First Draft - Preliminary Engineering Assessment of the Feasibility and Estimated Cost of Installing a State-of-the-Art BAFF Carp Deterrent at Mississippi Lock and Dam 5

Mississippi River Lock and Dam No. 5

Prepared for the University of Minnesota

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Certifications

I hereby certify that sections **1, 2, 3.2, 3.2, 3.5, 4, and 5** of this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

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Mark Ziemer MN PE #: 16122	Date

Abbreviations

AACE	Association for the Advancement of Cost Engineering
BAFF	Bio-Acoustic Fish Fence
CFD	Computational Fluid Dynamics
CWA	Clean Water Act
DNR	Department of Natural Resources
FGS	Fish Guidance Systems
FT	Feet
FT/S	Feet per second
GFBB	Graduated pulsed DC field electrical deterrent barrier
LD	Lock and Dam
NEPA	National Environmental Policy Act NEPA
OHWM	Ordinary High-Water Mark
SHPO	State Historic Preservation Office
WQC	Water Quality Certification
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service

Executive Summary

Previous evaluations by the Barr Engineering Co. (Barr) and the Sorensen research team (Dennis et al , ref. (1)) and Barr (ref. (2)) have demonstrated that there is considerable potential to block uncontrolled movement of invasive carp at Lock and Dam 5 with other sites downstream being less desirable. A key component to blocking carp at Lock and Dam 5 would be the addition of a carp deterrent system to the navigation lock where 5 to 10% of upstream moving carp would be expected migrate. This engineering assessment evaluated the feasibility and possible cost of adding such a carp deterrent. Results of the assessment are as follows:

1) Lock and Dam 5 is the only dam south of Lake Pepin that provides suitable conditions for adding a carp deterrent.
2) Of the existing commercial carp deterrent systems, a bio-acoustic fish fence (BAFF) is the most appropriate. Existing data suggests its efficacy and safety are adequate to meet needs.
3) The physical configuration of the navigation lock at Lock and Dam 5 is amenable to adding a BAFF.
4) Power supplies at Lock and Dam 5 can be upgraded to support a BAFF
5) The bottom topography at Lock and Dam 5 can support a BAFF.
6) The auxiliary lock at Lock and Dam 5 can be modified to support a fish elevator system to promote native fish passage (and carp removal) to offset possible effects of the BAFF on native fish.
7) The 18,500-foot earthen embankment associated with Lock and Dam 5 is only penetrated by four 3- to 4-foot-diameter culverts However, these culverts are impassible to all but a few select sizes of carp during select flood events.
8) Permitting requirements for adding a BAFF to Lock and Dam 5 have been identified and can be met.
9) The likely cost of adding a BAFF would range from $8,250,000 to $16,500,000 (AACE CLASS 4).
10) Possible human and operational risks of adding and operating a BAFF at Lock and Dam 5 have been identified and are all addressable.

Preface

This assessment was funded by the University of Minnesota using LCCMR funding to address the potential of adding a carp deterrent at Lock and Dam 5 to stop the uncontrolled invasion of invasive carp in Minnesota via the Mississippi River. Lock and Dam 5 was chosen for this study because previous engineering and biological assessments (ref. (2), ref. (1)) have shown that all four locks and dams south of this location are very permeable to the upstream passage of invasive carp because their spillways gates are either open frequently and/or their associated spillways/submersible dams frequently overtop. Whitty et al (ref. (3)) also show that a deterrent with as little as 66% efficiency could be placed in the lock at Lock and Dam 5; up to 98% of all carp could be prevented from entering Lake Pepin and moving further north. Invasive carp are highly efficient filter-feeders that likely would cause severe ecosystem disruption and a loss of recreational fisheries in Minnesota if they were to pass into Lake Pepin where breeding opportunities also appear to exist. Mature adult invasive carp are presently found in large numbers in Pool 8 (MN) so action north of Pool 8 at Lock and Dam 5 would be timely. This engineering assessment confirms that a BAFF carp deterrent with at least 66% efficiency could be installed at Lock and Dam 5.

(Although this report is considered preliminary all data presented are valid. A final report with more detail and some updates will be published in June 2022.)

1 Introduction

Four species of carp from Asia (bighead, silver, grass, and black) were inadvertently allowed to escape into the Mississippi River in Arkansas in the 1960s. Two of these fish species (bighead and silver carp, together known as 'bigheaded carp') are of extreme concern to river ecology and fisheries because they are highly efficient filter-feeders that compete for food with native fishes and can jump up to 9 feet out of the water, endangering anglers and other recreational users. Bigheaded carp (carp) now comprise up to half the fish biomass in some sections of the Mississippi River to the south of Minnesota where millions of dollars are being spent on their removal with limited success. Many fishes, including some of recreational importance, are notably of smaller size and number in these regions of high invasive carp abundance. The Sorensen research team at the University of Minnesota has identified locks and dams (LDs) – which regulate depth in the Upper Mississippi River – as a critical weakness in the expansion of these invasive carp. This is because carp, like all river fish, must pass through LDs to move upstream. However, their ability to do so is restricted by the infrastructure and associated high water velocities at these sites. LDs represent valuable pre-existing opportunities to control movements of invasive carp. Facilities and construction at all LDs are site specific with some representing much better opportunities to stop Carp than others. Local hydraulic conditions, operational differences, or specific design features can be more or less conducive for carp deterrence. Adult invasive Carp are now being routinely captured in Pool 8 (near Crescent Minnesota) and could breed, so it is important to stop their further movement upstream.

Lock and Dam 5 (LD5) has previously been identified as the best place to stop carp's upstream movement south of Lake Pepin and other key MN waterways (Appendix A). This conclusion was reached by engineering and biological analysis which demonstrated the following:

1) Unlike all LDs located to its south, LD5 lacks submerged spillways or other structures that Carp could use to swim around (Figure 2-1). Although LD5 does have four bypass culverts, they are very small (3- to 4-foot-diameter each, making up less than 15 feet of 18,500 feet (<0.1%) of a high earthen dam located to the east of LD5). In the event carp find these openings, only the largest (10%) can pass them during a 5-year flood (see Appendix C of this report). If stakeholders decide this to mitigate this risk, barrier options do exist.
2) The spillway gates of LD5 infrequently (less 2.5% of time in a typical year) open wide enough to allow invasive carp to pass (vs. an average 13% for typical LDs) and Whitty et al. (ref. (3)) has shown how the US Army Corps of Engineers (USACE) could, at no additional cost, adjust gate openings to further reduce passage through these structures.
3) Initial descriptions (Appendix A) of the 110-foot lock at LD5 suggest that it is suitable for the addition of a carp deterrent barrier similar to the one recently developed and is being successfully tested in Kentucky (ref. (1)).
4) LD5 also appears suitable for the addition of a native fish passage structure so any potential effects of adding a carp deterrence barrier could also be remediated.
5) Pool 5 above LD5 appears suitable for carp removal by the MN and WI DNR and also predator management strategies which would greatly enhance the value of a carp deterrent barrier at this location.

6) Zielinski and Sorensen (ref. (1)) have calculated that a deterrent with an efficiency of 66% would result in a near 99% block at LD5 (and Lake Pepin located to it north) where it to be installed in the navigation lock.

The purpose of this assessment was to determine if and how a carp deterrent could be installed at LD5 and to provide an initial cost estimate based on completing a 10% design. This assessment follows Barr Engineering Co.'s earlier report (ref. (2)) which showed that LD5 (and LD4) were the only suitable locations to block carp south of Lake Pepin. The main sections of this report cover the following:

1) Engineering overview of LD5 and its suitability to stop carp.
2) Assessing available commercially available deterrent barriers, including whether a bio-acoustic fish fence (BAFF), is the most appropriate technology for the lock at LD5.
3) Assessing whether the lock at LD5 could accommodate a BAFF by developing a 10% layout and design basis for the lock deterrent.
4) Assessing the probable development and construction cost of installing a BAFF to the lock at LD5.
5) Assessing future design phases, risks, and schedule for installing a BAFF at LD5.

2 Engineering Overview of Lock and Dam 5 and Invasive Carp

2.1 Overview of the Carp Problem and Lock and Dam 5 as a Solution

This section will be further developed in the final feasibility report scheduled for submittal by June 30, 2022.

2.2 Lock and Dam 5 Site Layout and Potential to Stop Carp Passage

Lock and dams (LDs), of which the US Army Corps of Engineers (USACE) maintains 29 north of St. Louis for the purposes of navigation, inherently impede upstream migration of fish by virtue of their significant infrastructure which spans the river. Lock and Dam 5 (LD5), like all LDs, has three components which could permit fish passage: (1) a navigation lock through which boats pass, (2) a spillway dam whose gates are adjusted (opened and shut) to maintain water depth for the lock, and (3) an embankment dam which protects the river shoreline (Figure 2-1). These structural components and their specific abilities to pass Carp and other fishes at LD5 are described below:

- **LD5's Navigation Lock**: LD5 has a single 110-foot-wide x 600-foot-long lock on its west bank to permit vessel passage (Figure 2-2). This lock is composed of an upstream and downstream set of miter gates, one of which is always closed. Both gates are closed during transition of the water elevation between upstream and downstream elevations. A culvert system embedded in this lock's concrete walls contains a series of ports and four valves to manage the water level in the lock as shown in Figure 2-2. Carp and other fish can "lock through" LD5's miter gates along with vessels whenever these gates are opened. Because there is little flow though the lock, this feature presents the greatest risk for carp passage. Whitty et al. (ref. (3)) calculate that about 5-10% of all upstream swimming carp may find this route. Coincident with miter gate opening, the locks have series of discharge ports that open to drain the lock and also could permit passage and need to be protected. The entire LD including the lock is submerged during rare floods that occur once a century and could in theory permit fish passage at that time (Figure 2-3 and Table 1). LD5's lock is very similar in design to other USACE locks including the one at Barkley Dam which currently has a BAFF deterrent.

- **LD5's Spillway Dam:** LD5 has a 1619-foot-long spillway dam with five roller gates and 28 tainter gates located to the west of the lock. Although these spillway gates are usually partially open, a variety of hydrodynamic calculations, numeric modeling, and empirical fish tracking studies have shown that conditions allow for upstream carp passage only when the gates are nearly fully open – a condition known as "open river". This also follows the assumption that the tailwater is higher than the gate sill which is the case for LD5 as shown in Figure 2-4. On average, this condition occurs less than 2.5% of the year, the least of any major LD in the Upper Mississippi River south of Lake Pepin, making it the most suitable place to control carp (ref. (2)). Further, spillway passage rates could be further reduced by modifying spillway gate settings in line with UASCE requirements (ref. (2)).

- **LD5's earthen embankment dam**: LD5 has an embankment dam that is not penetrable by fish unless a flood exceeds a 500-year (0.02 exceedance probability) event at which point it would also overtop the entire structure (and all those downstream) as shown in Figure 2-3. No event in the history of the dam has exceeded this elevation as shown in Table 3. There are also two sets of small conduits, called aeration culverts, that pass through the embankment dam that serve to provide water to the wetland downstream of the embankment dam. However, calculations show these culverts to be largely impassable (Appendix C).

2.3 LD5's Hydraulics and Hydrology and their Suitability to Accommodate a Carp Deterrent

The hydraulics of LD5 are suitable for installation of a carp deterrent barrier. The USACE maintains a 9-foot-deep navigation channel to provide sufficient draft for loaded barges. This water depth is also required over a carp deterrent system. Analysis shows that all deterrent system components within the lock width would be below the miter gate sill at elevation 638.6 feet (NAVD 88 vertical datum) which is approximately 12 feet below the normal tailwater elevation (Table 3). This analysis used daily headwater and tailwater measurements between 1934 and 2021 provided by the USACE. Annual peak headwater and tailwater elevations were ranked and assigned an approximate exceedance probability based on how often they had been exceeded during the period of record. The headwater elevation and tailwater elevation frequency estimates are shown in Table 3. Since the headwater and tailwater elevations are affected by the operation of the dam, an approach like those typically used for flood frequency estimates was not considered.

Figure 2-1 Lock and Dam 5 site

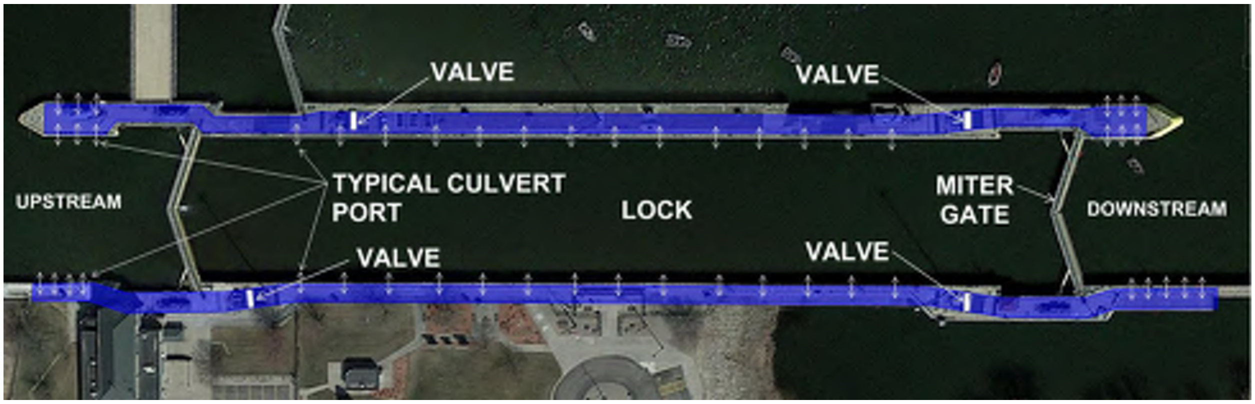


Figure 2-2 **Lock layout and discharge ports**

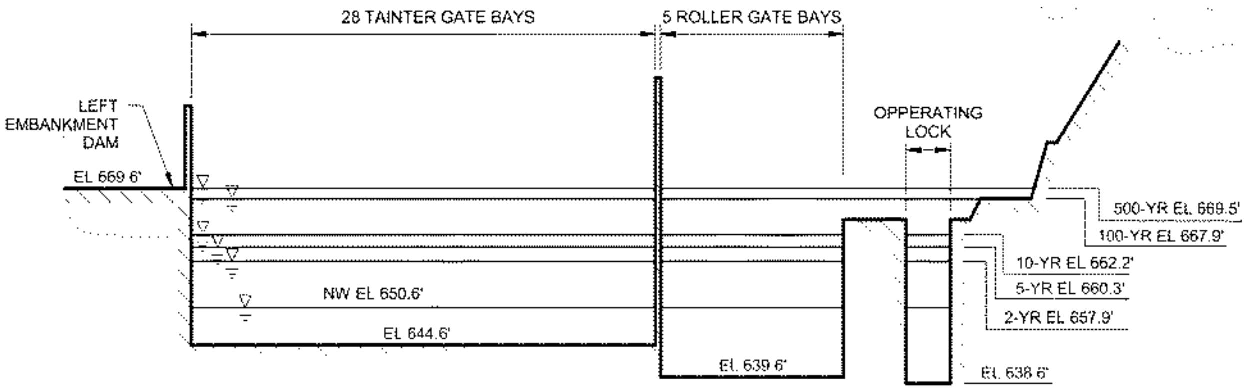


Figure 2-3 **Lock and Dam 5 profile looking downstream (looking south) with tailwater elevations**

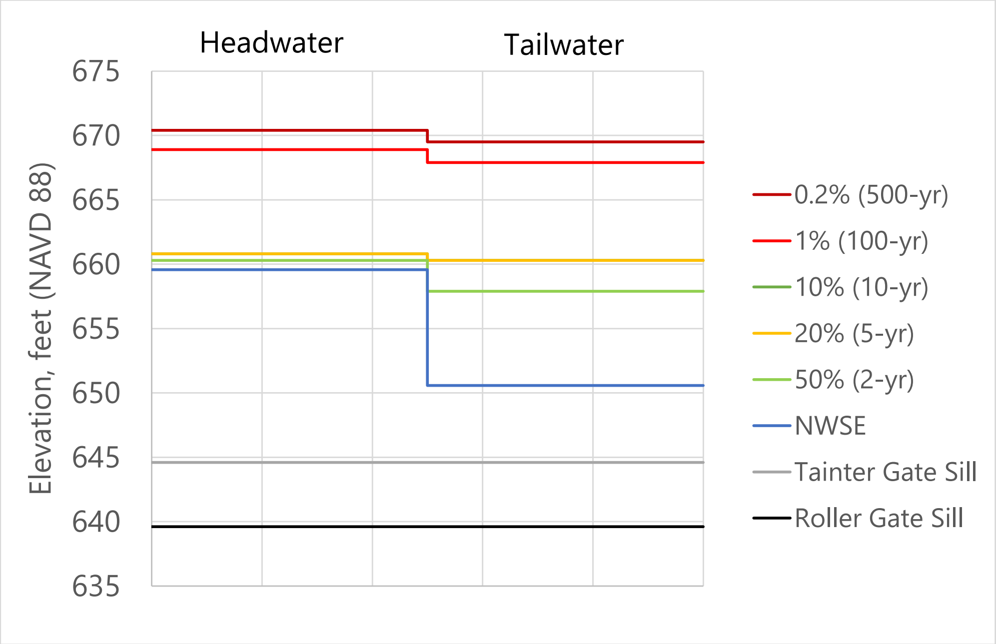


Figure 2-4 **Headwater and tailwater surface elevations for different flood events relative to spillway sills**

Table 1 Lock and dam above water feature and prudent historic flood elevations

Feature	Elevation, ft[1]
Lock walls	664.6[2]
2001 Flood	666.6[3]
East side embankment dam crest	669.6[2]
1965 Flood	668.7[3]

Notes:
1) Vertical datum: NAVD 88
2) As noted in Lock and Dam 5 water control manual
3) As noted on onsite plaques

Table 2 Lock and dam below water feature elevations

Feature	Elevation, ft[1, 2]
Lock miter gate sill	638.6
Roller gate sill	639.6
Tainter gate sill	644.6

Notes:
1) Vertical datum: NAVD 88
2) As noted in Lock and Dam 5 water control manual

Table 3 Headwater and tailwater annual exceedance elevations

Annual Exceedance Probability	Headwater, ft[1]	Tailwater, ft[1]	Water Depth, ft[1, 2]
Normal Water Elevation[3,5]	659.6	650.6	12.0
50% (2-yr)	660.3	657.9	19.3
20% (5-yr)	660.8	660.3	21.7
10% (10-yr)	662.8	662.2	23.6
2001 Flood	666.6	666.6[4]	28.0
1% (100-yr)	668.9	667.9	29.3
1965 Flood	668.7	668.7[4]	30.1
0.2% (500-yr)	670.4	669.5	30.9

Notes:
1) Vertical datum: NAVD 88
2) Water depth over miter gate sill elevation
3) As noted in Lock and Dam 5 water control manual
4) As noted on onsite plaques
5) Given Mississippi Lock and Dam 5 is a navigation lock, pool elevations are tightly controlled and consistently maintained meaning the normal water elevation and low-level water elevation are the same

3 Commercially Available Lock Carp Deterrents

Although there is much active research on various types of carp deterrent systems (ref. (6) ref. (7)), only two types of systems are presently commercially available and have received some level of testing. These are a graduated pulsed DC field electrical deterrent barrier (Smith Root, Vancouver OR; Diversified Technologies, Chicago?) and a bio-acoustic fish fence (BAFF) (Fish Guidance Systems, Ltd. UK). Electrical deterrent systems use pulses of high voltage DC power to deter fish and can be graded to increase repulsion. Commonly used for common carp, an electrical system has been installed in the Chicago Ship Canal. A BAFF uses a combination of sound, bubbles, and light to deter fish and one has been installed at Barkley Dam in Kentucky where it currently is being tested. These two deterrent systems were previously evaluated for potential use at Lock and Dam 1 in 2012 by Barr; an update is provided herein. Barr recommended a BAFF in 2012 and since then the BAFF has received considerable upgrades. In contrast, electrical barrier technology does not appear to have changed greatly although much information is proprietary. Like was done in 2012 when evaluating LD2, Barr considered several criteria when evaluating these deterrent systems at LD5: human safety, lock and dam operations, efficacy, and potential impacts to fish species other than Carp.

3.1 Safety

The BAFF as marketed by Fish Guidance Systems uses a proprietary combination of specific frequency sound waves, an air bubble curtain, and directional strobe lights (https://www.fgs.world/systems/baff-system/). None of the combined deterrent technologies in the BAFF have a high potential for risk to humans Barr (ref. (2)).

The graduated pulsed DC field electrical deterrent barrier (GFFB) system as marketed Smith-Root (https://www.smith-root.com/barriers) generates a graduated, pulsed field of DC current in the water. Smith-Root recommends that barriers be fenced and warning signs posted. In Chicago there are strict rules that passengers must go below deck to pass through the electrical barrier there. Various authors suggest that to achieve deterrence of all life stages of Carp the voltage gradient at the barrier may be higher than what is safe for humans, Holliman (ref. (8)), United States Army Corps of Engineers (USACE) (ref. (9)). In 2012 Barr expressed concerns about the safety of this system.

3.2 Efficacy

Barrier deterrence efficacy comparisons between a BAFF and GFFB for all life stages of Carp are complex and can be influenced by many variables. Dennis et al (ref. (1)) note a 98% efficacy without habituation under laboratory conditions while field research by the USFWS (ref. (8)) demonstrated a 57-94% efficacy for silver carp depending on season and protocol.

GFFB efficacy information as developed by Holliman (ref. (8)), USACE (ref. (9)) and Davis et al (ref. (11)) is most appropriate. Efficacy is directly determined by fish size (larger fish are more susceptible to electric current), water conductivity, and voltage. For larger fish, efficiencies can be as high as 99% but may be totally ineffective (0%) for small juveniles. Davis (ref. (11)) provides some indication that a GFFB at a lock installation can provide additional pathways for fish movement through a lock due to complex hydrodynamic and electrical interactions with certain types of vessels.

Field evaluations of a BAFF have been documented for year one of three at Barkley Dam, Kentucky and are not yet advanced to the levels of study regarding how complex hydrodynamic and/or sound and air bubble curtain interactions with vessel passage impacts fish passage through the lock USFWS (ref. (8)).

3.3 Operations

Potential impacts to lock operations and/or non-commercial vessel traffic have been discussed in detail in Barr (ref. (5)). A GFFB was identified as having the potential for some human safety concerns as well as the potential for unanticipated long-term structural concerns related to corrosion and/or replacement of some steel elements by insulated steel or fiberglass during installation. No operational concerns were identified in Barr (ref. (5)) for a BAFF installation at Lock and Dam 1 and none have been reported at Barkley Dam. For purposes of this evaluation, the considerations used for operations evaluation at Lock and Dam 1 are similar for a potential installation at LD5.

3.4 Impacts on Fish and Other Species

Installation of either a BAFF or GFFB at a lock has the potential to further reduce the potential for routine passage of aquatic species than already exists due to the presence of the lock and associated dam structures. The lock itself would become less available to aquatic organisms during locking operations due to the presence of a deterrence barrier. No changes to the frequency of upstream movements associated with open dam gates/high water conditions overtopping the dam would occur.

Because electrical systems associated with the GFFB act as a deterrent by establishing a pulsed DC electrical field that acts on the fish's muscular system, these systems have little potential to be species specific although gradients can be adjusted to make them less effective for all small fishes. Voltage gradients necessary to deter all life stages of Carp also have the potential to deter all life stages of other fishes and associated aquatic organisms such as mussels with host species of fishes required for completion of their life cycle and upstream distribution.

In contrast, the BAFF is a sensory deterrent which may thus affect different species of fish differently and selectively. In particular, Carp have a specialized hearing system that might allow a combination of specific sound frequencies and light within a bubble curtain to act as a behavioral deterrent to Carp while not impacting other species of fish in a similar way. Some potential exists to target a BAFF to Carp (ref. (1)). Notably, a BAFF installation at LD5 could be mounted downstream of the lock and at angle to guide fish away from the lock and into traps (carp removal) or a fish elevator system that could be installed in the auxiliary lock at LD5, thereby mitigating the possible effects of a BAFF on native fishes. The GFFB offers no such opportunity. The layout of LD5 allows for potential consideration of a fish elevator at the auxiliary lock to offset potential effects of the BAFF on native fish movements as might be deemed necessary. A variety of integrated upstream transfer mechanisms/techniques are available such as a fish elevator; some with long records of field usage with the associated costs and efficacy data available. These systems or combinations of systems will not be discussed here.

The three criteria above suggest that installation of a BAFF is the appropriate solution to deter invasive carp at LD5. Known human safety considerations of a GFFB at voltages high enough to deter all Carp life stages coupled with operational concerns at the physical lock structure led to this conclusion. Some unknowns regarding the impact of complex hydrodynamic interactions with vessel passage through a BAFF are still present.

4 Lock Deterrent Layout

4.1 Overview of Lock Deterrent Layout

BAFF deterrent systems are composed of equipment located both above and below the water. Both can be accommodated at LD5. The equipment below the water could lie at or near the river bottom (below marine traffic drafts) crossing the lock chamber at an angle like that is shown in red in Figure 4-1. The system is also shown as an isometric view in Figure 4-2. Deterrent systems are more effective when invasive carp are directed (guided) in an alternate direction further upstream. This angled alignment is more effective than an alignment perpendicular to the lock walls since invasive carp tend to keep moving upstream along deterrent as opposed to stacking up against it. In the case of LD5, this direction would be towards the auxiliary lock and spillway. At this location, a fish elevator or ladder could be installed to move desirable native fish upstream and capture invasive fish.

There are three sets of lock discharge ports (Figure 2-2). Two of these sets are within the lock profile and upstream of the proposed BAFF alignment. Therefore, they would not be passable by carp. However, the final set of discharge ports on the spillway side of the wall needs additional study and potentially further mitigation, perhaps with sound deterrents. This alignment also matches the alignment chosen for the first location at which a deterrent system was installed, Barkley Dam in Kentucky. The BAFF system in Kentucky is described in Appendix B.

Figure 4-1 Proposed deterrent site layout

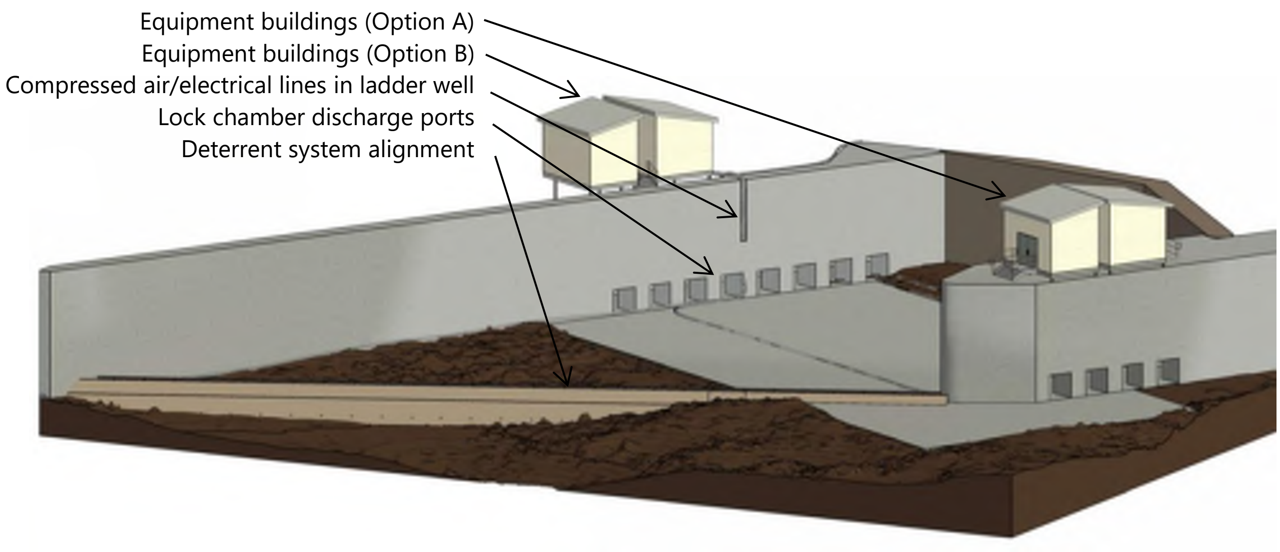


Figure 4-2 Proposed deterrent alignment and equipment building isometric

4.2 Civil/Structural Design

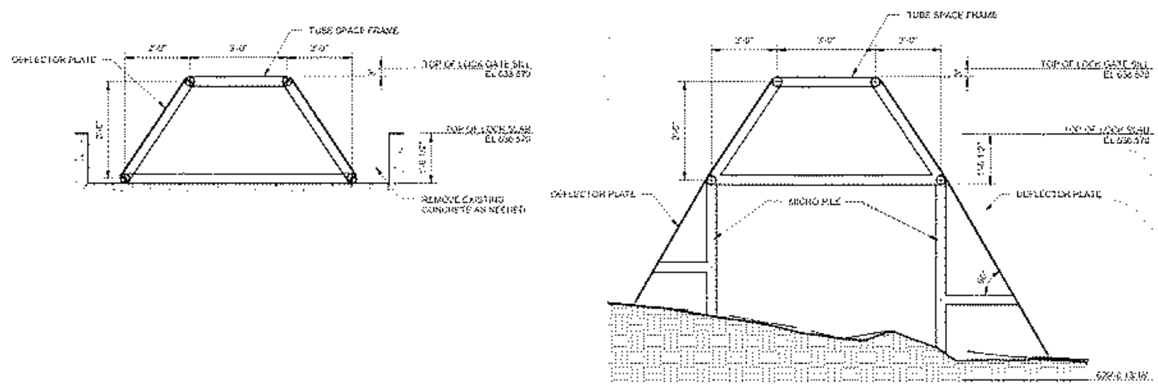
4.2.1 Below Water Equipment

The deterrent system equipment below the water line includes compressed air lines, sound projectors (underwater speakers), light arrays, and electrical hubs. This equipment runs the length of the system and needs to be supported and protected by a framing system. This system was a precast concrete system placed on the existing bedrock at Barkley Dam.

The proposed alignment of the deterrent system at LD5 would place the upstream third (approximately) of the deterrent over a concrete slab and the remaining downstream two-thirds over the river bottom as shown in Figure 4-2. Borings documented in the design drawings for the LD construction indicate sandy soils to at least 35 feet deep. A dive inspection conducted at LD5 on December 16, 2021, by J.F. Brennan indicates the presence of riprap along most of the proposed alignment and confirmed the presence of the concrete slab. The report documenting that dive inspection is included in Appendix E. The riprap on the north side of the area was approximately 2 feet to 4 feet in diameter and approximately 1 foot to 1.5 feet near the land wall. A bathymetric survey conducted by J.F. Brennan on December 21, 2021, confirms the presence of this riprap as well as seen by the textural differences in the contours. This bathymetric survey is included in Appendix F.

Given most of the deterrent system is over sandy soils and the remainder is over a concrete slab, a steel frame structure is recommended which can be anchored to the slab on the upstream third of the system. The portion over the river bottom would likely require pile supports over the sandy river bottom soils. These would likely be driven piles, helical piles, or micro piles. Both the slab-supported and pile-supported conditions are shown in Figure 4-3 (a) and (b), respectively. The layout in Appendix D also shows these sections.

The design basis for the Barkley Dam system included loading provisions for the impact of a buoy counterweight to drag along the river bottom and impact the system. Therefore, the framing system not only supported the equipment and connections but also served as armoring against these impacts. Therefore, deflector plates have been included to allow for such weights to drag up and over the system without damaging the enclosed equipment. To the extent this buoy anchor weight has any velocity and may damage the system through and impact force, the deflector plates could intentionally deform to absorb most of the impact. These plates could then be replaced as needed. These deflector plates would also serve to minimize openings for fish to penetrate below the system where the river bottom drops. While there would still be small gaps, invasive carp do not frequently swim at depths below the elevation of the projectors, lights, and bubble curtain resulting in little risk.



(a) frame over concrete slab (b) frame over river bottom

Figure 4-3 Deterrent system support and armoring frame

4.2.2 Above Water Equipment

Two structures are required to house two sets of equipment. The first structure is required to house the compressor and may come included with the compressor. The second structure is required to house miscellaneous electrical and control equipment for the sound projectors and light arrays. The aesthetics of these structures may be subject to the State Historic Preservation Office (SHPO) review and approval. As of this design layout, two options are presented for the location of these two structures:

- Option A: land wall. The primary advantage of this is that the structures stay on the land side and thus the electrical feed does not need to cross the lock chamber. Furthermore, access to the structures is not across the lock miter gates.
- Option B: river wall. The primary advantage is that virtually no additional steel support framing is required, and electrical and compressed air lines are minimized. However, availability on the river wall is somewhat limited and access to this location is further constrained by the miter gates.

4.3 Mechanical Design

The deterrent system used as a basis for this design requires compressed air to provide a bubble curtain along the entire length of the alignment. The length and depth of the deterrent system alignment are very similar to the same parameters for Barkley Dam, so the equipment sized for that location was used as a reference for this site. Most of the equipment is not designed to operate in outdoor ambient conditions for this location, so it is expected that it will be housed in a climate-controlled mechanical shelter or building. The following list summarizes the major mechanical equipment required for the bubble curtain and the ancillary equipment necessary to support the compressed air system:

- Equipment
  - Air Compressor
    - One 125-HP compressor will supply compressed air to the bubble curtain.
    - The compressor will have a VFD for added adjustability in discharge flow rate and pressure.
    - The compressor will have an integral after-cooler to reduce the dewpoint of the compressed air.
  - Dryer
    - One compressed air dryer will be included in the design. The dryer will be integral to the compressor or a stand-alone unit included in the mechanical building.
    - The dryer will dry the air to a minimum dewpoint of -20°F to reduce condensation inside the pipe and freezing during the winter months.
- Compressed air routing
  - The compressed air will pass through an air dryer, receiver, and flow controller before exiting the building. It will be trenched in the concrete across the lock wall and drop down a ladder well to tie-in to the bubble pipe within the deterrent structure.
  - The compressed air piping will split and be routed to both ends of the deterrent system to feed the bubble pipes from both ends for the purposes of creating a more evenly distributed bubble curtain.
  - All above grade piping will be 304L stainless steel of socket welded or buttwelded construction, depending on size.
  - Prior to entering the ladder well, the pipe will transition to HDPE and split into the individual feed pipes for the various bubbler pipes. All riser and underwater pipe will be HDPE suitable for UV exposure.
- Building Systems
  - Compressed air condensate drainage will be routed to a common condensate pump within the building, where it will be collected, pumped, and discharged to a suitable location outside the building.
  - The mechanical building HVAC will be designed to maintain interior temperature within equipment manufacturer’s requirements and OSHA standards for an unoccupied building. Building heating will be sized to preheat/condition compressor intake air during the winter months. To achieve this efficiently, a recirculation control system may be required to operate dampers and ensure the compressor intake air is tempered.

- The control building will also require HVAC to maintain a suitable temperature range for the control equipment. As with the mechanical building, this will be designed to maintain interior temperature within equipment manufacturer's requirements and OSHA standards for an unoccupied building.

4.3.1 Redundancy Options

The deterrent system must operate continuously for maximum effectiveness unless other measures are taken to address invasive carp passage concerns. There are several options for redundancy to mitigate fish passage during compressor maintenance outages, power outages, or other downtime. It is anticipated that a generator will be included to provide continued operation during a power outage. For the compressed air system specifically, there are several redundancy options:

- No redundancy. Fish may enter the lock during compressor maintenance allowing access to the lock culverts for direct passage or remaining in the lock and passing upstream at the next opportunity.
- Secondary permanent compressor onsite. This option would allow a compressor to be taken offline for maintenance or even long-term replacement without impacting the bubble curtain. The compressors may be sized for less than 100% redundancy (e.g., 2x75% or 2x50%), which would allow for a reduced bubble curtain without having as significant of a space and cost impact.
- Compressor trailer pad and hookup for temporary compressed air. This is the option that is currently included in the design. It would include a permanent connection for compressed air pipe from a temporary trailer-mounted compressor. This would have the least significant initial cost impact but may not be readily available with an equipment failure or practical for use during short-term maintenance outages.

4.4 Electrical Design

- A new electric utility service will be obtained from the local electric utility to serve the new air compressor, deterrent system building HVAC, and bio-acoustic system head-end equipment. Service voltage is anticipated to be 480V 3-phase, and service ampacity is anticipated to be 400 Amperes.
- A new electric service utility transformer is anticipated to be in or near the adjacent guest parking lot. A utility meter and connection equipment will be located close by.
- Standby generator will be connected to the electric system via automatic transfer switch. The transfer switch will sense if utility power is lost, start the generator, and transfer power to the generator for the duration of the utility power outage.
- Power is anticipated to be distributed to the deterrent system building via underground conduit, transitioning to a structure-mounted conduit on the existing lock structure. A 480V distribution panel, step-down transformer, and 120/208V distribution panel will be provided within the building. These panels will serve the air compressor, HVAC, building lights, deterrent head-end systems, and building convenience power.

- Supply cables for the deterrent system lights and speakers will be routed from the deterrent system building to the underwater lights and speakers. Cable routing will be coordinated adjacent to the compressed air supply piping.

4.5 Potential for Fish Elevator at Lock and Dam 5

A fish elevator could be installed in the auxiliary lock at LD5 to help move native fish deterred by the BAFF upstream. This section will be developed for the final feasibility report slated for submittal by June 30, 2022.

5 Estimate of Probable Development and Construction Cost

The opinion of probable (construction cost, remedial action cost, cost, etc.) provided in Table 4 below is classified per AACE 17R-97 Class 4 with an expected accuracy range of -30%/+40%. This Class 4 estimate and is made on the basis of Barr's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on a 10% concept level of design and project-related information available to Barr at this time. Leasing options for BAFF equipment would also likely be available from FGS although all construction and engineering would still be needed. The opinion of cost may change as more information becomes available and further design definition is completed. In addition, since we have no control over the cost of labor, materials, equipment, or services furnished by others, or over the contractor's methods of determining prices, or over competitive bidding or market conditions, Barr cannot and does not guarantee that proposals, bids, or actual cost will not vary from the opinion of probable cost prepared by Barr. The final feasibility report slated for submittal by June 30, 2022 and will have a more comprehensive discussion of the estimate of probable development and construction cost.

Table 4 Opinion of Probable Cost (in February 2022)

	Item	Estimate of Probable Construction Cost	Notes
1	Engineering	$468,000	8% of items 2-8 (excluding BAFF furnished cost); includes engineering, survey, geotech investigation, and construction observation
2	Mobilization and Demobilization	$800,000	Includes mobilization of contractor, dive crew, barges and crane
3	BAFF Components & Initial Installation	$7,242,000	BAFF enclosure and foundation, wiring to BAFF system, compressed air lines
4	Compressor Shed	$290,000	Pre-engineered building, compressor, HVAC, finishes
5	Electrical Shed	$141,000	Pre-engineered building, electrical panels, HVAC, finishes
6	Utilities and Power	$235,000	Transformer, generator, propane, electrical service
7	Contractor Overhead	$871,000	10% of items 2-6
8	Contingency	$1,741,000	20% of items 2-6
	Total:	**$11,788,000**	
	Lower Range (-30%)	$8,252,000	
	Upper Range (+40%)	$16,503,000	

Notes:

1) Cost estimate based on AACE (17R-97, Class 4, -30%/+40%)
2) Costs are based on conceptual 10% level of design
3) Budgetary quotes were supplied for the FGS BAFF system, compressor and shed enclosure
4) All numbers rounded to nearest thousand

Above costs are representative of the deterrent system designed, furnished, and installed. Additional accessory items that could be included in the overall costs are shown in Table 5 below. These items add redundancy to the system and could be included based on the owner's request. These costs are not representative of operational costs.

Table 5 Opinion of Probable Cost – Accessory Items

	Item	Estimate of Probable Construction Cost	Notes
1	Redundant Compressor Shed	$265,000	Addition of redundant shed and backup compressor, furnished and install during construction
2	30 Spare Sound Projectors	$1,590,000	Quote supplied from FGS, sound projectors spares used at ongoing maintenance intervals throughout the life of the system

Note(s):

1) Cost estimate based on AACE (17R-97, Class 4, -30%/+40%)
2) Costs are based on conceptual 10% level of design
3) Budgetary quotes were supplied for the FGS BAFF system, compressor and shed enclosure
4) All numbers rounded to nearest thousand

6 Design, Permitting, and Construction – Phases, Schedule, and Risks

6.1 Future Design

6.1.1 Design

The level of design considered for this report is 10% which is suitable to conclude that the project is feasible and present an engineer's estimate of probable design and construction cost. The following design phases will serve to coordinate between design disciplines, suppliers, contractors, and other stakeholders such as the USACE, MN DNR, WI DNR, and other local stakeholder groups.

A typical phasing schedule for a project of this type would result in a reviewable report, drawings, and specifications by stakeholders at the following levels:

- 30% design: conduct site survey, obtain river bottom borings, and obtain deterrent supplier preliminary drawings
- 60% design: obtain deterrent supplier detailed drawings
- 100% design
- Issued for construction

An example schedule is presented in Section 1.1 which gives development and review durations for each design phase. The schedule pressure on this project combined with the number of stakeholders involved requires an aggressive and transparent design schedule. The construction schedule constraints will require the schedule is met so disproportionate delays do not result from small slips in the early schedule.

6.1.2 Environmental Permitting

Table 6 summarizes the anticipated environmental permits/authorizations/consultations required based on the design information detailed in Section 4. This assumes that:

- The footprint of the below-water systems will be less than 1 acre such that it does not trigger a mandatory Environmental Assessment Worksheet (Minnesota Rules 4410.4300, Subpart 27.A.)
- Any ground-disturbing activities necessary to install the above-water systems will be less than 1 acre and not require coverage under the MPCA's Construction Stormwater General Permit (MNR10001)
- No tree clearing or water appropriation will be necessary
- The project does not require federal funding for construction

The USACE will responsible for compliance with the National Environmental Policy Act (NEPA). If the project requires a Standard Permit under Section 404 of the Clean Water Act/Section 10 of the Rivers and

Harbors Act and/or requires authorization under Section 408 of the Rivers and Harbors Act, the USACE may require an Environmental Assessment. The USACE will either prepare the Environmental Assessment internally or request the applicant to prepare it as part of the review process. Complete design and determination of construction impacts is necessary to confirm if the USACE will require an Environmental Assessment to comply with NEPA for the required authorizations

The USFWS Information for Planning and Consultation tool[1] indicates the following federally-listed species may be present near the project location:

- Northern long-eared bat (*Myotis septenrionalis*), Threatened
- Higgins Eye (pearlymussel) (*Lampsilis higginsii*), Endangered
- Sheepnose mussel (*Plethobasus cyphyus*), Endangered
- Karner blue butterfly (*Lycaeides melissa samuelis*), Endangered

The project will not occur within designated critical habitat for any of the species noted above. Construction will not require the removal of woody vegetation greater than 3 inches in diameter at breast height that may impact suitable habitat for Northern long-eared bat. Therefore, the USFWS Framework for Streamlined Section 7 Consultation can fulfill the Section 7 consultation requirements for the potential USACE authorizations.

Because construction activities will occur below the ordinary high-water mark (OHWM) of the Mississippi River, surveys and/or relocation for the mussel species noted above may be necessary to determine potential affects following the Minnesota Department of Natural Resources (DNR) and USFWS *Minnesota Freshwater Mussel Survey and Relocation Protocol* dated April 2013. The protocol specifies the following limitations for conducting mussel surveys and relocations:

- Surveys and relocation can only occur when air temperature is greater than 32°F and water temperature is greater than 40°F

- Surveys must occur within three years prior to construction

- Relocations must occur within two months of the onset of construction

The project requires construction activities below the OHWM of the Mississippi River and developed areas in uplands; impacts to the Karner blue butterfly are not anticipated.

A final determination of environmental review/permits/authorizations/consultations will be necessary based on the 60% and 100% designs.

[1] Accessed online February 18, 202 at https://ecos.fws.gov/ipac/

Table 6 Potential Environmental Permitting and Consultation Requirements

Agency	Authorization	Comments	Estimated Agency Review Timeframe	Information Necessary for Application/Consultation
USACE	Clean Water Act (CWA) Section 404 and Rivers and Harbors Act Section 10 authorization	Required for construction of structures below the OHWM of the Mississippi River. Depending on the final design, either a general or standard permit will be necessary.	3 months to 1 year	• Construction designs (typically 60% level) • Alternatives analysis (standard permit only)
USACE	Section 408 of the Rivers and Harbors Act of 1899 authorization	May be necessary for alteration of a Civil Works project	4 months to 1 year	Construction designs (typically 60% level)
USFWS	USACE consultation under Section 7 of the Endangered Species Act	May be necessary depending on USACE's determination of the potential to effect federally protected species.	Concurrent with USACE review	Mussel surveys if the USACE requires
SHPO	USACE consultation under Section 106 of the National Historic Preservation Act	May be necessary depending on USACE's determination of potential impacts to historic sites.	Concurrent with USACE review	Phase 1a Literature Review
MPCA	CWA 401 Water Quality Certification (WQC)	If the USACE determines that an individual permit is necessary for Section 404/Section 10, an application to the MPCA for an individual Section 401 WQC will be necessary.	Not applicable for Nationwide or Regional General Permits 1 year for an individual WQC for a Standard Permit	For an individual WQC, the following is necessary: • Construction designs (typically 60% level) • Alternatives analysis • Antidegradation analysis

Agency	Authorization	Comments	Estimated Agency Review Timeframe	Information Necessary for Application/Consultation

MPCA	Dredge Materials Management SDS Permit	Not required for the management of dredged material if:
		• less than 3,000 cubic yards with no surface water discharge and is either
		  o >/=93% sand
		  o Contaminate values less than soil reference values
		  o disposed of at a site/landfill that already has an MPCA permit for management of dredged material
		• greater than 3,000 cubic yards with no surface water discharge and disposed of at a site/landfill that already has an MPCA permit for management of dredged material yards
			6 months to 1 year	Dredge material characterization, quantity, and disposal location

DNR	Public Waters Work Permit	Required for construction of structures below the OHWM of the Mississippi River (identified Public Water).	3 to 6 months	• Construction designs (typically 60% level) • NHIS review
DNR	NHIS Review and Takings Permit for Threatened/Endangered Species	Required as to submit the Public Waters Work Permit application.	2 months	• Project description • Potential construction footprint

6.2 Schedule

An example schedule was prepared that is considered feasible (Figure 6-1). It assumes funding is approved and appropriated in 2022 enabling 30% design to start late in 2022. It is anticipated that final design will take approximately 9-12 months. After discussions with a contractor, the duration of construction is anticipated to be approximately 4 months and would likely be executed in the fall once barge traffic has stopped for the season. The final feasibility report slated for submittal by June 30, 2022 will have a more comprehensive discussion on project schedule.

Figure 6-1 Example schedule

6.3 Risks

Risks can be considered during the three general phases: design, construction, and operation. The potential risks at all phases can be mitigated but not eliminated. Based on lessons learned from the Barkley Dam project and discussions with project stakeholders, the following risks have been identified at this phase in design. Future design phases may expand this list and advance certain mitigation strategies. The final feasibility report slated for submittal by June 30, 2022 will have a more comprehensive list of risks and mitigation.

6.3.1 Design

1) **Unknown riprap depth:** The dive inspection report identified riprap downstream of the lock chamber in the vicinity of the proposed deterrent alignment. This riprap ranged from ±18 inches on the west side to ±36 inches on the east side. The 10% proposed layout calls for piles which cannot be driven through riprap.
   Mitigation: The divers were not able to determine the depth of the riprap. However, the riprap will likely need to be temporarily relocated to install the foundation system for the deterrent. Therefore, an exploration program is recommended to inform the 30% design.

2) **Uncertainty of soil properties:** As of this report, the design basis for the deterrent foundation system is based on a dive inspection and soil data from the original design in the form of soil borings that only describe the general consistency of the soil (fine sand with some deeper gravel in some borings). The dive inspection report indicates the presence of riprap on the river bottom with sands and silts below. Soil borings shown in the record drawings confirm the presence of sands and silts to the depth of the borings and the design calls for riprap in the location of the deterrent system.

Mitigation: Obtain two to three river bottom borings in the alignment to confirm riprap depth and soil characterization.

3) **Deterrent bubble curtain stability**: If a BAFF system is selected as the installed deterrent, a BAFF-style deterrent system efficacy is a function of many things—including the integrity of the bubble current. Many things can impact the bubble current integrity including barge traffic, lock discharge flows from the discharge ports (see Figure 2-2), and spillway currents rounding the river wall downstream nose. A better understanding of the flow vectors across the deterrent alignment from these various factors would inform future design.
   Mitigation: Perform computational fluid dynamics (CFD) model of the bubble curtain to understand the impacts of various flow velocities that cross the bubble curtain and the impact of adjacent hard structures such as vertical and slightly non-vertical walls.

4) **Deterrent system**: Initial observations of the BAFF system installed at Barkley Dam indicate the ends of the system where it ties into the adjacent concrete walls are potential weak points—particularly at the bull nose end. These tie-in locations require additional consideration to mitigate any weakness in the system. Of particular concern is the batter of the bullnose end of the river wall which pitches back 2 feet from bottom to top. As of this report, no modifications in the system design are included to address this concern as this is considered too detailed for a 10% level of design.
   Mitigation: Increase sound projector volume during lock discharges and/or minimize discharge when not needed (i.e., only during lock discharge).

5) **Lock chamber discharge outlets**: As shown in Figure 2-2, there are three sets of lock discharge outlets on the downstream end of the lock. Two of these outlet sets are within the lock width—and thus protected by—the deterrent system. However, one set of lock discharge outlets is outside the lock on the river side (east) of the river (east) wall. Moreover, fish may swim along the current alignment upstream right by the outlet as they avoid the deterrent itself. Lock staff indicated that the lock chamber discharge gates are opened to approximately 20% during the non-navigation season to keep a small current running through the lock chamber.
   Mitigation: Study the aspects of the discharge outlets that impact the potential for invasive carp to swim upstream including length and flow velocity. If this study indicates a sufficient risk of invasive carp passage, provide additional deterrent measures at the lock discharge outlet on the river side of the lock river wall. Operational changes to the partial gate openings could also be considered.

6) **Sedimentation**: The bathymetry in Appendix F indicates the downstream lock slab is relatively clear of silt. However, the presence of a deterrent system may impact sedimentation on or near the deterrent.
   Mitigation: Use the CFD model discussed above to understand the flow velocities and potential for sedimentation. Inspect the system 6-9 months after installation to determine if sedimentation may continue. Clean as needed with divers.

6.3.2 Construction

1) **Construction duration and schedule**: The navigation season varies somewhat but is generally from mid-March to mid-November every year. USACE staff indicated some small outages have been accommodated at LD sites, but these outages are typically a hand full of hours on five subsequent days or less. While many activities involved with the installation of a deterrent system can be performed without impact to navigation, any "in water" work would prevent navigation through the lock.
   Mitigation: Select a contractor early in the design process to determine a potential detailed schedule including what activities require a pause in navigation and the duration of those activities. Work with the USACE to determine what outages—if any—are acceptable during the navigation season and reconcile these allowances with the anticipated schedule. It is recommended this scheduling exercise occur earlier in the design process than is typical so modifications in the design can be considered to mitigate schedule concerns.

2) **Variability in river flows**: Any marine construction requires certain flow behaviors. Floods of some level typically pose safety and access concerns and would thus halt construction.
   Mitigation: Prepare a detailed construction schedule that serves to avoid times of the year that present an increased risk of adverse weather and river flows. Have contingency plans ready on how the schedule may change given a realistic weather event.

6.3.3 Operation

1) **Planned outage:** Planned outages are required to service—and potentially replace—deterrent components. During this maintenance, the deterrent system may be out for a period of hours or days during which invasive carp may cross the deterrent alignment upstream.
   Potential mitigation: Have planned outages occur close to—but just outside of—navigation season so the downstream miter gates and the lock discharge gates can remain closed. This still requires either (1) electro-fishing of the area between the deterrent and downstream miter gates after the deterrent is re-energized or (2) prevention of fish passage across the deterrent alignment using temporarily deployed sound projectors.

2) **Unplanned outage when lock is staffed:** Unplanned outages would result from the malfunctioning or failure of a deterrent system component at which point invasive carp could swim upstream of the deterrent until the system is restored. System components that exhibit the highest sensitivity to an unexpected outage include the compressor and the sound projectors.
   Potential mitigation: Keep the downstream lock miter gates and lock discharge gates closed until system can be restored. Electro fish the area between the downstream miter gates and deterrent after system is re-energized. Lock discharge gates are set at approximately 20% open all winter to provide adequate flow to prevent ice formation within the lock chamber. These gates could potentially be closed for isolated periods with USACE approval.

Relevant feedback from USACE: Navigation outages are rare. The longest has been the replacement of leaf gates at LD2. It took four 12-hour outages. Small outages (hours long) could be accommodated during navigation season.

3) **Unplanned outage when lock is not staffed:** Between approximately mid-November and mid-April, LD5 is only staffed 16 hours per day, 6 days per week. This means a deterrent system outage could occur while lock staff are not onsite to ensure closure of the downstream miter gates and lock discharge gates.
Mitigation: Have 24/7/365 remote monitoring of various aspects of the deterrent system. In the event of an outage, have a local contractor "on call" to address the outage. This can be sublimated by remote technical support who understand the system design and have access to the monitoring and outage data. Have spare equipment onsite for a reasonable amount of equipment.

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Appendices

Evaluation of Lock and Dams 4 Through 8

Site, Flow, and Lock Operation Characteristics Related to Invasive Carp Passage

Prepared for
University of Minnesota

January 2022

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Evaluation of Lock and Dams 4 Through 8 – Site, Flow, and Lock Operation Characteristics Related to Invasive Carp Passage

January 2022

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Appendix B – Hydraulic Data

Certifications

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Brian Siljenberg PE #: 50033	January 4, 2022 Date

Executive Summary

This report summarizes the findings of evaluations conducted on Mississippi River Lock and Dams 4 through 8 regarding the potential for invasive carp (carp) passage and deterrence. The site evaluation included a review of site features exhibiting the highest and lowest potential of invasive carp passage. Hydraulic evaluations included a review of river flows and gate operations from 2000 to 2020. The results were compared to published findings on similar data ranging from 1970 to 2000. A desktop study was completed to determine the feasibility to include a fish deterrence system, focusing on identifying locations where the deterrence system was only required at the lock.

The results of the hydraulic evaluation found that Lock and Dam 5 is the least likely to experience hydraulic conditions favorable for carp passage so it would be the favored site for carp deterrent system from that perspective. Additionally, only Lock and Dam 5 lacks both fixed crest spillways and submersible dams, avenues by which carp can pass during times of high water. Other site features such as lock width and availability of power were equal (or similar) and suitable to installing a carp deterrent such as a BAFF. Lock and Dam 4 located just short distance upstream of Lock and Dam 5 is the next most suitable site, suggesting the two sites could be used in tandem.

In sum, Lock and Dam 5 is recommended as the most promising site for implication of a barrier strategy because it: (1) is the least likely to experience conditions favorable for invasive carp passage; (2) lacks both fixed crest spillways and submersible dams, and (3) has a relatively small upstream pool with a relatively impassable Lock and Dam located upstream which could be used for monitoring and removal of invasive carp following rare flood events.

2 Site Evaluation

The primary purpose of lock and dams 4 through 8 is to maintain an upper pool upstream of the dam with sufficient depth to enable barge navigation. These locks and dams are called "run of the river" dams since all flow that approaches the dam must be passed in real time through the spillway features and any other ancillary conduits such as culverts or powerhouses. The location of these locks is shown in Figure 1.

The "dam" portion of the lock and dam is not designed to overtop and thus invasive carp passage is not possible. Several additional features (ex. fixed crest spillways) are considered sensitive to invasive carp passage and are also considered within this report.

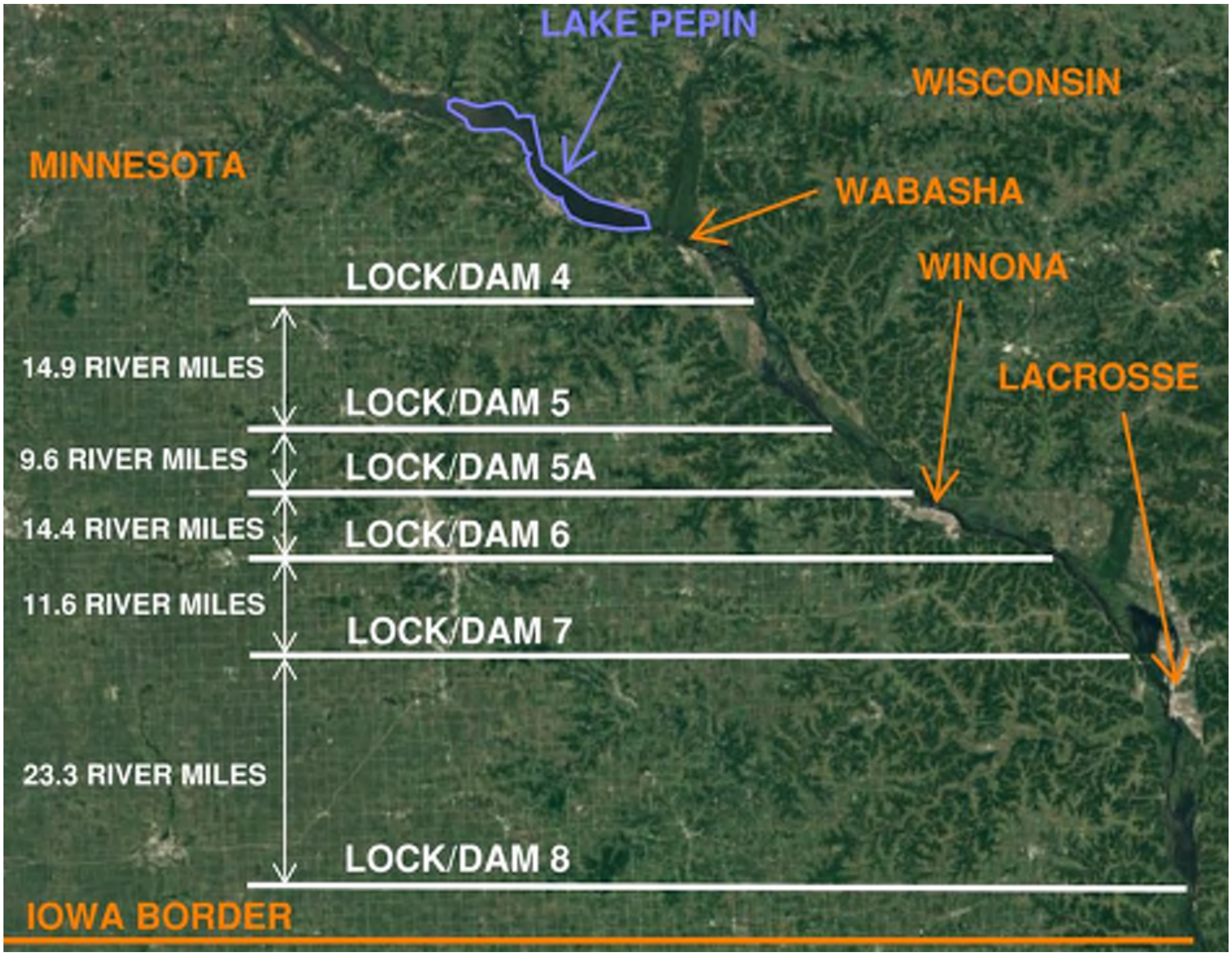


Figure 1 Lock and dam sites evaluated in scope of this study

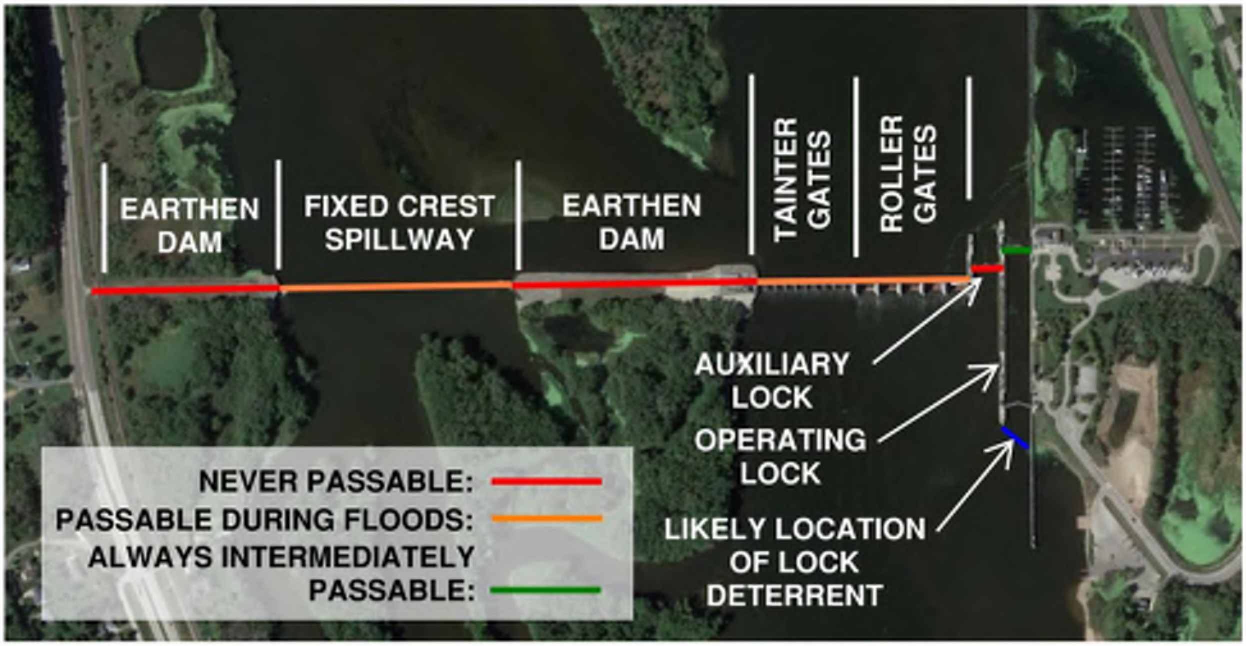


Figure 2 Typical lock and dam features

2.1 Lock and Dam Features Sensitive to Invasive Carp Passage

Lock and Dams are composed of several structural features that serve to create a headwater pool at a higher elevation than the tailwater pool. The structural features below all constituent a location where invasive carp could pass the dam alignment.

2.1.1 Lock

Description: Locks enable river traffic to pass the dam structure and manage the headwater and tailwater elevation differential as shown in Figure 3.

Sensitivity to invasive carp passage: Invasive carp can pass through the lock the same way river traffic does whereby one of the two sets of doors opens allowing traffic and fish inside the lock chamber. The most widely considered approach to minimize carp passage in a lock are submersed deterrent systems that employ sound and possible air (see below).

Potential mitigation of invasive carp passage: One type of deterrent system that has proven effective is a Bio-Acoustic Fish Fence (BAFF) that produces a combination of stimuli (light, sound, bubbles) the invasive carp find undesirable, yet river traffic can pass over.

2.1.2 Roller and tainter gates

Description: Roller and tainter gates are structurally different but functionally the same in that they constrict river flows through a gate that raises to open as shown in Figure 4. Their purpose is to maintain the upper pool elevation while allowing for the variable flow the river is subject to.

Sensitivity to invasive carp passage: The gates under normal flow operation result in high enough velocities that invasive carp cannot overcome the flow and thus cannot pass from downstream to upstream. However, higher flow events result in raising of the gates to adequately pass the flow. As the gates are raised, the flow velocity lowers. At some point, typically near the point of the gate being fully raised out of the water, velocities are sufficiently low to allow invasive carp passage. A more desirable site exhibits a smaller number of gates in their fully raised position a smaller percentage of time relative to the other sites. Gate count and size for each site is summarized in Table 2-3.

Potential mitigation of invasive carp passage: Operational changes can be considered to minimize the time in which gates are in the fully raised position permitting invasive carp passage. Individual gate settings can also often be adjusted within the scope of USACE control manuals to reduce passage by as much as 10-20%. However, this strategy is ultimately limited by the fact that once the gates are fully lifted (at times of flood), little additional benefit can be derived. Also, substantial modifications to gate operating schedules would have an impact on water management that the USACE would have to evaluate and approve. It is theoretically possible that mitigation of fish passage might be provided using an electric or bio-acoustic fish fence located upstream of these gates but this would almost certainly be prohibitively expensive because of the size of these structures. Another potential mitigation approach could be structural whereby a steel rack sized small enough to prevent invasive carp passage is positioned upstream of the gate. However, such a rack is not feasible as it would limit flow and collect debris requiring routine clearing by the USACE. A rack would also introduce a risk of flooding upstream should the rack plug during a flood event when the USACE could not clear the debris.

2.1.3 Fixed crest spillway and submersible dams

Description: Fixed crest spillways are concrete structures that are designed to routinely allow flow to pass over them, mostly only during flood events. A submersible dam is structurally different than a fixed crest spillway in that is made of an armored earthen embankment, yet it functions the same way although water typically rarely overtops these structures (which also vary in elevation). There is no way for operators to adjust or block flow, after the upstream pool exceeds the sill elevation the spillway or submersible dam, it will be overtopped.

Sensitivity to invasive carp passage: A fixed crest spillway or submersible dam exhibits a low risk of invasive carp passage until two conditions exist: (1) it is overtopped and (2) the tailwater is sufficiently high such that invasive carp on the downstream side can pass upstream. A more desirable site has smaller or no fixed crest spillway or submersible dam elements with lower elevations. Fixed crest element size and count for each site is summarized in Table 2-3.

Potential mitigation of invasive carp passage: Fixed crest spillways are especially vulnerable to carp passage. Nevertheless, both fixed crest spillways and submersible dams would require either a structural barrier such as a steel rack or an electric barrier to minimize this risk. A steel rack is not feasible for the same reasons outlined in Section 2.1.2. An electric barrier could be installed and would only need to function when water overtops the crest. However, electric barriers – especially of the length required these Mississippi Dam sites – would be expensive to install and maintain.

2.1.4 Culverts and sluiceways

Description: Culverts exist at all sites, either through the fixed crest spillway or submersible dam, or through the dam embankment. A majority of these culverts were added after the lock and dam's original construction as method to mitigate stagnant water in the sloughs downstream of the dam embankment. Sluiceways are notches in the crest of fixed crest spillways with the intent of permitting continuous flow at upper pool elevations below the main crest elevation. These sluiceways are several feet wide and exist at all spillways in this evaluation.

Sensitivity to invasive carp passage: Culverts and sluiceways can be a conduit for upstream moving invasive carp during high flow events when velocities are low and the tailwater exceeds the invert elevation of the culvert. Mitigation efforts are discussed in the site descriptions. The sensitivity of culverts to upstream invasive carp migration would also be a function of culvert slope and length, and water velocity. Steep and/or high-water velocities may exceed the invasive carp's ability to pass upstream. A more desirable site has fewer or no culverts and sluiceways. Culvert and sluiceway count for each site is summarized in Table 2-3.

Potential mitigation of invasive carp passage: Culverts and sluiceways are smaller in size than the other elements discussed above and thus could be mitigated through many different methods, including:

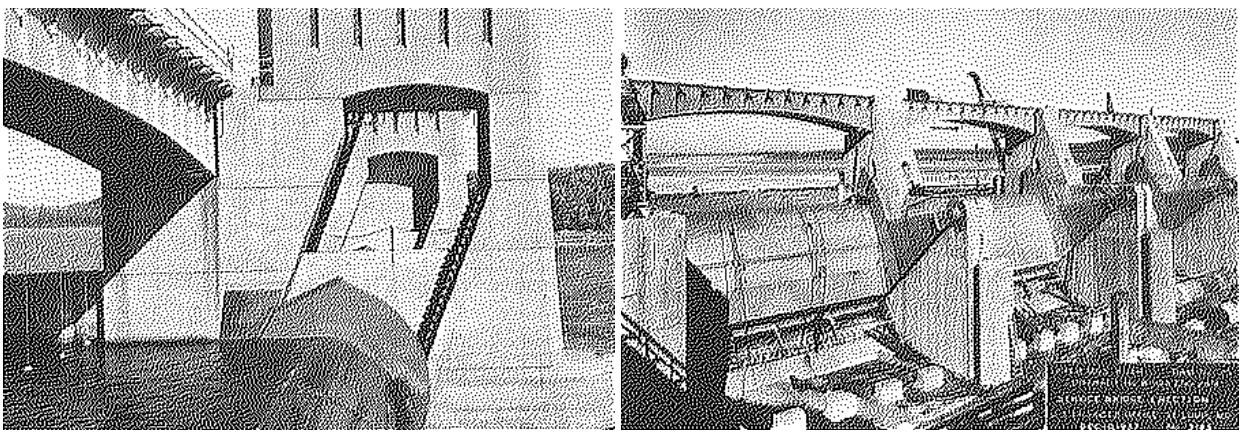
1. Remove the culvert or sluiceway
2. Install a grate over the culvert
3. Install an electric or bio-acoustic barrier downstream of the culvert/sluiceway
4. Monitor and selectively fish upstream pool following a flood

2.1.5 Upper Pool Size

Description: The purpose of the lock and dam system is to produce a series of deeper pools along the Mississippi to facilitate barge traffic where the river was historically not navigable part of the year. These pools create discrete sections of fish habitat. For the purposes of this study, the pool size is measured by its length along the centerline of the navigation channel and the lengths range from 43.9 miles upstream of LD 4 to 9.6 miles upstream of LD 5A.

Sensitivity to invasive carp passage: As described in Zielinski and Sorensen (2021) carp removal can be a mitigation approach for invasive carp. Therefore, pool size upstream of the lock and dam is a consideration in that a smaller pool is easier to monitor and remove invasive carp, thus making it more desirable. Smaller pools are also less likely to allow carp to reproduce.

Figure 3 Example of a Lock



(a) roller gate (National Park Service) (b) tainter gate (National Park Service)

Figure 4 Example of (a) a roller gate and (b) a tainter gate

2.2 Lock Fish Deterrent

For the purposes of this report, it is assumed that an underwater deterrent system would only be used at the lock where there is little (if any) flow velocity for invasive carp to overcome since deploying a system across all other features – while possible – would be fiscally prohibitive. The deterrent system would typically be located as shown in Figure 2. All lock chambers are 110-feet wide, and it can be assumed the angle of the system would be consistent throughout. The auxiliary lock chambers at all sites remains permanently closed. Therefore, there is no variability in these parameters to influence site selection.

Common fish deterrent systems need a power source which may include systems such as sound projectors, light arrays, and air compressors for bubbler systems. One commercially available system is called a Bio-Accoustic Fish Fence (BAFF). These utility supply systems would likely be housed on the nearby lock wall and powered from a local grid connection. There are two considerations that vary across sites related to the utility supply systems: (1) connection primary power to the utility supply systems and (2) the connection of the utility supply systems to the underwater barrier system.

2.2.1 Power Connection

Without a further detailed analysis of onsite power availability and consumption, it can conservatively be assumed for this study that additional power would be required from the nearby power grid. For the purposes of this evaluation, the distance from the likely utility location near the downstream end of the barrier system at the lock wall to the nearest observable power pole was measured and presented in Table 2-4.

2.2.2 Underwater Deterrent Connection

Common barrier systems may require the following utility connections from the utility supply system area:

1) Power for speakers and sound arrays
2) Low voltage communications for speakers and sound arrays
3) Compressed air for bubbler system

Given barge and other river traffic is common in the lock chamber, these connections require a safe route that does not hinder vessel passage. This can be achieved along the back side of the lock wall where accessible or down a ladder recess. The distance along the back side of a lock wall and within ladder recesses is relatively similar across all sites and therefore was not a major influence on site selection.

2.3 Lock and Dam Site Evaluations

The following sections outline site specific considerations extending from Lock and Dam 8 at the south (downstream) end of the study scope to Lock and Dam 4 on the north (upstream) end of the study scope as shown in Figure 1. This includes the existence of the lock and dam features sensitive to invasive carp passage listed above. Profiles illustrated to scale are shown in Figure 5 and itemized in Table 2-3.

2.3.1 Lock and Dam 8

Lock and dam 8 is located north of the Iowa-Minnesota border. The lock is located on the east bank of the river approximately 1,030-feet from the nearest power grid connection. There appears to be ample space near the downstream end of the lock to house barrier utility support systems. There are two submersible dams that combine for a total length of 2,275-feet. There are culverts in each submersible dam which provide continual flow to the Hastings Slough downstream of the dam along the west bank of the river.

2.3.2 Lock and Dam 7

Lock and dam 7 is located near LaCrosse, WI, just north of the I-90 river crossing. The lock is located on the west bank of the river approximately 630-feet from the nearest power grid connection. There appears to be ample space near the downstream end of the lock to house barrier utility support systems. There is a 1,000-foot fixed crest spillway that would likely require power from French Island. There are two sluiceways in this spillway that permit continuous flow to the slough directly downstream.

There is also an earthen dam and 670-foot submersible dam between French Island and the east bank of the river. Power would be required from the east bank of the river. There are two culverts in the 670-foot submersible dam that provide continuous flow to the east side of French Island.

Given invasive carp have been detected as far upstream as pool 8, it would be desirable to prevent their passage further upstream at Lock and Dam 7. However, the length of fixed crest spillway which would require a barrier combined with the culverts make this site very costly to implement a barrier.

2.3.3 Lock and Dam 6

Lock and dam 6 is located near Trempealeau, WI. The lock is located on the east bank of the river approximately 1,400-feet from the nearest power grid connection. There appears to be ample space near the downstream end of the lock to house barrier utility support systems. There is a 1,000-foot fixed crest spillway that would likely require power from east bank should a barrier system be installed. There are two sluice ways in the spillway that permit continuous flow to the slough directly downstream.

2.3.4 Lock and Dam 5A

Lock and dam 5A is located near the upstream edge of Winona, MN. The lock and spillway are located on the east side of the river with the lock on the west side of that complex residing on an island. High voltage power is evident crossing from the west bank of the river over a 1,000-foot fixed crest spillway. There are two sluice ways in the spillway that permit continuous flow to the slough directly downstream. There appears to be ample space near the downstream end of the lock to house barrier utility support systems.

2.3.5 Lock and Dam 5

Lock and dam 5 is located approximately 11 miles upstream of Winona, MN. The lock is located on the west bank of the river approximately 1,280-feet from the nearest power grid connection. There appears to be sufficient space near the downstream end of the lock to house barrier utility support systems, albeit not as much space as other locks. There are no fixed crest spillways or submersible dams at this site.

USACE documents indicate the presence of four culverts through the dam embankment which provide flow to the Indian Creek Slough on the east bank just upstream from the lock and spillway. If tailwater raises above the elevation of these culverts during flood events they could serve as a conduit for invasive carp passage. The water control manual states all culverts have stoplog slots where stoplogs are largely left out accept during floods.

Table 2-1 Aeration culverts listed in the water control manual for LD 5

Installation Year	Pipe	Flow
1956	36-inch CMP	70 CFS
1977	(3) 48-inch CMP	320 CFS

2.3.6 Lock and Dam 4

Lock and dam 4 is located approximately 7 miles downstream of Wabasha, MN. The lock is located on the west bank of the river approximately 1,280-feet from the nearest power grid connection. There appears to be sufficient space near the downstream end of the lock to house barrier utility support systems, albeit not as much space as other locks. There are no fixed crest spillways or submersible dams at this site.

USACE documents indicate the presence of six culverts as listed in Table 2-2 in the lock and dam 4 water control manual. Potential mitigation measures for these culverts are discussed in the previous section.

Table 2-2 Aeration culverts listed in the water control manual for LD 4

Site	Pipe
Clear lake	36-inch RCP
Lower Peterson Lake	48-inch CMP
3rd Lake	36-inch RCP
2nd and 1st Lake Single Intake	48-inch RCP
2nd Lake Outlet	48-inch RCP
1st Lake Outlet	48-inch RCP

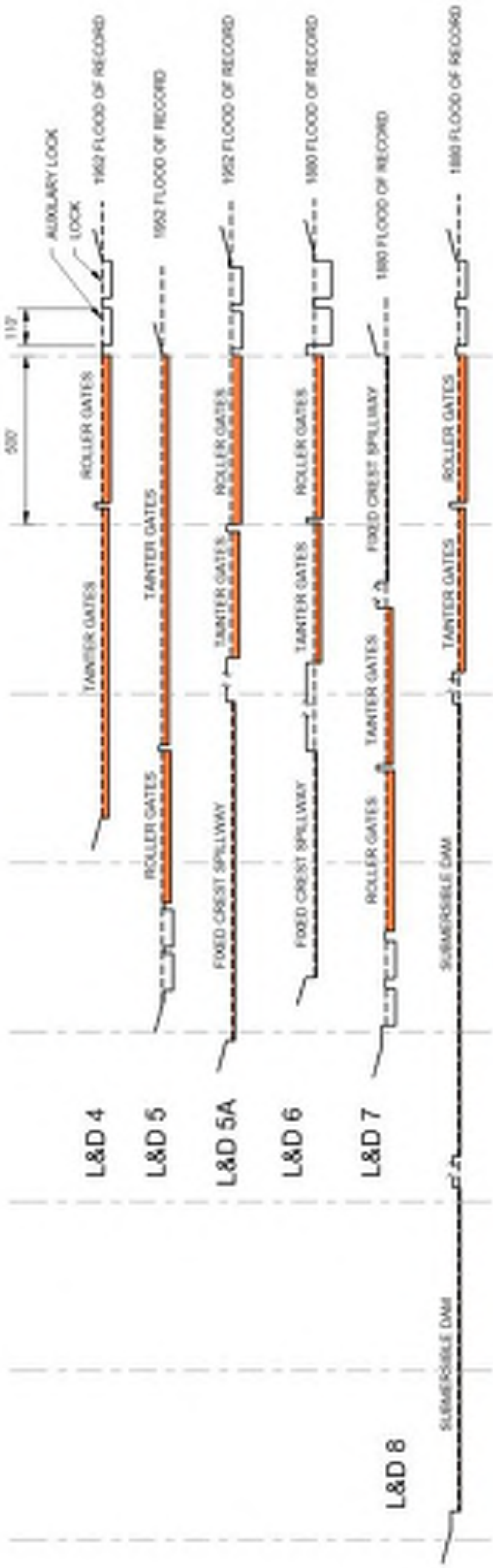


Figure 5 **Profiles of spillways and locks for Lock and Dams 4 through 8**

Table 2-3 Summary of site features relevant to invasive carp passage

Site	Roller Gates	Tainter Gates	Culverts or Sluices	Fixed Crest Spillway	Submersible Dam
Lock and Dam 8	5 Gates @ 80′ = 400′	10 Gates @ 35′ = 350′	2	NA	1 @ 937.5′ 1 @ 1337.5′
Lock and Dam 7	5 Gates @ 80′ = 400′	11 Gates @ 35′ = 385′	3	670′[1]	1,000′
Lock and Dam 6	5 Gates @ 80′ = 400′	10 Gates @ 35′ = 350′	4	1,000′	NA
Lock and Dam 5A	5 Gates @ 80′ = 400′	5 Gates @ 35′ = 105′	2	1,000′	NA
Lock and Dam 5	6 Gates @ 80′ = 480′	28 Gates @ 35′ = 980′	4	NA[3]	NA
Lock and Dam 4	6 Gates @ 80′ = 480′	22 Gates @ 35′ = 770′	5	NA[3]	NA

Note(s):

1) Each submersible dam at Lock and Dam 8 has a continuously flowing culvert feeding the Hastings Slough
2) Fixed crest spillway a sluice way, submerged culvert, and armored earthen section intended for overtopping during flood events.
3) There are four culverts through the dam embankment on the east side of the lock and spillway

Table 2-4 Estimated distance to local power grid connection

Site	Fixed crest spillway or submersible dam requiring a barrier	Estimated Distance to Nearest Power Pole for Local Power Grid Connection	Route Between Utility Supply Area and Underwater Barrier
Lock and Dam 8	2,275′	1,030′	Down Ladder Recess
Lock and Dam 7	670′	560′	Down Ladder Recess
Lock and Dam 6	1,000′	1,400′	Down Ladder Recess
Lock and Dam 5A	1,000′	0′[2]	Down Ladder Recess
Lock and Dam 5	NA	1,280′	Down Ladder Recess
Lock and Dam 4	NA	190′	Down Ladder Recess

Note(s):

1) Each submersible dam at Lock and Dam 8 has a continuously flowing culvert feeding the Hastings Slough
2) High voltage lines are evident crossing the fixed crest spillway from the west bank going to the powerhouse.

2.4 Site Evaluation Conclusions

The presence of a fixed crest spillway or submersible dam – which exists at Lock and Dam 5A through Lock and Dam 8 – was found to be a dominant site feature in that these elements would require a costly barrier over their length. Other site features such as lock width and availability of power were equal or similar across all sites. Based on site features alone, Lock and Dams 4 and 5 were found to be best suited for the implementation of an invasive carp barrier strategy.

3 Hydraulic Evaluation

The purpose of the hydraulic evaluation is to estimate the conditions under which invasive carp can pass through each lock and dam and the frequency at which these conditions are expected to occur. The result of this evaluation will identify which lock and dam(s) is the least favorable to invasive carp passage.

3.1 Hydraulic Evaluation Methods

The ability for carp to pass through a given Lock and Dam depends on the configuration of the structure as well as the flow through those structures over the course of a given year. These values change daily so an assessment of lock and dam permeability must consider conditions over the course of a year. Previously, most research on invasive carp passage has assumed that invasive carp passage occurs when a lock and dam raises its tainter gates and roller gates completely out of the water during times of high discharge. At these times, water velocities in the resulting flow fields are minimal. This condition is known as "open-river" because it resembles the conditions prior to the construction of the lock and dam when the river was fully open to flows. However, the exact conditions that determine open-river conditions at each lock and dam are complex and include discharge, upper pool height, and hydraulic head, all of which are estimates and not precise descriptors. Recent studies (Zielinski et al. 2018) show that the frequency of "open-river" conditions reported by USACE records are good, albeit imperfect, correlates of carp passage which vary with parameter used, dam structure, spillway gate operations, and local hydraulic conditions. USACE water control manuals provide guidance on how individual locks and dams should be operated by USACE engineers relative to discharge and pool height, and also when open-river conditions are expected. In this study we used 4 methods to estimate the actual amount of time that Locks and Dams 4-8 experience hydraulic conditions that likely permit invasive carp passage. The first 3 of these reflect different ways of estimating time in open-river, while the fourth uses carp passage data collected by Sorensen from Lock and Dam 8. We used the hydraulic conditions we measured to be present in the Mississippi River between 2000-2020.

3.1.1 Method 1: HW – TW < 1'

The first method assumes that invasive carp are only able to pass through a dam when the gates are lifted out of the water, also known as open river conditions. Under these conditions, the difference between the water surface elevation upstream and downstream of the dam (hydraulic head) is very small. Using daily measurements for water surface elevation at the headwater (upstream) and tailwater (downstream) of each Lock and Dam, the open river condition was assumed to be in effect for the following condition:

$$HW - TW < 1\, foot$$

The percentage of time for which this criteria was met is shown in Table 5.

3.1.2 Method 2: TW > 2nd Control

The second method also assumes that invasive carp are only able to pass through the dam under open river conditions. However, it differs from the first method is that this method assumes that the open river conditions were in effect only when the tailwater elevation was above the secondary control elevation (the elevation of the primary spillway and secondary spillway, if present).

$$TW > Secondary\ Control\ Elevation$$

This method was primarily used to quantify the lower limit for which open river conditions would occur. In other words, this condition is only met when the flow moving through the dam is so high that the tailwater is above the crest of the spillway. The percentage of time for which this criteria was met is shown in Table 5

3.1.3 Method 3: Q > Control

The third method also assumes that invasive carp are only able to pass through the dam under open river conditions. This method is different from the previous method in that it relies on the definition of open river conditions from the gate operations manual for each Lock and Dam. Daily flow (Q) measurements at each Lock and Dam were used, along with the control flow at which gates should be lifted out of the water, to check the following condition:

$$Q > control\ flow$$

Open river conditions are assumed to be met for any day when the flow exceeds the control flow specified for lifting the gates out of the water. Flow data was not available for Lock and Dam 6, so no evaluation was performed at this location. The percentage of time for which this criterion was met is shown in Table 5.

3.1.4 Method 4: Tainters > 10'

The final method does not rely on that assumption that invasive carp passage only occurs during open river conditions. Instead, this method is based on common carp passage data collected from 2019 – 2020 at Lock and Dam 8 and the actual conditions carp were noted to pass under. This data, summarized in Figure 6, shows that during 2019 common carp were observed passing through the gates when the flow in the river required that individual tainter gates were opened 10 feet according to the water control manual. During high, variable flow conditions at Lock and Dam 8, the tainter gates were moved between open river conditions and 10 feet open. This observation from the detailed Lock and Dam operations provided by the USACE was matched by the water control manual recommendations. The operations manual states that above the control flow, the gates should remain out of the water until flows drop below that control flow at which point they should be closed to 10 feet.

The dam operations data at Lock and Dam 8 indicates that the tainter gates are not opened more than 10 feet unless the control flow is exceeded. We found that the tainter gate height to put the gates back in the water following a period where the gates are out of the water is similar for each of the 6 Lock and Dams (i.e. for Lock and Dam 4 the height is 8 feet, for 5 it is 10 feet, for 5A it is 9 feet, and for 6 through 8 it is 10 feet). The flow at each Lock and Dam corresponding to these tainter gate heights was identified and compared to the daily flow. Any day when this flow was exceeded was assumed to be a passage day for invasive carp. The percentage of time for which this criteria was met is shown in Table 5

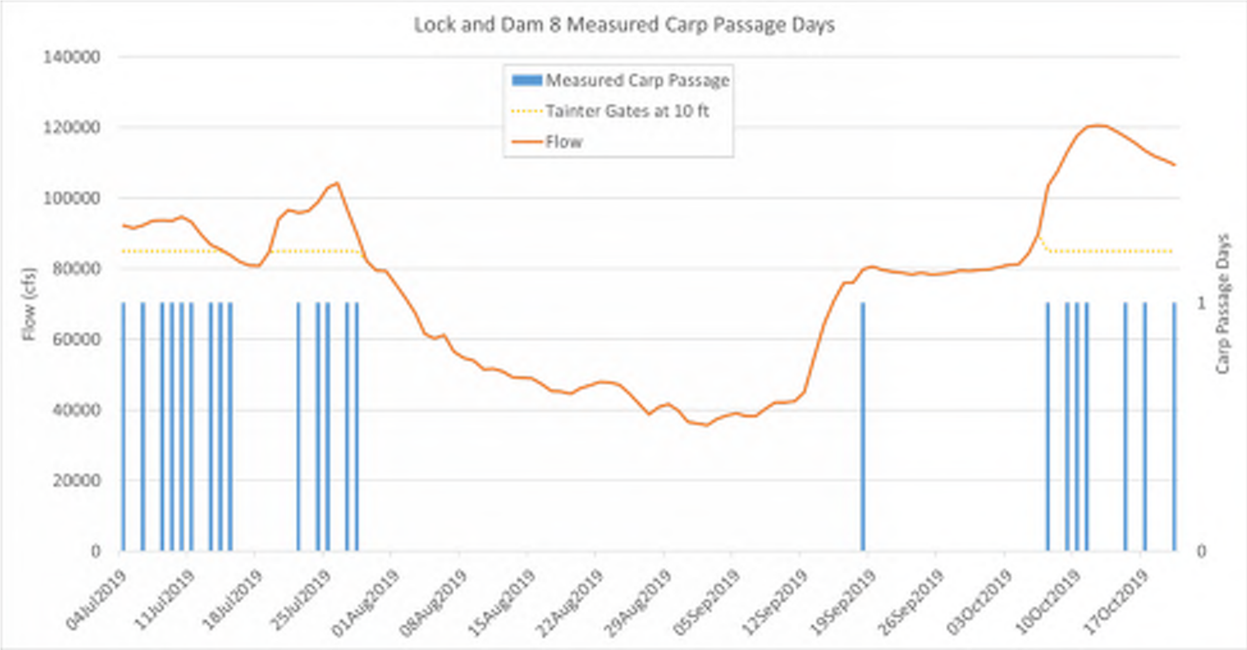


Figure 6 **Invasive carp passage days at Lock and Dam 8 (Sorensen Lab, University of Minnesota)**

Table 5 **Estimates for percentage of time passable for invasive carp from 2000 - 2020**

Location	Method 1: HW – TW < 1′	Method 2 TW > 2nd Control	Method 3 Q > Control	Method 4 Tainters > 10′
Lock and Dam 4	6.2%	3.4%	5.6%	7.8%
Lock and Dam 5	2.3%	1.1%	2.2%	2.5%
Lock and Dam 5A	19.2%	9.6%	16.2%	18.5%
Lock and Dam 6	12.4%	4.5%	NA	12.7%
Lock and Dam 7	6.6%	1.4%	6.0%	8.0%
Lock and Dam 8	6.9%	2.3%	6.4%	8.8%

3.2 Hydraulic Evaluation Results

The results of the hydraulic evaluation show that for each criterion considered, Lock and Dam 5 is the least likely to experience conditions favorable for invasive carp passage. While methods 1 through 3 are useful for understanding how often gates are lifted out of the water, invasive carp passage data at Lock and Dam 8 indicates that invasive carp can pass while the gates are still in the water (i.e. tainter gates are at 10ft). Using this data, a flow was identified at each lock and dam at which invasive carp are likely to be able to pass. This flow corresponds to the highest gate opening before and immediately after the gates are lifted out of the water.

3.3 Overtopping of Site Features

As discussed in Chapter 2, there are site features that may be subject to overtopping during certain flood events. These features are presented in Table 3-6 and include the embankment dam crest, fixed crest spillway, and submersible dam. The flood of records at each site show that the flood of record elevations are below the lowest embankment dam elevation in each case.

Table 3-6 Summary of site features relevant to invasive carp passage

Site	Lowest Embankment Dam Elevation	Fixed Crest Spillway or Submersible Dam	Flood of Record
Lock and Dam 8	639.5′	West Submersible Dam: 631.0′ East Submersible Dam: 631.0′	639.18′ (1965)
Lock and Dam 7	649.0′	Spillway: 639.0′ Onalaska Dam: 639.0′	648.18′ (1965)
Lock and Dam 6	654.5′	645.5′	654.65′ (1965)[1]
Lock and Dam 5A	664.0′	651.0′	663.74′ (1965)
Lock and Dam 5	670.0′	NA	668.73′ (1965)
Lock and Dam 4	677.0′	NA	676.45′ (1965)

Note(s):

1) Embankment raised 3′ during flood event

4 Conclusions

Although many site features are similar across the 6 locks and dams (ex. availability of power, lock width), the frequency that each lock and dam was susceptible to invasive carp passage via its spillway gates, and their vulnerability to passage via fixed crest spillways and submersible dams differed greatly. Upper pool size also varied. Based on the later features, Lock and Dam 5 is recommended as the most promising site for installing a carp deterrent system. This site is unique because only it: (1) lacks a fixed crest spillway or submersible dam, (2) has a relatively small upstream pool to facilitate monitoring and removal of invasive carp following a flood event, and (3) is the least likely to experience conditions favorable for invasive carp passage.

Table 4-1 Lengths of site features sensitive to invasive carp passage

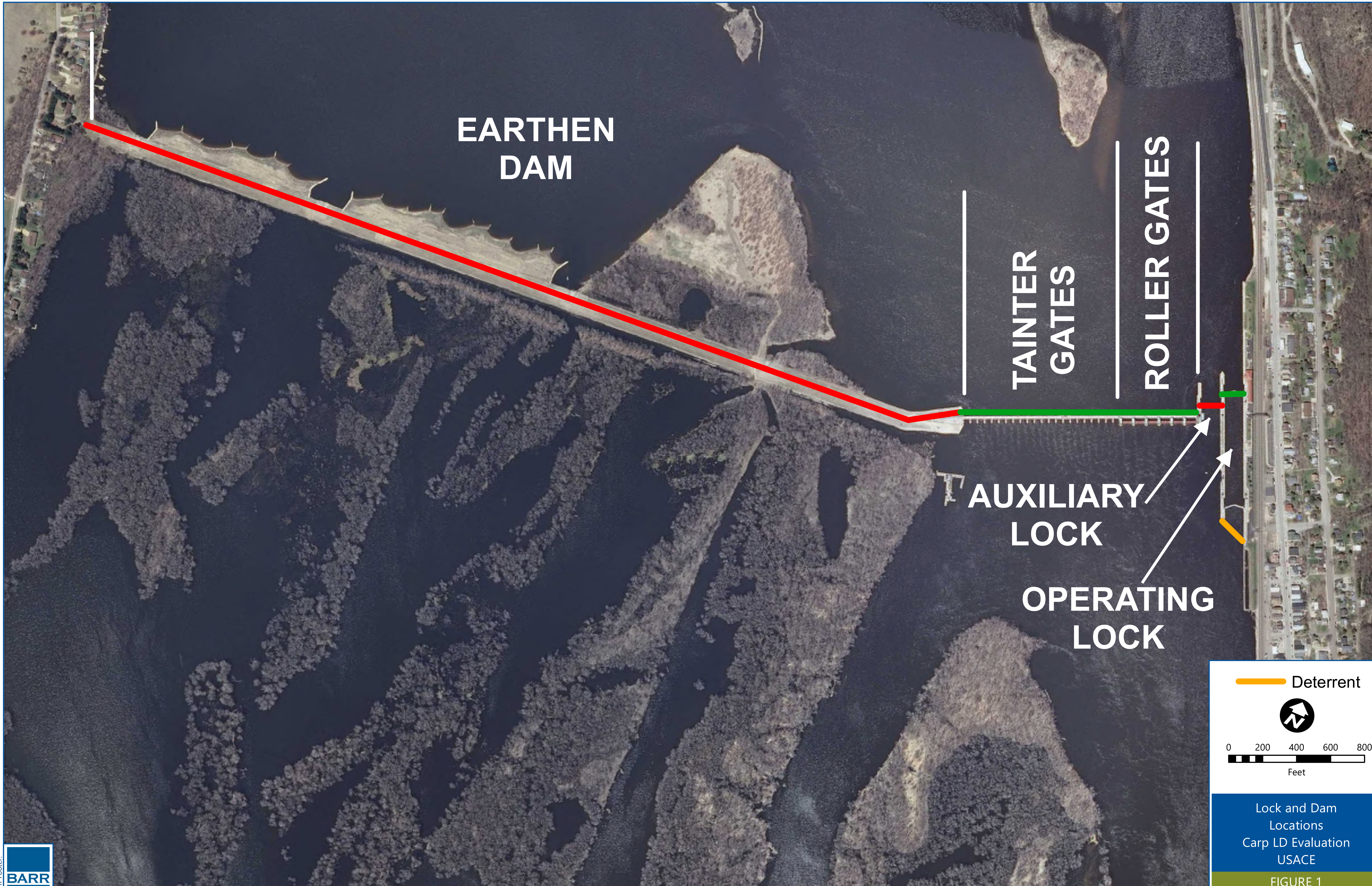
Site	Roller Gates	Tainter Gates	Culverts or Sluices	Fixed Crest Spillway	% Passable
Lock and Dam 8	5 Gates @ 80′ = 400′	10 Gates @ 35′ = 350′	2	1 @ 937.5′ 1 @ 1337.5′	8.8%
Lock and Dam 7	5 Gates @ 80′ = 400′	11 Gates @ 35′ = 385′	3	1 @ 670′[1] 1 @ 1,000′	8.0%
Lock and Dam 6	5 Gates @ 80′ = 400′	10 Gates @ 35′ = 350′	4	1,000′	12.7%
Lock and Dam 5A	5 Gates @ 80′ = 400′	5 Gates @ 35′ = 105′	2	1,000′	18.5%
Lock and Dam 5	**6 Gates @ 80′ = 480′**	**28 Gates @ 35′ = 980′**	4	**NA**	**2.5%**
Lock and Dam 4	6 Gates @ 80′ = 480′	22 Gates @ 35′ = 770′	5	NA	7.8%

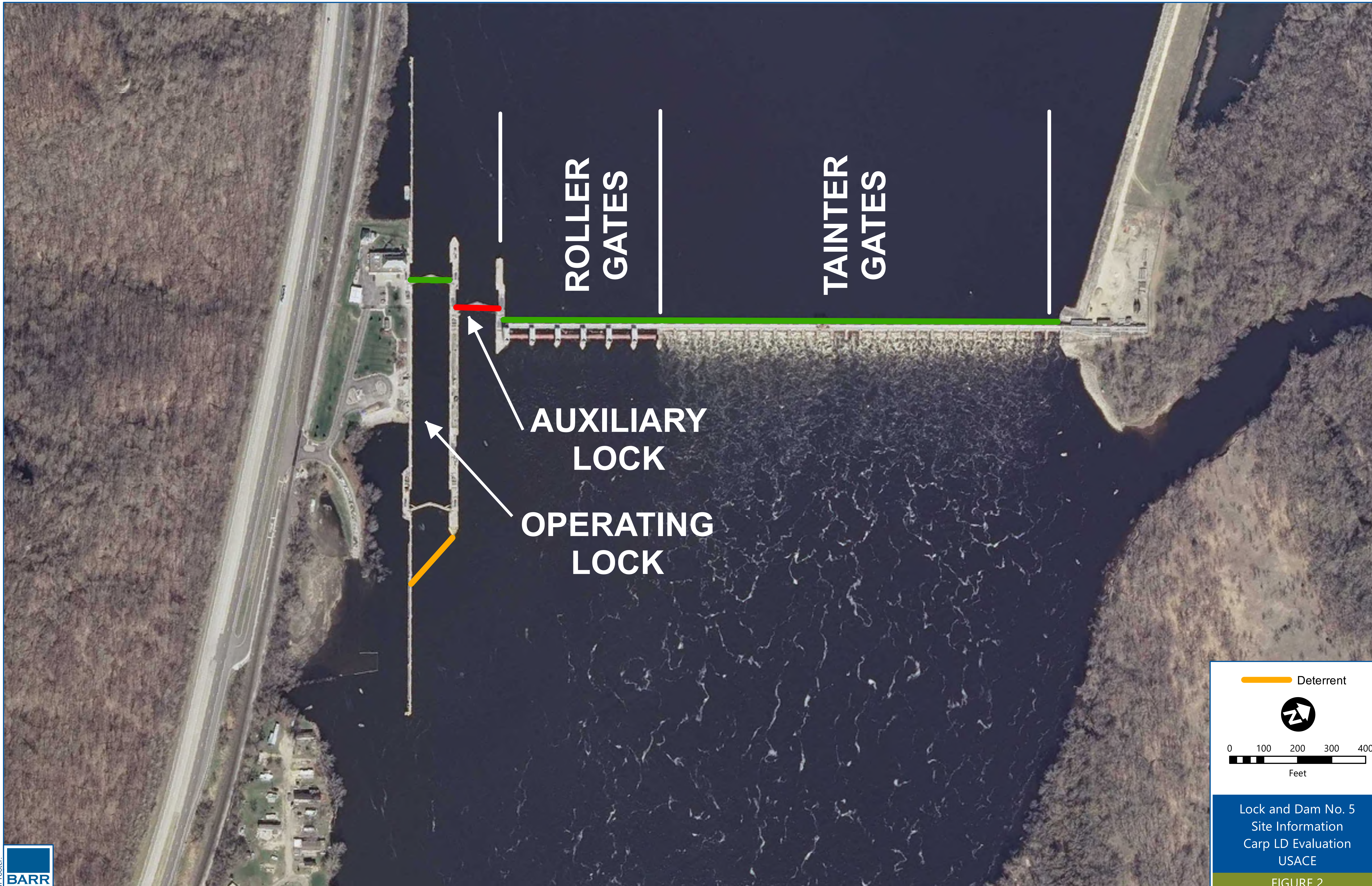
5 References

Zielinski, D.P.; Sorensen, P.W. Numeric Simulation Demonstrates That the Upstream Movement of Invasive Bigheaded Carp Can Be Blocked at Sets of Mississippi River Locks-and-Dams Using a Combination of Optimized Spillway Gate Operations, Lock Deterrents, and Carp Removal. *Fishes* **2021**, 6, 10. https://doi.org/10.3390/fishes6020010

Appendix A

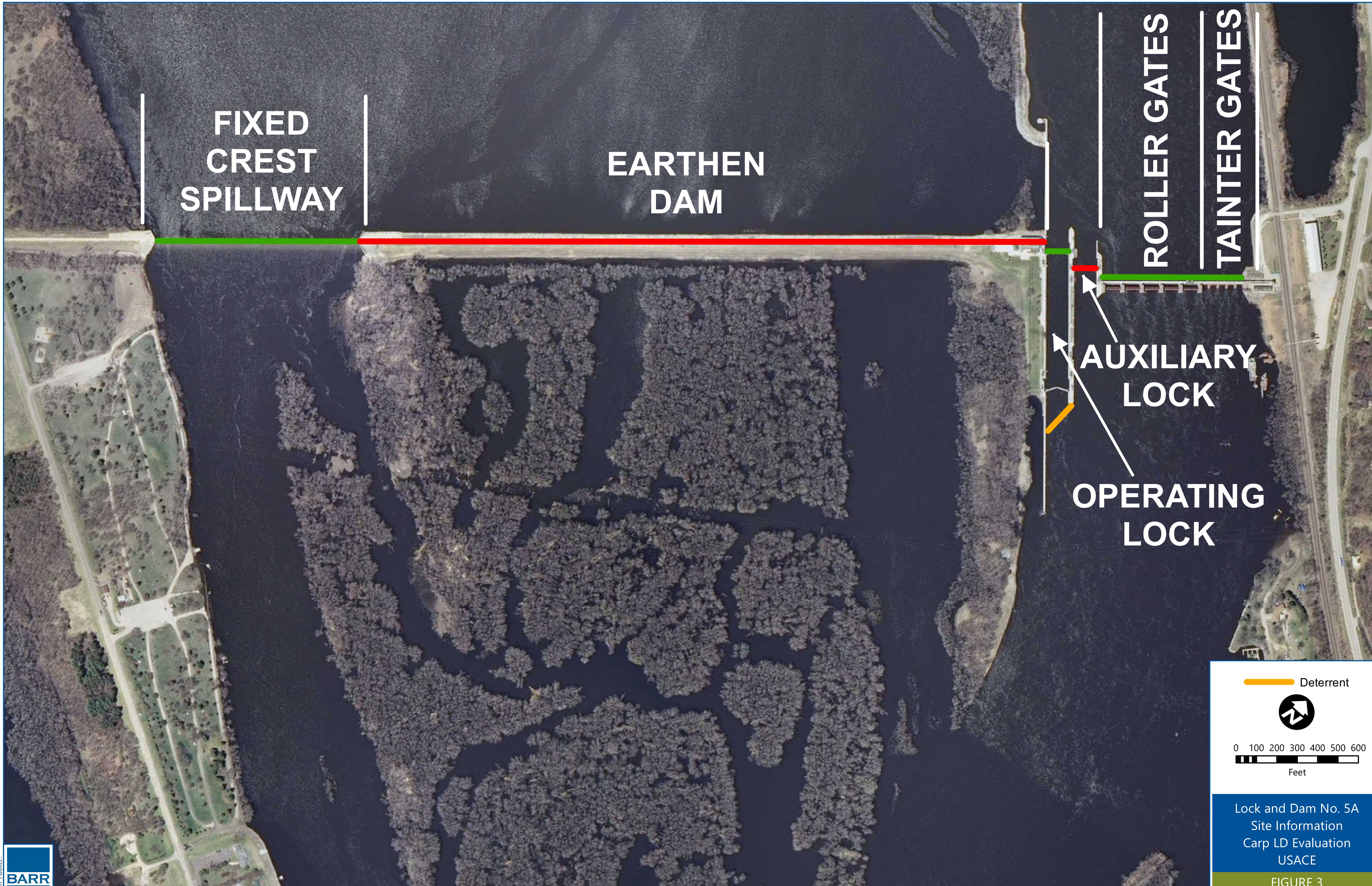
Site Maps

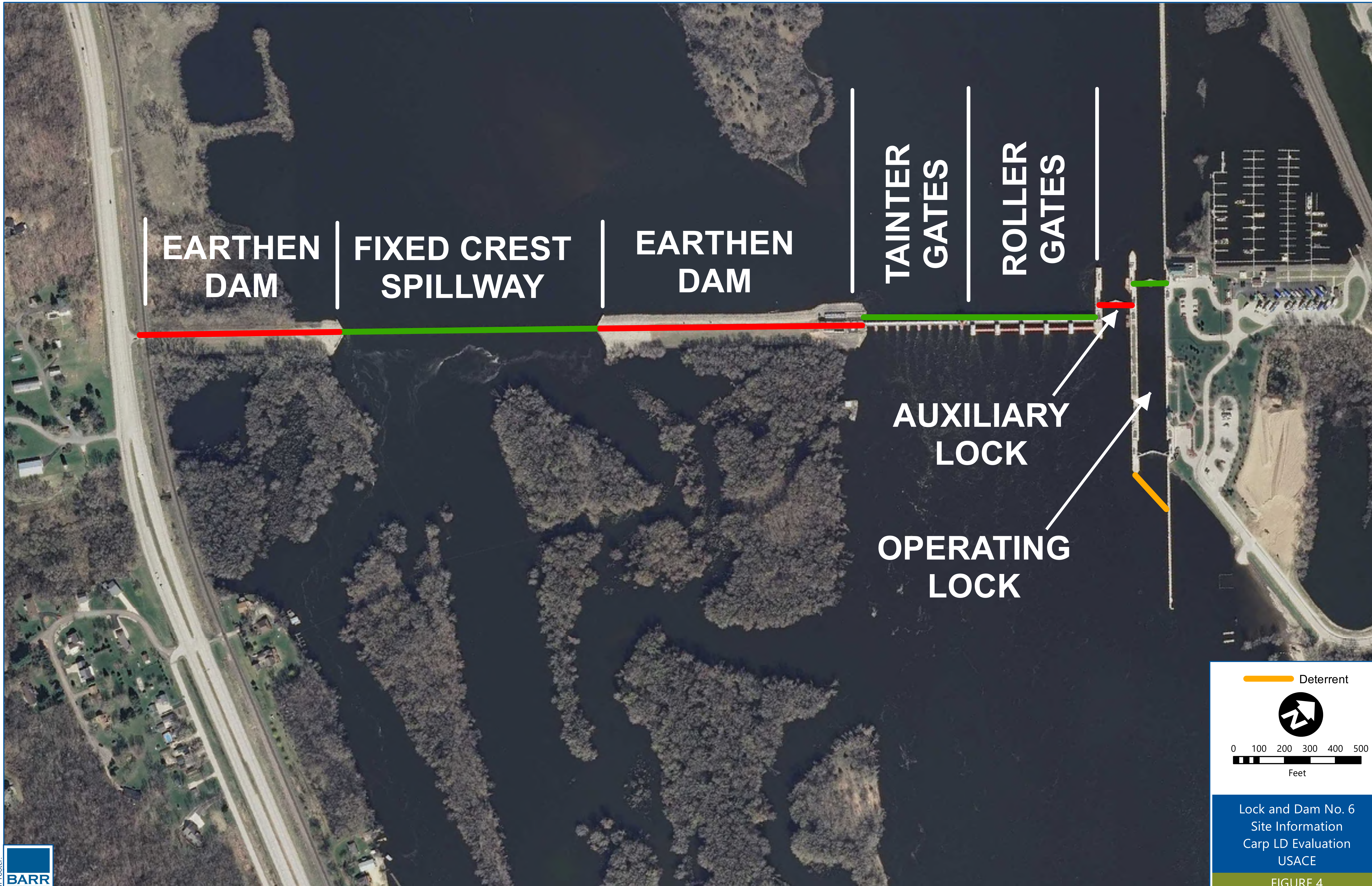

EARTHEN DAM
TAINTER GATES
ROLLER GATES
AUXILIARY LOCK
OPERATING LOCK
Deterrent
0
200
400
600
800
Feet
Lock and Dam Locations
Carp LD Evaluation
USACE
FIGURE 1
BARR
Barr Footer:



Lock and Dam No. 5
Site Information
Carp LD Evaluation
USACE

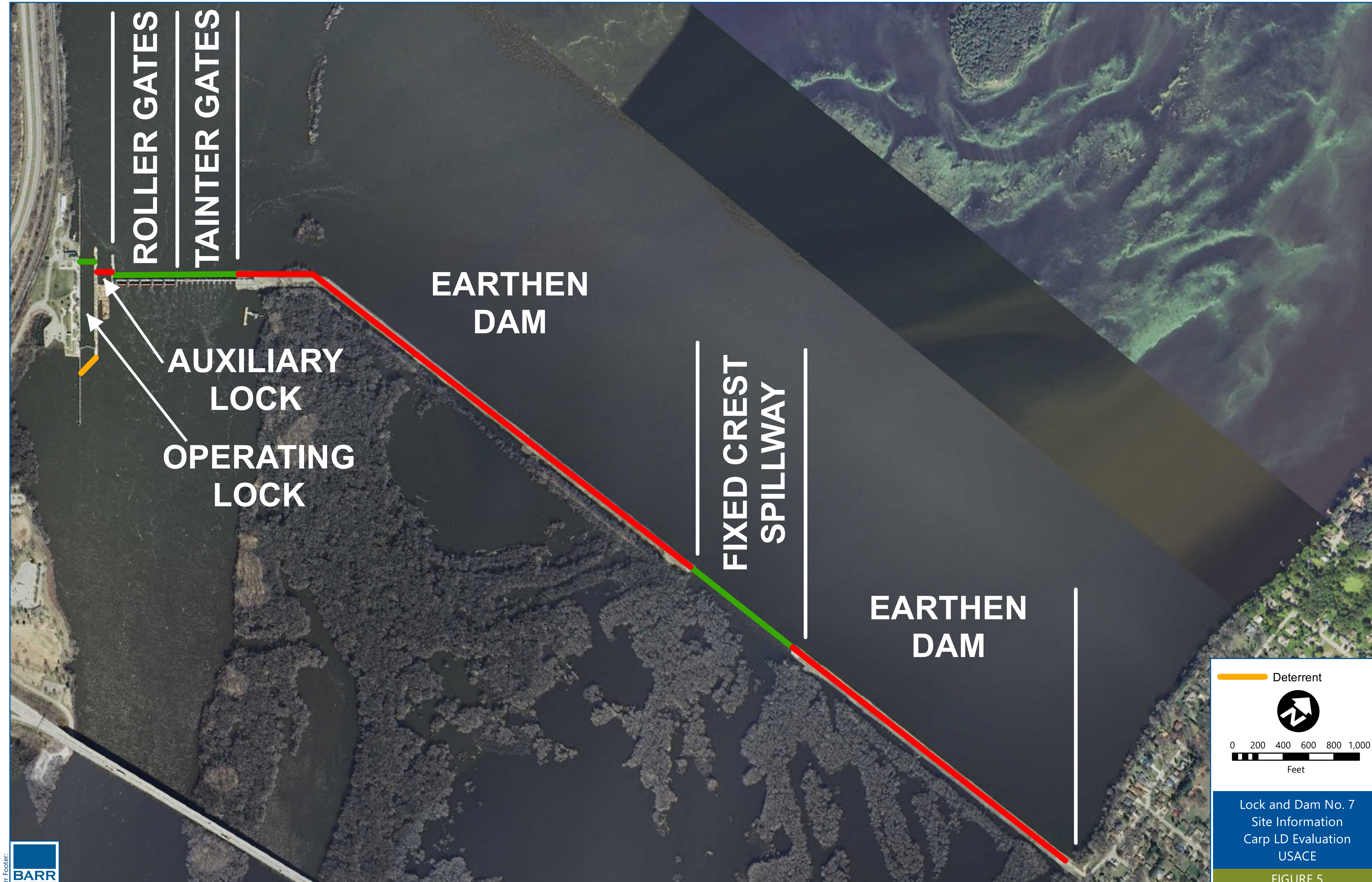
FIGURE 2

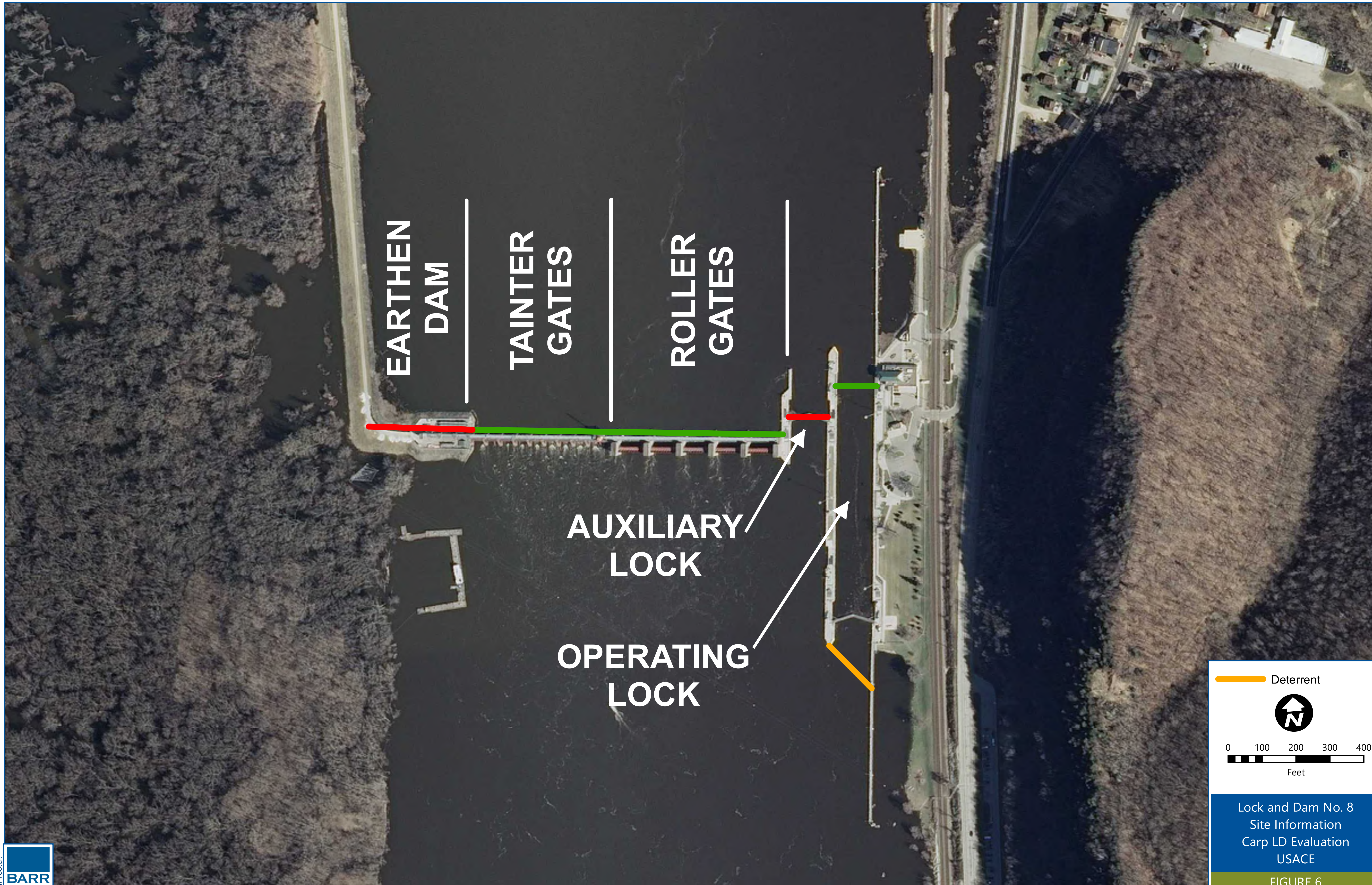

FIXED CREST SPILLWAY
EARTHEN DAM
ROLLER GATES
TAINTER GATES
AUXILIARY LOCK
OPERATING LOCK
Deterrent
0 100 200 300 400 500 600
Feet
Lock and Dam No. 5A
Site Information
Carp LD Evaluation
USACE
FIGURE 3
BARR
Barr Footer:



Lock and Dam No. 6
Site Information
Carp LD Evaluation
USACE

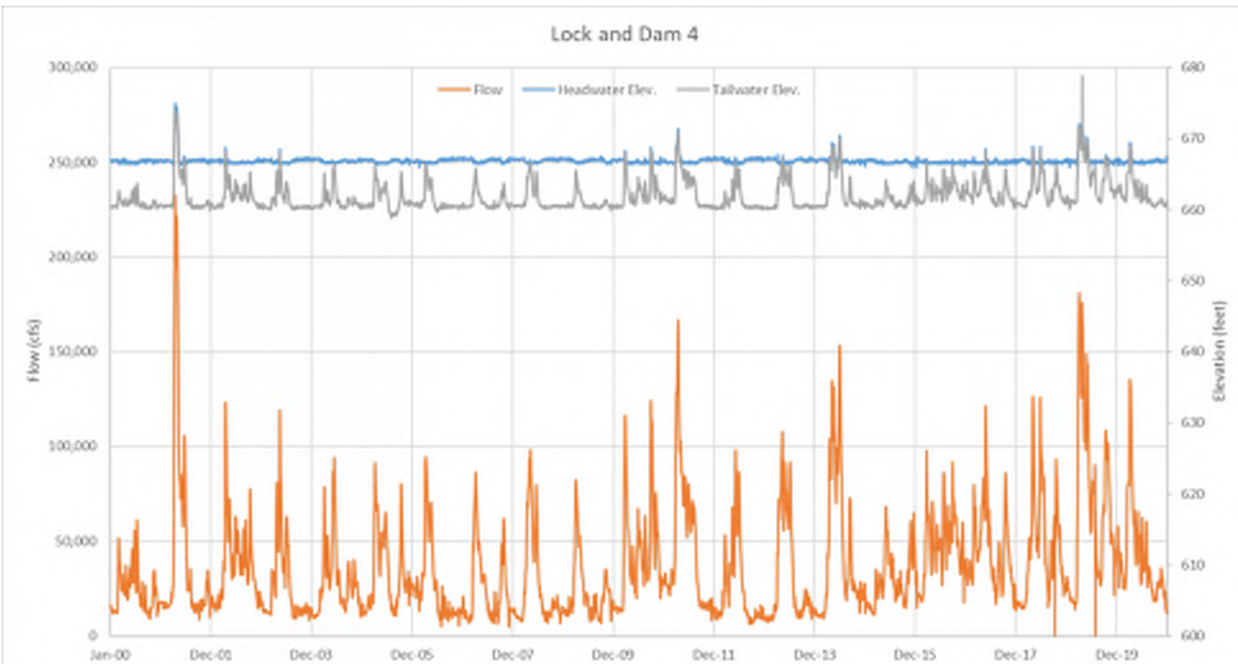
FIGURE 4

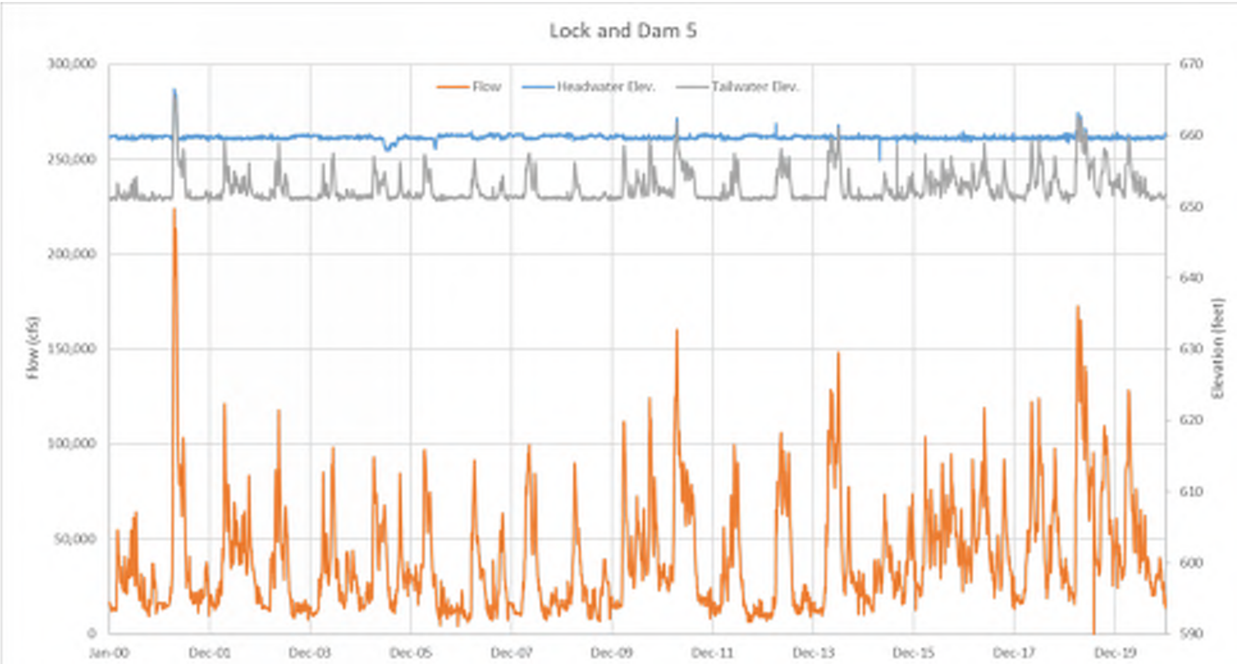

ROLLER GATES
TAINTER GATES
EARTHEN DAM
AUXILIARY LOCK
OPERATING LOCK
FIXED CREST SPILLWAY
EARTHEN DAM
Deterrent
0 200 400 600 800 1,000
Feet
Lock and Dam No. 7
Site Information
Carp LD Evaluation
USACE
FIGURE 5
BARR
Barr Footer:

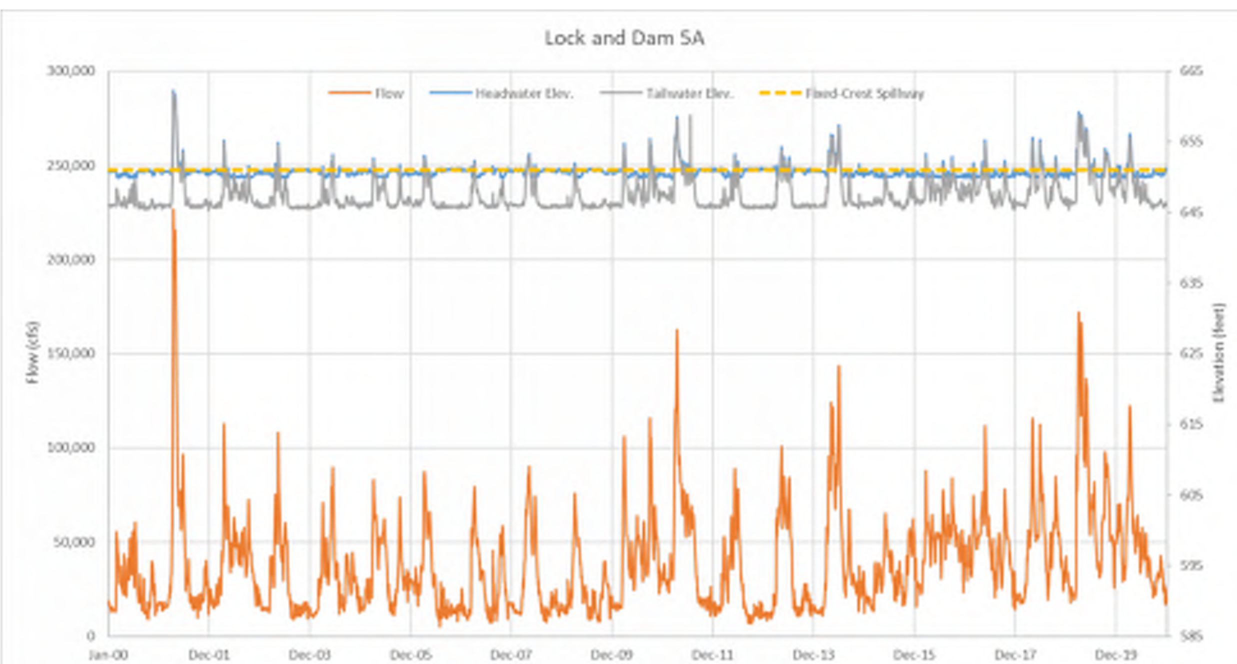

EARTHEN DAM
TAINTER GATES
ROLLER GATES
AUXILIARY LOCK
OPERATING LOCK
Deterrent
N
0 100 200 300 400
Feet
Lock and Dam No. 8
Site Information
Carp LD Evaluation
USACE
FIGURE 6
BARR
Barr Footer:

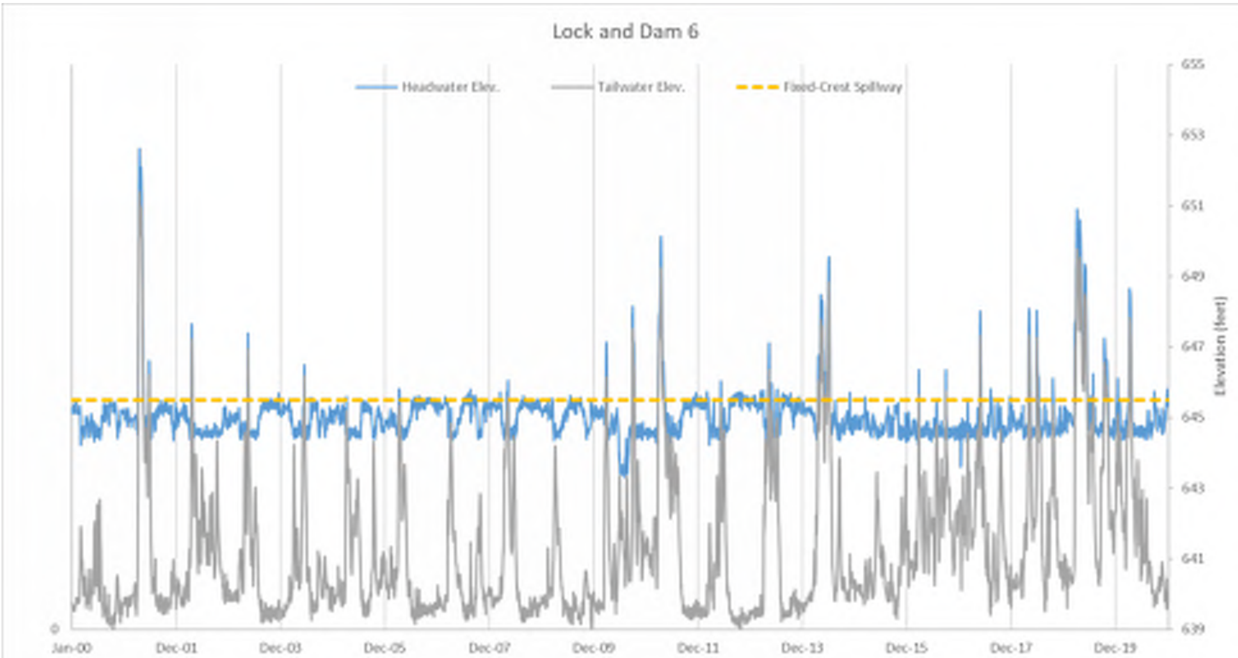
Appendix B

Hydraulic Data




Lock and Dam 5
Flow
Headwater Elev.
Tailwater Elev.
Flow (cfs)
Elevation (feet)
300,000
250,000
200,000
150,000
100,000
50,000
0
670
660
650
640
630
620
610
600
590
Jan-00
Dec-01
Dec-03
Dec-05
Dec-07
Dec-09
Dec-11
Dec-13
Dec-15
Dec-17
Dec-19


Lock and Dam 5A
Flow
Headwater Elev.
Tailwater Elev.
Fixed-Crest Spillway
Flow (cfs)
Elevation (feet)
300,000
250,000
200,000
150,000
100,000
50,000
0
665
655
645
635
625
615
605
595
585
Jan-00
Dec-01
Dec-03
Dec-05
Dec-07
Dec-09
Dec-11
Dec-13
Dec-15
Dec-17
Dec-19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Headwater Elev.
Tailwater Elev.
Fixed-Crest Spillway
Elevation (feet)
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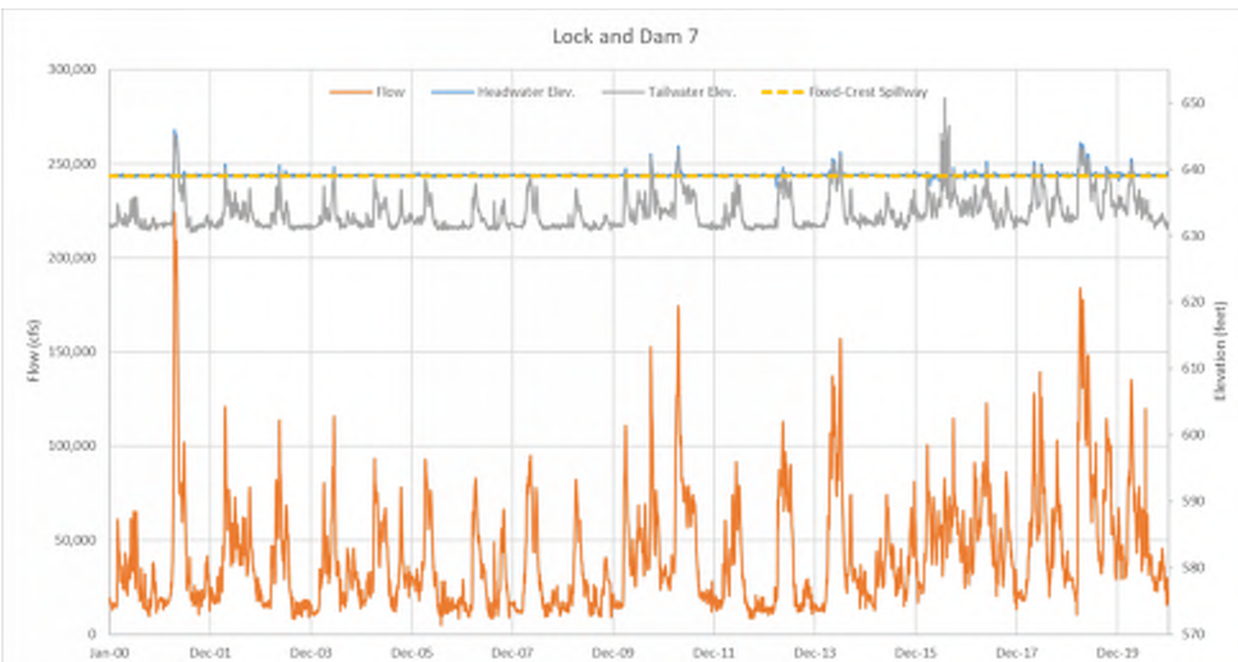
653
651
649
647
645
643
641
639
0
Jan-00
Dec-01
Dec-03
Dec-05
Dec-07
Dec-09
Dec-11
Dec-13
Dec-15
Dec-17
Dec-19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Tailwater Elev.
Fixed-Crest Spillway
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Elevation (feet)
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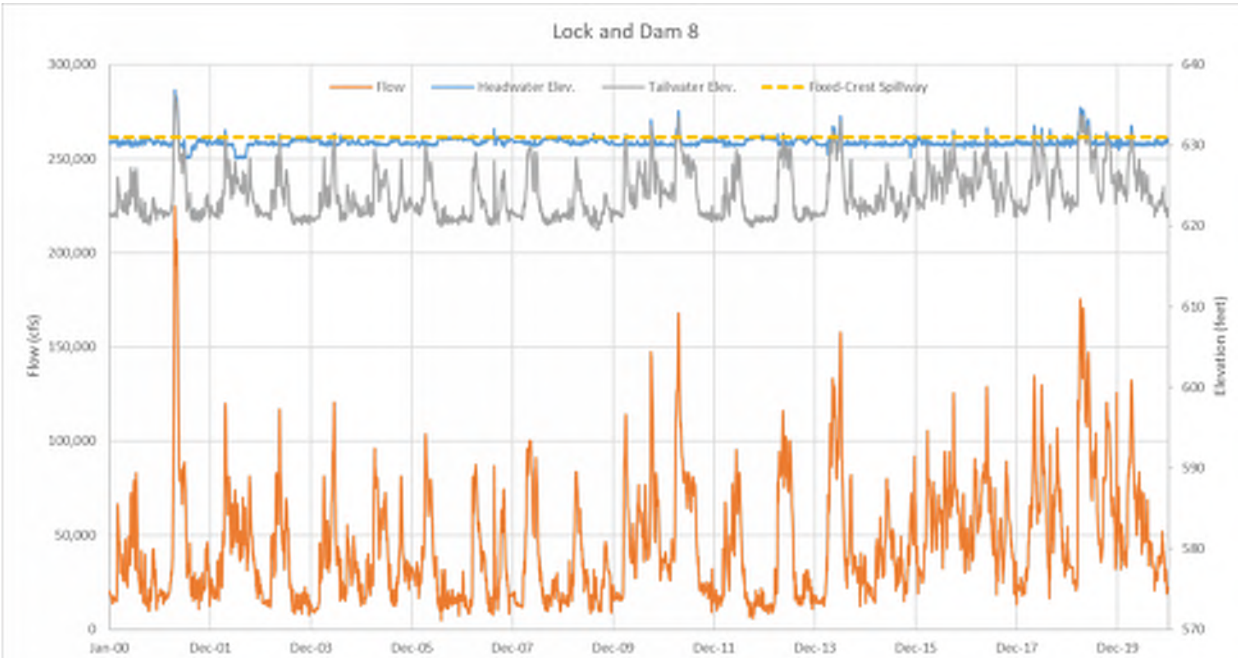
200,000
150,000
100,000
50,000
0
650
640
630
620
610
600
590
580
570
Jan-00
Dec-01
Dec-03
Dec-05
Dec-07
Dec-09
Dec-11
Dec-13
Dec-15
Dec-17
Dec-19


Lock and Dam 8
Flow
Headwater Elev.
Tailwater Elev.
Fixed-Crest Spillway
Flow (cfs)
Elevation (feet)
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250,000
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150,000
100,000
50,000
0
640
630
620
610
600
590
580
570
Jan-00
Dec-01
Dec-03
Dec-05
Dec-07
Dec-09
Dec-11
Dec-13
Dec-15
Dec-17
Dec-19

Appendix B

Description of Barkley Dam BAFF Installation and Associated Lesson's Learned

resourceful. naturally.
engineering and environmental consultants

BARR

Memorandum

To: File
From: BJ Siljenberg
Subject: Barkley Dam Lock BAFF Installation and Associated Lesson's Learned

A deterrent system called a bio-acoustic fish fence (BAFF) was installed by the United States Fish and Wildlife Service (USFWS) at Barkley Dam Lock on the Cumberland River just upstream from its confluence with the Ohio River in Western Kentucky. This system was installed crossing the 110-foot-wide lock chamber on the downstream side of the downstream miter gates similar to the proposed layout at Lock and Dam 5. While invasive carp are present upstream and downstream of Barkley Lock and Dam already, this system was installed for the purposes of research.

For the Barkley Dam Lock installation, Fish Guidance Systems (FGS) contracted directly with USFWS to install the system. FGS provided and maintained the equipment and hired Barr to engineer all aspects of the installation that were not covered by their engineers for the supplied system components. FGS hired J.F. Brennan to provide cost estimating and constructability reviews during design and ultimately install the system.

Lessons learned meetings were held with FGS and J.F. Brennan to discuss how the design and installation at Barkley Dam Lock could be improved. The detailed meeting minutes are presented in Appendix E and Appendix F for FGS and J.F. Brennan respectively. Key themes from those discussions follow:

- Provide more room in the underwater structure that houses and protects the BAFF system.
- Provide more room in the mechanical and electrical/control rooms at the surface.
- Have custom-built steel-framed buildings in lieu of prefabricated shipping container or CONEX Box style buildings.
- Have more frequent meetings during design to include the supplier and contractor throughout design.
- Include additional investigations at early design phases such as dive inspections, bathymetric surveys, site surveys, and geotechnical explorations.
- Assume redundancy in early design phases and remove if elected by stakeholders in later design phases.

Appendix C

Left Embankment Dam Conduit

Memorandum

To: File
From: BJ Siljenberg
Subject: Embankment Dam Conduits

As shown in Figure 1, the left dam embankment extends approximately 15,000 feet upstream (along the river) of the spillway and lock. There are two sets of conduits—or culverts—that penetrate this embankment dam: three 48-inch-diameter pipes on the upstream end and one 36-inch-diameter pipe about halfway down the embankment dam. These conduits were added after the original dam construction for the purpose of providing water to the Indian Creek slough.

The three 48-inch-diameter pipes contain a valve structure that enables closure from mid-November through mid-April. This closure is specified for environment reasons by either the Wisconsin or Minnesota DNR. When not closed, the culverts flow continuously. The 36-inch-diameter conduit flows continuously. A profile of the upstream culvert is shown in Figure 2. A profile of the single 36-inch-diameter conduit could not be obtained.

The culvert subject to continuous flow during normal water elevations produces the slowest flow velocity. This velocity was computed using the FHWA software HY-8 based on dimensions and elevations shown in Figure 2. The headwater and tailwater elevations corresponding to normal conditions up to a 0.2% annual exceedance probability were used a test scenario to estimate potential flow velocity through this culvert under a range of conditions, as shown in Table . These HY-8 results indicate that, under normal conditions, an average velocity of greater than 8 ft/s is expected across the 125-foot-long culverts. As headwater and tailwater elevations rise, the velocity is expected to decrease.

Invasive carp swimming performance data shows that carp may only be capable of swimming upstream through these culverts under certain conditions (1). Based on the length of the culvert, a carp would have to sustain a velocity (relative to the culvert) of 4.2 ft/s for 30 seconds, 2.1 ft/s for 1 minute, or 0.2 ft/s for 10 minutes. After adjusting for the flow velocities shown in Table , this amounts to a swimming velocity (relative to the water) of >7 ft/s for 30 seconds, >5 ft/s for 1 minute, or >3 ft/s for 10 minutes. The swimming performance data shows that a typical carp can sustain ~6.8 ft/s for 30 seconds, 5.5 ft/s for 1 minute, and 3.3 ft/s for 10 minutes. Based on these estimates, carp would have the highest probability to passthrough the culverts during flood conditions between the 20% annual exceedance headwater and 10% annual exceedance headwater conditions shown below. Additional work is required related to the risk of invasive carp swimming upstream through these culverts including a better understanding of outlier fish performance and probability fish would find the culverts a desirable passage to enter.

If this risk is deemed unacceptable by decision makers, a deterrent system of some sort would be prudent at the outlet of these culverts. At this location, other barrier types may be preferred over a second BAFF system. Physical barriers such as a screen would be highly problematic as it would regularly clog and require maintenance.

Figure 1 Lock and Dam 5

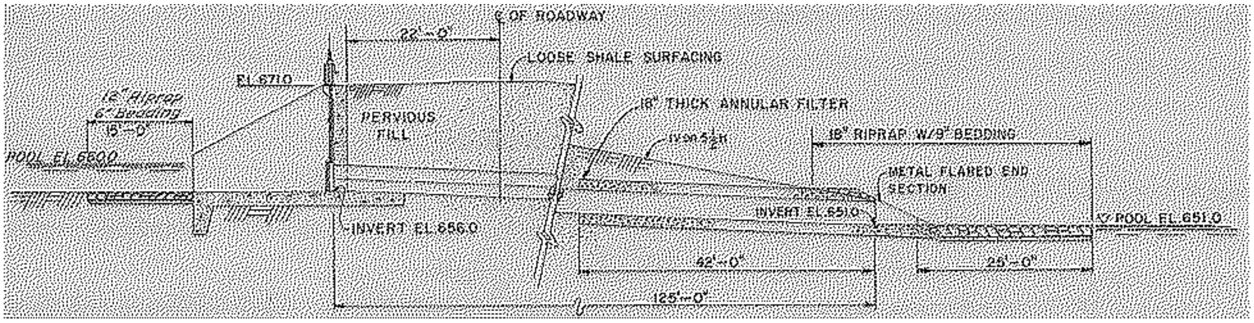

Figure 2 Cross sections of culverts through left dam embankment

Table 1 Culvert Flow Velocity Resulting from Extreme Events

Annual Exceedance Probability	Headwater, ft[1]	Tailwater, ft[1]	Culvert Velocity (ft/s)
Normal Water Elevation	659.6	650.6	8.3
50% (2-yr)	660.3	657.9	6.5
20% (5-yr)	660.8	660.3	3.0
10% (10-yr)	662.8	662.2	3.4
1% (100-yr)	668.9	667.9	4.2
0.2% (500-yr)	670.4	669.5	4.2

Notes:

1) Vertical datum: NAVD 88

Appendix D

10% Layout Drawings

1 SITE PLAN: LOCK AND DAM 5
1" = 30'-0"

10% DRAFT - NOT FOR CONSTRUCTION

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www.barr.com

Scale	NTS
Date	FEB 2022
Drawn	BEH
Checked	JDA
Designed	BJS
Approved	BJS

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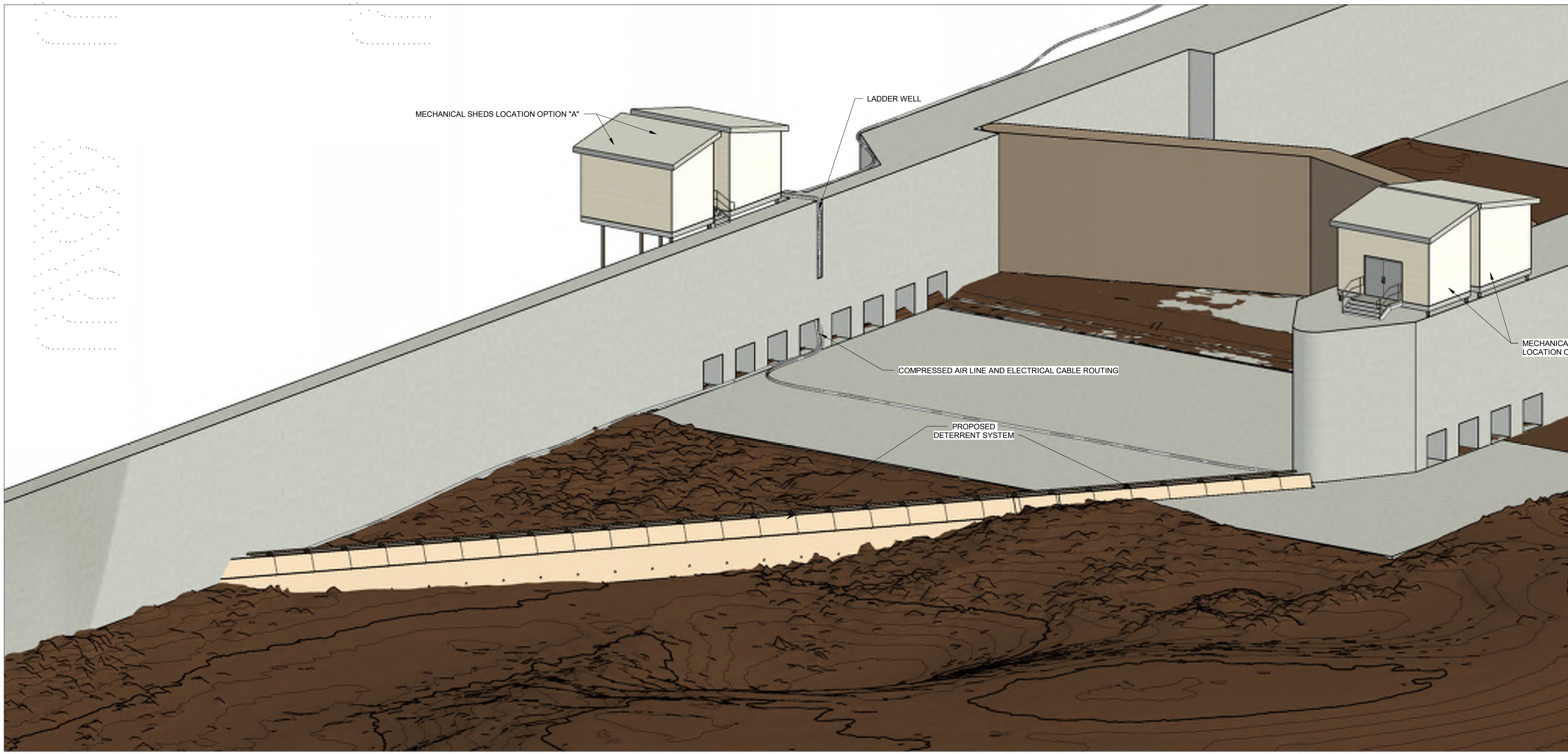
ST.PAUL, MN

LOCK AND DAM 5
MINNESOTA CITY, MINNESOTA
INVASIVE CARP DETERENT FEASIBILITY
SITE PLAN

BARR PROJECT NO. 49061003
CLIENT PROJECT NO.
DWG NO. S-01
REV NO. A



1 ORTHOGRAPHIC: LOCK AND DAM 5 - LOOKING UPSTREAM

NOTES:
1. VERTICAL DATUM FOR ALL ELEVATIONS: NAVD 88
2. BATHEMETRY COLLECTED DECEMBER 2021 BY J.F. BRENNNAN.
3. LOCK STRUCTURAL ELEMENTS PER RECORD DRAWINGS PROVIDED BY USACE.

10% DRAFT - NOT FOR CONSTRUCTION

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ST.PAUL, MN

LOCK AND DAM 5
MINNESOTA CITY, MINNESOTA

INVASIVE CARP DETERENT FEASIBILITY
ORTHOGRAPHIC

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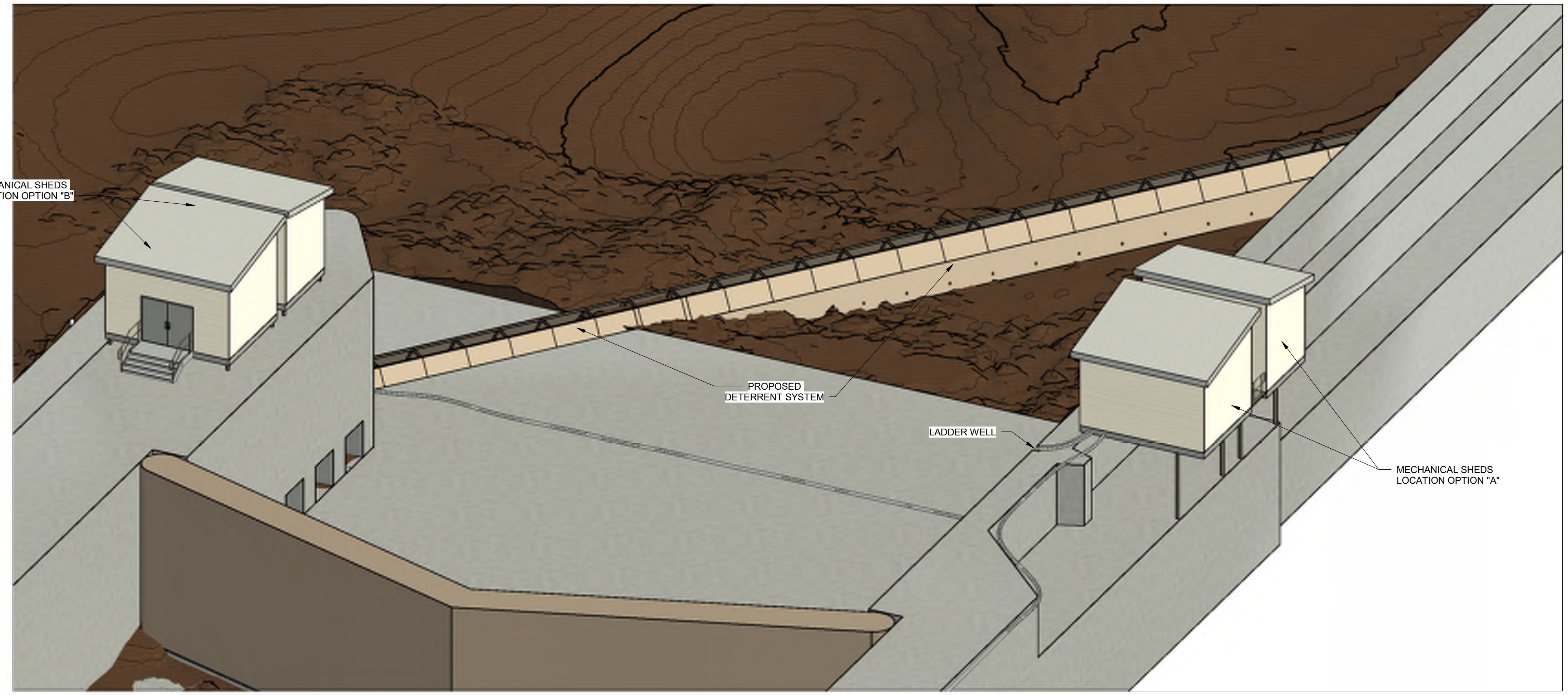
CLIENT PROJECT NO.
DWG NO. S-02
REV NO. A



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LOCK AND DAM 5
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INVASIVE CARP DETERENT FEASIBILITY
ORTHOGAPHIC

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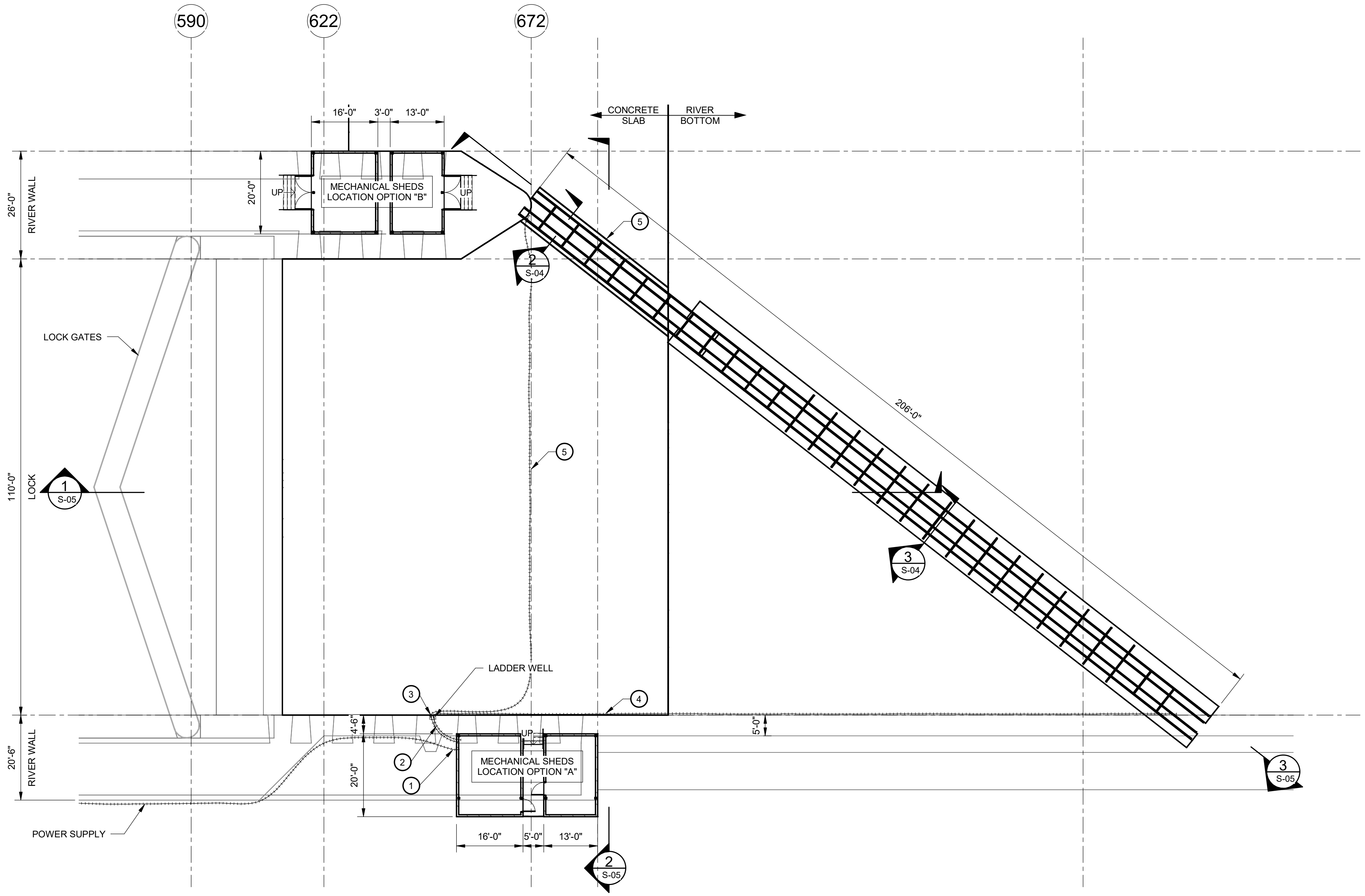
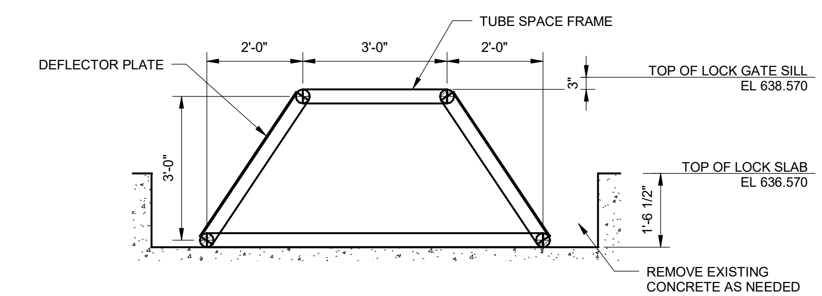
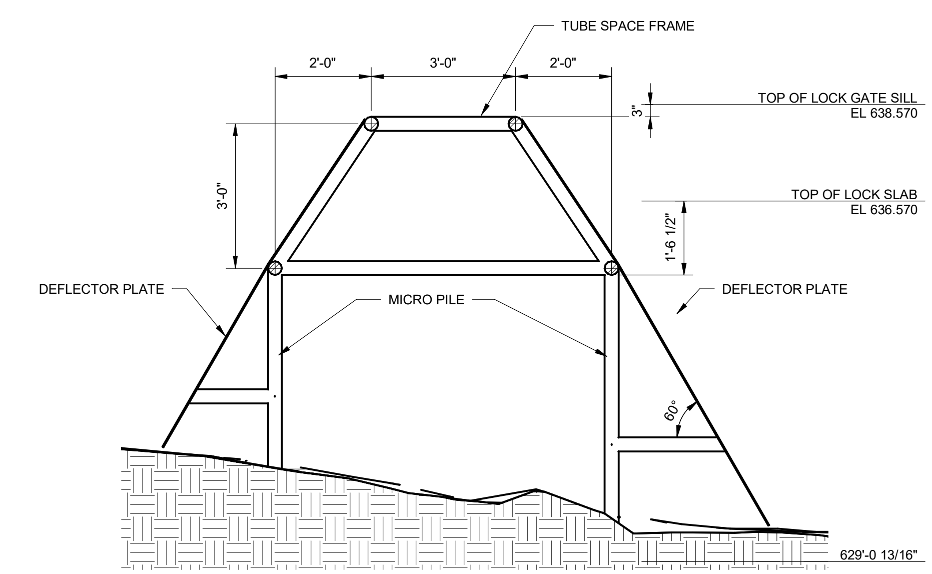
CLIENT PROJECT NO.
DWG NO. S-03
REV NO. A



1 S-01 PLAN: ELEVATION 666'-0"
1/16" = 1'-0"



2 S-04 SECTION: DETERRENT SYSTEM AT TOP OF LOCK SLAB
1/2" = 1'-0"



3 S-04 SECTION: DETERRENT SYSTEM AT NATURAL BOTTOM
1/2" = 1'-0"

KEY NOTES:

1. COMPRESSED AIR LINE AND ELECTRICAL CABLES ALONG BACK SIDE OF WALL
2. COMPRESSED AIR LINE AND ELECTRICAL CABLES THROUGH CHANNEL DEMOED INTO TOP OF CONCRETE WALL. STEEL GRATING PLACED OVER TOP
3. COMPRESSED AIR LINE AND ELECTRICAL CABLE DOWN LADDER RECESS
4. COMPRESSED AIR LINE AND ELECTRICAL CABLES AT BASE OF WALL BELOW BARGE DRAFT
5. 12" DEEP +/- OF CONCRETE SLAB DEMOLITION MAY BE REQUIRED
6. HALF OF COMPRESSED AIR LINES CROSS LOCK CHAMBER TO FEED FROM OPPOSITE SIDE

NOTES:
1. ALL MEMBERS AND GEOMETRY ARE DRAFT SUITABLE FOR FEASIBILITY EVALUATION COMENSURATE WITH A 10% LEVEL OF DESIGN.
2. DETERRENT EQUIPMENT NOT SHOWN.
3. APPROXIMATE LENGTH OF COMPRESSED AIR LINES: 390'-0"
4. APPROXIMATE LEGNTH OF ELECTRICAL CABLE: 730'-0"

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LOCK AND DAM 5
MINNESOTA CITY, MINNESOTA

INVASIVE CARP DETERENT FEASIBILITY
PLAN AND SECTIONS

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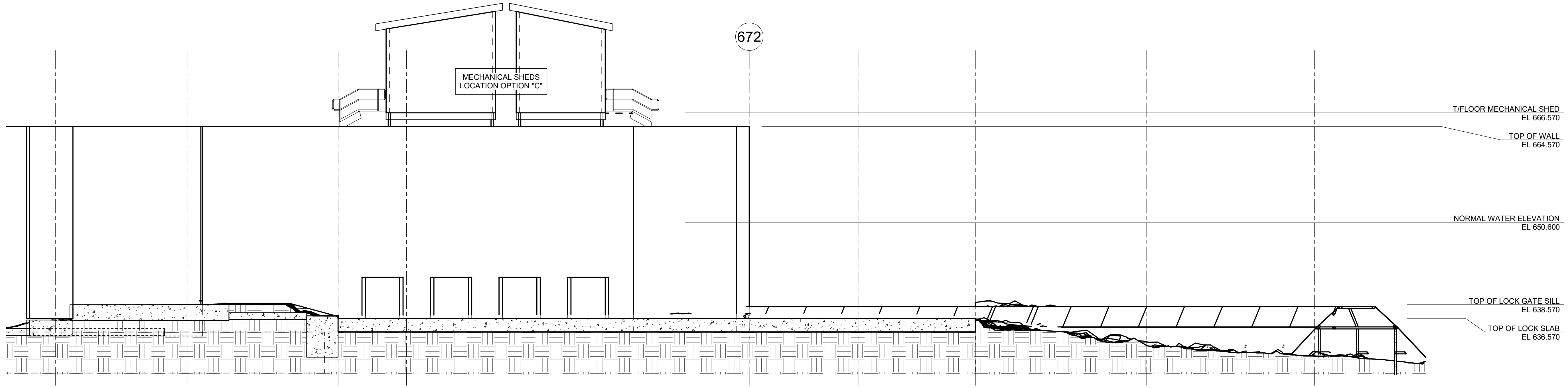
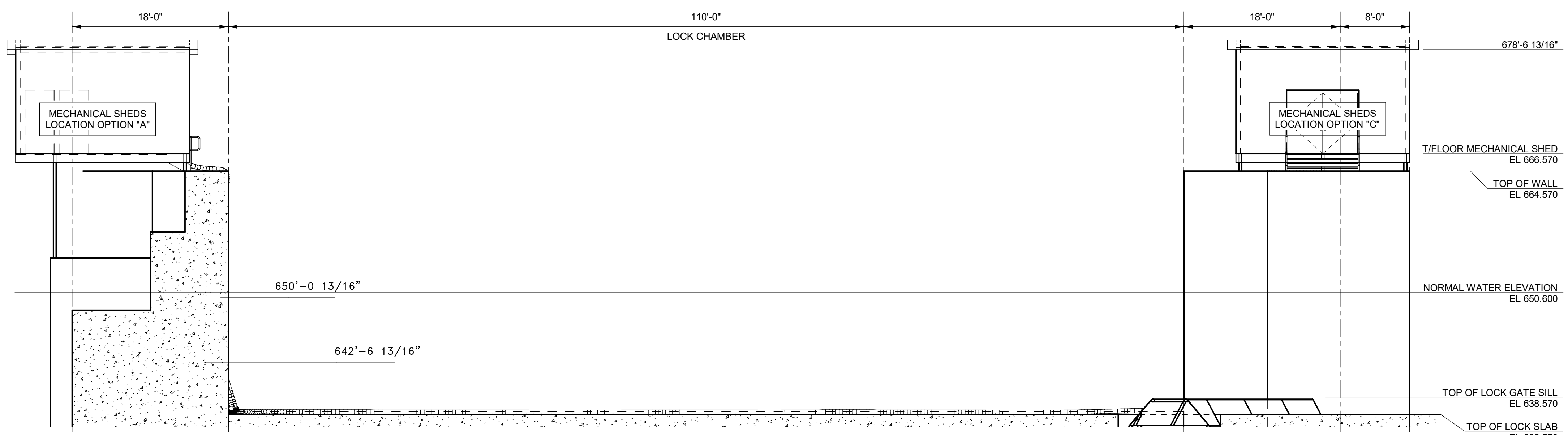
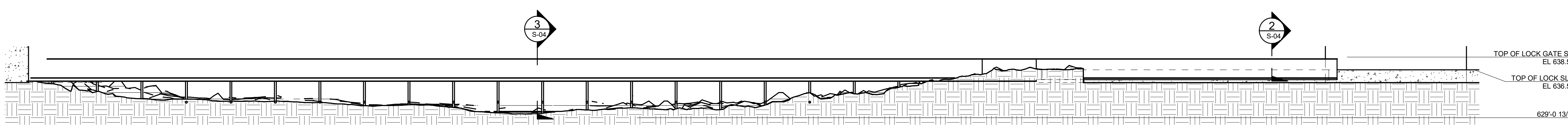
DWG NO. S-04
REV NO. A



1 S-04 SECTION: LOOKING NORTH EAST @ LOCK CENTERLINE
1/8" = 1'-0"



2 S-04 SECTION: LOOKING UPSTREAM
1/8" = 1'-0"



3 S-04 PROFILE: DETERRENT ALIGNMENT LOOKING UPSTREAM
1/8" = 1'-0"

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LOCK AND DAM 5
MINNESOTA CITY, MINNESOTA

INVASIVE CARP DETERENT FEASIBILITY
SECTIONS

BARR PROJECT NO. 49061003
CLIENT PROJECT NO.
DWG NO. S-05
REV NO. A

Appendix E

J.F. Brennan Dive Inspection Report

Underwater Inspection Report

Inspection Performed for:

BARR

Prepared by:

Marine Professionals Since 1919
BRENNAN

818 Bainbridge St.
La Crosse, WI 54603
608.784.7173
www.jfbrennan.com

Owner: U.S. Army Corps of Engineers
Structure: Lock and Dam 5
Location: Winona, Minnesota
Body of Water: Mississippi River
Inspection Date: December 16, 2021

1. Introduction/Background

J.F. Brennan Company, Inc. (Brennan) performed a dive inspection to assist in a feasibility study for installing a Bio-Acoustic Fish Fence (BAFF) system at Lock 5 near Winona, Minnesota on the Mississippi River.

<u>Structure Data</u>

Owner:	USACE
Structure:	Lock & Dam 5
Location:	Near Winona, Minnesota
Waterway Crossing:	Mississippi River

2. Method of Investigation

Date of Inspection: December 16, 2021

Brennan Dive Team:	Eric Hanson	Inspection Team Leader
	Jimmy Williams	Inspection Diver
	Korie Pittman	Tender
	Richard Rios	Standby Diver

The inspection was conducted using surface-supplied air equipment including a Kirby Morgan dive helmet with full diver-to-surface communications. All dives were conducted in accordance with Brennan's Safe Diving Practices Manual as well as all pertinent ADCI, OSHA, and USCG regulations. Additionally, all dives adhered to the dive schedules and decompression tables outlined in the U.S. Navy Dive Manual, Rev. 7.

The three (3) levels of underwater inspections are described as:

Level I - A simple visual or tactile (by feel) inspection, without the extensive use of tools or measuring devices. It is usually employed to gain an overview of the structure and will precede or verify the need for a more detailed Level II or Level III inspection.

Level II - A detailed inspection which involves physically cleaning or removing growth from portions of the structure. In this way, hidden damage may be detected and assessed for severity. This level is usually performed on at least a portion of a structure, supplementing a Level I.

Level III - A highly detailed inspection of a structure which is warranted if extensive repair or replacement is being considered. This level requires extensive cleaning, detailed measurements, and testing techniques that may be either destructive or non-destructive in nature.

3. Inspection Findings

<u>Lock & Dam 5</u>

The Lock was approximately 110-feet wide by 600-feet long. See 'Appendix B, B2' and 'Appendix C, C2' for more information.

- The inspection was conducted by running a cable diagonally from the I-wall's Bullnose to the Land wall (See 'Appendix A, Figure 1'). The diver then did a search pattern 30 to 40-feet upstream and downstream of that cable.
  - At the Land Wall: The cable was approximately 25-feet downstream from the Sill.
  - Approximately 50-feet East of Land Wall: The cable intersected the Sill.
  - At the I-Wall's Bullnose: The cable was approximately 40-feet upstream from the Sill.

- Concrete Sill: The Sill ran horizontally across the Lock, not diagonally like the cable that was ran for the inspection.
    - Sill location at the Land Wall: Station 780.
    - Sill location at the I-Wall: 40-feet downstream of the Bullnose.
    - The water depth throughout the Sill was 15-feet. No debris was found on-top of the concrete Sill, including items like trees and/or steel debris. There was moderate marine growth throughout (See 'Appendix A, Figure 2').
        - **However, some of the smaller riprap, near the I-Wall, has made its way onto the Sill. This riprap was 1 to 2-feet in diameter.**
    - The Sill's Vertical Face was flush with the riprap river bottom for majority of the Chamber.
        - As previously stated, the Sill's vertical face was covered with smaller riprap near the I-Wall.
        - Approximately 40-feet East of the Land Wall the Sill had a vertical face of 6-inches. This exposed vertical face was present for 10-feet. In that area there was minor undermining present.
        - Moving towards the Land Wall the Sill's Vertical Face once again became flush with the larger riprap covered river bottom.
- Upstream of Sill, Into the Lock Chamber:
    - Approximately 6-feet upstream, of the draft reading on the I-Wall, there was a 4-inch step down. This ran horizontally across the entire width of the chamber.
    - The I-Wall concrete was inspected for approximately 30-feet and appeared to be in good condition throughout (See 'Appendix A, Figures 3 & 4').
        - Due to flow conditions the diver was unable to inspect the Dam side of the I-wall.
        - There were no step-outs along the vertical portion of the I-Wall.
        - From the Draft Marker to the 45° angle on the Bullnose there were valve openings.
- Downstream of Sill:
    - Bottom substrate consisted of large and small riprap throughout. The larger riprap was 4-feet in diameter and centralized more towards the Land Wall. Approximately half-way across the Sill Face was when the riprap changed to the 1 to 2-foot diameter rock.
        - As the diver got closer to Station 960, the water depth increased to 18-feet.
    - The Land Wall's vertical face also did not have any step-outs. Overall, the concrete was in good condition with the typical minor age-related wear throughout (See 'Appendix A, Figures 5 & 6').
        - From Stations 780 (vertical face of Sill) to Station 800 there was an area of what looked to be like concrete overpour.
        - Near Station 800: Along the Land Wall there were grout bags placed. This area measured 30-feet long by 5-feet wide and 3-feet tall.
        - Near Station 900: The Land Wall had a section that was not completely flat, it appeared to be a previously repaired joint. It was in the shape of a triangle. At the top of the repair, it was flush with the wall, and at the bottom of the repair, it stuck out by 2-inches. The repair area measured 10-feet tall by 10-feet wide.

Routine Underwater Condition Assessment Rating Descriptions

Good: No visible or only minor damage was noted. Structural elements may show very minor deterioration, but no overstressing was observed. No repairs are required.

Satisfactory: Limited minor to moderate defects or deterioration are observed, but no overstressing was observed. No repairs are required.

Fair: All primary structural elements are sound, but minor to moderate defects or deterioration was observed. Localized areas of moderate to advanced deterioration may be present but do not significantly reduce the load-bearing capacity of the structure. Repairs recommended, but the priority of the recommended repairs was low.

Poor: Advanced deterioration or overstressing was observed on the widespread portions of the structure but does not significantly reduce the load-bearing capacity of the structure. Repairs may need to be carried out with moderate urgency.

Serious: Advanced deterioration overstressing, or breakage may have significantly affected the load-bearing capacity of primary structural components. Local failures are possible and loading restriction may be necessary. Repairs may be carried out on a high-priority basis with urgency.

Critical: Very advanced deterioration, overstressing or breakage has resulted in localized failure(s) of primary structure components. More widespread failures are possible or likely to occur, and load restriction should be implemented as necessary. Repairs may need to be carried out on a very high priority basis with strong urgency.

We appreciate the opportunity to work with USCE and BARR Engineering on this project. If you have any questions or concerns regarding the information within this report, please do not hesitate to contact me directly.

Respectfully submitted,

Joe Baldoni
Dive Division
cell 608.799.5952
jbaldoni@jfbrennan.com

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818 Bainbridge St., La Crosse, WI 54603
www.jfbrennan.com

Marine Professionals Since 1919
BRENNAN

Appendix A – Photographs

List of Figures

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Figure 3 - I-Wall: Overall Good Condition....A3
Figure 4 - I-Wall: Overall Good Condition....A4
Figure 5 - Land Wall: Overall Good Condition....A4
Figure 6 - Land Wall: Location of Sill Face....A5

Figure 1 - Inspection Area Map

Figure 2 - Concrete Sill: Marine Growth

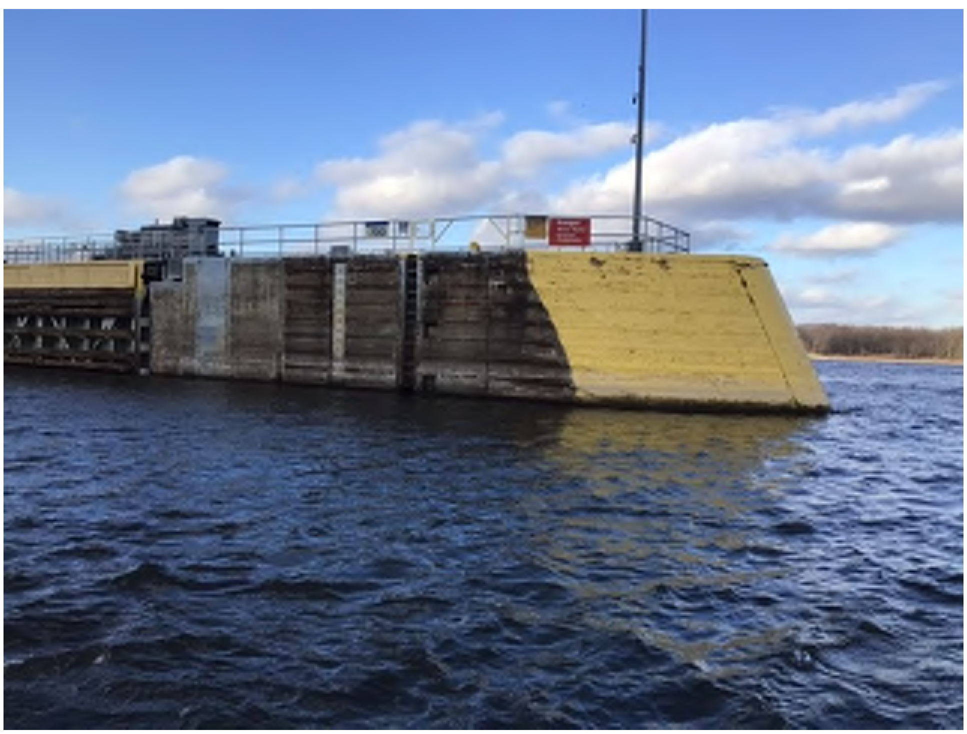


Figure 3 - I-Wall: Overall Good Condition

Figure 4 - I-Wall: Overall Good Condition

Figure 5 - Land Wall: Overall Good Condition

Figure 6 - Land Wall: Location of Sill Face

Appendix B – Drawings

<u>List of Drawings</u>

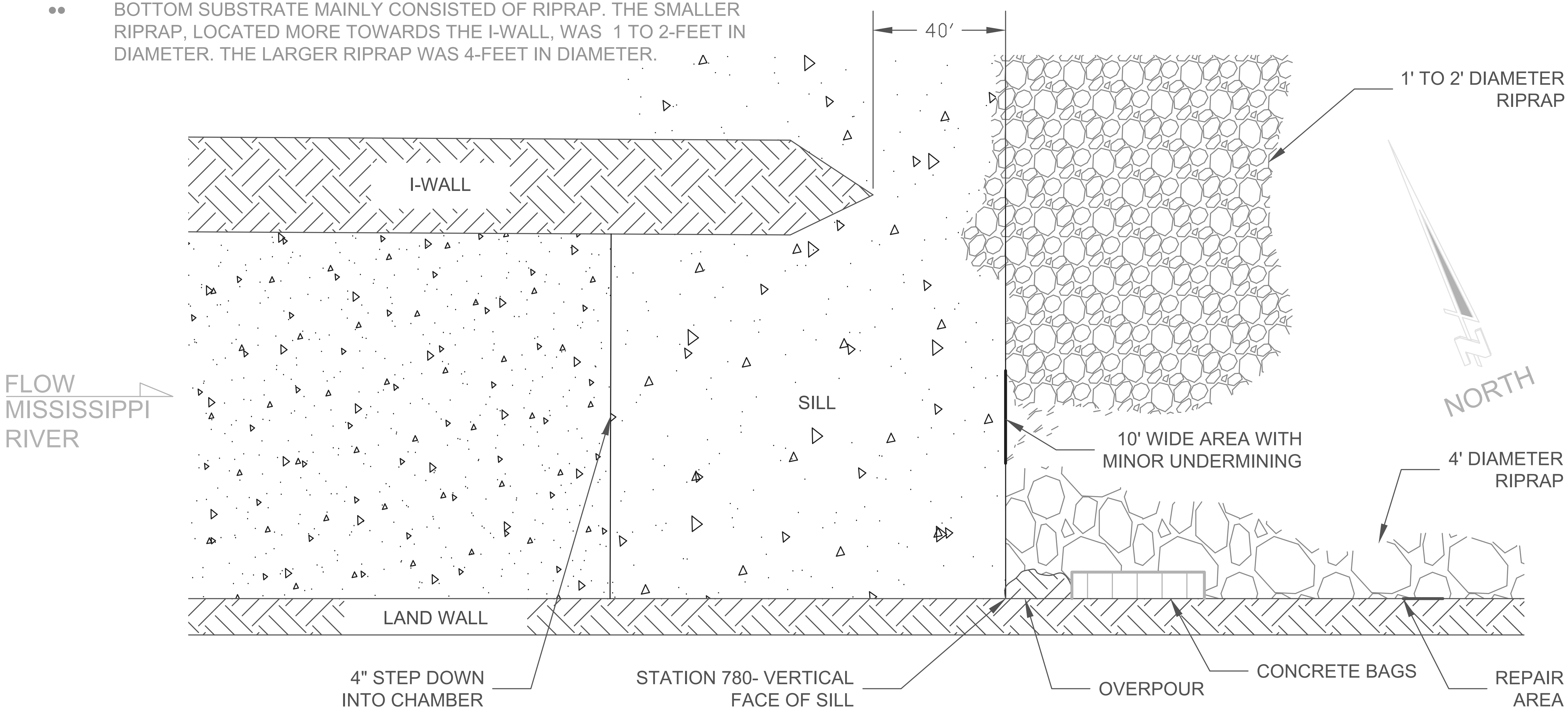
Drawing B2 Lock 5: BAFF Feasibility Study

LOCK 5: BAFF SYSTEM FEASIBILITY STUDY

N.T.S.

LOCK 5 NOTES:

- SILL LOCATION & DESCRIPTION:
  - FROM I-WALL: 40-FEET DOWNSTREAM FROM THE BULLNOSE.
  - FROM LANDWALL: STATION 780.
  - RIPRAP RIVER BOTTOM COVERED MAJORITY OF THE SILL'S VERTICAL FACE. THERE WAS A 10-FOOT WIDE AREA WHERE THE SILL WAS EXPOSED, WITH A 6-INCH VERTICAL FACE. MINOR UNDERMINING WAS OBSERVED.
  - WATER DEPTH WAS 15-FEET WITH MODERATE MARINE GROWTH COVERAGE. SOME MINOR AMOUNTS OF RIPRAP HAVE MADE ITS WAY ONTO THE SILL.
- UPSTREAM OF SILL:
  - THERE WAS A 4-INCH STEPDOWN INTO THE LOCK CHAMBER.
- DOWNSTREAM OF SILL:
  - BOTTOM SUBSTRATE MAINLY CONSISTED OF RIPRAP. THE SMALLER RIPRAP, LOCATED MORE TOWARDS THE I-WALL, WAS 1 TO 2-FEET IN DIAMETER. THE LARGER RIPRAP WAS 4-FEET IN DIAMETER.
- I-WALL:
  - OVERALL THE CONCRETE WAS IN GOOD CONDITION THROUGHOUT. THERE WERE NO STEP-OUTS ON THE VERTICAL FACE.
- LAND WALL:
  - DIRECTLY DOWNSTREAM OF THE SILL, STATION 780, THERE WAS AN AREA OF WHAT APPEARED TO BE CONCRETE OVERPOUR.
  - STATION 800: CONCRETE BAGS LINED THE WALL. THESE BAGS MEASURED 30-FEET LONG BY 5-FEET WIDE AND 3-FEET TALL.
  - STATION 900: OLD REPAIR AREA MEASURING 10-FEET TALL BY 10-FEET WIDE.
  - STATION 960: WATER DEPTH INCREASED TO 18-FEET DEEP.



CLIENT: U.S. ARMY CORPS OF ENGINEERS
STRUCTURE: LOCK & DAM 5
WATERWAY: MISSISSIPPI RIVER
INSPECTION DATE: DECEMBER 16, 2021
DRAWN BY: JOE BALDONI
PROJECT NUMBER:

J.F. BRENNAN CO., INC.
818 BAINBRIDGE STREET
LA CROSSE, WISCONSIN 54603
PHONE: (608)784-7173
FAX: (608)785-2090
www.jfbrennan.com

PREPARED BY: BRENNAN

PROJECT:
UNDERWATER INSPECTION REPORT
U.S. ARMY CORP OF ENGINEERS
WINONA, MINNESOTA
LOCK & DAM 5

DRAWING NUMBER
B2

Appendix F

J.F. Brennan Bathymetric Survey

211221 LOCK AND DAM 5
MULTI-BEAM BATHYMETRIC SURVEY

Horizontal Datum: State Plane NAD83 - Minnesota South

Horizontal Units: U.S. Survey Feet

Vertical Datum: NAVD88

Vertical Units: U.S. Survey Feet

Date of Survey: December 21, 2021

Location of Survey: Mississippi River @ USACE Lock and Dam 5

N E S W

J.F. Brennan Co., INC. Contact Information

818 Bainbridge St.
La Crosse, WI 54603

(608)-784-7173

0 50 100 200 300 400 500 Feet

1 inch = 25 feet

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Appendix G

Meeting Minutes: Barkley Dam Lock BAFF Installation Lessons Learned – J.F. Brennan

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Meeting Minutes
Lock & Dam 5 Baff Feasibility: Barkley Dam Baff Lessons Learned

meeting information

Lock & Dam 5 Fish Deterrent Feasibility
January 4, 2022
time: 2:30 PM (CST)
location: conference call

call-in number: (833) 450-1894
call-in code: 959-335-705#
project: 49061003.00

meeting attendees

J.F. Brennan (remote):

1) Raen Schechinger
2) Mike Weirs
3) Andy Giblin – Dive super for maintenance
4) Chase Slabaugh – Gen Super for dive division, from 2nd air line through maintenance
5) Joseph (Joe) Baldoni – Underwater inspections/reports
6) Blake Rocque – Asst. super for first Barkley
7) Adam Thorson – Barkley/LD8 planning/approvals

Barr Engineering (remote):

1) Jon Ausdemore (Principal/Civil Engineer)
2) BJ Siljenberg (PM/SE Engineer)
3) Brigham Erickson (ME Engineer)
4) Mark Ziemer (EE Engineer)

University of Minnesota (remote):

1) Peter Sorensen (Professor of Fish Biology, U of MN)

agenda items

- JFB heading down to Barkley in a couple weeks

1) <u>Team Communication</u>

i) Barr - J.F. Brennan interaction
   (1) Contracting – David hired Barr directly, decided to go Design Build after initial meetings.
   (2) (Raen) Design-Build (DB) was the correct method for JFB's perspective, there was limited Notice to Proceed (NTP) so procurement of some material/equipment needed to preceed some design; DB was necessary to alleviate schedule pressures.

    (3) (Jon) Could of used more reguar working meetings with JFB/FGS, could look at meeting every week (Ex. From other DB work).
    (4) (Raen) 30/60/90 design reviews in person with white board would be helpful. Remote meetings have their limitations.
    (5) (Adam) Nashville was a new district for JFB, generally worked well keeping same players involved throughout project.
    (6) (Raen) Action item list that was started mid-design was helpful.
  ii) Stakeholder Team
    (1) (Jon) David was working USFWS who was working with the USACE. There could have been some improvements in the linear communication chain (through FGS) approach.
    (2) (Brig) Establishing air quality requirements from USACE/USFWS was a challenge (Ref. linear communication chain above).
    (3) (Jon) Was Barr including JFB enough in early design? (Raen) probably enough, but more is easy to accommodate with Teams meetings.

2) <u>Cost Estimating/Budgeting</u>

a) (Raen) Connexes got bigger/more complex; air compressor got bigger, HVAC got more complicated between 30/60/90/100 design phases.
b) (Brig) Put compressor outside with weather housing to alleviate HVAC requirements.
c) (BJ) Always designing against the envelope rather than designing big/conservative early on and refining to smaller/more efficient as we went. Smaller/efficient early on resulted in added complexity later in design.
d) (Jon) David may have been under pressure to meet costs from this being a long-lead time pursuit for him leading to early pressure on costs.
e) (Jon) For a 10% design, do we start bringing in specialty contractors; (Raen) get a quote for compressor, electrical scope can change cost quite quite a bit; electrical should come on early

3) <u>Feasibility Design Phase</u>

a) Data collection
  i) (BJ) Given precision requirements, survey should be collected prior to 30 design phase.
  ii) (Raen) Needed boring in 30 design phase; had rock hardness been known up front, smaller milling head may have worked better, JFB did take a core sample: 30,000 psi (ish), employed jack hammering near wall; milling head could not reach wall.
  iii) (Mark) Uncertain where power would come from early on. Power consumption of equipment was consistent from early; voltage drop was resulting in larger/larger cable – a larger complication with project.
  iv) (Peter) Is there anything that can change for the BAFF to improve installation? – **Bring up at 1/5/22 meeting.**
  v) (Raen) There was enough missing information up front kept JFB in dark on costing.

4) **Detailed Design/Construction Phase**
   a) Site access/laydown
      i) (Raen) Specific to site, equipment does take up a lot of room. Get out to site early (for 30%)
   b) Equipment connexes
      i) (Raen) Every step we had to add one more thing.
      ii) (Brigham) Push harder to keep compressor outside. Push for larger building.
      iii) (Jon) Oil spill containment.
      iv) (Raen) Simple steel structure/insulated metal panels. Spider cranes could have helped erect a building in this location. Stick build/PEMB.
   c) Electrical routing/box
      i) (Mark) Get control equipment closer.
      ii) (Raen) Pulling cable went OK.
      iii) (BJ) Trough in BAFF was too narrow for cable.
      iv) (Raen) Extra foot would have paid off – even with rock ex – to provide more room to work in BAFF housing.
   d) Mechanical routing
      i) (Brigham) two compressed air lines needed to go to far side of system.
   e) BAFF housing, alignment, and foundation preparation (dredging/rock removal)
      i) (Raen) More room on back side where lights/wiring is. Bubbler pipes take entire top of this.
      ii) (Raen) Pretensioning went well;
      iii) (Tensioning/piles
      iv) (Raen) No changes to crane from lighter housing system.
      v) (Paul) No huge wins from smaller crane, extra BAFF units would have resulted in more labor
      vi) (Raen) JFB planned on over-excavating 6" below bottom of BAFF. Ended up being 3" shallower. This was compounded by 3" discrepancy in local datum vs. global datum that "ate" up 3" discrepancy. This resulted in BAFF system sitting on rock needing rock removing.
      vii) (Jon) Would template help? (Raen) check/confirm datum and over excavate 1'.
   f) Submittals and documentation
      i) (Jon) We treated this like a D-B-B for submittals. Should we have worked on some of the submittals together during design phases.
      ii) (Brigham) Working with local rep for air compressor. Information transfer was not smooth with Kentucky supplier. Bringing on supplier earlier would have reduced the re-submittals experienced during construction.
      iii) (Jon) Sign off protocol prior to being onsite.

5) **O/M Phase**
   a) Equipment connexes
      i) Oil spills from compressor with no collection pan caused mess.
   b) Electrical routing/box

i) (Mark) Outages/surges take out equipment, UPS's on equipment could help, would need generator for compressor, power would be out for 5 minutes during transition. Would want this for permenant installation.

ii) (Jon) Sedimentation in housing? (Raen) No significant sedimentation. Everytime O/M visit there is a little removal. Always account for half day or so of silt removal.

iii) (Raen) Used a Venturi to remove silt more than 100-feet downstream after rock removed from trench. This resulted from overnight barges fill rock trench.

6) <u>General</u>

a) (Raen) Understand details of lock structure, bathemytry, and lock gate sill will be critical to mitigating some costly issues experienced for Barkley.

b) (Peter) Precision of BAFF system at Lock Wall is important, fish are finding a weak spot where BAFF meets up against lock wall near land wall bull nose; this bull nose is tapered.

Appendix H

Meeting Minutes: Barkley Dam Lock BAFF Installation Lessons Learned – Fish Guidance Systems

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Meeting Minutes
Lock & Dam 5 Baff Feasibility: Barkley Dam Baff Lessons Learned

meeting information

Lock & Dam 5 Fish Deterrent Feasibility
January 5, 2022
time: 9:00 AM (CST),
3:00 PM (Southampton, UK)
location: conference call

call-in number: (833) 450-1894
call-in code: 473 300 984#
project: 49061003.00

meeting attendees

Fish Guidance Systems (remote):
1) David Lambert

Barr Engineering (remote):
1) Jon Ausdemore (Principal/Civil Engineer)
2) BJ Siljenberg (PM/SE Engineer)
3) Brigham Erickson (ME Engineer)
4) Mark Ziemer (EE Engineer)

University of Minnesota (remote):
1) Peter Sorensen (Professor of Fish Biology, U of MN)

agenda items

1) **BAFF System Effectiveness to-date at Barkley**
   a) Barkley system has worked well, USGS pamphlet was issued as draft, responses due later this week, data is in pamphlet and will be citable. Presentation is on 1/14 or 1/15 when publication is due. HDI real-time tracking, 2 studies – efficacy in 80% to 90% (fish are moved). Another study (Avemco) suggests efficiency in 90%'s (no transplantation). Two studies are independent in Peter's view.
   b) (Jon) estimated or predicted?
   c) (David) TVA has 4 of 10 as high priority, but no funding. Other sites in Ohio – funding issues there too. 2024 – 2025 before anything goes in (?). USACE Brandon Roads, would not sign NDA with FGS.
2) **Contract & Team Communication**
   a) Contract (DB)
      i) Went OK from FGS perspective
      ii) UK systems require less civil work, usually FGS is a sub
      iii) Georgiana Slough (CA) is 192m long, FGS is a sub
      iv) JFB was requiring a lot of detail on what is to be delivered (time to install, ect.)

    v) We can – and should – promote contract mechanism we think is best in report (i.e. DB)
  b) Barr – FGS/stakeholder team interaction
    i) Should have been talking more, there were some short turnarounds for commenting, there were times lacking sufficient time to thoroughly address comments despite being further down the design.
    ii) USACE – more meetings more often.
    iii) USACE – targeted meetings by discipline.

3) **<u>Design & Construction</u>**
  a) Cost estimating
    i) River level played in to $1M+
    ii) FGS equipment cost did not change
  b) Site data collection
  c) Equipment connexes/compressor/HVAC
    i) $250,000 for connex, was possibly not going out for competitive bid
    ii) Only two sockets in connex, lacking sufficient space for computer
    iii) (Brigham) Are we able to lock down compressor requirements (non variable) going forward. (David) Variation in river heights will require variable compressor.
    iv) Condensate pump did not work initially, replacement system failed and flooded.
    v) (Brigham) Adjustability at the manifold was added later in design. Was this helpful? (David) Entire air supply is automated for CA project, remotely operated. Bubbler pipe supplier said consistent flow was possible over length – turned out to not be consistent. Half supplies went to opposite end. 6 was installed at Barkley, mostly only run 4. Optimization that was original anticipated
    vi) Ingersol-Rand had monopoly in KY area. Went with Ingersol-Rand for CA job because we know what happened at Barkley. It is VFD – bigger unit of Barkley.
    vii) There have been issues with Air-Con system working, recycle air back in outside certain thresholds – was painful to setup. Oil in KY drops occasionally and needs more. Container has not been properly cleaned.
    viii) Same supplier for perforated tubes will be used. (Brigham) had a hard time obtaining pressure drop with length. (David) concurred, some weakness in middle as bubbling does drop with distance. New system for same length may require more complex supply.
    ix) (Brigham) Env requirements on air quality into river. USACE was noncommittal. (David) they got through permitting quicker because system was temp, that may have caused complications. Permanent system would likely be oil free. Compressor supplier for CA project has to deal with env requirements.
  d) Electrical routing/box
    i) Surges have damaged electronics. Surge protection has been added to every component. Lighting has struck twice now. Surge protection has a limited life (per FGS EE's). Surge protection was on main supply coming in.
    ii) Voltage drop (Mark)?. (David) power supply is now in hubs.

   iii) Power supply was originally committed to by USACE.
   iv) Second lightning strike took out motem.
- e) BAFF housing, alignment, and foundation preparation (dredging/rock removal)
   - i) Baff housing was small (JFB/BJ).
   - ii) (David) Smaller is cheaper. Doors don't open easy. Projectors are heavy (100 lbs) now and sluggish.
   - iii) One of the projectors was not installed one time and was found downstream.
   - iv) CA project is on an open truss/frame heightened above bottom on piles.
- f) Submittals and documentation

4) <u>O/M Phase</u>

- a) Equipment connexes/compressor/HVAC
- b) Electrical
- c) BAFF, BAFF housing, dredging
   - i) Silt is slowly getting worse with time and getting inside structure.

5) <u>Other Miscellaneous Lessons</u>

- a) There is a kink in the bubble curtain (in plan view), near bull nose.
- b) BAFF needs to come out of Barkley. Barkley was a trial.
- c) (Peter) Opening could be considered for Sturgeon. (David) Sturgeon may not respond to sound, but do to light. System could be raised (?).
- d) There was no redundancy (per USFWS) at Barkley, permenant site would need it. Mitigation for redundant system is to close lock. Carp favor top couple meters.

6) <u>Mississippi Lock and Dam 5 BAFF Feasability</u>

- a) -50%/+100% cost estimate scope (10% design level)
   - i) What redundancy will be required will have a significant impact on cost. We should plan on providing answers as eventual funder/owner (MN DNR?) will not be on board yet.
- b) Scope requested from FGS (needed later, not during this meeting)
   - i) Alignment and footprint
   - ii) General compressed air/electrical requirements
   - iii) General equipment (surface and submerged) size requirements

Appendix I

Meeting Minutes: US Army Corps of Engineers Feedback

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Meeting Minutes
Lock & Dam 5 Carp Deterrent Feasibility
USACE Initial Stakeholder Feedback

meeting information

Lock & Dam 5 Carp Deterrent Feasibility
January 28, 2022
time: 9:00 AM (CST) – 10:15 AM
location: conference call

call-in number: (833) 450-1894
call-in code: 420 803 169#
project: 49061003.00

meeting attendees

USACE – St. Paul (remote):
1) Nan Bischoff (St Paul District Office)
2) Judi Denzer (LD 5)
3) Matt Breise (L/D 5)
4) Chris Atkins (St Paul District Office)
5) Jim Rand (St Paul District Office)

University of Minnesota (remote):
1) Peter Sorensen (Professor of Fish Biology, U of MN)

Barr Engineering (remote):
1) Jon Ausdemore (Principal/Civil Engineer)
2) BJ Siljenberg (PM/SE Engineer)
3) Brigham Erickson (ME Engineer)
4) Mark Ziemer (EE Engineer)

agenda items

Feedback

1) Nan has been involved with discussion related to Carp deterrents from ~2012-2014
2) Peter: tested sound alone at LD 8, published last week, results indicate sound alone is not enough, preliminary results at Barkley Dam indicat
   a) Study of fish passage through lock/dam 8
3) Chris: any study of BAFF relative to electric barriers?
   a) Peter: air curtain 70%-90% effective (Barkley), no direct comparisons with electrica barriers (apples and oranges)
   b) Peter: electrical barriers tend to be ineffective on small fish, less safe (surface vessels and electric hazard), more expensive
4) BJ: Power outage frequency? Matt: no good data, but they do happen.

5) Matt: How loud is the system (compressor)? Location A may cause concerns with operations staff, further away is better. Existing comrpessors onsite can be loud.
   a) Brigham: Sound enclosures are available and will likely be specified if not enclosed in building; still determining. Can make selection subject to USACE review in procurement.
6) Nan: attachments to structure itself would require Section 408 process; impacts all options. Should not deter from selection, just a process.
7) Jim: could system be turned off in the winter? Lock 8 was taken down during Winter; fish could still pass through culverts.
   a) Peter: could probably be taken offline in winter, but 24/7/365 operation would provide more certainty. Needs further study.
8) Jim: impeding ladder wells may be an issue for lock users. There are dewater bulkhead slots just downstream of leaf gates that are only used for lock dewatering which occurs every 20 years +/-; another 15 years out on next one. Area C may be desirable if slots are used.
9) Jim: Lock chamber fill/discharge gates need to stay partially open to prevent ice buildup in lock chamber, engineers likely would not approve closing them over winter. They can be closed during navigation.
10) Jim: Ice lockages a performed in spring to pass debris/ice that collects upstream of locks. Confirming deterrent system downstream (bubble current) would not impede this. Peter/BJ commented that it is unlikely. Temporary outages (15 minutes +/-) could occur.
11) Matt: USACE primary power is cut weekly to test generator. If local power used for Deterrent, this outage would impact. BJ responded: not planning on using
12) Judy: Location C could work, crossing electrical would be a challenge. Depending on specific dimensions, operations could work with it. Vessels do tie off at end or spillway side of wall occasionally.
13) Judy: Location B, barges occasionally spud on backside of land wall, near location B.
14) Jim: major maintenance outages do occur (example: miter gates at LD2 – (4) 12-hour closures), shorter emergency outage example: toe accident related for brief perioids of time (hours not days).
15) Jim: planned outages outside navigation most likely acceptable, need to coordinate with major lock dewatering in ~15 years – spudded barges downstream of dewatering bulkheads.
16) Tonage starts to trick off North of Winona giving some flexibility for outages at LD5 that would be harder further downstream.
17) Judy: how big are utilities on land? Transformer: 6'x6' pad. Generator: 8'x16' slab, propane generator, 500 gal propane tank. There are a lot of visitors, are trying to make it more appealing. Has not seen lot completely full; could sacrifice a couple parking stalls in south west corner or place just off south west corner.

18) Storage for spare equipment, downstream?
    a) Judy: high water does flood road.
    b) Matt: shed are lifted, “last thing standing”

19) Site staffing: 12 weeks period after navigation when there is no staff at night, usually someone until 8pm, outage would need coordination off hours
    a) After Thanksgiving traffic starts slowing down, can bleed into early December, start staffing nights between end of February to beginning of March
20) Nan: is it the intent that the DNR would “own” the system?
    a) Peter: no clear answer yet. Barkley: started as leased by USFWS. USACE will likely own and KDNR will operate. Barr will not discuss ownership/leasing/realestate in report.
21) Sound projectors at spillway side lock discharge outlets?
    a) Matt: Tow boats/barges do tend to tie off on back side of river wall. Racks up the side would get rouined, need to coordinate sub-surface diver mounted equipment with draft of vessels.
22) Winter protocols for emabankment culverts:
    a) Upstream: closed in Fall/opened in Spring per DNR (Matt). They get operated for migratory birds, muskrats, ect.
    b) Debris concerns would get worse with any kind of structural grating.
23) USACE coordination going forward: send drafts of preliminary (February) and final (June) reports to USACE for review/comment (Nan)