ERDC/CERL TR-17-17

US Army Corps
of Engineers®
Engineer Research and
Development Center

ERDC
INNOVATIVE SOLUTIONS
for a safer, better world

Investigation of Mechanical Breakdowns Leading to Lock Closures

Stuart D. Foltz

June 2017

Construction Engineering
Research Laboratory

The U.S. Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at http://acwc.sdp.sirsi.net/client/default.

ERDC/CERL TR-17-17
June 2017

Investigation of Mechanical Breakdowns Leading to Lock Closures

Stuart D. Foltz

U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
2602 Newmark Dr.
Champaign, IL 61824

Final Report

Prepared for Headquarters, U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Project "Structural Monitoring System for Lock Structures to Prevent Failure"

Abstract

The U.S. Army Corps of Engineers (USACE) owns or operates 236 locks at 191 sites, more than half of which have surpassed their 50-year design life. There are increasing concerns about their continued safe, reliable operation into the future, especially considering the fact that routine maintenance, lock dewaterings, and inspections sometimes occur at less than optimal intervals. Although critical repairs are prioritized, delayed maintenance increases the risk of failures that result in lock closures. One significant factor that contributes greatly to the difficulty of lock condition assessment is that much of the lock infrastructure typically remains under water. When a lock is dewatered, it is common to find previously unidentified distress, deterioration, and damage. To address such maintenance issues, there is an increasing need to gather more accurate information on repair needs and to prioritize those repairs. This work investigated types and frequencies of lock failures so that sensors can be used more effectively to identify imminent lock operational failures and concerns for ongoing lock reliability. Numerous data sources were used to collect these data, even though most of these sources were not created for the purpose of collecting the type of data the work investigated. The data gap is also discussed in the report.

Contents

Tables and Figures

Tables

Figures

Preface

This study was conducted for Headquarters, U.S. Army Corps of Engineers (USACE) under Project "Structural Monitoring System for Lock Structures to Prevent Failure" (Work Items 1F18B1, L93CJ7, 4B1176). The technical monitor was William J. Lillycrop, Technical Director, Navigation.

The work was performed under the direction of the Materials and Structures Branch (CFM) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Vicki VanBlaricum was Chief, CEERD-CFM; Donald Hicks was Chief, CEERD-CF; and Kurt Kinnevan, CEERD-CZT, was the Technical Director for Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

COL Bryan S. Green was Commander of ERDC, and Dr. David W. Pittman was the Director.

1 Introduction

1.1 Background

The U.S. Army Corps of Engineers (USACE) owns or operates 236 locks at 191 sites (HQUSACE 2016). Although the locks at these sites generally perform reliably, more than half of these structures have surpassed their 50-year economic design life, and as such, there are increasing concerns about their continued safe, reliable operation. Specifically, questions exist regarding the adequacy, cost, and effectiveness of routine maintenance, repair, and rehabilitation.

As locks age and components wear or otherwise deteriorate, there is a correspondingly greater need for closer monitoring of the infrastructure. However, despite the fact that lock infrastructure is aging, routine maintenance, lock dewaterings, and inspections sometimes occur less frequently than they have in the past due to fiscal limitations. Consequently, the repair backlog at some locations is increasing, leaving some gates to operate in less than optimal condition. For example, if gates have deteriorated paint or lack cathodic protection then structural section loss will increase.

Although critical repairs are prioritized, delayed maintenance increases the risk of operational or catastrophic failure that results in lock closures. In fact, scheduled closures (generally for maintenance and repair) and unscheduled closures due to weather, collisions, and other reasons beside compromised infrastructure reliability, cause far more lock closures than operational failure of the lock infrastructure. However, of all closures, unscheduled closures are generally more disruptive and costly to the commercial lock users.

There is a need to regularly assess the condition of locks to detect signs of imminent failure, to minimize unscheduled closure, and to ensure that scheduled closures for maintenance and repair (M&R) are necessary and effective. One significant factor that contributes greatly to the difficulty of lock condition assessment, and that accounts for why lock repairs can be difficult to plan, prioritize, and accomplish is that much of the lock infrastructure typically remains under water. It is typical to assess lock conditions based on above water visual inspection, on equipment behavior when

gates are operated, and sometimes also on underwater inspections. Nevertheless, it is common to find previously unidentified distress, deterioration, and damage when a lock is dewatered. Maintenance personnel expect a certain amount of unforeseen damage on dewatering, and are prepared to include some unexpected repairs. However, conditions where unforeseen damages exceed the capability to repair during the scheduled dewatering period can result in extended closure, or a return to operation with some infrastructure concerns unaddressed. This is an important issue since such uncompleted repairs can in turn lead to an increased frequency of dewaterings to maintain operational reliability.

To address these maintenance issues, there is an increasing need to gather more accurate information on repair needs and to prioritize those repairs. Improved, affordable sensor technologies that can perform real-time monitoring of lock and lock gate conditions may fill this need. This work was undertaken to investigate types and frequencies of lock failures so sensors can be used more effectively to identify imminent lock operational failures and concerns for ingoing lock reliability.

1.2 Objective

The objectives of this work were to:

1. Determine the conditions and other issues that currently lead to lock closures and/or catastrophic failures
2. Identify sources of data that can be used to predict those lock closures and/or catastrophic failures
3. Analyze the information to help identify how sensors may be used to collect useful information related to lock condition and behavior
4. Make recommendations to enable development of the data collection most appropriate to address these maintenance issues and that will help assign resources to maximize potential benefits.

1.3 Approach

This work investigated records of historic unscheduled outages due to lock gate failures to determine the operational issues to be assessed and reported to the lock personnel. It was assumed that historical data could provide information on the environmental events and component failures that have caused shutdowns. A number of relevant data sources were known and, in the course of this work, additional data sources were identi-

fied. Further information was collected through interviews with experienced USACE employees who shared their insights and experiences related to lock operation, reliability, and repairs. From this collective information, an initial list of monitoring needs was developed based on a review and discussion of historical records.

2 Failure History Data Sources

In order to use sensors and monitoring data to more effectively detect infrastructure conditions leading to unscheduled lock closure, it is critical to determine what components have historically led to closures, the conditions leading up to these failures, the specifics of the failure modes and how they can be detected most effectively. Only then can the monitoring be most effectively focused on the highest priority failure modes. This chapter discusses some of the relevant information sources and what was found when they were investigated.

2.1 Lock Performance Monitoring System (LPMS)

Data on scheduled and unscheduled lock closures are entered into LPMS. This is typically done by the lock operator, but can also be done by the lockmaster or other lock personnel such as equipment mechanics. Lock operators typically have less training and experience than other lock personnel or District engineers and technicians, and are often less familiar with the lock infrastructure. However, while LPMS is a good place to capture closures, it may not be as good for capturing data on infrastructure failures that result in unscheduled closures.

2.1.1 Failure-related data in LPMS

While LPMS can capture limited information on scheduled and unscheduled lock closures, it was not set up to capture failure data. It is an operational database primarily designed to capture lockages and tonnage. The following LPMS data fields relate to scheduled and unscheduled lock closures, including those attributable to failing or failed lock infrastructure:

- Location (Engineer Reporting Organization Code [EROC], River code, Lock #)
- Begin stop date/time
- End stop date/time
- Scheduled (Y/N)
- Reason code.

LPMS includes 34 closures reasons in six different categories:

- weather conditions
- surface conditions
- tow conditions

- lock conditions
- other conditions
- unknown.

Appendix A contains the entire list of LPMS reason codes. Of these six categories, only the lock conditions reason codes are clearly relevant to infrastructure issues. Reason codes to more specifically designate types of accidents and collisions would be useful. However, one would expect that the reason code "Accident or collision in lock" in the Lock Conditions category would be used if accidents or collisions occurred in the lock. Regardless, the reason codes most relevant to infrastructure issues relate to allisions and the four reason codes listed in bold in Table 2-1.

These LPMS codes do not provide details on what components were involved in causing the unscheduled closure. Missing details include:

- the specific component
- what happened to the component
- how the condition was discovered
- whether the lock was inoperable or if it was undesirable to continue operation
- how the condition impacted operation
- the age, condition, and maintenance history of the component.

Table 2-1. LPMS lock condition reason codes.

Reason code	Description*
AA	Accident or collision in lock
BB	Closed (unmanned shift)
EE	**Repairing lock or lock hardware**
Q	Debris in lock recess or lock chamber
R	**Lock hardware or equipment malfunction**
M	Tow staff occupied with other duties
T	**Maintaining lock or lock equipment**
U	Ice on lock or lock equipment
Y	**Inspection or testing lock**

*Bold-faced entries are the most relevant to infrastructure issues.

2.1.2 Definitions and descriptions of LPMS reason codes

In the course of investigating the LPMS data, it was learned that the specifics of many data fields are left undefined:

1. There is no standard definition of how to categorize closures as scheduled or unscheduled. An informal survey of engineers and managers responsible for maintenance and repair of navigation infrastructure resulted in a variety of opinions on how far in advance scheduled repairs must be announced, ranging from 72 hours to more than a year. The most relevant definition of unscheduled is any closure with a lead time too small to allow shippers time to adjust. This means that the lead time is different for every lock and will vary, typically by season.
2. One might expect that, if a reason code R (a malfunction) were entered into LPMS, it might be followed by reason code EE or possibly T or Y (repairing, maintaining, inspecting). On investigation of LPMS data, this was not found to be the case. Users entered one code or the other, but not both sequentially.
3. There are three slightly different reason codes for collisions or accidents that include both accidents and collisions. In one case, the collision is specifically in the lock. In another, the accident is a tow accident. Otherwise, the reason codes are non-specific. It appears that in two cases, accidents could include personnel from the tow having fallen overboard or become injured, as well as accidents involving other people. None of these codes mention allisions.
4. There is a reason code for debris and another for debris in the lock.
5. There is no guidance on which code to use if more than one is applicable to the situation.
6. There is no guidance on selecting whether the repair was scheduled or unscheduled. This would seem to be a straight-forward question but as discussed in the next section, the entered data is often not what might be expected.

Without clear definitions of the reason codes, there can be no expectation that closures due to similar conditions will be entered in LPMS using the same reason code.

2.1.3 LPMS lock closure data

LPMS data for scheduled and unscheduled closures from 2007 to 2013 were obtained and reviewed. Appendix B contains a sample of these records. The records for 2007 to 2011 were limited to entries of closures no longer than 1 month even when the closure extended much longer. These monthly records were combined. For the 7 years, there were 297 records

listing unscheduled closures of greater than 24 hours for lock condition reason codes AA, EE, Q, R, S, and T. These records were further investigated by contacting district personnel. No further information was gained for 112 records. Of the remaining 185 records, 104 were determined to be for scheduled closures. Of the remaining 81 records, listed and categorized in Table 2-2, 45 were due to non-mechanical issues such as winter closures, debris, extended closures of auxiliary locks due to low priority, and extra days to complete scheduled repairs.

Table 2-2 roughly categorizes the mechanical breakdowns. None are for a component or in a gate location that is particularly frequent. Instead, there are a few breakdowns in each of many different locations. This makes sense. Among other factors, breakdowns occur due to design weaknesses, overstresses, wear out, and inadequate maintenance. One goal of the engineers and maintenance crews is to identify components that need maintenance or repair to avoid breakdowns. While they may have to focus more effort on certain components, one indicator of success is that no particular component of the gates suffers an inordinate number of breakdowns.

Table 2-2. LPMS unscheduled lock conditions, 2007-13.

Condition	Occurrences
Non-specific miter gate repairs, replacement, damage, failure, etc.	8
Various gate gears issues	3
Cable and chain issues	0
Limit switch	1
Hydraulics	2
Gate anchorage, anchor bolts, anchor bars, pins, etc.	2
Gate cracks or structural failure	2
Barge accidents	1
Electrical and power control issues	0
Gate noise	0
Gate vibrations	0
Diagonal or strap	5
Strut arm, attachment or pin	4
Quoin block repairs	2
Gudgeon	2
Bottom seal	0
Valve issues	1
Pintle issues	3
Various non-mechanical reasons	45

2.2 Headquarters Navigation Branch Emergency Closure Study (1999–2005)

Headquarters USACE Navigation Branch wanted to collect more detailed information on emergency closures than what was currently available from other sources. A data call was made to Districts and Divisions that resulted in the records (included in Appendix C). These records are the most detailed compiled listing of unscheduled lock closures that were found in the course of this investigation.

The text of the data call request was not available and details of the information sought were unclear. The data seem to indicate either the request was not very specific or some of the responders did not follow directions, whatever they were. For example, MVR reported closures for flood repairs at numerous locks in 2001, but there was no other mention of flood damage. There are only five instances of lock closure due to barge impact, although the USACE Great Lakes and Ohio River Division (LRD) reported many more barge impacts on the Ohio and Monongahela with no listed closure time. Unfortunately, while about 20 closures list gates that were repaired, replaced, changed, installed, etc., none mention specific issues. It is likely that some of the closures were not emergency closures and may have even been scheduled.

Table 2-3 lists these reported emergency closures roughly categorized by cause. (Appendix D includes a full listing.) If more specific descriptions were provided of the 21 emergency closures for non-specific miter gate repair, it might be possible to relate more closures to specific causes. However, as the data stand, the current list reinforces what was seen in the investigated LPMS closures. A wide variety of issues lead to emergency closures, yet no specific problem(s) that frequently cause unscheduled closures were identified.

Table 2-3. Types of emergency closures 1999-2005.

Cause	Occurrences
Non-specific miter gate repairs, replacement, damage, failure, etc.	21
Various gate gear issues	5
Cable and chain issues	7
Limit switch	0
Hydraulics	3
Gate anchorage, anchor bolts, anchor bars, pins, etc.	4
Gate cracks or structural failure	7

Cause	Occurrences
Barge accidents	5
Electrical and power control issues	1
Gate noise	4
Gate vibrations	4
Diagonal or strap	4
Strut arm, attachment or pin	3
Contact block repairs	4
Gudgeon	2
Bottom seal	5
Valve issues	2
Pintle issues	2
Various non-mechanical reasons	36
Flood damage repair (other repairs could be from flood damage)	11

2.3 Incident reports

EP 1130-2-520, *Navigation and Dredging Operations and Maintenance Guidance and Procedures* (HQUSACE 1996) requires districts to report accident and equipment failures through their Division office to Headquarters (italics added for emphasis):

> EP 1130-2-520, Chapter 2
>
> 2-6. Special Reports.
>
> a. Changes affecting navigation will be made promptly whenever information of immediate concern to navigation becomes known. Refer to ER 1130-2-520 for the circumstances requiring special reports. Items of information especially desired are: (1) channel condition as revealed by surveys; (2) changes in channel conditions, either by natural causes or by dredging or other work; (3) changes in approved projects for improvement with statements of results expected from proposed-operations; (4) descriptions of proposed dredging or other Federal work of improvement such as breakwater, pier, and revetment construction or alterations; (5) descriptions of proposed or completed municipal or private improvements in or affecting navigable waters; (6) *accidents or equipment failures at USACE locks and dams or along navigable waterways, that will result in closure of the lock or waterway for 24 hours or more, or will result in a significant impact to navigation*. For item (6), district commanders are to forward an incident report to HQUSACE (CECW-OD)

> through their MSC office as soon as possible following the incident. Reporting of navigation incidents to CECW-OD is required even though the districts may be sending situation reports to the HQ Emergency Operations Center during natural disasters or more regional or localized events.

Cursory checking indicates that personnel are aware of this requirement and that they typically comply. Because these are incident (and not failure) reports, they may not contain all the details such as make, model, age, etc., but they do often explain what component failed, and how and why it failed. Appendix E includes a sample incident report. Unfortunately, HQUSACE does not maintain an archive of these submittals. Although they do not typically include some of the desirable information, they would very likely provide a good understanding of the types of issues that lead to unscheduled equipment failures and accidents and contacts for additional information. The event descriptions could also provide details to supplement failure reports from other sources.

2.4 Navigation notices

Corps Districts typically post notices to industry of scheduled and unscheduled lock closures. These notices may occur long before the closure or after it has started. The notice will summarize the reason for the closure, include an estimate of when the lock will reopen or (for more uncertain situations) estimates of the next steps. Information on alternative routes, queuing, and locations for tows to wait may be included. While the notices will usually give a good indication of the cause of the closure, they do not typically give many of the details of what broke and why. Appendix F includes a sample navigation notice.

2.5 Lock logbooks and maintenance cards

At one time, many lock projects recorded nearly all maintenance, repairs, and infrastructure-related closures in a log book or on maintenance cards. With the introduction of LPMS and the Facilities Equipment and Maintenance (FEM) program, these paper records lost favor. In many locations, continued use of logbooks and maintenance cards was discouraged. Unfortunately, in many cases, the data were not captured in the newer electronic tools either. Increasingly few projects continue to maintain these records. Appendix G includes examples of various maintenance and repair records

but logbooks and maintenance cards were not reviewed for useful information.

2.6 Division maintenance and repair records

Some projects, regional offices, Districts, and Divisions keep their own records of lock repairs and closures in addition to any standard USACE records. Appendix H includes two examples of summaries of repairs performed in the USACE Louisville District (LRL) and LRD, and Appendix I includes a summary of lock closures in the Mississippi Valley Division (MVD). The LRL record lists major issues addressed during dewaterings over a period of years. The LRD record lists scheduled, unscheduled, and performed repair and major maintenance data for LRD from 2005 to 2010. Often this type of information is collected post hoc, which can reduce the integrity of the information. Many of the dates for start and end of the closure do not match the data entered into LPMS. This may be due to a delay in entering the information, or it could be due to differences in perspective between the operators and engineers. The MVD list of lock closures is a new initiative that was not compared to LPMS closure data because the dates of obtained data only overlap for four closures.

3 Recording and Reporting Data

To determine and predict lock infrastructure component failures, it is important to have good information on the reliability of lock components. USACE does not systematically collect information needed for estimating failure rates. The future of USACE data collection related to infrastructure reliability is likely to include the use of FEM. The open question is whether this will be accomplished in a way that provides robust data that include the details needed to accurately estimate reliability. This chapter, although not comprehensive, briefly discusses some of the concerns.

3.1 Facilities Equipment Maintenance (FEM)

FEM is a USACE software program based on the IBM product named "Maximo." FEM is primarily a maintenance management tool used for scheduling and tracking maintenance, parts, labor, other resources, budget items, and costs related to maintaining a given infrastructure. A key part of FEM is the use of job plans for recurring work, work requests for non-recurring work, and a tracking system for all work and related resources.

Table 3-1 lists the FEM modules and application available to support collection of cradle-to-grave asset costs.

Table 3-1. FEM Modules.

Module	Description
Asset Module Applications	
Asset	Used to track physical assets, to define relationships between assets, and to manage assets throughout their life cycles. The defined relationships serve to build asset hierarchies.
Inventory Module Applications	
Item Master/Inventory Inventory Usage Tools/Stocked Tools	Used to build and store information about all aspects of inventory materials, monitor the storeroom balance of inventory items and tools, and track the cost of inventory stock reorder items when stock is low.
Planning Module Applications	
Job Plans	Used to create and manage Job Plan records, which contain job tasks and information regarding estimated labor hours, materials, services, and tools that are required for the work.
Preventive Maintenance Module Applications	
Preventive Maintenance	Used to create PM records (PMs) that can generate PM Work Orders for documenting scheduled maintenance that is performed on a time or meter-based frequency.

Module	Description
Purchasing Module Applications	
Purchase Requisitions	Used to create and view purchase requisitions (PRS) for items, supplies, and services. PR information is sent via an interface to CEFMS from FEM.
Resources Module Applications	
Crafts Qualifications	Used to identify project/site/organization crafts (skill sets). Used to create qualification records (i.e. certificates, licenses, etc.) for use on Labor records to document employee's qualifications.
Work Orders Module Applications	
Work Request and tracking Labor Reporting	Used to create basic work orders, report problems or malfunctions, or request work to be done. Used to create and process work orders from planning the work to documentation of the labor, material and services used (beginning to end). Used to report hours of work performed against a Work Order.

As discussed in Section 2.5, before the introduction of FEM, many projects kept hardcopy maintenance records for their lock infrastructure. An important capability within FEM is routine maintenance management. A primary component of this is the use of a recurring scheduled maintenance plan. This has largely replaced the paper records. Labor requirements, parts, tools, and consumables can also be identified and readied for use based on requirements set up in FEM. Although FEM can also capture corrective maintenance, this data entry is not yet as well implemented within USACE. Some districts use FEM to record labor and track inventory.

FEM includes data fields for capturing information on the failure of components. It does this primarily through pick lists for Failure Classes, Problems, Causes, and Remedies. FEM presents opportunities for systematically capturing, organizing, and archiving information on faults and failures of infrastructure components. USACE has developed neither a policy nor objectives for collection of data regarding reliability of infrastructure. Section 3.2 further discusses information that might be collected to better determine the reliability of USACE infrastructure.

3.2 Recording data

3.2.1 Inventory

USACE has no comprehensive record of navigation components. Creating an inventory is a substantial effort but it is not just a failure reporting task. It is an integral step in implementing a maintenance management system

such as FEM. All tasks need to be tied to a component. The quality and detail of the inventory will determine the effort to create it and the uses that can be made from it. Age, size, type, manufacturer, location, usage, and many other details can enhance capabilities to effectively and efficiently manage infrastructure.

Recording the installation date would seem relatively easy and straightforward, but it is not. The primary complication is determining whether a rehabilitated component is considered "new" when a portion of its parts have been repaired or replaced. Criteria for judging this can be created, but it will take a significant effort to do the job well. This work would require an initial effort to develop guidance that can be consistently applied across the inventory to identify the metrics for replaced (new) versus simply being repaired. The ambiguity of "repair" vs. "replace" can be minimized by focusing on the lowest level of components identification possible. Recording of size, type, manufacturer, etc. all present similar difficulties. It is important that individual items can be grouped according to similar parameters in order to assess their performance as a statistical group.

3.2.2 Failure reporting

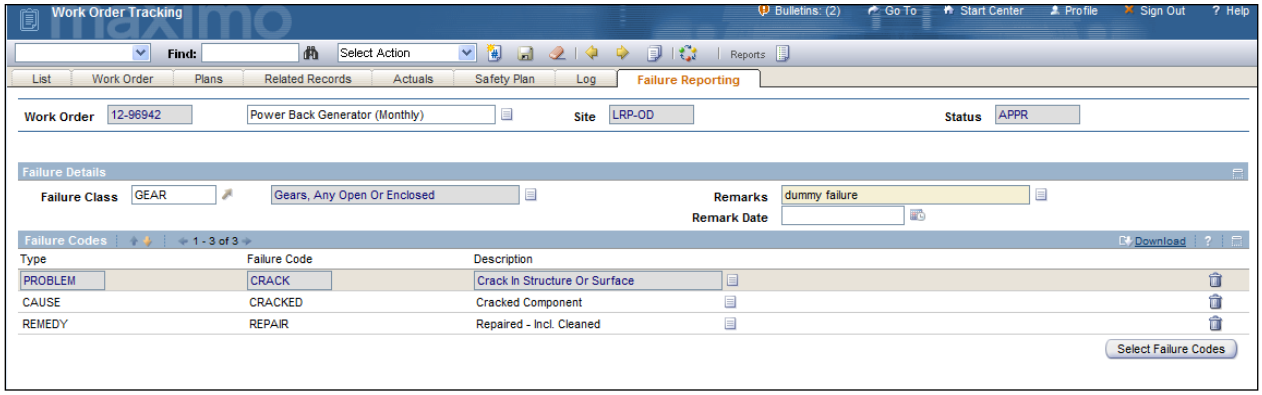
Failure reporting is important for a number of reasons, but it basically comes down to determining and recording what fails, how often, why, under what conditions, and with what consequences. FEM includes a work order page for recording the failure class, problem, cause, and remedy (Figure 3-1). Appendix C includes a full list of failure classes, problems, causes, and remedies.

At first glance, failure reporting seems to be quite simple. However, it is not. Each of the questions in the previous paragraph needs to be approached in a direct and explicit fashion to capture the desired information. Failure reporting must be accomplished using standardized categories to create usable failure statistics such as:

- *What has failed?* Identifying what has failed must be done in a consistent way. That means using classifications to identify the component and attributes to identify details such as the manufacturer, size, etc.
- *How often?* This is the best basis for estimating failure rates. It may also help identify systemic problems. The occurrence of a failure needs to be precisely defined. Is it based on a repair, subcomponent replacement, overhaul, total replacement, another basis, or some combination of these? The answer will determine how the data can be used.

- *Why?* The most valuable data are those that identify the failure mode. It makes a difference whether electric motor failures are from bearings that have been inadequately lubricated (and should be maintained), or from a short in the motor windings that cannot be maintained, but that might indicate a manufacturer defect.
- *What conditions?* If every USACE lock were constructed with a similar design, size, usage, operating environment, etc., determining failure rates could be done more accurately. There are a number of ways to capture these operating conditions, but it will require extensive forethought to most effectively account for these variables.
- *Suspensions?* How are replacements before failure to be recorded?
- *What consequences?* Should a failure be reported based on a stall, stoppage, non-routine application of maintenance, or other criteria?

Figure 3-1. Example FEM failure report.



With adequate data points and detail, failure data can assist in many ways. First, they can allow a statistical calculation of past failure rates. This is important for verifying estimates used in risk analysis. Failure data can also help identify common causes of failures, maintenance deficiencies, manufacturing defects, design flaws, and other system faults.

While failure data information is useful, it likely needs to be supplemented with additional information. Useful supplementation includes: (1) information that can be collected in FEM, such as age, (2) information that should be collected as standardized attributes, such as the manufacturer, model, size, etc., and (3) information such as condition as it relates to the specific failure mode. While this last piece of information (condition) could be accomplished by extensive data collection, possible alternatives could include post-failure estimates and automated condition monitoring.

3.2.3 Failure modes

Recording failures unambiguously also requires a focus on failure modes. Wiebull models are only meaningful when applied to failure data collected at this level. Because USACE operates locks of unique designs, loadings, and usage with diverse components of varying size and manufacture in diverse environments, good failure data also require more information to determine the contribution of each failure mode to the observed failures. The question is how this information should be captured. Demand relative to capacity is important, but it seems reasonable to ignore this factor for most USACE lock infrastructure, which is usually designed for much higher loads than are typically encountered. In USACE, usage or loading cycles are very important. Age may also be useful as a crude approximation of many contributors to failure, although age does not account for the uniqueness of each USACE structure. One way to capture that uniqueness is by using condition ratings that focus on each failure mode to develop a failure rate relationship based on usage and condition.

3.2.4 Downtime reporting

Currently, FEM makes no direct connection between downtime reporting and failure reporting, although both must be tied to a work order. Downtime reporting differs from failure reporting in that it is primarily concerned with recording what asset is unavailable and the duration of the outage. Figures 3-2 and 3-3 show the entry of this information into FEM. Note that downtime reporting is based on what is occurring during the downtime and does not include information on what led to the downtime. It also does not specifically distinguish between scheduled and unscheduled downtime.

There are presently five choices for types of downtime (Figure 3-3). Note that the list does not include any type of weather-related downtime, nor does it allow recording a boat accident, personnel injury, or other causes not listed in FEM. Although it is possible to record lock stoppages and shutdowns within the downtime reporting, there is no obvious best way to do that and there is currently no guidance on how it should be done. As a result, if a project started using FEM to record shutdowns, it is likely those shutdowns would be recorded in different ways across USACE so that it would be difficult to compile a history of shutdowns and their causes.

Figure 3-2. FEM downtime reporting selection.

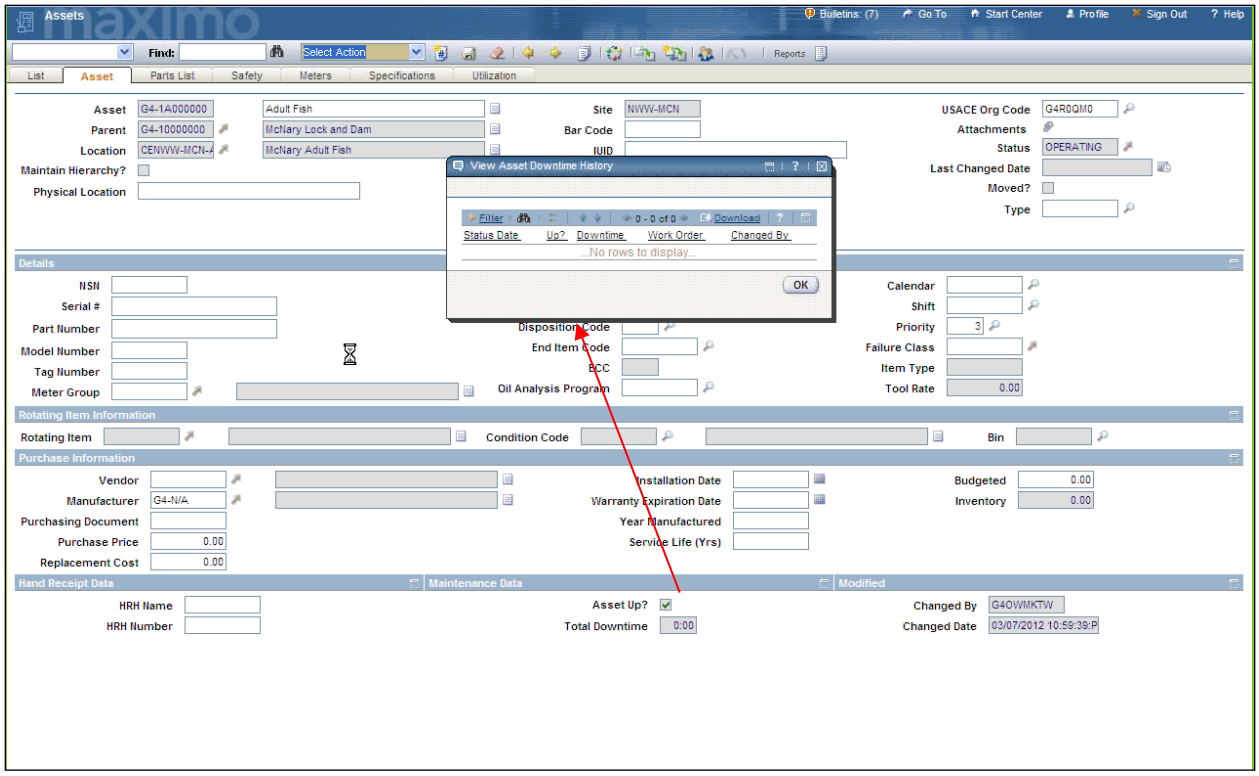
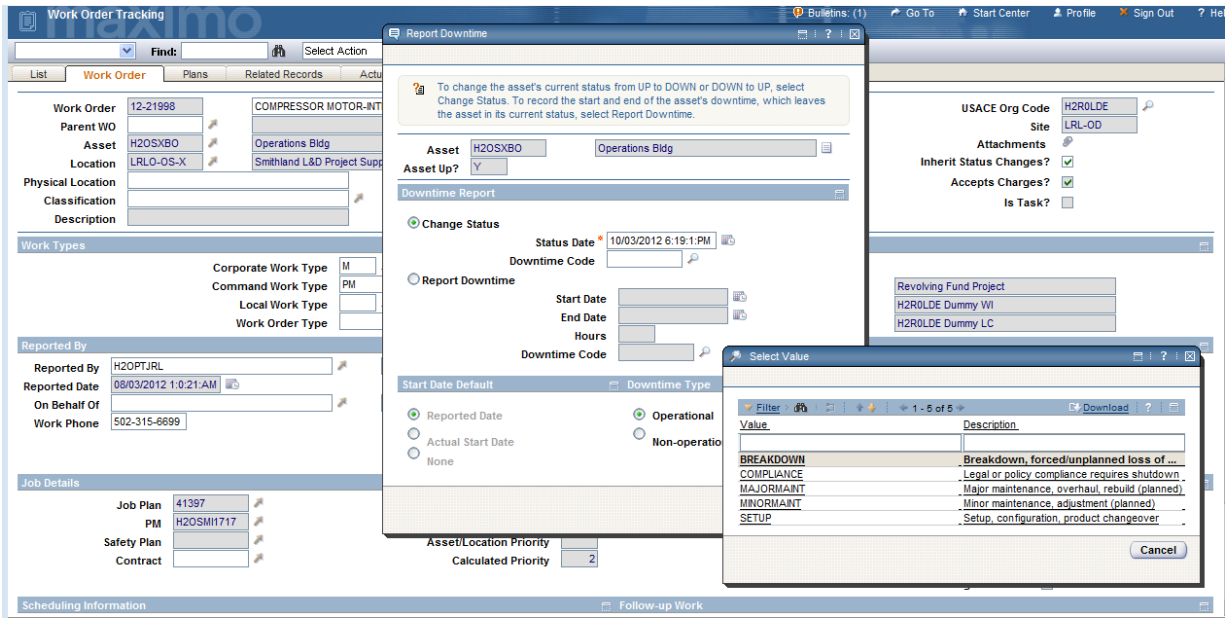


Figure 3-3. FEM downtime (details) reporting selection.



While there is no direct connection in FEM between downtime reporting and failure reporting, both are tied to a work order. That link within the user interface is weak because failure reporting is located on a work order tab and downtime reporting is on a pull-down menu but if both records for

an event are entered, they can be associated. It would be better if the user interface included a stronger link between the two. One option would be to prompt the user to enter a downtime report when exiting the failure reporting module and provide a similar prompt when exiting the downtime report.

3.3 Data usage

3.3.1 Lock performance reports

Until recently, the USACE Campaign Goal Objective 3C was to "Deliver reliable infrastructure using a risk-informed asset management strategy." For navigation, accomplishment of this goal was measured by looking at LPMS data for scheduled and unscheduled closures lasting longer than 1 day, and 7 days. See Figures 3-4, 3-5, and 3-6 and Table 3-2. This information has been included in numerous publications and presentations.

It was useful and informative to separate unscheduled closures attributed to mechanical breakdowns from other unscheduled closures. Unfortunately the LPMS reason codes used to identify unscheduled mechanical breakdowns (Table 2-1) include debris, icing, unmanned shifts, lock staff unavailable, and accidents in the lock, such as "man overboard" and potentially even allisions (although no LPMS reason code description specifically mentions allisions). If the goal is to determine infrastructure reliability, including closures for those reasons creates ambiguity.

Figure 3-4. LPMS lock closures reported for campaign goal objective 3C.

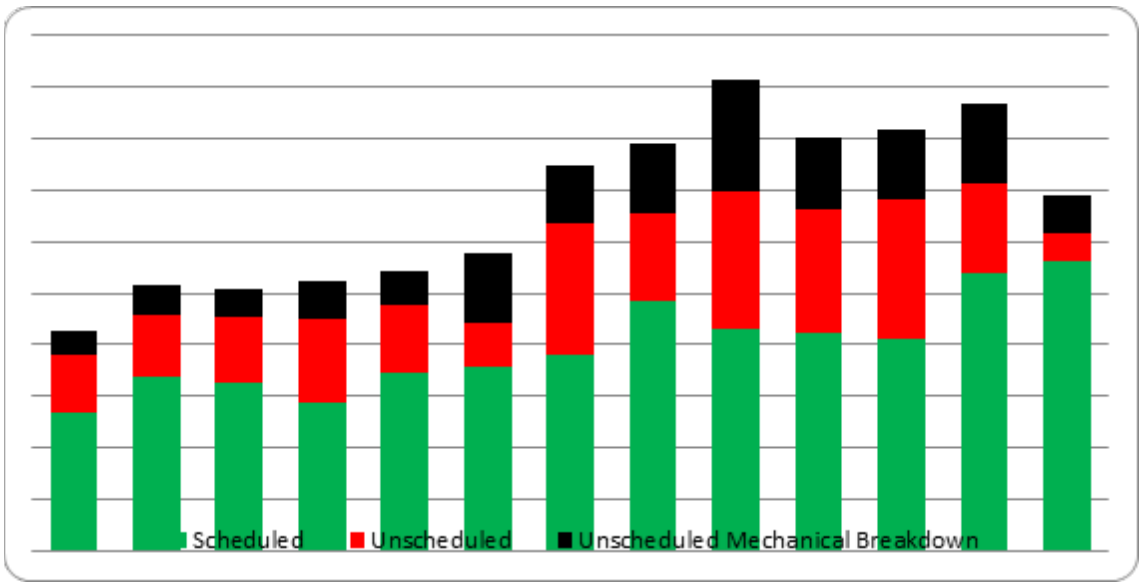


Figure 3-5. Scheduled and unscheduled closures.

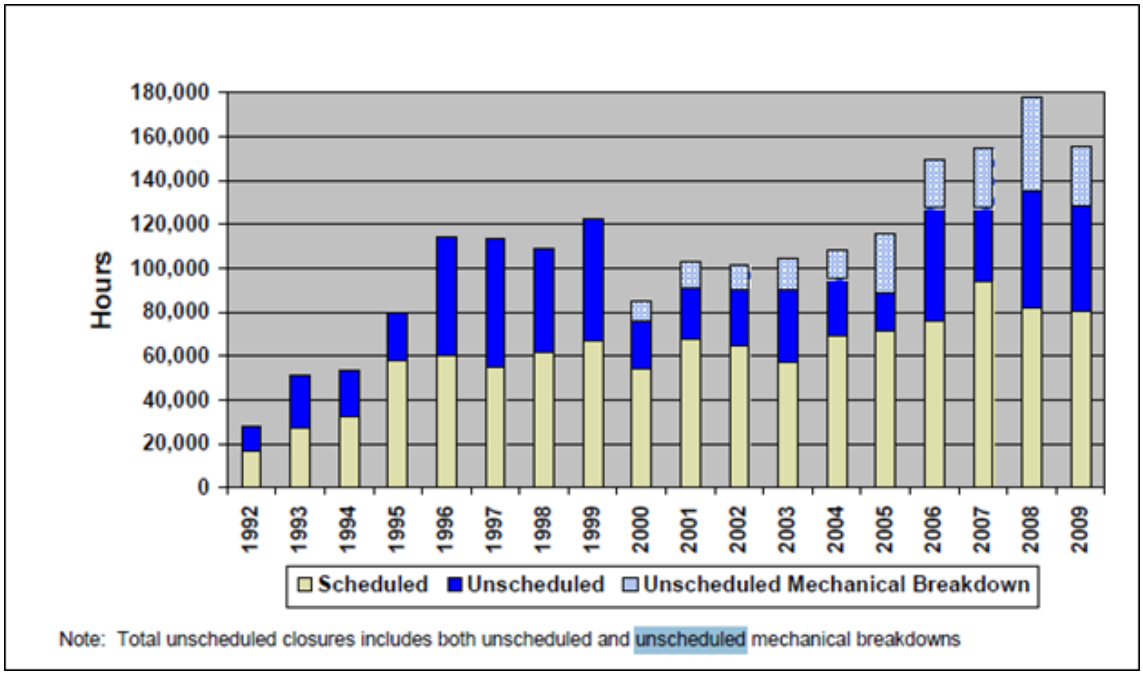


Figure 3-6. Increasing "downtime" at USACE locks on the inland waterways navigation.

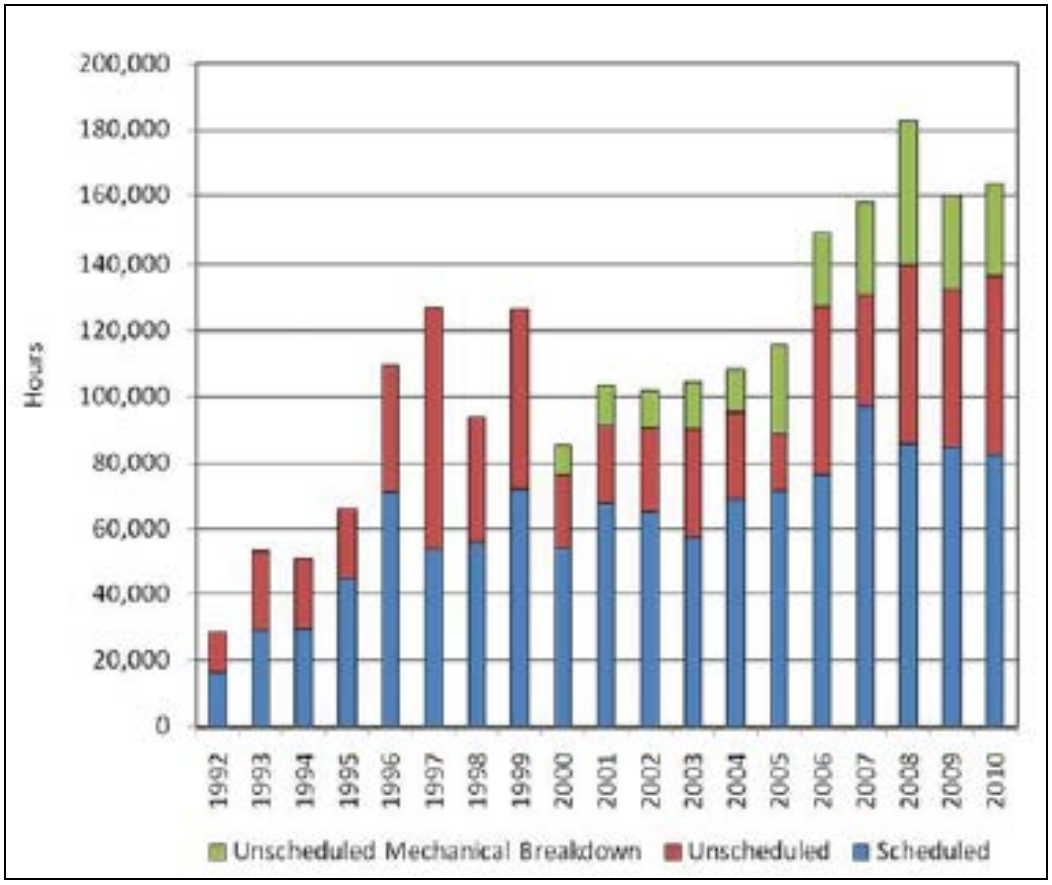


Table 3-2. Navigation high priority performance goal for inland and intracoastal navigation operations and maintenance (O&M) projects.

Fiscal Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Appropriation ($ Millions)	NA	NA	NA	$	$501	$491	$523	$660	$886	NA
Target- Instances of Lock Closures due to Mechanical Failures Lasting Longer than 24 Hours	NA	NA	NA	NA	NA	NA	NA	NA	37	38
Actual Instances of Lock Closures due to Mechanical Failures Lasting Longer than 24 Hours	45	45	36	19	33	38	42	37	61	NA
Total Hours for Lock Closures due to Mechanical Failures Lasting Longer than 24 Hours	13,448	12,575	9,265	5,029	9,817	9,317	16,033	11,096	19,562	NA
Target- Instances of Lock Closures due to Mechanical Failures Lasting Longer than 7 Days	NA	NA	NA	NA	NA	NA	NA	NA	19	21
Actual Instances of Lock Closures due to Mechanical Failures Lasting Longer than 7 Days	25	27	19	13	21	18	28	19	37	NA
Total Hours for Lock Closures due to Mechanical Failures Lasting Longer than 7 Days	12,255	11,399	7,929	4,728	8,871	7,805	15,073	9,675	17,638	NA

HPPG implemented in FY 10. Prior year targets were not established.

In addition to ambiguous or inapplicable closure codes, the limited investigation of LPMS data discussed in Section 2.1.3 indicates that the criteria used to determine whether a closure is “scheduled” or “unscheduled” are poorly defined and often not entered accurately. One particular example is the entry of month-long unscheduled closures in December, January, and February as EE-Repairing. These closures account for a large portion of the hours identified as unscheduled mechanical breakdown. While repairs may be occurring, the closure is in fact due to ice-related river and lock conditions. Similarly, an auxiliary lock may be closed for repairs for an extended period because it is a low priority to return to service quickly. The reduction in 2012 for unscheduled mechanical breakdowns comes largely from a reduction in entries of these two reasons. In the case of scheduled closures, it is useful to determine how often locks are closed for scheduled maintenance, inspection, and repair. However, a tabulation of all scheduled closures will include other reasons that may create ambiguity. For example, the decision not to staff some locks 24/7 increases scheduled closures. Clearly, if LPMS data are going to be used for metrics such as an USACE Campaign goal, the LPMS data must be relevant to the metric. It

may even be necessary to change the manner in which the LPMS data are collected.

3.3.2 Service life and performance of components

Comprehensive data on the life cycle (installation through replacement) of infrastructure components would create numerous options for planning and risk management. If USACE is to implement a fully functioning risk management program, it is critical to progress from subjective opinion based failure probabilities to statistics based estimates. This cannot be accomplished without collection of data related to failure of components as previously described.

In addition to risk analysis and other uses related to repair prioritization and budgeting, failure statistics (along with maintenance records) can help identify best practices for design and maintenance.

There are many different fender designs used throughout USACE. Local experience is important but without good service life data, there is no objective way to measure the cost-benefit of alternative designs which vary greatly in initial cost and service life or measuring the effects of weather, barge impacts, and other considerations.

Scheduled maintenance (or insufficient maintenance) can extend the life of infrastructure. Excessive maintenance does little good and in some cases can reduce the service life. Optimizing the maintenance based on past results can yield significant savings.

A history of repairs and component replacements with consistent recording of the cause can help identify defective components as well design or operational shortcomings.

4 Summary

4.1 Results

4.1.1 Mechanical breakdown data summary

While data are potentially available from numerous sources, this effort only found usable data available from two USACE-wide sources (LPMS and the Headquarters (HQ) data call described in Section 2.2) Data from LPMS need further investigation to obtain the minimum necessary details. Although the years covered by the two sources are discontinuous, the combination of these two sources (Table 4-1) yields a better indication of the conditions leading to unscheduled mechanical closures. The results indicate that there are a large number of conditions of similar frequency that lead to these closures.

Table 4-1. Unscheduled mechanical closure conditions.

Description	Table 2-2	Table 2-3	Combined
Non-specific miter gate repairs, replacement, damage, failure, etc.	8	21	29
Various gate gear issues	3	5	8
Cable and chain issues	0	7	7
Limit switch	1	0	1
Hydraulics	2	3	5
Gate anchorage, anchor bolts, anchor bars, etc.	2	4	6
Gate cracks or structural failure	2	7	9
Barge accidents	1	5	6
Electrical and power control issues	0	1	1
Gate noise	0	4	4
Gate vibrations	0	4	4
Diagonal or strap	5	4	9
Strut arm, attachment or pin	4	3	7
Quoin block repairs	2	4	6
Gudgeon	2	2	4
Bottom seal	0	5	5
Valve issues	1	2	3
Pintle issues	3	2	5
Various other reasons	45	28	73
Flood damage repair (other repairs could be from flood damage)		11	11

4.1.2 Employee interviews

Although the data collected give some indication of the common lock infrastructure problems leading to unscheduled closures, the data are still very limited and give neither a complete picture of the infrastructure issues, nor an accurate quantification of the extent that infrastructure issues lead to lock closures. To supplement the collected data and to gain further insights, it was decided to survey various USACE employees. A number of questions were asked of six senior USACE employees to gain their knowledge regarding unscheduled mechanical closures and also to gather their knowledge and opinions on how locks are and should be maintained. Appendix J includes copies of the questions and the experts' paraphrased responses. The questions were first briefly discussed with most of the experts by teleconference. Further comment was obtained from the experts individually either in writing or by interview. These further comments are shown in bolded font.

While each expert expressed their own particular concerns, the most common issue they identified was the need to gather information needed to plan repair work while the locks are dewatered. Details on needed repairs below the water line and the extent of these needed repairs must be based on reports of conditions after the previous dewatering repairs, updated with operational information such as noises and vibrations, and with information gathered by underwater inspection by divers. This information is often inadequate. Surprises are frequent and it can be difficult to accomplish the unplanned repair work in the allotted time.

4.2 Conclusions

USACE owns a large inventory of civil works structures, each of which is unique. Typically, there are few or no components in any one structure that are of the same make, model, size, manufacturer, designer, constructor, environment, or operational history as those in any other USACE structure. Furthermore, operation, maintenance, repair and rehabilitation is overseen by lock personnel, maintenance crews, engineers, and others, in multiple districts, all of whom differ in their experience and in their expectations of how the structures should be operated and maintained. These are only two of many factors that make it difficult to develop a comprehensive listing of conditions and other issues that currently lead to lock closures and/or catastrophic failures at all USACE locks.

This work reviewed data from 236 locks at 191 USACE sites and identified 119 unscheduled lock closures of durations over 24 hours that occurred due mechanical breakdowns. Of the 119 closures, records documenting 29 of the closures focused broadly on the miter gates. Eighty-five of the remaining 90 closures were attributed to the failure of 14 specific components, each of which caused four to nine closures. Note that these data were not exhaustive; better data collection would have yielded far more detailed reports, which would in turn have enabled better analysis of the noted closures. For example, data from one source were collected post hoc; data for the other period included only about 40% of the records.

This work attempted to augment these data with information culled from historical records, with some limited success. Based on the limited data collected, the conditions and causes —i.e., mechanical breakdowns and other infrastructure-related issues (such as allisions)— that led to these unscheduled lock closures appear to be highly varied. Some closures were attributed to combinations of many issues, and no single issue was identified as the cause of many closures. While the mechanical breakdowns leading to unscheduled closures are quite varied, there are a smaller number of issues of more frequent concern during scheduled maintenance.

USACE does not systematically track the causes of lock mechanical breakdowns. Data currently collected lack sufficient detail to allow a failure analysis beyond expert judgment of those involved. Similarly, USACE currently has only marginally applicable, incomplete data for estimating the reliability of infrastructure components. Component reliability is primarily determined based on subjective expert opinion, or on metrics that are themselves based on that expert opinion. This lack of objective, historical data makes it difficult to meaningfully identify or prioritize how to improve the reliability of a particular structure (or set of structures).

USACE does have the ability to collect data on mechanical breakdowns and reliability through existing available systems, specifically, LPMS and FEM. These systems could be better used to collect data in enough detail to form a real-time record of component failures and replacements could enable the identification of components with unacceptably low reliability. However, existing data are inadequate to support calculations of historical life averages and other statistical measures to in-service components. As

currently recorded, that data in each of these systems appear to have limited value in tracking mechanical breakdowns and reliability for many reasons, including, but not limited to:

- data availability (i.e., whether data are even collected)
- the intent of data collection
- data consistency (definition of what should be collected)
- data accuracy (requirements for what data is collected)
- data preservation.

Collection of more adequate data would be useful in identifying common issues and in identifying ways to reduce breakdowns most effectively through redesign, timely maintenance and inspection, improved dewatering effectiveness, automated data collection (sensors), and other methods. Because it is difficult to identify specific needed M&R (and the extent of that M&R) before dewatering, better information on repair needs before dewatering could assist in planning for M&R while dewatered, and could help shift schedules for dewatering from a time-based to a condition-based schedule.

4.3 Recommendations

While lock monitoring development efforts should continue to investigate how to identify impending mechanical breakdowns, an effort should also be made to capture relevant information to determine what needs to be repaired regardless of the short-term failure likelihood. The hidden nature of many developing distresses, particularly of those underwater, makes it imperative to gather consistent, accurate information that may be used to plan repairs long before failure is likely or impending.

This work recommends that USACE begin to systematically collect data on mechanical issues, failures, and replacements as they occur, in sufficient detail to determine the reliability of in-service components. Specifically, this work recommends that USACE standardize this data collection on the use of the Facilities Equipment and Maintenance (FEM) system, which is clearly the best option to collect and store this information. One potential benefit of using a single system to collect and compile data on operations and infrastructure is that it allows a standardization of the information used for performing statistical analysis. To fully reap the potential benefits this system can offer, the data must be collected in a uniform and con-

sistent manner. This is not currently being accomplished with infrastructure-related data within LPMS and FEM. To that end, it is recommended that detailed instructions be created and given to personnel on the data that must be collected, and how to consistently and accurately enter that information into FEM.

It would require a substantial effort to determine the failure reporting data needed for developing meaningful failure statistics. Recording of the information by project and district personnel would also be a significant effort. While LPMS is not intended for failure reporting, and it does not provide a good opportunity for collecting the best information, small improvements in LPMS data fields, reason codes, and user instructions could result in more meaningful data with little or no additional effort.

Navigation Notices have historical information that may be of some value, and incident reports include highly valuable information. These documents should be archived for future use. It was confirmed that the HQUSACE POC did not save the incident reports. USACE employees should be queried to determine if someone else has saved these valuable records.

Appendix A: LPMS Reason Codes

1	**Weather Conditions**	
	A	Fog
	B	Rain
	C	Sleet or Hail
	D	Snow
	E	Wind
	F	Lightning
2	**Surface Conditions**	
	G	Low Water
	H	Ice on or around tow
	I	River current or Outdraft condition
	J	Flood
	N	Operations (run-spill-divert water, flush seals-reserve etc.)
	O	Debris
3	**Tow Conditions**	
	K	Interference by other vessel(s)
	L	Tow malfunction or breakdown
	M	Tow staff occupied with other duties
	P	Tow accident or collision
4	**Lock Conditions**	
	AA	Accident or collision in lock
	BB	Closed (unmanned shift)
	EE	Repairing lock or lock hardware
	Q	Debris in lock recess or lock chamber
	R	Lock hardware or equipment malfunction
	S	Lock staff occupied with other duties
	T	Maintaining lock or lock equipment
	U	Ice on lock or lock equipment
	Y (y)	Inspection or testing lock
5	**Other Conditions**	
	CC	Grounding
	DD	Environmental (i.e. fish, animals, oil spills, etc.)
	FF	Lock OK; Unused for other reasons (i.e. River closing etc.)
	GG	Bye Time (reconnecting double lockage tows
	V	Tow detained by Coast Guard or Corps
	W	Collision or Accident
	X	Bridge or other structure (i.e. railway, pontoon, swing etc.)
	Z	Other
6	**Unknown**	
	UN	Unknown

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix B: LPMS Closure Data

EROC	RIVER CODE	LOCK NO	CHMBR NO	BEG STOP DATE	END STOP DATE	Duration days	SCHEDULED	REASON CODE
H2	OH	41	2	10/1/2011 0:00	10/31/2011 23:59	31.00	N	EE
H2	OH	52	5	3/1/2011 0:00	3/31/2011 23:59	31.00	N	Z
H2	OH	52	5	12/1/2011 0:00	12/31/2011 23:59	31.00	N	FF
H4	MN	24	4	1/1/2011 0:00	1/31/2011 23:59	31.00	N	Z
H4	MN	24	4	3/1/2011 0:00	3/31/2011 23:59	31.00	N	Z
H4	MN	24	4	5/1/2011 0:00	5/31/2011 23:59	31.00	N	Z
H4	MN	24	4	7/1/2011 0:00	7/31/2011 23:59	31.00	N	Z
H4	MN	24	4	8/1/2011 0:00	8/31/2011 23:59	31.00	N	Z
H4	MN	24	4	12/1/2011 0:00	12/31/2011 23:59	31.00	N	Z
H2	OH	41	2	8/1/2011 0:01	8/31/2011 23:59	31.00	N	EE
H1	OH	25	4	3/1/2011 0:00	3/31/2011 22:59	30.96	N	T
H4	MN	24	4	10/1/2011 0:00	10/31/2011 0:00	30.00	N	Z
H2	OH	41	2	9/1/2011 0:00	9/30/2011 23:59	30.00	N	EE
H2	OH	52	5	4/1/2011 0:00	4/30/2011 23:59	30.00	N	Z
H4	MN	24	4	4/1/2011 0:00	4/30/2011 23:59	30.00	N	Z
H4	MN	24	4	6/1/2011 0:00	6/30/2011 23:59	30.00	N	Z
H4	MN	24	4	9/1/2011 0:00	9/30/2011 23:59	30.00	N	BB
H2	OH	41	2	11/1/2011 0:01	11/30/2011 23:59	30.00	N	EE
H2	OH	41	4	6/1/2011 3:30	6/30/2011 20:40	29.72	N	EE
H4	MN	24	4	11/1/2011 0:00	11/30/2011 0:00	29.00	N	Z
B5	MI	22	1	1/3/2011 8:00	1/31/2011 23:59	28.67	N	EE
H4	MN	24	4	2/1/2011 0:00	2/28/2011 23:59	28.00	N	Z
B5	MI	22	1	2/1/2011 0:01	2/28/2011 23:59	28.00	N	EE
H2	OH	41	4	2/1/2011 0:01	2/28/2011 23:59	28.00	N	O
H4	AG	43	1	5/2/2011 22:00	5/30/2011 12:00	27.58	N	EE

Appendix C: FEM Failure Reporting Picklists

C.1 Failure classes

F_CODE	F_CLASS_DESC
ANNUN/REC	Annunciators, Event Recorders
BATTCHRGR	Battery Charging Systems
BATTERY	Batteries, Any
BEARING	Bearings & Anti-Friction Bushings, Any
BRAKE	Brakes, Any
BRIDGE	Bridges & Catwalks, All
BUILDINGS	Buildings, Basic Structure
BULKHEAD	Bulkheads, Stoplogs
BUOY/MOOR	Buoys, Floating Signs, Floating Moorage (Not FMBs)
BURNER	Burners, Flame Sources (Boilers, Furnaces, Weed Burners)
BUS/INS/EN	Buswork, Insulators & Associated Enclosures
CABLE/PWR	Cables, Power Transmission Or Distribution
CHANNEL	Channels - Diversion, Fishway, Canal, Raceway, Sluice, etc.
CHASSIS/SU	Chassis, Suspension, Shock Mounts
CIRCUITBKR	Circuit Breakers, All
COMM-DATA	Data Communication Equipment Incl. Cabling
COMM-RADIO	Radio Communication Equipment
COMM-TEL	Telecommunication Equipment Incl. Cabling
COMPRESSOR	Compressors, All
COMPUTER	Computer, General Purpose PC/Server
COOLING	Cooling Systems, All
CRANE-HOIS	Cranes, Hoists & Winches, Incl. Mobile
DOCK/PIER	Docks & Piers, Fixed & Floating Guidewalls
DOOR/GATE	Entry/Access Doors, Gates & Hatches (Not Water Control)
DRAINAGE	Drainage - Culverts, Ditches, Gutters, Lock Chamber Vents
ELEVATOR	Elevators
ENGINE	Engines, Internal Combustion
EXCITER	Excitation Systems
FAN/BLOWER	Fans & Blowers, Incl. Heatsink/Fan Combo
FENCE/BAR	Fences & Barriers, Guard Rails, Hand Rails, Guide Rails
FIREPREV	Fire Detection, Suppression & Alarm Systems
GATE-CRTL	Gates - Miter, Wicket, Intake, Lift, Tainter, Etc.
GEAR	Gears, Any Open Or Enclosed
GENERATOR	Generators, All
GOVERNOR	Governors, All Incl. Mechanical, Electronic, Digital
HEATX/RAD	Heat Exchangers, Radiators, Condensing Coils, Etc.
HVAC	Heating, Ventilating, Air Conditioning
INVERTER	DC/AC Inverters, All
LANDSCAPE	Landscaping, Turf
LEVEE/EMB	Levees & Embankments
LIGHTING	Lighting Systems

METER/MON	Meters, Monitors, Gauges, Sensors
MOBIL-TRAC	Mobile Tracked Equipment - Tractors, Excavators
MOBIL-WHL	Mobile Wheeled Equipment/Vehicles (Excl. Cranes)
MONOLITH	Monoliths, Concrete Structures
MOORINGBIT	Floating Mooring Bits (Fmbs)
MOTOR-ELEC	Motors - Electric (Not Engines)
MOTOR-OTHR	Motors - Any Non-Electric (Not Engines)
PAINT/COAT	Paint, Finish, Protective Coating
PARK/CAMP	Parks & Campgrounds
PENSTOCK	Penstocks
PIPING	Piping, Any
PLC	Programmable Logic Controllers
PLUMBING	Plumbing Fixtures Excl. Piping
POWER-XFER	Transmissions, Couplings, Clutches, Gearboxes, Belt Drive
PRESVESSEL	Pressure Vessels
PRINT/FAX	Printers/Fax/Copiers, Label, Tag, All-In-One, Etc.
PUMP	Pumps, Any
RAIL/ROLL	Rails (Track), Rolling Stock
RAMP/LDOCK	Ramps - Boat, Loading Docks
RELAY/SOL	Relays & Solenoids, Incl. Transfer, Electronic, Protective
RIGGING	Ropes, Chains, Slings, Rigging Hardware
ROAD/PKLOT	Roads & Parking Lots, Surface
SAFETY	Personal Safety And Rescue Equipment
SCADA	Scada, Gdacs, Control Systems Incl. Dedicated Computers
SCREEN/GRT	Screens And Grates - Fish, Debris, Lock Intake, Etc.
SECURITY	Security, Intrusion Detection, Access Control
SEPAR/FILT	Separators And Filters
SEWAGE/WW	Sewage & Waste Water Handling
SIGNAGE	Signage, Any
SWITCHAUTO	Switches, All Automatic Incl. Limit, Safety, Tamper, Etc.
SWITCHMAN	Switches, All Manually Operated
TANK	Storage Tanks (Not Pressure Vessels)
TEST/CALIB	Testing And Calibration Equipment
TOOL/MACH	Machine Tools, Stationary Power Tools Except Welders
TOWER	Tower Structures - Transmission, Comm, Etc.
TRANSFRMR	Transformers, All
TUNNEL	Tunnels & Galleries, Any Type
TURBINE	Turbines, Hydraulic Incl. Pelton Wheels Etc.
VALVE	Valves, All - Globe, Gate, Tainter, Etc.
VIDEO	Video Systems Incl. Cameras, Monitors, Recorders
VOLTREGLTR	Voltage Regulation Systems
WATER-RAW	Non-Potable Water Systems - River, Irrigation, Etc.
WATERCRFT	Watercraft, Boats, Barges Except Dredges
WATER_POT	Potable Water Systems - Treatment, Piping, Wells
WELDER	Welders, All

C.2 Problems

F_CODE	F_PROBLEM_DESC
ADJUSTFAIL	UNABLE TO ADJUST
ANIMALPEST	ANIMAL/PEST CONTROL PROBLEMS
BLIST/PEEL	BLISTERED, PEELING, DELAMINATED
BROKEN	BROKEN, SHEARED, SHATTERED
CLOG	CLOGGED, BLOCKAGE
CLOSE-FAIL	FAILS TO CLOSE
CONTAMINTN	CONTAMINATION, CORRUPTION, ANY
CORROSION	CORROSION, RUST, CAVITATION DAMAGE
CRACK	CRACK IN STRUCTURE OR SURFACE
DAMAGE-ACC	ACCIDENT OR COLLISION DAMAGE
DAMAGE-NAT	WEATHER/NATURAL DAMAGE, INCL. ANIMAL
DECAY	DECAY/ROT, DETERIORATION (NOT ELECTRONIC)
DEFACEMENT	DEFACEMENT/INTENTIONAL DAMAGE OF PROPERTY
DISCOLOR	DISCOLORED, UNUSUAL CHANGE IN COLOR/TRANSPARENCY
ENVIRO/HAZ	ENVIRONMENTAL/HAZMAT PROBLEMS OTHER THAN SPILLS
EROSION	EROSION, UNDERMINING, SINKHOLE, SUBSIDENCE
ERRATIC	ERRATIC/RANDOM OPERATION, UNSTABLE, FLICKERING,
EXPLOSION	EXPLOSION
FIRE	FIRE
FLOOD	FLOODING
HEAT-OVER	OVERHEATS
HEAT-UNDER	FAILS TO REACH OPERATING OR ADEQUATE TEMP
INACC/DIST	INACCURATE, DISTORTED, FALSE DISPLAY/READOUT/OUTPUT
LEAK	LEAKS, ANY
LIMITOVER	OVER/BEYOND HIGH LIMIT
LIMITUNDER	UNDER/BELOW LOW LIMIT
LOOSE	LOOSE OR DISLODGED
MISSING	ITEM./COMPONENT IS MISSING, MISPLACED, OUT OF POSITION
NOISE	NOISE, EXCESSIVE OR ABNORMAL, EXCL. ELECTRONIC
ODOR	ABNORMAL ODOR
OPEN-FAIL	FAILS TO OPEN
OPER-FAIL	FAILS TO OPERATE OR RUN
OUTOFSPEC	OPERATING OUT OF SPECIFICATION
PIT/POTHOL	SURFACE PITS/POTHOLES
POWER-OUT	POWER/CURRENT FAILURE
POWERUNDER	UNDER POWERED, POOR ACCELERATION
PRESS-OVER	PRESSURE OVER SPEC
PRESS-UND	PRESSURE UNDER SPEC, NO PRESSURE
RUPTURE	RUPTURED, BURST
SAFETY-REC	SAFETY RECALL
SECURITY	SECURITY/LAW ENFORCEMENT PROBLEMS

SEIZE/LOCK	SEIZED, LOCKED UP, FROZEN
SIGNALFAIL	NO OR POOR SIGNAL/TONE, POOR S/N RATIO
SINK/AWASH	SINKING, SUNK, AWASH, LOSS OF BOUYANCY
SMOKE/BURN	SMOKE, SCORCH MARKS, EVIDENCE OF BURNING
SPEEDOVER	TOO MANY RPMs OR CYCLES, TOO FAST
SPEEDUN-DER	TOO FEW RPMs OR CYCLES, TOO SLOW
SPILLENVIR	SPILL, OVERFLOW, ENVIRO/HAZMAT ISSUE
SPILLOTHER	SPILL, OVERFLOW, NOT ENVIRO/HAZMAT ISSUE
STALL/MISS	STALLS OR MISSES, HESITATES
START-ABNL	ABNORMAL OR UNEXPLAINED START
START-FAIL	WILL NOT START
STOP-ABNL	ABNORMAL OR UNEXPLAINED STOP, BREAKDOWN
STOP-FAIL	WILL NOT STOP OR SHUTDOWN
TENSION	TENSION TOO HIGH OR TOO LOW
VIBRATION	VIBRATION, EXCESSIVE OR ABNORMAL
WARNING	WARNING SIGNAL FROM A MONITORING DEVICE

C.3 Causes

F_CODE	F_CAUSE_DESC
ACCIDENT	ACCIDENT OR COLLISION
ADJUST-IMP	ADJUSTMENT IMPROPER, MISCONFIGURED, MISALIGNED, ETC.
ANIMALPEST	ANIMAL/PEST CONTROL PROBLEMS
ARCING	ARCING, ARCED
BATTERY	BATTERY LOW OR FAILED
BRITL/FATG	BRITTLE, CRYSTALIZED, FATIGUED
CALIBRATN	CALIBRATION INCORRECT
CAVITATION	CAVITATION
CIRCTBRD	ELECTRONIC CIRCUIT BOARD FAILURE
CLOG	CLOGGED, BLOCKAGE
CONDENSATN	CONDENSATION
COOLANT	COOLANT LEVEL OVER/UNDER, FAILED, LEAKED
CORROSION	CORROSION, RUST
CRACKED	CRACKED COMPONENT
DEBRIS	DEBRIS ACCUMULATION OR DAMAGE
DEFECTIVE	DEFECT, MANUFACTURING OR CONSTRUCTION
DIRTY	DIRTY
FASTENER	FASTENER/PIN/LOCKNUT/RIVET/RETAINER ETC. FAILED
FOROBJDAMG	FOREIGN OBJECT DAMAGE (FOD)
GROUND-EL	ELECTRICAL GROUNDING FAILED, FLOATING GROUND ETC.
HOLE/PERF	HOLED, PERFORATED, TORN, PIERCED
HUMAN/OPER	HUMAN/OPERATOR ERROR
INSTALLTN	INSTALLED/APPLIED/MOUNTED INCORRECTLY
JAM/BIND	JAMMED, WEDGED, BOUND UP, KINKED, TANGLED, PINCHED
LIMIT-DEV	LIMITING DEVICE/SWITCH/RELIEF VALVE FAILED/MISOPER-ATED
LOOSE	LOOSE OR DISLODGED
LUBRICATN	LUBRICATION - OVER, UNDER, FAILED, LEAKED

MISSING	ITEM/COMPONENT IS MISSING, MISPLACED, OUT OF POSITION
OVERLOAD	LOADED BEYOND CAPACITY OR RATING
OVERTIGHT	OVER TIGHTENED, OVER TORQUED, INSUFFICIENT SLACK/GIVE
POWER-OUT	POWER/CURRENT FAILURE
PRESS-OVER	PRESSURE OVER SPEC
PRESS-UND	PRESSURE UNDER SPEC, NO PRESSURE
SEAL/GASK	SEAL OR GASKET FAILURE
SHORT-CIRC	SHORT CIRCUIT, INCL SHORT TO GROUND, RESULTING TRIP
SOFTWARE	SOFTWARE/FIRMWARE FAILURES, CORRUPTION, ETC.
STATIC/EMF	STATIC ELECTRICITY, EMF EFFECTS
STRIPPED	STRIPPED THREADS OR LUGS
UNKNOWN	UNKNOWN, UNEXPLAINED, NO DIAGNOSIS
VAND/THEFT	VANDALISM, SABOTAGE, ARSON, THEFT
WATER-LEVL	UNUSUAL CHANGE IN WATER LEVEL
WEAR-EXCSV	WEAR - EXCESSIVE
WEAR-NRML	WEAR - NORMAL, WORN OUT FROM NORMAL USE/AGEING
WEATHER	WEATHER - LIGHTNING, WIND, RAIN, ICING, ETC.

C.4 Remedies

F_CODE	F_REMEDY_DESC
REPLACEPRT	REPLACED PART OR SUB-COMPONENT
REPAIR	REPAIRED - INCL. CLEANED
REPLACEALL	REPLACED ENTIRE UNIT
MANUF/FABR	MANUFACTURED/FABRICATED REPAIR PART LOCALLY
RTF	RUN TO FAILURE
OVERHAUL	OVERHAULED UNIT OR COMPONENT
NO_ACTION	NO ACTION TAKEN OR REQUIRED
ADJUST	ADJUSTED, REFILLED, DRAINED, ALIGNED, CALIBRATED, ETC.
SERVICE-XT	SERVICED BY EXTERNAL PROVIDER, ON OR OFF-SITE
PM-ADVANCD	PM SCHEDULE ADVANCED TO RESOLVE THE PROBLEM
REMOVE	REMOVED - NO LONGER NEEDED
SAFETYREP	REPAIRED/REPLACED PART OR ALL PER SAFETY RECALL/NOTICE

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix D: Emergency Closures 1999-2005

INFRASTRUCTURE EMERGENCY CLOSURES (1999 - 2005)

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
LRD									
/LRE									
	St. Marys River								
1	Soo Locks	1963	Jan-00	90	Quoin block repairs req'd	O&M	$125,000	Minor delay to shipping	Poe Lock - Bolts worked loose on quoin, quoin got caught in gate, quoin block got bent. Other locks were used during repairs
2	Soo Locks	1943	Jan-01	30	Miter gate strap failed	O&M	$75,000	Minor delay to shipping	MacArthur Lock - Other repairs delayed while crews worked on this repair
3	Soo Locks	1943	Jan-02	30	Emptying valve noise	O&M	$50,000	Delay as one valve used	MacArthur Lock - Gears were not adequately lubricated. Schedule problem corrected. Other repairs delayed during this repair
4	Soo Locks	1943	Aug-03/	240	Lock crane hit by vessel	O&M	$150,000	No delays to shipping	MacArthur Lock - Repairs made using O&M but reimbursed by vessel owner
				390			$400,000		
/LRH									
	Ohio River								
5	Willow Island Locks	1972	Jun-99	37	Quion block repair req'd	O&M	$1,037,000	Delays to shipping $0.9M	Broken bolts on quoin and miter blocks because of missing air lines.
6	Greenup Locks	1959	Nov-99	30	Miter gate bottom seal	O&M	$1,064,000	Delays to shipping $4.6M	During emergency repairs to the bottom seal/apron, the emergency gate cable broke causing further delays.
7	Greenup Locks	1959	Oct-99	13	Bottom seal and apron repair	O&M	$445,000	No delays to shipping	Auxiliary chamber, gate vibrations required dewatering and replacing bottom seal components.
8	R.C. Byrd Locks	1937/2002	Jun-00	11	Replace Valve cables	O&M	$195,000	No delays to shipping	Pickup cables broke and had to be replaced before serious damage to the valve occurred
9	Meldahl Locks	1962	Mar-00	10	Emergency gate cable repairs	O&M	$304,000	No delays to shipping	Auxiliary Chamber - Sheave nest and associated cable failure
10	Meldahl Locks	1962	Mar-01	53	Miter gate repairs	O&M	$1,484,000	No delays to shipping	Auxiliary lock upper gate, replaced apron and bottom seal, repaired cracked welds.
11	Willow Island Locks	1972	Oct-02	30	Miter Gate Repairs	O&M	$1,392,000	Delays to shipping $1.3M	Main Chamber, quoin and miter block repair. Repaired missing air lines.
12	Meldahl Locks	1962	Jun-02	41	Miter Gate vibrations	O&M	$1,148,000	No delays to shipping	Auxiliary Chamber - Excessive gate vibrations
13	Greenup Locks	1959	Sep-03	54	Miter Gate Repairs	O&M	$1,377,000	Delays to shipping $25M	Major delays as cracks in miter gates repaired. Other repairs in LRH delayed during this critical outage.
14	Meldahl Locks	1962	Dec-03	15	Miter gate noise	O&M	$760,000	Delay to shipping $1.5M	Dewater and inspect - Unable to make repairs because of high water; re-scheduled work for beginning of next season
15	Meldahl Locks	1962	Mar-04	40	Miter gate quoin repair	O&M	$1,853,000	Delays to shipping $6M	De-water and repair quoins/miter blocks and make adjustments to anchorage
	Greenup Locks	1959	Current	30	Tainter gate cable	O&M	$800,000	No delays to shipping	Tainter gate
	R.C. Byrd Locks	1937	Current	30	Gate machinery bay #6	O&M	$300,000	No delays to shipping	Gear box repairs are currently being made.
	R.C. Byrd Locks	1937	Current	60	Gate machinery bay # 5	O&M	$1,000,000	No delays to shipping	Plans to repair and change bull gear are on-going.
	Belleville Locks	1969	Current	15	Loss of Pool	O&M	$1,000,000	Industry & delay cost >40M	Four barges sunk on the dam preventing 5 gate bays from operating on 1/6/2005. Loss of pool from 1/18/05 - 2/1/05. Cost and impacts are estimates only.
				469			$11,059,000	(Total does not include current)	
	Kanawha River								
16	Marmet Locks	1934	Sep-99	13	Gate vibrations	O&M	$364,000	Delays to shipping	Land lock lower gate, replaced bottom seals
17	London Locks	1934	Oct-00	3	Roller gate repairs	O&M	$84,000	No delays to shipping	Replaced gate flap cable.
18	Marmet Locks	1934	Jul-03	1	Miter gate repairs	O&M	$28,000	Delays to shipping	River lock, lower gate. Heel kicked out preventing miter. Removed debris.
	Marmet Locks	1934	Current	750	Bulkhead crane inoperable	O&M	$1,500,000	No delays to shipping	Waiting on funding - Maintenance cannot be performed on roller gates without loosing pool.
	Marmet Locks	1934	Current	15	Roller chain inoperable	O&M	$300,000	No delays to shipping	Plans to repair are on-going. Changingout the chain is pending replacement and/or repairs to bulkhead crane and structure; currently no schedule.
	London Locks	1934	Current	750	Bulkhead crane inoperable	O&M	$1,500,000	No delays to shipping	Waiting on funding - Maintenance cannot be performed on roller gates without loosing pool.
				1532			$476,000	(Total does not include current)	
/LRL									
	Ohio River								
19	Cannelton Locks	1971	Sep-99	10	D/S river wall emptying valve	O&M	$292,500	Delay as one valve used	Valve skin plate separated from valve body.
20	Ls&D 53	1929	2002	750	Aux L upper guidewall	O&M	$1,500,000	Only rec boats can use	Contractor awaiting proper river conditions to begin guidewall repairs - if main chamber closes, no alternative is available for commercial navigation until repairs completed
21	McAlpine Lock	1961	Aug-04	11	Main ch miter gate cracks	O&M	$1,321,750	All traffic halted during repairs	Repairs to Green River 2 and Cannelton Main Chamber cancelled to perform emergency repairs here
				771			$3,114,250		
	Reservoirs								
22	Taylorsville Lake	1983	Jan-00	10	Emergency gate coupler failed	O&M	$35,000	Impact to rec boaters	Broken bolts had to be replaced and repairs to the emergency gate made
23	Mississinewa Lake	1967	FDR Restricti	1460	Dam settlement & instability	CG	$50,000,000	Summer pool 20' lower	First year (2001) of FDR pool lowering was an emergency closure - scheduled closure after that. Stabilization repairs underway - should be completed in 2005
24	Rough River Lake	1958	FDR Restricti	548	Sinkhole in d/s dam face	O&M	$1,500,000	Restricted FDR capacity	Repairs anticipated in 2006
25	J. E. Roush Lake	1969	Jan-02	180	Outlet gate stem damage	O&M	$30,000	None - weather cooperated	Gate failure during high flow conditions would require emergency gate use to halt flow
26	Salamonie Lake	1966	2003/	60	Lancaster Levee gate stem gent	O&M	$25,000	None - weather cooperated	Gate failure during high flow conditions would have resulted in flood damage behind levee.
27	Taylorsville Lake	1983	Jun-04	10	Emergency gate coupler failed	O&M	$50,000	Impact to rec boaters & FDR cap	Repairs scheduled for Oct 2004
				2268			$51,640,000		
/LRN									
	Tennessee River								
28	Pickwick Landing L	1984	Aug-01	2	Gate diagonal bar repair	O&M	$16,000	Delays to shippers $3,600	Main lock repair
29	Pickwick Landing L	1984	Sep-02	2	River gate elect malfunction	O&M	$6,300	No delays to shipping	Main lock repair
30	Wilson Locks	1959	Dec-02	2	Suspected cracked monolith	O&M	$6,400	Delays to shippers $100,000	Main lock monolith repair
31	Pickwick Landing L	1937	Mar-03	10	Saw cutting debris	O&M	$10,000	Minimal delays to shippers	
32	Pickwick Landing L	1937	Jun-03	2	Noise in u/s river gate machinery	O&M	$1,800	No delays to shipping	Auxiliary lock operating machinery repair
33	Pickwick Landing L	1937	Jun-03	2	Noise in u/s river gate machinery	O&M	$2,400	No delays to shipping	Auxiliary lock operating machinery repair
34	Kentucky Lock	1942	Feb-04	1	Repair broken boom wall chain	O&M	$39,800	Minimal delays to shippers	
35	Pickwick Landing L	1937	May-04	3	Miter gates strut pin replacement	O&M	$9,700	No delay cost to shippers	Auxiliary lock repair

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
36	Guntersville Aux Lock	1937	Jun-04	2	Replace miter gate anchor bars	O&M	$11,000	Minimal delays to shippers	
37	Kentucky Lock	1942	Dec-04	7	Repair lower miter gate	O&M	$95,000	Est. cost to shippers $250,000	Tow hit lower gate on 15 Dec 2004
				32			$198,400		
	Cumberland River								
38	Cheatham Lock	1952	Oct-03	2	Damage to lower miter gate	O&M	$15,000	No delays to shipping	Repairs completed in Sep 04
				2			$15,000		
/LRP									
	Monongahela River								
39	Point Marion L/D	1994	2000		Barge Accident	O&M	$9,813	Minimal to stakeholders	DSMW Gates
40	Maxwell L/D	1963	2000		Barge Accident	O&M	$4,220	Minimal to stakeholders	DSMW Gate
41	Maxwell L/D	1963	2001		Barge Accident	O&M	$14,536	Minimal to stakeholders	DSMW Gates
42	Maxwell L/D	1963	2001		Damaged USMW Sector Arm	O&M	$38,958	Minimal to stakeholders	Gate Operating Mach.Sector Arm
43	L/D 3	1907	2001		Barge Accident	O&M	$2,568	Minimal to stakeholders	USLW Gate 56'
44	L/D 3	1907	2001		Barge Accident	O&M	$8,960	Minimal to stakeholders	USMW Gate 56'
45	Opekiska L/D	1964	2003		Generator Failure	O&M	$61,353	Minimal to stakeholders	Replace Generator
46	L/D 2	1905	2004		Barge Accident	O&M	$13,928	Minimal to stakeholders	USLW Gate
47	L/D 3	1907	2004		Barge Accident	O&M	$5,316	Minimal to stakeholders	USMW Gate
48	L/D 3	1907	2004		Barge Accident	O&M	$14,367	Minimal to stakeholders	Land Guidewall Repair
49	Morgantown L/D	1950	2004		Barge Accident	O&M	$15,695	Minimal to stakeholders	US Guidewall Repair
50	Hildebrand L/D	1959	2004		#1 Dam Gate Machinery Failed	O&M	$50,000	Minimal to stakeholders	#1 Dam Gate Machinery
							$239,714		
	Ohio River								
51	Montgomery L/D	1936	1999		Barge Accident	O&M	$28,852	Minimal to stakeholders	USMW Gate 110'
52	Montgomery L/D	1936	1999		Barge Accident	O&M	$25,118	Minimal to stakeholders	USLW Gate 110'
53	Montgomery L/D	1936	1999		Barge Accident	O&M	$1,641	Minimal to stakeholders	Gate Damage
54	Montgomery L/D	1936	1999		Barge Accident	O&M	$11,761	Minimal to stakeholders	USMW Gate 110'
55	Emsworth L/D	1921	2000		USLW Gate Strut Arm Failure	O&M	$20,186	Minimal to stakeholders	USLW Gate Strut Arm
56	Emsworth L/D	1921	2000		Barge Accident	O&M	$26,430	Minimal to stakeholders	USMW Gate 110'
57	Emsworth L/D	1921	2000		Barge Accident	O&M	$7,389	Minimal to stakeholders	DS Gate Walkway 110'
58	Emsworth L/D	1921	2001		Dam Gate Failure	O&M	$26,195	Minimal to stakeholders	Repair Dam Gate Truck Assembly
59	Emsworth L/D	1921	2001		DSMS Gate FenderDamage 110"	O&M	$24,518	Minimal to stakeholders	Repair DSMW Gate Fender
60	Montgomery L/D	1936	2001		Barge Accident	O&M	$1,035	Minimal to stakeholders	DSLW Gate 110' Repair Fender
61	Emsworth L/D	1921	2002		Hydraulic Pipe Failure	O&M	$15,000	Minimal to stakeholders	Repair Piping
62	Emsworth L/D	1921	2002		Barge Accident	O&M	$4,920	Minimal to stakeholders	USMW Gate Fender 110'
63	Dashields L/D	1929	2003		Barge Accident	O&M	$24,283	Minimal to stakeholders	USLW Gate
64	Dashields L/D	1929	2003		Barge Accident	O&M	$13,370	Minimal to stakeholders	USLW Gate
65	Emsworth L/D	1921	2004		Dam Gate #11 Failure	O&M	$20,334	Minimal to stakeholders	Repair Dam Gate #11
66	Emsworth L/D	1921	2004		Dam Gate #11 Failure	O&M	$8,190	Minimal to stakeholders	Repair Truck Ass. Gate #11
67	Emsworth L/D	1921	2004		Bulkhead Failed Stress Test	O&M	$352,622	Minimal to stakeholders	Repair Alum Maint. Bulkhds.
68	Dashields L/D	1929	2004		Barge Accident	O&M	$24,283	Minimal to stakeholders	USLW Gate
69	Dashields L/D	1929	2004		Barge Accident	O&M	$40,109	Minimal to stakeholders	USLW Gate
70	Hannibal L/D	1973	2004		Barge Accident	O&M	$60,000	Minimal to stakeholders	UG Gates 1200'
71	Dashields L/D	1929	2004		Flood Damage	O&M	$20,000	Minimal to stakeholders	Grating Replacement
72	Montgomery L/D	1936	2004		Flood Damage	O&M	$20,000	Minimal to stakeholders	Grating Replacement
73	Emsworth L/D	1921	2004		Flood Damage	O&M	$10,000	Minimal to stakeholders	Replace Grinder Pumps
							$786,236		
	Allegheny River								
74	L/D 5	1927	2003		Valve Failure	O&M	$1,613	Minimal to stakeholders	DSLW Recess Valve
							$1,613		
	Reservoirs								
75	Berlin Dam	1943	1999		Autocon System Failure	O&M	$263	Minimal to stakeholders	Autocon System
76	Kinzua Dam	1965	1999		Operating Switch Failed	O&M	$2,578	Minimal to stakeholders	Dam Gate #3 Oper. Switch
77	Shenango Dam	1965	1999		Gate indicator malfunctioned	O&M	$3,283	Minimal to stakeholders	Repair Gate Indicator
78	Tionesta Dam	1941	1999		Sump Pump Failure	O&M	$1,046	Minimal to stakeholders	Repair Sump Pump
79	Youghigheny Dam	1944	1999		Emergency Gate Failure	O&M	$48,683	Minimal to stakeholders	Repair Emergency Gate
80	Conemaugh Dam	1952	2000		Generator Failure	O&M	$1,282	Minimal to stakeholders	Repair Generator
81	Stonewall Jack. Dam	1988	2000		Generator Failure	O&M	$7,063	Minimal to stakeholders	Repair Generator
82	Crooked Creek Dam	1940	2001		Electrical System Failure	O&M	$24,392	Minimal to stakeholders	Electrical System
83	Shenango Dam	1965	2001		Electrical System Failure	O&M	$6,539	Minimal to stakeholders	Replace Electrical Panel
84	Stonewall Jack. Dam	1988	2001		Automatic Transfer Switch Failure	O&M	$7,338	Minimal to stakeholders	Repair ATS
85	Tygart Dam	1938	2001		Valve Indicator Failure	O&M	$13,706	Minimal to stakeholders	Repair Valve Position Indicators
86	Youghigheny Dam	1944	2001		Bulkhead Hoist Failure	O&M	$9,630	Minimal to stakeholders	Repair Bulkhead Hoist
87	Crooked Creek Dam	1940	2002		Emergency Gate Contols Failure	O&M	2,175	Minimal to stakeholders	Repair Emergency Gate
88	Crooked Creek Dam	1940	2002		Electrical System Failure	O&M	$24,451	Minimal to stakeholders	Repair Electrical System
89	Crooked Creek Dam	1940	2002		Slucie Gate Failed	O&M	$55,000	Minimal to stakeholders	Repair Sluice Gates
90	Mosquito Dam	1944	2002		Gate Machinery Failed	O&M	$53,303	Minimal to stakeholders	Repair 4x8 Gate Machinery
91	Stonewall Jack. Dam	1988	2002		Automatic Transfer Switch Failure	O&M	$15,811	Minimal to stakeholders	Repair ATS

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
92	Stonewall Jack. Dam	1988	2002		Hydraulic Pump Controls Failure	O&M	$1,695	Minimal to stakeholders	Repair Pump Controls
93	Tygart Dam	1938	2002		Valve Position Indicators Failure	O&M	$35,709	Minimal to stakeholders	Repair Valve Control Ind.
94	Woodcock Dam	1973	2002		Sewage Lift Station Malfunction	O&M	$2,706	Minimal to stakeholders	Repair Sewage Lift Station
95	Youghiogheny Dam	1944	2002		Hoist Failure	O&M	$10,608	Minimal to stakeholders	Repair Bulkhead Hoist
96	Crooked Creek Dam	1940	2003		Wire Rope Failure	O&M	$149,754	Minimal to stakeholders	Replace Rope
97	Mosquito Dam	1944	2003		4x8 Gate Machinery Failure	O&M	$54,778	Minimal to stakeholders	Repair Gate Machinery
98	Stonewall Jack. Dam	1988	2003		Bulkhead Cable Failure	O&M	$8,808	Minimal to stakeholders	Replace Bulkhead Cable
99	Tygart Dam	1938	2003		Hydraulic Pump Failure	O&M	$1,034	Minimal to stakeholders	Repair Hydraulic Pump
100	Tygart Dam	1938	2003		Valve Failure	O&M	$10,617	Minimal to stakeholders	Repair Ring Jet Valve
101	Woodcock Dam	1973	2003		Gate Operating Machinery Failed	O&M	$1,606	Minimal to stakeholders	Repair Gate Operating Machinery
102	Youghiogheny Dam	1944	2003		Gate Hoist Motor Failure	O&M	$2,990	Minimal to stakeholders	Replace Motor
103	Berlin Dam	1943	2004		Highwater Damage to Dam	O&M	$60,000	Minimal to stakeholders	Repairs to Dam
104	Kinzua Dam	1965	2004		Generator Failure	O&M	$1,619	Minimal to stakeholders	Generator Repair
105	Stonewall Jack. Dam	1988	2004		Bulkhead Cable Failure	O&M	$9,118	Minimal to stakeholders	Replace Cable
106	Tygart Dam	1938	2004		Valve Failure	O&M	$17,387	Minimal to stakeholders	Repair Ring Jet Valve
107	Woodcock Dam	1973	2004		Gate Machinery Failure	O&M	$2,076	Minimal to stakeholders	Repair Gate Operating Machinery
108	Tionesta Dam	1941	2004		Wire Rope Failure Gate #2&3	O&M	$250,000	Minimal to stakeholders	Replace Wire Rope
							$897,048		
							$68,827,261		
								$50,000,000 CG	
								$18,827,261 O&M	

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
INFRASTRUCTURE EMERGENCY CLOSURES (1999 - 2005)									
MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
MVD /MVR									
	Illinois Waterway								
1	Marseilles L&D	1933	Jul-99	1.6	Miter gate pintle ball shim	O&M	$66,000	29 tows waiting - longest waited 2 d	Upstream River Gate was misaligned at gate closure. Maintenance crew was able to raise the gate, replace the shim and secure it.
2	Lagrange L&D	1939	Jan-02	2	Gate anchor broke	O&M	$70,000	40 tows waiting	Gate anchor was on the lower landwall miter gate. Cure time was needed after repairs - all done in wintry conditions.
3	Lagrange L&D	1939	Mar-02	16	New miter gate anchors	O&M	$37,000	44 tows waiting	New miter gate anchors were installed during 8 2-day closures.
4	Lagrange L&D	1939	Dec-02	1	Miter gate gudgeon loose	O&M	$16,000	8 tows waiting	Gudgeon pin in lower land wall miter gate worked its way loose. Reinstalled and topped to prevent future similar event.
5	Lagrange L&D	1939	Jan-03	1.2	Bull gear gate arm broke	O&M	$13,000	10 tows waiting	Bull gear gate arm on lowe miter gate broke
6	Starved Rock L&D	1933	Feb-04	1	Buffer box on miter gate broke	O&M	$17,000	6 tows waiting	Buffer box broke and plunger bolt sheared off. Maintenance crew assembled a replacement buffer box.
				22.8			$219,000		
	Mississippi River								
7	L&D 21	1938	Feb-99	7	Repaired #1 and #3 miter gates	O&M	$311,900	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
8	L&D 11	1937	Jul-99	1	Replaced failed strut arm on #2 mi	O&M	$40,500		
9	L&D 22	1938	Jan-00	47	Replaced machinery bases & elec	O&M	$1,201,200	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
10	L&D 21	1938	Jan-00	60	Installed bubbler system & replace	O&M	$2,700,000	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
11	L&D 19	1957	Jan-01	59	Repaired lower miter gates	O&M	$2,648,800	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
12	L&D 11	1937	Apr-01	28	Flood of 2001 - Repaired damage	O&M	$436,200		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
13	L&D 12	1939	Apr-01	31	Flood of 2001 - Repaired damage	O&M	$785,400		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
14	L&D 13	1938	Apr-01	30	Flood of 2001 - Repaired damage	O&M	$3,540,000		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
15	Ls&D 14	1922/1938	Apr-01	27	Flood of 2001 - Repaired damage	O&M	$521,400		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
16	Ls&D 15	1934	Apr-01	24	Flood of 2001 - Repaired damage	O&M	$1,048,200		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
17	L&D 16	1937	Apr-01	28	Flood of 2001 - Repaired damage	O&M	$1,129,800		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
18	L&D 17	1939	Apr-01	28	Flood of 2001 - Repaired damage	O&M	$1,146,600		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
19	L&D 18	1937	Apr-01	30	Flood of 2001 - Repaired damage	O&M	$1,471,200		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
20	L&D 20	1936	Apr-01	30	Flood of 2001 - Repaired damage	O&M	$2,522,400		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
21	L&D 21	1938	Apr-01	25	Flood of 2001 - Repaired damage	O&M	$1,276,200		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
22	L&D 22	1938	Apr-01	26	Flood of 2001 - Repaired damage	O&M	$3,689,400		Closure period includes time of flooding when lock not operable AND the repair time required to bring lock back into full operation.
23	Ls&D 15	1934	Aug-01	1	Repaired anchor bars & bushings	O&M	$41,000		
24	L&D 12	1939	Sep-02	1	Removed damaged miter gates, re	O&M	$41,500		
25	L&D 12	1939	Nov-02	1	Rem. Spare gates and repld. w/ re	O&M	$42,200		
26	Ls&D 15	1934	Nov-02	2.33	Reprd #8 miter gate speed reducer	O&M	$112,200		
27	L&D 17	1939	Dec-02	77	Repl. Embedded gate anchorage	O&M	$5,421,700	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
28	L&D 19	1957	Dec-02	77	Removed failed lower gates and re	O&M	$4,198,000	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
29	Ls&D 15	1934	Aug-03	501	Structural failure of lower miter gat	O&M	$2,000,000	Minimal - traffic locked through mai	Must inspect gates and send down divers to accurately estimate repair cost. Could range from $100,000 to $2,000,000. Assumed $2,000,000 until est. made
30	L&D 17	1939	Oct-03	1	Replaced spare gates w/repaired u	O&M	$42,900		
31	L&D 22	1938	Oct-03	1	Replaced upper miter gates with s	O&M	$42,900		
32	L&D 19	1957	Oct-03	1	Inspected welds on upper guard a	O&M	$42,900		
33	L&D 22	1938	Dec-03	91	Removed and repaired two miter g	O&M	$4,054,500	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
34	Ls&D 15	1934	Dec-03	76	Repld failed checkposts and install	O&M	$103,200	Minimal due to scheduled closure ti	Closure was during normal winter slow period - however, some traffic that could have passed was prevented from doing so.
35	Ls&D 15	1934	Aug-04	1	Structural failure lower miter gates	O&M	$42,900		

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
36	L&D 20	1936	Mar-04	8	Repld strut arm attachment & rebu	O&M	$353,800		
37	L&D 22	1938	Apr-04	2	Repld repaired miter gates & repld	O&M	$85,800		
				1322.33			41094700		
/MVS									
	Mississippi River								
38	Ls&D 27	1953	Jul-99	9.35	Main lock chain replacement	O&M	$180,000	19 additional tows waiting by completion	
39	Melvin Price Ls&D	1990	Aug-99	28	Repair gates (M/V Helen Lay accid	O&M	$1,024,000		
40	Ls&D 27	1953	Jan-00	5.5	U/S leaf chain replacement	O&M	$560,000	None - done during winter low use period	
41	Melvin Price Ls&D	1990	Jan-00	11	Main lock anchor bolt repair	O&M	$240,000	Tow avg delay time - 9 hours	
42	L&D 24	1940	Feb-00	8.62	Installation of 4 miter gates	O&M	$480,000	5 tows waiting at end of repair outage	
43	Melvin Price Ls&D	1994	Jul-00	1.33	Hydraulic cyl seal replacement	O&M	$15,000	Tow avg delay time - 4 hours	
44	Melvin Price Ls&D	1990	Aug-00	22	Main lock anchor bolt repair	O&M	$232,000	Tow avg delay time - 9 hours	
45	Melvin Price Ls&D	1990	Dec-00	96	Main lock miter gate failure	O&M	$3,220,000		
46	L&D 25	1939	Jan-01	1.4	#2 valve & #4 miter gate	O&M	$25,000	None - done during winter low use period	
47	L&D 25	1939	Apr-01	1.24	#4 miter gate failed to open	O&M	$21,000	#4 gate put in manual mode - slower	
48	L&D 25	1939	May-01	4.34	Miter gate change-out	O&M	$215,000		
49	Melvin Price Ls&D	1994	Aug-01	33	Miter gate tensioning bolt repl	O&M	$343,000	Tow avg delay time - 2 hours	Replaced tensioning bolts on auxiliary miter gate diagonals.
50	L&D 25	1939	Jan-02	3.5	Upstream miter gate change	O&M	$198,000	None - done during winter low use period	
51	Melvin Price Ls&D	1990	Jan-02	2	Main lock hydraulic line repair	O&M	$35,000	Tow avg delay time - 4 hours	
52	Ls&D 27	1953	Jul-04	16	Main lock diagonal repair	O&M	$800,000	Major impact 30 NB, 19 SB tows (	Tow delay costs: $18,918,750 - 15,135 delay hours!! Lock closed @ 0640 on 26 Jul 04, opened @ 1750 hours on 11 Aug
53	Melvin Price Ls&D	1994	Oct-04	88	Aux lock d/s miter gate repair (cont	O&M	$12,500,000	Concern about main chamber ops	Main chamber is handling the commercial and recreational traffic - a response plan has been prepared to cover "what if" scenario
				331.28			20088000		
						TOTAL	61401700		

INFRASTRUCTURE EMERGENCY CLOSURES (1999 - 2005)

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
NAD									
/NAB									
	Reservoir								
1	Raystown Lake	1973	2002	90	Leakage at tainter gate	O&M	$400,000	None since found early	Temp repairs in Nov 2002. In 2003, replaced gate guides and seal assemblies. If not repaired, flood damage reduction capability greatly reduced.
				90			$400,000		
	Other Structure								
2	DC Tidal Gates		Sep-03	456	Basin inlet & outlet gates	O&M	$900,000	Hurricane Isabel malfunction	Inlet gates were manually set during Hurricane Isabel. Temp repairs to outlet gates were effected by placing plywood panels to cover structural defects. Design underway.
				456			$900,000		
/NAP									
	Other Structure								
3	Summit Br. /WW	1964+	2002	Periodically	Alkali-Silica Reaction	O&M	$8,000,000	30,000 veh per day. Lane closures	Hazardous road conditions. DE State Route 896/301 across the Chesapeake and Delaware Canal. Bridge needed for emergency response. One of state's busiest.
							$8,000,000		
						TOTAL	$9,300,000		

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
INFRASTRUCTURE EMERGENCY CLOSURES (1999 - 2005)									
MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
NWD									
NWP									
	Columbia River								
1	John Day L&D	1968	Jan-02	140	Nav lock monolith cracking	O&M	$17,000,000	Lockage time incr. 15 min from 200	Concrete spalling forced shutdown of the north filling valves. Waterstop repairs were made; foundation was grouted; epoxy injected into cracks; anchors were installed
2	The Dalles L&D	1957	Mar-02	1.4	Lock post derrick bearing failure	O&M	$211,000	Rental barge crane for stoplog rem	Derrick crane required for maintenance stoplog placement and removal each year. If barge crane could not handle, severe slowing of lockages would have resulted.
3	John Day L&D	1968	Nov-02	11	U/S lock gate wire rope failure	O&M	$4,500,000	Lockage time increased by 60 min f	Lift gate and counterweights damaged significantly. Lubrication system and procedures were revised to prevent future similar proglems.
4	Bonneville L&D	1938	Jun-03	540	Dam spillway structural problem	O&M	$20,000,000	Spillway gates cannot be maintaine	Spillway deck & north approach bridge have weight restrictions due to structural weakness of the concrete. Dam gates cannot be lowered into repair and maintenance pit.
5	The Dalles L&D	1957	Aug-04	10	Domestic water supply ruptured	O&M	$50,000	Water supply to powerhouse cut of	Sinkhole discovered along water line. Restrooms and all drinking water was shut down. Chem toilets were brought in. Bottled water was provided.
				702.4			$41,761,000		
	Reservoir								
6	Fern Ridge Dam	1951	Dec-04	FDR Restric	D/S embankment slope seepage	CG	$20,000,000	Much lower level of flood damage r	This red. in flood control pool to increase dam safety took place at the end of CY 2004. Further studies will determine if seismic instability is also an issue - adding $55M.
							$20,000,000		
	Coastal Project								
7	Coos Bay N Jetty	1929	Dec-02	1	Jetty foundation failure	O&M	$1,000,000	Minimal impact to comm and rec ve	Emergency repairs made to breach in last year, but no solution to the root cause has been effected. Need $5M for permanent repairs.
				1			$1,000,000		
NWS									
	Reservoirs								
8	Howard Hanson Dam	1963	Jan-03	120	Gate control failure	O&M	$130,000	No direct impact - due to favorable	Damage created potential dam safety issues, employee safety issues and increased the potential for downstream flood damage.
9	Mud Mountain Dam	1953	Jul-04	120	Roller chain failure	O&M	$30,000	No direct impact - due to favorable	Roller chain on regulating gate failed. Potential dam safety issues and increased the potential for downstream flood damage. Gate still out of service.
				240			$160,000		
NWW									
	Snake River								
10	Ice Harbor Lock	1962	Apr-01	2	Upstream gate trunnion arm	O&M	$18,000	Comm and rec nav halted during re	Emergency repairs on the trunnion arm of the upstream lock gate to correct significant deficiencies noted during an inspection.
11	Little Goose Lock	1970	Nov-02	4.5	Repair gate trunnion arm bolts	O&M	$40,500	All comm and rec traffic halted dura	Other repairs had to be delayed and monies for this repair were taken from other needed repairs.
12	Lower Granite Lock	1975	Nov-02	4.5	Water leak and vibration	O&M	$32,000	Comm and rec nav halteed during r	A plate was welded to the downstream gate to seal water leakage and correct the vibration during lock operation.
13	Lower Monumental L	1969	Jun-03	1.25	Vert crack in downstream gate	O&M	$9,000	All rec and comm traffic halted dura	Crack repair was critical to prevent gate failure.
14	Ice Harbor Lock	1962	Sep-03	1.25	Downstream lock gate wheel	O&M	$11,250	No comm or rec lockages during re	Other repairs had to be delayed and monies for this repair were taken from other needed repairs.
15	Ice Harbor Lock	1962	Oct-03	0.75	Allision caused gate damage	O&M	$252,000	All rec traffic halted, comm only dur	Defective location sensor resulted in a cruise ship exiting the lock hitting the upstream lock gate. Floating bulkhead was used by comm traffic during gate repairs.
16	Ice Harbor Lock	1962	Nov-03	2	Repair of allision damage		"	All rec traffic halted during repair, 1	Commercial traffic was allowed 12 of each 24 hours during repairs.
17	Little Goose Lock	1970	Apr-04	5.33	North lock wall waterstop failure	O&M	$48,000	Rec lockage halted during repairs	Commercial traffic was allowd on demand during repairs. Leak caused large hole on outside wall of the lock.
18	Ice Harbor Lock	1962	Jul-04	0.5	Rec Craft - Man Overboard			All comm and rec traffic halted dura	Body found two days later downstream of lock
				22.08			$410,750		
							$63,331,750		
								$20,000,000 CG	
								$43,331,750 O&M	

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
INFRASTRUCTURE EMERGENCY CLOSURES (1999 - 2005)									
MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
SAD									
/SAJ									
	Caloosahatchee R								
1	Moore Haven Lock	1953	Jan-00	7	Binding sector gate	O&M	$35,000	All traffic was halted	Impact to stakeholders $110,000 during closure for repair of lower pin bushing and bolts.
				7			$35,000		
	St. Lucie Canal								
2	St. Lucie Lock	1941	Jun-04	7	Sector gate drive anchor	O&M	$50,000	All traffic was halted	Impact to stakeholders $110,000 during closure for repair of gate #2 anchorage.
				21			$50,000		
/SAM									
	Black Warrior R								
3	Bankhead Lock	1975	2000	30	Repair of d/s miter gate cracks	O&M	$378,170	Comm and rec traffic halted	D/s gate cracking forced emergency closure for crack welding in 2000.
6	Selden Lock	1957	Feb-04	2	Replace gudgeon pin u/s gate	O&M	$106,000	Comm and rec traffic halted	Minor impact on navigation. Replaced worn pin that could not be greased. Lockages could have been made during closure.
7	Bankhead Lock	1975	Sep-04	30	Repl d/s miter gates	CG	$26,000,000	Comm and rec traffic halted	D/S gate replacement required after extreme cracking noted in 1999 and welding in 2000 provided only temp repairs.
				62			$26,484,170		
	Tenn-Tom WW								
4	Amory Lock	1985	Apr-01	5	Conc erosion lower miter gate sill	O&M	$184,000	Comm and rec traffic halted	
5	Jamie Whitten	1985	Aug-01	21	Conc erosion in culvert system	O&M	$524,000	Comm and rec traffic halted	
				26			$708,000		
	Tombigbee River								
8	Demopolis Lock	1954	Sep-04	2.5	Intake valve malfunction	O&M	$300,000	Comm/rec traffic halted - 3 locks	Malfunction caused an eddy to form resulting in a potential danger to vessels.
				2.5			$300,000		
/SAS									
	Reservoir								
9	Hartwell Dam	1961	Aug-02	210	Repair of dam tainter gate welds	O&M	$6,500,000	FDR restricted until repairs compl	Tainter gate welds inspected. 7 of 12 gates have been repaired and are operational. Cost of $4.0 M. Awaiting funding.
				210			$6,500,000		
							$34,077,170		
								$26,000,000 CG	
								$ 8,077,170 O&M	

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
INFRASTRUCTURE EMERGENCY CLOSURES (1999 - 2005)									
MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
SWD									
/SWG									
	Gulf Intracoastal WW								
1	Colorado River Locks	1944	2002	1	Hinge pin failure	O&M	$30,000	5-day closure if grease did not take	Pin may hold up until next major maintenance in FY 2008. If failure had occurred during flood event, major problem.
				1			$30,000		
	Reservoir								
2	Wallisville Lake	1999	1999	b week long	Failing power control	O&M	$200,000	Prevents lock/dam operation	Plan to repair in FY 2005
3	Wallisville Lake	1999	ally from 1999	b week long	Affect of failing power control	O&M	$40,000	Siltation on the upstream	Once power logic control is replaced this will clear up
							$240,000		
/SWL									
	Arkansas River								
4	Murray L&D	1969	2002	4	Tainter gate gear drive teeth broke	O&M	$8,000	Cannot regulate pool during floods	A spare gearbox was installed. Have no funds to replace the damaged gearbox.
5	Dardanelle L&D	1969	Oct-02	1.33	Tainter gate Line-shaft bent	O&M	$2,000	Repair compl during dry spell	If floodwater condtions occurred during repairs, could not have regulated pool because of damage to Line-shaft.
6	Dardanelle L&D	1969	2003	1	Lock control electrical wire failure	O&M	$24,000	Repairs done with in-house labor	Electrical wire looked good on the outside, but had broken down on the inside. Could not lock nav traffic through reliably.
7	Ormond L&D	1969	03 to present	365	Barge impact damaged monolith	O&M	$320,000	U/S tow haulage inop - monolith	Repairs have not been effected. Awaiting decision on funding. Monolith design typical of most Arkansas River locks. Slower lockages
				371.33			$354,000		
	Reservoirs								
8	Table Rock Dam	1958	2002	DR reduced	Tainter gate arm bent	O&M	$1,200,000	Reduced max pool established	Major flood during repair period could have been catastrophic.
9	Clearwater Dam	1948	2002	DR reduced	Sinkhole developed on U/S face	CG	$3,000,000	Reduced max pool established	Repairs done during non-flood condtions. If not repaired and flood condtions occurred, potential for loss of dam and life.
10	Greers Ferry Dam	1962	Dec-02	1	Tainter gate cable hitch broken	O&M	$800	None	Repairs done quickly with spare parts.
							$4,200,800		
/SWT									
	Verdigris River								
11	Newt Graham L&D 18	1970	Jun-01	70	Tainter gate secondary gear box fa	O&M	$80,000	Tainter gate out of service while contract awarded and repairs completed.	Gear boxes were removed from spillway equipment deck and rebuilt. If flood had occurred before gear boxes were reset, could not properly regulated Navigation Pool, resulting in damage to overflow embankment and possible loss of Navigation Pool.
12	Newt Graham L&D 18	1970	Apr-04	5	Log Jam from high flows block U/S	O&M	$10,000	Closed Lock 5 days, though high flows had most traffic at a standstill.	SWT/ERDC to study US flow patterns to det if improvements can be made to divert log flows from lock approach channel and prevent future log jam closures. Avg cost to Nav Industry of $58,000/day.
				75			$90,000		
	Arkansas River								
13	Webbers Falls L&D 16	1970	May-04	5	Replace failed hydraulic piping in g	O&M	$15,000	Closed Lock to Traffic (Sched) for 5 days	Although this was a scheduled closure, failure of the pipes was imminent and would have closed lock to Navigation Traffic for a minimum of 5 days @ an average cost to the industry of $58,000 per day.
14	W D Mayo L&D 14	1970	Oct-04	7	Tainter gate brake failure/Line-sha	O&M	$7,000	None - repairs done with in-house labor	If flooding occurred before repairs made, could not reg Nav Pool due to damage to Line-shaft. Could have resulted in damage to overflow embankment and loss of Nav Pool.
				12			$22,000		
	Reservoir								
15	Canton Lake, OK	1948	2002	FDR reduce	Inadequate spillway stability	CG	$10,000,000	Increased D/S flooding	Maximum flood pool reduced from elevation 1638 to 1626 due to spillway stability issue.
							$10,000,000		
							$14,936,800	$ 1,936,800 O&M $13,000,000 CG	

MSC/ DIST	PROJECT	YEAR OPENED	CLOSURE MO - YR	CLOSURE LENGTH DAYS	REASON FOR CLOSURE	Funding	COST OF REPAIRS	IMPACT OF CLOSURE	REMARKS
36	Guntersville Aux Lock	1937	Jun-04	2	Replace miter gate anchor bars	O&M	$11,000	Minimal delays to shippers	
37	Kentucky Lock	1942	Dec-04	7	Repair lower miter gate	O&M	$95,000	Est. cost to shippers $250,000	Tow hit lower gate on 15 Dec 2004
				32			$198,400		
	Cumberland River								
38	Cheatham Lock	1952	Oct-03	2	Damage to lower miter gate	O&M	$15,000	No delays to shipping	Repairs completed in Sep 04
				2			$15,000		
/LRP									
	Monongahela River								
39	Point Marion L/D	1994	2000		Barge Accident	O&M	$9,813	Minimal to stakeholders	DSMW Gates
40	Maxwell L/D	1963	2000		Barge Accident	O&M	$4,220	Minimal to stakeholders	DSMW Gate
41	Maxwell L/D	1963	2001		Barge Accident	O&M	$14,536	Minimal to stakeholders	DSMW Gates
42	Maxwell L/D	1963	2001		Damaged USMW Sector Arm	O&M	$38,958	Minimal to stakeholders	Gate Operating Mach Sector Arm
43	L/D 3	1907	2001		Barge Accident	O&M	$2,568	Minimal to stakeholders	USLW Gate 56'
44	L/D 3	1907	2001		Barge Accident	O&M	$8,960	Minimal to stakeholders	USMW Gate 56'
45	Opekiska L/D	1964	2003		Generator Failure	O&M	$61,353	Minimal to stakeholders	Replace Generator
46	L/D 2	1905	2004		Barge Accident	O&M	$13,928	Minimal to stakeholders	USLW Gate
47	L/D 3	1907	2004		Barge Accident	O&M	$5,316	Minimal to stakeholders	USMW Gate
48	L/D 3	1907	2004		Barge Accident	O&M	$14,367	Minimal to stakeholders	Land Guidewall Repair
49	Morgantown L/D	1950	2004		Barge Accident	O&M	$15,695	Minimal to stakeholders	US Guidewall Repair
50	Hildebrand L/D	1959	2004		#1 Dam Gate Machinery Failed	O&M	$50,000	Minimal to stakeholders	#1 Dam Gate Machinery
							$239,714		
	Ohio River								
51	Montgomery L/D	1936	1999		Barge Accident	O&M	$28,852	Minimal to stakeholders	USMW Gate 110'
52	Montgomery L/D	1936	1999		Barge Accident	O&M	$25,118	Minimal to stakeholders	USLW Gate 110'
53	Montgomery L/D	1936	1999		Barge Accident	O&M	$1,641	Minimal to stakeholders	Gate Damage
54	Montgomery L/D	1936	1999		Barge Accident	O&M	$11,761	Minimal to stakeholders	USMW Gate 110'
55	Emsworth L/D	1921	2000		USLW Gate Strut Arm Failure	O&M	$20,186	Minimal to stakeholders	USLW Gate Strut Arm
56	Emsworth L/D	1921	2000		Barge Accident	O&M	$26,430	Minimal to stakeholders	USMW Gate 110'
57	Emsworth L/D	1921	2000		Barge Accident	O&M	$7,389	Minimal to stakeholders	DS Gate Walkway 110'
58	Emsworth L/D	1921	2001		Dam Gate Failure	O&M	$26,195	Minimal to stakeholders	Repair Dam Gate Truck Assembly
59	Emsworth L/D	1921	2001		DSMS Gate FenderDamage 110"	O&M	$24,518	Minimal to stakeholders	Repair DSMW Gate Fender
60	Montgomery L/D	1936	2001		Barge Accident	O&M	$1,035	Minimal to stakeholders	DSLW Gate 110' Repair Fender
61	Emsworth L/D	1921	2002		Hydraulic Pipe Failure	O&M	$15,000	Minimal to stakeholders	Repair Piping
62	Emsworth L/D	1921	2002		Barge Accident	O&M	$4,920	Minimal to stakeholders	USMW Gate Fender 110'
63	Dashields L/D	1929	2003		Barge Accident	O&M	$24,283	Minimal to stakeholders	USLW Gate
64	Dashields L/D	1929	2003		Barge Accident	O&M	$13,370	Minimal to stakeholders	USLW Gate
65	Emsworth L/D	1921	2004		Dam Gate #11 Failure	O&M	$20,334	Minimal to stakeholders	Repair Dam Gate #11
66	Emsworth L/D	1921	2004		Dam Gate #11 Failure	O&M	$8,190	Minimal to stakeholders	Repair Truck Ass. Gate #11
67	Emsworth L/D	1921	2004		Bulkhead Failed Stress Test	O&M	$352,622	Minimal to stakeholders	Repair Alum Maint. Bulkhds.
68	Dashields L/D	1929	2004		Barge Accident	O&M	$24,283	Minimal to stakeholders	USLW Gate
69	Dashields L/D	1929	2004		Barge Accident	O&M	$40,109	Minimal to stakeholders	USLW Gate
70	Hannibal L/D	1973	2004		Barge Accident	O&M	$60,000	Minimal to stakeholders	UG Gates 1200'
71	Dashields L/D	1929	2004		Flood Damage	O&M	$20,000	Minimal to stakeholders	Grating Replacement
72	Montgomery L/D	1936	2004		Flood Damage	O&M	$20,000	Minimal to stakeholders	Grating Replacement
73	Emsworth L/D	1921	2004		Flood Damage	O&M	$10,000	Minimal to stakeholders	Replace Grinder Pumps
							$786,236		
	Allegheny River								
74	L/D 5	1927	2003		Valve Failure	O&M	$1,613	Minimal to stakeholders	DSLW Recess Valve
							$1,613		
	Reservoirs								
75	Berlin Dam	1943	1999		Autocon System Failure	O&M	$283	Minimal to stakeholders	Autocon System
76	Kinzua Dam	1965	1999		Operating Switch Failed	O&M	$2,578	Minimal to stakeholders	Dam Gate #3 Oper. Switch
77	Shenango Dam	1965	1999		Gate indicator malfunctioned	O&M	$3,283	Minimal to stakeholders	Repair Gate Indicator
78	Tionesta Dam	1941	1999		Sump Pump Failure	O&M	$1,046	Minimal to stakeholders	Repair Sump Pump
79	Youghigheny Dam	1944	1999		Emergency Gate Failure	O&M	$48,683	Minimal to stakeholders	Repair Emergency Gate
80	Conemaugh Dam	1952	2000		Generator Failure	O&M	$1,282	Minimal to stakeholders	Repair Generator
81	Stonewall Jack. Dam	1988	2000		Generator Failure	O&M	$7,063	Minimal to stakeholders	Repair Generator
82	Crocked Creek Dam	1940	2001		Electrical System Failure	O&M	$24,392	Minimal to stakeholders	Electrical System
83	Shenango Dam	1965	2001		Electrical System Failure	O&M	$6,539	Minimal to stakeholders	Replace Electrical Panel
84	Stonewall Jack. Dam	1988	2001		Automatic Transfer Switch Failure	O&M	$7,338	Minimal to stakeholders	Repair ATS
85	Tygart Dam	1938	2001		Valve Indicator Failure	O&M	$13,706	Minimal to stakeholders	Repair Valve Position Indicators
86	Youghigheny Dam	1944	2001		Bulkhead Hoist Failure	O&M	$9,630	Minimal to stakeholders	Repair Bulkhead Hoist
87	Crocked Creek Dam	1940	2002		Emergency Gate Contols Failure	O&M	2,175	Minimal to stakeholders	Repair Emergency Gate
88	Crocked Creek Dam	1940	2002		Electrical System Failure	O&M	$24,451	Minimal to stakeholders	Repair Electrical System
89	Crocked Creek Dam	1940	2002		Slucie Gate Failed	O&M	$55,000	Minimal to stakeholders	Repair Sluice Gates
90	Mosquito Dam	1944	2002		Gate Machinery Failed	O&M	$53,303	Minimal to stakeholders	Repair 4x8 Gate Machinery
91	Stonewall Jack. Dam	1988	2002		Automatic Transfer Switch Failure	O&M	$15,811	Minimal to stakeholders	Repair ATS

Appendix E: Incident Reports

>-----Original Message-----
>From: K, Michael F HQ02
>Sent: Tuesday, February 05, 2013 6:19 AM
>To:
>Subject: Inner Harbor Navigation Canal (IHNC) Lock Closed - Damaged Miter
>Gate Strut Arm (UNCLASSIFIED)
>Importance: High
>
>Classification: UNCLASSIFIED
>Caveats: NONE
>
>
>INITIAL REPORT: MVD at 0206 hrs 5 Feb 2013
>
>BLUF: IHNC Lock in MVN - Gate #8 strut arm failed, but can be repaired
>first thing this morning after overnight weather front passes. Lock is
>closed with 29 tows on turn (awaiting transit). Unsafe working conditions
>prevented MVN staff from repairing immediately.
>
>What: IHNC Lock miter gate damaged strut arm, cause of failure unknown,
>but possibly from over-travel of gate/photo eye issue.
>
>When: Monday, 4 FEB 13, ~1900 hrs
>
>Where: New Orleans, LA
>
>Impacts: some to navigation customers with 29 tows on turn. Industry and
>USCG have been apprised of the situation. MVN believes the arm can be
>repaired in-place much faster than a complete swap out as the damage
>appears to be minimal. MVN does have the spare arm ready to go if needed,
>and Operations Division teams are ready to respond at daybreak. Poor
>weather conditions made it unsafe to address Monday night.

>----- Original Message -----
>From: K, Michael F HQ02
>Sent: Tuesday, January 22, 2013 11:46 AM
>To:
>Subject: Accident and Navigation Closure at Locks and Dam 27 Upper
>Mississippi River (UNCLASSIFIED)
>
>Classification: UNCLASSIFIED
>Caveats: NONE
>
>Initial Report: MVD
>
>Date and Time Reported: 22 Jan 2013 0816 hrs
>
>Circumstances: The Mississippi River is closed to navigation at Ls & D 27
>due to damages to the upstream lift gate in the Auxiliary (Aux) lock
>chamber when a barge struck it while being locked through early this
>morning.
>
>At about 0500 today, the operator at Lock 27 was filling the Aux chamber
>with the first cut of the MV CAPT W.D. Nunley. As the chamber was
>filling, there apparently was enough slack in the lines to allow the
>front barges to get up under the nap section of the upstream gate. The
>barges caused the gate to be raised out of the water and become skewed in
>the slot. MVS does not know the extent of the damages. Engineers are
>on-site assessing the damages, but the Aux Lock is closed.
>
>Impact on Lock Operations: The Main Lock is closed for major re-hab. So,
>until the Aux Chamber lift gate is repaired, no navigation traf-fic can
>traverse this section of the Mississippi River. This is the
>southern-most lock on the Mississippi River. More to Follow as MVS works
>through the details and repair activities.

Appendix F: Navigation Notices

US ARMY CORPS
OF ENGINEERS
ROCK ISLAND
DISTRICT

Navigation Notice

River:	Date:
ILLINOIS WATERWAY	5 June 2014
Location:	Effective Period:
T.J. O'Brien Lock RM 326.5	19 January 2015 to 06 March 2015
In Reply Refer to:	AMENDMENT
OD-IM	REF: IW 14-15

AMENDMENT AMENDMENT AMENDMENT AMENDMENT

ILLINOIS WATERWAY

LOCK CLOSURE

T.J. O'Brien Lock & Dam, RM 326.5

T.J. O'Brien Lock & Dam, RM 326.5 will close 47 Days, 0700 hrs on Monday, 19 January 2015 to 1730 hrs on Friday, 6 March 2015 to perform major maintenance on the upper sector gates. Lock dewatering is required to perform activities.

Mariners are requested not to tie up along the guide walls during this period.

Please contact T.J. O'Brien Lock and Dam, Channel 16 or (773) 646-2183 for further instructions.

//S//
Andrew Barnett, Chief
Illinois Waterway Maintenance Section

IW 14-19

US ARMY CORPS
OF ENGINEERS
ROCK ISLAND
DISTRICT

Navigation Notice

River:
ILLINOIS WATERWAY

Date:
02 April 2014

Location:
LaGrange Lock & Dam
RM 80.2

Effective Period:
20 May 2014
to
21 May 2014

In Reply Refer to:
OD-IM

ILLINOIS WATERWAY

LOCK CLOSURE

LaGrange Lock and Dam, RM 80.2

LaGrange Lock & Dam, RM 80.2 will close 36 hrs, 0600 on Tuesday, 20 May 2014 to 1800 hrs on Wednesday, 21 May 2014 to perform maintenance on miter gate machinery.

Mariners are requested not to tie up along the guide walls during this period.

Please contact LaGrange Lock and Dam, Channel 14 or (217) 225-3317 for further instructions.

//S//
Andrew Barnett, Chief
Illinois Waterway Maintenance Section

IW 14-10

US Army Corps
of Engineers
Jacksonville District

NOTICE TO NAVIGATION INTRESTS

Date: 08/25/2014
US ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT
ATTN: CESAJ-OD-SN
PO Box 4970
JACKSONVILLE, FL 32232-0019
904-232-3187

NOTICE NUMBER: 004
LOCAL NUMBER: 201408025
WATERWAY: CANAVERAL HARBOR LOCK
EFFECTIVE: 08/25/2014 00:00 thru 9/17/2014 24:00 EST

POC: http://www.saj.usace.army.mil/Missions/CivilWorks/Navigation/NoticestoNavigation.aspx

---

REVISED CANAVERAL LOCK
40' WIDTH RESTRICTION

REFERANCES:
a. 33 CFR Navigation and Navigable Waters
b. No. 20140604, dated 4 June 2014, SUBJECT; CANAVERAL LOCK 45 FOOT WIDTH RESTICTION.
c. No. 20140805, dated 5 August 2014, SUBJECT; CANAVERAL LOCK 45 FOOT WIDTH RESTICTION.

1. Notice to Navigation
Notice is given that Canaveral Lock will be conducting gate repairs 25 August to 17 September 2014. Before and during scheduled repairs Canaveral lock operations will be restricted to vessels 40 feet wide or less. Vessels greater than 40 feet wide will not be allowed lock passage. For up to date Canaveral Lock operational information contact the shift operator at 312-783-5421 between 0600-2130.

//signed//
WILLIAMS.CARL.MA
BRY.IV.1091240960
Chief Navigation &
Flood Risk Management
South Florida Operations

US Army Corps of Engineers
Pittsburgh District

Notice to Navigation Interests

In reply refer to Notice No. below

US Army Corps of Engineers, Pittsburgh District
1000 Liberty Avenue, Pittsburgh, PA 15222-4186
(412) 395-7650
http://www.lrp.usace.army.mil/or/or-f/navrpt.htm

Notice No. 14-41 Date: August 5, 2014

New Cumberland L/D, Ohio River, Mile 54.3
Closure of Both Lock Chambers

1. To All Whom It May Concern: Notice is given that the U.S. Army Corps of Engineers will close both lock chambers on Thursday August 7, 2014 at New Cumberland Lock and Dam Ohio River, Mile 54.3.

2. The 110-ft x 1,200-ft Primary Lock Chamber and the 110-ft x 600-ft Auxiliary Lock Chamber will be closed from 8:00 AM until 12:00 PM. During this four (4) hour outage New Cumberland Lock and Dam will be closed to all navigation traffic.

3. Minimal delays to navigation traffic can be expected.

FOR THE DISTRICT ENGINEER:

//Signed//
Richard C. Lockwood
Chief, Operations Division

US Army Corps of Engineers
Pittsburgh District

Notice to Navigation Interests

In reply refer to Notice No. below

US Army Corps of Engineers, Pittsburgh District
1000 Liberty Avenue, Pittsburgh, PA 15222-4186
(412) 395-7650
http://www.lrp.usace.army.mil/or/or-f/navrpt.htm

Notice No. 14-28 Date: June 6, 2014

Lock and Dam 3, Monongahela River, Mile 23.8
Closure of the 56-ft x 720-ft Land Lock Chamber

1. **To All Whom It May Concern:** Notice is given that the U.S. Army Corps of Engineers will close the 56-ft x 720-ft land lock chamber at Lock 3, Monongahela River to weld the flume way beam in preparation of the work being performed on the emptying valves, the miter sills, and the downstream landwall miter gate. The work will be take place during daylight hours staring Monday June 9, 2014 and ending Friday June 13, 2014.

2. The 56-ft x 720-ft land lock chamber will be **closed** to all river traffic from 7:30 A.M. until 4:00 P.M. during this work period.

3. The 56-ft x 751-ft extended river chamber will be **open** to navigation during this closure. Minimal delays to navigation can be expected.

4. Navigators are requested to use extreme caution when entering or leaving the river chamber during this closure of the land chamber to prevent a complete shutdown of navigation.

FOR THE DISTRICT ENGINEER:

\\SIGNED//
Richard C. Lockwood
Chief, Operations Division

US Army Corps
of Engineers
Pittsburgh District

Notice to Navigation Interests

In reply refer to
Notice No. below

US Army Corps of Engineers, Pittsburgh District
1000 Liberty Avenue, Pittsburgh, PA 15222-4186
(412) 395-7650

Notice No. 14-18 Date: June 18, 2014

Montgomery L/D, Ohio River, Mile 31.7
Closure of the 110-ft x 600-ft Primary Lock Chamber

1. **To All Whom It May Concern:** Notice is given that the U.S. Army Corps of Engineers Repair Fleet will close the 110-ft x 600-ft primary lock chamber to perform repairs to the downstream miter gates, replace miter gate anchorages, replace hydraulic gate and valve cylinders, and install waterway safety signs. The repair work is scheduled to begin at 12:01 A.M. on September 8, 2014 and will be completed by 11:00 P.M. on 26 September, 2014.

2. The 110-ft x 600-ft primary lock chamber at Montgomery L/D will be **closed** to all navigation during this work period and all navigation traffic will pass through the 56-ft x 360-ft auxiliary lock chamber. Major delays to navigation are expected.

3. The Corps will institute the following lockage procedure which has been developed in cooperation with the Waterways Association of Pittsburgh. Boat locking order will be determined by arrival time at Montgomery L/D, all pilots should radio Montgomery L/D at normal arrival points. All red flag barges in the tow must also be reported by the pilot during this radio call. No adding or swapping of barges will be allowed once the tow's lock turn has been established. All tows must be ready to lock when put on the waiting list. The lockages will be accomplished as a standard series of three tows in one direction. Because of approach conditions (outdrafts and short river guard walls), it is recommended that users limit their tow size to no more than a triple lockage. **Under normal river conditions the Lockmaster will allow, if requested by the pilot when calling for position of the tow, a towboat to lock through with a maximum of five (5) lockages. In no case will the first or last tow in a series of**

CELRP-OP
Navigation Notice No. 14-18

three tows be more than a four (4) cut lockage unless only larger tows are in line. By following this procedure, there will be a minimal tow make-up and approach time when changing directions without a program of "self-help" by navigation interests, the Corps can only handle up to a triple lockage with its on-site tow haulage equipment.

4. To help eliminate some of the waiting time for towboats, an arriving tow can designate to be broken up into a maximum of three (3) separate tows. Each tow will then be locked in accordance with the procedure outlined in paragraph 3 above. The pilot of the large tow will have to notify Montgomery L/D of the intent to breakup into smaller tows and must provide the Lockmaster with the names of the other towboats designated to handle the other tows not later than six (6) hours before their lockage turn. If the designated towboat(s) are not available when called by Montgomery L/D, they will lose their turn and go to the end of the waiting line.

5. During the closure of the 110-ft x 600-ft primary lock chamber closure, tows should move to the closest mooring cell for staging prior to their lockage turn, rather than waiting at landings. Then it will be necessary for tows, under normal river conditions, to follow one another on the river guard wall when a series of lockages are being made in one direction. Each tow in the series should be aware of the tow that they follow and be on the river guard wall as soon as that tow enters the lock chamber. While this practice will speed up the lockage process, it is imperative that tows exercise extreme caution when encountering outdraft or backlash conditions.

6. In an effort to reduce delay time at the locks, a program of "self-help" by navigation interests is necessary. A "self-help" program will allow waiting towboats to assist tows out of the lock chamber. The Lockmaster will designate the helper boats as tows arrive for position. The second and third towboats in the first series of lockages in the opposite direction will be the designated helper boats unless conditions, equipment or cargo prevent the use of that towboat as a helper. Any tow with a tank barge must be accompanied at all times by a towboat. It will be necessary for all towboats to monitor their radios 24 hours a day.

7. Other specific procedures to facilitate lockage operations through the small chamber have been developed in cooperation with the towing industry. The Corps is asking for everybody's

CELRP-OP
Navigation Notice No. 14-18

cooperation and help in making the locking operations go as smoothly as possible during the closure of the large chamber.

a. All excess rigging will be removed prior to entering the lock chamber. Remaining rigging should be ready to be knocked loose after the cut is secured in the lock chamber.

b. **On upbound tows, two locking lines, one head and one stern, must be available on each cut. On downbound tows, two locking lines, one head and one stern, must be available on each cut.** Each line must be at least 75 feet long and 1-1/2" in diameter. To minimize locking time, all lines will stay with each cut. Lines will not be permitted to be carried from one cut to another.

c. **Three deckhands are required during multiple lockages.**

d. All multiple cut tows will be made up in designated staging areas, clear of the lock gates, so as not to interfere with lockage operations.

e. The Montgomery lock filling system may cause turbulence and surging of water while filling the small chamber. **Deckhands need to be extra vigilant in tending lines to avoid an accident which could close the locks totally.**

8. Towboats are cautioned to use minimal power when operating over the lower sill to avoid forcing debris onto the miter sill. This debris could prevent the miter gates from closing and require stoppage of navigation until the material is removed by dredging or diving operations.

9. If critical industrial shipments are essential to sustain continued operation, the affected companies should immediately contact the Waterways Association of Pittsburgh. They will review all requests for priority before submitting them to the Corps for our consideration. If it becomes necessary to prioritize lockages through the small chamber, the Corps will make the final decision concerning lockage procedures as conditions and situations change. In accordance with standard Corps policy, the Lockmaster may also vary the locking procedure in an effort to equalize waiting times.

10. **Information concerning lockages will be broadcast by radio on Channel 13 (155.65 Mhz) and any towboat not answering a call from the locks will be dropped to the end of the waiting list.**

CELRP-OP
Navigation Notice No. 14-18

11. All towboats are to stay with their tows while waiting for lockages unless designated to assist other tows through the small lock.

12. Recreation boaters are discouraged from locking through Montgomery L/D, Ohio River during the lock chamber closure. You will encounter extremely long delays since priority will be given to scheduled commercial passenger vessels and commercial tows.

13. Navigators are requested to use caution when entering or leaving the river lock chamber during this closure of the land chamber to prevent a complete shutdown of navigation.

FOR THE DISTRICT ENGINEER:

//Signed//
Richard C. Lockwood
Chief, Operations Division

Appendix G: Maintenance Cards

DRAWING NUMBERS

APPARATUS FILE NO.
SPARE PART STOCK ITEMS

REMARKS [redacted], January 1966 Replaced Mandrel Spring Assembly -- 12, January 1966
5 AUGUST 1996 REPLACED MANDREL SPRING ASSEMBLY AND Filled With 5 GAL Grease

4 MARCH 2005 Replaced Belvik Spring AND Welded New Spring housing ON Strut Tube. WM

20 March INSTALLED 5/8 Spacer AFTer INSTALLED had 5 Threads Showing WM

Keeper broke ON GATE INCASTING

ENG FORM 1 AUG 50 1851 EQUIPMENT DATA

FILE NO. [redacted] LRLG 1200.110

EQUIPMENT: Strut and Spring Assy		INSPECTION DUE: Monthly	
LOCATION: Locks, Main Lock, River Wall, Downstream, New Cumberland		INSPECTIONS ANNUALLY: Quarter	
FURNISHED ON		DATE	
CONTRACTOR			
MFR.		TYPE	
MODEL OR STYLE NO.		SERIAL NO.	
H.P.	KW.	KVA	P.F.
R.P.M.	FREQ.	PHASE	TEMP. °C

OTHER DETAILED NAME PLATE OR DESCRIPTIVE DATA

OPERATING LOG

POSITION	OPERATORS 12-8 SHIFT	8-4 SHIFT	4-12 SHIFT
		Dilley	
		Ellenberger	
		Greenwood	
	Greenwood	Mayhand	
	Sears	Hartley	Bowles
	Reed	DeMotte Anderson	Munn

Day: FRI 24th Month: MAR Year: 05

DATE	TIME (Hour)	ENTRIES
2400	0800	Checked and operated lock machinery checked oil level, floating equipment and dam gates. Held safety meeting on double looking. Manned 1st floor operation. Mdy + troops on soon-Greenwood working with repair party crew. Assisted Greenwood on seal mould density checks 0010-0630.
0800	1600	Checked and operated all lock gate and miter valve operators, worked in both lock chambers. Lopez (welding flash) Completed repairs to lower 1200 pt side wall gate arm and bellcrank spring. Put the seconds in proper storage. Changed absorbent pads inspected all electric units. Repair crew here working on gate arm
1600	2400	Checked and operated lock machinery, checked all Bldgs, Sea Mule and oil level. Made visual inspection of dam and checked guy in NW Pier. Cleaned 2nd floor Operators Bldg and rest room. Cleaned Middle Bay in storage Bldg to put yard truck away. Checked Compressor, stored oil and put in arm. Removed all trash for Middle Wall. Safety meeting on Back up and have to present time. Secured, checks at 1610, 1900 and 2200.

NOTE-Make all entries in ink. Line out and initial all errors. For operations requiring small number daily entries, use one sheet for several days and insert dates in this column.

REVIEWED (Signature of supervisor in charge)

ENG 2198-E

Appendix H: Major Maintenance and Repair Summaries

H.1 LRD M&R summaries (2006- 2010)

Appendix E - Scheduled Work vs. Work Performed

Repair/Maintenance Schedule for 2005

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
Cumberland River System				
313.5	Cordell Hull Lock (Nashville District)	Inspection and Repairs	Mar 7 – Mar 31, 2005	Lock closed, no auxiliary lock available
216.1	Old Hickory Lock (Nashville District)	Inspection and Repair	May 10 – May 26, 2005	Lock closed, no auxiliary lock available
Green River System				
9.1	Lock and Dam 1 (Louisville District)	Sill repairs & dewatering	Aug 10 – Aug 27, 2005	Lock closed, no auxiliary lock
Kanawha River System				
82.2	London L&D (Huntington District)	Roller Gate Bottom Seal Mod Main Chamber Lower Gate Seal Repair/Mod Main Chamber Top Anchorage Adj/Repairs	May 23 – Jul 1, 2005	Main Lock Closed
67.7	Marmet L&D (Huntington District)	Roller gate Chain Repair/Replacement	Concurrent (14 days)	No Delays
31.1	Winfield Lock and Dam (Huntington District)	Aux Lock Repairs (Old Land Chamber Lower Gates)	Jul 4 – Jul 29, 2005	No Delays
Monongahela River System				
90.8	Point Marion L&Dewater (Pittsburgh District)	84' x 720' Lock Chamber Repair Lock Gates and Sills	Mar 29 - Apr 11, 2005	Single Chamber Closed
61.2	Maxwell L&D (Pittsburgh District)	Dewater 84' x 720' River Chamber, Repair Gates, Seals and Anchorages	May 2 - June 15, 2005	Chamber Closed Intermittent Delays
41.5	Lock and Dam 4 (Pittsburgh District)	Replace Downstream Lock Gates	Dec 6-8, 2005 No Traffic Can Pass	Single Chamber Closed

Ohio River System

	6.2	Emsworth L&D (Pittsburgh District)	Repair Dam Gates 3 & 11	Feb 22 – Mar 12, 2005	No Delays
	54.3	New Cumberland L&D (Pittsburgh District)	Dewater 110' X 600' Land Chamber Repair Lock Gates and Sills	Jul 6 – Aug 18, 2005	Small Chamber Closed No Traffic Can Pass
	54.3	New Cumberland L&D (Pittsburgh District)	Repairs to Service Bridge Lift Span over 110' X 600' Land Chamber	Aug 19 – Sep 2, 2005	No Delays
	84.2	Pike Island L&D (Pittsburgh District)	Dam Repairs - Tainter Gate Span over 110' X 600' Land Chamber	Sep 12 – Sep 30, 2005	No Delays
	84.2	Pike Island L&D (Pittsburgh District)	Replace River Wall Filling Valve Span over 110' X 600' Land Chamber	Oct 3 – Oct 21, 2005	Small Chamber Closed
	126.4	Hannibal L&D (Pittsburgh District)	Replace Land Wall Emptying Valve and Renovate Operating Machinery	Oct 24 - Nov 10, 2005	Small Chamber Closed Intermittent Delays
	161.7	Willow Island L&D (Huntington District)	Tainter gate Side Seal Repairs Main Chamber Floating Mooring Bitt Repairs Mod Aux Lock Miter gates for Lifting	Nov 14 – Dec 9, 2005	No Delays
	237.5	Racine Locks and Dam (Huntington District)	Main Lock Miter Gate Repairs Emergency Gate inspection/Repairs Tainter Gate Side Seal Repairs	Aug 1 – Oct 14, 2005	Main Lock Closed Self-Help
	203.9	Belleville L&D (Huntington District)	Main Lock Lower Gate Repairs Aux Lock Upper Gate Strut Arm Adj/Repair Bulkhead Crane Cable Replacement	Oct 17 – Nov 11, 2005	Main Lock Intermittent 8 hr Closures

Repair/Maintenance Schedule for 2005 (cont)

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile		Project	Repairs	Dates	Remarks
	279.2	RC Byrd L&D (Huntington District)	Culvert Valve Cable Repl. Strut Arm/Sector Pin Bushing Cylinder Changeout – Lower Gate Top Anchorage Adjustments	Concurrent (21 days)	Main Chamber Minor Delays
	341.0	Greenup L&D (Huntington District)	Main Lock Culvert Valve – RWE Aux Lock Upper Gate Strut Arm Springs Main Lock Culvert Valve – RWF Main Lock Floating Mooring Bitt Repairs	Mar 14 – May 20, 2005	Minor Delays
	531.5	Markland L&D (Louisville District)	Structural repairs and maintenance	Jun 4 – Jun 17, 2005	Main lock closed
	531.5	Markland L&D (Louisville District)	Replace Tainter Gate Cables	Jun 18 – Aug 19, 2005	No delays
	531.5	Markland L&D (Louisville District)	Replace Tainter Gate Cables	Sep 6 – Oct 22, 2005	No delays
	720.7	Cannelton L&D (Louisville District)	Structural repairs and maintenance	Jul 5 – Aug 6, 2005	Main lock closed
	776.1	Newburgh L&D (Louisville District)	Rebuild culvert valves	Apr 18– May 24,2005	No Closure No Delays
	776.1	Newburgh L&D (Louisville District)	Structural Repairs and Maintenance	Nov 7 – Nov 19, 2005	Main lock closed
	938.9	Locks and Dam 52	Rebuild two beartraps	Sept 6 – Oct 29, 2005	No Closure No Delays
	962.6	Locks and Dam 53	600' Lower Gate Repairs	Aug 22 - 24, 2005	Aux Chamber Closed

Note: Dates for originally scheduled work may not reflect dates of actual work

Repair/Maintenance Schedule for 2006

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
	Cumberland River System			
30.6	Barkley Lock (Nashville District)	Inspection and Repairs	11-27 Jul 06	Lock closed, transit via Barkley Can and Kentucky Lock
	Kanawha River System			
31.1	Winfield Lock and Dam (Huntington District)	Dewater Old River Chamber/ Gate Changeout Top Anchorage Adjustment Repair Wall Armor Repair	6 Mar- 5 May 06	No delays
31.1	Winfield Lock and Dam (Huntington District)	Flap Cable Replacement Roller Gate Chain	28 Aug – 29 Sep 06	No delays
67.7	Marmet Locks and Dam (Huntington District)	Roller Track Rim Bolts Roller Gate Chain Replacement	28 Aug - 22 Sep 06	No delays
82.2	London Lock and Dam (Huntington District)	Roller Gate Chain Replacement	28 Aug - 22 Sep 06	No delays
	Monongahela River System			
11.3	Braddock L&D (Pittsburgh District)	Repair Downstream Miter Gates, Install New Upstream Maintenance Bulkhead Slots and Sill in the 110' x 720' Lock Chamber	31 Aug - 19 Sep 06	Large chamber closed Small chamber open Major delays
23.8	Locks and Dam 3 (Pittsburgh District)	Dewater 56' x 720' Land Lock Chamber, Renovate Filling Valves, Operating Machinery and Replace Upstream Miter Gates	19 Jun - 20 Jul 06	Land chamber closed Extended river Chamber open Minor delays
41.5	Lock and Dam 4 (Pittsburgh District)	Replace Upstream Lock Gates	7-9 Nov 06	Single chamber closed No traffic can pass through lock
41.5	Lock and Dam 4 (Pittsburgh District)	Renovate 10x12 River Wall Filling Valve and Operating Machinery	13-22 Nov 06	Single chamber open Intermittent delays
108.0	Hildebrand L&D (Pittsburgh District)	Dewater Single 84' x 600' Chamber, Repair Miter Gates and Seals	2 May - 2 Jun 06	Single chamber closed No traffic can pass through lock
108.0	Hildebrand L&D (Pittsburgh District)	Install Gear Boxes on Dam Gate 1	Sep 11 – Oct 13 06	Single chamber closed No traffic can pass through lock
	Ohio River System			
6.2	Emsworth L&D (Pittsburgh District)	Repair Trucks on Dam Gate 5	9 - 20 Jan 06	No delays
6.2	Emsworth L&D (Pittsburgh District)	Repair Downstream Land Wall Miter Gate in the 110' x 600' Chamber	10-14 Apr 06	Major Delays
6.2	Emsworth L&D (Pittsburgh District)	Repair Dam Bulkhead, Main Channel	14 – 24 Aug 06	No delays
13.3	Dashields L&D (Pittsburgh District)	Repair Lock Gate Anchorages in the 110' x 600' Chamber	13-22 Feb 06	Large chamber closed Small chamber open Major delays
31.7	Montgomery L&D (Pittsburgh District)	Repair Upstream Miter Gates damaged in Navigation Accident	21-23 Mar 06	Large chamber closed Small chamber open Moderate delays
31.7	Montgomery L&D (Pittsburgh District)	Repair Operating Machinery on Land Wall Emptying Valve	24-30 Mar 06	Large chamber open Small chamber closed Intermittent delays
31.7	Montgomery L&D (Pittsburgh District) Small chamber closed	Remove Dam Gate No. 8 Construct Gravity Dam in Gate Bay No. 8	29 Oct – 20 Nov 06	No delays

Repair/Maintenance Schedule for 2006 (Cont)

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
31.7	Montgomery L&D (Pittsburgh District) Small chamber closed	Remove Dam Gate No. 4 Construct Gravity Dam in Gate Bay No. 4	29 Oct – 20 Nov 06	No delays
31.7	Montgomery L&D (Pittsburgh District)	Emergency Repairs to Dam Gates 6, 5, 2	29 Oct – 20 Nov 06	No delays
54.3	New Cumberland L&D (Pittsburgh District)	Renovate River Wall Emptying Valve and Renovate Operating Machinery	10-27 Oct 06	Large chamber open Small chamber closed Minor delays
161.7	Willow Island L&D (Huntington District)	Dewater Auxiliary Lock Chamber Inspect / Repair Auxiliary Chamber Gates, Dam Tainter Gate Side Seal Repairs	20 Nov - 15 Dec 06	Auxiliary lock closed No delays
203.9	Belleville Locks and Dam (Huntington District)	Repair Auxiliary Lower Gates Tainter Gate Repairs due to Barge Accident Belleville Bulkhead Crane Cables	30 Oct - 17 Nov 06	No delays
237.5	Racine Locks and Dam (Huntington District)	Dam Tainter Gate Side Seal Repairs (2), Mooring Bits	25 Sep - 27 Oct 06	Minor delays
279.2	RC Byrd Locks and Dam (Huntington District)	Sector Base Upper River Main both Leaves	14 - 25 Aug 06	Minor delays
341.0	Greenup Locks and Dam (Huntington District)	Auxiliary Lock Inspection/Repairs Culvert Valve MWE, LWE	8 May - 2 Jun 06	Auxiliary lock closed No delays
341.0	Greenup Locks and Dam (Huntington District)	Main Lock Inspection/Repairs	19 Jun - 7 Jul 06	Main lock closed Self-help
341.0	Greenup Locks and Dam (Huntington District)	Tainter Gate Trunnion Beam and Gate Side Seal	31 Jul – 11 Aug	No delays
436.2	Meldahl Locks and Dam (Huntington District)	Aux Lock Culvert Valve Repairs Dam Gate Side Seal Repairs Culvert Valves MWF, RWE Quoin and Miter Block Replacement	19 Jun - 28 Jul 06	No Delays
720.7	Cannelton L&D (Louisville District)	Structural repairs and maintenance	26 Jun - 29 Jul 06	Main lock closed
776.1	Newburgh L&D (Louisville District)	Culvert valve repairs and maintenance	15 Apr - 17 Jun 06	Auxiliary lock closed
938.9	Locks and Dam 52 (Louisville District)	Structural repairs and maintenance	3 Aug - 16 Sep 06	Auxiliary lock closed
938.9	Locks and Dam 52 (Louisville District)	Reinforce lock wall cells	19 Sep - 11 Nov 06	Intermittent main lock closures
	Tennessee River System			
22.4	Kentucky Lock (Nashville District)	Inspection and repairs	15 Aug - 7 Sep 06	Lock closed, transit via Barkley Canal and Barkley Lock
259.4	Wilson Main Lock (Nashville District)	Repair lower wall	20-25 Mar 06	Lock closed, 60 x 300 dual lift Auxiliary lock will be available
259.4	Wilson Main Lock (Nashville District)	Inspection and repairs	2 - 27 May 06	Lock closed, 60 x 300 dual lift Auxiliary lock will be available
259.4	Wilson Main Lock	Painting and repair completion Emergengy Repairs	3 Aug – 2 Dec 11	Lock closed, 60 x 300 dual lift Auxiliary Floating Caisson used to operate Lock Intermittently

Note: Dates for originally scheduled work may not reflect dates of actual work

Repair/Maintenance Schedule for 2007

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
	Allegheny River System			
14.5	C. W. Bill Young L/D (Pittsburgh District)	Renovate 8x10 land wall filling valve and repair hydraulic pipelines in the single 56'X360' chamber	12 - 30 Mar 07	Single chamber open Intermittent delays
62.2	Lock and Dam 9 (Pittsburgh District)	Replace hydraulic pipeline crossovers in the single 56'X360' chamber	21 - 25 May 07	Single chamber closed No traffic can pass through lock
	Kanawha River System			
82.2	London L&D (Huntington District)	Roller gate chain replacement	30 Apr - 1 Jun 07	No delays
	Monongahela River System			
11.3	Braddock L&D (Pittsburgh District)	Repair upstream miter gates, Install new downstream maintenance bulkhead slots and sill in the 110' x 720' lock chamber	26 Jun - 5 Jul 07	Large chamber closed Small chamber open Major delays
11.3	Braddock L&D (Pittsburgh District)	Install new downstream maintenance bulkhead slots and sill in the 110' x 720' lock chamber	23 Jul - 1 Aug 07	Large chamber closed Small chamber open Major delays
23.8	Locks and Dam 3 (Pittsburgh District)	Renovate downstream miter gates and repair emptying valves in the 56' x 720' lock chamber	8 - 17 May 07	Land chamber closed Extended river chamber open Minor delays
41.5	Lock and Dam 4 (Pittsburgh District)	Replace upstream lock gates in the single 56' x 720' lock chamber	10 - 12 Apr 07	Single chamber closed No traffic can pass Through lock
41.5	Lock and Dam 4 (Pittsburgh District)	Renovate 10x12 middle wall filling valve and operating machinery in the single 56' x 720' lock chamber	12 - 25 Apr 07	Single chamber open Intermittent delays
	Ohio River System			
6.2	Emsworth L&D (Pittsburgh District)	Repair downstream middle wall gate in the 110' x 600' lock chamber	10 - 14 Sep 07 Major delays	Large chamber closed Small chamber open
6.2	Emsworth L&D (Pittsburgh District)	Repair filling and emptying valves in the 56' x 360' lock chamber	17 Sep - 19 Oct 07	Small chamber closed Large chamber open Minor delays
31.7	Montgomery L&D (Pittsburgh District)	Renovate 13x14 land wall filling and emptying valves in the 110' x 600' lock chamber Emergency Repairs to Dam Gate #1	29 Oct - 16 Nov 07	Small chamber closed Large chamber open Intermittent delays
84.2	Pike Island Locks (Pittsburgh District)	Renovate land wall filling valve and operating machinery in the 110' x 600' lock chamber Repair Dam Gate #5	26 Nov - 14 Dec 07	Small chamber closed Large chamber open Minor delays
126.4	Hannibal L&D (Pittsburgh District)	Dewater 110'x1200' lock chamber and repair miter gates and seals	16 Jul - 24 Aug 07	Large chamber closed Small chamber open Moderate delays
161.7	Willow Island L&D (Huntington District)	EM Gate cable replacement UMW (Main) Strut Arm replacement Bulkhead seal repairs Thrust roller repair	19 Nov - 14 Dec 07	No delays
203.9	Belleville L&D (Huntington District)	Tainter Gate Repairs (barge accident) Hydraulic line repairs	29 Oct - 16 Nov 07	No delays

Repair/Maintenance Schedule for 2007 (Cont)

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
237.5	Racine L&D (Huntington District)	UMW Strut Arm repair Miter gate and valve hydraulic Cylinder repairs	5 Mar - 30 Mar 07	Minor delays
237.5	Racine L&D (Huntington District)	Dam tainter gate side seal repairs	17 Sep - 26 Oct 07	No delays
237.5	Racine L&D (Huntington District)	Replace Bulkhead Crane Cable	13 – 16 Nov 2010	No delays
237.5	Racine L&D (Huntington District)	Dam Tainter Line Shaft Repairs	8 – 19 Dec 2010	No delays
279.2	RC Byrd L&D (Huntington District)	Main chamber dewater Adjust LRW gate and bottom seal repairs	4 Jun - 6 Jul 07	Main lock closed Self help
341.0	Greenup L&D (Huntington District)	URW gate machinery repairs LMW main strut arm repairs	2 Apr - 27 Apr 07	Minor delays
436.2	Meldahl L&D (Huntington District)	Aux. Chamber Emergency Gates Dewater/Inspect dam bay #7 Culvert valve rehab (RWF or RWE)	9 Jul - 14 Sep 07	Minor Delays
436.2	Meldahl L&D (Huntington District)	Auxiliary Lock Emergency Gare Rehab Dewater/Inspect dam bay #7	19 Nov – 7 Dec 07	Minor Delays
531.5	Markland L&D (Louisville District)	Structural repairs and maintenance inspection	31 May - 15 Jun 07	Main lock closed
531.5	Markland L&D (Louisville District	Emergency Repairs, Miter Gate Cracks	9 – 31 Jul 07	Auxiliary lock closed
606.8	McAlpine L&D (Louisville District)	Main Lock Gate Repairs	18 – 22 Jun 07	Lock chamber closed
720.7	Cannelton L&D (Louisville District)	Structural repairs and maintenance inspection	25 Jun - 31 Jul 07	Main lock closed
846.0	JT Myers L&D (Louisville District)	Rebuild culvert valves	16 Apr - 19 May 07	Small Chamber closed
938.9	Locks and Dam 52 (Louisville District)	Structural repairs	7 - 13 Aug 07	Main lock closed
938.9	Locks and Dam 52 (Louisville District)	Structural repairs	21 - 27 Aug 07	Main lock closed
938.9	Locks and Dam 52 (Louisville District)	Beartrap repairs	28 Aug – 13 Nov 07	No Delays
	Tennessee River System			
22.4	Kentucky Lock (Nashville District)	Inspection and repairs	21 Aug - 13 Sep 07	Lock closed, transit via Barkley Canal and Barkley Lock
206.7	Pickwick Aux Lock (Nashville District)	Install new tow-haulage unit	19 Mar - 10 Apr 07	Auxiliary Lock closed
206.7	Pickwick Main Lock (Nashville District)	Inspection and repairs	10 - 23 Jul 07	Main lock closed
259.4	Wilson Aux Lock (Nashville District)	Repair lower damaged gate	5 - 21 Jun 07	Auxiliary lock closed
471.0	Chickamauga Lock (Nashville District)	Inspection	20 Mar - 10 Apr 07	Single lock closed, no traffic can pass through project

Note: Dates for originally scheduled work may not reflect dates of actual work

Repair/Maintenance Schedule for 2008

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
	Allegheny River System			
6.7	Lock and Dam 2 (Pittsburgh District)	Renovate Land Wall Filling Valve and Machinery, Repair Hydraulic Piping	6-23 May 08	Single Chamber Open Intermittent Delays
24.2	Lock and Dam 4 (Pittsburgh District)	Renovate Filling and Emptying Valves	27 May – 13 Jun 08	Chamber Width Restricted Intermittent Delays
	Cumberland River System			
148.7	Cheatham L&D (Nashville District)	Dewatering Inspection and Repairs	18 Aug – 9 Sep 08	Single Chamber Closed No Traffic
	Green River System			
9.1	L&D 1 and 2 (Louisville District)	GR#1 Sill Timbers, Piping, and Valves	4 Aug – 13 Sep 08	Single Chambers Closed No Traffic
63.1		GR#2 Mooring Bits, Piping and Valves		
	Kanawha River System			
31.1	Winfield L&D (Huntington District)	Roller gate chain, Aux Chamber Anchorage Repairs	16 Jun – 25 Jul 08	No Delays
	Monongahela River System			
11.2	Braddock L&D (Pittsburgh District)	Dewater Main Chamber, Tension Lock Gates, Repair Miter and Qoin Seals	24 Jun – 8 Jul 08	Main Chamber Closed Major Delays
11.2	Braddock L&D (Pittsburgh District)	Replace Middle Wall Filing Valve, Repair Operating Machinery	9 - 16 Jul 08	Auxiliary Chamber Closed Minor Delays
23.8	Locks and Dam 3 (Pittsburgh District)	Repair/Replace Miter Gates and Valve Operating Machinery	10 – 28 Mar 08	Auxiliary Chamber closed Minor Delays
108.0	Hildebrand L&D (Pittsburgh District)	Dewater Lock Chamber Renovate Lock Gates and Seals	31 Mar – 25 Apr 08	Single Chamber Closed No Traffic
115.4	Opekiska L&D (Pittsburgh District)	Renovate Filling and Emptying Valves	7 – 31 Oct 08	Minor Delays
	Ohio River System			
13.3	Dashields L&D (Pittsburgh District)	Miter gate Operating Machinery in Main Chamber (Work Staged from Auxiliary Chamber)	10 – 21 Nov 08	Auxiliary Chamber Closed Intermittent Delays
31.7	Montgomery L&D (Pittsburgh District)	Repair Upstream Miter Gate & Upstream Boulee Dam Main Chamber	3 – 5 Sep 08	Intermittent Delays
54.4	New Cumberland Locks and Dam (Pittsburgh District)	Renovate Middle Wall Emptying Valve and Operating Machinery	5 – 22 Aug 08	Auxiliary Chamber Closed Minor Delays
84.2	Pike Island Locks and Dam (Pittsburgh District)	Repair Dam Tainter Gate Arms No. 1, 5, and 6	14 Sep – 28 Oct 08	No Delays
203.9	Belleville L&D (Huntington District)	Tainter gate Arm Repairs, Tapered Pin Repairs, Main Lock, Lower Gates	10 Nov – 19 Dec 08	Main Chamber Closed
237.5	Willow Island L&D (Huntington District)	Aux. Miter Gate Rack Arm Repairs	24 Nov – 19 Dec 08	No Delays
237.5	Racine L&D (Huntington District)	Replace Bulkhead Crane Cable, Repair Line Shafts and Supports, Auxiliary	21 Apr – 16 May 08	No Delays
237.5	Racine L&D (Huntington District)	Dam Tainter Gate Side Seal Replacement	29 Sep – 7 Nov 08	No delays

Repair/Maintenance Schedule for 2008 (Cont)

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

	River Mile	Project	Repairs	Dates	Remarks
	237.5	Racine L&D (Huntington District)	Dam Tainter Line Shaft	1 – 19 Dec 08	No delays
	237.5	Racine L&D (Huntington District)	Dam Tainter Line Shaft Repairs	8 – 19 Dec 08	No delays
	279.2	RC Byrd L&D (Huntington District)	Rehab Middle Wall Fill Valve Lower Wall Empty Culvert Valve	10 Mar – 18 Apr 08	Auxiliary Chamber Closed
	279.2	RC Byrd L&D (Huntington District)	Main Lock Lower Gate Repairs	27 Oct – 28 Nov 08	Main Chamber Closed
	341.1	Greenup L&D (Huntington District)	Emergency Gate Rehab – Prelim. Work	19 May – 13 Jun 08	Auxiliary Chamber Closed
	341.1	Greenup L&D (Huntington District)	Emergency Gate Rehab Installation Middle Wall Empty Culvert Valve Rehab	28 Jul – 26 Sep 08	Auxiliary Chamber Closed
	341.1	Greenup L&D (Huntington District)	Emergency Gate Rehab Installation Middle Wall Empty Culvert Valve Rehab	27 Sep – 5 Dec 08	Auxiliary Chamber Closed
	606.8	McAlpine L&D (Louisville District)	Tainter Gate #1, Wire Rope Replacement	10 – 25 Jul 08	No Delays
	720.7	Cannelton L&D (Louisville District)	Rehab Two Culvert Valves, Sector Gate Machinery, Major Maintenance	8 Apr – 22 Jun 08	Auxiliary Chamber Closed
	720.7	Cannelton L&D (Louisville District)	Upper Gate Major Maintenance and Anchor Modifications	23Jun – 29 Jul 08	Main Chamber Closed
	720.7	Cannelton L&D (Louisville District)	Upper Gate Major Maintenance	9 Oct – 15 Nov 08	Auxiliary Chamber Closed
	776.0	Newburgh L&D (Louisville District)	Replace tainter gate Cable Connections	6 Oct – 15 Nov 08	No Delays
	846.0	JT Myers L&D (Louisville District)	Dam Pier #11 Concrete Erosion Repair	16 Sep – 4 Oct 08	No Delays
	Tennessee River System				
	206.7	Pickwick L&D (Nashville District)	Dewatering for Inspection and Repairs	28 May – 17 Jun 08	Auxiliary Chamber Closed
	206.7	Pickwick L&D (Nashville District)	Dewatering for Inspection and Repairs	8 – 21 Jul 08	Main Chamber Closed
	274.3	Wheeler L&D (Nashville District)	Dewatering for Inspection and Repairs	15 Apr – 5 May 08	Main Chamber Closed

Note: Dates for originally scheduled work may not reflect dates of actual work

Repair/Maintenance Schedule for 2009

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
	Allegheny River System			
6.7	Lock and Dam 3 CW Bill Young (Pittsburgh) District)	Replace DS Miter Gates Repair Gate Operating Machinery	14 – 23 Apr 09	3 day Single Chamber Closure
	Cumberland River System			
216.2	Old Hickory (Nashville) District)	Dewater and Inspect Chamber	27 Oct – 17 Nov 09	Single Chamber Closure
	Kanawha River System			
31.1	Winfield L&D (Huntington District)	RWE Valve Repair, Roller Gate Chain	18 May– 26 Jun 09	No Delays
31.1	Winfield L&D (Huntington District)	Continue RWE Valve Repair	7 – 18 Dec 09	No Delays
	Monongahela River System			
11.2	Braddock L&D (Pittsburgh District)	Repair Gate Operating Machinery Repair Miter and Qoin Seals	10 – 28 Aug 09	Auxiliary Chamber No Delays Anticipated
11.2	Braddock L&D (Pittsburgh District)	Replace Land Wall Filling Valve Renovate Operating Machinery	30 Nov – 7 Dec 09	Auxiliary Chamber No Delays Anticipated
23.8	Lock and Dam 3 (Pittsburgh District)	Dewater Chamber and Repair 8' Cylindrical Valvesy	11 May – 19 Jun 09	Auxiliary Chamber No Delays Anticipated
91.0	Point Marion L&D (Pittsburgh District)	Renovate Land Wall Emptying Valve	23 Mar –3 Apr 09	Minor Delays
	Ohio River System			
6.2	Emsworth L&D (Pittsburgh District)	Repair Emptying Valves	6 – 24 Jul 09	Main Chamber Closed
13.3	DaShields L&D (Pittsburgh District)	Repair US Land Wall and DS Middle	6 – 24 Jul 09 Wall Miter Gates	Main Chamber Closed
31.7	Montgomery L&D (Pittsburgh District)	Continuation of Repairs to Dam Gates	4 – 15 May 09	No Delays
31.7	Montgomery L&D (Pittsburgh District)	Continuation of Repairs to Dam Gates	30 Nov – 18 Dec 09	No Delays
84.2	Pike Island L&D (Pittsburgh District)	Repair Operating Machinery and Floating Mooring Bits	8 Sep – 16 Oct 09	Auxiliary Chamber Closed No Delays Anticipated
126.4	Hannibal L&D (Pittsburgh District)	Replace Land Wall Filling Valve Renovate Operating Machinery	1 – 19 Jun 09	Auxiliary Chamber Closed No Delays Anticipated
203.9	Belleville L&D (Huntington District)	Tainter gate Arm Repairs, Tapered Pin Repairs, Main Lock, Lower Gates	9 Mar – 15 May 09	Main Chamber Intermittent Delays
203.9	Belleville L&D (Huntington District)	Lower River Gate Gudgion Pin Repairs	22 Jun – 1 Jul 09	Main Chamber Closed
237.5	Racine L&D (Huntington District)	Emergency Gate Sheave/Anchorage Rehab	29 Jul – 21 Aug 09 16 Nov – 18 Dec 09	No Delays
279.2	RC Byrd L&D (Huntington District)	Dewater and Inspect Lower River Wall Miter Date Repairs	5 Oct – 13 Nov 09	Main Chamber Closed

Repair/Maintenance Schedule for 2009 (Cont)

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
341.1	Greenup L&D (Huntington District)	Dewater and Inspect in Preparation for Main Chamber Closure	29 Jul – 21 Aug 09	Auxiliary Chamber No Delays
341.1	Greenup L&D (Huntington District)	Dewater and Inspect Mooring Bit Repairs	5 Oct – 7 Nov 09	Main Chamber Closed
436.2	Meldahl L&D (Huntington District)	Miter Gate Preliminary, Miter Gate Sector Base Repairs	24 Aug – 30 Sep 09	No Delays
531.5	Markland L&D (Louisville District)	Dewater and Inspect Culvert Valve Machinery	28 Apr – 23 May 09 14 Sep – 27 Sep 09	Main Chamber Closed
531.5	Markland L&D (Louisville District)	Emergency Repairs to the Lower Gate Leaves	27 Sep – 31 Dec 09	Main Chamber Closed
720.7	Cannelton L&D (Louisville District)	Major Maintenance and Anchorage Mod, Emergency Gate Sheaves	1 Jun - 11 Jul 09	Main Chamber Closed
846.0	JT Myers L&D (Louisville District)	Anchorage Mod, Replace Miter and Quioin Blocks, Pintles and Gudgeon	14 Jul – 25 Aug 09	Auxiliary Chamber Closed
846.0	JT Myers L&D (Louisville District)	Dewater and Inspected	28 Aug - 9 Sep 09	Main Chamber Closed
918.5	Smithland L&D (Louisville District)	Tainter gate Repairs	14 Sep – 10 Oct 09	No Delays
964.4	L&D 52 (Louisville District)	Sill Repairs	14 Sep – 27 Sep 09	Auxiliary Chamber Closed
	Tennessee River System			
259.4	Wilson L&D (Nashville District)	Dewater and Inspect Chamber Wall Armor & Culvert Valve Work	14 Jul – 11 Aug 09	Main Chamber Closed
349.0	Guntersville L&D (Nashville District)	Dewater and Inspect Chamber	2 Jun – 23 Jun 09	Main Chamber Closed
424.7	Nickajack L&D (Nashville District)	Dewater and Inspect Chamber	21 Apr –12 May 09	Single Chamber Closed
471.0	Chickamauga L & D (Nashville District)	LRW Embedded Anchorage Replacement	27 Apr – 10 May 09	Main Chamber Closed

Note: Dates for originally scheduled work may not reflect dates of actual work

Repair/Maintenance Schedule for 2010

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
	Allegheny River System			
6.7	Lock and Dam 2 (Pittsburgh District)	Dewater and Inspect	8 – 31 Mar 10	Single Chamber Closed
24.2	Lock and Dam 4 (Pittsburgh District)	Renovate Emptying Valves 2, 3, 4, & 6	5 – 23 Apr 10	Width Restriction Intermittent Delays
	Kanawha River System			
31.1	Winfield L&D (Huntington District)	Replace 2 Remaining Roller Gate Chains (Dam Work)	14 Jun – 9 Jul 10	No Delays
82.8	London L&D (Huntington District)	Roller Gate Chain Replacement Sill Modifications (Dam Work)	1 Nov – 17 Dec 10	No Delays
	Monongahela River System			
11.2	Braddock L&D (Pittsburgh District)	Dewater Chamber. Repair/Replace Miter Sills, Gates, Seals, and Anodes	2 Aug – 3 Sep 10	Auxiliary Chamber No Delays Anticipated
11.2	Braddock L&D (Pittsburgh District)	Replace MWEV, Renovate Operating Machinery	15 - 23 Nov 10	Main Chamber Closed
	Ohio River System			
6.2	Emsworth L&D (Pittsburgh District)	Dewater Main Chamber Renovate Emptying Valves	3 – 28 May 10	Main Chamber Closed
6.2	Emsworth L&D (Pittsburgh District)	Repair U/S Miter Gates and Gate Operating Machinery	1 – 17 Dec 10	Main Chamber Closed
31.7	Montgomery L&D (Pittsburgh District)	Emergency Repairs Gates 3, 7, 9, & 10	7 Jun – 23 Jul 10	No Delays
84.2	Pike Island L&D (Pittsburgh District)	Install New Miter Gates	13 Sep – 5 Nov 10	Main Chamber Closed
161.7	Willow Island L&D (Huntington District)	Aux. Lock Lower Miter Gate, Repairs to Quoin and Miter Blocks	27 Sep – 5 Nov	Aux. Chamber Closure 9 Sep – 5 Nov
203.9	Belleville L&D (Huntington District)	Main Chamber, Upper Gate Opening Machinery, Side Seal Repairs	8 Mar – 23 Apr 10	No Delays
237.5	Racine L&D (Huntington District)	Dam Bulkhead Crane Rope replacement	28 Jun – 2 Jul 10	No Delays
279.2	RC Byrd L&D (Huntington District)	Dewater and Inspect, Adjust Miter Gate Alignment, Sector Base, and Strut Rehab	12 Jul – 20 Aug 10	Main Chamber Closed
341.1	Greenup L&D (Huntington District)	Replace Anchorage Arms Strut Pins & Sector Gear Repairs	8 Nov – 17 Dec	Main Chamber Closed
436.2	Meldahl L&D (Huntington District)	LowerGate Storage Beam Installation Miter Gate Anchorage Work	26 Apr – 11 Jun 10	No Delays
436.2	Meldahl L&D (Huntington District)	Miter Gate Prep and Installation Sector Base Repairs	23 Aug – 29 Oct 10	Auxiliary Chamber Closed
531.5	Markland L&D (Louisville District)	Lower Miter Gate Repairs & Installation Dependant on river conditions	1 Jan – 31 May 10	Main Chamber Closed
531.5	Markland L&D (Louisville District)	Unload New Lower Miter Gate Leaves At Louisville Repair Station	15 – 31 Mar 10	No Delays

Repair/Maintenance Schedule for 2010 (Cont)

Scheduled and Performed
Scheduled but Not Performed
Performed but Not Scheduled

River Mile	Project	Repairs	Dates	Remarks
531.5	Markland L &D (Louisville District)	Unload New Upper gate leaves At Markland L&D	1 – 31 Dec 10	No Delays
606.8	McAlpine L&D Old Chamber (Louisville District)	Rehab Culvert Valve Machinery And Gate Machinery Prep for Gate Change	1 Apr – 14 May 10	No Delays
606.8	McAlpine L&D (Louisville District)	New Lower Gate Installation	1 Jun – 15 Jul 10	Old Chamber Closed
606.8	McAlpine L&D (Louisville District)	Replace pintles & gudgeon pins & bushings	19 Apr – 5 Aug 10	New Chamber Closed
720.7	Cannelton L&D (Louisville District)	Dewater and Inspect Main Chamber (Anchorages not Mitering)	19 Jul – 7 Aug 10	Main Chamber Closed
846.0	JT Myers L&D (Louisville District)	Replace LMW Anchor Arm in Main Chamber	17 – 26 May 10	Main Chamber Closed
918.5	Smithland L&D (Louisville District)	Dewater and Inspect Land Chamber	12 – 28 Oct 10	Land Chamber Closed
918.5	Smithland L&D (Louisville District)	Dewater and Inspect River Chamber	29 Oct – 15 Nov 10	River Chamber Closed
964.4	L&D 52/53 (Louisville District)	52: Lower Miter Gate, Cell Bands 53: Lower Miter Gate, Culvert Valves	16 Aug – 9 Oct 10	52 Main Chamber Closed 53 Main Chamber Closed
	Tennessee River System			
22.3	Kentucky Lock (Nashville District)	Timbers Floating Boom Wall	8 Feb – 18 Mar 10	No Delays
471.0	Chickamauga Lock (Nashville District)	Dewater and Inspect	20 Jul – 16 Aug 10	Single Chamber Closed
529.9	Watts Bar Lock (Nashville District)	Dewater and Inspect Will not return for another 10 years	12 Oct – 2 Nov 10	Single Chamber Closed
471.0	Fort Loudon Lock (Nashville District)	Dewater and Inspect TVA will paint lower miter gates	20 Apr – 11 May 10	Single Chamber Closed
Clinch River	Melton Hill Lock (Nashville District)	Dewater and Inspect	8 – 29 Jun 10	Single Chamber Closed

Note: Dates for originally scheduled work may not reflect dates of actual work

H.2 LRL M&R summaries (2007-2011)

LRS Project Database

Work Item (Job Order)	Project Site	Work Accomplished	Begin Date	End Date	# Days Worked	Shifts	Actual Cost	Project Engineer
		CY 2007						
0L0354	JT Myer 600'	> Dewater and general inspection of land wall filling and emptying valves > Repair cracks in emptying valve arms and add stiffeners > Clean, weld and paint areas of moderate corrosion on valves > Replace pins and bushings in trunnion, piston rod, upper strut and lower strut > Replace springs, yoke stem bushing and spindle yoke stem nuts on valve strut arms > Replace valve hydraulic cylinders > Replace miter gate hydraulic cylinders on 2 gates in the 1200' chamber > Replace miter gate strut arm on one gate > Replace land wall intake screens	4-16-2007	5-17-2007	26	unknown	$1,210,559.71	Crutchfield
3HGDD9	Markland 600'	* Note: large amount of debris on apron required several days to clear > Dewater lower gates and repair structural cracking identified in dive inspection > Install total of four stiffener plates on miter gates > Repair j-seal on gate > Resurface wall quoin with polymer steel > Repair concrete at the sill > Repair loose hydraulic cylinder on 1200' gate	7-9-2007	7-30-2007	18	2 shifts - 10 hrs	$712,007.46	Keel
		CY 2008						
19C384	Cannelton 600'	> Recondition filling and emptying valves > Rehab the sector gear machinery	4-7-2008	5-14-2008	34	2 shifts	$1,650,999.22	Vessels & Woodbury
OH1C95	Cannelton 600' Lower Gates	* Note: broken lower tie back pin limited scope to lower gates; flooded out 5-11 June; mud on sill/apron required 3 days of dredging. > Dewater and inspect miter gates > Replaced broken latch pin > Both miter gates: install jacking guides, replace miter and quoin blocks, backer blocks, pintle balls and bushings, top anchorage system > Resurface wall quoin with polymer steel > Replace vertical strut pin bushings > Replace several grease lines on filling and emptying valves > Repair one sunken floating mooring bit	5-27-2008	7-8-2008	35	2 shifts - 10 hrs	$4,812,652.88	Crutchfield
	Cannelton 600' Upper Gates	> Dewater and inspect miter gates > Replaced latch pins > Both miter gates: install jacking guides, replace miter and quoin blocks, backer blocks, pintle balls and bushings, top anchorage system, recess bumpers > Resurface wall quoin with polymer steel > Remove and contract others to repair cracks in pintle castings > Adjust gate j-seal > Aligned culvert valve and replace piston rod bushing	10-9-2008	11-15-2008	44	2 shifts - 10 hrs		
J32JG0	JT Myer Pier 11	> Set small dewatering box and repaired scour hole at the base and in the face of pier 11 in-the-dry	9-15-2008	9-30-2008	14	2 shifts	$707,158.00	Vessels

		CY 2009						
BDF946	Cannelton 1200'	> Dewater & inspect 1200' chamber > Miter gates: 1- install jacking guides; 2- replace anchorage and anchorage arms; 3- replace miter and quoin blocks; 4- replace pintles and bushings; 5- repair rub fenders > Repair 3 mooring bit recess tracks > Resurface wall quoin blocks with polymer steel	6-1-2009	7-9-2009	35	2 shifts	$2,236,701.17	Keel
C5JB4J	JT Myers 600'	* Note: high water forced the fleet to rewater the chamber from 1-10 of August. - > Dewater & inspect 600' chamber > Miter gate major maint. all four gates: jacked, new pintles, pintle bushings, gudgeon pins, gudgeon bushings, miter blocks, & quoin blocks > Resurface wall quoin blocks with epoxy > Widen miter gate walkway	7-14-2009	9-4-2009	unknown	2 shifts	$2,136,340.00	Holcomb & Crutchfield
30JGB2	Markland 1200'	> Dewater lock and inspect all miter gates and valves > Repair lock wall armor plate > Repair mooring bit slot & add air bubbler > Replace eccentric pin > Apply polymer steel to quoin blocks > Repair steel and concrete on sill > Repair cracks in miter gates and repair fenders on gate	9-14-2009	9-27-2009	13	unknown	$711,430.50	Bower
		CY 2010						
1H3G77	McAlpine South Chamber	* Note: high water on 3 occasions, resulting in 38 days of lost work & increased dewatering efforts - > Miter and quoin block adjustment and repair > Replace pintle balls and bushings, and install grease lines to bushings > Replace anchor arms, gudgeon pins and gudgeon bushings > Miter gate jacking guide system fabricated and installed > Remove all greaseless strut pin bushings and replace with grease bushings > Adjust filling valve trunnion pins > Adjust miter gate hydraulic cylinder programming and counterbalance valves to eliminate surging	4-19-2010	8-5-2010	64	varied	$2,706,538.94	Woodbury & Moulton
32GBGK	Smithland Land Chamber	> Dewater, inspect and minor repairs to miter gates, culvert valves and culverts > Mooring bits in river chamber removed, wheel bushings turned and bit reinstalled > Culvert valves: 1- seal bolts installed; 2- valve ears welded up & line-bored; 3- weld cracks in valve > Miter gates: 1- adjust miter switch; 2- repair v-block and roller; 3- replace and repair fenders; 4- replace lower wall bumper; 5- repair cracks in gates by welding	11-1-2010	11-19-2010	15	2 shifts - 10 hrs	$553,069.82	Moulton

CY 2011								
B0421K	JT Myers 1200'	** Note: All work was suspended while the lock was flooded out April 25 - May 16* > Added gate walkway expansions > Replaced gate anchorage, pins, and bushings. Added anchorage shims > Reworked mitering devices: 1- shim plates added; 2- stop blocks added; 3- bolts replaced; 4- base replaced; etc. > Rebuild miter gate machinery: 1-Replace sector bushings; 2- Replace rack bar rollers; 3- Replace hydraulic cylinder seals; 4- Replace hydraulic cylinder/bell crank bushing; 5- New grease lines; 6- Add sleeve in sector arm cross pin block; 7- Replace sector arm body bound bolts. > Changeout two culvert valve (URW and LMW) hydraulic cylinders > Rebuild the gate strut arms; 1- Replace strut arm spring assembly; 2- Replace strut pins; 3- Replace tensioning rod and nut > Repair electrical conduit in dam pier machinery houses	4-Apr-2011	27-May-2011	24	1 shift - 10 hrs	$1,741,807.03	Woodbury & Fleck
G4HK6G	Markland 600'	** Note: Emergency gate wire rope was also replaced during this time period- see work item 162K56* > Replace emergency gate trash screen guide angle > Replace eccentric pins > Rework Struts: 1- spindle casting bushings & grease line; 2- arm spring assembly; 3- spindle; 4- horizontal pin at gate > Replace section of wall armor on bull nose > Filling and emptying valves: 1. Repaired, welded and line bored pickup casting; 2. Replace pickup casting turned bolts; 3. Replaced pin keepers; 4. Replace lower bell crank strut/pick up pin bushing; 5. Add grease line across bell crank to lower strut pin > Miter Gates: 1. Add stiffener plates; 2. Minor crack repair and girder repair; 3. Repair latch pin; 4. Replace j-seal and repair j-seal angle; 5. Repair wood bumper; 6. Add air lines in gate recess area; 7. Replace section of stainless steel sill	1-Jun-2011	30-Jun-2011	26	2 shifts - 10 hrs	$1,404,158.84	Fleck
162K56	Markland 600'	** Note: work was done simultaneously with other work at the project site - see work item G4HK6G* > Emergency gate wire rope replacement	7-Jun-2011	15-Jun-2011	8	1 shift - 10 hrs	$68,506.92	Vessels
9085H4	Markland 1200'	> Four new miter gate leaves > New embedded quoins > New strut arms, new anchor arms, etc.		in progress				Moulton & Vessels

Notes:

Database established August 2012. POC: Shawn Kenney, EIT - DA Intern with OP-TM.

Information on projects in CY 2011 and prior years was taken from job reports and therefore is only as accurate and detailed as recorded in the respective job report. Actual cost was taken from the "Physical Support Branch Job Order Analysis" spreadsheet.

Appendix I: MVD Lock Closure Data

DATE	TIME	REOPENED	DISTRICT	LOCATION	TOWS DELAYED	CAUSE
30-Oct-13	0800 HRS	1600 HRS, 30 OCT 13	MVR	LOCK AND DAM 15	UNK	REPAIR UPSTREAM BUBBLER SYSTEM
2-Dec-13		17-Mar-14	MVP	LOCK AND DAM 8	UNK	SCHEDULED DEWATERING AND MAINTENANCE
10, 11 DEC 13	0700 HRS	1900 HRS, 10, 11 DEC 13	MVR	LOCK AND DAM 22	UNK	INSTALL DOWNSTREAM BULKHEAD SILL BEAM
18-Dec-13	0700 HRS	1100 HRS, 4 MAR 13	MVR	LOCK AND DAM 18	UNK	INSTALLATION OF DOWNSTREAM LOCK BULKHEAD SLOTS
28-Dec-13		8-Aug-14	MVS	MEL PRICE LOCK AND DAM (MAIN CHAMBER)	UNK	BROKEN CABLES ON UPSTREAM LIFT GATE
3-Jan-14		14-Jan-14	MVN	IHNC LOCK	UNK	EMERGENCY REPAIRS TO BULL GEAR
7-Jan-14		6-Mar-14	MVR	LOCK AND DAM 22	UNK	SCHEDULED DEWATERING AND MAINTENANCE
10-Jan-14		16-Jan-14	MVR	LAGRANGE LOCK	UNK	MITER GATE ALLISION
28-Jan-14		29-Jan-14	MVN	BAYOU SORREL LOCK	UNK	REPLACED HYDRAULIC PUMP ON GATE #4
8-Feb-14		10-Feb-14	MVR	MARSEILLES LOCK AND DAM	UNK	MITER GATE MACHINERY FAILURE
23-Feb-14		24-Feb-14	MVN	IHNC LOCK	UNK	OIL SPILL ON MISSISSIPPI RIVER
17-Mar-14	0700 HRS	0700 HRS, 31 MAR 14	MVN	HARVEY LOCK	UNK	REPAIRS MADE TO GATE OPERATING MACHINERY
8, 9 APR 14	0700 HRS	1900 HRS, 8, 9 APR 14	MVR	LOCK AND DAM 21	UNK	LAY DOWN MITER GATES ALONG LOWER GUIDEWALL
15-Apr-14	0800 HRS	1600 HRS, 15 APR 14	MVR	LOCK AND DAM 19	UNK	REPLACEMENT AND UPGRATE OF LOGIC CONTROLS FOR THE LOCKS'S OPERATIONAL SYSTEM
15, 16 APR 14	0700 HRS	1900 HRS, 15, 16 APR 14	MVR	LOCK AND DAM 20	UNK	LAY DOWN MITER GATES ABOVE UPPER LANDWALL
19-Apr-14	0700 HRS	1000 HRS, 19 APR 14	MVR	LOCK AND DAM 20	2	M/V WISCONSIN (MARQUETTE) BROKE DOWN IN THE LOCK CHAMBER DUE TO OBSTRUCTION TO PROPELLER.
27-Apr-14	1930 HRS	0925 HRS, 28 APR 14	MVR	LOCK AND DAM 22	1	#4 MITER GATE (UPPER I-WALL) ELECTRICAL MALFUNCTION WHITH M/V JOSHUA DAVID ESPER'S (MARQUETTE) FIRST CUT IN LOCK CHAMBER.
29-Apr-14	0500 HRS	1030 HRS, 29 APR 14	MVR	MARSEILLES LOCK AND DAM	3	UPPER MITER GATE NOT OPERATING DUE TO ELECTRICAL PROBLEMS. M/V OMAR'S (INLAND MARINE) TOW IN CHAMBER.
30-Apr-14	0700 HRS, 1300 HRS	1100 HRS, 1700 HRS, 30 APR 14	MVR	LOCK AND DAM 18	UNK	DIVERS INSPECTING UPPER AND LOWER MITER GATES
30-Apr-14	1600 HRS	9-May-14	MVP	UPPER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
30-Apr-14	1600 HRS	9-May-14	MVP	LOWER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
30-Apr-14	1600 HRS	9-May-14	MVP	LOCK AND DAM 1	UNK	HIGH WATER
12-May-14	0800 HRS	22-May-14	MVP	UPPER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
12-May-14	0800 HRS	22-May-14	MVP	LOWER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
12-May-14	0800 HRS	22-May-14	MVP	LOCK AND DAM 1	UNK	HIGH WATER

19-May-14	2215 HRS	1130 HRS, 20 MAY 14	MVP	LOCK AND DAM 4	UNK	M/V ARDYCE RANDALL LOST A CLUTCH WHILE ATTEMPTING TO ENTER THE LOCK CHAMBER, BLOCKING THE UPPER APPROACH.
21-May-14	2217 HRS	1132 HRS, 20 MAY 14	MVP	LOCK AND DAM 6	UNK	M/V ARDYCE RANDALL LOST A CLUTCH WHILE ATTEMPTING TO ENTER THE LOCK CHAMBER, BLOCKING THE UPPER APPROACH.
22-May-14		28-May-14	MVN	SCHOONER BAYOU CONTROL STRUCTURE	UNK	HIGH SALINITY LEVELS. LELAND BOWMAN LOCK WAS USED AS AN ATERNATE ROUTE.
29-May-14	2030 HRS	30-May-14	MVN	IHNC LOCK	33	GATE #1 STRUT ARM FAILED
4-Jun-14	0800 HRS	13-Jun-14	MVP	UPPER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
4-Jun-14	0800 HRS	13-Jun-14	MVP	LOWER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
4-Jun-14	0800 HRS	13-Jun-14	MVP	LOCK AND DAM 1	UK	HIGH WATER
3, 5, 8, 10 JUN 14	0700 HRS	1900 HRS, 3, 5, 8, 10 JUN 14	MVR	LOCK AND DAM 18	UNK	REPLACED MITER GATES #1-#4 LEAVES
5, 10 JUN 14	0700 HRS	1700 HRS, 5, 10 JUN 14	MVR	LOCK AND DAM 22	UNK	REPLACED MITER GATES #1-#4 STRUT ARMS
16-Jun-14	1200 HRS	3-Jul-14	MVP	UPPER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
16-Jun-14	1200 HRS	3-Jul-14	MVP	LOWER SAINT ANTHONY FALLS LOCK	UNK	HIGH WATER
16-Jun-14	1200 HRS	3-Jul-14	MVP	LOCK AND DAM 1	UNK	HIGH WATER
23-Jun-14	0700 HRS	1700 HRS, 24 JUN 14	MVR	LOCK AND DAM 17	UNK	REPLACED MITER GATE #3 LEAF
25-Jun-14		25-Jun-14	MVN	BAYOU SORREL LOCK	7	DAMAGED HIGHWAY BRIDGE BLOCKING WATERWAY
25-Jun-14		26-Jun-14	MVR	LOCK AND DAM 18	1	MITER GATE #2 ANCHOR BAR REPLACEMENT
26-Jun-14		1800 HRS, 30 JUN 14	MVN	HARVEY LOCK	UNK	ONGOING REPAIRS TO THE GATE MACHINERY AT THE CANAL END OF THE STRUCTURE
27-Jun-14		14-Jul-14	MVR	LOCK AND DAM 17	UNK	HIGH WATER
29-Jun-14		29-Jun-14	MVR	LOCKPORT LOCK AND DAM	UNK	EMERGENCY MAINTENANCE ON LOWER RIGHT EMPTYING VALVE CYLINDER
30-Jun-14		13-Jul-14	MVR	LOCK AND DAM 16	UNK	HIGH WATER
1-Jul-14		13-Jul-14	MVR	LOCK AND DAM 18	UNK	HIGH WATER
2-Jul-14		5-Jul-14	MVR	LOCK AND DAM 12	UNK	HIGH WATER
2-Jul-14		2330 HRS, 15 JUL 14	MVR	LOCK AND DAM 20	UNK	HIGH WATER
3-Jul-14		5-Jul-14	MVR	LOCK AND DAM 13	UNK	HIGH WATER
3-Jul-14		6-Jul-14	MVR	LOCK AND DAM 14	UNK	HIGH WATER
3-Jul-14		7-Jul-14	MVR	LOCK AND DAM 15	UNK	HIGH WATER
4-Jul-14		15-Jul-14	MVR	LOCK AND DAM 21	UNK	HIGH WATER
4-Jul-14		16-Jul-14	MVR	LOCK AND DAM 22	UNK	HIGH WATER
5-Jul-14		11-Jul-14	MVR	LOCK AND DAM 19	UNK	HIGH WATER
6-Jul-14		14-Jul-14	MVS	LOCK AND DAM 24	UNK	HIGH WATER
8-Jul-14		14-Jul-14	MVS	LOCK AND DAM 25	UNK	HIGH WATER
13-Jul-14		15-Jul-14	MVR	LOCK AND DAM 14	UNK	M/V JOHN M RIVERS TOW BROKE LOOSE AND A BARGE WENT INTO THE DAM. THE REMAINDER OF THE TOW IS BLOCKING THE APPROACH TO THE LOCK.
24-Jul-14	0700 HRS	1900 HRS, 24 JUL 14	MVR	LOCK AND DAM 17	UNK	REPLACED #1 MITER GATE LEAF
26, 28 JUL 14	0700 HRS	1900 HRS, 26, 28 JUL 14	MVR	LOCK AND DAM 17	UNK	REPLACED #2 AND #4 MITER GATE LEAVES
5-Aug-14	1530 HRS	0230 HRS, 4 AUG 14	MVR	STARVED ROCK LOCK	5	M/V MISS DORIS (MARQUETTE) SPILLED 2 GAL. OF HYDRAULIC OIL IN LOCK CHAMBER
13-Aug-14	2359 HRS	1024 HRS, 14 AUG 14	MVN	IHNC LOCK	15	DEATH FROM CRANE BARGE HITTING FLORIDA AVENUE BRIDGE
9, 10 SEP 14	0600 HRS	1800 HRS, 9, 10 SEP 14	MVR	LOCKPORT LOCK	UNK	MAINTENANCE ON LOWER LEFT EMPTYING VALVE
22-Sep-14	0800 HRS	1920 HRS, 22 SEP 14	MVN	PORT ALLEN LOCK	UNK	LOG PREVENTING LOCK GATE #4 FROM FULLY OPENING
22-Sep-14	0500 HRS	2400 HRS, 26 SEP 14	MVK	JONESVILLE LOCK AND DAM	UNK	HYDRAULIC CYLINDER REPAIR

Appendix J: USACE Lock M&R Expert Interviews

John C, CELRD

These questions should be considered from multiple perspectives to include the operator, structural engineer, maintenance manager, etc.

Basic

What additional information would you like to have on the operational readiness of locks?

The most important information is to know how well the contact blocks transfer load. Poor load transfer is the precursor to most pintle issues and girder cracking so identifying load transfer issues early is key.

What information would help avoid emergency or unscheduled closures?

No input

More detailed

What additional information would you like to have for identifying, prioritizing and planning maintenance activities?

Again, the main issue is load transfer. This also includes interior gate members, not just contact blocks.

Is rotating machinery a concern? Is there adequate redundancy or is the failure rate low enough that there aren't concerns? What is done for scheduled maintenance? Is there-time based maintenance that could be based on cycles or monitored condition?

This is not a big concern, but it would probably be good to monitor motor loads and hydraulic pressure.

Are there fatigue-related issues you need more information for?

It would be good to record the loading cycles and the loads on the gudgeon anchorage.

What issues do you have with debris? Caught under gate? In the miter? In the quoin and can't close the gate? What happens when the gate closes with debris in quoin? How is it removed? What damage results?

The main issue is dealing with large debris fields. Otherwise, floating debris mainly just requires patience and use of the bubblers. In 20+ years Louisville only had issues with debris on the floor about a ½ dozen times.

What information would improve management of gate operations in the presence of debris or ice? What types of damage from debris, ice, collisions or other causes would you like to have different, better or more information about? **Ice and debris info is not really a concern. Most gates don't have collision issues when recessed. One exception is Cannelton that has a short bullnose. From a repair standpoint the impact load when mitered isn't a concern, but the structural engineer might be interested in that.**

- I can talk with Travis A., but do you have a structural engineer you'd recommend I talk to?
- **Larry D. in LRL.**

Dewatered

What are the primary concerns for inspection, maintenance and repair when dewatering? What would you like to know before dewatering that you don't?

- Condition of quoin and contact gaps.

  Yes, but repair of contact surface is assumed to be needed.

- Cracking of pintle and girders.

  It would be good to know about this prior to dewatering

  It would be useful to have better info on wear and slop in the valve trunnions and pins before dewatering to know whether to replace bushings.

When dewatered, what issues are most frequently resolved? Which ones most frequently left unresolved? What external drivers cause issues to be a priority or not addressed?

- Most likely to be unresolved are new or slowly progressing issues that can wait for pre-planned repair during next dewatering.
- Most likely not to be addressed are issues that take longer to repair than the scheduled closure or require manpower/equipment that is not available.

Contact block surfacing routinely gets addressed. Serious pintle cracking is the primary unexpected concern.

When dewatered, are pintle issues always addressed or not? Why?

- Depends on dewatering frequency, rate of damage progression, available resources for repair, knowledge of condition before dewatering.
- Other factors?
- **Not discussed. Are cracks always welded?**
- **Yes, cracks would always be welded. If warranted and there was no replacement pintle, the pintle would be removed and sent to a welding shop for crack repair and heat treating.**

When dewatered, how often are gaps in quoin blocks not fixed? Why not?

Are miter block gaps less critical?

- In LRD and SAM, quoin gaps are typically filled in.
- In NWP, adjustable blocks take longer to adjust than typical 1 week closures.
- **Addressing gaps in contact blocks is considered a critical issue for extending the life of gates, reducing life cycle cost and avoiding unscheduled closure.**

Other

Dewatering used to occur every 5 years with longer closures every 15 years. Current policy is to not dewater until rank is high enough in Asset Management. This means good information regarding development of problems is more critical for avoiding unscheduled closure and it is also needed to justify dewatering.

Pintle changes typically mean removing and re-setting contact blocks on gates.

- Would only one pintle be replaced if the other were in ok condition?

No, would always replace in mating pairs.

- If so, would contact blocks on one or both gates be reset?

Contact blocks would be replaced and reset.

Wall quoin blocks are more difficult to reset so they are repaired with Belzona.

Replacing one gate means replacing both for everything to mate up.

Phil S, CEMVP

These questions should be considered from multiple perspectives to include the operator, structural engineer, maintenance manager, etc.

Basic

What additional information would you like to have on the operational readiness of locks?

What information would help avoid emergency or unscheduled closures?

More detailed

What additional information would you like to have for identifying, prioritizing and planning maintenance activities?

From an engineering standpoint, the actual distribution of stresses throughout the structure under the various loading conditions would be a valuable tool in evaluating the suitability of existing conditions. This cannot be understated. Currently, we make assumptions on what these distributions are and can be either overly conservative or dangerously unconservative. Information can be obtained through a variety of means including instrumentation, photogrammatic coatings, LiDAR measurements, etc. This information would also be invaluable in advancing the state of the art of design and evaluation of HSS.

Is rotating machinery a concern? Is there adequate redundancy or is the failure rate low enough that there aren't concerns? What is done for scheduled maintenance? Is there-time based maintenance that could be based on cycles or monitored condition?

Are there fatigue-related issues you need more information for?

What are the fatigue stress cycle magnitudes and frequencies? Current practice is to guess and this can be conservative or not. It would also be useful to know what the stresses really are in the areas of concern. The three areas I see the most problems in HSS are corrosion and section loss, primarily due to lack of maintenance, damage due to impacts or mis-operations, and cracking form fatigue or fracture. The latter can be a nuisance or can lead to failures. A better handle on fatigue loadings would be helpful.

What issues do you have with debris? Caught under gate? In the miter? In the quoin and can't close the gate? What happens when the gate closes with debris in quoin? How is it removed? What damage results?

Added gravity load, damage during operation (debris gets wedged in a member), creates a good environment for corrosion.

What information would improve management of gate operations in the presence of debris or ice? What types of damage from debris, ice, collisions or other causes would you like to have different, better or more information about?

Ice loading is a big unknown. We do not have a good handle on stresses caused by thermally expanding ice, floating ice, ice acting as gravity.

Dewatered

What are the primary concerns for inspection, maintenance and repair when dewatering? What would you like to know before dewatering that you don't?

- Condition of quoin and gaps.
- Cracking of pintle and girders.
- **Mud and debris need to be cleared if you want to get a good inspection**
- **Differences of opinion between operators and engineers on what is important**
- **Any damaged areas, cracks, holes? How do these affect the safety and functionality of the gate and what are the priorities (based on safety and functionality)**

When dewatered, what issues are most frequently resolved? Which ones most frequently left unresolved? What external drivers cause issues to be a priority or not addressed?

- Most likely to be unresolved are new or slowly progressing issues that can wait for pre-planned repair during next dewatering.
- Most likely not to be addressed are issues that take longer to repair than the scheduled closure or require manpower/equipment that is not available.
- **Agree with these statements, but we need to assess what IS important and can’t wait until next time**

When dewatered, are pintle issues always addressed or not? Why?

- Depends on dewatering frequency, rate of damage progression, available resources for repair, knowledge of condition before dewatering.
- Other factors?

When dewatered, how often are gaps in quoin blocks not fixed? Why not?

Are miter block gaps less critical?

- In LRD and SAM, quoin gaps are typically filled in.
- In NWP, adjustable blocks take longer to adjust than typical 1 week closures.
- **MVP has vertically framed gates. Just pretend they are vertically framed and you don't need to worry about quoins.**

Allen D, CESAM

These questions should be considered from multiple perspectives to include the operator, structural engineer, maintenance manager, etc.

Basic

What additional information would you like to have on the operational readiness of locks?

I have developed and proposed a lock gate rating guide (including structural and coating) similar to that used in bridge inspection, tailored to miter gates. It has ten very descriptive ratings, that could be used to schedule the necessary frequency of inspection, and it clearly describes where the weaknesses are. This is also very useful to Operations personnel in knowing the relative condition of their project to others and where the problems are.

What information would help avoid emergency or unscheduled closures?

A similar inspection and rating guide could possibly be developed for mechanical issues.

More detailed

What additional information would you like to have for identifying, prioritizing and planning maintenance activities?

Implementation of the above rating guides, also careful monitoring of quoin block gap conditions. The monitoring of miter gate anchor arm movement, we use dual axis inclinometers and

laser levels, with very good results in predicting which anchor arms are likely to develop cracking.

Is rotating machinery a concern? Is there adequate redundancy or is the failure rate low enough that there aren't concerns? What is done for scheduled maintenance? Is there-time based maintenance that could be based on cycles or monitored condition?

Are there fatigue-related issues you need more information for?

In general better documentation of specific locations where cracks have been found and which have been repaired. Description of length and orientation etc., this may help in future planning of repairs or in identifying the cause of cracking especially for cracks that are associated with each other. Also the cathodic protection system status and history along with the coating system and water resistivity greatly affect fatigue crack development. In general in a corrosive environment with no CP and inadequate coating the fatigue cracking will likely be much more extensive.

What issues do you have with debris? Caught under gate? In the miter? In the quoin and can't close the gate? What happens when the gate closes with debris in quoin? How is it removed? What damage results?

Some projects have a lot of scalloped flange edges on the bottom girder, but no serious structural damage. Our Operations personnel would have a lot of knowledge of this issue, but have not relayed any concerns to me. The air blowers seem to work well and I have seen them open and close the gates when an obstruction occurs until it dislodges.

What information would improve management of gate operations in the presence of debris or ice? What types of damage from debris, ice, collisions or other causes would you like to have different, better or more information about?

Dewatered

What are the primary concerns for inspection, maintenance and repair when dewatering? What would you like to know before dewatering that you don't?

- Condition of quoin and gaps.
- Cracking of pintle and girders.
- **The rating guide proposed in the above, also our Operations personnel are very good, experienced, and very dedicated.**

They know what to expect and work closely with Engineering.
- **One waterway system is now using a diver and aluminum foil to measure quoin block gaps in the wet.**
- **Development or deployment of acoustic photo technology or other methods to get a preview of the cracking extent would certainly be helpful to the projects in lining up men and equipment to accomplish the needed repairs in the limited time available.**
- **A very important consideration that Engineers should be aware of is that the Operations personnel have a lot of work to do in a short time, men and equipment are tied up with critical work. The inspector will need man lifts, power washing etc. and other assistance at times, he needs to minimize any work delays. He needs to "know well" the difference between trivial and serious.**

When dewatered, what issues are most frequently resolved? Which ones most frequently left unresolved? What external drivers cause issues to be a priority or not addressed?

- Most likely to be unresolved are new or slowly progressing issues that can wait for pre-planned repair during next dewatering.
- Most likely not to be addressed are issues that take longer to repair than the scheduled closure or require manpower/equipment that is not available.

When dewatered, are pintle issues always addressed or not? Why?

- Depends on dewatering frequency, rate of damage progression, available resources for repair, knowledge of condition before dewatering.
- Other factors?
- **The quoin and pintle areas are typically the first thing we look at. The condition of these areas can mean calling in additional personnel and equipment for repairs.**

When dewatered, how often are gaps in quoin blocks not fixed? Why not?

Are miter block gaps less critical?

- In LRD and SAM, quoin gaps are typically filled in.
- In NWP, adjustable blocks take longer to adjust than typical 1 week closures.
- **In the past some projects focused on the miter blocks as far as resurfacing, probably thinking that they are easier to get to and accomplish the same thing. They were incorrect; a**

gap in the miter will only mean that the gate will tend to miter a little further downstream. However a gap between the quoin blocks will do serious damage probably beginning at about 1/8" gap if left for a long time period. A ¼" or more gap would probably do very severe damage in a short period of time

Travis A, CENWP

These questions should be considered from multiple perspectives to include the operator, structural engineer, maintenance manager, etc.

Basic

What additional information would you like to have on the operational readiness of locks?

Not just is the gate fully mitered, but what about fully open as well? There is a history of slop in operating equipment creating a situation where the gates are not fully retracted. This has resulted in damage to the timbers and ends of the gate. We need to know that the gates are fully mitered and fully retracted.

What information would help avoid emergency or unscheduled closures?

Pintle condition (bolts), Quoin block condition, miter block condition. In addition to this we have had several electrical issues in terms of contact/limit switches. The switches are on the arms out over the center of the lock that require a manbasket to access. Knowing where the switch is bad would assist with these unscheduled outages.

More detailed

What additional information would you like to have for identifying, prioritizing and planning maintenance activities?

Block wear rates, adjustment/contact information.

Is rotating machinery a concern? Is there adequate redundancy or is the failure rate low enough that there aren't concerns? What is done for scheduled maintenance? Is there-time based maintenance that could be based on cycles or monitored condition?

There is annual maintenance on these components. I don't know how many have failed, but I would imagine contact wear on the teeth.

Are there fatigue-related issues you need more information for?

Quoin post cracking is initially fracture that results from torsion on the quoin post due to lack of block contact. This cracking grows with each lockage and it is unclear at what rate cracks will grow in old steel because toughness and actual level of stress is unknown.

What issues do you have with debris? Caught under gate? In the miter? In the quoin and can't close the gate? What happens when the gate closes with debris in quoin? How is it removed? What damage results?

I know we have debris in the chamber at Bonneville and the Dalles, but I have not heard of it getting caught. This would be an ops question.

What information would improve management of gate operations in the presence of debris or ice? What types of damage from debris, ice, collisions or other causes would you like to have different, better or more information about?

We don't have ice. For debris it would simply be to know if the gate is caught on something.

Dewatered

What are the primary concerns for inspection, maintenance and repair when dewatering? What would you like to know before dewatering that you don't?

- Condition of quoin and gaps. – yes. Need to know gap for adjustment
- Cracking of pintle and girders. – yes- cracking at both locations is common.

When dewatered, what issues are most frequently resolved? Which ones most frequently left unresolved? What external drivers cause issues to be a priority or not addressed?

- Most likely to be unresolved are new or slowly progressing issues that can wait for pre-planned repair during next dewatering.
- Most likely not to be addressed are issues that take longer to repair than the scheduled closure or require manpower/equipment that is not available.

The real issue I see with this question is that on the Columbia River the dewaterings are supposed to be every 10 years. So what can wait ten years? There are many things that can wait a year, but waiting 10 years is not acceptable for many issues associated with cracking or block alignment.

When dewatered, are pintle issues always addressed or not? Why?

- Depends on dewatering frequency, rate of damage progression, available resources for repair, knowledge of condition before dewatering.
- Other factors?

We find loose bolts – we can tighten them or replace them – but unless we know about it beforehand, we are not ready to replace parts. We only have 2 week outages, which take 3 days on each end to dewater or rewater ... so there isn't time to react and order bolts etc.

When dewatered, how often are gaps in quoin blocks not fixed? Why not?

Are miter block gaps less critical?

- In LRD and SAM, quoin gaps are typically filled in.
- In NWP, adjustable blocks take longer to adjust than typical 1 week closures.

Takes too long to adjust blocks or fill gaps. Our gates are 100 feet tall. Belzona will crush under load so we cannot use it with 90 feet of head. We also don't have sufficient time to place it because cranes cannot reach the center of the locks with equipment and manbaskets to adjust the gap in the closed position such that we could pour against the other side of the miter for a mold. So we need scaffolding that we cannot get installed and fixed and removed in 2 weeks. So planning ahead for a special outage either to adjust blocks or fill gaps is critical.

Anthony P, CESAM

These questions should be considered from multiple perspectives to include the operator, structural engineer, maintenance manager, etc.

Basic

What additional information would you like to have on the operational readiness of locks?

I look at these two questions as the same. If there is additional information for readiness, that information would help avoid emergency or unscheduled closures. Cost/funding vs. downtime/consequences is always a driver. In districts with dual chambers this is not as much of a concern, but in SAM we have only single chambers so equipment failure leads to closing of the river. We have PLC control systems for lock operation. Additional information would be in the form of indicators of early signs of equipment failure, i.e. audio indicators (gudgeon pin pops when binding or improperly greased, unusual sounds from machinery that normally indicate a

problem), vibration indicators, stress/stain gauges on components that provide indication of abnormal stresses (anchorage links, operating arms, miter gates). Only problem with indicators is the durability of the instruments and long term reliability. Again, any early warning signs on equipment could prevent unscheduled closures.

What information would help avoid emergency or unscheduled closures?
Same as above

More detailed

What additional information would you like to have for identifying, prioritizing and planning maintenance activities?

See answer above. Also add monitoring of cracks in hydraulic structures (miter gates). Again this equipment is usually high cost and not durable for our environments.

Is rotating machinery a concern?

Yes and No, most of our machinery is slow moving so not many concerns with normal operation. Of course the size is large and we have high stresses and loading in machinery for miter gates. Loading is main concern that can lead to cracks in structure or components.

Is there adequate redundancy or is the failure rate low enough that there aren't concerns?

Redundancy is only in the lock valves (or spillway gates due to numbers). If problem occurs in one lock valve, that valve can be isolated and repaired without a closure of the lock. With the miter gates, there is no redundancy.

What is done for scheduled maintenance?

If issue is discovered, and does not immediately have to be repaired, then users can be notified and a closure can be coordinated with little impact. It's the unscheduled, immediate, need of a closure that impacts the users. However, if the repairs require extended time to repair then the users are impacted if not given a long enough lead time to prepare of the closure (a 15-30-day closure is normally coordinated a year in advance).

Is there-time based maintenance that could be based on cycles or monitored condition?

All equipment has cycle limitations. For example, we inspect anchorage links every three years and normally cracks are found on locks with the highest cycles.

Are there fatigue-related issues you need more information for?

Anchorage Links are one component that has to be monitored for cracks. Miter gates also, but can't be monitored as often due to fact that high stress areas are under water. De-waterings don't occur but every 5-10 years (more likely 10 years).

What issues do you have with debris?

Lots of debris that collects above spillway gates. Has to be passed through gates, which results in tore bottom seals. Do have one debris gate at RF Henry Lock and one at Millers Ferry powerhouse. Debris is also present in the locks, but we have air systems that blow/push debris from behind the gates prior to operation. Debris in the lock culverts damages the valve components and grease lines (many of the steel guards over the intakes have corroded and are missing).

Caught under gate? Sometimes, but rare. Have to cycle the gates several times to move debris or dislodge it.

In the miter? Sometimes, but rare. Have to cycle the gates several times to move debris or dislodge it.

In the quoin and can't close the gate? No, due to having air systems for quoin areas and gate recess areas.

What happens when the gate closes with debris in quoin? If occurred, the SAM gates are designed with floating pintle, so the pintle shoe/ball could move out to prevent damage to the gate. Once removed or dislodged, the gate would move back into its normal position.

is it removed? Either cycling of gates (move back and forth) or personnel with poles or hooks; from small boat or floating plant.

What damage results? None, if floating pintle design works (don't see why it would not work). However, if the log or object is large, then it would be possible to have enough movement in the gate to cause damage the anchorage link.

What information would improve management of gate operations in the presence of debris or ice? We don't have ice issues in SAM. Don't know of any information that would help on debris.

What types of damage from debris, ice, collisions or other causes would you like to have different, better or more information about? Damage from debris inside lock valve culverts is hard or impossible to detect.

Therefore, you could have grease lines broken and not know until the machinery starts making noise or vibrates.

Dewatered

What are the primary concerns for inspection, maintenance and repair when dewatering? Any normally underwater structures or components; pintle assembly condition, miter gate structure integrity, condition of paint, contact block surface condition, contact block gap, grease lines.

What would you like to know before dewatering that you don't? all of the above conditions

- Condition of quoin and gaps.
- Cracking of pintle and girders.

Past experience has proven that if you have a gap in the quoin and miter blocks that you could have cracks in the pintle socket and/or bottom gate girder and also broken pintle bolts (more load into the pintle that designed for).

When dewatered, what issues are most frequently resolved? Which ones most frequently left unresolved? What external drivers cause issues to be a priority or not addressed?

- Most likely to be unresolved are new or slowly progressing issues that can wait for pre-planned repair during next dewatering.
- Most likely not to be addressed are issues that take longer to repair than the scheduled closure or require manpower/equipment that is not available.

Of course the more issues or required maintenance that you are aware of, the more you can plan for and be prepared to accomplish during a scheduled de-watering. At SAM, we normally de-water a lock every 10 years unless a known issue exists that requires a major closure. Major closures are normally scheduled for 30-days and we do not have dual chambers so we have to perform the maintenance within that time frame and get the lock back on-line for the users. If we discover a major issue that needs to be addressed without waiting for another closure, we will coordinate with the users for extension (very rare); if the issue is justified and possible consequences verified, if not resolved immediately. Most of the time a major issue discovered during the closure can be repaired during current closure time, and if needed, a temporary repair can be made with a permanent repair postponed to later closure; less impact on the users. Anything we can do to prevent impact to the waterway users is first priority, and at the same time repair and maintain the equipment to the best condition possible.

When dewatered, are pintle issues always addressed or not? Why?

- Depends on dewatering frequency, rate of damage progression, available resources for repair, knowledge of condition before dewatering.
- Other factors?

With the pintle being the major component of the miter gate, any issue with the pintle is addressed (and first thing inspected). Sometimes you may have to make a temporary repair until a permanent repair or replacement can be properly scheduled.

When dewatered, how often are gaps in quoin blocks not fixed? Why not?

Are miter block gaps less critical?

- In LRD and SAM, quoin gaps are typically filled in.
- In NWP, adjustable blocks take longer to adjust than typical 1 week closures.

A gap in the quoin or miter blocks is bad; can cause damage to the pintle. Therefore we go into every lock closure prepared to correct contact block gap issues. If cracks in the pintle or broken pintle bolts are found, you know you probably have contact block gap issues and we also check the gap. If gap is discovered we re-surface the contact blocks with Belzona material. We have been using Belzona material for many years (15+ years) with great success.

Fred J, CEMVR

These questions should be considered from multiple perspectives to include the operator, structural engineer, maintenance manager, etc.

Basic

What additional information would you like to have on the operational readiness of locks?

What information would help avoid emergency or unscheduled closures?

For both of these it would help to have better information on history of what has caused “failures” in the past and what are the most common things that have maintenance or repair issues

More detailed

What additional information would you like to have for identifying, prioritizing and planning maintenance activities?

We do not perform systematic or regular dewatering so getting information on submerged components would be a benefit.

Is rotating machinery a concern? Is there adequate redundancy or is the failure rate low enough that there aren't concerns? What is done for scheduled maintenance? Is there-time based maintenance that could be based on cycles or monitored condition?

Are there fatigue-related issues you need more information for?

We have fatigue issues with gates, but I don't think we have a good handle on the stresses.

What issues do you have with debris? Caught under gate? In the miter? In the quoin and can't close the gate? What happens when the gate closes with debris in quoin? How is it removed? What damage results?

What information would improve management of gate operations in the presence of debris or ice? What types of damage from debris, ice, collisions or other causes would you like to have different, better or more information about? We could use more information on the loading conditions caused by moving gates through heavy ice.

Dewatered

What are the primary concerns for inspection, maintenance and repair when dewatering? What would you like to know before dewatering that you don't?

- Condition of quoin and gaps.
- Cracking of pintle and girders.

In general our dewatering are infrequent so we do not have much information on the underwater parts before dewatering, therefore planning repairs is problematic.

Hard to get a handle on loss of section from corrosion, pitting is common, and its effect on the structure. Lack of time and funding

When dewatered, what issues are most frequently resolved? Which ones most frequently left unresolved? What external drivers cause issues to be a priority or not addressed?

- Most likely to be unresolved are new or slowly progressing issues that can wait for pre-planned repair during next dewatering. correct

- Most likely not to be addressed are issues that take longer to repair than the scheduled closure or require manpower/equipment that is not available. Correct. Funding is issue also

When dewatered, are pintle issues always addressed or not? Why?

- Depends on dewatering frequency, rate of damage progression, available resources for repair, knowledge of condition before dewatering.
- Other factors?

When dewatered, how often are gaps in quoin blocks not fixed? Why not?

Are miter block gaps less critical?

- In LRD and SAM, quoin gaps are typically filled in.
- In NWP, adjustable blocks take longer to adjust than typical 1 week closures.

References

Farrar, Charles R., and Keith Worden. 2013. *Structural Health Monitoring: A Machine Learning Perspective*. New York: Wiley & Sons.

Foltz, Stuart D.; Bislip-Morales, Carlos B.; Hammack, E. Allen. 2013. *Asset Management and Facility Equipment Maintenance Nexus: Maintenance Effectiveness*, ERDC TR 13-16. Champaign, IL: Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/8600/ERDC-TR-13-16.pdf?sequence=1&isAllowed=y

Headquarters, U.S. Army Corps of Engineers (HQUSACE). 2016. *Navigation*. Web page, http://www.usace.army.mil/Missions/CivilWorks/Navigation.aspx

———. 1996. *Navigation and Dredging Operations and Maintenance Guidance and Procedures*. EP 1130-2-520. Washington, DC: HQUSACE, http://www.publications.usace.army.mil/Portals/76/Publications/EngineerPamphlets/EP_1130-2-520.pdf

IBM. 2016. *Maximo Asset Management*. Website, http://www-03.ibm.com/software/products/en/maximoassetmanagement/

IMTS Capital Investment Strategy Team. 2010. *Inland Marine Transportation Systems (IMTS) Capital Projects Business Model*. http://www.iwr.usace.army.mil/Portals/70/docs/Wood_doc/IMTS_Final_Report_13_April_2010_Rev_1.pdf

U.S. Army Corps of Engineers (USACE). 2011. *Sustainable Solutions to America's Water Resources Needs: Civil Works Strategic Plan 2011-2015*. Washington, DC: USACE.

———. 2011. *Department of the Army U.S. Army Corps of Engineers Civil Works Program Five-Year Development Plan Fiscal Year 2011 to Fiscal Year 2015*, http://www.usace.army.mil/Portals/2/docs/civilworks/5yr_devplan/fy11_5yrplan.pdf

Acronyms and Abbreviations

Term	Definition
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
EROC	Engineer Reporting Organization Code
FEM	Facilities Equipment and Maintenance
HQUSACE	Headquarters, U.S. Army Corps of Engineers
LPMS	Lock Performance Monitoring System
LRD	USACE Great Lakes and Ohio River Division
LRL	USACE Louisville District
M&R	Maintenance and Repair
MVD	USACE Mississippi Valley Division
O&M	Operations and Maintenance
SF	Standard Form
TR	Technical Report
USACE	U.S. Army Corps of Engineers

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
06/05/2017	Final	

4. TITLE AND SUBTITLE
Investigation of Mechanical Breakdowns Leading to Lock Closures

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT

6. AUTHOR(S)
Stuart D. Foltz

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
1F18B1, L93CJ7, 4B1176

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005,
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-17-17

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, U.S. Army Corps of Engineers
441 G St., NW
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)
CEERD-HT

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The U.S. Army Corps of Engineers (USACE) owns or operates 236 locks at 191 sites, more than half of which have surpassed their 50-year design life. There are increasing concerns about their continued safe, reliable operation into the future, especially considering the fact that routine maintenance, lock dewaterings, and inspections sometimes occur at less than optimal intervals. Although critical repairs are prioritized, delayed maintenance increases the risk of failures that result in lock closures. One significant factor that contributes greatly to the difficulty of lock condition assessment is that much of the lock infrastructure typically remains under water. When a lock is dewatered, it is common to find previously unidentified distress, deterioration, and damage. To address such maintenance issues, there is an increasing need to gather more accurate information on repair needs and to prioritize those repairs. This work investigated types and frequencies of lock failures so that sensors can be used more effectively to identify imminent lock operational failures and concerns for ongoing lock reliability. Numerous data sources were used to collect these data, even though most of these sources were not created for the purpose of collecting the type of data the work investigated. The data gap is also discussed in the report.

15. SUBJECT TERMS
Hydraulic structures, Structural failures, Locks (Hydraulic engineering), Service life (Engineering), Maintenance and repair

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	104	