending on the type of boat available and whether the helper boat must travel to reach the lock site. However, the costs in Table 4-3, although lower, are the expected costs assuming that demand for the assist boats would lead to nearly continuous utilization of the boat and its crew. In arriving at an annual cost, the daily costs were multiplied by 270 days, the approximate length of the navigation season on the UMR. In contrast to the upper sites, the lower UMR locks and IWW locks remain open virtually all year. However, lock usage on the UMR in winter is low and open pass conditions occur during significant portions of the year on the lower IWW, limiting the requirement for continuous switchboat availability. In addition, at many sites some of this cost is already being incurred due to existing use of the boats. At these sites, the incremental cost to fully implement this measure would be much lower.

Relationship to Other Measures. The use of helper boats is compatible with most measures. The scheduling program measure, approach improvements, and switchboats all can address approach time issues to some extent and, as a result, have reduced joint benefits if combined with a helper boat option.

Conclusion. The use of helper boats to assist approaches is currently occurring and is likely to increase in the without project, as sites congest. Additional helper boat assistance may reduce approach times at some sites for some tows, but the majority of benefits are already being captured and the incremental savings is highly variable and uncertain.

▪ Switchboats with Guidewall Extensions

Description of Measure. Switchboats typically have horsepower ranging from approximately 1,200 to 2,500 horsepower. Boats in the 1,800 to 2,000-horsepower range were determined to be able to safely extract the unpowered first cut of double lockages out along an extended guidewall. This process represents the major additional time savings, since it provides a faster extraction than the existing tow haulage and allows the next waiting tow (traveling in the same direction) to use the lock while the first tow remakes its couplings. Switchboats, like helper boats, can also assist tows in approaching the locks in adverse conditions and by moving ice and debris from around the chamber. Moving the cuts farther down along the extended guidewall can also reduce chambering times for downbound tows by allowing faster releases of water from the chamber. This faster

filling and emptying is possible because moving the first cut of downbound tows farther down the guidewall reduces the potential to snap a line.

To fully implement this measure the guidewalls must be extended approximately 600 feet, using either cellular sheet pile construction with precast concrete panels or DeLong Pier/spud barges. This would provide approximately 1,200 feet of wall outside the chamber, allowing the first cut to be moved far enough from the chamber that the powered cut can fully exit from the chamber for remake. This allows the next tow heading in the same direction to use the lock while the first tow recouples. In addition to improving the existing 600-foot lock's efficiency, switchboat assistance with approaches can increase safety by reducing the potential for a major accident or substantial delay related to a tow that is unable to successfully approach a lock.

Delay Reductions Methodology/Time Savings Estimates. Four steps in the lockage process were identified as having potential time savings associated with switchboat use: (1) approaching the lock, (2) pulling the first cut of double lockages, (3) remaking of double lockages, and (4) reducing chamber emptying times. The estimated savings for each of these areas, along with the approach used to determine the savings, is summarized below (see Figures 4-2A and B).

Several sources of data were evaluated to provide information on the potential time savings available for implementing helper boats. These sources include timing data from a 1975 report by Peat, Marwick, and Mitchell & Co. entitled, *Evaluation of Operational Improvements at Locks and Dam No. 26, Mississippi River*; the 1990 LPMS data; the 1995 timing data from Mel Price Lock; responses from the February 4-5, 1997, Expert Elicitation meeting with navigation industry; and interviews and site visits with lockmasters and navigation industry. This section summarizes the results of these efforts, as well as the average time savings for UMR Locks 11-25 and IWW locks from Lockport to La Grange.

Approaching the Lock. In general, switchboats can provide the same approach time savings benefits as helper boats. As the size and horsepower of assist boats increase, they become less maneuverable and effective in providing approach assistance, but the lockmasters generally reported switchboats would provide the same time savings as helper boats. As addressed in the helper boat summary, information from the expert elicitation meeting with lockmasters and navigation industry was used to estimate the time savings potential at UMR locks.

However, the fact that at many sites tows already use assistance under normal flows limits the potential incremental savings. There are also a wide range of potential factors affecting the potential savings, including variability of flow, site-specific differences, the pilot and crew skill levels, weather, etc. These factors make it very difficult to accurately predict what, if any, additional approach time savings is possible. In addition, when a queue is present and the lock operates with multiple turnback lockages, these benefits are even more limited since only fly and exchange lockages typically experience the full benefits of approach assistance.

Pulling the First Cut of Double Lockages. The potential was evaluated to have switchboats pull the unpowered cuts of doubles out of the lock. Assistance with this portion of the lockage primarily results in the ability to extract cuts faster than the existing tow haulage, take the cut farther along the guidewall, and hold the first cut (see Figures 4-2A and B). The data used to evaluate the potential benefits of having switchboats pull the cuts included data from tests conducted at the former Lock 26 by Peat, Marwick, and Mitchell (1975), 1990 LPMS data, and 1995 timing data from Melvin Price Lock. The initial findings and approach were verified as part of the expert elicitation process and through lockmaster interviews. It is important to note that the time savings estimates record the reduction in time needed to extract the cut clear of the gate, allowing the gate to close for the next cut. This is shorter than the entire time to move the cut to the end of the extended guidewall and tie off the cut.

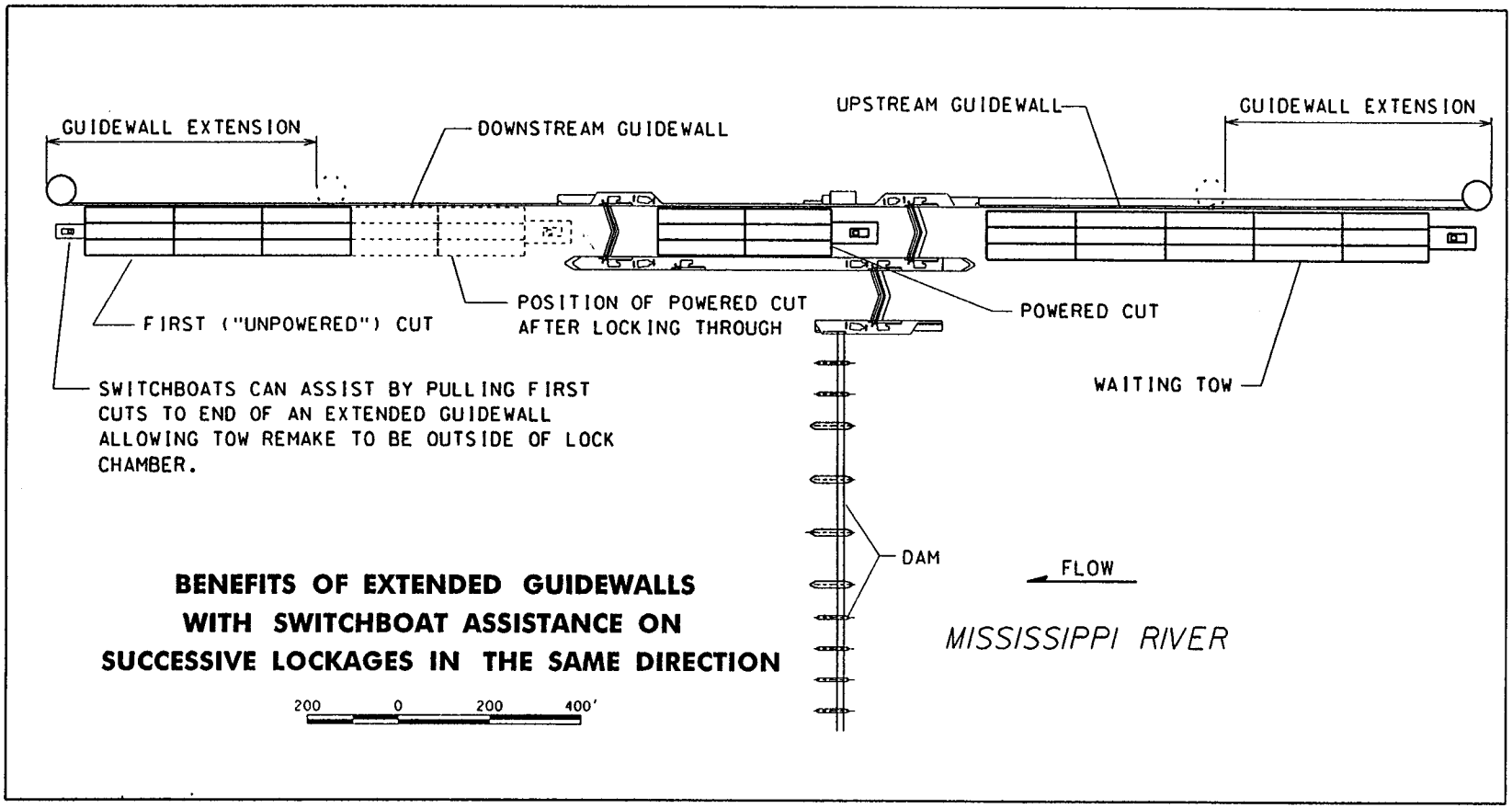
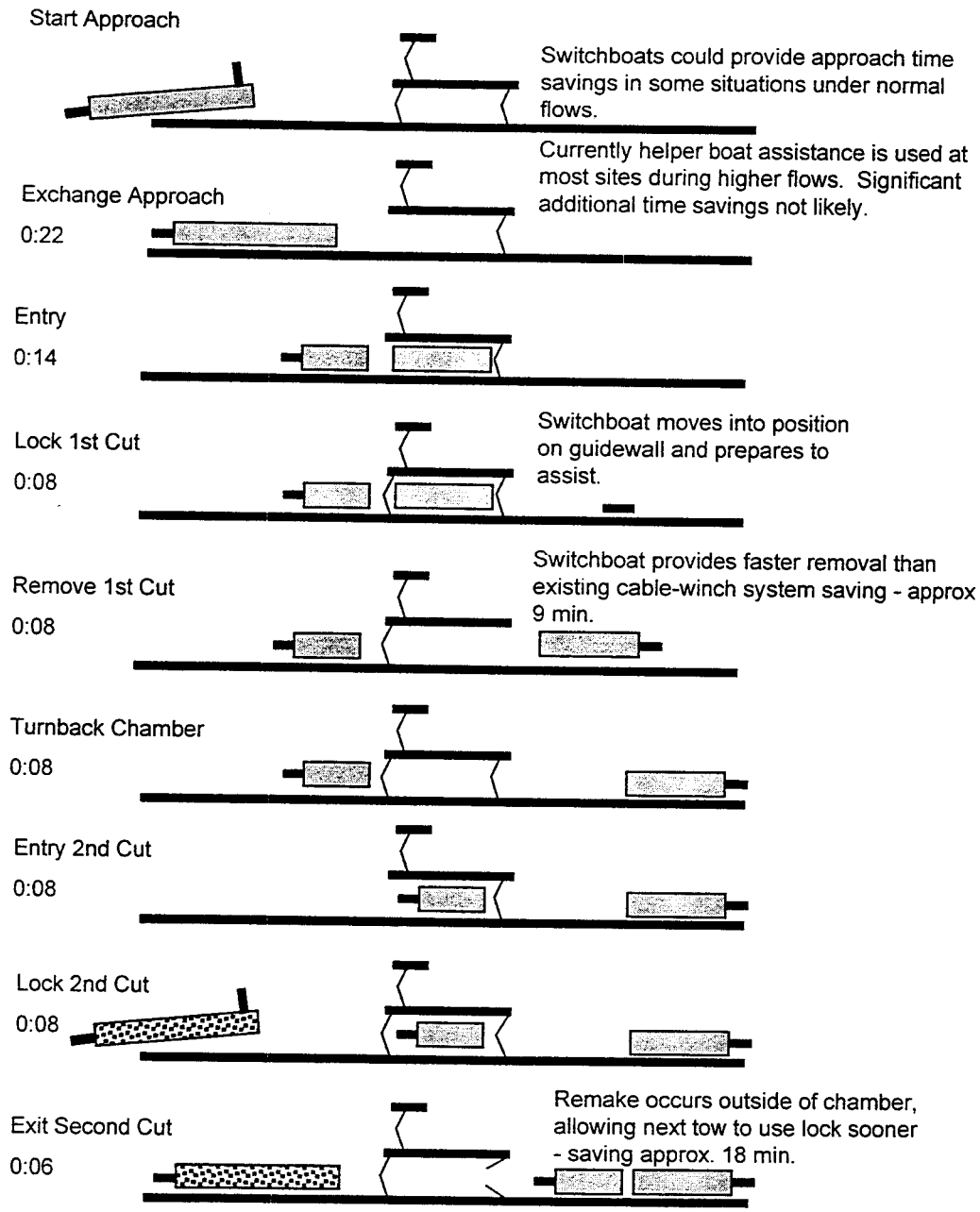


FIGURE 4-2A: Benefits of Extended Guidewalls with Switchboat Assistance on Successive Lockages in the Same Direction



Total Lockage Time 1:22

Approx. total time savings with Helper Boats vs. Existing Operations is 25-27 min. Remake/exit savings (18 min.) only benefits system, if next tow is traveling in the same direction (compare to figure 1-8).

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

FIGURE 4-2B: Double Lockage Elements - Two Switchboats with Guidewall Extensions

As part of a timing study conducted at the former Lock 26, a 900-horsepower helper boat (with manual winches which are slower than the electric winches currently used on most helper boats and switchboats) extracted the first cuts of double lockages along an extended guidewall. Over a 2-week period, the helper boats produced time savings of approximately 5 minutes on upbound and 11 minutes on downbound exits of the first cut over the use of the existing tow haulage. This reduced upbound exit times from 13 to 8 minutes and downbound exits from approximately 19 to 9 minutes.

Peat, Marwick, Mitchell & Co. (1975) also collected data on switchboat assistance at old Lock 26 over approximately a one-month period from November 19, 1973, to December 21, 1973. The switchboat used for the test was a 1,140-horsepower twin-screw tow with electric winches. The electric winches were very effective in quickly securing the cut. Comparing just extraction times for switchboats with the base period, indicated a time savings of 7 minutes for upbound and 13 minutes for downbound lockages. This resulted in reducing upbound exit times from approximately 13 minutes for tow haulage to 5 minutes with a switchboat. Downbound exits were reduced from 19 to 6 minutes. The numbers from both these tests are close to the estimates obtained using LPMS data, described below.

Data collected as part of LPMS were used to estimate the time savings of using a switchboat to extract the unpowered cut of a double lockage at each site. This was accomplished by comparing the existing times to extract the unpowered cut of double lockages using tow haulage at UMR Locks 11-25, 14 minutes upbound and 17 minutes downbound, with the exit time of a powered single cut, 5 and 6 minutes for upbound and downbound, respectively. This comparison is based on the assumption that the exit of a single tow from the chamber closely approximates the time required for a switchboat to pull an unpowered cut from the chamber. However, based on discussions with lockmasters and navigation industry, an additional two minutes was included to allow for the switchboat to make its coupling. The distributional characteristics of the single lockage data were assumed to hold for the switchboat extractions. However, adjustments of 2 minutes were made to increase the maximum and minimum values. This translates the existing distribution, while preserving the distributional characteristics.

Time Savings	=	Existing Extraction with Tow Haulage	-	(Exit of + 2 min. to make) Single couplings

At the expert elicitation and during interviews, the lockmasters and navigation industry generally affirmed that this was a close and valid approximation. The result was an estimated time savings of 7 and 9 minutes for upbound and downbound tows, respectively, on the UMR. Smaller time savings of 5 to 6 minutes were identified for the IWW locks. These numbers are similar to the results of the 1975 Lock 26 timing study, summarized above. The difference between upbound and downbound time savings relates to a combination of lower clearance of the tow over the downstream sill in combination with a greater percentage of empties moving upstream. The average resulting time savings and actual site to site numbers have been included in Table 4-4.

The estimated time savings in pulling cuts is supported by additional field data collected at Melvin Price Locks near Alton, Illinois, on the UMR. The data were collected from the use of the 600-foot lock during a closure of the facility's 1,200-foot lock chamber from February 27, 1995, to March 14, 1995. During this period, a 1,500-horsepower towboat pulled the first cut of double lockages from the 600-foot chamber along the 1,200-foot guidewall. While timing data for this site are not available for double lockages without towboat assistance since larger tows would normally use the 1,200-foot chamber, the various times collected provide insight into the relationship between various time elements. The timing data analyzed included the time from the recessing of the gates to the stern of the cut moving past the gate. During this test, the average time to pull the first cut with the towboat averaged 6 minutes for upbound and 7 minutes for downbound. In contrast to these numbers, the exits of singles took 5 minutes and 4 minutes, respectively, for upbound and downbound. These data generally support an allowance of 2 minutes for the making of couplings.

TABLE 4-4: SWITCHBOATS WITH GUIDEWALL EXTENSIONS

TABLE 4-4: PERFORMANCE OF SWITCHBOATS WITH GUIDEWALL EXTENSIONS

Lock Site		Annual Cost: boat, wall, site prep (Millions)*	% of Season Out-Draft Occurs	Time Savings (min.) Approach of Fly and Exch Downbound Double Lockages Lockmaster Estimates	EXTRACTING THE FIRST CUT OF DOUBLE LOCKAGES (MIN.) Current Time to Extract 1st Cut w/ Tow Haulage Min	Max	St Dev	Avg	New Time to Extract 1st Cut w/Helper Boat & Guidewall (Single Exit + 2 min) Min+2	Max+2	St Dev	Avg+2	Time Savings Extract Cut	EXIT OF THE SECOND CUT OF TURNBACK DOUBLE LOCKAGES (MIN.) Current Time for Exit of 2nd Cut of Double Lockage Min	Max	St Dev	Avg	New Time for Exit of 2nd Cut with Ext. Guidewall (Exit of Single) Min	Max	St Dev	Avg	Time Savings Remake Double	Reduced Chamber Time Doubles	Total Time Savings
11	US	$ 2.808	25	10 min normal flow	6.0	32.0	4.4	16.1	3.0	13.0	2.3	7.8	8.3	6.0	40.0	6.2	19.9	1.0	11.0	2.3	5.8	14.1		22.4
	DS	$ 2.149			8.0	49.0	4.5	17.5	4.0	20.0	2.8	8.6	8.9	4.0	45.0	6.7	20.9	2.0	18.0	2.8	6.6	14.3	- 0.1	23.2
12	US	$ 3.194	45	15-20 normal flow, 25+ outdraf	1.0	30.0	3.8	12.2	3.0	13.0	1.9	6.8	5.4	4.0	35.0	5.4	17.7	1.0	11.0	1.9	4.8	12.9		18.3
	DS	$ 2.132			5.0	33.0	3.7	16.0	4.0	17.0	2.9	7.9	8.1	4.0	61.0	7.3	22.1	2.0	15.0	2.9	5.9	16.2	- 0.1	24.2
13	US	$ 2.856	25	very limited	1.0	45.0	4.6	13.1	4.0	22.0	2.8	7.3	5.8	3.0	47.0	7.4	18.8	2.0	20.0	2.8	5.3	13.5		19.3
	DS	$ 2.140			1.0	51.0	4.3	15.6	3.0	13.0	1.7	7.0	8.6	3.0	44.0	7.3	22.1	1.0	11.0	1.7	5.0	17.1	0.1	25.8
14	US	$ 2.810	30	5-30 depending on flows	2.0	73.0	4.3	14.2	4.0	15.0	2.1	7.2	7.0	5.0	46.0	7.4	22.4	2.0	13.0	2.1	5.2	17.2		24.2
	DS	$ 2.006			4.0	67.0	4.1	15.1	4.0	19.0	2.8	8.1	7.0	7.0	92.0	8.3	25.1	2.0	17.0	2.8	6.1	19.0	- 0.1	25.9
15	US	$ 2.909	20	5-30 depending on flows	5.0	36.0	4.3	14.6	5.0	17.0	2.2	8.4	6.2	5.0	46.0	5.8	20.7	3.0	15.0	2.2	6.4	14.3		20.5
	DS	$ 1.752			2.0	27.0	2.6	12.9	6.0	15.0	2.2	9.6	3.3	8.0	61.0	7.3	27.2	4.0	13.0	2.2	7.6	19.6	2.4	25.3
16	US	$ 2.753	25	15-30 on average	4.0	53.0	4.9	14.4	4.0	15.0	2.4	7.4	7.0	4.0	56.0	7.4	19.4	2.0	13.0	2.4	5.4	14.0		21.0
	DS	$ 2.122			2.0	35.0	5.1	16.0	3.0	13.0	2.4	7.2	8.8	5.0	48.0	6.5	22.0	1.0	11.0	2.4	5.2	16.8	- 0.4	25.2
17	US	$ 2.919	35	Rarely a helper boat available	5.0	51.0	5.1	15.1	3.0	14.0	2.5	8.2	6.9	4.0	52.0	6.3	20.2	1.0	12.0	2.5	6.2	14.0		20.9
	DS	$ 2.416			2.0	54.0	4.7	19.5	5.0	15.0	2.3	8.0	11.5	6.0	48.0	6.4	22.8	3.0	13.0	2.3	6.0	16.8	0.0	28.3
18	US	$ 2.815	25	15 normal flw 20-30 higher flw	4.0	59.0	4.9	14.3	4.0	17.0	2.9	8.1	6.2	4.0	55.0	6.6	20.7	2.0	15.0	2.9	6.1	14.6		20.8
	DS	$ 2.164			4.0	39.0	4.2	17.4	3.0	15.0	2.3	7.3	10.1	6.0	96.0	7.7	23.0	1.0	13.0	2.3	5.3	17.7	- 0.3	27.6
19	US		25	10 on average									NA									NA		-
	DS												NA									NA	NA	-
20	US	$ 2.877	30	10 normal flw, 20+ higher flow	2.0	42.0	5.1	14.4	3.0	18.0	2.9	8.6	7.8	3.0	55.0	8.0	19.9	1.0	16.0	2.9	4.6	15.3		23.1
	DS	$ 1.990			1.0	56.0	5.1	16.9	3.0	15.0	2.5	6.8	10.1	5.0	61.0	7.3	24.3	1.0	13.0	2.5	4.8	19.5	0.4	30.0
21	US	$ 2.863	55	10 normal flow	1.0	70.0	4.6	13.1	3.0	11.0	2.1	5.9	7.2	2.0	64.0	7.4	21.4	1.0	9.0	2.1	3.9	17.5		24.7
	DS	$ 2.196			4.0	56.0	4.8	16.8	3.0	11.0	1.6	5.7	11.1	6.0	90.0	8.4	23.6	1.0	9.0	1.6	3.7	19.9	0.1	31.1
22	US	$ 2.946	40	15-20 normal flow, 30+ outdraf	1.0	41.0	4.1	15.0	4.0	17.0	2.2	7.0	8.0	4.0	76.0	7.1	21.3	2.0	15.0	2.2	5.0	16.3		24.3
	DS	$ 2.088			5.0	97.0	4.9	18.2	4.0	16.0	2.8	7.8	10.4	5.0	98.0	7.2	24.0	2.0	14.0	2.8	5.8	18.2	0.5	29.1
24	US	$ 2.666	40	10-15 avg flow	3.0	46.0	4.1	13.3	3.0	22.0	2.5	7.0	6.3	2.0	89.0	7.2	21.0	1.0	20.0	2.5	5.0	16.0		22.3
	DS	$ 1.971			1.0	42.0	4.1	20.4	5.0	24.0	3.0	8.3	12.1	2.0	62.0	6.7	22.8	3.0	22.0	3.0	6.3	16.5	1.6	30.2
25	US	$ 3.168	35	15 avg flow, 30-45 min outdraft	4.0	49.0	4.4	12.6	3.0	17.0	2.2	5.7	6.9	3.0	59.0	6.9	20.5	1.0	15.0	2.2	3.7	16.8		23.7
	DS	$ 2.242			5.0	80.0	5.0	18.1	3.0	29.0	3.3	6.4	11.7	2.0	162.0	9.6	22.5	1.0	27.0	3.3	4.4	18.1	1.1	30.9
MEL PRICE	US		NA	NA									NA									NA		-
	DS												NA									NA	NA	-
27	US		NA	NA									NA									NA		-
	DS												NA									NA	NA	-
LOCK-PORT	US	$1.129 no wall		10-15 normal, 20 + outdraft	2.0	46.0	6.1	13.9	4.0	22.0	3.0	8.2	5.7									NR		5.7
	DS	$1.129 no wall			3.0	40.0	5.8	12.7	4.0	19.0	2.6	7.1	5.6									NR	NA	5.6
BRAN-DON	US	$ 6.620		Assist tows overcome wind	8.0	53.0	5.2	15.5	3.0	26.0	3.4	8.3	7.2	5.0	49.0	9.0	25.4	1.0	24.0	3.4	6.3	19.1		26.3
	DS	$ 6.772			3.0	45.0	6.9	15.1	4.0	22.0	3.1	8.4	6.7	5.0	50.0	11.1	25.3	2.0	20.0	3.1	6.4	16.9	3.6	29.2
DRES-DEN	US	$ 6.514	25	fairly limited	3.0	31.0	3.8	13.6	4.0	12.0	1.7	7.7	5.9	2.0	47.0	8.9	25.7	2.0	10.0	1.7	5.7	20.0		25.9
	DS	$1.129 no wall			3.0	30.0	4.3	11.8	4.0	12.0	1.8	7.1	4.7									NR	NA	4.7
MAR-SEILLES	US	$ 6.574	30	0-5 normal, higher in outdraft	1.0	79.0	5.1	11.3	3.0	16.0	2.4	7.2	4.1	3.0	74.0	10.2	25.3	1.0	14.0	2.4	5.2	20.1		24.2
	DS	$ 6.666			1.0	52.0	4.5	10.3	4.0	32.0	4.4	8.3	2.0	2.0	59.0	11.3	25.4	2.0	30.0	4.4	6.3	19.1	1.8	22.9
STARV-ED ROCK	US	$ 6.494	15	0-5 normal, higher in outdraft	4.0	35.0	3.6	11.3	4.0	31.0	3.6	7.1	4.2	5.0	85.0	10.4	23.4	2.0	29.0	3.6	5.1	18.3		22.5
	DS	$ 6.566			4.0	35.0	4.3	11.6	4.0	12.0	1.8	7.0	4.6	2.0	68.0	10.7	23.6	2.0	10.0	1.8	5.0	18.6	1.5	24.7
PEO-RIA	US	$ 8.035	30	minimal lower flw, 15-30 highe	4.0	35.0	5.1	13.8	5.0	23.0	3.6	8.4	5.4	5.0	72.0	9.6	23.9	3.0	21.0	3.6	6.4	17.5		22.9
	DS	$ 8.085			5.0	44.0	5.7	14.5	4.0	14.0	2.2	7.7	6.8	3.0	64.0	11.4	27.2	2.0	12.0	2.2	5.7	21.5	-	28.3
LA GRANGE	US	$ 7.956	20	minimal lower flw, 15-30 highe	3.0	35.0	5.3	13.7	4.0	35.0	6.3	8.9	4.8	2.0	73.0	11.1	23.3	2.0	33.0	6.3	6.9	16.4		21.2
	DS	$ 7.984			3.0	75.0	6.2	15.6	4.0	14.0	2.4	7.6	8.0	3.0	85.0	13.5	26.8	2.0	12.0	2.4	5.6	21.2	-	29.2
Average	US	$ 2.891	28.7	5-20 min under lower flows	3.0	48.2	4.5	14.0	3.5	16.2	2.4	7.2	6.8	3.8	55.4	6.9	20.3	1.5	14.2	2.4	5.2	15.1		22.0
UMR 11-25	DS	$ 2.105			3.4	52.8	4.4	17.0	3.8	17.1	2.5	7.6	9.4	4.8	74.5	7.4	23.3	1.8	15.1	2.5	5.6	17.7	0.4	27.4
Average	US	$ 7.032	24.0	Limited under lower flows	3.6	44.9	4.9	13.3	3.9	23.6	3.4	8.0	5.3	3.1	57.1	8.5	21.0	1.6	18.7	3.0	5.1	18.6		23.9
Illinois	DS	$ 7.219			3.1	45.9	5.4	13.1	4.0	17.9	2.6	7.6	5.5	2.1	46.6	8.3	18.3	1.4	12.0	2.0	4.1	19.9	1.4	26.7

US = upstream, DS = downstream, NA = Not Applicable, NR = Not Recommended

* Costs shown are for permanent 600 ft upstream and downstream guidewall extensions using the federal discount rate of 7.125% and a 50 year project life.

Remaking of Double Lockages. Additional time savings can be obtained by pulling cuts out far enough along an extended guidewall so that the second (or powered) cut can exit the lock and remake without blocking the chamber. This process allows the next tow traveling in the same direction to use the lock earlier, thereby reducing delay times for all tows waiting in a queue. However, it does not reduce the actual remake time for the actual locking tow. It simply moves the remake process out of the lock chamber. To achieve this time savings with a switchboat, a guidewall extension providing a total of 1,200 feet of surface would be required. This time savings would result from alleviating the existing condition at locks with 600-foot guidewalls where a double lockage tow is unable to exit the chamber until it has remade its couplings, while keeping the chamber from servicing other tows. However, the time savings are only available for turnback lockages whereby the next tow locks in the same direction. If the next lockage is an exchange, going in the opposite direction, no additional time is saved since the tow is still blocking the approach during its remake. The potential time savings associated with moving the remake area out of the chamber has been documented in a number of reports. The 1975 Lock and Dam 26 report estimated a reduction of exit and clear times for upbound tows from 26 to 11 minutes and downbound tows from 25 to 12 minutes.

LPMS data were also analyzed to estimate the potential time savings of moving remake areas out of the chamber. To estimate the time savings, the actual exit times of the second cut of double lockages were used and compared with the exit times of singles. Based on the expert elicitation and interviews with lockmasters, the exit time of singles serves as a close approximation of the exit of the powered second cut of double lockages if the cut has been removed a sufficient distance from the chamber. Data from turnback lockages were used for these calculations, since the timing is stopped once the tow clears the gate, reducing variability associated with exchange and fly approach points. Using the formula shown below and 1990 LPMS data for Locks 11-25, time savings of 15 minutes for upbound tows and 18 minutes for downbound tows were calculated. These savings represent reduced existing tow exit times of the second cuts of downbound tows from 20 to 5 minutes and upbound tows from and 24 to 6 minutes. Based on the data, somewhat larger time savings appear possible for the Illinois River sites.

Time Savings = Existing Exit time of 2nd Cut (including remake) - Exit of Single

The 1995 data from Melvin Price lock support these assumptions. The exits of the second cut of double lockages when the first cut had been taken down the guidewall were 5 minutes and 6 minutes, respectively, for upbound and downbound. The exits of single lockage tows took 5 minutes and 4 minutes, respectively, for upbound and downbound. These values fit closely with the assumption that the exits of singles approximate the exit of the powered cut if the first cut has been removed from the chamber.

At the expert elicitation meeting, the panelists agreed with the assumption that the exit of a single can be used to approximate the exit of the powered cut if the first cut has been taken to the end of an extended guidewall. While remaking along the existing guidewall is not recommended in most situations, tows can be remade along the existing downstream guidewall at a few locks under some situations if the first cut is pulled to the last checkpost on the existing guidewall. Tows also could be remade along a guidewall with an extension shorter than 600 feet, but the time savings and safety are reduced. In these situations, pushing the second cut out of the chamber (clear of the miter gates) takes about 1.5 times longer than the exit of a single-lockage tow. This is primarily due to the fact that a second cut has to slow down to face up to the first cut while still in the chamber. In contrast, a single-lockage tow continues to accelerate away from the lock. Closing the miter gates and starting the lock chamber turnback can not be done until the powered cut is 50 to 100 feet from the gate if the boat is under power. If the tow is closer, as in the case of

remaking with its cut along a wall shorter than 1,200 feet, the tow must be settled down in position to remake with the unpowered cut prior to gate closing. Otherwise, the prop wash is sent at the closing miter gates. However, if there is approximately 700 feet from the gate to the first cut (as in the case of an extended 1,200-foot guidewall), the second cut exit will not be delayed and can exit in approximately the same time as a single.

Time Savings = Existing Exit time of 2nd Cut (including remake) - (1.5 * Exit of Single)

As a result, if less than 1,200-foot guidewalls are used, the expected time savings at UMR sites would be reduced using the above equations to approximately 13 minutes for upbound tows and 15 minutes for downbound. At IWW sites, the time savings would also decrease by 2 to 3 minutes to 16 minutes upbound and 17 minutes downbound.

Reducing Chamber Emptying Times. Typically, the rate of emptying the chamber is slowed when an unpowered cut is waiting in the downstream approach for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is pulled an additional 600 feet down an extended guidewall.

The Peat, Marwick, Mitchell & Co. (1975) report showed a savings of 4 minutes; however, the actual time savings is highly dependent on the water level elevation (head) difference between pools and location of discharge ports. The former Lock 26 had a greater difference in water level elevations (approximately 20 feet) between its upper and lower pools than most locks on the UMRS. As a result, at most UMR locks, which typically have smaller water level differences of 10 feet or less, much smaller time savings are likely. Using LPMS 1990 data, the potential for faster chambering times was calculated by comparing the chambering time for the first and last cuts of double lockages. This analysis showed that for the UMR sites, limited time savings of 0 to 2 minutes are all that is possible on average. Time savings estimates for each lock are shown on Table 4-4. At lower flows, when head differences are the greatest, slightly higher time savings are possible. At higher flows there would be little or no savings. Somewhat higher savings of 1 to 4 minutes are anticipated for the Upper IWW locks where the difference in water level elevations is greater.

Total Time Savings. As the following table indicates, a variety of time savings appears possible with the use of a switchboat and guidewall extension. In total, it appears possible to reduce the time a double lockage is using the lock by 20 to 30 minutes. However, the larger time savings are dependent on an extended guidewall and the ability to remake double lockage tows outside of the chamber. The time savings of using switchboats at the former Lock and Dam 26 site to extract unpowered cuts along an extended guidewall allowing recoupling outside of the chamber was summarized by Peat, Marwick, Mitchell & Co. in a 1975 report. Their analysis showed a time savings of 23 minutes for double lockage tows, based on a reduction in the overall lockage time from 125 to 102 minutes. This total time reduction only applies to turnback lockages, since the remaking tow uses the guidewall for a remake area. In addition, some savings to setover and knockout lockage types is also possible, but varies considerably based on the configuration of the tow, commodities being transported, and river conditions. These configurations only represent a small portion of total system traffic.

The numbers in Table 4-5 provide a summary of the expected average time savings, based on the analysis of LPMS data for UMR lock sites. Similar time savings were calculated for IWW sites. The time savings estimates are very similar to the former Lock 26 timing study. In addition, due to uncertainties in obtaining the approach time savings, only the 22- and 27-minute estimates for doubles associated with the other steps are used to convey the time savings possible for turnback doubles. The actual time savings for a queue depends on the lockage type, number of

tows requiring double lockages, how the extraction is handled, number of switchboats, and whether they are assisting with approaches.

While the tows waiting in queue benefit from the full 22- to 27-minute reduction in lockage time when the next tow locks in the same direction, the actual tow being assisted only experiences a time savings related to the faster extraction of the first cut. This is due to the fact that the tow must still remake, even though it is not blocking the chamber, before it can leave the lock wall.

TABLE 4-5: ESTIMATED AVERAGE TIME SAVINGS FOR SWITCHBOAT WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25

Delay Reduction	Double Lockages Benefits to Tows Waiting in Queue	Double Lockages Benefits to the Locking Tow
Pulling the unpowered cut	7 min. upbound 9 min. downbound	7 min. upbound 9 min. downbound
Remaking the tow (with extended guidewalls – turnback lockages only)	15 min. upbound 18 min. downbound	Tow still remakes, location is moved to end of the guidewall
Reduced chambering time	0-2 min. downbound	0-2 min. downbound
Total time savings potential*	22 min. upbound * 27 min. downbound *	7 min. upbound 9 min. downbound

* Total benefit to waiting tows assuming the next lockage is a turnback. Otherwise, benefits are limited to 7 min. upbound and 9 min. downbound.

Reconfiguration of Setover and Knockout Singles. In addition to the saving to double lockage tows highlighted above, guidewall extensions provide some savings potential to setover and knockout single tows. This savings is provided by allowing the tow types to reconfigure into a 600-foot arrangement on the guidewall rather than in the lock chamber. Table 4-39 highlights the site specific exit benefits that average 23 minutes for setovers and 7.5 minutes for knockouts. In some cases, these benefits could be doubled if the tows could reconfigure prior to entering the chamber as well. However, the impact of these savings is limited due to the relatively small number of tows in this category and the fact that in some cases the lock would be available prior to the completion of the reconfiguration. Additional information on the potential benefits to setover and knockout lockages is provided in the section on guidewall extensions.

Conditions Affecting Implementation. As stated under the helper boat option, there is considerable uncertainty in the ability to provide increased approach time savings. As a result, this analysis focused on the benefits of switchboats in assisting other steps in the lockage process.

One limitation of using switchboats to pull cuts along extended guidewalls is that they only realize remake time savings if the next tow is traveling in the same direction (turnback lockages). They also require extended (preferably 1,200-foot) guidewalls. Even with extended upper guidewalls, pulling cuts under outdraft conditions does present some safety risks under high flows.

Comments from navigation industry question the safety and reliability of using DeLong Pier/Spud Barge guidewall extensions. Although these facilities worked to a reasonably acceptable level at old Lock 26 as a short-term improvement, the approach to that particular lock was in slack water. It did not have the considerable outdraft conditions that exist at most of the other sites on the lower UMR. Industry commented that the greater the outdraft the harder it will be to make the approach and the greater the risk that a tow moving to the lock will hit the piers, moving them out of position or damaging them. In general, a pier/barge guidewall extension compared to a permanent wall would have relatively high annual maintenance costs and a shorter life. In particular, if the actual damage to the piers is greater than anticipated, it could significantly increase maintenance costs, expand periods of unavailability, and reduce usable life.

Cellular sheet-pile constructed guidewall extensions would provide more reliable performance and greater certainty in obtaining benefits since they are very similar to the walls in use on various portions of the inland waterway system.

Concern was also expressed that during outdraft conditions an 1,800-horsepower boat could not and should not try to back a cut out to the end of an extended DeLong Pier wall because the current coming under the wall extension could pull the tow off the wall. In addition, any gaps between the piers/barges could catch the tow, making it more vulnerable to outdraft currents. This creates a particularly dangerous situation because if the tow leaves the wall it could get pulled towards the dam without adequate horsepower to control the cut.

Industry does not believe DeLong Pier/spud barge guidewalls are an acceptable alternative, and they strongly recommend using a permanent guidewall extensions instead, especially for the upstream wall. If permanent walls are not provided, it may be necessary to extract the cut some distance, tie it off, bring the tow around to the downstream end and then push up to the end of the wall. With either method, a 2,200- to 2,400-horsepower boat would be recommended with temporary walls. However, with a permanent wall that cuts off flow and has unpowered traveling kevels, the switchboat should be able to extract cuts under all flow conditions using an 1,800-horsepower boat backing to the end of the wall.

Costs. Costs associated with this measure fall into two general categories—vessel costs and guidewall extension costs. These two items are discussed separately below.

Vessel Cost: The Corps of Engineers' *Draft Economic Planning Guidance for Shallow Draft Vessel Costs* estimates that switchboat replacement costs range from approximately $1.3 to $2.4 million depending on the type, size, horsepower, and features of the boat. The total daily, yearly, and hourly costs in 1996 dollars for operating a switchboat of various size categories have been summarized in Table 4-6A below. In addition, a factor of 13.5 percent was added for profit since the guidance only addresses operating costs.

Two switchboats would be required to provide maximum benefits, except at sites with an auxiliary lock, which could have one switchboat service tows traveling in either direction. As a general rule, boats used to pull cuts along the wall should be roughly 1,800 horsepower to have adequate control over the cut and be able to overcome outdraft currents under virtually all river conditions.

Three possible scenarios exist regarding how these boats could be supplied: (1) the government could purchase boats and provide assistance, (2) harbor services and tow companies with switchboats could provide assistance under government contract, or (3) the existing approach used for helper boats could be expanded to switchboats (a harbor service or tow company provides assistance and then bills the assisted vessel directly).

On the UMR-IWW System, most tows are currently charged a fee of approximately $250 per assistance or $150 per hour for the use of a helper boat or switchboat. The cost varies by site, depending on the type of boat available and whether the boat must travel to reach the lock site. However, the costs in the table below are the expected costs assuming that demand for the assist boats would lead to nearly continuous utilization of the boat and its crew. In arriving at an annual cost, the daily costs were multiplied by 270 days, the approximate length of the navigation season on the UMR. In contrast to the upper sites, the lower UMR locks and IWW locks remain open virtually all year. However, lock usage on the UMR in winter is low and open pass conditions occur on the lower IWW during significant portions of the year, limiting the requirement for continuous switchboat availability. In addition, some assist vessel cost is already being incurred at many sites due to the existing use of helper boats. At these sites, if switchboats could provide the same level of approach assistance, costs could be reduced accordingly.

TABLE 4-6A: DAILY COST TO OPERATE A SWITCHBOAT

Cost	1200 hp	1400-1600 hp	1800-2000 hp	2200-2400 hp
Capital Costs (cost recovery - 7.75% over 20 yrs)	$ 355	$ 445	$ 560	$ 680
Operating costs				
• Crew of 4-6	1,020	1,140	1,290	1,420
• Boat Costs (maintenance, supplies, insurance, taxes)	510	575	645	715
• Administration	190	215	240	265
• Fuel Cost (average power)	490	675	950	1,250
• Profit (13.5%)	345	410	495	585
Total Daily Costs	$ 2,910	$ 3,460	$ 4,180	$ 4,915
Total Yearly Costs (daily costs * 270 days)	$785,700	$934,200	$1,128,600	$1,327,100
Hourly Costs (daily costs/24 hrs)	$ 121	$ 144	$ 174	$ 205

Note: Fuel cost is $500 - $600 higher per day if under high power most of the time.
Source: FY97 Planning Guidance, Shallow Draft Vessel Costs.

Guidewall Extension Costs: The existing guidewalls can be extended in essentially two ways, using cellular sheet pile construction with precast concrete panels or DeLong Pier/spud barges. These two options have differences in cost, usable life, performance and safety, as discussed in the Conditions Affecting Implementation section.

There is a potential to use DeLong Piers or jack-up barges to serve as a guidewall extension, similar to the approach used during the 1970s for several years at Old Lock 26 (see Table 4-6B). The concept would extend the flat rubbing surface provided by the guidewall an additional 600 feet by aligning the piers/barges with the existing wall. These piers, which are made up of a barge anchored with pilings driven into the river bed, could be purchased or possibly obtained from government surplus. If new construction is required, a cost of approximately $700,000 would be incurred per 195-foot-long barge with four 30- to 36-inch-diameter spuds and ½-inch steel sides. In addition, approximately $40,000 per pier per year would be required to maintain and repair the piers (patching, pumping out, etc.). Major rehabilitation, including residing the piers, replacing bracing, and repainting, would be required approximately every 5 years at a cost of $200,000 per pier. In addition, a cell would be added immediately upstream or downstream of the extended wall to protect the barges and provide a pivot point for tows.

At some sites, additional costs would be required to excavate an adequate width to allow the barges to fit and to cover the additional cost of placing the spuds at rock founded sites. The first cost of these additions ranged from $60,000 to $330,000 at applicable sites. The one exception was the cost of $750,000 to remove the upstream dogleg guidewall at Lock 11. This includes the additional placement cost of approximately $10,000 per spud (4 spuds/barge) for placement at rock-founded sites (Locks 14, 15, 20, 22, 24, Lockport, Brandon, Marseilles, and Starved Rock).

TABLE 4-6B: COST OF GUIDEWALL EXTENSION USING DE LONG PIERS/JACK-UP BARGES

First Cost	Cost
- First Cost of Piers (3-200' Piers at $700,000 each)	$2,100,000
- Placement (1 week per wall at crew cost of $12,000 per day)	$60,000
- First Cost of a Protection Cell (30' diameter)	$400,000
Subtotal First Cost for Cell, 3 Piers, and Placement	$2,560,000
- Contingency 25%	640,000
Subtotal First Cost for Cell, 3 Piers, and Placement	$3,200,000
Annual Cost and Periodic Maintenance	**Cost**
- Annual O&M ($40,000 per pier)	$120,000
- Rehab Piers Every 5 Years (includes dry docking at $200k/barge)	$600,000
- Useful Life – Piers/Barges	20 years
- Annual O&M Cell	$20,000
- Useful Life – Cell	30 years

The second option is to provide permanent guidewall extensions using cellular sheet pile construction with precast concrete panels as a rubbing surface. These would be constructed primarily during winter closures to minimize impacts to navigation. The estimated first cost of permanent guidewall extensions averaged $23,450,000 for the upstream walls at UMR sites. This cost includes a cost of approximately $240,000 to extend the unpowered traveling kevel to assist in keeping the cut of barges along the upstream wall. The downstream wall first cost is considerably lower at $12,870,000, including $360,000 to provide an unpowered traveling kevel. The kevel cost is higher for the downstream wall since most upstream guidewalls currently have a kevel and rail, which would only need to be extended. For more information on the specifics of the design, construction methods, and detailed cost, see the guidewall extension section of this report. One key difference is that while permanent guidewall extensions have a much higher first cost, the annual maintenance cost of $32,000 is much lower and the expected life of 50 years is considerably longer. Costs for permanent guidewall extensions at IWW locks are estimated to be considerably higher due to greater impacts to navigation associated with the fact that there is not a winter closure time for construction. As a result, costs of impacts to navigation are anticipated at $60 to $80 million per wall extension.

Relationship to Other Measures. The use of switchboats is compatible with most measures. In particular, traditional or DeLong Pier guidewall extensions are required to fully implement using switchboats to extract cuts. The use of scheduling to increase the number of turnback lockages also increases the potential benefits of this measure.

The scheduling program measure and approach improvements can also address approach time issues to some extent and, as a result, have reduced joint benefits if combined with a switchboat option. Regarding pulling cuts, the tow haulage equipment, switchboats with remote remake, and industry self help measures provide similar assistance and would likely not be jointly selected.

Conclusion. Use of switchboats, in combination with extended guidewalls, could provide significant time savings and should be considered at sites experiencing significant delays.

- **Switchboats with Remote Remake Areas**

Description of Measure. In contrast to the previous measure, larger boats in the 2,200- to 2,400-horsepower range were determined to be necessary to safely extract the unpowered first cut and push it to a remote mooring under all flow conditions. The additional size allows them to remove an unpowered cut from the chamber and move it to a remote mooring facility, as shown in Figures 4-3A, B, and C. Adequate mooring sites out of the approach path are required to fully implement the measure. Due to safety concerns, switchboats would not be used to back cuts upriver, above the dam. Instead a short guidewall extension, roughly 300 feet, would be provided to allow the switchboat to extract the cut, tie it off, uncouple from the cut, move to the downstream end, recouple, and then push upstream to the remote mooring. This allows both exchange and turnback lockage types to use the chamber while the first tow is remaking. This increases the flexibility over scheduling or the use of switchboats with guidewall extensions, which rely on multiple, same direction lockages. Switchboats can also assist tows in approaching the locks in adverse conditions and by moving ice and debris from around the chamber. Using switchboats in combination with remote remake areas can also reduce chambering times by allowing faster releases of water from the chamber. This faster filling and emptying is possible because removing the first cut of downbound tows reduces the potential to snap a line.

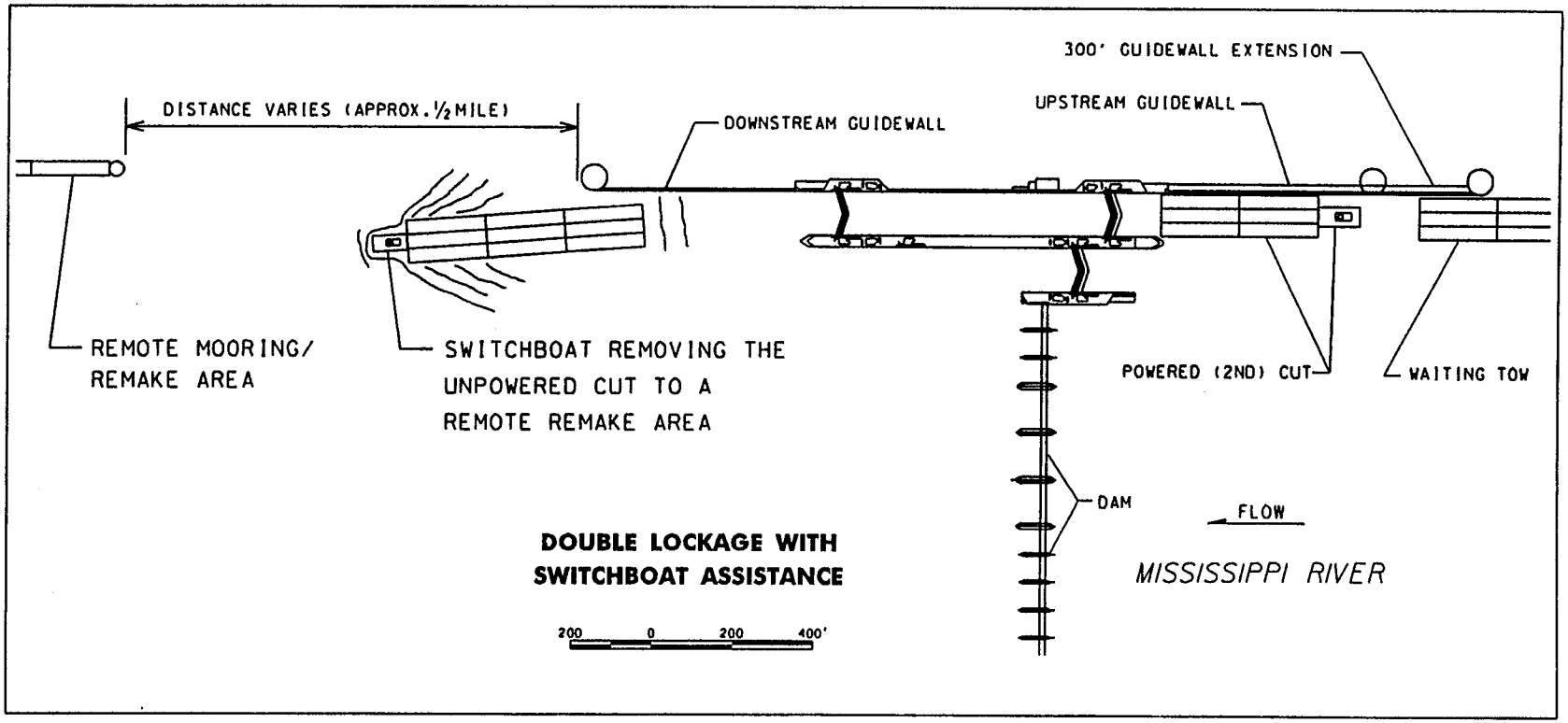
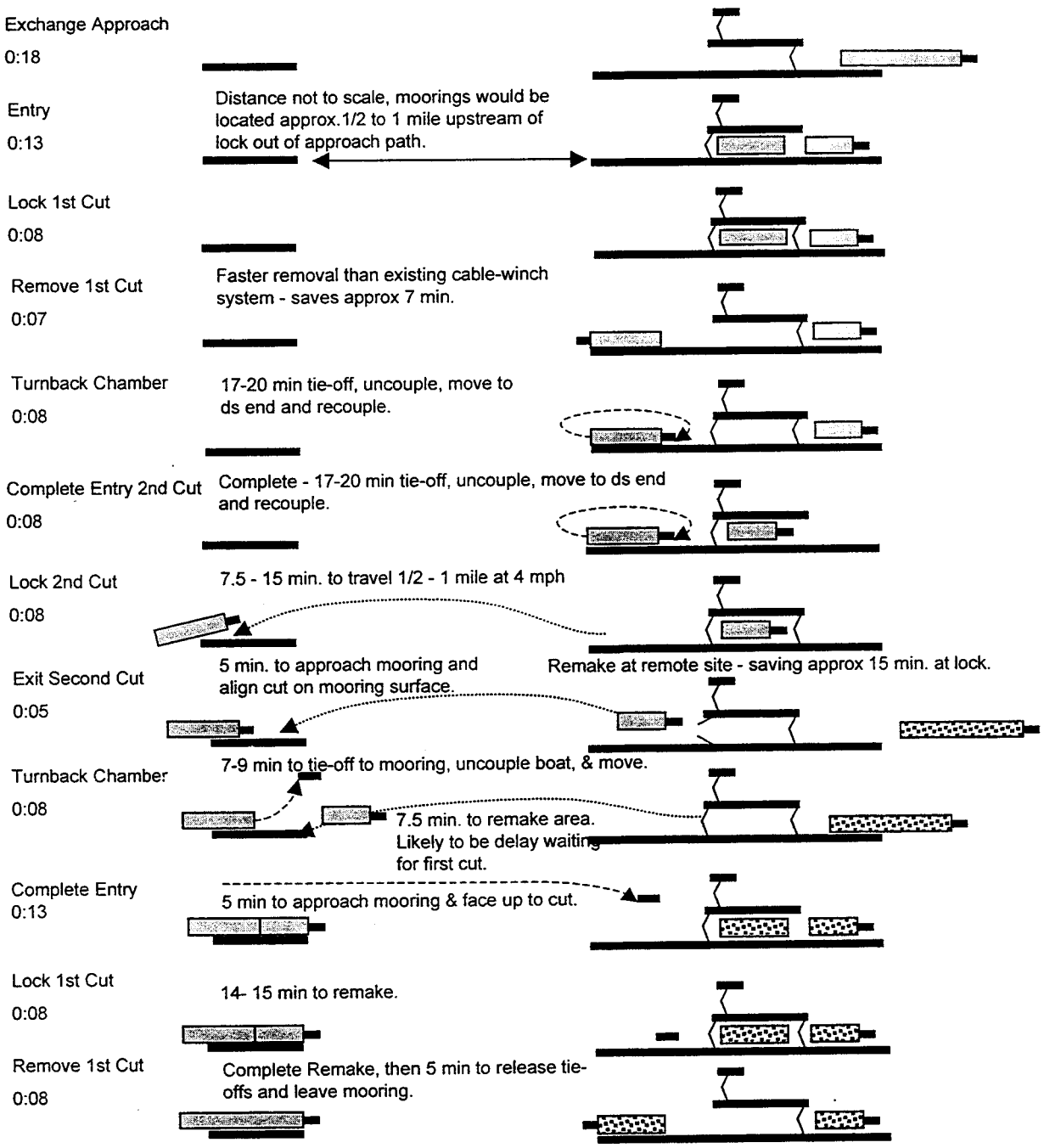


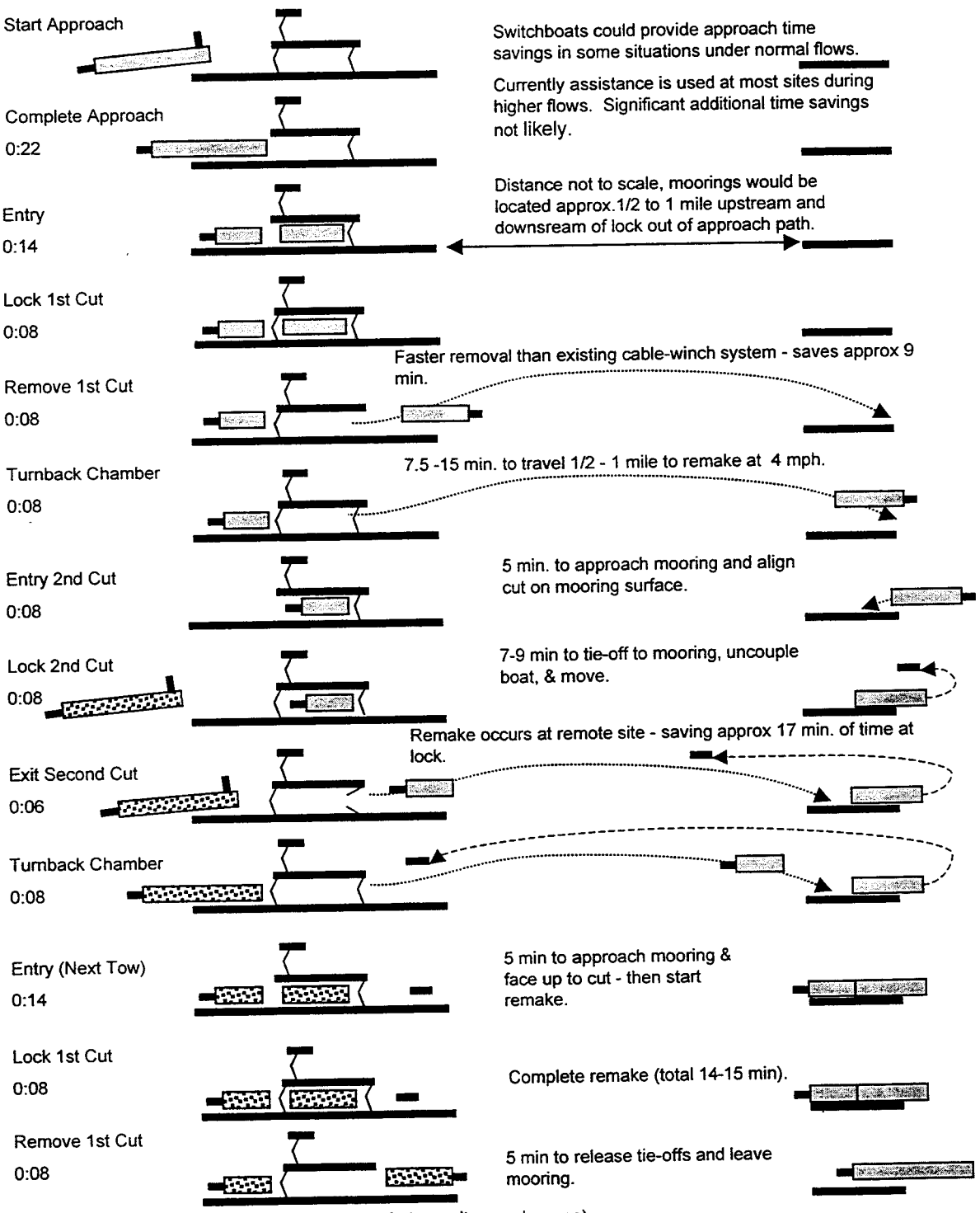
FIGURE 4-3A: Double Lockage with Switchboat Assistance



Total Lockage Time: 1:15 (at lock) 1:48 (remade tow exits remake area)

Savings approximately 22 min at lock, while individual tow requires additional 5 min.

FIGURE 4-3B: Double Lockage Elements - Two Switchboats and Remote Moorings Upstream Direction - 300-Foot Wall Extension



Total Lockage Time: 1:22 (at lock) 1:55 (remade tow exits remake area)

Savings approx. 25-27 min at lock, while individual tow locking requires additional. 5 min.

FIGURE 4-3C: Double Lockage Elements - Two Switchboats and Remote Moorings Downstream Direction

At most sites, the placement of upstream and downstream mooring facilities is required. The options for moorings include spud barges, moored barges, DeLong Piers, timber pile clumps, mooring cells or, in some cases, a waiting tow. If extended guidewalls were available at the locks, tows could remake along them and only the last tow of the N-up/N-down series would need to be taken to a mooring facility for remaking to open the approach for tows headed in the opposite direction.

Delay Reductions Methodology/Time Savings Estimates. The potential time savings of using switchboats centers on the ability to reduce the time required for: (1) approaching the lock, (2) pulling the first cut of double lockages, (3) remaking of double lockages, and (4) reducing chamber emptying times. The estimated savings for each of these areas, along with the approach used to determine the savings, are summarized below.

Information from a number of sources was reviewed and analyzed, including timing data from the 1975 Peat, Marwick, and Mitchell & Co. report entitled, *Evaluation of Operational Improvements at Locks and Dam No. 26, Mississippi River*; 1995 timing data from Mel Price Lock; 1990 LPMS data; responses from the February 4-5, 1997, Expert Elicitation meeting with navigation industry; and interviews and site visits with lockmasters and navigation industry. This section reports the results of these efforts and summarizes the average time savings for UMR Locks 11-25 and IWW locks from Lockport to La Grange.

Approaching the Lock. In general, switchboats can provide the same approach time savings benefits as helper boats. As the size and horsepower of assist boats increase, they become less maneuverable and effective in providing approach assistance, but the lockmasters generally reported switchboats would provide the same time savings as helper boats. As addressed in the helper boat summary, information from the expert elicitation meeting with lockmasters and navigation industry was used to estimate the time savings potential at UMR locks.

However, the fact that at many sites tows already use assistance under normal flows limits the potential incremental savings. Also, a wide range of factors affect the potential savings, including variability of flow, site-specific differences, the pilot and crew skill levels, weather, etc. These factors make it very difficult to accurately predict what, if any, additional approach time savings is possible. In addition, when a queue is present and the lock operates with multiple turnback lockages these benefits are even more limited since only fly and exchange lockages typically experience the full benefits of approach assistance.

Pulling the First Cut of Double Lockages. Assistance with this portion of the lockage results in the ability to extract cuts faster than the existing tow haulage, allowing the lock gates to close earlier and speed the lockage process. The switchboat can then take the unpowered cut along the guidewall or remove the unpowered cut to a remote site. The data used to evaluate the potential benefits of having switchboat assistance included data from the Lock and Dam 26 tests conducted by Peat, Marwick, and Mitchell (1975); 1995 timing data from Melvin Price Lock; 1990 LPMS data; and verification by lockmasters and industry. It is important to note that the time savings estimates record the reduction in time needed to extract the cut clear of the gate, allowing the gate to close for the next cut. This is shorter than the entire time to move the cut to the end of the extended guidewall and tie off the cut.

As summarized in the previous section, the study team reviewed the data Peat, Marwick, Mitchell & Co. (1975) collected on switchboat assistance at old Lock 26 from November 19, 1973, to December 21, 1973. The switchboat used for the test was a 1,140-horsepower twin-screw tow with electric winches. Comparing only extraction times for switchboats with the base period indicated a time savings of 7 minutes for upbound and 13 minutes for downbound lockages. This resulted in reducing times from the existing condition of approximately 13 minutes for tow

haulage to 5 minutes with a switchboat for upbounds. Downbound exits were reduced from 19 to 6 minutes.

The study team used data collected as part of the LPMS to estimate the time savings of using a switchboat to extract the unpowered cut of a double lockage at each site. This was done by comparing the average times for UMR Locks 11-25 to extract the unpowered cut of double lockages with the existing tow haulage, 14 minutes upbound and 17 minutes downbound, and the exit time of a powered single cut, 5 to 6 minutes for upbound and downbound, respectively. This includes the assumption that a switchboat pulling an unpowered cut from the chamber closely approximates the exit of a single lockage tow from the chamber. However, an additional 2 minutes was also included to allow for the switchboat to make its coupling. The distributional characteristics of the single lockage tow data were again assumed to hold for the switchboat extractions. The result was an estimated time savings of 7 to 9 minutes for upbound and downbound, respectively. The IWW locks showed somewhat smaller time savings of 5 minutes for upbound and 6 minutes for downbound. The specific data on each site are summarized in Table 4-7.

Time Savings	=	Existing Extraction with Tow Haulage	-	(Exit of Single + 2 min. to make couplings)

The estimated time savings in pulling cuts is supported by actual field data collected from February 27, 1995, to March 14, 1995. During this time period, a 1,500-horsepower switchboat was used at the Mel Price Lock and Dam near Alton, Illinois, on the UMR to pull cuts from the 600-foot auxiliary chamber along the 1,200-foot guidewall during a closure of the facility's 1,200-foot lock chamber. The switchboat was able to reach extraction speeds of 300 feet per minute. In addition, the switchboats were often able to face up and be ready for extraction prior to the gates being fully recessed. While times for this site are not available for double lockages without the switchboat, since larger tows would normally use the 1,200-foot chamber, the various times collected provide insight into the relationship between various time elements. The timings analyzed included the time from the recessing of the gates to the stern of the cut over the gate. During this test, the average time to pull the first cut with the switchboat averaged 6 minutes for upbound and 7 minutes for downbound. In contrast to these numbers, the exits of singles took 5 minutes and 4 minutes, respectively, for upbound and downbound. These data support the assumption that in general with a 2-minute allowance for the making of couplings, the exit of a single comes fairly close to approximating the extraction of an unpowered cut with a switchboat.

At the expert elicitation and during interviews, the lockmasters and navigation industry generally affirmed that the LPMS data analysis provided a close and valid approximation. These numbers are also similar to the results from the former Lock 26 and Melvin Price timing studies.

Remaking of Double Lockages (Exit and Clear Second Cut). The use of switchboats to pull cuts to remote moorings allows tows to remake out of the chamber, benefiting both exchange and turnback lockages since remake occurs clear of the lock chamber, guidewall, and approach path. The general sites under consideration for remake areas are shown in Figure 4-4. While this process allows the next tow to use the lock earlier, it does not reduce the actual remake time for a particular tow, it just occurs at a facility where it does not cause delay to tows in the queue. If the time is included to move both cuts to the remote mooring, align them, recouple, and then leave the mooring area, it is likely that the process will actually take as long or longer than the existing process. However, it does alleviate the existing condition at locks with 600-foot guidewalls where a double lockage tow is unable to exit the chamber until it has remade its couplings, keeping the chamber from servicing other tows.

The additional steps associated with using a switchboat and the remote moorings add variability to the lockage process and are highlighted in the following section.

TABLE 4-7: PERFORMANCE OF SWITCHBOATS WITH REMOTE REMAKE AREAS

LockSite		Annual Cost: boat, wall, site prep (Millions)*	% of Season Out-Draft Occurs	Time Savings (min.) Approach of Fly and Exch Downbound Double Lockages Lockmaster Estimates	EXTRACTING THE FIRST CUT OF A DOUBLE LOCKAGE (MIN.) Current Time to Extract 1st Cut w/ Tow Haulage Min	Max	St Dev	Avg	New Time to Extract Cut w/ Switchboat (Single Exit + 2 min) Min+2	Max+2	St Dev	Avg+2	Time Savings Extract Cut	EXIT OF THE SECOND CUT OF DOUBLE LOCKAGES (MIN.) Current Time for Exit of 2nd Cut of Double Lockage Min	Max	St Dev	Avg	New Time for Exit of 2nd Cut with Remote Remake (Exit of Single) Min	Max	St Dev	Avg	Time Savings Remake Double	Reduced Chamber Time	Total Time Savings
11	US	$ 2.765	25	10 min normal flow	6.0	32.0	4.4	16.1	3.0	13.0	2.3	7.8	8.3	6.0	40.0	6.2	19.9	1.0	11.0	2.3	5.8	14.1		22.4
	DS	$ 1.922			8.0	49.0	4.5	17.5	4.0	20.0	2.8	8.6	8.9	4.0	45.0	6.7	20.9	2.0	18.0	2.8	6.6	14.3	- 0.1	23.2
12	US	$ 2.958	45	15-20 normal flow, 25+ outdraft	1.0	30.0	3.8	12.2	3.0	13.0	1.9	6.8	5.4	4.0	35.0	5.4	17.7	1.0	11.0	1.9	4.8	12.9		18.3
	DS	$ 1.922			5.0	33.0	3.7	16.0	4.0	17.0	2.9	7.9	8.1	4.0	61.0	7.3	22.1	2.0	15.0	2.9	5.9	16.2	- 0.1	24.2
13	US	$ 2.789	25	very limited	1.0	45.0	4.6	13.1	4.0	22.0	2.8	7.3	5.8	3.0	47.0	7.4	18.8	2.0	20.0	2.8	5.3	13.5		19.3
	DS	$ 1.922			1.0	51.0	4.3	15.6	3.0	13.0	1.7	7.0	8.6	3.0	44.0	7.3	22.1	1.0	11.0	1.7	5.0	17.1	0.1	25.8
14	US	$ 2.777	30	5-30 depending on flows	2.0	73.0	4.3	14.2	4.0	15.0	2.1	7.2	7.0	5.0	46.0	7.4	22.4	2.0	13.0	2.1	5.2	17.2		24.2
	DS	$ 1.933			4.0	67.0	4.1	15.1	4.0	19.0	2.8	8.1	7.0	7.0	92.0	8.3	25.1	2.0	17.0	2.8	6.1	19.0	- 0.1	25.9
15	US	$ 2.827	20	5-30 depending on flows	5.0	36.0	4.3	14.6	5.0	17.0	2.2	8.4	6.2	5.0	46.0	5.8	20.7	3.0	15.0	2.2	6.4	14.3		20.5
	DS	$ 1.933			2.0	27.0	2.6	12.9	6.0	15.0	2.2	9.6	3.3	8.0	61.0	7.3	27.2	4.0	13.0	2.2	7.6	19.6	2.4	25.3
16	US	$ 2.738	25	15-30 on average	4.0	53.0	4.9	14.4	4.0	15.0	2.4	7.4	7.0	4.0	56.0	7.4	19.4	2.0	13.0	2.4	5.4	14.0		21.0
	DS	$ 1.922			2.0	35.0	5.1	16.0	3.0	13.0	2.4	7.2	8.8	5.0	48.0	6.5	22.0	1.0	11.0	2.4	5.2	16.8	- 0.4	25.2
17	US	$ 2.820	35	Rarely a helper boat available	5.0	51.0	5.1	15.1	3.0	14.0	2.5	8.2	6.9	4.0	52.0	6.3	20.2	1.0	12.0	2.5	6.2	14.0		20.9
	DS	$ 1.922			2.0	54.0	4.7	19.5	5.0	15.0	2.3	8.0	11.5	6.0	48.0	6.4	22.8	3.0	13.0	2.3	6.0	16.8	0.0	28.3
18	US	$ 2.769	25	15 normal flw 20-30 higher flw	4.0	59.0	4.9	14.3	4.0	17.0	2.9	8.1	6.2	4.0	55.0	6.6	20.7	2.0	15.0	2.9	6.1	14.6		20.8
	DS	$ 1.922			4.0	39.0	4.2	17.4	3.0	15.0	2.3	7.3	10.1	6.0	96.0	7.7	23.0	1.0	13.0	2.3	5.3	17.7	- 0.3	27.8
19	US		25	10 on average									NA									NA		0.0
	DS												NA									NA		0.0
20	US	$ 2.799	30	10 normal flw, 20+ higher flow	2.0	42.0	5.1	14.4	3.0	18.0	2.9	6.6	7.8	3.0	55.0	8.0	19.9	1.0	16.0	2.9	4.6	15.3		23.1
	DS	$ 1.933			1.0	56.0	5.1	16.9	3.0	15.0	2.5	6.8	10.1	5.0	61.0	7.3	24.3	1.0	13.0	2.5	4.8	19.5	0.4	30.0
21	US	$ 2.792	55	10 normal flow	1.0	70.0	4.6	13.1	3.0	11.0	2.1	5.9	7.2	2.0	64.0	7.4	21.4	1.0	9.0	2.1	3.9	17.5		24.7
	DS	$ 1.922			4.0	56.0	4.8	16.8	3.0	11.0	1.6	5.7	11.1	6.0	90.0	8.4	23.6	1.0	9.0	1.6	3.7	19.9	0.1	31.1
22	US	$ 2.845	40	15-20 normal flow, 30+ outdraft	1.0	41.0	4.1	15.0	4.0	17.0	2.2	7.0	8.0	4.0	76.0	7.1	21.3	2.0	15.0	2.2	5.0	16.3		24.3
	DS	$ 1.933			5.0	97.0	4.9	18.2	4.0	16.0	2.8	7.8	10.4	5.0	98.0	7.2	24.0	2.0	14.0	2.8	5.8	18.2	0.5	29.1
24	US	$ 2.705	40	10-15 avg flow	3.0	46.0	4.1	13.3	3.0	22.0	2.5	7.0	6.3	2.0	89.0	7.2	21.0	1.0	20.0	2.5	5.0	16.0		22.3
	DS	$ 1.933			1.0	42.0	4.1	20.4	5.0	24.0	3.0	8.3	12.1	2.0	62.0	6.7	22.8	3.0	22.0	3.0	6.3	16.5	1.6	30.2
25	US	$ 2.944	35	15 avg flow, 30-45 min outdraft	4.0	49.0	4.4	12.6	3.0	17.0	2.2	5.7	6.9	3.0	59.0	6.9	20.5	1.0	15.0	2.2	3.7	16.8		23.7
	DS	$ 1.922			5.0	80.0	5.0	18.1	3.0	29.0	3.3	6.4	11.7	2.0	162.0	9.8	22.5	1.0	27.0	3.3	4.4	18.1	1.1	30.9
MEL PRICE	US		NA	NA									NA									NA		0.0
	DS												NA									NA	NA	0.0
27	US		NA	NA									NA									NA		0.0
	DS												NA									NA	NA	0.0
LOCK-PORT	US	$1.129 no wall		10-15 normal, 20 + outdraft	2.0	46.0	6.1	13.9	4.0	22.0	3.0	8.2	5.7									NA		5.7
	DS	$ 1.933			3.0	40.0	5.8	12.7	4.0	19.0	2.6	7.1	5.6	6.0	57.0	11.8	24.3	2.0	17.0	2.6	5.1	19.2	6.8	31.6
BRAN-DON	US	$ 4.670		Assist tows overcome wind	8.0	53.0	5.2	15.5	3.0	26.0	3.4	8.3	7.2	5.0	49.0	9.0	25.4	1.0	24.0	3.4	6.3	19.1		26.3
	DS	$ 1.933			3.0	45.0	6.9	15.1	4.0	22.0	3.1	8.4	6.7	5.0	50.0	11.1	25.3	2.0	20.0	3.1	6.4	18.9	3.6	29.2
DRES-DEN	US	$ 4.618	25	fairly limited	3.0	31.0	3.8	13.6	4.0	12.0	1.7	7.7	5.9	2.0	47.0	8.9	25.7	2.0	10.0	1.7	5.7	20.0		25.9
	DS	$ 1.933			3.0	30.0	4.3	11.8	4.0	12.0	1.8	7.1	4.7	2.0	109.0	13.7	25.5	2.0	10.0	1.8	5.1	20.4	1.8	26.9
MAR-SEILLES	US	$ 4.648	30	0-5 normal, higher in outdraft	1.0	79.0	5.1	11.3	3.0	16.0	2.4	7.2	4.1	3.0	74.0	10.2	25.3	1.0	14.0	2.4	5.2	20.1		24.2
	DS	$ 1.933			1.0	52.0	4.5	10.3	4.0	32.0	4.4	8.3	2.0	2.0	59.0	11.3	25.4	2.0	30.0	4.4	6.3	19.1	1.8	22.9
STARV-ED ROCK	US	$ 4.608	15	0-5 normal, higher in outdraft	4.0	35.0	3.6	11.3	4.0	31.0	3.6	7.1	4.2	5.0	85.0	10.4	23.4	2.0	29.0	3.6	5.1	18.3		22.5
	DS	$ 1.933			4.0	35.0	4.3	11.6	4.0	12.0	1.8	7.0	4.6	2.0	68.0	10.7	23.6	2.0	10.0	1.8	5.0	18.6	1.5	24.7
PEO-RIA	US	$ 5.378	30	minimal lower flw, 15-30 higher	4.0	35.0	5.1	13.8	5.0	23.0	3.6	8.4	5.4	5.0	72.0	9.6	23.9	3.0	21.0	3.6	6.4	17.5		22.9
	DS	$ 1.922			5.0	44.0	5.7	14.5	4.0	14.0	2.2	7.7	6.8	3.0	64.0	11.4	27.2	2.0	12.0	2.2	5.7	21.5	-	28.3
LA GRANGE	US	$ 5.339	20	minimal lower flw, 15-30 higher	3.0	35.0	5.3	13.7	4.0	35.0	6.3	8.9	4.8	2.0	73.0	11.1	23.3	2.0	33.0	6.3	6.9	16.4		21.2
	DS	$ 1.922			3.0	75.0	6.2	15.6	4.0	14.0	2.4	7.6	8.0	3.0	85.0	13.5	26.8	2.0	12.0	2.4	5.6	21.2	-	29.2
Average	US	$ 2.810	28.7	5-20 min under lower flows	3.0	48.2	4.5	14.0	3.5	16.2	2.4	7.2	6.8	3.8	55.4	6.9	20.3	1.5	14.2	2.4	5.2	15.1		22.0
UMR 11-25	DS	$ 1.926			3.4	52.8	4.4	17.0	3.8	17.1	2.5	7.6	9.4	4.8	74.5	7.4	23.3	1.8	15.1	2.5	5.6	17.7	0.4	27.4
Average	US	$ 4.877	24.0	Limited under lower flows	3.6	44.9	4.9	13.3	3.9	23.6	3.4	8.0	5.3	3.1	57.1	8.5	21.0	1.6	18.7	3.0	5.1	18.6	2.2	23.9
Illinois	DS	$ 1.930			3.1	45.9	5.4	13.1	4.0	17.9	2.6	7.6	5.5	3.3	70.3	11.9	25.4	2.0	15.9	2.6	5.6	19.8	2.2	27.6

US = upstream, DS = downstream, NA = Not Applicable, NR = Not Recommended

* Costs shown are for permanent 300 ft upstream guidewall extensions and spud barge/cell remote moorings using the federal discount rate of 7.125% and a 20 year project life for spud barges and 50 year live for wall ext.

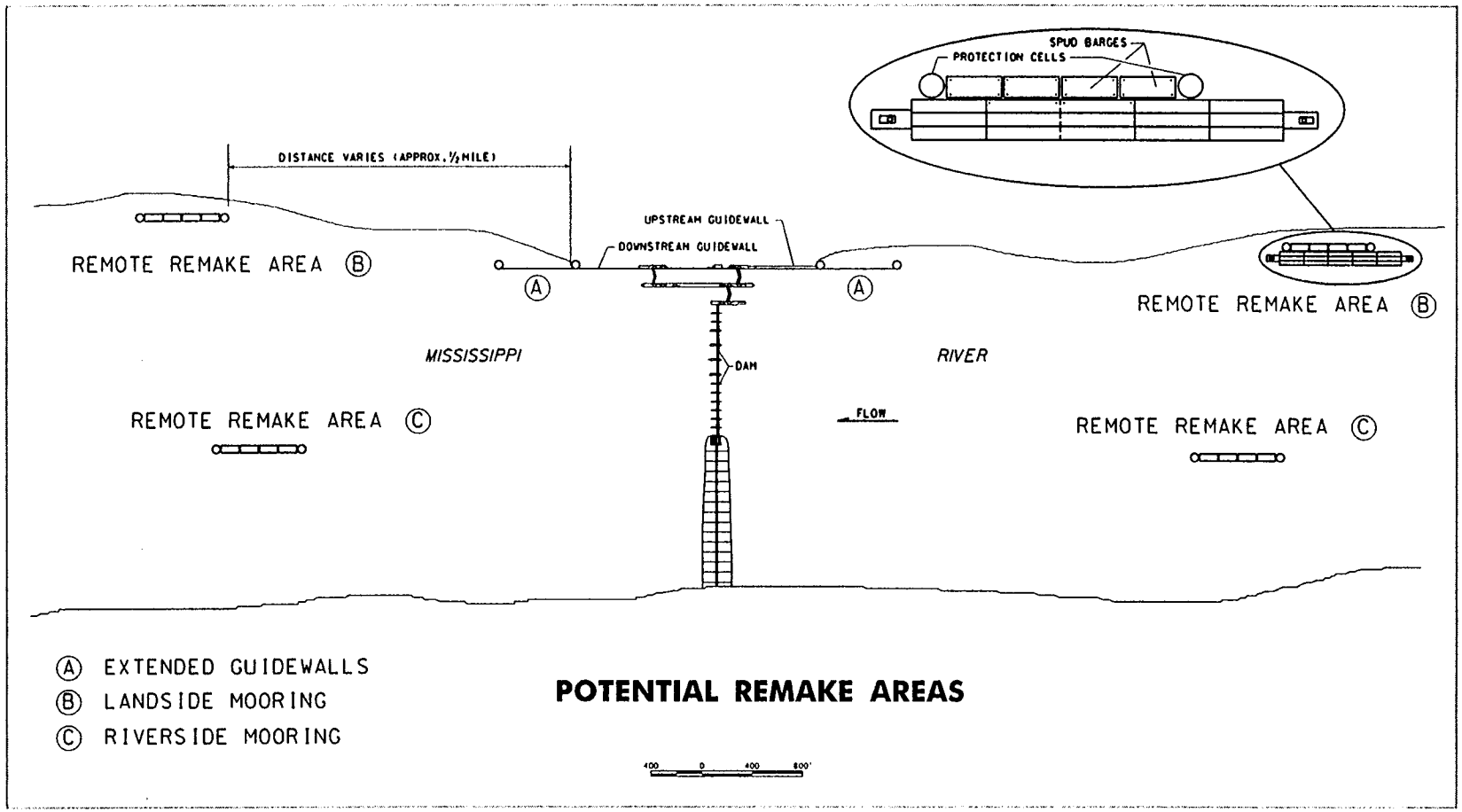


FIGURE 4-4: Potential Remake Areas

The potential time savings associated with moving the remake area out of the chamber has been timed and estimated in a number of reports. The 1975 Lock and Dam 26 test demonstrated the potential to reduce upbound exit and clear times for double lockages from 26 to 10 minutes for upbound and from 25 to 11 minutes for downbound. This resulted in a time savings of approximately 16 minutes on upbound and 14 minutes on downbound. The majority of this time is related to eliminating the need for the tow to remake while blocking the chamber.

The *Improved Tow Haulage Equipment* report prepared by Sverdrup as part of the UMR-IWW System Navigation study estimated remake time savings at approximately 15 minutes for lower UMR locks (Locks 20-25) and 19 minutes at La Grange Lock on the IWW. In estimating these time savings, Sverdrup used OMNI data (similar to LPMS data but with an additional time element) from all double lockages occurring in 1992 at these sites. The time for the exit of the second cut until the remade tow removed its headline and begins leaving the lock was analyzed. In order to isolate the remake time, 2 minutes was subtracted from the total time to account for the tow facing up to the cut, a movement of approximately 50 feet. The values are also similar to those provided by Louis Berger & Associates (1981) who estimated 13.5 minutes for recoupling.

The LPMS data were analyzed using the same procedure as in the helper boat test to estimate the potential time savings of moving remakes out of the chamber. In order to estimate the time savings, the actual exit times of the second cut of double lockages were used and compared with the exit times of singles.

Data from turnback lockages were used for these calculations since the timing is stopped once the tow clears the gate. Using turnback lockages reduces the variability associated with exchange and fly approaches. Based on the expert elicitation and interviews with lockmasters, the exit time of singles serves as a close approximation of the exit of the powered-second cut of double lockages if the first cut has been removed a sufficient distance from the chamber.

Using the formula listed below and 1990 LPMS data for UMR Locks 11-25, a time savings of 15 minutes for upbound tows and 18 minutes for downbound tows was calculated. This savings represents a reduction in the existing tow exit time of the second cuts from approximately 20 to 5 minutes and 24 to 6 minutes, respectively, for downbound and upbound tows. The average time savings for the IWW locks was somewhat larger at 19 minutes for upbound and 20 minutes for downbound. Data for all locks receiving detailed evaluation are shown in Table 4-7.

Time Savings = Existing Exit Time of 2nd Cut (including remake) - Exit of Single

At the elicitation, the panelists agreed with the assumption that the exit of a single can be used to approximate the exit of a powered cut if the first cut has been taken to a remote remake area or the end of an extended guidewall. As described in the previous section, data from Melvin Price lock were collected which also support these assumptions. The exits of the second cut when the first cut had been taken down the guidewall were 5 minutes and 6 minutes for upbound and downbound, respectively, while the exits of singles took 5 minutes and 4 minutes for upbound and downbound, respectively. These values fit closely with the assumption that the exits of singles approximate the exit of the powered cut if the first cut has been removed from the chamber.

Other Time Considerations: In addition, to simply identifying the savings of moving the remake out of the chamber to a remote mooring site, the study team analyzed the movements of the tow and switchboat. Of major concern was whether or not the switchboat and first cut could get to the mooring and tie off prior to the second cut arriving, if the switchboat could return to the lock in time to pull the next cut, whether or not the previous tow could complete its remake and exit the

moorings prior to the next tow being ready to use them, and the overall time it would require a tow to finish remaking and leave for its destination.

This analysis looked at Lock 21 (lock with fastest average filling and emptying time), Lock 24 (lock with slowest average filling and emptying times), and a reasonable minimum (as might occur during periods of high water). It also looked at the effects of mooring location, whether close to the lock (0.5 mile) or farther from the lock (1.0 mile). While not a detailed look at each site, the analysis helps to bound the expected performance.

Based on the following analysis, there will be times for upbound tows when the second cut is delayed in approaching the remote remake area, while the first cut is still tying off to the mooring and the switchboat is uncoupling. In addition, for moorings located more than ½ mile from the lock facility at locks with quick filling and emptying times (like Lock 21) and during periods of small elevation differences between pools, a single switchboat would not be able to extract the cuts and get back to the chamber in time to extract the following unpowered cut without delay. In these situations, the other switchboat would be brought from the lower pool, along side the first upbound towboat. It would then assist by pulling every other cut. Using these assumptions, under most situations the total reduction in lockage time to the queue identified in the previous sections of 22 minutes upbound and 27 minutes downbound for locks on the UMR could be obtained. If the other switchboat is not brought to the same pool, some reduction in time savings of up to 5 to 10 minutes per lockage is possible.

The analysis was based on the following assumptions. The switchboats would have a crew with two deckhands, and only one deckhand from the locking tow would go with the first cut to the remote remake site. For upstream tows, the switchboat would enter the lock and extract the cut by backing along the guidewall until the cut clears the gates by roughly 300 feet. This involves pulling cuts to the end of the new 300-foot extended guidewall. The cut is then tied off, the towboat uncouples, moves to the downstream end and recouples, the lines are released, and the cut moves upstream. Switchboats and tows could operate at 4 mph in moving cuts to the moorings and 6 mph in returning to the lock without a cut. In contrast, downbound tows would be backed to just below the remote remake area and then would approach the mooring moving upstream. The first column of Table 4-8 shows the assumptions used regarding the time for various steps in the lockage process. The assumptions of time for the various steps were used as input into the second column where the effects were analyzed for various steps in the process.

Six different steps and processes were analyzed:

1) The first analysis evaluated the potential for the exit of the second cut to be delayed due to the lengthy extraction and reconfiguration required of the first cut. This analysis showed that the chambering time, even at its minimum, will on average take considerably longer than the extraction and reconfiguration of the first cut, allowing adequate time for reconfiguration without blocking the exit of the second cut. In addition, delaying the exit of the second cut is not a concern for downbound tows, which will simply be backed to the mooring, taking considerably less time than the reconfiguration required for upbound tows.

2) This second analysis revealed that there are likely to be some delays for the second cut at the remote moorings as the switchboat finishes aligning, tying off the first cut, uncoupling, and moving out of the way (especially at sites with lower elevation differences and during periods of high water). While this does show the need for smooth operations, it does not demonstrate that there will necessarily be a delay to the next tow.

TABLE 4-8: ANALYSIS OF REMOTE REMAKE SAVINGS

Assumptions for Timing

	Estimate	Average
Extracting 1st Cut (gate has been cleared)		
Extract cut to end of GW	3-4 min	3.5
Tie-off cut	3-4 min	3.5
Uncouple switchboat	3 min	3
Move around cut and face-up	3-4 min	3.5
Recouple switchboat	3 min	3
Remove Lines	2 min	2
Sub-Total	17-20 min	18.5

Get 1st cut to mooring	**Estimate**	**0.5 mile**	**1 mile**
Move cut to mooring	.5-15 min	7.5	15
1st cut approach mooring	5 min	5	5
Tie-Off	3-4 min	3.5	3.5
Deck hand moves off cut	1-2 min	1.5	1.5
Uncouple and move tow	3 min	3	3
Sub-Total	.5-29 min	20.5	28
S/boat return to lock		5	10
2nd cut moves to Mooring		7.5	15

2nd Cut Mooring & Remake	**Estimate**	**Average**
2nd Cut approach Mooring	5 min	5
Remake	14-17 min	15.5
Clear Lines & Exit Mooring	3 min	3
Sub-Total	22-25 min	23.5

Lock Operations Times (Using 1990 LPMS Data??)	**Lock 21**	**Lock 24**	**1 Min Fill/Empty**
Turnback Chamber	6.3	10.2	5
Entry 2nd Cut	8	8	8
Lock 2nd Cut	6.2	10.2	5
Exit Chamber	5	5	5
Sub-Total	25.5	33.4	23
Turnback Chamber	6.3	10.2	5
Approach Next Tow	0	0	0
Entry 1st Cut/Uncouple	13.4	13.5	13.5
Lock 1st Cut	6.2	10.2	5
Sub-Total	25.9	33.9	23.5

Extract Cut - Clear Gate US	Lock 21	Lock 24	Avg
Switchboat	5.9	7	7.2

Analysis of Remote Remake - US with 300 foot wall

1/ Potential for First Cut to Delay	**Lock 21**	**Lock 24**	**Min**
Exit of Second Cut at the lock			
Turnback chamber & Lock Second Cut	25.5	33.4	23
Extract 1st cut, reconfigure, and leave wall	18.5	18.5	18.5
Total Available Time (Neg indicates Delay)	7	14.9	4.5

2/ Potential for Delay to 2nd Cut at Mooring	**Lock 21**		**Lock 24**		**Min Head (1 min Fill**	
will 1st Cut finishes tie-off & boat exits	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**
Turnback chamber, lock 2nd cut, move to remake	33.0	40.5	40.9	48.4	30.5	38.0
Extract 1st, reconfigure, tie-off at remote mooring	39.0	46.5	39.0	46.5	39.0	46.5
Total Available Time (Neg indicates Delay)	-6.0	-6.0	1.9	1.9	-8.5	-8.5

3/ Potential for Delay at Lock Pulling Next Cut	**Lock 21**		**Lock 24**		**Min Head (1 min Fill**	
due to Switchboat not returning in time	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**
Lock 2nd Cut of Tow & 1st Cut Next Tow	51.4	51.4	67.3	67.3	46.5	46.5
Extract 1st cut, take to mooring, and return	44.0	56.5	44.0	56.5	44.0	56.5
Total Available Time (Neg indicates Delay)	7.4	-5.1	23.3	10.8	2.5	-10.0

4/ Potential for Delay at Mooring as Next Tow	**Lock 21**		**Lock 24**		**Min Head (1 min Fill**	
Approaches & 1st Tow finishes remake & exits	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**
Second Tow to Lock and Ready to Approach Remake	83.3	95.9	100.3	107.8	79.7	97.2
Complete 1st Lockage & Remake at Mooring	62.5	70	64.4	71.9	62.5	70
Total Available Time (Neg indicates Delay)	20.8	25.9	35.9	35.9	17.2	27.2

5/ Total Change in Lockage Time for the	**Lock 21**		**Lock 24**		**Min Head (1 min Fill**	
Locking Tow Compared to Existing Conditions	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**	**0.5 mile**	**1 mile**
Complete 1st Lockage & Remake at Mooring	62.5	70	64.4	71.9	62.5	70
Existing Time Assuming SB Extract Cuts	48	48	55.9	55.9	45.5	45.5
Sub Total	14.5	22	8.5	16	17	24.5
Minus Additional Distance Traveled	7.5	15	7.5	15	7.5	15
Total Change in Time (+ means new process is slower)	7	7	1	1	9.5	9.5

6/ Analysis of Change in Time for Locking Tow						
Total Lockage Time - Not Including Approach	**Lock 21**		**Lock 24**		**Lock (Min)**	
With Switchboat & Remote	88	95.5	95.1	102.6	88.2	95.7
Existing with Tow Haulage	80.7	80.7	92.9	92.9	78	78
Sub Total	7.3	14.8	2.2	9.7	10.2	17.7
Minus Additional Distance Traveled	7.5	15	7.5	15	7.5	15
Total Change in Time (+ means new process is slower)	-0.2	-0.2	-5.3	-5.3	2.7	2.7

3) Next, the analysis looked at the operations required of the switchboat and whether or not it would be able to finish with one tow at the remote facility and return in time to extract the first cut of the next tow. The analysis demonstrates that at lock sites with remakes located roughly 1 mile from the locks and during times of minimum chambering times there is a potential for delay. It also demonstrates that even with modest variability the small margin at Lock 21 indicates that it will often be necessary to move the tow from the lower pool up to assist in extracting cuts. The fact that in many cases both assist boats would need to move to the same side of the lock to alternate pulling cuts greatly complicates operations. This also increases the likelihood of inefficiencies and delay.

4) A key concern of the analysis was to identify whether or not there is likely to be a delay for the next tow at the remote facility. This was an area of concern, that the delays would simply be transferred from the lock facility to the remake area. This analysis indicates that this should not be a regular problem for upbound tows. There appears to be 15 to 35 minutes of time available after the previous tow has completed its lockage. While this does provide an indication that there are not likely to be regular delays, at times of low elevation differences or at locks with fast filling and emptying times there may be occasional delays at the remote mooring.

5) This analysis compares the overall total lockage time required for a specific tow if it uses the remote remake versus the existing guidewall with just switchboat assistance on extracting the cut. This evaluation revealed that while not much different at locks with faster filling and emptying times and during periods of small elevation differences, the actual tow using remote remake will require more time (5 to 10 minutes) than if it just remade at the lock site.

6) The final analysis is similar to the previous one. However, rather than just looking at the lock process times following the extraction of the first cut, this analysis looks at changes in the total lockage time. It also compares the new time with switchboats and remote remake versus the existing lock extraction time using the slower cable winch system instead of switchboat assisted extractions. This evaluation revealed that in general the entire process will still save the tow a little time. This is essentially due to the fact that the faster extraction of the first cut compensates for the additional time associated with approaching the remote remake area.

General conclusion is that the operations should work as a way to reduce times without significantly reducing the benefits identified for faster extraction and remote remake. However, there are potentially significant limitations to this analysis and the overall benefits. These numbers represent means and as a result there are likely to be some considerable variations over time and from lockage to lockage. This new process involves more steps, risks, and variables than current operations. There is a high likelihood of some delay time periods occurring due to a given tow or group of tows taking longer on one or a number of steps. This could periodically significantly reduce the overall benefits.

Reducing Chamber Emptying Times. Typically, the rate of emptying the chamber is slowed when an unpowered cut is waiting in the downstream approach for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is removed and taken to a mooring facility for remaking. Figure 4-5 shows the location of the discharge ports relative to a first cut located along the existing wall or at a remote mooring.

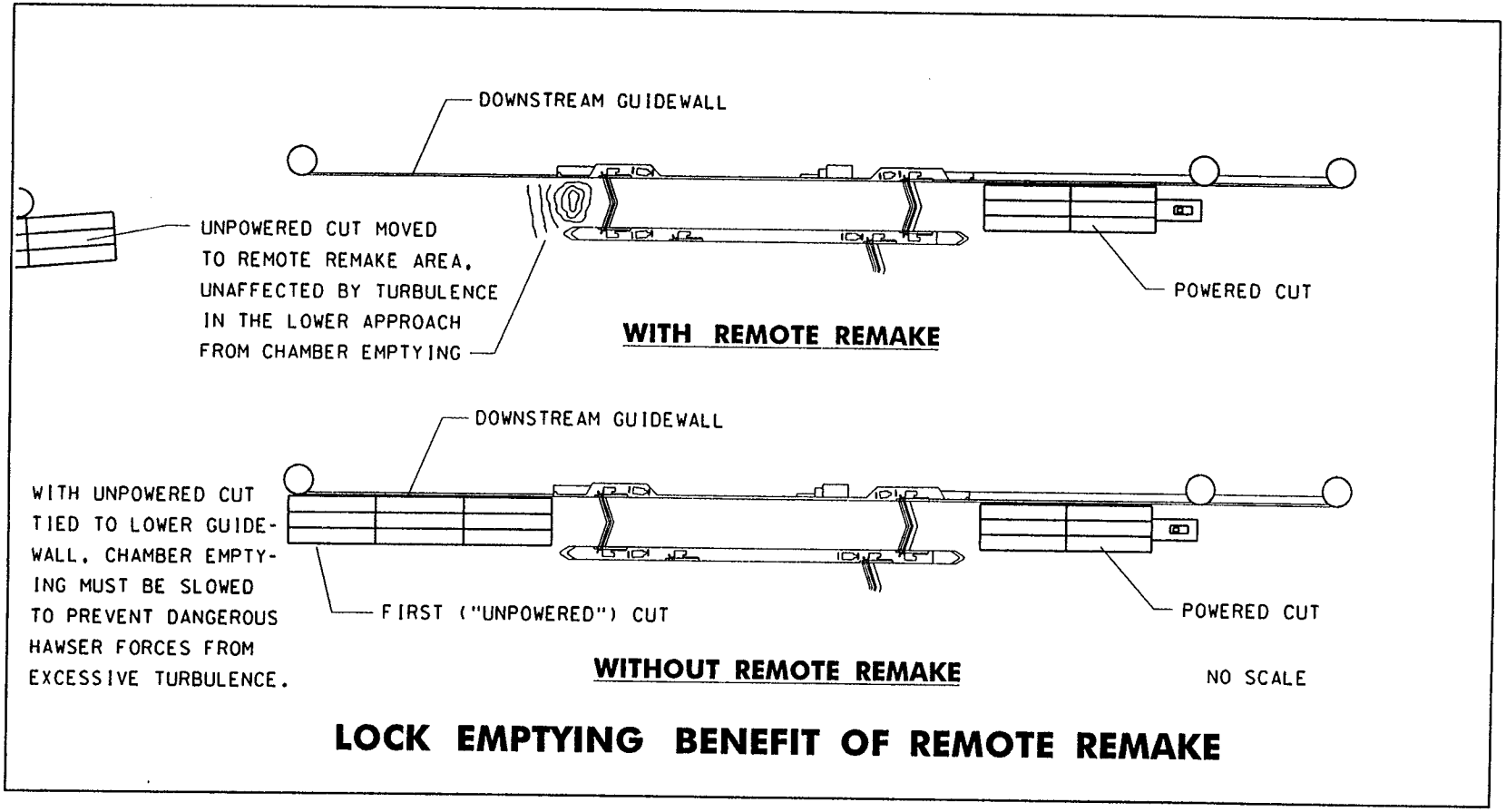


FIGURE 4-5: Lock Emptying Benefit of Remote Remake

The Peat, Marwick, Mitchell & Co. (1975) report showed a savings of 4 minutes; however, the actual time savings is highly dependent on the head difference and location of discharge. The former Lock 26 had a greater difference in water level elevations (approximately 20 feet) between its upper and lower pools than most locks on the UMRS. As a result, at most UMR locks, which typically have smaller water level differences of 10 feet or less, smaller time savings are likely. Using LPMS 1990 data, the potential for faster chambering times was calculated by comparing the chambering time for the first and last cuts of double lockages. This analysis showed that for the UMR sites, limited time savings of 0 to 2 minutes are all that is possible on average. Time savings estimates for each lock are shown in Table 4-7. At lower flows, when head differences are the greatest, slightly higher time savings are possible. At higher flows, there would be little or no savings. Somewhat higher savings of 1 to 7 minutes are anticipated for the Upper IWW locks where the difference in water level elevations is greater.

Total Time Savings. As the following table indicates, a variety of time savings appears possible with the use of a switchboat and remote remake areas at UMR locks. Similar time savings are possible at IWW sites. In total, it appears possible to reduce lock utilization times by 20 to 30 minutes. The use of switchboats at the former Lock and Dam 26 site to extract unpowered cuts and move them to mooring facilities away from the lock approach for remaking was summarized by Peat, Marwick, Mitchell & Co. in a 1975 report. Their analysis showed a time savings of 29 minutes for double lockage tows, reducing the overall lockage time from 125 to 96 minutes. This total time reduction applies only to the waiting tows since the particular tow being locked through must still remake at the mooring facility before proceeding. The switchboat measure provided the greatest time savings of the three measures they tested, including extended guidewalls and industry choice (which involved the use of helper boats and improved scheduling).

The numbers in Table 4-9 summarize the expected average time savings based on the analysis of LPMS data. The time savings estimates are very similar to the former Lock 26 timing study. The 22- and 27-minute estimates for doubles do not include potential approach time savings, but they do include the remake time savings possible for all types of doubles. The actual time savings for a queue depends on the lockage types, number of tows requiring double lockages, how the extraction is handled, number of switchboats, and whether they are assisting with approaches.

TABLE 4-9: ESTIMATED SAVINGS FOR SWITCHBOAT USE WITH REMOTE REMAKE AREAS AT UMR LOCKS 11-25

Delay Reduction	Double Lockages Benefits to Tows Waiting in Queue	Double Lockages Benefits to the Locking Tow
Pulling the unpowered cut	7 min. upbound 9 min. downbound	7 min. upbound 9 min. downbound
Remaking the tow (applies to both turnback and exchange lockages)	15 min. upbound 18 min. downbound	Tow still remakes, location is moved to end of the guidewall
Reduced chambering time	0-2 min. downbound	0-2 min. downbound
Additional time required to approach and align with cut at remote site	NA [2]	Delay 5 min. upbound Delay 5 min. downbound
Total time savings potential [1]	22 min. upbound * 27 min. downbound *	2 min. upbound 4 min. downbound

[1] Total does not include approach assistance, but assumes 300-ft upstream guidewall extension and remote mooring.
[2] The additional time to approach and align at the remote site does not impact other waiting tows.

While the tows waiting in queue generally can benefit from the full 22- to 27-minute reduction in lockage time, the actual tow being assisted is likely to require more time to use the lock and remake area than before. Estimates show that an upbound tow is likely to spend from 5 to 25 minutes more in the lockage process than it would currently. This is primarily due to the

additional time required to move both cuts to a remote site, approach the mooring, face up, and then remake. Downbound tows, which are not required to turn around, will have more limited increases in overall processing time at the locks and remake area, on the order of 0 to 20 minutes. However, since some of this additional time (roughly 7.5 to 15 minutes) is associated with moving to the mooring, which also moves the tow closer to its eventual destination, only the additional approach and maneuvering time represents an added inefficiency. This results in a more limited additional time of 0-10 minutes, depending on lock cycle times and distance to the moorings.

Conditions Affecting Implementation. A key requirement for the implementation of switchboats is the existence of moorings located out of the approach path. During the test at the former Lock 26 site, two 152-foot rock barges were used for remaking tows above the lock and five timber piles were placed approximately one-half mile downstream. Most tow pilots considered this length of just over 300 feet to be inadequate. As part of the expert elicitation, the participants were asked to estimate the minimum length required for remaking a tow on a landside mooring or riverside mooring. The elicitation responses were similar for the two locations—approximately 700 feet. After tabulating the responses, further discussion indicated that any length 600 feet or greater would be acceptable.

As part of the expert elicitation meeting, participants also addressed feasible mooring locations and horsepower requirements. The available remake sites vary by lock locations. As part of the 1975 switchboat test, the cuts had to be backed upstream 1½ miles or the switchboat had to turn the barges around and push them upstream. Downbound tows were taken approximately ½ mile below the lock to five timber pile clumps. The upstream mooring was located on the Illinois bank, the same side as the lock, while the downstream mooring was more towards the Missouri side in the tailwater of the dam. An observation coming out of the test was that, if possible, the downstream mooring should be placed to minimize the need for tows to cross the river and align in the tailwater of the dam.

As discussed in Section 3, remote remake areas were identified for most lock locations. However, at most locks on the IWW, the combination of a narrower channel and greater numbers of other structures around the locks reduces the potential remake areas. If remote remake sites can not be identified for a particular lock, guidewall extensions could be considered. However, the benefits would be reduced for exchange lockages, since remake savings with guidewall extensions only benefit turnback lockages.

As part of the expert elicitation, participants were asked to provide input on their willingness to use a riverside mooring above and below the lock using either a switchboat or industry boat under self help. The general results showed similar responses between willingness to use either type of boat. However, there were significantly more reservations about using upstream moorings on either the riverside or landside. The towboat captains and lockmasters cautioned that high flow conditions would prohibit the backing of cuts upstream away from most UMR locks if only a 1,200-horsepower boat were available. However, if a larger 2,000-horsepower switchboat were available, the experts felt that cuts could be pulled (backed) upstream 70 to 80 percent of the time at most locks. Downstream exits, which occur below the dam and without significant outdraft, involve less risk, and participants felt that a 1,200-horsepower switchboat would be able to pull cuts under all conditions when the system is open to navigation.

The Section 3 summary includes estimates from most lockmasters on the horsepower requirements at their locks. A towboat captain on some of the site visits stated that as a general rule towboats can push three times the load they can pull. Subsequent to the expert elicitation, additional concerns were expressed at the risk of backing cuts upstream and inadequate horsepower requirements. As a result of these concerns, the Coast Guard was consulted. Although specific horsepower requirements are not available for tows, the Coast Guard uses the general rule that tows should have 250 horsepower per loaded barge during extreme high flows. This results in the need for approximately a 2,250-horsepower boat to push nine loaded barges

upstream to a remote remake site under all flow conditions. Tows in this size category were selected for the analysis to provide an adequate margin of safety.

The use of remote remake areas, especially above the lock, increases risk, adds additional steps, and presents some safety concerns. More maneuvering and handling of barges is required. For example, if the switchboat turns the barges around to push upstream, the barges would need turning again before being placed along the mooring. This is a high risk activity. During the Lock 26 test, these actions which increase maneuvering above the dam did not result in any problems, but the increased handling of the barges upstream of the dam increases the chance of an accident and potential for damage to private property or the government facility.

Nearly all of these issues and concerns highlight the need to avoid backing cuts upstream on a regular basis if at possible. To reduce these high risk operations, the upstream guidewall would be extended 300 feet in order to provide enough room for the switchboat to extract the cut, tie it off, and then move around behind the cut to push it upstream. However, even this process adds steps and only reduces the potential for something to go wrong.

In addition, the pattern of flow and position of moorings affects the ability to use this measure. The increased numbers of operations required by remote remake (at least two additional approaches) also increase variability and the risks that the full time savings will not be achieved.

Costs. Implementing a switchboat measure involves three primary costs: switchboats, 300-foot upstream guidewall extensions, and moorings.

Vessel Cost: The cost of new switchboats varies from approximately $2.0 to $2.4 million depending on the type, size, horsepower, and features of the boat. Estimated implementation costs are summarized below. Two switchboats would be required to provide maximum benefits, except at sites with an auxiliary lock, which would allow one switchboat to service tows traveling in either direction.

As mentioned under the previous measure, switchboats could be provided by the Corps, privately owned and contracted by the government, or made available under the current arrangement where harbor services provide the boats and private towing companies pay on a per-assistance basis for a flat fee or hourly charge.

The switchboat costs shown below are from the U.S. Army Corps of Engineers *FY97 Planning Guidance, Shallow Draft Vessel Costs*, based on late 1996 price levels. These costs are intended to provide a general guide, but actual costs will vary. A factor of 13.5 percent was added for profit since the guidance only includes operating costs. The yearly cost was estimated by multiplying the daily cost by 270 days which is the approximate length of the navigation season. The St. Louis District of the Corps of Engineers incurred a cost of $150 per hour during 1995 when a 1,500-horsepower switchboat was provided at government expense to pull cuts. However, at sites with full implementation of switchboats, the existing use of helper boats could be eliminated, thereby reducing the incremental cost to implement the measure.

TABLE 4-10A: DAILY COST TO OPERATE A SWITCHBOAT		
Cost	**1800-2000 hp**	**2200-2400 hp**
Capital Costs (cost recovery - 7.75% over 20 yrs)	$ 560	$ 680
Operating Costs		
• Crew of 4-6	1,290	1,420
• Boat Costs (Maintenance, Supplies, Insurance, Taxes)	645	715
• Administration	240	265
• Fuel Cost (Average Power)	950	1,250
• Profit (13.5%)	495	585
Total Daily Costs	$ 4,180	$ 4,915
Total Yearly Costs (Daily Cost * 270 days)	$1,128,600	$1,327,100
Hourly Costs (Daily Costs/24 hrs)	$ 174	$ 205

Note: Fuel cost is $500 - $600 higher per day if under high power most of the time.
Source: FY97 Planning Guidance, Shallow Draft Vessel Costs.

Remote Mooring and Guidewall Extension Costs: Some significant additional cost would be associated with providing mooring facilities and guidewall extensions.

Based on the results of the elicitation, 600 to 700 feet of flat surface would be required per mooring. The recommended option would be the use of a combination of permanent sheet pile mooring cells and spud barges, as shown in Figure 4-4. A spud barge is a flat deck barge with four spuds or pilings that can be driven into the river bottom to anchor the barge in place. Using a spud barge size of 195 feet long, 35 feet wide, by 10 feet deep, each mooring would require four spud barges. The cells would provide a pivot point for tows landing and maneuvering at the remake area, offer some protection for the spud barges, and assist in locating the exact mooring location following winter storage of the barges. The cost per mooring would include the estimated cost of $700,000 per barge times the three barges that would be required, and an estimated cost of $400,000 per cell, including $60,000 for placement costs. Most sites in the study area would require the placement of a remote remake area both above and below the lock, doubling the overall cost.

There is a potential that some spud barges would be available on a temporary basis from government surplus, similar to the DeLong Piers used in the 1970s at old Lock 26. In either case, it can be expected that a cost of approximately $40,000 per barge per year would be required to maintain, repair, and move the barges. Major rehabilitation of the barges, including residing and replacing bracing, would be required approximately every 5 years at a cost of $200,000 per barge (see Table 4-10B). Although not included in the cost estimates, some form of lighting at the remake area may also be required to provide adequate safety and efficiency during night lockages.

TABLE 4-10B: COST OF REMOTE MOORINGS USING MOORING CELLS AND SPUD BARGES

First Cost	Cost
- First Cost of 2 Mooring Cells	$800,000
- First Cost of 3-200' Spud Barges ($700,000/barge)	$2,100,000
- Placement (1 week per wall at crew cost of $12,000 per day)	$60,000
Subtotal First Cost for Cell, 3 Piers, and Placement	$2,960,000
- Contingency 25%	740,000
Total First Cost of Mooring 2 Cells & 4 Spud Barges	$3,700,000
Annual Cost and Periodic Maintenance	Cost
- Annual O&M Cells ($20,000 per cell)	$40,000
- Annual O&M Spud Barges ($40k per barge)	$120,000
- Rehab Barges every 5 years (includes dry docking at $200k/barge)	$600,000
- Useful Life of Cells	30 years
- Useful Life of Spud Barges	20 years

In addition, the costs for extending the upstream guidewall an additional 300 feet are also included. Table 4-10C shows the costs using pier/barges. However, significant concerns have been raised with this type of wall, and a permanent guidewall extension is also under consideration. At some sites, additional costs would be required to excavate an adequate width to allow the barges to fit and to cover the additional cost of placing the spuds at rock founded sites. These costs would be approximately one-half those discussed under the 600-foot guidewall extensions associated with the previous measure. The costs for permanent 300-foot guidewall extensions were estimated at approximately one-half the cost of the 600-foot extension discussed previously. This results in an estimated average first cost of $11,725,000 and annual maintenance of $20,000 at UMR sites. This would again include the extension of the unpowered kevel. As mentioned previously, costs for impacts to navigation at IWW locks are anticipated to be on the order of $30 to $40 million per lock for a permanent 300-foot upstream guidewall extension.

TABLE 4-10C: COST OF 300-FOOT GUIDEWALL EXTENSION USING A MOORING CELL AND DE LONG PIERS/SPUD BARGES

First Cost	Cost
- First Cost of Piers - (2-150' Piers at $600,000 each)	$1,200,000
- Placement (1 week per wall at crew cost of $12,000 per day)	$60,000
- First Cost of a Protection Cell (30' diameter)	$400,000
Subtotal First Cost for Cell, 3 Piers, and Placement	$1,660,000
- Contingency 25%	415,000
Subtotal First Cost for Cell, 3 Piers, and Placement	$2,075,000
Annual Cost and Periodic Maintenance	Cost
- Annual O&M ($30,000 per pier)	$60,000
- Rehab Piers Every 5 Years (includes dry docking at $150k/barge)	$300,000
- Useful Life - Piers/Barges	20 years
- Annual O&M Cell	$20,000
- Useful Life - Cell	30 years

Relationship to Other Measures. The use of switchboats adds additional savings when combined with most measures. In particular, remote mooring facilities or extended guidewalls for remaking cuts out of the chamber are required for efficient use of switchboats to extract cuts. Scheduling both commercial and recreational vessels also assists in maximizing the benefits of switchboats.

In situations where switchboats are available, they fill the same role in most instances as tow haulage equipment and industry self-help policy. While these measures are not mutually

exclusive, a number of the benefits overlap, and the benefits of using an additional measure when others are in place are reduced. If switchboats remove the unpowered cuts to mooring facilities away from the locks for remaking, then the benefits of crew element improvements are reduced, since the recoupling would be done away from the lock while other tows are able to use the lock facility.

Conclusion. Switchboats in combination with remote mooring facilities provide time savings greater than those provided by industry self help and allow for remake assistance of exchange lockages with which switchboats with just guidewall extensions can not assist. However, this measure includes more operations and variability than using switchboats with guidewall extensions.

- **Industry Self Help**

Description of Measure. Industry self help relies on the towing industry to extract unpowered cuts without the assistance of lock personnel or equipment. In most cases, the line haul tows used have 2,500 to 6,000 horsepower, substantially larger, more powerful, and less maneuverable than either helper boats or switchboats. When self help is implemented, a waiting tow will tie off its barges and begin assisting other tows. This assisting boat acts as a switchboat by removing the unpowered cut from the lock and pulling it either along the guidewall or to a remote mooring. Under the existing procedure, a tow waiting to lock in the opposite direction is often used as a mooring. The powered cut is then able to simply lock through and proceed away from the chamber to the remake area. One advantage of a self-help policy is that, with little or no additional investment, it can serve as a temporary measure and be implemented as needed.

Implementing self help can require significant coordination and cooperation among the various towboat companies. A general self-help policy approach has been developed in coordination with industry for Locks 20 to 25 on the UMR and Peoria and La Grange Locks on the IWW. The general approach has been to go to a self-help situation only when enough tows are present to operate under the 3-up/3-down policy, typically four or five tows. However, in practice lockmasters stated that they normally are operating 6-up/6-down, with 10-12 tows in queue prior to implementing self help. If delays continue and increase, the Chairmen of RIAC (River Industry Action Committee) are notified to assist in developing and implementing a more productive self-help policy. This direct involvement of industry allows for increased coordination and a large amount of flexibility to address location and queue-specific issues.

Some use of this measure will likely continue into the future regardless of any actions taken by the Navigation Study. However, as part of adapting this measure for use as a standard procedure, various facilities could be provided to improve efficiency, safety, and reduce environmental impacts. Specifically providing 600-foot guidewall extensions would allow tows to safely remake at the lock site and eliminate the need for tows to regularly back cuts to remake areas. In addition, mooring cells could be added to the site to provide moorings for assisting tows to tie off their cuts to, as well as two cells for a waiting tow to tie off to when serving as the remote remake facility. This results in three potential ways to implement self help: without additional facilities, with remote moorings, and with guidewall extensions.

Description of Current Procedure. Actual implementation of self help relies on the presence of an adequate queue, favorable river conditions, and economic incentives. The following paragraphs and Figures 4-6A and B are provided to assist in visualizing the self-help procedure. Tows are numbered in the order of arrival with the #1 tow being closest to the lock. While considerable variability exists between sites, in general, waiting industry towboats remove the unpowered cuts from the lock and take them to the checkpost on the guidewall or an area away from the guidewall (i.e., a mooring facility or along side the #1 tow waiting to go the other

direction) for remaking similar to switchboats. For example, a downbound tow will remake along the #1 upbound tow if another suitable location is not available. Either the #2 or #3 upbound boat will pull cuts while the other one holds the other's barges. The crew of the #1 upbound tow should assist the downbound tow in remaking its couplings. This procedure and the reverse for upbound tows are preferred to maximize time savings. A diagram showing the general operation is shown on Figures 4-6A and B.

However, due to site conditions, not all cuts can easily be taken to reconfigure along the #1 tow or an adjacent mooring facility. In these instances, the assisting tow pulls the unpowered cut to the last pin on the guidewall (many of the southbound vessels on the UMR must operate this way). The boat pulling the cuts should then stand by until its crew has helped remake the coupling and it has assisted these tows away from the lock. In most instances (even where the #1 tow is being used for remaking), the last tow of the 3-up or 3-down series should be left along the wall to remake its couplings so the #1 tow can prepare to approach the lock. The other option is to take the last tow of the series down beyond the first tow and remake along the #2 waiting tow or other mooring area. The policy established for Locks 20-25, Peoria and La Grange, is provided in Appendix B.

In cases where large numbers of tows (six or more) are waiting to travel in one direction, additional measures will be taken in coordination with RIAC. These steps will minimize the number of tows reconfiguring in the chamber. Flexibility is a very important part of the current practice. The exact implementation needs to be able to account for the type of congestion (primarily downbound or upbound tows), river conditions (water level, outdraft, etc.), and factors associated with the particular river reach (availability of mooring facilities). In addition, varying river conditions at each site affect how the program will be implemented and its level of success.

Delay Reductions Methodology/Time Savings Estimates. Self help primarily provides assistance in reducing lockage times for double lockage tows. If the barges are moved from the lock facility for remaking, the following lockage elements can be reduced: (1) pulling the first cut, (2) remaking of double lockages, and (3) reducing chamber filling and emptying times. If the towboats assist with lock approaches, like helper boats, they can also reduce delays associated with approach times. However, line haul boats are less maneuverable and efficient in providing approach assistance and do not typically provide this type of assistance.

Five sources of data were evaluated to provide information on the potential time savings available for implementing switchboats. These sources include timing data from the 1975 Peat, Marwick, and Mitchell & Co. report entitled, *Evaluation of Operational Improvements at Locks and Dam No. 26, Mississippi River*; 1995 timing data from Mel Price Lock; 1990 LPMS data; responses from the February 4-5, 1997, Expert Elicitation meeting with navigation industry; and interviews, site visits, and panel discussions with lockmasters and navigation industry. This section reports the results of these efforts and summarizes the average time savings for UMR Locks 11-25 and IWW locks from Lockport to La Grange.

Pulling First Cut of Double Lockages. As part of self help, industry tows pull cuts from the lock chamber. They typically are able to extract cuts somewhat faster than the existing tow haulage and take the unpowered cut along the guidewall or remove the unpowered cut to a remote site. However, initial site visits and discussions with lockmasters revealed that due to the larger lines and reduced maneuverability of line haul boats, smaller time savings are anticipated from using line haul boats in comparison to switchboats.

As a result of limited data, the advice of experts was used to obtain information on the time savings potential of using industry boats under the self-help policy to pull cuts. The expert elicitation process provided an expected time savings of 3 minutes on upbound and 4 minutes on downbound lockages with a range of 1 to 6 minutes and 0 to 7 minutes, respectively.

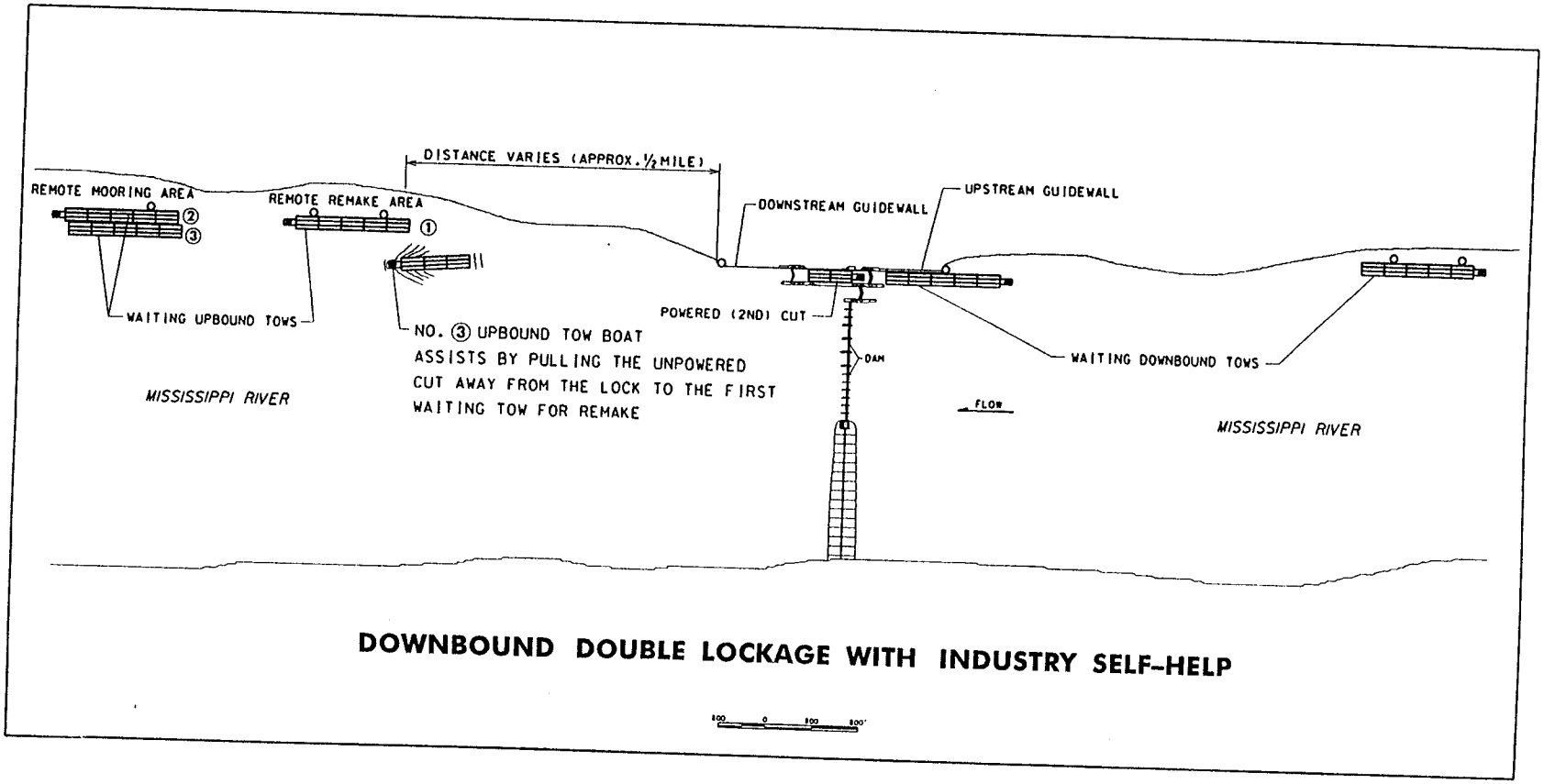
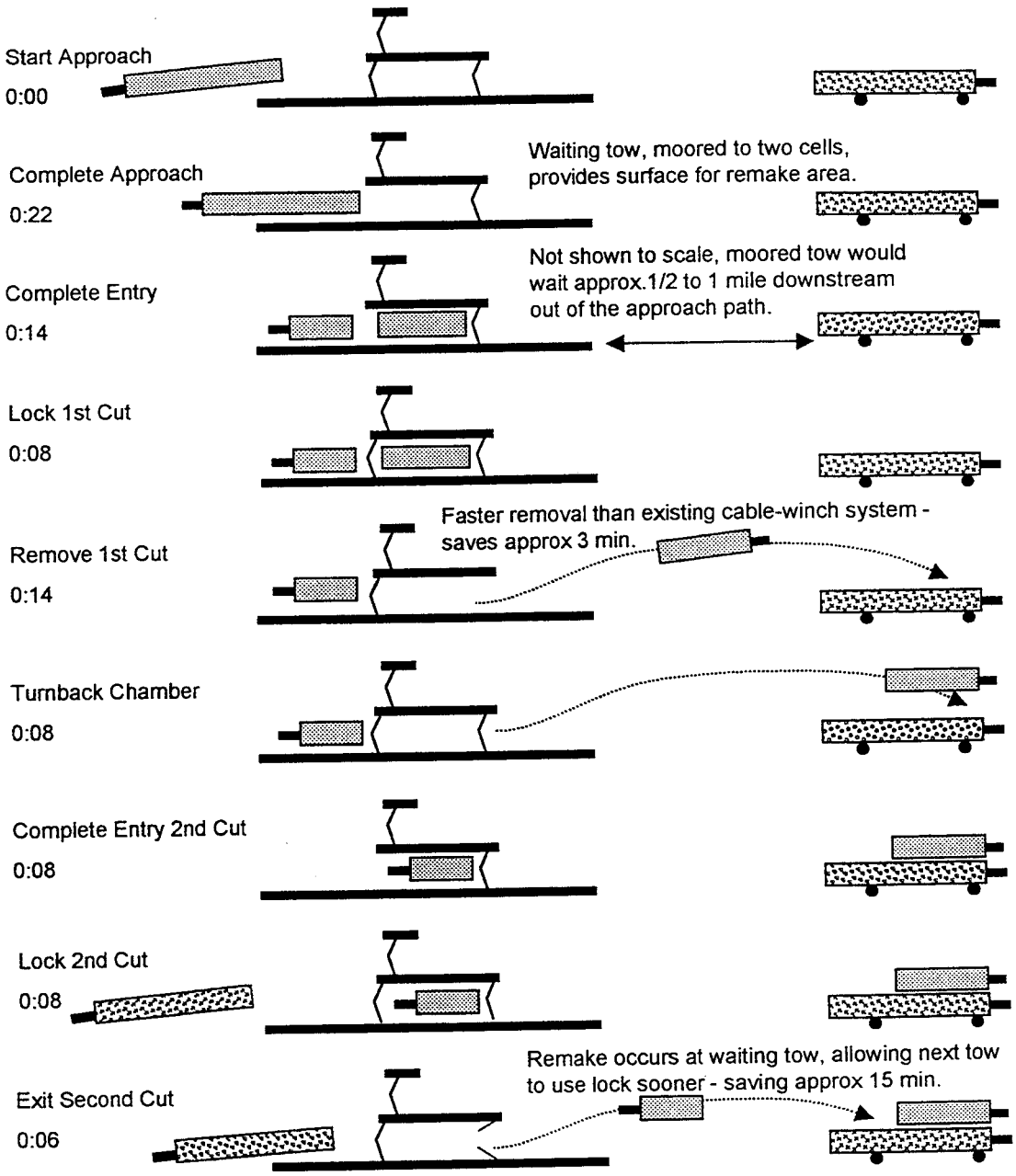


FIGURE 4-6A: Downbound Double Lockage with Industry Self Help



Total Lockage Time: 1:28 (at lock) 2:01 (remade tow exits remake area)

Savings approx. 15-20 min at lock, while individual tow requires additional 5 min.

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

FIGURE 4-6B: Double Lockage Elements - Industry Self Help with Mooring Cells

As with the switchboat analysis, the study team used data from the LPMS to estimate the time savings of using an industry boat to extract the unpowered cut of a double lockage at each site. This was done by comparing the existing time at UMR Locks 11-25 to extract the unpowered cut of double lockages with the existing tow haulage, 14 minutes upbound and 17 minutes downbound, and the exit time of a powered single cut, 5 to 6 minutes for upbound and downbound, respectively. As part of the elicitation, a former tow captain stated that using a line haul boat would require 6 to 8 minutes longer than a single exit. Further group discussion at the elicitation meeting lead to a general consensus that 6 minutes would provide a relatively accurate adjustment factor. Later discussions with UMR lockmasters lead to the recommendation that a factor of 8 minutes should be used instead. However, IWW lockmasters felt that the 6-minute factor was adequate due to better site conditions and increased numbers of smaller, more maneuverable tows. This longer coupling contrasts with a helper boat or switchboat that can make their couplings in approximately 2 minutes. The key differences are the size and number of the lines and reduced maneuverability of the larger boats. As a result, an additional 8 minutes for UMR locks and 6 minutes for IWW locks was included to allow for the boat to make its coupling. The distributional characteristics of the single lockage data are assumed to hold for the self-help extractions.

Time Savings	=	Existing Extraction with Tow Haulage	-	(Exit of Single + 6 or 8 min. to make couplings)

The result was an estimated time savings of 1 and 3 minutes for upbound and downbound, respectively. These results are in general agreement with the overall estimate provided by the elicitation process and lockmaster panel. Similar time savings are expected for the IWW locks of 1 to 2 minutes. With the longer recoupling time, there is an increased likelihood that on occasion the extraction may actually take longer than using the existing tow haulage. The estimated time savings vary from site to site and have been included in Table 4-11.

Remaking of Double Lockage Tows. As discussed in the Helper Boat and Switchboat sections, pulling unpowered cuts far enough from the chamber that the powered cut can exit the lock for remaking and free the lock to service the next tow produces significant time savings. Line haul boats, like switchboats, can pull cuts to remote moorings. However, due to safety concerns with backing upstream, self help could be used to pull cuts along an extended upstream guidewall. If this approach is taken, it reduces the time savings to just turnback lockages where the next tow is moving in the same direction. Downbound tows would be remade along a waiting tow clear of the approach path. This allows both exchange and turnback lockages to benefit since remake occurs clear of the lock chamber, guidewall, and approach path.

The *Improved Tow Haulage Equipment* report prepared by Sverdrup as part of the UMR-IWW System Navigation study estimated remake time savings at approximately 15 minutes for lower UMR locks (Locks 20-25) and 19 minutes at La Grange Lock on the IWW. In estimating these time savings, Sverdrup used OMNI data (similar to LPMS data, but with an additional time element) from all double lockages occurring in 1992 at these sites. The time for the exit of the second cut until the remade tow removed its headline and begins leaving the lock was analyzed. In order to isolate the remake time, 2 minutes was subtracted from the total time to account for the tow facing up to the cut (a movement of approximately 50 feet). The values are also similar to those provided by Louis Berger & Associates (1981) who estimated 13.5 minutes for recoupling.

TABLE 4-11: PERFORMANCE OF INDUSTRY SELP HELP

LockSite		Annual Cost: boat, wall, site prep (Millions)	EXTRACTING THE FIRST CUT OF A DOUBLE LOCKAGE (MIN.)									EXIT OF THE SECOND CUT OF DOUBLE LOCKAGES (MIN.)										
			Current Time to Extract 1st Cut w/ Tow Haulage				New Time to Extract Cut w/ Self Help (Single Exit + 8 min UMR) (Single Exit + 6 min IWW)				Time Savings Extract Cut	Current Time for Exit of 2nd Cut of Double Lockage				New Time for Exit of 2nd Cut with Remote Remake (Exit of Single)				Time Savings Remake Double	Reduced Chamber Time	Total Time Savings
			Min	Max	St Dev	Avg	Min+8	Max+8	St Dev	Avg+8		Min	Max	St Dev	Avg	Min	Max	St Dev	Avg			
11	US	$ 2.004	6.0	32.0	4.4	16.1	9.0	19.0	2.3	13.8	2.3	6.0	40.0	6.2	19.9	1.0	11.0	2.3	5.8	14.1		16.4
	DS	$ 1.344	8.0	49.0	4.5	17.5	10.0	26.0	2.8	14.6	2.9	4.0	45.0	6.7	20.9	2.0	18.0	2.8	6.6	14.3	- 0.1	17.2
12	US	$ 2.389	1.0	30.0	3.8	12.2	9.0	19.0	1.9	12.8	-0.6	4.0	35.0	5.4	17.7	1.0	11.0	1.9	4.8	12.9		12.3
	DS	$ 1.327	5.0	33.0	3.7	16.0	10.0	23.0	2.9	13.9	2.1	4.0	61.0	7.3	22.1	2.0	15.0	2.9	5.9	16.2	- 0.1	18.2
13	US	$ 2.052	1.0	45.0	4.6	13.1	10.0	28.0	2.8	13.3	-0.2	3.0	47.0	7.4	18.8	2.0	20.0	2.8	5.3	13.5		13.3
	DS	$ 1.346	1.0	51.0	4.3	15.6	9.0	19.0	1.7	13.0	2.6	3.0	44.0	7.3	22.1	1.0	11.0	1.7	5.0	17.1	0.1	19.8
14	US	$ 2.006	2.0	73.0	4.3	14.2	10.0	21.0	2.1	13.2	1.0	5.0	46.0	7.4	22.4	2.0	13.0	2.1	5.2	17.2		18.2
	DS	$ 1.202	4.0	67.0	4.1	15.1	10.0	25.0	2.8	14.1	1.0	7.0	92.0	8.3	25.1	2.0	17.0	2.8	6.1	19.0	- 0.1	19.9
15	US	$ 2.105	5.0	36.0	4.3	14.6	11.0	23.0	2.2	14.4	0.2	5.0	46.0	5.8	20.7	3.0	15.0	2.2	6.4	14.3		14.5
	DS	$ 0.948	2.0	27.0	2.6	12.9	12.0	21.0	2.2	15.6	-2.7	8.0	61.0	7.3	27.2	4.0	13.0	2.2	7.6	19.6	2.4	19.3
16	US	$ 1.949	4.0	53.0	4.9	14.4	10.0	21.0	2.4	13.4	1.0	4.0	56.0	7.4	19.4	2.0	13.0	2.4	5.4	14.0		15.0
	DS	$ 1.318	2.0	35.0	5.1	16.0	9.0	19.0	2.4	13.2	2.8	5.0	48.0	6.5	22.0	1.0	11.0	2.4	5.2	16.8	- 0.4	19.2
17	US	$ 2.115	5.0	51.0	5.1	15.1	9.0	20.0	2.5	14.2	0.9	4.0	52.0	6.3	20.2	1.0	12.0	2.5	6.2	14.0		14.9
	DS	$ 1.612	2.0	54.0	4.7	19.5	11.0	21.0	2.3	14.0	5.5	6.0	48.0	6.4	22.8	3.0	13.0	2.3	6.0	16.8	0.0	22.3
18	US	$ 2.011	4.0	59.0	4.9	14.3	10.0	23.0	2.9	14.1	0.2	4.0	55.0	6.6	20.7	2.0	15.0	2.9	6.1	14.6		14.8
	DS	$ 1.360	4.0	39.0	4.2	17.4	9.0	21.0	2.3	13.3	4.1	6.0	96.0	7.7	23.0	1.0	13.0	2.3	5.3	17.7	- 0.3	21.6
19	US										NA									NA		0.0
	DS										NA									NA		0.0
20	US	$ 2.073	2.0	42.0	5.1	14.4	9.0	24.0	2.9	12.6	1.8	3.0	55.0	8.0	19.9	1.0	16.0	2.9	4.6	15.3		17.1
	DS	$ 1.186	1.0	56.0	5.1	16.9	9.0	21.0	2.5	12.8	4.1	5.0	61.0	7.3	24.3	1.0	13.0	2.5	4.8	19.5	0.4	24.0
21	US	$ 2.059	1.0	70.0	4.6	13.1	9.0	17.0	2.1	11.9	1.2	2.0	64.0	7.4	21.4	1.0	9.0	2.1	3.9	17.5		18.7
	DS	$ 1.391	4.0	56.0	4.8	16.8	9.0	17.0	1.6	11.7	5.1	6.0	90.0	8.4	23.6	1.0	9.0	1.6	3.7	19.9	0.1	25.1
22	US	$ 2.141	1.0	41.0	4.1	15.0	10.0	23.0	2.2	13.0	2.0	4.0	76.0	7.1	21.3	2.0	15.0	2.2	5.0	16.3		18.3
	DS	$ 1.283	5.0	97.0	4.9	18.2	10.0	22.0	2.8	13.8	4.4	5.0	98.0	7.2	24.0	2.0	14.0	2.8	5.8	18.2	0.5	23.1
24	US	$ 1.862	3.0	46.0	4.1	13.3	9.0	28.0	2.5	13.0	0.3	2.0	89.0	7.2	21.0	1.0	20.0	2.5	5.0	16.0		16.3
	DS	$ 1.167	1.0	42.0	4.1	20.4	11.0	30.0	3.0	14.3	6.1	2.0	62.0	6.7	22.8	3.0	22.0	3.0	6.3	16.5	1.6	24.2
25	US	$ 2.362	4.0	49.0	4.4	12.6	9.0	23.0	2.2	11.7	0.9	3.0	59.0	6.9	20.5	1.0	15.0	2.2	3.7	16.8		17.7
	DS	$ 1.438	5.0	80.0	5.0	18.1	9.0	35.0	3.3	12.4	5.7	2.0	162.0	9.6	22.5	1.0	27.0	3.3	4.4	18.1	1.1	24.9
MEL PRICE	US										NA									NA		0.0
	DS										NA									NA	NA	0.0
27	US										NA									NA		0.0
	DS										NA									NA	NA	0.0
LOCK-PORT	US	$.325 no wal	2.0	46.0	6.1	13.9	8.0	26.0	3.0	12.2	1.7	6.0	68.0	12.8	28.3	2.0	20.0	3.0	6.2	22.1		23.8
	DS	$.325 no wal	3.0	40.0	5.8	12.7	8.0	23.0	2.6	11.1	1.6	6.0	57.0	11.8	24.3	2.0	17.0	2.6	5.1	19.2	6.8	27.6
BRAN-DON	US	$ 5.815	8.0	53.0	5.2	15.5	7.0	30.0	3.4	12.3	3.2	5.0	49.0	9.0	25.4	1.0	24.0	3.4	6.3	19.1		22.3
	DS	$ 5.968	3.0	45.0	6.9	15.1	8.0	26.0	3.1	12.4	2.7	5.0	50.0	11.1	25.3	2.0	20.0	3.1	6.4	18.9	3.6	25.2
DRES-DEN	US	$ 5.709	3.0	31.0	3.8	13.6	8.0	16.0	1.7	11.7	1.9	2.0	47.0	8.9	25.7	2.0	10.0	1.7	5.7	20.0		21.9
	DS	$.325 no wal	3.0	30.0	4.3	11.8	8.0	16.0	1.8	11.1	0.7	2.0	109.0	13.7	25.5	2.0	10.0	1.8	5.1	20.4	1.8	22.9
MAR-SEILLES	US	$ 5.770	1.0	79.0	5.1	11.3	7.0	20.0	2.4	11.2	0.1	3.0	74.0	10.2	25.3	1.0	14.0	2.4	5.2	20.1		20.2
	DS	$ 5.862	1.0	52.0	4.5	10.3	8.0	36.0	4.4	12.3	-2.0	2.0	59.0	11.3	25.4	2.0	30.0	4.4	6.3	19.1	1.8	18.9
STARV-ED ROCK	US	$ 5.689	4.0	35.0	3.6	11.3	8.0	35.0	3.6	11.1	0.2	5.0	85.0	10.4	23.4	2.0	29.0	3.6	5.1	18.3		18.5
	DS	$ 5.781	4.0	35.0	4.3	11.6	8.0	16.0	1.8	11.0	0.6	2.0	68.0	10.7	23.6	2.0	10.0	1.8	5.0	18.6	1.5	20.7
PEO-RIA	US	$ 7.230	4.0	35.0	5.1	13.8	9.0	27.0	3.6	12.4	1.4	5.0	72.0	9.6	23.9	3.0	21.0	3.6	6.4	17.5		18.9
	DS	$ 7.281	5.0	44.0	5.7	14.5	8.0	18.0	2.2	11.7	2.8	3.0	64.0	11.4	27.2	2.0	12.0	2.2	5.7	21.5	-	24.3
LA GRANGE	US	$ 7.151	3.0	35.0	5.3	13.7	8.0	39.0	6.3	12.9	0.8	2.0	73.0	11.1	23.3	2.0	33.0	6.3	6.9	16.4		17.2
	DS	$ 7.180	3.0	75.0	6.2	15.6	8.0	18.0	2.4	11.6	4.0	3.0	85.0	13.5	26.8	2.0	12.0	2.4	5.6	21.2	-	25.2
Average	US	$ 2.087	3.0	48.2	4.5	14.0	9.5	22.2	2.4	13.2	0.8	3.8	55.4	6.9	20.3	1.5	14.2	2.4	5.2	15.1		16.0
UMR 11-25	DS	$ 1.302	3.4	52.8	4.4	17.0	9.8	23.1	2.5	13.6	3.4	4.8	74.5	7.4	23.3	1.8	15.1	2.5	5.6	17.7	0.4	21.4
Average	US	$ 6.227	3.6	44.9	4.9	13.3	7.9	27.6	3.4	12.0	1.3	4.0	66.9	10.3	25.0	1.9	21.6	3.4	6.0	19.1		20.4
Illinois	DS	$ 6.414	3.1	45.9	5.4	13.1	8.0	21.9	2.6	11.6	1.5	3.3	70.3	11.9	25.4	2.0	15.9	2.6	5.6	19.8	2.2	23.6

US = upstream, DS = downstream, NA = Not Applicable, NR = Not Recommended

* Costs shown are for permanent 600 ft upstream and downstream guidewall extensions using the federal discount rate of 7.125% and a 50 year project life.

The LPMS data were again analyzed using the same procedure as in the Helper Boat and Switchboat sections to estimate the potential time savings of moving remakes out of the chamber. In order to estimate the time savings, the actual exit times of the second cut of double lockages were used and compared with the exit times of singles. Once again, data from turnback lockages were used. Using the formula shown below and average 1990 LPMS data for Locks 11-25, time savings of 15 minutes for upbounds and 18 minutes for downbound tows were calculated. Time savings for the IWW were calculated to be approximately 19 minutes upbound and 20 minutes downbound.

Time Savings = Existing Exit time of 2nd Cut (including remake) - Exit of Single

At the expert elicitation, the panelists agreed with the assumption that the exit of a single can be used to approximate the exit of a powered cut if the first cut has been taken to a remote remake area or the end of an extended guidewall. Otherwise, if the cut were only pulled along a shorter guidewall, the second cut must exit slower and meet up with the unpowered cut just beyond the gates, and a factor of 1.5 times the exit of a single is used. This results in the time savings for UMR locks dropping to 13 and 15 minutes, respectively, for upbound and downbound tows.

Reducing Chamber Emptying Times on Downbound Cuts. Typically, the rate of emptying the chamber is reduced when an unpowered cut is waiting in the downstream approach for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is removed and taken to a mooring facility for remaking or sufficiently far down an extended guidewall. The 1975 Lock 26 study reported savings of 4 minutes. However, the actual savings varies based on differences in water level elevation between pools. The smaller elevations at most UMR locks would result in a potential time savings of just 0 to 2 minutes. Some of the upper IWW locks have greater elevation differences and have time savings in the range of 1 to 7 minutes. Time savings estimates for each lock were calculated as described in the "Switchboat" section and are shown in Table 4-11.

Total Time Savings. Tables 4-12A and B provide a general indication of the level of time savings associated with the use of industry self help at UMR locks. The IWW sites would have similar time savings. The primary difference between the use of industry line haul boats and switchboats is that generally line haul boats do not provide approach assistance and their larger lines reduce the savings associated with pulling the first cut. However, in total, it appears possible to reduce double lockage times by approximately 15 to 20 minutes. The actual time savings for a queue depends on the scheduling approach, number of tows requiring double lockages, where the tows remake, and the number and experience of the assisting boats.

While tows in queue can benefit from the entire time savings, the actual tow locking through may actually spend more time in the lockage process. This is similar to the times associated with using switchboats and remote remake discussed previously. The additional time required to approach a remote mooring is an additional time requirement, reducing any time savings gained by the faster extraction. Remake times from the perspective of the locking tow remain virtually the same regardless of the location.

TABLE 4-12A: ESTIMATED SAVINGS OF INDUSTRY SELF HELP WITH REMOTE MOORINGS AT UMR LOCKS 11-25		
Delay Reduction	**Double Lockages Benefits to Tows Waiting in Queue**	**Double Lockages Benefits to the Locking Tow**
Pulling the Unpowered Cut	1 min. upbound 3 min. downbound	1 min. upbound 3 min. downbound
Remaking the Tow (applies to both turnback and exchange lockages)	15 min. upbound 18 min. downbound	Tow still remakes, location is moved
Reduced Chambering Time	0-2 min. downbound	0-2 min. downbound
Additional Time Required to Approach and Align with Cut at Remote Site	NA*	Delay 5 min. upbound Delay 5 min. downbound
Total Time Savings Potential	16 min. upbound 21 min. downbound	-4 min. upbound -2 min. downbound
* The additional time to approach and align at the remote site does not impact other waiting tows.		

The time savings numbers shown in the above table apply to the use of industry self help with remote remake and are applicable to exchange and turnback lockage types. The following table looks at the savings potential of industry self help in combination with guidewall extensions. The key differences with a guidewall extension are that the benefits only apply to turnback lockages and there is no additional time required for the actual tow to complete its lockage, such as approaching an additional mooring.

TABLE 4-12B: ESTIMATED SAVINGS OF INDUSTRY SELF HELP WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25		
Delay Reduction	**Double Lockages Benefits to Tows Waiting in Queue**	**Double Lockages Benefits to the Locking Tow**
Pulling the Unpowered Cut	1 min. upbound 3 min. downbound	1 min. upbound 3 min. downbound
Remaking the Tow (with extended guidewalls – turnback lockages only)	15 min. upbound 18 min. downbound	Tow still remakes, just location is moved out of chamber
Reduced Chambering Time	0-2 min. downbound	0-2 min. downbound
Total Time Savings Potential*	16 min. upbound * 21 min. downbound *	1 min. upbound 3 min. downbound
* Time savings would be virtually the same if tows were pulled to the last pin on the existing guidewall. However, the remake/exit of the second cut would take an additional 2 to 3 minutes, reducing the time savings and benefiting a smaller portion of tows.		

The numbers shown in the preceding table apply to the use of industry boats with 1,200-foot guidewalls. In cases where the cut is pulled to the last pin on the existing 600-foot guidewall, the benefits are reduced. In these instances, the time savings are reduced due to the fact that the second cut will exit more slowly, reducing the savings identified by 2 to 3 minutes. In addition, the existing guidewall does not have adequate length to allow the largest tows on the system, most 5,000 and 6,000-horsepower boats, to remake without blocking the chamber.

Self help, especially without the addition of facilities, may not be implementable under some conditions. The benefits shown would likely be unattainable for upbound tows during outdraft conditions. In addition, benefits would not accrue when smaller queues are present and during periods of lower economic incentive. There may also be unacceptable environmental impacts associated with routine use of remote remake if facilities are not provided. As a result, provision of mooring cells may be required as a way to avoid or minimize impacts.

Conditions Affecting Implementation. Two of the key elements to implementing an industry self-help policy are cooperation of the various industry groups and an adequate queue of roughly

10 or more tows (often do not implement until lock is operating 6-up/6-down). The potential for this coordination has been established by RIAC; however, additional discussions regarding each site on the system would likely be required to develop an agreeable policy for each site. There is also a need to address the willingness of various tow companies to handle each other's tows on a more regular and routine basis in contrast with existing practice which is typically associated with higher traffic levels or unusual events such as emergency closures, accidents, and ice conditions.

Some of the benefits may be somewhat more variable than under a switchboat or helper boat option. Industry self help relies on participation, coordination, and the presence of an adequate queue. The use of industry self help is limited to situations where an adequate queue is waiting at the lock site. Unlike a helper boat or switchboat option, self help can only be implemented where a large enough queue is present to allow a tow to assist others without causing additional delays by not being ready to lock when it has its turn. This reduces the ability to use self help in situations with moderate delay (e.g., three or six waiting tows).

The willingness of industry to participate in the long term is also based on the potential for increased risks, which could lead to higher rates of accidents and increased insurance rates. If higher accident rates are experienced resulting in higher costs, the use of these types of operations and facility requirements would be re-evaluated. The additional use of equipment and lines could also affect maintenance costs and equipment life.

There is also a need to determine whether formal mooring areas are required at each site. These could include multiple moorings at each site. For example, a mooring cell could be added some distance from the lock to hold the assisting tow's barges while it pulls cuts. Closer to the lock, mooring cells or bank anchors would be provided for waiting tows, allowing them to safely tie off while serving as remote moorings. These cells, or moorings, would generally be in the same locations identified for remote moorings under the "Switchboat" option (see plates in Appendix C). If suitable waiting areas and moorings are not identified, the tows may be required to remake along the existing or an extended guidewall, reducing benefits to just turnback doubles.

The overall level of effectiveness also varies based on the assisting captain, crew, and power and maneuverability of assisting towboats. The crew of a line haul boat would likely not know particular site conditions as well as a switchboat or helper boat crew assigned to one lock. The crew of designated assist tows (helper boats or switchboats) would also become highly efficient through repetition and specialization at one lock site in pulling and backing cuts to the designated remake areas. As with the switchboat measure, the use of remote remake areas provides the potential for increased likelihood and severity of private and government property damage if accidents occur.

Costs. In contrast, with the other towboat power option, it is more difficult to determine the cost of using industry self help. The actual cost of industry self help is limited to the additional fuel and risk and any added variable costs (wear and damage on its equipment). However, in identifying costs, only the cost of additional fuel was quantifiable given available data. Some expense related to increased insurance rates and increased wear on equipment would be expected, but the magnitude is unknown.

Table 4-13 summarizes the total daily operating cost for various towboat sizes. However, the full cost of operating a tow overstates the true cost of using line haul boats waiting in a queue, since all fixed costs would need to be paid regardless of whether the tow is assisting in pulling cuts or simply waiting a turn. The actual cost of implementing self help is most directly related to any additional fuel use, risk, and wear associated with the usage of the tow and equipment. However, the average cost of fuel may overstate the cost, since tows waiting for the lock often at least idle their engines and use some fuel. In order to account for the fact that waiting tows often idle their engines and not all lockages would require assistance, a lower cost of $50/hour or $324,000/year/boat was used. This figure was based on the average fuel use for the UMRS from Corps guidance. The yearly cost of $324,000 would cover fuel expense for 1 tow, 24 hours a day,

during the 270-day navigation season. It is anticipated that this overstates the need for assistance, especially in the early years of the analysis period.

TABLE 4-13: DAILY COSTS TO OPERATE A LINE HAUL BOAT

Cost	2800-3400 hp	4000-4400 hp	5000-6000 hp
Capital Costs (cost recovery - 7.75% over 20 yrs)	$ 910	$1,235	$1,615
Operating Costs			
• Crew - 8-10	1,650	1,930	2,215
• Boat Costs (maintenance, supplies, insurance, taxes)	830	965	1,110
• Administration	310	360	415
• Fuel Cost (average power)	1,465	1,720	1,985
Total Daily Costs	$5,165	$6,210	$7,340
Total Hourly Costs (daily costs/24 hrs)	$ 215	$ 259	$ 305
Variable Hourly Costs (avg. fuel cost per hour)	$ 61	$ 72	$ 83

Note: Fuel cost is $1,000 - $2,500 higher per day if under high power most of the time.
Source: FY97 Planning Guidance, Shallow Draft Vessel Costs.

There also are significant costs associated with additional mooring cells or remote remake areas, if they are implemented at a particular site. The cost for a cell is estimated at $500,000, with an additional estimated annual cost of $20,000. At most sites, it is anticipated that three cells would be required both above and below the lock. These cells would provide two cells as a mooring area for the tow, serving as a remake area, and one cell as a tie-off for the assisting tow's barges. For more information on cells, see the Adjacent Mooring Facilities section. Information on the cost of spud barges and mooring cells for use as remote remake areas was included in the Switchboat section.

The 600-foot upstream guidewall extension concept and costs would be the same as those discussed under the Switchboat with Guidewall Extension Alternative, resulting in a first cost of $3.2 million per wall for a cell and DeLong Pier wall versus $23,450,000 upstream and $12,870,000 downstream for permanent guidewall extensions using cellular sheet pile construction. IWW sites would again have high impact to navigation costs of roughly $60 to $80 million per wall.

Relationship to Other Measures. The use of industry self help adds additional savings when combined with most measures. In particular, mooring facilities or extended guidewalls for remaking cuts along greatly improves the efficiency of using self help to extract cuts and would be required at most sites to fully implement the measure. Scheduling both commercial and recreational vessels can also assist in maximizing the benefits of self help. However, the flexibility currently used in implementing N-up/N-down as part of the self-help policy diminishes the potential for future benefits associated with better scheduling.

The implementation of a self-help policy typically provides similar benefits as helper boats, switchboats, and improved tow haulage equipment. While these measures are not mutually exclusive, self help can provide a significant portion of the benefits at a lower incremental cost to industry. If the towboats remove the unpowered cuts to mooring facilities away from the locks for remaking, then the benefits of crew elements are reduced since the recoupling would be done away from the lock while other tows are using the lock facility.

Conclusion. Self help provides industry an option to obtain a portion of the towboat power assistance benefits at little additional out-of-pocket expense. As a result of expected performance improvements (time savings), which are near the level of helper boats and switchboats, and lower incremental cost, this measure is recommended to be carried forward for more in-depth consideration.

Tolls and Reports

The toll collecting and reporting measures are forms of demand management that seek to reduce delays through creating incentives to reduce overall lockage times and shift demand away from congested locks. These measures are being explored based on their current use and consideration as demand management measures for congested freeways, commercial airlines, and various utilities. Federal law currently prohibits the charging of tolls for watercraft passing through locks (33 U.S.C. 5). If a fee measure is ultimately selected for implementation, the recommendation to change the current Federal law would go forward with the final feasibility report. The issue of how the money collected would be used does not affect the study analysis. However, it is assumed that it would be designated for use in defraying navigation-related costs of the UMR-IWW System (navigation improvements, operation and maintenance, etc.) or placed in the Inland Waterways Trust Fund.

This section addresses four measures: congestion tolls, excess lockage time charges, lockage time charges, and publish lockage times. Of these measures, congestion tolls would have the greatest direct cost to industry. In contrast to the other measures in this section, which primarily focus on creating incentives for vessels to lock faster, congestion tolls are mainly directed at addressing overall demand for the locks. While primarily intended for commercial lockages, tolls and lockage charges could also be collected from recreational users.

▪ Congestion Tolls

Description of Measure. Tolls would be collected from tows and possibly recreational craft using congested locks. The use of congestion tolls in the form of peak-load pricing has been applied to the use of utilities such as phone service and energy. Increasingly, congestion tolls are being considered in transportation management for interstates and highways. While congestion tolls typically are charged during a particular peak period of demand, analysis has demonstrated that there is little regular variability in commercial waterway traffic except as influenced by seasonal weather. As a result, it would appear that a more effective use of the congestion toll is to charge a fee at all locks experiencing a significant delay or a licensing fee to operate on the system.

Applying congestion tolls does not expand or improve the ability to lock tows. Instead, they provide an incentive to avoid congestion and a mechanism to ration the lock's ability to process tows. However, the issue of how tolls would affect the demand for lockages, the behavior of the barge operators, and the potential creation of an incentive to change tow configurations need to be evaluated. Congestion tolls as a form of a user charge also raise issues surrounding the efficiency and equity character of the charges.

The tolls would be developed to shift some potential traffic away from congested locks to alternate modes or other parts of the inland waterway system. One option would be to set the toll at a level that internalizes the cost of delay the tow is causing to other tows in the queue. The amount of the toll collected would vary, with higher tolls for slow lockages at the most congested locks and lower tolls for fast lockages at locks with lower levels of traffic. Uncongested locks would not require a toll. This would create a mechanism to internalize the delay cost that tows using the locks place on other tows. Other options include basing the tolls for the system in part on the modal rate studies being conducted as part of the navigation study. The tolls could be set at

a level that would influence the modal choices and overall system traffic. A final and simpler approach administratively would be to charge a licensing fee to operate on the system. Only tows willing to pay for the license could operate on the system and if necessary the number of licenses could be limited.

Delay Reductions Methodology/Time Savings Estimates. The collection of a congestion toll would be targeted at reducing the overall traffic at congested locks. This measure, when properly implemented, can provide significant delay reductions by reducing traffic on the system and shifting marginal traffic movements to other modes or areas.

In order to appropriately set the level of tolls and adequately evaluate the impacts, a system evaluation is needed. This measure should be carried forward for analysis using the systems models being developed to analyze the UMR-IWW System as part of this study.

Conditions Affecting Implementation. A number of factors are likely to influence the ultimate implementation of this measure. One key concern is the response of the navigation industry that has historically opposed congestion tolls and other fee options. Depending on how the tolls are structured, users may not know if congestion tolls will be in effect until radioing or reaching the lock. In this instance, additional information on real-time traffic flow may be needed to assist industry in avoiding peak periods of delay. If tolls were extended to recreational users, the response of these users could also be very strong.

In addition, rationing systems traffic could result in negative regional economic impacts and changes in water compelled rate impacts on other modes. The tolls also have the potential to negatively impact the profitability of various towboat companies. Depending on how and when the tolls are collected, they have the potential to impact traffic levels even during noncongested periods, lowering system utilization below optimal levels.

A low-cost and unburdensome method of toll collection would need to be developed, both from staffing and budget perspectives. One potential for billing would be an adaptation of the existing LPMS database. As lockage data are collected, the program could be developed to record the company name and lockage time for consolidation and billing on a periodic basis.

Cost. The primary costs associated with this measure include developing a congestion toll structure, setting the level of the tolls, and toll collection. This measure would produce revenue in excess of costs. Tolls on recreational craft would need to be set at a lower level, but would still be higher at those locks with the greatest delay and lower at locks with less traffic and delay. A potential major cost to the nation and region is reduced transportation options and resultant increased shipping costs on remaining modes. A second cost would result from negative impacts to recreation, a significant economic activity in the study region.

The costs, shown in Tables 4-14 and 4-15, cover the entire system and not just a single lock site and include:

1. Determine sites needing tolls and develop a fee structure (Corps/Contractor Study, Public Meetings, and Coordination). The toll structure should be developed to shift demand without causing undue hardship to carriers that must use the system. Factors to include in setting the rate include: charging on a per lockage, per time, per barge, per tow, per ton basis, or per season, and whether or not and how to include recreational craft.

TABLE 4-14: FIRST COST TO DEVELOP A CONGESTION TOLL SYSTEM	
Item	**Cost**
Economic Study to Determine Need, Locations, Toll Level, Coord.	$295,000
Cost to Establish Bookkeeping and Billing System	76,500
Contingency 25%	93,500
Total	$465,000

The cost of the economic study was based on approximately 6 months of study effort, extensive coordination, two newsletters, and a round of public meetings. The cost to establish the bookkeeping and billing system is based on developing a database, mailing list, system for data sharing between districts, and notice to navigation industry.

2. Develop and implement a collection mechanism for the system (allows for staff time to collect and analyze data, prepare billings, and assist in collection).

TABLE 4-15: ANNUAL COST TO IMPLEMENT A CONGESTION TOLL SYSTEM	
Item	**Cost**
Collection and Summary of Data	$ 68,000
Billing and Collection	120,000
Contingency 25%	47,000
Total	$235,000

Relationship to Other Measures. Other time-reduction measures could be implemented along with congestion tolls. However, congestion tolls, focused on eliminating significant delays by reducing traffic at the most congested lock sites, could potentially reduce traffic to low enough levels to eliminate the need for other measures. Due to the complexity of a multiple fee structure and the goals of congestion tolls, it should not be combined with other fee collection measures.

Conclusion. Additional analysis to determine the feasibility of congestion tolls requires using the UMR-IWW System Navigation Study systems models to determine the actual ability to address congestion and whether there are sites and periods of congestion that tolls could address.

- **Excess Lockage Time Charges**

Description of Measure. This measure seeks to charge users who have an "excessive" lockage time at a particular lock. The fee creates an incentive specifically designed to modify the operations and behavior of the companies and crews with the slowest lockage times. In order to implement the measure, what constitutes an excess lockage time would be determined for each lock, and users who exceed that time would be assessed a fee. The level of the exceedance that triggers the charge would be based on a statistical analysis of the distribution of historic lockage times at a particular site. While the specifics of the measure would be determined at a later date in coordination with the navigation industry, the times would be determined on a site-specific basis

for normal conditions. Extremes in weather, river, and lock conditions would need to be taken into account.

While this measure involves the collection of a fee, it varies considerably from a congestion toll. In this case, the fee is set at a much lower level so that the incentive is to improve lockage efficiency rather than to limit use of the system. In addition, the charge is only applied to the tows with the longest lockage times rather than all of the tows in a queue. However, the charging of fees does have the potential to shift some marginal traffic movements off the system.

Delay Reductions Methodology/Time Savings Estimates. The collection of a fee for excessive lockage times creates an economic incentive for especially the slowest crews and companies to improve their practices to avoid the time charge. This could result in significant time savings for other tows at congested locks, since a slow tow in a queue can result in considerable delay to all the other waiting tows. It may also create further incentives for industry to pursue time savings measures such as increased use of approach assistance, additional crew training, development of better couplers, or other equipment improvements to reduce lockage times and avoid charges. However, there are many uncertainties in estimating the efficiency of this measure.

Conditions Affecting Implementation. As with congestion tolls, the response of the navigation industry is of primary interest. One of the main concerns with this measure is the potential to create incentives to reduce safety practices in an effort to lock faster and avoid charges. As a result, accidents involving damage to tows and the lock structure may increase.

This type of measure could present equity concerns among those locking. By design, the charges only apply to a portion of the total traffic using a lock in an attempt to create an incentive for tows to beat a time schedule. This leads to some inequity around the point where the fee is implemented. Tows locking just a few minutes faster may not pay any fee, while other tows taking just a little longer would pay the time charge. However, both tows in this example would nearly equally delay the entire queue. The charges may also disproportionately impact small operators and others less able to update equipment and provide additional personnel.

It would be very difficult to arrive at acceptable criteria to define "excess" by site and by lockage type that would be agreeable to the Corps, navigation industry, and recreational users. This is due to the problems associated with attempting to take into account variable site, weather, and river conditions. In addition, a suitable method of collection would need to be developed.

Costs. The costs of implementing this measure would be very similar to those of developing a congestion toll. These costs would again cover the whole system and would include:

1. Determine average time at particular locks by type and determine the level where fees should be leveed, develop a fee structure, and coordinate with public and navigation industry.

TABLE 4-16: FIRST COST TO DEVELOP EXCESS LOCKAGE TIME CHARGES

Item	Cost
Economic Study to Determine Need, Locations, Toll Level, Coord.	$295,000
Cost to Establish Bookkeeping and Billing System	76,500
Contingency 25%	93,500
Total	$465,000

The cost of the economic study was based on approximately 6 months of study effort, extensive coordination, two newsletters, and a round of public meetings. The cost to establish the bookkeeping and billing system is based on developing a database, mailing list, system for data sharing between districts, and notice to navigation industry.

2. Develop and implement collection mechanism for the system (allows for staff time to collect and analyze data, prepare billings, and assist in collection).

TABLE 4-17: ANNUAL COST TO IMPLEMENT EXCESS LOCKAGE TIME CHARGES

Item	Cost
Collection and Summary of Data	$ 68,000
Billing and Collection	120,000
Contingency 25%	47,000
Total	$235,000

While this measure could again provide revenues in excess of costs, it is less likely to since the charges would be set at a much lower level and would not apply to all lockages. This measure would likely not be extended to recreational craft.

Relationship to Other Measures. The collection of excessive lockage time charges would provide complementary benefits in combination with other small scale measures. Since the relative lockage time of the particular crew determines if a fee is collected, the incentive to eliminate slow lockages would remain even if other measures are in effect and average lockage times are reduced. However, it is recommended that the measure not be implemented with other fee collection measures due to the complexity of tracking and collecting multiple fees.

Conclusion. Defining an "excess lockage time" presents some problems based on variability in conditions over time. Additional analysis is required to determine the actual ability to address delays and determine whether there are sites and significant numbers of lockages that could be improved through the use of excess lockage time charges.

▪ Lockage Time Charges

Description of Measure. This measure seeks to charge all vessels based on the length of time the lock is in use. By charging the tow on a per-unit time basis, all vessels will be charged. As a result, all tows, not just the slowest, will have an incentive to improve their locking efficiency in order to reduce the charge they receive. However, these charges would only apply to the lockage elements where the vessel and its staff can affect the time. This would eliminate such times as gate opening and closing and chamber filling and emptying which are operations performed by the lock staff.

As with the excessive lockage time charge measure, this measure varies from a congestion toll. The fee, set at a lower level, provides an incentive to improve lockage efficiency rather than to limit use of the system. However, collecting a fee does have the potential to eliminate some traffic, especially with this measure since all tows will be charged a fee. The total amount of the fee would be directly related to the lockage time, encouraging operators to reduce their lockage times as much as possible.

Delay Reductions Methodology/Time Savings Estimates. The collection of a fee based on lockage times creates an economic incentive for all operators, especially for the slowest crews and companies, to improve their practices to reduce their charge. This could result in substantial time savings, since all tows in a queue would have an incentive to improve their times. It would also create an additional incentive for industry to use helper boats or switchboats if available and to pursue time saving measures such as additional crew training, development of better couplers, or other equipment improvements to reduce lockage times and avoid charges.

However, determining the actual delay reduction would be based on assumptions of industry's response to the incentive. It also assumes that additional cost-effective time savings are available to industry, beyond what they currently have an incentive to implement.

Conditions Affecting Implementation. As with the earlier toll measures, the response of the navigation industry is of primary interest. Time charges again have the potential to create incentives to reduce safety in an effort to lock faster and avoid charges. However, this may result in increased damage to the tows and lock structures. This may be especially true of this measure since the longer the lockage takes the greater the charge.

There would also likely be some difficulty in arriving at charges acceptable to the Corps of Engineers, navigation industry, and recreational users. A way of taking into account variable weather and river conditions should be included. In addition, a suitable method of collection must be developed.

Costs. The costs of implementing this measure would be very similar to those of developing a congestion toll or excess lockage time charge. These costs would again cover the entire system and would include:

1. Determine average time at particular locks by type and determine the level where fees should be leveed, develop a fee structure, and coordinate with public and navigation industry.

TABLE 4-18: FIRST COST TO DEVELOP LOCKAGE TIME CHARGES

Item	Cost
Economic Study to Determine Need, Locations, Toll Level, Coord.	$295,000
Cost to Establish Bookkeeping and Billing System	76,500
Contingency 25%	93,500
Total	$465,000

The cost of the economic study was based on approximately 6 months of study effort, extensive coordination, two newsletters, and a round of public meetings. The cost to establish the bookkeeping and billing system is based on developing a database, mailing list, system for data sharing between districts, and notice to navigation industry.

2. Develop and implement collection mechanism for the system (allows for staff time to collect and analyze data, prepare billings, and assist in collection).

TABLE 4-19: ANNUAL COST TO IMPLEMENT EXCESS LOCKAGE TIME CHARGES

Item	Cost
Collection and Summary of Data	$ 68,000
Billing and Collection	120,000
Contingency 25%	$47,000
Total	$235,000

This measure would again likely raise more than enough revenue to cover the costs. However, the fees and overall surplus would be considerably lower than for congestion tolls. This measure would likely need some modification before being applied to recreational craft.

Relationship to Other Measures. The collection of lockage time charges would provide benefits in combination with other time reduction measures. However, as the average lockage time is reduced due to the implementation of delay reduction measures, the economic incentives to improve locking efficiency associated with lockage time charges would be reduced. This measure should not be implemented with other fee collection structures due to the complexity of tracking and collecting multiple fees.

Conclusion. As with the other fee measures, additional analysis is required using the UMR-IWW System Navigation Study system models to determine the actual ability to address delay and whether there are sites and periods of congestion where lockage time charges could reduce overall delays. Some further analysis on the impacts on NED and RED may also be needed.

- **Publish Lockage Times**

Description of Measure. This measure seeks to identify those towboats and towboat companies whose crews have the fastest and slowest lockage times. Although this measure does not involve a direct economic incentive or charge to reduce time, it informs the particular companies and the entire industry of the performance of particular tows. Since it is in the best interest of all parties to reduce lockage times, this measure should assist companies and the industry in identifying which tows perform the best and which tows may need additional equipment, training, or crew members.

The lockage times for a particular tow, currently collected as part of the LPMS, would simply need to be formatted and published on the Corps of Engineers' Internet home page and in river industry periodicals (e.g., the *Waterways Journal, River Transportation News*, or others). In order to reduce the amount of reporting, just those tows locking fastest and slowest could be included as positive and negative incentives, respectively.

The publishing of information on performance has been carried out by the airline industry, city and county governments attempting to collect property taxes, and even agencies attempting to collect child support. In many cases, these efforts have been successful in raising the awareness of both the involved parties and the public and in bringing about improvement.

Delay Reductions Methodology/Time Savings Estimates. The publishing of lockage times highlights performance and creates a peer incentive for crews and companies to improve their practices in order to be listed as the best performers or to avoid being identified by the industry, their customers, and others as contributing significantly to delays. This could result in improvements in the lockage times of some companies. It may also create further incentives for industry to pursue additional time savings measures.

Since significant economic incentives already exist to maximize efficiency (the high operating costs of having a tow on the system), it is assumed that the primary time reductions would come from the limited number of tows that have significantly longer lockage times due to insufficient crew members, inadequate crew experience and training, and equipment issues.

The Corps of Engineers currently meets regularly with industry groups and shares information on companies or tows that create significant delays. A considerable amount of industry peer pressure also exists to reduce delays, and often just sharing information with the navigation industry can substantially improve performance.

Due to the unknown response of industry to the incentives created by this measure, its benefits are not quantifiable.

Conditions Affecting Implementation. The major condition affecting implementation is to determine how to get the information out and under review by the navigation industry. In addition, the response of industry to this information is difficult to accurately predict.

Costs. Since the data are currently collected and only need formatting and publishing, the cost of implementing this measure would be relatively low. The actual cost would be based on the format in which the data are published, frequency of publishing, and whether a publication would include the information at no charge. The cost of compiling, sorting, formatting, and publishing the data is estimated at $65,000 per year for the system.

Relationship to Other Measures. The publishing of lockage times can be used in combination with all other small scale measures, including the fee collection measures, since the peer incentive would exist whether or not other measures are implemented. However, if other measures significantly reduce delays, the pressure on slower tows to improve their performance could be substantially reduced.

Conclusion. Despite the relatively low cost of the measure, it is not likely to significantly decrease system delays. In addition, on-going communication with industry addresses many of these issues.

Recreational Vessels

Two separate measures regarding potential conflicts with recreational vessels at locks are being considered for application to address delays at locks. Increasing recreational and commercial usage of the UMR-IWW places commercial and recreational craft in competition for use of the locks at certain times. This section addresses the scheduling of recreational vessel usage and construction of recreational craft landings above and below the locks as ways to reduce these conflicts.

In addition to this analysis, recreational craft impacts are also under consideration as part of the system environmental studies. While only preliminary results are available, the recreational traffic projections show overall increases in recreational usage of the pools of approximately 15 to 25 percent. The greatest potential for increases occurs near major urban areas (e.g., St. Paul, St. Louis, Chicago, Peoria, and the Quad Cities). Many of these areas are the best suited for recreational traffic due to the presence of auxiliary locks, wicket dams, or lower commercial traffic levels. However, the impacts of increased recreational usage are likely to be felt throughout the system.

▪ Scheduling of Recreational Vessel Usage

Description of Measure. This measure would involve limiting recreational craft lockages to certain times of the day in order to minimize locking conflicts with commercial traffic. For example, recreational craft lockages would be offered at a set number of times during the day (e.g., morning, noon, evening). The purpose of scheduling is to maximize the use of the lock chamber for recreational craft lockages (number of recreational craft per lockage) while reducing or eliminating recreational lockages at other times. Although scheduling would reduce the flexibility of providing lockages whenever recreational craft are present, it would provide increased predictability as to when recreational craft would be able to utilize the lock chamber. It could also reduce safety hazards by minimizing the times when both commercial and recreational crafts are approaching a lock at the same time.

As discussed in the Background section of this report, recreational vessels have the lowest lockage priority of boats operating on the system. However, current navigation regulations, 33 CFR 207.300, state that the lockage of recreational crafts shall be expedited by locking them through with commercial craft, provided both parties agree. If the lockage of recreational craft(s) can not be accomplished within the time required for three other lockages, a separate lockage of recreational craft(s) shall be made. This regulation would need to be changed to allow a scheduling option to be implemented.

There are several different ways that scheduling could be implemented. It could be done on a voluntary basis where recreational craft would still lock at other times, or through industry scheduling with no allowance for recreational lockages outside of the designated times. In addition, scheduling can be implemented every day or just on weekends.

Delay Reductions Methodology/Time Savings Estimates. In determining how a scheduling program would be established and identifying the likely time savings, the study team was able to draw upon information collected during testing of this method at various locks on the UMRS. Additional sources of information included recreation studies and LPMS data. Recreational craft scheduling could be used as a way to eliminate the need to continually provide recreational craft lockages when commercial delays exist. However, this measure may result in increased delays to tows if they must wait until after scheduled recreational craft lockage times to use the locks even if no recreational crafts are present.

Background. In the mid-1970s, the St. Paul District of the Corps of Engineers experimented with scheduling recreational craft lockages at Locks 2, 3, and 7. In 1975, Locks 3 and 7 were utilized for the test, while in 1976 and 1977, Locks 2 and 7 were used. The test involved the development and implementation of designated recreational craft lockage times on weekends and holidays. Three to four half-hour time periods were designated each day for recreational lockages:

In 1975-1976	**In 1977**
9:00-9:30 a.m.	10:00 - 10:30 a.m.
12:00-12:30 p.m.	2:00 - 2:30 p.m.
4:00-4:30 p.m.	6:00 - 6:30 p.m.
7:00-7:30 p.m.	

For the testing, the Corps decided to strictly enforce the designated times for recreational lockages by not allowing commercial tows to lock during these periods. However, recreational craft were allowed to lock at other times. At times, the system worked well and recreational craft operators seemed to appreciate knowing when they would be able to lock through, but other times the scheduling created unnecessary delays for tows. If a tow arrived 30 to 60 minutes before a designated time but could not complete its lockage before the recreational lockage time, it was

forced to wait until after the recreational lockage period. Frequently, tows would be forced to wait, and no recreational craft would arrive for the designated time, especially in poor weather.

While some recreational boat operators took advantage of the dedicated times, the majority appeared to ignore the special scheduling and come and go as they pleased. Many tow operators considered the dedicated periods a costly irritant. After 3 years without significant supportive or negative data, the St. Paul District decided to discontinue the trial of dedicated time periods for recreational craft. The dedicated periods did not seem to significantly benefit recreational craft and did cause additional delays to commercial traffic. However, by allowing recreational lockages at other times, the incentive to use the designated periods was significantly reduced.

The St. Louis District conducted a similar test at Lock 25 during the 1980 navigation season. During this time period, three designated recreational lockage periods were established, as listed below. The test produced similar results to the tests in the St. Paul district. The test did not have a particularly strong positive or negative reaction by recreational boaters, but often commercial tows were delayed while few, if any, recreational craft used the lock during the designated times. Following the 1-year test, the scheduling of recreational craft was discontinued.

Designated Times

8:00 - 8:45 a.m.
12:00 - 12:45 p.m.
4:00 - 4:45 p.m.

In 1992, the St. Paul District placed a digital sign board, similar to the ones used on interstates, at the end of each guidewall at Lock and Dam 7 to inform recreational craft of the next estimated recreational craft lockage, provide safety tips, and give information on river conditions. While they have not deviated from the normal scheduling procedures, they are able to inform the recreational craft operators of the approximate time until the next recreational lockage. The test has been partially successful, but many recreational boaters still radio the lock before reading the sign. The location of the sign near the lock may contribute to this problem. These types of signs could be very valuable if a recreational scheduling policy were implemented (especially one with some flexibility) because the lock personnel could easily inform users of the next lockage time.

In addition to these tests of recreational scheduling measures, some information has been collected on recreational boaters' usage of the locks and river and their perceptions of lock conflicts.

The Institute for Water Resources (1989) report entitled, *An Analysis of Recreational Boating Impact on Navigation Lock Performance*, highlighted some of the areas to be considered in developing an approach to scheduling. The study indicated that the UMR-IWW System receives approximately 75 percent of its use from recreational boaters on weekends from April to October. In addition, many boaters travel relatively long distances, with the average trip of over 40 miles, and require lockages at more than one lock facility. Over 75 percent of the recreational boaters surveyed indicated they have experienced delays in lockages, and of those, 75 to 90 percent indicated that they experience delays on the weekends.

However, the results of this survey may be somewhat biased by the fact that surveying took place on weekends. Actual LPMS data for 1990 showed somewhat lower values for weekend use (Saturday and Sunday) with 56 percent of recreational boats locking and 45 percent of recreational lockages occurring on weekends. These values would be even higher if Friday evenings and holidays were included. However, as these numbers indicate, the number of boats per recreational lockage was higher on weekends. For the system as a whole (all days) on average two to three recreational boats are in the chamber during each recreational lockage. On weekends, this average is well over three, while on weekdays it is just over two recreational boats per lockage. However, over 50 recreational boats could reasonably fit in a 600-foot lock chamber.

The Corps of Engineers Waterways Experiment Station (1992) report, *Recreational Use of Chickamauga Lock, Tennessee, and Recreational Boaters' Perceptions of Lock Use Conflicts*, appears very applicable to the UMR-IWW System study despite being conducted on a different river system. One of the key findings was that while the length of delay was not a major source of frustration for boaters as long as it remained under 60 minutes, not knowing when delays would occur was viewed as a more significant problem. The survey also revealed that most recreational boaters will significantly reduce their use of the locks if delays increase or long delays are present. This highlights the potential that predictable times for recreational lockages may be valued by users as the system becomes more congested.

Calculations. To get an idea of the potential time savings, the study team looked at the lockage time required to implement a scheduling program versus what is actually occurring. The amount of time that recreational vessels would have the chamber designated to their use under a strictly enforced scheduling program can be calculated fairly simply.

Current recreational use of the system has a rather predictable pattern. Almost no recreational lockages occur from November through March at most locks on the system. Traffic levels grow steadily from May through July and then tapers down again through October. As a result of this pattern, scheduled times for recreation would only be needed from roughly May through October. This would address the majority of recreational lockages, and at other times they could be locked under the current policy.

If designated lockages were provided every day, this process would result in a number of recreational lockage periods equal to 3 (assuming 3 designated periods per day) times the 184 days from May through October, or 554 designated periods per year. By multiplying the 554 periods times 30 minutes per period, there would be 16,620 minutes or 276 hours per year.

However, with the highest recreational usage occurring on weekends, it may be most advantageous to only have the designated periods on weekends or to have a more limited number of lockages times on weekdays (two per day, morning and evening). If scheduling occurred only on weekends, this would result in lock usage of 78 hours per year.

A review of the LPMS data for the system revealed that recreational lockage times for Locks 11 to 25 averaged 14 minutes in 1990, while the IWW sites averaged 21 minutes. The primary time difference between the waterways is related to the water level difference between the upper and lower pools, which is greater on the IWW and affects the overall chambering times. These data show that on the IWW designated time periods of 40 to 45 minutes would likely be required to allow one upbound and one downbound lockage. Table 4-20 summarizes the number of lockages and lockage times by lock for recreational craft.

The yearly time savings would equal the current total lock usage time for recreational vessels (the number of recreational lockages times the time per lockage) minus the new time dedicated for recreational lockages under scheduling. The following formula was used to analyze the benefits of a scheduling program:

Total Savings = (No. rec lockages/yr x time/lockages) - time required for scheduling/yr

Even at a relatively low recreational usage level of 625 lockages per year (an approximate of the number of lockages at Locks 20-25 in 1990) and 14 minutes per lockage, a lock would have current recreational usage of 8,750 minutes per year or 145 hours per year. This is the total for the entire year, versus under-scheduling where it would be 276 hours if scheduled from May to October. In this instance, implementing daily scheduling would increase the period of time recreational craft are using the locks. However, many lock sites have considerably more recreational traffic. For example, at Lock 11 there were 2,092 recreational lockages in 1990 with an average lockage time of 16.3 minutes. This resulted in 568 hours of recreational use of the lock. Time savings would be possible if a recreational scheduling program were implemented at

TABLE 4-20: TIME SAVINGS POTENTIAL OF REC CRAFT SCHEDULING (Based on 1990 Data)

	Background Informtion				Weekend Usage (hrs/yr)			Total Usage (hrs/yr)		
LOCK	Total Number of Rec Vessels	Number of Rec Only Lockages	No. of Wkend Lockages	Avg Lockage Time (min.)	Actual Rec Usage	Total Usage w/Sched	Time Savings w/Sched	Actual Rec Usage	Total Usage w/Sched	Time Savings w/Sched
11	7,194	2,092	941	16.3	256	78	178	568	276	292
12	4,487	1,601	720	13.2	158	78	80	352	276	76
13	4,836	1,217	584	13.4	130	78	52	272	276	-4
14	1,290	643	161	14.6	39	78	-39	156	276	-120
14 AUX	5,561	1,605	1,156	15.7	302	78	224	420	276	144
15	142	79	36	23.3	14	78	-64	31	276	-245
15 AUX	5,826	2,400	1,296	15.8	340	78	262	630	276	354
16	1,398	710	348	14.8	86	78	8	175	276	-101
17	811	476	195	13.5	44	78	-34	107	276	-169
18	1,592	790	395	11.8	77	78	-1	155	276	-121
19	1,385	577	265	21.6	95	117	-22	207	414	-207
20	831	392	157	14.9	39	78	-39	97	276	-179
21	1,248	639	313	12.7	66	78	-12	135	276	-141
22	1,234	575	247	13.4	55	78	-23	128	276	-148
24	1,507	607	267	14.2	63	78	-15	143	276	-133
25	2,634	920	460	11.9	91	78	13	182	276	-94
Mel Price	3,650	1,165	513	15.1	129	78	51	292	276	16
Mel Price AUX	4,497	1,623	844	20.1	282	78	204	542	276	266
27	374	118	41	18.0	12	78	-66	35	276	-241
27 AUX	1,180	508	213	0.0						
LOCKPORT	1,324	587	235	29.0	113	117	-4	284	414	-130
BRANDON	1,556	706	297	28.7	142	117	25	338	414	-76
DRESDEN	3,717	1,298	636	20.6	218	117	101	445	414	31
MARSEILLES	3,436	1,172	621	24.8	257	117	140	484	414	70
STARVED ROCK	3,361	1,311	669	19.3	215	117	98	421	414	7
PEORIA	1,179	288	135	12.9	29	78	-49	62	276	-214
LAGRANGE	428	182	76	13.3	17	78	-61	40	276	-236
AVG 11-25*	2,624	883	408	14	97	81	15	210	288	(77)
AVG ILLINOIS	2,143	792	381	21	141	106	36	296	375	(78)

Lock Usage w/Scheduling column is based on 3 - 30 min. periods/day for UMR and 3 - 45 min periods for Upper IWW and 19.

Note*: Shading indicates sites with auxilary locks. These locks (14,15, Mel Price, & 27) were not included in avg.

Peoria and Lagrange data does not provide accurate picture, since open pass conditions occur during part of the year.

Mel Price lockages are overstated, 1992 and 1995 data used for main and aux. locks, respectively, both record nearly all lockages.

this site. However, there are currently few delays to commercial traffic at this site. Similar results were found when looking at scheduling on weekends only. Table 4-20 provides information on the analysis of UMR and IWW locks.

These calculations demonstrate the potential that at sites which currently have low to moderate levels of recreational traffic, such as the lower UMR sites, having designated recreational lockage times may actually increase delays. There would also be a large decrease in overall flexibility, in contrast to the current situation where recreational craft are often locked during the turning back of the chamber for tows heading in the same direction. This process allows for recreational lockages while minimizing impacts on overall delays. In addition, if recreational craft were also allowed to lock at other times, this measure could greatly increase the time recreational craft use the locks each year. Finally, this analysis did not consider the potential additional delays to tows, which arrive prior to recreation lockage times but are forced to wait until afterwards because they could not complete their lockage prior to the period.

Conditions Affecting Implementation. The major concern in implementing recreational scheduling is the potential for negative impacts and reactions from the commercial industry and recreational users. The more strictly the policy is enforced (e.g., allowing recreational craft lockages only during designated times and not allowing tows during these times), the greater the potential for a negative response from members of either user group. In addition, strictly enforcing the policy results in the loss of flexibility to lock recreational craft and could create significant delays for recreational craft trying to travel longer stretches of the river because they potentially could by forced to wait several hours before the next designated period. This strict application of the policy has not been attempted in the past.

Several factors are likely to play a major role in the effectiveness of any implementation of this measure. Public involvement and education of the recreational boating community and navigation industry would need to be a very high priority, both in regards to setting the times and in clearly communicating why they are needed and how they will be enforced.

While designated times have been tried, there was no particular enforcement of only locking recreational craft at certain times. By allowing lockages at other times, there was a greatly reduced incentive for recreational operators to utilize the designated times and, as a result, an overall reduction in the effectiveness of the measure to reduce delays at locks. If recommended, the type of scheduling to be implemented should consider the benefits of setting times that vary by site to take account of specific recreational and commercial traffic volumes versus having standard times for the entire system. On weekends and at some high volume sites, additional recreational lockage times may be justified.

Costs. Implementing recreational craft scheduling would be a relatively low-cost measure. The major costs, summarized in Table 4-21 below, would be to conduct a study to develop the schedule and select sites for implementation. Additional cost and effort would be involved with ensuring adequate coordination with user groups and the possible collection of survey data. Following the selection of a scheduling approach, additional funds would be required to notify interest groups and the public of any changes. In addition, developing adequate signage and publicizing any new schedule would involve some expense (post signs at Corps-owned boat ramps, distribute brochures, press releases, and public education efforts).

While not included in the costs, an electronic sign upstream and downstream of the lock could be added, like the one at Lock 7, to inform recreational users of the next available lockage. The signs include small panels to show operators what is being displayed. These electronic signs are relatively expensive, costing approximately $25,000 per lock to have the digital sign and software.

TABLE 4-21: FIRST COST TO DEVELOP RECREATION CRAFT SCHEDULING	
Item	**Cost**
Study to Develop Schedule, Identify Sites, and Public Involvement	$305,000
Signage and Public Awareness Campaign	110,000
Contingency 25%	105,000
Total	$520,000

In addition, an annual cost of approximately $35,000 would fund monitoring of the scheduling program, ongoing public awareness efforts, and replacement of the signs.

Besides direct costs, there may be the potential for negative economic impact, if changes in the recreational craft's ability to use the locks leads to reductions in recreational use of the system. According to the 1995 report, *Economic Impact of Recreation on the Upper Mississippi River System,* recreationists make over 12 million daily visits yearly to the UMR-IWW System. The visits contribute direct and secondary expenditures of over $1.2 billion, significantly benefiting the economy of the five study area states and helping to maintain approximately 18,000 jobs nationwide. Similar results were provided by the Upper Mississippi River Conservation Committee's 1982 report, *Outdoor Recreation: Big Business on the Upper Mississippi River System.* The Committee also estimated the recreational economic impact on the UMRS at approximately $1 billion per year.

Relationship to Other Measures. The scheduling of recreational craft would be compatible with all other small scale measures under consideration. However, if both scheduling of recreation craft and a scheduling program for commercial tows were implemented, additional coordination should go into ensuring that the measures work together.

Conclusion. Implementing recreational craft scheduling does not appear to be able to reduce delays at the most congested locks on the system. There would be some time savings potential at the upper lock sites, but currently these sites are not experiencing significant delays. In addition, there are concerns with the acceptability of a strictly enforced program to both commercial navigation and recreational interests.

- **Recreational Craft Landing Above and Below Lock**

Description of Measure. This measure calls for ensuring that adequate boat ramp facilities are available at either end of a pool near the lock in order to minimize the need for recreational craft to lock between pools due to a lack of access in one pool. This measure addresses the problem that in some locations the only available landing for several miles is located either just above or below a lock. At these locations, there is a potential for a large number of users to put their boats in the pool with the better access and then lock through to reach the desired pool. During periods of higher traffic, these additional recreational lockages could increase overall lock delays, especially in consideration of the current regulations requiring that at a minimum recreational craft are locked after every third commercial lockage. In addition, providing additional landings could increase safety by reducing the frequency of commercial and recreational boats waiting to use a lock.

Delay Reductions Methodology/Time Savings Estimates. This measure was carried forward based on its potential to reduce delays to commercial craft associated with recreational craft usage

of the locks by eliminating the need for some recreational craft to use the lock facilities. However, on further review, it does not appear likely that this measure will provide measurable or significant time savings benefits. The actual delay reduction possible is closely related to the reasons that recreational craft are currently using the locks (e.g., local traffic that simply enjoys locking, marina-based craft, and through-system travelers). In addition, the willingness of recreational users to wait for the lock influences the response of recreational craft users to increasing delays.

The study team conducted a two-step analysis to determine the potential time savings related to additional boat landings. The first step was to identify sites where a lack of recreational facilities exists that could be contributing to delays. Sources of information for this section included site visits, calls to the lockmasters, Division Bulletin No. 2, and review of the Navigation Charts. The second step involved looking at various recreational studies, LPMS data, and calling lockmasters to determine the likely response of boaters and potential time savings.

Currently, there are several hundred boat landings and marinas along the UMR-IWW System and its tributaries. In addition to state and privately owned facilities, the Corps operates over 30 ramps in the study area. However, the distribution of access points varies considerably from pool to pool, with stretches of 20 miles or more with no landings in some areas and up to several ramps within a short distance in others. The number and location of bridges can reduce the need for landings, since a single site can provide access for residents on both sides of the river. In areas where there are no bridges, landings would be needed on both sides of the river above and below the lock to provide equal access. Table 4-22 summarizes the lockage time for recreational craft heading upstream and downstream and highlights sites lacking adequate landings near the lock and dam facility.

The primary sites that could benefit from an additional landing facility would be Locks 12, 16, 17, 20, 22, 24, 25, and Mel Price. Despite these sites being identified from a review of information on boat ramp facilities, the lockmasters generally did not feel that significant delay reductions would occur. Other areas, such as in the pools above and below La Grange Lock and in Lockport pool, have a relatively low number of landings and longer distances between them, but current recreational usage does not appear to require additional facilities.

The primary focus in recent years at Corps-operated recreation sites has been maintenance, and in some cases rehabilitation, rather than new construction. While constructing additional ramps has been considered as a way to reduce recreational craft lockages, the study team was unable to identify situations where they were actually constructed to reduce conflicts. User surveys and recreational facilities assessments are the primary information available on this topic. The following paragraphs summarize the findings of a number of these reports. For example,

> *The GREAT studies identified public access needs in nearly every pool. In the upper river, all pools except Pools 2 and 10 have inadequate boat landings. In the middle reaches, a definite need for boat ramps has been shown for all but Pool 11. In the lower pools, user surveys have identified 'more public access' as one of the top two suggested recreation improvements (Upper Mississippi River Basin Association, Recreation in the Upper Mississippi River System: An Overview of Facility Needs, July 1983).*

While this does not directly address the availability of recreation facilities above and below the locks, it does indicate the general need for additional sites.

TABLE 4-22: RECREATION LOCKAGE TIME AND NEED FOR LANDING BY LOCK SITE

Lock Site and Direction		Average 1990 Rec. Lockage Time (Min.)	No. Craft Per Lockage (both directions)	Need of Boat Landing ("no" indicates adequate facilities currently exist)
11	US	16.2	3.31	no
	DS	16.4		no
12	US	13.2	2.47	no
	DS	13.2		IL side lacks landing for 17 mile stretch
13	US	13.5	3.62	no
	DS	13.3		no
14	US	14.9	1.83	no
	DS	14.3		no
14 Aux	US	15.9	3.46	same as above
	DS	15.5		same as above
15	US	23	1.71	no
	DS	23.5		no
15 Aux	US	15.7	3.35	same as above
	DS	15.8		same as above
16	US	15.2	1.83	IL side lacks landing for 9 mi
	DS	14.3		no
17	US	13.8	1.7	IL side lacks landing for 10 mi
	DS	13.1		no
18	US	12.2	1.94	no
	DS	11.3		no
19	US	23	2.28	no
	DS	20.1		no
20	US	15.8	1.96	IL side lacks landing for 16 mi
	DS	13.9		no
21	US	14.7	1.81	no
	DS	10.7		no
22	US	14	2.07	MO side lacks landing for 7 mi
	DS	12.8		IL side lacks landing for 5 mi
24	US	14.3	2.2	no
	DS	14		IL side lacks landing for 8 mi
25	US	12	2.71	MO side lacks landing for 9 mi
	DS	11.7		no
MEL PRICE	US	14.6	2.86	no
	DS	15.5		IL or MO side, 1 inadequate site available
MEL PRICE Aux	US	22.5	2.7	same as above
	DS	17.6		same as above
27	US	17.8	2.27	no
	DS	18.1		no
27 Aux	US		2.13	same as above
	DS			same as above
Average	US	15.9	2.4	
UMR 11-25	DS	15.0		

TABLE 4-22 (Continued)

Lock Site and Direction		Average 1990 Rec. Lockage Time (Min.)	No. Craft Per Lockage (both directions)	Need of Boat Landing ("no" indicates adequate facilities currently exist)
LOCK-PORT	US	31.9	1.82	No landings for 20 mi
	DS	26.1		no
BRAN-DON	US	31.4	1.72	no
	DS	26		No landings for 9 mi
DRES-DEN	US	21	2.44	no
	DS	20.1		no
MAR-SEILLES	US	27.5	2.51	no
	DS	22.1		no
STARVED ROCK	US	19.8	2.22	no
	DS	18.7		no
PEO-RIA	US	12.7	2.64	no
	DS	13.1		no
LA GRANGE	US	13.8	2.35	No landings for 8 mi
	DS	12.7		No landings for 9 mi
Average Illinois	US	22.6	2.2	
	DS	19.8		

The Institute for Water Resources (1989) report, *An Analysis of Recreational Boating Impact on Navigation Lock Performance*, highlighted some of the areas needing to be considered in determining the ability of additional facilities to address lock congestion. As part of the study, boaters using the locks were interviewed. The boaters indicated that most of their use of the system was on weekends, that many travel relatively long distances with the average trip distance of over 40 miles on water, and on average they had relatively larger craft with the average length of boat over 26 feet.

In December 1992, WES released a report entitled, *Recreational Use of Chickamauga Lock, Tennessee, and Recreational Boaters' Perceptions of Lock Use Conflicts*. While the survey was conducted on a different river system, much of the information seems very applicable to the UMR-IWW System Navigation Study. The survey revealed that the majority of recreational craft using the locks (61 percent) were marina-based, while only 18 percent of lock users originated their trips from boat ramps. When the users were asked if additional boat facilities would increase use of the locks, they indicated that additional marinas would increase the use of the lock facilities while additional boat ramps would have little impact on the number of recreational craft lockages. While this varies somewhat based on the site-specific conditions at each lock, this assessment was generally supported by the lockmasters.

The Waterways Experiment Station completed a draft report, *A Study of Water-Based Recreation on the Upper Mississippi River (Pools 7 and 8),* in September 1995. The study found that the recreational craft using the locks were primarily larger boats with greater than 300 horsepower (i.e., marina-based cabin cruisers). In contrast, the craft using the boat ramps averaged around 16 feet long and 80 horsepower. In addition, many of the lock users were coming from farther upstream or downstream. Of the boats locking through Lock 6 during the study, approximately 30 percent originated in Pools 3 and 4 and 20 percent in Pool 8. While this likely varies a great deal by lock, it indicates that the placement of additional boat landings within the pool may have little impact on the lock usage in this reach of the river.

In the early 1980s, as part of the *Comprehensive Master Plan for the Management of the Upper Mississippi River System*, the Upper Mississippi River Basin Commission studied the use of the river by recreational craft. A survey conducted as part of that effort indicated that while

managers and providers of recreational facilities felt that additional boat access points would help reduce recreational craft lockages, the majority of recreational users were unsure (63 percent) of the effects. However, both groups felt more ramps and marinas would lead to increased recreational usage of the river. The study also found that if commercial use of the locks increases, less recreational craft would use the locks.

Most of this information is in agreement. While some reduction in the number of recreational craft using the locks may be possible through the placement of additional boat ramps, significant reductions are not likely. In addition, there is the potential to further increase the number of recreational users in the areas around the lock, possibly negatively impacting safety. Some of the studies also highlight that many of the boats using the locks are marina-based and the presence or absence of landings is unlikely to affect their movements. The information also raises the issue that many recreational craft users appear to be fairly time sensitive and many may simply not use the locks if there are long delays.

In order to produce a time savings, the number of recreational craft lockages needs to be reduced and not just the number of recreational craft using the locks. Currently, on average two to three recreational craft are in the chamber for each recreational lockage. If traffic is reduced based on constructing new landings, there is no delay reduction unless the number of lockages is reduced. See Table 4-20 for information on the number of lockages per year.

Conditions Affecting Implementation. Several conditions could potentially impact the ability to provide additional ramps. The reaction of the recreational boating community is a major factor that will affect the overall impact of constructing additional landings. As some of the information summarized above indicates, recreational craft use the locks for a variety of reasons (e.g., enjoy lockages, marina based, want to use neighboring pool, and traveling long distances) and may have their desire to lock altered significantly by the presence of congestion and extended delays. In addition, a real potential exists that additional facilities may only further increase recreational boating levels and, as a consequence, conflict with commercial navigation. This may even increase recreational lockages. Further analysis is needed to determine the likelihood of an additional facility to reduce the number of recreational lockages, since at most sites on average two to three recreational craft are present in each lockage.

The development of new recreational facilities at formerly unused sites may present significant site-specific environmental impacts. However, the presence and extent of any impacts would not be known until an actual site and plan are selected.

Costs. The following tables summarize the expected costs associated with the development of a new boat landing at a currently undeveloped site. The estimated construction cost of $270,000 and annual operation cost of $12,500 are based on recent Corps construction and operations activities plus some contingencies. This cost does not include land cost for the boat landing site or environmental costs. These costs were not included because the specific sites where a new landing would be constructed were not identified as part of this analysis.

TABLE 4-23: FIRST COSTS OF DEVELOPING A BOAT RAMP AND PARKING LOT

Item	Cost
Site Location (identify & purchase if required)	Varies Based on Site
Construction	$180,000
Contingency 25%	45,000
Subtotal	225,000
Planning, Engineering, and Design (15% of project costs + 5% inspection)	45,000
Total First Costs (not including site acquisition)	$270,000

The estimated life of the ramp is approximately 30 years, at which time replacement of just the ramp is expected to cost approximately $30,000. This estimate is based on information from the past 5 years, during which time the Corps has replaced and rehabilitated eight boat ramps in the Rock Island District at an average cost of approximately $30,000 per ramp. The need for rehabilitation results from increasing damage to older facilities resulting from larger boats with increased prop wash, cumulative damage over time related to erosion and use, and desired improvements related to better serving the larger boats that are now using the river.

The annual costs include funding for ranger patrol of the site; a service contract for toilets; and vandalism, road, and flood repair. However, user fees will help to offset these costs. In 1995, the Corps began collecting user fees at some boat ramps. The fees of $2 per launch or $25 for a season pass generated $13,820 in the Rock Island District alone. However, only the funds in excess of the costs of establishing collection sites and providing monitoring, $6,225, will be used for maintenance at the recreation sites. The first year's fees were only collected for part of the season and the initial costs of establishing the system were incurred, so in future years the portion of the revenue for maintenance of the facilities should increase substantially.

TABLE 4-24: ANNUAL O&M COSTS OF A BOAT RAMP AND PARKING LOT

Item	Cost
Operation & Maintenance (ranger patrol; flood road & vandalism repair, toilets)	$12,000
Fee Collection	(2,000)
Subtotal	10,000
Contingency 25%	2,500
Total Annual O&M Costs	$12,500

The costs to develop and maintain additional boat facilities would likely be at Federal cost due to the difficulties associated with identifying a private operator to construct a ramp in the specific areas being considered. However, current regulations require a 50/50 cost share of any new construction with a sponsor. In addition, the sponsor must assume operation and maintenance responsibilities and costs, required by Public Law 89-72, as amended and supplemented by the Water Resources Development Act (WRDA) of 1986. If this measure is recommended, a request for an exception to the above stated laws could be made allowing for Corps ownership and operation of the sites.

Relationship to Other Measures. This measure can be combined with virtually all other measures. The possible exception would be if the location of a new landing area conflicted with the placement of mooring cells or tie-off areas for commercial barges waiting for lockages, engaging in self help, or using switchboats.

Conclusions. The primary benefits of the construction of additional boat landings would be a limited number of sites where there the current absence of adequate facilities is resulting in additional lockages. In addition, existing data do not strongly support the concept that additional landings will provide benefits in reducing the number of recreational lockages.

Optimizing Decisions

Optimizing decisions focuses on identifying how the existing system can be used more effectively to reduce delays and minimize transit times through the system. The 3-up/3-down policy, which is currently implemented when warranted by the presence of adequate queues, provides an example of

an optimizing decision. The policy of 3-up/3-down takes advantage of the fact that same direction lockages, where tows going the same direction are locked after one another, are generally faster than alternating between tows headed in opposite directions (this is especially true at low-head dams where chambering times are fast). The following section summarizes the potential to develop a computerized scheduling program to minimize delays during specific traffic situations present at a lock. These measures would not be required at all times, but their implementation would be triggered by the presence of delays which occur with varying frequencies at most lock sites.

- **Scheduling Program**

Description of Measure. The use of a scheduling program could achieve time savings by optimizing the sequence of the particular vessels present at a lock or series of locks. It would use a personal computer-based scheduling program that would develop a scheduling sequence for tows in a queue based on mathematical modeling of various types and configurations of queues. The potential delay reduction varies considerably based on the type of queue present, configuration of tows, weather, currents, etc. Scheduling primarily assists in maximizing lock efficiency, which can be achieved in a number of ways depending on the goals of the program. Two general approaches can be taken.

Under the first approach, the primary benefit of scheduling would be minimizing approach and reconfiguration times. For example, scheduling could result in a higher percentage of turnback lockages that generally take significantly less time than exchange lockages. Additional time savings could be achieved by locking recreational craft together and placing tows requiring only a single cut at the beginning and end of an N-up/N-down series. This type of program would provide flexible and responsive scheduling that would assist in maximizing throughput and reducing delays. A second approach would be to schedule tows to reduce delay per tow, delay per barge, or delay per loaded barge. Under this approach, the throughput remains relatively unchanged, but delay as defined by the criteria can be reduced.

The existing regulations for the navigation system, 33 CFR 207.300, state that the normal procedure for the system will be that vessels arriving first shall be locked first. However, the lockmaster may depart from this procedure when warranted. The regulations also state that recreational craft will not be required to wait for more than three commercial lockages before being locked through. In many cases, recreational craft are locked between every commercial lockage, and they can use the chamber when it is being turnbacked for the second cut of double lockages or the next tow. While these recreational craft lockages typically take a relatively short amount of time, approximately 15 minutes, they do impact the overall scheduling.

The proposed scheduling program would likely be housed and maintained in one location (i.e., a district office) and the locks would have on-line access to run the program as needed. This program would be used to assist in best managing variations in traffic levels at a lock. The computer program would be operated on a semi-real-time basis to produce a form of interactive scheduling. For example, during periods of low usage, the program would not be needed and a simple first come, first served policy could be used. As traffic increases and queues develop, a 3-up/3-down scheduling rule might be implemented. If queues persist or grow even longer, the scheduling program could be used to recommend and determine if other procedures would better maximize the locking facility and reduce delays. Depending on the level of detail in the scheduling algorithm, the program could provide detailed information on the specific lockage order of the particular tows.

While a program could be developed to schedule a specific lockage time for each tow at each lock as a form of system trip planning, this approach is not desired due to the variability in traveling the river and potential for unforeseen events that would result in the need to continually modify the schedule for all tows on the system. However, the program could optimize a group of

locks systemically. This type of scheduling would allow for closer coordination between locks so that tows are processed through the system and not just from one queue to the next.

A potential benefit of a detailed system model would be that it could be designed to maximize net benefits to the nation (NED). A sophisticated scheduling algorithm could be developed to reduce total delay time (per tow, per barge, etc.), reduce delay costs, maximize lock throughput, etc.; however, its use would require increased amounts of information on the type of barge, commodities carried, and operating costs of a particular tow.

Delay Reductions Methodology/Time Savings Estimates. The expected benefits of a scheduling program include the potential to improve on the current N-up/N-down policy in minimizing approach and exit times and to better optimize the system based on a particular scheduling approach (e.g., reduce average delay per tow, reduce per barge delay, etc.)

Several sources of data were evaluated to provide information on the potential time savings available for implementing a scheduling program. These sources, discussed in detail in this section, included: the 1981 Lewis Berger & Associates, Inc., report entitled, *Inventory of Potential Structural and Non-Structural Alternatives for Increasing Navigation Capacity - Upper Mississippi River System Master Plan*; the 1974 Daggett, *et al.* report entitled, *Use of Tow Sequencing Procedures to Increase the Capacity of Existing Lock Facilities*; the 1994 Ting and Schoneld draft report entitled, *Effects of Tow Sequencing on Capacity and Delay at a Two-Chamber Lock;* and the 1990 LPMS data. This section summarizes the findings and results of these sources.

Lewis Berger & Associates, Inc. (1981) summarized a 1960s test on the Welland Canal, connecting Lake Erie and Lake Ontario, which sought to minimize delay times by giving priority to tows and vessels with the shortest lockage times. While it did not involve the use of a computer program, it used alternative scheduling to maximize the lockage rate. The result of this test was that a greater tonnage could be transported in a given time using this method compared to a standard first come, first served basis. These results are related to the fact that a slow locking tow can significantly delay an entire queue of tows. However, if slower tows are required to wait a relatively short period of time to allow other vessels to lock, the additional delay does not significantly affect their overall transit times.

In 1974, WES developed a real-time scheduling system for use by lock personnel to determine the optimal order in which to schedule tows waiting for a lock. The system that allowed direct data entry into a terminal for analysis was used for Lock 51 on the Ohio River. The program was developed to schedule tows from a queue based on various scheduling criteria (e.g., minimize total waiting time, minimize wait in barges per minute, minimize total waiting costs, etc.). The program allowed the lockmaster to analyze the scheduling using the various criteria and provided the second and third options. This information increased the lockmaster's flexibility (especially in meeting unanticipated or uncontrollable situations such as outdraft, adverse weather, etc.) while still utilizing the program's capabilities. The study concluded that a computer-based program could significantly reduce transit times (total waiting time plus lockage time) at locks based on its ability to evaluate and make determinations of a large amount of data in a short time period. While only expanding system throughput by approximately 2 percent, the report estimated that better scheduling of tows could produce an average transit time savings of approximately 16 minutes per tow.

A 1994 University of Maryland draft report on the *Effects of Tow Sequencing on Capacity and Delay at a Two-Chamber Lock* summarized the benefits of using a scheduling program to maximize lockage efficiency. The program assessed the benefits of scheduling following two separate strategies: shortest processing time first and maximum saving or fastest throughput of a chamber in barges per unit time. The results of this study indicate that delay time savings of over 70 percent are possible using these scheduling approaches over a first come, first served policy at a two-chambered lock. However, these savings are significantly overstated in terms of the UMR-IWW System, since some efficiency measures such as 3-up/3-down are currently implemented in delay situations and very few locations have two chambers.

In evaluating the benefits of a scheduling program, Lewis Berger and Associates, Inc. (1981) were not able to identify significant changes in capacity. They estimated that implementing the measure might only increase lock capacity by approximately 3 percent. However, the use of scheduling can reduce various delays (e.g., delay per tow, minimize delay time per barge, reducing total delay cost, etc.). They also found diminishing returns as progressively more detailed scheduling is undertaken. In a separate assessment of the incremental benefits of various N-up/N-down policies, they found that the greatest benefits are associated with changing from 1-up/1-down to a 2-up/2-down, 3-up/3-down, or 4-up/4-down. These measures provide approximately 50 percent, 66 percent, and 75 percent of the potential benefits, respectively. While additional efficiencies are possible, they are incrementally smaller than the initial benefits of implementing a scheduling measure.

The use of a scheduling program does provide the opportunity to reduce delays in more ways than simply trying to lock the most tows through in the least amount of time. It can be used to minimize delays per tow, minimize delay per barge, maximize the lockage rates in tons of commodities, minimize total delay costs, etc. While many of these different approaches would produce similar results, they do vary to some extent and may provide different types of benefits to the nation and incentives for industry (e.g., to reduce empty backhauls, reconfigure tows to maximize lock usage, etc.).

Currently scheduling in the form of an N-up/N-down policy is employed most frequently at the lower locks on the system when queues warrant its use. These times typically occur following an accident, during lock downtime for repair, or during periods of high traffic movements. Many of the lockmasters reported that its use already exceeds 10 percent of the year at their sites, with some of the highest usage reported for Peoria and La Grange Locks.

Table 4-25 provides estimated potential time savings associated with better scheduling by evaluating approach and exit times using 1990 LPMS data. The time savings of replacing exchange lockages with turnbacks is approximately 8 minutes on single lockages and 16 minutes on doubles for the UMR Locks 11-25 (excluding Lock 19). IWW time savings are a little larger with potential savings of 10 minutes for single lockages and 19 minutes on doubles. However, this does not account for the extra time associated with turning back the chamber of 8 minutes for the UMR and 14 minutes for the IWW, which reduces the time savings. In addition, not all tows realize this lockage time savings because scheduling only increases the percentage of turnback lockages. Some exchange lockages still must occur. Moreover, some of the time savings is already accounted for by existing turnbacks and the periodic use of an N-up/N-down policy. Due to the number of variables involved in determining the actual time savings, the study's systems models would be required to fully evaluate what these types of time savings mean in terms of reducing delays at locks.

Conditions Affecting Implementation. Frequently, the lockmasters vary scheduling from first come, first served to various N-up/N-down procedures. While a 3-up/3-down scheduling system is often used during congested periods, a great deal of flexibility actually exists depending on the requirements of the situation. In many instances, this procedure is modified in coordination with the River Industry Action Committee (RIAC) to implement a more suitable procedure, such as 6-up/1-down or 4-up/4-down, when conditions and queue dictate. In situations where these alterations are already made, it greatly reduces the potential incremental benefits associated with the use of a scheduling program. The requirements of locking recreational craft after every third commercial lockage also impact the effectiveness of scheduling programs since each commercial cut is considered a separate lockage. Changing the requirement to, recreational craft shall be provided a lockage after every third lockage or two double lockages, would provide lockmasters more flexibility on when to work in recreational craft lockages.

TABLE 4-25: TIME SAVINGS (MIN) ASSOCIATED WITH REPLACING EXCHANGE WITH TURNBACK APPROACHES AND EXITS

Lock Site	Single Approach			Single Exit			Single Total	Double Approach			Double Exit			Double Total	Cham-ber
	Exch	Trnbk	Sav-ings	Exch	Trnbk	Sav-ings	Sav-ings	Exch	Trnbk	Sav-ings	Exch	Trnbk	Sav-ings	Sav-ings	Turn-back
11	8.2	4.4	3.8	6.5	6.2	0.3	4.1	13.7	8.4	5.3	21.3	20.4	0.9	6.2	9.2
12	9.5	5.3	4.2	8.0	5.1	2.9	7.1	16.7	10.7	6.0	25.0	20.2	4.8	10.8	8.0
13	8.8	2.6	6.2	5.9	5.1	0.8	7.0	14.3	5.5	8.8	23.4	20.6	2.8	11.6	8.2
14	8.6	2.6	6.0	8.6	5.6	3.0	9.0	17.2	6.5	10.7	31.3	23.8	7.5	18.2	8.5
15	16.0	4.0	12.0	9.4	6.9	2.5	14.5	31.2	5.6	25.6	28.2	24.1	4.1	29.7	9.7
16	7.2	3.2	4.0	5.8	5.2	0.6	4.6	18.5	7.4	11.1	23.1	20.8	2.3	13.4	7.9
17	10.2	4.0	6.2	10.0	5.9	4.1	10.3	24.7	11.8	12.9	27.6	21.5	6.1	19.0	7.0
18	10.3	3.4	6.9	6.1	5.5	0.6	7.5	20.3	9.0	11.3	23.6	21.8	1.8	13.1	7.5
19	26.5	13.9	12.6	13.7	9.1	4.6	17.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.2
20	10.9	4.8	6.1	8.0	4.6	3.4	9.5	20.2	9.2	11.0	27.7	22.2	5.5	16.5	7.8
21	9.9	3.9	6.0	6.0	3.7	2.3	8.3	22.6	9.9	12.7	25.3	22.5	2.8	15.5	6.2
22	9.7	4.5	5.2	10	5.4	4.6	9.8	25.8	11.5	14.3	30.6	22.7	7.9	22.2	6.9
24	8.0	3.2	4.8	8.5	5.4	3.1	7.9	19.4	7.3	12.1	26.5	21.9	4.6	16.7	9.7
25	8.4	3.0	5.4	4.3	4.0	0.3	5.7	18.2	6.3	11.9	24.2	21.6	2.6	14.5	9.0
Mel Price	14.3	4.7	9.6	11.1	7.7	3.4	13.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.4
27	15.9	4.1	11.8	11.6	7.8	3.8	15.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11.6
Lockport	9.7	4.4	5.3	8.0	5.6	2.4	7.7	20.3	9.4	10.9	37.8	26.6	11.2	22.1	21.3
Brandon	10.2	5.8	4.4	9.8	6.3	3.5	7.9	21.1	12.2	8.9	33.3	25.4	7.9	16.8	19.4
Dresden	9.4	5.5	3.9	8.2	5.3	2.9	6.8	15.1	8.5	6.6	30.4	25.6	4.8	11.4	13.5
Marseilles	11.4	4.8	6.6	11.0	5.7	5.3	11.9	18.3	7.3	11.0	34.6	32.8	1.8	12.8	17.9
Starved Rock	11.4	2.7	8.7	8.6	5.0	3.6	12.3	18.8	4.1	14.7	29.8	23.5	6.3	21.0	13.7
Peoria	10.6	3.6	7.0	9.1	6.0	3.1	10.1	20.7	5.6	15.1	31.9	25.5	6.4	21.5	7.9
La Grange	12.9	4.2	8.7	10.2	6.1	4.1	12.8	22.4	6.5	15.9	35.1	25.0	10.1	26.0	6.7
Avg UMR 11-25*	9.7	3.8	5.9	7.5	5.3	2.2	8.1	20.2	8.4	11.8	26.0	21.9	4.1	16.0	8.1
Avg Illinois	10.8	4.4	6.4	9.3	5.7	3.6	9.9	19.5	7.7	11.9	33.3	26.3	6.9	18.8	14.3

Note: * Avg UMR 11-25 excludes Lock 19.

The use of a computer-based scheduling program has some potential disadvantages. It would likely require additional timely and accurate data and coordination. Depending on how the system is implemented, it could result in a reduction in the flexibility of lockmasters while not being able to fully account for site conditions or crew capabilities. Conversely, a model designed to address site-specific optimization may be too narrow in scope to adequately address system issues. In addition, the use of a scheduling program could impact the equity of service by requiring significant deviation from a first come, first served policy. For example, it may focus on increasing the probability that a single or knockout single lockage would be scheduled as the last tow in an N-up/N-down sequence to minimize recoupling and exchange times.

Costs. The costs of implementing a scheduling program are relatively low and are primarily related to designing, testing, and running the program. These costs would be influenced by how the actual program would be implemented and maintained. Potentially reducing the costs is that

some similar types of scheduling programs have been developed (WES and University of Maryland) and could serve as a starting point. However, even if a developed model were used, it would still require additional efforts to adapt it for use on the UMR-IWW Navigation System. Table 4-26 summarizes the estimated first costs to develop a scheduling program for the system based in part on available information and models. In addition, an annual maintenance cost of $35,000 per year is anticipated to upgrade the model and provide some additional training to lock personnel.

TABLE 4-26: FIRST COSTS OF COMPUTERIZED SCHEDULING PROGRAM

Cost Item	Cost
Study	$253,000
Construct Model, Test, Refine, and Develop Manual	130,000
Training of Lock Staff	57,000
Subtotal	440,000
Contingency 25%	110,000
Total First Costs (not including site acquisition)	$550,000

Relationship to Other Measures. The use of a scheduling program would be compatible with virtually all other measures, and in some cases additional time reductions could be obtained through joint implementation. For example, the use of extended guidewalls and helper boats, which can eliminate the need to remake tows before exiting the chamber, would greatly benefit from joint implementation with scheduling which maximizes the number of turnback lockages. The scheduling of recreational craft or other measures to reduce their use of the locks could also assist in increasing the efficiency of moving commercial vessels through the locks.

Conclusion. Most of the benefits of a scheduling program are already being obtained by the use of a flexible N-up/N-down policy. However, scheduling does provide benefits to the system and should continue in some form.

STRUCTURAL SMALL SCALE MEASURES

Extended Guidewalls

A guidewall is generally a concrete wall extending upstream and downstream in line with the landside wall of the lock chamber. On the UMR and IWW, the guidewalls are on the landside of the approach channel. They are typically 600 feet long each to match the length of the chamber, but may be as long as 1,200 feet for those locks with 1,200-foot chambers (see Figure 1-4, Typical Lock Configuration). These walls are used by the towboats to physically guide their fleet of barges into the lock chamber in a straight line. If the barges are not straight, they may not fit in the chamber. (The lock chamber is typically 110 feet wide and a full tow of barges is typically 105 feet wide.) Approaching vessels face up against the guidewall in preparation for entry into the lock. Sometimes vessels tie up against the guidewall while waiting their turn into the lock. Guidewalls often have armor plating to protect them from the constant rubbing of the barges.

Guidewalls are also used to tie off unpowered cuts. An unpowered cut is a section of barges (usually 9 of them) that is taken from the front end of the towboat's 15-barge group and locked through without a towboat attached to them. These cuts fill the whole lock and must be pulled out or extracted by tow haulage equipment or assist boats. The unpowered cut is pulled out along the guidewall and tied off there, waiting for the towboat and its remaining barges (the powered cut) to lock through. When the powered cut is finished locking through, the gates open and the two halves are reattached. However, since the unpowered cut and guidewall are each 600 feet long, the second, powered cut remains partially inside the lock chamber while the two cuts are reattached. This means that the lock can not be used for other vessels until the two cuts are secured to each other and the towboat, now with its full fleet of 15 barges, moves out of the lock area.

Description of Measure. Extending existing 600-foot guidewalls to 1,200 feet allows the powered cut of a double lockage to make up with the unpowered cut completely outside of a 600-foot lock chamber. The lock is therefore free to turn back for the next vessel (traveling in the same direction) and is not impeded by the tow makeup on the guidewall. This is the major time savings benefit from this measure that works best when combined with other small scale measures such as powered kevels, unpowered kevels, switchboats, or industry self help that move the unpowered cut to the end of the extended guidewall.

The following text briefly describes the benefits of extended guidewalls. Immediately following this section is the joint benefits that result from combining this measure with various tow haulage options (e.g., powered and unpowered kevels). The benefits in combination with various towboat power options were discussed previously.

Delay Reductions Methodology/Time Savings Estimates. References used in evaluating the potential benefits from extended guidewalls include the following: 1) 1993 *Mississippi River Locks and Dams 11-22 Approach Improvements Rehabilitation Evaluation Report*; 2) 1995 *Improved Tow Haulage Equipment Interim Report*; 3) 1975 report on *Evaluation of Operational Improvements at Locks and Dam No. 26, Mississippi River*; 4) 1990 LPMS data; 5) interviews and lock site visits with lockmasters and navigation industry representatives; and 6) expert elicitation meeting.

The actual total time savings associated with extended guidewalls can be broken down into four components: 1) the reduction in approach time; 2) the reduction in the extraction time of the first cut; 3) the reduction in chambering time for the downbound powered cut by faster emptying of the chamber (the first cut is removed from the lock discharge area); and 4) the reduction in the remake of double lockage tows by allowing remake to occur outside the chamber along the

extended guidewall. There is also some potential to benefit the reconfiguration of setover and knockout single lockages.

Approximately 80 percent of all commercial lockages in the study area require a double lockage where the tow is locked through in two stages, an unpowered first cut and the powered cut. Opportunity exists to reduce turnback exit delays at locks with extended guidewalls when there is a means of extracting the unpowered first cut to the end of the extended guidewall. Extraction of the first cut can be done with tow haulage, switchboats, or industry self help. This opportunity to reduce turnback exit delays to waiting tows is seen in Tables 1-1 and 1-2, derived from the 1990 LPMS data. The information in these tables shows the increase in commercial traffic and in the percentage of turnback lockages as traffic moves to the lower end of the navigation study area on the UMR and IWW. As noted, Peoria and La Grange Locks have navigable pass, which accounts for the smaller number of tows processed through the lock at these sites.

Reduction in Approach Time. The lengthening of the guidewall provides two elements of time savings in the approach. First, the longer wall gives a larger "landing surface" for the tow to steer towards. Depending on which side of the chamber (landside or riverside) the guidewall is placed and the outdraft at the time of approach, the tow may be able to make a faster approach at a larger target. Safety is also enhanced if the tow is able to get on the guidewall sooner. Secondly, the tow will be able to stage itself just outside the lock chamber for a turnback lockage because it can fit on the entire wall (and not have any part of the tow "hanging off" the wall). When the lock is turned back, the tow will be able to move in immediately instead of leaving the bank, mooring buoy, or river's edge to make its approach. The approach time savings with extended guidewalls is site-specific and is included in the "Approach Channel Improvements" section of this report.

Reduction in Extraction Time of the First Cut. The potential for reduction in the extraction time of the first cut is directly attributable to other small scale measures in conjunction with extended guidewalls. Improved tow haulage assumes the presence of extended guidewalls as a structural base for the tow haulage system that extracts cuts more efficiently as well as farther along the extended guidewall. The potential reduction in the extraction time of the first cut with improved tow haulage is addressed in "Tow Haulage Equipment" which follows this section on extended guidewalls.

However, improved tow haulage is not the only possible means for faster extraction of the first cut. Switchboats and self help are other measures that can be used in combination with extended guidewalls to extract the first cut faster from the lock chamber.

The guidewall extension costs have to be included with those measures that assume the presence of 1,200-foot guidewalls.

Reduction in Chambering Time (Faster Emptying for Downbound Lockages). Typically, the rate of emptying the chamber is reduced when an unpowered cut is waiting below the lower lock gates for the powered cut to be locked through. The concern over creating turbulent water and possibly snapping lines is eliminated if the unpowered cut is pulled to the end of the extended guidewall by switchboat or tow haulage for remake. The time savings is dependent on the head differential and location of discharge. At lower flows, when the head differentials are greatest, the time savings would be greatest. At higher flows, there would be little or no savings. On average, a savings of 0 to 2 minutes would be likely at most UMR locks. Larger time savings are possible at some of the IWW locks where head differences are greater. The average savings for both the UMR and IWW locks is 1 minute.

Remake of Double Lockage Tows (Outside the Lock Chamber). A time savings is obtained with extended guidewalls by pulling first cuts to the end of the extended wall (with tow haulage or additional towboat power) so that the second cut can remake with the first cut without

occupying the chamber (see Figure 4-7A). This alleviates the current condition at locks with 600-foot guidewalls where a double lockage tow is unable to exit the chamber until it has remade its couplings, keeping the chamber from servicing other tows. This savings is only realized for turnback lockages where the next tow to be serviced is going in the same direction. If the next lockage is an exchange, going in the opposite direction, no time is saved since the tow is blocking the approach during its remake along the extended guidewall.

The potential time savings associated with moving the remake area out of the chamber was timed and estimated in the 1975 report on *Evaluation of Operational Improvements at Lock and Dam No. 26, Mississippi River*. This report showed a possible savings of approximately 15 minutes for upbound tows and 13 minutes for downbound tows at Lock 26. This resulted in a reduction of chamber exit times for upbound tows from 26 to 11 minutes and for downbound tows from 25 to 12 minutes.

LPMS data were used to estimate the potential time savings of moving the remake out of the chamber. In order to estimate the time savings, the actual exit times of the second cut (which includes the remake time) of double lockages were used and compared with the exit times of singles. Data from turnback lockages were used for these calculations, since the timing is stopped when the tow clears the miter gate, reducing variability associated with exchange and approach points. Results from an analysis of the LPMS data showed the potential time savings. Based on the expert elicitation and interviews with lockmasters, the exit time of singles serves as a close approximation of the exit time of the exit of the powered second cut of double lockages if the first cut has been removed a sufficient distance from the chamber. Using the 1990 LPMS data for the UMR and IWW locks and the formula below, average time savings of 16 minutes for upbound tows and 18 minutes for downbound tows were calculated. This savings represents a reduction in the existing tow exit time for the second cuts from 22 and 24 minutes to about 6 minutes, respectively, for upbound and downbound tows.

Time Savings = Existing Exit Time of 2nd Cut (including remake) - Exit of Single

The new remake time changes by lock site are shown in Table 4-30: Cost and Performance of Extended Guidewalls-Remake Time Improvement, from which the time savings are determined for normal flows.

The estimated time savings in remake time for double cut tows remaking along an extended guidewall is supported by field data collected from February 27 to March 14, 1995. During this time period, a switchboat was used to pull cuts along the 1,200-foot guidewalls at Melvin Price Locks and Dam near Alton, Illinois, on the UMR during a closure of the main 1,200-foot lock. The 1,500-horsepower switchboat pulled the first cut of double lockages from the 600-foot auxiliary lock chamber to the end of its 1,200-foot guidewalls. The switchboat held the cut at the guidewall until the second powered cut exited the lock chamber and remade with the first cut along the 1,200-foot guidewall, outside the lock chamber. During this period, timing data were obtained for 42 double lockages (see Table 4-27, Melvin Price Locks and Dam Timing Data). The timing data obtained for 32 of these double lockages (when the lock gate was recessed and the powered cut started its exit from the chamber to when the tow stern was over the gate sill) averaged 5.50 minutes or 5:30 (minutes, seconds). The close approximation of the powered cut exit time to that of a powered single is significant and supports the contention that the "Savings in Remake Time" with extended guidewalls is equal to the "Existing Exit Time of Second Cut" (including remake) minus the "Exit of a Single Tow."

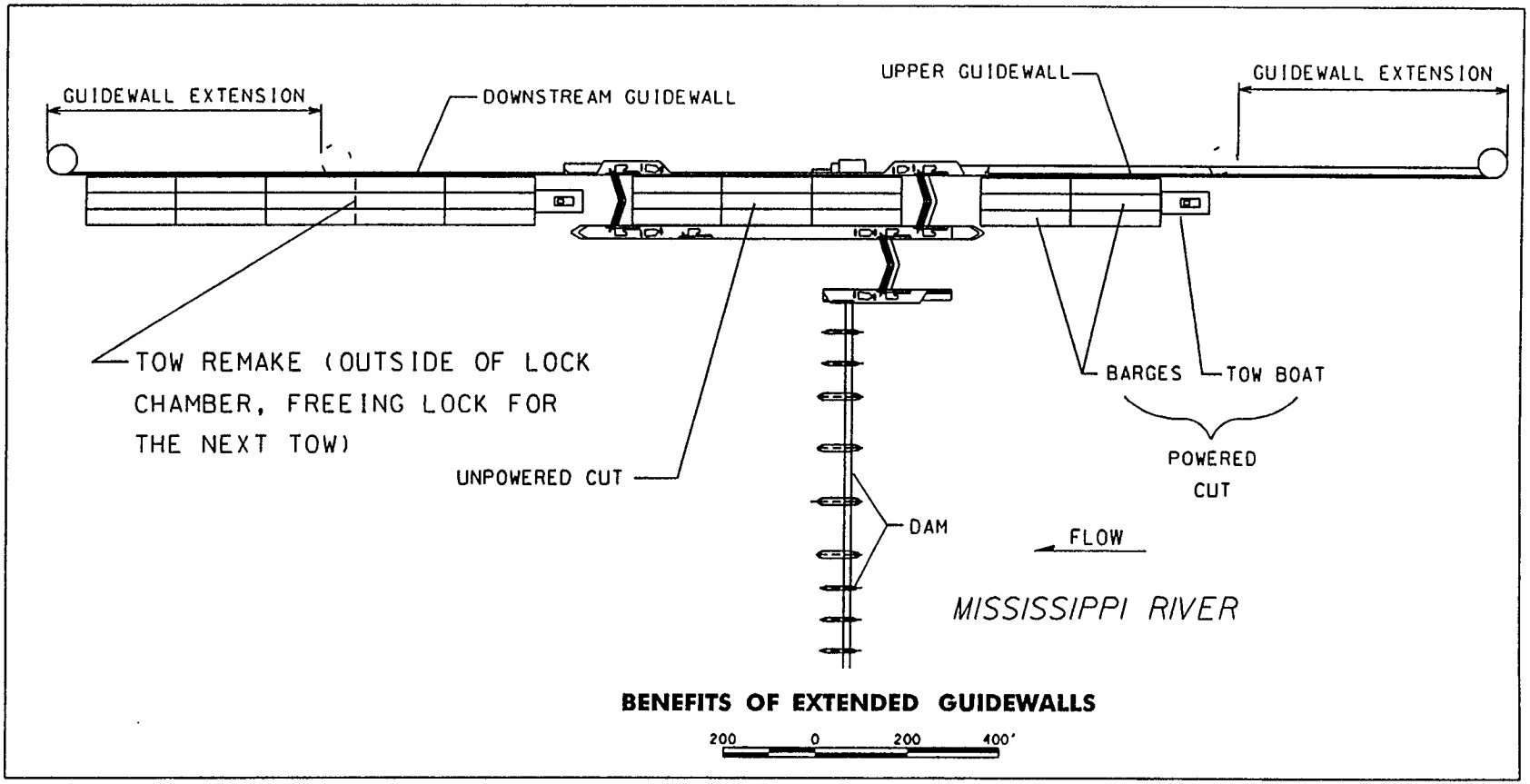


FIGURE 4-7A: Benefits of Extended Guidewalls

TABLE 4-27: MELVIN PRICE LOCKS AND DAM TIMING DATA

Upbound

Date	Obser No.	Gate Reces'd to 2nd Cut Begins Exit Minutes	2nd Cut Begins Exit To Tow Stern Over Sill Minutes	Tow Stern Over Sill to Cuts Bump Together Minutes
2/28/95	1	0.32	6.22	1.53
2/28/95	2	0.67	4.67	1.33
2/28/95	3	0.15	5.15	2.42
3/1/95	2	0.20	3.73	1.62
3/2/95	7	0.50	3.82	1.08
3/2/95	8	-	5.63	1.68
3/3/95	1	0.47	5.13	0.87
3/10/95	1	0.18	5.70	4.75
3/10/95	2	0.65	5.22	4.65
3/10/95	4	0.38	4.65	1.98
3/10/95	5	0.50	4.20	2.30
3/10/95	7	0.37	3.52	2.73
3/13/95	5	0.25	4.57	3.85
3/13/95	7	0.18	5.32	2.63
Average		0.37	4.82	2.39
		0.37 + 4.82 = **5.19** minutes		

Mel Price Locks and Dam
Timing Data
Downbound

Date	Obser No.	Gate Reces'd to 2nd Cut Begins Exit Minutes	2nd Cut Begins Exit To Tow Stern Over Sill Minutes	Tow Stern Over Sill to Cuts Bump Together Minutes
2/27/95	4	1.10	5.62	3.63
3/2/95	2	0.65	5.57	2.73
3/2/95	3	0.62	4.58	2.67
3/2/95	5	0.80	5.07	2.77
3/3/95	5	0.38	5.13	4.18
3/3/95	7	0.38	6.23	3.30
3/3/95	8	0.47	4.95	2.28
3/8/95	2	0.62	4.72	3.70
3/8/95	3	0.78	5.13	3.80
3/8/95	4	0.60	4.23	2.87
3/8/95	6	0.55	3.87	2.77
3/8/95	8	0.53	5.08	3.08
3/9/95	1	0.45	4.70	3.77
3/9/95	2	0.58	6.30	4.58
3/13/95	3	0.78	6.38	3.63
3/14/95	3	0.37	4.18	2.83
3/14/95	6	0.58	5.67	3.03
3/14/95	7	0.60	6.17	3.30
Average		0.60	5.20	3.27
		0.60 + 5.20 = **5.80** minutes		
Average, Upbound and Downbound			(5.19 + 5.80)/2 = **5.50** minutes	

Reconfiguration of Setover and Knockout Singles. In addition to the saving to double lockage tows highlighted above, guidewall extensions provide some savings potential to setover and knockout single tows. This savings is provided by allowing the tow types to reconfigure into a 600-foot arrangement on the guidewall rather than in the lock chamber. Table 4-39 highlights the site specific exit benefits that average 23 minutes for setovers and 7.5 minutes for knockouts. In some cases, these benefits could be doubled if the tows could reconfigure prior to entering the chamber as well. However, the impact of these savings is limited due to the relatively small number of tows in this category and the fact that in some cases the lock would be available prior to the completion of the reconfiguration.

Conditions Affecting Implementation. The condition affecting the implementation of upstream and downstream guidewall extensions at a lock site is, in fact, the resulting impact that the extensions impose at that lock site. For example, if an extension makes the tow approach/exit unsafe or severely impacts the flow conditions above or below the dam, the extension is not recommended. Lockmaster input was solicited on the applicability of guidewall extensions at specific lock sites.

Guidewall extensions are applicable to the UMR lock sites with the following exceptions:

Lock 15. The upper guidewall extension would consist of two guide cells above the existing guidewall to provide a pivot point to assist tows on their downbound approach to the lock located on the inside of a bend in the river channel.

Lock 19. A 1,200-foot lock. Extended guidewalls are not needed for remaking tows that pass as a single lockage, nor does the orientation of the lock to the approach accommodate 1,200-foot guidewalls. The upper guidewall extension would be either a 100-foot extension on the riverside lockwall or a 500-foot extension angled landward from the landside lockwall. Either helps to direct downbound tows into the lock. A model study recommends a ported upstream guardwall at this lock. For the lower approach, a 600-foot extension of the riverward lockwall will protect upbound tows from the dam outflow.

Melvin Price Locks. Both the main 1,200-foot lock and the auxiliary 600-foot lock have 1,200-foot guidewalls.

Guidewall extensions are applicable to IWW locks with the following exceptions and/or notations:

Lockport Lock. The upper approach wall is a long (longer than 1,200 feet) curved concrete wall with tie-off posts. A straight extension is not practical as the extension restricts the flow area and is a potential hazard to navigation. A straight extension of the lower guidewall, also slightly curved, is not recommended because the extension impedes the flow area below the dam to a width of approximately 150 feet and is a potential navigation hazard. Even if feasible, guidewall extensions would be of limited benefit due to the few turnback lockages experienced at this site.

Brandon Road Lock. Extending the upstream guidewall may require widening the existing guidewall, which is only 4 feet wide, especially if tow haulage is added. Extension of the downstream guidewall could worsen the hard push entrance into the lock if the narrow channel is not widened. Extensions would be on opposite side lockwalls that could cause operational problems with lock personnel assistance to deckhands.

Dresden Island Lock. A lower guidewall extension is not recommended because the extension may adversely impact a downbound tow's exit turn and approach to the narrow channel span of the Elgin, Joliet & Eastern Railway bridge just downstream of the lock.

Marseilles Lock. The existing lock/channel orientation requires extension of opposite side guidewalls: the existing upstream riverward guidewall and the existing downstream landward guidewall.

Starved Rock Lock. A downstream extension is possible but may be better suited to two guide cells. Cells assist with alignment into the lock chamber and perhaps lessen the impact from the dam outflow that tends to pin tows along the existing downstream guidewall. Cells also accommodate landside drainage.

Costs. Various factors affect the costs of guidewall extensions, including: (1) the existing conditions (existing guidewall lengths and required extension lengths); (2) type of wall, guidewall or guardwall; (3) wall design details for rock or sand foundations; and (4) impacts to navigation. These factors are discussed below.

(1) Existing Conditions. Tables 4-28 and 4-29 list the sites under study for small scale measures to include extended guidewalls. The existing guidewall lengths are shown, as well as the additional length needed to give an effective guidewall length of 1,200 feet. The effective length is the riverward projection of the wall or the actual length of wall extending from the end of the lock riverward wall.

(2) Guidewall Versus Guardwall. While the tables below refer to the needed guidewall extension lengths to make 1,200-foot guidewalls, a 1,200-foot guardwall will also allow double cuts to remake outside the lock chamber. Guidewalls and guardwalls are similar in both design and in function and mainly differ in location. While a guidewall is an extension of the lock chamber landside wall, a guardwall is an extension of the lock chamber riverside wall. Therefore, a guardwall is a wall structure located on the riverside of the approach channel. Upstream guardwalls are constructed with openings below the waterline. These openings allow water to flow from the approach channel out through the wall openings toward the dam gates. This flow (outdraft) tends to pull a downbound vessel against the guardwall, helping to align the vessel for entry into the lock. A guardwall also helps to prevent tows or breakaway barges from approaching the dam gates. There is some incremental benefit to safety and approach time with a 1,200-foot guardwall above the lock versus a 1,200-foot guidewall. The reduction in approach time with a guardwall is addressed in the "Approach Channel Improvements" section of this report.

In general, because a guardwall can trap debris and ice above the lock, many lockmasters feel the benefits of 1,200-foot guidewalls outweigh the benefits of guardwalls. The extra cost of a 1,200-foot guardwall versus the cost of a 600-foot guidewall extension must be incrementally justified by the additional benefits from a guardwall. A 1,200-foot guardwall or a guidewall extended to 1,200 feet both provide the same opportunity to extract the first cut of a double lockage faster with tow haulage or additional towboat power. Also, both provide the opportunity for double cuts to remake along the 1,200-foot wall, leaving the lock chamber free for the next turnback approach. Both provide these opportunities, but the extended guidewall is the least cost option and is used in the cost and performance analysis of moving the remake area outside the lock chamber.

For continuity, the design concept and design details, similar for both the guidewall extension and a guardwall, are discussed together in the following paragraphs.

TABLE 4-28: PROJECT LOCATIONS AND EXISTING\EXTENDED GUIDEWALL LENGTHS UPPER MISSISSIPPI RIVER

			Length of Existing Guidewall		Guidewall Extension Required	
Lock	River Mile	Location	Upper (ft)	Lower (ft)	Upper (ft)	Lower (ft)
11	583.0	Dubuque, IA	510 +626 @ skew	500	690	700
12	556.7	Bellevue, IA	517	500	683	700
13	522.5	Fulton, IL	517	500	683	700
14	493.3	Le Claire, IA	517	500	683	700
15	482.9	Rock Island, IL	490	718	CELLS	482
16	457.2	Muscatine, IA	517	500	683	700
17	437.1	New Boston, IL	517	500	683	700
18	410.5	Gladstone, IL	517	500	683	700
19	364.0	Keokuk, IA	0	480 @ skew	NA	NA
20	343.2	Canton, MO	517	500	683	700
21	324.9	Quincy, IL	517	500	683	700
22	301.2	Saverton, MO	517	500	683	700
24	273.4	Clarksville, MO	518	516	682	684
25	241.5	Cap au Gris, MO	512	516	688	684
Mel Price Aux. Lock	200.8	Alton, IL	1200	1200	NA	NA
27 Aux.Lock	185.5	Granite City, IL	600	600 Main Lockwall	600	1200

TABLE 4-29: PROJECT LOCATIONS AND EXISTING\EXTENDED GUIDEWALL LENGTHS-ILLINOIS WATERWAY

Lock	River Mile	Location	Length of Existing Guidewall		Guidewall Extensions	
			Upper (ft)	Lower (ft)	Upper (ft)	Lower (ft)
Lockport	291.0	Lockport, IL	1000	444	NA	NR
Brandon Rd	286.0	Joliet, IL	598	594	602	606
Dresden Is	271.5	Morris, IL	578	594	622	NA
Marseilles	244.6	Marseilles, IL	600	597	600	603
Starved Rock	231.0	Ottawa, IL	598	594	602	606 or Cells
Peoria	157.7	Peoria, IL	500	500	700	700
La Grange	80.2	Versailles, IL	625	550	575	650

(3) Design Details. Two guidewall/guardwall concept designs were developed. One design was based on a rock foundation and the other on a pile foundation driven in sand. These designs are significantly less expensive than the "traditional" wall designs that use a mass concrete gravity wall design for the entire length of the wall. Here, precast concrete beams are utilized to span between sheet pile cells to create the walls. Although further design refinement is possible, investigations to date indicated that basic stability requirements will limit the amount of additional material and cost savings in subsequent design phases.

Guidewall/Guardwall Concept for Rock Foundations. The concept for the rock-founded guardwall is adapted from the sand-founded guidewall concept described below and from a pile-founded guidewall design paper submitted at the 1995 Corps of Engineers Structural Engineering Conference. As discussed before, the primary difference between the guardwall and guidewall depends on the location of the wall. Usually the guardwall is placed on the riverside to prevent the tows from being drawn into the dam. The design is for the system navigation study, but quantity calculations were made based on site-specific elevations for the individual lock sites under study. The conceptual design for the rock-founded guidewall is shown on plate 28.

For the downstream guidewall extension, the substructure is comprised of 35.5-foot-diameter sheet pile cells spaced at a distance of 100 feet and founded on limestone. The cells derive their overturning stability from the cell diameter and mass. The bottom of the cell will be filled with tremie concrete to assist in stability and provide a seal to prevent the leakage of the concrete fill. Above the tremie seal, the sheet pile cells will be concrete filled. Precast concrete beams will span between cells, forming a wall. The beams can be formed from abrasion-resistant concrete and will also be armored for additional abrasion resistance. Inside the cell at the chamber side edge of the cell, concrete will be placed for the full height of the cell for support of the precast beams. The cell will be provided with a reinforced concrete cap to aid in cell structural integrity and stability. Manholes will be built into the concrete cap for inspection purposes and as an access for replacing fill material if required.

At least two prestressed concrete box beams will span between the sheet pile cells. Concrete columns will provide support between the beams. A wearing surface for the top of the beams can

be constructed or placed using precast sections or cast-in-place concrete. Handrails, checkposts and lights will be added to complete the guidewall.

A steel skirt will be provided to the upstream guardwalls to block off flow from the water line to a minimum depth of 11.0 feet. This skirt will reduce the volume and velocity of the water going through the guardwall, preventing tows from becoming "pinned" on the wall during lock entry and exit. A sheet pile wall will block the flow between the cells entirely for landside guidewalls. The steel skirt of the guardwall utilizes a braced, half-inch steel plate to reduce the amount of water flow through the sheet pile cell openings. The guidewall is located landside and utilizes braced sheet piling as a soil retaining wall or water flow cutoff depending on if the wall is used as a soil retaining wall. The preliminary design for the anchored soil retaining wall uses a PZ40 sheet pile and the water flow cutoff wall uses a PZ35 sheet pile.

A 54.29-foot-diameter cell will be constructed at the end of the guidewall to resist collisions from tows. The cells will be entirely filled with concrete to increase the mass of the cell for improved impact resistance. The beam and panel system will be continued to this end cell. A 1.75-inch-thick steel plate will wrap 180 degrees around the end cell to protect the sheets from impact.

For the upstream guidewall extension, "steel cans" are used at greater spacing, incorporating larger cans for intermittent protection during the navigation season. This allows the upper extension to be constructed over three or four winter lock closure periods, eliminating impacts to navigation.

Guidewall Concept for Sand Foundations. The following text briefly describes the guidewall concept used for sand/pile-founded foundations. The concept was adapted from the guidewalls used at Melvin Price Locks and Dam and is also adaptable to a guardwall on a sand/pile-founded foundation. The guidewall concept for sand foundations is shown on plate 29 that is adaptable to a 1,200-foot guardwall design. Plate 30 shows a design concept for a rock-founded 1,200-foot guardwall.

For the downstream guidewall design, the superstructure is composed of precast concrete beams that span approximately 80 feet between bearing points. The beams are stacked vertically like bulkheads, but will transfer their weight only to the bearing points and not along the length of the previously placed beam. Keyways will transfer lateral load between beams. The beams are armored to resist abrasion and impact.

The substructure or bearing is composed of the precast concrete bearing block that is supported by two high capacity, cast-in-place concrete piles each with an approximate diameter of 42 inches. Both the bearing block and the piles can be increased in size if required by more detailed analysis. The piles will be permanently cased with ¾-inch steel pipe. More detailed analysis could reduce or eliminate the length of casing required, resulting in a possible cost savings. The bearing blocks are precast concrete shells that are lowered onto the completed concrete piles, leveled, and filled with tremie concrete. They will be outfitted with pre-attached bearing devices (not designed at this level of investigation) that can be adjusted by divers to level the bearing surface. Each bearing point, 100 feet center to center, is backed up by a 35-foot-diameter sheet pile cell that is filled with crushed stone and capped with a ring of reinforced concrete. The ring will reinforce the top of the cell against impact and keep the middle of the cell open for visual inspection for settlement of fill material. The cell will be designed to resist the lateral load from barge impact. For this concept, it was sized with reference to similar cells already constructed. There will be a gap between the completed cell and the vertical surface of the stack of guidewall beams that will be filled with concrete or grout. A method of forming this area to receive concrete is to use a bladder (reinforced fabric bag) that will conform to the irregularly shaped gap. The bladder and concrete will be lodged in place by blocks welded to certain sheet piles and by deformations formed into the backside of the concrete beams. The bladder will remain in place. Alternatively, the connection can by formed by pneumatic forms that will also

conform to the irregular configuration of the connection. They will function more like conventional formwork in that they will form the perimeter of the gap and be removed once the concrete has achieved sufficient strength.

To achieve more energy absorbing characteristics (flexible guidewall), the gap between the cell and the stack of beams could be closed by marine fenders that will deform upon impact. The deformations can be large with heavy impact loads. Many fender geometries are available that could be mounted to adjustable steel framework that in turn would be mounted to the sheet pile cell. The large deflection of the fenders will induce moments into the concrete bearing piles that must be considered in a detailed analysis.

The top guidewall beam will have a tension strap connection to the reinforced concrete ring on the top of the cell to resist the possible rebounding effect that the stack of beams could experience upon heavy barge impact. In order for the rebound-restraining device to work for the entire stack of beams, post-tensioning rods will be installed vertically through the ends on the beams and anchor into the bearing seat. A more detailed analysis of the internal stability of the stack of guidewall beams could eliminate both the tension strap and the post-tensioning anchors.

The end cell of the guidewall is approximately 57 feet in diameter and is filled with concrete and founded on H-piles. The cell will be designed to resist impact from a fully loaded 15-barge tow. The cell will be notched during construction at the bearing seat in order to receive the stack of guidewall beams.

The upstream guidewall extension incorporates a greater number of larger cells. These cells provide intermittent protection during the navigation season. This allows the upper extension to be constructed over three or four winter lock closure periods, thus eliminating impacts to navigation during construction of the wall extension.

Extended Guidewall Costs. Cost estimates were prepared for extending the existing landside guidewalls at each of the lock sites. These estimates are based on the guidewall designs for rock or pile-founded foundations as shown on plates 28 and 29. The estimates reflect rock-founded conditions at Locks 14, 15, 20, 22, 24 and 27 in the UMR and the IWW locks except Peoria and La Grange. Unit prices are similar to those used for the guidewall construction cost estimates for the extension of the existing lock (Reference: *Large Scale Measures of Reducing Traffic Congestion, Conceptual Lock Designs, Interim Report*, July 1996). Estimates include a construction contingency of 25 percent. The average cost for the guidewall extensions (both upstream and downstream together) for a UMR pile-founded sand foundation lock site is about $37 million. The average first cost for rock foundation lock sites on the UMR (both upstream and downstream together) is about $33 million. The average cost for all applicable IWW sites (both upstream and downstream) is $23 million. Table 4-30 "Cost and Performance of Extended Guidewalls - Remake Time Improvement" shows costs for specific lock sites. In addition to the first cost, annual maintenance is estimated at $30,000 per guidewall or $60,000 per lock.

TABLE 4-30: COST AND PERFORMANCE OF EXTENDED GUIDEWALLS - REMAKE TIME IMPROVEMENT

Lock Site		Length (ft)	Cost [1] ($1,000's)	Impacts to Navigation[2] ($1,000's)	Existing Remake Time Double Cuts Turnback Exits		New Remake Time (2nd Cut Exit Chamber) Turnback Exit of Single	
					Mean Values	Std. Deviation	Mean Values	Std. Deviation
11	US	690	22,070	0	19.9	6.2	5.8	2.3
	DS	700	13,116	0	20.9	6.7	6.6	2.8
12	US	683	27,310	0	17.7	5.4	4.8	1.9
	DS	700	12,884	0	22.1	7.3	5.9	2.9
13	US	683	22,730	0	18.8	7.4	5.3	2.8
	DS	700	13,138	0	22.1	7.3	5.0	1.7
14	US	683	22,100	0	22.4	7.4	5.2	2.1
	DS	700	11,178	0	25.1	8.3	6.1	2.8
15	US	NR	NR	NR	20.7	5.8	NR	NR
	DS	482	7,726	0	27.2	7.3	7.6	2.2
16	US	683	21,330	0	19.4	7.4	5.4	2.4
	DS	700	12,754	0	22.0	6.5	5.2	2.4
17	US	683	23,580	0	20.2	6.3	6.2	2.5
	DS	700	16,753	0	22.8	6.4	6.0	2.3
18	US	683	22,230	0	20.7	6.6	6.1	2.9
	DS	700	13,263	0	23.0	7.7	5.3	2.3
19	US	NA	NA	NA	NA	NA	NA	NA
	DS	NA	NA	NA	NA	NA	NA	NA
20	US	683	23,070	0	19.9	8.0	4.6	2.9
	DS	700	10,904	0	24.3	7.3	4.8	2.5
21	US	683	22,880	0	21.4	7.4	3.9	2.1
	DS	700	13,690	0	23.6	8.4	3.7	1.6
22	US	683	24,000	0	21.3	7.1	5.0	2.2
	DS	700	12,226	0	24.0	7.2	5.8	2.8
24	US	682	20,200	0	21.0	7.2	5.0	2.5
	DS	684	10,640	0	22.8	6.7	6.3	3.0
25	US	689	27,000	0	20.5	6.9	3.7	2.2
	DS	684	14,328	0	22.5	9.6	4.4	3.3
MEL PRICE	US	NA	NA	NA	10.4	8.7	NA	NA
Aux Lock	DS	NA	NA	NA	7.7	5.5	NA	NA
27	US	600	13,500	0	5.1	3.0	NC	NC
Aux Lock	DS	1,200	30,000	0	6.4	4.0	NC	NC
LOCKPORT	US	NR	NR	NR	28.3	12.8	NR	NR
	DS	NR	NR	NR	24.3	11.8	NR	NR
BRANDON RD.	US	602	10,988	62,180	25.4	9.0	6.3	3.4
	DS	606	13,060	62,180	25.3	11.1	6.4	3.1
DRESDEN IS.	US	622	9,667	62,180	25.7	8.9	5.7	1.7
	DS	NR	NR	NR	25.5	13.7	NR	NR
MARSEILLES	US	600	10,366	62,180	25.3	10.2	5.2	2.4
	DS	603	11,620	62,180	25.4	11.3	6.3	4.4
STARVED RK.	US	602	9,393	62,180	23.4	10.4	5.1	3.6
	DS	606	10,528	62,180	23.6	10.7	5.0	1.8
PEORIA	US	700	12,440	80,700	23.9	9.6	6.4	3.6
	DS	700	13,009	80,700	27.2	11.4	5.7	2.2
LAGRANGE	US	575	11,367	80,700	23.3	11.1	6.9	6.3
	DS	650	11,630	80,700	26.8	13.5	5.6	2.4

US = upstream, DS = downstream, NA = not applicable, NR = not recommended, NC = no change

NOTES:

1. The environomental impacts are not included in the costs since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side. The cost for towboat power or tow haulage must be added for extracting the first cut to the end of the extended guidewall.

2. These costs are for switch boats, helper boats and temporary remote remake areas. Also included are economic impacts to the navigation industry (i.e., delays and closures) that are shown on construction timelines at Appendix D.

3. A lower guidewall extension is infeasible as a stand-alone improvment measure at Lock 17. Channel work would also be required for tow access to the extended wall. The channel work cost is included.

(4) **Impacts to Navigation During Construction of Extended Guidewalls.** Under this small scale measure, the upstream and downstream guidewalls at an existing lock would be extended to 1,200 feet to reduce congestion at the lock. While efforts were taken to minimize lock closures and delays, construction activities would likely have some adverse impact on navigation during construction. However, to the extent possible, construction activities are planned to occur during the 90-day winter closure (15 December to 15 March) when only limited amounts of traffic use the system.

The upstream guidewall extensions were originally assumed to require some significant periods of lock closure during the navigation season due to the time requirements for constructing a 600-foot wall extension. On reevaluation, an alternative was developed to stage construction over three to four winters. This would be accomplished by constructing 150- to 200-foot segments during the winter closure, starting from the end of the existing guidewall. An adequately sized cell would be constructed on the upstream end of the segment so that regular vessels could use the extended wall during the navigation season until the following winter when construction could resume. Some increased level of risk is involved with winter construction, and the potential for ice conditions to adversely impact construction is a possibility.

The construction of the downstream guidewall extension can occur more easily during the winter, since ice conditions are less severe in the lower pool. As planned for the upstream wall, the lock would be completely closed from 15 December to 15 March to complete the work. Crews would work two 10-hour shifts/day for 6 days per week. Inclement weather delays were also included.

Construction of extended guidewalls would involve work lasting 2 years for downstream guidewalls and 3 to 4 years for upstream guidewalls. The construction contracts would be at least one year longer to allow for planning, submittals, equipment procurements, template construction, ordering of precast beams and steel sheet piles, and adjustment time for the towing industry.

A construction schedule was developed that shows critical path activities that cause impacts (delays to navigation). The construction durations assume that for each wall one sheet pile driving floating plant is available and a separate floating plant would fill sheet pile cells and otherwise construct the cells. A floating plant with an H-pile driver would be used for two end cells.

Relationship to Other Small Scale Measures. Extended guidewalls relate to many other small scale measures for reducing the lock transit time of commercial traffic. Extended guidewalls alone allow for a safer lock approach and reduce the lock approach time, as detailed in the "Approach Channel Improvements" section of this report. Extended guidewalls, together with dike fields or other outdraft reducing measures above a lock, further reduce the lock downbound approach time. The lock chamber turnback time is faster for a turnback exit lockage with extended guidewalls if tow haulage or additional towboat power (switchboats or industry linehaul boats) is available to extract the first cut to the end of the extended guidewall. Unpowered kevels with extended guidewalls also allow for a quicker turnback of the chamber for a turnback exit lockage.

Conclusions/Summary. Extended guidewalls appear to be one of the most effective small scale measures for reducing lock transit time, especially when combined with other small scale measures as discussed above. Table 4-30 summarizes the costs and new remake times by lock site. The revised standard deviation is proportional to the ratio of the new mean remake time to the existing mean remake time.

DeLong Piers (An Alternative). DeLong Piers can be used as a temporary guidewall extension at a lesser first cost (Table 4-6B) than the traditional construction costs for guidewall extensions shown in Table 4-30. The structural integrity of DeLong Piers, however, limits their use as a potential time saver to combinations with switchboats or other towboat power options. The piers

also require higher levels of maintenance while potentially reducing safety and reliability. See the section on Switchboats with Guidewall Extensions for a description and costs of DeLong Piers.

Tow Haulage Equipment

Tow haulage equipment is the name given to any number of mechanical devices used to pull unpowered cuts of barges from the lock chamber. These devices transfer force from some land-based power source to the unpowered barges through a mechanical connection. The most common of these devices is a single line cable winch, which is presently used at the UMR-IWW lock sites. An improvement in tow haulage equipment for extracting first cuts of double lockage tows requires extended guidewalls plus new tow haulage equipment of one of several alternative designs. This combination removes the first cut more efficiently and farther from the lock chamber, reducing lock chambering time during tow remake. Two measures for improving the current tow haulage operation were evaluated: Powered Traveling Kevel and Endless Cable.

Unpowered Kevels are added as outgrowth of discussions on Tow Haulage Equipment and Extended Guidewalls and are evaluated later in this section.

- **Powered Traveling Kevel**

Description of Measure. 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 kevel is a rail-mounted kevel that provides power to extract the unpowered cut of barges from the lock. The current winch system and length of cable are eliminated. A lengthened guidewall with a powered kevel on rail allows the unpowered cut to be pulled a greater distance from the lock chamber. An unpowered kevel riding the same rail ahead of the powered kevel would hold the head of the unpowered cut along the extended guidewall as the cut moves down the wall.

- **Endless Cable**

Description of Measure. Endless cable systems extract unpowered cuts from the lock chamber by attaching the unpowered cut of barges to a fitting on the cable. This continuous cable is already in place and is powered to remove the cut. Endless cable systems eliminate the need to haul the cable off the drum in the current tow haulage systems. The unpowered cut is therefore removed more efficiently. An endless cable system would have greater benefit if combined with a guidewall extension to allow the powered cut to remake with the unpowered cut outside the lock chamber.

Background. The 1995 interim report, *Improved Tow Haulage Equipment,* assessed the technical feasibility of improvements to tow haulage equipment, *including the use of powered traveling kevels and endless cable systems*, and the resulting impacts to transit times in the locking process on the UMR and IWW. This effort included visiting other locks to observe various types of existing and improved tow haulage systems, collecting timing data, developing alternative configurations for the tow haulage, and evaluating these configurations with respect to locks within the study area. For this interim report, it was assumed that guidewalls would be extended to 1,200 feet and would be designed to serve as the foundation for a chosen tow haulage configuration. The findings from this interim report and other work on improved tow haulage equipment are presented here.

Current tow haulage equipment on the UMR and IWW generally were not designed for the efficient regular handling of unpowered cuts of river barges. The existing system consists of a single line winch, one each, located just above the upstream miter gate recess and just below the

lower miter gate recess. Once the first (unpowered) cut of the tow has been brought to the new pool level, the cable from the winch is passed to a deckhand on the cut. The deckhand secures the cable to a deck fitting near the stern of the first barge or the bow of the second barge in the cut. After the line is snugged, the winch is brought up to speed (generally about 50 feet per minute). The winch, in effect, whips the cut out of the lock chamber. This is due to the fact that once the point of connection passes the winch station, the winch can no longer exert a pulling force on the cut. Normally, the momentum of the cut of barges is sufficient to cause the entire cut to drift out of the lock chamber. Most of the winches in operation on the inland waterway system are rated at a top speed of 100 fpm. In practice, they are operated at a speed of 50 fpm because of safety concerns and the inability of the system to apply a restraining force to the barges.

Most 600-foot chamber lock sites in the study area have an unpowered traveling kevel on the upper guidewall. This kevel is mounted on a rail on the top of the guidewall and holds the head of the unpowered cut close to the guidewall while the cut is being extracted from the chamber. This counteracts the effect of outdraft which is prevalent at many lock sites. Outdraft is the current along the upstream guidewall that tends to pull a towboat or cut of barges away from the guidewall and towards the dam. The greater the amount of water flowing through the dam, the greater the outdraft will be. The 600-foot chambers in the study area that do not have an unpowered kevel on the upper guidewall include the auxiliary locks at Locks and Dams 26 and 27 on the UMR and the locks at Lockport, Brandon Road and Marseilles on the IWW. Dresden Island Lock has an unpowered kevel on the lower guidewall as well as the upper guidewall.

Tow Haulage Configurations Analyzed. To investigate alternative tow haulage systems, lock and dam sites were visited within the Ohio and Lower Mississippi River Divisions. These lock sites included Pickwick Locks and Kentucky Lock on the Tennessee River, David D. Terry Lock on the Arkansas River, Locks 7 and 4 on the Allegheny River, Montgomery Locks on the Ohio River, and Barkley Lock on the Cumberland River. These sites incorporate differing tow haulage configurations (kevel and rail layout) and either the endless cable or the pull/retard systems to power the kevel. Operations personnel were satisfied with the system in use at their particular lock site. However, these power systems have distinct differences in their makeup as will be discussed later.

Several possible tow haulage configurations could apply to the "standard lock" which has a 600-foot chamber and 1,200-foot guidewalls (existing guidewalls extended) on each end. The entire length of available wall is therefore 3,000 feet. The location of the guidewalls (riverside or landside) is assumed to have no impact on the cost of the tow haulage. The cost of the guidewall extensions, however, is impacted by location and will be addressed later in this report.

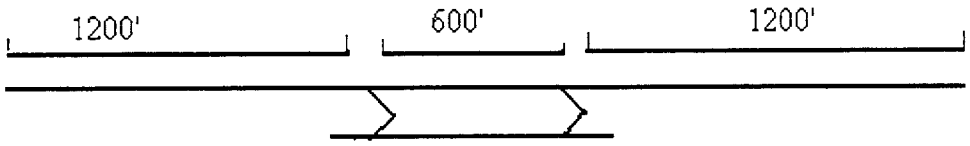
The powered traveling kevel extracts the unpowered cut in either direction using a rail-mounted device (kevel) that is powered by a winch and a cable system. This system is the most common one in use in the United States on locks that require multiple cut extractions.

Four configurations of tow haulage were studied and are identified below. For reference, they were named for the hundreds of feet that they cover. They are:

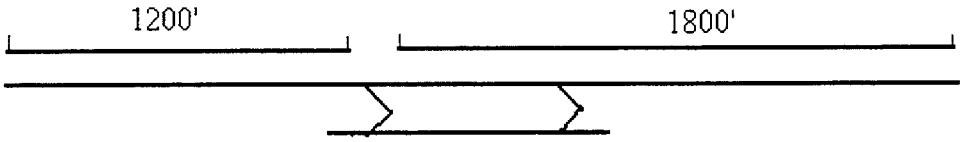
CONFIGURATION I	"12-6-12"
CONFIGURATION II	"12-18"
CONFIGURATION III	"30"
CONFIGURATION IV	"12-N-12"

("N" = utilization of the existing tow haulage system within the lock chamber)

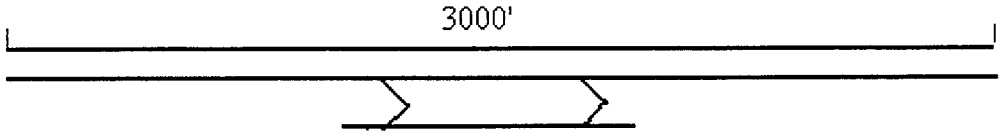
Configuration I "12-6-12." In this configuration, two kevels (one unpowered and one powered) travel the downstream guidewall (one to keep the head checked in and the other to power the cut down the wall). One powered kevel travels the length of the lock chamber for the initial pull. Two more travel the upstream guidewall (one to keep the head checked in and the other to power the cut down the wall).



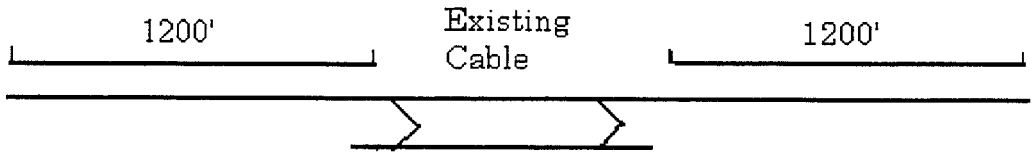
Configuration II "12-18." In this configuration, two kevels (one unpowered and one powered) travel the downstream guidewall (one to keep the head checked in and the other to power the cut down the wall). Two more kevels travel the length of the chamber and the upstream guidewall (one to keep the head checked in and the other to power the cut down the wall).



Configuration III "30." In this configuration, two kevels (one unpowered and one powered) travel the entire 3,000-foot length of the chamber and guidewalls combined (one to keep the head checked in and the other to power the cut down the wall).



Configuration IV "12-N-12." In this configuration, two kevels (one unpowered and one powered) travel the downstream guidewall (one to keep the head checked in and the other to power the cut down the wall). The initial pull from the chamber comes from the existing tow haulage winches with their long lengths of cable. Two more kevels travel the upstream guidewall (one to keep the head checked in and the other to power the cut down the wall).



Selected Tow Haulage Configuration. The "12-18" and "30" configurations were eliminated for the following reasons:

1. In both of these configurations, the rail/cable crosses the miter gate so that when open, the traveling kevel can traverse the gate recess. The rail on the miter gates would be exposed to damage from barge traffic, which on occasion hits the gates. Damage to the rail along the gate would put the tow haulage system out of service and could result in some delay and require self help to be implemented.

2. The process of raising and lowering the cable that spans the gate recess poses a safety concern as well as some duration of time.

3. There is a safety concern created by the raising of the cable as the process of raising the cable generates slack in the cable. This "slack" can cause backlash, excessive cable wear, and potential breakage when the haulage unit is engaged.

4. The long length of the cable in these two configurations would require an extremely large drum, even for the pull-retard system, which can use a multiple layer drum. If the drum and winches could not be recessed in the wall, the drum would cause a view obstruction for the lock operating staff.

5. The "30" configuration does not accommodate a change in wall elevation (lower guidewall) which occurs at some locations.

6. If there were a failure in a component of the tow haulage of these two configurations, double lockages would be very difficult or not possible at all unless self help were implemented.

The "12-6-12" and "12-N-12" tow haulage configurations were selected as configurations for the Navigation Study because:

1. Both configurations provide a "backup" system for double lockages. If the chamber tow haulage unit fails, the guidewall tow haulage unit could still extract the unpowered cut from the chamber.

2. Both do not cross the miter gates, preventing otherwise possible damage to the tow haulage rail from barge traffic hits to the miter gates.

3. Both accommodate changes in wall elevation.

4. Both minimize the drum size, however, these configurations are more expensive since they require more tow haulage units; but the benefits of system redundancy, safety, and minimizing shutdowns due to barge damage should outweigh the cost differential.

Power Units for the Traveling Kevel. Four types of units for powering the kevel were evaluated: 1) endless cable system, 2) pull/retard winch and cable system, 3) traction power system, and 4) cog rail system.

(1) Endless Cable System. The endless cable system in this context is a single drum system that utilizes double lines. This type of system, as seen at Pickwick, Kentucky and Barkley Locks, uses a single wrap on the drum that takes up from one end while it pays out the other end. This system requires a tension device to keep slack out of the cable when it is under a load or pressure rollers on the drum, as seen at Barkley Lock, to align the cable into the drum grooves as the drum takes up cable. The advantage of this system is the need to use only one winch for an entire length of tow haulage rail. The disadvantage is the size of that winch; the 1,000 feet of traveling kevel rail at Pickwick Locks required an 8-foot-diameter winch (because the cable can only have one layer on the drum). At Barkley Lock, 800 feet of traveling kevel rail required a nominal drum diameter of 5 feet and 6 feet in length. The endless cable system also requires additional space for the cable to be returned to the winch. Unless the cable feed and return configuration (horizontal or vertical) can be recessed into the lock/guidewalls, it will take up additional space along the top of the walls. This will present a problem at many of the lock sites in the study area where the top of the guidewall is 5 feet wide. However, the cable feed and return at Barkley Lock was only about 20 inches in separation. This could probably be accommodated within the existing guidewall, requiring additional setback/relocation of existing check posts, handrail, and lights. Of more concern would be the location of the winch drum that could require modification of the lockwalls.

(2) Pull/Retard Winch and Cable System. This system was in use at the Pittsburgh District locks visited: Locks 7 and 4 on the Allegheny River and Montgomery Locks on the Ohio River. This type of power system utilizes a multiple-layer winch on each end of a section of rail. One winch pulls against the other at a reduced torque to maintain a constant tension in the line and prevent slack cable from occurring in the system. The winches can be used in either direction by using a joystick control to reverse the pull/retard duties. The advantages of this system are that it can use smaller winch drums because of the multiple layers of wire that can be put on the drum, and that it has a positive slack reduction method that helps prevent backlash, improper winding, excessive wear, and cable breakage. This system has a display board to show the operating speed of the winch. It is a proven, reliable method for power transfer to a traveling kevel. A disadvantage of this system is the need to maintain two winches (instead of one as for the endless cable system).

(3) Traction Power System. This type of motive force would require the kevel to have its own power unit attached. It could pull the unpowered cut by using rubber tires to drive the kevel along the rail. The advantage of this system is the elimination of long cable runs, cable tension problems, and cable maintenance. The disadvantages include the fact that this is an unproven application for this type of technology, the need for guidewall space for the tires (rubber or steel) to grip the concrete, the weight requirements to provide traction friction, and the remote control mechanism that could be required to operate the device.

(4) **Cog Rail System**. This system would consist of a kevel with its own power unit attached. The power would pull the unpowered cut along a notched rail by using cogs to transfer the load to the rail and guidewall. The advantage of this system is that it does not require a traction force like the tire system. The disadvantages include the expense of a special cogged rail, the redesign of the kevel for use on the new rail, and that it is an unproven application of this technology.

Selected Power Unit for the Traveling Kevel. The Traction Power and Cog Rail systems were eliminated for the primary reason that both are unproven applications of the technology at a lock and dam facility. For the Navigation Study, a proven, reliable system was desired that would impart a high degree of confidence in both performance and associated cost.

The Pull/Retard and Endless Cable systems were both determined to be acceptable for the following reasons:

1. Both use proven technology for operation as demonstrated and observed at the various lock site visits.

2. Both have safety and operational benefits over the present single winch with cable system.

3. Both require minimal space along the wall. Many existing guidewalls as well as the chosen guidewall extension design have a 5-foot top width.

4. Identifiable less cost.

For Navigation Study purposes, the Pull/Retard system was deemed more desirable because:

1. Smaller winch drums are required, allowing continued unobstructed visibility at the lock sites.

2. The system has a slack prevention design that should minimize cable breakage.

3. The single run of cable minimizes space requirements on top of walls. A cable return could require another 18 inches of adjacent space.

The above reasons alone should not eliminate the Endless Cable system from reconsideration during site-specific feasibility studies. Cost trade-offs (two smaller winches versus one larger winch; one cable run versus a double run; perhaps more maintenance needed for two winches versus one, etc.) may give comparable cost estimates, assuming that the larger, single winch and its structural foundation could be reasonably incorporated into the existing lock/guidewall structures and extended guidewall structures. For instance, the single drum winch for the 800-foot Barkley Lock has a spread footing 16 feet by 14 feet by 4 feet deep located 40 feet perpendicular to the lockwall, and such a similar support foundation could be integrated into one of the supporting sheet pile cells for the extended guidewall design concept.

Delay Reduction Methodology/Time Savings Estimates. Four reference sources were used in evaluating the potential time savings for improved tow haulage equipment (powered kevel): the *Improved Tow Haulage Equipment 1995 Interim Report*; *Evaluation of Operational Improvements at Locks and Dam No. 26, Mississippi River*, 1975 report; 1990 LPMS data, and interviews and lock site visits with lockmasters and navigation industry representatives.

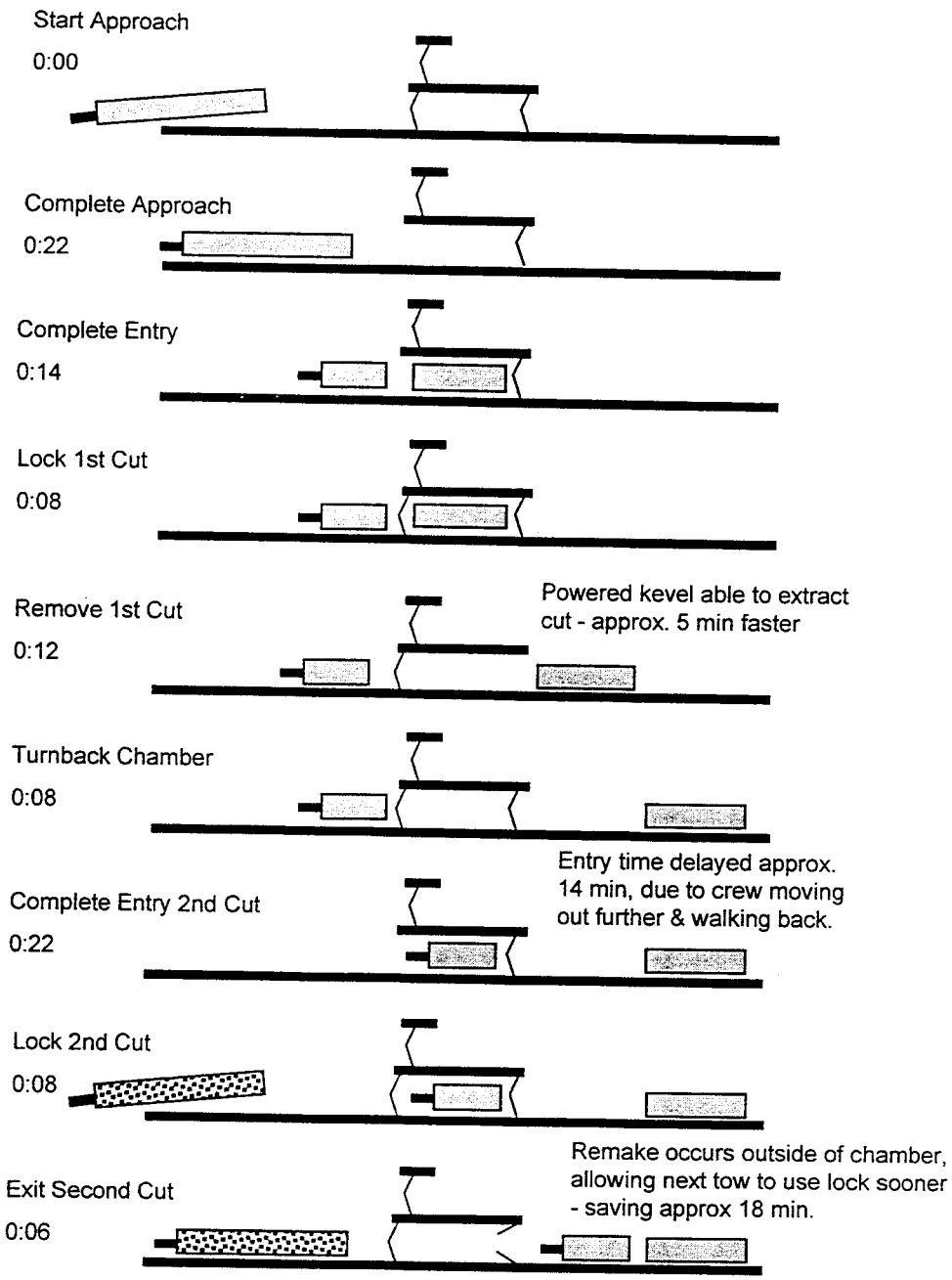
The time savings associated with improved tow haulage on extended guidewalls is derived from the potential for reduced extraction time of the first cut of a double lockage. Extended guidewalls also provide a potential reduction in lock approach time and in the lock chamber service time by allowing the remake of a double lockage to occur outside the chamber. Here, as related to improved tow haulage, only the reduction in extraction time of the first cut is addressed, since the extraction of the first cut is directly attributable to tow haulage. However, since improved tow haulage assumes the presence of extended guidewalls, the guidewall extensions (cost and total benefits) are needed in the final analysis in conjunction with improved tow haulage to realize the maximum time savings benefit.

Extraction of First Cut with Improved Tow Haulage (Powered Kevels). The time savings related to the extraction of the first cut can be achieved with a new tow haulage system. The current "unpowered" kevel/rail systems in the study area can not provide any time savings in the physical extraction of the first cut. However, the efficiency of the first cut removal process could be improved by providing a barge haulage system that can travel the full length of the lock approach wall and can both pull the barges, as well as provide restraint to slow and stop the barges once out of the chamber. Figures 4-7B and 4-7C show the general benefits and savings of powered kevels in combination with extended guidewalls and incremental benefits of additional personnel.

Table 4-31 shows the theoretical extraction time for the existing system operating at 50 fpm with a stopping distance of 400 feet. The existing system can only provide power in the extraction process to the point of location of the winch. At this point (400 feet from the end of the guidewall), the deceleration process begins. The deceleration was assumed to average 25 fpm, therefore taking 16 minutes. For a new tow haulage (power kevel) system operating at 100 fpm on 1,200-foot guidewalls, the stopping zone is clear of the lock gates.

TABLE 4-31: THEORETICAL TOW HAULAGE EXTRACTION TIMES

	Speed (fpm)	Accel. time (min.)	Accel. Dist. (ft)	Haul Time (min.)	Haul Dist. (ft)	Stop Time (min.)	Stop Dist. (ft)	Total Time (min.)	Total Dist. (ft)
Exist. System	50	1	25	5.5	275	16.0	400	**22.5**	700
New System	50	1	25	13.5	675	0.0	0	14.5	700
New System	100	1	50	6.5	650	0.0	0	**7.5**	700
New System	200	1	100	3.0	600	0.0	0	4	700

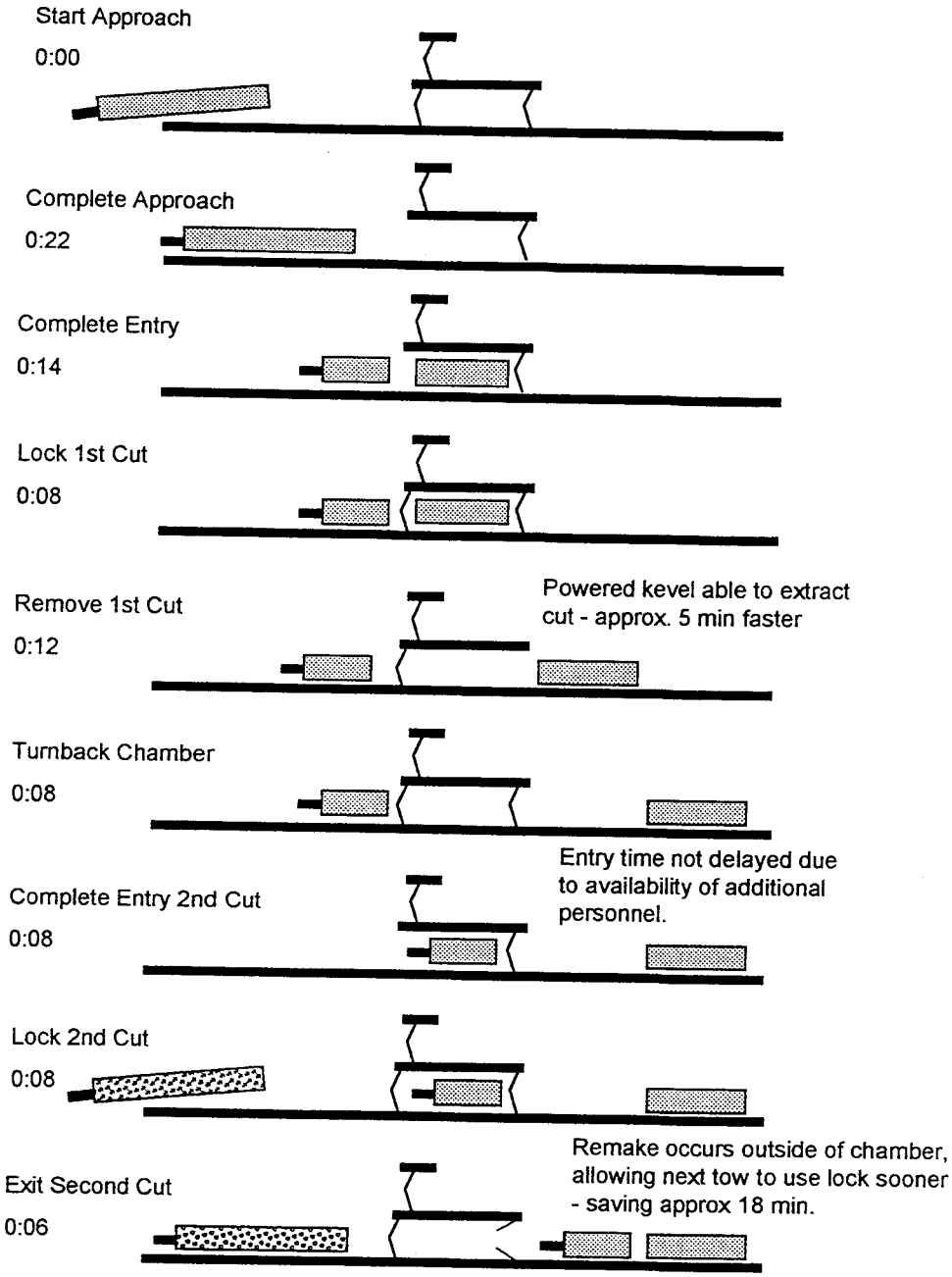


Total Lockage Time: 1:40

Savings with powered kevels is 5-10 minutes. However, remake/exit savings (18 minutes) only benefits system if next tow is traveling in same direction (turnback).

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

FIGURE 4-7B: Double Lockage Elements - Permanent Guidewall Extensions with Powered Kevel



Total Lockage Time: 1:26

Savings with powered kevels is 20-25 minutes. However, remake/exit savings (18 minutes) only benefits system if next tow is traveling in same direction (turnback).

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

FIGURE 4-7C: Double Lockage Elements - Permanent Guidewall Extensions with Powered Kevel and Additional Personnel

The total time of 22.5 minutes represents the theoretical time for the existing system to extract a fully loaded cut of nine barges from the chamber with no braking capability. The 1990 LPMS data show the time for extracting all first cuts with the existing system to average 14 minutes and 17 minutes in the upstream and downstream directions, respectively, for Locks 11 through 25 on the Mississippi River and 13 minutes in the upstream and downstream directions, respectively, for Lockport Lock through La Grange Lock on the IWW. The differences in the above theoretical time and the LPMS times are explained by the fact that: 1) LPMS yearly mean time per lock includes all makeup combinations for the first cut, both in number of barges and number of loaded barges (cuts with less barges and/or empties take less time to extract); 2) the assumed extraction speed is often faster than 50 fpm (70 fpm is about the maximum); and 3) the stopping time of 16 minutes over 400 feet is overestimated. The LPMS times vary by lock site, and these actual recorded times by lock site are used in the final analysis so as not to overstate the potential time savings with improved tow haulage.

The total time of 7.5 minutes from Table 4-31 represents the theoretical time for a new system (powered kevels) operating at a maximum speed of 100 fpm to extract a fully loaded cut of nine barges from the chamber. The 100 fpm maximum speed for a new tow haulage system was confirmed with lockmasters. The 12-6-12 and 12-N-12 tow haulage configurations require double handling of the tow line—once for the initial pull from the chamber and again for the pull down the guidewall. Two minutes are added for double handling of the tow line to give a total theoretical extraction time of 9.5 minutes with the new system.

The theoretical extraction time of 9.5 minutes is consistent with the 1975 timing study at old Lock 26. Over a one-month period, the operation of a traveling kevel was simulated during an upper guidewall extension test by a helper boat extracting the first cuts of upbound doubles. A helper boat was used because the installation of a kevel for the test was not feasible. Since the speed at which the cuts were extracted by the helper boat was inherently faster than a kevel with desired performance characteristics, a mathematical model was used to derive extraction times for the traveling kevel. The model used a top speed of 100 fpm and a maximum line pull of 15 kips, similar to the characteristics of the tow haulage under current study.

The performance characteristics of a tow haulage system (powered kevels) are determined by the capability to accelerate and decelerate the cut. For the old Lock 26 study, the model, with a kevel capable of providing the 15 kip line pull, was able to extract cuts from the chamber in 5 to 10 minutes. The actual extraction time is dependent on the number of empty and loaded barges in the cut and environmental factors. The timing chart shown below, Table 4-32, was developed from the mathematical model and shows the average time in minutes to extract cuts of various numbers of empty and loaded barges. One minute was added to these estimated times for attaching the kevel cable to the cut. The times were rounded up to the nearest 1/2 minute.

TABLE 4-32: OLD LOCK 26 STUDY
EXTRACTION TIMES FOR FIRST CUTS OF DOUBLES

	Number of Barges in the First Cut								
No. Loaded Barges	9	8	7	6	5	4	3	2	1
0	5.5	5.5	5.0	5.0	5.0	4.5	4.5	4.0	4.0
1	6.0	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0
2	6.5	6.5	6.0	6.0	6.0	6.0	5.5	5.5	
3	7.0	7.0	6.5	6.5	6.5	6.5	6.0		
4	7.5	7.5	7.0	7.0	7.0	7.0			
5	8.0	8.0	8.0	7.5	7.5				
6	8.5	8.5	8.5	8.0					
7	9.0	9.0	9.0						
8	9.5	9.5							
9	10.0								

The time shown for extracting a loaded 9-barge cut is 10 minutes. Although site-specific to old Lock 26, this is consistent with the 9.5 minutes for this improved tow haulage analysis.

Time Savings. For the Navigation Study, the LPMS data show higher mean extraction times for downbound cuts than upbound cuts at Mississippi River Locks 11 through 25 and the IWW locks at Peoria and La Grange. This is because more downbound tows than upbound tows are loaded. Therefore, extraction times for the existing tow haulage are typically higher for downbound cuts because there is more mass to move with a loaded cut and there is more water resistance when cuts are loaded to a deeper draft. It is reasonable to assume a similar time difference with improved tow haulage operating at the same force in both directions.

With a powered kevel system, the new extraction time is 9.5 minutes. Using 1990 LPMS data, the time savings for the extraction of the first cut of a double lockage at the lock sites can be given by:

For Upbound Traffic:

Time Savings = Exit Time of First Cut (Existing Tow Haulage) - 9.5 Minutes

For Downbound Traffic:

Time Savings = Exit Time of First Cut (Existing Tow Haulage) - 9.5 Minutes plus Exiting Time Difference Between DS & US Exit Times

This retains the same incremental additional time for extracting downbound cuts as could be expected for even new tow haulage that operates with the same pull in either direction. While this over simplifies the time savings, it also understates the savings as this assumes all cuts are nine loaded barges. For a more in-depth analysis, the above table from the old Lock 26 study could be used with some degree of reliability for estimating extraction times of various first cut configurations.

The time savings for extracting the first cut with a powered kevel system using the above equations is shown in the following Tables 4-33 and 4-34.

TABLE 4-33: TIME SAVINGS FOR EXTRACTING FIRST CUTS WITH A POWERED KEVEL UPPER MISSISSIPPI RIVER LOCKS

Lock	Existing Tow Haulage Mean (min)	Existing Tow Haulage Std Dev (min)	Improved Tow Haulage Mean (min)	Improved Tow Haulage Std Dev (min)	Time Savings Mean (min)
11 Upstream	16.7	16.3	9.5	9.3	7.2
Downstrm	17.5	4.5	10.3	2.6	7.2
12 Upstream	12.2	3.8	9.5	3.0	2.7
Downstrm	16.0	3.7	13.3	3.1	2.7
13 Upstream	13.1	4.6	9.5	3.3	3.6
Downstrm	15.6	4.3	12.0	3.3	3.6
14 Upstream	14.2	4.3	9.5	2.9	4.7
Downstrm	15.1	4.1	10.4	2.8	4.7
15 Upstream	15.4	25.9	NR	NR	NR
Downstrm	12.9	2.6	9.5	1.9	3.4
16 Upstream	14.4	4.9	9.5	3.2	4.9
Downstrm	16.0	5.1	11.1	3.5	4.9
17 Upstream	15.1	5.1	9.5	3.2	5.6
Downstrm	19.5	4.7	13.9	3.4	5.6
18 Upstream	14.3	4.9	9.5	3.2	4.8
Downstrm	17.4	4.2	12.6	3.0	4.8
19 Upstream	NA	NA	NA	NA	NA
Downstrm	NA	NA	NA	NA	NA
20 Upstream	14.4	5.1	9.5	3.4	4.9
Downstrm	16.9	5.1	12.0	3.6	4.9
21 Upstream	13.1	4.6	9.5	3.3	3.6
Downstrm	16.8	4.8	13.2	3.8	3.6
22 Upstream	15.0	4.1	9.5	2.6	5.5
Downstrm	18.4	8.5	12.9	6.0	5.5
24 Upstream	13.3	4.1	9.5	2.9	3.8
Downstrm	20.4	4.1	16.6	3.3	3.8
25 Upstream	12.6	4.4	9.5	3.3	3.1
Downstrm	18.1	5.0	15.0	4.1	3.1
M.P. Upstream	6.9	3.6	Auxiliary Lock with Helper Boat Assistance		
Downstrm	9.0	3.7	"	"	"
27 Upstream	7.3	4.4	Auxiliary Lock with Helper Boat Assistance		
Downstrm	8.3	2.6	"	"	"

NR – not recommended; NA – not applicable

The average time savings in the extraction of the first cut at UMR locks is about 5 minutes, both upstream and downstream.

TABLE 4-34: TIME SAVINGS FOR EXTRACTING FIRST CUTS WITH A POWERED KEVEL ILLINOIS WATERWAY LOCKS

Lock	Existing Tow Haulage Mean (min)	Existing Tow Haulage Std Dev (min)	Improved Tow Haulage Mean (min)	Improved Tow Haulage Std Dev (min)	Time Savings Mean (min)
Lckp Upstrm	13.9	6.1	NR	NR	NR
Dnstrm	12.7	5.8	NR	NR	NR
Brdn Upstrm	15.5	5.2	9.9	3.3	5.6
Dnstrm	15.1	6.9	9.5	4.3	5.6
Dres Upstrm	13.6	3.8	11.3	3.2	2.3
Dnstrm	11.8	4.3	NR	NR	NR
Mars Upstrm	11.3	5.1	10.5	4.7	0.8
Dnstrm	10.3	4.5	9.5	4.2	0.8
Strvd Upstrm	11.3	3.6	9.5	3.0	1.8
Dnstrm	11.6	4.3	9.8	3.6	1.8
Peor Upstrm	13.8	5.1	9.5	3.5	4.3
Dnstrm	14.5	5.7	10.2	4.0	4.3
LaGr Upstrm	13.7	5.3	9.5	3.7	4.2
Dnstrm	15.6	6.2	11.4	4.5	4.2

NR - not recommended

The average time savings in the extraction of the first cut at IWW locks is about 3 minutes, both upstream and downstream. For the UMR and IWW locks combined, the average time savings is about 4 minutes in both directions.

Conditions Affecting Implementation. While there is a real time savings for extracting the first cut with new improved tow haulage, the overall improvement in lock transit time for extracting the first cut faster is questionable unless additional staff are provided. The powered traveling kevel time savings with extended guidewalls does not appear as great as once thought. This is due to the present operating procedure and the movement of deckhands during a double lockage. Navigation Notice No. 1 requires a minimum of three personnel for safe handling of lines during double lockages. Generally, two deckhands ride the first cut of a double lockage as it is extracted from the lock chamber, moves down the guidewall, and is tied off to await remake with the second powered cut. A third deckhand walks the guidewall with the first cut, along with one lock person. A second lock person stays with the lock. The time it takes now under present conditions with 600-foot guidewalls for two of the deckhands (one deckhand stays with the first cut) to walk back to the second powered cut to accompany the powered cut into the lock chamber is about the same time that it takes to turn back the chamber and open the lock gates for the second cut to start its entry into the chamber. This was confirmed by lockmasters. In some cases, depending on existing upper and lower pool levels, the powered cut may have a slight wait for the deckhands' return before it can enter the lock chamber. With new tow haulage on guidewalls extended to 1,200 feet, the powered cut will have to wait for the deckhands' return in every instance. The time saved in extracting the unpowered cut faster is negated by the powered cut waiting for the deckhands to return before it can start entry into the chamber.

It is difficult to determine the wait time, but suffice to say that the powered cut will have to wait on the returning deckhands. The magnitude of the wait time can be roughly estimated from the following. After the unpowered cut clears the miter gates, it is moved about another 700 feet and tied off. The returning deckhands then have to walk about 2,000 feet back to the powered cut. During this time, the miter gates are closed (2 minutes), the chamber is filled/emptied (3-5 minutes), and the other miter gates opened for the powered cut entry (2 minutes). This total time averages 8 minutes. During this 8 minutes, from the previous Table 4-31, it takes 8 minutes to cover a haul distance of 600 feet and a stopping distance of 100 feet (assuming breaking capability

of the tow haulage by a gradual reversing of the pull/retard forces along with the larger breaking contribution from water friction forces). Add another 2 minutes for tying lines and another 12 minutes to walk the 2,000 feet (2 mph pace plus ladder climbing) and this totals 22 minutes. The powered cut would then be waiting about 14 minutes (22 minutes minus 8 minutes). This is about 9 minutes more than the time gained by the faster extraction of the first cut on the UMR and about 11 minutes more than the time saved by the faster extraction time on the IWW. Even though the powered cut entry is delayed, powered kevels in combination with extended guidewalls allow for reduced chambering time by faster emptying of the lock chamber on downbound first cuts and for the remake of the double cuts outside the lock chamber. This results in a net savings in the lock transit time as shown in Table 4-35A, "Cost and Performance of Powered Kevels with Extended Guidewalls." The average savings for turnback lockages is 6 minutes upbound and 9 minutes downbound. Adding two additional crew members to either the tow or lock facility would eliminate the 14 minutes of delay associated with the crew returning. This would increase the overall savings to 20 minutes upbound and 23 minutes downbound (see Table 4-35B).

A potential problem with an improved tow haulage operation has to do with the frequent high river levels experienced at many of the lock sites. During high river stages, high riding raker barges can damage the haulage system and other features along the guidewalls that are presently susceptible to damage such as handrails, posts, lights, etc. These could be costly repairs unless the lock is shut down to traffic during the higher river levels, preventing these potential damages.

Costs. Existing conditions were evaluated at six lock and dam sites within the study area to verify the feasible placement of both tow haulage configurations (12-6-12, and 12-N-12). Sites visited included Locks 25, 24, 22, 21, and 20 on the UMR and La Grange Lock on the IWW. These locks were chosen because they are the farthest downstream, having 600-foot chambers (as opposed to 1,200-foot chambers) and receive more commercial traffic than those locks upstream in the study area. Documentation included verification of existing lock site plans, measurements of existing clear zones, and identification of problem areas for incorporating the tow haulage configurations. These visits provided information that could be considered common to the other lock sites for placement of the improved tow haulage. Items affecting the cost of installation are considered typical to other sites as well. All arrangements are possible with the relocation of some existing features, such as handrail, check posts, ladders, and light stands, all of which can be relocated back from the wall face to accommodate the kevel rail. The existing upper guidewall kevel rail can remain in place at all locations and the new kevel rail butted to it for the upper guidewall extension. Differences in the top of wall elevation between the chamber wall and the lower guidewalls at Locks 15, 24, and La Grange are accommodated by both the 12-6-12 and 12-N-12 configurations as both configurations have independent tow haulage operations for the lock chamber and the guidewalls. The 1995 *Improved Tow Haulage Equipment* interim report has plate drawings for the 12-6-12 and 12-N-12 configurations.

La Grange Lock (others may be identified during site-specific feasibility studies) requires special consideration for the tow haulage design. This site is susceptible to dynamic river levels that rise above the walls with as little as a 1- to 2-hour warning. Lock personnel must disassemble and remove all equipment that could be damaged by high water and debris. Presently, the handrails fold down and the haulage winches are craned onto a flatbed truck for movement to higher ground. The existing unpowered kevels on both upper and lower guidewalls are being considered for removal as sand in the floodwater is taking a toll on the wheel bearings.

TABLE 4-35A: COST AND PERFORMANCE OF POWERED KEVELS WITH EXTENDED GUIDEWALLS

Lock Site	DIR	First Cost [1,2] ($1,000's)	Impacts to Navigation[3] ($1,000's)	Savings in Remake Time, Turnback Exits, Table 4-30 (mins.)	Plus Savings in 1st Cut Extraction Time, Tables 4-33 & 4-34 (mins.)	Plus Reduced Chambering Time (mins.)	Minus Wait Time For 2nd Cut (mins.)	Equals Time Savings Turnback Exits (mins.)
11	US	22,820	0	14.1	7.2	0.0	14.0	7.3
	DS	13,866	0	14.3	7.2	-0.1	14.0	7.4
12	US	28,060	0	12.9	2.7	0.0	14.0	1.6
	DS	13,634	0	16.2	2.7	-0.1	14.0	4.8
13	US	23,480	0	13.5	3.6	0.0	14.0	3.1
	DS	13,888	0	17.1	3.6	0.1	14.0	6.8
14	US	22,850	0	17.2	4.7	0.0	14.0	7.9
	DS	11,928	0	19.0	4.7	-0.1	14.0	9.6
15	US	NR	NR	NR	NR	NR	NR	NR
	DS	8,476	0	19.6	3.4	2.4	14.0	11.4
16	US	22,080	0	14.0	4.9	0.0	14.0	4.9
	DS	13,504	0	16.8	4.9	-0.4	14.0	7.3
17	US	24,330	0	14.0	5.6	0.0	14.0	5.6
	DS	17,503	0	16.8	5.6	0.0	14.0	8.4
18	US	22,980	0	14.6	4.8	0.0	14.0	5.4
	DS	14,013	0	17.7	4.8	-0.3	14.0	8.2
19	US	NA	NA	NA	NA	NA	NA	NA
	DS	NA	NA	NA	NA	NA	NA	NA
20	US	23,820	0	15.3	4.9	0.0	14.0	6.2
	DS	11,654	0	19.5	4.9	0.4	14.0	10.8
21	US	23,630	0	17.5	3.6	0.0	14.0	7.1
	DS	14,440	0	19.9	3.6	0.1	14.0	9.6
22	US	24,750	0	16.3	5.5	0.0	14.0	7.8
	DS	12,976	0	18.2	5.5	0.5	14.0	10.2
24	US	20,950	0	16.0	3.8	0.0	14.0	5.8
	DS	11,390	0	16.5	3.8	1.6	14.0	7.9
25	US	27,750	0	16.8	3.1	0.0	14.0	5.9
	DS	15,078	0	18.1	3.1	1.1	14.0	8.3
MEL PRICE	US	750	0	NC	NC	NC	NC	NC
Aux Lock	DS	750	0	NC	NC	NC	NC	NC
27	US	14,250	0	NC	NC	NC	NC	NC
Aux Lock	DS	NR	NR	NR	NR	NR	NR	NR
LOCKPORT	US	NR	NR	NR	NR	NR	NR	NR
	DS	NR	NR	NR	NR	NR	NR	NR
BRANDON RD.	US	11,738	62,180	19.1	5.6	0.0	14.0	10.7
	DS	13,810	62,180	18.9	5.6	3.6	14.0	14.1
DRESDEN IS.	US	10,417	62,180	20.0	2.3	0.0	14.0	8.3
	DS	NR	NR	NR	NR	NR	NR	NR
MARSEILLES	US	11,116	62,180	20.1	0.8	0.0	14.0	6.9
	DS	12,370	62,180	19.1	0.8	1.8	14.0	7.7
STARVED RK.	US	10,143	62,180	18.3	1.8	0.0	14.0	6.1
	DS	11,278	62,180	18.6	1.8	1.5	14.0	7.9
PEORIA	US	13,190	80,700	17.5	4.3	0.0	14.0	7.8
	DS	13,759	80,700	21.5	4.3	-	14.0	11.8
LAGRANGE	US	12,117	80,700	16.4	4.2	0.0	14.0	6.6
	DS	12,380	80,700	21.2	4.2	-	14.0	11.4
Average	US	23,958	0	15.2	4.5	0.0	14.0	5.7
UMR 11-25	DS	13,258	0	17.7	4.4	0.4	14.0	8.5
Average	US	11,454	68,353	18.6	3.2	0.0	14.0	7.7
Illinois	DS	12,719	69,588	19.9	3.3	1.4	14.0	10.6

US = upstream, DS = downstream, NA = not applicable, NR = not recommended, NC = no change

NOTES:

1. The environomental impacts are not included in the costs since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs include $750,000 for powered traveling kevels on the upper and lower guidewalls.
3. These costs are for switch boats, helper boats and temporary remote remake areas. Also included are economic impacts to the navigation industry from delays and closures that are shown on construction timelines at Appendix D.
4. At Lock 17 the downstream guidewall extension cost includes $3,657,000 for channel work (bank excavation).

TABLE 4-35B: COST AND PERFORMANCE OF POWERED KEVELS WITH EXTENDED GUIDEWALLS AND ADDITIONAL PERSONNEL

Lock Site	DIR	First Cost [1,2] ($1,000's)	Impacts to Navigation[3] ($1,000's)	Savings in Remake Time, Turnback Exits, Table 4-30 (mins.)	Plus Savings in 1st Cut Extraction Time, Tables 4-33 & 4-34 (mins.)	Plus Reduced Chambering Time (mins.)	Minus Wait Time For 2nd Cut (mins.)	Equals Time Savings Turnback Exits (mins.)
11	US	22,870	0	14.1	7.2	0.0	0.0	21.3
	DS	13,916	0	14.3	7.2	-0.1	0.0	21.4
12	US	28,110	0	12.9	2.7	0.0	0.0	15.6
	DS	13,684	0	16.2	2.7	-0.1	0.0	18.8
13	US	23,530	0	13.5	3.6	0.0	0.0	17.1
	DS	13,938	0	17.1	3.6	0.1	0.0	20.8
14	US	22,900	0	17.2	4.7	0.0	0.0	21.9
	DS	11,978	0	19.0	4.7	-0.1	0.0	23.6
15	US	NR	NR	NR	NR	NR	NR	NR
	DS	8,526	0	19.6	3.4	2.4	0.0	25.4
16	US	22,130	0	14.0	4.9	0.0	0.0	18.9
	DS	13,554	0	16.8	4.9	-0.4	0.0	21.3
17	US	24,380	0	14.0	5.6	0.0	0.0	19.6
	DS	17,553	0	16.8	5.6	0.0	0.0	22.4
18	US	23,030	0	14.6	4.8	0.0	0.0	19.4
	DS	14,063	0	17.7	4.8	-0.3	0.0	22.2
19	US	NA	NA	NA	NA	NA	NA	NA
	DS	NA	NA	NA	NA	NA	NA	NA
20	US	23,870	0	15.3	4.9	0.0	0.0	20.2
	DS	11,704	0	19.5	4.9	0.4	0.0	24.8
21	US	23,680	0	17.5	3.6	0.0	0.0	21.1
	DS	14,490	0	19.9	3.6	0.1	0.0	23.6
22	US	24,800	0	16.3	5.5	0.0	0.0	21.8
	DS	13,026	0	18.2	5.5	0.5	0.0	24.2
24	US	21,000	0	16.0	3.8	0.0	0.0	19.8
	DS	11,440	0	16.5	3.8	1.6	0.0	21.9
25	US	27,800	0	16.8	3.1	0.0	0.0	19.9
	DS	15,128	0	18.1	3.1	1.1	0.0	22.3
MEL PRICE	US	800	0	NC	NC	NC	NC	NC
Aux Lock	DS	800	0	NC	NC	NC	NC	NC
27	US	14,300	0	NC	NC	NC	NC	NC
Aux Lock	DS	NR	NR	NR	NR	NR	NR	NR
LOCKPORT	US	NR	NR	NR	NR	NR	NR	NR
	DS	NR	NR	NR	NR	NR	NR	NR
BRANDON RD.	US	11,788	62,180	19.1	5.6	0.0	0.0	24.7
	DS	13,860	62,180	18.9	5.6	3.6	0.0	28.1
DRESDEN IS.	US	10,467	62,180	20.0	2.3	0.0	0.0	22.3
	DS	NR	NR	NR	NR	NR	NR	NR
MARSEILLES	US	11,166	62,180	20.1	0.8	0.0	0.0	20.9
	DS	12,420	62,180	19.1	0.8	1.8	0.0	21.7
STARVED RK.	US	10,193	62,180	18.3	1.8	0.0	0.0	20.1
	DS	11,328	62,180	18.6	1.8	1.5	0.0	21.9
PEORIA	US	13,240	80,700	17.5	4.3	0.0	0.0	21.8
	DS	13,809	80,700	21.5	4.3	0.0	0.0	25.8
LAGRANGE	US	12,167	80,700	16.4	4.2	0.0	0.0	20.6
	DS	12,430	80,700	21.2	4.2	0.0	0.0	25.4
Average	US	24,008	0	15.2	4.5	0.0	0.0	19.7
UMR 11-25	DS	13,308	0	17.7	4.4	0.4	0.0	22.5
Average	US	11,504	68,353	18.6	3.2	0.0	0.0	21.7
Illinois	DS	12,769	69,588	19.9	3.3	1.4	0.0	24.6

US = upstream, DS = downstream, NA = not applicable, NR = not recommended, NC = no change

NOTES:

1. The annual cost of additional personnel is not shown; it would total approximately $518,000 per lock per year. The environomental impacts ar in the costs since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs include $750,000 for powered traveling kevels on the upper and lower guidewalls.
3. These costs are for switch boats, helper boats and temporary remote remake areas. Also included are economic impacts to the navigation industry from delays and closures that are shown on construction timelines at Appendix D.
4. At Lock 17 the downstream guidewall extension cost includes $3,657,000 for channel work (bank excavation).

Cost estimates were developed for both tow haulage configurations (12-6-12 and 12-N-12) at Lock and Dam 24 and at La Grange Lock (Tables 4-36A through 4-38). These estimates include costs for the required structural modifications along the walls for placement of the kevel rails and operating clearance for the powered traveling kevels. The required structural modifications are limited to: access ladder modifications for ladders on the lockwalls providing access from the river to the top of the lockwall; removal and installation of higher check posts adjacent to the kevel rails; and existing handrail elimination or setback. The cost estimates also include the following assumptions: 1) Winches for the existing system are to be removed for the 12-6-12 option and are to be used in place for the 12-N-12 option; 2) power/control cables are to be in rigid steel conduit along the back of the guidewalls to a point at the miter gate monoliths where the cables will transition to an existing pull box or cable trench; and 3) the pull/retard type winch system is used for costing, including a hydraulic-type power unit to drive the system. An electrically driven winch with a variable frequency drive could also be used to drive the system with the same order of cost magnitude as shown in the estimates for the hydraulic units.

The 25-percent contingency cost included in the estimates is adequate to cover any slight variations at the other lock sites in the study area. These variations are minor since the total length of tow haulage improvement is fairly constant at all the lock sites for either the 12-6-12 or the 12-N-12 configurations. Therefore, for the Navigation Study, the improved tow haulage costs for Lock 24 will be used for all other lock sites on the UMR. These first costs are $1,520,000 for the 12-6-12 configuration and $1,110,000 for the 12-N-12 configuration. Likewise, the costs for improved tow haulage at La Grange Lock will be used for all other lock sites on the IWW. These first costs are $1,440,000 for the 12-6-12 configuration and $1,025,000 for the 12-N-12 configuration.

Assuming the 12-6-12 configuration for all lock sites within the system study, the costs vary from $1,440,000 to $1,520,000. A first cost of $1,500,000 was used for each lock site, as shown in Table 4-35 ($750,000 for each upper and lower guidewall). In addition to the first cost of the powered kevels, an estimated annual maintenance cost of $9,000 per kevel or $18,000 per lock would be required.

The additional personnel are estimated to cost $518,000 annually per lock (two additional staff on duty, 24 hours per day, 270 days per year). An additional first cost of $100,000 per lock site was also included, associated with start up of the measure (e.g., contracting or hiring employees, training requirements, and miscellaneous expense).

Relationship to Other Small Scale Measures. Improved tow haulage (powered kevels) assumes the presence of a foundation on which the tow haulage is founded. The existing lock chamber wall, existing guidewalls and their extensions provide a foundation for the tow haulage. The total cost of implementing the improved tow haulage measure requires, therefore, the extended guidewalls and the associated cost of the guidewall extensions. The costs for the guidewall extensions are not included in the tow haulage (powered kevels) cost estimates but are shown in the Extended Guidewall Section of this report. The cost for guidewall extensions must be added to the improved tow haulage (powered kevels) cost to obtain the total cost of the improved tow haulage measure. In addition, the provision of additional personnel is highly recommended to eliminate the large delay associated with the crew walking back to the powered cut.

TABLE 4-36A: CONSTRUCTION COST ESTIMATE
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
LOCK AND DAM # 24 - MISSISSIPPI RIVER
12-N-12 ALTERNATE

ITEM DESCRIPTION	NO.	UNIT	COST	ITEM COST
1. 40 HP WINCH (w/POWER UNIT& POWER PANEL	4	EACH	$80,000	$320,000
2. 1" DIA WIRE ROPE (2@ 1400' - GUIDEWALLS)	2800	LF	$5	$14,000
3. 36" DIA SHEAVES W/ ASSEMBLY	4	EACH	$5,000	$20,000
4. 140# RAIL (W/ PLATES, CLIPS, & ANCHORS)	2000	LF	$60	$120,000
5. TOW HAULAGE BITTS	4	EACH	$3,000	$12,000
6. CONCRETE FOUNDATION FOR WINCHES	2	EACH	$10,000	$20,000
7. RIGID STEEL CONDUIT	4800	LF	$10	$48,000
8. POWER/CONTROL CABLES	4800	LF	$10	$48,000
9. MCC AND CONTROLS ADDITION/MODIFICATION	1	EACH	$10,000	$10,000
10. REMOVAL OF CHECKPOSTS	22	EACH	$250	$5,500
11. INSTALL NEW CHECKPOSTS	22	EACH	$3,500	$77,000
12. REMOVAL/RELOCATION OF HANDRAILING	500	LF	$20	$10,000
13. MISC. STRUCTURAL MODS. (LADDERS, TRENCHES)	1	EACH	$10,000	$10,000
14. REMOTE CONTROL STATION	2	EACH	$2,000	$4,000
15. TESTING/START-UP	1	EACH	$15,000	$15,000
16. TRAINING	1	EACH	$5,000	$5,000
PROJECT SUBTOTAL				$738,500
CONTINGENCIES (25%)				$186,500
PROJECT SUBTOTAL WITH CONTINGENCIES				$925,000
PLANNING, ENGINEERING, AND DESIGN (10%)				$92,500
CONSTRUCTION MANAGEMENT (10%)				$92,500
PROJECT TOTAL (EXCLUDING GUIDEWALL EXTENSIONS)				$1,110,000

TABLE 4-36B: CONSTRUCTION COST ESTIMATE
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
LA GRANGE LOCK AND DAM - ILLINOIS WATERWAY
12-N-12 ALTERNATE

ITEM DESCRIPTION	NO.	UNIT	COST	ITEM COST
1. 40 HP WINCH (w/POWER UNIT& POWER PANEL	4	EACH	$80,000	$320,000
2. 1" DIA WIRE ROPE (1400' EACH)	2800	LF	$5	$14,000
3. 36" DIA SHEAVES W/ ASSEMBLY	4	EACH	$5,000	$20,000
4. 140# RAIL (W/ PLATES, CLIPS, & ANCHORS)	1350	LF	$60	$81,000
5. TOW HAULAGE BITTS	4	EACH	$3,000	$12,000
6. CONCRETE FOUNDATION FOR WINCHES	2	EACH	$10,000	$20,000
7. RIGID STEEL CONDUIT	4800	LF	$10	$48,000
8. POWER/CONTROL CABLES	4800	LF	$10	$48,000
9. MCC AND CONTROLS ADDITION/MODIFICATION	1	EACH	$10,000	$10,000
10. REMOVAL OF CHECKPOSTS	20	EACH	$250	$5,000
11. INSTALL NEW CHECKPOSTS	20	EACH	$3,500	$70,000
12. REMOVAL/RELOCATION OF HANDRAILING	0	LF	$20	$00
13. MISC. STRUCTURAL MODS. (LADDERS, TRENCHES)	1	EACH	$10,000	$10,000
14. REMOTE CONTROL STATION	2	EACH	$2,000	$4,000
15. TESTING/START-UP	1	EACH	$15,000	$15,000
16. TRAINING	1	EACH	$5,000	$5,000
PROJECT SUBTOTAL				$682,000
CONTINGENCIES (25%)				$173,000
PROJECT SUBTOTAL WITH CONTINGENCIES				$855,000
PLANNING, ENGINEERING, AND DESIGN (10%)				$85,000
CONSTRUCTION MANAGEMENT (10%)				$85,000
PROJECT TOTAL (EXCLUDING GUIDEWALL EXTENSIONS)				$1,025,000

TABLE 4-37: CONSTRUCTION COST ESTIMATE
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
LA GRANGE LOCK AND DAM - ILLINOIS WATERWAY
12-6-12 ALTERNATE

ITEM DESCRIPTION	NO.	UNIT	COST	ITEM COST
1. 40 HP WINCH (w/POWER UNIT& POWER PANEL)	6	EACH	$80,000	$480,000
2. 1" DIA WIRE ROPE (1400', 1400', AND 700')	3500	LF	$5	$17,500
3. 36" DIA SHEAVES W/ ASSEMBLY	7	EACH	$5,000	$35,000
4. 140# RAIL (W/ PLATES, CLIPS, & ANCHORS)	1950	LF	$60	$117,000
5. TOW HAULAGE BITTS	5	EACH	$3,000	$15,000
6. CONCRETE FOUNDATION FOR WINCHES	2	EACH	$10,000	$20,000
7. RIGID STEEL CONDUIT	4800	LF	$10	$48,000
8. POWER/CONTROL CABLES	6000	LF	$10	$60,000
9. MCC AND CONTROLS ADDITION/MODIFICATION	1	EACH	$10,000	$10,000
10. REMOVAL OF WINCHES (W/CONTROLS)	2	EACH	$5,000	$10,000
11. REMOVAL OF CHECKPOSTS	30	EACH	$250	$7,500
12. INSTALL NEW CHECKPOSTS	30	EACH	$3,500	$105,000
13. REMOVAL/RELOCATION OF HANDRAILING	0	LF	$20	$0
14. MISC. STRUCTURAL MODS. (LADDERS, TRENCHES)	1	EACH	$10,000	$10,000
15. REMOTE CONTROL STATION	2	EACH	$2,000	$4,000
16. TESTING/START-UP	1	EACH	$15,000	$15,000
17. TRAINING	1	EACH	$5,000	$5,000
PROJECT SUBTOTAL				$959,000
CONTINGENCIES (25%)				$241,000
PROJECT SUBTOTAL WITH CONTINGENCIES				$1,200,000
PLANNING, ENGINEERING, AND DESIGN (10%)				$120,000
CONSTRUCTION MANAGEMENT (10%)				$120,000
PROJECT TOTAL (EXCLUDING GUIDEWALL EXTENSIONS)				$1,440,000

TABLE 4-38: CONSTRUCTION COST ESTIMATE
IMPROVED TOW HAULAGE (POWERED KEVEL) SYSTEM
LOCK AND DAM #24 - MISSISSIPPI RIVER
12-6-12 ALTERNATE

ITEM DESCRIPTION	NO.	UNIT	COST	ITEM COST
1. 40 HP WINCH (w/POWER UNIT & POWER PANEL)	6	EACH	$80,000	$480,000
2. 1" DIA WIRE ROPE (2@ 1400', 1 @ 700')	3500	LF	$5	$17,500
3. 36" DIA SHEAVES W/ ASSEMBLY	6	EACH	$5,000	$30,000
4. 140# RAIL (W/ PLATES, CLIPS, & ANCHORS)	2500	LF	$60	$150,000
5. TOW HAULAGE BITTS	5	EACH	$3,000	$15,000
6. CONCRETE FOUNDATION FOR WINCHES	2	EACH	$10,000	$20,000
7. RIGID STEEL CONDUIT	4800	LF	$10	$48,000
8. POWER/CONTROL CABLES	6000	LF	$10	$60,000
9. CONTROLS/MCC MODIFICATIONS AND ADD.	1	EACH	$10,000	$10,000
10. REMOVAL OF WINCHES (W/CONTROLS)	2	EACH	$5,000	$10,000
11. REMOVAL OF CHECKPOSTS	31	EACH	$250	$7,750
12. INSTALL NEW CHECKPOSTS	31	EACH	$3,500	$108,500
13. REMOVAL/RELOCATION OF HANDRAILING	1100	LF	$20	$22,000
14. MISC. STRUCTURAL MODS. (LADDERS, TRENCHES)	1	EACH	$10,000	$10,000
15. REMOTE CONTROL STATION	2	EACH	$2,000	$4,000
16. TESTING/START-UP SERVICES	1	EACH	$15,000	$15,000
17. TRAINING	1	EACH	$5,000	$5,000
PROJECT SUBTOTAL				$1,012,750
CONTINGENCIES (25%)				$253,250
PROJECT SUBTOTAL WITH CONTINGENCIES				$1,266,000
PLANNING, ENGINEERING, AND DESIGN (10%)				$127,000
CONSTRUCTION MANAGEMENT (10%)				$127,000
PROJECT TOTAL (EXCLUDING GUIDEWALL EXTENSIONS)				$1,520,000

Conclusions/Summary. In summary, a powered kevel system with extended guidewalls extracts first cuts of doubles faster than the current haulage system by an estimated 3 to 5 minutes. However, the lockage time is negatively impacted when the powered kevel takes the cut to the end of the extended guidewall unless additional staffing is provided. Under the current lock operating procedure, the entrance of the second (powered) cut into the turned-back lock chamber would be delayed an estimated 14 minutes by the return of the deckhands from the first cut. Therefore, the lockage time is negatively impacted by an estimated 9 to 11 minutes. However, with extended guidewalls, the total lock transit time for turnback lockages is still reduced by an average of 6 to 9 minutes, respectively, for upbound and downbound lockages. This is due to faster emptying of the lock chamber on downbound first cuts and the tow remake outside the chamber along the extended guidewall.

Two additional personnel could eliminate the need for the tow to wait for its crew to return. Although this would result in some increase in costs, the overall time savings would increase to 20 minutes upbound and 23 minutes downbound. This measure should be considered further for implementation.

- **Unpowered Kevels**

As discussed above, pulling the first cut with new tow haulage including powered kevels to the end of a 1,200-foot guidewall requires additional lockage time for deckhands to return and accompany the second cut into the lock chamber or the additional cost of adding personnel. An alternative to powered kevels is unpowered kevels.

Description of Measure. Using unpowered kevels to shorten the lock transit time for double lockages requires extended guidewalls. This measure provides two rail-mounted kevels along both extended upstream and downstream guidewalls. These kevels are not attached to any cable/winch power system (see Figures 4-8A and B).

With this alternative, the first cut of a double lockage is extracted from the lock chamber as is presently done with the existing tow haulage system (a single winch and cable system). The front of the cuts secured to the first kevel. The stern of the first cut is attached to the second kevel after the first cut clears the miter gate recess and is tied off to a safety line. Two of the three deckhands then walk back a maximum of 1,200 feet, as they do now, to accompany the powered second cut into the chamber. After the lock gates are opened, the powered cut faces up to the first cut. At this point, instead of completely remaking the cuts, as is presently done with the powered cut occupying part of the lock chamber, only the two outside couplings are remade. The powered cut then pushes the first cut to the end of the 1,200-foot guidewall with the two kevels riding the rail, helping to keep the first cut along the guidewall. In this scenario, the powered cut provides the power to move the first and second cuts away from the lock chamber while still having full control of the first cut, which is secured at the bow and stern to the kevels and to the powered cut by the two outside couplings. When the stern of the powered cut clears the gate recess, the chamber can be turned back to receive the next tow traveling in the same direction while the exiting tow completes its remake along the extended guidewall.

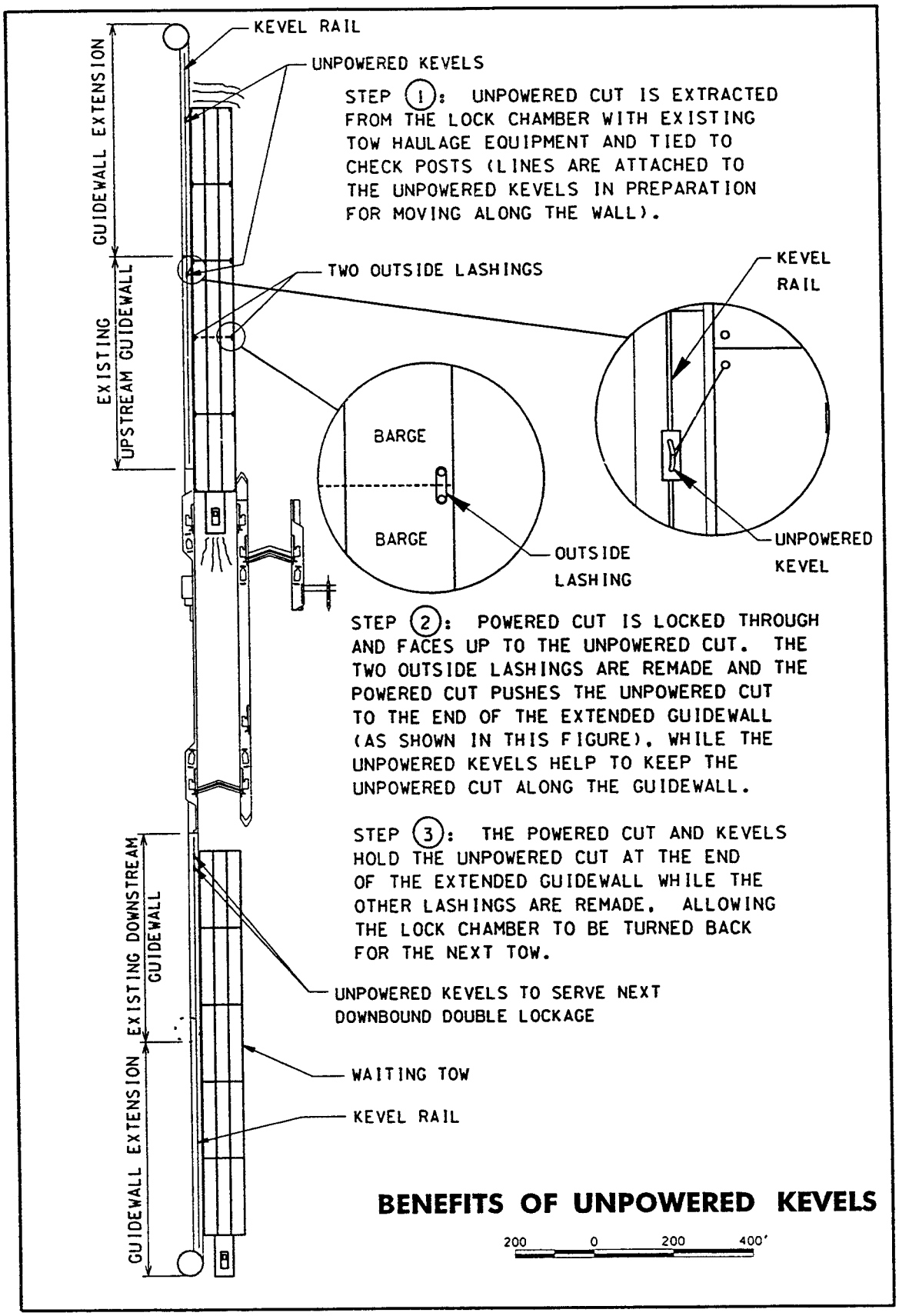
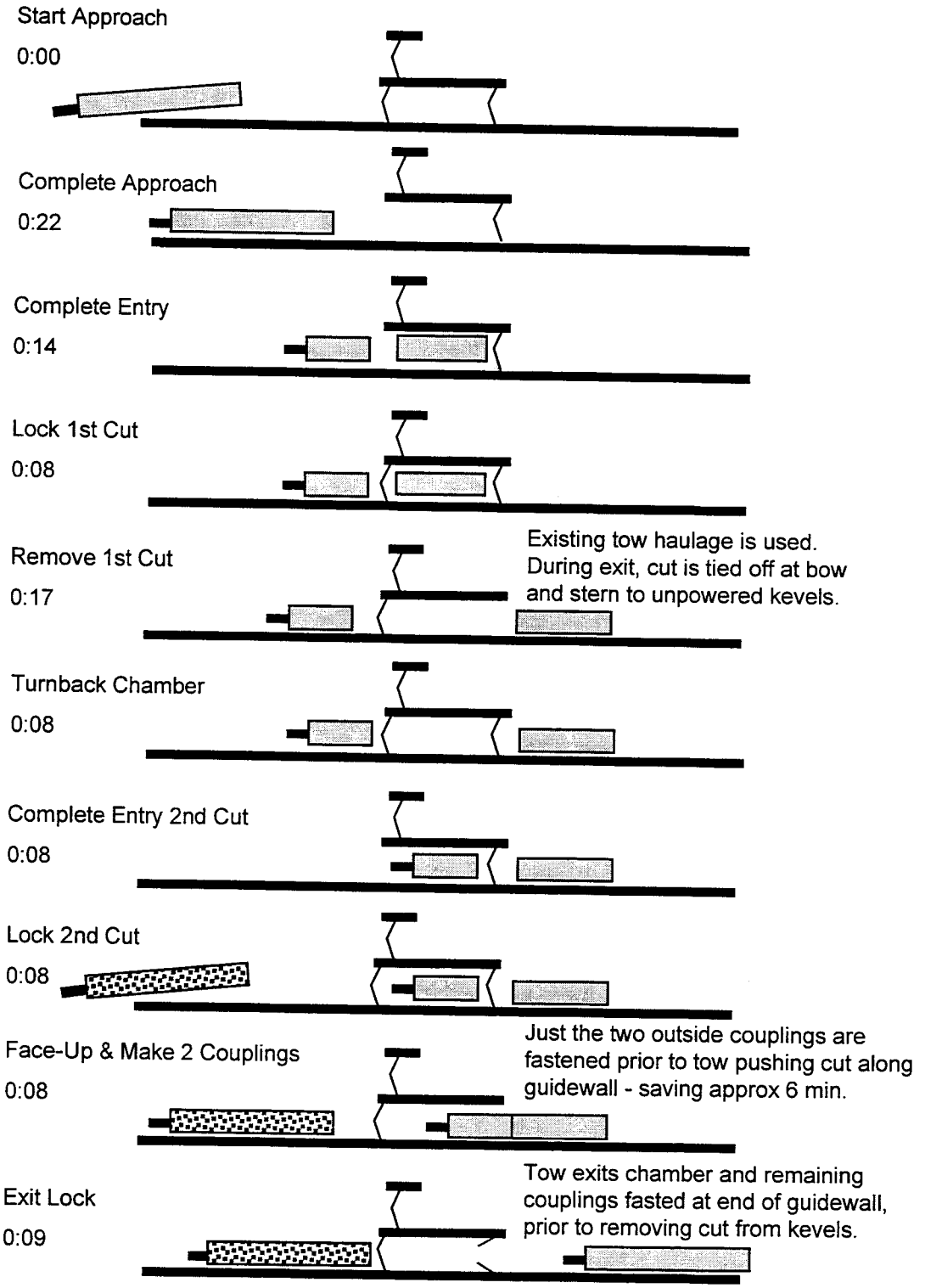


FIGURE 4-8A: Benefits of Unpowered Kevels



Total Lockage Time: 1:42 (exit chamber) 1:53 (leave guidewall). Total savings to queue is 6 min. However, only benefits system if next tow is traveling in same direction (turnback).

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

FIGURE 4-8B: Double Lockage Elements - Permanent Guidewall Extensions with Unpowered Kevel

Delay Reduction Methodology/Time Savings Estimate

Remake of Double Lockage Tows (Exit and Clear Second Cut). A time savings is obtained by allowing the powered cut to push the first cut to the end of the extended guidewall where the remake of the two cuts can be completed. This alleviates the existing condition at locks with 600-foot guidewalls where a double lockage tow is unable to exit the lock chamber until all of the couplings are remade, keeping the chamber from servicing other tows. This savings is only realized for turnback exit lockages where the next tow to be locked through is going in the same direction. The time savings is maximized when used in conjunction with the N-up/N-down policy where N tows are locked through in one direction before N tows are locked through in the opposite direction. If the next lockage is an exchange (going in the opposite direction), no time is saved since the exiting tow is blocking the approach during the remake completion along the extended guidewall.

LPMS data for 1990 were used in estimating the potential time savings. The average turnback exit times of double lockages were used from each lock site. This time includes the face up time for the powered cut to approach the first cut; the remake coupling time; and the tow exit time until the stern of the tow passes the gate sill. The time savings is the difference in the remake coupling time for remaking five wires (the sixth wire is remade after the tow leaves the guidewall) versus the time for remaking the two outside wires.

The existing procedure for remaking the five wires is reported in the "Crew Elements" section of this report. The remaking procedure involves the human element and consequently varies with crew experience and other elements such as weather conditions, time of day, etc. A baseline estimate of 12 minutes for remaking five wires was determined based on a limited number of timed observations in the 1995 *Universal Couplers and Crew Training* interim report. The estimate of 12 minutes is based on three people (typical crew) remaking the five wires. Each wire requires 3 minutes to lay the wire around the barge timberheads and 3 minutes to tighten the wire. Since there are five wires, two of the three deck crew have to perform each operation twice (three people lay a wire and tighten it, then two of the three lay another wire and tighten that one). Each wire requires 6 minutes to remake.

In this scenario, the two deckhands who walk back to accompany the powered cut through the lockage remake the two outside wires after the powered cut faces up to the first cut. Each deckhand does one wire, which requires 6 minutes. The total time savings is then the difference in the average estimated remake time of 12 minutes for all five wires and the remake time for the two outside wires, which is estimated at 6 minutes. This equates to a total average time savings of 6 minutes, which is assumed applicable to all turnback double lockages at all lock sites under study. Using a savings of 6 minutes, the new exit and clear time of the second cut from the lock chamber is given by:

New Lock Exit Time of 2nd Cut (including remake)	=	Existing Lock Exit Time of 2nd Cut (including remake)	-	6 minutes

Using the above formula and 1990 LPMS data, the average new exit time of the second cut for the UMR locks in the downbound direction goes from 23 minutes to 17 minutes and in the upbound direction goes from 20 minutes to 14 minutes. For the IWW locks, the average new lock exit time of the second cut in the downbound direction goes from 26 minutes to 20 minutes and in the upbound direction goes from 24 minutes to 18 minutes. This represents a savings of 6 minutes. See Table 4-39 for new lock exit times for turnback exits of double lockages.

TABLE 4-39: COST AND PERFORMANCE OF UNPOWERED KEVELS WITH EXTENDED GUIDEWALLS

Lock Site	DIR.	COSTS		DOUBLE EXIT SAVINGS			SETOVER EXIT SAVINGS			KNOCKOUT EXIT SAVINGS		
		Cost Unpowered kevels plus Guidewall Extension ($1,000's)[1,2]	Guidewall Construction Impacts to Navigation ($1,000's)[3]	Existing Clear/Exit Time Double Cuts Turnback Exits	New Clear/Exit Time 2nd Cut Exit Chamber	Ave. Time Savings (mins.)	Existing Turnback Exit of Single Setover	Turnback Exit of Single	Ave. Time Savings (mins.)	Existing Turnback Exit of Single Knockout	Turnback Exit of Single	Time Savings (mins.)
11	US	22,310	0	19.9	13.9	6.0	26.5	5.8	20.7	15.0	5.8	9.2
	DS	13,476	0	20.9	14.9	6.0	20.3	6.6	13.7	14.1	6.6	7.5
12	US	27,550	0	17.7	11.7	6.0	24.7	4.8	19.9	13.0	4.8	8.2
	DS	13,244	0	22.1	16.1	6.0	25.9	5.9	20.0	13.9	5.9	8.0
13	US	22,970	0	18.8	12.8	6.0	22.7	5.3	17.4	12.2	5.3	6.9
	DS	13,498	0	22.1	16.1	6.0	22.6	5.0	17.6	13.4	5.0	8.4
14	US	22,340	0	22.4	16.4	6.0	30.1	5.2	24.9	14.8	5.2	9.6
	DS	11,538	0	25.1	19.1	6.0	25.5	6.1	19.4	16.0	6.1	9.9
15	US	NR	NR	20.7	NR	NR	25.4	NR	NR	12.8	NR	NR
	DS	8,086	0	27.2	21.2	6.0	33.3	7.6	25.7	16.2	7.6	8.6
16	US	21,570	0	19.4	13.4	6.0	26.2	5.4	20.8	13.1	5.4	7.7
	DS	13,114	0	22.0	16.0	6.0	36.5	5.2	31.3	13.4	5.2	8.2
17	US	23,820	0	20.2	14.2	6.0	26.2	6.2	20.0	13.2	6.2	7.0
	DS	17,113	0	22.8	16.8	6.0	33.0	6.0	27.0	12.1	6.0	6.1
18	US	22,470	0	20.7	14.7	6.0	25.7	6.1	19.6	13.2	6.1	7.1
	DS	13,623	0	23.0	17.0	6.0	27.5	5.3	22.2	13.0	5.3	7.7
19	US	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	US	23,310	0	19.9	13.9	6.0	30.1	4.6	25.5	10.6	4.6	6.0
	DS	11,264	0	24.3	18.3	6.0	31.5	4.8	26.7	12.2	4.8	7.4
21	US	23,120	0	21.4	15.4	6.0	31.3	3.9	27.4	12.4	3.9	8.5
	DS	14,050	0	23.6	17.6	6.0	33.2	3.7	29.5	11.8	3.7	8.1
22	US	24,240	0	21.3	15.3	6.0	34.4	5.0	29.4	11.5	5.0	6.5
	DS	12,586	0	24.0	18.0	6.0	39.0	5.8	33.2	12.6	5.8	6.8
24	US	20,440	0	21.0	15.0	6.0	31.6	5.0	26.6	10.7	5.0	5.7
	DS	11,000	0	22.8	16.8	6.0	27.7	6.3	21.4	12.9	6.3	6.6
25	US	27,240	0	20.5	14.5	6.0	30.9	3.7	27.2	9.7	3.7	6.0
	DS	14,688	0	22.5	16.5	6.0	27.0	4.4	22.6	12.2	4.4	7.8
M PRICE AUX	US	360	NA	8.9	NC	NC	NC	NC	NC	10.7	4.3	6.4
	DS	360	NA	11.3	NC	NC	NC	NC	NC	8.3	5.3	3.0
27 AUX	US	13,860	0	NC	NC	NC	NC	NC	NC	NC	NC	NC
	DS	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
LOCK-PORT	US	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	DS	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
BRAN-DON	US	11,348	62,180	25.4	19.4	6.0	31.2	6.3	24.9	11.7	6.3	5.4
	DS	13,420	62,180	25.3	19.3	6.0	42.0	6.4	35.6	12.1	6.4	5.7
DRES-DEN	US	9,907	62,180	25.7	19.7	6.0	33.7	5.7	28.0	12.6	5.7	6.9
	DS	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
MAR-SEILLES	US	10,726	62,180	25.3	19.3	6.0	32.1	5.2	26.9	12.6	5.2	7.4
	DS	11,980	62,180	25.4	19.4	6.0	39.6	6.3	33.3	13.5	6.3	7.2
STARV-ED ROCK	US	9,633	62,180	23.4	17.4	6.0	34.6	5.1	29.5	12.6	5.1	7.5
	DS	10,888	62,180	23.6	17.6	6.0	31.9	5.0	26.9	13.2	5.0	8.2
PEO-RIA	US	12,680	80,700	23.9	17.9	6.0	34.5	6.4	28.1	13.9	6.4	7.5
	DS	13,369	80,700	27.2	21.2	6.0	33.7	5.7	28.0	14.1	5.7	8.4
LA GRANGE	US	11,607	80,700	23.3	17.3	6.0	29.1	6.9	22.2	11.6	6.9	4.7
	DS	11,990	80,700	26.8	20.8	6.0	27.3	5.6	21.7	13.5	5.6	7.9

US=upstream, DS=downstream, NA=not applicable, NR=not recommended, NC=no change

Notes:

1. The environmental impacts are not shown on the cost side since they are yet to be quantified. However, they make up a potentially important component of the costs (impacts) side.
2. These costs include $240,000 and $360,000 for unpowered kevels on the upper and lower guidewalls respectively.
3. These costs are for switch boats, helper boats and temporary remote remake areas. Also included are economic impacts to the navigation industry from delays and closures that are shown on construction timelines at Appendix D.
4. At Lock 17 the downstream guidewall extension cost includes $3,657,000 for channel work (bank excavation).

Exit and Clear Time for Setover and Knockout Singles. In addition to the savings in the exit and clear time of the powered cut of double lockages, a savings in the exit and clear time for setover and knockout lockages is possible with unpowered kevels.

Setover and knockout single lockages typically occur when a tow has a river configuration over 600 feet but can still fit in the chamber as a single with some reconfiguration. Navigation Notice 1-1998 states that reconfiguration is required to reduce the unnecessary need for double lockages (see Figure 1-9 for diagrams of setover and knockout lockages). The area of potential time savings for setover and knockout singles is in allowing the tow to reconfigure to its river configuration along the extended guidewall instead of the current practice of reconfiguring in the lock chamber. This is after the tow pushes out from the chamber in its lock configuration with the assistance of the unpowered traveling kevels. As the tow exits, the front barge next to the guidewall is attached to the first kevel. The rear barge is attached to the second kevel after the rear barge passes the gate recess. The kevels, riding the rail along the top of the extended guidewall, help to keep the tow next to the guidewall and under control as the tow exits the chamber and travels along the guidewall. Thus, the chamber can be turned back sooner for the next tow traveling in the same direction (turnback exit lockage) while the exiting tow reconfigures to its river configuration at the end of the extended guidewall.

Setovers and knockouts represent a small percentage of the total lockages. For example, at Lock 25 in 1990, setover and knockout lockages totaled 1.4 percent (51 tows) and 7.2 percent (271 tows) of the commercial traffic, respectively, out of over 3,700 commercial lockages. As a result of the limited number of these tows, the systemic impacts of improvements in these lockages will likely be relatively small. However, a significant reduction in lock chambering time for these tows in a turnback exit lockage is possible.

Navigation Notice 1-1998 requires a minimum of three deckhands to handle lines for setover lockages and a minimum of two deckhands to handle lines for knockout lockages. One of the three deckhands stays with the setover barge temporary lashing during a setover lockage. This leaves two deckhands on the barges to handle fore and aft lines to the wall for both setover and knockout configurations. One lock person tends the lockage from atop the guidewall. This arrangement satisfies the needs for extracting setover and knockout tows in their lock configurations using two unpowered kevels, providing the following assumptions are made: (1) The lock person secures the towlines from the deckhands riding the front and back barges over the first and second kevels, respectively; (2) when the extracted tow is ready for reconfiguration along the extended guidewall, the lock person removes the line from the second kevel and ties the line (backing line) to a check post; and (3) an automatic line release in the first kevel trips the line, allowing the deckhand at the front to secure the line (backing line) to a pin located lower in the guidewall. Backing lines hold the barge group in position while the towboat remakes into the river configuration.

LPMS data from 1990 were used in estimating the average per lockage time savings for setover and knockout turnback exit lockages. To approximate the potential time savings, the turnback exit times for single tows were subtracted from setover and knockout turnback exit times.

$$\text{Time Savings} = \text{Turnback Exit of Setover or Knockout} - \text{Exit of Single}$$

The average time savings were estimated for setover and knockout turnback exits using the above formula and 1990 LPMS data. The average new turnback exit time of knockouts for the UMR locks in the downbound direction goes from 30 minutes to 6 minutes for an average savings of 24 minutes. In the upbound direction for UMR locks, the average new exit time of setovers goes from 28 minutes to 5 minutes for an average savings of 23 minutes. The average new turnback exit time of setovers for the IWW locks in the downbound direction goes from 34 minutes to 6 minutes for an average savings of 28 minutes. In the upbound direction for IWW locks, the average new exit time of setovers goes from 32 minutes to 6 minutes for an average

savings of 26 minutes. Knockout exits have less potential for reduction in exit times using 1990 LPMS data. The average new turnback exit time of knockouts for the UMR locks in the downbound direction goes from 13 minutes to 6 minutes for an average savings of 7 minutes. In the upbound direction for UMR locks, the average new exit time of knockouts goes from 12 minutes to 5 minutes for an average savings of 7 minutes. The average new turnback exit time of setovers for the IWW locks in the downbound direction goes from 13 minutes to 6 minutes for an average savings of 7 minutes. In the upbound direction for IWW locks, the average new exit time of setovers goes from 12 minutes to 6 minutes for an average savings of 6 minutes. Table 4-39 shows setover and knockout exit time savings for each lock site.

Similar improvements in setover and knockout exiting times are possible as well. However, due to the considerable time required for some reconfigurations, they may not be able to complete these operations prior to the preceding tow finishing its lockage and the chamber becoming available.

Conditions Affecting Implementation. Unpowered kevels are applicable at all lock sites where extended guidewalls are implemented. The existing kevel rail on the existing upstream guidewalls at locks within the study area can remain in place to reduce the implementation cost. Existing upstream kevel rails exist at all locks on the UMR, except for the 600-foot auxiliary locks at Melvin Price Locks and Locks 27; and at all locks on the IWW, except for Lockport, Brandon Road, and Marseilles. Dresden Island has kevel rail on both existing upstream and downstream guidewalls.

Costs. Typical first cost estimates are shown in Table 4-40 for installing two unpowered kevels and a rail on the extended upstream and downstream guidewalls. These estimates do not include the guidewall extension cost or the impacts to industry during the construction of the guidewall extensions. These additional costs are included in Table 4-39 "Cost and Performance of Unpowered Kevels with Extended Guidewalls." In addition to the first costs shown, annual maintenance costs are estimated at $2,000 per unpowered kevel or $4,000 per lock.

TABLE 4-40: COST ESTIMATES UNPOWERED KEVEL/RAIL SYSTEMS

UPSTREAM GUIDEWALL

ITEM DESCRIPTION	NO.	UNIT	COST ($)	ITEM COST ($)
140# RAIL (W/ PLATES, CLIPS)	700	LF	60	42,000
TOW HAULAGE BITTS	2	EACH	3,000	6,000
MISC. STRUCTURAL MODS	1	EACH	5,000	5,000
MOORING BITTS (FLTG)	1	EACH	100,000	100,000
SUBTOTAL				153,000
CONTINGENCIES (25%+)				47,000
PROJECT SUBTOTAL				200,000
ENGR/ DESIGN & CONSTR MGMT				40,000
PROJECT TOTAL (EXCLUDING GUIDEWALL EXTENSION)				$240,000

TABLE 4-40 (Continued)

DOWNSTREAM GUIDEWALL				
140# RAIL (W/ PLATES, CLIPS)	130 0	LF	60	78,000
TOW HAULAGE BITTS	2	EACH	3,000	6,000
REM / INSTALL CHECK POSTS	11	EACH	4,000	44,000
REM/ RELOC HANDRAILING	500	LF	20	10,000
MISC. STRUCTURAL MODS	1	EACH	5,000	5,000
MOORING BITTS (FLTG)	1	EACH	100,000	100,000
SUBTOTAL				243,000
CONTINGENCIES (25%-)				57,000
PROJECT SUBTOTAL				300,000
ENGR/ DESIGN & CONSTR MNGT				60,000
PROJECT TOTAL (EXCLUDING GUIDEWALL EXTENSION)				360,000

Relationship to Other Measures. Extended guidewalls with unpowered kevels eliminate the need for switchboat assistance or formal industry self help to pull the first cut of double lockages for remake along an extended guidewall. The second cut, or prime mover, powers the first cut to the end of the guidewall. This measure enhances the N-up/N-down policy to minimize lock transit time. All other small scale measures can be considered for implementation in conjunction with unpowered kevels, except for DeLong Piers. Unpowered kevels are not compatible with DeLong Piers used as a temporary extension of a guidewall. Continual straight alignment of the kevel rail is needed for proper operation of the kevels, which is difficult to maintain with a segmented DeLong Pier foundation.

Conclusions/Summary. Some lock operation personnel expressed some preference toward this method of being able to remake double cuts along an extended guidewall and freeing up the lock chamber for quicker turnaround. Expected time savings for double lockages is 6 minutes. While the percentage of setover and knockout lockages is low at most lock sites (around 7%), excluding locks above Marseilles on the IWW, the turnback exit time savings is substantial for these lockages, especially setovers. Setover savings vary from about 23 to 28 minutes, respectively, on the UMR and IWW. Knockout savings vary from about 6 to 7 minutes.

Potential damage to an unpowered kevel/rail system should be less than to a powered kevel system during high river stages as there are no power winches or cable runs along the extended guidewalls susceptible to potential hits by tows (raker barges) or floodwater debris.

Adjacent Mooring Facilities

Adjacent mooring facilities are devices that allow a vessel a place to tie off while waiting for their turn to lock through. These mooring facilities provide an attachment point for the tows or their barges by use of a line. Without such facilities, the towboats may be forced to wait considerable distances from the locks and must either push into the riverbank, which can cause erosion and damage to shoreline vegetation, or wait out in the currents of the river, which wastes fuel. Both options can cause scour of the bank by the vessel's propwash. The location of these facilities was discussed with lockmasters and industry representatives (towboat captains/pilots). Reference was also made to the *Mississippi River Locks and Dams 11 -22 Approach Improvements Rehabilitation Evaluation Report*, dated June 1993. The general benefits of adjacent moorings are shown on

Figure 4-9, while the desired mooring locations are shown for each lock on plates 1 through 27 in Appendix C.

Design Details. There are three types of moorings: mooring buoys, land-based moorings or bank anchors, and mooring cells. The mooring buoys and land-based moorings are similar in design, making use of anchors that dig into the river bottom or nearby land. Their design makes them reasonably easy to relocate as necessary. The mooring buoys can be moved, if required, to several different locations over a period of time to determine the best location for a permanent mooring cell. Mooring cells are permanent structures that are made of steel sheet piling driven into the river bottom and filled with earthen materials and/or concrete. Cells can slightly alter localized river flow conditions (flow velocity vectors).

- **Mooring Buoys**

Description. Mooring buoy assemblies consist of two anchors connected to a concrete sinker that is connected to a large floating buoy with a heavy anchor/riser chain. The buoy is 12 feet in diameter, 3.5 feet high, and filled with polyurethane foam for buoyancy. The buoy is fitted with a mooring ring or other point to which a tow can attach a mooring line (see plate 32 in Appendix C). A new buoy design (non-cylindrical) is being tested, which should make buoys more usable and accessible to waiting tows.

- **Land-Based Moorings**

Description. Land-based moorings consist of an anchor and chain located on land adjacent to the lock approaches. The anchor is buried in the nearby bank, leaving the chain and mooring ring available for use by the tows (see plate 32 in Appendix C). The land-based moorings reduce the practice of nudging into the shoreline or tying up to trees along the riverbank to wait for lockage, thereby reducing erosion and damage to shoreline vegetation.

- **Mooring Cells**

Description. Mooring cells are constructed of sheet pile and are filled with earthen material and/or concrete. Mooring cells are preferred by industry because of their stability and ease of use. However, proper location of the cell is critical to its being used by tow operators as well as not being a hindrance to navigation. Achieving the proper location that suits all pilots, all river conditions, and all maneuvering techniques is very difficult. The cells are typically 30 to 40 feet in diameter and are fitted with a mooring ring or check posts for a point of attachment (see plate 33 in Appendix C). Cells are preferred by industry, especially upstream of a lock, because they provide a more positive tie-off for barges when a line boat is needed to assist with an emergency at the lock or to pull other cuts from the lock chamber during an N-up/N-down or self-help scenario at the lock.

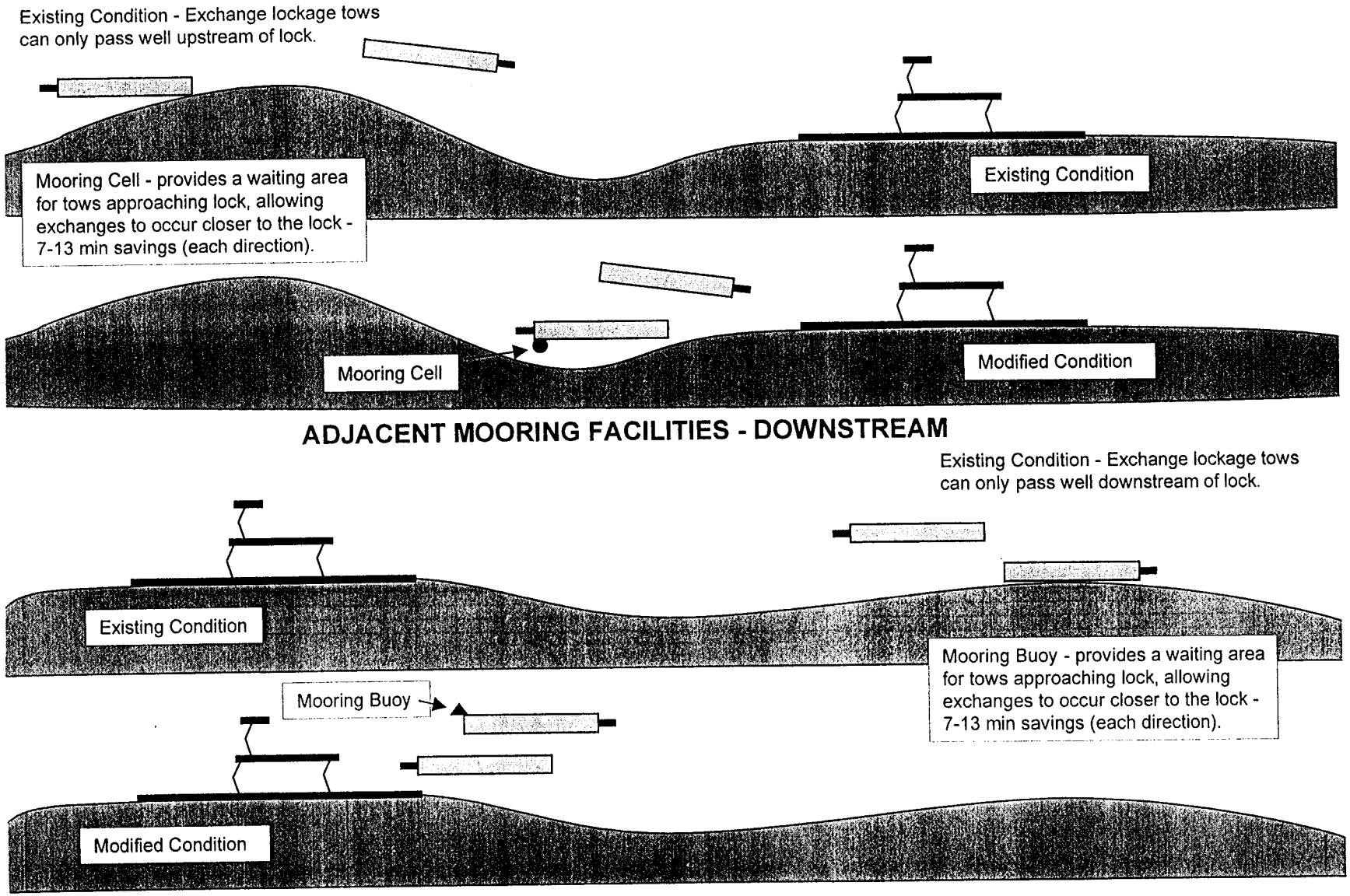


FIGURE 4-9: Adjacent Mooring Facilities - Upstream

Existing Conditions. Most lock sites in the study area do not have existing mooring facilities either above or below the lock, or have limited facilities could be augmented or improved. Table 4-41 shows the existing mooring facilities at the UMR locks, and Table 4-42 shows the existing mooring facilities at the IWW locks. The tables also identify the locations closest to the locks for a desired mooring facility. These locations were determined based on discussions with lockmasters and industry representatives (towboat captains/pilots) and review of prior reports.

Plates in Appendix C show locations for adding moorings at all lock sites, including those locations which do not bring tows closer to the lock. The plates also show potential locations for remote makeup areas to be used in combination with switchboats pulling first cuts of double lockages. There should be no impacts to navigation during installation of mooring facilities. Environmental impacts will be added to the cost after they are quantified.

Delay Reduction Methodology/Time Savings Estimates. Installation of adjacent mooring facilities benefits lock transit time if tows are able to moor closer to the lock while waiting their turn to lock through. This reduces the approach time to the lock after a moored tow starts its approach. Under present conditions, tows generally wait as close as they can to a lock. Installation of moorings where tows presently wait does not shorten the approach time, but having a dedicated mooring makes for safer operating conditions and moves tows off the riverbank, preserving shoreline vegetation. Also, fuel can be conserved if tows do not have to idle their engines to hold position (estimate 15 gal/hr to hold, 4 to 5 gal/hr idling out of gear).

Table 4-43 identifies lock sites where additional moorings will bring tows closer to the lock and save time on their approach. The location of these moorings was discussed with lockmasters and with industry representatives (tow captains/pilots) during on-site lock visits and followup discussions. LPMS data from 1990 were used to estimate the potential savings in the exchange approach time for doubles approaching the lock. The estimated time savings is based on an average travel speed of 4.5 miles per hour (3.9 knots per hour) for the shorter distance traveled to the lock on an exchange approach. Savings of roughly one-half the double savings would be applicable to single lockage tows at all sites except Lock 24, where singles already can approach more closely. Single lockage tows save less time on average since they are smaller, more maneuverable, and in some situations can wait closer to the lock. Total benefits are nearly double those shown in Table 4-43 for exchange lockages since moving the mooring closer not only shortens the approach, it also shortens exit times by a comparable amount.

Conditions Affecting Implementation. Conditions affecting implementation are few. Water depths appear sufficient at all sites for tows to access the identified mooring locations without any needed dredging or other channel excavation. Environmental impacts have to be considered and added to the cost side if detrimental.

Cost. The estimated first cost for mooring buoys and land-based moorings is $50,000 each. This is based on historical costs for placement of these types of moorings. The first cost of a mooring cell is estimated at $500,000. These costs are considered to be fairly consistent for mooring placements at any of the above lock sites. In addition, annual maintenance costs of $5,000 per buoy and $20,000 per cell are anticipated. The environmental impacts from new moorings are not included in these costs since they are yet to be determined, but these impacts make up a potentially important component of the cost.

Relationship to Other Small Scale Measures. Adjacent mooring facilities are related to remote makeup facilities used with switchboats or industry self help. Placement of either type facility (mooring facility or remote makeup area) has to be coordinated. Mooring facilities have to be located in consideration of any potential approach channel improvements implemented for a lock site. Adjacent mooring facilities can be used with all other small scale measures under consideration.

TABLE 4-41: PROJECT LOCATIONS AND EXISTING\DESIRED MOORING FACILITIES UPPER MISSISSIPPI RIVER

			Existing Mooring Facilities		Desired Mooring Facilities Closest to Lock	
Lock	River Mile	Location	Upper Pool	Lower Pool	Upper Pool	Lower Pool
11	583.0	Dubuque, IA	None	None	583.8RC	582.5LB
12	556.7	Bellevue, IA	557.4 RC CELL	None	558.0RB	556.0LC
13	522.5	Fulton, IL	523.5 LC CELL	None	None	None
14	493.3	Le Claire, IA	None	None	493.7RB	492.5LC
15	482.9	Rock Island, IL	None	None	483.8LB	482.6LB
16	457.2	Muscatine, IA	None	None	457.9LB	456.8LB
17	437.1	New Boston, IL	None	None	437.8LB	436.5RC
18	410.5	Gladstone, IL	411.6LC BUOY	None	411.0LB	409.7RC
19	364.0	Keokuk, IA	365.0RB 2CELLS	363.6RB 2CELLS	365.5RB	361.7RB
20	343.2	Canton, MO	None	None	344.0RB	342.8LC
21	324.9	Quincy, IL	None	None	325.3LB	324.5RC
22	301.2	Saverton, MO	301.8RC CELL	None	302.3RC	300.8LC
24	273.4	Clarksville, MO	274.5RB BK ANC	None	274.0RB	273.0RB
25	241.5	Cap au Gris, MO	242.1RB BK ANC	241.3LC BUOY	242.4RC	241.3LC
Mel Price Aux. Lock	200.8	Alton, IL	None	None	204.0LB BK ANC	200.6LB BK ANC
27 Aux.Lock	185.5	Granite City, IL	None	None	None	None

LB=Left Bank, RB=Right Bank, LC=Left Channel, RC=Right Channel, BK ANC=Bank Anchor

TABLE 4-42: PROJECT LOCATIONS AND EXISTING\DESIRED MOORING FACILITIES ILLINOIS WATERWAY

			Existing Mooring Facilities		Desired Mooring Facilities Closest to Lock	
Lock	River Mile	Location	Upper Pool	Lower Pool	Upper Pool	Lower Pool
Lockport	291.0	Lockport, IL	LB WALL	290.9LB CELLS	None	290.5LB
Brandon Rd	286.0	Joliet, IL	286.3RB CELLS NU	285.3RB CELLS NU	286.1RC WIND	285.0RB
Dresden Is	271.5	Morris, IL	272.0LB CELLS	270.9LC CELLS	272.4RB	270.2LB
Marseilles	244.6	Marseilles, IL	244.7LC 245.0RB NU	244.3RB NU BY TOWS	248.0LB CH	243.3LB
Starved Rock	231.0	Ottawa, IL	231.5LC	None	233.0RB	230.4LB/LC
Peoria	157.7	Peoria, IL	None	None	158.0LC	157.0LB
La Grange	80.2	Versailles, IL	80.9RB BUOY BROKEN	None	80.4RB	78.8LB

NU=Not Used

TABLE 4-43: COST AND PERFORMANCE OF ADJACENT MOORING FACILITIES

Upper Mississippi River

Lock	Miter Gate RM	Dir.	Wait at RM Exist	Wait at RM New	Cost ($1,000's)	Miles Closer	Time Savings Doubles (min) [1/]
12	556.6	UB	555.0LC	556.0LC	50	1.0	13
14	493.3	DB	494.6RC	493.7RB	500	0.9	12
14	493.3	UB	489.7LC	492.5LC	500	2.8	37 (35% of the time)
16	457.2	UB	455.5LC	456.2LC	50	0.7	(*)
18	410.5	UB	409.0RB	409.7RC	50	0.7	9
20	343.2	DB	346.0LB	345.0LB	500	1.0	(*)
20	343.2	UB	342.0LC	342.8LC	50	0.8	11
22	301.2	DB	303.6RB	302.3RC	500	1.3	(*)
22	301.2	UB	300.3RB	300.8LC	50	0.5	7
24	273.4	DB	274.5RB	274.0RB	500	0.5	7
25	241.5	UB	240.6RB	241.3LC	50	0.7	9
Melvin Price	201.6	UB	199.6LB	200.6LB	50	1.0	13

Illinois Waterway

La Grange	80.2	DB	80.9RB	80.4RB	500	0.5	7

UB = Upbound Direction of Travel, DB=Downbound Direction of Travel
(*) = Next mooring location (not closest to lock)
[1/] Approach time savings shown are for exchanges of double lockage tows. Similar savings for exchange exits are anticipated. Savings of roughly one-half this amount are anticipated for single lockage tows.

Conclusions/Summary. There is an opportunity to reduce some delay at those lock sites where a mooring facility closer to the lock will shorten the travel distance for tows on exchange approaches and exits. For a turnback lockage, the tow is usually waiting at the lock guidewall. However, some tows may not want to approach the guidewall unless the gates are opened. A closer mooring facility would benefit this condition. Benefits for downbound tows are related to flow conditions since higher flows worsen the outdraft, which usually lengthens the approach time.

Crew Elements

Crew elements refer to those measures with potential to improve the process of breaking and remaking tows involved in double lockages. Crew elements are identified here as a small scale structural measure because of its implied relationship to any structural modification in the existing barge coupling mechanism. Two measures were recommended for detailed analysis in the 1995 *General Assessment of Small Scale Measures* interim report: Universal Couplers/Hand Winches and Require Minimum Crew Size with Training.

In addition to "Universal Couplers/Hand Winches" and "Require Minimum Crew Size with Training," other measures were identified in the 1995 *Universal Couplers and Crew Training* report with potential to reduce the remake time of double lockages. These other measures are "Permanent Deck Winches" and "Additional Personnel." A "Power-Operated Ratchet," recently developed by industry, is also included as a potential time saver.

The development of a simple, quick-operating, and universally adaptable coupler, winch, or ratchet for joining barges could save considerable time in breaking and remaking tows.

An experienced crew that is large enough to handle a lockage can save time in the breaking and remaking of tows. The 1995 *Universal Couplers and Crew Training* interim report assessed the time savings associated with improvements to barge coupling equipment, as well as minimum crew training requirements. This report reviews the current practice regarding hardware, procedures, and personnel training related to the lashing of barges into a tow configuration as practiced on the UMR and IWW. The report assesses the impacts that these practices have on the efficiency of moving tows through the locks on these two river systems and discusses the existing opportunities for increasing the efficiency of the lockage process through changes in current practice. The basic premise of the report was to identify the impacts to lock transit time with improved barge lashing equipment or processes. Typically, the recoupling of barges takes a longer time than the uncoupling, and, for this reason, the focus of this effort is on identifying an improvement in the recoupling time. The findings from this interim report and other information impacting crew operations are summarized here.

Existing Conditions

Hardware Used. The hardware used in coupling barges consists of a combination of the following: wire rope, chain and steamboat ratchets. Winches are occasionally used to tighten couplings, but the majority of couplings are tightened using a steamboat ratchet.

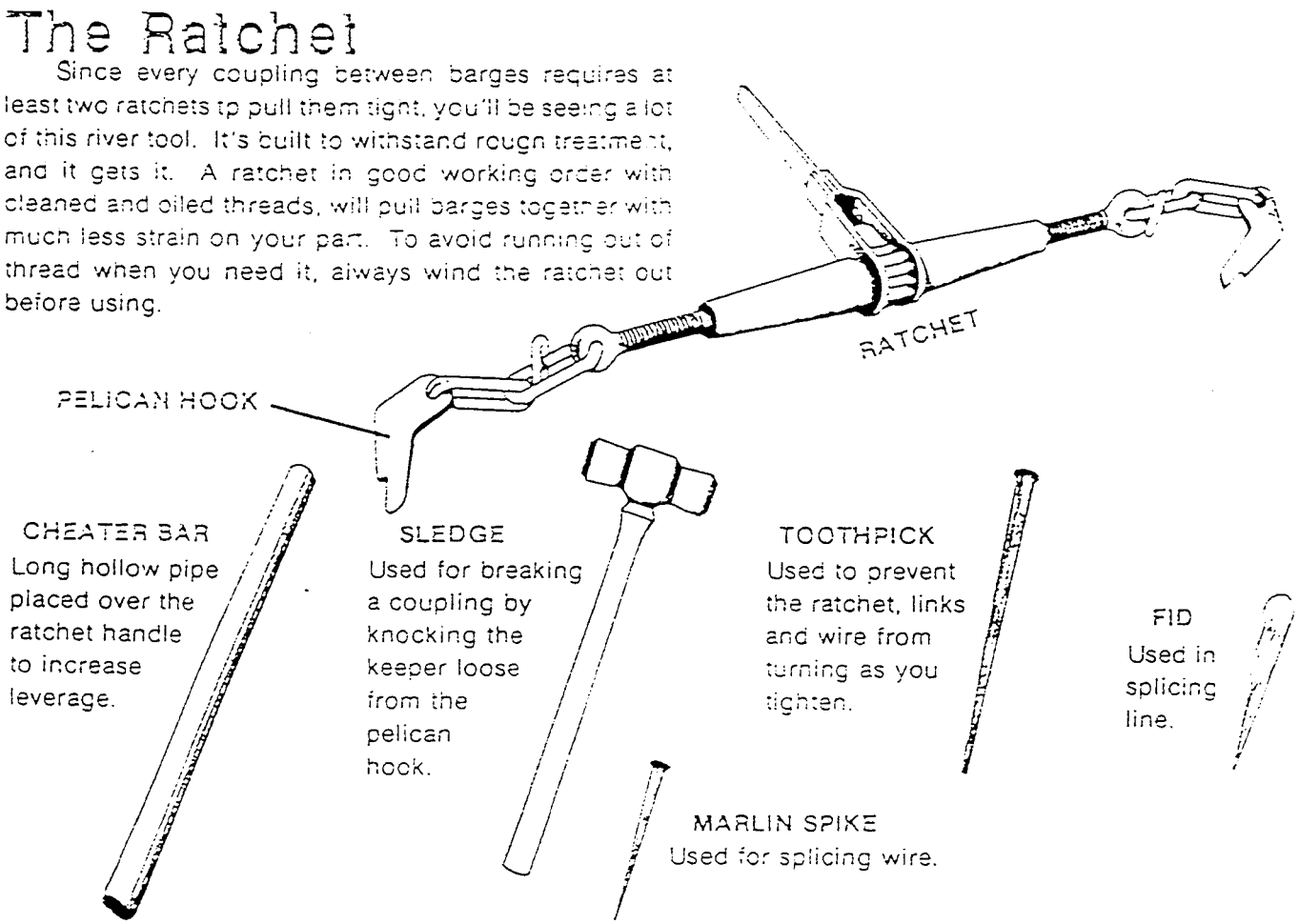
Steamboat Ratchets. Couplings are set taut with the use of a steamboat ratchet, a type of turnbuckle with a ratchet attached to the barrel. The ratchet has a handle that can be extended with a "cheater bar" and pelican hooks on one or both ends. A "toothpick" may also be used to prevent the ratchet from turning as it is tightened. The steamboat ratchets are completely removable and act as fasteners between chain and/or wire rope. This device has been in use for many years and has become the industry standard in couplings (see Figure 4-10).

Wire Rope and Chain. A 35-foot length of wire with eyes in both ends is used for making couplings between barges. The ratchet is hooked to the small eye, and the large eye is placed over a timberhead. Other lengths of wire rope can be used for couplings by adding chain links and shackles to extend them to the ratchet.

Sling. A sling, "hula hoop," or strap is a loop of wire that has been spliced together at its ends. It can be used to attach a chain to a kevel by looping it over the fitting and securing the chain with a shackle.

Procedure. The basic steps to "lay a wire" (attach a coupling) using a ratchet, wire, and sling, are as follows:

1. Run out the ratchet.
2. Place chain sling or strap over kevel.
3. Attach small eye of wire to the ratchet.
4. Lay the wire (run it around the timberheads).
5. "Jerk" the ratchet towards the chain sling to "pop" the wire and remove the slack.
6. Attach the ratchet to the chain sling.
7. Tighten ratchet. (Always position it so it tightens inboard.)
8. Use the cheater bar and toothpick to tighten the ratchet fully.
9. Remove the cheater bar and toothpick.



Source: The Deckhand's Manual, by Joan Fassler, 1980

FIGURE 4-10: "The Ratchet"

After the first section of the tow (first cut) has been locked through and pulled out and positioned along the guidewall, the lock chamber is turned back to receive the remaining barges and the towboat. After the second cut (powered cut) has been locked through and the lock gates opened, the towboat with remaining barges carefully pushes ahead and faces up to the first cut of barges. Once faced up, the deckhands and mate go to work remaking the lashings. First the wire rope must be threaded back and forth around the fittings of the two adjacent barges. Then, the free end is secured to the pelican hook of the ratchet. Finally, the ratchet must be properly tightened. Each of these operations is performed manually, and the lashings must be completed before the tow moves off the lock guidewall.

Configurations. The wire couplings used to attach barges together have special names depending on their use. They include: fore and aft wires, backing/towing wires, and scissor/jacking wires (see Figure 4-11A). Fore and aft wires in a coupling are used to couple barges end-to-end. They can be either three-part wires or four-part wires, depending on how many times they traverse the break between barges (see Figure 4-11B).

Factors Affecting Implementation of Hardware and Configuration Changes. The following elements affect the hardware and configurations used for barge couplings: vertical differential between barges at the break coupling, size of barges, the ability to pick up and drop off barges during intermediate stops, the barge condition and adaptability to structural modifications, and the ease of obtaining the required equipment (new couplings and related hardware).

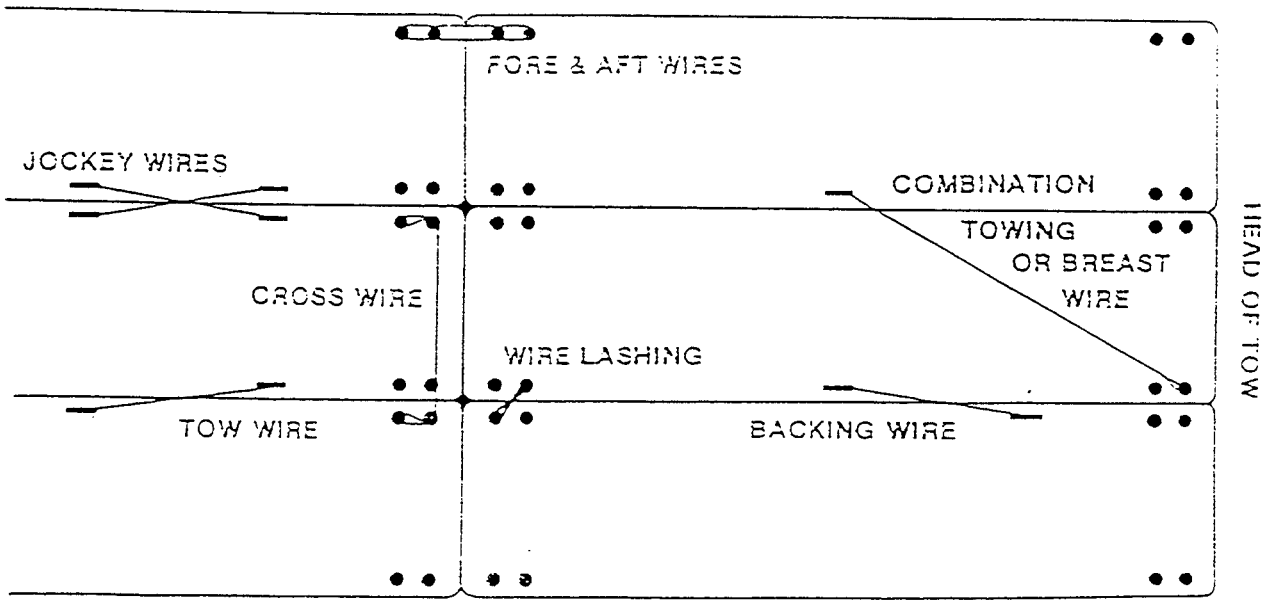
Coast Guard Licensing and Testing Requirements. According to the Coast Guard Regional Exam Center in St. Louis, there are no testing or licensing requirements for deckhands on the inland waterways.

Corps of Engineers Requirements for Lockage. Navigation Notice 1-1998 (Mississippi Valley Division, Great Lakes and Ohio River Division) requires a minimum of three people to handle lines during a double lockage. The captain/pilot can not act as a deckhand.

▪ Universal Coupler/Hand Winches

Description of Measure. Industry continues to pursue improvements to the barge lashing system for time savings and increased worker safety. The aim of these efforts is toward a new lashing/coupling mechanism for use at all points in the tow, not just the lashings that are worked during a double lockage. By improving the lashing system in general, the time to remake lashings during a double lockage will also be favorably impacted. Since the development of new hardware and lashing procedures will benefit the towing industry as a whole and these benefits will accrue for all lashing activity, not just relashing at locks, the industry will continue its interest and support of the continued development of such improvements.

However, the September 1995 *Universal Couplers and Crew Training* report concluded that while a universal coupler could be operated quickly resulting in significant time savings, the lack of existing technology for this application, combined with the investment cost to develop such a device, eliminates this measure from consideration. This concurs with the Berger Report (1981), that also addressed the issue of "Universally Acceptable Couplers or Hand Winches for Joining Barges."



Source: The Deckhand's Manual, by Joan Fassler, 1980

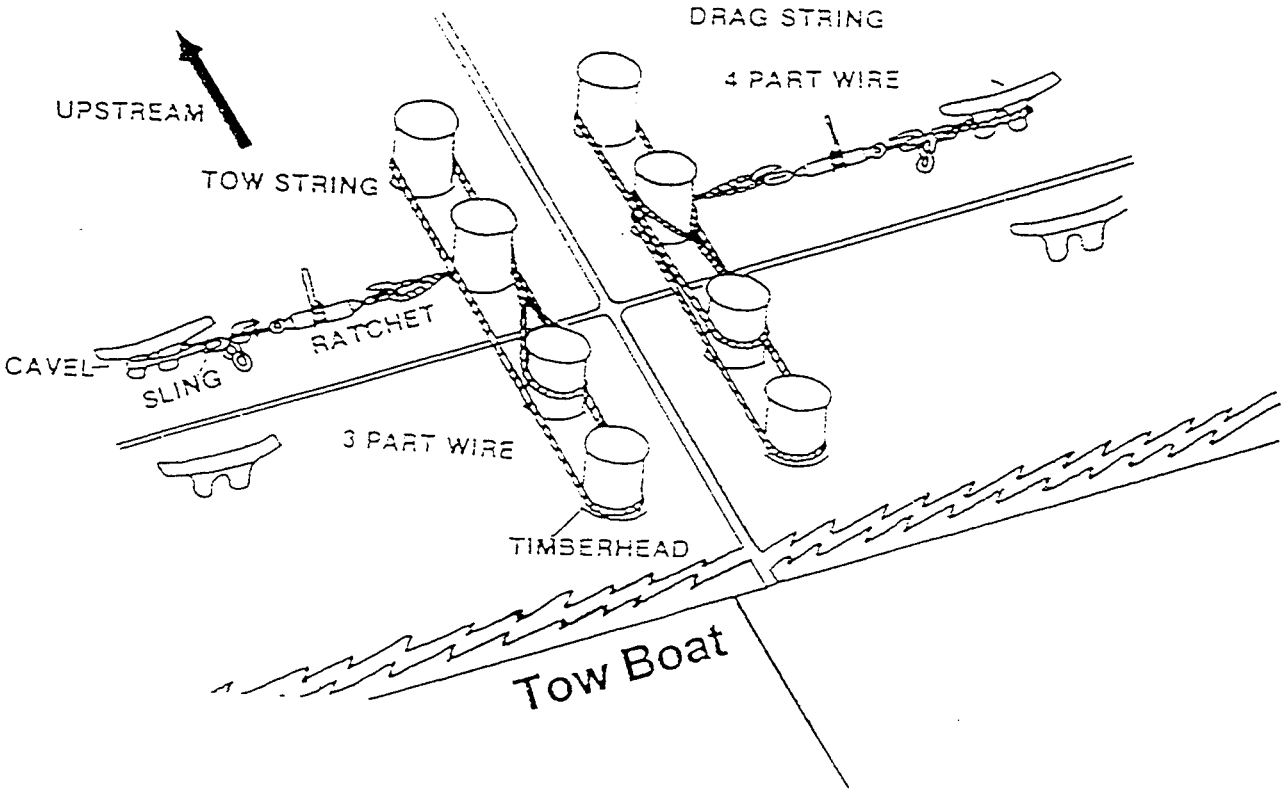
FIGURE 4-11A: "Wires Most Commonly Used and Their Descriptive Names"

BASIC FORE/AFT WIRE

This is the coupling used to couple the barges end to end. It can be either a 3 or 4 part wire.

3 PART WIRE: With 3 parts the eye of the wire is placed over a timberhead on the barge opposite on which the ratchet is placed.

4 PART WIRE: With 4 parts the eye of the wire will be placed over a timberhead on the same barge on which the ratchet is placed.



Source: The Deckhand's Manual, by Joan Fassler, 1980

FIGURE 4-11B: "Basic Fore/Aft Wire"

▪ Require Minimum Crew Size with Training

Description of Measure. This measure provides an experienced crew that is large enough to handle a lockage and save time in the breaking and remaking of tows. Training could reduce the variability involved in the makeup process.

Industry abides by current regulations. Industry provides the required crew size of three people (the captain/pilot can not act as a deckhand) to handle lines during a double lockage as required by the Corps of Engineers' Navigation Notice 1-1998.

The 1995 *Universal Couplers and Crew Training* report concluded that crew training is commonly handled as "on-the-job" training, though formal training programs are provided by some of the larger barge lines. (The Coast Guard does not require testing or licensing requirements for deckhands on the inland waterways.) Crew skill is reflected in the time consumed in the lashing process. There is no clear indication that one form of training produces crews with greater skill levels than another form of training. The *Universal Couplers and Crew Training* report concluded, as did the Berger Report which also included "Crew Training" as a measure for consideration, that "the vast majority of the towing companies are responsible and their present manning and equipment standards could satisfy any reasonable regulation" and that "there is no way of estimating the number of (marginal) companies, or the expense required to implement such a program." Thus, "standardization" of training for crews is eliminated as a method of reducing tow remake time.

▪ Permanent Deck Winches

Description of Measure. Some barge lines keep their equipment captive to their own fleets and have chosen to mount deck winches on the forward decks of all their barges. The deck winch is used in lieu of the steamboat ratchet to tighten the primary fore/aft lashings. The winch is permanently welded to the deck of the barge, and an ample length of wire rope is spooled on the drum of the winch. The speed of the unlashing, although not a significant element of total lockage time, could be substantially reduced. A deckhand must tighten the wheel of the winch slightly to permit the removal of the locking paw, then releasing the wheel. This simple step will "slack" the line sufficiently to permit its removal from all the timberheads and kevels.

Once the tow is again faced up, the line can be remade and the wheel on the winch is cranked to tighten the line. Tightening a single line with a winch will take only a few minutes; the operation is much cleaner as there are no pelican hooks, chains, toothpicks, or cheater bars to deal with. Secondary benefits will accrue to the towing industry since the simpler, faster operation will occur every time the barge with the winch is lashed into a tow, whether this occurs at a lock or somewhere else in the system.

Delay Reduction Methodology/Time Savings Estimates. The typical deck crew that handles the coupling and uncoupling of barges usually consists of three people—the mate and two deckhands. These three are responsible for remaking the two cuts after a double lockage. This coupling typically consists of five wires, each wrapped three to four times across the gap between barges. The kevel that is normally used for the sixth wire when the vessel is under way is used for the mooring lines when the unpowered cut is on the guidewall after locking through. Therefore, the sixth wire is typically not placed until after the tow has departed the guidewall. From the time that the cuts bump together until the tow leaves the guidewall, the major activity is remaking the five wires. Based on timing data collected for the 1995 *Universal Couplers and Crew Training* report, this process takes an average of 12 minutes. (The observed times varied from 7 minutes to about 18 minutes.)

Since most of the guidewalls on the UMR and the IWW are, like their lock chambers, only 600 feet long, a portion of the tow and the towboat remains in the lock chamber during the remake

of a double cut. With the tow in this position, the lock gates can not be closed and the chamber can not be turned back to receive the next tow until the first tow has been completely made up and departed (see Figures 4-12A and B). This *remake time* causes significant delays at many locks in the study area during peak operation times. *A reduction in the remake time is applicable to all double lockages and benefits all tows in the queue.*

The estimated time savings is in relation to the current remake procedure which, as described above, takes an average of 12 minutes as determined from a limited number of timed observations. This baseline time of 12 minutes is based on three people remaking five wires. Since there are five wires, two of the three deck crew have to perform each operation twice (three people lay a wire and tighten it, then two of the three lay another wire and tighten that one). Some of the following measures save time by freeing up this second operation of laying and tightening. Others reduce the laying time of the wire only, while others reduce the time to tighten.

Assumptions: (Baseline)
3 people on deck (mate and two deckhands)
5 wires to lay and tighten

Time: 12 Minutes (Baseline Estimate)
3 minutes to lay the wire
3 minutes to tighten the wire
2 wires per person

Time Savings (Permanent Deck Winches)

Assumptions:

1 person lays the wire and then operates the winch
Wire is permanently spooled on the winch
All barges at the coupling have/can utilize the winch

Time: 8 Minutes (4 minute savings, compared to the baseline time of 12 minutes)
2 minutes/wire to lay x 2 wires/person = 4 minutes
2 minutes/wire to tighten x 2 wires/person = 4 minutes

LPMS data for 1990 show the exit time for all double lockages to be from 20 to 27 minutes on the UMR and from 26 to 35 minutes on the IWW. This time includes the face up time for the (powered) second cut, the reconnect time, and the exit time for the remade tow from the lock chamber. With deck winches, the new exit times would be reduced by 4 minutes.

Conditions Affecting Implementation. The question has been raised that if the benefits are so great, why haven't all the barges been fitted with the deck winches. The answers from industry are three-fold. First, the deck winches are expensive. Second, the fleet is essentially interchangeable and a barge owned by one company may frequently be found in the tow of another company. Therefore, the assumed benefit would not necessarily be accrued by the company that made the investment. Third, for the system to work, it would require a costly mandate that all barges (at least those to be used for double lockages) be retrofitted with deck winches or that new barge construction provide for permanent deck winches.

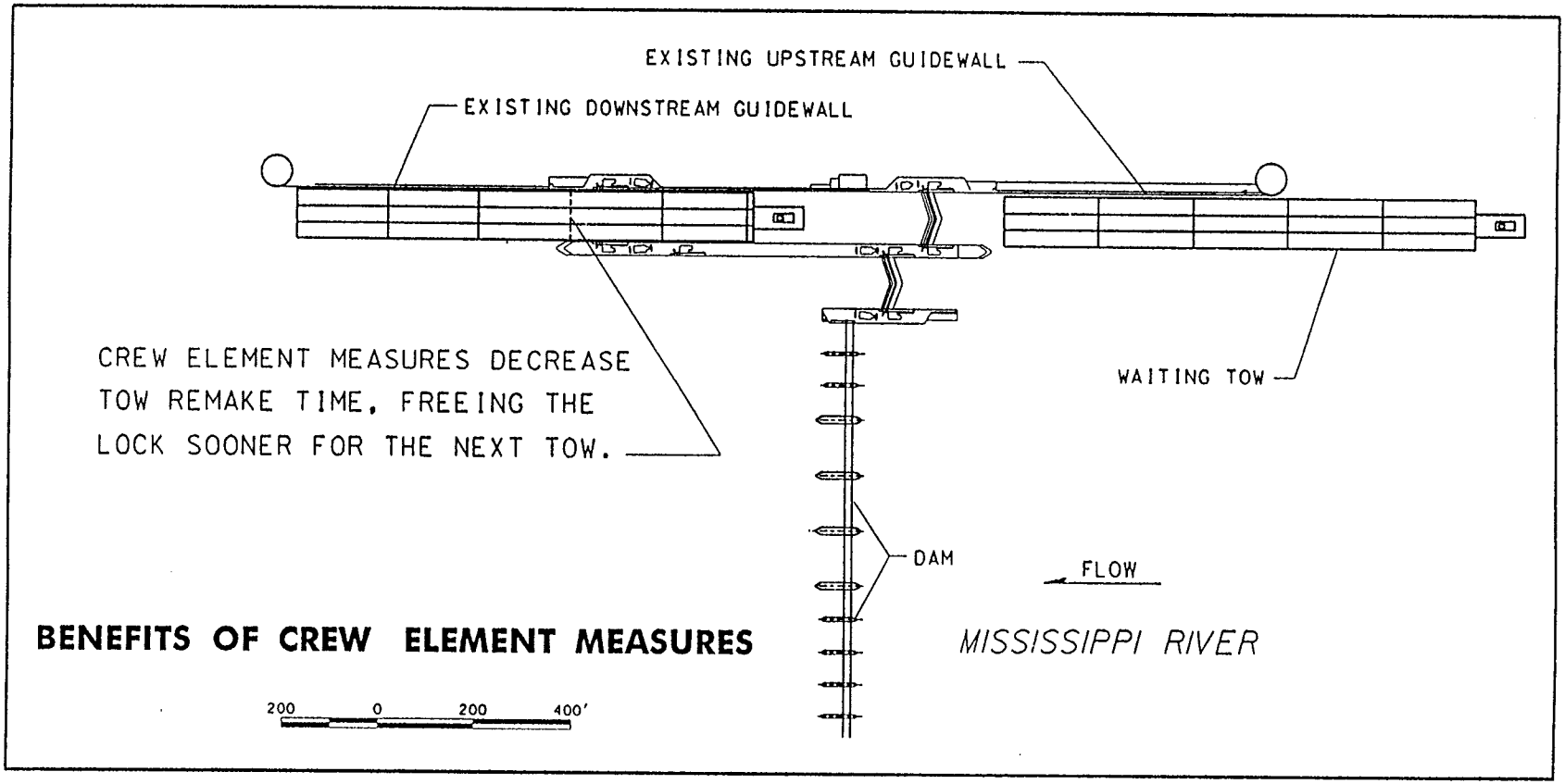
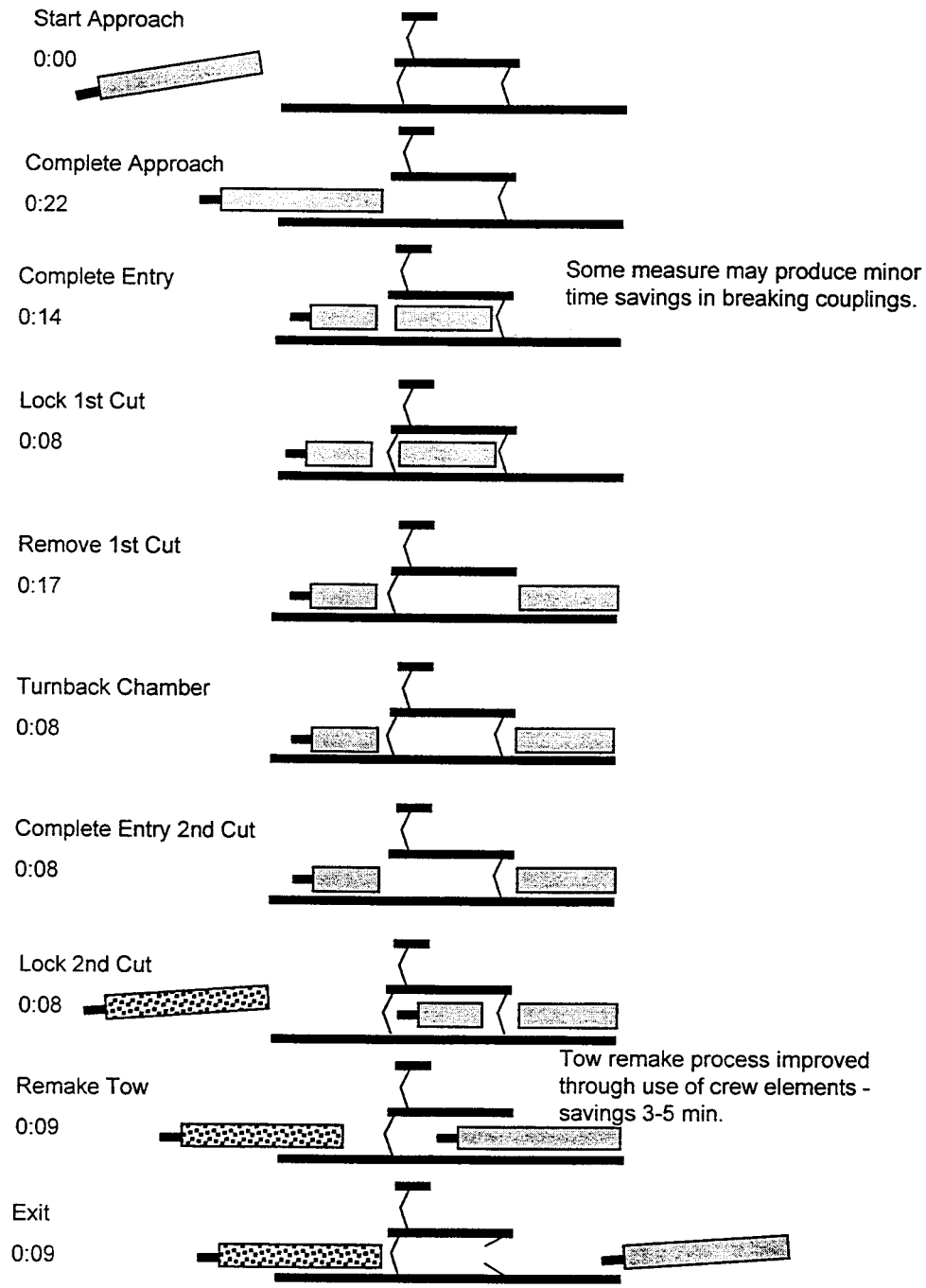


FIGURE 4-12A: Benefits of Crew Element Measures



Total Lockage Time 1:43

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

FIGURE 4-12B: Double Lockage Elements - Crew Element Benefits

Cost. The estimated cost of the measure is made up of two components: (1) initial start up cost to include capital expenditures and training, and (2) the annual costs, including maintenance/upkeep and salaries/salary related expenses. Training time and its cost are considered insignificant, and maintenance cost is assumed to be similar to the cost of maintaining the existing lashing system. Here, only the initial capital cost of the measure is considered. Also, measures are not evaluated on who will bear the expense (industry or the government).

To implement this measure, it was assumed that each barge in operation would need to be retrofitted with deck winches. There are a few exceptions to this because certain barge lines keep their fleet captive and some do not require double lockage. However, this is assumed to be a small percentage of the industry fleet. Therefore, the basis for this assumption was as follows:

a. Current practice by most companies is to exchange barges on a regular basis for economic reasons.

b. To minimize the amount of time that otherwise would be required to reconfigure the barge fleet if all the barges would not have deck winches.

The cost of a single deck winch was estimated to be $1,000 for equipment and installation. Based on an industry fleet of 13,000 barges and four winches per barge, the initial capital cost would be $52 million or $4,000/barge. In addition, annual maintenance costs of $400 per barge would also be required.

Relationship to Other Small Scale Measures. Permanent deck winches are complementary to other small scale measures, including extended guidewalls, to get the remade tow off the wall sooner for an exchange exit lockage.

Crew elements themselves seem mutually exclusive to each other, although the combination of permanent deck winches and additional personnel could be considered.

- **Additional Personnel**

Description of Measure. Since each tow has more wires to make between the first and second cut than there are deck personnel on duty, two deckhands are responsible for completing at least two lashings. If additional personnel were available at the lock, each person could be responsible for just one of the lashings.

The process of relashing the two segments of a tow involved in a double lockage is the responsibility of the deckhands and the mate. The most common practice is for each of the individuals to take responsibility for one or two of the five fore/aft lashings. There is no particular order in which these lashings must be tightened or loosened; therefore, when the crew member completes one of the lashings, he moves on to the next one.

This proposed efficiency measure would assign two experienced deckhands to each of the locks in the congestion area. After the unpowered cut of the tow is extracted from the lock and secured on the guidewall, the two extra deckhands would move to the deck of the barges. When the powered cut faces up to the unpowered cut, each person (five total) would take responsibility for remaking one lashing. Since all five lashings are being secured concurrently, the total remake process time would be reduced by one-half. When the lashing process is completed, the two additional deckhands would return to the top of the guidewall and await the next tow.

Time Savings (Additional Personnel)

Assumptions:

2 additional persons for a total of 5 persons
each person works a wire
5 wires

Time: 9 minutes (3 minutes savings, compared to the baseline time of 12 minutes)

3 minutes to lay the wire
4 minutes to tighten the wire
2 minutes to exit tow (1 minute to climb lockwall ladder x 2 persons)

LPMS data for 1990 show the exit time for all double lockages to be from 20 to 27 minutes on the UMR and from 26 to 35 minutes on the IWW. This time includes the face up time for the (powered) second cut, the reconnect time, and the exit time for the remade tow from the lock chamber. With additional personnel, the new exit times would be reduced by 3 minutes. There is some potential increase for inefficiencies associated with congestion on the deck. This is accounted for to some extent by a 1 minute increase in tightening time.

Conditions Affecting Implementation. This approach to reducing lockage time does not require any capital expenditures. It is anticipated that there is a sufficient pool of experienced deckhands that would fill these positions during their 30-day rest periods (or persons in the local area who could be trained). The issues to be resolved are how to pay them and who will pay them. Three possible scenarios exist:

1. They could become government employees;

2. They could become employees of a local harbor service or switching company that would be under contract to the government; or

3. They could become employees of a local harbor service or switching company whose services would be billed to the towing industry for each use.

Utilization would be required during periods mandated by the lockmaster (would need to be included in a Navigation Notice issued by the Corps of Engineers) in the same way that helper boats are required for specific river conditions.

Cost. There are no capital expenditures to implement this measure. Annual cost would be the cost of the part-time or contract-hire personnel. There would be a cost for maintaining logs of the availability of a pool of workers. Assuming that the additional personnel are required to be at the locks in the congested area 24 hours a day during the peak traffic periods, the cost is estimated at $1,200/day/lock (2 employees x 24 hours/day x $25/hour). The $25 cost assumes a multiple of 2.5 to 3.0 times the average wage for this type of work to include the anticipated indirect operational cost.

Relationship to Other Small Scale Measures. Additional Personnel is complementary to other small scale measures including extended guidewalls to get the remade tow off the wall sooner for an exchange exit lockage.

Crew elements themselves seem mutually exclusive to each other, although the combination of permanent deck winches and additional personnel could be considered.

▪ Power-Operated Ratchet

Description of Measure. A powered operated ratchet is a compact device that uses a 4-horsepower gas engine to power a hydraulic drive system that operates a specially designed wrench head to engage the barge (steamboat) ratchet. The device is portable and can be stationed on the center barge at the break couplings or possibly at the lock. The device allows one deckhand to follow behind the other two deckhands who are laying wires and tighten each wire in turn in 30 seconds to less than a minute per wire. The unit improves safety by eliminating the use of cheater pipes and requiring less physical labor. However, the unit is heavy (32 lbs.) and could cause injury if mishandled.

Time Savings (Power-Operated Ratchet)

Assumptions:

3 people lay first 3 wires
2 people continue to lay 1 additional wire
1 person tightens all 5 wires
5 wires to lay and tighten

Time: 7 minutes (5 minute savings, compared to the baseline time of 12 minutes)

3 minutes to lay the wire
4 minutes to tighten all the wires

LPMS data for 1990 show the exit time for all double lockages to be from 20 to 27 minutes on the UMR and from 26 to 35 minutes on the IWW. This time includes the face up time for the (powered) second cut, the reconnect time, and the exit time for the remade tow from the lock chamber. A powered ratchet reduces exit time by an estimated 5 minutes.

Conditions Affecting Implementation. To some extent, the towing industry recently has started to use the power-operated ratchet with favorable opinion. There is no known condition adversely impacting implementation of this measure, other than safety from mishandling.

Cost. The unit cost is about $7,500. The learning curve to operate the unit is short, perhaps three or four lockages with on-the-job training. An option would be a lock-provided power ratchet instead of tow provided. Lock placement necessitates the placement of a ratchet with a hoist at both the upper and lower guidewalls at a point where the couplings are remade. A lock person would lower the ratchet after the first cut is tied off along the guidewall. After the second cut faces up to the first cut, the ratchet is available for tightening the wires. The lock person would then raise the ratchet after five wires were remade. The tow line would then be released from the wall and the sixth wire remade using the present procedure (cheater pipe) for tightening the wire.

The first cost is estimated at $172,500. This includes $22,500 for three ratchets (one standby) and $75,000 for installation of a hoist mechanism at each guidewall. An additional lock person would be needed to operate the hoist on a 24-hour basis. This would be an added annual cost of $259,000.

Relationship to Other Small Scale Measures. The power-operated ratchet is complementary to other small scale measures, including extended guidewalls, to get the remade tow off the wall sooner for an exchange exit lockage. However, its use excludes the need for the other two crew element measures—permanent deck winches and additional personnel.

General Conclusions/Summary. Table 4-44 summarizes the advantages and disadvantages of the above measures. The relative low cost and limited testing of the tow-provided, power-operated ratchet could make it a viable measure for implementation, especially when its estimated time savings for remaking cuts is somewhat greater than other measures. However, potential injury from mishandling is a concern, and usage of the tool would be at the discretion of individual towing companies.

TABLE 4-44: SUMMARY OF CREW ELEMENT MEASURES

Measure	Advantages	Disadvantages
Deck Winch Time Savings: 4 min. First Cost: $4,000/barge, system cost	Saves time Eliminates steamboat ratchet Safer to operate Secondary time/cost benefits Proven use (petroleum barges)	Major capital expenditure Operational benefit not always realized by investor Used by many companies Stays with barge, not towboat Requires higher maintenance
Additional Personnel Time Savings: 3 min. Cost: $1,200/day/lock	Saves time Seasonal flexibility No permanent modifications No capital investment costs Minimal training required	Availability when needed Organizational/pay arrangement Some non-productive time Liability concerns
Power-Operated Ratchet Time Savings: 5 min. First Cost: $7,500/unit/tow provided $172,500/lock provided plus $259,000 annual operating cost	Saves time Can be safer to operate than cheater pipes No permanent modifications Proven use, although limited to date Portable Cost	Short-term history of operation Heavy and could lead to personal injury if mishandled

Approach Channel Improvements

Background. Approach channel improvements can consist of many different measures and combinations of these measures to increase safety and reduce the approach time to a lock. Approach channel improvements are usually considered within a 1.5-mile travel distance from the lock. The 1995 *General Assessment of Small Scale Measures* report listed several potential measures under the category heading of "Improvements to Approach Channels." These included:

Approach Channel Widening/Realignment
Adjacent Mooring Facilities
Funnel-Shaped Guidewalls
Wind Deflectors
Extended Guidewalls
Add Guide Cells
Reconfigure Bullnose
Radar Reflectors
Electronic Guidance System

The *General Assessment* report screened most of the above from further consideration because they "do not reduce delays (congestion) at locks or are economically inefficient." Approach Channel Widening/Realignment was not recommended because it was deemed "not cost effective." Adjacent Mooring Facilities and Extended Guidewalls were recommended for further analysis and are addressed in this report.

Demonstrated Value of Approach Channel Improvements. Approach Channel Improvements include Approach Channel Widening/Realignment, which is the widening or realignment of the channel and installation of river training structures or submerged dikes in the lock approach area to improve the tow path or direction the tow travels when approaching a lock. Model testing of Locks 22 and 25 at the Corps of Engineers Waterways Experiment Station (WES) demonstrated, among many other things, that the addition of a dike field above Lock 22 aligns the flow with the lock chamber and creates a straighter, more efficient downbound tow path to the lock. The estimated cost of only adding the dike field (5 dikes), while being expensive, could save appreciable time on a downbound approach to the lock. Testing also showed the improvements that other measures could make in the lock approach, including the addition of a 1,200-foot guardwall to Lock 22 along with the dike field above the lock.

It became apparent from the model studies that the addition of approach channel improvements and the potential time savings they provide at relatively less cost (compared to new lock construction) make approach channel improvements a potentially viable option to reducing lock transit time and subsequent delays. It was decided, therefore, to revisit the performance value of Approach Channel Improvements as applicable to the lock sites within the Navigation Study area.

In addition to the potential to improve approach time, another benefit is the opportunity to greatly increase safety and lower the rates of accidents.

Improvements Evaluated. Approach improvements included not only approach channel improvements, but structural improvements or additions to the lock facility as well, such as extended guidewalls or new 1,200-foot guardwalls that alone provide incremental time savings benefits to the lock approach at some locks. The evaluated improvements are listed below, generally in order of increasing magnitude of time savings. These measures are shown on Figure 4-13.

1) Extended guidewalls
2) Channel improvements
3) Extended guidewalls plus channel improvements
4) Location 3 (auxiliary lock/miter gate bay) guardwall alone
5) Location 2 (existing lock) guardwall alone
6) Channel improvements plus a location 3 guardwall
7) Extended guidewalls plus channel improvements plus a location 3 guardwall
8) Channel improvements plus a location 2 guardwall

Without site-specific model studies, there is a limited basis for estimating the time savings that would be achieved by these measures at each site. Due to the uncertainties in quantifying potential time savings, the study team held a Lock Approach Assessment Workshop to collectively assess potential approach improvements to locks under the system study and to approximate their time savings potential when compared to existing approach conditions. The existing conditions were earlier determined from previous lock site visits and included input from lockmasters, industry representatives (tow captains/pilots), and a lock site survey analysis. Participants at the

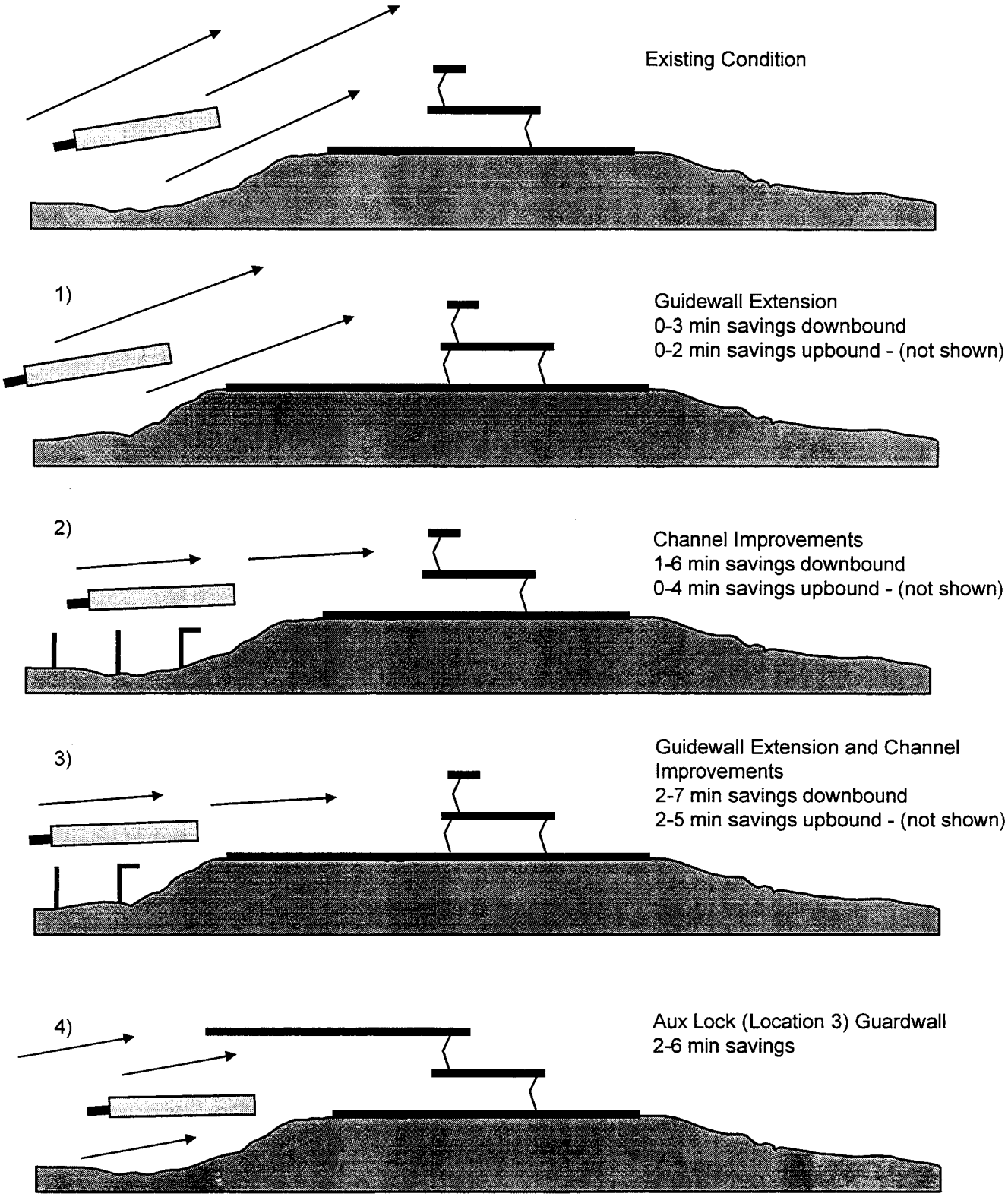


FIGURE 4-13: Existing Approach and Potential Approach Improvements Downbound Direction (page 1 of 2)

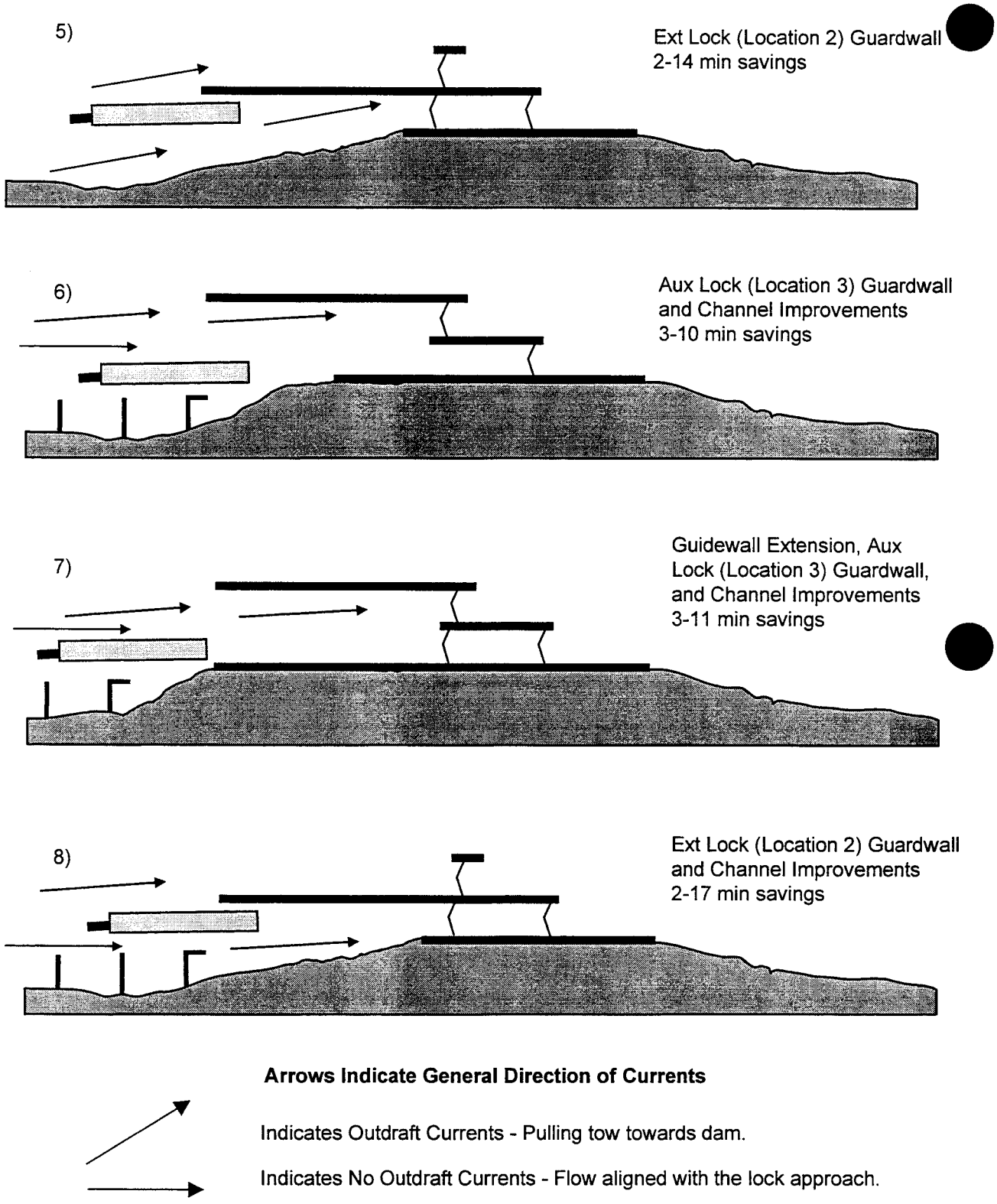


FIGURE 4-13: Existing Approach and Potential Approach Improvements Downbound Direction (page 2 of 2)

workshop included Corps of Engineers staff from various offices, including the Waterways Experiment Station. Field data, physical and numerical model results, and the experience of the team members were the basis for approximating the approach time savings using a rating system for the approach improvements at each of the UMR lock and dam study sites. The benchmark for this rating system is the maximum improvement obtained in the Lock and Dam 22 physical model testing. This site currently has the longest fly approach times (i.e., approaches that are not influenced by other tow movements). Therefore, the best improvement at Lock and Dam 22 is thought to be the upper limit of improvement at other sites.

In the physical model, the maximum improvement achieved for the typical (50 percent duration) flow was a 35 percent reduction in the downbound approach time for Lock and Dam 22. Each of the improvements was rated on a 0 to 10 scale representing the relative level of improvement. With this scale, a rating of 10 equals 35 percent improvement and a rating of 0 equals no improvement. In general, the percent time savings equals the rating divided by 10, times 35 (e.g., a rating of 1 is estimated to yield 1/10 x 35 = 3.5 percent improvement). The estimated percent savings was then multiplied by the known approach times from the LPMS timing data and that value (savings in minutes) was subtracted from the approach time to give the new approach time.

Improvements to existing upbound approaches and their potential time savings, although less significant than downbound approach improvements, were also evaluated on the same 0 to 10 scale. Upbound approach improvements include the lower guidewall extension, channel improvements, and combinations of these.

Mean values from 1990 LPMS data were used in estimating the potential time savings for each improvement. Tows requiring a double lockage (doubles) were used in the time savings analysis. Doubles comprise about 80 percent of the commercial traffic and, because of their size (1,200 feet long) and inherent maneuvering problems, benefit the most from these improvements which reduce maneuvering, especially by downbound tows due to outdraft. Both the fly approach and the exchange approach benefit by improved approach conditions. For the system study, it is assumed that there is minimal, if any, net lock transit time savings for a turnback approach, which benefits from approach improvements, but endures some waiting time for the lock to be turned back.

Table 4-45 shows the 0 to 10 scale rating for each of the approach improvements by lock site from which the percent savings was computed. These values are shown converted into time savings on subsequent tables. The 0 to 10 rating values for combinations of approach improvements are not obtained from adding the ratings of individual channel improvements. In many cases, two channel measures together provide only a fraction of the sum of their individual improvements. The diminishing returns are due to the fact that the individual measures are addressing the same problem of how to improve the efficiency (and safety) of the lock approach.

Some measures are not feasible by themselves but become viable in combination with channel work. This is demonstrated at the following lock sites:

At Lock 14, a location 2 guardwall (upstream extension of the riverside lockwall) is not recommended as a stand-alone measure. Extensive channel work, however, allows for a location 2 guardwall, and this combination provides a better lock approach.

TABLE 4-45: RELATIVE IMPROVEMENT OF INDIVIDUAL AND COMBINATIONS OF "CHANNEL" IMPROVEMENTS

	UPPER MISSISSIPPI RIVER LOCKS										
	UPPER LOCK APPROACH								LOWER LOCK APPROACH		
	1	2	3	4	5	6	7	8	1	2	3
LOCK. NO	EXTENDED GUIDEWALL	CHANNEL IMPROVEMENT	1+2	LOC 3 GRD WALL	LOC 2 GRD WALL	2+4	1+2+4	2+5	EXTENDED GUIDEWALL	CHANNEL IMPROVEMENT	1+2
25	0 to 1	2 to 3	2 to 4	3 to 4	NR	5 to 6	6 to 7	9 to 10	0 to 1	3 to 4	4 to 5
24	0 to 1	3 to 4	3 to 5	3 to 4	2 to 3	5 to 6	6 to 7	9 to 10	1 to 2	2 to 3	3 to 4
22	0 to 1	3 to 4	3 to 5	3 to 4	NR	5 to 6	6 to 7	9 to 10	0 to 1	NR	NA
21	0 to 1	3 to 4	3 to 5	NR	NR	5 to 6	6 to 7	8 to 9	1 to 2	NR	NA
20	0 to 1	3 to 4	3 to 5	NR	NR	5 to 6	5 to 7	9 to 10*	0 to 1	3 to 4	3 to 5
19	NA	NR	NA	NA	4 to 6	NA	NA	3 to 4 MOD GRWL	1 to 2	2 to 3	4 to 5
18	2 to 3	1 to 2	3 to 5	NR	NR	NR	NR	NR	2 to 3	NR	NA
17	0 to 1	3 to 4	4 to 5	4 to 5	9 to 10	5 to 6	6 to 7	NR	NR	3 to 4	4 to 5
16	0 to 1	5 to 6	5 to 6	NR	NR	6 to 7	6 to 8	9 to 10	2 to 3	2 to 3	2 to 4
15	NR	5 to 6	NA	NR	NR	6 to 7	NR	8 to 10	0 to 2	2 to 4	3 to 5
14	0 to 1	3 to 5	3 to 5	NA	NR	NA	NA	8 to 10*	2 to 3	0 to 1	3 to 4
13	0 to 1	NR	NA	NR	NR	NA	NA	NA	0 to 1	NR	NA
12	0 to 1	NR	NA	5 to 7	9 to 10	NA	6 to 8	NA	0 to 1	1 to 3	3 to 5
11	NR	3 to 5	3 to 5	3 to 4	NR	5 to 6	5 to 7	8 to 10	0 to 2	NR	NA

Col 8 (2+5) includes removal of the existing guide wall and bank shaping

Example of estimated time saving for Lock 25 channel improvements

0.2 x 0.35 x 23.8 = 1.7min. (minimum potential saving); 0.3 x 0.35 x 23.8 = 2.5 min. (maximum potential savings)

0.2 = 20% of total potential savings

0.35 = 35% total potential saving based on field and model data for L/D 22

23.8 = mean approach time from lock timing data (1990 double lockages-downstream direction-fly approach)

	ILLINOIS WATERWAY LOCKS										
	UPPER LOCK APPROACH								LOWER LOCK APPROACH		
	1	2	3	4	5				1	2	3
LOCK	EXTENDED GUIDEWALL	CHANNEL IMPROVEMENT	1+ 2	LOC 3 GRD WALL	LOC 2 GRD WALL				EXTENDED GUIDEWALL	CHANNEL IMPROVEMENT	1+2
LA GRANGE	0 to 2	1 to 3	2 to 4	NA	8 to 10*				0 to 1	1 to 2	1 to 3
PEORIA	2 to 4	1 to 3	3 to 5	NA	NR				0 to 1	NR	NA
STARVED RK	NR	NR	NA	NA	NR				0 to 3	7 to 10	7 to 10
MARSEILLES	NR	0 TO 5; 10	NA	NA	NA				1 to 3	NR	NA
DRESDEN IS	1 to 3	NR	NA	7 to 9	8 to 10				NR	3 to 7	NA
BRANDON RD	NR	0 to 3	NA	NA	NR				NR	1 to 3	NA
LOCKPORT	NR	NR	NA	NA	NR				NR	NR	NA

NR = Not recommended, NA = Not Applicable

* Requires extensive channel excavation for an existing lock guardwall (loc2).

At Lock 16, a location 3 guardwall (upstream extension of the auxiliary gate bay riverside wall) is not recommended as a stand-alone measure. If extensive channel work is included, the location 3 guardwall can be included and together provide a better downbound lock approach than the channel work alone.

At Lock 17, the lower guidewall can not be extended without doing extensive bank excavation. Bank excavation alone, however, makes the approach to the existing guidewall better. Bank excavation plus a guidewall extension is a better improvement.

While approach time savings estimates for other UMR lock sites are made here for the systems study based on the extensive Lock 22 model study, model studies should also be done during site-specific studies for other lock sites to determine and verify appropriate channel improvements. A less costly option for model studying other lock sites may be the use of a micro model that has been successfully used in determining if improved approach conditions could be achieved at Lock 24.

The Lock 22 model study results are not applicable to the locks on the IWW. Flow characteristics differ for the IWW. The waterway is narrower and the outdraft above the locks is not as severe as on the UMR. Since the approach channel improvements are aimed primarily at reducing the existing outdraft impacts to the lock approach time, the relative improvements these measures provide to IWW locks are not comparable to the estimated improvements at the UMR locks. Therefore, the 0 to 10 rating that was used as a factor in estimating the potential time savings for the UMR locks is used only to identify the relative magnitude of potential improvement between improvements identified for each of the IWW lock sites.

The IWW improvements should provide a safer lock approach. However, with the exception of improving the downbound approach canal to Marseilles Lock, the reduction in lock approach time at the Illinois Waterway locks is considered negligible. Navigation model studies may identify potential time savings from these improvements, including the realignment of the upper approach channel at La Grange Lock.

A somewhat different method to estimate potential time savings was required at Marseilles Lock. The primary potential benefit is the opportunity to improve the current situation where tows can not pass in the roughly 2.5-mile-long canal leading to the lock. This means that tows making an exchange approach must either be waiting at the existing mooring site right by the lock when the exiting tow starts up the canal or be forced to wait at the next nearest mooring, Ballard's Island (roughly 3.5 miles above the lock). A detailed analysis of 1996 LPMS data revealed that nearly 75 percent of the exchange lockages were able to occur with tows waiting at the mooring right at the lock. In these situations, the entire exchange (exchange exit plus exchange approach) averaged just over 30 minutes. In contrast, the approximately 25 percent of exchange lockages that did not occur right at the lock averaged roughly 140 minutes. This difference is related to the additional travel time. However, if a passing area were provided in the canal, tows could pass one another at an intermediate point, reducing the average delay. By moving the exchange point to approximately 1.5 miles above the lock, the potential site of a passing area, the average difference could be reduced by 55 to 60 percent. This would provide an average savings of roughly 60 minutes per exchange (30 minutes per exchange exit and 30 minutes per exchange approach).

Cost. The construction costs were estimated from quantities for each of the above eight improvements where applicable at each lock site. An additional cost of $450,000 for a model study must be added to the cost of the improvement measures where applicable to identify the optimum approach improvement. Locks 22 and 25 are excluded from this additional cost since model studies have been completed for these two sites.

At UMR lock sites, construction activities can be completed during the winter closure, and, as such, impacts to navigation during construction are anticipated to be minimal. IWW sites do not have a comparable period of winter closure. As a result, IWW navigation impacts were quantified in terms of the needs during construction (helper boats, switchboats, temporary remote remake

areas) and impacts to industry due to anticipated delays and closures, shown on construction time lines in Appendix D.

Environmental impacts are an important additional component to the cost. These impacts will be added to the cost by the Environmental Work Group.

Summary of Approach Channel Improvements

Each of the eight potential approach channel improvements is discussed below. The cost and time savings (performance) for the potential improvements are summarized in tables for each lock site as applicable.

1. Extended Guidewalls

Description of Measure. The existing upstream and downstream 600-foot landside guidewalls are extended to 1,200 feet (see Figure 4-14A).

The actual total time savings associated with extended guidewalls can be broken down into four components as briefly discussed in the "Extended Guidewalls" section of this report. These components are: (1) the reduction in approach time, (2) reduction in the extraction time of the first cut of a double lockage (when used with tow haulage or additional towboat power), (3) reduction in chambering time from faster emptying of the chamber on downbound cuts, and (4) reduction in chambering time by allowing the remake of a double lockage to occur outside the lock chamber along the extended guidewall. *This section discusses the potential reduction in approach time.*

Upstream guidewall extensions allow tows to be in a more controlled state farther up the approach, lessening the impacts from dam outdraft on their downbound approach to a lock. The upper extension provides a larger target for tows to steer toward and easier maneuvering of their stern to the guidewall for securing a line to the wall and working the head of the tow to the wall for proper alignment and entry into the lock chamber.

Downstream guidewall extensions provide a larger landing surface for upbound tows that typically are not subjected to outdraft.

Time Savings. Except for Lock 18, whose downbound approach times would be expected to decrease 2 to 3 minutes, the other UMR lock sites are expected to have a 1-minute or less decrease (improvement) in approach time. The upbound approach times decrease by about 1 minute. Table 4-46 shows the new fly and exchange approach times for the pertinent lock sites. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 1 of Table 4-45. The calculated savings were subtracted from the existing times to obtain the improved times. The revised standard deviation is proportional to the ratio of the new mean time to the existing mean time.

Conditions Affecting Implementation. Refer to the "Extended Guidewalls" section of this report for lock locations where guidewall extensions are not applicable for the UMR and IWW locks.

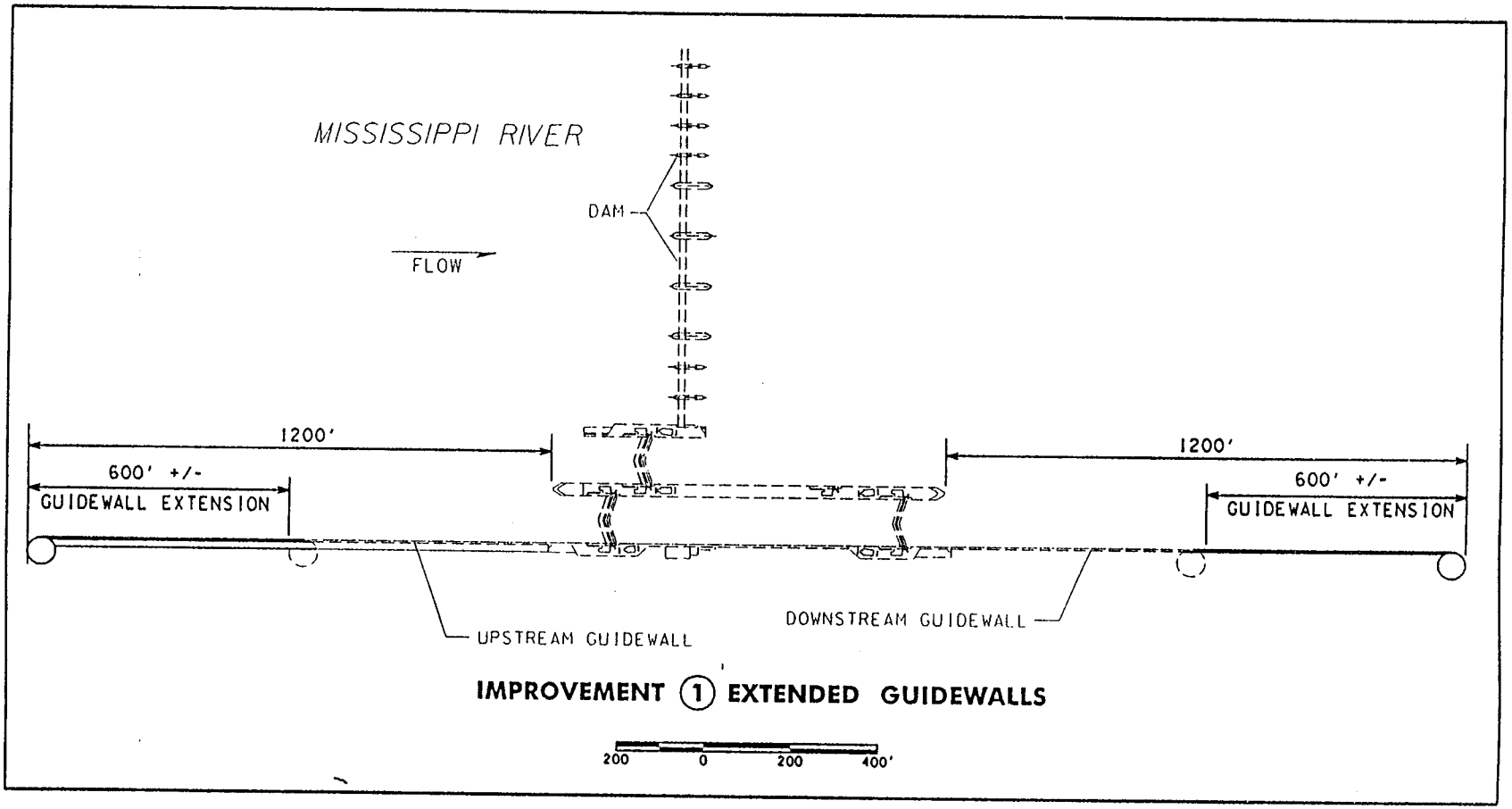


FIGURE 4-14A: Improvement 1 Extended Guidewalls

TABLE 4-46: COST AND PERFORMANCE OF EXTENDED GUIDEWALLS - APPROACH TIME IMPROVEMENT

Lock Site		Length (ft)	Cost [1] ($1,000's)	Impacts to Navigation[2] ($1,000's)	Existing Approach Times: Doubles; Fly Approach Time		Existing Approach Times: Doubles; Exchange Approach Time		Approach Time w/ Extended Guidewalls: Doubles; New Fly Approach Time		Approach Time w/ Extended Guidewalls: Doubles; New Exchange Approach Time		Savings: Double Fly Appr	Savings: Double Exchange Appr
					Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	US	NR	NR	NR	28.1	12.5	16.3	10.6	NR	NR	NR	NR	NR	NR
	DS	700	13,116	0	17.5	8.1	11.0	8.0	16.9	7.8	10.6	7.7	0.6	0.4
12	US	683	27,310	0	20.5	9.7	18.5	9.5	20.1	9.5	18.2	9.3	0.4	0.3
	DS	700	12,884	0	15.7	6.4	14.8	10.6	15.4	6.3	14.5	10.4	0.3	0.3
13	US	683	22,730	0	18.0	7.7	16.0	10.7	17.7	7.6	15.7	10.5	0.3	0.3
	DS	700	13,138	0	13.7	6.5	12.6	8.2	13.5	6.4	12.4	8.1	0.2	0.2
14	US	683	22,100	0	24.4	12.3	16.9	11.3	24.0	12.1	16.6	11.1	0.4	0.3
	DS	700	11,178	0	15.3	8.6	17.6	10.0	14.0	7.9	16.1	9.1	1.3	1.5
15	US	NR	NR	NR	24.0	14.7	30.8	14.9	NR	NR	NR	NR	NR	NR
	DS	482	7,726	0	16.7	9.7	31.8	23.4	16.1	9.4	30.7	22.6	0.6	1.1
16	US	683	21,330	0	31.7	14.8	22.0	12.8	31.1	14.5	21.6	12.6	0.6	0.4
	DS	700	12,754	0	19.5	7.7	14.9	9.9	17.8	7.0	13.6	9.0	1.7	1.3
17	US	683	23,580	0	40.5	15.4	32.5	15.4	39.8	15.1	31.9	15.1	0.7	0.6
	DS	700	13,546	0	21.9	8.3	16.2	9.2	NA[3]	NA[3]	NA[3]	NA[3]	NA[3]	NA[3]
18	US	683	22,230	0	32.1	14.3	21.0	14.1	29.3	13.1	19.2	12.9	2.8	1.8
	DS	700	13,263	0	16.1	6.9	19.4	13.5	14.7	6.3	17.7	12.3	1.4	1.7
19	US	NA	NA	NA	17.7	13.8	24.6	13.0	NA	NA	NA	NA	NA	NA
	DS	600	9,617	0	18.3	9.2	29.0	18.2	17.3	8.7	27.5	17.3	1.0	1.5
20	US	683	23,070	0	31.7	15.2	18.3	10.3	31.1	14.9	18.0	10.1	0.6	0.3
	DS	700	10,904	0	30.9	15.2	22.3	13.0	30.4	15.0	21.9	12.8	0.5	0.4
21	US	683	22,880	0	33.3	14.4	22.6	15.2	32.7	14.1	22.2	14.9	0.6	0.4
	DS	700	13,690	0	22.7	19.4	22.6	12.5	21.5	18.4	21.4	11.8	1.2	1.2
22	US	683	24,000	0	49.9	15.9	27.9	18.1	49.0	15.6	27.4	17.8	0.9	0.5
	DS	700	12,226	0	35.9	14.6	23.6	13.2	35.3	14.4	23.2	13.0	0.6	0.4
24	US	682	20,200	0	22.2	12.1	22.8	15.5	21.8	11.9	22.4	15.2	0.4	0.4
	DS	684	10,640	0	15.9	8.9	15.5	9.3	15.1	8.5	14.7	8.8	0.8	0.8
25	US	689	27,000	0	23.8	12.8	19.0	10.7	23.4	12.6	18.7	10.5	0.4	0.3
	DS	684	14,328	0	15.1	7.7	17.1	11.1	14.8	7.5	16.8	10.9	0.3	0.3
MEL PRICE	US	NA	NA	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
	DS	NA	NA	NA	17.3	7.1	21.2	10.4	NA	NA	NA	NA	NA	NA
27	US	600	13,500	0	13.4	8.6	16.0	11.5	NC	NC	NC	NC	NC	NC
	DS	1,200	30,000	0	14.5	7.5	13.6	10.4	NC	NC	NC	NC	NC	NC
LOCK PORT	US	NR	NR	NR	13.0	9.0	26.2	13.2	NR	NR	NR	NR	NR	NR
	DS	NR	NR	NR	11.3	6.0	15.2	7.4	NR	NR	NR	NR	NR	NR
BRAN-DON	US	NR	NR	NR	17.9	7.7	16.8	10.1	NR	NR	NR	NR	NR	NR
	DS	NR	NR	NR	21.4	7.0	25.1	10.9	NR	NR	NR	NR	NR	NR
DRES DEN	US	622	9,667	62,180	14.5	7.9	14.5	8.1	NC	NC	NC	NC	NC	NC
	DS	NR	NR	NR	13.9	7.1	15.7	6.9	NR	NR	NR	NR	NR	NR
MARS EILLES	US	NR	NR	NR	20.3	5.9	13.9	6.4	NR	NR	NR	NR	NR	NR
	DS	603	11,620	62,180	20.7	6.5	22.5	11.7	NC	NC	NC	NC	NC	NC
STARV ED ROCK	US	NR	NR	NR	10.9	8.8	17.9	2.0	NR	NR	NR	NR	NR	NR
	DS	606	10,528	62,180	9.6	4.8	19.6	10.1	NC	NC	NC	NC	NC	NC
PEO RIA	US	700	12,440	80,700	18.7	9.7	19.1	10.1	NC	NC	NC	NC	NC	NC
	DS	700	13,009	80,700	16.7	10.7	22.1	12.7	NC	NC	NC	NC	NC	NC
LA GRANG	US	575	11,367	80,700	19.8	11.2	22.9	11.5	NC	NC	NC	NC	NC	NC
	DS	650	11,630	80,700	17.1	9.3	21.9	10.4	NC	NC	NC	NC	NC	NC
Average UMR 11-25	US	683	23,312	0	28.4	13.3	22.1	13.0	29.1	12.8	21.1	12.7	0.7	0.5
	DS	675	12,072	0	19.7	9.8	19.2	12.2	18.7	9.5	18.5	11.8	0.8	0.9
Average Illinois	US	632	11,158	74,527	14.4	7.5	16.4	7.7	NC	NC	NC	NC	NC	NC
	DS	640	11,697	71,440	13.8	6.4	17.8	8.8	NC	NC	NC	NC	NC	NC

US = upstream, DS = downstream, NA = not applicable, NC = no change, NR = not recommended

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not included in the costs since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs are for switch boats, helper boats and temporary remote remake areas. Also included are economic impacts to the navigation industry (i.e., delays and closures) that are shown on construction timelines at Appendix D.
3. A guidewall extension is infeasible as a stand-alone improvment measure at this site. Channel work would also be required.

Cost. Construction costs for extending both upper and lower guidewalls at the pertinent UMR lock sites range from about $30 to $40 million per site initially, with additional annual maintenance costs of $60,0000 per lock site ($30,000/wall extension). Refer to the "Extended Guidewalls" section of this report for the costs and impacts to navigation during construction of the guidewall extensions at the pertinent lock sites. Table 4-46 summarizes the costs. The environmental impacts must be added to the costs. Guidewall extension costs are less for the IWW locks but impacts to navigation are high since there is year-round navigation on the IWW. Locks are not closed to navigation as they are on the UMR to allow for staged construction of the guidewall extensions.

Relationship to Other Small Scale Measures. Extended guidewalls alone provide for a safer, slightly reduced lock approach time and are complementary with most measures. The downbound lock approach time is further reduced when guidewall extensions are combined with channel improvements. Extended guidewalls used with powered or unpowered kevels or additional towboat power allow the remake of a double lockage outside the lock chamber, thus allowing a quicker turnback of the lock chamber for a turnback exit lockage.

Conclusions/Summary. Extending the existing lock guidewalls allows for a safer lock approach and slightly reduces the lock approach time. Guidewall extensions provide yet a greater reduction to the overall lock transit time when combined with other small scale measures to extract the first cut of a double lockage faster from the lock chamber and to allow for tow remake outside the chamber along the extended guidewall.

2. Channel Improvements

Description of Measure. Channel Improvements can be one or several additions to the approach channel to better align the tow with the lock before the tow bow (front of the barges) gets to the lock approach wall. A good, safe, efficient lock approach is important in the overall locking process. Locks built 50 to 60 years ago and their lock approaches were not designed to handle the size (length) of today's tows. Additional transit time is added to the locking process when tows maneuver excessively to align with the lock chamber. This can be due in large part because of unfavorable cross currents or an inadequately aligned approach channel or a combination of both and other factors requiring tow captains/pilots in some cases to bring the tow to a stop, back up a distance, and then proceed forward to the lock.

Downbound tows have greater approach difficulties than upbound tows because of the outdraft that is common at most UMR locks. An outdraft is a current that flows from the upstream shoreline across the lock approach to the dam gates. This current requires tows to flank their approach for some distance above the lock, maneuvering their stern to the shoreline as they approach the lock guidewall. Outdraft is especially severe during higher than normal river flows when currents are swifter. For upbound tows, the flow, which spreads out below the dam toward the shoreline, helps push the tow to the lower landside guidewall, thus making for an easier upbound approach most of the time. Sometimes this current pins a tow along the lower guidewall, making downbound exits from the wall difficult.

In general, a straight approach of three tow lengths or 3,600 feet from the end of the approach wall (a 1,200-foot guidewall or a 1,200-foot guardwall) is desirable for the downbound approach. Two tow lengths or 2,400 feet is considered a minimum for the downbound approach. This criteria can be relaxed for the upbound approach on a site-specific basis since tows are not subjected to a severe outdraft.

Outdraft is not as severe a problem at locks on the IWW, especially at locks above Peoria Lock. Peoria Lock and La Grange Lock both have wicket gate dams that allow open pass travel

(bypass the lock) when the wickets are lowered during high river flows. The two tow-length criteria can be relaxed for the downbound approach as well as the upbound approach.

Figure 4-14B shows the various measures considered to provide a better approach channel. Following is a brief description of each measure:

Submerged dikes (groins) are placed above the lock to reduce the magnitude of the outdraft. They are constructed of rock, and their top elevation is a minimum of 15 feet below pool elevation. If the water is deep enough, 20 feet is preferred.

Dike fields are placed upstream of the lock to reduce the outdraft. They are constructed of rock, and their top elevation is usually 2 feet above pool elevation. They are placed perpendicular or at a slight angle to the shoreline. The distance between the dikes varies, but commonly they are placed about 1,000 feet apart.

Vane dikes are placed parallel to the channel to reduce the current to the dam from the shoreline (outdraft). They can be used when the distance from the riverbank to the channel's edge is too far, making placement of dikes from the shoreline uneconomical. These dikes are constructed of rock with their top at 2 feet above normal pool elevation. They are set back from the navigation channel and have gaps between them to allow some passage of flow.

All of the above tend to align the river flow with the lock chamber.

Dredging/bank excavation is recommended if the channel needs to be shifted to better align with the lock, especially for the downbound approach, where a straight alignment is desired for two tow lengths (2,400 feet) minimum above the lock approach wall. Dredging/bank excavation can be recommended downstream to make the approach/exit more efficient near the approach wall.

Trail dikes are angled off the downstream end of the riverward lockwall to keep flow from pinning downbound tows on the lower approach wall, making their exit difficult. These dikes are 50 to 100 feet long and are constructed of rock. A short concrete wall can be a more permanent solution.

Time Savings. At sites where channel improvements are applicable, the downbound approach times decrease by approximately 3 minutes (range 1 to 6 minutes). The average upbound approach times decrease by about 2 minutes. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 2 of Table 4-45. Table 4-47 shows the estimated improved approach times. The calculated savings were subtracted from the existing times to obtain the improved times. The revised standard deviation is proportional to the ratio of the new mean time to the existing mean time. Marseilles Lock is an exception where savings of approximately 60 minutes or more are possible on roughly 25 percent of exchange lockages (30 minutes savings on upbound exits/30 minutes on downbound approaches).

Conditions Affecting Implementation. Environmental impacts affect the implementation of this measure and are being quantified. Disposal of potential dredged material is of concern, especially large quantities.

Identified channel improvements are listed below for each lock site, and these improvements are shown on plates 1 through 27 of Appendix C. A straight approach of at least two tow lengths is provided for the downbound approach unless otherwise noted below.

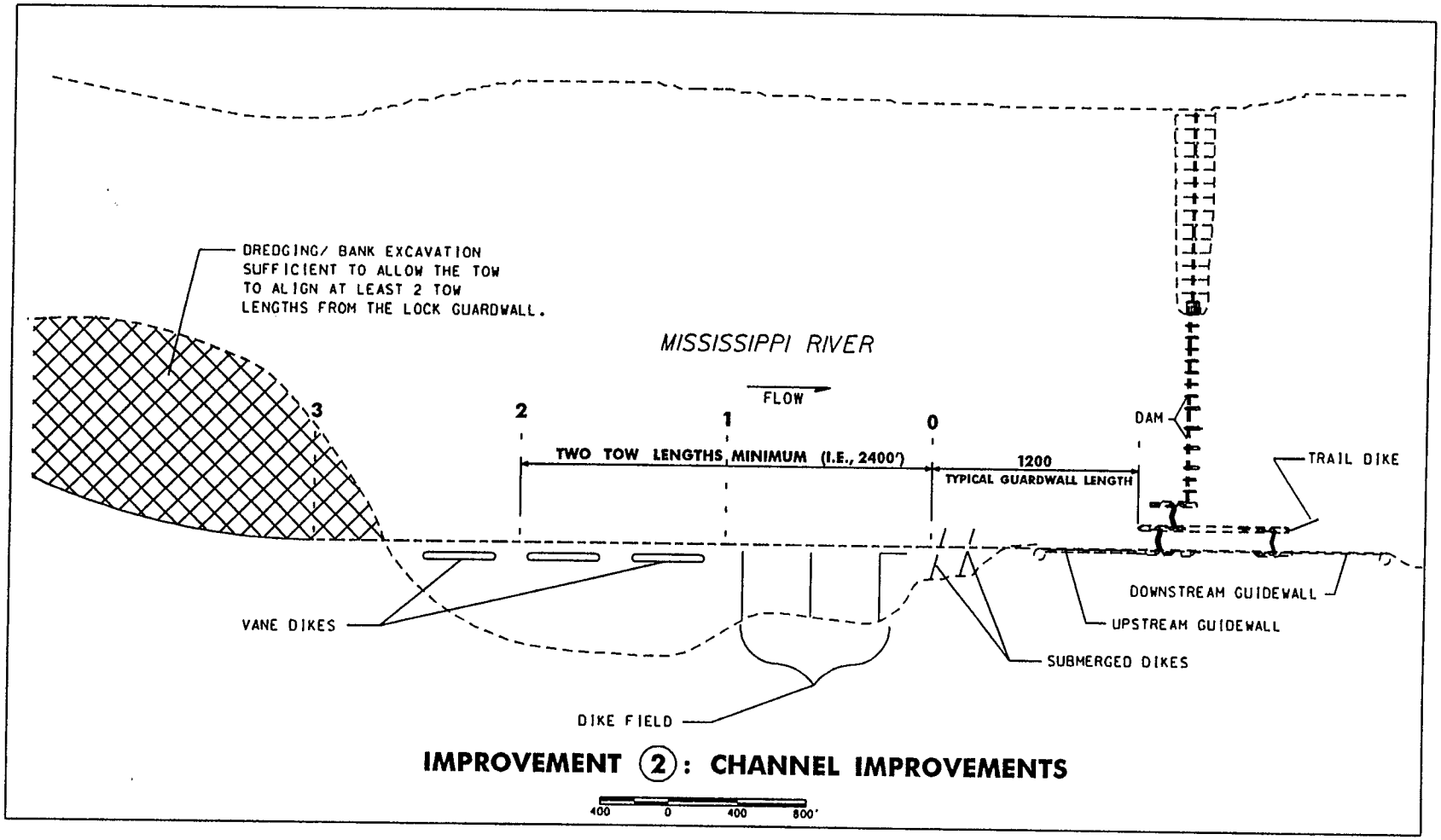


FIGURE 4-14B: Improvement 2, Channel Improvements

Upper Mississippi River Locks

Lock 11: Plate 1. US, Reconstruct the wing dike located 1,900 feet above the lock and add a dike 1,000 feet above it. Add three vane dikes above the newly constructed dike to shift the navigation channel 500 feet east. No dredging is required. DS, No improvements identified.

Lock 12: Plate 2. US, No improvements identified other than straightening (filling in) of the bankline above the lock. Cost and benefits identified with the extension of the upper landside guidewall. DS, Shorten the wing dikes along the left descending bank. Add a trail dike off the riverside lockwall.

Lock 13: Plate 3. This lock has as efficient approaches. US, No improvements identified. DS, No improvements identified.

Lock 14: Plate 4. US, Dredge the pocket area above the lock to the breakwater and riverward of the breakwater. (Have 0 tow lengths of straight approach.) DS, Add a trail dike off the riverside lockwall. Dredge below the extended guidewall area.

US Expanded Channel Realignment: Plate 5 (For 1/2 tow length of straight approach above a 1,200-foot existing lock guardwall.) Need to extend the channel excavation landward of the breakwater into the Le Claire Canal.

Lock 15: Plate 6. US, Add a system of five submerged dikes above the lock. (Have 0 tow lengths of straight approach.) DS, Add a trail dike off the end of the auxiliary lock river wall. Add a deflection dike at the outlet of Sylvan Slough.

Lock 16: Plate 7. US, The maximum improvement is a channel shift. With just a guidewall extension (have 0 tow lengths of straight approach), there is little improvement in the downbound approach time. DS, Add a trail dike off the riverward lockwall.

Lock 17: Plate 8. US, Add a system of five dikes above the lock only with a guidewall extension. Shorten the two wing dams above the dam to open up the flow area. DS, Excavate the riverbank below the guidewall.

Lock 18: Plate 9. US, Dredge small area at RM 411.3. (Have less than 1 tow lengths of straight approach.) DS, No improvements identified.

Lock 19: Plate 10. This is a 1,200-foot lock. US, The approach has been model studied. From the model study, placement of the four submerged dikes above the lock is a small improvement and alone is not recommended. Placement of the dikes is in conjunction with the non-standard guardwall shown here which gives a slightly better approach. Plate 11. This plan shows a ported guardwall. (Have 0 tow lengths of straight approach.) DS, Dredge the area below the lock (rock excavation) to provide a wider turn area and extend the lock riverside wall 600 feet to protect tows from the dam outflow.

Lock 20: Plate 12. US, Straighten the bankline with fill. Place three submerged dikes. Dredge the area above the lock to widen the turn. (Have 0 or 1 tow length of straight approach depending on the extent of the channel widening.) DS, Dredge the area below the lock for better approach/exit conditions.

Lock 21: Plate 13. US, Fill and straighten the bankline immediately above the lock. Excavate the riverbank to widen the channel above the lock. Place five submerged dikes above the lock to reduce outdraft. (Have 0 tow lengths of straight approach.) DS, No improvements identified.

Lock 22: Plate 14. US, Add five dikes above the lock to align the current with the lock and reduce the outdraft. DS, No improvements identified.

Lock 24: Plate 15. US, Add 3 wing dikes. DS, Add a trail dike off the end of the riverward lockwall.

Lock 25: Plate 16. US, Shorten the L-head dike located about 3,900 feet above the dam and realign the channel to about 5,000 feet above the dam. DS, Channel excavation including the right descending riverbank at RM 240.8 provides a straighter approach/exit from the approach wall.

Melvin Price Locks and Dam: Plate 17. No identified channel improvements.

Lock 27: Plate 18. No identified channel improvements. US, A cell 400 feet upstream of the existing cell may assist with the downbound approach alignment.

Illinois Waterway Locks. The identified improvements should provide a safer lock approach. With the exception of improving the upper approach canal at Marseilles Lock, the reduction in approach times is considered negligible.

Lockport Lock: Plate 19. US, No identified channel improvements. DS, No identified channel improvements.

Brandon Road Lock: Plate 20. US, No improvements identified other than a wind cell above the right descending lockwall. DS, Vane dikes at RM 285.4 could help realign the dam outflow and reduce the existing cross currents in this area. The approach channel is narrow, often resulting in a hard push into the lock chamber (piston effect). Extracting first cuts of downbound tows with tow haulage can take several tries before the exit is accomplished. There is a high potential of improvement if the channel can be improved. Any excavation to widen and/or deepen the channel is in rock.

Dresden Island Lock: Plate 21. US, No improvements identified. DS, Add a system of vane dikes to keep the dam outflow in line with Little Dresden Island and the approach to the narrow channel span of the Elgin, Joliet & Eastern Railway bridge.

Marseilles Lock: Plates 22-24. US, Add one or two passing areas, one above the lock and one about halfway along the 2.5-mile approach canal. DS, no improvements identified. May consider vane dikes to direct the flow at RM 244.15 away from passing traffic.

Starved Rock Lock: Plate 25. US, No improvements identified. DS, Add a "closure structure" of vane dikes upstream of Plum Island to limit the flow from the dam into the approach channel and reduce eddy currents which impact upbound tows, thus resulting in a more controlled approach to the lock. The siltation in the channel along Plum Island may be lessened or could be made worse. This should be studied further as part of any detailed improvement plan.

Peoria Lock: Plate 26. US, Add vane dikes above the guidewall to reduce the outdraft. Placement of the control dikes may be limited by the commercial docks along the left riverbank. Have one tow length of straight approach. DS, No improvements identified.

La Grange Lock: Plate 27. US, Excavate/dredge the riverbank to widen and shift the channel. Add five wing dikes along the left descending riverbank. (Have one tow length of straight approach.) A model study is needed to identify potential time savings. DS, Add a trail dike off the end of the riverward lockwall.

Cost. Table 4-47 summarizes the estimated first costs for these channel improvements. At sites where channel improvements are applicable, the costs vary from about $200,000 to $5 million. At Lock 16, the cost is as high as $14 million if the upper channel is relocated. In addition, annual maintenance costs also would be required. These additional costs average $170,000 (range $11,000 to $680,000) and $65,000 for downstream approaches (range $8,000 to $227,000). The costs do not include environmental impacts that will be added after they are quantified. There are no impacts to navigation during construction of channel improvements.

Relationship to Other Small Scale Measures. Channel improvements are complementary with most measures and alone reduce downbound approach times by an average 12 percent. Channel improvements can impact the location of adjacent and remote mooring facilities at a lock site.

Conclusions/Summary. The estimated savings in lock approach time at some locks is significant with channel improvements. Physical model testing should be considered to determine and verify the improvements needed to provide the most efficient navigation approach.

3. Extended Guidewalls Plus Channel Improvements

Description of Measure. Extended Guidewalls Plus Channel Improvements combines extending the guidewalls with the site-specific channel improvements discussed above for each of the lock sites. An example is shown in Figure 4-15 for a generic lock site. The costs are greater, but there are incremental time savings benefits with both improvements in place at some lock sites.

Time Savings. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 3 of Table 4-45. The calculated savings were subtracted from the existing times to obtain the improved times. The revised standard deviation is proportional to the ratio of the new mean time to the existing mean time. Improved approach times are shown in Table 4-48. The average improvement in the downbound fly approach time is about 5 minutes, with a maximum improvement of about 7 minutes. The average improvement in the downbound exchange approach time is about 3 minutes, with a maximum improvement of about 5 minutes. The average improvement in the upbound approach times is about 3 minutes.

Conditions Affecting Implementation. Refer to the "Extended Guidewalls" section of this report for lock locations where guidewall extensions are not applicable for the UMR and IWW locks and to the previous section on "Channel Improvements" for conditions affecting implementation of these combined measures. If one of the two individual measures was previously not recommended, the combination is not applicable.

Costs. Table 4-48 gives the first costs for extended guidewalls plus channel improvements. In addition, annual maintenance costs would also be required. These additional costs average over $200,000 (range from $40,000 to $710,000) for upstream improvements and over $90,000 (range from $38,000 to $236,000) for downstream improvements. Any impacts to navigation are the same as described for the extended guidewalls improvement and must be included. Environmental impacts have to be added to the cost by the Environmental Work Group.

TABLE 4-47: COST AND PERFORMANCE OF CHANNEL IMPROVEMENTS

			APPROACH TIME CHANGES									
			Existing Approach Times				Approach Times w/ Channel Improvements				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
Lock Site		COSTS[1] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	US	4,590	28.1	12.5	16.3	10.6	24.2	10.8	14.0	9.1	3.9	2.3
	DS	NR	17.5	8.1	11.0	8.0	NR	NR	NR	NR	NR	NR
12	US	NR	20.5	9.7	18.5	9.5	NR	NR	NR	NR	NR	NR
	DS	810	15.7	6.4	14.8	10.6	14.6	6.0	13.8	9.9	1.1	1.0
13	US	NR	18.0	7.7	16.0	10.7	NR	NR	NR	NR	NR	NR
	DS	NR	13.7	6.5	12.6	8.2	NR	NR	NR	NR	NR	NR
14	US	985	24.4	12.3	16.9	11.3	21.0	10.6	14.5	9.7	3.4	2.4
	DS	355	15.3	8.6	17.6	10.0	15.0	8.4	17.3	9.8	0.3	0.3
15	US	742	24.0	14.7	30.8	14.9	19.4	11.9	24.9	12.0	4.6	5.9
	DS	240	16.7	9.7	31.8	23.4	14.9	8.7	28.5	21.0	1.8	3.3
16	US	13,600	31.7	14.8	22.0	12.8	25.6	12.0	17.8	10.4	6.1	4.2
	DS	150	19.5	7.7	14.9	9.9	17.8	7.0	13.6	9.0	1.7	1.3
17	US	2,937	40.5	15.4	32.5	15.4	35.5	13.5	28.5	13.5	5.0	4.0
	DS	3,207	21.9	8.3	16.2	9.2	19.2	7.3	14.2	8.1	2.7	2.0
18	US	210	32.1	14.3	21.0	14.1	30.4	13.5	19.9	13.4	1.7	1.1
	DS	NR	16.1	6.9	19.4	13.5	NR	NR	NR	NR	NR	NR
19	US	NR	17.7	13.8	24.6	13.0	NR	NR	NR	NR	NR	NR
	DS	4,075	18.3	9.2	29.0	18.2	16.7	8.4	26.5	16.6	1.6	2.5
20	US	4,700	31.7	15.2	18.3	10.3	27.8	13.3	16.1	9.1	3.9	2.2
	DS	1,275	30.9	15.2	22.3	13.0	27.1	13.3	19.6	11.4	3.8	2.7
21	US	2,268	33.3	14.4	22.6	15.2	29.2	12.6	19.8	13.3	4.1	2.8
	DS	NR	22.7	19.4	22.6	12.5	NR	NR	NR	NR	NR	NR
22	US	4,836	49.9	15.9	27.9	18.1	43.8	14.0	24.5	15.9	6.1	3.4
	DS	NR	35.9	14.6	23.6	13.2	NR	NR	NR	NR	NR	NR
24	US	1,600	22.2	12.1	22.8	15.5	19.5	10.6	20.0	13.6	2.7	2.8
	DS	150	15.9	8.9	15.5	9.3	14.5	8.1	14.1	8.5	1.4	1.4
25	US	1,020	23.8	12.8	19.0	10.7	21.7	11.7	17.3	9.7	2.1	1.7
	DS	850	15.1	7.7	17.1	11.1	13.3	6.8	15.0	9.7	1.8	2.1
MEL PRICE	US	NR	22.3	10.7	18.1	10.1	NR	NR	NR	NR	NR	NR
	DS	NR	17.3	7.1	21.2	10.4	NR	NR	NR	NR	NR	NR
27	US	NR	13.4	8.6	16.0	11.5	NR	NR	NR	NR	NR	NR
	DS	NR	14.5	7.5	13.6	10.4	NR	NR	NR	NR	NR	NR
LOCK-PORT	US	NR	13.0	9.0	26.2	13.2	NR	NR	NR	NR	NR	NR
	DS	NR	11.3	6.0	15.2	7.4	NR	NR	NR	NR	NR	NR
BRAN-DON	US	500	17.9	7.7	16.8	10.1	NC	NC	NC	NC	NC	NC
	DS	300	21.4	7.0	25.1	10.9	NC	NC	NC	NC	NC	NC
DRES-DEN	US	NR	14.5	7.9	14.5	8.1	NR	NR	NR	NR	NR	NR
	DS	400	13.9	7.1	15.7	6.9	NC	NC	NC	NC	NC	NC
MAR-SEILLES	US	2,000	20.3	5.9	13.9	6.4	See Note[2]	See Note[2]	See Note[2]	See Note[2]	See Note[2]	See Note[2]
	DS	NR	20.7	6.5	22.5	11.7	NR	NR	NR	NR	NR	NR
STARV ED ROCK	US	NR	10.9	8.8	17.9	2.0	NR	NR	NR	NR	NR	NR
	DS	500	9.6	4.8	19.6	10.1	NC	NC	NC	NC	NC	NC
PEO RIA	US	350	18.7	9.7	19.1	10.1	NC	NC	NC	NC	NC	NC
	DS	NR	16.7	10.7	22.1	12.7	NR	NR	NR	NR	NR	NR
LA GRANGE	US	2,500	19.8	11.2	22.9	11.5	NC	NC	NC	NC	NC	NC
	DS	150	17.1	9.3	21.9	10.4	NC	NC	NC	NC	NC	NC
Average UMR 11-25	US	3,408	28.4	13.3	22.1	13.0	27.1	12.2	19.8	9.3	4.0	3.0
	DS	1,111	19.7	9.8	19.2	12.2	15.3	7.4	16.3	10.4	1.6	1.7
Average Illinois	US	1,338	14.4	7.5	16.4	7.7	See Note[2]	See Note[2]	See Note[2]	See Note[2]	See Note[2]	See Note[2]
	DS	338	13.8	6.4	17.8	8.8	NC	NC	NC	NC	NC	NC

US = upstream, DS = downstream, NA = not applicable, NC = no change, NR= not recommended

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not included in the costs since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. Due to method of data recording and site factors, additional analysis was required to determine the time savings. This analysis revealed that at Marseilles lock roughly 25% of exchange approaches could be improved by 30 min. This savings also applies to roughly the same percentage of exchange exits for a combined savings of 60 minutes.

TABLE 4-48: COST AND PERFORMANCE OF EXTENDED GUIDEWALL PLUS CHANNEL IMPROVEMENTS

			APPROACH TIME CHANGES									
			Existing Approach Times				Approach Time with Improvements				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
Lock Site		COSTS[1,2] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	US	26,660	28.1	12.5	16.3	10.6	24.2	10.8	14.0	9.1	3.9	2.3
	DS	NA	17.5	8.1	11.0	8.0	NA	NA	NA	NA	NA	NA
12	US	NA	20.5	9.7	18.5	9.5	NA	NA	NA	NA	NA	NA
	DS	13,694	15.7	6.4	14.8	10.6	13.5	5.5	12.7	9.1	2.2	2.1
13	US	NA	18.0	7.7	16.0	10.7	NA	NA	NA	NA	NA	NA
	DS	NA	13.7	6.5	12.6	8.2	NA	NA	NA	NA	NA	NA
14	US	23,085	24.4	12.3	16.9	11.3	21.0	10.6	14.5	9.7	3.4	2.4
	DS	11,533	15.3	8.6	17.6	10.0	13.4	7.5	15.4	8.8	1.9	2.2
15	US	NA	24.0	14.7	30.8	14.9	NA	NA	NA	NA	NA	NA
	DS	7,966	16.7	9.7	31.8	23.4	14.4	8.4	27.4	20.2	2.3	4.4
16	US	34,930	31.7	14.8	22.0	12.8	25.6	12.0	17.8	10.4	6.1	4.2
	DS	12,904	19.5	7.7	14.9	9.9	17.5	6.9	13.3	8.8	2.0	1.6
17	US	26,517	40.5	15.4	32.5	15.4	34.1	13.0	27.4	13.0	6.4	5.1
	DS	16,753	21.9	8.3	16.2	9.2	18.5	7.0	13.6	7.7	3.4	2.6
18	US	22,440	32.1	14.3	21.0	14.1	27.6	12.3	18.1	12.2	4.5	2.9
	DS	NA	16.1	6.9	19.4	13.5	NA	NA	NA	NA	NA	NA
19	US	NA	17.7	13.8	24.6	13.0	NA	NA	NA	NA	NA	NA
	DS	13,692	18.3	9.2	29.0	18.2	15.4	7.7	24.4	15.3	2.9	4.6
20	US	27,770	31.7	15.2	18.3	10.3	27.3	13.1	15.7	8.8	4.4	2.6
	DS	12,179	30.9	15.2	22.3	13.0	26.6	13.1	19.2	11.2	4.3	3.1
21	US	25,148	33.3	14.4	22.6	15.2	28.6	12.4	19.4	13.0	4.7	3.2
	DS	NA	22.7	19.4	22.6	12.5	NA	NA	NA	NA	NA	NA
22	US	28,836	49.9	15.9	27.9	18.1	42.9	13.7	24.0	15.6	7.0	3.9
	DS	NA	35.9	14.6	23.6	13.2	NA	NA	NA	NA	NA	NA
24	US	21,800	22.2	12.1	22.8	15.5	19.1	10.4	19.6	13.3	3.1	3.2
	DS	10,790	15.9	8.9	15.5	9.3	14.0	7.8	13.6	8.2	1.9	1.9
25	US	28,020	23.8	12.8	19.0	10.7	21.3	11.5	17.0	9.6	2.5	2.0
	DS	15,178	15.1	7.7	17.1	11.1	12.7	6.5	14.4	9.3	2.4	2.7
MEL	US	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
PRICE	DS	NA	17.3	7.1	21.2	10.4	NA	NA	NA	NA	NA	NA
27	US	NA	13.4	8.6	16.0	11.5	NA	NA	NA	NA	NA	NA
	DS	NA	14.5	7.5	13.6	10.4	NA	NA	NA	NA	NA	NA
LOCK-	US	NA	13.0	9.0	26.2	13.2	NA	NA	NA	NA	NA	NA
PORT	DS	NA	11.3	6.0	15.2	7.4	NA	NA	NA	NA	NA	NA
BRAN-	US	NA	17.9	7.7	16.8	10.1	NA	NA	NA	NA	NA	NA
DON	DS	NA	21.4	7.0	25.1	10.9	NA	NA	NA	NA	NA	NA
DRES-	US	NA	14.5	7.9	14.5	8.1	NA	NA	NA	NA	NA	NA
DEN	DS	NA	13.9	7.1	15.7	6.9	NA	NA	NA	NA	NA	NA
MAR-	US	NA	20.3	5.9	13.9	6.4	NA	NA	NA	NA	NA	NA
SEILLES	DS	NA	20.7	6.5	22.5	11.7	NA	NA	NA	NA	NA	NA
STARV	US	NA	10.9	8.8	17.9	2.0	NA	NA	NA	NA	NA	NA
ED ROCK	DS	11,028	9.6	4.8	19.6	10.1	NC	NC	NC	NC	NC	NC
PEO	US	12,790	18.7	9.7	19.1	10.1	NC	NC	NC	NC	NC	NC
RIA	DS	NA	16.7	10.7	22.1	12.7	NA	NA	NA	NA	NA	NA
LA	US	13,867	19.8	11.2	22.9	11.5	NC	NC	NC	NC	NC	NC
GRANGE	DS	11,780	17.1	9.3	21.9	10.4	NC	NC	NC	NC	NC	NC
Average	US	26,521	28.4	13.3	22.1	13.0	27.2	12.0	18.8	11.5	4.6	3.2
UMR 11-25	DS	12,743	19.7	9.8	19.2	12.2	16.2	7.8	17.1	11.0	2.6	2.8
Average	US	13,867	14.4	7.5	16.4	7.7	NC	NC	NC	NC	NC	NC
Illinois	DS	11,404	13.8	6.4	17.8	8.8	NC	NC	NC	NC	NC	NC

US = upstream, DS = downstream, NA = not applicable, NC = no change

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not included in the costs since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. The impacts to navigation are the same as shown for the extended guidewall measure and must be added to the cost estimates.

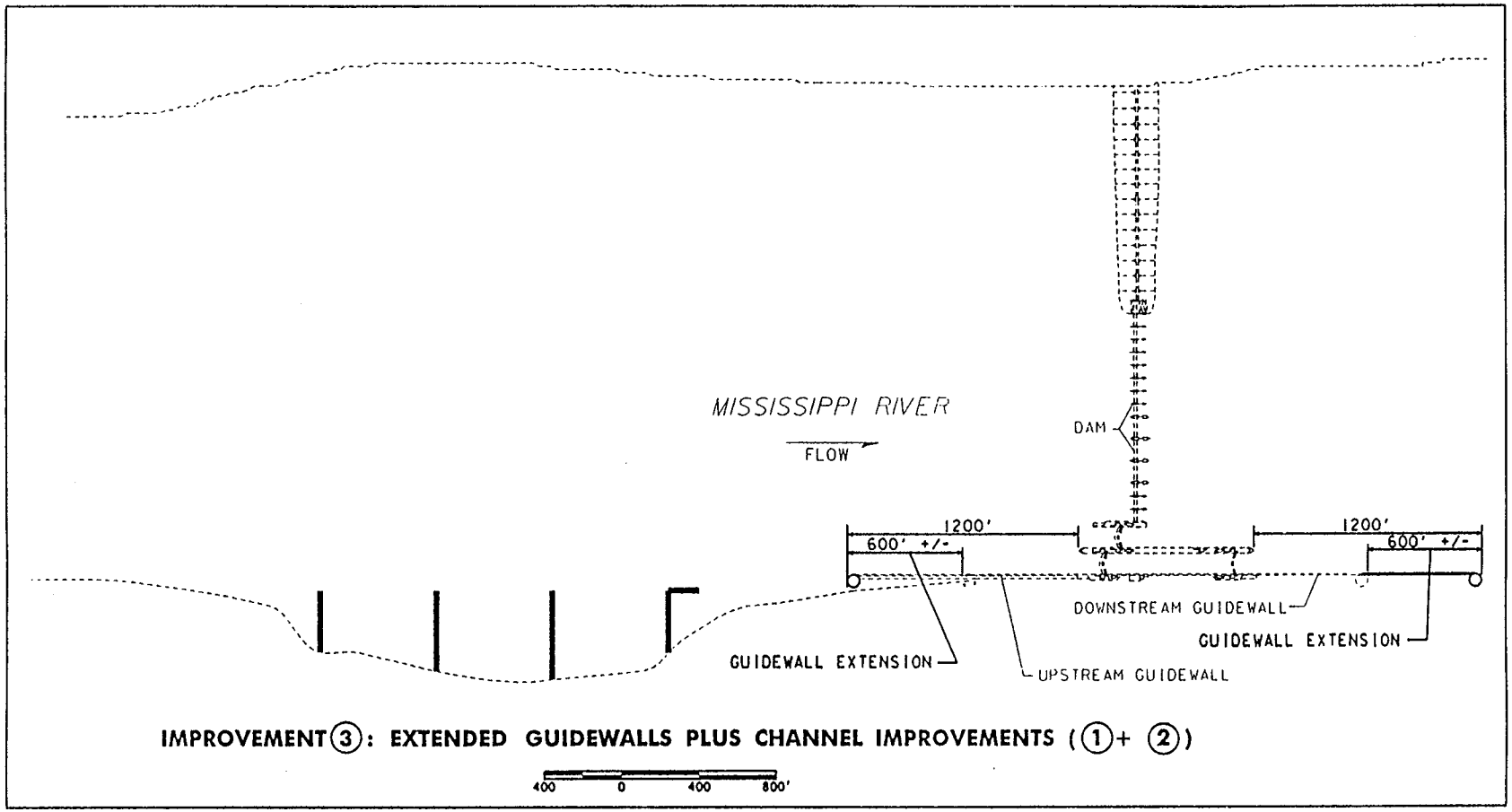


FIGURE 4-15: Improvement 3: Extended Guidewalls Plus Channel Improvements

Relationship to Other Small Scale Measures. This combination is complementary with most other measures. Channel improvements can impact the location of adjacent and remote mooring facilities.

Conclusions/Summary. The combination of extended guidewalls and channel improvements gives a somewhat greater reduction in lock approach times than the individual measures do separately. Channel improvements generally provide a greater incremental approach time savings at less cost than guidewall extensions, and after confirmation by site-specific model studies, should be considered further as a betterment to lock transit time.

4. Auxiliary Lock (Location 3) Guardwall (Alone)

Description of Measure. A location 3 guardwall is constructed as a 1,200-foot upstream extension of the river wall of the auxiliary lock/miter gate bay (see Figure 4-16). While a guidewall is an extension of the lock chamber landside wall, a guardwall is a wall structure on the riverside of the approach channel, usually an extension of the riverside lockwall. Here, the guardwall is located farther riverward at the river wall of the auxiliary gate bay. Upstream guardwalls are constructed with openings below the waterline. These openings allow water to flow from the approach channel to the dam gates. This flow (outdraft) tends to pull a tow toward the guardwall. If the guardwall is located as an extension of the riverside lockwall, this helps to align the tow for entry into the lock chamber. In this case, with the wall located riverward of the lock chamber, there is some reduction in the outdraft and alignment of the current with the existing 600-foot guidewall which a tow still has to use to align itself for entry into the lock chamber. The 1,200-foot guardwall provides some added safety in preventing tows or breakaway barges from approaching the dam gates, causing potential damage to the dam and the barges as well as their cargo. Usually an opening is constructed at water level at the end of the guardwall nearest the miter gate bay. This opening, or trash chute, allows debris or ice in the approach channel area to flow back to the river.

Time Savings. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 4 of Table 4-45. These improvement ratings give average time savings of 3 to 4 minutes for the exchange and fly approach at the pertinent lock sites with a maximum savings of 6 minutes in the fly approach at Locks 17 and 22. This measure is not recommended by itself at a number of sites (see Table 4-49).

Conditions Affecting Implementation. The placement of a location 3 guardwall alone without any other upstream channel improvement is applicable at only a few lock sites where the existing riverbank above the lock goes landward, providing room for a tow (1,200 feet long) to approach the lock. A location 3 guardwall placement is possible at Mississippi River Locks 11, 12, 17, 22, 24, and 25. On the IWW, a location 3 guardwall placement is possible only at Dresden Island, the only lock on the IWW with an auxiliary gate bay.

Costs. The guardwall design is similar to the guidewall design except for the openings allowing flow to the dam gates. The design is discussed in the Extended Guidewall section of this report and is shown on plates 29 through 31 of Appendix C. Costs were calculated for Lock 21 (pile-founded site) and for Lock 22 (rock foundation). These costs were used to prorate costs for guardwalls at the other applicable lock sites. Table 4-49 shows the first cost for the location 3 guardwall, which includes the cost to remove the existing 500-foot dogleg guardwall at Locks 11, 24 and 25. In addition, annual maintenance costs of $10,000 per site are anticipated. Environmental impacts, an important component to the costs, will be added to the costs by the Environmental Work Group. Impacts to navigation during construction of a location 3 guardwall are described below.

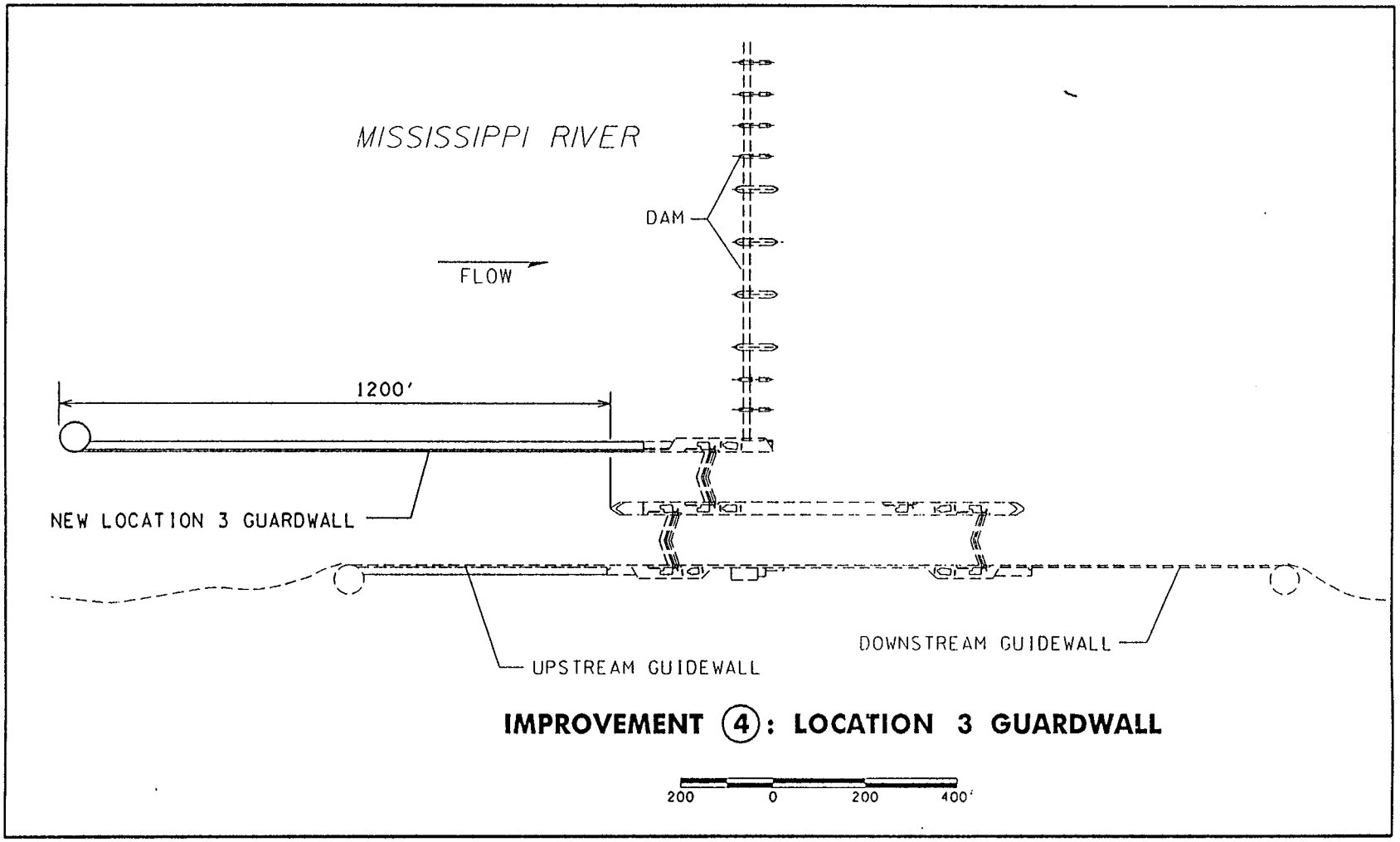


FIGURE 4-16: Improvement 4: Location 3 Guardwall

TABLE 4-49: COST AND PERFORMANCE OF LOCATION 3 UPSTREAM GUARDWALL (ALONE)

	COSTS[1]		APPROACH TIME CHANGES									
			Existing Approach Times				APPROACH TIMES W/ LOC 3 US GUARDWALL				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
Lock Site	Basic Guardwall Cost ($1,000's)	Impacts to Navigation[2] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	18,919	10,348	28.1	12.5	16.3	10.6	24.7	11.0	14.3	9.3	3.4	2.0
12	18,168	9,723	20.5	9.7	18.5	9.5	16.2	7.7	14.6	7.5	4.3	3.9
13	NR	NR	18.0	7.7	16.0	10.7	NR	NR	NR	NR	NR	NR
14	NA	NA	24.4	12.3	16.9	11.3	NA	NA	NA	NA	NA	NA
15	NR	NR	24.0	14.7	30.8	14.9	NR	NR	NR	NR	NR	NR
16	NR	NR	31.7	14.8	22.0	12.8	NR	NR	NR	NR	NR	NR
17	18,252	9,723	40.5	15.4	32.5	15.4	34.1	13.0	27.4	13.0	6.4	5.1
18	NR	NR	32.1	14.3	21.0	14.1	NR	NR	NR	NR	NR	NR
19	NA	NA	17.7	13.8	24.6	13.0	NA	NA	NA	NA	NA	NA
20	NR	NR	31.7	15.2	18.3	10.3	NR	NR	NR	NR	NR	NR
21	NR	NR	33.3	14.4	22.6	15.2	NR	NR	NR	NR	NR	NR
22	15,895	13,964	49.9	15.9	27.9	18.1	43.8	14.0	24.5	15.9	6.1	3.4
24	15,506	14,589	22.2	12.1	22.8	15.5	19.5	10.6	20.0	13.6	2.7	2.8
25	22,724	10,348	23.8	12.8	19.0	10.7	20.9	11.2	16.7	9.4	2.9	2.3
MEL PRICE	NA	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
27	NA	NA	13.4	8.6	16.0	11.5	NA	NA	NA	NA	NA	NA
LOCKPORT	NA	NA	13.0	9.0	26.2	13.2	NA	NA	NA	NA	NA	NA
BRANDON RD.	NA	NA	17.9	7.7	16.8	10.1	NA	NA	NA	NA	NA	NA
DRESDEN IS.	15,479	13,964	14.5	7.9	14.5	8.1	NC	NC	NC	NC	NC	NC
MARSEILLES	NA	NA	20.3	5.9	13.9	6.4	NA	NA	NA	NA	NA	NA
STARVED RK.	NA	NA	10.9	8.8	17.9	2.0	NA	NA	NA	NA	NA	NA
PEORIA	NA	NA	18.7	9.7	19.1	10.1	NA	NA	NA	NA	NA	NA
LAGRANGE	NA	NA	19.8	11.2	22.9	11.5	NA	NA	NA	NA	NA	NA
Avg UMR 11-25	18,244	11,449	28.4	13.3	22.1	13.0	26.5	11.2	19.6	11.4	4.3	3.3
Avg Illinois	15,479	13,964	14.4	7.5	16.4	7.7	NC	NC	NC	NC	NC	NC

US = upstream, NA = not applicable, NR = not recommended (impracticle or economically inefficient), NC = no change

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not shown on the cost side since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs are for a temporary spud barge wall and helper boat assistance. Also included are economic impacts to the navigation industry (i.e., delays and closures) that are shown on construction timelines at Appendix D.

Impacts to Navigation. Under this small scale improvement, a guardwall would be added to the upstream end of the river wall at locks where such an improvement would reduce congestion at the lock. The construction activities would have an adverse impact on navigation during construction at IWW sites. UMR site impacts can be minimized or avoided to a large extent.

The guardwall would be approximately 1,200 feet long and designed to withstand impact loads from barges, although it would rarely be hit by tows. Its primary purpose would be to protect tows from the effects of outdraft at the lock. Site-specific adjustments to the concept would be required, but should not affect the analysis for determining the impacts to navigation that is summarized herein. Some projects have an existing guardwall that would be removed prior to construction.

At UMR lock sites, construction would generally be limited to the winter lock closure periods. During this time, 150- to 200-foot increments of the wall would be constructed and finished adequately to allow unimpacted navigation during the next season. Construction would last 3 to 4 years for the upstream guidewall extension and 2 years for the downstream wall.

At IWW sites, which do not have a true winter closure, construction would have adverse impacts to navigation. The primary feature that allows for reducing navigation delays (and concurrent construction) is a temporary spud barge guardwall that extends approximately 1,500 feet into the upper pool from the intermediate lockwall. Downbound tows would use the wall with the aid of a helper boat. Travel in the vicinity of the temporary wall and construction area would be slowed, causing a delay to navigation. Upbound tows would use the existing upstream guidewall to remake tows or with some practice, perhaps the new temporary wall could be used to remake the tows. Either use should have no additional adverse impacts to navigation.

Once the temporary guardwall is installed at the IWW sites, construction activities would occur behind its protective line. The on-site construction activities would last about 2 years for pile-founded guardwalls and 1.5 years for rock-founded guardwalls. Construction activities would require short closures at the end and beginning of the navigation seasons. There would be some weeks in which navigation would not be allowed while the construction workers would be in the area, which effectively reduces the availability of the lock to generally 16 hours per day. Usually, construction crews would work normal work weeks, except crews would be doubled during periods of lock closure.

A construction schedule for the critical path items that affect navigation was developed and the impacts to navigation were summarized to determine economic loss to the navigation industry due to construction activities. Appendix D summarizes delay time at IWW locks due to construction.

There would be additional first costs to construct the wall above the plant, labor, and materials for the wall proper. There are costs for the helper boat and temporary spud barge wall. The costs would be slightly higher for pile-founded guardwalls since the helper boat is required for a longer duration. The costs from both delay time to navigation and assistance to tows during construction are reported as impacts to navigation.

Relationship to Other Small Scale Measures. A location 3 guardwall alone is complementary with most other measures. Implementing this measure by definition excludes other approach channel improvements, including extended guidewalls and related measures (tow haulage, switchboats) that provide for tow remake outside the lock chamber along an extended lock chamber wall. This measure can be combined with an extension of the lower guidewall to allow remake outside the lock chamber for downbound tows.

Conclusions/Summary. It is estimated that a location 3 guardwall alone provides a similar reduction in lock approach time as extended guidewalls with channel improvements. A location 3 guardwall alone does not provide any other reduction in lock transit time.

5. Existing Lock (Location 2) Guardwall (Alone)

Description of Measure. A location 2 guardwall is constructed as a 1,200-foot upstream extension of the river wall (intermediate wall) of the existing lock (see Figure 4-17). At this location, the guardwall provides maximum benefits to downbound tows. The guardwall is constructed with openings below the waterline similar to a location 3 guardwall to allow water from the approach channel to flow to the dam gates. This flow (outdraft) pulls a tow to the guardwall and helps to align the tow with the lock chamber. Therefore, the existing guidewall is not used. The guidewall is removed and the bankline tapered to provide a 200-foot-wide opening for the tow as the tow approaches the guardwall. The guardwall construction and existing guidewall demolition must be performed together to maintain acceptable and safe conditions for approaching the lock chamber. The 1,200-foot guardwall provides some added safety in preventing tows or breakaway barges from approaching the dam gates, causing potential damage to the dam and the barges and their cargo as well. Usually an opening is constructed at water level at the end of the guardwall nearest the lock. This opening or trash chute allows floating debris or ice to flow back to the river and prevents accumulation above the lock in the approach channel.

Time Savings. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 5 of Table 4-45. These improvement ratings indicate 11- to 14-minute savings for Lock 17, and more moderate improvements for the other sites where this measure is applicable. Table 4-50 shows the estimated improved approach times for the pertinent lock sites.

Conditions Affecting Implementation. The placement of a location 2 guardwall alone without any other upstream channel improvement is applicable at fewer lock sites than those lock sites where a location 3 guardwall is applicable. This is because not all the sites where a location 3 guardwall is possible have adequate room for a 1,200-foot-long tow to approach the existing lock when the guardwall is at location 2 without additional channel work to reduce outdraft at high flows. A location 2 guardwall placement is possible at Mississippi River Locks 12, 17, 19, and 24, although outdraft during high flows at Lock 24 would impede tows approaching the guardwall. At Lock 19, the placement of a location 2 guardwall was model studied and is shown on plate 11 in Appendix C, and noted as Plan A-Modified in the model study. On the IWW, a location 2 guardwall placement is possible at Dresden Island.

Costs. The guardwall design is similar to the guidewall design, except for the openings allowing flow to the dam gates. The design is discussed in the Extended Guidewall section of this report and is shown on plates 29 through 31 (Appendix C). Costs were calculated for Lock 21 (pile-founded site) and for Lock 22 (rock foundation) and were used to prorate costs for guardwalls at the other applicable lock sites. Table 4-50 shows the first cost for the location 2 guardwall, including the cost to remove the existing 500-foot dogleg guardwall at Lock 24. In addition, annual maintenance costs of $30,000 per lock are anticipated. Environmental impacts, an important component to the costs, will be added to the costs by the Environmental Work Group. Impacts to navigation during construction of a location 2 guardwall are described below.

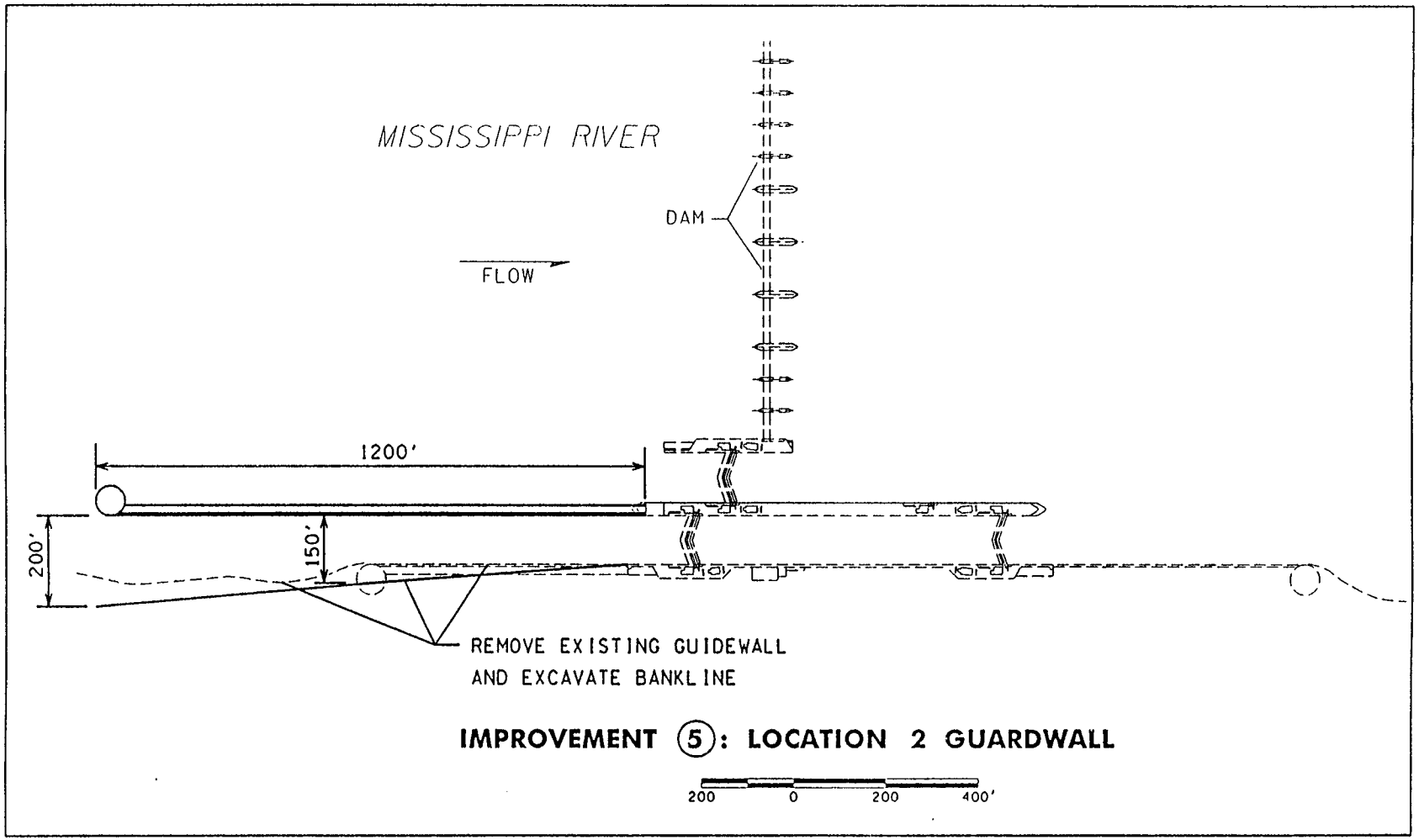


FIGURE 4-17: Improvement 5: Location 2 Guardwall

TABLE 4-50: COST AND PERFORMANCE OF LOCATION 2 UPSTREAM GUARDWALL (ALONE)

	COSTS[1]		APPROACH TIME CHANGES									
			Existing Approach Times				Approach Time with Improvements				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
Lock Site	Basic Guardwall Cost ($1,000's)	Impacts to Navigation[2] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	NR	NR	28.1	12.5	16.3	10.6	NR	NR	NR	NR	NR	NR
12	21,168	318,000	20.5	9.7	18.5	9.5	13.7	6.5	12.3	6.3	6.8	6.2
13	NR	NR	18.0	7.7	16.0	10.7	NR	NR	NR	NR	NR	NR
14	NR	NR	24.4	12.3	16.9	11.3	NR	NR	NR	NR	NR	NR
15	NR	NR	24.0	14.7	30.8	14.9	NR	NR	NR	NR	NR	NR
16	NR	NR	31.7	14.8	22.0	12.8	NR	NR	NR	NR	NR	NR
17	21,252	318,000	40.5	15.4	32.5	15.4	27.0	10.3	21.7	10.3	13.5	10.8
18	NR	NR	32.1	14.3	21.0	14.1	NR	NR	NR	NR	NR	NR
19	14,400	190,500	17.7	13.8	24.6	13.0	14.6	11.4	20.3	10.7	3.1	4.3
20	NR	NR	31.7	15.2	18.3	10.3	NR	NR	NR	NR	NR	NR
21	NR	NR	33.3	14.4	22.6	15.2	NR	NR	NR	NR	NR	NR
22	NR	NR	49.9	15.9	27.9	18.1	NR	NR	NR	NR	NR	NR
24	16,506	190,500	22.2	12.1	22.8	15.5	20.2	11.0	20.8	14.1	2.0	2.0
25	NR	NR	23.8	12.8	19.0	10.7	NR	NR	NR	NR	NR	NR
MEL PRICE	NA	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
27	NA	NA	13.4	8.6	16.0	11.5	NA	NA	NA	NA	NA	NA
LOCKPORT	NR	NR	13.0	9.0	26.2	13.2	NR	NR	NR	NR	NR	NR
BRANDON RD.	NR	NR	17.9	7.7	16.8	10.1	NR	NR	NR	NR	NR	NR
DRESDEN IS.	17,479	190,500	14.5	7.9	14.5	8.1	NC	NC	NC	NC	NC	NC
MARSEILLES	NA	NA	20.3	5.9	13.9	6.4	NA	NA	NA	NA	NA	NA
STARVED RK.	NR	NR	10.9	8.8	17.9	2.0	NR	NR	NR	NR	NR	NR
PEORIA	NR	NR	18.7	9.7	19.1	10.1	NR	NR	NR	NR	NR	NR
LAGRANGE	NR	NR	19.8	11.2	22.9	11.5	NR	NR	NR	NR	NR	NR
Avg UMR 11-25	18,332	254,250	28.4	13.3	22.1	13.0	18.9	9.8	18.8	10.4	6.4	5.8
Avg Illinois	17,479	190,500	14.4	7.5	16.4	7.7	NC	NC	NC	NC	NC	NC

US = upstream, NA = not applicable, NR = not recommended (impracticle or economically inefficient), NC = no change

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not shown on the cost side since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs are for a temporary spud barge wall and helper boat assistance. Also included are economic impacts to the navigation industry (i.e., delays and closures) that are shown on construction timelines at Appendix D.

Impacts to Navigation. Under this small scale improvement, a guardwall would be added to the upstream end of the intermediate wall at locks where such an improvement would reduce congestion at the lock. The construction activities would have an adverse impact on navigation during construction.

Most activities would occur in the navigation season since construction during the winter in the upper pool is assumed to be impossible from 1 January to 1 March due to ice conditions.

The construction of this feature would generally have severe impacts to navigation and a large potential for construction delays, damage to features under construction, and towboat accidents. First, the existing upstream guidewall would be excavated and demolished, followed by installation of a temporary spud barge guardwall upstream of the intermediate lockwall. During intermittent, lengthy closures, features of the permanent guardwall would be constructed and the temporary wall would be incrementally removed. The construction time for on-site activities would be about 3 years for pile foundations and about 2.5 years for a rock-founded guardwall.

When the lock would be available for navigation during the construction duration, helper boats would assist downbound tows onto the temporary wall. Downbound tows would be delayed as they move through the construction area. Construction and navigation would generally not occur simultaneously. The helper boat would act as a switchboat to pull first cuts of upbound tows to reduce congestion and to safeguard the construction area. The remake of upbound tows could occur on the long temporary wall, allowing quicker turnback of the chamber to service other upbound tows.

There would be additional first costs to construct the wall above the plant, labor, and materials for the wall itself. There would be costs for the helper boat and temporary spud barge wall. The costs would be slightly higher for pile-founded guardwalls since the helper boat is required for a longer duration. The costs from both delay time to navigation and assistance to tows during construction are reported as impacts to navigation.

Relationship to Other Small Scale Measures. A location 2 guardwall alone is complementary with most other measures, except for helper boats and switchboats to assist tows into the lock chamber due to a lack of maneuvering space. A lower guidewall extension can be combined with this measure to allow downbound tows to remake outside the lock chamber.

Conclusions/Summary. Of the four sites on the UMR where a location 2 guardwall (alone) is applicable, only at Locks 12 and 17 is there an apparent additional reduction in downbound approach time over what a location 3 guardwall provides.

6. Channel Improvements Plus an Auxiliary Lock (Location 3) Guardwall

Description of Measure. Channel improvements plus a location 3 guardwall combine the channel improvements discussed above with placement of a location 3 guardwall (see Figure 4-18). This combination provides some incremental benefit over placement of each of the two measures separately.

Time Savings. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 6 of Table 4-45. The average savings in the downbound fly approach time for the applicable sites is about 6 minutes. The average savings in the downbound exchange approach time is about 5 minutes. The calculated savings were subtracted from the existing times to obtain the improved times. The revised standard deviation is proportional to the ratio of the new mean time to the existing mean time. The improved approach times are shown in Table 4-51.

Conditions Affecting Implementation. Channel improvements plus a location 3 guardwall is applicable to all the UMR lock sites except the following: Locks 12, 13, 14, 18, 19, Melvin Price and Locks 27. Channel improvements plus a location 3 guardwall is not applicable to any of the lock sites on the IWW because these locks, other than Dresden Island, do not have an auxiliary gate bay. Also, since there are no identified upstream channel improvements for Dresden Island, this combination is not applicable at Dresden Island.

Additional upstream channel widening is needed at UMR Lock 20 to provide just one tow length of straight approach above a location 3 guardwall, as shown on plate 12 (Appendix C). The cost of this additional excavation/dredging including the environmental impacts may not incrementally justify any small reduction in approach time.

Costs. The first costs for channel improvements plus a location 3 guardwall are given in Table 4-51. The impacts to navigation are the same as described for the location 3 guardwall (alone). Costs include the removal of the existing dogleg guardwall at Locks 11, 24, and 25. In addition, annual maintenance costs averaging approximately $250,000 (range $60,000 to $680,000) are anticipated.

Relationship to Other Small Scale Measures. Channel improvements plus a location 3 guardwall is complementary with most other measures. Implementing this measure excludes other approach channel improvements, including extended guidewalls and related measures (tow haulage, helper boats, switchboats) that provide for tow remake outside the lock chamber along an extended upper lock chamber wall. This measure can be combined with a lower guidewall extension to allow remake outside the lock chamber for downbound tows.

Conclusions/Summary. Channel improvements plus a location 3 guardwall provide an incremental savings in the downbound approach time over what these measures provide independently. As with any of the approach channel improvements discussed in this section, physical model testing should be considered during site-specific lock studies to verify the most efficient approach improvements.

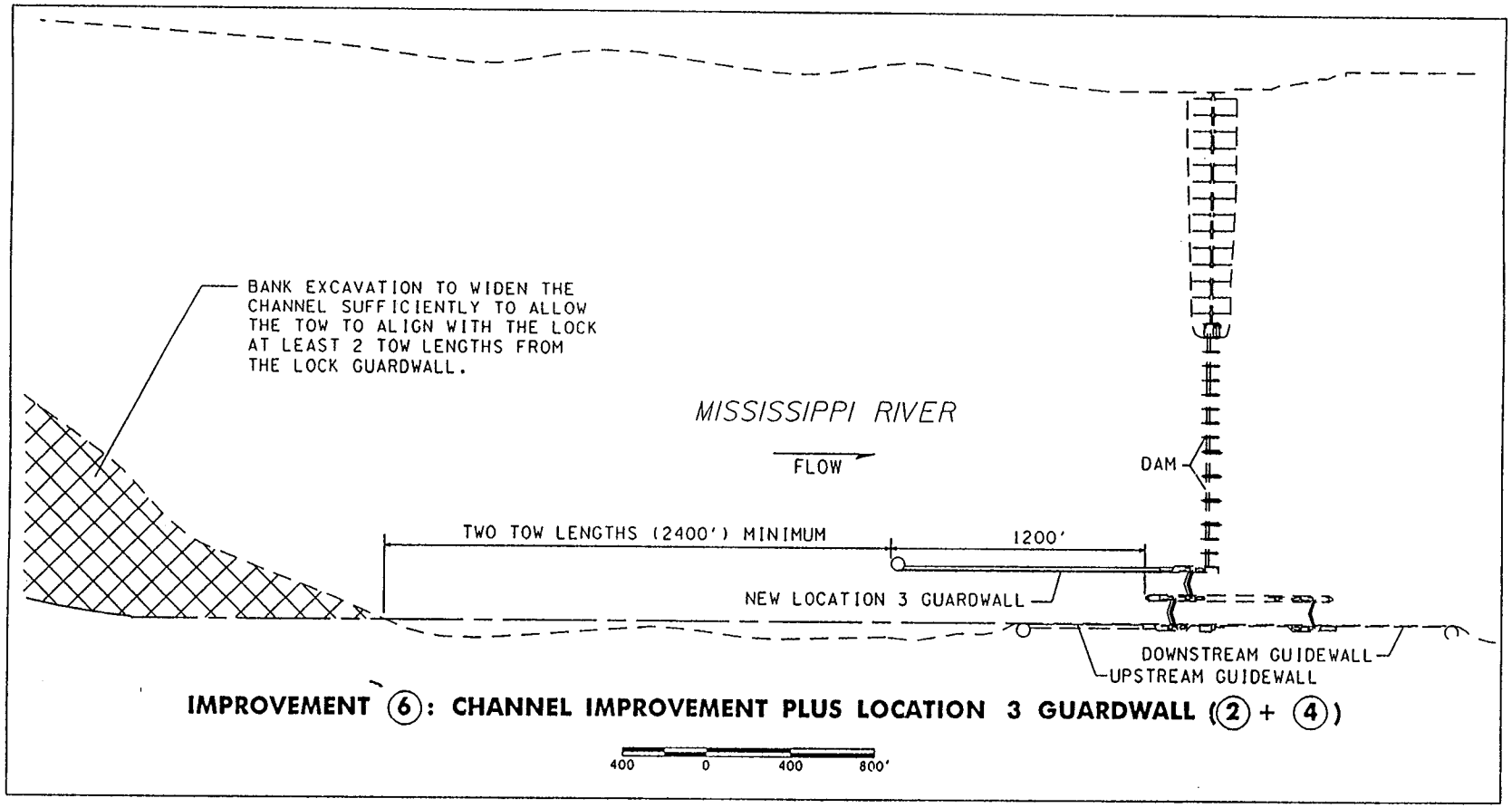


FIGURE 4-18: Channel Improvements Plus Location 3 Guardwall

TABLE 4-51: COST AND PERFORMANCE OF CHANNEL IMPROVEMENT PLUS LOCATION 3 UPSTREAM GUARDWALL

	COSTS[1]		APPROACH TIME CHANGES									
			Existing Approach Times				Approach Time with Improvements				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
Lock Site	Basic Improvement Cost ($1,000's)	Impacts to Navigation[2] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	23,509	10,348	28.1	12.5	16.3	10.6	22.7	10.1	13.2	8.6	5.4	3.1
12	NA	NA	20.5	9.7	18.5	9.5	NA	NA	NA	NA	NA	NA
13	NA	NA	18.0	7.7	16.0	10.7	NA	NA	NA	NA	NA	NA
14	NA	NA	24.4	12.3	16.9	11.3	NA	NA	NA	NA	NA	NA
15	15,265	13,964	24.0	14.7	30.8	14.9	18.5	11.3	23.8	11.5	5.5	7.0
16	32,112	10,348	31.7	14.8	22.0	12.8	24.5	11.4	17.0	9.9	7.2	5.0
17	21,189	9,723	40.5	15.4	32.5	15.4	32.7	12.4	26.3	12.5	7.8	6.2
18	NA	NA	32.1	14.3	21.0	14.1	NA	NA	NA	NA	NA	NA
19	NA	NA	17.7	13.8	24.6	13.0	NA	NA	NA	NA	NA	NA
20	28,535	14,589	31.7	15.2	18.3	10.3	25.6	12.3	14.8	8.3	6.1	3.5
21	21,945	10,348	33.3	14.4	22.6	15.2	26.9	11.6	18.2	12.2	6.4	4.4
22	20,731	13,964	49.9	15.9	27.9	18.1	40.3	12.8	22.5	14.6	9.6	5.4
24	17,106	14,589	22.2	12.1	22.8	15.5	17.9	9.8	18.4	12.5	4.3	4.4
25	23,744	10,348	23.8	12.8	19.0	10.7	19.2	10.3	15.4	8.7	4.6	3.6
MEL PRICE	NA	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
27	NA	NA	13.4	8.6	16.0	11.5	NA	NA	NA	NA	NA	NA
LOCKPORT	NA	NA	13.0	9.0	26.2	13.2	NA	NA	NA	NA	NA	NA
BRANDON RD.	NA	NA	17.9	7.7	16.8	10.1	NA	NA	NA	NA	NA	NA
DRESDEN IS.	NA	NA	14.5	7.9	14.5	8.1	NA	NA	NA	NA	NA	NA
MARSEILLES	NA	NA	20.3	5.9	13.9	6.4	NA	NA	NA	NA	NA	NA
STARVED RK.	NA	NA	10.9	8.8	17.9	2.0	NA	NA	NA	NA	NA	NA
PEORIA	NA	NA	18.7	9.7	19.1	10.1	NA	NA	NA	NA	NA	NA
LAGRANGE	NA	NA	19.8	11.2	22.9	11.5	NA	NA	NA	NA	NA	NA
Avg UMR 11-25	22,682	12,025	28.4	13.3	22.1	13.0	25.4	11.3	18.8	11.0	6.3	4.7
Avg Illinois	NA	NA	14.4	7.5	16.4	7.7	NA	NA	NA	NA	NA	NA

US = upstream, NA = not applicable, NR = not recommended (impracticle or economically inefficient).

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not shown on the cost side since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs are for a temporary spud barge wall and helper boat assistance. Also included are economic impacts to the navigation industry (i.e., delays and closures) that are shown on construction timelines at Appendix D.

7. Extended Upstream Guidewall Plus Channel Improvements Plus an Auxiliary Lock (Location 3) Guardwall

Description of Measure. An extended upstream guidewall plus channel improvements plus a location 3 guardwall provides a slight incremental savings to the approach time over the combination of channel improvements plus a location 3 guardwall. In addition to lessening the delays due to outdraft resulting from channel improvements and a location 3 guardwall, the tow has the benefit of an extended 1,200-foot guidewall on which to land and align with the lock chamber (see Figure 4-19).

Time Savings. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 7 of Table 4-45. The calculated savings were subtracted from the existing times to obtain the improved times. The revised standard deviation is proportional to the ratio of the new mean time to the existing mean time. The improved approach times are shown in Table 4-52. The downbound exchange approach times decrease by an average of 5 minutes.

Conditions Affecting Implementation. Extending the upstream guidewall plus channel improvements plus a location 3 guardwall is applicable to all the UMR lock sites except the following: Locks 13, 14, 15, 18, 19, Melvin Price Locks and Locks 27. A site-specific model study of Lock 18 is needed to verify this assumption. An upper guidewall extension plus channel improvements plus a location 3 guardwall is not applicable to any of the lock sites on the IWW because these locks, other than Dresden Island, do not have an auxiliary gate bay. Also, since there are no identified upstream channel improvements for Dresden Island, this combination is not applicable at Dresden Island.

Additional upstream channel widening is needed at UMR Lock 20 to provide just one tow length of straight approach above a location 3 guardwall, as shown on plate 12 (Appendix C).

Costs. The first costs range from $38 to $54 million for this combination of measures, as shown in Table 4-52, plus the economic impacts to navigation during construction. The costs include the removal of the existing shorter guardwall where applicable. Additional annual maintenance will also be required averaging roughly $300,000 per lock (range $91,000 to $720,000). Environmental costs will be included once identified, if this measure is recommended for further analysis.

Conclusions/Summary. The basic cost for this improvement is higher than the more efficient improvement which is discussed next: Channel Improvement Plus an Existing Lock (Location 2) Guardwall. However, the impacts to navigation are much less during construction of the extended guidewall and auxiliary lock guardwall than during construction of an existing lock guardwall that is in closer proximity to the navigation channel.

8. Channel Improvements Plus an Existing Lock (Location 2) Guardwall

Description of Measure. The combination of channel improvements plus a location 2 guardwall (upstream extension of the existing lock riverwall) generally provides the most efficient downbound approach to a lock (see Figure 4-20). This improvement includes removing the existing landside guidewall and tapering the bankline to provide a 200-foot navigable opening at the upper end of the location 2 guardwall. The guardwall construction and existing guidewall demolition must be performed together to maintain acceptable and safe conditions for approaching the lock chamber.

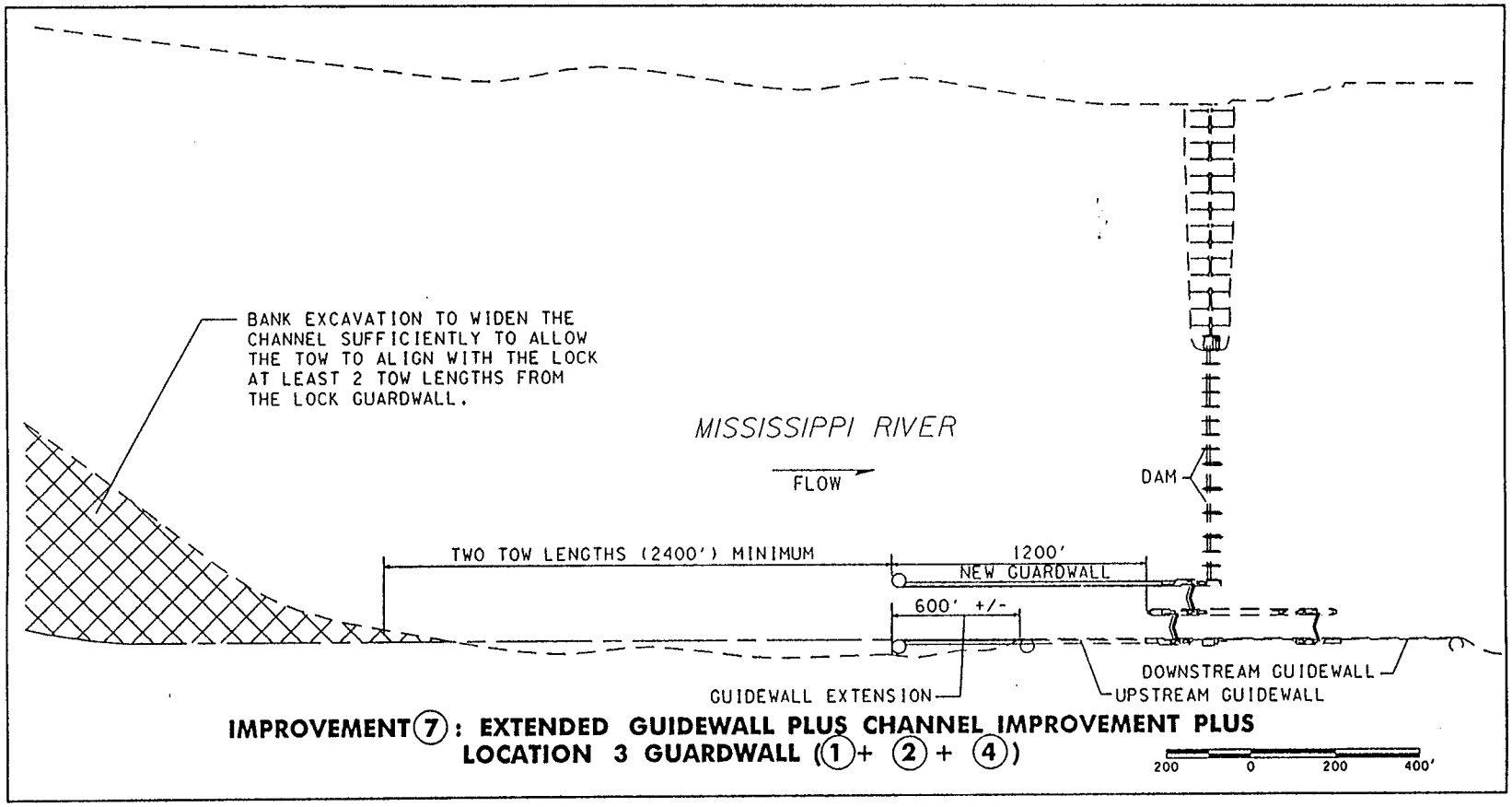


FIGURE 4-19: Extended Guidewall Plus Channel Improvement Plus Location 3 Guardwall

TABLE 4-52: COST AND PERFORMANCE OF US GUIDEWALL EXTENSION PLUS CHANNEL IMPROVEMENT PLUS LOCATION 3 UPSTREAM GUARDWALL

	COSTS[1]		APPROACH TIME CHANGES									
			Existing Approach Times				Times w/ the combined Improvement				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
Lock Site	Basic Improvement Cost ($1,000's)	Impacts to Navigation[2] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	45,579	10,348	28.1	12.5	16.3	10.6	22.2	9.9	12.9	8.4	5.9	3.4
12	45,478	9,723	20.5	9.7	18.5	9.5	15.5	7.3	14.0	7.2	5.0	4.5
13	NA	NA	18.0	7.7	16.0	10.7	NA	NA	NA	NA	NA	NA
14	NA	NA	24.4	12.3	16.9	11.3	NA	NA	NA	NA	NA	NA
15	NR	NR	24.0	14.7	30.8	14.9	NR	NR	NR	NR	NR	NR
16	53,442	10,348	31.7	14.8	22.0	12.8	23.9	11.2	16.6	9.7	7.8	5.4
17	44,769	9,723	40.5	15.4	32.5	15.4	31.3	11.9	25.1	11.9	9.2	7.4
18	NA	NA	32.1	14.3	21.0	14.1	NA	NA	NA	NA	NA	NA
19	NA	NA	17.7	13.8	24.6	13.0	NA	NA	NA	NA	NA	NA
20	51,605	14,589	31.7	15.2	18.3	10.3	25.1	12.0	14.5	8.2	6.6	3.8
21	44,825	10,348	33.3	14.4	22.6	15.2	25.7	11.1	17.5	11.8	7.6	5.1
22	44,731	13,964	49.9	15.9	27.9	18.1	38.5	12.3	21.6	14.0	11.4	6.3
24	37,306	14,589	22.2	12.1	22.8	15.5	17.2	9.4	17.6	12.0	5.0	5.2
25	50,744	10,348	23.8	12.8	19.0	10.7	18.4	9.9	14.7	8.3	5.4	4.3
MEL PRICE	NA	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
27	NA	NA	13.4	8.6	16.0	11.5	NA	NA	NA	NA	NA	NA
LOCKPORT	NA	NA	13.0	9.0	26.2	13.2	NA	NA	NA	NA	NA	NA
BRANDON RD.	NA	NA	17.9	7.7	16.8	10.1	NA	NA	NA	NA	NA	NA
DRESDEN IS.	NA	NA	14.5	7.9	14.5	8.1	NA	NA	NA	NA	NA	NA
MARSEILLES	NA	NA	20.3	5.9	13.9	6.4	NA	NA	NA	NA	NA	NA
STARVED RK.	NA	NA	10.9	8.8	17.9	2.0	NA	NA	NA	NA	NA	NA
PEORIA	NA	NA	18.7	9.7	19.1	10.1	NA	NA	NA	NA	NA	NA
LAGRANGE	NA	NA	19.8	11.2	22.9	11.5	NA	NA	NA	NA	NA	NA
Avg UMR 11-25	46,497.7	11,553.3	28.4	13.3	22.1	13.0	24.2	10.6	17.2	10.1	7.1	5.0
Avg Illinois	NA	NA	14.4	7.5	16.4	7.7	NA	NA	NA	NA	NA	NA

US = upstream, NA = not applicable, NR = not recommended (impractical or economically inefficient).

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not shown on the cost side since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs are for a temporary spud barge wall and helper boat assistance during construction. Also included are economic impacts to the navigation industry (i.e., delays/closures) that are shown on construction timelines at Appendix D.

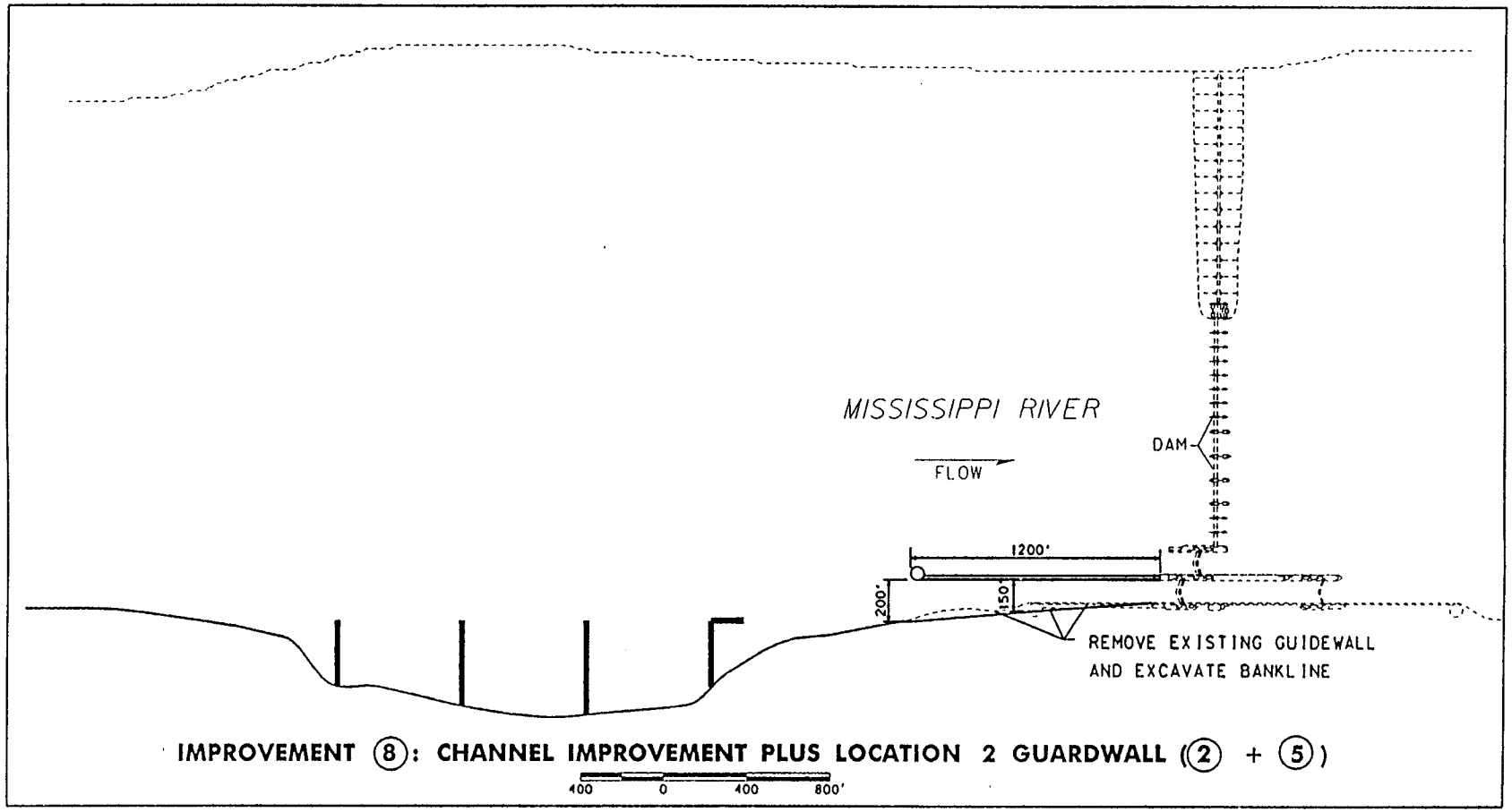


FIGURE 4-20: Channel Improvements Plus Location 2 Guardwall

Time Savings. The improved fly and exchange approach times were determined using the average relative improvement ratings from column 8 of Table 4-45. The calculated savings were subtracted from the existing times to obtain the improved approach times. The revised standard deviation is proportional to the ratio of the new mean time to the existing mean time. The improved approach times are shown in Table 4-53. The average improvement in the downbound fly approach time at the pertinent lock sites is about 9 minutes. The average improvement in the exchange approach time is about 7 minutes.

Conditions Affecting Implementation. Channel improvements plus an existing lock guardwall is applicable to all the UMR lock sites except Locks 12, 13, 17, 18, Melvin Price Locks and Locks 27. For Locks 13 and 18, an existing lock guardwall is not considered to be a time saver. Site-specific model studies are needed to confirm this. At Locks 12 and 17, an existing lock guardwall without any channel improvements already improves the approach as much as can be expected. The Melvin Price 600-foot auxiliary lock has a 1,200-foot guardwall. At Locks 27, the 600-foot auxiliary lock does not have an outdraft problem necessitating a 1,200-foot guardwall.

Some lock sites require more extensive channel widening/shifting to accommodate an existing lock guardwall. Excavation into the Old Le Claire Canal at Lock 14 is needed to provide just one tow length of straight approach above an existing lock (location 2) guardwall (see plate 5 of Appendix C). A location 2 guardwall at Lock 16 (as well as a location 3 guardwall) requires extensive shifting of the upper channel (see plate 7 of Appendix C). At Lock 20, additional extensive channel widening is needed above the lock to gain only one tow length of straight approach above the guardwall (see plate 20 of Appendix C).

For the IWW, channel improvement plus an existing lock (location 2) guardwall is applicable only at La Grange Lock, and this is questionable. Extensive channel excavation is needed above the lock and this does not provide even one tow length of straight approach (the desired minimum two-tow length criteria can be relaxed for the IWW) (see plate 27 of Appendix C).

Costs. The combined first costs for upstream channel improvements and an existing lock (location 2) guardwall are shown in Table 4-53. Costs include the removal of the existing guidewall and tapering the bankline to provide a 200-foot-wide navigable opening at the upper end of the guardwall plus the removal of the existing dogleg guardwall as applicable. In addition, maintenance costs are estimated at approximately $280,000 (range $30,000 to $587,000) annually per lock. Impacts to navigation are the same as for constructing an existing lock (location 2) guardwall.

Relationship to Other Small Scale Measures. This combination of channel improvements plus an existing lock guardwall is complementary with most other measures except for helper boats and switchboats assisting downbound tows into the lock chamber. This improvement may eliminate the need for assistance into the chamber. A lower guidewall extension can be combined with this measure to allow downbound tows to remake outside of the lock chamber. This measure can impact the location of adjacent and remote mooring facilities at a lock site.

Conclusions/Summary. Channel improvements with an existing lock (location 2) guardwall generally provides the most efficient downbound lock approach where outdraft is a major concern such as at the UMR locks. At some locks, the desired minimum straight approach of two tow lengths (2,400 feet) above the guardwall is not attainable without additional major channel widening and/or relocation.

TABLE 4-53: COST AND PERFORMANCE OF CHANNEL IMPROVEMENT PLUS LOCATION 2 UPSTREAM GUARDWALL

Lock Site	COSTS[1]		APPROACH TIME CHANGES									
			Existing Approach Times				Times w/ the Combined Improvements				Savings	
			Doubles; Fly Approach Time		Doubles; Exchange Approach Time		Doubles; New Fly Approach Time		Doubles; New Exchange Approach Time		Double Fly Appr	Double Exchange Appr
	Basic Improvement Cost ($1,000's)	Impacts to Navigation[2] ($1,000's)	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Values	Std. Deviation	Mean Savings	Mean Savings
11	24,509	318,000	28.1	12.5	16.3	10.6	19.3	8.6	11.2	7.3	8.8	5.1
12	NA	NA	20.5	9.7	18.5	9.5	NA	NA	NA	NA	NA	NA
13	NA	NA	18.0	7.7	16.0	10.7	NA	NA	NA	NA	NR	NR
14*	24,751	190,500	24.4	12.3	16.9	11.3	18.8	9.5	13.1	8.8	5.6	3.8
15	15,265	190,500	24.0	14.7	30.8	14.9	16.4	10.0	21.1	10.2	7.6	9.7
16	33,112	318,000	31.7	14.8	22.0	12.8	21.2	9.9	14.7	8.6	10.5	7.3
17	NA	NA	40.5	15.4	32.5	15.4	NA	NA	NA	NA	NA	NA
18	NA	NA	32.1	14.3	21.0	14.1	NA	NA	NA	NA	NR	NR
19	10,800	190,500	17.7	13.8	24.6	13.0	15.5	12.1	21.6	11.4	2.2	3.0
20*	31,535	190,500	31.7	15.2	18.3	10.3	21.2	10.2	12.2	6.9	10.5	6.1
21	24,945	318,000	33.3	14.4	22.6	15.2	23.4	10.1	15.9	10.7	9.9	6.7
22	23,731	190,500	49.9	15.9	27.9	18.1	33.3	10.6	18.6	12.1	16.6	9.3
24	18,106	190,500	22.2	12.1	22.8	15.5	14.8	8.1	15.2	10.3	7.4	7.6
25	24,744	318,000	23.8	12.8	19.0	10.7	15.9	8.6	12.7	7.2	7.9	6.3
MEL PRICE	NA	NA	22.3	10.7	18.1	10.1	NA	NA	NA	NA	NA	NA
27	NA	NA	13.4	8.6	16.0	11.5	NA	NA	NA	NA	NA	NA
LOCKPORT	NA	NA	13.0	9.0	26.2	13.2	NA	NA	NA	NA	NA	NA
BRANDON RD.	NA	NA	17.9	7.7	16.8	10.1	NA	NA	NA	NA	NA	NA
DRESDEN IS.	NA	NA	14.5	7.9	14.5	8.1	NA	NA	NA	NA	NA	NA
MARSEILLES	NA	NA	20.3	5.9	13.9	6.4	NA	NA	NA	NA	NA	NA
STARVED RK.	NA	NA	10.9	8.8	17.9	2.0	NA	NA	NA	NA	NA	NA
PEORIA	NA	NA	18.7	9.7	19.1	10.1	NA	NA	NA	NA	NA	NA
LAGRANGE*	22,879	318,000	19.8	11.2	22.9	11.5	Model study to identify approach time savings.				Model Study	
Avg UMR 11-25	23,150	241,500	28.4	13.3	22.1	13.0	20.0	9.8	15.6	9.3	8.7	6.5
Avg Illinois	22,879	318,000	14.4	7.5	16.4	7.7	Model study to identify approach time savings.				Model Study	

NA = not applicable, * these sites require maximum shown channel excavation.

NOTES:

1. An additional cost of $450k/site is anticipated for a model study to verify the site specific optimum. The environomental impacts are not shown on the cost side since they are yet to be quantified. However, they make up a potentially important component of the cost (impacts) side.
2. These costs are for a temporary spud barge wall and helper boat assistance. Also included are economic impacts to the navigation industry (i.e., delays and closures) that are shown on construction timelines at Appendix D.

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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

UNIVERSE OF SMALL SCALE MEASURES

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APPENDIX A - UNIVERSE OF SMALL SCALE MEASURES

Through the review of background reports, an examination of the locking process, and a brainstorming session, the universe of small scale measures was determined by a multi-discipline team. The team participation and investigation procedures are written up in a June 1995 interim report entitled "General Assessment of Small-Scale Measures." The resulting 10 categories of measures (92 total measures) are listed in Table A-1 below.

TABLE A-1: UNIVERSE OF SMALL SCALE MEASURES

Identifying No.	Name of Small Scale Measure
1.	**SCHEDULING OF LOCK OPERATIONS**
1a.	N-Up/N-Down
1b.	Ready to Serve Policy
1c.	Self Help Policy
1d.	Scheduling Program
2.	**ASSISTANCE TO LOCKAGES**
2a.	Helper Boats
2b.	Switchboats
2c.	Endless Cable System
2d.	Unpowered Traveling Kevel
2e.	Powered Traveling Kevel
2f.	Hydraulic Assistance
3.	**IMPROVEMENTS TO APPROACH CHANNELS**
3a.	Approach Channel Widening/Realignment
3b.	Adjacent Mooring Facilities
3c.	Funnel-Shaped Guide walls
3d.	Wind Deflectors
3e.	Extend Guide walls
3f.	Add Guide Cells
3g.	Reconfigure Bullnose
3h.	Radar Reflectors
3i.	Electronic Guidance System
4.	**AREA-WIDE CHANNEL IMPROVEMENTS**
4a.	Remove/Adjust Bends, One-way Reaches, Bridges
4b.	Improve Navigation Aids and Channel Markings
4c.	Innovative Dredging Strategies
4d.	Water Flow Management Policies
4e.	Increase Channel Width
4f.	Isolate Recreational Facilities & Marinas Away from Channel
4h.	Dual Channel at Restrictive Bridges

TABLE A-1: UNIVERSE OF SMALL SCALE MEASURES (Continued)

Identifying No.	Name of Small Scale Measure
5.	**TOW CONFIGURATION AND OPERATIONS**
5a.	Mandate Use of Bow Thrusters
5b.	Mandate Use of Prototype Bow Thrusters
5c.	Tow Size Standardization
5d.	Cooperative Equipment sharing/Scheduling
5e.	Institute Waterway Traffic Management
5f.	Increase Number and Size of Fleeting Areas
5g.	Fuel Monitoring & Management
5h.	Use of Heavy Fuels
5i.	New Barge and Boat Bottom Treatments
5j.	Improved Barge and Boat Hull Designs
5k.	Barge Stacking for Backhauls
5l.	Container Movement
5m.	New Backhaul Opportunities
5n.	Universal Couplers/Hand Winches
5o.	Increase Speed Limits in Restricted Reaches
5p.	Reduce Liability of Tow Operators for Damage
5q.	Require Minimum Crew Size and Training
5r.	Mandate Minimum Horsepower
6.	**LOCK OPERATING EQUIPMENT/PROCEDURES**
6a.	Modify Intake Structures
6b.	Modify Discharge Structures
6c.	Modify Wall Ports
6d.	Install Self-Cleaning Trash Racks
6e.	Centralize Controls
6f.	Portable Controls
6g.	Automate Controls
6h.	Install Floating Mooring Bits
6i.	Upgrade Valve Operating Equipment
6j.	Upgrade Gate Operating Equipment
6k.	Install Gate Wickets in Miter Gates
6l.	Provide Explicit Operating Guides
6m.	Fenders, energy Absorbers
6n.	Require Vessels to Stay Clear of Emptying/Filling System
6o.	Operate Dam Gates Based on Lockage
6p.	Lift Gates at Lock
7.	**ICE CONDITIONS**
7a.	Mechanical Ice Cutting Device
7b.	Skin Plates
7c.	Air Bubbler System
7d.	Heat Plates
7e.	Heated Water Jet
7f.	Clear Ice from Barges
7g.	Ice Chutes

TABLE A-1: UNIVERSE OF SMALL SCALE MEASURES (Continued)	
Identifying No.	**Name of Small Scale Measure**
8.	**RECREATIONAL VESSELS**
8a.	Recreational Vessel Bypass Lifts
8b.	Scheduling of Recreational Vessel Usage
8c.	License Recreational Craft Operators
8d.	Recreational Craft Landing Above and Below lock
9.	**COST ALLOCATION**
9a.	Apply Congestion Tolls
9b.	Allocation of Operations and Maintenance Costs
9c.	Low Head Hydroelectric Units
9d.	Privatization of Lock Operations
9e.	Excess Lockage Time Charges
9f.	Lockage Time Charges
10.	**OTHER**
10a.	Increase Lock Staffing
10b.	Automate Dam Controls
10c.	Radar at Lock
10d.	Real-Time Channel Depth and Weather Monitoring
10e.	Improved Lighting
10f.	Publish Lockage Times by User
10g.	Create Indraft
10h.	Operational Philosophy/Industry Attitude
10i.	Deepen River Upstream of Gates
10j.	Pilot Communication (Bulletin Board)
10k.	Closed Circuit Television (CCTV) at Lock
10l.	Wicket Gates in Dam
10m.	Automated Lockage System from Queue Point
10n.	Specified Navigation Season

The general assessment report briefly defines each of these measures. However, the majority were discarded and only those surviving the initial screening were included in this report.

NAVIGATION NOTICE #1
AND INDUSTRY SELF HELP POLICY

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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
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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. General

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.

APPENDIX E

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 EJH 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,

Thomas 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 singles 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.

PLATES

A

P

P

E

N

D

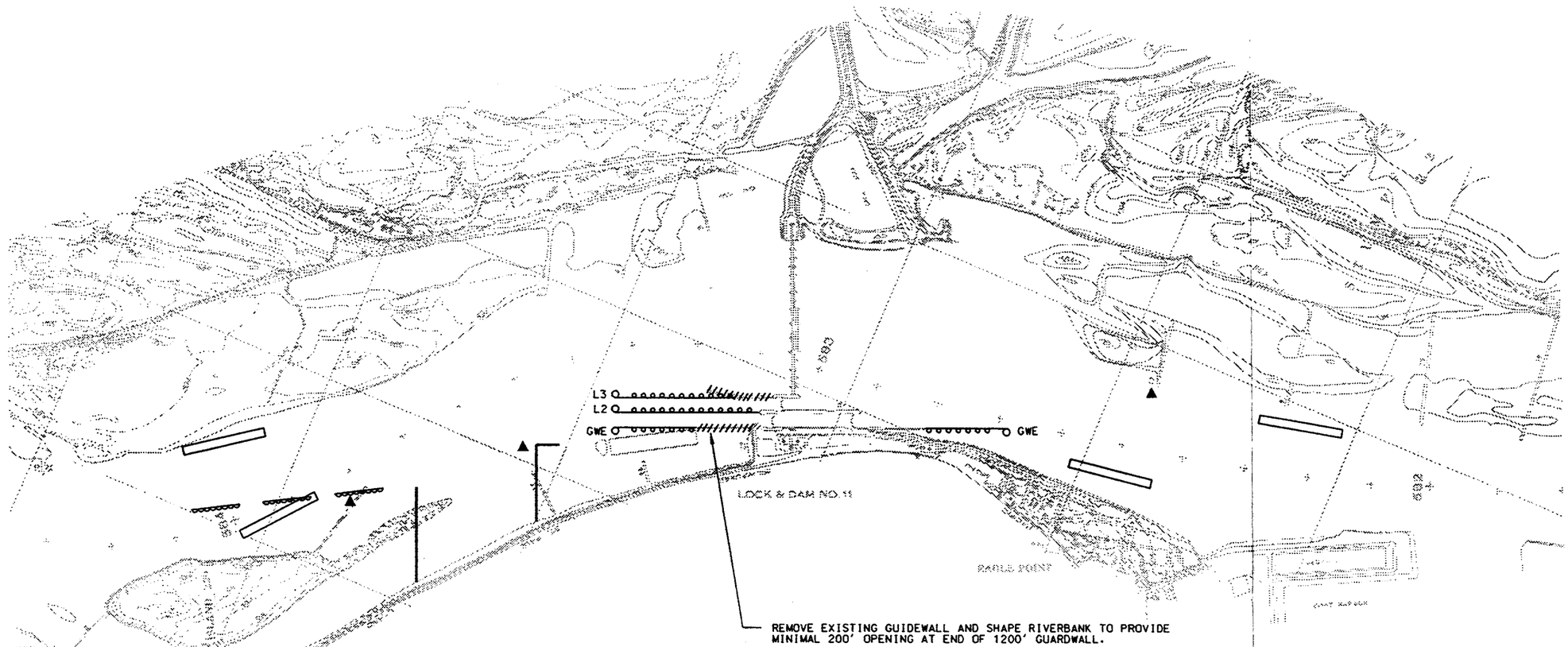
I

X

C

APPENDIX C - PLATES

The following plates show the approach channel improvements by lock site including extended guidewalls if applicable. The improvements are superimposed on one plate for most of the lock sites. This can lead to some confusion. For example, if some dredging is done to improve the approach channel alignment, a remote make-up facility may be possible as shown which otherwise is not possible (e.g., Plate 20). Likewise, all potential upper approach wall locations are shown (guidewall and guardwall), from which only one location may be considered for potential implementation. Realize also that different combinations of improvements are possible such as guidewall extensions with channel improvement or guardwall and channel improvement, etc.



LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 11

APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN

Date:

PLATE 1

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31-JUL-1997 08:23
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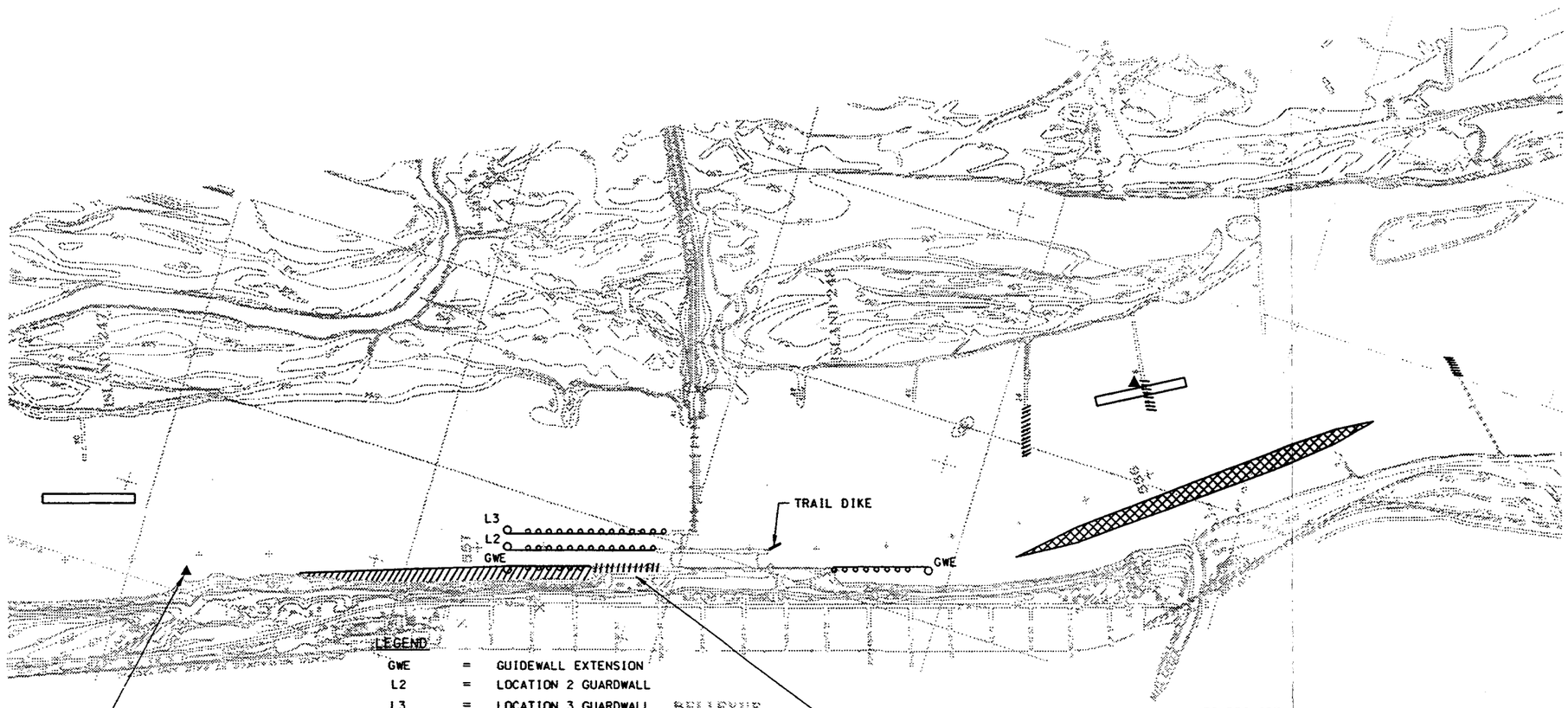

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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	LOCK AND DAM NO.12 APPROACH CHANNEL IMPROVEMENTS
Scale: AS SHOWN	PLATE 2
Date:	

31-JUL-1997 08:25
e:*projects*nso3*nso3p012.dgn

31-JUL-1997 08:25
e:*projects*nso3*nso3p012.dgn

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 13
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 3

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31-JUL-1997 09:05
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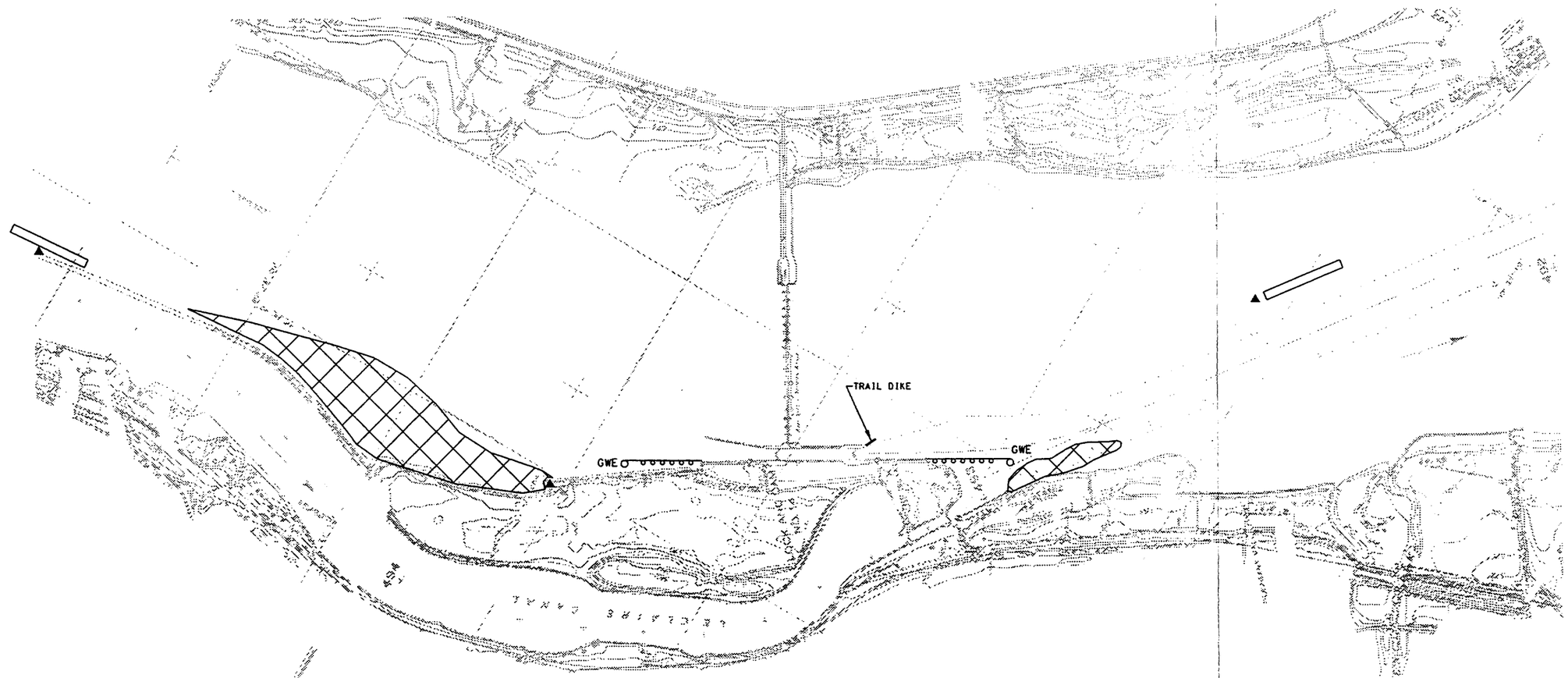

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT

SCALE: 1"= 500'

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 14

APPROACH CHANNEL IMPROVEMENTS

MINIMAL CHANNEL EXCAVATION

Scale: AS SHOWN

Date:

PLATE 4

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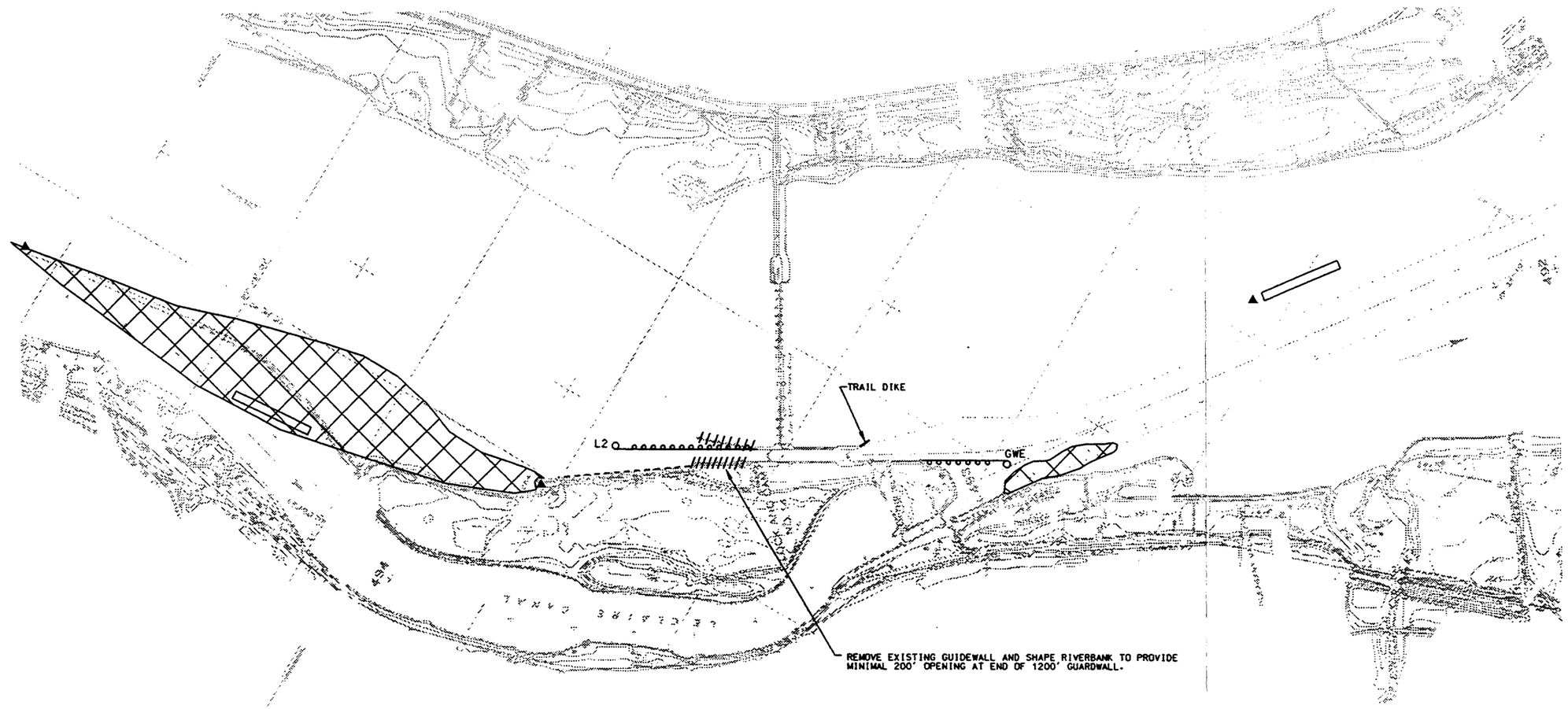

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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LOCK AND DAM NO. 14
APPROACH CHANNEL IMPROVEMENTS
MAXIMUM CHANNEL EXCAVATION

Scale: AS SHOWN
Date:

PLATE 5

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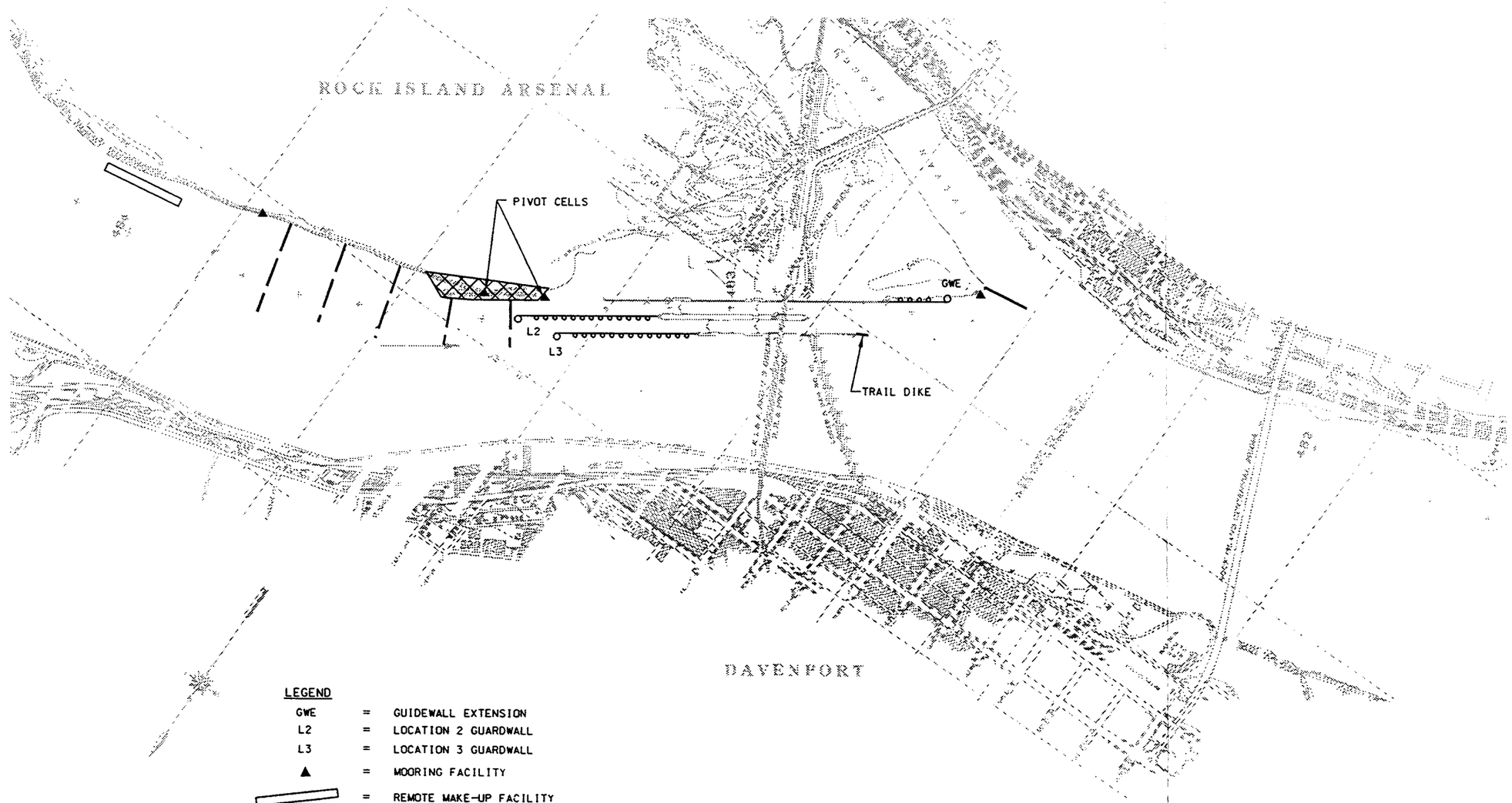

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 15

APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN

Date:

PLATE 6

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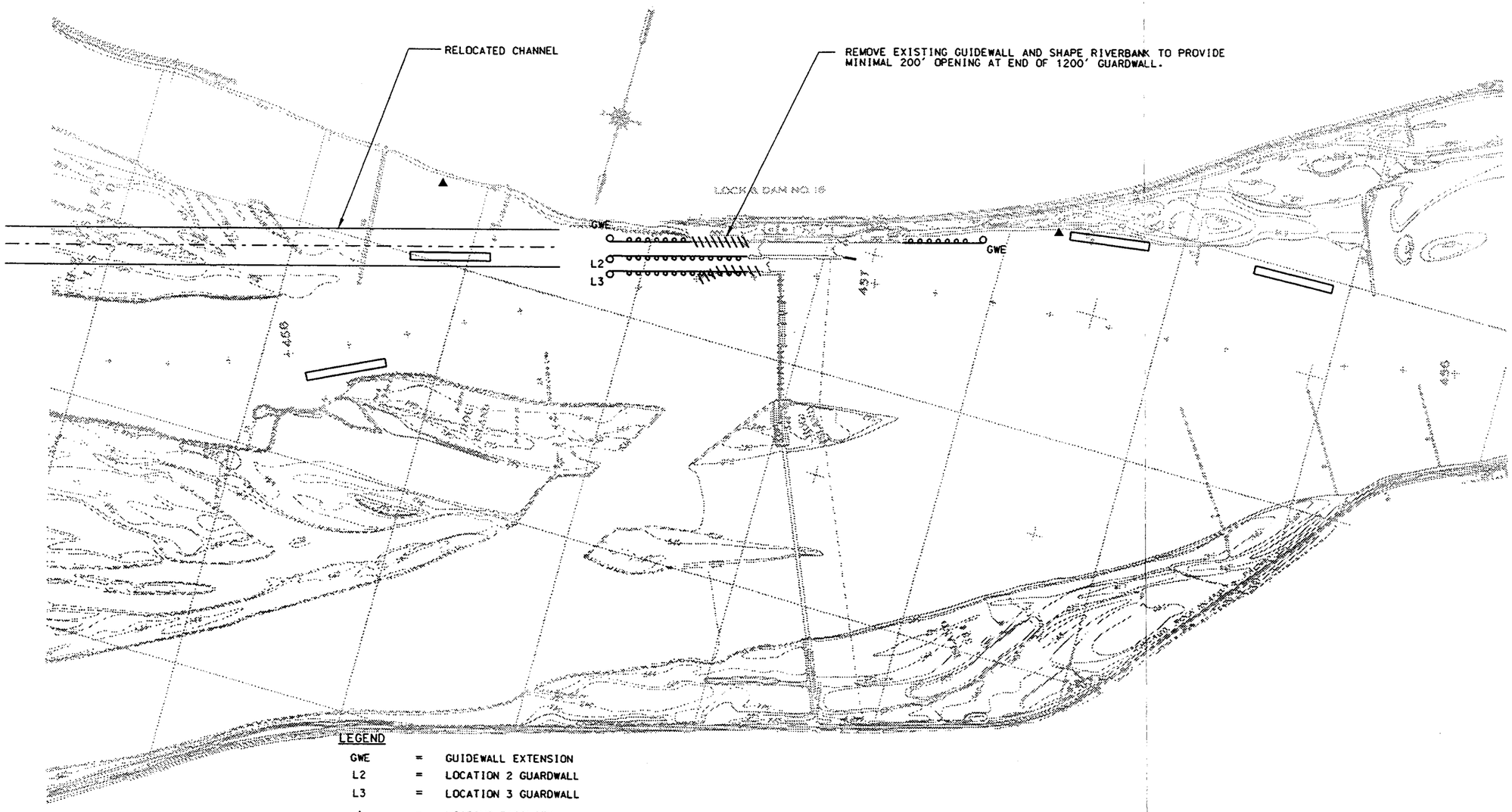

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 16
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 7

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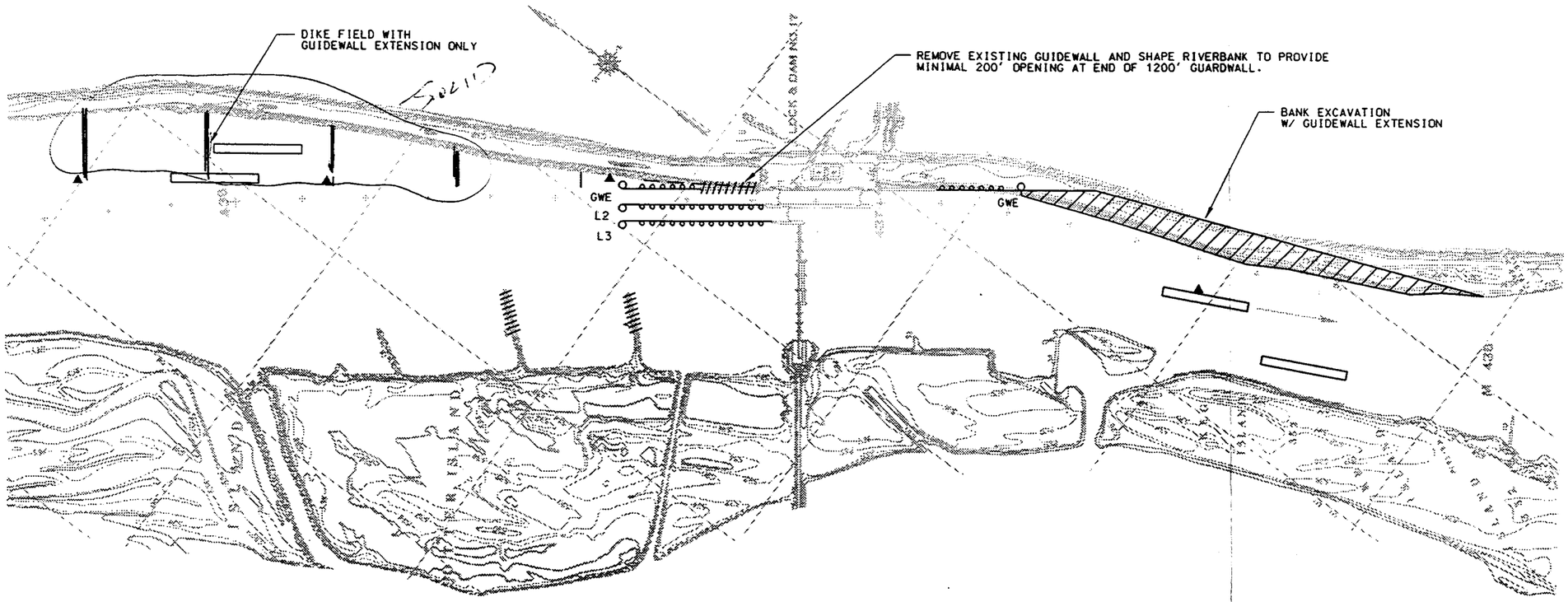

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER &
ILLINOIS WATERWAY
SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 17
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 8

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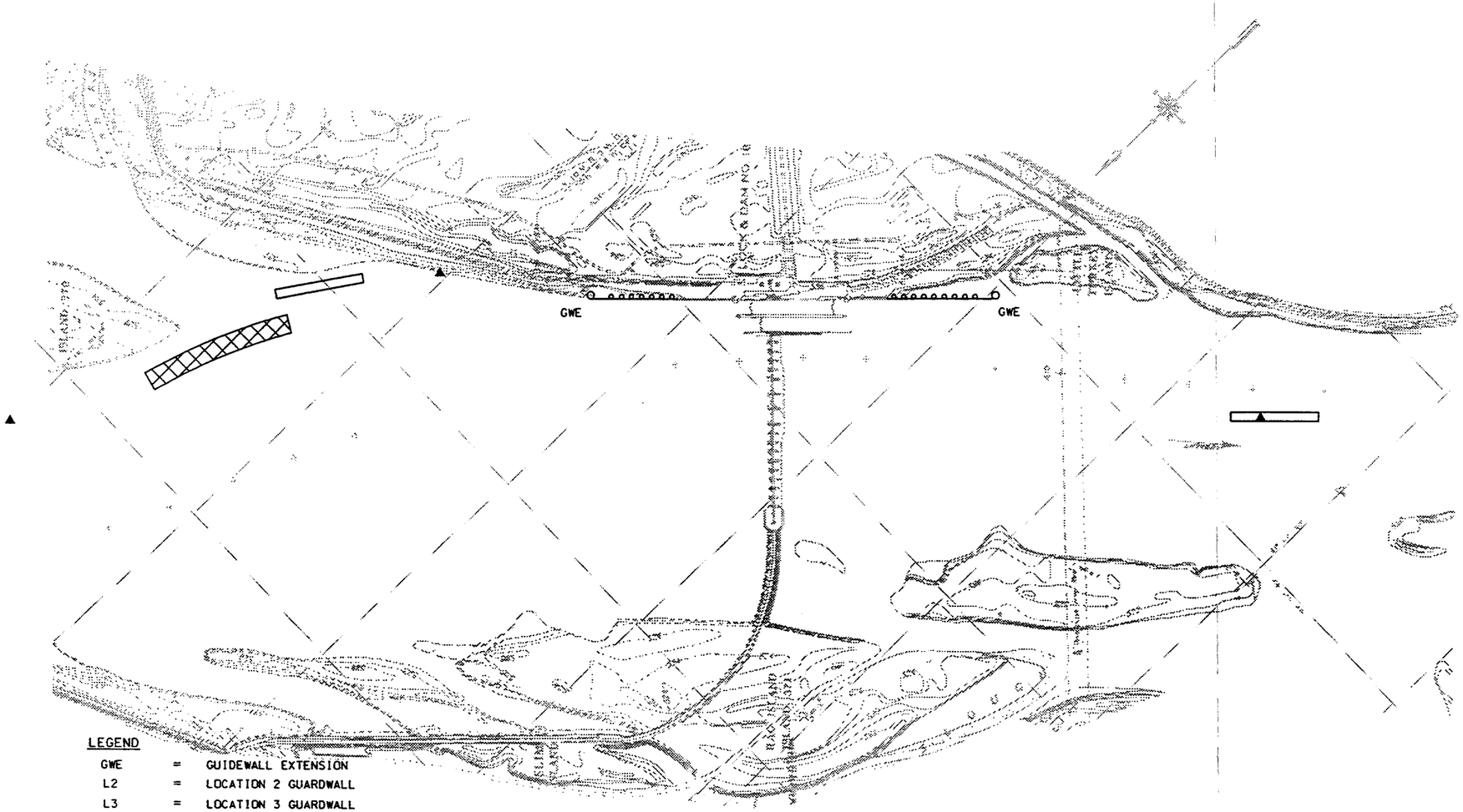

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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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. 18 APPROACH CHANNEL IMPROVEMENTS
Scale: AS SHOWN	PLATE 9
Date:	

31-JUL-1997 09:09
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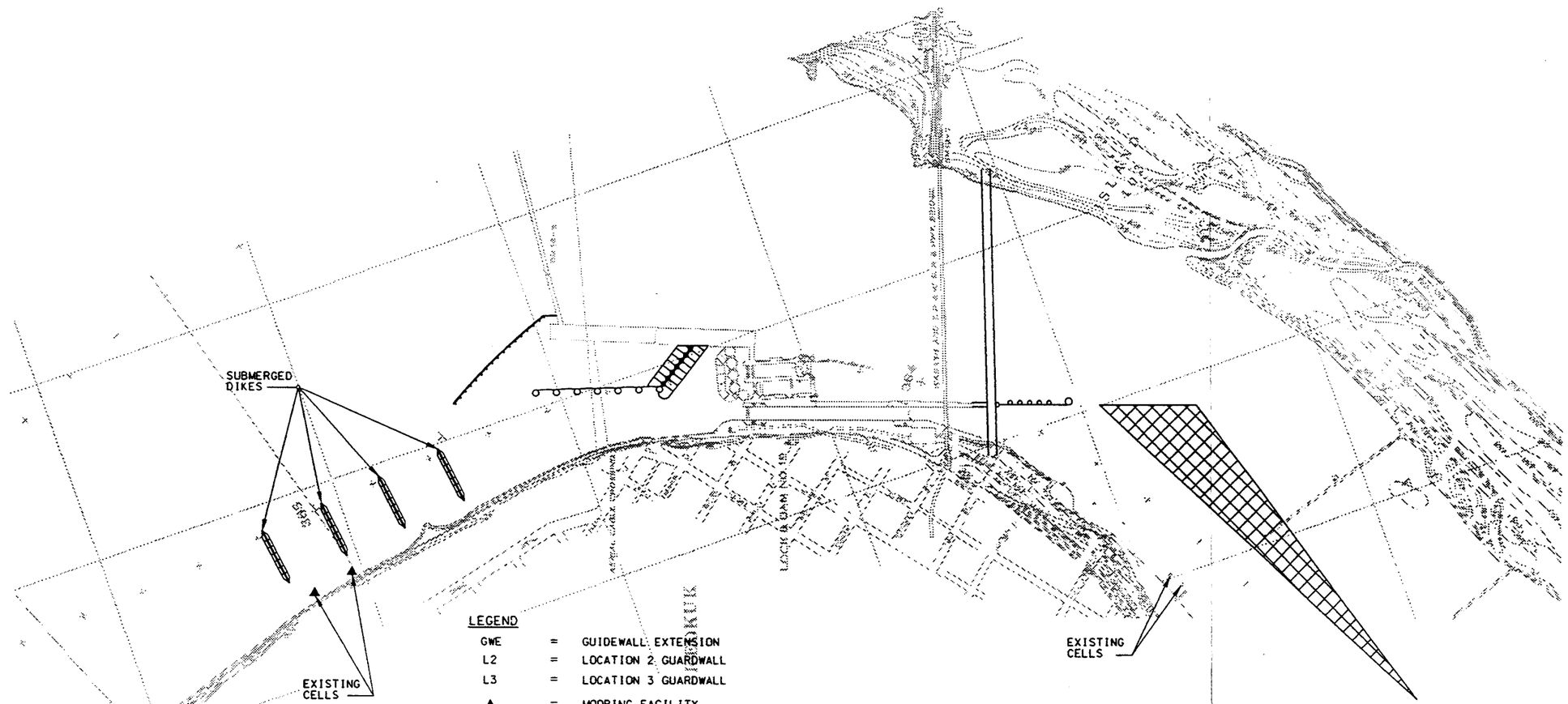
31-JUL-1997 09:09
e:\projects\nso3\nso3p018.dgn



LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE: 1"= 500'

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 19
APPROACH CHANNEL IMPROVEMENTS
NON-STANDARD GUARD WALL

Scale: AS SHOWN
Date:

PLATE 10

31-JUL-1997 09:13
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31-JUL-1997 09:13
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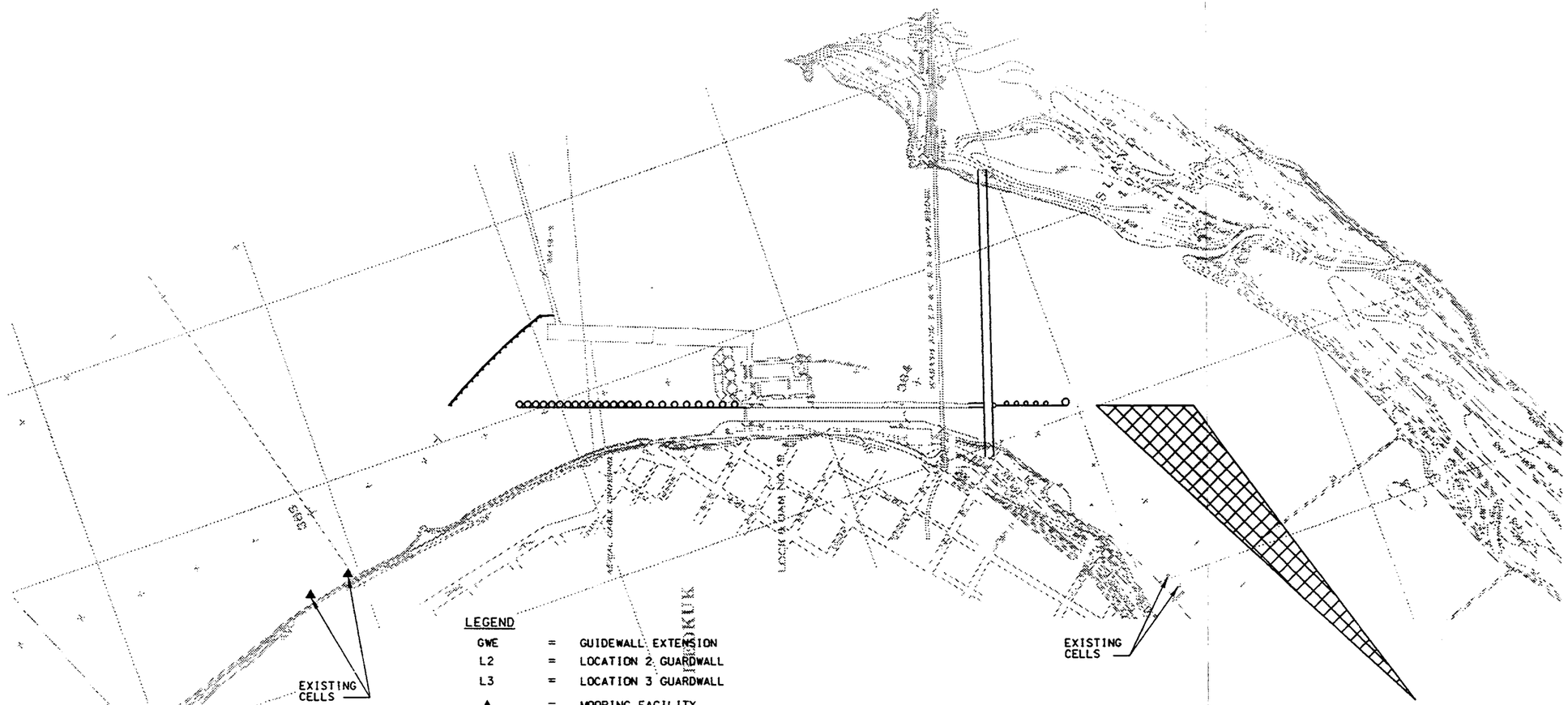

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO. 19
APPROACH CHANNEL IMPROVEMENTS
GUARD WALL

Scale: AS SHOWN
Date:

PLATE 11

31-JUL-1997 09:10
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31-JUL-1997 09:10
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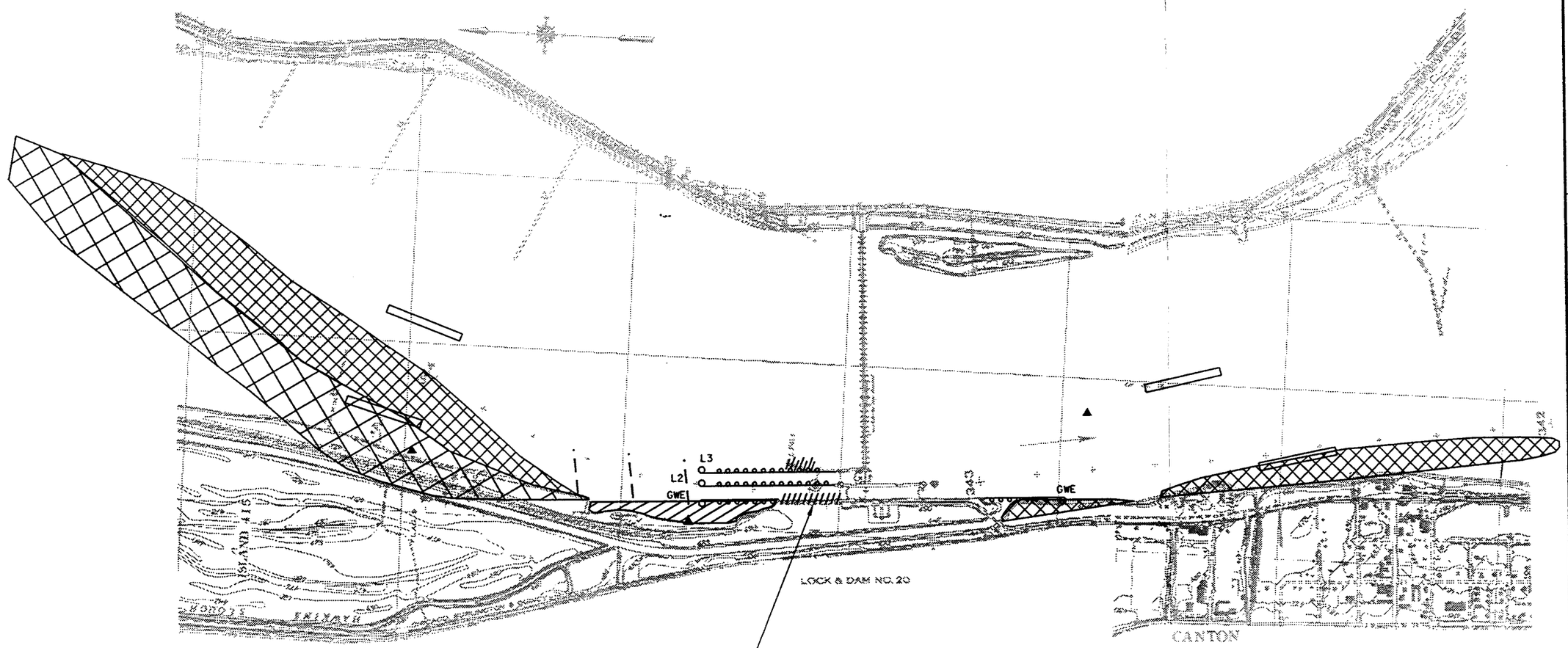

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO.20
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 12

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31-JUL-1997 08:31
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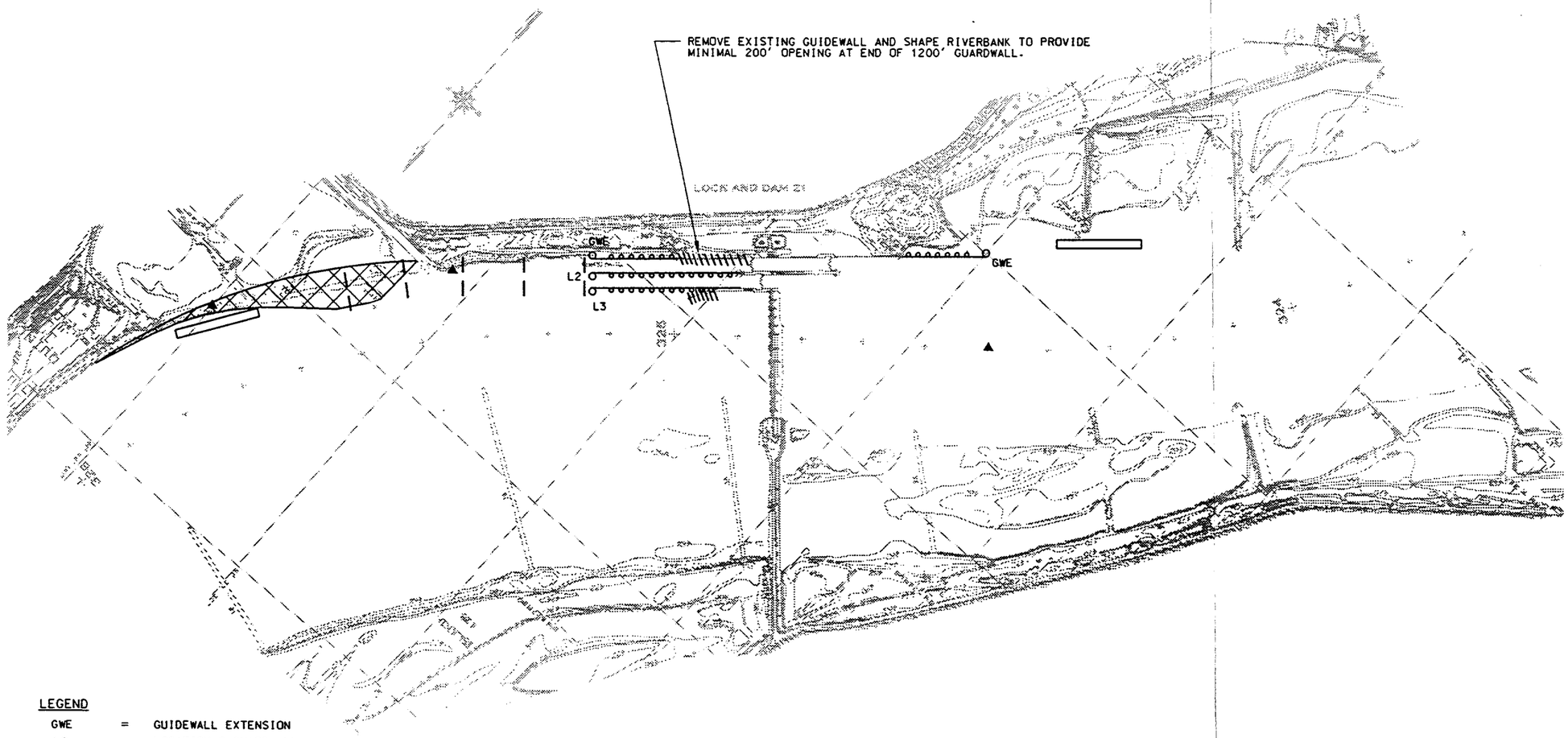

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 250 0 500 1000FT
SCALE IN FEET

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UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY SYSTEM NAVIGATION STUDY

LOCK AND DAM NO.21
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 13

31-JUL-1997 08:33
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31-JUL-1997 08:33
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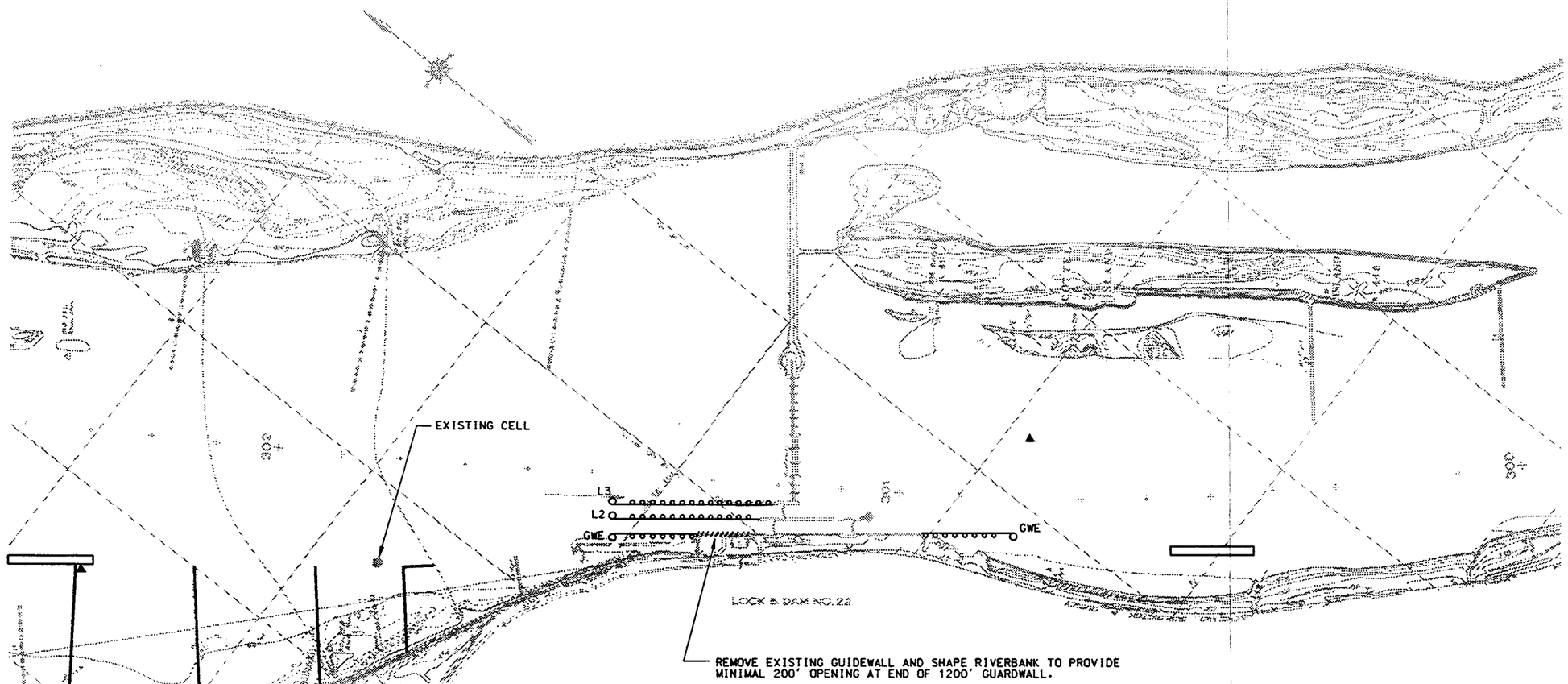

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP 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

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
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 14

31-JUL-1997 08:34
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31-JUL-1997 08:34
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LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

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.24
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 15

31-JUL-1997 08:36
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31-JUL-1997 08:36
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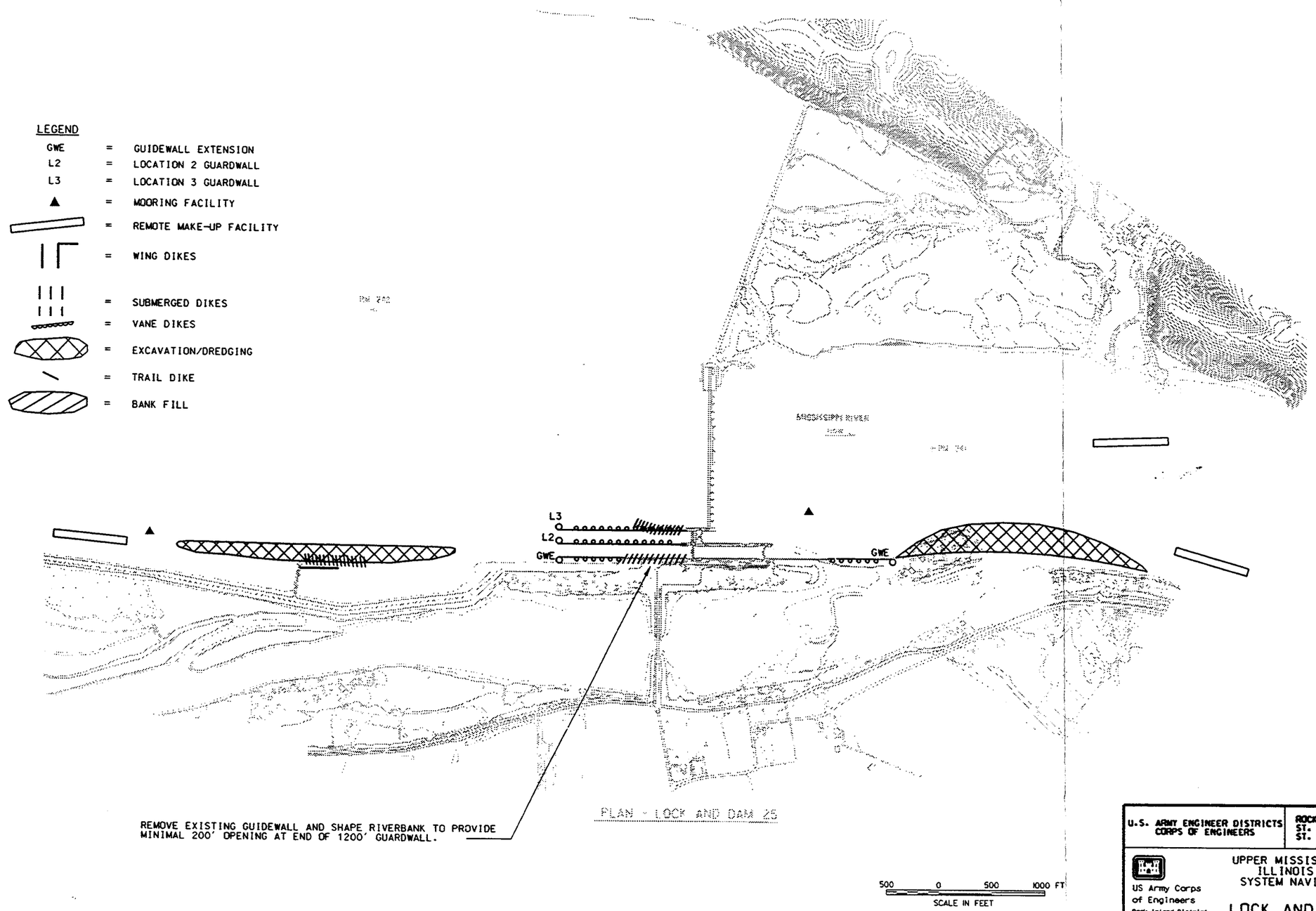

PLAN - LOCK AND DAM 25

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

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
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 16

31-JUL-1997 08:37
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31-JUL-1997 08:37
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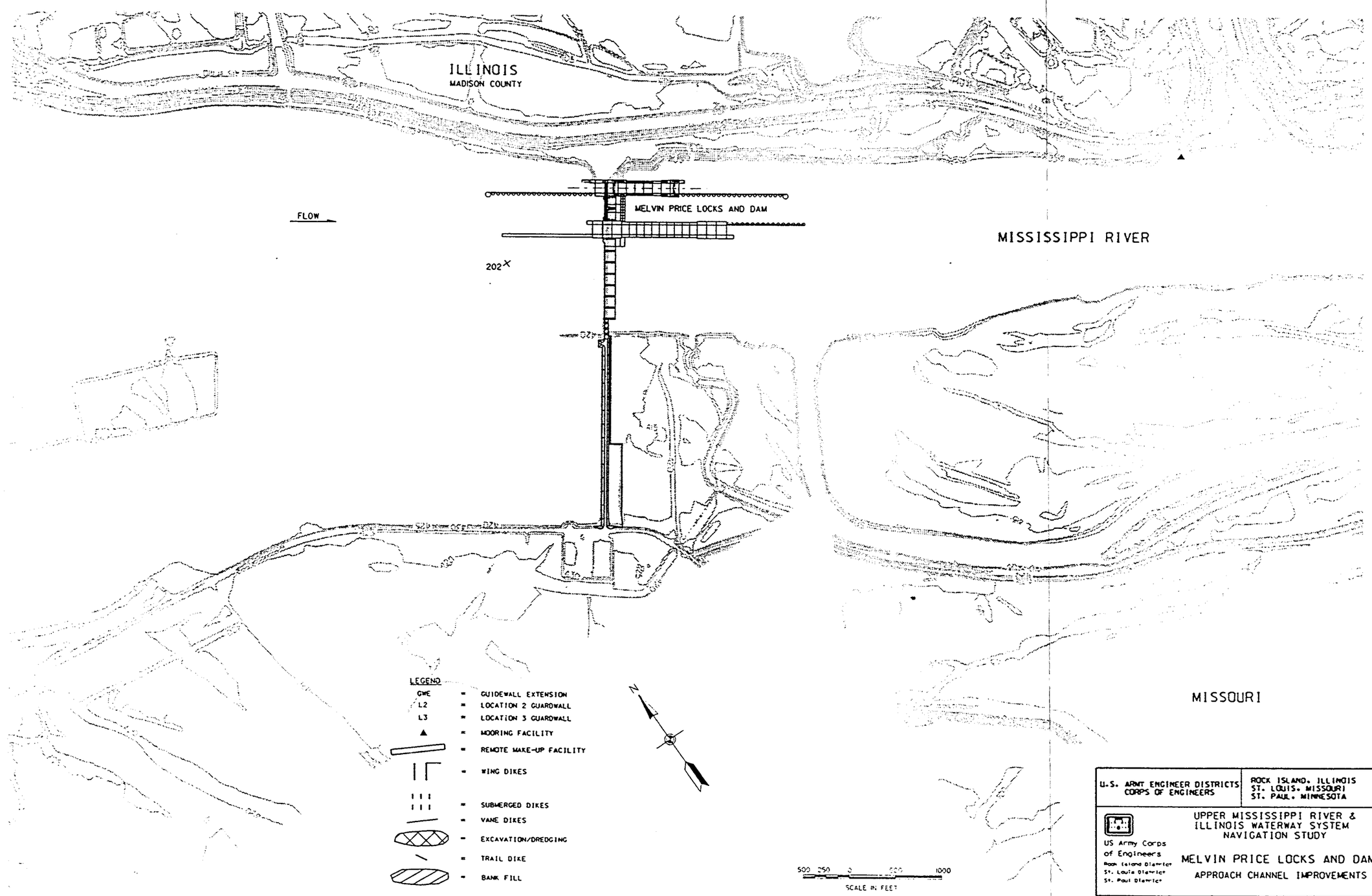


U.S. ARMY ENGINEER DISTRICTS
CORPS OF ENGINEERS

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

MELVIN PRICE LOCKS AND DAM

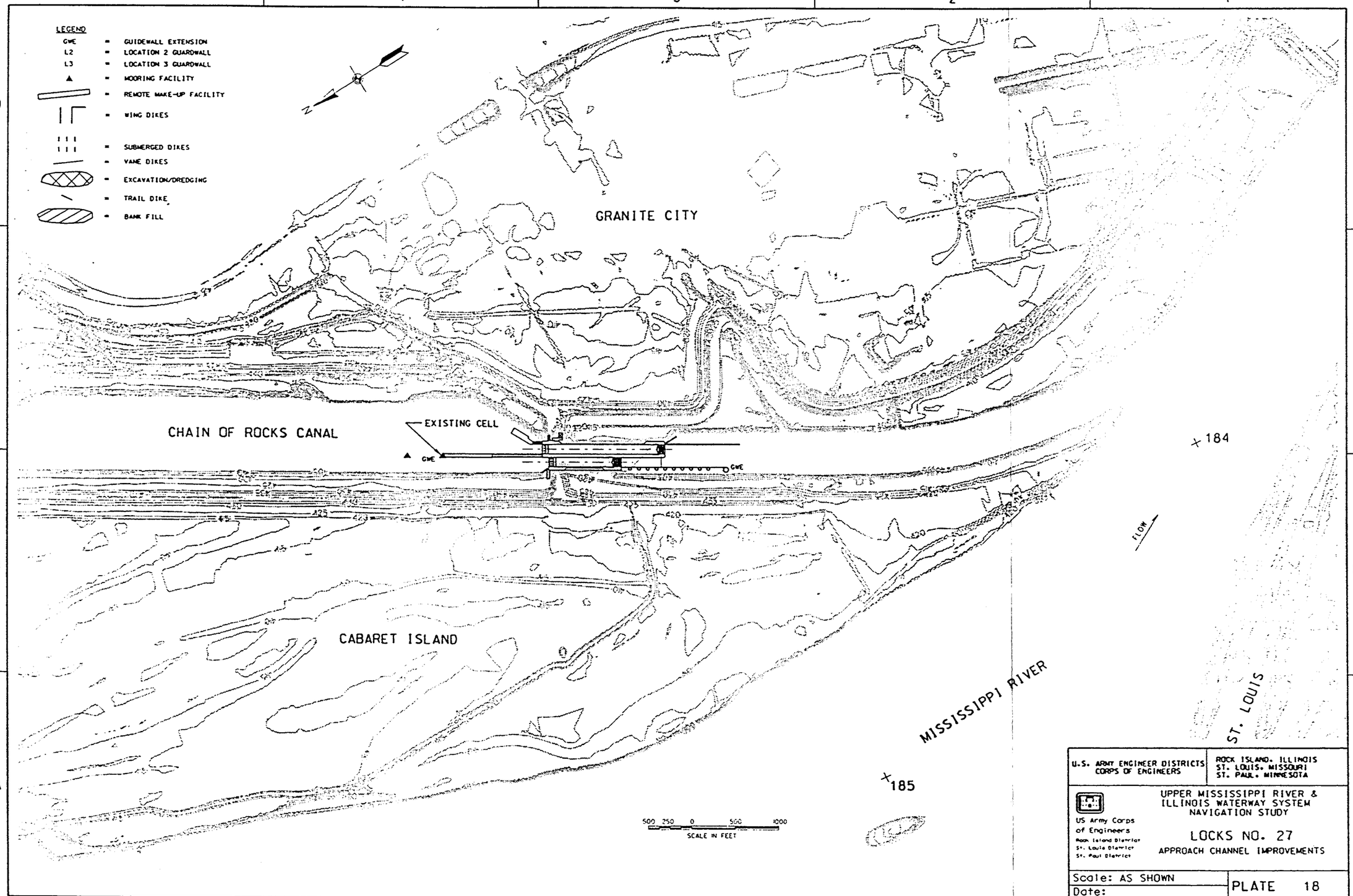
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN

Date:

PLATE 17

17-JUL-1997 14:00
o:*projects*nso3*stud26.dgn



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

LOCKS NO. 27

APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN

Date:

PLATE 18

21-JUL-1997 12:15
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LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

250 125 0 250 500FT
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

LOCKPORT LOCK
APPROACH CHANNEL IMPROVEMENTS

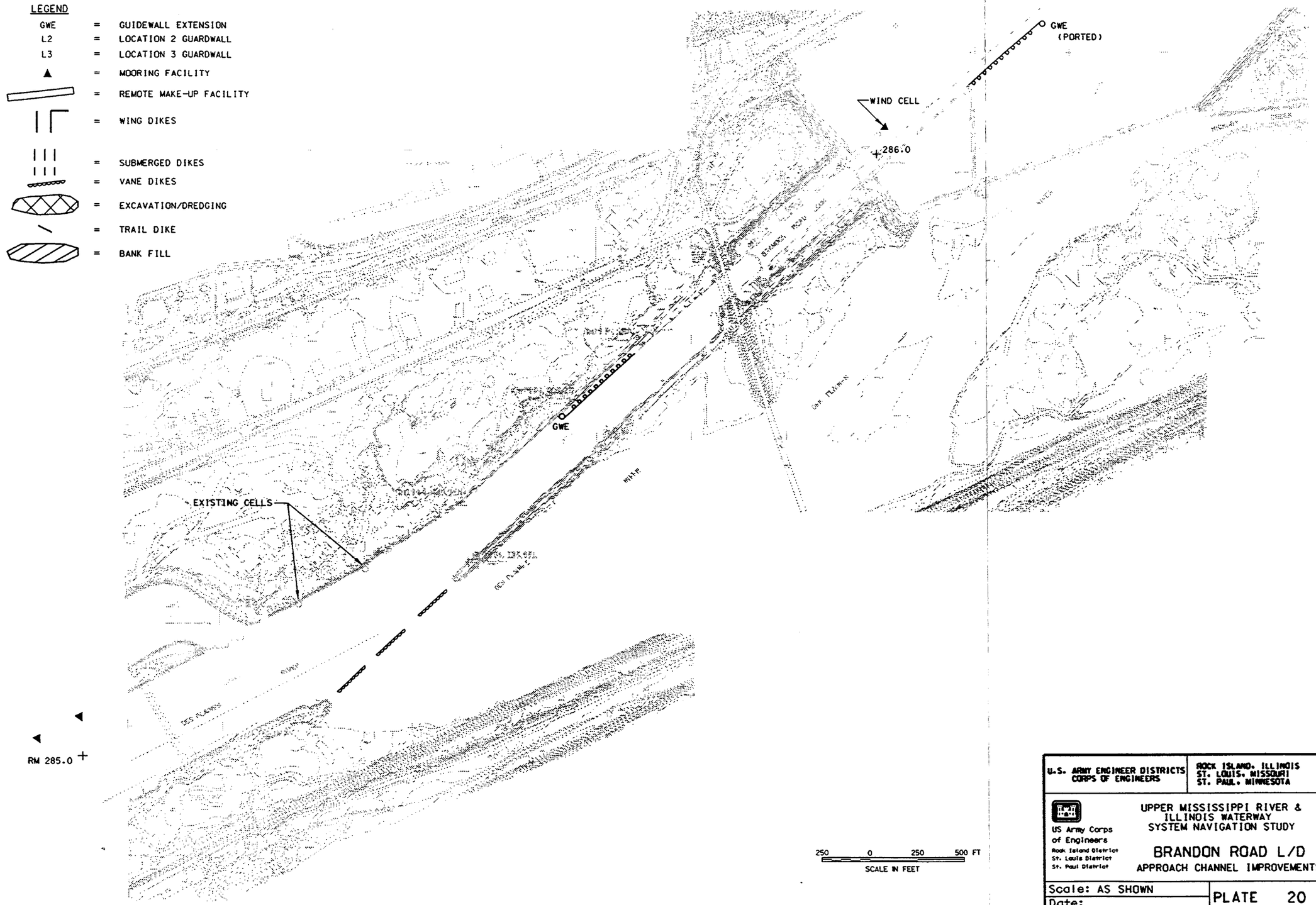
Scale: AS SHOWN
Date:

PLATE 19

31-JUL-1997 09:31
e:*projects*nso3*nso3plck.dgn

LEGEND

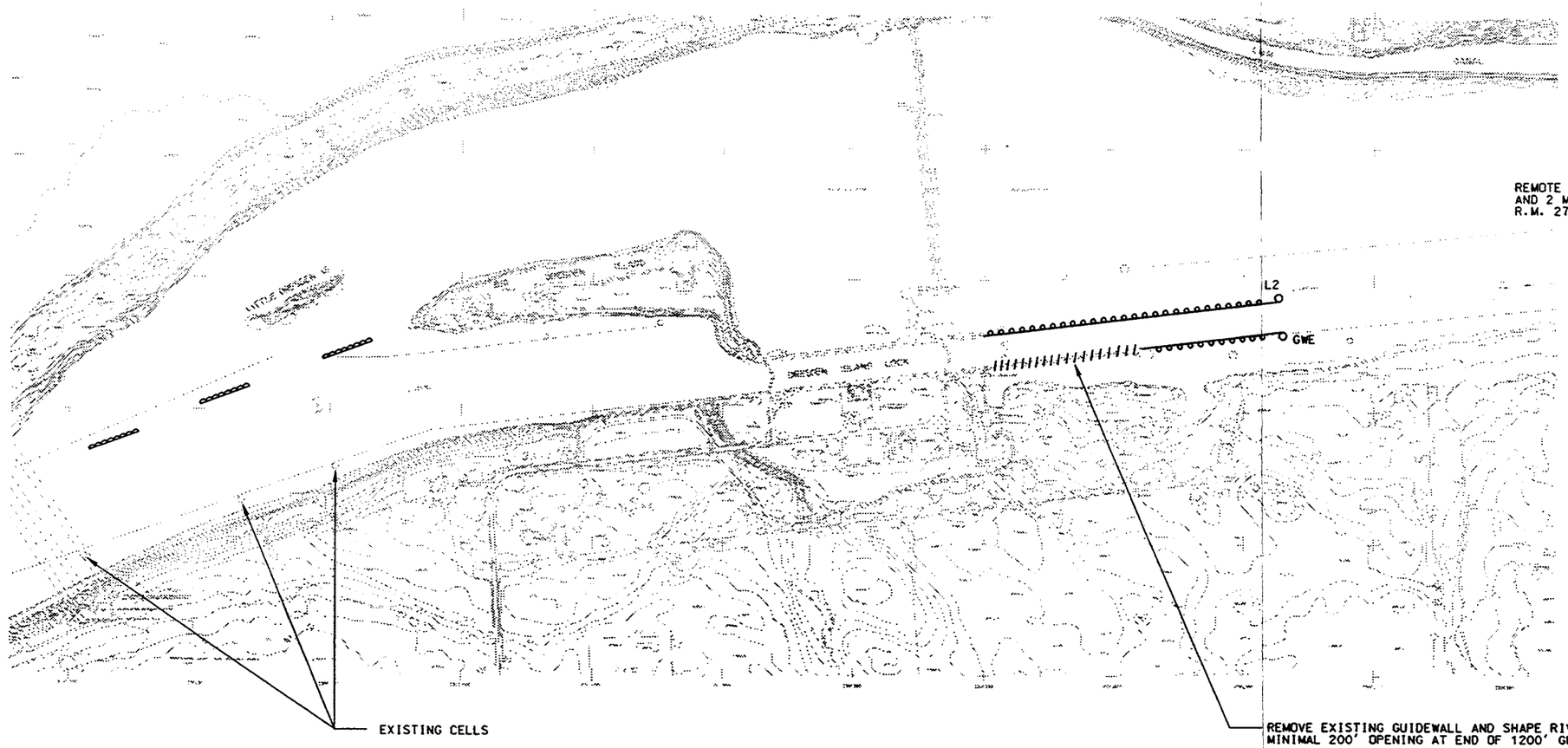
GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL



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
	BRANDON ROAD L/D APPROACH CHANNEL IMPROVEMENTS
Scale: AS SHOWN	PLATE 20
Date:	

31-JUL-1997 09:25
e:\projects\nso3\nso3pbrd.dgn

31-JUL-1997 09:25
e:\projects\nso3\nso3pbrd.dgn



LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

250 0 250 500 FT
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

DRESDEN ISLAND L/D
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 21

31-JUL-1997 09:03
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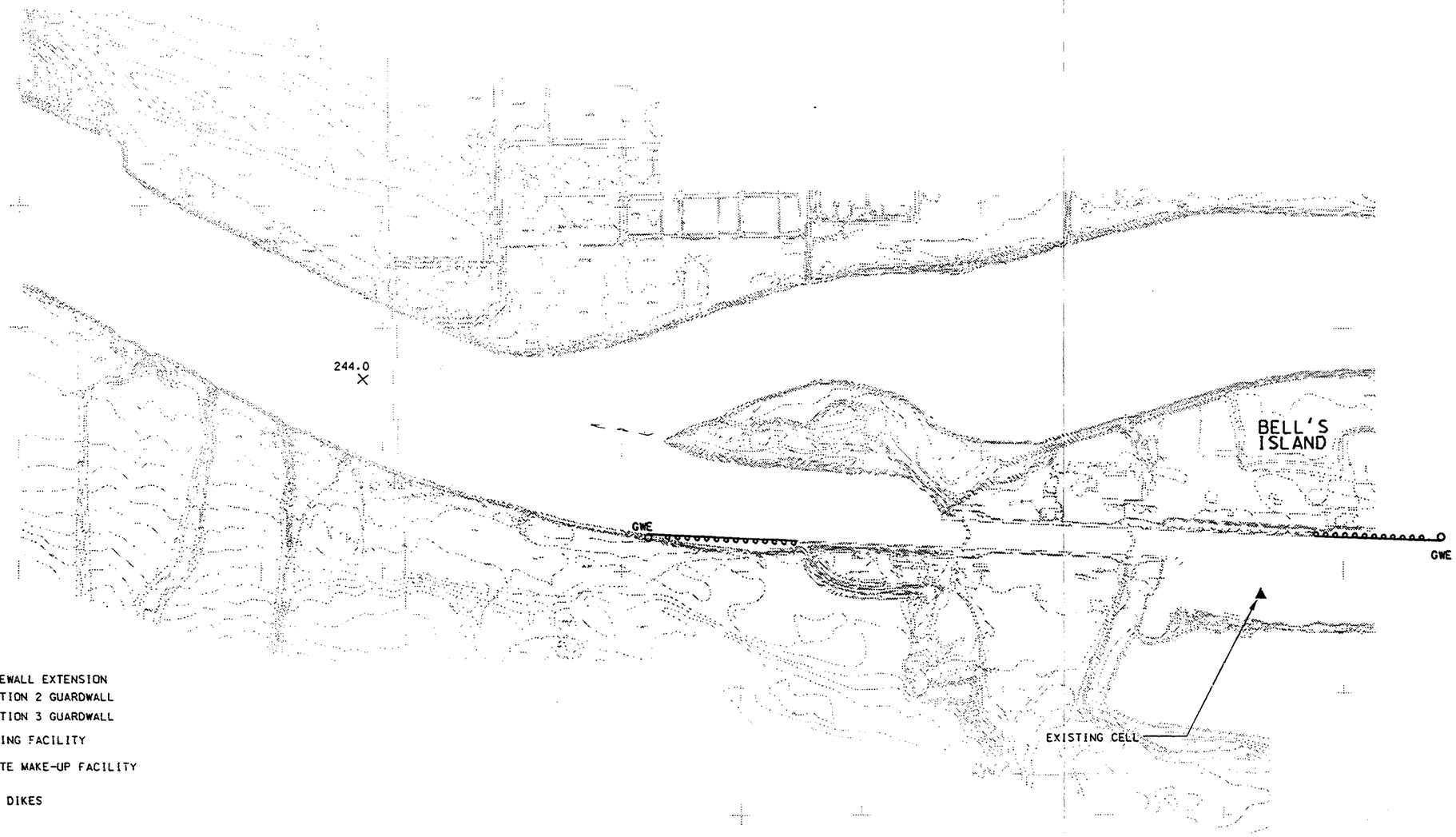

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

250 0 250 500 FT
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

MARSEILLES LOCK & DAM
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 22

21-JUL-1997 15:12
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21-JUL-1997 15:12
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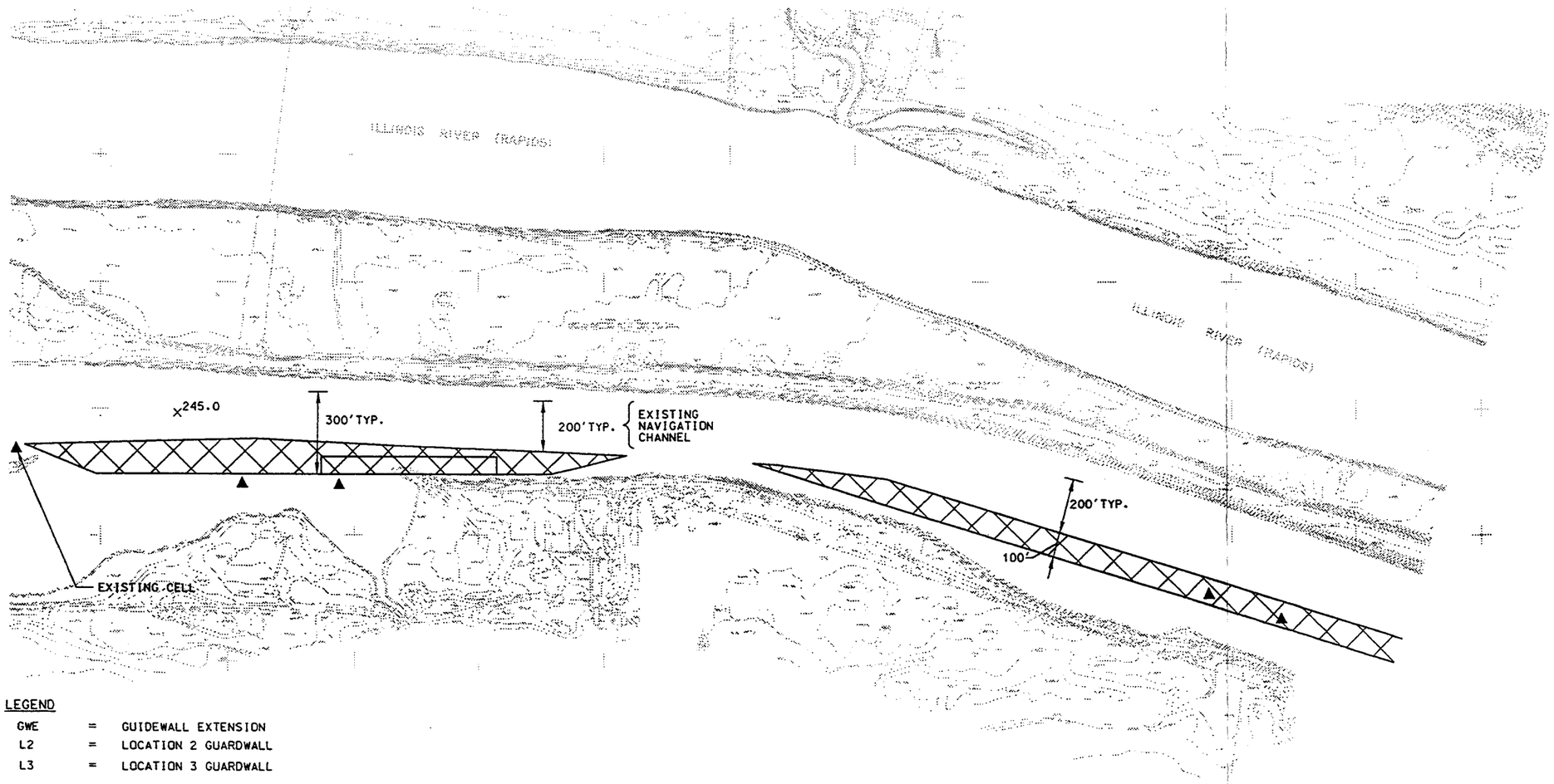

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

250 0 250 500 FT
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

MARSEILLES LOCK & DAM
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 23

21-JUL-1997 15:34
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21-JUL-1997 15:34
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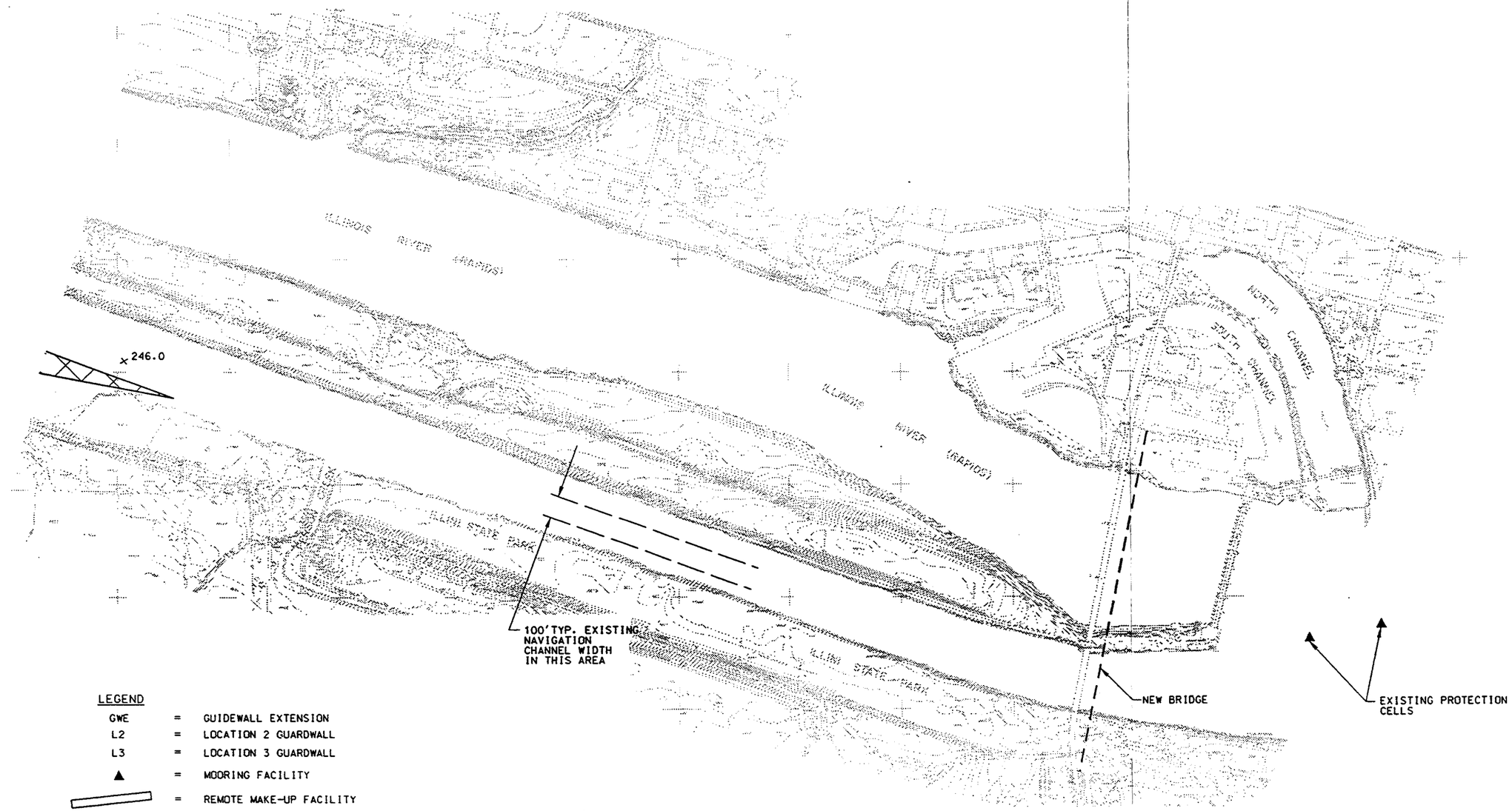

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

250 0 250 500 FT
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

MARSEILLES LOCK & DAM
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 24

15-JUL-1997 12:24
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15-JUL-1997 12:24
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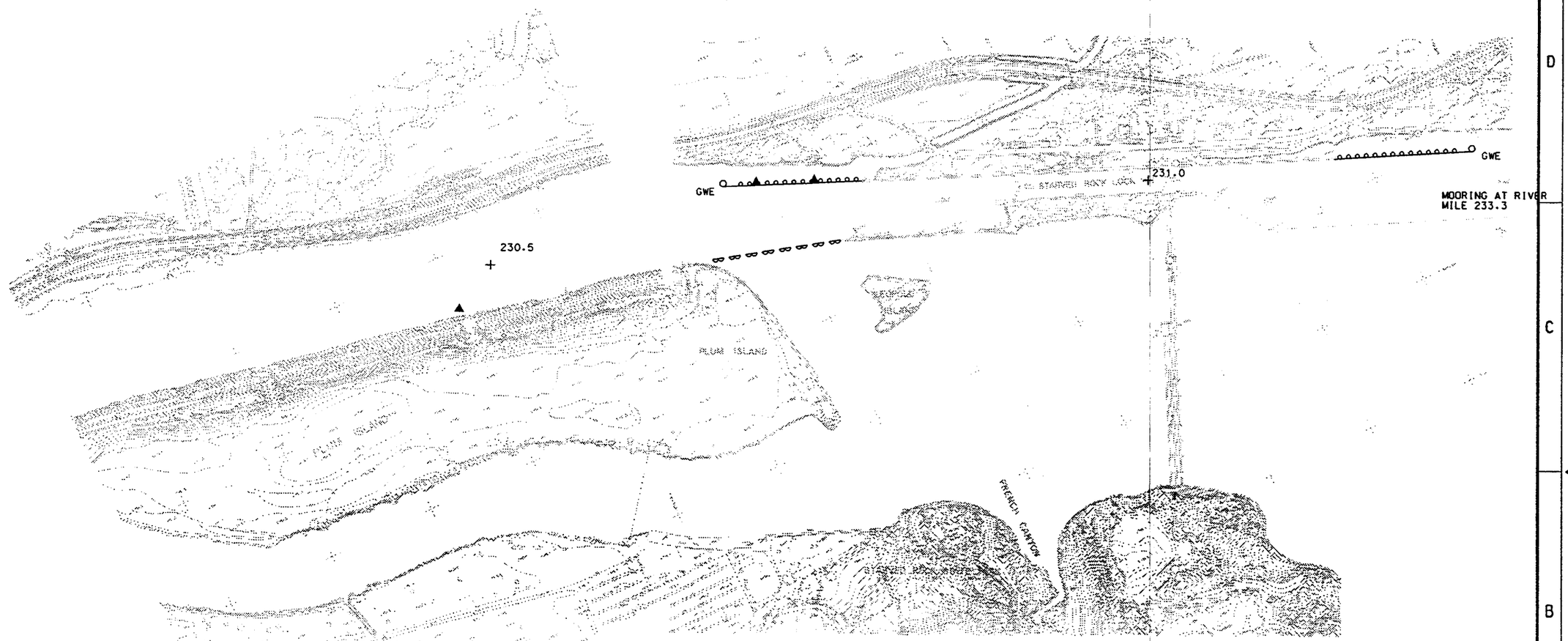

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

250 0 250 500 FT
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

STARVED ROCK L/D
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 25

21-JUL-1997 15:45
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21-JUL-1997 15:45
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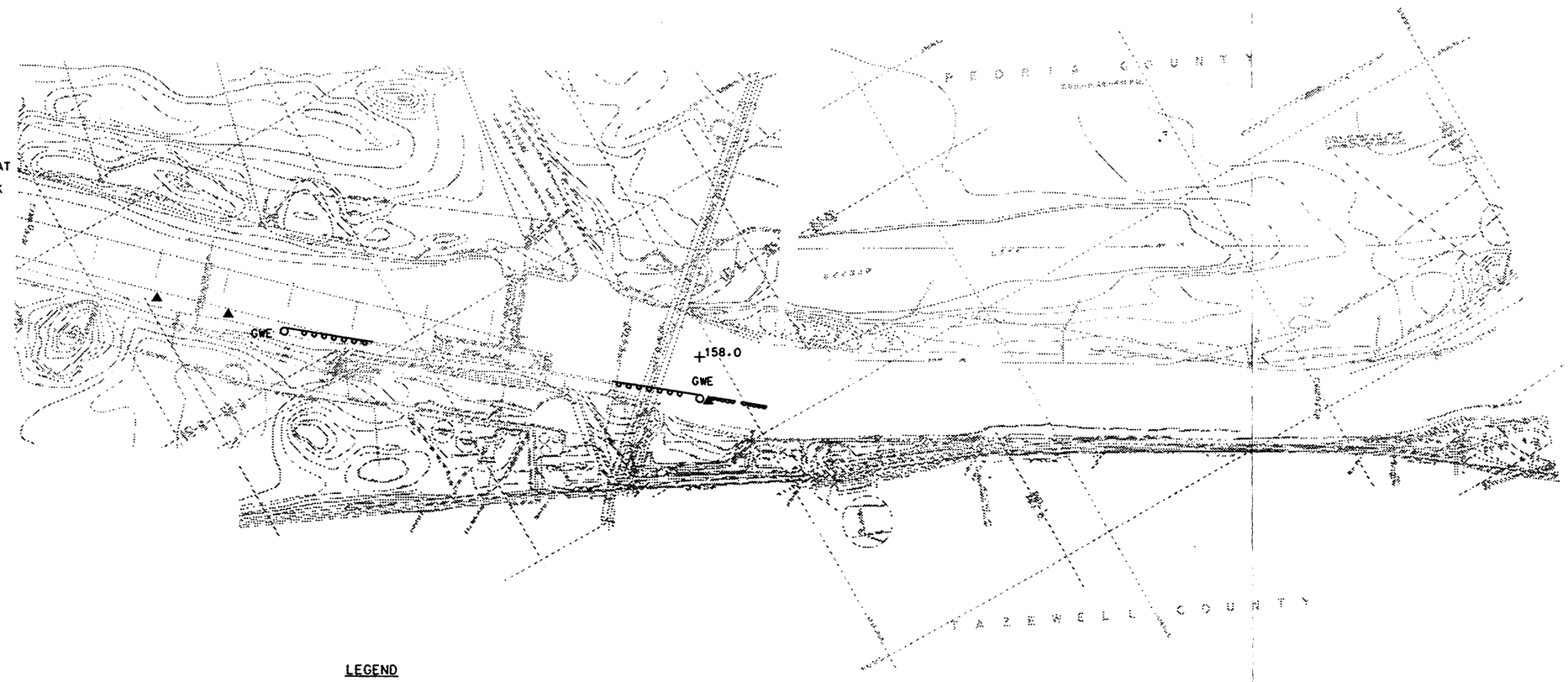

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 0 500 1000FT
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

PEORIA LOCK & DAM

APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN

Date:

PLATE 26

31-JUL-1997 08:48
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31-JUL-1997 08:48
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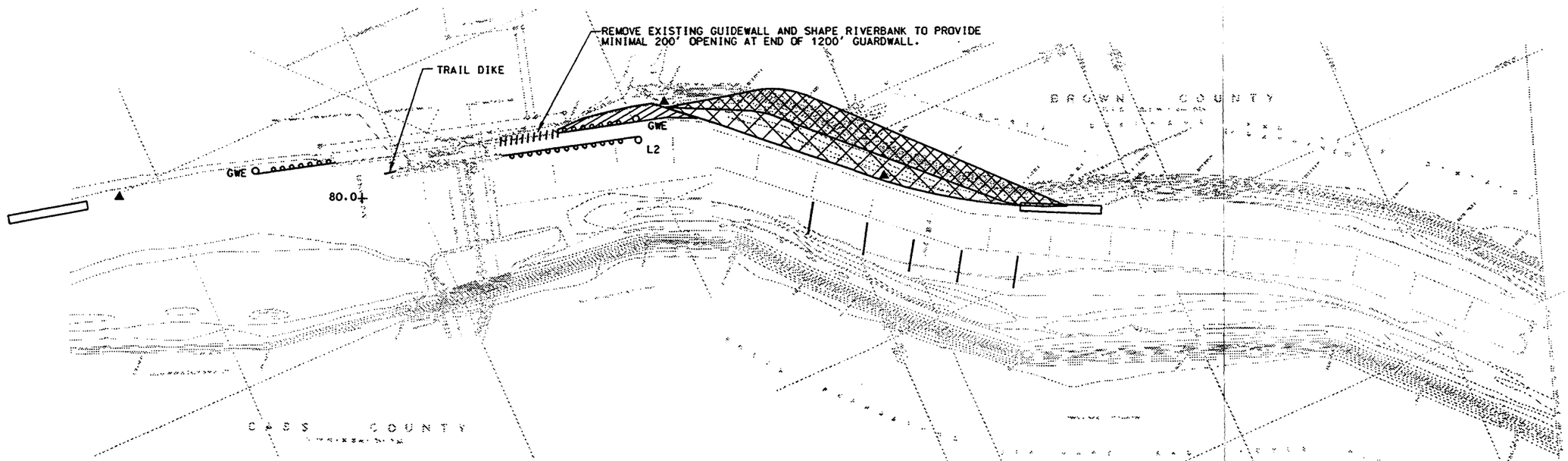

LEGEND

GWE	=	GUIDEWALL EXTENSION
L2	=	LOCATION 2 GUARDWALL
L3	=	LOCATION 3 GUARDWALL
▲	=	MOORING FACILITY
	=	REMOTE MAKE-UP FACILITY
	=	WING DIKES
	=	SUBMERGED DIKES
	=	VANE DIKES
	=	EXCAVATION/DREDGING
	=	TRAIL DIKE
	=	BANK FILL

500 0 500 1000FT
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

LAGRANGE LOCK & DAM
APPROACH CHANNEL IMPROVEMENTS

Scale: AS SHOWN
Date:

PLATE 27

31-JUL-1997 08:53
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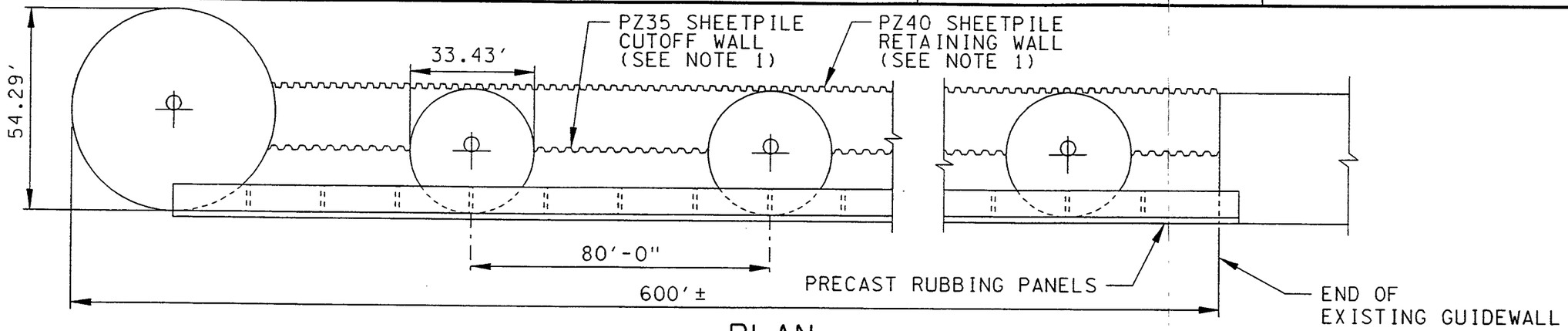
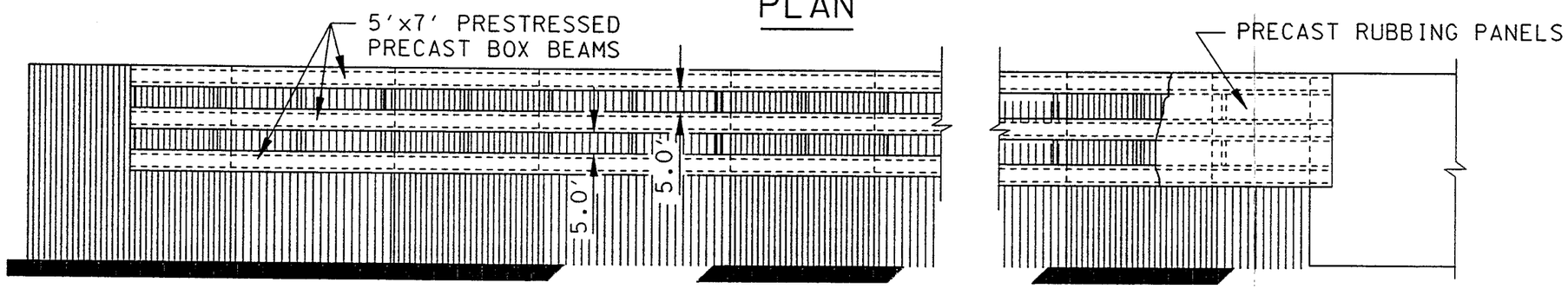
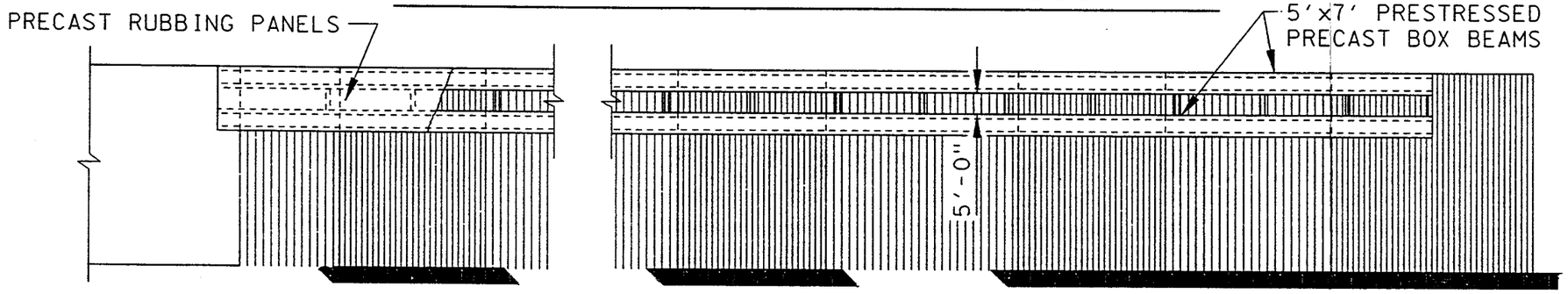
31-JUL-1997 08:53
e:*projects*nso3*nso3plgr.dgn



PLAN



ELEVATION OF DOWNSTREAM GUIDEWALL



ELEVATION OF UPSTREAM GUIDEWALL

NOTES:

1. IF THE GUIDEWALL IS LOCATED WHERE IT ALSO FUNCTIONS AS A RETAINING WALL, THE PZ40 SHEETPILING WILL BE USED AS SHOWN, AND IT WILL BE BRACED AND ANCHORED. IF THE GUIDEWALL IS NOT FUNCTIONING AS A RETAINING WALL, FLOW BETWEEN CELLS WILL BE STOPPED BY THE PZ35 SHEETPILE CUTOFF WALL AS SHOWN. ONE OR THE OTHER LINES OF SHEETPILING WILL BE USED, NOT BOTH.

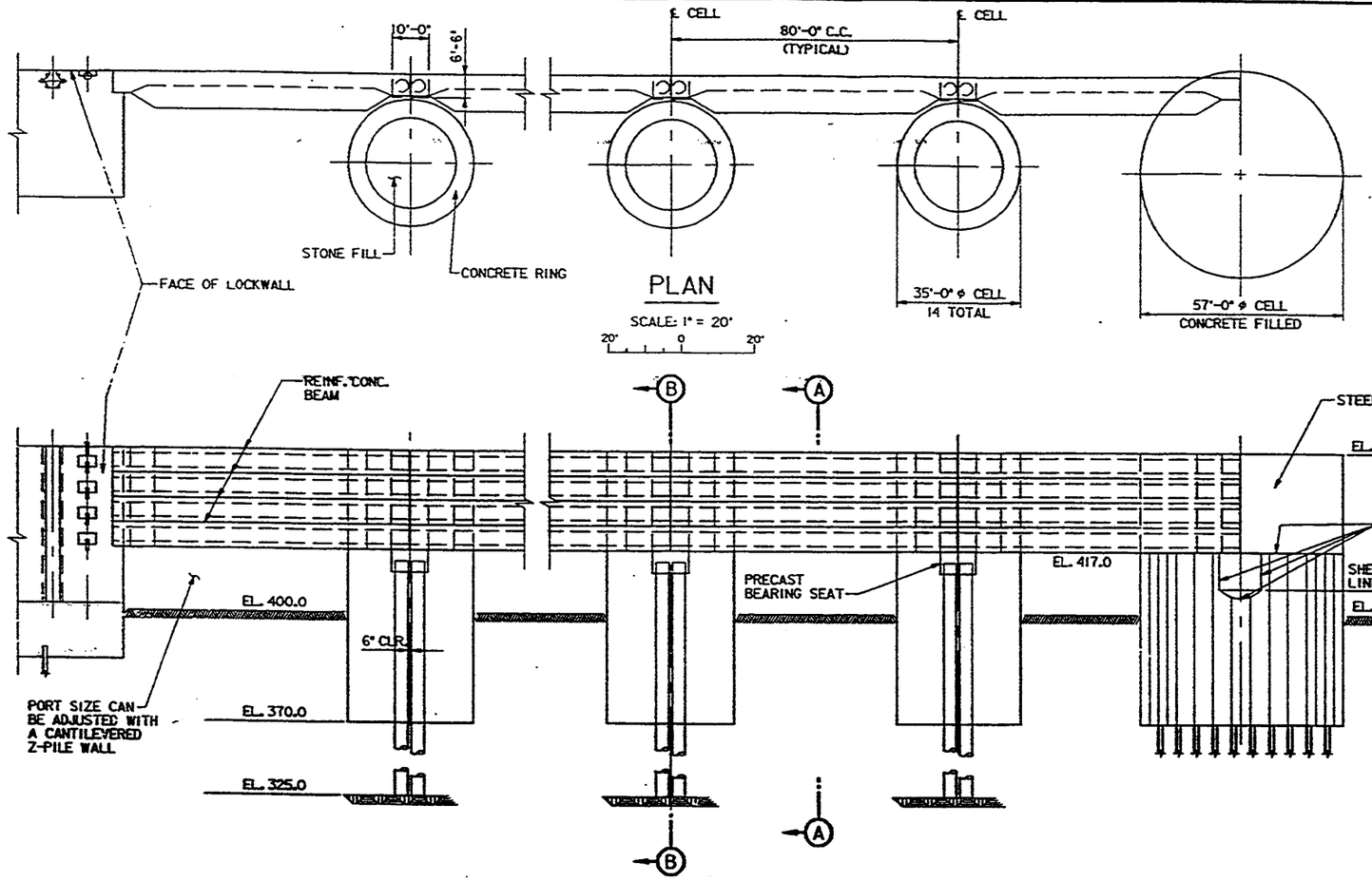
30 15 0 30 60FT

SCALE: 1"= 30'

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
	UNPORTED GUIDEWALL EXTENSION PLAN AND ELEVATION
Scale: As Shown	PLATE 28

17-JUL-1997 14:32
e:*projects*ns00*platrgw2.dgn

17-JUL-1997 14:32
e:*projects*ns00*platrgw2.dgn

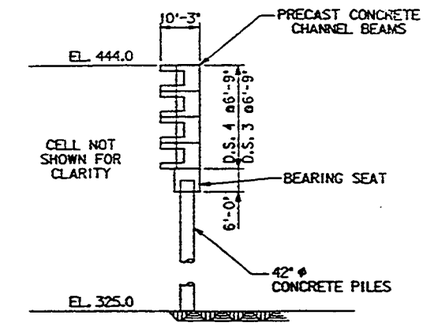


PLAN

SCALE: 1" = 20'

ELEVATION OF DOWNSTREAM GUIDEWALL

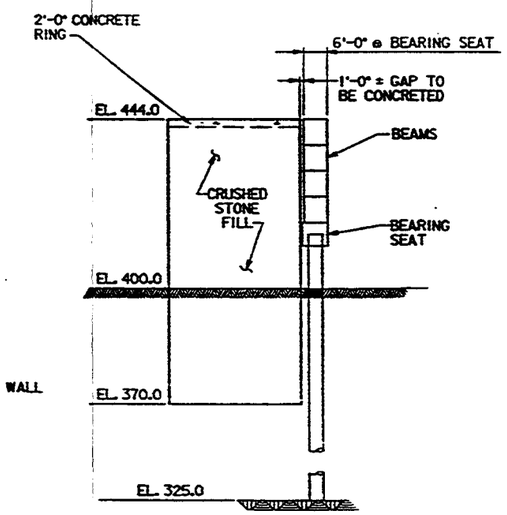
SCALE: 1" = 20'



SECTION A-A

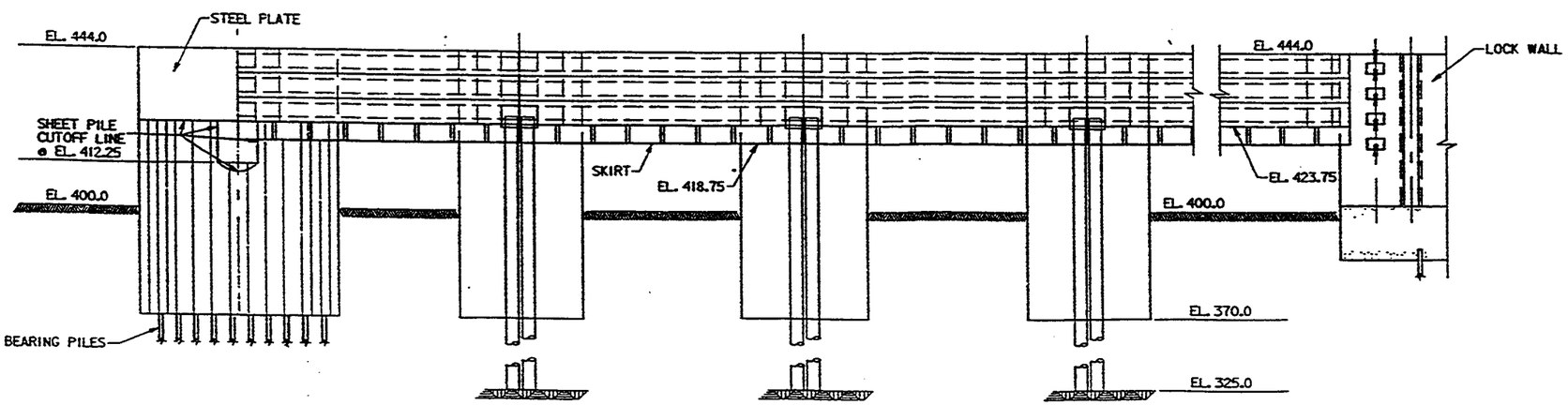
BEAMS, BEARING SEAT AND PILES

SCALE: 1" = 20'



SECTION B-B

SCALE: 1" = 20'

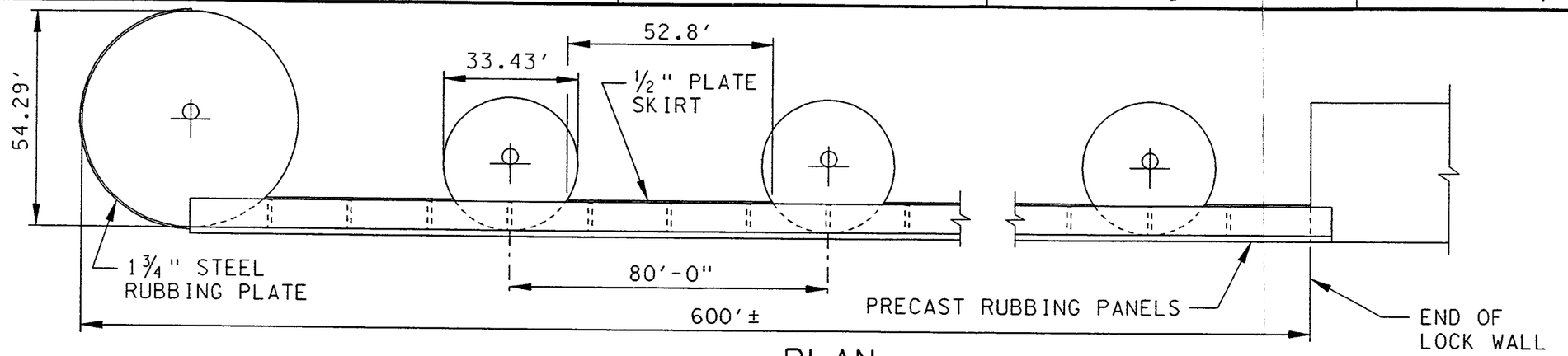


ELEVATION OF UPSTRTEAM GUIDEWALL

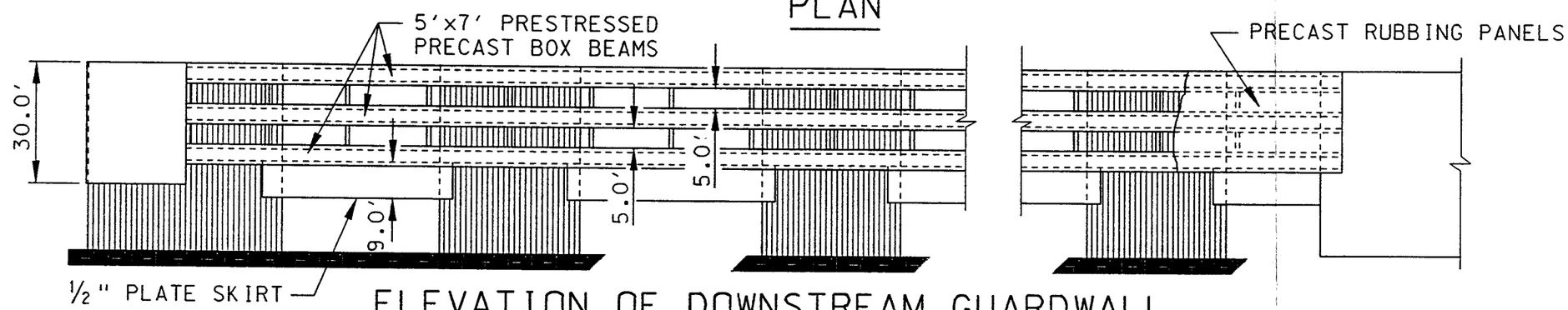
NOTE: ELEVATIONS SHOWN ARE REPRESENTATIVE OF LOCK NO. 25.

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
	U. S. AND D. S. GUIDEWALL EXTENSIONS PLAN, ELEV. AND SECT.
Scale: 20:1	PLATE 29

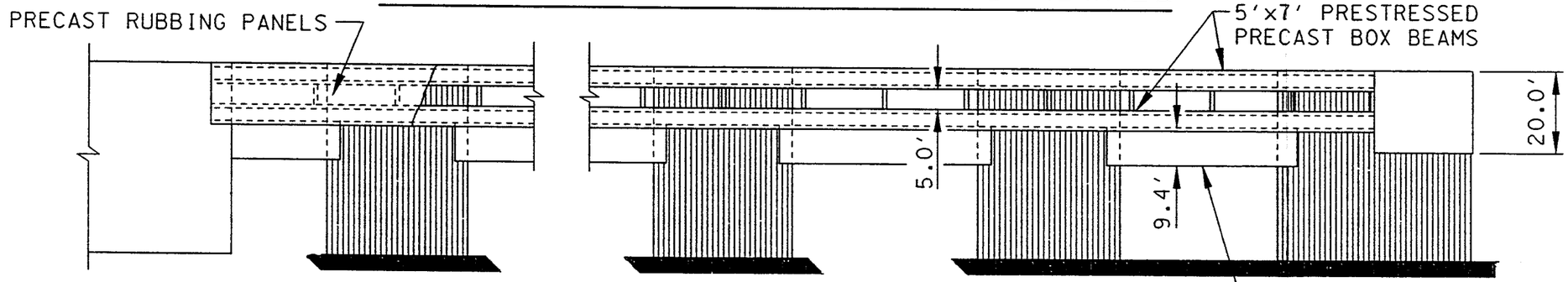
24-JAN-1996 15:23



PLAN



ELEVATION OF DOWNSTREAM GUARDWALL



ELEVATION OF UPSTREAM GUARDWALL

30 15 0 30 60FT

SCALE: 1"= 30'

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
	PORTED GUARDWALL PLAN AND ELEVATION
Scale: As Shown	PLATE 30

17-JUL-1997 14:34
e:\projects\ns00\platrgw1.dgn

17-JUL-1997 14:34
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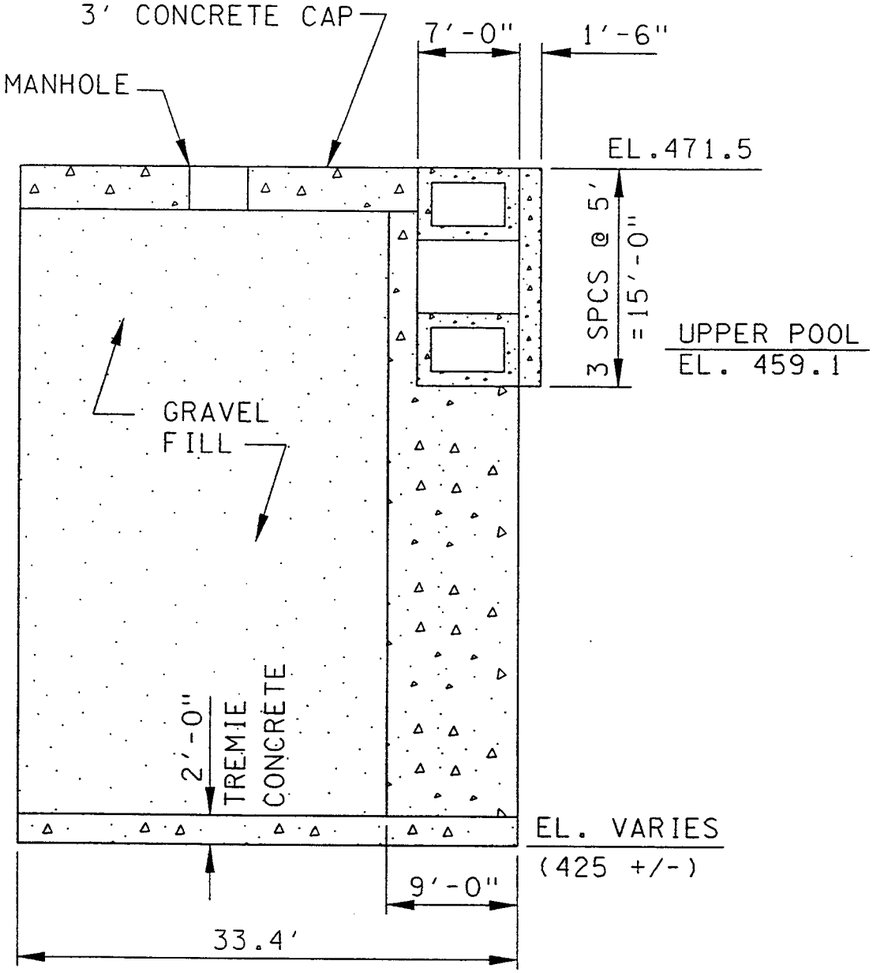
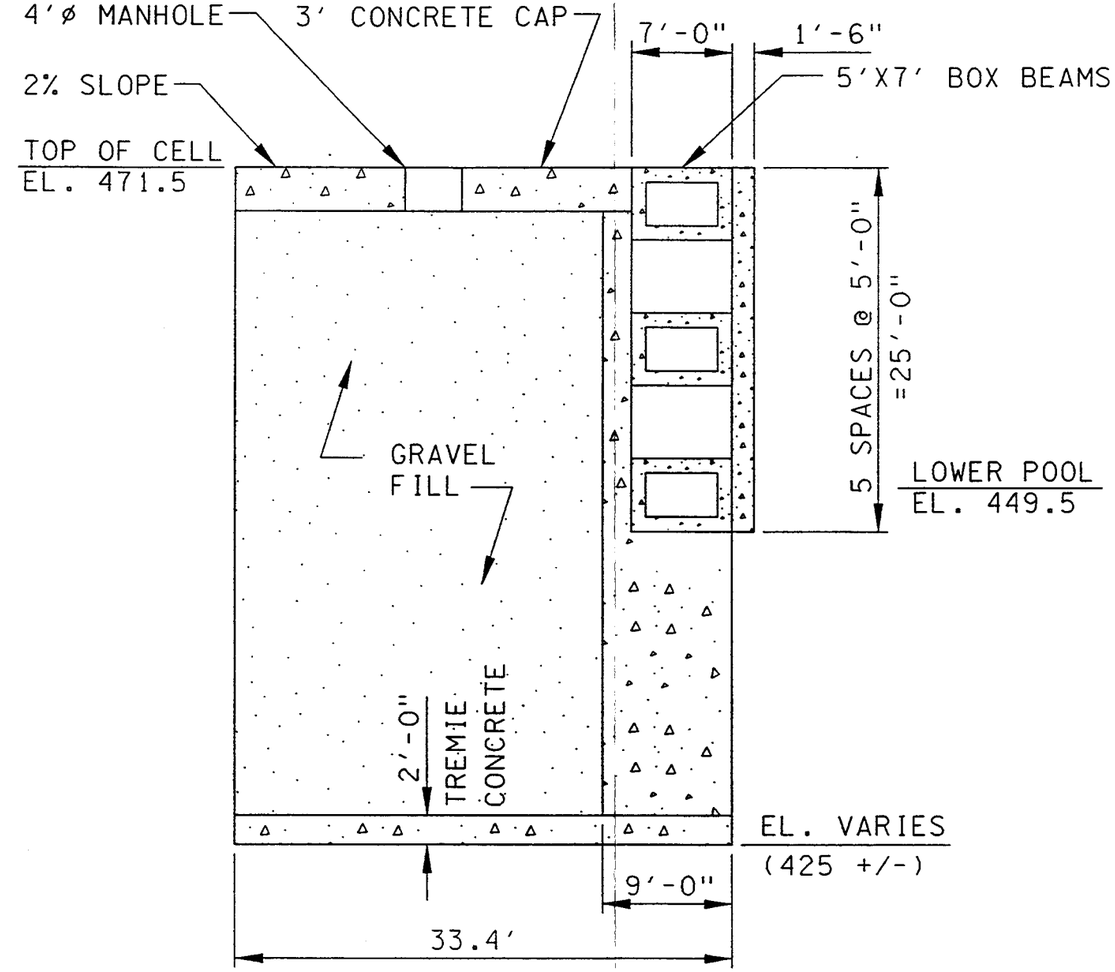


UPSTREAM GUIDE/GUARDWALL CELL



DOWNSTREAM GUIDE/GUARDWALL CELL

NOTE: ELEVATIONS SHOWN ARE REPRESENTATIVE OF LOCK NO. 22

10 5 0 10 20FT

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 **GUIDE AND GUARDWALL SHEETPILE CELLS TYPICAL SECTIONS**
Scale: As Shown	PLATE 31

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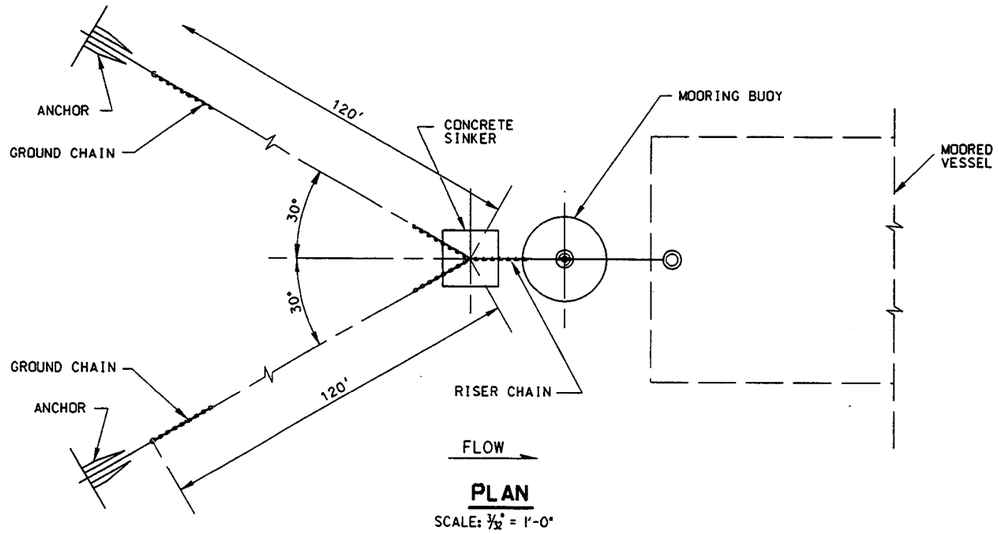
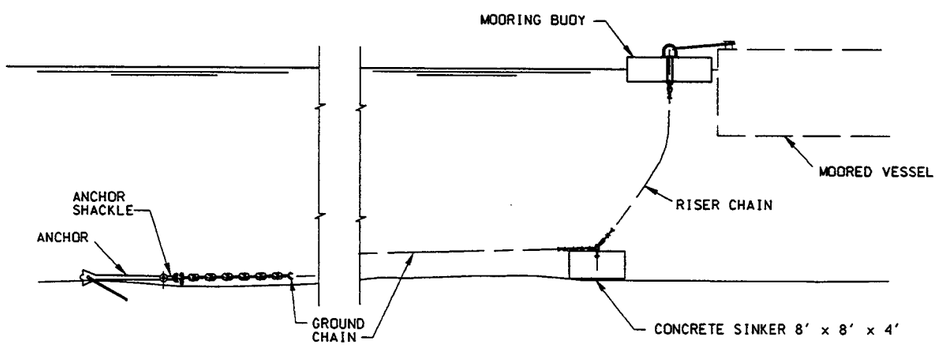


PLAN

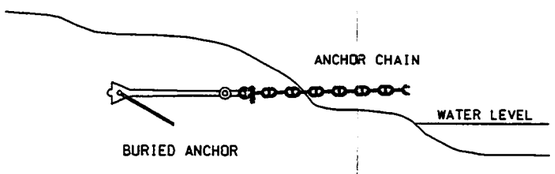
SCALE: 3/32" = 1'-0"



ELEVATION

SCALE: 3/32" = 1'=0"

FLOATING BUOY



LAND-BASED MOORING DETAIL

NOT TO SCALE

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 **MOORING BUOY**
Scale: AS SHOWN Date:	PLATE **32**

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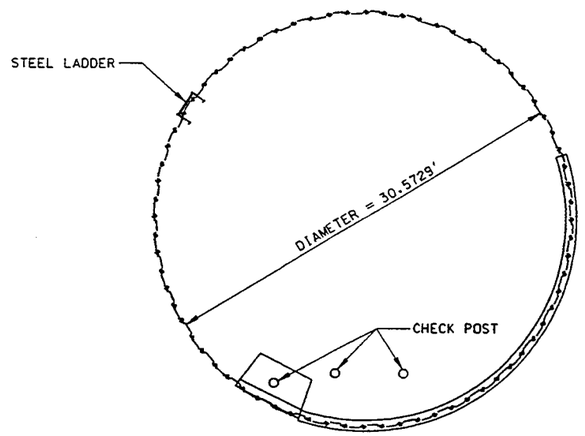
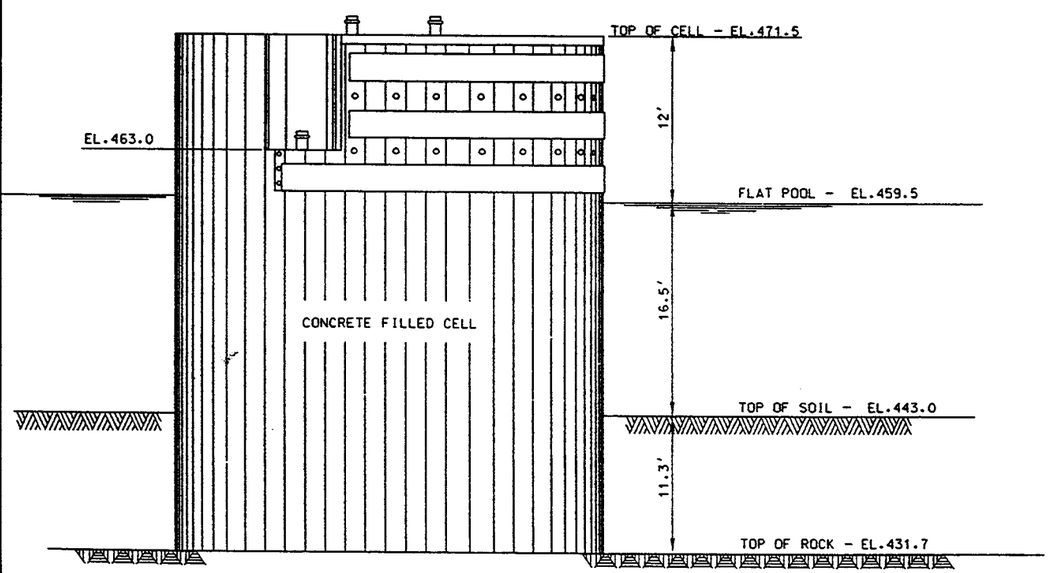


PLAN



ELEVATION

NOTE: ELEVATIONS SHOWN ARE OF LOCK NO. 22

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 PERMANENT MOORING CELL GENERAL VIEW
Scale: AS SHOWN Date:	PLATE 33

IMPACTS TO NAVIGATION TIME DELAY CHARTS

A

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Impacts to Navigation Time Delay Charts

The following charts show, in part, lock closure time and delays to the navigation industry during construction of lock approach walls. The closure time and delay time is depicted for the various locations of the approach wall/walls to include:

Extension of the existing lock upper and lower guidewalls
Construction of an upstream guardwall at the existing lock (Location 2).
Construction of an upstream guardwall at the existing auxiliary lock/gatebay (Location 3).

The lock sites are grouped as rock founded or pile founded sites. Accumulated closure/delay time is typically greater for the pile founded sites which require a longer time to construct the foundation.

Darker shaded line depicts complete closure of the lock in ***days*** during the navigation season.

Lighter shaded lines depict reduced navigation ***weeks*** (128 vs 168 hours). During these reduced navigation weeks, there are also delays in minutes for downbound and upbound tows.

The total time delay impact to the navagation industry is the accumulated time for complete closure, reduced navigation and tow delay time.

The ***cost*** impact to the navigation industry from the total time delay impact will be reported by the Economics Work Group.

IMPACTS TO NAVIGATION DURING CONSTR: Small Scale Improvements

Upstream Guardwall on Existing Lock

L&D No.	Impacts to Navigation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
11, 12, 16	Full Nav Weeks																																											
17, 21, 25													41				4			4		4					17			4		4		4					17			4		
LaGrange																																												
	Closure Days																																											
																115			45		45			45					40		40		40		40							40		14	
	Downbound exch and fly delayed 11.5 min.																																											
																	4			4		4					17			4		4		4					17			4		
	Upbound exit delayed 9.4 min.(Note 1)																																											
																	4			4		4					17			4		4		4					17			4		
	Helper Boat Assist(u-upbound, d-downbound)																																											
	(SEE NOTE 2)												41				4d			4d		4d					17d			4d		4d		4d					17d			4d		
	Switch boat use(u-upbound, d-downbound)																																											
																	4u			4u		4u					17u			4u		4u		4u					17u			4u		

Notes:
1. Although the tow is delayed, the chamber will not be delayed. It can be turned back in a normal timeframe.
2. Although a helper boat is being used, it will not reduce or add to the time in approaching the lock. Its main purpose is to safeguard the construction.

Upstream Guardwall on Existing Lock

L&D No.	Impacts to Navigation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
14, 15, 19	Full Nav Weeks																																										
20, 22, 24													41				4		4			4					15		4		4												
Dresden																																											
	Closure Days																																										
																101		45			45		45					30		30		14											
	Downbound exch and fly delayed 11.5 min.																																										
																	4		4			4					15		4		4												
	Upbound exit delayed 9.4 min.(Note 1)																																										
																	4		4			4					15		4		4												
	Helper Boat Assist(u-upbound, d-downbound)																																										
	(SEE NOTE 2)												41				4d		4d			4d					15d		4d		4d												
	Switch boat use(u-upbound, d-downbound)																																										
																	4u		4u			4u					15u		4u		4u												

Notes:
1. Although the tow is delayed, the chamber will not be delayed. It can be turned back in a normal timeframe.
2. Although a helper boat is being used, it will not reduce or add to the time in approaching the lock. Its main purpose is to safeguard the construction.

Upstream and Downstream Guidewall Extensions

L&D No.	Impacts to Navigation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
	Full Nav Weeks																														
	Reduced Nav Weeks (128 hours per week)												9												39						
Peoria																															
LaGrange	Closure Days															90												94			
	Downbound exch and fly delayed 11.5 min.																								39						
	Upbound exit delayed 9.4 min.(Note 1)																								39						
	Helper Boat Assist(u-upbound, d-downbound)												9												39d						
	Switch boat use(u-upbound, d-downbound)												9												39u						
	Arrive Ready to Serve using switchboat and Adjacent Mooring Facilities												9												39d						
	Remote Remake of Tows (Note 2)												9												39U						

L&D No.	Impact to Navigation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
	Full Nav Weeks																								14						
Lockpo	Reduced Nav Weeks (128 hours per week)												14									25									
Brandon																															
Dresden	Closure Days															90												90			
Marseilles																															
Starved Rk	Downbound exch and fly delayed 11.5 min.																					25									
	Upbound exit delayed 9.4 min. (Note 1)																					25									
	Helper Boat Assist(u-upbound, d-downbound)												14									25d									
	Switch boat use(u-upbound, d-downbound)												14									25u									
	Arrive Ready to Serve using switchboat and Adjacent Mooring Facilities												14									25d									
	Remote Remake of Tows (Note 2)												14									25u									

Notes:
1. Although the tow is delayed, the chamber will not be delayed. It can be turned back in a normal timeframe.
2. Upbound tows can remake on adjacent mooring facilities. Amount of use of the procedure is dependent on flow conditions and the switch boat's ability to safely pull first cut upstream.

Location 3 Guardwall Addition

L&D No.	Impacts to Navigation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
11, 12, 16	Full Nav Weeks																																
17, 21, 25													26		9																		
	Reduced Nav Weeks (128 hours per week)																																
	Closure Days																																
													15			15									15			15				7	
	Downbound exch and fly delayed 11.5 min.																																
																									39		9				15		
	Helper Boat Assist(u-upbound, d-downbound)																																
													26d												39d		9d				15d		

L&D No.	Impacts to Navigation	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
15, 20, 22	Full Nav Weeks																																
24											26				9																		
Dresden	Reduced Nav Weeks (128 hours per week)																																
													7				7																
	Closure Days																																
													15			15									15								
	Downbound exch and fly delayed 11.5 min.																																
																									39								
	Helper Boat Assist(u-upbound, d-downbound)																																
													33d												39d								