DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
ROBERT A. YOUNG BUILDING - 1222 SPRUCE ST.
ST. LOUIS, MISSOURI 63103-2833

March 6, 2015

Regional Planning and Environment Division North
Environmental Compliance Branch

Dear Reviewer:

An electronic copy of the Draft Environmental Assessment (EA) and Draft Finding of No Significant Impact (FONSI) for the proposed project, "*Mouth of the Meramec, Mosenthein Reach -Ivory Landing Phase 5 RM 160-162.5*", is attached for your review. The EA was prepared according to the requirements of the National Environmental Policy Act, and serves to notify the public of the proposed project and requests assistance in identifying the probable environmental impacts of the project alternatives.

We invite your comments related to the content of the attached documents. Please note that the Draft Finding of No Significant Impact is unsigned. This document will be signed into effect only after having carefully considered comments received as a result of this 30-day public review. Please address your comments or questions to Francis Walton, of the Environmental Compliance Branch (CEMVP-PD-C), at telephone number (314) 331-8102, facsimile number (314) 331-8606, or e-mail at <francis.j.walton@usace.army.mil>, by close of business on April 9, 2015.

Sincerely,

Timothy K. George
Chief, Environmental Compliance Section

DRAFT ENVIRONMENTAL ASSESSMENT

WITH

DRAFT FINDING OF NO SIGNIFICANT IMPACT

REGULATING WORKS PROJECT

MOUTH OF THE MERAMEC
MOSENTHEIN REACH – IVORY LANDING, PHASE V
RM 160 – 162.5

MONROE COUNTY, ILLINOIS
ST. LOUIS COUNTY, MISSOURI
ON THE
MIDDLE MISSISSIPPI RIVER SYSTEM

FEBRUARY 2015

US Army Corps of Engineers
St. Louis District

U.S. Army Corps of Engineers, St. Louis District
Regional Planning and Environment Division North
1222 Spruce St.
St. Louis, MO 63103-2833

TABLE OF CONTENTS

Contents

1. Purpose of and Need for Action

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 (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 Middle Mississippi River (MMR).[1] The MMR is defined as that portion of the Mississippi River that lies between its confluence with the Ohio and the Missouri rivers (hereinafter referred to as the Project; Figure 1). This ongoing Project is also 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, i.e. dikes. 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 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 and the occurrence of vessel accidents through the construction of regulating works. Therefore, pursuant to the Congressionally authorized purpose of the Project, the District continually monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable.

[1] Congress originally authorized the project of improving navigation of the Mississippi River from the mouth of the Missouri to New Orleans in the Rivers and Harbors Act dated May 24, 1824, by the removal of trees that were endangering the safety of navigating the river. In the Rivers and Harbors Act dated June 10, 1872, Section 2, Congress mandated that an examination and/or survey be completed of the Mississippi River between the mouth of the Missouri River and the mouth of the Ohio River, providing the first Congressional action to define this portion of the Mississippi River as distinct from the rest of the Mississippi River. Congress authorized the specific improvement of the Mississippi River between the mouth of the Missouri River and the mouth of the Ohio River in the Rivers and Harbors Act dated March 3, 1873. Between 1874-1892, Congress expanded this section of the Mississippi River to include that portion between the mouth of the Missouri and the mouth of the Illinois, but in the Rivers and Harbors Act dated July 13, 1892, Congress removed this additional section of the river and once again referred to it as the Mississippi River between the mouth of the Ohio River and the mouth of the Missouri River. In the Rivers and Harbors Act dated June 25, 1910, Congress provided exactly how this Project was to be carried out by authorizing the construction, completion, repair, and preservation of "[i]mproving [the] Mississippi River from the mouth of the Ohio River to and including the mouth of the Missouri River: Continuing improvement in accordance with the plan adopted in [1881], which has for its object to eventually obtain by regularization works and by dredging a minimum depth." The 1881 plan called for the removal of rock hindering navigation, the contraction of the river to compel the river to scour its bed (now known as regulating works), and to be aided by dredging, if necessary. The 1881 plan also provided for bank protection improvements (now known as revetment) wherever the river is causing any serious caving of its banks. (Letter from the Secretary of War, dated November 25, 1881, 47th Congress, 1st Session, Ex. Doc. No. 10). The Project's current dimensions of the navigation channel were established in the Rivers and Harbors Acts dated January 21, 1927 and July 3, 1930. The Rivers and Harbors Act dated January 21, 1927 modified the Project pursuant to the Chief of Engineers recommendations, which further detailed the purpose of the Project to construct the channel through regulating works and augment this by dredging, stating that dredging should be reduced to a minimum. The Project was also later modified to provide for the Chain of Rocks Canal and Lock 27 in the Rivers and Harbors Acts dated March 2, 1945 to address the rock formation hindering navigation in this area, and the rock filled low water dam at the Chain of Rocks was authorized in the Rivers and Harbors Act dated July 3, 1958 to assure adequate depth over the lower gate sills at Locks and Dam 26.

To the extent possible under existing authorities, environmental laws, regulations, and policies, the District considers the environmental consequences of its activities as it constructs and operates the Project and acts accordingly. An important component of each activity is the use of scientific, economic, and social knowledge to understand the environmental context and effects of District actions in a collaborative manner, employing an open, transparent process that respects the views of Federal and State stakeholders, individuals, and groups interested in District activities.

Frequent dredging has been required in the area of the proposed Regulating Works, Mosenthein/Ivory Landing Phase 5 construction work area (Mosenthein/Ivory Landing Phase 5 work area; see a detailed discussion of this in Section 3, Affected Environment). Therefore, after analysis of this area, the District concluded that construction of the Mosenthein/Ivory Landing Phase 5 work area is reasonable and necessary to address the repetitive channel maintenance dredging in order to provide a sustainable, less costly navigation channel in this area. The District has concluded through analysis and modeling that construction of river training structures would provide a sustainable alternative to repetitive maintenance dredging. Construction of the Mosenthein/Ivory Landing Phase 5 work area is proposed to begin in September 2015 and take two months to complete.

The planning of specific construction areas, including the Mosenthein/Ivory Landing Phase 5 work area, required extensive coordination with resource agency partners and the navigation industry. The U.S. Fish and Wildlife Service, Missouri Department of Conservation, Illinois Department of Natural Resources, and multiple navigation industry groups were included in the planning of the Mosenthein/Ivory Landing Phase 5 work and provided comments related to navigation industry concerns and environmental resource issues that are documented in the District's Technical Report M68, *The Mouth of the Meramec River HSR Model, Mississippi River, River Miles 165.00 – 156.00, Hydraulic Sediment Response Model Investigation* (USACE 2014).

Prior Reports - This site-specific Environmental Assessment (EA) is tiered off of the 1976 Environmental Impact Statement (1976 EIS) covering the District's Regulating Works Project – *Mississippi River between the Ohio and Missouri Rivers (Regulating Works)*, (USACE 1976). The 1976 EIS was recently reviewed by the District to determine whether or not the document should be supplemented. The District has concluded that the Regulating Works Project has not substantially changed since 1976 but that there are significant new circumstances and information on the potential impacts of the Regulating Works Project on the resources, ecosystem and human environment to warrant the preparation of a Supplemental EIS (SEIS).

The significant new circumstances and information on the potential impacts of the Regulating Works Project relevant to this EA include the following:

- New federally threatened and endangered species have been listed since preparation of the 1976 EIS. Information on threatened and endangered species and impacts on those species can be found in Section 3, Section 4, and Appendix B of this document.
- New information exists on the changes in average river planform width (the river's outline or morphology as defined by the tree line) in response to river training structure

placement. Information on recent studies of planform width can be found in Section 3 of this document.

- New information exists on the impacts of river training structures and dredging on fish and macroinvertebrates. Information on fish and macroinvertebrates and projected impacts can be found in Sections 3 and 4 of this document.
- The District has implemented new programs to restore fish and wildlife habitat on the MMR. Information on the Biological Opinion Program and the Avoid and Minimize Program can be found in Section 4 of this document.
- New information exists on the effects of navigation on fish and wildlife resources. Information on navigation effects can be found in Appendix C, Cumulative Impacts Analysis.

The Mosenthein/Ivory Landing Phase 5 EA incorporates new information and circumstances relevant to the impacts of the action on the environment to the greatest extent possible. Should the analyses undertaken as part of the SEIS process reveal any new impacts on the resources, ecosystem, and human environment not accounted for in this EA, measures will be taken within our authority to avoid, minimize, and/or compensate for the impacts during that process as appropriate. Information on the SEIS can be found on the District's SEIS web site:

http://www.mvs.usace.army.mil/Missions/Navigation/SEIS.aspx

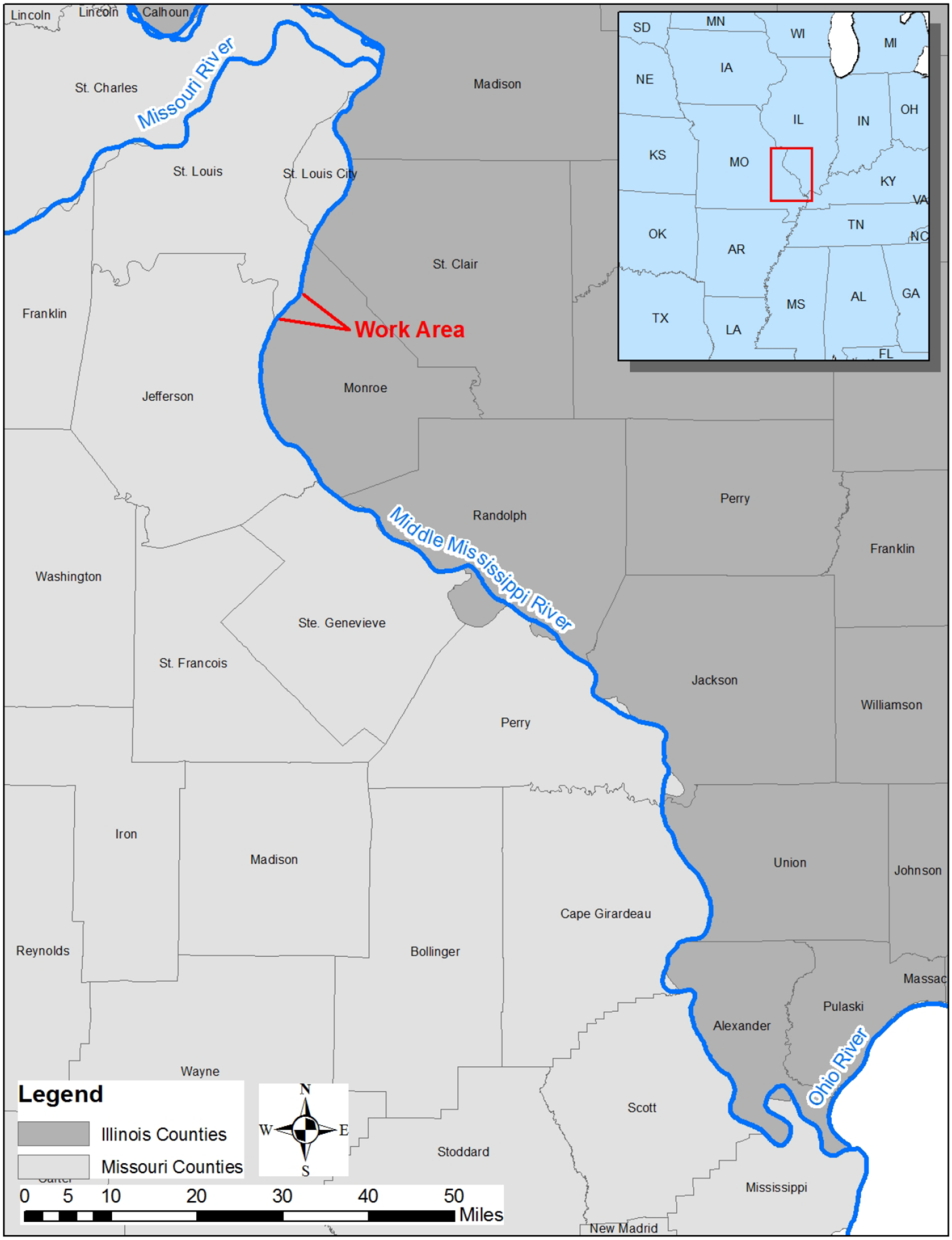

Figure 1. Work area location.

2. Alternatives Including the Proposed Action

This section describes the alternatives or potential actions that were considered as ways to address the issues with maintaining the authorized depth and width of the navigation channel at the Mosenthein/Ivory Landing Phase 5 work area. Alternatives will be described and their environmental impacts and usefulness in achieving the Project objectives will be compared.

Alternative 1: No Action Alternative. The No Action Alternative consists of not constructing any new river training structures in the work area but continuing to maintain the existing river training structures. Dredging would continue as needed to address the shoaling issues in the work area to fulfill the Project's navigation purpose.

Alternative 2: Proposed Action. Phase 5 will consist of four bendway weirs on the right descending bank and three dikes on the left descending bank between RMs 160 and 162.5. (see Table 1 and Figures 2, 3 and 4 below).The primary purpose of the Phase 5 work is to reduce the amount of repetitive dredging required to maintain the authorized depth and width of the navigation channel in the work area. By constructing new regulating works structures in the work area, the energy of the flowing river would be focused to maintain the channel and thereby eliminate or reduce the amount of maintenance dredging. A secondary purpose of the work is to enhance or improve aquatic habitat diversity. Under the Proposed Action, the weirs would be used to redirect channel flows to reduce dredging. The dikes would serve this purpose also, but would also enhance aquatic habitat by directing some of the flow to the side channels and channel border areas.

Table 1. Work to be Completed by River Mile and Purpose of Work.

Location by mile	Work to be completed	Purpose
Weir 162.30R Weir 162.20R Weir 162.10R Weir 162.00R	Construct bendway weirs along the right descending bank.	Direct energy of the river toward the thalweg to reduce the need for dredging.
Dike 161.70L (Rootless) Dike 161.50L (Rootless) Dike 161.10L (Rootless)	Construct rootless dikes along the left descending bank.	The dikes will direct flow toward the repetitive dredging area in the main channel and will guide some of the flow toward the secondary channel and channel border area.

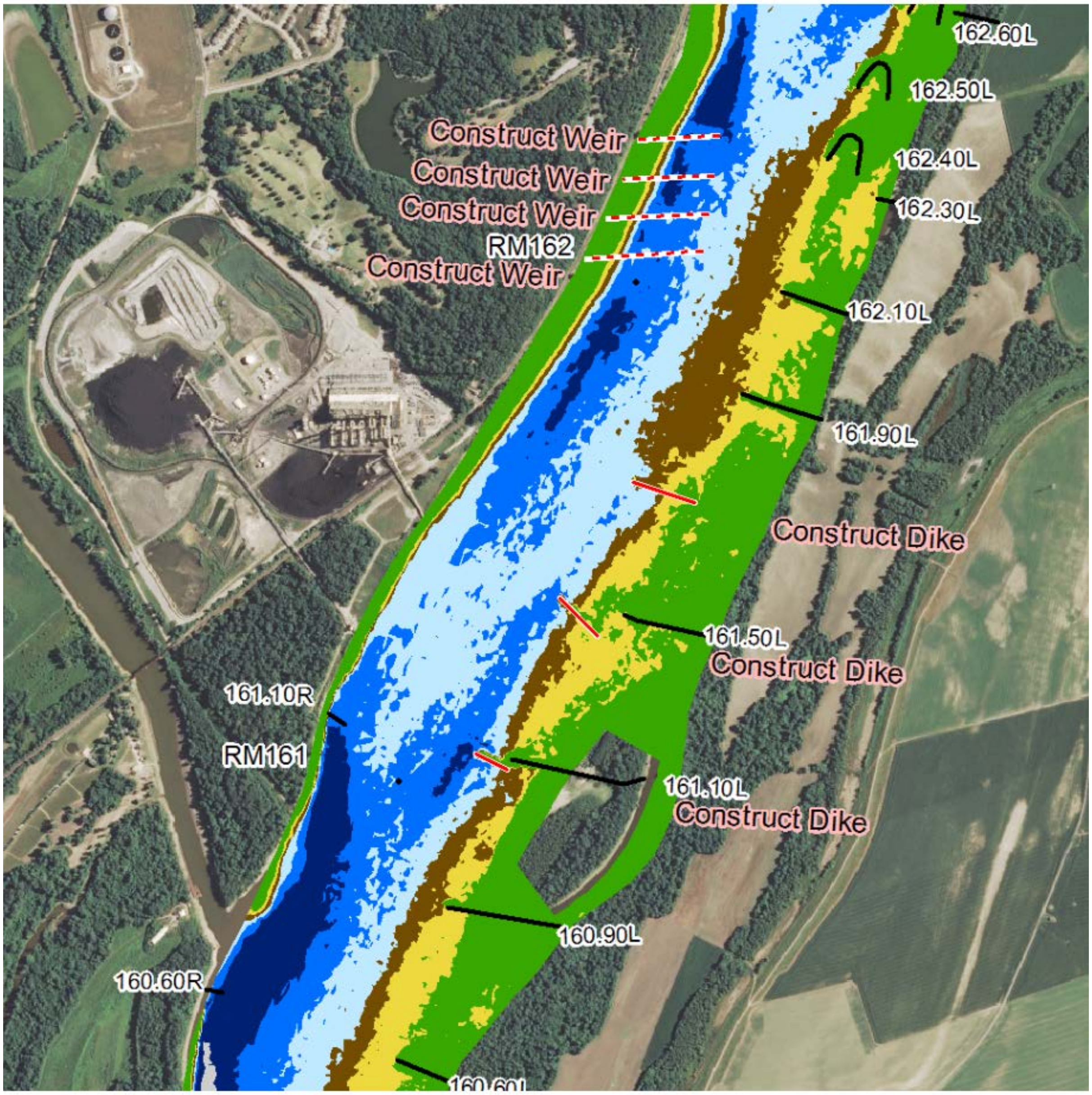

Figure 2. Locations of proposed weirs and dikes.

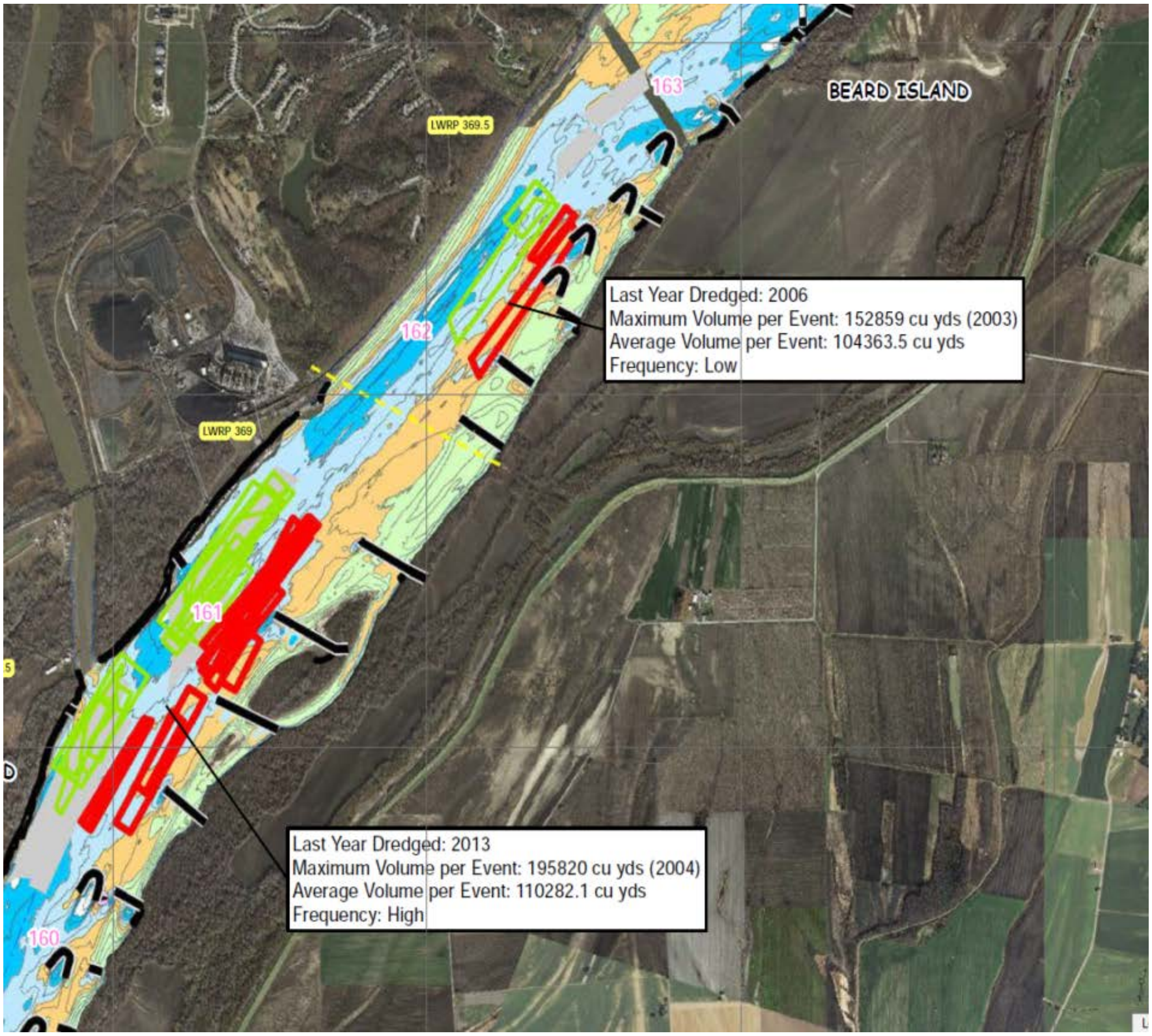

Figure 3. Dredging and Placement Sites Located in the Phase 5 Work Area.

Development of Alternatives - The District has concluded Alternatives 1and 2 are the only reasonable alternatives that meet the Project purpose and should be extensively evaluated. The District's alternative evaluation process considered only those alternatives that will obtain and maintain a safe and reliable 9-foot navigation channel in the work area to be consistent with the objectives and the authority of the Middle Mississippi River Regulating Works Project. The only reasonable, feasible, and authorized methods to keep the navigation channel open is through continued maintenance dredging or construction of regulating works to minimize the dredging required. Some of the other alternatives considered but deemed unreasonable include those discussed in the 1976 EIS. The 1976 EIS adequately addresses why some alternatives are not reasonable, such as ceasing all activity or building locks and dams. Maintenance of the navigation channel in this reach of the river requires frequent, costly dredging. Therefore, pursuant to the Project's authority, the District began developing alternatives to include regulating works to minimize the dredging in this reach of the river, thereby providing a less costly and more reliable navigation channel.

For the Mosenthein-Ivory Phase 5 work area, the District developed alternatives using widely recognized and accepted river engineering guidance and practice, and then screened and analyzed different configurations of regulating works with the assistance of a Hydraulic Sediment Response model (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 work area in question 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 Mosenthein/Ivory Landing Phase 5 work area the District developed the Mouth of the Meramec HSR model study. The Mouth of the Meramec HSR model study analyzed 16 different configurations of river training structures to determine the best combinations for reducing the need for dredging in the lower Mosenthein/Ivory reach while minimizing environmental impacts and not impacting fleeting areas on the LDB or the Ameren MO water intake at 161.5 (R).

Alternative 16, Plate 39 of the study, was recommended as the most desirable alternative because of its observed ability to significantly reduce elevations observed in the repetitive dredging area between RM 162.00 and RM 160.00. This alternative also included rootless dike structures instead of traditional dikes. This was done in an effort to provide split flow and more channel border habitat in the area. The rootless Dike 161.50 was placed at an angle in an attempt to divert a small amount of additional flow towards the small side channel located along the left descending bank. It should be noted that throughout testing, no sediment movement was observed within the side channel; however, at the model's scale it may not have been observable. Overall, this alternative enhanced navigation safety for industry by providing a deeper navigation channel while maintaining and potentially creating additional channel border habitat within the work area. See Figure 4 for a qualitative side by side comparison of modeled existing conditions and the potential bathymetric results.

During the alternative evaluation process, the District worked closely with industry and natural resource agency partners to further evaluate potential alternatives in this reach of the river, including the 16 configurations analyzed in the HSR model. Ameren representatives voiced concern about impacts to the Ameren facility in the area. The USFWS questioned why several alternatives that required less placement of rock, but seemed to yield satisfactory navigation channel results, were not considered. Ultimately, USACE chose Alternative 16 because it lowered the main channel elevation the most and was supported by agencies participating in the April 17, 2014, HSR Model Coordination Meeting.

This process resulted in the Proposed Action, which reasonably met the Project purpose while creating the possibility of more channel border habitat. Based on this extensive evaluation of alternatives, the District determined that the Proposed Action was the only reasonable alternative to dredging at the current level and that more extensive analysis of any of the additional configurations of regulating works in the EA would be unnecessary. Detailed information on the Alternatives development process, partner agency coordination, and alternatives eliminated from further consideration can be found in the on-line HSR model study report. . See Appendix D of the HSR report for minutes of the Meramec HSR coordination meeting.

Ultimately, construction of four weirs and three dikes between RMs 162.5 and 160 was determined to provide the best results for the work area. Detailed information on the Alternatives considered can be found in the on-line Mouth of the Meramec HSR model study report:

http://mvs-wc.mvs.usace.army.mil/arec/Reports_HSR_Model.html

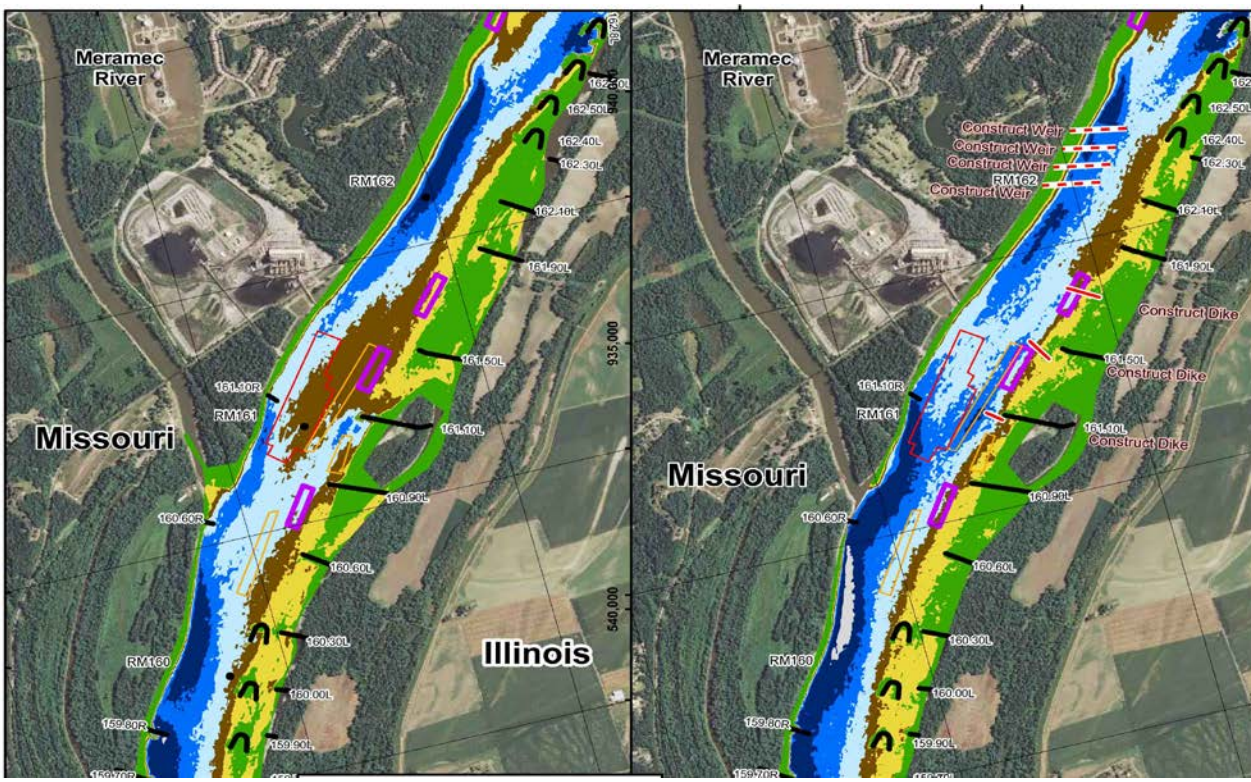

Figure 4. HSR model images showing how the structures will reduce river deposition.

Summary of Environmental Consequences - The impacts of each Alternative on the human environment are covered in detail in Section 4, Environmental Consequences. Table 2 below provides a summary of the impacts of each Alternative by resource category.

Table 2. Summary of impacts of the No Action Alternative and the Proposed Action.

	No Action Alternative	**Proposed Action**
Achievement of Project objectives	Does not reduce the need for repetitive maintenance dredging in the area, and, therefore, does not meet the Project objectives.	Is expected to reduce the amount of repetitive maintenance dredging in the area, thereby reducing federal expenditures and meeting Project objectives.
Impacts on Stages	No impacts anticipated.	No impacts anticipated at average and higher flows. Trend toward slightly lower stages at low flows expected to continue.
Impacts on Water Quality	Localized, temporary increase in suspended sediment concentrations at discharge sites.	Localized, temporary increase in suspended sediment concentrations during construction activities.
Impacts on Air Quality	Minor, local, ongoing impacts due to use of dredging equipment.	Minimal air quality impacts; below *de minimis* levels.
Impacts on Fish and Wildlife	Entrainment of fish and macroinvertebrates at dredge locations. Avoidance of dredge and disposal areas by mobile organisms. Loss of fish and macroinvertebrates at disposal sites.	Avoidance of sites during construction. No conversion of aquatic habitat to terrestrial. Increased fish and macroinvertebrate use of structure locations due to increased bathymetric, flow, and substrate diversity.
Impacts on Threatened and Endangered Species	May affect but not likely to adversely affect threatened and endangered species.	Only limited impacts to threatened and endangered species anticipated.
Impacts on Navigation	Continued requirement for repetitive maintenance dredging and associated potential for barge groundings.	Reduction in the amount and frequency of repetitive maintenance dredging in the area; reduction in barge grounding rates
Impacts on Historic and Cultural Resources	Impacts to historic and cultural resources unlikely.	No known historic resources would be affected. Impacts to unknown historic and cultural resources unlikely.

3. Affected Environment

This section presents details on the historic and existing conditions of resources within the work area that would potentially be affected by Project-related activities. The section is broken into four resource categories: physical resources, biological resources, socioeconomic resources, and historic and cultural resources. This section does not address impacts of the Alternatives, but provides a background against which Alternatives can be compared in Section 4, Environmental Consequences.

Physical Resources

Stages - 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 (see Figure 5 below). 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.

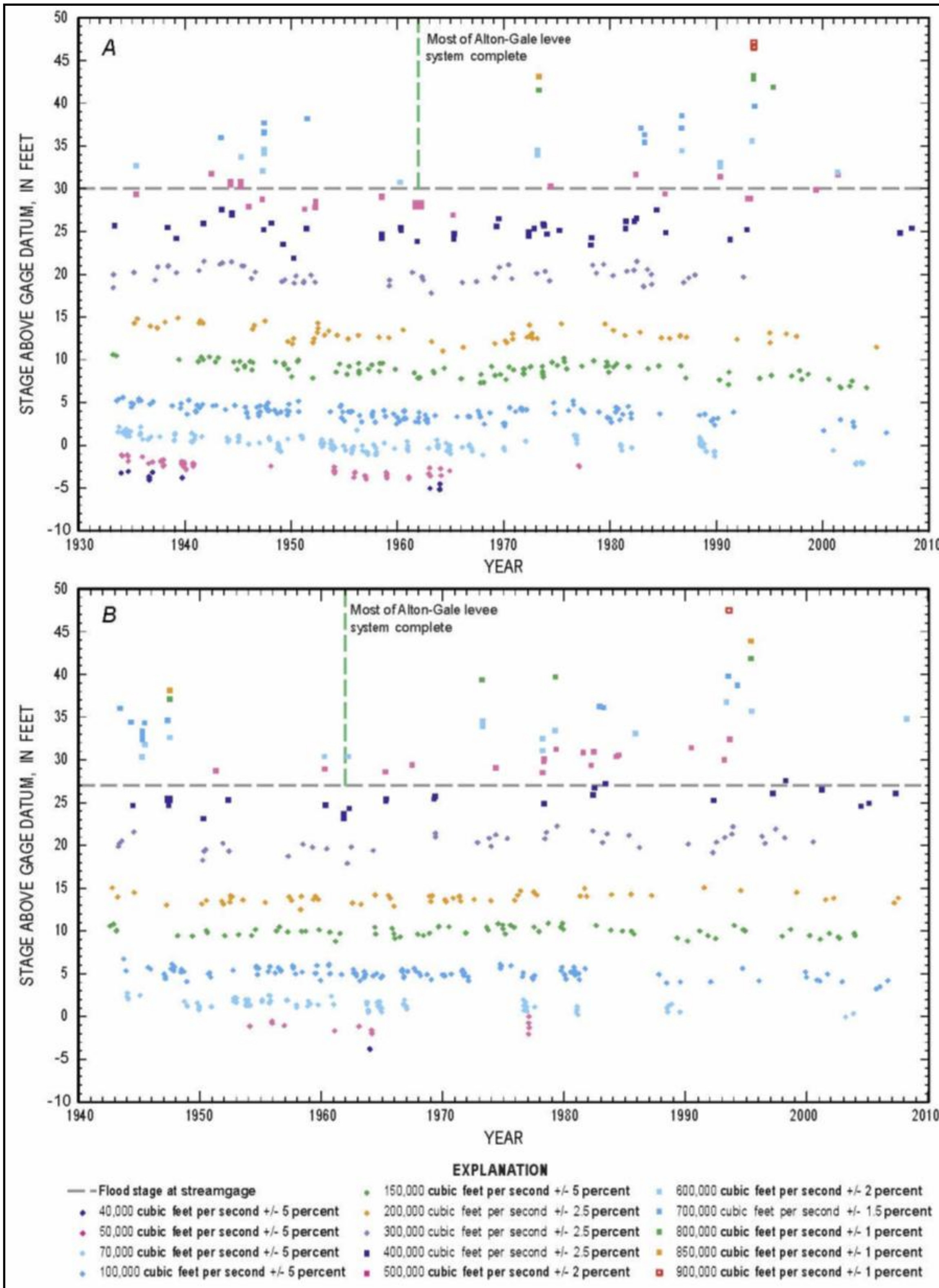

Figure 5. Stage for a given discharge range with time from measurements made at the streamgages at (A) St. Louis, Missouri, and (B) Chester, Illinois, on the Middle Mississippi River (from Huizinga 2009).

Water Quality – Consideration of water quality encompasses a wide range of physical, hydrologic, and biological parameters. Watershed influences, including tributary streams, point and non-point pollution sources, flow alteration due to navigation structures, and drought and flood events all influence water quality. Variations in land use practices, cover types, and watershed area will determine the level and type of sediment, nutrient, and contaminant inputs into the Mississippi River and its tributaries. The Mississippi River has a long history of water quality impairment due to contamination from industrial, residential, municipal, and agricultural sources. Recent changes in wastewater treatment laws and technologies, regulation of point source discharges, and changes in public awareness have contributed to overall improvements in 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. The Mississippi River is on the 2014 303(d) list for Missouri between St Louis, MO, and Ste Genevieve, MO.

Illinois has fish consumption advisories for the Mississippi River for channel catfish (one meal per week), common carp (one meal per week), and sturgeon (one meal per month) due to PCB contamination. Missouri has fish consumption advisories for the Mississippi River for shovelnose sturgeon (1 per month) due to PCB and chlordane contamination, and for flathead catfish, blue catfish, channel catfish, and common carp (1 per week) due to PCB, chlordane, and mercury contamination.

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. On the Missouri side, the Mosenthein/Ivory Landing Phase 5 work area (St. Louis Co.) is designated as a moderate nonattainment area for 8-hour ozone (1997 standard), a marginal nonattainment area for 8-hour ozone (2008 standard), and a moderate nonattainment area for particulate matter-2.5 (1997 standard) (USEPA 2015). On the Illinois side, the work area (Monroe Co.) is designated as a maintenance area for 8-hour ozone (1997 standard), a marginal nonattainment area for 8-hour ozone (2008 standard), and a moderate nonattainment area for particulate matter2.5 (1997 standard) (USEPA 2015).

Biological Resources

Fish and Wildlife – The changes in fish and wildlife habitat in the Mississippi River Basin that have occurred over the past 200 years are well documented. Many studies have analyzed the historic changes in habitat in the Mississippi River Basin from pre-colonization times to present day (e.g., Simons et al. 1974; UMRBC 1982; Theiling et al. 2000; WEST 2000; and Heitmeyer 2008). A variety of actions have impacted the makeup of the Mississippi River basin since colonization including urbanization, agriculture, levee construction, dam construction, and river training structure placement. Many of the changes in the Middle Mississippi River planform are attributable to improvements made for navigation including river training structure placement and associated sedimentation patterns.

An analysis of changes in river planform in the MMR was recently conducted by the District (Brauer et al. 2005; Brauer et al. 2013). The analysis utilized historic and modern maps, surveys, and aerial photography to calculate changes through time in planform width, channel width, channel surface area, side channel width, etc. The analysis demonstrates that the MMR went through a period of planform widening in the mid-nineteenth century followed by a period of planform narrowing from the end of the nineteenth century through the mid-twentieth century. The period of narrowing corresponded to the widespread use of river training structures and bank protection for navigation improvements. The first training structures were mainly permeable wooden structures which focused the river's energy into the main channel by reducing the velocities between the structures, causing sediment to deposit in channel border areas. This sediment deposition caused a significant narrowing effect on the channel. Since 1968, however, the channel width appears to have reached dynamic equilibrium with very little change (see Figure 6 below). In the 1960s, the Corps began constructing impermeable dikes primarily out of stone. The use of impermeable dikes reduced the rate of deposition between the structures when compared to the previously used permeable structures. Another change was the reduction of the design elevation of dike fields. Unlike in the past, the area between the structures did not fill with sediment, grow vegetation and become part of the floodplain. In the 43 years between 1968 and 2011 the average planform width remained relatively steady with a net reduction in average planform width of 167 feet. This was the result of the changes in structure material, structure elevation, and bank protection.

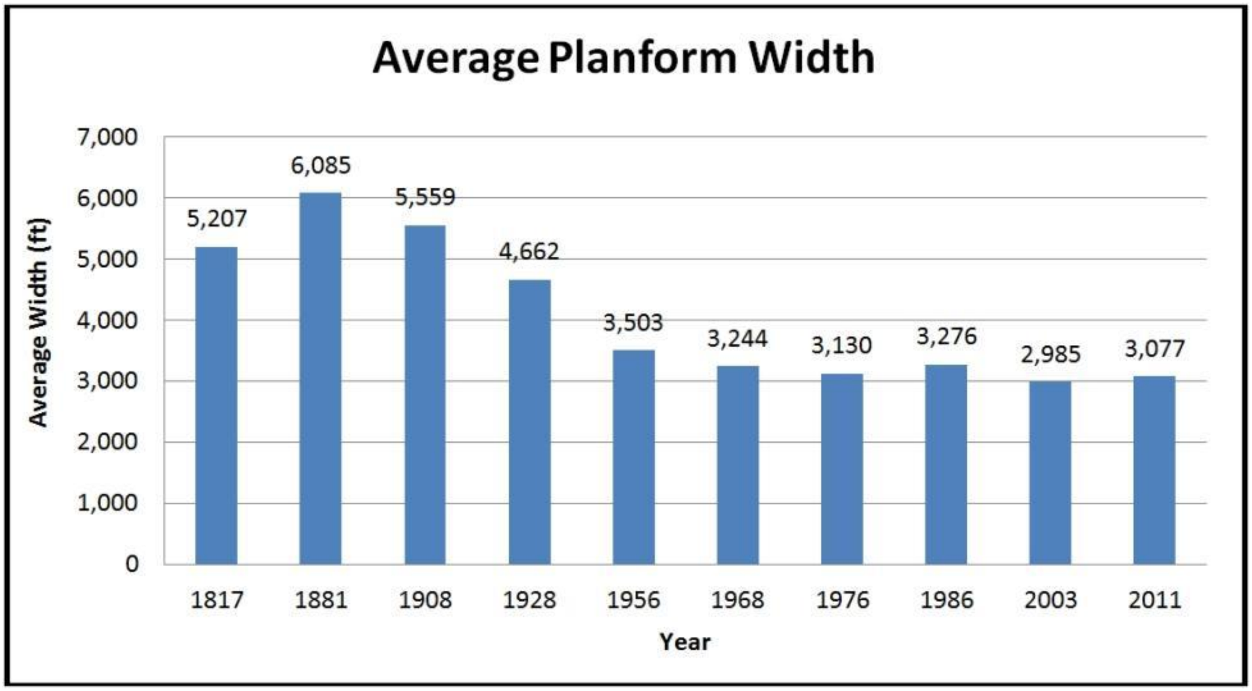

Figure 6. Average planform width of the MMR from 1817 to 2011.

In response to natural resource agency partner concerns about the potential impacts of traditional dikes on fish and wildlife habitat, the St. Louis District began to experiment with innovative dike configurations that attempt to achieve the navigational objectives of a safe and dependable navigation channel in an environmentally sensitive manner. The District has designed and implemented many different dike configurations including notched dikes, rootless dikes, L-dikes, W-dikes, chevron dikes, multiple roundpoint structures, etc. The intent of the innovative dike designs is to provide bathymetric (depth) and flow diversity compared with the traditional structures constructed since the 1960s while maintaining the function of deepening the navigation channel. The District currently builds very few traditional wing dike structures in the MMR.

The fish community in the area is expected to be typical of the Middle Mississippi River fish community in general. Fish community monitoring in the area conducted from 2003 to 2007 (RM 183 to 182; Schneider 2012) collected a total of 35 species of fish representing 14 families. The most commonly encountered native species included channel catfish (*Ictalurus punctatus*), freshwater drum (*Aplodinotus grunniens*), gizzard shad (*Dorosoma cepedianum*), goldeye (*Hiodon alosoides*), blue catfish (*I. furcatus*), shoal chub (*Macrhybopsis hyostoma*), smallmouth buffalo (*Ictiobus bubalus*), and flathead catfish (*Pylodictis olivaris*). These species accounted for approximately 85% of the fish captured, by number. Also included in the collections were 5 species of non-native fish including silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), and bighead carp (*Hypophthalmichthys nobilis*). These species accounted for approximately 5% of the fish captured, by number. Silver carp were likely under-represented in the collection due to the sampling methodologies employed. The Middle Mississippi River sees some commercial and recreational fishing pressure. Commercial fishermen typically target common carp, bigmouth and smallmouth buffalo, catfish, freshwater drum, and recently silver carp. Recreational fishermen typically target catfish.

Macroinvertebrates are an important part of the river ecosystem as they serve as a food source for a variety of fish and wildlife species. Common macroinvertebrate fauna encountered in the MMR consist of a variety of oligochaete worms, flies, mayflies, caddisflies, and stoneflies. Sampling by Battle et al. (2007) near Cape Girardeau, Missouri showed densities of macroinvertebrates in fine substrates downstream from wing dikes ranging from approximately 3,700 to 11,700 individuals per square meter. Sixty-eight taxa were collected from fine sediments with the dominant groups being oligochaete worms, midges, and mayflies. Densities on rocks on the upstream side of wing dikes ranged from 57,800 to 163,000 individuals per square meter. Fifty taxa were collected from rock substrate with the dominant group being caddisflies.

Threatened and Endangered Species – Based on coordination with the U.S. Fish and Wildlife Service, 13 federally threatened or endangered species could potentially be found in the area. The 13 species, federal protection status, and habitat description are shown in Table 3. No critical habitat is located in the work area.

Table 3. Federally listed threatened and endangered species potentially occurring in the work area.

Species	Federal Status	Habitat
Gray bat (*Myotis grisescens*)	Endangered	Caves
Indiana bat (*Myotis sodalis)*	Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: small stream corridors with well developed riparian woods; upland forests
Northern long-eared bat (*Myotis septentrionalis*)	Proposed Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: the understory of forested hillsides and ridges, small stream corridors with well developed riparian woods; upland forests.
Pallid sturgeon (*Scaphirhynchus albus*)	Endangered	Mississippi and Missouri Rivers.
Least tern (*Sterna antillarum*)	Endangered	Bare alluvial and dredged spoil islands.
Decurrent false aster (*Boltonia decurrens*)	Threatened	Disturbed alluvial soils.
Illinois cave amphipod *(Gammarus acherondytes)*	Endangered	Cave streams in Illinois sinkhole plain.
Mead's milkweed (*Asclepias meadii*)	Threatened	Moderately wet (mesic) to moderately dry (dry mesic) upland tallgrass prairie or glade/barren habitat.

Species	Federal Status	Habitat
Running buffalo clover (*Trifolium stoloniferum*)	Endangered	This species may be found in partially shaded woodlots, mowed areas and along streams and trails.
Pink mucket (*Lampsilis abrupta*)	Endangered	This species is found in mud and sand and in shallow riffles and shoals swept free of silt in major rivers and tributaries.
Scaleshell mussel (*Leptodea leptodon*)	Endangered	Lives in medium-sized and large rivers with stable channels and good water quality.
Sheepnose mussel (*Plethobasus cyphyus*)	Endangered	Rivers and streams.
Spectaclecase mussel (*Cumberlandia monodonta*)	Endangered	Spectaclecase mussels are found in large rivers where they live in areas sheltered from the main force of the river current.

Socioeconomic Resources

Navigation - 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. The St. Louis Harbor is the third busiest inland port in the nation. Approximately 106 million tons of cargo passed through the MMR in 2011 (USACE 2013). Food and farm products (37 million tons), coal (26 million tons), crude materials (14 million tons), fertilizers (12 million tons), and petroleum products (10 million tons) accounted for the majority (93%) of shipments in 2011.

Repetitive channel maintenance dredging occurs regularly in the area from RM 160 to 161 and less frequently from RM 161 to 163 (see Figure 3). The high frequency dredging area around the RM 160 area averages 110,282 cubic yards per event, the highest amount being almost twice that total. The low frequency dredging area at RM 161 averages 104,364 cubic yards per event. Dredging costs in the area (RM 156 -165) over the past 10 years have averaged approximately $359,925 per year.

Historic and Cultural Resources

Compared to some other segments of the Mississippi River, the course of the Mosenthein Reach has remained relatively consistent for the last 150 years. As with much of the river in the American Bottom, there has been narrowing with the accretion of land on the Illinois side. By 1908, however, the Illinois bankline in the immediate work area stabilized near its current position and the only major change to the Missouri bank was the accretion of land below the Missouri bluffs at the mouth of the Meramec River (see Appendix F).

During the summer of 1988 when the Mississippi River was at one of its lowest levels on record, 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 wreck sites to the work area were over two miles away, both upstream and downstream.

Most of the proposed structures are next to dredged channels, which probably resulted in channel slump and sediment reworking in the locations. The Mosenthein Reach has been regularly dredged over the years, and it is likely that any unrecorded wreckage located in the path of those dredge events was destroyed and removed during the process. The USACE has been conducting such activities to deepen the navigation channel of the Middle Mississippi since 1896 (Manders and Rentfro 2011:61).

The river bed in the work area is surveyed every one to two years, with the latest survey having been completed on May 14, 2013. The single-beam survey was conducted with range lines spacing of approximately 200 feet. No topographic anomalies suggesting wrecks were visible on the resulting bathymetric map.

4. Environmental Consequences

The Environmental Consequences Section of this report details the impacts of the Alternatives on the human environment. The section is organized by resource, in the same order in which they were covered in Section 3, Affected Environment. Within each resource category, impacts will be broken out by Alternative. The No Action Alternative consists of not constructing any new river training structures in the area, but continuing to maintain the existing river training structures. Dredging under the No Action Alternative would continue as needed to address the shoaling issues in the area. The Proposed Action consists of constructing three dikes (all three of which could be considered rootless) and four bendway weirs between RMs 160 and 162 on the left descending bank.

Physical Resources

Stages

Impacts of the No Action Alternative on Stages – 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.

Impacts of the Proposed Action on Stages – With implementation of the Proposed Action, stages at average and high flows both in the work area vicinity 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 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 A. 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 of the Regulating Works program on stage impacts, USACE concludes that flood risks are not increased.

With respect to water surface elevations at low flows, analysis of the data shows a trend of decreasing stages over time. This decrease could be a result of river training structure placement and/or a decrease in the sediment load in the river due to construction of reservoirs on

Mississippi River tributaries (Huizinga 2009). The same conclusion regarding decreasing stages at low flows was reached in the 1976 Regulating Works EIS (USACE 1976). The 1976 EIS concluded that, as a result of stage decreases, many of the remaining side channels in the MMR might be lost at some point in the future due to sedimentation. While much research has been performed on the impacts of river training structures at high flows, similar research has not been performed on the impacts at low flows. However, since the 1976 EIS, there has been an increasing recognition of the importance of side channel habitat on the MMR and increased emphasis on side channel restoration. Through the District's Biological Opinion Program (http://mvs-wc.mvs.usace.army.mil/arec/Bio_Op.html), Avoid and Minimize Program (http://mvs-wc.mvs.usace.army.mil/arec/AM.html), innovative river training structure design, and other restoration initiatives, side channel restoration and preservation on the MMR has occurred and will continue to occur for the foreseeable future, resulting in a substantial preservation of the side channels that existed in 1976. While the Proposed Action may have some minor local effect on water surface elevations at lower flows, any impacts locally or cumulatively are being minimized through the use of innovative river training structures and through other District programs, which have currently seen success in restoring and preserving side channels affected by river training structures.

Water Quality

Impacts of the No Action Alternative on Water Quality – Periodic dredging activities would continue to cause re-suspension of river sediments at the point of discharge, causing turbidity, increased suspended sediment concentration, and decreased light penetration. The impact would be localized and would dissipate quickly. Dredged sediments in the area are typically sand with little associated fines and would, therefore, not be expected to release contaminants into the water column at concentrations that alone or in combination with other contaminants would cause toxic effects to aquatic organisms.

Impacts of the Proposed Action on Water Quality – Construction activities would cause temporary increases in turbidity and suspended sediment concentrations in the immediate vicinity of the structure locations. The impact would be localized and would dissipate quickly. Sediments in the area are typically sand with little associated fines and would, therefore, not be expected to release contaminants into the water column at concentrations that alone or in combination with other contaminants would cause toxic effects to aquatic organisms.

The proposed dike structures are designed to change the sedimentation patterns in the area and would, therefore, cause some minor temporary changes in the suspended sediment concentration in the immediate area.

Limestone material used for construction could potentially affect local water chemistry (e.g., alkalinity, hardness, and pH). However, given the prevalence of limestone in the watershed geology and the quick dissipation of any associated fine materials in the water column, the impact is likely to be negligible.

The District is currently in the process of obtaining authorization for the work under sections 404 and 401 of the Clean Water Act. All permits necessary for completion of the work have been applied for and will be obtained prior to implementation.

Air Quality

Impacts of the No Action Alternative on Air Quality – Air quality in the vicinity of the work area would be expected to be similar to current conditions. Equipment used for repetitive dredging activities would generate emissions on an occasional, ongoing basis from the use of petroleum products. An analysis was conducted to determine the conformity of the repetitive dredging to the State Implementation Plan (SIP) for the states of Missouri and Illinois. The MV Dredge Potter (2400 hp) is expected to be used about 45 days per year to perform this dredging in the work area's reach of the river (river miles 160.0-171.0), and this is a worst-case scenario based on historic dredging records (2000-2013). During operation, this maintenance dredging equipment would generate emissions including volatile organic compounds (VOCs), oxides of nitrogen (NOx), and particulate matter (PM). Based on use of this equipment, the quantitative assessment estimates annual emissions of 1.8 tons of VOCs, 60.8 tons of NOx, and 17.7 tons of PM. These estimates are below the de minimis levels set for the nonattainment areas, which are 50 tons per year of VOCs, 100 tons per year of NOx, and 100 tons per year of PM.

The worst-case scenario assessment also shows that maintenance dredging is not regionally significant as estimated emissions would not exceed 10% of the total emissions in the nonattainment area. In 2012, VOC emissions from all sources in Monroe County, Illinois, were 2,301 tons, NOx emissions from all sources were 2,124 tons, and PM10 and PM2.5 emissions from all sources were 754 and 349 tons, respectively (USEPA undated). In 2012, VOC emissions from all sources in St. Louis County, Missouri, were 32,362 tons, NOx emissions from all sources were 35,070 tons, and PM10 and PM2.5 emissions from all sources were 31,662 and 7,444 tons, respectively (USEPA undated).

Based on this worst-case scenario analysis, air quality impacts from maintenance dredging performed in the work area's reach of the river are minor.

Impacts of the Proposed Action on Air Quality – When a federal action is being undertaken in a nonattainment area, the federal agency responsible for the action is required to determine if its action conforms to the applicable State Implementation Plan (SIP). A SIP is a plan that provides for implementation, maintenance, and enforcement of the National Ambient Air Quality Standards (NAAQS) and includes emission limitations and control measures to attain and maintain the NAAQS. An analysis was conducted to determine the conformity of the Mosenthein/Ivory Landing Phase 5 work to the SIPs for the states of Missouri and Illinois.

Equipment needed to construct the proposed features is assumed to include two push boats (880 hp) and a dragline crane (300 hp). Assuming these features would not eliminate the need for maintenance dredging in the work area, the MV Dredge Potter (2400 hp) is assumed to be required as a worst-case scenario for all the time of the No Action alternative. During operation, this equipment would generate emissions including volatile organic compounds (VOCs), oxides of nitrogen (NOx), and particulate matter (PM). Based on use of this equipment, the quantitative assessment estimates annual emissions of 2.2 tons of VOCs, 73.3 tons of NOx, and 20.6 tons of PM. These estimates are below the de minimis levels set for the nonattainment areas, which are 50 tons per year of VOCs, 100 tons per year of NOx, and 100 tons per year of PM.

The worst-case scenario assessment also shows that maintenance dredging plus construction is not regionally significant as estimated emissions would not exceed 10% of the total emissions in the nonattainment area. In 2012, VOC emissions from all sources in Monroe County, Illinois, were 2,301 tons, NOx emissions from all sources were 2,124 tons, and PM10 and PM2.5 emissions from all sources were 754 and 349 tons, respectively (USEPA undated). In 2012, VOC emissions from all sources in St. Louis County, Missouri, were 32,362 tons, NOx emissions from all sources were 35,070 tons, and PM10 and PM2.5 emissions from all sources were 31,662 and 7,444 tons, respectively (USEPA undated).

Based on this worst-case scenario analysis, air quality impacts from the proposed construction activities in combination with maintenance dredging performed in this work area's reach of the river would be minor.

Biological Resources

Fish and Wildlife

Impacts of the No Action Alternative on Fish and Wildlife – Periodic maintenance dredging and dredged material disposal operations would have the potential to affect fish and wildlife resources through direct removal of individual organisms (entrainment) at the dredging site. The degree to which fish and wildlife resources are impacted is largely a factor of the density of the organisms in the area of the dredge cut at the time of dredging operations. Macroinvertebrate densities tend to increase with greater sediment stability, lower water velocities, and higher silt and organic matter concentrations (Galat et al. 2005). Given the shifting nature of the sediments, high water velocities, and low silt concentrations in the main channel of the MMR, the area is not ideal habitat for colonization by bottom-dwelling macroinvertebrates (Koel and Stevenson 2002; Sauer 2004), but likely provides habitat for low densities to exist. Various fish species likely utilize the habitat as well and could be impacted at dredge sites. The Corps' Engineer Research and Development Center published a Technical Note in 1998 that summarized existing literature regarding potential impacts to aquatic organisms from dredging operations (Reine and Clarke 1998). Fish entrainment rates varied widely among species and studies and were reported as ranging from <0.001 to 0.594 fish/cubic yard of material dredged.

The St. Louis District recently contracted a dredge monitoring study for the Chain of Rocks East Canal Levee Project (Badgett 2010). The project involved the use of sand dredged from the main channel of the MMR for construction of a seepage berm on the Chain of Rocks Canal Levee. Because there was concern that dredging operations could entrain endangered pallid sturgeon in the project area, monitoring of dredged material was conducted to quantify impacts of dredging operations on the fish community. A total of approximately 1,000,000 cubic yards of material was dredged during the project, and fish entrainment monitoring was conducted during approximately 15% of the operation. No pallid sturgeon were captured during the study. Nine shovelnose sturgeon and 38 other fish representing 6 species were captured during the study.

Aside from direct impacts from dredge entrainment, fish and wildlife could also be impacted directly by disposal of dredged material. Organisms in the vicinity of the disposal area could be affected by changes in water quality including increased suspended solids and could be covered by settling sediments. Increased suspended solids in the water column could cause abrasion of body and respiratory surfaces. Most mobile organisms in the vicinity of the disposal location, however, would likely avoid the area during dredging operations. Changes in water quality would be short-lived and localized in extent.

Recovery of fish and wildlife resources at the dredge and disposal location occurs over a period of weeks, months, or years, depending on the species in question (USACE 1983). Areas with unstable sediment such as those in the main channel of the MMR are much more likely to have associated fish and wildlife species more adapted to physically stressful conditions and, therefore, would be more likely to withstand stresses imposed by dredging and disposal and recover more quickly (USACE 1983).

In a 1974 study (Solomon 1974) benthic organisms collected from dredged, disposal, and river border locations varied in abundance and diversity. Lowest abundance and diversity were observed at previously dredged sites; greater abundance and diversity at existing disposal sites; and highest values were observed at river border areas. The association of benthic organisms with median grain size of sediment samples was not well defined; however, it was apparent that greater numbers of organisms were associated with the smaller sediment particles (those corresponding to silt or clay and to the lower size range of fine sand). The sediment in the disposal and river border areas ranges from silt and/or clay to fine- and medium-sized sand. These finer grained substrate materials provide a more favorable habitat for benthic organisms. The majority of the dredging and dredge placement in the MMR takes place within repetitive dredging areas and placement areas that are located in the main channel, where fewer benthic organisms are found; therefore, dredging impacts to benthic organisms would likely be limited.

In summary, the amount of dredging going forward would remain similar to what has been experienced recently. Dredging and disposal impacts would include potential entrainment of aquatic species as well as behavioral changes associated with noise and turbidity levels. Some mortality of individual fish and invertebrates would be anticipated. Overall impacts to the fish and invertebrate communities in the area would be expected to be localized, minor, and short-term in nature.

Impacts of the Proposed Action on Fish and Wildlife

Dike Effects – The hydrodynamics around training structures are complex and vary greatly depending upon the type of training structure in question and where it is located within the river channel. A traditional wing dike constructed perpendicular to flow and tied in to the river bank would be expected to deepen the adjacent navigation channel, cause a scour hole to develop at the dike tip, and cause sediment accretion downstream from the structure near the river bank. Shields (1995) studied 26 groups of traditional dikes in the Lower Mississippi River and determined that the aquatic volume and area of associated low-velocity habitat (important aquatic habitat) were reduced by 38% and 17%, respectively. Most of the changes occurred shortly after construction, and after initial adjustment, habitat area and volume fluctuated around a condition of dynamic equilibrium. As detailed in Section 3 above, dike construction on the

MMR has, historically, caused a narrowing of the river planform over time due to this sediment accretion process followed by growth of terrestrial vegetation. However, the analysis of changes in river planform in the MMR recently conducted by the District (Brauer et al. 2005; Brauer et al. 2013) demonstrates that channel widths in the MMR appear to have reached a state of dynamic equilibrium where very little conversion to terrestrial habitat is occurring subsequent to river training structure placement. In addition, innovative structures such as the proposed rootless dikes are intended to provide bathymetric diversity, flow refuge, and split flow conditions that differ from traditional wing dikes. Based on the model studies conducted for the work area and District experience with similar river training structures, the proposed dikes are expected to reduce the elevation in the repetitive dredging area. In addition the rootless dikes and angled dike would help to improve channel border habitat by encouraging flow toward the side channel or channel border on the left descending bank.

Regardless of the specific configuration of the river training structures utilized, rock structures can provide improved habitat for fish by providing areas of reduced flow, a more diverse substrate, and additional cover. In addition, they can provide more suitable substrate for a wide variety of benthic organisms. Barko et al. (2004) found that species richness was greatest at wing dikes in the Middle Mississippi River for both adult and age-0 fishes when compared with main channel borders. However, they did find differences in species composition. Hartman and Titus (2009) studied dikes and reference sites on the Kanawha River, West Virginia and found that fish used dikes as much as or more than sites without dikes and that differences in taxonomic composition occurred. A study of larval fish use of dike structures on the Kanawha River found significantly higher capture rates of larval fish at dike sites than at reference sites (Niles and Hartman 2009). The difference in capture rates was attributed to reduced velocities provided by dikes. On the Upper Mississippi River, Madejczyk et al. (1998) found that fish abundance and diversity measures differed little among channel border habitat types in Pool 6, but significantly larger fish were present at locations with structure (wing dikes, woody snags) than at sites with bare shorelines.

Limited sampling conducted by the St. Louis District at an offset dike field in the MMR at RM 60.0 to 57.5 (USACE 2012) showed an increase in bathymetric, flow, and sediment diversity from pre-construction to post-construction and showed similar fish community composition pre- and post-project. Schneider (2012) investigated fish community and habitat changes associated with chevron dike construction in the MMR St. Louis Harbor and found increased fish and habitat diversity associated with chevron dikes as compared to pre-construction conditions and open water control sites.

In summary, the proposed rootless dikes are not expected to result in a loss of aquatic habitat due to sedimentation and conversion to terrestrial habitat. These structures are expected to increase bathymetric, flow, and sediment diversity in the immediate vicinity of the structures. Fish response to these changes in habitat is difficult to predict quantitatively, but, based on prior studies, fish use of the area may increase after construction related disturbance ends.

Bendway Weir Effects - Bendway weirs are designed to reduce dredging requirements in river bends by controlling point bar development (Davinroy 1990). They consist of a series of low-level submerged dikes (top elevation 351 NAVD88) constructed around the outer edge of a river bend. Each bendway weir is angled 30 degrees upstream of perpendicular to divert flow, in progression, toward the inner bank. The result is hydraulically controlled point bar development, reduced erosion of the outside bank, and a wider and safer navigation channel.

While providing benefits for navigation and channel maintenance, bendway weirs also provide complex habitat for macroinvertebrate and fish communities. Extreme main channel water depths found at outside bends without bendway weir fields are thought to be of little fisheries value (Baker et al. 1991).The bendway weir fields themselves provide a more heterogeneous environment than the surrounding homogenous sand substrate, resulting in greater species richness and diversity of benthic invertebrates (Ecological Specialists, Inc. 1997a, 1997b).

Hydroacoustic surveys of fishes were conducted by Kasul and Baker (1996) in four river bends of the Middle Mississippi River between Cairo, Illinois, and Cape Girardeau, Missouri (RM 2-50). Comparisons of fish density based on the hydroacoustic surveys suggested that bendway weirs increased the local abundance of fishes in affected areas of the river channel more than two-fold when compared to bends without weirs.

While the presumed benefits of bendway weir fields on fish communities at outside bends are acknowledged by natural resource agency partners, there is also concern that there may be an associated negative impact on fish communities at the adjacent inside bend point bar. The effects of bendway weirs on point-bar fishery habitat were studied on the Lower Mississippi River (Schramm et al. 1998) by comparing the changes in late-falling and low-river stage electrofishing catch rates of prevalent fishes before (1994) and after (1996) installation of bendway weirs at Victoria Bend relative to the changes in catch rates of the same fishes at Rosedale Bend, a nearby reference site without bendway weirs. Large interyear variation in catch rates was observed and, for most prevalent species, catch rates declined from 1994 to 1996 in sandbar habitats. However, significant declines in catch rates of prevalent species at Victoria Bend relative to changes in catch rates at the reference site were only noted for gizzard shad. Conversely, catch rates of goldeye, channel catfish, and flathead catfish at sandbar habitat during late-falling river stage significantly declined from 1994 to 1996 at Rosedale Bend while catch rates remained similar at Victoria Bend. Based on this limited study, the bendway weirs appeared to reduce gizzard shad abundance but, at certain river stages, may have improved habitat conditions for threadfin shad, goldeye, channel catfish, and flathead catfish.

In order to attempt to address resource agency partner concerns about the potential impacts of bendway weir fields on inside bend point bar habitat, the District completed a study in 2011 entitled "*Analysis of the Effects of Bendway Weir Construction on Channel Cross-Sectional Geometry*" (USACE 2011). The study utilized bathymetric data collected before and after weir construction at 21 bendways in the MMR and one in Pool 24. The bathymetric data were used to analyze the cross-sectional changes in channel bed geometry associated with the bendway weirs. Area, width, wetted perimeter, and slope were compared pre- to post-weir installation. The inner bend longitudinal slope was of particular interest due to concerns that the slopes were increasing, threatening shallow water habitat. The study showed that channel width at Low Water Reference Plane (LWRP) increased for 77% of the cross sections with an average increase of approximately 330 ft. The average slope decreased for 59% of all cross sections, with an average decrease of 1.27 ft. per 100 ft. The study concluded that bendway weirs are largely achieving their primary goal of widening the navigable portion of the channel without a serious detrimental effect on inside bar slopes.

The proposed placement of four bendway weirs in the work area is expected to improve fish and macroinvertebrate habitat in the outside bend by providing substrate diversity, flow refuge, and increased macroinvertebrate colonization surface area. The impacts on fish and macroinvertebrate habitat on the inside bend opposite the bendway weirs are uncertain. Studies to date do not provide conclusive results for predicting fish or macroinvertebrate community response to bendway weir placement at adjacent inside bends.

Threatened and Endangered Species

A programmatic (Tier I) consultation (USACE 1999), conducted under Section 7 of the Endangered Species Act, considered the systemic impacts of the operation and maintenance of the 9-Foot Channel Navigation Project on the Upper Mississippi River System (including the MMR) and addressed listed species as projected 50 years into the future (USFWS 2000). The consultation did not include individual, site specific effects or new construction. It was agreed that site specific impacts and new construction impacts would be handled under separate Tier II consultation. Although channel structure impacts were covered under the Tier I consultation, other site and species specific impacts could occur. As such, the Mosenthein/Ivory Landing Phase 5 work required Tier II consultation. Accordingly, the District prepared a Tier II Biological Assessment to determine the potential impacts of the work on federally threatened and endangered species (see Appendix B).

The Mosenthein-Ivory Landing Phase 5 Biological Assessment concluded that although adverse impacts to pallid sturgeon and the least tern associated with the proposed action have been avoided and minimized to the greatest extent possible and design modifications have been incorporated to provide habitat benefits, pallid sturgeon and the interior least tern may still be adversely affected. However, the adverse effects of the work on the pallid sturgeon and the least tern are consistent with those anticipated in the programmatic Biological Opinion and the District has implemented the Reasonable and Prudent Measures and Terms and Conditions prescribed therein as appropriate.

Although the bald eagle was removed from the federal list of threatened and endangered species in 2007, it continues to be protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (BGEPA). The BGEPA prohibits unregulated take of bald eagles, including disturbance. The U.S. Fish and Wildlife Service developed the National Bald Eagle Management Guidelines (USFWS 2007) to provide landowners, land managers, and others with information and recommendations regarding how to minimize potential project impacts to bald eagles, particularly where such impacts may constitute disturbance. No bald eagle nest trees are known to occur in the immediate vicinity of the work area at this time. If any nest trees are identified in the work area, the National Bald Eagle Management Guidelines will be implemented to minimize potential impacts and appropriate coordination with the U.S. Fish and Wildlife Service will be conducted.

Socioeconomic Resources

Navigation

Impacts of the No Action Alternative on Navigation – With the No Action Alternative, repetitive maintenance dredging activities would be expected to continue at a rate similar to recent history. Over the last ten years dredging costs in the area (RMs 156 – 165) have averaged approximately $359,925 per year. These expenditures would be expected to continue in the future.

Impacts of the Proposed Action on Navigation – Implementation of the Proposed Action is expected to reduce the amount and frequency of repetitive maintenance dredging necessary in the area. Barge grounding rates would also be expected to decrease in the area. Extensive coordination with navigation industry partners was conducted and Ameren's concerns with impacts to their intake facility at RM 161.5 (R) were addressed. Accordingly, impacts to fleeting areas as well as other navigation concerns have been avoided. The rootless dike at RM 161.7 will be located in a designated fleeting area, but it is no longer in use. The cost of the Proposed Action is not expected to exceed $3,500,000.

Historic and Cultural Resources

Impacts of the No Action Alternative on Historic and Cultural Resources – Continued dredging operations under the No Action Alternative are not anticipated to impact any known historic and cultural resources in the area. Any undocumented historic and cultural resources that may have existed in the area likely would have been destroyed by previous dredging activities. Future maintenance dredging under the No Action Alternative would likely occur in the same locations as previous dredging, and, therefore, would be unlikely to impact undocumented historic and cultural resources.

Impacts of the Proposed Action on Historic and Cultural Resources – All construction work on the dikes and weirs 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, 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.

Both the Illinois and Missouri State Historic Preservation Officers (SHPO) concurred that the proposed actions would not affect listed or eligible historic properties. A copy of the correspondence is included in Appendix F. 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 to this date no objections to the project were raised. A copy of the consultation letter is included in Appendix F.

Climate Change. To date, no official guidance applicable to the Middle Mississippi River Regulating Works Project has been established for federal agencies in determining impacts of proposed actions on climate change or the impacts of climate change on proposed actions. Nonetheless, a general assessment of climate trends and the most likely future climate conditions can assist decision makers in characterizing the potential impacts of their actions on climate change and the potential impacts of climate change on water resources and the future efficacy of infrastructure.

As part of the requirements of the Global Change Research Act enacted in 1990, the United States Global Change Research Program periodically conducts National Climate Assessments. National Climate Assessments are intended to evaluate, integrate, and assess the most current climate change information available and make it available to the public. National Climate Assessments were prepared in 2000 and 2009 and the third report was published in 2014 (Mellilo et al. 2014). The information below (Kunkel et al. 2013a; Kunkel et al. 2013b) comes from the technical reports prepared in support of the third National Climate Assessment and represents the most up-to-date information available on climate trends and forecasts for the area.

For the National Climate Assessment analysis, the Midwest was defined as Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, Ohio, and Missouri. Despite a large degree of interannual variability, analyses of recent trends for annual precipitation totals and extreme precipitation events in the Midwest show upward trends (Kunkel et al. 2013a; Karl et al. 2009). Predictions of future precipitation characteristics for the Midwest are characterized by a high degree of variability and uncertainty (Winkler et al. 2012; Kunkel et al. 2013a), but the following conclusions about simulated future precipitation in the Midwest were drawn (Kunkel et al. 2013a):

- *The greatest simulated increases in average annual precipitation are seen in the far north, while a decrease is indicated in the southwestern corner of the region. Seasonal changes are generally upward in winter, spring, and fall and downward in summer in the south. However, the range of model-simulated precipitation changes is considerably larger than the multi-model mean change. Thus, there is great uncertainty associated with future precipitation changes in these scenarios.*

- *Simulated changes in the number of days with precipitation exceeding 1 inch are upward for the entire Midwest region, with increases of up to 60% (for the A2 scenario at mid-century). The largest changes are seen in the states bordering Canada. The increases are statistically significant generally in the north, but not in the south.*

- *Statistically significant decreases in the number of consecutive days with less than 0.1 inches of precipitation are simulated for the north (for the A2 scenario at mid-century). Elsewhere changes are not statistically significant.*

- *Many of the modeled values of decadal precipitation change are not statistically significant, with respect to 2001-2010, out to 2091-2099.*

Precipitation trends for the Great Plains watershed are also important considerations for the Middle Mississippi River given the contribution of the Missouri River to Middle Mississippi River flows. For the National Climate Assessment analysis, the Great Plains was defined as Montana, North Dakota, South Dakota, Wyoming, Nebraska, Kansas, Oklahoma, and Texas (Kunkel et al. 2013b). The following general conclusions about simulated future precipitation in the Great Plains were drawn (Kunkel et al. 2013b):

- *Southern regions show the largest simulated decreases in average annual precipitation, while northern areas show increases. NARCCAP models show increases across most of the region in all seasons except summer. For the most part, these changes are either not statistically significant or the models do not agree on the sign of the change. An exception is the modeled changes in the far northern and far southern portions of the region for 2070-2099 under the high (A2) emissions scenario where the models simulate statistically significant increases and decreases, respectively. For most time periods and locations, the range of model-simulated precipitation changes is considerably larger than the multi-model mean change. Thus, there is great uncertainty associated with future precipitation changes in these scenarios.*

- *Nearly the entire region is simulated to see increases (up to 27%) in the annual number of days with precipitation exceeding 1 inch (for the A2 scenario at mid-century), with small areas in the far western portions of the region simulated to see slight decreases (up to 23%). However, these changes are mostly not statistically significant.*

- *Consecutive days with little or no precipitation (less than 0.1 inches) are simulated to increase in the south by 3-13 days per year and decrease in parts of the north by up to 8 days per year (for the A2 scenario at mid-century). The decreases in Texas and Oklahoma are mostly statistically significant.*

- *Many of the modeled values of decadal precipitation change are not statistically significant, with respect to 2001-2010, out to 2091-2099.*

Given the high degree of variability and uncertainty in weather patterns in general and in predictions of future weather patterns in particular, quantifying future Project impacts is inexact. However, if the assumption is made that changes in future precipitation in the Middle Mississippi River watershed are going to be characterized by increased average annual precipitation, more frequent extreme rainfall events, and consequently more frequent and greater flood events, then the basic functionality of river training structures and their ability to change sedimentation patterns should not be affected going forward. Also, given that the District has concluded that river training structures do not increase flood heights (see Section 4, Environmental Consequences and Appendix A), river training structures would not contribute any increase to potential future flood events. Nonetheless, climate change could impact navigation by changing sedimentation patterns and associated impediments to navigation, increasing the need for dredging, and decreasing the dependability of the navigation channel due to floods and droughts (Moser et al. 2008; Karl et al. 2009).

With respect to impacts on climate change, implementation of the Proposed Action would result in some minor greenhouse gas emissions due to equipment used for construction activities, rock transportation, etc. However, the Proposed Action would result in an overall decrease in greenhouse gas emissions due to the reduction in the amount of repetitive maintenance dredging required in the work area.

Cumulative Impacts

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 Mosenthein/Ivory Landing Phase 5 EA cumulative impact analysis generally followed the steps laid out by the handbook.

As detailed in Appendix C and summarized in Table 4 below, the cumulative impact analysis involved determining the incremental impact of the 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 Middle Mississippi River. Clearly the human environment in the Middle Mississippi River has been, and will continue to be, impacted by a wide range of actions. The cumulative impact analysis evaluates the same resources (Physical Resources [River Stages, Water Quality, and Air Quality]; Biological Resources [Fish and Wildlife: Dike Effects, Threatened & Endangered Species, and Climate Change]; Socioeconomic Resources [Navigation]; and Historic & Cultural Resources) that were evaluated in the Environmental Consequences section. In addition, the cumulative impacts for the No Action Alternative and Action Alternative were evaluated for navigation effects and side channel impacts.

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. However, this analysis is meant to characterize the incremental impact of the current action in the broader context of other actions affecting the same resources. Although past actions associated with the Regulating Works Project have impacted these resources, the current method of conducting business for the 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. Although our understanding of the actions that bear upon the resources of the Middle Mississippi River continues to evolve, equilibrium in habitat conditions appears to have been reached. Accordingly, only minimal impacts to the resources, ecosystem and human environment are anticipated for the Mosenthein-Ivory Phase 5 work area.

Table 4. Summary of cumulative impacts.

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Proposed Action
Stages	Flows and stages impacted by watershed land use changes, levee construction, mainline and watershed dam construction, consumptive water use, climate change	Continued impacts due to land use changes in watershed, consumptive water use, levee construction, climate change	Continued impacts due to land use changes in watershed, consumptive water use, levee construction, climate change	No impacts on stages anticipated	No impacts on stages anticipated at average and high flows. At low flows, current trend of decreasing stages expected to continue.
Water Quality	Increasing human populations and industrialization result in increased water quality problems. Establishment of Clean Water Act, NEPA, USEPA, state environmental agencies and associated regulations greatly improve conditions.	Continued population growth and development result in increased potential for water quality impacts. Continued regulation enforcement and societal recognition prevent water quality degradation.	Continued regulation enforcement and societal recognition. Continued population growth and development result in increased potential for water quality impacts.	Localized, temporary increase in suspended sediment concentrations at dredge material discharge sites	Localized, temporary increase in suspended sediment concentrations during construction activities.
Air Quality	Increasing human populations and industrialization result in deterioration of air quality. Establishment of Clean Air Act, NEPA, USEPA, air quality standards improve conditions. Non-attainment status in work area.	Continued population growth and development result in increased potential for air quality impacts. Continued regulation enforcement and societal recognition. Continued non-attainment status in work area.	Continued population growth and development result in increased potential for air quality impacts. Continued regulation enforcement and societal recognition. Possible achievement of attainment status through implementation of State Implementation Plans.	Minor and local impacts due to use of dredging equipment	Minimal air quality impacts; below *de minimis* levels

Table 4. (cont.)

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Proposed Action
Fish and Wildlife (including threatened and endangered species)	Transformation of river system from natural condition to pooled lock and dam system above Chain of Rocks; in MMR, loss of floodplain habitat due to levees, agriculture, urbanization; loss of natural river habitat – loss of dynamic habitat due to river channel stabilization with dikes/ revetment; loss of side channel habitat; dredging impacts; navigation impacts; USACE, other federal, state, and private habitat restoration and land mgmt programs reverse habitat loss; introduction of exotic species/reduced native species biomass; implementation of innovative river training structures to provide habitat diversity; recognition of T&E species through Endangered Species Act; listing of multiple T&E species in MMR; implementation of District Biological Opinion Program and Avoid and Minimize Program	Maintenance of current habitat conditions due to maintenance of lock and dam system above Chain of Rocks and existing dikes/revetment; continued implementation of Regulating Works Project; continued use of innovative river training structures to provide habitat diversity; habitat restoration and land mgmt through USACE, other federal, state, and private programs; habitat changes associated with recent and current innovative dike construction; maintenance of current floodplain habitat conditions due to continued agriculture use/ maintenance of existing levees/ urbanization; dredging impacts; navigation impacts; native species continue to be impacted by exotic species; continued implementation of Biological Opinion Program and Avoid and Minimize Program; restoration/maintenance of side channel habitat	Continued maintenance of habitat conditions due to maintenance of lock and dam system above Chain of Rocks and maintenance of existing dikes/revetment; dredging impacts; navigation impacts; continued implementation of Regulating Works Project; continued use of innovative river training structures to provide habitat diversity; continued habitat restoration and land mgmt through USACE, other federal, state, and private programs; maintenance of current floodplain habitat conditions due to continued agriculture use/ maintenance of existing levees/ urbanization; new exotic species likely to be introduced; continued implementation of Biological Opinion Program and Avoid and Minimize Program; restoration/maintenance of side channel habitat	Entrainment of some fish and macroinvertebrates at dredge locations; avoidance of dredge and disposal areas by mobile organisms; some loss of fish and macroinvertebrates at disposal sites; may affect but not likely to adversely affect threatened and endangered species	Avoidance of sites during construction; no conversion of aquatic habitat to terrestrial; increased fish and macroinvertebrate use of structure locations due to increased bathymetric, flow, and substrate diversity; no significant impacts to threatened and endangered species anticipated

Table 4. (cont.)

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Proposed Action
Navigation	1927 River and Harbor Act authorized USACE to provide a 9-foot channel on MMR; USACE transformed free-flowing Mississippi River system into navigable waterway with 37 lock and dam complexes above Chain of Rocks, some dredging, dikes, revetment; growth of port facilities and inland waterways and traffic throughout Mississippi River system provided for movement of commodities with local, national, and international importance	Operation of lock and dam system above Chain of Rocks continues; traditional and innovative stone dike, revetment construction, rock removal, and dredging continue to provide safe and dependable navigation channel; navigation continues to be an important part of local / national / international transportation and commerce activities	Operation of lock and dam system above Chain of Rocks continues; traditional and innovative stone dike, revetment construction, rock removal, and dredging continue to provide safe and dependable navigation channel; navigation continues to be an important part of local / national / international transportation and commerce activities	Continued requirement for periodic maintenance dredging at rates similar to recent history.	Reduction in the amount and frequency of repetitive maintenance dredging in the area; reduction in barge grounding rates
Historic and Cultural Resources	Historic and cultural resources subjected to natural processes and manmade actions (e.g., erosion, floodplain development); recognition of importance of historic and cultural resources through National Historic Preservation Act (and others)	Historic and cultural resources continue to be impacted by human activities as well as natural processes; continued societal recognition of importance of historic and cultural resources	Historic and cultural resources continue to be impacted by human activities as well as natural processes; continued societal recognition of importance of historic and cultural resources	Impacts to historic and cultural resources unlikely.	No known historic resources would be affected. Impacts to unknown historic and cultural resources unlikely.

Mitigation

Mitigation measures are used to avoid, minimize, or compensate for adverse impacts to environmental resources. The Mosenthein/Ivory Landing Phase 5 work has avoided and minimized adverse impacts throughout the alternative development process. As a result of coordination with resource agencies, no adverse impacts have been identified that would require compensatory mitigation.

5. Relationship of Proposed Action to Environmental Requirements

Federal Policy	Compliance Status
Bald Eagle Protection Act, 16 USC 668-668d	Full
Clean Air Act, 42 USC 7401-7542	Full
Clean Water Act, 33 USC 1251-1375	Partial 1*
Comprehensive Environmental Response, Compensation, and Liability Act, 42 USC 9601-9675	Full
Endangered Species Act, 16 USC 1531-1543	Full
Farmland Protection Policy Act, 7 USC 4201-4208	Full
Fish and Wildlife Coordination Act, 16 USC 661-666c	Full
Land and Water Conservation Fund Act, 16 USC 460d-461	Full
Migratory Bird Treaty Act of 1918, 16 USC 703-712	Full
National Environmental Policy Act, 42 USC 4321-4347	Partial 2*
National Historic Preservation Act, 16 USC 470 et seq.	Full
Noise Control Act, 42 USC 7591-7642	Full
Resource Conservation and Recovery Act, 42 USC 6901-6987	Full
Rivers and Harbors Act, 33 USC 401-413	Partial 1*
Water Resources Development Acts of 1986 and 1990	Full
Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (EO 12898)	Full
Floodplain Management (EO 11988 as amended by EO 12148)	Full
Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities (EO 11282 as amended by EO's 11288 and 11507)	Full
Protection and Enhancement of Environmental Quality (EO 11991)	Full
Protection and Enhancement of the Cultural Environment (EO 11593)	Full
Protection of Wetlands (EO 11990 as amended by EO 12608)	Full
Responsibilities of Federal Agencies to Protect Migratory Birds (EO 13186)	Full

1* Full compliance will be obtained prior to construction.
2* Full compliance after submission for public comment and signing of FONSI

6. List of Preparers

Name	Role	Experience
Mike Rodgers	Project Manager	14 years, hydraulic engineering
Jasen Brown	Project Manager	14 years, hydraulic engineering
Eddie Brauer	Engineering Lead	14 years, hydraulic engineering
Kip Runyon	Environmental Lead	18 years, biology
Francis Walton	Environmental; Threatened and Endangered Species	15 years, environmental compliance
Tim George	Air Quality	25 years, ecology
Tom Keevin	Cumulative Impacts	35 years, aquatic ecology
Kevin Slattery	HTRW	17 years, environmental science
Mark Smith	Historic and Cultural Resources	22 years, archaeology
Danny McClendon	Regulatory	29 years, regulatory compliance and biology
Keli Broadstock	Legal Review	3 years USACE, 6 years private sector law

7. Literature Cited.

Baker, J.A., K.J. Killgore, and R.L. Kasul. 1991. Aquatic habitats and fish communities in the lower Mississippi River. Aquatic Sciences. 3: 313–356.

Barko, V.A., D.P. Herzog, R.A. Hrabik, and J.S. Scheibe. 2004. Relationship among fish assemblages and main channel border physical habitats in the unimpounded Upper Mississippi River. Transactions of the American Fisheries Society, 133:2, 371-384.

Battle, J.M., J.K. Jackson, B.W. Sweeney. 2007. Annual and spatial variation for macroinvertebrates in the Upper Mississippi River near Cape Girardeau, Missouri. Fundamental and Applied Limnology. 168/1: 39-54.

Badgett, N. 2010. Final Report: Monitoring of Dredged Material for Fish Entrainment with Special Emphasis on the Pallid Sturgeon, Phase III North Berms Dredging, Chain of Rocks Canal, Mississippi River, Madison County, IL. Prepared by Ecological Specialists, Inc. for the U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

Brauer, E.J., D.R. Busse, C. Strauser, R.D. Davinroy, D.C. Gordon, J.L. Brown, J.E. Myers, A.M. Rhoads, and D. Lamm. 2005. Geomorphology Study of the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District, Applied River Engineering Center, St. Louis, Missouri. 43 pp.

Brauer, E.J., R.D. Davinroy, L. Briggs, and D. Fisher. 2013. Draft Supplement to *Geomorphology Study of the Middle Mississippi River (2005)*. U.S. Army Corps of Engineers, St. Louis District, Applied River Engineering Center, St. Louis, Missouri. 12 pp.

CEQ 1997. Considering Cumulative Effects under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, D.C.

Davinroy, R. D. 1990. Bendway weirs, a new structural solution to navigation problems experienced on the Mississippi River. Permanent International Association of Navigation Congresses 69:5-18.

Ecological Specialists, Inc. 1997a. Macroinvertebrates associated with Carl Baer bendway weirs in the Mississippi River. In: Melvin Price Locks and Dam, Progress Report 1997 for Design Memorandum No. 24 Avoid and Minimize Measures. U.S. Army Corps of Engineers, St. Louis District.

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

Hartman, K.J. and J.L. Titus. 2009. Fish use of artificial dike structures in a navigable river. River Research and Applications. 26: 1170-1186.

Heitmeyer, M.E. 2008. An evaluation of ecosystem restoration options for the Middle Mississippi River Regional Corridor. Greenbrier Wetland Services Report 08-02, Advance, MO.

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/)

Karl, T.R., J.M. Melillo, and T.C. Peterson, (eds.). 2009. Global Climate Change Impacts in the United States, Cambridge University Press.

Kasul, R. L., and J. A. Baker. 1996. Results of September 1995 hydroacoustic surveys of fishes in five reaches of the Middle Mississippi River (RM 2-50). Waterways Experiment Station Report prepared for the St. Louis District, U.S. Army Corps of Engineers.

Keevin, T. M., J. S. Tiemann, and K. S. Cummings. 2015. The Freshwater mussel fauna of the Middle Mississippi River. Northeastern Naturalist.

Koel, T. M., and K. E. Stevenson. 2002. Effects of dredge material placement on benthic macroinvertebrates of the Illinois River. Hydrobiologia 474:229-238.

Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, S.D. Hilberg, M.S. Timlin, L. Stoecker, N.E. Westcott, and J.G. Dobson. 2013a. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 3. Climate of the Midwest U.S., NOAA Technical Report NESDIS 142-3, 95 pp.

Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, M.C. Kruk, D.P. Thomas, M.D. Shulski, N.A. Umphlett, K.G. Hubbard, K. Robbins, L. Romolo, A. Akyuz, T.B. Pathak, T.R. Bergantino, and J.G. Dobson. 2013b. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 4. Climate of the U.S. Great Plains, NOAA Technical Report NESDIS 142-4, 82 pp.

Madejczyk, J.C., N.D. Mundahl, and R.M. Lehtinen. 1998. Fish assemblages of natural and artificial habitats within the channel border of the Upper Mississippi River. American Midland Naturalist, Vol. 139, No. 2, pp. 296-310.

Manders, D., & B. Rentrfro (2011). *Engineers Far From Ordinary*. St. Louis: St. Louis District USACE.

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Moser, H., P.J Hawkes, K.D. White, S. Mai, O.A. Arntsen, P. Gaufres, and G. Pauli. 2008. Waterborne transport, ports and waterways—A review of climate change drivers, impacts, responses and mitigation: Brussels, PIANC, 58 p.

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

Reine, K., and D. Clarke. 1998. "Entrainment by hydraulic dredges–A review of potential impacts." Technical Note DOER-E1. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Sauer, J. 2004. Multiyear synthesis of the macroinvertebrate component from 1992 to 2002 for the Long Term Resource Monitoring Program. 2004. Final report submitted to U.S. Army Corps of Engineers from the U.S. Geological Survey, Upper Midwest Environment Sciences Center, La Crosse, Wisconsin, December 2004. Technical Report LTRMP 2004-T005. 31 pp. + Appendixes A–C.

Schneider, B. 2012. Changes in fish use and habitat diversity associated with placement of three chevron dikes in the Middle Mississippi River. M.S. thesis, Southern Illinois University Edwardsville.

Schramm, H.L., Jr., L.H. Pugh, M.A. Eggleton, and R.M. Mayo. 1998. Lower Mississippi River Fisheries Investigations 1996 Annual Report. Report prepared by the Mississippi Cooperative Fish and Wildlife Research Unit for the Lower Mississippi Valley Division, U.S. Army Corps of Engineers.

Shields, Jr., F. D. 1995. Fate of Lower Mississippi River habitats associated with river training dikes. Aquatic Conservation and Freshwater Ecosystems 5:97-108.

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.

Solomon, R. C., J. H . Johnson, C. R. Bingham, and B. K. Colbert. 1974. Physical, biological, and chemical inventory and analysis of selected dredged and disposal sites; Middle Mississippi River. U. S. Army Eng. Exp. St., Vicksburg.

Theiling, C.H., C. Korschgen, H. De Haan, T. Fox, J. Rohweder, and L. Robinson. 2000. Habitat Needs Assessment for the Upper Mississippi River System: Technical Report. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. Contract report prepared for U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri. 248 pp.

Tiemann, J. 2014. Freshwater mollusks of the middle Mississippi River. Illinois Natural History Survey Prairie Research Institute, Technical Report 2014 (03). 70 pp.

UMRBC 1982. Comprehensive Master Plan for the Management of the Upper Mississippi River System. Upper Mississippi River Basin Commission, Minneapolis, Minnesota. 193pp.

USACE 1976. Environmental Statement, Mississippi River between the Ohio and Missouri Rivers (Regulating Works). U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri.

USACE. 1983. Dredging and dredged material disposal. Engineer Manual 1110-2-5025. U.S. Army Corps of Engineers, Washington, DC.

USACE. 1999. Tier I of a two tiered Biological Assessment - Operation and Maintenance of the Upper Mississippi River Navigation Project within St. Paul, Rock Island, and St. Louis Districts. Mississippi Valley Division, Vicksburg, MS.

USACE 2011. Analysis of the effects of bendway weir construction on channel cross-sectional geometry. U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

USACE. 2012. Devils Island offset dikes: pre- and post-construction monitoring completion report. U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

USACE. 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.

USACE. 2014. Technical Report M68, The Mouth of the Meramec River HSR Model Mississippi River, River Miles 165.00 – 156.00, Hydraulic Sediment Response Model Investigation. U.S. Army Corps of Engineers, St. Louis District, St. Louis, MO.

USEPA. Undated. Current Status of Air Quality and Air Quality Management Activities in the St. Louis Area. Available at: http://www.epa.gov/airquality/aqmp/pdfs/may2009/LLStLouis.pdf (Accessed January 21, 2015).

USEPA 2015. U. S. Environmental Protection Agency green book nonattainment areas for criteria pollutants as of January 30, 2015. http://www.epa.gov/airquality/greenbk/ . Accessed 19 February 2015.

USFWS 2000. Biological opinion for the operation and maintenance of the 9-foot navigation channel on the Upper Mississippi River System. U. S. Department of the Interior, Fort Snelling, Minnesota.

USFWS 2002. Status assessment report for the spectaclecase, *Cumberlandia monodonta*, occurring in the Mississippi River system (U.S. Fish and Wildlife Service Regions 3, 4, 5, and 6. U.S. Fish and Wildlife Service, Asheville, North Carolina.

USFWS 2007. National Bald Eagle Management Guidelines. U.S. Fish and Wildlife Service, Arlington, VA.

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.

WEST Consultants, Inc. 2000. Upper Mississippi River and Illinois Waterway Navigation Feasibility Study – Cumulative Effects Study, Volumes 1-2. Prepared by WEST Consultants, Inc. for the U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois.

Winkler, J.A., R.W. Arritt, and S.C. Pryor. 2012. Climate Projections for the Midwest: Availability, Interpretation and Synthesis. In: *U.S. National Climate Assessment Midwest Technical Input Report*. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators. Available from the Great Lakes Integrated Sciences and Assessment (GLISA) Center, http://glisa.msu.edu/docs/NCA/MTIT_Future.pdf.

FINDING OF NO SIGNIFICANT IMPACT (FONSI)

DRAFT FINDING OF NO SIGNIFICANT IMPACT
MOSENTHEIN/IVORY LANDING PHASE 5 REGULATING WORKS
MIDDLE MISSISSIPPI RIVER MILES 160 – 162.5
MONROE COUNTY, IL
ST. LOUIS COUNTY, MO

I. In accordance with the National Environmental Policy Act, I have reviewed and evaluated the documents concerning the Regulating Works, Mosenthein/Ivory Landing Phase 5 construction, Monroe County, Illinois and St. Louis 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.

II. 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 address repetitive dredging in the area. This would be accomplished by the construction of four bendway weirs and three dikes.

b. No significant impacts to federally listed 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 repetitive dredging expenditures would continue.

III. 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 Regulating Works, Mosenthein/Ivory Landing Phase 5 construction, Monroe County, Illinois and St. Louis County, Missouri.

__________________________ ______________________________________

(Date)

ANTHONY P. MITCHELL
COL, EN
Commanding

ENVIRONMENTAL ASSESSMENT

WITH

FINDING OF NO SIGNIFICANT IMPACT

REGULATING WORKS PROJECT
MOSENTHEIN/IVORY LANDING PHASE 4
MIDDLE MISSISSIPPI RIVER MILES 160 – 162.5
MONROE COUNTY, IL
ST. LOUIS COUNTY, MO

FEBRUARY 2015

APPENDICES

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

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 traning 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 streamflow for equal stages following the transfer of streamgaging 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 streamflow 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 streamflow 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 streamflow 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 the 50%, 20%, and 10% annual chance exceedance events. Xia (2009) used an Adaptive Hydraulics (AdH) model to study the changes in water surface resulting from the construction of 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 streamflow 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 streamgage 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 streamflows below 200,000 cfs. In streamflows 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 streamflows 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.

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.

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 streamflow 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.

3.2.3 Theoretical Analysis

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. p156-163.

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. 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., 139(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 B. Biological Assessment

TIER II BIOLOGICAL ASSESSMENT
MOUTH OF THE MERAMEC
MOSENTHEIN REACH – IVORY LANDING, PHASE V
MRM 161 – 162.5
MONROE COUNTY, ILLINOIS
ST. LOUIS COUNTY, MISSOURI
ON THE
MIDDLE MISSISSIPPI RIVER SYSTEM

November 2014

U.S. Army Corps of Engineers
St. Louis District
Planning and Environmental Branch (CEMVP-PD-C)
Attn: Francis Walton
1222 Spruce Street
St. Louis, Missouri 63103-2833
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TIER II BIOLOGICAL ASSESSMENT
MOUTH OF THE MERAMEC
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ST. LOUIS COUNTY, MISSOURI

1. Programmatic Endangered Species Compliance

A programmatic (Tier I) consultation, conducted under Section 7 of the Endangered Species Act, considered the systemic impacts of the operation and maintenance of the 9-Foot Channel Navigation Project on the Upper Mississippi River System (UMRS) and addressed listed species as projected 50 years into the future (U.S. Fish and Wildlife Service 2000). The consultation did not include individual, site specific project effects or new construction. It was agreed that site specific project impacts and new construction impacts would be handled under a separate Tier II consultation. Although channel structure impacts were covered at the program and ecosystem level under the Tier I consultation, other site and species specific impacts may occur. As such, the Mosenthein Reach – Ivory Landing, Phase V (Mouth of the Meramec) project requires a Tier II consultation.

Mosenthein Reach – Ivory Landing, Phase III (Phase III) and Phase IV also required a Tier II consultation. The Phase III consultation was completed on September 9, 2010 with receipt of a Tier II Biological Opinion provided by Matthew Mangan of the Fish and Wildlife Service. Phase III included placing two traditional wing dikes within the river at RM 182 and placing revetment on unprotected shoreline at RM 171.3 to 173.3. The Corps received a “no effect” and “not likely to adversely affect” decision for listed species, as well as a “not likely to result in incidental take of the pallid sturgeon beyond the amount of incidental take described in the 2000 Biological Opinion”.

The purpose of the Phase IV project was to stabilize the shoreline and prevent future erosion in the immediate area of the stabilization in order to maintain a safe and dependable navigation channel. The project involved placing revetment on the unprotected shoreline of the left descending bank between RMs 171 - 172 and between RMs 173.5-175 in the Middle Mississippi River. The Corps received a “no effect” and “not likely to adversely affect” decision for listed species, as well as a “not likely to result in incidental take of the pallid sturgeon beyond the amount of incidental take described in the 2000 Biological Opinion”.

Phase V of the project will consist of four bendway weirs on the right descending bank and three dikes on the left descending bank between RMs 161.1 and 162.3.

2. Project Authority

The project is authorized under the UMRS Regulating Works Project that was authorized by the River and Harbor Act of 1930. It consists of a 9-foot deep navigation channel that is not less than 300-feet wide with additional width in the bends. Project improvements are achieved by means of dikes, revetment, construction dredging, and rock removal. This project promotes maintenance of a safe and dependable navigation channel. Project funding will come from the Regulating Works Construction General funding.

3. Project Need

The purpose of the Phase V project weirs is to focus the energy of the water in order to reduce dredging and maintain a safe and dependable navigation channel. The Phase V dikes will promote flow into the side channels. The project involves placing weirs and rock dikes from approximately RM 161 to RM 162.5 in the Middle Mississippi River (Figures 1 and 2 and Table 1).

Figure 1. Mosenthein Reach – Ivory Landing, Phase V Site Location Maps

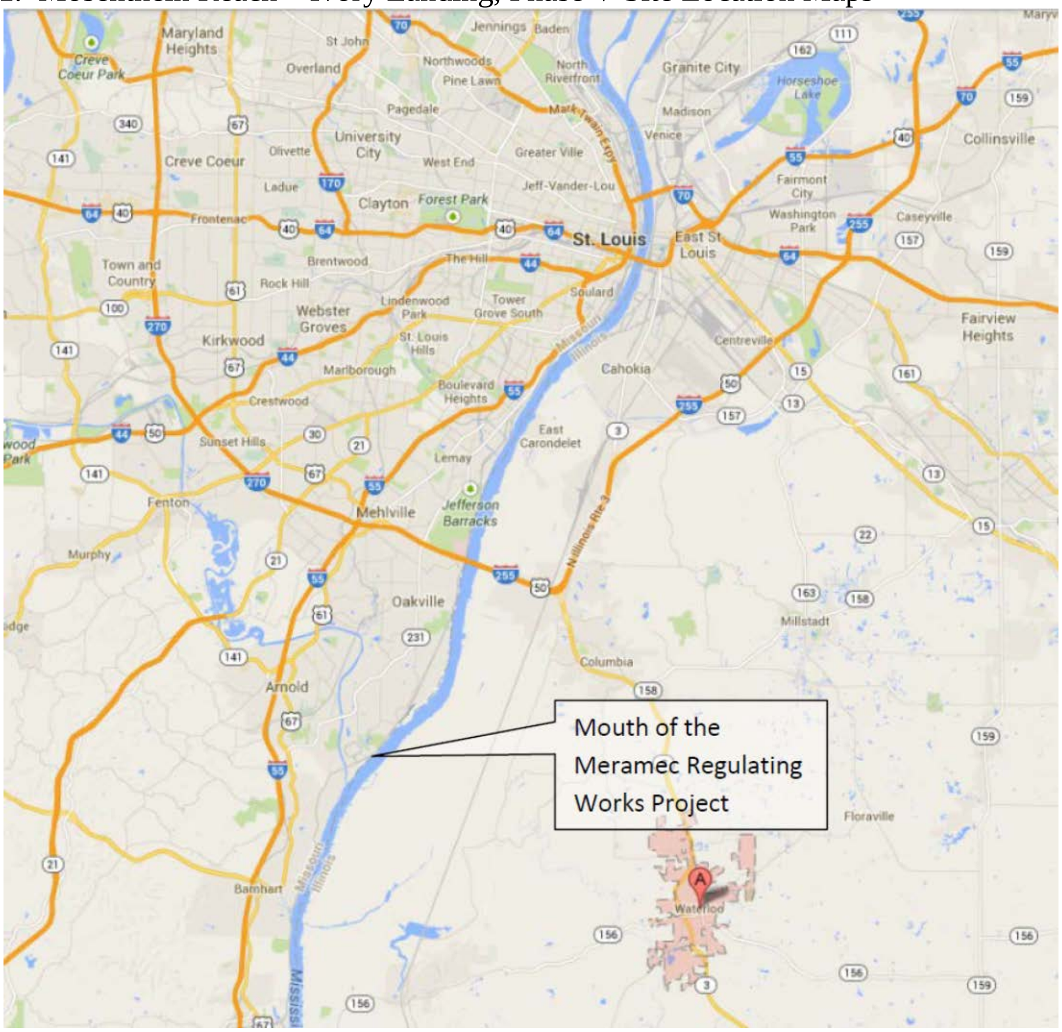


Table 1. Work to be Completed by River Mile and Purpose of Work.

Location by mile	Work to be completed	Purpose
Weir 162.30R Weir 162.20R Weir 162.10R Weir 162.00R	Construct bendway weirs along the right descending bank.	Direct energy of the river toward the thalweg to reduce the need for dredging.
Dike 161.70L Dike 161.50L (Rootless Extension) Dike 161.10L (Rootless Extension)	Construct dikes along the left descending bank.	Two of these are rootless extensions of the existing dikes. They were at angles (and therefore rootless) to provide more environmental diversity than a typical extension.

Figure 2. Mosenthein Reach – Ivory Landing, Phase V Weir and Dike Locations

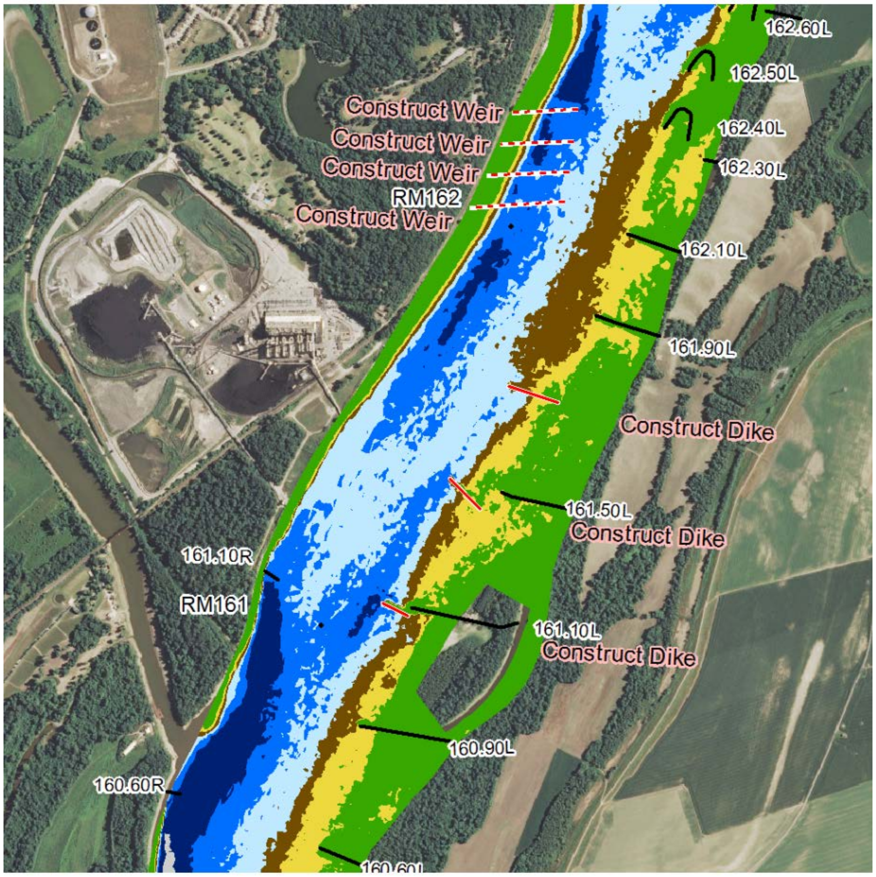
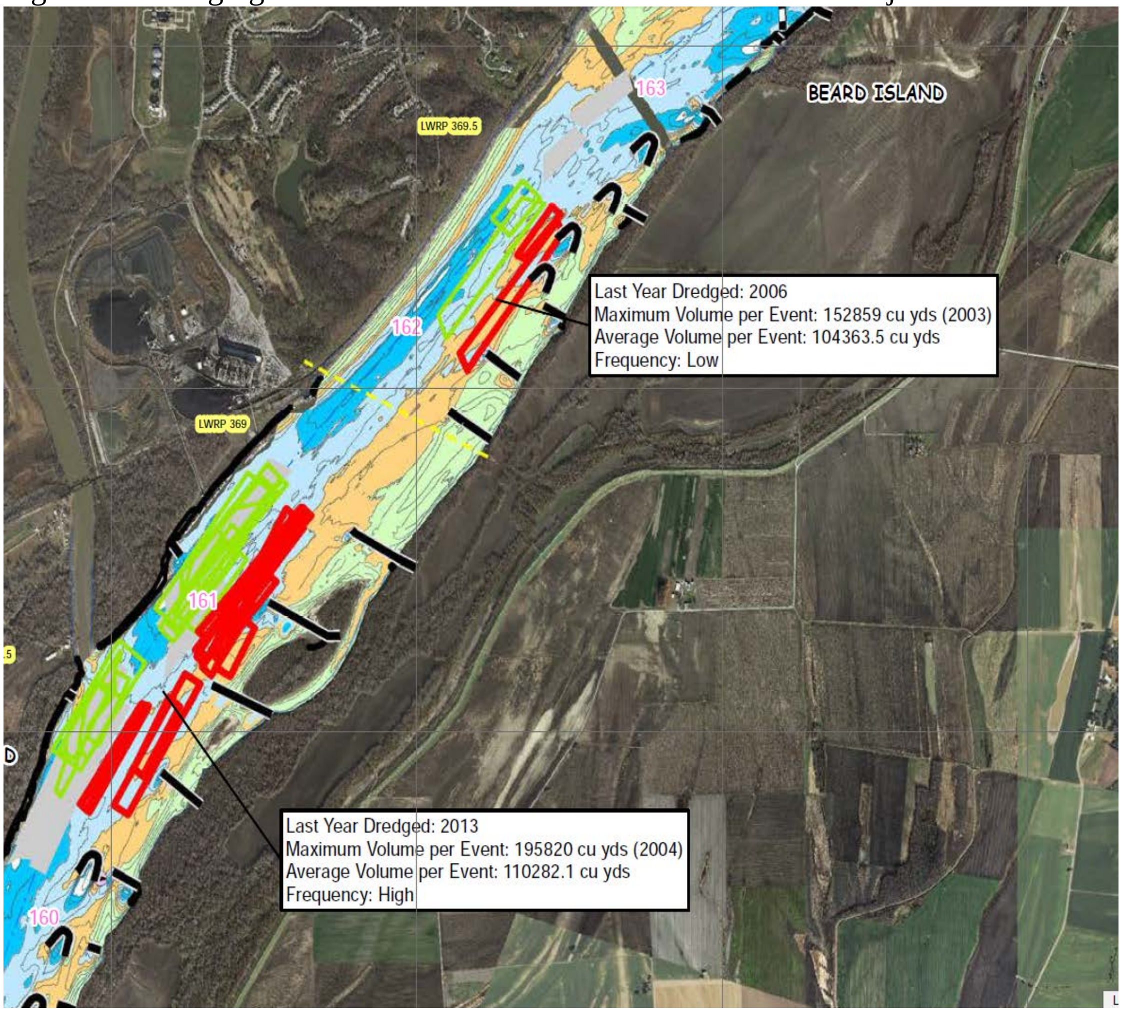


Figure 3 – Dredging and Placement Sites Located in the Phase V Project Area



4. Impact Assessment

The proposed project includes placing weirs between RM 162 – 162.4 and dikes between RM 161.0 – 161.7 in the Mississippi River. The impact of the rock structures is expected to be localized. The weirs and dikes will prevent channel widening and the loss of a safe and dependable navigation channel. Alternative 16, Plate 39, (Figure 2) was recommended as the most desirable alternative because of its observed ability to significantly reduce elevations observed in the repetitive dredging areas between RM 162.00 and RM 160.00 (see Figure 3). This alternative also includes rootless dike structures instead of traditional dikes. This was done in an effort to provide more environmental diversity in the project area. The rootless Dike 161.50 was placed at an angle in an attempt to divert a small amount of additional flow towards the small side channel located along the LDB. It should be noted that throughout testing, no sediment movement was observed within the side channel. Increased water flow into the side channel may improve oxygen levels, water temperatures, waste removal and nutrient levels necessary for a productive fishery. Overall, this alternative enhanced navigation safety for industry by providing a deeper navigation channel while maintaining and potentially improving environmental features within the project area.

5. Species Covered in this Consultation:

A list of species that may occur within the Phase V project area was obtained from the U.S. Fish and Wildlife Information, Planning and Conservation System website on 29 July 2014. Those species are listed in Table 2:

Table 2 - Listed Species That May Occur in the Project Area

Species	Federal Status	Habitat
Gray bat (*Myotis grisescens*)	Endangered	Caves
Indiana bat (*Myotis sodalis)*	Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: small stream corridors with well developed riparian woods; upland forests
Northern long-eared bat (*Myotis septentrionalis*)	Proposed Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: the understory of forested hillsides and ridges, small stream corridors with well developed riparian woods; upland forests.
Pallid sturgeon (*Scaphirhynchus albus*)	Endangered	Mississippi and Missouri Rivers.
Least tern (*Sterna antillarum*)	Endangered	Bare alluvial and dredged spoil islands.
Decurrent false aster (*Boltonia decurrens*)	Threatened	Disturbed alluvial soils.
Illinois cave amphipod *(Gammarus acherondytes)*	Endangered	Cave streams in Illinois sinkhole plain.
Mead's milkweed (*Asclepias meadii*)	Threatened	Moderately wet (mesic) to moderately dry (dry mesic) upland tallgrass prairie or glade/barren habitat.
Running buffalo clover (*Trifolium stoloniferum*)	Endangered	This species may be found in partially shaded woodlots, mowed areas and along streams and trails.
Pink mucket (*Lampsilis abrupta*)	Endangered	This species is found in mud and sand and in shallow riffles and shoals swept free of silt in major rivers and tributaries.
Scaleshell mussel (*Leptodea leptodon*)	Endangered	Lives in medium-sized and large rivers with stable channels and good water quality.
Sheepnose mussel (*Plethobasus cyphyus*)	Endangered	Rivers and streams.

Table 2 - Listed Species That May Occur in the Project Area		
Spectaclecase mussel (*Cumberlandia monodonta*)	Endangered	Spectaclecase mussels are found in large rivers where they live in areas sheltered from the main force of the river current. This species often clusters in firm mud and in sheltered areas, such as beneath rock slabs, between boulders and even under tree roots.

Gray Bat (*Myotis grisescens)* - The gray bat is listed as endangered and occurs in several Illinois and Missouri counties where it inhabits caves both summer and winter. This species forages over rivers and reservoirs adjacent to forests. No caves would be impacted by the proposed action; therefore, this project would have no effect on the gray bat.

Indiana Bat (*Myotis sodalis*) - The range of the Indiana bat includes much of the eastern half of the United States, including Missouri and 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 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.

Disturbance and vandalism, improper cave gates and structures, natural hazards such as flooding or freezing, microclimate changes, land use changes in maternity range, and chemical contamination are the leading causes of population decline in the Indiana bat (USFWS 2000, 2004). To avoid impacting this species, tree clearing activities should not occur during the period of 1 April to 30 October.

The project areas where rock will be placed are inundated and the rock will be placed using a barge. No trees will be impacted by the project. This project would not result in the destruction of any riparian or forested habitats; therefore, placement of river regulatory structures would have no effect on the Indiana bat.

Northern Long-Eared Bat (*Myotis septentrionalis*) - Northern long-eared bats spend winter hibernating in caves and mines. According to the U.S. Fish and Wildlife Service website, northern long-eared bats typically use large caves or mines with large passages and entrances; constant temperatures; and high humidity with no air currents. During summer, northern long-eared bats roost singly or in colonies underneath bark, in cavities, or in crevices of both live and dead trees. Males and non-reproductive females may also roost in cooler places, like caves and mines. This bat seems opportunistic in selecting roosts, using tree species based on suitability to retain bark or provide cavities or crevices. It has also been found, rarely, roosting in structures like barns and sheds. After fertilization, pregnant females migrate to summer areas where they roost in small colonies and give birth to a single pup. Maternity colonies, with young, generally have 30 to 60 bats, although larger maternity colonies have been observed. Northern long-eared bats emerge at dusk to fly through the understory of forested hillsides and ridges feeding on moths, flies, leafhoppers, caddisflies, and beetles, which they catch while in flight using echolocation (USFWS 2014a). This project would not result in the destruction of any riparian or forested habitats; therefore the project would have no effect on the northern long-eared bat.

Pallid Sturgeon (*Scaphirhynchus albus*) - The estimated population of pallid sturgeon in the Middle Mississippi River (MMR) ranges between 1600 and 4900 individuals (Garvey et al. 2009). Pallid sturgeon are very rare relative to shovelnose sturgeon in the MMR (a 1:82 ratio), whereas at Baton Rouge, Louisiana the ratio is 1:6. Threats to population recovery of pallid sturgeon include limited rearing and nursery habitat and loss of mature female adults. Pallids apparent non-reproductive habitat includes wing dikes with sandy substrate, and areas with contrasting flow velocities, complexes of island point bars, and side channels. During low water as in late summer, pallids are found more in the main channel. Reproductive habitat includes the Chain of Rocks area, known gravel bars in the MMR, tributary confluences and side channels (Garvey et al. 2009).

According to Garvey et al. (2009), adult pallid habitat for foraging and holding station in flow in the MMR is adequate and related primarily to the wing dike areas, although all habitats have been occupied. Hypothetically, some wing dikes may mimic natural depositional areas adjacent to the main channel (e.g., upstream island tips within the main channel). These areas provide an ecotone between flow with deposition and cause an accumulation of insects and small insectivorous fish that facilitate foraging, growth and ultimately reproductive condition. The availability and quality of reproductive habitat for spawning and production of offspring in the MMR is unknown (Garvey et al. 2009). If adult pallid sturgeon densities increase, wing dikes creating preferred habitat will likely become limited and habitat restoration that creates needed main-channel conditions should be a priority (Garvey et al. 2009).

It is the position of the U.S. Fish and Wildlife Service (2000) that over time, channel training structures have adversely affected pallid sturgeon by altering 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 channel 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). According to the Service, this has potentially reduced the availability of pallid sturgeon spawning habitat through the loss of habitat complexity (USFWS 2000).

The weirs associated with Phase V will focus the river's energy to move sediment out of the main sailing line. One of the dikes will direct river flows toward the thalweg and two dikes will deflect flow into a secondary channel to improve the habitat.

Construction activities may result in short-term adverse effects for pallid sturgeon; however, these adverse effects are expected to occur at a localized scale.

Although adverse impacts to pallid sturgeon associated with this project have been avoided and minimized to the greatest extent possible and design modifications have been incorporated to provide habitat benefits, pallid sturgeon may still be adversely affected by the project. However, the adverse effects of the project on the pallid sturgeon are consistent with those anticipated in the programmatic Biological Opinion and the District has implemented the Reasonable and Prudent Measures and Terms and Conditions prescribed therein as appropriate for the project.

Least Tern (*Sterna antillarum*) – This species is a colonial, migratory water bird which resides and breeds along the Mississippi River during the spring and summer. Least terns 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 terns 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). In alluvial rivers, sandbars are dynamic channel bedforms. Individual sandbars typically wax and wane over time as fluvial processes and the construction of river engineering works adjust channel geometry according to varying sediment load and discharge. There is limited data on site fidelity for Mississippi River least terns. Given the highly dynamic bed and planform of the historic river, 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 that are emergent during the 15 May to 31 August period are potentially available to least terns (USACE 1999). A 1999 report (USACE 1999) estimated that there were approximately 20,412 acres of nonvegetated sandbar habitat above the MMR LWRP. About 4,975 acres (111 ac/RM) were located between the Mouth of the Ohio and Thebes Gap (RM 0-45) and 15,437 acres (103 ac/RM) between Thebes Gap and the Mouth of the Missouri River (RM 45-195). Currently, reoccurring nesting is known near Marquette Island (RM 50.5), Bumgard Island (RM 30) (USFWS 2004), and Brown's Bar (RM 24.5-23.5). Some nesting attempts have also been made at Ellis Island (RM 202), however these are not considered to be reoccurring. While the Mississippi River appears to have a large amount of sandbar habitat, much of this habitat is not likely available to least terns for nesting and may not be located near suitable foraging habitats (USFWS 2000).

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 stem river habitats or backwater lakes or overflow areas. Radiotelemetry studies have shown that terns 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 and eddies along natural and revetted banks, and at "run outs" from floodplain lakes where forage fish may be concentrated (USACE 1999).

In total, the weirs and dikes associated with Phase V may not change the quantity of sandbar habitat in the project area.

Although adverse impacts to the least tern associated with this project have been avoided and minimized to the greatest extent possible and design modifications have been incorporated to provide habitat benefits, the least tern may still be adversely affected by the project. However, the adverse effects of the project on the least tern are consistent with those anticipated in the programmatic Biological Opinion and the District has implemented the Reasonable and Prudent Measures and Terms and Conditions prescribed therein as appropriate for the project.

Decurrent False Aster (*Boltonia decurrens*) - This species is listed as threatened and is known to occur in several Illinois counties in the floodplain of the Illinois and Mississippi River. It is considered to potentially occur in any county bordering the Illinois River and Jersey, Madison and St. Clair Counties bordering the Mississippi River. It occupies disturbed alluvial soils in the floodplains of these rivers. Federal regulations prohibit any commercial activity involving this species or the destruction, malicious damage or removal of this species from Federal land or any other lands in knowing violation of State law or regulation, including State criminal trespass law. The species' present distribution is likely outside the project area. In addition, the construction activities will be water based. The construction will occur in the river, with no impact to floodplain soils or terrestrial habitats in which decurrent false aster typically occurs. This species is unlikely to be impacted by the project; therefore, this project will have no effect on the decurrent false aster.

Mead's Milkweed (*Asclepias meadii*) - Habitats include mesic to dry tallgrass and upland prairies with sandstone or chert bedrock, prairie hay meadows, railroad rights-of-way, prairie remnants, virgin mesic silt loam prairies, and igneous glades. Historically, Mead's milkweed ranged throughout much of Missouri. It is presently found in the Osage Plains region and the St. Francois mountains region of the Ozarks (MDC 2014). According to the Center for Plant Conservation, all of the tallgrass prairie populations of this species in Wisconsin, Illinois, and Indiana have been destroyed by agriculture, and the only remaining native eastern populations occupy glade habitat in southeastern Missouri and southern Illinois. No tallgrass prairie habitat will be impacted by the project; therefore, this project will have no affect on Mead's milkweed (CPC2014a).

Running Buffalo Clover (*Trifolium stoloniferum*) - According to the Center for Plant Conservation, this plant prefers partly sunny locations with moist, fertile soils that have been exposed to long-term moderate disturbance patterns (including mowing, trampling, and grazing). This plant is often found in the ecotone between open forest and prairie (CPC 2014b). No disturbed prairie will be impacted by this project; therefore, this project will have no effect on the running buffalo clover.

Illinois Cave Amphipod (*Gammarus acherondytes*) – This species inhabits the bottoms of pools and riffles in large cave streams, where they creep among cobbles and under stones. Amphipods feed on small particles of organic debris and on decomposers such as bacteria and fungi. Because they ingest large quantities of this material, they are exposed to contamination from a variety of pollutants. This species is only found in karst caves within 10 miles of Waterloo, Illinois (Monroe County). This species is located ten miles from the project area and no karst caves will be impacted; therefore, the project would no effect on the Illinois cave amphipod.

Pink Mucket (*Lampsilis abrupta*) - This mussel is found in mud and sand and in shallow riffles and shoals swept free of silt in major rivers and tributaries (USFWS 2014b). The pink mucket typically inhabits medium to large rivers with strong currents; however, it has also been able to survive and reproduce in areas of impounded reaches with river/lake conditions without standing water (NatureServe 2014, USFWS 1985). Substrate preferences include sand, gravel, and pockets between rocky ledges in high velocity areas and mud and sand in slower moving waters. Individuals have been found at depths up to one meter in swiftly moving currents and in much deeper waters with slower currents (Gordon and Layzer 1989). Reproduction requires a stable, undisturbed habitat and a sufficient population of fish hosts to complete the mussel's larval development. Live mussels or fresh shells have been observed since 1978 in the Osage, Gasconade and Meramec rivers (MDC 2012). This species is not known to occur in the Mississippi River; therefore, this project should have no effect on the pink mucket.

Scaleshell Mussel (*Leptodea leptodon*) – The scaleshell occurs in medium to large rivers with low to medium gradients. It primarily inhabits stable riffles and runs with gravel or mud substrate and moderate current velocity. The scaleshell requires good water quality, and is usually found where a diverse assortment of other mussel species is concentrated. More specific habitat requirements of the scaleshell are unknown, particularly of the juvenile stage. Water quality degradation, sedimentation, channel destabilization, and habitat destruction are contributing to the decline of the scaleshell throughout its range. As stated in the USFWS' Scaleshell Recovery Plan, the scaleshell, although very rare, can only be consistently found in three Missouri streams including the Meramec, Bourbeuse, and Gasconade rivers (USFWS 2010). The scaleshell is not known to exist in the Mississippi River; therefore, this project should have no effect on the scaleshell mussel.

Sheepnose Mussel (*Plethobasus cyphyus*) – The sheepnose is listed as a federally endangered species and occurs in the Meramec and Bourbeuse rivers in Missouri (MDC 2012). This species inhabits gravel and mixed sand and gravel habitats in medium to large rivers. The sheepnose is thought to be extant in five pools (3, 5, 15, 20 and 22) in very low numbers. In the Upper Mississippi River, the sheepnose is an example of a rare species becoming rarer. Despite the discovery of juvenile recruitment in Mississippi River Pool 7, the sheepnose population levels in the Upper Mississippi River appear to be very small and of questionable long-term viability given the threats outlined below. The sheepnose and other mussel populations in the Upper Mississippi River are seriously threatened by zebra mussels. Even if some level of sheepnose recruitment was documented, the status of this species in the Mississippi is highly jeopardized, with imminent extirpation a distinct possibility (USFWS 2003). This species is not found in the project area; therefore, this project would have no effect on the sheepnose mussel.

Spectaclecase Mussel (*Cumberlandia monodonta*) – This federally endangered mussel is "known to occur in the Meramec River and may potentially occur in the Mississippi River north of Monroe County, Illinois" (USFWS undated). The spectaclecase is a large mussel attaining 9 to 10 inches in length. Its shell is greatly elongated, compressed, and relatively thin. Its historical distribution includes 45 rivers found in much of the Mississippi River basin, Ohio River system, Cumberland and Tennessee River basins, and part of the lower Mississippi River basin in Arkansas. In Cummings and Mayer (1992), the range for this species as displayed in Illinois and Missouri includes the middle and upper Mississippi River, Illinois River, and an area south of the Missouri River corresponding largely with the Ozark highlands. A distribution map by Oesch (1995) also shows two records from the Mississippi River near Clarksville, Missouri. However, in an assessment of the status of population viability at known locations of occurrence across its range, USFWS (undated) considered all spectaclecase populations in the Mississippi River in Illinois and Missouri to be either extirpated or "non-viable or unknown." None were classified as having "some evidence of viability." Habitat destruction and degradation are the chief causes of imperilment, including reservoir construction, channelization, chemical contamination, mining, and sedimentation. Habitats are found in medium to large rivers with low to high gradients, and include shoals and riffles with slow to swift currents over coarse sand and gravel. Substrates sometimes consist of mud, cobble, and boulders (USFWS 2011). The spectaclecase is not known to exist in the project area, but may occur ten river miles north of the project area. Therefore, the proposed construction would have no effect on the spectaclecase mussel.

6. Literature Cited

Anderson, E.A. 1983. "Nesting Productivity of the Interior or Least Tern in Illinois." Unpublished Report. Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, Illinois, 19 pp.

Center for Plant Conservation (CPC 2014a) Mead's Milkweed http://www.centerforplantconservation.org/collection/cpc_viewprofile.asp?CPCNum=308 Accessed 2014.

Center for Plant Conservation (CPC 2014b) Running Buffalo Clover http://www.centerforplantconservation.org/collection/cpc_viewprofile.asp?CPCNum=4331 Accessed 2014.

Cummings, K.S. and C.A. Mayer. 1992. Field Guide to Freshwater Mussels of the Midwest. Illinois Natural History Survey Manual 5, Champaign.

DeLonay, A. 2010. Comprehensive Sturgeon Research Program: Spawning, Habitat Use, and Behavior of Pallid Sturgeon in the Lower Missouri River – Update. Middle Basin Pallid Sturgeon Workgroup Winter Meeting Minutes. January 26th-27th, 2010.

Garvey, J.E., E.J. Heist, R.C. Brooks, D.P. Herzog, R. A. Hrabik, K.J. Killgore, J. Hoover, and C. Murphy. 2009. Current status of the pallid sturgeon in the Middle Mississippi River: habitat, movement, and demographics. Saint Louis District, US Army Corps of Engineers. http://fishdata.siu.edu/pallid

Gordon, M.E. and Layzer, J.B. 1989. Mussels (Bivalvia: Unionoidea) of the Cumberland River review of life histories and ecological relationships. Biological Report 89(15): 1-99.

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.

Missouri Department of Conservation. (2012) A Guide to Missouri's Freshwater Mussels, Jefferson City, MO: Missouri Department of Conservation.

Missouri Department of Conservation. (MDC 2014) Mead's Milkweed. http://mdc.mo.gov/discover-nature/field-guide/mead-s-milkweed Accessed: 2014

Moseley, L.J. 1976. "Behavior and Communication in the Least Tern (Sterna albifrons)." Ph.D. Dissertation, University of North Carolina, Chapel Hill. 164 pp.

NatureServe. 2014. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: August 11, 2014).

Oesch, R.D. 1995. Missouri Naiads: A Guide to the Mussels of Missouri. Missouri Department of Conservation, Jefferson City, MO.

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)

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.

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, December 1999.

U.S. Fish and Wildlife Service. 1985. Recovery Plan for the Pink Mucket Pearly Mussel (*Lampsilis orbiculata*). Atlanta, GA. 52 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, 2003 Status Assessment Report for the Sheepnose, Plethobasus cyphyus, Occurring in the Mississippi River System (U.S. Fish and Wildlife Service Regions 3, 4, and 5)

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. 2010. Scaleshell Mussel Recovery Plan (Leptodea leptodon). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 118 pp.

U.S. Fish and Wildlife Service. 2011. Spectaclecase Fact Sheet. Available http://www.fws.gov/midwest/endangered/clams/spectaclecase/SpectaclecaseFactSheetJan2011.html. (Accessed: August 31, 2011)

U.S. Fish and Wildlife Service. 2014a. Fact Sheet http://www.fws.gov/midwest/endangered/mammals/nlba/pdf/NLEBinterimGuidance6Jan2014.pdf (Accessed 30 July 2014).

U.S. Fish and Wildlife Service. 2014b. http://ecos.fws.gov/docs/life histories/F00G.html Pink Mucket (Accessed 30 July 2014).

U.S. Fish and Wildlife Service. Undated. Status assessment for three imperiled mussel species: spectaclecase (Cumberlandia monodonta,), sheepnose (Plethobasus cyphyus), and rayed bean (Villosa fabalis). Mollusk Subgroup, Ohio River Valley Ecosystem Team. Available http://www.fws.gov/orve/online_symposium_three_mussels.html. (Accessed: August 31, 2011).

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.

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Appendix C. Cumulative Impacts Analysis

Cumulative Impacts Analysis

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 Mosenthein/Ivory Landing Phase 5 EA cumulative impact analysis generally followed the steps laid out by the handbook.

Cumulative impact analysis involved determining the incremental impact of the 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 Middle Mississippi River. Clearly the resources, ecosystem and human environment in the Middle Mississippi River have been, and will continue to be, impacted by a wide range of actions. The cumulative impact analysis evaluates the same resources (Physical Resources [River Stages, Water Quality, and Air Quality]; Biological Resources [Fish and Wildlife: Dike Effects, Threatened & Endangered Species, and Climate Change]; Socioeconomic Resources [Navigation]; and Historic & Cultural Resources) that were evaluated in the Environmental Consequences section. In addition, the cumulative impacts for the No Action Alternative and Action Alternative were evaluated for navigation effects and side channel impacts.

The Regulating Works Project, in combination with the other actions throughout the watershed, has had past impacts, both positive and negative, on the resources, ecosystem and human environment. However, this analysis is meant to characterize the incremental impact of the current action in the broader context of other actions affecting the same resources. Although past actions associated with the Regulating Works Project have impacted these resources, the current method of conducting business for the 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. Although our understanding of the actions that bear upon the resources of the Middle Mississippi River continues to evolve, equilibrium in habitat conditions appears to have been reached. Accordingly, only minimal impacts to the resources, ecosystem and human environment are anticipated for the Mosenthein-Ivory Phase 5 project.

Physical Resources

River Stages

A summary of research on the effects of river training structures on flood heights is provided in Appendix A. As noted in the Environmental Consequences (Physical Resources, River Stages) section, the District has concluded that river training structures do not affect water surface elevations at higher flows. With respect to water surface elevations at low flows, analysis of data show a trend of decreasing stages. It is not known if this is a result of construction of river training structures or the reduction of sediment load due to the construction of reservoirs on Mississippi River tributaries (Huizinga 2009). Reduced stages was acknowledged in the 1976 Regulating Works EIS (USACE) and the potential loss of side channels was discussed. The District acknowledges the importance of side channels and has continued to monitor the changes in the morphology and geometry of existing side channels. To offset potential impacts to side channels the District has initiated side channel restoration planning (USACE 1999a; Nestler et al. 2012) and has conducted a number of restoration projects. The number of side channels has been substantially preserved through these monitoring and restoration efforts combined with natural processes within the side channels.

Based on this analysis, the impacts of No Action and the Proposed Action, when evaluated in relation to past and present stage heights, are not anticipated to rise above what would occur naturally. The potential reduction in stages and impacts on side channels were addressed in the 1976 EIS. Potential impacts, if they are being caused by river training structures, should be offset by side channel restoration/enhancement features constructed in the future by the District under various authorities and the use of innovative river training structure configurations designed to divert flow into existing side channels.

Water Quality

Prior to the implementation of the Clean Water Act, the MMR was an open sewer and a convenient place to dump solid waste (Bi-State Development Agency 1954; U.S. Public Health Service 1958). Raw sewage, untreated industrial waste, and ground garbage were discharged into the MMR (in 1952, approximately 212 tons/day of garbage [animal and vegetable waste] were collected in St. Louis, ground, and discharged.) This resulted in high oxygen demand; extremely high fecal coliform levels; low dissolved oxygen levels (< 5 mg/l); transport of toilet paper, animal entrails, and other solid wastes; elimination of aquatic life below St. Louis and reduction of aquatic life for a large portion of the MMR; and unpalatable fish where they did exist (Ellis 1931; Ellis 1943; Platner 1943; Bi-State Development Agency 1954; U.S. Public Health Service 1958; Baldwin 1970). Severely degraded water quality conditions in the MMR rose to the level of a human health hazard and a conference was convened in St. Louis (U.S. Public Health Service 1958) to discuss remedies.

Water quality in the MMR has improved dramatically since the implementation of the Clean Water Act. Although the MMR has improved, it currently exceeds suggested nutrient (total nitrogen and phosphorus) guidelines either part of the time (nitrogen) or most of the time (phosphorous) (Johnson and Hagerty 2008). As discussed in the affected environment section, there are also fish consumption advisories for PCB, chlordane, and mercury contamination. During major storm events, raw sewage enters the river because of sewage treatment plant overloads due to combined (sewage/stormwater) sewage systems. Crites et al. (2012) found that water quality conditions in Buffalo Chute (River Mile 26) during isolation (mid-June through March during their study) from the river channel were not conducive to supporting healthy native fish communities. Thermal and chemical stratifications coupled with high water temperatures and anoxic conditions were observed during the summer months during two years of study.

Johnson and Hagerty (2008) indicated that future changes in nutrient inputs to the river are difficult to predict, and largely a function of outputs from sewage treatment plants and runoff from fertilizer application on land. There are ongoing efforts in the St. Louis area to improve wastewater treatment and alleviate the problems associated with combined sewage systems. These efforts should improve nutrient loading and eventually eliminate raw sewage overflow events. It is not anticipated that nutrients from agriculture will rise; however, this is driven by agricultural economics. The St. Louis District has conducted side channel restoration planning (USACE, 1999a; Nestler et al. 2012) and has been restoring side channels under various authorities. Water quality and aquatic ecosystem improvement are basic goals of these restoration efforts. So, water quality conditions in the MMR are expected to improve with time.

The No Action Alternative would have no additional impacts (existing level of dredging associated short-term turbidity plume) on water quality. The Proposed Action would have only minor, short-term construction impacts on water quality. Navigation traffic levels and associated turbidity pulses will remain the same under both the No Action and Proposed Action. As such, the impacts of No Action and the Proposed Action, when evaluated in relation to past, present, and future water quality impacts, are not anticipated to rise to the level of a significant impact.

Air Quality

The work area is currently designated as attainment areas for four of six criteria air pollutants (carbon monoxide, nitrogen oxides, sulfur dioxide, and lead) (USEPA 2013). The Missouri side of the Mosenthein/Ivory Landing Phase 5 work area is designated as a moderate nonattainment area for 8-hour ozone (1997 standard), a marginal nonattainment area for 8-hour ozone (2008 standard), and a moderate nonattainment area for particulate matter-2.5 (1997 standard) (USEPA 2013). On the Illinois side of the MMR, the work area is designated as a maintenance area for 8-hour ozone (1997 standard), a marginal nonattainment area for 8-hour ozone (2008 standard), and a moderate nonattainment area for particulate matter-2.5 (1997 standard) (USEPA 2013). There are no known foreseeable projects in the work area that would adversely impact air quality.

The No Action Alternative consisting of maintenance dredging would have minor impacts on air quality. The Proposed Action would have only minor, short-term, air quality impacts associated with the use of construction equipment. This construction activity would be represented by two pushboats and a barge-mounted crane. Navigation traffic levels and associated engine exhaust would remain the same under both the No Action and Action Alternatives. As such, the impacts of No Action and the Proposed Action, when evaluated in relation to past, present, and future air quality, are not anticipated to rise to the level of a significant impact.

Biological Resources (Fish & Wildlife)

Dike & Revetments (Dikes, Bendway Weirs, and Revetment)

Currently, there are 1,375 river training structures on the MMR, which include wing dikes, bendway weirs, chevrons, and other configurations. Of this total, 175 are bendway weirs. The pace of construction has changed over time and the shape, size, elevation and configuration of river training structures has also changed. The St. Louis District built approximately 450 river training structures in the late 19^{th} century and another 250 in the 1930s. The District constructed 150 bendway weirs from 1990 to 2000. Table 1 lists work areas that are considered likely to be constructed in the reasonably foreseeable future.

The St. Louis District has one Regulating Works HSR model study that is almost complete and will likely result in future construction: the Upper Brown's Bar HSR Model Study. The Upper Brown's Bar HSR Model Study is a river engineering design that will reduce or eliminate the need for repetitive dredging at approximately UMR 24. The Red Rock Landing Report will be completed in FY 16 and construction is projected for FY 18. Success of the Regulating Works Project is dependent on careful evaluation of conditions on the Middle Mississippi River over time while incrementally implementing river training structures to provide a safe and dependable navigation channel while reducing the need for repetitive dredging. Future needs are based on priority work locations that are determined by examining repetitive dredging problems on the Middle Mississippi River. The District then develops alternatives using widely recognized and accepted river engineering guidance and practice, and then screens and analyzes different configurations of regulating works with the assistance of a Hydraulic Sediment Response (HSR) model. During the alternative evaluation process, the District works closely with industry and natural resource agency partners to further evaluate potential alternatives, including configurations analyzed in the HSR model. This process results in alternatives which reasonably meet the project purpose while also avoiding/minimizing environmental impacts. The timing of future construction is heavily dependent on Congressional funding and modeling results.

Table 1. List of Regulating Works work areas showing location and structure type that are under construction or considered likely to be constructed in the reasonably foreseeable future (USACE 2012a; USACE 2012b; USACE 2013a; USACE 2013b).

Major Reach	Status	Localized Reach	Work in Reach
Mosenthein-Ivory Landing Phase 4 (RM 195-154)	Contract Awarded	St. Louis Harbor	Revetment RM (175-171) Raise Dike 181.7L Dike 173.4L
Eliza Point/Greenfield Bend Phase 3 (RM 20 - 0)	Under Construction	Bird's Point (RM 4 - 0)	Rootless Dike 3.0L Weir 2.6R Weir 2.5R Weir 2.3R Weir 2.2R

Major Reach	Status	Localized Reach	Work in Reach
Grand Tower Phase 5 (RM 90 - 67)	Construction in FY 16	Crawford Towhead (RM 75 - 71)	Chevron 73.6L Dike Extension 72.9L Chevron 72.5L
		Vancil Towhead (RM 70-66)	Weir 69.15L Weir 68.95L Weir 68.75L Diverter Dike 68.10L Diverter Dike 67.80L Diverter Dike 67.50L Repair Dike 67.80L Shorten Dike 67.30L Shorten Dike 67.10L 600 ft revetment
Dogtooth Bend Phase 5 (RM 40-20)	Under Construction	Bumgard (RM 33-27)	Weir 34.20L Weir 34.10L Weir 32.50L Weir 32.40L Weir 32.30L Weir 32.20L Dike 31.60R Weir 30.80R Weir 30.70R
Mosenthein _Ivory Landing Phase 5	Construction in FY 15	Mouth of the Meramec (RM 160-162.5)	Weir 162.30R Weir 162.20R Weir 162.10R Weir 162.00R Rootless Dike 161.70L Rootless Dike 161.50L Rootless Dike 161.10L
Dogtooth Bend Phase 6 (Upper Brown's Bar)	Construction in FY17	Upper Brown's Bar (RM 23-26)	Weir 25.70L Weir 25.60L Weir 25.40L Weir 25.20L Dike Extension 25.40L Dike Extension 25.30L Dike Extension 25.20L Offset Rootless Extension 25.30R Offset Rootless Extension 24.80R Offset Rootless Extension 24.70R Notch Closure 24.80R Partial Removal 24.70R Dike 23.75R
Red Rock Landing	Construction in FY 18	Red Rock Landing (RM 96-104)	To Be Determined

A discussion of the environmental impacts of dike and weirs is contained in Section 4 Environmental Consequences (**Physical Resources**: River Stages and **Biological Resources**: Dike Effects and Weir Effects). Potential cumulative impacts of the Regulating Works Project on biological resources fall into a number of general categories: 1. Biological effects of training structures and their construction, and the biological implications of existing and reduced dredging; 2. Potential impacts of reduced channel migration; and, 3. Potential effects of changed flow patterns.

1. Construction impacts (actual construction related impacts) would be minimal under the no action alternative because no new construction (no construction impacts) would occur and structure repair would have minimal impacts. Under the no action alternative, dredging frequency, quantity, and area dredged would remain similar to what it is today. Benthic invertebrates in the dredged area would be killed and dredged material disposal would cover and kill benthic invertebrates in the disposal area. These areas would recover at a rate that is most likely site specific, but the cycle would continue the next time dredging is required (Koel and Stevenson 2002).

   Under the action alternative, benthic invertebrates in any future construction areas would be covered by the structure (rock) and killed. The area under the structures would be covered and unavailable for future colonization by benthic invertebrates. The environmental effects of training structures have been described in detail in Section 4 – Environmental Consequences. Although the benthic fauna type will change, rock is far more attractive to benthic invertebrates than shifting sand and the density (numbers/meter) will increase dramatically. This increase in benthic invertebrate density will also be more attractive to fish species. Construction of dikes has been suggested as a method for ecological enhancement (Radspinner et al. 2010) of river ecosystems. The St. Louis District has worked with partner agencies to develop innovative training structure configurations that fully serve their intended navigation function while providing environmental benefits at the same time. The structures themselves directly create/enhance aquatic habitat and provide fishery benefits. For example, chevron dike construction in St. Louis Harbor provided increased habitat diversity and increased fish use (Schneider 2012); off-bank dike notching has been used for island creation (River Mile 100 Islands) which has benefited the fishery (Allen 2010); wing dikes provide adult (Barko et al. 2004) and larval fish (Niles and Hartman 2009) habitat, wing dike tips provide summer habitats for juvenile rheophilic fishes (Bischoff and Wolter 2001) and dike scour holes provide fish habitat, especially during the winter. Under the action alternative, future dredging and associated impacts to the benthic fauna would be reduced in frequency and quantity.

   Following a period of widening and instability on the MMR, historic dike construction caused a narrowing of the river planform due to sediment accretion followed by terrestrial vegetation growth (Brauer et al. 2005; Brauer et al. 2013). Continued operation and maintenance of the training structures has maintained the narrowed channel. Figure 6 in the EA shows the average planform width of the MMR from 1817 through 2011. Since 1968, the channel width appears to have reached a dynamic equilibrium with very little change occurring. It is anticipated that dynamic equilibrium in channel width will be maintained with little change resulting from additional training structure construction. As such, the impacts of No Action and the Proposed Action, when evaluated in relation to past, present, and future biological impacts of structure construction and operation and maintenance of the structures, are not anticipated to rise to the level of a significant impact.

2. As noted in Cumulative Impact Analysis (Side Channels), the potential for the natural development of new MMR side channels, which is a natural geomorphic process in fluvial river systems (Grenfell et al., 2012), has been restricted by the placement of stone revetment on the bankline as part of the Regulating Works Project. Bankline revetment restricts channel migration and has fixed the MMR in place, thus eliminating the potential for new natural side channel development. Since no new natural side channels are being created, it is essential to engineer new side channels through the manipulation of existing river training structures and new innovative river training structure configurations as well as maintain and restore those that remain through other programs authorized to so. Based on the analysis conducted in the Side Channel Section, the impacts of No Action and the Proposed Action, when evaluated in relation to past, present, and future condition of MMR side channels, are not anticipated to rise beyond the levels previously described in the 1976 EIS.

3. Dikes change flow patterns and increase both velocity and turbulence near the structure (Yossef and de Vriend 2011; Jia et al. 2009; and Ouillon and Dartus 1997 and others). McElroy et al. (2012) have recently found that fish use particular paths for migrations that take advantage of flow velocities (both high and low velocities) to reduce their energy output during migrations. Currently, the extent of this potential impact in the MMR is unknown, and the means to obtain a full understanding of how this information may or may not impact the MMR is not known as this would be scientifically difficult to evaluate. The Corps continues to apprise, analyze, and consider any research or potential issues with respect to the impact of changing flow patterns on fish and wildlife.

Navigation Traffic

The movement of commercial navigation traffic has both physical and biological effects (Table 2) that affect the ecosystem health of the MMR. These impacts are discussed in greater detail in USACE (2004) and Söhngen et al. (2008). With respect to cumulative impacts (past, present, and future actions), the impacts of commercial navigation traffic resulted from the original development of the navigation project and subsequent operation and maintenance of the navigation channel. Because none of the actions associated with operation and maintenance will increase traffic and associated impacts, the impacts of the No Action Alternative and the Action Alternative are identical. In other words, only an action (construction project) that would increase traffic would also increase impacts beyond what we have today.

Table 2: Potential Aquatic Impacts Associated with the Movement of Tows on the Middle Mississippi River

Impact	**Reference**
Fish Recruitment	(Nielsen et al. 1986; Arlinghaus et al. 2002; Huckstorf et al. 2010)
Propeller Mortality	
Adult Fish	(Gutreuter et al. 2003; Killgore et al. 2005; Killgore, et al. 2011; Miranda & Killgore 2013)
Adult Fish during Lockage	(Keevin et al. 2005)
Larval Fish	(Holland and Sylvester 1983; Holland 1987; Odum et al, 1992; Killgore et al. 2001; Bartell & Campbell 2000)
Fish Disturbance (Displacement from Channel)	(Todd et al. 1989; Wolter and Bischoff 2001; Gutreuter et al. 2006)
Wave Wash	
Physical	(Bhowmik et al 1999)
Fish	(Sheehan et al. 2000a, 2000b; Wolter & Arlinghaus 2003; Wolter et al. 2005; Kucera-Hirzinger et al. 2009; Gabel et al. 2011b)
Invertebrate	(Bishop & Chapman 2004; Gabel et al. 2008; Gabel et al. 2011a, 2011b)
Shoreline Drawdown/Dewatering	(Adams et al 1999; Maynord 2004; Maynord & Keevin 2005)
Towboat Induced Turbidity	
Channel	(Smart et al. 1985; Savino et al. 1994; Garcia et al. 1999; In addition, there are numerous publications on the adverse effects of turbidity on benthic invertebrates and fish.)
Phytoplankton	(Munawar et al. 1991)
Side Channel/Backwaters	(Pokrefke et al. 2003)
Hull Sheer	
Larval Fish	(Morgan II, et al. 1976; Maynord 2000; Keevin et al. 2002)
Turbulence	(Killgore et al. 1987; Mazumder et al. 1993; Deng et al. 2005)
Towboat Dispersal of Exotic Species	(Keevin et al. 1992)
Towboat Noise & Fish Disturbance	(Wysocki et al. 2006)
Bank Erosion	(Bhowmik et al. 1999; Nanson et al. 1993)
Risk of Accidents & Hazardous Spills	(University of Memphis 1998; Marmorstein 2000)
Changed Velocities	(Maynord 2000; Sheehan et al. 2000a; Sheehan et al. 2000b

Although, there are many potential impacts associated with the movement of towboats through the system as described in USACE (2004) and Söhngen et al. (2008) and summarized in Table 2, the impact of greatest concern in the MMR is larval and adult fish mortality associated with towboat propeller entrainment.

Existing (2000) traffic in the Middle Mississippi River was responsible for the annual equivalent adult mortality of 262,853 fish, based on the number of larval fish killed passing through towboat propellers (USACE 2004, page 91). Annual equivalent adult mortality resulting from the incremental increase in traffic due to the construction of 1,200 foot locks on the Upper Mississippi River (USACE 2004 – a project not funded for construction) was projected to be between 11,612 and 79,274 fishes in the Middle Mississippi River for the year 2040 (USACE 2004, 396-397).

Killgore et al. (2011) published a towboat propeller entrainment paper for adult fish for the pooled portion of the Upper Mississippi River. It indicated that fish entrainment was low (< 1 fish/km) in wide, deep and fast sections of the river, while it was variable and occasionally high (> 30 fish/km) in narrow, shallow, and slow reaches of the UMR. If you used the value of 1 fish/km injured or killed (the MMR is wide, deep and fast), then approximately 151,161 fish would be injured or killed per year (313.822 km x 19,938 towboats/year x .024 injury-mortality rate) in the Middle Mississippi River under existing traffic conditions. This number overestimates mortality, because only a fraction of towboats/year actually navigate the entire length of the system (only 7,750 locked through Locks 27).

Additionally, another 34,972 adult fish are killed per year locking through Locks 27 (4.5125 average fish mortality per lockage x 7,750 commercial lockages in 2001) (Keevin et al. 2005). Entrainment mortality of some fish species, for example the shovelnose sturgeon, combined with other mortality factors (commercial fishing) may be responsible for unsustainable population levels in the Upper Mississippi River (Miranda and Killgore 2013).

In addition to the above projected mortality numbers, an unknown number of fish would be killed due to egg mortality from propeller entrainment (Holland and Sylvester 1983; Odum et al, 1992), shoreline dewatering (Adams et al 1999; Maynord & Keevin 2005), hull shear (Morgan II, et al. 1976; Maynord 2000; Keevin et al. 2002), and fish being washed out of protected areas (especially during the winter) due to wave wash (Sheehan et al. 2000a, 2000b; Wolter and Arlinghaus 2003; Wolter et al. 2005; Kucera-Hirzinger et al. 2009).

Based on this analysis, the impacts of No Action and the Proposed Action (no increases in navigation traffic), when evaluated in relation to past, present, and future impacts associated with the movement of navigation traffic, are not anticipated to rise beyond the existing conditions and projected traffic increases which have been addressed in USACE (2004).

Side Channels

With the draining of floodplain lakes for agricultural development and the reduction of overbank flooding during high flows due to levee construction, side channels represent the major source of off-channel water bodies on the MMR. Secondary channels typically provide a well-defined gradient between flowing to non-flowing water depending on their level of connectivity to the main channel. Based on the level of water flow, secondary channels can function as wetlands, isolated backwaters, connected backwaters, isolated secondary channels (at low stages), and flowing secondary channels. Level of connectivity also affects substrates, water quality conditions (Crites et al. 2012), benthic invertebrate communities (Bij de Vaate et al. 2007; Paillex et al. 2009) and fish faunas (Barko and Herzog 2003; Barko et al. 2004). Flowing secondary channels, those connected to the main channel, generally have course bottom substrates (i.e., sand and gravel) and support large river aquatic species (suckers, minnows, and darters) tolerant of current and/or turbidity. Disconnected secondary channels generally have finer substrate types (sand and silt) and support lentic species that prefer moderate to low current and low turbidity levels (Barko and Herzog 2003). This diversity of habitat provides important feeding, spawning, nursery, and overwintering habitat for fish (Lowery et al. 1987; Scheaffer and Nickum 1986; Grift et al. 2001), and habitat for other environmentally sensitive invertebrates, fish, and wildlife (Eckblad et al. 1984; Siegrest and Cobb 1987; Barko and Herzog 2003). Secondary channels also export nutrients, detritus, plankton, invertebrates, and fish to the main channel and the Gulf of Mexico (Eckblad et al. 1984; Cellot 1996; Simons et al. 2001; Hein et al. 2004; Preiner et al. 2008).

Secondary channels are also important because they are a refuge for fish escaping navigation related disturbances. Galat and Zweimuller (2001) and Wolter and Bischoff (2001) hypothesized that commercial navigation traffic may push fish toward the littoral zone or into secondary channels. Gutreuter et al. (2006) estimated the magnitude of traffic-induced reduction of fishes in the main channel of the Upper Mississippi River by comparing fish abundance in the navigation channel relative to abundance in secondary channels. They found the presence of some species was unaffected by traffic disturbances; whereas, the presence of others was reduced. Thus, secondary channels contribute to the overall health of the riverine system (Baker et al. 1991; Simons et al. 2001).

Due to the placement of rock closing structures, almost all MMR side channels are isolated from the main channel based on river stages and the crown elevation of the closing structure. The purpose of closing structures is to shunt water to the main channel to support navigation flows. Of the extant thirty-two side channels, only one (Cottonwood Side Channel) does not have closing structures. The remaining MMR side-channels are in various successional stages, including wetlands, isolated backwater, connected backwaters, isolated side channels (at low stages), and flowing side channels. The successional stage is related to ground elevation and river discharge, which translate into the level of connectivity to the main channel. The current median level of connectivity on a monthly basis for MMR side channels is shown in Table 3.

Table 3: A visual representation of flow conditions for Middle Mississippi River side channels showing months when channels are connected to the river and flowing (green) and when they are not flowing (red) based on median monthly stages and 2011 bathymetric data. Yellow represents side channels with high barriers restricting flow during all but extremely high water events (Modified from Keevin et al. 2014).

Side Channel (River Mile)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Duck (195)	red	green	green	green	green	green	green	green	green	green	green	green
Mosenthein (189)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow
Arsenal (176)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow
Jefferson Barracks (168)	red	green	green	green	green	green	green	green	green	green	green	green
Atwood (161)	green	green	green	green	green	green	green	green	green	green	green	green
Calico (148)	red	red	green	green	green	green	green	green	red	red	red	red
Osborne (146)	red	red	green	green	green	green	green	red	red	red	red	red
Harlow (144)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow
Salt Lake (139)	red	red	green	green	green	green	green	red	red	red	red	red
Fort Chartres (134)	red	red	red	green	green	green	red	red	red	red	red	red
Establishment (132)	red	red	green	green	green	green	green	red	red	red	red	red
Moro (122)	red	red	green	green	green	green	green	red	red	red	red	red
Kaskaskia (118)	red	red	red	green	green	green	red	red	red	red	red	red
Crains (105)	red	red	red	red	red	red	red	red	red	red	red	red
Liberty (103)	green	green	green	green	green	green	green	green	green	green	green	green
Jones (97)	red	green	green	green	green	green	green	green	green	red	green	red
Cottonwood (79)	green	green	green	green	green	green	green	green	green	green	green	green
Crawford (74)	red	red	red	green	green	green	red	red	red	red	red	red
Vancil Towhead (67)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow
Schenimann (62)	red	red	green	green	green	green	green	red	red	red	red	red
Picayune (61)	red	red	green	green	green	green	green	green	red	red	red	red
Marquette (51)	green	green	green	green	green	green	green	green	green	green	green	green
Santa Fe (39)	red	red	red	green	green	green	red	red	red	red	red	red
Billings (34)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow

Table 3 (cont.)

Side Channel (River Mile)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bumgard (31)												
Buffalo (26)												
Browns (25)												
Thompson (19)												
Sister (14)												
Boston (10)												
Angelo (5)												

The 1976 MMR Regulating Works EIS indicated that most of the side channels would be lost "Based on Colorado State University studies of man-induced changes in the Middle Mississippi River, most of the side channel and main channel border habitat will eventually become filled with sediment (Simons, Schumm, and Stevens, 1974), unless artificial means, i.e., dredging, are employed to maintain side channels (page 216)." This is supported by the findings of Theiling et al. (2000) who found that, based on a GIS analysis of land cover change, MMR side channels were showing trends toward filling with sediment. Contrary to these conclusions, an analysis of MMR geomorphology by Brauer (2013) found that, similar to main channel widths, side channel widths have reached a dynamic equilibrium and remained relatively steady since 1968. These trends were found both in average trends and reach scale trends. These trends were also found in Guntren 2011. This study found that while some side channels decreased over the course of the study, others were increasing, suggesting that side channels in the MMR are dynamic. Further, since the 1976 EIS, there has been an increasing recognition of the importance of side channel habitat on the MMR and increased emphasis on side channel restoration. Through the District's Biological Opinion Program (http://mvs-wc.mvs.usace.army.mil/arec/Bio_Op.html), Avoid and Minimize Program (http://mvs-wc.mvs.usace.army.mil/arec/AM.html), innovative river training structure design, and other restoration initiatives, side channel restoration and preservation on the MMR has occurred and will continue to occur for the foreseeable future, resulting in a substantial preservation of the side channels that existed in 1976.

The potential for the natural development of new MMR side channels, which is a natural geomorphic process in fluvial river systems (Grenfell et al., 2012), has been restricted by the placement of stone revetment on the bankline as part of the navigation system's Regulating Works Project. Bankline revetment restricts channel migration and has fixed the MMR in place, thus eliminating the potential for new natural side channel development. Since no new natural side channels are being created, it is essential to engineer new side channels as well as maintain and restore those that remain.

The reduced potential for the natural formation of new side channels and the current degree of connectivity to the main channel is the existing condition. Any future construction of bankline revetment will not impact the potential for major channel migration and the creation of a new side channel complex. There are no plans to build new closing structures on any side channels. The St. Louis District understands the biological importance of side channels and has conducted environmental planning, in coordination with our agency partners, for side channel restoration in the MMR (USACE, 1999a; Nestler et al., 2012). A number of side channel projects have been completed to improve flow and create more diverse aquatic habitat (i.e., environmental dredging of Sister Chute to provide more open water; environmental engineering to create/restore habitat in Santa Fe Chute, Marquette Chute, Jones Chute, and Establishment Chute) under a variety of authorities outside of the Regulating Works Project. It is anticipated that more side channel restoration will occur in the future as discussed above.

Based on this analysis, the impacts of No Action and the Proposed Action, when evaluated in relation to past, present, and future condition of MMR side channels, are not anticipated to rise to the level of being significant.

Threatened and Endangered Species

Section 7 consultation, under the Endangered Species Act, and compliance with the Act has a very structured coordination process between an action agency (the St. Louis District for this work area) and the U.S. Fish and Wildlife Service. In 1999, a Biological Assessment was prepared for the operation and maintenance of the 9-foot navigation project on the Upper Mississippi River (USACE 1999b). The U.S. Fish & Wildlife Service prepared a Biological Opinion in response to the BA (USFWS 2000). The Service made a jeopardy determination for a number of species and provided Reasonable and Prudent Alternatives to avoid jeopardy. The Service also prepared an Incidental Take Statement and provided Reasonable and Prudent Measures for a number of species. The Biological Opinion assessed the impacts of past and on-going operation and maintenance activities. An agreement was made that Tier II Biological Assessments would be prepared to address potential future site specific impacts of construction projects related to the operation and maintenance of the navigation project. This coordination and compliance process has been followed since 2000.

Recently, four Biological Assessments were prepared for construction of regulating works (USACE 2012a; USACE 2012b; USACE 2013a; USACE 2013b) on the MMR. For these work areas, the U.S. Fish and Wildlife Service conducted a Tier II Formal Consultation. The Service determined that the work falls within the scope of the programmatic BO issued for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System and that incidental take was considered programmatically in the BO. As such no new incidental take statement was included with the opinions. It was the Service's biological opinion that the Proposed Actions are not likely to jeopardize the continued existence of the pallid sturgeon.

The impacts of the Proposed Actions, when considered in relation to the past and present (2000 study evaluation baseline) did not rise to the level that any of the species being evaluated would be jeopardized or that the existing incidental take criteria were exceeded. In addition, the St. Louis District has implemented a number of projects under a variety of authorities to benefit the pallid sturgeon (e.g., placement of large woody structures; incorporation of woody debris into dikes; environmental dredging of Sister Chute; environmental engineering to create/restore habitat in Santa Fe Chute, Marquette Chute, Jones Chute, and Establishment Chute; dike modification to create habitat; design and utilization of innovative dike configurations to create habitat diversity; testing of flexible dredge pipe for future habitat creation; etc.) and least tern (e.g., modification of island tip at Ellis Island to create nesting habitat; creation of nesting habitat on floating barges; sandbar isolation from shoreline in the MMR to provide nesting habitat) These types of restoration/rehabilitation/enhancement projects will continue into the future to benefit threatened and endangered species in the MMR.

Climate Change

A cumulative impact assessment of the impact of climate changes on the MMR is highly speculative because the projected trends are so general and can be offsetting predictions (one area receives more rain while another receives less). Should climate change result in more frequent and more severe storms, then there is a potential for more sediment input into the system which “might” result in more dredging (under the No Action Alternative and the Proposed Action), depending on the level of increase. The Proposed Action should offset some of the need for additional dredging in the existing repetitive dredging area, but the nature and extent of future dredging requirements under different climate change scenarios is nearly impossible to predict. If flow levels rise, there is a possibility that the side channels would be connected to the main channel more often (under both the No Action and Action Alternatives), depending on the level and duration of stage increase. Although highly speculative based on the existing data, the past, present, and future impacts of both the no action and the Proposed Action, are not anticipated to rise to the level of being significant.

Socioeconomic Resources

The Mississippi River is essential to the economies of the counties and states that border it. The people living and working in those places rely on the river system for their livelihood. Water transportation supports thousands of jobs throughout the river corridor, and the Nation, in a variety of industries. Agricultural, mining, and manufacturing industries; public utilities; waterside commercial development; and water-based recreational activities depend on the inland waterway for their livelihood. The Regional Economic Development study conducted as part of the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study (USACE 2004) traced expenditures and transportation cost savings throughout the economy in terms of additional full-time employment, wage and salary income, and output of the value of the goods produced. The analysis reported that within the study area States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, 21,891 man-years of employment are generated by water based industries. This benefit also has an impact on other regions as well as the entire United States. In the states bordering the study area, income generated by these business activities was estimated to be over $509 million, and for the entire United States it was estimated to be over $1.2 billion. Inland water transportation generates thousands of jobs and millions of dollars in taxes for State and Federal governments.

The Middle Mississippi River Regulating Works Project is an integral part of the inland water transportation system. The long-term goal of the 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 and the occurrence of vessel accidents through the construction of regulating works. Past Regulating Works Project actions have been successful in providing a sustainable and safe navigation channel, reducing vessel accidents, and reducing the average annual dredging requirements in the MMR. Present and reasonably foreseeable future actions are expected to continue this trend.

Historic and Cultural Resources

Historic and cultural resources within and in proximity to the Middle Mississippi River have been, and continue to be, subjected to natural riverine processes (e.g., bankline and riverbed erosion). Anthropogenic changes to the system have also impacted those resources since at least the 18th century. As Euro-American settlements developed along the river, levee systems began to be constructed by landowners and communities for flood control. Beginning in the mid-19th century, structures were constructed in the river to modify water-flow to either decrease or increase sedimentation in specific locations. Dikes, for example, directed the water current to eliminate sandbars, and hurdles were used to close off chutes between towheads and riverbanks causing them to fill with sediment, and effectively narrow the river. While specific cultural resources might be adversely impacted by increased waterflow and resulting erosion, others were protected by increased sedimentation. In 1879 the Mississippi River Commission (MRC) was created by Congress to promote commerce and prevent flooding. Part of the MRC mission was to permanently locate and deepen the navigation channel and stabilize river banks. The construction of dikes and embankments has greatly reduced bankline erosion and halted river migration, thereby protecting cultural resources, both known and unknown, from destruction.

All construction and modification work on dikes and weirs is carried out using barges, without recourse to land access; therefore, any potential 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. Historic research and bathymetric surveys are conducted to determine if any wrecks are likely to be present prior to construction.

The construction of revetments can potentially have adverse effects on cultural resources. As with other training structures work is conducted via barge, without recourse to land access. The placement of the rock, however, has the potential to damage or destroy any resource on the bankline. With all revetment segments, historical research is conducted on the proposed location to determine if it is on recently accreted land or cut-banks in an existing, older, landform. Recently accreted land is highly unlikely to contain deeply buried cultural resources. If necessary terrestrial surveys are conducted to determine if any cultural resources are present.

Long term impacts of the river training structures is continued bankline stability, reducing the likelihood of cultural resources being damaged or destroyed by erosion.

Continued dredging operations under the No Action Alternative are not anticipated to impact any known historic and cultural resources in the work area. Any undocumented historic and cultural resources that may have existed in the work area likely would have been destroyed by previous dredging and disposal activities. Future maintenance dredging and disposal under the No Action Alternative would likely occur in the same locations as previous dredging, and, therefore, would be unlikely to impact undocumented historic and cultural resources.

The Proposed Action would have no impact on known historic resources and impacts to unknown resources are very unlikely. As such, the past, present, and future impacts to historic and cultural resources of No Action and the Proposed Action, are not anticipated to rise to the level of being significant.

References

Adams, S.R., T.M. Keevin, K.J. Killgore, and J.J. Hoover. 1999. Stranding potential of young fishes subjected to simulated vessel-induced drawdown. Transactions of the American Fisheries Society 128:1230-1234.

Allen, T. C. 2010. Middle Mississippi River islands: historical distribution, restoration planning, and biological importance. Ph.D. Dissertation, University of Missouri-St. Louis. 170 pp.

Arlinghaus, R., C. Engelhardt, A. Sukhodolov, and C. Wolter. 2002. Fish recruitment in a canal with intensive navigation: implications for ecosystem management. Journal of Fish Biology 61:1386-1402.

Baker, J.A., K.J. Killgore, and R.L. Kasul. 1991. Aquatic habitats and fish communities in the Lower Mississippi River. CRC Reviews in Aquatic Sciences 3:313-414.

Baldwin, R. E. 1970. Palatability of three species of fish and aroma of water from sites on the Mississippi River. Journal of Food Science 35:413-417

Barko, V.A., and D.P. Herzog. 2003. Relationship among side channels, fish assemblages, and environmental gradients in the unimpounded Upper Mississippi River. Journal of Freshwater Ecology 18:377-383.

Barko, V.A., M.W. Palmer, and D.P. Herzog. 2004. Influential environmental gradients and spatiotemporal patterns of fish assemblages in the unimpounded Upper Mississippi River. American Midland Naturalist 152:369-385.

Bartell, S.M., and K. Campbell. 2000. Ecological risk assessment of the effects of incremental increase in commercial navigation on fish. Upper Mississippi River-Illinois Waterway System Navigation Study ENV 16.

Bhowmik, N.D. Soong, T. Nakato, M. Spoor, J. Anderson, and D. Johnson. 1999. Bank erosion field survey report of the Upper Mississippi River and Illinois Waterway. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 8.

Bij de Vaate, A., A.G. Klink, M. Greijdanus-Klaas, L.H. Jans, J. Oosterbaan, and F. Kok. 2007. Effects of habitat restoration on the macroinvertebrate fauna in a foreland along the River Waal, the Main distributary in the Rhine Delta. River Research and *Applications* 23:171-183.

Bischoff, A., and C. Wolter. 2001. Groyne-heads as potential summer habitats for juvenile rheophilic fishes in the lower order, Germany. Limnologica 31:17-26

Bishop, M.J., and M.G. Chapman. 2004. Managerial decisions as experiments: an opportunity to determine the ecological impacts of boat-generated waves on macrobenthic infauna. Estuarine Coastal and Shelf Science 61:613-622.

Bi-State Development Agency. 1954. Mississippi River water pollution investigation. St. Louis Metropolitan Area. 378 pp.

Brauer, E.J., R.D. Davinroy, L. Briggs, and D. Fisher. 2013. Draft Supplement to *Geomorphology Study of the Middle Mississippi River (2005)*. U.S. Army Corps of Engineers, St. Louis District, Applied River Engineering Center, St. Louis, Missouri. 12 pp.

Brauer, E.J., D.R. Busse, C. Strauser, R.D. Davinroy, D.C. Gordon, J.L. Brown, J.E. Myers, A.M. Rhoads, and D. Lamm. 2005. Geomorphology Study of the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District, Applied River Engineering Center, St. Louis, Missouri. 43 pp.

Cellot, B. 1996. Influence of side-arms on aquatic macroinvertebrate drift in the main channel of a large river. Freshwater Biology 35:149-164.

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

Deng, Z., G.R. Guensch, C A. McKinstry, R.P. Mueller, D.D. Dauble, and M C. Richmond. 2005. Evaluation of fish-injury mechanisms during exposure to turbulent shear flow. Canadian Journal of Fisheries and Aquatic Sciences 62:1513-1522.

Ellis, M. M. 1931. A survey of conditions affecting fisheries in the Upper Mississippi River. U.S. Bureau of Fisheries. Fishery Circular 5. 18 pp.

Ellis, M. M. 1943. A study of the Mississippi River from Chain of Rocks, St. Louis, Missouri, to Cairo, Illinois, with special reference to the proposed introduction of ground garbage into the river by the City of St. Louis. U.S. Fish and Wildlife Service Special Science Report 8. 22 pp.

Eckblad, J.W., C.S. Volden, and L.S. Weilgart. 1984. Allochthonous drift from backwaters to the main channel of the Mississippi River. American Midland Naturalist 111:16-22.

Gabel, F., M.T. Pusch, P. Breyer, V. Burmester, N. Walz, and X.-F. Garcia. 2011a. Differential effect of wave stress on the physiology and behavior of native versus non-native benthic invertebrates. Biological Invasions 13:1843-1853.

Gabel, F. S. Stoll, P. Fischer, M.T. Pusch, X.-F. Garcia. 2011b. Waves affect predator-prey interactions between fish and benthic invertebrates. Oecologia 165:101-109.

Gabel, F., X.-F. Garcia, M. Brauns, A. Sukhodolov, M. Leszinski, and M.T. Pusch. 2008. Resistance to ship-induced waves of benthic invertebrates in various littoral habitats. Freshwater Biology 53:1567-1578.

Galat, D.L., and I. Zweimuller. 2001. Conserving large-river fishes: is the highway analogy an appropriate paradigm? Journal of the North American Benthological Society 20:255-265.

Garcia, M.H., D.M. Admiraal, and J.F. Rodriguez. 1999. Laboratory experiments on navigation-induced bed shear stresses and sediment resuspension. Int. J. Sed. Res. 14:303-317.

Grenfell M, Aalto R, Nicholas A. 2012. Chute channel dynamics in large, sand-bed meandering rivers. Earth Surface Processes and Landforms 37:315-331.

Grift, R.E., A.D. Buijse, W.L.T. Van Densen, and J.G.P. Klein Breteler. 2001. Restoration of the river-floodplain interaction: benefits for the fish community in the River Rhine. Archiv für Hydrobiologie 12:173-185.

Guntren, E. M. 2011. Modeling Planform Changes Over Time in Middle Mississippi River Side Channels to Determine General Trends and Impacts on Aquatic Habitats. M.S. Thesis, Southern Illinois University Edwardsville.

Gutreuter, S., J.M. Dettmers, and D.H. Wahl. 2003. Estimating mortality rates of adult fish from entrainment through the propellers of river towboats. Transactions of the American Fisheries Society 132:646-661.

Gutreuter, S., J.M. Vallazza, and B.C. Knights. 2006. Persistent disturbance by commercial navigation alters the relative abundance of channel-dwelling fishes in a large river. Canadian Journal of Fisheries and Aquatic Sciences 63:2418-2433.

Hein, T., C. Baranyi, W. Reckendorfer, and F. Schiemer. 2004. The impact of surface water exchange on nutrient and particle dynamics in side-arms along the River Danube, Austria. Science of the Total Environment 328:207-218.

Holland, L.E. 1987. Effects of brief navigation-related dewatering on fish eggs and larvae. North American Journal of Fisheries Management 7:145-147.

Holland, L.E., and J.R. Sylvester. 1983. Distribution of larval fishes related to potential navigation impacts on the upper Mississippi River, Pool 7. Transactions of the American Fisheries Society 112:293-301.

Huckstorf, V., W.-C. Lewin, T. Mehner, and C. Wolter. 2011. Impoverishment of YOY-fish assemblages by intensive commercial navigation in a large lowland river. River Research and Applications 27:1253-1263.

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/)

Jia, Y., S Scott, Y. Xu, and S. Wang. 2009. Numerical study of flow affected by bendway weirs in Victoria Bendway, the Mississippi River. Journal of Hydraulic Engineering 135:902-916.

Johnson, B.L., and K.H. Hagerty, editors. 2008. Status and trends of selected resources of the Upper Mississippi River System. U.S. Geological Survey,Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, December 2008. Technical Report LTRMP 2008-T002. 102 pp + Appendixes A-B.

Keevin, T.M., B.L. Johnson, E.A. Laux, T.B. Miller, K.P. Slattery, and D.J. Schaeffer. 2005. Adult fish mortality during lockage of commercial navigation traffic at Lock and Dam 25, Upper Mississippi River. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 58. 14 pp.

Keevin, T.M., E. Marks Guntren, and R. Barkau. 2014. Middle Mississippi River side channels: Existing hydraulic connectivity to the river with implications for restoration planning. Report, in preparation.

Keevin, T.M., R.E. Yarbrough, and A.C. Miller 1992. Long-distance dispersal of zebra mussels (*Dreissena polymorpha*) attached to hulls of commercial vessels. Journal of Freshwater Ecology 7: 437.

Keevin, T.M., S.T. Maynord, S.R. Adams, and K.J. Killgore. 2002. Mortality of fish early life stages resulting from hull shear stress associated with passage of commercial navigation traffic. Upper Mississippi River - Illinois Waterway System Navigation Study ENV Report 35. 17 pp.

Killgore, K.J., A.C. Miller, and K.C. Conley. 1987. Effects of turbulence on yolk-sac larvae of paddlefish. Transactions of the American Fisheries Society 116:670-673.

Killgore, K.J., L.W. Miranda, C.E. Murphy, D.M. Wolff, J.J. Hoover, T.M. Keevin. S. T.Maynord, and M.A.Cornish. 2011. Fish entrainment through towboat propellers in the Upper Mississippi-Illinois Waterway System. Transactions of the American Fisheries Society 140:570-581.

Killgore, J., C. Murphy, D. Wolff, and T. Keevin. 2005. Evaluation of towboat propeller-induced mortality of juvenile and adult fishes. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 56. 14 pp.

Killgore, K. J., S. T. Maynord, M. D. Chan, and R. M. Morgan II. 2001. Evaluation of propeller-induced mortality on early life stages of selected fish species. North American Journal of Fisheries Management 21:947-955.

Koel, T. M., and K. E. Stevenson. 2002. Effects of dredge material placement on benthic macroinvertebrates of the Illinois. Hydrobiologia 474:229-238.

Kucera-Hizinger, V., E. Schludermann, H. Zornig, A. Weissenbacher, M. Schabuss, and F. Schiemer. 2009. Potential effects of navigation-induced wave wash on the early life history stages of riverine fish. Aquatic Science 71:94-102.

Lowery, D. R., Pasch, R. W., and E. M. Scott. 1987. Hydroacoustic survey of fish populations of the lower Cumberland River. Final Report to the U.S. Army Corps of Engineers. U.S. Army Corps of Engineers, Nashville, TN.

Marmorstein, J. 2000. Analysis of the impact of infrastructure improvements on the risk of accidents and hazardous spills. Report Prepared for the U.S. Army Corps of Engineers.

Maynord, S. T. 2000. Velocity patterns downstream of Mississippi River dikes with and without tow traffic. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 21.

Maynord, S. T. 2004. Decay of tow-induced drawdown in backwaters and secondary channels. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 45.

Maynord, S. T., and T. M. Keevin. 2005. Commercial navigation traffic induced shoreline dewatering on the Upper Mississippi River: Implications for larval fish stranding. Upper Mississippi River - Illinois Waterway System Navigation Study ENV Report 55. 14 pp.

Mazumder, B. S., N. G. Bhowmik, and T. W. Soong. 1993. Turbulence in rivers due to navigation Traffic. Journal of Hydraulic Engineering 119:581-597.

McElroy, B., A. DeLonay, and R. Jacobson. 2012. Optimum swimming pathways of fish spawning migrations in rivers. Ecology 93:29-34.

Miranda, L.E., and K.J. Killgore. 2013. Entrainment of shovelnose sturgeon by towboat navigation in the Upper Mississippi River. Journal of Applied Ichthyology 29:316-322.

Morgan II, R.P., R.E. Ulanowicz, V.J. Rasin, Jr., L.A. Noe, and G.B. Gray. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis*, and white perch, *M. Americana*. Transactions of the American Fisheries Society 105:149-154.

Munawar, M., W.P. Norwood, and L.H. McCarthy. 1991. A method for evaluating the impacts of navigationally induced suspended sediments from the Upper Great Lakes Connecting Channels on primary productivity. Hydrobiologia 219:325-332.

Nanson, G.C., A. von Krusenstierna, E.A. Bryant, and M.R. Renilson. 1993. Experimental measurements of river-bank erosion caused by boat-generated waves on the Gordon River, Tasmania. Regulated Rivers: Research and Management 9:1-14.

Nestler J.M., D.L Galat, and R.A.Hrabik. 2012. Side channels of the impounded and Middle Mississippi River: Opportunities and challenges to maximize restoration potential. Report of a Workshop held 10-14 January 2011 for the Corps of Engineers Navigation & Environmental Sustainability Program (NESP) and Water Operations Technology Support Program (WOTS), and Missouri Department of Conservation.

Nielsen, L.A.R.J. Sheehan, D.J. Orth. 1986. Impacts of navigation on riverine fish production in the United States. Polish Archives of Hydrobiology 33:277-294.

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

Odum, M.C., D.J. Orth, and L.A. Nielsen. 1992. Investigation of barge-associated mortality of larval fishes in the Kanawha River. Virginia Journal of Science 43:41-45.

Ouillon, S. and D. Dartus. 1997. Three-dimensional computation of flow around groyne. Journal of Hydraulic Engineering 123: 962–970.

Paillex, A, S. Dolédec, E. Castella, and S. Mérigoux. 2009. Large river floodplain restoration: predicting species richness and trait responses to the restoration of hydrological connectivity. Journal of Applied Ecology 46:250-258.

Platner, W. S. 1946. Water quality studies of the Mississippi River. U.S. Fish and Wildlife Service Special Science Report 30. 77 pp.

Pokrefke, T.J., C. Berger, J.P. Rhee, S.T. Maynord. 2003. Tow-induced backwater and secondary channel sedimentation, Upper Mississippi River System. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 41.

Preiner, S., I. Drozdowski, M. Schagerl, F. Schiemer, and T. Hein. 2008. The significance of side-arm connectivity for carbon dynamics of the River Danube, Austria. Freshwater Biology 53:238-252.

Radspinner, R. R., P. Diplas, A. F. Lightbody, and F. Sotiropoulos. 2010. River training and ecological enhancement potential using in-stream structures. Journal of Hydraulic Engineering 136:967-980.

Savino, J.F., M.A. Blouin, B.M. Davis, P.L. Hudson, T.N. Todd, and G.W. Fleischer. 1994. Effects of pulsed turbidity and vessel traffic on lake herring eggs and larvae. Journal Great Lakes Research 20:366-376.

Scheaffer, 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.

Schneider, B. 2012. Changes in fish use and habitat diversity associated with placement of three chevron dikes in the Middle Mississippi River. M.S. thesis, Southern Illinois University Edwardsville.

Sheehan, R.J., P.S. Willis, M.A. Schmidt, and J.M. Hennessy. 2000a. Determination of the fate of fish displaced from low-velocity habitats at low temperatures. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 32.

Sheehan, R.J., P.S. Willis, M. Schmidt, and J.M. Hennessy. 2000b. Determination of tolerance of fish in low-velocity habitats to hydraulic disturbance at low temperatures. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 33.

Shields, F. D., Jr., C. M. Commer, and S. Tesa III. 1995. Toward greener riprap: environmental considerations from microscale to macroscale. Pp. 557-574. *In*: River, Coastal and Shoreline Protection: Erosion Control Using Riprap and Armourstone, Thorne, C. R. et al. (eds). John Wiley and Sons: Chichester.

Siegrest, J.M., and S.P. Cobb. 1987. Evaluation of bird and mammal utilization of dike systems along the Lower Mississippi River. USACE Lower Mississippi River Environmental Program. Report 10.

Simons, J.H. E.J., C. Bakker, M.H.J. Schropp, L.H. Jans, F.R. Kok, and R.E. Grift. 2001. Man-made secondary channels along the River Rhine (The Netherlands): results of post-project monitoring. Regulated Rivers: Research & Management 17:473-491.

Smart, M.M., R.G. Rada, D.N. Nielsen, and T.O. Clafin. 1985. The effect of commercial and recreational traffic on the resuspension of sediment in navigation pool 9 on the Upper Mississippi River. Hydrobiologia 126:263-274.

Söhngen, B., J. Koop, S. Knight, J. Rythönen, P. Beckwith, N. Ferrari, J. Iribarren, T. Keevin, C. Wolter, S. Maynord. 2008. Considerations to Reduce Environmental Impacts of Vessels. Permanent International Navigation Congress (PIANC) Report Series #99: 113 pp. + CD Appendices.

Theiling, C., M.R. Craig, and K.S. Lubinski. 2000. Side channel sedimentation and land cover change in the Middle Mississippi River reach of the Upper Mississippi River System. U.S. Geological Survey Report. 82 pp.

Todd, B.L., F.S. Dillon, and R.E. Sparks. 1989. Barge effects on channel catfish. Illinois Natural History Survey, Aquatic Ecology Technical Report 89/5, Champaign, Illinois.

University of Memphis. 1998. Accidents and hazardous spills analysis for Upper Mississippi River Basin. Transportation Studies Institute, prepared for the U.S. Army Corps of Engineers, Rock Island District.

USACE. 1999a. Middle Mississippi River side channels: A habitat rehabilitation and conservation initiative. U.S. Army Corps of Engineers, Rock Island District. 31 pp. + Appendices.

USACE. 1999b. Tier I of a two tiered Biological Assessment - Operation and Maintenance of the Upper Mississippi River Navigation Project within St. Paul, Rock Island, and St. Louis Districts. Mississippi Valley Division, Vicksburg, MS.

USACE. 2004. Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study. U.S. Army Corps of Engineers, St. Paul, Rock Island, and St. Louis Districts.

USACE. 2006. Environmental Assessment with Draft Finding of No Significant Impact: Explosive Removal of Rock Pinnacles and Outcroppings Considered to be Navigation Obstructions During Low-Flow Periods on the Middle Mississippi River. St. Louis District, U.S. Army Corps of Engineers. 31 pp.

USACE. 2009. Tier II Supplemental Environmental Assessment with Draft Finding of No Significant Impact: Removal of Rock Pinnacles and Outcroppings Considered to be Navigation Obstructions During Low-Flow Periods on the Middle Mississippi River. 10 pp.

USACE. 2012. Supplemental Environmental Assessment with Draft Finding of No Significant Impact: Removal of Rock Pinnacles and Outcroppings Considered to be Navigation Obstructions During Low-Flow Periods on the Middlle Mississippi River. 26 pp.

USACE. 2012a. Tier II Biological Assessment: Grand Tower, Crawford Towhead, Vancill Towhead (Grand Tower Phase V Regulating Works), MRM 80.6-67, Operation and Maintenance of the 9-foot Navigation Channel on the Upper Mississippi River System. U.S. Army Corps of Engineers, St. Louis District. 16 pp.

USACE. . 2012b. Tier II Biological Assessment: Regulating Works Project, Eliza Point/Greenfield Bend Phase 3, MRM 20.0-0, Alexander County, Illinois, Mississippi County, Missouri, on the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District. 12 pp.

USACE. 2013a. Tier II Biological Assessment: Dogtooth Bend Phase 5, River Miles 40-20, Alexander County, Illinois, Scott and Mississippi Counties, Missouri, on the Middle Mississippi River. U.S. Army Corps of Engineers, St. Louis District. 14 pp.

USACE. 2013b. Tier II Biological Assessment: Regulating Works Project, Mosenthein/Ivory Landing Phase 4, Middle Mississippi River Miles 175-170, St. Clair County, IL, St. Louis City, MO. U.S. Army Corps of Engineers, St. Louis District. 16 pp.

USEPA. 2013. U. S. Environmental Protection Agency green book nonattainment areas for criteria pollutants as of July 31, 2013. http://www.epa.gov/airquality/greenbk/ . Accessed 13 August 2013.

USFWS. 2000. Biological opinion for the operation and maintenance of the 9-foot navigation channel on the Upper Mississippi River System. U. S. Department of the Interior, Fort Snelling, Minnesota.

U.S. Public Health Service. 1954. Transcript of conference. Pollution of interstate waters: Mississippi River, St. Louis Metropolitan Area. 121 pp + Appendix.

Wolter, C., and R. Arlinghaus. 2003. Navigation impacts on freshwater fish assemblages: the ecological relevance of swimming performance. Reviews in Fish Biology and Fisheries 13:63-89.

Wolter, C., and A. Bischoff. 2001. Seasonal changes of fish diversity in the main channel of the large lowland river Oder. Regulated Rivers: Research and Management 17:595-608.

Wolter, C., R. Arlinghaus, A. Sukhodolov, and C. Engehardt. 2005. A model of navigation-induced currents in inland waterways and implications for juvenile fish displacement. Environmental Management 34:656-668.

Wysocki, L.E., J P. Dittami, and F. Ladich. 2006. Ship noise and cortisol secretion in European freshwater fishes. Biological Conservation 128:501.508.

Yossef, M., and H. de Vriend. 2011. Flow details near river groynes: experimental investigation. Journal of Hydraulic Engineering 137:504-516.

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

REGULATING WORKS PROJECT
MOSENTHEIN/IVORY LANDING PHASE 5
MIDDLE MISSISSIPPI RIVER MILES 160-162.5
MONROE COUNTY, IL
ST. LOUIS COUNTY, MO

FEBRUARY 2015

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

CONTENTS

APPENDIX D

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

1. PROJECT DESCRIPTION

A. Location. The Mosenthein/Ivory Landing Phase 5 work area is located in the Middle Mississippi River (MMR) between river miles (RM) 160 and 162.5 in St. Louis County, Missouri, and Monroe County, Illinois. The MMR is defined as that portion of the Mississippi River 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 Mosenthein/Ivory Landing Phase 5 work as part of its 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, i.e. dikes and weirs. The Mosenthein/Ivory Landing Phase 5 work is designed to address repetitive maintenance dredging conditions in the area. The work involves construction of three dikes 161.1 -161.7 (L), and placement of weirs at four locations on the right descending bank from river mile 162.0 to 162.3.

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-1800's. 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 regulation works to reduce the need for repetitive channel maintenance dredging in the area.

D. General Description of the Fill Material.
Fill material would include quarry run limestone consisting of graded "A" stone. Size requirements for graded "A" stone are shown below in Table 1. Stone (165,100 tons) required for construction would be obtained from commercial stone quarries in the vicinity of the work area capable of producing stone which meets USACE specifications.

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 Placement Site.
The proposed work would consist of the following (see Table 2):

Construction of three dikes between river miles 160.1 and 160.7 (L)
- Approximately 330, 500, and 615 linear feet.
- Top elevation of 384 feet (NAVD 88) for the two downstream and 385 ft (NAVD88) for upper dike.

Placement of four weirs between river miles 162.0 – 162.3
- Approximately 520, 645, 720 and 700 linear feet.
- Top elevation of approximately 351 feet (NAVD88).

Table 2 – Mosenthein-Ivory Landing Phase 5 Construction

Middle Mississippi Reach	Site Specific Reach	River Mile	Structure	Elevation (NAVD 88)	Volume (tons)	Approximate Length
Mosenthein/Ivory Landing Phase V (RM 165-156)	Mouth of the Meramec (RM 162.5-160)	162.30R	Weir	351	8,200	520
		162.20R	Weir	351	7,700	645
		162.10R	Weir	351	12,500	720
		162.00R	Weir	351	12,100	700
		161.70L	Rootless Dike	385	30,500	615
		161.50L	Rootless Dike Extension	384	36,900	500
		161.10L	Rootless Dike Extension	384	57,200	330
			Total Rock Volume (approximate)		165,100	

F. Description of the Placement Method.
Placement of 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.

2. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations

I. **Elevation and Slope.**

Dikes

There would be an immediate change in substrate elevation and slope over the areal extent of the dike locations 161.1-161.7 (L). The dikes would consist of a rock mound of uniform shape, between 330 and 615 feet long, placed approximately 600 to 1000 feet off the existing bankline and extending toward the navigation channel. The top elevation of the dikes would be 384 and 385 feet NAVD88. 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 both ends of the dikes. Areas immediately downstream of the dikes would experience some areas of accretion and some areas of scour.

- These "rootless" dikes will be placed along the LDB side of the channel in an effort to increase the energy in the navigation channel, resulting in increased depths and a reduction in the need for repetitive channel maintenance dredging.
- The configuration of these dike structures, specifically the "rootless" feature, is an effort to increase the environmental benefits that may result from the construction of these dikes.
- The structures will be constructed of Graded A-Stone (Limestone) placed from floating plant (no bankline access needed).
- The benthic habitat area of the dikes at RM 162.3 – 162.0 is approximately 3.5 acres.

Weirs

There would be an immediate change in substrate elevation and slope over the areal extent of the weir locations between RM 162.0-162.3 (R). The weirs would consist of a rock mound of uniform shape, between 720 and 520 feet long, placed approximately 400 feet off the existing bankline and extending toward the navigation channel. The top elevation of the weirs would be 351 feet (NAVD88). Side slopes would be approximately 1 vertical on 1.5 horizontal on the upstream side and 1 vertical on 3 horizontal on the downstream side. After placement, the elevation of crossover areas downstream of the weirs would experience some reduction.

- By reducing scouring action along the outside bend between RM 162.3 and 162.0, these 4 bendway weir structures (built so that barge tows can pass over the top of the submerged structures) should increase the scouring energy in the area just downstream, which has been an area needing repetitive dredging to maintain a safe and dependable navigation channel.
- The structures will be constructed of Graded A-Stone (Limestone) placed from floating plant (no bankline access needed).
- The benthic habitat area of the weirs at RM 162.3 – 162.0 is approximately 4 acres.

II. **Sediment Type.** The work area is located entirely within the existing channel of the Middle Mississippi River. The Middle Mississippi River channel is comprised mainly of sands with some gravels, silts, and clays. The stone used for construction would be Graded "A" limestone.

III. **Fill Material Movement.** No bank grading or excavation would be required for placement of stone. Draglines and/or track hoes would pull rock from floating barges and place the material into the river and on the banks. Fill materials would be subject to periodic high flows which may cause some potential movement and dislodging of stone. This may result in the need for minor repairs; however, no major failures are likely to occur.

IV. **Physical Effects on Benthos.** Material placement 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 area during construction. Greater utilization of the location by fish is expected after construction due to the expected increase in densities of macroinvertebrates.

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 used for construction is deposited onto the riverbed. 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 rootless dikes would create split flow conditions at river stages below the top structure elevations of 384 and 385 feet NAVD88. The rootless dikes would increase channel depth in the main channel and along the adjacent bankline. The weirs at 162.0-162.3 (R) would refocus river toward the crossover portion of the channel.

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 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 construction activities.

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. S**ediments 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. Fish habitat is expected to improve at the dike placement site due to improved flow, bathymetry, and prey resource conditions.

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 expected increase in densities of macroinvertebrates and areas of improved flow and bathymetry.

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 Middle Mississippi River. Improvements in lower trophic levels (macroinvertebrates) subsequent to completion should benefit the aquatic food web. Minor negative impacts on fish and macroinvertebrate communities due to reduced woody debris should not significantly impact 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. The adverse impacts to threatened and endangered species expected to result from this work are consistent with those anticipated in the programmatic Biological Opinion and the District has implemented the Reasonable and Prudent Measures and Terms and Conditions prescribed therein as appropriate for the project.

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 certifications would be obtained from the states of Illinois and Missouri. All other 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 offset dikes to increase habitat diversity in the Middle Mississippi River 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 Mosenthein/Ivory Landing Phase 5 work.

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 constructing any new structures in the area but continuing to maintain the existing river training structures. Dredging would continue as needed to address the shoaling issues in the area.
2. Proposed Action - The Proposed Action consists of construction of three dikes at RM 161.1-161.7 (L) and placement of weirs at four locations from RM 162 (R) to 162.3 (R).

C. Certification under Section 401 of the Clean Water Act would be obtained from the Missouri Department of Natural Resources and the Illinois Environmental Protection Agency prior to implementation.

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 improve the integrity of an authorized navigation system.

__________________________ ______________________________________

(Date)

ANTHONY P. MITCHELL
COL, EN
Commanding

Appendix E. Public Comments and Responses

Appendix F. 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:

February 04, 2015

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

Ms. Judith Deel, Senior Archaeologist
Office of Historic Preservation
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, Missouri 65102

Subject: Mosenthein Reach – Ivory Landing Phase 5 Project: River Training Structures

Dear Ms. Deel:

The United States Army Corps of Engineers (USACE) is presently planning the construction, or modification, of seven river training structures in the Mississippi River between river miles 161 and 162.5 (Figure 1). The structures comprise the Mosenthein Reach – Ivory Landing Phase 5 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.

There are a number of types of river training structures including dikes, revetments, bendway weirs, and chevrons. As noted, dikes redirect the river's own energy to manage sediment distribution within the river channel to provide adequate depth for navigation. While the original dikes of the nineteenth century had been largely pile structures, by the middle of the twentieth century many had been converted to stone-fill types. Revetments are structures placed along the river bank to stabilize or protect the bank from erosion. They are usually constructed out of stone, but a variety of other materials have been used including concrete-mat, willow mattresses, and gabions. First constructed in 1989, submerged bendway weirs widen the navigation channel in rivers bends by creating a favorable redistribution of current velocities and sediments. A more-recent development are chevrons built in the river itself. Chevrons create and promote split flows rather than unidirectional deflections and provide more diverse aquatic habitats. River training structures continue to be constructed, as they provide a more cost-effective and environmentally friendly solution for moving sediment through the river system than dredging alone.

Project

It is proposed that seven river training structures be modified or constructed (Figure 1). Four of the structures would be located in Monroe County, Illinois, and three would be in St. Louis County, Missouri (Table 1). All new dikes and weirs will not extend to the bankline or tie into existing revetments. No bankline revetment work is proposed.

Table 1.

Feature	Type	County	State
Dike 141.70L	New	Monroe	IL
Dike 161.50L	Rootless Extension	Monroe	IL
Dike 161.10L	Rootless Extension	Monroe	IL
Weir 162.30R	New	St. Louis	MO
Weir 162.20R	New	St. Louis	MO
Weir 162.10R	New	St. Louis	MO
Weir 162.00R	New	St. Louis	MO

Potential Effects on Cultural Resources

All the river training structures are constructed 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.

Compared to other segments of the Mississippi River, the bankline of this section of the Mosethein Reach has remained relatively consistent for the last 150 years (Figure 2). By 1908 the Illinois bankline stabilized near its current position and the only major change to the Missouri bankline was the accretion of land below the Missouri bluffs at the mouth of the Merrimack River (Figure 3).

Possible Shipwrecks

During the summer of 1988 when the Mississippi River was at its lowest level on record, 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 wrecks were located over two miles above and below the project features.

Most of the proposed structures are next to dredged channels, which probably resulted in channel slump and sediment reworking in the locations (Figure 4). The Mosethein Reach has been regularly dredged over the years, and it is likely that any unrecorded wreckage located in the path of those dredge events was destroyed and removed during the process. While exact location information is not available for dredging events prior to 1979, USACE has been conducting such activities to deepen the navigation channel of the Middle Mississippi since 1896 (Manders and Rentfro 2011:61).

The river bed in the project area is surveyed every two to three years, with the latest survey having been completed on May 14, 2013. The single-beam survey was conducted with range lines spacing of approximately 200 feet. No topographic anomalies suggesting wrecks are visible on the resulting bathymetric map (Figure 5).

Given the features' construction method (with no land impact), the previous disturbance of the riverbed, 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,

Chris Pallas for

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

Enclosure

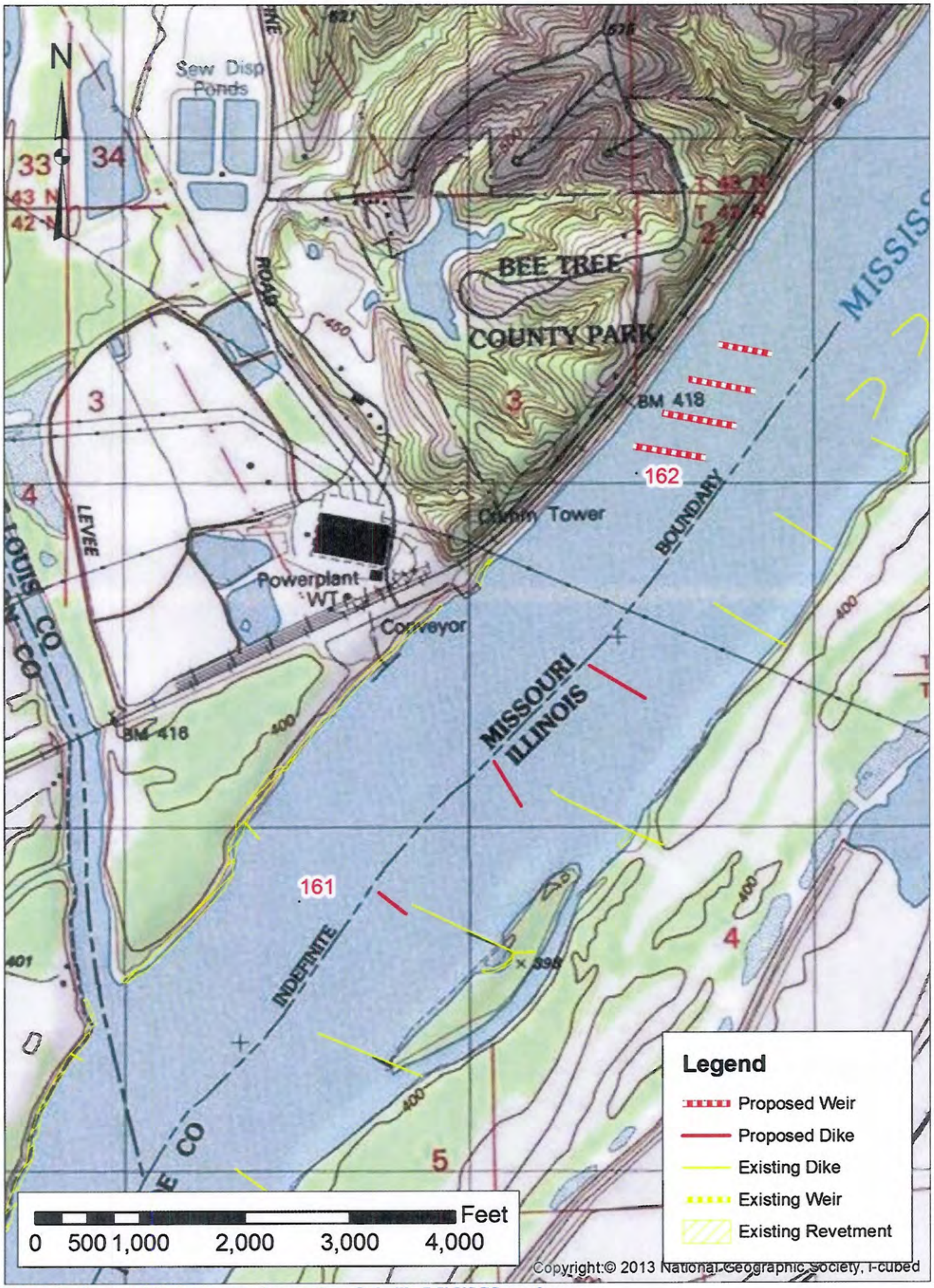

Figure 1. Proposed features superimposed on Oakville 7.5' USGS quad map.

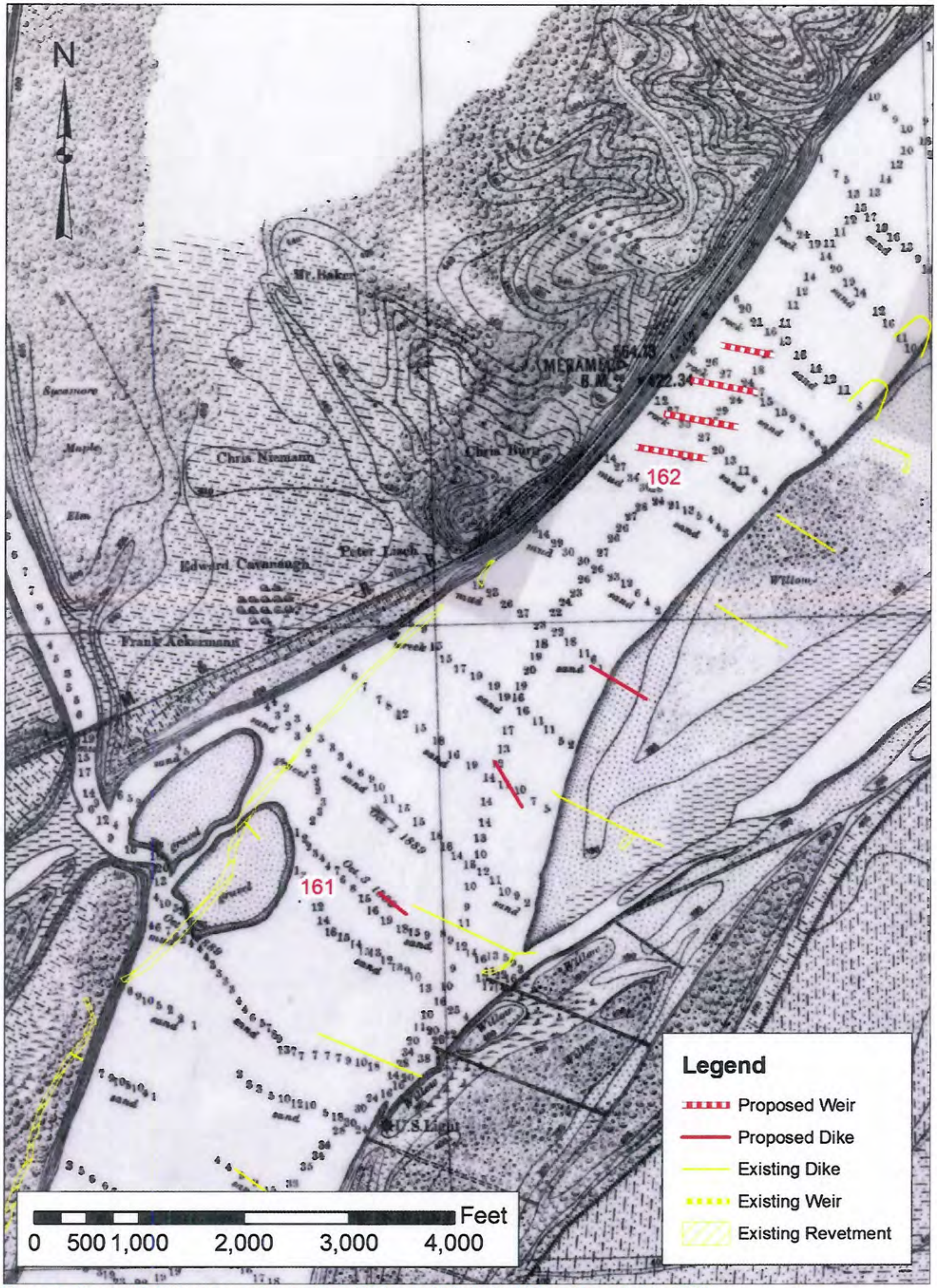

Figure 2. Proposed features superimposed on 1881 map (Mississippi River Commission 1881).

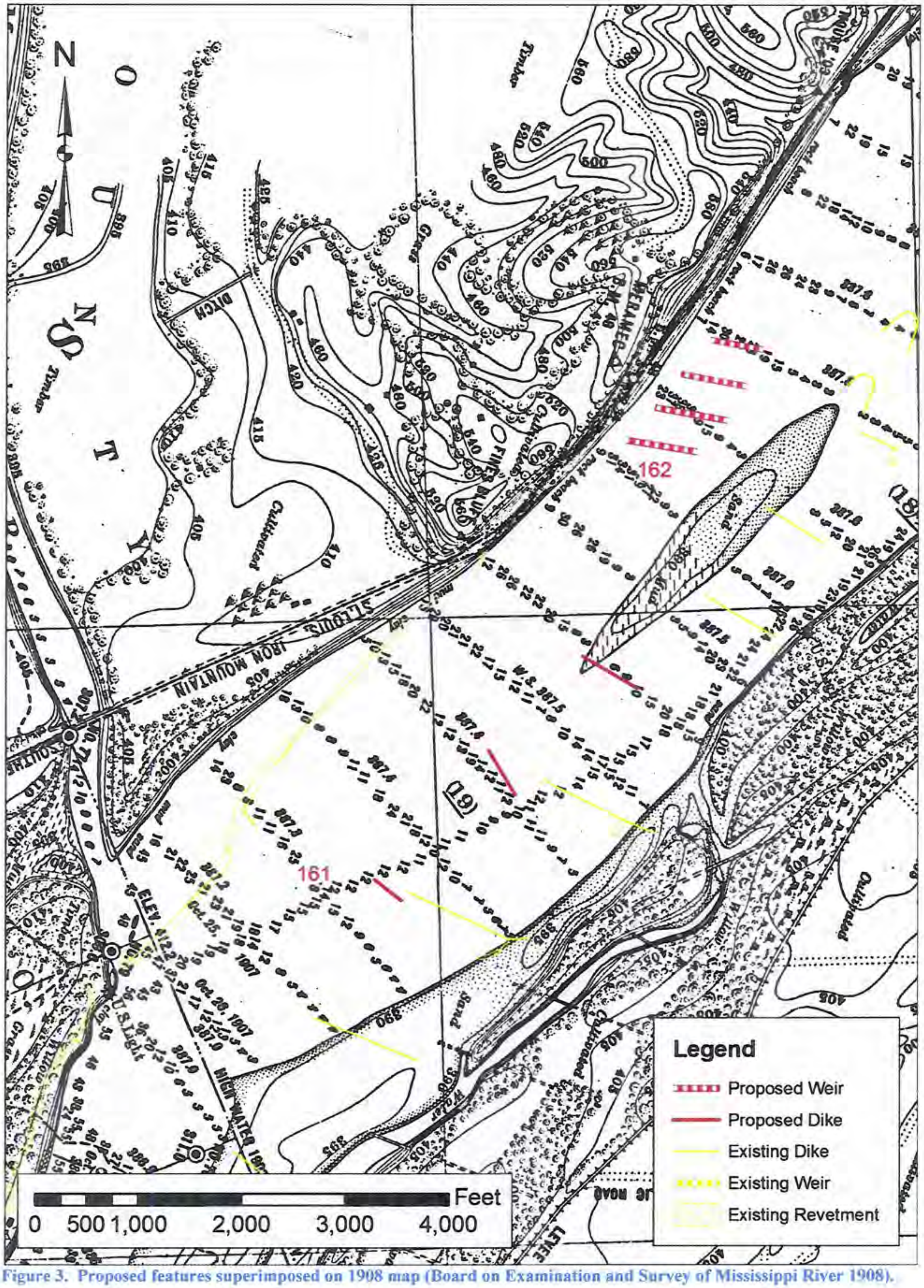

Figure 3. Proposed features superimposed on 1908 map (Board on Examination and Survey of Mississippi River 1908).

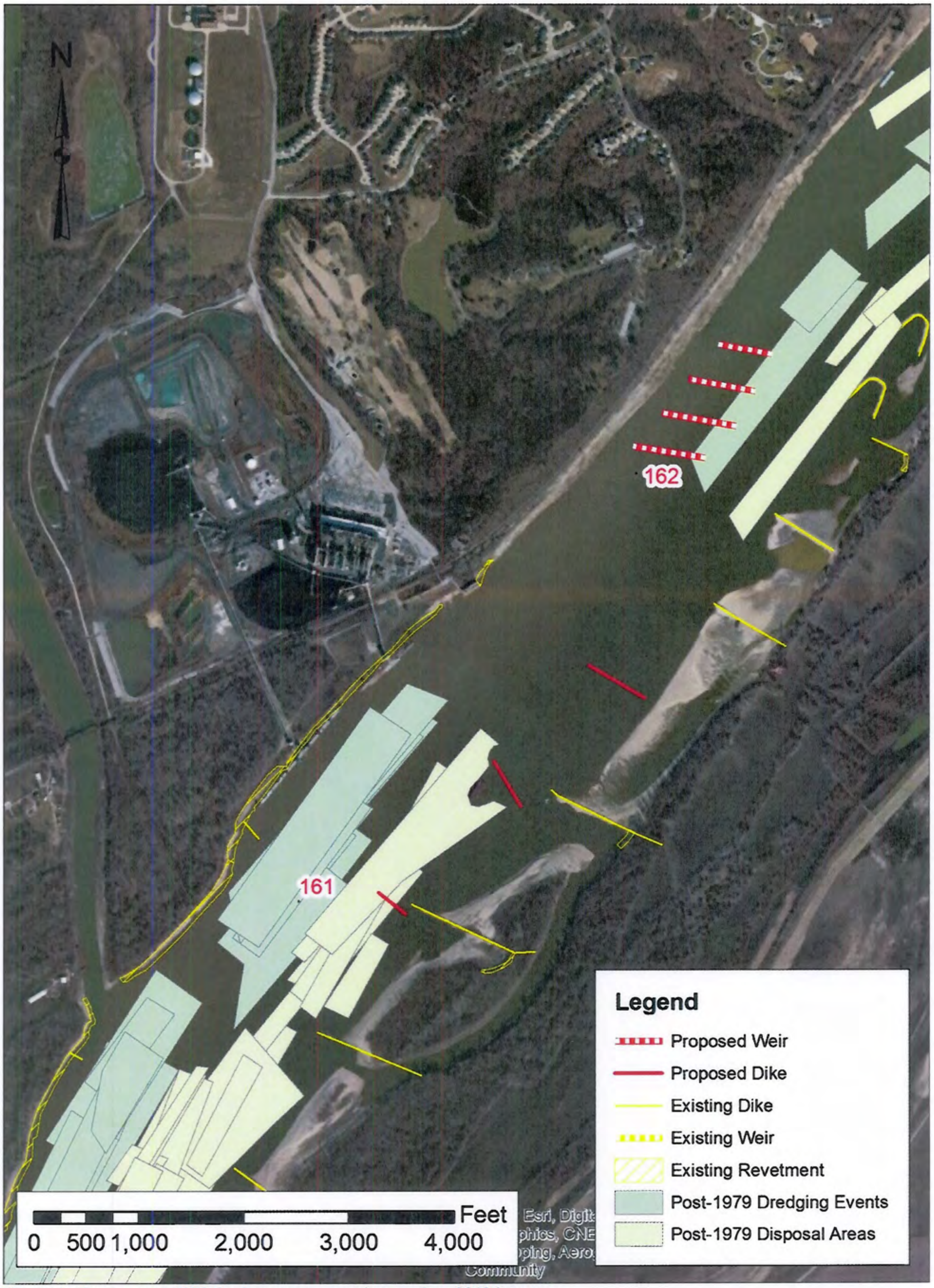

Figure 4. Known post 1979 dredge events superimposed on 2012 imagery.

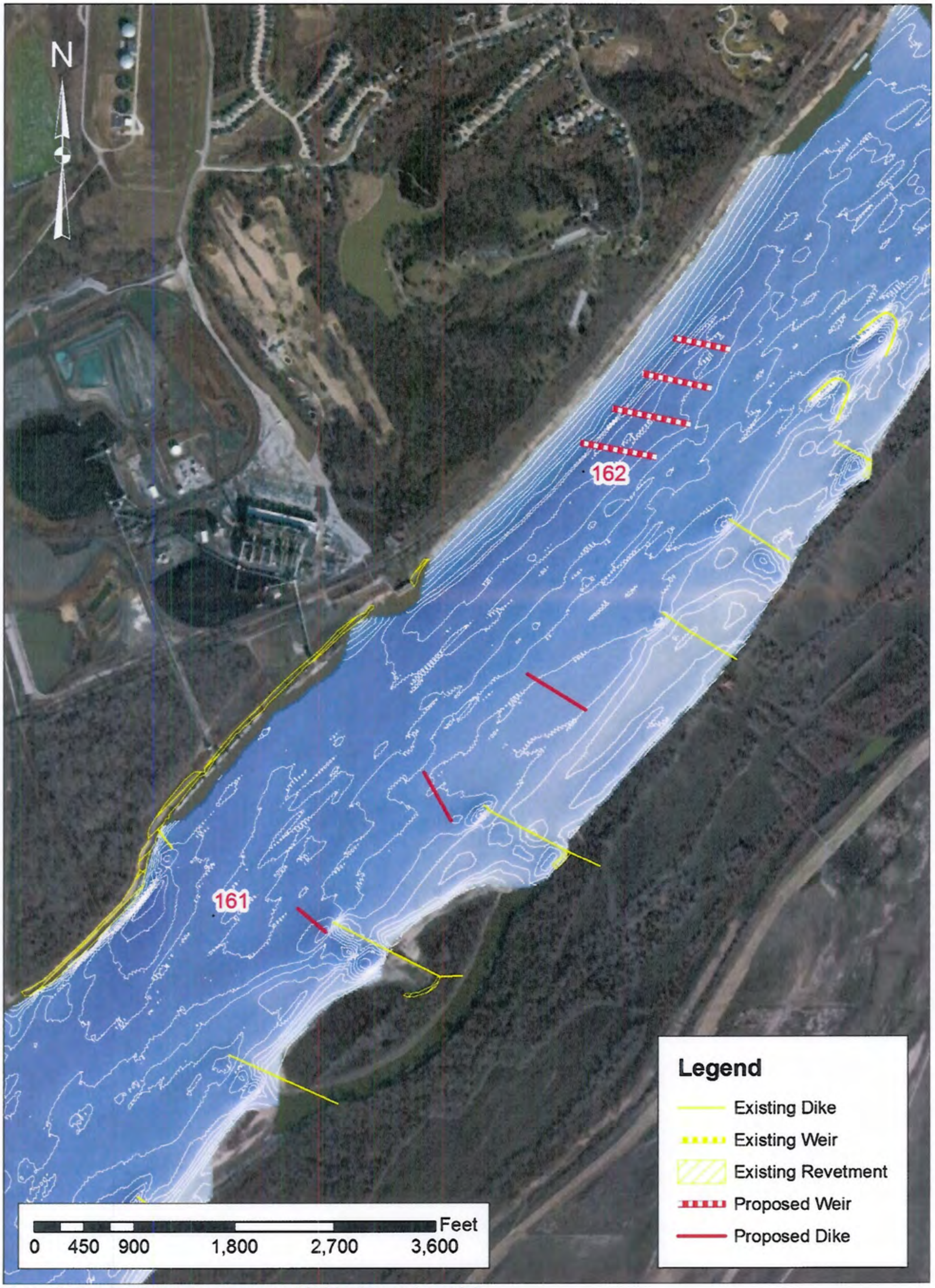

Figure 5. Proposed features shown on 2013 bathymetric model.

References Cited

Manders, D., & B. Rentrfro (2011). *Engineers Far From Ordinary*. St. Louis: St. Louis District USACE.

STATE OF MISSOURI Jeremiah W. (Jay) Nixon, Governor • Sara Parker Pauley, Director
DEPARTMENT OF NATURAL RESOURCES
www.dnr.mo.gov

February 11, 2015

Michael K. Trimble, Ph.D.
Chief, Curation & Archives Analysis Branch
St. Louis District, Corps of Engineers
1222 Spruce Street
St. Louis, Missouri 63103-2833

Re: Mosenthein Reach – Ivory Land Phase 5 Project: River Training Structures (COE) St. Louis County, Missouri

Dear Dr. Trimble:

Thank you for submitting information on the above referenced project for our review pursuant to Section 106 of the National Historic Preservation Act (P.L. 89-665, as amended) and the Advisory Council on Historic Preservation's regulation 36 CFR Part 800, which requires identification and evaluation of cultural resources.

We have reviewed the information provided concerning the above referenced project. Based on this review we concur with your recommendation that there will be **no historic properties affected** and, therefore, we have no objection to the initiation of project activities.

Please be advised that, should project plans change, information documenting the revisions should be submitted to this office for further review. In the event that cultural materials are encountered during project activities, all construction should be halted, and this office notified as soon as possible in order to determine the appropriate course of action.

If you have any questions, please write Judith Deel at State Historic Preservation Office, P.O. Box 176, Jefferson City, Missouri 65102 or call 573/751-7862. Please be sure to include the SHPO Log Number (**101-SL-15**) on all future correspondence or inquiries relating to this project.

Sincerely,

STATE HISTORIC PRESERVATION OFFICE

Mark A. Miles

Mark A. Miles
Director and Deputy State
Historic Preservation Officer

MAM:jd

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

REPLY TO
ATTENTION OF:

February 04, 2015

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

Rachel Leibowitz, Ph.D.
Deputy State Historic Preservation Officer
Illinois Historic Preservation Agency
1 Old State Capitol
Springfield, IL 62701

Subject: Mosenthein Reach – Ivory Landing Phase 5 Project: River Training Structures

Dear Dr. Leibowitz:

The United States Army Corps of Engineers (USACE) is presently planning the construction, or modification, of seven river training structures in the Mississippi River between river miles 161 and 162.5 (Figure 1). The structures comprise the Mosenthein Reach – Ivory Landing Phase 5 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.

There are a number of types of river training structures including dikes, revetments, bendway weirs, and chevrons. As noted, dikes redirect the river's own energy to manage sediment distribution within the river channel to provide adequate depth for navigation. While the original dikes of the nineteenth century had been largely pile structures, by the middle of the twentieth century many had been converted to stone-fill types. Revetments are structures placed along the river bank to stabilize or protect the bank from erosion. They are usually constructed out of stone, but a variety of other materials have been used including concrete-mat, willow mattresses, and gabions. First constructed in 1989, submerged bendway weirs widen the navigation channel in rivers bends by creating a favorable redistribution of current velocities and sediments. A more-recent development are chevrons built in the river itself. Chevrons create and promote split flows rather than unidirectional deflections and provide more diverse aquatic habitats. River training structures continue to be constructed, as they provide a more cost-effective and environmentally friendly solution for moving sediment through the river system than dredging alone.

Project

It is proposed that seven river training structures be modified or constructed (Figure 1). Four of the structures would be located in Monroe County, Illinois, and three would be in St. Louis County, Missouri (Table 1). All new dikes and weirs will not extend to the bankline or tie into existing revetments. No bankline revetment work is proposed.

Table 1.

Feature	Type	County	State
Dike 141.70L	New	Monroe	IL
Dike 161.50L	Rootless Extension	Monroe	IL
Dike 161.10L	Rootless Extension	Monroe	IL
Weir 162.30R	New	St. Louis	MO
Weir 162.20R	New	St. Louis	MO
Weir 162.10R	New	St. Louis	MO
Weir 162.00R	New	St. Louis	MO

Potential Effects on Cultural Resources

All the river training structures are constructed 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.

Compared to other segments of the Mississippi River, the bankline of this section of the Mosethein Reach has remained relatively consistent for the last 150 years (Figure 2). By 1908 the Illinois bankline stabilized near its current position and the only major change to the Missouri bankline was the accretion of land below the Missouri bluffs at the mouth of the Merrimack River (Figure 3).

Possible Shipwrecks

During the summer of 1988 when the Mississippi River was at its lowest level on record, 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 wrecks were located over two miles above and below the project features.

Most of the proposed structures are next to dredged channels, which probably resulted in channel slump and sediment reworking in the locations (Figure 4). The Mosethein Reach has been regularly dredged over the years, and it is likely that any unrecorded wreckage located in the path of those dredge events was destroyed and removed during the process. While exact location information is not available for dredging events prior to 1979, USACE has been conducting such activities to deepen the navigation channel of the Middle Mississippi since 1896 (Manders and Rentfro 2011:61).

The river bed in the project area is surveyed every two to three years, with the latest survey having been completed on May 14, 2013. The single-beam survey was conducted with range lines spacing of approximately 200 feet. No topographic anomalies suggesting wrecks are visible on the resulting bathymetric map (Figure 5).

Given the features' construction method (with no land impact), the previous disturbance of the riverbed, 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,

Chris Pulliam

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

Enclosure

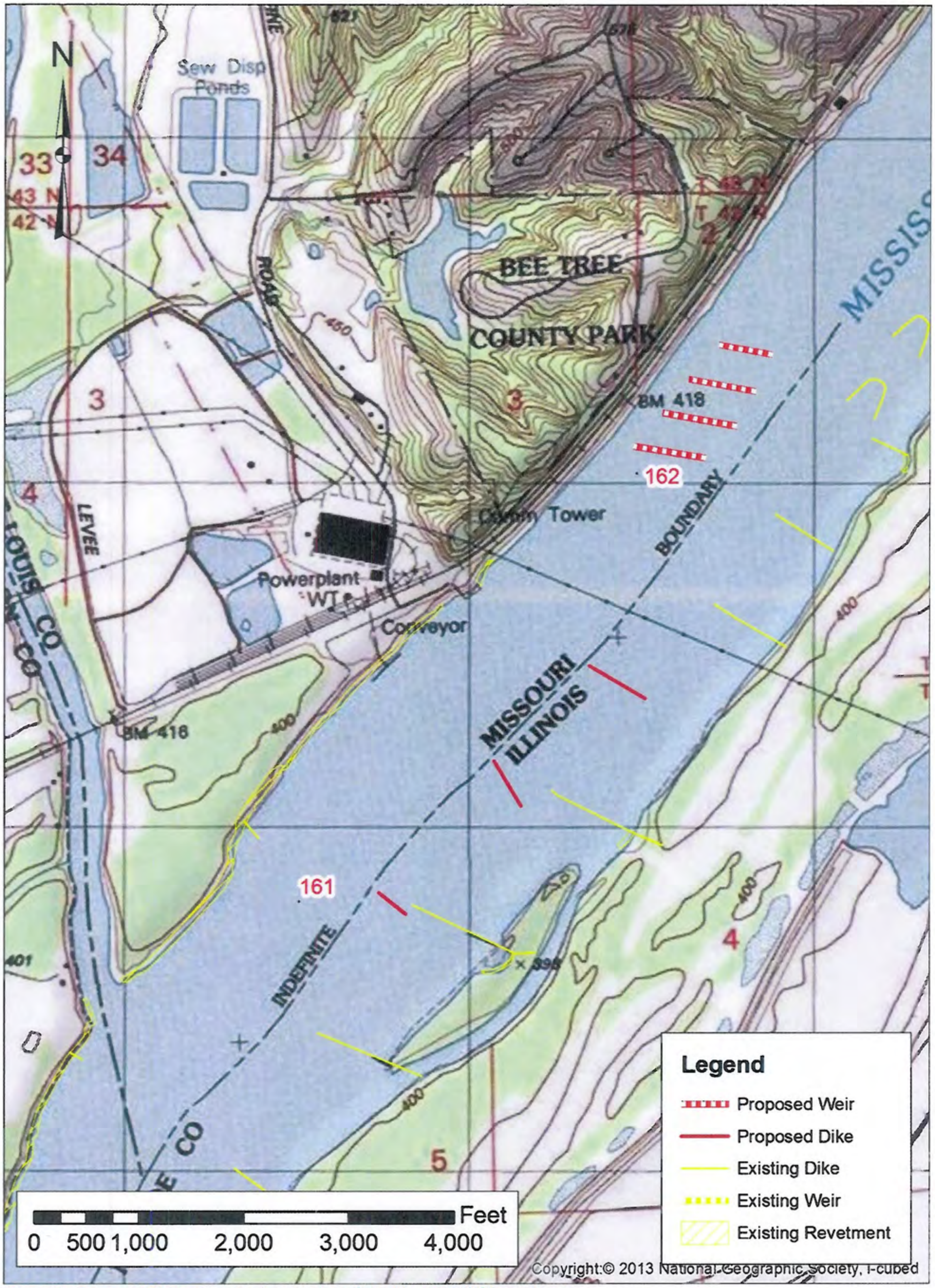

Figure 1. Proposed features superimposed on Oakville 7.5' USGS quad map.

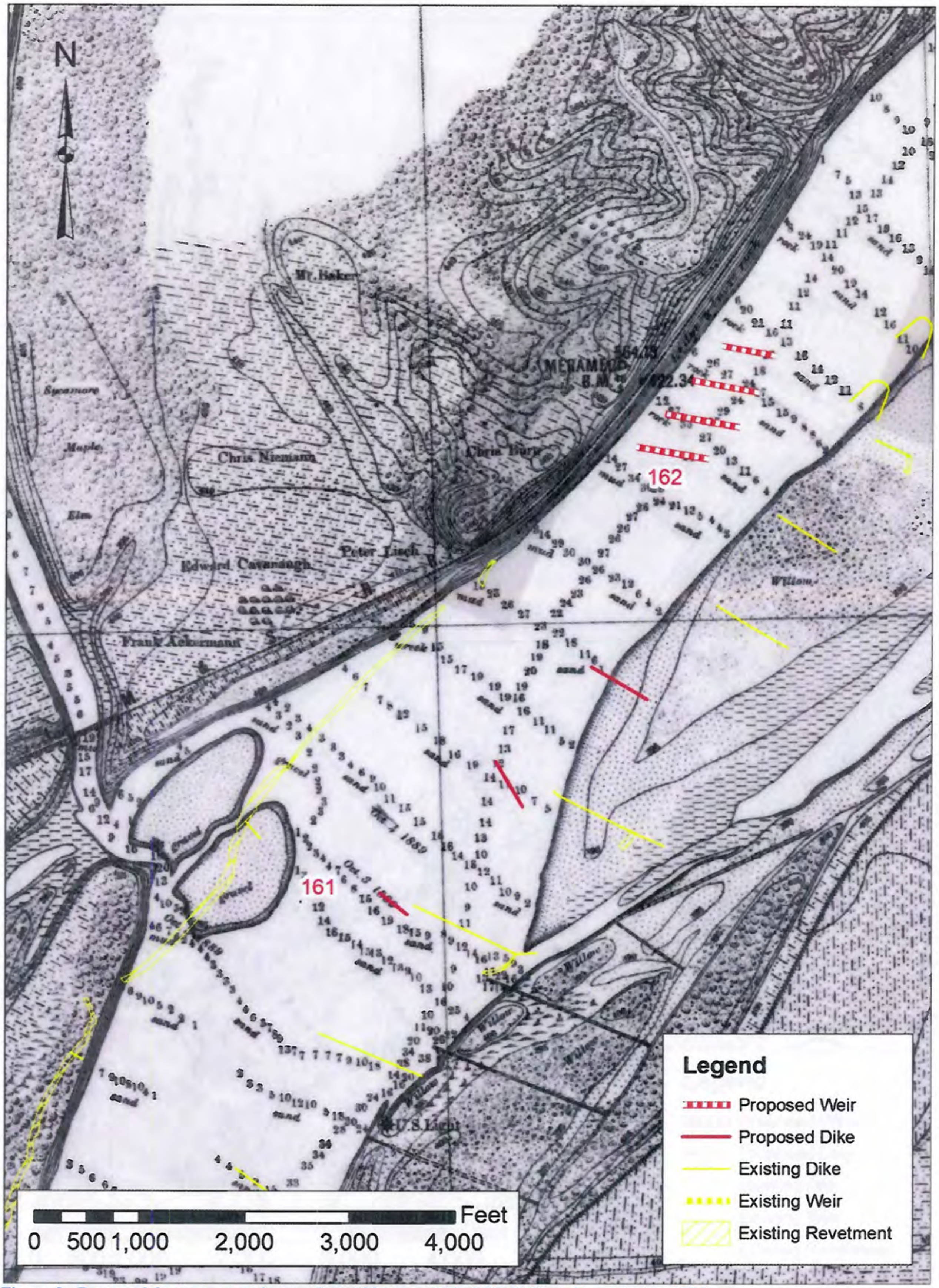

Figure 2. Proposed features superimposed on 1881 map (Mississippi River Commission 1881).

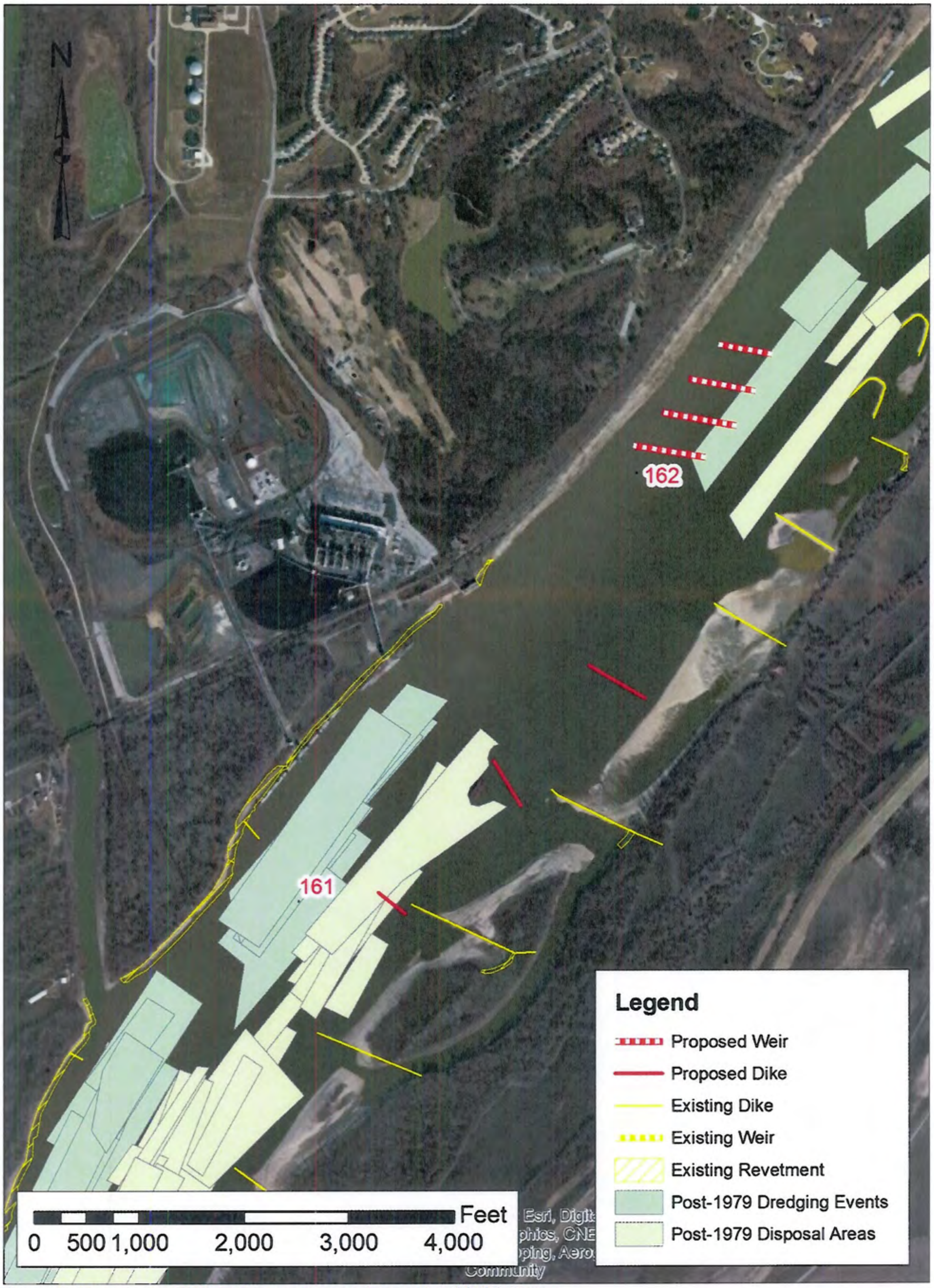

Figure 4. Known post 1979 dredge events superimposed on 2012 imagery.

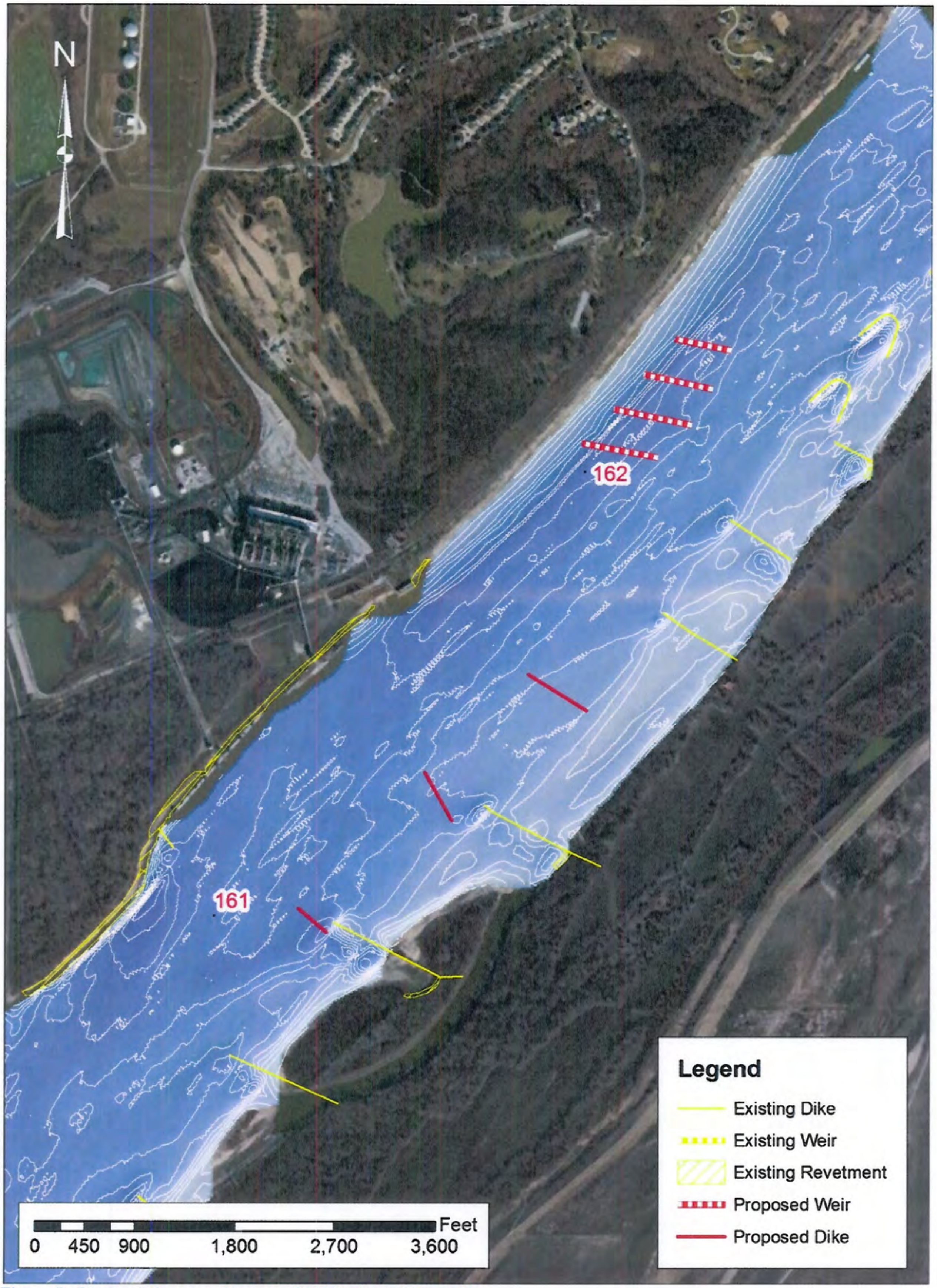

Figure 5. Proposed features shown on 2013 bathymetric model.

References Cited

Manders, D., & B. Rentrfro (2011). *Engineers Far From Ordinary*. St. Louis: St. Louis District USACE.

ILLINOIS HISTORIC
Preservation
AGENCY

FAX 217/524-7525

Monroe County PLEASE REFER TO: IHPA LOG #045021315
Merrimac
Mississippi River miles 161 to 162.5
COESTL
New construction, river training structures - Mosenthein Reach-Ivory Landing Phase 5

February 25, 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

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

REPLY TO
ATTENTION OF:

February 17, 2015

Engineering and Construction Division
Curation and Archives Analysis Branch

COPY

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 river training structures in one reach of the middle Mississippi River. River training structures are used to help reduce sediment deposition in the navigation channel and to limit the need for dredging. The U.S. Army Corps of Engineers, St. Louis District proposes adding, or modifying, seven (7) training structures.

The project is located along the Mississippi River in Monroe County, Illinois, and St. Louis County, Missouri (see Table1 below 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 improve navigation, reduce dredging in the channel, and enhance wildlife habitat along the river.

Table 1. Proposed FY 14 River Training Structure

Major Reach	Localized Reach	Work	County	State
Mosethein-Ivory Landing Phase 5 (RM 195-154)	St Louis Harbor (RM161-163)	Dike 161.70L	Monroe	IL
		Dike 161.50L	Monroe	IL
		Dike 161.10L	Monroe	IL
		Weir 162.30R	St. Louis	MO
		Weir 162.20R	St. Louis	MO
		Weir 162.10R	St. Louis	MO
		Weir 162.00R	St. Louis	MO

In 1866 the Federal Government allocated funding for a 4-foot navigation channel between Minneapolis and St. Louis. In 1887 this channel was deepened to a 4.5-foot channel, and in 1907 it was once again deepened to a 6-foot channel from the confluence of the Mississippi and Missouri rivers to Minneapolis. This was achieved using a system of wing and closing dikes in conjunction with river dredging.

In 1927 Congress ordered USACE to study the feasibility of a 9-fooot 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. 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. They

provide a more cost-effective solution for moving sediment thought the river system than dredging alone. While mitigating the need for environmentally disruptive dredging, newer designs also attempt to preserve and enhance the environmental components of the river through the creation of diverse wildlife habitats.

Training structures will be incorporated into the pre-existing system of structures already located along the river (see attachment Figure 2). There are numerous types of river training structures including dikes, revetments, rootless dikes, and bendway weirs. Among the types proposed in the work outlined in this letter are the following.

- Rootless dikes are wing dikes that are not connected to the shore. They redirect the river's own energy to manage sediment distribution within the river channel. The gap between the structure and the bank promotes habitat diversity.

- Bendway weirs are submerged rock structures that are positioned from the outside bankline of a river-bend and angled upstream toward the river flow. These underwater structures extend directly into the navigation channel and shift the current away from the outside bankline. This controls channel scouring and reduces riverbank erosion, resulting in wider and safer navigation channel through the bend without the need for periodic dredging.

Impacts to potentially significant historic properties are not anticipated during this work. River training structures are constructed 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 is highly unlikely that any more ephemeral cultural material remains on the river bed. The Corps of Engineers has conducted a shipwreck survey during times of historic 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 from 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 maps and information about this project and notify our office if you have any concerns, such as a 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 March 27, 2015, if you have any areas of concern. If you have any questions regarding this matter, please contact Ms. Roberta L. Hayworth, Native American Coordinator at (314) 331-8833, or at roberta.l.hayworth@usace.army.mil. Thank you in advance for your timely review of this request. A copy of this letter has been furnished to Mr. Joseph Blanchard.

Sincerely,

Chris Pallan for

COPY

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

Attachments

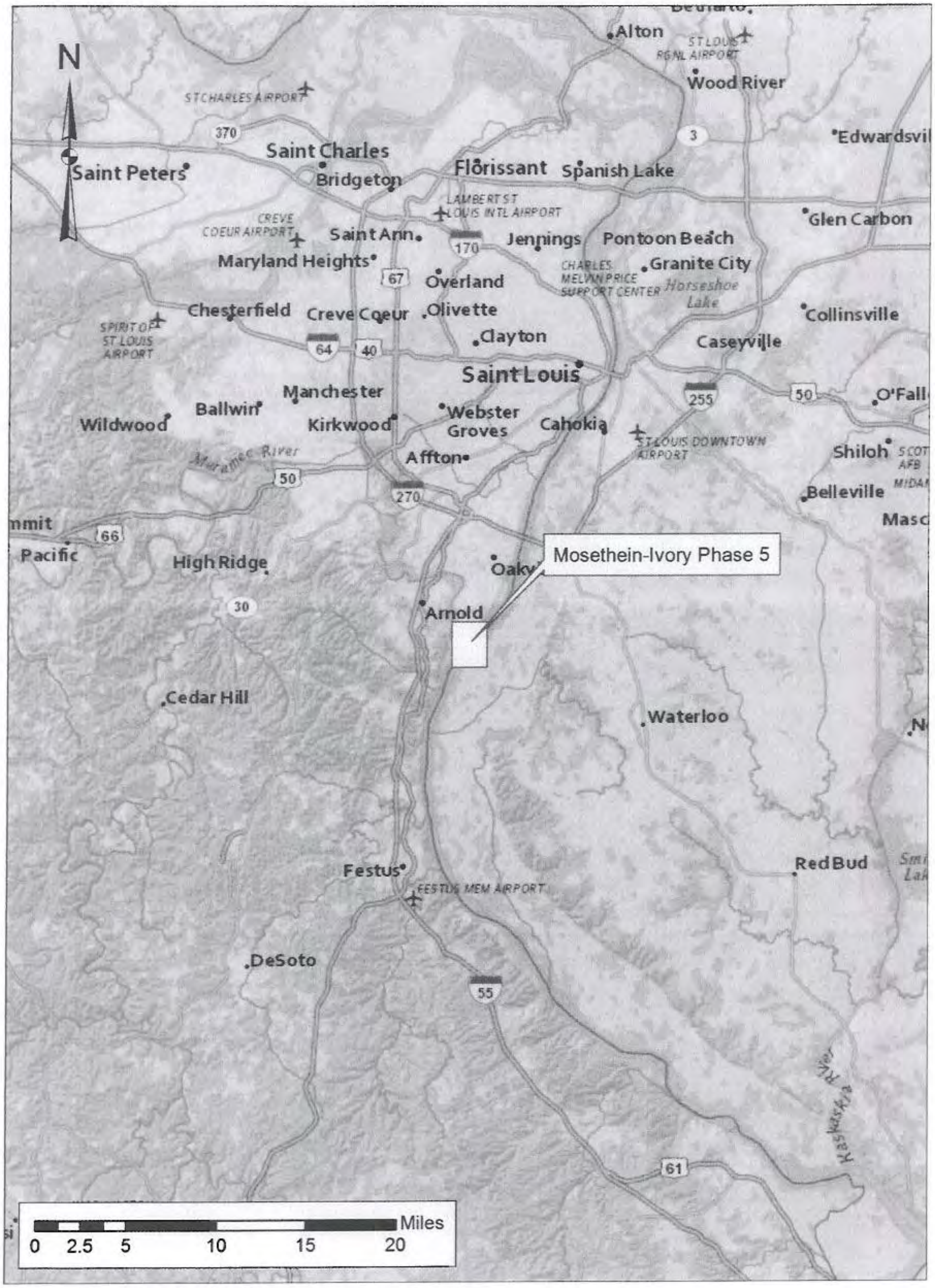

Figure 1. General project location.

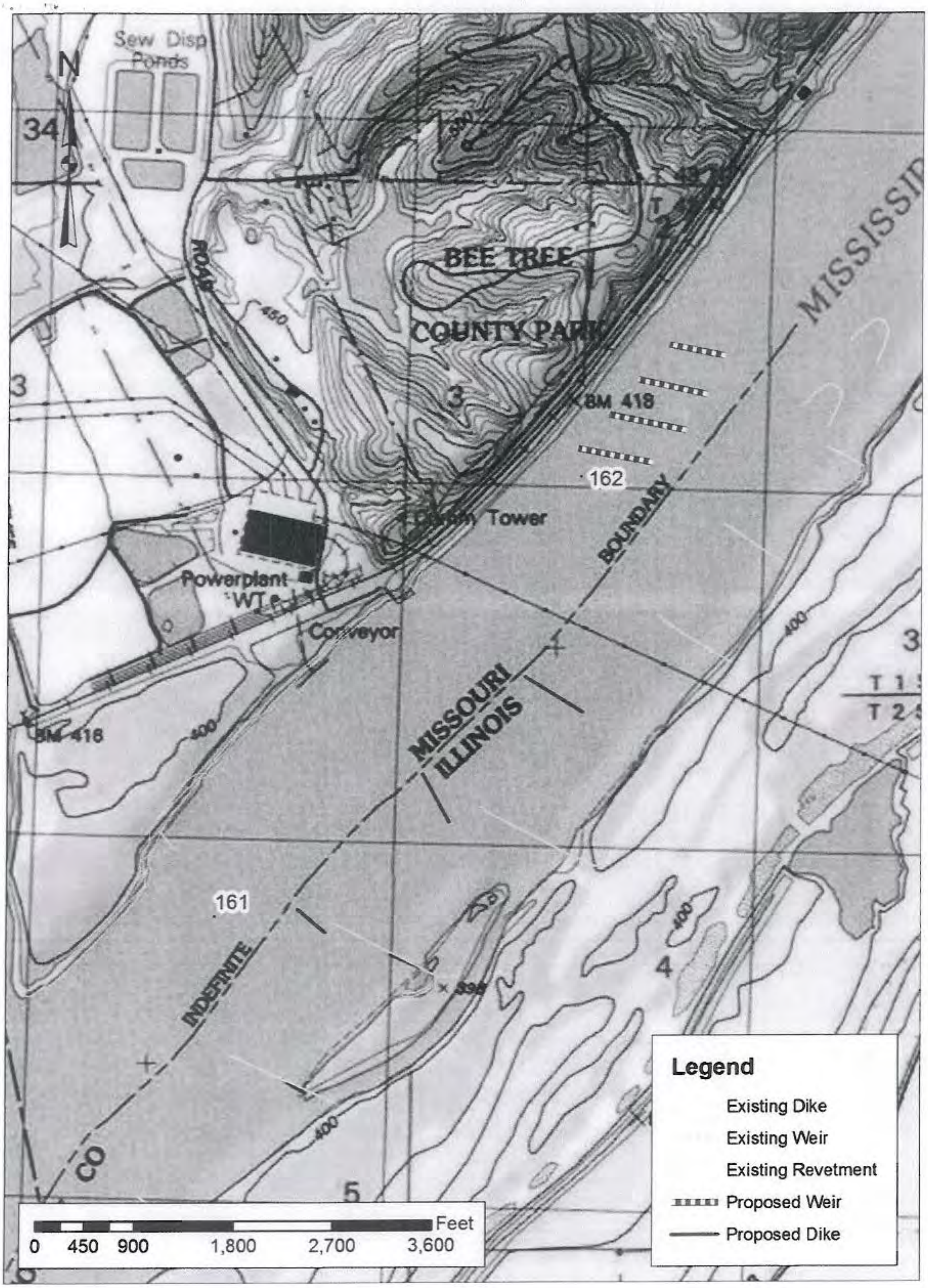

Figure 2. Location of project features.

SAME LETTER SENT:

TRIBAL CHAIRPERSONS

Governor Edwina Butler-Wolfe
Absentee-Shawnee Tribe
2025 S. Gordon Cooper Drive
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SAME LETTER SENT:

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Eagle Pass, Texas 78853

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Kickapoo Tribe of Oklahoma
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McCloud, Oklahoma 74851

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Miami, Oklahoma 74355

Chairman John Berrey
Quapaw Tribe of Indians
P.O. Box 765
Quapaw, Oklahoma 74363

SAME LETTER SENT:

TRIBAL REPRESENTATIVE:

Mr. Joseph Blanchard
Tribal Historic Preservation Officer
Absentee-Shawnee Tribe
2025 Gordon Cooper Drive
Shawnee, Oklahoma 74810-9381

Ms. Robin DuShane
Eastern Shawnee Tribe of Oklahoma
P.O. Box 350
Seneca, Missouri 64856

Ms. Kim Jumper
Shawnee Tribe
P.O. Box 189
Miami, Oklahoma 74355

Dr. Richard Allen
Cherokee Nation
P.O. Box 948
Tahlequah, Oklahoma 74465

Ms. Lisa Larue-Baker
Tribal Historic Preservation Officer
United Keetoowah Band of Cherokee
Indians of Oklahoma
P.O. Box 746
Tahlequah, Oklahoma 74464

Ms. Nekole Allogood
Dir. Cultural & Historic
Preservation Office
Delaware Nation, Oklahoma
P.O. Box 825
Anadarko, Oklahoma 73005

Dr. Bryce Obermeyer
Tribal Historic Preservation Officer
Delaware Tribe of Indians
Roosevelt Hall, Room 212
1200 Commercial Street
Emporia, Kansas 66801

Ms. Kelli Mosteller
Tribal Historic Preservation Officer
Citizen Potawatomi Nation
Cultural Heritage Center
1601 S. Gordon Cooper Dr.
Shawnee, Oklahoma 74801

Ms. Melissa Cook
Tribal Historic Preservation Officer
Forest County Potawatomi
Cultural Center
8130 Mishkoswen Drive, P.O. Box 340
Crandon, Wisconsin 54520

Mr. Todd Williamson
Match-e-be-nash-she-wish Pottawatomi
P.O. Box 218
Dorr, Michigan 49323

Mr. Earl Meshigaud
Hannahville Indian Community
P.O. Box 351, HY 2 & 41
Harris, Michigan 49845

Mr. John Rodwan
Nottawaseppi Huron Band of
Potawatomi, Michigan
2221-1&1/2 Mile Road
Fulton, Michigan 49052

Mr. Mike Zimmerman
Tribal Historic Preservation Officer
Pokagon Band of Potawatomi
P.O. Box 180, 58620 Stink Road
Dowagiac, Michigan 49047

Ms. Jancita Warrington
Prairie Band Potawatomi Nation
Government Center
16281 Q Road
Mayetta, Kansas 66509

Mr. William Quackenbush
Tribal Historic Preservation Officer
Ho-Chunk Nation of Wisconsin
P.O. Box 667
Black River Falls, Wisconsin 54615

Ms. Emily DeLeon
Tribal Historic Preservation Officer
Winnebago Tribe of Nebraska
P.O. Box 687
Winnebago, Nebraska 68071

Mr. F. Martin Fee
Tribal Historic Preservation Officer
Iowa Tribe of Kansas and Nebraska
3345 Thrasher Road
White Cloud, Kansas 66094

Mr. Kent Collier
Kickapoo Tribe of Oklahoma
P.O. Box 70
McCloud, Oklahoma 74851

Mr. Curtis Simon
Kickapoo Tribe of Indians of Kansas
1107 Goldfinch Road
Horton, Kansas 66439

Ms. Sandra Massey
Sac & Fox Nation of Oklahoma
920883 S. Hwy. 99
Building A
Stroud, Oklahoma 74079

Mr. Gary Bahr
Sac & Fox Nation of Missouri
305 North Main Street
Hiawatha, Kansas 66434

Mr. Jonathan Buffalo
Sac & Fox Tribe of the Mississippi
349 Meskwaki Road
Tama, Iowa 52339

Mr. George Strack
Tribal Historic Preservation Officer
Miami Tribe
P.O. Box 1326
202 S. Eight Tribes Trail
Miami, Oklahoma 74355

Dr. Andrea Hunter
Historic Preservation Office
The Osage Nation
627 Grandview
Pawhuska, Oklahoma 74056

Ms. Cynthia Stacy
Peoria Tribe
118 S. Eight Tribes Trail
P.O. Box 1527
Miami, Oklahoma 74355

Mr. Everett Brandy
Tribal Historic Preservation Officer
Quapaw Tribe of Oklahoma
P.O. Box 765
Quapaw, Oklahoma 74363

Sent: Wednesday, February 18, 2015 10:14 AM

To: Hayworth, Roberta L MVS

Cc: Holly Noe

Subject:[EXTERNAL] Re: letter (UNCLASSIFIED)

Follow Up Flag: Follow up

Flag Status: Flagged

Thank you, Roberta. I have received it, read it, and am now sending you your response.

We concur with the findings and recommendations, and:

The United Keetoowah Band of Cherokee Indians in Oklahoma has reviewed your project under Section 106 of the NHPA, and at this time, have no comments or objections. However, if any human remains are inadvertently discovered, please cease all work immediately and contact us. The United Keetoowah Band of Cherokee Indians in Oklahoma reserves the right to re-enter consultation on this project at any time.

Thank you,

Lisa C. Baker

Acting THPO

United Keetoowah Band of Cherokee Indians in Oklahoma

Appendix G. Distribution List

RECEIVED EMAIL NOTICE

Harold.dodd@aclines.com

tabeardslee@gmail.com

Shannon.hughes@kirbycorp.com

Tim.Enos@aclines.com

Davedewey.rme@gmail.com

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semoport@semoport.com

scrowley@marquettetrans.com

preitz@reitzjens.com

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Richard_c_nelson@fws.gov

Butch.Atwood@Illinois.gov

Dave.Herzog@mdc.mo.gov

odorothy@iwla.org

sametm@nwf.org

mgherschler@gmail.com

npinter@geo.siu.edu

Adams, R

Adrian, D MVS

Amato, Joel

Amy Salveter (USFWS):

Andria, Kathy Banner Press

Barker Farris,Osage Nation

Barnes, Robert

Bax, Stacia

Bellville,Colette

Bensman, Jim

Boaz, Tracy

Boehm, Gerry

Brescia, Chris

Brown, Danny

Brown, Doyle

Bruce Morrison, Great Rivers Law:

bryan.simmons@fws.gov

Buan, Steve

Buffalo, Jonathan

Burlingame, Chuck

Byer, J R

Caito, J

Campbell-Allison, Jennifer

Carney, Doug

Cecil Ceorst

Chicago Commods

Chief John Red

City of Portage des Sioux

Clare Mannion

Clements, Mark

Coder, Justin S

Congressman Clay

Congressman Sam Graves

Corker, Ashley

Cruse, Lester

Darst, E B

Deel, Judith

Deutsch, Charles W (Charlie) MVS

Dewey, Dave

Diedrichsen, Mike IDNR, OWR:

Senator Blunt

Docks

Dougherty, Mark

Ebey, Mike

Elizabeth Hubertz

Elmestad, Gary

Engle, Lance MVS

Fabrizio, Christi

Favilla, Christy

Fay Houghton

Foster, Bill

Fung, Jenny Missouri Coalition

G, Jeff

Genz, Greg

Glenn, S

Goodwin, Bill

Gordon, David MVS

Greer, Courtney

Grider, Nathan

Gross, Andrea

Hammond, Cheryl

Hanke Terminals

Hanneman, M

Hansens Harbor

Harding, Scott

Held, Eric

Henleben, Ed

Hilburn, Craig

HMT Bell South

Hogan-Smith, Shelly

Hoppies Marine

Howard, Chuck

Hughes, Shannon

Hunter, Andrea

Hussell, B

IL SHPO

Jaci.winship@mail.house.gov

Jamison, Larry

JBS Chief

Jefferson Port Authority

Jeffries, June M MVS

Jeremy Pivor

Joeana Middleton,

Sen. McCaskill:

Johnson, Erick

Johnson, Frank

Joseph Standing Bear Schranz

Kenneth Miller

Knowles, Kim

Lamm, Dawn MVS

Lange, James

Lauer, Steve

Leary, Alan

Lee, Richard J

Leipus, Ed

Leiser, Ken

Lipeles, Maxie

Louis Marine

Manders, Jon

Matthew Mangan

Mauer, Paul

Mccollum, Harold R (Raymond)

MDNR Land Rec

MDNR

Melgin, Wendy

Missouri Corn Growers Association

Muench, Lynn

Muir, T

Nelson, Lee

Novak, Ron

O'Carroll, J

Patrick Baldera, Chain of Rocks WTP

Paurus, Tim

Pehler, Kent

Peter Goode

Phillip, C

Pondrom, Gary

Popplewell, Mickey

Porter, Jason

Reitz, Paul

Rickert, Ron

Roark, Bev

Rodenberg, V

Rose Schulte

Rowe, Kelly

S, Tom

Salty, TRJ

Sauer, Randy

Schieffer, Ed

SEMO

Senator Blunt Office

Shoulberg, J

Slay, Glen

Smith, David

Southern Illinois Transfer

Spoth, Robert

Stahlman, Bill

Staten, Shane

Sternburg, Janet

Stout, Robert

Strauser, Deanne M

Teah, Philip

Todd, Brian

Tow Inc

Tyson, J

Urban, David

US Congressman Enyart:

USEPA Region 7

Vest, John C MVS

Weber, Angie

Welge, Owen L

Werner, Paul

Wilmsmeyer, Dennis

Wkn, Dave

York Bridge Co.

Zupan, T

RECEIVED HARDCOPY IN MAIL

Russell Bradley
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The Osage Nation
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Pawhuska, Ok 74056

Joseph Standing Bear Schranz
Midwest Soaring
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Chicago, IL 60638

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

Fay Houghton
Land Management Director
Winnebago Tribe of Nebraska
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Winnebago, NE 68071

Leon Campbell, Chairman
Iowa Tribe of Kansas and Nebraska
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White Cloud, Kansas 66094