FINAL AMENDED ENVIRONMENTAL ASSESSMENT

WITH

FINDING OF NO SIGNIFICANT IMPACT

REGULATING WORKS PROJECT
GRAND TOWER PHASE 5
CRAWFORD TOWHEAD AND VANCILL TOWHEAD
MIDDLE MISSISSIPPI RIVER MILES 74-67
UNION COUNTY, IL
CAPE GIRARDEAU COUNTY, MO

June 2016

US Army Corps
of Engineers
St. Louis District

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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

[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.

of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable.

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, Grand Tower Phase 5 construction work area (Grand Tower 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 Grand Tower 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 and revetment would provide a sustainable alternative to repetitive maintenance dredging. Construction is expected to begin in 2016 or 2017.

The planning of specific construction areas, including the Grand Tower Phase 5 work area, requires extensive coordination with resource agency partners and the navigation industry. The U.S. Fish and Wildlife Service (USFWS), Missouri Department of Conservation (MDC), Illinois Department of Natural Resources (IDNR), and multiple navigation industry groups were included in the planning of the Grand Tower Phase 5 work area and provided comments related to navigation industry concerns and environmental resources issues, as documented in Technical Report M62, Vancill Towhead HSR MODEL, River Miles 72.00 – 65.00, Hydraulic Sediment Response Model Investigation.

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 Grand Tower 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

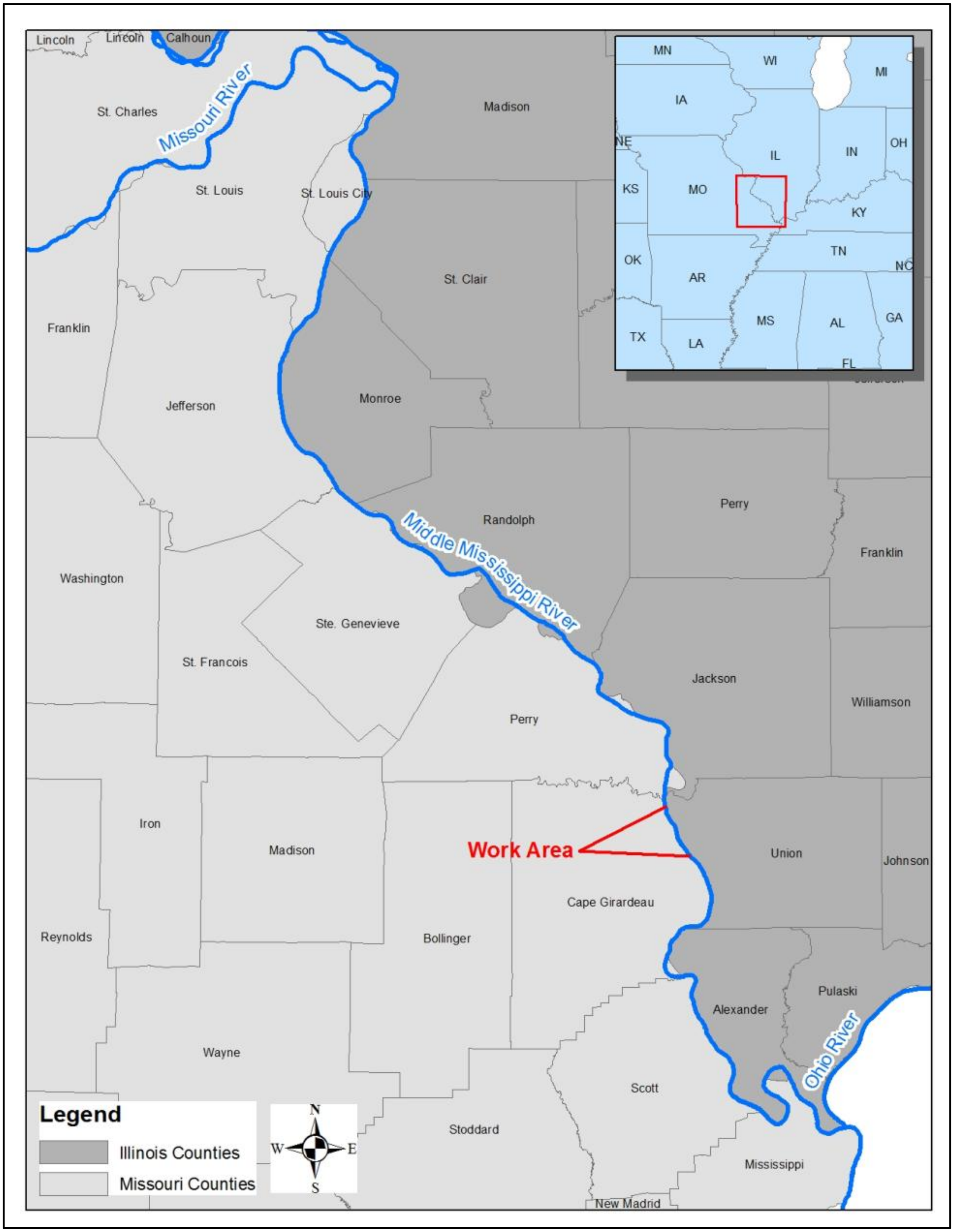

Figure 1. Work area location within the Middle Mississippi River, Miles 74 to 67.

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, width, and alignment of the navigation channel at the Grand Tower Phase 5 work area shown in Figures 2, 3, and 4. 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 (shallowing of the navigation channel) issue in the work area to fulfill the Project's navigation purpose.

Alternative 2: Proposed Action. The Proposed Action is located in the Crawford and Vancill Towhead reaches of the Mississippi River, RM 74 to 67 as shown in Figures 3 and 4. The Crawford Towhead portion includes the construction of two chevrons and the extension of one dike along the left descending bank (L) between RM 74 and 72. The Vancill Towhead portion is located between RM 70.0 and 67.0 and includes construction of 3 weirs along the right descending bank (R), and 3 diverter dikes (S-dikes) along the left descending bank, repair of dike 67.8L, revetment at dike 67.30(L) and the shortening of dikes 67.30(L) and 67.10(L) along the left descending bank. Table 1 includes a description of the Proposed Action.

Table 1. Features associated with the Proposed Action. Elevations are approximate and are subject to revision during structure design.

Crawford Towhead		
Location by River Mile	**Proposed Feature**	**Purpose**
73.6(L)	Construct 300ft x 300ft chevron. Top elevation of the chevron will be 339 ft. (+18 LWRP14[2]).	Needed to constrict the navigation channel and promote habitat diversity.
72.9(L)	Extend existing dike 300 feet. Top elevation of the chevron will be 339 ft. (+18 LWRP14)	Needed to maintain contraction width in the navigation channel.
72.5(L)	Construct 300ft x 300ft chevron. Top elevation of the chevron will be 339 ft. (+18 LWRP14)	Needed to constrict the navigation channel and promote habitat diversity.

[2] The datum to which the navigation channel is maintained for the open river portion of the MMR is the Low Water Reference Plane, commonly abbreviated as LWRP. LWRP is a 3D hypothetical model of the water surface developed to approximate a common "low water" river level at all points on the Mississippi River between river mile 200 and 0. In 1975 to provide uniformity and continuity throughout the Division, the Lower Mississippi Valley Division established a methodology for computing LWRP for the open portion of the Mississippi River. This standardized the datum to which the navigation channel was maintained for each District. To calculate LWRP, the 97 percent discharge was calculated for the period 1954 through 1973. Flows prior to 1954 were not used due to changes in the effects of the reservoirs up to that point. LWRP was calculated for each gaging station and the latest low water profiles were used to shape the LWRP profile between gaging stations. In 2014 LWRP was recalculated on the MMR utilizing the additional gage data collected since the previous LWRP was established and recent low water profiles. The time period 1967 through 2014 was selected to reflect the time that the entire Missouri River reservoir system was complete and in full operation. The new LWRP14 was also calculated in reference to the North American Vertical Datum 88 (NAVD 88).

Vancill Towhead		
Location by River Mile	**Proposed Feature**	**Purpose**
69.15(R)	Construct Weir 800 feet long. Top elevation of the weir will be 304 ft. (-15 feet LWRP14).	Needed to increase the energy at Vancill Towhead (between RM 68.0 and RM 67.0).
68.95(R)	Construct Weir 800 feet long. Top elevation of the weir will be 304 ft. (-15 feet LWRP14).	Needed to increase the energy at Vancill Towhead (between RM 68.0 and RM 67.0).
68.75(R)	Construct Weir 800 feet long. Top elevation of the weir will be 304 ft. (-15 feet LWRP14).	Needed to increase the energy at Vancill Towhead (between RM 68.0 and RM 67.0).
68.10(L)	Construct Diverter Dike (S-dike) 750 feet long. Top elevation of the dike will be 336 ft. (+18 feet LWRP14).	Needed to constrict main channel and improve aquatic habitat.
67.80(L)	Construct Diverter Dike (S-dike) 750 feet long. Top elevation of the dike will be 336 ft. (+18 feet LWRP14)	Needed to constrict main channel and improve aquatic habitat.
67.50(L)	Construct Diverter Dike (S-dike) 750 feet long. Top elevation of the dike will be 336 ft. (+18 feet LWRP14)	Needed to constrict main channel and improve aquatic habitat.
67.80(L)	Repair Dike (350 feet). Top elevation of the dike will be 336 ft. (+18 feet LWRP14).	Needed to maintain contraction width in the main channel.
67.30(L)	Shorten Dike 660 feet. Top elevation of the dike will be 336 ft. (+18 feet LWRP14).	Needed to allow formation of a secondary side channel in concert with S-dikes.
67.10(L)	Shorten Dike 300 feet. Top elevation of the dike will be 336 ft. (+18 feet LWRP14).	Needed to allow formation of a secondary side channel in concert with S-dikes.
67.30(L)	Place 300 ft. of revetment where dike attaches to riverbank. (+27 feet LWRP14)	To prevent erosion of the riverbank downstream of the dike.

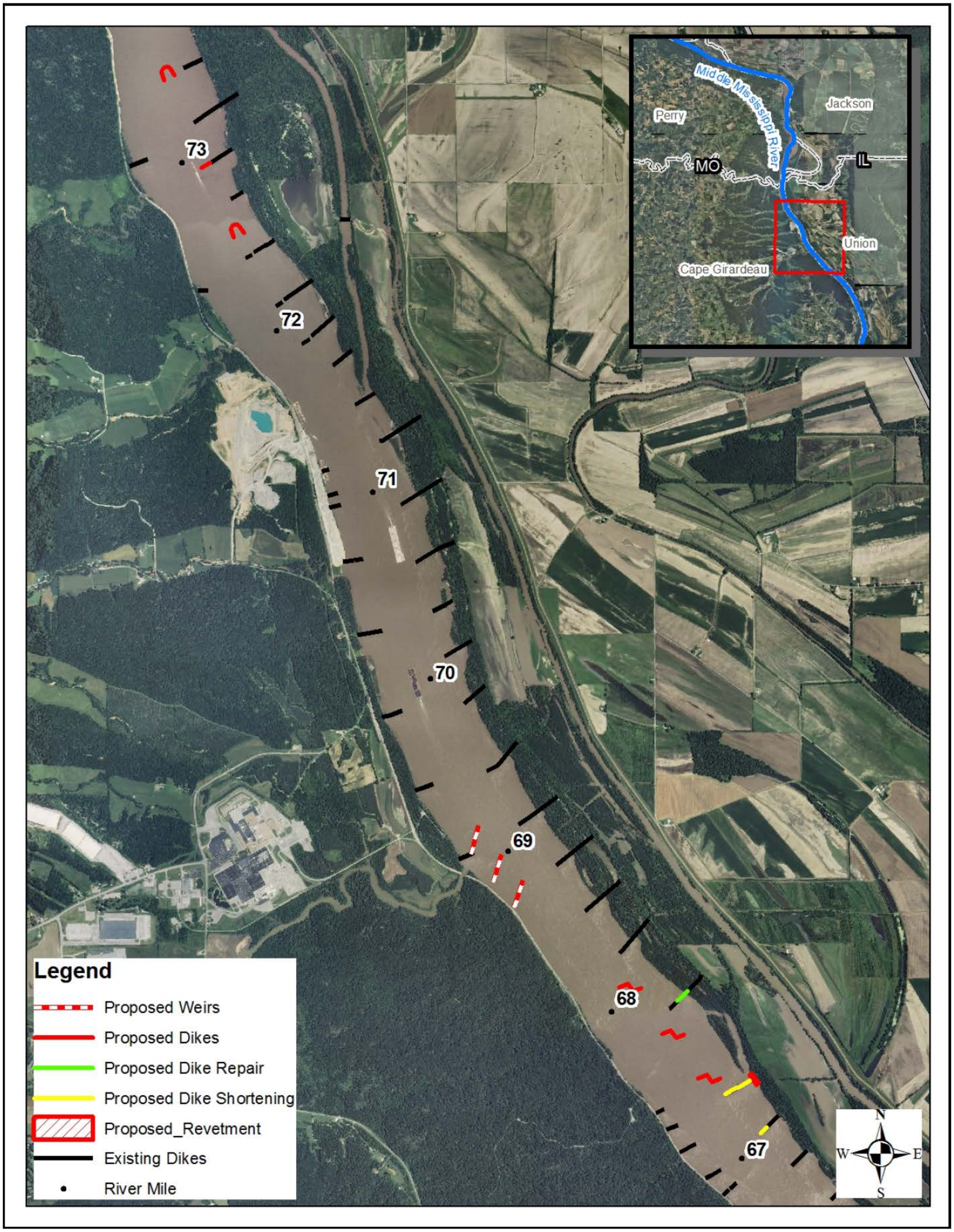

Figure 2. Features associated with the Proposed Action at Grand Tower Phase 5 work area.

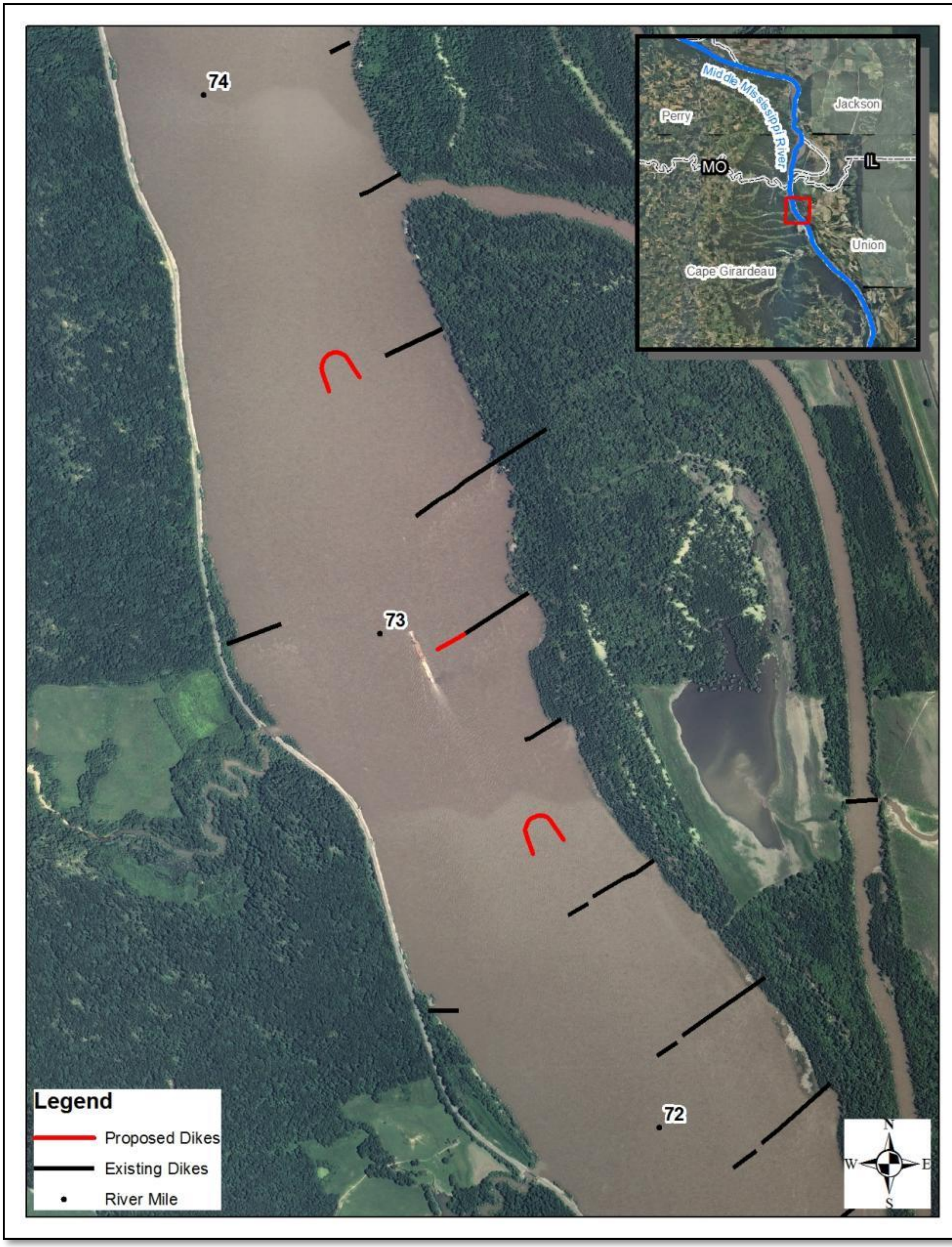

Figure 3. Features associated with the Proposed Action, Crawford Towhead.

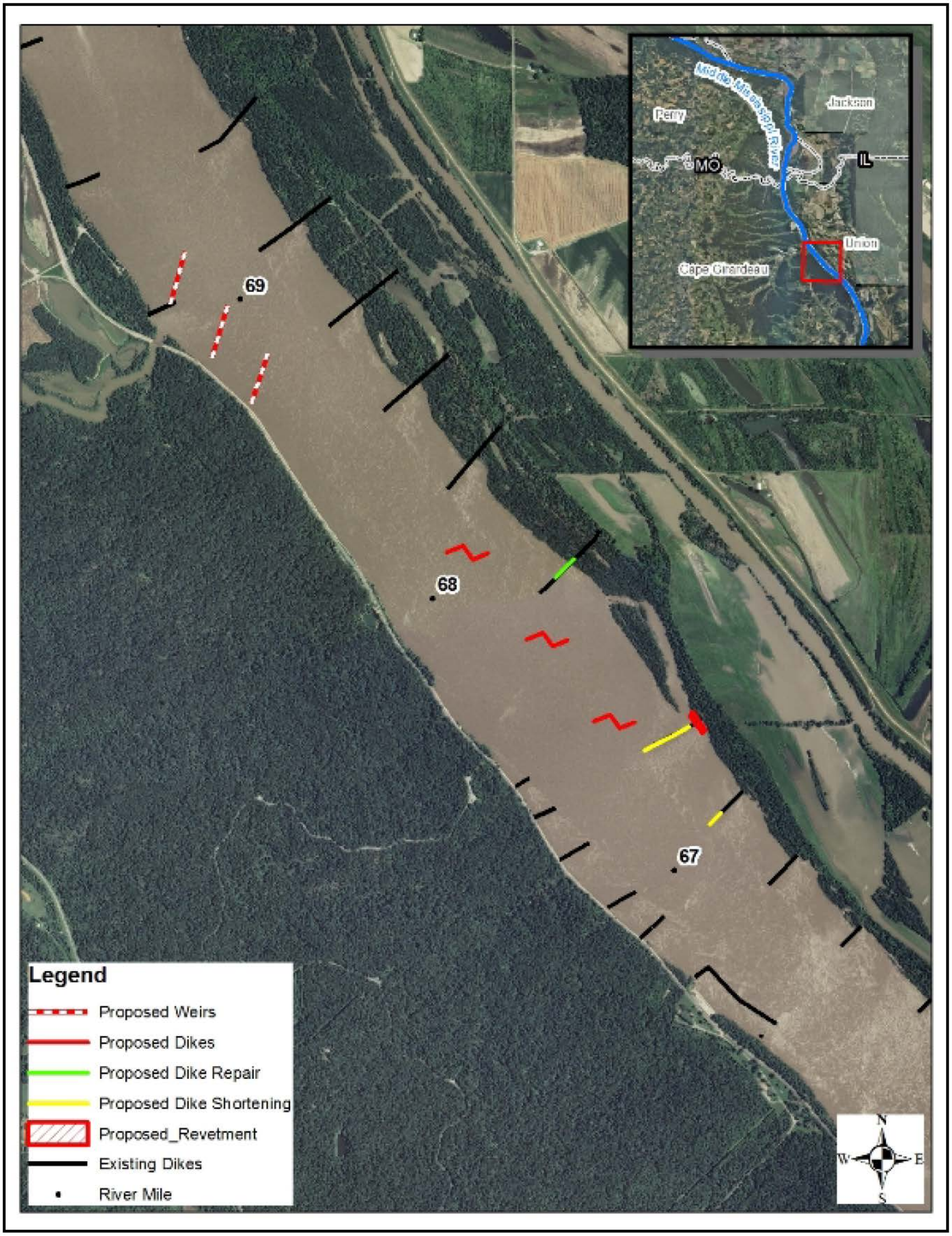

Figure 4. Features associated with the Proposed Action, Vancill Towhead.

Development of Alternatives.
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 Grand Tower Phase 5 work area, the District developed alternatives using widely recognized and accepted river engineering guidance and practice, and then screened and analyzed 37 different configurations of regulating works with the assistance of a Hydraulic Sediment Response model (HSR model) for the Vancill Towhead area. 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 an HSR model starts with the District calibrating the model to replicate work area conditions. Various configurations of river training structures are then applied to the model to determine their efficacy in addressing the needs of the work area. For the Vancill Towhead area, 37 different configurations of river training structures and revetment were modeled to determine the best combinations to reduce the need for dredging, improve the navigation channel alignment, and minimize environmental impacts. 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 37 configurations analyzed in the HSR model. Ultimately all partner concerns were satisfactorily resolved and a consensus was reached on an acceptable Alternative. This process resulted in the Proposed Action, which reasonably met the Project purpose while also avoiding/minimizing environmental impacts. 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 for Vancill Towhead:

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

Pursuant to 40 CFR § 1502.21 and CEQ Guidelines, the Vancill Towhead HSR model study report is fully incorporated by reference into this EA for the purpose of reducing the size of this EA and not duplicating applicable analyses.

In accordance with the Reasonable and Prudent Measures and Terms and Conditions of the Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System, including the MMR (USFWS 2000), there was a need at Vancill Towhead to improve aquatic habitat by increasing the flow and sediment transport through the Vancill Towhead side channel and along the left descending bank. However, the distance between the thalweg (main flow) and the side channel entrance and left bank made the task challenging. Therefore, the approach taken in the recommended alternative was to create a secondary side channel with river training structures known as diverter dikes or “S-dikes”. River engineers at the Applied River Engineering Center have found that S-dike structures not only redistribute flow and sediment, but have the ability to control the energy coming off of the right side or the left side of the structure. S-dike structures are useful for creating secondary side channels because they angle upstream to capture water from the main channel and direct it towards the area of interest, while providing enough roughness and constriction to maintain a navigable channel. There is minimal erosion along the riverbank because an eddy forms at the S-dike’s downstream tip. Figure 5 below shows a drawing of how the structure works. As flow and sediment hit the structure, depending on the orientation of the dike, a portion of the flow and sediment will be taken from the main source of flow towards a lower energy area on the opposite side of the dike (USACE 2012). Overall, Alternative 33 would maintain the navigation channel, reduce the frequency of dredging, and improve the quality and quantity of aquatic habitat at Vancill Towhead.

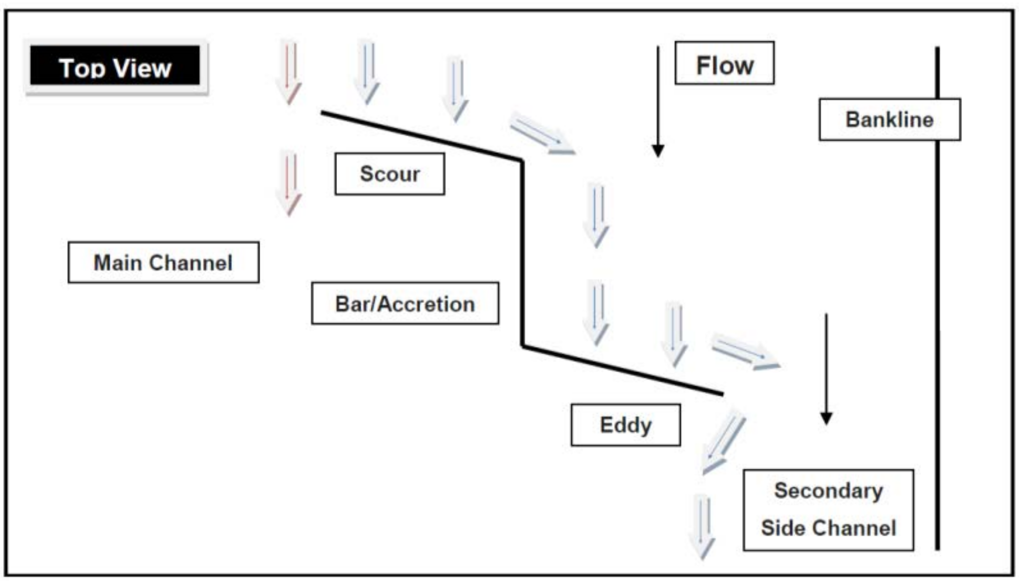

Figure 5 – S-Dike Flow Pattern

No HSR investigation was completed for Crawford Towhead. Hydraulic engineers developed alternatives using widely recognized and accepted river engineering guidance and practice, and then discussed the alternatives with the River Resources Action Team (RRAT) members during the 2009 RRAT work sites coordination visit and the May 2013 RRAT Executive meeting. The final design included two chevrons and a dike extension that met the work area objectives while incorporating the environmental concerns of the RRAT. USACE has constructed numerous chevrons and weirs in the MMR, and a model would have been an unnecessary expense because engineering judgment was all that was necessary to predict the effects of the structures in this location. The proposed Crawford Towhead structures would result in a reduction in shoreline erosion, improved navigation conditions for commercial river traffic, and the improvement of aquatic habitat.

Summary of Environmental Consequences

The impacts of each Alternative on the resources, ecosystem and 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.

Criteria	**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 and stabilize the bankline in the area, thereby reducing federal expenditures and meeting Project objectives.
Impacts on River Stages	No impacts anticipated.	No impacts anticipated at average and higher flows. Trend to slightly lower stages at low flows expected to continue.
Impacts on Water Quality	Localized, temporary increase in suspended sediment concentrations at dredge 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.	Temporary, minor, local impacts due to one-time use of construction equipment.

Criteria	No Action Alternative	Proposed Action
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. Uncertain impacts on fish and macroinvertebrates at inside bend opposite of proposed bendway weir locations. Minor loss of fish and macroinvertebrate habitat due to reduced woody debris inputs.
Impacts on Threatened and Endangered Species	May affect but not likely to adversely affect threatened and endangered species.	No significant impacts to threatened and endangered species anticipated.
Impacts on Navigation	Continued requirement for periodic maintenance dredging at rates similar to recent history.	Reduction in the amount and frequency of periodic maintenance dredging in the area. Increased channel reliability in work area.
Impacts on Historic and Cultural Resources	No known historic resources would be affected. Impacts to unknown 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

General – There are two side channels in the vicinity of the work area: Crawford Chute and Vancill Towhead Side Channel. Crawford Chute is on the left descending bank between river miles 73.8 and 71.4. Based on bathymetric data and median monthly river stage data, Crawford Chute is connected to the main channel (i.e. water is flowing through the side channel) for 5 months of the year, on average. Vancill Towhead Side Channel is on the left descending bank between river miles 67.7 and 67.3. No bathymetric data is available for Vancill Towhead Side Channel due to lack of adequate depth for sampling. It is likely disconnected from the main channel year-round except during high water events. Connectivity of side channels is important in determining the habitat provided to fish and influences species diversity, population densities, fish dispersal, as well as predator-prey interactions. Figures 6 and 7 below provide time series imagery showing the formation of both side channels.

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 and U.S. Geological Survey (USGS). The USGS has been the primary agency responsible for stream gaging since 1933. Due to discrepancies in methodology and instrumentation used by the Corps and USGS it is impossible to analyze the entire period of record with confidence; therefore only data collected by the USGS will be used here to describe the changes in stage for fixed discharges over time (Watson et al. 2013a; Watson et al. 2013b; Huizinga 2009; Munger et al. 1976).

Stages have been decreasing over time for flows below 200,000 cfs at the St. Louis gage (Figure 8). 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.

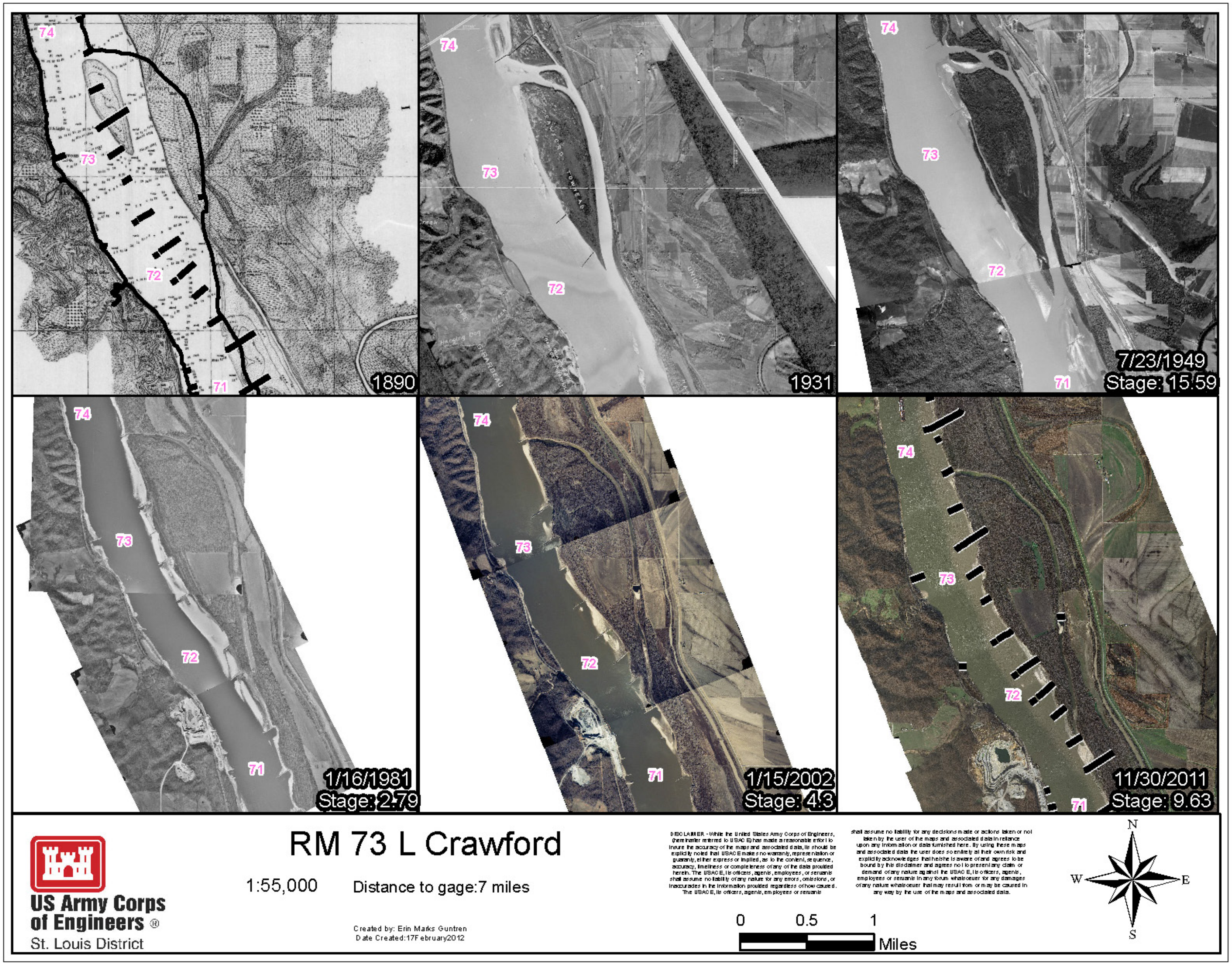

Figure 6. Time series imagery showing formation of Crawford Chute.

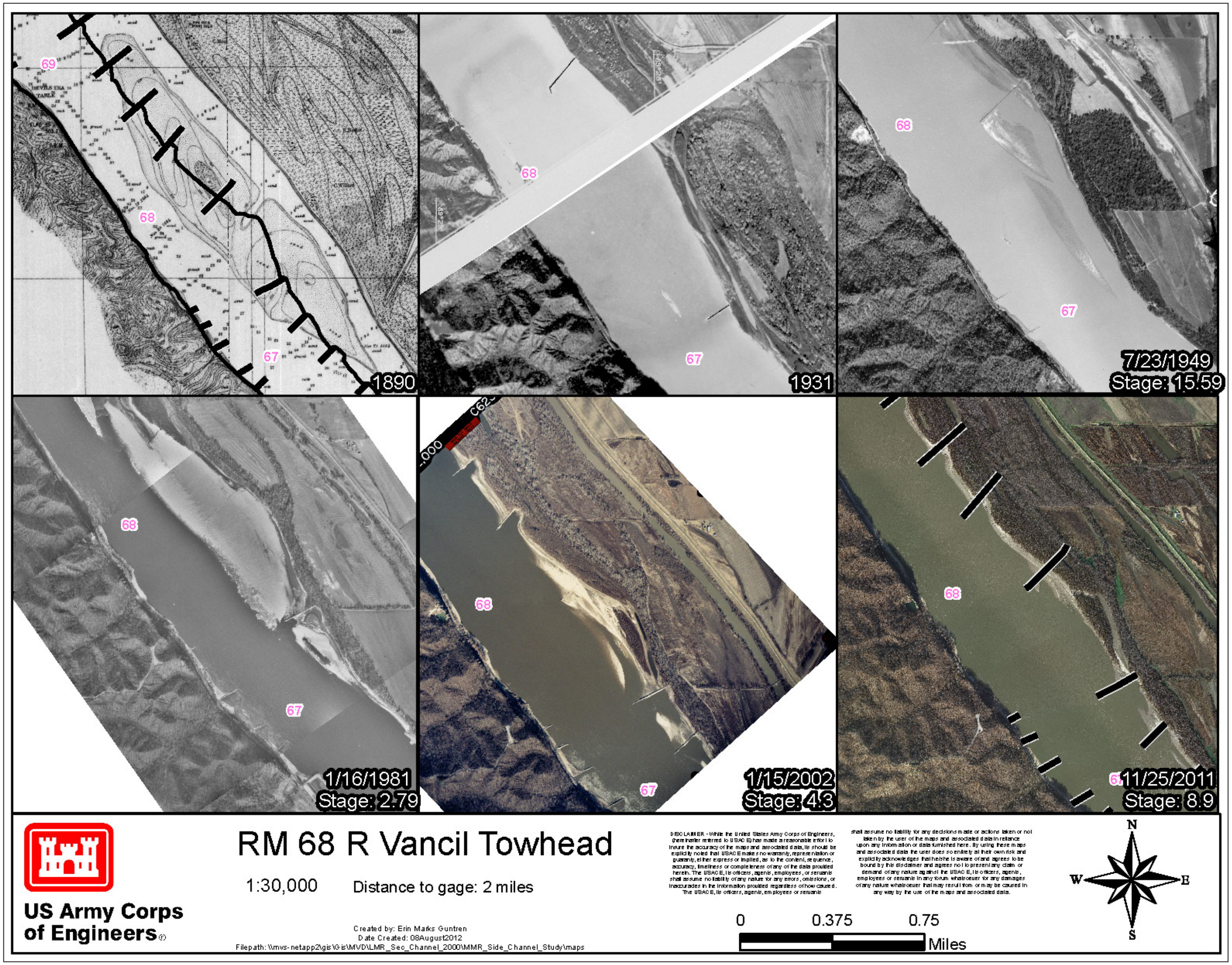

Figure 7. Time series imagery showing formation of Vancill Towhead Side Channel.

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.

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 for fish consumption due to mercury and polychlorinated biphenyls (PCB) contamination and impaired for primary contact recreation due to fecal coliform bacteria contamination (IEPA 2014). The Mississippi River in the vicinity of the work area is not on the 2014 303(d) list for Missouri (MDNR 2014).

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 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. Cape Girardeau County, Missouri and Union County, Illinois are designated as attainment areas for all six criteria air pollutants (USEPA 2013).

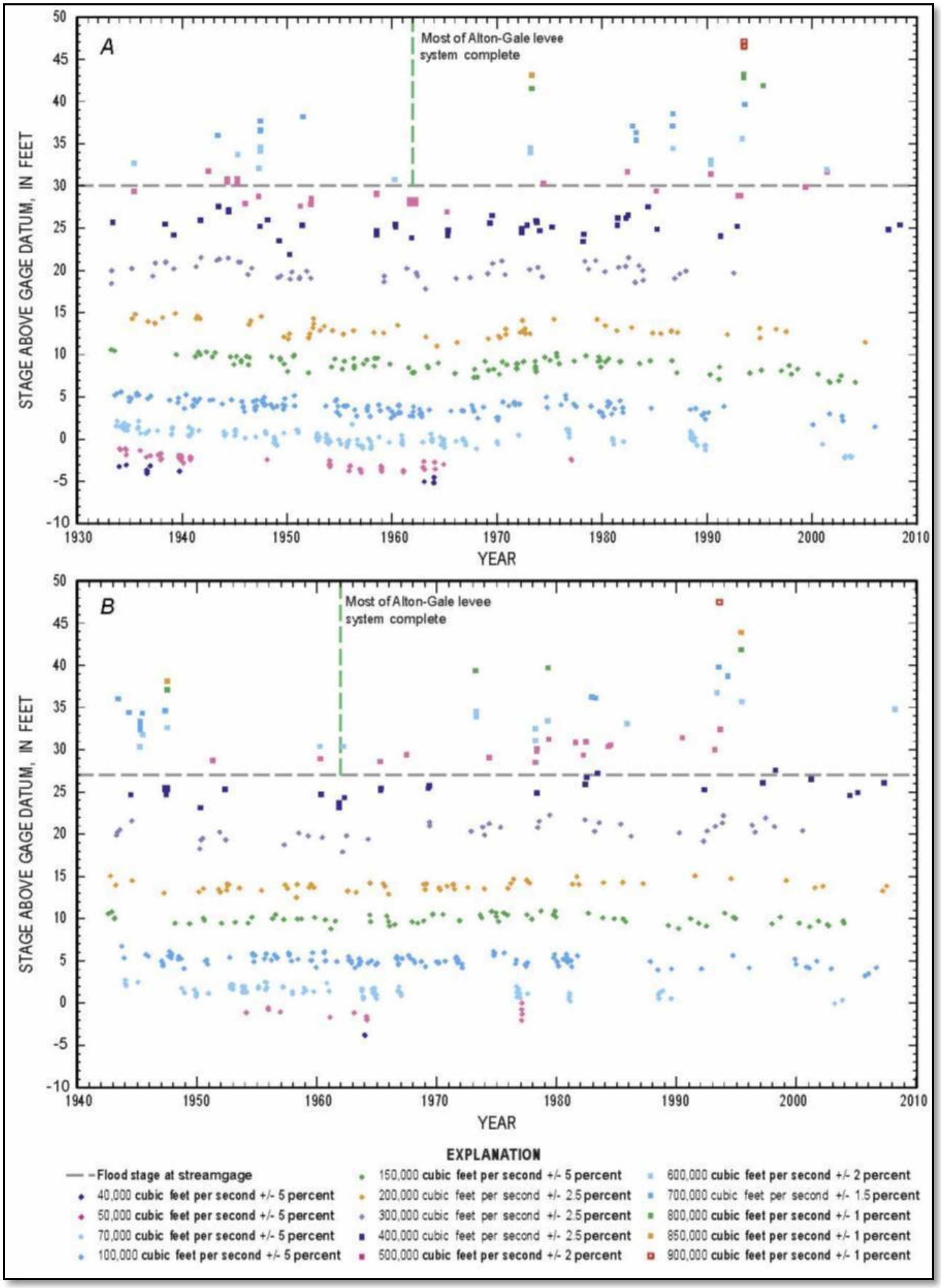

Figure 8. Stage for a given discharge range with time from measurements made at the streamgages at (A) St. Louis, Missouri, and (B) Chester, Illinois, on the MMR (from Huizinga 2009).

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 (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 MMR 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 (Figure 9). 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.

Starting in the 1990s, 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.

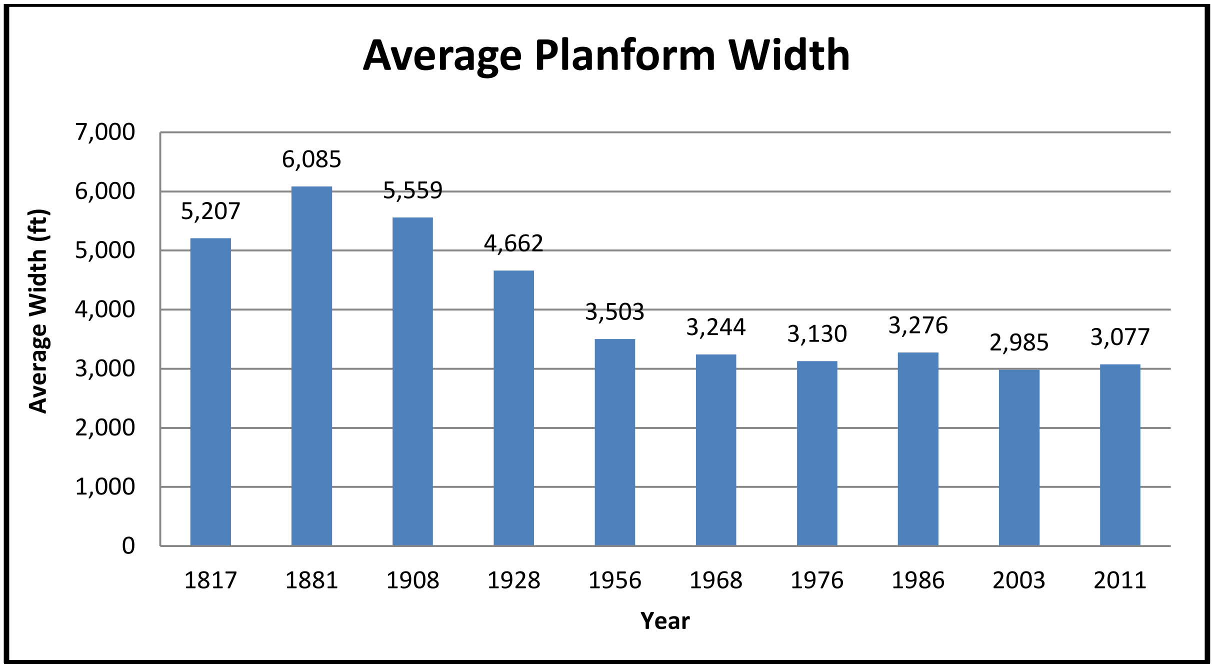

Figure 9. Average planform width of the MMR from 1817 to 2011.

The fish community in the area is expected to be typical of the MMR fish community in general. Fish community monitoring (Stone Dike Alterations Project Study) was conducted in the Trail of Tear reach vicinity, RM 68.5 – RM 64.5, from July 2005 to June 2008(Caswell 2008). Of the 59 species of fish collected in the main channel border areas and wing dikes, the most commonly encountered native species included gizzard shad (*Dorosoma cepedianum*), channel catfish (*Ictalurus punctatus*), blue catfish (*I. furcatus*), flathead catfish (*Pylodictis olivaris*), freshwater drum (*Aplodinotus grunniens*), emerald shiner (*Notropis atherinoides*), red shiner (*Cyprinella lutrensis*), river shiner (*N. blennius)*, smallmouth buffalo (*Ictiobus bubalus*), black buffalo (*I. niger*), channel shiner (*N. wickliffi*), shortnose gar (*Lepisosteus platostomus*), bluegill (*Lepomis macrochirus*), shoal chub (*Macrhybopsis hyostoma*), and river carpsucker (*Carpiodes carpio*). These species accounted for approximately 85% of the fish captured, by number. Emerald shiner accounted for 25 percent of the fish captured, by number. Also included in the collection were 4 species of non-native fish including common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), and bighead carp (*Hypophthalmichthys nobilis*). These species accounted for approximately 9% of the fish captured, by number, with the vast majority being common carp. Silver carp were likely under-represented in the collection due to the sampling methodologies employed. The area 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.

Macroinvertebrates were also collected from rock surfaces in bendway weir fields in the MMR at river mile 164 near Oakville, Missouri (Ecological Specialists 1997a) and at river mile 30 near Commerce, Missouri (Ecological Specialists 1997b). Twenty-nine taxa were collected at river mile 164 with caddisflies being the overwhelmingly dominant group; midges were also abundant. Density averaged 14,662 individuals per square meter. Thirty-four taxa were collected at river mile 30 with caddisflies again the overwhelmingly dominant group; midges were present but not as abundant as at river mile 164. Density averaged 16,240 individuals per square meter. Sampling conducted in sand substrate at a nearby bendway without weirs (river mile 20) yielded 7 taxa and 965 individuals per square meter with oligochaete worms being the overwhelmingly dominant group.

Threatened and Endangered Species - According to the USFWS database queries, seven federally threatened or endangered species could potentially be found in the area (Cape Girardeau County, Missouri and Union County, IL). The seven species, federal protection status, and habitat can be found in Table 3. No critical habitat is located in the work area.

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

Species	Federal Status	Habitat
Indiana bat (*Myotis sodalis)*	Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: small stream corridors with well-developed riparian woods; upland and bottomland forests
Least tern (interior population) (*Sterna antillarum*)	Endangered	Large rivers - nest on bare alluvial and dredge spoil islands
Pallid sturgeon (*Scaphirhynchus albus*)	Endangered	Mississippi and Missouri Rivers
Decurrent false aster (*Boltonia decurrens*)	Threatened	Disturbed alluvial soils. (Cape Girardeau Co. only)
Piping plover *(Charadrius melodus)* Northern Great Plains Breeding Population	Threatened	Riverine sandbars

Rufa Red knot *(Calidris canutus rufa)*	Threatened	Shorebird that migrates through Missouri - irregularly observed feeding on mudflats, sandbars, shallowly flooded areas and pond margins along the Missouri and Mississippi Rivers from May 1 through September 30.
Northern long-eared bat (*Myotis septentrionalis*)	Threatened	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.

Socioeconomic Resources

Navigation

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

Repetitive channel maintenance dredging occurs regularly in the area between RM 74 and 67 (see Figures 10, 11, 12 and 13). This area has required dredging 21 times since 2000 at an average cost of approximately $730,000 per year.

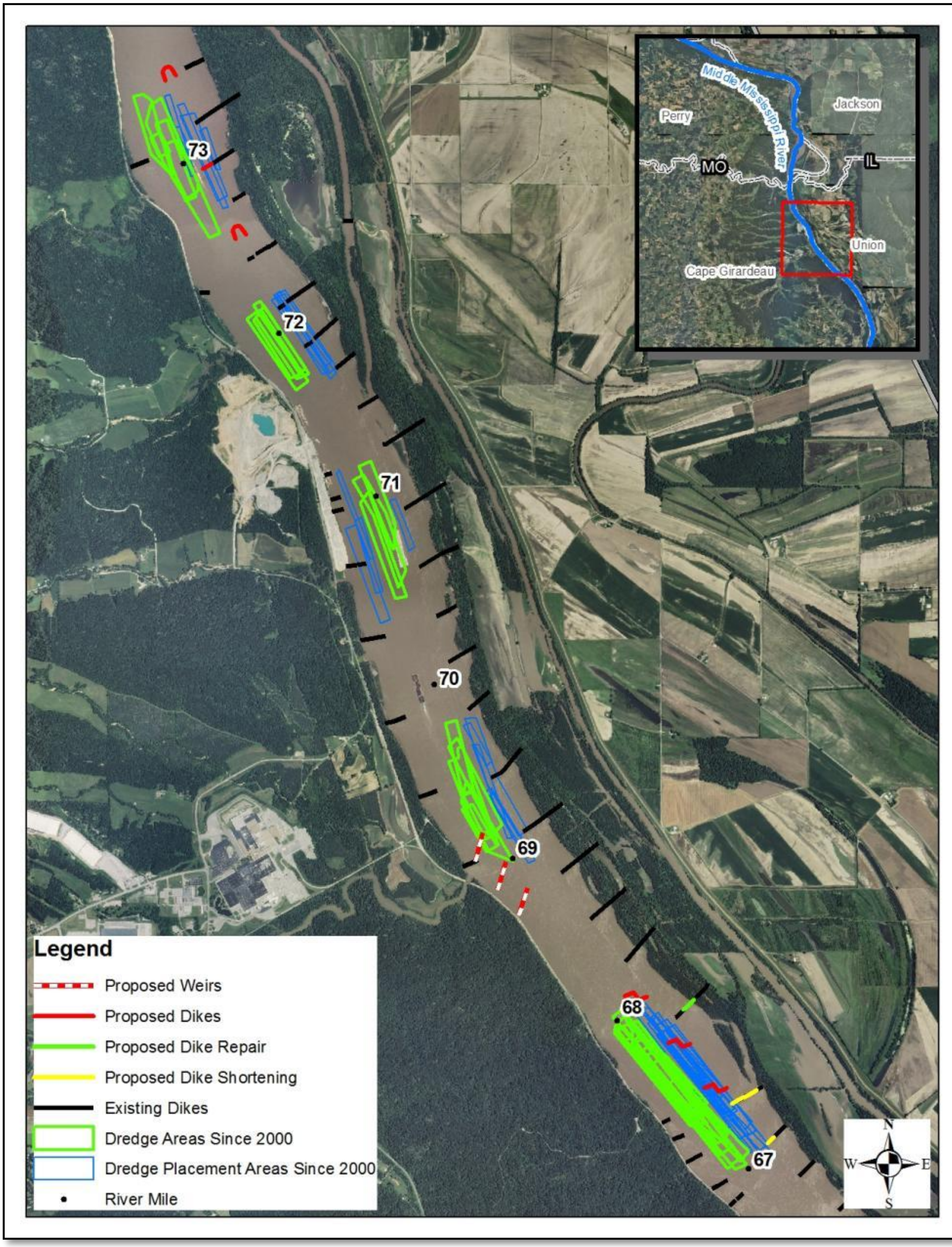

Figure 10. Repetitive dredging areas in the vicinity of the Grand Tower work area since 2000.

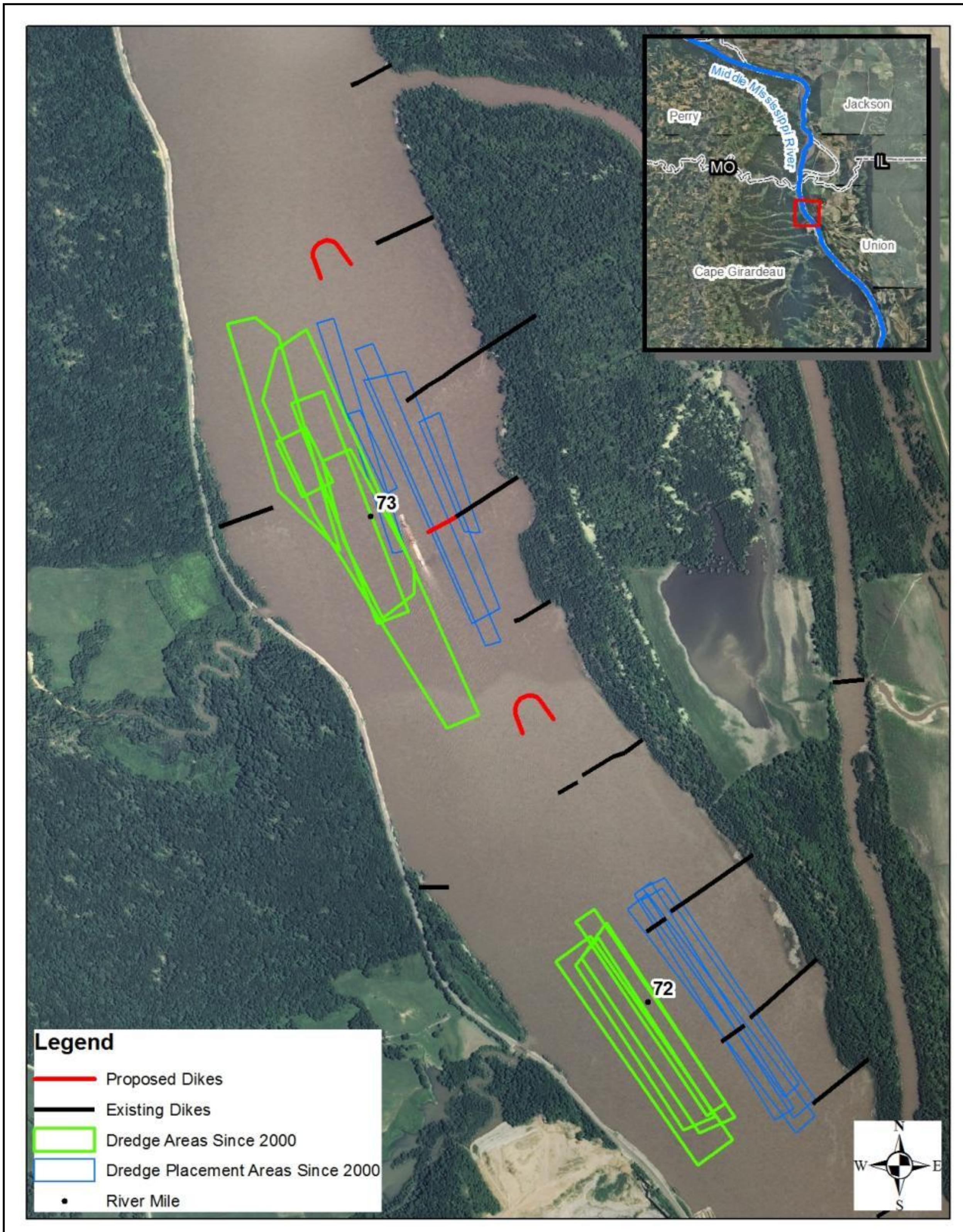

Figure 11. Repetitive dredging areas in the vicinity of Crawford Towhead since 2000.

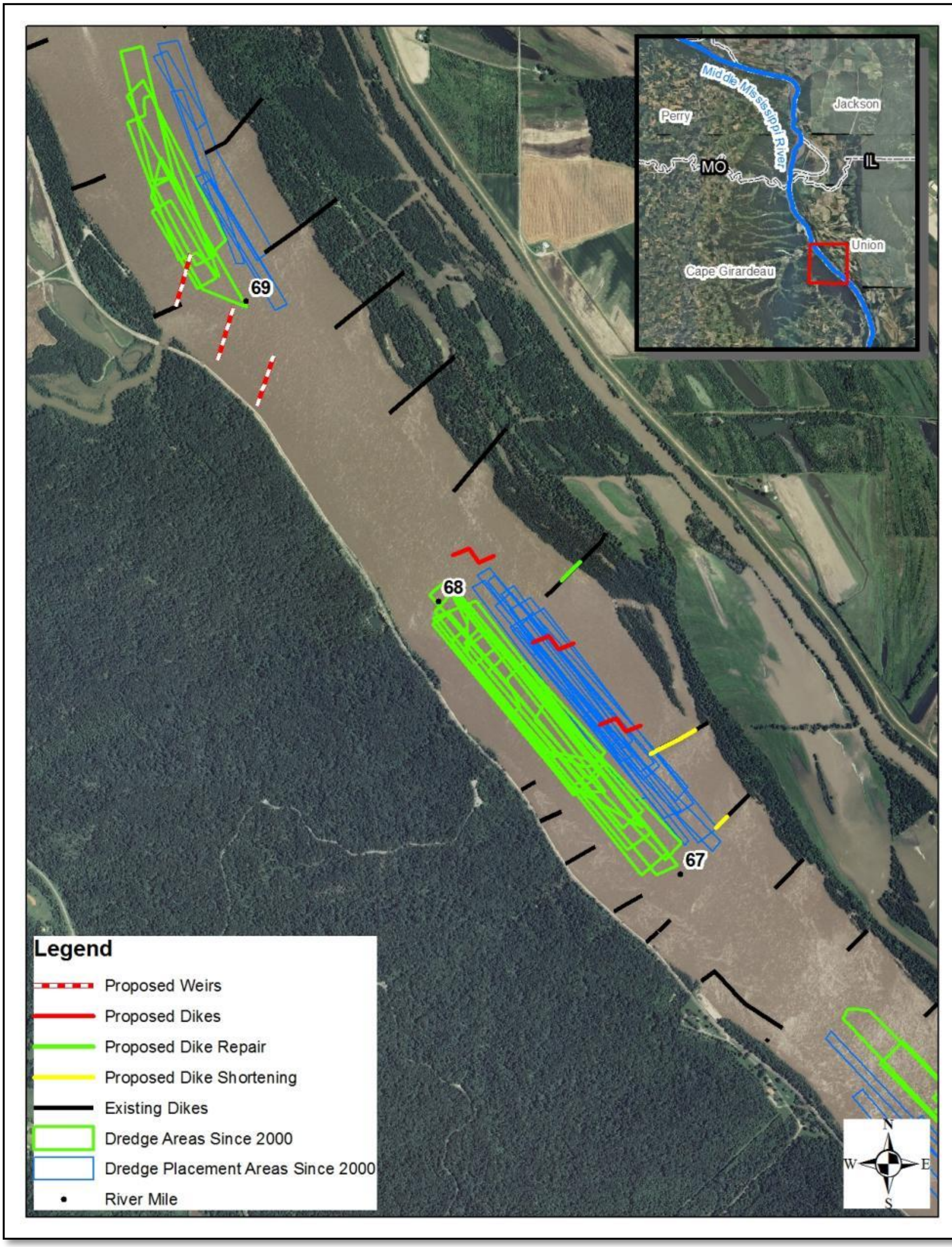

Figure 12. Repetitive dredging areas in the vicinity of Vancill Towhead since 2000.

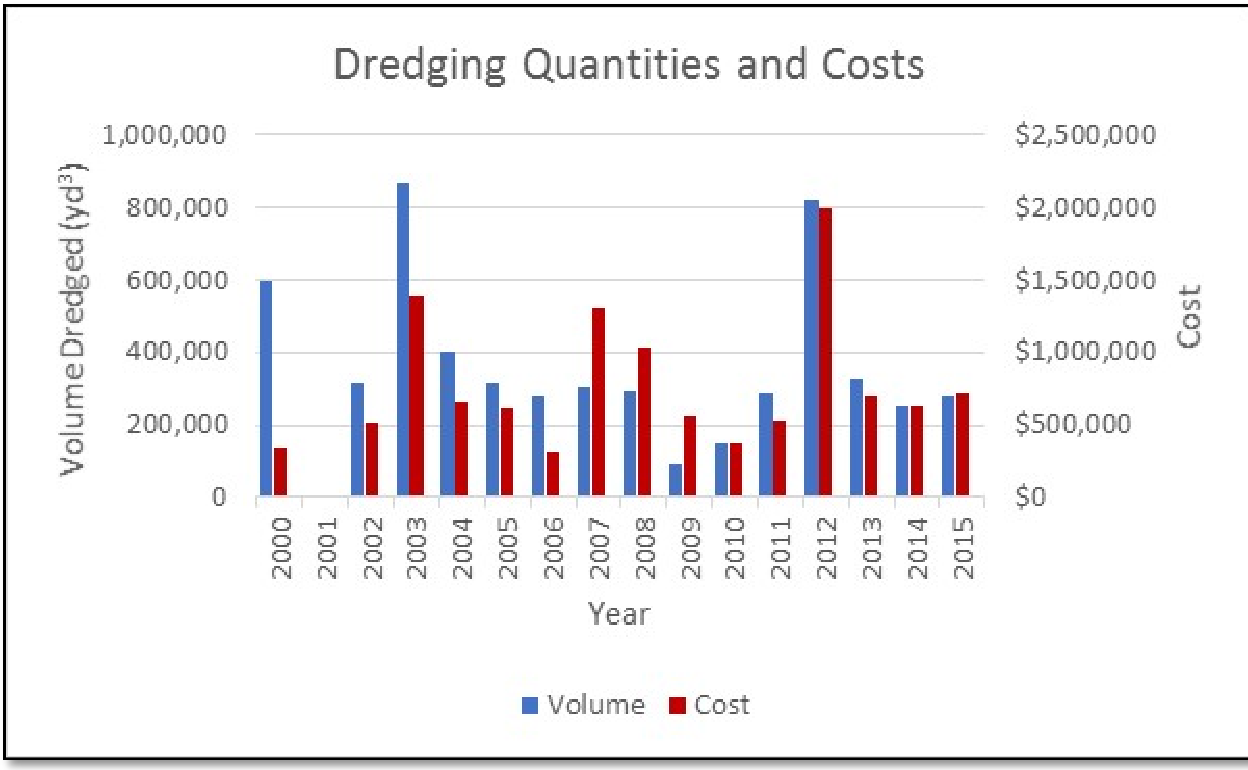

Figure 13. Dredging quantities and costs in the work area from 2000 to 2015.

Historic and Cultural Resources

The Grand Tower Reach of the Mississippi River has narrowed considerably in the past one hundred and fifty years. The location of the Missouri bank, being a bluff line, has remained largely unchanged. The Illinois floodplain, however, has accreted westward largely due to the growth and incorporation of various towheads. The locations of all the proposed structures were in the Mississippi River in 1881. In the late nineteenth century, however, Vancill towhead formed, and in 1904 USACE constructed a hurdle (closure structure) across its eastern chute to connect it to the Illinois floodplain. Consequently, by 1909 the effective river bankline had shifted to approximately today's location. Any cultural resources that might be adversely affected by the placement of revetment must post-date the development of Vancill towhead.

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 on 300 miles of the Mississippi River, within the St. Louis District, between Saverton, Missouri, and the mouth of the Ohio River. The nearest wrecks to the work area were sighted about five and a half miles away, both upstream and downstream. During the 2012 low water event, a wreck was reported within the work area, but on the right bank, opposite the proposed structures and behind an existing dike (67.2R).

As part of a 2003 USACE study, archival research documented over seven hundred wrecks in the Middle Mississippi and two vessels are recorded as having been wrecked at Vancill landing. The first is the Sultana recorded as either abandoned between 1844 and 1852 according to one source, or wrecked on June 12, 1851 according to another. The second wreck is the Walk in the Water recorded as abandoned between 1846 and 1855. A local resident, however, reported that his father told him it was the Paw-Paw, which broke up in the winter ice of 1865 (Southeast Missourian, 7 January 2011).

The story of the Paw-Paw is not entirely clear. County Court records indicate that the boat bought by Willis Vancil (sic) et al. for use as a transport was the "Steam ferry boat Jennie 'D' lying at Cape Girardeau, Mo., and was used for ferrying from Cape Girardeau to points opposite at the Illinois Shore…" (Southeast Missourian, 7 September 1999). In 1868, however, Vancils (sic) did pay $1,200 for, "the wreck and Machinery of the Steamer Paw Paw, now lying at Cape Girardeau Mo." It is possible that they bought the equipment to renovate and repair the Jennie 'D.' According to "Way's Packet Directory" the Paw Paw was a center-wheel steamboat built in St. Louis in 1862 and sold to Samuel Vencil (sic) at Mound City, Illinois, on August 17th, 1865 and dismantled soon thereafter. Regardless of its identity, the wreck will not be affected by the Grand Tower Phase 5 work.

High-resolution multi-beam surveys were conducted of the work area river bed on June 4, 2012, June 21, 2012 or October 23, 2013 (depending on the river section). No topographic anomalies suggesting wrecks are visible on the resulting bathymetric map.

4. Environmental Consequences

The Environmental Consequences Section of this report details the impacts of the Alternatives on the resources, ecosystem and 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 or revetment in the area but continuing to maintain the existing river training structures. Dredging under the No Action Alternative would continue at levels similar to recent history as needed to address the shoaling issue in the area. The Proposed Action consists of the Grand Tower Phase 5 work area which includes the Crawford and Vancill Towhead areas. The Crawford Towhead work area includes the construction of two chevrons and the extension of one dike between RM 74 and 72. The Vancill Towhead work area is located between river miles 70.0 and 67.0 and includes construction of 3 weirs, 3 diverter dikes (S-dikes), repair of dike 67.8L, revetment at dike 67.30(L) and shortening of dikes 67.30(L) and 67.10(L) (USACE 2012).

Physical Resources

Stages

Impacts of the No Action Alternative on Stages – Stages in the work area vicinity and the MMR 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 MMR are expected to be similar to current conditions. An abundance of research has been conducted analyzing the impacts of river training structures on water surfaces dating to the 1930s. This research has analyzed historic gage data, velocity data, and cross sectional data. Physical and numerical models have also been used to determine the effects of dikes on water surfaces. It should be noted that some published research supports the contention that river training structures raise flood heights. A summary of research on the effects of river training structures on flood heights can be found in Appendix 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. Further, at the public hearing for the original draft EA for the Grand Tower Phase 5 work area, multiple individuals questioned the impact on stage at high flows for the project due to the use of the diverter dikes (S-dikes) (see Appendix E). Therefore, the District performed additional two dimensional hydrodynamic numerical modeling on the Vancill Towhead portion of the Grand Tower Phase 5 work area to evaluate the impact of the proposed construction on flood levels (see Attachment 1 to Appendix A). The model study verified that the proposed structures in the Vancill Towhead reach have no impact on water surfaces for a 1% of annual chance of exceedance (ACE) discharge (949,011 cfs). This result is consistent with the body of literature on the topic of the impact of river training structure construction on flood levels (Appendix A). Based on all of the analyses and modeling of the impacts on stages of the Regulating Works Project and, specifically, the Vancill Towhead portion of the Grand Tower Phase 5 work area, the Corps 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 (see Appendix C, Cumulative Impacts Analysis).

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 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 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 has obtained the required Water Quality Certification from both Missouri and Illinois for the Grand Tower Phase 5 work area. Attached as Appendix D is a 404(b)(1) evaluation, and the District will further review and provide proper approval of the Grand Tower Phase 5 work area following public review and finalizing NEPA documentation.

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. Impacts would be minor and local in nature.

Impacts of the Proposed Action on Air Quality – Air quality in the vicinity of the work area would be expected to be similar to current conditions. Equipment used for construction activities would generate emissions from the use of petroleum products, but impacts would be temporary, minor, and local in nature.

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. Approximately 1,000,000 cubic yards of material was dredged during the project, and fish entrainment monitoring was conducted during roughly 15% of the operation. No pallid sturgeon were captured during the study. However, 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 courser sediments with fewer benthic organisms are found, limiting benthic organism impacts.

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 river 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 diverter dikes are intended to provide bathymetric diversity, flow refuge, and split flow conditions that differ from traditional wing dikes. Based on the Vancill Towhead HSR model study and District experience with similar river training structures, the S-dikes are expected to create a secondary channel to improve aquatic habitat. River engineers at the Applied River Engineering Center have found that S-dike structures not only redistribute flow and sediment, but have the ability to control the energy coming off of the right side or the left side of the structure. In HSR model testing, S-dike structures have demonstrated an ability to create secondary side channels because they angle upstream to capture water from the main channel and direct it towards the area of interest, while providing enough roughness and constriction to maintain a navigable channel. The S-dike is expected to cause minimal erosion along the bankline because an eddy is formed at its tip (USACE 2012).

After construction, the following changes may occur in the Vancill reach. The three bendway weirs would reduce scouring along the outside bend between RM 69.20 to RM 68.60. The thalweg would be located along the right descending bank instead of crossing over towards the left descending bank between RM 68.50 to RM 67.50. Due to the S-dike structures, the constriction of the channel would result in less deposition from RM 68.00 to RM 67.00. The navigation channel may deepen (from -7 feet to -12 feet LWRP14) and widen (from 0 feet to 1200 feet). More flow would occur along the left descending bank. Flow and sediment transport would occur behind the S-Dike structures. The secondary side channel would extend further downstream to RM 66.75 creating more shallow water habitats. The channel would also deepen (from -15 feet to -25 feet LWRP14) between RM 67.00 and RM 66.30 along the right descending bank (near the boat ramp location). Higher velocities would occur along the right descending bank where most of the flow is concentrated. Slower velocities would occur around the S-dike structures and downstream from them (USACE 2012). This scenario would indicate that while the bar at RM 67.5 would be reduced, these structures would create more aquatic habitat diversity that would be beneficial to the river’s fisheries as shown in Figure 14.

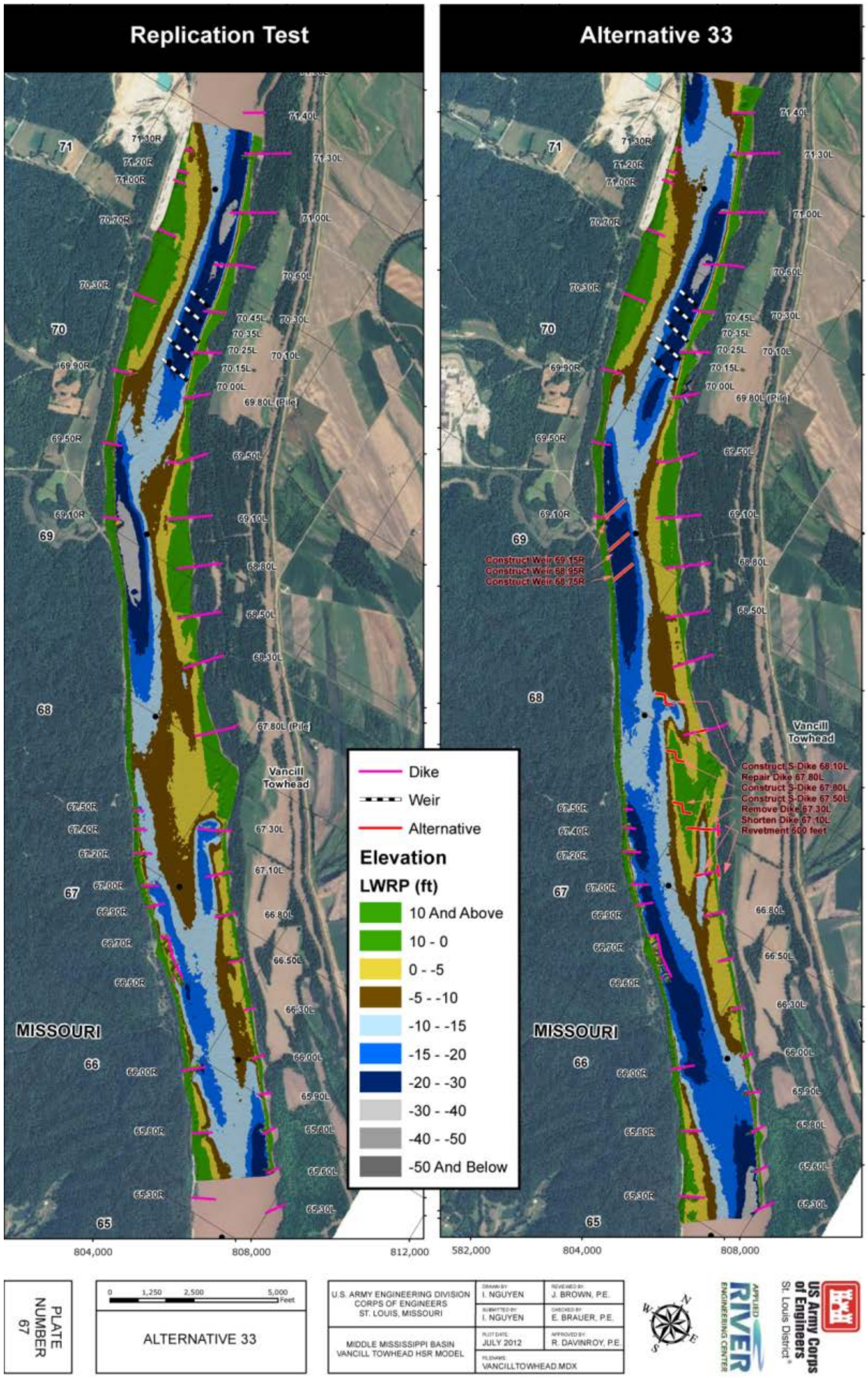

Figure 14 – A Visual Depiction of the Impacts of the Proposed Action in the work area.

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 MMR 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 (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 use and increased habitat diversity associated with chevron dikes as compared to pre-construction conditions and open water control sites.

Chevrons, dike structures designed as a blunt-nosed arch shape, have typically been used to redistribute flow and sediment to maintain the navigation channel. The chevrons will use the energy of the river to redistribute water flow, but unlike traditional dikes that create a unidirectional deflection, they create a split flow. The riverside bank of the chevron directs flow to maintain the navigation channel while the other side directs flow toward the riverbank. Not only do chevrons divert river flow toward the main channel similar to a wingdam, they also create several different types of river habitat, with variable depth and flow velocities. During high water events, river flows overtopping the structures would create a large scour hole just downstream of the structure's apex. After the flows drop below the crest of the structure, the scour hole formed at high flow becomes an area of deep slack water. This environment is conducive to the needs of overwintering fish, and provides the ideal conditions for a juvenile and larval fish nursery. The uneven rock structure would provide good escape cover and foraging habitat for young fish. These structures have been proven to be effective at promoting bathymetric diversity, including a low velocity habitat behind the chevron itself.

In summary, the proposed construction is not expected to result in a loss of aquatic habitat due to sedimentation and conversion to terrestrial habitat. The structures are expected to increase bathymetric, flow, and sediment diversity in the immediate vicinity of the work area. Fish response to these changes in habitat is difficult to predict quantitatively, but, based on prior studies, the habitat requirements of the fish community will continue to be met in the work area.

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 15 feet below the low water reference plane) 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 MMR 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 bendway 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 three bendway weirs in the work area is expected to improve fluvial specialist and fluvial dependent fish habitat and macroinvertebrate habitat in the outside bend by providing substrate diversity, flow refugia, and increased surface area for macroinvertebrate colonization. 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.

Revetment Effects – The proposed revetment is designed to prevent the continued erosion and migration of the associated bankline in the area. Preventing bankline erosion could have a minor negative impact on the fish community in the area. Bankline erosion frequently leads to woody debris inputs to the system. Woody debris is an important habitat component in the MMR, providing nutrient inputs, macroinvertebrate colonization substrate, and habitat diversity for fish and wildlife resources. Although woody debris inputs through bankline erosion would be prevented, woody debris would still enter the system from the area during overbank flow events.

Similar to rock dike structures, revetment can improve fish habitat by providing substrate diversity, additional cover, and more suitable substrate for a wide variety of benthic macroinvertebrate colonization (Beckett et al. 1983; Bingham 1982; Dardeau et al. 1995; Fischenich 2003; Nord and Schmulbach 1973; Payne et al. 1989; White et al. 2010). Farabee (1986) studied fish at two revetted and two natural main channel border sites in Pool 24 over a 3-year period. Although the number of species at each bankline type were similar, total fish collected was greater on banklines with revetments, especially where larger stone was present. On the Lower Mississippi River, Pennington et al. (1983) found that the number of fish species taken from natural and revetted banks were similar. However, the relative abundance of individual species was different in the two habitats, with sport and commercial species more abundant by weight on revetted banks.

In summary, the proposed revetment is likely to reduce the amount of beneficial woody debris entering the system from the area through bankline erosion. However, woody debris would continue to enter the system during overbank flow events, and revetment would benefit fish and wildlife by providing rock substrate.

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 Grand Tower Phase V (Crawford and Vancill Towheads) work required Tier II consultation. Accordingly, the District prepared Tier II Biological Assessments to determine the potential impacts of the work on federally threatened and endangered species (Appendix B).

As outlined in the Biological Assessments and associated USFWS correspondence (Appendix B), the determination has been made that the Proposed Action is not likely to adversely affect Indiana bat, northern long-eared bat, least tern, spectaclecase mussel, sheepnose mussel, and decurrent false aster. With respect to pallid sturgeon exact impacts remain unclear, although adverse impacts 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 as described in Section 2, Development of Alternatives. However, the potential adverse effects of the work on 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. Thus, the determination has been made that no significant impacts to pallid sturgeon are anticipated.

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 USFWS 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 USFWS will be conducted.

Socioeconomic Resources

Navigation

Impacts of the No Action Alternative on Navigation – With the No Action Alternative, periodic maintenance dredging activities would be expected to continue at a rate similar to recent history. Dredging costs in the area since 2000 have averaged approximately $730,000 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 by approximately 85%. This reduction is a projected average based on previous work in chronic dredging locations on the MMR. Actual reductions in the amount and frequency of dredging are dependent on a number of natural factors including the hydrograph and the amount of sediment entering the system. Extensive coordination with navigation industry partners was conducted in order to ensure that unintended navigation impacts were avoided. The cost of the Proposed Action is not expected to exceed $8,000,000.

Historic and Cultural Resources

Impacts of the No Action Alternative on Historic and Cultural Resources – Continued dredging and disposal 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 and disposal under the No Action Alternative would likely occur in the same locations as previous dredging and disposal, and, therefore, would be unlikely to impact undocumented historic and cultural resources.

Impacts of the Proposed Action on Historic and Cultural Resources – All construction and modification work on the river structures 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. 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.

As with other training structures, construction of revetment would be 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 was conducted on the proposed location. The proposed work was determined to be on recently accreted land. Recently accreted land is highly unlikely to contain deeply buried cultural resources. The revetment section is located on Vancill towhead, which formed at the end of the nineteenth century and is extremely unlikely to be the location of any cultural resources.

Given the features' construction method (with no land impact), the previous disturbance of the riverbed, the fact that all feature locations were within the river until the end of the nineteenth century, and the lack of any survey evidence for extant wrecks, it is our opinion that the proposed undertaking will have no significant effect on cultural resources. 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 no objections to the work were raised. Copies of the consultation letter and response are included in Appendix F.

Climate Change.

A large body of scientific evidence indicates that increases in greenhouse gases[3] (GHG) in the Earth's atmosphere are contributing to changes in national and global climatic conditions (Melillo et al. 2014). These changes include such things as increases in average temperature,

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

changes in precipitation patterns, and increases in the frequency and intensity of severe weather events. These changes have the potential to impact a wide sector of the human environment including water resources, agriculture, transportation, human health, energy, and aquatic and terrestrial ecosystems. Therefore, it is important to understand the potential impacts of federal actions on GHG emissions and climate change as well as the potential changes that may occur to the human environment that could affect the assumptions made with respect to determining the impacts and efficacy of the federal action in question.

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

Summary of Observed Climate Findings:

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

Summary of Future Climate Projection Findings:

> *There is strong consensus in the literature that air temperatures will increase in the study region, and throughout the country, over the next century. The studies reviewed here generally agree on an increase in mean annual air temperature of approximately 2 to 6 ºC (3.6 to 10.8 ºF) by the latter half of the 21st century in the Upper Mississippi Region. Reasonable consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long term future compared to the recent past.*
>
> *Projections of precipitation found in a majority of the studies forecast an increase in annual precipitation and in the frequency of large storm events. However, there is some evidence presented that the northern portion of the Upper Mississippi Region will experience a slight decrease in annual precipitation. Additionally, seasonal deviations from the general projection pattern have been presented, with some studies indicating a potential for drier summers. Lastly, despite projected precipitation increases, droughts*

are also projected to increase in the basin as a result of increased temperature and [evapotranspiration] *rates.*

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

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. As summarized above, there is no consensus with respect to forecasts for future streamflow in the basin. Whether future climate patterns in the Upper Mississippi River basin result in a reduction or increase in streamflow compared to current conditions, 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. Construction of river training structures could, however, contribute to the trend of decreasing stages at low flows. Given that it is not possible to determine the relative contribution of river training structures to this trend versus lack of sediment from tributary streams and given the uncertainty in future streamflows, it is not possible to determine the exact magnitude of this potential effect. However, given the relatively small observed decreases in stages, the effect going forward is anticipated to be minor. Regardless of any river training structure-related impacts, 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 Grand Tower 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 MMR. Clearly the human environment in the MMR has been, and will continue to be, impacted by a wide range of actions. The cumulative impact analysis evaluates the same resources (Physical Resources [Stages, Water Quality, and Air Quality]; Biological Resources [Fish and Wildlife: Dike Effects, Bendway Weir Effects, Revetment 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 MMR continues to evolve, equilibrium in habitat conditions appears to have been reached. Accordingly, no significant impacts to the resources, ecosystem and human environment are anticipated for the Grand Tower Phase 5 Regulating Works 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. 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 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 attainment status in work area.	Occasional and ongoing minor and local impacts due to use of dredging equipment	Temporary, minor, local impacts to air quality due to one-time use of construction equipment

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 being stabilized 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 maintenance of 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; Uncertain impacts on fish and macroinvertebrates at inside bend opposite of proposed bendway weir locations; Minor loss of fish and macroinvertebrate habitat due to reduced woody debris inputs; May affect but not likely to adversely affect threatened and endangered species; Adversely affects pallid sturgeon but meets the requirements of the reasonable and prudent measures described in 2000 Biological Opinion.

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

[1] Also included for compliance are all regulations associated with the referenced laws. All guidance associated with the referenced laws were considered. Further, all applicable Corps of Engineers laws, regulations, policies, and guidance have been complied with but not listed fully here.
[2] Full compliance will be obtained prior to construction activities.
[3] This list of Executive Orders is not exhaustive and other Executive Orders not listed may be applicable.

6. Conclusion

The St. Louis District has assessed the impacts of the Proposed Action on the physical, biological, socioeconomic, and historic and cultural resources of the work area and determined that the proposed work would have no significant direct, indirect, or cumulative impacts upon the human environment.

7. List of Preparers

Name	Role	Experience
Mike Rodgers	Project Manager	14 years, hydraulic engineering
Eddie Brauer	Engineering Lead	14 years, hydraulic engineering
Kip Runyon	Environmental Lead	18 years, biology
Francis Walton	EA Contributor and Threatened and Endangered Species	15 years, environmental compliance
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	4 years USACE, 6 years private sector law

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FINDING OF NO SIGNIFICANT IMPACT (FONSI)
GRAND TOWER PHASE 5 REGULATING WORKS
MIDDLE MISSISSIPPI RIVER MILES 74-67
UNION COUNTY, IL
CAPE GIRARDEAU COUNTY, MO

I. In accordance with the National Environmental Policy Act, I have reviewed and evaluated the documents concerning the Regulating Works, Grand Tower Phase 5 construction, Union County, Illinois and Cape Girardeau 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, biological, cultural, and socioeconomic effects. My evaluation of significant factors has contributed to my finding:

a. The work would address repetitive dredging conditions in the area. This would be accomplished by placing revetment; constructing two chevrons, three diverter dikes (S-dikes), and three bendway weirs; and modifying four existing dikes.

b. No significant impacts to natural resources, fish and wildlife resources and federally threatened or endangered species are anticipated. There would be no appreciable degradation to the physical environment (e.g., stages, air quality, and water quality) due to the work.

c. The proposed work would have no adverse effect upon historic properties or archaeological resources.

d. The "no action" alternative was evaluated and determined to be unacceptable as unnecessarily high 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. The Proposed Action has been coordinated with the appropriate resource agencies and the public, and there are no significant unresolved issues. Therefore, an Environmental Impact Statement will not be prepared prior to proceeding with the proposed Regulating Works, Grand Tower Phase 5 construction, Union County, Illinois and Cape Girardeau County, Missouri.

10 June 2016
(Date)

ANTHONY P. MITCHELL
COL, EN
Commanding

FINAL ENVIRONMENTAL ASSESSMENT

WITH

FINDING OF NO SIGNIFICANT IMPACT

REGULATING WORKS PROJECT
GRAND TOWER PHASE 5
CRAWFORD TOWHEAD AND VANCILL TOWHEAD
MIDDLE MISSISSIPPI RIVER MILES 74-67
UNION COUNTY, IL
CAPE GIRARDEAU COUNTY, MO

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

An abundance of research has been conducted analyzing the impacts of river training structures on water surfaces dating to the 1930s. This research includes numerical and physical models as well as analyses of historic gage data, velocity data, and cross sectional data. In addition to continued monitoring and analysis, the U.S. Army Corps of Engineers (Corps) has conducted a literature review of all available literature on the impact of river training structures on flood levels. A summary of research on the topic is detailed below. Based on an analysis of this research by the Corps and other external reviewers, the District has concluded that river training structures do not impact flood levels.

2. Studies concluding no impact on flood levels

2.1 Historic Research

One of the early studies specifically addressing the effect of river training structure construction on water surfaces was conducted during the extreme high water of June and July 1935 (Ressegieu 1952). This study was prompted by the differences in observed 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 on the Illinois bank.

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

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

2.2.3 *Statistical Evaluation*

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

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

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

2.2.4 Numerical and physical modeling studies

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

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

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

2.2.5 Analysis of Updated Evaluations

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

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

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

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

The Corps has researched and analyzed all available literature that either purports or has been claimed to purport that river training structures increase flood heights. Comments and information provided to the Corps on this topic have included studies claiming to link the construction of instream structures to increases in flood levels. However, less than half of the journal articles, technical notes, book chapters, and conference papers referenced or provided attempt to link the construction of instream structures to increases in flood levels. The remaining studies referenced or provided do not discuss the construction of instream structures and/or increases in flood levels. Some of the 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. For instance, 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), so 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 provided to the Corps 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 led 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. 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.

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.

3.4 Papers using physical observations to link instream structure construction to flood level increases

Criss & Luo (2016) is preliminary analysis of the December 2015/January 2016 flood on the Meramec and Middle Mississippi Rivers that presents arguments that although the Meramec Basin, lower Missouri River Basin and parts of the Mississippi River basin received record or near record rainfall, the record flooding observed in December 2015 and January 2016 was a result of isolation of the rivers from their floodplains by levee construction and channelization of the Mississippi River. The authors detail preliminary observations and do not present any analysis on instream structures and how they impact flood levels.

In haste to submit the paper for publication ("Manuscript received January 8, 2016" by the journal) the authors omit relevant data and analysis, mischaracterize the antecedent ground and river conditions, and evaluate incorrect data. The authors do not evaluate channel conveyance on the Mississippi River. Had they evaluated conveyance, the authors would have recognized through a comparison of measured stage and discharge data that stages at Chester for the same discharges were lower in 2015 than in the 1993 and 1973 floods. For example, for a flow of 824,000 cfs at the Chester gage the observed stage on 12/29/2015 was 41.0 feet. The stages for similar discharges on 7/14/1993 (824,000 cfs) and on 5/2/1973 (833,000 cfs) were 43.13 feet and 42.36 feet respectively. The authors also mischaracterize the antecedent ground and river conditions. The St. Louis area received above normal rainfall throughout the month of December resulting in record daily river stages. For example, on December 26, 2015 the St. Louis gage was nearly 1.5 ft above the previous record for this day set in 1982. The authors use incorrect information in their analysis. For instance, the authors state that the stage on the Meramec River at Pacific was slightly lower in 2015 than 1982. This is not true; the stage at Pacific hit a new record of 33.42 on 12/30/2015 which surpassed the previous record of 32.71 on 12/6/1982.

4. Other studies provided to the Corps that do not link the construction of instream structures to increases in flood levels

Other journal articles, editorials and conference papers have been provided to the Corps, claiming to conclude that instream structures increase flood levels. However, the Corps has determined upon review and analysis of these references, they have been incorrectly referenced as linking the construction of instream structures to increases in flood levels as follows:

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), Criss (2016) 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).

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Attachment 1 to Appendix A: Hydrodynamic Study of Vancill Towhead Reach on the Middle Mississippi River

US Army Corps
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St. Louis District

Hydrodynamic Study of Vancill Towhead Reach on the Middle Mississippi River

March 2016

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1 Introduction

1.1 Background

In September 2012 the United States Army Corps of Engineers, St. Louis District (USACE) conducted a Hydraulic Sediment Response (HSR) model study of the Middle Mississippi River at Vancill Towhead, River Miles 72.0-65.0, to develop and evaluate alternatives to address a repetitive dredging problem. The Vancill Towhead study area is located between Cape Girardeau County, Missouri and Union County, Illinois, approximately 100 miles south of St. Louis, Missouri. For a general project location please see Figure 1.Project Location.Figure 1.

The result of the model study was a recommended alternative to help reduce the need for repetitive channel maintenance dredging necessary to maintain the authorized safe and dependable navigation channel in this reach, commonly referred to as Grand Tower Phase 5. Three of the new structures in the recommended alternative were S-Dike Structures. This configuration of river training structure has never been constructed before. The S-Dike was designed to increase navigation channel depths while also providing diverse environmental habitats in the area around the structures. For more information on the HSR model study and S-Dike Structures please see http://mvs-wc.mvs.usace.army.mil/arec/Reports_HSR_Model.html, Technical report M62, Vancill Towhead HSR Model River Miles 72.0-65.0 Hydraulic Sediment Response Model Investigation.

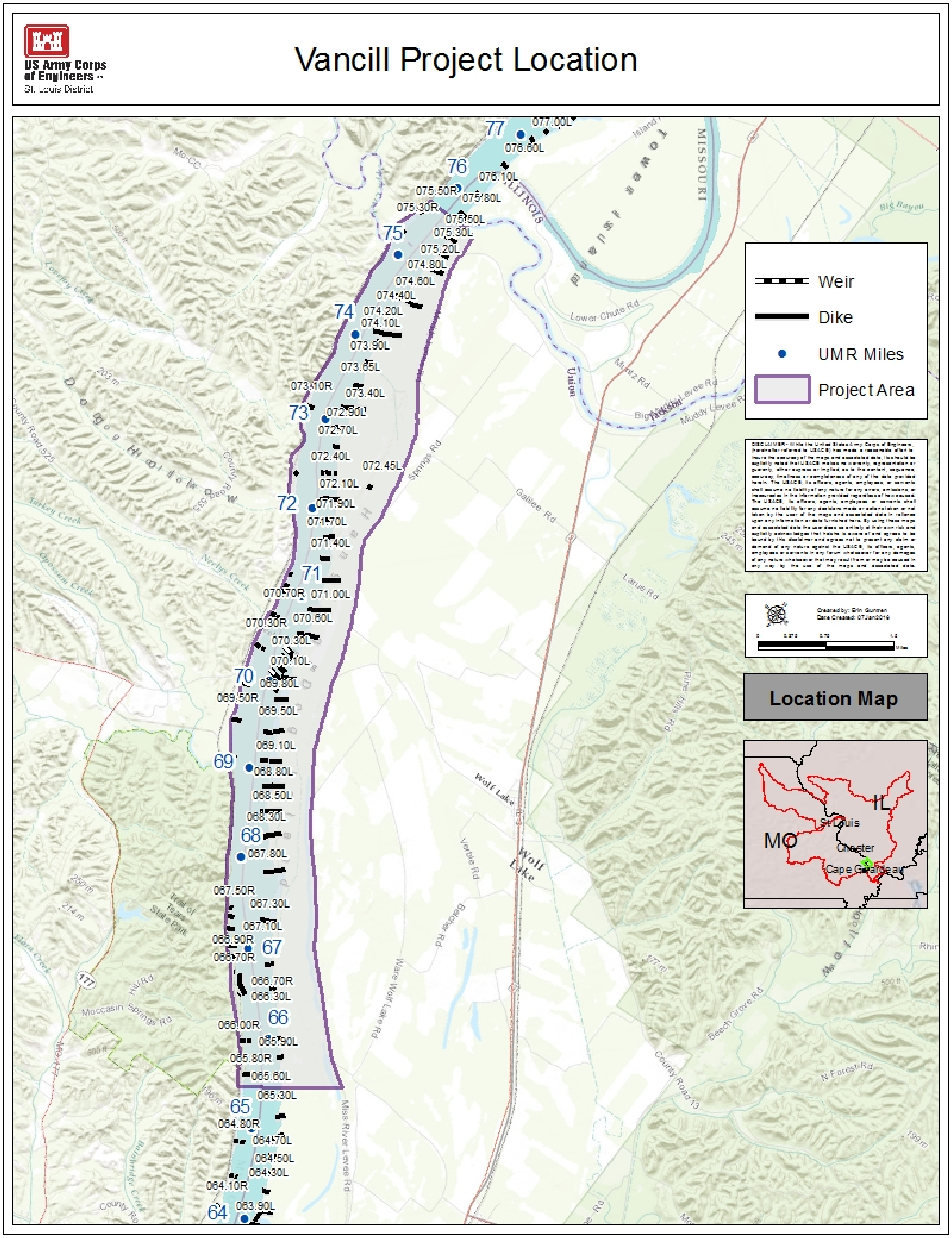
At a public hearing on the Grand Tower Phase 5 Draft Environmental Assessment (EA) in Grand Tower, Illinois on February 19th, 2014, the public raised concerns about the proposed S-Dikes at Middle Mississippi River Miles 68.10, 67.80, and 67.50 because this shape of river training structure had not been used before. To address this concern, the St. Louis District initiated a 2D numerical model study to investigate the recommended alternative's, including the new S-Dikes, effect on the water surface elevation for the 1 percent annual chance exceedance event. The results of this study will be incorporated into the appropriate National Environmental Policy Act (NEPA) documentation for Grand Tower Phase 5.

1.2 Approach

The model study utilized Adaptive Hydraulics (AdH) Version 4.5. AdH is a finite element modeling package that evaluates two-dimensional shallow water calculations. Adh was designed to solve water problems within riverine systems and estuaries. AdH works in conjunction with Surface Water Modeling System (SMS). SMS is used for mesh generation and visualization of results calculated in AdH.

AdH model development and calibration are discussed in Chapter 2. The model results and conclusions for the model study are included in Chapter 3.

Figure 1.Project Location.



2 AdH Model Development

2.1 Geometry

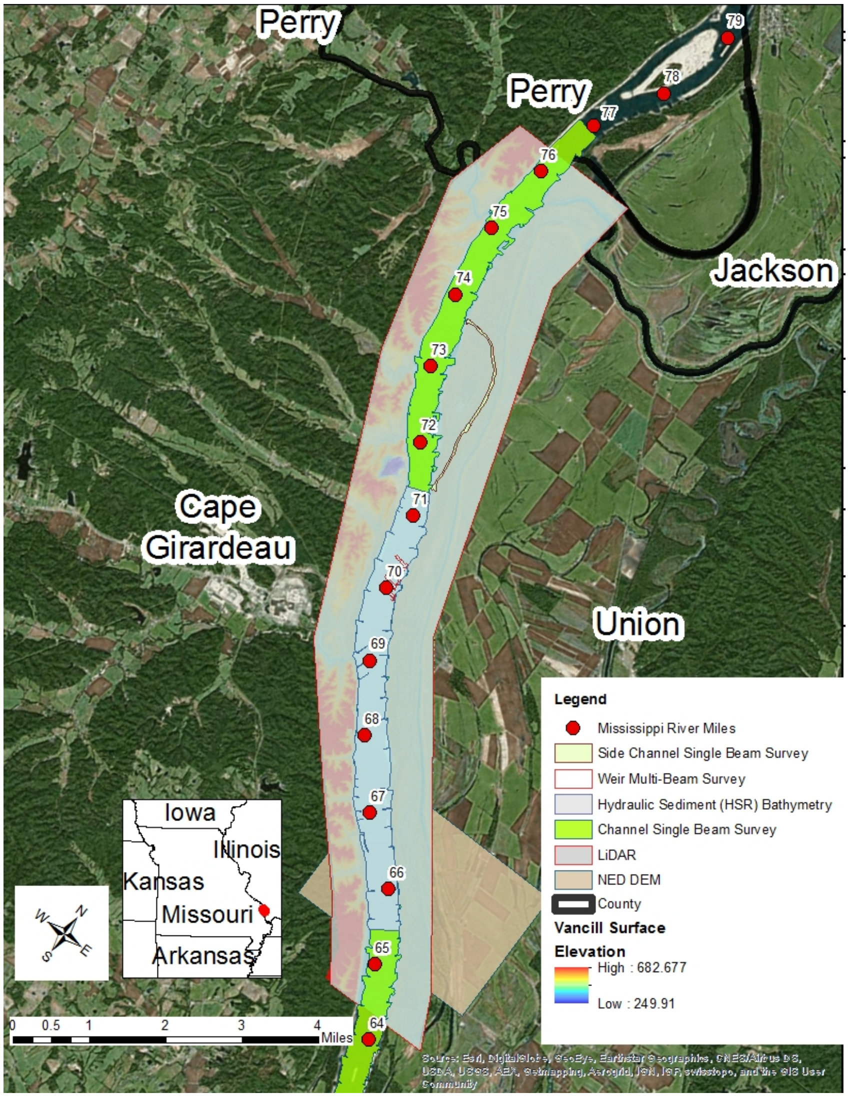
The elevation data used to create the AdH computational mesh was compiled using several datasets that covered both above and below the waterline. The sources include a combination of Light Detection and Ranging surveys (LiDAR), National Elevation Dataset (NED), and hydrographic surveys which consisted of single beam and multi-beam survey data. HSR base condition and recommended alternative bathymetry was also supplied for the study area. LiDAR and NED data is collected above the water surface. Hydrographic or bathymetric surveys are used to collect elevation data below the water surface. Table 1 lists the elevation datasets used to create the mesh.

Table 1. Source of Elevation Datasets

Survey	Survey Type	Vertical Datum	Date
Crawford Chute Side Channel Survey	Multi Beam Hydrographic Survey	(NGVD29)	March-2011
Structure Survey	Multi Beam Hydrographic Survey	(NGVD29)	January-2012
Hydraulic Sediment Response Model Base Condition	HSR Bed Scan	(NAVD88)	
Hydraulic Sediment Response Model Recommended Alternative	HSR Bed Scan	(NAVD88)	
Main Channel Survey	Single Beam Hydrographic Survey	(NGVD29)	April-2015
Upper Mississippi River LiDAR	LiDAR	(NAVD88)	December-2012
National Elevation Data Set	DEM	(NGVD29)	April-2015

Data in NGVD29 was converted to NAVD88 using a datum shift of -0.5 feet. The surveys were merged together to create a single elevation dataset representing all areas above and below the waterline within the numerical model mesh domain. The data was merged such that HSR and more accurate elevation data has priority over less accurate data. The order in which the data was merged was: HSR Bathymetry, Multi-beam hydrographic survey, Single beam hydrographic survey, LiDAR, and NED. The merged elevation data is show in Figure 2

Figure 2. Merged Elevation Data.



USACE has employed Hydraulic Sediment Response (HSR) modeling, formerly called Micro Modeling (Davinroy, 1994, Gaines 2002) since 1994 to address a variety of problems related to shoaling and scour on inland waterways in the United States (Davinroy 1999). Modeled waterways include the Mississippi, Atchafalaya, White, Missouri, Ohio, Brazos, and Kaskaskia Rivers. The small-scale physical models use synthetic bed material to simulate bed response, and use various materials to represent fixed boundary features such as banks, islands, dike structures, rock, and consolidated clay formations. Design alternatives have been developed from model output to solve problems such as repetitive maintenance dredging, side channel restoration, and other navigation related issues.

2.1.1 Base Condition

The base condition geometry is based on the HSR replication effort that produce a geometry that closely matched the actual field conditions in the area. For more information on model replication please see HSR model study please see Technical report M62, Vancill Towhead HSR Model River Miles 72.0-65.0 Hydraulic Sediment Response Model Investigation.

2.1.2 Proposed Construction Alternative

Several alternatives were investigated during the HSR modeling effort. The HSR model recommended alternative was the most desirable because of its ability to solve the dredging problem at Vancill Towhead while avoiding and minimizing negative environmental impacts. This alternative also alleviates sediment deposition at the boat ramp along the Right Descending Bank (RDB) at RM 66.65, while having no significant impacts on the navigation channel. Bathymetry results show that the thalweg between RM 68.00 and RM 67.00 was directed along the RDB by three S-Dikes. The thalweg depths increased in the main channel and more scour occurred near Dike 66.70R and the boat ramp.

The goal to improve the environmental diversity at Vancill Towhead involved increasing the flow and sediment transport through the side channel. However, the location of the side channel entrance being so far away from the thalweg made the task nearly impossible. Therefore the approach taken in the recommended alternative created a secondary side channel with river training structures. Overall, this alternative would eliminate the repetitive dredging, maintain the navigation channel and enhance the environmental diversity near Vancill Towhead.

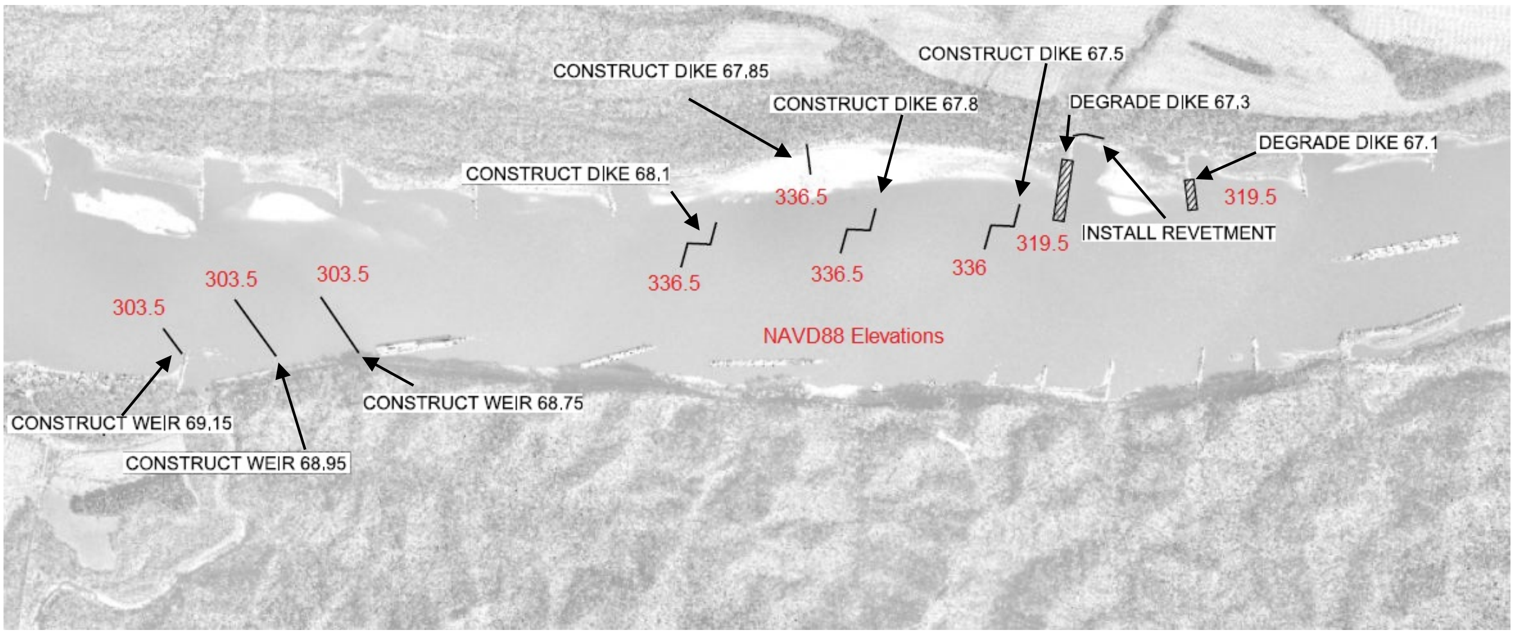
For more information on HSR recommended alternative and other alternatives investigated during the HSR effort, please see Technical report M62.

Construction plans were created based on the recommended alternative with some slight design changes such as revetment location changes which will not affect channel bathymetry. The proposed construction alternative includes the following features and is shown in Figure 3.

- Construct Weir 69.15R
- Construct Weir 68.95R
- Construct Weir 68.75R
- Construct Diverter Dike 68.10L (S-Dike)

- Construct Diverter Dike 67.80L (S-Dike)
- Construct Diverter Dike 67.50L (S-Dike)
- Repair Dike 67.80L
- Degrade Dike 67.30L
- Degrade Dike 67.10L
- Install Revetment downstream of dike 67.3L

Figure 3. Proposed Construction Alternative



2.2 Calibration

2.2.1 Discharge Data and Water-surface Elevation Data

2.2.1.1 Establishing Initial Boundary Conditions Utilizing HEC-RAS

Discharge data and water-surface elevation data was obtained from a calibrated unsteady HEC-RAS version 4.1 model of the Mississippi River. The following description was taken from the HEC-RAS 4.1 User Manual Forward. "The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) software allows you to perform one-dimensional steady and unsteady flow river hydraulics calculations." The HEC-RAS model was used to develop continuous discharge and water surface elevation boundary conditions for the AdH model and water surface elevations at cross section locations through the study reach.

For the Vancill Towhead study the HEC-RAS model included the reach between the gage at Chester, Illinois and the gage at Thebes, Illinois (RM 109.90-43.70). On the Upper Mississippi River, river mile 0 is at the confluence of the Ohio River and increases in distance upstream from there. The gage at Chester provided the upstream flow boundary condition data and the gage at Thebes provided the downstream stage boundary condition data. Stage data from the Chester gage and the other three gages between the Chester gage and the Thebes gage (see Table 2) were used for model calibration.

Table 2. Gage Locations.

Gage Description	Gage Longitude	Gage Latitude
Chester River Mile 109.9	89°50'08"	37°54'13"
Grand Tower River Mile 82.06	89°30'45"	37°39'29"
Moccasin Springs River Mile 66.30	89°27'24"	37°27'01"
Cape Girardeau River Mile 52.1	98°31'05"	37°18'07"
Thebes Rive Mile 43.70	89°28'03"	37°12'59"

2.2.1.2 HEC-RAS Model Calibration

The HEC-RAS model was calibrated to observed field data for several years and a large range of flows. The comparison of observed elevations to HEC-RAS model elevations can be found in figures 4, 5, 6, and 7. The comparisons to the field data and HEC-RAS model plot very close to each other well with-in acceptable range for model calibration.

Figure 4. Chester Elevation Gage HEC-RAS Model compared to Field Data.

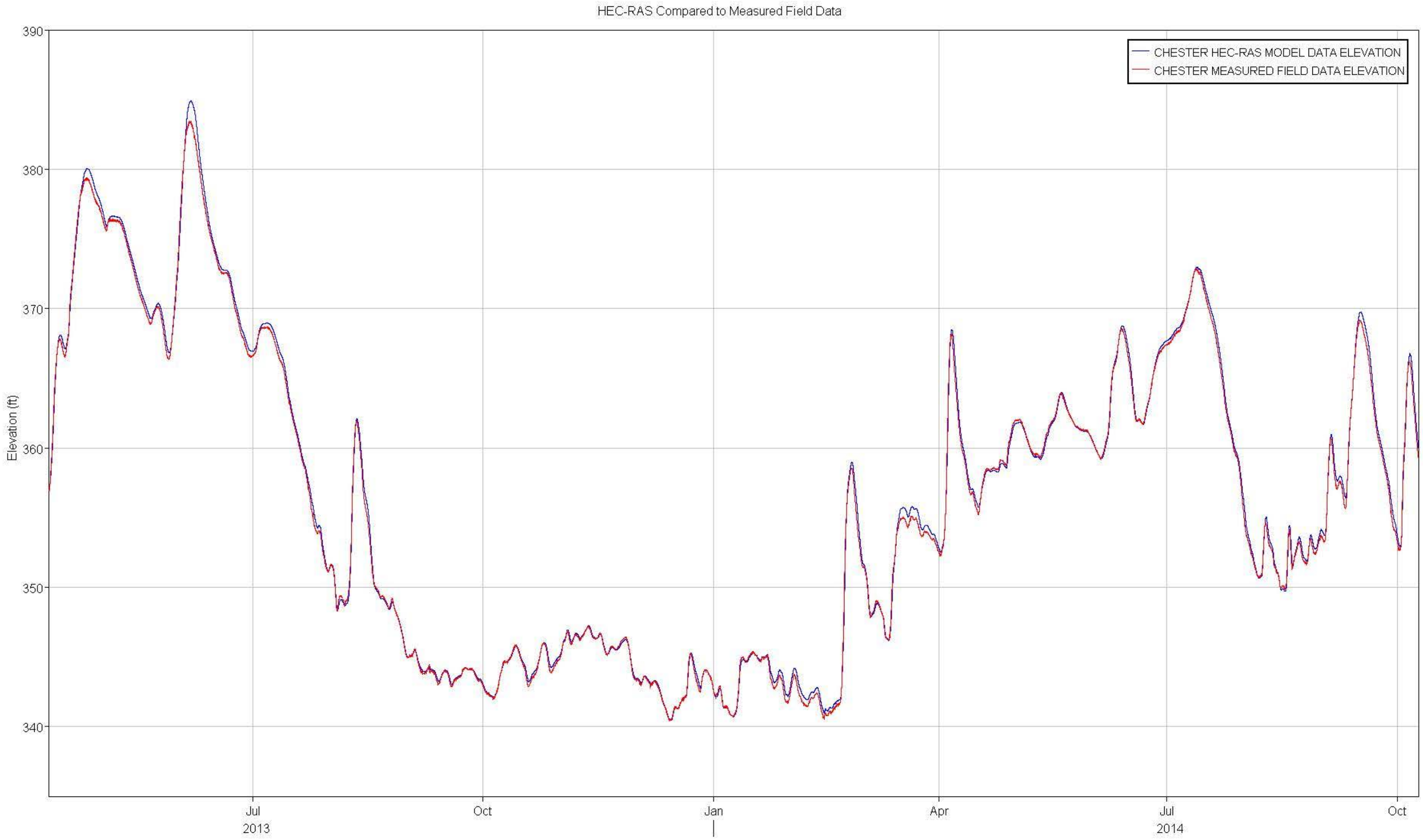


Figure 5. Grand Tower Elevation Gage HEC-RAS Model compared to Field Data.

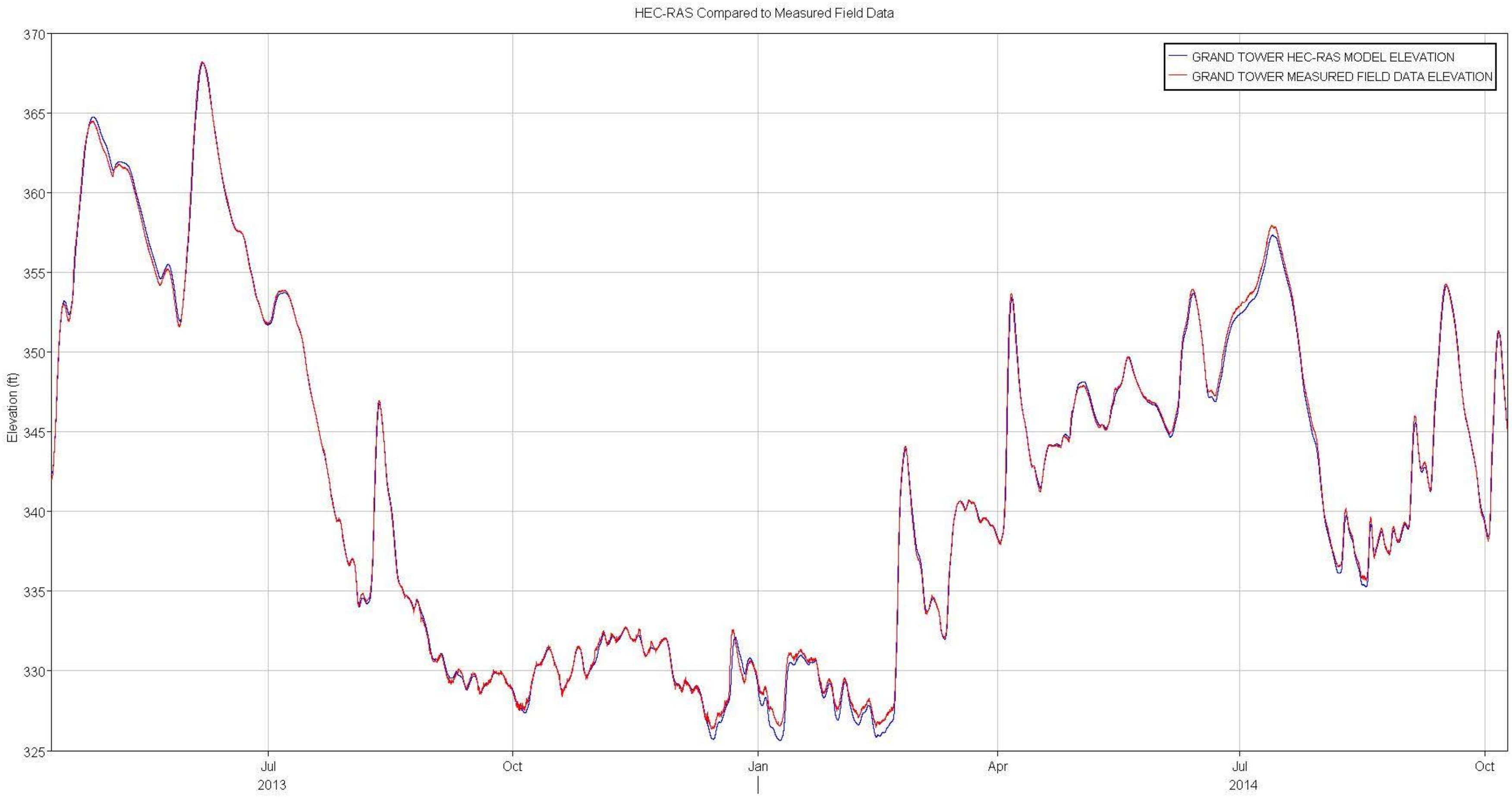


Figure 6. Moccasin Springs Elevation Gage HEC-RAS Model compared to Field Data.

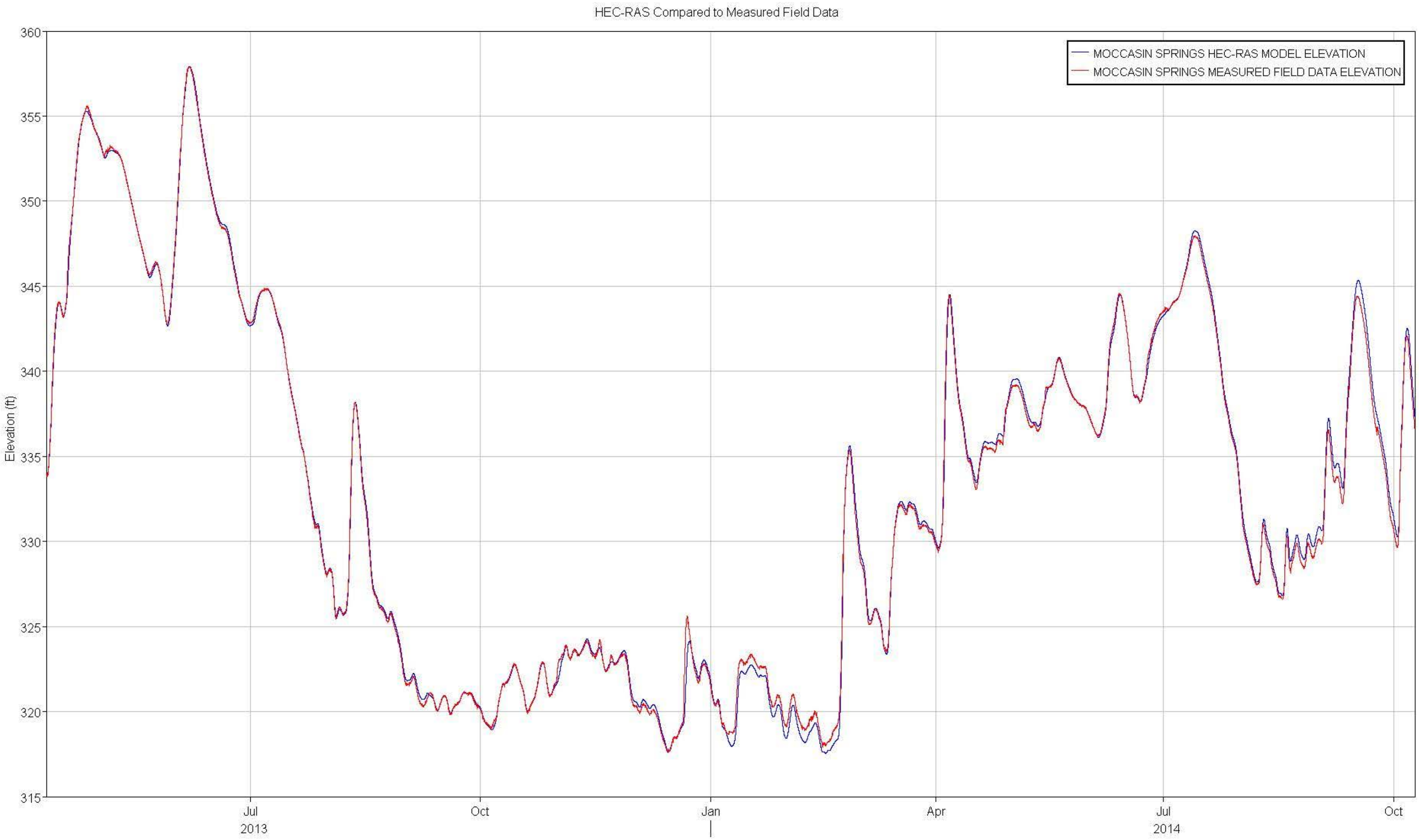
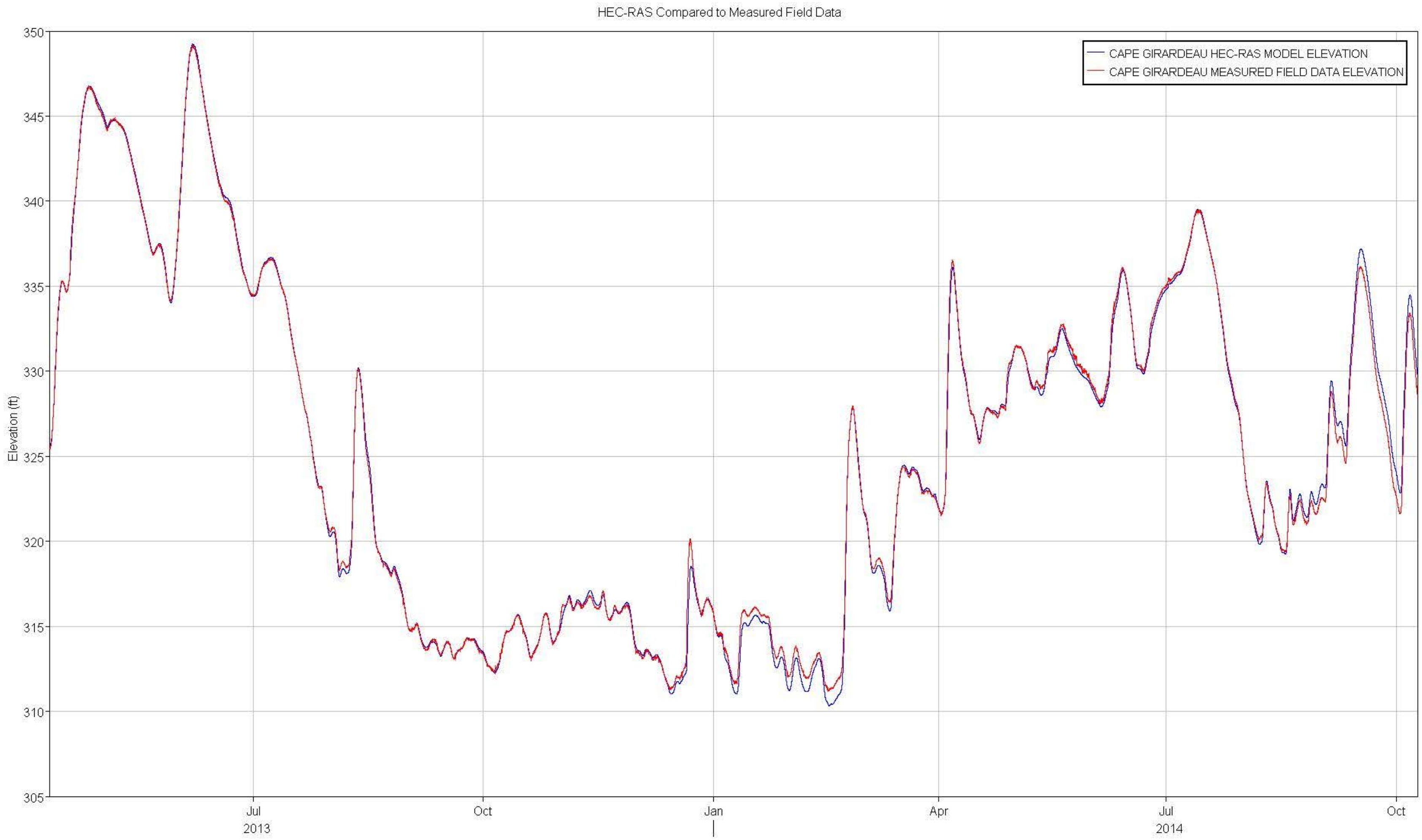


Figure 7. Cape Girardeau Elevation Gage HEC-RAS Model compared to Field Data.



2.2.1.3 Flow and Stage Boundary Conditions

The calibrated Mississippi River HEC-RAS model provided flow and elevation hydrographs. The flow boundary was located at RM 75.65 with the elevation boundary located at RM 65.40. Figure 8 and Figure 9 contain the flow and elevation boundary conditions.

Figure 8. Flow Boundary Conditions RM 75.65.

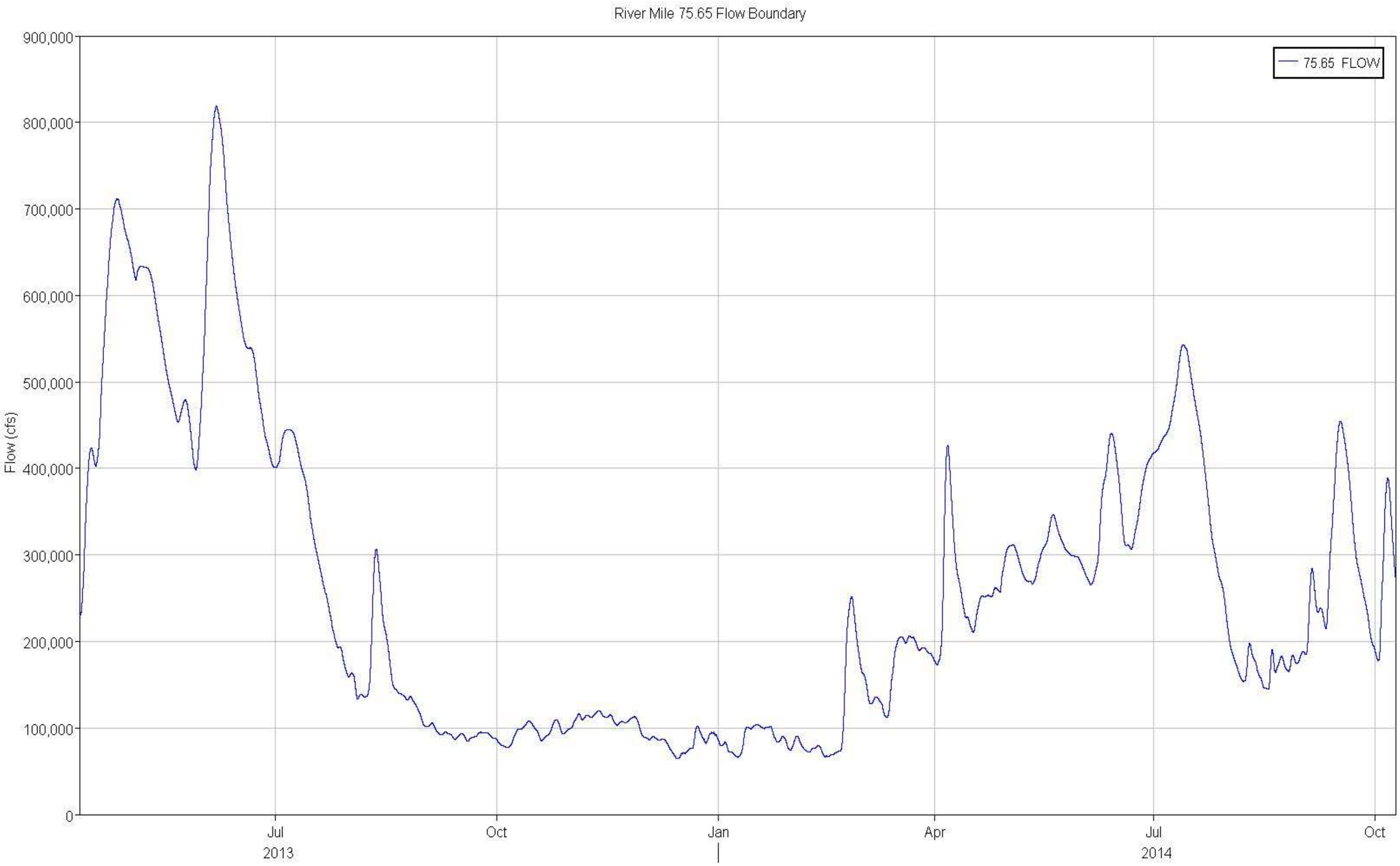
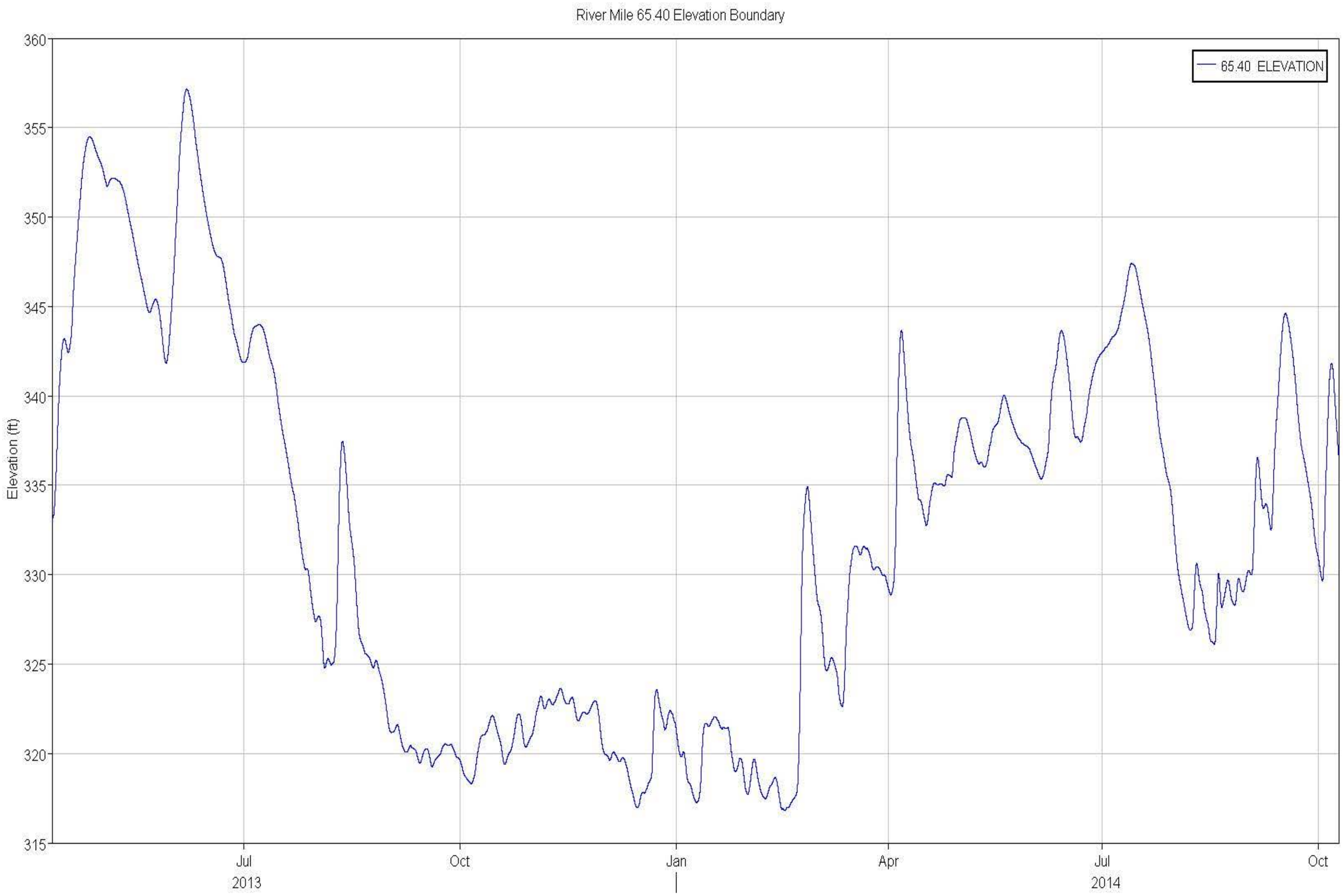


Figure 9. Elevation Boundary Conditions RM 65.40.



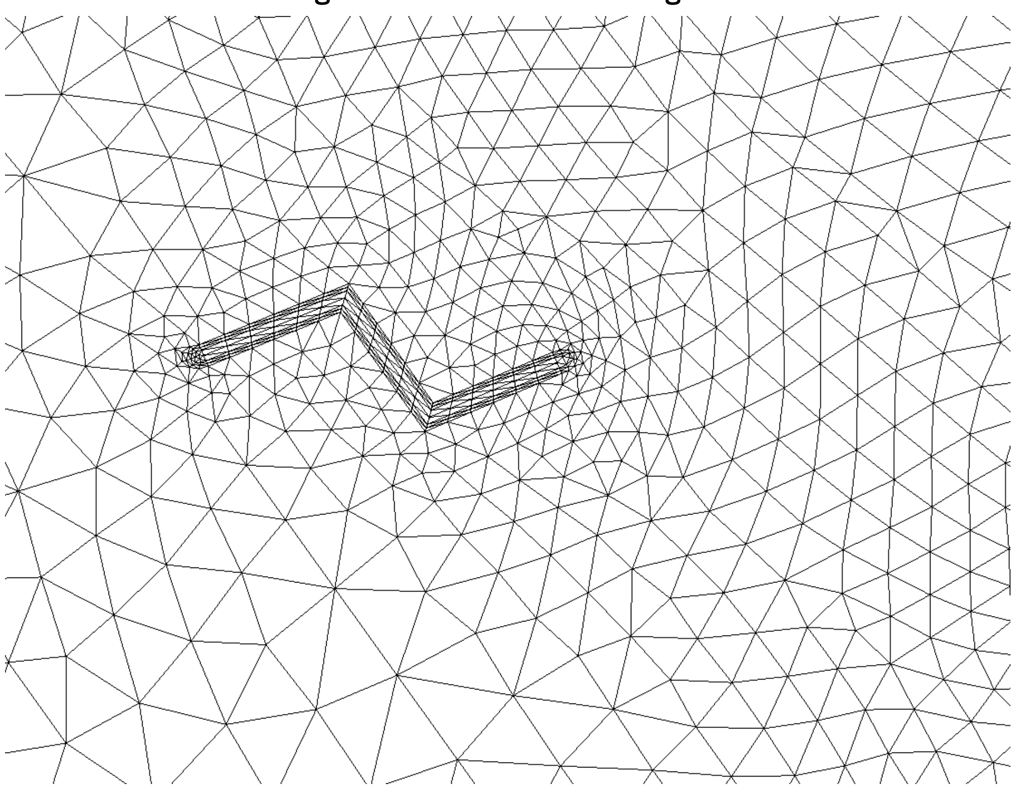
2.2.2 Initial AdH Setup Conditions

To develop an AdH model, three items are needed. These items include a numerical mesh file, boundary conditions (discussed above), and a hot start file.

2.2.2.1 Mesh Development

A numerical model mesh was created in order to utilize an AdH model. The mesh file was generated using SMS 11.2.3. The mesh is used to define the surface and extents of the area being evaluated. The extents of the mesh were from approximate river mile 65.4-75.65. The mesh is generated by using triangular elements and nodes at various spacing that would be overlaid over an elevation data set to create a surface mesh. The space between nodes were adjusted to change the size of the triangular elements, thus increasing detail as needed in areas such as the structures in the river. The upstream and downstream limits of the mesh were far enough away from the study area so effects of boundary conditions would be dissipated before reaching the study area. See Figure 10 for an example of triangular elements and nodes created in SMS to create the surface mesh.

Figure 10. Surface Mesh Triangles.



2.2.2.2 Hot Start Initial Conditions

The hot start initial condition is used for initial setup and stability of the model. The hot start establishes an initial depth of water and velocity when available. The hot start file used initial depth of water and was established for this study from HEC-RAS model profiles.

2.2.3 Modeling Properties

2.2.3.1 Bed Roughness

Three roughness types were used to define the roughness in the reach. The three factors were Unsubmerged Rigid Vegetation (URV), Equivalent Roughness Height (ERH), and Manning n values.

Unsubmerged Rigid Vegetation is used to compute a shear stress coefficient for computing shear stress through rigid, unsubmerged vegetation. URV takes into account bed roughness height, density, and diameter of the vegetation. This information was not available in the study area. But data was used from a similar density of trees from another location on the Mississippi River located near RM 183. The URV was used in areas with a heavy stand of trees.

Equivalent Roughness Height value is the average height of the roughness particles found on the bed or a given area. The ERH card was used for river training structures as well as the revetment.

The initial Manning's n values were obtained from Open-Channel Hydraulics, (Chow 1959). These values were taken from Chow and calibration was achieved by adjusting these values within an acceptable range.

The roughness values used in the model study can be seen below in Tables 3, 4, and 5.

Table 3. Equivalent Roughness Height

AdH Material	Roughness Height (ft)
Rock Bluff Line	1.15
Dikes	1.15
Weirs	1.15

Table 4. Unsubmerged Rigid Vegetation

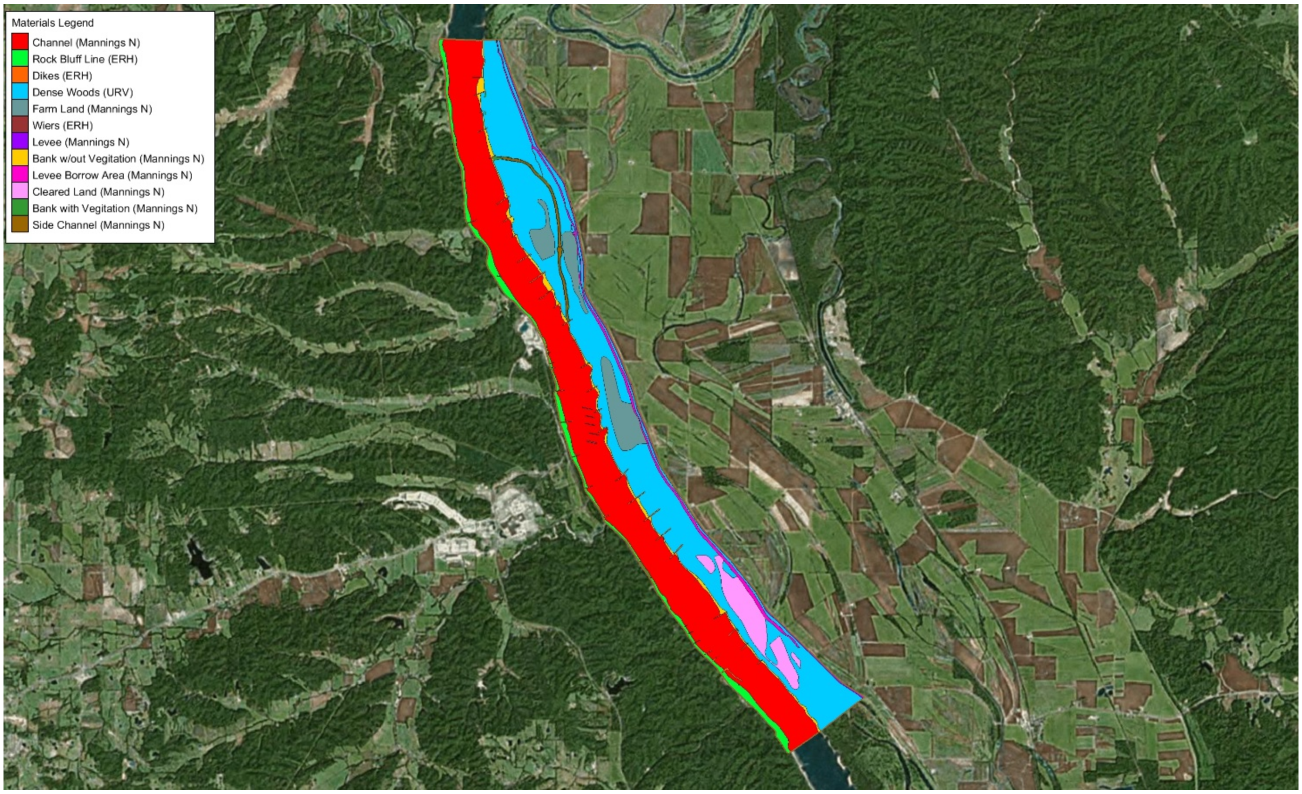
AdH Material	Roughness Height (ft)	Average Stem Diameter (ft)	Average Stem Density (trees/acre)
Dense Woods	0.16	1.71	29.4

Table 5. Manning's n Values

AdH Material	Roughness Coefficient
Channel	0.031
Levee	0.030
Bank with Vegetation	0.035
Bank without Vegetation	0.027
Levee Borrow Area	0.030
Cleared Land	0.035
Farm Land	0.032
Side Channel	0.030

The materials in the model were used to establish roughness parameters in the model domain. The material boundaries were set using 2014 aerial photography and elevation data. The aerial photograph was used to delineate areas with similar properties such as wooded area and farm land. The elevation data assisted in helping to delineate structures in the river that could not be seen by aerial photography. Figure 11 shows where the materials were used in the study area.

Figure 11. Bed Material Map.



2.2.3.2 Eddy Viscosity

The estimated Eddy Viscosity used in this study was the Smagorisnsky method, with a coefficient of 0.2. The Smagorinsky method was chosen because it is a common eddy viscosity method for rapidly changing velocity directions, such the changing velocities around the river training structures in the model.

The following was taken from the section 4.5.4 of the AdH version 4.5 user's manual describing the Smagorinsky Method. The Smagorinsky formulation was used to compute the eddy viscosity. This option utilizes the area of the element as the length scale, A, and a user specified coefficient, C. The algorithm is given below.

$$v_t = C^2 A\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)\right]^{0.5}$$

Lilly (1967) analytically derived the value of C to be between 0.16 and 0.20. The C value of 0.20 is a standard value used in the AdH modeling software. Sensitivity of the model to this parameter was checked using both values. Resulting water surface elevations and velocity fields were similar and varied by an extremely small margin.

2.2.3.3 Computation Environment

The numerical modeling was executed on the ERDC High-Performance Computing (HPC) Cray XE6 (Garnet) parallel processing supercomputer, in conjunction with the US Air Force Research Laboratory (AFRL) HPC SGI Ice X (Spirit). The numerical model was computed with both HPC platforms due to time restrictions and long wait times. It was verified that model results remained the same on both HPC platforms. The model was executed using 256 parallel processors on Garnet and 128 parallel processors on Spirit. A time step of 300 seconds was used, allowing the model to reduce the time step for stability and accuracy as needed.

2.2.4 Calibration Results

2.2.4.1 AdH Calibration

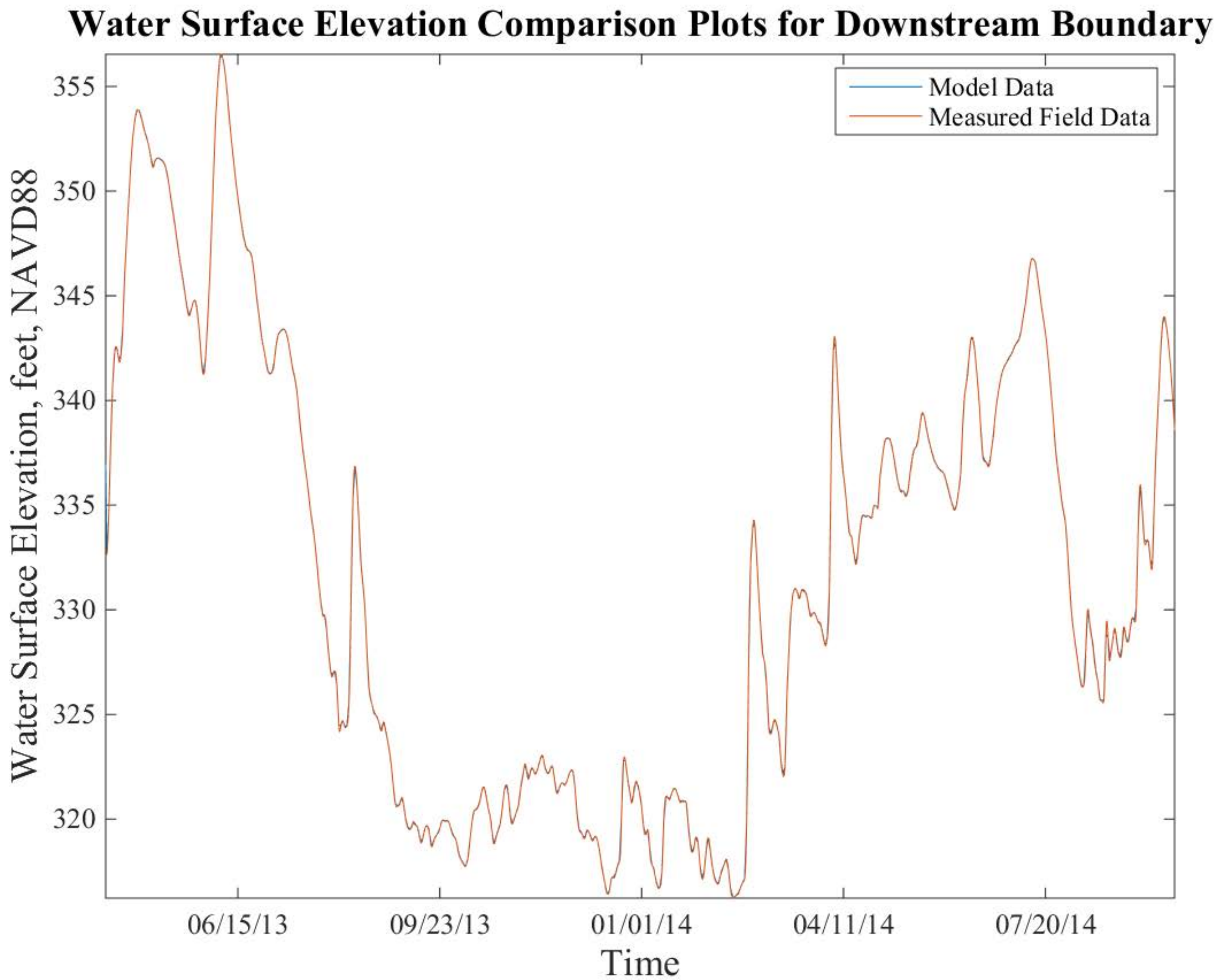
The output from the calibrated HEC-RAS model was used for the boundary conditions for the 2D model. The 2D model was calibrated using the mesh created using the base condition geometry described in 2.1. The 2D model was run by making small adjustments to the Manning's n values in the channel to achieve water surface elevations that closely match those from the HEC-RAS model. The adjustments to the n-values were still within the range of acceptable use for a river channel of this type. The elevations were compared at specific locations from the HEC-RAS model, as well as the Moccasin Springs gage data. This data was used for calibration and verification of the 2D AdH model. Plots displaying the results of the calibration can be found in figures 12 – 27.

The plots in figures 12, 14, 16, 18, 20, 22, 24, and 26 compare the water surface elevation (WSE) of the 2D AdH model and the HEC-RAS model, with respect to time. The plots show that the computed WSEs match well, especially with flows in which the structures are submerged. For this study, it was important higher flows and elevations matched closely because the effects of structures on WSEs during flood events was the greatest concern expressed by the public.

The plots in figures 13, 15, 17, 19, 21, 23, 25, and 27 compare the water surface elevations of the 2D AdH model (located on the y-axis) and the HEC-RAS model (located on the x-axis). This plot is an additional method to show the model calibration, by seeing how closely the points fell on the diagonal line in the plot. These figures also show that the AdH model results match the HEC-RAS model results more closely for higher stage conditions. A perfect match between the models would be represented by all points landing on the diagonal line.

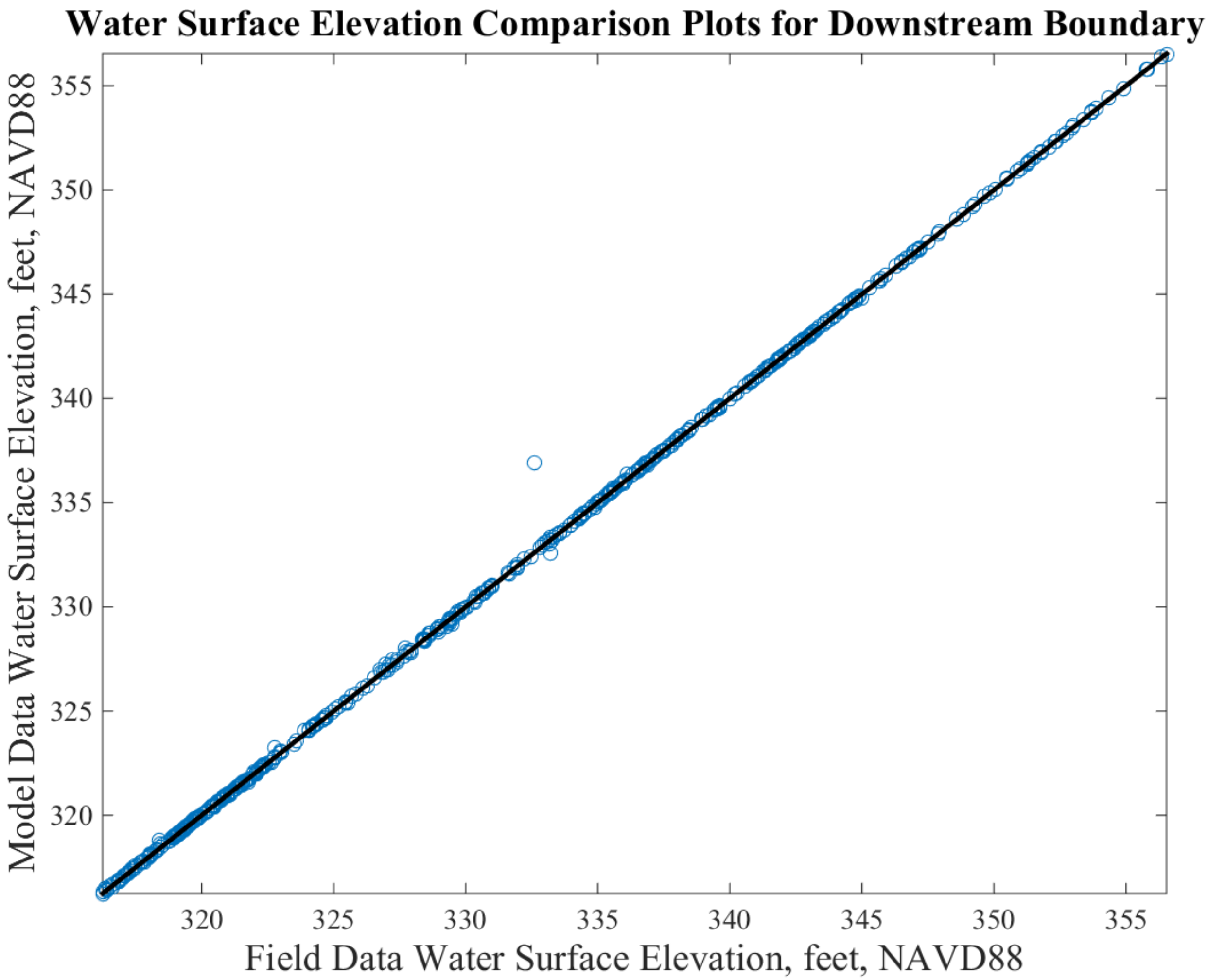
In figure 13, the data between the AdH model and HEC-RAS model match exactly. This is because figure 12 is comparing the downstream elevation boundary. Note that the HEC-RAS model values are labeled Measured Field Data in all of these figures.

Figure 12. Downstream Boundary Water surface elevation comparison



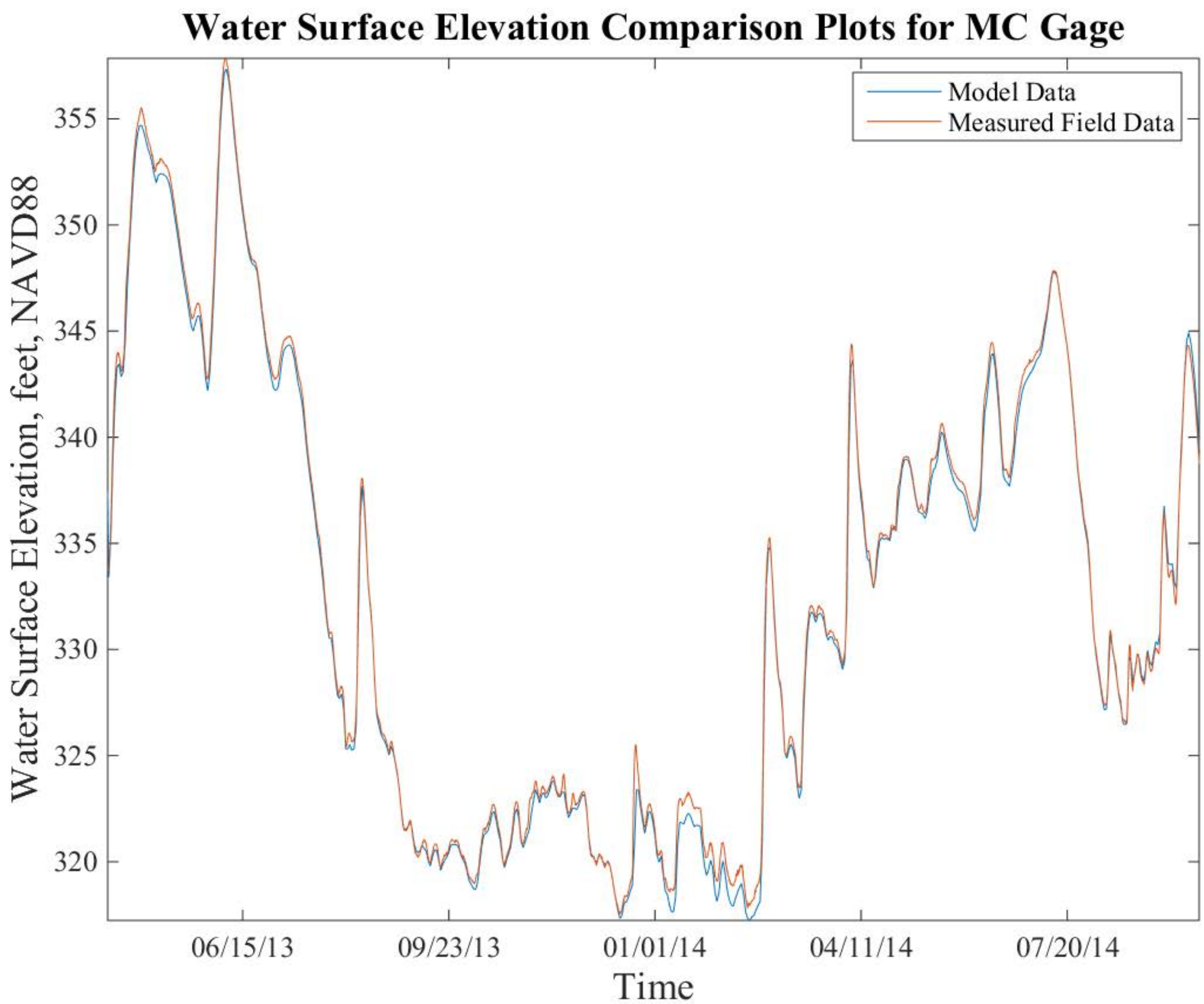
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot.

Figure 13. Downstream Boundary Box Plot



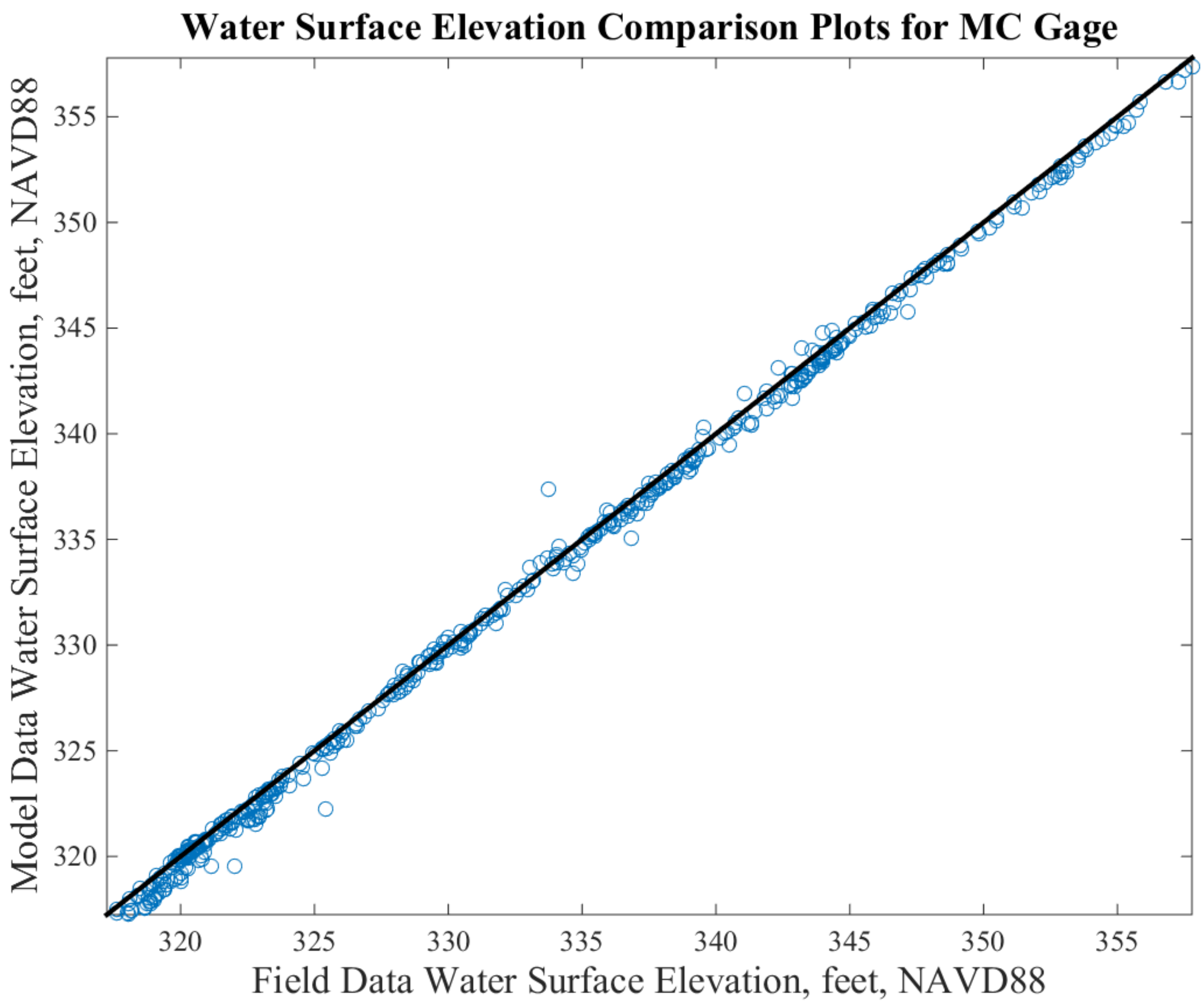
Note: the outlier at approximately model elevation 337 is caused by initial conditions and does not affect the results of the remainder of the model simulation.

Figure 14. Moccasin Springs Gage Water surface elevation comparison



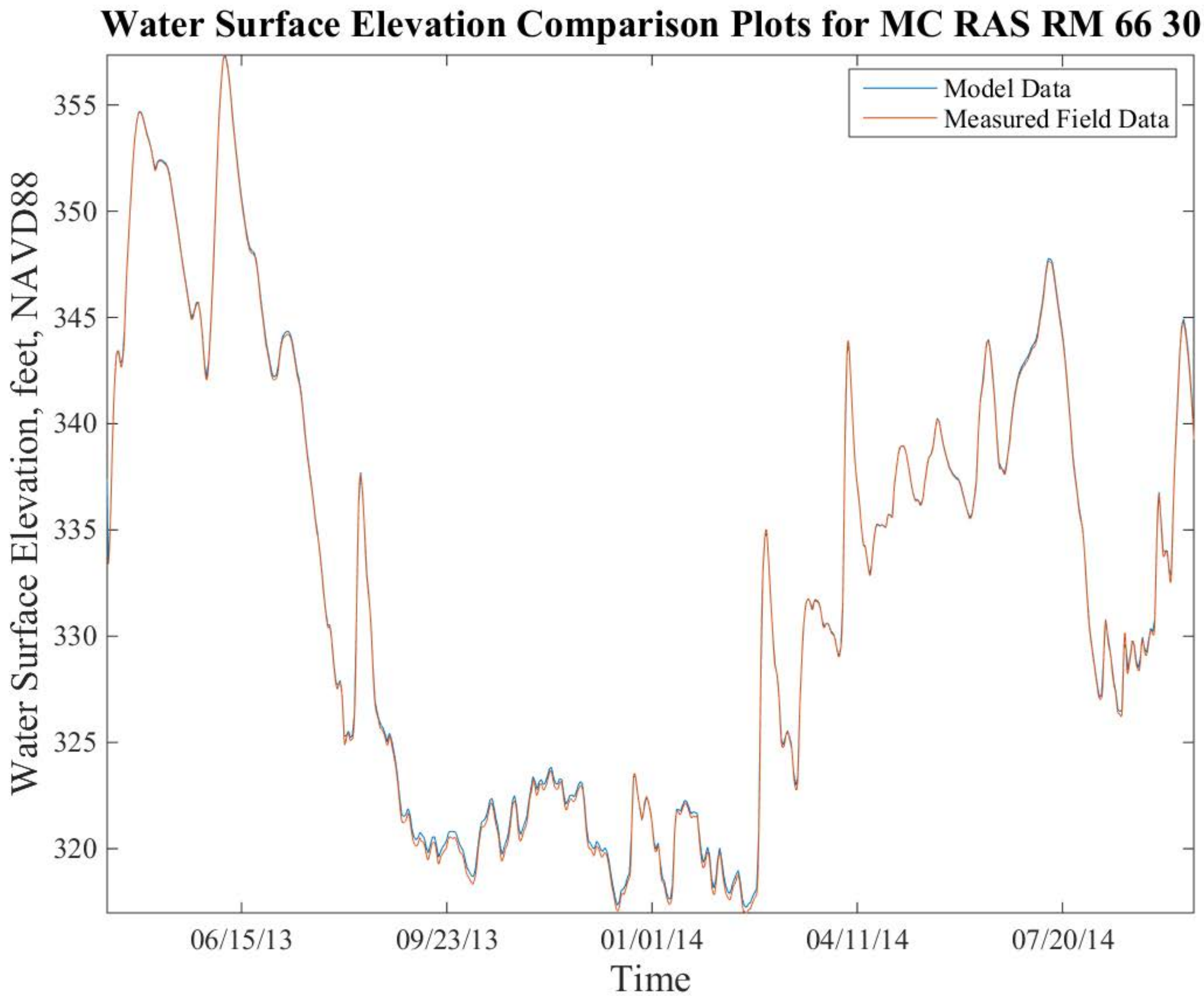
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot.

Figure 15. Moccasin Springs Gage Box Plot



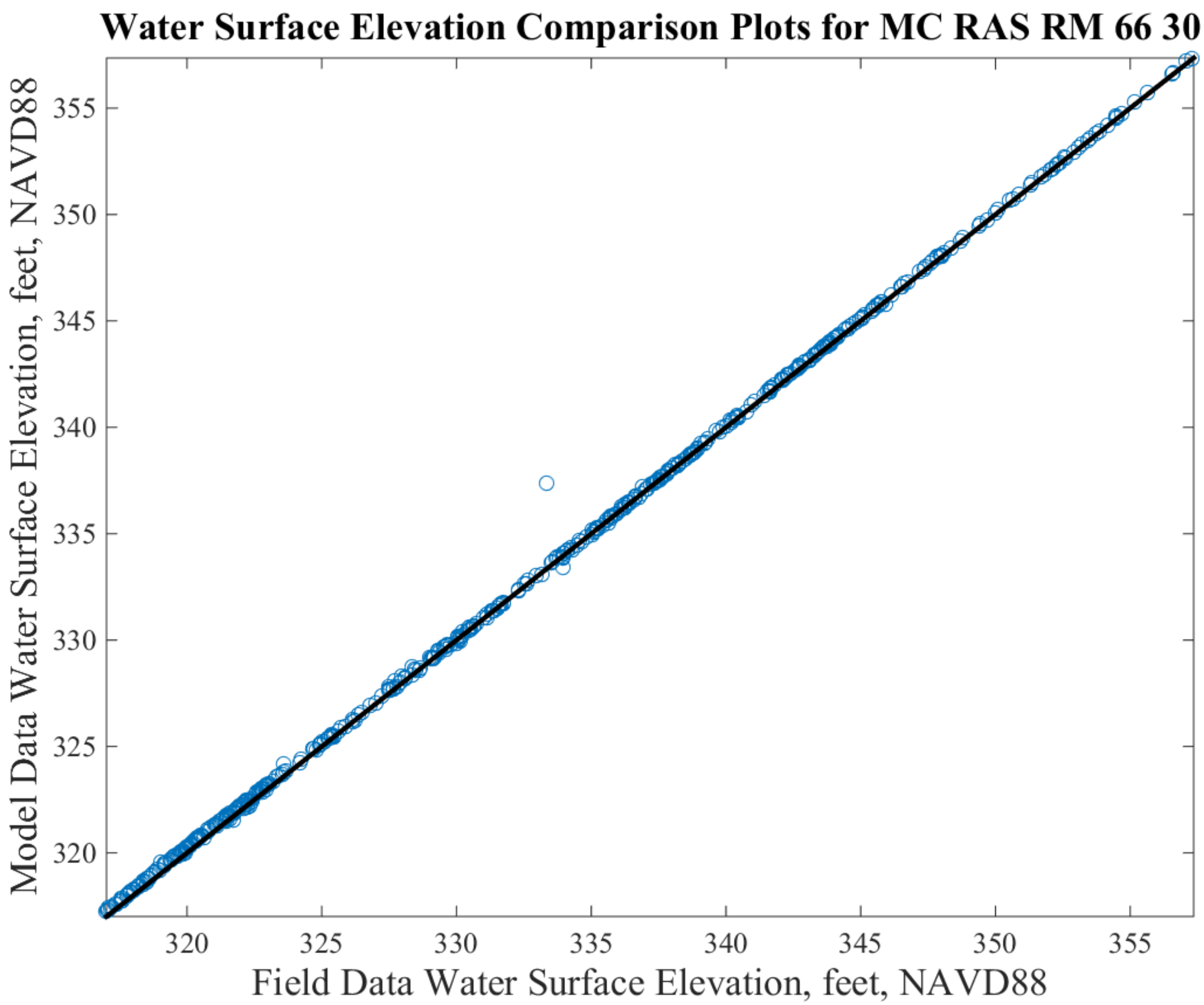
Note: the outlier at approximately model elevation 337 is caused by initial conditions and does not affect the results of the remainder of the model simulation.

Figure 16. River Mile 66.30 Water surface elevation comparison



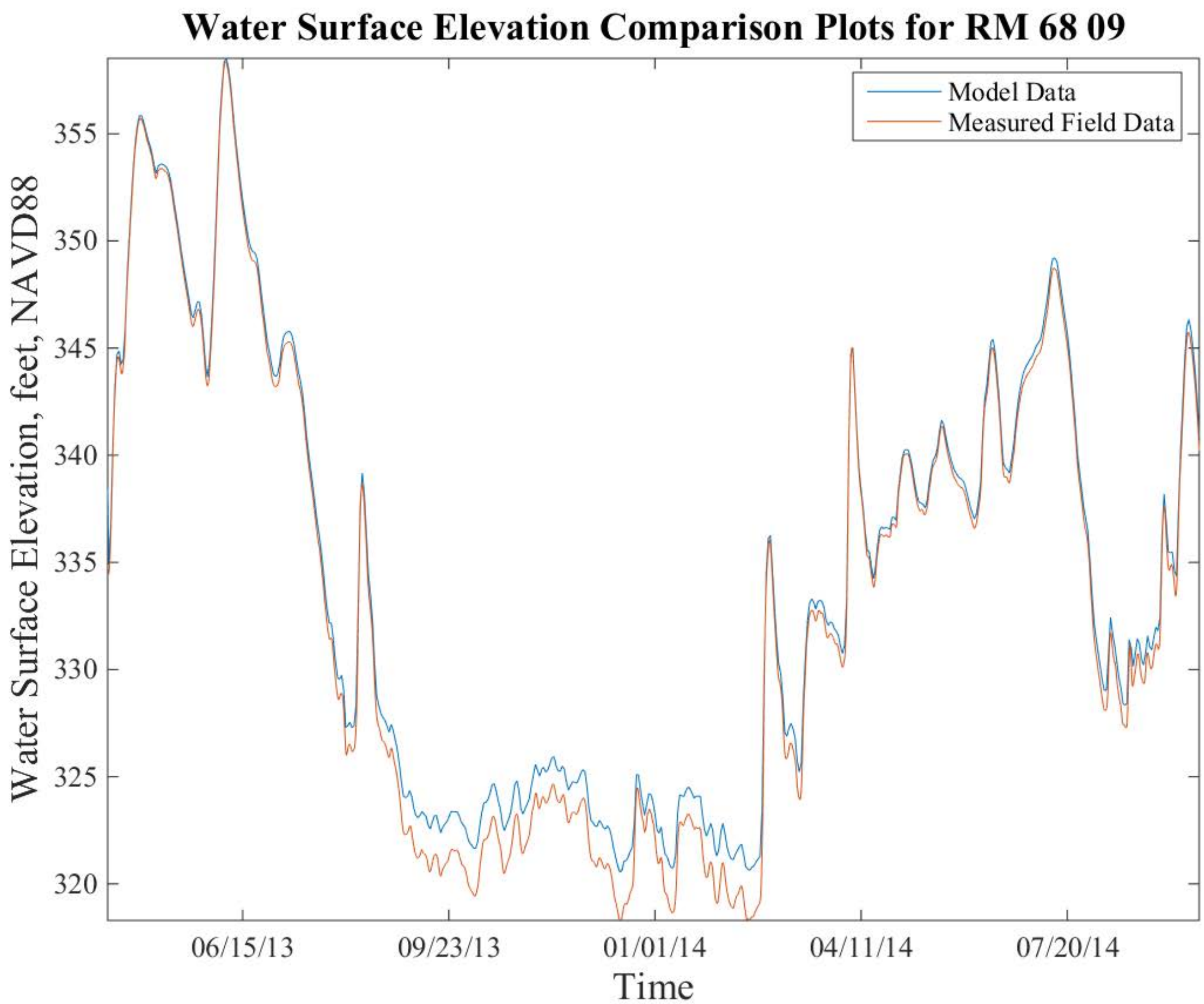
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot.

Figure 17. River Mile 66.30 Box Plot



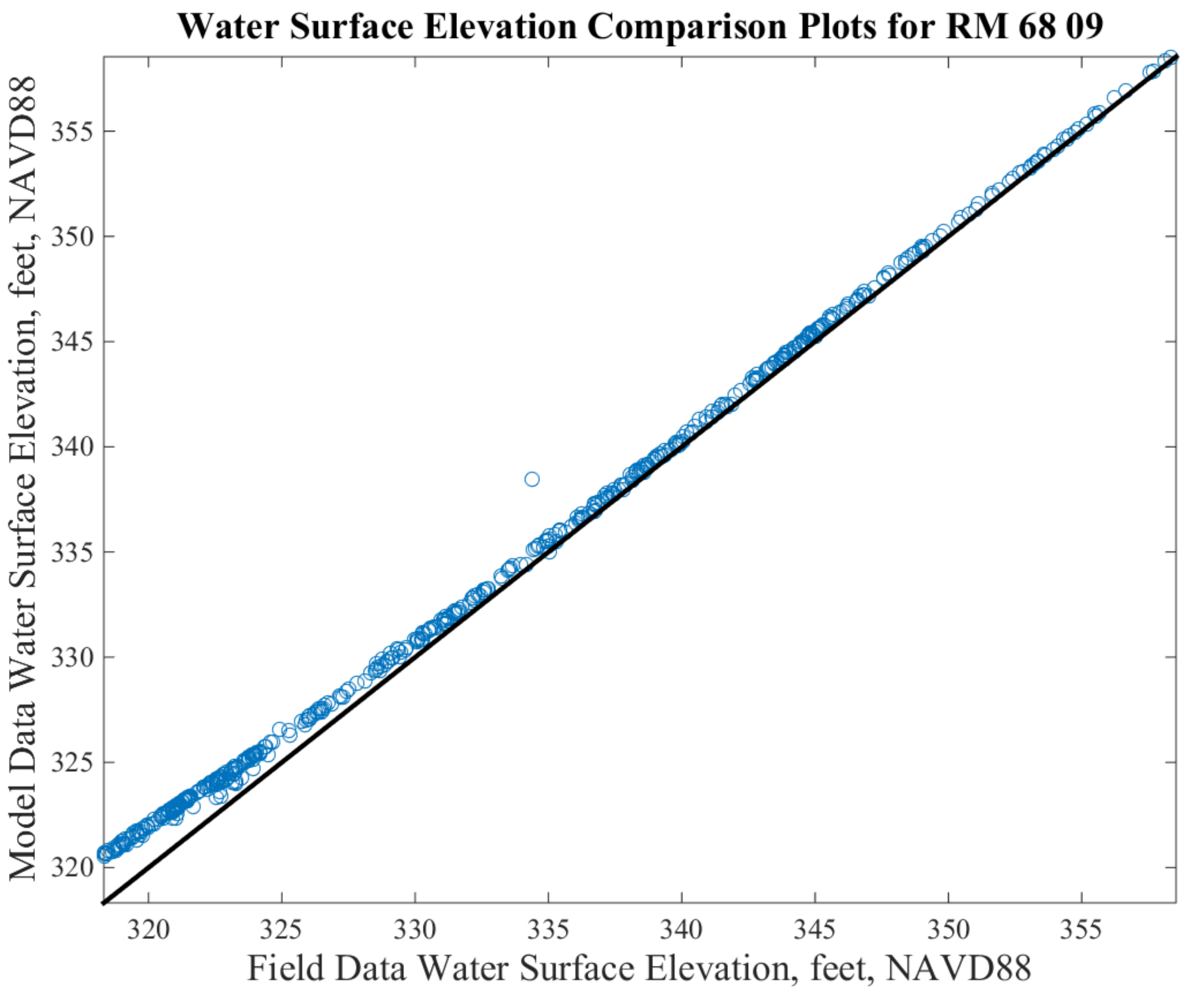
Note: the outlier at approximately model elevation 338 is caused by initial conditions and does not affect the results of the remainder of the model simulation.

Figure 18. River Mile 68.09 Water surface elevation comparison



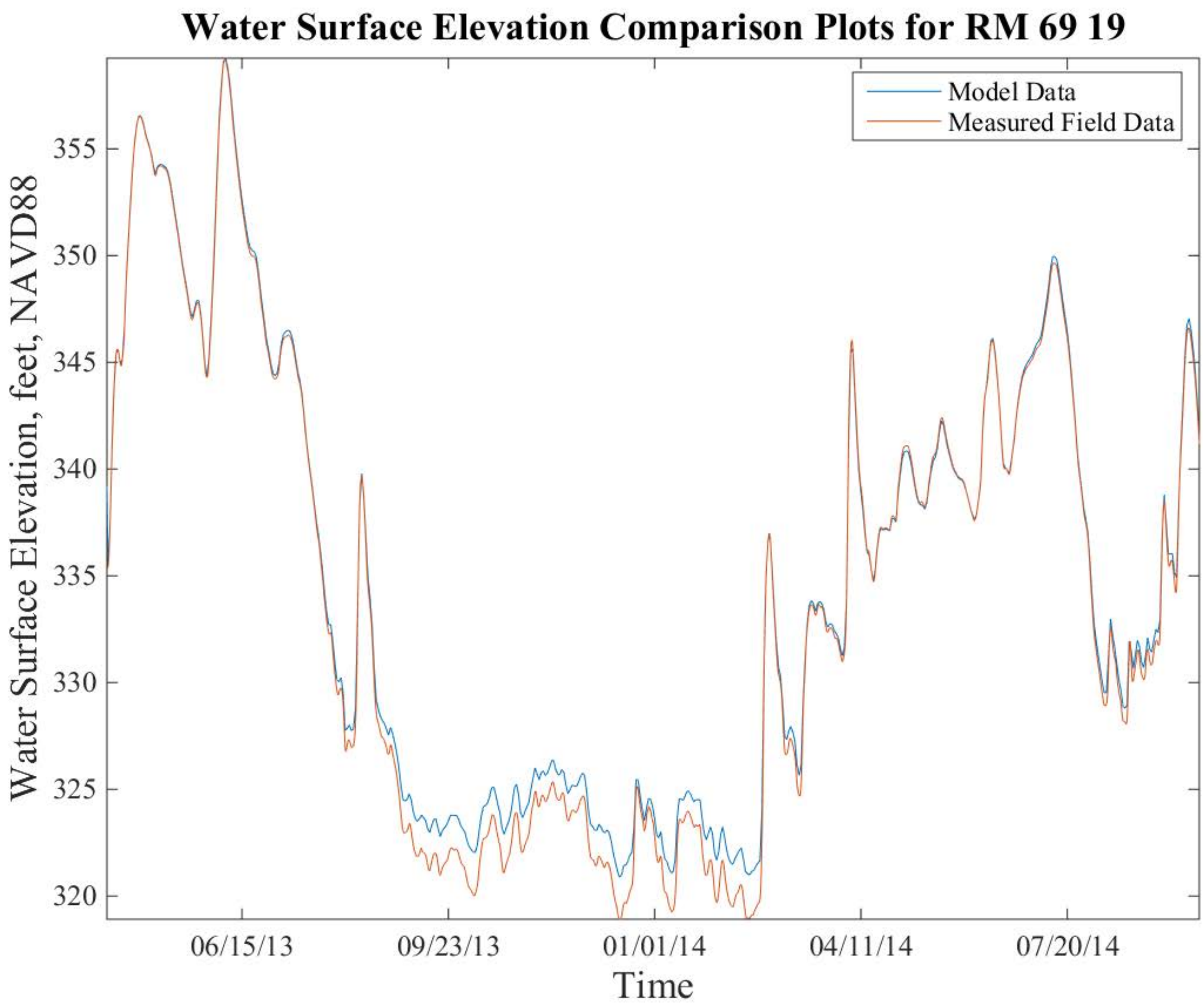
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 19. River Mile 68.09 Box Plot



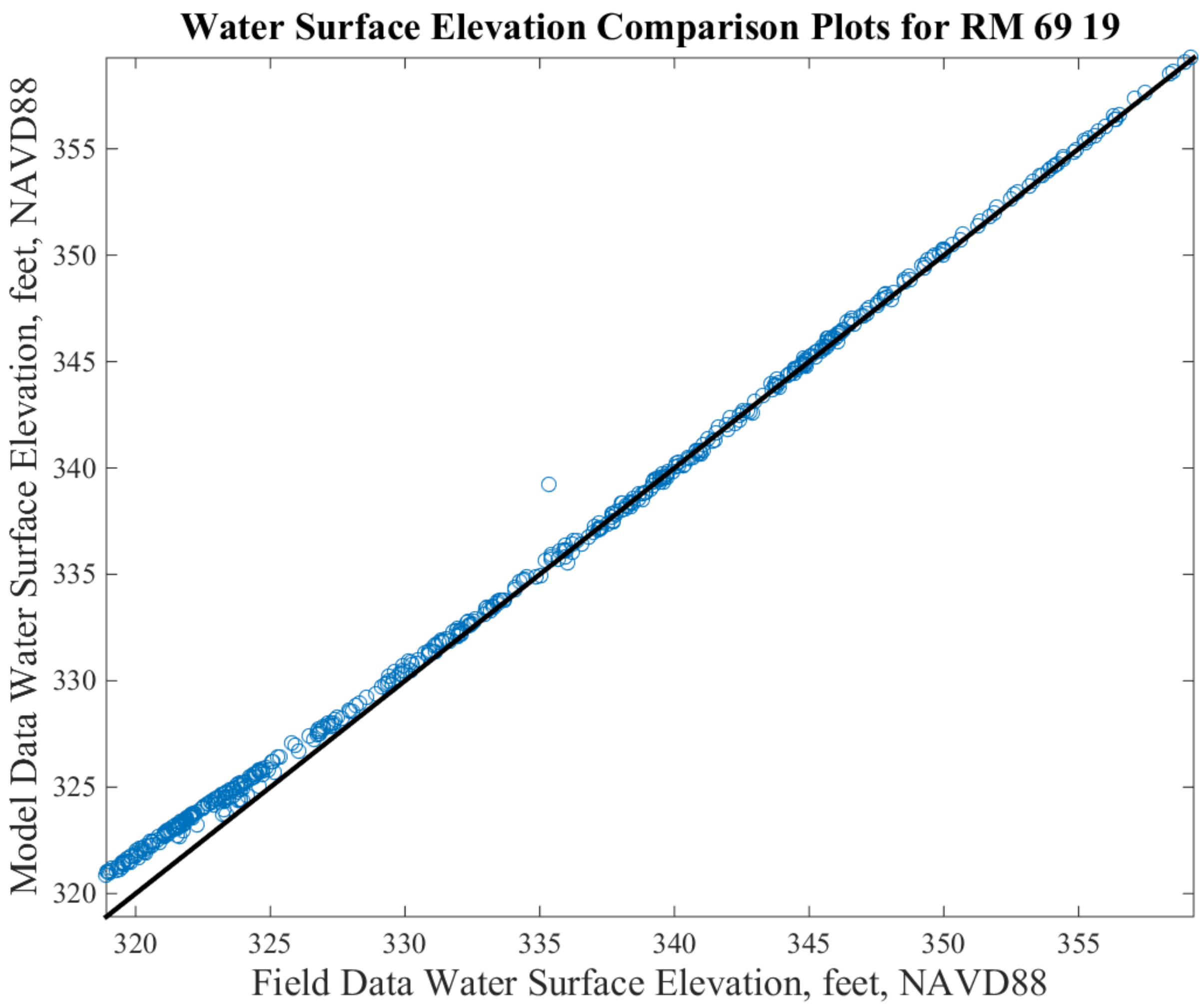
Note: the outlier at approximately model elevation 339 is caused by initial conditions and does not affect the results of the remainder of the model simulation. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 20. River Mile 69.19 Water surface elevation comparison



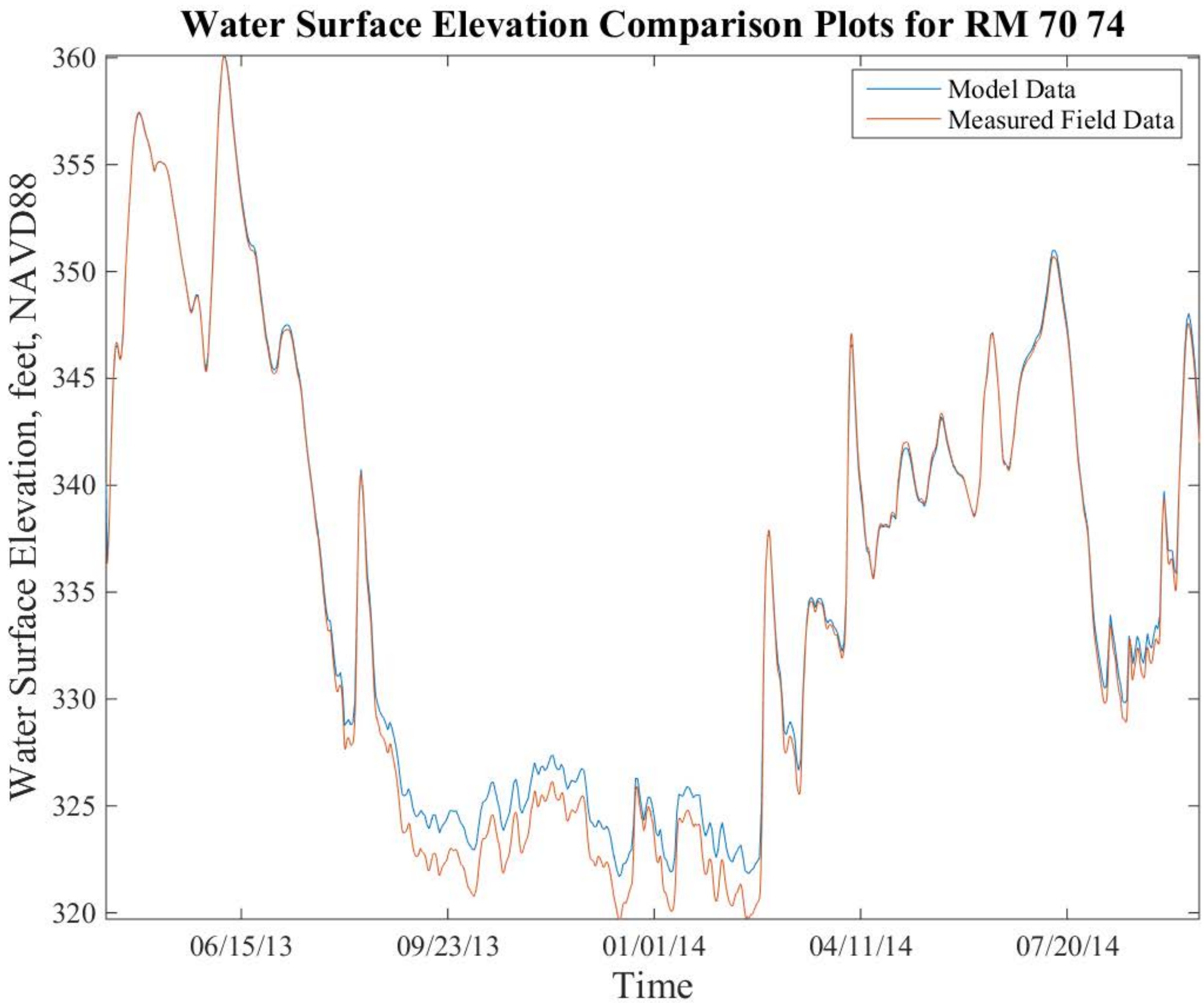
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 21. River Mile 69.19 Box Plot



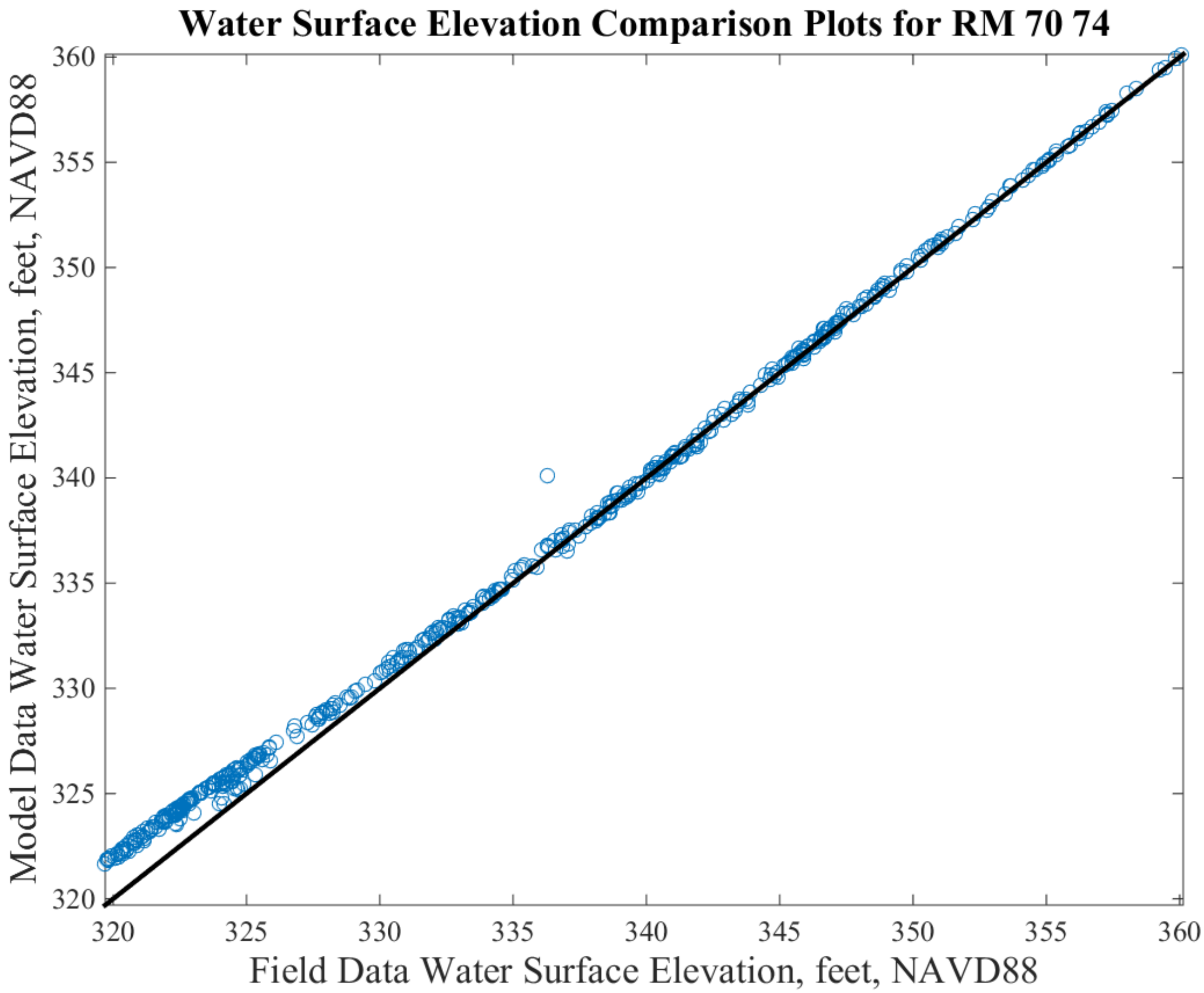
Note: the outlier at approximately model elevation 341 is caused by initial conditions and does not affect the results of the remainder of the model simulation. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 22. River Mile 70.74 Water surface elevation comparison



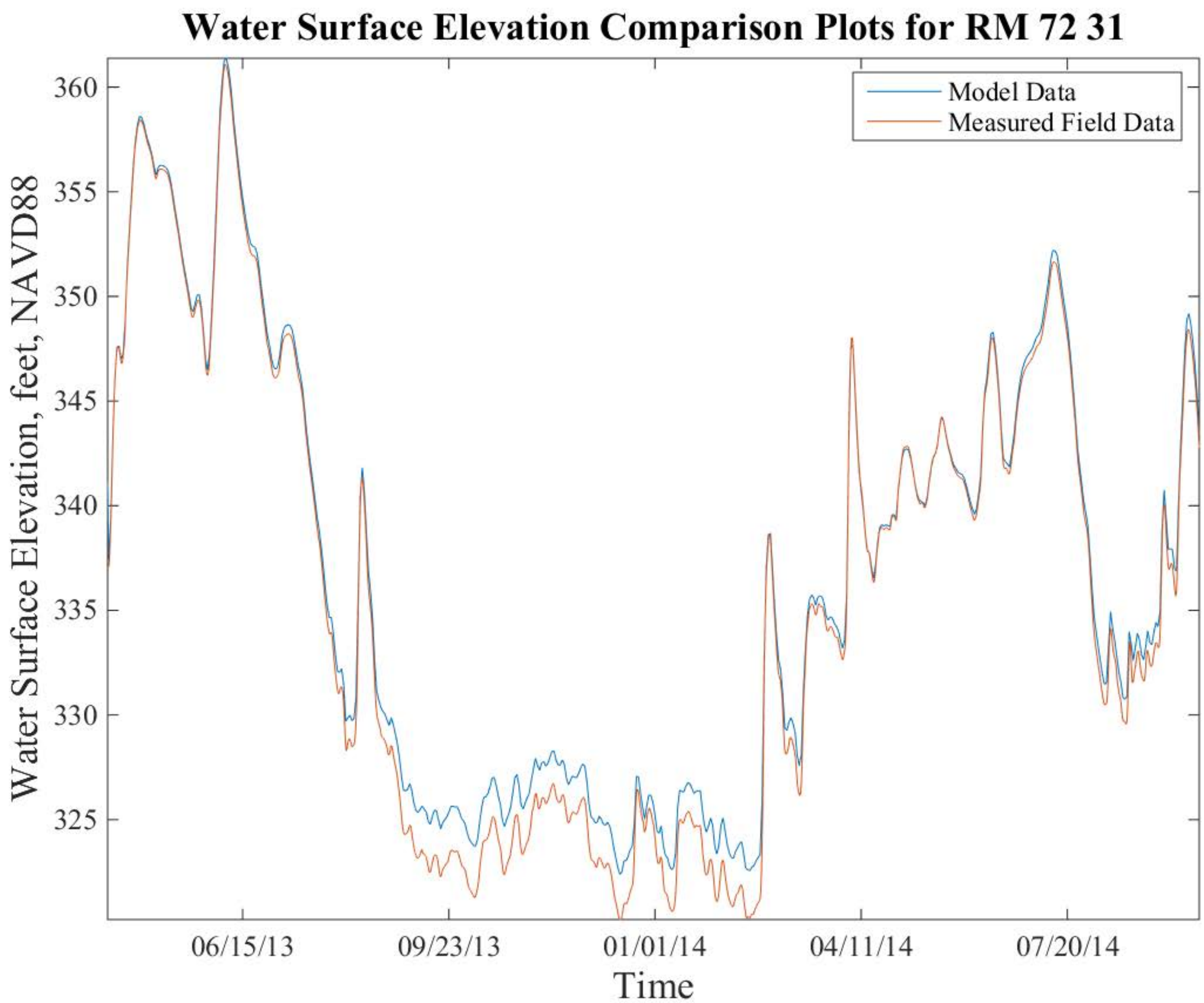
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 23. River Mile 70.74 Box Plot



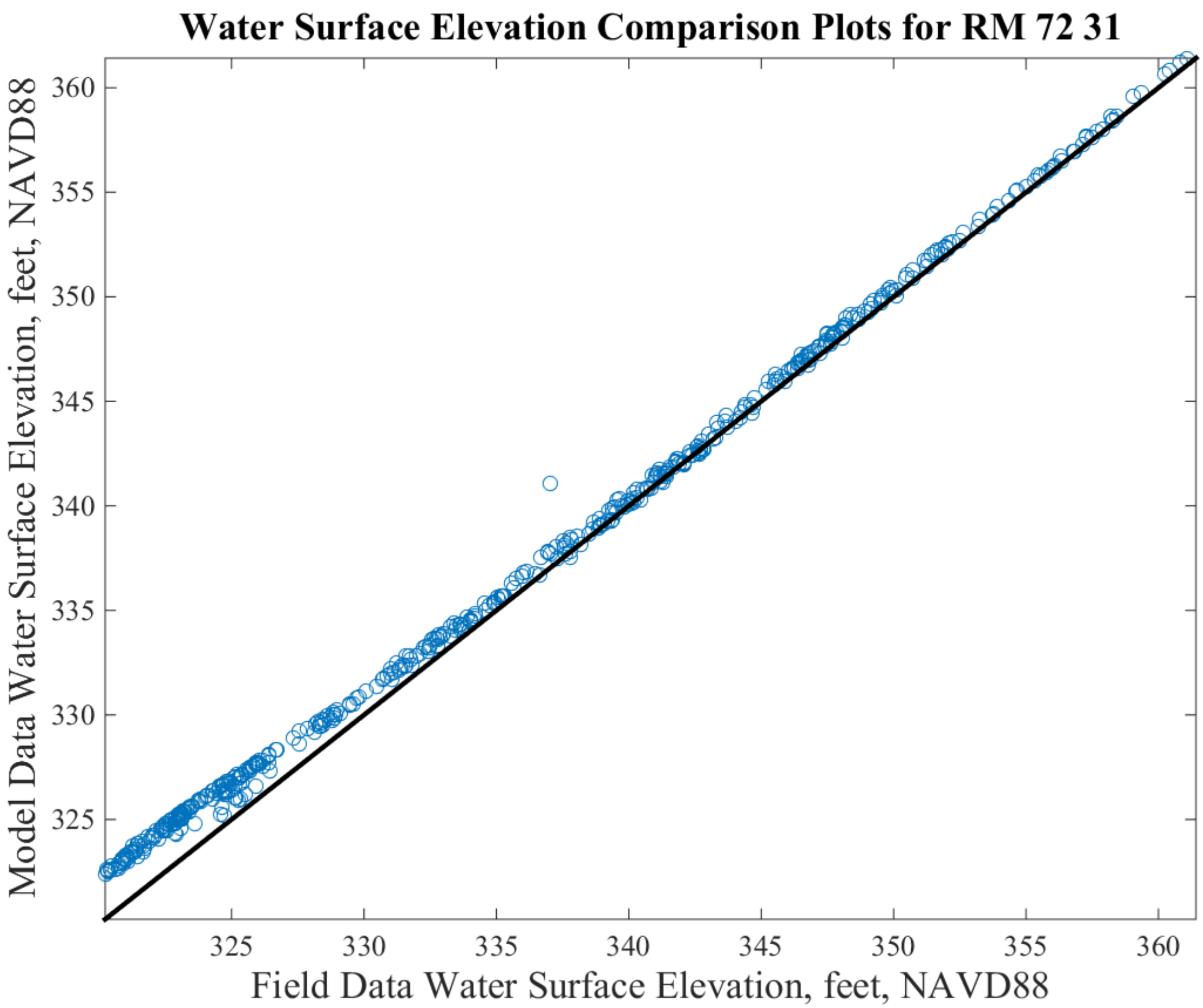
Note: the outlier at approximately model elevation 342 is caused by initial conditions and does not affect the results of the remainder of the model simulation. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 24.River Mile 72.31 Water surface elevation comparison



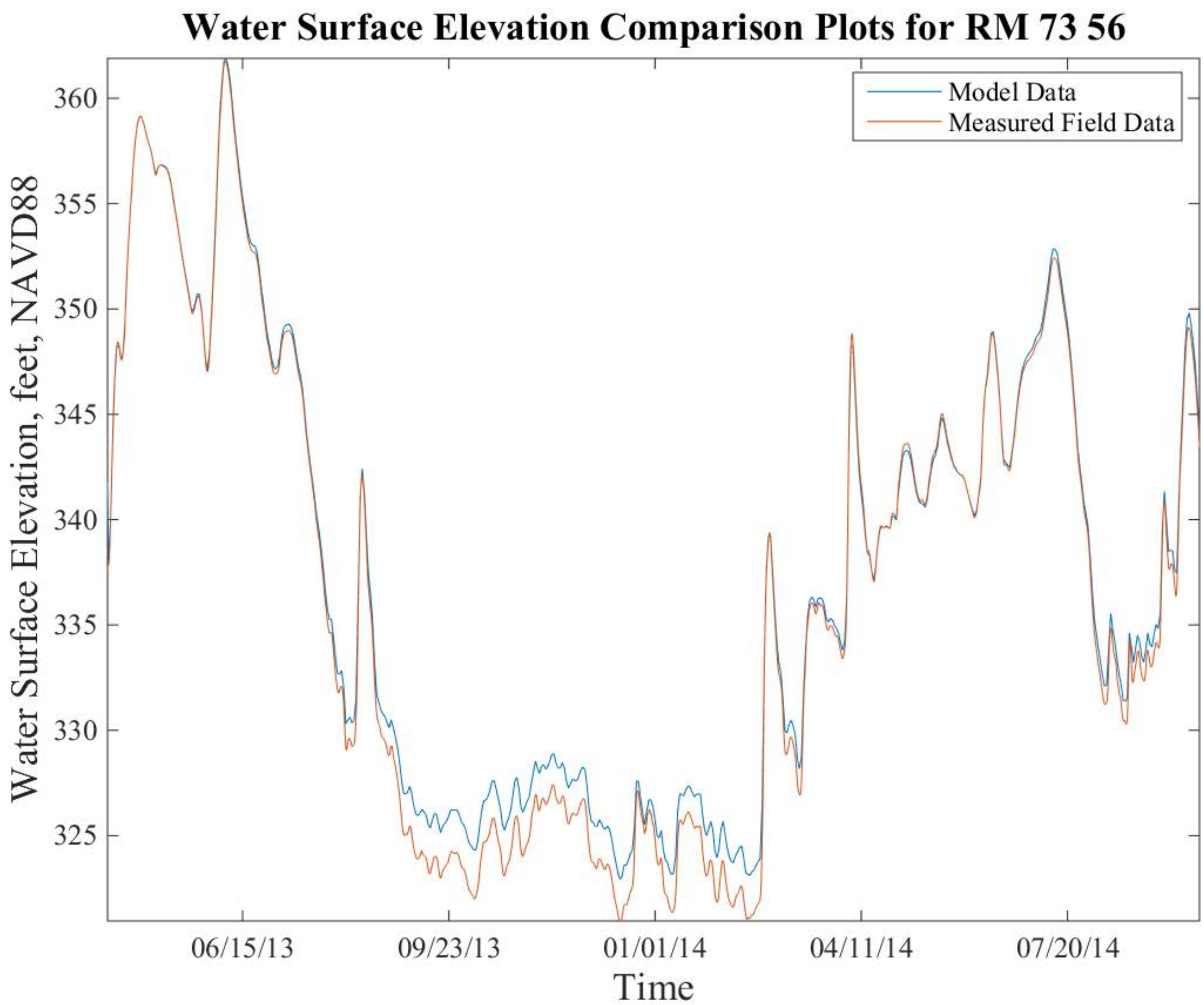
Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 25. River Mile 72.31 Box Plot



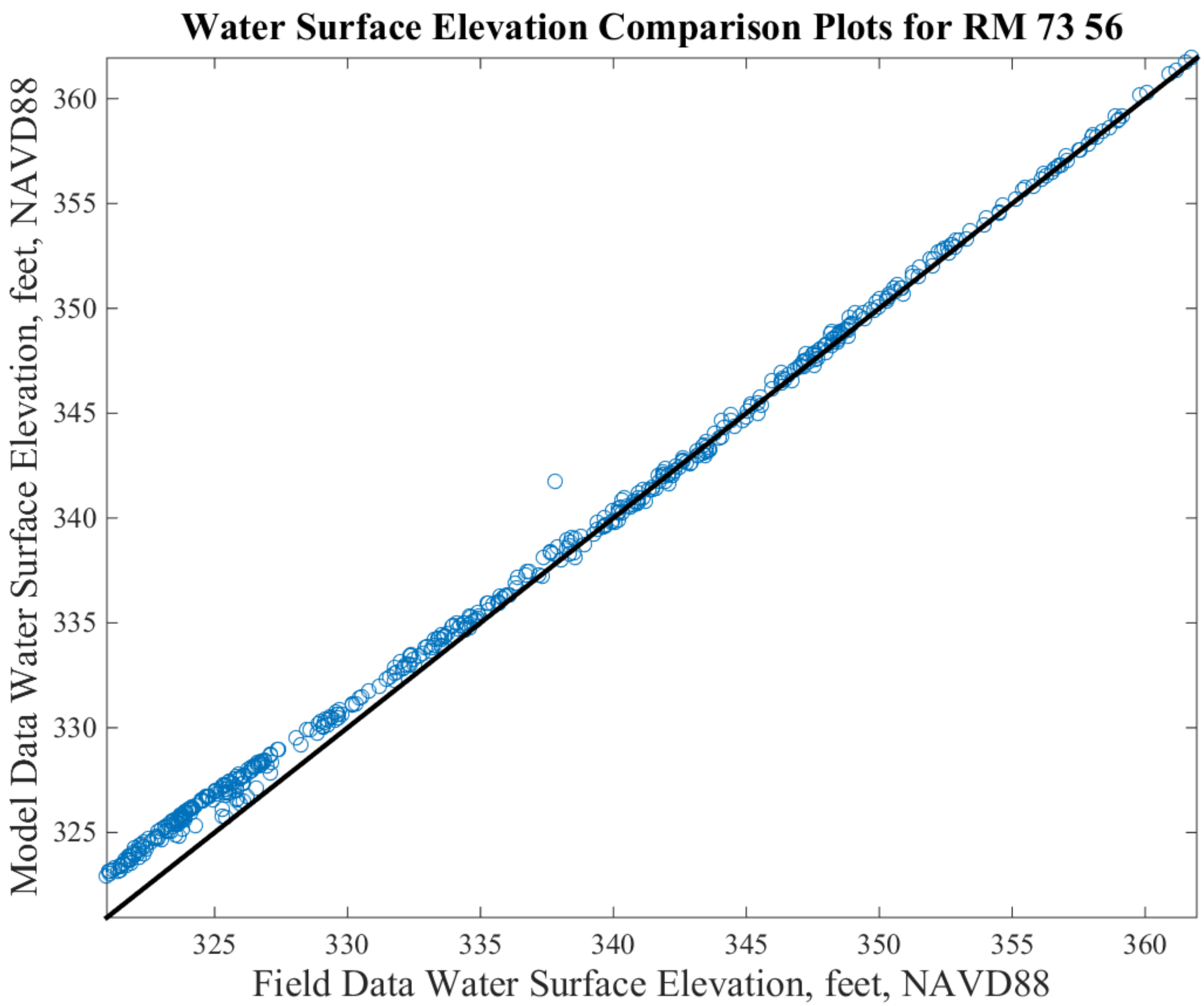
Note: the outlier at approximately model elevation 343 is caused by initial conditions and does not affect the results of the remainder of the model simulation. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 26. River Mile 73.56 Water surface elevation comparison



Note that the HEC-RAS model values are labeled Measured Field Data in figure. The AdH data is the model data represented in the plot. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

Figure 27. River Mile 73.56 Box Plot



Note: the outlier at approximately model elevation 343 is caused by initial conditions and does not affect the results of the remainder of the model simulation. There is some divergence in the lower elevations of the model, however it does not have an effect on the higher elevations which is the focus of the study.

2.2.4.2 Acoustic Doppler Current Profiler (ADCP)

Velocity fields within the study area were measured using Acoustic Doppler Current Profiler (ADCP). ADCP is a hydroacoustic current meter that uses the Doppler effect of sound waves to measure water current velocities throughout the water column. Velocities collected using ADCP were compared to calculated velocities to verify model calibration. To make a direct comparison, since AdH is a two dimensional model, depth average velocities were calculated from the ADCP data.

The ADCP data was collected in the study area on May 29, 2015. The flow on the day that the ADCP data was collected was 308,000 cfs at the Upstream Boundary with a water surface elevation of 338.2 feet NAVD88 as the Downstream Boundary. The AdH model was run with these boundary conditions to provide a direct comparison which could be used to evaluate how well the calculated velocities matched those observed in the field.

The ADCP data is displayed using arrows to denote the direction of the velocity. The ADCP is a validation to the water surface elevation calibration of the AdH model. The AdH model closely matches the ADCP data in both magnitude and direction in both the channels and around the structures in the river. Figure 28 below shows ADCP compared to AdH model in the area where s-dike structures will be placed. Figure 29 shows ADCP compared to the AdH model around one of the existing dike structures.

Figure 28. ADCP (top) compared to AdH Model Velocity (bottom) in the Proposed S-Dike Construction location.

Note: Background Photo is for imagery purposes only. The photo does not represent the conditions on the day the ADCP was taken.

Figure 29. ADCP (top) compared to AdH Model Velocity (bottom) near current structure.

Note: Background Photo is for imagery purposes only. The photo does not represent the conditions on the day the ADCP was taken.

3 AdH Simulation of Proposed Construction Alternative

3.1 Modeling Simulation

The AdH models for the base condition and the proposed construction alternative were run using the same boundary conditions and model parameters (viscosity, Manning's n, ERH, and URV values). This was done to ensure that the only changes were the structure changes and bathymetry response. The two comparisons were run using steady flow simulations using 1% Annual Chance of Exceedance (ACE) discharge of 949,011 cfs at the upstream end and elevation of 360.89 ft at the downstream end. The 1 percent annual chance exceedance was selected based on the concern for WSE impacts during flooding events.

3.2 Results

The proposed structures in the Vancill Towhead reach have no impact on water surfaces for a 1% of annual chance of exceedance (ACE) discharge of 949,011 cfs. Throughout the study reach, including upstream and along the banklines, the difference in water surface elevation between the base condition and the proposed construction alternative did not exceed 0.05 feet which is the accepted standard for 'no rise' by permitting agencies. A few isolated local areas adjacent to the proposed structures showed an increase in water surface that exceeded 0.05 feet which did not propagate upstream, downstream or laterally. Figure 30 below shows the water surface elevation comparison. The results of this AdH model study are consistent with previous analyses on the impact of river training structures on flood levels (USACE 2014, Huizinga 2009, Watson et al. 2013).

Velocity magnitude for the base condition and the proposed construction alternative is shown in figures 31 and 32. The purpose of the proposed structures is to change the sediment transport within the reach. In the near term, the constriction from the S-dikes causes scour in the main channel and along the bankline side of the structures. This results in a deeper navigation channel and the development of a sustainable side channel. As equilibrium is reached within the reach and the resulting channel dimensions are achieved, the increased velocities in the main channel return to values consistent with the pre-construction scenario (shown in figure 32) (Watson et al. 2009). Previous studies have shown that the cross sectional area of the resulting channel geometry and channel conveyance are similar or greater than the pre-construction scenario (Little et al. 2015).

Figure 30. WSE difference of proposed construction alternative and base condition

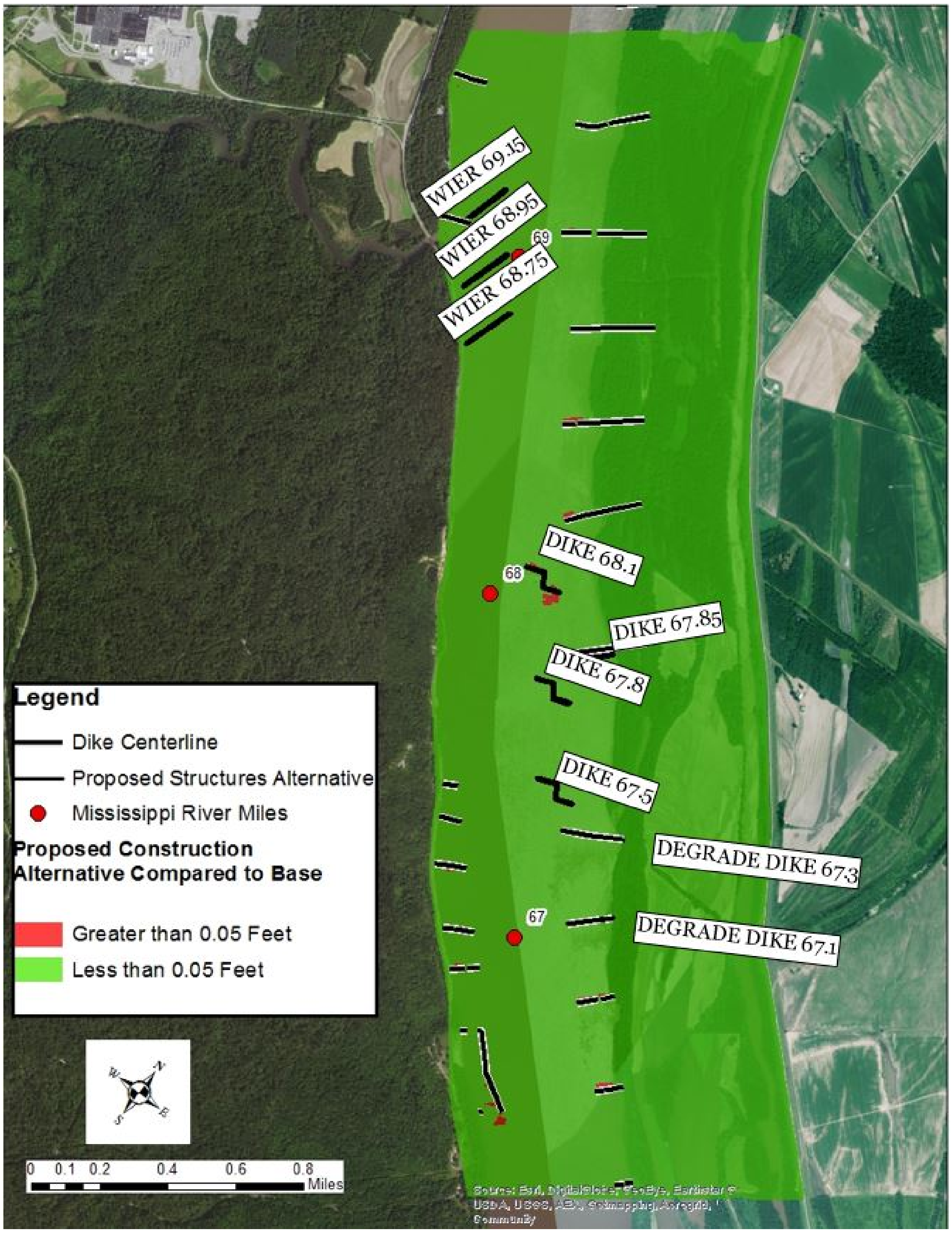


Figure 31. Base Condition Velocity.

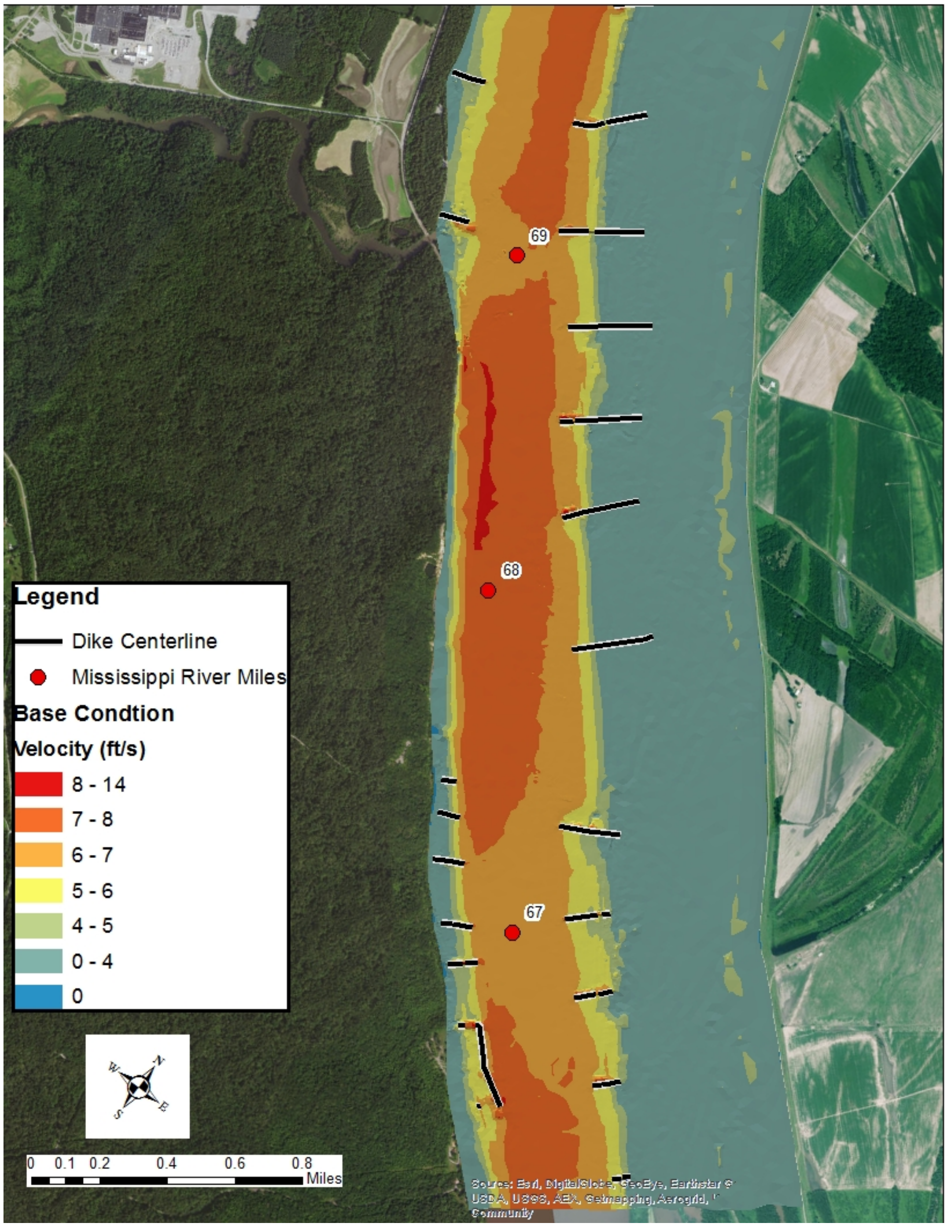
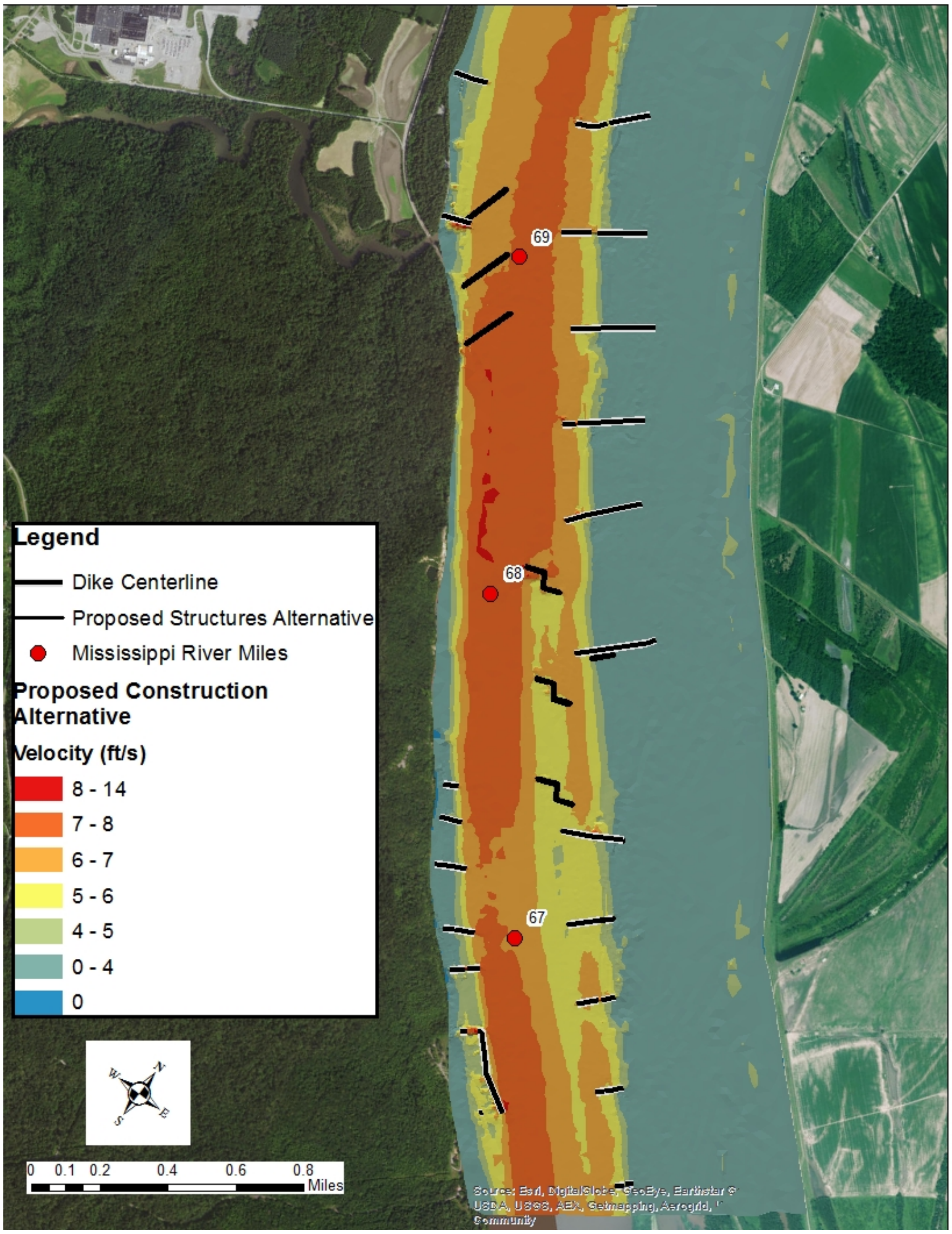


Figure 32. Proposed Construction Alternative Velocity.



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5 Acronyms

Name	Acronym
United States Army Corps of Engineers	USACE
Hydraulic Sediment Response	HSR
National Environmental Policy Act	NEPA
Adaptive Hydraulics	AdH
Surface Water Modeling System	SMS
River Mile	RM
Hydrologic Engineering Center River Analysis System	HEC-RAS
National Geodetic Vertical Datum of 1929	NGVD29
North American Vertical Datum of 1988	NAVD88
Light Detection and Ranging	LiDAR
National Elevation Dataset	NED
Right Descending Bank	RDB
Unsubmerged Rigid Vegetation	URV
Equivalent Roughness Height	ERH
2 Dimensional	2D
Water Surface Elevation	WSE
Engineering Research and Development Center	ERDC
High-Performance Computing	HPC

Air Force Research Laboratory	AFRL

HYDRODYNAMIC STUDY OF VANCILL TOWHEAD REACH ON THE MIDDLE MISSISSIPPI RIVER

COMPLETION OF AGENCY TECHNICAL REVIEW

The Agency Technical Review (ATR) was completed on the Hydrodynamic Study of Vancill Towhead reach on the Middle Mississippi River on March 1, 2016. The ATR was conducted to comply with the requirements of EC 1165-2-214. During the ATR, compliance with established policies, principles, and procedures, utilizing justified and valid assumptions, was verified. This included review of: assumptions, methods, procedures, and material used in analyses; the appropriateness of data used and level obtained; and reasonableness of the result, including whether the product meets the customer's needs consistent with the law and existing US Army Corps of Engineers policy. The ATR was accomplished by an independent team of Technical Specialist Hydraulic Engineers from outside of MVS. All comments resulting from the Agency Technical Review have been resolved and comments have been closed in DrChecks[sm].

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Aaron W. Buesing — Date
Hydraulic Engineer
Regional Technical Specialist
Agency Technical Review Team
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Appendix B. Biological Assessments and USFWS Coordination

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

Planning and Environmental Branch
Regional Planning and Environmental Division North
U.S. Army Corps of Engineers
St. Louis District
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December 2012

Introduction

This tier II biological assessment is being prepared specifically for the Grand Tower, Crawford Towhead and Vancill Towhead regulating works projects (Grand Tower Phase V rock contract). The purpose of this BA is to assess the specific effects of the proposed actions at these respective sites on endangered species that may occur in these respective river reaches and to comply with the requirements of the Reasonable and Prudent Measures and implementing terms and conditions provided in the 2000 Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. The work sites are located in the Middle Mississippi River Regional Corridor Reach 3 and 4, or the Stone Dike Alteration Report reaches 14 and 15 (Big Muddy and Trail of Tears respectively). Grand Tower is located in the MMRRC study's Crain's Reach (Assessment Reach 3), subarea Owl Creek (MRM 80.5-84.5). Crawford Towhead is located in the Big Muddy Reach (MRM 80-71). Vancill Towhead is located within the 8.5 mile Trail of Tears Reach (MRM 71-62.5). Crawford and Vancill towheads are located in the MMRRC's Hamburg Reach (Assessment Area 4).

Tier I of a two-tiered biological assessment for the Operation and Maintenance of the 9-Foot Navigation Channel on the UMRS was prepared by the U.S. Army Corps of Engineers in April 1999 (USACE 1999a). In April 2000, the U.S. Fish and Wildlife Service issued its Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the UMRS. The Service determined that the continued operation and maintenance of the project would jeopardize the continued existence of the pallid sturgeon (*Scaphirhynchus albus*) and the Higgins' eye pearly mussel (*Lampsilis higginsi*). Reasonable and prudent alternatives were provided, which would allow the continued operation and maintenance of the project while offsetting adverse impacts to the species and avoiding jeopardy. Incidental Take Statements with reasonable and prudent measures were also provided. In addition, the Service found that the project would result in incidental take for the least tern (*Sterna antillarum*) and the winged mapleleaf mussel (*Quadrula fragosa*). Incidental Take Statements with reasonable and prudent measures were provided. The Service also determined that the project would likely adversely affect the bald eagle (*Haliaeetus leucocephalus*) and the Indiana bat (*Myotis sodalis*). Incidental take was not anticipated for these species. The range of the gray bat (*Myotis grisescens*) also occurs in project area. However, this species was not discussed in the Biological Opinion (USFWS 2000).

Project Description

The Grand Tower project includes the construction of a dike at 80.6L. The Crawford Towhead project includes the construction of two chevrons and the extension of one dike between MRM 74 and72. The Vancill Towhead project is located between Mississippi River miles 70.0 and 67.0 and includes construction of 3 weirs, 3 diverter (S-Dike) dikes, repair of dike 67.8, shortening of dike 67.3 and the removal of one wing dike at RM 67.3 (generally alternative 33 of the Vancill Towhead hydraulic sediment response model study) (USACE 2012). Figure 1 is a location and vicinity map of the study reaches. Figures 2 through 5 show the proposed actions. Specifically, the projects would involve the following actions in order to attain the desired conditions:

Grand Tower		
Project Action	**Project Description**	**Rationale**
Construct Dike 80.6L	Construct a 500 ft. upstream angled dike to an elevation of 340 ft NGVD.	To reduce shoaling and dredging in this reach.

Crawford Towhead		
Project Action	**Project Description**	**Rationale**
Chevron 73.65L	Construct 300ft x 300ft chevron. Top elevation of the chevron will be +18.5 LWRP.	Needed to constrict the navigation channel.
Extend Dike 72.9L	Extend existing dike 300 feet. Top elevation of the chevron will be +18.5 LWRP.	Needed to maintain contraction width in the navigation channel.
Chevron 72.55L	Construct 300ft x 300ft chevron. Top elevation of the chevron will be +18.5 LWRP.	Needed to maintain contraction width in the navigation channel.

Vancill Towhead		
Project Action	**Project Description**	**Rationale**
Construct Weir 69.15L	Construct weir 800 feet long Top elevation of the weir will be -15 feet LWRP	Needed to increase the energy at Vancill Towhead (between RM 68.0 and RM 67.0)
Construct Weir 68.95L	Construct weir 800 feet long Top elevation of the weir will be -15 feet LWRP	Needed to increase the energy at Vancill Towhead (between RM 68.0 and RM 67.0)
Construct Weir 68.75L	Construct Weir 800 feet long Top elevation of the weir will be -15 feet LWRP	Need to increase the energy at Vancill Towhead (between RM 68.0 and RM 67.0)
Construct Diverter Dike 68.10L (S-Dike)	Construct Diverter Dike 750 feet long Top elevation of the dike will be +18 feet LWRP	Needed to create secondary side channel
Construct Diverter Dike 67.80L (S-Dike)	Construct Diverter Dike 750 feet long Top elevation of the dike will be +18 feet LWRP	Needed to create secondary side channel

Vancill Towhead		
Project Action	**Project Description**	**Rationale**
Construct Diverter Dike 67.50L (S-Dike)	Construct Diverter Dike 750 feet long Top elevation of the dike will be +18 feet LWRP	Needed to create secondary side channel
Remove Dike 67.30L o	Remove entire 950 feet of dike Top elevation of the dike will be +18 feet LWRP	Needed to connect the secondary side channel to the main channel
Repair Dike 67.80L	Restore Dike to 350 foot length Top elevation of the dike will be +18 feet LWRP	Needed to constrict the secondary side channel to the main channel
Shorten Dike 67.10L	Shorten dike 300 feet. Top elevation of the dike will be +18 feet LWRP	Needed to connect the secondary side channel to the main channel

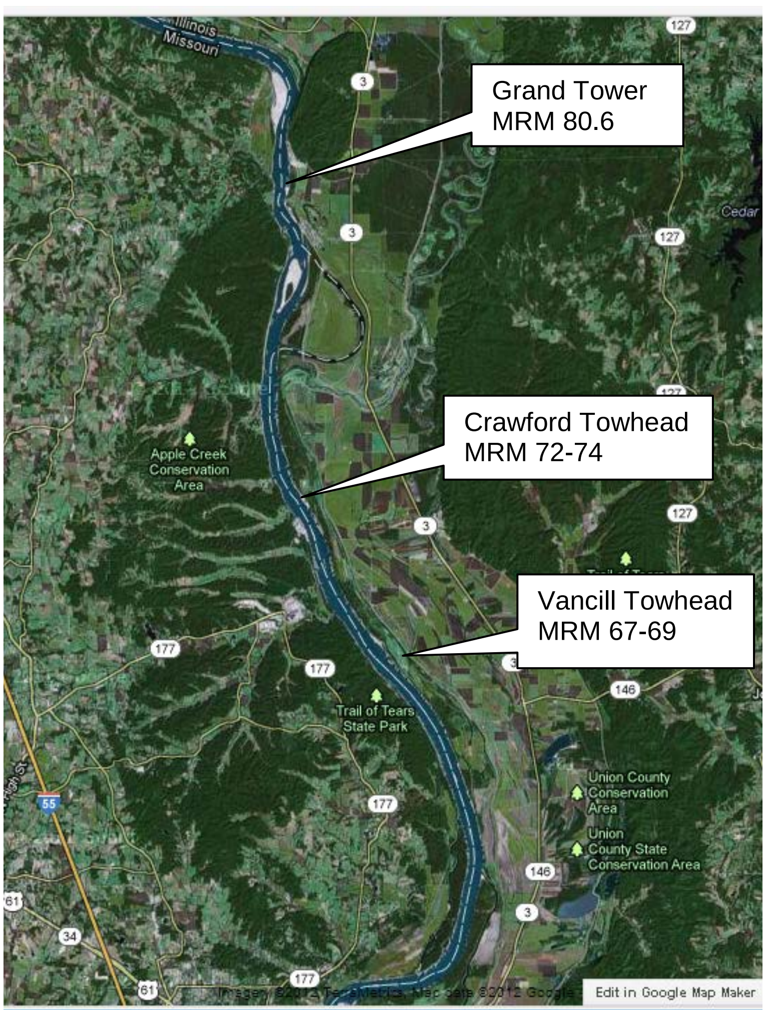

Figure 1 Project Locations

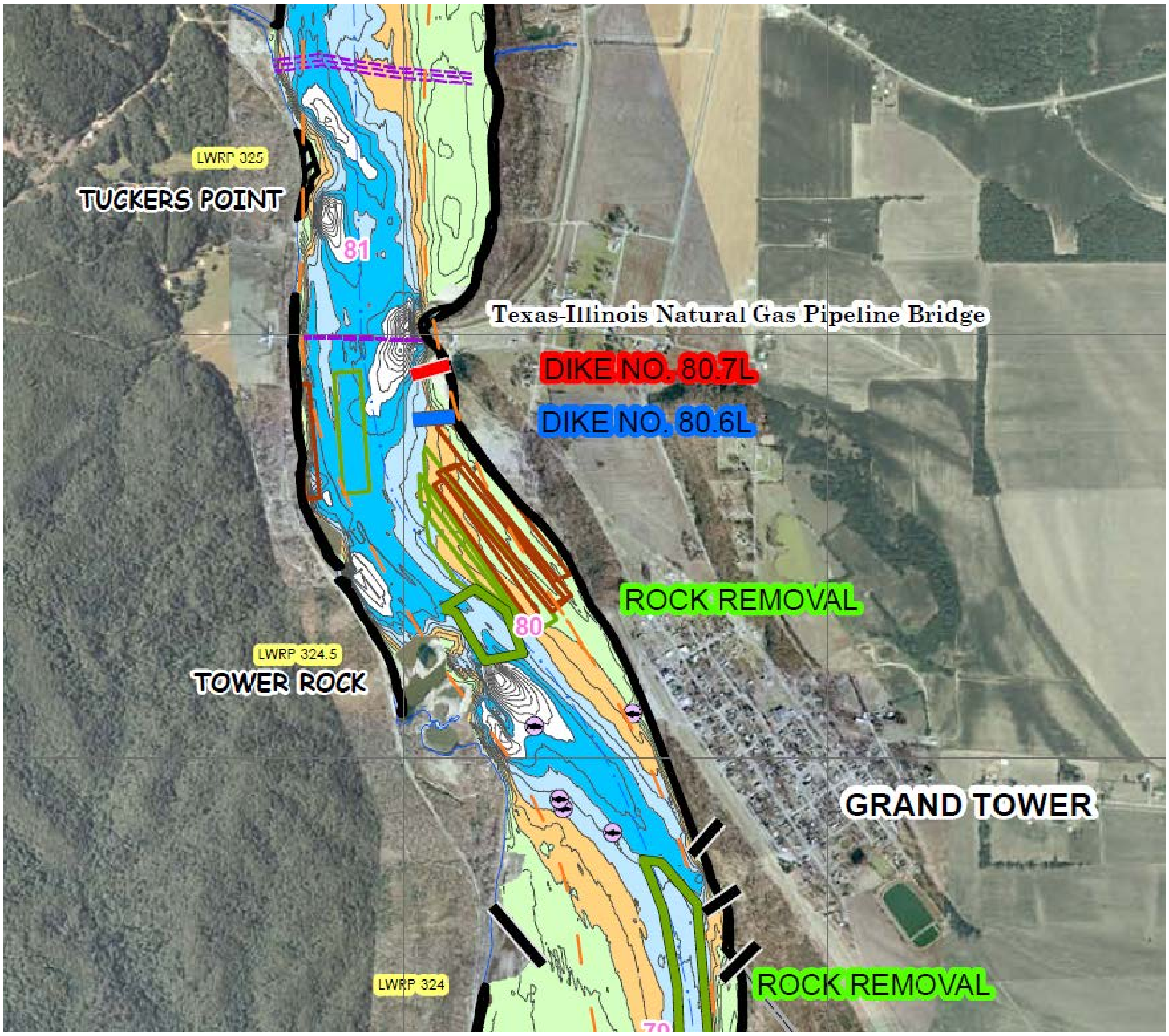

Figure 2 Grand Tower Dike 80.6L

Grand Tower Project Area Description

This project is located within a reach of the river that has been identified as important pallid sturgeon habitat due to the presence of crossover habitat and mid-channel bars. The dike location is just above Cottonwood Island which is recognized as important pallid sturgeon habitat.

The Missouri Department of Conservation requested in their FY 2009 coordination comments that proposed plans for dikes at 80.6L and 80.7L be left until last and should only be completed if absolutely necessary to alleviate the need to dredge this reach.

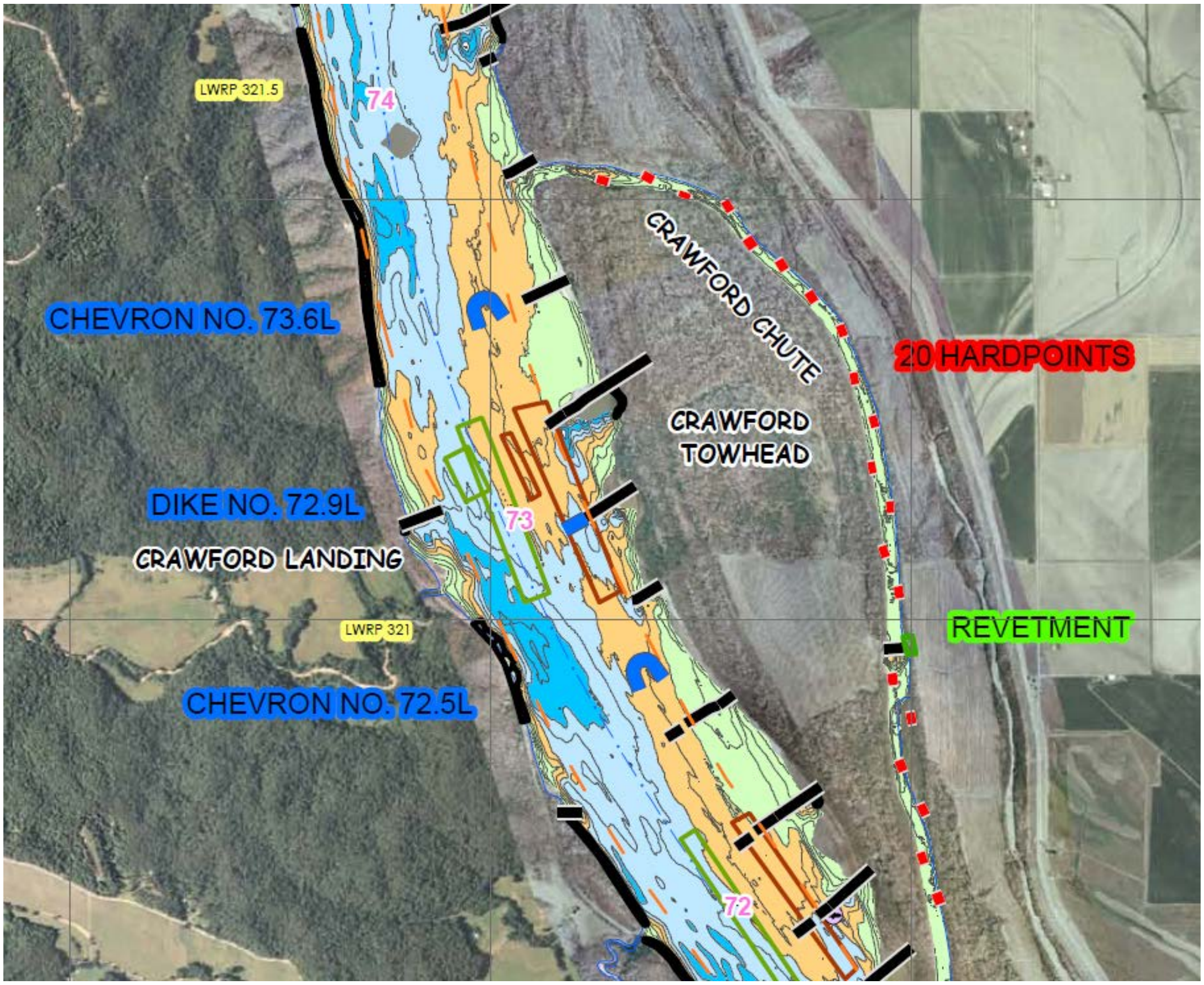

Figure 3 – Proposed Crawford Towhead Regulating Works Structures.

Crawford Towhead

The 2012 Stone Dike Alteration Report stated the opportunity for habitat improvement is rated as high for the LDB MRM 73 towhead chute. This Big Muddy dikes subarea (MRM 71-80) is foraging habitat for least terns and habitat for pallid sturgeon. There are pallid sturgeon locations at RM 69.5, 69.6, 69.8, 70.3, 71.8, 77.1, 78.2, 78.7, 79.5, and 79.8 especially around Cottonwood Island. Cottonwood Chute, including its substrate, is one of the most valuable habitat areas for the pallid sturgeon in the MMR.

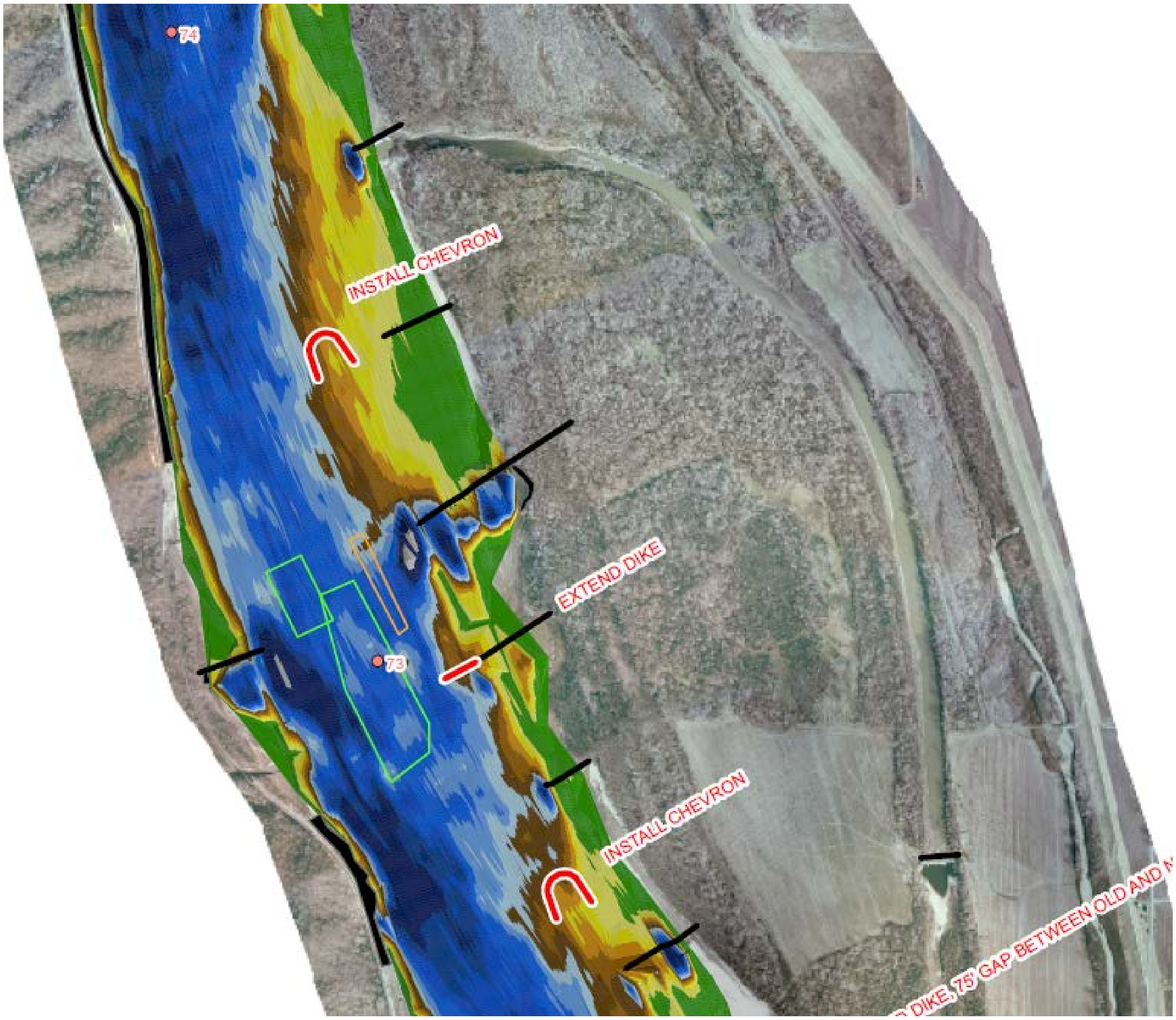

Figure 4 – Crawford Towhead – Shows Effects of Proposed Structures on Model Bathymetry

Vancill Towhead

The Vancill Towhead hydraulic sediment response study reach is bordered by Cape Girardeau County in Missouri and Union County in Illinois and includes a 7-mile stretch of the Mississippi River, between RM 72.00 to RM 65.00. Vancill Towhead, located along the left descending bank (LDB) of the Mississippi River between RM 67.60 to RM 67.30, covers an area of 11.4 acres.

Figure 5 is a 2010 aerial photograph illustrating the planform and nomenclature of the Middle Mississippi River between RM 72.00 and RM 65.00. Adjacent to Vancill Towhead, surveys show adequate navigation depths. However, in reality, the channel shoals considerably. The surveys reflect the channel being artificially maintained by dredging. Repetitive dredging location in the Vancill Towhead reach that is being addressed by this HSR model, between river mile RM 68.0 and RM 67.0 generally takes place in the middle of the river channel and disposal is generally along the left descending bank (LDB) side of the channel (Nguyen 2012).

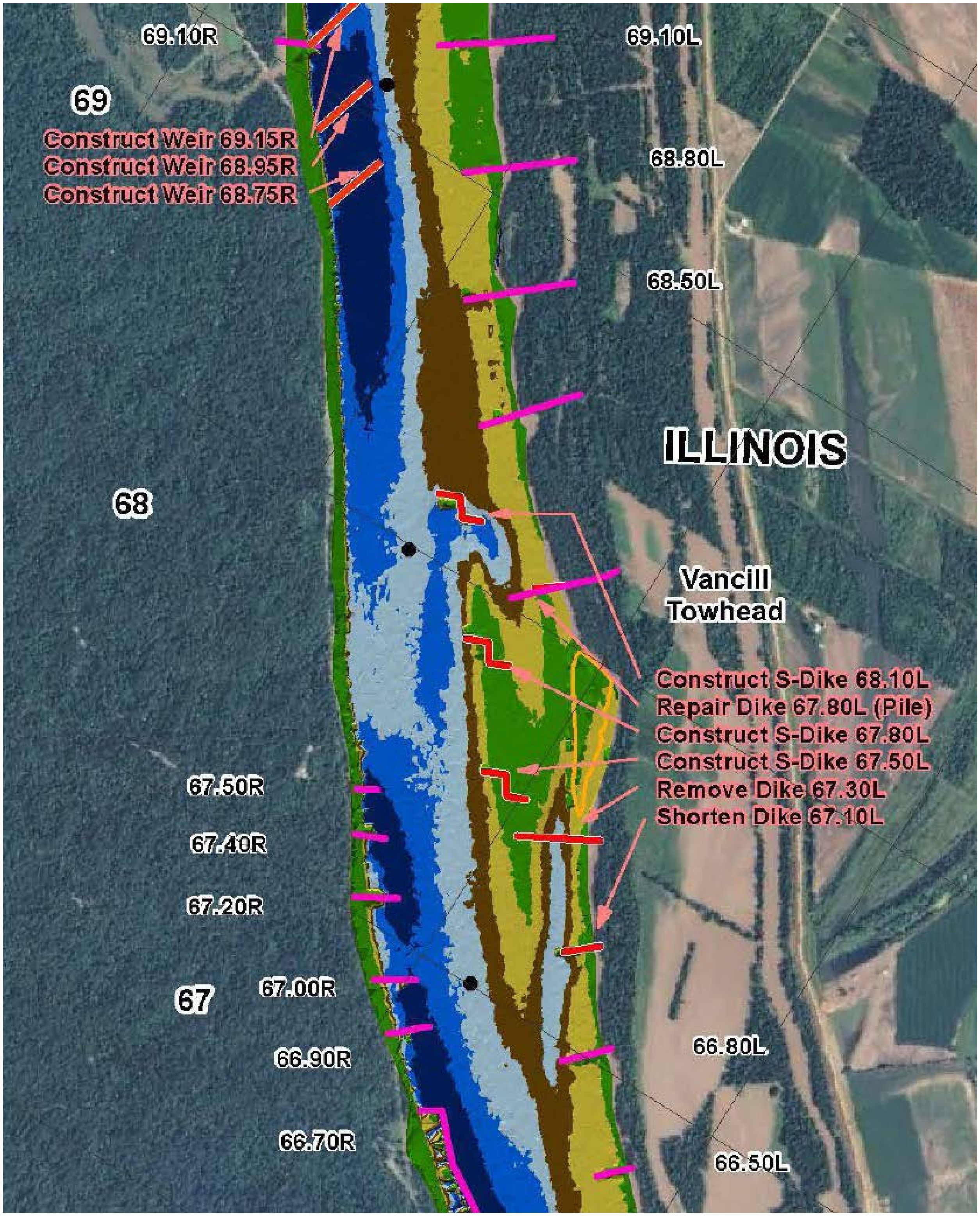

Figure 5 – Proposed Construction at Vancill Towhead: The graphic also shows the effects of the proposed project on channel bathymetry.

Phase V Construction

Construction of the projects will be accomplished during 2013 when there is sufficient water depth. Construction will include placing rock from a barge directly onto the river bank or substrate. For dike removal and shortening, the rock will be removed by backhoe and placed on a barge and relocated to a new site.

Phase V Operation and Maintenance

When necessary, damages to the rock structures may require additional rock. This will be accomplished in a method similar to construction, but the rock will be placed on an existing rock structure.

Phase V Conservation Measures

Construction of the diverter dikes and the modification of dikes at the entrance and exit of the Vancill Towhead side channel should increase flow, connectivity and habitat diversity within the side channel.

Species Covered in this Consultation:

The U.S. Fish and Wildlife Service's endangered species website was accessed on 4 December 2012 to determine what listed species may occur within the project area. Those species are included in Table 1.

Table 1 - Listed Species in Project Area (Cape Girardeau and Perry Counties, Missouri and Union and Jackson Counties, Illinois)

Species	Fed Status	Habitat
Indiana bat (*Myotis sodalis)*	Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: small stream corridors with well developed riparian woods; upland and bottomland forests. (Jackson, Union, Cape Girardeau, Perry)
Gray bat *(Myotis grisescens)*	Endangered	Caves and mines; rivers & reservoirs adjacent to forests. (Jackson)
Least tern (interior population) (*Sterna antillarum*)	Endangered	Large rivers - nest on bare alluvial and dredge spoil islands. (Jackson, Union, Cape Girardeau, Perry)
Pallid sturgeon (*Scaphirhynchus albus*)	Endangered	Mississippi and Missouri Rivers, (Jackson, Union, Cape Girardeau, Perry)
Grotto sculpin (*Cottus* sp.)	Proposed as Endangered	Cave and surface streams. (Perry)

Table 1 - Listed Species in Project Area (Cape Girardeau and Perry Counties, Missouri and Union and Jackson Counties, Illinois)		
Decurrent false aster (*Boltonia decurrens*)	Threatened	Disturbed alluvial soils. (Cape Girardeau)
Spectaclecase (*Cumberlandia monodonta*)	Endangered	Medium to large rivers with low to high gradients, and include shoals and riffles with slow to swift currents over coarse sand and gravel
Sheepnose (*Plethobasus cyphyus*)	Endangered	Shallow areas in larger rivers and streams. Bourbeuse, Gasconade (Osage Fork), Meramec, and Mississippi Rivers

Effects Analysis

The proposed project includes constructing bendway weirs, chevrons, and dikes.

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

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

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 September.

Modification measures resulting in aquatic habitat improvement should contribute to the species’ forage base. Wing dike alteration and construction is anticipated to be primarily performed by river-based equipment and has minimal potential to affect Indiana bats because forested habitats would not be affected. Additionally, creation of secondary channels and associated island or shallow water habitat and scour holes through dike notching and construction is expected to provide bathymetric diversity necessary to provide habitat for a range of aquatic species and life stages. Islands which become naturally reforested over time would be expected to contribute to long-term forest species diversity and structural diversity beneficial to forest-dwelling bats, including the Indiana bat (USFWS 2004).

This project would not result in the destruction of any riparian habitat and construction is generally scheduled to occur in the winter months when Indiana bats are not present. Thus, wing dike modification and the construction of weirs, “S” dikes and chevrons to create diverse aquatic habitats "may affect but is not likely to adversely affect" the Indiana bat.

Least Tern – The interior population of the least tern (*Sterna antillarum*) is characterized as a colonial, migratory waterbird, which resides and breeds along the Mississippi River during the spring and summer. Least 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 1999b). Sparsely vegetated portions of sandbars and islands are typical breeding, nesting, rearing, loafing, and roosting sites for least terns along the Middle Mississippi River (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 1999b). In alluvial rivers, sandbars are dynamic channel bedforms. Individual sandbars typically wax and wane over time as fluvial processes adjust channel geometry according to varying sediment load and discharge, the construction of river engineering works, and other influences. 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 1999b). A 1999 report (USACE 1999b) estimated that there were approximately 20,412 acres of non-vegetated sandbar habitat above the MMR low water reference point (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 at Marquette Island (RM 50.5), Bumgard Island (RM 30), and Brown’s Bar (RM 24.5-23.5) (USFWS 2004). Some nesting attempts have also been made at Ellis Island (RM 202), however these are not considered to be reoccurring.

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 1999b). 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 1999b). 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 1999b).

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

Wing dikes are prominent channel regulating features common in main channel habitats. They are used to concentrate flow in the main channel in order to reduce the need for dredging. Wing dams are usually constructed in groups called dike fields. These areas are depositional zones that often fill from the bank outward toward the channel. Notching dikes, lowering their profile, adding trails, or altering their angle to the channel are some actions that can be used to increase habitat diversity through the creation of new scour holes, sandbars, and flow refugia. When wing dike alteration is done on the dike field level, or in association with new structure placements, new side channels, islands, and off-channel areas can be created (USFWS 2004). This project involves constructing “S” dikes, weirs, chevrons and modifying dikes. Habitat diversity in the area should be increased by the creation of secondary channels. The weirs will reduce the possibility of point bar development and shallow feeding areas.

Thus, the project "may affect but is not likely to adversely affect" the least tern.

Pallid Sturgeon – 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 affecting 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). Additionally, some authors believe that loss of habitat contributes to the hybridization of pallid and shovelnose sturgeon (Carlson et al. 1985, Keenlyne et al. 1993, Campton et al. 1995, 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). Thus, as a result, previously aquatic habitats are now dry at low discharges (Wlosinski 1999). According to the Service, this has potentially reduced the availability of pallid sturgeon spawning habitat through the loss of habitat complexity (USFWS 2000).

As stated in the USFWS 2000 Biological Opinion "bendway weirs were developed to inhibit point-bar establishment in bends and channel crossings and to reduce the need for dredging in these areas. They consist of a series of submerged dikes (15 ft. below the LWRP) generally constructed around the outer edge of a river bend. In recent years, bendway weirs have also been utilized in other depositional areas in the MMR. Each dike is angled 30 degrees upstream of perpendicular to divert flow, in progression, towards the inner bank. The result is hydraulically controlled point bar development and reduced channel downcutting throughout the bend."

Also the 2000 USFWS Biological Opinion offers "In general terms, the results of various studies indicate that fish redistribute across the channel cross-section from the inside bank to the outside bank as a result of bendway weirs (USFWS 2000). This is most likely in response to increases in macroinvertebrate abundance (Ecological Specialists, Inc. 1997) and the low velocity fields that develop behind each weir. Bendway weirs also cause channel bottom aggradation along the outside bend, which may have some benefit by reducing water level fluctuations in adjacent side channels. This benefits pallid sturgeon by (1) increasing the availability of larval and juvenile rearing habitat; (2) increasing the availability of seasonal refugia; and (3) increasing substrate diversity, which influences macroinvertebrate production, thus, increasing the natural forage base of pallid sturgeon."

In addition, the 2000 USFWS Biological Opinion states "While the above beneficial effects of bendway weirs are noted, the effect of bendway weirs on inside bend point bar habitat is unclear." (USFWS 2000). As stated previously, bendway weirs control point bar development and are also being utilized to address other depositional areas. Bendway weirs also increase water velocities along the inside bend by redirecting channel flow. Shallow water, low slope, sandbar habitat is thought to be important to juvenile pallid sturgeon, and perhaps, other life stages. According to Sheehan et al. (1998) pallid sturgeon exhibited a positive selection for downstream island tips (depositional areas) in terms of habitat use versus availability. As existing sandbar habitat continues to accrete and revert to woody vegetation, aquatic sandbar habitat will continue to decline in quantity. Thus, bendway weirs likely reduce larval and juvenile rearing habitat and feeding habitat for all life stages." However, a study completed in 2011 by the St.Louis District Hydologic and Hydraulics Section entitled "*Analysis of the Effects of Bendway Weir Construction on Channel Cross-Sectional Geometry"* (USACE 2011) concluded that "The average slope decreased for 59 percent of all cross sections, with an average decrease of 1.27 ft. per 100 ft. The 10 ft vertical segment slopes were roughly even between decreases and increases, with ~70% of the slope changes falling with natural variation as defined by the study methodology. These results indicate the bendway weirs are largely achieving their primary goal of widening the navigable portion of the channel without a serious detrimental effect on the inside bar slope."

Wing dikes are prominent channel regulating features common in main channel habitats. They are used to concentrate flow in the main channel in order to reduce the need for dredging. Wing dams are usually constructed in groups called dike fields. These areas are depositional zones that often fill from the bank outward toward the channel. Notching dikes, lowering their profile, adding trails, or altering their angle to the channel are some actions that can be used to increase habitat diversity through the creation of new scour holes, sandbars, and flow refugia. When wing dike alteration is done on the dike field level, or in association with new structure placements, new side channels, islands, and off-channel areas can be created (USFWS 2004).

Wing dam and dike fields within the MMR are currently utilized by pallid sturgeon (Sheehan and Heidinger 2001, USACE 2005). Deep scour holes that develop in association with wing dams provide seasonal refugia, particularly during winter. Pallid sturgeon also utilize the sand bar habitat that accretes between wing dikes and chevron dikes. Although their preference for this habitat is poorly understood, at a minimum it is believed these areas provide important foraging habitat (USFWS 2004). Though outside the project area, the Carterville Fisheries Research Office recently collected juvenile sturgeon in high concentrations over the flooded sandbar on the western shore of Rockwood Island between RM 102 and 101. Juvenile sturgeon were also collected from Liberty Chute below the rock closing structure at RM 101.1, and juvenile shovelnose were collected within Liberty Chute (USACE 2005). Juvenile sturgeon were also collected over flooded portions of the Mile 100 Islands during the spring of 2005 (USACE 2005). While the 2000 Biological Opinion RPA identified modification of channel training structures as a medium priority for pallid sturgeon, wing dam/dike alterations are critical to improving habitat diversity in the MMR for a wide range of species (USFWS 2004).

Thus, "S" dike construction and dike modifications should result in the diversification of aquatic habitats, including formation of secondary channels and shallow water habitats beneficial to the pallid sturgeon. The rock dike substrate provides habitat for epilithic macroinvertebrates that are capable of colonizing in very high densities and providing an important food source for fish (USFWS 2000).

Construction activities may result in short-term adverse effects for pallid sturgeon. Activities that impact any existing deepwater habitat may result in displacement of pallid sturgeon. Disruption of existing sand bar habitat may impact foraging habitat. However, these adverse effects are expected to occur at a local, individual dike scale. The creation of scour holes and side channel and associated island or shallow water habitat through dike construction is expected to create additional larval/juvenile rearing habitat and seasonal refugia, and improve forage food production (USFWS 2004).

The 2012 Stone Dike Alteration study noted that the Vancill study reach includes known foraging habitat for least terns and habitat for pallid sturgeon. There are known pallid sturgeon locations at RM 70.5L, 70.3R, 69.8L, 69.5L, 62.8 and 63.2. In the pre-HSR study discussion, the US Fish and Wildlife Service (USFWS) stated that in the reach being studied, there was a gravel bar along the right descending bank (RDB) at river mile RM 70.3. He also noted that some pallid sturgeon were found at the downstream end of the Vancill Towhead bar (Corps 2012).

It is the position of the St. Louis District that short-term adverse impacts that may occur are limited, and the long-term impacts associated with reduced dredging and increased habitat diversity, which is expected as a consequence of river training structure modification and weir placement, are predicted to be beneficial to pallid sturgeon. Thus, this project should result in the diversification of aquatic habitats, including formation of secondary channels and shallow water habitats beneficial to fish in general. Thus the project "may affect but is not likely to adversely affect" the pallid sturgeon.

Decurrent false aster – The decurrent false aster is presently known from scattered floodplain localities from the confluence of the Mississippi River with the Illinois River south to Madison County, Illinois (USFWS 1990a). Its natural habitat was lake shores and stream banks with abundant light. Populations presently grow in natural habitat, but are more common in disturbed lowland areas where they appear to be dependent on human activity for survival (USFWS 1990). Because this species is not known to occur in the project area, the project "may affect, but is not likely to adversely affect" the decurrent false aster.

Sheepnose mussel – The sheepnose is listed as a federally endangered species and occurs in the Meramec River in Jefferson, Missouri. 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) and 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 project could potentially benefit this species by providing some of its necessary habitat features, i.e. shallow shoal habitats and flow refugia. This project "may affect, but not likely to adversely affect the sheepnose mussel.

Spectaclecase – 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 any nearby locations. The proposed construction "may affect, but is not likely to adversely affect" the spectaclecase mussel.

Grotto sculpin - The **grotto sculpin** (*Cottus* sp.) is a candidate species that is found in cave streams. No cave streams will be impacted by this project; therefore, this project will have "no effect" on this species.

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United States Department of the Interior

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February 22, 2013

Colonel Christopher G. Hall
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103-2833

Attn: Francis Walton

Dear Colonel Hall:

Thank you for your letter dated December 20, 2012, requesting review of the Tier II Biological Assessment (BA) prepared for the Grand Tower, Crawford Towhead, and Vancill Towhead Regulating Works Projects. The Grand Tower Regulating Works Project was previously coordinated in a Tier II BA dated August 8, 2005, and in a response letter from the Service dated September 8, 2005, thus that project will not be addressed in this letter. The Crawford Towhead Regulating Works Project was partially addressed by a Tier II BA dated October 1, 2009, and in a subsequent response letter from the Service dated May 20, 2010. The Service recommends that a separate BA be developed to address the remaining portion of the Crawford Towhead Regulating Works Project. The remainder of this letter addresses the Vancill Towhead Regulating Works Project located in Union County, Illinois and Cape Girardeau County, Missouri.

The proposed Vancil Towhead project involves construction of 3 weirs, 3 diverter (S-Dike) dikes, repair of a dike, shortening of a dike, and the removal of one wing dike between approximate Upper Mississippi River miles 67.0 and 70.0. The Tier II Biological Assessment for this project was prepared in order to comply with the requirements of the 2000 Biological Opinion for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. The 2000 Biological Opinion was prepared as a result of the programmatic consultation under Section 7 of the Endangered Species Act of 1973, as amended, which evaluated the effects of operation and maintenance of the 9-foot navigation channel on federally listed threatened and endangered species.

The Tier II Biological Assessment evaluated the impacts of the proposed project on the endangered gray bat (*Myotis grisescens*), endangered Indiana bat (*Myotis sodalis*), endangered least tern (*Sterna antillarum*), endangered pallid sturgeon (*Scaphirhynchus albus*), endangered spectaclecase mussel (*Cumberlandia monodonta*), endangered sheepnose mussel (*Plethobasus cyphyus*), threatened decurrent false aster (*Boltonia decurrens*), and proposed as endangered grotto sculpin (*Cottus sp.*). The Corps had determined that the proposed project will have no effect on the gray bat and grotto sculpin. This precludes the need for further action on this project as required under Section 7 of the Endangered Species Act of 1973, as amended, for the gray bat and grotto sculpin. The Corps has determined that the proposed project is not likely to adversely affect the Indiana bat, least tern, spectaclecase mussel, sheepnose mussel, and decurrent false aster. Based on the location and description of the proposed project, the Service concurs that the proposed project is not likely to adversely affect the Indiana bat, least tern, spectaclecase mussel, sheepnose mussel, and decurrent false aster.

The purpose of constructing the proposed project is to inhibit point-bar establishment and eliminate channel crossings, thus reducing the need for channel maintenance dredging. Our concern is that the proposed construction is likely to reduce/remove habitats utilized by larval and juvenile pallid sturgeon. Information in the BA indicates that the construction of "S" dikes and dike modifications is expected to form secondary channels and shallow water habitat that will provide additional larval/juvenile rearing habitat and seasonal refugia, and improve forage food production which should result in long-term beneficial effects for pallid sturgeon. Thus, the Corps has determined that the proposed project is not likely to adversely affect the pallid sturgeon. It is unclear to the Service whether these river training structure modifications (with resulting hydro-geomorphologic changes) and the reduction in channel maintenance dredging can fully compensate for the project impacts. Thus, the Service does not concur that the proposed project is not likely to adversely affect the pallid sturgeon. However, the Service concurs that the proposed project, as designed, meets the requirements of the Reasonable and Prudent Measures with implementing Terms and Conditions described in the 2000 Biological Opinion. Should this project be modified, or new information indicate listed or proposed species may be affected, consultation or additional coordination with this office, as appropriate, should be initiated.

An additional concern with the proposed project is that it falls within the "control" reach for the Navigation and Ecosystem Sustainability Program (NESP), Herculaneum Side Channel Restoration Project. Due to the limited funding for NESP, discussion has occurred about utilizing the Herculaneum reach as a "control" reach for this project. The Service recommends that a monitoring plan be developed to evaluate this project and utilize data previously collected for the Herculaneum Side Channel Restoration Project.

Thank you for the opportunity to provide comment on the Tier II Biological Assessment. For additional coordination, please contact me at (618) 997-3344, ext. 345.

Sincerely,

/s/ Matthew T. Mangan

Matthew T. Mangan
Biologist in Charge

cc: IDNR (Atwood)
MDC (Herzog, Sternburg)

TIER II BIOLOGICAL ASSESSMENT
CRAWFORD TOWHEAD
MRM 74 – 72
UNION COUNTY, ILLINOIS
CAPE GIRARDEAU COUNTY, MISSOURI
ON THE
MIDDLE MISSISSIPPI RIVER SYSTEM

Planning and Environmental Branch
Regional Planning and Environmental Division North
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August 2013

TIER II BIOLOGICAL ASSESSMENT
CRAWFORD TOWHEAD
MRM 74 - 72
UNION COUNTY, ILLINOIS
CAPE GIRARDEAU 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 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 Crawford Towhead project requires a Tier II consultation.

2. Project Authority

The project is authorized under the Regulating Works Project that was authorized by the River and Harbor Acts of 1910, 1927, and 1930. The project provides a safe and dependable navigation channel. It consists of a navigation channel 9-feet deep and not less than 300 feet wide with additional width in the bends, from the mouth of the Ohio River to the mouth of the Missouri River, a distance of approximately 195 miles. Project improvements are achieved by means of dikes, revetment, construction dredging, and rock removal. Crawford Towhead is located in the Big Muddy Reach (MRM 80-71).

3. Project Need

The purpose of the Crawford Towhead project is to increase flow in the navigation channel to reduce the need for dredging and enhance the aquatic habitat diversity within the reach. The 2012 Stone Dike Alteration Report stated the opportunity for habitat improvement is rated as high for the LDB MRM 73 towhead chute. Figure 1 shows the project area.

The Crawford Towhead project includes the construction of two chevrons and the rootless dike extension between MRM 74 and 72. Specifically, the Crawford Towhead project would involve the following actions in order to attain the desired conditions:

Crawford Towhead		
Project Action	**Project Description**	**Rationale**
Chevron 73.65L	Construct 300 ft x 300 ft chevron. Top elevation of the chevron will be +18.5 LWRP.	Needed to constrict the navigation channel.
Rootless Dike 72.9L	Place 300 foot rootless dike. Top elevation of the chevron will be +18.5 LWRP.	Needed to maintain contraction width and improve bathymetric diversity.
Chevron 72.55L	Construct 300 ft x 300 ft chevron. Top elevation of the chevron will be +18.5 LWRP.	Needed to maintain contraction width in the navigation channel.

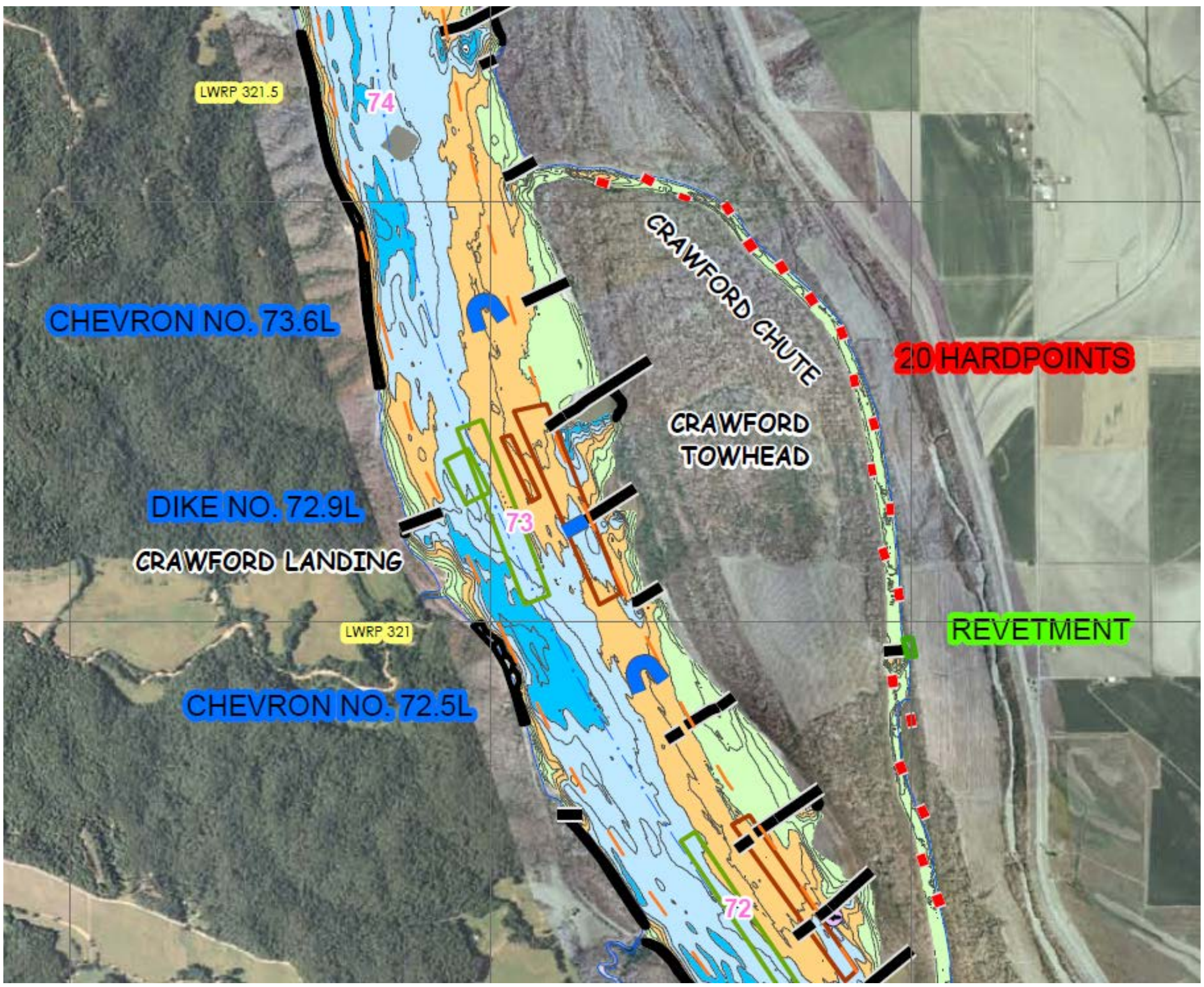

Figure 1

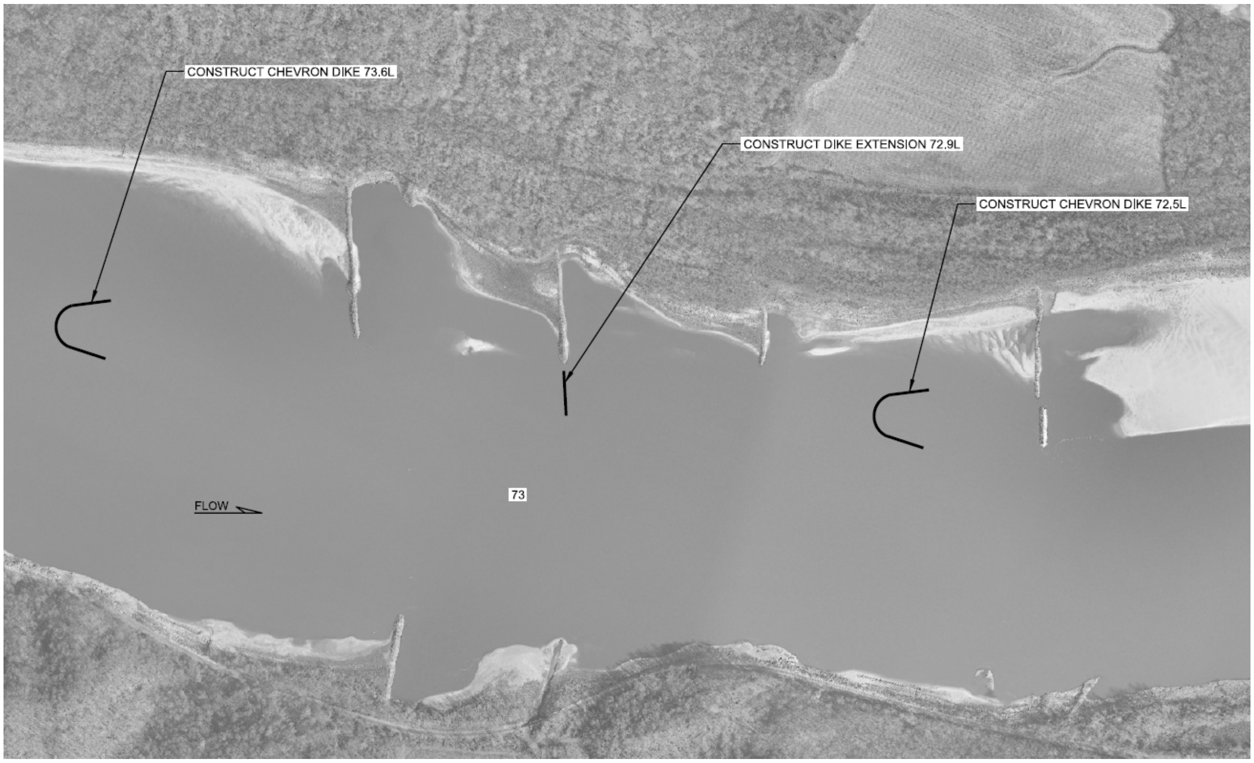

Figure 2 – Crawford Towhead

4. Species Covered in this Consultation:

A list of species that are likely to occur within the Crawford Towhead project area (Union Co. Illinois; Cape Girardeau, Missouri) was obtained from the U.S. Fish and Wildlife Service Region 3 website on August 5, 2013. Those species are included in Table 1.

This Big Muddy dikes subarea (MRM 71-80) is foraging habitat for least terns and habitat for pallid sturgeon. There are pallid sturgeon locations at RM 69.5, 69.6, 69.8, 70.3, 71.8, 77.1, 78.2, 78.7, 79.5, and 79.8 especially around Cottonwood Island. Cottonwood Chute, MRM 77 to 80, including its substrate, is one of the most valuable habitat areas for the pallid sturgeon in the MMR.

Table 1 - Listed Species in Project Area

Species	Federal Status	Habitat
Indiana bat (*Myotis sodalis)*	Endangered	Hibernacula: Caves and mines; Maternity and foraging habitat: small stream corridors with well developed riparian woods; upland and bottomland forests
Least tern (interior population) (*Sterna antillarum*)	Endangered	Large rivers - nest on bare alluvial and dredge spoil islands
Pallid sturgeon (*Scaphirhynchus albus*)	Endangered	Mississippi and Missouri Rivers

Table 1 - Listed Species in Project Area		
Decurrent false aster (*Boltonia decurrens*)	Threatened	Disturbed alluvial soils. (Cape Girardeau)

5. Impact Assessment

Introduction: The proposed project includes constructing two chevrons and a rootless dike extension. Dikes and wing dams are prominent channel regulating features common in main channel habitats in the Middle Mississippi River. They are used to concentrate flow in the main channel in order to reduce the need for dredging. Chevron dikes were designed to divert flow into a portion of the navigation channel impacted by sediment accumulation on the point bar at a river bend where the river channel splits.

See Figure 3 for a graphic that shows the expected deposition and scour patterns at the Crawford Towhead project area.

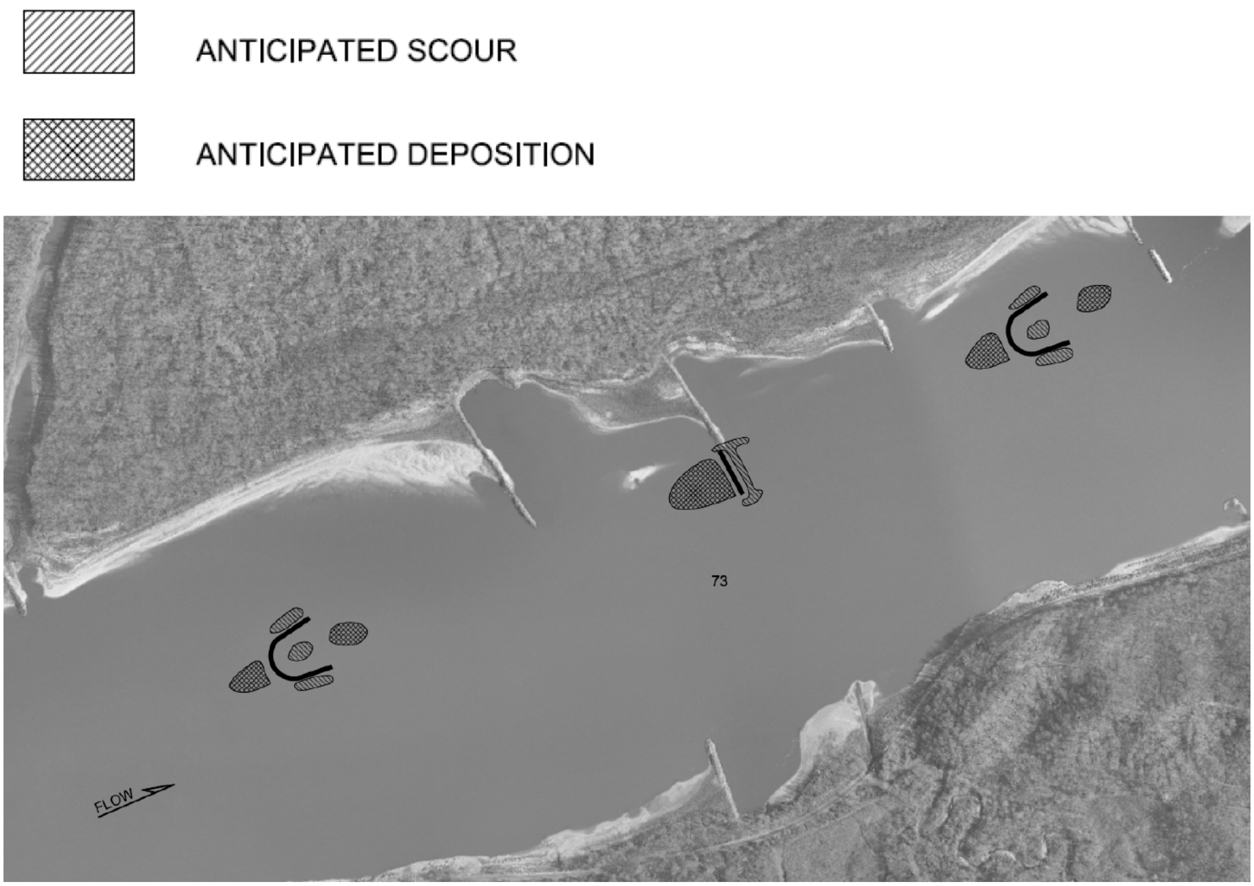

Figure 3 – Anticipated Deposition and Scour Patterns at Proposed Chevrons and Rootless Dike Extension MRM 72-74

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

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 September.

Modification measures resulting in aquatic habitat improvement should contribute to the species' forage base. Rootless dike extension and chevron construction is anticipated to be primarily performed by river-based equipment and has minimal potential to affect Indiana bats because forested habitats would not be affected. Additionally, creation of secondary channels and associated island or shallow water habitat and scour holes through rootless dike extension and chevron construction is expected to provide bathymetric diversity necessary to provide habitat for a range of aquatic species and life stages. Islands which become naturally reforested over time would be expected to contribute to long-term forest species diversity and structural diversity beneficial to forest-dwelling bats, including the Indiana bat (USFWS 2004).

This project would not result in the destruction of any riparian habitat and construction is scheduled to occur in the winter months when Indiana bats are not present. Thus, construction of the chevrons and rootless dike extension "may affect but is not likely to adversely affect" the Indiana bat.

Least Tern – The interior population of the least tern (*Sterna antillarum*) is characterized as a colonial, migratory waterbird, which resides and breeds along the Mississippi River during the spring and summer. Least 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 Middle Mississippi River (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 adjust channel geometry according to varying sediment load and discharge, the construction of river engineering works, and other influences. 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 waterbird. 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 non-vegetated sandbar habitat above the MMR low water reference point (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). At the time of the report, reoccurring nesting was known at Marquette Island (RM 50.5), Bumgard Island (RM 30), and Brown's Bar (RM 24.5-23.5) (USFWS 2004). Some nesting attempts had also been made at Ellis Island (RM 202), however these were not considered to be reoccurring.

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, Niles and Hartman 2009).

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

This project involves constructing a rootless dike extension within a dike field and two chevrons. Wing dikes are prominent channel regulating features common in main channel habitats. They are used to concentrate flow in the main channel in order to reduce the need for dredging. Wing dams are usually constructed in groups called dike fields. These areas are depositional zones that often fill from the bank outward toward the channel. When wing dike alteration is done on the dike field level, or in association with new structure placements, new side channels, islands, and off-channel areas can be created (USFWS 2004). Habitat diversity in the area should be increased by the creation of secondary channels, along with deep scour holes and shoaling within the dike fields, especially with the effect of the rootless dike as shown on Figure 3.

By completing regulating works projects at a local scale, long-term beneficial effects for least tern should accrue from the incorporation of structure modifications resulting in the creation of additional side channels and sandbars. Such activities may create additional nesting and rearing habitat and improve forage food production.

Thus dike and chevron construction should result in the diversification of aquatic habitats, including formation of secondary channels and shallow water habitats beneficial to the least tern, as well as fish in general (the species' forage base), and "may affect but are not likely to adversely affect" the least tern.

It is anticipated that the project will be completed prior to least tern nesting.

Pallid Sturgeon (*Scaphirhynchus albus*) **-** The U.S. Fish and Wildlife Service (2000) has held the position that over time, channel training structures have adversely affected pallid sturgeon by affecting 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). Additionally, some authors believe that loss of habitat contributes to the hybridization of pallid and shovelnose sturgeon (Carlson et al. 1985, Keenlyne et al. 1993, Campton et al. 1995, USFWS 2000), although a study by Hartfield and Kuhajda (Hartfield et al. 2009) disputes that conclusion. Hartfield and Kuhajda's review found no evidence of any direct link between habitat modification and hybridization in species of *Scaphirhyncus*. 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). Thus, as a result, previously aquatic habitats are now dry at low discharges (Wlosinski 1999). According to the Service, this has potentially reduced the availability of pallid sturgeon spawning habitat through the loss of habitat complexity (USFWS 2000).

Wing dam and dike fields within the MMR are currently utilized by pallid sturgeon, including the project study area between Mississippi River miles 90.0-67.0 (Sheehan and Heidinger 2001, USACE 2005). Deep scour holes that develop in association with wing dams and rootless dikes provide seasonal refugia, particularly during winter. Pallid sturgeon also utilize the sand bar habitat that accretes between wing dikes. Although their preference for this habitat is poorly understood, at a minimum it is believed these areas provide important foraging habitat (USFWS 2004). Though outside the project area, the Carterville Fisheries Research Office has collected juvenile sturgeon in high concentrations over the flooded sandbar on the western shore of Rockwood Island between RM 102 and 101. Juvenile sturgeon were also collected from Liberty Chute below the rock closing structure at RM 101.1, and juvenile shovelnose were collected within Liberty Chute (USACE 2005). Juvenile sturgeon were also collected over flooded portions of the Mile 100 Islands during the spring of 2005 (USACE 2005). The rock dike substrate provides habitat for epilithic macroinvertebrates that are capable of colonizing in very high densities and providing an important food source for fish (USFWS 2000).

Chevron dikes were designed to divert flow into a portion of the navigation channel impacted by sediment accumulation on the point bar at a river bend where the river channel splits. The dikes divert flow into the main channel by presenting the hydraulic appearance of a solid object without isolating the side channel with a closing structure. Flow between the structures maintains a permanent side channel connection, which provides important off-channel habitat for fishes. The rock dike substrate provides habitat for epilithic macroinvertebrates that are capable of colonizing in very high densities and providing an important food source for fish (USFWS 2000). As shown in Figure 2, chevron dikes also create habitat heterogeneity and appear to increase invertebrate abundance and diversity (Ecological Specialist, Inc. 1997, USFWS 2000) and provide useful and valuable habitat for a large variety of riverine fishes (Atwood 1997, USFWS 2000). According to Sheehan et al. (1998), pallid sturgeon exhibit a strong preference for downstream island tips. Over the long-term, construction of chevrons in the MMR would likely benefit pallid sturgeon by improving habitat diversity, including restoration of shallow water sandbar or island tip habitat. This project involves the construction of two chevron dikes which would be configured to maintain flow between the chevron structure and the adjacent shoreline and which should promote the formation of a scour hole, and shoaling area, sandbar, or island.

Construction activities may result in short-term adverse effects for pallid sturgeon. Activities that impact any existing deepwater habitat may result in displacement of pallid sturgeon. Disruption of existing sand bar habitat may impact foraging habitat. However, these adverse effects are expected to occur at a local, individual dike scale. By completing regulating works projects with incorporated modifications to increase habitat diversity at the scale of the dike field, long-term beneficial effects for pallid sturgeon should result. The creation of scour holes and side channel and associated island or shallow water habitat through dike extension and chevron construction is expected to create additional larval/juvenile rearing habitat and seasonal refugia, and improve forage food production (USFWS 2004).

It is the position of the St. Louis District that short-term adverse impacts that may occur are insignificant, and the long-term impacts associated with reduced dredging and increased habitat diversity, which is expected as a consequence of river training structure construction and modification, are predicted to be beneficial to pallid sturgeon. Thus, rootless wing dike extension and chevron dike construction would result in the creation of diverse aquatic habitats that would be beneficial to fish in general, and "may affect but is not likely to adversely affect" the pallid sturgeon.

Decurrent false aster – The decurrent false aster is presently known from scattered floodplain localities from the confluence of the Mississippi River with the Illinois River south to Madison County, Illinois (USFWS 1990). Its natural habitat was lakeshores and stream banks with abundant light. Populations presently grow in natural habitat, but are more common in disturbed lowland areas where they appear to be dependent on human activity for survival (USFWS 1990). Because this species is not known to occur in the project area, the project should have "no affect" on the decurrent false aster.

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United States Department of the Interior

U.S. FISH AND WILDLIFE SERVICE
Marion Illinois Sub-Office (ES)
8588 Route 148
Marion, Illinois 62959
(618) 997-3344

August 9, 2013

Colonel Christopher G. Hall
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103-2833

Attn: Francis Walton

Dear Colonel Hall:

Thank you for your email dated August 8, 2013, requesting review of the Tier II Biological Assessment prepared for the Crawford Towhead Regulating Works Project located in Union County, Illinois and Cape Girardeau County, Missouri. The proposed project involves constructing two chevrons and a rootless dike extension between approximate Upper Mississippi River (UMR) miles 72.0 and 74.0. Previous work for this project included the construction of three rootless dike extensions between UMR miles 71.9 and 72.4. The Tier II Biological Assessment was prepared in order to comply with the requirements of the 2000 Biological Opinion for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. The 2000 Biological Opinion was prepared as a result of the programmatic consultation under Section 7 of the Endangered Species Act of 1973, as amended, which evaluated the effects of operation and maintenance of the 9-foot navigation channel on federally listed threatened and endangered species.

The Tier II Biological Assessment evaluated the impacts of the proposed project on the Indiana bat (*Myotis sodalis*), endangered least tern (*Sterna antillarum*), endangered pallid sturgeon (*Scaphirhynchus albus*), and decurrent false aster (*Boltonia decurrens*). The Corps has determined that the proposed project will have no effect on the decurrent false aster. This precludes the need for further action on this project as required under Section 7 of the Endangered Species Act of 1973, as amended, for the decurrent false aster. The Corps has determined that the proposed project is not likely to adversely affect the Indiana bat and least tern. Based on the location and description of the proposed project, the Service concurs that the proposed project is not likely to adversely affect the Indiana bat and least tern.

The purpose of constructing the proposed project is to increase flow in the navigation channel and inhibit point-bar establishment, thus reducing the need for channel maintenance dredging. Our concern is that the proposed construction is likely to reduce/remove habitats utilized by larval and juvenile pallid sturgeon. Information in the BA indicates that the construction of the chevrons and dike extension are expected to create scour holes, secondary channels, and shallow water habitat that will provide additional larval/juvenile rearing habitat and seasonal refugia, and improve forage food production which should result in long-term beneficial effects for pallid sturgeon. Thus, the Corps has determined that the proposed project is not likely to adversely affect the pallid sturgeon. It is unclear to the Service whether these river training structure modifications (with resulting hydro-geomorphologic changes) and the reduction in channel maintenance dredging can fully compensate for the project impacts. Thus, the Service does not concur that the proposed project is not likely to adversely affect the pallid sturgeon. However, the Service concurs that the proposed project, as designed, meets the requirements of the Reasonable and Prudent Measures with implementing Terms and Conditions described in the 2000 Biological Opinion.

Should this project be modified, or new information indicate listed or proposed species may be affected, consultation or additional coordination with this office, as appropriate, should be initiated. Thank you for the opportunity to provide comment on the Tier II Biological Assessment. For additional coordination, please contact me at (618) 997-3344, ext. 345.

Sincerely,

/s/ Matthew T. Mangan

Matthew T. Mangan
Biologist in Charge

cc: IDNR (Atwood)
MDC (Herzog, Sternburg)

United States Department of the Interior

U.S. FISH AND WILDLIFE SERVICE
Marion Illinois Sub-Office (ES)
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January 17, 2014

Colonel Christopher G. Hall
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103-2833

Attn: Mr. Danny McClendon

Dear Colonel Hall:

Thank you for the opportunity to review and comment on the Environmental Assessment (EA), Unsigned Finding of No Significant Impact (FONSI), and Public Notice P-2856 addressing the Grand Tower Phase 5 Regulating Works Project located in Union County, Illinois and Cape Girardeau County, MO. The Crawford Towhead portion of the proposed project involves construction of two chevrons and one dike extension between Upper Mississippi River Miles 72 and 74 and the Vancill Towhead portion of the proposed project involves construction of three weirs and three diverter dikes (S-dikes), shortening of two dikes, repair of one dike, and revetment between Upper Mississippi River Miles 67.3 and 67.1. Alternatives considered for this project included no action and a preferred alternative described above. These comments are prepared under the authority of and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.); the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq*.); and, the National Environmental Policy Act (83 Stat. 852, as amended P.L. 91-190, 42 U.S.C. 4321 et seq.).

Fish and Wildlife Resources

The purpose of constructing the proposed project is to address bankline erosion, channel widening, and a repetitive channel maintenance dredging issue to ensure adequate navigation depth and width. Information provided in the EA indicates that the proposed dikes are expected to increase bathymetric, flow, and sediment diversity in the immediate vicinity of the structures. The bendway weirs are expected to improve fish and macroinvertebrate habitat in the outside bend by providing substrate diversity, flow refuge, and increased macroinvertebrate colonization surface area. The revetment is expected to increase surface area for macroinvertebrate colonization. While not disagreeing with this assessment, the Service is concerned that the proposed construction is likely to reduce/remove habitats on the inside bends that are utilized by larval and juvenile fisheries resources. The Service is also concerned about the cumulative loss of habitat and potential impacts on fisheries resources in the Mississippi River from past, present, and reasonably foreseeable future actions utilized to maintain the navigation channel. The Service recommends that the U.S. Army Corps of Engineers (Corps) continue to utilize its authorities and programs (Biological Opinion Program, Avoid and Minimize Program, and Environmental Management Program) to restore/enhance habitats in the Mississippi River. The Service also recommends that the Corps seek a post authorization change to provide for environmental protection and enhancement under the Regulating Works Project as described in the 1976 Environmental Impact Statement (EIS). As stated in the 1976 EIS, “the overall effects of the attainment of a nine-foot-navigation channel upon the riverine ecosystem has not been beneficial” and “A significant amount of fish and wildlife habitat has been affected.”

An additional concern with the proposed project is that the Vancill Towhead portion of the project falls within the “control” reach for the Navigation and Ecosystem Sustainability Program (NESP), Herculaneum Side Channel Restoration Project. Due to the limited funding for NESP, discussions occurred about utilizing the Herculaneum reach as a “control” reach for this project. Monitoring has been being proposed to evaluate the regulating works project and utilize data previously collected for the Herculaneum Side Channel Restoration Project. The Service concurs with the proposed monitoring.

Threatened and Endangered Species

The EA includes a Tier II Biological Assessment (BA) which was prepared in order to comply with the requirements of the 2000 Biological Opinion for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. The 2000 Biological Opinion (BO) was prepared as a result of the programmatic consultation under Section 7 of the Endangered Species Act of 1973, as amended, which evaluated the effects of operation and maintenance of the 9-foot navigation channel on federally listed threatened and endangered species. The BA evaluated the impacts of the proposed project on the endangered gray bat (*Myotis grisescens*), endangered Indiana bat (*Myotis sodalis*), endangered least tern (*Sterna antillarum*), endangered pallid sturgeon (*Scaphirynchus albus*), endangered sheepnose mussel (*Plethobasus cyphyus*), endangered spectaclecase mussel (*Cumberlandia monodonta*), threatened decurrent false aster (*Boltonia decurrens*), and proposed as endangered grotto sculpin (*Cottus sp.*).

In the Tier II BA the Corps determined that the proposed project will have no effect on the gray bat and grotto sculpin and is not likely to adversely affect the Indiana bat, least tern, pallid sturgeon, sheepnose mussel, spectaclecase mussel, and decurrent false aster. In a letter dated August 9, 2013, regarding Crawford Towhead and in a letter dated February 22, 2013, regarding Vancill Towhead, the Service provided concurrence that the proposed projects are not likely to adversely affect the Indiana bat, least tern, sheepnose mussel, spectaclecase mussel, and decurrent false aster. However, the Service did not concur that the proposed projects are not likely to adversely affect the pallid sturgeon. It is unclear to the Service whether the river training structure modifications (with resulting hydro-geomorphologic changes) and the reduction in channel maintenance dredging can fully compensate for the project impacts; therefore, the Service believes the proposed project is likely to adversely affect the pallid sturgeon and that Tier II formal consultation is necessary.

Tier II Formal Consultation

The Service has determined that the proposed project 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 (Section 1.2.4.2 River Regulatory Structures). The effects of this proposed action on the pallid sturgeon are consistent with those anticipated in the programmatic BO (Section 8.3.1.2 Maintenance of the 9-Foot Channel Project), and the appropriate Terms and Conditions associated with the Reasonable and Prudent Measures (RPMs) identified in the programmatic BO have been adhered to (Sections 8.5.3 and 8.5.4). Specifically, the Corps adhered to Term and Condition 2 and RPM 1 by submitting the project to the Service for a 30 day review period and incorporating Service recommendations for aquatic habitat improvement into project construction plans. Based on this information, it is the Service's biological opinion that the proposed project is not likely to jeopardize the continued existence of the pallid sturgeon. Incidental take was considered programmatically in the BO (Section 8.5 Incidental Take Statement) and will be evaluated at program level. Thus no incidental take statement is included with this opinion.

This concludes formal consultation on the proposed action. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

Conclusion

Thank you for the opportunity to provide comment on the EA, FONSI, and Public Notice. For additional coordination, please contact me at (618) 997-3344, ext. 345.

Sincerely,

/s/ Matthew T. Mangan

Matthew T. Mangan
Biologist in Charge

cc: IDNR (Atwood)
MDC (Sternberg)

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

1 March 2016

Reply to:
Regional Planning and Environment Division North
Environmental Compliance Branch (CERPEDN-PD-C)

U.S. Fish and Wildlife Service
Marion Illinois Sub-Office (ES)
8588 Route 148
Marion, Illinois 62959
Attn: Matt Mangan

Dear Matt:
Since the preparation and coordination of the Tier II Biological Assessment for the Grand Tower Phase 5 Regulating Works project in 2012 and 2013, three new species have been added to the listed species for Cape Girardeau County, Missouri and Union County, Illinois. These include the piping plover, rufa red knot, and northern long-eared bat. A supplemental biological assessment for these species has been prepared and is attached.

Please review the attached supplemental biological assessment and provide comments at your earliest convenience.

If you have any questions about this assessment, please contact Mr. Kip Runyon of our Environmental Planning Section at (314) 331-8396 (kip.r.runyon@usace.army.mil).

Sincerely,

Brian Johnson

Brian L. Johnson
Chief, Environmental Compliance

Grand Tower Phase 5

Supplemental Biological Assessment (1 March 2016)

The USFWS website (http://www.fws.gov/midwest/endangered/lists/cty_indx.html) was accessed on March 1, 2016 and the following species were noted for Cape Girardeau County, Missouri, and Union County, Illinois that were not covered by previous consultation for the Grand Tower Phase 5 Regulating Works project.

Species	Status	Habitat
Piping plover *(Charadrius melodus)* Northern Great Plains Breeding Population	Threatened	Riverine sandbars
Rufa Red knot *(Calidris canutus rufa)*	Threatened	Shorebird that migrates through Missouri - irregularly observed feeding on mudflats, sandbars, shallowly flooded areas and pond margins along the Missouri and Mississippi Rivers from May 1 through September 30.
Northern long-eared bat (*Myotis septentrionalis*)	Threatened	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.

Piping Plover: Piping plovers use wide, flat, open, sandy beaches with very little grass or other vegetation. Nesting territories often include small creeks or wetlands. Piping plovers are migratory birds and occasionally are seen on Missouri shorelines or at wetlands. In the spring and summer they breed in the northern United States and Canada. There are three locations where piping plovers nest in North America: the shorelines of the Great Lakes, the shores of rivers and lakes in the Northern Great Plains, and along the Atlantic Coast. In the fall, plovers migrate south and winter along the coast of the Gulf of Mexico or other southern locations (USFWS 2015a).

There is no known piping plover nesting habitat in the project area. This bird is a rare migrant along the Middle Mississippi River, and during migration, exposed sand bars in the area may provide temporary feeding habitat. This project would not eliminate or substantially reduce sandbars within the project area. Therefore, this project would have no effect on the piping plover.

Rufa Red Knot: The rufa red knot is a robin-sized shorebird that annually migrates from the Canadian Arctic to southern Argentina. Changing climate conditions are already affecting the bird's food supply, the timing of its migration, and its breeding habitat in the Arctic. The shorebird also is losing areas along its range due to development. New information shows some knots use interior migration flyways through the South, Midwest, and Great Lakes. Small numbers (typically fewer than 10) can be found during migration in almost every inland state over which the knot flies between its wintering and breeding areas. This shorebird is irregularly observed feeding on mudflats, sandbars, shallowly flooded areas and pond margins along the Missouri and Mississippi Rivers from May 1 through September 30 (USFWS 2014).

There is no known rufa red knot nesting habitat in the project area. This bird is a rare migrant along the Middle Mississippi River, and during migration, exposed substrates and shallow water in the project area may provide temporary feeding habitat. This project would not eliminate or substantially reduce exposed substrates or shallow water within the project area. Therefore, this project would have no effect on the rufa red knot.

Northern Long-Eared Bat (*Myotis septentrionalis*) **-** Northern long-eared bats spend winter hibernating in caves and mines (USFWS 2015b). 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.

Suitable northern long-eared bat summer habitat may occur in the forested areas adjacent to the work area. All construction would be completed by river-based equipment and the proposed work would not result in the destruction of any riparian or forested habitats. However, unforeseen effects from construction activities (e.g., noise), could potentially disturb northern long-eared bats adjacent to the work area. As such, the proposed action may affect but is not likely to adversely affect the northern long-eared bat.

References:

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U.S. Fish and Wildlife Service. 2015a. Piping plover fact sheet. Dated April 23, 2015. http://www.fws.gov/midwest/endangered/pipingplover/pipingpl.html. Accessed March 1, 2016.

U.S. Fish and Wildlife Service. 2015b. Northern long-eared bat fact sheet. Dated April 2015. http://www.fws.gov/midwest/endangered/pipingplover/pipingpl.html. Accessed March 1, 2016.

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 Grand Tower 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, Bendway Weir 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 floodplain impacts, 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 Grand Tower Phase 5 project.

A cumulative impact analysis was recently conducted for four Environmental Assessments with signed Findings of No Significant Impact for the Regulating Works Project on the MMR (USACE 2014a, 2014b, 2014c, 2015). A comprehensive analysis of the cumulative impacts of the Upper Mississippi River Navigation Project on the geomorphic and biological resources of the UMR has been described in two publications (WEST Consultants, Inc. 2000a, 2000b) prepared for the Programmatic Environmental Impact Statement for the UMR-IWW System

Navigation Feasibility Study (USACE 2004). These studies provided a cumulative effects analysis of the 9-foot Navigation project for the entire UMR and the MMR. West Consultants, Inc. (2000a) provided a geomorphic assessment of the cumulative effects on geomorphology, sediment transport, and dredging. West Consultants, Inc. (2000b) provided a biological assessment of the cumulative effects of geomorphic changes, physical habitat changes, impoundment and river regulation, channel training structures, dredging and material placement, the Environmental Management Program habitat projects, connectivity of UMRS habitats, changes in the UMRS Basin, changes in UMR floodplain land use and land cover, effects of both point and non-point-source discharges to UMRS, fish entrainment and impingement at electrical generating plants, and exotic and nuisance species. In addition, the UMR-IWW System Navigation Feasibility Study (USACE 2004) contains a comprehensive description of the environmental impacts of navigation traffic for existing traffic levels and modeled traffic levels for each decade to 2050.

In addition to the above National Environmental Policy Act documents, there currently exists an extensive literature describing the historic, current, and future geomorphic and ecological condition of the UMR, either including or specific to the MMR. The U.S. Geological Survey (USGS) conducted two (USGS 1999; Johnson and Hagerty 2008) ecological status and trends analyses of the UMR. The initial Status and Trends Report (USGS 1999) provided a thorough introduction to the UMRS including extensive descriptions of historical context, watershed geology and land use, floodplain forests, bird populations, water quality, fishes, aquatic vegetation and macroinvertebrates. The 1999 report (USGS 1999) provided the background information upon which the 2008 report (Johnson and Hagerty 2008) built. The 2008 Status and Trends Report focused on measuring changes in potential indicators of system health as derived from Long Term Resource Monitoring Program data. Twenty-four ecosystem indicators were chosen because they relate to many of the primary resource problems or outcomes important to managers. The 24 indicators were grouped into seven categories: hydrology, sedimentation, water quality, land cover, aquatic vegetation, invertebrates, and fish. Each indicator was evaluated for status across locations, including the MMR, and for trends over time, with estimates of uncertainty, when possible. The USGS also conducted a Habitat Needs Assessment for the UMR as part of Environmental Management Program (Theiling et al. 2000). The primary objectives of the Habitat Needs Assessment were the evaluation of existing conditions throughout the UMRS, forecasting future habitat conditions, and quantifying ecologically sustaining and socially desired future habitat conditions. Heitmeyer (2008) provided a detailed description of the historic physical and biological conditions specific to the MMR, changes to those conditions, and restoration and management recommendations.

Pursuant to 40 CFR 1502.21 and CEQ Guidelines, the above documents and analyses are incorporated by reference into this analysis for the purpose of reducing the size of this document and not duplicating applicable analyses. 40 CFR § 1502.21 requires that material incorporated by reference must be “reasonably available for inspection”. The documents are available for review at:

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

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 were 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 all six criteria air pollutants (ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead) (USEPA 2013). There are no known foreseeable projects in the work area that would adversely impact air quality. The No Action Alternative would have no additional impacts on air quality. The Proposed Action would have only minor, short-term, air quality impacts associated with the use of construction equipment. Navigation traffic levels and associated engine exhaust will 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)

Middle Mississippi River Floodplain

There are a number of competing theories on how river ecosystems operate (Johnson et al. 1995; McCain 2013). The flood pulse concept (Junk et al. 1989) is currently the most widely accepted theory for explaining the ecology of large floodplain rivers like the Mississippi River (Heiler et al. 1995; Gutreuter et al. 1999), but some aspects of large river ecosystems are not considered (Johnson et al. 1995). The flood pulse concept states that floodplain inundation is "the principle driving force responsible for existence, productivity, and interactions of the major biota in river-floodplain systems" (Junk et al. 1989). Regardless of inability of any single theory to completely explain the complex workings of large flood-plain rivers (Johnson et al. 1995; McCain 2013), one thing is clear, periodic inundation of the floodplain is extremely important and many organisms, both aquatic and terrestrial, are not only adapted to pulsed flooding, but require it.

A considerable number of scientific papers have been published describing the ecological importance of connectivity between the river and its floodplain for the Mississippi River and major tributary rivers. Periodic inundation (pulsed flooding) of the floodplain results in both sequestering and transport of nutrients (e.g., Schramm, Jr. et al. 2009); increased productivity of phytoplankton, zooplankton, and benthic invertebrates (e.g., Galat et al. 1998; Gosch et al. 2014); and spawning, feeding, and nursery areas for riverine fish (Barko et al. 2006). Floodplain inundation and connectivity with the river has been shown to be related to increased fish growth rates (Gutreuter et al. 1999; Schramm Jr. and Eggleton 2006; Jones and Noltie 2007; Phelps et al. 2014). Miranda (2005) found that the level of floodplain lake connectivity with the river plays an important role in structuring the fish fauna that is correlated with variables such as lake size, depth, distance from the river, and age. Annual floods homogenize the floodplain and provide connectivity to various degrees, allowing exchange of fish faunas between the river and floodplain that directly affect the fish species assemblages.

There are specific MMR examples of the importance of periodic flooding of the MMR for resident species. For example, the alligator gar (*Lepisosteus spatula*), a species extirpated from the MMR, historically used the floodplain during spring high water periods, most likely for spawning and rearing of young (Keevin and Lopinot 2015). The disconnection of the Mississippi River from its floodplain by agricultural levees may be partially responsible for the extirpation of this species in the northern portion of its range. The decurrent false aster (*Boltonia decurrens*), a Federally threatened plant species, life history is adapted to periodic inundation (Smith and Keevin 1998) and persistence of the species requires flooding to reduce competition (Smith et al. 1998).

Heitmeyer (2008) provides a detailed description of the historic physical and biological conditions of the MMR floodplain, changes to those conditions, and provides restoration and management recommendations. The MMR floodplain and river channel area encompass approximately 660,000 acres (Table 1), with approximately 202,000 acres (Table 2) of the river channel and the floodplain in the narrow strip of land between the river and the levees known as batture lands. The majority of the land in the floodplain can generally be categorized as rural and agrarian in nature. These areas are protected by an extensive levee and drainage system. Levees are prominent features and provide urban and agricultural flood protection for almost the entire length of the MMR, resulting in about 67% of foodplain area behind levees, while 33% of the land is outside of levee protection in the batture. In the MMR, almost all of the active (frequently flooded) floodplain is in the batture lands. The percentage of floodplain protected by levees is unlikely to change greatly because no new major realignment of levees is anticipated. However, there are currently on-going efforts to raise levees for urban flood protection. The establishment of the Middle Mississippi River Refuge (USFWS 2015) has resulted in re-establishment of floodplain connectivity in limited areas where levees were not repaired after the flood of 1993.

Currently, approximately 51% of the total floodplain is in agricultural production (Table 1), while 28% of the batture is in agriculture (Table 2). The only available land cover data for the time period around 1976 covers only the portion of the MMR that lay riverward of the levee (batture lands), limiting a comparison of changes between 1975 and 2011 to the batture. Between 1975 and 2011, agricultural land in the batture was reduced by 28% from 78,267 acres to 56,334 acres.

Forest is the second most abundant land cover class, currently occupying 18 percent of the total floodplain area (Table 1) and approximately 27% of the batture lands (Table 2). Between 1975 and 2011, forest cover increased by 15.3% in the batture. Area of floodplain forest declined in 24 of 31 reaches of the UMRS between 1989 and 2000 with a system-wide decrease of 5%, or 17,000 acres (Johnson and Hagerty 2008). In contrast, there was a slight increase of 1,200 acres (2%) in the MMR. The trend for floodplain forest is considered to be degrading in the impounded UMRS, but stable in the MMR.

Open water and developed lands currently occupy 12 and 9% of the total MMR floodplain, respectively. Between 1975 and 2011 open water increased 13.8% and developed land decreased 2.1% within the batture. The remaining three categories, grass/forbs, marsh, and sand/mud, each currently account for less than 5 percent of the floodplain. Between 1975 and 2011, marsh increased 7,744 acres (113%), grass/forbes area increased 2,931 acres (216 %), and sand/mud decreased 3,995 acres (72%), within the batture.

Table 1. MMR floodplain land cover categories, acreages, and percentages (based on Corps of Engineers' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014).

Land Cover Category	2011 Acreage (% of Total)
Agriculture	341,665 (51.1%)
Forest	120,404 (18.0%)
Open Water	82,575 (12.4%)
Developed	62,760 (9.4%)
Marsh	29,801 (4.5%)
Grass/Forbs	29,618 (4.4%)
Sand/Mud	1,755 (0.3%)
Total	668,576

Table 2. MMR land cover categories, acreages, and percentages of the narrow strip of land between the river and levees known as batture lands for 1975 and 2011 (based on Corps of Engineers' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014).

Land Cover Category	1975 Acreage (% of Total)	2011 Acreage (% of Total)
Open Water	58,599 (29.0%)	66,688 (33.1%)
Agriculture	78,267 (38.8%)	56,334 (27.9%)
Forest	47,321 (23.5%)	54,566 (27.0%)
Marsh	6,861 (3.4%)	14,605 (7.2%)
Grass/Forbs	1,360 (0.7%)	4,291 (2.1%)
Developed	3,744 (1.9%)	3,664 (1.8%)
Sand/Mud	5,573 (2.8%)	1,578 (0.8%)
Total	201,725	201,725

The U.S. Fish and Wildlife Service established the Middle Mississippi River National Wildlife Refuge on May 31, 2000 (USFWS 2015). The refuge lands were purchased in response to the flood of 1993. The refuge currently consists of seven divisions that total nearly 7,000 acres (Meissner Island Division, River Mile (RM) 153.5–155.5L – 78 acres; Harlow Island Division, RM 140.5-144R - 1,255 acres; Beaver Island Division, RM 116-118R - 245 acres; Horse Island Division, RM 111-112R - 2,110 acres; Rockwood Island Division RM 99-104L – 722 acres; Crain Island Division, RM 104-107 – 553 acres; Wilkinson Island Division, RM 88.5-93L - 2,532 acres) spread out along the MMR. Much of the refuge land had previously been cut off from the floodplain by private levees protecting agricultural land. Most of the levees were breached by the 1993 flood and have not been repaired. The refuge now provides access to the floodplain for native fish during high water stages and creates a corridor of floodplain forest habitat for migratory birds and resident wildlife. The refuge was designated as an important Bird Area in 2008.

Frequent flooding occurs on refuge tracts due to their position in the river floodplain. Modifications to man-made structures such as levees promote healthy and diverse fish habitat for native Mississippi River fishes. Where possible, old river channels and swales on refuge lands will be managed with passive water control structures to provide for seasonal wetlands for migratory birds. By allowing these lands to flood and re-connect with the river, the refuge contributes to the overall health of the ecosystem. Former agricultural lands are being allowed to return to forested habitat, with the occasional tree plantings to promote species diversity and abundant food for native wildlife. Many species of fish and wildlife should benefit from the habitat restoration, and the public will have increased opportunities for wildlife-dependent outdoor recreation.

Under both the No Action Alternative and the Action Alternative, the future condition of the floodplain is, for the most part, independent of the 9-foot Navigation Project in the MMR. The impacts of No Action and the Proposed Action, when evaluated in relation to past, present, and future condition of the MMR floodplain, are not anticipated to rise to the level of being significant. The floodplain has historically been isolated from the river and important biological functions that are dependent on riverine connectivity have been lost for most of the MMR floodplain. It is anticipated that the MMR levee system will be improved and maintained to meet current federal standards for urban flood protection. Agricultural levees will also be maintained to meet federal standards for agricultural flood protection and repaired under the PL 84-99 program, if levee districts are in the program, meet federal requirements, and request federal assistance. Development on the floodplain (i.e., housing development, industry, roads, etc.) is totally independent of the Regulating Works Project. The isolation and protection of the floodplain was a societal decision and can only be changed by Congressional action or private sector investment (i.e., private sector entities, other than the agricultural sector, purchasing the land and reconnecting the river to the floodplain for fish and wildlife purposes). This has happened to a minor degree with the establishment of the Middle Mississippi River Refuge. However, there are no known plans by environmental groups or individuals to purchase large segments of the floodplain for fish and wildlife purposes.

It is possible that in the future navigation related development (i.e., port development, loading/unloading facility development, operation and maintenance of existing facilities, etc.) may occur. A comprehensive economic analysis to determine potential future navigation related facility needs has not been conducted. However, it is anticipated that development would occur adjacent to existing facilities where infrastructure is already in place. The St. Louis District has concluded that the construction of training structures in the MMR does not affect water surface elevations at higher flows. Based on the Corps' analyses, training structure construction activities will not result in increased flood risks to the MMR floodplain.

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

Currently, there are approximately 1,375 river training structures on the MMR, which include wing dikes, bendway weirs, chevrons, and other configurations. Of this total, approximately 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 19th century and another 250 in the 1930s. The District constructed 150 bendway weirs from 1990 to 2000. The proposed work area is between River Miles (RM) 74 and 67. Table 3 below lists work areas that are considered likely to be constructed in the reasonably foreseeable future.

The Regulating Works Project sustained significant damages during the 2015/2016 flood event. There were three locations where bankline failures occurred: RM 33.3L at Len Small Levee District (LD), RM 120.45R at Ste. Genevieve #2 LD and RM 35.5R Powers Island LD. Operation and Maintenance funds were used to restore the bankline at all three locations but the bankline failure at Len Small requires additional efforts. The bankline failure and associated scour hole will require new construction to prevent a channel cutoff from forming. If a channel cutoff were to occur, the Mississippi River would be shortened by approximately 14 miles with the end result a loss of the navigation channel. Efforts are underway to design bank stability and grade control to prevent a channel cutoff from occurring.

The St. Louis District has two Regulating Works HSR model studies that are ongoing and likely to result in future construction or modification of river training structures: the Red Rock Landing Phase 3 and Mosenthein-Ivory Landing Phase 6 HSR model studies. The Red Rock Landing Phase 3 HSR Model Study is a river engineering design that will reduce or eliminate the need for repetitive dredging at approximately UMR 100-94. The Red Rock Landing Phase 3 Report will be completed in FY 16 and construction is projected for FY 18 pending funding. The Mosenthein-Ivory Landing Phase 6 HSR Model Study is a river engineering design that will reduce or eliminate the need for repetitive dredging at approximately UMR 183. The Mosenthein Phase 6 Report will be completed in FY 16 and construction is projected for FY 18 pending funding. 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 commercial navigation 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 3. 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, 2012b, 2013a, 2013b,2014a, 2014b, 2014c, 2014d, and 2015).

Major Reach	Status	Localized Reach	Work in Reach
Mosenthein-Ivory Landing Phase 4 (RM 195-154)	Contract Awarded in FY 14; Under Construction	St. Louis Harbor	Revetment RM (175-171) Dike 173.4L
Eliza Point/Greenfield Bend Phase 3 (RM 20 - 0)	Contract Awarded in FY 14; Under Construction	Bird's Point (RM 4 - 0)	Rootless Dike 3.0L Revetment RM 3.0L Weir 2.6R Weir 2.5R Weir 2.3R Weir 2.2R
	Contract Award FY 16; Construction in FY 17	Boston Bar (RM 10.3 – 7.0) Biological Opinion Program	Dike 10.30L Remove Dike Dike 10.10L Notch Pile Dike Dike 10.10L Remove Dike Dike 10.05L Side Channel Enhancement Dike Dike 7.90L Remove Dike
Dogtooth Bend Phase 5 (RM 40-20)	Contract Awarded in FY 14; Under Construction	Bumgard (RM 33-27)	Weir 34.20L Weir 34.10L Weir 32.50L Weir 32.40L Weir 32.30L

Major Reach	Status	Localized Reach	Work in Reach
			Weir 32.20L Dike 31.60R Weir 30.80R Weir 30.70R
Mosenthein-Ivory Landing Phase 5 (RM 195-154)	Contract Awarded in FY 15; Construction Pending	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
Grand Tower Phase 5 (RM 90 - 67)	Contract Award FY 17 Pending Funding	Crawford Towhead (RM 75 - 71)	Chevron 73.6L Dike Extension 72.9L Chevron 72.5L
		Vancill 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 6 (RM 40-20)	Contract Award in FY 16; Construction in FY 17	Len Small (RM 34-33)	All work is landward of the river channel to prevent a channel cutoff from occurring. Revet scour hole Construct grade control Construct false bankline
Red Rock Landing Phase 3 (RM 103-90)	Contract Award FY 18 Pending Funding	Red Rock Landing (RM 103-90)	To Be Determined
Mosenthein-Ivory Landing Phase 6 (RM 195-154)	Contract Award FY 18 Pending Funding	St. Louis Harbor (RM 85-81)	To Be Determined

A discussion of the environmental impacts of dikes 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.

<u>Navigation Traffic</u>

The movement of commercial navigation traffic has both physical and biological effects (Table 4) 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.

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 4, 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).

Table 4. 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

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).

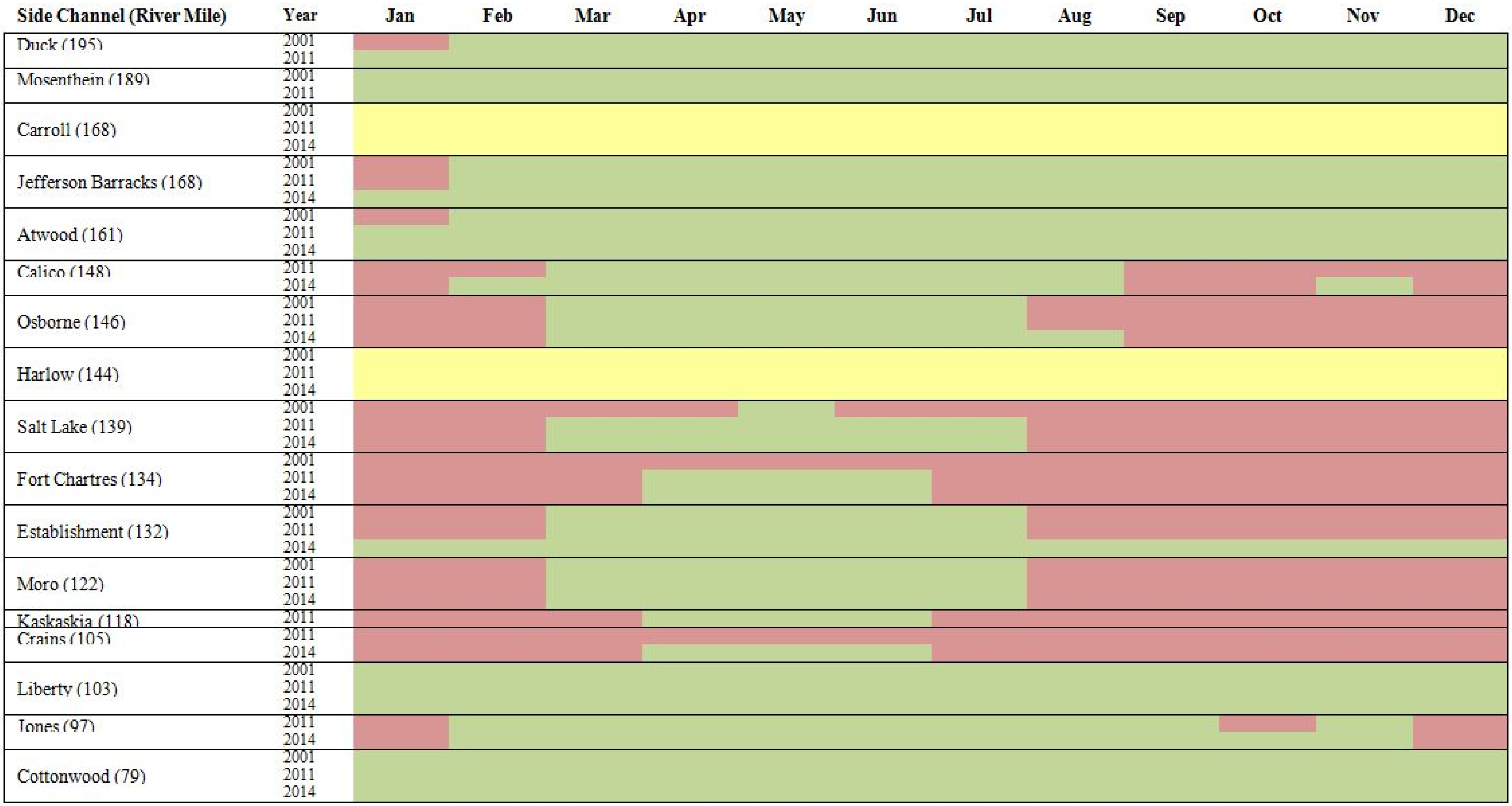
Due to the placement of rock closing structures, almost all MMR side channels are isolated from the main channel based on river stages and the crown elevation of the closing structure. The purpose of closing structures is to shunt water to the main channel to support navigation flows. Of the extant thirty-two 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 MMR side channel connectivity on a monthly basis for the years 2001, 2011, and 2014 is shown in Table 5. Note that the level of connectivity has remained relatively stable or increased slightly in 2014**.**

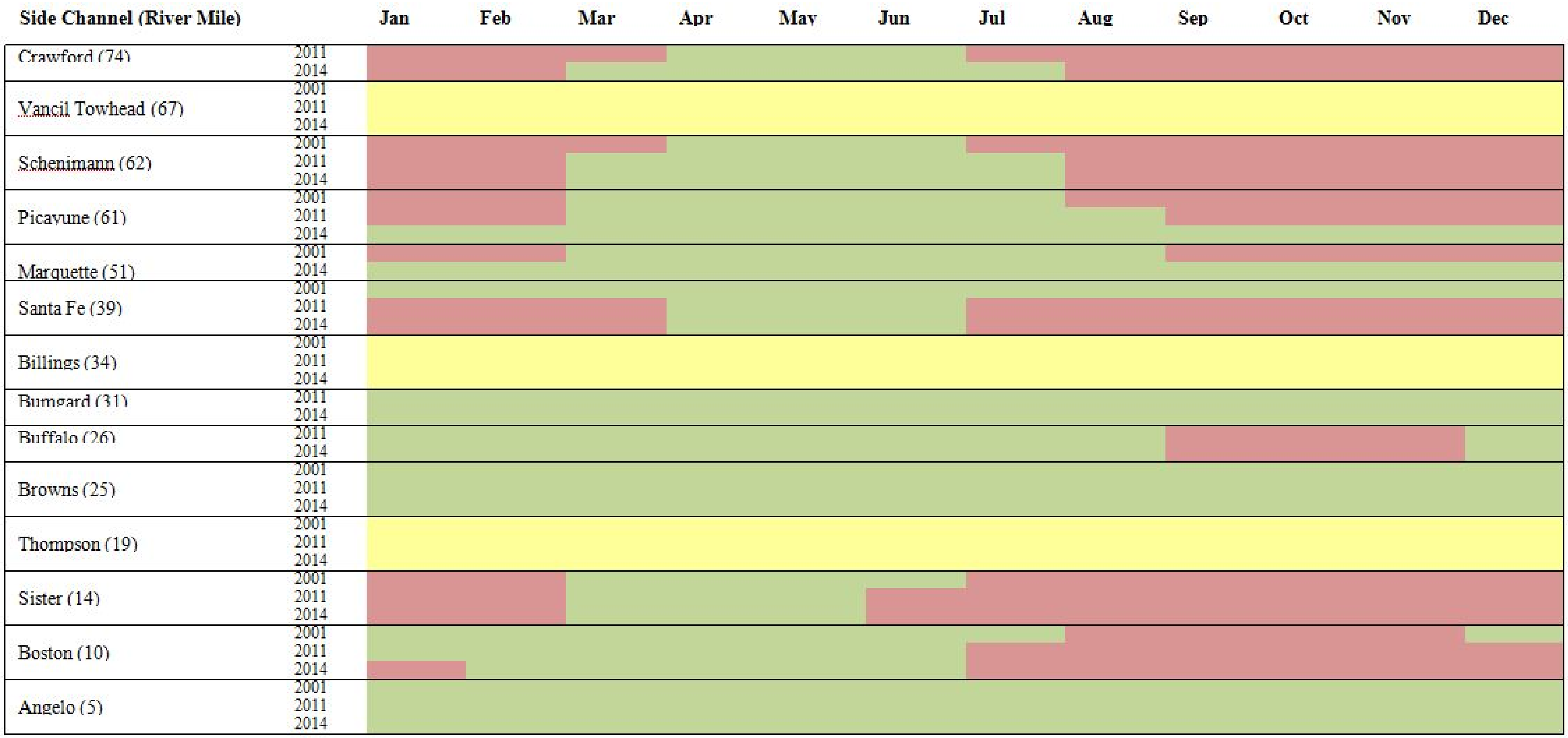
The 1976 MMR Regulating Works EIS indicated that most of the side channels would be lost "Based on Colorado State University studies of man-induced changes in the Middle Mississippi River, most of the side channel and main channel border habitat will eventually become filled with sediment (Simons, Schumm, and Stevens, 1974), unless artificial means, i.e., dredging, are employed to maintain side channels (page 216)." This is supported to some extent by the findings of Theiling et al. (2000) who examined land cover evolution at six side channel study sites using geographic information system (GIS) coverages derived from aerial photographs taken in 1950 or 52, 1975, 1989, and 1994. The study found that the six MMR side channels evaluated 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.

Side channel bathymetry is dynamic and changes with flood events which scour some areas and redeposit sediments in other areas. In an ongoing study of side channels being conducted by the St. Louis District, it has been found that the total water volume of MMR side channels has been increasing over the past 15 years (See Figure 1).

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.

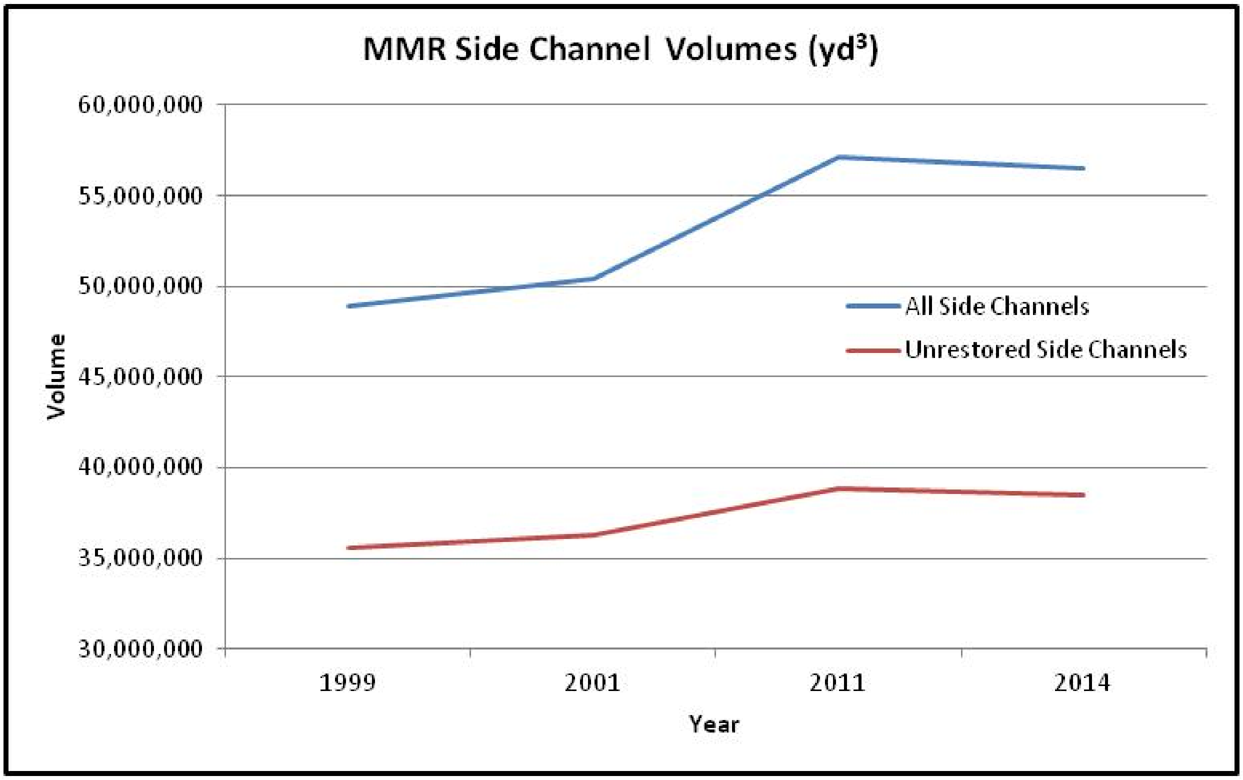
Table 5: A visual representation of flow conditions for Middle Mississippi River side channels showing months when channels are connected to the river and flowing (green) and when they are not flowing (red) based on median monthly stages and 2001, 2011, and 2014 bathymetric data. Yellow represents side channels with high barriers restricting flow during all but extremely high water events.





Side Channel (River Mile)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Crawford (74) 2011 2014
Vancil Towhead (67) 2001 2011 2014
Schenimann (62) 2001 2011 2014
Picayune (61) 2001 2011 2014
Marquette (51) 2001 2014
Santa Fe (39) 2001 2011 2014
Billings (34) 2001 2011 2014
Bumgard (31) 2011 2014
Buffalo (26) 2011 2014
Browns (25) 2001 2011 2014
Thompson (19) 2001 2011 2014
Sister (14) 2001 2011 2014
Boston (10) 2001 2011 2014
Angelo (5) 2001 2011 2014

Figure 1. Total volume in cubic yards of all MMR side channels for which data were available and for those unrestored MMR side channels for which data were available.



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; USACE 2014d) 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.

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

REGULATING WORKS PROJECT
GRAND TOWER PHASE 5
MIDDLE MISSISSIPPI RIVER MILES 74-67
UNION COUNTY, IL
CAPE GIRARDEAU COUNTY, MO

June 2016

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 Grand Tower Phase 5 work area is located in the Middle Mississippi River (MMR) between river miles 74 and 67 in Cape Girardeau County, Missouri and Union County, Illinois near the town of Grand Tower, Illinois. This area includes the Crawford and Vancill Towheads. 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 U.S. Army Corps of Engineers St. Louis District is proposing to construct the Grand Tower 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. The Grand Tower Phase 5 work is designed to address repetitive dredging and unsafe navigation conditions in the area. The Proposed Action includes the construction of two chevrons and the extension of one dike in the Crawford Towhead between RM 74 and 72. The Vancill Towhead area is located between RM 70.0 and 67.0 and includes construction of 3 weirs, 3 diverter dikes (S-dikes), repair of dike 67.8, revetment at 67.3 and shortening of dikes 67.3 and 67.1.

C. Authority and Purpose. The Middle Mississippi River Regulating Works Project is specifically and currently authorized pursuant to the Rivers and Harbors Acts beginning in the mid-1800s. These authorize USACE to provide a 9-foot-deep by minimum of 300-foot-wide, with additional width in bends, navigation channel at low river levels.

The purpose of this work is to provide a sustainable, safe and dependable navigation channel through regulating works to reduce the need for repetitive channel maintenance dredging in the area.

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. Stone (35,000 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.

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:

Table 1. Proposed Action Grand Tower Phase 5

Proposed Feature	**Feature Description**
Crawford Towhead	
Construct Chevron 73.6L	Construct 300ft x 300ft chevron. Top elevation of the chevron will be +18 LWRP14.
Extend Dike 72.9L	Extend existing dike 300 feet. Top elevation of the chevron will be +18 LWRP14.
Construct Chevron 72.5L	Construct 300ft x 300ft chevron. Top elevation of the chevron will be +18 LWRP14.
Vancill Towhead	
Construct Weir 69.15R	Construct Weir 800 feet long Top elevation of the weir will be -15 feet LWRP14
Construct Weir 68.95R	Construct Weir 800 feet long Top elevation of the weir will be -15 feet LWRP14
Construct Weir 68.75R	Construct Weir 800 feet long Top elevation of the weir will be -15 feet LWRP14
Construct Diverter Dike 68.10L (S-dike)	Construct Diverter Dike 750 feet long Top elevation of the dike will be +18 feet LWRP14
Construct Diverter Dike 67.80L (S-dike)	Construct Diverter Dike 750 feet long Top elevation of the dike will be +18 feet LWRP14
Construct Diverter Dike 67.50L (S-dike)	Construct Diverter Dike 750 feet long. Top elevation of the dike will be +18 feet LWRP14.
Repair Dike 67.80L	Repair Dike (350 foot of length). Top elevation of the dike will be +18 feet LWRP14.
Shorten Dike 67.30L	Shorten Dike 660 feet. Top elevation of the dike will be +18 feet LWRP14.
Shorten Dike 67.10L	Shorten Dike 300 feet. Top elevation of the dike will be +18 feet LWRP14.
Place Revetment 67.3L	Place 300 ft. of revetment where dike attaches to riverbank.

F. Description of the Placement Method.
Placement of material would be accomplished by trackhoe 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.** There would be an immediate change in substrate elevation and slope over the areal extent of the structure placement locations. The bendway weirs would consist of a rock mound of uniform shape along the outside bend extending into the navigation channel. The top elevation of the weirs would be 304 feet (-15 LWRP14). 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, sediment would be captured between the underwater weirs raising the channel depth along the outside bend; however, the elevation of the bendway weirs and associated trapped sediments would remain at 304 feet allowing for passage of barge traffic even during low river stages. A small portion of the opposite point bar would be eroded as the currents shift away from the outside bend. The slope of the opposite point bar would be expected to remain similar to existing conditions.

Dikes are usually built perpendicular to the river flow and vary considerably in height and length. The extended or restored stone dikes at RM 72.9 (339 ft - +18 LWRP14) and RM 67.8 (336 ft - +18 LWRP14) will redirect the river's own energy to provide a variety of effects including managing the sediment response distribution within the channel to deepen the channel and provide adequate depth for navigation.

Chevrons, dike structures designed as a blunt nosed arch shape, have typically been used to redistribute flow and sediment to maintain the navigation channel. The chevrons will use the energy of the river to redistribute water flow, but unlike traditional dikes that create a unidirectional deflection, they create a split flow. The riverside bank of the chevron directs flow to maintain the navigation channel while the other side directs flow toward the riverbank. These structures have been proven to be effective at promoting bathymetric diversity, including a low velocity habitat behind the chevron itself. Chevrons will be placed at RM 73.65 and 72.55 at approximately 339 ft. (+18 LWRP14) respectively.

River engineers at the Applied River Engineering Center have found that S-Dike structures not only redistribute flow and sediment, but have the ability to control the energy coming off of the right side or the left side of the structure. S-Dike structures are useful for creating secondary side channels because they angle upstream to capture water from the main channel and direct it towards the area of interest, while providing enough roughness and constriction to maintain a navigable channel. The S-dike will cause minimal erosion along the bankline because an eddy is formed at its tip. As flow and sediment hit the structure, depending on the orientation of the dike, a portion of the flow and sediment will be taken from the main source of flow towards a lower energy area on the opposite side of the dike. (USACE 2012)

The S-dike or diverter dike would consist of a rock mound of uniform shape in the main channel border near RM 67.5. The top elevation of the S-dikes would be 336 feet (+18 LWRP14). Side slopes would be approximately 1 vertical on 1.5 horizontal.

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” Stone.

III. **Fill Material Movement.** No bank grading or excavation would be required for the installation of structures. Draglines and/or trackhoes would pull rock from floating barges and place the material into the river. Fill materials would be subject to periodic high flows which may cause some potential movement and dislodging of stone from the structures. 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 low densities of oligochaetes, chironomids, caddisflies, and turbellaria. 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 use 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 bendway weirs would redirect the swift currents away from the outside bend, toward the opposite point bar, allowing for a wider and safer navigation channel. Current patterns shifting toward the opposite point bar would cause a small portion of the point bar to be eroded. The chevron dikes would create split flow conditions at river stages below the structure's top elevation of 339 feet (LWRP14 +18). The S-dike would direct flow toward a secondary channel and chute at Vancill Towhead.

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 are 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. Long-term beneficial effects should occur as macroinvertebrates colonize new rock substrate and fish utilize macroinvertebrate prey resources.

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.** Shifting sediments at structure placement sites likely harbor low densities of oligochaetes, chironomids, caddisflies, and turbellaria. 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 structure placement sites due to improved flow, bathymetry, and prey resource conditions. The impacts on fish and macroinvertebrate habitat on the inside bend opposite the weirs are uncertain. Studies to date do not provide conclusive results for predicting fish or macroinvertebrate community response to weir placement at adjacent inside bends.

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.

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 Assessments. No significant adverse impacts to threatened and endangered species are expected to result from this work.

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 have been obtained from the states of Illinois and Missouri (see Appendix F). All other permits necessary for the completion of the work have been applied for and will 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, chevron dikes and bendway weirs have been used extensively throughout the Lower, Middle, and Upper Mississippi River System to provide a safe and dependable navigation channel. S-dikes are a new type of dike structure. 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 chevron and rootless 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, no significant cumulative impacts on the aquatic ecosystem are identified for the Grand Tower 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 river training structures in the area but continuing to maintain the existing river training structures. Dredging would continue as needed to address the shoaling issue in the area.

2. Proposed Action - The Proposed Action consists of the Crawford Towhead work area and the Vancill Towhead work area. The Crawford Towhead work includes the construction of two chevrons and the extension of one dike between RM 74 and 72. The Vancill Towhead work is located between RMs 70.0 and 67.0 and includes construction of 3 bendway weirs, 3 diverter (S-Dike) dikes, repair of dike 67.8, revetment at dike 67.3 and shortening of dikes 67.3 and 67.1 (generally Alternative 33 of the Vancill Towhead Hydraulic Sediment Response (HSR) Model Investigation).

C. Certification under Section 401 of the Clean Water Act has been obtained from the Missouri Department of Natural Resources and the Illinois Environmental Protection Agency (see Appendix F).

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.

10 June 2016
(Date)

ANTHONY P. MITCHELL
COL, EN
Commanding

Appendix E. Public Comments and Responses

Appendix E. Public Comments and Responses

TABLE OF CONTENTS

SIU SOUTHERN ILLINOIS UNIVERSITY GEOLOGY
CARBONDALE

Prof. Nicholas Pinter
Director, IGERT Program in Watershed
Science and Policy
& Professor of Geology
Southern Illinois University
Carbondale, IL, 62901, USA
Phone 618 453 7375
Fax 618 453 7393
npinter@geo.siu.edu

Jan. 9, 2014

U.S. Army Corps of Engineers
attn.: CEMVS-OD-F (Danny McClendon)
1222 Spruce Street
St. Louis, MO 63103-2833

re: P-2856

To Whom It May Concern:

This letter is in response to your Public Notice P-2856 regard the proposed construction of new river training structures between Middle Mississippi River (MMR) river miles 67 and 74, referred to as the Grand Tower Phase 5 Regulating Works Project.

I hereby request one or more public hearings to discuss the impacts of, and alternatives to the proposed project. I request that at least one of these meetings be held in Illinois, preferably in Wolf Lake, IL.

The public hearing(s) should be held to solicit input and public involvement regarding the Corps Finding of No Significant Impact resulting from this project. This Finding is inconsistent with available evidence and inconsistent with majority scientific opinion, in particular regarding the effects of such river training structures on flood levels, levee performance, and public safety. The Corps has initiated a Supplemental Environmental Impact Study to assess the effects of river training structures, including the question of flood magnification. No new structures should be planned or built until a comprehensive, balanced, and independent assessment is completed.

The proposed Grand Tower project is of particularly grave concern, given its location, in the Mississippi channel at Wolf Lake, Illinois along the Big Five Levee System. Corps inspections have identified a number of deficiencies in this levee system, and there are serious concerns about its performance during future floods even without additional stresses. Empirical hydrologic data, geospatial analyses, hydraulic modeling, and engineering theory all suggest that elevated flood levels are associated with river training structures, in particular upstream of these structures due to backwater effects.

Furthermore, the proposed Grand Tower project includes construction of new "S-dikes" at this location. The purpose of inventing new types of dikes structures is unclear, and the rationale for experimenting with these untested inventions in the real-world Mississippi River is very tenuous. The St. Louis District and its Applied River Engineering Center must make extra efforts to consult with floodplain residents, levee boards, navigational interests, and other stakeholders in order to justify the need for such new structures and document that thorough studies, including full two-dimensional and three-dimensional numerical hydraulic modeling, have preceded any construction.

In addition to flood hazard, levee, and public safety concerns, public hearing(s) should be held to solicit input and public engagement on the role of river training structures in management of the Middle Mississippi River. River training structures are have become the signature project of the Corps' St. Louis District, but the purported benefits of these structures – including for river habitat improvement, navigation, and sediment transport – have not been rigorously documented or discussed by affected stakeholders. The "Draft Environmental Assessment with Unsigned Finding of No Significant Impact" for the new Grand Tower project includes little or no stakeholder involvement and an inadequate assessment of alternatives to the proposed construction activities.

Sincerely:

Nicholas Pinter

Prof. Nicholas Pinter

SHAWNEE

Community Unit School District #84

3365 State Rt. 3 North Wolf Lake, Illinois 62998

DISTRICT OFFICE
3365 State Rt. 3 N.
Wolf Lake, IL 62998
(618) 833-5709
(618) 833-4171 FAX
Shelly Clover-Hill
Superintendent

SHAWNEE
JR-SR HIGH SCHOOL
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(618) 833-5307
(618) 833-7133 FAX
Mike Hanson
Principal

SCHOOL COUNSELOR
Karen Schaefer
800-818-3224
(618) 833-5307
(618) 833-5468 FAX

January 10, 2013

U.S. Army Corps of Engineers
ATTN.: CEMVS-OD-F (Danny McClendon)
1222 Spruce Street
St. Louis, MO 63103-2833

To Whom It May Concern:

My name is Jamie Nash-Mayberry and I teach high school social sciences in Wolf Lake, Illinois at Shawnee High School. For the past four years my students and I have been researching flooding issues, including the continued building of wing dikes along our school district which stretches from Grand Tower to the northern edge of Thebes, Illinois. I was recently informed via Public Notice P-2856 of your plans to build more dikes into the river including new S dikes. My students and I are gravely concerned about this matter. We feel the S dikes are experiments on us, and feel all dikes in general should be limited. We have spoken with geologists from both SIUC and the Netherlands and read their research, listened to researchers from Washington University, and have spoken to local levee commissioners. All concur that the river does not need more dikes, and that they can contribute to increased flooding problems. We presented our research to the Mississippi River Coordinating Council of Illinois and they are currently investigating the issue. While they do this, we ask that you use other methods of managing the channel such as dredging, releasing water from other rivers, and blowing up shale rock as you have done previously.

I am requesting a public hearing occur so that we can voice our concerns. I might be able to obtain permission for the meeting to be held at Shawnee High School in Wolf Lake, Illinois. We have held levee summits there. I hope you will listen to the citizens on this matter. We have used models of the river and realize that one of the problem's with these wing dikes is that you have to keep putting them in because they simply relocate the sediment to a new location. Before long, the entire river will be filled with rock from your dikes, and there will be no place for the water to go except up and over the levees.

Sincerely,

Jamie Nash-Mayberry
618-713-0475
jnash25@gmail.com

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SHAWNEE

Community Unit School District #84

3365 State Route 3 North, Wolf Lake, Illinois 62998

January 10, 2014

U.S. Army Corps of Engineers
ATTN.: CEMVS-OD-F (Danny McClendon)
1222 Spruce Street
St. Louis, MO 63103-2833

To Whom It May Concern:

My name is Shelly Clover-Hill and I am the Superintendent of Shawnee Community Unit School District #84 in Wolf Lake, Illinois. I was recently informed via Public Notice P-2856 of your plans to build more dikes into the Mississippi River including new S dikes. I am deeply concerned about this matter given the deteriorating levee conditions surrounding our school district – especially the Grand Tower area.

Our students, along with their teacher Jamie Nash-Mayberry, have been researching the negative effects of wing dikes. Research shows that wing dikes contribute to increase flooding which is something the communities in our district cannot afford. If the levee is not repaired in Grand Tower, it is very likely there will be major flooding there as early as this spring.

I am requesting a public hearing so we may voice our concerns. I am offering Shawnee High School in Wolf Lake, Illinois as a meeting site for this public hearing.

Thank you very much for your consideration.

Sincerely,

Shelly Clover-Hill

Shelly Clover-Hill
Superintendent
Shawnee CUSD #84

2014-126

FEB. 21, 2014
U.S. ARMY CORPS OF ENG.

DEAR SIR:

I ATTENDED YOUR MEETING AT SHAWNEE HIGH SCHOOL ON WEDNESDAY EVENING.

I LISTENED TO THE PEOPLE WHO SPOKE. I FEEL THE SAME AS THEY DO.

IN MY OPINOIN YOUR MAN MADE STRUCTURES ARE UNNECESSARY AND ONLY RAISE THE LEVEL OF THE RIVER. AS MANY DYKES AS YOU HAVE IN THE AREA, HOW CAN YOU JUSTIFY PUTTING IN MORE. AS FAR AS DREDGING YOU WILL BE CONTINUITY DOING SO.

IT WOULD BE BETTER IF YOU TOOK THAT MONEY AND THE MONEY YOU WOULD USE ON STUDIES AND PUT DIRECTLY ON REPAIRING OUR LEVEES.

MY FAMILY HAS LIVE IN THIS AREA FOR FIVE GENERATIONS. I DONT WANT TO BE THE LAST GENERATION TO LIVE HERE.

THANK YOU
David S. Korando
2112 SWAN POND ROAD
JACOB, ILLINOIS
62950

US Army Corps of Engineers
St. Louis District

Comment Form

Regulating Works on the Middle Mississippi River
Environmental Assessments

Your input helps us to identify issues for evaluation in the Environmental Assessment for Regulating Works on the Middle Mississippi River. Please complete this comment form today or mail to the address below. Comments must be received no later than March 7, 2014.

Comments may be mailed to:

U.S. Army Corps of Engineers – St. Louis District
Attn: Regulatory Branch (CEMVS-OD-F)
1222 Spruce St.
St. Louis, MO 63103-2833

Please provide your comments below (Please print legibly):

There are entirely to many dikes in the Mississippi River some are good but alot of the dikes are not needed The chevron dikes are a waste of tax payers money There is no Reason what so ever in closing off that much of the River The more Rock the corps puts in the River the more flooding there will be Cape Bend is closing off just one narrow channel all up and down the Mississippi River.

Signature: Virgil W. Knupp Date: 3-4-2014

Name: VIRGIL W. KNUPP Title: CAPTAIN RETIRED

Mailing address: P.O BOX 223

City, State, Zip code: GRAND TOWER ILL. 62942

Phone: 618-924-3879 Fax: E-mail:

Thank you for your interest and participation!

Member ISBA

ROBERT D. LARSON
ATTORNEY AT LAW
307 HENRY STREET, SUITE 310
P.O. BOX 434
ALTON, ILLINOIS 62002
----
(618) 462-4448
FAX (618) 462-5897

Email Address
larsonlaw@gmail.com

February 28, 2014

Army Corps of Engineers
Attn: Regulatory Branch
1222 Spruce Street
St. Louis, MO 63103-2833

Re: File Numbers 2013-742 and 2013-743
Comments on Draft Environmental Assessment with Unsigned Finding of No Significant Impact, Regulating Works Project Grant Tower Phase 5, Crawford Towhead and Vancill Towhead, Middle Mississippi River Miles 74-67 Union County, IL Cape Girardeau County, MO; Public Notice P-2856 (2013-742)

Dear Mr. McClendon:

I am a recreational boater who has sailed on the Mississippi and associated waters since 1976.

I urge the Corps to withdraw the Grand Tower EA and place the proposed Grand Tower project on hold at least until the Corps completes the recently announced supplemental environmental impact statement for the Middle Mississippi River Regulating Works Project, Missouri and Illinois (SEIS). The Grand Tower EA does not comply with the requirements of the National Environmental Policy Act (NEPA) and presents flawed science as the basis for its conclusion of no significant impacts. As a whole, the EA is far too limited and lacking in scientific support to adequately assess risks to public safety and the environment or to determine whether less damaging alternatives are available.

I urge the Corps to expand the SEIS to evaluate the full suite of operations and maintenance (O&M) activities for the Upper Mississippi River – Illinois Waterway (UMR-IWW) navigation system. As the Corps is well aware, the Regulating Works Project, including the proposed Grand Tower project, is just one of a number of activities carried out by the Corps to maintain navigation on the UMR-IWW. In addition to construction of river training structures, other O&M activities include water level regulation, dredging and disposal of dredged material, construction of revetment, and operation and maintenance of the system's 37 locks and dams. Since all O&M activities are designed to maintain a single project, individual activities should not be evaluated in isolation.

Army Corps of Engineers
Attn: Regulatory Branch
February 28, 2014
Page Two

I urge the Corps to initiate a National Academy of Sciences study on the effect of river training structures on flood heights to inform development of the SEIS. A National Academy of Sciences review is critical for ensuring that: (a) the SEIS is based on the best possible scientific understanding of the role of river training structures on increasing flood heights; (b) the SEIS produces recommendations that will provide the highest possible protection to the public; and (c) the public will have confidence in this aspect of the evaluation and recommendation contained in the final SEIS.

I urge the Corps to impose a moratorium on the construction of new river training structures pending completion of the SEIS. As discussed below, extensive peer-reviewed science demonstrates that river training structures have increased flood levels by up to 15 feet in some locations and 10 feet in broad stretches of the Mississippi River where these structures are prevalent. In light of these findings, it is critical that additional river training structures not be built unless and until a comprehensive SEIS establishes that such construction will not contribute to increased flood risks to communities.

Thank you for your consideration.

Very truly yours,

Robert D. Larson

RDL/ckl

PUBLIC HEARING

RIVER TRAINING STRUCTURE CONSTRUCTION ACTIVITIES
FOR THE GRAND TOWER PHASE 5 PROJECT AND
THE DOGTOOTH BEND PHASE 5 PROJECT

Taken at Shawnee High School Library, 3365 State
Route 3 North, Wolf Lake, Illinois
Between the hours of 6:55 p.m. and 7:29 p.m.

February 19, 2014

Sherrie L. Merz, RDR/CSR/CCR

CSR No. 084-002840

CCR No. 995

A P P E A R A N C E S

COLONEL CHRISTOPHER G. HALL, Commander
St. Louis District
U.S. Army Corps of Engineers

MARY MARKOS, Hearing Moderator
Public Affairs Specialist
St. Louis District
U.S. Army Corps of Engineers

JASEN BROWN, Project Manager
Hydraulic Engineer
St. Louis District
U.S. Army Corps of Engineers

(On the record at 6:55 p.m.)

COLONEL HALL: Good evening, everybody. I'm Colonel Chris Hall, the Commander of the St. Louis District, U.S. Army Corps of Engineers. I will be the presiding officer over tonight's hearing, and my staff and I are here to listen and to obtain feedback from you all, to hear your concerns, understand what your concerns are and to gain that feedback.

We have two draft environmental assessments for the river training structures, construction activities for the Grand Tower Phase 5 project, and the Dogtooth Bend Phase 5 project. And I think there's some information in the back on those specific projects if you haven't already seen that.

As I said, again, the purpose of this hearing is to comply with the requirements of our National Environmental Policy Act, NEPA, and the Clean Water Act and whereby we obtain public information and views and comments on our proposed projects.

But before we get started, I would like to thank the Shawnee High School and particularly Jamie Nash-Mayberry. Jamie, thanks for opening up your school and providing this great forum for us to be here tonight.

And I would also like to introduce those individuals seated here with me. I have Mr. Jasen Brown to my right. Jasen is one of our hydraulics engineers in our hydraulics engineering branch, and he's managing the project. I also have Miss Mary Markos on my left who is a member of our awesome public affairs staff, who will explain tonight's hearing and the procedures that we're going to walk through here in just a minute.

Before we get to that, I'd like to introduce two folks that I'm aware of, Mr. Carl Maple of Congressman Enyart's office. Carl, in the back there, thanks for being here. We appreciate it. And Patti Clancy -- Clark, I'm sorry, Patti -- from Lieutenant Governor Simon's office. Thank you, Patti, for being here as well.

Okay. Are there any other elected officials here that I missed that were signed up? Okay. Moving on then, what I'd like to do is again thank you for being here. I appreciate it, and I look forward to hearing from you and again getting that feedback. But right now, I'll go ahead and turn it over to Mary who's going to talk through kind of how we're going to work through this procedure.

MS. MARKOS: Thank you, Colonel. As I said, as you entered the library, you were asked to sign in and you were given the opportunity to make a public comment. If you have not done that, and you want to make a comment, please raise your hand, and we'll get a card to you. Those cards can be passed down or forward, and we'll get them up here so that you can be added to the list to speak.

As Colonel Hall said, the purpose of tonight's hearing is for us to hear your thoughts and concerns. This is not a discussion, and it is not a question and answer session. We are here to listen to you. The hearing is being transcribed in its entirety by a stenographer, so we ask those speakers that do come up to speak directly into the mike, to state their name and address and any organization or agency that they are representing.

The way this will go is I will call individuals forward. We have approximately 14 people that would like to speak. Each individual will be allowed or given three minutes to make their remarks. We're asking that everyone give them the opportunity without interruption. When we get to the two-minute mark for all speakers, I will hold up a yellow card so they know that their time is about up.

If you are speaking and your time runs out before you get the opportunity to finish your statement, we have those comment sheets that I mentioned earlier that you can fill out, and they will be included in the record. As I said, this hearing is for us to hear from you. We ask that everyone does not interrupt the speakers so that everyone does have the opportunity to express their concerns.

The public record will be open through Friday March 7th. Anyone who wishes to add further comments to fill out a comment sheet or submit comments to our office can do so before that time. Written statements submitted after the public hearing after tonight must be mailed to the Corps of Engineers' Office. That address is on the fact sheet which is available at the sign-in desk, and all the information will also be posted on the website. That website is also on this fact sheet.

As I said, will all speakers please remember to state their name and their zip code and to speak clearly into the microphone. At this time, our first speaker is Mr. William Ellis. Mr. Ellis, would you like to come forward?

Okay. So our first speaker tonight will be Miss Amanda Damptz. Miss Amanda Damptz from SIU Carbondale, would you like to come forward and speak?

MS. AMANDA DAMPTZ: My name is Amanda Damptz. I'm from SIU Carbondale, and I would just like to make one brief comment, that the National Wildlife Federation has targeted these two dike projects and put issues on the action alert system. And as of this afternoon, there's 17,000 people nationwide that have signed up in opposition to the construction of these dikes.

MS. MARKOS: Thank you, ma'am. Our next speaker, I'd like to call up LaRae Verble-Whitaker from the Shawnee School Board.

MS. LARAE VERBLE-WHITAKER: My name is LaRae Verble-Whitaker. I'm from Wolf Lake, Illinois. I'm a community member. I'm also a Shawnee Valley Water Board member, and I'm also Shawnee School District Board President. Right now, I would like to ask the board or actually ask the Army Corps of Engineers to please consider further studies with your experiments and please consider what you're doing before you go forth or at least postpone them, because right now, our levees are, as you know, very fragile.

And we are working very hard to get them back to a standard where they can withhold some water, but please give them some time. And postponing a project a couple years, what will that hurt? I know it's experimental, and please just consider that. Thank you.

COLONEL HALL: Thank you.

MS. MARKOS: Thank you. Our next speaker is Miss Shelly Clover Hill.

MS. SHELLY CLOVER HILL: My name is Shelly Clover Hill, and I am the proud superintendent of Shawnee District 84. And before I get started, I would like to say to our current and former students and their teacher Miss Jamie Nash-Mayberry how proud this district is of you guys for highlighting the issues with the levee, so thank you very much.

And I'd like to thank you for giving us the opportunity this evening to have this hearing and thank you for listening.

COLONEL HALL: My pleasure.

MS. SHELLY CLOVER HILL: With the safety of all of our community's students and school district in mind, I urge you to suspend the dike construction at Dogtooth Bend and Grand Tower until after thorough scientific assessment of dikes and other maintenance activities is completed using computer modeling and real world testing of their effects.

As you know, the current states of the levees in our surrounding area, they are weakened. We are all very concerned about them. We are concerned about our homes. We are concerned about our businesses and our farms and, of course, our school district. So we would urge you to suspend those activities until further research can be conducted. Thank you very much for listening. I appreciate your time.

COLONEL HALL: Thank you.

MS. MARKOS: Our next speaker is Mr. Jim Taflinger.

MR. JIM TAFLINGER: Hello. I'm Jim Taflinger, Len Small Levee District, live in Miller City. We've had Weir dikes in Dogtooth Bend for over 20 years. They work. They don't cause any other problem with high water, because they work on normal flow of the river.

My concern is that we need to use hard points or some kind of a diking system to protect on the opposite side of the Weir dikes so you don't have land erosion and loss of acreage on islands. And the second thing I'd like to say is that we need to put more hard points in the chute banks along the river to protect.

We're having so much loss of river bank, because you no longer put dikes across the, you know, across the sloughs and the -- what am I trying to say -- and if you put hard points, they sure work on the island of Santa Fe Chute. You've got hard points staggered on both sides, and it's working fine. So we don't have any loss of stream bank against our levees. But as I said, the Weir dikes are working. Do I get a star for being for it?

COLONEL HALL: Thank you, sir.

MS. MARKOS: Thank you, sir. What I'm going to do is I'll read the next two names of speakers. That way everyone can start working their way to the mike. Our next speaker will be Mr. Ron Shepard, and following Mr. Shepard, we will have Miss Olivia Dorothy, please.

MR. RON SHEPARD: Ron Shepard, Wolf Lake. I just want to say that the dikes as I see, and being over on the river after every time the water is up and all the sand and sludge that's just left behind and building up the land, the dikes apparently aren't doing that much good and hasn't for several years. So I don't see why to continue to put money into something that apparently is not working that well. Thank you very much.

COLONEL HALL: Thank you, sir.

MS. MARKOS: Thank you. Olivia Dorothy, and following Olivia we will have Miss Elena Houston.

MS. OLIVIA DOROTHY: Good evening. My name is Olivia Dorothy, and I'm actually from Rock Island, Illinois, so I had quite a drive coming down here. I work for the Izaak Walton League of America, and I also am the facilitator for the Nicollet Island Coalition, which is a collaboration of conservation and taxpayer organizations on the Upper Mississippi River. That includes the Prairie Rivers Network, National Wildlife

Federation, the Sierra Club, Missouri Coalition for the Environment, and others.

Tonight I want to ask you to please withdraw the Dogtooth Bend and Grand Tower projects in their environmental assessments until the supplemental environmental impact statements for the Middle Mississippi for regulating works project is complete.

The St. Louis District of the Army Corps has already determined that the 1976 environmental impact statement is outdated, flawed and otherwise inadequate for continued applicability on the Mississippi River. To tier these projects, that 1976 document is unacceptable.

The driving impetus for updating the 1976 environmental impact statement is concerned that river training structures are increasing the flood risk along the Mississippi River and its riverfront communities. Both of these projects will construct 18 new structures in the Mississippi River, including an S dike, a structure that has never before been built.

This raises significant concerns since there have been more than 50 peer-reviewed studies, and I have the list here to provide you with that correlate increasing flood risk to river training structures such as those proposed to be built at Dogtooth Bend and Grand

Tower.

Additionally, very limited evidence exists documenting the environmental impacts and cost effectiveness of the river training structures that will be built at Dogtooth Bend and Grand Tower. Much of that evidence identifying these structures as environmentally preferable and cost effective is anecdotal, and the district relies too much on the HSR model, which other professional organizations call unreliable due to its inability to provide accurate predictions. This is why it's essential for the environmental impact statement for the Middle Mississippi River regulating works projects be completed before the Dogtooth Bend and Grand Tower projects advance.

If done correctly, the supplemental environmental impact statement for the Middle Miss regulating works projects will include an independent study evaluating the flood risk associated with river training structures, a moratorium on the construction of river training structures until the environmental impact statement is completed, and the independent study can ensure their safety, and a properly expanded project purpose preferable one that encompasses the entire 9-foot channel project.

This supplemental review on the Middle Miss regulating works may render the construction of the river training structures at Dogtooth Bend and Grand Tower unadvisable. At the very least, it is likely the supplemental environmental impact statement for the regulating works will install new conditions and restrictions that will apply to projects like Dogtooth and Grand Tower.

Since there are so many concerns about the safety of river training structures and the likelihood that new rules will apply to the construction of them after the supplemental EIS on the Middle Miss is complete, I insist the Dogtooth Bend and Grand Tower projects be postponed. Thank you.

MS. MARKOS: Miss Elena Houston and then Mr. Kenneth Verble, please.

MS. ELENA HOUSTON: Hello. I am Elena Houston. I'm from Grand Tower, and as a former student of Shawnee High School, I've seen a lot of research that has been done on wing dikes and the effects they have on flooding. And from what I've seen, that it hasn't been very beneficial in relation to flooding. So before you guys put these dikes in, I would just like for more research to be done to show that it's not going to affect us in negative ways. Thank you.

MS. MARKOS: Thank you.

COLONEL HALL: Thank you.

MS. MARKOS: Mr. Kenneth Verble and then Miss Jamie Nash-Mayberry.

MR. KENNETH VERBLE: My name is Kenneth Verble. I live in Wolf Lake, and a farm owner and concerned with anything that affects the river and any flooding that may occur from it. I guess one of my first thoughts was have we done a computer modeling program to determine what these dikes are going to do in the future? Have we looked at the existing dikes as to what they have done? Just noticed in your brochure here that Congress has given us a blank check to go out and build these things, but I don't see anything going back towards what's happened in the past, such as the old dikes that have built up and consumed the water volume that used to exist. It's no longer there, so water can't take its place during any high waters.

So I would like to see you use some of that money to do both things. I'm sure Congress didn't allot that money just to keep the river 9 foot deep, 300 foot wide. I'm sure they had other things in mind to protect the citizens in the Bottoms as well as the traffic on the river. So those things should be studied.

And that computer model I would like to see, and also, who are you reporting to within the state?

This is Illinois. When you're on the Illinois side, somebody in Illinois needs to be working with the Corps of Engineers, say yes, I agree with you or no, I don't agree with you, yes, you've done the right studies and this independent agency over here has verified that.

And being from a background of codes and standards, you never go with one study. You have more than one study, and then you mock it up, make sure your studies are right. The mock-ups and studies will cost more than the actual project. So those things need to be done and not forgotten.

So again, looks like we got a blank check to work on this river. Let's work on both sides of it to benefit the farmer, the Bottoms and the traffic.

MS. MARKOS: Miss Jamie Nash-Mayberry and then Miss Jessica Spurlock.

MS. JAMIE NASH-MAYBERRY: My name is Jamie Nash-Mayberry. I'm from Cobden, Illinois 62920, but I'd like to claim myself as a Bottoms person. Many of you already know me, and you know that my students and I have studied this issue extensively. We came to your Corps base in St. Louis, and Eddie Brauer presented his side of the issue. And we kept an open mind, but we couldn't deny what all the other sources we examined were saying.

We didn't just talk to Dr. Nicholas Pinter of SIU, a geologist, geographer; we went on. We talked to others. We talked to Fredrik Huthoff of the Netherlands. He was studying abroad. We talked to a Washington University professor. We read peer-reviewed journals. We even read comments from the National Wildlife Federation.

And then we talked to the real experts, the locals, who've seen these dikes be put in over the years. And the thing is, they all concluded the same thing, that these wing dikes lead to increased flood heights.

Here's my point: If we're wrong, all of us, the consequences are really minimal. But if you are wrong as the Corps, the consequences are enormous. Why not stop putting them in, get an outside group to come in, do a study -- and I don't mean a group that you're paying; an outside group -- and have them conclude what's happening here? And you could spend your money blowing up shale to help the barges. You could dredge to help the barges. You could use your money to open up other rivers to help the barges, or perhaps you could even use that money to fix some of these slides in Grand Tower.

But the National Wildlife Federation just a minute ago recommended the National Academy of Sciences could come in and do a study. I know they've tried before to do that, and I don't understand why you haven't had them come in and do the study. My conclusion is you're afraid of what they might conclude and perhaps the future lawsuits that might follow that.

Finally, I simply ask this of you: Think about the consequences of all these people. I know you have hearts. You've come down here. You've done excellent presentations for my students and I anytime we've asked, so I know you're caring people. I know that. I'm asking you to care about these people and think about what the risk might be.

And finally, because many of them didn't sign up to comment -- but I know how they feel -- how many of you out there would be in favor if the Corps stopped putting wing dikes in until an outside group could study it further? Show of hands. Thank you.

COLONEL HALL: Thank you.

MS. MARKOS: Miss Jessica Spurlock and then Mr. Braden Mezo.

MS. JESSICA SPURLOCK: My name is Jessica Spurlock. I live in Wolf Lake, Illinois, and I'm a senior this year at Shawnee High School and a proud supporter and proud to be a part of Save the Levee

Project. Grand Tower, if there was to be another flood, and it be to where the levees would break, it would be disastrous, and we would lose our district because it's a third. And we all know -- half of it now is from what Miss Nash-Mayberry has told us -- in this construction, there would be new S dikes. And that is new, and that has not been tested yet further.

There should be more people looking into this S dike program like the National Academy of Science look into it and see what they think and their opinion is on it on how these dikes will or will they not break our levees and if the levee will rise if these dikes are put in. Thanks.

COLONEL HALL: Thank you.

MS. MARKOS: Mr. Braden Mezo, and then we have Dr. Nicholas Pinter.

MR. BRADEN MEZO: My name is Braden Mezo, and I am a senior at Shawnee High School. And it is common knowledge that there are going to be many new -- that this project will present as many different kinds of wing dikes, the S dike as previously mentioned. Knowing that it had not been tested thoroughly yet, I believe that this raises many concerns, and I humbly request that you put a little bit more research into it.

Being a resident of this area, it is very important to me that I graduate from this school. I do not want to lose my home, and it is very important to me. So I humbly request you put it off maybe for a year or two. Like it was said before, what can it hurt? And that is all. Thank you.

COLONEL HALL: Thank you.

MS. MARKOS: After Mr. Pinter, we will have Mr. Virgil Knupp.

PROFESSOR NICHOLAS PINTER: My name is Nicholas Pinter, Professor at Illinois University of Carbondale. I wanted to thank the Colonel and the rest of the Corps staff for making the drive down here. We heard a rumor that the Corps had requested police protection here in Wolf Lake. We were a little amused by this, not sure what you expected to find south of 64. We hope you find us a little bit more hospitable than you feared.

COLONEL HALL: I've been in worse places.

PROFESSOR NICHOLAS PINTER: Nice to hear, I think. So I have about two and a half minutes left to talk about a hundred-plus years of research on a link between wing dikes and the river training structures and flooding. And I can't do that, so just a couple quick points.

One is the starting point for this

discussion. So we sat down with Corps staff, some of them in this room and their consulting scientists in 2008, I believe. And there was one area of broad agreement, and that is flood risk, flood levels and flood frequencies on our stretch of river, the Middle Mississippi River, had increased by most agreement dramatically during the last decades to a century or more, which really brings all this to a question of what exactly is causing this increase in flood levels.

And what we need to do is point out anyone needs to look at the maps in Jamie's room, look at the number of these structures that have been in place, thousands of these structures on this river over the past decades. This is the epicenter of wing dike construction, certainly in the country, and if there is a river anywhere in the world with more of these structures of greater density than the Middle Mississippi River, we haven't found it yet, and we've been looking for it.

So I guess what I would suggest is, Colonel, we just returned to the conversation we had several years ago when you first arrived in St. Louis, where my colleagues and I suggested the same thing that you've heard in the room tonight, that you're hearing from your staff that these navigation structures do not cause any increase in flood levels, and you're hearing the opposite from a number of academic scientists. What are you to do with that?

So what you've heard, particularly from Miss Nash-Mayberry already, is you can take one or the other, or given that public safety is the question that we're all most concerned about, you can say you don't know the answer to that question, and you're going to send it out to another group, an independent group, with no vested interest in the answer to that question to finally assess the result of that question.

The National Academy of Scientists is a suggestion that's been made a number of times tonight. We suggest that that study be initiated as part of the supplemental environmental impact statement that is now just being initiated and, meanwhile, that a moratorium be declared, that no new structures be built on our Middle Mississippi River until their safety be thoroughly addressed. Thank you very much.

MR. VIRGIL KNUPP: My name is Virgil Knupp, and I'm from Grand Tower. I worked on the river for 35 years for Luhr Brothers. We built a lot of these dikes out there, and about 40 percent of them we don't need. We're over-diked. That's why we had the flood. If we had a flood the same height as '93 right now, it would go over the levee at Grand Tower. That's how many dikes you've put in since then.

And you extended dikes down there at Pikayune, 75 feet, five dikes, 75 feet each. They didn't need to be extended. They need to be took out. And all the way down to Caruthersville, the dike down there is over three quarters of the river closed off. Behind Wolf Island, there's two dikes that blocks the island off. There's two trap holes in behind it. That's why they flooded down on the Missouri side that time.

There's too much river shut off with these dikes. If some of these dikes were shortened up, the one above Robinson Bayou, you can take a hundred 50 foot of that dike out and all the way around that bend some of them dikes. Down above the Boot Point Bridge, them dikes, you ain't got a channel left no more. It's not the Mississippi River. It's the Mississippi Creek.

It's over-diked, and that's where the flooding is coming out. It's putting too much strain on the levees. It's nothing to take and sit 8, 10, 12 hours on a boat trying to get up to another hole. It's that swift out there anymore. And you don't have no room no more. And as far as swift, a lot of times they get in Grand Tower chute, it shoots them out.

So they don't need no more dikes in here. Don't need none down south. What they need is to figure out a way to eliminate some of the dikes and still hold the channel so that next flood we have is not going to top. If we have another one like '93, it's over. It's coming over.

Wolf Lake had all them boils out on their levees that year and they thought they was going to lose it. Well, that's going to affect Grand Tower, Howardton, Gorham, Jacob, Neunert, all the way up to Cora levee -- well, you might as well say McClure, East Cape. Everybody is going to go if they don't take some of the pressure off of some of these dikes. They're just too long, too many.

I mean, a lot of them I don't even know what they're in there for. They're worthless. They ain't no good. And they're too long. If you fly over Caruthersville north of Robinson Bayou and look at the dike and look at how much water you have left, one boat at a time can go through there. If it wasn't for them dikes, you could put four boats through there at a time, side by side. That's how much of it, take that off.

But as far as that dike they're going to put in up there at Grand Tower, I can show you how to put that in without all of them straight-out dikes. And it will work better than what you're going to do. It will kick the sand off. The sand won't have to be dredged no more.

Because I worked with them building dikes for 35 years, and I know a lot about the dikes, what it's going to do. Because we like to lost a dike -- we changed I don't know how many channels. The channel used to be over here. The channel is over here now. The channel used to be over here; it's not there no more. Down at Buck Island where the casino is, the channel that's on the opposite side of the river, now it's over here on this side of the river, and that's all diked off completely. So that's it. Okay. Thank you.

COLONEL HALL: Thank you.

MS. MARKOS: That's our list of anyone who turned in a card stating they would like to make a comment. Is there anyone else at this time who would like to make a comment? If not, I'll turn the hearing back over to you.

COLONEL HALL: Okay. As I said before, we're here to listen. I'm here to listen. I appreciate the comments. I appreciate the passion. And all of this is part of the process to make a determination on how we go forward with these. I think it was mentioned we have a supplemental EIS in progress. We are doing separate environmental assessments for these projects in order to establish where we're going with them until that supplemental EIS is complete, and I heard some comments on the timing of that and what you would desire to have that be. We'll take all these things under advisement, I will with my staff. But again I appreciate your feedback. That's what we're here for. I wanted to hear from you all personally and understand what it is that -- what your viewpoints are and what your concerns are.

So again, as Miss Markos said, we will still -- I think we'll be taking written comments until March 7th, so if there's something on your mind you want to make sure we understand, please get that in to us. This is part of the process. And I don't take it lightly, or I wouldn't be here.

MR. VIRGIL KNUPP: Me neither.

COLONEL HALL: Again, thank all of you and safe travels home. And listen, I grew up in a small town, no stoplights, farm community, so it wasn't protected by dikes, you know. It's about 50 miles from Lake Erie in Northeastern Ohio. So I have no fear of being in a small community. Trust me, I've been in Sauder City (phonetic). That's what I was remarking when --

MR. VIRGIL KNUPP: Well, you can kind of see, though, they want to overlook small towns, like there's not enough there. It's not like St. Louis or Chicago. But everybody has got their thing. They're all tied up. Their livelihood is here.

MS. MARKOS: Again, thank you guys all for coming. We appreciate it very much.

(Off the record at 7:29 p.m.)

CERTIFICATE

I, SHERRIE L. MERZ, Registered Diplomate Reporter, Certified Shorthand Reporter and Certified Court Reporter, do hereby certify that the foregoing Public Hearing was taken by me at the Shawnee High School Library, 3365 State Route 3 North, Wolf Lake, Illinois, and that this transcript is a true and correct record of the proceedings recorded by me.

I further certify that I am neither attorney nor counsel for nor related nor employed by any of the parties to the action in which this deposition is taken; further, that I am not a relative or employee of any attorney or counsel employed by the parties hereto or financially interested in this action.

IN WITNESS WHEREOF, I have hereunto subscribed my name this 26th day of February, 2014.

Sherrie L Merz

SHERRIE L. MERZ, RDR, CSR, CCR

National Wildlife Federation
American Rivers
Missouri Coalition for the Environment
Prairie Rivers Network

April 22, 2016

Via Email: kip.r.runyon@usace.army.mil

Mr. Kip Runyon
Environmental Planning Section
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103

Re: Amended Draft Environmental Assessment with Unsigned Finding of No Significant Impact, Regulating Works Project Grand Tower Phase 5, Crawford Towhead And Vancill Towhead, Middle Mississippi River Miles 74-67 Union County, IL Cape Girardeau County, MO (March 2016)

Dear Mr. Runyon:

The National Wildlife Federation, American Rivers, Prairie Rivers Network, Missouri Coalition for the Environment (collectively, the Conservation Organizations) appreciate the opportunity to submit these comments on the above-referenced amended draft environmental assessment for the Grand Tower Phase 5 project (the Grand Tower EA).

The National Wildlife Federation (NWF) is the Nation's largest conservation education and advocacy organization. NWF has almost six million members and supporters and conservation affiliate organizations in fifty states and territories. NWF has a long history of interest and involvement in the programs of the U.S. Army Corps of Engineers (Corps) and the management and protection of the Mississippi River. NWF is a strong supporter of ecologically sound efforts to restore the Mississippi River and the nation's many other damaged rivers, coasts, and wetlands.

American Rivers protects wild rivers, restores damaged rivers, and conserves clean water for people and nature. Since 1973, American Rivers has protected and restored more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects, and an annual America's Most Endangered Rivers® campaign. Headquartered in Washington, DC, American Rivers has offices across the country and more than 200,000 members, supporters, and volunteers. The Upper Mississippi River is one of 11 priority river basins where American Rivers is concentrating and integrating our work to protect and restore rivers over the next 5 years.

The Missouri Coalition for the Environment is Missouri's independent, citizens' environmental organization for clean water, clean air, clean energy, and a healthy environment. The Missouri Coalition for the Environment works to protect and restore the environment through education, public engagement, and legal action.

Prairie Rivers Network is Illinois' only statewide river conservation organization and is the Illinois affiliate of the National Wildlife Federation. We are a 501(c)(3), tax-exempt nonprofit based in Champaign, Illinois. Our mission is to protect the rivers of Illinois and to promote the lasting health and beauty of watershed communities. We use sound science and policy analysis to stand up for strong, fair laws to protect clean water and natural areas. We engage citizens, businesses, and governments across Illinois in this effort, providing them with the policy information, scientific data, technical assistance, and outreach programs needed to support effective river advocacy. A recognized leader on issues involving the implementation and enforcement of the Clean Water Act in Illinois, Prairie Rivers Network leads efforts to improve clean water standards, review pollution permits, protect wetlands, reduce polluted runoff from farms and streets, and restore natural areas along rivers and streams.

General Comments

The National Wildlife Federation calls on the Corps to heed the extensive and scientifically-grounded opposition to the proposed Grand Tower Phase 5 project. To prioritize public safety and environmental protection over the agency's desire to reduce dredging costs through this project, the Corps should:

1. Initiate a National Academy of Sciences study on the effect of river training structures on flood heights to inform the Corps' decisions on the use of river training structures. A National Academy of Sciences review is critical for ensuring that: (a) the environmental analyses of new river training structure projects are based on the best possible scientific understanding of the role of those structures on flood heights; (b) recommendations regarding construction of new river training structures protect people and wildlife; and (c) the public will have confidence in the Corps' analyses and decisions.

2. Withdraw the Grand Tower EA and place the proposed Grand Tower Phase 5 project on hold until the Corps has accounted for the findings of the requested National Academy of Sciences study and completed the supplemental environmental impact statement for the Middle Mississippi River Regulating Works Project (SEIS) currently underway.[1] New river training structures should not be built unless the National Academy of Sciences and a comprehensive and legally adequate SEIS establish that such construction will **not** contribute to increased flood risks to communities.

3. Expand the SEIS to evaluate the full suite of operations and maintenance (O&M) activities for the Upper Mississippi River – Illinois Waterway (UMR-IWW) navigation system. The Regulating Works Project, including the proposed Grand Tower project, is just one of a number of activities carried out by the Corps to maintain navigation on the UMR-IWW. In addition to construction of river training structures, other O&M activities include water level regulation, dredging and disposal of dredged material, construction of revetment, and operation and maintenance of the system's 37 locks and dams. Since all O&M activities are designed to maintain a single project, individual activities should not be evaluated in isolation.

As the Corps is aware, conservation organizations, independent scientists, and the public have

[1] 78 Fed. Reg. 77108 (December 20, 2013). NWF appreciates the Corps' decision to prepare the SEIS but urges the Corps to prepare a supplemental EIS for the Corps' entire suite of navigation operations and maintenance activities on the Upper Mississippi River – Illinois Waterway (UMR-IWW) navigation system.

repeatedly asked the Corps to take these actions due to concerns with the public safety and environmental impacts of the project.

The public's strong opposition to the project was most recently made clear at the Corps' March 9, 2016 public meeting at Shawnee High School in Wolf Lake, Illinois. Of particular concern is the risk that the proposed project would increase flood heights in an area that is immediately adjacent to a levee with critical safety issues.

Extensive peer-reviewed science demonstrates that river training structures have caused significant increases in flood heights in broad stretches of the Mississippi River.[2] Peer reviewed science also shows that the excessive constriction caused by river training structures and levees has led to fundamental changes in the way the Middle Mississippi River responds to flood events.[3] In the face of this science, new river training structures should not be constructed unless the National Academy of Sciences and a comprehensive and legally-sufficient SEIS establish that such construction will **not** contribute to increased flood risks for communities.

Specific Comments

While the Corps has provided some responses to the comments submitted by the National Wildlife Federation and others on the original Grand Tower EA (the 2014 Comments),[4] those responses do not meaningfully address the concerns raised. The Conservation Organizations incorporate the 2014 Comments as though fully set forth herein and provides additional comments below. A copy of the 2014 Comments are provided at Attachment A.

[2] Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, 2010. Empirical modeling of hydrologic response to river engineering, Mississippi and Lower Missouri Rivers. River Research and Applications, 26: 546-571; 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. There is also a global consensus that river training structures can and do increase flood heights as evidenced by actions being carried out by the government of the Netherlands to modify hundreds of river training structures "as part of a nationwide effort to reduce flood risk in [the Rhine River] floodplain" at significant cost. Government Accountability Office, GAO-12-41, Mississippi River, Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures (December 2011) (GAO Study on River Training Structures) (concluding that the Corps is out of compliance with both the National Environmental Policy Act and the Clean Water Act).
[3] Robert E. Criss, Mingming Luo, *River Management and Flooding: The Lesson of December 2015–January 2016, Central USA*, Journal of Earth Science, Vol. 27, No. 1, p. 117–122, February 2016 ISSN 1674-487X (DOI: 10.1007/s12583-016-0639-y).
[4] Comments of the National Wildlife Federation, Izaak Walton League of America, Missouri Coalition for the Environment, Prairie Rivers Network, and Sierra Club on Draft Environmental Assessment with Unsigned Finding of No Significant Impact, Regulating Works Project Grand Tower Phase 5, Crawford Towhead And Vancill Towhead, Middle Mississippi River Miles 74-67 Union County, IL Cape Girardeau County, MO; Public Notice P-2856 (2013-742), submitted January 24, 2014 (the 2014 Comments).

A. Construction of the Grand Tower Phase 5 Project Will Put the Public at Risk

As discussed above, the Conservation Organizations once again urge the Corps to initiate a National Academy of Sciences (NAS) study to examine the effect of river training structures on flood heights. An NAS review is a common sense approach that is critically important given the overwhelming scientific consensus that river training structures increase flood heights. This consensus directly contradicts the Corps' assertions that river training structures do not affect flood levels. An NAS review is also essential to address the concerns expressed by the local community. As has been made abundantly clear by both the extent and content of public opposition at the March 9, 2016 and February 19, 2014 public hearings on the project, the local community strongly opposes the project and does not trust the Corps' analyses.

In the face of the overwhelming scientific consensus and intense public opposition, the Corps should not construct new structures without a detailed and comprehensive analysis by the National Academy of Sciences. An NAS study would cost far less than the proposed project, and the costs of the study would be far outweighed by the public benefits of an NAS review.

As discussed in the 2014 Comments, the Corps' conclusions regarding the effects of river training structures is directly contradicted by an extensive body of peer-reviewed scientific literature. Science shows that river training structures, constructed by the Corps to reduce navigation dredging costs, have significantly increased flood levels by up to 15 feet in some locations and 8 feet and more in broad stretches of the river where these structures are prevalent.[5] Independent scientists have determined that the more than 40,000 feet of "wing dikes" and "bendway weirs" constructed by the Corps in the Mississippi during the 3 years prior to the great flood of 1993 contributed to record crests in 1993, 1995, 2008, and again in 2011. Even studies commissioned by the St. Louis District and cited in the Grand Tower EA (*e.g.*, Watson et al., 2013a) find statistically significant increases in water levels for flood flows.

The risks posed by river training structures are particularly problematic for the proposed Grand Tower project given the project's location in the Mississippi River channel at Wolf Lake, Illinois along the Big Five Levee System. Corps inspections have identified a number of deficiencies in this levee system, and there are serious concerns about its performance during future floods even without additional stresses.

Importantly, the science directly contradicting the Corps' findings on river training structures continues to accumulate. In his comments on the Grand Tower EA, Robert E. Criss, Ph.D., a professor in the Department of Earth and Planetary Sciences at Washington University in St. Louis, concludes:

> "The consequences of current management strategy on floodwater levels are clearly shown by data from multiple gauging stations on the Middle Mississippi River (Figures). The Chester and Thebes stations were selected as they are the closest stations to the project area that have long, readily available historical records (USGS, 2016). **These figures conclusively document that floodwater levels have been greatly magnified along the Middle Mississippi River, in the timeframe when most of the in-channel navigational structures were constructed. If these**

[5] Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, 2010. Empirical modeling of hydrologic response to river engineering, Mississippi and Lower Missouri Rivers. River Research and Applications, 26: 546-571; 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.

> **structures are not the cause, then we are left with no explanation for this profound, predictable effect.** That USACE proposes more in-channel construction activities only two months after another "200-year" flood (as defined by USACE, 2004, 2016) occurred in this area proves that their structures and opinions are not beneficial, but harmful."[6]

Dr. Criss adds that measurements at the Mississippi River at St. Louis and the Missouri River at Herman "document similar damaging and incontestable trends for other river reaches managed in the same manner."[7] A copy of Dr. Criss' comments are provided at Attachment B.

A 2016 Journal of Earth Science study co-authored by Dr. Criss highlights the significance of the Corps' excessive channelization of the Middle Mississippi River. That study concludes that the Middle Mississippi River has been so constricted by river training structures and levees that it is now exhibiting "the flashy response" to flooding "typical of a much smaller river":[8]

> "Ehlmann and Criss (2006) proved that the lower Missouri and middle Mississippi Rivers are becoming more chaotic and unpredictable in their time of flooding, height of flooding, and magnitude of their daily changes in stage. This chaotic behavior is primarily the result of extreme channelization of the river, and its isolation from its floodplain by levees (e.g., Criss and Shock, 2001; GAO, 1995; Belt, 1975). The channels of the lower Missouri and middle Mississippi Rivers are only half as wide as they were historically, along a combined reach exceeding 1 500 km, as clearly shown by comparison of modern and historical maps (e.g., Funk and Robinson, 1974).

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> The aftermath of storm Goliath [which led to the December 2015 floods] provides another example in an accelerating succession of record floods, whose tragic effects have been greatly magnified by man. The heavy rainfall was probably related to El Nino, and possibly intensified by global warming. . . . The Mississippi River flood at St. Louis was the third highest ever, yet it occurred at the wrong time of year, and its brief, 11-day duration was truly anomalous. Basically, this great but highly channelized and leveed river exhibited the flashy response of a small river, and indeed resembled the response of Meramec River, whose watershed is smaller by 160×. Yet, only a few percent of the watershed above St. Louis received truly heavy rainfall during this event; the river rose sharply because the water simply had nowhere else to go.
>
> Further downstream, new record stages on the middle Mississippi River were set. Those record stages would have been even higher, probably by as much as 0.25 m, had levees not failed and been overtopped. The sudden drop of the water level near the flood crest at Thebes clearly demonstrates how levees magnify floodwater levels. In this vein, it is very significant that the

[6] Comments on Draft Environmental Assessment by Robert E Criss, Washington University, March 3, 2016 (emphasis added).
[7] *Id*.
[8] Robert E. Criss, Mingming Luo, *River Management and Flooding: The Lesson of December 2015–January 2016, Central USA*, Journal of Earth Science, Vol. 27, No. 1, p. 117–122, February 2016 ISSN 1674-487X (DOI: 10.1007/s12583-016-0639-y).

water levels on the lower Meramec River were highest, relative to prior floods, proximal to a new levee and other recent developments.

Forthcoming calls for more river management, including higher levees and other structures, must be rejected. Additional "remediations" to this overbuilt system will only aggravate flooding in the middle Mississippi Valley (see Walker, 2016).

***

In contrast, Goliath's extraordinary rainfall impacted only a tiny fraction of the huge, 1.8 million km2 Mississippi River Basin above St. Louis, yet flooding occurred which was truly remarkable for the high water level, time of year, and brief duration.

This continental-scale river exhibited the flashy response typical of a much smaller river such as the Meramec. This unnatural response is clearly consistent with the dramatic channelization of the middle Mississippi River and its isolation from its floodplain by levees, as clearly pointed out by Charles Belt more than 40 years ago. It is time for this effect to be accepted and for flood risk and river management to be reassessed."[9]

A copy of this study is provided at Attachment C.

The Corps' conclusion that river training structures do not affect flood heights has been disproved by research led by Nicholas Pinter, Ph.D., currently the Shlemon Chair in Applied Geology at the University of California Davis. In a series of exchanges published in the Journal of Hydraulic Engineering, Dr. Pinter has specifically rebutted both the methodology and conclusions in the Watson studies relied on extensively in the Grand Tower EA. *See e.g.*, Grand Tower EA at 14, 17, A-28, A-30, A-31, A-32, A-34, A-37, A-40, A-48. The series of exchanges between Dr. Pinter and Watson are provided at Attachment D. The Conservation Organizations urge the Corps to fully consider the information provided by Dr. Pinter in these rebuttals.

Critically, Dr. Pinter's research shows that flood stages increase more than 4 inches for each 3,281 feet of wing dike built within 20 river miles downstream. These impacts are cumulative—the more structures placed in the river, the higher the flood increases:

> "[O]ur analyses demonstrate that wing dikes constructed downstream of a location were associated with increases in flood height ("stage"), consistent with backwater effects upstream of these structures. Backwater effects are the rise in surface elevation of flowing water upstream from, and as a result of, an obstruction to water flow. These backwater effects were clearly distinguishable from the effects of upstream dikes, which triggered simultaneous incision and conveyance loss at sites downstream. On the Upper Mississippi River, for example, stages increased more than four inches for each 3,281 feet of wing dike built within 20 RM (river miles) downstream. These values represent parameter estimates and associated uncertainties for relationships significant at the 95 percent confidence level in each reach-scale model. The 95-percent level indicates at least a 95% level of certainty in correlation or other statistical

[9] Robert E. Criss, Mingming Luo, *River Management and Flooding: The Lesson of December 2015–January 2016, Central USA*, Journal of Earth Science, Vol. 27, No. 1, p. 117–122, February 2016 ISSN 1674-487X (DOI: 10.1007/s12583-016-0639-y).

> benchmark presented, and is considered by scientists to represent a statistically verified standard. Our study demonstrated that the presence of river training structures can cause large increases in flood stage. For example, at Dubuque, Iowa, roughly 8.7 linear miles of downstream wing dikes were constructed between 1892 and 1928, and were associated with a nearly five-foot increase in stage. In the area affected by the 2008 Upper Mississippi flood, more than six feet of the flood crest is linked to navigational and flood-control engineering."

Reply Declaration of Nicholas Pinter, Ph.D., 2014 at paragraph 24. This declaration is provided at Attachment E along with the Opening Declaration of Nicholas Pinter submitted for the same matter.[10] NWF urges the Corps to fully consider the information in both of these declarations.

B. The New 2D Model Must be Certified Prior to Use and the Model's Application to the Grand Tower Project Must be Peer Reviewed

The Grand Tower EA relies on a new 2D numerical model to study the effect of the proposed Vancill Towhead projects on water surface elevation in the 1 percent chance exceedance flood. The Conservation Organizations were unable to locate any reference to certification of this new model, or to agency technical review of the model as applied to the Grand Tower Phase 5 project.[11] Both are required and must be completed before the Corps relies on the model for making a final decision on the Grand Tower Phase 5 project.

The Corps' internal guidance clearly requires certification of the new model before it can be used for planning activities. The purpose of model certification is to ensure, among other things, that models used by the Corps are technically and theoretically sound, computationally accurate, transparent, and in compliance with Corps policy:

> "**Use of certified or approved models for all planning activities is mandatory**. This policy is applicable to all planning models currently in use, models under development and new models. District commanders are responsible for delivering high quality, objective, defensible, and consistent planning products. Development of these products requires the appropriate use of tested and defensible models. National certification and approval of planning models results in significant efficiencies in the conduct of planning studies and enhances the capability to produce high quality products. The appropriate PCX will be responsible for implementing the model certification/approval process. The goal of certification/approval is to ensure that Corps planning products are theoretically sound, compliant with Corps policy, computationally accurate, based on reasonable assumptions regarding the availability of data, transparent, and described to address any limitations of the model or its use. The use of a certified/approved model does not constitute technical review of the planning product. The selection and application of the model and the input data is still the responsibility of the users and is subject to Agency Technical Review and Independent External Peer Review (where applicable). Once a model is certified/approved, the PCXs will be responsible for assuring that model

[10] Reply Declaration of Nicholas Pinter, Ph.D. in Support of Plaintiffs' Motion for Preliminary Injunction, NWF et al v. Corps of Engineers, Case No. 14-00590-DRH-DGW, (S.D. ILL), 2014; Declaration of Nicholas Pinter, Ph.D. in Support of Plaintiffs' Motion for Preliminary Injunction, Case No. 14-00590-DRH-DGW, (S.D. ILL), 2014.

[11] If the certification and technical reviews have been done, they should have been provided to the public along with the Grand Tower EA for review and comment.

documentation and training on the use of the model are available (either from the PCX or the model developers), and for coordinating with model developers to assure the model reflects current procedures and policies. All certification/approval decisions will be in effect for a period specified by the Model Certification HQ Panel, not to exceed seven years."

EC 1105-2-412, Assuring Quality of Planning Models at paragraph 6 (emphasis added). Similarly, the use and application of the new model for individual projects is subject to the requirements of the Corps' peer review process. *See, e.g.*, EC 1105-2-408 and EC-1105-2-410.

Certification and independent review are critical because hydraulic modeling involves many subjective choices, each of which can fundamentally affect the model outcome. To provide accurate analyses, a hydrologic model must, among other things: use the correct roughness coefficients, use the correct eddy viscosity, be based on accurate baseline conditions, employ appropriate underlying assumptions, and utilize appropriate flow levels for model runs.

The Conservation Organizations highlight the following critical questions regarding the Corps' new model. These questions should be addressed in the certification and independent review processes, and the results should be shared with the public. The model should then be modified as necessary before it is utilized by the Corps to analyze the Grand Tower (or any other) project.

1. Roughness Coefficient Values: Use of inaccurate roughness coefficient values will result in extensive errors and biases in the model and model output. Did the Corps use the appropriate roughness coefficient values? Should the Corps have used more recent data and sources than Chow 1959 for establishing baseline Manning's roughness numbers (there is an extensive array of new research and updated sources on this issue[12])? Did the Corps properly calibrate and manipulate the Manning's roughness numbers or are the calibrations overly simplistic? Did the Corps use a sufficient number of different roughness coefficients or did it fail to account for the full range of different habitat types in this reach of river?

2. Eddy Viscosity: Use of an inappropriate eddy viscosity will result in errors and biases in the model and model output. Has the Corps utilized the appropriate eddy viscosity method? Did the Corps use the appropriate eddy viscosity coefficient? Did the Corps use the appropriate velocities and velocity calibrations in the model (the model relies on velocities based on the May 29, 2015 when flow rates were 308,000 cfs, but the model was run using a one percent annual exceedance flow of 949,011 cfs)?

3. Base Condition Geometry: Errors in the base condition geometry will create errors in the model and model outputs. The base condition geometry is likely to be highly inaccurate as it is based on "the HSR replication effort." Grand Tower EA at 9. As we have repeated pointed out, HSR

[12] See for example, Barnes (1967) and Coon (1998) at https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0ahUKEwiaguWhyvvLAhXBKWMKHTgHDaUQFggzMAM&url=http%3A%2F%2Fpubs.usgs.gov%2Fwsp%2Fwsp_1849%2Fpdf%2Fwsp_1849.pdf&usg=AFQjCNFgtfINfV9irYApATazmjdpzzb7VQ; https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0ahUKEwiaguWhyvvLAhXBKWMKHTgHDaUQFggtMAI&url=http%3A%2F%2Fpubs.usgs.gov%2Fwsp%2F2441%2Freport.pdf&usg=AFQjCNEpnygptNieDogbenduAq-Auok6eg.

models cannot be relied upon to provide accurate planning information as they lack "predictive capability". Stephen T. Maynord, Journal of Hydraulic Engineering, *Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model* (April 2006). Maynord concludes that because of the "lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication." A copy of this study is attached to these comments at Attachment F.

4. Underlying Assumptions: Dr. Pinter's research shows that the impacts of wing dikes grow larger for larger floods (*i.e*., the dike becomes hydrodynamically rougher with larger discharge). The Conservation Organizations understand that the Corps' model assumes that flow over a submerged dike is smooth and laminar such that the impacts of the dike would diminish proportionally as flood height increases. A model based on the Corps' incorrect assumption will produce flawed results. Was the model constructed using the correct assumption regarding the impact of river training structures under larger discharges?

5. Flows Used for Model Runs: The Corps has evaluated only the impacts from a 1% annual exceedance flood (a 100 year flood). The Corps should also be evaluating impacts for larger flood events. Once the model is properly developed, the Corps should evaluate the impacts of the project using at least the 200 year flood, 500 year flood, and the Project Flood used for the MR&T program.

Moreover, the model does not look at the impacts of the entire Phase 5 set of projects. Indeed, no modeling was done at all for the structures proposed for the Crawford Towhead reach. The Corps instead concluded that only professional judgment was required to develop this portion of the project:

> "No HSR investigation was completed for Crawford Towhead. Hydraulic engineers developed alternatives using widely recognized and accepted river engineering guidance and practice, and then discussed the alternatives with the River Resources Action Team (RRAT) members during the 2009 RRAT trip and the May 2013 RRAT Executive meeting. The final design included two chevrons and a dike extension that met the work area objectives while incorporating the environmental concerns of the RRAT. USACE has constructed numerous chevrons and weirs in the MMR, and a model would have been an unnecessary expense because engineering judgment was all that was necessary to predict the effects of the structures in this location."

Grand Tower EA at 11-12. The Crawford Towhead portion of the project includes two new chevrons and the extension of one dike. It is unacceptable for the Corps to base the design and approval of these large scale projects on nothing more than "professional judgment."

C. The Grand Tower EA Uses an Improperly Narrow Project Purpose

While the Conservation Organizations appreciate the Corps' efforts to expand the project purpose in response to our 2014 Comments, the Corps continues to use an impermissibly narrow project purpose that precludes consideration of reasonable alternatives that do not include river training structures. The Conservation Organizations urge the Corps to adopt an appropriate project purpose, such as "to provide for navigation in a manner that ensures public safety and protects fish and wildlife habitat."

Establishing an appropriate project purpose is extremely important as the purpose is closely tied to the range of reasonable alternatives that must be evaluated. All reasonable alternatives that accomplish the project purpose must be examined, while alternatives that are not reasonably related to project purpose do not have to be examined.[13] As a result, an overly narrow project purpose defeats the very purpose of NEPA:

> "One obvious way for an agency to slip past the strictures of NEPA is to contrive a purpose so slender as to define competing "reasonable alternatives" out of consideration (and even out of existence). The federal courts cannot condone an agency's frustration of Congressional will. If the agency constricts the definition of the project's purpose and thereby excludes what truly are reasonable alternatives, the EIS cannot fulfill its role. Nor can the agency satisfy the Act. 42 U.S.C. § 4332(2)(E)."[14]

As discussed in Section E of these comments, the requirement to analyze reasonable alternatives applies to both environmental assessments and environmental impact statements.

The Grand Tower EA appears to rely on the following project purpose: "to address the repetitive channel maintenance dredging in order to provide a sustainable, less costly navigation channel in this area." Grand Tower EA at 2. This project purpose is unreasonably narrow for at least three reasons.

First, the stated project purpose precludes selection of an alternative that does not include river training structures or other actions that reduce "repetitive channel maintenance dredging" despite the fact that a safe and reliable navigation channel can be – and has been – maintained without the proposed Grand Tower Phase 5 structures. For example, the Grand Tower EA rejects the no action alternative precisely because it "[d]oes not reduce the need for repetitive maintenance dredging in the area, and, therefore, does not meet the Project objectives." Grand Tower EA at 12, Table 2.

Second, the stated project purpose is much narrower than the project purpose identified in a number of Rivers and Harbors Acts, which according to the Grand Tower EA is "to provide a safe and dependable navigation channel." Grand Tower EA at 1.

Third, the stated project purpose ignores a host of Congressional directives that guide the Corps' actions. A proper statement of project purpose must consider "the views of Congress, expressed, to the extent that an agency can determine them, in the agency's statutory authorization to act, **as well as in other Congressional directives**."[15]

[13] *Methow Valley Citizens Council v. Regional Forester*, 833 F.2d 810, 815-16 (9th Cir. 1987).
[14] *Simmons v. United States Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997); *City of Carmel-by-the-Sea v. United States Dep't of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997) ("an agency cannot define its objectives in unreasonably narrow terms"); *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 195-96 (D.C. Cir. 1991), *cert. denied*, 502 U.S. 994 (1991) ("an agency may not define the objectives of its action in terms so unreasonably narrow that only one alternative from among the environmentally benign ones in the agency's power would accomplish the goals of the agency's action"); *City of New York v. United States Dep't of Transp.*, 715 F.2d 732, 743 (2d Cir. 1983), *cert. denied*, 456 U.S. 1005 (1984) ("an agency will not be permitted to narrow the objective of its action artificially and thereby circumvent the requirement that relevant alternatives be considered").
[15] *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991) (emphasis added).

Such directives include at least the following. The Corps' Congressionally-mandated missions which include reducing flood damages and protecting the environment (33 U.S.C. § 2316). The National Water Resources Planning Policy which requires "all water resources projects" to protect and restore the functions of natural systems and to mitigate any unavoidable damage to natural systems. 42 U.S.C. § 1962-3. The National Environmental Policy Act which directs the "Federal Government to use all practicable means" to "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations." 42 U.S.C. § 4331(b). The Fish and Wildlife Coordination Act which directs that "wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development" and that water resources development is to prevent loss and damage to fish and wildlife and improve the health of fish and wildlife resources. Fish and Wildlife Coordination Act, 16 U.S.C. §§ 661, 662. Many additional directives to protect the environment and fish and wildlife are found, *inter alia*, in the Clean Water Act, the Endangered Species Act, and the Clean Air Act.

The project purpose in the Grand Tower EA is impermissibly narrow as it ignores key legal directives and drives consideration of only those alternatives that recommend construction of river training structures which the Corps argues will reduce dredging costs.

D. The Grand Tower EA Fails to Demonstrate Project Need, Fails to Provide Meaningful Cost Information, and Fails to Provide a Benefit-Cost Assessment

The Grand Tower EA fails to demonstrate that the proposed projects are needed. The Grand Tower EA also fails to provide meaningful cost information or a benefit-cost assessment which could assist in determining project need. Properly demonstrating project need is fundamental to an adequate NEPA analysis and is absolutely critical in this case given that the proposed project creates far more risks to public safety (by increasing flood hazards) than the current dredging regime which has a long history of effectively maintaining navigation.

The Grand Tower EA does not even attempt to claim that the project is needed to maintain a reliable navigation channel. Indeed, the Grand Tower EA acknowledges that the current dredging regime is sufficient to maintain a safe navigation channel in this portion of the Mississippi River: "there have not been any reports of groundings or hindrance to navigation in this reach in recent years." Grand Tower EA at E83.

The Grand Tower EA instead claims that the project should be constructed to fend off a vague and unsubstantiated risk that dredging funding and resources may not be available under certain extreme conditions that may (or may not) occur at some point in the future. According to the Grand Tower EA:

> "There is a risk associated with not constructing the work due to the Corps' ability to respond to extreme dredging situations as was encountered in the low water event of 2012/2013. To meet the dredge demand of that event, the Corps had to redirect O&M funding from other O&M needs as well as bring on an additional dredge boat. . . . For future low water periods, the funding and/or resources needed to maintain the authorized channel by use of dredging alone may not be available."

Grand Tower EA at E83. The Corps' ability to respond to the 2012/2013 low water event further undercuts this already highly tenuous claim. During the extreme conditions in 2012/2013, the Corps was able to mobilize additional dredges and remove rock ledges (pinnacles) to address the severe low water levels on the Middle Mississippi. Moreover, despite the low water conditions, "traffic through the restricted reaches at Thebes, Illinois was largely unchanged between 2011 and 2012."[16]

Indeed, according to one assessment conducted by the Corps' St. Louis District:

> "The entire 2012 low water effort resulted in a navigation channel that remained open for commerce throughout the drought, without any groundings or accidents within the channel, and generally led to a much more reliable channel for shippers."[17]

Moreover, since the proposed project will merely reduce – not eliminate – the need for future dredging in the project area, there is no way to know whether the proposed project would in fact reduce the need for dredging under any future low water conditions. *See* Grand Tower EA at 36 (the proposed action is only "expected to reduce the amount and frequency of repetitive maintenance dredging necessary in the area.")

Moreover, despite clearly acknowledging that the project will not eliminate the need for dredging in the project area, the Grand Tower EA fails to provide any type of assessment regarding the amount of dredging that would still be required if the Phase 5 projects are constructed. Indeed, the Corps has argued that it would be "inappropriate" to conduct such an assessment:

> "Quantitative forecasts of dredging reduction as a result of the proposed action would be inappropriate given the dynamic nature of the MMR. Though the design process for river training structure configurations is geared toward identifying the alternative most likely to minimize the need for repetitive channel maintenance dredging (per the Project's authorization) while also taking into consideration environmental impacts, the need for repetitive channel maintenance is also heavily impacted by the MMR hydrograph and sediment loads from tributaries such as the Missouri River."

Grand Tower EA at E83-E84. **However, this is precisely the type of information that the Corps' analysis should provide**. Indeed, this information is critical for assessing both the economic and environmental costs of the proposed project as compared to the no action alternative. Without this information, it is not possible to assess whether the economic benefits of the proposed project will outweigh the project's economic, public safety, and environmental costs.

The Grand Tower EA also fails to provide detailed information on the projected construction costs or recent dredging costs. The Grand Tower EA also fails to explain why both the construction and dredging costs have increased significantly since December 2013 when the original Grand Tower EA was released:

(a) Construction Costs: The Grand Tower EA states that project costs are not expected to exceed $8 million. Grand Tower EA at 36. This is **double** the $4 million cost estimate provided in the December 2013 original Grand Tower EA. Original Grand Tower EA at 32.

[16] USACE, *Event Study 2012 Low-Water and Mississippi River Lock 27 Closures*, August 2013 at 15.
[17] David C. Gordon (Chief, Hydraulic Design Section, U.S. Army Corps of Engineers – St. Louis District) and Michael T. Rodgers (Project Manager, U.S. Army Corps of Engineers – St. Louis District), *Drought, Low Water, And Dredging Of The Middle Mississippi River In 2012* (available at http://acwi.gov/sos/pubs/3rdJFIC/Contents/4C-Gordon.pdf).

(b) Dredging Costs: The Grand Tower EA states that the area between RM 74 and 67 has required dredging 21 times since 2000 at an average cost of approximately $730,000 per year. Grand Tower EA at 22, 36. The original Grand Tower EA stated that this same area had been dredged 18 times since 2000 at an average cost of cost of $368,000 per dredging event, and that dredging costs in the project area "over the past 12 years have averaged approximately $550,000." Original Grand Tower EA at (17, 36).

A **detailed** breakdown of dredging costs and dredged amounts by location and year, and a detailed breakdown of projected project construction costs is needed to understand the changes in these numbers, and to evaluate the true economic costs and benefits of the proposed project. The Corps should also fully explain why the cost estimate for the proposed project has doubled since 2013.

The Grand Tower EA should also provide the following information to properly assess the project's economic and environmental costs and benefits:

- A benefit-cost analysis for the proposed Grand Tower project.
- The projected future costs of required dredging under the no action alternative calculated for the life of the proposed Grand Tower project, and an assessment of the ability of dredging to continue to maintain navigation in those stretches.
- The construction and full life cycle maintenance costs of the proposed Grand Tower project, and the projected costs of the dredging that will still be needed even if the project is constructed.
- The increased risks of upstream or nearby levee failures should the proposed Grand Tower project increase flood heights.

This information would assist the public and decision makers in assessing both the need for, and the true costs and benefits of, the project. This information is particularly critical for assessing the need of a project that includes untested and never-before-built river training structures. As discussed above, extensive science shows that the proposed Grand Tower project has credible potential to significantly increase the risk of flooding to river communities and floodplain areas.

E. The Grand Tower EA Fails to Evaluate a Reasonable Range of Alternatives and Fails to Meaningfully Review the No Action Alternative

The Grand Tower EA examines only two alternatives, the no action alternative and the proposed alternative. As discussed in our 2014 Comments, this is legally insufficient because an environmental assessment must examine a full range of reasonable alternatives.[18] The Grand Tower EA also fails to meaningfully evaluate the no action alternative.

[18] While other configurations of river training structures were examined prior to preparation of the environmental assessment, this does not exempt the Corps from the requirement to examine a reasonable range of alternatives in the EA. Moreover, evaluations of alternative configurations of river training structures cannot satisfy the requirement to evaluate a reasonable range of alternatives because each alternative would have the same end result – construction of river training structures in the project area. *State of California v. Block*, 690 F.2d 753, 767 (9th Cir. 1982) (holding that an inadequate range of alternatives was considered where the end result of all eight alternatives evaluated was development of a substantial portion of wilderness).

"Consideration of alternatives is critical to the goals of NEPA even where a proposed action does not trigger the EIS process."[19] This is because the consideration of alternatives required by NEPA is both independent of, and broader than, the requirement to prepare an environmental impact statement.[20] As a result an environmental assessment, like an environmental impact statement, "must evaluate a reasonable range of alternatives to the agency's proposed action, to allow decision-makers and the public to evaluate different ways of accomplishing an agency goal."[21]

The consideration of alternatives is "the heart" of the NEPA review process. To satisfy the requirements of NEPA, the Grand Tower EA must "[r]igorously explore and objectively evaluate all reasonable alternatives." 40 C.F.R. § 1502.14. "Reasonable alternatives include those that are practical or feasible from a technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant."[22]

NEPA requires more than a brief, out-of-hand rejection of alternatives and this standard applies to both action and no action alternatives:

> "NEPA's requirement that alternatives be studied, developed, and described both guides the substance of environmental decisionmaking and provides evidence that the mandated decisionmaking process has actually taken place. Informed and meaningful consideration of alternatives – including the no action alternative – is thus an integral part of the statutory scheme.[23]

The alternative ultimately recommended in the Grand Tower EA must also comply with the full suite of federal laws and policies designed to protect the environment. These include, the Endangered Species Act, the Clean Water Act, the Migratory Bird Treaty Act, and the mitigation requirements applicable to Corps civil works projects (33 U.S.C. § 2283(d)). The alternative also must comply with the National Water Resources Planning Policy established by Congress in 2007.[24] This policy requires that all water resources projects protect and restore the functions of natural systems, and mitigate any damage to those systems that cannot be avoided. 33 U.S.C 1962-3.

[19] *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228-29 (9th Cir. 1988), *cert. denied*, 489 U.S. 1066 (1988).
[20] *Bob Marshall Alliance*, 852 F.2d 1223; *City of New York v. United States Department of Transportation*, 715 F.2d 732, 742 (2d Cir.1983), *cert. denied*, 465 U.S. 1055 (1984); *Environmental Defense Fund, Inc. v. Corps of Engineers*, 492 F.2d 1123, 1135 (5th Cir.1974).
[21] *Pacific Marine Conservation Council v. Evans*, 200 F. Supp. 2d 1194, 1206 (N.D.Cal 2002); *Akiak Native Community v. United States Postal Serv.*, 213 F.3d 1140, 1148 (9th Cir. 2000) (EA must consider a reasonable range of alternatives).
[22] Forty Most asked Questions Concerning CEQ's NEPA Regulations, 46 Fed. Reg. 18,026 (March 23, 1981).
[23] *Bob Marshall Alliance*, 852 F.2d at 1228 (internal citations omitted).
[24] Enhancement of the environment has been an important federal objective for water resources programs for decades. Corps regulations in place since 1980 state that: "Laws, executive orders, and national policies promulgated in the past decade require that the quality of the environment be protected and, where possible, enhanced as the nation grows. . . . Enhancement of the environment is an objective of Federal water resource programs to be considered in the planning, design, construction, and **operation and maintenance of projects**. Opportunities for enhancement of the environment are sought through each of the above phases of project development. Specific considerations may include, but are not limited to, actions to preserve or enhance critical habitat for fish and wildlife; maintain or enhance water quality; improve streamflow; preservation and restoration of certain cultural resources, and the preservation or creation of wetlands." 33 C.F.R. § 236.4 (emphasis added).

The Grand Tower EA should be substantially revised to ensure that the Corps gives full consideration to a reasonable range of alternatives. This evaluation must be carried out under an appropriate project purpose (*see* Section C above) and be based on accurate science and an accurate assessment of future dredging needs both with and without the project in place. As part of this analysis, the Corps should fully and comprehensively evaluate at least the following alternatives:

- The No Action alternative. The Grand Tower EA fails to meaningfully evaluate the No Action alternative and fails to give this alternative appropriate consideration.

- Maintaining the authorized navigation channel through alternative approaches, including such things as alternative dredging strategies, and/or depositing sediment dredged from the river in upland locations rather than disposing the sediment adjacent to the main channel.

- Minimizing the use of new river training structures, including by placing restrictions on the number and/or types of structures that can be utilized in the project area based on a robust scientific assessment of the cumulative impacts of the various types of river training structures.

- Removing and/or modifying existing river training structures in the project area to redirect flow; reduce flood risks; and restore backwater, side channel, and braided habitat.

The Grand Tower EA does not evaluate a reasonable range of alternatives. It instead looks only at the proposed alternative and the no action alternative. In addition, the no action alternative was not fully considered.

F. The Grand Tower EA Fails to Properly Evaluate the Full Suite of Environmental Impacts

The Grand Tower EA fails to evaluate the full suite of impacts, provides only the most limited analysis of those impacts it does evaluate, and fails to provide a reasonable explanation between the information presented and the conclusions drawn.

In addition, the Grand Tower EA appears not to include important information that should already have been assembled by the Corps in preparing the SEIS for the Regulating Works. This SEIS is supposed to comprehensively assess the impacts of this project and evaluate reasonable alternatives for carrying out this project. The Corps has been working on this SEIS since December 2013. 78 Fed. Reg. 77108 (December 20, 2013).

1. The Grand Tower EA Fails to Properly Evaluate Hydrologic Impacts

The evaluation of hydrologic impacts is particularly critical given the extensive amount of peer reviewed science demonstrating that river training structures are causing significant increases in flood heights in the Middle Mississippi River and the proposed project's location at Wolf Lake, Illinois along the Big Five Levee System (which Corps inspectors have determined have a number of deficiencies).

Despite this importance, the Grand Tower EA fails to evaluate hydrologic impacts in any meaningful way for at least the following four reasons.

First, the Grand Tower EA is based on a flawed scientific assessment of the role that river training structures play in increasing flood heights and the implications of the Corps extensive construction of river training structures on the hydrologic functioning of the Middle Mississippi River. *See* Section A and our 2014 Comments for a detailed discussion of this issue.

Second, the Grand Tower EA relies on a new 2D numerical model to study the effect of the proposed Vancill Towhead projects on water surface elevation that does not appear to have been certified or subjected to agency technical review. Important questions and concerns with the model (including its reliance on a non-predictive micro model for baseline conditions) are discussed in Section B of these comments.

Third, the Corps admits that no modeling at all was done for the structures proposed for the Crawford Towhead reach. The Corps instead concluded that only professional judgment was required to develop this portion of the project:

> "No HSR investigation was completed for Crawford Towhead. Hydraulic engineers developed alternatives using widely recognized and accepted river engineering guidance and practice, and then discussed the alternatives with the River Resources Action Team (RRAT) members during the 2009 RRAT trip and the May 2013 RRAT Executive meeting. The final design included two chevrons and a dike extension that met the work area objectives while incorporating the environmental concerns of the RRAT. USACE has constructed numerous chevrons and weirs in the MMR, and a model would have been an unnecessary expense because engineering judgment was all that was necessary to predict the effects of the structures in this location."

Grand Tower EA at 11-12. The Crawford Towhead portion of the project includes two new chevrons and the extension of one dike. It is unacceptable for the Corps to base the design and approval of these large scale projects on nothing more than "professional judgment."

Fourth, the Grand Tower EA does not meaningfully examine the direct, indirect, and cumulative impacts of the proposed project on flood heights, changes in flow patterns, or channel diversity.

Because of these failings, the public and decision makers cannot know what the true impacts of the proposed Grand Tower project will be on the river's hydrology.

2. The Grand Tower EA Fails to Adequately Evaluate Impacts to Fish and Wildlife, Including Endangered Species

The Grand Tower EA fails to adequately evaluate the impacts to fish and wildlife. Notably, the Grand Tower EA fails to discuss impacts to any species at all except some fish, macroinvertebrates, and federally endangered species. Despite the significance of the river to the health of a host of migratory birds and waterfowl, these categories of species are not discussed at all.

The Corps also has not conducted the modeling or monitoring needed to draw the conclusion that the project will have no adverse impacts to fish and wildlife. For example, as discussed in these comments, the Grand Tower EA fails to adequately assess the hydrologic and cumulative impacts and thus it has no basis for assessing the resulting changes in habitat for fish and wildlife species.

Critically for the evaluation of fish and wildlife impacts, the Corps' conclusions on fish and wildlife impacts fail to account for the large-scale loss of backwater and side channel habitat in the Mississippi River and the potential for additional losses of natural side channels, crossover habitat and mid-channel bars if the proposed Grand Tower project is constructed. The Corps' vague reference to other Corps programs working to restore and preserve this type of habitat does not cure this critical failing. See Grand Tower EA at 23 (other USACE programs "have currently seen success in restoring and preserving side channels affected by river training structures.")

These failings are particularly problematic for assessing potential impacts to endangered species. As noted in the December 2012 Biological Assessment (but not in the text of the Grand Tower EA) the project is located in important habitat for both the endangered pallid sturgeon and the endangered least tern:

> This project is located within a reach of the river that has been identified as important pallid sturgeon habitat due to the presence of crossover habitat and mid-channel bars. The dike location is just above Cottonwood Island which is recognized as important pallid sturgeon habitat. The Missouri Department of Conservation requested in their FY 2009 coordination comments that proposed plans for dikes at 80.6L and 80.7L be left until last and should only be completed if absolutely necessary to alleviate the need to dredge this reach.
>
> * * *
>
> This Big Muddy dikes subarea (MRM 71-80) is foraging habitat for least terns and habitat for pallid sturgeon. There are pallid sturgeon locations at RM 69.5, 69.6, 69.8, 70.3, 71.8, 77.1, 78.2, 78.7, 79.5, and 79.8 especially around Cottonwood Island. Cottonwood Chute, including its substrate, is one of the most valuable habitat areas for the pallid sturgeon in the MMR.

Grand Tower EA, Appendix B at 5-6.

The Grand Tower EA asserts that the project will not adversely impact fish and wildlife, including the endangered least tern and pallid sturgeon, because the proposed project will create more diverse habitats, but the EA fails to provide any evidence to support that contention. Indeed, only the most minimal monitoring appears to have been carried out to assess the impacts of chevrons, and no monitoring has been carried out on the impacts of the newly developed S-dikes.

It is far more likely that the proposed Grand Tower project will add to the loss of diverse river habitats, since like other river training structures, their very purpose is to create a deeper, self-scouring channel which in turn leads to losses in natural backwater and braided channel habitats. These impacts are well recognized by the U.S. Fish and Wildlife Service which has concluded that construction of river training structures have adversely affected the pallid sturgeon and least tern by destroying vital habitat.

3. The Grand Tower EA Fails to Properly Evaluate Climate Change

While the Grand Tower EA includes a limited discussion of climate change, the Corps' fundamental conclusion regarding the impacts of climate change is flawed. The Grand Tower EA also fails to fully evaluate climate change, both in the main body of the EA and in the cumulative impacts assessment.

The Grand Tower EA climate change discussion concludes:

> "As summarized above, there is no consensus with respect to forecasts for future streamflow in the basin. Whether future climate patterns in the Upper Mississippi River basin result in a reduction or increase in streamflow compared to current conditions, 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)."

Grand Tower EA at 39.

This conclusion includes at least two major flaws. First, it is based on an incorrect analysis of the impacts of river training structures on flood heights. As we have stated repeatedly throughout these and many other comments, it is critical that the Corps get this science right. Second, the Grand Tower EA suggests that river training structures lead to reduced water levels during low flow conditions. This would aggravate the low flow conditions that may result from increased droughts or changes in sedimentation patterns. However, this river training structure impact is completely ignored in the climate change analysis.

4. The Grand Tower EA Fails to Properly Evaluate Cumulative Impacts

The Conservation Organizations appreciate the Corps' efforts to expand its cumulative impacts analysis. However, that analysis continues to fall far short of what is needed to properly assess the incremental impacts of the proposed project when added to other past, present, and reasonably foreseeable future actions.

Notably, the entire cumulative impacts "assessment" appears to be driven by a fundamentally incorrect and circular conclusions:

> "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."

Grand Tower EA at C-2.

This "conclusion" is entirely circular as it states that any adverse impacts of the river training structures will be offset by the very same "innovative" structures that the EA is supposed to be assessing. This circular argument does not, and cannot, satisfy the requirements of NEPA.

This "conclusion" flies in the face of reality because it suggests that river training structures in fact do not cause adverse impacts. Extensive peer reviewed science and evidence contained in many of the reports referenced by, and incorporated into, the Grand Tower EA demonstrate that the activities carried out to operate and maintain navigation in the Mississippi River—including construction of river training structures—have caused significant harm to the river ecosystem and the species that rely on a healthy river and floodplain. It is nonsensical to conclude that past actions have pushed the river into a significant state of decline, but that additional such actions will not add to that decline.

The cumulative impacts analysis also fails to assess the significant changes in the middle Mississippi river due to the extensive construction of river training structures, and the cumulative effect of adding even more structures. For example, as discussed in Section A above, Dr. Pinter has concluded that that flood stages increase more than 4 inches for each 3,281 feet of wing dike built within 20 river miles downstream. These impacts are cumulative—the more structures placed in the river, the higher the flood heights.

The cumulative impacts analysis fails to discuss the changes wrought by the 1993, 2011, 2014 and other significant flood events, or the changes in the way the Middle Mississippi River is responding to flood events. As discussed in Section A above, peer reviewed science concludes that the Middle Mississippi River has been so constricted by river training structures and levees that it is now exhibiting "the flashy response" to flooding "typical of a much smaller river."[25]

Notably, the cumulative impacts analysis also fails to acknowledge the severity of past impacts. Instead, the Grand Tower EA minimizes the adverse impacts by stating that 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." Grand Tower EA at 40, C-1. Failure to recognize the severity of past harm severely undermines the cumulative impacts assessment.

As discussed in our 2014 Comments, maintaining navigation on the Mississippi River requires "continuous regular operations and maintenance" at a cost of more than $120 million each year.[26] A significant body of scientific evidence, much of which was prepared with the Corps' input, demonstrates that the Corps' O&M activities are a significant cause of the severe decline in the ecological health of the UMR-IWW system and have completely altered the natural processes in the Upper Mississippi River.[27]

In a 1999 report on the Status and Trends of the Upper Mississippi River System, the U.S. Geological Survey concluded that the Corps' O&M activities in the UMR-IWW system were: destroying critical habitats including the rivers' backwaters, side channels and wetlands; altering water depth; destroying

[25] Robert E. Criss, Mingming Luo, *River Management and Flooding: The Lesson of December 2015–January 2016, Central USA*, Journal of Earth Science, Vol. 27, No. 1, p. 117–122, February 2016 ISSN 1674-487X (DOI: 10.1007/s12583-016-0639-y).
[26] USACE Brochure, Upper Mississippi River – Illinois Waterway System Locks and Dams (September 2009) available at http://www.mvr.usace.army.mil/brochures/documents/UMRSLocksandDams.pdf; Congressional Research Service, *Inland Waterways: Recent Proposals and Issues for Congress* (July 14, 2011) at 15.
[27] U.S. Geological Survey, Ecological Status and Trends of the Upper Mississippi River System 1998: A Report of the Long Term Resource Monitoring Program (April 1999) (1999 Status and Trends Report).

bathymetric diversity; causing nonnative species to proliferate; and severely impacting native species.[28] The 1999 Status and Trends Report also rated the health of the Mississippi River System as follows:

1. The Lower Reach of the Illinois River is degraded for all 6 criteria of ecosystem health evaluated by the report.[29]
2. The Unimpounded Reach of the Mississippi River is degraded for 3 criteria, heavily impacted for 2 criteria, and moderately impacted for 1 criterion.
3. The Lower Impounded Reach of the Mississippi River (Pools 14-26) is degraded for 2 criteria, heavily impacted for 3 criteria, and moderately impacted for 1 criterion.
4. The Upper Impounded Reach of the Mississippi River (Pools 1-13) is degraded for 1 criterion and moderately impacted for 5 criteria.

The 1999 Status and Trends report further concluded that no segment of the Upper Mississippi River system was unchanged from historic conditions, or deemed to require no management action to maintain, restore or improve conditions. Equally important, no segment of the system was improving in quality.[30]

In December 2008, the U.S. Geological Survey issued a second report on the status and trends of selected resources in the Upper Mississippi River system which also found that the Corps' O&M activities were causing significant adverse impacts.[31] For example:

> The current condition of the UMRS is heavily influenced by its agriculture-dominated basin and by the dams, channel training structures, dredging, and levees that regulate flow distribution during most of the year. Although substantial improvements in some conditions have occurred since the 1960s because of improvements in sewage treatment and land use practices, the UMRS still faces substantial challenges including
>
> 1. High sedimentation rates in some backwaters and side channels;
> 2. An altered hydrologic regime resulting from modifications of river channels, the floodplain, and land use within the basin, and from dams and their operation;
> 3. Loss of connection between the floodplain and the river, particularly in the southern reaches of the UMRS;
> 4. Nonnative species (e.g., common carp [*Cyprinus carpio*], Asian carps [*Hypophtalmichthys* spp.], zebra mussels [*Dreissena polymorpha*]);
> 5. High levels of nutrients and suspended sediments; and
> 6. Degradation of floodplain forests.[32]

[28] *Id*.
[29] "Degraded" is the lowest possible grade issued by the report and is defined as a condition where the factors associated with the criteria "are now below ecologically acceptable levels" and where "[m]ultiple management actions are required to raise these conditions to acceptable levels." 1999 Status and *Trends Report* at 16-2.
[30] 1999 Status *and Trends Report at* 16-1 to 16.-2.
[31] Johnson, B. L., and K. H. Hagerty, editors. 2008. U.S. Geological Survey, *Status and Trends of Selected Resources of the Upper Mississippi River System,* December 2008, Technical Report LTRMP 2008-T002. 102 pp + Appendixes A–B (Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin) (2008 Status and Trends Report).
[32] *Id*. at 3.

The 2008 Status and Trends report also recognized that there has been "a substantial loss of habitat diversity"[33] in the system over the past 50 years due in large part to excessive sedimentation and erosion:

> In all reaches, sedimentation has filled-in many backwaters, channels, and deep holes. In the lower reaches, sediments have completely filled the area between many wing dikes producing a narrower channel and new terrestrial habitat. Erosion has eliminated many islands, especially in impounded zones.[34]

Additional activities, including construction of the proposed Grand Tower project will add to these impacts. *See* Attachment A for additional information that should be addressed in a meaningful cumulative impacts analysis.

(a) Cumulative Impacts of Climate Change

As discussed above, the Grand Tower EA impacts section include a short discussion of climate change. However, the discussion of climate change in the cumulative impacts analysis is restricted to one paragraph which concludes that the impacts of the proposed action "are not anticipated to rise to the level of being significant." Grand Tower EA at C-21.

As discussed at length in our 2014 Comments, the Corps is required as a matter of law to evaluate the cumulative impacts of climate change.[35] This evaluation is extremely important as:

> "Climate change can increase the vulnerability of a resource, ecosystem, or human community, causing a proposed action to result in consequences that are more damaging than prior experience with environmental impacts analysis might indicate . . . . [and] climate change can magnify the damaging strength of certain effects of a proposed action."
>
> * * *
>
> "Agencies should consider the specific effects of the proposed action (including the proposed action's effect on the vulnerability of affected ecosystems), the nexus of those effects with projected climate change effects on the same aspects of our environment,

[33] *Id*. at 6.
[34] *Id*. at 6.
[35] *See Center for Biological Diversity v. Nat'l Hwy Traffic Safety Administration*, 538 F.3d 1172, 1217 (9th Cir. 2008) (holding that analyzing the impacts of climate change is "precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct" and that NEPA requires analysis of the cumulative impact of greenhouse gas emissions when deciding not to set certain CAFE standards); *Center for Biological Diversity v. Kempthorne*, 588 F.3d 701, 711 (9th Cir. 2009) (NEPA analysis properly included analysis of the effects of climate change on polar bears, including "increased use of coastal environments, increased bear/human encounters, changes in polar bear body condition, decline in cub survival, and increased potential for stress and mortality, and energetic needs in hunting for seals, as well as traveling and swimming to denning sites and feeding areas.").

> and the implications for the environment to adapt to the projected effects of climate change."[36]

Notably, climate change could significantly exacerbate the public safety impacts of the proposed Grand Tower project because climate change-induced variability in the Upper Mississippi River Basin will likely lead to more extreme weather and higher flows than have been experienced in the past. The Conservation Organizations urge the Corps to *begin* its assessment of climate change impacts by evaluating:

- The Midwest regional inputs to the National Climate Assessment.[37]

- The 2013 Regional Climate Trends and Scenarios for the Midwest U.S. showing that for the Midwest region, annual and summer trends for precipitation in the 20th century are upward and statistically significant; the frequency and intensity of extreme precipitation in the region has increased, as indicated by multiple metrics; and models predict increases in the number of wet days (defined as precipitation exceeding 1 inch) for the entire Midwest region, with increases of up to 60%.[38]

- The 2009 U.S. Global Change Research Program report showing that the Midwest experienced a 31% increase in very heavy precipitation events (defined as the heaviest 1% of all daily events) between 1958 and 2007.[39] That study also reports that during the past 50 years, "the greatest increases in heavy precipitation occurred in the Northeast and the Midwest." [40] Models predict that heavy downfalls will continue to increase:

> Climate models project continued increases in the heaviest downpours during this century, while the lightest precipitation is projected to decrease. Heavy downpours that are now 1-in-20-year occurrences are projected to occur about every 4 to 15 years by the end of this century, depending on location, and the intensity of heavy downpours is also expected to increase. The 1-in-20-year heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now. . . . Changes in these kinds of extreme weather and climate events are among the most serious challenges to our nation in coping with a changing climate.[41]

[36] Council on Environmental Quality, *Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions* (February 18, 2010). The CEQ guidance makes it clear that analyzing the impacts of climate change is not restricted to evaluating whether a project could itself exacerbate global warming. The magnifying and additive effects of global warming also must be evaluated.
[37] The Midwest regional assessment can be accessed at http://glisa.msu.edu/great_lakes_climate/nca.php (visited January 22, 2014).
[38] 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, 2013: 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. (available at http://scenarios.globalchange.gov/regions/midwest).
[39] Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009, at page 32 (available at http://nca2009.globalchange.gov/).
[40] *Id*.
[41] *Id*.

- The March 2005 study by the U.S. Geological Survey showing upward trends in rainfall and streamflow for the Mississippi River.[42]

(a) Cumulative Impacts of Climate Change on Migratory Species

Climate change may also significantly exacerbate the impacts on the many migratory species that utilize the Mississippi River, Mississippi River Flyway, and the project area, and these impacts must be analyzed. Migratory species in the project area include the endangered least tern. The additive and magnifying effect of climate change on migratory species is of particular concern given the importance of the Mississippi River as a major migratory pathway. This issue—and indeed, direct and indirect impacts to migratory species—are not discussed at all in the Grand Tower EA.

As recognized by the United Nations Environment Program and the Convention on the Conservation of Migratory Species of Wild Animals, migratory wildlife is particularly vulnerable to the impacts of climate change:

> "As a group, migratory wildlife appears to be particularly vulnerable to the impacts of Climate Change because it uses multiple habitats and sites and use a wide range of resources at different points of their migratory cycle. They are also subject to a wide range of physical conditions and often rely on predictable weather patterns, such as winds and ocean currents, which might change under the influence of Climate Change. Finally, they face a wide range of biological influences, such as predators, competitors and diseases that could be affected by Climate Change. While some of this is also true for more sedentary species, migrants have the potential to be affected by Climate Change not only on their breeding and non-breeding grounds but also while on migration."

> "Apart from such direct impacts, factors that affect the migratory journey itself may affect other parts of a species' life cycle. Changes in the timing of migration may affect breeding or hibernation, for example if a species has to take longer than normal on migration, due to changes in conditions *en route*, then it may arrive late, obtain poorer quality breeding resources (such as territory) and be less productive as a result. If migration consumes more resources than normal, then individuals may have fewer resources to put into breeding . . . ."

* * *

> "Key factors that are likely to affect all species, regardless of migratory tendency, are changes in prey distributions and changes or loss of habitat. Changes in prey may occur in terms of their distributions or in timing. The latter may occur though differential changes in developmental rates and can lead to a mismatch in timing between predators and prey ("phenological disjunction"). Changes in habitat quality (leading ultimately to habitat loss) may be important for migratory species that need a coherent network of sites to facilitate their migratory journeys. Habitat quality is especially

[42] USGS Fact Sheet 2005-3020, Trends in the Water Budget of the Mississippi River Basin, 1949-1997.

> important on staging or stop-over sites, as individuals need to consume large amounts of resource rapidly to continue their onward journey. Such high quality sites may [be] crucial to allow migrants to cross large ecological barriers, such as oceans or deserts."[43]

Migratory birds are at particular risk from climate change. Migratory birds are affected by changes in water regime, mismatches with food supply, sea level rise, and habitat shifts, changes in prey range, and increased storm frequency.[44]

The Grand Tower EA must carefully consider whether the impacts of climate change could exacerbate the impacts of the proposed Grand Tower Project.

G. The Grand Tower EA Fails to Properly Evaluate Mitigation Needs

Because the Grand Tower EA fails to adequately evaluate project impacts, it also fails to adequately evaluate whether compensatory mitigation is required.

H. The 1976 EIS Does Not, and Cannot, Cure the Deficiencies of the Grand Tower EA

The 1976 Regulating Works EIS does not—and cannot—cure the deficiencies of the Grand Tower EA for at least two principle reasons.

First, the 1976 Regulating Works EIS does not discuss the proposed Grand Tower project or analyze impacts to the area that would be affected by the proposed Grand Tower project. As a result, the Grand Tower EA may not be tiered to the 1976 Regulating Works EIS.

The 1976 Regulating Works EIS does not discuss the proposed Grand Tower project, does not discuss the Grand Tower project area, and does not evaluate the direct, indirect, or cumulative impacts of the proposed Grand Tower project. Indeed, the 1976 Regulating Works EIS could not have evaluated the impacts of the structures proposed for the Grand Tower project because most of the types of structures included in that project were not invented until well after 1976. The 1976 EIS provides only a general analysis of river training structures that covers the entire Middle Mississippi River. The 1976 EIS does not – and of course, cannot – address the massive changes that have taken place in the physical and ecological conditions of the river and its watershed; the world's climate; and the state of scientific understanding of the river and the role that management actions have on the river system.

Under these circumstances, the law is clear that the Grand Tower EA may not be tiered to the 1976 EIS. While tiering "to a previous EIS is sometimes permissible, the previous document must actually discuss the impacts of the Project at issue" and must supplement the environmental assessments' own

[43] UNEP/CMS Secretariat, Bonn, Germany, *Migratory Species and Climate Change: Impacts of a Changing Environment on Wild Animals* (2006) at 40-41 (available at http://www.cms.int/publications/pdf/CMS_CimateChange.pdf).
[44] *Id*. at 42-43.

analysis.[45] The Corps' contention that the 1976 EIS need not actually discuss the Grand Tower work area[46] is directly contradicted by this well-settled legal requirement.

Second, even if the 1976 Regulating Works EIS had explicitly discussed the Grand Tower project or project area (which it did not), the Grand Tower EA still could not be tiered to the 1976 Regulating Works EIS. The 1976 EIS must be (and is being) updated as matter of law so can no longer be relied upon to supplement the information provided in the Grand Tower EA.[47]

The St. Louis District is currently supplementing the 1976 Regulating Works EIS because "there are *significant new circumstances and information on the potential impacts* of the Regulating Works Project on the resources, ecosystem and human environment." Grand Tower EA at 2 (emphasis added); 78 Fed. Reg. 77108 (December 20, 2013) (stating that significant new information and circumstances require preparation of a supplemental environmental impact statement for the Middle Mississippi River Regulating Works Project, Missouri and Illinois).

It is not enough that the Grand Tower EA allegedly "incorporates new information and circumstances relevant to the impacts of the action on the environment to the *greatest extent possible*." Grand Tower EA at 3 (emphasis added). Nor may the Corps take action on the Grand Tower project now, before any supplemental EIS is prepared, and then impose additional mitigation measures in the future "[s]hould 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." Grand Tower EA at 3. An agency may not dodge its obligation to analyze the reasonably foreseeable, site-specific environmental consequences of a larger program merely by saying that the consequences might be analyzed later.[48] Indeed, such procrastination is antithetical to NEPA's basic charge to undertake analysis and integrate it into agency decision making as early as possible.[49]

[45] *South Fork Band Council of Western Shoshone of NV. v. United States Dept. of Interior*, 588 F.3d 718, 726 (9th Cir. 2009) (citing *Muckleshoot Indian Tribe v. United States Forest Serv.*, 177 F.3d 800, 810 (9th Cir. 1999) (holding that reliance on the EIS accompanying an earlier planning document was improper because it did not discuss the subsequent specific Project in detail); *Klamath-Siskiyou Wildlands Center v. Bureau of Land Management*, 387 F.3d 989, 998 (9th Cir. 2004) (tiering to an EIS was insufficient to cure an EA's shortcomings where the EIS contained only general statements about the cumulative effects of logging in the area but mentioned no information specific to the timber sales at issue); *Idaho Conservation League v. U.S. Forest Service*, 2012 WL 3758161 D.Idaho, (2012) (Case No. 1:11-CV-00341-EJL, August 29, 2012, not reported in F.Supp.2d)(holding that the "documents to which the EA in question is tiered must actually supplement the EA's own analysis and address the particular impacts of the Project in question in order to satisfy NEPA.").

[46] *See* Grand Tower EA at E-82 ("It is not necessary for the 1976 EIS to specifically discuss the Grand Tower work area as this would defeat the entire concept of tiering provided in the CEQ regulations and guidance. The 1976 EIS generally includes analysis of regulating works and their impacts (see response to Comment 16 above). The Grand Tower EA incorporates this information and includes a description and analysis of new circumstances and information on regulating works generally as well as impacts to the site-specific Grand Tower work area. The Prior Reports discussion in Section 1 of the EA has been revised to provide specifics on the new information and circumstances addressed.")

[47] *Minnesota Public Interest Research Group v. Butz*, 498 F.2d 1314, 1323 n. 29 (8th Cir. 1974); *Association of Public Agency Customers, Inc. v. Bonneville Power Administration*, 126 F.3d 1158, 1184 (9th Cir. 1997); *Salmon River Concerned Citizens v. Robertson*, 32 F.3d 1346, 1356 (9th Cir. 1994).

[48] *Kern v. U.S. Bureau of Land Management*, 284 F.3d 1062, 1072 (9th Cir. 2002).

[49] *See* 40 C.F.R. 1501.2, 1502.5.

I. The Proposed Grand Tower Project Should Be Examined an EIS

As discussed above, the Conservation Organizations call on the Corps to withdraw the Grand Tower EA and place the proposed Grand Tower Phase 5 project on hold until the Corps has accounted for the findings of the requested National Academy of Sciences study and completed the SEIS for the Middle Mississippi River Regulating Works Project. New river training structures should not be built unless the National Academy of Sciences and a comprehensive and legally adequate SEIS establish that such construction will **not** contribute to increased flood risks to communities.

Should the Corps deny this request, it should prepare a full environmental impact statement (EIS) for the Grand Tower Phase 5 project. The Grand Tower Phase 5 projects are large-scale, highly controversial, and have a high probability of causing significant harm to the environment. The Grand Tower EA does not contain the information necessary to support the Corps' conclusion that an EIS is not required for this major federal action. For example, the Grand Tower EA does not provide the environmental data underlying the Corps' analysis of impacts.[50]

The very purpose of an EA is to determine whether an EIS must be prepared. This requires that the EA take a "hard look" at the project and its impacts. An EA may not be based on "bald conclusions, unaided by preliminary investigation."[51] To the contrary, an EA "must support the reasonableness of the agency's decision not to prepare [an] EIS."[52] "Were an EA simply a statement that an agency can take an action without filing an EIS, EA's would not fulfill the mandate of NEPA nor provide the decisionmaker or the public with information about the choice."[53]

The proposed Grand Tower project should be evaluated in the 1976 Regulating Works SEIS or should be the subject of a project specific EIS that examines the impacts of the project in detail.[54]

J. The Clean Water Act Section 404(b)(1) Evaluation Fails to Provide an Accurate Assessment

The many failings in the Grand Tower EA have resulted in a Clean Water Act Section 404(b)(1) Evaluation that fails to provide an accurate and supportable assessment of the impacts of the proposed project. Among other problems, the 404(b)(1) Evaluation concludes that:

- The proposed Grand Tower project would have "no discernible effects on normal water level fluctuations or overall river stages" and "would not have a significant adverse effect on human health and welfare." Grand Tower EA at D-5, D-8. As discussed above, extensive peer reviewed

[50] E.g., *Klamath-Siskiyou Wildlands Ctr. v. BLM*, 387 F.3d 989 (9th Cir. 2004) (An EA must contain specific information on impacts; "generalized conclusory statements are inadequate"); *Save the Yaak Committee v. Block*, 840 F.2d 714, 719 (9th Cir. 1988) (holding EA inadequate for lack of wildlife discussion); 40 C.F.R. § 1508.9 (EA must "[b]riefly provide <u>sufficient</u> evidence and analysis for determining whether to prepare an environmental impact statement or a finding of no significant impact").
[51] *Maryland-National Capital Park and Planning Commission v. U. S. Postal Service*, 487 F.2d 1029, 1040 (D.C. Cir. 1973).
[52] *Southern Oregon Citizens Against Toxic Sprays, Inc. v. Clark*, 720 F.2d 1475, 1480 (9th Cir. 1983).
[53] *Sierra Club v. Watkins*, 808 F. Supp. 852, 871 (D.D.C. 1991).
[54] *Minnesota Public Interest Research Group v. Butz*, 498 F.2d at 1323 and n. 29.

science demonstrates that the construction of river training structures has a significant impact on river stages at flood levels that can put the public at extreme risk of increased flooding. In addition, the Grand Tower EA recognizes that there has been a decrease in surface elevation at low flows that could be due to river training structures and/or a decrease in the sediment load in the Mississippi River due to reservoir construction. Grand Tower EA at 27-28. The Grand Tower EA goes on to state that those impacts are being minimized through other Corps programs, but the Corps cannot rely on vague references to other programs to ignore this issue in either the 404(b)(1) analysis or the environmental assessment.

- The significant cumulative impacts of river training structure construction in the Mississippi River have somehow been addressed by extensive coordination and the use of innovative river training structures including chevrons and rootless dikes. Grand Tower EA at d-7. However, the Corps provides no evidence whatsoever that these new types of structures somehow minimize the cumulative effects of river training structure construction on habitat loss and increased flooding. As discussed above, the Grand Tower EA also fails to meaningfully evaluate the cumulative impacts of the proposed project.

- No other practical alternatives have been identified. Grand Tower EA at D-8. However, as discussed above, the Grand Tower EA has improperly defined the project purpose to exclude consideration of practical alternatives and failed to examine a reasonable range of alternatives as required by law.

K. Conclusion

For at least the reasons set forth in these comments, the Grand Tower EA is legally deficient and cannot be relied upon to satisfy the requirements of NEPA for the proposed project. The Conservation Organizations urge the Corps to withdraw the Grand Tower EA and put the project on hold until the Corps has accounted for the findings of the requested National Academy of Sciences study and completed the SEIS for the Middle Mississippi River Regulating Works Project. New river training structures should not be built unless the National Academy of Sciences study and a comprehensive and legally adequate SEIS establish that such construction will **not** contribute to increased flood risks to communities.

Sincerely,

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Attachments

Attachment A

to the

Comments of the Conservation Organizations on the Grand Tower EA

National Wildlife Federation
Izaak Walton League of America
Missouri Coalition for the Environment
Prairie Rivers Network
Sierra Club

January 24, 2014

Via Email: Danny.D.Mcclendon@usace.army.mil

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Chief, Regulatory Branch
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
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Re: Comments on Draft Environmental Assessment with Unsigned Finding of No Significant Impact, Regulating Works Project Grand Tower Phase 5, Crawford Towhead And Vancill Towhead, Middle Mississippi River Miles 74-67 Union County, IL Cape Girardeau County, MO; Public Notice P-2856 (2013-742)

Dear Mr. McClendon:

The National Wildlife Federation, Izaak Walton League of America, Missouri Coalition for the Environment, Prairie Rivers Network, and Sierra Club (collectively, the Conservation Organizations") appreciate the opportunity to submit these comments on the above-referenced Grand Tower Phase 5 Draft Environmental Assessment with Unsigned Finding of No Significant Impact (the Grand Tower EA).

The National Wildlife Federation (NWF) is the Nation's largest conservation education and advocacy organization. NWF has more than four million members and supporters and conservation affiliate organizations in forty-seven states and territories. NWF has a long history of interest and involvement in the programs of the U.S. Army Corps of Engineers (Corps) and the management and protection of the Mississippi River. NWF is a strong supporter of ecologically sound efforts to restore the Mississippi River and the nation's many other damaged rivers, coasts, and wetlands.

Founded in 1922, the Izaak Walton League is one of the nation's oldest and most respected conservation organizations. With a powerful grassroots network of more than 240 local chapters nationwide, the League takes a common-sense approach toward protecting our country's natural heritage and improving outdoor recreation opportunities for all Americans.

The Missouri Coalition for the Environment is Missouri's independent, citizens environmental organization for clean water, clean air, clean energy, and a healthy environment. The Missouri Coalition for the Environment works to protect and restore the environment through education, public engagement, and legal action.

Prairie Rivers Network is Illinois' only statewide river conservation organization and is the Illinois affiliate of the National Wildlife Federation. We are a 501(c)(3), tax-exempt nonprofit based in Champaign, Illinois. Our mission is to protect the rivers of Illinois and to promote the lasting health and beauty of watershed communities. We use sound science and policy analysis to stand up for strong, fair laws to protect clean water and natural areas. We engage citizens, businesses, and governments across Illinois in this effort, providing them with the policy information, scientific data, technical assistance, and outreach programs needed to support effective river advocacy. A recognized leader on issues involving the implementation and enforcement of the Clean Water Act in Illinois, Prairie Rivers Network leads efforts to improve clean water standards, review pollution permits, protect wetlands, reduce polluted runoff from farms and streets, and restore natural areas along rivers and streams.

Founded by legendary conservationist John Muir in 1892, the Sierra Club is now the nation's largest and most influential grassroots environmental organization – with more than two million members and supporters. The Sierra Club's members are inspired by nature, working together to protect our communities and the planet.

General Comments

The Conservation Organizations urge the Corps to withdraw the Grand Tower EA and place the proposed Grand Tower project on hold at least until the Corps completes the recently announced supplemental environmental impact statement for the Middle Mississippi River Regulating Works Project, Missouri and Illinois (SEIS).[1] The Grand Tower EA does not comply with the requirements of the National Environmental Policy Act (NEPA) and presents flawed science as the basis for its conclusion of no significant impacts. As a whole, the EA is far too limited and lacking in scientific support to adequately assess risks to public safety and the environment or to determine whether less damaging alternatives are available. The Conservation Organizations also call on the Corps to:

1. Expand the SEIS to evaluate the full suite of operations and maintenance (O&M) activities for the Upper Mississippi River – Illinois Waterway (UMR-IWW) navigation system. As the Corps is well aware, the Regulating Works Project, including the proposed Grand Tower project, is just one of a number of activities carried out by the Corps to maintain navigation on the UMR-IWW. In addition to construction of river training structures, other O&M activities include water level regulation, dredging and disposal of dredged material, construction of revetment, and operation and maintenance of the system's 37 locks and dams. Since all O&M activities are designed to maintain a single project, individual activities should not be evaluated in isolation.

2. Initiate a National Academy of Sciences study on the effect of river training structures on flood heights to inform development of the SEIS. A National Academy of Sciences review is critical for ensuring that: (a) the SEIS is based on the best possible scientific understanding of the role of river training structures on increasing flood heights; (b) the SEIS produces recommendations that will provide the highest possible protection to the public; and (c) the public will have

[1] 78 Fed. Reg. 77108 (December 20, 2013). The Conservation Organizations appreciate the Corps' decision to prepare the SEIS but urge the Corps to prepare a supplemental EIS for the Corps' entire suite of navigation operations and maintenance activities on the Upper Mississippi River – Illinois Waterway (UMR-IWW) navigation system.

confidence in this aspect of the evaluation and recommendations contained in the final SEIS.

3. Impose a moratorium on the construction of new river training structures pending completion of the SEIS. As discussed below, extensive peer-reviewed science demonstrates that river training structures have increased flood levels by up to 15 feet in some locations and 10 feet in broad stretches of the Mississippi River where these structures are prevalent. In light of these findings, it is critical that additional river training structures not be built unless and until a comprehensive SEIS establishes that such construction will not contribute to increased flood risks to communities.

Because of the significant potential for increasing the risk of flooding for river communities, the Conservation Organizations also request a public hearing on the proposed Grand Tower project during which members of the public will have an opportunity to present oral testimony directly to the decision makers for this proposed project.

Specific Comments

A. The Corps May Not Tier The Grand Tower EA to the 1976 Regulating Works EIS

The Grand Tower EA states that it is being "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)* . . . ." Grand Tower EA at 1. But as the Corps has acknowledged, the 1976 Regulating Works EIS requires supplementation, in the form of a Supplemental EIS, because "there are *significant new circumstances and information on the potential impacts* of the Regulating Works Project on the resources, ecosystem and human environment." Grand Tower EA at 1 (emphasis added); 78 Fed. Reg. 77108 (December 20, 2013) (stating that significant new information and circumstances require preparation of a supplemental environmental impact statement for the Middle Mississippi River Regulating Works Project, Missouri and Illinois).

However, the law is clear that the Corps may not tier the Grand Tower EA to the 1976 Regulating Work EIS because: (1) there have been material changes in circumstances and significant new information on environmental impacts since completion of the 1976 Regulating Works EIS which requires preparation of a supplemental EIS as a matter of law; and (2) the 1976 Regulating Works EIS does not discuss the proposed Grand Tower project. As a result, the 1976 Regulating Works EIS may not (and as a factual matter, could not) cure the many deficiencies in the Grand Tower EA.

1. The 1976 Regulating Works EIS Must Be Supplemented

As set forth in the Council on Environmental Quality NEPA regulations, tiering is appropriate only when the sequence of statements or analyses is:

> (a) From a program, plan, or policy environmental impact statement to a program, plan, or policy statement of analysis of lesser scope or to a site-specific statement or analysis.
>
> (b) From an environmental impact statement on a specific action at an early stage (such as need and site selection) to a supplement (which is preferred) or a subsequent

> statement or analysis at a later stage (such as environmental mitigation). Tiering in such cases is appropriate when it helps the lead agency to focus on the issues which are ripe for decision and exclude from consideration issues already decided or not yet ripe.

40 C.F.R. § 1508.28.

However, even under these circumstances tiering is ***inappropriate*** when there has been "a *material change in circumstances* or a departure from the policy covered in the overall EIS."[2] A "*significant circumstantial change* is the triggering factor requiring a new or supplemental EIS" which cannot be addressed by merely tiering to a prior "programmatic EIS."[3]

It is not enough that the Grand Tower EA will allegedly "incorporate any new information and circumstances . . . to the *greatest extent possible*." Grand Tower EA at 1 (emphasis added). Nor may the Corps take action on the Grand Tower project now, before any supplemental EIS is prepared, and then impose additional mitigation measures in the future based on what "the analyses undertaken as part of the SEIS process reveal." *Id*. Instead, the Corps is "required" to prepare "an individual EIS for each" specific project within the Regulating Works Project, including for the proposed Grand Tower project.[4]

Because the 1976 Regulating Works EIS must be supplemented, tiering to the 1976 Regulating Works EIS is inappropriate and cannot cure the many deficiencies in the Grand Tower EA.

2. The 1976 Regulating Works EIS Does Not Discuss the Proposed Grand Tower Project

While tiering "to a previous EIS is sometimes permissible, the previous document must actually discuss the impacts of the Project at issue" and must supplement the environmental assessments' own analysis.[5] The 1976 Regulating Works EIS does not discuss the proposed Grand Tower project and does not evaluate its direct, indirect, or cumulative impacts. Indeed, the 1976 Regulating Works EIS could not have evaluated the impacts of the structures proposed for the Grand Tower project because most of the types of structures included in that project were not invented until well after 1976.

As a result, the 1976 Regulating Works EIS cannot – and does not – cure any of the many shortcomings in the Grand Tower EA.

[2] *Minnesota Public Interest Research Group v. Butz*, 498 F.2d 1314, 1323 n. 29 (8th Cir. 1974) (emphasis added); *Association of Public Agency Customers, Inc. v. Bonneville Power Administration*, 126 F.3d 1158, 1184 (9th Cir. 1997); *Salmon River Concerned Citizens v. Robertson*, 32 F.3d 1346, 1356 (9th Cir. 1994).

[3] *Association of Public Agency Customers, Inc. v. Bonneville Power Administration*, 126 F.3d at 1184.

[4] *Minnesota Public Interest Research Group v. Butz*, 498 F.2d at 1323 n. 29.

[5] *South Fork Band Council of Western Shoshone of NV. v. United States Dept. of Interior*, 588 F.3d 718, 726 (9th Cir. 2009) (citing *Muckleshoot Indian Tribe v. United States Forest Serv.*, 177 F.3d 800, 810 (9th Cir. 1999) (holding that reliance on the EIS accompanying an earlier planning document was improper because it did not discuss the subsequent specific Project in detail); *Klamath-Siskiyou Wildlands Center v. Bureau of Land Management*, 387 F.3d 989, 998 (9th Cir. 2004) (tiering to an EIS was insufficient to cure an EA's shortcomings where the EIS contained only general statements about the cumulative effects of logging in the area but mentioned no information specific to the timber sales at issue); *Idaho Conservation League v. U.S. Forest Service*, 2012 WL 3758161 D.Idaho, (2012) (Case No. 1:11-CV-00341-EJL, August 29, 2012, not reported in F.Supp.2d)(holding that the "documents to which the EA in question is tiered must actually supplement the EA's own analysis and address the particular impacts of the Project in question in order to satisfy NEPA.").

B. The Grand Tower EA Fails to Demonstrate a Need for the Proposed Project and Improperly Restricts the Project Purpose

The Grand Tower EA is deficient because it: (1) fails to demonstrate a need for the proposed Grand Tower project; and (2) improperly restricts the project purpose.

The Grand Tower EA states that the proposed Grand Tower Project "is needed to address repetitive channel maintenance dredging issues in the project area. Frequent dredging has been required in order to address channel depth, width, and alignment issues. Without dredging, there are five locations between river miles (RM) 67 and 74 where shoaling occurs, which can result in impacts to navigation. Placement of rock river training structures would provide a sustainable alternative to repetitive maintenance dredging." Grand Tower EA at 1.

1. The Grand Tower EA Fails to Demonstrate Project Need

The Grand Tower EA fails to demonstrate a need for the proposed project. Properly demonstrating project need is fundamental to an adequate NEPA review. It is absolutely critical in this case given that the proposed project creates far more risks to public safety (by increasing flood hazards) than the current dredging regime which has a long history of effectively maintaining navigation.

The current dredging regime is clearly sufficient to maintain navigation in this portion of the Mississippi River since navigation has not been stopped due to lack of channel depth. The Conservation Organizations are unaware of any navigation closures in the project reach resulting from the inability of dredging activities to maintain an adequate channel depth and the Grand Tower EA does not identify any such closures.

Despite assertions within the EA to the contrary, the proposed Grand Tower project has credible potential to significantly increase the risk of flooding to river communities and floodplain areas. As discussed in more detail below, there is extensive peer reviewed science linking river training structures, including dikes and bendway weirs in particular, to significant increases in flood heights.[6] This science shows that these structures have increased flood levels by up to 15 feet in some locations in the Mississippi River and 10 feet in broad stretches of the Mississippi River where these structures are prevalent.[7] Even studies commissioned by the St. Louis District and cited in the Grand Tower EA (e.g., Watson et al., 2013a) find statistically significant increases in water levels for flood flows.

[6] While the Corps continues to deny that river training structures lead to increased flood heights, this effect is so well recognized that the Dutch have "begun lowering dozens of wing dikes along a branch of the Rhine River and [have] plans to lower hundreds more as part of a nationwide effort to reduce flood risk in that river's floodplain." Government Accountability Office, GAO-12-41, Mississippi River, Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures (December 2011) (GAO Study on River Training Structures) (concluding that the Corps is out of compliance with both the National Environmental Policy Act and the Clean Water Act).

[7] Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, 2010. Empirical modeling of hydrologic response to river engineering, Mississippi and Lower Missouri Rivers. River Research and Applications, 26: 546-571; 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.

Flood height increases are particularly problematic upstream of river training structures due to backwater effects. This effect is particularly problematic for the proposed Grand Tower project given the project's location in the Mississippi River channel at Wolf Lake, Illinois along the Big Five Levee System. Corps inspections have identified a number of deficiencies in this levee system, and there are serious concerns about its performance during future floods even without additional stresses.

The Grand Tower project includes an all-new type of dike structure, described as "S-dikes." According to the Grand Tower EA these new structures have only been prototyped using the St. Louis District's table-top physical model (its "Hydraulic Sediment Response" or HSR model). No computer modeling or real world testing of these new structures is reported. The Conservation Organizations believe that it is unwise to construct such relatively untested structures in the Mississippi River, particularly at a location immediately adjacent to a levee with critical safety issues.

To assist the public and decision makers in determining whether there is in fact a need for the proposed Grand Tower project, the Grand Tower EA should evaluate at least the following information in addition to fully assessing the project's environmental impacts:

- The projected future costs of required dredging under the no action alternative calculated for the life of the proposed Grand Tower project,[8] and an assessment of the ability of dredging to continue to maintain navigation in those stretches.
- The number of times, if any, when dredging has been insufficient to maintain navigation in the Project area.
- The construction[9] and full life cycle maintenance costs of the proposed Grand Tower project, and the projected costs of the dredging that will still be needed even if the project is constructed. The Grand Tower EA makes clear that implementation of the project is only "expected to reduce the amount and frequency of dredging necessary in the project area," it will not end the need for dredging. Grand Tower EA at 31. As a result, an accurate comparison of costs with and without the project must include future dredging costs with the project in place.
- The potential adverse impacts to navigation from the proposed Grand Tower project (the Conservation organizations have been advised that river training structures can create difficulties for safe navigation).
- The increased risks of upstream or nearby levee failures should the proposed Grand Tower project increase flood heights.

[8] The Grand Tower EA states that the project area has been dredged 18 times since 2000 at an average cost of $368,000 per event, and that dredging costs in the project area over the past 12 years have averaged approximately $550,000 per year. Grand Tower EA at 17, 30. The EA summarily concludes that these expenditures would be expected to continue under the no action alternative in the future but provides no additional information.

[9] The Grand Tower EA states that the proposed Grand Tower project is estimated to cost $4 million, but fails to provide any assessment of how that number was reached. It also fails to provide life cycle maintenance costs or the costs of dredging that will need to continue even if the proposed project is constructed. The Grand Tower EA also does not provide a benefit-cost analysis for the proposed project.

This information would assist the public and decision makers in assessing both the need for, and the true costs and benefits of, the project. The Grand Tower EA addresses none of these critical issues, and does not provide a benefit-cost analysis for the proposed project.

2. The Grand Tower EA Improperly Restricts the Project Purpose

The Grand Tower EA defines the purpose of this project as the placement of rock river training structures to reduce repetitive dredging. This project purpose is so narrow that it precludes consideration of reasonable alternatives. For example, this narrow project purpose precludes consideration of alternative measures for maintaining channel depth and essentially precludes adoption of the no action alternative despite the fact that navigation can be maintained through dredging. A more appropriate project purpose would be "to maintain navigation in the project area."

Establishing an appropriate project purpose is extremely important as the purpose is closely tied to the range of reasonable alternatives that must be evaluated. All reasonable alternatives that accomplish the project purpose must be examined in an environmental impact statement, while alternatives that are not reasonably related to project purpose do not have to be examined.[10]

Indeed, an overly narrow project purpose defeats the very purpose of NEPA:

> "One obvious way for an agency to slip past the strictures of NEPA is to contrive a purpose so slender as to define competing "reasonable alternatives" out of consideration (and even out of existence). The federal courts cannot condone an agency's frustration of Congressional will. If the agency constricts the definition of the project's purpose and thereby excludes what truly are reasonable alternatives, the EIS cannot fulfill its role. Nor can the agency satisfy the Act. 42 U.S.C. § 4332(2)(E)."[11]

The project purpose in the Grand Tower EA is impermissibly narrow as it drives consideration of only those alternatives that recommend construction of river training structures.

C. The Grand Tower EA Fails to Evaluate a Reasonable Range of Alternatives

The Grand Tower EA examines only two alternatives, the no action alternative and the proposed alternative. This is legally insufficient because an environmental assessment must examine a full range of reasonable alternatives.[12]

[10] *Methow Valley Citizens Council v. Regional Forester*, 833 F.2d 810, 815-16 (9th Cir. 1987).
[11] *Simmons v. United States Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997); *City of Carmel-by-the-Sea v. United States Dep't of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997) ("an agency cannot define its objectives in unreasonably narrow terms"); *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 195-96 (D.C. Cir. 1991), *cert. denied*, 502 U.S. 994 (1991) ("an agency may not define the objectives of its action in terms so unreasonably narrow that only one alternative from among the environmentally benign ones in the agency's power would accomplish the goals of the agency's action"); *City of New York v. United States Dep't of Transp.*, 715 F.2d 732, 743 (2d Cir. 1983), *cert. denied*, 456 U.S. 1005 (1984) ("an agency will not be permitted to narrow the objective of its action artificially and thereby circumvent the requirement that relevant alternatives be considered").
[12] While other configurations of river training structures were examined prior to preparation of the environmental assessment, this does not exempt the Corps from the requirement to examine a reasonable range of alternatives in the EA. Moreover, evaluations of alternative configurations of river training structures cannot satisfy the

An environmental assessment, like an environmental impact statement, "must evaluate a reasonable range of alternatives to the agency's proposed action, to allow decision-makers and the public to evaluate different ways of accomplishing an agency goal."[13] This is because the consideration of alternatives required by NEPA is both independent of, and broader than, the requirement to prepare an environmental impact statement.[14] As a result "[c]onsideration of alternatives is critical to the goals of NEPA even where a proposed action does not trigger the EIS process."[15]

The Grand Tower EA does not evaluate a reasonable range of alternatives. It instead looks only at the proposed alternative and the no action alternative.

D. The Grand Tower EA Fails to Properly Evaluate the Full Suite of Impacts to the Environment

The Grand Tower EA fails to evaluate the full suite of impacts, provides only the most limited analysis of those impacts it does evaluate, and fails to provide a reasonable explanation between the information presented and the conclusions drawn.

In addition, the Grand Tower EA appears not to include important information already assembled by the Corps on the impacts of the Regulating Works program. This would include the information utilized by the Corps when it "determined that there is sufficient significant new information regarding the potential impacts of the [Regulating Works] project on the human environment to warrant the preparation of a supplemental environmental impact statement." 78 Fed. Reg. 77108 (December 20, 2013).

1. The Grand Tower EA Fails to Properly Evaluate Hydrologic Impacts

The extensive amount of peer reviewed science demonstrating that river training structures are causing significant increases in flood heights in the Middle Mississippi River, and the proposed project's location at Wolf Lake, Illinois along the Big Five Levee System (which Corps inspectors have determined have a number of deficiencies) makes the evaluation of the hydrologic impacts of the project particularly critical. Despite this, however, the Grand Tower EA fails to evaluate hydrologic impacts in any meaningful way for at least the following reasons.

First, the proposed alternative was developed using a Hydraulic Sediment Response model (HSR model), which "is a small-scale physical sediment transport model used by the District to replicate the mechanics

requirement to evaluate a reasonable range of alternatives because each alternative would have the same end result – construction of river training structures in the project area. *State of California v. Block*, 690 F.2d 753, 767 (9th Cir. 1982) (holding that an inadequate range of alternatives was considered where the end result of all eight alternatives evaluated was development of a substantial portion of wilderness).

[13] *Pacific Marine Conservation Council v. Evans*, 200 F. Supp. 2d 1194, 1206 (N.D.Cal 2002); *Akiak Native Community v. United States Postal Serv.*, 213 F.3d 1140, 1148 (9th Cir. 2000) (EA must consider a reasonable range of alternatives).

[14] *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223 (9th Cir. 1988), *cert. denied*, 489 U.S. 1066 (1988); *City of New York v. United States Department of Transportation*, 715 F.2d 732, 742 (2d Cir.1983), *cert. denied*, 465 U.S. 1055 (1984); *Environmental Defense Fund, Inc. v. Corps of Engineers*, 492 F.2d 1123, 1135 (5th Cir.1974).

[15] *Bob Marshall Alliance*, 852 F.2d at 1228-29.

of river sediment transport." Grand Tower EA at 5. However, such models cannot be relied upon to provide accurate planning information as they lack "predictive capability". Stephen T. Maynord, Journal of Hydraulic Engineering, *Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model* (April 2006). Maynord concludes that because of the "lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication." A copy of this study is attached to these comments at Attachment A. The Corps should be utilizing the most up-to-date modeling to evaluate the potential impacts of the proposed project such as by using state of the art two-dimensional and three-dimensional hydrodynamic models with inputs that recognize the current conditions in the river system.

Second, the Corps admits that no modeling at all was done for the structures proposed for the Crawford Towhead reach: "No HSR investigation was completed for Crawford Towhead since the bathymetry was uncomplicated." Grand Tower EA at 10. The Corps instead concluded that only professional judgment was required to develop this portion of the project. The Corps should not be using "professional judgment" to design and approve construction at any location, but should instead utilize the most up-to-date modeling to evaluate the potential impacts of proposed projects on public safety and the environment, including through use of state of the art two-dimensional and three-dimensional hydrodynamic model with inputs that recognize the current conditions in the river system.

Third, The Grand Tower EA and Appendix A fail to analyze the full range of scientific studies that address the role of river training structures in raising flood heights. They also fail to provide a reasonable explanation as to why the conclusions from this extensive body of science should be rejected. Since 1986, at least 51 scientific studies have been published linking the construction of river training structures to increased flood heights. More than 15 studies published from 2000-2010 demonstrate the role of river training structures on flood heights in the Mississippi River. These studies show that river training structures constructed by the Corps to reduce navigation dredging costs have increased flood levels by 10 to 15 feet and more in some locations of the Mississippi River during large floods. A list of the 51 studies assessing the role of instream structures on increasing flood heights is attached to these comments at Attachment B. We request that these studies be included in the record for this project. While the Grand Tower EA presents findings of St. Louis District consultants in an attempt to cast doubt on various aspects of the extensive research on river training structures, the Conservation Organizations note that the burden of proof is on the Corps to establish the safety and efficacy of river training structures *before* building any additional structures. The Grand Tower EA does not do this.

Fourth, the Grand Tower EA fails to address a global consensus that river training structures can and do increase flood heights. For example, the government of the Netherlands is expending a significant amount of resources to modify hundreds of river training structures to reduce flood risks.[16]

Because of these failings, the public and decision makers cannot know what the true impacts of the proposed Grand Tower project will be on flooding. Potential impacts can be deadly and must be taken seriously by the Corps. As noted above, the Conservation Organizations urge the Corps to initiate a National Academy of Sciences study to evaluate this issue.

[16] Government Accountability Office, GAO-12-41, Mississippi River, Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures (December 2011) at 41.

2. The Grand Tower EA Fails to Properly Evaluate Cumulative Impacts

The Grand Tower EA fails to properly evaluate – and account for – cumulative impacts. Notable failings in this section include the failure to assess the cumulative impacts of the Corps' many other activities on the Mississippi River, including already constructed river training structures, and the failure to assess the cumulative impacts of climate change.

New training structures proposed in the Grand Tower reach were prototyped (using the St. Louis District's table-top modeling system) only on a local basis and over short time scales. This approach and the EA fail to recognize that this incremental approach in no way addresses system-wide changes to the Middle Mississippi River system. Moreover, the new surge in construction of training structures in the past several years appears to be merely shifting the loci of sedimentation which could eventually lead to even more river training structure construction.

Instead of conducting an appropriate cumulative impacts analysis, the EA contains just one highly generalized and speculative table (Table 4). The Grand Tower EA uses this table to draw the following sweeping and unsupported conclusion:

> "The Regulating Works Project, in combination with the other stressors 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 – involving partner agencies throughout the planning process, avoiding and minimizing impacts during the planning process, and utilizing innovative river training structures to provide habitat diversity while still providing benefits to the navigation system – has been successful in accomplishing the desired effect of avoiding significant environmental consequences. Although our understanding of the processes and stressors that bear upon the resources of the Middle Mississippi River continues to evolve, equilibrium in habitat conditions appears to have been reached. Accordingly, no significant impacts to the resources, ecosystem and human environment are anticipated for the Grand Tower Phase 5 Regulating Works Project."

Grand Tower EA at 32.

(a) Cumulative Impacts of Other Corps Activities on the Mississippi River

The Grand Tower EA fails to meaningfully evaluate the cumulative impacts of the Corps' many other activities on the Mississippi River. These include the full suite of past, present, and reasonably foreseeable future O&M activities for the Mississippi River navigation system and other reasonably foreseeable projects including construction of river training structures in the Herculaneum Reach for so-called restoration purposes.

The numbers of river training structures, and their impacts, are significant. For example, the Conservation Organizations understand that between 1980 and 2009, the Corps built at least 380 new river training structures in the Middle Mississippi, including 40,000 feet of wing dikes and bendway weirs between 1990 and 1993. The Corps built at least 23 chevrons between 2003 and 2010. The proposed Grand Tower project would add 2 new chevrons, 3 new S-dikes, 3 new weirs, 1 dike extension, and additional new revetment. The Corps has also recently proposed at least the following additional projects utilizing a significant number of river training structures:

- The Dogtooth Bend project which would include 8 new bendway weirs and 1 new dike.
- The Eliza Point project which would include 4 new bendway weirs and 1 new rootless dike.
- The Moosenthein Ivory project which would include 1 new rootles dike and 2.2 miles of new revetment.
- The Herculaneum Reach project which would include 12 new chevrons in a narrow, 3.5 mile stretch of the Mississippi River (creating the River's largest concentration of chevrons).

The Corps also carries out other major O&M activities to maintain navigation on the 1,200 miles of the UMR-IWW. These activities include: dredging and disposal of dredged material, water level regulation, construction of revetment, and operation and maintenance of the system's 37 locks and dams. Maintaining this navigation system requires "continuous regular operations and maintenance" at a cost of more than $120 million each year.[17]

The Grand Tower EA fails to address in any meaningful way – or account for – the very significant adverse impacts caused by these O&M activities. A significant body of scientific evidence, much of which was prepared with the Corps' input, demonstrates that the Corps' O&M activities are a significant cause of the severe decline in the ecological health of the UMR-IWW system and have completely altered the natural processes in the Upper Mississippi River.[18]

In a 1999 report on the Status and Trends of the Upper Mississippi River System, the U.S. Geological Survey concluded that the Corps' O&M activities in the UMR-IWW system were: destroying critical habitats including the rivers' backwaters, side channels and wetlands; altering water depth; destroying bathymetric diversity; causing nonnative species to proliferate; and severely impacting native species.[19] The 1999 Status and Trends Report also rated the health of the Mississippi River System as follows:

1. The Lower Reach of the Illinois River is degraded for all 6 criteria of ecosystem health evaluated by the report.[20]
2. The Unimpounded Reach of the Mississippi River is degraded for 3 criteria, heavily impacted for 2 criteria, and moderately impacted for 1 criterion.
3. The Lower Impounded Reach of the Mississippi River (Pools 14-26) is degraded for 2 criteria, heavily impacted for 3 criteria, and moderately impacted for 1 criterion.
4. The Upper Impounded Reach of the Mississippi River (Pools 1-13) is degraded for 1 criterion

[17] USACE Brochure, Upper Mississippi River – Illinois Waterway System Locks and Dams (September 2009) available at http://www.mvr.usace.army.mil/brochures/documents/UMRSLocksandDams.pdf; Congressional Research Service, *Inland Waterways: Recent Proposals and Issues for Congress* (July 14, 2011) at 15.
[18] U.S. Geological Survey, Ecological Status and Trends of the Upper Mississippi River System 1998: A Report of the Long Term Resource Monitoring Program (April 1999) (1999 Status and Trends Report).
[19] *Id*.
[20] "Degraded" is the lowest possible grade issued by the report and is defined as a condition where the factors associated with the criteria "are now below ecologically acceptable levels" and where "[m]ultiple management actions are required to raise these conditions to acceptable levels." 1999 Status and *Trends Report* at 16-2.

and moderately impacted for 5 criteria.

The 1999 Status and Trends report further concluded that no segment of the Upper Mississippi River system was unchanged from historic conditions, or deemed to require no management action to maintain, restore or improve conditions. Equally important, no segment of the system was improving in quality.[21]

In December 2008, the U.S. Geological Survey issued a second report on the status and trends of selected resources in the Upper Mississippi River system which also found that the Corps' O&M activities were causing significant adverse impacts.[22] For example:

> The current condition of the UMRS is heavily influenced by its agriculture-dominated basin and by the dams, channel training structures, dredging, and levees that regulate flow distribution during most of the year. Although substantial improvements in some conditions have occurred since the 1960s because of improvements in sewage treatment and land use practices, the UMRS still faces substantial challenges including
>
> 1. High sedimentation rates in some backwaters and side channels;
> 2. An altered hydrologic regime resulting from modifications of river channels, the floodplain, and land use within the basin, and from dams and their operation;
> 3. Loss of connection between the floodplain and the river, particularly in the southern reaches of the UMRS;
> 4. Nonnative species (e.g., common carp [*Cyprinus carpio*], Asian carps [*Hypophtalmichthys* spp.], zebra mussels [*Dreissena polymorpha*]);
> 5. High levels of nutrients and suspended sediments; and
> 6. Degradation of floodplain forests.[23]

The 2008 Status and Trends report also recognized that there has been "a substantial loss of habitat diversity"[24] in the system over the past 50 years due in large part to excessive sedimentation and erosion:

> In all reaches, sedimentation has filled-in many backwaters, channels, and deep holes. In the lower reaches, sediments have completely filled the area between many wing dikes producing a narrower channel and new terrestrial habitat. Erosion has eliminated many islands, especially in impounded zones.[25]

In addition to this significant environmental harm, an extensive body of peer-reviewed scientific literature also demonstrates that river training structures constructed by the Corps to help maintain the

[21] 1999 Status *and Trends Report at* 16-1 to 16.-2.
[22] Johnson, B. L., and K. H. Hagerty, editors. 2008. U.S. Geological Survey, *Status and Trends of Selected Resources of the Upper Mississippi River System,* December 2008, Technical Report LTRMP 2008-T002. 102 pp + Appendixes A–B (Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin) (2008 Status and Trends Report).
[23] *Id*. at 3.
[24] *Id*. at 6.
[25] *Id*. at 6.

9 foot navigation channel are significantly increasing the risks of floods for riverside communities.[26] These structures, constructed by the Corps to reduce navigation dredging costs, have increased flood levels by up to 15 feet in some locations and 10 feet in broad stretches of the river where these structures are prevalent.[27] While the Corps continues to deny the validity of this science, the flood height inducing effects of river training structures are so well recognized that the Dutch have "begun lowering dozens of wing dikes along a branch of the Rhine River and [have] plans to lower hundreds more as part of a nationwide effort to reduce flood risk in that river's floodplain." [28]

The Grand Tower EA fails to meaningfully address these impacts.

(b) Cumulative Impacts of Climate Change

Despite a clear legal requirement to do so, the Grand Tower EA fails to evaluate the additive and magnifying effects of climate change on the proposed Grand Tower project. Of critical concern is the additive and magnifying effect of climate change on increased flood risks and on harm to migratory species.

The Corps is required as a matter of law to evaluate the cumulative impacts of climate change.[29] This evaluation is extremely important as:

> "Climate change can increase the vulnerability of a resource, ecosystem, or human community, causing a proposed action to result in consequences that are more damaging than prior experience with environmental impacts analysis might indicate . . . . [and] climate change can magnify the damaging strength of certain effects of a proposed action."
>
> * * *
>
> "Agencies should consider the specific effects of the proposed action (including the proposed action's effect on the vulnerability of affected ecosystems), the nexus of those effects with projected climate change effects on the same aspects of our environment,

[26] See Attachment B listing 51 peer reviewed studies linking instream structures to increased flood heights.
[27] Pinter, N., A.A. Jemberie, J.W.F. Remo, R.A. Heine, and B.A. Ickes, 2010. Empirical modeling of hydrologic response to river engineering, Mississippi and Lower Missouri Rivers. River Research and Applications, 26: 546-571; 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.
[28] Government Accountability Office, GAO-12-41, Mississippi River, Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures (December 2011).
[29] *See Center for Biological Diversity v. Nat'l Hwy Traffic Safety Administration*, 538 F.3d 1172, 1217 (9th Cir. 2008) (holding that analyzing the impacts of climate change is "precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct" and that NEPA requires analysis of the cumulative impact of greenhouse gas emissions when deciding not to set certain CAFE standards); *Center for Biological Diversity v. Kempthorne*, 588 F.3d 701, 711 (9th Cir. 2009) (NEPA analysis properly included analysis of the effects of climate change on polar bears, including "increased use of coastal environments, increased bear/human encounters, changes in polar bear body condition, decline in cub survival, and increased potential for stress and mortality, and energetic needs in hunting for seals, as well as traveling and swimming to denning sites and feeding areas.").

> and the implications for the environment to adapt to the projected effects of climate change."[30]

Notably, climate change could significantly exacerbate the public safety impacts of the proposed Grand Tower project because climate change-induced variability in the Upper Mississippi River Basin will likely lead to more extreme weather and higher flows than have been experienced in the past. The Conservation Organizations urge the Corps to *begin* its assessment of climate change impacts by evaluating:

- The Midwest regional inputs to the National Climate Assessment.[31]

- The 2013 Regional Climate Trends and Scenarios for the Midwest U.S. showing that for the Midwest region, annual and summer trends for precipitation in the 20th century are upward and statistically significant; the frequency and intensity of extreme precipitation in the region has increased, as indicated by multiple metrics; and models predict increases in the number of wet days (defined as precipitation exceeding 1 inch) for the entire Midwest region, with increases of up to 60%.[32]

- The 2009 U.S. Global Change Research Program report showing that the Midwest experienced a 31% increase in very heavy precipitation events (defined as the heaviest 1% of all daily events) between 1958 and 2007.[33] That study also reports that during the past 50 years, "the greatest increases in heavy precipitation occurred in the Northeast and the Midwest."[34] Models predict that heavy downfalls will continue to increase:

> Climate models project continued increases in the heaviest downpours during this century, while the lightest precipitation is projected to decrease. Heavy downpours that are now 1-in-20-year occurrences are projected to occur about every 4 to 15 years by the end of this century, depending on location, and the intensity of heavy downpours is also expected to increase. The 1-in-20-year heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now. . . . Changes in these kinds of extreme weather and climate events are among the most serious challenges to our nation in coping with a changing climate.[35]

[30] Council on Environmental Quality, *Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions* (February 18, 2010). The CEQ guidance makes it clear that analyzing the impacts of climate change is not restricted to evaluating whether a project could itself exacerbate global warming. The magnifying and additive effects of global warming also must be evaluated.
[31] The Midwest regional assessment can be accessed at http://glisa.msu.edu/great_lakes_climate/nca.php (visited January 22, 2014).
[32] 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, 2013: 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. (available at http://scenarios.globalchange.gov/regions/midwest).
[33] Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009, at page 32 (available at http://nca2009.globalchange.gov/).
[34] *Id*.
[35] *Id*.

- The March 2005 study by the U.S. Geological Survey showing upward trends in rainfall and streamflow for the Mississippi River.[36]

Climate change may also significantly exacerbate the impacts on the many migratory species that utilize the Mississippi River, Mississippi River Flyway, and the project area, and these impacts must be analyzed. As recognized by the United Nations Environment Program and the Convention on the Conservation of Migratory Species of Wild Animals, migratory wildlife is particularly vulnerable to the impacts of climate change:

> "As a group, migratory wildlife appears to be particularly vulnerable to the impacts of Climate Change because it uses multiple habitats and sites and use a wide range of resources at different points of their migratory cycle. They are also subject to a wide range of physical conditions and often rely on predictable weather patterns, such as winds and ocean currents, which might change under the influence of Climate Change. Finally, they face a wide range of biological influences, such as predators, competitors and diseases that could be affected by Climate Change. While some of this is also true for more sedentary species, migrants have the potential to be affected by Climate Change not only on their breeding and non-breeding grounds but also while on migration."
>
> "Apart from such direct impacts, factors that affect the migratory journey itself may affect other parts of a species' life cycle. Changes in the timing of migration may affect breeding or hibernation, for example if a species has to take longer than normal on migration, due to changes in conditions *en route*, then it may arrive late, obtain poorer quality breeding resources (such as territory) and be less productive as a result. If migration consumes more resources than normal, then individuals may have fewer resources to put into breeding . . . ."
>
> * * *
>
> "Key factors that are likely to affect all species, regardless of migratory tendency, are changes in prey distributions and changes or loss of habitat. Changes in prey may occur in terms of their distributions or in timing. The latter may occur though differential changes in developmental rates and can lead to a mismatch in timing between predators and prey ("phenological disjunction"). Changes in habitat quality (leading ultimately to habitat loss) may be important for migratory species that need a coherent network of sites to facilitate their migratory journeys. Habitat quality is especially important on staging or stop-over sites, as individuals need to consume large amounts of resource rapidly to continue their onward journey. Such high quality sites may [be] crucial to allow migrants to cross large ecological barriers, such as oceans or deserts."[37]

[36] USGS Fact Sheet 2005-3020, Trends in the Water Budget of the Mississippi River Basin, 1949-1997.
[37] UNEP/CMS Secretariat, Bonn, Germany, *Migratory Species and Climate Change: Impacts of a Changing Environment on Wild Animals* (2006) at 40-41 (available at http://www.cms.int/publications/pdf/CMS_CimateChange.pdf).

Migratory birds are at particular risk from climate change. Migratory birds are affected by changes in water regime, mismatches with food supply, sea level rise, and habitat shifts, changes in prey range, and increased storm frequency.[38]

The Grand Tower EA must carefully consider whether the impacts of climate change could exacerbate the impacts of the proposed Grand Tower Project.

3. The Grand Tower EA Fails to Adequately Evaluate Impacts to Fish and Wildlife, Including Endangered Species

The Corps has not conducted the modeling or monitoring needed to draw the conclusion that the project will have no adverse impacts to fish and wildlife. For example, as discussed above, the Grand Tower EA fails to adequately assess the hydrologic and cumulative impacts and thus it has no basis for assessing the resulting changes in habitat for fish and wildlife species. Critically for the evaluation of fish and wildlife impacts, the Grand Tower EA ignores the large-scale loss of backwater and side channel habitat in the Mississippi River and the potential for additional losses of natural side channels, crossover habitat and mid-channel bars if the proposed Grand Tower project is constructed. The Corps' vague reference to other Corps programs working to restore and preserve this type of habitat does not cure this critical failing. See Grand Tower EA at 23 (other USACE programs "have currently seen success in restoring and preserving side channels affected by river training structures.")

These failings are particularly problematic for assessing potential impacts to endangered species. As noted in the December 2012 Biological Assessment (but not in the text of the Grand Tower EA) the project is located in important habitat for both the endangered pallid sturgeon and the endangered least tern:

> This project is located within a reach of the river that has been identified as important pallid sturgeon habitat due to the presence of crossover habitat and mid-channel bars. The dike location is just above Cottonwood Island which is recognized as important pallid sturgeon habitat. The Missouri Department of Conservation requested in their FY 2009 coordination comments that proposed plans for dikes at 80.6L and 80.7L be left until last and should only be completed if absolutely necessary to alleviate the need to dredge this reach.
>
> * * *
>
> This Big Muddy dikes subarea (MRM 71-80) is foraging habitat for least terns and habitat for pallid sturgeon. There are pallid sturgeon locations at RM 69.5, 69.6, 69.8, 70.3, 71.8, 77.1, 78.2, 78.7, 79.5, and 79.8 especially around Cottonwood Island. Cottonwood Chute, including its substrate, is one of the most valuable habitat areas for the pallid sturgeon in the MMR.

The Grand Tower EA asserts that the project will not adversely impact fish and wildlife, including the endangered least tern and pallid sturgeon, because the proposed project will create more diverse habitats, but the EA fails to provide any evidence to support that contention. Indeed, only the most minimal monitoring appears to have been carried out to assess the impacts of chevrons, and no monitoring has been carried out on the impacts of the newly developed S-dikes.

[38] *Id*. at 42-43.

It is far more likely that the proposed Grand Tower project will add to the loss of diverse river habitats, since like other river training structures, their very purpose is to create a deeper, self scouring channel which in turn leads to losses in natural backwater and braided channel habitats. These impacts are well recognized by the U.S. Fish and Wildlife Service which has concluded that construction of river training structures have adversely affected the pallid sturgeon and least tern by destroying vital habitat.

E. The Grand Tower EA Fails to Properly Evaluate Mitigation Needs

Because the Grand Tower EA fails to adequately evaluate project impacts, it also fails to adequately evaluate whether compensatory mitigation is required.

F. The Clean Water Act Section 404(b)(1) Evaluation Fails to Provide an Accurate Assessment

The many failings in the Grand Tower EA have resulted in a Clean Water Act Section 404(b)(1) Evaluation that fails to provide an accurate and supportable assessment of the impacts of the proposed project. Among other problems, the 404(b)(1) Evaluation concludes that:

- The proposed Grand Tower project would have "no discernible effects on normal water level fluctuations or overall river stages" and "would not have a significant adverse effect on human health and welfare." As discussed above, extensive peer reviewed science demonstrates that the construction of river training structures has a significant impact on river stages at flood levels that can put the public at extreme risk of increased flooding. In addition, the Grand Tower EA recognizes that there has been a decrease in surface elevation at low flows that could be due to river training structures and/or a decrease in the sediment load in the Mississippi River due to reservoir construction. Grand Tower EA at 22-23. The Grand Tower EA goes on to state that those impacts are being minimized through other Corps programs, but the Corps cannot rely on vague references to other programs to ignore this issue in either the 404(b)(1) analysis or the environmental assessment.

- The significant cumulative impacts of river training structure construction in the Mississippi River have somehow been addressed by extensive coordination and the use of innovative river training structures including chevrons and rootless dikes. However, the Corps provides no evidence whatsoever that these new types of structures somehow minimize the cumulative effects of river training structure construction on habitat loss and increased flooding. As discussed above, the Grand Tower EA also fails to meaningfully evaluate the cumulative impacts of the proposed project.

- No other practical alternatives have been identified. However, as discussed above, the Grand Tower EA has improperly defined the project purpose to exclude consideration of practical alternatives and failed to examine a reasonable range of alternatives as required by law.

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G. Conclusion

For at least the reasons set forth in these comments, the Grand Tower EA is legally deficient and cannot be relied upon to satisfy the requirements of NEPA for the proposed project. The Conservation Organizations urge the Corps to withdraw the Grand Tower EA and put the project on hold at least until the Corps completes a legally adequate supplemental environmental impact statement that examines all O&M activities carried out on the Upper Mississippi River – Illinois Waterway navigation system.

Sincerely,

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Attachments

Attachment A

to the

Comments of the Conservation Organizations on the Grand Tower EA

Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model

Stephen T. Maynord, A.M.ASCE[1]

Abstract: The micromodel is an extremely small physical river model having a movable bed, varying discharge, and numerous innovations to achieve quick answers to river engineering problems. In addition to its size being as small as 4 cm in channel width, the vertical scale distortion up to 20, Froude number exaggeration up to 3.7, and no correspondence of stage in model and prototype, place the micromodel in a category by itself. The writer was assigned to evaluate the micromodel's capabilities and limitations to ensure proper application. A portion of this evaluation documents the deviation of the micromodel from similarity considerations used in previous movable bed models. The primary basis for this evaluation is the comparison of the micromodel to the prototype. The writer looked for comparisons that had (1) a reasonable calibration of the micromodel and (2) about the same river engineering structures constructed in the prototype that were tested in the micromodel and (3) a prediction by the micromodel of the approximate trends in the prototype. Evaluation of these comparisons shows a lack of predictive capability by the micromodel. Differences in micromodel and prototype likely result from uncertainty in prototype data and the large relaxations in similitude. Based on the lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication for which it has been useful and should be of value to the profession.

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CE Database subject headings: Scale models; Channel flow; Sediment; River beds; Water discharge.

Introduction

The micromodel is an extremely small physical river model having a movable bed and varying discharge. It was developed in 1994 by the St. Louis District (Davinroy 1994) of the U.S. Army Corps of Engineers (USACE). Horizontal scales of up to 1:20,000 result in micromodel channel widths as small as 4 cm. Previous Mississippi River micromodels typically reproduced about 20 km of the river on the standard 1.9-m-long micromodel table. The micromodel has been used to predict the bathymetry and flow pattern trends for proposed river training structures for purposes of navigation and environmental effects. To date, over 20 reports have been published detailing micromodel studies. The writer was assigned to a USACE team in 1999 to evaluate the capabilities and limitations of the micromodel. The two other members of the evaluation team were developers and present users of the micromodel. The team could not reach a consensus on the capabilities of the micromodel and the USACE had the USACE Committee on Channel Stabilization (CCS) provide an evaluation of the micromodel based on a meeting with the team members. The CCS (USACE 2004) report concluded that the micromodel is not a detailed design tool but that the micromodel can be used for screening alternatives except for study types where human life or the overall project are at risk. For such critical study types, the CCS concluded micromodel use should be "limited." The CCS report states that "During the discussions, it became apparent to some that there is a considerable gap between the pure academic/scientific views of the micromodel technology and the practical use of the micromodel as a tool in an overall river engineering process which has been used on large rivers in MVD (Mississippi Valley Division of the USACE)." The inability to resolve the issue of whether to evaluate the river engineering process that uses a micromodel, or only the micromodel, was a major impediment to the evaluation. The proper evaluation parameter for the river engineering process is whether the project was a success. The proper evaluation parameter for the micromodel is comparison of bathymetric and flow features to the prototype. This writer is evaluating one component of the river engineering process, the micromodel, and whether it can approximately predict the bathymetric and flow features of a large river like the Mississippi.

Some observers of micromodel technology have been critical of its use. Falvey (1999) stated "*Civil Engineering* and the St. Louis District are doing the profession a disservice by implying that a micro-model is a tool that can be used for serious engineering investigations." Yalin, an expert in movable bed modeling, was able to observe and discuss the micromodel with the evaluation team. Yalin stated in a letter to this writer, "I regret that such a 'model' cannot be used for predictive purposes." Both criticisms were almost certainly the result of the micromodel's small size and lack of adherence to similarity principles used in movable bed modeling. From early in the team evaluation, this writer felt that if the size and similarity issues were significant, their effects would be seen in attempts to use the micromodel to predict response in the river. For that reason, this writer spent a large portion of the multiyear study evaluating micromodel-prototype comparisons, particularly predictions.

The objective of this paper is to present results of an evaluation funded by the USACE Research and Development Program

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Note. Discussion open until September 1, 2006. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on October 18, 2004; approved on February 3, 2005. This paper is part of the ***Journal of Hydraulic Engineering***, Vol. 132, No. 4, April 1, 2006. ©ASCE, ISSN 0733-9429/2006/4-343–353/$25.00.

to determine the capabilities and limitations of the micromodel. Specific focus is directed at critical study types where human life or the overall project is at risk if the model is not correct.

Movable Bed Modeling

Yalin (1971) states that a model can be scientifically valid only if measured quantities in the model are related to their counterparts in the prototype by scale ratios that satisfy the criteria of similarity. Ettema (2001) presents the dimensionless parameters associated with flow of water and sediment in channels with a bed of cohesionless particles including movable bed models (MBMs) as

$$\Pi_A = f_A\left[D\left(\frac{g(\rho_s-\rho)}{\rho\nu^2}\right)^{1/3}, \frac{\rho Ri}{D(\rho_s-\rho)}, \frac{\rho_s}{\rho}, \frac{D}{R}, \frac{B}{R}, \frac{\sigma}{\rho giR^2}\right] \quad (1)$$

where the dependent variable A in Π_A might be flow resistance, thalweg sinuosity, sediment transport, or some other variable in alluvial channels; D=particle size; g=gravity; ρ_s=particle density; ρ=water density; ν=kinematic viscosity of water; R=hydraulic radius; i=slope; B=channel width; and σ=surface tension. Scale distortions arise when the dimensionless parameters on the right side of the equation are not the same in model and prototype. However, some of the dimensionless ratios, under certain conditions, do not cause significant effects when model and prototype values differ. For example, in a model of sufficient size, the last parameter on the right side of Eq. (1) will not be the same in model and prototype but the effects of differences in surface tension in model and prototype will be negligible. It remains to be determined if the surface tension term can be neglected in a micromodel. The first term on the right hand side is a particle density term which shows that if a lightweight bed material is used, the particle size in the model will be larger than in the prototype. The second term is the Shields parameter that is present in almost all movable bed model criteria and defines the amount of movement of sediment. The third term (ρ_s/ρ) is often ignored because density effects are addressed in the first and second terms of the right side of the equation. The fourth term on the right hand side, D/R, is the relative roughness that is rarely equal in model and prototype of sand bed streams and is often assumed to have negligible effects on model results. However, Ettema et al. (1998) have shown significant scale effects of D/R on bridge pier scour. The fifth term on the right side is the aspect ratio that is another term that can rarely be maintained the same in MBM and prototype of sand bed rivers.

Three techniques have been used in MBM (and are used in the micromodel) to increase model Reynolds number and sediment mobility in the model and, in some MBMs, to achieve equal Shields parameter in model and prototype. In the Shields parameter, the water density ρ is fixed, prototype sediment density ρ_s is relatively constant, and the model particle size D cannot be scaled down due to particle cohesion problems and will be roughly the same in model and prototype when dealing with sand bed alluvial streams. Therefore, if the model Shields parameter is to be increased or made equal to the prototype, the only parameters that can be varied in the model are ρ_s, R, and i. Adjustment of these three parameters has led to three techniques often used jointly in MBMs as follows.

1. *Lightweight sediment*. Minimum specific gravity of MBM sediment has been about 1.05 but sediment this light has to be carefully handled and model flooding and startup are difficult. Walnut shells having a specific gravity of 1.3 have been used. Coal having a specific gravity of 1.3 is common. A wide range of plastics are available. ASCE (2000) describes some of the various sediment types used in MBM.
2. *Vertical scale distortion*. Vertical scale distortion is the second technique used to achieve correct sediment movement. Vertical scale distortion results in attempting to model a prototype channel with a model that has an aspect ratio (width/depth) that is less than the prototype. Jaeggi (1986) concludes that morphological processes are highly dependent on the aspect ratio and that a distorted model should be avoided. Glazik (1984) stated that distortion should be avoided in movable bed river models but that a value of 1.5 (ratio of model horizontal scale to vertical scale) provided adequate results. Suga (1973) reports that distortions used in his laboratory's MBM studies were 5 or less and concludes that distortion should not be used when scour depth and location are the main subjects. Foster (1975) presented cross section plots of velocity from a model with a distortion of 3 and an undistorted model of the St. Lawrence River. Foster concluded "The velocities in the distorted model shifted several hundred feet (prototype) toward the outside of the bend from those in the undistorted model." Channel width in this reach was 360–460 m (1,200–1,500 ft). Zimmerman and Kennedy (1978) conducted research on curved channels to determine the transverse bed slope in bends and concluded distorted models can be used if distortion is limited to no more than 2 or 3. ASCE (2000) suggests a limit of 6. While these previous studies consider distortion to be a necessary evil and have recommended limitations, application of regime theory to MBM requires distortion.
3. *Increased model slope*. Increased model slope is the third technique used to achieve correct sediment movement. This leads to a Froude number in the model that is greater than that of the prototype, which then raises concerns about the ability of the model to reproduce flow patterns. Einstein and Chien (1955) allow some exaggeration of model Froude number but do not recommend a limit. In an example presented by Gujar (1981), a Froude number exaggeration of $\mathsf{F}_m/\mathsf{F}_p=2.5$ was classified as large whereas 1.67 was classified as acceptable. Latteux (1986) reported that a Froude number exaggeration of 2.5 was unsatisfactory but 2.2 provided acceptable results. Vollmers (1986) used Froude number exaggeration of 1.4 in the MBM of the Elbe estuary, which had a vertical scale distortion of 8. Froude number exaggeration is based on the concept that the Froude number has limited significance for low values typical of alluvial streams. A problem arises when the Froude number is exaggerated to the point where it is no longer insignificant in the model.

Calibration versus Validation and Base Test

The terms calibration and validation must be defined as used herein. Based on ASCE (2000), "Model calibration is the tuning of the model to reproduce a single known event. Tuning the model to reproduce the prototype behavior in this event does not ensure that the model will reproduce different or future events. However, if the model cannot reproduce a known event, little confidence can be maintained that the model will reproduce future events." Vernon-Harcourt [in Freeman (1929)] used the validation concept in which he calibrated his model until it reproduced a known prototype condition. He then tested the model against a different set of prototype boundary conditions (validation) to see if it could reproduce these known changes. If satisfactory in the validation, Vernon-Harcourt then declared the model ready for prediction. The same validation concept is used herein to evaluate predictive/screening capability of the micromodel.

The micromodel uses the concept of a base test in which the calibrated model is run with a hydrograph and the resulting bathymetry and flow patterns are referred to as the base test. All plans/project alternatives are run with the same base test hydrograph and all plan results are compared to the base test results. Changes from base test results to plan results are assumed indicative of what changes will occur in the prototype. The use of a base test may reduce the required accuracy of the model somewhat but there should be some resemblance of model predictions to what occurs in the prototype.

Types of Physical Movable Bed Models

Graf (1971) categorizes MBMs as rational models that are semiquantitative and empirical models that are qualitative. The Graf categories generally correspond to the degree to which the Eq. (1) parameters are equal in model and prototype.

Rational Movable Bed Models

Graf (1971) credits Einstein and Chien (1955) with development of the rational method of MBMs. Yalin (1965) and de Vries and van der Zwaard (1975) also developed methods that fall under Graf's category of a rational MBM. The rational method is simply a more rigorous adherence to the similarity criteria in Eq. (1) and generally requires large models to apply the method. Rational models are characterized by low vertical scale distortion, low Froude number exaggeration, and equality of Shields parameters in model and prototype.

Empirical Movable Bed Models

Graf's second category, empirical MBMs, places less reliance on similarity requirements and allows greater relaxation of the Eq. (1) parameters. Warnock (1949) states, "Instead of arranging the various hydraulic forces involved to meet definite requirements laid down in any law of similitude, the successful prosecution of a movable-bed model study requires that the combined action of the hydraulic forces bring about similitude with respect to the all-important phenomenon of bed movement, which is the essence of this type of model study." Although less rigorous than the rational MBM, most empirical models attempt to limit vertical scale distortion and Froude number exaggeration. Empirical MBMs have a Shields parameter that is generally less than the prototype that is required in order to limit model size, vertical scale distortion, and Froude number exaggeration. Empirical MBMs previously used at the Engineering Research and Development Center (ERDC, formerly Waterways Experiment Station) employed coal as the model bed material and had a model Shields parameter of less than 0.1, whereas the prototypes being studied had Shields parameters in excess of 1. Glazik and Schinke (1986) describe MBM experience using a model Shields parameter significantly less than the prototype. Due to the importance of the equality of the Shields parameter in the model and prototype, empirical models are generally limited to assessing bathymetric response.

Other Movable Bed Models

Some MBMs do not fit into the two categories delineated by Graf (1971). Freeman (1929) discusses early studies by Reynolds and Vernon-Harcourt, which were similar to the empirical model but used Froude scale velocities and simulated water levels in models with large vertical scale distortions. Reynolds conducted a study of the Mersey estuary in England in a model with a vertical distortion of 27.

Pertinent Features of the Micromodel

Micromodel Description and Operation

Gaines and Maynord (2001) provide details of the design and operation of the micromodel and only a brief summary is presented herein. Past micromodel studies have selected horizontal scales so that the modeled reach will fit on a standard 0.9-m-wide by 1.9-m-long flume table that is equipped with a recirculating pump, sump, and regulating valves. Sediment is recirculated in the micromodel. Horizontal scales range up to 1:20,000 and minimum model channel widths of 4 cm are employed in the main channel and lesser model widths in side channels or tributaries. The model banks are cut vertically and the channel is filled with granular plastic that ranges in size from 0.25 to 1.2 mm and has a specific gravity of 1.48. Some recent experiments have explored using lower density model sediment. The downstream end of the channel has a fixed free overfall. Islands are simulated with solid boundaries and vertical banks in the model. After having problems of exaggerated scour with solid river training structures typically found in MBMs, river training structures in the micromodel such as dikes or bendway weirs are represented by pervious steel mesh having 3×3 mm^2 openings. A typical micromodel is shown in Fig. 1.

In the calibration process, the micromodel bed is not premolded to a specific bed condition as done in other types of MBMs. Calibration of the model begins with selection of the high and low flow used to simulate the effects of the variable hydrograph in the prototype. High flow is based on a visual assessment of both the amount of sediment movement and the energy level in the model. Low flow is based on the model producing a slight amount of sediment movement. Model hydrograph cycle times have ranged from 1.8 to 6 min with 3 to 5 min being typical. To assess whether the model is calibrated, the model is run for numerous hydrograph cycles until the bed reaches equilibrium. The model is surveyed using an innovative laser profiler and the model bathymetry is compared to the trends of available prototype surveys. If the trends are replicated in the model, the model is declared calibrated and ready for screening alternatives. If the trends are not replicated in the model, adjustments are made to one or more of the following: (1) flume table slope; (2) amount of sediment in the model; (3) size, shape, and elevation of the fixed free overfall at the downstream end; (4) inflow baffling; (5) discharge hydrograph; and (6) vertical scale and datum. Various vertical scales and vertical datum are used to convert model bathymetry to corresponding prototype numbers throughout the calibration process to achieve the best agreement of model and prototype bathymetry.

Micromodel Contrasted with Previous Movable Bed Models

Of the two Graf (1971) categories, the micromodel is closest to the empirical MBM category. While similarity laws are not fol-

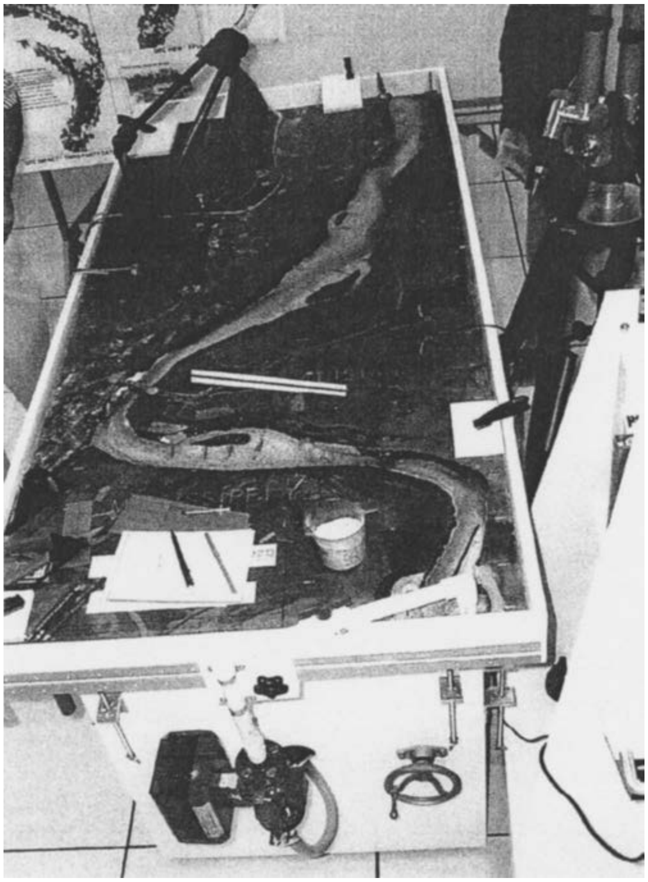

Fig. 1. Micromodel of Vicksburg Front, Mississippi River. Micromodel scale = 1 : 14,400 horizontal, 1:1,200 vertical.

lowed closely in empirical MBMs, there are definite differences between the micromodel and most previous empirical models as follows.

1. Small size. The micromodel is one to two orders of magnitude smaller than most empirical models. Model channel widths are as low as 4 cm. Model channel depths as low as 1 cm are an order of magnitude less than the minimum of 10 cm recommended in Gujar (1981). No requirements for minimum Reynolds number are used in the micromodel. The small model depths result in large distortion of relative roughness.
2. Large vertical scale distortion. With a few exceptions, distortion ratios used in the micromodel are at least twice that in most empirical models. Micromodels commonly use distortions of 8 to 15.
3. No correspondence of stage in micromodel and prototype. Most empirical models relate stage to a corresponding stage in the prototype.
4. Low stages run in micromodel. Typical alluvial streams have dominant or channel forming discharges that are roughly at a bank-full stage. Maximum stages in the micromodel are about 2/3 of bank full.
5. Calibration of micromodel based on equilibrium bed. Previous MBMs conduct calibration by starting with a known bed configuration, running representations of the subsequent stage and discharge hydrographs, and comparing the ending bed topography in model and prototype (Franco 1978). The micromodel starts with an unmolded bed, runs a generic hydrograph for many repetitions until the bed reaches equilibrium, and compares the equilibrium bed to as many prototype hydrographic surveys as possible to see if the correct trends are reproduced.
6. The small size of the micromodel and the relatively heavy (heavy for plastic) bed material (specific gravity 1.48) results in steep slopes in the micromodel. Water-surface slopes of the few micromodels that have been measured are about 1%. Steep slopes result in significant exaggeration of the Froude number. Froude numbers in the two micromodel studies where appropriate measurements were taken, are 2.7 and 3.7 times the prototype Froude number.
7. Model sediment, when scaled to prototype dimensions using a typical vertical scale, is 0.6–1.2 m in diameter.
8. No similarity of friction in the micromodel. Even with the large exaggeration of the relative roughness, the large distortion in the micromodel results in the model being too smooth, which is typical of highly distorted models. This smoothness is possibly the reason the micromodel cannot be used to simulate high stages.
9. Micromodel uses porous dikes to solve the exaggerated scour problems around dikes that occur in distorted models.
10. Due to short duration hydrographs, no bed molding, and automated bathymetry measurement, the micromodel can evaluate an enormous number of conditions in a short period of time.

The most significant differences in the micromodel compared to empirical models are small size, large vertical scale distortion, large Froude number/slope distortion, and no correspondence of stages. These differences place the micromodel in the third category of "other" in addition to rational and empirical models. Rational models are designed and operated with similarity considerations and only small deviations are allowed. Empirical models often do not follow similarity criteria, but the manner in which they are operated results in the existence of significant but limited deviations from similarity criteria. In like manner, the operation of micromodels results in even larger departures from similarity criteria.

Proposed Uses of the Micromodel

The categorization of micromodel and other MBM capabilities can be dealt with in a variety of ways. One option is to categorize based on structure type such as bendway weirs versus traditional dikes. Another option is to categorize based on problem type such as minimization of maintenance dredging in the main navigation channel versus rehabilitation of side channels for environmental enhancement. Ettema (2001) differentiates MBMs based on the degree of freedom of lateral movement, with micromodels of a long constriction having a greater chance of success than those in which lateral movement of the thalweg is relatively unrestricted. The categorization adopted herein is based on the categorization developed in CCS (ASCE 2004) as follows.

1. Demonstration, education, and communication. This includes demonstration of river engineering concepts including the generic effects of structures placed in the river.
2. Screening tool for alternatives to reduce maintenance and dredging of the navigation channel. Failure to perform as predicted would not be damaging to the overall project or endanger human life.
3. Screening tool for alternatives of channel and navigation alignments. This category does not include navigable bridge approaches. Failure to perform as predicted would not be

damaging to the overall project or endanger human life.

4. Screening tool for environmental evaluation of river modifications, side channel modifications, notches in dikes, etc. Failure to perform as predicted would not be damaging to the overall project or endanger human life.
5. Screening tool for major navigation problems, around structures such as lock approaches, bridge approaches, confluences, etc. Failure to perform as predicted could be damaging to the overall project or endanger human life.

For category 1, the micromodel has proven to be useful and beneficial as a demonstration, education, and communication tool, and the developers have presented a valuable tool to the profession. Many of the benefits of the micromodel to the river engineering process have been a result of its value in demonstration, education, and communication. The micromodel has allowed diverse groups to reach a consensus on controversial projects. All parties in this evaluation agreed that the micromodel is effective for demonstration, education, and communication. A demonstration tool shows the generic effects of a river training structure such as traditional contracting dike causing a shoaling area to reduce or a redirection of the currents and no specific dimensions are attached to the dike characteristics or the observations from the micromodel.

Categories 2–5 require greater capability than a demonstration tool. Any conclusions about the screening capabilities of the micromodel should answer the following three questions: (1) What is a screening tool? (2) What does it take to show any model is a screening tool? (3) What facts show the micromodel is a screening tool? A screening tool is able to identify likely or unlikely solutions or rank/compare alternatives. Screening tools are used to discard some alternatives and select others for further study. Some view a screening tool as quantitative relative to model inputs like dike length, elevation, location, orientation, etc. Others view a screening tool as completely qualitative with model inputs such as dike characteristics having little or no quantitative significance. A screening tool does not always predict the correct trends but should be correct some or most of the time. A screening tool is different from a demonstration tool because it crosses the threshold between nonprediction and prediction or, stated otherwise, the threshold between telling the user information he/she might not have known. To show that any model is a screening tool requires a modest record of an approximate prediction of trends that occurred in the prototype.

The CCS concluded that screening in categories 2–4 can be based on analysis of both bathymetry and surface flow patterns but screening for category 5 can only be based on bathymetry because surface flow patterns are not considered adequate for category 5 problems. This CCS criterion is a major limitation for category 5 problems because this writer has not seen a category 5 problem that could be addressed without analysis of surface flow patterns.

Model/Prototype Comparisons

General

The previous discussion shows that the micromodel is operated with large differences from similarity principles. The remaining question is whether these differences are significant. This writer presents model-prototype comparisons to address this question of significance. Although the primary question is whether the micromodel can predict prototype response in a calibrated model, the

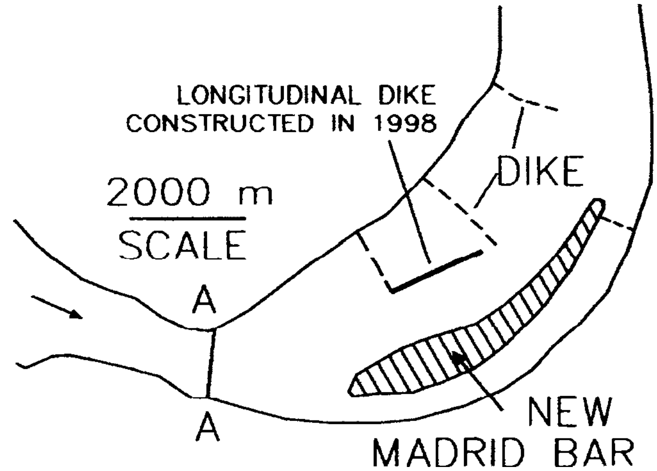

Fig. 2. Schematic of New Madrid, Mississippi River. Micromodel scale=1 : 19,000 horizontal, 1:1,200 vertical.

ability of the micromodel to be adequately calibrated, i.e. replicate existing conditions, is the only information available in many micromodel studies. The reports from previous micromodel studies were evaluated to determine the ability of the micromodel regarding both calibration and prediction but the selected comparisons focus on projects that provide insight into the predictive capabilities of the micromodel. Some of the project comparisons were selected because those projects have been cited as evidence of micromodel success. Other micromodels achieved reasonable calibrations while some did not. These other micromodels are not discussed herein because these models did not provide information on predictive capabilities and because of page limitations in this paper.

New Madrid, Mississippi River

The New Madrid, Mississippi River micromodel study (Davinroy 1996) was conducted to develop a structural solution to repetitive maintenance dredging in the main navigation channel. The calibration has large departures in depth within the problem area compared to the prototype. Fig. 2 shows the channel schematic and the location of cross section AA about one channel width upstream of New Madrid Bar. Section AA is the location of some of the structures used in alternative tests. As shown in Fig. 3, scour reached an elevation of about 21 m below the low water reference plane (LWRP) in the prototype compared to 6 m below

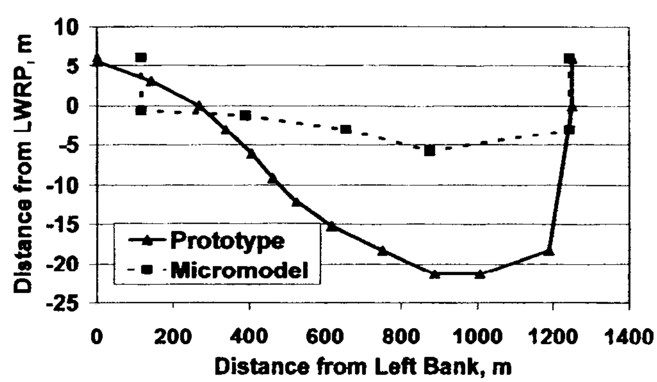

Fig. 3. Prototype and micromodel cross sections at New Madrid

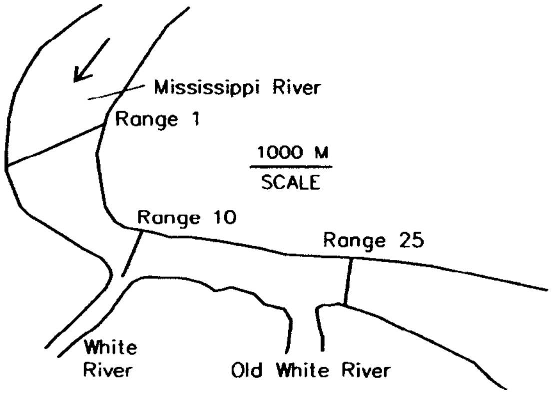

Fig. 4. Schematic of the Mouth of the White River, Mississippi River. Micromodel scale = 1 : 12,000 horizontal, 1:1,200 vertical.

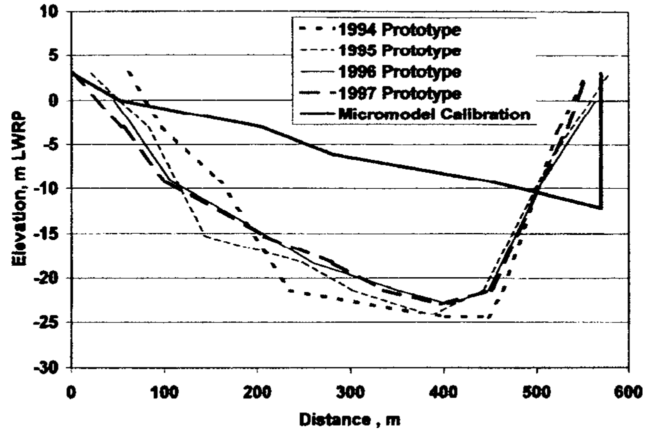

Fig. 6. Cross section at the Mouth of the White River, Range 17

the LWRP in the calibrated model. The LWRP is the stage in the Mississippi River that is exceeded about 97% of the time. The channel cross section area below LWRP = 0.0 is roughly 1/3 of bank-full cross section area. The bank-full stage is about 9–10 m above the LWRP. The New Madrid study also provides information on prediction. The longitudinal dike shown in Fig. 2 was constructed in 1998. The longitudinal dike was studied in the 1996 micromodel study but was not one of the two recommended plans. The 1996 report stated that tests with a longitudinal dike indicated (1) slight channel deepening and (2) the navigation channel narrowed approximately 120 m. Subsequent prototype experience with a similar longitudinal dike in place has shown reduced dredging and an increase in the width of the navigation channel. While the project appears to be successful, the micromodel did not predict the trends of the prototype.

Mouth of the White River

The primary objective of the Mouth of the White River (MOWR) study (Gordon et al. 1998) was to evaluate design alternatives that would provide improved conditions for navigation near the MOWR (Fig. 4). The MOWR study involved navigation conditions at the confluence of two navigable rivers, the Mississippi and White Rivers. The micromodel calibration test comparison with the prototype was satisfactory upstream of the mouth, but at and downstream of the mouth, the model bathymetry differed significantly from the prototype. Fig. 5 shows the hydraulic depth (area/top width) at the LWRP along the reach. Differences in hydraulic depth in the calibration are up to 10 m at Range 19. Fig. 6 shows a cross section plot from the calibration at about Range 17 where the bed of the micromodel is up to 15 m higher than the average of 4 years of relatively consistent prototype survey data. The MOWR study is pertinent to this evaluation because (1) the micromodel procedure allows many attempts at calibration; (2) 4 years of prototype data used for calibration were relatively consistent; and (3) the best calibration was unsatisfactory. In addition to large differences in the calibration, the micromodel plan closest to the plan constructed in the prototype had top elevation of the bendway weirs at elevation −4.6 m LWRP compared to an average elevation of −7.6 m LWRP as surveyed in the prototype. The difference in calibration and in the bendway weir elevations means that the Mouth of the White River provides little information about the predictive capabilities of the micromodel.

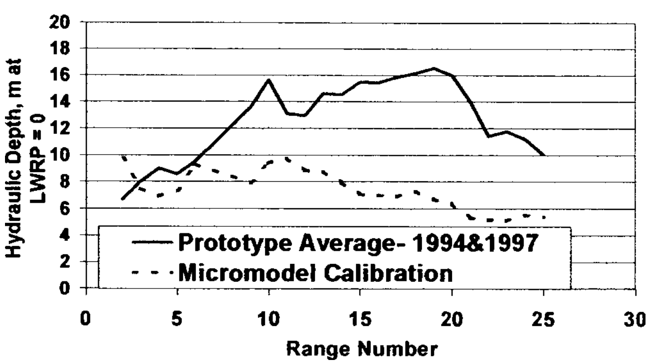

Fig. 5. Hydraulic depth at Mouth of the White River

Vicksburg Front

The Vicksburg Front comparison addresses the validity of bathymetry trends and surface currents in a calibrated micromodel and does not provide any information on prediction/validation. Maynord (2002) presents results of a comparison of surface currents in the Vicksburg Front micromodel and the prototype. Confetti streaks and particle image velocimetry (PIV) were used to determine surface velocities in the Vicksburg Front micromodel. Recording global positioning system (GPS) units used in differential mode were placed on surface floats in the bend of the Mississippi River at Vicksburg, Mississippi. The GPS floats were placed at various locations across the channel upstream of the bend at Vicksburg and retrieved at the lower end of the bend. The average stage in the river during the 4-day measurement period and the stage in the micromodel were almost identical. Fig. 7 shows a schematic of the Vicksburg bend and the location of a cross section at river mile 439.5 where velocities were compared from the GPS prototype and the PIV micromodel. Fig. 8 shows the cross section velocity plot from the micromodel and prototype. Velocities in the micromodel were converted to prototype using the square root of the vertical scale ratio that is the ratio typically applicable to distorted models. The plot shows the exaggeration of velocity that is typical of MBMs. In this case the exaggeration is large, about 3.7 times the Froude scale velocities. The plot also shows velocities in the micromodel are concentrated on the left descending bankline when compared to the prototype data. The concentration of flow on the left bank in the

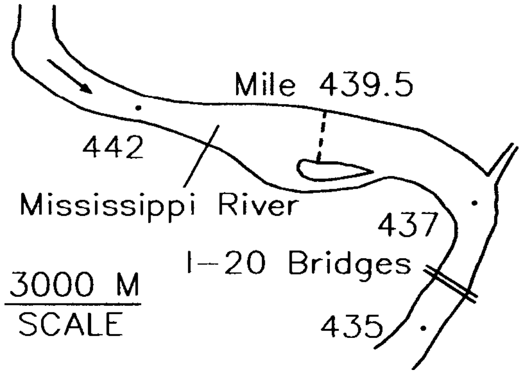

Fig. 7. Schematic of Vicksburg Front, Mississippi River. Micromodel scale = 1 : 14,400 horizontal, 1:1,200 vertical.

micromodel is consistent with the incorrect sediment deposition in the micromodel along the right bank at river mile 437.5 that does not occur in the prototype.

Kate Aubrey

The Kate Aubrey reach of the Mississippi River has experienced shoaling problems that required repeated dredging. Two micromodels of the Kate Aubrey reach were constructed as part of the USACE micromodel evaluation to validate or test predictive capability. The Kate Aubrey models were a major component of the team evaluation. The two micromodels included a traditional size micromodel having a 1:16,000 horizontal scale and 1:900 vertical scale and a larger (2×) micromodel having a 1:8,000 horizontal scale and 1:600 vertical scale. Both micromodels were calibrated to 1975 and 1976 bathymetry. The predicted micromodel bathymetry was compared to the 1998 bathymetry (Fig. 9) and was not similar to the prototype in both the 1:8,000 (Fig. 10) and 1:16,000 (Fig. 11) micromodels. The problem area is centered at about mile 791–792. Extensive dredging was conducted in this reach in 1988 and may have contributed to some of the differences between model and prototype. However, the high flows during the mid-1990s would likely minimize the effects of dredging ten years earlier in 1988 and the dredging impacts would not show up in the 1998 bathymetry. The Kate Aubrey comparisons leads to the conclusion that a micromodel can be calibrated yet not be validated and thus, cannot be used for prediction of alternative effects.

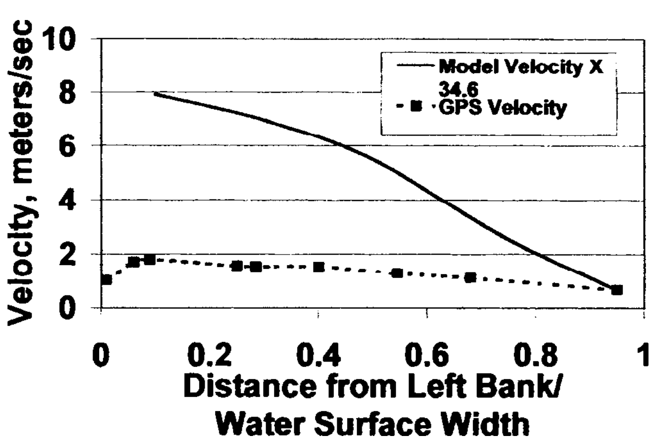

Fig. 8. Prototype GPS and micromodel velocities at Vicksburg Front

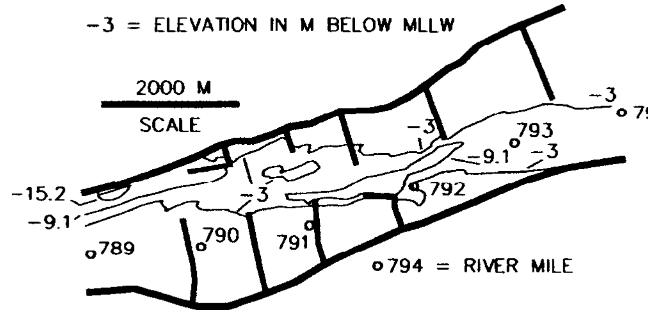

Fig. 9. Kate Aubrey, Mississippi River, 1998 prototype bathymetry. Flow from right to left.

Bolter's Bar

The Bolter's Bar micromodel study was conducted to evaluate alternatives to alleviate dredging in the main channel without adversely affecting side channels. A schematic of the reach with the dikes that were present in 1997–1998 is shown in Fig. 12. The dredging problem was primarily between river miles 225 and 226. Fig. 13 shows the plan constructed in the prototype in 2002 that includes four chevron dikes on the right side of the navigation channel between river miles 225 and 226, a longitudinal dike on the right bank at river mile 226, and raising and notching the existing closure dike. The four left bank dikes between river miles 226 and 225.4 were removed from the micromodel but remain in the prototype. Little is known about the characteristics of the left bank dikes. The micromodelers have stated they believe the left bank dikes have little impact on the bathymetry. Since the 2002 construction of the improvement plan, dredging has been reduced in the reach and survey data show an improved navigation channel through the problem dredging reach. However, the difference in model and prototype because of the left bank dikes and the limited time since construction make it difficult to evaluate this validation/prediction.

Lock and Dam 24

The Lock and Dam 24 micromodel was conducted to evaluate means of reducing outdraft. Outdraft results from the cross currents in the upstream lock approach that cause a tow to move toward the dam rather than into the lock (Fig. 14). Outdraft is a dangerous condition at many locks and dams and has resulted in numerous accidents. The guardwall in the Lock and Dam 24 micromodel was solid but the guardwall in the prototype was ported which means that it has openings at the bottom to pass flow out of

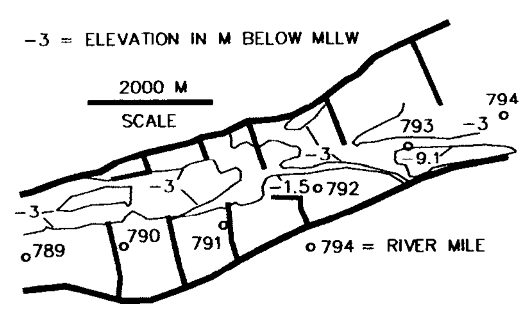

Fig. 10. Kate Aubrey, Mississippi River, 1:8,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

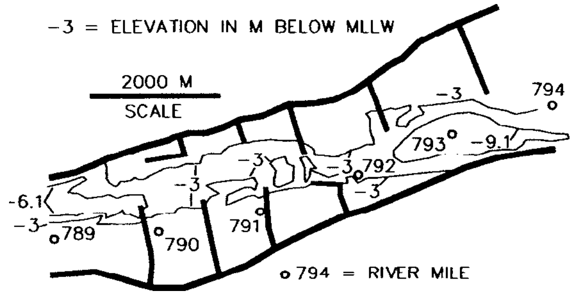

Fig. 11. Kate Aubrey, Mississippi River, 1:16,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

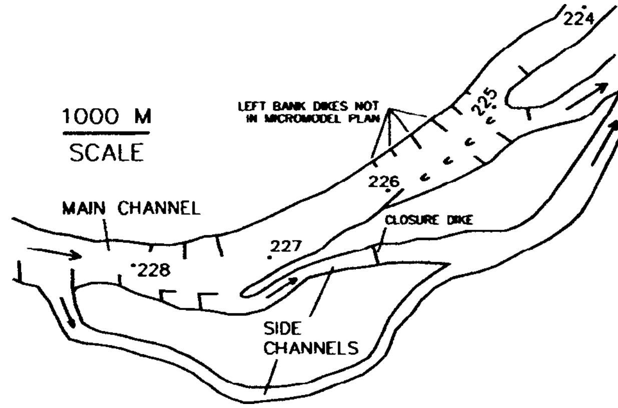

Fig. 13. Schematic of Bolter's Bar, Mississippi River, with project. Micromodel scale = 1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

the lock approach. A solid guardwall was used in the micromodel to represent a worst case and because the guardwall ports often clog with debris. The currents behind the guardwall in the prediction of the micromodel did not agree with the currents measured in the prototype. The micromodel showed slackwater just upstream of the area between the upper end of the guardwall and the bank. The prototype showed significant currents in this area. This raises two possibilities. If the ports were clogged at the time of prototype measurement, the model predicted incorrect currents. If the ports were open during prototype measurement, the difference in guardwall configuration could explain all or part of the difference in flow patterns and the Lock and Dam 24 comparison provides no information about the predictive capabilities of the micromodel.

Comparison of Micromodel and ERDC Coal Bed Models

In addition to the Kate Aubrey micromodels built and studied by the evaluation team, another major portion was an evaluation of micromodels relative to coal bed models previously used at ERDC. This component of the evaluation began with the objective of using comparison of model and prototype cross section areas, channel widths, and other bathymetric parameters to determine if a MBM was calibrated rather than using the subjective/ visual comparisons that have been used traditionally. Several modelers were skeptical about quantifying whether a model was calibrated.

The techniques developed for determining calibration were also used to compare the coal-bed model and the micromodel. For example, the ratio of difference in model and prototype cross section area to cross section area in the prototype was determined for each cross section. A mean squared error (MSE) measure of dispersion of the data was defined as the square of this ratio for each cross section that was averaged over the length of the model (except for entrance and exit reaches). For cross sectional area, the MSE for 16 coal bed models ranged from 0.014 to 0.33 with an overall average MSE for all models of 0.12. The MSE for area in 14 micromodels ranged from 0.024 to 0.456 with an overall average MSE for all models of 0.16. The MSE for area in the MOWR micromodel discussed previously was 0.16. An MSE of 0.16 for area means that prototype and model area differed by an average of 40% of the prototype area over the length of the model. Other bathymetric parameters used in the comparison were (1) thalweg location had overall MSE = 0.11 in the coal bed and 0.05 in the micromodel; (2) width had the same overall MSE = 0.06; and (3) hydraulic depth had overall MSE = 0.09 in the coal bed and 0.14 in the micromodel. Because of limited prototype data, the bathymetry parameters were evaluated at an elevation of 0.0 LWRP that is a low stage. Consequently, these error measures are somewhat larger than would be the case had data been available at higher stages. An LWRP of 0.0 is significant for navigation purposes because it roughly corresponds to the width

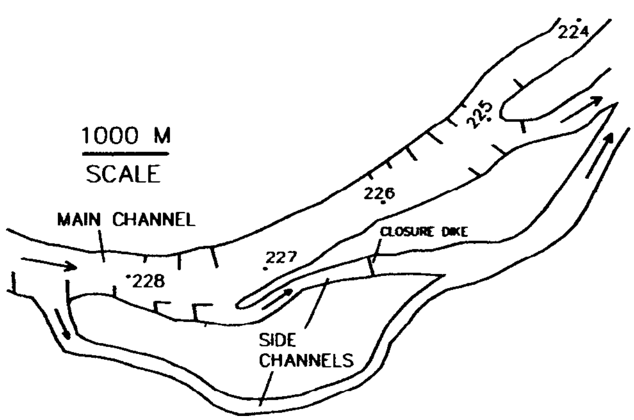

Fig. 12. Schematic of Bolter's Bar, Mississippi River, without project. Micromodel scale = 1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

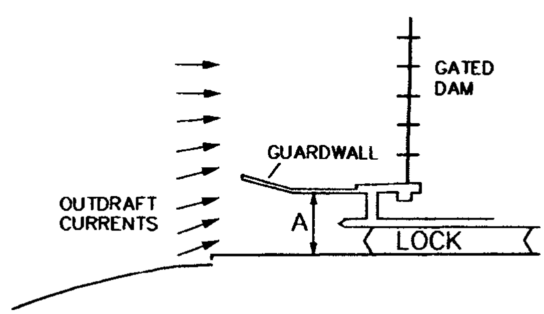

Fig. 14. Schematic of Lock 24 outdraft at upstream lock approach on Mississippi River. Micromodel scale = 1 : 9,600 horizontal, 1:600 vertical. Dimension "A" in micromodel is about 0.8 cm versus a prototype distance of about 80 m.

of the navigable portion of the channel. With the exception of one model (Kate Aubrey), the comparison micromodels were all different projects than the comparison coal-bed models. Gaines (2002) used similar geometric techniques with only the Kate Aubrey coal-bed and micromodels and concluded that "Therefore, there is no advantage in using the larger scale models (coal-bed models) to evaluate river training structures over the small-scale models (micromodels)." This writer does not place significant weight on the comparison of coal-bed models and micromodels because of the following.

1. The comparison was based on calibration only. As stated in ASCE (2000), calibration does not ensure the model will predict. As stated previously, the micromodel is significantly different from previous empirical models like the ERDC coal-bed models and equivalency based only on calibration is not valid.
2. The adjustment of vertical scale and vertical datum in the calibration process should insure that reach averaged values will be close in micromodel and prototype. To a lesser extent, this same factor is true in the coal bed model because of other adjustments.

Basis of Unsatisfactory Calibration and Validation

Why are the previous calibrations and validations (predictions) of micromodels unsatisfactory? Some of the differences can be attributed to variability and uncertainty in the prototype bathymetry data. The large relaxations in similarity criteria must also be a primary factor. Ettema and Muste (2004) conducted scale effect fixed-bed flume experiments and found that thalweg alignment and extent of separation around spur dikes do not scale with model length scale for a range of small models. Ettema and Maynord (2002) note that in hydraulic models, the usual causes of scale effects are (1) large length scales; (2) distortion of vertical scale relative to horizontal scale; (3) inflation of bed sediment size; and (4) amplification of channel slope. All of these scale effect causes are present in the micromodel as discussed previously. In addition to these four causes, the micromodel does not have correspondence of stage in model and prototype. Since all four causes plus the stage issue are present in the micromodel and there are unknown interactions, it is not possible to state which specific causes are responsible for the differences in model and prototype shown previously. At the small dimensions of flow in the micromodel, Reynolds and Weber numbers are sufficiently different than at full scale as to influence flow behavior and distribution (Ettema 2001). Froude number exaggerations up to 3.7 and vertical scale distortion up to 20 are likely causes of poor agreement of lateral velocity distribution and thus bathymetry in the model. Struiksma and Klaasen (1987) report scale effect problems resulting from exaggerations in Froude number and from bed roughness not being reproduced. Ettema (2001) and Ettema and Muste (2002) conclude that micromodels can be useful in situations where the thalweg is constrained to only vertical movement such as in a long constriction. In cases where the thalweg can move laterally, model utility diminishes quickly.

Is the Micromodel Capable of Quantitative Inputs?

Quantitative inputs describe dikes or other river engineering structures by their length, elevation, location, etc. River engineering often uses contraction of the channel to achieve a desired navigation channel. The amount of contraction of a proposed plan and thus dike characteristics cannot be specified when the water levels and thus the channel area are not modeled. The effectiveness of a dike cannot be assumed equal in model and prototype when the model velocities are roughly 2.7 to 3.7 times higher than scaling by Froude criteria. While the porous dikes used in the micromodel have some significant advantages, they have not been shown to address the problems of incorrect water level and high velocities regarding quantitative inputs.

Conclusions and Recommended Capabilities and Limitations

The micromodel, because of its small size and large deviations from similarity considerations, is different from previous MBMs and does not fit into either of Graf's categories of empirical or rational models. In addition to its size being as small as 4 cm channel width, large vertical scale distortion, large Froude number exaggeration, and no correspondence of stage in model and prototype, place the micromodel in a category by itself.

The micromodel is effective for demonstration, education, and communication and the developers have provided a valuable tool to the profession.

The disagreement over the micromodel concerns screening capability and can best be resolved by answering the following three questions: (1) What is a screening tool? (2) What does it take to show any model is a screening tool? (3) What facts show the micromodel is a screening tool? A screening tool is able to identify likely or unlikely solutions or rank/compare alternatives. A screening tool is used for prediction in order to eliminate some alternatives and keep others for further study. To show that any model is a screening tool requires a modest record of prediction of the approximate trends that occurred in the prototype. The pertinent facts regarding screening capability in the micromodel are as follows.

1. The two Kate Aubrey models provided unsatisfactory predictions of bathymetry.
2. The New Madrid micromodel predicted narrowing of navigation channel but widening occurred in the prototype. New Madrid is one of the examples of a successful project not being a successful model-prototype comparison.
3. Bolter's Bar appears to come closest to a successful prediction but the comparison has uncertainty because the left bank dikes are present in the prototype and not present in the micromodel prediction.
4. The calibrated Vicksburg Front model had velocity and sedimentation trends that did not agree with the prototype.
5. No prediction evidence is provided by the Mouth of the White River micromodel because the calibration differs greatly from the prototype and the bendway weirs have a different elevation in model and prototype.
6. Predicted model velocities did not agree with the prototype at Lock and Dam 24. Depending on whether the guardwall ports were clogged during the time of prototype measurement, the micromodel predictions were either incorrect or can be explained by the difference in micromodel and prototype ports.
7. The micromodel achieves calibration similar to coal-bed models used at ERDC based on bathymetric parameters averaged over most of the length of the model. Data were not available to evaluate prediction using these same parameters.
8. The large departures from similarity principles in the micro-

model and no correspondence of water level in the micromodel and prototype are of concern.

This writer found successful projects that had been micromodeled but looked for micromodel-prototype comparisons that had (1) a reasonable calibration; (2) about the same river engineering structures constructed in the prototype that were tested in the model; and (3) a prediction of the correct trends in the prototype. The evidence is not overwhelming (because there are relatively few studies providing information on prediction) but shows a lack of predictive capability. Based on the lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication for which it is effective and useful. This conclusion differs from the CCS (ASCE 2004) report that concluded screening capability for all but category 5 problems.

Quantitative inputs have little significance in the micromodel because the water level is not correct and the velocities are 2.7 to 3.7 times greater than given by Froude scaling.

Screening for category 5 studies that are complex and where human life or the overall project are at risk such as navigation near structures, bridge approaches, and confluences is of particular importance to this evaluator. In this writer's opinion, the micromodel should not be used for category 5 problems. This conclusion is consistent with the recommendations of the CCS (ASCE 2004) for category 5 problems.

Acknowledgments

The study described herein was funded by the USACE. The views expressed herein are the writer's. Diverse views of micromodel capability exist within the USACE.

Notation

The following symbols are used in this paper:

- B = channel width;
- D = particle size;
- F_m = Froude number in model;
- F_p = Froude number in prototype;
- g = gravitational acceleration;
- i = slope;
- R = hydraulic radius;
- ν = kinematic viscosity;
- ρ = water density;
- ρ_s = particle density; and
- σ = surface tension.

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Attachment B

to the

Comments of the Conservation Organizations on the Grand Tower EA

Attachment B

Studies Linking the Construction of Instream Structures to Increases in Flood Levels

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Attachment B

to the

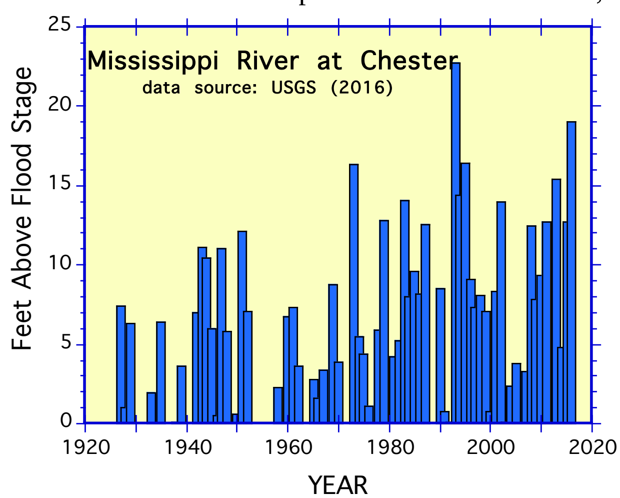
Comments of the Conservation Organizations on the Grand Tower EA

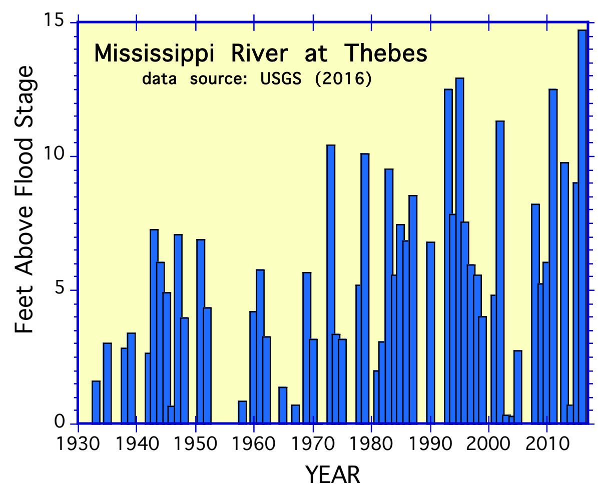
Comment by on Draft Environmental Assessment: March 3, 2016
Public Notice P-2856 (2013-742)

Robert E. Criss, Washington University

Once again, the USACE concludes in draft P-2856 that its river management policies and associated structures have no adverse effect on floodwater levels. Once again USACE provides more modeling and results of contested experimental methodologies to justify their plans for additional in-channel structures. Draft P-2856 fails to mention a corpus of contrary studies and evidence that clearly show that these claims are baseless. Concerns over the planned course of river management were advanced by Charles Ellet as early as 1852, and the deleterious consequences were clearly manifest a century later (Belt, 1975).

The consequences of current management strategy on floodwater levels are clearly shown by data from multiple gauging stations on the Middle Mississippi River (Figures). The Chester and Thebes stations were selected as they are the closest stations to the project area that have long, readily available historical records (USGS, 2016). These figures conclusively document that floodwater levels have been greatly magnified along the Middle Mississippi River, in the timeframe when most of the in-channel navigational structures were constructed. If these structures are not the cause, then we are left with no explanation for this profound, predictable effect. That USACE proposes more in-channel construction activities only two months after another "200-year" flood (as defined by USACE, 2004, 2016) occurred in this area proves that their structures and opinions are not beneficial, but harmful.





Figures: Progressive increase in peak annual flood water levels at the long-term gauging stations at Chester and Thebes on the Middle Mississippi River. Analogous figures for the Mississippi River at St. Louis and the Missouri River at Herman (e.g., Criss, 2001) document similar damaging and incontestable trends for other river reaches managed in the same manner.

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Attachment C

to the

Comments of the Conservation Organizations on the Grand Tower EA

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River Management and Flooding: The Lesson of December 2015–January 2016, Central USA

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ABSTRACT: The huge winter storm of December 23–29, 2015 delivered heavy rainfall in a broad swath across the USA, deluging East-Central Missouri. Record high river levels were set at many sites, but damages were most pronounced in developed floodplain areas, particularly where high levees were built or river channels greatly narrowed. An average of 20 cm of rain that mostly fell in three days impacted the entire 10 300 km^2 Meramec Basin. Compared to the prior record flood of 1982, the highest relative stage (+1.3 m) on Meramec River occurred at Valley Park proximal to (1) a new levee, (2) a landfill in the floodway, (3) large floodplain construction fills, and (4) tributary creek basins impacted by suburban sprawl. Even though only a small fraction of the 1.8 million km^2 Mississippi River watershed above St. Louis received extraordinary rainfall during this event, the huge channelized river near and below St. Louis rapidly rose to set the 3rd-highest to the highest stages ever, exhibiting the flashy response typical of a much smaller river.
KEY WORDS: floods, Mississippi River, levees, floodplain development.

0 INTRODUCTION

Human modification of landscapes and climate are profoundly impacting rivers and streams. Urbanization with its attendant impervious surfaces and storm drains is known to accelerate the delivery of water to small streams, causing flash flooding, channel incision and widening, and loss of perennial flow. The landscapes of large river basins in the central USA have been profoundly modified by agricultural activities and development. Meanwhile, large river channels have been isolated from their floodplains by progressively higher levees, and dramatically narrowed by wing dikes and other navigational structures (e.g., Pinter et al., 2008; Funk and Robinson, 1974). Direct consequences are higher, more frequent floods and underestimated flood risk (Criss, 2016; Belt, 1975). In many areas rainfall is becoming heavier, exacerbating flood risk (e.g., Pan et al., 2016), while new floodplain developments greatly magnify flood damages (Pinter, 2005).

The extraordinary winter storm of December 23–29, 2015 provides additional evidence for progressive climate change, while delivering more tragic examples of record flood levels and underestimated flood risk. What is perhaps most remarkable is that the flood on the middle Mississippi River had a much shorter duration than its prior major floods, and closely resembled the flashy response of a small river. This paper discusses how the Meramec River and the middle Mississippi River responded to this massive storm, and examines how their recent response differed from prior events.

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1 STORM SYNOPSIS

Very strong El Nino conditions developed during fall 2015, bringing some welcome relief to the California drought as well as anomalously warm temperatures to much of the USA. An extraordinary winter storm, appropriately named "Goliath", delivered heavy rainfall in a broad belt across the central USA, as a long cold front developed parallel to, and south of, a southwest to northeast-trending part of the jet stream. Rain delivery was greatest in the central USA, particularly southwest of St. Louis, Missouri (Fig. 1). The three-day rainfall delivered by Goliath is considered to be a "25-year" to "100-year" event at most meteorological stations in this region (NOAA, 2013). With this huge addition of late December precipitation, the record-high annual rainfall total (155.5 cm) was recorded at St. Louis in its official record initiated in 1871 (NWS, 2016a), although less reliable records suggest that annual rainfall was greater in 1848, 1858 and 1859. Flooding associated with Goliath resulted in great property damage and caused at least 12 fatalities in Missouri, 7 in Illinois, 2 in Oklahoma and 1 in Arkansas.

The extraordinary rainfall that fell at St. Louis on Dec. 26–28 closely followed significant rainfall on Dec. 21–23. The earlier storm saturated the ground, so runoff from the second pulse was greatly amplified.

2 MERAMEC RIVER FLOOD

Meramec River drains a 10 300 km^2 watershed in East-Central Missouri, and enters the Mississippi River 30 km south of St. Louis (Fig. 2). This river has very high wildlife diversity

Criss, R. E., Luo, M. M., 2016. River Management and Flooding: The Lesson of December 2015–January 2016, Central USA. *Journal of Earth Science*, 27(1): 117–122. doi:10.1007/s12583-016-0639-y. http://en.earth-science.net

and is one of the very few un-impounded rivers in the USA (Criss and Wilson, 2003; Frederickson and Criss, 1999; Jackson, 1984). Population density is low, except for the lower basin near St. Louis. Intense rainfall events cause flash flooding of the basin, as recorded by numerous long-term gauging stations (Fig. 2). Winston and Criss (2002) described one such flash flood, and the references cited in the aforementioned publications provided abundant information on the basin.

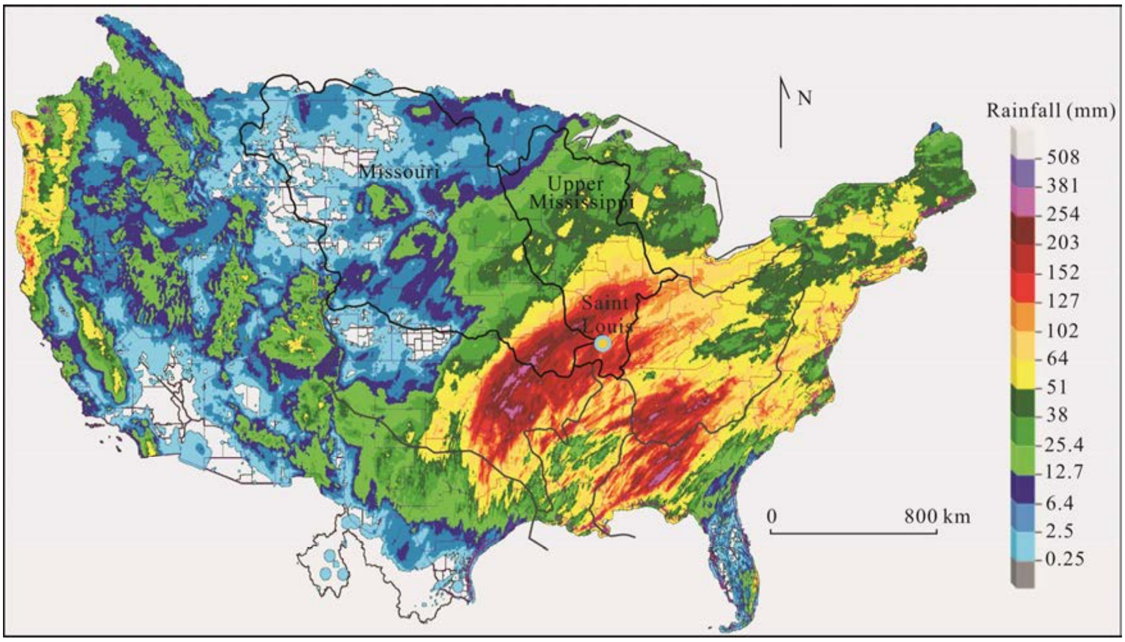

Figure 1. Map showing the observed, 7-day precipitation for December 22–29, 2015, according to NWS (2016a). Superimposed on this map are the boundaries of the upper Mississippi and Missouri watersheds (labeled) and other major river basins. Goliath delivered an average of 20 cm of rain to the entire Meramec River Basin (Fig. 2), but extraordinary rainfall exceeding 10 cm (orange, red and purple shading) impacted only a small fraction of the huge Mississippi-Missouri watershed upstream of St. Louis (blue dot near center).

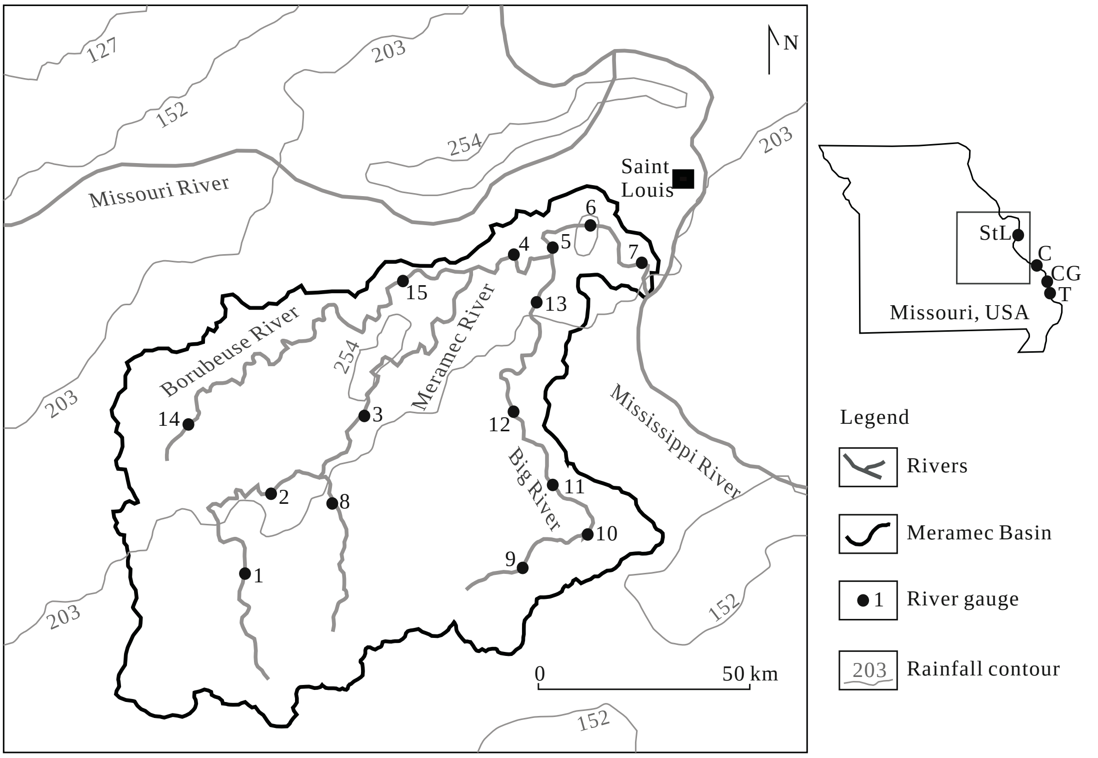

Figure 2. Map of East-Central Missouri showing the 10 300 km^2 Meramec River Basin (dark outline) and contours for precipitation delivered from December 22–29, 2015 according to NWS (2016a). Labeled dots are river gauging stations; stage hydrographs for the stations along the main stem of Meramec River (#1 to #7) are shown in Fig. 3. Water levels at Union (#15), Eureka (#5), Valley Park (#6) and Arnold (#7) set new records, while that at Pacific (#4) came close. The index map of Missouri shows the area of detail, and the location of river gauges at St. Louis (StL), Chester (C), Cape Girardeau (CG) and Thebes (T) along the middle Mississippi River (cf. Fig. 6).

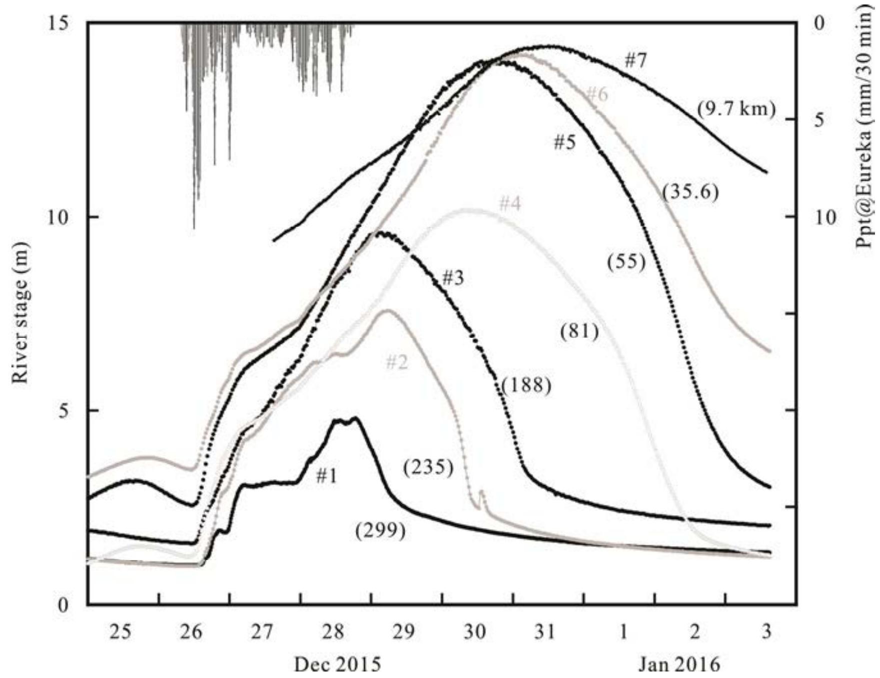

Figure 3. Stage hydrographs showing the propagation of the 2015 flood wave down the main stem of Meramec River, for sites #1 to #7 on Fig. 2. Numbers in parenthesis are the distance in km above the confluence with the Mississippi River to the south of St. Louis. Hydrographs for each site are plotted relative to its local datum, except that 0.75 m was added to the Valley Park hydrograph (#6) for clarity. Thin bars at upper left represent 30 minute precipitation (right scale). Data from USGS (2016) and NWS (2016b).

Goliath delivered an average of 20 cm of rain, mostly in 3 days, to the Meramec River Basin (Fig. 2). The resultant flood wave rapidly grew as it propagated downstream (cf. Yang et al., 2016), moving at a rate of about 3 km/h in the lower basin, where it set all-time record high stages (Fig. 3).

Runoff after storm Goliath was extraordinary, with flows attaining a value approaching 4 500 m^3/s, as documented by direct field measurements at the Eureka gauging station on December 30 (USGS, 2016). Of the precipitation delivered above Eureka by Goliath, 85% returned as runoff at Eureka in only 14.3 days. For comparison, the average, long-term annual flow at Eureka is only 92 m^3/s for a basin that receives an average of about 109 cm of precipitation per year, indicating an average runoff fraction of only 27% that is similar to the ~30% average for the USA.

3 COMPARISON TO 1982

The prior flood of record in most of the lower Meramec Basin occurred on December 6, 1982, during another very strong El Nino condition, although at some basin sites the flood of August 1915 was more extreme. Given the strong similarities in time-of-year, ENSO condition and basin response, it is very useful to compare the peak water levels of 1982 to those of 2015 (Fig. 4). The river stage at Pacific was slightly lower in 2015 than in 1982; this site is not rated for discharge, but the observed stage is consistent with the recent combined peak flows upstream at Sullivan and Union also being slightly lower in 2015. Big River enters the main stem of Meramec River about 4.8 km above the Eureka gauging station, and the peak flow at the lowermost station along it (#13 on Fig. 2) was about 150 m^3/s greater in 2015 than in 1982. Given these small differences, one might expect that the 2015 peak flow at Eureka would closely match that of 1982, but direct field measurements at Eureka on Dec. 30, 2015 suggest that the peak flow was 4 500 m^3/s (USGS, 2016), when it was only 4 100 m^3/s in 1982 (USGS, 1983). Taking this 400 m^3/s difference at face value, and using the rating curves (USGS, 2016, 1983), the associated river stage at Eureka should have been only about 0.5 to 0.6 m higher at Eureka in 2015 than in 1982, when the observed difference was 0.97 m.

Alternatively, the estimated difference between the 2015 and 1982 stages at Eureka would be only about 0.25 m if it is assumed that the flow at Pacific was identical in the two years, and the ~150 m^3/s difference for the flows on the lower Big River is accounted for. That the observed 2015 stage at Eureka was much higher than suggested by these two estimates (crosses, Fig. 4) demands explanation.

An even greater difference between the 2015 and 1982 river levels occurred at Valley Park (Fig. 4). This area has changed in the following way between these floods: (1) the size and height of a landfill at Peerless Park (cover photo) was greatly increased, significantly restricting the effective width of the Meramec River floodway mapped by FEMA (1995); (2) the 5.1 km-long Valley Park levee (Fig. 5) was constructed in 2005, restricting the width of the inundation area of the regulatory "100-year flood" (see FEMA, 1995) by as much as 70%, while reducing floodwater storage capacity; (3) the adjacent basins of three small tributaries, Williams, Fishpot and Grand Glaize Creeks, experienced rapid suburban development, destroying the riparian border, increasing the impervious surface, and making flash floods frequent (Hasenmueller and Criss, 2013); and (4) the floodplain area experienced continued commercial development on construction fill, impeding overbank flow while amplifying flood damages. It would appear that these changes added at least 1.0 m to the 2015 water levels at Valley Park, and at least 0.4 m upstream at Eureka, compared to what levels would have been in the 1982 landscape condition. Water levels may also have increased at Arnold due to such changes, but this is not clear, because the Mississippi River level was nearly 2 m higher in 2015 than in 1982 at the mouth of Meramec River during its flooding. This higher level at the confluence would impede the flow of the lowermost Meramec River, and flatten and elevate its water surface.

One final difference is that water temperatures measured by USGS (2016) were higher in 1982 (~13 °C) than in 2015 (~6 °C) near the times of peak flooding, so both the density and viscosity of water were higher in 2015. The associated effects on river levels are complex and not easy to determine. Nevertheless, if the 2015 peak stage and flow at Pacific were both similar to those in 1982, as is seemingly demanded by available data, temperature effects at Eureka are probably small.

Eight great floods (site stage >11 m) occurred at Eureka since 1915. For the six that occurred prior to 1995, the local stage at Valley Park was 0.96 to 1.40 m lower (avg. 1.20 m) than the local stage at Eureka. Only two >11 m floods occurred at Eureka since, in 2008 and 2015, and for those the local stage at Valley Park was only 0.68 and 0.59 m lower than that at Eureka. These relative differences clearly indicate that the stages of large floods at Valley Park have recently increased, relative to stages at Eureka, by about 0.8±0.5 m. New developments such as the 2005 Valley Park levee are the probable cause for this large difference.

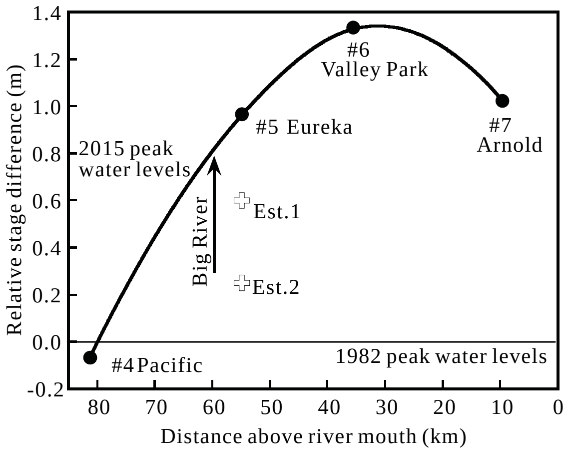

Figure 4. Relative difference between the peak water levels of December 30–31, 2015 and those of December 6, 1982 at different sites in the lower Meramec Basin (cf. Fig. 2). This difference was greatest close to Valley Park, where a large levee was built in 2005; this and other changes appear to have increased stages at Valley Park as well as upstream and downstream. Two estimates (crosses) suggest what the stage difference between these floods should have been at Eureka, had the 2015 flood occurred under the 1982 landscape condition (see text). Big River (arrow) enters the Meramec River from the south, 4.8 km upstream of Eureka.

Figure 5. The Valley Park levee looking south, only 1 hour after the flood gates were reopened on January 2, 2016. The floodwater level (dark) almost breached the levee and exceeded the estimated level for a "100-year flood" (FEMA, 1995) by nearly 2 m, forcing evacuation of the protected area to the left. Bicyclist (circled) on levee top shows scale. Photo by Robert E. Criss.

4 THE JANUARY 2016 FLOOD ON THE MIDDLE MISSISSIPPI RIVER

Only a day after the peak flooding on the lower Meramec River, water levels on the Mississippi River at St. Louis were the 3rd highest ever recorded, and only a few days later, record stages were set downstream at Cape Girardeau and Thebes (Fig. 6). This flood is truly remarkable in several respects.

First, the Mississippi River at St. Louis was above flood stage for only 11 days during this recent flood, compared to 104 successive days in 1993 and 77 days in 1973, the only years with higher floods at St. Louis. We have found a good trend between peak stage and flood duration, with the greatest anomaly being this recent flood, and the next greatest being the brief 2013 flood which ranks 7th. Clearly, during January 2016 the middle Mississippi River experienced what might be considered a flash flood, as it exhibited a response similar to rivers whose basins are a hundred times smaller.

Second, the January 2016 flood occurred at the wrong time of year. Great floods on large midwestern rivers have historically occurred during spring, when heavy precipitation is

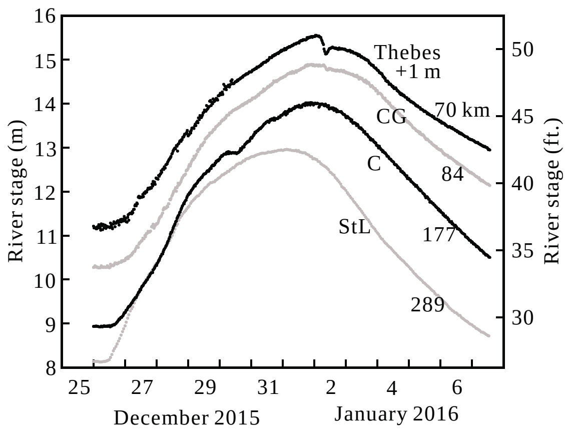

Figure 6. Stage hydrographs at St. Louis (StL), Chester (C), Cape Girardeau (CG) and Thebes, showing propagation of the 2015–2016 flood wave down the middle Mississippi River (cf. Fig. 2). The official stages depicted for each station are relative to its local datum, except that 1 m was added to the data at Thebes (top curve) for clarity. Numbers on curves are distance in kilometers above the Ohio River. The effect of a downstream levee being overtopped is evident near the flood crest at Thebes. This flood is remarkable for its short duration, time of year, and for the new record levels set at Cape Girardeau and Thebes. Data from USGS (2016).

added to rivers swollen with snowmelt. A partial exception was the August 1 peak of the great 1993 flood, but the protracted period of flooding was initiated during late spring. The other significant exception was the 10th highest flood at St. Louis, which occurred on December 7, 1982. Just like the current event, the 1982 flood peak on the Mississippi at St. Louis occurred only one day after the lower Meramec flood peak of December 6, 1982, discussed above. Ehlmann and Criss (2006) proved that the lower Missouri and middle Mississippi Rivers are becoming more chaotic and unpredictable in their time of flooding, height of flooding, and magnitude of their daily changes in stage. This chaotic behavior is primarily the result of extreme channelization of the river, and its isolation from its floodplain by levees (e.g., Criss and Shock, 2001; GAO, 1995; Belt, 1975). The channels of the lower Missouri and middle Mississippi Rivers are only half as wide as they were historically, along a combined reach exceeding 1 500 km, as clearly shown by comparison of modern and historical maps (e.g., Funk and Robinson, 1974).

Third, while the area of extreme precipitation during December 26–28, 2015 spanned the entire Meramec Basin, only 5% of the gigantic watershed of the Mississippi River above St. Louis experienced 7-day rainfall greater than 10 cm (Fig. 1). Nevertheless, because the Mississippi and Missouri rivers are so channelized and leveed proximal to St. Louis, the rainfall that was rapidly delivered to the nearby part of the watershed had nowhere to go, so river levels surged. Downstream, river stages were even higher because of the addition of floodwaters from Meramec River, affecting Chester, and then from the addition of Kaskaskia River, affecting the narrow Mississippi at Cape Girardeau and Thebes. For these sites, the fraction of their upstream watersheds affected by great December precipitation was only slightly larger than for St. Louis.

Finally, the record high water levels just set at Cape Girardeau and Thebes would have been even higher, but for the damaging surge of overbank floodwater that followed the overtopping of the Len Small Levee north of Cairo. The stage hydrograph for Thebes clearly shows that a sharp, 0.5 m reduction occurred when the water was still rising (Fig. 6), so the stage recorded just prior to that drop underestimates what the peak level would have been. A smaller but similar effect occurred slightly later at Cape Girardeau.

5 DISCUSSION

The aftermath of storm Goliath provides another example in an accelerating succession of record floods, whose tragic effects have been greatly magnified by man. The heavy rainfall was probably related to El Nino, and possibly intensified by global warming. Heavy rainfall impacted the entire Meramec basin, which accordingly flooded. But new record stages were set only in areas that have undergone intense development, which is known to magnify floods and shorten their timescales.

The Mississippi River flood at St. Louis was the third highest ever, yet it occurred at the wrong time of year, and its brief, 11-day duration was truly anomalous. Basically, this great but highly channelized and leveed river exhibited the flashy response of a small river, and indeed resembled the response of Meramec River, whose watershed is smaller by 160×. Yet, only a few percent of the watershed above St. Louis received truly heavy rainfall during this event; the river rose sharply because the water simply had nowhere else to go.

Further downstream, new record stages on the middle Mississippi River were set. Those record stages would have been even higher, probably by as much as 0.25 m, had levees not failed and been overtopped. The sudden drop of the water level near the flood crest at Thebes clearly demonstrates how levees magnify floodwater levels. In this vein, it is very significant that the water levels on the lower Meramec River were highest, relative to prior floods, proximal to a new levee and other recent developments. Forthcoming calls for more river management, including higher levees and other structures, must be rejected. Additional “remediations” to this overbuilt system will only aggravate flooding in the middle Mississippi Valley (see Walker, 2016).

Finally, this event provides abundant new examples of greatly underestimated flood risk. During this event, water levels on the lower Meramec River were 1 to 2 m above the official “100-year” flood levels (e.g., FEMA, 1995), while those that at Cape Girardeau and Thebes were 0.5 and 0.7 m higher, respectively. New commercial and residential developments in floodplains are foolhardy.

6 CONCLUSIONS

The huge winter storm of Dec. 23–29, 2015 delivered heavy rainfall in a broad swath across the USA, with as much as 25 cm of rain falling on East-Central Missouri in three days. The entire 10 300 km^2 Meramec Basin received an average of ~20 cm of rain during this event, and the river responded with a dramatic pulse that grew as it propagated downstream at ~3 km/h. Record high water levels were set at several sites, all in areas where the floodplain was developed, runoff was accelerated, high levees were built, or the floodway was restricted. In particular, compared to the prior record flood of 1982 on the Meramec River, the highest relative stage (+1.3 m) was seen proximal to a landfill in the floodway and to a new levee and that restricted the effective width of the “100-year” water surface by as much as 65%.

In contrast, Goliath’s extraordinary rainfall impacted only a tiny fraction of the huge, 1.8 million km^2 Mississippi River Basin above St. Louis, yet flooding occurred which was truly remarkable for the high water level, time of year, and brief duration. This continental-scale river exhibited the flashy response typical of a much smaller river such as the Meramec. This unnatural response is clearly consistent with the dramatic channelization of the middle Mississippi River and its isolation from its floodplain by levees, as clearly pointed out by Charles Belt more than 40 years ago. It is time for this effect to be accepted and for flood risk and river management to be reassessed.

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Attachment D

to the

Comments of the Conservation Organizations on the Grand Tower EA

Discussion of "Analysis of the Impacts of Dikes on Flood Stages in the Middle Mississippi River" by Chester C. Watson, David S. Biedenharn, and Colin R. Thorne

DOI: 10.1061/(ASCE)HY.1943-7900.0000786

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Thanks to Watson and colleagues (original paper) for bringing further attention to the issue of flood magnification on portions of the Mississippi and other navigable rivers. Unfortunately their article does more to cloud this issue than clarify it. The original paper claims to present an "objective review" (p. 1072, 1077) of the specific gauge technique and the hydraulic impacts of navigational dikes. It should be understood that this article is functionally identical to Watson and Biedenharn (2009), a consulting report commissioned by the St. Louis District of the U.S. Army Corps of Engineers for the purpose of refuting previous studies showing rising flood levels linked to ongoing dike construction on the Middle Mississippi River (MMR).

Watson et al.'s review of the broader issues here—empirical increases in flood levels and frequencies on the Mississippi River system, and the causal mechanisms thereof—is a highly incomplete analysis. It ignores the large breadth of methodologies, study rivers, locations, and years of record in previous studies. Instead, Watson et al. limit their analyses to a single station (St. Louis, MO) on a single river, using a truncated data record (Pinter 2010, 2015), and their criticisms target a single methodology (specific gauge analysis) largely in a single 12-year-old paper (Pinter et al. 2001). In actuality, numerous scientific studies and Corps of Engineers reports, dating back to the 19th century, have noted large increases in flood levels in association with wing-dike construction. For example, Hathaway (unpublished data, 1933) concluded "[i]t would appear that the bankful [sic] carrying capacity of the Missouri River would be permanently reduced by existing works, such as dikes and revetments used in shaping and controlling the stream for modern barge transportation." Recent studies have utilized hydrologic analyses; rigorous statistics; geospatial analyses; and one-dimensional, two-dimensional, and three-dimensional (1D, 2D, and 3D) hydraulic modeling to confirm, both empirically and theoretically, the potential for significant increases in flood levels in response to the dense emplacement of wing-dike structures, such as employed on the MMR. For example, Pinter et al. (2008, 2010) reported results from a 4-year NSF-funded initiative to assemble more than 8 million hydrologic data for the Mississippi-Missouri system, using Corps structure-history databases, and digitizing and rectifying river maps and surveys dating back to the mid-1800s. A large multivariate statistical model showed that many river engineering toolkits showed no association with increased flooding (e.g., much of the Lower Mississippi), but large empirical increases occurred when and where many wing-dikes were built in proximity to long-term measurement stations.

In place of reviewing this broad body of research, Watson et al. instead simply make a dogmatic assertion that "dikes are designed to have strong impacts at low flows that diminish as discharge increases and disappear at flows above bankfull," paraphrasing statements from St. Louis District staff that submerged wing dikes become "invisible to the river's flow." A recent U.S. Government Accountability Office (GAO) study noted the discrepancy between assertions of "hydraulic invisibility" and empirical evidence to the contrary, concluding that "despite the Corps' efforts, professional disagreement remains over the cumulative impact of river training structures during periods of high flow," disagreement that should be resolved through additional "physical and numerical modeling" (GAO 2011). In fact, recent modeling studies demonstrate the significant effects of flow turbulence and large-scale vertical and horizontal eddy circulation (Huthoff et al. 2013a, b), flow dynamics that are undeniably clear by observation of these structures during flood events. The Dutch government just completed a €45 million program to lower 450 wing dikes (groynes) on the Rhine system as part of its "Room for the River" strategy to reduce flood levels.

The Watson et al. manuscript attempts to refute the suggestion that wing dikes may increase flood levels, but the actual work here is limited to specific gauge analysis. The paper presents itself as the final word on the specific gauge technique, but Watson et al. make broad and surprising statistical errors. To begin with, they calculate p values to test null hypotheses of no trend over time in specific stages (stages for fixed discharge values), asserting, "For p-values greater than 0.1, the null hypothesis is accepted." In fact, failure to meet such a confidence threshold (typically 95% or 99%) means that the null hypothesis cannot be rejected with that level of confidence. Freshman textbooks teach students to avoid this error: "Null hypotheses are never accepted. We either reject them or fail to reject them . . . failing to reject H_0 does not mean that we have shown that there is no difference" (Dallal 2001). Nonetheless, Watson et al. repeatedly assert that their statistics prove that MMR specific stages are invariant over time. Furthermore, between rejecting H_0 for p values <0.01 and (erroneously) accepting H_0 for $p > 0.1$, the authors create a new statistical outcome of "inconclusive." Where Watson et al.'s own analyses show significant increases in flood stages (above the 99% confidence level), the authors use "visual inspection of the data" to infer secondary mechanisms and use *post facto* subdivisions of their time series in order to mask the statistical trend. In fact, our research group long ago reviewed such secondary factors, including the effects of sediment concentrations and water temperature on stages, and quantified these effects on MMR stages (e.g., Pinter et al. 2000; Remo and Pinter 2007). Statistical trends, when significant, represent long-term driving forces, such as wing-dike impacts, rising up from the many known sources of short-term variability.

It is hard to deny that some process is driving flood levels higher on rivers such as the MMR and Lower Missouri River. Historical time series of stage data, which are unequivocally homogenous over time (e.g., Criss and Winston 2008), show strong and statistically significant increases, and these increases exceed by ~10× the maximum credible increases in climate-driven and land-cover-driven flows (e.g., Pinter et al. 2008). Watson et al. obliquely acknowledge the upward trend in flood magnitudes and frequencies, but conjecture that levee construction is the cause. In reaching this conclusion, Watson et al. present no evidence, but instead speculate about enhanced momentum losses due to channel-overbank flow shear and about voluminous "sediment accumulation ... between the channel and the levee"; speculative processes that are contradicted by real-world measurements (e.g., Bhowmik and Demissie 1982; Heine and Pinter 2012). In fact, the large multivariate study by Pinter et al. (2010) identified the age, location, and extent of every large levee system added to the Mississippi–Lower Missouri system during the past 100+ years, documenting that levees do contribute some but not all of the observed flood-level increases on the MMR and elsewhere (confirming modeling by Remo et al. 2009). These issues are too important to be addressed by unsupported speculation, especially when voluminous data exist to rigorously test these hypotheses.

Despite protestations to the contrary, the Watson et al. paper reveals broad areas of agreement with earlier studies on wing-dike impacts. They acknowledge that the "USACE has constructed numerous river engineering structures in and along the MMR." In fact, Watson et al. significantly underestimate the number of such structures by starting their count around 1930. Most dike construction on the Mississippi River near St. Louis was early, with 26,500 linear meters of dikes built prior to 1930 in the 10 river miles (16.5 km) centered on St. Louis. Wing dikes and similar training structures have been, and continue to be, the dominant tool for navigation engineering on the MMR, with a total of 1,200 linear meters of dikes per 1.0 km of channel. Watson et al. state that stages for the lowest, in-channel flows trend downward over time after wing-dike construction, which has been noted at St. Louis and other gauging stations by all previous studies. Dike-induced flow acceleration in the navigation channel stimulates bed scour, which lowers the water-surface elevation for low flows. Watson et al. also note that stage trends for larger in-channel flows go flat (become statistically "inconclusive"), as flow retardation by dikes balances the increased depths. And for flood flows, they acknowledge a statistically significant upward trend overall. In fact, measured flood stages at St. Louis in 1993 were ∼1.2 m higher than for equal flows in the 1940s, even though most dike construction was earlier. Where we differ is that Watson et al. ignore the very large range of other research quantitatively showing how much of this increase, and similar and larger increases at numerous other stations, is linked to levee construction and how much is attributable to wing-dike construction.

There are legitimate discussions that researchers could have, for example the advantages of different approaches to specific gauge analysis (e.g., Watson's "rating curve" and "direct step" approaches), but instead Watson et al. limit themselves to reviewing a single technique on a single river at a single station using a truncated period of record (Pinter 2010, 2015). There is clear empirical evidence of statistically significant increases in flood magnitudes and frequencies on the Mississippi and other rivers, and extensive research and broad-based evidence that river-training structures have contributed to these increases. Current dike construction projects on the Mississippi River rely on the Watson et al. paper and the corresponding consulting report (Watson and Beidenharn 2009) as the central demonstration that large-scale new dike fields will not impact flood levels. Sound engineering design, environmental assessment, and flood-risk management should be based on vigorous science rather than advocacy and misdirection.

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Discussion of "Mississippi River Streamflow Measurement Techniques at St. Louis, Missouri" by Chester C. Watson, Robert R. Holmes Jr., and David S. Biedenharn

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Thanks to the authors of the original paper for another manuscript addressing pressing issues of hydrology and flooding on the Middle Mississippi River (MMR). Like another paper (Watson et al. 2013) and discussion (Pinter 2014), the authors of the original paper present findings from studies funded by the St. Louis District of the U.S. Army Corps of Engineers (USACE), in this case presenting elements of the Watson and Biedenharn (2009) and Huizinga (2009) reports. The original paper reviews historical discharge measurements and measurement techniques on the MMR, and in particular, discharges measured by the USACE prior to circa 1940. Unfortunately, the authors of the original paper present this review without necessary background and literature review, for example with no mention of Pinter (2010), a statistical study that tested the same issues. Outside readers will not understand the context or the purpose of the Watson et al. (2013) paper without additional background.

The seemingly arcane question of historical discharge measurements has been the focus of extensive discussion on the MMR. These discussions began with studies identifying rising trends in flood magnitudes and frequencies on the MMR and selected other river reaches. The long-term hydrologic effects of climate change, land use, and upstream dam storage on MMR flooding have also been documented and quantified (e.g., Pinter et al. 2002, 2008, 2010), but multiple studies have identified in-channel navigational construction (a variety of dikes and dike-like structures; see review in Pinter et al. 2010; Pinter 2014) as the largest influence on MMR flood trends over time. Put simply, this is the source of contention driving USACE investment in this issue and driving ongoing work on both sides.

After record flooding in 1973, Belt (1975) and Stevens et al. (1975) published studies linking flood-level increases over time with ongoing construction of navigational channel works. The MMR appears to be the most densely diked river reach in the United States, and perhaps of any river worldwide, with an average of about 1,370 m (linear) of dikes and weirs constructed per kilometer of MMR channel. The Belt (1975) and Stevens et al. (1975) papers stimulated vigorous discussion, in particular four letters responding to te Stevens et al. (1975), as follows: (1) Dyhouse (1976), (2) Stevens (1976), (3) Strauser and Long (1976), and (4) Westphal and Munger (1976), and various opinion articles disseminated by the St. Louis District of the USACE (e.g., P. R. Munger, et al., Contract DACW-43=75-C-0105, presented at U.S. Army Corps of Engineers, St. Louis, Missouri, 1976; Dyhouse 1985, 1995). Critiques included the argument that early discharge data on the Mississippi River cannot be compared with recent data because early discharge measurements (<1933 at St. Louis) used floats to measure flow velocity rather than Price current meters. In order to test this assertion, "[t]he Corps commissioned the University of Missouri Rolla to evaluate historical methods of discharge measurement, investigating the accuracy of the techniques and the need for any adjustments to historical discharge data" (Dyhouse 1985). Stevens (1979) completed same-day measurements of velocity and discharge near Chester, Illinois, using Price current meters and several varieties of floats.

Watson et al. repeat a now familiar assertion that Stevens (1979) identified systematic and significant differences between float-based and meter-based measurements. That is not the case. Stevens (1979) concluded that "an experienced person, using accepted techniques, can obtain excellent discharge determinations using any of the velocity measuring vehicles." Watson et al. points to differences between float-based and meter-based measurements, but the only broad differences in the Stevens (1979) results involved surface floats (as opposed to other varieties of floats), a technique used for only 10 of the thousands of early MMR discharge measurements. All 10 surface-float measurements were made in 1881 during very low flows at St. Louis (no surface-float measurements at the other gaging stations; i.e., Chester or Thebes). Furthermore, Stevens (1979) explicitly conclude that their results "do not substantiate correction of all recorded past discharges that have been determined using floats." And yet exactly such data modifications have been made, justified by citing Stevens (1979).

The Upper Mississippi River System Flow Frequency Study (UMRSFFS) was initiated in 1997 to update flow frequencies previously quantified in 1975 along the Upper Mississippi, Missouri, and Illinois River systems. When the UMRSFFS was released in 2004, areas of increased flood frequencies were identified in other USACE districts, but the new flood profiles were broadly lower through the St. Louis District, including drops of up to 52 cm (1.7 ft) for the 100-year flood. These decreases were puzzling given the empirical hydrologic trends, and remained enigmatic despite detailed review of the UMRSFFS methodology and results. A Freedom of Information Act request for additional UMRSFFS documentation (Missouri Coalition for the Environment v. U.S. Army Corps of Engineers, 07–2218) was refused by the USACE on the basis of "deliberative process privilege," a ruling subsequently upheld by a U.S. District Court. The St. Louis District results became clear only with the discovery of Dieckmann and Dyhouse (1998), a presentation made at a United States interagency meeting. Dieckmann and Dyhouse (1998) reported that "flood peak discharges at St. Louis prior to 1931 [and at the Chester and Thebes gages prior to c. 1940] were adjusted downward to reflect over-estimates made throughout the period when floats were primarily used for velocity measurements," citing Stevens (1979). These post facto data changes are nowhere presented in the public UMRSFFS methodology. More recent hydrologic measurements also were altered (Pinter 2010). Together these modified input data were used to calculate UMRSFFS flow frequencies and are now the basis for flood profiles and new flood-hazard maps throughout the St. Louis District. Similarly, the USGS Missouri Water Science Center has now altered its flood peak dataset, reducing the 1844 flood flow at St. Louis from 38,200 to 28,300 m^3/s (1.35 million to 1 million ft^3/s), based on Dyhouse (1995) and Dieckmann and Dyhouse (1998), and despite detailed analysis of 1844 measurements by Stevens (1979) suggesting a flow of 38,500 m^3/s (1.36 million ft^3/s) at St. Louis. Most scientists would argue for much greater caution before altering original data.

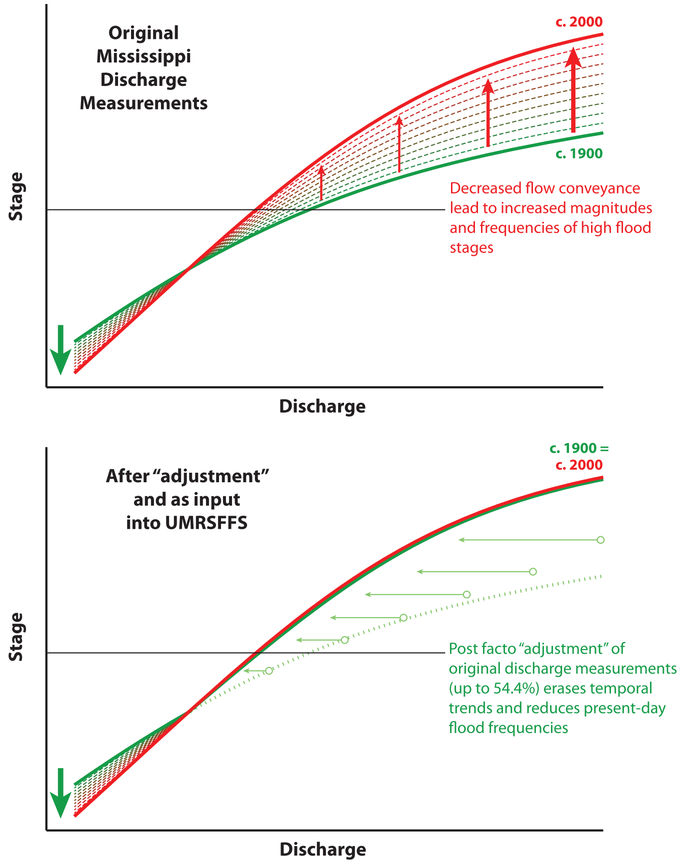

Fig. 1. (Color) Conceptual illustration showing how modification of historical discharge measurements (Dieckmann and Dyhouse 1998) erases temporal trends in MMR rating curves documented by previous researchers, including increases in flood stages for fixed discharges (red arrows); these modifications also reduce calculated flood frequencies

The effect of modifying early discharge measurements, as suggested by Dieckmann and Dyhouse (1998) and Watson et al., is to erase temporal trends in MMR rating curves (including rising flood stages) that previous researchers had ascribed primarily to construction of navigational structures in and along the MMR channel (Fig. 1). In the process, flood frequencies and magnitudes calculated using these input discharges are significantly reduced. The Dieckmann and Dyhouse (1998) data modifications reduced the UMRSFFS output flood magnitudes by up to 10% and more, for example a reduction of $> 3{,}100\ m^3/s$ ($> 110{,}000\ ft^3/s$) for the 100-year flood at St. Louis (Pinter 2010). Pinter et al. (2012) completed flood-loss modeling on the MMR, quantifying losses with and without the data adjustment mentioned previously; flood damages modeled based on the adjusted input discharges were up to 79% less than calculated using the original and unaltered annual flow maxima.

Pinter (2010) presented the issue of data adjustment in the UMRSFFS and set out to test the hypothesis that older discharge measurements were systematically overestimated relative to later USGS measurements. The study tested this hypothesis using 2,150 historical discharge measurements digitized from the three principal stations [(1) St. Louis, (2) Chester, and (3) Thebes] on the Middle Mississippi River, including 626 float-based discharges and 1,516 meter-based discharges, and including 122 paired measurements (pairs of meter-based and float-based measurements taken at the same locations on the same days). In all statistical tests, the hypothesis that early discharges were overestimated was rejected; on the contrary, in the cases where differences between early and later discharges were significant, the pre-USGS discharge measurements averaged slightly less (not more) than the later measurements. These statistical tests included separate analyses of the paired values and of all floats versus all meters, and separate tests at all three gaging stations.

The authors of the original paper provide no new data, and their one new analysis is a statistical comparison in one paragraph spanning pp. 1067–1068. The rest of their review discusses sources of variability in streamflows (e.g., temperature-based and bed-related hysteresis), largely duplicating Watson et al. (2013); see reply in Pinter (2014). That statistical comparison evaluates discharge values from Stevens (1979) and Ressegieu (Memo to division engineer, presented at Upper Mississippi Valley Division, U.S. Army Corps of Engineers, St. Louis, Missouri, 1952). Assessment of this comparison is impossible, because the authors of the original paper provide neither these data nor any indication of which data they looked at. One concern is that the authors of the original paper utilize the very small number of measurements in Stevens (1979) and Ressegieu (Memo to division engineer, presented at Upper Mississippi Valley Division, U.S. Army Corps of Engineers, St. Louis, Missouri, 1952), eschewing the several thousand meter-based and float-based discharges, including numerous paired measurements, assembled in Corps (1935). A copy of Ressegieu (Memo to division engineer, presented at Upper Mississippi Valley Division, U.S. Army Corps of Engineers, St. Louis, Missouri, 1952), which is a memo and internal assessment by the St. Louis District dated May 27, 1952, was recently obtained from the St. Louis District. Ressegieu (Memo to division engineer, presented at Upper Mississippi Valley Division, U.S. Army Corps of Engineers, St. Louis, Missouri, 1952) followed Congressional hearings in which "A House committee Thursday blasted the army engineers for their navigation work on the lower Missouri River, asserting that a 250-million dollar program appears actually to have increased flooding" (Sioux City Journal 1952), just as Stevens (1979) was initiated by the St. Louis District just after publication of Belt (1975). Ressegieu (Memo to division engineer, presented at Upper Mississippi Valley Division, U.S. Army Corps of Engineers, St. Louis, Missouri, 1952) looked at Mississippi discharge measurements and reached the same conclusion as Stevens (1979), that USACE "'rod float' measurements … for all practicable purposes may be considered equal" to USGS metered discharges," exactly contrary to the Dieckmann and Dyhouse (1998) rationale for altering pre-USGS discharge measurements.

Until now, most USACE workers and consultants have ascribed the source of purported heterogeneity in historic discharge data to the use of floats for velocity measurements (Dyhouse 1976, 1985, 1995; Stevens 1976; Strauser and Long 1976; Westphal and Munger 1976; Dieckmann and Dyhouse 1998; P. R. Munger, et al., Contract DACW-43=75-C-0105, presented at U.S. Army Corps of Engineers, St. Louis, Missouri, 1976). Pinter (2010) showed that the large majority of early discharges were based on Price current meters, and that float-based charges are not systematically higher (if anything lower) than meter-based measurements. Watson et al. now shift stance and assert that historical discharge bias results from changes in Price current meter design and measurements made from boats versus bridges. The finding of the authors of the original paper, that "pre-1930s discrete streamflow measurement data are not of sufficient accuracy to be compared with modern streamflow values" seems to be a conclusion in search of supporting evidence. Even Ressegieu (Memo to division engineer, presented at Upper Mississippi Valley Division,

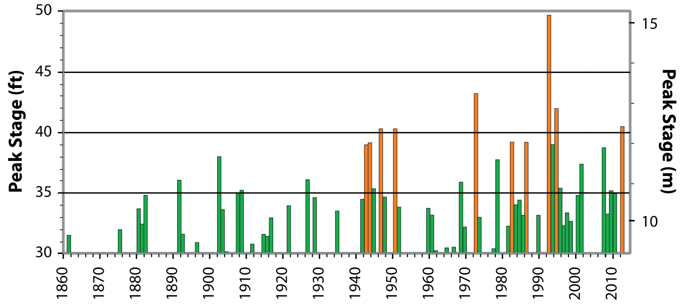

Fig. 2. (Color) Peak stages above flood level (30 ft above datum) for the Mississippi River at St. Louis; homogenous daily stages date back to 1861, and the 10 highest flood peaks (in orange) all occur in the latter half of the record; probability that this represents the random distribution of a stationary time-series is on the order of 0.00098

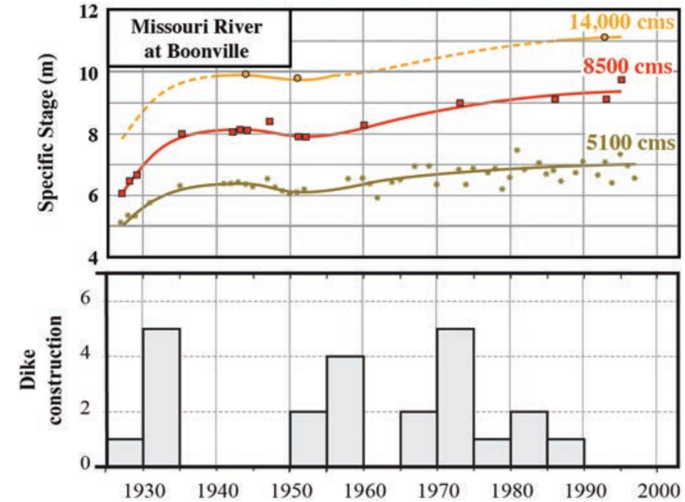

Fig. 3. (Color) Like most stations analyzed by Pinter et al. (2008, 2010), and others, discharges on the Missouri River at Boonville were developed exclusively by the USGS; flood stages increased when and where new navigational dikes were constructed (number of dike segments built within the 3.2 km of channel centered on the gage; data from Pinter and Heine 2005)

U.S. Army Corps of Engineers, St. Louis, Missouri, 1952) concluded that "it is not recommended that the C. of E. measured discharges be revised." At a minimum, the narrow analysis in the original paper does not justify redacting or altering thousands of discharge measurements, which represent key evidence of the hydrologic, hydraulic, and geomorphic response of the Mississippi River to its early engineering history.

Watson et al. concludes that "previous attempts ... to assign a positive trend in stage ... for a particular streamflow across the 1933 date boundary are incomplete without accounting for the pre-1933 measurement bias." Again, this is a familiar assertion, and several previous publications (Criss and Winston 2008; Criss 2009; Pinter et al. 2001, 2002, 2008) have shown that stage data alone provide a useful so-called empirical reality check that is independent of any question of discharge data homogeneity (Fig. 2). Stage data are dense, precise, and unequivocally homogenous (once any datum shifts have been noted). Criss and Winston (2008) examined the long and homogenous stage record for the Mississippi River at Hannibal, Missouri, with the period 1973–2013 experiencing 14 floods at or above the predicted 10-year level in the past 40 years, seven above the 25-year level, four at the ≥50-year level, and two at the ≥200-year level [Criss and Winston (2008), data updated through 2013]. Criss (2009) tested records of peak stages at stations on the Mississippi, Missouri, and other rivers, and found that observed flood stages pervasively exceeded UMRSFFS predictions, with significance levels ranging from 90–99.9%. Stage time series are sufficiently long, dense, and precise that rising trends clearly exceed the quantified effects of climate change and levee construction alone. Watson et al. focuses solely on pre-USGS versus post-USGS discharges (pre-1933 and post-1933 at St. Louis, 1942 at Chester, and 1941 at Thebes), but the large majority of the 67 stations analyzed in Pinter et al. (2008, 2010) utilized only USGS discharge values. All of those results showed rising stage trends in heavily diked river reaches (e.g., Fig. 3). Watson et al. carefully limit their discussion to the St. Louis location alone, when their conclusion that rising stage trends are "simply the result of mixing two discrete observation data sets" is negated, by definition, at locations where all discharges are from the USGS; in fact, the majority of all sites studied.

Pinter (2010) was a technical analysis, but the paper and subsequent discussions (e.g., Wald 2010) raised troubling questions. The UMRSFFS report and its appendices exceed several thousand pages but included no explanation of the large-scale adjustment of input data in the St. Louis District's portion of the study. These adjustments remained unknown until the discovery of the Dieckmann and Dyhouse (1998) report, although the data modifications affected resulting flood frequencies more than any other study assumption (e.g., choice of statistical distribution, or skew values), which are outlined in the UMRSFFS in great detail. No quantitative analysis was done to justify this data manipulation, which instead apparently was based on Stevens (1979) and on flume experiments; "adjustments in the data made by the corps were correct [because f]low tests using scale models determined that actual water flows in floods occurring in 1844 and 1903 could not possibly have been as high as were estimated using instruments of the time" [G. Dyhouse, quoted in Wald (2010)]. The Watson et al. paper serves to provide post facto justification for altering historical input data in the UMRSFFS and other applications. Even putting aside the specific technical question of historical data homogeneity, scientists and engineers should agree that the highest possible thresholds for (1) rigorous analysis, (2) transparency, and (3) burden of proof should apply before original measurement data are manually altered. Those thresholds should be highest of all for hydrologic data and flood-frequency analyses, which directly impact floodplain and river management projects, policies, and public safety.

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Closure to "Analysis of the Impacts of Dikes on Flood Stages in the Middle Mississippi River" by Chester C. Watson, David S. Biedenharn, and Colin R. Thorne

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We welcome discussion of our paper and appreciate Dr. Pinter's interest in it. In this closure, we seek to reduce the "cloudiness" that reading our paper has apparently introduced to the discusser's understanding of the impact of dikes on flood stages by reiterating the paper's purpose and findings and by clarifying the procedural steps within it. However, before doing so, we must correct the discusser's understanding that the published paper is "*functionally identical*" to Watson and Biedenharn (2009). This is false. It is true that similarities exist between these documents in that both apply specific gauge techniques, but the same can be said of multiple publications by the authors, none of which are "*functionally identical*." The unique feature of the published paper is that it sets out, clearly and for the first time, a general methodology for specific gauge analysis, with the intent of reducing confusion concerning how this technique should be performed and what can and cannot be concluded from its outcomes.

The discusser criticizes our use of data from a single hydrometric station (St. Louis) and we agree that it would have been preferable to illustrate weaknesses of the rating curve method and advantages of the direct step method using multiple stations. Indeed, the original manuscript included further examples, for the gauges at Chester and Thebes; however, the published paper was condensed according to the *Journal of Hydraulic Engineering* guidelines. Notwithstanding this, and although data for Chester and Thebes would have reinforced the points made in our paper, we believe that, even using a single example, the published paper provides reliable guidance for standardizing specific gauge analyses to improve their objectivity and reliability. This is significant because it pertains to the misinterpretation that underlies much of the discusser's critique. Dr. Pinter suggests that, "The Watson et al. manuscript attempts to refute the suggestion that wing dikes may increase flood levels, but the actual work here is limited to specific gauge analysis." In responding, it may be helpful to reiterate the aim of the published paper, as stated in the Abstract, which is to provide

"an objective review of the specific gauge analysis technique that explains how the method should be performed and the results interpreted; identifies strengths and limitations; examines the uncertainties associated with application to the Middle Mississippi River given the available data; and reassesses the conclusions that can and cannot reasonably be drawn regarding the impacts of dikes and levees on flood stages, based on specific gauge analysis of the Middle Mississippi River."

It follows that in limiting our discourse to consideration of evidence acquired using specific gauge analysis, we were not choosing to "ignore the very large range of other research" but focusing on material relevant to achieving the aim of our paper, the purpose of which is restated above. In fact, we agree wholeheartedly with Dr. Pinter that multiple sources of evidence can and should be accessed when investigating the hydrologic, hydraulic, and morphological impacts of engineered structures (including wing dikes) on fluvial systems, but doing so was beyond the scope of our paper.

Building on his misconception that the purpose of our paper was to "refute the suggestion that wing dikes may increase flood levels," Dr. Pinter describes our statement that, "dikes are designed to have strong impacts at low flows that diminish as discharge increases and disappear at flows above bankfull," as a "dogmatic assertion." This is wrong; it is actually a statement of fact. Dikes are designed to have diminishing effect with increasing stage and to have no effect at bankfull flow. Whether particular dike fields perform in accordance with that design intention is a different matter and one for which conflicting evidence exists. In this context, we strongly agree with Dr. Pinter that the performance of dikes in low flow merits and requires further investigation, and recommend that this is given high priority.

The discusser writes that our purpose in visually inspecting and subdividing the time series of stages recorded at St. Louis was to "*mask the statistical trend*." It was not. Inspection of the data should be the first step in any statistical treatment and our purpose was to identify any breaks in the trends and subdivide the time series accordingly, in order to recognize and account for the effects of extreme floods that are known to cause abrupt changes to channel morphology and conveyance capacity in large alluvial rivers for a variety of reasons.

Our use of statistics is also criticized, and this deserves a considered response. In setting the level of significance for a statistical test, the key is to guard against making either a type I or type II error. A type I error is made through incorrect rejection of a true null hypothesis. That is, a type I error would be made if we were to incorrectly reject the null hypothesis and conclude that there likely is a trend in the stages for a given discharge, when actually there is not. A type II error is failure to reject a false null hypothesis. That is, we don't reject the null hypothesis and conclude that there likely is no trend in water stages when actually there is a trend. The probability (p-value) should be selected to make it difficult to make whichever type of error is the least preferable. Using a very low p-value guards against a type I error. Using a high p-value guards against making a type II error. But in our study, neither type of error is better or worse than the other. Hence, we sought to guard against *both* type I and type II errors, while also recognizing the high level of uncertainty in the data. Our way of achieving this was to use not one, but two p-values, creating a statistical outcome of "inconclusive" for probabilities falling between them. This reflects the fact that for the purposes of the analysis performed to detect trends in stages for specific discharges, there is no safe side onto which to put the risk of making either a type I or type II error. The result is that, in deciding whether or not to reject the null or alternative hypotheses, we sought a clear indication from the statistics; and where we didn't find a clear indication, we logically deemed the test to have been *inconclusive*. That seemed, and still seems, sensible to us.

The authors note that, notwithstanding his criticisms of our paper, Dr. Pinter (Pinter et al. 2010) agrees that levee construction *has* raised flood elevations in the Middle Mississippi River, and we recommend that interested readers access the large and rich body of literature debating the extent to which engineering interventions (including levees) are responsible for some, though not all, of the observed flood-level increases in the Middle Mississippi River and elsewhere.

We are encouraged by the fact that Dr. Pinter chooses to close his discussion by recognizing the legitimacy of our discussion of different approaches to specific gauge analysis (i.e., the rating curve and direct step approaches). We are flattered that he believes current dike construction projects on the Mississippi River rely on the published paper and Watson and Biedenharn (2009) as the "*central demonstration that large-scale new dike fields will not impact flood levels*," though we must point out that this is not actually true. Professional Engineers with the U.S. Army Corps of Engineers and related federal (and state) agencies charged with design and construction of river-training works conduct thorough analyses for all federally-funded projects, and it is inconceivable that they would rely on the results of one academic paper and a single research report.

That said, the authors cannot but agree with Dr. Pinter that: "Sound engineering design, environmental assessment, and flood-risk management should be based on vigorous science rather than advocacy and misdirection." Further, we are confident that readers of the *Journal of Hydraulic Engineering* are sufficiently astute to differentiate between vigorous science and advocacy and misdirection in the papers, discussions, and closures selected for publication in this and other learned journals.

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Closure to "Mississippi River Streamflow Measurement Techniques at St. Louis, Missouri" by Chester C. Watson, Robert R. Holmes Jr., and David S. Biedenharn

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The writers welcome the discussion of the original paper. The discusser voices concern that the original paper did not include a literature review adequate to provide so-called outside readers with the proper context for the research reported in the original paper. The original paper covers all the data available to the writers and reviews of the methods and techniques of discharge measurement of which the writers are aware. The original paper did not include extended bibliographies and long tabulations of data that are available from referenced sources. All sources of data were clearly referenced in the original paper and the writers remain confident that it will satisfy the needs of the great majority of readers of the *Journal*.

The discusser states that the original paper asserts that Stevens (1979) identified systematic and significant differences between the performance of the AA, 61 cm (24 in.), and 91 cm (36-in.) Price meters. This is incorrect. At no point in the original paper is it asserted that Stevens (1979) indicated this point. What is stated in the original paper, and restated in this closure, is that the authors of the original paper found the Stevens (1979) data to generally indicate a discharge overestimation bias in pre-1933 discharge measurement methods that were employed prior to implementation of USGS standard methods.

The Stevens (1979) conclusion that, "an experienced person, using accepted techniques, can obtain excellent discharge determination using any of the velocity measuring vehicles" needs to be put in context and, in the writers' opinion, corrected. Stevens (1979) made some fundamental errors (in the writers' opinion) in the definition of what constitutes a so-called excellent discharge measurement. Stevens (1979, p. 38) considered all measurements within ±10% of the reference measurement to be excellent, basing this rationale (incorrectly, in the writers' opinion) on the statement that, "an excellent discharge measurement, according to WRD criteria, is within ±5 percent of the actual flow" [WRD is the Stevens (1979) reference to the USGS]. The USGS considers an excellent measurement to be within ±2% of the true discharge and, furthermore, considers measurements that differ from the true discharge by more than ±8% to be poor (Turnipseed and Sauer 2010). To illustrate this, consider that according to the Year 2014 St. Louis rating curve, a stage of 9.4 m (30 ft) corresponds to a discharge of 14,980 m^3/s (529,000 ft^3/s). Varying that discharge by ±10% would result in a difference of no less than 1.46 m (4.8 ft) in the stage. This suggests that the Stevens (1979) conclusion concerning what constitutes an excellent discharge measurement is invalid; many of the gagings that Stevens (1979) considers excellent would more correctly be considered poor by current USGS standards.

The discusser states that large differences were found only in the discharge measurements based on surface floats. Whereas Stevens (1979) notes that 57% of the rod floats had differences greater than ±10% of the true discharge Stevens (1979) also found serious errors in boat meter measurements, stating that 34% of the boat meter measurements (made using pre-1933 methods and equipment) were in error by more than ±5% but less than ±10%, while 7% were in error by more than ±10%. More importantly, the analysis in the original paper indicates that all pre-USGS standardization methods have a significant overestimation bias when compared to the post-1933 discharge gaging methods.

The original paper provides accounts of these early methods of discharge measurement; surface floats, ice cake, rod floats, and meters. In the discussion, it is stated that a large majority of early discharges were based on Price meters. This is incorrect, at least for measured discharges relevant to debate concerning the existence of historical trends in flood magnitudes and stages. Table 1 in the original paper shows that, for discharges greater than 11,330 m^3/s, meters were not used in the majority of the measurements until the last 5 years of the pre-1933 era, and that between 1866 and 1927 the majority of the measurements in this range were made using equipment other than meters.

The discusser suggests that the original paper was "... eschewing the several thousand meter-based and float-based discharges, including numerous paired measurements ..." The data used in the original paper were those having concurrent measurements of discharge with multiple techniques and in comparison with a Price AA meter using techniques developed by the USGS. Stevens (1979) and Ressegieu (1952) provided a total of hundreds of measurements. The writers are not aware of thousands of measurements meeting these criteria.

In closing, the discusser is thanked for interest in the paper while noting, but not responding to the wider discourse on possible trends in flood stages and the validity (or otherwise) of attempting to correct historical discharges measured using pre-USGS standard methods and equipment to account of bias. Discussion of the points raised in the discussion should (and no doubt will) continue, and the discusser's comments require no specific responses on the writers' part as they have no relevance to the original paper and because the writers believe that readers of the *Journal* can judge the merit of the discusser's arguments based on the substantive literature on this subject and their own cognizance of the issues raised in the discussion.

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Attachment E

to the

Comments of the Conservation Organizations on the Grand Tower EA

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IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF ILLINOIS

NATIONAL WILDLIFE FEDERATION, PRAIRIE RIVERS NETWORK, MISSOURI COALITION FOR THE ENVIRONMENT, RIVER ALLIANCE OF WISCONSIN, GREAT RIVERS HABITAT ALLIANCE, and MINNESOTA CONSERVATION FEDERATION, Plaintiffs, vs. UNITED STATES ARMY CORPS OF ENGINEERS; LT. GENERAL THOMAS P. BOSTICK, Commanding General and Chief of Engineers, LT. GENERAL DUKE DELUCA, Commander of the Mississippi Valley Division of the Army Corps of Engineers, Defendants.	CASE NO. 14-00590-DRH-DGW **DECLARATION OF NICHOLAS PINTER, Ph.D. IN SUPPORT OF PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION; EXHIBITS 1-3** HEARING: TBD TIME: TBD

I, Nicholas Pinter, declare as follows:

Professional Experience and Background

1. I am a Professor in the Geology Department and Environmental Resources and Policy Program at the Southern Illinois University, and Director of the SIU's Integrative Graduate Education, Research and Training (IGERT) program in "Watershed Science and Policy." I have a Ph.D. (1992) from the University of California, Santa Barbara and an M.S. (1988) from Penn State University. I have authored, edited, or contributed to at least five books and authored over 39 peer-reviewed, published scholarly articles in rivers, flood hazard, and related fields.

2. My primary field of expertise is in earth-surface processes (geomorphology) applied to a broad range of theoretical questions and practical applications. Much of my recent work focuses on rivers, fluvial geomorphology, flood hydrology, and floodplains. This research includes field-based work, modeling, and significant public-policy involvement.

3. My lab uses hydrologic and statistical tools, 1D and 2D hydraulic modeling, and loss-estimation modeling to quantify the impacts of river and floodplain engineering, and to assess regional floodplain management strategies and mitigation solutions. My research group has also compiled a large NSF-funded GIS database of over 100 years of channel hydrography, floodplain topography, and engineering construction and infrastructure on over 2500 miles of the Mississippi and Missouri Rivers in order to empirically test the causal connections between channel and floodplain modifications and flood response. Another recent NSF-funded project assessed the impacts of progressive levee growth along the Mississippi River through hydraulic modeling of multiple calibrated time steps and multiple change conditions.

4. My research group also runs a series of FEMA-funded grants doing hazard modeling and mitigation planning across the central United States. To date, the group has completed more than 40 FEMA disaster mitigation studies, and we have a number of new plans and plan updates on-going. One principal modeling tool is the Hazus-MH package that, along with various GIS-based and modeling tools, allows estimation of disaster damages and effects for a range of hazards and disaster scenarios. This modeling capability nicely bridges the gap between pure hydrologic and hydraulic analyses (as well as site-specific earthquake studies) and broad societal impacts.

5. My Curriculum Vitae is attached hereto as Exhibit 1.

Documents Reviewed for this Declaration

6. I am familiar with the literature regarding the morphology and dynamics of the Mississippi and other rivers and the interaction between river engineering structures and floods, including the studies cited in Appendix A, Summary of Research on the Effects of River Training Structures on Flood Levels, to the Final Environmental Assessments with Finding of No Significant Impact prepared by the U.S. Army Corps of Engineers ("Corps") for the Dogtooth Bend, Monsenthein/Ivory Landing, and Eliza Point/Greenfield Bend projects, and the Draft Environmental Assessment and Unsigned Finding of No Significant Impact for the Grand Tower project.

7. I have reviewed the Environmental Assessments with Finding of No Significant Impact for the Dogtooth Bend, Monsenthein/Ivory Landing, and Eliza Point/Greenfield Bend projects, and the Draft Environmental Assessment and Unsigned Finding of No Significant Impact for the Grand Tower project.

Analysis

8. I have been asked to form an independent professional opinion as to whether building new river training structures, including those planned by the Corps in the Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield Bend, and Grand Tower projects, may pose a significant risk of irreparable harm to the natural environment and to people and the property of people who live, work, attend school, or recreate in the floodplains, including by raising flood stage heights on the Mississippi River. As discussed in the following analysis, I conclude that the Corps' proposed projects, and river training structures generally, do pose such a risk.

9. Damages from floods worldwide have risen dramatically over the past 100 years (Munich Re Group, 2007). While much of this increase is due to economic development in floodplains (Pinter, 2005; Pielke, 1999), it is also clear that flooding itself has physically increased in magnitude and frequency on many rivers, including the Mississippi River. (Pinter et al., 2006a; Pinter et al., 2006b; Helms et al., 2002). Historical time series of stage data, which are

unequivocally homogenous over time (Criss and Winston, 2008), show strong and statistically significant increases of flood heights on the Mississippi River over time.

10. A number of processes can lead to flood magnification or otherwise alter flood response in a river basin. These include climate change, agricultural practices, forestry practices, urbanization, road construction, construction of other impervious surfaces, loss of wetlands, decreases in floodplain storage areas, construction and operation of dams, and modifications and engineering of river channels. The range of these changes can alter the volume and timing of runoff (discharge or flow of water) entering and moving through river systems. In addition, other natural or human-induced changes to river channels and their floodplains can alter the conveyance of flow with the river channels, resulting in increases or decreases in water levels (including flood stages) for the same discharge.

11. The Mississippi River has been intensively engineered by the Corps over the past 50 to 150-plus years (depending on the reach), and some of these modifications are associated with large decreases in the river's capacity to convey flood flows. Numerous scientific investigations including Corps reports, some dating back to the 1950s, have noted large increases in flood levels in association with wing-dike construction. For example, investigators recognized as early as 1952 that "the carrying capacity of the river has been decreased so materially by the [river training] work that floods have occurred at such points as Waverly, Boonville and Hermann, Mo., at lower gauge readings with smaller volumes of water than the 1929 flood stage." (Schneiders, 1996 at 346). These investigations have prompted some agencies to rethink their river management strategies. In the Netherlands, for example, the government has begun modifying river training structures on the Rhine River to reduce this recognized risk. General Accounting Office, "Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures (December 2011) ("GAO Report") at 41. To date, however, the Corps has never addressed in an EIS the vast body of peer-reviewed, independent research showing that river-training structures increase flood heights. *Id.*

12. My research has looked extensively at the extent and causes of flood magnification, particularly on the Mississippi River. This research documents that climate, land-use changes, and

river engineering have contributed to statistically significant increases in flooding along portions of the Mississippi River system. However, the most significant cause of flood height increases on the Middle Mississippi River and Lower Missouri River can be traced to the construction of wing dikes and other river training structures. Indeed, flood height increases on those river segments exceed by a factor of ten the maximum credible increases that could be expected from climate-driven and land-cover-driven flow increases (e.g., Pinter et al., 2008). The large multivariate study by Pinter et al. (2010) identified the age, location, and extent of every large levee system added to the Mississippi-Lower Missouri system during the past century, documenting that levees do contribute some but not all of the observed flood-level increases on the Middle Mississippi and elsewhere (confirming modeling by Remo et al., 2009; see Exhibit 2 to this declaration).

13. Recent theoretical analysis has shown that increased flood levels caused by wing-dike construction are "consistent with basic principles of river hydro- and morphodynamics" (Huthoff et al., 2013). This study concluded that even with extremely conservative parameters used in modeling, "the net effect of wing dikes will be higher flood levels." *Id.*

14. This theoretical analysis is supported by empirical studies that have utilized hydrologic analyses; rigorous statistics; geospatial analyses; and 1D, 2D, and 3D hydraulic modeling to confirm, empirically as well as theoretically, the potential for significant increases in flood levels in response to the dense emplacement of wing-dike structures, such as employed on the Middle Mississippi River. Among this body of research, my research group was funded by the National Science Foundation to construct two large river-related databases to rigorously test for trends in flood magnitudes over time on over 4000 kilometers (over 2400 miles) of the Mississippi and Missouri Rivers, and to quantify the impacts on flood levels from each unit of channel and floodplain infrastructure construction or other change.

15. Our hydrologic database consists of more than 8 million discharge and river stage values, including new synthetic discharges generated for 41 stage-only stations. This hydrologic database was used to test for significant trends in discharges, stages, and ''specific stages.'' We also conducted an extensive review of the validity of using discharge data taken from different types of measurement devices (float meters vs. other types of meters). Pinter (2010) tested whether

it was appropriate to utilize older discharge measurements by examining 2150 historical discharge measurements digitized from the three principal stations on the Middle Mississippi River (MMR), including 626 float-based discharges and 1516 meter-based discharges, and including 122 paired measurements. All statistical tests we performed demonstrated that it was appropriate to utilize both older historical discharge data and newer discharge data as those different types of measurement tools produced accurate discharge measurements.

16. Our geospatial database consists of the locations, emplacement dates, and physical characteristics of over 15,000 structural features constructed along the study rivers over the past 100 to 150 years. In developing this database we utilized: more than 4000 individual map and survey sheets; structure-history databases from six Corps Districts; databases from other agencies including the Coast Guard; and archival maps and surveys digitized and calibrated into a modern coordinate system and frame of reference. Within this database we parameterized 130 bridges, 54 dam structures, 25 artificial meander cut-offs, 1093 levees, and 13,231 wing-dam segments, among many other structures.

17. Together these two databases were used to generate reach-scale statistical models of hydrologic response. These models quantify changes in flood levels at each station in response to construction of wing dikes, bendway weirs, meander cutoffs, navigational dams, bridges, and other river modifications.

18. Our analyses show that while climate and other land-use changes did lead to increased flows, *the largest and most pervasive contributors to increased flooding on the Mississippi River system were wing dikes and related navigational structures*. In contrast, large reaches of the Mississippi and Missouri Rivers with little or no dike construction showed *no* significant increases in flood levels. System-wide, the hydrologic pattern was that large-scale increases in flood levels occurred when and where large numbers of dikes and dike-like structures have been built. Progressive levee construction was the second largest contributor.

19. Our analyses demonstrate that wing dikes constructed downstream of a location were associated with increases in flood height ("stage"), consistent with backwater effects upstream of these structures. Backwater effects are the rise in surface elevation of flowing water upstream

from, and as a result of, an obstruction to water flow. These backwater effects were clearly distinguishable from the effects of upstream dikes, which triggered simultaneous incision and conveyance loss at sites downstream. On the Upper Mississippi River, for example, stages increased more than four inches for each 3,281 feet of wing dike built within 20 RM (river miles) downstream. These values represent parameter estimates and associated uncertainties for relationships significant at the 95 percent confidence level in each reach-scale model. The 95-percent level indicates at least a 95% level of certainty in correlation or other statistical benchmark presented, and is considered by scientists to represent a statistically verified standard. Our study demonstrated that the presence of river training structures can cause large increases in flood stage. For example, at Dubuque, Iowa, roughly 8.7 linear miles of downstream wing dikes were constructed between 1892 and 1928, and were associated with a nearly five-foot increase in stage. In the area affected by the 2008 Upper Mississippi flood, more than six feet of the flood crest is linked to navigational and flood-control engineering.

20. More than 143 linear miles of wing dikes have been constructed on the Middle Mississippi River over the past 100 years (Remo and Pinter 2007; Remo et al. 2008). This represents about 3,960 feet of wing dikes per mile (or about 2,460 feet per kilometer) of channel. Wing dikes have also been heavily utilized on the Lower Missouri River, with over 383 linear miles constructed since 1890. This represents nearly 3,700 feet of wing dike per mile (or about 2,300 feet per kilometer) of channel in the Lower Mississippi River. These and similar river training structures are utilized to assist in river bank protection and stimulate channel scour which can reduce the amount of dredging required to maintain adequate navigation depths (e.g. COPRI 2012).

21. The effects of wing dikes and other structures during flooding should not be confused with effects during periods of low flow. There is general agreement that during low in-channel flows, wing dikes lead to lowered water levels. This happens because the dikes cause channel incision, which is a process of channel adjustment by which channel flow removes sediment from the stream bed and ultimately establishes a lower bed elevation. Channel incision is a process that has been well documented after dike construction in many (but not all) areas of the alluvial Mississippi and Missouri Rivers (e.g., Pinter and Heine 2005; Maher 1964).

22. For example, water levels at St. Louis measured during periods of low to average flows have decreased over a period of about 60 years. This decrease reflects the well documented effects of dike construction (also dredging) that has constricted the channel, eroded the channel bed, and thus lowered such non-flood water levels. Downstream at the Chester and Thebes measurement stations, water levels have also decreased during low flows, but they have risen for all conditions from average flows up to large floods. At Grand Tower, Illinois, water levels for just average flows have increased by almost three feet due to dike and weir construction. Near Grand Tower, bedrock underlies parts of the Middle Mississippi channel and limits incision (Jemberie et al. 2008). At all of these locations, *at flood flows* (flows equal to four or more times the average annual discharge level), *water levels have increased by three to ten feet or more.*

23. Many other studies confirm and corroborate these findings. Particularly after the record-breaking floods on the Middle Mississippi, researchers sought to answer why such large increases in flood levels had occurred for the same discharges (volumes of flow) that had been observed in the past. (e.g., Belt 1975; Stevens et al. 1975). Since then, multiple studies involving hydrologic time-series analyses, statistical analyses, geospatial analyses, and hydraulic modeling have correlated the timing and spatial distribution of dike construction with increases in flood stages (e.g., Criss and Shock 2001; Wasklewicz et al. 2004; Jemberie et al. 2008; Pinter et al. 2008; Remo et al. 2009; Pinter et al. 2010, and others).

24. Wing dikes and other river training structures increase flood heights during high water because of the way they interact with river flow and the way they change the shape and form of the river channel. Since the beginning of historical "training" (engineering of the river to facilitate navigation) of the Mississippi and Missouri rivers, construction of dikes has narrowed large portions of these river channels to one-half or less of their original width. In addition, construction of dikes, bendway weirs, and other in-channel navigational structures has increased the "roughness" of the channel, leading to decreased flow velocities during floods.

25. Channel roughness is a measure of objects and processes that cumulatively resist the flow of water through a given reach of a river, including drag effects of sedimentary grains, bedforms (e.g., ripples and dunes on the bed), vegetation, turbulence, eddy circulation, and many

others. A rough river bed exerts more resistance than a smooth river bed, resulting in slower flow of water. All other factors being equal, a flood that passes through a river reach with half the average flow velocity will result in average water depths that are double what they would otherwise be.

26. Recent modeling studies demonstrate the significant effects of flow turbulence and large-scale vertical and horizontal eddy circulation (Huthoff et al., 2013) of river training structures during flood events. Other recent studies have focused on flow dynamics around submerged wing dikes and their impact on channel flow resistance (e.g., Yossef 2005; Yossef and de Vriend 2011; Azinfar and Kells 2011). These studies show that submerged wing dikes create flow mixing in their wake zones (e.g., Yossef 2005; Yeo and Kang 2008; Jamieson et al. 2011). These recirculating flows consume energy from the bulk flow field, causing increases in effective resistance near wing dikes and through wing-dike fields. The impact of wing dikes on flow resistance was quantified by Yossef (2004, 2005), whose proposed relationship allows for an initial assessment of wing-dike impact on water levels (e.g., Azinfar 2010). According to Yossef's laboratory experiments, the effective cumulative hydraulic roughness of the bank zone relates to the size and longitudinal distance between the wing dikes.

27. The role of river training structures in increasing flood heights is well recognized. For example, in the Netherlands, the impacts of wing dikes (navigational "groynes") on flood levels have both been recognized and taken into account in flood protection strategies. The government of the Netherlands recently completed a €45 million program to lower 450 wing dikes (groynes) on the Rhine system as part of its strategy to reduce flood levels.

28. Changes in channel geometry and roughness related to river engineering tools employed for improved navigation and flood control are the principal drivers behind changes in flood stage on the Mississippi River. The increases in flood stage are caused by both the direct effects of wing dikes, meaning interaction with flow, and the indirect effects of wing dikes, meaning the effects of the wing dike in changing the shape or form of the river bed. Hydrodynamic simulations of indirect and direct effects of wing dikes show decreases in velocity, increases in roughness, and corresponding increases in flood stage.

29. River training structures constructed by the Corps to help maintain the nine-foot navigation channel have caused large-scale increases in flood levels, up to 15 feet in some locations and by some measures, and six to ten feet over broad stretches of the river where these structures are prevalent. Such large increases in flood heights in these rivers have occurred when and where – and only when and where – wing dikes, bendway weirs, and other river training structures have been built. These structures have led to significant increases in the frequency and magnitude of large floods.

30. The projects now proposed on the Middle Mississippi River are particularly problematic for several reasons. First, as mentioned above, bedrock underlies parts of the Middle Mississippi channel near the Grand Tower project, which limits incision (Jemberie et al. 2008). In such locations, the ameliorating effect of new wing dikes in causing bed incision is reduced or eliminated, leading in the past to the largest observed increases in flood levels.

31. The new dike construction projects now proposed on the Middle Mississippi are also problematic because they threaten nearby levees that already have identified deficiencies. The Dogtooth Bend Project is immediately downstream of one of the sites where the Len Small levee failed during floods in 2011 (Dogtooth Bend EA at E2). This 5,000-foot breach yielded to fast-moving water that "scored farmland, deposited sediment, and created gullies and a crater lake" (K.R. Olson and L.W. Morton, "Impacts of 2011 Len Small levee breach on private and public Illinois lands," *Journal of Soil and Water Conservation*, Vol. 68:4, attached as Exhibit 3).

32. The proposed Grand Tower project spans approximately seven River Miles along the Big Five Levee Drainage and Levee Districts, including the Preston, Clear Creek, East Cape, and Miller Pond levees, together protecting over 49,000 acres of Illinois floodplain. The proposed Grand Tower wing dike project also lies just downstream of the Degognia/Fountain Bluff and Grand Tower Drainage and Levee Districts, protecting a further 56,000 acres. Currently, every segment of these levee systems have "Unacceptable" ratings following Corps inspections and assessment. The Dogtooth Bend Project likewise poses an unusually high potential for flood damage. The Cairo levee system ("Mississippi and Ohio Rivers Levee System at Cairo & Vicinity") is located a few miles downstream of the Dogtooth Bend Project. Although the greatest

effects of wing dikes occur upstream, statistically significant increases in flood levels have also been identified downstream. Corps inspections have identified major deficiencies in the Cairo levee system, leading to its current "Unacceptable" rating in the National Levee Database.

33. My work with local levee commissioners and other informed officials has revealed deep concern and widespread discussion about levee safety and performance during future floods, even without additional stresses. For at least the past decade, local stakeholders have repeatedly called for the St. Louis District of the Corps of Engineers to rigorously and independently assess the cumulative impacts of wing-dike construction in the Middle Mississippi River. Instead, a new wave of dike construction has been undertaken, with each new project evaluated – perfunctorily – on an individual basis and without regard to cumulative effects.

34. The new dike construction projects here – at Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield Bend, and Grand Tower – pose significant threats of increased flooding and flood risk. They are the latest manifestations of a flawed process that has allowed construction of hundreds of new dikes and dike-like structures that are causing elevated flood stages throughout the Middle Mississippi River. Unless these new dike construction projects are halted to allow their reconsideration based on a comprehensive Supplemental Environmental Impact Statement that takes the foregoing studies and analyses into consideration, needless and potentially severe flooding will likely occur.

35. I declare under penalty of perjury that the foregoing facts are true of my personal knowledge, that the foregoing expressions of professional judgment are honestly held in good faith, that I am competent to and if called would so testify, and that I executed this declaration on June 24, 2014 in Chicago, Illinois.

Nicholas Pinter

Nicholas Pinter, Ph.D

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Yossef, M.F.M., 2004. The effect of submergence level on the resistance of groynes—An experimental investigation. Advances in hydroscience and engineering (CD-ROM), National Center for Computational Hydroscience and Engineering, University, MS.

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

Yossef, M.F.M., and H.J. De Vriend, 201. Flow details near river groynes: Experimental investigation. Journal of Hydraulic Engineering 137: 504–516.

EXHIBIT 1

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EDUCATION

1988 - 1993 PhD., Geology, University of California, Santa Barbara
1986 - 1988 M.S., Geology, Penn State University, Univ. Park, PA
1982 - 1986 B.A., Geology and Archaeology, Cornell University, Ithaca, NY

RESEARCH AREAS

- Geomorphology: the geology of the earth-surface
- Human influences on landscapes and geomorphic processes
- Rivers, flooding, and floodplain management

PROFESSIONAL POSITIONS

1996 - Full Professor (since 7/05), Southern Illinois University
Author: Prentice Hall and John Wiley & Sons
1995 -1996 Postdoctoral Researcher, Yale University

RECENT HONORS/AWARDS

- 2013-2018: Fulbright Specialist, U.S. State Dept., Bureau of Educational and Cultural Affairs (roster)
- 2013: Nominee: W.K. Kellogg Foundation & APLU Engagement Award (to SIU Olive Branch team)
- 2012: Illinois Mitigation Award: Illinois Association of Floodplain and Stormwater Managers
- 2010: Marie Curie Fellowship (IIF), European Commission
- 2010: Fulbright Fellowship (declined; see above)
- 2009: Leo Kaplan Research Award, Sigma Xi, SIU Chapter
- 2008: SIU College of Science, Outstanding Researcher award
- 2007: Alexander von Humboldt Foundation, Germany Research Renewal Fellowship
- 2005, 2006: SIU nominee, Jefferson Fellows Program; National Academy of Sciences
- 2003 Friedrich Wilhelm Bessel Prize; Alexander von Humboldt Foundation
- 2002 John D. and Catherine T. MacArthur Foundation, Research and Writing Award
- 2000 Fulbright Foundation Fellowship
- 1999 Charles A. Lindbergh Foundation Prize

BOOKS, WORKSHOPS, EDITED VOLUMES, and OTHER PROF. ACTIVITIES

Invited Written Testimony: Statement submitted for hearings entitled "A Review of the 2011 Floods and the Condition of the Nation's Flood Control Systems," before the Senate Environment and Public Works Committee, United States Senate, Washington DC, October 18, 2011.

Panelist, U.S. National Academy of Science: Committee on Missouri River Recovery and Associated Sediment Management Issues, 2008-2010.

Associate Editor: Environmental & Engineering Geoscience, Association of Environmental & Engineering Geologists, Denver, CO.

Convener, American Association for the Advancement of Science Workshop: Managing rivers and floodplains for the new millennium. AAAS national meeting, 2006.

External Reviewer, National Research Council, The National Academies: Review of the U.S. Army Corps of Engineers Restructured Upper Mississippi River-Illinois Waterway Navigation Study.

Member, Advisory Board: The Nature Conservancy Great Rivers Center (Upper Mississippi, Parana-Paraguay, and Upper Yangtze River systems).

Lead Editor: Pinter, N., G. Grenerczy, J. Weber, S. Stein, and D. Medak, 2006. The Adria Microplate: GPS Geodesy, Tectonics, and Hazards. Spring Verlag.

Expert Witness: e.g., B&H Towing, Inc., Case No. 06-05-0233 (U.S. District Court, Southern District of W. Virginia); Great Rivers Habitat Alliance v. U.S. Army Corps of Engineers, No. 4:05-CV-01567-ERW (U.S. District Court, Eastern District of Missouri); Great Rivers Habitat Alliance v. City of St. Peters, No. 04-CV-326900 (Circuit Court of Cole County, Missouri); Henderson County Drainage District No. 3 et al. v. United States, No. 03-WL-179780 (Ct. Fed. Cls, Kansas City), etc.

Associate Editor: Geomorphology, Elsevier Science, 2004-2008

Instructor, European Union Advanced School on Tectonics: 3D Monitoring of Active Tectonic Structures, International Centre for Theoretical Physics, Trieste, April 18-22, 2005.

Convener, NATO Advanced Research Workshop: The Adria microplate: GPS geodesy, tectonics, and hazards. Veszprém, Hungary; April, 2004.

Convener, Pardee Keynote Symposium: Pinter, N., and J.F. Mount, 2002, Flood hazard on dynamic rivers: Human modification, climate change, and the challenge of non-stationary hydrology. Geological Society of America national meeting, 2002.

Author: Keller, E.A. and N. Pinter, 2002. Active Tectonics: Earthquakes and Landscape. Prentice-Hall.

Co-Editor: Burbank, D.W., and N. Pinter, 1999. Landscape evolution: The interactions of tectonics and surface processes. Basin Research, vol. 11, num. 1.

Author: Pinter, N, 1996. Exercises in Active Tectonics. Prentice Hall.

Convener and Instructor: Pazzaglia, F.J., and N. Pinter, 1996. Geomorphic expression of active tectonics. Short course at the 1996 Geological Society of America meeting, Denver.

Convener, Theme Session: N. Pinter, and D.W. Burbank, 1996. Feedbacks between tectonics and surface processes in orogenesis. Geological Society of America meeting, Denver.

Author: Pinter, N., and S. Pinter, 1995. Study Guide for Environmental Science. J. Wiley & Sons.

REFERENCES

Thomas Gardner	Trinity University, San Antonio, TX 78212	tgardner@trinity.edu	210-736-7655
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Seth Stein	Northwestern Univ., Evanston, IL 60208	seth@earth.northwestern.edu	847-491-5265

FUNDED PROJECTS

Active: NSF Infrastructure Management for Extreme Events: Community resilience through pro-active mitigation in the rural Midwest.

Active: NSF IGERT: Multidisciplinary, team-based training watershed science and policy. (Lead PI: Pinter; $3.2 million) **+ International Supplement**

Active: FEMA: Illinois multi-hazard mitigation initiative (Lead PI: Pinter; with Indiana University-Purdue University at Indianapolis). ~40 awarded + ~12 pending.

NSF RAPID: A massive floodplain reconnects: physical and biotic responses of the Birds Point levee breach in the Mississippi River (J. Garvey, lead PI).

IEMA: Illinois statewide flood-hazard assessment (J. Remo, lead PI).

Walton Family Foundation: Olive Branch, IL Relocation Initiative: Community Disaster-Recovery Networking

NSF Sedimentology and Paleobiology program: Testing hypotheses of latest Pleistocene paleo-environmental collapse, Northern Channel Islands, California (Lead PI: Pinter; collaborative project with Northern Arizona University; Univ. of Oregon)

Emergency Management Institute curricula: HAZUS-MH for earthquakes.

U.S. Steel: Levee-breach modeling, Metro East Drainage and Levee District area.

European Commission, Marie Curie IIF Program: Early anthropogenic signatures on landscapes: geomorphic, paleobotanical, and other paleo-environmental fingerprints.

NSF, Geography and Regional Science: A multivariate geospatial model of levee impacts on flood heights, Lower Mississippi River + **International Supplement** awarded

National Geographic Society: Testing a hypothesis of latest Pleistocene paleo-environmental collapse, Northern Channel Islands, California.

USGS Upper Midwest Environmental Sciences Center: Development of a virtual hydrologic and geospatial data repository for the Mississippi River System

NSF, Office of International Science and Engineering: U.S.-Chile: Morphotectonic evolution of the U.S.-Chile: Mejillones Peninsula, northern Chile using precise GPS measurement of uplifted coastal terraces

NSF Hydrologic Sciences Program: Multivariate geospatial analysis of engineering and flood response, Mississippi River System, USA.

NSF, International Science and Engineering: US-Chile cooperative research on the Cenozoic paleoceanographic and paleoclimatic evolution of northern and central Chile. (Ishman and Pinter)

NATO Science Program: The Adria microplate: GPS geodesy, tectonics, and hazards.

John D. and Catherine T. MacArthur Foundation: Exporting Natural Disasters: Flooding and Flood Control on Transboundary Rivers

NATO: The Adria Microplate: Postdoctoral Fellowship for Dr. G. Grenerczy.

USGS National Cooperative Geologic Mapping Program (6/03-5/04). Plio-Pleistocene Deposits of the White/Inyo Mountains Range Front, Inyo and Mono Counties, CA

Alexander von Humboldt Foundation: Human forcing of hydrologic change and magnification of flood hazard on German Rivers

NASA (9/01-8/02)). Assessing mass wasting and landslide susceptibility using GIS and remotely sensed imagery, Santa Cruz Island, California. (ESS Fellowship for E. Molander)

Association of State Floodplain Managers (9/01-8/02). Rapid revision of flood-hazard mapping. (Fellowship for R. Heine)

Missouri Coalition for the Environment (7/01-5/02). Hydrologic history of the Lower Missouri River.

NOAA Channel Islands National Marine Sanctuary (12/99-6/02). Orthorectification of 1997, pre-El Niño air-photo set from the California Channel Islands.

Petroleum Research Fund (7/99-10/01). Timing and rates of basin inversion from tectonic geomorphology, Pannonian Basin, Hungary. (**Supplement** [5/00-4/01] for an ACS-PRF Summer Fellow)

USGS National Cooperative Geologic Mapping Program (5/00-4/01). Mapping landslide susceptibility, Santa Cruz Island, California: A field- and GIS-based analysis.

National Park Service, Channel Islands National Park (4/00-9/00). Orthorectification of 1998, post-El Niño air-photo set from the California Channel Islands.

USGS National Cooperative Geologic Mapping Program (6/99-5/00). Mapping coastal terraces and Quaternary cover on Santa Rosa and San Miguel Islands, California, using dual-frequency kinematic GPS positioning.

NSF Active Tectonics Program (3/97-2/00), (**Supplement** granted). Testing models of fault-related folding, Northern Channel Islands, California.

NASA (9/00-8/01)). Assessing mass wasting and landslide susceptibility using GIS and remotely sensed imagery, Santa Cruz Islands, California. (ESS Fellowship for W.D. Vestal)

National Earthquake Hazards Reduction Program (7/97-12/99): Slip on the Channel Islands/Santa Monica Mountains Thrust. (**Supplement** granted)

NSF, Instrumentation and Facilities Program (8/97-7/99): Acquisition of a GIS-dedicated UNIX workstation laboratory.

SIU Office of Research Development (8/97-5/99). Effects of levee construction and channelization on stage-discharge flood response of the Upper Mississippi River.

National Research Council (1997). Active tectonics of the Pannonian Basin, Hungary.

National Earthquake Hazards Reduction Program (2/92-7/93). Latest Pleistocene to Holocene rupture history of the Santa Cruz Island fault. (with Ed Keller)

PUBLICATIONS

Books: National Research Council, 2010. Missouri River Planning: Recognizing and Incorporating Sediment Management. National Academy Press: Washington, DC.

Pinter, N., G. Grenerczy, J. Weber, S. Stein, and D. Medak (eds.), 2006. The Adria Microplate: GPS Geodesy, Tectonics, and Hazards. Springer Verlag.

Keller, E.A. and N. Pinter, 2002. Active Tectonics: Earthquakes and Landscape, 2nd Edition. Prentice-Hall: Upper Saddle River, NJ.

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Pinter, N., and S. Pinter, 1995. Study Guide for Environmental Science. John Wiley & Sons: New York.

Papers: Huthoff, F., N. Pinter, and J.W.F. Remo, 2014. Reply to discussion of "Theoretical analysis of stage magnification caused by wing dikes, Middle Mississippi River, USA". Journal of Hydraulic Engineering, in press.

Huthoff, F., J.W.F. Remo, and N. Pinter, in press. Improving flood preparedness using hydrodynamic levee-breach and inundation modeling: Middle Mississippi River, USA. Journal of Flood Risk Management.

Pinter, N., S. Baer, L. Chevalier, R. Kowalchuk, C. Lant, and M. Whiles, 2013. An "IGERT" model for interdisciplinary doctoral education in water-related science and policy. Journal of Contemporary Water Research and Education, 150: 53-62.

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Remo, J.W.F., A. Khanal, and N. Pinter, 2013. Assessment of chevron dikes for the enhancement of physical-aquatic habitat within the Middle Mississippi River, USA. Journal of Hydrology, 501: 146-162.

Huthoff, F., H. Barneveld, N. Pinter, J. Remo, H. Eerden, 2013. Optimizing design of river training works using 3-dimensional flow simulations. In Smart Rivers 2013 (Conference Proceedings), Liege, Belgium and Maastricht , Netherlands, 23-27 September, 2013.

Remo, J.W.F., and N. Pinter, 2012. Hazus-MH earthquake modeling in the central USA. Natural Hazards, 63:1055–1081.

Dierauer, J., N. Pinter, J.W.F. Remo, 2012. Evaluation of Levee Setbacks for Flood-Loss Reduction, Middle Mississippi River, USA. Journal of Hydrology, 450: 1-8.

Pinter, N., J. Dierauer, J.W.F. Remo, 2012. Flood-damage modeling for assessing impacts of flood frequency adjustment, Middle Mississippi River, USA. Hydrologic Processes, 26: 2997–3002.

Remo, J.W.F., M. Carlson, N. Pinter, 2012. Hydraulic and flood-loss modeling of levee, floodplain, and river management strategies, Middle Mississippi River, USA. Natural Hazards, 61: 551-575.

Pinter, N., 2012. Early history of the Upper Mississippi River In Brad Walker (Ed.), Our Future? A Vision for a Land, Water and Economic Ethic in the Upper Mississippi River Basin, pp. 10-12. St. Louis: Missouri Coalition for the Environment.

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Heine, R.A., and N. Pinter, 2012. Levee effects upon flood levels: An empirical assessment. Hydrological Processes, 26: 3225–3240.

Boslough, M., K. Nicoll, V. Holliday, T. L. Daulton, D. Meltzer, N. Pinter, A. C. Scott, T. Surovell, Ph. Claeys, J. Gill, F. Paquay, J. Marlon, P. Bartlein, C. Whitlock, D. Grayson, and T. Jull, 2011. Arguments and evidence against a Younger Dryas impact event. Proceedings of the AGU Chapman Conference on Climates, Past Landscapes, and Civilizations, Santa Fe, NM, 21-25 March, 2011.

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: 50-66.

Pinter, N., A.C. Scott, T.L. Daulton, A. Podoll, C. Koeberl, R.S. Anderson, and S.E. Ishman, 2011. The Younger Dryas impact hypothesis: A requiem. Earth-Science Reviews, 106: 247–264.

Flor, A.D., N. Pinter, and J.W.F. Remo, 2011. The ups and downs of levees: GPS-based change detection, Middle Mississippi River USA. Geology, 39: 55-58.

Pinter, N., S. Fiedel, and J.E. Keeley, 2011. Fire and vegetation shifts in the Americas at the vanguard of Paleoindian migration. Quaternary Science Reviews, 30: 269-272.

Flor, A.D., N. Pinter, and J.W.F. Remo, 2010. Evaluating levee failure susceptibility on the Mississippi River using logistic regression analysis. Engineering Geology, 116: 139-148.

Daulton, T.L., N. Pinter, and A.C. Scott, 2010. No evidence of nanodiamonds in Younger Dryas sediments to support an impact event. PNAS, 107: 16043–16047.

Scott, A.C., N. Pinter, M.E. Collinson, M. Hardiman, R.S. Anderson, A.P.R. Brain, S.Y. Smith, F. Marone, and M. Stampanoni, 2010. Fungus, not comet or catastrophe, accounts for carbonaceous spherules in the Younger Dryas 'impact layer'. Geophysical Research Letters, 37: doi:10.1029/2010GL043345.

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

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Anderson, R.S., S. Starratt, R.B. Jass, and N. Pinter, 2009. Fire and vegetation history on Santa Rosa Island, Channel Islands: Long-term environmental change in southern California. Journal of Quaternary Science, DOI: 10.1002/jqs.

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. Available online, URL: http://www.ces.slu.edu/.

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.

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.

Pinter, N., and S.E. Ishman, 2008. Reply to comments on "Impacts, mega-tsunami, and other extraordinary claims." GSA Today, vol. 18(6): e14.

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.

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.

Pinter, N., and S.E. Ishman, 2008. Impacts, mega-tsunami, and other extraordinary claims. GSA Today, 18(1): 37-38.

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.

Bada, G., Grenerczy, G., Tóth, L., Horváth, F., Stein, S., Cloetingh, S., Windhoffer, G., Fodor, L., Pinter, N., Fejes, I., 2007. Motion of Adria and ongoing inversion of the Pannonian basin: Seismicity, GPS velocities and stress transfer. In: Stein, S., Mazzotti, S., (Eds.), Continental Intraplate Earthquakes: Science, Hazard, and Policy Issues. Geological Society of America Special Paper 425, p. 243–262, doi: 10.1130/2007.2425(16).

Remo, J.W.F., and N. Pinter, 2007. Retro-modeling of the Middle Mississippi River. Journal of Hydrology 337: 421-435.

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., 2006. New Orleans revival recipes. Issues in Science and Technology, 22(3): 5-6.

Pinter, N., and G. Grenerczy, 2006. Recent advances in peri-Adriatic geodynamics and future research directions. In N. Pinter, G. Grenerczy, J. Weber, S. Stein, and D. Medak (eds.), The Adria Microplate: GPS Geodesy, Tectonics, and Hazards, pp. 1-20. Springer Verlag.

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., and M.T. Brandon, 2005. How erosion builds mountains. Scientific American Special, 15(2) 74-81.

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

Pinter, N., 2005. Applications of tectonic geomorphology for deciphering active deformation in the Pannonian Basin, Hungary. In L. Fodor and K. Brezsnyánszky (eds.), Proceedings of the Workshop on "Applications of GPS in Plate Tectonics in Research on Fossil Energy Resources and in Earth-quake Hazard Assessment, Occasional Papers of the Geological Institute of Hungary, 204: 25-51.

Pinter, N., and W.D. Vestal, 2005. El Niño-driven landsliding and postgrazing recovery, Santa Cruz Islands, California. Journal of Geophysical Research, 110, F2, doi. 10.1029/2004JF000203.

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.

Schweigert, P., N. Pinter, and R.R. van der Ploeg, 2004. Regression analysis of weather effects on the annual concentrations of nitrate in soil and groundwater. Journal of Plant Nutrition and Soil Science, 167: 309-318.

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.

Scott, A.T., and N. Pinter, 2003. Extraction of coastal terraces and shoreline-angle elevations from digital terrain models, Santa Cruz and Anacapa Islands, California. Physical Geography, 24: 271-294.

Gieska, M., R.R. van der Ploeg, P. Schweigert, and N. Pinter, 2003. Physikalische Bodendegradierung in der Hildesheimer Börde und das Bundes-Bodenschutzgesetz. Berichte über Landwirtschaft 81(4): 485-511.

Pinter, N., C.C. Sorlien, and A.T. Scott, 2003. Isostatic subsidence in response to thrust faulting and fold growth. American Journal of Science, 303: 300-318.

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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.

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Pinter, N., B. Johns, B. Little, and W.D. Vestal, 2001. Fault-related folding in California's Northern Channel Islands documented by rapid-static GPS positioning. GSA Today, 11(5): 4-9.

Pinter, N., R. Thomas, and N.S. Philippi, 2001. 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.

Lueddecke, S.B., N. Pinter, and S. McManus, 2001. Greenhouse effect in the classroom: A project- and laboratory-based curriculum. Journal of Geological Education, 49: 274-279.

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.

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Burbank, D.W., and N. Pinter, 1999. Landscape evolution: The interactions of tectonics and surface processes. Basin Research, 11: 1-6.

Pinter, N., C.C. Sorlien, and A.T. Scott, 1998. Late Quaternary folding and faulting of the Santa Cruz Island, California. In P.W. Weigand (ed.), Contributions to the Geology of the Northern Channel Islands, Southern California. Pacific Section, American Association of Petroleum Geologists: Bakersfield, CA, MP-45: 111-122.

Pinter, N., S.B. Lueddecke, E.A. Keller, and K. Simmons, 1998. Late Quaternary slip on the Santa Cruz Island fault, California. Geological Society of America Bulletin, 110: 711-722.

Lueddecke, S.B., N. Pinter, and P. Gans, 1998. Plio-Pleistocene ash falls, sedimentation, and range-front faulting along the White-Inyo Mountains front, California. Journal of Geology, 106: 511-522.

Pinter, N., and M.T. Brandon, 1997. How erosion builds mountains. Scientific American, 276(4): 74-79.

Pinter, N., and M.T. Brandon, 1997. Comment l'erosion construit les montagnes. Pour La Science, 236: 78-84

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Sorlien, C.C., and N. Pinter, 1997. Faulting and folding on Santa Cruz Island, California. In J.R. Boles and W. Landry (eds.), Santa Cruz Island Geology Field Trip Guide, San Diego: San Diego Association of Geologists, pp. 72-90.

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Pinter, N., and E.A. Keller, 1995. Geomorphic analysis of neotectonic deformation, northern Owens Valley, California. Geologische Rundschau, 84: 200-212.

Pinter, N., E.A. Keller, and R.B. West, 1994. Relative dating of terraces of the Owens River, northern Owens Valley, California and correlation with moraines of the Sierra Nevada. Quaternary Research, 42: 266-276.

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Gardner, T.W., D. Verdonck, N. Pinter, R.L Slingerland, K.P. Furlong, T.F. Bullard, and S.G. Wells, 1992. Quaternary uplift astride the aseismic Cocos Ridge, Pacific coast, Costa Rica. Geological Society of America Bulletin, 104: 219-232.

Pinter, N., and M.M. Fulford, 1991. Late Cretaceous basement foundering of the Rosario embayment, Peninsular Ranges forearc basin: Backstripping of the El Gallo Formation, Baja California Norte, Mexico. Basin Research, 3: 215-222.

Pinter, N., and E.A. Keller, 1991. Comment on "Surface uplift, uplift of rocks, and exhumation of rocks." Geology, 19: 1053.

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Gardner, T.W., J.B. Ritter, C.A. Shuman, J.C. Bell, K.C. Sasowsky, and N. Pinter, 1991. A periglacial stratified slope deposit in the Valley and Ridge Province of central Pennsylvania, USA: Sedimentology, stratigraphy, and geomorphic evolution. Permafrost and Periglacial Processes, 2: 141-162.

Pinter, N., and T.W. Gardner, 1989. Construction of a polynomial model of sea level: Estimating paleo-sea levels continuously through time. Geology, 17: 295-298.

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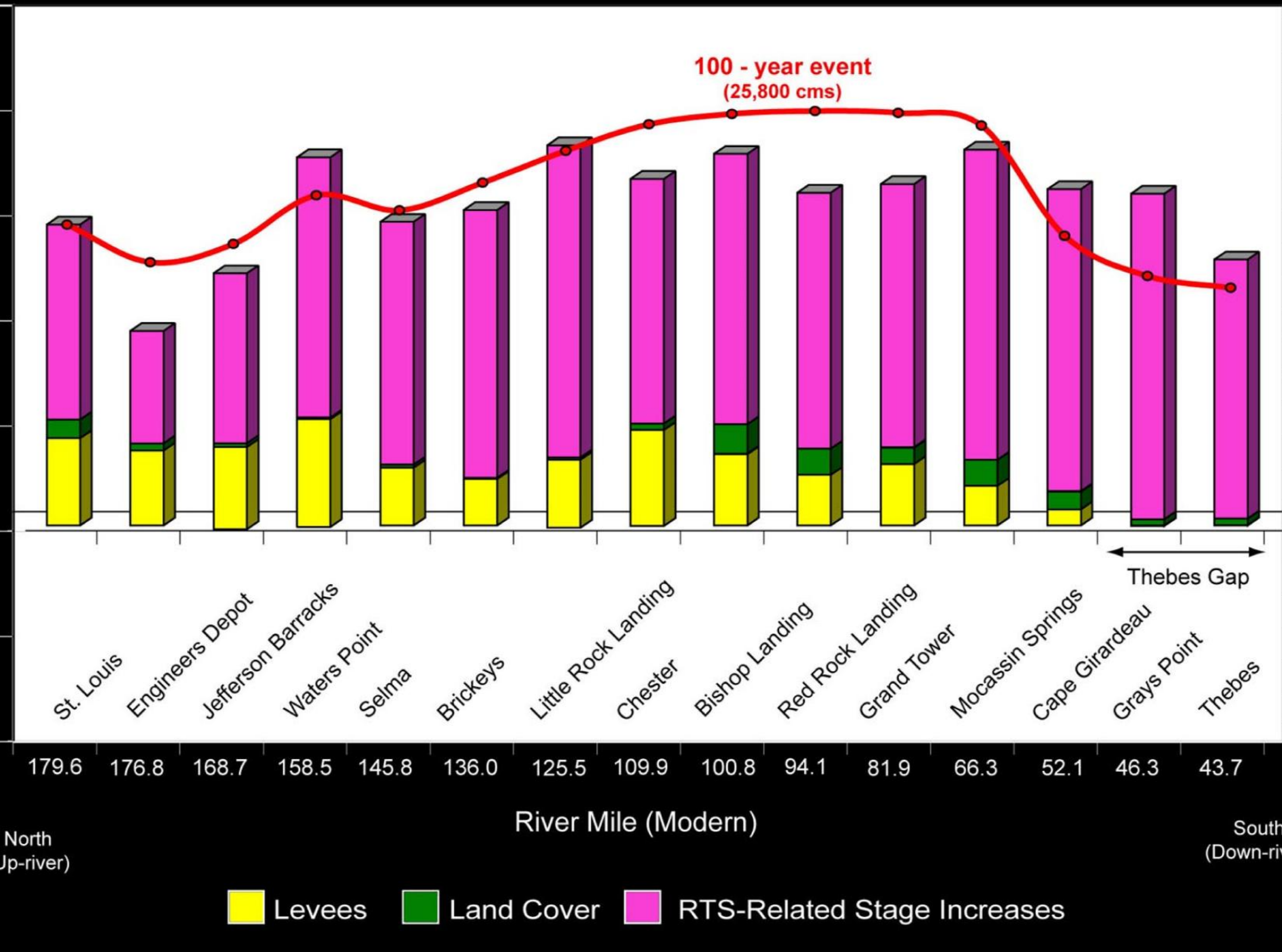
EXHIBIT
2



100 - year event
(25,800 cms)
Thebes Gap
St. Louis
Engineers Depot
Jefferson Barracks
Waters Point
Selma
Brickeys
Little Rock Landing
Chester
Bishop Landing
Red Rock Landing
Grand Tower
Mocassin Springs
Cape Girardeau
Grays Point
Thebes
179.6
176.8
168.7
158.5
145.8
136.0
125.5
109.9
100.8
94.1
81.9
66.3
52.1
46.3
43.7
River Mile (Modern)
North
(Up-river)
South
Levees
Land Cover
RTS-Related Stage Increases

EXHIBIT
3

doi:10.2489/jswc.68.4.89A

FEATURE

Impacts of 2011 Len Small levee breach on private and public Illinois lands

Kenneth R. Olson and Lois Wright Morton

Agriculture, the dominant land use of the Mississippi River Basin for more than 200 years, has substantively altered the hydrologic cycle and energy budget of the region (NPS 2012). Extensive systems of US Army Corps of Engineers (USACE) and private levees from the Upper Mississippi River near Cape Girardeau, Missouri, southward confine the river and protect low-lying agricultural lands, rural towns, and public conservation areas from flooding. The Flood of 2011 severely tested these systems of levees, challenging public officials and landowners to make difficult decisions, and led to extensive damage to crops, soils, buildings, and homes. One of these critical levees (figure 1), the Len Small, failed, creating a 1,500 m (5,000 ft) breach (figure 2) where fast-moving water scoured farmland, deposited sediment, and created gullies and a crater lake. The Len Small levee, built by the Levee and Drainage District on the southern Illinois border near Cairo to protect private and public lands from 20-year floods, is located between mile marker 21 and mile marker 35 (figure 1). It connects to Fayville levee that extends to Mississippi River mile marker 39, giving them a combined length of 34 km (22 mi) protecting 24,000 ha (60,000 ac) of farmland and public land, including the Horseshoe Lake Conservation area. The repair of the breached levee, crater lake, gullies, and sand deltas began in October of 2011 and continued for one year.

HISTORICAL GEOLOGICAL FEATURES OF THE WESTERN ALEXANDER COUNTY

The Mississippi River is a meandering river of oxbows and cutoffs, continuously eroding banks, redepositing soil, and changing paths. Its willful historic meandering is particularly apparent in western Alexander County, Illinois, where a topographical map shows swirls and curves and an oxbow lake, Horseshoe Lake, where the river once flowed south of Thebes and east of the modern day Len Small levee. The loess-covered upland hills (Fehrenbacher et al. 1986) of the Shawnee National Forest just north of Route 3 (figure 1) give way to a low-lying plain between the Mississippi and Ohio rivers. The ancient Ohio River drained through the Cache River valley during the Altonian and Woodfordian glacial advances (60,000 to 30,000 years B.P.) and converged with the Mississippi River waters just northwest of Horseshoe Lake. The Cache River valley is 3 km (1.9 mi) wide and carried a substantive flow of water from the eastern Ohio River Basin

Figure 1

Map of Alexander County, Illinois, including the Len Small levee and the northern part of the Commerce to Birds Point levee, Missouri, areas.

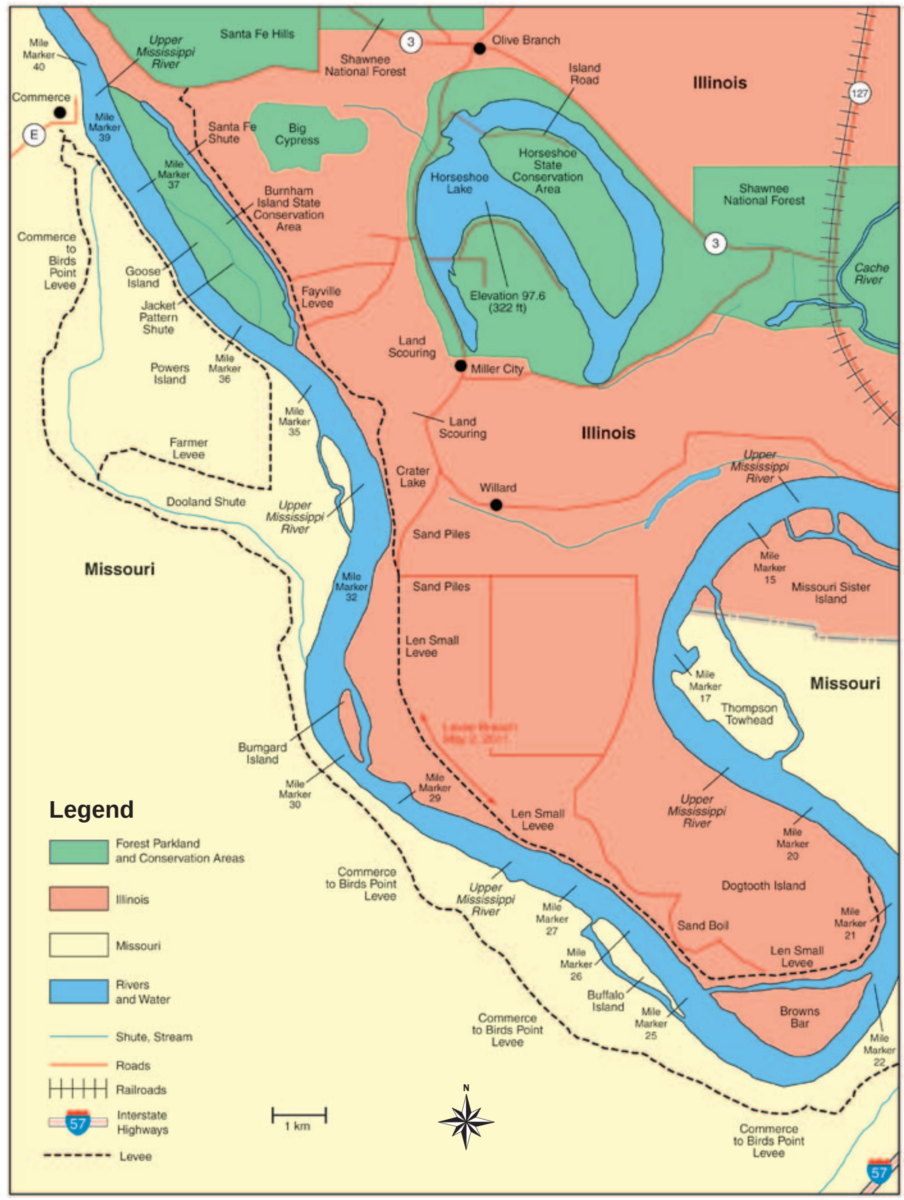


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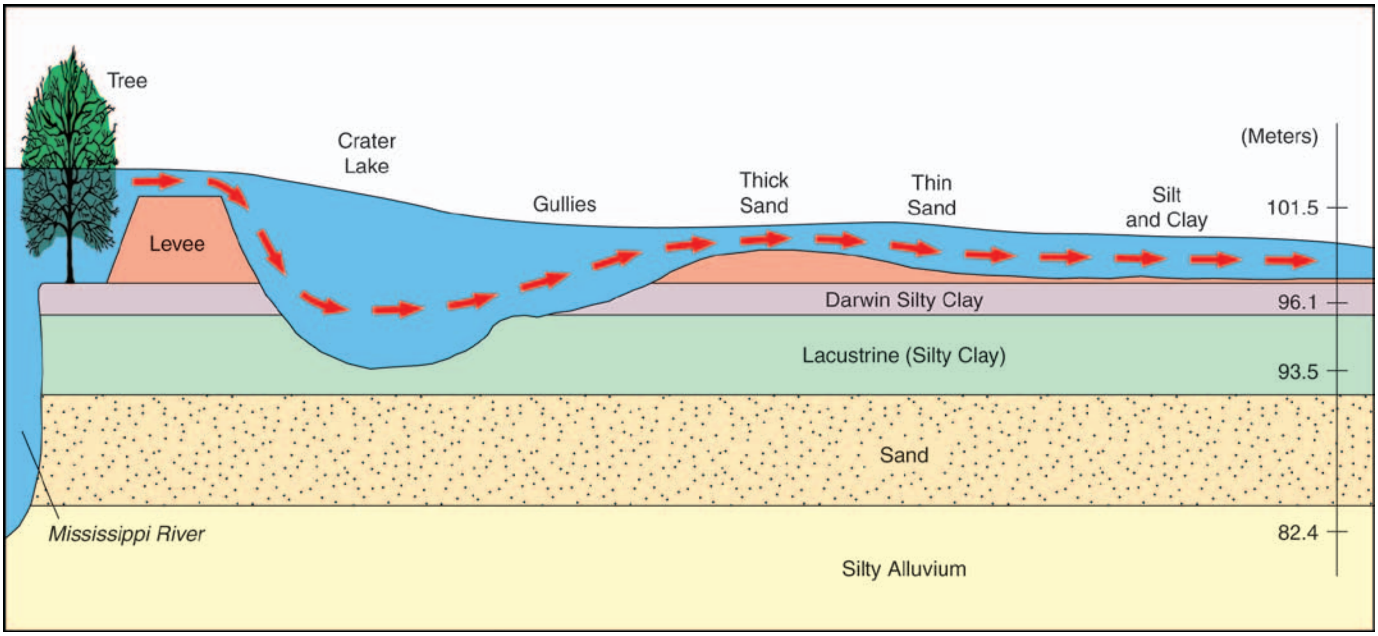
Figure 2

Diagram of Len Small levee failure and creation of crater lake, gullies, and sand delta.



in addition to the local waters from the Cache River valley into the Mississippi River valley. Historically, the region has been a delta, confluence and bottomlands dating back 30,000 to 800,000 years B.P., with many of the Illinois lands shown on the maps located on both sides of the Upper Mississippi River as its channel changed locations over time. As a result, the fertile farmland of western Alexander County soils formed in alluvial and lacustrine deposits.

Horseshoe Lake (figure 3), a former oxbow and remnant of a large meander of the Mississippi River, is now a state park of 4,080 ha (10,200 ac) (Illinois DNR 2012). This oxbow lake, formerly a wide curve in the river, resulted from continuous erosion of its concave banks and soil deposition on the convex banks. As the land between the two concave banks narrowed, it became an isolated body of water cutoff from the main river stem through lateral erosion, hydraulic action, and abrasion. With 31 km (20 mi) of shoreline, the 1.3 m (4 ft) deep lake is the northernmost natural range for Bald cypress (*Taxodium distichum* L.) and Tupelo (*Nyssa* L.) trees (figure 3) and has an extensive growth of American lotus (*Nelumbo lutea*), a perennial aquatic plant, and native southern hardwoods which grow well in lowlands and areas which are subject to seasonal flooding.

Figure 3

The bald cypress trees and American lotus at Horseshoe Lake conservation area.

The agricultural lands which surround this oxbow lake are highly productive alluvial soils —mostly Weinbach silt loam, Karnak silty clay, Sciotoville silt loam, and Alvin fine sandy loam. Almost two-thirds of the area (16,000 ha [40,000 ac]) protected by the Len Small and Fayville levees is privately owned. Corn (*Zea mays* L.), soybeans (*Glycine max* L.), and wheat (*Triticum* L.) are the primary crops, with some rice (*Oryza sativa* L.) grown in this area.

THE COMMERCE TO BIRDS POINT, CAIRO, AND WESTERN ALEXANDER COUNTY LEVEES

In early May of 2011, the floodwaters at the Ohio River flood gage in Cairo, Illinois, had reached 18.7 m (61.7 ft) (NOAA 2012). The Ohio River was 6.7 m (22 ft) above flood stage and had been causing a back-up in the Mississippi River floodwater north of the Cairo confluence prior to the USACE opening of the Birds Point–New Madrid Floodway. For more than a month, the Mississippi River back-up placed significant pressure on the Len Small and Fayville levees (figure 1). As a result, approximately 1,500 m (5,000 ft) of the Len Small levee was breached (figure 2) near mile marker 29 (figure 1) on the morning of May 2, 2011.

The flood protection offered by the Len Small and Fayville levees is important to the landowners, homeowners, and farmers in southwestern Alexander County, Illinois. However, the Len Small and Fayville levees are not the mainline levees which control the width and height of the Mississippi River. The controlling mainline levees are the frontline Cairo levee located in Illinois (Olson and Morton 2012a) and the Commerce to Birds Point levee in Missouri (figure 4). These two frontline levees, by design, are much higher and stronger than the Len Small and Fayville levees. The Len Small and Fayville levees were built by the local levee district and are not part of the Mississippi River and Tributaries project for which USACE has responsibility (figure 5). The Cairo levee has a height of 19.4 m (64 ft), or 101.4 m (334.5 ft) above sea level, and levee failure would destroy the City of Cairo. The frontline Commerce to Birds Point levee has a height of 19.8 m (65.5 ft), and its failure would result in more than 1 million ha (2.5 million ac) of agricultural bottomlands in Missouri Bootheel and Arkansas on west side of the Mississippi River being flooded (figure 5). Commerce to Birds Point levee connects to a setback levee on the west side of the Birds Point–New Madrid Floodway, which extends the protection another 51 km (33 mi) to the south where it joins the frontline levee at New Madrid, Missouri, further extending the protection of the Bootheel bottomlands (Camillo 2012; Olson and Morton, 2012a, 2012b, 2013). The failure of the Hickman (Kentucky) levee on the east side of the Mississippi River would have resulted in the flooding of 70,000 ha (170,000 ac) of protected bottomlands in Tennessee and Kentucky (figure 5). The floodwater height and pressure on the Commerce to Birds Point and Birds Point to New Madrid levees has increased over the years during Mississippi River flooding events with the construction of the Len Small and Fayville levees and with a strengthening of the levee near Hickman, Kentucky, which had the effect of narrowing the Mississippi River Floodway corridor and removing valuable floodplain storage areas for floodwaters.

Figure 4

The Commerce to Birds Point mainline US Army Corps of Engineers levee.

THE MISSISSIPPI RIVER COMMISSION AND ITS ROLE IN LEVEE CONSTRUCTION ALONG THE MISSISSIPPI RIVER AND TRIBUTARIES

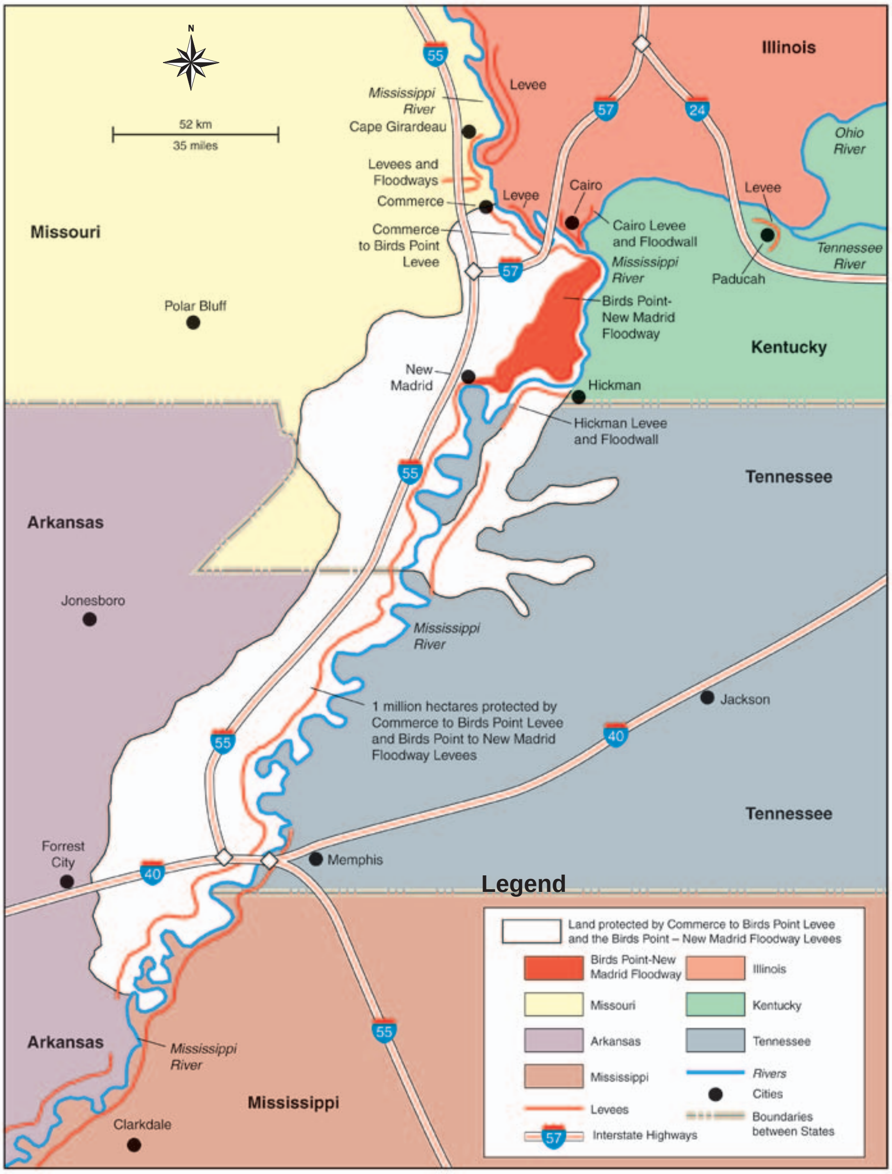
The Mississippi River Commission (MRC) was established by Congress in 1879 to combine the expertise of the USACE and civilian engineers to make the Mississippi River and tributaries a reliable shipping channel and to protect adjacent towns, cities, and agricultural lands from destructive floods (Camillo 2012). The Mississippi River Commission has a seven-member governing body. Three of the officers are from the USACE, including the chairman who is the final decision maker when it comes to decisions like opening the floodways. Another member is an Admiral from National Oceanic and Atmospheric Administration (NOAA), and the other three members are civilians, with at least two of the civilian members being civil engineers. Each member is appointed by the President of the United States. Senate confirmation is no longer necessary. The MRC is the lead federal agency responsible for addressing the improvement and maintenance of the Mississippi River and Tributaries project, including flow and transportation systems.

Between 1899 and 1907, MRC assisted local levee districts in Missouri with construction of a federal levee between Birds Point, Missouri, and Dorena, Illinois. At that time, the MCR jurisdiction was limited to the areas below the confluence of the Ohio and Mississippi rivers (Camillo 2012; Olson and Morton 2012a, 2012b), which is at the southern tip of Illinois (Fort Defiance State Park). This levee is located approximately where the current frontline levee of the Birds Point–New Madrid Floodway was constructed between 1928 and 1932 after Birds Point to Dorena levee failed in 1927.

In 1902, the MRC helped Kentucky construct a levee from the Hickman,

Figure 5

The bottomlands in Missouri and Arkansas protected by the Commerce to Birds Point mainline levee and bottomlands in Tennessee and Kentucky protected by the Hickman levee.



Kentucky, bluff to Tennessee, where it connected with another levee to extend the levee system 7.8 km (5 mi) to Slough Landings, Tennessee. During this time period, a portion of the natural floodplain near Cape Girardeau was walled off by a local Missouri levee to provide protection of farmland adjacent to the river (figure 1). These two levees narrowed the river channel and during high-water events on the Mississippi River increased floodwater back-up, placing tremendous pressure on the existing systems of levees and floodwalls above and below the Cairo confluence (Camillo 2012; Olson and Morton 2012a, 2012b).

The Commerce to Birds Point levee (figure 5) has long been considered by the MRC and the USACE to be the most critical levee in the Mississippi River valley since it protects nearly 1 million ha (2.5 million ac) of prime agricultural bottomlands in Arkansas and Missouri Bootheel. The Commerce to Birds Point levee, shown in figures 1 and 4, had two major threats (1973 and 1993) from past major flooding events. During the 1973 flood, a 455 m (1,500 ft) section of the Commerce to Birds Point levee fell into the Mississippi River. The caving extended to the top of the levee. The USACE Memphis District placed 21,600 t (18,000 tn) of riprap stone carried in by barges to prevent additional caving (Camillo 2012). The Len Small levee on the Illinois side of the Mississippi River (figure 1) and across from the Commerce to Bird Point levee, Missouri, had historically overtopped or failed during larger flooding events, thereby reducing the pressure on the Commerce to Birds Point levee. The local levee and drainage district and owners of the Len Small levee strengthened their levee during the 1980s, which increased pressure on the Commerce to Birds Point levee when the river flooded. As a result, in the 1993 flood event, the Len Small levee held and the Mississippi remained confined as it climbed to within 1 m (3 ft) of the top of the Commerce to Birds Point levee. Sand boils developed in the Commerce levee were treated until the underseepage stabilized. In 1995, USACE Memphis District raised the height and strengthened the Commerce to Birds Point levee and installed relief wells.

LOCAL AND MISSISSIPPI RIVER FLOODING OF FARMLAND AND TOWNS LOCATED IN WESTERN ALEXANDER COUNTY

The 2011 flood and record peak on the Ohio River caused the Mississippi River near the confluence to back up for many kilometers to the north and affected all bottomlands in Alexander County, Illinois, that were located on the east side of Upper Mississippi River (figure 1). Since the gradient on the Mississippi River is between 12 and 25 cm km^{-1} (0.5 to 1 ft mi^{-1}), the Mississippi River water rose an additional 5.5 m (18 ft) above the flood stage further north. This occurred at a time when the Ohio River was 6.7 m (22 ft) above flood stage and the Mississippi River north of Cape Girardeau, Missouri, was 3 m (9.9 ft) above flood stage. Cities farther to the north like St. Louis, Missouri, were only subjected to floodwaters 2 m (6.6 ft) above flood stage as a result of water flowing from the Upper Mississippi and Missouri rivers.

The May 2nd topping and breach of the Len Small levee occurred just a few hours before the pressure of record flood levels was relieved with the opening of the Birds Point–New Madrid Floodway at 10:00 p.m. Illinois farmers, landowners, and homeowners protected by the Len Small levee might have benefited if the floodway had been opened on April 28th or 29th (2011) when the first weather forecast was issued with a projected Ohio River peak level of 18.3 m (60.5 ft) or higher on the Cairo gage. This is the criteria set in 1986 USACE operational plan that needs to be met before the USACE can artificially breach the levee at Birds Point and use New Madrid Floodway to relieve river pressure and store excess floodwaters. There were a number of reasons why the USACE did not open the floodway on April 28, 2011, and waited until the evening of May 2, 2011. These reasons included the possibility that the forecasted peak would never happen and concern about the damage it would have caused to the 53,200 ha (133,000 ac) of farmland and buildings in the Birds Point–New Madrid Floodway. Consequently, the USACE continued to monitor the situation and waited a few more days before making the final decision to load the trinitrotoluene (TNT) (once loaded it would be difficult to remove if not exploded) into the Birds Point fuse plugs and blow it up on May 2, 2011 (Camillo 2012). The other reasons for the delay were the mega sand boil in Cairo, the heavy local rains in the area of the confluence of the Ohio and Mississippi rivers, and the new peak forecast of 19.2 m (63.5 ft) (Camillo 2012). All these events occurred on May 1, 2011, the day the Supreme Court rejected the Missouri Attorney General's lawsuit filed in an attempt to block the USACE from opening the Birds Point–New Madrid Floodway in an effort to protect Missouri citizens and property.

Flooding of Alexander County from the Ohio and Cache rivers resulted in some flooding in the town of Olive Branch in late April and on May 1, 2011. This was before the Len Small breach occurred on May 2, 2011, and there was some damage to private and public lands prior to the breach. Floodwater from the Mississippi River added to the local flooding caused by the middle Cache River in late April when the record high Ohio River returned to its historic path and poured through the 2002 unrepaired Karnak levee breach into the middle Cache River valley and flooded the Olive Branch and Horseshoe Lake area. These floodwaters eventually drained back into the Mississippi River near Route 3 and through the diversion near mile marker 15 (figure 1) and through the Len Small levee breach.

Figure 6

Land scouring, gullies, and erosion north of the Len Small levee breach.

As a result of Cache River valley floodwater flowing through the Karnak levee breach and the additional Mississippi River floodwaters pushing through the Len Small breach, 4,000 ha (10,000 ac) of farmlands lost the winter wheat crop or were not planted in 2011, and about half of that land (mostly Weinbach silt loam, Karnak silty clay, Sciotoville silt loam, and Alvin fine sandy loam) (Parks and Fehrenbacher 1968) had significant soil damages, including land scouring and sediment deposition, or was slow to drain. Crater lakes, land scouring (figure 6), gullies, and sand deltas were created when the Len Small levee breached and removed agricultural land from production (Olson 2009; Olson and Morton 2012b). Most of the other farmland in Alexander County dried out sufficiently to permit planting of wheat in fall of 2011. It appears that all of Alexander County soils dried sufficiently by spring of 2012 to allow the planting of corn and soybeans. It is not clear how much 2011 farm income replacement came from flood insurance since not all Alexander County, Illinois, farmers had crop insurance. In addition, roads and state facilities were impacted by floodwaters which passed through the Len Small breach.

Illinois agricultural statistics recorded that 1,800 fewer ha (4,500 ac) of corn and 2,600 less ha (6,500 ac) of soybeans were harvested in Alexander County in 2011 compared to 2010. The area produced 1,570,000 bu of corn in 2010 but only 710,000 bu in 2011. The soybean production level was 1,200,000 bu in 2010 but dropped to 865,000 bu in 2011 due to flooding, crop, and soil damage. The floodwaters also scoured the agricultural lands in some places and deposited sand at other locations.

FLOODING OF PUBLIC AND PRIVATE BOTTOMLANDS WITH AND WITHOUT LEVEE PROTECTION IN WESTERN ALEXANDER COUNTY, ILLINOIS

All bottomlands north of the confluence between the Mississippi River and the western Alexander County levees with an elevation of less than 100.7 m

(332 ft) above sea level were flooded when the Mississippi River backed up. Approximately 24,000 ha (60,000 ac) of public and private alluvial lands, both levee protected and without levees, were flooded along the east and north sides of the Mississippi River (figure 1) between mile markers 12 and 39. The 1957 to 1963 soil maps of the area show alluvial soils consisting of recently deposited sediment that varies widely in texture (from clay to sand) with stratified layers. The natural vegetation on these alluvial bottomlands ranges from recent growth of willows (*Salix* L.) and other plants to stands of cottonwood (*Populus deltoides* L.), sycamore (*Platanus occidentalis* L.), and sweet gum (*Liquidambar styraciflua* L.).

The map (figure 1) shows the public and private lands of the southwest Alexander County, Illinois, area that were impacted by the flood of 2011. Approximately one third of the area (8,000 ha [20,000 ac]) is in public lands, including uplands (the Shawnee National Forest and Santa Fe Hills) and bottomlands (Burnham Island Conservation, Horseshoe State Conservation area, Goose Island, Big Cypress, and the land adjacent to the Len Small and Fayville levees). The unleveed bottomlands and public conservation areas sustained flood damage but were more resilient than the private agricultural and urban lands inside the levees. The Mississippi bottomlands are riparian forests (transition ecosystems between the river and uplands) with fertile, fine textured clay or loam soils that are enriched by nutrients and sediments deposited during flooding (Anderson and Samargo 2007). Bottomlands that experience periodic flooding have hydrophytic plants and hardwood forests that provide valuable habitat for resident and migratory birds. The Illinois Department of Natural Resources has an extensive research program monitoring migratory birds and waterfowl at Horseshoe Lake. Although these alluvial river bottomland species are well adapted to periodic flood cycles which can last several days to a month or more (Anderson and Samargo 2007), the impact of the 2011 flood duration (2 to 4 weeks) on these wetlands habitat and woodlands has not been assessed.

Figure 7

A farmstead protected by a farmer-built levee.

There are a number of towns and villages in western Alexander County, including Olive Branch, Miller City, and Cache. Floodwaters covered roads and railroads and damaged some bridges, homes, and other building structures. In western Alexander County, floodwater destroyed 25 Illinois homes and damaged an additional 175 homes and building structures located on Wakeland silt loam and Bonnie silt loam soils (Parks and Fehrenbacher 1968) or similar alluvial floodplain soils. The Olive Branch area (figure 1) was one of the hardest hit according to Illinois Emergency Management Agency.

Agricultural and forest lands on the riverside of the Len Small levee are not protected from flooding and store significant amounts of floodwater with minimal damage to the crops such as soybeans, which can be planted later in the spring or early summer. This farmland was under water prior to planting for the entire months of April and May, 2011. After both the Ohio and Mississippi rivers dropped and drained by late June of 2011, these fields were planted to soybeans. Late May and early June is the normal planting time for soybeans in the area, so a small soybean yield reduction was noted.

REPAIR OF LEN SMALL LEVEE IN WESTERN ALEXANDER COUNTY

In the fall of 2011, local farmers and members of the Len Small Levee District patched the Len Small levee. They created a sand berm 1 m (3 ft) lower than the original levee. They hoped the USACE would cover the levee with a clay cap and restore it at least to the original height. The USACE agreed to do this in August of 2012 after receiving additional funds from Congress. The project was completed in 90 days. Some individual farmers created berms around their farmsteads (figure 7) to protect their farmsteads from any future flooding that might occur.

In June of 2012, the USACE received US$802 million in emergency Mississippi River flood-repair funding for up to 143 high-priority projects to repair levees, fix river channels, and repair other flood-control projects in response to the spring of 2011 flood, which set records from Cairo, Illinois, to the Gulf of Mexico. Both the Birds Point–New Madrid Floodway levee repair and the Cairo area restoration projects were high on the list with the USACE targeting US$46 million to repair the damage to Cairo area, including the Alexander County area flood-control systems (Camillo 2012; Olson and Morton

2012a, 2012b). Improvements were completed throughout Alexander County, including work on pump stations, drainage systems, and small levees, some of which failed in April of 2011. These projects were funded by the county matching funds with the USACE and a combination of grants from the Delta Regional Authority and the State of Illinois (Koenig 2012). The creation of a larger drainage system running through northern Alexander and Union counties included large culverts and levees designed to better protect Illinois communities such as East Cape Girardeau, McClure, Gale, and Ware, and help keep water from collecting in low-lying bottomland areas.

CONCLUSIONS

In 2011, the record Ohio River flood resulted in the USACE blasting open the Birds Point levee fuse plug as waters reached a critical height on the Cairo gage. However, this unprecedented flood level at the confluence put tremendous pressure on and under the Mississippi levees to the north in western Alexander County. The delay in the decision to blow up the Birds Point fuse plugs and frontline levees had significant consequences for rural Illinois landowners, farmers, and residents in Alexander County near the Len Small levee that failed the morning of May 2, 2011, at a time when the peak flow on the Ohio River caused the Mississippi River water to back up many kilometers to the north. Local flooding and damage to building structures, crops, and soils initially occurred in late April of 2011when the Ohio River at flood stage poured through the Post Creek cutoff and a previously unrepaired Karnak levee breach and rushed to the west through the middle Cache River valley. Consequently, the town of Olive Branch would have flooded even if the Len Small breach had not occurred. The Len Small levee situation does not seem to have been a factor in the USACE decision-making process or have affected the time of the opening of the Birds Point–New Madrid levee fuse plug. The USACE did consider the need to protect the Cairo mainline levee and floodwall and the Commerce to Birds Point main line levee from a breach, as well as potential impact on landowners in the Birds Point–New Madrid Floodway. The mega sand boil in Cairo, the heavy local rains on May 1st in the Mississippi River watershed, and the new peak forecast of 19.2 m (63.5 ft) on the Cairo gage proved opening the Floodway was the correct decision. The frontline Commerce to Birds Point levee did not fail, and more than 1 million ha (2.5 million ac) of agricultural bottomlands in Missouri Bootheel and Arkansas were protected from flooding. Even if the Birds Point–New Madrid levee had been opened four days sooner at a time when the record level floodwaters were 1.3 m (4 ft) lower, the prolonged record Mississippi River floodwater levels and pressure on the Len Small levee, which continued for weeks, would likely have still resulted in the Len Small levee breach a few days later.

ACKNOWLEDGEMENTS

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CERTIFICATE OF SERVICE

I hereby certify that on July 3, 2014, I electronically filed the Declaration of Nicholas Pinter, Ph.D. in Support of Plaintiffs' Motion for Preliminary Injunction and Exhibits 1, 2 and 3 thereto with the Clerk of the Court using the CM/ECF system which will send notification of such filings to all registered counsel participating in this case. There are no non-registered participants in this case.

Respectfully submitted,

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IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF ILLINOIS

NATIONAL WILDLIFE FEDERATION, PRAIRIE RIVERS NETWORK, MISSOURI COALITION FOR THE ENVIRONMENT, RIVER ALLIANCE OF WISCONSIN, GREAT RIVERS HABITAT ALLIANCE, and MINNESOTA CONSERVATION FEDERATION, Plaintiffs, vs. UNITED STATES ARMY CORPS OF ENGINEERS; LT. GENERAL THOMAS P. BOSTICK, Commanding General and Chief of Engineers, LT. GENERAL DUKE DELUCA, Commander of the Mississippi Valley Division of the Army Corps of Engineers, Defendants.	CASE NO. 14-00590-DRH-DGW **REPLY DECLARATION OF NICHOLAS PINTER, Ph.D. IN SUPPORT OF PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION** HEARING: TBD TIME: TBD

I, Nicholas Pinter, declare as follows:

1. The facts set forth in this Declaration are based upon my personal knowledge. If called as a witness, I could and would testify to these facts. As to those matters that present an opinion, they reflect my professional opinion and judgment on the matter. I make this Declaration in support of plaintiffs National Wildlife Federation *et al*.'s reply memorandum of points and authorities in support of their motion for preliminary injunction halting construction of any new river training structures as part of the U.S. Army Corps of Engineers' ("Corps'") management of the Upper Mississippi River System, including those planned as part of the Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield and Grand Tower projects.

2. I am a Professor in the Geology Department and Environmental Resources and Policy Program at the Southern Illinois University ("SIU"), and Director of the SIU's Integrative Graduate Education, Research and Training ("IGERT") program in "Watershed Science and Policy." I have over 20 years' experience in the fields of geology, geomorphology, fluvial geomorphology and flood hydrology. My qualifications, professional experience and background are set forth in my original June 24, 2014 (filed July 3) declaration ("Original Declaration" or "Pinter Declaration"), and Exhibit 1 thereto. Pinter Dec. ¶¶ 1-5 & Exh. 1.

<u>Documents Reviewed for this Declaration</u>

3. In preparing this Declaration, I reviewed the following documents in addition to the documents listed in paragraphs 6 and 7 of my original declaration: (1) Defendants' Opposition to Plaintiffs' Motion for a Preliminary Injunction ("Opposition Brief"), (2) the Declaration of Edward J. Brauer ("Brauer Declaration"), (3) the Declaration of Michael G. Feldman ("Feldman Declaration") and Attachments 1 and 2 thereto, and (4) the Declaration of Jody H. Schwarz in Support of Defendants' Opposition to Plaintiffs' Motion for a Preliminary Injunction ("Schwarz Declaration") and Exhibits 1 through 6 thereto.

<u>Analysis</u>

4. I was asked prior to preparing my Original Declaration to form an independent professional opinion as to whether building new river training structures, including those planned by the Corps in the Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield Bend and

Grant Tower projects, may pose a significant risk of irreparable harm to the natural environment and to people and the property of people who live, work, attend school and/or recreate in the floodplain, including by raising flood stage heights on the Mississippi River. As discussed below, my original conclusion remains the same after reviewing the Opposition Brief and the Brauer, Feldman and Schwarz declarations. I conclude that the Corps' proposed projects, and river training structures generally, *do* pose a significant risk of irreparable harm to the natural environment, human safety and human property. As discussed in detail below, neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations provides evidence that river training structures do *not* raise flood levels.

5. I was also asked prior to preparing this Reply Declaration to review the Feldman Declaration and, to the extent he discusses topics within my area of expertise, to form an independent professional opinion as to his claims regarding the benefits of river training structures and the costs of delaying or permanently tabling the Dogtooth Bend, Monsenthein/Ivory Landing and Eliza Point/Greenfield Bend projects. As discussed in detail below, I conclude after reviewing Mr. Feldman's Declaration that he overstates some of benefits of river training structures as well as the costs of delaying or permanently tabling the proposed the Dogtooth Bend, Monsenthein/Ivory Landing and Eliza Point/Greenfield projects.

A. The Information and Conclusions in My Original Declaration Remain Accurate and Unchanged.

6. As I attested in paragraph 9 of my Original Declaration, damages from floods worldwide have risen dramatically over the past 100 years (Munich Re Group, 2007). While much of this increase is due to economic development in floodplains (Pinter, 2005; Pielke, 1999), it is also clear that flooding itself has physically increased in magnitude and frequency on many rivers, including the Mississippi River. (Pinter et al., 2006a; Pinter et al., 2006b; Helms et al., 2002). Historical time series of stage data, which are unequivocally homogenous over time (Criss and Winston, 2008), show strong and statistically significant increases of flood heights on portions of

the Mississippi River over time. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations rebuts these facts.

7. As I attested in paragraph 10 of my Original Declaration, a number of processes can lead to flood magnification or otherwise alter flood response on a river. These include climate change, agricultural practices, forestry practices, urbanization and construction of other impervious surfaces, loss of wetlands, decreases in floodplain areas, construction and operation of dams, and modifications and engineering of river channels. The range of these changes can alter the volume and timing of runoff (discharge or flow of water) entering and moving through river systems. In addition, other natural or human-induced changes to river channels and their floodplains can alter the conveyance of flow within the river channel, resulting in increases or decreases in water levels (including flood stages) for the same discharge. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations rebuts these facts.

8. As I attested in paragraph 11 of my Original Declaration, the Mississippi River has been intensively engineered by the Corps over the past 50 to 150-plus years (depending on the reach), and some of these modifications are associated with large decreases in the river's capacity to convey flood flows. Numerous scientific investigations, including Corps reports, some dating back to the early 1900s or earlier, have noted large increases in flood levels in association with wing-dike construction. For example, investigators recognized as early as 1933 that "bankful [sic] carrying capacity [of the Missouri River] would be permanently reduced by existing works, such as dikes and revetments used in shaping and controlling the stream for modern barge transportation" (Hathaway, 1933 (quote); Schneiders, 1996 at 346 (same)). Harrison (1953) likewise found that at discharges greater than 50,000 cubic feet per second the "controlled [channel of the Missouri River] has [a] smaller capacity, having 35% less discharge at bankfull stage," one "principal reason" for which was the "increase in roughness" caused by "[t]raining dikes protruding into the flow." These findings that river training structures increase flood levels have been confirmed worldwide and are considered accepted knowledge elsewhere. In the Netherlands, for example, the government has begun modifying river training structures on the Rhine River to lower flood levels (U.S. Government Accountability Office, "Mississippi River: Actions Are Needed to Help Resolve

Environmental and Flooding Concerns about the Use of River Training Structures, December 2011; "GAO Report") at 41. To date, however, the Corps has never addressed in an EIS the vast body of peer-reviewed, independent research showing that river-training structures increase flood heights. *Id.* These facts are unrebutted by both the Corps in its Opposition Brief and Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations.

9. The Corps and Mr. Brauer do both contend, however, that contrary to the weight of the published studies discussed above and below, the "results of . . . independent expert external reviews all lead to the conclusion that river training structure construction has *not* resulted in an increase in flood levels." Brauer Dec. ¶ 8 (emphasis added); Opposition Brief at 13. But Mr. Brauer fails to describe or cite to the alleged "external reviews," and thus provides no evidence on which to judge his assertion. Mr. Brauer also provides no evidence refuting, among other things, the aforementioned evidence discussed in Hathaway (1933) and Schneiders (1996) that "the carrying capacity of the [Missouri] river has been decreased so materially by the [river training] work that floods have occurred at such points as Waverly, Boonville and Hermann, Mo., at lower gauge readings with smaller volumes of water than the 1929 flood stage." Mr. Brauer asserts that Schneiders (1996) does not "draw any conclusions on the impact of river training structure construction on flood levels." Brauer Dec. ¶ 12. But his assertion is directly refuted by the quoted passage from Schneiders (1996). It is only by ignoring or improperly discrediting the evidence I have cited that Mr. Brauer is able to claim that none of the "additional 11 references cited by Dr. Pinter . . . would lead the Corps to a different conclusion on the impacts of river training structure construction on flood levels and public safety than what was established in the EAs." Brauer Dec. ¶ 13.

10. Mr. Brauer and the analysis in Appendix A to the environmental assessments ("EAs") for the Dogtooth Bend, Monsenthein/Ivory Landing and Eliza Point/Greenfield projects are also wrong in concluding that 51 studies attached to the comments of the National Wildlife Federation, Izaak Walkton League of America, Missouri Coalition for the Environment, Prairie Rivers Network and Sierra Club on the draft EAs, including many of my own studies, do *not* "support[] the conclusion that flood levels have . . . been increased as a result of construction of

river training structures." Brauer Dec. ¶ 9. For example, in discrediting many of "the 51 studies provided to the Corps" as only discussing "flow frequency, physical modeling and model scale distortion [or] levee construction" rather than "the construction of river training structures and/or increases in flood levels," Mr. Brauer makes the unfounded and erroneous conclusion that any research study without "river training structure" in its title is not relevant to the effect of such structures on flood levels. Brauer Dec. ¶ 10. To the contrary, all of the topics covered by those studies are necessary for understanding the processes by which river training structures interact with flow and affect flood levels. Increases in flood frequency, for example, are merely a statistical transformation of – meaning they are essentially the same as – increases in flood levels. As discussed further below, Mr. Brauer is also wrong that the all of my research and others' studies that "link river training structures to an increase in flood levels" contains "[m]ajor errors" that "put[] into question [the studies'] conclusion that the construction of river training structures impacts flood levels and consequently public safety." Brauer Dec. ¶ 16.

11. As I attested in paragraph 12 of my Original Declaration, my research has looked extensively at the extent and causes of flood magnification, particularly on the Mississippi River. This research documents that climate, land-use changes, and river engineering have contributed to statistically significant increases in flooding along portions of the Mississippi River system. However, the most significant cause of flood height increases on the Middle Mississippi River and Lower Missouri River can be traced to the construction of wing dikes and other river training structures. Indeed, flood height increases on those river segments exceed by a factor of ten the largest possible flood-stage increases due to observed increases in climate-driven and land-cover-driven flow (e.g., Pinter et al., 2008). In addition, the large multivariate study by Pinter et al. (2010) identified the age, location, and extent of every large levee system added to the Mississippi-Lower Missouri system during the past century, documenting that levees do contribute some but not all of the observed flood-level increases on the Middle Mississippi and elsewhere (confirming modeling by Remo et al., 2009; see Exhibit 2 to my Original Declaration). As discussed further below, Mr. Brauer wrongly discredits my research and others' studies that reach similar conclusions for having allegedly "[m]ajor flaws," including "use of inaccurate early discharge," "use of

estimated daily discharge data," "statistical errors," "not counting for other physical changes within the channel," and "the use of non-observed interpolated synthetic data points."

12. As I attested in paragraph 13 of my Original Declaration, recent theoretical analysis has shown that increased flood levels caused by wing-dike construction are "consistent with basic principles of river hydro- and morphodynamics" (Huthoff et al., 2013). This study concluded that even with extremely conservative parameters used in modeling, "the net effect of wing dikes will be higher flood levels." *Id.* Mr. Brauer criticizes Huthoff et al. (2013) as having "major errors" that "lead[] to incorrect conclusions on the magnitude of change in water surface by the author." Brauer Dec. ¶ 22. Mr. Brauer is not only wrong, he overstates his own criticisms in his (Brauer and Duncan) comment letter to Journal of Hydraulic Engineering, in which Huthoff et al. (2013) was published after peer review. Huthoff et al. (2013) presents fluid dynamical calculations showing that increases in flood levels are consistent with wing-dike construction in river channels. Brauer and Duncan submitted a comment letter to the journal suggesting that Huthoff et al.'s method was "oversimplified" and "simplistic," on which Mr. Brauer bases his criticism of the paper in his declaration. Huthoff et al., however, have submitted for publication a detailed rebuttal of Brauer and Duncan's critique, concluding that "reasonable assumptions *do* lead to significant surcharges [stage increases due to wing dikes] . . . and Huthoff et al. (2013) reach the modest conclusion that wing-dike-induced stage increases 'are consistent with basic principles of river hydro- and morphodynamics'" (Huthoff et al., 2014, submitted) (emphasis added).

13. As I attested in paragraph 14 of my Original Declaration, the theoretical analysis of Huthoff et al. (2013) is supported by empirical studies that have utilized hydrologic analyses; rigorous statistics; geospatial analyses; and 1D, 2D, and 3D hydraulic modeling to confirm, empirically as well as theoretically, the potential for significant increases in flood levels in response to the dense emplacement of wing-dike structures, such as employed on the Middle Mississippi River. Among this body of research, my research group was funded by the National Science Foundation to construct two large river-related databases to rigorously test for trends in flood magnitudes over time on over 4000 kilometers (over 2400 miles) of the Mississippi and Missouri

Rivers, and to quantify the impacts on flood levels from each unit of channel and floodplain infrastructure construction or other change.

14. As I attested in paragraph 15 of my Original Declaration, our hydrologic database consists of more than 8 million discharge and river stage values, including new synthetic discharges generated for 41 stage-only stations. This hydrologic database was used to test for significant trends in discharges, stages, and ‘‘specific stages.’’ We also conducted an extensive review of the validity of using discharge data taken from different types of measurement devices (float meters vs. other types of meters). Pinter (2010) tested whether it was appropriate to utilize older discharge measurements by examining 2150 historical discharge measurements digitized from the three principal stations on the Middle Mississippi River (“MMR”), including 626 float-based discharges and 1516 meter-based discharges, and including 122 paired measurements. All statistical tests we performed demonstrated that it was appropriate to utilize both older historical discharge data and newer discharge data as those different types of measurement tools produced accurate discharge measurements.

15. Mr. Brauer asserts that our conclusion in Pinter (2010) that older and newer discharge data alike produce accurate discharge measurements is invalid because “Pinter (2010) fails to go further in comparing [the pre-1933 discharge measurements] with the post-1933 [U.S. Geological Survey (‘USGS’)] data to confirm that the two data sets can be used together.” Brauer Dec. ¶ 18. Mr. Brauer misrepresents Pinter (2010). The explicit purpose and methodology of the paper was to compare float-based discharge measurements with meter-based measurements, which the Corps has repeatedly singled out as the source of purported bias in the older discharge measurements.

16. Mr. Brauer further contends that “[e]arly discharge data collected before the implementation of standard instrumentation and procedures by the USGS in 1933 has been proven to be inaccurate (Ressegieu 1952, Dyhouse 1976, Dyhouse 1985, Dieckmann and Dyhouse 1998, Huizinga 2009, Watson el al. 2013a).” Brauer Dec. ¶ 18 (quote); Opposition Brief at 14 (same). Mr. Brauer is wrong. None of these sources prove that early discharge measurements – measurements made by the Corps’ St. Louis District – are incorrect. To the contrary, and as

outlined above, Pinter (2010) completed a detailed statistical analysis of side-by-side measurements (using velocity meters as well as floats, which is the point of contention here) and found that the early measurements are as reliable as and fully comparable with the later measurements. This conclusion reiterates the conclusions of a study in the 1970s by the Corps itself (Stevens, 1979). Mr. Brauer's purportedly dispositive citations are not analyses and provide little or no new information on this subject. Ressegieu (1952) is an internal Corps memo. Dyhouse (1976) is an opinion letter critiquing an academic study. Dyhouse (1985) is an unpublished opinion article, without any analysis. Dieckmann and Dyhouse (1998) is an intergovernmental presentation that that asserts flaws in early discharges without any supporting evidence. Huizinga (2009) and Watson et al. (2013) are both Corps-funded studies that question early discharge values without providing evidence that they are invalid. Pinter (2014) details thorough responses to Watson et al. (2013) demonstrating its shortcomings.

17. Mr. Brauer's focus on and criticism of our use of pre-1933 discharge data is further undermined by the fact that the large majority of the 67 stations analyzed in Pinter et al. (2008, 2010) utilized only the later, post-1933 USGS discharge values. Analyses of these numerous USGS-only measurement gages show stage increases fully consistent with gages consisting of both early and later measurements.

18. In addition to Mr. Brauer's erroneous claims that much of our hydrologic data is too early to be accurate, he also wrongly contends that our hydrologic database and subsequent analyses are flawed because they "use . . . daily discharge data" and data "fabricated using interpolation schemes." Brauer Dec. ¶¶ 19 (first quote), 20 (second quote); Opposition Brief at 14 (same). I rebut each of these two erroneous claims in turn below.

19. Mr. Brauer asserts that a "major error in Dr. Pinter's analyses is the use of daily discharge data." Brauer Dec. ¶ 19. Our use of daily discharge data is not in error. Daily discharge values are published and used by the Corps, USGS and many other agencies and scientists worldwide, and are the accepted technical standard for a wide range of analyses and modeling, including by the Corps. With specific respect to their use in determining flood-level trends, daily discharge values (derived from daily stage measurements, combined with accepted rating curves)

produce the same overall results as do the much more limited number of direct measurements. Disqualifying all Corps and USGS daily discharge datasets as Mr. Brauer suggests would do *nothing* to prove that flood level trends have not increased. Instead of demonstrating some contrary trend, disqualifying these datasets would merely reduce the number of discharge values and thereby lower the statistical significance of the increasing flood level trends already found (see Pinter, 2014).

20. Mr. Brauer claims that a "majority of the hydrologic data" in our hydrologic database "(data at 49 of the 67 stations on the Mississippi River and Lower Missouri River) were fabricated using interpolation schemes developed by Jemberie et al. (2008), and they are not real data points." Brauer Dec. ¶ 20. Mr. Brauer misrepresents the data used in Jemberie et al. (2008). That study created a numerical algorithm for utilizing nearby stations and the year-to-year pattern of hydrologic behavior in order to interpolate the shape of trends for the largest flows, which occur only every few years. As Jemberie et al. (2008) makes clear, the overall trends and conclusions therefrom are determined only by the *measured* values in *large flood years*, which are most events for assessing the relationship between flood stage and river training structures. The *interpolations* based on measurements for smaller floods help suggest the likely patterns during the *intervening years*. Jemberie et al. (2008) also uses flow measurements from nearby stations to infer discharges during select years, which improves the accuracy of the overall data. For example, one station may lack direct flood measurements in 1940, but another station just a few miles upstream may have full measurements for that year. On a river as large as the MMR, neighboring sites have nearly identical flows. Jemberie et al. (2008) creates these neighboring discharge estimates by scaling each site proportional to its drainage basin area, and explicitly excluding any pair of measurement sites separated by a major tributary input. Jemberie et al. (2008) and its discharge data and estimates are methodologically sound. Mr. Brauer offers no specifics to show otherwise, or demonstrate any flaws in our use of the study's data.

21. As I attested in paragraph 16 of my Original Declaration, we developed a geospatial database alongside our hydrologic database. Our geospatial database consists of the locations, emplacement dates, and physical characteristics of over 15,000 structural features constructed along

the study rivers over the past 100 to 150 years. In developing this database we utilized: more than 4000 individual map and survey sheets; structure-history databases from six Corps Districts; databases from other agencies including the Coast Guard; and archival maps and surveys, all digitized and calibrated into a modern coordinate system and frame of reference. Within this database we parameterized 130 bridges, 54 dam structures, 25 artificial meander cut-offs, 1093 levees, and 13,231 wing-dam segments, among many other structures. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations disputes these facts.

22. As I attested in paragraph 17 of my Original Declaration, we used our hydrologic and geospatial databases together to generate reach-scale statistical models of hydrologic response. These models quantify changes in flood levels at each station in response to construction of wing dikes, bendway weirs, meander cutoffs, navigational dams, bridges, and other river modifications. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations disputes these facts.

23. As I attested in paragraph 18 of my Original Declaration, our analyses show that while climate and other land-use changes did lead to increased flows, *the largest and most pervasive contributors to increased flooding on the Mississippi River system were wing dikes and related navigational structures*. In contrast, large reaches of the Mississippi and Missouri Rivers with little or no dike construction showed *no* significant increases in flood levels. System-wide, the hydrologic pattern was that large-scale increases in flood levels occurred when and where large numbers of dikes and dike-like structures have been built. Progressive levee construction was the second largest contributor. While, as discussed elsewhere in this Declaration, the Corps and Mr. Brauer make several erroneous criticisms of our hydrologic data and analyses thereof, they do not contend that we did not make the stated conclusions from our analyses.

24. As I attested in paragraph 19 of my Original Declaration, our analyses demonstrate that wing dikes constructed downstream of a location were associated with increases in flood height ("stage"), consistent with backwater effects upstream of these structures. Backwater effects are the rise in surface elevation of flowing water upstream from, and as a result of, an obstruction to water

flow. These backwater effects were clearly distinguishable from the effects of upstream dikes, which triggered simultaneous incision and conveyance loss at sites downstream. On the Upper Mississippi River, for example, stages increased more than four inches for each 3,281 feet of wing dike built within 20 RM (river miles) downstream. These values represent parameter estimates and associated uncertainties for relationships significant at the 95 percent confidence level in each reach-scale model. The 95-percent level indicates at least a 95% level of certainty in correlation or other statistical benchmark presented, and is considered by scientists to represent a statistically verified standard. Our study demonstrated that the presence of river training structures can cause large increases in flood stage. For example, at Dubuque, Iowa, roughly 8.7 linear miles of downstream wing dikes were constructed between 1892 and 1928, and were associated with a nearly five-foot increase in stage. In the area affected by the 2008 Upper Mississippi flood, more than six feet of the flood crest is linked to navigational and flood-control engineering. While, as discussed elsewhere in this Declaration, the Corps and Mr. Brauer make several erroneous criticisms of our hydrologic data and analyses thereof, they do not contend that we did not make the stated conclusions from our analyses.

25. In addition, the Corps and Mr. Brauer wrongly contend that my Original Declaration is "fatally flawed" because I "discuss[] [my and others' research on] many rivers and river reaches [not on the MMR] in an attempt to imply that dikes on the MMR . . . are increasing flood levels." Opposition Brief at 14 (first quote); Brauer Dec. ¶ 24(a) (second quote). Different reaches of the Mississippi River do vary in some of their characteristics, but the same laws of physics apply to the MMR as to the other rivers and river reaches I discuss and allow for valid comparisons. Contrary to the Corps' and Mr. Brauer's opposite contention, understanding the impacts of Middle Mississippi River training structures can *not* be limited to looking only at the Middle Mississippi River. Understanding how different rivers and river reaches are managed (e.g., whether river training structures are used) and the resulting impacts from those management practices are *critical* to assessing how river training structures impact flood stage height. Our research and studies by other researchers show that while there are little or no increasing flood trends on stretches of the Mississippi and other rivers with few or no river training structures, there are large increases in

flood trends at locations (like on the MMR) where and at times when many new river training structures are built.

26. As I attested in paragraph 20 of my Original Declaration, more than 143 linear miles of wing dikes have been constructed on the Middle Mississippi River over the past 100 years (Remo and Pinter 2007; Remo et al. 2008). This represents about 3,960 feet of wing dikes per mile (or about 2,460 feet per kilometer) of channel. Wing dikes have also been heavily utilized on the Lower Missouri River, with over 383 linear miles constructed since 1890. This represents nearly 3,700 feet of wing dike per mile (or about 2,300 feet per kilometer) of channel in the Lower Mississippi River. These and similar river training structures are utilized to assist in river bank protection and stimulate channel scour which can reduce the amount of dredging required to maintain adequate navigation depths (e.g. COPRI 2012). Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations rebuts these facts.

27. As I attested in paragraph 21 of my Original Declaration, the effects of wing dikes and other structures during flooding should not be confused with effects during periods of low flow. There is general agreement that during low in-channel flows, wing dikes lead to lowered water levels at most locations. This happens because the dikes cause channel incision, in which flow removes sediment from the stream bed and ultimately establishes a lower bed elevation. Channel incision is a process that has been well documented after dike construction in many (but not all) areas of the alluvial Mississippi and Missouri Rivers (e.g., Pinter and Heine 2005; Maher 1964). Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations rebuts these facts.

28. As I attested in paragraph 22 of my Original Declaration, incision has caused water levels during periods of low flow (not floods) to decrease over time at the St. Louis, Chester, and Thebes measurement stations, as well as at other, intermediate locations. For all flood flows (flows equal to four or more times the average annual discharge level), however, water levels have increased *by three to ten feet or more* at all of these locations along the MMR. At Grand Tower, Illinois, water levels for just average flows have increased by almost three feet due to dike and weir construction. Near Grand Tower, bedrock underlies parts of the Middle Mississippi channel and

limits incision (Jemberie et al. 2008). The majority of these facts are unrebutted by both the Corps in its Opposition Brief and Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations. However, as discussed and rebutted below, Mr. Brauer erroneously claims that there is no bedrock near the proposed Grand Tower project location. Brauer Dec. ¶ 24(g).

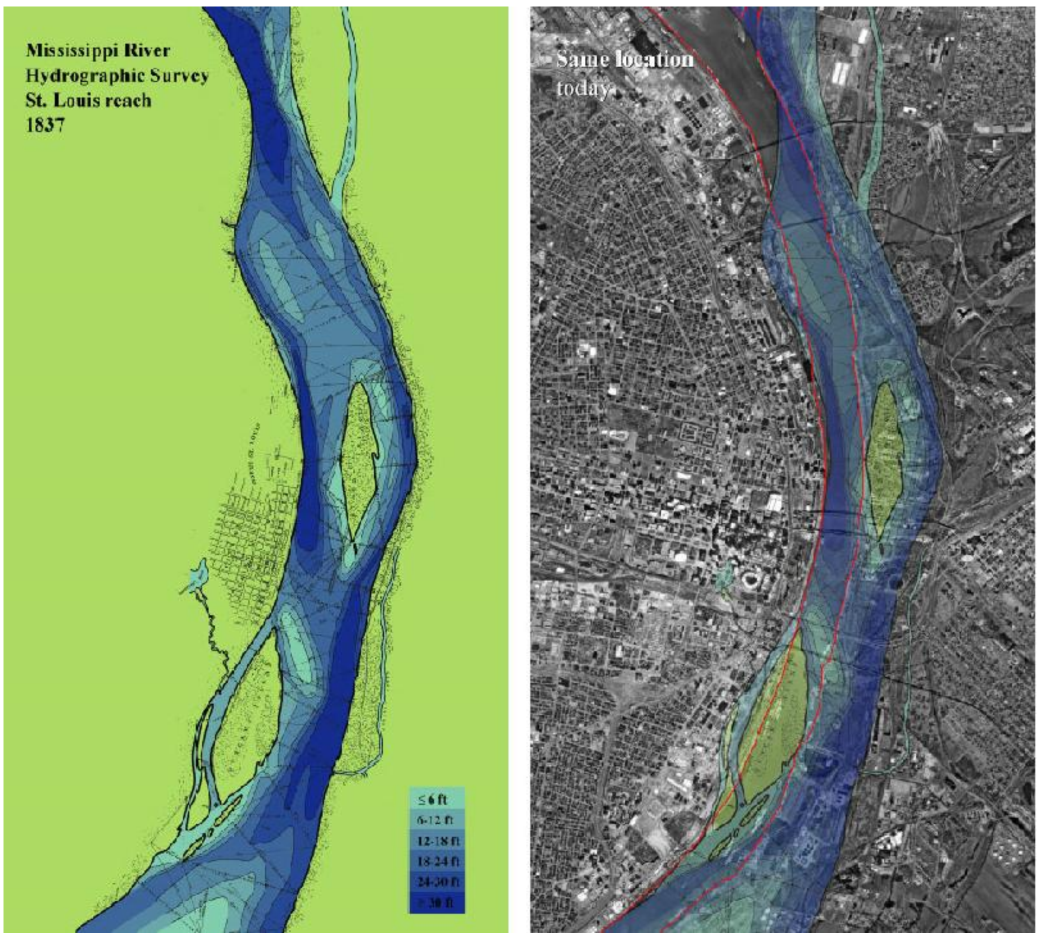
29. As I attested in paragraph 23 of my Original Declaration, many other studies confirm and corroborate these findings on the flow-dependent effects of river training structures. Particularly after the record-breaking floods on the Middle Mississippi, researchers sought to answer why such large increases in flood levels had occurred for the same discharges (volumes of flow) that had been observed in the past. (e.g., Belt 1975; Stevens et al. 1975). Since then, multiple studies involving hydrologic time-series analyses, statistical analyses, geospatial analyses, and hydraulic modeling have correlated the timing and spatial distribution of dike construction with increases in flood stages (e.g., Criss and Shock 2001; Wasklewicz et al. 2004; Jemberie et al. 2008; Pinter et al. 2008; Remo et al. 2009; Pinter et al. 2010, and others).

30. As I attested in paragraph 24 of my Original Declaration, wing dikes and other river training structures increase flood heights during high water because of the way they interact with river flow and the way they change the shape and form of the river channel. Since the beginning of historical "training" (engineering of the river to facilitate navigation) of the Mississippi and Missouri rivers, construction of dikes has narrowed large portions of these river channels to one-half or less of their original width. In addition, construction of dikes, bendway weirs, and other in-channel navigational structures has increased the "roughness" of the channel, leading to decreased flow velocities during floods.

31. Mr. Brauer responds by suggesting that I "may be referring to a river other than the MMR" in my statement that dike construction on the Mississippi and Missouri rivers has narrowed large portions of their channels to one-half or less of their original width. Brauer Dec. ¶ 24(c). I am not. And my original statement is correct. Wing dikes can reduce flow conveyance during floods and thereby increase flood levels either by reducing a river's cross-sectional area, by increasing the roughness of the channel or both. Extensive width reductions occurred on the MMR

during the late 19th and early 20th centuries, with little long-term change thereafter. As shown by Figure 1 below, some portions of the MMR were narrowed to half or less of their original width.

Figure 1. Mississippi River at St. Louis, as surveyed by Robert E. Lee in 1837 (left), and compared with the modern width of the channel (right). The original survey has been superimposed on the right panel. The current channel is shown by the red lines on the right panel. The red-lined channel boundaries shown in the right panel demonstrate that, indeed, this portion of the MMR is half or less the width today as it was in 1837. Historical channel geometry, including depths, digitized from original survey maps.



32. Mr. Brauer also asserts that although the MMR channel "has been narrowed due to river training structure construction," studies "have shown (Maher 1964, Biedenharn et al. 2000)" that "the cross sectional area of the deeper channel is preserved and the [channel's] ability to pass flow (conveyance) is the same or in some cases increased." Brauer Dec. ¶ 24(c). He claims that

"[f]ield data taken on the MMR have shown that the narrower and deeper channel will have the same cross sectional area and average velocity as before the placement of the structure." Brauer Dec. ¶ 14. But his assertion contradicts published analyses demonstrating that the actual response of the MMR to river training structures over time has been a reduction in both cross-sectional area and velocity during large flood events due to, among other things, increased channel "roughness" (e.g. Pinter et al., 2000; Remo et al., 2009). Mr. Brauer's contention that the MMR channel's conveyance has either remained the same or increased is true only for *small non-flood* flows.

33. As I attested in paragraph 25 of my Original Declaration, channel roughness is a measure of objects and processes that cumulatively resist the flow of water through a given reach of a river, including drag effects of sedimentary grains, bedforms (e.g., ripples and dunes on the bed), vegetation, turbulence, eddy circulation, and many others. A rough river bed exerts more resistance than a smooth river bed, resulting in slower flow of water. All other factors being equal, a flood that passes through a river reach with half the average flow velocity will result in average water depths that are double what they would otherwise be. Mr. Brauer claims that my "description of the relationship between velocity and depth" is "oversimplified and misleading" because in "rivers that are natural, compound channels, all factors are not equal." Brauer Dec. ¶ 24(d). But Mr. Brauer ignores the fact that the velocity-depth relationship I describe is a physical law of hydrodynamics. Before analyzing how other factors affect that relationship, it is essential to start with a description and understanding of first principles, which is precisely what I have done.

34. As I attested in paragraph 26 of my Original Declaration, recent modeling studies demonstrate the significant effects of river training structures during flood events on flow turbulence and large-scale vertical and horizontal eddy circulation (Huthoff et al., 2013). Other recent studies have focused on flow dynamics around submerged wing dikes and their impact on channel flow resistance (e.g., Yossef 2005; Yossef and de Vriend 2011; Azinfar and Kells 2011). These studies show that submerged wing dikes create flow mixing in their wake zones (e.g., Yossef 2005; Yeo and Kang 2009; Jamieson et al. 2011). These recirculating flows consume energy from the bulk flow field, causing increases in effective resistance near wing dikes and through wing-dike fields. The impact of wing dikes on flow resistance was quantified by Yossef (2004, 2005), whose

proposed relationship allows for an initial assessment of wing-dike impact on water levels (e.g., Azinfar 2010). According to Yossef's laboratory experiments, the effective cumulative hydraulic roughness of the bank zone relates to the size and longitudinal distance between the wing dikes.

35. Neither the Corps nor Mr. Brauer disputes that river training structures cause flow resistance. Brauer Dec. ¶ 24(e). Mr. Brauer does, however, contend that "the flow resistance is greatest at stages in which the dikes are the least submerged (stages below flood stages)." *Id*. Mr. Brauer's contention states his interpretation of hydraulic theory; in fact no laboratory, numerical, or field study has comprehensively tested if such a relationship exists or quantified how the depth of flow over overtopped dikes alters the effective resistance. Contrary to such theory, empirical studies show that the stage increases caused by new wing dike fields are proportionally greater for larger flows (e.g., Belt 1975; Criss and Shock 2001; Wasklewicz et al. 2004; Jemberie et al. 2008; Pinter et al. 2008; Remo et al. 2009; Pinter et al. 2010, and others). Additional data-based research is needed to reconcile hydraulic theory with observations. Reasonable hypotheses for the observed pattern include effects of flow velocity, which increases dramatically with increasing discharge, on net resistance. The Corps and Mr. Brauer consistently turn the scientific method on its head by beginning with a conclusion – the assumption that river training structures do not increase flood levels – and fashioning arguments to fit that assumption.

36. The Corps and Mr. Brauer also attempt to discount the applicability of a small subset of the studies demonstrating that river training structures increase channel roughness, reduce conveyance and increase flood stage levels on the grounds that they are "fixed bed physical flume studies (Azinfar and Kells 2009, 2008, 2007, and Azinfar 2010)." Brauer Dec. ¶ 23 (quote); Opposition Brief at 14. But they ignore the fact that experimental studies in controlled circumstances are still relevant evidence that river training structures can increase flood stage heights, along with hydrologic analyses, statistical analyses, geospatial analyses, fluid dynamical calculations, and 1D, 2D and 3D hydraulic modeling. Each of these types of research has its advantages and limitations, which is why accurate scientific synthesis looks at the conclusions from the full corpus of scientific research. Fixed-bed physical models are imperfect simulations of water flow over river training structures, but they are nonetheless relevant. Indeed, physical modeling

like that done in the Azinfar and Azinfar and Kells studies that the Corps and Mr. Brauer criticize as irrelevant is the *primary tool* used by the Corps' St. Louis District, albeit with a sedimentary bed, for the design and prototyping of all new river training structures.

37. As I attested in paragraph 27 of my Original Declaration, the role of river training structures in increasing flood heights is well recognized. For example, in the Netherlands, the impacts of wing dikes (navigational "groynes") on flood levels have both been recognized and taken into account in flood protection strategies. The government of the Netherlands recently completed a €45 million program to lower 450 wing dikes (groynes) on the Rhine system as part of its strategy to reduce flood levels.

38. Mr. Brauer questions the relevancy of the Dutch example to the Mississippi River, contending that the "structures used on the MMR are much different in size, spacing, and top elevation than those used by the Dutch." Brauer Dec. ¶ 24(f). Yet while Dutch groynes do differ from MMR dikes in some details, Mr. Brauer fails to cite a single study showing that the Dutch groynes are more likely to cause flood stage increases that the MMR dikes.

39. As I attested in paragraph 28 of my Original Declaration, changes in channel geometry and roughness related to river engineering tools employed for improved navigation and flood control appear to be the principal drivers behind changes in flood stage on the Mississippi River. The increases in flood stage are caused by both the direct effects of wing dikes, meaning interaction with flow, and the indirect effects of wing dikes, meaning the effects of the wing dike in changing the shape or form of the river bed. Hydrodynamic simulations of indirect and direct effects of wing dikes show decreases in velocity, increases in roughness, and corresponding increases in flood stage. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations specifically addresses paragraph 28 of my Original Declaration. I rebut elsewhere in this Declaration the Corps' and Mr. Brauer's general criticisms of my research and the other studies supporting my conclusion that river training structures increase flood stage heights and that the new dike construction projects here – at Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield Bend, and Grand Tower – will do the same and threaten public safety.

40. As I attested in paragraph 29 of my Original Declaration, river training structures constructed by the Corps to help maintain the nine-foot navigation channel have caused large-scale increases in flood levels, including increases of six to ten feet over broad stretches of the river where these structures are prevalent. Such large increases in flood heights in these rivers have occurred when and where – and only when and where – wing dikes, bendway weirs, and other river training structures have been built. These structures have led to significant increases in the frequency and magnitude of large floods. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations specifically addresses paragraph 29 of my Original Declaration. I rebut elsewhere in this Declaration the Corps' and Mr. Brauer's general criticisms of my research and the other studies supporting my conclusion that river training structures increase flood stage heights and that the new dike construction projects here – at Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield Bend, and Grand Tower – will do the same and threaten public safety.

41. As I attested in paragraph 30 of my Original Declaration, the projects now proposed on the Middle Mississippi River are particularly problematic for several reasons. First, as mentioned above, bedrock underlies parts of the Middle Mississippi channel near the Grand Tower project, which limits incision (Jemberie et al. 2008). In such locations, the ameliorating effect of new wing dikes in causing bed incision is reduced or eliminated, leading in the past to the largest observed increases in flood levels.

42. Mr. Brauer asserts that "[t]here is no support for the claim by Dr. Pinter" that there is bedrock underlying parts of the channel near the Grand Tower Project. Brauer Dec. ¶ 24(g). He contends that the "nearest bedrock formation (at an elevation capable of having an impact) to the Grand Tower work area is approximately five and a half miles upstream and over twenty miles downstream." *Id*. Mr. Brauer is wrong. Bedrock *is* present in this river reach, and it is alarming that the Corps' St. Louis District has designed and modeled (in their table-top physical model) the proposed new Grand Tower dikes in apparent ignorance of such a fundamental and important characteristic of the MMR channel. Specifically, historical surveys show that bedrock crops out at the channel-bottom surface, or in the shallow subsurface just beneath, forming a ledge along the

western margin of the channel around river mile ("RM") 68.7, and between RM 70.0-70.3 and RM 71.1-72.7 – *i.e.* through a significant portion of the Grand Tower project area. Mr. Brauer contends to the contrary that "bed samples taken in the Grand Tower reach confirm that the bed material is a combination of medium to coarse sands and pebbles up to one inch in diameter." *Id*. He is mistaken. In a river like the MMR, which transports an active sedimentary bed load at all times throughout its length, isolated channel grab samples will *always* yield sand and gravel, even on river reaches with an underlying bedrock substrate. Such samples in no way "confirm" that the channel is only underlain by sediment.

43. The presence of bedrock in the Grand Tower project area helps explain why observed flood stage increases have been so severe along this portion of the MMR. As discussed above, new wing dikes raise flood levels, but they also induce scour of the bed, which creates additional cross-sectional area within the central portion of the channel and reduces the net increases. However, where, as in the section of the MMR in the Grand Tower project area, a bedrock substrate inhibits scour, there is less or no cross-sectional area increase to reduce the flood stage increases. In these circumstances, the risk of large flood stage increases and the corresponding risk to public safety are at their peak.

44. As I attested in paragraph 31 of my Original Declaration, the new dike construction projects now proposed on the Middle Mississippi are also problematic because they threaten nearby levees that already have identified deficiencies. The Dogtooth Bend Project is immediately downstream of one of the sites where the Len Small levee failed during floods in 2011 (Dogtooth Bend EA at E2). This 5,000-foot breach yielded to fast-moving water that "scored farmland, deposited sediment, and created gullies and a crater lake" (K.R. Olson and L.W. Morton, "Impacts of 2011 Len Small levee breach on private and public Illinois lands," *Journal of Soil and Water Conservation*, Vol. 68:4, attached as Exhibit 3 to my Original Declaration). Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations rebuts these facts.

45. As I attested in paragraph 32 of my Original Declaration, the proposed Grand Tower project spans approximately 7 River Miles along the Big Five Levee Drainage and Levee Districts,

including the Preston, Clear Creek, East Cape, and Miller Pond levees, together protecting over 49,000 acres of Illinois floodplain. The proposed Grand Tower wing dike project also lies just downstream of the Degognia/Fountain Bluff and Grand Tower Drainage and Levee Districts, protecting a further 56,000 acres. Currently, all segments of these levee systems have "Unacceptable" ratings following Corps inspections and assessment. The Dogtooth Bend Project likewise poses an unusually high potential for flood damage. The Cairo levee system ("Mississippi and Ohio Rivers Levee System at Cairo & Vicinity") is located a few miles downstream of the Dogtooth Bend Project. Although the greatest effects of wing dikes occur upstream, statistically significant increases in flood levels have also been identified downstream. Corps inspections have identified major deficiencies in the Cairo levee system, leading to its current "Unacceptable" rating in the National Levee Database. The majority of these facts are unrebutted by both the Corps in its Opposition Brief and Mr. Brauer, Mr. Feldman and Ms. Schwarz in their declarations.

46. The one thing in paragraph 32 of my Original Declaration that Mr. Brauer disputes is my conclusion that statistically significant increases in flood levels have also been identified downstream. Brauer Dec. ¶ 24(b). My conclusion is based on two of my published studies, Pinter et al. (2008) and (2010), which identify both large increases in flood levels *upstream* of new river training structures and smaller, but statistically significant, increases *downstream* of new structures. Mr. Brauer declares this to be impossible, but he bases his opinion solely on his interpretation of hydraulic theory, not any published research. In fact, turbulence and eddy circulation downstream of wing dikes represent a plausible mechanism for empirical increases in flood stages after dike construction. Mr. Brauer cannot wish away observed empirical trends based on his understanding of hydraulic theory.

47. As I attested in paragraph 33 of my Original Declaration, my work with local levee commissioners and other informed officials has revealed deep concern and widespread discussion about levee safety and performance during future floods, even without additional stresses. For at least the past decade, local stakeholders have repeatedly called for the St. Louis District of the Corps of Engineers to rigorously and independently assess the cumulative impacts of wing-dike construction in the Middle Mississippi River. Instead, a new wave of dike construction has been

undertaken, with each new project evaluated – perfunctorily – on an individual basis and without regard to cumulative effects. Neither the Corps in its Opposition Brief nor Mr. Brauer, Mr. Feldman or Ms. Schwarz in their declarations rebuts these facts.

B. Reply to the Feldman Declaration

48. As discussed in detail below, I conclude after reviewing the Feldman Declaration that Mr. Feldman overstates some of benefits of river training structures as well as the costs of delaying or permanently tabling the proposed the Dogtooth Bend, Monsenthein/Ivory Landing and Eliza Point/Greenfield projects.

49. Mr. Feldman asserts that "under the Upper Mississippi River Biological Opinion issued by the U.S. Fish and Wildlife Service and the Upper Mississippi River Restoration-Environmental Management Program, new river training structures are constructed for the purpose of providing environmental benefits for fish and wildlife." Feldman Dec. ¶ 4. Yet little or no benefit of river training structures to endangered fish species on the MMR has ever been demonstrated. The Corps has touted many of its navigational dike projects as having environmental benefits (*e.g.* DuBowy, P.J., 2012 and cover of same magazine issue), but rigorous monitoring has shown no actual species benefits associated with these activities (e.g., Papanicolaou et al., 2011).

50. Mr. Feldman claims that, "[a]s the Mississippi River is a dynamic system due to natural variances that affect sedimentation, impacts associated with delay of not awarding the contracts or constructing the features provided in those contracts will increase the length of that delay." Feldman Dec. ¶ 8. Mr. Feldman is mistaken that any large change in the Mississippi River's sediment flux or geomorphic conditions would occur if the proposed river training structure projects are delayed. For many decades, the Corps' St. Louis District has maintained the 9-foot navigation channel through dredging. In the absence of new river training structures, the Corps could continue to maintain the navigation channel through dredging. And outside factors being equal, no large change in the river's sediment flux would occur, nor, contrary to Mr. Feldman's conclusion, would there be any increased costs due to sediment accumulation.

51. Mr. Feldman contends that "[s]ignificant delays in awarding contracts and/or not constructing any new training structures will delay the overall Regulating Works Project completion date." Feldman Dec. ¶ 17. But in assuming that the construction of additional river training structures could eliminate the need for future dredging, Mr. Feldman ignores growing anecdotal evidence suggesting that recent river training structure construction is largely just *shifting locations* of the required dredging instead of *reducing* or *eliminating* the *long-term need* for dredging.

52. Mr. Feldman asserts that the "benefit to cost ratio for the Regulating Works Project construction completion is 18 to 1," and that the project "is one of the most valuable projects in the nation in terms of returns on investment." Feldman Dec. ¶ 17. But Mr. Feldman's claim is based on the erroneous assumption that new river training structures have zero impact on flood levels. As discussed thoroughly above and in my Original Declaration, and as document by Pinter et al. (2012), even small increases in flood levels cause large increases in flood risk that can overwhelm any purported cost-savings from reduced dredging. Furthermore, as just discussed, Mr. Feldman ignores the growing anecdotal evidence suggesting that recent river training structure construction is largely just shifting locations of the required dredging instead of reducing or eliminating the long-term need for dredging.

Conclusion

53. The new dike construction projects here – at Dogtooth Bend, Monsenthein/Ivory Landing, Eliza Point/Greenfield Bend, and Grand Tower – pose significant threats of increased flooding and flood risk. They are the latest manifestations of a flawed process that has allowed construction of hundreds of new dikes and dike-like structures that are causing elevated flood stages throughout the Middle Mississippi River. Unless these new dike construction projects are halted to allow their reconsideration based on a comprehensive and independent Supplemental Environmental Impact Statement that takes the foregoing studies and analyses into consideration, needless and potentially severe flooding will likely occur. The costs of halting the projects would be much less than Mr. Feldman claims in his declaration. Indeed, halting the projects would

significantly reduce taxpayer expenditures – along with societal and environmental hardship – by reducing long-term flood risk and flood damages.

54. I declare under penalty of perjury that the foregoing facts are true of my personal knowledge, that the foregoing expressions of professional judgment are honestly held in good faith, that I am competent to and if called would so testify, and that I executed this declaration on August 13, 2014 in Chicago, Illinois.

Nicholas Pinter

Nicholas Pinter, Ph.D

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CERTIFICATE OF SERVICE

I hereby certify that on August 13, 2014, I electronically filed the Reply Declaration of Nicholas Pinter, Ph.D. in Support of Plaintiffs' Motion for Preliminary Injunction with the Clerk of the Court using the CM/ECF system which will send notification of such filings to all registered counsel participating in this case. There are no non-registered participants in this case.

Respectfully submitted,

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Attachment F

to the

Comments of the Conservation Organizations on the Grand Tower EA

Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model

Stephen T. Maynord, A.M.ASCE[1]

Abstract: The micromodel is an extremely small physical river model having a movable bed, varying discharge, and numerous innovations to achieve quick answers to river engineering problems. In addition to its size being as small as 4 cm in channel width, the vertical scale distortion up to 20, Froude number exaggeration up to 3.7, and no correspondence of stage in model and prototype, place the micromodel in a category by itself. The writer was assigned to evaluate the micromodel's capabilities and limitations to ensure proper application. A portion of this evaluation documents the deviation of the micromodel from similarity considerations used in previous movable bed models. The primary basis for this evaluation is the comparison of the micromodel to the prototype. The writer looked for comparisons that had (1) a reasonable calibration of the micromodel and (2) about the same river engineering structures constructed in the prototype that were tested in the micromodel and (3) a prediction by the micromodel of the approximate trends in the prototype. Evaluation of these comparisons shows a lack of predictive capability by the micromodel. Differences in micromodel and prototype likely result from uncertainty in prototype data and the large relaxations in similitude. Based on the lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication for which it has been useful and should be of value to the profession.

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CE Database subject headings: Scale models; Channel flow; Sediment; River beds; Water discharge.

Introduction

The micromodel is an extremely small physical river model having a movable bed and varying discharge. It was developed in 1994 by the St. Louis District (Davinroy 1994) of the U.S. Army Corps of Engineers (USACE). Horizontal scales of up to 1:20,000 result in micromodel channel widths as small as 4 cm. Previous Mississippi River micromodels typically reproduced about 20 km of the river on the standard 1.9-m-long micromodel table. The micromodel has been used to predict the bathymetry and flow pattern trends for proposed river training structures for purposes of navigation and environmental effects. To date, over 20 reports have been published detailing micromodel studies. The writer was assigned to a USACE team in 1999 to evaluate the capabilities and limitations of the micromodel. The two other members of the evaluation team were developers and present users of the micromodel. The team could not reach a consensus on the capabilities of the micromodel and the USACE had the USACE Committee on Channel Stabilization (CCS) provide an evaluation of the micromodel based on a meeting with the team members. The CCS (USACE 2004) report concluded that the micromodel is not a detailed design tool but that the micromodel can be used for screening alternatives except for study types where human life or the overall project are at risk. For such critical study types, the CCS concluded micromodel use should be "limited." The CCS report states that "During the discussions, it became apparent to some that there is a considerable gap between the pure academic/scientific views of the micromodel technology and the practical use of the micromodel as a tool in an overall river engineering process which has been used on large rivers in MVD (Mississippi Valley Division of the USACE)." The inability to resolve the issue of whether to evaluate the river engineering process that uses a micromodel, or only the micromodel, was a major impediment to the evaluation. The proper evaluation parameter for the river engineering process is whether the project was a success. The proper evaluation parameter for the micromodel is comparison of bathymetric and flow features to the prototype. This writer is evaluating one component of the river engineering process, the micromodel, and whether it can approximately predict the bathymetric and flow features of a large river like the Mississippi.

Some observers of micromodel technology have been critical of its use. Falvey (1999) stated "*Civil Engineering* and the St. Louis District are doing the profession a disservice by implying that a micro-model is a tool that can be used for serious engineering investigations." Yalin, an expert in movable bed modeling, was able to observe and discuss the micromodel with the evaluation team. Yalin stated in a letter to this writer, "I regret that such a 'model' cannot be used for predictive purposes." Both criticisms were almost certainly the result of the micromodel's small size and lack of adherence to similarity principles used in movable bed modeling. From early in the team evaluation, this writer felt that if the size and similarity issues were significant, their effects would be seen in attempts to use the micromodel to predict response in the river. For that reason, this writer spent a large portion of the multiyear study evaluating micromodel-prototype comparisons, particularly predictions.

The objective of this paper is to present results of an evaluation funded by the USACE Research and Development Program

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Note. Discussion open until September 1, 2006. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on October 18, 2004; approved on February 3, 2005. This paper is part of the ***Journal of Hydraulic Engineering***, Vol. 132, No. 4, April 1, 2006. ©ASCE, ISSN 0733-9429/2006/4-343–353/$25.00.

to determine the capabilities and limitations of the micromodel. Specific focus is directed at critical study types where human life or the overall project is at risk if the model is not correct.

Movable Bed Modeling

Yalin (1971) states that a model can be scientifically valid only if measured quantities in the model are related to their counterparts in the prototype by scale ratios that satisfy the criteria of similarity. Ettema (2001) presents the dimensionless parameters associated with flow of water and sediment in channels with a bed of cohesionless particles including movable bed models (MBMs) as

$$\Pi_A = f_A\left[D\left(\frac{g(\rho_s-\rho)}{\rho\nu^2}\right)^{1/3}, \frac{\rho Ri}{D(\rho_s-\rho)}, \frac{\rho_s}{\rho}, \frac{D}{R}, \frac{B}{R}, \frac{\sigma}{\rho giR^2}\right] \quad (1)$$

where the dependent variable A in Π_A might be flow resistance, thalweg sinuosity, sediment transport, or some other variable in alluvial channels; D=particle size; g=gravity; ρ_s=particle density; ρ=water density; ν=kinematic viscosity of water; R=hydraulic radius; i=slope; B=channel width; and σ=surface tension. Scale distortions arise when the dimensionless parameters on the right side of the equation are not the same in model and prototype. However, some of the dimensionless ratios, under certain conditions, do not cause significant effects when model and prototype values differ. For example, in a model of sufficient size, the last parameter on the right side of Eq. (1) will not be the same in model and prototype but the effects of differences in surface tension in model and prototype will be negligible. It remains to be determined if the surface tension term can be neglected in a micromodel. The first term on the right hand side is a particle density term which shows that if a lightweight bed material is used, the particle size in the model will be larger than in the prototype. The second term is the Shields parameter that is present in almost all movable bed model criteria and defines the amount of movement of sediment. The third term (ρ_s/ρ) is often ignored because density effects are addressed in the first and second terms of the right side of the equation. The fourth term on the right hand side, D/R, is the relative roughness that is rarely equal in model and prototype of sand bed streams and is often assumed to have negligible effects on model results. However, Ettema et al. (1998) have shown significant scale effects of D/R on bridge pier scour. The fifth term on the right side is the aspect ratio that is another term that can rarely be maintained the same in MBM and prototype of sand bed rivers.

Three techniques have been used in MBM (and are used in the micromodel) to increase model Reynolds number and sediment mobility in the model and, in some MBMs, to achieve equal Shields parameter in model and prototype. In the Shields parameter, the water density ρ is fixed, prototype sediment density ρ_s is relatively constant, and the model particle size D cannot be scaled down due to particle cohesion problems and will be roughly the same in model and prototype when dealing with sand bed alluvial streams. Therefore, if the model Shields parameter is to be increased or made equal to the prototype, the only parameters that can be varied in the model are ρ_s, R, and i. Adjustment of these three parameters has led to three techniques often used jointly in MBMs as follows.

1. *Lightweight sediment*. Minimum specific gravity of MBM sediment has been about 1.05 but sediment this light has to be carefully handled and model flooding and startup are difficult. Walnut shells having a specific gravity of 1.3 have been used. Coal having a specific gravity of 1.3 is common. A wide range of plastics are available. ASCE (2000) describes some of the various sediment types used in MBM.
2. *Vertical scale distortion*. Vertical scale distortion is the second technique used to achieve correct sediment movement. Vertical scale distortion results in attempting to model a prototype channel with a model that has an aspect ratio (width/depth) that is less than the prototype. Jaeggi (1986) concludes that morphological processes are highly dependent on the aspect ratio and that a distorted model should be avoided. Glazik (1984) stated that distortion should be avoided in movable bed river models but that a value of 1.5 (ratio of model horizontal scale to vertical scale) provided adequate results. Suga (1973) reports that distortions used in his laboratory's MBM studies were 5 or less and concludes that distortion should not be used when scour depth and location are the main subjects. Foster (1975) presented cross section plots of velocity from a model with a distortion of 3 and an undistorted model of the St. Lawrence River. Foster concluded "The velocities in the distorted model shifted several hundred feet (prototype) toward the outside of the bend from those in the undistorted model." Channel width in this reach was 360–460 m (1,200–1,500 ft). Zimmerman and Kennedy (1978) conducted research on curved channels to determine the transverse bed slope in bends and concluded distorted models can be used if distortion is limited to no more than 2 or 3. ASCE (2000) suggests a limit of 6. While these previous studies consider distortion to be a necessary evil and have recommended limitations, application of regime theory to MBM requires distortion.
3. *Increased model slope*. Increased model slope is the third technique used to achieve correct sediment movement. This leads to a Froude number in the model that is greater than that of the prototype, which then raises concerns about the ability of the model to reproduce flow patterns. Einstein and Chien (1955) allow some exaggeration of model Froude number but do not recommend a limit. In an example presented by Gujar (1981), a Froude number exaggeration of F_m/F_p=2.5 was classified as large whereas 1.67 was classified as acceptable. Latteux (1986) reported that a Froude number exaggeration of 2.5 was unsatisfactory but 2.2 provided acceptable results. Vollmers (1986) used Froude number exaggeration of 1.4 in the MBM of the Elbe estuary, which had a vertical scale distortion of 8. Froude number exaggeration is based on the concept that the Froude number has limited significance for low values typical of alluvial streams. A problem arises when the Froude number is exaggerated to the point where it is no longer insignificant in the model.

Calibration versus Validation and Base Test

The terms calibration and validation must be defined as used herein. Based on ASCE (2000), "Model calibration is the tuning of the model to reproduce a single known event. Tuning the model to reproduce the prototype behavior in this event does not ensure that the model will reproduce different or future events. However, if the model cannot reproduce a known event, little confidence can be maintained that the model will reproduce future events." Vernon-Harcourt [in Freeman (1929)] used the validation concept in which he calibrated his model until it reproduced a known prototype condition. He then tested the model against a different set of prototype boundary conditions (validation) to see if it could reproduce these known changes. If satisfactory in the validation, Vernon-Harcourt then declared the model ready for prediction. The same validation concept is used herein to evaluate predictive/screening capability of the micromodel.

The micromodel uses the concept of a base test in which the calibrated model is run with a hydrograph and the resulting bathymetry and flow patterns are referred to as the base test. All plans/project alternatives are run with the same base test hydrograph and all plan results are compared to the base test results. Changes from base test results to plan results are assumed indicative of what changes will occur in the prototype. The use of a base test may reduce the required accuracy of the model somewhat but there should be some resemblance of model predictions to what occurs in the prototype.

Types of Physical Movable Bed Models

Graf (1971) categorizes MBMs as rational models that are semi-quantitative and empirical models that are qualitative. The Graf categories generally correspond to the degree to which the Eq. (1) parameters are equal in model and prototype.

Rational Movable Bed Models

Graf (1971) credits Einstein and Chien (1955) with development of the rational method of MBMs. Yalin (1965) and de Vries and van der Zwaard (1975) also developed methods that fall under Graf's category of a rational MBM. The rational method is simply a more rigorous adherence to the similarity criteria in Eq. (1) and generally requires large models to apply the method. Rational models are characterized by low vertical scale distortion, low Froude number exaggeration, and equality of Shields parameters in model and prototype.

Empirical Movable Bed Models

Graf's second category, empirical MBMs, places less reliance on similarity requirements and allows greater relaxation of the Eq. (1) parameters. Warnock (1949) states, "Instead of arranging the various hydraulic forces involved to meet definite requirements laid down in any law of similitude, the successful prosecution of a movable-bed model study requires that the combined action of the hydraulic forces bring about similitude with respect to the all-important phenomenon of bed movement, which is the essence of this type of model study." Although less rigorous than the rational MBM, most empirical models attempt to limit vertical scale distortion and Froude number exaggeration. Empirical MBMs have a Shields parameter that is generally less than the prototype that is required in order to limit model size, vertical scale distortion, and Froude number exaggeration. Empirical MBMs previously used at the Engineering Research and Development Center (ERDC, formerly Waterways Experiment Station) employed coal as the model bed material and had a model Shields parameter of less than 0.1, whereas the prototypes being studied had Shields parameters in excess of 1. Glazik and Schinke (1986) describe MBM experience using a model Shields parameter significantly less than the prototype. Due to the importance of the equality of the Shields parameter in the model and prototype, empirical models are generally limited to assessing bathymetric response.

Other Movable Bed Models

Some MBMs do not fit into the two categories delineated by Graf (1971). Freeman (1929) discusses early studies by Reynolds and Vernon-Harcourt, which were similar to the empirical model but used Froude scale velocities and simulated water levels in models with large vertical scale distortions. Reynolds conducted a study of the Mersey estuary in England in a model with a vertical distortion of 27.

Pertinent Features of the Micromodel

Micromodel Description and Operation

Gaines and Maynord (2001) provide details of the design and operation of the micromodel and only a brief summary is presented herein. Past micromodel studies have selected horizontal scales so that the modeled reach will fit on a standard 0.9-m-wide by 1.9-m-long flume table that is equipped with a recirculating pump, sump, and regulating valves. Sediment is recirculated in the micromodel. Horizontal scales range up to 1:20,000 and minimum model channel widths of 4 cm are employed in the main channel and lesser model widths in side channels or tributaries. The model banks are cut vertically and the channel is filled with granular plastic that ranges in size from 0.25 to 1.2 mm and has a specific gravity of 1.48. Some recent experiments have explored using lower density model sediment. The downstream end of the channel has a fixed free overfall. Islands are simulated with solid boundaries and vertical banks in the model. After having problems of exaggerated scour with solid river training structures typically found in MBMs, river training structures in the micromodel such as dikes or bendway weirs are represented by pervious steel mesh having 3×3 mm^2 openings. A typical micromodel is shown in Fig. 1.

In the calibration process, the micromodel bed is not pre-molded to a specific bed condition as done in other types of MBMs. Calibration of the model begins with selection of the high and low flow used to simulate the effects of the variable hydrograph in the prototype. High flow is based on a visual assessment of both the amount of sediment movement and the energy level in the model. Low flow is based on the model producing a slight amount of sediment movement. Model hydrograph cycle times have ranged from 1.8 to 6 min with 3 to 5 min being typical. To assess whether the model is calibrated, the model is run for numerous hydrograph cycles until the bed reaches equilibrium. The model is surveyed using an innovative laser profiler and the model bathymetry is compared to the trends of available prototype surveys. If the trends are replicated in the model, the model is declared calibrated and ready for screening alternatives. If the trends are not replicated in the model, adjustments are made to one or more of the following: (1) flume table slope; (2) amount of sediment in the model; (3) size, shape, and elevation of the fixed free overfall at the downstream end; (4) inflow baffling; (5) discharge hydrograph; and (6) vertical scale and datum. Various vertical scales and vertical datum are used to convert model bathymetry to corresponding prototype numbers throughout the calibration process to achieve the best agreement of model and prototype bathymetry.

Micromodel Contrasted with Previous Movable Bed Models

Of the two Graf (1971) categories, the micromodel is closest to the empirical MBM category. While similarity laws are not fol-

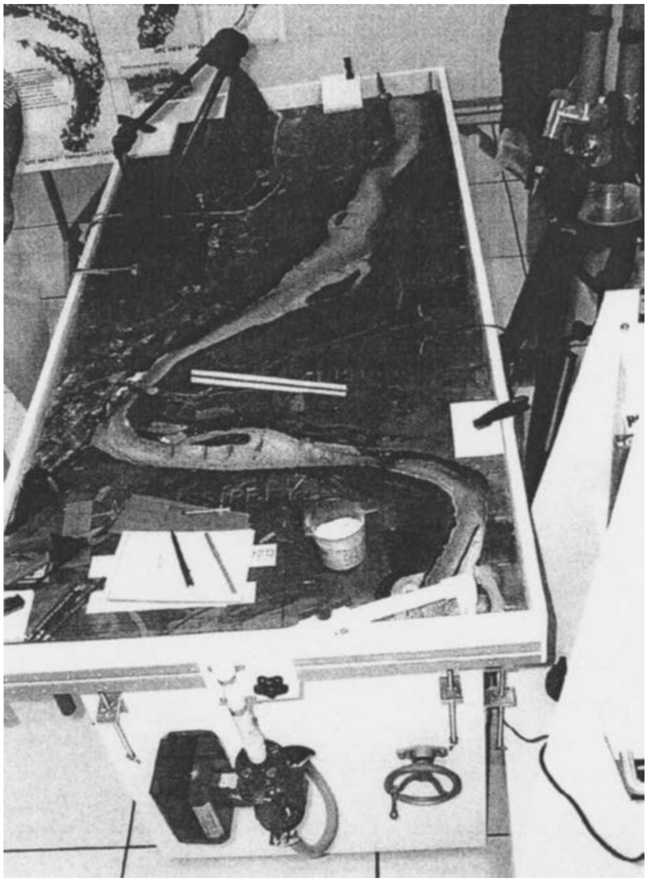

Fig. 1. Micromodel of Vicksburg Front, Mississippi River. Micromodel scale = 1 : 14,400 horizontal, 1:1,200 vertical.

lowed closely in empirical MBMs, there are definite differences between the micromodel and most previous empirical models as follows.

1. Small size. The micromodel is one to two orders of magnitude smaller than most empirical models. Model channel widths are as low as 4 cm. Model channel depths as low as 1 cm are an order of magnitude less than the minimum of 10 cm recommended in Gujar (1981). No requirements for minimum Reynolds number are used in the micromodel. The small model depths result in large distortion of relative roughness.
2. Large vertical scale distortion. With a few exceptions, distortion ratios used in the micromodel are at least twice that in most empirical models. Micromodels commonly use distortions of 8 to 15.
3. No correspondence of stage in micromodel and prototype. Most empirical models relate stage to a corresponding stage in the prototype.
4. Low stages run in micromodel. Typical alluvial streams have dominant or channel forming discharges that are roughly at a bank-full stage. Maximum stages in the micromodel are about 2/3 of bank full.
5. Calibration of micromodel based on equilibrium bed. Previous MBMs conduct calibration by starting with a known bed configuration, running representations of the subsequent stage and discharge hydrographs, and comparing the ending bed topography in model and prototype (Franco 1978). The micromodel starts with an unmolded bed, runs a generic hydrograph for many repetitions until the bed reaches equilibrium, and compares the equilibrium bed to as many prototype hydrographic surveys as possible to see if the correct trends are reproduced.
6. The small size of the micromodel and the relatively heavy (heavy for plastic) bed material (specific gravity 1.48) results in steep slopes in the micromodel. Water-surface slopes of the few micromodels that have been measured are about 1%. Steep slopes result in significant exaggeration of the Froude number. Froude numbers in the two micromodel studies where appropriate measurements were taken, are 2.7 and 3.7 times the prototype Froude number.
7. Model sediment, when scaled to prototype dimensions using a typical vertical scale, is 0.6–1.2 m in diameter.
8. No similarity of friction in the micromodel. Even with the large exaggeration of the relative roughness, the large distortion in the micromodel results in the model being too smooth, which is typical of highly distorted models. This smoothness is possibly the reason the micromodel cannot be used to simulate high stages.
9. Micromodel uses porous dikes to solve the exaggerated scour problems around dikes that occur in distorted models.
10. Due to short duration hydrographs, no bed molding, and automated bathymetry measurement, the micromodel can evaluate an enormous number of conditions in a short period of time.

The most significant differences in the micromodel compared to empirical models are small size, large vertical scale distortion, large Froude number/slope distortion, and no correspondence of stages. These differences place the micromodel in the third category of "other" in addition to rational and empirical models. Rational models are designed and operated with similarity considerations and only small deviations are allowed. Empirical models often do not follow similarity criteria, but the manner in which they are operated results in the existence of significant but limited deviations from similarity criteria. In like manner, the operation of micromodels results in even larger departures from similarity criteria.

Proposed Uses of the Micromodel

The categorization of micromodel and other MBM capabilities can be dealt with in a variety of ways. One option is to categorize based on structure type such as bendway weirs versus traditional dikes. Another option is to categorize based on problem type such as minimization of maintenance dredging in the main navigation channel versus rehabilitation of side channels for environmental enhancement. Ettema (2001) differentiates MBMs based on the degree of freedom of lateral movement, with micromodels of a long constriction having a greater chance of success than those in which lateral movement of the thalweg is relatively unrestricted. The categorization adopted herein is based on the categorization developed in CCS (ASCE 2004) as follows.

1. Demonstration, education, and communication. This includes demonstration of river engineering concepts including the generic effects of structures placed in the river.
2. Screening tool for alternatives to reduce maintenance and dredging of the navigation channel. Failure to perform as predicted would not be damaging to the overall project or endanger human life.
3. Screening tool for alternatives of channel and navigation alignments. This category does not include navigable bridge approaches. Failure to perform as predicted would not be

damaging to the overall project or endanger human life.

4. Screening tool for environmental evaluation of river modifications, side channel modifications, notches in dikes, etc. Failure to perform as predicted would not be damaging to the overall project or endanger human life.
5. Screening tool for major navigation problems, around structures such as lock approaches, bridge approaches, confluences, etc. Failure to perform as predicted could be damaging to the overall project or endanger human life.

For category 1, the micromodel has proven to be useful and beneficial as a demonstration, education, and communication tool, and the developers have presented a valuable tool to the profession. Many of the benefits of the micromodel to the river engineering process have been a result of its value in demonstration, education, and communication. The micromodel has allowed diverse groups to reach a consensus on controversial projects. All parties in this evaluation agreed that the micromodel is effective for demonstration, education, and communication. A demonstration tool shows the generic effects of a river training structure such as traditional contracting dike causing a shoaling area to reduce or a redirection of the currents and no specific dimensions are attached to the dike characteristics or the observations from the micromodel.

Categories 2–5 require greater capability than a demonstration tool. Any conclusions about the screening capabilities of the micromodel should answer the following three questions: (1) What is a screening tool? (2) What does it take to show any model is a screening tool? (3) What facts show the micromodel is a screening tool? A screening tool is able to identify likely or unlikely solutions or rank/compare alternatives. Screening tools are used to discard some alternatives and select others for further study. Some view a screening tool as quantitative relative to model inputs like dike length, elevation, location, orientation, etc. Others view a screening tool as completely qualitative with model inputs such as dike characteristics having little or no quantitative significance. A screening tool does not always predict the correct trends but should be correct some or most of the time. A screening tool is different from a demonstration tool because it crosses the threshold between nonprediction and prediction or, stated otherwise, the threshold between telling the user information he/she might not have known. To show that any model is a screening tool requires a modest record of an approximate prediction of trends that occurred in the prototype.

The CCS concluded that screening in categories 2–4 can be based on analysis of both bathymetry and surface flow patterns but screening for category 5 can only be based on bathymetry because surface flow patterns are not considered adequate for category 5 problems. This CCS criterion is a major limitation for category 5 problems because this writer has not seen a category 5 problem that could be addressed without analysis of surface flow patterns.

Model/Prototype Comparisons

General

The previous discussion shows that the micromodel is operated with large differences from similarity principles. The remaining question is whether these differences are significant. This writer presents model-prototype comparisons to address this question of significance. Although the primary question is whether the micromodel can predict prototype response in a calibrated model, the

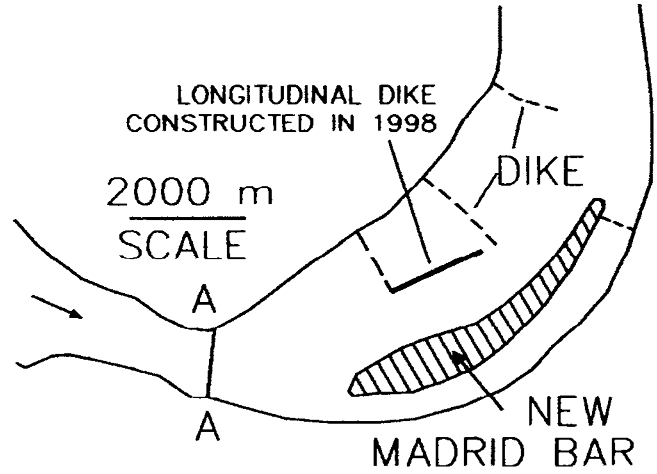

Fig. 2. Schematic of New Madrid, Mississippi River. Micromodel scale=1:19,000 horizontal, 1:1,200 vertical.

ability of the micromodel to be adequately calibrated, i.e. replicate existing conditions, is the only information available in many micromodel studies. The reports from previous micromodel studies were evaluated to determine the ability of the micromodel regarding both calibration and prediction but the selected comparisons focus on projects that provide insight into the predictive capabilities of the micromodel. Some of the project comparisons were selected because those projects have been cited as evidence of micromodel success. Other micromodels achieved reasonable calibrations while some did not. These other micromodels are not discussed herein because these models did not provide information on predictive capabilities and because of page limitations in this paper.

New Madrid, Mississippi River

The New Madrid, Mississippi River micromodel study (Davinroy 1996) was conducted to develop a structural solution to repetitive maintenance dredging in the main navigation channel. The calibration has large departures in depth within the problem area compared to the prototype. Fig. 2 shows the channel schematic and the location of cross section AA about one channel width upstream of New Madrid Bar. Section AA is the location of some of the structures used in alternative tests. As shown in Fig. 3, scour reached an elevation of about 21 m below the low water reference plane (LWRP) in the prototype compared to 6 m below

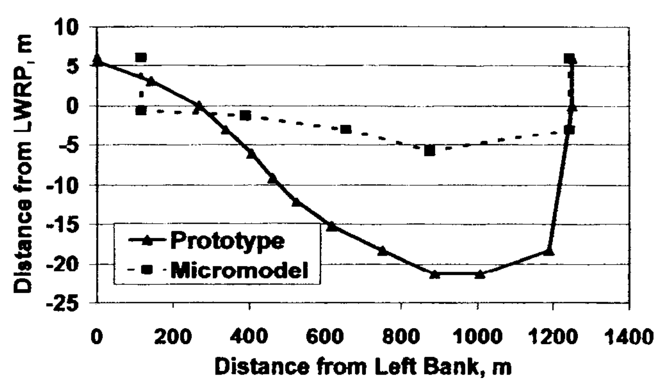

Fig. 3. Prototype and micromodel cross sections at New Madrid

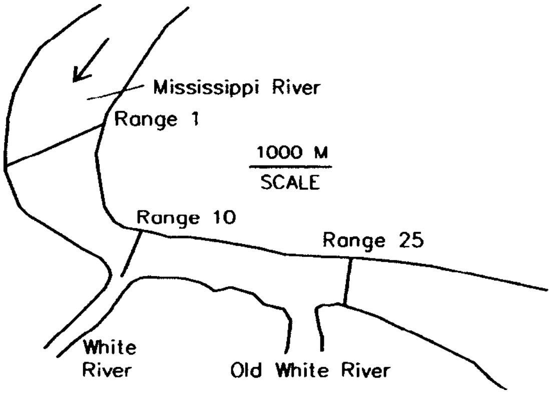

Fig. 4. Schematic of the Mouth of the White River, Mississippi River. Micromodel scale = 1 : 12,000 horizontal, 1:1,200 vertical.

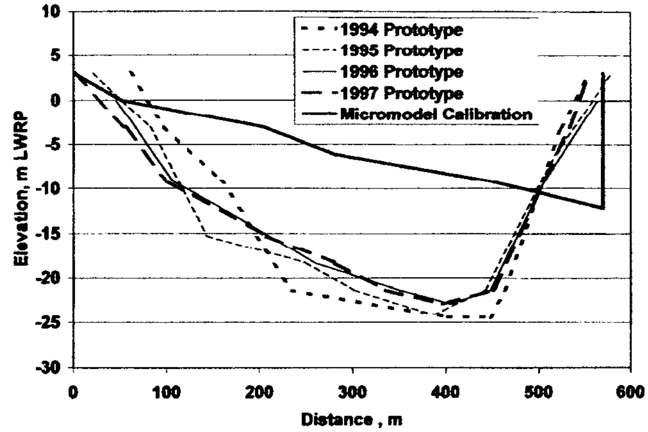

Fig. 6. Cross section at the Mouth of the White River, Range 17

the LWRP in the calibrated model. The LWRP is the stage in the Mississippi River that is exceeded about 97% of the time. The channel cross section area below LWRP = 0.0 is roughly 1/3 of bank-full cross section area. The bank-full stage is about 9–10 m above the LWRP. The New Madrid study also provides information on prediction. The longitudinal dike shown in Fig. 2 was constructed in 1998. The longitudinal dike was studied in the 1996 micromodel study but was not one of the two recommended plans. The 1996 report stated that tests with a longitudinal dike indicated (1) slight channel deepening and (2) the navigation channel narrowed approximately 120 m. Subsequent prototype experience with a similar longitudinal dike in place has shown reduced dredging and an increase in the width of the navigation channel. While the project appears to be successful, the micromodel did not predict the trends of the prototype.

Mouth of the White River

The primary objective of the Mouth of the White River (MOWR) study (Gordon et al. 1998) was to evaluate design alternatives that would provide improved conditions for navigation near the MOWR (Fig. 4). The MOWR study involved navigation conditions at the confluence of two navigable rivers, the Mississippi and White Rivers. The micromodel calibration test comparison with the prototype was satisfactory upstream of the mouth, but at and downstream of the mouth, the model bathymetry differed significantly from the prototype. Fig. 5 shows the hydraulic depth (area/top width) at the LWRP along the reach. Differences in hydraulic depth in the calibration are up to 10 m at Range 19. Fig. 6 shows a cross section plot from the calibration at about Range 17 where the bed of the micromodel is up to 15 m higher than the average of 4 years of relatively consistent prototype survey data. The MOWR study is pertinent to this evaluation because (1) the micromodel procedure allows many attempts at calibration; (2) 4 years of prototype data used for calibration were relatively consistent; and (3) the best calibration was unsatisfactory. In addition to large differences in the calibration, the micromodel plan closest to the plan constructed in the prototype had top elevation of the bendway weirs at elevation −4.6 m LWRP compared to an average elevation of −7.6 m LWRP as surveyed in the prototype. The difference in calibration and in the bendway weir elevations means that the Mouth of the White River provides little information about the predictive capabilities of the micromodel.

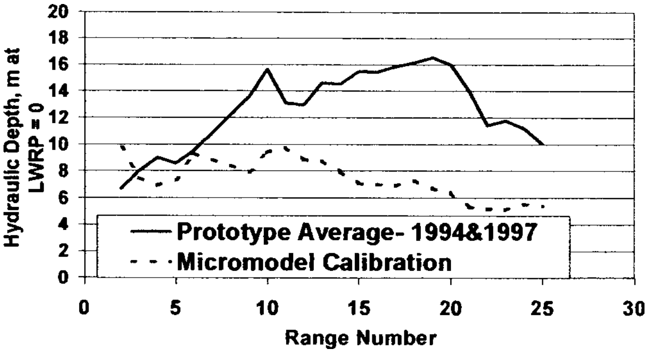

Fig. 5. Hydraulic depth at Mouth of the White River

Vicksburg Front

The Vicksburg Front comparison addresses the validity of bathymetry trends and surface currents in a calibrated micromodel and does not provide any information on prediction/validation. Maynord (2002) presents results of a comparison of surface currents in the Vicksburg Front micromodel and the prototype. Confetti streaks and particle image velocimetry (PIV) were used to determine surface velocities in the Vicksburg Front micromodel. Recording global positioning system (GPS) units used in differential mode were placed on surface floats in the bend of the Mississippi River at Vicksburg, Mississippi. The GPS floats were placed at various locations across the channel upstream of the bend at Vicksburg and retrieved at the lower end of the bend. The average stage in the river during the 4-day measurement period and the stage in the micromodel were almost identical. Fig. 7 shows a schematic of the Vicksburg bend and the location of a cross section at river mile 439.5 where velocities were compared from the GPS prototype and the PIV micromodel. Fig. 8 shows the cross section velocity plot from the micromodel and prototype. Velocities in the micromodel were converted to prototype using the square root of the vertical scale ratio that is the ratio typically applicable to distorted models. The plot shows the exaggeration of velocity that is typical of MBMs. In this case the exaggeration is large, about 3.7 times the Froude scale velocities. The plot also shows velocities in the micromodel are concentrated on the left descending bankline when compared to the prototype data. The concentration of flow on the left bank in the

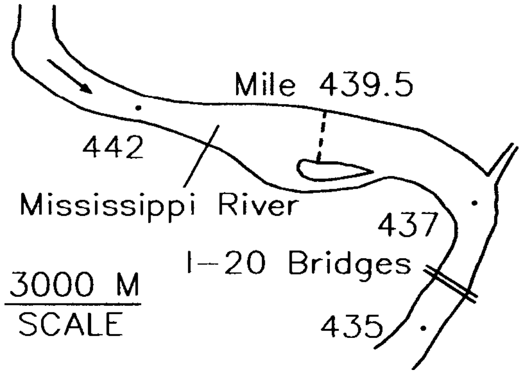

Fig. 7. Schematic of Vicksburg Front, Mississippi River. Micromodel scale = 1 : 14,400 horizontal, 1:1,200 vertical.

micromodel is consistent with the incorrect sediment deposition in the micromodel along the right bank at river mile 437.5 that does not occur in the prototype.

Kate Aubrey

The Kate Aubrey reach of the Mississippi River has experienced shoaling problems that required repeated dredging. Two micromodels of the Kate Aubrey reach were constructed as part of the USACE micromodel evaluation to validate or test predictive capability. The Kate Aubrey models were a major component of the team evaluation. The two micromodels included a traditional size micromodel having a 1:16,000 horizontal scale and 1:900 vertical scale and a larger (2×) micromodel having a 1:8,000 horizontal scale and 1:600 vertical scale. Both micromodels were calibrated to 1975 and 1976 bathymetry. The predicted micromodel bathymetry was compared to the 1998 bathymetry (Fig. 9) and was not similar to the prototype in both the 1:8,000 (Fig. 10) and 1:16,000 (Fig. 11) micromodels. The problem area is centered at about mile 791–792. Extensive dredging was conducted in this reach in 1988 and may have contributed to some of the differences between model and prototype. However, the high flows during the mid-1990s would likely minimize the effects of dredging ten years earlier in 1988 and the dredging impacts would not show up in the 1998 bathymetry. The Kate Aubrey comparisons leads to the conclusion that a micromodel can be calibrated yet not be validated and thus, cannot be used for prediction of alternative effects.

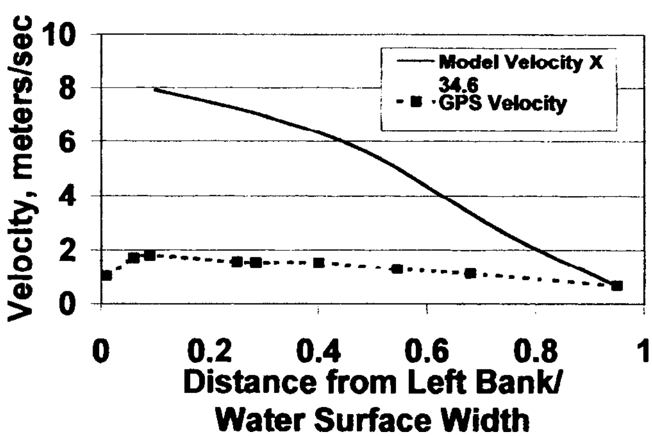

Fig. 8. Prototype GPS and micromodel velocities at Vicksburg Front

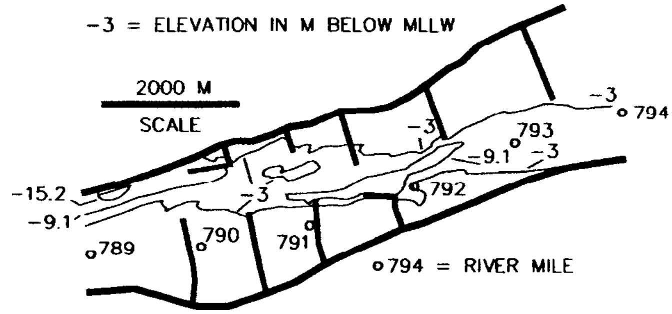

Fig. 9. Kate Aubrey, Mississippi River, 1998 prototype bathymetry. Flow from right to left.

Bolter's Bar

The Bolter's Bar micromodel study was conducted to evaluate alternatives to alleviate dredging in the main channel without adversely affecting side channels. A schematic of the reach with the dikes that were present in 1997–1998 is shown in Fig. 12. The dredging problem was primarily between river miles 225 and 226. Fig. 13 shows the plan constructed in the prototype in 2002 that includes four chevron dikes on the right side of the navigation channel between river miles 225 and 226, a longitudinal dike on the right bank at river mile 226, and raising and notching the existing closure dike. The four left bank dikes between river miles 226 and 225.4 were removed from the micromodel but remain in the prototype. Little is known about the characteristics of the left bank dikes. The micromodelers have stated they believe the left bank dikes have little impact on the bathymetry. Since the 2002 construction of the improvement plan, dredging has been reduced in the reach and survey data show an improved navigation channel through the problem dredging reach. However, the difference in model and prototype because of the left bank dikes and the limited time since construction make it difficult to evaluate this validation/prediction.

Lock and Dam 24

The Lock and Dam 24 micromodel was conducted to evaluate means of reducing outdraft. Outdraft results from the cross currents in the upstream lock approach that cause a tow to move toward the dam rather than into the lock (Fig. 14). Outdraft is a dangerous condition at many locks and dams and has resulted in numerous accidents. The guardwall in the Lock and Dam 24 micromodel was solid but the guardwall in the prototype was ported which means that it has openings at the bottom to pass flow out of

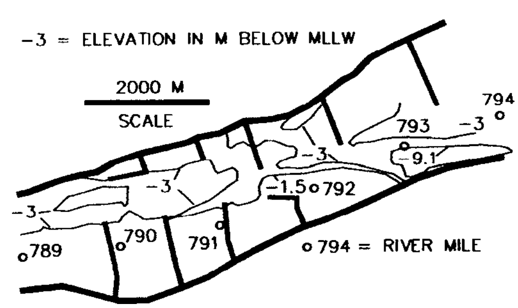

Fig. 10. Kate Aubrey, Mississippi River, 1:8,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

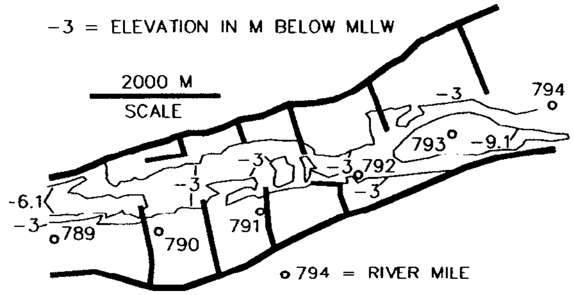

Fig. 11. Kate Aubrey, Mississippi River, 1:16,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

the lock approach. A solid guardwall was used in the micromodel to represent a worst case and because the guardwall ports often clog with debris. The currents behind the guardwall in the prediction of the micromodel did not agree with the currents measured in the prototype. The micromodel showed slackwater just upstream of the area between the upper end of the guardwall and the bank. The prototype showed significant currents in this area. This raises two possibilities. If the ports were clogged at the time of prototype measurement, the model predicted incorrect currents. If the ports were open during prototype measurement, the difference in guardwall configuration could explain all or part of the difference in flow patterns and the Lock and Dam 24 comparison provides no information about the predictive capabilities of the micromodel.

Comparison of Micromodel and ERDC Coal Bed Models

In addition to the Kate Aubrey micromodels built and studied by the evaluation team, another major portion was an evaluation of micromodels relative to coal bed models previously used at ERDC. This component of the evaluation began with the objective of using comparison of model and prototype cross section areas, channel widths, and other bathymetric parameters to determine if a MBM was calibrated rather than using the subjective/visual comparisons that have been used traditionally. Several

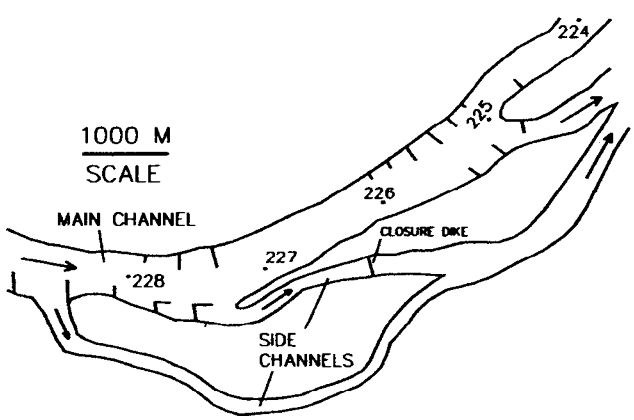

Fig. 12. Schematic of Bolter's Bar, Mississippi River, without project. Micromodel scale = 1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

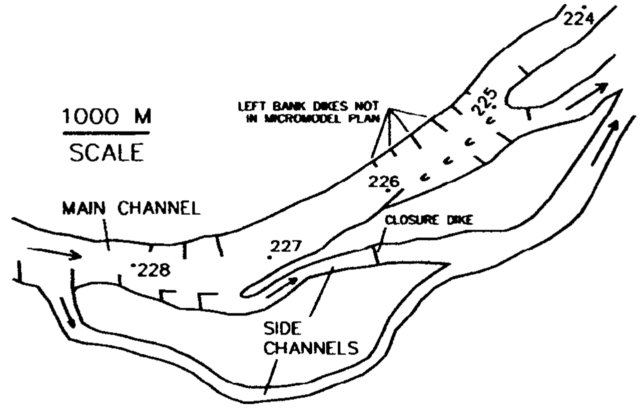

Fig. 13. Schematic of Bolter's Bar, Mississippi River, with project. Micromodel scale = 1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

modelers were skeptical about quantifying whether a model was calibrated.

The techniques developed for determining calibration were also used to compare the coal-bed model and the micromodel. For example, the ratio of difference in model and prototype cross section area to cross section area in the prototype was determined for each cross section. A mean squared error (MSE) measure of dispersion of the data was defined as the square of this ratio for each cross section that was averaged over the length of the model (except for entrance and exit reaches). For cross sectional area, the MSE for 16 coal bed models ranged from 0.014 to 0.33 with an overall average MSE for all models of 0.12. The MSE for area in 14 micromodels ranged from 0.024 to 0.456 with an overall average MSE for all models of 0.16. The MSE for area in the MOWR micromodel discussed previously was 0.16. An MSE of 0.16 for area means that prototype and model area differed by an average of 40% of the prototype area over the length of the model. Other bathymetric parameters used in the comparison were (1) thalweg location had overall MSE = 0.11 in the coal bed and 0.05 in the micromodel; (2) width had the same overall MSE = 0.06; and (3) hydraulic depth had overall MSE = 0.09 in the coal bed and 0.14 in the micromodel. Because of limited prototype data, the bathymetry parameters were evaluated at an elevation of 0.0 LWRP that is a low stage. Consequently, these error measures are somewhat larger than would be the case had data been available at higher stages. An LWRP of 0.0 is significant for navigation purposes because it roughly corresponds to the width

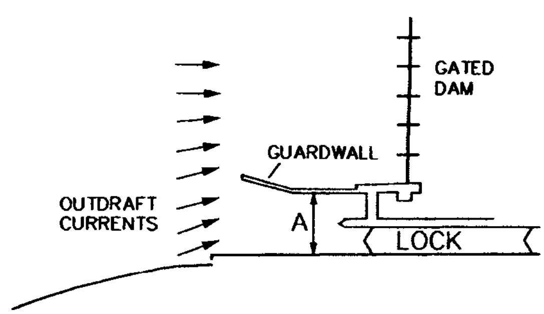

Fig. 14. Schematic of Lock 24 outdraft at upstream lock approach on Mississippi River. Micromodel scale = 1 : 9,600 horizontal, 1:600 vertical. Dimension "A" in micromodel is about 0.8 cm versus a prototype distance of about 80 m.

of the navigable portion of the channel. With the exception of one model (Kate Aubrey), the comparison micromodels were all different projects than the comparison coal-bed models. Gaines (2002) used similar geometric techniques with only the Kate Aubrey coal-bed and micromodels and concluded that "Therefore, there is no advantage in using the larger scale models (coal-bed models) to evaluate river training structures over the small-scale models (micromodels)." This writer does not place significant weight on the comparison of coal-bed models and micromodels because of the following.

1. The comparison was based on calibration only. As stated in ASCE (2000), calibration does not ensure the model will predict. As stated previously, the micromodel is significantly different from previous empirical models like the ERDC coal-bed models and equivalency based only on calibration is not valid.
2. The adjustment of vertical scale and vertical datum in the calibration process should insure that reach averaged values will be close in micromodel and prototype. To a lesser extent, this same factor is true in the coal bed model because of other adjustments.

Basis of Unsatisfactory Calibration and Validation

Why are the previous calibrations and validations (predictions) of micromodels unsatisfactory? Some of the differences can be attributed to variability and uncertainty in the prototype bathymetry data. The large relaxations in similarity criteria must also be a primary factor. Ettema and Muste (2004) conducted scale effect fixed-bed flume experiments and found that thalweg alignment and extent of separation around spur dikes do not scale with model length scale for a range of small models. Ettema and Maynord (2002) note that in hydraulic models, the usual causes of scale effects are (1) large length scales; (2) distortion of vertical scale relative to horizontal scale; (3) inflation of bed sediment size; and (4) amplification of channel slope. All of these scale effect causes are present in the micromodel as discussed previously. In addition to these four causes, the micromodel does not have correspondence of stage in model and prototype. Since all four causes plus the stage issue are present in the micromodel and there are unknown interactions, it is not possible to state which specific causes are responsible for the differences in model and prototype shown previously. At the small dimensions of flow in the micromodel, Reynolds and Weber numbers are sufficiently different than at full scale as to influence flow behavior and distribution (Ettema 2001). Froude number exaggerations up to 3.7 and vertical scale distortion up to 20 are likely causes of poor agreement of lateral velocity distribution and thus bathymetry in the model. Struiksma and Klaasen (1987) report scale effect problems resulting from exaggerations in Froude number and from bed roughness not being reproduced. Ettema (2001) and Ettema and Muste (2002) conclude that micromodels can be useful in situations where the thalweg is constrained to only vertical movement such as in a long constriction. In cases where the thalweg can move laterally, model utility diminishes quickly.

Is the Micromodel Capable of Quantitative Inputs?

Quantitative inputs describe dikes or other river engineering structures by their length, elevation, location, etc. River engineering often uses contraction of the channel to achieve a desired navigation channel. The amount of contraction of a proposed plan and thus dike characteristics cannot be specified when the water levels and thus the channel area are not modeled. The effectiveness of a dike cannot be assumed equal in model and prototype when the model velocities are roughly 2.7 to 3.7 times higher than scaling by Froude criteria. While the porous dikes used in the micromodel have some significant advantages, they have not been shown to address the problems of incorrect water level and high velocities regarding quantitative inputs.

Conclusions and Recommended Capabilities and Limitations

The micromodel, because of its small size and large deviations from similarity considerations, is different from previous MBMs and does not fit into either of Graf's categories of empirical or rational models. In addition to its size being as small as 4 cm channel width, large vertical scale distortion, large Froude number exaggeration, and no correspondence of stage in model and prototype, place the micromodel in a category by itself.

The micromodel is effective for demonstration, education, and communication and the developers have provided a valuable tool to the profession.

The disagreement over the micromodel concerns screening capability and can best be resolved by answering the following three questions: (1) What is a screening tool? (2) What does it take to show any model is a screening tool? (3) What facts show the micromodel is a screening tool? A screening tool is able to identify likely or unlikely solutions or rank/compare alternatives. A screening tool is used for prediction in order to eliminate some alternatives and keep others for further study. To show that any model is a screening tool requires a modest record of prediction of the approximate trends that occurred in the prototype. The pertinent facts regarding screening capability in the micromodel are as follows.

1. The two Kate Aubrey models provided unsatisfactory predictions of bathymetry.
2. The New Madrid micromodel predicted narrowing of navigation channel but widening occurred in the prototype. New Madrid is one of the examples of a successful project not being a successful model-prototype comparison.
3. Bolter's Bar appears to come closest to a successful prediction but the comparison has uncertainty because the left bank dikes are present in the prototype and not present in the micromodel prediction.
4. The calibrated Vicksburg Front model had velocity and sedimentation trends that did not agree with the prototype.
5. No prediction evidence is provided by the Mouth of the White River micromodel because the calibration differs greatly from the prototype and the bendway weirs have a different elevation in model and prototype.
6. Predicted model velocities did not agree with the prototype at Lock and Dam 24. Depending on whether the guardwall ports were clogged during the time of prototype measurement, the micromodel predictions were either incorrect or can be explained by the difference in micromodel and prototype ports.
7. The micromodel achieves calibration similar to coal-bed models used at ERDC based on bathymetric parameters averaged over most of the length of the model. Data were not available to evaluate prediction using these same parameters.
8. The large departures from similarity principles in the micro-

model and no correspondence of water level in the micromodel and prototype are of concern.

This writer found successful projects that had been micromodeled but looked for micromodel-prototype comparisons that had (1) a reasonable calibration; (2) about the same river engineering structures constructed in the prototype that were tested in the model; and (3) a prediction of the correct trends in the prototype. The evidence is not overwhelming (because there are relatively few studies providing information on prediction) but shows a lack of predictive capability. Based on the lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication for which it is effective and useful. This conclusion differs from the CCS (ASCE 2004) report that concluded screening capability for all but category 5 problems.

Quantitative inputs have little significance in the micromodel because the water level is not correct and the velocities are 2.7 to 3.7 times greater than given by Froude scaling.

Screening for category 5 studies that are complex and where human life or the overall project are at risk such as navigation near structures, bridge approaches, and confluences is of particular importance to this evaluator. In this writer's opinion, the micromodel should not be used for category 5 problems. This conclusion is consistent with the recommendations of the CCS (ASCE 2004) for category 5 problems.

Acknowledgments

The study described herein was funded by the USACE. The views expressed herein are the writer's. Diverse views of micromodel capability exist within the USACE.

Notation

The following symbols are used in this paper:

B = channel width;
D = particle size;
F_m = Froude number in model;
F_p = Froude number in prototype;
g = gravitational acceleration;
i = slope;
R = hydraulic radius;
ν = kinematic viscosity;
ρ = water density;
ρ_s = particle density; and
σ = surface tension.

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Comment Responses

Note: Any comments provided that were not relevant to the Grand Tower Phase 5 work area were not addressed herein. For further information please contact Mr. Kip Runyon in our Environmental Planning Section at 314-331-8396 or kip.r.runyon@usace.army.mil.

Responses to Written Comments on the Original Draft EA

Responses to January 9, 2014 Professor Nicholas Pinter (SIUC) Comments

Comment 1: *I hereby request one or more public hearings to discuss the impacts of, and alternatives to the proposed project. I request that at least one of these meetings be held in Illinois, preferably in Wolf Lake, IL. The public hearing(s) should be held to solicit input and public involvement regarding the Corps Finding of No Significant Impact resulting from this project.*

Response: A public hearing was held to solicit public input as requested.

Comment 2: *…the Corps Finding of No Significant Impact…is inconsistent with available evidence and inconsistent with majority scientific opinion, in particular regarding the effects of such river training structures on flood levels, levee performance, and public safety.*

Response: The Corps of Engineers considers public safety to be of paramount importance when designing and evaluating projects. The agency believes strongly that the best available science shows that this project will not increase flood heights, and consequently the project does not pose a significant risk to public safety. The Corps, other federal agencies and academic institutions have performed extensive research dating back to at least the 1930s on the physical effects of river training structures, including their impact on flood heights, and have concluded that river training structures do not raise flood heights. These evaluations have fully considered all available literature and science. In an effort to update this research, the Corps commissioned independent technical reviews to examine if river training structures had measureable impacts on flood stages within the Middle Mississippi River. The conclusions of the independent technical reviews reaffirmed that river training structures do not raise the stage of the river and do not increase flood risk. Further, additional modeling was completed on the proposed structures for the Vancill Towhead reach of the Grand Tower Phase 5 work area, which did not show an increase in stages or an increased flood risk. Appendix A of the EA, Summary of Research on the Effects of River Training Structures on Flood Levels, has been expanded to more clearly articulate the District's position on the existing body of research on the topic and includes a report for the additional modeling of Vancill Towhead proposed structures.

Comment 3: *The Corps has initiated a Supplemental Environmental Impact Study to assess the effects of river training structures, including the question of flood magnification. No new structures should be planned or built until a comprehensive, balanced, and independent assessment is completed.*

Response: The District has concluded that river training structures do not raise river stages and do not pose a significant risk to public safety (see response to Comment 2 above and the revised Appendix A). The Supplemental Environmental Impact Statement (SEIS) that the District has initiated will include any new information or circumstances on flood heights that was not addressed in the 1976 EIS pursuant to current law, regulations, and guidance. However, a comprehensive, balanced, and independent assessment of the flood height issue has already been conducted and included in the Grand Tower Phase 5 EA. Further, as described in Section 1, Purpose of and Need for Action, Prior Reports, the Grand Tower Phase 5 EA has incorporated 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 human environment not accounted for in the EA, measures will be taken within the Corps' authority to avoid, minimize, and/or compensate for the impacts during that process as appropriate. Therefore, the District does not believe that a moratorium on construction is warranted.

Comment 4:
The proposed Grand Tower project is of particularly grave concern, given its location, in the Mississippi channel at Wolf Lake, Illinois along the Big Five Levee System. Corps inspections have identified a number of deficiencies in this levee system, and there are serious concerns about its performance during future floods even without additional stresses. Empirical hydrologic data, geospatial analyses, hydraulic modeling, and engineering theory all suggest that elevated flood levels are associated with river training structures, in particular upstream of these structures due to backwater effects.

Response: See response to Comment 2 above and the revised Appendix A.

Comment 5: *Furthermore, the proposed Grand Tower project includes construction of new "S-dikes" at this location. The purpose of inventing new types of dikes structures is unclear, and the rationale for experimenting with these untested inventions in the real-world Mississippi River is very tenuous. The St. Louis District and its Applied River Engineering Center must make extra efforts to consult with floodplain residents, levee boards, navigational interests, and other stakeholders in order to justify the need for such new structures and document that thorough studies, including full two-dimensional and three-dimensional numerical hydraulic modeling, have preceded any construction.*

Response: See response to Comment 2 above and the revised Appendix A for additional modeling completed on the Vancill Towhead portion of the Grand Tower Phase 5 work area, which includes the S-dikes. Further, for a description of the purpose of the S-dikes, see revised Section 2 of the EA, Alternatives including the Proposed Action, Development of Alternatives, and Appendix F of the HSR Model Report referenced and link.

Comment 6: *River training structures are have become the signature project of the Corps' St. Louis District, but the purported benefits of these structures – including for river habitat improvement, navigation, and sediment transport – have not been rigorously documented or discussed by affected stakeholders. The "Draft Environmental Assessment with Unsigned Finding of No Significant Impact" for the new Grand Tower project includes little or no stakeholder involvement and an inadequate assessment of alternatives to the proposed construction activities.*

Response: The District closely monitors the implementation of all river training structures to ensure navigation, sediment transport, and fish and wildlife goals and objectives are being adequately addressed. In addition, the District works continually with fish and wildlife resource agency and navigation industry partners to ensure that projects are implemented with their input. Section 2 of the EA, Alternatives Including the Proposed Action, has been expanded to more clearly articulate the alternatives analysis process utilized.

Responses to January 10, 2014 Jamie Nash-Mayberry Comments

Comment 7: *My name is Jamie Nash-Mayberry and I teach high school social sciences in Wolf Lake, Illinois at Shawnee High School. For the past four years my students and I have been researching flooding issues, including the continued building of wing dikes along our school district which stretches from Grand Tower to the northern edge of Thebes, Illinois. I was recently informed via Public Notice P-2856 of your plans to build more dikes into the river including new S dikes. My students and I are gravely concerned about this matter. We feel the S dikes are experiments on us, and feel all dikes in general should be limited. We have spoken with geologists from both SIUC and the Netherlands and read their research, listened to researchers from Washington University, and have spoken to local levee commissioners. All concur that the river does not need more dikes, and that they can contribute to increased flooding problems. We presented our research to the Mississippi River Coordinating Council of Illinois and they are currently investigating the issue. While they do this, we ask that you use other methods of managing the channel such as dredging, releasing water from other rivers, and blowing up shale rock as you have done previously.*

Response: See response to Comment 2 above and the revised Appendix A with respect to the claim that river training structures increase flooding problems. For the Grand Tower Phase 5 work area, the District considered all reasonable feasible alternatives to meet the Regulating Works Project purpose as defined by Congress to obtain and maintain the navigation channel through the construction of regulating works to reduce costly dredging to a minimum (see also Section 1 of the EA, Purpose of and Need for Action). See Section 2, Alternatives Including the Proposed Action, Development of Alternatives, for a detailed explanation of the alternative development process used by the District for the work area. Through this process the District determined that the only reasonable and feasible alternatives for this area would be to continue costly dredging in this area or to attempt to provide a more sustainable navigation channel through the construction of river training structures. The Corps welcomes and will participate in any independent reviews or research funded by an outside agency or organization that will further the science and understanding of the impacts of river training structures on flood heights.

Comment 8: *I am requesting a public hearing occur so that we can voice our concerns.*

Response: A public hearing was held to solicit public input as requested.

Comment 9: *We have used models of the river and realize that one of the problem's with these wing dikes is that you have to keep putting them in because they simply relocate the sediment to a new location. Before long, the entire river will be filled with rock from your dikes, and there will be no place for the water to go except up and over the levees.*

Response: Analysis of dredging data has proven that the construction of river training structures has achieved the goal of reducing dredging. See response to Comment 2 above and the revised Appendix A for the District's analysis on river training structure impacts on stages.

Responses to January 10, 2014 Shelly Clover-Hill Comments

Comment 10: *Research shows that wing dikes contribute to increase flooding which is something the communities in our district cannot afford.*

Response: See response to Comment 2 above and the revised Appendix A.

Comment 11: *I am requesting a public hearing so we may voice our concerns.*

Response: A public hearing was held to solicit public input as requested.

Responses to January 24, 2014 National Wildlife Federation, Izaak Walton League of America, Missouri Coalition for the Environment, Prairie Rivers Network, and Sierra Club Comments

Comment 12: *The Conservation Organizations urge the Corps to withdraw the Grand Tower EA and place the proposed Grand Tower project on hold at least until the Corps completes the recently announced supplemental environmental impact statement for the Middle Mississippi River Regulating Works Project, Missouri and Illinois (SEIS). The Grand Tower EA does not comply with the requirements of the National Environmental Policy Act (NEPA) and presents flawed science as the basis for its conclusion of no significant impacts. As a whole, the EA is far too limited and lacking in scientific support to adequately assess risks to public safety and the environment or to determine whether less damaging alternatives are available.*

Response: The District does not believe that it is necessary to place the Grand Tower Phase 5 work area on hold while the SEIS is being prepared. As described in Section 1, Purpose of and Need for Action, Prior Reports, the Grand Tower Phase 5 EA has incorporated 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 human environment not accounted for in the EA, measures will be taken within the Corps' authority to avoid, minimize, and/or compensate for the impacts during that process as appropriate. The Grand Tower Phase 5 EA preferred alternative was the least environmentally damaging alternative of the alternatives considered in the HSR Model Report that also adequately addressed the dredging issues in the work area. Section 2 of the EA, Alternatives

Including the Proposed Action, has been expanded to more clearly articulate the alternative evaluation process and incorporate the HSR Model Report into the EA. The District believes that the Grand Tower EA is in compliance with all applicable laws and policies, including NEPA, and adequately assesses impacts to the human environment to support the conclusions drawn.

Comment 13: *Initiate a National Academy of Sciences study on the effect of river training structures on flood heights to inform development of the SEIS. A National Academy of Sciences review is critical for ensuring that: (a) the SEIS is based on the best possible scientific understanding of the role of river training structures on increasing flood heights; (b) the SEIS produces recommendations that will provide the highest possible protection to the public; and (c) the public will have confidence in this aspect of the evaluation and recommendations contained in the final SEIS.*

Response: See response to Comment 2 above and the revised Appendix A. The Corps recognizes that a few academics do not agree with the conclusions of the Corps, other federal agencies, and academic institutions. Due to the extensive research supporting the conclusions of the Corps, we do not believe that there is sufficient evidence to warrant funding costly and time-consuming research efforts at this time. The Corps welcomes and will participate in any independent reviews or research funded by an outside agency or organization that will further the science and understanding of the impacts of river training structures on flood heights.

Comment 14: *Impose a moratorium on the construction of new river training structures pending completion of the SEIS. As discussed below, extensive peer-reviewed science demonstrates that river training structures have increased flood levels by up to 15 feet in some locations and 10 feet in broad stretches of the Mississippi River where these structures are prevalent. In light of these findings, it is critical that additional river training structures not be built unless and until a comprehensive SEIS establishes that such construction will not contribute to increased flood risks to communities.*

Response: See responses to Comments 2 and 3 above and the revised Appendix A.

Comment 15: *Because of the significant potential for increasing the risk of flooding for river communities, the Conservation Organizations also request a public hearing on the proposed Grand Tower project during which members of the public will have an opportunity to present oral testimony directly to the decision makers for this proposed project.*

Response: A public hearing was held to solicit public input as requested.

Comment 16: *The Corps may not tier the Grand Tower EA to the 1976 Regulating Works EIS…The 1976 Regulating Works EIS Must Be Supplemented.*

Response: The District believes that it is appropriate to tier the Grand Tower EA to the 1976 EIS even though the 1976 EIS is being supplemented. The 1976 EIS is not being supplemented due to a change in the Regulating Works Project but due to new circumstances and information relevant to environmental concerns of the Regulating Works Project on the human environment. The fact that the 1976 EIS is being supplemented does not invalidate the document. The 1976 EIS discussed and analyzed generally the impacts of regulating works; such analysis still applies today. The Grand Tower EA describes and analyzes new circumstances and information relevant to the Grand Tower work area and includes these new circumstances and information in the analysis of potential impacts rather than relying solely on the general analysis in the 1976 EIS. The Prior Reports discussion in Section 1 of the EA has been revised to provide specifics on the new information and circumstances addressed.

Comment 17: *The Corps may not tier the Grand Tower EA to the 1976 Regulating Works EIS…The 1976 Regulating Works EIS does not discuss the proposed Grand Tower Project.*

Response: It is not necessary for the 1976 EIS to specifically discuss the Grand Tower work area as this would defeat the entire concept of tiering provided in the CEQ regulations and guidance. The 1976 EIS generally includes analysis of regulating works and their impacts (see response to Comment 16 above). The Grand Tower EA incorporates this information and includes a description and analysis of new circumstances and information on regulating works generally as well as impacts to the site-specific Grand Tower work area. The Prior Reports discussion in Section 1 of the EA has been revised to provide specifics on the new information and circumstances addressed.

Comment 18: *The Grand Tower project includes an all-new type of dike structure, described as "S-dikes." According to the Grand Tower EA these new structures have only been prototyped using the St. Louis District's tabletop physical model (its "Hydraulic Sediment Response" or HSR model). No computer modeling or real world testing of these new structures is reported. The Conservation Organizations believe that it is unwise to construct such relatively untested structures in the Mississippi River, particularly at a location immediately adjacent to a levee with critical safety issues.*

Response: See response to Comment 5 above and the revised Appendix A.

Comment 19: *The Grand Tower EA Fails to Demonstrate Project Need . . . the Grand Tower EA should evaluate . . . the projected future costs of required dredging under the no action alternative calculated for the life of the proposed Grand Tower Project, and an assessment of the ability of the dredging to continue to maintain navigation in those stretches.*

Response: See the discussion of Navigation under the Socioeconomic Resources of Sections 3 and 4 of the EA. Repetitive channel maintenance dredging costs since 2000 are provided. In total, the cost of dredging during this period was $11,672,000, or approximately $730,000 per year. Utilizing best engineering judgment, under the no action alternative, dredging would continue at levels similar to recent history as needed to address the shoaling issue in the area to keep the navigation channel open. Also see discussion below in the responses to Comments 20 and 21.

However, the long-term goal of the Regulating Works Project, as authorized by Congress, is to alleviate or eliminate the amount of annual maintenance dredging and the occurrence of vessel accidents through the construction of river training structures to provide a sustainable navigation channel and reduce federal expenditures. See Section 1 of the EA for more detail on the Purpose and Need of the Project.

Comment 20: *The Grand Tower EA Fails to Demonstrate Project Need . . . the Grand Tower EA should evaluate . . . the number of times, if any, when dredging has been insufficient to maintain navigation in the Project area.*

Response: While there have not been any reports of groundings or hindrance to navigation in this reach in recent years, the long-term goal of the Regulating Works Project, as authorized by Congress, is to alleviate or eliminate the amount of annual maintenance dredging through the construction of river training structures to provide a sustainable navigation channel and reduce federal expenditures. See response to Comment 19 above and Section 3 of the EA, Affected Environment, Socioeconomic Resources, for dredging needs in this reach.

There is a risk associated with not constructing the work due to the Corps' ability to respond to extreme dredging situations as was encountered in the low water event of 2012/2013. To meet the dredging demand of that event, the Corps had to redirect O&M funding from other O&M needs as well as bring on an additional dredge boat. It is not a reliable plan to assume the availability of additional funding and additional dredging resources to deal with future extreme events.

For future low water periods, the funding and/or resources needed to maintain the authorized channel by the use of dredging alone may not be available. This is why it is imperative that the Corps continue to construct the Regulating Works Project with the proposed river training structures as planned. Should another low water event occur and the funding and additional dredge boat not be available, there could be significant impacts to the navigation industry and consumers.

Comment 21: *The Grand Tower EA Fails to Demonstrate Project Need . . . the Grand Tower EA should evaluate . . . the construction and full life cycle maintenance costs of the proposed Grand Tower project, and the projected costs of the dredging that will still be needed even if the project is constructed.*

Response: Quantitative forecasts of dredging reduction as a result of the proposed action would be inappropriate given the dynamic nature of the MMR. Though the design process for river training structure configurations is geared toward identifying the alternative most likely to minimize the need for repetitive channel maintenance dredging (per the Project's authorization) while also taking into consideration environmental impacts, the need for repetitive channel maintenance is also heavily impacted by the MMR hydrograph and sediment loads from tributaries such as the Missouri River.

However, a review of two recent low water dredging seasons provides a quantitative look at the reduction of dredging as a result of the Regulating Works Project. During the 1988 dredge season, the river gage at St. Louis dropped below zero for 94 days. During this time, the Corps dredged approximately 19.1 million cubic yards of material to keep the channel open down to a stage of -4 ft on the St. Louis Gage. However, during the 2012 dredge season, the St. Louis Gage dropped below zero for 160 days. During this time the Corps dredged approximately 9.3 million cubic yards of material to keep the channel open while water surfaces dropped as low as -4.4 ft on the St. Louis Gage. Note that even though the river stayed below zero on the St. Louis Gage for much longer, and the channel was maintained to a greater depth, the 2012 dredge season showed over a 50% reduction in dredge quantities versus the 1988 dredge season. Also notable was a significant decrease in accidents within the navigation channel when comparing the 1988 and 2012 dredge seasons.

The maintenance cost of a structure or set of structures is heavily dependent on year to year conditions on the MMR. Significant flood events, ice flows, and even barge impacts can contribute to the need for structure maintenance. The budget for Operation &Maintenance of the Regulating Works Project on the entire 195 river mile stretch of the MMR is approximately $3,000,000 in a typical year. It is not anticipated at this time that additional construction will lead to an increase in the operation and maintenance budget.

Comment 22: *The Grand Tower EA Fails to Demonstrate Project Need . . . the Grand Tower EA should evaluate . . . the potential adverse impacts to navigation from the proposed Grand Tower project (the Conservation Organizations have been advised that river training structures can create difficulties for safe navigation).*

Response: The Corps has coordinated the proposed alternative with the River Industry Action Committee (RIAC), as it does for all work involving the placement of river training structures. No specific safety or efficiency issues were brought to the attention of Corps personnel.

Comment 23: *The Grand Tower EA Fails to Demonstrate Project Need . . . the Grand Tower EA should evaluate . . . the increased risks of upstream or nearby levee failures should the proposed Grand Tower project increase flood heights*.

Response: See response to Comment 2 above and the revised Appendix A that the Corps does not believe that construction of new river training structures increases flood heights. Therefore, construction of the Grand Tower Phase 5 work area would not have any impact on upstream or nearby levees that needs to be discussed in the EA.

Comment 24: *The Grand Tower EA Improperly Restricts the Project Purpose.*

Response: Section 1, Purpose of and Need for Action, of the Grand Tower EA has been expanded to more clearly articulate the Congressionally authorized Project purpose.

Comment 25: *The Grand Tower EA fails to evaluate a reasonable range of alternatives.*

Response: For the Grand Tower Phase 5 EA work area, the Corps considered all reasonable and feasible alternatives to meet the Regulating Works Project purpose as defined by Congress. See Section 2 of the EA, Alternatives Including the Proposed Action, which has been expanded to more clearly articulate the alternatives analysis process utilized.

Comment 26: *The Grand Tower EA fails to properly evaluate hydrologic impacts…the proposed alternative was developed using a Hydraulic Sediment Response model (HSR model)… such models cannot be relied upon to provide accurate planning information as they lack "predictive capability."*

Response: The screening of alternatives using an HSR model is one of many steps in the river engineering process used to solve complex river engineering problems. Alternatives tested in the HSR model or other river engineering tools are initially developed by experienced river engineers using accepted river engineering guidance and practice. The alternatives considered are coordinated directly with all project partners including resource agencies, navigation industry, and other interested stakeholders to develop the recommended alterative. The recommended alternative proposed is then subject to technical review both within the District and Division before the final design.

HSR models have proven to be an effective tool to compare and analyze bathymetry and velocity trends of multiple alternatives. The purpose of HSR models is to predict the hydraulic response of the tested alternatives, not to analyze hydrologic impacts including water surface changes. HSR model technology has been used successfully in solutions for over 50 complex sediment transport problems on 9 different rivers spanning 10 Corps districts. Monitoring of approximately 20 constructed projects has demonstrated the predictive capability of HSR models.

HSR modeling technology and projects developed using HSR models have gained recognition through numerous design awards from the Corps, environmental and navigation organizations and the engineering community. Projects developed using HSR models have been the subject of national and international technical papers and presentations including the PIANC Certificate of Recognition for following the "Working with Nature" philosophy by achieving our desired engineering outcome in conjunction with environmental considerations.

Comment 27: *…the Corps admits that no modeling at all was done for the structures proposed for the Crawford Towhead reach: "No HSR investigation was completed for Crawford Towhead since the bathymetry was uncomplicated." Grand Tower EA at 10. The Corps instead concluded* *that only professional judgment was required to develop this portion of the project. The Corps should not be using "professional judgment" to design and approve construction at any location, but should instead utilize the most up-to-date modeling to evaluate the potential impacts of proposed projects on public safety and the environment, including through use of state of the art two-dimensional and three-dimensional hydrodynamic model with inputs that recognize the current conditions in the river system.*

Response: Hydraulic engineers developed alternatives for Crawford Towhead using widely recognized and accepted river engineering guidance and practice, and then discussed the alternatives with the River Resources Action Team (RRAT) members during the 2009 RRAT trip and the May 2013 RRAT Executive meeting. The final design included two chevrons and a dike extension that met the work area objectives while incorporating the environmental concerns of the RRAT. USACE has constructed numerous chevrons and weirs in the MMR. Through monitoring and analysis of these existing structures (including two- and three-dimensional hydrodynamic modeling) engineers are able to predict the effects of the structures in this location on public safety and the environment. Through coordination with navigation and environmental project partners it was determined that the proposed Crawford Towhead structures would result in a reduction in shoreline erosion, improved navigation conditions for commercial river traffic, and the improvement of aquatic habitat.

Comment 28: … *the Grand Tower EA and Appendix A fail to analyze the full range of scientific studies that address the role of river training structures in raising flood heights. They also fail to provide a reasonable explanation as to why the conclusions from this extensive body of science should be rejected.*

Response: See response to Comment 2 above and the revised Appendix A.

Comment 29: *...the Grand Tower EA fails to address a global consensus that river training structures can and do increase flood heights. For example, the government of the Netherlands is expending a significant amount of resources to modify hundreds of river training structures to reduce flood risks.*

Response: There does not exist a "global consensus" that river training structures can and do increase flood heights. A literature review on the topic reveals an abundance of research conducted by scientists around the world that supports the conclusion that river training structures do not increase flood heights (see the revised Appendix A).

Dikes (referred to in the Netherlands as 'groynes') are being modified in the Netherlands in conjunction with other measures including the lowering of the floodplain, deepening of the summer bed, creation of storage basins, levee relocation, creation of high water diversion channels, and obstacle removal as part of the "Room for the River" program. The structures used on the Middle Mississippi River are much different in size, spacing, and top elevation than those used by the Dutch; the MMR structures have greater spacing, smaller crown width and are constructed to a much lower top elevation. Unlike the structures in the Netherlands, which have a crest elevation of top of bank, the structures on the MMR are constructed to an elevation of approximately one-half bankfull. Structures used on the MMR will still be lower than the modified structures in the Netherlands and research shows they have no impact on flood levels. The Corps continues to work with engineers from the Netherlands to monitor and study the impacts of dikes both in the Netherlands and the United States.

Comment 30: *The Grand Tower EA fails to properly evaluate cumulative impacts…of other Corps activities on the Mississippi River.*

Response: Appendix C of the EA supplements the Cumulative Impacts analysis and includes information on other river training structures presently planned for construction. The Herculaneum Reach project referenced in the comments was proposed under the Navigation and Ecosystem Sustainability Program (NESP). It is currently considered highly unlikely that any NESP projects will receive funding anytime in the future, and, therefore, the Herculaneum Reach project is not considered part of the reasonably foreseeable future.

The impacts of Corps O&M activities in support of navigation as well as a host of other factors affecting the human environment in the Mississippi River have been well documented for decades in a multitude of publications (including the 1976 Middle Mississippi River Regulating Works EIS). This understanding is clearly acknowledged and addressed in the EA as well as in the Cumulative Impacts Analysis (Appendix C), which incorporates by reference this information from other sources.

Comment 31: *The Grand Tower EA fails to properly evaluate cumulative impacts…of climate change.*

Response: Climate change information has been added to the EA in Section 4, Environmental Consequences.

Comment 32: *The Grand Tower EA fails to adequately evaluate impacts to fish and wildlife, including endangered species.*

Response: Development of the Grand Tower project was conducted in close coordination with fish and wildlife resource partner agencies. As outlined in the Biological Assessments (Appendix B of the EA) and the associated response letter from the U.S. Fish and Wildlife Service (Appendix F), the project falls within the scope of the programmatic Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System (programmatic BO). The effects of the proposed Grand Tower project on endangered species are consistent with those anticipated in the programmatic BO and the District has adhered to the appropriate Terms and Conditions and associated Reasonable and Prudent Measures prescribed therein.

Comment 33: *The Grand Tower EA fails to properly evaluate mitigation needs.*

Response: The Grand Tower Phase 5 Project avoided and minimized adverse impacts throughout the alternative development process and no adverse impacts that would require compensatory mitigation were identified. Further, coordination with Federal and state natural resource agencies during the planning and public review processes did not raise the need for compensatory mitigation for this work area.

Comment 34: *The Clean Water Act Section 404(b)(1) evaluation fails to provide an accurate assessment…the Grand Tower EA recognizes that there has been a decrease in surface elevation at low flows that could be due to river training structures and/or a decrease in the sediment load in the Mississippi River due to reservoir construction. Grand Tower EA at 22-23. The Grand Tower EA goes on to state that those impacts are being minimized through other Corps programs, but the Corps cannot rely on vague references to other programs to ignore this issue in either the 404(b)(1) analysis or the environmental assessment.*

Response: The District believes that the EA and 404(b)(1) provide an accurate and supportable assessment of the impacts of the proposed action. In addition, Appendix C, Cumulative Impacts Analysis, provides information on the status of MMR side channels.

Responses to February 21, 2014 David S. Korando Comments

Comment 35: *In my opinion, your man made structures are unnecessary and only raise the level of the river. As many dykes as you have in the area, how can you justify putting in more. As far as dredging you will be continuity doing so. It would be better if you took that money and the money you would use on studies and put directly on repairing our levees.*

Response: See response to Comment 2 above and the revised Appendix A. The proposed structures are designed to reduce the repetitive maintenance dredging required in the area, thereby reducing taxpayer expenditures. See Section 1 of the EA, Purpose of and Need for the Action, for more detail on this. Also see response to Comment 21 above for a discussion of how the Regulating Works Project is reducing the overall dredging in the MMR. The District does not have the authority to utilize funding appropriated for the Regulating Works Project for levee repairs.

Responses to February 21, 2014 Virgil W. Knupp Comments

Comment 36: *There are entirely to many dikes in the Mississippi River some are good but a lot of the dikes are not needed. The chevron dikes are a waste of taxpayers money. There is no reason whatsoever in closing off that much of the river.*

Response: The structures in the MMR are designed to reduce repetitive maintenance dredging required to provide a safe and dependable navigation channel. Use of structures to reduce dredging reduces taxpayer expenditures. See Section 1 of the EA, Purpose of and Need for the Action, for more detail on this. Also see response to Comment 21 above for a discussion of how the Regulating Works Project is reducing the overall dredging in the MMR. Chevron dikes were developed by the District in close coordination with fish and wildlife resource agency partners. The innovative design of chevron dikes provides habitat diversity while still providing benefits to the navigation channel.

Comment 37: *The more rock the Corps puts in the river the more flooding there will be.*

Response: See response to Comment 2 above and the revised Appendix A.

Responses to February 28, 2014 Robert Larson Comments

Comment 38: *Mr. Larson's comments were identical to Comments 12, 13, and 14 described above.*

Response: See responses to Comments 12, 13, and 14 above.

Public Hearing Comment Responses

There was a Public Hearing held on February 19, 2014 at Shawnee High School in Wolf Lake, IL that addressed both the Dogtooth Bend Phase 5 work area and the Grand Tower Phase 5 work area. The full transcript of the public hearing is included in this Appendix. Only comments relevant to the Grand Tower Phase 5 work area are addressed in the responses below.

Comment 39: MS. AMANDA DAMPTZ: *I'm from SIU Carbondale, and I would just like to make one brief comment, that the National Wildlife Federation has targeted these two dike projects and put issues on the action alert system. And as of this afternoon, there's 17,000 people nationwide that have signed up in opposition to the construction of these dikes.*

Response: The Corps is aware of the strong public interest in the Regulating Works Project on the Middle Mississippi River and will address all public comments directly or within the NEPA documents for the project.

Comment 40: MS. LARAE VERBLE-WHITAKER: *I'm from Wolf Lake, Illinois. I'm a community member. I'm also a Shawnee Valley Water Board member, and I'm also Shawnee School District Board President. Right now, I would like to ask the board or actually ask the Army Corps of Engineers to please . . . consider what you're doing before you go forth or at least postpone them, because right now, our levees are, as you know, very fragile.*

And we are working very hard to get them back to a standard where they can withhold some water, but please give them some time. And postponing a project a couple years, what will that hurt?

Response: See responses to Comments 2 and 3 above and the revised Appendix A, which details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area.

Comment 41: MS. SHELLY CLOVER HILL: *My name is Shelly Clover Hill, and I am the proud superintendent of Shawnee District 84.*

With the safety of all of our community's students and school district in mind, I urge you to suspend the dike construction at Grand Tower until after thorough scientific assessment of dikes and other maintenance activities is completed using computer modeling and real world testing of their effects.

As you know, the current states of the levees in our surrounding area, they are weakened. We are all very concerned about them. We are concerned about our homes. We are concerned about our businesses and our farms and, of course, our school district. So we would urge you to suspend those activities until further research can be conducted.

Response: See responses to Comments 2, 3, and 23 above and the revised Appendix A, which details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area.

Comment 42: MR. JIM TAFLINGER: *I'm Jim Taflinger, Len Small Levee District, live in Miller City. We've had Weir dikes in Dogtooth Bend for over 20 years. They work. They don't cause any other problem with high water, because they work on normal flow of the river.*

My concern is that we need to use hard points or some kind of a diking system to protect on the opposite side of the Weir dikes so you don't have land erosion and loss of acreage on islands. And the second thing I'd like to say is that we need to put more hard points in the chute banks along the river to protect.

We're having so much loss of river bank, because you no longer put dikes across the, you know, across the sloughs and the -- what am I trying to say -- and if you put hard points, they sure work on the island of Santa Fe Chute. You've got hard points staggered on both sides, and it's working fine. So we don't have any loss of stream bank against our levees. But as I said, the Weir dikes are working.

Response: Based on professional judgment and HSR Model test results, Corps personnel do not anticipate that the weirs being constructed for Grand Tower Phase 5 work area will cause any significant bankline erosion along the bank opposite the proposed weirs. The proposed bendway weirs already have rock dikes on the opposite river bank that should work to minimize bankline erosion. The Corps will continue to monitor bankline conditions in this area, and will remediate any bankline erosion that may impact the navigation channel.

Comment 43: MR. RON SHEPARD: *Wolf Lake. I just want to say that the dikes as I see, and being over on the river after every time the water is up and all the sand and sludge that's just left behind and building up the land, the dikes apparently aren't doing that much good and* *hasn't for several years. So I don't see why to continue to put money into something that apparently is not working that well.*

Response: River engineering and river training structures, such as the dikes discussed at the meeting, support the Corps' navigation mission by promoting a safe and efficient navigation channel. See response to Comment 21 above for a discussion of how the Regulating Works Project is reducing the overall dredging in the MMR. Additionally, river training structures reduce dredging costs and create biologically diverse habitats. Please refer to Section 1 of the EA, Purpose and Need for Action for additional information.

Comment 44: MS. OLIVIA DOROTHY: *I work for the Izaak Walton League of America, and I also am the facilitator for the Nicollet Island Coalition, which is a collaboration of conservation and taxpayer organizations on the Upper Mississippi River. That includes the Prairie Rivers Network, National Wildlife Federation, the Sierra Club, Missouri Coalition for the Environment, and others.*

Response: Ms. Dorothy's comments at the public hearing raised identical concerns and comments that were provided in writing by the same Conservation Organizations, so please see the comments and responses on the written correspondence (Comments 12-34) and the public hearing transcript for Ms. Dorothy's full public hearing comment.

Comment 45: MS. ELENA HOUSTON: *I'm from Grand Tower, and as a former student of Shawnee High School, I've seen a lot of research that has been done on wing dikes and the effects they have on flooding. And from what I've seen, that it hasn't been very beneficial in relation to flooding. So before you guys put these dikes in, I would just like for more research to be done to show that it's not going to affect us in negative ways.*

Response: See responses to Comments 2, 3, and 23 above and the revised Appendix A which details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area.

Comment 46: MR. KENNETH VERBLE: *I live in Wolf Lake, and a farm owner and concerned with anything that affects the river and any flooding that may occur from it. I guess one of my first thoughts was have we done a computer modeling program to determine what these dikes are going to do in the future? Have we looked at the existing dikes as to what they have done? Just noticed in your brochure here that Congress has given us a blank check to go out and build these things, but I don't see anything going back towards what's happened in the past, such as the old dikes that have built up and consumed the water volume that used to exist. It's no longer there, so water can't take its place during any high waters.*

So I would like to see you use some of that money to do both things. I'm sure Congress didn't allot that money just to keep the river 9 foot deep, 300 foot wide. I'm sure they had other things in mind to protect the citizens in the Bottoms as well as the traffic on the river. So those things should be studied.

And that computer model I would like to see, and also, who are you reporting to within the state? This is Illinois. When you're on the Illinois side, somebody in Illinois needs to be working with the Corps of Engineers, say yes, I agree with you or no, I don't agree with you, yes, you've done the right studies and this independent agency over here has verified that.

And being from a background of codes and standards, you never go with one study. You have more than one study, and then you mock it up, make sure your studies are right. The mock-ups and studies will cost more than the actual project. So those things need to be done and not forgotten.

So again, looks like we got a blank check to work on this river. Let's work on both sides of it to benefit the farmer, the Bottoms and the traffic.

Response: Please refer to Section1, Purpose and Need for Action, in the EA for a discussion of the congressional authorization of the Regulating Works Project. See Section 2, Alternatives Including the Proposed Action, for a discussion of the modeling done on the Grand Tower Phase 5 area. See responses to Comments 2, 3, and 23 above and the revised Appendix A for a discussion and analysis of the research conducted on river training structures' effect on stages, which also details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area. See response to Comment 21 above for a discussion of how the Regulating Works Project is reducing the overall dredging in the MMR.

The Corps routinely coordinates with state agencies from Missouri and Illinois for the Regulating Works Project, including Grand Tower Phase 5. Agencies include the Illinois Department of Natural Resources (IDNR) and the Illinois Environmental Protection Agency (IEPA). Further, the Corps has obtained Water Quality Certification from IEPA pursuant to the Clean Water Act Section 401 specifically for the Grand Tower Phase 5 work.

Comment 47: MS. JAMIE NASH-MAYBERRY: *You know that my students and I have studied this issue extensively. We came to your Corps base in St. Louis, and Eddie Brauer presented his side of the issue. And we kept an open mind, but we couldn't deny what all the other sources we examined were saying.*

We didn't just talk to Dr. Nicholas Pinter of SIU, a geologist, geographer; we went on. We talked to others. We talked to Fredrik Huthoff of the Netherlands. He was studying abroad. We talked to a Washington University professor. We read peer-reviewed journals. We even read comments from the National Wildlife Federation.

And then we talked to the real experts, the locals, who've seen these dikes be put in over the years. And the thing is, they all concluded the same thing, that these wing dikes lead to increased flood heights.

Here's my point: If we're wrong, all of us, the consequences are really minimal. But if you are wrong as the Corps, the consequences are enormous. Why not stop putting them in, get an outside group to come in, do a study -- and I don't mean a group that you're paying; an outside group -- and have them conclude what's happening here? And you could spend your money blowing up shale to help the barges. You could dredge to help the barges. You could use your money to open up other rivers to help the barges, or perhaps you could even use that money to fix some of these slides in Grand Tower.

But the National Wildlife Federation just a minute ago recommended the National Academy of Sciences could come in and do a study. I know they've tried before to do that, and I don't understand why you haven't had them come in and do the study. My conclusion is you're afraid of what they might conclude and perhaps the future lawsuits that might follow that.

Finally, I simply ask this of you: Think about the consequences of all these people. I know you have hearts. You've come down here. You've done excellent presentations for my students and I anytime we've asked, so I know you're caring people. I know that. I'm asking you to care about these people and think about what the risk might be..

Response: See responses to Comments 2, 3, and 23 above and the revised Appendix A for a discussion and analysis of the research conducted on river training structures' effects on stages, which also details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area. The Corps is currently expending funds for the Regulating Works Project pursuant to its authority on rock removal and dredging where necessary as well as constructing river training structures and revetment. However, see Section 1, Purpose and Need, for an explanation of the Corps' authority to minimize dredging by constructing regulating works. Further, the Corps lacks the legal authority to expend funds appropriated by Congress for one project, in this case the Regulating Works Project, on other projects or activities.

Comment 48: MS. JESSICA SPURLOCK: *My name is Jessica Spurlock. I live in Wolf Lake, Illinois, and I'm a senior this year at Shawnee High School and a proud supporter and proud to be a part of Save the Levee Project. Grand Tower, if there was to be another flood, and it be to where the levees would break, it would be disastrous, and we would lose our district because it's a third. And we all know -- half of it now is from what Miss Nash-Mayberry has told us -- in this construction, there would be new S dikes. And that is new, and that has not been tested yet further.*

There should be more people looking into this S dike program like the National Academy of Science look into it and see what they think and their opinion is on it on how these dikes will or will they not break our levees and if the levee will rise if these dikes are put in. Thanks.

Response: See responses to Comments 2, 3, and 23 above and the revised Appendix A, which details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area.

Comment 49: MR. BRADEN MEZO: My *name is Braden Mezo, and I am a senior at Shawnee High School. And it is common knowledge that there are going to be many new – that this project will present as many different kinds of wing dikes, the S dike as previously mentioned. Knowing that it had not been tested thoroughly yet, I believe that this raises many concerns, and I humbly request that you put a little bit more research into it.*

Being a resident of this area, it is very important to me that I graduate from this school. I do not want to lose my home, and it is very important to me. So I humbly request you *put it off maybe for a year or two. Like it was said before, what can it hurt? And that is all. Thank you.*

Response: See responses to Comments 2 and 3 above and the revised Appendix A, which details the additional modeling completed for the Vancill Towhead portion of the Grand Tower Phase 5 work area.

Comment 50: PROFESSOR NICHOLAS PINTER: *My name is Nicholas Pinter, Professor at Illinois University of Carbondale.*

Response: Mr. Pinter's comments at the public hearing raised identical concerns and comments that he provided in writing, so please see the comments and responses on the written correspondence (Comments 1-6) and the public hearing transcript.

Comment 51: MR. VIRGIL KNUPP: *I'm from Grand Tower. I worked on the river for 35 years for Luhr Brothers.*

Response: Mr. Knupp's comments at the public hearing raised identical concerns and comments that he provided in writing with specific examples of areas of the Mississippi River not relevant to the Grand Tower Phase 5 area, so please see the comments and responses on the written correspondence (Comments 36-37) and the public hearing transcript for Mr. Knupp's full public hearing comment.

Responses to April 22, 2016 National Wildlife Federation, American Rivers, Missouri Coalition for the Environment, and Prairie Rivers Network Comments on the Amended Grand Tower Phase 5 Environmental Assessment

In response to public comments on the draft EA released for public review on December 20, 2013, the Corps evaluated the potential impacts of the proposed structures at Vancill Towhead on flood levels using a two-dimensional hydrodynamic model. The EA was amended to respond to public comments and include the results of the numerical model, neither of which provided any significant new information to substantially change the EA or the work to be completed as part of Grand Tower Phase 5. On March 9, 2016, the amended EA was posted on the St. Louis District's website as well as sent to all prior commenters for awareness of the model results.

On April 22, 2016, National Wildlife Federation, American Rivers, Missouri Coalition for the Environment, and Prairie Rivers Network provided comments on the amended EA in addition to the comments they submitted on January 24, 2014. These comments were reviewed and considered in making a final decision on the Grand Tower Phase 5 work area. However, a majority of the April 22, 2016 comments raised similar concerns and comments that were provided on January 24, 2014, which is logical since the amended EA did not change in any substantial way, other than to include the two-dimensional hydrodynamic model results and respond to the comments received on the draft EA. Therefore, the responses to the original comments are still applicable and will not be repeated here for the same concerns and comments (See Responses to Comments 12-34 above).

Further, all comments in the April 22, 2016 letter pertaining to the same research showing that river training structures increase flood heights that has previously been provided to the Corps will not be further addressed since this issue has been fully evaluated and considered by the Corps. However, Appendix A has been updated to include information on new research referenced in the April 22, 2016 comments pertaining to river training structures and flood heights. As noted in response to Comment 2 above, the Corps considers public safety to be of paramount importance when designing and evaluating projects. The agency believes strongly that the best available science shows that this project will not increase flood heights, and consequently the project does not pose a significant risk to public safety.

Responses to April 22, 2016 comments differing substantially from those provided on January 24, 2014 can be found below.

Comment 52: ***B. The New 2D Model Must be Certified Prior to Use and the Model's Application to the Grand Tower Project Must be Peer Reviewed***

Response: The Adaptive Hydraulics Model (AdH) is not a "new" model; it was released to the public in September 2007 and has been used in many studies published in peer reviewed engineering journals. AdH is listed as a USACE Hydrology, Hydraulics and Coastal Community of Practice (HH&C CoP) preferred model for river hydraulics applications. It has been validated by the HH&C CoP for use in planning studies and satisfies the requirements of the Corps' Scientific and Engineering Technology (SET) Initiative as detailed in (ES)-08101. Software validation is a corporate determination that a piece of software is a technically and theoretically sound and functional tool that can be applied during the planning, engineering and design process by knowledgeable and trained staff for purposes consistent with the software's purpose and limitations. AdH was certified in June 2012 by Federal Emergency Management Agency (FEMA), recognizing AdH modeling software as a nationally accepted hydraulic software for two-dimensional modeling.

The Hydrodynamic Study of Vancil Towhead Reach on the Middle Mississippi River underwent a series of agency reviews including District Quality Control (DQC) and Agency Technical Review (ATR) which complies with the requirements of EC 1165-2-214. A certification of agency technical review has been added to the report.

Comment 53: *To provide accurate analyses, a hydrologic model must, among other things: use the correct roughness coefficients, use the correct eddy viscosity, be based on accurate baseline conditions, employ appropriate underlying assumptions, and utilize appropriate flow levels for model runs.*

Response: DQC and ATR reviewed the assumptions, methods, procedures, and material used in the analysis, the alternatives evaluated, the appropriateness of the data used and level obtained, and the reasonableness of the results. This includes the roughness coefficient values, eddy viscosity, and baseline geometry.

In addition to the agency reviews, the District worked with the USACE Engineer Research and Development Center, the developers of AdH, throughout the modeling process to ensure the model was developed and applied correctly as well as to validate the results.

Comment 54: *Underlying Assumptions: Dr. Pinter's research shows that the impacts of wing dikes grow larger for larger floods (i.e., the dike becomes hydrodynamically rougher with larger discharge). The Conservation Organizations understand that the Corps' model assumes that flow over a submerged dike is smooth and laminar such that the impacts of the dike would diminish proportionally as flood height increases. A model based on the Corps' incorrect assumption will produce flawed results. Was the model constructed using the correct assumption regarding the impact of river training structures under larger discharges?*

Response: The modeler does not have the ability to manipulate the two-dimensional shallow water equations used by the model. These equations were evaluated in the model validation process described above and have been determined to be correct.

The conclusion found in early research by Dr. Pinter that dikes become "hydrodynamically rougher with larger discharge" has been proven to be incorrect by many scientists and engineers (Chow 1959, Stevens et al. 1975, Yossef 2005, Azinfar and Kells 2007, PIANC 2009, Watson & Biedenharn 2010 and Sukhodolov 2013). Even an article co-authored by Dr. Pinter demonstrates that the roughness in a dike reach decreases with increasing water levels (Huthoff et al. 2013).

The understanding of the Conservation Organizations on the assumption of smooth and laminar flow over a submerged dike is incorrect. AdH accounts for losses around the structures through modification of turbulence and roughness terms. During the validation process the roughness values are modified to capture the behavior of the system, including roughness over the structures to account for additional losses. The validation of the model was evaluated as part of ATR.

Comment 55: *Flows Used for Model Runs: The Corps has evaluated only the impacts from a 1% annual exceedance flood (a 100 year flood). The Corps should also be evaluating impacts for larger flood events.*

Response: The 1% annual chance exceedance flood was used because it is the regulatory discharge. To provide a national standard, the 1% annual chance exceedance (ACE) flood has been adopted by Federal Emergency Management Agency as the regulatory discharge or base flood for flood insurance purposes. A 1% ACE has a 1% of annual chance of being equaled or exceeded in any given year. The 1% ACE floodplain is shown on the Flood Insurance Rate Map. Since the roughness of the dikes decreases with increasing water levels, it can be concluded that there are no impacts of the project on floods that are greater than the 1% ACE discharge.

Comment 56: *Moreover, the model does not look at the impacts of the entire Phase 5 set of projects. Indeed, no modeling was done at all for the structures proposed for the Crawford Towhead reach.*

Response: The types of structures used in the Crawford Towhead reach have been evaluated for flood level impacts through the use of multi-dimensional numerical modeling and other technical analyses (Appendix A). It is not expected that the impacts of the structures in the Crawford Towhead reach would be different than what has been observed in the past.

Public concern was raised on the Vancill Towhead portion of the project due to configuration of the diverter dikes. Since the impact of this configuration of dikes on flood levels has not been evaluated in the past the Corps used a multi-dimensional numerical model to evaluate these impacts. The results of the Hydrodynamic Study of Vancill Towhead Reach on the Middle Mississippi River combined with the previous analysis on the topic leads the Corps to conclude that the structures constructed in the Grand Tower Phase 5 work location will not increase flood levels.

Comment 57: ***C. The Grand Tower EA Uses an Improperly Narrow Project Purpose***

Response: Section 1, Purpose of and Need for Action, of the Grand Tower Phase 5 EA clearly articulates the Congressionally authorized Project purpose to obtain and maintain a navigation channel in the Middle Mississippi River nine feet deep and at least 300 feet wide, with additional width in bends, through rock removal, bank stabilization, and the construction of river training structures to reduce dredging to obtain and maintain the channel to a minimum. The Project is carried out as prescribed by Congress, and as referenced in the revised Section 5, Relationship of

Proposed Action to Environmental Requirements, is in compliance with all applicable laws, regulations, and policies.

Comment 58: ***D. The Grand Tower EA Fails to Demonstrate Project Need, Fails to Provide Meaningful Cost Information, and Fails to Provide a Benefit-Cost Assessment***

Response: Section 3 of the EA, Affected Environment, Socioeconomic Resources, Navigation has been updated to include information on dredge quantities in the work area since 2000. Section 4 of the EA, Environmental Consequences, Socioeconomic Resources, Navigation has been updated to include information on the anticipated reduction in dredging quantity and frequency.

With respect to cost estimates, due to Federal contracting laws and regulations, detailed government estimates for future contract work cannot be disclosed. The $4 million cost of the Proposed Action provided in the original EA was only an estimate of the not-to-exceed construction costs. The $8 million cost provided in the amended EA includes all costs associated with implementation of the Proposed Action including not-to-exceed construction costs, additional costs associated with the two-dimensional modeling, Corps labor expenses, etc. and provides a more accurate estimate of the true cost of implementation.

Comment 59: ***E. The Grand Tower EA Fails to Evaluate a Reasonable Range of Alternatives and Fails to Meaningfully Review the No Action Alternative***

Response: For the Grand Tower Phase 5 EA work area, the Corps considered all reasonable and feasible alternatives to meet the Regulating Works Project purpose as defined by Congress. The Corps determined that the only reasonable and feasible alternatives for this area would be to continue costly dredging in this area or to attempt to provide a more sustainable navigation channel through the construction of river training structures. While only the preferred river training structure alternative from the HSR Model Report and the No Action Alternative were evaluated in detail in the Phase 5 EA, there were 37 different alternatives for various river training structure configurations considered by the Corps (as noted in the EA, the HSR Model Report is fully incorporated by reference and is part of the EA). The Corps determined that the preferred alternative from the HSR modeling and the No Action Alternative were the only alternatives that needed to be fully evaluated in the Phase 5 EA because alternatives that did not adequately address the dredging issue and avoid or minimize environmental impacts were not deemed reasonable alternatives to consider further. Both the Proposed Action and the No Action Alternative are accurately and adequately addressed in the EA.

The suggestions provided in the comments for consideration of other alternatives are for programmatic evaluation of the entire Regulating Works Project. The 1976 EIS addressed various alternatives at the programmatic level, and the pending SEIS will take into account the new information and circumstances since 1976 to fully discuss the reasonable and feasible programmatic alternatives for the Regulating Works Project. Therefore, the alternatives suggested are outside of the scope of the Phase 5 EA project purpose – to obtain and maintain the navigation channel with a focus of reducing costly dredging through the construction of river training structures.

Even still, the Corps did consider the alternatives recommended in the comments and came to the conclusion that these were not reasonable or feasible alternatives meeting the project purpose for the Grand Tower Phase 5 work area.

- Pursuant to 33 CFR § 336.1(c)(1), "[I]t is the Corps' policy to regulate the discharge of dredged material from its projects to assure that dredged material disposal occurs in the least costly, environmentally acceptable manner, consistent with engineering requirements established for the project." The Corps coordinates all dredge disposal with Federal and state resource agencies on a continual basis to ensure such disposal is done in an environmentally acceptable manner. The Corps continually evaluates dredging measures and disposal strategies. The current approach of dredging in the work area has been determined to be the most economically viable and environmentally acceptable option.

- Removing, modifying, minimizing, or restricting construction of new river training structures would not meet the Project purpose. These measures could possibly be considered if the Corps deemed that compensatory mitigation was needed for the Phase 5 EA work area. However, the Corps has determined that no compensatory mitigation is needed because significant impacts have been avoided or minimized by the design of the river training structures.

Comment 60: ***F. The Grand Tower EA Fails to Properly Evaluate the Full Suite of Environmental Impacts...3. The Grand Tower EA Fails to Properly Evaluate Climate Change***

Response: Information on reduced stages at low flows has been added to the climate change discussion in Chapter 4, Environmental Consequences.

Comment 61: ***F. The Grand Tower EA Fails to Properly Evaluate the Full Suite of Environmental Impacts...4. The Grand Tower EA Fails to Properly Evaluate Cumulative Impacts...***

Notably, the entire cumulative impacts "assessment" appears to be driven by a fundamentally incorrect and circular conclusions:

> *"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."*

Response: The quoted section clearly is not meant to address "the entire cumulative impacts assessment"; it is specifically in reference to any potential impacts that river training structures could have on side channels due to reduced stages at low flows. Indeed, the Corps has implemented and continues to implement side channel restoration and enhancement projects that frequently use innovative river training structure designs.

Comment 62: ***F. The Grand Tower EA Fails to Properly Evaluate the Full Suite of Environmental Impacts...4. The Grand Tower EA Fails to Properly Evaluate Cumulative Impacts...(a) Cumulative Impacts of Climate Change***

Response: The climate change analysis summarized in the main body of the Grand Tower Phase 5 EA and in Appendix C are based on the best available and most recent climate change science and adequately address climate change issues associated with the proposed work. The USACE 2015 publication used in this analysis, Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions, Upper Mississippi Region 07, does, in fact, include information from the referenced National Climate Assessment and Global Change Research Program.

Comment 63: ***H. The 1976 EIS Does Not, and Cannot, Cure the Deficiencies of the Grand Tower EA.***

Response: The Corps does not purport that the 1976 EIS serves to cure any deficiencies in the Grand Tower Phase 5 EA. As described above in response to Comments 16 and 17 and in the Prior Reports portion of Section 1, the Grand Tower Phase 5 EA is tiered to the 1976 EIS (a programmatic NEPA document covering all aspects of the Regulating Works Project – i.e., regulating works, revetment, dredging, and Chain of Rocks area work). The Grand Tower Phase 5 EA incorporates by reference and relies on the information in the 1976 EIS that is still applicable to the Regulating Works Project as well as the Grand Tower Phase 5 work area. The Grand Tower Phase 5 EA fully evaluates environmental impacts as to the site-specific work and includes a current description and analysis of any new circumstances and information on regulating works generally since the 1976 EIS as well as impacts to the site-specific Grand Tower Phase 5 work area. This tiered analysis from the 1976 EIS, even while being supplemented, is in accordance with law and the recent CEQ guidance issued December 18, 2014, Memorandum for Heads of Federal Departments and Agencies, subject: Effective Use of Programmatic NEPA Reviews.

Comment 64: ***I. The Proposed Grand Tower Project Should Be Examined an EIS***

Response: As specified in the Grand Tower Phase 5 EA, the Corps has reviewed any and all pertinent information pertaining to the potential impacts of the proposed action on the human environment. Based on this “hard look”, the Corps has made the determination that the potential impacts of the proposed action are not significant and, therefore, that a site-specific EIS is not warranted. Clearly the roughly 50 pages of information and analysis in the main body of the EA, in addition to information contained in the appendices, cannot be considered “simply a statement" that an EIS is not necessary. The Grand Tower Phase 5 EA contains the information necessary to support this conclusion.

Appendix F. Agency and Tribal Government Coordination

Appendix F. Agency and Tribal Government Coordination

TABLE OF CONTENTS

Illinois Historic
Preservation Agency

1 Old State Capitol Plaza, Springfield, IL 62701-1512

FAX (217) 782-8161
www.illinoishistory.gov

Union County
Grand Tower to Ware
New Construction or Modification, Grand Tower Phase 5
Between Upper Mississippi River Miles 75 and 66
IHPA Log #010102413

November 6, 2013

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 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 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 have any further questions, please contact me at 217/785-5027.

Sincerely,

Anne E. Haaker

Anne E. Haaker
Deputy State Historic
Preservation Officer

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

October 28, 2013

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

Re: Grand Tower Phase 5 River Training Structures (COE) Cape Girardeau County, Missouri

Dear Dr. Trimble:

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

We have reviewed the information provided concerning the above referenced project. We concur with your determination that the proposed Grand Tower Phase 5 River Training Structures Project will have **no adverse effect** on any properties that may be eligible for inclusion in the National Register of Historic Places.

Please be advised that, should project plans change, information documenting the revisions should be submitted to this office for further review and comment on possible effects to historic properties. 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 (**001-CG-14**) 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

c Dr. Mark Smith, COE/SL

Recycled Paper

STATE OF MISSOURI

Jeremiah W. (Jay) Nixon, Governor • Sara Parker Pauley, Director

DEPARTMENT OF NATURAL RESOURCES

www.dnr.mo.gov

JAN 21 2014

Mr. Kevin P. Slattery
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce St.
St. Louis, MO 63103

Cape Girardeau County
P-2856/2013-742/CES002769

Dear Mr. Slattery:

The Missouri Department of Natural Resources' Water Protection Program has reviewed your request for Clean Water Act Section 401 Water Quality Certification (WQC) to accompany the U.S. Army Corps of Engineers' (USACE) Permit No. P-2856/2013-742 in which the USACE's St. Louis District is proposing to construct three bendway weirs near Mississippi River Mile (RM) 69.00; diverter dike structures near RM 68.00; dike repair, dike shortening, and construction of revetment near RM 67.50; and two chevrons and one rootless dike extension near RM 73.00 as part of the Grand Tower Phase 5 – Vancill and Crawford Towhead Project. The purpose of the structures is to reduce repetitive dredging and enhance alignment for safe and dependable navigation as well as provide environmental diversity. All site access will be via the river and all construction will be from floating plant. The project is located in the Middle Mississippi River between RMs 67.0 and 74.0 in Cape Girardeau County, Missouri.

This WQC is being issued under Section 401 of Public Law 95-217, The Clean Water Act of 1977 and subsequent revisions. This office certifies that the proposed project will not cause the general or numeric criteria to be exceeded nor impair beneficial uses established in the Water Quality Standards, 10 CSR 20-7.031, provided the following conditions are met:

1. Unwanted dredged material and river water extracted from only the Mississippi River may be placed back into the Mississippi River. You shall not dispose of waste materials, water, or garbage below the ordinary high water mark of any other water body, in a wetland area, or at any location where the materials could be introduced into the water body or an adjacent wetland as a result of runoff, flooding, wind, or other natural forces.

2. Operations in the Mississippi River shall be conducted such that there will be no unreasonable interference with navigation by the existence or use of the activity.

3. A Total Maximum Daily Load (TMDL) was approved for Chlordane and Polychlorinated Biphenyls (PCB) on November 3, 2006, and allocations were set at zero pounds per day. No new Chlordane or PCB loading of the Mississippi River is allowed. Any excavated Chlordane or PCB contained sediment shall be disposed of at an appropriate upland disposal facility.

4. Fuel, oil and other petroleum products, equipment, construction materials and any solid waste shall not be stored below the ordinary high water mark at any time or in the adjacent floodway beyond normal working hours. All precautions shall be taken to avoid the release of wastes or fuel to streams and other adjacent waters as a result of this operation.

5. Petroleum products spilled into any water or on the banks where the material may enter waters of the state shall be immediately cleaned up and disposed of properly. Any such spills of petroleum shall be reported as soon as possible, but no later than 24 hours after discovery to the Missouri Department of Natural Resources' Environmental Emergency Response number at (573) 634-2436.

6. Only clean, nonpolluting fill shall be used. The following materials are not suitable for bank stabilization and shall not be used due to their potential to cause violations of the general criteria of the Water Quality Standards (10 CSR 20-7.031 (3)(A)-(H)):

   a. Earthen fill, gravel, broken concrete where the material does not meet the specifications stated in the Missouri Nationwide Permit Regional Conditions (http://www.nwk.usace.army.mil/Portals/29/docs/regulatory/nationwidepermits/2012/MORegCon.pdf) and fragmented asphalt, since these materials are usually not substantial enough to withstand erosive flows;
   b. Concrete with exposed rebar;
   c. Tires, vehicles or vehicle bodies, construction or demolition debris are solid waste and are excluded from placement in the waters of the state;
   d. Liquid concrete, including grouted riprap, if not placed as part of an engineered structure; and
   e. Any material containing chemical pollutants (including but not limited to creosote or pentachlorophenol).

7. To the maximum extent practicable, use bioengineering methods for bank stabilization that minimize the amount of sediment and other pollutants entering the water ways. As opportunity allows, limit the amount of rock or other hard points while increasing the amount of native vegetation or a combination of rock and vegetation.

8. Best Management Practices shall be used during all phases of the project to limit the amount of discharge of water contaminants to waters of the state. The project shall not involve more than normal stormwater or incidental loading of sediment caused by construction disturbances.

9. Conduct activity at low flows and water levels to limit the amount of sediment disturbance caused by the heavy equipment. Limit the duration and extent that the heavy equipment is required to be in-stream.

10. The WQC is based on the plans as submitted. Should any plan modifications occur, please contact the Department to determine whether the WQC remains valid or may be amended or revoked.

Pursuant to Chapter 644.052.9, RSMo, commonly referred to as the Missouri Clean Water Law, this WQC shall be valid only upon payment of a fee of seventy-five dollars ($75.00). The enclosed invoice contains the necessary information on how to submit your fee. Payment must be received within fifteen (15) days of receipt of this WQC. Upon receipt of the fee, the applicable office of the USACE will be informed that the WQC is now in effect and final.

You may appeal to have the matter heard by the Administrative Hearing Commission (AHC). To appeal, you must file a petition with the AHC within thirty (30) days after the date this decision was mailed or the date it was delivered, whichever date was earlier. If any such petition is sent by registered mail or certified mail, it will be deemed filed on the date it is mailed; if it is sent by any method other than registered mail or certified mail, it will be deemed filed on the date it is received by the AHC.

This WQC is part of the USACE's permit. Water Quality Standards must be met during any operations authorized. If you have any questions, please contact Ms. Stacia Bax by phone at (573) 526-4586, by e-mail at stacia.bax@dnr.mo.gov, or by mail at the Missouri Department of Natural Resources, Water Protection Program, Operating Permits Section, P.O. Box 176, Jefferson City, MO 65102-0176. Thank you for working with the Department to protect our environment.

Sincerely,

WATER PROTECTION PROGRAM

Chris Wieberg, Chief
Operating Permits Section

CW:sbp

Enclosures

c: Mr. Jasen Brown, U.S. Army Corps of Engineers, St. Louis District
Mr. Bradley Ledbetter, Southeast Regional Office
Mr. Kevin Vanover, Southeast Regional Office

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 • (217)782-2829

PAT QUINN, GOVERNOR LISA BONNETT, DIRECTOR

217/782-3362

RECEIVED

BY:

FEB - 6 2014

St. Louis District
Corps of Engineers
Regulatory Branch
1222 Spruce Street
St. Louis, MO 63103

Re: U.S. Army Corps of Engineers (Union County)
Dike and Weir Construction – Mississippi River Miles 67-74
Log # C-0681-13 [CoE appl. # 2013-742]

Gentlemen:

This Agency received a request on October 11, 2013 from the U.S. Army Corps of Engineers requesting necessary comments concerning the construction of dikes and weirs along the Mississippi River miles 67 to 74. We offer the following comments.

Based on the information included in this submittal, it is our engineering judgment that the proposed project may be completed without causing water pollution as defined in the Illinois Environmental Protection Act, provided the project is carefully planned and supervised.

These comments are directed at the effect on water quality of the construction procedures involved in the above described project and are not an approval of any discharge resulting from the completed facility, nor an approval of the design of the facility. These comments do not supplant any permit responsibilities of the applicant toward the Agency.

This Agency hereby issues certification under Section 401 of the Clean Water Act (PL 95-217), subject to the applicant's compliance with the following conditions:

1. The applicant shall not cause:

   a. violation of applicable water quality standards of the Illinois Pollution Control Board, Title 35, Subtitle C: Water Pollution Rules and Regulations;

   b. water pollution defined and prohibited by the Illinois Environmental Protection Act; or

   c. interference with water use practices near public recreation areas or water supply intakes.

2. The applicant shall provide adequate planning and supervision during the project construction period for implementing construction methods, processes and cleanup procedures necessary to prevent water pollution and control erosion.

3. Any spoil material excavated, dredged or otherwise produced must not be returned to the waterway but must be deposited in a self-contained area in compliance with all state statutes, regulations and permit requirements with no discharge to waters of the State unless a permit has been issued by this Agency. Any backfilling must be done with clean material and placed in a manner to prevent violation of applicable water quality standards.

4. All areas affected by construction shall be mulched and seeded as soon after construction as possible. The applicant shall undertake necessary measures and procedures to reduce erosion during construction. Interim measures to prevent erosion during construction shall be taken and may include the installation of staked straw bales, sedimentation basins and temporary mulching. All construction within the waterway shall be constructed during zero or low flow conditions. The applicant shall be responsible for obtaining an NPDES Storm Water Permit prior to initiating construction if the construction activity associated with the project will result in the disturbance of 1 (one) or more acres, total land area. An NPDES Storm Water Permit may be obtained by submitting a properly completed Notice of Intent (NOI) form by certified mail to the Agency's Division of Water Pollution Control, Permit Section.

5. The applicant shall implement erosion control measures consistent with the "Illinois Urban Manual" (IEPA/USDA, NRCS; 2013).

6. The proposed work shall be constructed with adequate erosion control measures (i.e., silt fences, straw bales, etc.) to prevent transport of sediment and materials downstream.

7. The fill material used in waters of the State shall be predominantly sand or larger size material, with <20% passing a #230 U. S. sieve.

8. Asphalt, bituminous material and concrete with protruding material such as reinforcing bar or mesh shall not be 1) used for backfill, 2) placed on shorelines/streambanks, or 3) placed in waters of the State.

This certification becomes effective when the Department of the Army, Corps of Engineers, includes the above conditions # 1 through # 8 as conditions of the requested approval issued pursuant to Section 404 of PL 95-217.

This certification does not grant immunity from any enforcement action found necessary by this Agency to meet its responsibilities in prevention, abatement, and control of water pollution.

Sincerely,

Alan Keller, P.E.
Manager, Permit Section
Division of Water Pollution Control

SAK:TJF:0681-13.docx

cc: IEPA, Records Unit
IEPA, DWPC, FOS, Marion
IDNR, OWR, Springfield
USEPA, Region 5
Mr. Kevin Slattery, U.S. Army Corps of Engineers, St. Louis District

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

REPLY TO
ATTENTION OF:

August 16, 2013

Engineering and Construction Division
Curation and Archives Analysis Branch

COPY

Ms. Glenna J. Wallace, Chief
Eastern Shawnee Tribe of Oklahoma
P.O. Box 350
Seneca, Missouri 64865

Dear Chief Wallace:

This letter addresses the construction of river training structures in four major areas 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 proposes adding, or modifying, twenty seven (27) training structures.

This project is located along the Mississippi River from St. Louis Harbor, located in St. Clair County, Illinois, south along the Mississippi River to the counties of Alexander located in Illinois, and Mississippi located in Missouri (see Figure 1). See Figures 2–7 for the location and structure types to be constructed on both the Illinois and Missouri sides of the Mississippi River. Federal monies have been received for the river training structures. The project areas are located on private land both in Missouri and Illinois. 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.

In 1866 the Federal Government allocated funding for a 4-foot navigation channel between Minneapolis and St. Louis. In 1878 this channel was deepened to a 4.5-foot channel, and in 1907 it was once again deepened to a 6-foot channel. This was achieved using a system of wing and closing dikes in conjunction with river dredging. On July 3, 1930, the Rivers and Harbors Act was amended, and the lock and dam system along the upper Mississippi River, from Minneapolis to St. Louis, was put in place. However, the middle and lower sections of the Mississippi River, below St. Louis, remains an open river navigation channel.

Training structures will be incorporated into the pre-existing system of structures already located along the river. There are numerous types of river structures including dikes, revetments, and bendway weirs. Below is a description of the different types of training structures proposed for this project. See Table 1 for the proposed location and type of structure to be constructed.

- **Wing dikes** are the oldest form of river training structure. They are constructed from the bankline into the river generally at a perpendicular angle to the current (see Figure 2 for an example). They redirect the river's own energy to manage sediment distribution within the river channel. While the original dikes of the nineteenth century were largely pile structures, by the middle of the twentieth century many had been converted to stone-fill types.

- **L-dikes** are shaped like an L with the shorter arm extending to the bank and the longer arm parallel with the current (see Figure 2 for an example). They are used to restrict sediment-carrying bottom currents from moving into the area between a series of dikes.

- **Rootless dikes** are wing dikes that are not connected to the shore (see Figure 3 for an example). The gap between the structure and the bank promotes habitat diversity.

- **Diverter (or S-) dikes** are in-stream structures useful in creating secondary side channels as they capture water from the main channel and direct it toward areas of interest, while still providing enough roughness and constriction to maintain a navigable channel (see Figure 5 for an example). They cause minimal erosion along the bankline because eddies are formed at their downstream tip.

- **Chevrons** are blunt nosed arch-shaped structures constructed parallel to the river flow (see Figure 4 for an example). Like other dikes they utilize the energy of the river to redistribute water flow, but unlike traditional dikes that create a unidirectional deflection, they create a split flow. The riverside bank of the chevron directs flow to maintain the navigation channel while the other side directs flow toward the near bank region. These structures have been proven to be effective at promoting environmental diversity, including a low velocity habitat behind the chevron itself.

- **Revetments** are structures placed along the river bank to stabilize or protect the bank from erosion (see Figure 3 for an example). They are usually constructed out of stone, but a variety of other materials have been used including concrete-mat, willow mattresses, and gabions.

COPY

- **Bendway weirs** are submerged rock structure that are positioned from the outside bankline of a river-bend and angled upstream toward the river flow (see Figure 7 for an example). 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 a 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 via barge, 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. USACE has conducted shipwreck surveys 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 ensure historical shipwrecks are not adversely impacted.

River embankments can potentially have adverse affects on cultural resources. As with other training structures they are conducted via barge, without recourse to land access. The placement of the rock on the shoreline, however, has the potential to affect any resources on that shoreline. With all embankment features, historical research is conducted on the proposed location to determine if the area 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 appropriate, pedestrian and/or shovel test surveys will be conducted to investigate all proposed locations. Should an inadvertent discovery of human remains occur, then state 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 following Federally recognized tribes are being notified of this project.

Absentee-Shawnee Tribe of Oklahoma
Eastern Shawnee Tribe of Oklahoma
Shawnee Tribe
Cherokee Nation
United Keetoowah Band of Cherokee of Oklahoma
Delaware Nation, Oklahoma
Delaware Tribe of Indians, Oklahoma
Citizen Potawatomi Nation
Forest County Potawatomi Community
Match-e-be-nash-she-wish Band of Potawatomi of Michigan
Hannahville Indian Community
Nottawaseppi Band of Huron Potawatomi
Pokagon Band of Potawatomi
Prairie Band Potawatomi Nation
Ho-Chunk Nation of Wisconsin
Winnebago Tribe of Nebraska
Iowa Tribe of Kansas and Nebraska
Iowa Tribe of Oklahoma
Kickapoo Traditional Tribe of Texas

Kickapoo Tribe of Oklahoma
Kickapoo Tribe of Indians of Kansas
Sac & Fox Nation of Oklahoma
Sac & Fox Nation of Missouri in Kansas
and Nebraska

Sac & Fox Tribe of the Mississippi
in Iowa
Miami Tribe of Oklahoma
Osage Nation of Oklahoma
Peoria Tribe of Oklahoma
Quapaw Tribe of Indians, Oklahoma

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 construction sites. Please notify our office no later than October 4, 2013, if you have any areas of concern. If you have any questions regarding this matter, please contact Ms. Roberta L. Hayworth, Native American Coordinator directly at (314) 331-8833, or by electronic mail at roberta.l.hayworth@usace.army.mil. Thank you in advance for your timely review of this request.

Sincerely,

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

COPY

Enclosures

Copy Furnished:
Mr. Joseph Blanchard

COPY

Major Reach	Localized Reach	Work	County	State
Mosethein-Ivory Landing Phase 4 (RM 195-154)	St Louis Harbor	Revetment RM 175-171	St. Clair	IL
		Raise Dike 181.7L	St. Clair	IL
		Dike 173.4L	St. Clair	IL
Eliza Point/Greenfield Bend Phase 3 (RM20-0)	Bird's Point (RM 4-0)	Rootless Dike 3.0L	Alexander	IL
		Weir 2.6R	Mississippi	MO
		Weir 2.5R	Mississippi	MO
		Weir 2.3R	Mississippi	MO
		Weir 2.2R	Mississippi	MO
Grand Tower Phase 5 (RM90-67)	Crawford Towhead (RM 75-71)	Chevron 73.6L	Union	MO
		Dike Extension 72.9L	Union	MO
		Chevron 72.5L	Union	MO
	Vancil Towhead (RM 70-66)	Weir 69.15R	Cape Girardeau	MO
		Weir 68.95R	Cape Girardeau	MO
		Weir 68.75R	Cape Girardeau	MO
		Diverter Dike 68.10L	Union	IL
		Diverter Dike 67.80L	Union	IL
		Diverter Dike 67.50L	Union	IL
		Repair Dike 67.80L	Union	IL
		Shorten Dike 67.30L	Union	IL
		Shorten Dike 67.10L	Union	IL
		600 feet Revetment	Union	IL
Dogtooth Bend Phase 5 (RM 40-20)	Bumgard (RM 33-27)	Weir 34.20L	Alexander	IL
		Weir 34.10L	Alexander	IL
		Weir 32.50L	Alexander	IL
		Weir 32.40L	Alexander	IL
		Weir 32.3L	Alexander	IL
		Weir 32.2L	Alexander	IL
		Shorten Dike 32.0L	Alexander	IL
		Extend Dike 31.8L	Alexander	IL
		Extend Dike 31.6L	Alexander	IL
		Dike 31.6R	Scott	MO
		Extend Dike 31.4L	Alexander	IL
		Extend Dike 31.2L	Alexander	IL
		Extend Dike 31.1L	Alexander	IL
		Weir 30.80R	Scott	MO
		Weir 30.70R	Scott	MO

Table 1

Proposed FY 2014 river training structure projects

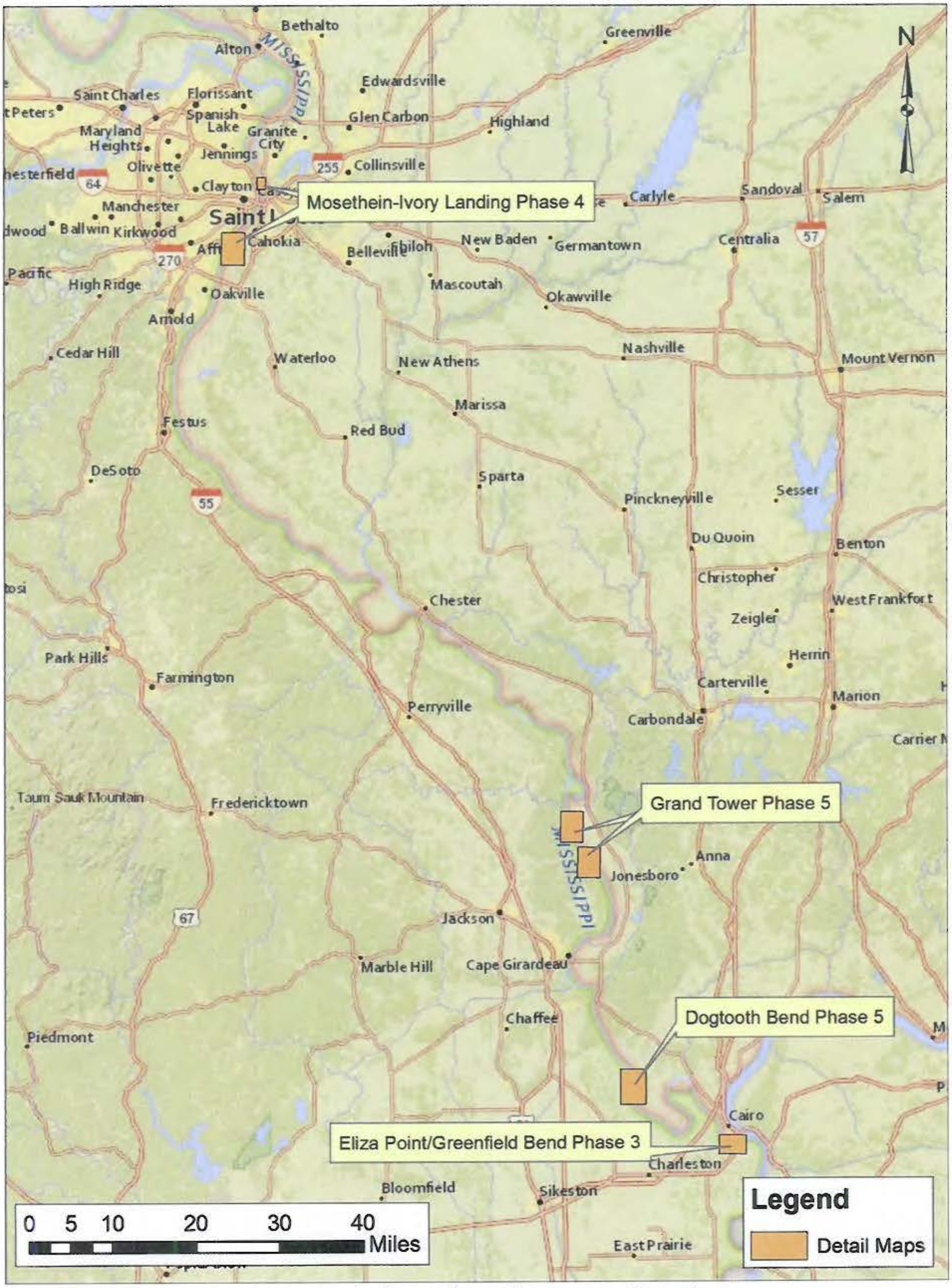

Figure 1. Location of proposed work.

Figure 2. Location of Dike 181.7L in St. Louis Harbor.

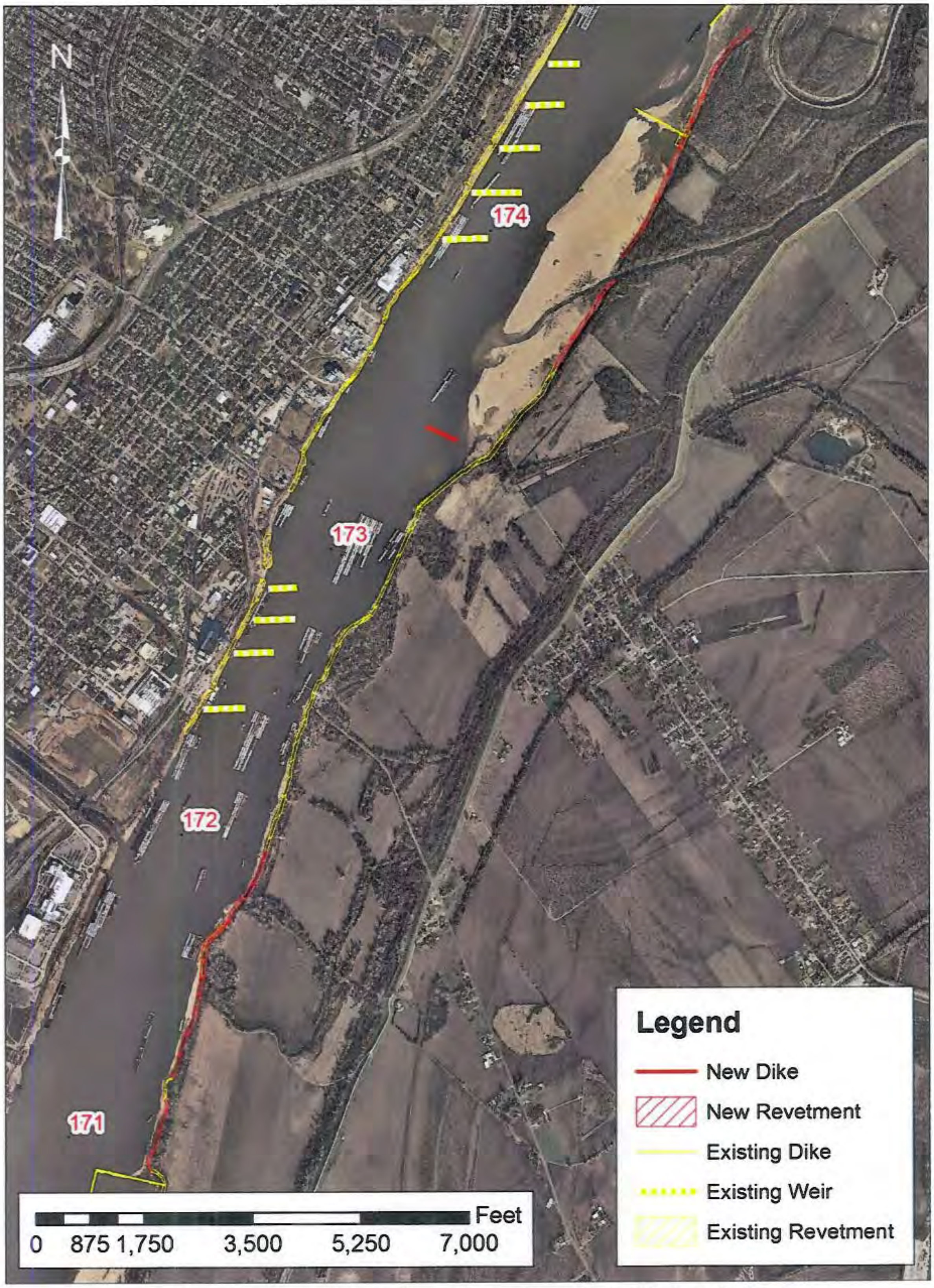

Figure 3. Location of proposed work in St. Louis harbor.

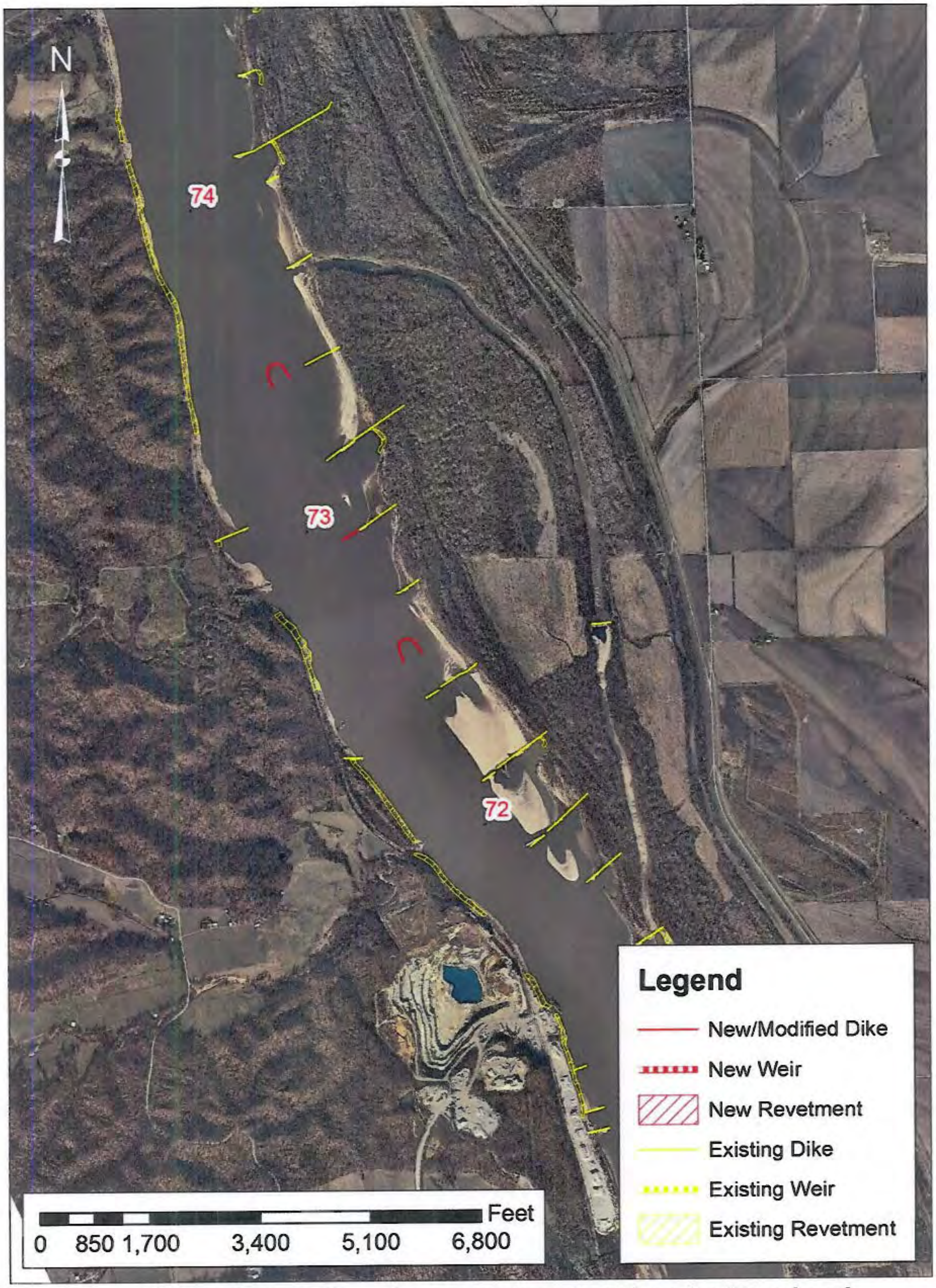

Figure 4. Location of proposed work at Crawford Towhead.

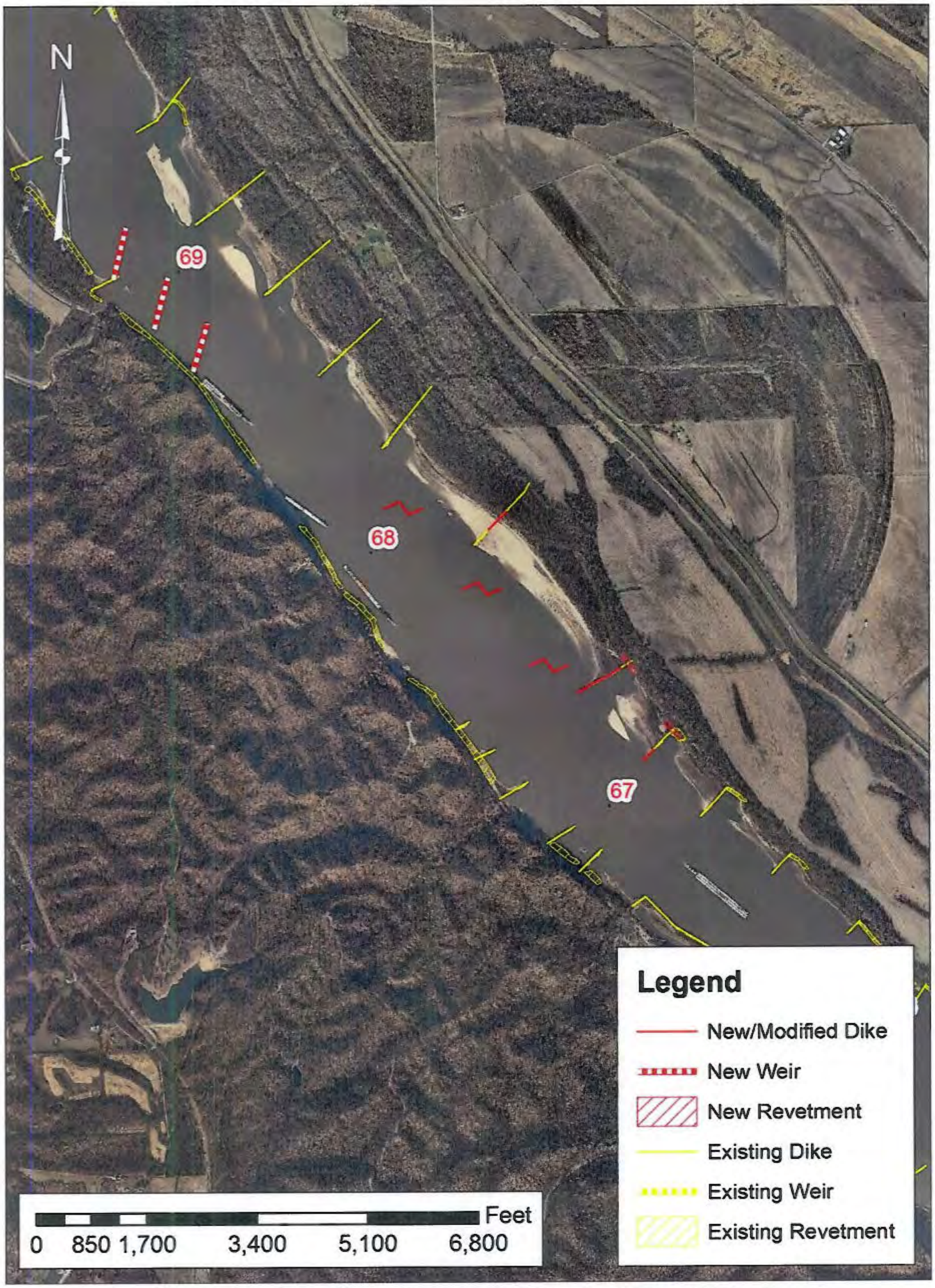

Figure 5. Location of proposed work at Vancil Towhead.

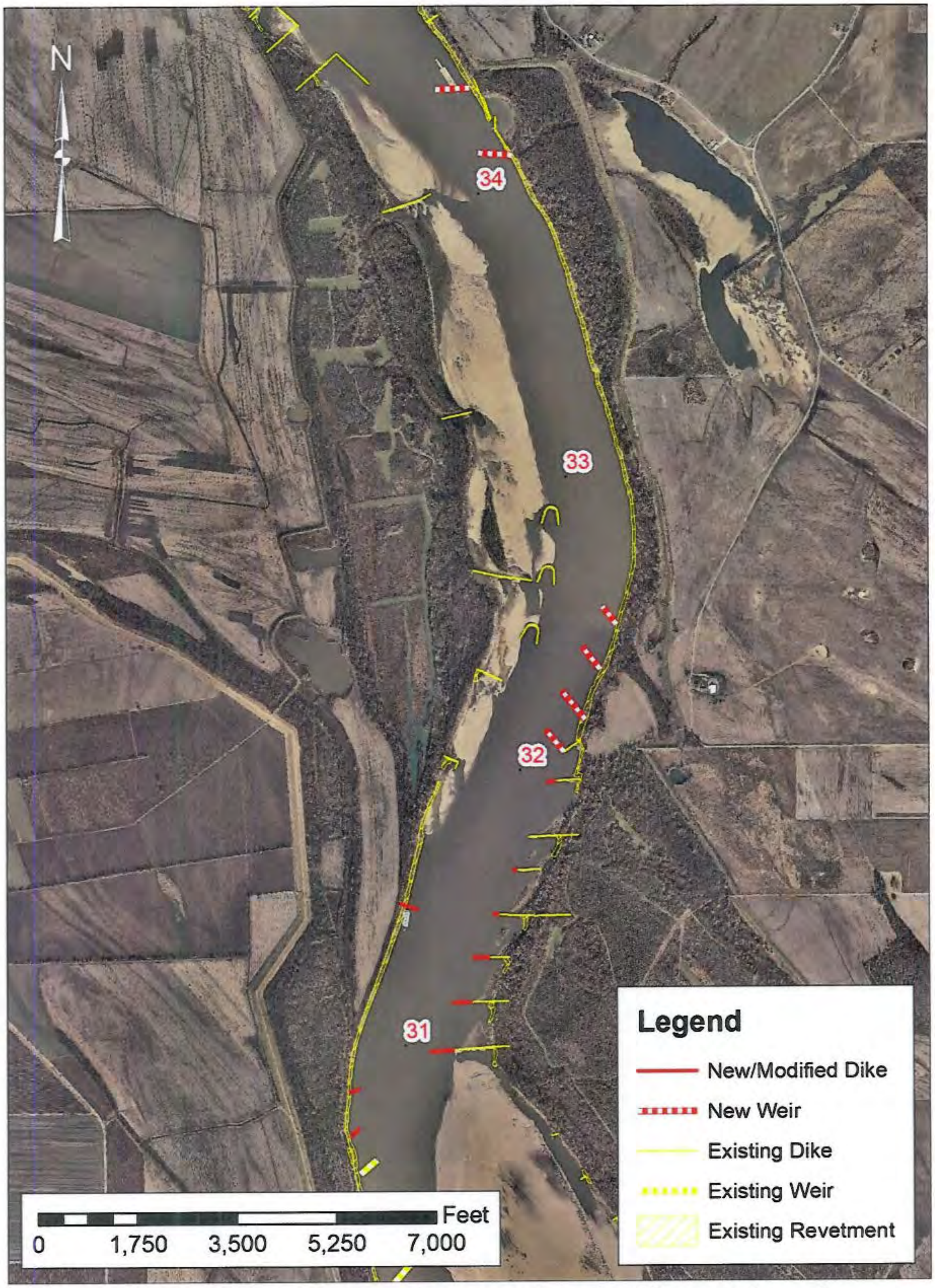

Figure 6. Location of proposed work at Bumgard reach.

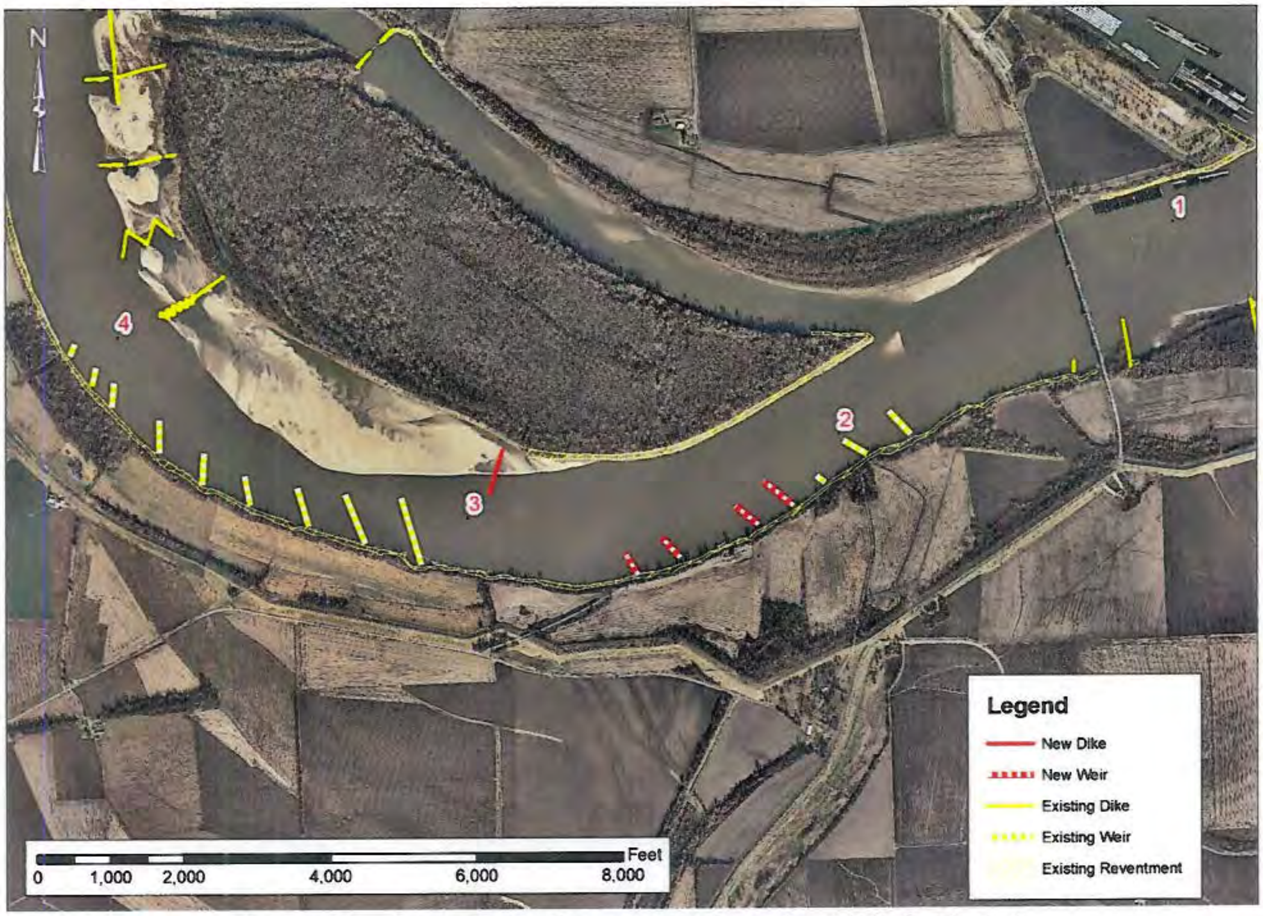

Figure 7. Location of proposed work at Birds Point.

SAME LETTER SENT
TRIBAL CHAIRPERSONS

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

Ms. Glenna J. Wallace, Chief
Eastern Shawnee Tribe of Oklahoma
P.O. Box 350
Seneca, Missouri 64865

Mr. Ron Sparkman, Chairman
Shawnee Tribe
P.O. Box 189
Miami, Oklahoma 74355

Mr. Bill John Baker, Principal Chief
Cherokee Nation
P.O. Box 948
Tahlequah, Oklahoma 74465

Mr. George Wickliffe, Chief
United Keetoowah Band of Cherokee
Indians of Oklahoma
P.O. Box 746
Tahlequah, Oklahoma 74464

Mr. Kerry Holton, President
Delaware Nation, Oklahoma
P.O. Box 825
Anadarko, Oklahoma 73005

Ms. Paula Pechonick, Chief
Delaware Tribe of Indians
170 N. Barbara
Bartlesville, Oklahoma 74006

Mr. John Barrett, Chairman
Citizen Potawatomi Nation, Oklahoma
1601 S. Gordon Cooper Drive
Shawnee, Oklahoma 74801

Mr. Harold Frank, Chairman
Forest County Potawatomi
Community, Wisconsin
P.O. Box 340
Crandon, Wisconsin 54520

Mr. D.K. Sprague, Chairman
Match-e-be-nash-she-wish Band of
Potawatomi Indians of Michigan
P.O. Box 218
Dorr, Michigan 49323

Mr. Kenneth Meshigand, Chairman
Hannahville Indian Community, Michigan
N14911 Hannahville Blvd. Rd.
Wilson, Michigan 49896-9728

Mr. Homer Mandoka, Chairman
Nottawaseppi Huron Band of
Potawatomi, Michigan
2221—1 ½ Mile Road
Fulton, Michigan 49052

Mr. Matthew Wesaw, Chairman
Pokagon Band of Potawatomi Indians,
Michigan and Indiana
P.O. Box 180
Dowagiac, Michigan 49047

Mr. Steve Ortiz, Chairman
Prairie Band Potawatomi Nation
Government Center
16281 Q Road
Mayetta, Kansas 66509

Mr. Jon Greendeer, President
Ho-Chunk Nation of Wisconsin
W 9814 Airport Road
Black River Falls, Wisconsin 54675

Mr. John Blackhawk, Chairman
Winnebago Tribe of Nebraska
P.O. Box 687
Winnebago, Nebraska 68071

Mr. Tim Rhodd, Chairman
Iowa Tribe of Kansas and Nebraska
3345 Thrasher Road # 8
White Cloud, Kansas 66094

Ms. Janice Rowe-Kurak, Chairwoman
Iowa Tribe of Oklahoma
Route 1, Box 721
Perkins, Oklahoma 74059

Mr. Juan Garza, Chairman
Kickapoo Traditional Tribe of Texas
HC 1, Box 9700
Eagle Pass, Texas 78853

Mr. Tony Salazar, Chairman
Kickapoo Tribe of Oklahoma
P.O. Box 70
McCloud, Oklahoma 74851

Mr. Steve Cadue, Chairman
Kickapoo Tribe of Indians of the
Kickapoo Reservation in Kansas
P.O. Box 271
Horton, Kansas 66439

Mr. George Thurman, Principal Chief
Sac & Fox Nation, Oklahoma
920883 S. Hwy. 99
Building A
Stroud, Oklahoma 74079

Mr. Michael Dougherty, Chairman
Sac & Fox Nation of Missouri in
Kansas and Nebraska
305 N. Main Street
Hiawatha, Kansas 66434

Mr. Frank Blackcloud, Chairman
Sac & Fox Tribe of the
Mississippi in Iowa
349 Meskwaki Road
Tama, Iowa 52339

Mr. Thomas E. Gamble, Chief
Miami Tribe of Oklahoma
P.O. Box 1326
202 S. Eight Tribes Trail
Miami, Oklahoma 74355

Mr. John D. Red Eagle, Principal Chief
The Osage Nation
P.O. Box 779
Pawhuska, Oklahoma 74056

Mr. John Froman, Chief
Peoria Tribe of Indians of Oklahoma
P.O. Box 1527
118 S. Eight Tribes Trail
Miami, Oklahoma 74355

Mr. John Berrey, Chairman
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
of Indians of Oklahoma
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
United Keetoowah Band of Cherokee
Indians of Oklahoma
2450 S. Muskogee Avenue
Tahlequah, Oklahoma 74464

Ms. Tamara Francis Fourkiller
Delaware Nation, Oklahoma
P.O. Box 825
Anadarko, Oklahoma 73005

Dr. Bryce Obermeyer
Delaware Tribe of Indians
Tribal Historic Preservation Office
Roosevelt Hall, Room 212
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Ms. Kelli Mosteller
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Shawnee, Oklahoma 74801

Ms. Melissa Cook
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Cultural Center, Library & Museum
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Ho-Chunk Nation of Wisconsin
P.O. Box 667
Black River Falls, Wisconsin 54615

Ms. Emily DeLeon
Winnebago Tribe of Nebraska
Little Priest Tribal College
P.O. Box 270
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

Ms. Curtis Simon
Kickapoo Tribe of Indians of the
Kickapoo Reservation in Kansas
1107 Goldfinch Road
Horton, Kansas 66439

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

Mr. Edmore Green
Sac & Fox Nation of Missouri
in Kansas and Nebraska
305 North Main Street
Hiawatha, Kansas 66434

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

Mr. George Strack
Tribal Historic Preservation Officer
Miami Tribe
P.O. Box 1236
202 S. Eight Tribes Trail
Miami, Oklahoma 74355

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

Mr. Frank Hecksher
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118 S. Eight Tribes Trail
P.O. Box 1527
Miami, Oklahoma 74355

Ms. Jean Ann Lambert
Tribal Historic Preservation Officer
Quapaw Tribe of Indians
P.O. Box 765
Quapaw, Oklahoma 74363

Delaware Tribe Historic Preservation Office
1200 Commercial St
Roosevelt Hall, RM 212
Emporia State University
Emporia, KS 66801
(620) 341-6699
bobermeyer@delawaretribe.org

August 23, 2013

U.S. Army Corps of Engineers
St. Louis District
Attn: Michael K. Trimble, Ph.D.
1222 Spruce Street
St. Louis, Missouri 63103-2833

Re: Construction of River Training Structures along the Mississippi River

Dear Michael K. Trimble,

Thank you for informing the Delaware Tribe on the proposed construction associated with the above referenced project. Our review indicates that there are no religious or culturally significant sites in the project area. As such, we defer comment to your office as well as to the State Historic Preservation Office and/or the State Archaeologist.

We wish to continue as a consulting party on this project and look forward to receiving a copy of the cultural resources survey report if one is performed. We also ask that if any human remains are accidentally unearthed during the course of the survey and/or the construction project that you cease development immediately and inform the Delaware Tribe of Indians of the inadvertent discovery.

If you have any questions, please feel free to contact this office by phone at (620) 341-6699 or by e-mail at bobermeyer@delawaretribe.org

Sincerely,

Brice Obermeyer

Brice Obermeyer
Delaware Tribe Historic Preservation Office
1200 Commercial St
Roosevelt Hall, RM 212
Emporia State University
Emporia, KS 66801

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CHEROKEE NATION®
P.O. Box 948 • Tahlequah, OK 74465-0948 • 918-453-5000 • cherokee.org

Office of the Chief

Bill John Baker
Principal Chief
ᏫᎵ ᏣᏂ ᏗᏚᏚ᏷ᏍᎩ
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S. Joe Crittenden
Deputy Principal Chief
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082613

Michael K. Trimble, Ph.D.
Chief, Curation and Archives / Analyses Branch
Dept. of the Army
St. Louis District, Corps of Engineers
61222 Spruce St.
St. Louis, MO 63103

Re: construction of river training structures in 4 major areas

Dr. Trimble:

The Cherokee Nation appreciates the opportunity to comment upon the “construction of river training structures in 4 major areas”. The Cherokee Nation does not currently maintain records of cultural resources in this geographic area. Thus, we would request you conduct your inquiries with the Illinois and Missouri State Historic Preservation Offices and any geographically appropriate/pertinent Tribal Historic Preservation Office(s). However, if during the conduct of these projects, items of cultural significance are discovered, the Cherokee Nation requests you recontact our Offices for further consultation. If you have any questions or require further information, please contact Mr. Pat Gwin, Administration Liaison, at 918/453-5704. Thank you.

Sincerely,

Pat Gwin, Administration Liaison

Kickapoo Tribe of Oklahoma

P.O.Box 70
407 N. Hwy 102
McLoud, Oklahoma 74851

Administration Department
Phone: 405-964-7053; Fax: 405-964-7065
Email: kwilson@kickapootribeofoklahoma.com

August 29, 2013

Department of the Army
U.S. Army Corps of Engineers
St. Louis District
ATTN: Roberta L. Hayworth
Engineering and Construction Division
Curation and Archives Analysis Branch
1222 Spruce Street
St. Louis, MO 63103-2833

RE: Proposed FY 2014 River Training Structure Projects: RM 195-154; RM20-0; RM90-67 & RM 40-20

Dear Ms. Hayworth:

Thank you for consulting with the Kickapoo Tribe of Oklahoma in regard to the above referenced site(s). At this time, the Kickapoo Tribe of Oklahoma has no objections to the proposed project at the intended site(s). However, in the event burial remains and/or artifacts are discovered during the development or construction process, the Kickapoo Tribe of Oklahoma would ask for immediate notification of such findings.

Should I be of any further assistance, please contact me at (405) 964-4227.

Sincerely,

Kent Collier
NAGPRA Contact
Kickapoo Tribe of Oklahoma

Cc: File

From: Lisa LaRue-Baker - UKB THPO [ukbthpo-larue@yahoo.com]
Sent: Wednesday, September 18, 2013 1:53 PM
To: Hayworth, Roberta L MVS
Cc: verna
Subject: [EXTERNAL] Mississippi River Training Facilities

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 and contact us immediately.

Thank you,

Lisa C. Baker
Acting THPO
United Keetoowah Band of Cherokee Indians in Oklahoma
PO Box 746
Tahlequah, OK 74465

TRIBAL HISTORIC PRESERVATION OFFICE

Winnebago Tribe of NE P.O. Box 687 Winnebago, NE 68071 402-878-3313

November 10, 2013

US Army Corps of Engineers
Attn: CEMVS-OD-F
1222 Spruce St
St Louis, Missouri 63103

RE: P-2857 & 2856

Dear Mr. McClendon,

Thank you for your recent letter to the Tribal Historic Preservation Office of the Winnebago Tribe of Nebraska. The Preservation Office would like to inform you that the Winnebago Tribe of Nebraska does not have cultural properties in the area of your proposed construciton.

You may proceed with your proposed construction, but if there are any burial sites or other cultural properties found we would like for your office to notify the appropriate office right away. Thank you.

Sincerely,

Emily Smith-DeLeon

THPO, Winnebago Tribe of NE

Smith_deleon77@yahoo.com

TRIBAL HISTORIC PRESERVATION OFFICE

Date: **May 7, 2014**

RE: **USACE public notice Grand Tower phase 5 project regulating works project**

St. Louis District, USACE
Danny D. McClendon
1222 Spruce Street
St. Louis, MO 63101

Dear Mr. McClendon,

Please accept my apologies for the delay in our response to this project. The Osage Nation Historic Preservation Office has evaluated your submission and concurs that the proposed USACE public notice Grand Tower phase 5 project regulating works project most likely will not adversely affect properties of cultural or sacred significance to the Osage Nation. The Osage Nation has no further concern with this project.

In accordance with the National Historic Preservation Act, (NHPA) [16 U.S.C. 470 §§ 470-470w-6] 1966, undertakings subject to the review process are referred to in S101 (d) (6) (A), which clarifies that historic properties may have religious and cultural significance to Indian tribes. Additionally, Section 106 of NHPA requires Federal agencies to consider the effects of their actions on historic properties (36 CFR Part 800) as does the National Environmental Policy Act (43 U.S.C. 4321 and 4331-35 and 40 CFR 1501.7(a) of 1969). As a part of the scoping process the St. Louis District, USACE has fulfilled NHPA and NEPA compliance by consulting with the Osage Nation Historic Preservation Office in regard to the proposed USACE public notice Grand Tower phase 5 project regulating works project.

The Osage Nation has vital interests in protecting its historic and ancestral cultural resources. We do not anticipate that this project will adversely impact any cultural resources or human remains protected under the NHPA, NEPA, the Native American Graves Protection and Repatriation Act, or Osage law. If, however, artifacts or human remains are discovered during project-related activities, we ask that activities cease immediately and the Osage Nation Historic Preservation Office be contacted.

Should you have any questions or need any additional information please feel free to contact me at the number listed below. Thank you for consulting with the Osage Nation on this matter.

Barker Fariss, Ph.D.
Senior Archaeologist

627 Grandview, Pawhuska, OK 74056, (918) 287-5328, Fax (918) 287-5376

United States Department of the Interior

U.S. FISH AND WILDLIFE SERVICE
Marion Illinois Sub-Office (ES)
8588 Route 148
Marion, Illinois 62959
(618) 997-3344

January 17, 2014

Colonel Christopher G. Hall
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103-2833

Attn: Mr. Danny McClendon

Dear Colonel Hall:

Thank you for the opportunity to review and comment on the Environmental Assessment (EA), Unsigned Finding of No Significant Impact (FONSI), and Public Notice P-2856 addressing the Grand Tower Phase 5 Regulating Works Project located in Union County, Illinois and Cape Girardeau County, MO. The Crawford Towhead portion of the proposed project involves construction of two chevrons and one dike extension between Upper Mississippi River Miles 72 and 74 and the Vancill Towhead portion of the proposed project involves construction of three weirs and three diverter dikes (S-dikes), shortening of two dikes, repair of one dike, and revetment between Upper Mississippi River Miles 67.3 and 67.1. Alternatives considered for this project included no action and a preferred alternative described above. These comments are prepared under the authority of and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.); the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq*.); and, the National Environmental Policy Act (83 Stat. 852, as amended P.L. 91-190, 42 U.S.C. 4321 et seq.).

Fish and Wildlife Resources

The purpose of constructing the proposed project is to address bankline erosion, channel widening, and a repetitive channel maintenance dredging issue to ensure adequate navigation depth and width. Information provided in the EA indicates that the proposed dikes are expected to increase bathymetric, flow, and sediment diversity in the immediate vicinity of the structures. The bendway weirs are expected to improve fish and macroinvertebrate habitat in the outside bend by providing substrate diversity, flow refuge, and increased macroinvertebrate colonization surface area. The revetment is expected to increase surface area for macroinvertebrate colonization. While not disagreeing with this assessment, the Service is concerned that the proposed construction is likely to reduce/remove habitats on the inside bends that are utilized by larval and juvenile fisheries resources. The Service is also concerned about the cumulative loss of habitat and potential impacts on fisheries resources in the Mississippi River from past, present, and reasonably foreseeable future actions utilized to maintain the navigation channel. The Service recommends that the U.S. Army Corps of Engineers (Corps) continue to utilize its authorities and programs (Biological Opinion Program, Avoid and Minimize Program, and Environmental Management Program) to restore/enhance habitats in the Mississippi River. The Service also recommends that the Corps seek a post authorization change to provide for environmental protection and enhancement under the Regulating Works Project as described in the 1976 Environmental Impact Statement (EIS). As stated in the 1976 EIS, "the overall effects of the attainment of a nine-foot-navigation channel upon the riverine ecosystem has not been beneficial" and "A significant amount of fish and wildlife habitat has been affected."

An additional concern with the proposed project is that the Vancill Towhead portion of the project falls within the "control" reach for the Navigation and Ecosystem Sustainability Program (NESP), Herculaneum Side Channel Restoration Project. Due to the limited funding for NESP, discussions occurred about utilizing the Herculaneum reach as a "control" reach for this project. Monitoring has been being proposed to evaluate the regulating works project and utilize data previously collected for the Herculaneum Side Channel Restoration Project. The Service concurs with the proposed monitoring.

Threatened and Endangered Species

The EA includes a Tier II Biological Assessment (BA) which was prepared in order to comply with the requirements of the 2000 Biological Opinion for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. The 2000 Biological Opinion (BO) was prepared as a result of the programmatic consultation under Section 7 of the Endangered Species Act of 1973, as amended, which evaluated the effects of operation and maintenance of the 9-foot navigation channel on federally listed threatened and endangered species. The BA evaluated the impacts of the proposed project on the endangered gray bat (*Myotis grisescens*), endangered Indiana bat (*Myotis sodalis*), endangered least tern (*Sterna antillarum*), endangered pallid sturgeon (*Scaphirynchus albus*), endangered sheepnose mussel (*Plethobasus cyphyus*), endangered spectaclecase mussel (*Cumberlandia monodonta*), threatened decurrent false aster (*Boltonia decurrens*), and proposed as endangered grotto sculpin (*Cottus sp.*).

In the Tier II BA the Corps determined that the proposed project will have no effect on the gray bat and grotto sculpin and is not likely to adversely affect the Indiana bat, least tern, pallid sturgeon, sheepnose mussel, spectaclecase mussel, and decurrent false aster. In a letter dated August 9, 2013, regarding Crawford Towhead and in a letter dated February 22, 2013, regarding Vancill Towhead, the Service provided concurrence that the proposed projects are not likely to adversely affect the Indiana bat, least tern, sheepnose mussel, spectaclecase mussel, and decurrent false aster. However, the Service did not concur that the proposed projects are not likely to adversely affect the pallid sturgeon. It is unclear to the Service whether the river training structure modifications (with resulting hydro-geomorphologic changes) and the reduction in channel maintenance dredging can fully compensate for the project impacts; therefore, the Service believes the proposed project is likely to adversely affect the pallid sturgeon and that Tier II formal consultation is necessary.

Tier II Formal Consultation

The Service has determined that the proposed project 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 (Section 1.2.4.2 River Regulatory Structures). The effects of this proposed action on the pallid sturgeon are consistent with those anticipated in the programmatic BO (Section 8.3.1.2 Maintenance of the 9-Foot Channel Project), and the appropriate Terms and Conditions associated with the Reasonable and Prudent Measures (RPMs) identified in the programmatic BO have been adhered to (Sections 8.5.3 and 8.5.4). Specifically, the Corps adhered to Term and Condition 2 and RPM 1 by submitting the project to the Service for a 30 day review period and incorporating Service recommendations for aquatic habitat improvement into project construction plans. Based on this information, it is the Service's biological opinion that the proposed project is not likely to jeopardize the continued existence of the pallid sturgeon. Incidental take was considered programmatically in the BO (Section 8.5 Incidental Take Statement) and will be evaluated at program level. Thus no incidental take statement is included with this opinion.

This concludes formal consultation on the proposed action. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

Conclusion

Thank you for the opportunity to provide comment on the EA, FONSI, and Public Notice. For additional coordination, please contact me at (618) 997-3344, ext. 345.

Sincerely,

/s/ Matthew T. Mangan

Matthew T. Mangan
Biologist in Charge

cc: IDNR (Atwood)
MDC (Sternberg)

From: Shepard, Larry [mailto:Shepard.Larry@epa.gov]
Sent: Friday, January 24, 2014 6:11 PM
To: Doerr, Jaynie G MVS
Cc: Brown, Jasen L MVS; Westlake, Kenneth
Subject: [EXTERNAL] RE: US EPA Region 7 Comments on the draft Environmental Assessments supporting the Dogtooth Bend Phase 5 and Grand Tower Phase 5 projects under USACE, St. Louis District Public Notices P-2857 and P-2856

Thank you for the opportunity to review the draft Environmental Assessments supporting the Dogtooth Bend Phase 5 and Grand Tower Phase 5 projects. Both site-specific EAs are tiered from the 1976 Environmental Impact Statement covering the Corps of Engineers, St. Louis District's 'Regulating Works Project-Mississippi River between the Ohio and Missouri Rivers.' The District recently public noticed its intent to supplement this EIS (2013-744) after determining that there is sufficient significant new information regarding the potential impacts of the Project on the environment. EPA Region 7 intends to participate in this process and we will provide comments to the District as a part of the National Environmental Policy Act scoping process as well as review and rate the draft SEIS under the Clean Air Act, Section 309. Please consider the following comments pertaining to the site-specific EAs supporting each of the projects. In addition, I am copying Mr. Jasen Brown with MVS on these comments as a means of initiating our input into the SEIS development process.

Dogtooth Bend

The proposed action consists of construction of two weirs near River Mile 34, four weirs near RM 32, a dike at RM 31.6 and two weirs near RM 31. Placement of rock training structures would provide a sustainable alternative to repeated maintenance dredging in this reach of the Middle Mississippi River. Fill material would include approximately 35,000 tons of quarry run limestone from the local area. The draft EA includes a 'no action' alternative which would rely on existing training structures and continued maintenance dredging and an 'action' alternative selected from 85 possible structure designs and placements which are intended to reduce the need for the existing frequency of maintenance dredging.

Alternatives Analysis

We would recommend that the planned SEIS for the Regulating Works Project include a thorough characterization of how site- or project-specific NEPA documents tiering from the SEIS will include a robust range of alternatives. For example, this EA includes only two alternatives – no action and action, referencing some 85 possible alternatives for structure design and placement which were narrowed to one (Alternative 75). A detailed characterization in the SEIS of the process by which a robust range of alternatives will be developed within each tiering document and further narrowed for detailed assessment would support what appears to be a truncated assessment in the individual project document. At a minimum, the SEIS should characterize a general process and rationale for how the development, selection and assessment of alternatives in tiered NEPA documents meeting individual project purpose is consistent with CEQ regulations governing alternatives analysis. While there are obvious reasons why carrying forward 85 action alternatives does not serve the purposes of NEPA and makes for a confusing assessment, there should also be some greater comfort and assurance with assessing the impacts of only 2 alternatives within the tiered documents defined by ‘action’ and ‘no action.’ Potentially, the best place to provide that analysis and rationale is the SEIS rather than each project-specific NEPA document.

Affected Environment

The EA would be improved with a more thorough characterization of important river habitat potentially affected by either alternative, e.g., the Bumgard Island “complex” referenced on page 6. Whether as ‘physical’ or ‘biological’ resources, important habitat should be identified, described and delineated in these project-specific NEPA documents. Perhaps extended descriptions of habitat types, their source of importance, their availability in the MMR and the river conditions necessary to their maintenance could be addressed in the SEIS. Reach-specific habitats within each project affected area should be included in the project-specific NEPA documents.

Environmental Consequences

We recommend that the SEIS comprehensively address the impacts of river training structures resulting in lowered stages/water surface elevations at lower flows. Bed loss in navigable rivers with river training structures designed to reduce the need for dredging to maintain a navigable channel or “self-scouring” channels is being documented elsewhere and the inclusion of the assessment of impacts of such bed loss on infrastructure and river habitat is critically important to the NEPA assessment.

We recommend that an updated and comprehensive assessment of the impacts of maintenance dredging on aquatic life be included within the SEIS to support project-specific impact assessments.

Although this EA reflects a recent expansion in the amount of biological data describing the impacts of training structures on aquatic organisms, particularly fish, we suggest that, where current data is inconclusive regarding the impacts of structure types, design and placement on the aquatic community, the SEIS include additional recent data or include a commitment by the Corps to acquire additional necessary data. Regardless of the availability of additional data, the SEIS should include a comparative analysis of the impacts of different structures and placement on river biota.

This EA would be improved with a detailed discussion of the impacts of each alternative on specific resources associated with the Bumgard Island "complex" and any other important shoreline habitats between River Mile 35 and 27. This was a significant omission within this assessment.

We would expect the planned SEIS to include a comprehensive and updated assessment of the cumulative impacts of the entire Regulating Works Project within the MMR, including all existing and planned structure placement and other actions undertaken by entities other than the Army Corps of Engineers.

Grand Tower

The proposed action includes the construction of two chevrons and the extension of one dike in the Crawford Towhead between RMs 72 and 74; and construction of 3 weirs, 3 diverter dikes or S dikes, repair of a dike at RM 67.8, construction of a revetment at RM 67.3 and shortening the dikes at RMs 67.3 and 67.1 in the Vancill Towhead between RMs 67 and70. Placement of rock training structures would provide a sustainable alternative to repeated maintenance dredging in this reach of the Middle Mississippi River. Fill material would include approximately 35,000 tons of quarry run limestone from the local area. The draft EA includes a 'no action' alternative which would rely on existing training structures and continued maintenance dredging and an 'action' alternative which, for the Vancill Towhead area, was selected from 37 possible structure designs and placements intended to reduce the need for the existing frequency of maintenance dredging. As the Crawford Towhead site bathymetry was uncomplicated and the project objectives more limited, this component of the 'action' alternative was formulated using engineering judgment to reduce shoreline erosion, improve conditions for navigation and improve aquatic habitat.

Alternatives Analysis

See the comment above addressing similar issues with the Dogtooth Bend Phase 5 project.

Affected Environment

Again, please review the comments offered above for the Dogtooth Bend project regarding the need to include in this EA a more thorough characterization of important river habitat potentially affected by either alternative, e.g., Crawford chute, Vancill Towhead side channel, other shallow water habitat in the affected reaches.

Environmental Consequences

Again, refer to the comments offered for the Dogtooth Bend project, particularly regarding the absence of a detailed discussion of the impacts of each alternative on specific resources associated with important reach habitat.

Again, thank you for the opportunity to review these two documents and we look forward to working with the District on the planned SEIS for these projects. If you have any questions regarding these comments, please contact me using the information listed below.

Sincerely,

Larry Shepard

NEPA Team

U.S. Environmental Protection Agency

Region 7

11201 Renner Blvd.

Lenexa, Kansas 66219

913-551-7441

shepard.larry@epa.gov

Response to August 23, 2013 Delaware Tribe Comment Letter

Comment 1: *Our review indicates that there are no religious or culturally significant sites in the project area. As such, we defer comment to your office as well as to the State Historic Preservation Office and/or the State Archaeologist.*

We wish to continue as a consulting party on this project and look forward to receiving a copy of the cultural resources survey report if one is performed. We also ask that if any human remains are accidentally unearthed during the course of the survey and/or the construction project that you cease development immediately and inform the Delaware Tribe of Indians of the inadvertent discovery.

Response: Coordination with the appropriate State Historic Preservation Offices has been conducted (see coordination letters in this appendix). If any human remains are unearthed, construction will cease and all appropriate parties will be notified.

Response to August 26, 2013 Cherokee Nation Comment Letter

Comment 1: *The Cherokee Nation does not currently maintain records of cultural resources in this geographic area. Thus, we would request you conduct your inquiries with the Illinois and Missouri State Historic Preservation Offices and any geographically appropriate/pertinent Tribal Historic Preservation Office(s). However, if during the conduct of these projects, items of cultural significance are discovered, the Cherokee Nation requests you recontact our Offices for further consultation.*

Response: Coordination with the appropriate State and Tribal Historic Preservation Offices has been conducted (see coordination letters in this appendix). If items of cultural significance are discovered during construction your Offices will be contacted for further consultation.

Response to August 29, 2013 Kickapoo Tribe Comment Letter

Comment 1: *At this time, the Kickapoo Tribe of Oklahoma has no objections to the proposed project at the intended site(s). However, in the event burial remains and/or artifacts are discovered during the development or construction process, the Kickapoo Tribe of Oklahoma would ask for immediate notification of such findings.*

Response: If any burial remains and/or artifacts are discovered, all appropriate parties will be notified as soon as possible.

Response to September 18, 2013 United Keetoowah Band Comment Letter

Comment 1: … *if any human remains are inadvertently discovered, please cease all work and contact us immediately.*

Response: If any human remains are discovered, construction will cease and all appropriate parties will be notified as soon as possible.

Response to November 10, 2013 Winnebago Tribe Comment Letter

Comment 1: *You may proceed with your proposed construction, but if there are any burial sites or other cultural properties found we would like for your office to notify us right away…*

Response: If any burial sites or other cultural properties are found during construction, all appropriate parties will be notified as soon as possible.

Response to May 7, 2014 Osage Nation Comment Letter

Comment 1: *If, however, artifacts or human remains are discovered during project-related activities, we ask that activities cease immediately and the Osage Nation Historic Preservation Office be contacted.*

Response: If any artifacts or human remains are found during construction, all appropriate parties will be notified as soon as possible.

Responses to January 17, 2014 U.S. Fish and Wildlife Service Comments

Comment 1: *The Service recommends that the U.S. Army Corps of Engineers (Corps) continue to utilize its authorities and programs (Biological Opinion Program, Avoid and Minimize Program, and Environmental Management Program) to restore/enhance habitats in the Mississippi River. The Service also recommends that the Corps seek a post authorization change to provide for environmental protection and enhancement under the Regulating Works Project as described in the 1976 Environmental Impact Statement (EIS). As stated in the 1976 EIS, "the overall effects of the attainment of a nine-foot-navigation channel upon the riverine ecosystem has not been beneficial" and "A significant amount of fish and wildlife habitat has been affected."*

Response: The District will continue to utilize existing authorities and programs, including the Biological Opinion Program, Avoid and Minimize Program, and Environmental Management Program, as appropriate, to restore and enhance Mississippi River habitats. As part of the current process to supplement the 1976 Middle Mississippi River Regulating Works Environmental Impact Statement, the District will utilize the alternatives and analysis provided in the 1976 EIS, including the post authorization change, and will update and consider the information as appropriate.

Responses to January 24, 2014 USEPA Comments

Comment 1: *We would recommend that the planned SEIS for the Regulating Works Project include a thorough characterization of how site- or project-specific NEPA documents tiering from the SEIS will include a robust range of alternatives.*

Response: The SEIS will include a thorough characterization of how subsequent site-specific NEPA documents will be tiered. In addition, for the Grand Tower Phase 5 EA, Section 2, Alternatives Including the Proposed Action, has been expanded to more clearly articulate the alternatives analysis process utilized.

Comment 2: *The EA would be improved with ... a more thorough characterization of important river habitat potentially affected by either alternative, e.g. Crawford chute, Vancill Towhead side channel, other shallow water habitat in the affected reaches.*

Response: Section 3, Affected Environment, in the Grand Tower EA has been expanded accordingly. Important habitat types and their availability in the MMR will be discussed in the SEIS.

Comment 3: *This EA would be improved with ... a detailed discussion of the impacts of each alternative on specific resources associated with important reach habitat.*

Response: Section 4, Environmental Consequences, in the Grand Tower Phase 5 EA has been expanded accordingly.

Appendix G. Distribution List

The following individuals and organizations received a hard copy mailing of the Public Notice (December 2013):

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

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

Anne Haaker
IL State Historic Preservation Office
Springfield, IL 62701

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

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

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

Honorable Blaine Luetkemeyer
1118 Longworth HOB
Washington, DC 20515

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

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

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

Kelly Isherwood
5072 Oak Tree Lane
House Springs, MO 63051

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

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

Mike Larson
MDNR
Land Reclamation Program
Jefferson City, MO 65102

Honorable Lacy Clay
6830 Gravois
St. Louis, MO 63116

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

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

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

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

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

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

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

Jack Norman
906 N. Metter Avenue
Columbia, IL 62236

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

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

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

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

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

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

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

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

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

Russell Cissell
1075 LeSieur
Portage des Sioux, MO 63373

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

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

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

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

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

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

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

Honorable William Enyart
23 Public Square
Belleville, IL 62220

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

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

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

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

Senator Larry Bomke
307 Capitol Building
Springfield, IL 62706

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

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

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

Honorable Rodney Davis
2004 Fox Drive
Champaign, IL 61820

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

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

The following individuals and organizations received e-mail notification of the Public Notice (December 2013):

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

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

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

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