Boston Bar Side Channel Restoration and Island Creation Project
Middle Mississippi River (RM 10.2 – 7.6 L)
Alexander County, Illinois

DRAFT ENVIRONMENTAL ASSESSMENT WITH UNSIGNED FINDING OF NO SIGNIFICANT IMPACT

Biological Opinion Program

U.S. Army Corps of Engineers, St. Louis District
Regional Planning & Environmental Division North (CEMVS-PD-P)
1222 Spruce Street
St. Louis, Missouri 63103-2833
Telephone Number: (314) 331-8496

March 2016

Table of Contents

Chapter 1 Purpose and Need for Action ... 1
1.1 Introduction ... 1
1.2 Authority ... 1
1.3 Proposed Federal Action ... 2
1.4 Need for Action ... 2
1.5 Scoping ... 3
1.5.1 Tribal Scoping ... 3
1.5.2 Public Scoping ... 3
1.5.3 Agencies and Organization Scoping ... 3
1.6 Project Objectives ... 3
Chapter 2 Alternatives Including the Proposed Action ... 5
2.1 Alternative Development ... 5
2.2 Alternatives Eliminated from Further Consideration ... 5
2.3 Alternatives Considered in Detail ... 6
2.4 Details of Preferred Alternative ... 6
Chapter 3 Affected Environment ... 11
3.1 Physical Setting ... 11
3.2 Stages ... 14
3.3 Water Quality ... 15
3.4 Fisheries and Aquatic Habitat ... 17
3.5 Hazardous, Toxic, and Radioactive Wastes (HTRW) ... 18
3.6 Federally Threatened and Endangered Species: Tier II Biological Assessment ... 18
3.7 Socioeconomic Resources ... 19
3.8 Environmental Justice (EO 12898) ... 20
3.9 Air Quality ... 20
3.10 Noise Levels ... 20
3.11 Historic and Cultural Resources ... 21
3.12 Prime or Unique Farmland (7USC 4201) ... 21
3.13 Climate Change and Greenhouse Gas Emissions ... 25

Chapter 4 Environmental Consequences 27
4.1 Physical Setting 27
4.1.1 Alternative 1 – No Action 27
4.1.2 Alternative 2 – Preferred Alternative 27
4.2 Stages 27
4.2.1 Alternative 1 – No Action 27
4.2.2 Alternative 2 – Preferred Alternative 28
4.3 Water Quality 28
4.3.1 Alternative 1 – No Action 28
4.3.2 Alternative 2 – Preferred Alternative 28
4.4 Fisheries and Aquatic Habitat 28
4.4.1 Alternative 1 – No Action 28
4.4.2 Alternative 2 – Preferred Alternative 29
4.5 Hazardous and Toxic Wastes (HTRW) 29
4.6 Federally Threatened and Endangered Species: Tier II Biological Assessment 29
Gray Bat 30
Indiana Bat 30
Northern Long-Eared Bat 31
Least Tern 31
Pallid Sturgeon 32
Rabbitsfoot Mussel 33
Sheepnose Mussel 34
4.7 Socioeconomic Resources 34
4.8 Environmental Justice 34
4.8.1. Alternative 1 – No Action 34
4.8.2 Alternative 2 – Preferred Alternative 34
4.9 Air Quality 34
4.9.1. Alternative 1 – No Action 34
4.9.2 Alternative 2 – Preferred Alternative 34
4.10 Noise 35
4.9.1. Alternative 1 – No Action 35
4.9.2 Alternative 2 – Preferred Alternative 35

4.11 Historic and Cultural Resources 35
4.11.1. Alternative 1 – No Action 35
4.11.2 Alternative 2 – Preferred Alternative 35
4.12 Prime and Unique Farmland 35
4.13 Climate Change and Greenhouse Gas Emissions 36
4.14 Cumulative Effects 36
5. Relationship to other Environmental Laws and Regulations 38
6. List of Preparers 39
7. Literature Cited 40
DRAFT FINDING OF NO SIGNIFICANT IMPACT 45
APPENDICES 46
Appendix A. Hydraulic Sediment Response Model Report* 1
Appendix B. Agency and Tribal Government Coordination 2
Appendix C. Clean Water Act Section 404(b)(1) Evaluation 3
Appendix D. Summary of Research on the Effects of River Training Structures on Flood Levels .. 4
Appendix E. Distribution List 5

DRAFT ENVIRONMENTAL ASSESSMENT

Boston Bar Side Channel Restoration and Island Creation Project
Middle Mississippi River (RM 10.2 – 7.6 L)
Alexander County, Illinois

Chapter 1 Purpose and Need for Action

1.1 Introduction

The U.S. Army Corps of Engineers (Corps), Mississippi Valley Division (MVD), St. Louis District (District), has prepared this Environmental Assessment (EA) to evaluate the potential impacts associated with the proposed Boston Bar Side Channel Restoration and Island Creation Project. Boston Bar is located along the left descending bank of the MMR between river miles 10.2 – 7.6, approximately 7.6 miles upstream of the confluence with the Ohio River. The project area is located in Alexander County, Illinois, approximately 1.5 miles northwest of Cairo, Illinois, and 22.5 miles southeast of Cape Girardeau, Missouri (Figures 1-2).

This EA has been prepared in accordance with the National Environmental Policy Act (NEPA) of 1969 and the Council on Environmental Quality's Regulations (40 Code of Federal Regulations §1500-1508), as reflected in the USACE Engineering Regulation 200-2-2.

Impacts on environmental resources are discussed in detail in the Draft Environmental Assessment and summarized in the Unsigned Finding of No Significant Impact (FONSI).

1.2 Authority

The Congress of the United States, through the enactment of a series of Rivers and Harbors Acts beginning in 1824, authorized the Secretary of the Army, by and through the U.S. Army Corps of Engineers St. Louis District, to provide a safe and dependable navigation channel, currently 9-feet deep and not less than 300-feet wide, with additional width in the bends as required on the reach between the confluences of the Ohio and Missouri rivers (RM 0-195), known as the Middle Mississippi River (MMR). The navigation project for the MMR is commonly referred to as the Regulating Works Project. The Regulating Works Project utilizes bank stabilization and sediment management to maintain bank stability and ensure adequate navigation depth and width. Bank stabilization is achieved by revetments, while sediment management is achieved by river training structures. Other activities performed to obtain the navigation channel are rock removal and construction dredging. The Project is maintained through dredging and any needed maintenance to already constructed features. Therefore, both regulating works structures and dredging are all part of the overall Regulating Works Project. The long-term goal of the Regulating Works Project, as authorized by Congress, is to provide a sustainable and safe navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of river training structures.

In performing this responsibility, the Corps is committed to complying with the Endangered Species Act (ESA). In executing responsibilities under the ESA, the Corps recognizes that there is to be deference to the U.S. Fish and Wildlife Service (Service). It is incumbent upon the Service to provide biological advice and guidance that allows the Corps to achieve compliance with the ESA within the Corps' statutory authorities and appropriations. Through implementation of the proposed federal action described herein, the District will remain in compliance with the ESA for the Regulating Works Project.

1.3 Proposed Federal Action

The proposed Federal action is implementation of a side channel restoration and island creation project at Boston Bar. The goal of the project is to restore habitat for two federally endangered species: the pallid sturgeon (*Scaphirhynchus albus*) and the interior least tern (*Sterna antillarum*). The project consists of modifying the configuration of river training structures at Boston Bar to allow more flow into the side channel within the project area, enhancing connectivity of the side channel with the main stem of the Mississippi River and improving the overall habitat heterogeneity of the MMR. Specifically, traditional rock dikes and closing structures will be removed from the project area, and a side channel enhancement dike (SCED) will be constructed at the entrance to Boston Chute. The project also includes the construction of least tern nesting habitat using dredge disposal material from channel maintenance dredging.

1.4 Need for Action

Through a voluntary formal consultation process between the Corps and the Service, a Biological Opinion for the Operation and Maintenance of the 9-foot Navigation Channel on the Upper Mississippi River System (UMRS) was submitted to the Corps from the Service on May 15, 2000 (U.S. Fish and Wildlife Service 2000). The Upper Mississippi River System was defined in the Biological Opinion as the commercially navigable portions of the Mississippi (Upper River Miles 0-854), Illinois (River Miles 0-327), Kaskaskia, Minnesota, St. Croix, and Black rivers (UMRS). There are multiple Corps authorized projects for the 9-foot navigation channel within the UMRS, including the Regulating Works Project.

After continued discussions, the Corps submitted a letter to the Service on August 11, 2000. This letter described how the Corps proposed to precede with the future operation and maintenance of the 9-foot channel navigation projects for the UMRS in light of its ESA obligations and the information provided to the Corps in the Service's Biological Opinion of May 15, 2000.

The Service's Biological Opinion provided a number of requirements under a “Reasonable and Prudent Alternative” to avoid the likelihood of jeopardizing the continued existence of the federally endangered pallid sturgeon. One such requirement was to implement aquatic habitat restoration measures in the MMR that are expected to benefit the pallid sturgeon, such as side channel restoration. Further, the Service’s Biological Opinion provided “Reasonable and Prudent Measures” to minimize the incidental take of the federally endangered least tern, such as incorporating modifications to river training structures to maintain flow between sandbars and the adjacent shoreline and using dredge disposal material in the MMR to restore sandbar habitat. This project is being conducted in accordance with the Reasonable and Prudent Alternative and the Reasonable and Prudent Measures.

1.5 Scoping

Scoping is an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action. Scoping was conducted early in the planning process using a variety of communication methods with affected public, agencies, organizations, and tribes. The input received during scoping was incorporated in the process of decision making for this project; however, the District must ultimately make the decision what direction the project will follow.

1.5.1 Tribal Scoping

The United States government has a unique legal relationship with federally recognized American Indian Tribes, based on the inherent powers of Tribal sovereignty and self-government. The District will uphold this special relationship and implement its activities in a manner consistent with it. Communication with 28 federally recognized tribes affiliated with the St. Louis District was initiated by the District's tribal liaison with a Corps letter dated 16 January, 2016 (Appendix B). All responses to this coordination received by the District will be included in the final version of this report.

1.5.2 Public Scoping

Public scoping activities will be held prior to the development of the Final EA. In accordance with NEPA, this environmental assessment will be made available to the public for a 30-day public review period. The report will be made available on the District's website along with mailed letters to interested members of the public addressing where to find the report and how to provide comments.

1.5.3 Agencies and Organization Scoping

A sedimentation improvement study workshop for the Boston Bar area was conducted in May, 2011, prior to the development of this report. Sixteen technical experts from the District, Missouri Department of Conservation, Illinois Department of Natural Resources, U.S. Fish and Wildlife Service, and the Archer Daniels Midland Company attended the workshop to provide input on the project objectives and potential project features.

1.6 Project Objectives

1) Improve connectivity between Boston Chute and the main stem of the Mississippi River
2) Create island sandbar habitat

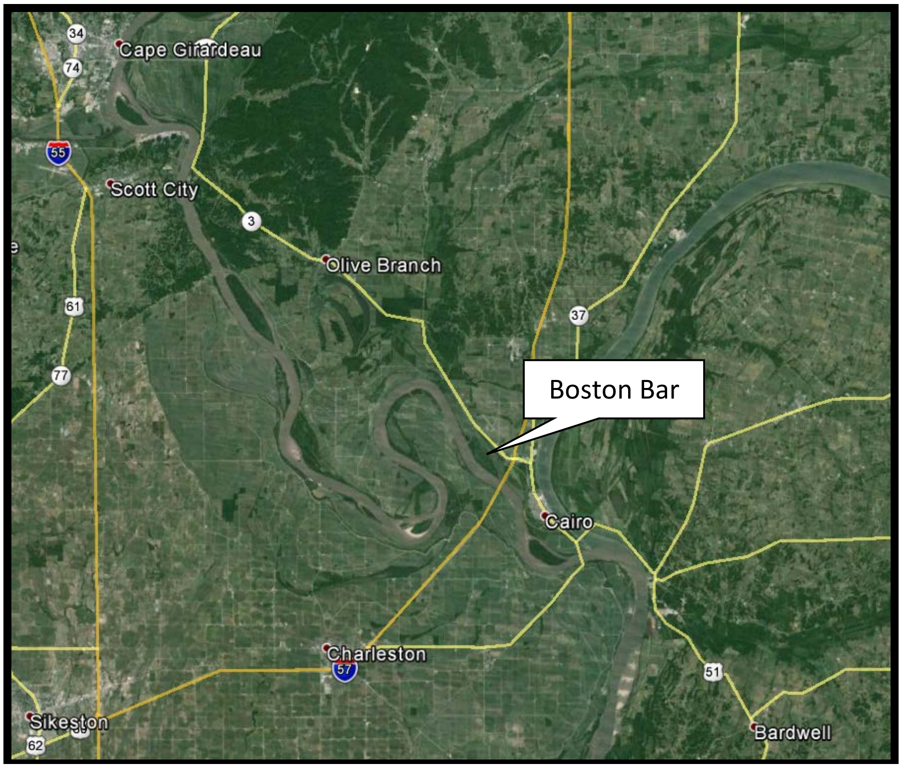


Figure 1. Boston Bar vicinity; Alexander County, Illinois.

Figure 2. Boston Bar project location, Alexander County, Illinois.

Chapter 2 Alternatives Including the Proposed Action

This chapter presents the alternatives being considered for implementation of the Boston Bar Side Channel Restoration and Island Creation Project. It describes the No Action Alternative and one action alternative in detail and provides a summary comparison.

2.1 Alternative Development

NEPA requires agencies to evaluate a range of reasonable alternatives to a proposed Federal action. The alternatives were developed to meet the purpose and need of the proposal, while minimizing and avoiding environmental impacts. The proposed action alternative was developed from input provided through scoping. With the assistance of technical experts from the aforementioned agencies and organizations, the District developed Alternative 2, described below, using widely recognized and accepted river engineering guidance and practice, and then screened and analyzed different configurations of project features with the assistance of a Hydraulic Sediment Response (HSR) model. HSR models are small-scale physical sediment transport models used by the District to replicate the mechanics of river sediment transport. HSR models allow the District to develop multiple configurations of river training structures for addressing the specific objectives of the project in a cost-effective and efficient manner. The process of alternatives development using HSR models starts with the District calibrating the model to replicate work area conditions. Various configurations of river training structures are then applied to the models to determine their effectiveness in addressing the needs of the work area. For the Boston Bar work area, the District developed the Upper Mississippi River, Boston Bar Bi-Op 2011, Hydraulic Sediment Response Model Study. The report from this study is attached as Appendix A.

The HSR model analyzed 11 different configurations of river training structures and 10 different dredge disposal locations, for a total of 21 different alternatives. The study resulted in multiple combinations of river training structures meeting the project objectives of enhancing connectivity to Boston Chute while not increasing sediment input into Boston Chute or negatively impacting the navigation channel. Further, multiple dredge disposal locations met the purpose and need, maintained the design height, and did not experience significant erosion. The agencies and organizations that participated in the scoping reached consensus on which configuration of river training structures and dredge disposal location best met the project objectives. Detailed information on the Alternatives development process, partner agency coordination, and alternatives eliminated from further consideration can be found in the HSR model report (Appendix A).

2.2 Alternatives Eliminated from Further Consideration

Based on the findings from the HSR model, river training structure configurations or dredge disposal areas that did not meet the objectives of the project or impeded navigation were eliminated and were not moved forward for further investigation. See HSR Model Report for further details (Appendix A).

2.3 Alternatives Considered in Detail

Based on the findings from the HSR Model and coordination with the resource partners, two alternatives were considered for further detailed analysis. The two alternatives are summarized as follows:

- Alternative 1 (No Action by the Corps): If implemented, there would be no increase in connectivity between Boston Chute and the main stem of the Mississippi River, and dredged disposal material would not be used to create island sandbar habitat. Ongoing sediment accretion within the side channel could eventually result in permanent loss of this important off-channel habitat.
- Alternative 2 (Preferred Alternative): If implemented, this alternative would improve connectivity between Boston Chute and the main stem of the Mississippi River and dredged material would be used to create island sandbar habitat for nesting least tern.

The existing conditions and impacts of each alternative on environmental resources are compared and described in Chapter 3, *Affected Environment* and Chapter 4, *Environmental Consequences.*

2.4 Details of Preferred Alternative

The preferred alternative is Alternative 2 – restore the side channel and sandbar habitat. The proposed action includes the creation of sandbar habitat adjacent to Boston Bar using dredge disposal material from future channel maintenance dredging that occurs within the immediate vicinity. Since the year 2000, the district has dredged approximately 1.1 million cubic yards of sediment from the navigation channel within the vicinity of Boston Bar, and used the traditional side-casting method with a rigid pipe to deposit the material parallel to the dredge cuts (Figure 3). Using the District's flexible-floating dredge disposal pipe, dredge disposal material will be concentrated in a circular area between two dikes (8.25L and 8.0L) adjacent to Boston Bar, building a sandbar approximately 280,000 ft^2 in area to an elevation of 314 ft NGVD (Figure 4). Based on bathymetry, hydrologic data, and modeling of stage-discharge relationships, building a sandbar to this specific elevation at this river mile will likely create conditions that allow for 100 continuous days of sandbar exposure during the least tern breeding season (Allen 2010).

The proposed action also includes the modification of the river training structures around Boston Bar (Table 1 and Figure 5). At the upper end of Boston Bar, the plan calls for complete removal of two traditional dikes (10.3L and 10.1L) that divert flow toward the navigation channel and away from the entrance of Boston Chute, notching of the pile dike (10.3L) at the entrance of Boston Chute, and the construction of a side channel enhancement dike (SCED; 10.05L) at the entrance of Boston Chute. The SCED will be angled slightly upstream, it is designed to divert flow into Boston Chute rather than away. Lastly, the plan includes the complete removal of the dike/closing structure (7.9L) near the exit of Boston Chute. The primary purpose of modifying the river training structure configuration within the Boston Bar project area is to increase flow into the side channel, thereby increasing the duration of connectivity with the main stem of the Mississippi River and allowing fish access to this important habitat type. Furthermore, the increased flow through Boston Chute will likely reduce the accretion rate within the side channel, thereby increasing the longevity of this off-channel habitat. It is important to note that implementation of this project will decrease the total number of river training structures in the MMR.

Table 1. Description of the proposed river training structure configuration.

Structure	RM	Action	Length (ft)	Final Elevation (ft NGVD)
SCED	10.05 (L)	Construct	650	294
Pile Dike	10.3 (L)	Notch	250	274
Dike	10.3 (L)	Remove	650	274
Dike	10.1 (L)	Remove	575	274
Dike	7.9 (L)	Remove	560	273

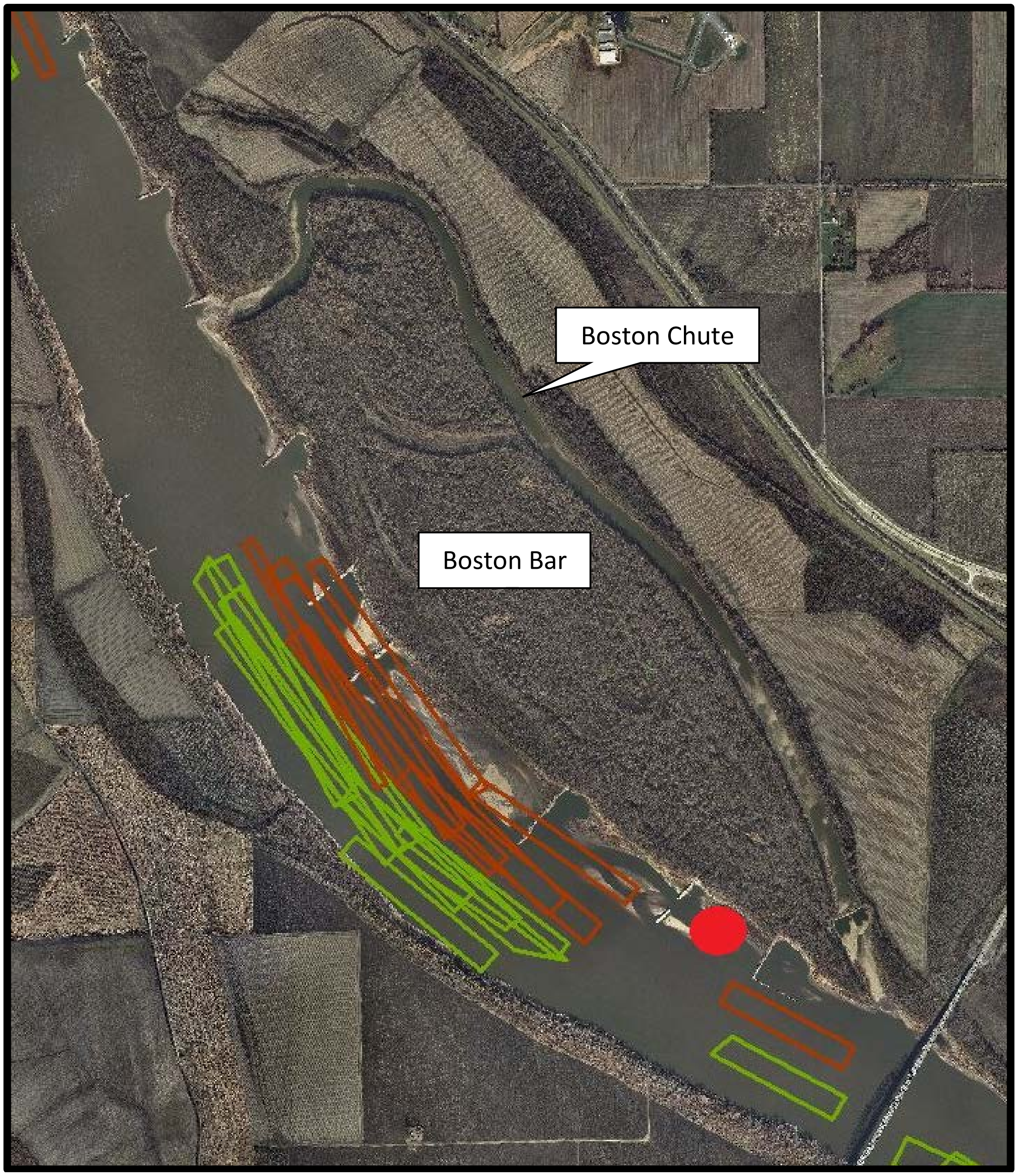


Figure 3. Approximate location of channel maintenance dredge cuts (green boxes) and dredge disposal locations (red boxes) performed in the Boston Bar vicinity since the year 2000, and the proposed location for future dredge disposal (red circle).

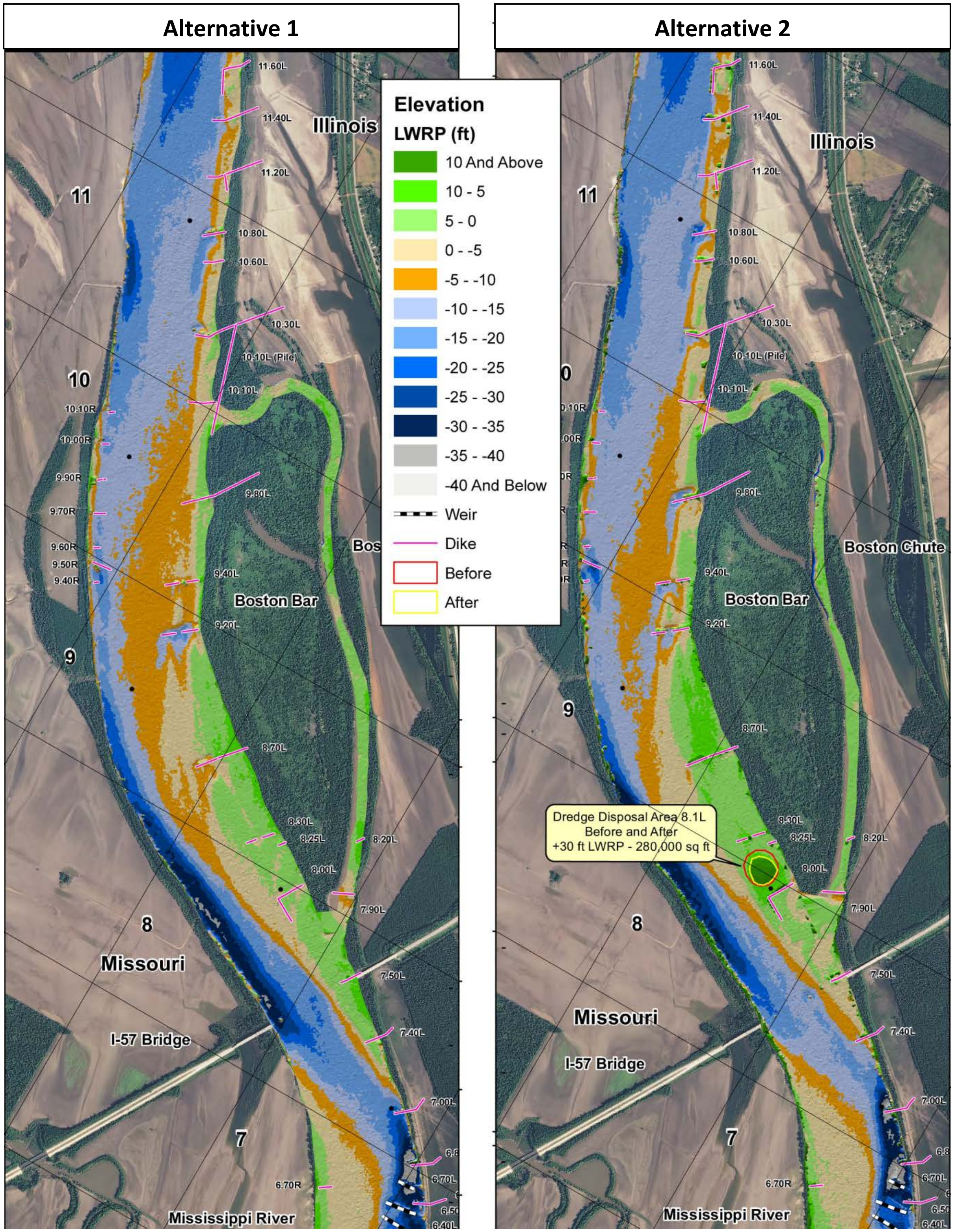


Figure 4. HSR model results of proposed dredge disposal location.

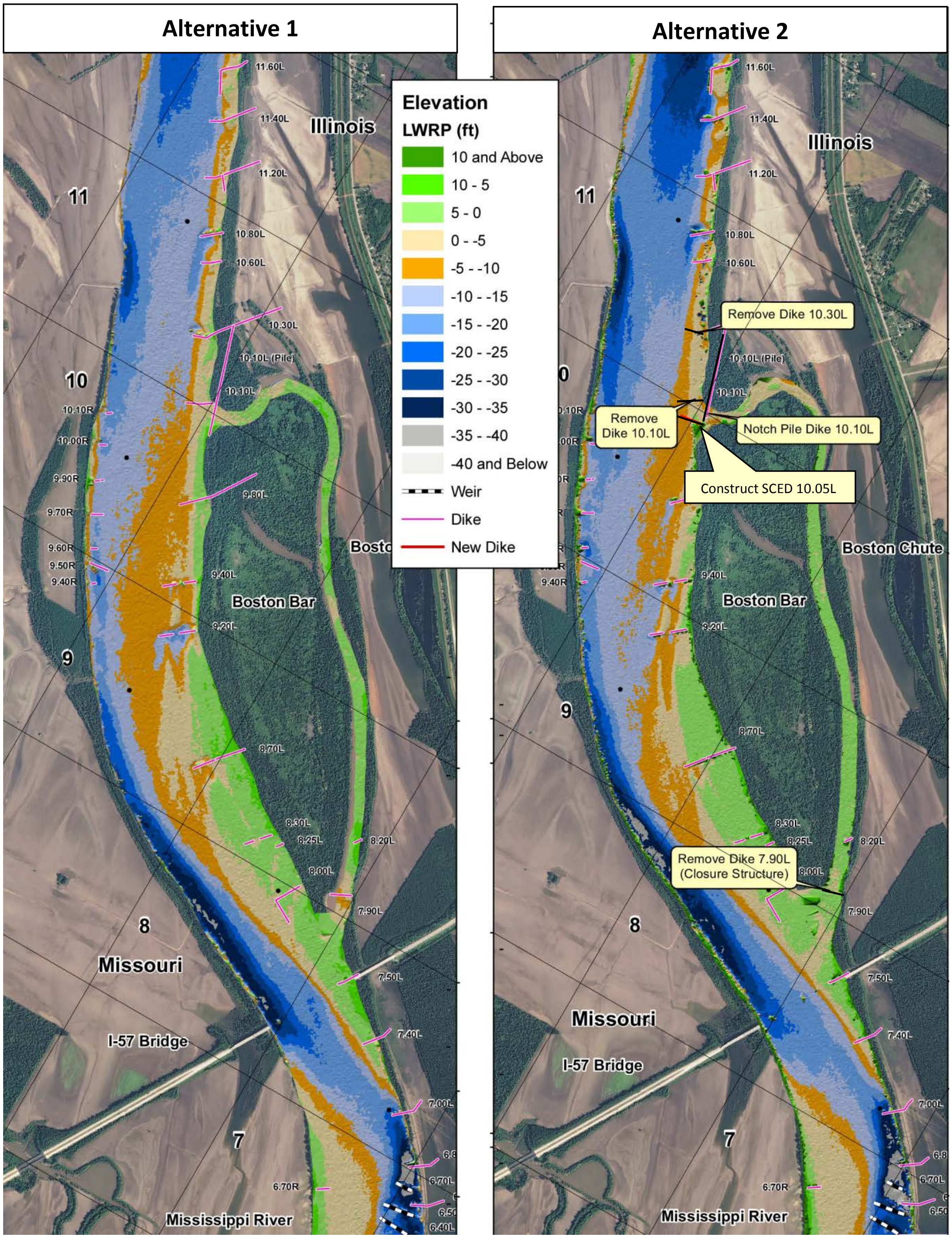


Figure 5. HSR model results of proposed river training structure configuration.

Chapter 3 Affected Environment

Chapter 3 is organized by resource topic. This chapter describes the historic and existing conditions of resources to be affected by the alternatives under consideration. This is not a comprehensive discussion of every resource within the study area, but rather focuses on those aspects of the environment that were identified as issues during scoping or may be affected by the alternatives. The impacts of each alternative are described in Chapter 4, *Environmental Consequences.*

3.1 Physical Setting

The Boston Bar project area consists of a segment of the main channel in the MMR, plus a single side channel and island formation. The side channel, Boston Chute, is 2.87 miles long with an average width of approximately 250 ft. Boston Chute is relatively sinuous compared to other side channels in the MMR, bending north at the entrance before turning east, then southeast, and reconnecting with the main stem downstream (Figure 2). Based on hydrographic surveys taken in 2011, its average bottom elevation is roughly +5 ft low water reference plane (LWRP). A pile dike acts as a closing structure at the entrance (Figure 6) and a rock closing structure is located in the downstream portion of the side channel (Figures 7). Behind this closing structure, a deep scour hole has developed that provides suitable depths for overwintering fish. Lastly, the remnants of an old pile dike cross roughly half of the side channel upstream of the rock closing structure (Figure 9).

The side channel creates the 587 acre island known as Boston Bar. The island was farmed during the 19th century and the first half of the 20th century, but has not been used for agricultural purposes in many years. Based on aerial imagery taken in 2015, the island is currently covered by forest communities likely typical of the regions bottomland hardwood forests, with areas of moist soil plant production occurring at lower elevations. Two meander scars hold pools of isolated water within the island. It should be noted that this project is confined strictly to aquatic areas. Although directly adjacent to land, no work will be conducted on any terrestrial habitat, and therefore there are no anticipated terrestrial impacts associated with the proposed project. As such, a more detailed description of terrestrial resources (e.g., habitat, soils, wildlife) is not included in this report.

The main channel portion of the project area is characteristic of the MMR; it is heavily modified with river training structures. On the left descending bank, five traditional dike structures and an L-dike extend from Boston Bar toward the navigation channel, and two more traditional dike structures extend toward the navigation channel upstream of the entrance to Boston Chute (Figure 8). Four of these traditional dikes were constructed in recent years, and notches were left in them to enhance bathymetric diversity and reduce sedimentation between the dikes. In FY09, dikes 9.40L and 9.20L were constructed, in FY10 dike 8.3L was constructed, and in FY11, dike 8.7L was constructed. Recent surveys in the immediate area of these dikes have revealed the success of the notches, which have created scour holes and enhanced bathymetric diversity near the main channel border adjacent to Boston Bar. Most of the main channel border of

Figure 6. Photo of rock dike (10.1L) and pile dike (10.3L) at the entrance of Boston Chute.

Figure 7. Photo of rock dike/closing structure (7.9L) near the exit of Boston Chute.

Figure 8. Photo of rock dikes (10.3L) and (10.1L) upstream of Boston Chute.

Figure 9. Photo of pile dike (8.2L) near the exit of Boston Chute.

Boston Bar has not been revetted, with revetment covering less than 2,500 ft. Opposite of Boston Bar, the right descending bank is also heavily modified. Seven relatively short dikes comprise a dike field between 10.10R and 9.40R, and the remainder of the bank is completely revetted.

3.2 Stages

Figure 10 displays the monthly average annual hydrograph (data from entire period of record) from four nearby gage locations compared to the height of dike 7.90L (+11 feet LWRP). Graphs of these average annual hydrographs indicate that during the period from August 1 to November 30, the water level is typically below the closing structure height. This has likely contributed significantly to the shallow depths within Boston Chute. Figure 6 shows helicopter photographs from 2006 of the Boston Chute closing structure when the river stage was below

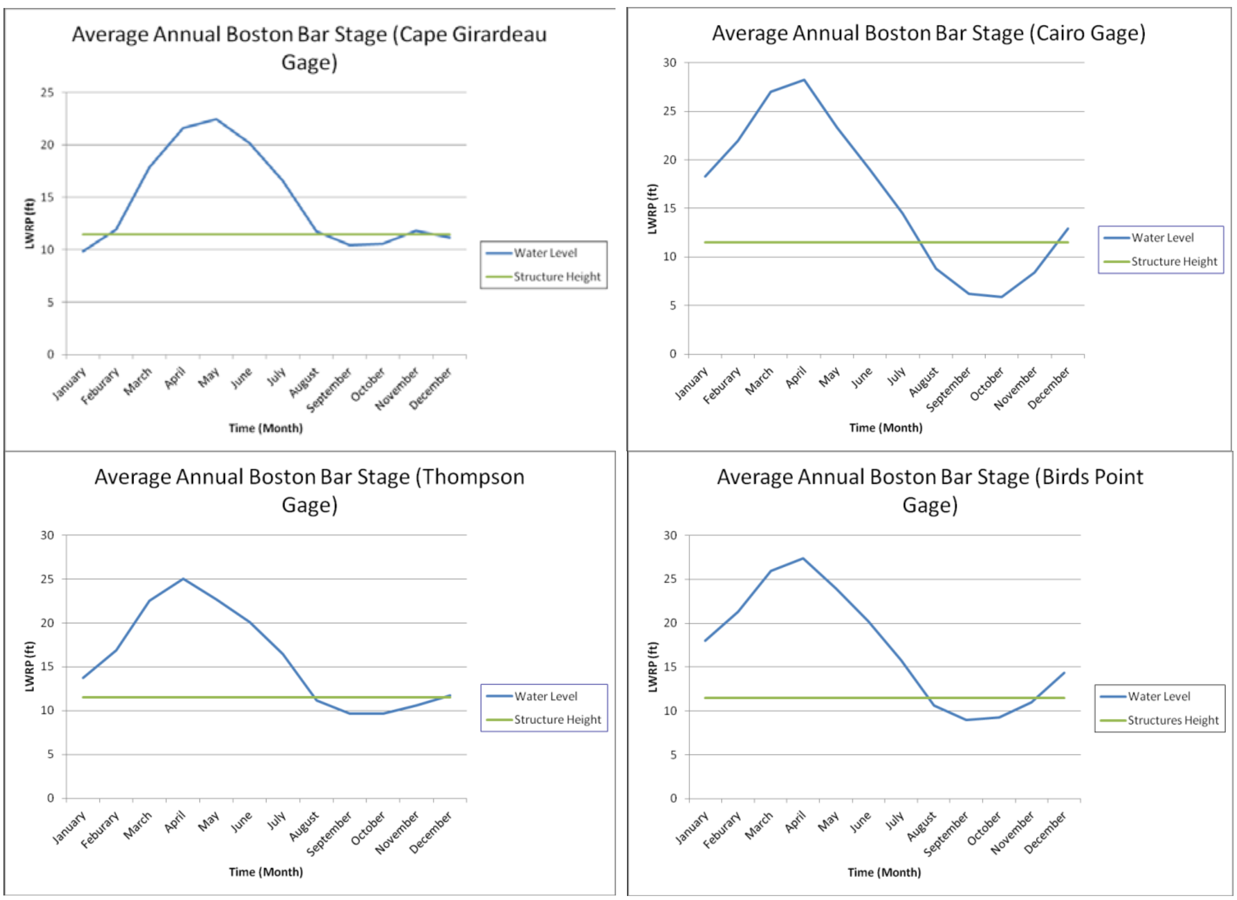


Figure 10. Monthly average annual hydrograph (data from entire period of record) from four nearby gage locations compared to height of dike/closing structure 7.90L (+11 feet LWRP). +11 feet LWRP.

Rated gages, locations where both discharge and stage is collected and combined to create a rating curve, are good sources of long term stage and discharge data. Only three rated gages exist on the MMR: St. Louis, Chester and Thebes. Due to backwater effects from the Ohio

River the gage at Thebes is not a good indicator of changes in stage over time. Throughout the period of record (1866 to present) the two agencies that have been responsible for the collection of gage data on the MMR are the Corps of Engineers and U.S. Geological Survey (USGS). The USGS has been the primary agency responsible for stream gaging since 1933. Due to discrepancies in methodology and instrumentation used by the Corps and USGS it is impossible to analyze the entire period of record with confidence; therefore, only data collected by the USGS will be used here to describe the changes in stage for fixed discharges over time (Watson et al. 2013a; Watson et al. 2013b; Huizinga 2009; Munger et al. 1976).

Stages have been decreasing over time for flows below 200,000 cfs at the St. Louis gage (Figure 11). For other in-bank flows between 200,000 cfs and 500,000 cfs there has been no change over time. There is a slight upward but statistically insignificant trend for stages at the overbank flow of 700,000 cfs. Stages at Chester for lower in-bank flows up to 200,000 cfs have decreased with time. There was no change in stages at flows of 200,000 cfs and 400,000 cfs. There was a slightly increasing trend at 300,000 cfs. For overbank flows of 500,000 cfs and 700,000 cfs, there were slight increasing trends observed at the Chester gage.

In general, at both the St. Louis and Chester gages there has been a decrease in stage over time for lower flows, no change in stages over time for flows between midbank and bankfull, and a slight increase in stages for high overbank flows (Huizinga 2009). Huizinga (2009) and Watson et al. (2013a) attributed the slight increase in out of bank flows to the construction of levees and the disconnection of the river from the floodplains. Both Watson et al. (2013a) and Huizinga (2009) observed a shift occurring in the out of bank flows in the mid-1960s and attributed it to the completion of the Alton to Gale levee system which paralleled the entire MMR. At these high flows navigation structures are submerged by 7 to 10 feet.

3.3 Water Quality

Section 303(d) of the Clean Water Act requires states to generate lists of impaired water bodies every two years. Impaired water bodies are those that do not meet state water quality standards for the water bodies' designated uses. On the 2014 303(d) list for Illinois, the Mississippi River in the vicinity of the work area was listed as impaired (IEPA 2015). The Mississippi River is on the 2014 303(d) list for Missouri between St Louis, MO, and Ste. Genevieve, MO (MDNR 2014); however, the Mississippi River in the vicinity of the work area is not listed as impaired by the state of Missouri.

Illinois has 2015 fish consumption advisories for the Mississippi River for sturgeon (all sizes, one meal per month) due to PCB contamination (IDPH 2015). Missouri has fish consumption advisories for the Mississippi River for shovelnose sturgeon (all sizes, 1 per month), flathead catfish (>17", 1 per week), blue catfish (>17", 1 per week), channel catfish (>17", 1 per week), common carp (>21", 1 per week), and sturgeon eggs (do not eat) due to PCB, chlordane, and mercury contamination (MDHSS 2015).

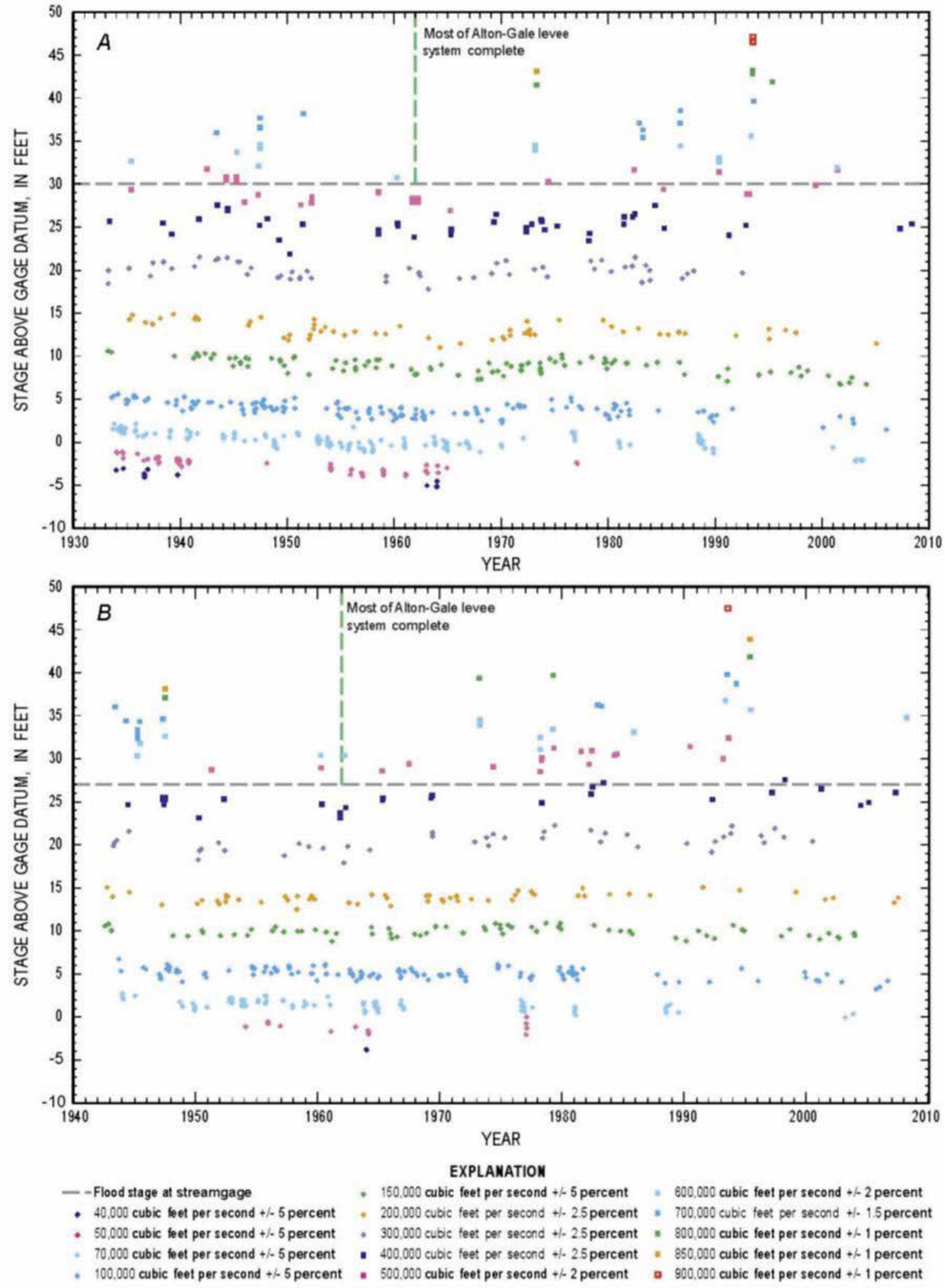


Figure 11. Stage for a given discharge range with time from measurements made at the Stream gages at (A) St. Louis, Missouri, and (B) Chester, Illinois, on the Middle Mississippi River (from Huizinga 2009).

In regards to Boston Chute, water quality data were not collected for the purposes of this project, and no such data are known to exist. However, previous studies have demonstrated that isolation from the main channel can have deleterious impacts on water quality within side channels. In the MMR specifically, Crites et al. (2012) demonstrated that prolonged isolation of Buffalo Chute caused stratification and anoxic conditions within the side channel, likely causing the observed decline in fish richness and diversity within the side channel. Buffalo Chute is located on the right descending bank of the Mississippi River at RM 24.7 – 26 R, only 14 miles upstream of Boston Chute, with no major tributaries in between the two side channels. Impacts similar to those observed in Buffalo Chute likely occur in Boston Chute when isolated from the main channel for an extended period of time.

3.4 Fisheries and Aquatic Habitat

The work area consists of a variety of habitat types, including main channel, main-channel border unstructured, main-channel border wing-dike, and side-channel. Because of this, the project area likely fulfills the habitat requirements for the major habitat guilds of large river fishes: fluvial specialists, fluvial dependents, and macrohabitat generalists. Fluvial specialists are species found almost exclusively in lotic (flowing water) habitat, and require flowing water for all of their life cycles (Kinsolving and Bain 1993). Fluvial dependent species will occur in both lentic (non-flowing water) and lotic habitats, but require flowing water during one or more life stages (e.g., reproduction; Galat et al. 2005a). Macrohabitat generalist species are also commonly found in both lentic and lotic habitats, but do not require flowing water for any particular life stage (Kinsolving and Bain 1993). Stretches of unstructured main-channel and main channel border areas provide the preferred habitat of MMR fluvial specialists and fluvial dependents: moderate depths of flowing water over a sandy substrate. Main channel border wing dike areas produce pockets of lentic habitat in the form of flow refugia and plunge pools, providing habitat often used by macrohabitat generalists. Boston Chute provides arguably the most important habitat type in the MMR, as it creates lateral connectivity and is likely used as a surrogate for floodplain and backwater habitat by many species in the MMR. Data collected by the Upper Mississippi River Restoration Program, Long Term Resource Monitoring (UMRR-LTRM) element in the MMR demonstrates that most macrohabitat generalists are collected in greater abundance from side channels compared to other macrohabitat types (Simmons 2015), presumably due to the shallow, low-velocity habitat they provide at certain river stages.

UMRR-LTRM fish community monitoring conducted in the MMR from river miles 80 to 29 from 2000 to 2014 collected 99 species of fishes. The most commonly encountered native and non-native species can be found in Table 2 below. Due to the fact that the habitat in the work area is similar to the MMR habitats sampled by the UMRR-LTRM, it is presumed that species composition in the work area would be similar as well.

Although Boston Chute has not been sampled for benthic invertebrates, the side channel's benthic fauna would be expected to contain species more typical of backwaters than flowing side channels (Neuswagner et al. 1982). Side channels in the middle Mississippi River are known to support freshwater mussels (Keevin and Cummings 2000), although the densities are extremely low and the fauna is typically species that occur in backwater habitats (i.e., *Anadonta grandis, Leptodea fragilis,* and *Potamilus ohiensis).* These three species made up 87.5 percent of the total number of specimens collected during Keevin and Cummings' (2000) mussel survey of the MMR. Their survey is likely representative of the mussels that may occur within Boston Chute.

Table 2. Common species of fish collected in the MMR by UMRR-LTRM from 2000 to 2014.

Species	Percent of Total Catch	Habitat Use Guild*
Native Species		
Gizzard shad (*Dorosoma cepedianum*)	21.6	Macrohabitat Generalist
Emerald shiner (*Notropis atherinoides*)	11.0	Macrohabitat Generalist
Freshwater drum (*Aplodinotus grunniens*)	10.6	Macrohabitat Generalist
Channel catfish (*Ictalurus punctatus*)	9.9	Macrohabitat Generalist
Channel shiner (*Notropis wickliffi*)	6.7	Fluvial Specialist
Red shiner (*Cyprinella lutrensis*)	3.9	Macrohabitat Generalist
Shortnose gar (*Lepisosteus platostomus*)	3.3	Macrohabitat Generalist
Smallmouth buffalo (*Ictiobus bubalus*)	2.8	Macrohabitat Generalist
River carpsucker (*Carpiodes carpio*)	2.1	Macrohabitat Generalist
Bluegill (*Lepomis macrochirus*)	1.9	Macrohabitat Generalist
White bass (*Morone chrysops*)	1.9	Fluvial Dependent
Black crappie (*Pomoxis nigromaculatus*)	1.1	Macrohabitat Generalist
Blue catfish (*Ictalurus furcatus*)	1.1	Fluvial Specialist
Non-Native Species		
Common carp (*Cyprinus carpio*)	5.6	Macrohabitat Generalist
Silver carp (*Hypophthalmichthys molitrix*)	4.8	Fluvial Dependent

* Habitat use guild classification based on Galat et al. (2005a).

3.5 Hazardous, Toxic, and Radioactive Wastes (HTRW)

A Phase 1 Environmental Site Assessment is currently being performed in general conformance with the scope and limitations of the ASTM standards E-1527-05 and E1528-06 and the Standards and Practices for All Appropriate Inquiries (AAI), 40 CFR Part 312. Significant findings are not anticipated from the Phase 1 Environmental Site Assessment and results will be included in the final version of this Environmental Assessment. In the event of significant findings, further public review and/or NEPA documentation will be conducted, as appropriate.

3.6 Federally Threatened and Endangered Species: Tier II Biological Assessment

This section and section 4.6 of this report are being used to satisfy the requirements of completing a Tier II Biological Assessment for this project. In compliance with Section 7(c) of the

Endangered Species Act of 1973, as amended, the St. Louis District consulted with the U.S. Fish and Wildlife Service, Marion Ecological Services Sub-Office. Via email communication on December 10, 2015, the Service provided a list of species that could potentially occur within the vicinity of the project area. According to the Service, five federally endangered species and two federally threatened species may occur within the project area (Table 3). There is no federally designated critical habitat in the proposed project area.

Table 3. Federally listed threatened and endangered species that could potential occur within the vicinity of the project area.

Species	Status	Habitat
Gray bat (*Myotis grisescens*)	Endangered	Caves: feeding – rivers/reservoirs adjacent to forests
Indiana bat (*Myotis sodalis)*	Endangered	Hibernates in caves and mines. Maternity and foraging habitat: small stream corridors with well-developed riparian woods; upland and bottomland forests
Northern long-eared bat (*Myotis septentrionalis*	Threatened	Hibernates in caves and mines; swarming in surrounding wooded areas in autumn. Roosts and forages in upland forests during spring and summer.
Least tern (interior population) (*Sterna antillarum*)	Endangered	Large rivers - nest on bare alluvial and dredge spoil islands
Pallid sturgeon (*Scaphirhynchus albus*)	Endangered	Mississippi and Missouri Rivers
Rabbitsfoot *(Quadrula cylindrica cylindrica)*	Threatened	Ohio River
Sheepnose mussel (*Plethobasus cyphyus*)	Endangered	Shallow areas in larger rivers and streams

3.7 Socioeconomic Resources

The Middle Mississippi River is a critically important navigation corridor that provides for movement of a wide variety of commodities of local, national, and international importance. Over 89 million tons of cargo passed through the MMR in 2013, the most recent year with data available (USACE 2013). Food and farm products (24 million tons), coal (17 million tons), crude materials (15 million tons), petroleum products (14 million tons), chemicals and related products (10 million tons), and primary manufactured goods (9 million tons) accounted for the majority (99%) of shipments in 2013.

The Boston Bar project area is surrounded by rural land with relatively low population densities. In 2010, Alexander County, Illinois, had a total population size of 8,238 individuals, according to the U.S. Census Bureau's 2010 Demographic Profile, which has likely declined to an estimated 7,492 individuals as of 2014 (http://factfinder.census.gov; Accessed online January 10, 2016). Based on the 2010 Demographic Profile, 50.8 percent were male, 60.9 percent were Caucasian, and 35.4 percent were African American. According to 2014 estimates, the median household income is $25,495, 36.8 percent of the population lives below the poverty level, and the unemployment rate is 8.1 percent.

3.8 Environmental Justice (EO 12898)

Environmental justice refers to fair treatment of all races, cultures and income levels with respect to development, implementation and enforcement of environmental laws, policies and actions. Environmental justice analysis was developed following the requirements of Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Population and Low-Income Populations, 1994) and the Department of Defense's Strategy on Environmental Justice (March 24, 1995).

The purpose of environmental justice analysis is to identify and address, as appropriate, human health or environmental effects of the proposed action on minority and low income populations. Following the above directives, the methodology to accomplish this includes identifying minority and low-income populations within the study area by demographic analysis. Although a substantial portion of the population of Alexander County, Illinois, consists of minorities and people living below the poverty level (see section 3.7), the proposed action would occur entirely within aquatic areas on the Mississippi River. As such, impacts to minority and low-income populations in Alexander County are not anticipated.

3.9 Air Quality

The Clean Air Act requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants: ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead. EPA regulates these pollutants by developing human health-based or environmentally-based permissible pollutant concentrations. EPA then publishes the results of air quality monitoring, designating areas as meeting (attainment) or not meeting (nonattainment) the standards or as being maintenance areas. Maintenance areas are those areas that have been redesignated as in attainment from a previous nonattainment status. A maintenance plan establishes measures to control emissions to ensure the air quality standard is maintained in these areas. Alexander County, Illinois, is currently in attainment for all criteria pollutants (USEPA 2015).

3.10 Noise Levels

Transportation related noise, such as that created by navigation traffic, railroads, planes, and small highways, is the main source of noise within the study area. Additional noise can be attributed to gun shots that occur during hunting season. Agricultural and open space areas typically have noise levels in the range of 34-70 decibels depending on their proximity to transportation arteries.

3.11 Historic and Cultural Resources

As with many reaches of the Middle Mississippi River, the course Boston Bar reach has changed considerably in the last 150 years. In the late 19th century the work locations were actually on the Missouri side of the river (Figure 12). In 1908 they were on ephemeral sand bars in the middle of the river (Figure 13). It was only in the second quarter of the 20th century that Boston Bar began to resemble its current configuration (Figure 14).

All of the proposed work would be accomplished via barge, without recourse to land access; therefore, any effects are limited to submerged cultural resources. Primary among these are historic period shipwrecks. Given the continual river flow and associated sedimentary erosion, deposition, and reworking, it is highly unlikely that any more ephemeral cultural material remains on the river bed.

During the summer of 1988 when the Mississippi River was at a particularly low level, the St. Louis District Corps of Engineers conducted an aerial survey of exposed wrecks between Saverton, Missouri, and the mouth of the Ohio River. The nearest observed wreck to the project features was located approximately three miles upstream. The river bed in the project area is surveyed at a minimum once every two years, with the latest processed survey having been completed in 2014. The multi-beam survey detected no topographic anomalies suggesting the presence of unknown wrecks.

In accordance with Section 106 of the National Historic Preservation Act of 1966 and its implementing regulation 36 CFR 800, the District began consultation with the Illinois Historic Preservation Agency with a letter dated 1 October, 2015 (Appendix B).

3.12 Prime or Unique Farmland (7USC 4201)

Although agricultural land is located near the project area, the proposed action would occur entirely within aquatic areas of the Mississippi River. As such, Prime or Unique Farmland does not exist within the project area.

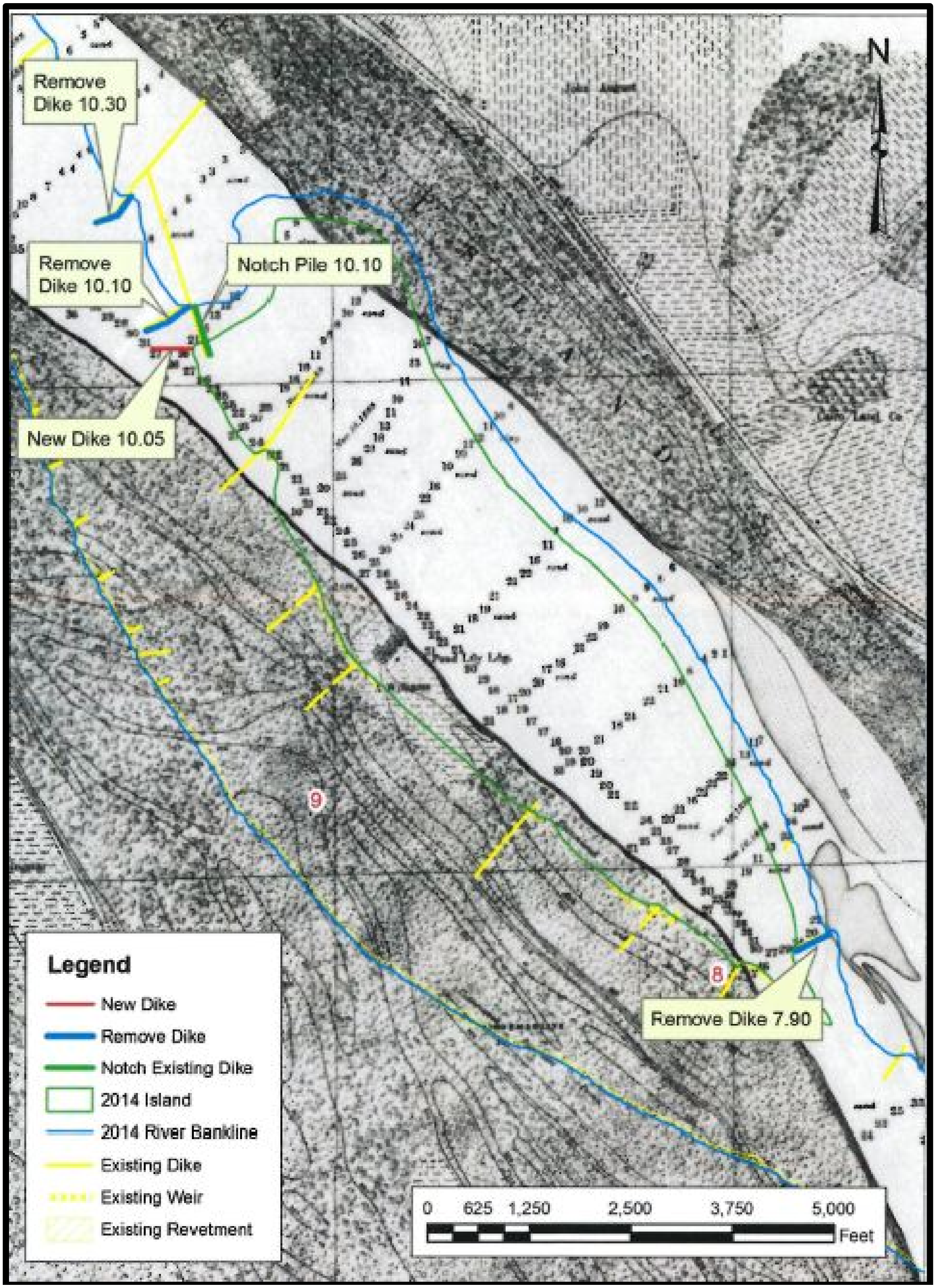


Figure 12. Proposed features superimposed on 1881 map (Mississippi River Commission 1881).

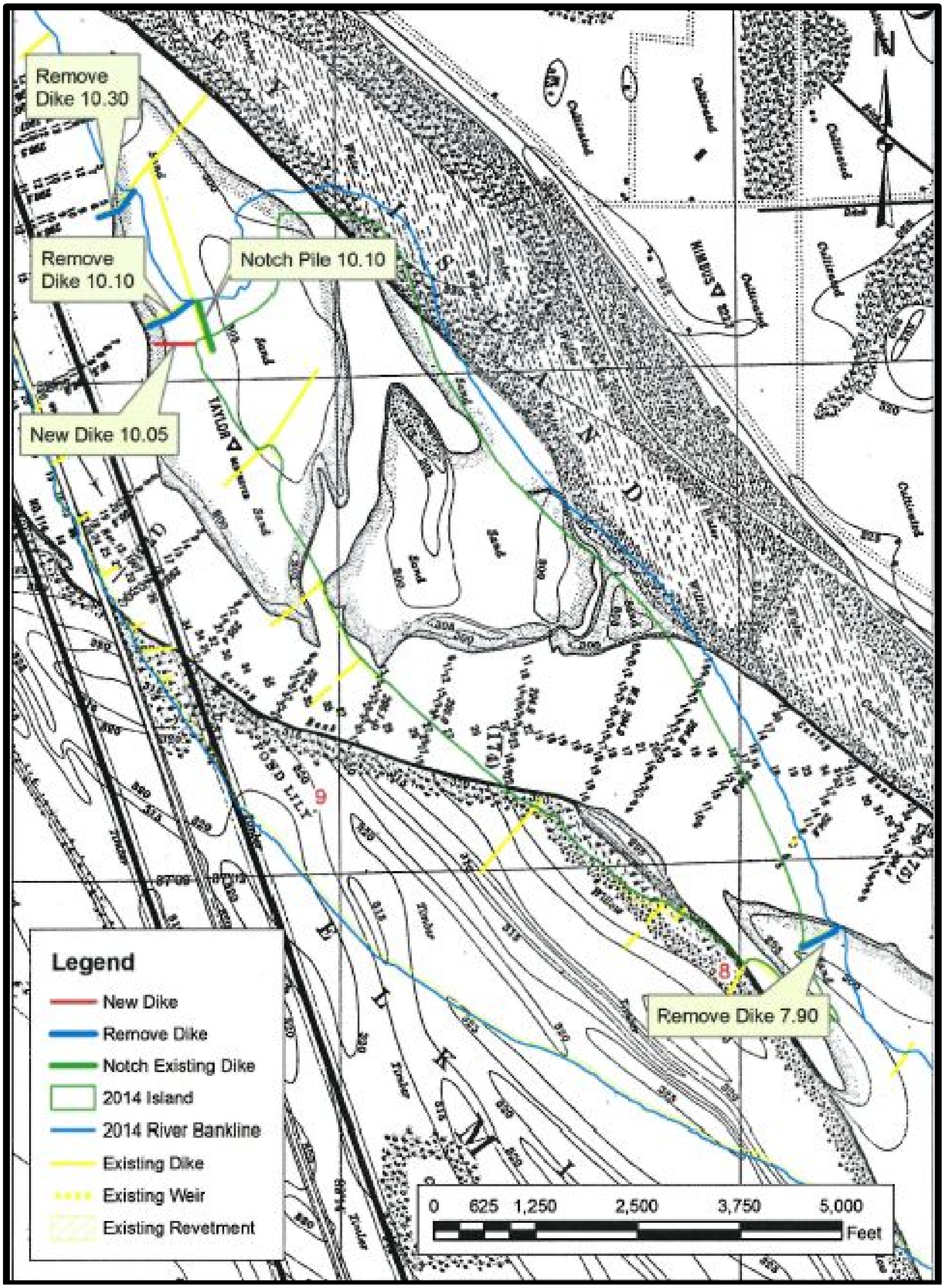


Figure 13. Proposed features superimposed on 1908 map (Board on Examination and Survey of Mississippi River 1908).

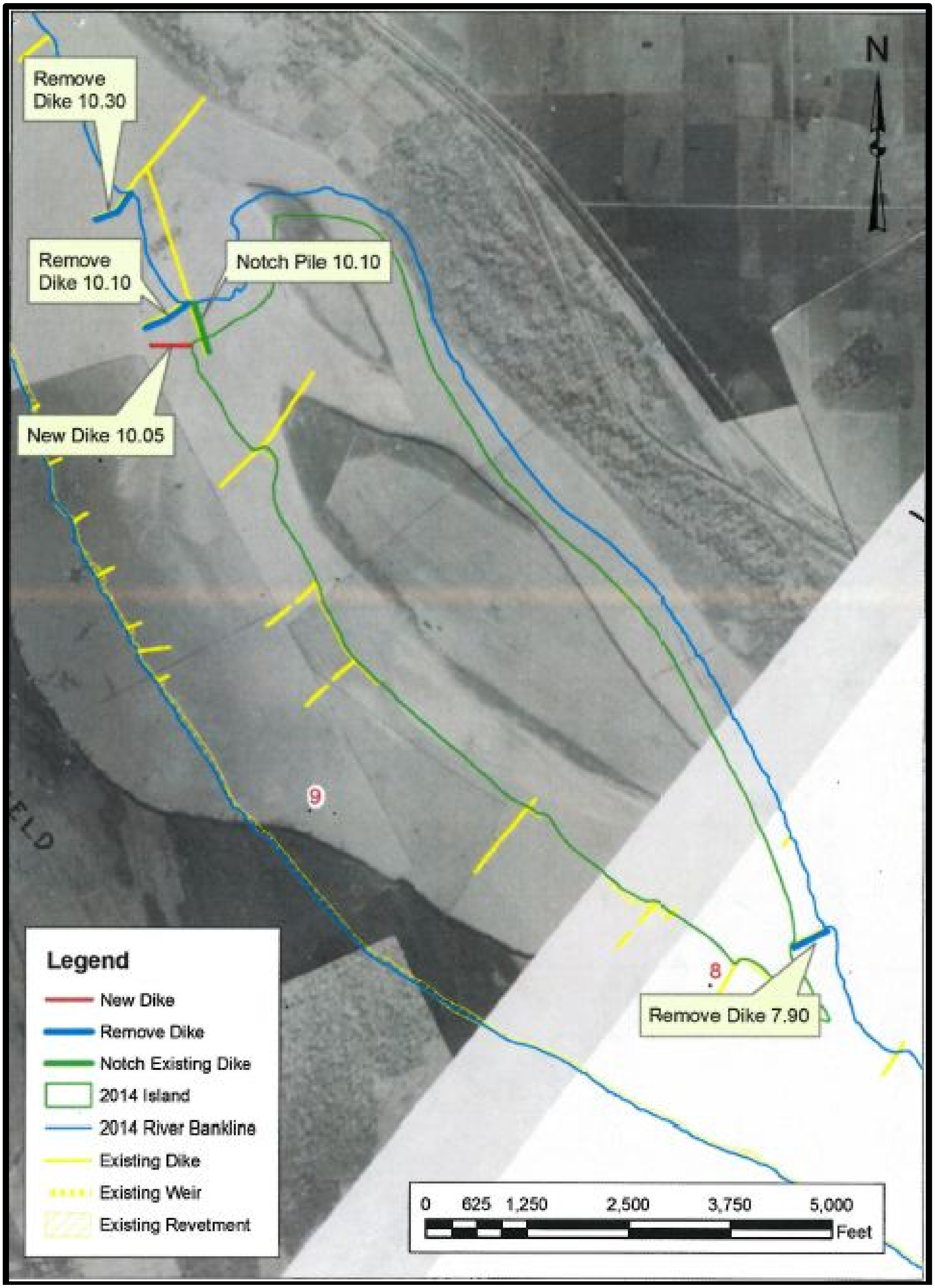


Figure 14. Project features superimposed on 1925 aerial imagery.

3.13 Climate Change and Greenhouse Gas Emissions

A large body of scientific evidence indicates that increases in greenhouse gases[1] (GHG) in the Earth's atmosphere are contributing to changes in national and global climatic conditions (Melillo et al. 2014). These changes include such things as increases in average temperature, changes in precipitation patterns, and increases in the frequency and intensity of severe weather events. These changes have the potential to impact a wide sector of the human environment including water resources, agriculture, transportation, human health, energy, and aquatic and terrestrial ecosystems. Therefore, it is important to understand the potential impacts of federal actions on GHG emissions and climate change as well as the potential changes that may occur to the human environment that could affect the assumptions made with respect to determining the impacts and efficacy of the federal action in question.

Accordingly, the Corps is undertaking climate change preparedness and resilience planning and implementation in consultation with internal and external experts using the best available climate science and climate change information. The Corps is preparing concise and broadly-accessible summary reports of the current climate change science with specific attention to USACE missions and operations for the continental United States, Alaska, Hawaii, and Puerto Rico. Each regional report summarizes observed and projected climate and hydrological patterns cited in reputable peer-reviewed literature and authoritative national and regional reports. The following information on climate trends and future climate projections comes from the climate change and hydrology literature synthesis report for the Upper Mississippi River region (USACE 2015).

Summary of Observed Climate Findings:

The general consensus in the recent literature points toward moderate increases in temperature and precipitation, and streamflow in the Upper Mississippi Region over the past century. In some studies, and some locations, statistically significant trends have been quantified. In other studies and locales within the Upper Mississippi Region, apparent trends are merely observed graphically but not statistically quantified. There has also been some evidence presented of increased frequency in the occurrence of extreme storm events (Villarini et al., 2013). Lastly, a transition point in climate data trends, where rates of increase changed significantly, was identified by multiple authors at approximately 1970.

Summary of Future Climate Projection Findings:

There is strong consensus in the literature that air temperatures will increase in the study region, and throughout the country, over the next century. The studies reviewed here generally agree on an increase in mean annual air temperature of approximately 2 to 6 ºC (3.6 to 10.8 ºF) by the latter half of the 21st century in the Upper Mississippi Region. Reasonable consensus is

[1] A greenhouse gas is any gas that absorbs infrared radiation in the atmosphere. The major GHGs are carbon dioxide, methane, and nitrous oxide. Less prevalent greenhouse gases include hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride (UNFCCC 2014).

also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long term future compared to the recent past.

Projections of precipitation found in a majority of the studies forecast an increase in annual precipitation and in the frequency of large storm events. However, there is some evidence presented that the northern portion of the Upper Mississippi Region will experience a slight decrease in annual precipitation. Additionally, seasonal deviations from the general projection pattern have been presented, with some studies indicating a potential for drier summers. Lastly, despite projected precipitation increases, droughts are also projected to increase in the basin as a result of increased temperature and ET rates.

A clear consensus is lacking in the hydrologic projection literature. Projections generated by coupling [Global Climate Models] *with macro scale hydrologic models in some cases indicate a reduction in future streamflow but in other cases indicate a potential increase in streamflow. Of the limited number of studies reviewed here, more results point toward the latter than the former, particularly during the critical summer months.*

Chapter 4 Environmental Consequences

This chapter describes the impacts of each considered alternative for each resource topic discussed from Chapter 3. The depth of analysis of the alternatives corresponds to the scope and magnitude of the potential environmental impact. This chapter compares the adverse and beneficial effects (direct, indirect, and cumulative) and significance of each alternative.

4.1 Physical Setting

4.1.1 Alternative 1 – No Action

Under the no action alternative, the physical setting of the project area would remain in its current condition. Dikes 10.1L and 10.3L would continue to constrict flow within the project area, directing it toward the navigation channel and away from the entrance of Boston Chute. It is likely that Boston Chute would continue to experience prolonged periods of isolation from the main-stem of the Mississippi River as well as reduced flow velocity through the channel. Without the proposed action, the reduced flow leaves Boston Chute susceptible to higher accretion rates, thereby reducing the longevity of this already limited physical feature of the MMR.

Furthermore, dredge disposal material would not be used to create sandbar habitat for least tern nesting. Rather, future channel maintenance dredging would continue disposing of dredged material using a rigid pipe and the traditional side-casting method. This would do nothing to enhance bathymetric diversity and create nesting habitat for least tern adjacent to Boston Bar.

4.1.2 Alternative 2 – Preferred Alternative

With the proposed action, there will be a net decrease in the total number of river training structures in the MMR, allowing the river flow more naturally through the project area. Results of the HSR model study indicate that additional water would more readily flow through Boston Chute. Closing structures would no longer reduce flow velocity within the side channel, and the rate of accretion within the side channel would most likely be reduced. Large-scale adverse impacts to the physical setting of the project areas are not anticipated.

If dredging for channel maintenance is necessary in the future, the District would utilize the flex-pipe to concentrate the dredged material adjacent to Boston Bar, building a sandbar island to the dimensions specified herein. It is likely that the constructed island would eventually erode away after one or more high flow events, which are not accounted for in the HSR model.

4.2 Stages

4.2.1 Alternative 1 – No Action

Stages in the work area vicinity and the Middle Mississippi River would be expected to be similar to current conditions under the No Action Alternative.

4.2.2 Alternative 2 – Preferred Alternative
With implementation of the Proposed Action, stages at average and high flows both in the project area vicinity and in the MMR are expected to be similar to current conditions. An abundance of research has been conducted analyzing the impacts of river training structures on water surfaces dating to the 1930s. This research has analyzed historic gage data, velocity data, and cross sectional data. Physical and numerical models have also been used to determine the effects of dikes on water surfaces. It should be noted that some published research supports the contention that river training structures raise flood heights. A summary of research on the effects of river training structures on flood heights can be found in Appendix D. Based on an analysis of this research by the Corps and other external reviewers, the District has concluded that river training structures do not affect water surface elevations at higher flows. Based on all of the analyses on stage impacts from river training structures, the District concludes that flood risks would not be increased nor decreased as a result of the proposed action.

The reduction in the overall number of structures associated with implementation of the Proposed Action is not anticipated to have an appreciable impact on stages at low flows.

4.3 Water Quality

4.3.1 Alternative 1 – No Action
The no action alternative would result in neither temporary, nor long-term changes to water quality within the project area. Furthermore, the potential for poor water quality within Boston Chute during periods of isolation would continue in the future.

4.3.2 Alternative 2 – Preferred Alternative
With the proposed action, the duration of connectivity between Boston Chute and the main stem of the Mississippi River would increase and water would flow more readily through the entire channel. This would reduce the likelihood of poor water quality within Boston Chute (e.g., anoxic conditions, stratification, high temperatures). Temporary increases in turbidity are likely to occur during the removal of dike structures, construction of the SCED, and creation of the sandbar habitat using dredge disposal material. Turbidity levels are expected to return to pre-construction levels once the project is complete. No long-term negative impacts to water quality are anticipated. No violations of any Illinois water quality standards are anticipated.

Prior to project implementation, the District will be in full compliance will all sections of the Clean Water Act. A Clean Water Act Section 404(b)(1) Evaluation is attached as Appendix C.

4.4 Fisheries and Aquatic Habitat

4.4.1 Alternative 1 – No Action
Under the no action alternative, the aquatic habitat and assemblage of aquatic organisms would remain the same. Dikes 10.3L and 10.1L would continue to create areas of turbulent water near the dike tips and low velocity areas directly behind the dikes, which may be used as flow refugia and foraging areas by some fishes. Fish and other aquatic organisms would continue to have access to Boston Chute during high river stages, but would be restricted

access during lower river stages. There is also the likelihood that fishes will become trapped within the side channel when it becomes isolated from the main stem of the river, and succumb to the changes in water quality resulting from extended periods of isolation. Further, least tern nesting habitat would not be created using channel maintenance dredge disposal. Development of sandbars with the specific characteristics necessary for successful least tern reproduction (e.g., elevation, vegetation, isolation) would be entirely dependent on the modified hydrology within the project area.

4.4.2 Alternative 2 – Preferred Alternative

Under the proposed action, the assemblage of aquatic organisms would likely remain the same, but the overall aquatic habitat within the project area would be vastly improved. Removal of dikes 10.3L and 10.1L would eliminate some flow refugia within the project area, but there is already an exorbitant amount of flow refugia provided by river training structures in the project area, and throughout the entire MMR. Removal of these dikes would allow a more natural channel border, reminiscent of the historic MMR, to develop in their place (e.g., natural sandbars, unstructured channel border). Further, removal of these dikes and the closing structures, coupled with the construction of the SCED, would improve connectivity to Boston Chute, making this important off-channel habitat available to fishes for longer durations. The deep scour hole would then be available during the late fall when fish begin moving into overwintering areas. Deep, sluggish, well oxygenated water is extremely important for fish that seek out these habitats during winter because of their reduced swimming capabilities (Bodensteiner and Lewis 1992; Knights et al*.* 1995). The additional water volume, improved habitat conditions, and connectivity during the summer months should also improve their nursery function as well. This type of backwater habitat is in limited supply in the MMR and will serve an important and improved nursery function (Shaeffer and Nickum 1986).

The only adverse impacts associated with the proposed action are minimal. Construction of the SCED will permanently bury a small area of riverbed, as well as the benthic invertebrates that occur there during construction. Also, disposal of dredge material within the main channel border to create the least tern nesting habitat will smother benthic invertebrates as well. Re-colonization of invertebrates is anticipated to occur within a year. Mussels are not known to occur in the shifting sand areas (disposal sites) of the MMR.

4.5 Hazardous and Toxic Wastes (HTRW)

The District is currently performing a Phase I Environmental Site Assessment for the Boston Bar project area. Upon completion of the assessment, environmental consequences of the project alternatives related to HTRW will be analyzed and included in the final version of this report.

4.6 Federally Threatened and Endangered Species: Tier II Biological Assessment

In accordance with the Endangered Species Act, a list of federally threatened and endangered species was obtained from the Service. This satisfies the requirement for Section 7 Consultation under the Endangered Species Act. This section will also serve as the effects determination portion of the Biological Assessment required by the Endangered Species Act. The gray bat, Indiana bat, least tern, pallid sturgeon, rabbitsfoot, fat pocketbook, and decurrent false aster are listed as federally threatened or endangered species that may occur within the vicinity of the project area.

Gray Bat

The gray bat (*Myotis grisescens)* is listed as endangered and occurs in several Illinois and Missouri counties where it inhabits caves both summer and winter. This species forages in riparian forest canopy and over rivers and reservoirs adjacent to forests.

Alternative 1 – No Action - No caves would be impacted under this alternative. As such, this alternative will have no effect on gray bat.

Alternative 2 – Preferred Alternative - No caves would be impacted by the proposed action. All construction activities will occur on land. Therefore, this action will have no effect on gray bat.

Indiana Bat

The range of the Indiana bat (*Myotis sodalis*) includes much of the eastern half of the United States, including southern Illinois. Indiana bats migrate seasonally between winter hibernacula and summer roosting habitats. Winter hibernacula include caves and abandoned mines. Females emerge from hibernation in late March or early April to migrate to summer roosts. During the summer, the Indiana bat frequents the corridors of small streams with well-developed riparian woods, as well as mature upland forests. It forages for insects along stream corridors, within the canopy of floodplain and upland forests, over clearings with early successional vegetation (old fields), along the borders of croplands, along wooded fencerows, and over farm ponds in pastures. Females form nursery colonies under the loose bark of trees (dead or alive) and/or cavities, where each female gives birth to a single young in June or early July. A maternity colony may include from one to 100 individuals. A single colony may utilize a number of roost trees during the summer, typically a primary roost tree and several alternates. Some males remain in the area near the winter hibernacula during summer months, but others disperse throughout the range of the species and roost individually or in small numbers in the same types of trees as females.

The leading causes of the Indiana bat population decline includes disturbance, vandalism, improper cave gates and structures, natural hazards such as flooding or freezing, microclimate changes, land use changes in maternity range, and chemical contamination (USFWS 2000, 2004). To avoid incidental take of this species, the Service recommends tree clearing activities should not occur during the period of 1 April to 30 September. In addition, trees suitable for bat roosts or maternity colonies should not be removed without first performing a bat survey.

Alternative 1 – No Action - Under the no action alternative, terrestrial habitat adjacent to the project area would remain in its current condition. Trees that provide adequate roosting habitat for Indiana bat would not be impacted. Therefore, this alternative would have no effect on Indiana bat.

Alternative 2 – Preferred Alternative - This project does not call for the removal of any trees; all construction will be completed by river-based equipment and will not result in the destruction of any forested riparian habitat. However, unforeseen effects from construction activities (e.g., noise), could potentially disturb Indiana bats roosting on the land adjacent to the project area. As such, the proposed action may affect, but is not likely to adversely affect the Indiana bat.

Northern Long-Eared Bat

The northern long-eared (*Myotis septentrionalis*) bat is a federally threatened bat species. The northern long-eared bat is sparsely found across much of the eastern and north central United States, and all Canadian provinces from the Atlantic Ocean west to the southern Yukon Territory and eastern British Columbia. Northern long-eared bats spend winter hibernating in large caves and mines. During summer, this species roosts singly or in colonies underneath bark, in cavities, in crevices of both live and dead trees. Foraging occurs in interior upland forests. Forest fragmentation, logging and forest conversion are major threats to the species. One of the primary threats to the northern long-eared bat is the fungal disease, white-nose syndrome, which has killed an estimated 5.5 million cave-hibernating bats in the Northeast, Southeast, Midwest and Canada. Suitable northern long-eared bat summer habitat may occur in the forested areas adjacent to the project area.

Alternative 1 – No Action - Under the no action alternative, terrestrial habitat adjacent to the project area would remain in its current condition. Trees that provide adequate roosting habitat for northern long-eared bat would not be impacted. Therefore, this alternative would have no effect on Indiana bat.

Alternative 2 – Preferred Alternative - This project does not call for the removal of any trees; all construction will be completed by river-based equipment and will not result in the destruction of any forested riparian habitat. However, unforeseen effects from construction activities (e.g., noise), could potentially disturb northern long-eared bats roosting on the land adjacent to the project area. As such, the proposed action may affect, but is not likely to adversely affect northern long-eared bat.

Least Tern

The interior population of the least tern (*Sterna antillarum*) is characterized as a colonial, migratory waterbird, which resides and breeds along the Mississippi River during the spring and summer. Least tern arrive on the Mississippi River from late April to mid-May. Reproduction takes place from May through August, and the birds migrate to the wintering grounds in late August or early September (USACE 1999). Sparsely vegetated portions of sandbars and islands are typical breeding, nesting, rearing, loafing, and roosting sites for least tern along the MMR. Nests are often at higher elevations and well removed from the water’s edge, a reflection of the fact that nesting starts when river stages are relatively high (USACE 1999).

Given the highly dynamic nature of the historic MMR planform, the ability to return to previously used colony sites is not likely a critical life history requirement. The availability of sandbar habitat to least terns for breeding, nesting, and rearing of chicks from 15 May to 31

August is a key variable in the population ecology of this water bird. Only portions of sandbars that are not densely covered by woody vegetation and are emergent during the 15 May to 31 August period are potentially available to least terns (USACE 1999).

Least terns are almost exclusively piscivorous (Anderson 1983), preying on small fish, primarily minnows (Cyprinidae). Prey size appears to be a more important factor determining dietary composition than preference for a particular species or group of fishes (Moseley, 1976; Whitman, 1988, USACE 1999). Fishing occurs close to the nesting colonies and may occur in both shallow and deep water, in main channel and backwater habitats. Radiotelemetry studies have shown that least tern will travel up to 2.5 miles to fish (Sidle and Harrison, 1990, USACE 1999). Along the Mississippi River, individuals are commonly observed hovering and diving for fish over current divergences (boils) in the main channel, in areas of turbulence, over eddies along natural and revetted banks, and at "run outs" from floodplain lakes where forage fish may be concentrated (USACE 1999, Niles and Hartman 2009).

According to the Service, existing wing dikes have the ongoing effect of altering natural river habitat processes, thereby reducing the quality, quantity, and diversity of habitat in the MMR. The Service asserts that continued disruption of natural processes will affect least tern by (1) reducing the availability of bare sandbar nesting habitat; (2) reducing the availability of foraging habitat; and (3) reducing the abundance of forage food (USFWS 2000).

Alternative 1 – No Action - Under the no action alternative, dredge disposal material would not be used to create sandbar habitat designed for least tern nesting. Rather, dredged material would be disposed with the traditional side-cast method, and habitat for nesting least tern would remain in its current condition within the MMR. This alternative would have no effect on least tern.

Alternative 2 – Preferred Alternative - The proposed action was developed in part to directly benefit least tern. Using dredge disposal material to increase the total area of nesting habitat in the MMR will improve the potential for successful reproduction and recruitment of least tern. Also, removing dikes to increase flow into Boston Chute may indirectly benefit least tern. By decreasing the constriction of flow toward the navigation channel in the project area, natural sandbars are more likely to develop on their own, further increasing the area available for least tern nesting. Although designed to benefit least tern, short term effects brought on by construction activities (e.g., noise, emissions) may negatively affect least tern. Thus, the project may affect, but is not likely to adversely affect least tern.

Pallid Sturgeon

The pallid sturgeon is federally endangered big-river fish species. It is the position of the Service that over time, river training structures have adversely affected pallid sturgeon by impacting the quality and quantity of habitats in the MMR to which the species is adapted (e.g., braided channels, irregular flow patterns, flood cycles, extensive microhabitat diversity, and turbid waters). According to the Service, this loss of habitat has reduced pallid sturgeon reproduction, growth, and survival by (1) decreasing the availability of spawning habitat; (2) reducing larval and juvenile pallid sturgeon rearing habitat; (3) reducing the availability of seasonal refugia; and (4) reducing the availability of foraging habitat (USFWS 2000). The Service also asserts that these habitat changes have also reduced the natural forage base of the pallid sturgeon, and is another likely contributing factor in its decline (Mayden and Kuhajda 1997, USFWS 2000). The Service states that river training structures have also altered the natural hydrograph of the MMR by contributing to higher water surface elevations at lower discharges than in the past and to a downward trend in annual minimum stages (Simons et al. 1974, Wlosinski 1999, USFWS 2000). As a result, areas that were historically aquatic habitats are now dry at low discharges (Wlosinski 1999). This has potentially reduced the availability of pallid sturgeon spawning habitat through the loss of habitat heterogeneity (USFWS 2000).

Alternative 1 – No Action - Under the no action alternative, connectivity between the main stem of the MMR and Boston Chute would not be enhanced. The side channel would continue to become isolated from the main stem of the MMR for prolonged periods, restricting pallid sturgeon from accessing this off-channel habitat. This alternative would have no effect on pallid sturgeon.

Alternative 2 – Preferred Alternative - The proposed action was developed in part to directly benefit pallid sturgeon. Removal of dikes and closing structures, coupled with the construction of a SCED, will enhance connectivity between the main stem of the MMR and Boston Chute. This will provide pallid sturgeon access to this important off-channel habitat for longer durations and ultimately increase habitat heterogeneity in the MMR. The District has concluded that short-term adverse impacts may occur during construction but are limited, and the benefit of increasing connectivity to Boston Chute far outweigh those potential impacts. Thus, the project may affect, but is not likely to adversely affect the pallid sturgeon.

Rabbitsfoot Mussel

The rabbitsfoot mussel (*Quadrula cylindrica*) is a federally threatened freshwater mussel species. Parmalee and Bogan (1998) described the following habitat requirements for the rabbitsfoot mussel. The rabbitsfoot mussel is primarily an inhabitant of small to medium-sized streams and some larger rivers. It usually occurs in shallow areas along the bank and adjacent runs and shoals where the water velocity is reduced. Specimens may also occupy deep water runs, having been reported in 9-12 feet of water. Bottom substrates generally include sand and gravel. This species seldom burrows but lies on its side (Watters 1988; Fobian 2007).

Alternative 1 – No Action - This species occurs in the lower 20 miles of the St. Francis River in Missouri (USFWS 2009), and in the Ohio River in Alexander County, Illinois. Historically, it is not known to occur in the Mississippi River. The no action alternative will have no effect on the rabbitsfoot mussel.

Alternative 2 – Preferred Alternative - This species occurs in the lower 20 miles of the St. Francis River in Missouri (USFWS 2009), and in the Ohio River in Alexander County, Illinois. Historically, it is not known to occur in the Mississippi River. Therefore, the proposed action will have no effect on the rabbitsfoot mussel.

Sheepnose Mussel
The sheepnose mussel (*Plethobasus cyphyus*) is a medium-sized mussel that grows to about 5 inches in length. The sheepnose is primarily a larger-stream species. It occurs most often in shallow shoal habitats with moderate to swift currents over coarse sand and gravel (Oesch 1984). Habitats with sheepnose may also have mud, cobble, and boulders. Specimens in larger rivers may occur in deep runs (Parmalee and Bogan 1998). Strayer (1999a) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events.

Alternative 1 – No Action - This species is not currently known to occur in the project vicinity on the Mississippi River. The no action alternative will have no effect on sheepnose mussel.

Alternative 2 - Preferred Alternative - This species is not currently known to occur in the project vicinity on the Mississippi River; therefore, the proposed action will have no effect on sheepnose mussel.

4.7 Socioeconomic Resources

Neither alternative would negatively impact the navigation channel, commercial traffic will continue as normal adjacent to the project area. During the development of Alternative 2 (proposed action), any modification to the river training structure configuration that negatively affected the navigation channel was removed from consideration. No significant impacts to the growth of the community or region would be realized as a direct result of the proposed action.

4.8 Environmental Justice

4.8.1. Alternative 1 – No Action

Under the no action alternative, no impacts to low income and minority populations are anticipated.

4.8.2 Alternative 2 – Preferred Alternative

The proposed action would occur entirely within aquatic areas of the Mississippi River, therefore no impacts to any human population are anticipated. As such, the proposed project would not disproportionately affect low income or minority populations.

4.9 Air Quality

4.9.1. Alternative 1 – No Action

Under the no action alternative, air quality would remain in its current condition.

4.9.2 Alternative 2 – Preferred Alternative

With the proposed action, short-term affects to air quality would occur. Emissions from equipment would be generated during project construction. However, no adverse long-term air quality impacts are anticipated in the region as a result of the proposed action.

4.10 Noise

4.9.1. Alternative 1 – No Action
Under the no action alternative, noise levels would remain the same in the area.

4.9.2 Alternative 2 – Preferred Alternative
Under the proposed action, noise levels are expected to increase only during construction activities. The overall long-term noise level would not increase. Impacts resulting from noise levels are minimal; it may unsettle organisms in the area during dike removal and construction of the SCED.

4.11 Historic and Cultural Resources

4.11.1. Alternative 1 – No Action
Under the no action alternative, there would be no risk to any known historic or cultural resources that may exist within the project area unbeknown to the District.

4.11.2 Alternative 2 – Preferred Alternative
Impacts of the proposed action on Historic and Cultural Resources are as follows. All construction work on the dikes will be carried out via barge, without recourse to land access; therefore, any effects are limited to submerged cultural resources. Primary among these are historic period shipwrecks. The continual river flow and associated sedimentary erosion, deposition, and reworking make it highly unlikely that any more ephemeral cultural material remains on the river bed.

Given the features' construction method (with no land impact), the previous disturbance of the riverbed, the channel migration recorded for the location in the nineteenth century, and the lack of any survey evidence for extant wrecks, it is our opinion that the proposed undertaking will have no significant effect on cultural resources.

The Illinois State Historic Preservation Agency concurred that the proposed actions would not affect listed or eligible historic properties. A copy of the correspondence is included in Appendix B. If, however, cultural resources were to be encountered during construction, all work would stop in the affected area and further consultation would take place.

Twenty-eight federally recognized tribes affiliated with the St. Louis District were consulted and no objections to the project were raised. A copy of the consultation letter is included in Appendix B.

4.12 Prime and Unique Farmland
The project area is located strictly within aquatic areas of the MMR; no agricultural land exists within the project area. As such, neither alternative will have any impact to Prime and Unique Farmland. The District has concluded the proposed action will have no impact on river stages and therefore will not impact agricultural land adjacent to the project area.

4.13 Climate Change and Greenhouse Gas Emissions

The proposed action would have no significant effect on climate resulting from greenhouse gas emissions. The amount of greenhouse gas emissions from construction activities would be negligible due to the limited duration of construction. No permanent increase to greenhouse gas emissions would be realized as a result of the proposed action.

In the foreseeable future, climate change will not impact the environmental consequences of the proposed action. However, long-term changes to climate could alter regional weather patterns, thereby impacting the seasonal hydrology pattern of the Mississippi River. Changes to the timing and duration of peak flows and low flows in the MMR could influence the duration of connectivity between Boston Chute and the main stem MMR. Whether this will increase or decrease connectivity between the main stem MMR and Boston Chute is unforeseeable at this time. Considering the possibility of low flow periods increasing in duration, thereby decreasing connectivity between Boston Chute and the main stem MMR, the proposed action would have the added benefit of addressing this potential change before it occurs. By enhancing connectivity now, potential low flow periods resulting from climate change would have less impact on the connectivity to this important off-channel habitat. Connectivity at peak flows is not anticipated to be affected by the proposed action.

4.14 Cumulative Effects

The Council on Environmental Quality (CEQ) regulations define cumulative impacts as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 CFR §1508.7). In order to assist federal agencies in producing better cumulative impact analyses, CEQ developed a handbook, "Considering Cumulative Effects under the National Environmental Policy Act" (CEQ 1997).

Accordingly, the cumulative effects of the Regulating Works Project were discussed in detail in the cumulative effects analysis for the Mosenthein-Ivory Phase 5 Environmental Assessment (completed FY15), which generally followed the steps laid out by the CEQ handbook. The Mosenthein-Ivory Phase 5 cumulative effects analysis involved determining the incremental impact of that project's alternatives on resources in the area in the context of all of the other past, present, and reasonably foreseeable future actions that might also impact each resource category. The analysis looked beyond the footprint of the work area to include impacts to the resources throughout the MMR. Clearly the human environment in the MMR has been, and will continue to be, impacted by a wide range of actions.

The aforementioned analysis is incorporated by reference into this document to serve as the cumulative effects analysis for this project, and is available upon request. The cumulative effects analysis evaluated the same resources that were evaluated in chapters 3 and 4 of this Environmental Assessment, as well as impacts to navigation and side channels in the MMR. The District has determined that an additional cumulative effects analysis for this project is not necessary because (1) both projects are located in the MMR, (2) the past, present, and reasonably foreseeable future actions are generally identical, and (3) the proposed action would have no additional incremental impacts to any resources, rather, it would alleviate the impacts of past actions.

The Regulating Works Project, in combination with the other actions throughout the watershed, has had past impacts, both positive and negative, on the human environment. Although past actions associated with the Regulating Works Project have impacted these resources, the current method of conducting business for the Regulating Works Project includes involving partner agencies throughout the planning process, avoiding and minimizing environmental impacts, and utilizing innovative river training structure configurations to provide fish habitat while still providing benefits to the navigation system.

5. Relationship to other Environmental Laws and Regulations

Table 4. Federal policy compliance status.

Federal Laws[1]	**Compliance Status**
Abandoned Shipwreck Act of 1987, as amended, 43 USC § 2101, et seq.	Full
American Indian Religious Freedom Act, as amended, 42 USC § 1996	Full
Archaeological and Historic Preservation Act, as amended, 54 USC § 312501, et seq.	Full
Bald and Golden Eagle Protection Act, as amended, 16 USC § 668, et seq.	Full
Clean Air Act, as amended, 42 USC § 7401, et seq.	Full
Clean Water Act, as amended, 33 USC § 1251, et seq.	Partial[2]
Comprehensive Environmental Response, Compensation, and Liability Act, as amended, 42 USC § 9601, et seq.	Full
Endangered Species Act, as amended, 16 USC § 1531, et seq.	Full
Farmland Protection Policy Act, as amended, 7 USC § 4201, et seq.	Full
Federal Water Project Recreation Act, as amended, 16 USC §460l-12, et seq. and 16 USC § 662	Full
Fish and Wildlife Coordination Act, as amended, 16 USC § 661, et seq.	Full[3]
Flood Control Act of 1944, as amended, 16 USC § 460d, et seq. and 33 USC § 701, et seq.	Full
Food Security Act of 1985, as amended, 16 USC § 3801, et seq.	Full
Land and Water Conservation Fund Act of 1965, as amended, 16 USC § 460l-4, et seq.	Full
Migratory Bird Treaty Act of 1918, as amended, 16 USC § 703, et seq.	Full
National Environmental Policy Act, as amended, 42 USC § 4321, et seq.	Partial[3]
National Historic Preservation Act, as amended, 54 USC § 300101, et seq.	Full
National Trails System Act, as amended, 16 USC § 1241, et seq.	Full
Noise Control Act of 1972, as amended, 42 USC § 4901, et seq.	Full
Resource Conservation and Recovery Act, as amended, 42 USC § 6901, et seq.	Full
Rivers and Harbors Appropriation Act of 1899, as amended, 33 USC § 401, et seq.	Partial[2]
Wilderness Act, as amended, 16 USC § 1131, et seq.	Full
Executive Orders[4]	
Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, EO 12898, February 11, 1994, as amended	Full
Floodplain Management, EO 11988, May 24, 1977, as amended	Full
Invasive Species, EO 13112, February 3, 1999, as amended	Full
Protection and Enhancement of Environmental Quality, EO 11991, May 24, 1977	Full
Protection and Enhancement of the Cultural Environment, EO 11593, May 13, 1971	Full
Protection of Wetlands, EO 11990, May 24, 1977, as amended	Full
Recreational Fisheries, EO 12962, June 7, 1995, as amended	Full
Responsibilities of Federal Agencies to Protect Migratory Birds, EO 13186, January 10, 2001	Full
Trails for America in the 21st Century, EO 13195, January 18, 2001	Full

[1] Also included for compliance are all regulations associated with the referenced laws. All guidance associated with the referenced laws were considered. Further, all applicable Corps of Engineers laws, regulations, policies, and guidance have been complied with but not listed fully here.
[2] Required permits, coordination will be sought during document review.
[3] Full compliance after submission for public comment and signing of FONSI.
[4] This list of Executive Orders is not exhaustive and other Executive Orders not listed may be applicable.

6. List of Preparers

Table 5. List or report preparers, including their role and level of experience.

Name	Role	Experience
Mike Rodgers, P.E.	Project Manager	14 years, hydraulic engineering
Asher Leff	Engineering Lead	7 years hydraulic engineering
Shane Simmons	Environmental Lead	3 years, biology
Francis Walton	Environmental Compliance; Threatened and Endangered Species	15 years, environmental compliance (retired)
Tom Keevin, Ph.D.	Cumulative Impacts	35 years, aquatic ecology (retired)
Kevin Slattery	HTRW	17 years, environmental science
Mark Smith, Ph.D.	Historical and Cultural Resources	22 years, archaeology
Danny McClendon	Regulatory	29 years, regulatory compliance; biology
Keli Broadstock	Legal review	3 years USACE, 6 years private sector law

7. Literature Cited

Anderson, E.A. 1983. Nesting Productivity of the interior least tern in Illinois. Unpublished Report. Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, Illinois, 19 pp.

Bodensteiner, L. R., and W. M. Lewis. 1992. Role of temperature, dissolved oxygen, and backwaters in the winter survival of freshwater drum (*Aplodinotus grunniens*) in the Mississippi River. Canadian Journal of Fisheries and Aquatic Science 49:173-184.

Campton, D.E., A.I. Garcia, B.W. Bowen, and F.A. Chapman. 1995. Genetic evaluation of pallid, shovelnose and alabama sturgeon (*Scaphirhynchus albus*, *S. platorhynchus*, and *S. suttkusi*) based on control region (d-loop) sequences of mitochondrial DNA. Report from Dept. of Fisheries and Aquatic Sciences, Univ. of Florida, Gainesville, Florida.

Carlson, D.M., W.L. Pflieger, L. Trial, and P.S. Haverland. 1985. Distribution, biology, and hybridization of *Scaphirhynchus albus* and *S. platorhynchus* in the Missouri and Mississippi Rivers. Environmental Biology of Fishes. 14:51-59.

Crites, J.W., Phelps, Q.E., McCain, K.N., Herzog, D.P. and Hrabik, R.A., 2012. An investigation of fish community and water quality compositions in an isolated side channel of the upper Mississippi River. Journal of Freshwater Ecology, 27(1), pp.19-29.

Fobian, T.B. 2007. Reproductive biology of the rabbitsfoot mussel (*Quadrula cylindrica*) (Say, 1817) in the upper Arkansas River system, White River system, and the Red River system. Unpublished M.S. thesis, Missouri State University, Springfield. 104 pp.

Galat, D. L., Berry, C. R., Gardner, W. M., Hendrickson, J. C., Mestl, G. E., Power, G. J., Stone, C. and Winston, M. R. 2005a. Spatiotemporal patterns and changes in Missouri River fishes. *in* Rinne, J. N., Hughes, R. M., and Calamusso, R. (eds.). Historical changes in fish assemblages of large American rivers, , Bethesda, Maryland: American Fisheries Society. Symposium 45.

Galat, D. L., C. R. Berry, Jr., E. J. Peters, and R. G. White. 2005b. Missouri River Basin. Pp. 427–480 *in* A. C. Benke and C. E. Cushing (eds.). Rivers of North America, Elsevier, Oxford.

Hartfield, P., and B.R. Kuhajda. 2009. Threat Assessment: Hybridization between pallid sturgeon and shovelnose sturgeon in the Mississippi River. U.S. Fish and Wildlife Service, Jackson, Mississippi. Unpubl. Report.

Huizinga, R.J. 2009. Examination of direct discharge measurement data and historic daily data for selected gages on the Middle Mississippi River, 1861-2008. U.S. Geological Survey Scientific Investigations Report 2009-5232. 60pp. (Available at http://pubs.usgs.gov/sir/2009/5232/)

Illinois Department of Public Health (IDPH). Illinois Fish Advisory. Mississippi River west of Illinois. 2015. http://www.idph.state.il.us/envhealth/fishadvisory/mississippiriver.htm. Accessed 5 November 2015.

Illinois Environmental Protection Agency. 2015. Integrated Water Quality Report and 303d Lists. Appendix A-2. Illinois' 2014 303(d) List, (sorted by water name). http://www.epa.state.il.us/water/tmdl/303-appendix/2014/appendix-a2.pdf. Accessed 5 November 2015.

Keenlyne, K.D., L.K. Graham, and B.C. Reed. 1993. Natural hybrids between two species of Scaphirhynchinae sturgeon. U.S. Fish and Wildlife Service, Pierre, South Dakota. Unpubl. Report.

Keevin, T. M., and K. S. Cummings. 2000. The freshwater mussel fauna of the middle Mississippi River. Melvin Price Locks and Dam, Design Memorandum No. 24 Avoid and Minimize Measures, Progress Report 1999. 15 pp.

Kinsolving, A.D. and M.B. Bain. 1993. Fish assemblage recovery along a riverine disturbance gradient. Ecological Applications 3:531–544. http://dx.doi.org/10.2307/1941921

Knights, B. C., B. L. Johnson, and M. B. Sandheinrich. 1995. Responses of bluegills and black crappies to dissolved oxygen, temperature, and current in backwater lakes of the Upper Mississippi River during winter. North American Journal of Fisheries Management. 15:390-399.

Knox, J.C., 1984. Fluvial responses to small scale climate changes. In Developments and Applications of Geomorphology (pp. 318-342). Springer Berlin Heidelberg.

Mayden, R.L., and B.R. Kuhajda. 1997. Threatened fishes of the world: *Scaphirhynchus albus* (Forbes and Richardson, 1905) (Acipenseridae). Environmental Biology of Fishes. 48:420-421.

Melillo, J. M., T. C. Richmond, and G. W. Yohe, Eds. 2014. Climate change impacts in the United States: the third National Climate Assessment. U.S. Global Change Research Program. doi:10.7930/J0Z31WJ2.

Missouri Department of Health and Senior Services (MDHSS). 2015. 2015 Missouri Fish Advisory, A Guide to Eating Missouri Fish.

http://health.mo.gov/living/environment/fishadvisory/pdf/fishadvisory.pdf. Accessed 5 November 2015.

Missouri Department of Natural Resources (MDNR). 2014. 2014 EPA Approved Section 303(d) Listed Waters. http://dnr.mo.gov/env/wpp/waterquality/docs/epa-approved-2014-303d.pdf. Accessed 5 November 2015

Moseley, L.J. 1976. Behavior and communication in the least tern (*Sterna albifrons*). Ph.D. Dissertation, University of North Carolina, Chapel Hill. 164 pp.

Munger, P.R., G.T. Stevens, S.P. Clemence, D.J. Barr, J.A. Westphal, C.D. Muir, F.J. Kern, T.R. Beveridge, and J.B. Heagler, Jr. 1976. SLD potamology study (T-1). University of Missouri-Rolla, Institute of River Studies, Rolla, Missouri.

Niles, J.M., K.J. Hartman. 2009. Larval fish use of dike structures on a navigable river. North American Journal of Fisheries Management 29:1035–1045.

Neuswagner, D. J., W. W. Taylor, and J. B. Reynolds. 1982. Comparison of macroinvertebrate herpobenthos and haptobenthos in side channel and slough in the Upper Mississippi River. Freshwater Invertebrate Biology 1:13-24.

Oesch, R.D. 1984. Missouri naiades: a guide to the mussels of Missouri. Missouri Department of Conservation, Jefferson City. 270 pp.

Parmalee, P.W. and A.E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville, TN. 328. pp.

Ridenour, C. J., Wyatt J. D., and T.D. Hill. 2011. Habitats of age-0 sturgeon in the Lower Missouri River. Transactions of the American Fisheries Society, 140:5, 1351-1358

Shaeffer, W. A., and J. G. Nickum. 1986. Backwater areas as nursery habitats for fishes in Pool 13 of the upper Mississippi River. Hydrobiologia 136:131-140.

Sheehan, R.J., and R. C. Heidinger. 2001. Middle Mississippi River Pallid Sturgeon Habitat Use Project. In: Upper Mississippi River Basin, Mississippi River Missouri and Illinois, Progress Report 2000, Design Memorandum Number 24, Avoid and Minimize Measures, June 2001.

Sidle, J.G. and W.F. Harrison. 1990. Recovery Plan for the Interior Population of the Least Tern (*Sterna antillarum*). U.S. Fish and Wildlife Service, Twin Cities, Minnesota. 90 pp. (1)

Simmons, S.M. 2015. A comparison of fish communities between the main channel and side channels of the Middle Mississippi River. Unpublished M.S.Thesis. Southeast Missouri State University.

Simons, D.B., S.A. Schumm, and M.A. Stevens. 1974. Geomorphology of the Middle Mississippi River. Report DACW39-73-C-0026 prepared for the U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri. 110 pp.

Strayer, D.L. 1999. Use of flow refuges by unionid mussels in rivers. Journal of the North American Benthological Society 18(4):468-476.

U.S. Army Corps of Engineers. 1999. Biological assessment, interior population of the least tern, *sterna antillarum*, regulating works project, Upper Mississippi River (river miles 0-195) and Mississippi River and tributaries project, channel improvement feature, Lower Mississippi River (river miles 0-954.5, AHP). U. S. Army Corps of Engineers, Mississippi Valley Division/Mississippi River Commission, Vicksburg, Mississippi.

U.S. Army Corps of Engineers. 2005. Tier II biological assessment: grand tower regulating works, U.S. Army Corps of Engineers. August 2005

U.S. Army Corps of Engineers. 2013. Waterborne commerce of the United States. U.S. Army Corps of Engineers Navigation Data Center Waterborne Commerce Statistics Center. http://www.navigationdatacenter.us/wcsc/wcsc.htm. Accessed 21 August 2013.

U.S. Army Corps of Engineers. 2015. Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Water Resources Region 07, Upper Mississippi. Civil Works Technical Report, CWTS-2015-13, USACE, Washington, DC.

U.S. Environmental Protection Agency. 2015. U. S. Environmental Protection Agency green book nonattainment areas for criteria pollutants as of October 1, 2015. http://www3.epa.gov/airquality/greenbk/ancl.html.

U.S. Fish and Wildlife Service. 1989. A recovery plan for the fat pocketbook pearly mussel (*Potamilus canax)* (Green 1832). U.S. Fish and Wildlife Service. Atlanta, Georgia. 22 pp.

U.S. Fish and Wildlife Service. 1990. Decurrent false aster recovery plan. Twin Cities, Minnesota: U.S. Fish and Wildlife Service. 26 pp.

U.S. Fish and Wildlife Service. 2000. Biological opinion for the operation and maintenance of the 9-food navigation channel on the Upper Mississippi River System, May 15, 2000.

U.S. Fish and Wildlife Service. 2004. Final biological opinion for the Upper Mississippi River-Illinois waterway system navigation feasibility study, August 2004.

U.S. Fish and Wildlife Service. 2009. Rabbitsfoot candidate form. http://www.fws.gov/midwest/endangered/clams/pdf/rabbistfoot_cand_elevation.pdf.

Watson, C.C., D.S. Biedenharn, and C.R. Thorne. 2013a. Analysis of the impacts of dikes on flood stages in the Middle Mississippi River. Journal of Hydraulic Engineering 139:1071-1078.

Watson, C.C., R.R. Holmes, and D.S. Biedenharn. 2013b. Mississippi River streamflow measurement techniques at St. Louis, Missouri. Journal of Hydraulic Engineering 139:1062-1070.

Watters, G.T. 1988. A survey of the freshwater mussels of the St. Joseph River system, with emphasis on the federally endangered white cat's paw pearly mussel. Unpublished report, Indiana Department of Natural Resources, West Lafayette. 127 pp.

Whitman, P.L. 1988. Biology and conservation of the endangered interior least tern: a literature review. Biological Report 88(3). U.S. Fish and Wildlife Service, Division of Endangered Species, Twin Cities, Minnesota.

Wlosinski, J. 1999. Hydrology. Pages 6-1 to 6-10 in USGS, ed., Ecological Status and Trends of the Upper Mississippi River System. USGS Upper Midwest Environmental Sciences Center, LaCrosse, Wisconsin. 241 pp.

DRAFT FINDING OF NO SIGNIFICANT IMPACT
BOSTON BAR SIDE CHANNEL RESTORATION AND ISLAND CREATION PROJECT
MIDDLE MISSISSIPPI RIVER (RM 10.2 – 7.6 L)
ALEXANDER COUNTY, ILLINOIS

1. In accordance with the National Environmental Policy Act, I have reviewed and evaluated the documents concerning the Boston Bar Side Channel Restoration and Island Creation Project, Alexander County, Missouri. As part of this evaluation, I have considered:

    a. Existing resources and the No Action Alternative.

    b. Impacts to existing resources from the Proposed Action.

2. The possible consequences of these alternatives have been studied for physical, environmental, cultural, social and economic effects, and engineering feasibility. My evaluation of significant factors has contributed to my finding:

    a. The work would enhance habitat diversity in the Middle Mississippi River. This would be accomplished through removal of river training structures, construction of a side channel enhancement dike, and using dredge disposal material to build sandbar habitat.

    b. No adverse impacts to federally threatened or endangered species are anticipated.

    c. No significant impacts are anticipated to natural resources, including fish and wildlife resources. The proposed work would have no effect upon significant historic properties or archaeological resources. There would be no appreciable degradation to the physical environment (e.g., stages, air quality, and water quality) due to the work.

    d. The No Action Alternative was evaluated and determined to be unacceptable as the St. Louis District is obligated to perform such activities to remain in compliance with the Endangered Species Act.

3. Based on the evaluation and disclosure of impacts contained within the Environmental Assessment, I find no significant impacts to the human environment are likely to occur as a result of the proposed action. Therefore, an Environmental Impact Statement will not be prepared prior to proceeding with the proposed Boston Bar Side Channel Restoration and Island Creation Project, Alexander County, Illinois.

____
(Date)

____
ANTHONY P. MITCHELL
COL, EN
Commanding

Boston Bar Side Channel Restoration and Island Creation Project
Middle Mississippi River (RM 10.2 – 7.6 L)
Alexander County, Illinois

DRAFT ENVIRONMENTAL ASSESSMENT WITH UNSIGNED FINDING OF NO SIGNIFICANT IMPACT

March 2016

APPENDICES

Appendix A. Hydraulic Sediment Response Model Report*

*Note: The plates associated with the Hydraulic Sediment Response Model Report can be found at the following link:

http://mvs-wc.mvs.usace.army.mil/arec/Documents/HSR_Models/Boston_Bar/M59_Boston_Bar_Plates.pdf

TECHNICAL

REPORT

M59

FINAL REPORT— October, 2011

US Army Corps of Engineers
St. Louis District

UPPER MISSISSIPPI RIVER
BOSTON BAR BI-OP 2011
HYDRAULIC SEDIMENT RESPONSE MODEL STUDY

Authors: Ivan H. Nguyen, Ashley N. Cox, Jasen L. Brown P.E., Robert D. Davinroy, P.E., Jason Floyd, Dana Fischer, and Emily Rivera

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
HYDROLOGIC AND HYDRAULICS BRANCH
APPLIED RIVER ENGINEERING CENTER
FOOT OF ARSENAL STREET
ST. LOUIS, MISSOURI 63118

Sponsored by and Prepared for: U. S. Army Corps of Engineers,
St. Louis District Biological Opinion Program

APPLIED RIVER ENGINEERING CENTER

INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a sedimentation improvement study of the Mississippi River at Boston Bar from RM 10.2 to RM 7.6. Approximately 3.4 miles of Boston Chute was also studied. As part of the pilot project portion of the Biological Opinion (Bi-Op) program, this study was funded by the U.S. Army Corps of Engineers, St. Louis District.

The study was conducted between May 2011 and October 2011 at the Applied River Engineering Center (AREC), U.S. Army Corps of Engineers, St. Louis District. The study was performed by Mr. Ivan H. Nguyen, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, P.E., Chief of River Engineering Section for the St. Louis District. Additional personnel from the St. Louis District included: Mr. Leonard Hopkins, P.E., Chief of Hydrologic and Hydraulic Branch, Ms. Ashley N. Cox, Hydraulic Engineer, Mr. Jason Floyd, Engineering Technician, Mr. Jasen L. Brown, P.E., Hydraulic Engineer, Ms. Emily Rivera, Student Co-Op, and Ms. Dana Fischer, Student Co-Op.

Personnel involved in overseeing this study and supplying knowledge and critical river data included: Mr. Brian L. Johnson, Chief of Environmental Planning Section, Mr. Lance Engle, Dredge Manager, Mr. Shawn Kempshall, River Surveyor, and Mr. Michael T. Rodgers, Project Manager. Personnel from other agencies involved in the study included: Mr. Atwood Butch from the Illinois Department of Natural Resource, Mr. Matthew Mangan from the U.S. Fish and Wildlife, Mr. Dave Knuth from the Missouri Department of Conservation, and Mr. Bernard Heroff from the Archer Daniels Midland Company (Industry Barges).

TABLE OF CONTENTS

INTRODUCTION 1

TABLE OF CONTENTS 2

BACKGROUND 3

1. PROBLEM DESCRIPTION 3
2. STUDY PURPOSE AND GOALS 3
3. STUDY REACH 4

A. Structures 4
B. Average Annual Hydrograph 4
C. Boston Chute 4
D. Real Estate 5
E. Geomorphology 5
F. Recent Construction 6
G. Environmental Features 6
H. Study Reach Channel Characteristics and General Trends 6
  i. Mississippi River 6
  ii. Boston Chute 7
I. Field Observation 7

HSR MODELING 8

1. MODEL CALIBRATION AND REPLICATION 8
2. SCALE AND BED MATERIALS 9
3. APPURTENANCES 9
4. FLOW CONTROL 9
5. DATA COLLECTION 10

A. 3-D Laser Scanner 10
B. Flow Visualization 10

6. REPLICATION TEST 10
7. DESIGN ALTERNATIVE TESTING 12

A. Phase I: Island Creation 12
B. Phase II: Structure Tests 20

CONCLUSION 32

1. EVALUATION AND SUMMARY OF TEST RESULTS 32
2. RECOMMENDATIONS 34
3. INTERPRETATION OF MODEL TEST RESULTS 35

EXTENDED STUDY 36

1. NEW SIDE CHANNEL 36

FOR MORE INFORMATION 38

1. APPENDIX A: PLATES
2. APPENDIX B: FLOW VISUALIZATION

BACKGROUND

1. Problem Description

Side channels are a critical biological component of the Mississippi River. Most side channels within the Middle Mississippi River (MMR) lack bathymetric diversity. They contained relatively few scour holes and had uniform bed response at high elevation. Boston Chute, located along the left descending bank (LDB) of the Mississippi River between River Miles (RM) 10.2 and RM 7.6, experienced similar problems. The chute was very shallow and connected to the Mississippi River only during high flows. Sedimentation is a problem in Boston Chute mainly due to closure structures and the back flooding of the Ohio River. There is a critical need to rehabilitate and conserve these critical aquatic habitats.

2. Study Purpose and Goals

The purpose of this study was to address the need for additional biologic habitat inside Boston Chute as well as adjacent to Boston Bar, and communicate the results of the analysis of various river engineering measures.

The goals of the study were to:

i. Investigate and provide analysis on the existing flow mechanics of the Mississippi River near Boston Bar.
ii. Calibrate a Hydraulic Sediment Response (HSR) model to replicate prototype bathymetry and velocity distribution of the Mississippi River near Boston Bar.
iii. Evaluate a variety of remedial measures utilizing the HSR model with the objective of identifying the most effective and economical plan to enhance biologic diversity within Boston Chute as well as adjacent to Boston Bar.
iv. Communicate to environmental agencies, other Corps personnel, and river industry personnel the results of the HSR model tests and the plans for improvements.

3. Study Reach

The study reach was located between Scott County in Missouri and Alexander County in Illinois. Boston Bar, located along the LDB of the Mississippi River, between RM 10.2 and RM 7.6, covers an area of approximately 2860 acres. Plate (1) is a location and vicinity map of the study reach.

A. Structures

Plate (2) is a 2010 aerial photograph illustrating the planform and nomenclature of the Lower Mississippi River between RM 12.0 and 6.0. At the time of this study, the study reach had a total of 43 structures: 2 closure structures within Boston Chute, 2 L-dikes, 4 notched dikes, 26 longitudinal dikes, and 9 weirs. The right descending bank (RDB) was completely revetted except at the dike field between RM 10.10 and 9.40.

There was a pile dike (Dike 10.30L) located across the upstream end of Boston Chute and a rock closing structure (Dike 7.90L) located across the lower end of Boston Chute. These structures acted as closure structures. However, Dike 7.90L appeared to control the flow through Boston Chute because it was constructed of rock, while Dike 10.30L was constructed of wood piles and allowed more flow to pass through it.

B. Average Annual Hydrograph

Plate (5) shows the monthly average annual hydrograph (data from entire period of record) from four nearby gage locations compared to height of Dike 7.90L (+11 feet LWRP). Graphs of these average annual hydrographs indicated that during the period from August 1 to November 30, the water level was typically below the closure structure height. This likely contributed significantly to the shallow depths within Boston Chute. Plate (6) shows 2006 helicopter photographs of Boston Bar and Boston Chute closure structures where the river stage was below +11 feet LWRP.

C. Boston Chute

Boston Chute had an average width of approximately 250 feet, ranging from 125 to 550 feet. There were two secondary channels just upstream on the island; however these have been filled with sediment. According to a 2010 & 2011 hydrographic surveys of Boston Chute, the average bottom elevation was about +5 feet LWRP. See Plate (4)

D. Real Estate

In this reach, most land is agricultural. However, the island is considered non-farmland. Boston Bar was mainly used for paper production and cottonwood or sycamore planting on an 8-10 year rotation. It was owned by Christine Chambliss. The area upstream of Boston Bar between RM 10.6 and 11.2 along the Illinois side was owned by John Waggener and Christine Wolford. Along the Missouri bank, RM 10.0 to 9.4 was owned by Norbert Rowling, RM 10.3 to RM 10.1 was owned by Margaret Stricker, and RM 10.3 and up is owned by Stallings Farms.

E. Geomorphology

To understand the planform of the river near Boston Bar, an investigation was conducted on the historical changes, both manmade and natural, those lead up to the present day condition. Plate (7) shows geomorphic planform changes between RM 12.0 and 4.0 encompassing the years from 1917 to 2003, and was sourced from "Geomorphology of the Middle Mississippi River" produced by the St. Louis District (2005). Historic aerial photographs revealed that the Mississippi River channel in the area of Boston Bar had changed significantly over time. Numerous dike and weir fields were built along both descending banks. These river training structures caused the study reach to change. Plate (2) shows all existing structures within the reach and the condition as of 2010.

The 1928 aerial photo Plate (8) of the project area showed Boston Bar smaller and Boston Chute wider than its 2010 dimensions. The I-57 Bridge was not constructed until 1978. Between 1928 and 1978, there were two islands in the middle of the Mississippi channel. The difference between 1928 and 2010 aerial photos can be seen on Plates (9).

The 1968 Aerial photograph (Plate 10) showed most of the structures in the reach were in place and the river planform was very similar to that of the 2010 aerial photograph. The difference between the 1968 and 2010 aerial photos was that Boston Bar had two separate inflow channels that combined into one outflow channel. However, the upstream inflow channel slowly filled in while the downstream channel remained open. The difference between 1968 and 2010 aerial photos can be seen on Plates (11). Plate (12) through (15) shows historic aerial photographs taken in 1942, 1956, 1976, and 1982 of Boston Bar and Boston Chute.

F. Recent Construction

There were three recent construction efforts near Boston Bar reach. In FY09, Dikes 9.40L and 9.20L were notched. In FY10 Dike 8.3L was notched. In FY11, Dike 8.7L was notched. Surveys in the immediate area of the dike notches indicated that the notches created scour holes and bathymetric diversity. Plate (4) shows a post construction hydrographic survey.

G. Environmental Features

According to biologists in the Environmental Branch of the Corps of Engineers, St. Louis District, only one mussel bed existed within the study reach, around I-57 bridge pier. See Plate (2).

H. Study Reach Channel Characteristics and General Trends

i. Mississippi River

The thalweg entered the study reach along the RDB between RM 12.0 – 11.2, and transitioned to the LDB between RM 11.2-10.7, where it remained until RM 7.5. Shoaling occurred along the LDB between RM 10.0 and 9.0 with depths ranged from -15 feet and -5 feet LWRP. At the I-57 Bridge crossing, the thalweg shifted back to the LDB. At this location (RM 7.5-6.8), depths between -35 feet and -15 feet LWRP were observed. The survey showed adequate navigation depths, however, in reality many areas of the channel shoal considerably, and the survey reflects the channel is being artificially maintained by dredging. An example where the bar between RM 10.2 and 7.6

has shoaled prior to the dredge cut is shown on Plate (20) in the 2008 hydrographic survey. The 2010 and 2011 combined hydrographic surveys (Plate 4) showed post dredge conditions.

Hydrographic surveys from the last 10 years showed periodic shoaling occurred in the navigation channel between RM 11.65 and RM 10.80, RM 9.6 and RM 8.5, as well as between RM 7.40 and RM 6.35. This aggradation has created dredging issues at three locations. Plate (16) shows three main dredging locations located within the study reach. Also, Plate (17) through (22) shows hydrographic surveys taken in 1998, 2005, 2006, 2008 and 2009. Boston Chute was not included in these surveys.

ii. Boston Chute

The 2010 and 2011 combined hydrographic survey, Plate (4), showed significant sediment deposition within Boston Chute at the entrance and exit. This aggradation has limited the flow coming into the chute, which makes the chute limited in providing adequate aquatic habitat. A meander pattern was observed at the entrance of Boston Chute with depths between -10 feet to +5 feet LWRP. The thalweg within this meandering side channel entrance crossed from bank to bank three times before the bathymetry flattened out at +10 ft LWRP thru RM 7.8. A scour hole caused by Closure Dike 7.90L had depths that were up to -20 feet LWRP.

I. Field Observation

Personnel from the Applied River Engineering Center inspected the study reach on August 1, 2011. This visit allowed the site to be photographed and studied. Sediment samples were taken in three locations inside Boston Chute. It was found that the materials inside Boston Chute were primarily clay with some mixed sand. The area along Boston Bar in the main channel between RM 9.0 and 8.0 yielded the same result. However, two sediment samples taken at the dredge area in the main channel at RM 8.5 were found to have mostly sand. Photographs from the site visit can be seen on Plate (23).

HSR MODELING

An HSR model study was conducted for the purpose trying to increase flow through Boston Chute and also creating sustainable islands or isolated band bars along the main channel. All of these measures were studied so as not to increase repetitive dredging in the main channel.

1. Model Calibration and Replication

The HSR modeling methodology employed a calibration process designed to replicate the conditions in the river at the time of the model study. Replication of the model was achieved during calibration and involved a three step process.

First, planform "fixed" boundary conditions of the study reach, i.e. banklines, islands, side channels, tributaries and other features were established according to the 2010 high resolution aerial photography. Various other fixed boundaries were also introduced into the model including any channel improvement structures, underwater rock, clay and other non-mobile boundaries.

Second, "loose" boundary conditions of the model were developed. Bed material was introduced into the channel throughout the model to an approximate level plane. The combination of the fixed and loose boundaries served as the starting condition of the model.

Third, steady state discharge simulation tests were run through the model. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The mobile bed developed from a static, flat, arbitrary bed into a fully-formed, dynamic, and three dimensional bed responses. The resulting bed configuration was surveyed numerous times during the calibration tests and compared to recent river bathymetry. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bed bathymetry were similar to observed recent river bathymetry, and the tests were repeatable, the model was considered replicated and alternative testing then began.

2. Scale and Bed Materials

The HSR model employed a horizontal scale of 1 inch = 500 feet, or 1:6,000, and a vertical scale of 1 inch = 58 feet, or 1:696, for an 8.6 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those observed in the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.40. Plate (24) is a photograph of the Boston Bar HSR model used in this study.

3. Appurtenances

The HSR model insert planform was constructed according to the 2010 high-resolution aerial photography of the study reach. The insert was then mounted in a standard HSR model flume. The riverbanks of the model were constructed from dense polystyrene foam, clay, and polymesh to develop proper bendway mechanics. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.008 inch/inch. River training structures in the model were constructed of galvanized steel mesh to generate appropriate scaled roughness.

4. Flow Control

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to control the flow of water and sediment into the model. For all model tests, flow entering the model was held steady at 3.0 Gallon per Minutes (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the actual river, this steady state flow was used to replicate existing conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

5. <u>Data Collection</u>

Data from the HSR model was collected with a three dimensional (3D) laser scanner and flow visualization.

A. 3-D Laser Scanner

The river bed in the model was surveyed with a high definition, 3D laser scanner that collects a dense cloud of xyz data points. These xyz data points were then georeferenced to real world coordinates and triangulated to create a 3D surface. The surface was then color coded by elevation using standard color tables that are also used in color coding prototype surveys. This process allowed a direct comparison between HSR model bathymetry surveys and prototype bathymetry surveys.

B. Flow Visualization

Flow visualization is a tool used to monitor the flow patterns in a HSR model. The preferred method at the Applied River Engineering Center is to dye the water black and seed the water surface with dry white sediment (Poly-Urea-grit) at the model entrance. The dry sediment floats on the top of the water surface and provides a visual representation of surface flow patterns in the model. A high definition video camera is used to record approximately 30 seconds of the sediment floating through the study area. The recording is processed with software that reduces the original recording to approximately 20% of the original speed. The video speed reduction allows viewer to more easily track the flow patterns.

6. <u>Replication Test</u>

Once model replication was achieved through the calibration process, the resultant bathymetry served as a benchmark for the comparison of all future model alternative tests. In this manner, the actions of any alternative, such as new channel improvement structures, realignments, side channel modifications, etc, were compared directly to the replicated condition. General trends were evaluated for any major differences positive or negative between the alternative and the replication by comparing the surveys of the two and also carefully observing the model while the actual testing was taking place.

Plate (25) shows the results of the replication test. Plate (26) is a detailed comparison between the 2010 & 2011 combined hydrographic survey of Boston Bar and the model replication. The 1998 survey of the Mississippi River was also used when comparing the model to prototype. As observed in both prototype surveys and the model, the thalweg was located along the LDB before crossing to the RDB between RM 12.0 and 11.0, where it remained until RM 8.0. Sediment deposition was observed in the dike fields along the LDB from the model entrance to RM 7.0 and had depths that ranged between +10 feet to -5 feet LWRP. Between RM 10.2 and 7.6, the main channel experienced excessive sediment deposition with depths approximately +5 feet LWRP.

A scour hole was observed at RM 10.8 as the thalweg crossed from the LDB to the RDB with depths of approximately -30 feet LWRP. The thalweg then passed through a dike field and descended through a sharp bend before it crossed over to the LDB at RM 7.0 with depths ranged between -40 feet and -25 feet LWRP. Adjacent to the dike field, two scour holes were observed from two notched dikes (Dike 9.40L and 9.20L) had depths as low as -20 feet LWRP. Both the model and prototype showed similar trends

Similar to the prototype, Boston Chute had depths that ranged between +10 feet and 0 feet LWRP. Approximately one mile down the chute, depths decreased to +10 feet LWRP and remained constant to RM 7.8. The scour hole caused by closure structure 7.9L had depths that were as low as -10 feet LWRP. However, the scour hole did not extend further downstream in the chute as it entered the Mississippi. Deposition occurred at both the entrance and exit condition of Boston Chute in both the model and prototype with depths up to +10 feet LWRP.

The trends in the crossing of the main channel between RM 7.5 and 7.0 and the deposition that occurred along the bar along the RDB were very similar in both the model and the prototype. The crossing in the model had depths that ranged between -20 feet and -10 feet LWRP while the prototype had greater depths that were as deep as

-30 feet LWRP. The thalweg crossed over a weir field from RM 7.0 to end of study reach with depths between -40 feet and -30 feet LWRP in both the model and prototype.

7. Design Alternative Testing

Design alternative testing involved two phases of study. Phase 1 involved the testing of disposable locations for dredge material for the creation of island or shallow sandbar adjacent to Boston Bar. Phase 2 involved the testing of various structural alternatives intended to increase flow in Boston Chute.

A. Phase I: Island Creation

U.S. Army Corps of Engineers (USACE) personnel and agency partners have desired for a number of years to use dredge material as sandbar and island habitat because of its potential to increase the populations of endangered bird species such as the Least Tern and American Avocet. The HSR Model was used with the purpose of determining the best location for dredge disposal area adjacent Boston Bar.

In all alternatives, dredge disposal areas were studied under dominant, steady state energy conditions. This was accomplished in order to simplify testing and observe general long term trends at the tested disposable location. Tests were conducted to examine whether the dredge disposal area would erode due to the flow of the river. The design height for the dredge disposal area was set to +30 ft LWRP. This was accomplished by placing a scoop of sediment, roughly 1.5 inches in diameter in the model (or 450,000 sq. ft scaled to real world size), at the proposed locations while the model was still running. This was to simulate actual dredging events. Each test was run for 30 minutes to allow the model bed time to sufficiently respond to changes. The resultant dredge disposal area was closely analyzed for any changes in size and depth.

Alternative 1: Dredge Disposal Area 8.4L

Plate (27) shows the bathymetry of Alternative 1. The dredge disposal area was located 500 feet off the LDB at RM 8.4 between two notched dikes, Dike 8.70L and Dike 8.30L. The goal of this alternative was to utilize Dike 8.70L to protect the dredge disposal area.

Table1: Alternative 1 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.4	500	30	30	500,000	350,000

Test results indicated that the dredge disposal area did not scour away due to the flow of the river. The resultant dredge disposal area measured approximately 350,000 sq. ft in area and had depths at roughly +30 feet LWRP. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal area. The dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 2: Dredge Disposal Area 8.1L

Plate (28) shows the bathymetry of Alternative 2. The dredge disposal area was placed 500 feet off the LDB at RM 8.1 between three notched dikes, Dike 8.30L, 8.25L and 8.0L. The goal of this alternative was to utilize Dike 8.30L and Dike 8.70L to protect the dredge disposal area.

Table 2: Alternative 2 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	280,000

Test results indicated that the dredge disposal area did not scour away due to the flow of the river. The resultant dredge disposal area measured approximately 280,000 sq. ft in area and had depths at roughly +30 feet LWRP. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal area. Based on observations, the proposed area had the lowest energy. This made sense because it is inside of a bend and there are two structures, one upstream and one downstream, to help protect the dredge disposal area. The dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 3: Dredge Disposal Area 8.9L

Plate (29) shows the bathymetry of Alternative 3. The dredge disposal area was placed 300 feet off the LDB of Boston Bar at RM 8.9 between two notched dikes, Dike 9.20L and Dike 8.70L. The goal of this alternative was to utilize Dike 9.20L to redirect protect the dredge disposal area.

Table 3: Alternative 3 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.9	300	30	16	450,000	125,000

Test results indicated that the dredge disposal area scoured significantly due to the flow of the river. Observations showed that the flow coming off notched Dike 9.20L was causing the scour. The dredge disposal area depths decreased from +30 feet LWRP to +16 feet LWRP while surface area reduced in half to approximately 125,000 sq. ft in area. The dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 4: Dredge Disposal Area 8.8L

Plate (30) shows the bathymetry of Alternative 4. The dredge disposal area was placed 300 feet off the LDB of Boston Bar at RM 8.8 between two notched dikes, Dike 9.20L and Dike 8.70L. The goal of this alternative was to utilize Dike 9.20L to redirect protect the dredge disposal area.

Table 4: Alternative 4 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.8	300	30	22	450,000	200,000

Test results indicated that the dredge disposal area was scoured significantly due to the flow of the river. Similar to alternative 3, the flow coming off Dike 9.20L was causing the scour. However, the scour was far less. The resultant dredge disposal area measured approximately 200,000 sq. ft in area and had depths at roughly +22 ft LWRP. Overall, the dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 5: Dredge Disposal Area 8.7L

Plate (31) shows the bathymetry of Alternative 5. The dredge disposal area was placed 200 feet off the LDB of Boston Bar at RM 8.8 between two notched dikes, Dike 9.20L and Dike 8.70L. The goal of this alternative was to move even further away from notch Dike 9.20L.

Table 5: Alternative 5 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.7	200	30	28	450,000	300,000

Test results indicated that the dredge disposal area was far enough that flow coming off Notch Dike 9.20L had insignificant effects. The resultant dredge disposal area was measured at approximately 300,000 sq. ft in area and had depths at roughly +28 ft

LWRP. Most of the available energy for sediment transport was observed along the RDB. Observations and bathymetric surveys showed that the dredge disposal area was stable. Overall, the dredge disposal area also did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 6: Dredge Disposal Area 8.7L

Plate (32) shows the bathymetry of Alternative 6. This alternative placed the dredge disposal area against Boston Bar and Dike 8.70L at RM 8.7. The dredge disposal area would then become an extension of Boston Bar or a shallow sandbar. The goal of this alternative was to utilize both Boston Bar and Dike 8.70L to help protect the dredge disposal area.

Table 6: Alternative 6 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (sq. ft) Before	Area (sq. ft) After
8.7	0	30	24	450,000	200,000

Test results indicated that the dredge disposal area was scoured away due to the flow of the river. The resultant sand bar measured approximately 200,000 sq. ft in area and had depths of roughly +24 ft LWRP. Most of the available energy available for sediment transport was observed along the RDB. Overall, the sand bar did not cause any unwanted problems to the main channel, Boston Bar and Chute.

Alternative 7: Dredge Disposal Areas 8.7L, 8.4L and 8.0L

Plate (33) shows the bathymetry of Alternative 7. This alternative consisted of the combination of Alternatives 1, 2 and 6. The goal of this alternative was to determine the effects of the combining Alternatives 1, 2, and 6, as these 3 alternatives had individually produced favorable resultant bathymetries.

Table 7: Alternative 7 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	300,000
8.4	500	30	30	450,000	400,000
8.7	0	30	24	450,000	350,000

Test results indicated that all three dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas measured approximately 300,000 sq. ft, 450,000 sq. ft, and 350,000 sq. ft in area and had depths at roughly +30 ft, +30 ft, and +24 ft LWRP respectively. Most of the energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 8: Dredge Disposal Areas 8.7L & 8.4L

Plate (34) shows the bathymetry of Alternative 8. This alternative consisted of the combination of Alternative 1 and Alternative 6. The goal of this alternative was to determine the effects of the combining Alternatives 1 and 6, as these 2 alternatives had individually produced favorable resultant bathymetries.

Table 8: Alternative 8 Summary

RM	Distance (ft)	Elevation Before	Elevation After	Area (ft^2) Before	Area (ft^2) After

		LWRP (ft)	LWRP (ft)		
8.4	500	30	30	450,000	350,000
8.7	0	30	24	450,000	350,000

Test results indicated that both dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas 8.7L and 8.4L measured approximately 450,000 sq. ft and 450,000 sq. ft in area and had depths at roughly +30 ft and +24 LWRP respectively. Most of the energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 9: Dredge Disposal Areas 8.7L & 8.0L

Plate (35) shows the bathymetry of alternative 9. This alternative is a combination of alternative 6 and alternative 2. The goal of this alternative was to determine the effects of the combining Alternatives 2 and 6, as these 2 alternatives had individually produced favorable resultant bathymetries.

Table 9: Alternative 9 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	375,000
8.7	0	30	24	450,000	300,000

Test results indicated that both dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas 8.7L and 8.1L measured approximately 375,000 sq. ft, and 300,000 sq. ft in area and had depths at roughly +30 ft and +24 LWRP respectively. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 10: Dredge Disposal Areas 8.4L & 8.0L

Plate (36) shows the bathymetry of Alternative 10. This alternative consisted of the combination of Alternative 1 and Alternative 2. The goal of this alternative was to determine the effects of the combining Alternatives 1 and 2, as these 2 alternatives had individually produced favorable resultant bathymetries.

Table 10: Alternative 10 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	380,000
8.4	500	30	30	450,000	380,000

Test results indicated that both dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas 8.4L and 8.1L measured approximately 380,000 sq. ft, and 380,000 sq. ft in area and had depths at roughly +30 ft and +30 ft LWRP respectively. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

B. Phase II: Structure Tests

The goal of phase II was to analyze various alternatives with the intent of increasing flow and enhancing aquatic habitat diversity inside Boston Chute. This was accomplished by placing, removing and notching river training structures in the model. Similar to Phase I testing, the model was operated for at least 30 minutes to allow the model bed time to sufficiently respond to changes.

Alternative 11: Closure Dike 7.90L

Plate (37) shows the resultant bathymetry of Alternative 11. Closure Structure 7.90L was removed to depth of -10 ft LWRP for the purpose of increasing flow through Boston Chute.

Table 11: Alternative 11 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	7.9	Remove	All	Chute	-10

Test results indicated that model bathymetry did not cause any significant changes when compared to the replication test. However, the scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 12: Dike 10.05L

Plate (38) shows the resultant bathymetry of Alternative 12. This alternative consisted of constructing a new dike located at the tip of Boston Bar at RM 10.05. The new dike measured 500 ft in length, +2 ft LWRP in height, and angled upstream. Dike 10.1L, Dike

10.30L, Dike 7.90L, and Pile Dike 10.10L were removed to a depth of -10 ft LWRP. The goal was to increase flow inside Boston Chute.

Table 12: Alternative 12 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)
Dike	10.05	New	500	LDB	+2
Pile	10.10	Remove	All	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated the chute experienced degradation between RM 10.6 and 10.0 with depths ranged between -5ft and 0ft LWRP. Approximately one mile down the chute, depths decreased to +10 ft LWRP and remained constant through RM 7.8. The scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 12B: Dike 10.05L Test 2

Plate (39) shows the resultant bathymetry of Alternative 12B. This alternative had the same setup as Alternative 12. However, Pile Dike 10.10L was notched instead of removed.

Table 12B: Alternative 12B Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)

Dike	10.05	New	500	LDB	+2
Pile	10.10	Notch	250	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that the chute experienced degradation between RM 10.6 and 10.0 with depths that ranged between -5ft and 0ft LWRP. Approximately one mile down the chute, depths decreased to +10 ft LWRP and remained constant through RM 7.8. The scour hole downstream of Dike 7.90L filled in with sediment. No sediment movement but higher flow was observed inside of Boston Chute. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar and Chute.

Alternative 13: Dike Removal

Plate (40) shows the resultant bathymetry of Alternative 13. Pile Dike 10.1L and Dike 7.90L in Boston Chute were removed to depth of -10ft LWRP. The goal was to increase flow in Boston Chute.

Table 13: Alternative 13 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)
Dike	10.10	Remove	All	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated no significant changes in the bathymetry. The scour hole downstream of Dike 7.90L filled in with sediment. Higher flows were observed inside

Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 13B: Dike Removal

Plate (41) shows the resultant bathymetry of Alternative 13B. Pile Dike 10.1L was notched while Dike 7.90L was removed in Boston Chute to depth of -10ft LWRP. The goal was to increase flow in Boston Chute.

Table 13 B: Alternative 13B Summary

Structure	RM	Type	Length(ft)	Bank	LWRP(ft)
Pile Dike	10.10	Notch	250	Chute	-10
Dike	7.9	Remove	All	Chute	-10

Test results indicated no significant changes in the bathymetry. The scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 14: Chevrons

Plate (42) shows the resultant bathymetry of Alternative 14. This alternative consisted of removing Dike 10.10L and 10.30L to depths of -10 ft LWRP. Two chevrons, located 300 ft off the bank line, were tested along the LDB of where the existing dikes were located. The goal of this alternative was to test whether the flow split from the chevrons could increase flow in Boston Chute.

Table 14: Alternative 14 Summary

Structure	RM	Type	Dimension (ft)	Bank	LWRP (ft)
Chevron	10.3	New	500x500	LDB	+2
Chevron	10.2	New	500x500	LDB	+2
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10

Test results indicated that the main channel between RM 10.0 and 9.0 experienced degradation and had depths -10 feet LWRP and deeper. However, shoaling occurred between RM 10.2 and 9.8 along the LDB which limits the amount of flow coming through Boston Chute. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 15: Master Plan Proposal

Plate (43) shows the resultant bathymetry of Alternative 15. This proposed alternative involved 21 hard points along both banks between RM 10.1 and 8.0 that were presented in the 2011 Master plan. Each hard point was placed in 500 foot increments from each other. They were all perpendicular to the bank line with depths of +2 feet LWRP. The goal of these hard points was to create scour holes in the hopes of adding more aquatic diversity within the Chute.

Table 15: Alternative 15 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Hard Point	10.1	New	80	LDB	+2
Hard Point	10.0	New	50	RDB	+2

Hard Point	9.9	New	80	LDB	+2
Hard Point	9.8	New	80	RDB	+2
Hard Point	9.7	New	80	LDB	+2
Hard Point	9.6	New	80	RDB	+2
Hard Point	9.5	New	80	LDB	+2
Hard Point	9.4	New	80	LDB	+2
Hard Point	9.3	New	80	RDB	+2
Hard Point	9.2	New	80	LDB	+2
Hard Point	9.1	New	80	RDB	+2
Hard Point	9.0	New	80	LDB	+2
Hard Point	8.9	New	80	RDB	+2
Hard Point	8.8	New	80	LDB	+2
Hard Point	8.7	New	80	LDB	+2
Hard Point	8.6	New	80	LDB	+2
Hard Point	8.5	New	80	LDB	+2
Hard Point	8.4	New	80	RDB	+2
Hard Point	8.3	New	80	LDB	+2
Hard Point	8.2	New	80	RDB	+2
Hard Point	8.1	New	80	LDB	+2

Test results indicated no significant changes in the bathymetry between Alternative 15 and the replication test. The twenty one hard points inside Boston Chute caused the velocities to decrease considerably. No sediment movement was observed.

Alternative 16: Boston Chute 18 Hard Points

Plate (44) shows the resultant bathymetry of Alternative 16. 18 hard points, each measuring 50 feet in length, were placed in 500 foot increments inside of Boston Chute. They were aligned perpendicular from the bank line and had depth of +2 feet LWRP. Dike 10.1L and 10.3L in the main channel and Dike 7.90L in Boston Chute were removed to depth of -10 ft LWRP. The goal was to increase flow and habitat diversity in Boston Chute.

Table 16: Alternative 16 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Hard Point	10.3	New	80	LDB	+2
Hard Point	10.2	New	80	LDB	+2
Hard Point	10.1	New	80	LDB	+2
Hard Point	9.9	New	80	RDB	+2
Hard Point	9.8	New	80	RDB	+2
Hard Point	9.7	New	80	RDB	+2
Hard Point	9.6	New	80	RDB	+2
Hard Point	9.5	New	80	RDB	+2
Hard Point	9.4	New	80	RDB	+2
Hard Point	9.3	New	80	RDB	+2

Hard Point	9.2	New	80	LDB	+2
Hard Point	9.1	New	80	LDB	+2
Hard Point	8.9	New	80	LDB	+2
Hard Point	8.8	New	80	LDB	+2
Hard Point	8.7	New	80	LDB	+2
Hard Point	8.6	New	80	LDB	+2
Hard Point	8.5	New	80	LDB	+2
Hard Point	8.4	New	80	LDB	+2

Table 16-2: Alternative 16 Summary 2

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10
Pile	10.10	Notch	200	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated no significant changes to model bathymetry. However, the Boston Chute entrance between RM 10.2 and 9.8 experienced sediment deposition due to the removal of Dike 10.30L and Dike 10.10L. Depths were between of -5 ft and 0 ft LWRP. Approximately one mile down the chute, depths decreased to +10 ft LWRP and remained constant through RM 7.8. Observations showed no sediment movement and decrease in velocities in Boston Chute.

Alternative 17: Remove and Notch

Plate (45) shows the bathymetry of Alternative 17. This Alternative consisted of notching Pile Dike 10.10L and removing Dike 10.30L, Dike 10.10L, and Dike 7.90L to depth of -10 ft LWRP. The goal was to increase flow inside Boston Chute.

Table 17: Alternative 17 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10
Pile Dike	10.10	Notch	200	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that Boston Chute inflow channel experienced sediment deposition with depths ranging between +10 and -5 ft LWRP. The scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 18: Master Plan Proposal with Modifications

Plate (46) shows the resultant bathymetry of Alternative 18. This alternative was involved testing the proposed construction found in the 2011 Master Plan (21 hard points in Boston Chute). However, this alternative also consisted of notching Pile Dike 10.10L to depth of -10ft LWRP and removing Dike 10.30L, Dike 10.10L and Dike 7.90L to depths of -10 ft LWRP. The goal was to increase flow and habitat diversity within Boston Chute.

Table 18: Alternative 18 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Hard Point	10.1	New	80	LDB	+2
Hard Point	10.0	New	50	RDB	+2
Hard Point	9.9	New	80	LDB	+2
Hard Point	9.8	New	80	RDB	+2
Hard Point	9.7	New	80	LDB	+2
Hard Point	9.6	New	80	RDB	+2
Hard Point	9.5	New	80	LDB	+2
Hard Point	9.4	New	80	LDB	+2
Hard Point	9.3	New	80	RDB	+2
Hard Point	9.2	New	80	LDB	+2
Hard Point	9.1	New	80	RDB	+2
Hard Point	9.0	New	80	LDB	+2
Hard Point	8.9	New	80	RDB	+2
Hard Point	8.8	New	80	LDB	+2
Hard Point	8.7	New	80	LDB	+2
Hard Point	8.6	New	80	LDB	+2
Hard Point	8.5	New	80	LDB	+2
Hard Point	8.4	New	80	RDB	+2
Hard Point	8.3	New	80	LDB	+2

Hard Point	8.2	New	80	RDB	+2
Hard Point	8.1	New	80	LDB	+2

Table 18-2: Alternative 18 Summary 2

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10
Pile Dike	10.10	Notch	200	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that RDB between RM 10.30 and 10.10 experienced less depth because Dike 10.30L and Dike 10.10L were not in place to constrict the main channel. However, immediately outside of Boston Chute entrance, the river bed eroded uniformly with depths approximately -5 ft LWRP. For Boston Chute, minor scour was observed at Boston Chute entrance with depths between -5 ft and +5 feet LWRP. The scour hole downstream of Dike 7.90L was filled in with sediment.

Alternative 18B: Dike Structure 10.05

Plate (47) shows the resultant bathymetry of Alternative 18B. This alternative consisted of constructing a new dike structure located at the tip of Boston Bar, RM 10.05. The new dike measured 1200 ft in length, +2ft LWRP in height, and perpendicular to the flow. Dike 10.1L, Dike 10.30L, and Dike 7.90L were removed while Pile Dike 10.10L was notched to depth of -10 ft LWRP. The goal was to increase depths inside Boston Chute.

Table 19: Alternative 19 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)

Dike	10.05	New	1200	LDB	+2
Pile	10.10	Notch	250	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that the main channel experienced aggradation along the LDB between RM 10.6 and 10.0 with depths ranging between -5 feet and -10 feet LWRP. Boston Chute entrance also experienced similar problems with depths ranged from +10 feet and +15 feet LWRP. For the rest of the chute, depths decreased to +10 feet LWRP and remained constant through RM 7.8. The scour hole downstream of Dike 7.90L filled in with sediment. No sediment movement was observed inside of Boston Chute. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

CONCLUSION

1. Evaluation and Summary of Test Results

For Phase I, in order to determine the best alternative, certain criteria, based on the study purpose and goals, were used to evaluate each alternative. The most important consideration was whether the dredge disposal area maintained its area and depth. There were several alternatives that met this requirement, including Alternatives 7 through 10, which were combinations of other alternatives. If more than one dredge disposal area were to be built at Boston Bar, they should be considered. However, for the purposes of the conclusions of this report, only alternatives involving one dredge disposal location were considered for recommendation.

Table 19: Phase I Test Summary

Alternative	Dredge Disposal Area(s)	Distance From Boston Bar (ft)	No Significant Erosion	Maintained Design Height (ft)
1	8.4L	500	X	X
2	8.1L	500	X	X
3	8.9L	300		
4	8.8L	300		
5	8.7L	200	X	X
6	8.7L	0		
7	8.1L, 8.4L & 8.7L	500, 500 & 0	X	X
8	8.4L & 8.7L	500 & 0	X	X
9	8.1L & 8.7L	500 & 0	X	X
10	8.4L & 8.1L	500 & 500	X	X

For Phase II, in order to determine the best alternative, certain considerations, based on the study purpose and goals were used to evaluate each alternative. The first consideration was that the alternative had to increase flow through Boston Chute. The second consideration was that the alternative must not introduce additional sediment in Boston Chute. The third consideration was that the alternative would not negatively impact the navigation channel. Finally, the fourth consideration was that the alternative should preserve all if not part of Pile Dike 10.10L and 8.20L inside Boston Chute. The ideal alternative would have been able to meet all four conditions; however, no alternatives met all four conditions. There were quite a few alternatives that met three of the four conditions. Some alternatives that met most of the criterion were not recommended due to the necessity of pile dike removal inside Boston Chute. These were Alternatives 11, 12, 13 and 16.

Table 20: Phase II Test Summary

Alternative	Increase Flow In Boston Chute	No Sediment Increase In Boston Chute	Maintain Navigation Channel	Preserved Pile Dikes	Improve Navigation Channel
Alternative 11	X	X	X		
Alternative 12	X	X	X		
Alternative 12B	X	X	X	X	
Alternative 13	X	X	X		
Alternative 13B	X	X	X	X	
Alternative 14			X	X	X
Alternative 15		X	X	X	
Alternative 16		X	X		

Alternative 17	X	X		X	
Alternative 18		X	X	X	
Alternative 18		X		X	

2. Recommendations

Alternative 2 (Plate 28) was recommended as the most desirable alternative for dredge disposal placement because the area did not experience significant erosion and maintained the design height. This alternative could considerably reduce the lack of habitat diversity within the reach by providing more nesting locations for Least Terns. The recommended design for Alternative 2 included the following.

Table 21: Recommended Alternative from Phase I

RM	Distance Away From Boston Bar (ft)	LWRP (ft)	Area (sq. ft)
8.1	500	30	280,000

Alternative 12B, Plate (39), was recommended as the most desirable alternative because of its observed ability to increase flow and keep sediment away from Boston Chute while having no significant impacts on the navigation channel. The alternative consisted of notching Pile Dike 10.10L; removing Dike 7.90L, Dike 10.10L and Dike 10.30L; and constructing Dike 10.05L at the tip of Boston Bar. Testing showed this alternative would increase flow into Boston Chute. According to flow visualization test results (Appendix B), this alternative significantly increased flow within Boston Chute. The recommended design for Alternative 12B included the following:

Table 23: Recommended Alternative from Phase II

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)
Dike	10.05	New	500	LDB	+2
Pile	10.10	Notch	250	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

3. Interpretation of Model Test Results

In the interpretation and evaluation of the model test results, it should be remembered that these results are qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to error as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high and low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodible variables. Flood flows were not simulates in this study.

This model study was intended to serve as a tool for the river engineer as a guide in the assessing the general trends that could be expected to occur in the Mississippi River from a variety in imposed design alternatives. Measures for the final design may be modified based upon engineering knowledge and experience, real estate and construction considerations, economic and environmental impacts, or any other special requirement.

EXTENDED STUDY

1. New Side Channel

At the July 22, 2011, Boston Bar calibration meeting, there were many suggestions and opinions made to help guide the testing process. One of those suggestions involved excavating the secondary inflow channels located upstream of Boston Bar to increase flow in Boston Chute. During the testing process, these channels were not taken into consideration because they were not connected to the main channel or Boston Chute.

There were two secondary side channels located upstream of Boston Bar. However, only one was excavated in this extended study because one of them was too narrow. The new side channel could potentially provide more flow and environmental diversity to the reach by connecting the main channel with Boston Chute. The goal of this extended study was to determine what would happen inside Boston Chute if a side channel was opened.

Table 24: New Side Channel Summary

Type	RM	Depth LWRP (ft)	Channel Width (ft)	Bank	Length (ft)
Side Channel	10.6 – 10.3	-5	80	LDB	1000

Note: Part of Dike 10.30L and Dike 10.10L were removed in the process.

New Side Channel on Existing Planform

Plate (48) shows the bathymetry of Alternative (19). The test showed that when opening another side channel entrance, insignificant amount of flow was introduced through Boston Chute. Model bathymetry of Boston Chute was similar to the replication test with depths ranging from -5ft and +10ft LWRP. No sediment movement was observed inside of Boston Chute. The new side channel did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

New Side Channel on Phase II Recommended Alternatives

Plate (49) shows the bathymetry of Alternative 20. Test results indicated that the chute experienced higher flow due to the new inflow channel and the removal of Dike 10.30L and 10.10L. While higher flows were observed inside Boston Chute, the increased flow was insufficient to mobilize model sediment. The new side channel did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute. See flow visualization test results, Appendix B.

FOR MORE INFORMATION

For more information about HSR modeling or the Applied River Engineering Center, please contact Robert Davinroy, P.E., Jasen Brown, P.E., or Ivan Nguyen at:

Applied River Engineering Center
U.S. Army Corps of Engineers - St. Louis District
Hydrologic and Hydraulics Branch
Foot of Arsenal Street
St. Louis, Missouri 63118

Phone: (314) 865-6326, (314) 865-6322, or (314) 865-6358
Fax: (314) 865-6352

E-mail: Robert.D.Davinroy@usace.army.mil
Jasen.L.Brown@usace.army.mil
Ivan.H.Nguyen@usace.army.mil

Or you can visit us on the World Wide Web at:

http://www.mvs.usace.army.mil/arec/

APPENDIX A: PLATES

Plate	1	Location Map and Vicinity
Plate	2	Study Reach Planform and Nomenclature
Plate	3	Field Photographs: Helicopter Screen Shot November 2010
Plate	4	2010 & 2011 Combined Hydrographic Surveys
Plate	5	Boston Bar Hydrograph
Plate	6	Field Photographs: Helicopter Photos Sept. 2006
Plate	7	Boston Bar Geomorphology (Geomorphology Study Appendix A)
Plate	8	1928 Aerial Photograph
Plate	9	1928 & 2010 Planform
Plate	10	1968 Aerial Photograph
Plate	11	1968 & 2010 Planform
Plate	12	1942 Boston Bar Map
Plate	13	1956 Boston Bar Map
Plate	14	1976 Aerial Photograph
Plate	15	1982 Aerial Photograph
Plate	16	Dredge Cut & Disposal Locations
Plate	17	1998 Hydrographic Survey
Plate	18	2005 Hydrographic Survey
Plate	19	2006 Hydrographic Survey
Plate	20	2008 Pre-Dredge Hydrographic Survey
Plate	21	2008 Post-Dredge Hydrographic Survey
Plate	22	2009 Hydrographic Survey
Plate	23	Site Visit Photographs
Plate	24	Model Photograph
Plate	25	Replication Test
Plate	26	2010 & 2011 Combined Hydrographic Survey and Replication Test
Plate	27	Alternative 1: Island 8.4L
Plate	28	Alternative 2: Island 8.0L

Plate 29 Alternative 3: Island 8.9L
Plate 30 Alternative 4: Island 8.8L
Plate 31 Alternative 5: Island 8.7L
Plate 32 Alternative 6: Island 8.7L
Plate 33 Alternative 7: Island 8.7L, 8.4L & 8.0L
Plate 34 Alternative 8: Island 8.7L & 8.4L
Plate 35 Alternative 9: Island 8.7L & 8.0L
Plate 36 Alternative 10: Island 8.4L & 8.0L
Plate 37 Alternative 11: Dike 7.90L
Plate 38 Alternative 12: Dike 10.05L
Plate 39 Alternative 12B: Dike 10.05L
Plate 40 Alternative 13: Remove Closure Structures
Plate 41 Alternative 13B: Notch and Remove Closure Structures
Plate 42 Alternative 14: Two Chevrons
Plate 43 Alternative 15: 2011 Master Plan
Plate 44 Alternative 16: 18 Hard Points at Bends
Plate 45 Alternative 17: Remove and Notch
Plate 46 Alternative 18: New Side Channel
Plate 47 Alternative 19: Phase I New Side Channel
Plate 48 Alternative 20: Phase II Alternative 12B New Side Channel
Plate 49 Alternative 21: Phase II Alternative 13B New Side Channel

APPENDIX B: FLOW VISUALIZATION RESULTS

The first condition recorded was the replication test, or existing conditions as seen in Figure 1 below. Remember that dry sediment was introduced along the LDB for all videos, not uniformly across the channel. (Please note that there is a DVD available with this report to view the videos.)

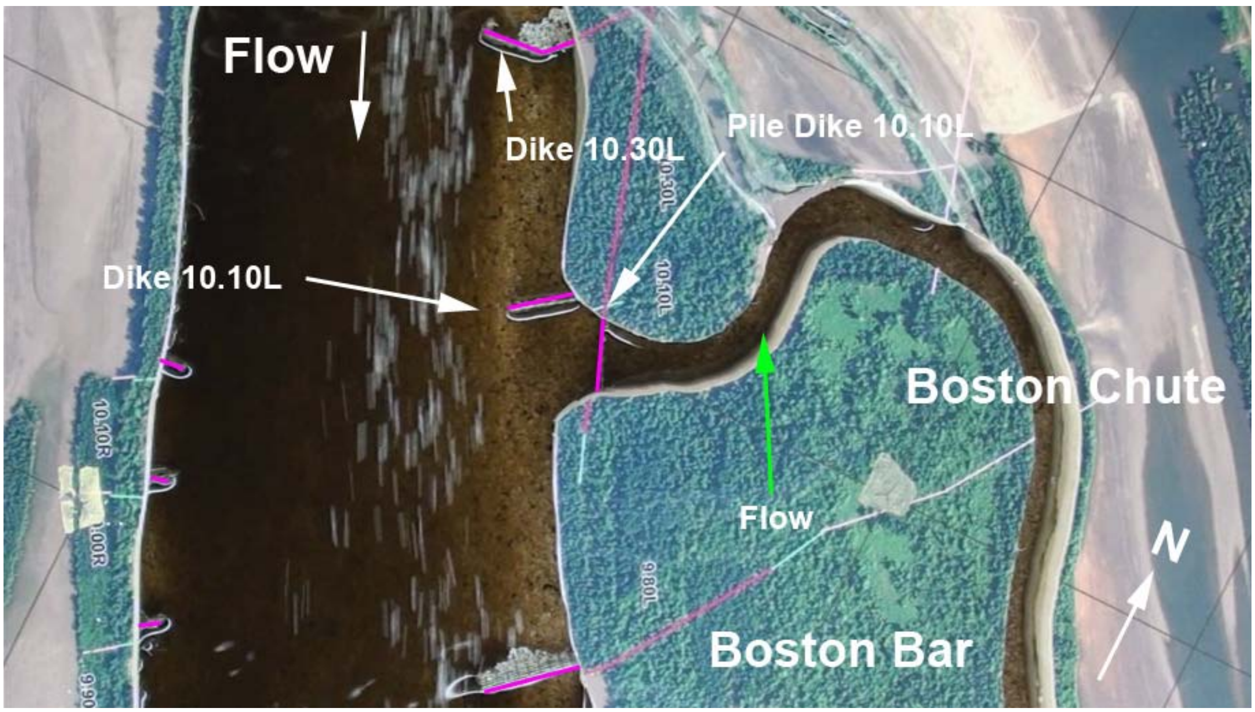


Figure 1: Flow Visualization - Replication Test

The flow exited the sharp bend at RM 14.0 and maintained a straight path just upstream of Figure 1’s extents. As seen in the snapshot of the existing conditions, the resultant flow was concentrated in the center of the main channel of Figure 1. Immediately downstream, the flow kept the same path. There was minimum flow observed inside Boston Chute. All structures are highlighted in pink for increased visibility.

The next condition recorded was post construction with the recommended alternative (Alternative 12B) of removing Dike 10.30L, 10.10L and 7.90L; notching Pile Dike

10.10L; and constructing Dike 10.05L as seen in Figure 2 below. All structures were highlighted in pink for increase visibility.

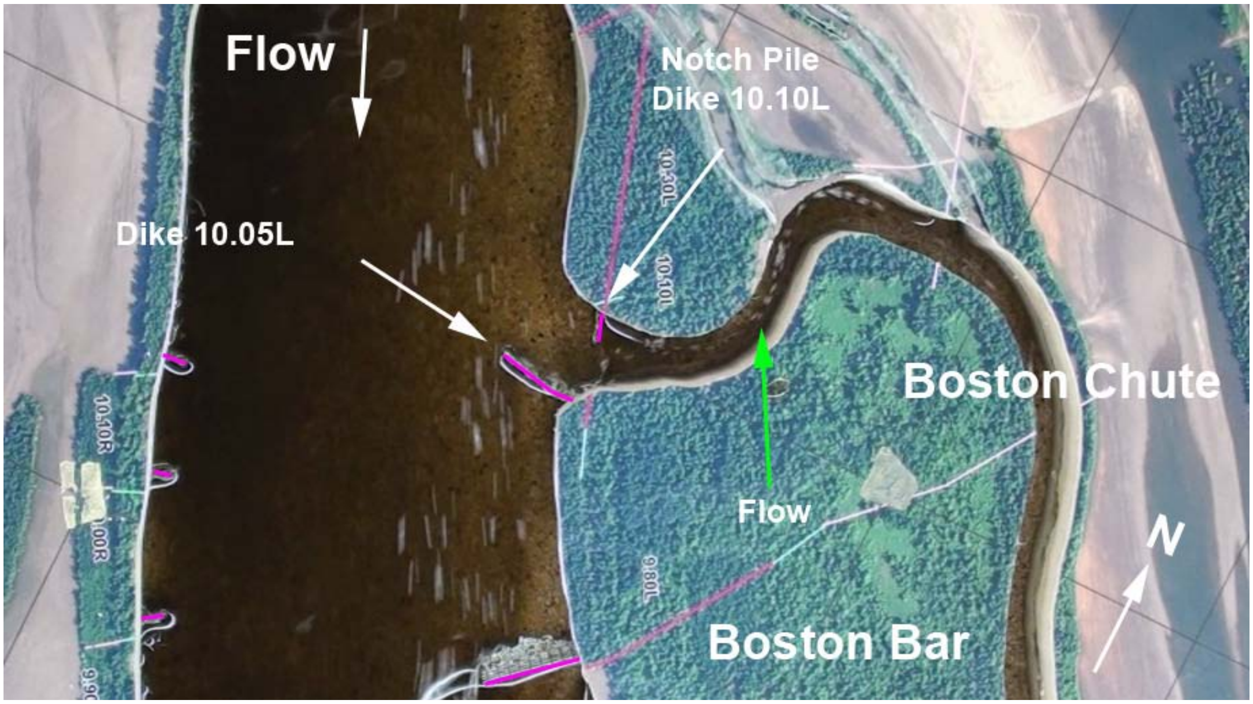


Figure 2: Alternative 12B Flow Visualization

Again, the flow exited the sharp bend at RM 14.0 and maintained a straight path just upstream of Figure 2's extents. As seen in the snapshot of the post construction conditions, the resultant flow was dispersed into two directions along the LDB. Dike 10.05L split the concentrated flow, sending the majority of the flow down the main channel and the rest towards Boston Chute. Compared to the existing conditions, there was increased in flow in Boston Chute.

Appendix B. Agency and Tribal Government Coordination

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT CORPS OF ENGINEERS
1222 SPRUCE STREET
ST. LOUIS, MISSOURI 63103-2833

REPLY TO
ATTENTION OF:

October 01, 2015

Engineering and Construction Division
Curation and Archives Analysis Branch (EC-Z)

Ms. Rachel Leibowitz
Deputy State Historic Preservation Officer
Illinois Historic Preservation Agency
1 Old State Capitol Plaza
Springfield, Illinois 62701-1507
Subject: Boston Bar Side Channel Restoration and Island Creation Project

Dear Ms. Leibowitz:

The United States Army Corps of Engineers (USACE) is presently planning the construction of one, the modification of another, and the removal of three river training structures in the Boston Bar Reach of the Mississippi River between river miles 7 and 11 (Figure 1). The actions comprise the Boston Bar Side Channel Restoration and Island Creation Project. We are contacting your office to initiate consultation under Section 106 of the National Historic Preservation Act of 1966, as amended (NHPA), and its implementing regulation 36 CFR 800.

Background

In 1866 the Federal Government allocated funding for the creation of a 4-foot channel between Minneapolis and St. Louis. This channel was subsequently deepened when Congress authorized USACE to create a 4.5-foot channel in 1878 and then, in 1907, a 6-foot channel from the confluence of the Mississippi and Missouri rivers to Minneapolis. These works were achieved using a system of wing and closing dams in conjunction with river dredging. Wing dams constrict the flow of a river thereby speeding its current to provide bed-scour in the main river channel. Closing dams blocked off side channels and chutes to similarly control water flow.

In 1927 Congress ordered USACE to study the feasibility of a 9-foot channel on the Upper Mississippi. On July 3, 1930, an amended Rivers and Harbors act was signed by President Hoover authorizing the creation of the channel. For the Upper Mississippi above St. Louis, the primary mechanism implemented to achieve this goal was the lock-and-dam system built in the 1930s and 1940s. The use of river training structures such as wing dikes, however, continued to be valuable in the maintenance of an open river navigation channel below the locks as they provide a more cost-effective and environmentally friendly solution for moving sediment through the river system than dredging alone.

Project

Side channels are a critical biological component of the Mississippi River. Many side channels within the Middle Mississippi, however, lack bathymetric diversity. Boston Chute is very shallow and connected to the river only during high flows. Sedimentation is a problem both due to the historical use of closure structures and back flooding of the Ohio River. It is crucial that the valuable aquatic habitat be rehabilitated.

As part of the 2000 Biological Opinion Program, St. Louis District is conducting the Boston Bar Side Channel Restoration and Island Creation Project. A hydraulic sediment response model study examined a number of alternatives to improve the flow in Boston Chute, while not having any significant impacts to the Mississippi River navigation channel. The alternatives were also examined to determine the best location for dredge disposal to create a least tern nesting island.

The recommended alternative removes three of the existing rock dikes and notches a pile structure. One new rock dike would be constructed (Figure 1). All the structures are located in Alexander County, Illinois (Table 1).

Table 1. Project Features

Structure	Type	Length (ft)	Bank
Dike 10.05	New	500	LDB
Pile 10.10	Notch	250	Chute
Dike 10.10	Remove	All	LDB
Dike 10.30	Remove	All	LDB
Dike 7.90	Remove	All	Chute

Potential Effects on Cultural Resources

All the river training structures are constructed and modified/removed via barge, without recourse to land access; therefore, any effects are limited to submerged cultural resources. Primary among these are historic period shipwrecks. Given the continual river flow and associated sedimentary erosion, deposition, and reworking, it is highly unlikely that any more ephemeral cultural material remains on the river bed.

The bankline of the Boston Bar Reach has significantly changed in the past century and a half. In the late 19th century the work locations were actually on the Missouri side of the river (Figure 2). In 1908 they were on ephemeral sand bars in the middle of the river (Figure 3). It was only in the first quarter of the 20th century that Boston Bar began to resemble its current configuration (Figures 4 and 5).

Possible Shipwrecks

During the summer of 1988 when the Mississippi River was at a particularly low level, the St. Louis District Corps of Engineers conducted an aerial survey of exposed wrecks between Saverton, Missouri, and the mouth of the Ohio River. The nearest observed wreck to the project features was located approximately twenty three miles upstream.

In 2014 a multi-beam high resolution bathymetry survey was conducted in the project area. No topographic anomalies suggesting wrecks are visible on the resulting bathymetric model (Figures 6 and 7).

Given the features' construction/modification method (with no land impact), the previous disturbance of the riverbed, the channel migration recorded for the locations in the nineteenth century, and the lack of any survey evidence for extant wrecks, it is our opinion that the proposed undertaking will have no significant effect on cultural resources.

If you have any questions or comments, please feel free to contact me at (314) 331-8466 or Dr. Mark Smith at (314) 331-8831 (e-mail: mark.a.smith4@usace.army.mil).

Sincerely yours,

Michael K. Trimble, Ph.D.
Chief, Curation and Archives Analysis Branch

Enclosure

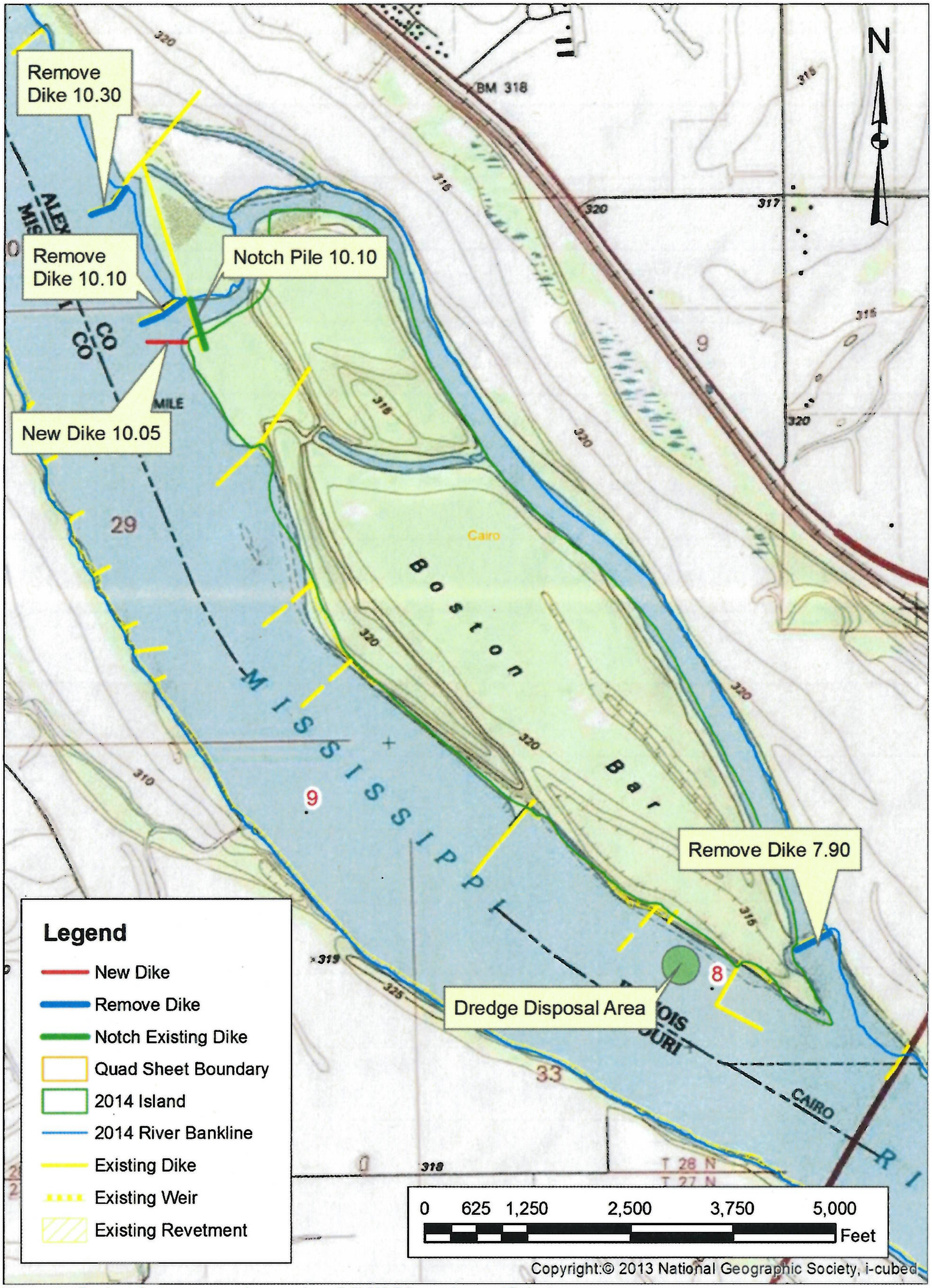


Figure 1. Project features superimposed on 7.5' USGS quad map (Cairo).

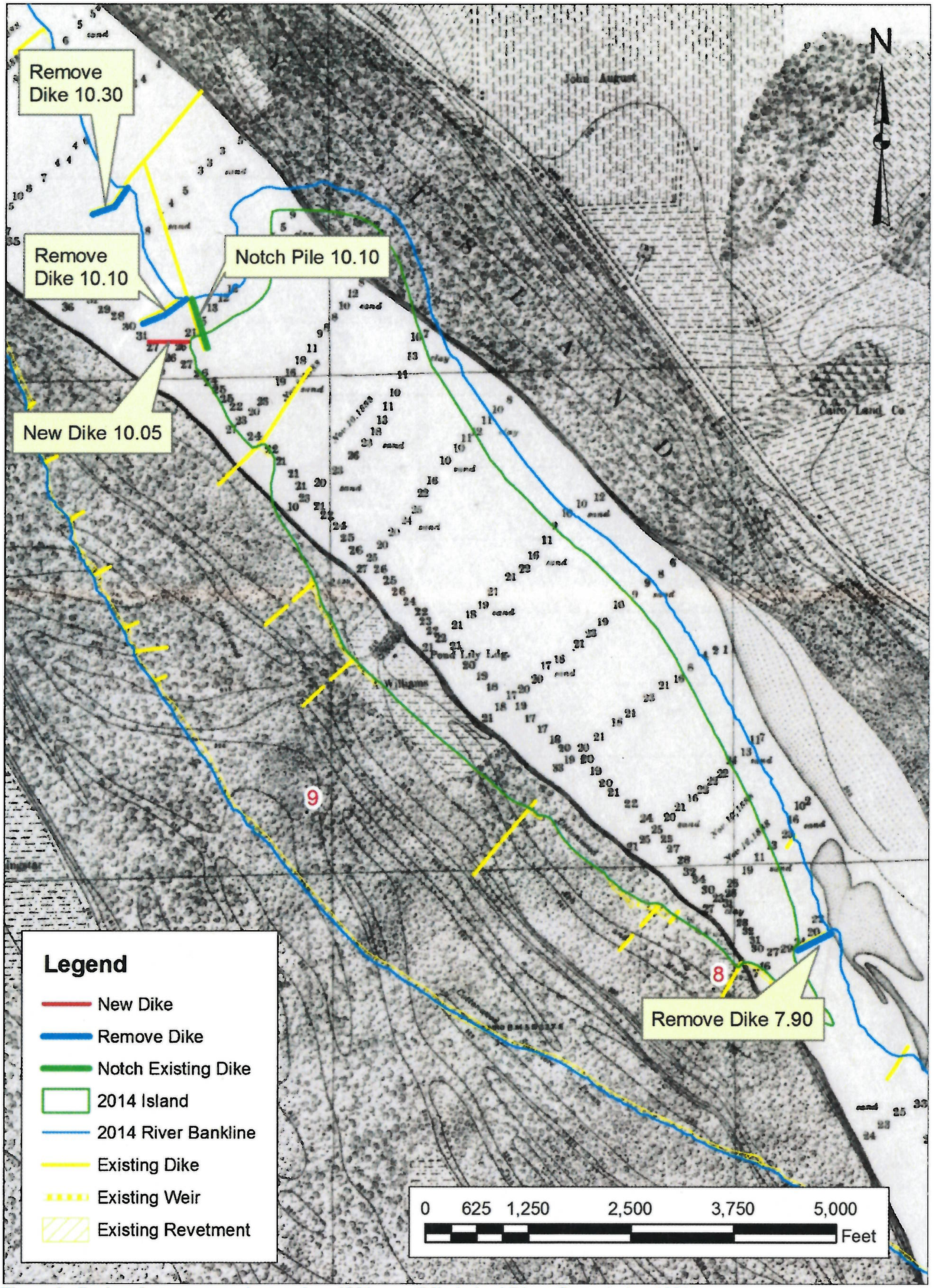


Figure 2. Project features superimposed on 1881 map (Mississippi River Commission 1881).

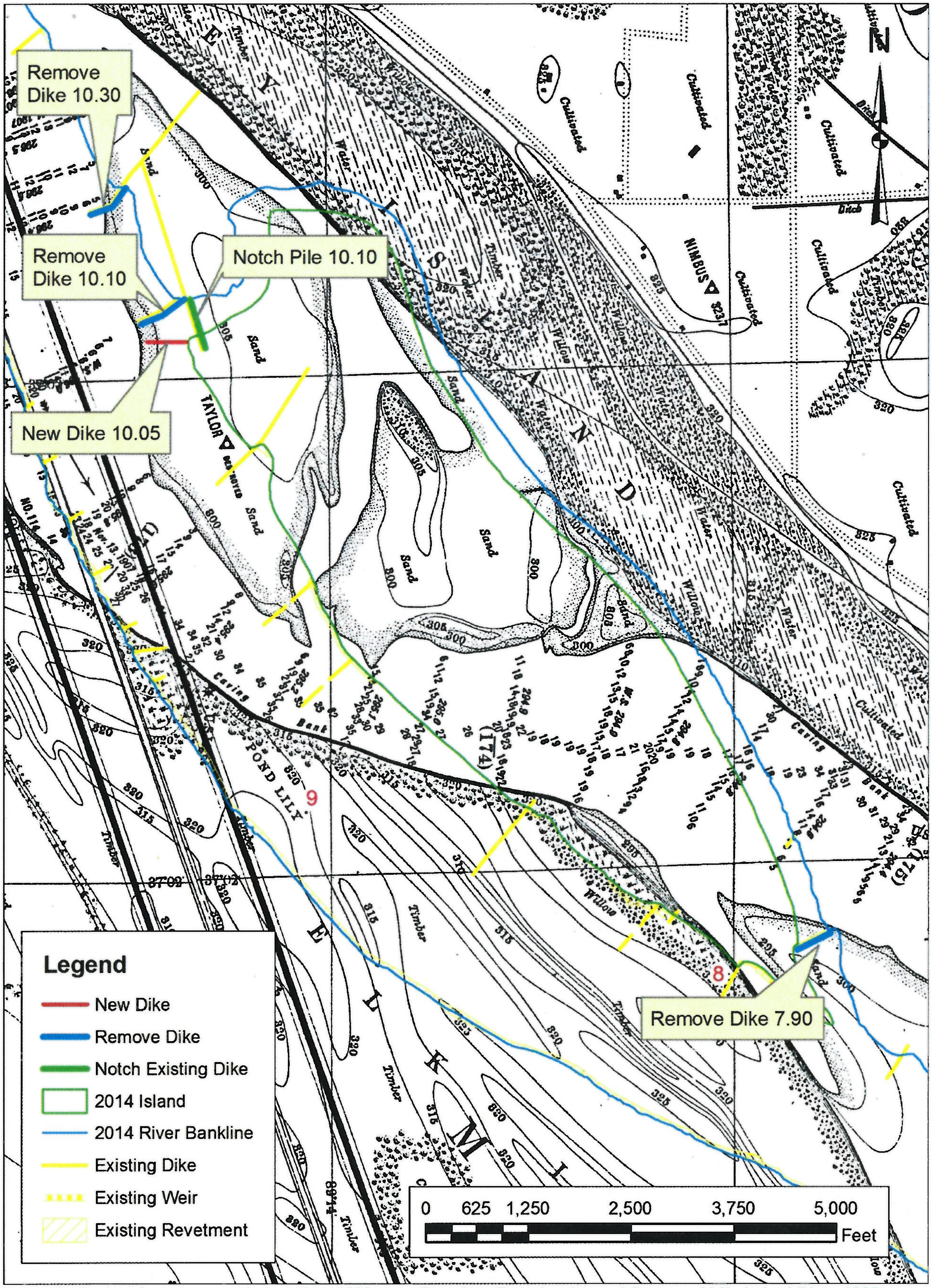


Figure 3. Project features superimposed on 1908 map (Board on Examination and Survey of Mississippi River 1908).

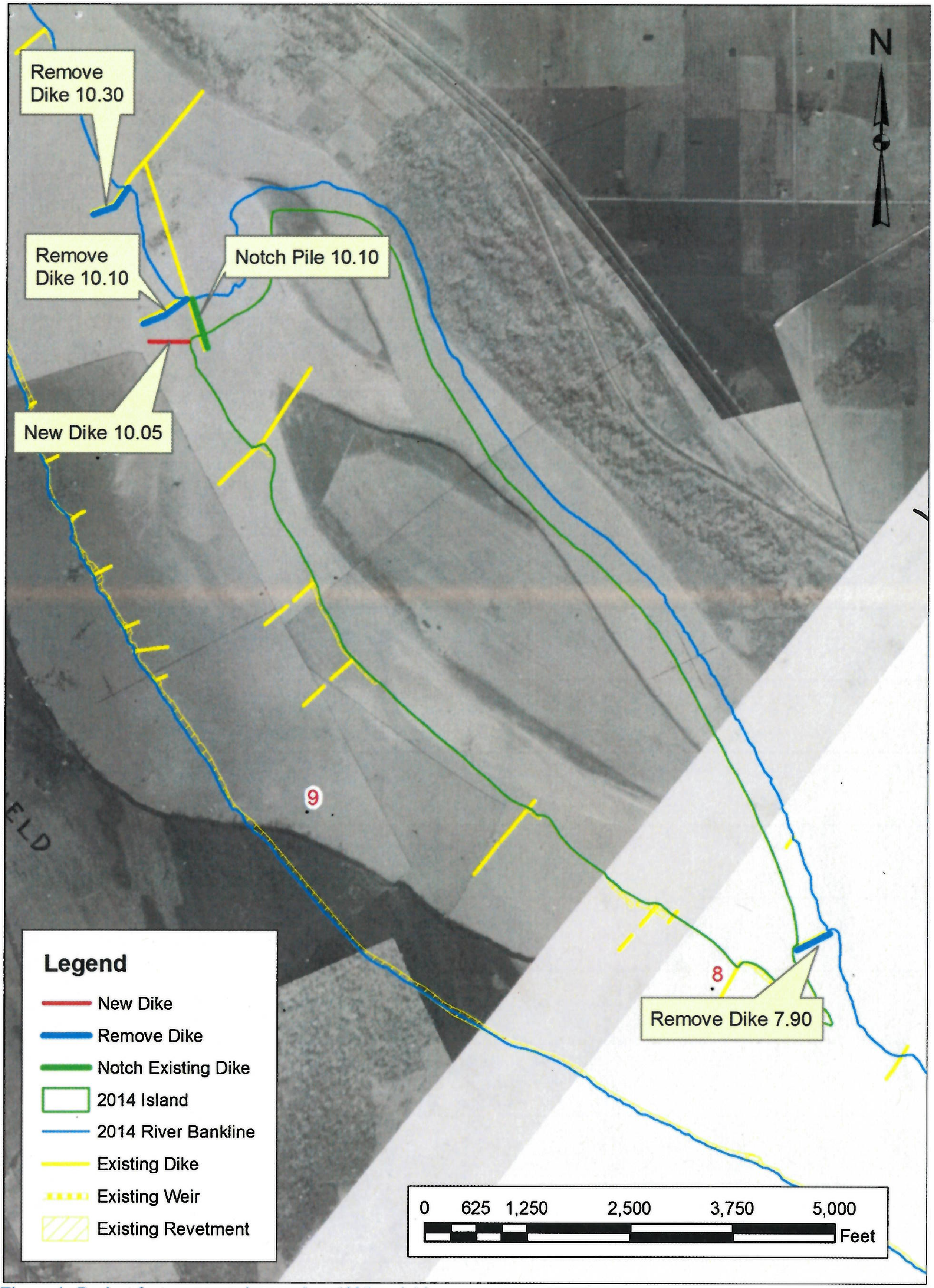


Figure 4. Project features superimposed on 1925 aerial imagery.

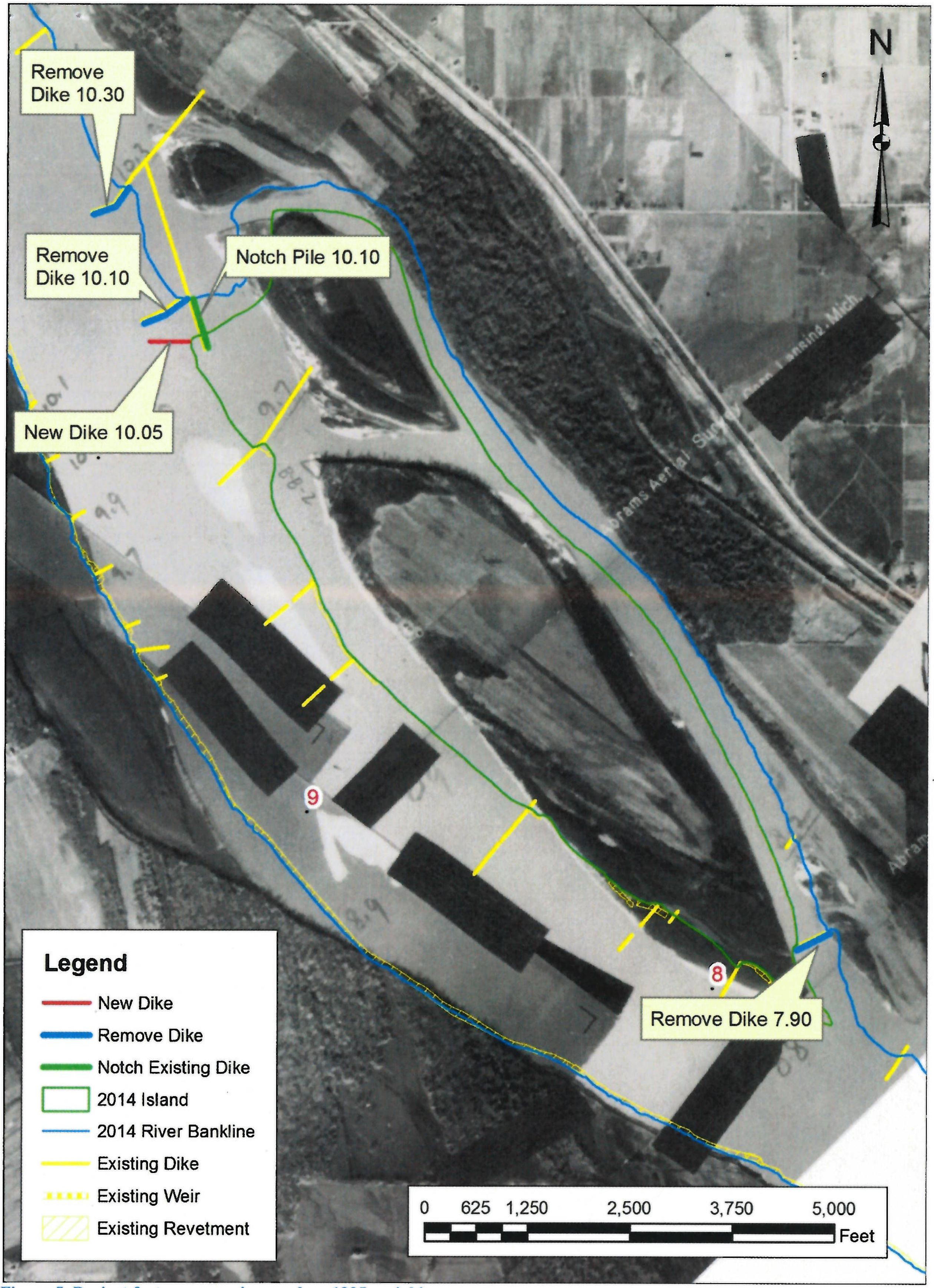


Figure 5. Project features superimposed on 1925 aerial imagery.

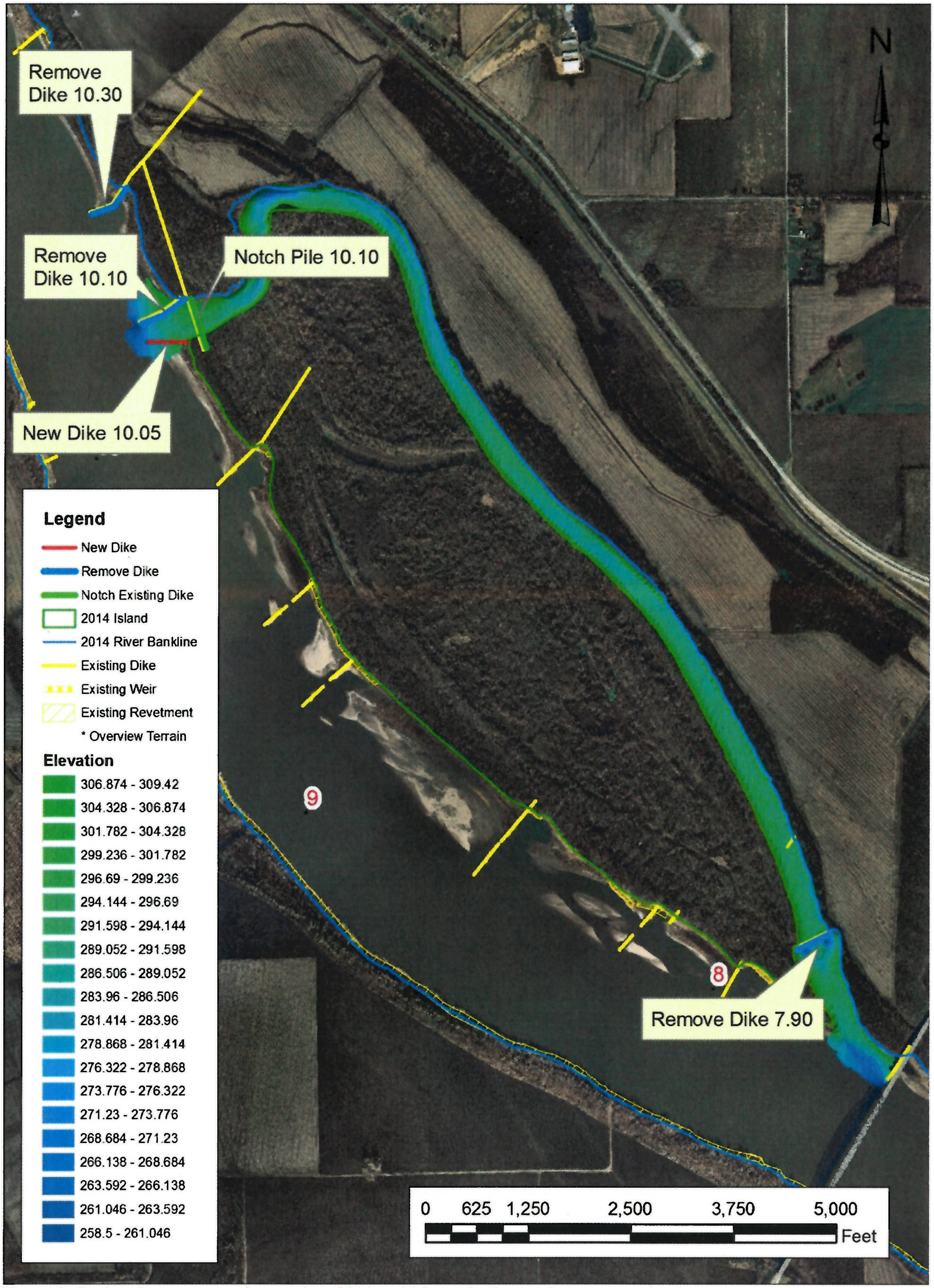


Figure 6. Project features superimposed on 2014 multi-beam bathymetric survey.

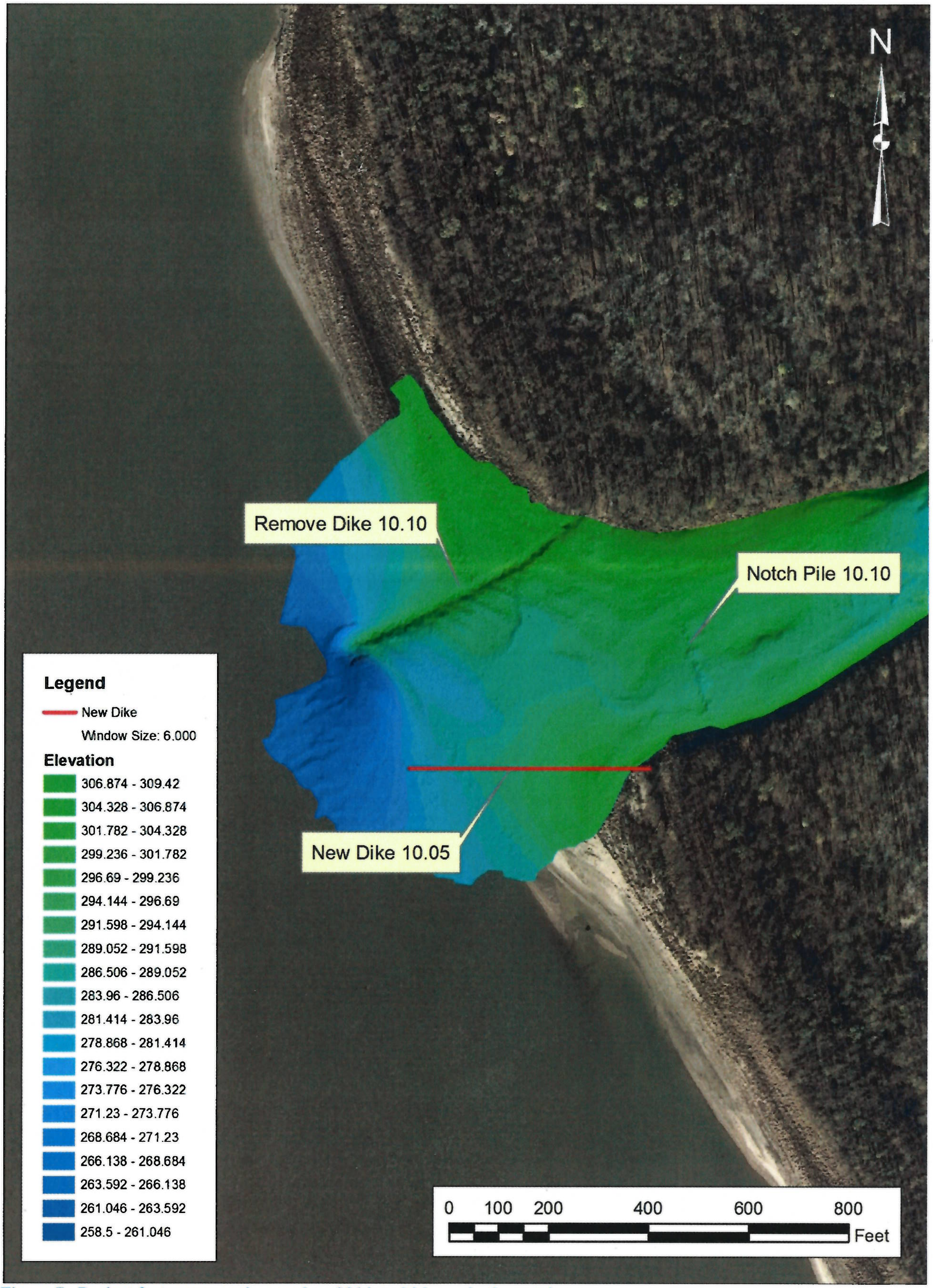


Figure 7. Project features superimposed on 2014 multi-beam bathymetric survey.

Illinois Historic
Preservation Agency
1 Old State Capitol Plaza, Springfield, IL 62701-1512
FAX 217/524-7525
www.illinoishistory.gov

Alexander County PLEASE REFER TO: IHPA LOG #021100515
Cairo
Mississippi River mile 7 to 11
COESTL
Training structure improvements - Boston Bar Side Channel Restoration

October 21, 2015

Michael K. Trimble, Ph.D., Chief
Department of the Army
St. Louis District, Corps of Engineers
Curation and Archives Analysis Branch (EC-Z)
1222 Spruce St.
St. Louis, MO 63103-2833

Dear Chief Trimble:

We have reviewed the documentation submitted for the referenced project(s) in accordance with 36 CFR Part 800.4. Based upon the information provided, no historic properties are affected. We, therefore, have no objection to the undertaking proceeding as planned.

Please retain this letter in your files as evidence of compliance with section 106 of the National Historic Preservation Act of 1966, as amended. This clearance remains in effect for two (2) years from date of issuance. It does not pertain to any discovery during construction, nor is it a clearance for purposes of the Illinois Human Skeletal Remains Protection Act (20 ILCS 3440).

If you are an applicant, please submit a copy of this letter to the state or federal agency from which you obtain any permit, license, grant, or other assistance.

Sincerely,

Rachel Leibowitz, Ph.D.
Deputy State Historic
Preservation Officer

January 14, 2016

Engineering and Construction Division
Curation and Archives Analysis Branch

Governor Edwina Butler-Wolfe
Absentee-Shawnee Tribe of Indians of Oklahoma
2025 South Gordon Cooper Drive
Shawnee, Oklahoma 74810-9381

Dear Governor Butler-Wolfe:

This letter addresses the construction of one, modification of one, and removal of three river-training structures in the Boston Bar Reach of the Mississippi River. These actions comprise the Boston Bar Side Channel Restoration and Island Creation Project. The U.S. Army Corps of Engineers, St. Louis District (USACE) proposes adding, modifying, and removal of a total of five (5) training structures.

The project is located along the Mississippi River between river miles 7 and 11 in Alexander County, Illinois (see Table 1 and attachment Figure 1). This federal action falls under Section 106 of the National Historic Preservation Act (NHPA), in conjunction with the National Environmental Policy Act (NEPA) and the Clean Water Act (CWA). This project is being implemented to enhance wildlife habitat along the river.

Table 1. Project Features

Structure	**Type**	**Length (ft)**
Dike 10.05	New	500
Pile 10.10	Notch	250
Dike 10.10	Remove	All
Dike 10.30	Remove	All
Dike 7.90	Remove	All

In 1866 the Federal government allocated funding for the creation of a 4-foot channel between Minneapolis and St. Louis. This channel was subsequently deepened when Congress authorized USACE to create a 4.5-foot channel in 1887 and then, in 1907, a 6-foot channel from the confluence of the Mississippi and Missouri rivers to Minneapolis. These works were achieved using a system of wing and closing dams in conjunction with river dredging. Wing dams constrict the flow of a river thereby speeding its current to provide bed-scour in the main river channel. Closing dams blocked off side channels and chutes to similarly control water flow.

In 1927 Congress ordered USACE to study the feasibility of a 9-foot channel on the Upper Mississippi. On July 3, 1930, an amended Rivers and Harbors Act was signed by President Hoover authorizing the creation of the channel. For the Upper Mississippi above St. Louis, the primary mechanism implemented to achieve this goal was the lock-and-dam system built in the 1930s and 1940s. The use of river-training structures such as wing dikes, however, continued to be valuable in the maintenance of an open river navigation channel below the lock as they provide a more cost-effective and environmentally friendly solution for moving sediment through the river system than dredging alone. While mitigating the need for environmentally disruptive dredging, newer deigns also attempt to preserve and enhance the environmental components of the river through the creation of diverse wildlife habitats.

Side channels are a critical biological components of the Mississippi River. Many side channels within the Middle Mississippi, however, lack diversity: Boston Chute is very shallow and connected to the river only during high flows. Sedimentation is a problem both due to the historical use of closure structures and back flooding of the Ohio River. It is crucial that the valuable aquatic habitat be rehabilitated. A number of alternatives were examined to determine the best locations to improve the flow in Boston Chute, while not having any significant impacts to the Mississippi River navigation channel. There alternatives were also examined to determine the best location for dredge disposal to create a nesting island. The recommended alternative is to remove three of the existing rock dikes, notch one pile structure, and construct one new rock dike (Figure 1).

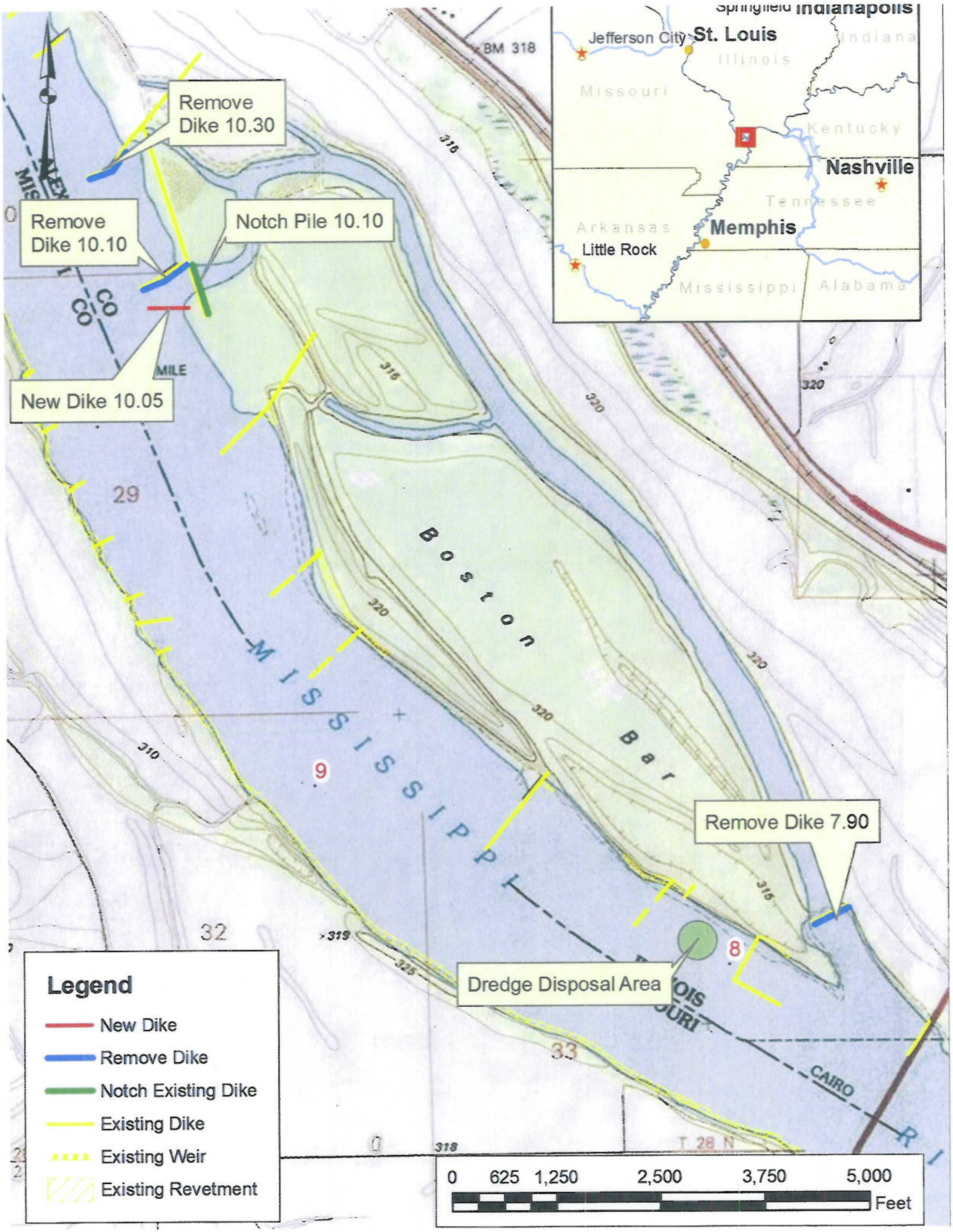
Impacts to potentially significant historic properties are not anticipated during this work. River training structures are constructed, modified, or removed using barges, without recourse to land access; therefore, any impact is limited to submerged cultural resources. Primary among these are historic period shipwrecks. Given the continual river flow and associated sedimentary erosion, deposition, and reworking, it's highly unlikely that any more cultural material remains on the river bed. USACE has conducted a shipwreck survey during times of low water levels and maintains a database of known shipwrecks for the Middle Mississippi. All proposed locations for river-training structures are compared to the database as well as aerial imagery for low water years to insure historical shipwrecks are not adversely impacted. Should an inadvertent discovery of human remains occur, then state or federal law will be followed, and work will stop within the area of the discovery. Tribes will be notified, and any human remains will be treated with respect and dignity.

The U.S. Army Corps of Engineers, St. Louis District is requesting you review the map and information about this project and notify our office if you have any concerns, such as traditional cultural properties or sacred sites that are located within or near the project sites that need to be addressed. Please notify our office no later than February 19, 2016, if you have any areas of concern. If you have questions regarding this project, please contact Ms. Roberta Hayworth at (314) 331-8833 or at roberta.l.hayworth@usace.army.mil or Mr. Chris Koenig at (314) 331-8151 or at chris.k.koenig@usace.army.mil. A copy of this letter has been furnished to Mr. Leonard Longhorn.

Sincerely,

Michael K. Trimble, Ph.D.
Chief, Curation and Archives
Analysis Branch

Attachment


Remove Dike 10.30
Remove Dike 10.10
Notch Pile 10.10
New Dike 10.05
Boston Bar
MISSISSIPPI
Remove Dike 7.90
Dredge Disposal Area
Springfield
Indianapolis
Jefferson City
St. Louis
Indiana
Illinois
Missouri
Kentucky
Nashville
Tennessee
Arkansas
Memphis
Little Rock
Mississippi
Alabama
Legend
New Dike
Remove Dike
Notch Existing Dike
Existing Dike
Existing Weir
Existing Revetment
0
625
1,250
2,500
3,750
5,000
Feet

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Marion Ecological Services Sub-Office
MARION ILLINOIS SUB-OFFICE, 8588 ROUTE 148
MARION, IL 62959
PHONE: (618)997-3344 FAX: (618)997-8961
URL: www.fws.gov/midwest/Endangered/section7/s7process/step1.html

Consultation Code: 03E18100-2016-SLI-0081 December 10, 2015
Event Code: 03E18100-2016-E-00089
Project Name: Boston Bar Side Channel Restoration and Island Creation Project

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The attached species list identifies any federally threatened, endangered, proposed and candidate species that may occur within the boundary of your proposed project or may be affected by your proposed project. The list also includes designated critical habitat if present within your proposed project area or affected by your project. This list is provided to you as the initial step of the consultation process required under section 7(c) of the Endangered Species Act, also referred to as Section 7 Consultation.

Section 7 of the Endangered Species Act of 1973 requires that actions authorized, funded, or carried out by Federal agencies not jeopardize federally threatened or endangered species or adversely modify designated critical habitat. To fulfill this mandate, Federal agencies (or their designated non-federal representative) must consult with the Service if they determine their project “may affect” listed species or critical habitat.

Under 50 CFR 402.12(e) (the regulations that implement Section 7 of the Endangered Species Act) the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally. You may verify the list by visiting the ECOS-IPaC website http://ecos.fws.gov/ipac/ at regular intervals during project planning and implementation and completing the same process you used to receive the attached list. As an alternative, you may contact this Ecological Services Field Office for updates.

Please use the species list provided and visit the U.S. Fish and Wildlife Service's Region 3 Section 7 Technical Assistance website http://www.fws.gov/midwest/endangered/section7/s7process/index.html. This website contains step-by-step instructions which will help you determine if your project will have an adverse effect on listed species and will help lead you through the Section 7 process.

For all wind energy projects and projects that include installing towers that use guy wires or are over 200 feet in height, please contact this field office directly for assistance, even if no federally listed plants, animals or critical habitat are present within your proposed project or may be affected by your proposed project.

Although no longer protected under the Endangered Species Act, be aware that bald eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*) and Migratory Bird Treaty Act *(*16 U.S.C. 703 *et seq*), as are golden eagles. Projects affecting these species may require measures to avoid harming eagles or may require a permit. If your project is near an eagle nest or winter roost area, see our Eagle Permits website http://www.fws.gov/midwest/midwestbird/EaglePermits/index.html to help you determine if you can avoid impacting eagles or if a permit may be necessary.

We appreciate your concern for threatened and endangered species. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment

Official Species List

Provided by:

Marion Ecological Services Sub-Office
MARION ILLINOIS SUB-OFFICE
8588 ROUTE 148
MARION, IL 62959
(618) 997-3344
http://www.fws.gov/midwest/Endangered/section7/s7process/step1.html

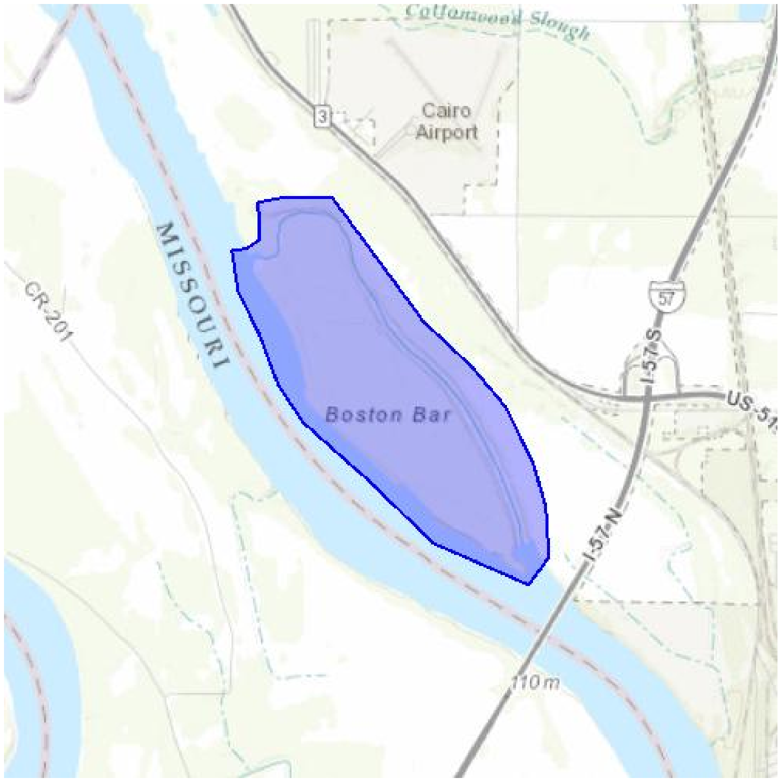
Consultation Code: 03E18100-2016-SLI-0081
Event Code: 03E18100-2016-E-00089

Project Type: ** OTHER **

Project Name: Boston Bar Side Channel Restoration and Island Creation Project
Project Description: Middle Mississippi River (RM 10.2 - 7.6 L). Alexander County, Illinois, and Scott County, Missouri. The purpose of the project is to increase connectivity between Boston Chute and the main-stem of the Mississippi River by removing dikes and construting a side channel enhancement dike, as well as create an island using dredge disposal material during future channel maintenance dredging.

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

Project Location Map:



Project Coordinates: MULTIPOLYGON (((-89.23104286193846 37.05675253648049, -89.22245979309082 37.047504980968164, -89.21791076660156 37.04414818209648, -89.21464920043945 37.04106527686204, -89.21207427978516 37.03674899921184, -89.21095848083495 37.03346024202566, -89.21061515808105 37.02982874050856, -89.21258926391602 37.027704574230206, -89.22151565551756 37.03078802193639, -89.22735214233398 37.03531018546877, -89.2338752746582 37.03990059119242, -89.23619270324707 37.04270950856679, -89.2379093170166 37.046408899699564, -89.23996925354004 37.049834101110534, -89.2404842376709 37.05284815049062, -89.23928260803223 37.05298514989097, -89.2379093170166 37.05367014318299, -89.23808097839355 37.05641005451955, -89.23584938049316 37.05682103268718, -89.23104286193846 37.05675253648049)))

Project Counties: Alexander, IL

Endangered Species Act Species List

There are a total of 7 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

Birds	**Status**	**Has Critical Habitat**	**Condition(s)**
Least tern *(Sterna antillarum)* Population: interior pop.	Endangered		
Clams			
rabbitsfoot *(Quadrula cylindrica ssp. cylindrica)*	Threatened	Final designated	
Sheepnose Mussel *(Plethobasus cyphyus)*	Endangered		
Fishes			
Pallid sturgeon *(Scaphirhynchus albus)* Population: Entire	Endangered		
Mammals			
Gray bat *(Myotis grisescens)* Population: Entire	Endangered		
Indiana bat *(Myotis sodalis)* Population: Entire	Endangered		
Northern long-eared Bat *(Myotis*	Threatened		

septentrionalis)			

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Appendix C. Clean Water Act Section 404(b)(1) Evaluation

Boston Bar Side Channel Restoration and Island Creation Project
Middle Mississippi River (RM 10.2 - 7.6 L)
Alexander County, Illinois

March 2016

APPENDIX C
CLEAN WATER ACT
SECTION 404(b)(1) EVALUATION

Contents

1. PROJECT DESCRIPTION 2

A. Location 2

B. General Description 2

C. Authority and Purpose 2

D. General Description of the Fill Material. 2

E. Description of the Proposed Action 3

F. Description of the Placement Method 4

2. FACTUAL DETERMINATIONS 4

A. Physical Substrate Determinations 4

B. Water Circulation, Fluctuation, and Salinity Determinations 6

C. Suspended Particulate/Turbidity Determinations 6

D. Contaminant Determinations. 7

E. Aquatic Ecosystem and Organism Determinations 7

F. Proposed Placement Site Determinations 8

G. Determinations of Cumulative Effects on the Aquatic Ecosystem. 8

H. Determinations of Secondary Effects on the Aquatic Ecosystem. 9

3. FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON PLACEMENT 9

APPENDIX C
CLEAN WATER ACT
SECTION 404(b)(1) Evaluation

1. PROJECT DESCRIPTION

A. Location. The Boston Bar work area is located along the left descending bank of the Middle Mississippi River (MMR) between river miles 10.2 – 7.6, approximately 7.6 miles upstream of the confluence with the Ohio River, in Alexander County, Illinois. The MMR is defined as the reach that lies between its confluences with the Ohio and Missouri Rivers.

B. General Description. The Corps of Engineers St. Louis District is proposing to construct the Boston Bar Side Channel Restoration and Island Creation Project as part of its Biological Opinion Program. The goal of the project is to restore habitat for two federally endangered species: the pallid sturgeon (*Scaphirhynchus albus*) and the interior least tern (*Sterna antillarum*). The project consists of modifying the configuration of river training structures at Boston Bar to allow more flow into the side channel within the project area, enhancing connectivity of the side channel with the main stem of the Mississippi River and improving the overall habitat heterogeneity of the MMR. Specifically, traditional rock dikes and closing structures will be removed from the project area, and a side channel enhancement dike (SCED) will be constructed at the entrance to Boston Chute. The project also includes the construction of least tern nesting habitat using dredge disposal material from channel maintenance dredging.

C. Authority and Purpose. The Middle Mississippi River Regulating Works Project is specifically and currently authorized pursuant to Rivers and Harbors Acts beginning in the mid-1800s. These authorize USACE to provide a 9-foot-deep by minimum of 300-foot-wide, with additional width in the bends, navigation channel at low river levels. The purpose of this work is to provide a sustainable, safe and dependable navigation channel through regulating works to reduce the need for repetitive channel maintenance dredging in the area.

In performing this responsibility, the Corps is committed to complying with the Endangered Species Act (ESA). In executing responsibilities under the ESA, the Corps recognizes that there is to be deference to the U.S. Fish and Wildlife Service (Service). It is incumbent upon the Service to provide biological advice and guidance that allows the Corps to achieve compliance with the ESA within the Corps' statutory authorities and appropriations. Through implementation of the proposed federal action described herein, the District will remain in compliance with the ESA for the Regulating Works Project.

D. General Description of the Fill Material.
Fill material for dike construction would include quarry run limestone consisting of graded “A” stone. Size requirements for graded “A” stone are shown below in Table 1. Stone (2,114 tons) required for construction would be recycled stone from adjacent dike removal efforts. Original source of stone was commercial stone quarries in the vicinity of the work area capable of producing stone which meets USACE specifications.

Fill material for sandbar creation would consist of dredged material from the adjacent main channel. MMR main channel sediments typically consist mostly of sand with very little fine-grained material. Recent sampling of MMR main channel sediments indicates that the average composition was more than 99% sand and gravel and less than 1% fine-grained.

Table 1 - GRADED "A" STONE	
Stone Weight (LBS)	Cumulative % Finer by Weight
5000	100
2500	70-100
500	40-65
100	20-45
5	0-15
1	0-5

E. Description of the Proposed Action.
The proposed work would consist of the following (see Table 2):

Removal of three rock dikes between river miles 7.1 and 10.3 L

- Approximately 560, 575, and 650 linear ft.
- Final elevation of 274 ft. (NGVD) for dikes 10.1L, 10.3L, and 273 ft. (NGVD) for dike 7.9 L.

Notching of pile dike 10.3L.

- Approximately 250 linear ft.
- Final elevation of 274 ft. (NGVD).

Construction of a SCED at RM 10.05 L.

- Approximately 650 linear ft.
- Final elevation of 294 ft. (NGVD).

Dredge disposal between dikes 8.0 and 8.3 L.

- Approximately 6.5 acres.
- Final elevation of 314 ft. (NGVD)
- Final area and elevation are dependent on volume of channel maintenance dredge disposal.

Table 2 - Boston Bar Construction						
River Mile	Structure	Action	Elevation ft. (NGVD)	Volume (CY)	Approximate Length	
10.05 (L)	SCED	Construct	294	2114.2	650	
10.3 (L)	Pile Dike	Notch	274	-14061.8	-250	
10.3 (L)	Dike	Remove	274	-9762.4	-650	
10.1 (L)	Dike	Remove	274	-7772.4	-575	
7.9 (L)	Dike	Remove	273	-26582.0	-560	
		Total Rock Volume (pile dike excluded)		-42002.6		

F. Description of the Placement Method.
Placement and removal of dike material would be accomplished by track hoe or dragline crane. Stone would be transported to placement sites by barges. All construction would be accomplished from the river and all work would be performed below ordinary high water. Channel maintenance dredge disposal will be done using the St. Louis District's flexible floating dredge disposal pipe (flex-pipe).

2. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations

I. Elevation and Slope.

SCED
There would be an immediate change in substrate elevation and slope over the areal extent of the SCED at RM 10.05 L. The SCED would consist of a rock mound of uniform shape, approximately 650 ft. long, angled slightly upstream and extending toward the navigation channel. The top elevation of the SCED would be 294 ft. (NGVD). Side slopes would be approximately 1 vertical on 1.5 horizontal. After placement, sediment patterns in the immediate vicinity of the structures would change with scour occurring off the end of the SCED. Areas immediately downstream of the SCED would experience some areas of accretion and some areas of scour.

The SCED would be placed along the LDB side of the channel at the entrance to Boston Chute. It would be angled slightly upstream in order to divert water into the side channel, resulting in increased flow velocity in the side channel, increased duration of connectivity with the main-stem of the Mississippi River, and decreased sediment accretion rates.

The SCED will be constructed of Graded A-Stone (Limestone) placed from floating plant (no bankline access needed). The benthic habitat that would be buried by the SCED at RM 10.05 L is approximately 0.15 acres.

Rock Dike Removal
There would be an immediate change in substrate elevation and slope over the areal extent of the dike locations between RM 7.9 – 10.3 L. The dikes consist of a rock mound of uniform shape, between 560 and 650 feet long, placed off the existing bankline and extending toward the navigation channel. After removal, the elevation would be 274 ft. (NGVD).

The structures consist of Graded A-Stone (Limestone), and will be removed by floating plant (no bankline access needed). Approximately 1.1 acres of benthic habitat will be exposed after the dikes are removed.

Pile Dike Removal
There would not be an immediate change in substrate elevation or slope over the areal extent of the pile dike at 10.3 L. The dike consists of a wooden piles spaced 5 ft. apart, and driven to approximately 15 ft. into the substrate. Approximately 250 ft. of the pile dike will be removed from the entrance to Boston Chute.

Sandbar Creation with Dredge Disposal
After channel maintenance dredging is performed, there would be an immediate change in substrate elevation and slope over the areal extent of the dredge disposal location between dikes 8.0 and 8.3 L.

II. Sediment Type.
The work area is located within the existing channel of the MMR and within the side channel known as Boston Chute. The Middle Mississippi River channel is comprised mainly of sands with some gravels, silts, and clays. Channel maintenance dredge disposal material is anticipated to be mostly sand. The stone used for construction of the SCED would be Graded “A” limestone.

III. Fill Material Movement.
Rock fill material used in construction of the dikes is intended to be very stable and resistant to the erosive forces of the river. Nonetheless, some erosion of stone does occur, particularly during high flow events and winter ice conditions. This may result in the need for minor repairs; however, no major failures are likely to occur.

The dredged material placement site used for sandbar creation is expected to eventually return to its original elevation, with fill material gradually eroding and migrating downstream. How quickly this occurs is largely dependent on the river stages subsequent to placement. Higher stages and flows will likely result in greater erosion.

IV. Physical Effects on Benthos.
Rock placement and dredge disposal should not significantly affect benthic organisms. Shifting sediments at structure placement sites likely harbor oligochaetes, chironomids, caddisflies, turbellaria, and other macroinvertebrates. High densities of hydropsychid caddisflies and other

macroinvertebrates would be expected to colonize the large limestone rocks after construction. Fish would temporarily avoid the work areas during construction and dredge disposal. Greater utilization of the location by fish is expected after construction due to the expected increase in densities of macroinvertebrates, as well as enhanced access to the side channel.

V. Actions Taken to Minimize Impacts.
Best Management Practices for construction would be enforced.

B. Water Circulation, Fluctuation, and Salinity Determinations

I. Water.
Some sediments (mostly sands) would be disturbed when the rock is deposited onto the riverbed, during dike removal, and during dredge disposal. This increased sediment load would be local and minor compared to the natural sediment load of the river, especially during high river stages.

II. Current Patterns and Circulation.
The SCED would continue to constrain the main channel of the MMR, helping to maintain the navigation channel, while diverting flow into Boston Chute. Construction of the SCED, coupled with the removal of rock dikes, closing structures, and a pile dike, would increase the flow velocity in Boston Chute, as well as the duration of connectivity between Boston Chute and the main-stem MMR.

III. Normal Water Level Fluctuations.
Stages at average and high flows both in the vicinity of the work area and on the MMR are expected to be similar to current conditions. Stages at low flows on the MMR show a decreasing trend over time and this trend is expected to continue with implementation of the Proposed Action.

IV. Actions Taken to Minimize Impacts. Best Management Practices for construction would be enforced.

C. Suspended Particulate/Turbidity Determinations

I. Expected Changes in Suspended Particles and Turbidity Levels in Vicinity of Placement Site.
Increases in suspended particulates and turbidity due to construction and dredge disposal activities are expected to be greatest within the immediate vicinity of the rock structures. The increased sediment load would be local and minor compared to the natural sediment load of the river. This would cease soon after construction completion.

II. Effects on Chemical and Physical Properties of the Water Column

a. Light Penetration. There would be a temporary reduction in light penetration until sediments suspended as part of construction activities settled out of the water column.
b. Dissolved Oxygen. No adverse effects expected.

c. Toxic Metals and Organics. No adverse effects expected.
d. Aesthetics. Aesthetics of work sites are likely to be adversely affected during construction, but are expected to return to normal after construction.

III. Effects on Biota.
The work would likely result in some short-term displacement of biota in the immediate vicinity of construction activities due to temporary decreases in water quality and disturbance by construction equipment.

IV. Actions Taken to Minimize Impacts. Impacts are anticipated to be minimized by the use of clean, physically stable, and chemically non-contaminating limestone rock for construction.

D. Contaminant Determinations.
It is not anticipated that any contaminants would be introduced or translocated as a result of the proposed action.

E. Aquatic Ecosystem and Organism Determinations

I. Effects on Plankton.
The work could have a temporary, minor effect on plankton communities in the immediate vicinity of the work area. This would cease after construction completion.

II. Effects on Benthos.
Sediments at structure placement sites likely harbor oligochaetes, chironomids, caddisflies, turbellaria, and other macroinvertebrates. Construction activities would eliminate some of these organisms. High densities of hydropsychid caddisflies and other macroinvertebrates would be expected to colonize the large limestone rocks after construction. Fish would be expected to temporarily avoid the area during construction. Greater utilization of the location by fish is expected after construction due to the expected increase in densities of macroinvertebrates, and enhanced access to the side channel.

Sediments at the sandbar creation site likely harbor oligochaetes, chironomids, caddisflies, turbellaria, and other macroinvertebrates. Dredged material placement would eliminate some of these organisms. However, due to the relatively small footprint of the sandbar in relation to similar main channel border habitat throughout the MMR, this impact is anticipated to be minor.

III. Effects on Nekton.
Nekton would be temporarily displaced during construction activities, but would return shortly after completion. Greater utilization of the area by fish may occur after construction due to the enhanced connectivity with Boston Chute.

IV. Effects on Aquatic Food Web.
Temporary reductions in macroinvertebrate and fish communities during construction in the relatively small work area should not significantly impact the aquatic food web in the MMR. Improvements in lower trophic levels (macroinvertebrates) subsequent to completion should benefit the aquatic food web.

V. Effects on Special Aquatic Sites.
There are no special aquatic sites within the work area.

VI. Threatened and Endangered Species.
Presence of, or use by, endangered and threatened species is discussed in the Environmental Assessment and Biological Assessment. This work is specifically intended to benefit endangered species.

VII. Other Wildlife.
The work would likely result in some very localized, short-term displacement of wildlife in the immediate vicinity of construction activities. Displacement would end immediately after construction completion.

VIII. Actions Taken to Minimize Impacts.
Best Management Practices for construction would be enforced.

F. Proposed Placement Site Determinations

I. Mixing Zone Determinations.
The fill material is inert and would not mix with the water. The lack of fine particulate typically contained in rock fill and main channel sediments indicates negligible chemical or turbidity effects resulting from the proposed action.

II. Determination of Compliance with Applicable Water Quality Standards.
Section 401 water quality certification has been applied for. All permits necessary for the completion of the work would be obtained prior to implementation.

III. **Potential Effects on Human Use Characteristics.**
The proposed work would have no adverse impact on municipal or private water supplies; water-related recreation; aesthetics; or parks, national and historic monuments, national seashores, wilderness areas, research sites or similar preserves. During construction the area would not be available for recreational and commercial fishing.

G. Determinations of Cumulative Effects on the Aquatic Ecosystem.
Dikes and weirs have been used extensively throughout the Lower, Middle, and Upper Mississippi River System to provide a safe and dependable navigation channel. Due to concerns from natural resource agency partners about the potential cumulative impacts of river training structures, and other actions within the watershed, on the aquatic ecosystem, the St. Louis District has been utilizing innovative river training structures such as side channel enhancement dikes to increase habitat diversity in the MMR while still maintaining the navigation channel. The District conducts extensive coordination with resource agency and navigation industry partners to ensure that implementation is accomplished effectively from an ecological and navigation viewpoint. Although minor short-term construction-related impacts to local fish and wildlife populations are likely to occur, only minimal cumulative impacts on the aquatic

ecosystem are identified for the Boston Bar Side Channel Restoration and Island Creation Project.

H. Determinations of Secondary Effects on the Aquatic Ecosystem.
No adverse secondary effects would be expected to result from the proposed action.

3. FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON PLACEMENT

A. No significant adaptations of the 404(b)(1) guidelines were made relative to this evaluation.

B. Alternatives that were considered for the proposed action included:

1. No Action Alternative - The No Action Alternative consists of not removing dikes and closing structures, not constructing the SCED, and not using dredge disposal material from future channel maintenance dredging to build sandbar habitat.

2. Proposed Action - The Proposed Action consists of removing three rock dikes at RM 7.9-10.3 L, notching a pile dike at RM 10.3 L, constructing a SCED at 10.05 L, and using dredge disposal material from future channel maintenance dredging to build sandbar habitat between dikes 8.0 and 8.3 L.

C. Certification under Section 401 of the Clean Water Act has been applied for.

D. The proposed fill activity is in compliance with Applicable Toxic Effluent Standards of Prohibition under Section 307 of the Clean Water Act.

E. No significant impact to threatened or endangered species is anticipated from this work. Prior to construction, full compliance with the Endangered Species Act would be documented.

F. No municipal or private water supplies would be affected by the proposed action, and no degradation of waters of the United States is anticipated.

G. The work area is situated along an inland freshwater river system. No marine sanctuaries are involved or would be affected by the proposed action.

H. The materials used for construction would be chemically and physically stable and non-contaminating

I. The proposed construction activity would not have a significant adverse effect on human health and welfare, recreation and commercial fisheries, plankton, fish, shellfish, wildlife, or special aquatic sites. No significant adverse effects on life stages of aquatic life and other wildlife dependent on aquatic ecosystems are expected to result. The proposed construction activity would have no significant adverse effects on aquatic ecosystem diversity, productivity, and stability. No significant adverse effects on recreational, aesthetic, and economic values would occur.

J. No other practical alternatives have been identified. The proposed action is in compliance with Section 404(b)(1) of the Clean water Act, as amended. The proposed action would not significantly impact water quality and would enhance habitat diversity in the Middle Mississippi River.

____
(Date)

____
ANTHONY P. MITCHELL
COL, EN
Commanding

Appendix D. Summary of Research on the Effects of River Training Structures on Flood Levels

APPENDIX D

Summary of Research on the Effects of River Training Structures on Flood Levels

1. Introduction

With implementation of the Proposed Action, stages at average and high flows both in the vicinity of the project area and on the Middle Mississippi River are expected to be similar to current conditions. An abundance of research has been conducted analyzing the impacts of river training structures on water surfaces dating to the 1930s. This research includes numerical and physical models as well as analyses of historic gage data, velocity data, and cross sectional data. In addition to continued monitoring and analysis, the U.S. Army Corps of Engineers (Corps) has conducted a literature review of all available literature on the impact of river training structures on flood levels. A summary of research on the topic is detailed below. Based on an analysis of this research by the Corps and other external reviewers, the District has concluded that river training structures do not impact flood levels.

2. Studies concluding no impact on flood levels

2.1 Historic Research

One of the early studies specifically addressing the effect of river training structure construction on water surfaces was conducted during the extreme high water of June and July 1935 (Ressegieu 1952). This study was prompted by the differences in observed stream flow for equal stages following the transfer of stream gaging responsibility from the Corps to the United States Geological Survey (USGS) in March 1933. When observed field data showed a major change in the stage for which a specific discharge was passing, the Corps and USGS initiated a study to determine the cause. This study addressed the accuracy of the standard equipment and method of observation between the two agencies. Similar simultaneous stream flow studies were conducted between 1935 and 1948. In 1952, the results of all of the studies were analyzed and it was concluded that, on average, the discharges measured by the Corps generally exceeded those measured by the USGS by zero percent at mean stage to slightly more than ten percent at high stages. Ressegieu (1952) concluded that "the reduction in floodway capacity was not an actual physical reduction but an apparent reduction caused by a discrepancy in the accuracy of measuring stream flow by older methods and equipment". The conclusions by Ressegieu (1952) were analyzed along with new information and confirmed by Watson et al. (2013a).

Monroe (1962) conducted a comprehensive analysis of all factors which are believed to have had some effect on the St. Louis rating curve including: accuracy of discharge measurements, man-made obstructions and hydrology and hydraulic changes. Monroe (1962) observed a spread in stage for equivalent discharge at flows with stages of about 35 and 40 ft on the St. Louis gage. The analysis concluded that the change in stage for higher flows was due to the construction and raising of levees between 1935 and 1951. In an analysis of river training structures, Monroe (1962) found that "the contraction by permeable dikes has had a negligible effect on the increase in flood heights." A number of natural factors were found to affect stages for equivalent discharge including: season (water temperature), rapidity of rise of the flood wave, amount of flow contribution by the upper Mississippi River and the amount of bed material carried by the Missouri River.

In a comprehensive study of hydrologic, hydraulic, geologic and morphologic factors which relate to the Mississippi River downstream of Alton, IL, Munger et al. (1976) studied the changes in hydraulics on the Mississippi River resulting from river confinement by levees and the construction of river training structures. As was the case in previous studies using gage data, the reliability of early discharge data collected by the Corps was brought into question. In a study of velocity, stage and discharge data, Munger et al. (1976) concluded that "generalizations about the effect of dikes on stage-discharge relations are not justified." When examining cross section shape and velocity distributions at the St. Louis gage, it was observed that there had been no striking changes in cross-section shape or velocity distributions at the section between 1942 and 1973.

Dyhouse (1985, 1995) found through numerical and physical modeling that published discharges for historic floods, including 1844 and 1903, were overestimated by 33 and 23 percent, respectively. Dyhouse concluded that the use of early discharge data collected by the Corps, including historic peak flood discharges in conjunction with stream flow measurements by the USGS, will result in incorrect conclusions.

Other reach scale numerical and physical models studying the effect of river training structures on water surfaces include USACE (1996) which used a Hydrologic Engineering Center (HEC-2) model used to analyze pre- and post- construction water surface elevations for the Nebraska Point Dike field on the Lower Mississippi River. For each cross section analyzed, the dike field construction lowered water surface elevations and reduced overbank discharges for the50%, 20%, and 10% annual chance exceedance events. Xia (2009) used an AdaptiveHydraulics (AdH) model to study the changes in water surface resulting from the constructionof a dike field. In this fixed bed analysis, Xia found that changes in water surface elevation due to the dikes was greatest at average flows and decreased with increasing and decreasing river flow. Azinfar and Kells (2007) developed a multiple function model to predict the drag coefficient and backwater effect of a single spur dike in a fixed bed. This study concluded that increasing submergence levels resulted in a decreasing backwater effect.

In a moveable bed model study conducted to develop structural alternatives for a power plant on the Minnesota River, Parker et al. (1988) measured water surface changes from a baseline for a series of dikes and determined that construction of the structures had a negligible effect on flood stages compared to calibration values. Yossef (2005) used a 1:40 scale fixed bed physical model of the Dutch River Waal to study the morphodynamics of rivers with groynes (dikes are referred to as groynes in other parts of the world including the Netherlands) including their effect on water surface. Yossef found that on the River Waal, the effect of groynes decreased with increasing submergence. It was also observed that the maximum possible water level reduction of the design flood (378,000 cfs) by lowering all of the groynes in the system was 0.06 meters (2.4 inches).

Other international research supports the conclusion that river training structures do not impact flood levels. An international technical working group made up of experts from around the world organized by PIANC, the World Association for Waterborne Transport Infrastructure, analyzed the impact of dikes on high discharges. It was determined that dikes can be designed to avoid high water impacts by having a top elevation below mean high water (similar to what is used on the Middle Mississippi River (MMR). The report describes that although dikes may increase hydraulic resistance, the erosion of the low water bed may compensate for the water level upset entirely. The report also cites conventional practice that requires dikes to be designed so they do not increase stage during high discharges (PIANC 2009). As an engineering organization, the Corps follows this conventional practice and ethical code to ensure that dike construction does not cause an impact to public safety.

2.2 Updated Evaluations

2.2.1 Watson & Biedenharn

To update ongoing evaluations of the physical effects of river training structures, the Corps initiated a new study on the possible effect of these structures on water surfaces in 2008. This series of studies included an analysis of past research, an analysis of the available gage data on the MMR, an analysis of historic measurement technique and instrumentation and its effect on the rating curve, specific gage analysis, numerical and physical modeling. In addition to the research conducted by the Corps, the St. Louis District engaged with external technical experts in the fields of river data collection, river engineering, geomorphology, hydraulics and statistics.

In a review of historic stream flow data collected prior to the USGS, Watson & Biedenharn (2010) determined that pre-USGS data should be omitted for the following reasons: (1) It has been confirmed through simultaneous measurement comparisons that there is much uncertainty in the historic data due to differences in methodology and equipment; (2) there is much uncertainty with respect to the location of the discharge range; (3) there is insufficient measured data at the higher flow ranges to produce reliable specific gage records; and (4) the homogeneous data set containing all discharges collected by the USGS provides an adequate long-term, consistent record of the modern-day river system including periods of significant dike construction. A more detailed description of the limitations of early discharge measurements can be found in Watson et al. (2013a).

In their analysis, Watson & Biedenharn (2010) studied the specific gage records at the three rated gages on the MMR: St. Louis, Chester and Thebes. A summary of the analysis techniques used and a detailed analysis of the specific gage record at St. Louis can be found in Watson et al. (2013b). The analysis for the gage at Thebes was omitted due to the effect of backwater from the Ohio River. For each stream gage studied, the specific gage record was analyzed and compared with a record of river training structure construction for a reach extending 20 river miles downstream. All data used in their study were collected by the USGS and retrieved from the USGS website (http://www.usgs.gov).

Bankfull stage at the St. Louis gage is approximately +30 feet with a corresponding discharge of approximately 500,000 cubic feet per second (cfs). Flows below 400,000 cfs are contained within the top bank and flows above 700,000 cfs are well above the top-bank elevation. The time period 1933-2009 was studied. The top elevation of training structures in this reach was between +12 and +16 feet referenced to the St. Louis gage. All structures are completely submerged at discharges exceeding 280,000 cfs. In their analysis, Watson and Biedenharn (2010) found a statistically significant slightly decreasing trend in stream flows below 200,000 cfs. In stream flows between 300,000 cfs and 500,000 cfs, a statistically significant horizontal trend in stages was observed. At 700,000 cfs a non-statistically significant, slightly increasing trend in stages was observed. The slight upward trend in stages at 700,000 cfs had considerable variability in the data and was strongly influenced by the 1993 flood.

Bankfull stage at the Chester gage is approximately +27 feet with a corresponding discharge of approximately 420,000 cfs. The time period 1942-2009 was studied. The top elevation of navigation structures in this reach was +14 to +17 feet referenced to the Chester gage. All structures are completely submerged at discharges exceeding 280,000 cfs. The only statistically significant trend found was a slightly decreasing trend for stream flows below 100,000 cfs. There was a horizontal trend for 200,000 and 400,000 cfs. There was a slightly increasing trend at 300,000 cfs. For both overbank flows, 500,000 cfs and 700,000 cfs, there were slight increasing trends.

After a closer examination of the specific gage trends it was apparent that the long term trends for both St. Louis and Chester were not continuous and there was a shift in stages that occurred in 1973. This year was significant because (1) 1973 was marked by the occurrence of a major flood event that is documented as having significant impacts on the morphology of the MMR, (2) the year 1973 marked the end of a remarkably flood free period and (3) the pre-1973 period was characterized by extensive dike construction whereas the post-1973 period saw 50% less dike construction. When the record was broken into pre- and post-1973 sections, different trends were observed. Prior to 1973 at all gages studied, there were no increasing trends for any of the flows. Post-1973 there were no increasing stage trends for within-bank flows at any of the gages. A slightly increasing stage trend occurred for overbank flows of 500,000 cfs (statistically significant) and 700,000 cfs (not statistically significant) at the Chester gage. A majority of the construction of river training structures on the Middle Mississippi was performed prior to 1973.

In conjunction with the specific gage record, Watson & Biedenharn (2010) and Watson et al. (2013) analyzed the record of training structure construction including an analysis of the top elevation of the structures. The typical top elevation of the structures was 10-16 feet below the top bank. Since the top elevation is so far below top-bank elevations, the most dramatic impacts of the structures should be in the low to moderate stages below top bank where the specific gage analysis revealed decreasing or no trends (Sukhodolov, 2013; Watson & Biedenharn 2010; USGAO 2011, PIANC 2009, Azinfar & Kells 2007, Stevens et al. 1975, Chow 1959).

Watson & Biedenharn (2010) concluded that, "based on the specific gage records, there has been no significant increase in stages for within-bank flows that can be attributable to river training structure construction. Any increase in overbank flood stages may be the result of levees, floodplain encroachments, and extreme hydrologic events; and cannot be attributed to river training structures based solely on specific gage records."

2.2.2 United States Geological Survey

Huizinga (2009) conducted a specific gage analysis using the direct step method on only data collected by the USGS for the gages at St. Louis and Chester. Similar to Watson & Biedenharn (2010), an apparent decrease of stage with time for smaller, in bank discharges was observed at both the St. Louis and Chester gages. This decrease in stage was attributed to the construction of river training structures and/or a decrease in sediment load available for transport on the Mississippi River due to the construction of reservoirs on the main stem tributaries of the Mississippi River, particularly the Missouri River.

Huizinga (2009) found a slight increase in stage over time for higher flows at both St. Louis and Chester over the entire period of record. The transitional discharge was 400,000 cfs and 300,000 cfs for the St. Louis and Chester gages respectively. These discharges correspond to stages of +25 feet at St. Louis and +22 feet at Chester. At these stages the navigation structures are submerged by 5-13 feet. Huizinga (2009) attributed the slight increase in out of bank flows to the construction of levees and the disconnection of the river to the floodplains. Similar to Watson & Biedenharn (2010), Huizinga (2009) observed a shift occurring in the out of bank flows in the mid-1960s and attributed it to the completion of the Alton to Gale levee system which paralleled the entire Middle Mississippi River.

In an analysis of cross sectional data collected at the St. Louis and Chester gages, it was found that although the shape of the cross section had changed, the cross sectional area for moderate (400,000 cfs) and high (600,000 cfs) flows remained relatively constant throughout the period of record. The construction of river training structures immediately upstream of the Chester gage provided a case study on the effect of the absence and construction of structures on the cross section over time. Prior to the construction of the structures, the channel thalweg repeatedly shifted between the left and right banks. Following the construction of the structures, the cross sections displayed much less variability. An overall stabilizing effect of the structures was seen on the cross section for discharges of 100,000 cfs and 400,000 cfs. The cross sectional area for the first and last measurements of the period of record remained similar despite the river training structure construction upstream for all discharges.

Huizinga (2009) conducted a study of all rating curves developed for St. Louis and Chester, including those developed prior to 1933 by the Corps. When comparing daily values from the Corps from 1861-1927 to the original USGS rating in 1933 there appeared to be an abrupt change in the upper end of the ratings used before 1933. When these daily values developed by the Corps were adjusted to compensate for the overestimation of Corps discharge measurements detailed in the simultaneous discharge measurement studies between the Corps and USGS, the adjusted daily discharge values plotted in line with the original USGS rating. This study is further evidence of the overestimation of early discharges.

2.2.3 *Statistical Evaluation*

A critical review of the statistical analysis used to support specific gage analyses by Pinter et al., (2001) and Pinter and Thomas (2003) was conducted by V.A. Samaranayake (2009) from the department of Mathematics and Statistics at Missouri University of Science and Technology. Samaranayake (2009) concluded that the analysis presented by Pinter et al., (2001) and Pinter and Thomas (2003) did not support the conclusions that river training structures are increasing stages for higher discharges. In an evaluation of the two types of specific gage analysis, Samaranayake (2009) concluded that the direct step method was the most appropriate on the MMR. This is due to the data points being more homogeneous than those obtained from the rating method as far as variance is concerned and therefore they can be considered devoid of simultaneity bias and other such artifacts.

Samaranayake (2009) also found that, when using computed daily discharge values, the researcher is essentially recreating the original USGS rating curves used to obtain the daily discharges. The computed daily discharge data lacks the natural variability found in measured streamflow and can lead to conclusions that are due to artifacts created by errors in the original rating curves. This error is compounded by the fact that the USGS uses the same rating curves for several years producing results that, rather than being independent, are correlated across several years.

Samaranayake (2009) questioned the cause and effect relationship concluded by Pinter et al., (2001). The straight trend lines concluded by Pinter et al. (2001) revealed an increasing trend in stages reflecting a smooth gradual increase. Dike construction was not constant throughout history. The history of dike construction revealed much variability in magnitude throughout the period of record and did not directly correlate with the trends observed by Pinter (2001). Pinter et al., (2001) failed to prove that the relationship between stage trends on the MMR and dike construction was statistically significant.

2.2.4 Numerical and physical modeling studies

The Iowa Institute of Hydraulic Research (IIHR) at the University of Iowa performed a series of hydrodynamic simulations of a recently constructed chevron field and dike extension using the United States Bureau of Reclamation Sedimentation and River Hydraulics Two-Dimensional (SRH-2D) modeling software (Piotrowski et al. 2012). Simulations studied the impact of the construction on water surfaces and the magnitude of natural variation on water surfaces. The results indicated that structures did not cause significant differences in reach-scale water surface elevations. The simulations also found that the differences in pre- and post-construction water surface elevations were less than the differences resulting from natural variability in two post-construction scenarios.

In a hydrodynamic study of the Vancill Towhead reach of the Middle Mississippi River, USACE (2016) evaluated the impact of a proposed set of river training structures on water surfaces for a discharge with a 1% annual chance of exceedance using an Adaptive Hydrauilcs (AdH) model. These structures included weirs and S- shaped dikes. The AdH model study incorporated sediment transport by evaluating water surfaces for pre- and post- construction scenarios from a physical sediment transport model. The study concluded that the proposed structures in the Vancill Towhead reach have no impact on water surfaces for a 1% of annual chance of exceedance (ACE) discharge of 949,011 cfs.

A physical sediment transport model at the University of Illinois, Urbana-Champaign was used to test the effect of submerged dikes and dike fields on water surfaces (Brauer 2013). The study tested flows and stages along a rating curve from ½ bankfull to a flow with a 0.5% annual chance exceedance. The study concluded that the magnitude of the effect of dikes on water surfaces was smaller than the natural variability in the stage and discharge relationship and decreased with increasing flow/submergence. The study also found that there was no direct cumulative effect for up to four structures.

2.2.5 Analysis of Updated Evaluations

Dike elevation information relative to the gages at St. Louis, Chester and Thebes are important in the interpretation of the specific gage results. On the MMR, dike elevations are well below the top-bank elevations and are submerged by over thirty feet during major floods. The most dramatic impacts of the dikes are expected to be observed in the low to moderate stages below top bank (Sukhodolov, 2013; Watson & Biedenharn, 2010; USGAO,2011; PIANC, 2009; Azinfar & Kells, 2007; Stevens et al., 1975; Chow 1959). Once the flows spill overbank, the specific gage trends are impacted by changes in the floodplain including bridge abutments, levee construction, vegetation changes, etc. (Huizinga 2009, Heine and Pinter 2012). The effect of levees on the stages of larger floods is more pronounced than at lesser floods due to the additional conveyance loss of the floodplain (Simons et al. 1975, Heine and Pinter 2012).

The magnitude of the stage changes for overbank discharges observed by Watson & Biedenharn (2010), Watson et al. (2013), and Huizinga (2009) are consistent with the expected changes due to the construction of levees along the MMR. The Upper Mississippi River Comprehensive Plan (USACE 2008) calculated that levees contributed an increase of up to 2.9 feet at St. Louis, Missouri and up to 7.3 feet at Chester, Illinois of the 1% annual chance exceedance flood (100-year). The Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries report (USACE 1995) calculated that agricultural levees contributed an average peak stage increase of up to 4.9 feet on the MMR between St. Louis and Cape Girardeau. The Mississippi Basin Model (MBM) tests showed an increase of up to 4 feet compared to 1820 conditions, depending on discharge and location of flooding (Dyhouse 1995). The magnitude of levee impact is dependent on the roughness of the floodplain being protected. The values detailed above generally assume agricultural land.

Through the use of numerical and physical models, Piotrowski (2012) and Brauer (2013) reinforced the conclusion that river training structures do not impact flood flows. Additionally, Piotrowski (2012) and Brauer (2013) quantified the impact of natural variability in the channel on stage. Brauer (2013), through the use of a moveable bed model, demonstrated the importance of sediment transport and bed changes when analyzing how river training structures influence stages. In a study specific to the Middle Mississippi River, USACE (2016) found that construction of a series of S- dikes does not impact water surfaces for a discharge with a 1% annual chance of exceedance.

3. Analysis of research proposing a link between instream structures and an increase in flood levels.

The Corps has researched and analyzed all available literature that either purports or has been claimed to purport that river training structures increase flood heights. Comments received on the draft Environmental Assessment have provided a list of 51 studies claimed to link the construction of instream structures to increases in flood levels. However, only 21 of the 51 journal articles, technical notes, book chapters, and conference papers cited attempt to link the construction of instream structures to increases in flood levels. The remaining thirty studies cited do not discuss the construction of instream structures and/or increases in flood levels. Some of the cited papers simply reference the research of others as background information. Others discuss the topics of flow frequency, physical modeling and model scale distortion, and levee construction. Others are on topics unrelated to instream structures and/or flood levels.

This appendix only discusses in detail the journal articles, technical notes, book chapters, and conference papers whose conclusions claim a link between instream structure construction and an increase in flood levels. Some of the analyses are presented in multiple papers. Since the analysis in Pinter et al. (2000) is the basis for Pinter et al. (2001a), Pinter et al. (2001b), Pinter et al. (2002), Pinter et al. (2003), Pinter and Heine (2005), Pinter et al. (2006b) and Szilagyi et al.

(2008), only Pinter et al. (2000) will be discussed in detail. Similarly, the analysis in Jemberie et al. (2008) is the basis for Pinter et al. (2008), Pinter (2009), and Pinter et al. (2010). Only Jemberie et al. (2008) will be discussed in detail.

The studies whose conclusions claim a link between instream structure construction and an increase in flood levels have been grouped below into three categories: specific gage analysis, numerical simulations and physical fixed bed modeling.

3.1 Specific Gage Analysis

Fifteen of the journal articles, technical notes, book chapters, conference papers and editorials proposing a link between instream structures and an increase in flood levels rely on the use of specific gage analysis.

3.1.1 Description

Specific gage analysis is a graph of stage for a specific fixed discharge at a particular gaging location plotted against time (Watson et al 1999). The use of specific gage analysis is a simple and straightforward method to illustrate aggradation and degradational trends in a river or the response of a river to various alterations in the channel. Similar to most engineering analyses, the interpretation of specific gage records can be complex.

Specific gage analysis is an analysis of field data collected at gage locations along a river. The measurements that are collected at the gage locations are stage (water height), velocity (speed of the water) and cross sectional area (area of the channel). Velocity and area are multiplied together to calculate the discharge which is the volume of water passing a fixed location. It is important to ensure that the methodology and instrumentation used to collect velocity and cross sectional area has not changed during the period of record being examined. If it has changed, it is important to understand how those changes in instrumentation and methodology impact the results. As detailed above, the period of record on the MMR includes two distinctly different data sets.

3.1.2 Papers using specific gage analysis to link instream structure construction to flood level increases

The first use of specific gage analysis to link instream structures to apparent changes to the stage-discharge relationship on the Middle Mississippi River dates back to Stevens et al. (1975) and Belt (1975). Flaws in the source data, methodology and analysis used by Stevens et al. (1975) were addressed by Stevens (1976), Dyhouse (1976) Strauser & Long (1976) and Westphal & Munger (1976). These include the following: use of limited cross-sectional data from one highly engineered reach of the MMR (St. Louis harbor) to represent the entire Middle Mississippi River; use of the unmeasured 1844 flood discharge and the 1903 flood discharge, which was measured only at Chester and Thebes using a different analysis to draw sweeping conclusions; use of early inaccurate and overestimated discharge measurements in conjunction with more accurate contemporary measurements; and the lack of a direct correlation between dike construction and trends in water surface changes.

Through a comparison of trends in stage and stream flow measurements from floods from 1862-1904 to those after the 1980s, Criss & Shock (2001) concluded that stages have increased over time on rivers due to the construction of river training structures. Criss & Shock (2001) also analyzed rivers with and without river training structures to determine the impact structures have on water surfaces. The conclusions of Criss & Shock (2001) are driven by the comparison of two distinctly different data sets: early discharges collected by the Corps and contemporary discharges collected by the USGS. As detailed above, combining early Corps discharge measurements with contemporary USGS discharge measurements without appropriately accounting for the differences in accuracy of those measurements can result in flawed conclusions.

Pinter et al. (2000) used specific gage analysis to study changes to the stage-discharge relationship, cross-sectional area and velocity on the Middle Mississippi River. A specific gage trend was developed using daily stage and discharge data from the Middle Mississippi River gages at St. Louis, Chester, and Thebes. Pinter et al. (2000) concluded that engineering modifications on the Middle Mississippi River have caused changes in the cross-sectional geometry and flow regime leading to a decrease in stages for low discharges and rising stages for water levels starting at 40%-65% of bankfull discharge and above. Since their analysis shows rises in stages are greater for larger discharges, the authors conclude that the impact of the changes is greatest for large flood events.

One limitation of specific gage analysis is that it can only be performed on rated gages (gages with a discharge record). Jemberie et al. (2008) developed a refined specific gage approach attempting to overcome this limitation by developing “synthetic discharges” at stage only gages. The synthetic discharges were created by interpolating discharge values at nearby gages to create a stage- discharge relationship at stage only gages. Rare discharges were created using “enhanced interpolation” to formulate a continuous specific gage time series for large, rare discharges. The results of the refined specific gage study were that stages that correspond to flood discharges increased substantially at all stations consistent with what was documented by Pinter (2001).

3.1.3 Errors in specific gage papers

3.1.3.1 Use of a non-homogeneous data set

The analysis in Pinter et al. (2000) and Jemberie et al. (2008) includes data, assumptions and analysis techniques that have been brought into question by engineers and scientists within the Corps, USGS and academia. The period of record data set used by Pinter et al. (2000) and Jemberie et al. (2008) combines daily discharge measurements from rating curves developed by both the Corps of Engineers and USGS. The use of daily discharge data from the entire period of record implies the assumption that the rating curves have been developed using the same methods throughout the period of record and the measured discharges used to develop the rating curves were collected similarly throughout the period of record. On the MMR, this assumption is not valid since the period of record of discharge measurements is two distinctly different data sets as discussed above.

In an effort to disprove the long standing joint conclusion of the Corps and USGS that Corps measurements overestimated discharges compared to the USGS standard used after 1933 (Ressegieu 1952, Huizinga 2009, Watson et al. 2013a, Dyhouse 1976, Dyhouse 1985, Dyhouse 1995, Dieckmann & Dyhouse 1998), Pinter (2010) analyzed 2,015 measurements collected by the Corps on the Middle Mississippi River. The author concluded that early Corps discharges were not overestimated but were, in fact, underestimated. Based on this faulty conclusion, the author questions the adjustment of early data in the Upper Mississippi

River System Flow Frequency Study and the flood frequencies and flood profiles used by the Corps on the Middle Mississippi River.

Pinter (2010) did not analyze a data set sufficient to prove his hypothesis. The source data used by the author, *Corps of Engineers, 1935, Stream-flow measurements of the Mississippi River and its Tributaries between Clarksville, MO., and the Mouth of the Ohio River 1866-1934*, included only early Corps measurements using different instruments and methodologies employed by the Corps. The author did not analyze any measurements collected using USGS instruments and methodology or compare any early Corps measurements to ones collected by the USGS.

3.1.3.2 Use of Daily Discharge Values

The analysis by Pinter et al. (2000) used daily discharge values instead of measured discharges. Daily discharge values are values of discharge that are extracted from the rating curve using a measured value of stage for a specified gage location. A rating curve is a relationship between stage and discharge that is developed by creating a smooth equation using observed measured data. Rating curves usually incorporate data from multiple years to develop their relationship and therefore are not reflective of the river for one particular year.

The use of daily discharge data over direct measured discharges for the creation of a specific gage record is discouraged by many experts including Stevens (1979), Samaranayake (2009), Huizinga (2009) and Watson and Biedenharn (2010). Stevens (1979) recommended that "measured discharges should gain quick acceptance over estimates obtained from rating curves because they reveal the relationship that exists between discharge and the controlling variables at the time of measurement." Samaranayake (2009) cautioned against the use of data obtained from rating curves since "such data lacks the natural variability one finds in actual data and can lead to conclusions that are due to the artifacts created by errors in the original rating curves." Watson and Biedenharn (2010) acknowledged that it is often tempting to use the computed daily discharge values since they increase the number of data points and improve the statistics of the rating curve, but caution that these values are not valid and risk masking actual trends.

3.1.3.3 Analysis of early Corps and USGS rating curve development

Compounding the issues with using daily discharge measurements is the use of rating curves developed by multiple agencies using different standards and practices. Over the sixty-six years between 1861-1927, the Corps created five independent rating curves for the St. Louis gage. Curves were developed for the time periods 1861-1881, 1882-1895, 1896-1915, 1916-1918 and 1919-1927. Each curve was created with discharges collected within that time period. In most cases, the discharge measurements were not collected continuously through the rating period. For example, the first rating period which spans 1861 to 1881 was created using only 181 discharge measurements. All but four of the measurements were made in 1880 and 1881 (Huizinga 2009).

The rating curves employed by the USGS (starting in 1933 in St. Louis) are not as static as the early ratings used by the Corps. USGS rating curves are often shifted and changed to account for changes in the shape, size, slope and roughness of the channel. To keep the ratings accurate and up to date, USGS technicians visit each streamgage about once every 6 weeks to measure flow directly. The USGS also emphasizes measuring extreme high and low flows since they are less common and can greatly impact the ends of the rating curve.

Regardless of whether the early Corps or contemporary USGS rating curves are used, daily discharge measurements extracted from a rating curve do not represent the characteristics of the river at the gage location for a particular year. To analyze changes over time it is recommended to create independent annual rating curves using measured discharges all collected in a specific year or analyze measured discharges for specific discharge ranges over time.

3.1.3.4 Statistical Errors

There are significantly fewer points associated with the larger discharge values of the specific gage records than the more frequent discharges. For example, as of March 2014 there have been approximately 3,435 discharge measurements collected at the St. Louis gage since 1933. Only 253 measurements (7.4 percent) have been collected for flows above bankfull (500,000 cfs). Only 80 measurements (2.3 percent) have been collected for flows above 700,000 cfs. Forty percent of the measurements observed for flows greater than 700,000 cfs were collected during the 1993 flood.

When using the direct step method of specific gage analysis, the uncertainty for the flows with limited data is revealed in the statistics (Watson & Biedenharn 2010). Pinter et al. (2000) used the rating curve method of specific gage analysis using daily discharge which the author called "a powerful tool for reducing scatter in hydrologic time-series" (Pinter 2001). As with most dependent variable values predicted using a regression equation, the error in the regression equation is less close to the mean of the independent variable and increases toward the more extreme values (small and large discharge values). The net result is that Pinter et al. (2000) generated data that has varying degrees of error variance and the use of ordinary least squares estimation under such circumstances has lead to incorrect results (Samaranayake 2009).

3.1.3.5 Physical Changes on the MMR

Inherent in the use of a specific gage that spans a long time period is the understanding that errors and inconsistencies associated with the measurement of discharge and stage are captured in the record. Substantial changes in the river, if not accounted for, would all render the specific gage record unreliable.

For example, Pinter et al. (2000) uses a single linear regression to represent the trend for a given discharge value curve. This is problematic since it does not accurately represent all the time periods in the record. There are shorter periods of time observed in the presented specific gage records when stages are decreasing rather than increasing, and the linear trend sorely misrepresents the observed changes. Other problems with this approach are there were major physical changes that occurred throughout the period of record which are reflected by changes in the stage-discharge record. These include the capture of the Kaskaskia River which shortened the MMR by 5 miles, the construction of reservoirs which reduced the sediment load in the MMR, and the construction of levees throughout the period of record including the completion of the Alton to Gale levee system.

3.1.3.6 Creation and use of "Synthetic Discharges" and "enhanced interpolation"

Much of the analysis of Jemberie et al. (2008) is similar to the analysis of Pinter et al. (2000) and has the same issues as described above. The new contributions of Jemberie et al. (2008) are the development of 'synthetic discharges' for unrated gages and 'enhanced interpolation' to calculate continuous specific-stage time series for rare discharges.

The development of 'synthetic discharges' is simply the development of a discharge record for gages where discharge was not measured by interpolating between rated gages. The purpose of creating a discharge record is so a specific gage analysis can be performed at that gage. Since the discharge record at the 'synthetic gages' is inherently dependent on the discharge record at the legitimately rated gages, the data at the 'synthetic' gages are not independent and should not be treated as such. The creation of a rating for the 'synthetic gages' incorporates an abundance of uncertainty due to the many assumptions that need to be made.

Compounding the problems with interpolating between gages to create a discharge value at an unrated gage is the use of daily discharges as the source data for the interpolation. As detailed above, daily discharges are not measured values. The use of daily discharge values incorporates more error and uncertainty into the fabricated rating at the 'synthetic gages'.

For rare high flows, the true rating curve for an unrated gage may be heavily influenced by levee overtopping or other phenomena which would only be reflected through discharge measurements. The author does not detail or account for the impact of the assumptions made on the 'data' created for the 'synthetic gages'.

The practice of using 'enhanced interpolation' to generate a continuous time series for a particular fixed discharge is not supported by the Corps and many other engineers and scientists. Similar to the 'synthetic gage' data, the data created using 'enhanced interpolation' is based off of an interpolation scheme and is not measured data. The fabricated values are dependent on the other values used to create the time series trend.

To create the data using 'enhanced interpolation' one must assume that the time series for Q and $_*Q_t$ is continuous and linear. Watson et al. (2013b), Watson and Biedenharn (2010), Huizinga (2009) and Brauer (2009) have all shown that this assumption is not valid. Another assumption necessary is that there is only one specific stage value for each independent discharge, specifically at the highest and lowest discharges. Analyses of measured discharges have shown that stage is dependent not only on discharge but other physical characteristics of the channel (bed roughness, vegetation, sediment load, temperature, etc.). The use of 'enhanced interpolation' masks the natural variability in the relationship between stage and discharge.

Jemberie et al. (2008) does not make any attempt to verify the validity of the 'enhanced interpolation' technique by proving the relationship using stage and discharge relationships at rated gages.

3.1.4 Summary

A majority of the journal articles, technical notes, book chapters, and conference papers whose conclusions claim a link between instream structure construction and an increase in flood levels rely on specific gage analysis. The specific gage analyses that conclude that instream structures impact flood levels are all driven by the use of source data and methodology not supported by many engineers and scientists in the fields of river data collection, river engineering, geomorphology, hydraulics and statistics. Specific gage analysis studies conducted on the MMR also conclude that instream structures do not impact flood levels (Huizinga 2009, Watson & Biedenharn 2010 and Watson et al. 2013). The Corps does not give credibility to the conclusions of the specific gage analysis studies that attempt to link instream structures with increases in flood level due to the methodology and data use errors.

3.2 Papers using numerical simulations to link instream structure construction to flood level increases

3.2.1“Retro-Modeling”

Remo and Pinter (2007) developed a one-dimensional unsteady-flow “retro-model” of the Middle Mississippi River using historical hydrologic and geospatial data to assess the magnitude and types of changes in flood stages associated with twentieth century river engineering.

Comparison of the retro-model results with the 2004 Upper Mississippi River System Flow Frequency Study (UMRSFFS) revealed increases in flood stages of 0.7 – 4.7 m. The difference in flood stages between the UMRSFFS and retro-model increased with increasing discharge.

3.2.1.1 Errors in “Retro-Modeling” studies

3.2.1.1.1 Source Data

The large stage differences between current and early discharge estimates are partly due to the use of incorrect discharge values for historic hydrographs and floods occurring prior to 1933 as discussed above. The retro-modeling period of 1900-1904 includes one major flood in 1903 and a small one in 1904. The original estimated historic discharge of 1,020,000 cfs at St. Louis is used for the peak of the 1903 flood. This flow was originally developed for St. Louis from discharge measurements made at Chester. Tests conducted with the Mississippi Basin Model in the late 1980s found that a match of the 1903 high water marks through the entire reach of stream at St. Louis occurred for a discharge of about 790,000 cfs. The actual value of the 1903 discharge at St. Louis is likely to be approximately 230,000 cfs (or 23 percent) less than the value used by Remo and Pinter (2007) in the model calibration.

3.2.1.1.2 Channel Roughness

Manning’s ‘n’ is the value most often modified to achieve a calibration of the model results to known stages. Manning’s ‘n’ represents the relative roughness of a channel. The larger the Manning’s ‘n’ the more resistance there is to flow. Forcing a calibration of the high and incorrect discharge of the 1903 flood would require a surprisingly low ‘n’ value for the channel of about 0.02, as used by Remo and Pinter (2007). The authors observe that the ‘n’ values for the historical period were systematically at the lower end of the published ranges. In practice, this usually indicates a problem with the model geometry or input data.

The authors describe HEC-RAS as only allowing a single roughness coefficient value in the channel and separate values for the floodplains. The limitation of having “fixed” values was described as a source of model uncertainty. This statement by the authors is untrue — not only does HEC-RAS have the ability to vary the ‘n’ value horizontally across the cross sections, but it can also be varied for flow or season. All of these techniques are standard hydraulic engineering practice. Horizontal variation of the roughness may be necessary to generate reasonable model results and has a solid foundation in the literature, as noted by Remo and Pinter (2007).

3.2.1.1.3 Model Assumptions

One assumption that could affect model results is the absence of flows from tributaries in the model calibration. Another problematic model assumption is that land use in unmapped areas was forested. Large tracts of timber in the Mississippi Valley were harvested in the late 1800s and early 1900s. The 'retro-model' also does not appear to consider how under the natural (before levee construction) conditions, flood water entering the floodplain over natural levees likely returned to the channel through a series of backwater swamps and channels. This may explain the apparent tendency of the model to over predict stages on the falling limb of the hydrograph. This natural drainage system was likely altered during conversion of the floodplain to agricultural production.

3.2.1.2 Corps Conclusions and Analysis

The calibration of the "retro-model" has been questioned by the Corps due to the use of early Corps discharges, surprisingly low 'n' values used, and other model assumptions detailed above. The Corps believes that the surprisingly low Manning's roughness values were necessary to compensate for the overestimated flows used in the model and are not representative of the characteristics of the historic channel.

The Corps takes the conclusions of Remo & Pinter (2007) very seriously and has attempted to work with the authors to verify the model results and gain a full understanding of the physical processes driving their concluded increase in flood stage. This research was carried out with support from the US National Science Foundation (NSF) grants EAR-0229578 and BCS-0552364. National Science Foundation policy states that, "Investigators are expected to share with other researchers, at no more than incremental cost and within a reasonable time, the primary data, samples, physical collections and other supporting materials created or gathered in the course of work under NSF grants." However, to date, the authors have refused to provide the model, data or any other supporting materials to the Corps' St. Louis District, although multiple requests for this information have been made.

3.2.2 Retro and Scenario Modeling

Remo et al. (2009) is an expansion of Remo and Pinter (2007). In addition to the comparison of the 'retro-model' to the UMRSFFS, Remo et al. (2009) run a series of scenario models to quantify the impact of levees, channel change and land cover. Remo et al. (2009) concluded that on the MMR in the "St. Louis Reach" levees accounted for 0.1 – 1.0 m of increase in stage, changes in channel geometry accounted for a stage increase of 0.1-2.9 m, changes in total roughness accounted for a stage increase of 0.1 – 1.4 m, and changes in land cover accounted for a stage increase of up to 0.4 m.

Similar to the model effort of Remo and Pinter (2007), the Corps has attempted to work with the authors to verify the model results and gain a full understanding of the physical processes driving their concluded increase in flood stage. To date the authors have refused to provide a copy of the model and associated data used to develop the conclusions of Remo et al. (2009) for review by the Corps in spite of the NSF policy requirements detailed above. This research was funded by NSF Grants EAR-0229578 and BCS-0552364.

Remo et al. (2009) concludes that "changes in total roughness (channel and floodplain Manning's n) between the ca. 1900 retro-model and the values used in the UMRSFFS UNET model explained much of the increases in stage observed along St. Louis Study reach." The Corps believes these stage changes are due to errors in the modeling process as detailed above and are not representative of physical changes on the MMR.

3.2.2 Retro and Scenario Modeling

Huthoff et al. (2013) used a simplified theoretical analysis to test the impact of wing dikes on flood levels. This analysis used a simplified cross section to test three scenarios: with no wing dikes, with wing dikes without bed response, and with wing dikes including bed response. The overall channel discharge is calculated for each stage using Manning's equation for steady uniform flow. The discharge for separate flow compartments is calculated using the divided channel method. The Manning's roughness for the dike region is calculated using a flow resistance equation from Yossef (2004, 2005). The author concludes that although the roughness in the dike reach decreases with increasing water levels, the submergence is not great enough for the roughness to return to the base roughness. The authors conclude that the increase in stage for four times the average flow ($4Q_{ave}$) due to the wing dikes is 0.6 m, 0.7 m, 1.1 m and 0.6 m at St. Louis, Chester, Grand Tower and Thebes, respectively.

3.2.3.1 Errors in Theoretical Analysis

3.2.3.1.1 Applicability of Effective Roughness Equation

The theoretical analysis proposed by Huthoff et al. (2013) is an oversimplified method to quantify an extremely complex and dynamic hydraulic problem. The basis of this analysis is the effective 'n' value formula developed by Yossef (2004, 2005) which was developed using a fixed bed physical model scaled to represent a reach of the Dutch River Waal which has much different geometry, dike size, and dike spacing than those used on the Middle Mississippi River. Although this relationship can be used to give insight into the effective roughness in the dike zone and submergence, it is only suitable to deduce trends rather than quantify accurate magnitudes of change.

3.2.3.1.2 Bank Roughness

As detailed in the editor's note, Huthoff et al. (2013) initially submitted a manuscript with an error in the calculation of Manning's roughness which resulted in an overestimation of the roughness by a factor of 10. Due to the theoretical model's sensitivity to the bank roughness value, this overestimation was the primary driver for the stage changes concluded. A simple correction of the calculation error with no additional manipulation in input data results in stage changes of -0.12 m at St. Louis, +0.21 m at Chester, +0.84 m at Grand Tower, and -0.00 m at Thebes for $4Q_{ave}$. In addition to correcting the error, the authors changed the input values of bank roughness, mean dike crest elevation, and assumed bed level changes. The impact of each of these input changes in the model was an increase in stage for $4Q_{ave}$. The bank roughness values used in Huthoff et al. (2013) were much lower than what is typically used for the MMR and much lower than those used for the main channel. The authors used a combination of 'n' values from different sources: the bank values were arbitrarily taken from literature whereas the values for other zones were taken from a hydraulic model. This resulted in velocity distribution in the channel that had high velocities along the bank and lower velocities in the channel at high flow. This is contrary to observed and theoretical velocity patterns in an open channel (Chow 1959).

3.2.3.1.3 Model Verification

The model used in this analysis did not have adequate validation to prove that it has the ability to reproduce empirical results. The attempt of validation showed that the model matched the empirical values which it was calibrated to. The author did not validate the model to an independent observed flow which is customary engineering practice. The author also did not attempt to verify the ability of the model to reproduce any flood flows.

3.2.3.2 Discussion

Since the relationship by Yossef (2004, 2005) was developed studying a river whose geometry and structures are very different to those used on the MMR, it cannot be used to quantify accurate magnitudes of change on the MMR. Although the model used by Huthoff et al. (2013) has many limitations preventing it from being used quantitatively, insight can be gained by the shape of the relationship between water level and dike roughness. The reduction of roughness with an increase in submergence is consistent with what has been observed by many scientists and engineers (Sukhodolov 2013; Watson & Biedenharn 2010; GAO 2011; PIANC 2009; Azinfar & Kells 2007; Stevens et al. 1975; Chow 1959) and in conflict with what has been concluded by Pinter (2000) and Remo & Pinter (2007).

3.3 Physical Fixed Bed Modeling

Azinfar and Kells (2009, 2008, and 2007) use the results of fixed bed physical model studies to analyze flow resistance and backwater effect of a single dike. The authors use the conclusions of Criss & Shock (2001), Pinter et al. (2001) and Pinter (2004) as a foundation for their research. The purpose of the analysis in Azinfar and Kells (2009, 2008, and 2007) was to "quantify the amount of backwater effect that occurs so that the impacts of spur dike construction can be determined by those charged with managing the river system."

Azinfar and Kells (2007) developed a multi-functional backwater model calibrated to fixed bed physical model studies by Oak (1992) to study the backwater effect due to a single spur dike in an open-channel flow. Parameters analyzed using the model include the spur dike aspect ratio (height/length), spur dike opening ratio (1-length/channel width), spur dike submergence ratio (water depth/height) and upstream Froude number. Azinfar and Kells (2007) found that the parameter that has the greatest effect on the drag coefficient of a spur dike was the submergence ratio— the more the structure is submerged, the less the drag coefficient and therefore the less impact it has on water surfaces. This conclusion is contrary to the conclusion of Pinter (2000) and Remo & Pinter (2007) that conclude that the impact of dikes on water surfaces increases with increasing discharge and are highest at flood stage.

Azinfar and Kells (2008) propose a predictive relationship developed in Azinfar and Kells (2007) that can be used to obtain a first-level estimate of the backwater effect due to a single, submerged spur dike in an open channel flow. Azinfar and Kells (2009) conclude that in a rigid flume an increase in blockage due to a spur dike is the main parameter responsible for an increase in the drag coefficient and associated flow resistance.

There is no debate that in a fixed bed scenario any channel blockage will produce a backwater effect. This is due to the decrease in cross sectional area resulting from the presence of the structure. The conclusions of Azinfar and Kells (2009, 2008, and 2007) reinforce why incorporating sediment transport is critical in having a full understanding of the impacts of dikes on water surfaces, particularly flood levels. The purpose of dikes is to induce bed scour and deepen the channel. Analysis of cross sectional changes on the Mississippi River has shown that once equilibrium is reached, although the dimensions of the channel may be different (i.e., deeper and narrower), the cross sectional area is preserved.

4. Studies cited that do not link the construction of instream structures to increases in flood levels

Other journal articles, editorials and conference papers have been incorrectly referenced as linking the construction of instream structures to increases in flood levels:

1. Chen and Simmons (1986), Roberge (2002), Pinter et al. (2006a), Sondergaard and Jeppesen (2007), Theiling and Nestler (2010), and Borman et al. (2011) simply reference the research detailed in the aforementioned papers as background but do not present any new analysis.

2. Bowen et al. (2003), Wasklewicz et al. (2004), Ehlmann and Criss (2006), Criss and Vinston (2008), Criss (2009) and Pinter et al. (2012) analyze flow frequency and/or propose changes to the way flow frequency is calculated. They do not present any new analysis linking instream structures to increasing flood levels.

3. Struiksma and Klaasen (1987), Ettema and Muste (2004), and Maynord (2006), are about physical modeling and model scaling and distortion and do not discuss instream structure construction or flood levels.

4. Pinter (2005) and Van Ogtrop et al. (2005) present arguments linking the construction of levees to increases in flood levels. These papers do not present any analysis on instream structures and how they impact flood levels.

5. Maher (1964) presents changes in river regime of the Mississippi River and the variations in rating curves with respect to time and stage. The analysis includes causes for some of the stage- discharge relationship changes. The author analyzes the changes of three reaches of the MMR over three different time periods. Maher (1964) concludes that "the construction of levees in the Mississippi River floodplain during the period 1908-1927 has been the main factor in reducing floodway capacity to approximately 54% of the 1908 area. Between 1927 and 1943, when no additional levees were constructed, the floodway capacity remained practically constant, being reduced in area by only an additional ½ of 1%." Maher (1964) does not attempt to link the construction of instream structures to increases in flood levels.

6. Paz et al. (2010) describes a HEC-RAS model study of the Paraguay River and its tributaries with limited data.

7. Doyle and Havlick (2009) examines current infrastructure and current understanding of environmental impacts for different types of infrastructure. This paper discusses the impact of levees on flooding.

8. Remo et al. (2008) discusses a database compiled by the authors with hydrologic and geospatial data on the Mississippi, lower Missouri and Illinois rivers. No analysis is conducted or conclusions drawn.

9. Remo and Pinter (2007) is a conference paper that discusses the database compiled by the authors detailed in Remo et al. (2008) and summarizes "retro-modeling" as a tool to analyze historic changes.

10. O'Donnell and Galat (2007) discusses river enhancement projects on the Upper Mississippi

River and recommends improvement in management practices and project data collection, entry, management, and quality control/assurance across agencies.

11. Jai et al. (2005) used CCHE3D, a three-dimensional model for free surface turbulent flows developed at the National Center for Computational Hydroscience and Engineering, to study the helical secondary current and near-field flow distribution around one submerged weir. The model was validated using flow data measured during a physical model study conducted at the Coastal and Hydraulic Laboratory of ERDC. The models used in this study did not simulate sediment transport and channel change. Although water surface elevation contours are discussed near the submerged weir, the paper does not present a detailed analysis of the structures' impact on water surfaces.

12. Pinter et al. (2004) provides an evaluation of dredging on a particular reach of the Middle and Upper Mississippi River based on dredging records obtained from the USACE St. Louis District. Although references to the impact of river training structures on flood stages are made several times, Pinter et al. (2004) does not have any analysis, discussion or conclusions on the topic.

13. Smith and Winkley (1996) examine the response of the Lower Mississippi River to a variety of engineering activities. This paper presents a brief history of engineering investigation on the Lower Mississippi River, analyzes the impact of artificial cutoffs on the channel geometry and water surface profiles, analyzes the impact of channel alignment activities on channel morphology and the apparent impact of all of the Lower Mississippi River engineering activities on sediment dynamics in the channel. There is no discussion or analysis by Smith and Winkley (1996) on how the construction of river training structures impacts flow levels.

14. Huang and Ng (2006) use a CCHE3D model calibrated to a fixed bed physical model to study basic flow structure around a single submerged weir in a bend. Conclusions are made on the near field changes in water surface. With the weir installed, the water surface elevation reflected the existence of the weir in the whole channel with an increase in the water surface elevation upstream of the weir due to an increase in resistance when the flow approaches the weir. Downstream of the weir the model found a decrease in water surface due to the acceleration of the flow after passing through the weir. Huang and Ng (2006) describe the changes in water surface as a "local effect." The scenario analyzed in Huang and Ng (2006) is for a single weir added to a fixed bed channel with no change in channel bathymetry, thus presenting an obstruction to flow. The author does not test flood flows or attempt to extrapolate his results to conclude that instream structures raise flood levels.

5. Studies the Corps was unable to gain access to

The Corps was unable to retrieve copies of the following study and therefore was unable to use it in their analysis of the impact of instream structures on flood levels:

Clifford, N.J., Soar, P.J., Gurnell, A.M., Petts, G.E., 2002. Numerical flow modeling for eco-hydraulic and river rehabilitation applications: a case study of the River Cole, Birmingham, U.K.. In River Flow 2002, Bousmar D, Zech Y (eds). Swets & Zeitlinger/Balkema: Lisse; 1195-1204.

6. Conclusion

Based upon all of the available research analyzed above, the Corps has concluded that river training structures do not impact flood levels. The research efforts, as detailed in the published papers, book chapters, editorials and conference proceedings that conflict with the Corps' conclusions all rely on analysis, assumptions and data that is not supported by engineers and scientists within the Corps, other Federal Agencies with expertise in water resources, and academia.

The claims in the literature detailed above that river training structures have an impact on flood flows are not new. The Corps was concerned in the 1930s that the construction of dikes may have reduced the floodway capacity of the MMR (Ressegieu 1952). The Corps worked with the USGS and other experts to understand the issue and determined that there was not a change in floodway capacity rather a change in the way data was collected. Through the incorrect use of early Corps discharge data (Watson et al. 2013a) scientists in the 1970s again claimed that dikes have increased flood levels. In response, the Corps worked with experts from academia to understand the issue and study the problem using the latest technology. The conclusions of the experts reinforced previous conclusions that river training structures do not increase flood levels.

Recently, the Corps worked with experts from other agencies and academia to evaluate the impact of river training structures on flood levels. The conclusions of these studies reinforce the previous conclusions that river training structures do not increase flood levels. As has been the case throughout the history of the Regulating Works Project, the Corps will continue to monitor and study the physical effects of river training structures using the most up-to-date methods and technology as it becomes available.

The majority of research attempting to link river training structures to an increase in flood heights is based off of a handful of research efforts primarily by researchers from three academic institutions: Washington University (Criss, Shock), Southern Illinois University –Carbondale (Pinter, Remo, Jemberie, Huthoff), and University of Saskatchewan (Azinfar, Kells). The Corps takes the claims of these researchers very seriously and has made repeated attempts to engage and collaborate with them to fully understand their conclusions that link river training structures to increases in flood levels. These efforts have had limited success (USGAO 2011).

7. References

Azinfar, H., and J.A. Kells, 2009. Flow resistance due to a single spur dike in an open channel. Journal of Hydraulic Research, 47: 755-763.

Azinfar, H., J.A. Kells, 2008. Backwater prediction due to the blockage caused by a single, submerged spur dike in an open channel. Journal of Hydraulic Engineering, 134:1153-1157.

Azinfar, H., and J.A. Kells, 2007. Backwater effect due to a single spur dike. Canadian Journal of Civil Engineering, 34: 107-115.

Belt, C.B. 1975. The 1973 flood and man's constriction of the Mississippi River. Science, 189: 681-684.

Brauer, E.J., and Duncan, D.L., in press. Discussion of "Theoretical Analysis of Wing Dike Impact on River Flood Stages" by Fredrik Huthoff, Nicholas Pinter and Jonathan W.F. Remo. Journal of Hydraulic Engineering

Brauer, E.J. 2009. The limitations of using specific gage analysis to analyze the effect of navigation structures on flood heights in the Middle Mississippi River.Vienna, Austria, Proceedings of the 4th international congress of Smart Rivers '21. Sept 6-9. p 156-163.

Brauer, E.J. 2012. The effect of river training structures on flood heights on the Middle Mississippi River. San Jose, Costa Rica. Proceedings of the 6th edition of the International Conference on Fluvial Hydraulics. Sept 5-7. CRC Press.

Brauer, E.J. 2013. The Effect of Dikes on Water Surfaces in a Mobile Bed. MS Thesis. University of Illinois, Urbana-Champaign.

Bormann, H., N. Pinter, and S. Elfert, 2011. Hydrological signatures of flood trends on German Rivers: Flood frequencies, flood heights, and specific stages. Journal of Hydrology 404 (2011) 50–66.

Bowen, Z.H., Bovee, K.D., Waddle, T.J. 2003. Effects of Regulation on Shallow-Water Habitat Dynamics and Floodplain Connectivity. Transactions of the American Fisheries Society 132, 809-823.

Chen Y.H., and Simmons D.B., 1986. Hydrology, hydraulics, and geomorphology of the Upper Mississippi River system. Hydrobiologia 136, 5-20.

Chow, V.T., 1959. Open-channel hydraulics: New York, McGraw-Hill.

Clifford, N.J., Soar, P.J., Gurnell, A.M., Petts, G.E., 2002. Numerical flow modeling for eco-hydraulic and river rehabilitation applications: a case study of the River Cole, Birmingham, U.K.. In River Flow 2002, Bousmar D, Zech Y (eds). Swets & Zeitlinger/Balkema: Lisse; 1195-1204.

Criss, R.E., 2009. Increased flooding of large and small watersheds of the central USA and the consequences for flood frequency predictions. In R. E. Criss and Timothy M. Kusky (Eds.), Finding the Balance between Floods, Flood Protection, and River Navigation, pp. 16-21. Saint Louis University, Center for Environmental Sciences.

Criss, R.E., and W.E. Vinston, 2008. Public Safety and Faulty Flood Statistics. Environmental Health Perspectives, 116: A516.

Criss, R. E., & Shock, E. L. 2001. Flood enhancement through flood control. Geology,29 (10), 875-878.

Doyle, M.W., D.G. Havlick, 2009. Infrastructure and the Environment. Annual Review of Environment and Resources, 34: 349-373.

Dieckmann, R.J., Dyhouse, G.R. 1998. Changing history at St. Louis – adjusting historic flows for frequency analysis. First Federal Inter-Avency Hydrologic Modeling Conference, April 20-22, 1998. Las Vegas, NV.

Dyhouse, G.R. 1995. Effects of Federal Levees and Reservoirs on 1993 Flood Stages in St. Louis. Washington, DC. National Research Council, Transportation Research Board, Record No. 1483. 7p.

Dyhouse, G.R. 1985. Comparing flood stage-discharge data- Be Careful! In Hydraulics and Hydrology in the Small Computer Age: Proceedings of the Specialty Conference. Waldrop WR (ed.) American Soc. Of Civil Engineers Hydraulics Divison: New York; 73-78.

Dyhouse, G.R. 1976. Discussion of "Man-induced changes of Middle Mississippi River". Journal of the waterways harbors, and coastal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 277-279.

Ehlmann, B.L., and R.E. Criss, 2006. Enhanced stage and stage variability on the lower Missouri River benchmarked by Lewis and Clark. Geology, 34: 977-980.

Ettema, R., Muste, M. 2004. Scale effects in flume experiments on flow around a spur dike in a flat bed channel. Journal of Hydraulic Engineering. 130 (7), 635-646.

Heine, R.A., Pinter, N. 2012. Levee effects upon flood levels: an empirical assessment. Hydrological Processes, 26, 3225-3240. DOI: 10.1002/hyp.8261.

Huang, S.L., Ng C. 2007. Hydraulics of a submerged weir and applicability in navigational channels: Basin flow structures. International Journal for Numerical Methods in Engineering 69, 2264-2278.

Huizinga, R.J. 2009. Examination of measurement and historic daily data for several gaging stations on the Middle Mississippi River, 1861-2008. U.S. Geologicial Survey Scientific Investigations Report 2009-5232. 60p. (Also available at http://pubs.usgs.gov/sir/2009/5232/)

Huthoff, F., N. Pinter, J.W.F. Remo, 2013. Theoretical analysis of wing dike impact on river flood stages. Journal of Hydraulic Engineering. 139(5), 550-556. DOI:10:1061/(ASCE)HY.1943-7900.0000698.

Jai, Y., Scott S., Xu, Y., Huang, S. and Wang, S.S.Y. 2005. Three-dimensional numerical simulation and analysis of flow around submerged weir in a channel bendway. Journal of Hydraulic Engineering. 131, 682-693.

Jemberie, A.A., N. Pinter, and J.W.F. Remo, 2008. Hydrologic history of the

Mississippi and Lower Missouri Rivers based upon a refined specific-gage approach. Hydrologic Processes, 22: 7736-4447, doi:10.1002/hyp.7046.

Maher, T.F. 1964. Study of regulation works on stream flow. Paper presented at ASCE Meeting, Cincinnati, Ohio, February, 1-24.

Maynord, S.T. 2006. Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model. Journal of Hydraulic Engineering 132, 343-353. Monroe, R.H. 1962. U.S. Geological Survey, unpublished data.

Munger, P.R., Stevens, G.T., Clemence, S.P., Barr, D.J., Westphal, J.A., Muir, C.D., Kern, F.J., Beveridge, T.R., and Heagler, Jr., J.B. 1976. SLD Potamology Study (T-1). University of Missouri-Rolla, Institute of River Studies, Rolla, Missouri.

O' Donnell, K.T. Galat D.L., 2007. River Enhancement in the Upper Mississippi River Basin: Approaches Based on River Uses, Alterations, and Management Agencies. Restoration Ecology, 15, 538-549.

Parker, G., Garcia, MH, Joannesson, J. and Okabe, K. 1988. Model Study of the Minnesota River near Wilmarth Power Plant, Minnesota, Project Report No. 284, Saint Anthony Falls Hydraulic Laboratory, University of Minnesota.

Paz, A.R., J.M. Bravo, D. Allasia, W. Collischonn, and C.E.M. Tucci, 2010. Large-scale hydrodynamic modeling of a complex river network and floodplains. Journal of Hydrologic Engineering, 15: 152-165.

PIANC, 2009. Sustainable waterways within the context of navigation and flood management. Envi-Com Report n°107-2009.

Pinter, N., J. Dierauer, and J.W.F. Remo, 2012. Flood-loss modeling for assessing impacts of flood-frequency adjustment, Middle Mississippi River, USA. Hydrologic Processes, doi:10.1002/hyp.9321.

Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, 2010. Cumulative impacts of river engineering, Mississippi and Lower Missouri Rivers. River Research and Applications,26: 546-571.

Pinter, N., 2010. Historical discharge measurements on the Middle Mississippi River, USA: No basis for "changing history." Hydrological Processes, 24: 1088-1093.

Pinter, N., 2009. Non-stationary flood occurrence on the Upper Mississippi-Lower Missouri River system: Review and current status. In R. E. Criss and Timothy M. Kusky (Eds.), Finding the Balance between Floods, Flood Protection, and River Navigation, pp. 34-40. Saint Louis University, Center for Environmental Sciences.

Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.S. Ickes, 2008. Flood trends and river engineering on the Mississippi River system, Geophysical Research Letters, 35, L23404, doi:10.1029/2008GL035987.

Pinter, N., R.R. van der Ploeg, P. Schweigert, and G. Hoefer, 2006. Flood Magnification on the River Rhine. Hydrological Processes, 20: 147-164.

Pinter, N., B.S. Ickes, J.H. Wlosinski, and R.R. van der Ploeg, 2006. Trends in flood stages: Contrasting trends in flooding on the Mississippi and Rhine river systems. Journal of Hydrology, 331: 554-566.

Pinter, N., 2005. Policy Forum: One step forward, two steps back on U.S. floodplains. Science, 308: 207-208.

Pinter, N., and R.A. Heine, 2005. Hydrodynamic and morphodynamic response to river engineering documented by fixed-discharge analysis, Lower Missouri River, USA. Journal of Hydrology, 302: 70-91.

Pinter, N., K. Miller, J.H. Wlosinski, and R.R. van der Ploeg, 2004. Recurrent shoaling and dredging on the Middle and Upper Mississippi River, USA. Journal of Hydrology,290: 275-296.

Pinter, N., and R. Thomas, 2003. Engineering modifications and changes in flood behavior of the Middle Mississippi River. In R. Criss and D. Wilson, (eds.), At The Confluence: Rivers, Floods, and Water Quality in the St. Louis Region, pp. 96-114.

Pinter, N., R. Thomas, and J.H. Wlosinski, 2002. Reply to U.S. Army Corps of Engineers Comment on "Assessing flood hazard on dynamic rivers." Eos: Transactions of the American Geophysical Union, 83(36): 397-398.

Pinter, N., J.H. Wlosinski, and R. Heine, 2002. The case for utilization of stage data in flood-frequency analysis: Preliminary results from the Middle Mississippi and Lower Missouri River. Hydrologic Science and Technology Journal, 18(1-4): 173-185.

Pinter, N., R. Thomas, and N.S. Philippi, 2001b. Side-stepping environmental conflicts: The role of natural-hazards assessment, planning, and mitigation. E. Petzold-Bradley, A. Carius, and A. Vincze (eds.), Responding to Environmental Conflicts: Implications for Theory and Practice, p. 113-132. Dordrecht: Kluwer Academic Publishers.

Pinter, N., R. Thomas, and J.H. Wlosinski, 2001a. Flood-hazard assessment on dynamic rivers. Eos: Transactions of the American Geophysical Union, 82(31): 333-339.

Pinter, N., R. Thomas, and J.H. Wlosinski, 2000. Regional impacts of levee construction and channelization, Middle Mississippi River, USA. In J. Marsalek, W.E. Watt, E. Zeman, and F. Sieker (eds.), Flood Issues in Contemporary Water Management, p. 351-361. Dordrecht: Kluwer Academic Publishers.

Piotrowski, J.A., Young, N.C., Weber, L.J. 2012. Supplemental Investigatoin of the Influence of River Training Structures on Flood Stages From River Mile 179.5 to 190.0 of the Middle Mississippi River. Submitted to the U.S. Army Corps of Engineers, St. Louis, Missouri.

Remo, J.W.F., N. Pinter, and R.A. Heine, 2009. The use of retro- and scenario- modeling to assess effects of 100+ years river engineering and land cover change on Middle and Lower Mississippi River flood stages. Journal of Hydrology, 376: 403–416.

Remo, J.W.F., N. Pinter, B. Ickes, and R. Heine, 2008. New databases reveal 200 years of change on the Mississippi River System. Eos, 89(14): 134-135.

Remo, J.W.F, and Pinter, N., 2007. The use of spatial systems, historic remote sensing and retro-modeling to assess man-made changes to the Mississippi River System. In: Zaho, P. et al. (eds.), Proceedings of International Association of Mathematical Geology 2007: Geomathematics and GIS Analysis of Resources, Environment and Hazards. State Key Laboratory of Geological Processes and Mineral Resources, Beijing, China, pp. 286-288.

Remo, J.W.F., and N. Pinter, 2007. Retro-modeling of the Middle Mississippi River. Journal of Hydrology. doi: 10.1016/j.hydrol.2007.02.008.

Ressegieu, F.E. 1952. Comparative discharge measurements, Mississippi River by USGS and Corps of Engineers. St. Louis District, U.S. Army Corps of Engineers.

Roberge, M., 2002. Human modification of the geomorphically unstable Salt River in metropolitan Phoenix. Professional Geographer, 54: 175-189.

Samaranayake, V.A. 2009. The statistical review of three papers on specific gage analysis. Report to U.S. Army Corps of Engineers, St. Louis District.

Smith, L. M., and Winkley, B.R. 1996. The response of Lower Mississippi River to river engineering. Engineering Geology. 45, 433-455.

Sondergaard, M., and E. Jeppesen, 2007. Anthropogenic impacts on lake and stream ecosystems, and approaches to restoration. Journal of Applied Ecology, 44: 1089-1094.

Stevens, M. A., Simons, D. B., & Schumm, S. A. 1975. Man-induced changes of Middle Mississippi River. Journal of the Waterways Harbors and Coastal Engineering Division, 119-133.

Stevens, G.T. 1976. Discussion of “Man-induced changes of Middle Mississippi River”.Journal of the waterways, harbors, and costal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 280.

Strauser, C.N. and N.C. Long. 1976. Discussion of “Man-induced changes of Middle Mississippi River”. Journal of the waterways, harbors, and costal engineering division. Proceedings of the American Society of Civil Engineers. 102(WW2). 281-282.

Struiksma, N. Klaasen, G.J., 1987. On scale effects in moveable river models. Communication No. 381, Delft Hydralics Laboratory, Delft, The Netherlands.

Sukhodolov, A.N. 2014. Hydrodynamic of groyne fields in a straight river reach: insight from field experiments. Journal of Hydraulic Research. 52:1, 105-120. DOI:10.1080/00221686.2014.880859.

Szilagyi, J., N. Pinter, and R. Venczel, 2008. Application of a routing model for detecting channel flow changes with minimal data. Journal of Hydrologic Engineering,13: 521-526.

Theiling, C.H., and J.M. Nestler, 2010. River stage response to alteration of Upper Mississippi

River channels, floodplains, and watersheds. Hydrobiologia, 640: 17-47.

USACE. 1996. Barfield Bend Potomology Study Update, Mississippi River, Hydraulics and Hydrology Branch.

USACE. 2008. Upper Mississippi River Comprehensive Plan. U.S. Army Corps of Engineers Rock Island District, St. Louis District, St. Paul District.

USACE, 2016. Hydrodynamic Study of Vancill Towhead Reach on the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District.

USACE. 1995. Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries.

USACE. 1942. Mississippi River flood discharge capacity. Prepared by U.S. Army Engineer District, St. Louis.

USACE. 1935. Stream-flow measurements of the Mississippi River and its Tributaries between Clarksville, MO and the Mouth of the Ohio River 1866-1934, Hydrologic Pamphlet No. 1, U.S. Engineer Office, St. Louis, MO. U.S. Government Printing Office: Washington, D.C.

U.S. Government Accountability Office (USGAO). 2011. "Mississippi River: Actions are needed to help resolve environmental and flooding concerns about the use of river training structures". Rep. GAO-12-41, Washington, DC.

Van Ogtrop, F.F., A.Y. Hoekstra, and F. van der Meulen, 2005. Flood management in the Lower Incomati River Basin, Mozambique: Two alternatives. Journal of the American Water Resources Association, 41: 607-619.

Wasklewicz T.A., J. Grubaugh, and S. Franklin, 2004. 20th century stage trends along the Mississippi River. Physical Geography, 25: 208-224.

Watson, C.C. and Biedenharn, D.C. 2010. Specific gage analyses of stage trends on the Middle Mississippi River. Report to U.S. Army Corps of Engineers, St. Louis District.

Watson, C.C., R.R. Holmes, D.S. Biedenharn. 2013a. Mississippi River Streamflow Measurement Techniques at St. Louis, Missouri. J. Hydraulic Engineering: 139:1062-1070.

Watson, C.C., Holmes, R.R., Jr., and Biedenharn, D.S., 2013a. Mississippi River streamflow measurement techniques at St. Louis, Missouri. Journal of Hydraulic Engineering, 39(10), 1062-1070.

Watson, C.C., D.S. Biedehnarn, C.R. Thorne. 2013b. Analysis of the Impacts of Dikes on Flood Stages in the Middle Mississippi River. J. Hydraulic Engineering. 139:1071-1078.

Watson, C.C., and Biedenharn, D.S. 2010. Specific gage analysis of stage trends on the Middle Mississippi River. Report to U.S. Army Corps of Engineers, St. Louis District.

Watson, C.C, Biedenharn, D.S., Scott, S.H., 1999. Channel Rehabilitation: Process, Design, and Implementation. U.S. Army Corps of Engineers.

Westphal, J.A. and P.R. Munger. 1976. Discussion of "Man-induced changes of Middle Mississippi River". Journal of the waterways, harbors, and costal engineering division.

Proceedings of the American Society of Civil Engineers. 102(WW2). 283-284.

Xia, R. 2009. “Using computational model- ADH to evaluate relationship of water surface elevation to wing dikes”. World Environmental and Water Resource Congress. ASCE.

Yossef, M.F. 2002. The effect of groynes on rivers: Literature review. Delft Cluster project no. 03.03.04.

Yossef, M.F.M. 2005. Morphodynamics of rivers with groynes, Delft University Press, Delft.

Appendix E. Distribution List

The following individuals and organizations received a hard copy mailing of the Public Notice:

Governor Jay Nixon
P.O. Box 720
Jefferson City, MO 65102

The Osage Nation
Assistant Chief Scott Bighorse
627 Grandview
P.O. Box 779
Pawhuska, Ok 74056

Anne Haaker
IL State Historic Preservation Office
Springfield, IL 62701

Russell Bradley
Kickapoo Tribe in Kansas
Chairman
1107 Goldfinch Road
Horton, KS 66439

MDNR Division of State Parks
Planning and Development
PO Box 176
Jefferson City, MO 65102

Yvonne Homeyer
Webster Groves Nature Society
1508 Oriole Lane
St. Louis, MO 63144

Honorable Blaine Luetkemeyer
1118 Longworth HOB
Washington, DC 20515

Senator Gary Forby
903 West Washington, Suite 5
Benton, IL 62812

Honorable Claire McCaskill
5850 A Delmar Blvd
St. Louis, MO 63112

Advisory Council on Historic Preservation
1100 Pennsylvania Avenue NW, Suite 803
Old Post Office Building
Washington, DC 20004

Kelly Isherwood
5072 Oak Tree Lane
House Springs, MO 63051

Pat Malone
IDNR Natural Resource Review
1 Natural Resource Way
Springfield, IL 62702

Raymond Hopkins
RIAC/ARTCO
P.O. Box 2889
St. Louis, MO 63111

Mike Larson
MDNR
Land Reclamation Program
Jefferson City, MO 65102

Honorable Lacy Clay
6830 Gravois
St. Louis, MO 63116

Honorable Ann Wagner
301 Sovereign Court, Suite 201
Ballwin, MO 63011

Honorable John M. Shimkus
15 Professional Park Drive
Maryville, IL 62062

Representative Ed Schieffer
Missouri House of Representatives
201 West Capitol Avenue
Jefferson City, MO 65101-6806

US Coast Guard Marine Safety Office
Commanding Officer
225 Tully Street
Paducah, KY 42003

Rose M. Schulte
2842 Chadwick Dr.
St. Louis, MO 63121

Honorable Roy Blunt
United States Senator
2502 Tanner Drive – Suite 208
Cape Girardeau, MO 63703

Leon Campbell, Chairman
Iowa Tribe of Kansas and Nebraska
3345B Thrasher Road
White Cloud, Kansas 66094

Jack Norman
906 N. Metter Avenue
Columbia, IL 62236

Donald Rea
City of St. Louis
Water Division
10450 Riverview Drive
St. Louis, MO 63137

Nick Nichols
City of St. Louis Port Authority
1520 Market Street
St. Louis, MO 63103

Timothy V. Johnson, M.C.
IL15
202 N. Prospect Rd., Suite 203
Bloomington, IL 61704

Nellie Keo
Kickapoo Tribe in Kansas
Land/NAGPRA Office
1107 Goldfinch Road
Horton, KS 66439

Hoppies Marine
P.O. Box 44
Kimmwick, MO 63053

Environmental Coordinator
Planning and Compliance Office
Natural Park Service, Midwest Region
601 Riverfront Drive
Omaha, NE 68102-4226

Joseph Standing Bear Schranz
Midwest Soaring
5158 S. Mobile Avenue
Chicago, IL 60638

Great Rivers Environ. Law Center
705 Olive Street, Ste. 614
St. Louis, MO 63101

Mike Diedrichsen
IDNR Natural Resource Review
1 Natural Resource Way
Springfield, IL 62702

Representative Daniel Beiser
528 Henry Street
Alton, IL 62002-2611

Senator John Jones
2929 Broadway
Suite 5
Mt. Vernon, IL 62864

Dave Schulenburg
US EPA
Wetland and Watersheds Section
WW16J
77 W. Jackson Boulevard
Chicago, IL 60604-3590

Senator Larry Bomke
307 Capitol Building
Springfield, IL 62706

Honorable Aaron Schock
235 S. Sixth Street
Springfield, IL 62701

Honorable Sam Graves
906 Broadway
P.O. Box 364
Hannibal, MO 63401

Southern Illinois Sand Company
P.O. Box 262
Chester, IL 62233

David Jones
Environmental Director
Nottawaseppi Huron Band of
Potawatomi
2221 1-1/2 Mike Road
Fulton, MI 49052

Governor Pat Quinn
Office of the Governor
207 State House
Springfield, IL 62706

Honorable William Enyart
23 Public Square
Belleville, IL 62220

Honorable Richard Durbin
525 South 8th Street
Springfield, IL 62703-1601

Senator Mark Kirk
Springfield Senate Office
607 East Adams, Suite 1520
Springfield, IL 62701

Honorable Rodney Davis
2004 Fox Drive
Champaign, IL 61820

Russell Cissell
1075 LeSieur
Portage des Sioux, MO 63373

Patrick J. Lamping
Executive Director
The Jefferson County Port Authority
PO Box 603
Hillsboro, MO 63050

Fay Houghton
Land Management Director
Winnebago Tribe of Nebraska
P.O. Box 687
Winnebago, NE 68071

Mr. Ed Schieffer
183 Thornhill Cemetery Road
Troy, MO 63379

Senator Dale Righter
88 Broadway Avenue, Suite 1
Mattoon, IL 61938-4597

Senator James Clayborne Jr.
Kenneth Hall State Office Building
#10 Collinsville Avenue
East St. Louis, IL 62201

Honorable Jason Smith
2502 Tanner Drive, Suite 205
Cape Girardeau, MO 63703

The following individuals and organizations received e-mail notification of the Public Notice:

Adams, R.
Adrian, D.
Amato, Joel
Andria, Kathy
Atwood, Butch
Bacon, T.
Barnes, Robert
Bax, Stacia
Beardslee, Tom
Bellville, Colette
Bensman, Jim
Boaz, Tracy
Boehm, Gerry
Brandom, Ellen
Brescia, Chris
Brown, Danny
Brown, Doyle
Buan, Steve
Buffalo, Jonathan
Burlingame, Chuck
Byer, J. R.
Caito, J.
Campbell-Allison, Jennifer
Carney, Doug
Clements, Mark
Coder, Justin S.
Crowley, Steve
Cruse, Lester
Darst, E. B.
Deel, Judith
Dewey, Dave
Dock Hardware and Marine Fabrication
Dodd, Harold
Dorothy, Olivia
Dougherty, Mark
Duncan, Cecil
Ebey, Mike
Elmestad, Gary
Enos, Tim
Erickson, Tom
Fabrizio, Christi
Favilla, Christy
Foster, Bill
Goldstein, Jeff

Genz, Greg
Glenn, S.
Goode, Peter
Goodwin, Bill
Greer, Courtney
Gross, Andrea
Hammond, Cheryl
Hanke Terminals
Hanneman, M.
Hansen, Rick
Hansens Harbor
Harding, Scott
Held, Eric
Henleben, Ed
Herschler, Mike
Herzog, Dave
Hilburn, Craig
Hogan-Smith, Shelly
Howard, Chuck
Hubertz, Elizabeth
Hughes, Shannon
Hunter, Andrea
Hussell, B.
Illinois Corn Growers Association
Illinois Department of Natural Resources
Illinois Environmental Protection Agency
Jamison, Larry
Johnson, Erick
Johnson, Frank
Johnson, Tom
Knowles, Kim
Knuth, Dave
Lauer, Steve
Leary, Alan
Leipus, Ed
Leiser, Ken
Lensing, Brian
Lipeles, Maxie
Louis Marine
Mangan, Matthew
Mannion, Clare
Mauer, Paul
Melgin, Wendy
Miller, Kenneth
Miller, Melissa
Missouri Corn Growers Association

Missouri Department of Conservation
Missouri Department of Natural Resources
Muench, Lynn
Muir, T.
Nelson, Lee
Nelson, Rick
Novak, Ron
O'Carroll, J.
Overbey, Dan
Paurus, Tim
Pehler, Kent
Phillip, C.
Pinter, Nicholas
Pivor, Jeremy
Pondrom, Gary
Popplewell, Mickey
Porter, Jason
Red, Chief John
Reichert, Joe
Reitz, Paul
Reuters Chicago
Rickert, Ron
Roark, Bev
Rodenberg, V.
Rowe, Kelly
Samet, Melissa
Sauer, Randy
Schieffer, Ed
Shepard, Larry
Shoulberg, J.
Slay, Glen
Smith, David
Southeast Missouri Regional Port Authority
Southern Illinois Transfer
Spath, Robert
Stahlman, Bill
Staten, Shane
Sternburg, Janet
Stevens, Mark
Stout, Robert
Streight, Tom
Teah, Philip
Todd, Brian
Tow Inc.
Tyson, J.
Urban, David

U.S. Coast Guard Marine Safety Office
U.S. Environmental Protection Agency Region 7
Weber, Angie
Welge, Owen
Werner, Paul
Wilmsmeyer, Dennis
York Bridge Co.
Zupan, T.