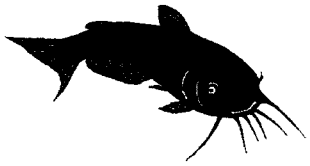
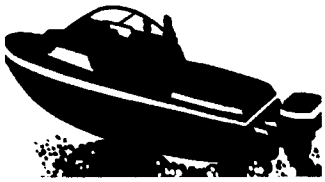
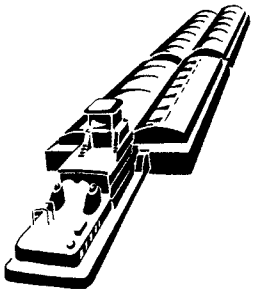
Upper Mississippi River - Illinois Waterway System Navigation Study





Summary of Small-Scale Measures Screening



Interim Report

April 1999

US Army Corps of Engineers

Rock Island District
St. Louis District
St. Paul District

SYLLABUS

The Upper Mississippi River-Illinois Waterway System Navigation Study (Navigation Study) is a feasibility study addressing navigation improvement planning for the Upper Mississippi River and Illinois Waterway (UMR-IWW) system for the years 2000-2050. This study assesses the need for navigation improvements at 29 locks on the Upper Mississippi River and 8 locks on the Illinois Waterway and the impacts of providing these improvements. More specifically, the principal problem being addressed is the potential for significant traffic delays on the system within the 50-year planning horizon, resulting in economic losses to the Nation. The study will determine whether navigation improvements are justified and, if so, the appropriate navigation improvements, sites, and sequencing for the 50-year planning horizon. The feasibility study also includes the preparation of a system Environmental Impact Statement (EIS).

The goal of this interim report is to summarize the entire process of identifying and screening the small-scale measures, leading up to the selection of a final set for use along with large-scale measures in developing alternative plans. However, the final product of the System Navigation Study is the feasibility report, which will constitute the decision document for processing to Congress. Small-scale measures are navigation improvements of smaller scope than constructing a new lock or extending the existing lock chamber. The process first identified a universe of 92 potential small-scale measures that might improve system efficiency. The items were then qualitatively screened to select those measures most suitable for further detailed analysis. These first two steps are presented in greater detail in the *General Assessment of Small Scale Measures* report dated June 1995. Following the selection of a smaller group of the most promising measures, the *Detailed Assessment of Small Scale Measures* (December 1998) was conducted to quantify the costs, performance, and impacts of the measures. This additional information provided the necessary details for a final secondary screening summarized in this report. The five measures remaining after this screening (guidewall extensions with powered kevels, switchboats with guidewall extensions, congestion tolls/lockage time charges, mooring facilities, and approach channel improvements) will be incorporated into the systemic analysis for use in developing alternative plans and the final evaluation and comparison of costs, benefits, and impacts.

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SUMMARY OF SMALL-SCALE MEASURES SCREENING

SUMMARY

The goal of this report is to summarize the identification and screening of the small-scale measures. The process began by identifying the universe of potential small-scale measures that might have an impact on system efficiency. These measures were obtained from previous studies, Corps staff recommendations, and coordination with members of private industry, State resource and transportation agencies, the U.S. Fish and Wildlife Service, the U.S. Coast Guard, and the U.S. Environmental Protection Agency. In all, 92 measures were identified. The next step of the process used a qualitative analysis to select those measures most suitable for further detailed analysis. The measures remaining after qualitative screening were then subjected to a thorough analysis to quantify the costs, performance, and impacts of the measures. After further development and analysis, the measures were distinguished based on whether they fell in the with- or without-project condition. This additional information provided the necessary details for a final secondary/quantitative screening. The value of this analytical process, which continually screens out the least promising measures, is that study resources are continually concentrated on those items showing the greatest promise based on the Corps planning criteria. This report fully documents the reasoning underlying the screening process.

The result of this entire process was the identification of five small-scale measures for use along with large-scale alternatives in the development of alternative plans and systemic analysis of costs, benefits, and impacts using the Navigation Study economic model. The measures include: (1) guidewall extensions with powered kevels; (2) switchboats with guidewall extensions; (3) congestion tolls/lockage time charges; (4) mooring facilities; and (5) approach channel improvements. These five measures identified by this analysis are the most promising measures in terms of addressing the study objective of assessing system efficiency improvements to reduce commercial delays at the lock sites. However, some of the other small-scale measures screened from consideration do have some potential to provide limited benefits in improving operations, increasing safety, or enhancing site-specific efficiency. While they will not be considered further as part of the new study, they are being evaluated under separate study efforts and in the future could be implemented with operation and maintenance funding.

Major products which served as references for this analysis include: the development of the universe of small-scale measures and qualitative screening summarized in the reports entitled, *General Assessment of Small Scale Measures* (June 1995); *Improved Tow Haulage* (September 1995*)* and *Universal Couplers and Crew Training* (September 1995); and the quantification of the cost and performance information included in the report entitled, *Detailed Assessment of Small Scale Measures* (December 1998). The focus in this report is to document and summarize the screening process.

BACKGROUND

Small-Scale Measure Definition and Role

Small-scale measures are navigation improvements of smaller scope than constructing a new lock or extending the existing lock chamber. While these measures are less costly than new lock construction, they also provide smaller reductions in lockage time.

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 during periods of congestion.

Steps in the Lockage Process

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.

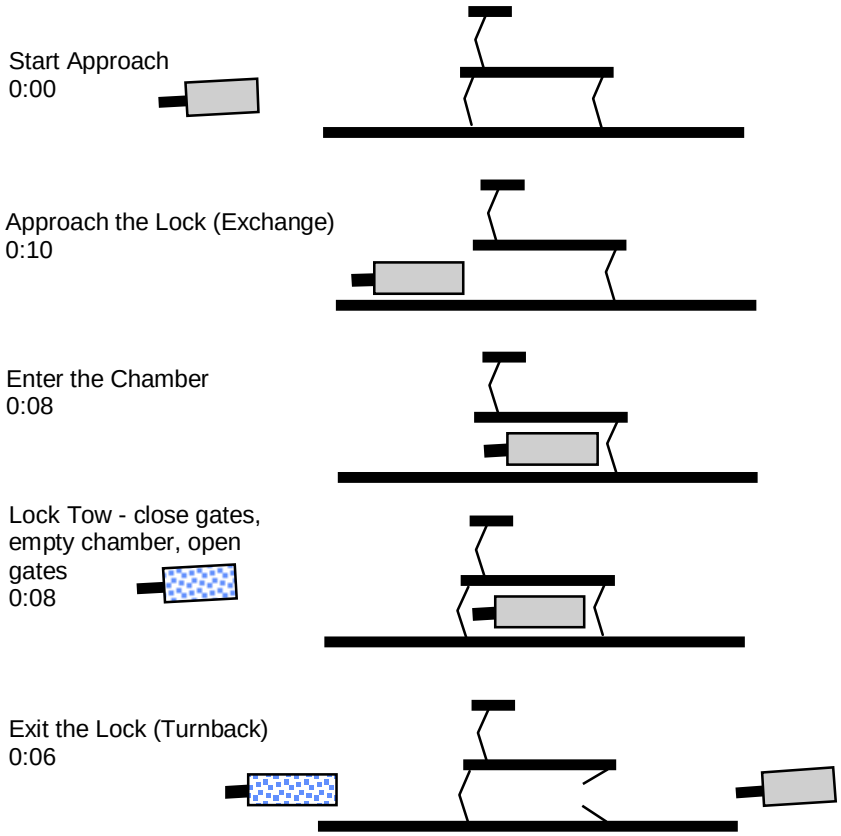
Many steps in the lockage process are of relatively short duration or are not easily alterable with small-scale measures, such as entering the chamber, gate operations, and chamber filling and emptying. In general, the small-scale measures considered in this study seek to reduce the longer time elements,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

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 nearly 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. During this multi-step process, the tow sends half its barges through the lock at a time, tying up the lock while it disconnects the two sets of barges, sends each half through separately, and then reconnects and moves out of the way. At 600-foot chambers, double lockages typically take between 80 minutes and 2 hours, compared to a range of 20 to 40 minutes for single lockages. Considerable variability in lockage times occurs due to differences in lockage types, lock sites, river and weather conditions, and crew and boat factors.

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 duration of each lockage step. Figures 1 and 2 compare a typical single lockage process with a double lockage process (note some steps have been consolidated for simplification). In addition to the reduced number of steps, single lockages typically have faster approach times due to greater maneuverability and less susceptibility to adverse currents associated with their smaller size.

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

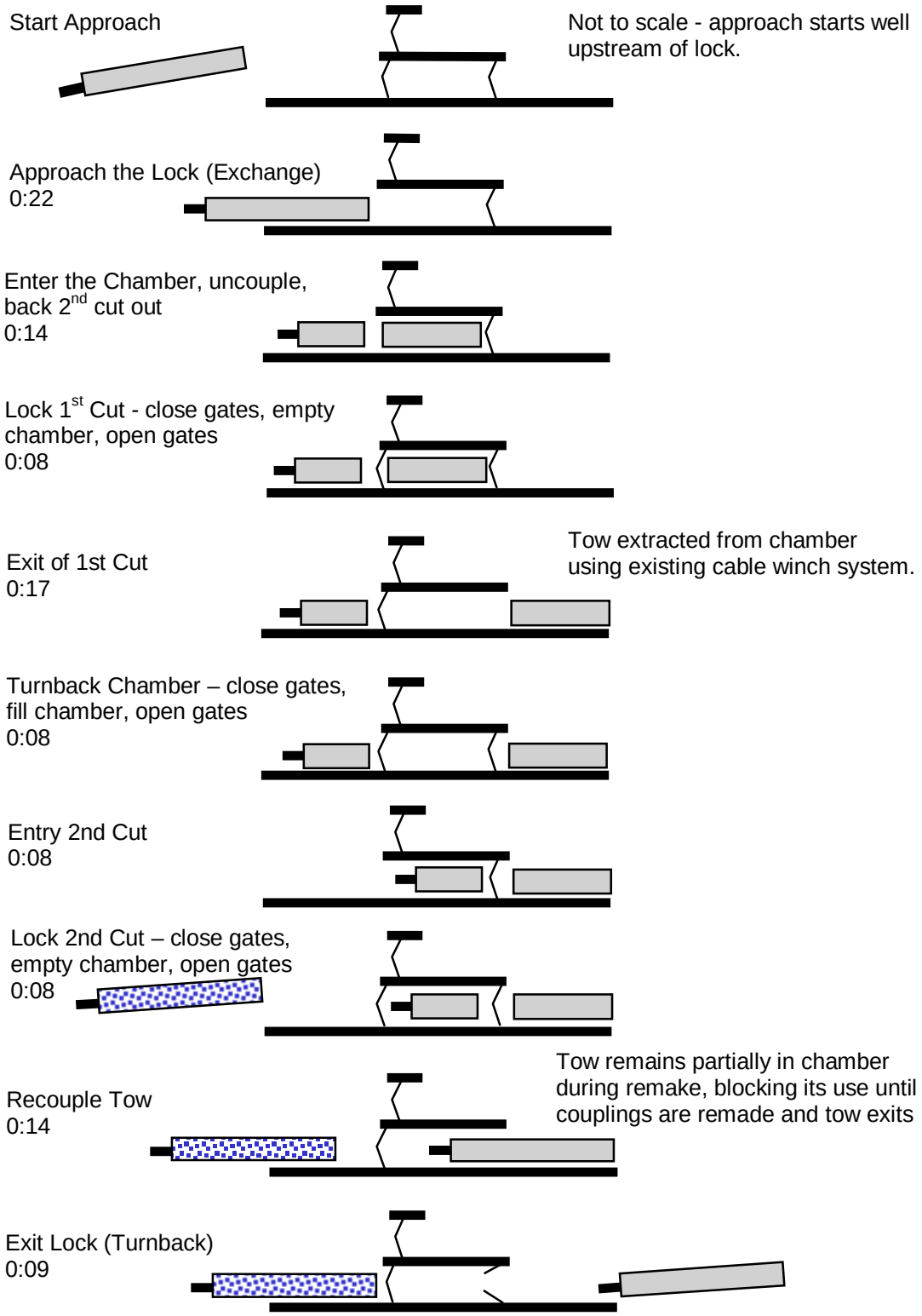
(1) Approach the lock
(2) Enter the chamber
(3) Close gates
(4) Fill or empty the lock chamber
(5) Open gates
(6) Exit the lock



Total Lockage Time 0:34

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

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



Total Lockage Time 1:48

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

FIGURE 2: Double Lockage Elements Downbound at Existing 600-Foot Lock

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. For a vessel traveling downstream (downbound vessel), either before or during the approach, the chamber is filled to the upper pool level and the upper gates opened. 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. 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 (emptying) valves. The water in the chamber flows back into the culvert and then out into the lower pool, lowering the water level in 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 exit process begins when the tow starts to move out of the chamber and ends when the tow is clear of the lock area and the next tow can use the lock. The process is reversed for tows 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 the lock
(2) Enter the chamber
(3) Uncouple the tow and back the second cut out of chamber*
(4) Close gates
(5) Fill or empty the lock chamber
(6) Open gates
(7) First cut exits the lock chamber*
(8) Close gates*
(9) Fill or empty the lock chamber {opposite direction of step (5)}*
(10) Open gates*
(11) Second cut enters the lock chamber*
(12) Close gates*
(13) Fill or empty the lock chamber {same as step (5)}*
(14) Open gates*
(15) Recouple the tow*
(16) Exit the lock

*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 nearly 1,200-foot-long tows transiting through 600-foot-long locks.

Double lockages require several additional steps. The full tow approaches the lock 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 nine barges, fill the whole lock. The towboat and remaining barges then back away and allow the first cut to lock through. 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 helper boat) 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 gates are closed, the chamber is turned back (goes through the gate operations and filling to get the chamber back to the upper pool elevation of the second, or powered, cut). As soon as the upper gates are 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-foot 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 is addressed by several of the small-scale options considered as part of this study. The process is reversed for tows going upstream (upbound vessels).

QUALITATIVE SCREENING

Identification of Measures

In 1994, through the review of background reports, an examination of the locking process, and a brainstorming session, a multi-disciplinary team composed of personnel from the Corps of Engineers, the navigation industry, State resource and transportation agencies, the U.S. Fish and Wildlife Service, the U.S. Coast Guard, and the U.S. Environmental Protection Agency developed the universe of potential small-scale measures. The team participation and investigation procedures, as well as definitions of each measure, are written up in an interim report entitled *General Assessment of Small Scale Measures*. The resulting 10 categories of measures (92 total measures) are listed in Table 2 on pages 8 and 9.

Qualitative Screening Process

The universe of small-scale measures included measures of varying value. Therefore, after the list was complete, it was necessary to screen these measures to the more promising alternatives. To do this, a qualitative screening process was used that employed the four general planning criteria: completeness, effectiveness, efficiency, and acceptability.

While the above are an excellent set of general criteria for evaluating an overall investment plan, they can be unwieldy when used to screen individual small-scale measures. For this reason, another set of criteria, consistent with the general criteria, was developed. These criteria serve as the "qualities" to be evaluated in the qualitative analysis.

A qualitative analysis was accomplished to provide a framework for screening potential small-scale measures. Under this framework, all measures can be analyzed with a reasonable expenditure of resources. This permits focusing study resources on those measures showing the greatest potential for achieving beneficial impacts relative to the costs of implementation. Table 1 below lists these criteria and their relationship with the general criteria described above.

TABLE 1: SMALL-SCALE SCREENING CRITERIA

Specific Screening Criteria	Planning Guidance Criteria
1. No Potential to Reduce Lock Delay	Effectiveness/Completeness
2. Not Technically Feasible	Effectiveness
3. Not Safe	Acceptability
4. Not Environmentally Acceptable	Acceptability
5. Is Economically Inefficient	Efficiency
6. Is Not Cost Effective	Efficiency
7. Industry Cooperation	Acceptability
8. Addressed in O&M Program [1]	Completeness

[1] Whereas criteria 1 through 7 evaluate the merits of the small-scale measure itself, criterion 8 determines whether the measure has already been implemented or could be implemented through existing authorities of the Corps' Operations and Maintenance Program, many of which would yield negligible or minor benefits in terms of system efficiency.

The specific screening criteria are largely self-explanatory; however, their definitions and use in screening are described in more detail in the *General Assessment* report. The analysis was accomplished by sequentially applying each criterion to all measures not eliminated by a previous criterion; that is, all 92 potential small-scale improvements were examined subject to the first criterion. The measures not screened out based on the first criterion were then formally examined subject to the second criterion and so forth. This "satisficing" approach keeps only those measures that satisfactorily clear all eight of the screening hurdles. The criteria that applied to eliminate each measure are shown in Table 2.

Qualitative Screening Results

The result of this initial screening was a substantial reduction in the initial list of 92 measures. Table 3 on page 10 shows the 16 measures selected by the initial screening process. The table also includes some measures initially screened out (unpowered traveling kevels, powered ratchets, additional personnel, and approach channel improvements) which were reconsidered subsequent to the qualitative screening based on additional information and further analysis. The footnotes to the table identify these measures and the reason for their inclusion in the analysis. In addition to these measures, the concept of placing "Wicket Gates in Dam" (item 10 l in Table 2), which survived the initial screening, was reclassified as a large-scale measure due to its large capital cost.

The small-scale measures carried forward from the initial screening were grouped with similar measures and then placed into two broad categories—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 primarily with changes in public policy or management practice. Under these categories, the measures have been grouped with other similar measures. These measures were determined to be worthy of further study. The following section documents the efforts to quantify their costs, impacts, and performance and further screens them based on the additional information.

TABLE 2: UNIVERSE OF SMALL-SCALE MEASURES

Id. No.	Name of Small-Scale Measure	No Delay	Not Tech.	Not Safe	Not Environ.	Econ Ineff.	Not Cost Eff.	Industry	Corps O&M	Recommended for Further Study
1.	**Scheduling of Lock Operations**									
1a.	N-Up/N-Down								x	
1b.	Ready to Serve Policy						x			
1c.	Self Help Policy									x
1d.	Scheduling Program									x
2.	**Assistance to Lockages**									
2a.	Helper Boats									x
2b.	Switchboats									x
2c.	Endless Cable System									x
2d.	Unpowered Traveling Kevel								x	
2e.	Powered Traveling Kevel									x
2f.	Hydraulic Assistance								x	
3.	**Improvements to Approach Channels**									
3a.	Approach Channel Widening/Realignment						x			
3b.	Adjacent Mooring Facilities									x
3c.	Funnel-Shaped Guidewalls					x				
3d.	Wind Deflectors					x				
3e.	Extend Guidewalls									x
3f.	Add Guide Cells	x								
3g.	Reconfigure Bullnose	x								
3h.	Radar Reflectors	x								
3i.	Electronic Guidance System					x				
4.	**Area-Wide Channel Improvements**									
4a.	Remove/Adjust Bends, One-Way Reaches, Bridges	x								
4b.	Improve Navigation Aids and Channel Markings	x								
4c.	Innovative Dredging Strategies	x								
4d.	Water Flow Management Policies	x								
4e.	Increase Channel Width	x								
4f.	Isolate Recreational Facilities & Marinas Away from Channel	x								
4h.	Dual Channel at Restrictive Bridges	x								
5.	**Tow Configuration and Operations**									
5a.	Mandate Use of Bow Thrusters						x			
5b.	Mandate Use of Prototype Bow Thrusters						x			
5c.	Tow Size Standardization							x		
5d.	Cooperative Equipment Sharing/Scheduling							x		
5e.	Institute Waterway Traffic Management							x		
5f.	Increase Number and Size of Fleeting Areas	x								
5g.	Fuel Monitoring & Management	x								
5h.	Use of Heavy Fuels	x								
5i.	New Barge and Boat Bottom Treatments	x								
5j.	Improved Barge and Boat Hull Designs	x								
5k.	Barge Stacking for Backhauls							x		
5l.	Container Movement	x								
5m.	New Backhaul Opportunities	x								
5n.	Universal Couplers/Hand Winches									x
5o.	Increase Speed Limits in Restricted Reaches	x								
5p.	Reduce Liability of Tow Operators for Damage	x								
5q.	Require Minimum Crew Size and Training									x
5r.	Mandate Minimum Horsepower							x		

TABLE 2 (Continued)

Id. No.	Name of Small-Scale Measure	No Delay	Not Tech.	Not Safe	Not Environ.	Econ Ineff.	Not Cost Eff.	Industry	Corps O&M	Recommended for Further Study
6.	**Lock Operating Equipment/Procedures**									
6a.	Modify Intake Structures					x				
6b.	Modify Discharge Structures					x				
6c.	Modify Wall Ports					x				
6d.	Install Self-Cleaning Trash Racks								x	
6e.	Centralize Controls								x	
6f.	Portable Controls								x	
6g.	Automate Controls								x	
6h.	Install Floating Mooring Bits	x								
6i.	Upgrade Valve Operating Equipment								x	
6j.	Upgrade Gate Operating Equipment								x	
6k.	Install Gate Wickets in Miter Gates			x						
6l.	Provide Explicit Operating Guides								x	
6m.	Fenders, Energy Absorbers	x								
6n.	Require Vessels to Stay Clear of Emptying/Filling System	x								
6o.	Operate Dam Gates Based on Lockage								x	
6p.	Lift Gates at Lock					x				
7.	**Ice Conditions**									
7a.	Mechanical Ice Cutting Device								x	
7b.	Skin Plates								x	
7c.	Air Bubbler System								x	
7d.	Heat Plates								x	
7e.	Heated Water Jet								x	
7f.	Clear Ice from Barges		x							
7g.	Ice Chutes					x				
8.	**Recreational Vessels**									
8a.	Recreational Vessel Bypass Lifts					x				
8b.	Scheduling of Recreational Vessel Usage									x
8c.	License Recreational Craft Operators	x								
8d.	Recreational Craft Landing Above and Below Lock									x
9.	**Cost Allocation**									
9a.	Apply Congestion Tolls									x
9b.	Allocation of Operation and Maintenance Costs	x								
9c.	Low Head Hydroelectric Units	x								
9d.	Privatization of Lock Operations	x								
9e.	Excess Lockage Time Charges									x
9f.	Lockage Time Charges									x
10.	**Other**									
10a.	Increase Lock Staffing	x								
10b.	Automate Dam Controls	x								
10c.	Radar at Lock	x								
10d.	Real-Time Channel Depth and Weather Monitoring	x								
10e.	Improved Lighting								x	
10f.	Publish Lockage Times by User									x
10g.	Create Indraft		x							
10h.	Operational Philosophy/Industry Attitude							x		
10i.	Deepen River Upstream of Gates				x					
10j.	Pilot Communication (Bulletin Board)	x								
10k.	Closed Circuit Television (CCTV) at Lock	x								
10l.	Wicket Gates in Dam									x Included in Large-Scale
10m.	Automated Lockage System from Queue Point		x							
10n.	Specified Navigation Season	x								

TABLE 3: QUALITATIVE SCREENING SMALL-SCALE MEASURES
Non-Structural Measures
Towboat Power
Helper Boats
Switchboats
Self Help
Tolls and Reports
Congestion Tolls
Excess Lockage Time Charges
Lockage Time Charges
Publish Lockage Times
Recreational Vessels
Scheduling of Recreational Vessel Usage
Recreational Craft Landing Above and Below Deck
Optimizing Decisions - Scheduling Program
Structural Measures
Extended Guidewall
Tow Haulage Equipment
Powered Traveling Kevel
Endless Cable
Unpowered Traveling Kevels [1]
Mooring Facilities (Adjacent to Lock Approach)
Crew Elements
Universal Couplers/Hand Winches
Permanent Deck Winches
Powered Ratchets [2]
Minimum Crew Size with Training
Additional Personnel [3]
Approach Improvements [4]

[1] As an outgrowth of discussions on the Extended Guidewalls and Tow Haulage Equipment measures, the Unpowered Traveling Kevels measure, once screened, was added to the list of surviving measures for its reconsideration.

[2] The Powered Ratchets measure was initially considered infeasible due to unavailability; however, subsequent development concerning this measure put it back in contention. The manufacture of a commercially available powered ratchet has been put into limited use by the navigation industry, with some favorable results.

[3] The Additional Personnel measure was an outgrowth of discussions on the other crew elements measures.

[4] The Approach Improvements measure was initially thought to have limited value. Later hydraulic model studies indicated that, on a site-specific basis, channel improvements might offer significant timesaving.

SECONDARY SCREENING

Screening Process

This section summarizes the secondary screening of measures based on the data and information provided in the *Detailed Assessment of Small Scale Measures*. This report provided the necessary additional analysis and quantification of cost and performance data needed to further evaluate and screen the measures prior to carrying the "best" measures forward for use in the development of alternative plans.

The study team conducted a preliminary secondary screening on August 12-13, 1997, following a review of the cost and performance information. The results of that screening are summarized in Tables 4 and 7 on pages 13 and 18, respectively. Subsequent to that meeting, however, concerns regarding the cost and performance data led to further information gathering, analysis, and refinement of the cost and performance information. As a result of these changes, the study team revisited the secondary screening on August 27-28, 1998. This final secondary screening revisit resulted in substantive changes to the preliminary secondary screening, which are documented separately and summarized in Table 9 on pages 24 and 25.

Following the discussion of the process used to quantify the costs and performance and the two-part secondary screening, a separate section provides a brief description of each of the small-scale measures carried forward from the *General Assessment* report. This section summarizes the final cost and performance data and information on the final outcome of the secondary screening process. The information provides only a brief overview of the definition of the measures, time savings potential, and cost provided in the *Detailed Assessment of Small Scale Measures* report.

Quantification of Cost and Performance

The *General Assessment* report highlighted the most promising measures in terms of potential systems efficiency. Following the compilation of this list, it was necessary to conduct additional focused research and information gathering to determine if these options were actually viable alternatives and if so to identify their specific cost and performance. In order to compare the measures and conduct the screening, efforts were taken to put the costs and performance data in common terms.

<u>Costs</u>. The implementation of most measures results in costs being incurred over the life of a project. For example, the initial construction of a measure may result in a relatively large expenditure in the first few years. Once in place, the measure will likely require some operations and maintenance costs and eventually repair or replacement of all or part of the measure. In order to summarize this stream of expenditures for comparison to other measures, an annual cost was computed by following Corps of Engineers guidance and using the total life cycle costs recorded in the *Detailed Assessment*. In most cases, the small-scale costs include a 25 percent contingency factor.

Annual costs are computed by first determining the expected stream of expenditures required by a project over its life, the cost, and the time frame it is incurred. These costs are then discounted to a common year (1997 was used for this analysis) to show the total cost if all expenses occurred in a single year. For this analysis, the 1998 Federal discount rate of 7.125 percent was used. The following formula was then used to allocate those costs on an annual basis over the expected project life (20 years or 50 years, depending on the improvement category). The important

consideration was that measures that were used to screen out other measures were comparable (i.e., had equal lives and were evaluated on an annual cost basis).

$$\text{Annual Cost} = \text{Total Present Cost } [\{i(1+i)^n\}/\{(1+i)^n-1\}]$$
$$i = \text{interest (discount) rate}$$
$$n = \text{number of years}$$

Performance. In a similar manner, the performance of the measures was summarized in minutes saved per lockage whenever possible to provide comparability. However, since the savings potential often varies by the type of lockage, the direction the tow is traveling, and a number of other factors, in many cases additional information is necessary to clarify the benefits.

The information developed for each of the surviving measures is summarized in the following sections and in Tables 5 and 7 on pages 14 and 18, respectively. While only a single value is shown for simplicity, ranges were determined for most performance elements.

Preliminary Secondary Screening (August 1997)

In August 1997, the study team conducted the preliminary secondary screening documented in this section. The screening was conducted using the quantitative cost and performance data and additional information on the viability and effectiveness of the measures collected following the completion of the *General Assessment* report. The screening was only preliminary in the sense that it was to be reviewed after finalization and verification of the cost and performance numbers occurred.

The secondary screening was again conducted using the planning screening criteria of completeness, effectiveness, efficiency, and acceptability along with the quantified data. The team began by first comparing the measures in each improvement category (towboat power, tolls and reports, etc.). This way, a comparison could be done to screen out the measures within groups, which provide less benefits at the same or greater cost or the same benefits at a greater cost. Following this evaluation of each group of measures, any justified screening between groups could be accomplished. In addition, other measures, which were not readily quantified in terms of benefits or costs, were further qualitatively evaluated based on the additional information collected subsequent to the *General Assessment* report. Table 4 on the next page summarizes the secondary screening process.

Table 5 on page 14 summarizes the cost and time saving information available at the time of the screening, along with some updates recommended and considered as part of the process. The projected costs were annualized over 20 years for all measures except the approach channel improvement measures, which were evaluated using a 50-year life. These costs did not include the cost of work that may be needed to avoid, minimize, or mitigate environmental or cultural impacts. In this screening of measures, the important factor was comparability of items being evaluated against each other. For example, guidewall extension/remote remake options and approach channel improvement options will have some environmental impacts. However, within the categories that were compared in the screening, no major differences in environmental or cultural impacts are anticipated (e.g., all guidewall and remote remake options have similar site-specific environmental impacts compared to one another). Some other measures such as the adjacent moorings are anticipated to be able to avoid significant impacts through proper placement, and have been implemented as measures to avoid or minimize environmental impacts in some cases. However, these costs are recognized as important factors in evaluating various alternative plans

TABLE 4: SUMMARY OF PRELIMINARY SECONDARY SCREENING (AUGUST 12-13, 1997)

Measure	Completeness	Effectiveness	Efficiency	Acceptability	Comments
Towboat Power					
Helper Boat w/DeLong Pier Guidewall					Recommended for further formulation.
Switchboat w/Remote Remake					Recommended for further formulation.
Industry Self Help w/Cells					Recommended for further formulation.
Tolls and Reports					
Congestion Tolls					Recommended for further formulation.
Excess Lockage Time Charges	X				Not implementable due to high degree of variability in uncontrollable conditions affecting lockage times.
Lockage Time Charges					Recommended for further formulation.
Publish Lockage Times		X			No benefit to be gained, since this information is already shared with the RIAC (River Industry Action Committee).
Recreational Vessels					
Recreational Craft Scheduling		X		X	Actual experience showed no significant benefits; possibility for negative impact at lower locks; only assists limited sites; and acceptability concerns.
Recreational Craft Landings		X			No guaranteed benefits of measure; most sites already have adequate facilities; some potential to induce more rec craft use.
Optimizing Decisions					
Scheduling Program		X			Part of the without-project condition. Lockmasters currently work with RIAC to implement the most effective scheduling when large queues are present.
Extended Guidewalls					
w/Powered Kevels			X		Provides less benefits at greater cost than towboat power w/associated moorings/temporary walls.
w/Unpowered Kevels			X		Provides less benefits at greater cost than towboat power w/associated moorings/temporary walls.
Mooring Facilities					
Cell or Buoy					Recommended for further formulation.
Crew Elements					
Universal Couplers	X				A viable unit has not been developed.
Crew Training		X			Crews already using various training methods without significant differences in performance.
Permanent Deck Winches			X		Provides fewer benefits in remake than the powered ratchet at a greater cost.
Additional Personnel			X		Same as above.
Powered Ratchets					Recommended for further formulation.
Approach Channel Improvements					
Guidewall Extension - US			X		Channel improvements provide majority of the approach benefits to be gained at a much lower cost.
Channel Improvements - US					Recommended for further formulation.
Guidewall Ext .+ Chan Imp. - US			X		Channel improvements provide majority of the approach benefits to be gained at a much lower cost.
Aux. Lock Guardwall - US			X		Same as above.
Existing Lock Guardwall - US			X		Same as above.
Aux. Lock Guardwall + Chan Imp. - US			X		Same as above.
Ex. Lock Guardwall + Chan Imp. - US			X		Same as above.
Guidewall Extension - DS			X		Same as above.
Channel Improvements - DS					Recommended for further formulation.
Guidewall Ext .+ Chan Imp. - DS			X		Channel improvements and towboat power options provide majority of the approach benefits to be gained at a much lower cost.

TABLE 5: INITIAL SMALL-SCALE MEASURES COST AND PERFORMANCE

Measure	Mean Time Savings for Double Lockage Tows	Average Annual Cost [3]
2 Helper Boats w/DeLong Pier Guidewall Extension [1]	22 min upbound[2] 27 min downbound[2]	$1.8 mil/lock
2 Switchboats w/Remote Moorings [1]	22 min upbound 27 min downbound	$2.5 mil/lock
Industry Self Help w/Moorings	18 min upbound 23 min downbound	$1.2 mil/lock
Congestion Tolls	Not quantified	$280k/system[4]
Excess Lockage Time Charges	Not quantified	$280k/system[4]
Lockage Time Charges	Not quantified	$280k/system[4]
Publish Lockage Times	Limited	$65k/system[4]
Recreational Craft Scheduling	Limited	$85k/system[4]
Recreational Craft Landings	Limited	$38k/landing[4]
Scheduling Program	Limited	$87k/system[4]
Guidewall Ext with Unpowered Kevel	6 min upbound[2] 6 min downbound[2]	$2.4 mil/lock
Guidewall Ext with Powered Kevel	11 min upbound[2] 14 min downbound[2]	$2.4 mil/lock
Adjacent Moorings	7-13 min/exchange	$16k/buoy $68k/cell
Per Deck Winches	4 min all	$800/barge or $10 mil/system (13,000 barges)
Add Personnel	3 min all	$334k/lock
Powered Ratchets on Tows	5 min all	$565k/system
Powered Ratchets at Locks	5 min all	$280k/lock[4]
Approach Channel Improvements	3 min downbound 2 min upbound	$530k/site (11 sites DB) $220k/site (8 sites UB)
Other Approach Improvements	1-7 min downbound 1-3 min upbound	$1.7-$20.1 mil/site $950k-$1.1 mil/site

Notes:
[1] Potential to provide additional approach time savings for downbound lockages.
[2] Only applicable to turnback lockages.
[3] Costs were updated to reflect Federal discount rate of 7.125 (1998 rate) versus the 7.375 rate (in effect in 1997). In addition, the costs exclude impacts to navigation during construction (except for the other approach improvements) and environmental costs.
[4] Costs revised following the screening meeting, but not affecting the outcome.

and will be included as costs in the system economic analysis. Costs associated with impacts to navigation during construction were estimated for guardwall and guidewall options and are anticipated to be avoided in other situations. Also included in the summaries are estimates of the time savings each measure could help achieve per double lockage.

In general, the numbers available at the time indicated that towboat power options appeared to provide the greatest delay reduction potential (largest time savings per lockage). Other measures recommended to be carried forward included Congestion Tolls/Lockage Time Charges, Mooring Facilities, Powered Ratchets, and Approach Channel Improvements. A discussion of the specific evaluation used for each measure follows.

Towboat Power - The study team concluded that no screening out of measures in this category was possible at this time. In general, the measures (Helper Boats with Guidewalls, Switchboats with Remote Remake, and Industry Self Help) provided additional benefits as costs increased. Further evaluation and screening will require the use of the economic models to evaluate the incremental benefits of the additional savings possible with more costly measures versus the anticipated future system demand.

Tolls, Time Charges, and Reports - The four different measures in this category seek to reduce delays through creating incentives to reduce overall lockage times and shift demand away from congested locks. Only a paired comparison of the various toll measures was possible since the system economic model must be used to set the level of any charges and determine the potential benefits. However, both the Excess Lockage Time Charges and Publish Lockage Times measures were screened out as described below.

Congestion Tolls - This measure was carried forward for analysis using the system models.

Excess Lockage Time Charges - The Excess Lockage Time Charges measure was screened out based on the completeness criterion. An excess lockage time cannot be determined, since defining excess is highly site specific and could not equitably account for the great amount of variability in lockage times due to weather, flow, fog, ice, and wind. 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, lockage time charges, which could be implemented at the same cost, create an incentive for all lockages to improve.

Lockage Time Charges - This measure was not screened out, but could be viewed as a sub-category or way to implement a congestion toll. In addition to being a form of demand management measure, the real time savings benefit of a time charge is that it creates an incentive for industry to adopt other new measures to reduce the fees they pay. However, rather than any single measure, the lockage time charge encourages each company to pursue the measures most beneficial for them and creates an incentive for the development of innovative technologies.

Publish Lockage Time - This measure was screened out on the basis of effectiveness. Despite the relatively low cost of the measure, it is not likely to significantly decrease system delays. In addition, nearly all of the benefits are currently captured since ongoing communications and coordination between the lockmasters, the RIAC (River Industry Action Committee), and the towboat companies address many of these issues. In particular, lockmasters currently share information with the navigation industry on tows that take excessive amounts of time in approaching or using the locks.

Scheduling of Recreational Vessels - This measure was screened out on the effectiveness and acceptability criteria. This decision was based on past test implementation at a number of lock sites that did not demonstrate measurable benefits or generate the support of recreational boaters or the navigation industry, and a time analysis that showed it may actually increase delay times at the most congested locks.

Recreational Craft Landings - This measure was screened out on the effectiveness criterion. It cannot be determined what impact this will have on the recreational demand for the locks. The presence of additional recreational facilities could actually increase recreational demand for the lock. Due to the fact that most recreational lockages contain multiple recreational craft, some reduction in the number of recreational craft using the lock may not actually significantly reduce the number of recreational craft lockages. In addition, landings are already in place at most sites with the greatest recreational demand, and many of the lockmasters report that numerous recreational lockages appear to be conducted simply for the experience of using the lock and are not based on the adequacy of landings. Other surveys have indicated a higher percentage of recreational lockages associated with marina-based craft and those boats making longer trips (multiple pools); these types of lockages would not be reduced with additional landings.

While both measures specific to recreational craft were screened out, it was noted that the implementation of any improvement measure would also benefit recreational craft by reducing delays at the lock sites. Whether a measure is specifically targeted to provide benefits to recreational craft does not mean that recreational users will not be better accommodated. In addition, various lock chamber sizes were evaluated as part of the screening of large-scale improvements, including non-commercial or recreational craft chambers, and these measures were screened out based on cost and performance.

Scheduling Program - The group discussed that while a computerized scheduling program is not currently available at the lock sites, the lockmasters in coordination with the RIAC currently implement various N-up/N-down and even N-up/M-down as appropriate. N-up/N-down is a procedure where a certain number of boats are locked in one direction, before a number of boats are locked in the opposite direction. The available information indicates that as N-up/N-down and N-up/M-down scheduling is adapted to a specific queue, very few additional benefits could be gained by going to any other scheduling. As a result, the study team screened out this measure on the effectiveness criterion, since most of the potential benefits are already accounted for as part of the without-project condition.

Guidewall Extensions with Powered or Unpowered Kevels - These two measures were screened out based on the efficiency criterion. They address the same steps in the lockage process as the towboat power options, but provide smaller time savings at a higher cost. In addition, delay impacts to navigation were not shown, but were preliminarily estimated in the $50 million to $80 million range per lock; potential environmental impacts from the construction footprint had not been identified but would be similar to the towboat power options. This screening also included the elimination of the pull/retard and endless cable system options, which were both under consideration as mechanisms to power the kevels.

Mooring Facilities - Both mooring cells and buoys were carried forward for further analysis based on the low cost and high time savings potential. It was highlighted that the savings shown can be doubled for exchange lockages since the time savings in moving the mooring closer reduces the exit times as well as the approach times. Some time savings are also possible for single lockage tows.

Both cells and buoys were carried forward. The general assumption was that cells would be placed above the lock and buoys below unless the site is on rock. At rock-founded sites, a cell would be used below the lock as well as above due to the higher cost of anchoring a buoy.

Crew Elements - Crew elements refer to those measures with potential to improve the process of breaking and remaking tows involved in double lockages. Five crew element measures received consideration: Universal Couplers, Crew Training, Permanent Deck Winches, Additional Personnel, and Powered Ratchets. Based on additional information gathering and analysis since the *General Assessment* report, two measures—Universal Couplers and Crew Training—were screened out on the completeness and effectiveness criteria, respectively. Since a universal coupler has not been developed at this time and industry currently meets crew requirements and provides various types of training, no additional delay reduction is anticipated from these measures.

All of the crew element measures address the same time element (remake of doubles). As a result, these measures can be screened based on direct comparison. Using this process, Permanent Deck Winches and Additional Personnel were eliminated on the efficiency criterion since they provide less benefits than Powered Ratchets at a higher cost.

The remaining measure, Powered Ratchets, could be implemented in one of two ways: placing the units on all double lockage tows or making the units available at each lock site with significant numbers of doubles and delay. Both options would provide the same time savings, but it would be significantly less costly to provide the winches on each tow rather than at each of the 18 lock sites identified as having large numbers of double lockages. This cost difference is primarily due to the added cost of needing an additional lock employee to operate the small crane, lowering the powered ratchet. In addition, some question remained about the feasibility and safety of providing the units at the locks. As a result, placing powered ratchets at the locks was screened out under the efficiency criterion.

Approach Improvements - A variety of alternative approach improvements (dike fields, submerged dikes, channel realignment, guardwalls, and guidewalls) could reduce the maneuvering required by tows at lock sites, saving time in lock approaches and exits. Approach channel improvements were considered alone and in combination with structural improvements, such as extended guidewalls and guardwalls in alternative positions. While approach improvements were originally screened from further consideration as part of the qualitative evaluation, the physical model studies of Locks 22 and 25 conducted as part of the large-scale evaluation for 1,200-foot locks demonstrated that approach improvements could provide significant benefits and merited further consideration.

In total, the study team looked at eight different potential combinations of upstream approach improvements. Only the first three improvements are applicable to the downstream approach. As the following table shows, the best upstream option from an overall time savings perspective at most sites is channel improvements with a 1,200-foot guardwall extension at the existing lock (location 2). However, both guidewalls and guardwalls have very high first costs in addition to the delay costs they can impose on navigation during construction.

TABLE 6: APPROACH CHANNEL IMPROVEMENTS INCREMENTAL COST ANALYSIS

Improvement	Average Cost	Avg Savings (Min.)/ Exchange Approach	Min Saved/ $1 Mil Invested	Incremental Cost	Incremental Savings (Min.)	Incremental Min Saved/ Inc $1 Mil Invested
Upstream						
1) Extended Guidewalls (GW)	$1,770,005	0.6	0.32	NA	NA	NA
2) Channel Improvements	$530,315	2.9	5.47	NA	NA	NA
3) Extended GW + Chan Impr.	$2,192,333	3.1	1.41	$1,662,018	0.2	0.12
4) Location 3 (auxiliary lock) guardwall alone	$2,217,710	3.2	1.43	$2,217,710	0.3	0.12
5) Location 2 (existing lock) guardwall alone	$20,118,776	5.8	0.29	$20,118,776	2.9	0.14
6) Chan Impr + Loc 3 GW	$2,828,139	4.7	1.65	$2,297,824	1.8	0.77
7) Extended GW + Chan Impr + Loc 3 GW	$4,571,962	4.9	1.08	$4,041,646	2.0	0.50
8) Chan Impr + Loc 2 GW	$19,758,560	6.5	0.33	$19,228,245	3.6	0.19
Downstream						
1) Extended Guidewalls	$952,827	0.9	0.97	NA	NA	NA
2) Channel Improvements	$220,178	2.0	9.08	NA	NA	NA
3) Extended GW + Chan Impr.	$1,081,472	2.9	2.67	$861,293	0.9	1.03

Based on a paired comparison of the incremental costs and benefits (minutes saved/exchange approach/$1 million invested), the most cost-effective measure in this category is Channel Improvements (immediately above and below the lock). This measure saves over 5 minutes and 9 minutes on exchange lockages, respectively, per $1 million invested for upstream and downstream improvements. While some additional savings are possible, they are much less cost-effective and preliminary system model runs do not demonstrate justification for these high-cost items. The other options, while potentially providing some additional time savings, do so at a much greater cost. In addition, increased numbers of turnback lockages (same direction) associated with increasing traffic will reduce the number of exchange lockages. The benefits of approach improvements are significantly reduced for turnback lockages, since in many cases the next tow in line can complete all or part of its approach and be essentially ready to enter the lock when the previous tow completes its lockage.

The channel improvements are generally only applicable to the UMR locks. The IWW locks have considerably less outdraft and, as a result, no time savings were expected for approach improvements. The one exception is Marseilles Lock, which could benefit from channel improvements in the narrow canal above the lock.

This screening process resulted in identifying eight measures, summarized in Table 7 below, to tentatively be carried forward for use in the plan formulation process of developing alternative plans and evaluation with the system economic models.

TABLE 7: SURVIVING SMALL-SCALE MEASURES
Helper Boats with DeLong Pier Guidewall Extensions
Switchboats with Remote Remake Facilities
Industry Self Help with Mooring Cells
Congestion Tolls
Lockage Time Charges
Mooring Facilities (Cells or Buoys)
Powered Ratchets
Approach Channel Improvements

Final Review and Revision of Measures

Once a shorter list of the eight most viable measures was identified based on the available data, the study team shared this information with the navigation industry and the U.S. Department of Transportation Maritime Administration. The purpose of sharing the information was to confirm the technical adequacy and to provide an opportunity for review and comment on implementability issues prior to finalizing the screening. This process started with a short summary report on January 30, 1998, and concluded with a Lockmaster Expert Panel Process on July 30, 1998. Reviewers included The American Waterways Operators; the Maritime Administration; the River Industry Action Committee (RIAC); MARC 2000, a number of private companies, and Corps of Engineers Operations Division personnel. This process resulted in considerable comments, discussions, and additional data gathering and analysis.

The navigation industry provided consolidated written comments on the measures on February 23, 1998, and verbal comments at follow-up meetings in February, March, and May of 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. In addition, further review by the study team and other Corps staff lead to further definition of the with- and without-project conditions and refinement of the guidewall option and methods to implement the kevel options. The study team clarified that for this system study the with-project condition would include all small-scale measures potentially implemented on a system basis by a Federal action for system efficiency reasons. This was based on the fact that even though the Corps might have authority to undertake some measures in the without-project condition, this is not necessarily the likely and foreseeable future due to funding constraints, uncertainty in authority as applied, environmental compliance issues, or potential for significant system efficiency benefits. As part of a potential system efficiency application of the measures, it was determined to be most appropriate to account for them in the with-project. However, defining a measure as with-project for this study should not affect the implementation of the measures on a site basis for other reasons (safety, avoid and minimize, etc.) outside of this study, even if minor efficiency gains result, if the measure has existing authority. This will allow the study to identify the best system efficiency measures while only needing to recommend authority for measures not already authorized. This approach and further efforts revealed that helper boats, industry self help without additional facilities, and powered ratchets all fall in the without-project condition. They are already being implemented to some extent and do not require any Federal action. An overview of what has been revisited and updated is listed below and summarized in Table 8 on page 23.

Helper Boats - Based on industry comments and verification by the U.S. Coast Guard, the study team determined that helper boats lack sufficient power to dependably and safely extract unpowered cuts. Their primary benefit is to assist tows on approaches. This limits their potential future use to the same periods of time they are currently being used. Since no Federal action is required, this measure falls into the without-project condition.

Switchboats (Formerly Helper Boats) w/Guidewall Extensions (Constructed with Spud Barges or Cellular Sheetpiles) - Based on industry concerns, further evaluations, and discussions with the U.S. Coast Guard, the study team increased the boat size required for routine use in pulling cuts along an extended wall to 1,800 to 2,000 hp up from 800 to 1,000 hp. This reduces risks associated with the potential to have under-powered tows during some conditions and the potential for unpowered cuts to be drawn into the dam, and provides an increased margin of safety. Use of the larger boats moved this measure into the switchboat category, whereas previously 800 to 1,000 hp helper boats were assumed to be capable of performing the operation. In addition, further verification of boat costs with the Corps' Institute for Water Resources (IWR), which conducted a survey of navigation industry boat costs, revealed that a margin for profit was not included in the boat costs. As a result, a profit factor of 13.5 percent was added to cover the anticipated expense associated with contracting or hiring these boats. In total, these changes raised the boat cost from approximately $100 per hour to $175 per hour.

The cost of DeLong pier/spud barges was reassessed through contacting barge manufacturers Jeffboat and Trinity. Cost estimates were obtained for two barge sizes: 195 feet x 35 feet x 10 feet and 150 feet x 35 feet x 10 feet. The general design would include ½-inch steel sides versus the 3/8-inch steel used for regular barges, increased bracing, and 4 spuds of 30- to 36-inch diameter. The costs averaged $700,000 for the 195-foot length and $600,000 for the 150-foot length. In addition, it was determined that a cell should be included immediately upstream or downstream of the spud barge wall to protect it and provide a pivot point for tows. On a site-specific basis, costs were included for items such as bank excavation and spud barge costs, and a 25 percent

contingency factor was added to the pier/barge costs to cover uncertainties in design, such as lighting, ladders, and tie-offs.

Despite the changes, major concerns remained, leading to the elimination of DeLong pier/spud barges in favor of permanent guidewall extensions. This decision was based on concerns over safety, risk, dependability, usable life, maintenance needs, and uncertainty in the ability to realize time savings and the presence of a better performing alternative. In particular, spud barges would allow flow under the wall extension and could not provide a suitable surface for extending the unpowered kevels, which hold cuts along the guidewall. Both of these factors increase the potential for an unpowered cut to be drawn from the wall and into the dam or taken down river. In addition, this type of measure may become ineffective due to the potential for the spud barges to be damaged or moved out of position by approaching tows. The actual dependability of the piers/barges and the frequency and level of maintenance necessary to keep the spud barges operational is not well known. It is likely that due to the increased need for maintenance and higher potential for damage to spud barges that these structures may contribute to delays in some situations. These concerns, along with a revised design to the permanent guidewall extension (described below) which essentially eliminated impacts to navigation, allowed the study team to determine that permanent guidewall extensions should be used as part of any long-term implementation of this measure.

While some questions were raised regarding time savings, no changes where made. However, it was clarified that there is a difference between the savings to a particular tow using the lock and to the queue of waiting tows. The actual lockage time for a particular tow is only reduced by the faster extraction of the first cut (estimated at 7 minutes upbound and 9 minutes downbound for UMR locks). This is due to the fact that the tow must still remake along the extended guidewall. However, the next tow heading in the same direction (turnback) and other tows waiting in the queue benefit by the entire 22- to 27-minute savings in reduced lock usage time.

Switchboats with Remote Remake - Further analysis of boat size lead to increasing the required horsepower of switchboats operating with remote remake facilities to 2,200 to 2,400 hp to provide minimum safety under all flow conditions. While a 1,800 to 2,000 hp boat could work in most situations, the Coast Guard's rule of thumb of horsepower for safe operation in extreme high water is 250 hp per loaded barge. This means that nine loaded barges, the typical unpowered cut, would require roughly 2,250 hp. Boats of this larger size cost an estimated $205 per hour (including the factor for profit discussed previously) versus the $150 per hour previously estimated for smaller boats.

Due to safety concerns over backing cuts upstream, especially during high water periods, the additional costs associated with extending the upstream guidewall 300 feet were added. This provides room for the switchboat to extract the first cut along the wall, tie off the cut, move around to the downstream end, recouple, and move the cut upstream to the remote mooring. The higher costs of permanent guidewall construction and revised spud barge costs were incorporated into the cost estimates. These additional features are required to make upstream remote remake a viable operation.

This process was analyzed for its impacts on lockage times. While no quantifiable change is expected in the original time savings estimate, there is a higher likelihood of variability and increased potential for the time savings not to be realized for some tows. On average, the next tow should get to use the chamber 22 to 27 minutes faster. However, the actual time required for a tow to utilize the lock and remote site will increase by approximately 10 to 20 minutes over the existing lockage time. This time includes the 7.5 to 15 minutes required to move the approximately ½ to

1 mile upstream or downstream to the remote site. As a result, on average it is estimated that tows will only require approximately 5 more minutes in actual lockage/remake operations than they currently use. However, this process of moving cuts upstream essentially doubles the number of steps in the lockage process and increases the potential that if anything goes wrong on one of the steps, delays may occur that reduce or even eliminate the benefits to the queue. At a number of sites where the remote remake location is likely to be close to a mile from the lock chamber, it would be necessary to move both assist boats to one side of the lock to alternate pulling cuts. This is required to avoid delays associated with the switchboat not returning in time to pull the next cut.

Industry Self Help (With and Without Facilities) - The study team clarified that continued use of industry self help without the addition of facilities would be addressed in the without-project condition. It is already implemented in periods of major delay and will likely continue to be in the future. However, expanded use of industry self help in combination with structural improvements (guidewall extensions, remake facilities, etc.) would fall in the with-project condition. The study team also determined that even if facilities are not required for implementation, routine use of banks or unprotected areas may require the provision of facilities from an environmental protection standpoint.

At most sites, this measure is not currently implemented unless the lock has experienced a closure due to repairs or high water and very large queues of 10 to 12 tows or more are present. Based on safety concerns, industry recommends that the upstream guidewall be extended an additional 600 feet in combination with future use of this measure. This would provide a remake area without requiring the standard operation to involve the risk of backing cuts upstream above the dam to a remote remake site. Navigation industry highlighted that historically industry self-help has only been used as a stopgap measure to address temporary extreme delay situations.

As part of further researching industry self help and its potential for future use, a lockmaster expert panel meeting was held July 27-28, 1998, to gather data on current use and their expectations for future usage. Through lock data collection and the meeting, it was verified that currently industry self help is only used on a very limited basis. On average only 1 to 1.5 percent of the tows using the most congested locks now receive assistance through self help. In addition, due to a number of site-specific factors, this usage is not likely to increase significantly unless additional facilities are provided (guidewall extensions or remote remake).

During the lockmaster expert panel meeting, UMR lockmasters stated that little, if any, time savings was likely to occur if industry boats were just used to pull the first cut of double lockage tows from the chamber in place of using the tow haulage. The main saving with self help is in allowing remake to occur outside of the chamber, not in faster extractions. On further discussion, the lockmasters stated that the time required for line haul boats to face up to the unpowered cut and make its coupling was understated in the time analysis. This time was originally estimated at 6 minutes (face up and coupling), but the UMR lockmasters recommended using a factor of 8 minutes, which reduced the potential extraction time savings by 2 minutes for UMR locks. The IWW lockmasters felt the 6-minute factor was adequate due to site differences and presence of additional smaller tows, which are more efficient in face up and coupling operations. Following this update, the UMR upstream time savings was revised to 16 minutes upbound and 21 minutes downbound. However, the actual UMR barge using the lock only benefits by the 1 minute upbound and 3 minutes downbound associated with slightly faster extraction of the first cut. This is due to the fact that the even though the tow is not blocking the chamber, it still must take the time to remake before leaving the lock or remote site.

As part of the expert panel meetings and follow-up calls, lockmasters also provided site-specific data regarding how often and under what circumstances they believe these measures will be implemented. This information will be used in defining the without-project condition, which includes increased use of industry self help, and the various uses of industry self help with facilities in the with-project condition.

Guidewall Extension Costs - Constructing upstream guidewall extensions was originally assumed to require several significant periods of lock closure during the navigation season due to the requirements for constructing a 600-foot-long wall extension. These closures would result in millions of dollars of impacts to navigation. On reevaluation, an alternative was developed to stage construction over three to four winters (during the essentially non-navigable period). This would be accomplished by constructing 150- to 200-foot segments during the winter closure, starting from the end of the existing guidewall. The downstream walls that have less impacts from ice and flow conditions are anticipated to be constructed in one winter closure. The walls would be constructed using cellular sheetpile cells spaced approximately 100 feet apart connected by pre-cast concrete beams which would serve as the rubbing surface. Revisions to the design did not affect the downstream construction cost, but resulted in nearly doubling the first cost of the upstream guidewall, increasing it from approximately $12 million dollars per wall to $23 million. However, the increase in first cost is anticipated to be more than offset by the reduced impacts to navigation during construction.

The revisions to the guidewall designs along with evaluating the costs over its 50-year design life make this a viable option. In addition, permanent guidewalls addresses most of the safety concerns raised by providing a sturdy fixed wall, eliminating flow under the upstream guidewall, and providing an adequate structure to support unpowered or powered traveling kevels to hold cuts along the wall.

Powered Kevels with Guidewall Extension - Shortly after the preliminary screening, additional data analysis revealed that chambering times (gate closure and lock filling and emptying) occur faster than initially estimated. This lowers the average savings associated with powered kevels by 5 minutes (increasing total delay to the entry of the powered cut from 9 to 14 minutes associated with delays in crew returning to the second cut). The additional delay was due to the fact that during the lock chambering the crew had some time to walk back to the powered cut after tying off the unpowered cut along the extended wall, without further delaying the entry of the powered cut. This lowered the potential benefits of this measure to 6 minutes for upbound tows and 9 minutes for downbound tows.

However, following the identification of an improved approach to constructing the upstream wall extension, the study team reevaluated options to implement the powered kevel option. One option, adding additional personnel (2 persons per shift, 24 hours per day, 270 days per year) at the locks to move with the first cut, would eliminate the delays associated with the crew walking back to the second cut. The additional personnel, who could be hired for an estimated cost between $333,500 and $525,000 per lock, would improve the time savings by 14 minutes per turnback lockage, resulting in a savings of 20 minutes upbound and 23 minutes downbound.

Powered Ratchets - The study team clarified that this measure, which is currently being tested on a limited number of towboats, is part of the without-project condition. Their ultimate level of use depends on industry implementation and no Federal action by the Corps is required. However, industry raised concerns with back injuries, stating that the units are bulky and not likely to become widely used. This measure will be considered as part of the without-project condition. Due to a

high level of uncertainties in its eventual implementation, it is not possible to estimate the level of its future use.

TABLE 8: REVISED SMALL-SCALE MEASURES COST AND PERFORMANCE

Measure	Mean Time Savings for Double Lockage Tows	Average Annual Cost [3]
2 Switchboats with Guidewall Extension [1]	22 min upbound [2] 27 min downbound [2]	$5.0 mil/lock
2 Switchboats w/Remote Moorings [1]	22 min upbound 27 min downbound	$4.7 mil/lock
Industry Self Help without Facilities	Varies by site	$324k to $648k/lock
Industry Self Help with Guidewall Extension	16 min upbound [2] 21 min downbound [2]	$3.4 mil/lock
Industry Self Help with Remote Moorings	16 min upbound 21 min downbound	$1.1 mil/lock
Guidewall Ext with Unpowered Kevel	6 min upbound [2] 6 min downbound[2]	$2.7 mil/lock
Guidewall Ext with Powered Kevel	20 min upbound [2] 23 min downbound [2]	$3.3 mil/lock

Notes:
[1] Potential to provide additional approach time savings for downbound lockages.
[2] Only applicable to turnback lockages.
[3] Costs reflect Federal discount rate of 7.125 (1998 rate and 50-year project life). The costs exclude environmental costs, but revised design avoids significant impacts to navigation during construction.

Continued Industry Concerns - Despite the updates to the measures, industry continued to express concerns over the broader issue of increased risk and safety associated with towboat power measures. They stressed that spud barge walls, remote remake operations, and industry self help all increase risk and, while not directly quantifiable, increase the potential for higher rates of accidents, increased insurance premiums, and ultimately higher operating costs. Many of these concerns remain unquantified despite considerable study team efforts due to the limited past implementation of these types of measures and large number of possible variables associated with the sites, river and weather conditions, and crews and tows.

Final Secondary Screening (August 1998)

On August 27-28, 1998, the navigation study team met to reassess the August 1997 screening in light of the additional information that had been collected, modifications to the cost and performance of the measures, and clarification of the with- and without-project conditions. These changes made subsequent to the 1997 screening of the measures resulted in some items, which had previously been eliminated, no longer being clearly dominated by other measures. In particular, due to cost increases, towboat power measures no longer clearly out-performed guidewall extensions with powered or unpowered kevels. In addition, clarifying that powered ratchets are part of the without-project condition created the need to revisit the screening of the other crew element measures. Table 9 summarizes the revisions to the 1997 screening. Documented changes include revised towboat power measures and clarification of the with- and without-project condition (summarized in the preceding section) and further screening (summarized below). The screening of the other measures not affected by the additional information remained unchanged and is not discussed.

TABLE 9: SUMMARY OF FINAL SECONDARY SCREENING (AUGUST 27-28, 1998)

Measure	Completeness	Effectiveness	Efficiency	Acceptability	Without Project	Comments
Towboat Power						
Helper Boat					X	Already occurring in the without-project condition.
Switchboat w/Guidewall Extension						Recommended for further formulation.
Switchboat w/Remote Remake	X					Not recommended due to concerns with viability of remote remake.
Industry Self Help without Facilities					X	Part of the without-project condition.
Industry Self Help w/Guidewall Ext			X			Not recommended due to similar cost and superior performance of Guidewall Ext with Powered Kevels.
Industry Self Help w/Remote Remake	X					Not recommended due to concerns with viability of remote remake.
Tolls and Reports						
Congestion Tolls						Recommended for further formulation.
Excess Lockage Time Charges	X					Not implementable due to high degree of variability in uncontrollable conditions affecting lockage times.
Lockage Time Charges						Recommended for further formulation.
Publish Lockage Times		X				No benefit to be gained, since this information is already shared with RIAC.
Recreational Vessels						
Recreational Craft Scheduling		X		X		Actual experience showed no significant benefits; possibility for negative impact at lower locks; only assists limited sites; and acceptability concerns.
Recreational Craft Landings		X				No guaranteed benefits of measure; most sites already have adequate facilities; some potential to induce more recreational craft use.
Optimizing Decisions						
Scheduling Program		X				Part of the without-project condition. Lockmasters currently work with RIAC to implement the most effective scheduling when large queues are present.
Extended Guidewalls						
w/Powered Kevels						Recommended for further formulation.
w/Unpowered Kevels			X			Not recommended due to similar cost and superior performance of Guidewall Ext with Powered Kevels.
Mooring Facilities						
Cell or Buoy						Recommended for further formulation.
Crew Elements						
Universal Couplers	X					A viable unit has not been developed.
Crew Training		X				Crews already using various training methods, without significant differences in performance.
Permanent Deck Winches					X	Unquantified part of the without-project condition.
Additional Personnel		X				Limited potential time savings, added variability, and safety risks do not warrant implementation.
Powered Ratchets on Tows					X	Unquantified part of the without-project condition.
Powered Ratchets at Locks	X					Uncertainty of performance, reliability, acceptability, and safety do not warrant implementation.

TABLE 9 (Continued)

Measure	Completeness	Effectiveness	Efficiency	Acceptability	Without Project	Comments
Approach Improvements						
Guidewall Extension - US			X			Channel improvements provide majority of the approach benefits to be gained at a much lower cost, but guidewalls may be provided as part of other measure.
Channel Improvements - US						Recommended for further formulation.
Guidewall Ext + Chan Imp - US			X			Channel improvements provide majority of the approach benefits to be gained at a much lower cost, but guidewalls may be provided as part of other measure.
Aux. Lock Guardwall - US			X			Channel improvements provide majority of the approach benefits to be gained at a much lower cost.
Existing Lock Guardwall - US			X			Same as above.
Aux. Lock Guardwall + Chan Imp - US			X			Same as above.
Ex. Lock Guardwall + Chan Imp - US			X			Same as above.
Guidewall Extension - DS			X			Channel improvements provide majority of the approach benefits to be gained at a much lower cost, but guidewalls may be provided as part of other measure.
Channel Improvements - DS						Recommended for further formulation.
Guidewall Ext + Chan Imp - DS			X			Channel improvements provide majority of the approach benefits to be gained at a much lower cost, but guidewalls may be provided as part of other measure.

During the secondary screening revisit, the focus was on evaluating the implications of the revised cost and performance information as well as new qualitative data on items such as uncertainties in performance and increased safety issues. In general, the screening process recommended that, based on a large number of qualitative factors, the use of remote remake on a routine basis should not be recommended. In addition, guidewall extensions implemented in combination with either powered kevels or switchboats provide the greatest system benefits. Regarding crew element measures, permanent deck winches and powered ratchets on tows were defined as an unquantified part of the without project, while additional personnel and powered ratchets at the locks were screened based on limited effectiveness and concerns over safety.

Towboat Power - Initial discussions centered on the viability of remote remake options. Based on the information summarized below, the team recommended that for this system study the use of remote remake facilities as a routine, system efficiency measure be eliminated from consideration under the completeness criterion. This is due to the fact that analysis is not able to account for all actions or to ensure implementation. This qualitative screening resulted in the elimination of switchboats with remote remake and industry self help with remote remake. However, on more limited basis, its use may be acceptable, for example, to clear excessive queues following a lock closure or during brief construction periods.

While remote remake has been tested on a short-term basis at Old Lock 26 in the 1970's and is periodically conducted as part of industry self help to clear large queues following lock closures, it presents a number of issues of concern regarding routine, long-term, system-wide implementation. Remote remake requires additional operations, most notably two additional approaches per

lockage, as each cut must separately approach the remake area. It also involves more movements out in the uncontrolled areas immediately upstream and downstream of the lock. Of particular concern are the operations conducted immediately above the lock which are vulnerable to strong outdraft conditions and present the potential for high levels of property damage if any process goes wrong. The following list summarizes the rationale used for screening the use of remote remake as a potential system-wide long-term measure:

- ***Risk*** - The additional steps add risk and increase the potential for something to go wrong by involving more people, boats, and operations. Many of these rely on human performance, which can vary in dependability and add risk. Routine remote remake would increase risk over current levels.

- ***Safety*** - Reduced safety related to the added steps and risk. In addition, the operations occurring at the remote remake area would be isolated from the lock. The lock has people available to assist in the case of an emergency, which is not the case with remote remake facilities.

- ***Time Savings*** - Variability is larger with this measure than guidewall extensions or other measures due to the increased number of steps, operations, and individuals involved. This reduces the study team's confidence that the time savings identified will be achieved. In addition, it is very likely that periodically no time will be saved and on occasion these operations could result in delaying lockages.

- ***Implementation*** - Despite efforts to develop a measure that could be implemented under all flow conditions, the regularity of use is somewhat questionable. Based on concerns expressed by industry, they may simply choose not to implement the measure on occasion or regularly due to the unacceptability of risk and safety issues from their perspective.

- ***Dependability/Reliability*** - The as yet unquantified site and flow condition factors at potential remake locations may limit the amount of time the remote site can practically be used or at a minimum its efficiency. Many of these issues cannot be fully understood without a site-specific model study or physical test.

- ***Maintenance*** - Remote remake provides additional challenges and funding needs as the Corps will have to provide service to these high maintenance facilities (spud barge option) that may not even be in view of the lock and dam facility. In addition, investment in remote remake does not allow for cost reduction in other measures like guidewall extensions (guidewall extensions can be incorporated into a usable component if lock expansion becomes justified in the future).

- ***River Congestion Issues and Concerns*** - Use of remote remake and especially industry self help, which involves three tows or more in the operations, increases the risk of collisions and the potential for delay and inefficiencies as tows congest the immediate area at the lock.

Guidewall Extensions - Subsequent to screening the remote remake options, the remaining measures that provided the largest system benefits all involved the use of a guidewall extension. These measures included switchboats, industry self help, powered kevels, and unpowered kevels. In addition, it was noted that the major portion of the cost of all of these measures was associated with the construction of the guidewall.

A qualitative and quantitative comparison was conducted based on the similarities in cost of these measures. This evaluation was based on essentially a cost effectiveness analysis (efficiency criterion) that revealed that the greatest savings per unit cost is associated with the powered kevel option. As a result, this measure was successively compared to the other guidewall option.

The unpowered kevel option was screened out based on the efficiency criterion due to the fact that it provides considerably less time savings benefits than the other guidewall extension options (e.g., powered kevels or switchboats), while it has comparable costs to the powered kevel option.

The study team also screened out the industry self help with guidewall extension measure based on efficiency. This measure has a similar cost to the powered kevel option, but provides less benefit per lockage. Also, the use of self help depends on the presence of a large queue (lockmasters indicated at least 5, but more commonly 10 to 12 tows must be at the site prior to implementation). The implementation also requires considerable coordination, time, and effort to organize, and once in operation has highly variable performance based on factors associated with the assisting tow and its equipment and crew.

While switchboats with guidewalls cost considerably more than guidewall extensions with powered kevels, they do provide some additional time savings. As a result, switchboats with guidewall extensions will need to be considered further in the plan formulation process. However, based on the fact that most benefits are provided at a lower cost by the powered kevel option, the study team anticipates that if either measure is justified that powered kevels would be recommended for implementation prior to the switchboat option. This fact would allow the initial efforts in the plan formulation process to focus on determining if a guidewall extension option is justified. If it is, the further evaluation of how to implement the measure can remain somewhat open, since once guidewalls are in place a switchboat or even industry self help on a limited basis could be implemented relatively easily.

Crew Elements - Based on further evaluation following the clarification that powered ratchets on tows are part of the without-project condition, it became apparent that the study team would need to reevaluate powered ratchets provided at the locks, permanent deck winches, and additional personnel measures. These measures initially had been screened out on the basis of being less effective than powered ratchets on tows.

On further evaluation, the study team recommended that permanent deck winches be included along with powered ratchets on tows as an unquantified part of the without-project condition. This recommendation was based on the fact that like powered ratchets, they are in limited use at the present time. However, their ultimate level of use depends on industry initiative. Both measures have relatively limited savings potential and some significant drawbacks slowing their implementation (i.e., high cost or potential for back injuries) and as such are not likely to significantly influence future lockage times or the system analysis.

The use of the powered ratchets at the lock was considered as a potential with-project improvement. However, it was eliminated as a potential improvement measure on the completeness criterion due to safety concerns related to potential injuries from lowering the unit onto each tow and possible back injuries associated with moving the units around on the tows. This measure also raised concerns over the limited testing, unproven reliability, and the fact that tows may come to rely on its availability. This could contribute to increased delays during periods when the units break down or become unavailable.

The study team eliminated the additional personnel measure from consideration on the effectiveness criterion based on the limited time savings potential and uncertainty associated with implementation. These concerns, along with the additional variability and safety risks associated with involving more people in the lockage process, simply do not warrant its implementation.

Other Measures: No further revisions to the other measures were necessary due to the fact that no substantive changes had occurred affecting the earlier decisions to either screen or carry measures forward.

SMALL-SCALE CONCLUSIONS

The initial qualitative screening process and the secondary screening summarized above resulted in narrowing the potential range of small-scale measures from 92 to 5. Table 10 summarizes the surviving measures that were carried forward for further analysis using the system economic models and used in developing alternative plans.

TABLE 10: WITH-PROJECT SMALL-SCALE MEASURES
Guidewall Extensions with Powered Kevels
Switchboats with Guidewall Extensions
Congestion Tolls/Lockage Time Charges
Mooring Facilities (Cells or Buoys Adjacent to Lock Approach)
Approach Channel Improvements

In addition, clarifications in the without-project future lead to the inclusion of several small-scale measures. Table 11 summarizes the small-scale measures that are likely to occur to some level in the without-project condition. Due to the lack of information and high degree of uncertainty regarding the potential for increased helper boat use and implementation of deck winches and powered ratchets, these items will not be accounted for in the economic analysis. If new information becomes available in the years subsequent to this study, the Corps may choose to reevaluate this decision. The future use of industry self help and lock operating procedures in the without project will be considered to the extent possible.

TABLE 11: WITHOUT-PROJECT SMALL-SCALE MEASURES
Helper Boats
Industry Self Help without Additional Facilities
Deck Winches
Powered Ratchets
Lock Operating Procedures (N-up/N-down)

SUMMARY OF MEASURES

The following section provides a brief description, a summary of the final cost and performance estimates developed, and a summary of the final secondary screening analysis for each measure analyzed during the secondary screening.

- **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. In addition, it was determined that switchboats and industry self help could be implemented in combination with guidewall extensions or remote remake facilities. Clarification of the with- and without-project conditions revealed that helper boats and industry self help implemented without additional facilities are part of the without-project condition and as such do not represent new improvement measures.

Remote remake conducted in combination with either switchboats or industry self help was screened as unacceptable for routine system-wide implementation. This screening was determined based on the additional steps, increased risk, reduced safety, uncertainty in time savings, lower dependability, and high maintenance associated with this measure. Finally, the use of industry self help with guidewall extensions was screened based on the fact that it is out-performed at a similar cost by powered kevels with guidewall extensions. This process resulted in only Switchboats with Guidewall Extensions from this category providing a potential with-project improvement option.

Helper Boats.

Description of Measure: The use of helper boats (800 to 1,200 hp) to guide a tow heading downstream into a lock chamber is currently used at times as a safety measure. The helper boat helps counter the effects of river currents (outdraft) on the upstream approach, thereby allowing a more controlled and efficient (quicker) entry into the chamber. This measure looked at the potential incremental benefits of expanding the use of helper boat assistance that is already regularly occurring at most lock sites. Using helper boats to pull unpowered cuts along extended guidewalls was also evaluated, but it was determined that they have inadequate horsepower to safely conduct this operation under all conditions.

Time Savings: Helper boats provide time savings based on their ability to improve the lock approach process. Improving other steps in the process, such as pulling the first cut of double lockages, was not considered to be safe with this size of boat. In total, it appears that only limited additional benefits would be gained by increasing the use of helper boats. Some additional time savings would be possible if additional tows, not currently using a helper boat, had assistance on downbound approaches. Table 12 identifies the potential savings identified; however, these savings are limited by the fact that many tows already receive assistance. At most sites, nearly all tows currently receive assistance during outdraft conditions, the time when their use is most beneficial. In addition, these benefits are even more limited in situations where a queue exists and most lockages are turnbacks, since only fly and exchange lockages benefit significantly.

TABLE 12: ESTIMATED AVERAGE TIME SAVINGS FOR HELPER BOAT WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25

Delay Reduction	Straight Single	Knockout and Setovers	Straight Double
Approach (normal flows, fly and exchange)	6 min downbound	8 min downbound	11 min downbound

* Time savings shown is only for the limited number of tows not currently receiving assistance.

Cost: The cost of a helper boat ranges from $430,000 to $785,000 per year per boat for 270 days of use, roughly $100 per hour.

Screening Recommendation: This measure is part of the without-project condition based on the fact that helper boat assistance is currently occurring and increasing 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 are highly variable and uncertain.

Switchboat with Extended Guidewalls.

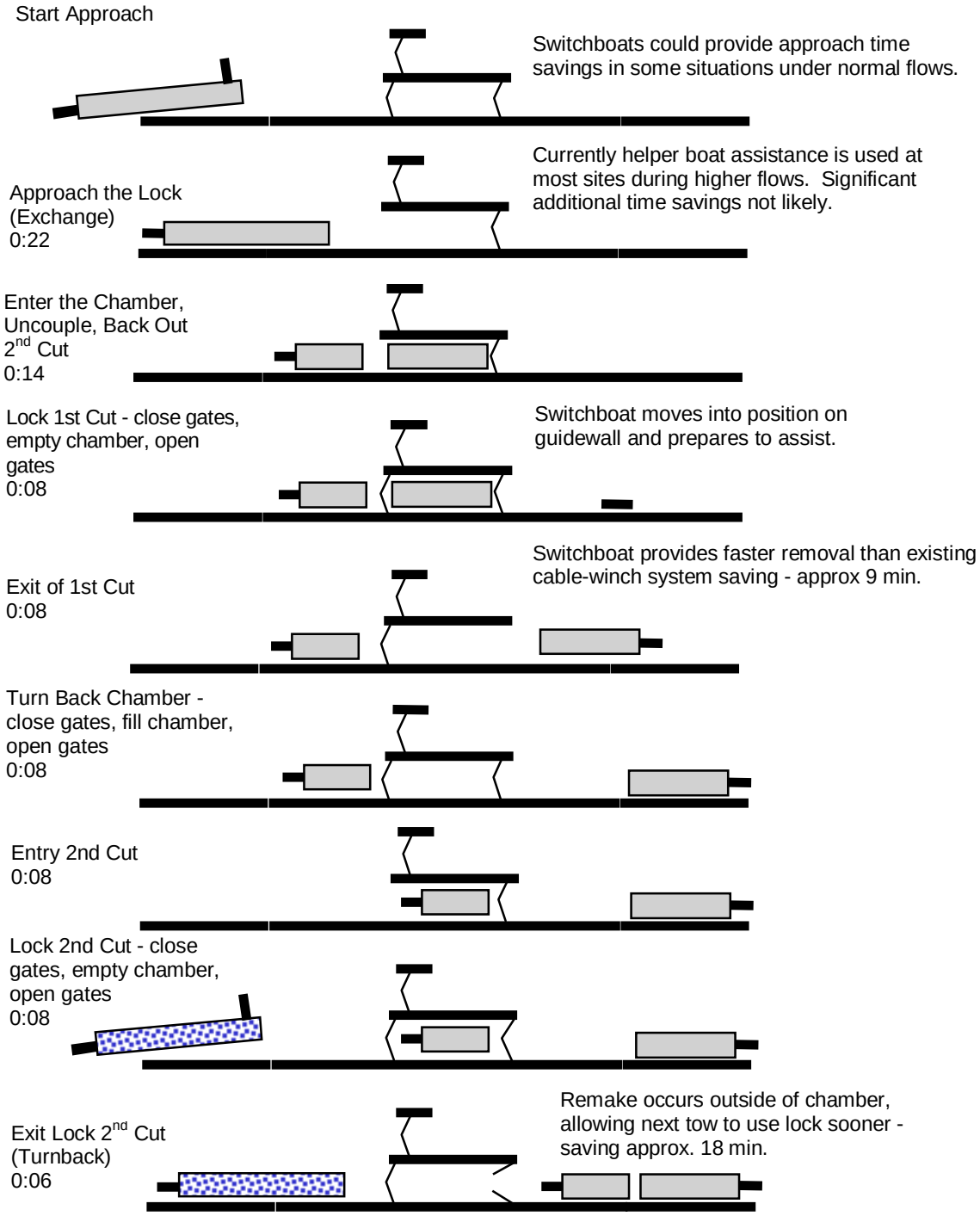
Description of Measure: Using switchboats in combination with extended guidewalls was one of two primary ways identified to implement switchboat use (see Figure 3). Switchboats in the 1,800 to 2,000 hp range were determined to be able to safely extract the unpowered first cut of double lockages out along 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. Two separate options were considered to extend the guidewalls: cellular sheetpile construction with pre-cast concrete panels or DeLong pier/spud barges. The guidewall extension 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: Switchboats primarily provide time savings based on their ability to improve two steps in the lockage process: pulling the first cut and remaking the tow outside of the chamber. Switchboats allow for faster extractions of the unpowered first cut than the existing cable winch system. If cuts are extracted along an extended guidewall, the recoupling (remake) can occur outside of the chamber, allowing the next tow traveling in the same direction to use the lock. Also, in some situations switchboats can provide some benefit to currently unassisted approaches and downbound chambering times, but on average these savings are very limited. For tows traveling downstream, moving the unpowered cut farther down the guidewall allows faster chamber emptying since the danger of breaking lines would be reduced. However, due to the limited water elevation differences at most locks on the UMR, the savings is less than 1 minute.

TABLE 13: 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
Total Time Savings Potential*	22 min upbound * 27 min downbound *	7 min upbound 9 min downbound

* Total does not include approach assistance, but assumes extended guidewalls.



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 3: Double Lockage Elements - 2 Switchboats with Guidewall Extensions

Total savings benefits to tows waiting in queue are estimated at 22 minutes per double lockage for an upbound (upstream) tow and 27 minutes for a tow heading downstream at UMR Locks 11 to 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 it still must remake even if the chamber is available. This lowers the savings to 7 and 9 minutes, respectively.

Cost: The annual cost of an 1,800 to 2,000 hp switchboat is approximately $1,129,000 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.

Guidewall extension costs and useful life vary considerably based on the method used. One option is to provide permanent guidewall extensions using cellular sheetpile construction with pre-cast concrete panels as a rubbing surface. The estimated first cost of permanent guidewall extensions averaged $23.5 million for the upstream walls and $12.9 million for the downstream walls. This cost includes an unpowered traveling kevel, which improves safety by keeping the cuts along the wall. One key difference is that while permanent guidewall extensions have a much higher first cost, the annual cost of $32,000 is much lower and the expected life of 50 years is considerably longer.

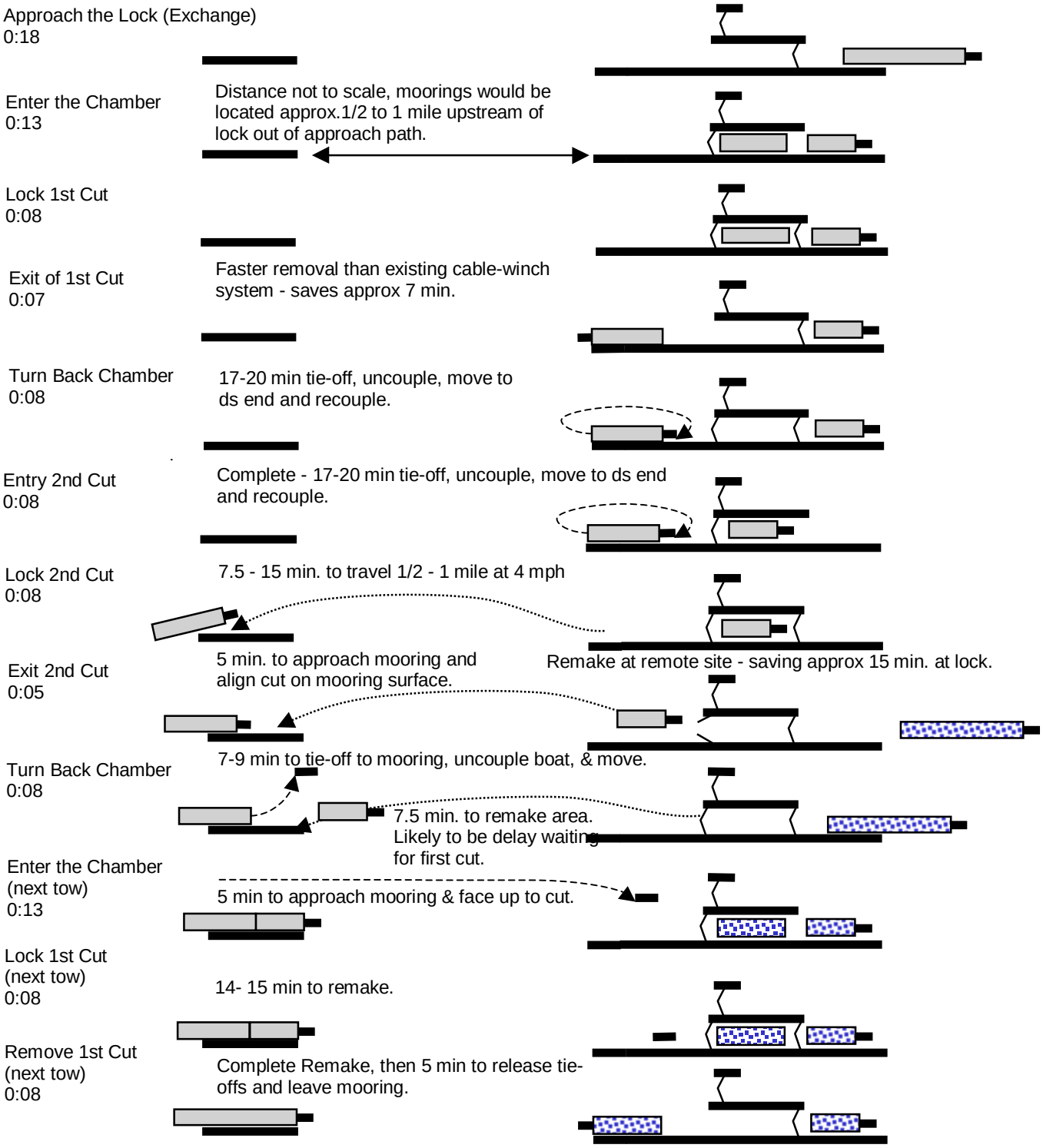
The second option is to purchase DeLong piers/spud barges ($700,000 each) for an estimated first cost per wall of $3.2 million for 3 piers and placement using a heavy lift crane. Annual upkeep of the piers is estimated at $40,000 per pier for patching and pumping out water. Every fifth year these piers would be dry docked, resided, and repainted at a cost of approximately $200,000 per pier. With the planned rehabilitation, the piers have an estimated useful life of 20 years.

The estimated annual costs range from $3.3 million per lock site for two boats and spud barge guidewall extensions with a 20-year project life to $5.0 million per lock site for two boats and cellular sheetpile constructed guidewalls with a 50-year life. Costs for a permanent guidewall extension 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, the annual cost to implement switchboats with the permanent guidewall extension on the IWW is over $13.1 million per lock site.

Screening Recommendation: This measure was carried forward for further analysis in the plan formulation phase. However, the use of spud barges was eliminated as an option for extending the guidewalls based on safety, usable life, and maintenance concerns. In particular, a spud barge extension increases risk by allowing flow under the wall extension and by not providing a suitable surface for extending the unpowered kevels, which can hold cuts along the guidewall. Both of these factors increase the potential for an unpowered cut to be pulled from the wall and into the dam or moved down river. In addition, this type of measure is less reliable and may become ineffective due to the potential for the barges to be damaged or moved out of position by approaching tows.

Switchboats with Remote Mooring Facilities.

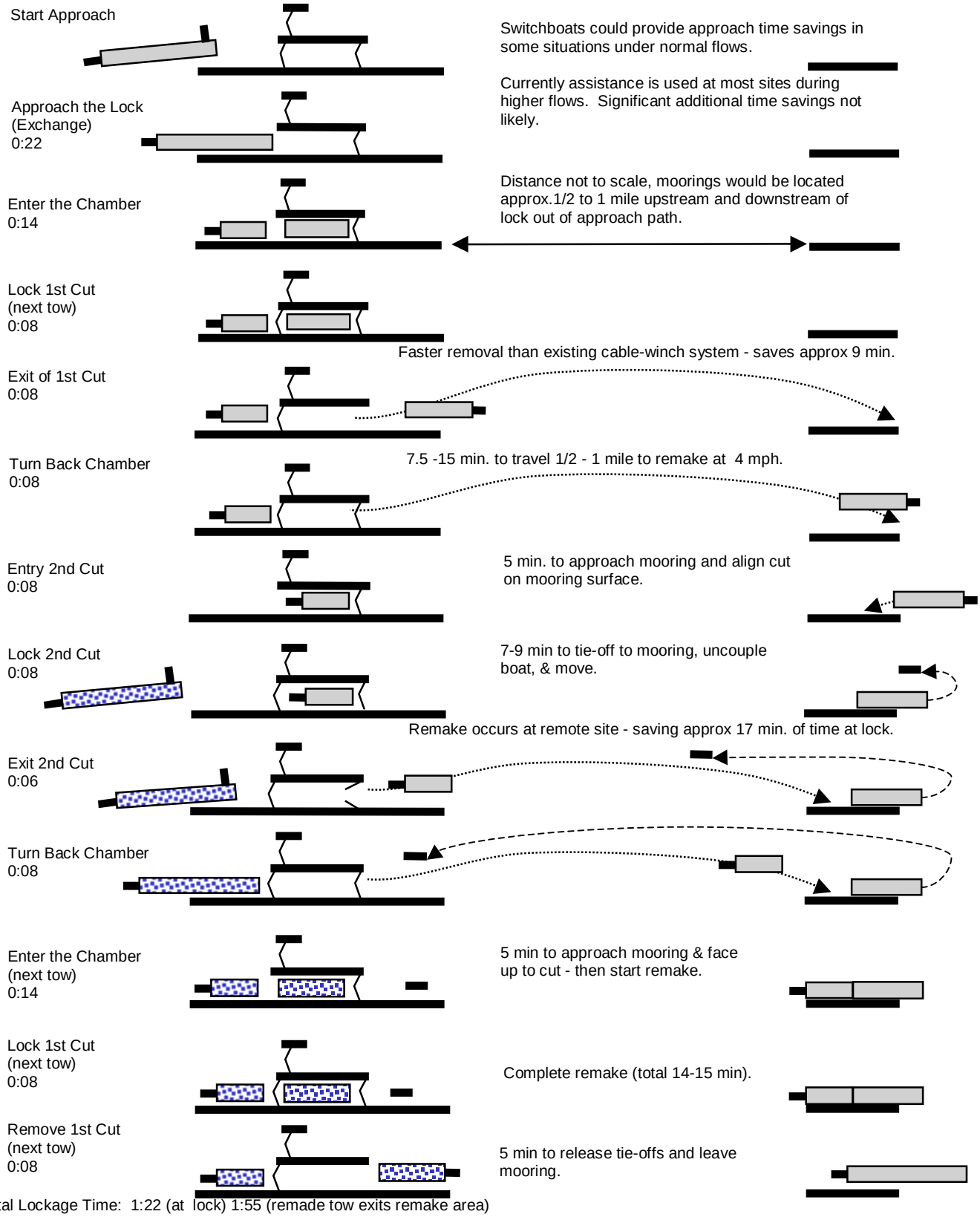
Description of Measure: In contrast to the previous measure, larger boats in the 2,200 to 2,400 hp range were determined to be necessary to safely extract the unpowered first cut and push it to a remote mooring under all flow conditions. The additional size allows them to remove an unpowered cut from the chamber and move it to a remote mooring facility (see Figures 4 and 5).



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: Double Lockage Elements - 2 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 5: Double Lockage Elements - 2 Switchboats and Remote Moorings Downstream Direction

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. By pulling the unpowered barges away from the chamber, guidewall and approach path to a remote mooring facility, the lock is freed up for tows waiting in either direction (unlike guidewall extension options that only move barges out of the way of tows heading in the same direction). They can also help tows approach locks and can move ice and debris out of the way. Their use requires construction of the 300-foot upstream guidewall extension and mooring facilities, flat landing surfaces constructed of mooring cells and spud barges, above and below the lock.

Time Savings: Switchboats primarily provide time savings based on their ability to improve two steps in the lockage process: pulling the first cut and remaking the tow outside of the chamber. Switchboats allow for faster extractions of the unpowered first cut than the existing cable winch system. Removing the cut to a remote mooring area for remake frees the chamber for the next tow traveling in either direction. As mentioned under the previous measure, removing the unpowered cut of downbound tows from the guidewall allows limited improvements in chamber emptying times since the danger of breaking lines would be eliminated.

Tows waiting in queue generally can benefit from the full 22- to 27-minute reduction in lockage time. However, 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 currently would. 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 that 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 a reduction in efficiency. This results in a more limited additional time of approximately 5 minutes, associated with the need for an additional approach at the mooring area. By using larger boats and moving the switchboat around on the wall so it can push upstream, the operations seek to minimize safety concerns and provide benefits under virtually all flow conditions.

TABLE 14: 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 (with extended guidewalls - turnback lockages only)	15 min upbound 18 min downbound	Tow still remakes; location is moved to end of the guidewall
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.

Cost: Implementing a switchboat measure involves three primary costs: switchboats, remote moorings, and 300-foot upstream guidewall extension. The cost of a 2,200- to 2,400-horsepower switchboat is estimated at $1.3 million per year per boat for 270 days of use. Most lock sites would require two boats to obtain full benefits.

Remote moorings require the construction of two cells and the purchase of three spud barges having an estimated first cost of $3.7 million per mooring including placement costs. Annual upkeep and periodic maintenance costs are shown in Table 15 below. The first costs of the 300-foot upstream guidewall extension range from $2.1 million for a DeLong pier wall to $11.7 million for cellular sheetpile construction.

These costs result in an estimated annual cost of $4.2 million per lock with a DeLong pier/spud barge guidewall extension to $4.7 million per lock with cellular sheetpile construction guidewall extension (for two boats, upper and lower moorings, and a 300-foot guidewall extension). As mentioned under the previous measure, the costs for a permanent guidewall extension at IWW locks are considerably higher, resulting in an average annual cost of $6.6 million per lock site.

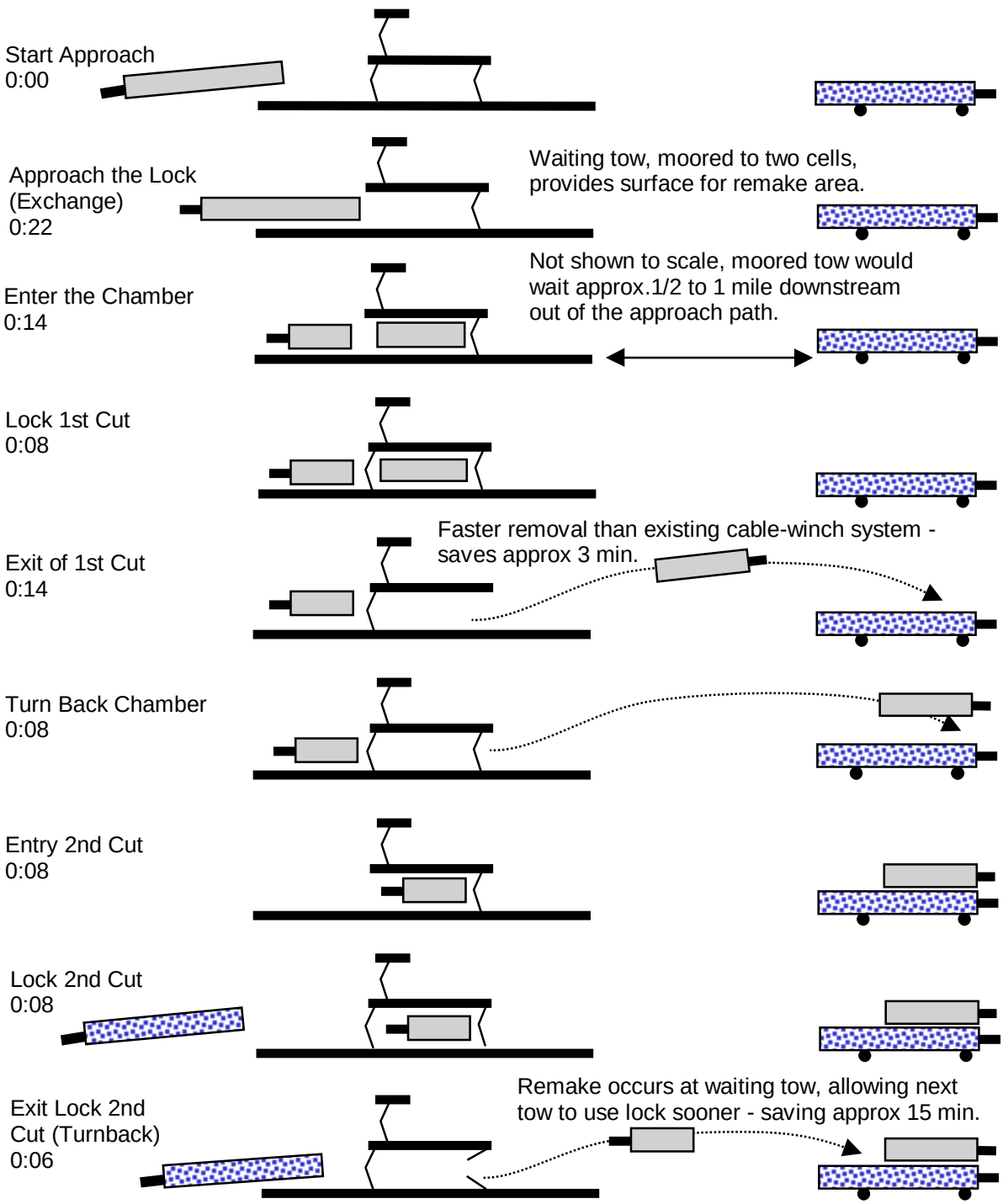
TABLE 15: COST OF REMOTE MOORINGS USING MOORING CELLS AND SPUD BARGES

First Cost Items	Cost
- First Cost of 2 Mooring Cells	$ 800,000
- First Cost of 3 200-foot 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 Items	**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

Screening Recommendation: This measure was initially recommended for further consideration. However, based on further review and consideration, remote remake was screened out as unacceptable for routine system-wide implementation. This screening was determined based on the additional steps, increased risk, reduced safety, uncertainty in time savings, lower dependability, and high maintenance associated with this measure.

Industry Self Help.

Description of Measure: Already put in place on occasion, this measure relies on navigation industry tows to help one another extract unpowered cuts without the assistance of lock personnel or equipment when there is significant congestion at a lock. When used, a towboat would not just wait in line for its turn to lock. Instead, it would act similarly to a switchboat, removing an unpowered cut from the lock chamber and taking it along an extended guidewall or away from the lock for recoupling along a waiting tow traveling in the opposite direction (see Figure 6). This leaves the lock open for the next waiting tow. Self help eliminates the need for tow haulage equipment. Some use of this measure will likely continue into the future regardless of any actions recommended by the Navigation Study. However, as part of adapting this measure for use as a



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 6: Double Lockage Elements - Industry Self Help with Mooring Cells

potential routine procedure, mooring cells or guidewall extensions could be provided to improve efficiency, safety, and reduce environmental impacts.

Industry self help can fall in either the without- or with-project condition depending on whether additional facilities are provided. If additional facilities are not provided, it remains a part of the without-project condition. It was also determined that even if facilities are not required for physical implementation, routine use of banks or unprotected areas may require the provision of facilities from an environmental protection standpoint. If guidewall extensions or remote remake facilities are provided as part of implementing the measure, it becomes a with-project alternative.

Time Savings: Industry self help primarily provides time savings based on its ability to improve tow steps in the lockage process: pulling the first cut and remaking tows outside of the chamber. While some additional time savings would be possible if additional tows had assistance on approaches, the less maneuverable line haul boats generally do not provide this type of assistance. Industry line haul boat assistance allows for a marginally faster extraction of the unpowered first cut than the existing cable winch system. However, more time is required than with switchboat assistance due to the reduced maneuverability and heavier lines. Removing the cuts to a remote mooring area for remake frees the chamber for the next tow traveling in either direction. In addition, for tows moving downstream, removing the unpowered cut from the guidewall would allow for somewhat faster emptying of the chamber since the danger of breaking lines would be reduced. However, due to the limited elevation difference at UMR sites, this savings averages less than 1 minute.

Industry self help provides estimated time savings to tows in queue of 16 minutes upbound and 21 minutes downbound for UMR Locks 11 to 25. However, benefits to the actual tow vary based on where the tows remake, the scheduling approach, the number of tows requiring double lockages, and the number and experience of the assisting boats. The numbers shown in the following 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 (as at some locks in the without-project condition), the benefits are reduced. In these instances, the time savings are 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 an adequate length to allow the largest tows on the system (most 5,000 and 6,000 hp boats) to remake without blocking the chamber. The use of remote facilities reduces benefits to the particular tow by roughly 5 minutes due to the additional approach required at the remote facility.

TABLE 16: 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
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 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 (approximately 30 percent of the navigation season); benefits would not accrue when smaller queues are present and at some site-specific locations due to physical constraints.

Cost: The boat costs of industry self help are limited to the additional variable costs required for their use since they are already waiting in queue. These costs are estimated at $324,000 per year per lock direction. This allows for $50 per hour of additional fuel use 24 hours a day for 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. The construction of three cells ($500,000 each) has an estimated first cost of $1.5 million. Annual upkeep of the piers is estimated at $20,000 per cell. Cells have an estimated useful life of 30 years. The estimated first cost of permanent guidewall extensions averaged $23.5 million for the upstream walls and $12.9 million for the downstream wall.

The average annual cost for self help depends on how the measure is implemented: $324,00 to $648,000 for just the assisting boats, $1.1 million per lock (for remote remake - three mooring cells above and three below the lock plus the fuel cost of assisting boats), and up to $3.4 million per lock (for permanent guidewall extensions). Illinois Waterway costs for guidewall extensions would again be higher and implementation with self help is estimated at $11.5 million annually per site.

Screening Recommendation: This measure was initially recommended to be carried forward as part of the with-project condition. However, based on further review and consideration, industry self help with remote remake was screened out as unacceptable for routine, system-wide implementation. This screening was determined based on the additional steps, increased risk, reduced safety, uncertainty in time savings, lower dependability, and high maintenance associated with this measure. In addition, industry self help with guidewall extensions was screened based on the fact that it is out performed at a similar cost by powered kevels with guidewall extensions.

However, some continued use of industry self help without additional facilities is expected to continue as part of the without-project condition.

- **Tolls and Reports**

The toll collecting and reporting measures seek to reduce delays through creating incentives to reduce overall lockage times and shift demand away from congested locks. Only a comparison of the various toll measures was possible, since the system models would need to be used to set the level of any charges and determine the potential benefits. However, both the Excess Lockage Time Charges and Publish Lockage Times measures were screened out as described below.

Congestion Tolls.

Description of Measure: Tolls could be collected to alter the distribution of towboat traffic on the system, reducing delays at the locks. This measure could be implemented only if a current Federal law prohibiting charging of tolls for watercraft passing through locks is changed. If implemented,

tolls would be collected from tows, and possibly from recreational craft, using congested locks. It assumes that a fee could be charged at locks experiencing significant delay or that a licensing fee would be charged for use of the system. The goal would be to shift potential traffic away from congested locks to alternative modes of transportation or other portions of the inland waterway system.

Time Savings: Not quantified at the time of the screening. A system-wide evaluation is needed to determine the toll levels and evaluate impacts.

Cost: The primary costs associated with this measure include developing a congestion toll structure, setting the level of the tolls, and ongoing 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 highest 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 the possibility of reducing transportation options and as a result increasing shipping costs on remaining modes; and secondly negatively impacting recreation, a significant economic activity in the study region. These cost estimates result in an average annual cost of $280,000 to implement congestion tolls for the system.

TABLE 17: COSTS TO DEVELOP A CONGESTION TOLL SYSTEM

First Cost to Develop Toll Structure, Level, System	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	$ 65,000
Annual Toll Collection Costs	**Cost**
Collection and Summary of Data	$ 68,000
Billing and Collection	$120,000
Contingency 25%	$ 47,000
Total	$235,000

Screening Recommendation: This measure was carried forward for analysis using the system models.

<u>Excess Lockage Time Charges</u>.

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.

Time Savings: Not quantified at the time of the screening. It could result in significant time savings for the tows that currently take the longest, but determination of the actual delay reduction would require assumptions of industry response.

Cost: Estimated costs are the same as Congestion Tolls—$280,000 annually for the system.

Screening Recommendation: The Excess Lockage Time Charges measure was screened out based on the completeness criterion. An excess lockage time cannot be determined, since defining excess is highly site specific and could not equitably account for the great amount of variability in lockage times due to variable weather, flow, fog, ice, and wind. 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, lockage time charges, which could be implemented at the same cost, create an incentive for all lockages to improve.

Lockage Time Charges.

Description of Measure: This measure seeks to charge all vessels based on the length of time the lock is in use. While similar to congestion tolls, these charges would be set at a lower level in an effort to create an incentive to improve efficiency rather than reduce the use of a congested lock. Tows would not be charged, however, for lockage elements that they cannot control such as gate opening and closing and chamber filling and emptying time.

Time Savings: Not quantified at the time of the screening. It could result in significant time savings since all tows in a queue would have an incentive to reduce lockage time by whatever means. For example, the charge could encourage the use of powered ratchets, higher horsepower line haul boats, greater use of towboat assistance, etc. A system-wide evaluation is needed to determine the appropriate charge and to evaluate impacts. Determination of the actual delay reduction will be based on assumptions of industry response.

Cost: Same as for Congestion Tolls—$280,000 annually for the system.

Screening Recommendation: This measure was not screened, but could be viewed as a sub-category or way to implement a congestion toll. In addition to being a form of demand management measure, the real time savings benefit of a time charge is that it creates an incentive for industry to adopt other measures to reduce the fees they pay. However, rather than any single measure, the lockage time charge encourages each company to pursue the measures most beneficial for them and creates an incentive for the development of innovative technologies.

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 would assist companies and the industry in identifying which tows perform the best and which tows may need additional equipment, training, or crew members. This publicity should encourage all companies to improve their performance through peer pressure and public recognition.

Time Savings: Not quantifiable based on existing data, but limited due to current level of coordination and information sharing which already occurs.

Cost: 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, the 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 annually for the system.

Screening Recommendation: This measure was screened out on the basis of effectiveness. Despite the relatively low cost of the measure, it is not likely to significantly decrease system delays. In addition, nearly all of the benefits are currently captured since ongoing communications and coordination between the lockmasters, the River Industry Action Committee (RIAC), and the towboat companies address many of these issues. In particular, lockmasters currently share information on those tows taking excessive amounts of time in approaching or using the locks.

- **Recreational Vessels**

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 category addresses the scheduling of recreational vessel usage and construction of recreational craft landings above and below the locks as ways to reduce these conflicts and associated delays.

These two measures directed at recreational craft lockage issues were eliminated as part of the quantitative screening. However, it is important to note that the implementation of any improvement measure would also benefit recreational craft by reducing overall delays. Because a measure is not specifically targeted to provide benefits to recreational craft does not mean that recreational users will not be better accommodated. In addition, as part of the screening of large-scale improvements, various lock chamber sizes were evaluated, including non-commercial or recreational craft chambers. These measures were also screened out based on costs and benefits.

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.

Time Savings: In the mid-1970's, the St. Paul District of the Corps of Engineers experimented with scheduling recreational craft lockages at Locks 2, 3, and 7. The St. Louis District conducted a similar test at Lock 25 during the 1980 navigation season. The tests did not result in 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. A quantitative assessment comparing existing recreational use and the time required of designated periods showed little or no time savings potential at the lower lock sites which currently have the greatest commercial delays. While some savings appear possible at the upper sites, there currently are not significant delays in the area.

Cost: Implementing recreational craft scheduling would be a relatively low-cost measure. The major costs, summarized in the table 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, possible collection of survey data, notifying the public of any changes, and developing adequate signage and publicizing any new schedule.

TABLE 18: FIRST COSTS TO DEVELOP RECREATIONAL 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. These costs would result in a total annual cost of approximately $85,000 for the system.

Screening Recommendation: This measure was eliminated on the effectiveness and acceptability criteria. This decision was based on the past study results and time analysis, which did not demonstrate significant benefits to the system.

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.

Time Savings: Non-quantifiable time savings are based on existing data. Potential sites include Locks 12 downstream, 16 upstream, 17 upstream, 20 upstream, 22 both directions, 24 downstream, 25 upstream, Melvin Price downstream, Lockport upstream, Brandon Road downstream, and La Grange both directions. Despite these sites being identified from a review of information on boat ramp facilities, the lockmasters at these sites generally did not feel that significant delay reductions would occur. Some 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.

Cost: The following tables summarize the expected costs associated with the development of a new boat landing at a currently undeveloped site. The estimated costs of $270,000 for construction and $12,500 for annual operations are based on recent Corps construction and operations activities plus some contingencies. This results in a total average annual cost of $38,000 per landing, not including land costs or environmental impacts.

TABLE 19: FIRST COSTS OF DEVELOPING A BOAT RAMP AND PARKING LOT	
Item	**Cost**
Site Location (Identify and 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

Screening Recommendation: This measure was screened out on the effectiveness criterion. It cannot be determined what impact this will have on the recreational demand for the locks. The presence of additional recreational facilities could actually increase recreational demand for the lock. Due to the fact that most recreational lockages contain multiple recreational craft, some reduction in the number of recreational craft using the lock may not actually significantly reduce the number of recreational craft lockages. In addition, landings are already in place at most sites with the greatest recreational demand, and many of the lockmasters report that numerous recreational lockages appear to be conducted simply for the experience of using the lock and are not based on the adequacy of landings. Other surveys have indicated a higher percentage of recreational lockages associated with marina-based craft and those boats making longer trips (multiple pools); these types of lockages would not be reduced with additional landings.

- **Optimizing Decisions**

Optimizing decisions focus 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).

Scheduling Program.

Description of Measure: This measure seeks to achieve timesaving by optimizing the scheduling sequence of tows using a PC-based scheduling program. The program would be based on mathematical modeling of various types and configurations of queues.

Time Savings: The time savings are not directly quantifiable with existing data. Lewis Berger and Associates, Inc. (1981) in evaluating the benefits of a scheduling program were not able to identify significant changes in system throughput. They estimated that implementing the measure might only increase lock throughput by approximately 3 percent. 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.

Cost: 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. Table 20 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. These expenses result in a total annual cost of $87,000 for the system.

TABLE 20: FIRST COSTS OF COMPUTERIZED SCHEDULING PROGRAM

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

Screening Recommendation: While a computerized scheduling program is not currently available at the lock sites, the lockmasters in coordination with the River Industry Action Committee (RIAC), currently implement N-up/N-down and even N-up/M-down scheduling as appropriate. The available information indicates that as N-up/N-down and N-up/M-down scheduling is adapted to a specific queue, very few additional benefits could be gained by going to any other scheduling. As a result, the study team screened out this measure on the effectiveness criterion, since the benefits are already captured as part of the without-project condition. However, scheduling as currently implemented does provide substantial benefits and should continue.

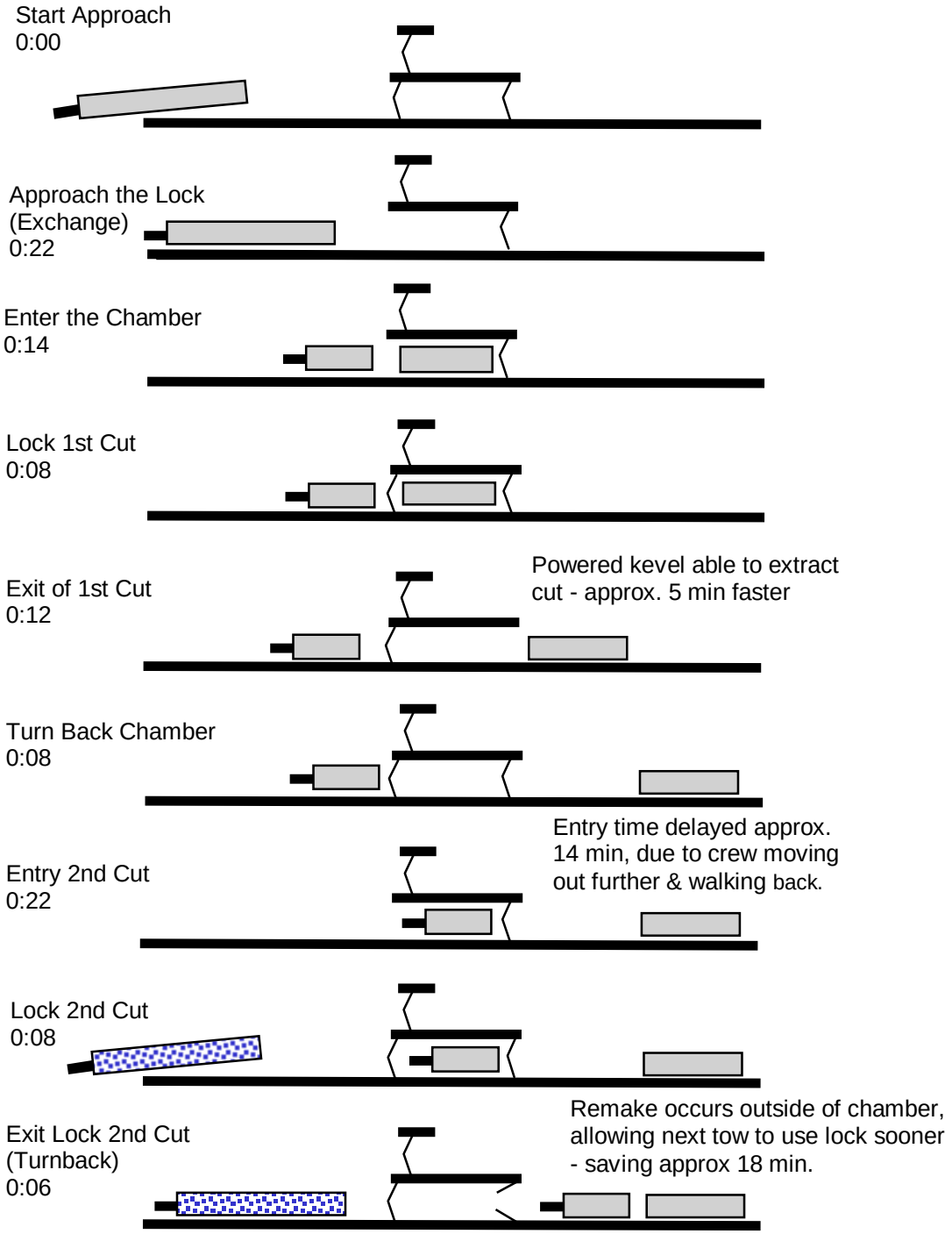
- **Guidewalls and Tow Haulage Equipment**

Extending the existing 600-foot guidewalls to 1,200 feet would allow the powered cut to remake with the unpowered cut completely outside of a 600-foot lock chamber. The lock is therefore free to turn back for the next vessel and is not impeded while double lockage tows reconfigure on the guidewall. For the measure to work, it must be combined with other small-scale improvements such as powered kevels, unpowered kevels, helper boats, switchboats, or industry self help. Extended guidewalls can also provide some minor benefit with approaches, described separately under "Approach Improvements." This section addresses the implementation of permanent guidewall extensions with either powered or unpowered kevels. The use of towboat power measures in combination with a permanent guidewall extension was addressed previously.

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 (rail mounted) kevel provides power to extract the unpowered first cut from the lock. The current winch system and length of cable are eliminated. The guidewall can be lengthened and the unpowered cut of barges pulled a greater distance from the lock chamber with a powered traveling kevel on the guidewall. An unpowered kevel, riding the same rail ahead of the powered kevel, can be used to hold the head of the cut along the guidewall as the cut moves down the guidewall.

The powered unit for the kevel system could use either an endless cable, pull/retard, traction powered, or cog rail system. Due to preferred characteristics and costs, the pull/retard system was selected for use in the evaluation. Additionally the measure could be implemented with or without the provision of additional staff. However, the presence of two additional staff at the lock can make the measure much more effective (see Figures 7 and 8).

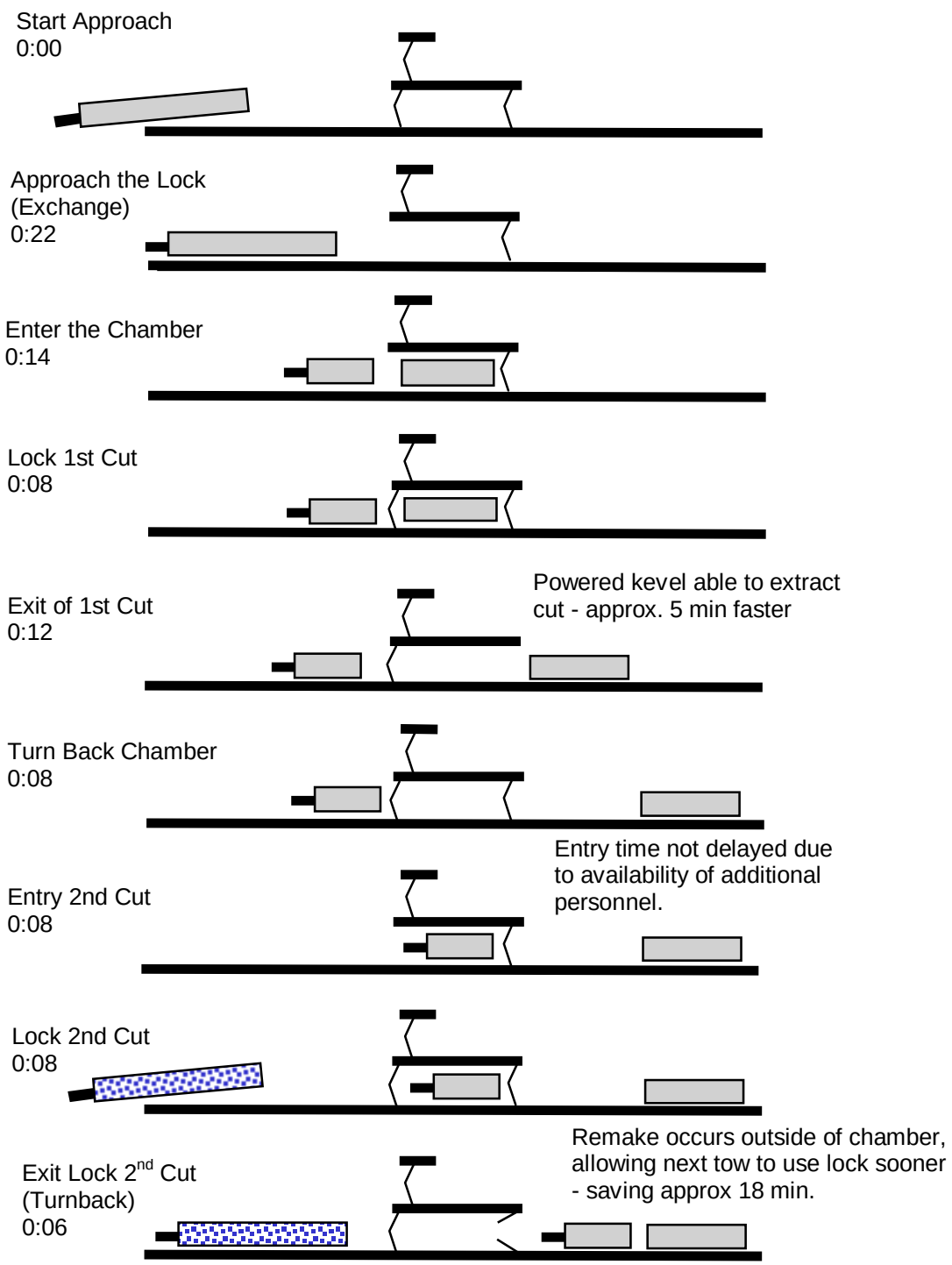


Total Lockage Time: 1:40

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 7: 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 8: Double Lockage Elements - Permanent Guidewall Extensions with Powered Kevel and Additional Personnel

Time Savings: Powered traveling kevels provide time savings based on their ability to improve two steps in the lockage process: pulling the first cut and remaking the tow outside the chamber. A powered kevel system with extended guidewalls extracts first cuts of double lockages faster than the current haulage system by an estimated 5 minutes, but the lockage time is negatively impacted when the powered kevel travels farther to the end of the extended guidewall. 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 (22 minutes required for movement of cuts and deckhands less the 8 minutes required for turning back the chamber). The lockage time for an individual tow is negatively impacted by an estimated 9 minutes. However, extracting the cuts along an extended guidewall allows the recoupling (remake) to occur outside of the chamber, allowing the next tow traveling in the same direction to use the lock. In addition, for tows moving downstream, removing the unpowered cut from the guidewall would allow for somewhat faster emptying of the chamber since the danger of breaking lines would be reduced. However, due to the limited elevation difference at UMR sites, this saving averages less than 1 minute.

The total average time savings for powered traveling kevels with extended guidewalls are 6 minutes upbound and 9 minutes for downbound lockages. These time savings only apply to turnback lockages where the next tow is heading in the same direction.

TABLE 21: 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
Total Time Savings Potential	6 min upbound 9 min downbound	-9 min upbound -9 min downbound

The provision of two additional employees at the lock or on the tows eliminates the need for the crew to walk back prior to the entry of the second cut. This eliminates the 14 minutes of delay and improves the time savings for tows waiting in queue to 20 minutes upbound and 23 minutes for downbound lockages. In addition, the actual tow using the lock benefits as well, actually saving 5 minutes in its lockage time.

TABLE 22: ESTIMATED AVERAGE TIME SAVINGS FOR POWERED TRAVELING KEVELS WITH GUIDEWALL EXTENSIONS AT UMR LOCKS 11-25 WITH PROVISION OF TWO ADDITIONAL DECKHANDS

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
Total Time Savings Potential	20 min upbound 23 min downbound	5 min upbound 5 min downbound

Cost: The average first cost for the guidewall extension is $23 million for upstream guidewalls and $12 million for downstream walls. However, costs vary per lock site. Powered kevel first cost (pull/retard system) is $1.5 million per lock site ($750,000 per guidewall) including haulage for the lock chamber. This cost is considered constant for all lock sites.

Constructing upstream guidewall extensions was 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. These types of closures would result in millions of dollars of impacts to navigation. On reevaluation, an alternative was developed to stage construction over three to four winters (during the essentially non-navigable period). This would be accomplished by constructing 150- to 200-foot segments during the winter closure, starting from the end of the existing guidewall. The downstream walls, which have less impacts from ice and flow conditions, are anticipated to be constructed in one winter closure. At IWW locks, which do not have a definite winter closure period, significant impacts to navigation on the order of $62 million to $81 million are anticipated per wall.

The annual maintenance cost for each of the upper and lower guidewalls is estimated at $30,000 per year based on a historical review of MVR guidewall repair cost for the past 15 years. For the powered kevels, the annual maintenance cost is estimated at $25,000. However, maintenance for the current haulage system (two winches with cable) is $8,000 per year. The additional cost per wall is equal to $25,000 minus $8,000 divided by 2 walls, or roughly $9,000 per wall.

The additional personnel are estimated to cost $518,000 annually per lock (two additional staff people, 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 associated with contracting or hiring employees, training requirements, and miscellaneous expense.

These costs result in a total average annual cost of $2.8 million per lock without additional personnel and $3.3 million per lock with the additional personnel. The higher costs associated with impacts to navigation on the IWW result in costs of $11.0 million and $11.5 million per lock site, respectively. However, the cost of environmental mitigation associated with the footprint impacts has not been included.

Screening Recommendation: Powered kevels implemented along with additional personnel is recommended for further consideration. While initially screened out based on the efficiency criterion compared with towboat power options, subsequent increases in the towboat costs and improved operations of this measure associated with additional personnel have demonstrated its

need for further consideration in the plan formulation process. However, the use of this measure without additional personnel was screened out based on efficiency. For the relatively small additional cost of added personnel, considerable benefits are provided.

Unpowered Traveling Kevels.

Description of Measure: In combination with extended guidewalls, dual unpowered traveling kevels would provide greater control of the unpowered cut, allowing the powered cut, with minimal connection to the unpowered cut, to push clear of the lock for remake (see Figure 9).

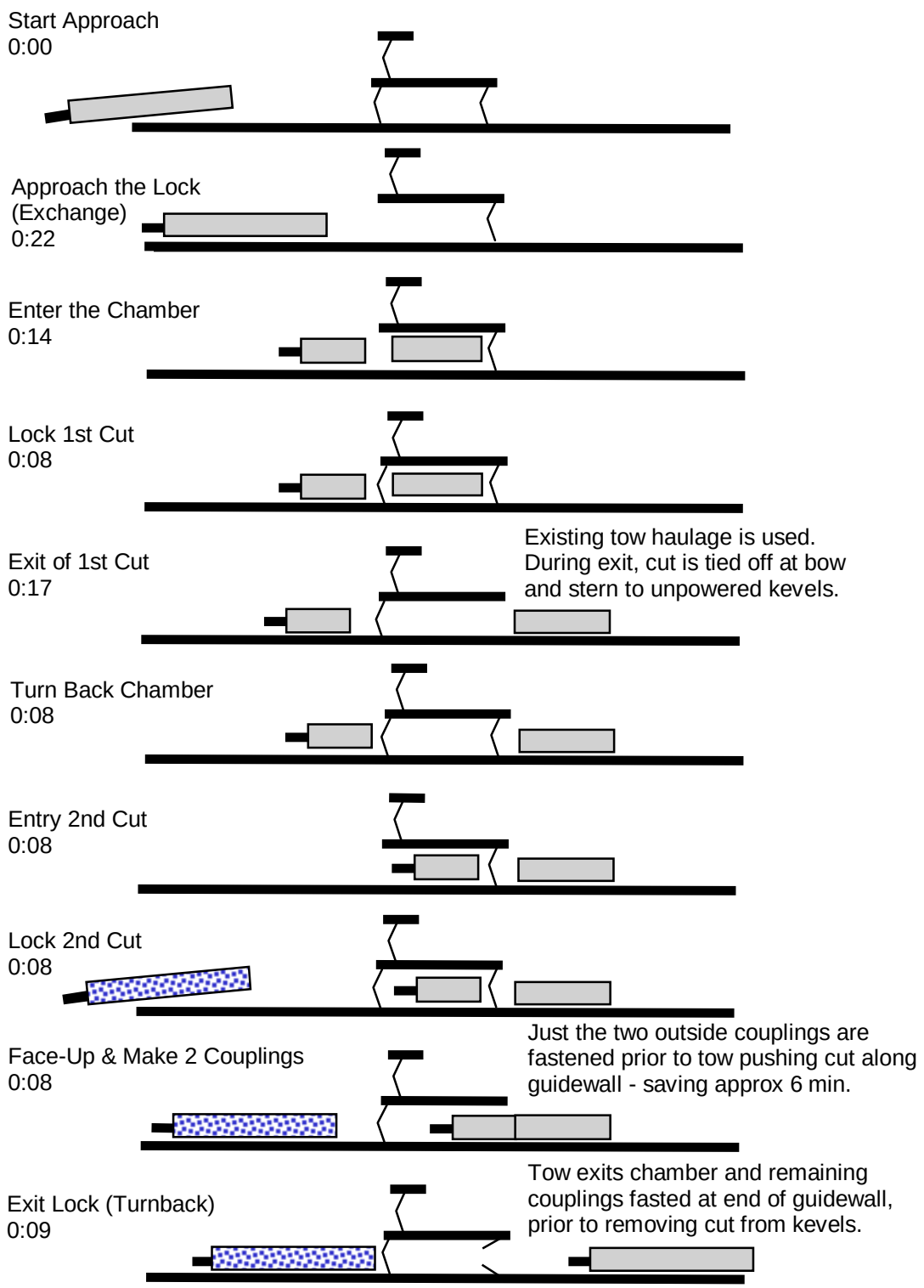
This measure provides two rail-mounted kevels, not attached to any cable/winch power system, along both extended upstream and downstream guidewalls. The first cut of a double lockage is extracted from the lock chamber as is presently done with the existing tow haulage system (a single winch and cable system). The front of the cut is then secured to the first kevel and the stern attached to the second kevel. Two of the three deckhands then walk back 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. Once out of the chamber, three of the four remaining couplings are made prior to removing the lines from the traveling kevels and exiting the lock wall. The sixth coupling is remade after the tow leaves the lock wall.

Time Savings: Unpowered kevels provide savings in the exit of the second cut. Rather than fully remaking the tow while blocking the chamber, only the two outside lines are attached while the tow is in the chamber, resulting in an estimated time savings of 6 minutes. This savings is the difference in remaking five wires as is currently done versus the time for remaking just the two outside wires. The time savings only applies to turnback lockages where the next tow is heading in the same direction and can use the chamber while the first tow completes its remake at the end of the guidewall.

Cost: The average first cost for the guidewall extension is $23 million for upstream guidewalls and $12 million for downstream walls. However, costs vary per lock site. Unpowered kevel first costs are estimated at $300,000 per guidewall. As discussed under the previous measure, at IWW locks that do not have a definite winter closure period to allow construction, significant impacts to navigation on the order of $62 million to $81 million are anticipated per wall.

The annual maintenance cost for each of the upper and lower guidewalls is estimated at $30,000 per year based on a historical review of MVR guidewall repair cost for the past 15 years. For the unpowered kevels, the annual maintenance cost is estimated at $4,000 for the lock or $2,000 per wall, based on existing maintenance costs.

These costs result in a total average annual cost of $2.7 million per lock for UMR sites and $10.9 million per lock for IWW sites. However, this cost does not include environmental costs.



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 9: Double Lockage Elements - Permanent Guidewall Extensions with Unpowered Kevel

Screening Recommendation: The unpowered kevel option was screened out based on efficiency because it provides considerably less time savings benefit than the powered kevel with guidewall extension and additional personnel option, while having comparable costs. However, the team will continue to consider this option if the powered kevel option is recommended for eventual implementation as a possible variation on the kevel option (e.g., unpowered kevels in combination with an improved winch and additional personnel, etc.).

- **Adjacent Moorings**

Adjacent mooring facilities are devices that provide 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 must either push into the river bank, which causes damage to shoreline vegetation and increases near-shore sediment resuspension, or wait out in the currents of the river, which wastes fuel.

Mooring Facilities.

Description of Measure: New mooring facilities above or below the lock could consist of mooring cells or buoys attached to a mooring line. These structures, which provide waiting areas where tows can be tied off, can improve efficiency in two ways. First, they can provide a waiting area closer to the lock where a tow can safely wait clear of a narrow approach, thereby allowing a tow exiting in the opposite direction to pass. By waiting closer, the exchange approach and exit times can be reduced (see Figure 10). Secondly, when used with a switchboat or an industry self-help process (as described in the Towboat Power section) and properly placed, adequate moorings provide a place where tows can remake, making the lock available sooner for the next tow waiting in either direction.

Time Savings: The exchange approach time savings (when a tow is approaching a lock from the opposite direction as the exiting tow) ranged from 7 to 13 minutes. This time savings was based on the potential to reduce approach distances as shown in Table 23, calculated using an average vessel approach speed. The following sites were identified for implementation of moorings: Lock 12 upbound, Lock 14 both directions, Lock 18 upbound, Lock 20 upbound, Lock 22 upbound, Lock 24 downbound, Lock 25 upbound, Melvin Price Lock upbound, and La Grange Lock downbound. Similar time savings are possible for exchange exits. In evaluating this measure, the Economics Work Group will analyze the benefits of the combined exit and approach times. Accounting for the exit savings as well will essentially double the approach benefits shown. However, this measure provides only minimal benefits to turnback lockages that occur with increased regularity at congested locks.

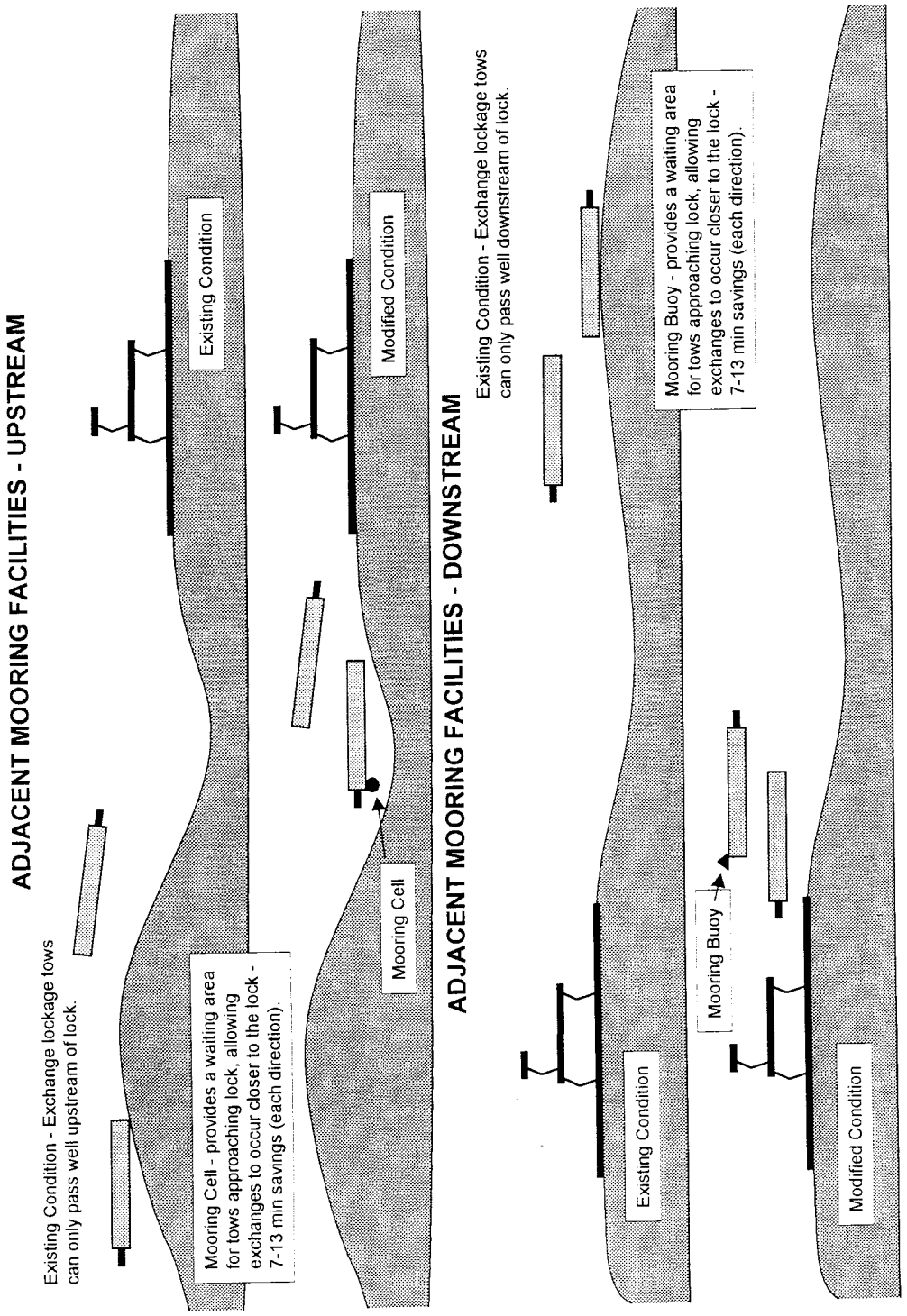


FIGURE 10: Adjacent Mooring Facilities

TABLE 23: COST AND PERFORMANCE OF ADJACENT MOORING FACILITIES

Lock	Miter Gate RM	Dir.	Wait at RM Exist	Wait at RM New	Cost ($1,000's)	Miles Closer	Time Savings (min) Doubles [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)
18	410.5	UB	409.0RB	409.7RC	50	0.7	9
20	343.2	UB	342.0LC	342.8LC	50	0.8	11
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 mooring, located downstream of lock, DB-downbound mooring located upstream of lock
L-left descending side, R-right descending side, C-location along navigation channel, B-location along bank.

[1/] Approach time savings shown are for exchange of double lockage tows. Similar savings for exchange exits are anticipated. Savings of roughly one-half this amount are anticipated for single lockage tows.

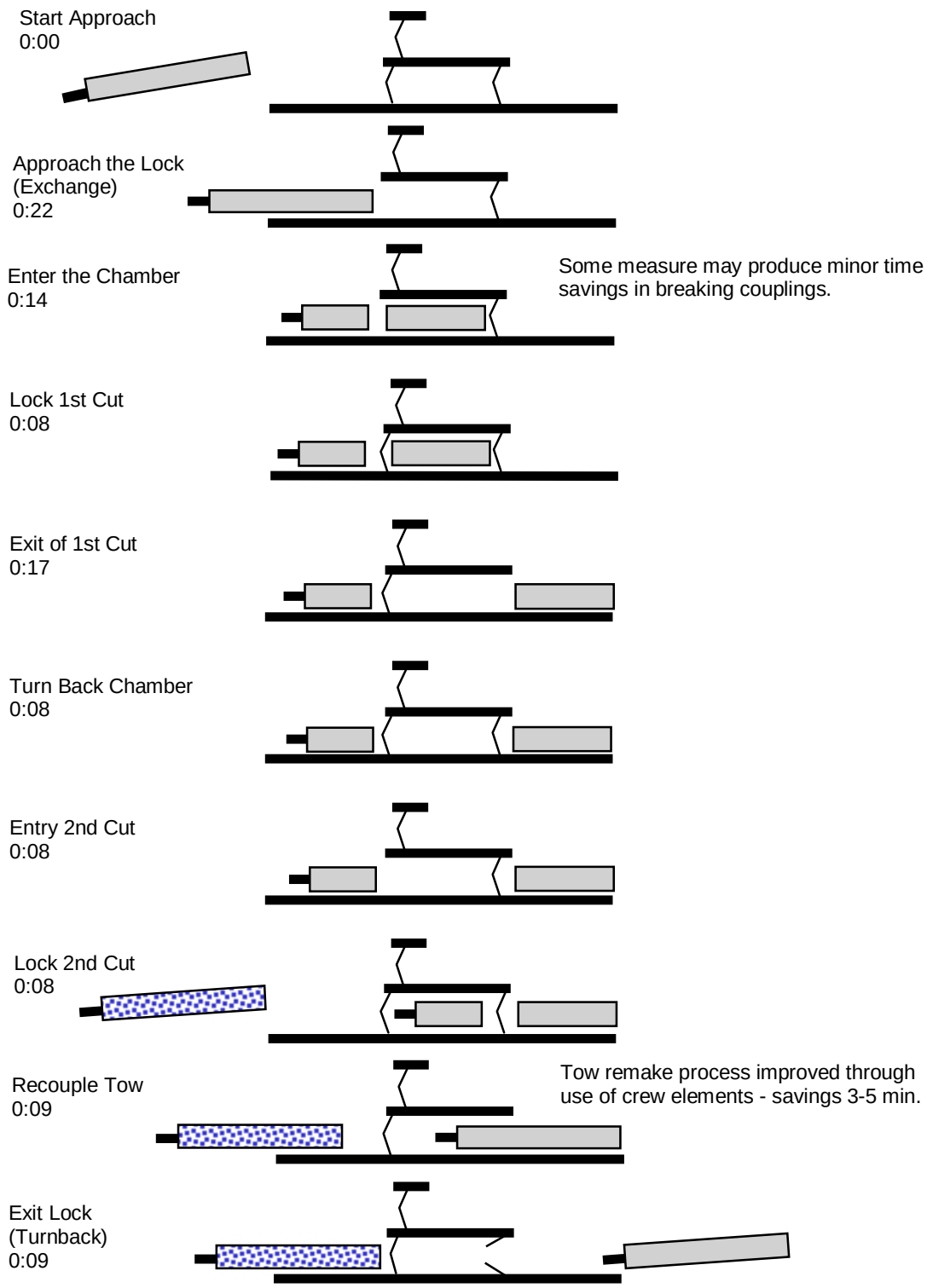
Cost: Based on past historical data, the average cost for a mooring buoy is estimated at $50,000 installed. In addition, an annual maintenance cost of $5,000 was used to cover costs associated with cable breakage and periodic repositioning. Major maintenance in the form of buoy replacement is planned on a 5-year basis. These expenditures result in an annual cost of $16,000 per buoy.

The average cost for a mooring cell is estimated at $500,000, based on past historical costs. This cost was used for both rock- and pile-founded sites, but some site-specific differences in cost are anticipated. An annual maintenance cost of $20,000 was used based on a review of repair costs to existing cells. These expenditures result in an annual cost of $68,000 per mooring cell.

Screening Recommendation: Both mooring cells and buoys were recommended to be carried forward for further analysis. As a general assumption, cells would be placed above the lock and buoys below unless the site is on rock. At rock-founded sites, a cell would be used below the lock as well as above for better anchorage.

- **Crew Elements**

Crew elements refer to those measures with the potential to improve the process of breaking and remaking tows involved in double lockages (see Figure 11). Five crew element measures received consideration. Based on additional information collected and further analysis since the *General Assessment* report, two measures—Universal Couplers and Crew Training—do not appear to have the ability to provide performance improvements.



Total Lockage Time 1:43

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

FIGURE 11: Double Lockage Elements - Crew Element Benefits

Clarification of the with- and without-project condition verified that powered ratchets and permanent deck winches are part of the without-project condition. These measures do not represent new improvement measures. However, their ultimate level of use depends on industry initiative. Both measures have relatively limited savings potential and some significant drawbacks impeding their implementation (i.e., high cost or potential for back injuries) and as such are not likely to significantly influence future lockage times or the system analysis.

The Additional Personnel measure was eliminated from consideration based on limited time savings potential and uncertainty associated with implementation. These concerns, along with the additional variability and safety risks associated with involving more people in the lockage process, simply do not warrant its implementation.

The estimated time savings of each alternative was estimated in relation to the current remake procedure described below, which takes approximately 12 minutes. 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

Universal Couplers.

Description of Measure: The development of a simple, quick-operating, and universally adaptable coupler for joining barges could save considerable time in breaking and remaking tows.

Time Savings: Not quantified.

Cost: Not quantified.

Screening Recommendation: Universal couplers were eliminated based on the completeness criterion, since a viable option is not available for implementation.

Minimum Crew Size with Training.

Description of Measure: Providing well-trained and large enough crews to more efficiently handle lockages could save time in the breaking and remaking of tows.

Time Savings: Not quantified.

Cost: Not quantified.

Screening Recommendation: The Crew Training measure was eliminated based on the effectiveness criterion. Companies currently implement various types of crew training with non-measurable performance benefits associated with the different types of training. Industry also provides the required crew size of 3 people (the captain/pilot cannot act as a deckhand) to handle lines during a double lockage as required by the Corps of Engineers' Navigation Notice 1-1998.

There is no clear indication that one form of training produces crews with greater skill levels than another form of training. In general, the vast majority of the towing companies are responsible and their present staffing and equipment standards could satisfy any reasonable regulation.

Permanent Deck Winches.

Description of Measure: Mounting deck winches on the decks of all the barges of a company's fleet could reduce the time to tighten the primary fore/aft couplings. The speed of the uncoupling could also be reduced.

Time Savings: The following analysis resulted in an estimated savings of 4 minutes per double lockage compared with the baseline time shown above.

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 minute/wire to tighten x 2 wires/person = 4 minutes

Cost: The first cost is estimated at $4,000 per barge ($1,000/winch times 4 winches per barge). The annual maintenance cost was estimated at $400 per system barge for cable replacement and winch maintenance. The average annual cost for implementation is $800 per barge or $10.3 million for the system's approximately 13,000 barges.

Screening Recommendation: Permanent deck winches have been put into limited use, primarily on petroleum/chemical barges, and as such are actually part of the without-project condition. However, widespread implementation of permanent deck winches on the more numerous covered hopper barges is not anticipated due to the barrier created by the relatively high costs and potential for the company making the expenditure to not gain the full benefits. The concern over the benefits is related to the fact that the hopper barge fleet is essentially interchangeable and a barge owned by one company may frequently be found in the tow of another company. As a result, the assumed benefit of purchasing winches would not necessarily be accrued by the company that made the investment.

Additional Personnel.

Description of Measure: Providing extra personnel, stationed at each lock to assist the deckhands, could save remake time. Since each tow has more wires to make between the first and second cut than there are deck personnel on duty, each deckhand is responsible for completing at least two lashings. If additional personnel were available at the lock, each one could be responsible for just one of the lashings.

Time Savings: The following analysis resulted in an estimated savings of 3 minutes per double lockage compared with the baseline time shown above.

Assumptions:
2 additional persons for a total of 5 persons
each person works a wire
5 wires

Time: 9 minutes (3 minute 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)

Cost: There are no capital expenditures required to implement this measure. However, a first cost of roughly $100,000 would be required for initial setup/surveys of available personnel and system management. Annual cost would be the cost of the part-time or contract-hire personnel. Assuming that the additional personnel are required to be at the locks 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 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. This measure, if implemented over the entire 270-day navigation season, would result in an average annual cost of $334,000 per lock for the system.

Screening: The Additional Personnel measure was eliminated from consideration based on the limited time savings potential and uncertainty associated with implementation. These concerns, along with the additional variability and safety risks associated with involving more people in the lockage process, simply do not warrant its implementation.

Power Operated Ratchets.

Description of Measure: This device, which uses a 4-horsepower gas engine to power a hydraulic driven shaft, would be stationed on a center barge at the break couplings. It would improve efficiency and cut down on a double lockage time by increasing the speed of the recoupling process. It also improves safety and requires less physical labor than the current way the barges are reconnected after a double lockage. Although this measure was not carried forward initially from the *General Assessment* because the technology did not exist, it has since been introduced on the system.

In addition, powered ratchets could be implemented by: placing the units at each lock site with significant numbers of doubles and delay. Both would have similar time savings potential.

Time Savings: The following analysis resulted in an estimated savings of 5 minutes per double lockage compared with the baseline time shown above.

Assumptions:
3 people lay first three 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

Cost: The unit cost is about $7,500, with one unit required per double lockage tow. Annual maintenance costs for the units are estimated at $500 per year. Replacement of the unit would occur every 5 years; however, historical maintenance and useful life information are not available due to the recent development and availability of the unit. These costs result in an average annual cost of $600,000 for the system assuming one device on each of the 250 tows operating on the system.

Placing the units at each of the system locks would require a small crane to lower the ratchet, as well as an additional lock employee to operate the crane. Adding one additional staff person, available 24 hours per day during the navigation season, would cost an estimated $259,000 annually. In addition, a first cost of $172,500 would be incurred associated with providing a crane to lower the unit onto the tows. Annual upkeep and periodic maintenance would also be required, resulting in an estimated total average annual cost of $280,000 per lock site.

Screening Recommendation: Powered ratchets could be implemented in one of two ways: placing the units on all double lockage tows or making the units available at each lock site with significant numbers of doubles and delay.

Analysis of the with- and without-project conditions clarified that powered kevels on tows are part of the without-project condition. This measure, while only recently developed, is currently being tested on a limited number of towboats. However, their ultimate level of use depends on industry implementation, and no Federal action by the Corps is required. Initial results of the testing reported by industry are that while the units have potential to reduce lockage time they are bulky and have the potential to increase rates of back injuries. As a result, it is not clear how readily, if at all, these units will be implemented, and as a result this measure will not be incorporated into the economic analysis.

The use of the powered ratchets at the lock was considered as a potential with-project improvement. However, it was eliminated as a potential improvement measure due to safety concerns related to potential injuries from lowering the unit onto each tow and back injuries associated with moving the units around on the tows. This measure also raised concerns over the unproven reliability and the fact that tows may come to rely on its availability. This could contribute to increased delays during periods when the units break down or become unavailable.

- **Approach Improvements**

By providing a variety of alternative approach improvements (dike fields, submerged dikes, channel realignment, guardwalls, and guidewalls) the maneuvering required by tows could be reduced, saving time in the lock approaches and exits. Approach improvements were considered alone and in combination with structural improvements or additions to the lock facility, such as extended guidewalls and guardwalls in alternative positions. While approach improvements were originally screened out from further consideration as part of the qualitative evaluation, the physical model studies of Locks 22 and 25 conducted as part of the large-scale evaluation for 1,200-foot locks demonstrated that approach improvements could provide significant benefits and merited further consideration.

In total, the study team looked at eight different potential combinations of upstream approach improvements, listed below and shown in Figure 12. Only the first three improvements are applicable to the downstream approach. The best upstream option from an overall time savings perspective at most sites is channel improvements with a 1,200-foot guardwall extension at the

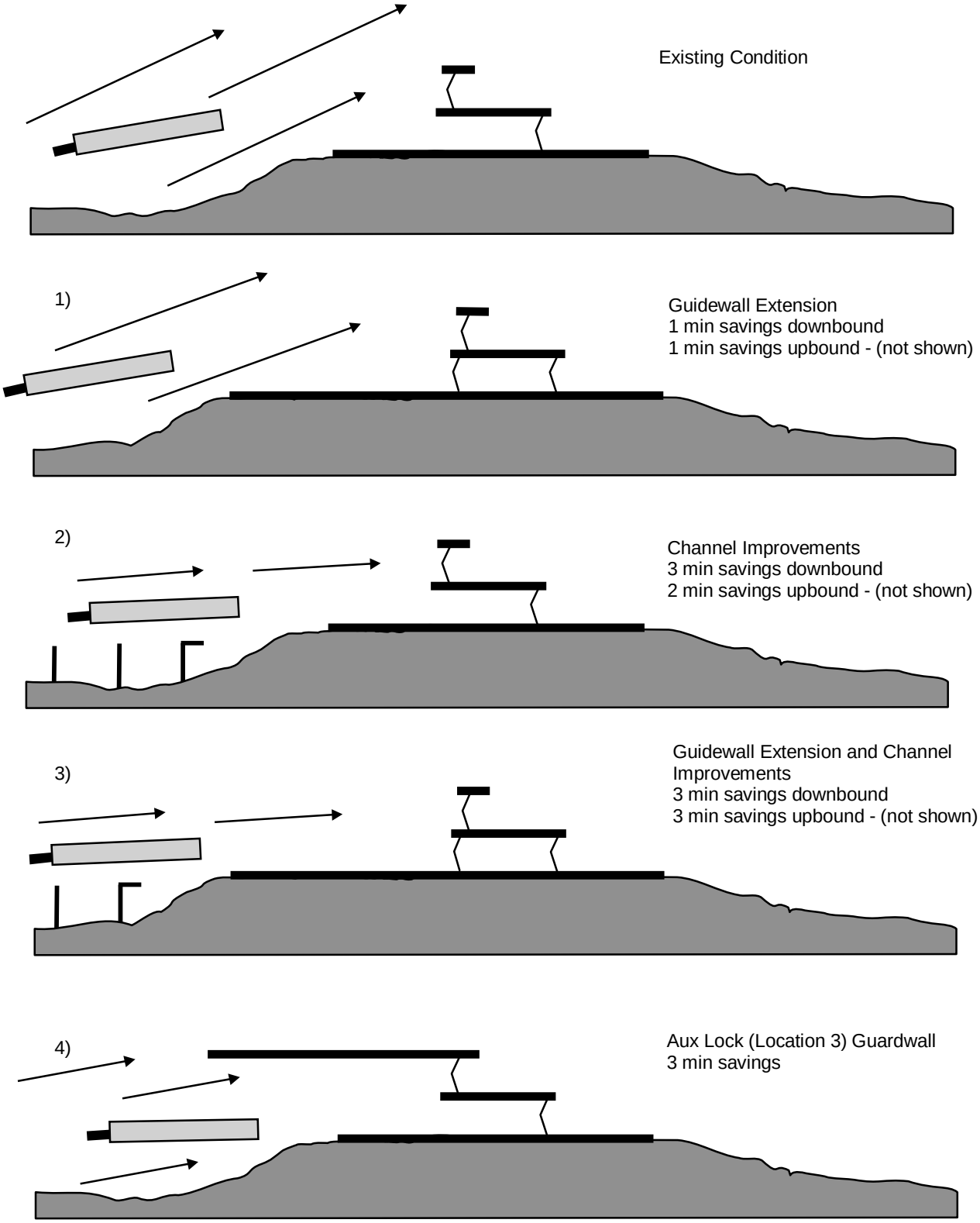
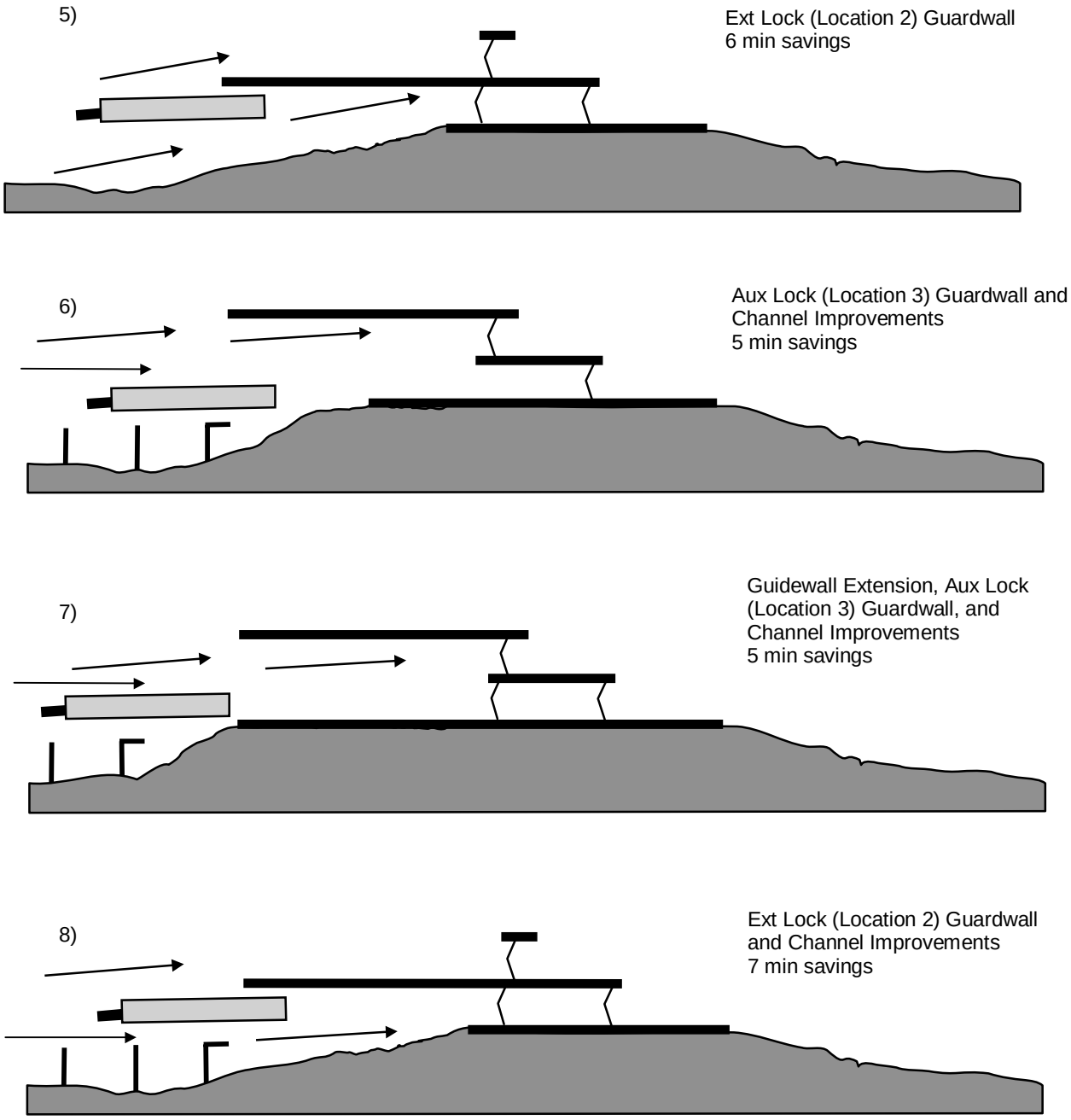


FIGURE 12: Existing Approach and Potential Approach Improvements Downbound Direction (1 of 2)



Arrows Indicate General Direction of Currents

Indicates Outdraft Currents - Moving tow towards dam.

Indicates No Outdraft Currents - Flow aligned with the lock approach.

Time Savings indicate average savings for exchange lockages.

FIGURE 12: Existing Approach and Potential Approach Improvements Downbound Direction (2 of 2)

existing lock (location 2). However, both guidewalls and guardwalls have very high first costs in addition to the delay costs they impose on navigation during construction.

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

The results from the Lock 22 physical model study were used in estimating approach time savings at the other UMR locks for the applicable approach improvements. Time savings relate to the average approach times for 1990. This captures the variance in approach times during higher flow conditions as well as lower flow conditions. Site-specific model studies at an estimated cost of $450,000 per site are needed to confirm and identify the optimum approach improvements at each UMR lock site. This modeling would be needed for all sites, except Locks 22 and 25, which have been completed.

The Lock 22 model study results are not applicable to the locks on the IWW. Flow characteristics differ for the IWW, and the outdraft above the locks is not as severe as on the UMR. Thus, approach improvements were thought to have negligible impacts on reducing approach times for the IWW locks.

Based on a comparison, it appears that the most cost-effective measure in this category is channel improvements (immediately above and below the lock) and that the other options, while potentially providing some additional time savings, do so at a much greater cost. In addition, increased numbers of turnback lockages (same direction) associated with increasing traffic will reduce the number of exchange lockages. The benefits of approach improvements are significantly reduced for turnback lockages since in many cases the next tow in line can complete all or part of its approach and be essentially ready to enter the lock when the previous tow completes its lockage. Environmental costs were not identified for each of the specific options, but will be identified and included in further formulation involving the surviving measures.

Each of the eight potential approach improvements is summarized in Table 24 below and discussed separately in the following section.

TABLE 24: APPROACH IMPROVEMENT MEASURES: TIME SAVINGS AND COST

Downbound Measures	Savings (Min)[1]	Cost (Mil)[2]	Sites[3]
1. Extended Guidewalls	1	1.7	11
2. Channel Improvements	3	0.5	11
3. Extended Guidewalls Plus Channel Imp.	3	2.2	10
4. Location 3 Guardwall Alone	3	2.2	6
5. Location 2 Guardwall Alone	6	20.1	4
6. Channel Imp. + L3 Guardwall	5	2.8	9
7. Extend Guidewall, Chan Imp., & L3 Guardwall	5	4.6	9
8. Channel Imp. + Location 2 Guardwall	7	19.8	10
Upbound Measures			
1. Extended Guidewalls	1	1.0	13
2. Channel Improvements	2	0.2	8
3. Extended Guidewalls Plus Channel Imp.	3	1.1	9

[1] Average time savings for exchange lockages, actual savings vary based on lock site, flow, etc.
[2] Average annual cost in millions includes impacts to navigation, but not environmental costs.
[3] Number of applicable sites, UMR Locks 11-25.

1. Extended Guidewalls

Description of Measure: Extending the existing 600-foot guidewalls to 1,200 feet provides time savings to several steps in the lockage process as discussed earlier under the Guidewall and Tow Haulage measures. However, this section only addresses the potential reduction in approach time.

Upstream guidewall extensions allow tows to be in a more controlled state farther up the approach, slightly 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 not subjected to outdraft due to the direction of the flow.

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. These time savings apply to the lock locations where guidewall extensions are applicable for the UMR and IWW locks. These time savings apply to the UMR locks where guidewall extensions are applicable.

Cost: The average first cost for the guidewall extension is $23 million for the upstream guidewalls and $12 million for downstream guidewalls. 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.

The annual maintenance cost for each of the upper and lower guidewalls is estimated at $30,000 per year based on a historical review of Rock Island District guidewall repair cost for the past 15 years. These costs result in an average annual cost of $1.7 million upstream and $1.0 million downstream per guidewall extension. The higher cost of the upstream wall is associated with essentially avoiding impacts to navigation; however, the environmental impact costs have not been included.

Screening Recommendation: Extending the existing lock guidewalls as a stand-alone approach improvement was screened out on the efficiency criterion. Channel improvements provide greater benefits at a lower cost. While guidewall extensions with power kevels remain under consideration, the approach benefits of 1 minute are too small and uncertain to merit consideration in the system analysis. However, it is likely that some limited benefits would result.

2. Channel Improvements

Description of Measure: This measure includes a variety of possible modifications, including dike fields, submerged dikes, vane dikes, dredging, bank filling, bank excavation and channel relocation—all designed to control channel currents and improve the path of a tow as it enters a lock. Such improvements have been found to significantly reduce approach times and make conditions safer, depending upon the location, combination of improvements, and river conditions at the time.

Time Savings: The time savings for typical exchange approaches average 3 minutes downbound and 2 minutes upbound at UMR locks. 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. These factors reduce the potential benefits associated with channel improvements at IWW locks.

The estimated saving in lock approach time at some locks is significant with channel improvements. Physical model studies are needed to confirm the improvements needed to provide the most efficient navigation approach.

Cost: First costs vary significantly from a few hundred thousand to several million dollars based upon the individual site and flow conditions. The annual cost for upper lock approach improvements averaged $530,000 per site, while lower lock improvements averaged $220,000 per site. This included model studies, initial implementation, and ongoing maintenance. Environmental impacts were identified by the Environmental Work Group but have not been included. As with the other approach improvement measures, these impacts may affect the implementation of this measure. Disposal of potential dredged material is of concern, especially when large quantities are involved. In addition, real estate impacts may be substantial where extensive channel widening is anticipated, for example, at Lock 20. There are no anticipated impacts to navigation during the construction of channel improvements. In addition, there is also some potential that approach improvements could reduce costs to industry by reducing or eliminating the need for and cost of helper boat assistance on approaches.

Screening Recommendation: Channel improvements were carried forward based on the cost and performance expectations. These improvements provide a large portion of the potential approach improvement benefits for a small portion of the cost.

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. The costs are greater, but there are some incremental time saving benefits with both improvements in place at some lock sites.

Time Savings: 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. This combination is only possible at sites where both guidewall extensions and channel improvement have been identified.

Costs: The costs for extended guidewalls plus channel improvements essentially combines the costs identified for the two earlier measures. This results in an average annual cost of approximately $2.2 million for upstream improvements and $1.1 million for downstream improvements. The impacts to navigation are the same as described for the Extended Guidewalls improvement. Environmental impacts would also need to be included if this measure is carried forward.

Screening Recommendation: The combination of extended guidewalls and channel improvements was screened out on the efficiency criterion. It provides marginally more time savings than channel improvements alone at a much higher cost. While guidewall extensions with powered kevels remain under consideration and could be combined with channel improvements, the incremental benefit of combining the two measures of 0.5 to 1 minute is too small and uncertain to merit consideration in the system analysis. However, it is likely that some limited incremental benefit would actually result.

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 12). 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. 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 that 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.

Time Savings: The analysis showed average time savings of 3 to 4 minutes for the exchange and fly approach at the pertinent lock sites with a maximum saving of 6 minutes in the fly approach at Locks 17 and 22.

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. This measure has an average annual cost of $2.2 million.

Screening Recommendation: The auxiliary lock guardwall option was screened out based the efficiency criterion. It provides very little additional time savings than channel improvements

alone at a much higher cost. In addition, considerable concerns where expressed about the potential for guardwalls to trap debris and ice.

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 12). 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.

Time Savings: These improvements result in an average 6-minute time savings for downbound exchange lockages. At Lock 17, the average savings is 11 minutes for exchange lockages, but at the other sites the improvements are less dramatic. Placement of a location 2 guardwall alone without any other upstream channel improvement is applicable only at UMR Locks 12, 17, 19, and 24, although outdraft during high flows at Lock 24 would impede tows approaching the guardwall. On the IWW, a location 2 guardwall placement is only possible at Dresden Island.

Costs: The guardwall design is similar to the guidewall design except for the openings allowing flow to the dam gates. This measure has an average annual cost of $20.1 million per applicable site. The cost includes model study to verify the time savings and considerable impacts to navigation.

Impacts to navigation costs during construction of guardwall improvements include both the cost for assistance to navigation during construction (helper boats, switchboats, and temporary remote remake areas) and impacts to industry due to increased delays and closures. The construction in the upper pool at this location is anticipated to cause impacts to existing navigation on the order of $190 million to $318 million per applicable site. This magnitude of impacts to navigation is expected, since most construction activities would occur during the navigation season. Construction during winter in the upper pool at this guardwall location is assumed to be impossible from 1 January to 1 March due to ice conditions. Once again, environmental costs were not included.

Screening Recommendation: Of the four sites on the UMR where a location 2 guardwall (alone) is applicable, at three (Locks 12, 17, and 19) there is an apparent additional reduction in downbound approach time over what channel improvements alone provide. However, based on the high costs of this measure it was screened out on the efficiency criterion based on the fact that the very small additional time savings over channel improvements alone does not warrant the large additional expense. In addition, considerable concerns where expressed about the potential for guardwalls to trap debris and ice, adversely affecting some lockages.

6. Channel Improvements Plus an Auxiliary Lock (Location 3) Guardwall

Description of Measure: Channel improvements plus a location 3 guardwall combines the channel improvements discussed above with placement of a location 3 guardwall (see Figure 12). Together this combination provides some incremental benefit over placement of each of the two measures separately.

Time Savings: The average saving in the downbound fly approach time for the applicable sites is about 6 minutes. The average saving in the downbound exchange approach time is about 5 minutes.

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. Additional upstream channel widening is needed at Mississippi River Lock 20 to provide just one tow length of straight approach above a location 3 guardwall as shown on plate 12. The cost of this additional excavation/dredging including the environmental impact may not incrementally justify any small reduction in approach time.

Costs: This measure has an average annual cost of $2.8 million. The costs include a model study and removal of the existing dogleg guardwall at Locks 11, 24, and 25. Environmental costs were not included.

Screening Recommendation: Channel improvements plus a location 3 guardwall, together provide an incremental saving in the downbound approach time over what these measures provide independently. However, this measure was screened out based the efficiency criterion. It provides little additional time savings over channel improvements alone at a much higher cost. In addition, considerable concerns where expressed about the potential for guardwalls to trap debris and ice, adversely affecting some lockages.

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 provide a slight incremental saving to the approach time over what the combination of channel improvements plus a location 3 guardwall provides. In addition to lessening the delays due to outdraft, which channel improvements and a location 3 guardwall do, the tow has the benefit of an extended, 1,200-foot guidewall on which to land and align with the lock chamber (see Figure 12).

Time Savings: The downbound exchange approach times decrease by an average of 5 minutes. 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. This measure is not applicable to any of the lock sites on the IWW. Additional upstream channel widening is needed at Mississippi River Lock 20 to provide just one tow length of straight approach above a location 3 guardwall.

Costs: The average annual cost is $4.6 million, not including environmental impacts. The costs include model studies and the removal of the existing shorter guardwall where applicable.

Screening Recommendation: This measure was screened out based the efficiency criterion. It provides very little additional time savings than channel improvements alone at a much higher cost. In addition, considerable concerns where expressed about the potential for guardwalls to trap debris and ice, adversely affecting some lockages.

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 12). 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.

Time Savings: 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.

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 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. Some lock sites require more extensive channel widening/shifting to accommodate an existing lock guardwall including UMR Locks 14, 16, and 20. For the IWW, this measure is applicable only at La Grange Lock, and this is questionable.

Costs: The average annual cost is $19.8 million, based in large part on the high economic impacts to navigation during construction. These impacts are estimated at $190 million to $318 million per lock site. This magnitude of impacts to navigation is expected, since most construction activities would occur during the navigation season. Construction during winter in the upper pool at this guardwall location is assumed to be impossible from 1 January to 1 March due to ice conditions. The costs also include model testing and 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. Environmental costs have not been included.

Screening Recommendation: 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. However, construction in the upper pool causes major impacts to existing navigation, and these anticipated impacts cause this measure to be screened out. The additional time savings of approximately 4 minutes over channel improvements alone does not justify the additional $19.2 million dollars when other lower cost options are available. In addition, considerable concerns where expressed about the potential for guardwalls to trap debris and ice, adversely affecting some lockages.