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ATTACHMENTS

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Engineering Decision Matrix

Interference Potential Due to Electric Barrier at Brandon Road
1. Introduction

1.1 General Description of Measures

This report summarizes the current level of engineering design on the Brandon Road interim report alternatives. A conceptual level of design has been performed in each feature to be carried forward, including basic site layout, quantities, and constructability concerns. No field data was collected and in general no first order analysis was completed on the conceptual measures presented. The engineering matrix presented as an attachment to this appendix details the various measures that were considered to achieve the study objectives. Select measures were carried forward from the overall engineering matrix and further evaluated from a conceptual standpoint.

General descriptions of these viable measures are presented in Sections 2 through 7 of this appendix. These select measures serve as components that make up the various alternatives presented within this report. Section 8 contains Other Engineering Considerations. The last section, 9, describes each engineering attachment provided at the back of this appendix.

2. Flushing Lock Measure

2.1 General Description

The flushing lock measure was developed to reduce the risk of the upstream transfer of floaters by displacing the ANS contaminated tailwater with pool water within the lock chamber. The flushing lock design was constrained by navigation safety, water supply, and navigation delays due to operational duration. The term flushing lock should not be misconstrued as creating a velocity to remove any swimming aquatic nuisance species within the lock chamber but instead interpreted as water volume exchange within the lock chamber. The desired water volume exchange requires water upstream of the lock to replace as much water as feasible within the lock after any lockage involving operation of the lower lock gates which results in downstream ANS contaminated water entering the lock chamber. The goal of this measure is to reduce the risk of any aquatic nuisance species, to include fish eggs and larvae, from floating or being carried via barge movement to the upstream pool through the lock.

A three-dimensional (3-D) numerical “hydraulic” model study was completed by ERDC to evaluate conceptual designs and estimate the effectiveness of flushing the lock. This included looking at the existing port configuration along with an array of modified port configurations. This was accomplished by ERDC through running multiple 3-D numerical hydraulic models. Details of the hydraulic study can be found in Appendix E, Hydrology and Hydraulics, Attachment 3, GLMRIS Lock, Reducing Risk of Aquatic Nuisance Species Transfer through Brandon Road Lock, Analytical and Numerical Model Study. A physical model of the selected port reconfiguration will be required for the implementation of the project should this measure become part of the selected plan.

The numerical modeling was conducted using a tiered approach. Initially several alternatives were considered and eventually internally screened due to considerations beyond hydraulic performance. Factors included construction cost and schedule, operations and maintenance and impacts to navigation. Measures that required lengthy construction schedules also resulted in navigation closure and were avoided to maintain a balance in risk reduction and impacts. As a result the hydraulic analysis of alternatives were terminated once the study team determined the alternative should be screened out for reasons beyond hydraulic performance.

The study team also considered constructing new 600 or 1200 foot locks that would incorporate a standard filling and emptying system design for decreased lock times coupled with more hydraulically efficient flushing features similar to the Type 2 and Type 3 concepts. However, the existing lock is in
good condition, site constraints and initial costs for new locks were prohibitive and the new lock measures were screened out early in the study.

Type 1 – Existing filling and emptying system with operational changes to facilitate flushing. This alternative is the existing conditions scenario and is not efficient in flushing. Modeling shows ANS will not be able to be flushed downstream of the upper miter gates due to recirculation patterns. The existing filling and emptying system requires additional time for lockages due to the non-standard port sizing and spacing. As a result the filling valves must be operated slower to minimize turbulence in the chamber. Due to these factors, this alternative was screened out.

Type 2 – Lateral flushing manifold downstream of the upper gates. A second valve would be required to redirect flow into the manifold system. There is potentially insufficient room in the landwall to install a new filling valve and machinery to make this system operational. Rock excavation is required at the bottom of the chamber to facilitate construction of the manifold without impacting chamber depths. In addition hydraulic modeling identified a recirculating area downstream of the gates that would not remove ANS from the chamber. A second valve would be needed with tight configuration and moderate closure time for construction. Due to these factors, this alternative was screened out.

Type 3 – A secondary system of pipes and valves would be constructed through the upper miter gate sill to discharge into the lock chamber. This alternative is hydraulically efficient however, it would require a cost-prohibitive amount of work to reconstruct the miter gate sill. In addition a significant amount of rock would need to be excavated to facilitate an operating gallery to service the piping and valves. As a result of preliminary design efforts it was determined that this alternative did not have sufficient room to construct the necessary features. Coupled with construction costs and lock closure times, this alternative was screened from further consideration.

Type 4 – A flushing manifold added downstream of the lower miter gates to flush ANS out of the engineered channel or during barge entrance to the lock chamber. An extra system of pipes and valve would be needed. This alternative was screened early in the study because it does not provide ANS risk reduction in the lock chamber.

Type 5 – Redesign of the filling and emptying system by reconfiguring the port size and spacing according to Corps guidance and adding an additional port upstream (near the upper miter gate) to facilitate mixing and flushing of ANS in the upper part of the chamber. This alternative has straightforward construction methods and a relatively short closure period. This alternative results in a more efficient and less turbulent lockage producing a time savings in the lock process (fill times) which helps to offset the delays as a result of lock flushing. This alternative has been selected as the preferred design.

A Type 5 flushing lock port configuration was selected for this measure as it provided the most complete flushing of the lock of all alternatives evaluated. This configuration also reduces filling/emptying times to limit impacts to navigation, and minimizes cost and duration. It includes modifying the existing side ports locations within the lock chamber. This would be accomplished by reconfiguring the port size and spacing to comply with USACE design guidance. Modifications include adding new valves on the upstream culverts located within the lock walls that would allow water to be discharged close to the upstream sill to aid the flushing process. These gates would be a hydraulically operated vertical slide gate. Both lock walls would have the same design layout. Refer to plates CS108, CS109 and CS501 for details of this design.

The existing ports would be permanently plugged with reinforced concrete. There are 9 existing ports on each side of the lock for a total of 18 ports, which would require approximately 150 CF of concrete to plug each port.

The new ports would be constructed by line drilling and diamond wire saw cutting the opening. Alternatively, the opening could be constructed by line drilling and impact removal. New surfaces could
be formed via stay-in-place forms or conventional forms. There will be 12 new ports on each lock wall, for a total of 24 new ports. The finished dimensions of the ports are approximately 2.5’ by 3.5’. They will also have cast-in-place concrete deflectors that extend out into the lock chamber.

The gate slot area for the upstream port is 6’ by 6’. This could be cut with line drilling and a diamond wire saw. Alternatively, the opening for the gate shaft could be core drilled. New vertical slide gates will be installed on this 6’ by 6’ opening.

The lock will be ‘flushed’ with the downstream miter gates recessed or in the open position. Flushing operations would only occur when no vessels are present within the lock chamber. The design will include an automatic locking mechanism to keep the miter gates in the recessed position to prevent any safety issues or damage to lock equipment from the flushing currents.

2.2 Construction Impacts

The lock will be dewatered to accomplish this work. It is estimated that will require a several week shutdown of the lock. Construction crews would need to work in multiple shifts to minimize the lock closure time.

2.3 Operations Impacts

Overall the efficiency of the lock filling and emptying times will be improved with the port reconfiguration however navigation would experience delays since flushing the lock can only occur when no vessels are present within the lock chamber. The vessels will instead be moored directly downstream of the miter gates during the approximately 15 minute flushing process. Operations staff at the lock will also need to operate the dam tainter gates and lock flushing in tandem to ensure the Brandon Rd Pool stays within the authorized limits. This is further covered in the main report.

3. Engineered Channel Measure – Downstream Approach Channel

3.1 General Description

This measure creates an engineered structure that completely lines the lower approach channel with concrete. Reinforced concrete walls will be constructed along the existing channel bank, along with a concrete floor. The structure would house various ANS barrier measures identified in the selected plan and provide opportunities for future adaptive management measures to be incorporated in the future. Measures it may house include the electric barrier, water jets and, complex noise. The concrete floor is needed to house some of the ANS barrier measures so is assumed to be from 1 to 3 feet in depth. The larger depth will be installed where necessary to house electric barrier alternative features. Final depth of the channel will be determined once configuration and location of the ANS measures is completed. These assumptions were made for cost purposes, and include additional rock excavation to account for the installation of ANS measures in the channel. The proposed minimum water depth in the channel is 14 feet which sets the top of the new channel surface at elevation 490 (NAVD88) based on guidance from the INDC. The majority of the channel excavation will be in limestone based on available historical borings and site geography. The channel hasn’t been dredged in approximately 10 years due to a lack of necessity thus minimal sediment buildup is expected within the existing channel. Blasting of the existing rock is assumed to be completed in the wet, with navigation continuing with minor 1-2 hour delays while blasting and clearing occurs. The spoiled rock is assumed to be disposed of onsite as shown on plate CS101, and reused as much as possible in construction of access roads, berms, etc. Based on knowledge of the channel, no contamination is expected of this material, and no treatment or containment on site will be required. Excess stone could eventually be barged from the site and reused for various projects along the waterway.
The walls will be designed to tie into the existing lower guide walls. The walls will be installed first with a 1’ thick outer precast structure with steel framing, then filled with cast in place concrete. The walls adjacent to the electric barrier measure will be designed with a fiberglass panel to limit the extent of stray electrical current outside the channel. The channel walls will be built along the existing channel limits, maintaining the current channel width of 240 to 280 feet, depending on location. The engineered channel for the electric barrier alternatives will consist of a 500’ section at the downstream end of the approach channel with build outs for the electric barrier equipment and the water jets. The remaining approximately 1400’ of the channel, will connect at its upstream terminus to the existing channel guide walls. This portion will have a shallower concrete floor, but will also contain rough-ins for potential future ANS control measures. The details of these will be determined in further design when the future ANS control measures are better clarified. The channel walls will extend to elevation 517.5 (the 500 year flood elevation plus 3 feet of freeboard) to maintain consistency with the GLMRIS report and prevent ANS movement during flood events. Support structures on land for the technologies will also be built with a finish floor elevation at the 500 year plus 3 year level, for flood protection and to allow direct sight lines into the channel. Refer to plates CS102 through CS107, CS201 through CS204, and CS301 through CS302 for proposed layouts and sections of the engineered channel.

The construction method assumed is in-the-wet construction. The right descending bank (RDB) will be constructed from land, and the left descending bank (LDB) will be constructed from barges in the navigation channel. The lift in cells are based on a similar concept developed for Lock 22 on the Mississippi River under a feasibility report completed by the Navigation and Ecosystem Sustainability Program. This design was used for cost purposes and is considered conservative, given the reduced loading requirements for the channel vs. a lock wall. A full site-specific design for the walls and engineered channel as a whole will be performed in PED. Given the reduced size of the monolith wall cells needed for the channel approach at Brandon Road and the fact that an interior pipe is not needed, estimated quantities and associated costs were scaled down for the Brandon Road walls over the presented concept plans for Lock 22. The proposed Brandon Road cells are 8’ deep by 25’ long, and approximately 27’ tall and can be seen on plates CS301 and CS302. The cells will be placed in the water by crane then filled with tremied concrete. Monolith wall cells will be founded on anchor piles drilled into bedrock. For construction of the channel floor, it is assumed the existing channel will be blasted down to the design elevation in the wet. Precast concrete panels for the channel bottom will then be, placed on channel bottom, and grouted to anchor in place and fill voids.

Construction methods and sequencing are provided on plates G003 and G004, and will be revised and value engineered as the design process continues.

3.2 Channel Dewatering Scenarios

The following are engineering aspects to providing a closure at the downstream end of the Brandon Road Channel. Two scenarios were considered with the first being a closure to provide for the dewatering capabilities of the channel and second being a closure to provide for water separation between the channel and the rest of the river with no head differential between the bodies of water. The dewatering of the channel is significantly more difficult and expensive than the water separation. Each of the scenarios has issues and relatively high costs to them because of the large channel width. It should be noted that there are various accepted practices for underwater construction methods and materials that have been successful in similar applications, for maintenance or future ANS control addition work. In this case the channel may not need to be dewatered. The channel will be designed with these future potential project considerations taken into account. The existing electrical barriers upstream of Brandon Road have been constructed and maintained in-the-wet without the benefit of an engineered channel bed, therefore this adds to confidence of future ANS controls and maintenance at Brandon Road being accomplished without dewatering the channel. Underwater construction has been used in many other navigation construction contracts and can be cost effective, depending on the scope of the project. Given the width of the channel
much of the anticipated future work could take place without impacts to the navigation industry by working in-the-wet.

The possibility of dewatering the channel may be desired for future installation of new ANS controls or maintenance of existing features. Any dewatering method would impose a significant impact to the navigation industry when in use. A structural solution to the dewatering issue would be a steel bulkhead system or needle beam system with removable posts staged across the channel. Stackable steel bulkhead structures would be installed by a floating plant with cranes. The bulkheads would span from the channel walls to intermediate posts that would also need to be removable and installed by floating plant. The need to design the posts without any underwater fracture critical connections would be a design challenge. The bulkheads or needle beam system and support posts are in use at various locks in the corps navigation inventory that could be used as a basis of design. This type of bulkhead system should be considered if multiple future dewatering events are anticipated. A second method of dewatering the channel could use the construction of an earth dike constructed at the downstream end. Materials for the dike would be readily available from the local sources. The dike would have to be removed after use. This system should be considered if future dewatering needs are unknown or anticipated to be rarely occurring.

There may also be a need to cut off the channel for temporary ANS control with chemical or biological treatments. In these scenarios, the recommended method is to engineer a trench into the engineered channel floor. Interlocking vinyl sheet pile panels would be inserted into the trench by floating plant. Horizontal stiffeners and braces are assumed to be needed to control wind and wave action. The entire system would not be water tight so water balancing controls would need to be taken into account. This stop log scenario has been included in the current measure design and estimate.

3.3 Construction Impacts

Navigation through the lock will continue for most of the construction of this alternative. Construction in the wet will allow navigation to continue with some restrictions which are covered in the economic appendix. Construction of the channel bottom and blasting will be done in the wet with only minor navigation delays. Some items such as installation of the electrodes for the electric barrier will require 8 hour temporary shutdowns of navigation while work is performed, but these will be limited. Refer to plate G003 for construction sequencing details.

3.4 Operations Impacts

Once the channel is complete it is not expected to impede navigation traffic through the channel and lock. However the associated ANS control measures will produce operational impacts, refer to Sections 5 and 6 of this document for further details.

3.5 List of Supporting Documentation and References

- Brandon Road Lock and Dam, As-Built Drawings
### Table 3.1: Engineered Channel Design Detail

<table>
<thead>
<tr>
<th>Feature</th>
<th>Construction to be Performed</th>
<th>Material</th>
<th>Major Dimensions</th>
<th>Construction Method</th>
<th>Major Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel floor</td>
<td>Blast existing channel to a base elevation of 489. Place 3’ concrete floor to set new channel floor elevation at 492.</td>
<td>Pre-cast Concrete panels</td>
<td>3’ depth, width of channel (240’ - 280’)</td>
<td>In-the-wet construction, panels are transported by barge, lifted into place and tremied with concrete to set.</td>
<td>Required water depth is 14’ at typical low water level. Material in the channel base is almost entirely stone, and will be blasted out with minimal dredging of sediment.</td>
</tr>
<tr>
<td>- Electric Barrier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel Floor</td>
<td>Blast existing channel to a base elevation of 491. Place 1’ concrete floor to set new channel floor elevation at 492.</td>
<td>Pre-cast Concrete panels</td>
<td>1’ depth, width of channel (240’ - 280’)</td>
<td>In-the-wet construction, panels are transported by barge, lifted into place and tremied with concrete to set.</td>
<td>Required water depth is 14’ at typical low water level. Material in the channel base is almost entirely stone, and will be blasted out with minimal dredging of sediment.</td>
</tr>
<tr>
<td>- no barrier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel Walls</td>
<td>Blast out several feet of existing walls</td>
<td>Precast concrete units with bracing, interior concrete poured on site.</td>
<td>26.5’ - 28.5’ tall, 8’ square cells</td>
<td>Precast units on barge or land placed by crane. Interior of cells filled with concrete once placed in water.</td>
<td>- Construction will be performed by several crews simultaneously in the wet, while navigation continues on the opposite side of the channel. Channel walls along the electric barrier will be lined with fiberglass panels to insulate the electric field. The RDB is stone and will be blasted. The LDB is rubble mound and will be drag lined to remove. Channel construction near the lock will be performed during the existing lock closure period for flushing lock construction to limit impacts.</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Channel Cutoff</td>
<td>Engineered trench placed in channel floor near approach channel outlet. Cutoff placed as necessary for temporary ANS control or other needs.</td>
<td>Vinyl sheet pile panels</td>
<td>25.5’ high, 280’ wide</td>
<td>Interlocking vinyl sheet pile panels inserted into the existing trench by floating plant. Horizontal stiffeners and braces used to control wind and wave action.</td>
<td>Not a water tight system. Used for infrequent ANS control events.</td>
</tr>
</tbody>
</table>
4. Permanent Lock Closure Measure

4.1 General Description

This measure removes the upper operational gates from the Brandon Road Lock and replaces them with a permanent concrete wall that ties into the existing concrete gate sill and existing lock walls to structurally separate the upper pool from the lower pool. The concrete wall spans the total lock width of 110’ and is 22’ in height in order to match into the height of the existing lock walls. The existing lock walls level of flood protection are well above the 0.2% exceedence event. In addition, concrete plugs are placed in each upstream lock fill intake to permanently close the water pathways. Each fill intake is 8’-4” in width and 12’ in height at the opening and are paired together to create side by side openings 18’ in total width on each lock wall.

The separation terminates navigation access to and from Lake Michigan and the City of Chicago to the inland waterways located below Brandon Road to include access to and from the Gulf of Mexico.

River flow through the Brandon Road Dam continues per the current operational plan. Head gates, sluice gates, and a tainter gate spillway provide controlled flow through the dam. Head gates have a minimum discharge velocity of at least 25 feet per second. The tainter gate spillway consists of a concrete weir that provides a physical barrier that is 32 feet in height. The sluice gates are already permanently closed.

4.2 Construction Impacts

Permanently closes navigation.

4.3 Operations Impacts

All navigation is terminated through the lock. Operation of the lock equipment ceases but continues for gates located throughout the dam. This measure requires an act of congress to change navigation mission established under provisions within the 1930 River and Harbor Act. The mission requires the United States to maintain a navigation channel at least 9 foot in depth throughout the Illinois Waterway.

5. Electric Barrier and Water Jet Measure

5.1 General Description

This measure will be installed within the engineered channel (see paragraph 3.1).

The Electric Barrier measure will be incorporated with the engineered channel and water guns. The design of this barrier is based off of Permanent Barrier I (PB1), located in Romeoville, IL. The Brandon Road Barrier differs from PB1 in that it will have three (3) narrow arrays instead of two. The purpose for the additional narrow array is to have the ability to run two narrow arrays concurrently while the third one is for redundancy. The purpose of running two narrow arrays concurrently is to better fortify the electric field, specifically to better deter small fish that are three (3) inches or smaller.

The rectifiers for the three arrays at the Brandon Road Electric Barrier are designed to have a capacity of 4.3 MW. The increased power capacity is desired to provide more flexibility to accommodate channel conditions, such as water conductivity, and potential future changes in operating parameters. On land there will be three sets of DC rectifiers and pulsers, each set for the one of the three narrow arrays. The third set is a backup that can be put into operation if either of the other two are off-line for maintenance. There is a bus bar and switching system that can transfer operation of the arrays between the pulsers and rectifiers.

Each set of rectifiers and pulsers for the barrier will be directly connected to an array. Permanent Barrier I eliminated the switching and bus bar systems, like at Barriers IIA and IIB, due to significant maintenance
demands and the bus bar system being a major source of air-borne electromagnetic fields that are a potential health and safety concern. Eliminating this type of system should reduce the electromagnetic field (EMF), allow an inactive array to be activated more quickly, and will be simpler from an operations and maintenance perspective. The direct connection will also be utilized at the Brandon Road Barrier. As with the Romeoville site it is intended to continue to develop and utilize more “off the shelf” technology. Currently the rectifiers and pulsers are custom pieces of equipment which were developed by Smith-Root and SPANG. These types of components are necessary to produce the in water field, but having a sole provider creates risks of availability and lack of knowledge to maintain and/or operate the system.

The electrical field will be transmitted to the water via steel electrodes that are secured within the engineered channel. The electrodes are connected through boreholes to components inside a control building. The electrodes and parasitic structures will both consist of 5 in. x 5 in. steel bars resting within precast slots along the engineered channel bottom. All of the electrodes and parasitic arrays will span the width of the canal and be at or below the existing channel elevation. The parasitic arrays are situated on either side of the electrode field and help contain the electrical field to the area designed for fish deterrence. The in-water structures will not be an impediment to navigation because the required navigation depth at the barriers is 9 ft. from low pool.

A benefit of the Brandon Road site compared to Romeoville is the depth of the channel. The channel depth of the Brandon Road site is approximately 15’, as compared to approximately 25’ at Romeoville. The shallower depth should allow for less power required to produce the desired field strength. There has been no design completed on this low water application.

An additional benefit is the lower conductivity of the water as compared to Romeoville. The amount of power that must be generated on land to maintain the desired electric field in the water varies with the water conductivity. When the water conductivity is high, more power is needed to maintain the same in-water voltage than when the conductivity is lower. The conductivity at the Romeoville site varies widely over the year and, for short periods of time, can peak at levels two to three times the average level. Peak conductivities often occur after snow thaws, when it is theorized that large amounts of salt runoff from roadways into the canal. This is not the case at the Brandon Road site.

If the canal conductivity gets too high, Romeoville Barriers IIA and IIB reach a point where they don’t have enough power to maintain the desired operating parameters. When this occurs, the operating parameters must be “folded back”. The barriers automatically reduce power as needed based on a foldback algorithm in the operating programming. As currently programmed, first the pulse duration is gradually reduced to a preset value (currently 1.7 ms). If this doesn’t sufficiently reduce power demand, the operating voltage is reduced. Operating parameter foldbacks have occurred at both Barriers IIA and IIB. Obviously it is undesirable to reduce the operating parameters from the identified optimal parameters. Basing the Brandon Road Barrier off of PB1, which has a larger rectifier design, is intended to allow the barrier to operate at a conductivity of up to 2,500 uS/cm without having to fold back any of the operating parameters. Conductivities higher than this are extreme outlier events and, while possible, are highly unlikely.

The additional power capability also provides the ability to accommodate potential future changes in operating parameters. While the existing operating parameters are based on research completed on small Bighead Carp, research on optimal operating parameters is ongoing. There is the possibility that future adjustments to operating parameters could be made to further optimize barrier effectiveness.

The intent at the Brandon Road Barrier is to receive utility power from two independent incoming power lines. Power from that line goes through a transformer and then is distributed to the sets of DC rectifiers and pulsars. This will provide independence amongst the arrays and redundancy in case there are problems with the incoming utility power or on-site equipment on one of the lines. A final design will be dependent on what is feasible for the electrical utility and costs of the various options.
The Chicago District hired Black & Veatch, who in turn hired Safe Engineering Services (SES) to develop a Current Distribution Electromagnetic Fields Grounding and Soil Structure Analysis (CDEGS) model of the Romeoville site as well as remediation schemes. SES’s findings are documented in “Engineering Analysis Report, Fish Barrier Site EMI and Grounding Mitigation Analysis” (Prepared for: Black and Veatch by Safe Engineering Services and Technologies, LTD. February 2015). The Romeoville barriers and the proposed Brandon Road site have similar geology. That is, both are Silurian dolomite overlying Maquoketa Shale, which overlies Cambrian Ordovician sandstone. Both locations are in the Des Plaines River valley, which was eroded to the bedrock surface during the end of the last glaciation. Because both sites are of similar geology and barrier configuration, the Romeoville site will provide a worst case. An insulated channel is proposed to the Brandon Road site.

Because the electrodes for the Romeoville barriers are already in place, an engineered channel is not presently feasible at that location. Therefore SES proposed a dense metal mesh as close to the canal as possible. Due to the presence of structures, the design was to install ground rods 56 ft deep, 40 ft apart, 40 ft from the canal. The ground rods were proposed to be connected to the site grounding system. This design was implemented as 50 ft rods, 20 ft apart, 40 ft from the canal and connected to the site grounding system. The effect was to reduce the spread of stray voltage off site. For instance, touch potential on railroad rails was reduced from 100 to 20 V. Other on site mitigation has included installation of a 6 in x 6 in copper mesh tied to structures and backfilled with a conductive granular backfill designed for grounding. This has proved highly effective at reducing touch potential to less than one volt where this mitigation method has been installed.

Without mitigation, the majority of the ground potential rise has been observed in the direct vicinity of the barriers with most stray voltage dissipating within 300 ft of the barriers. This is discussed in “Summary of ground current issues at the fish barriers (Romeoville) and the proposed GLMRIS barrier at Brandon Rd.” (CELRC-TS-D. 26 Jan 2015). However, though notable voltage potential rise dissipates relatively quickly, there has been spread of barrier direct current (DC) pulses at the Romeoville site one order of 1000 ft. This large spread of pulsed DC lead to concerns with respect to corrosion and harmonic interference. Concern with respect to the influence of this stray voltage on corrosion of adjacent structures was discussed in “Brandon Road Lock Fish Barrier Corrosion Risk Assessment” (Chicago and Rock Island District, Oct 2015). The conclusion of the risk assessment was the risk was low and that there were readily available methods to mitigate should corrosion become a concern. Regarding harmonic interference, coordination with the Brandon Road Lock and adjacent Brandon Road Bridge (IDOT) was documented in “Memorandum for File. Subject: Potential for harmonic interference of proposed barrier at Brandon Road on the Brandon Road Bridge, Brandon Lock, and motors” (CELRC-TS-DG, 27 Sep 2016). This report shows negligible potential for harmonic interference at the bridge or the lock due to the proposed fish barrier. The report is included here as Attachment 4 to this appendix.

For the electric barrier, operations and support buildings will be constructed on the land adjacent to the engineered channel wall. Buildings are assumed to be similar in size and construction to the Permanent Barrier I buildings at the Romeoville barriers. No site investigation was performed on this land as it is privately owned, but some of the site history is known and fly ash is known to be present. It is assumed that the foundations for the buildings and associated roadways will need to be over-excavated for larger foundations given the poor soil conditions. All excavated material from the site will be taken to a landfill for disposal, assumed to be the Laraway Recycling and Disposal facility 3 miles from the project site. Any other disturbed areas of the site will be covered with an engineering control barrier, assumed for the purposes of this design to be a paved asphalt cap.

Safety during operation of the electric barriers is an important part of their implementation. Extensive testing will be performed by the Coast Guard following installation of the electric barriers to determine what limits on navigation and limits on operation of the barrier will be required to ensure the safety of mariners in the Brandon Rock Lock vicinity. Refer to section 7.4.4 of the main report, Injury or Mortality
potential, for a more detailed discussion of potential impacts to waterway users. Refer to Section 9.2 of the main report for a more detailed description of proposed electric barrier operation in the TSP.

A new mooring location will be constructed for barge flotillas well downstream of the approach channel for alternatives that include the electric barrier measure. If operators need to reconfigure prior to going through BR Lock because of safety requirements or considerations associated with the electric barrier, a new temporary mooring area is proposed approximately 1.8 miles downstream of the lock, and is shown on plate CS111. Reference designs for the new mooring cells have been used from the LaGrange L&D mooring cell and the L&D Number 14 Mooring cell projects, prepared by Rock Island District. Reference cell designs are 25 to 30' from the bottom of the channel to top of cell. Foundations were driven another 50’ to reach bedrock. The Brandon Rd mooring cells will be shallower given the location of bedrock, thus these designs and associated costs are considered conservative. Four mooring cells will be installed in the new reconfiguration area, each being spaced approximately 400’ apart to best accommodate barges. A flotilla can leave barges at the site while it performs multiple lock transits, and a second flotilla can wait to begin transiting the lock. The mooring area is not currently maintained as a part of the Illinois River navigation channel, so dredging will be required to allow flotillas in the area. Dredging quantities have been estimated for the proposed mooring area using Rock Island’s Illinois River bathymetry database. This work will be mechanical dredging of sediment from the channel. The area will be dredged to an average depth of 14’ from pool to allow full depth barges, and to be consistent with the new depth of the approach channel. The mooring area to be dredged and maintained is 1500’ long by 210’ wide, or 315,000 SF. Adjacent to the site on land are two active railroads, so coordination will be required to assure the site has no impact on the existing utilities and bankline.

The dredged sediment is not suitable for beneficial use or open water placement based on initial sampling and will need to be landfilled. Problems with the material include metals, PCBs and nutrients. Sediment will be dredged mechanically and moved by barge upstream to the NRG site located adjacent to the right descending bankline along the lower lock approach channel. The material will be mechanically off-loaded, and placed in a lined dewatering area. Water within the dredge material cannot be allowed to seep into the ground as it is assumed it could spread contamination from the dredge material. The dewatering area will be lined with clay or a geotextile. The dredge sediment will need to be dewatered prior to disposal. Detained dredge water will be allowed to sit as long as possible for settling and then go to an on-site, temporary "package" plant. The package plant contains a treatment process for the detained water to include filtration and then ammonia removal by breakpoint chlorination. A granular activated carbon (GAC) filter will follow the dechlorination step, and then the water will be discharged to the river. The sediment will sit on the property until dried, and then will be hauled in trucks to a landfill. The assumed landfill location is Laraway Disposal, which is adjacent to the reconfiguration mooring area. Existing infrastructure is prohibitive in locating the dredge handling procedures closer to the landfill.

Water jets will be incorporated along with the electric barrier to help remove fish entrained between the barges. Multiple longitudinal rows of jets will be installed in the engineered channel, each with approximately 8 to 10, 12 inch diameter jets evenly spaced. The sizing of the jets will be studied in PED to determine if a smaller nozzle size will be effective against ANS. Conceptually there will be several of these rows across the bottom of engineered channel, to cover all flotillas crossing through the electrical barrier. The jets will face towards the lock end of the channel, at an approximately 22 degree angle from the vertical. Based on testing performed by ERDC CHL, this alignment and angle of jets will provide the best chance of clearing fish entrained in barges. In laboratory tests trials were performed using forward facing, rear facing, and vertical jets. The most effective at removing fish were the forward facing jets placed at a slight 22.5 angle off of the vertical. This configuration is also undergoing field tests at the current electric barrier system in Romeoville. This jet angle design decision was based on several pieces of information. The barge configuration considered is a fully loaded leading box barge followed by a rake barge. This is the worst case scenario for entraining fish. In the case of the barge stopping over the jets or moving forward slowly, the jets will impinge first on the box barge, then at an angle to the rake as
the barge moves over top. Thus, the jets are countering the tendency for the forward moving barges to entrain water in the recess by forcing water off of the vertical box barge surface and moving it laterally. This has a similar effect as a hard reverse maneuver performed with no jets. The water impinges on the box surface as the tow goes backward. The concept of testing a forward facing jet came from the success of the hard reverse maneuver. The low jet angle also reduces the maximum extent of the forward water motion so the fish aren't pushed too far upstream. In the field testing, the flow field over the jets was measured and the results will be analyzed to see the full jet-induced flow field and determine the distance that the jets are pushing water upstream. This field and laboratory testing for the water jet system will be ongoing, and the measure design updated according to the results.

Jets and their associated piping will be constructed of non-conductive material, due to their close proximity to the electric barrier. Water intakes for the jets will be placed in the downstream pool, either across the peninsula from the approach channel or further downriver, pending outcomes of hydraulic modeling. Pumps will be installed in a pump station at the intake. Several alternatives for running the pumps have been considered, such as including a water tank adjacent to the engineered channel to store water for jets. These options will be considered further in more detailed design, to optimize the operation of the water jet system.

5.2 Construction Impacts

Navigation through the channel and lock will be shut down for several periods during the construction of the Electric Barrier and Water Jets, in association with the Engineered Channel (see paragraph 3.1). It is assumed that all traffic will halt for 3-4 months twice during the construction of the engineered channel. The remainder of the construction such as installation of the walls will occur during temporary 8 hour shutdowns each day, allowing barge traffic to continue for the remaining 16 hours.

5.3 Operations Impacts

The electric barrier will likely cause some restrictions on how quickly traffic can pass through the approach channel and lock. The U.S. Coast Guard will perform an assessment of the electric barrier once it is constructed and provide instructions on how traffic can safely pass through the lock. In order to complete the economic analysis of the impacts of this measure, the design team made educated assumptions on what these restrictions would be, based on knowledge from the currently operating electric barriers and input from the navigation industry and the Coast Guard. These potential restrictions include: no cutting of barge fleets in the area of the lock and approach channel; a length restriction on fleets passing through the approach channel; restrictions on when operators can be outside of the tow cabin; requirements for tying barges together with conductive material, intermittent operation of the electric barrier, and others. In addition to these impacts, infrequent temporary navigations shutdowns can be expected for maintenance work. Refer to the Economic Appendix for full details of the assumed restrictions.

5.4 List of Supporting Documents and References

- Permanent Barrier I Plans and Specifications
- Final Efficacy Report

6. Complex Noise

6.1 General Description

This measure will be installed within the engineered channel (see paragraph 3.1). The system will require an incoming power system and a control building on the west bank of the channel. Power requirements are conventional as the speakers are off-the-shelf items already in use in other aquatic environments with
standard power system. Speakers would be installed in the wet without dewatering measures, following the construction of the engineered channel. The design concept calls for a total 200 aquatic speakers throughout the approach channel, gradually increasing in frequency upstream to the lock. Speakers may also be installed in the lock itself, based on the results of future testing. The design is based on initial testing of smaller systems, and will be optimized as design progresses.

Operations and support buildings will be constructed on the land adjacent to the engineered channel. Buildings are assumed to be similar in size and construction to the Permanent Barrier I buildings at the Romeoville electrical barriers. No site investigation was performed on this land as it is privately owned, but some of the site history is known and fly ash is known to be present. It is assumed that the foundations for the buildings and associated roadways will need to be over-excavated for larger foundations given the poor soil conditions. All excavated material from the site will be taken to a landfill for disposal, assumed to be the Laraway Recycling and Disposal facility 3 miles from the project site. Any other disturbed areas of the site will be covered with an engineering control barrier, assumed for the purposes of this design to be a paved asphalt cap.

6.2 Construction Impacts

Construction will be performed in the wet, and so will require only temporary navigation shutdowns during regular lock operation. Impacts will be relatively minor.

6.3 Operations Impacts

This measure should not interfere with regular navigation through the lock once installed and operational. Infrequent, temporary navigations shutdowns can be expected for maintenance work. These would be scheduled in advance to limit the effect on navigation.

6.4 List of Supporting Documentation and References


- USGS and UMN-Duluth South Research: Acoustic Deterrence of Bigheaded Carps.

- In-Situ tests of sound-bubble-strobe light barrier technologies to prevent range expansions of Asian carp. Ruebush, 2012.

7. Non-Structural Measures

7.1 Boat Launches

The majority of the non-structural measures require no engineering or construction. In order to facilitate effective monitoring and emergency response in the area of Brandon Road however, new boat launches are proposed near the Lock in Brandon Road and Dresden Island Pools.

The upstream launch into Brandon Road pool will be built on the land owned by USACE for lock operations. It will include of a new roadway up to the water’s edge, since the current slope is not easily drivable. The launch itself will be a gravel ramp into the water with a floating wooden dock.

The downstream launch into Dresden Island pool will be built at one of two locations, depending on the alternative. For the non-structural alternative, the launch will be constructed on the isthmus of land.
adjacent to the approach channel. A gravel road with secure gate access will lead from Brandon Road to a parking area, and a boat launch into the approach channel. For the technology alternatives, the boat launch will be built further downstream, just south of the approach channel outlet. The access road to the electric barrier and/or complex noise control buildings will extend to a parking and launch area.

8. Operation and Maintenance Costs – Measure Summaries

Operation and Maintenance costs for each of the alternative measures was not included in the construction cost estimate. The O&M costs were estimated based on knowledge of existing systems and parametric costs as follows. Costs include the salary costs of the operational staff for each measure; the staffing requirements are detailed in the following section. All costs are rounded to the nearest hundred thousand for significant digit consistency. All costs here are engineering estimates, which were then annualized and incorporated into the project time stream in the economic analysis. Separate costs were calculated for the continued Monitoring and Adaptive Management work, and are covered in that section of the report.

8.1 Electric Barrier

Operation and Maintenance estimates for the Electric Barrier measure can be estimated using known costs from the Romeoville CSSC Electric Barrier. The barrier is assumed to run 24 hours a day, 7 days a week in this estimate. Permanent Barrier I, which the Electric Barrier measure design is based on, has costs of $3.4M for operation and $1.3M for maintenance. This includes electrical bills, spare parts, and other incidentals. It can be assumed that electrical costs would be comparable, as the Brandon Road channel is twice as wide as the CSSC channel, but only half as deep. Labor will be an additional cost for the electric barrier measure. Staffing requirements for the electric barrier measure are detailed below and will include 8 full time employees. Assuming $100/hr for each employee at 40 hours a week, labor costs are estimated at $2M. At this point in design, all costs are assumed to be the same for the continuous barrier measure and the intermittently operating barrier measure. This yearly total is estimated at $7M. In addition, a one-time cost for replacing electrodes is assumed over a 25-year span. The cost for this installation based on installation costs at Permanent Barrier I is $3.7M. In addition, $12M of upgrades to the electrical equipment are estimated every 10 years.

8.2 Mooring Area

Alternatives including the electric barrier also include a new mooring area installed to the south of the Brandon Road Lock. Maintenance of the mooring area will require dredging, which is estimated at one dredge event during the 50-year project period. This area is not currently dredged, so significant sediment buildup is not expected. To required maintenance dredging assumed is 3-4 feet in depth across half the proposed mooring area, or 20,000 CY. The estimated additional one-time cost for this item is $6M, as the material will need to be dredged, treated and disposed of in a landfill as in the initial dredging effort.

8.3 Water Jets

Operation and Maintenance costs were estimated as a percentage of the installation costs, absent an existing project to use for comparison. $500,000 or approximately 15% of the installation cost was assumed for a yearly cost, to cover normal maintenance and repairs, along with the cost to run the pumps. Pump replacements are estimated to occur every 15 years at a cost of $300,000. This is based on the pumps running 1 hour for each lockage, and an average of 9 lockages a day.

8.4 Complex Noise

Operation and Maintenance costs were estimated as a percentage of the installation costs. Based on other similar installations, the speakers used are standard and do not require unusual maintenance. $500,000 or 15% of the installation cost is assumed per year, to cover normal maintenance and major repairs. Under
the electric barrier and complex noise alternatives, the staff for the electric barrier is also assumed to operate the complex noise system. Under the Complex noise/flushing lock/water jet alternative, additional staff will be needed at the site to run the system. 2 full time employees are assumed at $150,000 for an additional $300,000. Staffing requirements detailed below.

8.5 Flushing Lock
Operation and Maintenance costs were estimated as a percentage of the installation costs. $300,000 or approximately 15% of installation cost is assumed per year, to cover normal maintenance and major repairs.

8.6 Engineered Channel
Normal Operation and Maintenance costs for the engineered channel are assumed to include only the cost of periodic inspections of the channel walls and floor, which are negligible for this estimating purpose.

8.7 Lock Closure
Normal Operation and Maintenance costs for lock closure to cover only the cost of inspection of the lock, which is negligible for this estimating purpose.

8.8 Boat Launches
The estimated O&M costs for the two boat launches are $20,000/year. This is to cover minor repairs, addition of gravel, repairs to safety fencing and lighting, and similar items.

9. Operation and Maintenance Staffing Requirements – Alternative Summaries

9.1 Technology Alternative – Electric Barrier
Staffing requirements for the Electric Barrier Alternative will be mainly for the electric barrier itself, and can be estimated based on the Romeoville Electric Barrier. For the Brandon Road electric barrier, eight full time equivalent employees are estimated: five operators, one electrician, one mechanic, and one supervisor. No further staffing will be required for the flushing lock, water jets or engineered channel. The existing lock staff and electric barrier staff will cover any normal issues that arise from these items.

9.2 Technology Alternative – Complex Noise
In this alternative, the only measure that will require additional staffing is the complex noise system, as the engineered channel, water jets and flushing lock will not need regular operators. 2 FTE are assumed to supplement the existing lock operation staff to operate and address any issues with the complex noise system.

9.3 Technology Alternative – Complex Noise with Electric Barrier
Staffing requirements for this alternative will be the same as for the electric barrier alternative. Eight full time equivalent employees are estimated for the electric barrier: five operators, one electrician, one mechanic, and one supervisor. These employees will also cover any operational needs for the complex noise system, along with the flushing lock, water jets and engineered channel; no additional staffing is required.

9.4 Lock Closure Alternative
No staffing will be required for the lock closure alternative.
10. Other Engineering Considerations

10.1 Real Estate

No detailed real estate investigations have been performed at this point. The Brandon Road Lock, channel, and associated operating area are owned by the government. The adjacent lands to the northwest of the channel that are proposed to be used for access, construction, and operational structures for certain alternatives are privately owned.

A number of engineering assumptions were made for the proposed real estate easement site. Based on the environmental history of the site, contamination is expected. Any area of the site that will be disturbed by construction activities is therefore assumed to need an engineering cap. The cap proposed is asphalt paving with a gravel base, to cover any disturbances and serve as a parking area. For measures that require excavation for the access road, installation of utilities, and new building construction (this includes the electric barrier, water jets and complex noise), all excavated material will need to be hauled off-site. The assumed disposal site for this contaminated material is the Laraway Recycling and Disposal Facility approximately 3 miles from the site in Joliet, IL. Refer to the real estate appendix for a full explanation of the site assumptions.

10.2 Utilities

No utility investigations have been performed at during the conceptual plans development. Power is available at the lock control building, and would need to be extended to the proposed building site adjacent to the south end of the channel for the electrical barrier and complex noise measures. The water jets measure will require construction of a water intake and pump station running to the south end of the channel as well.

10.3 Access Roads/Haul Routes

For most project measures, an access road is assumed to be built running parallel to the approach channel, from the current Brandon Road to the south end of the channel. Temporary haul roads will be built on site as necessary for channel excavation and construction activities.

10.4 Surveying and Mapping

LIDAR data was used for existing site topography, and bathymetric data in the approach channel was obtained from a 2012 survey. The horizontal datum is based on the Illinois State Plane Coordinate System, East Zone, 1983. The vertical datum is based on North American Vertical Datum (NAVD) of 1988.

10.5 Construction and Operational Costs

Full cost estimate information is included in the Cost Engineering Appendix. Refer also to Chapter 5 of the main report for an evaluation of the relative plans costs, construction impacts, and operation and maintenance issues.

10.6 Further Engineering Design

The engineering work completed for this report was at an appropriate level for a concept comparison. The attached ‘Engineering Decision Matrix’ provides documentation of some work that was completed by the team to document early assumptions and issues with proposed projects, and to narrow down the potential measures and concepts that are recommended to move forward to feasibility design. Sufficient work was completed to create a base project cost estimated, with assumptions and unknowns documented. Further work to be completed for a complete project design includes, among others, construction methods and
concept optimization, design calculations for all components, HTRW assessment, survey, geotechnical exploration and analysis, and a physical model of the flushing lock feature.

Attachments

Quantity Takeoffs

Plates

Engineering Decision Matrix

Interference Potential Due to Electric Barrier at Brandon Road
Quantity Takeoffs
### Channel Base Excavation

<table>
<thead>
<tr>
<th>Channel Length (ft)</th>
<th>Channel Base Depth</th>
<th>Excavation Depth</th>
<th>Material Removed (CY)</th>
<th>Spoil Pile Area (sf)</th>
<th>Spoil Pile Height (ft)</th>
<th>Spoil Base Diameter (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>490</td>
<td>489</td>
<td>35350</td>
<td>60900</td>
<td>30</td>
<td>45</td>
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</tbody>
</table>

### Channel Bank Excavation

<table>
<thead>
<tr>
<th>Channel Length (ft)</th>
<th>Channel depth (ft)</th>
<th>Excavation depth into wall (ft)</th>
<th>Material Removed (CF)</th>
<th>Material Removed (CY)</th>
<th>Weight Material removed (TONS)</th>
<th>Spoil Pile Area (sf)</th>
<th>Spoil Pile Height (ft)</th>
<th>Spoil Base diameter (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

### Assumptions:
- Volume of Channel Bank Spoil: 16,854 CY
- Channel Base will be 3.5 feet of concrete above excavation depth in 500' length for electric barrier.
- Channel will be stabilized with 11 tons of shotcrete, with minimum settlement. Channel hasn't been impacted in >10 years because of lack of sediment build up.
- Volume of Channel Base Excavation was estimated using the example volume report in literature.
- Channel minimum depths are set at 11 ft to meet hydraulic recommendations.

### Channel Walls

- Preformed concrete cells with reinforcing concrete placed in water, then the interior is poured in place with tremied concrete. LDB has precast walls on front and back face, while RDB has precast wall on front face only.
- Assume width equal to the greatest width of existing walls, the 8' base.
- Top brace elevation is 489'.
- Top slope of wall is 3:1.

#### Precast Concrete Cells

<table>
<thead>
<tr>
<th>Channel</th>
<th>Steel member</th>
<th>B/N</th>
<th>Beams per cell</th>
<th>Length per beam</th>
<th>Total Length (ft)</th>
<th>Total Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDB</td>
<td>W12 x 53</td>
<td>12</td>
<td>4</td>
<td>33</td>
<td>156</td>
<td>4380</td>
</tr>
<tr>
<td>LDB</td>
<td>W12 x 53</td>
<td>12</td>
<td>4</td>
<td>33</td>
<td>156</td>
<td>4380</td>
</tr>
</tbody>
</table>

### Assumptions:

- Channel Base Excavation:
  - Channel Base Excavation:
  - Volume of Channel Base Excavation:
  - Channel Base Excavation:
  - Volume of Channel Base Excavation:

### Permanent Cofferdam for Channel

- Preformed concrete cells with reinforcing concrete placed in water, then the interior is poured in place with tremied concrete. LDB has precast walls on front and back face, while RDB has precast wall on front face only.
- Assume width equal to the greatest width of existing walls, the 8' base.
- Top brace elevation is 489'.
- Top slope of wall is 3:1.
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<td>4</td>
<td>33</td>
<td>156</td>
<td>4380</td>
</tr>
</tbody>
</table>

### Assumptions:

- Channel Base Excavation:
  - Channel Base Excavation:
  - Volume of Channel Base Excavation:
  - Channel Base Excavation:
  - Volume of Channel Base Excavation:

### Permanent Cofferdam for Channel

- Preformed concrete cells with reinforcing concrete placed in water, then the interior is poured in place with tremied concrete. LDB has precast walls on front and back face, while RDB has precast wall on front face only.
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<td>156</td>
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<tr>
<td>LDB</td>
<td>W12 x 53</td>
<td>12</td>
<td>4</td>
<td>33</td>
<td>156</td>
<td>4380</td>
</tr>
</tbody>
</table>

### Assumptions:

- Channel Base Excavation:
  - Channel Base Excavation:
  - Volume of Channel Base Excavation:
  - Channel Base Excavation:
  - Volume of Channel Base Excavation:
### Channel Base

**Assumptions:**
- 1' Concrete installed on floor of channel outside of 500' length for installation of barriers. Channel width 240' here. Precast concrete panels placed in the wet.
- 500' of channel for barriers is 3' deep built of precast panels, installed in the wet.
- Each Precast panel is 25' long, and half the width of channel (use 270' as average in barrier installation area)

<table>
<thead>
<tr>
<th>Channel length</th>
<th>Dispersal Barrier</th>
<th>Standard Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>1400</td>
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</table>

- Depth of concrete base (FT)
- Avg width channel (FT)
- Volume Concrete (CY)
- Fiberglass (SF)

<table>
<thead>
<tr>
<th></th>
<th>15000</th>
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<tr>
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<table>
<thead>
<tr>
<th>Total Channel Length: 1900 ft</th>
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</thead>
<tbody>
<tr>
<td>Total Volume concrete for base: 33667</td>
</tr>
</tbody>
</table>

### Boat Launches

**Assumptions:**
- Gravel roads and parking constructed of 6" course gravel base (CA 1), followed by 4" surface gravel (CA 6)
- Boat Launch Dimensions: 110' long by 12' wide, with a 39' minimum draft.
- Boat Launch made of 8" CA-6 over geotextile
- Floating wooden dock surrounds boat launch, 4' wide by 100' long

**North Boat Launch**

<table>
<thead>
<tr>
<th>Area (sf)</th>
<th>Volume CA-1 (CY)</th>
<th>Volume CA-6 (CY)</th>
<th>Area geotextile (SF)</th>
<th>Area floating dock (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel Road</td>
<td>3431</td>
<td>64</td>
<td>42</td>
<td>381</td>
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<tr>
<td>Boat Launch</td>
<td>1320</td>
<td>25</td>
<td>147</td>
<td>400</td>
</tr>
</tbody>
</table>

**Clay for Ramp (CY):**

| 1283 |

**South Boat Launch**

<table>
<thead>
<tr>
<th>Area (sf)</th>
<th>Volume CA-1 (CY)</th>
<th>Volume CA-6 (CY)</th>
<th>Area geotextile (SF)</th>
<th>Area floating dock (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel Road</td>
<td>3129</td>
<td>58</td>
<td>38</td>
<td>348</td>
</tr>
<tr>
<td>Gravel Parking</td>
<td>14941</td>
<td>277</td>
<td>193</td>
<td>1665</td>
</tr>
<tr>
<td>Boat Launch</td>
<td>1320</td>
<td>32</td>
<td>147</td>
<td>400</td>
</tr>
<tr>
<td>Description</td>
<td>Width (ft)</td>
<td>Height (ft)</td>
<td>Depth (ft)</td>
<td>Volume (CY)</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------</td>
<td>-------------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Concrete Wall</td>
<td>110</td>
<td>22</td>
<td>8</td>
<td>717</td>
</tr>
<tr>
<td>Upstream Fill Intakes</td>
<td>8.33</td>
<td>12</td>
<td>18</td>
<td>67</td>
</tr>
</tbody>
</table>

Concrete Volume for Wall and 2 walls of intakes: 850 CY
Mooring Area
Assumptions:
1. Cells will have a rock foundation based on the proposed mooring location. Design based on cell design from L&D 14.
2. Mooring area will be 1500’ long by 210’ wide (315,000 sf).
3. Based on the size of the area, 4 mooring cells will be needed.
4. Water depth will be dredged to/maintained at 14’ depth.
5. Dredging quantities are based on IL waterway bathymetry provided by/maintained by Rock Island District.
6. Dredging will be by mechanical of sediment only (no rock blasting), information provided by Craig Hess.

<table>
<thead>
<tr>
<th>Mooring cell</th>
<th>$1.5M</th>
<th>EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>*See estimated costs from Lock and Dam No. 14, Mooring Cell Project</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dredging
Assumptions:
1. Average depths for each area were taken as the average of the depth range (shown to the right).
2. For the deepest 11 - 20 foot range, depths were assumed to be near the low end of the depth range, since this area is near the edge of the channel.
3. Dredged material may be contaminated based on previous dredge projects in the Illinois River, and so is assumed to be disposed of in a landfill.
4. Site adjacent to the Approach channel to be used for processing (dewatering and treatment of water) of dredged sediment.
5. Assumed disposal landfill is 20 miles from dredge processing site.

<table>
<thead>
<tr>
<th>Depth (ft from pool)</th>
<th>Avg Depth for Area</th>
<th>Goal Depth</th>
<th>Area (sf)</th>
<th>Dredge QTY (CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 9</td>
<td>4.50</td>
<td>14.00</td>
<td>161,713.00</td>
<td>56,899.02</td>
</tr>
<tr>
<td>10.50</td>
<td>10.50</td>
<td>14.00</td>
<td>44,804.00</td>
<td>5,807.93</td>
</tr>
<tr>
<td>11 - 20</td>
<td>15.00</td>
<td>14.00</td>
<td>62,323.00</td>
<td>-</td>
</tr>
</tbody>
</table>

Total: 268,840.00 62,706.94
Design Plates
BRANDON ROAD INTERIM REPORT

THIS SET OF DRAWINGS IS BASED ON LESS THAN 10% LEVEL OF DESIGN. IT WAS DEVELOPED TO HELP ASSURE THAT THE DESIGN AND COST ENGINEERING TEAM HAD THE SAME ASSUMPTIONS, PROVIDE A BASIS FOR THE QUANTITIES, AND ASSIST THE REVIEWERS WITH UNDERSTANDING THE PROPOSED ALTERNATIVES AT THE SITE LOCATION.

FEATURE DESCRIPTION:

ELECTRICAL FISH BARRIER - A PERMANENT ELECTRICAL FISH BARRIER WILL BE INSTALLED WITHIN THE CHANNEL.

ENGINEERED CHANNEL - A CONCRETE CHANNEL LINER WILL BE CONSTRUCTED ALONG THE ENTIRE LENGTH OF THE EXISTING APPROACH CHANNEL TO THE LOCK, WITH BUILD-OUTS FOR THE INSTALLATION OF VARIOUS ANCILLARY MEASURES.

WATER JETS - A WATER INTAKE SYSTEM AND PUMPS WILL BE INSTALLED, LEADING TO A SERIES OF WATER JETS INSTALLED WITHIN THE CHANNEL.

COMPLEX NOISE - A SYSTEM OF SPEAKERS WILL BE INSTALLED WITHIN THE CHANNEL.

FLUSHING LOCK - THE EXISTING LOCK WILL BE REDESIGNED WITH NEW SIDE PORTS AND A CONTROL GATE, AND EXISTING PORTS ARE PLUGGED.

LOCK CLOSURE - CONCRETE FEATURES WILL BE INSTALLED AT THE UPSTREAM END OF THE EXISTING LOCK, TO PREVENT ANY FUTURE OPERATION OF THE LOCK.

MOORING LOCATION - A NEW DOWNSTREAM MOORING LOCATION FOR BARGE FLOTILLAS.

FEATURES TO BE COMBINED FOR THE MEASURES BELOW:

1) TECHNOLOGY ALTERNATIVE 1: ENGINEERED CHANNEL + WATER JETS + ELECTRIC BARRIER + FLUSHING LOCK + MOORING LOCATION

2) TECHNOLOGY ALTERNATIVE 2: ENGINEERED CHANNEL + WATER JETS + COMPLEX NOISE + FLUSHING LOCK

3) TECHNOLOGY ALTERNATIVE 3: ENGINEERED CHANNEL + WATER JETS + COMPLEX NOISE + FLUSHING LOCK + ELECTRIC BARRIER

4) LOCK CLOSURE

5) NON-STRUCTURAL ALTERNATIVE

SOLICITATION NO.:

CONTRACT NO.:

ISSUE DATE: 2/10/2017

TSP MILESTONE
### GENERAL NOTES

2. The vertical datum shall be based on North American Vertical Datum of 1988 (NAVD 88).
3. The topographic and planimetric information presented is from existing LiDAR data and represents conditions existing at that time. Actual conditions may vary.
4. The Contractor shall perform all work within the specified work limits.
5. Services of a registered land surveyor are required for the specified work limits.
6. The Contracting Officer’s Representative is to be notified of the Contractor’s intentions to install all mechanical equipment.
7. All mechanical equipment shall be installed in accordance with the layout of work limits and fence line.
8. The Contractor shall perform all work within time.
9. The Horizontal Datum is based on Illinois Department of Transportation.

### STANDARD ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACDE</td>
<td>Army Corps of Engineers</td>
</tr>
<tr>
<td>CBE</td>
<td>Catch Basin</td>
</tr>
<tr>
<td>CL</td>
<td>Central Line</td>
</tr>
<tr>
<td>CON</td>
<td>Contracting Officer's Representative</td>
</tr>
<tr>
<td>CDE</td>
<td>Corps of Engineers</td>
</tr>
<tr>
<td>SOP</td>
<td>Corrugated Steel Pipe</td>
</tr>
<tr>
<td>TLA</td>
<td>Diameter</td>
</tr>
<tr>
<td>TRM</td>
<td>Digital Terrain Model</td>
</tr>
<tr>
<td>SOL</td>
<td>Electrical Hand Hole</td>
</tr>
<tr>
<td>EME</td>
<td>Electrical Man Hole</td>
</tr>
<tr>
<td>ELE</td>
<td>Elevation</td>
</tr>
<tr>
<td>EXP</td>
<td>Expansion Joint</td>
</tr>
<tr>
<td>HFL</td>
<td>Fire Hydrant</td>
</tr>
<tr>
<td>GFL</td>
<td>Gas Line Low Pressure</td>
</tr>
<tr>
<td>HFL</td>
<td>High Water Level</td>
</tr>
<tr>
<td>HDP</td>
<td>Illinois Department of Transportation</td>
</tr>
<tr>
<td>LOU</td>
<td>Local Control Panel</td>
</tr>
<tr>
<td>MIN</td>
<td>Minimum</td>
</tr>
<tr>
<td>MW</td>
<td>Manhole</td>
</tr>
<tr>
<td>NGD</td>
<td>National Geodetic Vertical Datum</td>
</tr>
<tr>
<td>NML</td>
<td>Natural Material Line</td>
</tr>
<tr>
<td>NWAD</td>
<td>North American Vertical Datum</td>
</tr>
<tr>
<td>NTS</td>
<td>Not to Scale</td>
</tr>
<tr>
<td>OBI</td>
<td>Ocean Buoy Inc.</td>
</tr>
<tr>
<td>PAV</td>
<td>Pipe Aerial View</td>
</tr>
<tr>
<td>PRD</td>
<td>Reinforced Concrete Pipe</td>
</tr>
<tr>
<td>RSP</td>
<td>Riser, Sheet Pile</td>
</tr>
<tr>
<td>TYP</td>
<td>Typical</td>
</tr>
<tr>
<td>VHF</td>
<td>Verify in Field</td>
</tr>
<tr>
<td>VRT</td>
<td>Vertical</td>
</tr>
<tr>
<td>WC</td>
<td>Water Control</td>
</tr>
<tr>
<td>WEL</td>
<td>Water Level</td>
</tr>
<tr>
<td>WP</td>
<td>Work Point</td>
</tr>
</tbody>
</table>

### LEGEND AND GENERAL NOTES

#### SYMBOLS

- **STORM MANHOLE**: Water level
- **WATER MANHOLE**: Electrical Hand Hole
- **ELECTRICAL SIGNAL MAST ARM**: Guy Wire
- **TRIANGULATION POINT**: Utility Pole
- **ELECTRICAL MANHOLE**: Tree
- **MONITORING WELL**: Catch Basin
- **WATER VALVE VAULT**: Catch Basin Round
- **FIRE HYDRANT**: Grid Letter/Number

#### PATTERNS

- **RIPRAP**: Planting Type 1
- **ROCK**: Planting Type 2
- **COMPACTED FILL**: Planting Type 3
- **UNDISTURBED EARTH**: Planting Type 4
- **DRIED ROCK GRANITE**: Planting Type 5
- **CONCRETE**: Planting Type 6

#### DRAWING AREA TITLE

- **DRAWING AREA TITLE INDICATOR**: Direction of Cut
- **GRID LETTER/NUMBER**: Detail Where Sheet is Shown
- **SECTION**: Section Where Sheet is Shown

#### SECTION INDIQUATION

- **GRID LETTER/NUMBER**: Section Indication
- **DRAWING AREA TITLE**: Drawing Area Title
1ST SEQUENCE

- **EXISTING CHANNEL BOTTOM**
- **8' DEPTH BY 25' LENGTH**
- **PLACE PRECAST CONCRETE CELLS**
- **1.0' EVERYWHERE ELSE**
- **3.5' FOR BARRIER**

2ND SEQUENCE

- **DRILL, BLAST AND EXCAVATE CENTER PORTION OF THE CHANNEL**
- **EXISTING GUIDE WALLS (8' THICK).**
- **EXISTING CHANNEL BOTTOM**
- **1.0' TO 3.5' OF STONE FROM BOTTOM OF CHANNEL. ACTUAL DEPTH MAY VARY AND MUST BE DETERMINED BY DRILL, BLAST AND EXCAVATE ACTIVITIES.**

3RD SEQUENCE

- **PLACE AND MOLD CONCRETE CELLS AND SET PANELS MANUFACTURED FROM EXCAVATION MATERIALS STORED ON-SITE.**
- **PRECAST MEMBERS WILL BE PLACED AT THE BOTTOM VIA MARINE CRANE.**

4TH SEQUENCE

- **PLACE PRECAST CONCRETE CELLS (8' DEPTH BY 25' LENGTH) TO EXTEND TO TOP OF EXCAVATION WALLS.**
- **GROUT WILL BE PUMPED UNDER MEMBERS TO FILL VOIDS.**
- **POST-CONSTRUCTION OBSERVATION AND TESTING.**

5TH SEQUENCE

- **PLACEMENT AS 125' LF WIDTH (250'/2=125').**
- **FILL PONDS WITH EXISTING SOIL.**

6TH SEQUENCE

- **PLACE PONDS WITH EXISTING SOIL.**
- **CONCRETE Poured IN PLACE TO FILL WALL.**
- **MIXTURE OF CRUSHED STONE MATERIALS STORED ON-SITE AND EXISTING SOIL.**

7TH SEQUENCE

- **PLACE PONDS WITH EXISTING SOIL.**
- **PRECAST PANELS WILL BE PLACED AT THE BOTTOM VIA MARINE CRANE.**
- **MEMBERS WILL BE PLACED UNDER WATER TO FULL DEPTH.**

8TH SEQUENCE

- **PLACE PONDS WITH EXISTING SOIL.**
- **PRECAST PANELS WILL BE PLACED AT THE BOTTOM VIA MARINE CRANE.**
- **MEMBERS WILL BE PLACED UNDER WATER TO FULL DEPTH.**

NOTES:

1. **THIS STORY BOARD PROVIDES REVIEWERS WITH THE ASSUMED METHOD OF CONSTRUCTION.**
2. **SEE SHEET CS-301 AND R-006 FOR TYPICAL DETAIL OF PRECAST CELLS.**
3. **MAINTAINING NAVIGATION DURING CONSTRUCTION IS A PROJECT PRIORITY. DESIGN ASSUMPTIONS MAY CHANGE AS THE PROJECT EVOLVES.**
4. **NAVIGATION IS NOT EXPECTED TO OCCUR DURING BLASTING. BLASTING ACTIVITIES ARE EXPECTED TO BE COMPLETED IN WAVES.**
5. **IT IS POSSIBLE TO REUSE THE EXCAVATED STONE MATERIALS STORED ON-SITE BY SETTING UP A PORTABLE CRUSHING PLANT AND DISTRIBUTION NETWORK TO OFFSET PROJECT COSTS.**
6. **WALL THICKNESS IN THE ENGINEERED CHANNEL WAS ASSUMED TO BE THE SAME THICKNESS AS THE ORIGINAL SMALL WALL OF STEEL.**
7. **GROUT WOULD BE PUMPED UNDER PANELS TO BECOME IN PLACE.**

**U.S. ARMY CORPS OF ENGINEERS**

**CONSTRUCTION SEQUENCING**

**ENGINEERED CHANNEL WALL CONSTRUCTION IS IN PROGRESS**
**Blasting and Charge Placing Detail**

For reaches that require less than a foot of excavation, a grinder is used. For reaches with a depth of greater than a foot, drilling and blasting is used. A spud barge fitted with rail and drill rig drills holes at 10 feet CTC each way and sets blasting charges. Navigation is not allowed above the holes. Restricted navigation is allowed adjacent to holes.

**Drilling and Blasting**

Once the holes and blasting charges are set, navigation is halted. The barge moves and detonates the charges.

**Bathymetry**

Bathymetry is collected to confirm that the area is not obstructed to navigation.

**Excavation**

Blasted material is mechanically excavated. Material is transferred to land side on-site disposal. Excavation can occur during drilling activities.

**Area to Be Blasted**

Bathymetry is collected to confirm that the area is not obstructed to navigation.

**Completed Section**

Excavation.
GENERAL NOTES

1. REFER TO SHEETS CS201 AND CS301 FOR TYPICAL SECTIONS OF THE ENGINEERED CHANNEL.
2. ELECTRIC DISPERAL BARRIER FEATURE INCLUDES THE FOLLOWING COMPONENTS:
   a) ELECTRICAL DISTRIBUTION BUILDING.
   b) ELECTRIC MACHINERY BUILDING FROM THE ENGINEERED CHANNEL.
   c) ACCESS ROAD FROM THE ELECTRIC DISPERAL BARRIER TO THE DISTRIBUTION BUILDING.
   d) ELECTRIC PLANT AND PARASITIC STRUCTURES IN CANAL TO SUPPLY THREE SOURCES.
   e) SUBSTATION, WITH REDUNDANT FEEDS FROM TWO DIFFERENT POWER SOURCES.
   f) ELECTRODES AND PARASITIC STRUCTURES IN CANAL, TO SUPPLY THREE SOURCES.
   g) ENGINEERED CHANNEL WALLS, SUBSTATION, WITH REDUNDANT FEEDS FROM TWO DIFFERENT POWER SOURCES.
   h) BACKUP POWER FACILITY, INCLUDES GENERATORS, AUTOMATIC TRANSFER SWITCH AND FACILITY SWITCHGEAR.
3. ELECTRIC DISPERSAL BARRIER FEATURE INCLUDES THE FOLLOWING COMPONENTS:
   a) ELECTRIC DISPERAL BARRIER BUILDING.
   b) EQUIMENT AND OPERATING BUILDING.
   c) ELECTRODE ARRAYS FOR WATER JETS INSTALLED IN THE VICINITY OF THE ELECTRIC BARRIER IN THE CHANNEL.
   d) ACCESS ROAD TO FACILITY.
   e) GROUNDING FIELD, PROVIDES A DEEP EARTH GROUND.
   f) ACCESS ROAD TO FACILITY.

4. LAYOUT FOR WATER JETS IS FOR EXAMPLE ONLY, AND IS STILL BEING FINALIZED VIA MODELING. THE CURRENT CONCEPT IS LONGITUDINAL ARRAYS OF 3.
5. LAYOUT FOR WATER JETS IS FOR EXAMPLE ONLY, AND IS STILL BEING FINALIZED VIA MODELING. THE CURRENT CONCEPT IS LONGITUDINAL ARRAYS OF 3.
6. LAYOUT FOR WATER JETS IS FOR EXAMPLE ONLY, AND IS STILL BEING FINALIZED VIA MODELING. THE CURRENT CONCEPT IS LONGITUDINAL ARRAYS OF 3.

ENGINEERED CHANNEL WATER JETS AND ELECTRIC BARRIER
1. REFER TO SHEETS CS201 AND CS301 FOR TYPICAL SECTIONS OF WATER JETS, ENHANCED DRAINAGE AND ELECTRIC BARRIER.
GENERAL NOTES

1. PRIOR TO SUBMITTING THIS SHEET FOR COMPLIANCE REVIEW, REVIEW FOR TYPICAL DETAILS OF WATER JETS, COMPLEX NOISE AND ENGINEERED CHANNEL

ENGINEERED CHANNEL WALLS

ACCESS ROAD

TIE INTO EXISTING GUIDE WALL

MATCHLINE TO SHEET CS105

ENGINEERED CHANNEL, WATER JETS AND COMPLEX NOISE

REFER TO SHEETS CS202 AND CS302 FOR TYPICAL DETAILS OF WATER JETS,

BRANDON ROAD INTERIM REPORT

ACCESS ROAD

TIE INTO EXISTING GUIDE WALL

MATCHLINE TO SHEET CS105

ENGINEERED CHANNEL WALLS

ACCESS ROAD

TIE INTO EXISTING GUIDE WALL

MATCHLINE TO SHEET CS105

ENGINEERED CHANNEL, WATER JETS AND COMPLEX NOISE

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MATCHLINE TO SHEET CS105

ENGINEERED CHANNEL WALLS

ACCESS ROAD

TIE INTO EXISTING GUIDE WALL

MATCHLINE TO SHEET CS105

ENGINEERED CHANNEL, WATER JETS AND COMPLEX NOISE

REFER TO SHEETS CS202 AND CS302 FOR TYPICAL DETAILS OF WATER JETS,
ENGINEERED CHANNEL WATER JETS AND COMPLEX NOISE

SCALE: 1" = 40'

1. REFER TO SHEETS CS202 AND CS302 FOR TYPICAL SECTIONS OF WATER JETS, COMPLEX NOISE SYSTEM AND ENGINEERED CHANNEL.

ENGINEERED CHANNEL WALLS

TIE INTO EXISTING GUIDE WALL

TO LOCK ROAD TO THE NORTH

ACCESS ROAD, TIE INTO EXISTING
EXISTING PORTS TO BE FILLED

GENERAL NOTES
1. WALL DRIVING PORTS ON EACH WALL WILL BE FILLED WITH CONCRETE
during construction.
2. REFER TO SHEET CS501 FOR DETAILS OF REVISED FILLING PORTS.
GENERAL NOTES

1. REFER TO SHEET CS501 FOR DETAILS OF REVISED FILLING PORTS.
GENERAL NOTES

1. Upper gates of the existing lock to be replaced with a permanent concrete wall that ties into the existing concrete gate sill and upper gates of the existing lock walls.

2. Concrete plane is placed in each upstream lock fill intake. Intake 1, span 18' wide and 12' high on each of the lock walls.

3. Existing lock walls. Wall spans 110' width of lock and is 22' in height.

4. Concrete wall that ties into the existing concrete gate sill and upper gates of the existing lock to be replaced with a permanent concrete wall.

SCALE: NTS

PART SECTION CC - ENLARGED

LONGITUDINAL SECTIONS ON CENTER LINE

CONTRACT NO. 5
DEPARTMENT OF PURCHASES AND CONSTRUCTION
DIVISION OF WATERWAYS
THE ILLINOIS WATERWAY
BRANDON ROAD LOCK & DAM
GENERAL DRAWING

STATE OF ILLINOIS

12/10/2015

P&M: 451617 - CS110.dgn

M. J. GRUBSKY, PE

M. J. GRUBSKY, PE
NEW MOORING AREA

NEW MOORING CELL

GENERAL NOTES

1. REFER TO REFERENCE SHEET R-007 FOR REFERENCE DESIGN OF MODEL. REFER TO SHEET C-112 FOR LOCATION OF DREDGED MATERIAL.

2. LOCK AND DAM 10.8 MILES TO BRANDON RD

3. LOCK AND DAM 1.8 MILES TO BRANDON RD

4. REFER TO SHEET C-112 FOR LOCATION OF UNUSED MATERIAL DISPOSAL.

SCALE: 1" = 200'

NEW MOORING LOCATION
GENERAL NOTES

1. REFER TO SHEET C-111 FOR NEW MOORING AREA TO BE DREDGED.

2. DREDGING MATERIAL UTILIZATION AND DISPOSAL TO OCCUR AT LOCATIONS SHOWN ON SHEET C-112.

DISPOSAL SITE USE IS COMPLETED. BUT WILL NOT BE CONSTRUCTED UNTIL AFTER DREDGED MATERIAL CHANNEL. ELECTRIC BARRIER FEATURES ARE SHOWN FOR REFERENCE, IS TO BE COMPLETED DURING CONSTRUCTION OF THE ENGINEERED DREDGED MATERIAL DEWATERING AND REMOVAL TO A LANDFILL.

REFER TO SHEET C-111 FOR NEW MOORING AREA TO BE DREDGED.

1. DECANT AREA

2. MOORING AREA DREDGED MATERIAL DISPOSAL

MOORING AREA DREDGED MATERIAL DISPOSAL
GENERAL NOTES

1. Boat launch is required for fish monitoring and emergency response actions.

2. Launches are included in all technology alternatives and the nonstructural alternative. The downstream launch will be located within the approach channel, or south of it depending on which alternative is being constructed.

BOAT LAUNCH CAN BE EXPANDED AS NECESSARY. THROUGH EXISTING LOCK FACILITIES. PARKING SECURE ACCESS AND PARKING AVAILABLE.

BOAT LAUNCH ALTERNATIVE IS BEING CONSTRUCTED.

1. Launches are required for fish monitoring and emergency response actions.

2. Launches are included in all technology alternatives and the nonstructural alternative. The downstream launch will be located within the approach channel, or south of it depending on which alternative is being constructed.
ENGINEERED CHANNEL, WATER JETS AND ELECTRIC BARRIER PROFILE

HORIZONTAL SCALE: 1" = 50'  VERTICAL SCALE: 1" = 2.5'

TYPICAL LOW WATER LEVEL = 504.2
TYPICAL HIGH WATER LEVEL = 509.6

IN FUTURE DESIGN
FINAL LOCATION TBD

PIPING FOR JETS,
ENGINEERED CHANNEL, WATER JETS AND ELECTRIC BARRIER PROFILE

TYPICAL HIGH WATER LEVEL = 509.6'
TYPICAL LOW WATER LEVEL = 504.2'

ENGINEERED CHANNEL, WATER JETS AND ELECTRIC BARRIER PROFILE

TIE INTO EXISTING GUIDEWALL
WATER JETS - TYPICAL SECTION 1

CHANNEL WALL - TYPICAL SECTION

COMPLEX NOISE SYSTEM - TYPICAL SECTION

CHANNEL WALL TYPICAL BRACING DETAIL

1. REFER TO REFERENCE SHEET R-006 FOR DETAILS OF A SIMILAR COMPLEX NOISE SYSTEM DETAIL.
2. LAYOUT OF COMPLEX NOISE SYSTEMS IS SHOWN AS AN EXAMPLE. GREAT variability IN LAYOUT OF BIBs AND SUPPORTS WILL BE COUPLED WITH CHANGES IN WIND PROFILES AND SITE.
3. REFER TO REFERENCE SHEET R-006 FOR DETAILS OF A SIMILAR COMPLEX NOISE SYSTEM LAYOUT. GREAT variability IN LAYOUT OF BIBs AND SUPPORTS WILL BE COUPLED WITH CHANGES IN WIND PROFILES AND SITE. A SIMILAR COMPLEX NOISE SYSTEM LAYOUT WILL BE COMPLETED DURING FURTHER FEASIBILITY AND PED. EXAMPLE BASED ON CONCEPTUAL LEVEL DESIGN. DETAILED ANALYSIS AND LAYOUT OF COMPLEX NOISE AND WATER JETS SYSTEMS ARE SHOWN AS AN EXAMPLE. GREAT variability IN LAYOUT OF BIBs AND SUPPORTS WILL BE COUPLED WITH CHANGES IN WIND PROFILES AND SITE. A SIMILAR COMPLEX NOISE SYSTEM LAYOUT WILL BE COMPLETED DURING FURTHER FEASIBILITY AND PED. EXAMPLE BASED ON CONCEPTUAL LEVEL DESIGN. DETAILED ANALYSIS AND LAYOUT OF COMPLEX NOISE AND WATER JETS SYSTEMS ARE SHOWN AS AN EXAMPLE.

N.T.S.
3.5' DEEP NOTCH AMOUNT OF STRUCTURAL REINFORCEMENT REQUIRED.
NOTES:
1. FIBERGLASS PANEL WILL BE MECHANICALLY ATTACHED TO THE PRECAST PANEL PRIOR TO INSTALLATION.
2. PRECAST PANEL SEE SHEET C7 FOR USE IN WIDTH OF THE ELECTRIC BARRIER. FOR
   PRECAST PANELS INSTALLED IN THE VICINITY OF THE ELECTRIC BARRIER, NO
   FIBERGLASS WILL BE INSTALLED IN PANELS.
3. PRECAST PANEL, CONCRETE WITH SILICA FUME, CONCRETE WITH SILICA FUME.

CONCEPTUAL PRECAST PANEL FOR ELECTRIC BARRIER

SCALE: 3" = 1'
6"
Engineering Decision Matrix

This matrix was developed early on in the feasibility design process. A brainstorm of numerous possible ANS control measures and related features was developed, and basic relevant design information was collected or proposed by the team. The team brainstormed future investigation that would need to be performed for each viable alternative, and what risks were present if moving forward on design. The matrix then provided a jumping off point as the team moved into conceptual design and investigation on the various ANS control measures. Some measures were carried forward into the alternatives analysis, and other were weeded out based on cost, navigation impacts, risk to life safety, etc. The matrix is provided here for documentation of the screening analysis performed in the early stages of the study.
<table>
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<th>Project Number</th>
<th>Engineering Resource</th>
<th>Location</th>
<th>Description</th>
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<th>Cost</th>
<th>Personnel</th>
<th>Life-Cycle</th>
<th>Operating and Maintenance</th>
<th>Construction</th>
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<th>Conformance to CEM goals</th>
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<td>Non-structural adjustments to existing lock</td>
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Chemical Treatment of Water - Removal of Floaters, Hiddibilans and Swimmers
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<tr>
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<th>Description</th>
<th>Screening Status</th>
<th>Designated</th>
<th>Compatibility</th>
<th>Construction Cost</th>
<th>Measure Description</th>
<th>Efficacy</th>
<th>Estimated Costs</th>
<th>Engineering Channel - Barrier Measures to Better Outcomes</th>
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</table>
| John Doe      | New Barrier  | Unacceptable      | Moderate   | Unacceptable   | $100M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | John Doe needs to consider the benefits of a new barrier and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 
| Jane Smith    | New Approach | Unacceptable      | Moderate   | Unacceptable   | $75M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | Jane Smith needs to consider the benefits of a new approach and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 
| Mary Johnson  | New Solution | Unacceptable      | Moderate   | Unacceptable   | $25M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | Mary Johnson needs to consider the benefits of a new solution and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 
| Bill Murphy   | New Strategy | Unacceptable      | Moderate   | Unacceptable   | $20M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | Bill Murphy needs to consider the benefits of a new strategy and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 
| Susan Harris  | New Process  | Unacceptable      | Moderate   | Unacceptable   | $15M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | Susan Harris needs to consider the benefits of a new process and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 
| David Wilson  | New Technology| Unacceptable      | Moderate   | Unacceptable   | $10M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | David Wilson needs to consider the benefits of a new technology and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 
| Emily Foster  | New Methodology| Unacceptable      | Moderate   | Unacceptable   | $5M 30 years  | 500kCycles in 5 years (on average) | No change | Unknown       | Emily Foster needs to consider the benefits of a new methodology and the costs associated with its implementation. Jackson et al. estimated a savings of 500kCycles in 5 years (on average) with this approach. 

*Note: The above table represents a subset of the data and is meant to illustrate the process of evaluating and selecting engineering channel barrier measures to better outcomes. Jackson et al. estimated savings of 500kCycles in 5 years (on average) with the implementation of these measures. The table includes cost estimates and designations for each measure. The measures are evaluated based on their compatibility, cost, and estimated benefits in reducing chemical incidents. The table also highlights the screening status for each measure, which is determined based on factors such as safety, operation, and cost. The measures are compared against established criteria to ensure they meet acceptable standards for implementation.*
<table>
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<th>Confidence in A/B/C species control</th>
<th>Confidence for SW Design</th>
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### Barrier Measures to Order Outcomes

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</table>

### Summary

- **Canoe Basin:** Unacceptable due to high cost and potential for moderate to high consequences.
- **Channel Adjacent Structures:** Unacceptable due to high cost and potential for high consequences.
- **Be:** Unacceptable due to high cost and potential for high consequences.
- **Be:** Unacceptable due to high cost and potential for high consequences.
- **Be:** Unacceptable due to high cost and potential for high consequences.
- **Be:** Unacceptable due to high cost and potential for high consequences.

### Critical Assumptions

- Impact estimation methods.
- Cost estimation methods.
- Safety and health considerations.
- Environmental impact assessments.

### Total Project Cost Summary

- **Canoe Basin:** $2.5M Permenant
- **Channel Adjacent Structures:** $250K
- **Be:** $500K
- **Be:** $100k
- **Be:** $12M
- **Be:** $100M

---

### Additional Notes

- The cost estimates are based on preliminary assessments and may require further refinement.
- The potential consequences are based on preliminary assessments and may require further refinement.
- The mitigation strategies are based on preliminary assessments and may require further refinement.

---

*Note: The table continues with similar entries for additional measures.*
Interference Potential Due to Electric Barrier at Brandon Road
BRANDON ROAD LOCK FISH BARRIER CORROSION RISK ASSESSMENT
EXECUTIVE SUMMARY

A risk assessment of the Brandon Road Lock to evaluate the economic impacts associated with potential stray current corrosion was completed by a multi-discipline, multi-district team of engineers and scientists. The general framework of the USACE Dam Safety Periodic Assessment methodology to estimate economic risk was used for this evaluation. Experts in navigation lock design/operations, as well as corrosion and stray current impact, were part of the evaluation that was facilitated by an experienced senior engineer with the USACE Risk Management Center.

Incremental Risk

The economic risks associated with the placement of an electrically-charged fish barrier within the vicinity of the Brandon Road Lock are considered moderate. The risk assessment team evaluated numerous potential failure modes (PFM) related to stray current corrosion of primary lock features considered to be potentially at risk. This included all major steel structures (lock gates, valves, mooring cells, etc) and reinforced concrete structures with steel embedded in the structure. A total of 17 PFMs were evaluated by the team and three were determined to be risk drivers. While the remaining 14 PFMs were screened out from further consideration, this doesn’t necessarily mean they aren’t important from a day-to-day operation standpoint. It’s just that the risk-driving PFMs were considered to have significantly more risk compared the ones eliminated from further consideration as part this assessment. Each of the three risk-driver PFMs relate to the lower miter gate in some fashion. One is for the anchorage, another for the gate structure with emphasis on the pintle area, and the final one relates to the operating machinery. The range of failure likelihood was between ‘Low’ to ‘Moderate’ depending upon the PFM. Each had a similar level of estimated economic impacts in the range of $10 - $100 million (per failure mode) when considering both disruption to navigation and physical repair costs. The vast majority of the economic impacts are driven by disruption of navigation (lock closure) following a failure. The economic risk matrix plot developed by the team is shown in Figure 1.

Confidence and Major Uncertainties

The team had a moderate level of confidence in the estimated risks. Most of the uncertainty is driven by the fact that there isn’t a USACE facility in existence where an electrically-charged feature (fish barrier) has been placed in the immediate vicinity of a navigation lock. While the team believes there are several measures that can be taken to mitigate this risk, there exists a level of uncertainty as to what level of stray current may be present at the lock structure once the fish barrier is put into service. The level of stray current that will be present drives the uncertainty associated with assigning failure likelihood categories. The team had a higher level of confidence in estimating the consequences of a failure occurring based upon the information available for navigation impacts and the range of closure times estimated for the various PFMs. The estimates for lock closure time varied for each of the PFMs but they were all long enough to push the consequences well into the moderate category ($10-100 million).
Recommendations

As part of this evaluation, the team was asked to develop a series of recommendations related to the planned fish barrier. These are listed herein.

- Provide grounding on both sides of lock channel to control stray current in surrounding areas.
- Line the navigation channel to limit stray current and power consumption.
- Install parasitic structures around new barrier similar to those at the Romeoville site.
- Make sure ancillary structures (bridge, bridge supports, power plant intake, etc) near the fish barrier are included in baseline corrosion potential survey.
- Remove any features not being used that would see increases in corrosion, such as mooring cells in downstream approach (see 2012 PA Report).
- Any mooring cells that are to remain in place should be included as part of baseline corrosion survey.
- Schedule a lock chamber dewatering and baseline corrosion survey before fish barrier is installed and on 5-year intervals following installation of fish barrier. This (detailed inspection dewaterings) should be done at least two times.
following the installation of the fish barrier. As a side note, the lock chamber hasn’t been dewatered since 1995 when the lower miter gates were replaced.

- If stray current known to occur, add cathodic protection system to the miter gate and any other features where applicable.
- Numerical and experimental modeling to evaluate the potential for stray current reaching the lock and potential mitigation strategies.
- Conduct a life safety risk assessment before installation of fish barrier. This should include risks to USACE workers, other workers in areas, shippers, and the general public. It is recommended using the USACE life safety risk evaluation procedures for dams as a guide.
- Investigate alternative methods to control invasive aquatic species to ensure the electrical current methodology provides the most effective and safest method of meeting project needs.
- Investigate power plant intake pipe and determine appropriate actions to take prior to or at the time the fish barrier is constructed.
- Ensure MVR staff is aware of potential for accelerated corrosion at site and pending measurements of stray current, budget increased maintenance for equipment replacement or repair on more frequent schedule (such as electrical controls, etc).
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CHAPTER 1: FINDINGS AND RECOMMENDATIONS

Introduction

The Chicago District (LRC) has recently installed a series of electrically-charged fish barriers in the Chicago Sanitary and Ship Canal to halt the migration of invasive aquatic species. A demonstration barrier and series of three other barriers within close proximity to one another are in place or being constructed near Romeoville, IL. The district is also evaluating installing an additional electrical fish barrier just downstream of Brandon Road Lock. The intent of adding the fish barrier at Brandon Road Lock is to further enhance measures in place to limit invasive aquatic species movement between bodies of water. One of the concerns with placing an electrically-charged fish barrier in the vicinity of Brandon Road Lock is the potential for stray current corrosion on the steel structures as the lock. While the fish barrier project is being run by LRC, Brandon Road Lock is operated under the jurisdiction of the Rock Island District. An overview of potential issues is provided in more detail in Appendix A for the reader’s use as necessary.

In an effort to better understand the risks involved with potential stray current corrosion issues at the lock, LRC pulled together a multi-discipline team of engineers and scientists to assess the economic risks associated with corrosion-induced deterioration of major lock features. This was done through a facilitated potential failure modes analysis (PFMA) that focused solely on potential stray corrosion impacts of the Brandon Road Lock. The team was asked not to focus on life safety issues as part of this exercise with the intent that would be evaluated as part of a future assessment. The makeup of the team is detailed in Chapter 2 of this document along with their area of expertise.

Risk Assessment

A total of 17 potential failure modes (PFMs) were identified by the risk assessment team for consideration. Fourteen of these were not developed in detail as they were not considered to be “risk-drivers” for the evaluation. These PFMs are discussed in Chapter 3 with their reasoning for exclusion. The following risk-driver PFMs were evaluated by the risk assessment team:

- PFM 1: Structural failure of the lower miter gate anchorage system
- PFM 2: Fatigue related failure of lower miter gate including pintle area
- PFM 9: Failure of lower miter gate operating machinery

A risk matrix has been established to portray the economic risk associated with this evaluation. The risk matrix classifies each risk-driving PFM graphically with likelihood of failure on the vertical axis and the associated economic consequences on the horizontal axis. The economic risk matrix for this project is shown in Figure 2.
PFM 1: Structural failure of lower miter gate anchorage

The risk assessment (RA) team assigned a failure likelihood of LOW/MODERATE for this PFM. The lower miter gates at Brandon Road Lock are one of the most critical features at the project. There is no redundancy associated with the lower miter gates since it is a single lock project with no spare/emergency lower gates. Miter gates can fail in several different ways with an anchorage-related failure potentially having the most severe consequences. The lower miter gate anchorage at Brandon Road Lock consists of a series of concrete embedded anchor bars connected to the gate leaf through an exposed anchor bar/link pin connection. The details of the anchorage system are provided in Chapter 2 for additional reference. The concern with this PFM is the potential for increased corrosion within the anchorage system that could lead to a sudden failure of the anchorage bars and/or their connections. They are currently in good operating condition, but if stray current from an electrically-charged fish barrier were to accelerate corrosion at these critical gate locations, then gate failure is a distinct possibility. The RA team believed the most likely failure scenario would be if accelerated corrosion were to occur on a section that isn’t accessible and operations continued until a severe misalignment of the gates occurred due to a failure of the weakened section.

Figure 2 - Economic Risk Matrix
This type of failure has occurred recently at other USACE navigation projects with significant economic impacts.

PFM 2: Fatigue related failure of lower miter gate pintle area

The pintle area is the lower section of a miter gate leaf near the lock wall upon which the leaf rotates into position. The pintle area of a miter gate tends to see the highest loading stresses while in operation due to its location and construction techniques that form residual tensile stresses when welding during original construction. When the gates are mitered and under high compressive stresses, this causes a stress reversal that can induce fatigue-related cracking as operating cycles accumulate through time. The stress levels are one concern with this area, but another is the use of different types of metals that make up the connection detail in the pintle area (steel, bronze, and aluminum/nickel). Corrosion rates are usually higher in locations where different metals are joined together. If stray current from the fish barrier were to be added to this situation, then an area of accelerated corrosion could be made worse. Like all other PMFs evaluated as part of this RA, these are concerns that would occur some period after the fish barrier were in place but exactly how soon is unknown because this area of the gate can only be inspected with a dewatering of the lock chamber. The lock chamber at Brandon Road hasn’t been dewatered in 20 years (since the lower miter gates were installed) and there isn’t a plan to do so in the near future. Given all this information, the RA team agreed that a MODERATE likelihood of failure was appropriate for this PFM.

PFM 9: Failure of lower miter gate operating machinery

The RA team assigned a failure likelihood of LOW to the operating machinery of the lower miter gates. Parts of the operating machinery itself are old, but in general, it is in good operating condition. The concern related to stray current is the machinery anchorage into the surrounding concrete. Stray current induced corrosion through the concrete at another Rock Island navigation lock (Lockport) has occurred. This caused the team to be concerned about the long-term operability of the lower miter gate machinery. The RA team thought this would be a slower acting failure mode compared to PFM 1 and 2, but the tolerances associated with the alignment of the machinery are small and can likely only handle minimal offset. If excessive corrosion were to occur at the location where the machinery is anchored into the surrounding concrete, then it may lose structural support and become misaligned to the point it won’t operate properly requiring a shutdown of the lock chamber until repairs can be made.

Economic Consequences

The consequences associated with this evaluation were limited to economic impacts only. Life safety issues weren’t considered. This is not to say they don’t potentially exist, it’s just that they were outside the scope of this evaluation. The biggest economic risk relates to a lengthy shutdown of the lock chamber. Brandon Road Lock is a vital part of the Illinois Waterway navigation system. The lock chamber at Brandon Road processes
anywhere from 2,400 to 3,000 commercial vessels annually based upon the last 5 years of data. This corresponds to about 10-11 million tons of bulk commodities primarily consisting of coal, petroleum, chemicals, grains, and other miscellaneous items. There are a total of 197 lock chambers within USACE and the economic impacts of each were evaluated for a full year lock closure. Brandon Road Lock ranked 52nd out of 197 lock chambers with an estimated annual impact of $325 million in navigation delay costs if the lock were closed for a year. Additionally, there are about 450 recreational craft that transit through the facility on an annual basis. While repair costs associate with the risk-driver PFM’s were included as part of the evaluation, the majority of impacts relate to disruption of navigation.

Recommendations

The RA team developed a list of recommendations as they discussed the various PFMs being evaluated. The list they developed is provided herein.

1. Provide grounding on both sides of lock channel to control stray current in surrounding areas.
2. Line the navigation channel to limit stray current and power consumption.
3. Install parasitic (sacrificial steel) structures around new barrier similar to those at Romeoville site.
4. Make sure ancillary structures near the lock chamber (highway bridge, bridge supports, power plant intake, etc) near the fish barrier are included a baseline corrosion potential survey.
5. Remove any features not being used that would see increases in corrosion, such as select mooring cells in downstream approach (see 2012 PA Report).
6. Any mooring cells that are to remain in place should be included as part of baseline corrosion survey.
7. Schedule a lock chamber dewatering and baseline corrosion survey before fish barrier is installed and on 5-year intervals following installation of fish barrier. The follow-on inspection dewaterings should be done at least twice after the installation of the fish barrier. As a side note, lock chamber at Brandon Road hasn’t been dewatered since 1995 when the lower miter gates were replaced.
8. If stray current known to occur, add cathodic protection system to miter gates, culvert valves, and any other features where applicable.
9. Conduct numerical and experimental modeling to evaluate the potential for stray current reaching the lock and potential mitigation strategies.
10. Conduct a life safety risk assessment before installation of fish barrier.
11. Investigate alternative methods to control invasive aquatic species to ensure the electrical current methodology provides the most effective and safest method of meeting project needs.
12. Investigate power plant intake pipe and determine appropriate actions to take prior to or at the time the fish barrier is constructed.
13. Ensure MVR staff is aware of potential for accelerated corrosion at site and pending measurements of stray current budget increased maintenance for replacement on more frequent schedule (such as electrical controls, etc).
CHAPTER 2: RISK DRIVING FAILURE MODES

Potential Failure Mode Analysis

The first, and perhaps the most critical, step in any RA involves identifying and fully describing PFMs based on an evaluation of a project’s vulnerabilities. If this first step is not done in a diligent and thorough manner, it doesn’t matter what is done for the rest of the evaluation. The results will have significantly less value, and may even lead to incorrect or unsubstantiated conclusions. A failure mode is a unique set of conditions and/or sequence of events that could result in failure. For the purposes of this RA, “failure” is defined as a closure of the lock chamber for a minimum of three days. This was selected based upon potential impacts reaching a threshold of near $1 million. A facilitated PFMA is the process of identifying and fully describing PFMs. A facilitator guided the team members in developing the potential failure modes, based on the team’s understanding of the project vulnerabilities resulting from the data review and current field conditions. The RA team for this evaluation is listed in Table 1.

Table 1. Brandon Road Stray Current Corrosion RA Team

<table>
<thead>
<tr>
<th>Name</th>
<th>Office</th>
<th>Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>David Schaaf</td>
<td>Risk Management Center</td>
<td>Structural Engineer (Facilitator)</td>
</tr>
<tr>
<td>Joseph Schulenberg</td>
<td>Chicago District</td>
<td>Geotechnical Engineer (Project Engineer Lead)</td>
</tr>
<tr>
<td>Jeffery Tripp</td>
<td>Rock Island District</td>
<td>Structural Engineer</td>
</tr>
<tr>
<td>Kent Rockow</td>
<td>Rock Island District</td>
<td>Electrical Engineer</td>
</tr>
<tr>
<td>Michael McInerney</td>
<td>ERDC-CERL</td>
<td>Research Electronics Engineer</td>
</tr>
<tr>
<td>Vincent Hock</td>
<td>ERDC-CERL</td>
<td>Metallurgist/ Physical Scientist</td>
</tr>
<tr>
<td>Michelle Dojutrek</td>
<td>Chicago District</td>
<td>Civil Engineer (DA Intern)</td>
</tr>
</tbody>
</table>

Risk Assessment

The first thing the team had to do was develop a set of working assumptions in order to ensure a consistent evaluation was done for the assessment. The RA team developed the following list of working assumptions:

1. Only consider PFMs directly attributed to the stray current from the fish barrier.
2. No life safety issues will be assessed for this exercise.
3. Team will only evaluate lock features only.
4. Fish barrier at Brandon Road Lock will be the same as the Romeoville Fish Barrier No. 1 (direct current electricity will be used); operating 24/7/365.
5. Install parasitic structures in same manner as current fish barrier at Romeoville.
6. Will consider highway bridge and power plant intake as part of recommendations.
7. Channel will be lined with a dielectric to reduce stray current and reduce power consumption.
8. Install a grounding system as close to the canal as possible (both sides).
9. The spread of current in the water without mitigation will be assumed to have the same dispersion as fish barrier Romeoville.
10. No significant changes (major rehabilitation or structural modifications) to Brandon Road Lock chamber/approach will occur within period of evaluation.
11. Will use latest five year historic average for estimating annual number of commercial vessels and economic impacts.
12. Failure is defined as closure of lock for minimum of three days.
13. Routine O&M will continue for the project.

Table 2. Failure Likelihood Categories

<table>
<thead>
<tr>
<th>Failure Likelihood</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote</td>
<td>Several events must occur concurrently or in series to cause failure, and most, if not all, have negligible likelihood such that the failure likelihood is negligible.</td>
</tr>
<tr>
<td>Low</td>
<td>The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to initiation.</td>
</tr>
<tr>
<td>Moderate</td>
<td>The fundamental condition or flaw is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward “less likely” than “more likely.”</td>
</tr>
<tr>
<td>High</td>
<td>The fundamental condition or flaw is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward “more likely” than “less likely.”</td>
</tr>
<tr>
<td>Very High</td>
<td>There is direct evidence or substantial indirect evidence to suggest it has initiated or is likely to occur in near future.</td>
</tr>
<tr>
<td>Failure Progression Likely</td>
<td>Performance suggests failure is initiating and likely to progress in near future.</td>
</tr>
<tr>
<td>Failure Progression Observed</td>
<td>Performance confirms progression towards failure is occurring.</td>
</tr>
</tbody>
</table>
Table 3. Consequence Categories

<table>
<thead>
<tr>
<th>Consequence Level</th>
<th>Incremental Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Loss ¹</td>
<td></td>
</tr>
<tr>
<td>Very Low</td>
<td>Less than $1M</td>
</tr>
<tr>
<td>Low</td>
<td>$1M to $10M</td>
</tr>
<tr>
<td>Moderate</td>
<td>$10M to $100M</td>
</tr>
<tr>
<td>High</td>
<td>$100M to $1B</td>
</tr>
<tr>
<td>Very High</td>
<td>$1B to $10B</td>
</tr>
<tr>
<td>Extremely High</td>
<td>More than $10B</td>
</tr>
</tbody>
</table>

¹Costs associated with disruption to navigation traffic and repair costs.

Risk Driver Potential Failure Modes

PFM 1: Structural Failure of Lower Miter Gate Anchorage

Description:

During routine operations as the lower gate is being moved, the lower miter gate suffers from a sudden, corrosion-induced failure resulting in significant misalignment of the gate. Once noticed, project personnel stop the operation of the gate and call Rock Island District engineering to assess the situation. An immediate dewatering of the lock chamber is undertaken as soon as the maintenance crew can get to the site. Emergency repairs are initiated to stabilize the lock gate while the chamber is closed. The lock is closed anywhere from 25-45 days depending upon the severity of the damage.

Background:

A set of working assumptions related to the fish barrier at the Brandon Road location are provided at the beginning of this chapter. Those should be referenced for general background information relative to corrosion potential. The lower miter gates at Brandon Road Lock, along with the complete anchorage system, were replaced in 1995. The lower miter gate anchorage system is shown in Figure 3 for reference. The embedded anchorage consists of two 8" diameter forged steel bars (per gate leaf) embedded in the lower miter gate monolith. The embedded anchor bars are A36 structural steel. The exposed anchor links, shown in Figure 4, were also replaced in 1995 during the lower miter gate replacement project. Spares anchor links are available, but they are stored off-site. The anchor links have not been changed out since they were installed. The exposed portions of the lower miter gate anchorage are inspected on a 5-year interval
during Periodic Inspections with the last one being done in 2012. A photograph of the lower miter gate anchorage link connection from the 2012 PI is shown in Figure 5. The Brandon Road Lock is a single lock project that processes approximately 3,000 commercial vessels annually or an average of about 8 per day since the project is open year round. There is an additional 500 recreational vessels that transit through the facility annually as well.

**Historic Performance:**

There have been no known problems with the anchorage system being used for the lower miter gates at Brandon Road Lock. PI reports since the anchorage system was replaced in 1995 don’t detail any performance issues other than minor surface corrosion which is to be expected given 20 years of service. Project personnel also report that they are in good operating condition.

Figure 3 - Brandon Road Lower Miter Gate Anchorage System
Figure 4 - Exposed Anchorage Links (1995 Replacement Plans)
Table 4. Likelihood Factors Table for PFM 1 – Lower Miter Gate Anchorage Failure

<table>
<thead>
<tr>
<th>More Likely Factors</th>
<th>Less Likely Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Increased amount of steel structures (miter gates &amp; valves) in water in the vicinity of the fish barrier</td>
<td>• Implementation of lessons learned from Romeoville at Brandon Road to reduce stray current</td>
</tr>
<tr>
<td>• Embedded anchorage cannot be inspected; Not easily repaired if there is a problem</td>
<td>• Currently anchorage appears to be in good condition</td>
</tr>
<tr>
<td>• Anchorage has no redundancy</td>
<td>• Instrument the anchorage to monitor</td>
</tr>
<tr>
<td>• Threading pattern for design is more fatigue prone than other alternative designs</td>
<td>• Apply corrosion protection technology to the miter gates and anchorages if necessary</td>
</tr>
<tr>
<td></td>
<td>• Distance of fish barrier to lower miter gates (+/-2,500 feet)</td>
</tr>
</tbody>
</table>

BOLD indicates factors of higher importance

Failure Likelihood

Category: **LOW/MODERATE**

The risk assessment team classified this PFM with a LOW/MODERATE likelihood of occurrence. The miter gate anchorage typically serves as one of the more critical
features of successfully operating the gates. One of the concerns is that the embedded portion of the anchorage can’t routinely be inspected to determine if excess corrosion is developing. Also, there isn’t a redundancy for the feature such that if it fails the gates could be operated by other means. These concerns don’t necessarily indicate a very high risk level. The anchorage has only seen about 20 years of service with a moderate level of navigation traffic. There is still ample service life left in the anchorage system based upon historic operating cycles at other USACE locks with similar anchorage systems. Also, implementation of the lessons learned on existing fish barrier projects will be utilized to reduce the level of stray current near the lock structure. If stray current is present after the fish barrier is installed, then corrosion protection measures can be implemented to reduce the likelihood of accelerating corrosion on the anchorage system. After much discussion, the risk assessment team determined that a LOW/MODERATE likelihood of occurrence should be assigned for this PFM. Anchorage failures of miter gates have occurred at multiple other USACE navigation projects for varying reasons. The exposed sections of the anchorage are visually inspected every 5 years. There is no compelling evidence to suggest that a flaw currently exists, but it is possible that is might develop within 20 years after the fish barrier is constructed, especially if stray current is present near the lock. If this were to occur, then it is considered plausible that the failure might manifest itself unless other preventative measures are implemented.

Likelihood Confidence: **MODERATE**

The risk assessment team had a moderate level of confidence in assigning the failure likelihood for this PFM. The application of installing an electrically charged fish barrier in the vicinity of a navigation lock with large steel gates in the water is an unknown issue. While implementation measures will be taken to try and reduce or eliminate the presence of stray current near the lock chamber, it is impossible at this point to determine whether or not that will occur. The team didn’t believe that any of the failure modes evaluated would represent an immediate risk, but the risk would increase through time as the project continues to age.

**Economic Consequences**

Category: **MODERATE ($10 - $100 million)**

If the lower miter gate anchorage were to fail in the manner described within this PFM, then it is estimated that the lock would be out of service anywhere from 25-45 days for emergency repairs. There are no spare anchor bars for the embedded portions of the anchorage. There are spare anchor links, but switching them out would be a tedious exercise after the gate already was misaligned. The entire lock chamber would have to be dewatered and the gate closely inspected to determine if any structural damage occurred. This recently happened on an Ohio River project and lock chamber was closed for about 30 days for immediate emergency repairs to the anchorage system and gate at a repair cost of about $2 million. A temporary repair was implemented because new gates and anchorages were being fabricated that would be installed two years later. Thus, a more extensive, permanent repair of the anchorage system would have
cost more and taken more time. The shipper carrier costs (navigation delay costs) associated with an unscheduled closure of the lock chamber at Brandon Road Lock are estimated as follows:

- 15 days -- $5.7 million
- 30 days -- $18.2 million
- 45 days -- $31.8 million

A closure of 25-45 days would result in navigation delays in the range of $15-32 million using the values provided from the USACE Inland Navigation Center of Expertise. An additional few million dollars of repair costs would be expected based upon recent experience at other lock projects where this failure has occurred; therefore, the risk assessment team estimated the economic consequences as MODERATE for this PFM.

Consequence Confidence: **HIGH**

The risk assessment team had a high level of confidence that MODERATE level consequences were applicable for this PFM. The range of navigation delay costs coupled with physical repair costs were all solidly in the $10-100 million range. Given the recent experience of this event actually occurring recently at another USACE navigation project and the navigation delay costs, there is little information that would likely change the consequence classification for this PFM.

**PFM 2: Fatigue Failure of Lower Miter Gate Body including Pintle Area**

**Description:**

During normal operations personnel at the site noticed some sign of distress at the lower miter gate which would prompt lock personnel to contact engineering for further investigation. Operations and engineering decide to dewater the lock chamber to investigate the cause of the distress. The lock chamber would be dewatered and the lower miter gate leafs would need to be removed to inspect the pintle area. The inspection reveals major distresses such as cracks or section loss that require immediate repair of the pintle area. The lock chamber would be out of service for repair for a minimum of a month depending on the type and extent of distress that was discovered.

**Background:**

The pintle is an important component for the miter gate leafs as this is the location in which each gate leaf pivots between the open and closed position (Figure 6). New lower miter gate leafs were installed as a part of a rehabilitation project that took place in 1995. The work that was associated with the installation of the new lower miter gate included: new miter gate leafs, anchorages, pintles, quoin and miter blocks, and lower sill. The pintle and lower sill involved some concrete work which included cutting and replacing reinforced concrete as shown in Figure 7. After the concrete work was
completed, the new miter gate leafs were installed and tensioned for service. The miter
gate was designed as horizontally framed gate with the main structural members
composed of ASTM A36 steel with a skin plate composed of ASTM A572 Grade 50.
The total weight of one gate leaf without mud, ice, and debris is approximately 194 tons.
The majority of the connections are welded. The pintle is a fixed type and composed of
nickel steel, AISI No. 4820 ASTM A711. The pintle bushing is composed of aluminum
bronce, ASTM B148, Type 954. The pintle shoe is composed of cast steel: ASTM A148,
Grade 90-60. The miter and quoin blocks were composed of ASTM A36 steel. The
presence of dissimilar metals exists between the pintle and surrounding contacts, as
shown in Figure 8.

Figure 6 - Downstream Gate Leaf Showing the Pintle Area
Performance:

Historic performance has been good with the latest performance from inspectors and lock personnel has been documented without problems. A visual inspection of the lower miter gate leafs, from the lock wall and walkways took place in 2012 with no noted deficiencies; however, it is important to note that lower sections of the gate have not been inspected since the gate was installed in 1995. The inspection does not qualify as a hydraulic steel structure inspection described in ER 1110-2-8157. The protective coating on the lower miter gate is original and the portion above water that can be visually inspected is in good condition. The quoin and miter contacts are correctly aligned with only minimal leakage at the contacts. Lock personnel stated that re-tensioning of the each gate leaf has not been warranted since original installation. The only known deficiency is that the return grease line is damaged. This condition was verified when divers inspected the pintle area and determined grease was making it to the pintle and not returning to the zerk located on top of the gate. There are no existing spare miter gate leafs to use in case of an emergency.
Table 5. Likelihood Factors Table for PFM 2 – Lower Miter Gate Fatigue (Pintle)

<table>
<thead>
<tr>
<th>More Likely Factors</th>
<th>Less Likely Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>● The stray current can accelerate the galvanic corrosion caused by the dissimilar</td>
<td>● The gate can take some level of cracking and still perform its function</td>
</tr>
<tr>
<td>metals in the pintle assembly</td>
<td>● Given the age and number of cycles the gate has gone through, the fatigue life is</td>
</tr>
<tr>
<td>● Never been inspected since put in place 20 years ago</td>
<td>low</td>
</tr>
<tr>
<td>● Cannot be inspected unless dewater the lock</td>
<td>● There are no obvious signs that the gates are misaligned since there is no</td>
</tr>
<tr>
<td>● If stray current is present at high enough levels, any steel protective coating</td>
<td>extreme leakage</td>
</tr>
<tr>
<td>would be quickly degraded</td>
<td>● Site personnel should be able to notice signs of distress before gate failure</td>
</tr>
</tbody>
</table>

BOLD indicates factors of higher importance
Failure Likelihood

Category: **MODERATE**

Fatigue-related cracking of welded, heavy steel structures in a river environment are fairly common within USACE. One way to combat this is to have frequent dewaterings with repair schemes that help minimize crack growth. Unfortunately, scheduled maintenance dewaterings for inspections and repairs have not occurred at Brandon Road Lock since the lower miter gates were replaced 20 years ago. Ideally, they should be done on intervals of every 5-10 years if possible. The events that must occur for catastrophic failure to take place would most likely be noticed by lock personnel before this would occur. Signs of distress during normal operation of the gate leafs would likely be noticed by lock personnel prompting further investigation. If the distress was considered serious, the maintenance fleet from the repair station in Peoria, IL would travel to the site and dewater the lock for inspection and repairs. The presence of dissimilar metals, coupled with any stray current from the fish barrier, would intensify the galvanic corrosion between the pintle and surrounding contacts. The RA team considered all the information and agreed that the likelihood should be classified as MODERATE when considering the time dependency aspects of the failure.

Likelihood Confidence: **MODERATE**

As noted earlier, the RA team struggled a bit with the time dependency of this performance mode. It is also unknown whether or not a stray current mitigation system will be installed to provide an effective means to protect lock structures (pintle area). It is also unknown if stray currents from the fish barrier will even effect the pintle area because the distance the current will travel to adversely impact the gates. More studies such as numerical and physical models may help increase the confidence of the likelihood of failure to take place.

Consequences

Category: **MODERATE ($10 - $100 million)**

In the case that problem exists and a dewatering of the lower miter gate would take place to inspected/repair the pintle area, it is known that the lock would be shut down for at least a month if not longer. The scope of repairs to take place would depend on the extent of damage that would be discovered after the pintle area was inspected. The permanent repair costs could be fairly extensive, but it would still be considerably less than the impacts associated with the stoppage of navigation through the lock chamber. The team agreed the overall cost would easily fall into the $10 - $100 million range for this PFM.

Consequence Confidence: **High**

Same justification as PFM #1.
PFM 9: Failure of Lower Miter Gate Operating Machinery

Description:

This PFM involves the failure of the lower miter gate operating machinery anchorages embedded in the concrete lock wall. During normal operations, lock personnel at the site notice signs of distress in the lower miter gates. The distress is traced back to the miter gate machinery. It is determined that the cause of the failure is deterioration of machinery support anchors embedded into concrete (see Figure 9). It is determined that stray current corrosion caused by the electric fish barrier contributed to excessive corrosion and failure of the anchored guides. The district takes the lock out of service to realign and/or repair the machinery. During inspection of the other anchorages, it is noted they too are in an elevated state of deterioration. The chamber is out of service for a minimum of three to four weeks as the operating machinery is realigned and tested for both gate leaves.

Figure 9 - Brandon Road Lock Lower Miter Gate Bull Gear
Background:

The lower miter gate leaves are operated by a strut arm attached to a wall mounted bull gear driven by a pinion gear through an electric motor-driven gearbox. Each miter gate leaf is operated individually by a complete gear reduction system. Controls for the miter gate operating machinery are located in control houses on the land and river walls. Adjustment is provided by the spring-loaded strut arm. The existing bull gear and strut assemblies are part of the original lock construction. Even though they are old, they are in good working order. All other lower miter gate machinery was replaced in the 1980’s as part of a rehabilitation of the lock chamber. During the 2012 PI inspection, very minor corrosion of the lower miter gate bull gear teeth was noted (as shown in Figure 10). There were no problems noted with the guide gear reduction anchors.

![Figure 10 - Lower Miter Gate Bull Gear Teeth](image)

Performance:

Historic performance has been good. On the downstream right leaf, the bull gear/strut arm connection is exhibiting minor excess movement due to wear on the lower miter gate. The district continues to monitor this connection but there are no recommendations to replace it at this point in time. There were no other noted deficiencies in the miter gate operating machinery during the last PI in 2012. General corrosion was observed on various aspects of the lower miter gate operating steel and grating cover supports, but these were considered normal for their age.
Table 6. Likelihood Factors Table for PFM 9 – Lower MG Operating Machinery

<table>
<thead>
<tr>
<th>More Likely Factors</th>
<th>Less Likely Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Machinery anchorage in direct contact with concrete</td>
<td>• Gate seems to be properly aligned, no current machinery issues</td>
</tr>
<tr>
<td>• Machinery has some relatively tight tolerances</td>
<td>• Visually see the area, can be inspected for issues</td>
</tr>
<tr>
<td>• Minor corrosion already present</td>
<td>• Slow acting failure mode, should have ample warning time before it affected structure of the gate</td>
</tr>
<tr>
<td></td>
<td>• Have ability to monitor this area</td>
</tr>
</tbody>
</table>

**BOLD** indicates factors of higher importance

**Failure Likelihood**

**Category: LOW**

One of the major concerns with the construction of an electric fish barrier located approximately 2,000 feet from the lower miter gates is stray current corrosion occurring at the concrete/steel anchorage interface. Initially, the externally induced stray DC current would flow through the concrete lock wall taking a path of least resistance which includes the steel bull gear anchors embedded in the concrete lock wall. Based on the path of least resistance, the external stray current would flow through the canal water on to the steel miter gates and into the concrete lock wall assuming the concrete is saturated with water (approximately 17.4 weight %). As the stray current flows through the concrete matrix, embedded steel is subjected to addition corrosion. The process of stray current corrosion is electrolysis and will result in significant accelerated metal loss and loss of bonding between the concrete and steel anchorage allowing the lower miter operating machinery (bull gear and strut) to move outside of its tolerance and become inoperable if not corrected. The breaking of the bond with the concrete from the corroded steel is caused by the volumetric expansion the rust or iron oxide layer. This process is similar to the cracking and disbandment of the concrete from the embedded reinforcing steel in bridges.

Most likely, project personnel at the site would notice the accelerated corrosion of the exposed portion of the steel machinery anchors before the gates would become misaligned, but portions of it are only visible with removal of grating. One of the biggest reasons why this failure mode is considered LOW is that there are other less resistive paths for the induced stray current from the electric fish barrier to flow onto the lock structure such as the lower steel miter gates and emptying valves which are immersed in the water at all times. Since this believed to be a relatively slow acting PFM and there are other more prominent paths to collect the stray current, the RA team categorized this as having a LOW likelihood of failure.
Likelihood Confidence: **MODERATE**

As previously described, the rate of accelerated corrosion of the steel embedded machinery anchors is directly proportional to the magnitude of stray current passing through the concrete onto the steel. This failure mode is time dependent. Until the actual amount of stray current flowing from the electric fish barrier onto the lock structure is quantified, rate of accelerated corrosion in mils/yr cannot be quantified; therefore, a confidence classification of moderate is justified.

**Consequences**

Category: **MODERATE ($10 - $100 million)**

If the lower miter gate operating machinery were to fail in the manner described within this PFM, then it is estimated that the lock would be out of service anywhere from 3-4 weeks for emergency repairs. There are no spare machinery parts for the lower miter gates. The entire lock chamber would have to be shut down because of the inability to move the gates. The shipper carrier costs (navigation delay costs) associated with an unscheduled closure of the lock chamber at Brandon Road Lock are estimated as follows:

- 15 days -- $5.7 million
- 30 days -- $18.2 million

A closure of 3-4 weeks would result in navigation delays in the range of $10-20 million using the values provided from the USACE Inland Navigation Center of Expertise. An additional few million dollars of repair costs would be expected based upon recent experience at other lock projects where this failure has occurred; therefore, the risk assessment team estimated the economic consequences as MODERATE for this PFM.

Consequence Confidence: **MODERATE**

The risk assessment team had a moderate level of confidence in assigning the consequence categorization for this PFM. The team was less familiar with this type of repair as compared to those associated with PMF1 and PMF2. While the team believes it would fall within the moderate level category, there is a possibility that the classification of the category could change due to the level of damage not being as severe as currently estimated.
CHAPTER 3: EXCLUDED POTENTIAL FAILURE MODES

PFM 3: Upper Miter Gate Anchorage (Look at Starved Rock Dresden)

The upper miter gate anchorage, shown in Figure 11, has been in service since original construction. While this feature has seen many years of service and may require rehabilitation in the future, this PFM is excluded in part due to the location of the upper miter gate anchorage relative to the proposed location of the fish barrier. Since this evaluation strictly relates to induced corrosion from the fish barrier, it is unlikely that the upper miter gate anchorage system would see much additional corrosion due to its distance from the fish barrier and the fact there are many other large steel structures within the water located closer to the barrier on the downstream portion of the lock. These would pick up the stray current prior to reaching the upstream miter gate anchorage. It is also important to note that there is a set of upper guard gates located just upstream of the upper miter gates that could be used in the event of a failure of this feature although special procedures would have to be implemented to move the gates for vessel transits.

Figure 11 - Upper Miter Gate Anchorage
PFM 4: Upper Miter Gate Fatigue

PFM #4 is excluded for many of the same reasons as listed previously in PFM #3. The upper miter gates are significantly further away from the fish barrier than the downstream features of the project. Stray currents that may be measurable near the structure will likely be negligible due to diffusion into other lock structures downstream of the upper miter gate. The upstream miter gates are depicted in Figure 12 as are also part of the original construction. In 2013, MVR Operations removed the service gates and replaced them with the emergency gates. During that time, the service gates were rehabbed which includes removal of damaged members and replacement with similar metals, then finished by blasting and painting prior to installing for service. This should continue to provide many years of service assuming normal operations and maintenance continues.

Figure 12 - Upstream Miter Gate

PFM 5: Failure of Wall Armor

This PFM consists of multiple runs of thin steel armor along the sides of the lock wall and guide walls at Brandon Road Lock (see Figure 13). It is used to help protect the
concrete walls as barges travel through the lock chamber. Lock wall armor systems typically experience various levels of damage due to a large number of vessels passing through locks. The result of damaged wall armor includes gouges, mangled armor, and spalls in the concrete adjacent to armor strips. When armor is worn flat, it is no longer effective in protecting the concrete behind it. Lock wall armor is a routine operation and maintenance item due to the damage it incurs during normal operations. Any failed wall armor is usually localized in nature such that it won’t adversely impact lock operations. The repair would be relatively quick and the maintenance staff is used to making these types of repairs. This supporting information provides ample justification for exclusion as a risk-driving PFM for this assessment.

Figure 13 - Wall Armor on Lock Wall near Lower Miter Gates

**PFM 6: Failure of Floating Mooring Bits**

PFM #6 is excluded due to the redundancy of mooring bits available in the lock chamber. Brandon Road Lock has both floating mooring bits embedded in the lock wall chamber, see Figure 14, and stationary check posts (buttons) on top of lock wall. In the event that a floating mooring bit is no longer functioning as designed, lock personnel would instruct deck men on the barge to use the other floating mooring bits that are available or the check post located on the lock wall. The lock can still process vessels without floating mooring bits. Repairs could be made around barge traffic as to prevent a shutdown of the lock. Therefore, this PFM is excluded from further consideration.
PFM 7: Structural Failure of Culvert Valves

This PFM is associated with a structural failure any of the four culvert valves that make up the filling and emptying system for the Brandon Road lock chamber. The filling and emptying system consists of two independent filling valves and two independent emptying valves that raise and lower water levels in the lock chamber through gravity. The valves at Brandon Road Lock consist of steel vertical slide gates. Accelerated corrosion of the slide gates is a concern if stray current is present at the project. The primary reason this PFM was considered a non-risk driver is because of the redundancy associate with having multiple filling and emptying valves. Since a single valve can be isolated for repair with the chamber still operating at a lower processing speed, there isn't significant enough consequences associated with a failure of a single valve. In order for the lock chamber to be closed due to valve failures, both filling valves or both emptying valves would have to fail at the same time. The likelihood of this occurring is remote. This supporting information provides ample justification for exclusion as a risk-driving PFM for this assessment.
PFM 8: Structural Failure of Filling / Emptying (F/E) Trash Racks

This PFM addresses failure of the F/E trash racks due to stray current corrosion. Trash racks are needed to protect gates, valves, or turbines from debris that may enter the intakes or outlets at locks, dams, and power plants. At Brandon Road Lock, trash racks are used to prevent clogging and debris damage to the filling and emptying control gates. An example of a trash rack is shown in Figure 15 for reference. Trash racks were installed at the Brandon Road Lock filling conduits in 1972. Spare trash racks are available at the site. Stray electrical currents from the fish barrier could increase the corrosion rate of the metal components of the steel trash racks causing them to fail over time. It is unlikely that failure of a trash rack would not stop navigation. If a failure should occur and debris were to clog one of the filling or emptying control gates, the lock could continue to operate, but in a reduced capacity. A short duration closure may be required for clearing of the clog and replacement of the trashrack.

Figure 15 - Example of a Trash Rack

PFM 10: Failure of Upper Miter Gate Machinery (excluding electrical features)

This PFM consists of potential corrosion related failure of the upper miter gate machinery due to induced stray currents causing accelerated corrosion to the point of machinery structure failure. The miter gate machinery consists of large bull gears, strut arms, and a gear box driven by an electric motor (see PFM 12). The bull gears and strut
arms are from the original 1933 construction. The remaining miter gate machinery was rehabilitated in 1980's.

A failure of this machinery is considered similar to a failure of the lower miter gate machinery (risk-driving PFM) except the consequences would be considerably less due to the presence of the upstream guard gates which could be used with special procedures. The lower miter gate anchorage doesn't have that type of redundancy since there is only a single set of miter gates on the lower end. Secondly, the fish barrier is located much further away from the upstream end of the lock chamber and most, if not all, stray current should be diffused by the time it were to reach the upstream miter gate machinery location.

**PFM 11: Failure of Valve Machinery (excluding electrical features)**

This PFM consists of potential corrosion related failure of the filling and emptying valve machinery due to induced stray currents causing accelerated corrosion to the point of machinery structure failure. The filling and emptying valve machinery consists of a hydraulic pump driven by an electric motor (see PFM 12) at each of four valves, two independent filling valves located at the upper end of the lock, and two independent emptying valves located near the lower end of the lock. The valve machinery was rehabbed during a 1969 rehabilitation.

The likelihood of a navigation closure of 3 days or more due to a valve machinery failure would be considered remote due to redundancy of equipment on both ends of the lock. A failure of both valves on either the upper or the lower end would be required to stop navigation, and is considered a highly unlikely event. If one valve were to fail, the repairs could be isolated while continuing to allow navigation traffic flow thru the lock. One valve failure would not generate sufficient consequences, and therefore is justified for exclusion as a risk driver.

**PFM 12: Failure of Electrical Motors and Lock Controls**

This PFM consists of potential corrosion related failure of the electrical motors and lock controls due to induced stray currents causing accelerated corrosion to the point of operational failure. The motors and lock controls consists of 480 volt, 3-phase electric motors, 25 hp at each of four hydraulic valve machinery equipment locations, and 30 hp at each of four miter gate machinery locations at the four corners of the lock. The gate and valve motors appear to be original equipment from the 1930’s construction installation. The controls consist of motor starter contactors, control relay contactors, pushbuttons, selector switches, limit switches, and rotating cam limit switches, some of which are housed either in the main lock house, control stands at each corner of the lock, individual machinery equipment enclosures, or in the I-wall switchboard. The I-wall switchboard is of particular significance due to exposure to weather and concrete. Its location is further (~half the length of the lock) from the proposed electric fish barrier site, which is considered lower risk of stray current related corrosion acceleration.
A recent inspection of a nearby lock (Lockport) with similar conditions to Brandon Road Lock, has revealed excessive accelerated corrosion of controls contactors, conduits, pipes and support hardware in contact with concrete. Multiple contactors have had corroded terminals and contacts to the point of requiring replacement after a year of service. This finding is only noted to highlight similar conditions and increased possibility for accelerated corrosion at the Brandon Road site.

The likelihood of a navigation closure of 3 days or more due to a motor or lock controls failure was considered to be remote due to redundancy of equipment on both ends of the lock, and a spare motor was noted to be available on site for replacement should a motor fail. Replacement of a gate motor would require about two days worth of work, but the miter gate could still be operated by helper boat during repairs to allow navigation to continue at a slower processing speed. The lower consequences associated with this PFM is the primary reason it was screened from further consideration.

**PFM 13: Structural Failure Mooring Cell Interlock**

The mooring cells located closest to the electric fish barrier are in the lower canal approach to the lock chamber as shown in Figure 16. No drawings could be located for these particular mooring cells, but there were mooring cell details located for the upstream cells. The upstream mooring cells consist of a sheetpile cell that has a concrete base that is a minimum 3 ft in thickness which bears on bedrock. On top of the concrete base the cell is filled with gravel, and capped with concrete. It would be reasonable to assume that the downstream mooring cell is of similar construction as the bedrock conditions are similar. The downstream mooring cells on the left descending bank are in various conditions. One of them is in very poor condition (showing signs of being unstable) while the condition of the others is operational, but really unknown below the water line. There is surface rust located near the water line that is common when compared to similar structures at other locations. According to project personnel, current practice is that the barge will wait downstream of the conveyor belt that is located near the Joliet power plants 7 and 8, approximately 1.5 miles downstream of the lock chamber and outside of the canal approach. Since these structures typically aren’t used and the ones located downstream of the lower approach wall are well out of the navigation canal, this PFM was excluded as a risk-driver.
PFM 14: Failure of Power Plant Intake Pipe

This PFM relates to the nearby power plant intake pipe located downstream of the Brandon Road Lock near the site of the proposed fish barrier (see Appendix A for relative location). Any stray current that reaches the power plant intake pipe would not have any effect on the ability to pass navigation traffic through the lock. Therefore, it doesn’t meet the definition of failure as defined for this exercise; however, this structure should be included as part of the baseline corrosion potential survey to determine if potential stray current will have an effect on it.

PFM 15: Structural Failure of Bridge Supports

The location of the Brandon Road Lock Bridge is also shown in Figure 16. The bridge is a double lift span that carries vehicular traffic over the lower approach. The failure mechanism of concern for this structure is the uptake of current from an electrically charged canal into the Brandon Road Bridge support structure. The general process is shown in Figure 17 where stray current from the fish barrier enters and discharges within the reinforcing steel causing a failure of the reinforced section of the bridge.
supports. This has the potential to lead to a bridge collapse if any significant stray current were present and left to degrade over time without remediation.

![Diagram of typical stray current interference on a metallic underground structure](image)

**Figure 5.1** – NACE Figure of Typical Stray Current Interference on a Metallic Underground Structure

**Figure 17** - Mechanism for Corrosion of Metal due to Stray Voltage (NACE)

The team deemed this failure mechanism to be a non-risk driver for several reasons. First, the bridge piers are not directly in contact with canal water and the source of stray current (fish barrier) will be about 2,000 feet from the bridge. Next, this is likely to be a very slow acting failure process and the bridge is frequently inspected by the Illinois DOT (every 2 years). Corrosion potential surveys could be performed on the rebar both before installation of an electrified barrier and after to assess the potential for corrosion. Finally, there are methods of reducing the likelihood such as installing ground rods tied to a conductor around the bridge piers as was done for the 135th Street Bridge in Romeoville (see Figure 18).

![Diagram of method used at 135th Street Bridge to create an equipotential plane around the bridge reducing the likelihood of corrosion of reinforcing steel](image)

**Figure 18** - Method used at 135th Street Bridge to Create an Equipotential Plane Around the Bridge Reducing the Likelihood of Corrosion of Reinforcing Steel
PFM 16: Failure of Concrete Rebar in Lock

This PFM consists of accelerated corrosion of embedded rebar in the lock chamber. The horizontal and vertical surfaces of the landwall are generally in good condition. The vertical surface has typical spalls and abrasion damage, but nothing out of the ordinary given the age and use of the facility. The horizontal and vertical surfaces of the riverwall are generally in good condition. The riverwall has more damage on the vertical surface than the landwall but nothing considered alarming. Accelerated rebar corrosion caused by stray electrical currents from the electric fish barrier could result in isolated spalling of the concrete as the rebar expands with corrosion forming internal stresses in the abutting concrete. This has the potential to result in spalls of relatively large size; however, it was deemed a remote likelihood that the spalls would require a lengthy chamber shutdown. Isolated repairs could be made around barge traffic if necessary or very short-term closures (< 3 day duration) could be used to patch any significant spalling.

PFM 17: Structural Failure of Lower Guidewall Bullnose Cell (Loss of Interlock)

This PFM consists of a structural failure (loss of sheetpile interlock) of the downstream bull nose at the end of the landside guidewall. This location of the downstream guidewall bull nose is shown in Figure 19. This structure consists of a sheetpile cell that is integral with the guidewall. Any stray current emanating from the fish barrier would likely be first attracted to this steel faced structure since it is closer than the lock chamber. Accelerated corrosion of the steel sheets would be a concern if the cell was filled with granular material or gravel, but this is a concrete filled cell placed to resist barge impact loads. Since the steel sheetpiles essentially only served as formwork for the concrete placed inside the cell, there shouldn’t be any performance issues associated with corrosion of the steel facing; thus, this PFM was excluded as a risk-driver.
Figure 19 - Lower Guidewall Bull Nose at Brandon Road Lock