Cover Sheet

Project Title: Mississippi River Between the Ohio and Missouri Rivers (Regulating Works)

Proposed Action: The St. Louis District of the U.S. Army Corps of Engineers proposes to continue construction, operation, and maintenance of the 9-foot navigation channel on the Middle Mississippi River.

Location: Missouri and Illinois

Type of Statement: Final Supplement

Lead Agency: U.S. Army Corps of Engineers

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Abstract: The St. Louis District of the U.S. Army Corps of Engineers (Corps) is charged with obtaining and maintaining a navigation channel on the Middle Mississippi River (MMR) that is nine feet deep and 300 feet wide with additional width in bends as necessary (commonly called the Regulating Works Project). As authorized by Congress, the Project is obtained by construction of revetment, rock removal, and river training structures to maintain bank stability and ensure adequate, reliable navigation depth and width. The Regulating Works Project is maintained through dredging and any needed maintenance to constructed features. The long-term goal of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of river training structures. This document is intended to provide an update to the Project's 1976 Environmental Impact Statement by analyzing the impacts of the Project in the context of new circumstances and information that currently exist. Based on the Project's Congressional authority and continued benefit of the remaining construction, the Preferred Alternative is to continue with new construction of the Project with the future potential addition of compensatory mitigation for unavoidable adverse effects to main channel border habitat on a site-by-site basis.

FINAL SUPPLEMENT I

to the

FINAL ENVIRONMENTAL STATEMENT

MISSISSIPPI RIVER

BETWEEN THE

OHIO AND MISSOURI RIVERS

(REGULATING WORKS)

May 2017

US Army Corps
of Engineers
St. Louis District

U.S. Army Corps of Engineers
St. Louis District
1222 Spruce St.
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Executive Summary

Purpose and Need. The St. Louis District (District) of the U.S. Army Corps of Engineers (Corps) is charged with obtaining and maintaining a navigation channel on the Middle Mississippi River (MMR) that is nine feet deep, 300 feet wide with additional width in bends as necessary. The MMR is defined as that portion of the Mississippi River that lies between its confluence with the Ohio and the Missouri Rivers (Figure ES-1). This ongoing Project is also commonly referred to as the Regulating Works Project. As authorized by Congress, the Regulating Works Project utilizes bank stabilization, rock removal, and sediment management to maintain bank stability and ensure adequate navigation depth and width. Bank stabilization is achieved by revetment and river training structures, while sediment management is achieved by river training structures. The Regulating Works Project is maintained through dredging and any needed maintenance to already constructed features. The long-term goal of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of regulating works. Therefore, pursuant to the Congressionally authorized purpose of the Project, the District continually identifies and monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable. The District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel.

The environmental impacts of the Regulating Works Project were originally documented in the 1976 Environmental Impact Statement (1976 EIS) *Mississippi River between the Ohio and Missouri Rivers (Regulating Works)*, (USACE 1976). The 1976 EIS was recently reviewed by the District and by the Corps' Planning Center of Expertise for Inland Navigation (PCXIN) to determine whether or not the document should be supplemented. The District and the PCXIN concluded that, although the Project had not changed substantially, there were significant new circumstances and information relevant to the Regulating Works Project and its potential impacts that warranted consideration of a supplement. The significant new circumstances and information on the potential impacts of the Regulating Works Project include the following:

- New federally threatened and endangered species have been listed since preparation of the 1976 EIS.
- The District has implemented new programs to restore fish and wildlife habitat on the MMR.
- New information exists on the changes in average river planform width in response to river training structure placement.
- New information exists on the impacts of river training structures on water surface elevations.
- New information exists on the impacts of river training structures and dredging on fish and macroinvertebrates.
- New information exists on the effects of navigation on fish and wildlife resources.
- New information exists on the status of MMR side channels.

Therefore, the purpose of this Supplemental EIS (SEIS) is to provide an update to the 1976 EIS by analyzing the impacts of the Regulating Works Project in the context of the new circumstances and information that currently exist.

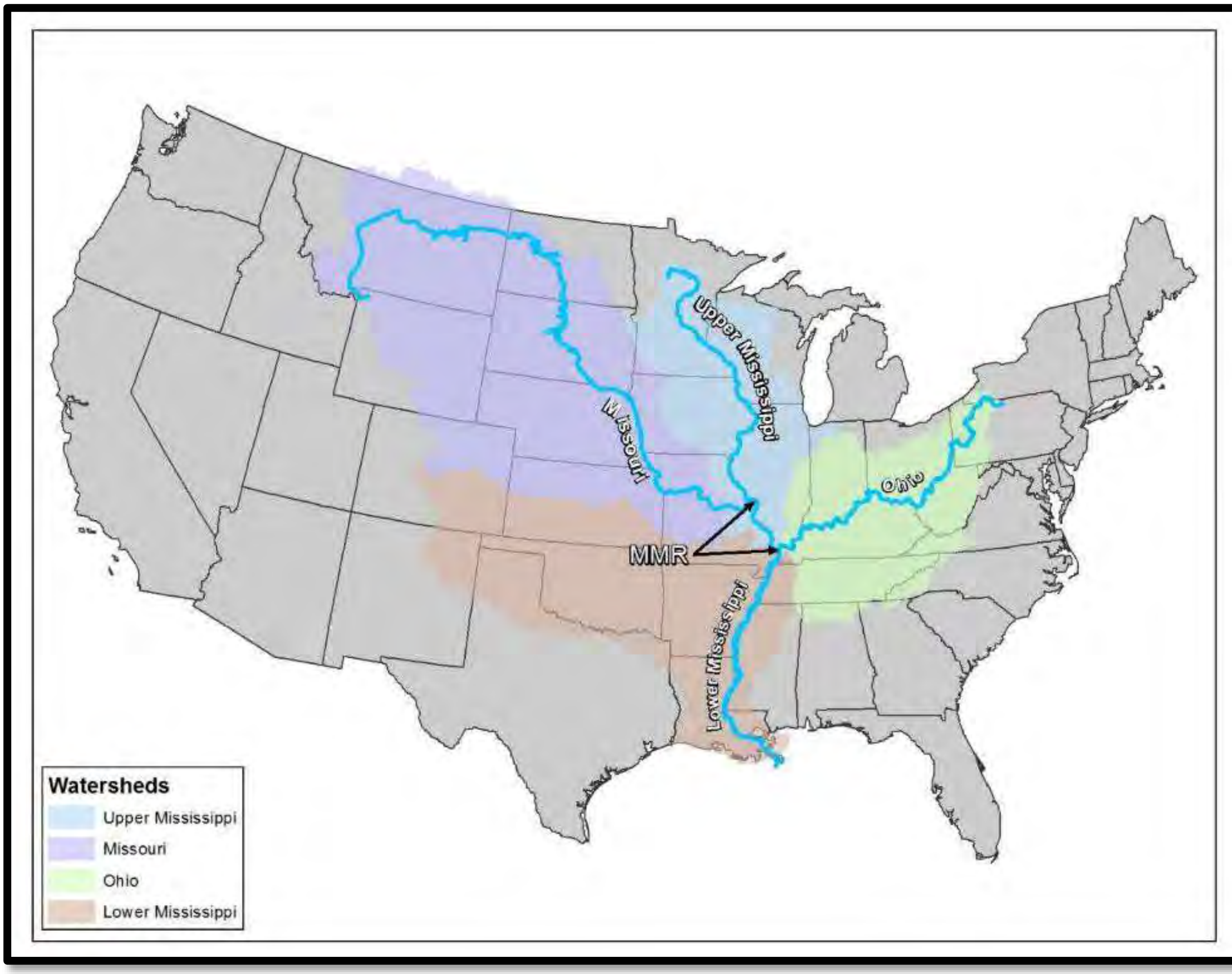

Figure ES-1. Location of the MMR within the Upper Mississippi River watershed.

Alternatives. Congress provided the manner in which the navigation channel for the MMR should be obtained and maintained via the original Regulating Works Project authorization in 1910 and a modification to the authorization in 1927. The purpose of this SEIS is not to consider a change to that authorization through reevaluating the need for the Regulating Works Project or the methods to be used to accomplish the goals of the project. Rather, this document analyzes the impacts of the Regulating Works Project as it is currently constructed, operated, and maintained with current information that has become available since the completion of the 1976 EIS.

Accordingly, this document examines the impacts of two Alternatives:

The **Continue Construction Alternative (No Action)** – This Alternative would involve continuing with construction of new river training structures or revetment for navigation purposes until such time as the cost of placing more structures is no longer justified by the resultant reduction in repetitive dredging quantities and associated costs, including costs for any mitigation. This is currently estimated to require approximately 4.4 million tons (2.9 million cubic yards) of rock. This estimate is based on assumptions of Congressional funding levels, rock prices, dredging costs, sediment loads, mitigation costs, etc. and therefore could differ from actual implementation. Environmental impacts of the work associated with this alternative would continue to be avoided and minimized to the extent practicable. Placement of river training structures is expected to increase the acreage of low-velocity habitat that is considered important habitat for many MMR fish species. However, placement of river training structures is also expected to reduce shallow to moderate-depth, moderate- to high-velocity habitat which is important for some MMR fish guilds that have seen declines in abundance since the mid-1900s. Analysis of the impacts of the Continue Construction Alternative to main channel border habitat suggests that future construction of river training structures will potentially result in the consideration of compensatory mitigation measures.

The Continue Construction Alternative would also involve continuing to dredge as necessary, completing known bankline stabilization projects to reduce the risk of a channel cutoff, placing additional revetment, and continuing to maintain existing structures. Dredge quantities would be expected to decrease from their current average annual quantity of approximately 4 million cubic yards to approximately 2.4 million cubic yards after construction of new river training structures is complete.

In keeping with Council on Environmental Quality (CEQ) guidance, this Alternative is considered the No Action Alternative as it represents no change from the current implementation of the Project. Although this Alternative includes the potential consideration of compensatory mitigation measures, this fact does not change the basic features associated with the Alternative, how the features address the problems in the Project Area, or how they are constructed, operated, and maintained; the potential consideration of compensatory mitigation only affects the total amount of remaining construction that is considered economically justified due to the costs of mitigation. Therefore, the Continue Construction Alternative is still considered to be the No Action Alternative.

The **No New Construction Alternative** – This Alternative would involve not constructing any new river training structures for navigation purposes, but continuing to maintain the navigation channel only by dredging and maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Under this alternative, maintenance dredging would continue at roughly the current average rate of approximately 4 million cubic yards per year.

Environmental impacts of the work associated with this alternative would continue to be avoided and minimized to the extent practicable. It is not anticipated that this alternative would have any unavoidable significant impacts that would result in the consideration of compensatory mitigation.

The following table provides a brief summary comparison of the impacts of the No New Construction Alternative and the Continue Construction Alternative.

Summary of Environmental Consequences.

Resource Category	No New Construction Alternative	Continue Construction Alternative
Fishery Resources	• Minor effects to adult/juvenile/larval fish from dredge entrainment • Continued creation of islands/sandbars with flexible dredge pipe	• Conversion of estimated 8% (1,100 acres) of remaining unstructured main channel border habitat to structured habitat, potentially necessitating compensatory mitigation* • Minor effects to adult/juvenile/larval fish from dredge entrainment • General increase in fish use of structure locations due to increased low-velocity habitat and increased bathymetric, flow, and substrate diversity • Continued creation of islands/sandbars with flexible dredge pipe
Stages	• No impacts on stages anticipated, but trend of decreasing stages at low flows expected to continue	• No impacts on stages anticipated at average and high flows • At low flows, river training structure construction would contribute an unknown amount to continuing trend of small reductions in stages
Geomorphology	• No impacts to geomorphology anticipated	• Cross sectional area, hydraulic depth, conveyance, and channel volume will remain constant or generally increase.
Side Channels	• No impacts to side channels anticipated • District side channel restoration projects under other programs/projects would continue	• River training structure construction would contribute an unknown amount to small reductions in stage at low flows that would have minor adverse effects on side channel habitat by reducing quantity and connectivity of habitat • District side channel restoration projects under different programs/projects would continue
Water Quality	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites and at river training structure construction sites
HTRW	• No HTRW impacts anticipated	• No HTRW impacts anticipated
Air Quality and Climate Change	• Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions expected to remain at approximately 27,950 tons per year from dredging and maintenance activities	• Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions reduced by approximately 40% (to 16,970 tons per year) after completion of construction of new river training structures due to reduced dredging requirement

Resource Category	No New Construction Alternative	Continue Construction Alternative
Benthic Macro-invertebrates	• Dredging impacts limited to approximately 2% of riverine habitat on average, per year, indefinitely	• Increased benthic macroinvertebrate use of river training structure placement locations due to increased bathymetric, flow, and substrate diversity • Dredging impacts limited to approximately 2% of riverine habitat on average, per year, decreasing to 1% with construction of new river training structures
Threatened and Endangered Species	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • No effect or may affect but not likely to adversely affect for species listed since 2000	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • No effect or may affect but not likely to adversely affect for species listed since 2000
Human Resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources
Navigation	• Continued requirement for periodic maintenance dredging at an annual average rate of approximately 4 million cubic yards indefinitely • Higher risk of channel closures due to the sole use of just-in-time dredging to keep the navigation channel open once chronic dredging locations impact the channel	• Reduction in the amount and frequency of periodic maintenance dredging from 4 million cubic yards to 2.4 million cubic yards • Reduction in barge grounding rates • Increased channel reliability and decreased risk of channel closures due to decreased frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages.
Historic and Cultural Resources	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely

*The stated impact of 1,100 acres is a programmatic estimate based on the best available information. Actual impact acreages and compensatory mitigation measures will not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis, as new construction sites are identified.

Implementation of the Project. One of the recurring challenges with characterizing the impacts of the Regulating Works Project on the human environment is the fact that the timing, location, and configuration of future construction sites are currently unknown. This uncertainty is due to the dynamic nature of the flows and sedimentation patterns of the MMR and the fact that chronic dredging sites are addressed, by necessity, on an ongoing, as-needed basis. Accordingly, this SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward. The specific impacts associated with each future river training structure construction area would be covered in Tier II site specific Environmental Assessments (SSEAs). SSEAs would also detail any compensatory mitigation planning and associated adaptive management and monitoring that is required based on the impact assessments in the SSEAs.

Compensatory Mitigation. Although construction of river training structures does benefit some MMR fish species by providing low-velocity habitats, this does not offset or compensate for the anticipated adverse effects to shallow to moderate-depth, moderate- to high-velocity habitat. The adverse effects impact a different habitat type with a different function for a different group of fish than do the benefits. Due to these potential unavoidable adverse effects to main channel border habitat associated with future construction of river training structures, the District anticipates that these impacts will result in the consideration of compensatory mitigation. Potential mitigation measures may include, but are not limited to, the following: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities (see Appendix C for a broad, programmatic mitigation plan). Detailed compensatory mitigation planning would be accomplished on a site-specific level with the aid of a main channel border habitat model that is currently under development by the Corps.

Areas of Controversy

Flood Heights. There is research claiming that the construction of river training structures affects flood heights. The Corps takes these claims very seriously. The Corps has conducted several studies on the issue, completed a thorough analysis of all available research (included in this SEIS as Appendix A), and concluded that river training structures do not affect water surface elevations at higher flows.

Mitigation. In both scoping and public review comments, Federal and state natural resource agency partners have stated that the Corps should mitigate for adverse effects going back to at least 1976. The authority for mitigation of the Regulating Works Project is discretionary, and in general, the Corps plans for and implements mitigation associated with proposed actions (see Appendix K, response to USFWS Comment No. 13 in Appendix E, and response to National Wildlife Federation Comment No. 10 in Appendix H for detailed explanation of the Project's mitigation authority). The impact identified in the SEIS that may result in the consideration of compensatory mitigation was not a known negative, potentially significant impact until the completion of additional analyses to obtain unknown and unavailable information as part of the SEIS. Therefore, potential compensatory mitigation for the Regulating Works Project would be conducted for adverse effects that have occurred or will occur since publication of the Notice of Intent to prepare this SEIS in the Federal Register in December 2013 as committed to in the SSEAs for that work. However, the Corps' standing ecosystem restoration mission and associated authorities, outside of the Regulating Works Project authority, could be used to restore ecological resources affected by past activities of the Corps and others (see Appendix K and response to USFWS Comment No. 13 in Appendix E for more details on these other authorities).

1976 Post Authorization Change Alternative. Federal and state natural resource agency partners have continued to ask that the Corps seek the Post Authorization Change (PAC) referenced in the 1976 EIS to add fish and wildlife as a Project purpose. The District fulfilled the commitments made in the 1976 EIS; however, this purpose was never added to the Project by Congress to utilize Regulating Works Project construction funding for ecosystem restoration or enhancement measures. Additionally, all of the activities described in the 1976 EIS for the PAC can now be accomplished through other authorities. See Appendix K for additional details regarding these existing authorities.

Geographic Scope of Analysis. The District received scoping comments indicating that the SEIS should address all of the navigation channel operation and maintenance activities in the Upper Mississippi River – Illinois Waterway System (UMR-IWW) instead of focusing only on the MMR. Recognizing the dynamic nature of the river in certain regions, Congress authorized many different navigation projects throughout the UMR-IWW. The Congressional authority for and management of the navigation channel on the MMR is very different from other projects within the UMR-IWW, primarily because the MMR is open river and the rest of the UMR-IWW consists of a series of pools created and managed through locks and dams. As such, the District concluded that a separate analysis for the MMR is appropriate.

Preferred Alternative. Based on the Project's Congressional authority and continued benefit of the remaining construction, the Continue Construction Alternative with the described potential consideration of compensatory mitigation is the Preferred Alternative. With implementation of the Continue Construction Alternative, the District anticipates constructing future river training structures that equate to approximately 4.4 million tons of rock, which will reduce dredging to approximately 2.4 million cubic yards on an average annual basis. This reduction in dredging will result in a more reliable channel while also taking into account impacts to habitat. The economic viability of the Regulating Works Project will continue to be evaluated as part of the Corps budget process, and therefore, the actual remaining quantity of construction may vary due to changes in rock prices, dredging costs, mitigation costs, etc.

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Acronyms and Abbreviations

AEP	Annual Exceedance Probability
APE	Area of Potential Effect
AQCR	Air Quality Control Region
ASTM	American Society for Testing and Materials
ATR	Agency Technical Review
BGEPA	Bald and Golden Eagle Protection Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CH_4	Methane
CO_2 Eq	Carbon Dioxide Equivalent
CPUE	Catch per Unit Effort
dB	Decibels
DOE	Determination of Eligibility
DQC	District Quality Control
EA	Environmental Assessment
EC	Engineering Circular
ECP	Environmental Condition of Property
EIS	Environmental Impact Statement
EO	Executive Order
ERDC	Engineering Research and Development Center
ESA	Environmental Site Assessment
et al.	And Others
ft	Feet
GHG	Greenhouse Gases
hp	Horsepower
HSR	Hydraulic Sediment Response
HTRW	Hazardous, Toxic, and Radioactive Waste
IDNR	Illinois Department of Natural Resources
IDPH	Illinois Department of Public Health
IEPA	Illinois Environmental Protection Agency
IWW	Illinois Waterway
kPa	Kilopascals
LDB	Left Descending Bank
LMR	Lower Mississippi River
LTRM	Long Term Resource Monitoring

LWRP	Low Water Reference Plane
m/s	Meters per Second
m^2	Square Meters
MDC	Missouri Department of Conservation
MDHSS	Missouri Department of Health and Senior Services
MDNR	Missouri Department of Natural Resources
mg/L	Milligrams per Liter
MMR	Middle Mississippi River
MOU	Memorandum of Understanding
MRC	Mississippi River Commission
MSD	Metropolitan Sewer District
MVD	Mississippi Valley Division
N/A	Not Applicable
NAAQS	National Ambient Air Quality Standards
NAVD	North American Vertical Datum
NEPA	National Environmental Policy Act
NESP	Navigation and Ecosystem Sustainability Program
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxides
NRHP	National Register of Historic Places
NTU	Nephelometric Turbidity Units
O&M	Operations and Maintenance
PAC	Post Authorization Change
PCB	Polychlorinated Biphenyl
PCXIN	Planning Center of Expertise for Inland Navigation
PM	Particulate Matter
RDB	Right Descending Bank
REC	Recognized Environmental Condition
RIAC	River Industry Action Committee
RIETF	River Industry Executive Task Force
RM	River Mile
RMO	Review Management Organization
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RRAT	River Resources Action Team
RTS	River Training Structures
SEIS	Supplemental Environmental Impact Statement
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan

SO_2	Sulfur Dioxide
SPL	Sound Pressure Level
SSEA	Site-Specific Environmental Assessment
STL	Saint Louis
TOCs	Total Organic Compounds
UMR	Upper Mississippi River
UMR-IWW	Upper Mississippi River – Illinois Waterway
UMRR	Upper Mississippi River Restoration
UMRS	Upper Mississippi River System
USACE	U.S. Army Corps of Engineers
USC	United States Code
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOCs	Volatile Organic Compounds
yd^3	Cubic Yards
YOY	Young-of-the-Year
µg/L	Micrograms per Liter
µPa	Micropascals

Chapter 1. Purpose of and Need for Action

1.1 Purpose of and Need for the Regulating Works Project

1.1.1 History, Authority, and Purpose of the Regulating Works Project

Beginning in 1824, the Congress of the United States authorized the Secretary of the Army, by and through the U.S. Army Corps of Engineers (Corps), to make improvements to the Mississippi River, and some of its major tributaries, for the purpose of obtaining and maintaining an inland navigation channel for waterway commercial transportation throughout the United States. Ultimately for the Mississippi River, Congress authorized obtaining and maintaining at least a nine foot deep navigation channel from the Gulf of Mexico to Minneapolis, Minnesota, through multiple projects by various methods and management. Early on in the Chief of Engineers' reports and Congress' authorizations, it was evident that there were distinct areas of the Mississippi River that would require different management techniques, and thus, different projects, in order to provide a suitable navigation channel. These differences resulted in three distinct segments of the river governed by the influx of major tributaries: the Lower Mississippi (from the Gulf of Mexico to the confluence of the Ohio River (LMR)); the Middle Mississippi (from the confluence of the Ohio River to the confluence of the Missouri River (MMR)); and the Upper Mississippi (from the confluence of the Missouri River to Minneapolis, Minnesota (UMR)) (Figure 1-1).

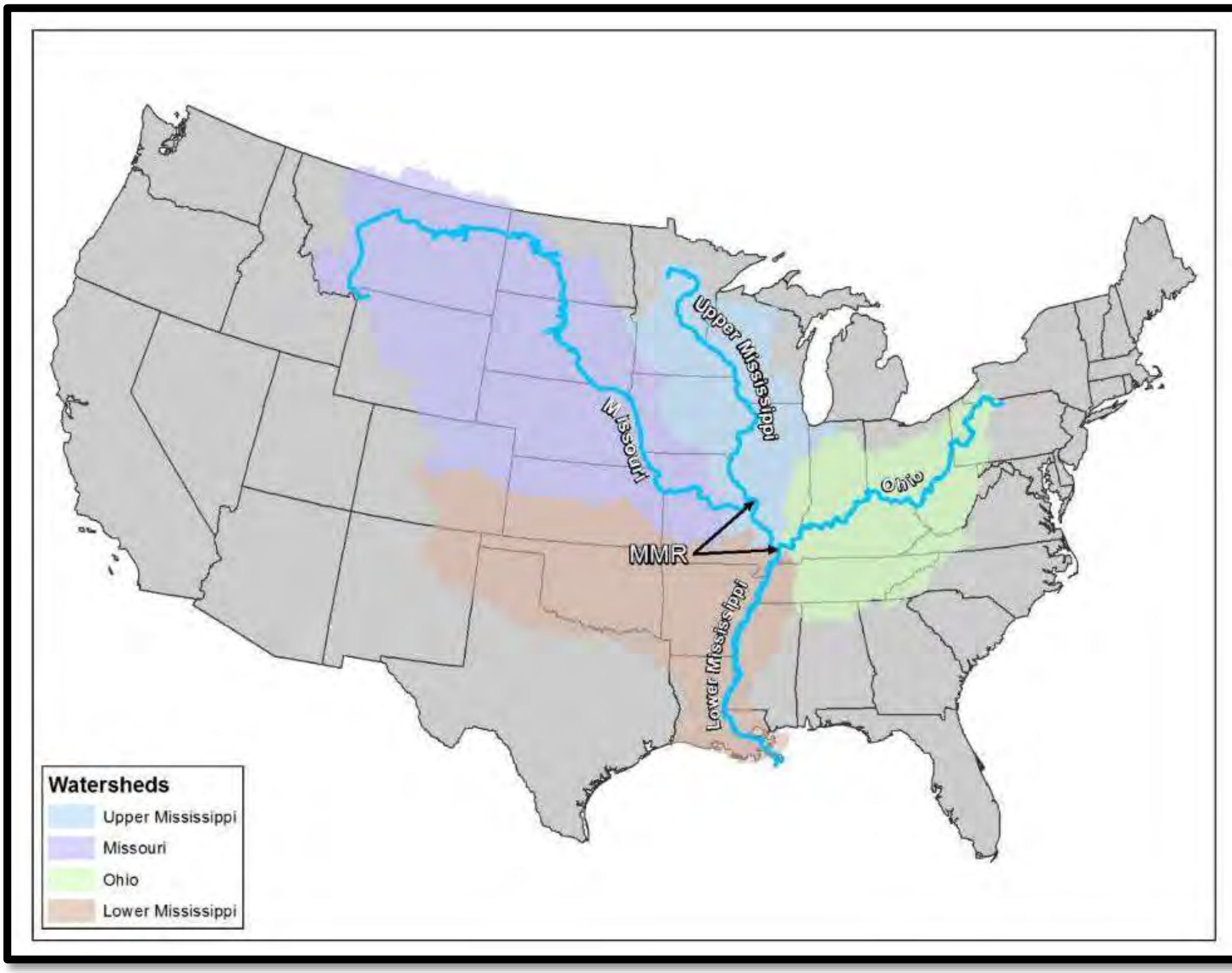

Figure 1-1. Location of the MMR within the Upper Mississippi River watershed.

While the MMR has sometimes been included when referring to the Upper Mississippi River, the Congressional authority and management of these two segments of the navigation channel are very different. While it took until 1930 for Congress to authorize the ultimate plan for the navigation channel in the UMR (construction of a series of locks and dams),[1] Congress authorized the ultimate plan for how the navigation channel should be obtained and maintained for a majority[2] of the MMR in 1910 and eventually established the current navigation channel

[1] *See* Rivers and Harbors Acts dated July 3, 1930 and August 30, 1935 and the following Chief of Engineers reports: House Document No. 290, 71st Congress, 2nd Session and House Document No. 137, 72nd Congress. These references provide the general framework for the authority and development of the UMR to obtain and maintain a navigation channel through a series of locks and dams. These reports further divided the UMR into segments that were unique and presented different challenges and issues for obtaining and maintaining a suitable navigation channel. There are also additional authorities and projects within the UMR. For a discussion of the UMR authorities and projects and how the various segments' ecosystems differ, see U.S. Army Corps of Engineers, Final Integrated Feasibility Report and Programmatic Environmental Impact Statement for the UMR-IWW System Navigation Feasibility Study, §§ 1.5.1, 1.5.2, and 1.6.1, Sept. 24, 2004, commonly referred to as NESP.
[2] See Section 1.1.7 and Appendix K for discussion about the Chain of Rocks area of the MMR.

dimensions of 9 feet deep and not less than 300 feet wide, with additional width in the bends as required, in 1927.

In the Rivers and Harbors Act of 1910, Congress authorized obtaining and maintaining the MMR to be carried out in accordance with the plan in 1881, which was described in detail in the Mississippi River Commission (MRC) progress report dated November 25, 1881 (the MMR as defined above being 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 1-2)). The MRC's specific plan in 1881 for the MMR stated that "the system to be pursued is that of contraction, thus compelling the river to scour out its bed; this process being aided, if necessary by dredging. Wherever the river is causing any serious caving of its banks, the improvement will not be permanent until the bank has been protected and the caving has been stopped" and that "it may be advisable to remove some bowlders [sic] and perhaps to cut off some points of rocks, which at low-water hamper navigation" (Senate Executive Doc. No. 10 (47th Congress, 1st Session) (hereinafter referred to as the 1881 Report)). The Congressionally authorized modification to the Project in the Rivers and Harbors Act of 1927, changing the depth and width of the authorized navigation channel, was based upon the Chief of Engineers' report dated December 17, 1926. This Chief of Engineers report described the current and future status of the Project as follows: "Although great benefits have resulted from the work already done, it is essential that additional regulating works and bank protection be carried to a point where a minimum of dredging is required and a stable channel is available at all times... [The Chief of Engineers also concurred in the District Engineers' recommendation that] the regulating works and revetment be completed and that dredging, which affords only temporary relief, be resorted to only when and to the extent that the needs of navigation then existing require" (House Committee Doc. No. 12 (70th Cong., 1st Session)). For a detailed history of the Regulating Works Project and its authorization, see Appendix K.

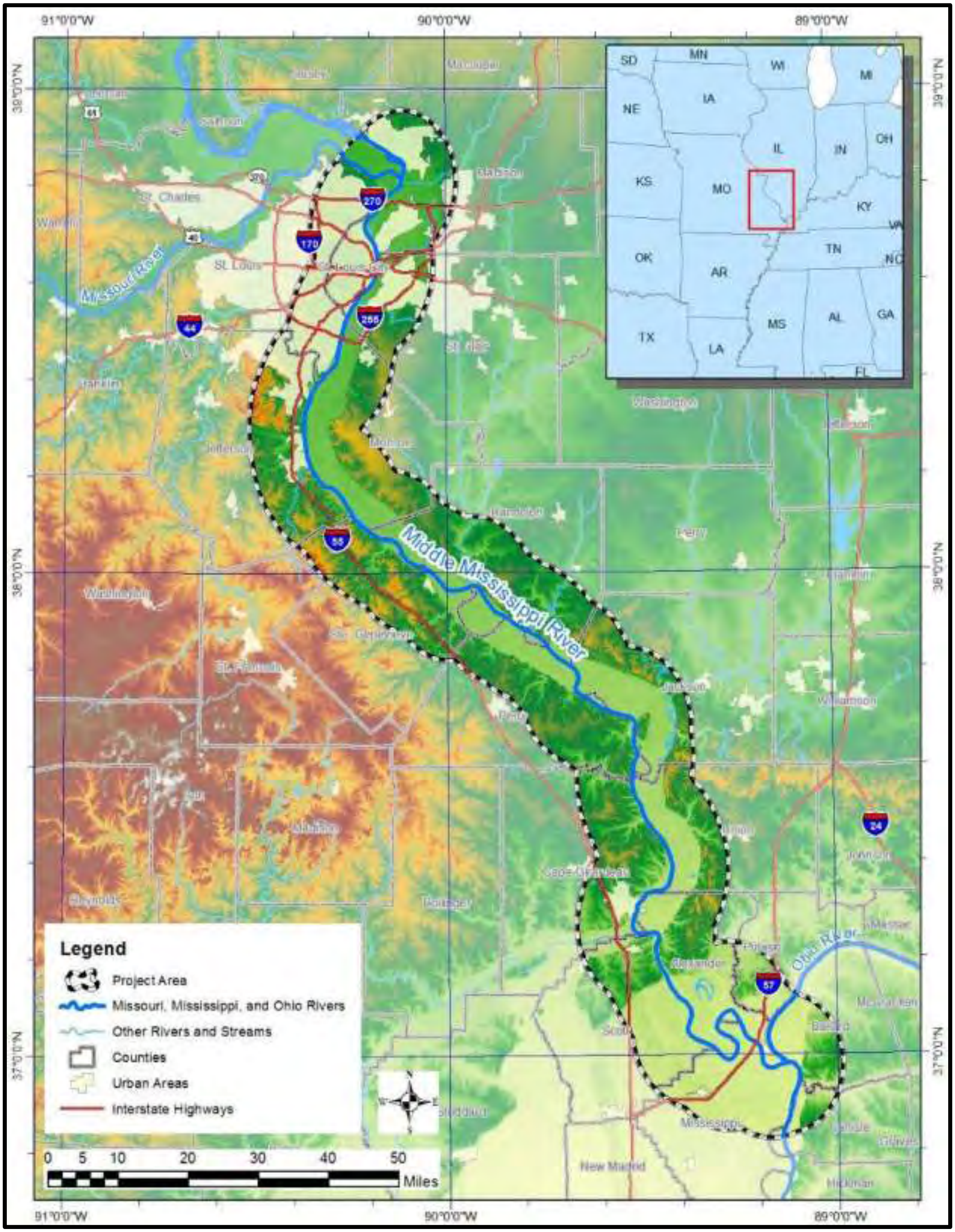

Figure 1-2. General location of the Project Area.

Therefore, since 1910 the plan described in the 1881 Report and in the 1926 Chief of Engineers' report, as Congressionally authorized, has been ongoing by 1) constructing and maintaining regulating works, also called river training structures, to scour the river bed for the purpose of reducing maintenance dredging to a minimum; 2) constructing and maintaining bank protection/stabilization, also called revetment; and 3) removing rock hindering navigation, all to obtain and maintain a navigation channel in the MMR nine feet deep and at least 300 feet wide, with additional width in bends. This ongoing Project is commonly referred to as the Regulating Works Project, and the Project is carried out by the Corps' St. Louis District (District). River training structures are structures constructed for the purpose of re-directing the river's energy to achieve a desired velocity and/or scour pattern to deepen or provide better alignment for the navigation channel. Revetment is bank protection placed on or along the bankline to prevent bankline erosion and maintain bankline integrity. Today, river training structures and revetment are normally constructed with stone which has been found over the years to be the most effective and cost efficient, although other materials have been and can be used (see Appendix K for more details on the history and current construction of river training structures and revetment, as well as all rock removal efforts to date). Since the long-term goal and purpose of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of regulating works, the District continually identifies and monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable. The District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel.

1.1.2 Interagency Coordination

The process the District uses to coordinate Regulating Works Project actions with partner resource agencies has evolved over the course of the history of the Project as environmental laws and regulations and the methods of implementing the Project have changed. Through coordination with partner resource agencies the District has transformed the way it designs and implements all phases of the Project in such a way as to avoid and minimize adverse effects to fish and wildlife resources to the extent practicable. Avoiding and minimizing adverse effects results in innovative implementation of the Project such as:

- Use of innovative structure configurations to create habitat diversity – innovative structures result in unique depth and velocity patterns compared to traditional structures (see 3.2.2 Geomorphology for information on innovative structure designs)
- Use of innovative structures to facilitate creation of split-flow conditions to mimic island/side channel habitat and braided channel habitat – notched dikes, offset dikes, rootless dikes, multiple roundpoint structures, W-dikes, and S-dikes have been used to replicate these conditions
- Avoidance of sensitive fish and wildlife areas where placement of structures and/or changes in current patterns might have adverse effects
- Avoidance of impacts to depths, velocities, and connectivity of side channels

It should be noted that incorporation of such measures to avoid and minimize impacts into the Regulating Works Project does change the efficiency with which the Project maintains the navigation channel and reduces dredging. This is due to the fact that structures with innovative designs typically require more rock to achieve the same amount of dredging reduction as a traditional wing dike. Likewise, as impacts to particular areas are avoided, the degree to which the Project can address a dredging issue in the area may be reduced. This reduction in Project efficiency affects the economics of the Project and may translate to a higher average annual dredging quantity upon Project completion.

The current interagency coordination process the District uses was officially codified in a 2002 Memorandum of Understanding (MOU) between the District and the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Missouri Department of Conservation. The MOU created the River Resources Action Team (RRAT) as the official forum to be used for interagency coordination of all Regulating Works Project and other project actions. The RRAT was created to:

- Enhance and formalize the interagency coordination process;
- Foster a cooperative interagency partnership;
- Ensure consistency of interagency coordination;
- Identify a collaborative mechanism for project coordination;
- Provide effective implementation of the 2000 Biological Opinion; and
- Use a team approach to restore and protect UMR watersheds and ecosystems.

Through the RRAT the District coordinates all Project activities with interagency coordination meetings at least twice per year and on an as needed basis for specific work areas or activities.

Specifically for the SEIS, in addition to discussions at the semi-annual RRAT meetings and continual communication throughout the SEIS process, the District coordinated with the partner resource agencies as follows:

- SEIS interagency scoping meeting – 20 February 2014
- SEIS habitat analysis meeting – 22 July 2015
- SEIS habitat analysis meeting – 9 February 2016

Specific details on the coordination that typically takes place for new construction, dredging, and bank stabilization activities under the Regulating Works Project can be found in the respective sections below.

1.1.3 Process for New Construction under the Regulating Works Project

Given the dynamic nature of the flows and sediment transport characteristics of the MMR, work sites are, by necessity, developed, analyzed, and then re-analyzed on an ongoing basis as the data associated with ongoing and frequently dredged locations are assessed and as new dredging issues arise. The District maintains the dredging data, which includes the frequency and volume of material removed from chronic dredging sites. The data is used to rank the dredging locations based on annual dredging requirements at each site over the last ten years. Sites are ranked on a yearly basis, after new dredging data is added. The more recent dredging requirements (1 to 5 years) are weighted more heavily than the dredging that occurred prior (6 to 10 years) to help the District to better react and produce designs according to changing river conditions. The higher ranked dredging sites are continuously analyzed and assessed to determine if maintenance of existing structures is needed and/or if the construction of new river training structures would offer a more practical and cost effective long-term solution than continued dredging. See Appendix I, Channel Improvement Master Plan, for recent dredge and disposal areas and potential future work locations. For each site where river training structures may be the best solution, the District develops alternatives using widely recognized and accepted river engineering guidance and practice. Also, 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 to avoid and minimize impacts. The District does this through close coordination with partner resource agencies under the auspices of the River Resources Action Team (see Section 1.1.2 above). Different configurations of regulating works are frequently screened and analyzed with the assistance of a Hydraulic Sediment Response model (HSR model). HSR models are small-scale physical sediment transport models used by the District to replicate the mechanics of river sediment transport. HSR models allow the District to analyze multiple configurations of river training structures for addressing the specific objectives of the work area in question in a cost-effective and efficient manner. Through model meetings with RRAT representatives, various configurations of river training structures are applied in the models to determine their effectiveness in addressing the needs of the chronic dredging site, improving the navigation channel alignment (if applicable), and avoiding and minimizing environmental impacts. Partner coordination efforts, comments on various river training structure configurations, recommendations for avoiding and minimizing impacts, etc. are included in HSR model documentation for each site where the model is utilized. HSR models are not necessary in all situations and other engineering solution development techniques may be used as appropriate. Regardless of what process is used to develop alternatives to address repetitive dredging locations, an important component of each activity is the use of scientific, economic, and social knowledge to understand the environmental context and effects of the Project 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 (Figure 1-3).

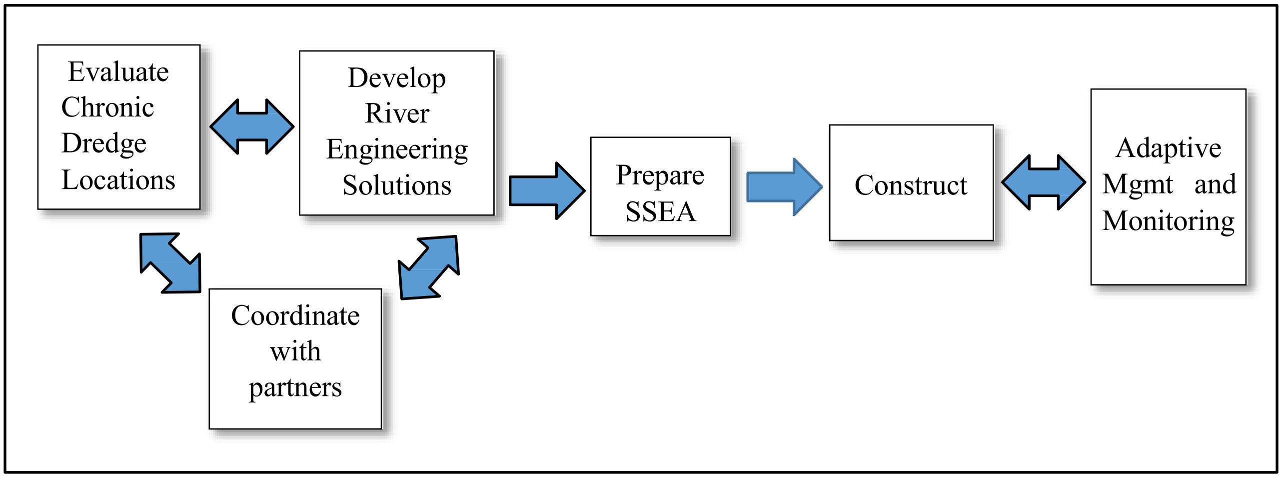

Figure 1-3. Flow chart of river training structure development process for maintaining the MMR navigation channel.

The review of regulating works projects follows the requirements of the Corps Engineering Circular EC 1165-2-214, which established an accountable, comprehensive, life-cycle review strategy for Civil Works products by providing a seamless process for review from initial planning through design, construction and operation, maintenance, repair, replacement and rehabilitation.

The Channel Improvement Master Plan, general work plan and typical plans and specifications are reviewed annually. Under District Quality Control (DQC), the general work plans are submitted to senior members of the Hydraulics and Hydrology and River engineering disciplines in the District office not involved in the plans' development for review and comment.

Agency Technical Reviews (ATR) on the District's proposals are conducted by Mississippi Valley Division (MVD) personnel, Channel Improvement Coordinators and Design and Operations personnel associated with the Channel Improvement Project from each District within MVD, and MVD Civil Works Integration Division personnel. MVD serves as the Review Management Organization (RMO). This usually takes place at the annual Engineering Actions (E-Actions) meeting. Team members objectively review the proposals and provide comments which are resolved and documented into a report.

The objectives of the ATR, as outlined in the Mississippi River and Tributaries Project Channel Improvement Feature Regulating Works Project Review Plan, are to ensure that (1) the project meets the Government's scope, intent and quality objectives, (2) design concepts are valid, feasible, safe, functional and constructible, (3) appropriate methods of analysis were used and basic assumptions are valid and used for the intended purpose, (4) the source, amount and level of detail of the data used in the analyses are appropriate for the complexity of the project, (5) the project complies with accepted practice and design criteria within the industry, (6) all relevant engineering and scientific disciplines have been effectively integrated, (7) content is sufficiently complete for the current phase of the project and provides an adequate basis for future development efforts, and (8) project documentation is appropriate and adequate for the project phase.

1.1.4 Process for Dredging under the Regulating Works Project

The first step in the dredging process (Figure 1-4) is to determine which locations require dredging. A Channel Patrol Boat performs channel reconnaissance surveys using depth soundings in order to identify possible dredging locations. If the surveys show areas that could be problematic for navigation (based off of the river forecast[3] or anticipated low water levels), a more detailed pre-dredge survey of the area is completed. Engineers may also narrow down which areas might require dredging based on past experience and knowledge of historically problematic areas. The pre-dredge survey is analyzed to determine if dredging is required. If dredging is required, the survey is used to lay out the dredge cuts and approximate the volume of material to be moved, along with scheduling and coordination needs. Once the dredging is complete, a post-dredge survey is done to determine if the problematic area has been adequately addressed. Later, additional channel surveys will be performed at the site to monitor conditions and determine if or when additional dredging will be needed in the future.

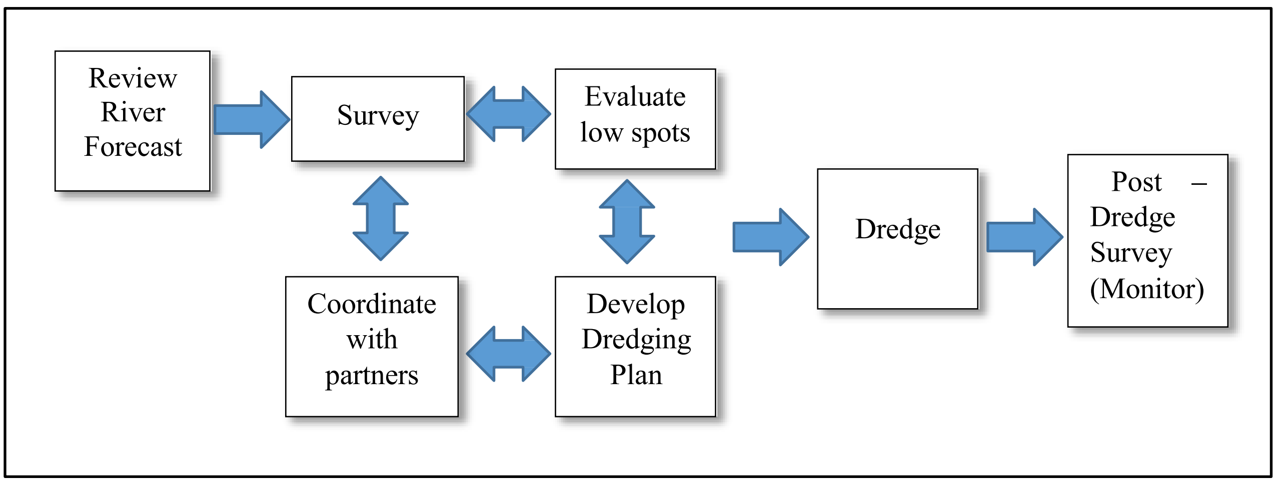

Figure 1-4. Flow chart of dredging development process for maintaining the MMR navigation channel.

Pre-Dredge Sampling

The Illinois Environmental Protection Agency and Missouri Department of Natural Resources Clean Water Act Section 401 water quality certification permit conditions require analysis of dredged material. The process used to collect the samples is outlined in the Inland Testing Manual (ITM) (EPA-823-B-98-004 Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual). During initial channel patrols, potential dredging locations are sampled per the ITM and reviewed by personnel in the Environmental and Munitions Branch. Depending on the composition of the materials sampled at the potential dredge location, additional environmental testing will be performed per the ITM prior to dredging. All of this data is then compiled at the end of the dredging season and submitted to the permitting agencies. Ultimately, the results of this sampling and analysis determines whether or not the dredged

[3] River forecasts are projections of future river stages provided by the National Weather Service.

material can be placed in unconfined open water or if the material must be placed in a confined upland area.

Dredged Material Management

Dredged material disposal practices must be in compliance with the Federal Standard (33 CFR §335-338), requiring the least costly, environmentally acceptable option that is consistent with engineering requirements. Depending on the outcome of the environmental sampling as outlined in the ITM, decisions are made on the disposal technique and the preferred placement location is then coordinated with state and federal partners. Once feedback from the disposal location is received there can be adjustments made to the disposal location. Options for dredged material placement are either unconfined open-water placement, or confined upland placement.

Unconfined Open-Water Placement

Placing the dredged material with unconfined in-river placement, in close proximity to the dredge location, is generally the least costly environmentally acceptable alternative. Preferred placement locations are areas that have been historically used, avoid sensitive areas, minimize impacts to the environment, and avoid impacts to local facilities. The preferred open water placement locations are pre-coordinated with the resource agencies to avoid and minimize environmental impacts and are documented in the Dredge Master Plan.

Confined Upland Placement

Upland placement has additional costs associated with it, such as longer pipelines, booster pumps, dozers, land side access and containment preparation, management of return water requirements, and possibly land acquisition. Upland placement is significantly more expensive and is generally only a competitive alternative when open-water, in-river placement would violate water quality certification conditions.

Beneficial Use of Dredged Material

Beneficial use of dredged material is an effort that the Corps supports through various programs. In general, beneficial use projects require a sponsor to fund the incremental cost related to the beneficial use option that is over and above the Federal Standard placement option. Potential projects will be evaluated as they become available, consistent with current Corps guidance and funding capability in these other programs.

Dredge Coordination

All dredging is coordinated with state and federal natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits. This is accomplished through the River Resources Action Team (see Section 1.1.2 above). RRAT personnel input is incorporated annually into the Dredge Master Plan (DMP; see below). The District updates the DMP annually with analysis of the previous year's data and a forecast of anticipated dredge locations for the next dredge season. The DMP is provided to RRAT personnel every March for review and comment. In addition, prior to each dredging event, the locations of upcoming dredge cuts and disposal areas are sent to RRAT personnel and other stakeholders to ensure any potential adverse effects are avoided and minimized.

Clean Water Act coordination with the states of Illinois and Missouri is done when permits are applied for or renewed and throughout the dredging season as needed per any permit conditions. In addition to this coordination, the yearly dredging information, to include the updated Dredge Master Plan along with all data analysis performed, is supplied to the states' 401 water quality permitting authority.

Dredge Master Plan

The Dredge Master Plan lays out recommendations from resource agency partners and other stakeholders for preferred dredge placement at frequent dredging locations. The DMP is updated annually with the previous year's dredging information and with recommendations received from resource agency partners or stakeholders. Information on the previous dredge season includes dredge locations and quantities, methods of disposal, and sediment grain size analysis. Using the DMP allows dredge planning efforts to be more proactive, avoid and minimize impacts to the environment, and potentially identify specific dredge areas and placement locations that may require further study or analysis.

Typical Dredge Plant

Due to large dredge volumes and availability of nearby placement, nearly all MMR dredging is done with two types of hydraulic dredges, a dustpan or a cutterhead dredge. On occasion, mechanical dredging using a floating crane is performed for small assignments or where nearby placement is not acceptable.

Cutterhead Dredge

A cutterhead dredge uses a rotating auger head that allows it to work through sands, clay or harder material on the river bottom. The dredged material is pumped up to the dredge and out a pipeline to an approved placement area. Generally, a cutterhead dredge has at least 3,000 feet of pipeline and can deposit material further away than a dustpan dredge. The cutterhead dredge moves by using a walking or traveling spud carriage and swing anchor lines and generally moves more slowly than a dustpan dredge. Cutterhead dredges are better suited for areas with less traffic versus the main navigation channel of the MMR.

Dustpan Dredge

The hydraulic dustpan dredge was specifically designed by the Corps for use on the Mississippi River as it is very efficient at excavating sand material from the riverbed. Water jets at the end of the suction head, or dustpan, agitate the sand into a slurry which is then pumped up into the dredge and transported outside the navigation channel through a rigid pontoon pipeline that is typically 800 to 1,000 feet long (Figure 1-5). Using the rigid pontoon pipeline is often referred to as side-casting, since the rigid pontoon pipeline is held in a fixed position relative to either side of the dredge, and is continuously moving as the dredge works upstream through the dredge area. The Dustpan dredge, working only from its hauling anchor lines, can quickly move off the dredge area to pass traffic and then return to the same exact spot. This ability allows significantly higher production time as compared to a cutterhead dredge, especially in high traffic areas like the MMR.

Dustpan Dredge with Floating Flexible Pipeline
Some MMR dredging is now accomplished using floating flexible pipeline (Figure 1-5). The St. Louis District recently purchased a self-floating flexible pipeline to facilitate construction of sandbar/island habitat in association with dredging activities and in compliance with the Project's Endangered Species Act obligations. The floating flexible pipeline has advantages over typical rigid pontoon pipeline because the discharge end of the pipe can be held in a fixed location instead of side-casting the dredged material. With flexible pipeline, as long as the discharge location is within a certain distance of the dredge, the position of the discharge can be fixed irrespective of the location of the dredge. Fixed-point discharge allows the buildup of material to higher elevations than is normally possible with the traditional side-casting method using rigid pontoon pipeline. This technique can be used to place "piles" of material to create expanses of shallow sandbar and/or ephemeral island habitat. Sandbar and island habitat is considered to be important fish habitat that is less abundant in the MMR than it was historically. One of the limitations of the floating flexible pipeline is that it is not used during colder temperatures when frost or ice may form on the pipe making it hazardous for workers to assemble or disassemble the pipeline.

Implementation of the flexible dredge pipe into the District's dredging program is an ongoing process. Since its first use in 2011, the flexible dredge pipe has been utilized for approximately 8% of the District's dredging workload, based on cubic yards dredged. There are a range of variables such as additional cost, efficiency, stability of constructed habitats, ecological benefits, safety during cold weather, etc. that factor into what percentage of the District's maintenance dredging work ends up being conducted with flexible dredge pipe. It is unknown at this time what that percentage will be in the future and the percentage will likely vary considerably from year to year depending on river levels, dredge requirements, and other factors. As with standard rigid pipe, all dredge cut and disposal areas using flexible dredge pipe are coordinated with natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits.

Figure 1-5. Dredged material disposal in the MMR using standard rigid discharge pipe (top) and floating flexible discharge pipe (bottom).

1.1.5 Dredging Reduction under the Regulating Works Project

As discussed above, the purpose of the Regulating Works Project is to obtain and maintain the authorized navigation channel through regulating works and dredging, with a goal of reducing costly dredging to a minimum. Various forms of the District's dredging data date back to 1964 (Figure 1-6). Unfortunately much of this data contains very little of the metadata information that is needed to verify the calculation or the source of the data or to determine its quality. The amount dredged in any particular dredge season is dependent on a number of independent environmental and operational factors. Therefore, caution must be applied when using this data to summarize yearly dredging totals and when attempting to statistically establish short and long term dredging trends. The need for dredging and the quantity of dredged material is directly related to the hydrograph. Generally, less dredging is observed in dredge seasons where higher flows are observed. Conversely, in dredge seasons with low water, more dredging is observed. The amount of material dredged is also related to the rise and fall in the hydrograph. More dredging has been observed following a flood with a faster rate of fall in the hydrograph. In addition, the amount of sediment entering the MMR is dependent on the origin of the flow. A simple plot of dredging quantity versus year does not adequately account for these factors. In an attempt to account for the dependency of dredge data on the days under low water, the dredge quantities were plotted against the number of days below zero on the St. Louis gage (Figure 1-7).

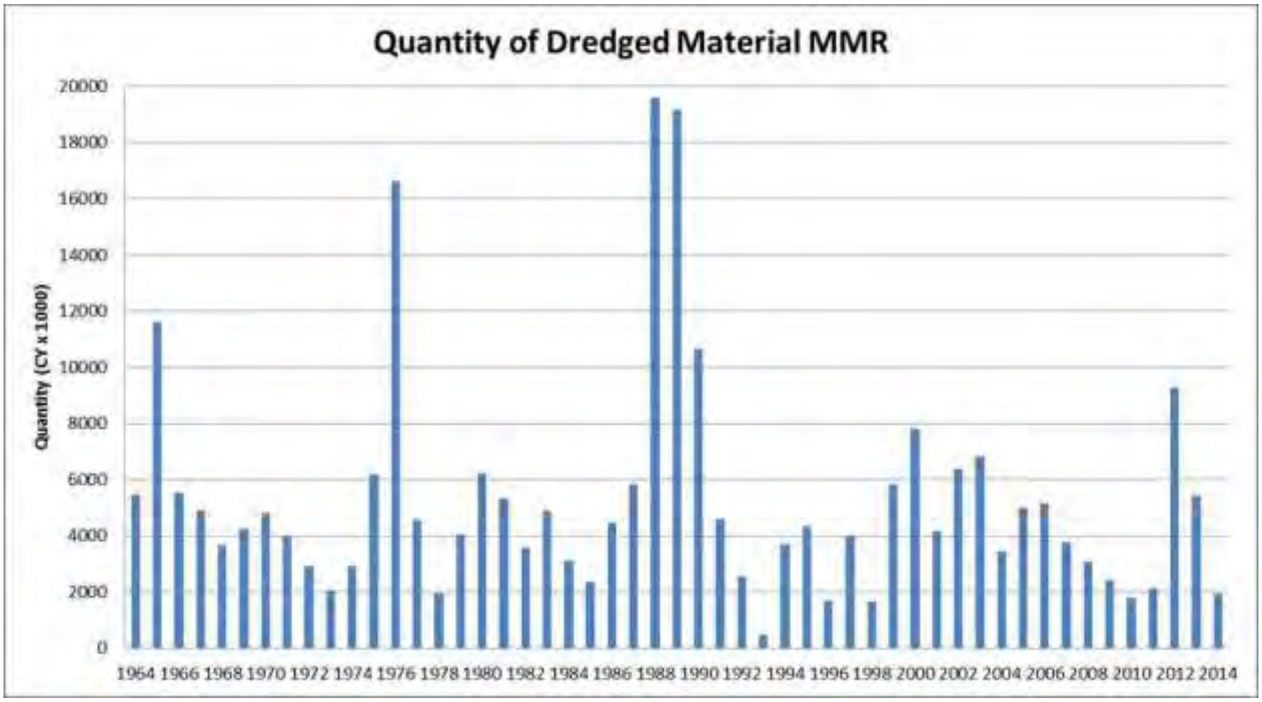

Figure 1-6. Volume of material (yd3) dredged from the MMR by year from 1964 to 2014. Includes both Corps and contract dredges.

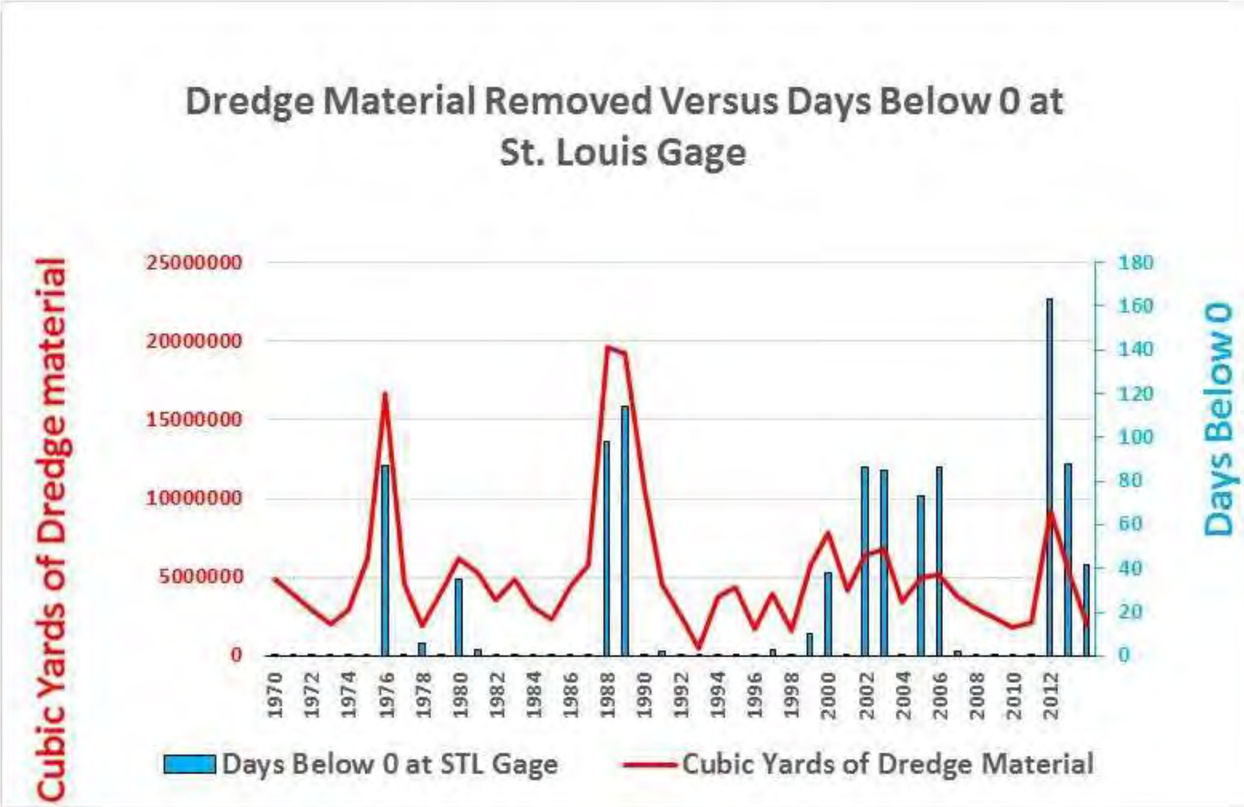

Figure 1-7. Comparison of quantity of material dredged to number of days stage was below 0 ft on St. Louis gage.

Operational and decisional factors must also be considered when examining the data. Dredging totals by site are often dependent on equipment availability; river stage fluctuation, ice, and weather at the time of dredging; equipment malfunction and repair; dredging depth and forecast information; dredging/channel width; dredge schedule and risk assessment (i.e. the effect of the current forecast on the transit time needed to move to other sites to be dredged and risk assessed for dredging critical sites and locations); and the decision-making process based on all previous factors discussed, including both operational and environmental variables. For instance, in 2009 operational changes that affected the decision making process were undertaken to improve the District's responsiveness to dredging. A Project Delivery Team (PDT) consisting of personnel from river engineering, water management, dredging, surveying, and environmental disciplines was formed to decide when and where to dredge. Decision-making regarding dredging has been the responsibility of this PDT from 2009 to present.

Improvements in surveying capabilities have also dramatically increased District responsiveness and improved decision-making. Equipment improvements such as multi-beam sonar as well as increased surveying capacity utilizing two contract surveying companies have also led to an increased awareness of the conditions of the navigation channel.

Water management and forecasting have also greatly improved. During low water, critical coordination occurs throughout the day and night with water managers upstream of St. Louis, including the Rock Island District for the Upper Mississippi and Illinois Rivers and the Northwest Division for the Missouri River. The St. Louis District constantly monitors inflows and adjusts the outflow at Mel Price Locks and Dam to alleviate impacts of water level fluctuations through the St. Louis Harbor.

During low water, channel patrol efforts using the Corps M/V Pathfinder are increased to identify problem areas and replace or move buoys to better mark the narrowing channel. Assuring the channel is well marked prevents groundings which may further degrade the channel and defers dredging until a dredge can be assigned to that specific location. Schedules for the patrols between the Corps and the U.S. Coast Guard are coordinated to maximize coverage on the system.

Changes in dredging criteria, changes in the decision-making process, and the dependent nature of the dredging data make it nearly impossible to develop statistical trends solely from the roll-up of the yearly dredging data set. To help illustrate the reduction of dredging resulting from the construction of river training structures, an analysis of three recent low water dredging seasons, 1988/89, 2003 and 2012, was conducted. During the 1988/89 drought, the river dropped below 0.0 feet at the St. Louis gage for 206 days, with a minimum daily stage of -5.4 ft., and the District needed to dredge approximately 38.1 million cubic yards of material. During the 2003 low-water event, the St. Louis gage dropped below 0.0 for 136 days, with a minimum daily stage of -4.5 ft., but only 7.6 million cubic yards of material needed to be dredged. Between July 2012 and February 2013, when the river dropped below 0.0 feet at the St. Louis gage for 160 days, with a minimum daily stage of -4.6 ft, the District had to dredge just under 9.3 million cubic yards of material. It is important to note that to this point funding for dredging has been available, through redirecting O&M funding from other O&M needs, for maintaining the channel to the authorized dimensions during low water periods.

An evaluation of specific dredging locations has also proven valuable. The District developed a ranking system of chronic dredging locations in order to prioritize the construction of river training structures. The system is based on a weighted average of the last 5 and 10 years of dredging in two-mile river segments. The top ten dredging locations by volume in 1988/89 are shown in Table 1-1. The table shows the volume of material removed from these locations in 1988/89. The table also shows that the river engineering program has reduced the amount dredged from these locations by an average of 83%.

While the drought of 1988/89 encompassed two full dredging seasons and the drought of 2012/13 was only in one dredge season, the events can be compared considering that no two droughts are the same. Not only was significantly less material removed in 2012 by comparing that year to either 1988 or 1989, but the channel was fully prepared for a stage of -7.0 at St. Louis, which was a full 3 feet lower than in 1988/89.

Table 1-1. The top ten ranked dredging locations in 1988/89 compared to 2012.

River Mile	1988-89 Rank	Dredged in 1988-89 (cy)	Construction between 1988-2012 (Tons)	Current Rank	Dredged in 2012 (cy)	Percent Reduction
52 - 54	1	2,228,800	115,116	38	35,468	-98%
42 - 44	2	1,892,600	181,961	36	225,500	-88%
66 - 68	3	1,706,700	154,736	5	530,976	-69%
38 - 40	4	1,646,000	86,693	6	323,781	-80%
6-8	5	1,545,700	368,874	34	167,213	-89%
46 - 48	6	1,257,800	26,331	8	450,047	-64%
30 - 32	7	1,246,400	182,967	24	112,748	-91%
28 - 30	8	1,232,400	65,938	37	0	-100%
166 - 168	9	1,204,300	312,815	16	366,400	-70%
14 - 16	10	1,125,000	107,560	33	350,308	-69%
TOTAL		15,085,700			2,562,441	-83%

A closer look at the most troublesome dredging locations in 1988/89 compared to 2012 reveals even more dramatic results. In 1988/89 the worst 20 miles of river for dredging (as displayed in Table 1-1) accounted for over 15 million cubic yards of dredging over those two years. The worst dredging location for the 1988/89 time frame was the stretch of river from River Mile (RM) 54 to 52, near Cape Girardeau, Missouri. This stretch was responsible for over 2.2 million cubic yards of dredging between 1988 and 1989. Since then, bendway weirs have been placed at the upstream extent of the stretch. In 2012, less than 36,000 yards were dredged in this reach for a 98% reduction.

The second-most dredged location in 1988/89 was between RM 44 and 42, near Thebes, Illinois. This reach of river required nearly 1.9 million cubic yards of dredging, with the dredging partially necessitated by the presence of submerged rock pinnacles that constrained the navigable channel. Since 1989, several additional dikes were constructed to better maintain flow alignment in the navigation channel. Efforts have also been made to remove the rock pinnacles to increase navigable channel width, both in 1989 and in 2012. In 2012, only 225,000 yards of material were dredged for a reduction of 88%.

The third-most dredged location was between RM 68 and 66, near Moccasin Springs, Missouri. In 1988/89, this area required over 1.7 million cubic yards of dredging. Dike extension was used in this reach to reduce dredging by 69% in 2012. Although this is a significant reduction, the reach still ranks currently as the 5th highest priority for work on the Middle Mississippi River based on dredging. To address the ranking, this stretch was recently studied with an HSR model with the principle goal of further alleviating the need for dredging. Construction of several innovative river training structures in this reach is ongoing. The Project will not only reduce dredging in the main channel, but will add significant environmental enhancement in the form of a side channel or chute.

1.1.6 Process for Bank Stabilization

Banklines along the river are maintained using revetment and in some cases river training structures as part of the Regulating Works Project. The channel has been stabilized from meandering, a key component of navigation design and sustainability. Between RM 0 and 200, approximately 1,473,000 linear feet of bankline has been protected. Based on comparative bankline analysis on the Middle and Lower Mississippi Rivers, the average natural erosion rate has been found to be approximately 10 feet per year. This equates to approximately 338 acres per year of land that would be mobilized without the Regulating Works Project. In addition to navigation, there is important infrastructure in or along the river that is sustainable because of the revetment. This includes bridge abutments, loading and unloading facilities, water supply intakes, pump stations, pipe crossings, and others. Floodwalls for major towns and cities and earthen levees are also protected in many areas because of the revetment incorporated from the Regulating Works Project. Although important, infrastructure protection is considered a secondary benefit of revetment and is not a factor in the selection of areas for revetment construction.

Bankline monitoring and revetment placement is a continuous process. Banklines are inspected in a number of ways: helicopter inspection trips and video, aerial or satellite imagery, and on the ground reports of observed issues. Helicopter inspection trips are taken every one to two years depending on the occurrence of any recent flooding events. On these inspection trips, geo-referenced video is recorded for future analysis, and notes are made as sites are flown over that need further investigation. Once back in the office, the locations noted during the helicopter inspection trip are further examined via aerial and satellite imagery, and the bankline is analyzed for any significant degradation. If it is determined that a site is experiencing erosion, then the surrounding area is evaluated to determine if the erosion is detrimental to the navigation channel. Detrimental effects could be in the form of additional sediment being added to the system in an area that already requires dredging or the widening of the channel that is marginally maintaining itself. Revetment is also sometimes needed to maintain the integrity of existing structures that are used to maintain the navigation channel. Some sites are identified by landowners or other entities reporting a caving bank. These sites are then analyzed the same way as sites that are discovered via other methods.

Once sites are identified by the District's Hydraulic Design Section as having bankline erosion that could impact the navigation channel, a design for the revetment is developed. These designs are compiled along with aerial and/or helicopter photos and submitted to the District's Environmental Compliance Branch. The sites are then discussed internally to ensure any issues identified by Environmental Compliance are addressed. After the sites are agreed upon internally, the list with descriptions and photos is provided to the state and federal resource agency partners for their review (USFWS, MDC, and IDNR). These agencies are given two weeks to reply with comments on the individual worksites. Once all comments are received and compiled, they are evaluated and the District responds to any agency concerns or issues with the particular site and/or design. There may be additional coordination with the agency partners to discuss worksites and reach the appropriate decision on balancing the needs of the navigation channel and any environmental concerns. Once this decision is reached, the designs are then prepared for inclusion in that year's operation and maintenance contract.

On the MMR there exist locations where a major channel cutoff[4] could form, creating a new course of the Mississippi River, greatly impacting the navigation channel and causing disastrous environmental and economic consequences. A permanent cutoff would cause an upstream migrating headcut in the navigation channel at the cutoff source point on the river. This headcut would not only impact navigation and increase dredging, but would severely impact existing revetment and river training structures. Structures would be compromised, and maintenance repairs or complete redesign and construction would be required. In the event of a cutoff, navigation on the Mississippi River could be disrupted indefinitely, with significant navigation shutdowns lasting months at a time depending upon the severity of the event and availability of dredges. It is estimated that without the above bank stabilization measures, a permanent cutoff could have occurred in the past or would occur in the future due to an event with as little as a 10% annual exceedance probability (AEP).

One such potential cutoff location is at Thompson Bend (river mile 22). Beginning in 1980 the District, local land owners, and other organizations teamed together in an effort to prevent a cutoff from occurring across the neck of the Dry Bayou – Thompson Bend peninsula along the Mississippi River. The creation of a riparian buffer at key locations along with management plans and some other repairs were implemented in an effort to force the Mississippi River to maintain its current course. This created a buffer strip of fast-growing, water-resistant hardwoods planted between the riverbank and the flood plain to prevent erosion. This work required obtaining real estate interests in the land above the ordinary high water mark, but the work proved to be successful for avoiding a navigation channel cutoff, as well as being environmentally friendly. In the future, continued maintenance will be needed on the tree screens so they don't become overgrown or die off. Also, large amounts of woody debris have deposited in the Thompson Bend area during high flow events, limiting tree screen growth. Ways of reducing woody debris concentration will also need to be investigated for the long-term re-establishment in this area.

During the winter flood of 2015/2016 the Len Small Levee overtopped and eventually breached. Due to the proximity of the levee to the river bankline and the fact that there was not a competent riparian corridor, 1,000 feet of bankline was lost and a large scour hole formed landside of the levee. This posed a significant issue to the MMR navigation channel because if the bankline was not repaired, a channel cutoff could potentially form, shortening the river by 13.5 miles and inducing a headcut through the system. Repairs to the bankline were completed in early spring of 2016, and a contract was awarded to stabilize the highest priority locations along the scour hole to reduce the overall advancement of the scour hole. During the design process and working with natural resource agencies and landowners, the District implemented avoid and minimize measures to ensure that there were minimal impacts to the environment during the repairs. Additionally, the District sought to use the natural river processes to stabilize the scour

[4] A channel cutoff (also referred to as a meander cutoff or river cutoff) occurs when a new and relatively short channel is formed across the neck of a meander bend resulting in a new shorter and steeper channel alignment.

hole by letting it naturally silt in and allow for the re-establishment of native plants for increased roughness, decreasing the ability for a channel cutoff to form at later dates. This methodology was successful after the 1993 flood at a breach just upstream of this most recent bankline failure. Currently, there are proposals for the levee to be replaced; however, if the levee is not replaced, additional measures to protect the navigation channel may become necessary.

1.1.7 Rock Removal and Chain of Rocks

Pursuant to the 1881 Report, the Regulating Works Project also has the authority to address particularly troublesome parts of the MMR where rock is hindering the navigation channel. This has been addressed in various areas of the MMR in the past and, in 1945, Congress modified the Regulating Works Project by authorizing the construction of a lateral canal with locks to completely bypass the Chain of Rocks area of the MMR (river mile 190), where rock formations were hindering the navigation channel at low water (commonly referred to as Chain of Rocks Canal and Locks 27). The Chain of Rocks Canal and Locks 27 are still in operation, and any major modifications or repairs to the locks and canal or their operations undergo separate National Environmental Policy Act (NEPA) analysis. The operation of Locks 27 is also included in the Rivers Project Master Plan.

Rock obstructions during low water events have been obstacles to navigation at other locations on the MMR as well. Rock removal was conducted in 1964, 1983, 1988, 2006, 2009, and 2013 for locations between river miles 82 and 38. Each rock removal location is unique and several removal techniques have been used by the District (e.g. grinding, blasting, and excavation). Site-specific environmental assessments (SSEAs) have been prepared for all rock removal activities and are available on the SEIS website at the following address:

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

Close interagency coordination is necessary for all rock removal activities to ensure the unique circumstances of each location do not result in any unforeseen adverse effects to fish and wildlife resources. After completion of the rock removal contract awarded in 2013, the District does not currently foresee any future rock removal needed at this time; however, the District continually monitors the MMR for any unknown rock hindrances to confirm that no additional rock removal work is necessary. SSEAs would continue to be prepared for site-specific rock removal activities in the future, as necessary.

See the 1976 EIS and Appendix K for more detailed information about the history and authority of rock removal and the Chain of Rocks area, as well as the low water dam constructed at Chain of Rocks to address issues hindering navigation at the former Lock and Dam 26.

1.2 Purpose of and Need for NEPA Supplement

The District began the NEPA review process in December 2011 after committing to doing an Environmental Assessment (EA) on river training structure construction in response to the GAO Report 12-41 entitled *Mississippi River: Actions are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures*. As part of this EA, a request for scoping comments was released and public meetings and meetings with interest groups (resource agencies and navigation industry) were held. In the spring of 2012, also in response to the GAO Report, the District took a hard look at the Regulating Works Project 1976 EIS (1976 EIS) *Mississippi River between the Ohio and Missouri Rivers (Regulating Works)*, (USACE 1976). The focus of the District review of the 1976 EIS was to determine whether or not the document should be supplemented. Council on Environmental Quality (CEQ) regulations (40 CFR §1502.9(c)) provide direction on circumstances requiring agencies to supplement environmental impact statements:

> *(c) Agencies:*
> 1. *Shall prepare supplements to either draft or final environmental impact statements if:*
>   *(i) The agency makes substantial changes in the proposed action that are relevant to environmental concerns; or*
>   *(ii) There are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.*
> 2. *May also prepare supplements when the agency determines that the purposes of the Act will be furthered by doing so.*

The result of this hard look was a recommendation that the 1976 EIS be supplemented due to the amount of new information and circumstances that could affect the Project's impacts. This recommendation was not because there had been a substantial change to the Project since 1976 to warrant an SEIS, nor was there any one key piece of new information that could be identified as "significant" to warrant an SEIS. However, the cumulative nature of the new information without having had any NEPA analysis and documentation specific to the Project since 1976 (other than the EAs for rock removal), warranted the preparation of an SEIS to describe this new information, analyze it, and assess the impacts of the Project as it exists today. The District had taken prior hard looks at the 1976 EIS, but since the Navigation and Ecosystem Sustainability Program (NESP) was pending and there had not been a substantial change to the Project, the District had not previously found that a supplement to the 1976 EIS was warranted. The District was aware of new information and had been applying this information in its avoidance and minimization measures in designing, constructing, and maintaining the project (see Section 1.1.2 Interagency Coordination). The driving force of the decision to supplement the 1976 EIS was the fact that neither site-specific documentation nor a programmatic document had been prepared to capture all of this information and the measures being taken by the District to account for the new information since 1976. Because the Project was unique in its nature of being an on-going construction project and since the last EIS there was a significant amount of new information not considered in any subsequent NEPA documentation, it was determined that a supplement was warranted. Further, the EA for river training structures had been initiated and multiple scoping comments (USFWS, IDNR, MDC, and National Wildlife Federation) noted that an SEIS for the Project should be prepared.

The District also engaged the Corps' Planning Center of Expertise for Inland Navigation (PCXIN) to review the 1976 EIS and analyze the new information and circumstances to provide additional expertise outside of the District on whether or not the 1976 EIS should be supplemented. The PCXIN likewise concluded that there had been no substantial changes to the Regulating Works Project but that there was persuasive evidence of a substantial body of information related to environmental concerns.

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

- New federally threatened and endangered species have been listed since preparation of the 1976 EIS.
- The District has implemented new programs to restore fish and wildlife habitat on the MMR.
- New information exists on the changes in average river planform width[5] in response to river training structure placement.
- New information exists on the impacts of river training structures on water surface elevations.
- New information exists on the impacts of river training structures and dredging on fish and benthic macroinvertebrates[6].
- New information exists on the effects of navigation on fish and wildlife resources.
- New information exists on the status of MMR side channels.

Congress provided the manner in which the navigation channel for the MMR should be obtained and maintained via the original Regulating Works Project authorization in 1910 and a modification to the authorization in 1927. The purpose of this SEIS is not to consider a change to that authorization through reevaluating the need for the Regulating Works Project or the methods to be used to accomplish the goals of the Project. Rather, this document analyzes the impacts of the Regulating Works Project as it is currently constructed, operated, and maintained with current information that has become available since the completion of the 1976 EIS and with information from recent analyses the District has conducted to address unknown or unavailable information relevant to potential impacts of the Project. These additional analyses as part of the SEIS process include:

- Analysis of the effects of river training structures on stages;
- 3-D Numerical Hydraulic Model to clarify impacts of river training structures on MMR depth and velocity characteristics;
- Channel geometry and geomorphology analyses to determine changes in channel shape characteristics over time;
- Side channel geometry analyses to determine changes in side channel depth and connectivity characteristics over time;
- Analysis of areal extent of MMR habitats and river training structures to document changes in channel configuration over time; and

[5] The planform of a river is defined as the outline or shape of the river as viewed from above. The planform width in this analysis was measured from tree line to tree line.

[6] Macroinvertebrates by definition are animals without backbones that can be seen with the naked eye. Benthic refers to organisms that that live in or on the bottom of a body of water. Benthic macroinvertebrates in the Middle Mississippi River typically consist of various life stages of flies, caddisflies, mayflies, worms, damselflies, dragonflies, and various other organisms. Benthic macroinvertebrates colonize most surfaces and substrates in river systems and provide an important food source for fish and other animals.

- Larval fish sampling to provide densities of larval fish in the MMR.

When the District began the process to consider supplementing the 1976 EIS in 2013, a decision was made to complete SSEAs for all new Regulating Works Project construction prior to completion of the SEIS, including work associated with the District's Endangered Species Act obligations, in order to evaluate the new information and circumstances on a site-specific basis. These SSEAs made a commitment that 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 the SSEAs, measures would be taken within the Corps' authority to avoid, minimize, and/or compensate for the impacts during the SEIS process as appropriate. These SSEAs finalized to date include the following:

- Mosenthein-Ivory Landing Phase 4 (April 2014)
- Eliza Point-Greenfield Bend Phase 3 (April 2014)
- Dogtooth Bend Phase 5 (April 2014)
- Mosenthein-Ivory Landing Phase 5 (June 2015)
- Boston Bar Side Channel Restoration and Island Creation Project (April 2016)
- Grand Tower Phase 5 (June 2016)
- Dogtooth Bend Phase 6 (July 2016)

Prior to the decision to supplement the 1976 EIS, SSEAs were prepared as needed for rock removal activities (for locations between river miles 82 and 38) and Locks 27 rehabilitation (river mile 185) conducted under the Regulating Works Project. Rock removal and Locks 27 rehabilitation are covered by the Regulating Works authorization but were not specifically evaluated in the 1976 EIS. Accordingly, SSEAs for rock removal were completed in 1983, 1988, 2006, 2009, and 2013 and an SSEA was prepared for major rehabilitation of Locks 27 in 2002. Measures to avoid and minimize adverse effects were included in the SSEAs, as appropriate. No adverse effects necessitating compensatory mitigation were identified. SSEAs would continue to be prepared for site-specific activities in the future, as necessary. All of the referenced SSEAs can be found at http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx.

1.3 Identification of 1976 EIS Updates

Much of the information in the 1976 EIS is still relevant today and does not require supplementing in this document. The following is a breakdown of what information found in the 1976 EIS is still considered relevant and what information is updated in this SEIS.

Table 1-2. Comparison of information contained in the 1976 EIS and information being updated in this SEIS.

1976 EIS Section and Resource Description	Action	Location of Updated Information in this SEIS
1. Project Description and History	Update	1. Purpose of and Need for Action 2. Appendix K
2. Existing Environmental Setting		
2.1 Physical Elements		
2.1.1 River Channel Configuration and Stages	Update	3.2.1 Stages 3.2.2 Geomorphology
2.1.2 Regional Geologic Elements	No update necessary	N/A
2.1.3.1 Soils – General	No update necessary	N/A
2.1.3.2 Surficial Soils	No update necessary	N/A
2.1.3.3 Riverbed Soils	No update necessary	N/A
2.1.4 Water Quality	Update	3.2.3 Water Quality
2.1.5 Climatological Elements	Update	3.2.5 Air Quality and Climate Change
2.1.6 Air Quality	Update	3.2.5 Air Quality and Climate Change
2.2 Biological Elements		
2.2.1 Aquatic Communities	Update	3.3.1 Benthic Macroinvertebrate Resources 3.3.2 Fishery Resources
2.2.2 Terrestrial Communities	No update necessary	N/A
2.2.3 Rare and Endangered Species	Update	3.3.4 Threatened and Endangered Species
2.3 Cultural Elements		
2.3.1 Demography	Update	3.4.1 Human Resources
2.3.2 Economic Characteristics	Update	3.4.1 Human Resources
2.3.3 Land Use	Update	3.4.1 Human Resources
2.3.4 Outdoor Recreation	Update	3.4.1 Human Resources
2.3.5 Cultural resources	Update	3.5 Historic and Cultural Resources
3. Relationship of the Proposed Action to Land Use Plans	No update necessary	
4. Impact of the Action on the Environment		
4.1 Physical Impacts		
4.1.1 Impact to River Regime		
4.1.1.1 Early Alterations to the River	No update necessary	N/A
4.1.1.2 Existing Channel Configuration	Update	3.2.2 Geomorphology
4.1.1.3 Effect of Channel Maintenance Dredging	Update	4.3.1 Impacts on Benthic Macroinvertebrate Resources 4.3.2 Impacts on Fishery Resources

1976 EIS Section and Resource Description	Action	Location of Updated Information in this SEIS
4.1.1.4 Narrowing of River Width and Decrease in surface Area	Update	4.2.2 Impacts on Geomorphology
4.1.1.5 Lowering of Riverbed Elevation	Update	4.2.1 Impacts on Stages 4.2.2 Impacts on Geomorphology
4.1.1.6 Effect on Flows	Update	4.2.1 Impacts on Stages
4.1.1.7 Changes in Sediment Discharge	No update necessary	
4.1.1.8 Effect on River Stages	Update	4.2.1 Impacts on Stages
4.1.1.9 Existing Side Channels and Future Configurations of the River	Update	4.2.2 Impacts on Geomorphology
4.1.2 Impacts on Geologic Elements	No update necessary	N/A
4.1.3 Impacts on Soils	No update necessary	N/A
4.1.4 Impact of Operation and Maintenance of Present Navigation Channel on Water Quality	Update	4.2.3 Impacts on Water Quality 4.6 Cumulative Impacts
4.2 Biological Impacts		
4.2.1 Aquatic Communities		
4.2.1.1 Dikes and Revetment	Update	4.3.1 Impacts on Benthic Macroinvertebrate Resources 4.3.2 Impacts on Fishery Resources
4.2.1.2 Maintenance Dredging and Disposal of Dredged Material	Update	4.3.1 Impacts on Benthic Macroinvertebrate Resources 4.3.2 Impacts on Fishery Resources
4.2.1.3 Tow Boat Operations	Update	4.6 Cumulative Impacts
4.2.2 Terrestrial Communities	No update necessary	N/A
4.2.3 Impact on Rare and Endangered Species	Update	4.3.3 Impacts on Threatened and Endangered Species
4.3 Cultural Impacts	Update	4.4.1 Impacts on Human Resources 4.4.2 Impacts on Navigation 4.5 Impacts on Historic and Cultural Resources
5. Adverse Environmental Effects which are not Avoidable	Update	Chapter 4. Environmental Consequences
6. Alternatives	Update	2. Alternatives Including the Proposed Action

1976 EIS Section and Resource Description	Action	Location of Updated Information in this SEIS
7. The Relationship between Local Short-term Uses of Man's Environment and the Maintenance and Enhancement of Long-term Productivity	Update	4.7 Relationship of short-term uses and long-term productivity
8. Any Irreversible and Irretrievable Commitments of Resources which are Involved in the Continuing Action	Update	4.8 Irreversible and irretrievable commitments of resources
9. Coordination with Others	Update	Chapter 5. Consultation, Coordination, and Compliance

The analyses provided in Chapters 3 and 4 of this document focus on the significant resources for which new circumstances and information exist and also provide updated information on the environmental setting of the Project Area to provide updated context for the analysis of impacts.

1.4 Scoping/Public Involvement

The National Environmental Policy Act (NEPA) affords all persons, organizations, and government agencies the right to review and comment on proposed major federal actions that are evaluated by a NEPA document. This is known as the "scoping process." The scoping process was the initial step in the preparation of the SEIS and helped identify (1) the range of actions (project, procedural changes), (2) alternatives (both those to be rigorously explored and evaluated and those that may be eliminated), and (3) the range of environmental resources considered in the evaluation of environmental impacts.

A Notice of Intent to prepare a Supplemental Environmental Impact Statement was published in the Federal Register on December 20, 2013. On the same date a special public notice (Public Notice No. 2013-744) requesting comments regarding the scope of the SEIS was sent to federal, state, and local agencies and interested groups and individuals. A media advisory announcing the scoping meetings was provided to more than 35 media outlets on January 8, 2014, including regional print and broadcast outlets and wire services. Announcements for the public scoping meetings appeared on the Corps web and social media pages and in the following publications the week prior to the events:

- *The Alton Telegraph*
- *The Southern Illinoisan*
- *The Southeast Missourian*

The public scoping meetings were held on:

- Tuesday, January 14, 2014
  National Great Rivers Museum, Classroom #2
  Locks and Dam Way
  Alton, IL 62002

- Wednesday, January 15, 2014
  Chester City Hall
  1330 Swanwick St.
  Chester, IL 62233

- Thursday, January 16, 2014
  Missouri Dept. of Conservation
  Cape Girardeau Nature Center, Multipurpose Room
  2289 County Park Dr.
  Cape Girardeau, MO 63701

A total of 17 participants signed in for the scoping meetings, with 5 at Alton, IL, 5 at Chester, IL, and 7 at Cape Girardeau, MO.

Natural resource partner agencies were invited to participate in the Scoping Process via the RRAT Executive Board. A meeting with the RRAT Executive Board was held on February 20, 2014. Each agency decided in the meeting that they would provide comments on the SEIS via agency letters to the Corps. Letters received are included in the Scoping Report which is available on the SEIS website at the following address:

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

River Industry personnel were invited to participate in the Scoping Process via a conference call on April 23, 2014, with River Industry Executive Task Force (RIETF) and River Industry Action Committee (RIAC) personnel.

A total of 79 unique comments were received during the comment period. However, the total number of communications generating these comments was 17,731. Table 1-3 provides a breakdown of the comments received.

Table 1-3. Scoping comments by organization / comment method.

Commenter	No. of Communications	No. of Unique Comments
National Wildlife Federation Action Alert System Emails	17,154	5*
Izaak Walton League of America Congress Web System Emails	464	4*
Traditional Mail	1	1
Izaak Walton League of America	1	4
National Wildlife Federation, American Rivers, Great Rivers Environmental Law Center, Missouri Coalition for the Environment, Prairie Rivers Network, River Alliance of Wisconsin	1	4
USEPA Region 7	1	9
Missouri Coalition for the Environment	2	6
United States Fish and Wildlife Service	1	6
Missouri Department of Conservation	1	22
Public Meeting Comment Cards	5	17
Total	17731	79

*Template email. Three percent or less of emails were modified.

The comments were categorized according to their applicability to the SEIS. SEIS categories include: Purpose and Need; Alternatives; Affected Environment; Environmental Consequences; and Consultation, Coordination, and Compliance with Regulations. An individual scoping comment may have been categorized under more than one SEIS subject matter heading.

Purpose and Need
A majority of the comments received in this category indicated that the Corps should expand the scope of the SEIS to include the entire Upper Mississippi River - Illinois Waterway (UMR-IWW) System instead of focusing on the Middle Mississippi River portion of that system and that a moratorium should be imposed on construction of new river training structures until the analyses of impacts are complete.

Alternatives
The most frequent comment in the Alternatives category suggested that the Corps should fully evaluate all reasonable alternatives. It was suggested that an alternative that protects and restores the Mississippi River should be selected. It was also suggested that the No Action Alternative should be defined.

Affected Environment
Comments related to the Affected Environment covered a broad range of topics. The most frequent dealt with the claim that river training structures increase flood heights, the need to expand the scope of the SEIS to the entire UMR-IWW, and the need to initiate a National Academy of Sciences study to evaluate the impacts of river training structures on flood risks.

Environmental Consequences
Comments related to Environmental Consequences covered a broad range of topics. As with the Affected Environment comments, the most frequent dealt with the claim that river training structures increase flood heights, the need to expand the scope of the SEIS to the entire UMR-IWW, and the need to initiate a National Academy of Sciences study to evaluate the impacts of river training structures on flood risks.

Consultation, Coordination, and Compliance with Regulations
Two comments were received that fell under this category. The comments indicated that the Corps should specify the manner by which it intends to permit individual projects under the Clean Water Act and that the SEIS should include external independent review.

Chapter 2. Alternatives Including the Proposed Action

This chapter describes the alternatives or potential actions that were considered as ways to proceed with the Regulating Works Project construction, operation, and maintenance as authorized in light of the new information and circumstances since 1976. In this chapter, the alternative development process used to arrive at two alternatives is described. The resultant alternatives and their environmental impacts and usefulness in achieving the Project objectives are summarized and compared. For a detailed discussion of the environmental impacts of both alternatives, see Chapter 4. For clarification, the alternatives considered in the 1976 EIS are also briefly discussed in this chapter.

2.1 Alternatives Considered

Alternative Development Process
As described in Section 1.2 Purpose of and Need for NEPA Supplement, this SEIS is not a planning study or re-evaluation of how a project should be carried out, but an updated environmental compliance document of an already authorized, on-going project; Congress has already provided the manner in which the navigation channel for the MMR is to be obtained and maintained via the Regulating Works Project authorization. Detailed consideration of any alternatives outside of this authorization would require a planning study for either modification of the Project or new authorization from Congress.

<u>Alternatives considered outside the Project Authorization</u>

The District received many scoping comments about conducting environmental restoration and enhancement measures for fish and wildlife habitat as part of the Regulating Works Project; however, after a thorough review and analysis of the history of the Project and all legislation applicable to the Project, it was determined that there was no authority for the District to proceed with these measures without specific funding from Congress and a cost-share partner to support such measures (See Appendix K and response to USFWS Comment No. 13 in Appendix E for more details). Since there has historically been a steady funding stream for habitat restoration through the Upper Mississippi River Restoration (UMRR) Program, it was determined that if a cost-share partner were available for environmental restoration work on the MMR, that work would be much more likely to receive study funding and approval for implementation through UMRR (rather than as a new start under the Regulating Works Project). Further, if funding and a cost-share partner were to become available as part of the Regulating Works Project for an ecosystem restoration new start, a separate feasibility study would be required for such project, which would include and incorporate the required NEPA documentation. Therefore, this alternative was not deemed a reasonable or feasible alternative to be considered further as part of the SEIS.

The District also received scoping comments to consider other ways to obtain and maintain the channel in the MMR such as altering water releases from the Upper Mississippi River. However, the locks and dams in the Upper Mississippi River have water control plans that address and maintain those particular projects' purpose(s) under that authority. While there is the possibility to alter some water control procedures to assist in maintaining the navigation channel in the MMR, it was shown during the drought in 2012 that the impact of these alterations was not substantial enough to consider this as a reasonable alternative for the purpose of the SEIS or a new planning study.

The District also received many scoping comments requesting that a comprehensive NEPA document be completed for both the Upper Mississippi River and the MMR, including a number of navigable tributaries to these portions of the river. The navigation projects in the Upper Mississippi River and the MMR were authorized separately by Congress with the recognition that different areas of the watershed had varying issues to be addressed in obtaining and maintaining a safe and dependable navigation channel. Therefore, any look at all of these projects combined would be a comprehensive watershed study that was well beyond the District's decision to supplement the Regulating Works Project's EIS, and such a study would require higher approval authority if not additional Congressional authorization. Further, large scale studies of the watershed were authorized and conducted in the late 1970s/early 1980s and again in the 1990s into the first part of this century. Congress took action on both of those studies, resulting in the legislation for the Upper Mississippi River Restoration Program in 1986 and the Navigation and Ecosystem Sustainability Program in 2007 (see Appendix K for more details).

Therefore, it was determined that there was no reasonable or viable alternative to be examined further outside of the already authorized Regulating Works Project to warrant transitioning the SEIS to a planning study. Therefore, the SEIS would proceed as an update of the Project's NEPA environmental compliance document to analyze and document the new information and circumstances since 1976. Alternatives to be considered further would need to meet the Project's authorized purpose: to obtain and maintain the navigation channel through regulating works and dredging, with the goal of reducing costly dredging to a minimum.

<u>Analysis of Alternatives for the Authorized Regulating Works Project</u>

The 1976 EIS included an analysis of the following array of alternative methods for obtaining and maintaining the 9-foot navigation channel on the MMR:

- Maintain existing actions – Continue construction of regulating works to reduce dredging.
- Cease all operation and maintenance activities – This alternative was a "no action" alternative in that no dredging and no maintenance of existing structures would occur. The 9-foot navigation channel on the MMR, and consequently navigation in general, would eventually cease to exist under this scenario.
- Locks and Dams – This alternative considered construction of a series of locks and dams along the length of the MMR.
- Post-authorization change – This alternative considered the modification of the authority for the Regulating Works Project to include fish and wildlife habitat restoration as a project purpose to allow the District to compensate for adverse effects of the Project. This modification would have facilitated environmental dredging of side channels, beneficial use of dredged material, construction of wooden pile dikes,

and dike alterations to benefit MMR fish and wildlife resources. See Appendix K for a full discussion on the post-authorization change described in the 1976 EIS.

For purposes of the SEIS, ceasing all operations and maintenance activities on the Project was not considered a reasonable or feasible alternative due to the fact that it would not satisfy the Project purpose of providing a safe and dependable 9-foot navigation channel on the MMR through the construction of regulating works to reduce costly dredging. Constructing locks and dams was not considered a reasonable or viable alternative because it too was beyond the scope of the purpose of the SEIS to update the 1976 EIS with new circumstances and information and would require new Congressional authority to even be studied. The components considered as part of the post-authorization change alternative in the 1976 EIS have been incorporated over time as components of the Regulating Works Project or are addressed under other authorities currently available to the District for the purpose of ecosystem restoration and, as discussed above, such programs are more likely to be funded and implemented as opposed to a new study start for ecosystem restoration under the Regulating Works Project. See Appendix K for details on these additional authorities. Accordingly, the post-authorization change alternative was not considered further for the SEIS.

Therefore, the baseline alternatives for the SEIS were to continue construction of regulating works to reduce costly dredging or to cease any new construction and continue to maintain the Project through dredging and existing regulating works.

As described in Section 1.2, additional analyses were started to obtain unknown and/or unavailable information to better understand and quantify the impacts of the Regulating Works Project. Throughout this process, up to four alternatives were identified as potential alternatives to meet the Project purpose under the Project's existing authority: 1) no further construction and continue dredging at current levels and maintaining existing structures, 2) maximum dredging reduction with new construction, 3) the most cost-effective dredging reduction with new construction, and 4) an alternative in-between the maximum dredging reduction and no new construction alternatives to avoid environmental impacts. This last alternative had been requested by natural resource agencies.

The no further new construction alternative had already been identified as a baseline alternative to be considered in detail in the SEIS. The alternative for maximum dredging reduction was initially considered not to be viable because the point of reducing dredging is to save money, so increasing the overall Project cost with additional structures without economic considerations was not reasonable to be considered in detail. However, in order to further evaluate this as well as identify a cost-effective amount of new construction, an estimated remaining construction quantity was developed based on a comparison of dredging costs versus construction costs, utilizing the best available information to estimate these costs (see attachment 1 to Appendix C). As described in attachment 1 to Appendix C, it was determined that the maximum dredging reduction obtainable was 1.3 million cubic yards per year. It was then estimated that the quantity of material necessary to construct enough dikes on the MMR to reduce dredging to this level was approximately 6.5 million tons if traditional perpendicular dikes were used and 8.5 million tons if chevrons were used (for estimation purposes, chevrons were chosen to provide for the extreme end of potential rock quantity using only innovative structures to avoid and minimize impacts).

Since the Project will continue to include innovative structures to avoid and minimize impacts and remain within ESA compliance, the average quantity of an equal distribution of chevrons and traditional dikes was presumed for future construction to reduce dredging to a maximum (7.5 million tons of stone). The estimated end point would be the point where continuing to build structures is no longer economically advantageous compared to dredging. When this analysis was completed it was revealed that the maximum dredging reduction with a combination of traditional and innovative structures would still be cost-effective. Therefore, these two alternatives were in fact the same. Further, since maximum dredging reduction was already cost-effective utilizing avoid and minimize measures, merely selecting any random dredge reduction amount between the maximum reduction and no new construction for a middle ground alternative would have failed to meet the Project purpose and would not have been based on any scientifically reasonable explanation.

The next decision was how to incorporate any compensatory mitigation within the SEIS alternatives (see Appendix C for explanation of the estimated costs of compensatory mitigation). Once estimated compensatory mitigation costs were factored into the estimated construction and dredging costs, the final cost-effective, average annual dredging requirement was increased to 2.4 million cubic yards and the amount of new construction decreased to 4.4 million tons of rock, while also accounting for the potentially significant impact that had been identified. Reducing the amount of new construction with more dredging was exactly the alternative that had been requested in scoping comments, and was substantially less construction than the maximum dredging reduction alternative (see Table 2-1 for approximate rock quantities and remaining dredging requirements associated with the alternatives). Therefore, a decision was made that the SEIS need only consider two alternatives in detail: 1) continue construction to a cost-effective endpoint using estimated amounts for new construction (including avoid and minimize measures), dredging, and potential compensatory mitigation; and 2) stop all new construction and proceed with the current levels of dredging and maintaining existing structures.

Table 2-1. Approximate rock quantities and remaining average annual dredge requirement associated with the alternatives considered.

Alternative	Rock Quantity Required for New Structures	Remaining Average Annual Dredge Requirement
Maximum dredging reduction using only traditional structures with no avoidance or minimization measures	6.5 million tons	1.3 million yd^3
Maximum dredging reduction using only innovative structures to avoid and minimize impacts	8.5 million tons	1.3 million yd^3
Maximum dredging reduction while incorporating an average of traditional structures and avoid and minimize measures.	7.5 million tons	1.3 million yd^3
Minimize dredging while incorporating avoid and minimize measures and potentially implementing compensatory mitigation.	4.4 million tons	2.4 million yd^3
No new construction	0	4 million yd^3

Alternative 1 – No Action Alternative: The No Action Alternative for this SEIS represents no change in the current implementation of the Regulating Works Project. Under a normal feasibility study seeking authorization for a new project, the No Action Alternative would mean that no action is to be taken. However, in the instance of an ongoing program, the No Action Alternative refers to no change in program direction. According to CEQ guidance (CEQ 1981):

> *There are two distinct interpretations of "no action" that must be considered, depending on the nature of the proposal being evaluated. The first situation might involve an action ... where ongoing programs initiated under existing legislation and regulations will continue, even as new plans are developed. In these cases "no action" is "no change" from current management direction or level of management intensity. To construct an alternative that is based on no management at all would be a useless academic exercise. Therefore, the "no action" alternative may be thought of in terms of continuing with the present course of action until that action is changed.*

Accordingly, the No Action Alternative for this SEIS represents continuing with construction, operation, and maintenance of the Regulating Works Project as it is currently being implemented, as described in Chapter 1, with the addition of analyzing the potential for compensatory mitigation on a site-specific basis as described in 2.2, Chapter 4, and Appendix C. The potential addition of compensatory mitigation measures to this Alternative does not change the basic features associated with the Alternative, how the features address the problems in the Project Area, or how they are constructed, operated, and maintained. Therefore, this Alternative is still considered to be the No Action Alternative. As discussed above, the alternative of not maintaining the navigation channel on the MMR is not a viable option. This alternative was fully evaluated in the 1976 EIS and is not considered further here. However, the impacts of the No Action Alternative (continuing current construction, operation, and maintenance activities of the Regulating Works Project) still need to be considered and evaluated in detail given that the reason for completing an SEIS was that new circumstances and information on the impacts of the Project exist. To avoid confusion, the No Action Alternative will be referred to as the **Continue Construction Alternative** from here forward in this document.

Alternative 2: Alternative 2 consists of not constructing any new river training structures for navigation purposes but continuing to maintain the navigation channel by dredging and by maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Maintenance dredging would continue at roughly the current average rate, which is approximately 4 million cubic yards per year. To avoid confusion, this Alternative will be referred to as the **No New Construction Alternative** from here forward in this document. Under this alternative, should major bankline stabilization work become necessary, e.g., to avoid a channel cutoff, the proper procedures and policies for requesting funding and insuring compliance of the work would be taken, including preparation of an SSEA.

Chain of Rocks Canal, Locks 27, Low Water Dam 27, and Rock Removal (See Appendix K for a full description of these features). These features of the Regulating Works Project are different from the construction of regulating works to reduce dredging in that they are not under on-going construction, but have clear construction completion. Further rock removal is not expected to be needed after completion of the current contract; if additional need arises in the future, the work would be evaluated under a tiered SSEA as had been done in the past. The general operation and maintenance of the Chain of Rocks features of the Regulating Works Project have not changed since they were constructed in the mid-20th century. The 1976 EIS generally addressed their construction and impacts, noting that Low Water Dam 27 is basically self-operating. There is no actively managed water control at Chain of Rocks, and the baseline condition and impacts of the UMR locks were described in detail in the NESP feasibility study and Environmental Impact Statement documentation. SSEAs for any major rehabilitation or repairs to the canal or Locks 27 have been and will continue to be prepared. Further, the operation and maintenance of the locks are included in the Rivers Project Master Plan, which is circulated for public review when updated. Therefore, there are no new significant circumstances or information relative to these features of the Regulating Works Project to be addressed in detail in this SEIS. Additional construction for rock removal will be addressed as needed in the future, and the continued operation and maintenance of the Chain of Rocks features are not specifically discussed in this SEIS but are part of both alternatives considered.

Endangered Species Act Compliance. As part of the Endangered Species Act compliance for operation and maintenance of the Regulating Works Project, the District minimizes the impacts to endangered species and enhances habitat where possible, typically through construction of side channel enhancement features, modification of existing structures, and creation of ephemeral islands with the flexible dredge pipe. See 3.3.4 and 4.3.4 below, Appendix B, and Appendix K for more information on the Project's Endangered Species Act compliance. Both alternatives will continue to be in compliance with the Endangered Species Act as legally required.

2.2 Evaluation of Alternatives

Continue Construction Alternative. The Continue Construction Alternative consists of future River Training Structure (RTS) construction that avoids and minimizes impacts and is equivalent to approximately 4.4 million tons of additional rock placed, a reduction of average maintenance dredging from the current level of approximately 4 million cubic yards per year to approximately 2.4 million cubic yards per year, completion of currently known bankline stabilization projects to reduce the risk of a channel cutoff, additional revetment as needed, and maintenance of existing structures. The amount of estimated remaining RTS construction under this alternative is based on the expected quantity of reduced dredging per increment of RTS construction, estimated construction costs, estimated dredging costs, and estimated mitigation costs. A more detailed description of how the remaining quantity of construction was estimated for this alternative can be found in Appendix C.

While the avoid and minimize mitigation measures implemented to date have been effective, the new information and circumstances further studied and analyzed as part of this SEIS reveal that the continued construction of RTS under this alternative would be expected to have a significant impact on main channel border habitat due to the potential loss of approximately 1,100 acres (8%) of the remaining unstructured main channel border habitat. Although construction of river training structures does benefit some MMR fish species by providing low-velocity habitats, this does not offset or compensate for the anticipated adverse effects to shallow to moderate-depth, moderate- to high-velocity habitat due to the fact that the adverse effects impact a different habitat type with a different function for a different group of fish than the benefits do.

This impact is considered potentially significant on technical, institutional, and public merits. The impact is potentially technically significant due to the magnitude of the potential adverse effect to unstructured main channel border habitat in comparison to the amount of that habitat remaining and the amount of similar habitat that has been lost in the past. Likewise, it is technically significant due to the decline in abundance of the species of fish that utilize the habitat and the fact that remnant habitats with these depth and velocity attributes are important biologically for the continued existence of these species. The impact is considered potentially significant on institutional grounds due to the importance that the Corps, through its Environmental Operating Principles, places on environmental sustainability, proactive consideration of the environmental consequences of Corps activities, and the creation of mutually supporting economic and environmental solutions. Congress recognized the Upper Mississippi River System as a "…nationally significant ecosystem and a nationally significant commercial navigation system" in Section 1103 of the Water Resources Development Act of 1986. Natural resource agency partners place high priority on protecting and sustaining the aquatic resources of the Mississippi River. The State of Illinois recognizes the Sturgeon Chub as significant in listing it as a state endangered species. The State of Missouri recognizes the Sturgeon Chub as a vulnerable species due to a restricted range, relatively few populations or occurrences, recent and widespread declines, or other factors making it vulnerable to extirpation. The impact is considered potentially significant to the public due to the intrinsic value the public places on the environment and its continued protection. Specific public interest in the Sturgeon Chub and the Sicklefin Chub is demonstrated by formal petitions by the public in 1994 and in 2016 to list the species as threatened or endangered under the Endangered Species Act.

While impacts would continue to be avoided and minimized to the extent practicable, it is expected that unavoidable impacts would potentially result in the consideration of compensatory mitigation. Appendix C provides a detailed discussion, including key assumptions, of how impacts and associated mitigation were estimated.

The primary benefit provided by this alternative is the reduction in average annual maintenance dredging per the Project's Congressional authorization while also avoiding, minimizing, and potentially compensating for environmental impacts of the Project. Maintaining reliable navigation on the MMR is dependent upon a reliable channel. While it is not feasible (technically or economically) to completely eliminate dredging, reducing the average annual quantity results in a more passively managed channel. A reduced quantity of "just-in-time" dredging[7] occurrences reduces the chances that these needs will not be met in the future.

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[7] Just-in-time dredging refers to dredging during low water to ensure that problematic areas are dredged prior to the river levels falling to critical depths. This process entails proper scheduling and sequencing of the dredge projects using the best available survey data and forecast data to ensure that the dredge will arrive on each project site just prior to the river reaching critical depth. There are several risks involved when just-in-time dredging is used to maintain the navigation channel. Due to the dynamic nature of the river, survey data are only good at the time of survey and depths can change rapidly, the forecasts can change based on new information, the dredge equipment is prone to mechanical breakdowns, and new dredging locations can affect the schedule. Just-in-time dredging

No New Construction Alternative. The No New Construction Alternative consists of average maintenance dredging of approximately 4 million cubic yards per year, completion of bankline stabilization projects to reduce the risk of a channel cutoff, additional revetment, and maintenance of existing structures. Under this alternative, no additional RTS would be constructed for navigation purposes.

Environmental impacts of the work associated with this alternative would continue to be avoided and minimized to the extent practicable. It is not anticipated that this alternative would have any unavoidable significant impacts that would result in the consideration of compensatory mitigation.

Uncertainty. The evaluation of both alternatives is based on the best available information at the time this document was prepared. Because the exact location and quantity of future dredging needs as well as the future RTS locations and designs are unknown, programmatic analysis was used to estimate remaining construction and associated impacts. The process used to develop a remaining construction estimate, the underlying assumptions used to determine impacts, and the programmatic approach to potential mitigation is described in Appendix C.

The overall economic analysis of the Regulating Works Project is updated periodically (approximately every 5 years) as part of the internal Corps budgeting process and these economic updates are used to justify future expenditures. While the analysis of both alternatives assumed that sufficient operations and maintenance as well as construction funding will be available in the future, the actual funding that is provided will be dependent on future economic analyses of the Project. The purpose of this document is to analyze the environmental impacts of the Regulating Works Project in the context of the new circumstances and information that have become available since the 1976 EIS was produced. Accordingly, this SEIS does not include a detailed economic evaluation of the Regulating Works Project. The future economic updates that are performed for the Project will include current information on construction costs, dredging costs, and any mitigation costs. These future economic updates may also result in an updated estimated quantity of construction and mitigation, which will be appropriately evaluated and assessed when completed.

requires that the schedule, sequencing, and project parameters are constantly adjusted to account for the changing variables. Advanced maintenance dredging is the preferred method but changing channel conditions sometimes dictate that just-in-time dredging is required.

2.3 Comparison of Alternatives

The table below summarizes the main components, key assumptions, extent of achievement of project objectives, and impacts to environmental resources of each alternative. See Chapter 4 for a more detailed description of the environmental consequences of each alternative.

	No New Construction Alternative	**Continue Construction Alternative**
Summary	• No new river training structures constructed • Navigation channel maintained through dredging • Bankline erosion monitored and new revetment constructed as needed to stabilize bankline • Existing river training structures maintained as needed • No significant impacts to warrant consideration of compensatory mitigation	• Construction of new river training structures in chronic dredging locations • Approximately 4.4 million tons of rock used for construction of new river training structures • Bankline erosion monitored and new revetment constructed as needed to stabilize bankline • Existing river training structures and revetment maintained as needed • Adverse effects would continue to be avoided and minimized to the greatest extent practicable • Would increase amount of low-velocity habitat and would increase bathymetric, flow, and substrate diversity • Would potentially result in the consideration of compensatory mitigation for unavoidable adverse effects of new construction. • Potential mitigation measures may include, but are not limited to: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. • Potential compensatory mitigation is addressed programmatically in this document. Specifics of mitigation planning would be addressed in tiered site-specific Environmental Assessments

	No New Construction Alternative	Continue Construction Alternative
Assumptions	• Average annual dredge quantity would remain at approximately 4 million cubic yards throughout project life with substantial year to year variation	• Average annual dredge quantity would gradually decrease from the current 4 million cubic yards to an estimate of 2.4 million cubic yards as river training structures are built to reduce dredging in chronic dredging areas until construction economically justified to completion
Achievement of Project Objectives	• Does not achieve Congressionally authorized project objective of reducing federal expenditures by reducing dredging to a minimum	• Achieves project objective of reducing annual maintenance dredging to a technically and economically achievable minimum while avoiding, minimizing, and potentially compensating for environmental impacts
Impacts on Stages	• No impacts on stages anticipated, but trend of decreasing stages at low flows expected to continue	• No impacts on stages anticipated at average and high flows • At low flows, river training structure construction would contribute an unknown amount to continuing trend of small reductions in stages
Impacts on Geomorphology	• No impacts to geomorphology anticipated beyond continued provision of 9-foot navigation channel	• Cross sectional area, hydraulic depth, conveyance, and channel volume will remain constant or generally increase • Continued provision of 9-foot navigation channel
Impacts on Side Channels	• No impacts to side channels anticipated • District side channel restoration projects under other programs/projects would continue	• No direct adverse effects to side channel quantity or quality anticipated due to avoidance and minimization measures • River training structure construction would contribute an unknown amount to small reductions in stage at low flows that would have minor adverse effects on side channel habitat by reducing quantity and connectivity of habitat • District side channel restoration projects under other programs/projects would continue
Impacts on Water Quality	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites	• Localized, temporary increase in suspended sediment concentrations anticipated at dredged material discharge sites and at river training structure construction sites

	No New Construction Alternative	Continue Construction Alternative
Impacts on HTRW	• No HTRW impacts anticipated	• No HTRW impacts anticipated
Impacts on Air Quality and Climate Change	• Minor and local impacts to air quality due to use of dredging equipment and equipment used for maintenance of existing structures • Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions expected to remain at approximately 27,950 tons per year from dredging and maintenance activities	• Temporary, minor, local impacts to air quality due to one-time use of construction equipment • Reduction in future emissions due to dredging reduction • Emissions in non-attainment areas anticipated to be below *de minimis* levels • Greenhouse gas emissions reduced by approximately 40% (to 16,970 tons per year) after completion of construction of new river training structures due to reduced dredging requirement
Impacts on Benthic Macroinvertebrate Resources	• Entrainment of benthic macroinvertebrates at dredge locations • Burial of benthic macroinvertebrates at disposal locations • Dredging impacts limited to approximately 2% of riverine habitat on average, per year, indefinitely	• Increased benthic macroinvertebrate use of river training structure placement locations due to increased bathymetric, flow, and substrate diversity • Entrainment of benthic macroinvertebrates at dredge locations • Burial of benthic macroinvertebrates at disposal locations • Dredging impacts limited to approximately 2% of riverine habitat on average, per year, decreasing to 1% with construction of new river training structures
Impacts on Fishery Resources	• Estimated dredge entrainment of less than 0.06% of adult and juvenile fish per year, on average • Estimated dredge entrainment of approximately 0.002% of larval fish per year • Creation of islands/sandbars with flexible dredge pipe	• Avoidance of sites during construction activities • General increase in fish use of structure locations due to increased low-velocity habitat and increased bathymetric, flow, and substrate diversity • Future construction would result in conversion of estimated 8% (1,100 acres) of remaining unstructured main channel border habitat to structured, leading to potential loss of fish movement corridors and loss of shallow to moderate-depth, medium- to high-velocity main channel border habitat important to some guilds of MMR fish community and potentially necessitating compensatory mitigation*

	No New Construction Alternative	Continue Construction Alternative
		• Estimated entrainment of less than 0.06% of adult and juvenile fish per year, on average, decreasing to less than 0.04% with construction of new river training structures • Estimated entrainment of approximately 0.002% of larval fish per year, on average, decreasing to approximately 0.001% with construction of new river training structures • Creation of islands/sandbars with flexible dredge pipe
Impacts on Threatened and Endangered Species	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • No effect or may affect but not likely to adversely affect for species listed since 2000	• Impacts to threatened and endangered species consistent with 2000 Biological Opinion • No effect or may affect but not likely to adversely affect for species listed since 2000
Impacts on Human Resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources	• No disproportionately high adverse effects to minority or low-income populations • Localized, temporary, minor impacts to recreational resources
Impacts on Navigation	• Continued provision of 9-foot navigation channel • Continued requirement for periodic maintenance dredging at an annual average rate of approximately 4 million cubic yards indefinitely • Higher risk of channel closures due to the sole use of just-in-time dredging to keep the navigation channel open once chronic dredging locations impact the channel	• Continued provision of 9-foot navigation channel • Reduction in the amount and frequency of periodic maintenance dredging from current annual average of approximately 4 million cubic yards to approximately 2.4 million cubic yards as river training structures are built to reduce dredging in chronic dredging locations • Reduction in barge grounding rates • Increased channel reliability and decreased risk of channel closures due to decreased frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages
Impacts on Historic and Cultural Resources	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely	• No anticipated impacts to known historic resources • Impacts to unknown historic and cultural resources unlikely

*The stated impact of 1,100 acres is a programmatic estimate based on the best available information. Actual impact acreages and compensatory mitigation will not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.

2.4 Identification of the Preferred Alternative

Based on the Project's Congressional authority and the continued benefit of the remaining construction, the Continue Construction Alternative with the described avoidance, minimization, and potential compensatory mitigation is the Preferred Alternative. With implementation of the Continue Construction Alternative, the District anticipates constructing future river training structures that equate to approximately 4.4 million tons of rock, which will reduce dredging to approximately 2.4 million cubic yards on an average annual basis. This reduction in dredging will reduce the amount of costly dredging needed into the foreseeable future and result in a more reliable channel, while also taking environmental impacts into consideration. The economic viability of the Regulating Works Project will continue to be evaluated as part of the Corps budget process and therefore the actual remaining quantity of construction may vary due to changes in rock prices, dredging costs, mitigation costs, etc.

2.5 Future Implementation of the Regulating Works Project

Under the Preferred Alternative, the Regulating Works Project would still be implemented in substantially the same way as described in Chapter 1 with the addition of the consideration of compensatory mitigation for the loss of shallow to moderate-depth, moderate- to high-velocity habitat. Given that the exact locations, configurations, and types of river training structures to be implemented at future chronic dredging sites are not known at this time and would not be known until future planning is conducted site by site as described in Chapter 1, this SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward. The specific impacts associated with each work area would be covered in Tier II SSEAs. SSEAs would also include a detailed mitigation plan and associated adaptive management and monitoring that is required based on the impact assessment in the SSEAs (see Appendix C for further details on programmatic compensatory mitigation planning). SSEAs would also include discussion of the contributions of the site-specific work to the cumulative impacts of the Project. Any and all required Clean Water Act, Rivers and Harbors Act, and other permits and authorizations would be sought during the SSEA process, as necessary. SSEAs would normally be posted for a 30-day public comment period. Dredging activities and revetment construction are not anticipated to require SSEAs as the impacts of these activities are adequately characterized and quantified in the 1976 EIS and in this SEIS, but future evaluation of these activities will continue to confirm that additional NEPA documentation is not necessary.

Chapter 3. Affected Environment

3.1 Introduction

This chapter presents details on the historic and existing conditions of significant resources within the Project area that would potentially be impacted directly, indirectly, or cumulatively by Project-related activities. The resources described in this section are those recognized as significant by laws, executive orders, regulations, and other standards of federal, state, or regional agencies and organizations; technical and scientific agencies, groups, and individuals; and the general public. The emphasis in this document is on significant resources that may be impacted by the action or that are not likely to be impacted by the action but provide important context for the analysis of impacts that require updating from the 1976 EIS.

The chapter is broken into four general resource categories: Physical Resources, Biological Resources, Socioeconomic Resources, and Historic and Cultural Resources. This chapter does not address impacts of the Alternatives, but provides a background or baseline against which Alternatives can be compared in Chapter 4, Environmental Consequences.

The Project Area, commonly referred to as the Middle Mississippi River, is that portion of the Mississippi River that lies between the confluence with the Missouri River and the confluence with the Ohio River. Counting of river miles on the Middle Mississippi River begins at mile 0 at the Ohio River confluence near Cairo, IL, and ends at mile 195 at the Missouri River confluence north of St. Louis, MO. The Missouri River contributes almost 50 percent of the flow of the MMR (USGS 1999) and contributes approximately 70% of the suspended sediment load (Heimann 2016). The average flow of the Middle Mississippi River, during the period 1931-2000, at St. Louis is approximately 200,000 cubic feet per second (cfs). Other major tributaries to the MMR include the Meramec River at RM 160, the Kaskaskia River at RM 117, and the Big Muddy River at RM 75 (Figure 3-1) which contribute average flows of approximately 3,200 cfs, 3,800 cfs, and 1,900 cfs, respectively (WEST 2000).

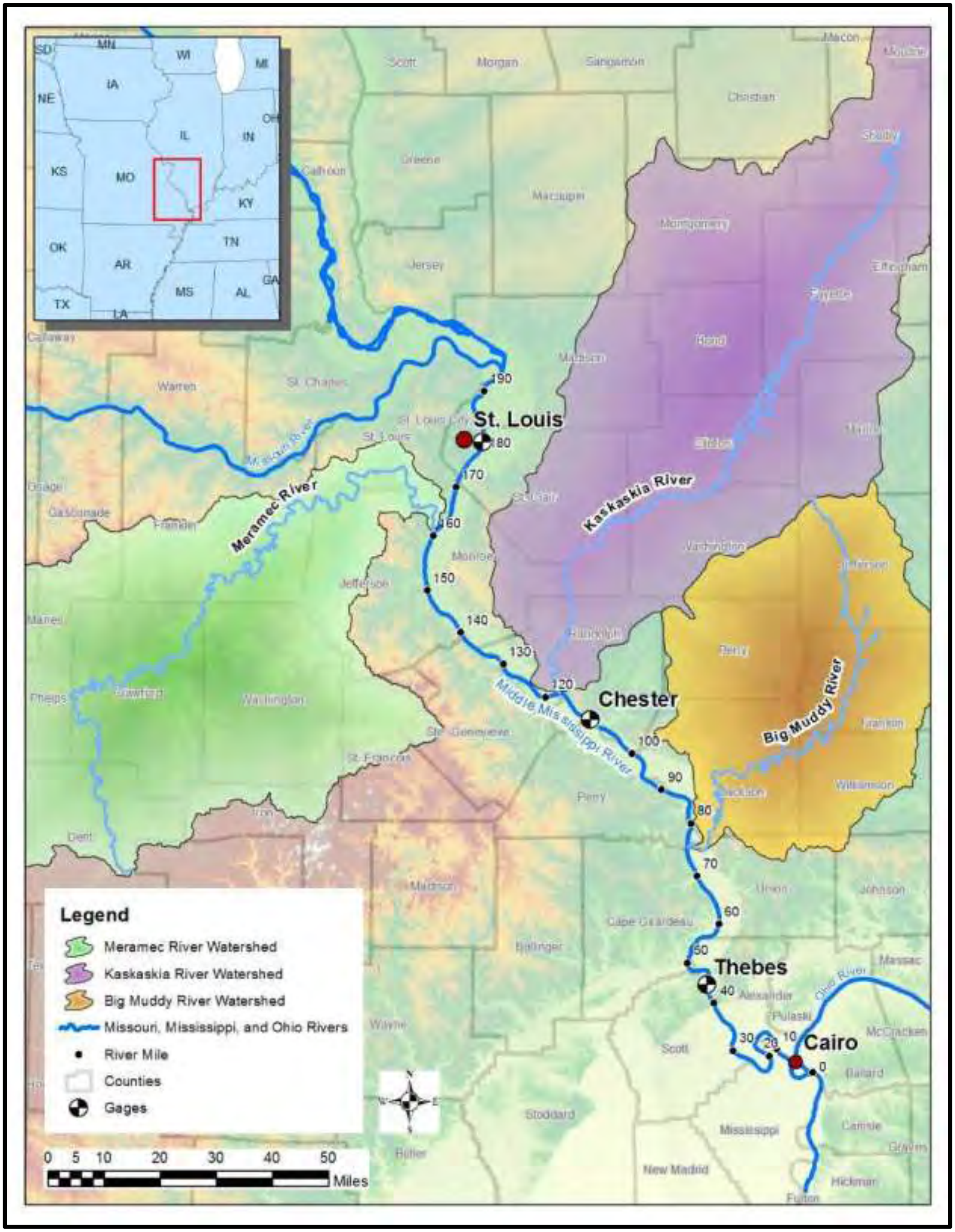


Figure 3-1. Major tributary watersheds in the Middle Mississippi River.

Average annual precipitation for St. Louis is approximately 38 inches (NOAA 2014). Average annual snowfall for St. Louis is approximately 19 inches (NOAA 2014). Average temperature for St. Louis is 56.3 degrees Fahrenheit. The average daily high and low temperatures in July, the hottest month of the year, are 89 and 71 °F. The average daily high and low temperatures in January, the coldest month of the year, are 40 and 24 °F (NOAA 2014). Precipitation is typically greatest in spring and summer and lowest in fall and winter (NOAA 2014). The highest flows and stages on the Middle Mississippi River typically occur in April and May and the lowest tend to be in December and January (Figure 3-2 and Figure 3-3). The stage and corresponding flow for flood stage, approximate elevation of the top of river training structures and the Annual Exceedance Probability (AEP) for the Mississippi River at St. Louis, MO, and Chester, IL, can be found in Table 3-1.

Recently, a GIS analysis was conducted to quantify the amount of dike construction that has occurred on the Middle Mississippi River throughout history. Existing dikes were digitized from historic surveys from the years 1876, 1881, 1908, 1914, 1929, 1942, 1956, 1968, 1977, 1983, and 2014. To measure the total amount of dike construction each structure was measured from the original, earliest starting point. In later years it is possible that part of the structure was covered with sediment, vegetation and part of the floodplain.

Figure 3-4 and Figure 3-5 show dike construction trends over time. Figure 3-6 shows quantity of material placed in the MMR since 1976. For a thorough history of the Regulating Works Project and general discussion of construction of river training structures and revetment in the MMR, see Appendixes F and K. As detailed in Appendixes F and K, the combination of a series of major floods in 1943, 1945, and 1951 and ice destroyed many existing regulating works structures. This time period saw a net decrease in the number and length of structures on the MMR.

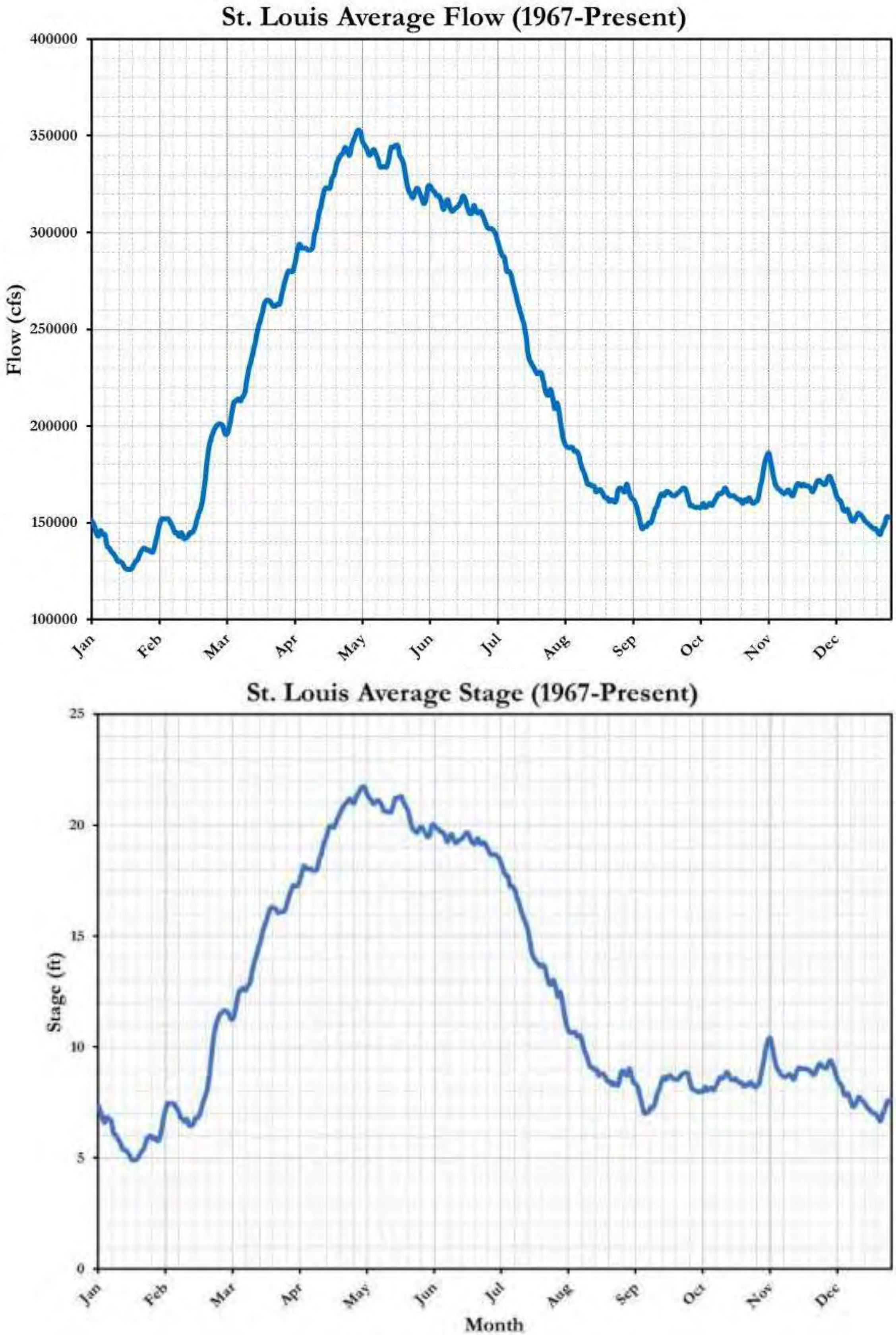


Figure 3-2. Daily average MMR flows and stages at St. Louis over the period 1967-present.

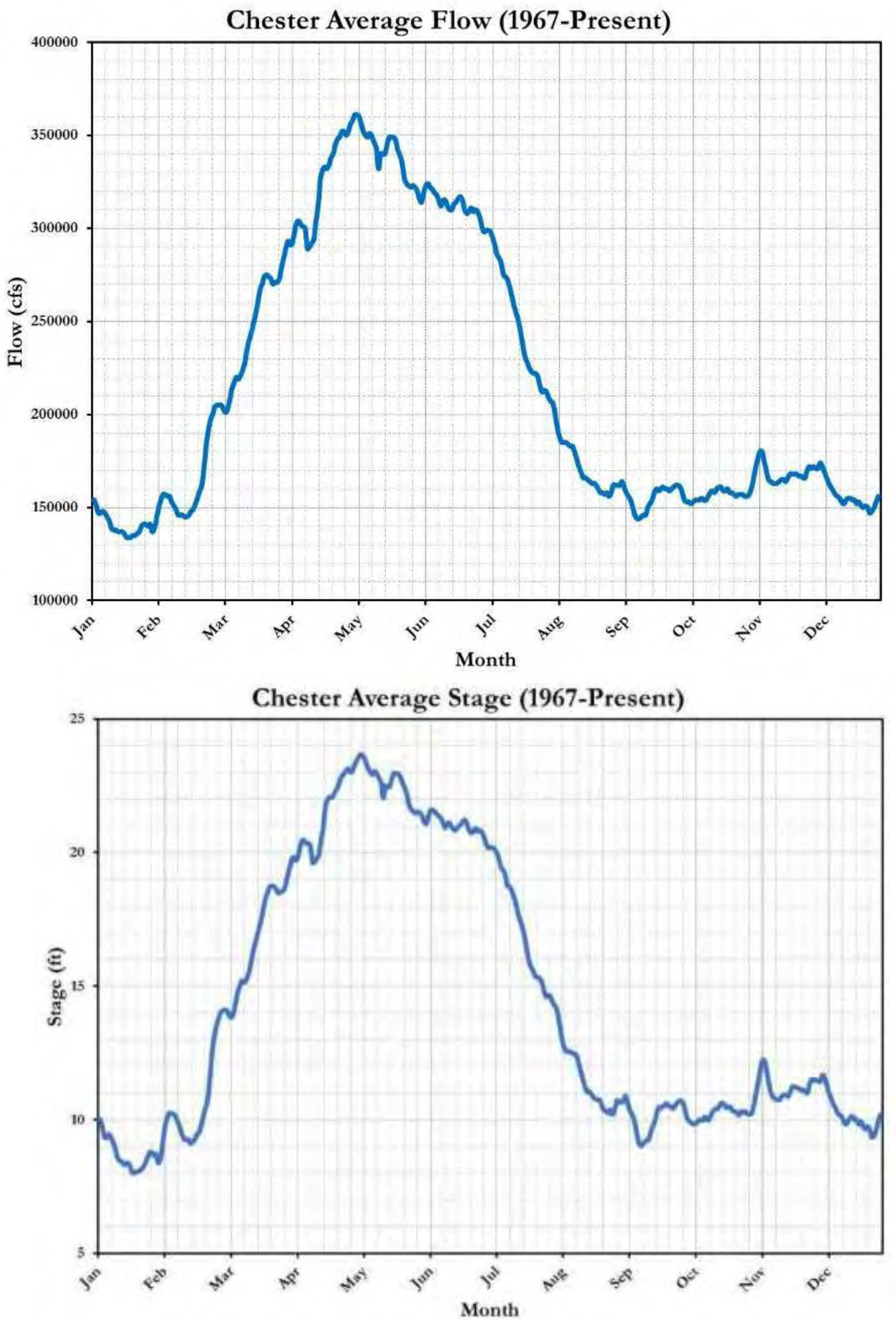


Figure 3-3. Daily average MMR flows and stages at Chester over the period 1967-present.

Table 3-1. Annual Exceedance Probability (AEP): Mississippi River at St. Louis, MO, and Chester, IL. Period of Record: 1898 – 1998 (USACE 2004)

Annual Exceedance Probability (AEP): Mississippi River at St. Louis, MO	Stage (ft)	Flow (cfs)
Structure Top Elevation	15.00	247,000
0.50 (2- year)	29.96	450,000
Flood Stage	30.00	510,000
0.20 (5 – year)	35.76	590,000
0.10 (10 – year)	38.46	670,000
0.04 (25 – year)	41.96	780,000
0.02 (50 – year)	44.06	850,000
0.01 (100 – year)	46.06	910,000
0.005 (200 – year)	47.86	1,000,000
0.002 (500 – year)	50.56	1,120,000

Annual Exceedance Probability (AEP): Mississippi River at Chester, IL	Stage (ft)	Flow (cfs)
Structure Top Elevation	15.55	225,000
0.50 (2- year)	31.15	480,000
Flood Stage	27.0	422,000
0.20 (5 – year)	36.65	622,000
0.10 (10 – year)	39.75	707,000
0.04 (25 – year)	43.05	805,000
0.02 (50 – year)	46.05	893,000
0.01 (100 – year)	47.95	948,000
0.005 (200 – year)	50.15	1,020,000
0.002 (500 – year)	51.15	1,140,000

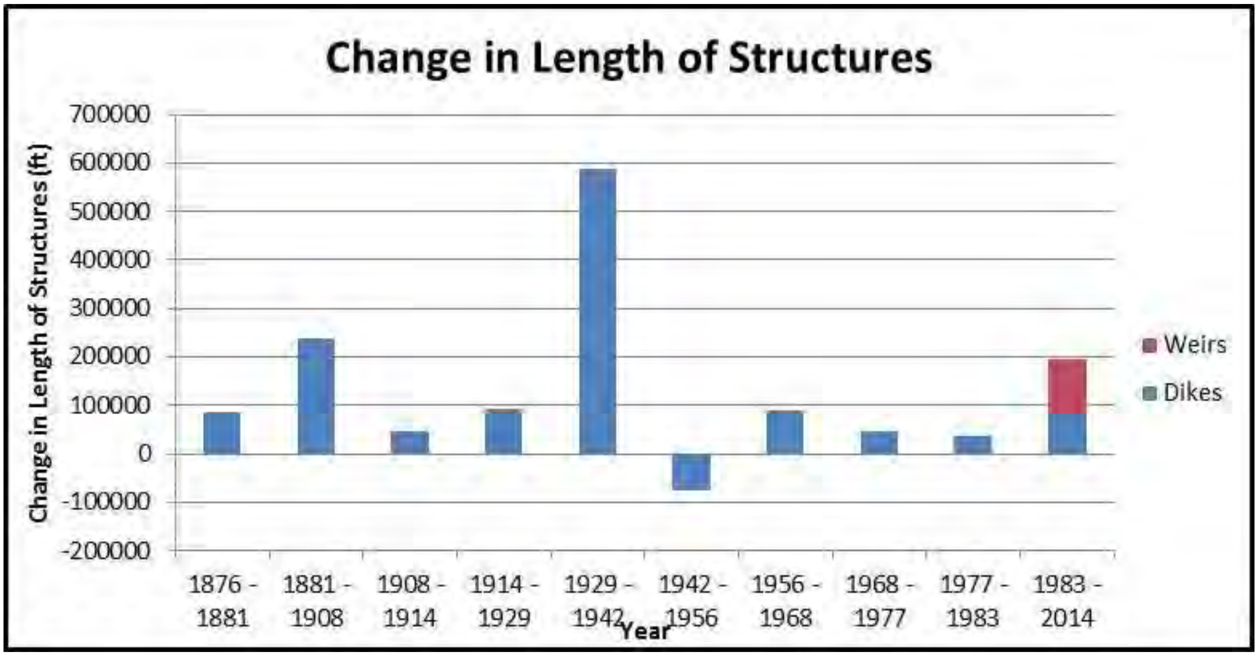


Figure 3-4. Change in total length of MMR river training structures from 1876 to 2014.

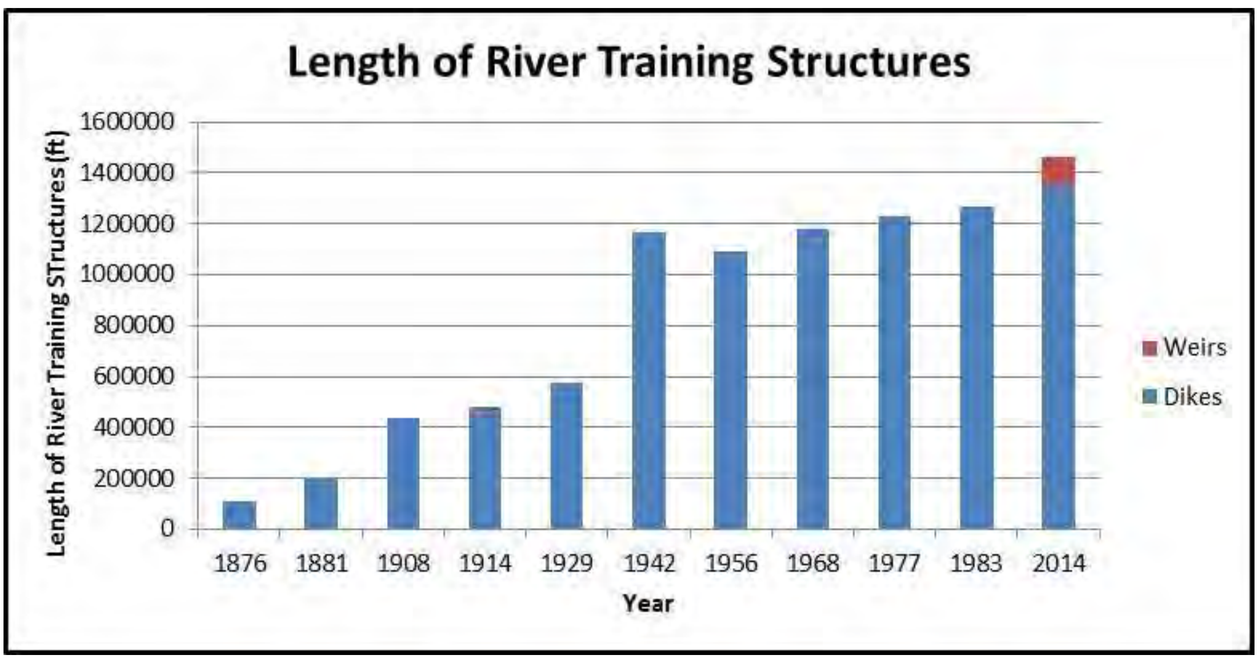


Figure 3-5. Total length (linear feet) of MMR river training structures constructed from 1876 to 2014.

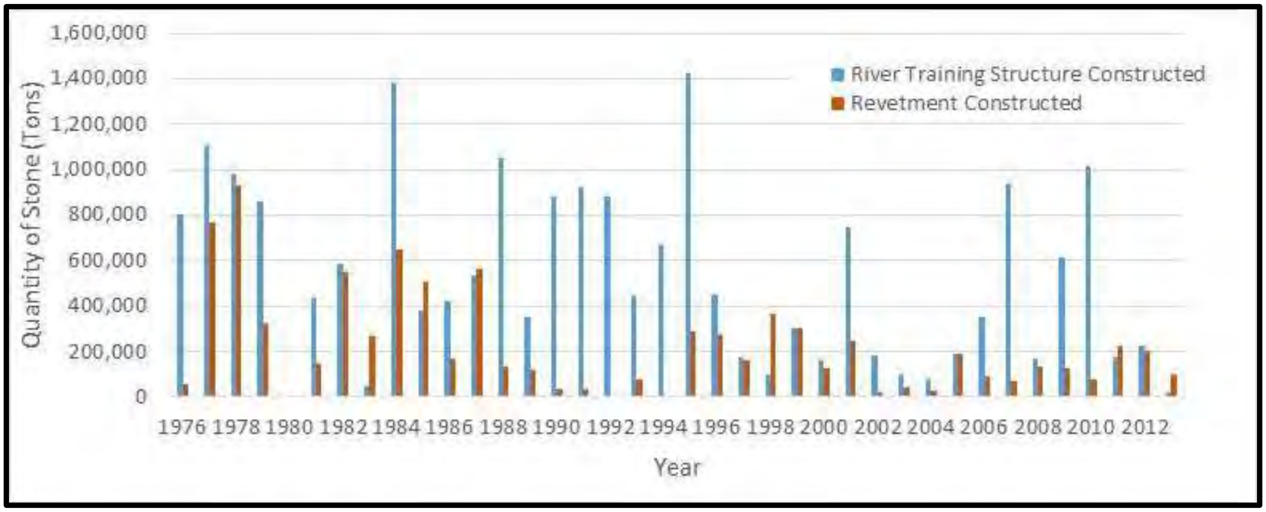


Figure 3-6. Quantity of stone placed in the MMR since 1976.

3.2 Physical Resources

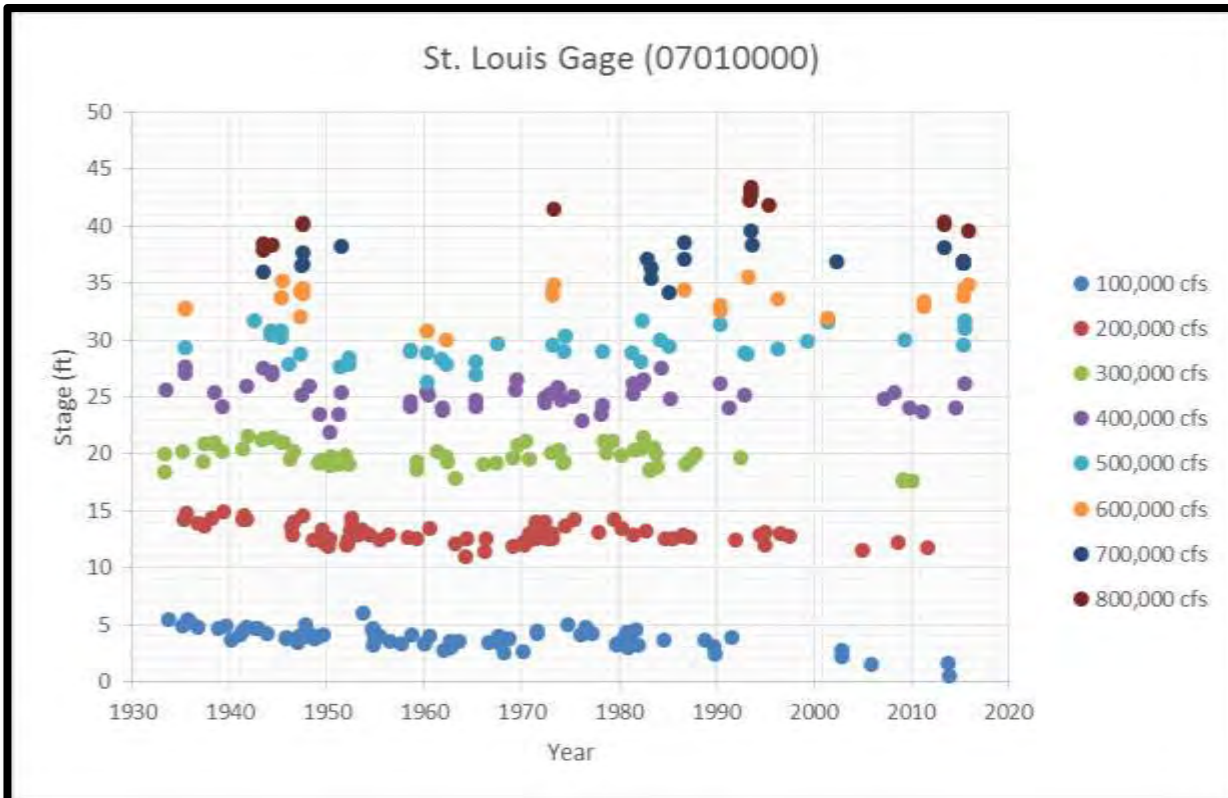
3.2.1 River Stages

Rated gages, locations where both discharge and stage are 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 (River Mile 179.6), Chester (River Mile 109.9), and Thebes (River Mile 43.7). 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 Corps has collected stage and discharge data dating back to the mid nineteenth century. 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 the 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 3-7). 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 (Figure 3-7). There was no change in stages at flows of 200,000 cfs and 400,000 cfs. There was a slightly increasing trend at 300,000 cfs. For overbank flows of 500,000 cfs and 700,000 cfs, there were slight increasing trends observed at the Chester gage.

In general, at both the St. Louis and Chester gages there has been a decrease in stage over time for lower flows, no change in stages over time for flows between midbank and bankfull, and a slight increase in stages for high overbank flows (Huizinga 2009). The decrease in stage over time for lower flows 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). Huizinga (2009) and Watson et al. (2013a) attribute 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 15 feet.



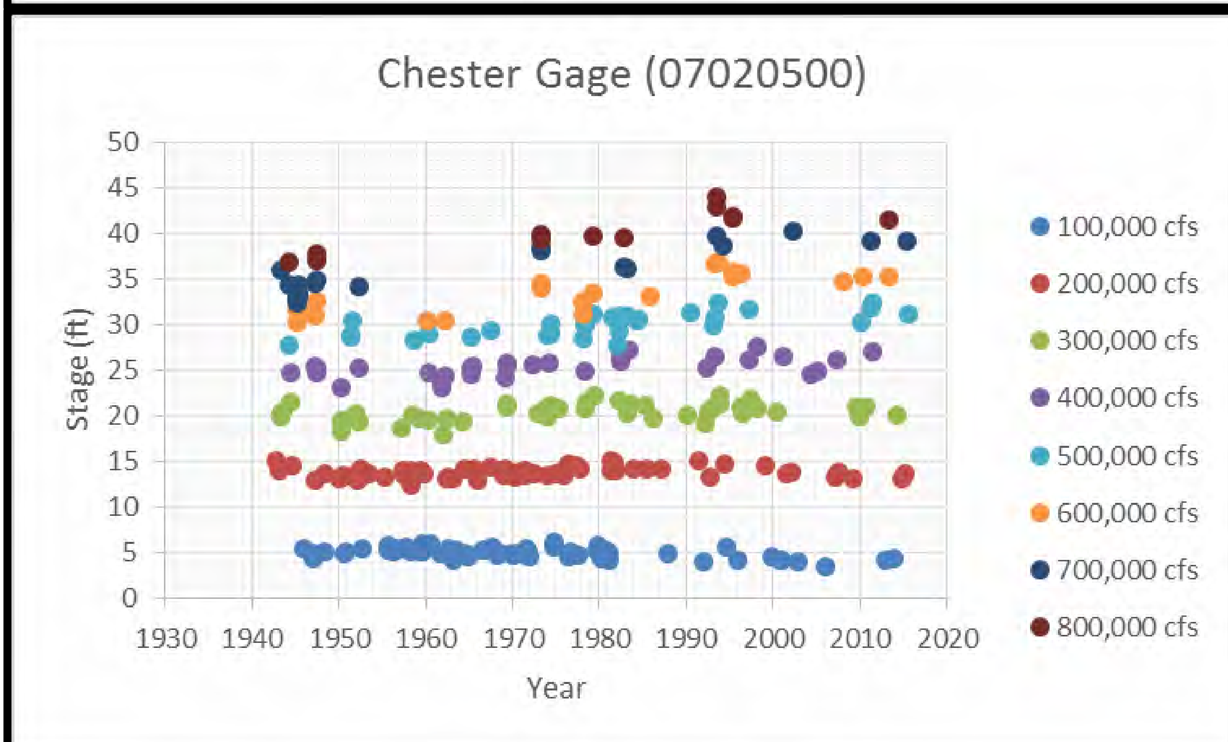


Figure 3-7. Stage for a given discharge range with time from measurements made at the streamgages at St. Louis, Missouri (top) and Chester, Illinois (bottom) on the MMR. Data retrieved from usgs.gov on 15 March 2016.

3.2.2 Geomorphology

The following discussion of the geomorphology of the Project Area is broken into three broad habitat categories: main channel/main channel border, side channels, and islands. For reference, the relative abundance of these habitats is provided in Table 3-2.

Table 3-2. Acreage of main channel, main channel border, side channel, and island habitat in the MMR in 1976 and 2014.

	1976 Acreage	2014 Acreage
Main Channel	20,834	25,134
Main Channel Border	29,911	24,592
Side Channels	3,893	4,128
Islands	11,465	11,375

Main Channel / Main Channel Border

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 (Figure 3-8). These trends were observed throughout the MMR on both the planform and main channel (Figure 3-9 and Figure 3-10). The period of narrowing corresponded to the widespread use of river training structures and bank protection for navigation improvements. The dramatic increase in planform and channel width in 1881 found between River Miles 110.25 and 120.0 is the result of the channel cutoff that occurred on the Mississippi River when it captured the Kaskaskia River. 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. 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. Typical river training structure configurations and descriptions can be found in Table 3-3.

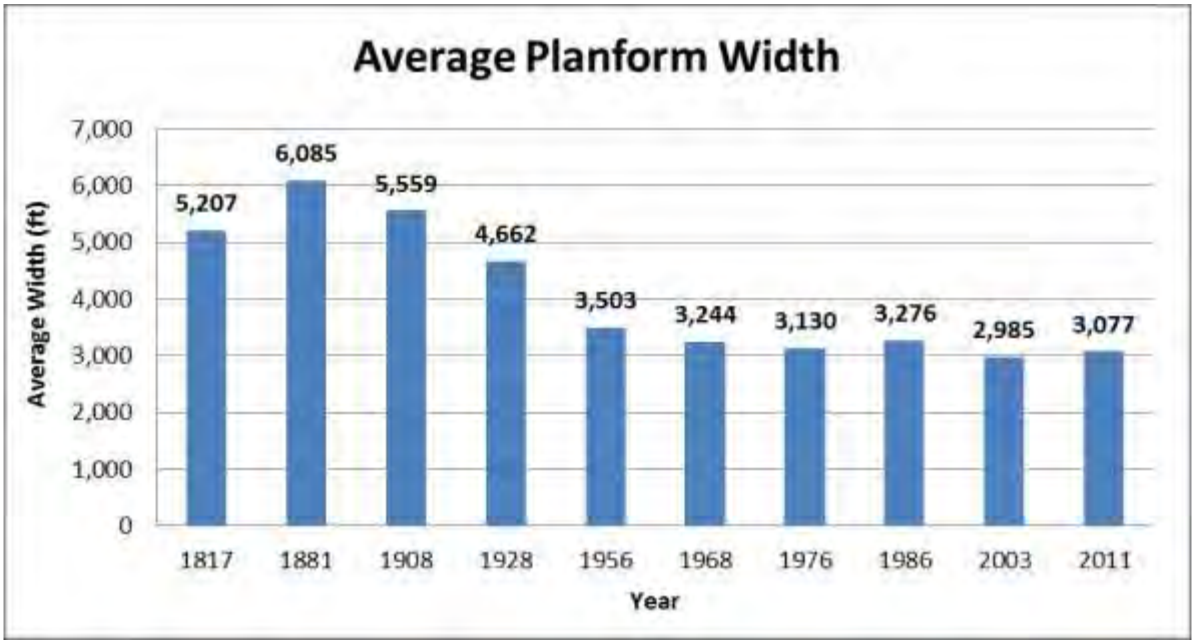


Figure 3-8. Average planform width of the MMR from 1817 to 2011.

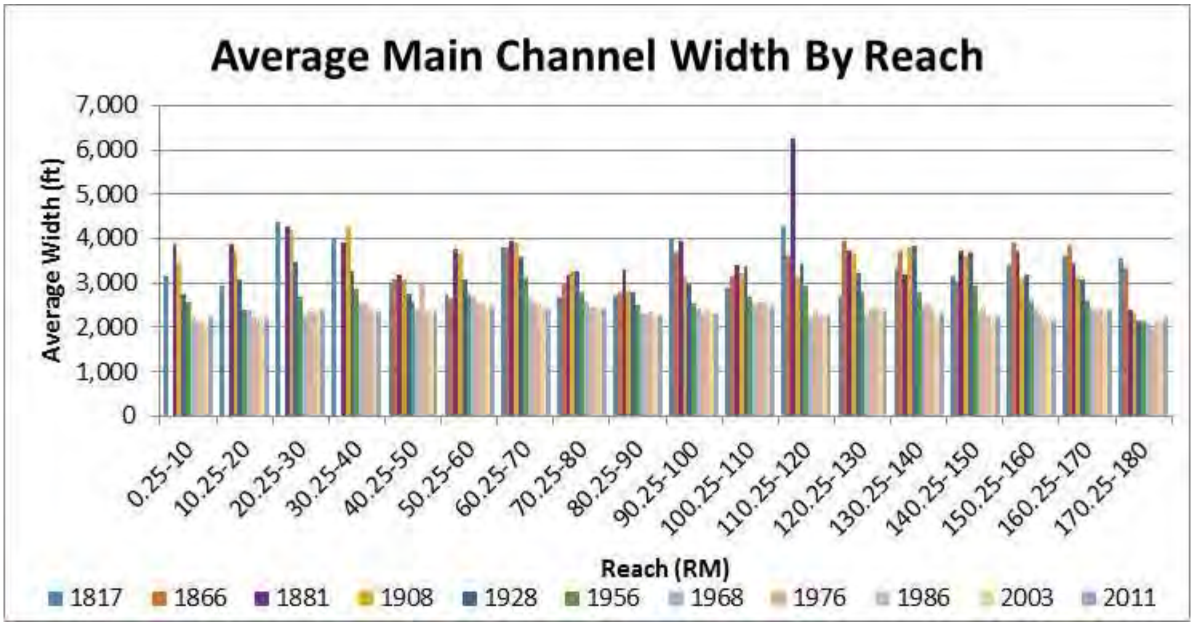


Figure 3-9. Average planform width of the MMR by 10-mile reach from 1817 to 2011.

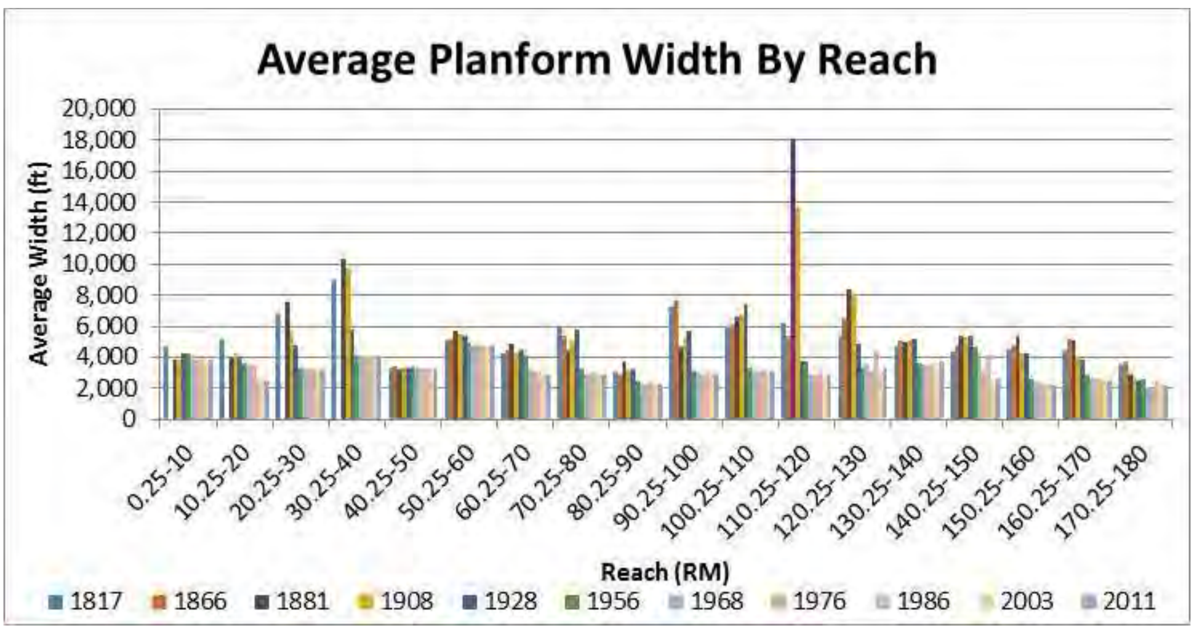


Figure 3-10. Average planform width of the main channel of the MMR by 10-mile reach from 1817 to 2011.

Changes in cross sectional area, hydraulic depth, conveyance and channel volume were studied using historical channel surveys from the years 1956, 1977, 1986, 1993, and 2013. Generally there has been an increase in cross sectional area, hydraulic depth[8], conveyance[9] and volume

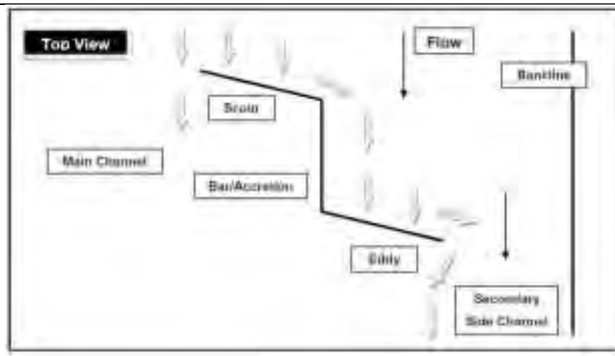
[8] Hydraulic depth is defined as the cross sectional area of the water perpendicular to the direction of flow in the channel divided by the width of the free surface.
[9] Conveyance is defined as the carrying capacity of a channel.

throughout the period of record (Little et al. 2016). The Regulating Works Project has contributed to these changes, although it is uncertain to what extent. The purpose of dike construction is to manipulate the channel cross section to achieve the authorized navigation channel dimensions. In many cases, the new channel dimensions have resulted in a channel with increased conveyance.

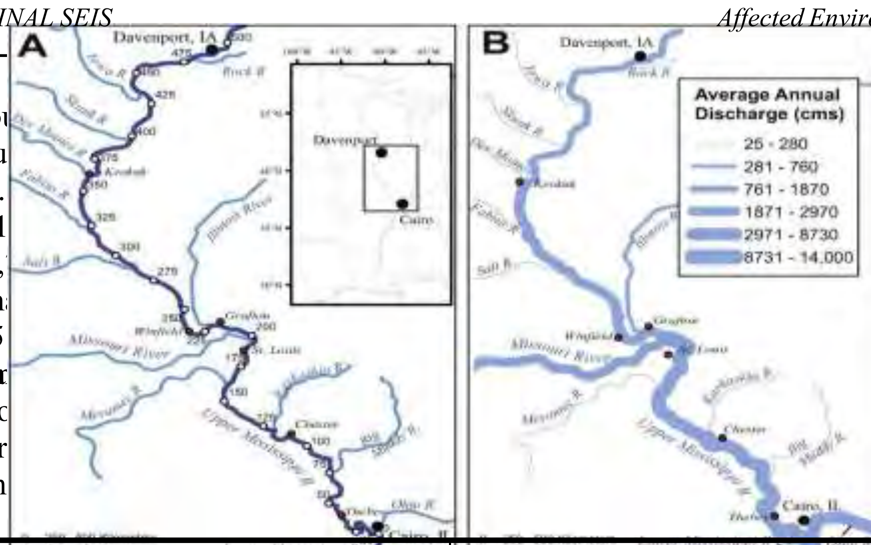
Table 3-3. Types of river training structures used in the MMR.

Dike Name(s)	Picture(s)	Description
Spur Dike; Wing Dam; Jetty		Extends perpendicularly from the riverbank toward the main river channel. This is the most common type of dike and has been constructed on the MMR since the 19th Century.
Rootless Dike		Offset from the river bank, meaning the structure starts some distance off the bank. The typical offset distance is 100 feet or more. The rootless section provides environmental diversity by altering flow and sediment transport. Many times, multiple dikes are left rootless and positioned in a line to create a secondary channel for environmental enhancement. Construction of these structures did not begin until after 1970.
L-head Dike; Trail Dike		Extends from the riverbank like a spur dike but also has a section at the dike end that extends downstream. The L-head section spreads the energy of the flow over a larger area and can be used to increase the spacing between dikes, to reduce scour on the end of the dike, or to extend the effects of the dike system further downstream. The L-head also tends to block the movement of sediment behind the dike by reducing the formation of eddies downstream. This type of dike did not become common on the MMR until after 1970.
Closure Dike		Built in side channels, or chutes, to reduce or eliminate the flow through these secondary channels, thereby allowing more flow to be concentrated in the main channel. Spur dikes divert sediment into the side channel and closure dikes reduce the velocity of the flow in the side channel, leading to increased sediment deposition and potentially the eventual closure of the side channel or a reduction in its size. Closure dikes have been constructed on the MMR since the 19th Century.

Bendway Weir		Low-level, fully submerged rock structures positioned from the outside bankline of a river bend and angled upstream toward the flow. These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's secondary currents in a manner which controls excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging. The first bendway weirs were constructed on the MMR in 1989.
Chevron		Blunt-nosed, arch-shaped structures that are constructed parallel to flow, utilizing the energy of the river to redistribute flow and sediment. They are usually placed adjacent to the river bank to allow flow separation and create both channel deepening, side channel development, and middle bar formation. Chevrons were first constructed on the MMR in 2001.
Hard Point		Very short rock dikes that are used to stabilize side channel river banks. These navigation structures extend from the river bank into the river and do not cause a significant buildup of sediment. Their contribution to habitat improvement is the creation of scour holes under the hard points. Hard points were first constructed after 1970.
Notched Dike; Notched Closure Dike	 Source: U.S. Army Corps of Engineers (left); U.S. Fish and Wildlife Service (right)	Dikes with notches added that allow the river to move in and out between them, thus creating a greater diversity of river habitats while still allowing the dike to perform its primary function of directing flow into the main channel for navigation. Notching a closure structure can prevent the side channel from filling with sediment and form areas of deep water and shallow water, creating a diversity of habitat and attracting different species of fish. River engineers first began experimenting with notched dikes in the late 1960s and they became much more prevalent on the MMR after the 1970s. In some cases, new dikes were designed with notches, and in other cases, notches were added to existing dikes.

Multiple Roundpoint Structure (MRS)		Alternating rows of rock mounds within the footprint of a typical dike. They are used like a dike to maintain the navigation channel and to create flow and bathymetric diversity within a dike field. The main benefit of these structures is to create diverse flow and scour patterns for aquatic improvement. MRSs were not constructed on the MMR until after the 1970s. Currently, there is only one MRS field on the MMR.
W-dike		Structures that have four legs and are shaped like the letter "W," with the apex of two legs facing upstream. Flows are directed toward the apexes, forming two scour holes and one depositional bar downstream. The tips of the W-dikes behave like traditional dike structures, constricting the channel and increasing sediment transport through an area. The landward side of a W-dike can be attached to the bankline. Construction of these structures did not begin until after 1970.
S-dike; Diverter Dike		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. The first S-dikes will be constructed in the near future.
Dike Extension		Used when a dike is not performing adequately and additional channel constriction is needed. The extension may incorporate a gap between the existing structure and new construction, which performs like a notch and can provide a dynamic system for environmental enhancement.

Sediment. The main so[...]
Missouri River contribu[...] y
percent of the sediment.
Between 1968 and 2011 [...] r at
St. Louis, MO was 102,[...] the
Missouri River at Herm[...]
Tons/yr and 24,027,165[...]
between Herman, MO a[...] .
The approximated bedl[...]
large, low-gradient river[...]
percent of total sedimen[...]



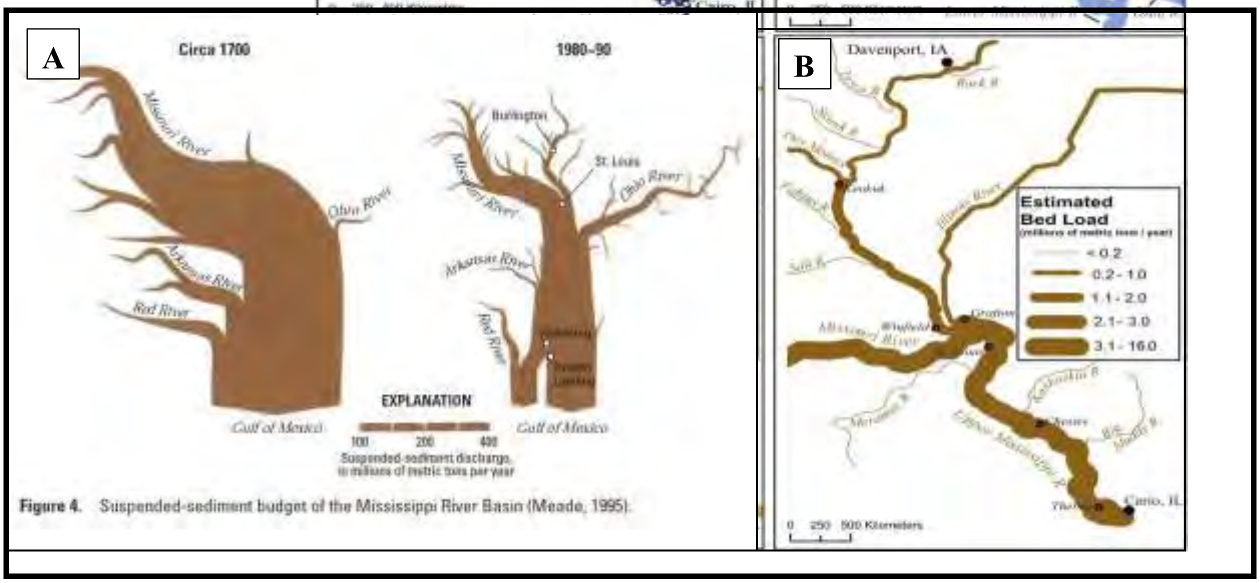


Figure 3-11. A.) Suspended-Sediment budget of the Mississippi River Basin (Meade 1995), B.) Mean annual bedload on the Mississippi River Basin (Remo 2016).

Suspended sediment load has decreased at Grafton, IL, St. Louis, MO, and Hermann, MO between 1976 and 2009 by 3.62%/yr, 4.57%/yr and 1.66% year respectively (Figure 3-12). This is primarily due to impoundments on tributaries, agricultural conservation practices, and depletion of stored sediments in the system. Suspended sediment load also decreased at Chester, IL, and Thebes, IL, by 1.45% and 1.40%, respectively.

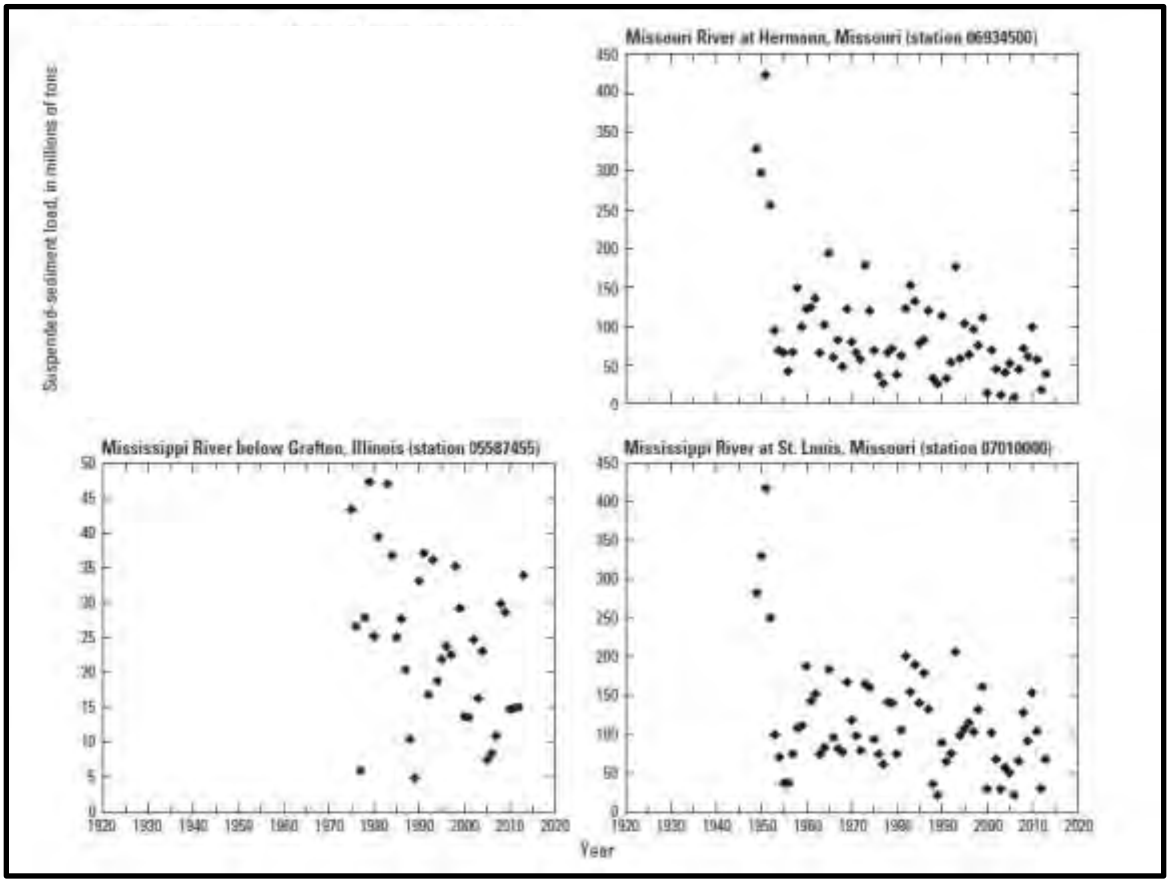


Figure 3-12. Temporal changes in suspended-sediment loads at selected stations in the Missouri and Mississippi River Basins, 1930-2014 (Heimann et al. 2011).

Bed materials on the MMR are composed mainly of medium-course sands and gravels (Figure 3-13). The reach-averaged D50 grain diameter was calculated to be 0.74 ± 0.70 mm (Figure 3-144; Gaines and Priestas 2013). On average, greater quantities of granule material (> 2.00 mm) was found in the thalweg compared to samples collected outside of the thalweg. Greater percentages of silt and lesser amounts of sand were generally collected near river banks, although with considerable variability (Gaines and Priestas 2013).

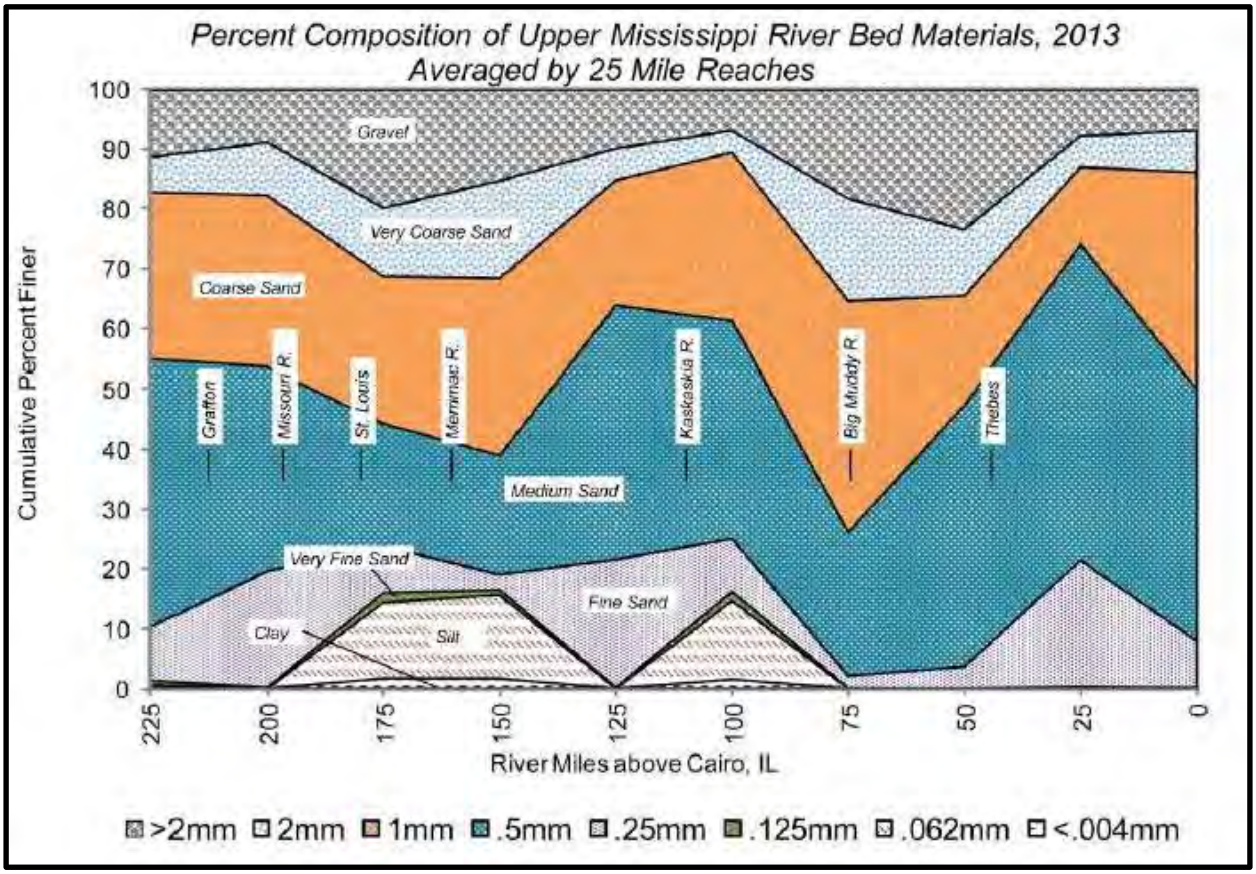


Figure 3-13. Composition of 2013 thalweg bed material averaged by 25-mile reaches, UMR: Grafton to Cairo, IL (Gaines and Priestas 2013).

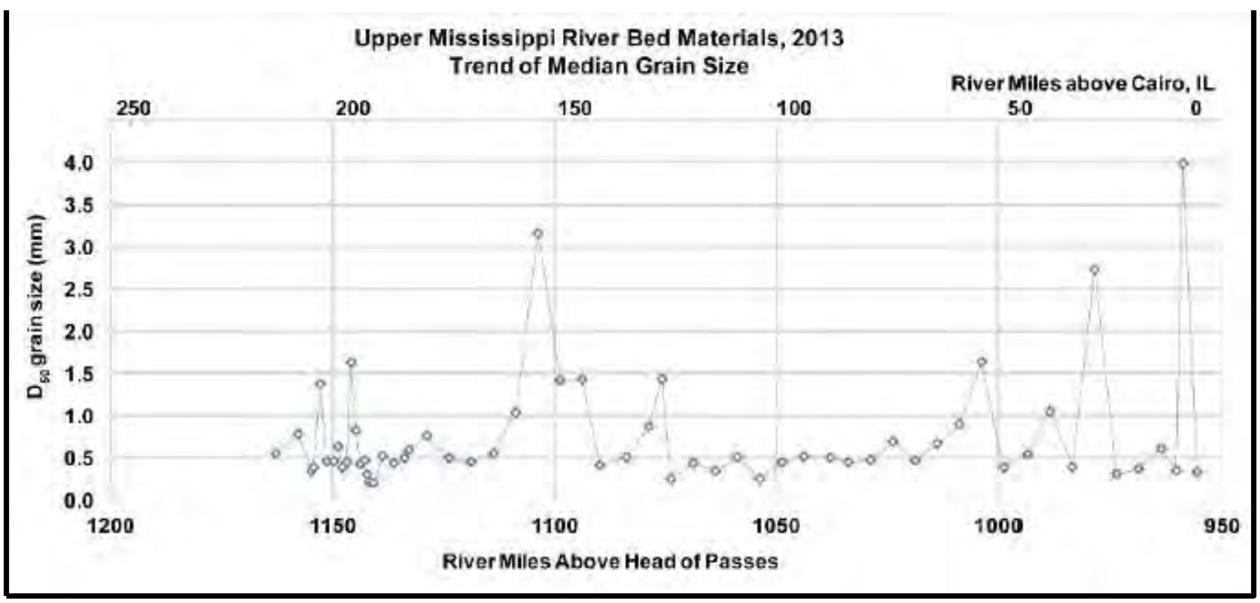


Figure 3-14. Variability for D50 sizes, UMR, Grafton, IL, to Cairo, IL (Gaines and Priestas 2013).

Limited bedload transport data exists on the MMR. Figure 3-15 details existing measurements and estimates for bedload on the Missouri and Mississippi Rivers (Heimann 2016).

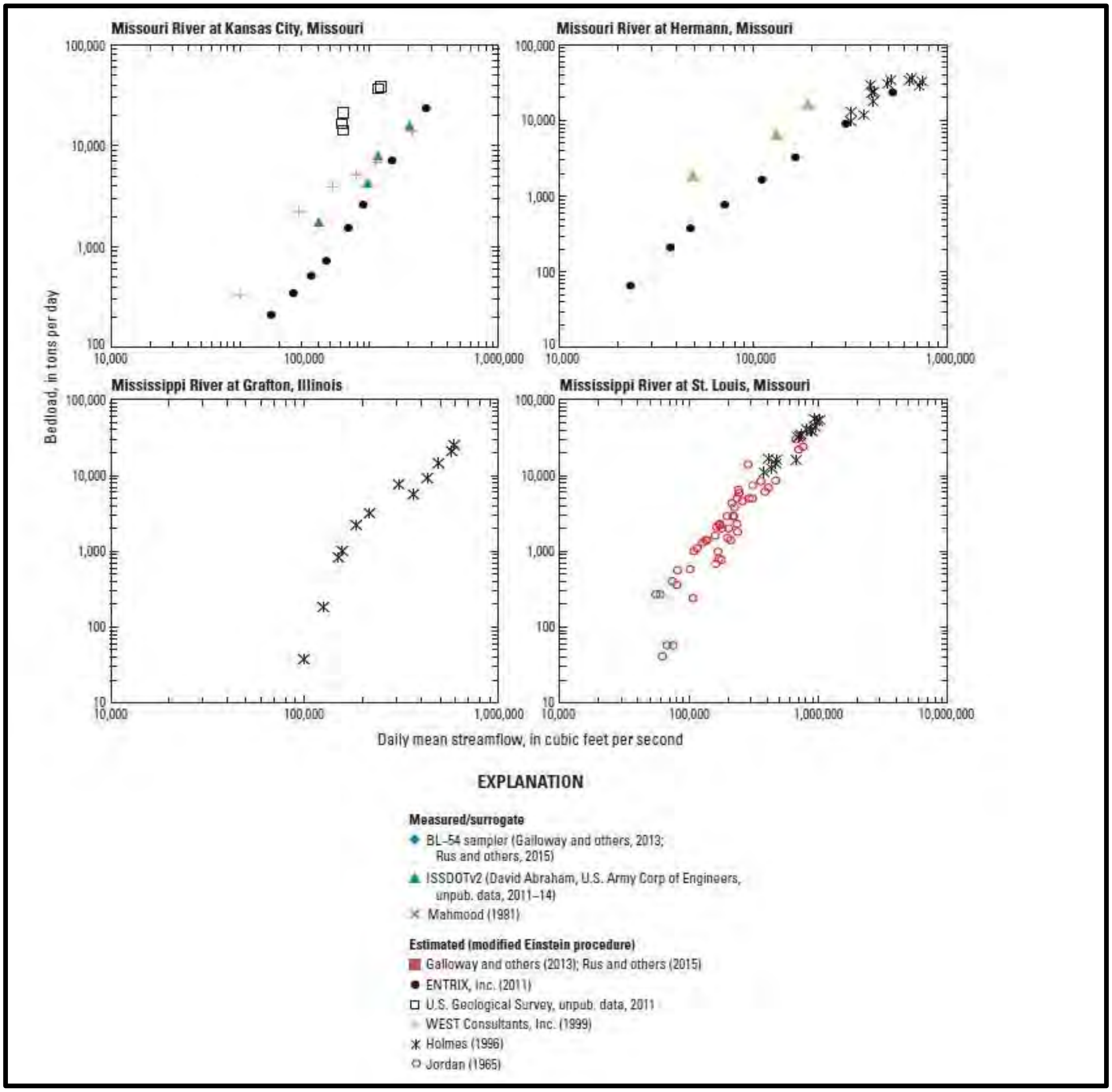


Figure 3-15. Bedload and daily average streamflow for Lower Missouri River and Mississippi River main-stem stations, 1950-2014 (Heimann 2016).

Side Channels

Side channels have been shown to be extremely important fish habitat in the Middle Mississippi River. 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. MMR side channels have mean depths and velocities lower than the main channel and generally provide a greater range of habitat conditions in a smaller area (Sobotka and Phelps 2016). Side 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, side channels can function as wetlands, isolated backwaters, connected backwaters, isolated side channels (at low stages), and flowing side channels. Level of connectivity also affects substrates, water quality conditions (Crites et al. 2012), benthic macroinvertebrate communities (Bij de Vaate et al. 2007; Paillex et al. 2009) and fish faunas (Barko and Herzog 2003; Barko et al. 2004a). Flowing side 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 side 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 (Scheaffer and Nickum 1986; Lowery et al. 1987; Grift et al. 2001), and habitat for other environmentally sensitive macroinvertebrates, fish, and wildlife (Eckblad et al. 1984; Siegrest and Cobb 1987; Barko and Herzog 2003; Sobotka and Phelps 2016). Side 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). As such, side channels are important to the health of the river ecosystem as a whole, and are even more important in the Middle Mississippi River because of the loss of hydraulic connectivity to the floodplain.

Side channels are also important because they are a refuge for fish escaping navigation related disturbances. Galat and Zweimuller (2001) and Wolter and Bischoff (2001) hypothesize that commercial navigation traffic may push fish toward the littoral zone or into side 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 side channels. They found the presence of some species was unaffected by traffic disturbances, whereas the presence of others was reduced. Thus, side channels contribute to the overall health of the riverine system (Baker et al. 1991; Simons et al. 2001).

For preparation of the 1976 EIS, the District conducted several studies (Johnson et al. 1974; Ragland 1974; Schramm and Lewis 1974) of side channel characteristics that documented the formation processes, existing biological and physical conditions, and importance of Middle Mississippi River side channels. Simons et al. (1974) concluded that, unless steps were taken to prevent it, "...ultimately nearly all natural and man-induced side channels should completely fill with sediment and become undistinguishable from the flood plain." However, the EIS cautioned that the Simons et al. findings were based on dike specifications from the previous decade and "...it is now the current practice of the St. Louis District to construct dikes to a lower elevation than previously used. It is anticipated that the lower dike elevations will cause numerous channels to be perpetually maintained along and between these structures because of regime changes in the channel between low and high flow and the associated scouring effects over and around the low dikes."

There are currently 32 side channels existing in the MMR (Figure 3-16). As outlined in the following sections, the District has undertaken several recent analyses on these side channels to document the historic and current conditions of the side channels and to help determine whether or not they are deteriorating as predicted in the 1976 EIS. Analyses include:

- Geomorphology study of the MMR using historic and modern maps, surveys, and georeferenced aerial photography to calculate changes in side channel planform through time;
- Calculation of side channel volumes and mean depths using survey data from the 1950s, 1980s, 1990s, 2000s, and 2010s to determine if changes have occurred over time in overall side channel size and depth characteristics; and
- Calculation of side channel connectivity using recent survey data and period of record hydrograph data to provide information on the accessibility of side channel habitat to fish.

Figure 3-16. Locations and names of all existing Middle Mississippi River side channels.

Planform Analysis

As described above 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. With respect to side channel condition, the analysis provides information on the changes through time in side channel width and recent stability, or lack thereof. The analysis demonstrates that side channels generally went through a period of narrowing from the mid-1800s through the mid-1900s, followed by relative stability since the 1950s (Figure 3-17). The planform widening that occurred in the early 1800s was the result of major changes in the watershed and bank erosion due to clearing of riparian vegetation. As can be seen in the images of Angelo Chute in Figure 3-18, MMR side channels typically went through a period of rapid development and change from the late 1800s through the mid-1900s in response to river training structure placement that started in the late 1800s. By the mid-1900s, the positions of most side channels were relatively fixed with very little change in planform occurring since the 1980s. A full record of time series maps similar to Figure 3-18 for all MMR side channels can be found at:

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

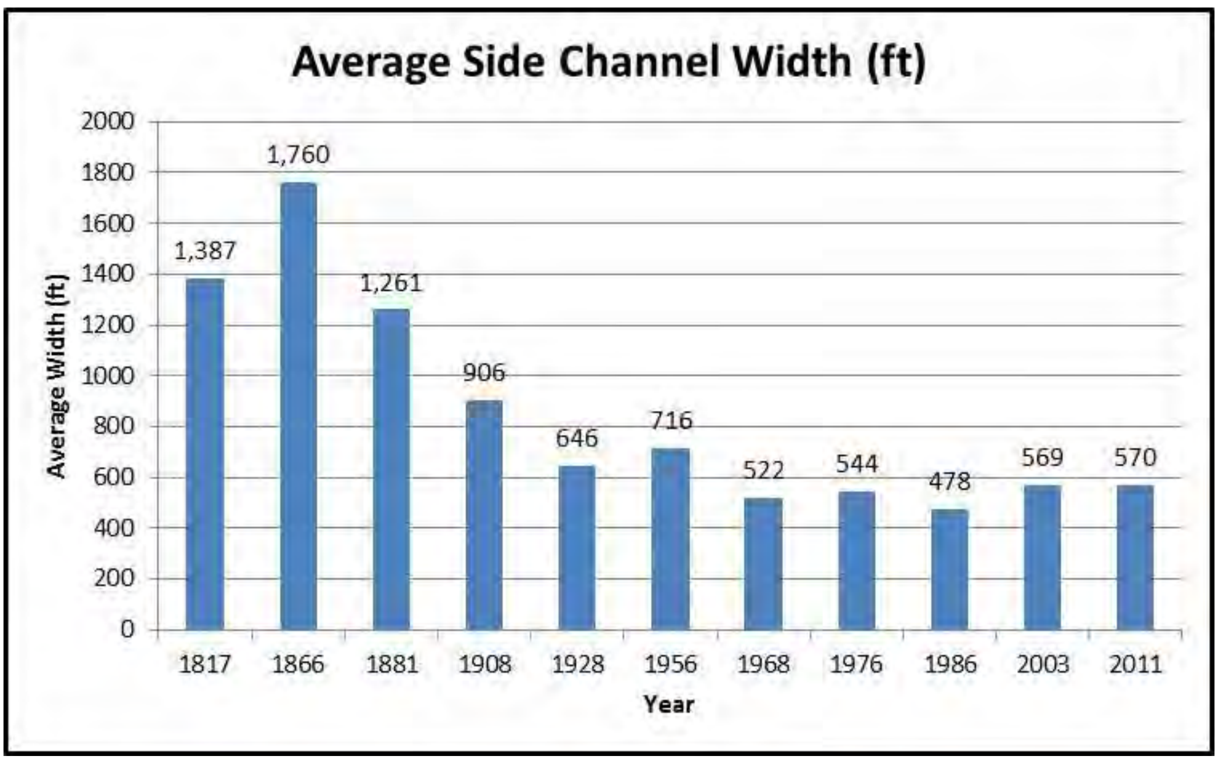


Figure 3-17. Average planform width of MMR side channels from 1817 to 2011 (from Brauer et al. 2013).

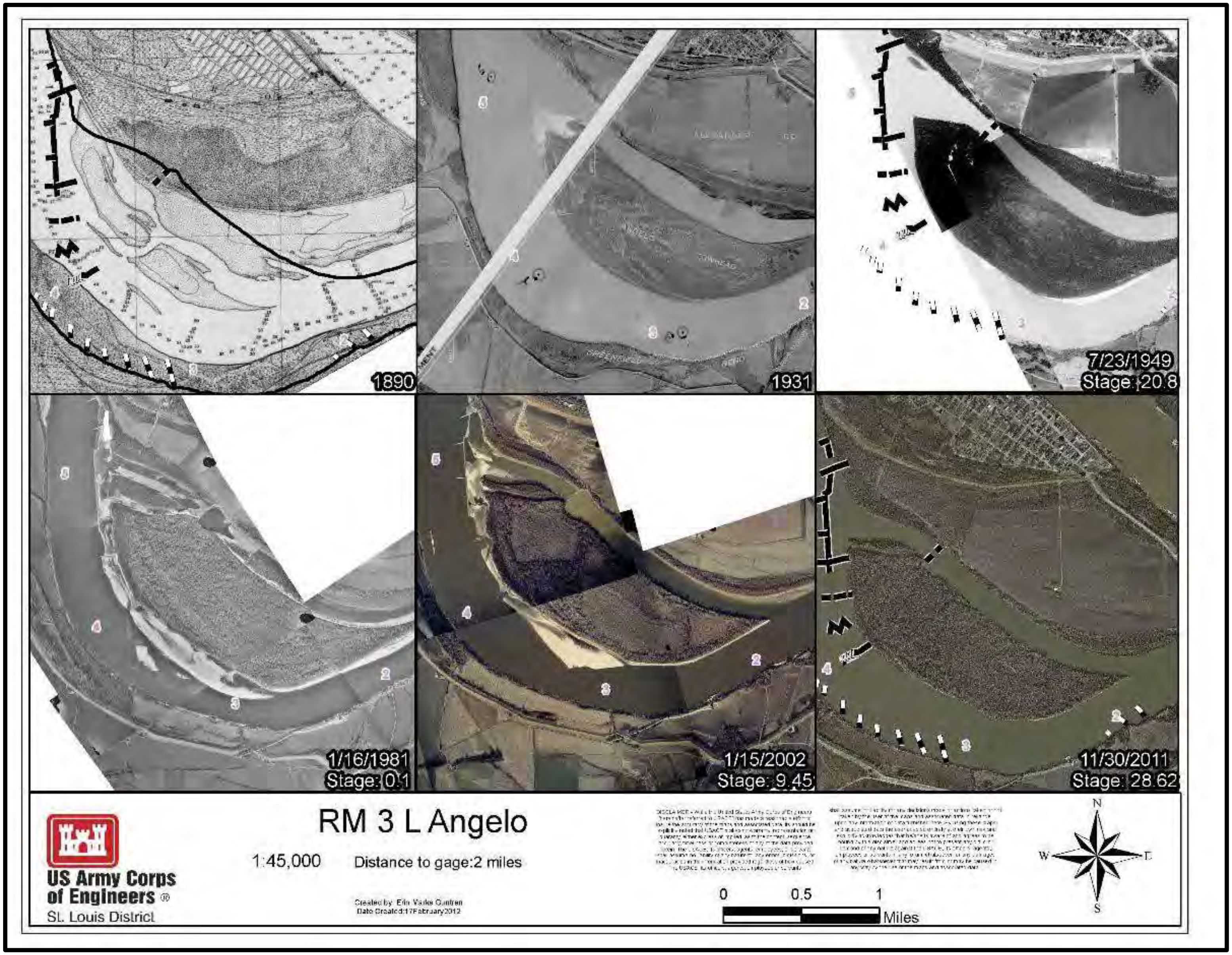


Figure 3-18. Time series imagery showing the formation and recent stability of Angelo Chute.

Bathymetric Analyses

Based on the geomorphology study and historic photography, most MMR side channels have not changed significantly in planform characteristics since the mid-1900s. However, it is possible that the depth characteristics could change without any change in planform characteristics – the side channels could be shallowing or deepening without any associated change in width. The quality and quantity of habitat provided by an individual side channel is closely tied to its depth characteristics. Accordingly, a series of analyses were conducted by the District to determine what changes have been occurring to side channel depth characteristics. For historic bathymetry, side channel transect surveys from 1956, 1986, 1993, and 2001 were used. Historic data sets do not exist for all side channels and some side channels are too shallow and/or remote to be easily accessible by survey boats. In addition, transect surveys by their very nature do not provide complete coverage of the surveyed side channels, only providing depth information at regular intervals throughout the side channel, depending on the spacing of each particular survey (e.g., see 1000-ft. transect spacing in Figure 3-19). However, transect surveys are the only quantitative information available on the historic depth conditions of MMR side channels, and are, therefore, the best available information for determining historic trends in MMR side channel bathymetric characteristics.

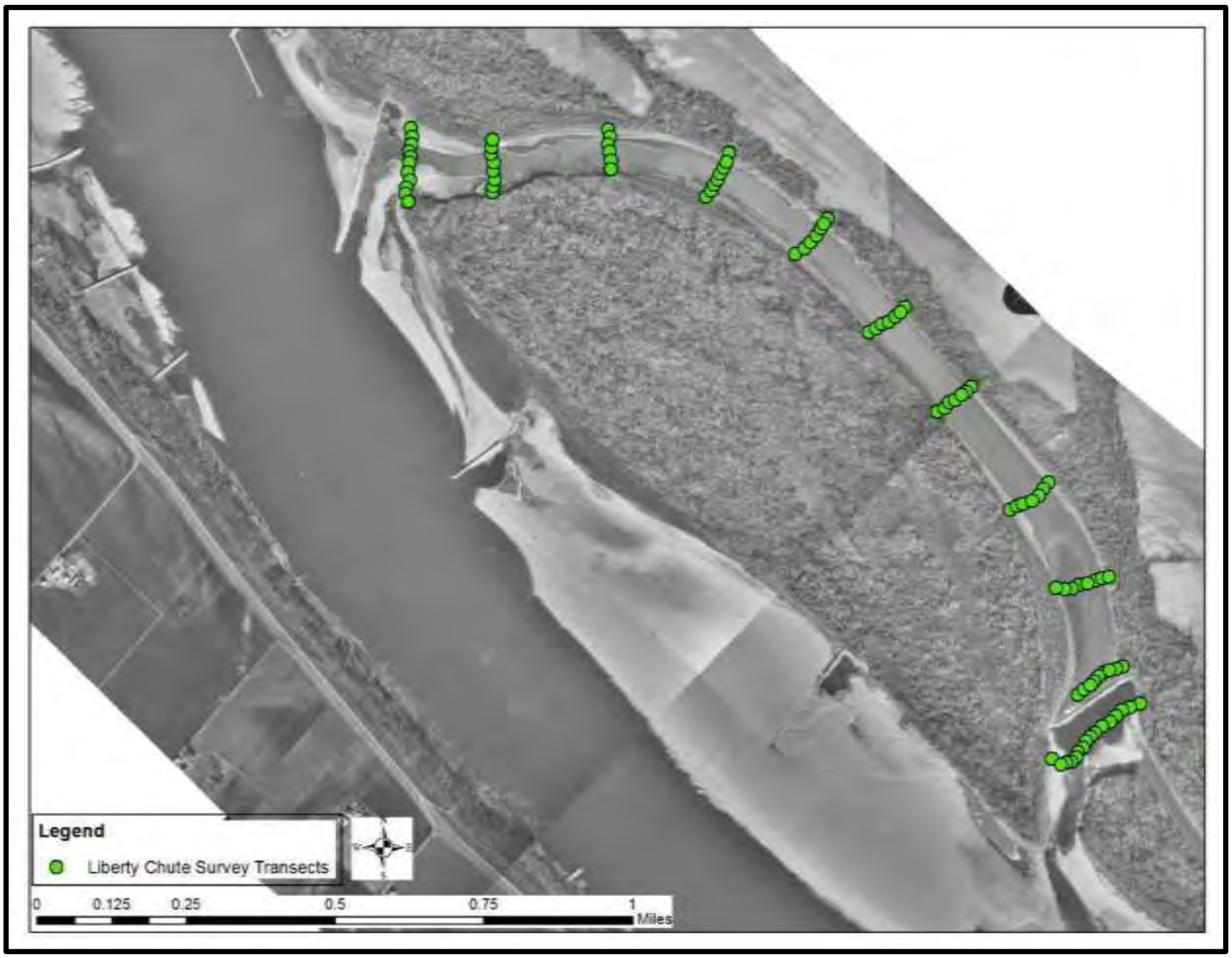


Figure 3-19. Example of spacing of historic transect survey data (Liberty Chute, 1986 survey, 1000-ft. intervals, 1981 imagery).

From the historic transect data, volume and mean depths were calculated for each time period for which surveys were available. Mean depth was determined to provide the best overall indicator of changes in depth characteristics of side channels over time and is presented here. The results of the transect mean depth data analysis can be found in Table 3-4. In order to facilitate comparisons of volume and mean depth measurements between years, the analysis for each side channel was limited to the common area that was covered by all survey years. This eliminated the possibility of data skewing due to differing survey footprints among years.

In addition to the historic transect data analysis, the District also analyzed recent high quality multi-beam side channel survey data. Multi-beam surveys provide 100% coverage of the survey area (Figure 3-20) and can provide hyper-accurate bathymetric detail, lending to a better ability to accurately track changes in depth through time. This could provide information on potential recent trends in side channel depths as well as provide an indication of the amount of short-term variability in side channel bathymetry. Multi-beam surveys were available for MMR side channels starting in 1999. Availability of multi-beam data between 1999 and 2014 varied by side channel with some having as many as seven surveys and some having as few as two. Regardless of the number of surveys available, very accurate comparisons could be made between years for which multi-beam surveys were available. Similar to transect data, volume and mean depth were calculated for all multi-beam surveys. Mean depth results can be found in Table 3-4. Side channel volume results can be found in Figure 3-21. Again, in order to facilitate comparisons between survey years, the analysis was limited to the common footprint covered by all survey years.

Based on the analysis of transect and multi-beam data, overall depth characteristics of MMR side channels appear to be stable or increasing, although a considerable amount of interannual variability occurs due to shifting sandbar formations in response to changing river stages and flows. Of the 20 side channels for which bathymetric surveys were available for a period spanning at least 15 years, 13 showed an increase in average depth over the period of record and 7 showed a decrease. Likewise, total volume of MMR side channels has increased in the last 15 years.

Figure 3-20. Example of multi-beam survey data (Osborne Chute, 2014 survey, 2012 imagery).

Table 3-4. Results of bathymetric analysis. Values are mean depth (in feet below April median water surface elevation to provide an estimate of average water depth during high water). Red-shaded cells denote a decrease in mean depth from the previous survey. Green-shaded cells denote an increase in mean depth from the previous survey.

Name	River Mile**	1956	1986	1993-1996	1998-1999	2001-2004	2011	2014
Duck*	195R	No Data						
Mosenthein	188L	No Data						
Carroll	168L	No Data						
Jefferson Barracks	167L			9.43	11.18	12.96	15.60	17.02
Atwood	161L	6.58		10.61		15.28	18.51	18.78
Calico	148L	12.53		10.72	9.95	10.43	10.86	11.26
Osborne	145L	11.17	12.97	10.29	11.38	12.17	13.88	16.08
Harlow	143R	No Data						
Salt Lake	138L	8.17	11.82	9.43	8.75		11.03	12.08
Fort Chartres	133L	17.45	8.65	6.30		6.93	7.19	6.83
Establishment*	131R		10.09	11.50	15.15		17.30	17.83
Moro	122L		11.56		10.63	10.60	12.76	9.16
Kaskaskia	118R	No Data						
Crains	104R				9.14		7.89	7.52
Liberty	101L		19.45		17.37	15.63	15.22	13.81
River Mile 100 Islands	100R	No Data						
Jones*	97R			13.07	14.60	12.75	18.18	18.50
Cottonwood	78R	20.95	15.27	15.62		15.69	13.37	12.34
Crawford	73L		8.77	7.95	7.72	7.48	10.67	11.64
Vancil	68R	No Data						
Schenimann	60R			16.13		19.17	21.31	22.28
Picayune	58L					20.98	23.48	24.76
Marquette*	49L	16.20		17.70		14.51	19.99	19.26
Santa Fe*	38L			16.52		18.02		
Billings	33R	No Data						
Bumgard*	30L				17.18		20.20	19.79
Buffalo	25R	21.12		22.98	19.09	19.35	21.00	21.83
Browns	23L	21.44	20.14	20.95		18.25	20.47	20.51
Thompson	17R	No Data						
Sister*	12R			21.56		18.40	20.45	22.42
Boston	9L						19.49	19.19
Angelo	3L			24.47		24.93	28.31	27.83

*Denotes side channels that have had restoration measures implemented (Table 3-6).

** R and L denote Right Descending Bank and Left Descending Bank, respectively, indicating the side of the river the side channel occupies (as viewed by a person looking downstream).

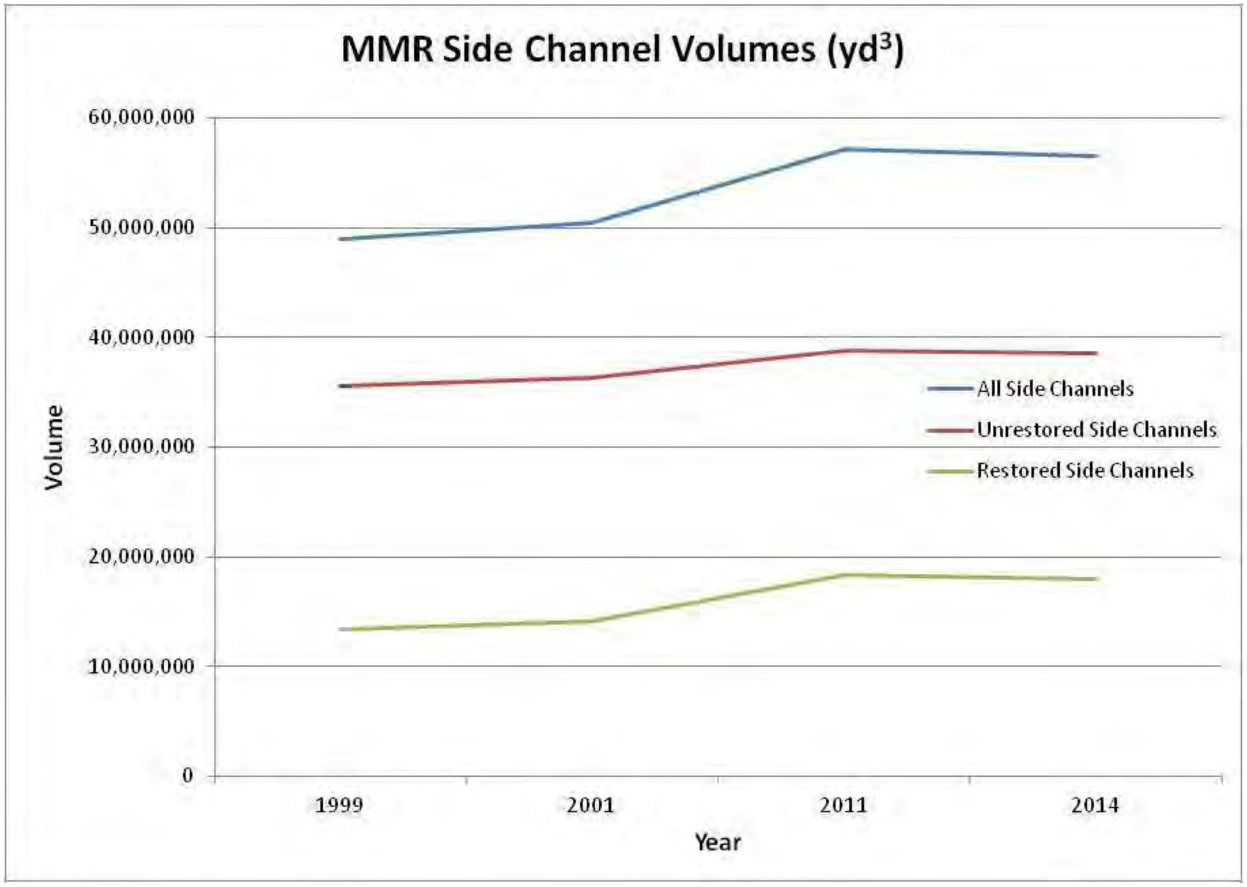


Figure 3-21. Total volume in cubic yards of MMR side channels for which multibeam datasets were available.

Connectivity Analysis

The District also recently conducted a connectivity analysis of MMR side channels to determine to what degree side channel habitat is accessible to fish from the main channel and vice versa. The connectivity of side channels is an important factor in determining the habitat they provide to fish. Due to the placement of rock closing structures, almost all MMR side channels are isolated from the main channel at certain river stages dependent upon the top elevation of the closing structure and any associated sedimentation patterns (Figure 3-22). The original purpose of closing structures was to shunt water to the main channel to support navigation flows. Of the existing thirty-two side channels, only one, Cottonwood, does not have a closing structure. The remaining MMR side-channels are in various successional stages, including wetlands, isolated backwaters, connected backwaters, isolated side channels (at low stages), and flowing side channels. The successional stage is related to side channel bed elevation and river stage, which translate into the level of connectivity to the main channel.

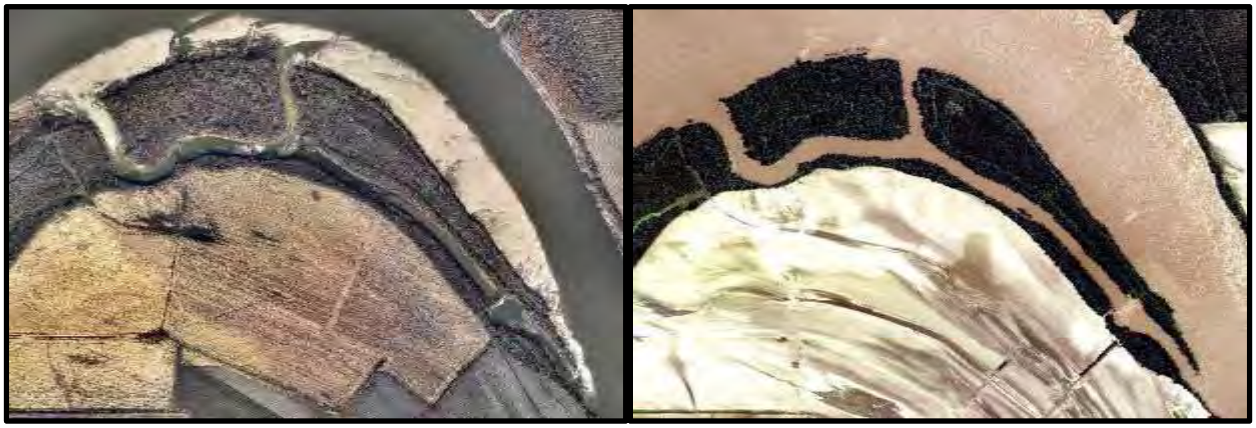


Figure 3-22. Low-water (left, 2012) and high-water (right, 2009) imagery of Sister Chute showing the difference in side channel connectivity based on river stage.

To determine the degree of connectivity of MMR side channels, multi-beam bathymetric surveys and median monthly river stages based on the period of record hydrograph were used. Bathymetric surveys were used to determine the choke points, or points that control the flow of water based on their elevation, of all side channels to determine at what river stage the side channels would be connected to the main channel. These choke point elevations were then compared to median monthly river stages to determine during which months the side channels would be connected. Median monthly river stages were used in order to provide an analysis of 'typical' connectivity conditions by month. This analysis was conducted for each side channel for every year that a multi-beam survey was available. An example of the choke points in one side channel can be found in Figure 3-23. The results of the connectivity analysis can be found in Table 3-5. In addition to the degree of connectivity, rates of change for choke point elevations were also considered to determine how quickly choke points were changing. Only those side channels for which multibeam datasets from 2001 and 2014 existed were used to calculate average annual changes in choke point elevations to avoid drawing conclusions from short time periods. The results of this analysis can be found in Figure 3-24.

Similar to average depth and volume characteristics, connectivity of MMR side channels reflects the expected variability in bathymetry but also holds to the general trend of stability or improvement. Of the 25 side channels for which connectivity was calculated for more than one year, 14 showed improved connectivity, 8 remained the same, and 3 showed decreased connectivity. Of the 15 side channels for which choke point elevations were available for 2001 and 2014, 13 showed improved chokepoints and 2 showed worsening chokepoints.

Figure 3-23. Example of connectivity analysis (Establishment Chute). Blue shading indicates the areas of the side channel that would be inundated at the point when the side channel becomes connected to the main channel. Yellow lines and yellow numbers indicate choke points and elevations. In this case, flow through the side channel would only occur at elevations of 13.8 or higher, as that is the highest of the three choke point elevations. This choke point elevation was then compared to mean monthly stages at the site to determine connectivity by month (see Table 3-5).

Table 3-5. 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. Gray represents side channels with insufficient data and/or with high barriers restricting flow during all but extremely high water events (modified from Keevin et al. 2016).

Side Channel		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Duck*	2001	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	2011	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	2014	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Mosenthein	2011	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	2014	Red	Green	Green	Green	Green	Green	Green	Green	Red	Red	Green	Red
Jefferson Barracks	2001	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red
	2011	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	2014	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Atwood	2001	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	2011	Red	Red	Red	Green	Green	Green	Red	Red	Red	Red	Red	Red
	2014	Red	Red	Red	Green	Green	Green	Red	Red	Red	Red	Red	Red
Calico	2011	Red	Red	Green	Green	Green	Green	Green	Green	Red	Red	Red	Red
	2014	Red	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Red
Osborne	2001	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
	2011	Red	Red	Green	Green	Green	Green	Green	Green	Red	Red	Red	Red
	2014	Red	Red	Green	Green	Green	Green	Green	Green	Red	Red	Red	Red
Harlow		Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray	Gray
Salt Lake	2001	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
	2011	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
	2014	Red	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Red
Fort Chartres	2001	Red	Red	Red	Green	Green	Green	Red	Red	Red	Red	Red	Red
	2011	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
	2014	Red	Red	Red	Green	Green	Green	Red	Red	Red	Red	Red	Red
Establishment*	2011	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
	2014	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Moro	2001	Red	Red	Green	Green	Green	Green	Green	Green	Red	Red	Red	Red
	2011	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	2014	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Kaskaskia	2001	Red	Red	Red	Green	Green	Green	Red	Red	Red	Red	Red	Red
	2011	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
	2014	Red	Red	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
Crains	2011	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	2014	Red	Red	Red	Green	Green	Green	Red	Red	Red	Red	Red	Red

*Denotes side channels that have had restoration measures implemented (Table 3-6).

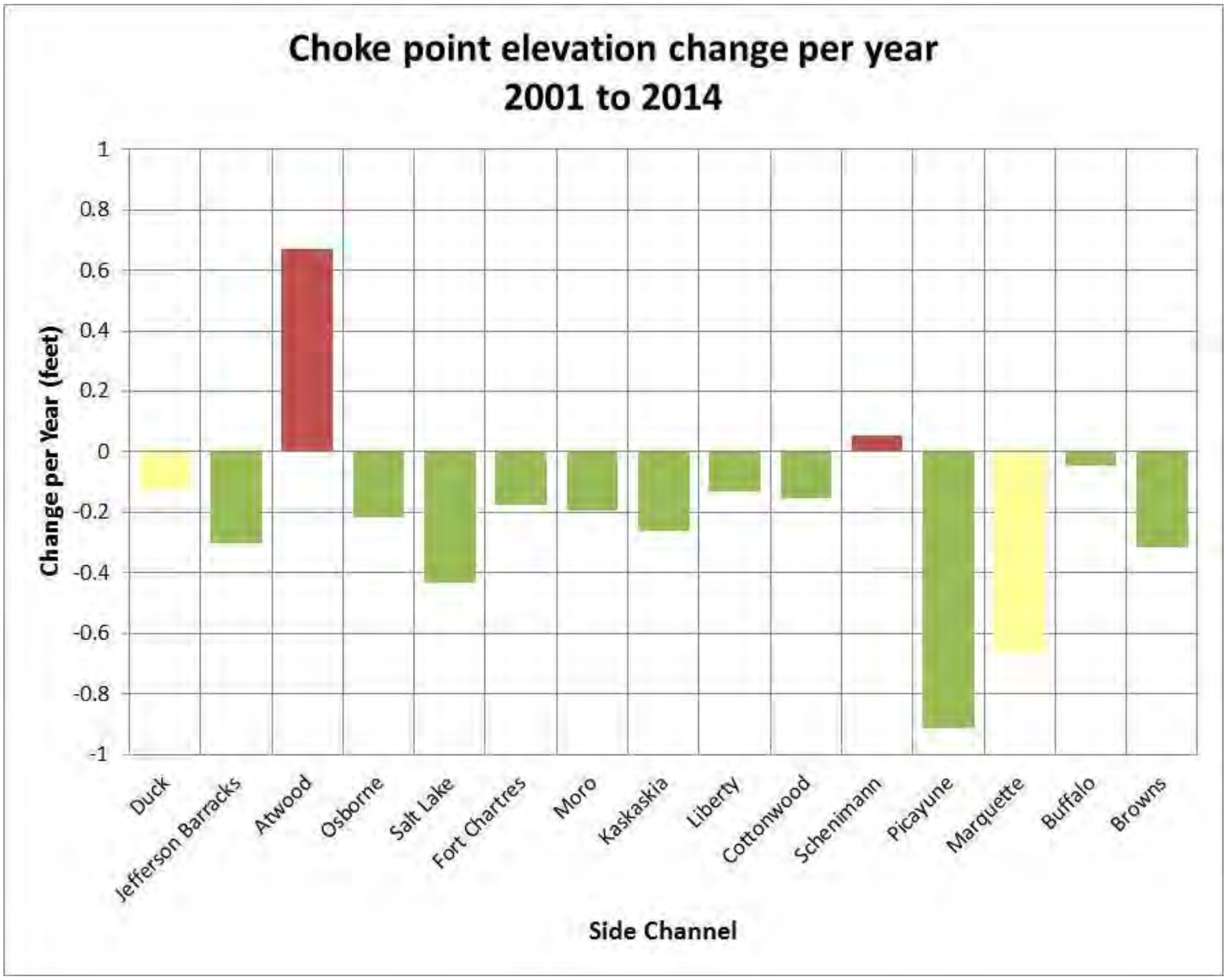


Figure 3-24. Recent changes in elevations of choke points of MMR side channels. Changes are provided for only those side channels for which 2001 and 2014 multibeam bathymetric datasets were available. Changes are in feet per year, with green representing a decrease in elevation and red representing an increase. Yellow shading indicates side channels where restoration activities occurred.

Side Channel Restoration Efforts

Beginning in the late 1990s, the District started to undertake side channel restoration projects under various authorities, including avoidance and minimization measures as part of the Regulating Works Project. These efforts typically consist of features to improve the connectivity of the side channel and/or improve the habitat within the side channel. Improvements have involved the removal or notching of closing structures and other dikes, placement of hard points within the side channel to increase habitat diversity, and dredging to deepen and improve the connectivity of the side channel. Table 3-6 provides details of all side channel restoration efforts undertaken in the MMR by the District to date. Clear before-and-after differences can be seen in the mean depth and connectivity characteristics of some of the restored side channels, particularly those that involved closing structure notching and/or dike removal (Table 3-4 and Table 3-5 above). For example, subsequent to dike removal and closing structure notching in 2008, Jones Chute's mean depth increased by approximately 5.5 feet. Similarly, after closing structure and dike notching in 2012, Establishment Chute's connectivity improved substantially. Based upon available funding and continued authority, it is expected that the District will continue to plan and implement MMR side channel restoration projects.

Table 3-6. Middle Mississippi River side channel restoration efforts.

Side Channel	Year Restoration Initiated	Features Implemented
Santa Fe	1997	Hard point construction
Bumgard	1999	Hard point construction
Duck	2001	Hard point construction
Marquette	2001	Closing structure notching
Sister	2006	Environmental dredging
Jones	2008	Dike Removal, closing structure notching, dike construction, hard point construction
Establishment	2012	Dike/closing structure notching, side channel enhancement dike construction to increase volume of water flowing through side channel

Summary of Findings on Side Channels

Drawing broad, general conclusions about the status of MMR side channels is difficult due to the unique characteristics of each individual side channel and due to the dynamic nature of the system of which they are a part. Trends can be difficult to discern when clouded by the variability that is added by extreme flood and drought events that are part of every large river system. However, focusing on long-term trends helps to eliminate the noise imparted by short-term anomalies and some general trends can be seen in the long-term records. Based on aerial photography and geomorphology characteristics, most MMR side channels appear to be very stable in planform characteristics, with very little change occurring since the mid-1900s. Based on bathymetric surveys, overall depth characteristics likewise appear to be stable or improving, although a considerable amount of interannual variability occurs. Connectivity of MMR side channels reflects the variability in depth characteristics as well but also holds to the general trend of stability or improvement.

These trends were also considered without inclusion of side channels that have undergone any type of restoration activity in order to gain an understanding of the "natural" trends of MMR side channels without intervention (see Table 3-6 for a list of side channels where restoration projects have occurred). A total of 32 side channels exist in the MMR, 25 of which would be considered unrestored. Of the 25 unrestored side channels, 15 have bathymetric surveys available for a period spanning at least 15 years. Of those 15, 8 showed an increase in average depth over the period of record and 7 showed a decrease (Table 3-4). Total volume of unrestored MMR side channels has increased slightly in the last 15 years (Figure 3-21). Of the 19 unrestored side channels for which connectivity was calculated for more than one year, 9 showed improved connectivity, 6 remained the same, and 4 showed decreased connectivity (Table 3-5).

The above general conclusions about MMR side channel characteristics hold true for the majority of MMR side channels. However, there are several side channels that are typically inaccessible due to log jams or tree encroachment and consequently cannot be readily surveyed. Carroll Island Chute underwent a fairly rapid transition to what is now largely terrestrial habitat (Figure 3-25). Harlow Island Chute has undergone a similar transformation. Within the last 10 years, Crains and Billings Chutes have become partially filled with log jams. Some of the log jams cleared from Crains during a recent high water event, but others remained. The long-term fate of these side channels is difficult to predict with any degree of certainty.

Figure 3-25. Imagery of Carrol Island Chute (river mile 168) showing filling and conversion to terrestrial habitat from 1981 to 2012.

Thompson Chute has experienced tree encroachment on the upper and lower ends, but appears to be stable in planform throughout the rest of the channel. Without the ability to obtain bathymetric surveys it is difficult to say whether or not Thompson is maintaining its depth. Vancil is a very small side channel that is difficult to access for surveying purposes and it is difficult to predict whether or not Vancil is filling in.

It should be noted that the River Mile 100 Islands side channel (Figure 3-26) is not a naturally formed side channel and is dissimilar in morphology to other MMR side channels. The islands associated with this particular side channel were formed as a result of the wing dikes being constructed with notches in them to encourage sandbar/island formation. Similar results may be possible in other locations on the MMR either through dike notching and/or with the use of the floating flexible dredge pipe currently in use by the District (see Section 4.3.2 Impacts on Fishery Resources for information on the floating flexible dredge pipe).

Figure 3-26. River Mile 100 Islands side channel during high water (looking downstream).

Islands

Along with the side channels that occur in conjunction, islands play an important role in the ecology of large rivers (Johnson and Jennings 1998; Hintz et al. 2014). Anthropogenic loss of island habitat has resulted in a reduction in habitat heterogeneity in large rivers due to the loss in braiding, meandering, channel complexity, complex habitat patterns, and snag abundance.

Thorp (1992) found that Ohio River islands had a significant positive effect on invertebrate density and diversity that appeared to be related to the heterogeneity of physical habitat characteristics associated with islands. Current velocity and substrate size were diminished in the narrow channels between islands and the shoreline, and the area of the littoral zone increased within an otherwise deepwater region. Hintz et al. (2014) showed habitat heterogeneity around

MMR islands was an extremely important factor controlling shovelnose sturgeon abundance. At the course spatial scale, submerged woody vegetation was positively related to shovelnose sturgeon abundance. At the fine spatial scale, depth and flow were important.

Ephemeral islands/sandbars constructed with dredged material also appear to provide habitat conditions similar to natural islands for both aquatic and terrestrial organisms, as long as habitat heterogeneity is incorporated into the design and material placement (Chipps et al. 1997; Strucker et al. 2012, 2013). The St. Louis District uses flexible dredge pipe to create ephemeral islands from dredged material (see Section 1.1.4 Process for Dredging under the Regulating Works Project).

Chips et al. (1997) found an increase in species richness combined with similar trophic structure among fish communities at dredge disposal sites (island creation) compared with the pre-island construction conditions. They concluded that construction of islands with dredged material has the potential to increase species richness and create shallow-water habitat that is essential for fish rearing habitat. Strucker et al. (2013) found that the federally endangered Least Terns (*Sternula antillarum*) nest success was 1.8 times greater on sandbars (ephemeral islands) constructed with dredged material than on natural sandbars. Micro-habitat selection by Least Terns was responsible for the apparent differences in sandbar selection. Least tern selected nest sites had coarser and larger substrate materials at the nest, more debris, and less vegetation than the surrounding area. Nests on constructed habitats had a greater percentage of coarse substrates, more debris and less vegetation than nests in naturally created habitats. Strucker et al. (2012) found that constructed habitat supported fish communities, the food of least terns, at similar levels of relative abundance to natural habitats. Allen (2010) studied the use of the MMR Mile 100 islands by fishes. Allen found that, although islands and reference sites (nearby areas between dikes without islands) did not differ significantly in catch per unit effort, the islands had greater total, adult, and young-of-year species richness than reference sites.

Recent studies of MMR island habitat (Allen 2010; Brauer et al. 2005; Brauer et al. 2013) found that islands predictably followed a pattern of change similar to side channels. Island acreage in the MMR went through a period of rapid expansion in the 1800s followed by a period of rapid contraction in the early 1900s (Figure 3-27). MMR island acreage has been relatively stable since the mid-1900s.

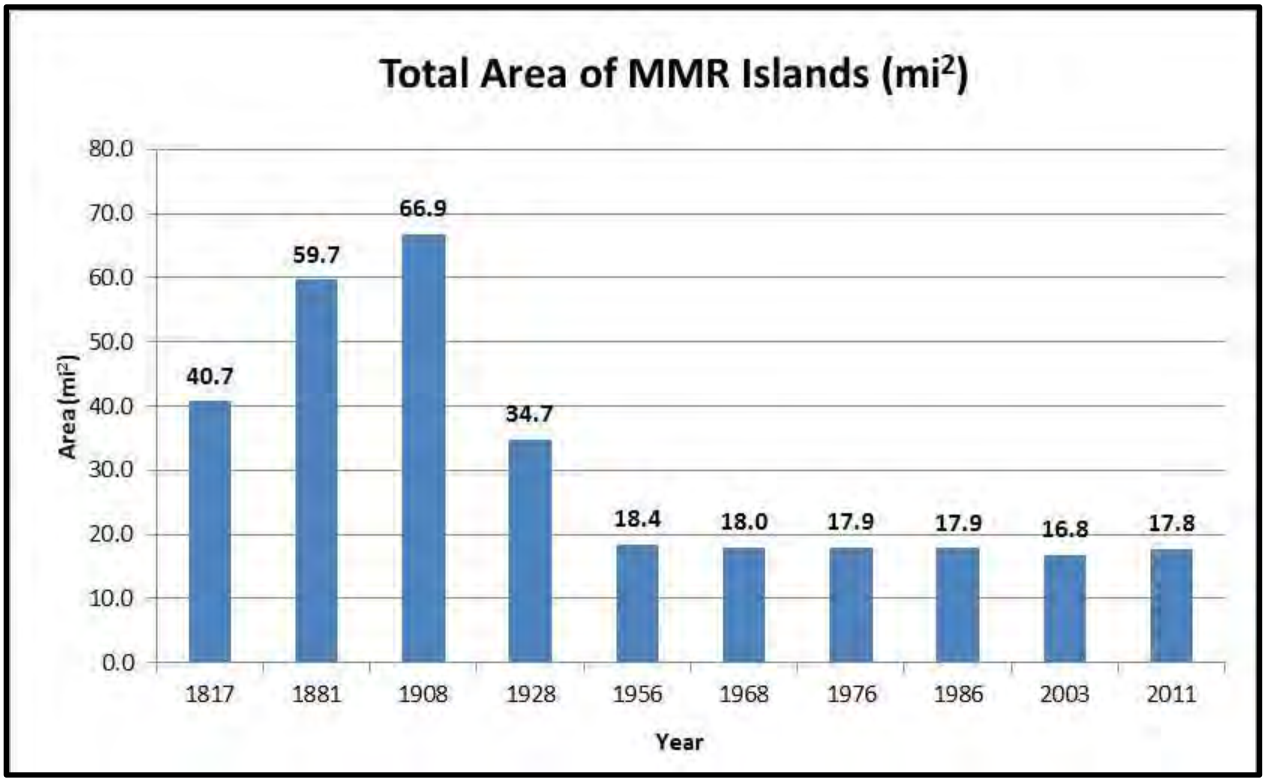


Figure 3-27. Total area of MMR islands in square miles from 1817 to 2011 (from Brauer et al. 2013).

3.2.3 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. However, recent changes in wastewater treatment laws and technologies, regulation of point source discharges, and changes in public awareness have contributed to dramatic overall improvements in water quality since the 1970s. Water quality monitoring has been conducted in the MMR through the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring (LTRM) element since 1991. Analysis of LTRM data (Johnson and Hagerty 2008) shows that 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). During major storm events, raw sewage still enters the river because of sewage treatment plant overloads due to combined (sewage/stormwater) sewage systems.

Although the USEPA has oversight authority, particularly with regard to interstate water quality, it is the responsibility of the individual states to implement most of the Clean Water Act, including the establishment of water quality standards. 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. However, there are inconsistencies among state water quality standards. Specific water quality criteria for individual pollutants may vary depending on the designated use for a specific segment of the Mississippi River. The Middle Mississippi River was included on the 2014 state of Missouri 303(d) list for St. Louis City, St. Louis County and St. Genevieve County due to fecal coliform contamination from point and non-point sources of wastewater treatment plant effluent and urban storm water. The 2014 state of Illinois 303(d) list places use restrictions for human contact-recreation due to fecal coliform contamination and fish consumption due to mercury and PCB contamination along the length of the Middle Mississippi River.

There are also fish consumption advisories for the MMR for both Missouri and Illinois. Missouri has fish consumption advisories for the Mississippi River for Shovelnose Sturgeon (one meal per month) and for Flathead Catfish, Blue Catfish, Channel Catfish, and Common Carp (one meal per week) due to PCB, chlordane, and mercury contamination (MDHSS 2015). 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 (IDPH 2014).

3.2.4 HTRW

Environmental Site Assessments

Corps regulations (ER 1165-2-132 and ER 200-2-3) and District policy require procedures be established to facilitate early identification and appropriate consideration of potential hazardous, toxic, or radioactive waste (HTRW) in reconnaissance, feasibility, preconstruction engineering and design, land acquisition, construction, operations and maintenance, repairs, replacement, and rehabilitation phases of water resources studies or projects by conducting Environmental Condition of Property (ECP) Assessments. The Corps specifies that these assessments follow the process/standard practices for conducting Phase I Environmental Site Assessments (ESA) published by the American Society for Testing and Materials (ASTM).

This assessment was prepared using the following ASTM Standards:

- E1527-13: Standard Practice for Environmental Site Assessments – Phase I Environmental Site Assessment Process
- E1528-06: Standard Practice for Limited Environmental Due Diligence – Transaction Screen Process (interview questionnaires)
- E2247-08: Standard Practice for Environmental Site Assessments – Phase I Environmental Site Assessment Process for Forestland or Rural Property

The purpose of an ECP is to identify, to the extent feasible in the absence of sampling and analysis, the range of contaminants (i.e., Recognized Environmental Conditions[10] or RECs) within the scope of the U.S. Environmental Protection Agency's (EPA) Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and petroleum products.

All proposed improvements and construction projects are evaluated for potential soil contamination, groundwater quality, surface water quality and issues related to hazardous substance uptake by biota. Site visits are conducted to observe present conditions and check for the presence of chemical spill residue, die-back of vegetation, and prior environmentally hazardous activities. Historical aerial photography of the vicinity and U.S. Geological Survey (USGS) maps are also used to study drainage patterns and topography.

Information is obtained through reviews of records and reports, reviews of environmental databases, site reconnaissance, and interviews of persons knowledgeable of the property history. The readily available electronic records of the U.S. Environmental Protection Agency (USEPA) EnviroMapper and state and local databases are reviewed to identify Superfund sites, toxic releases, or hazardous waste sites within or directly adjacent to the potential project sites.

Records Review
A modified Phase I- Environmental Site Assessment records search was conducted to identify superfund sites, toxic chemical spills, or hazardous waste sites directly adjacent to or within the banks of the Middle Mississippi River. The readily available electronic records of the USEPA, the Missouri Department of Natural Resources (MDNR), the Illinois Environmental Protection Agency (IEPA), and the USGS found numerous permitted, regulated, and documented sources of chemical pollutants along both banks of the Middle Mississippi River. This review also found areas which could potentially be impacted by the alternatives.

Findings of Records Review

Sauget Area 2 Superfund Site
The Sauget Area 2 Superfund Site is located on the left descending bank (LDB) near river mile (RM) 178 (Figure 3-28). The site consists of four landfills and four backfilled lagoons. The sites contain hazardous wastes that resulted from treatment and disposal of industrial, municipal, and chemical wastes. In 2005, USEPA contractors collected and analyzed sediments from the Mississippi River for total organic carbon, volatile organic carbon, polychlorinated biphenyl (PCB), pesticides, herbicides and sediment grain-size. Core samples collected from 28 sample locations along the river adjacent to the site had elevated levels of organochlorine pesticides, aromatic hydrocarbons, and PCBs. Samples collected from the left descending bank of the river near Jefferson Barracks chute at RM 170 and from the right descending bank at RM 172 contained concentrations of pesticides and PCBs exceeding Ecological Screening Levels. In 2006, USEPA completed the installation of a 3,500-foot long, 140-foot deep jet grouted barrier wall between the down gradient boundary of the site and the Mississippi River. Measures were

[10] Recognized Environmental Conditions are defined by ASTM E1527-13 as "...the presence or likely presence of any hazardous substances or petroleum products in, on, or at a property..."

put in place to protect the shoreline from erosion along with controls to prevent disturbance of soil and waste. The soil and waste on the site were capped with layers of soil, asphalt, crushed rock and other materials to contain contamination. A pumping system was installed to collect and store oil, petroleum products and liquids including chlorinated solvents present on the site. Continued cleanup is planned for the site including further capping of waste sites with soil, asphalt, crushed rock and other materials to contain contamination; installation of a pumping system to collect contaminants in a well at the site; and further measures to prevent Mississippi River shoreline erosion adjacent to the site.

Doe Run Lead Smelter

Runoff from the area around the Doe Run lead smelter in Herculaneum, Missouri, flows into Joachim Creek and discharges into the Mississippi River along the RDB at RM 151.4. The runoff from this area carries with it lead- and zinc-contaminated fine sediment from the smelter facility and the slag pile adjacent to the creek. The contaminated sediments are most likely washed into the river during high flow events since these metals have been detected below the confluence of Joachim Creek.

Laboratory tests were performed on sediment samples collected up and down river of Herculaneum at varying times between 1999 and 2009 by the USGS, IEPA, and MDNR. The average lead and zinc concentrations upstream between Joachim Creek and St. Louis were 15.2 and 62.2 µg/L respectively. The average concentrations at the Joachim Creek outfall were measured at 1710 and 4920 µg/L respectively and far exceeded the values commonly reported as toxic to aquatic life. The average lead and zinc concentrations recorded between 0.2 and 6 miles below the outfall were 15.3 and 50.9 µg/L respectively and 50 miles downstream the averages were 14.1 and 63.3 µg/L respectively. These test results indicate that the insoluble lead and zinc particles settle less than a mile from where they are discharged and are not transported farther downstream by the river.

The company reached a comprehensive settlement with the USEPA and the state of Missouri to discontinue its smelting operations in Herculaneum. Cleanup activities were undertaken to remedy the lead- and zinc-contaminated fine sediments leaving the Herculaneum Smelter site. The selected removal action included engineering measures to contain and treat water runoff, control erosion, provide flood protection, provide long-term stability, and mitigate wetland disturbance. This remedial action also included construction of a flood protection berm, a storm water retention basin, and an engineered cover for the slag material.

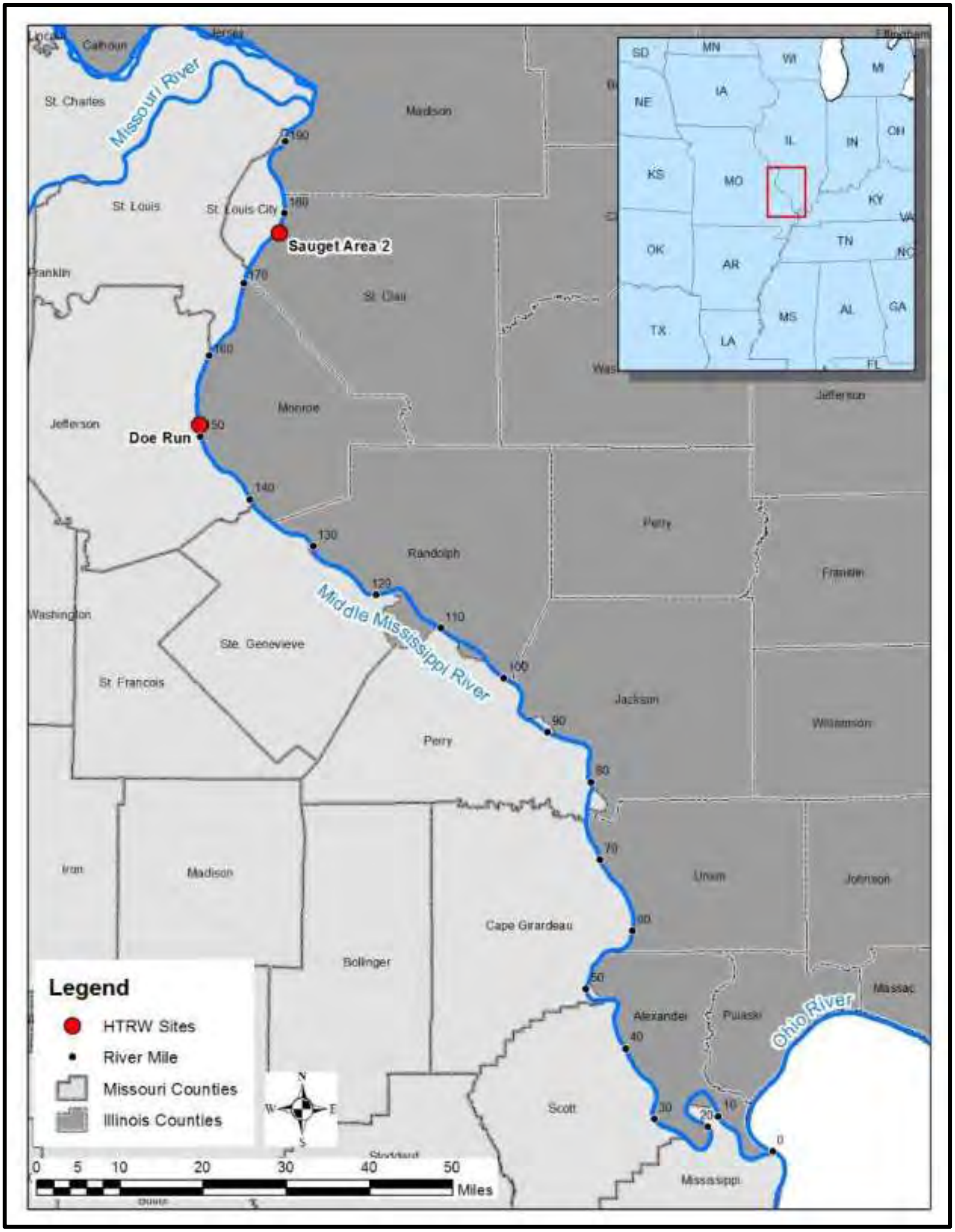


Figure 3-28. Locations of potential HTRW issues within the Project Area discovered through a modified Phase I Environmental Site Assessment records search.

3.2.5 Air Quality and Climate Change

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

Figure 3-29 and Table 3-7 contain information on the nonattainment areas in Missouri and Illinois counties in the Project Area. All of the nonattainment areas are located in close proximity to the St. Louis Metropolitan area and include St. Louis City, St. Louis County, Jefferson County, Madison County, St. Clair County, Monroe County, and Randolph County.

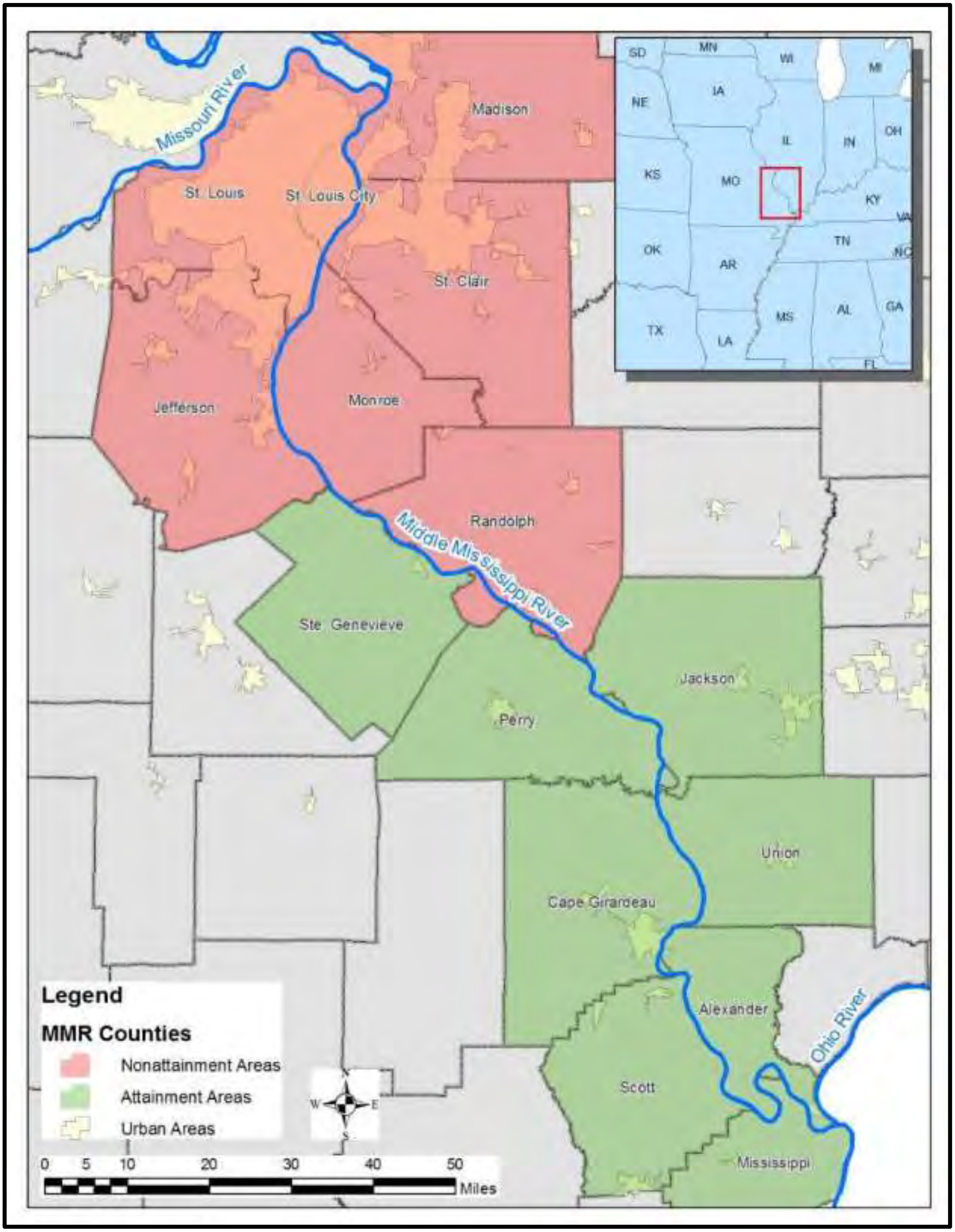


Figure 3-29. Attainment/Nonattainment status of Missouri and Illinois MMR counties for six criteria air pollutants (based on 5 December 2013 USEPA data).

Table 3-7. Nonattainment areas in Missouri and Illinois within the Project Area (based on 5 December 2013 USEPA data).

County	Pollutant	Classification*
Missouri		
St. Louis County	8-hour Ozone (1997 Standard)	Moderate
	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
St. Louis City	8-hour Ozone (1997 Standard)	Moderate
	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
Jefferson County	8-hour Ozone (1997 Standard)	Moderate
	8-hour Ozone (2008 Standard)	Marginal
	Lead (1978 Standard)	N/A
	Lead (2008 Standard)	N/A
	Particulate Matter – 2.5 (1997 Standard)	N/A
	Sulfur Dioxide (2010 Standard)	N/A
Illinois		
Madison County	8-hour Ozone (2008 Standard)	Marginal
	Lead (2008 Standard)	N/A
	Particulate Matter – 2.5 (1997 Standard)	N/A
St. Clair County	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
Monroe County	8-hour Ozone (2008 Standard)	Marginal
	Particulate Matter – 2.5 (1997 Standard)	N/A
Randolph County	Particulate Matter – 2.5 (1997 Standard)	N/A

*Nonattainment area designations based on Environmental Protection Agency classification system of marginal, moderate, serious, severe 15, severe 17, or extreme. See https://www3.epa.gov/airquality/greenbook/define.html for more information.

Climate Change.
A large body of scientific evidence indicates that increases in greenhouse gases[11] (GHG) in the Earth's atmosphere are contributing to changes in national and global climatic conditions (Melillo et al. 2014). These changes include such things as increases in average temperature, changes in precipitation patterns, and increases in the frequency and intensity of severe weather events. These changes have the potential to impact a wide sector of the human environment including water resources, agriculture, transportation, human health, energy, and aquatic and terrestrial ecosystems. Therefore, it is important to understand the potential impacts of federal actions on GHG emissions and climate change and the potential changes that may occur to the human environment which could subsequently affect the assumptions made when determining the impacts and efficacy of the federal action in question.

[11] 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).

GHG emissions in the United States in 2014, the most recent year for which data were available, totaled 6.9 billion metric tons CO_2 Equivalent[12] (CO_2 Eq). As shown in Figure 3-30, CO_2 accounted for the majority of that total at 81%. The vast majority of U.S. CO_2 emissions come from the combustion of fossil fuels (94% in 2014, the latest year for which information was available). Fossil fuel combustion in the U.S. is largely for electricity generation, transportation, and industrial activities (Figure 3-31). Current data and analysis of regional climate change can be found in Section 4.2.5 Impacts on Air Quality and Climate Change.

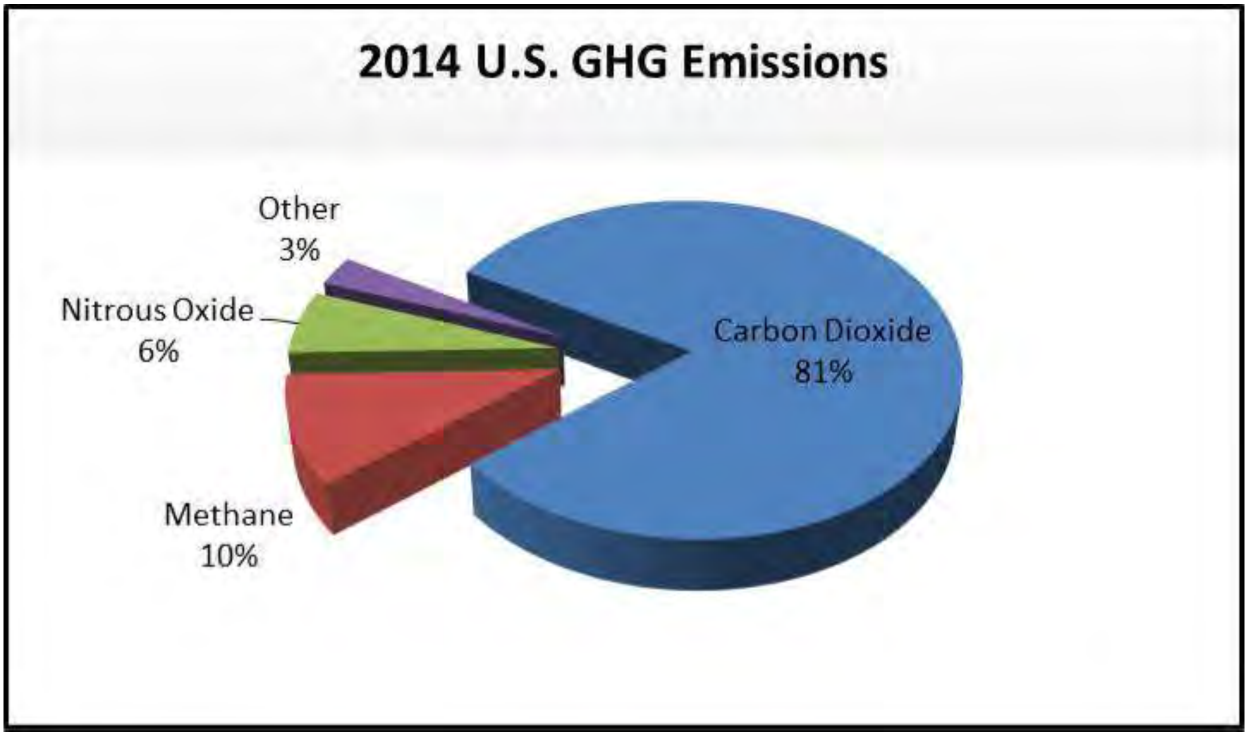


Figure 3-30. 2014 U.S. GHG Emissions (percentages based on metric tons of CO2 Eq; from USEPA 2016).

[12] CO_2 Eq is a standard metric used to express the global warming potential of different greenhouse gases. The energy absorbing capabilities of gases are converted to the equivalent energy absorbing capability of carbon dioxide in order to make emissions information more readily compared and understood (USEPA 2014).

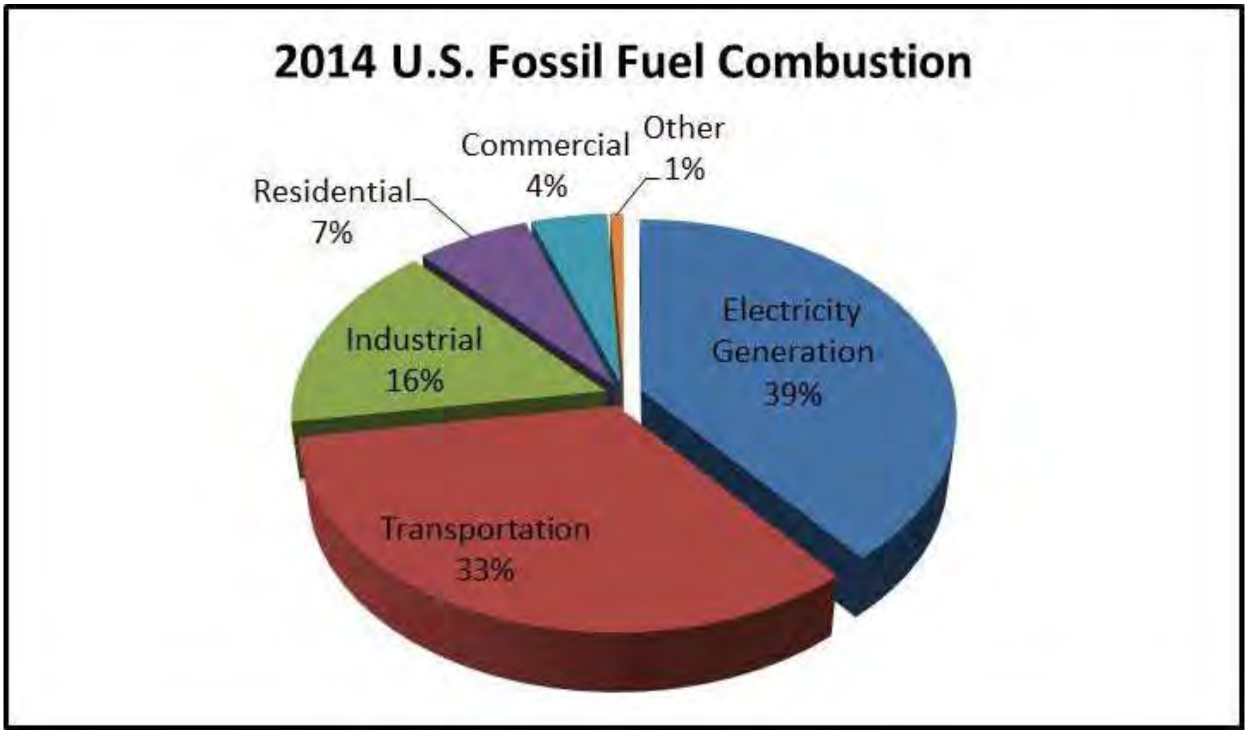


Figure 3-31. 2014 U.S. Fossil Fuel Combustion (percentages based on metric tons of CO2Eq; from USEPA 2016).

3.3 Biological Resources

The following discussion of the biological resources of the Project Area is broken into three broad habitat categories: main channel, main channel border, and side channels. For reference, the relative abundance of these habitats is provided in Table 3-8.

Table 3-8. Acreage of main channel, main channel border, and side channel habitat in the MMR in 1976 and 2014.

	1976 Acreage	2014 Acreage
Main Channel	20,834	25,134
Main Channel Border	29,911	24,592
Side Channels	3,893	4,128

3.3.1 Benthic Macroinvertebrate Resources

Macroinvertebrates feed predominantly on fine particulate organic matter, bacteria, phytoplankton, and zooplankton. They are an extremely important part of the MMR food web and serve as a food source for a variety of fish and wildlife species. They are at the base of the food web and are eaten by almost every larger organism. Harrison and Morse (2012) compiled a list of benthic invertebrates that inhabit the Mississippi River based on the published literature and recorded 215 total taxa. They note that the benthic invertebrate fauna of the Mississippi River has been poorly documented and existing records are patchy with some macrohabitats being sampled extensively, while others, such as the main channel, remain largely unknown. The total number of taxa will undoubtedly increase substantially and understanding of their life history and ecology will increase as new studies are conducted.

Prior to the implementation of the Clean Water Act (1972), the MMR acted as 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 and low dissolved oxygen levels (< 5 mg/l) and a benthic fauna that was dominated by a pollution tolerant benthic macroinvertebrate community. During a water pollution study (Bi-State Development Agency 1954) conducted in the MMR during 1951 and 1952, only 13 species of benthic macroinvertebrates were collected at 14 sites from St. Louis (RM 196.2) to below Cape Girardeau (River Mile 48.0), and pollution-tolerant tubificid worms completely dominated the benthic fauna. Tubificid worms are often referred to as sewer worms or sludge worms because they are often found in sewage sludge below sewage outfalls. Tubificids survive with little oxygen by waving hemoglobin-rich tail ends to exploit all available oxygen.

During the fall of 1952, tubificid worms reached their maximum abundance when they averaged 2,764 per square yard. For comparison, six relatively clean-water stations on the Mississippi River between LaCrosse, Wisconsin, and Dubuque, Iowa, averaged 28 per square yard. Although historic benthic macroinvertebrate collection data are sparse, poor water quality conditions undoubtedly persisted into the late 1970s or early 1980s. In a recent benthic macroinvertebrate study in the MMR near Cape Girardeau, Battle et al. (2007) collected 68 taxa from fine sediments and 50 taxa from rock substrate, indicating that water quality has improved considerably.

In the Programmatic EIS for the UMR-IWW System Navigation Feasibility Study (USACE 2004), freshwater mussels (as a specialized group of benthic macroinvertebrates) were considered a significant resource and the potential impacts of increased navigation traffic were evaluated for this specialized group of organisms. Freshwater mussels were certainly deserving of the “significant resource” status because of their high density (mussel beds) and ecological importance in parts of the UMR (Newton et al. 2011); the large number of native U.S. mussel species that are considered extinct, endangered, threatened or of special concern (Williams et al. 1993); recent changes in UMR mussel assemblages (Ziegler et al. 2012); the fact that about 60% of the 50 species present in the UMR historical record are now state or federally listed species (Tucker and Theiling 1999); and the multitude of potential anthropogenic factors that may be responsible for their population declines (Downing et al. 2010).

Although the MMR does support scattered mussels along the main channel border, within side channels, and in floodplain lakes (Keevin et al., 2016, submitted; Tiemann 2014), the densities in the river and side channels are extremely low, with no known mussel beds. This is the presumed historic condition in the MMR due to the unstable sand substrate, constantly moving sand waves, and high turbidity levels. Bartsch (1916) suggested that “the heavy load of mud” from the Missouri River was responsible for the lack of freshwater mussels in the MMR. Ellis (1931) concluded that silt was prohibitive for many species in the MMR. Van der Schalie and van der Schalie (1950) indicated that the Mississippi River, below the mouth of the Missouri River, was “poor in mussel production because of the tremendous loads of erosion silt carried into it from the extensive treeless plains draining the Missouri River.” This condition is not unexpected; sand bed rivers normally do not support mussel populations because of their unstable substrates (Hagg 2012).

The four most abundant species collected from MMR side channels and floodplain lakes (borrow pit lakes) during 1989-1990, representing 92% of the total number of specimens collected, were the Giant Floater (*Pyganodon grandis)*, Fragile Papershell (*Leptodea fragilis)*, Pink Papershell (*Potamilus ohiensis)*, and Flat Floater (*Anodonta suborbiculata)* (Keevin et al., 2016, submitted). These are all short-lived, thin-shelled species that are either habitat generalists or show a preference for sluggish water found in floodplain lakes, sloughs, and oxbows (Parmalee 1967; Oesch 1995; Cummings and Mayer 1992).

Young mussels, called glochidia, are gill/skin parasites on fish. They can be moved long distances by migrating fish. They drop off the host fish when they mature and their survival depends on dropping on suitable habitat (Haag 2012). It is quite possible that the giant floater, fragile papershell, pink papershell and flat floater are the only resident mussels of the MMR and that the other species collected in small numbers were transported to the MMR by fishes from the Upper Mississippi River and tributary rivers to the MMR that support a diverse mussel fauna. In summary, the main channel and main-channel border of the MMR do not provide suitable mussel habitat. It is possible that the MMR supports only four resident mussel species in side channels and floodplain lakes. Due to the lack of a significant mussel resource in the MMR, an impact analysis for this important group of macroinvertebrates will not be conducted.

Main Channel

The bottom substrate of the main channel of the MMR consists of course, shifting sand with a minimum amount of fine organic particulate matter. The sand is constantly moving in a downstream direction as sand waves. The height and periodicity of the sand waves change in response to water velocity and temperature (water density). This constantly shifting sand habitat with minimal food resources for resident benthic macroinvertebrates does not support a diverse benthic macroinvertebrate community; however, organisms do live in this habitat. Dettmers et al. (2001a) found that benthic macroinvertebrates were abundant in the main channel of the Mississippi River (Pool 26). Organisms in the sediments consisted primarily of a few specialized larval chironomids (primarily *Robackia* and *Rheosmittia*), nematodes, and sand- dwelling oligochaetes (*Barbidrilus* spp.). The mean density of macroinvertebrates in the upper, free-flowing portions of Pool 26 was greater than 80,000/m^2 in the main channel. The upper reaches of UMR pools are free-flowing and provide physical conditions (flow velocities and sediments) that are similar to the MMR. Solomon et al. (1974) sampled recently dredged main channel sites on the MMR and found extremely low densities of only one genus of chironomids (nonbiting midges) and a few individuals of two genera of Trichoptera (caddisflies). Some chironomids are referred to as blood worms because of their blood color due to high hemoglobin content used to obtain oxygen in hypoxic conditions (Figure 3-32). No oligochaete worms were collected by Solomon et al. (1974) in the main channel whereas Battle et al. (2007) found them to be the most abundant macroinvertebrate in channel border habitat. This discrepancy (no oligochaetes found by Solomon et al. in the main channel) is likely due to the size mesh used in the sieves to screen samples. Solomon et al. (1974) used a mesh size almost twice as large as Battle et al. (2007).

Figure 3-32. Larval chironomid. This group of benthic macroinvertebrates is referred to as blood worms because of their high hemoglobin levels, which is an adaptation for low oxygen conditions. Photo from Sauer (2004).

Although densities of main channel macroinvertebrates in shifting sand areas can be high, the total biomass per unit of area is generally small. For example, in the Sand River (Alberta, Canada), benthic macroinvertebrate density ranged from 12,000 to 78,000 individuals/m^2 (*Robackia* and *Rheosmittia* contributed a mean of 80.6% of the biomass and 92.8% of the total numbers of macroinvertebrates), while the total biomass was low (50–490 mg/m^{2}dry mass). However, when you consider that 44% of the MMR is main channel habitat, representing approximately 24,000 acres, the total number, density, and biomass of benthic macroinvertebrates that live in the MMR main channel is extremely large.

Main Channel Border

Common macroinvertebrate fauna encountered in the main channel border of the MMR consist of a variety of oligochaete worms, flies, mayflies, caddisflies, and stoneflies. Sampling by Battle et al. (2007) near Cape Girardeau, Missouri, shows 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. Poulton and Allert (2012) demonstrate that the size of dike pools (the scour holes below training structures) and the chemistry of sediments and overlaying water best explain the diversity and productivity of aquatic macroinvertebrates in lower Missouri River dike pools. So, it would be expected that the diversity and density of macroinvertebrates would differ somewhat below each MMR dike depending on the size of the scour hole, sediment characteristics, and flow.

Macroinvertebrates were also collected from rock surfaces in bendway weir fields in the MMR at RM 164 near Oakville, Missouri (Ecological Specialists 1997a), and at RM 30 near Commerce, Missouri (Ecological Specialists 1997b). Twenty-nine taxa were collected at RM 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 RM 30 with caddisflies again the overwhelmingly dominant group; midges were present but not as abundant as at RM 164. Density averaged 16,240 individuals per square meter. Sampling conducted in sand substrate at a nearby bendway without weirs (RM 20) yielded seven taxa and 965 individuals per square meter with oligochaete worms being the overwhelmingly dominant group. Rock training structures have been shown to support high densities of aquatic macroinvertebrates when compared to the natural substrate of the main channel border, which in turn provides high quality foraging habitat for fish.

There is concern from partner resource agencies that changes in watershed land cover characteristics, historic removal of woody snags from the river for navigation, and shoreline stabilization with revetment have reduced the amount of woody debris in the MMR, thereby reducing an important substrate for macroinvertebrate colonization. As part of implementation of the 2000 Biological Opinion, the District constructed wooden pile dikes and woody bundles in the MMR and incorporated some woody structure into rock river training structures (USACE 2013). Macroinvertebrates were collected from wood surfaces at one of the areas with a pile dike and woody bundles (RM 187 north of St. Louis, Missouri) in 2003 (Ecological Specialists 2004) as well as from the surrounding sand substrate. Wood structure sampling yielded 34 taxa of macroinvertebrates and sand substrate yielded 18. Hydropsychid caddisflies were by far the most abundant taxonomic group in both areas. Overall density of macroinvertebrates averaged 5,724 individuals per square meter for wood structures and 1,123 individuals per square meter for sand substrate. Wood structures generally harbored a significantly higher density and species richness than the sand substrate. Rock structure sampling in the MMR yielded similar species richness and similar or somewhat higher density and diversity when compared to wood surfaces sampled in this study.

Side Channels

The most recent survey of benthic macroinvertebrates in MMR side channels was conducted by Ragland (1974) in three side channels (Liberty, River Miles 100.2.-102.8; Ft. Chartres, RM 132.3-134.2; and Osborne, RM 144.5-146.4) and three adjacent main channel border locations. Aquatic insects comprised 96% of the total organisms collected. Oligochaetes represented another 3%, with a large number of other organisms in lesser numbers representing the final 1%. Oligochaetes, damselflies, and larval chironomids were consistently captured in greater numbers from side channels than from the main channel border habitat. Mayfly nymphs, pupal chironomids and larval caddisflies were captured in greater numbers from main channel border locations than from side channels. Considering that every MMR side channel currently has a different level of connectivity to the main channel (see Section 3.2.2 Geomorphology) and associated flow characteristics, it would be expected that the species composition, diversity, and density of macroinvertebrates would be somewhat different in each side channel. For example, isolated side channels would be expected to support more lake-like faunas while free-flowing side channels would support more riverine faunas. The more isolated side channels would also be expected to have poorer water quality and support fewer species (e.g., Crites et al 2012). Cellot (1996) found that certain macroinvertebrate species were more abundant in the main channel downstream of the more lotic (flowing water) of two side channels studied on the Upper Rhône River (France) than upstream of the side channel, indicating that side channels provide drifting macroinvertebrates to the main channel. This was not found to be the case in the main channel below the more lentic (lake-like) side channel. Thus, side channels are important in providing macroinvertebrate drift to the main channel depending on the degree of connectivity to the river.

3.3.2 Fishery Resources

Historically, Smith et al. (1971) reported that 134 fish species had been collected from the Upper Mississippi River, with 30 of those species being stragglers[13] that are accidental in the Mississippi River. An evaluation of their species distribution maps indicates that historically 84 fish species had been collected from the MMR, with 19 of those species being stragglers or tributary species and one exotic (Common Carp, *Cyprinus carpio*). The Missouri Department of Conservation (MDC) has conducted a comprehensive fish sampling program as part of the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element in the Cape Girardeau, Missouri, area since 1993. During that period, they have collected a total of 110 species (range of species collected = 45-68 per year, average = 61 species per year), of which 39 are stragglers or tributary species and six are exotic species (USGS 2014a). In 1971 there were 64 native MMR species and two exotic species and in 2014 there were 65 native species and seven exotic species. Since the original establishment of the Common Carp, six additional exotic species have become established or have expanded their ranges into the MMR: the Grass Carp (*Ctenopharyngodon idella*), Silver Carp (*Hypophthalmichthys molitrix*), Bighead Carp (*H. nobilis*), Striped Bass (*Morone saxatilis*), Striped Mullet (*Mugil cephalus*), and Rainbow Smelt (*Osmerus mordax*). In addition, it is likely only a matter of time before the

[13] A species is considered a straggler or stray specimen in a location if it is outside the normal geographic range of the species.

exotic Black Carp (*Mylopharyngodon piceus*) and the Round Goby (*Neogobius melanostomus*) become part of the MMR fish fauna. Three species have been extirpated from the MMR since the Smith et al. (1971) publication: the Alligator Gar (*Atractosteus spatula*), the Flat Head Chub (*Platygobio gracilis*) and the Plains Minnow (*Hybognathus placitus*), last collected during annual sampling in 1996. A number of species not collected in the MMR by Smith et al. (1971) are now considered residents (e.g., Western Sand Darter, *Ammocrypta clara*) based on more extensive sampling by the MDC.

The MMR sees some commercial and recreational fishing pressure. The number of commercial fishermen from Missouri has been declining since 2000 as has the commercial fish harvest (Tripp et al. 2012). The most commonly harvested fish are buffalofishes, catfishes, Asian carp, and Common Carp. Asian carp have recently overtaken Common Carp as the fourth most harvested group of fish by weight (Tripp et al. 2012). Recreational fishermen typically target catfish.

Main Channel

The importance of the main channel to aquatic organisms has been poorly studied (Baker et al. 1991) and aquatic ecologists are only recently gaining a better understanding of the importance of the main channel to the overall structure and function of large-river ecosystems. Additional studies have been recommended (Dettmers et al 2001a; Galat and Zweimmuller 2001) to resolve this lack of understanding. At the time that the 1976 EIS was prepared, the consensus of aquatic ecologists was that the main channel was "generally poor habitat for aquatic biota" and project-related impacts would be minor. Subsequently, from the 1980s to the 1990s, the flood pulse concept (Junk et al. 1989) envisioned the main channel as being "used principally as a route for gaining access to adult fish feeding areas, nurseries, spawning grounds, or as refuge at low water or during winter in temperate zones." This was referred to as the "*highway analogy*" where the main channel served as a highway, fish were the vehicles, and the flood-plain provided off-highway services.

The consensus that the main channel is poor habitat or serves only as a highway for fish movement between aquatic habitat types has changed based on recent research. The suggestion that the main channel serves only as a highway for fish movement has been evaluated and rejected (Galat and Zweimmuller 2001; Dettmers et al 2001b). Research indicates that the main channel is used by a variety of fish species ranging from single-season users to permanent residents (Dettmers et al. 2001a, 2001b; Galat and Zweimuller 2001; Wolter and Bischoff 2001). An evaluation of the fish assemblages of seven large rivers in North America and Europe revealed that 38-58% of native fishes depend on channel habitat for one or more of their primary life functions (Galat and Zweimuller 2001). Wolter and Bischoff (2001) found that in the River Oder (Germany), of the 30 species of fish captured during their study, 20 species were found in the main channel and 27 species at the shoreline. Three species were exclusively main channel species and an additional six species were more frequent there. Dettmers et al. (2001b) collected 26 fish species in the main channel of the Mississippi River (Pool 26). Over half (58%) of the 26 fish species they collected were present in the main channel during either three or four seasons, whereas only 31% (8 species) were collected during a single season (Dettmers et al. (2001a). The Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) was a persistent resident of the main channel. Dettmers et al. (2001b) suggested that there are four patterns of fish use of main channel troughs in the Upper Mississippi River. Some species (e.g., Black Crappie (*Pomoxis nigromaculatus*) and Shortnose Gar (*Lepisosteus platostomus*)) appear to use the main channel trough to move among various habitats. These species were collected only in the autumn, and only a single individual was collected each year. A second group of fishes (Bigmouth Buffalo (*Ictiobus cyprinellus*) and carpsuckers (*Carpiodes spp*.)) used the main channel trough primarily during a single season, usually autumn. These fishes remain in the main channel trough for 1-2 months, but were not collected in the main channel during the remainder of the year. The third group of fishes (e.g., Freshwater Drum (*Aplodinotus grunniens*) and Smallmouth Buffalo (*I. bubalus*)) used the main channel trough for multiple, but not all, seasons within the year. These species leave the main channel for such life-history requirements as spawning or overwintering. The final group (e.g., Shovelnose Sturgeon) are residents and are present during the entire year. Thus, the main channel is not "poor habitat" as outlined in the 1976 EIS (USACE 1976) and many fish species depend on it to a much greater degree than previously thought.

Based on limited sampling of the MMR main channel (USGS 2014a) due to safety issues related to sampling the high-velocity, turbulent main channel, the common species were Blue Catfish (*Ictalurus furcatus*), Channel Catfish, Freshwater Drum, Shovelnose Sturgeon and Gizzard Shad.

Main Channel Border

As with the main channel, there are Upper Mississippi River fish species that clearly select the main channel border as their preferred habitat (Gutreuter et al. 2010). Habitat preference is based on seasonal considerations (spawning, food availability, overwintering, etc.), including temperature and flow conditions. There undoubtedly is also a temporal component, with fish moving to different water depths and habitat types during different times of the day (diurnal vs. nocturnal conditions).

The most commonly encountered native species in the main channel border include (USGS 2014a): Gizzard Shad, Channel Catfish, Freshwater Drum, Emerald Shiner (*Notropis atherinoides*), Smallmouth Buffalo, Channel Shiner (*Notropis wickliffi*), White Bass, Shortnose Gar, Blue Catfish, and River Carpsucker. These species accounted for approximately 70% of the fish captured, by number. Also included in the collection were 4 species of non-native fish including Common Carp, Silver Carp, Grass Carp, and Bighead Carp. These species accounted for approximately 11% of the fish captured, by number, with the vast majority being Common Carp. Silver Carp were likely underrepresented in the collection due to the sampling methodologies employed.

Love et al. (2016) found higher catch rates of juveniles of six common MMR fish species (Channel Catfish, Blue Catfish, Freshwater Drum, Shovelnose Sturgeon, Paddlefish, and Channel Shiner) in shallower (less than 4.0 meters) and slower velocity (less than 0.6 m/s) habitat that is more characteristic of the main channel border. Hintz et al. (2015) found that juvenile Shovelnose Sturgeon most frequently used flooded terrestrial vegetation on two MMR islands. Flooded channel border vegetation at the islands may have provided areas with increased food availability and may have also allowed Shovelnose Sturgeon to avoid predators. Phelps et al. (2010) found that juvenile Shovelnose Sturgeon catch rates in the MMR were highest around main channel border river training structures and island areas. These main channel border areas provided the low-velocities, moderate depths, and sand substrates used most frequently by Shovelnose Sturgeon in the study.

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. Side 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, side channels can function as wetlands, isolated backwaters, connected backwaters, isolated side channels (at low stages), and flowing side channels.

Flowing side 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 side 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). The degree of connectivity to the river also affects side channel water quality and fish species composition (Crites et al. 2012). 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 macroinvertebrates, fish, and wildlife (Eckblad et al. 1984; Siegrest and Cobb 1987; Barko and Herzog 2003). Side 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). Side channels are also important because they are a refuge for fish escaping navigation related disturbances (Galat and Zweimuller 2001; Wolter and Bischoff 2001; Gutreuter et al. 2006). Information on the status of MMR side channels can be found in Section 3.2.2 Geomorphology above.

The most commonly encountered native species in MMR side channels include (USGS 2014a): Gizzard Shad, Channel Catfish, Freshwater Drum, Red Shiner (*Cyprinella lutrensis*), Emerald Shiner, Channel Shiner, River Carpsucker, Bluegill *(Lepomis macrochirus*), and Shortnose Gar. These species accounted for approximately 70% of the fish captured, by number. Also included in the collection were 4 species of non-native fish including Common Carp, Silver Carp, Grass Carp, and Bighead Carp. These species accounted for approximately 8% of the fish captured, by number, with the vast majority being Common Carp. Silver Carp were likely underrepresented in the collection due to the sampling methodologies employed.

3.3.3 Terrestrial Communities

River planform analyses conducted by the District (Brauer et al. 2005; Brauer et al. 2013; see Section 3.2.2 Geomorphology of this document for details) indicate that the MMR planform is no longer narrowing and creating new riparian habitat as it had been in the late 19th and early 20th centuries. Planform width has been relatively stable since the 1960s. This fact, in combination with the fact that construction techniques no longer utilize bank scraping when placing rock on the bank, leads to the conclusion that potential impacts of the Project on terrestrial communities are minimal. Accordingly, the information in the 1976 EIS on terrestrial communities is incorporated by reference and no further analysis will be conducted in this Supplement.

3.3.4 Threatened and Endangered Species

In 1999 the Corps prepared a Tier I Biological Assessment for the Operation and Maintenance of the Upper Mississippi River Navigation Project within the St. Paul, Rock Island, and St. Louis Districts to determine the impacts of operation and maintenance of the 9-foot navigation channel on threatened and endangered species (USACE 1999b). The Corps chose to prepare one Biological Assessment for the Upper Mississippi River Navigation System, defined as the commercially navigable portions of the Mississippi, Illinois, Kaskaskia, Minnesota, St. Croix, and Black Rivers north of the confluence of the Ohio and Mississippi rivers, although this area contains multiple Congressionally authorized projects to obtain and maintain a navigation channel in various ways. Subsequently, the Fish and Wildlife Service prepared a Biological Opinion on the O&M of the 9-foot navigation channel (USFWS 2000). The 1999 Biological Assessment and 2000 Biological Opinion can be found on the District's web site at:

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

In their Biological Opinion, the Service analyzed the impacts of impoundment and water level regulation, dredging and disposal, clearing and snagging, channel structures and revetment, tow traffic, and other direct, indirect, and cumulative actions on the Indiana Bat (*Myotis sodalis*), Decurrent False Aster (*Boltonia decurrens*), Bald Eagle (*Haliaeetus leucocephalus*), Higgins' Eye Pearlymussel (*Lampsilis higginsi*), Winged Mapleleaf Mussel (*Quadrula fragosa*), Least Tern (*Sterna antillarum*), and Pallid Sturgeon (*Scaphirhynchus albus*). The Higgins' Eye Pearlymussel and Winged Mapleleaf Mussel are not found in the MMR and, therefore, are not impacted by the Regulating Works Project. With respect to species currently relevant to the Regulating Works Project, the Service concluded that the continued operation and maintenance of the 9-foot navigation channel:

- would jeopardize the continued existence of the Pallid Sturgeon;
- would not jeopardize the continued existence of the Least Tern, but would result in incidental take;
- would likely adversely affect the Indiana Bat, but impacts would be offset by management actions or would be negligible and would not rise to the level of incidental take; and
- would adversely affect the Decurrent False Aster, but would not jeopardize its continued existence.

Based on these determinations, the Service recommended appropriate actions for the Corps to take in order to avoid impacts to Pallid Sturgeon and Least Terns.

For Pallid Sturgeon, the Service recommended a Reasonable and Prudent Alternative (RPA) for O&M of the 9-foot navigation channel that the Corps could implement to avoid the likelihood of jeopardizing the continued existence of the species. The RPA consisted of four components:

1. Conduct a Pallid Sturgeon habitat study in the MMR.
2. Facilitate development of a Pallid Sturgeon conservation and restoration plan that includes:
    a. A habitat restoration plan for each river reach and
    b. A population and habitat restoration monitoring plan.
3. Implement, as described in the conservation and restoration plan, a long-term aquatic habitat restoration program in the MMR. Annual Reports must be submitted by 30 June each year.
4. Until the conservation and restoration plan is implemented, implement short-term aquatic habitat restoration measures and studies.

The Service also recommended Reasonable and Prudent Measures (RPMs) necessary to minimize the incidental take of Pallid Sturgeon until the RPAs are fully implemented:

1. Incorporate modifications to channel training structures to improve diversity (e.g. notching, woody debris).
2. Beneficially use dredge material when possible and use thalweg[14] disposal otherwise.
3. Do not maintenance dredge during the presumed Pallid Sturgeon spawning window (12 April to 30 June).
4. Release live Pallid Sturgeon after data/tissue samples have been collected.
5. Review data collected with implementation of RPAs to further minimize incidental take.

Finally, the Service imposed Terms and Conditions associated with the Pallid Sturgeon RPMs:

1. At beginning of each fiscal year, provide a list of new construction projects for which Tier II evaluation is needed.
2. Submit channel training structure maintenance projects to the Service for 30-day review and incorporate their habitat improvement recommendations.
3. Conduct monitoring to measure loss of main channel and side channel habitat.
4. Coordinate dredging and disposal with the Service, IDNR, and MDC.
5. If dredging from 12 April to 30 June, prepare a tier II Biological Assessment.
6. Implement monitoring of thalweg disposal.
7. Provide an annual dredge material management report to the Service.
8. Preserve dead Pallid Sturgeon on ice and give to the University of Alabama.

For the Least Tern, the Service recommended RPMs to minimize take:

1. Incorporate modifications to channel training structure maintenance projects to maintain flow between sandbars and the adjacent shoreline and to reduce conversion of bare sandbar habitat to woody vegetation.

[14] Thalweg is defined as a line drawn along a river channel that connects its deepest points.

2. Evaluate dredge material disposal techniques in the MMR to examine opportunities and develop recommendations for restoring/enhancing sandbar habitat and aquatic habitat. Implement the recommendations where feasible and appropriate.
3. Utilize existing authorities to reduce the accretion of existing and/or newly established sandbars to the bankline and to reduce woody vegetation colonization.

The Service also imposed Terms and Conditions associated with the Least Tern RPMs:

1. Provide the Service with a list of new construction projects at the beginning of each fiscal year.
2. Submit channel training structure maintenance projects to the Service for a 30-day review period. Incorporate Service recommendations where feasible and appropriate.
3. Monitor sandbar habitat trends in the MMR.
4. Continue to coordinate dredging and disposal activities with the Service, Illinois Department of Natural Resources (IDNR), and Missouri Department of Conservation (MDC).
5. Provide a dredge material management report to the Service annually.
6. Provide the Service an annual report of actions taken regarding implementation of RPMs.

The Corps initiated implementation of the Pallid Sturgeon and Least Tern RPA, RPMs, and Terms and Conditions as recommended by the Service in 2000 subsequent to the issuance of the Biological Opinion. Since that time the District has implemented a variety of studies aimed at increasing understanding of the status and needs of the species in the MMR and has implemented numerous habitat restoration projects aimed at improving conditions for the species in the MMR (See Table 3-9). Habitat restoration undertaken by the District includes a variety of dike construction and alteration, side channel restoration, and island and sandbar creation projects. Activities also include use of innovative structures to avoid and minimize impacts while improving the navigation channel. The District prepares annual reports summarizing all Biological Opinion activities. These reports can be found on the District's web site at:

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

Table 3-9. Biological Opinion related activities undertaken by the District in the MMR since 2000 and potential future activities.

Activity	Purpose	Year(s)
Side Channel Restoration		
Sister Chute	Dredge lower end of Sister Chute to improve connectivity and depth	2006
Establishment Island	Improve connectivity/depth with dike notching, side channel enhancement dike placement	2012-2015
Boston Chute	Improve connectivity and depth with dike notching/removal/placement	2016-2017
Structure Placement and/or Modification for Habitat Diversity		
Chester Reach stone dike alterations River Mile 120 to 103	Notch a number of existing dikes for habitat diversity	2001-2002
Cliff Cave-Kimmswick stone dike alterations River Mile 168 to 156.6	Notch a number of existing dikes and construct 7 chevrons to improve habitat diversity	2009-2011
Red Rock to Tower Rock stone dike alterations River Mile 93.0 to 86.0	Construct three chevrons, trail dike, notch dike to improve habitat diversity	2005-2008
Jefferson Barracks stone dike alterations River Mile 171.5 to 168.5	Notch dike for habitat diversity	2006
Waters Landing stone dike alterations River Mile 106.0 to 100.0	Remove dike, extend dike, notch dike, construct 3 chevrons to enhance habitat diversity	2010-2011
Big Muddy River Confluence stone dike alterations River Mile 75.5L	Notch existing dikes to improve habitat diversity	2007-2011
Woody structure placement	Place woody structure to increase habitat diversity	2001-2002
Incorporation of woody debris in dikes	Place driftwood into selected dikes to increase habitat diversity	2001-2002
Use of Innovative Structures to Avoid and Minimize Impacts while Reducing Dredging		
Fort Chartres/Establishment Island chevron construction River Mile 132.5 to 129.5 R	Use innovative structures (chevrons) to improve habitat diversity while improving navigation channel	2006-2007
Fort Chartres/Establishment Island reach monitoring River Mile 132.5 to 129.5R	Monitoring fish community to determine impacts of structure construction while improving navigation channel	2002-2004; 2009-2010
St. Louis Harbor chevrons construction River Mile 183.0 to 182.4	Use innovative structures (chevrons) to improve habitat diversity while improving navigation channel	2006-2007
Kaskaskia Bend dike notching River Mile 125.0 to 112.0	Use notched dikes to improve habitat diversity while improving navigation channel	2008
Red Rock Landing chevron construction River Mile 100.1 to 99.9L	Use innovative structures (chevrons) to improve habitat diversity while improving navigation channel	2007
Red Rock Landing offset dike construction River Mile 96.9 to 96.6R	Use innovative structures (offset dikes) to improve habitat diversity while improving navigation channel	2011
Grand Tower chevron construction River Mile 82.0L	Use innovative structures (chevron, notched dike) to improve habitat diversity while improving navigation channel	2009

Activity	Purpose	Year(s)
Dogtooth Bend chevron construction River Mile 36.7L to 32.4R	Use innovative structures (chevrons) to improve habitat diversity while improving navigation channel	2010
Eliza Point/Greenfield Bend W-dike and multiple roundpoint structure construction River Mile 4.2 to 4.0 L	Use innovative structures (W-dike and multiple roundpoint structures) to improve habitat diversity while improving navigation channel	2010-2011
Devils Island offset dikes construction River Mile 59.8 to 58.3R	Use innovative structures (offset dikes) to improve habitat diversity while improving navigation channel	2011
Thebes offset dikes construction River Mile 39.4 to 38.6R	Use innovative structures (offset dikes) to improve habitat diversity while improving navigation channel	2012
Grand Tower Phase 5 dike construction River Mile 72.0 to 65.0L	Use innovative structures (S-dikes and chevrons) to improve habitat diversity while improving navigation channel	2016
Mosenthein Ivory Phase 4 rootless dike construction River Mile 173.4L	Use innovative structure (rootless dike) to improve habitat diversity while improving navigation channel	2015
Eliza Point/Greenfield Bend rootless dike construction River Mile 3.0L	Use innovative structure (rootless dike) to improve habitat diversity while improving navigation channel	2016
Mosenthein Ivory Phase 5 rootless dike construction River Mile 161.5L	Use innovative structure (rootless dikes) to improve habitat diversity while improving navigation channel	2016
Red Rock Phase 4 multiple roundpoint structure construction River Mile 102L	Use innovative structures (multiple roundpoint structures) to improve habitat diversity while improving navigation channel	TBD
Island/Sandbar Habitat Creation with Flex Pipe		
River Mile 100	Create ephemeral island/sandbar habitat	2013
River Mile 103R	Create ephemeral island/sandbar habitat	2013
River Mile 103.7R	Create ephemeral island/sandbar habitat	2013
River Mile 104R	Create ephemeral island/sandbar habitat	2011
River Mile 166.5	Create ephemeral island/sandbar habitat	2015
River Mile169.0	Create ephemeral island/sandbar habitat	2015, 2016
River Mile 171.0	Create ephemeral island/sandbar habitat	2015, 2016
River Mile 184.0	Create ephemeral island/sandbar habitat	2015
River Mile 174.6	Create ephemeral island/sandbar habitat	2016
Burnham Island	Create ephemeral island/sandbar habitat	2017
Buffalo Island River Mile 26.0	Create ephemeral island/sandbar habitat	TBD
Boston Bar Island/Sandbar Creation River Mile 12 to 6	Create ephemeral island/sandbar habitat	TBD
Minton Point River Mile 54L	Create ephemeral island/sandbar habitat	TBD
Owl Creek River Mile 83R	Create ephemeral island/sandbar habitat	TBD
River Mile 90.4R	Create ephemeral island/sandbar habitat	TBD
River Mile 130R	Create ephemeral island/sandbar habitat	TBD
Waters Point River Mile 158R	Create ephemeral island/sandbar habitat	TBD
Studies, Surveys, Monitoring, etc.		
Pallid Sturgeon habitat use and population demographic studies	Collect Pallid Sturgeon habitat use and demographic information to clarify status of species and habitat needs	2000-Present
Pallid Sturgeon habitat study	Monitor the relationship between river training structures and Pallid Sturgeon	2000-Present

Activity	Purpose	Year(s)
Development of Pallid Sturgeon conservation and restoration plan	Develop comprehensive plan to guide and prioritize monitoring and restoration needs of Pallid Sturgeon in MMR	2000-Present
Shovelnose Sturgeon fin clip swim test	Determine impacts of fin clips to facilitate use of technique in habitat and population demographics study	2001-2002
Juvenile sturgeon flume study	Determine velocity and substrate preferences of Pallid and Shovelnose Sturgeon	2002-2003
Pallid Sturgeon stocking feasibility report	Determine if stocking Pallid Sturgeon is a viable/advisable restoration method in the MMR.	2002-2004
Bathymetric surveys	Monitor main channel and side channel habitat to track trends	2000-Present
Gravel bar surveys	Begin to quantify amount of gravel bar habitat in MMR; determine potential spatial relationships with Pallid Sturgeon	2000 and 2002
Geomorphology studies	Compare various physical parameters of the MMR from early 1800s to present	2002-2005
Macroinvertebrate use of woody structure study	Determine the degree of use of woody structures in the MMR by macroinvertebrates as compared to other substrates.	2004
Development of MMR stone dike alteration plan	Inventory and prioritize MMR dikes for modification to improve habitat diversity	2000-Present
Thalweg dredged material disposal pilot tests	Test feasibility of disposal of dredged material in the thalweg of the MMR	2003
Range wide sturgeon conference	Share information on sturgeon conservation and biology; conference held in St. Louis	2005
Side channel connectivity analysis	Determine degree of connectivity of MMR side channels to guide restoration activities	2004
River mile 100 island study	Compare fish assemblages at islands vs. control sites to determine benefits of islands and notched dikes	2004-2010
Flex pipe Technical Report 57	Explore engineering considerations for island and sandbar creation using flexible floating dredge disposal pipe in the MMR	2012
Modification of revetment tests	Test new solutions (other than typical revetment) to protect roundouts below dikes at various locations on MMR	2003-2004
Indiana bat surveys	Collect Indiana Bat information to document presence/absence in Project area	2010-2012, 2014
Floating flexible dredge disposal pipe purchase	Facilitate island/sandbar habitat creation with dredged material	2009
Fish monitoring at structure placement sites	Determine changes in fish community after structure placement	2000-Present
Woody Structure Monitoring	Determine changes in woody structure placement sites 10 years post-construction	2013
Bathymetric monitoring of most sites	Determine changes in bathymetry at structure placement locations	2000-Present
Fish monitoring at flex pipe site	Determine fish use of flex pipe sites	2011-Present
Burnham pre- and post-flex pipe fish and bathymetric monitoring	Determine changes in fish community and bathymetry at flex pipe site	2013-Present
Vancil Towhead Fish Monitoring	Determine changes in fish community after structure placement	2005-Present
Devils Island offset dikes monitoring	Determine changes in fish community, depth, substrate, flows after structure placement	2009-2012

Activity	Purpose	Year(s)
Dogtooth Bend chevron monitoring	Determine changes in fish community and water quality after structure placement	2012
Greenfield/Eliza Bend structure monitoring	Determine changes in fish community, depth, substrate, flows after structure placement	2012
Red Rock Landing offset dikes monitoring	Determine changes in fish community, depth, substrate, flows after structure placement	2012
Sister Chute Bathymetric Monitoring	Determine longevity of restoration by dredging	2005-2011
Jones Chute Water Quality Monitoring	Determine impacts of restoration on water quality	2006-2009
St. Louis Harbor Chevrons Monitoring River Mile 183.0 to 182.4	Determine changes in fish and bathymetry after structure placement	2006-2011

Implementation of the recommendations of the Biological Opinion is coordinated extensively and continually with the Service, IDNR, MDC, and other experts and interested parties. Implementation of the District's Biological Opinion activities is expected to continue until such time as the species are considered recovered or it is determined that the District's actions are no longer jeopardizing the species or resulting in incidental take.

Due to this recent analysis of the impacts of operation and maintenance activities on endangered species, the fact that no additional impacts are anticipated beyond those addressed in the 2000 Biological Opinion, and due to the associated ongoing habitat restoration, monitoring, and coordination that the St. Louis District continues to undertake, a Biological Assessment was not prepared in conjunction with this SEIS for the species covered by the previous consultation process. However, site-specific Tier II Biological Assessments covering all appropriate species have been and will continue to be prepared for construction of specific work areas in the MMR. Relevant new information on threatened and endangered species has been and will continue to be included in these site-specific Tier II Biological Assessments, as appropriate. For example, new information and guidance on protection of Indiana Bat habitat is included in site-specific Tier II Biological Assessments, as appropriate, through close coordination with the Service. With respect to new threatened and endangered species that have been listed since issuance of the 2000 Biological Opinion (Table 3-10), a Biological Assessment has been prepared in conjunction with this SEIS (Appendix B).

As indicated above, one of the Terms and Conditions associated with the Pallid Sturgeon RPMs was to prepare a tier II Biological Assessment should dredging become necessary during the presumed Pallid Sturgeon spawning window of 12 April to 30 June. Although dredging during the presumed window of pallid sturgeon reproduction is rare, there are times that it is required. In 2001 the District prepared the Tier II Biological Assessment on emergency dredging procedures (USACE 2001). In 2002 the Service prepared a corresponding Tier II Biological Opinion on emergency dredging procedures (USFWS 2002). The 2001 Biological Assessment and 2002 Biological Opinion can be found on the District's web site at:

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

In their Biological Opinion the Service determined that emergency dredging would not likely jeopardize the continued existence of the Pallid Sturgeon but that it would result in incidental take exceeding the amount covered by the 2000 Biological Opinion. To minimize the impacts of incidental take of Pallid Sturgeon the Service recommended the following RPMs:

1. Emergency dredging should not exceed 500,000 cubic yards in any given year or consultation must be reinitiated.
2. Emergency dredging should not exceed 1.5 million cubic yards in a 10-year period or consultation must be reinitiated.
3. All dredged material disposal options will be considered.
4. An evaluation process will be developed to monitor fish entrainment rates. This process will be implemented should it become necessary to conduct emergency dredging.

Terms and Conditions associated with these RPMs included:

1. A summary report must be provided to the Service each year in which emergency dredging is necessary.
2. Within two years, provide a plan of study to the Service which outlines the process developed to monitor fish entrainment from emergency dredging.
3. Within one year of each emergency dredging event, provide a report to the Service of the fish entrainment monitoring results.

To date, no dredging during the presumed 12 April to 30 June Pallid Sturgeon spawning window has occurred on the MMR since issuance of this Biological Opinion.

Table 3-10. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area (based on USFWS Information, Planning, and Conservation (IPaC) website: https://ecos.fws.gov/ipac/; accessed 6 February 2017).

Species Covered by Previous Consultation	Federal Status
Least Tern (*Sterna antillarum*)	Endangered – listed in 1985
Piping Plover (*Charadrius melodus*)*	Threatened – listed in 1985
Pink Mucket (*Lampsilis abrupta*)	Endangered – listed in 1976
Illinois Cave Amphipod (*Gammarus acherondytes*)	Endangered – listed in 1998
Pallid Sturgeon (*Scaphirhynchus albus)*	Endangered – listed in 1990
Decurrent False Aster (*Boltonia decurrens*)	Threatened – listed in 1988
Eastern Prairie Fringed Orchid (*Platanthera leucophaea*)	Threatened – listed in 1989
Mead's Milkweed (*Asclepias meadii*)*	Threatened – listed in 1988
Price's Potato-bean (*Apios priceana*)	Threatened – listed in 1990
Running Buffalo Clover (*Trifolium stoloniferum*)	Endangered – listed in 1987
Small Whorled Pogonia (*Isotria medeoloides*)	Threatened – listed in 1982
Gray Bat (*Myotis grisescens*)	Endangered – listed in 1976
Indiana Bat (*Myotis sodalis*)	Endangered – listed in 1967
Species Listed Since Issuance of 2000 Biological Opinion	**Federal Status**
Red Knot (*Calidris canutus rufa*)*	Threatened – listed in 2015
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013
Scaleshell Mussel (*Leptodon leptodon*)	Endangered – listed in 2001
Sheepnose Mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered – listed in 2012
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012
Grotto Sculpin (*Cottus specus*)	Endangered – listed in 2013
Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened – listed in 2015
Eastern Massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016

* These species were not listed as potentially occurring in the Project area in the most recent IPaC consultation but are listed here due to inclusion in previous consultations.

3.4 Socioeconomic Resources

3.4.1 Human Resources

This Section provides an overview of the socioeconomic characteristics of the Project Area. Information on population densities, employment and income statistics, and race characteristics is provided in order to characterize the socioeconomic status of the inhabitants of the MMR corridor.

A total of fifteen Missouri and Illinois counties are immediately adjacent to the MMR (Figure 3-33). The total population of these 15 counties in 2014 was approximately 2.4 million (Table 3-11), with the vast majority of that total (2.1 million) living in the St. Louis area (St Louis City and St. Louis, Jefferson, Madison, and St. Clair Counties; Figure 3-34; U.S. Census Bureau 2014). Most of the remaining Project Area counties are rural in nature with low population densities and few cities over 10,000 people.

Employment statistics for counties adjacent to the MMR indicate that the primary employment sector for Project Area counties is Educational Services, Health Care, and Social Assistance, accounting for 25.5% of employment on both the Missouri and Illinois sides of the river (Table 3-12; U.S. Census Bureau 2014). High Agriculture, Forestry, Fishing and Hunting, and Mining sector numbers in the counties in the southern portion of the Project Area reflect the rural nature of those counties. In general, overall Project Area employment statistics are similar to the overall employment statistics for the states of Missouri and Illinois, with all employment sector percentages being within 2.5% of statewide averages.

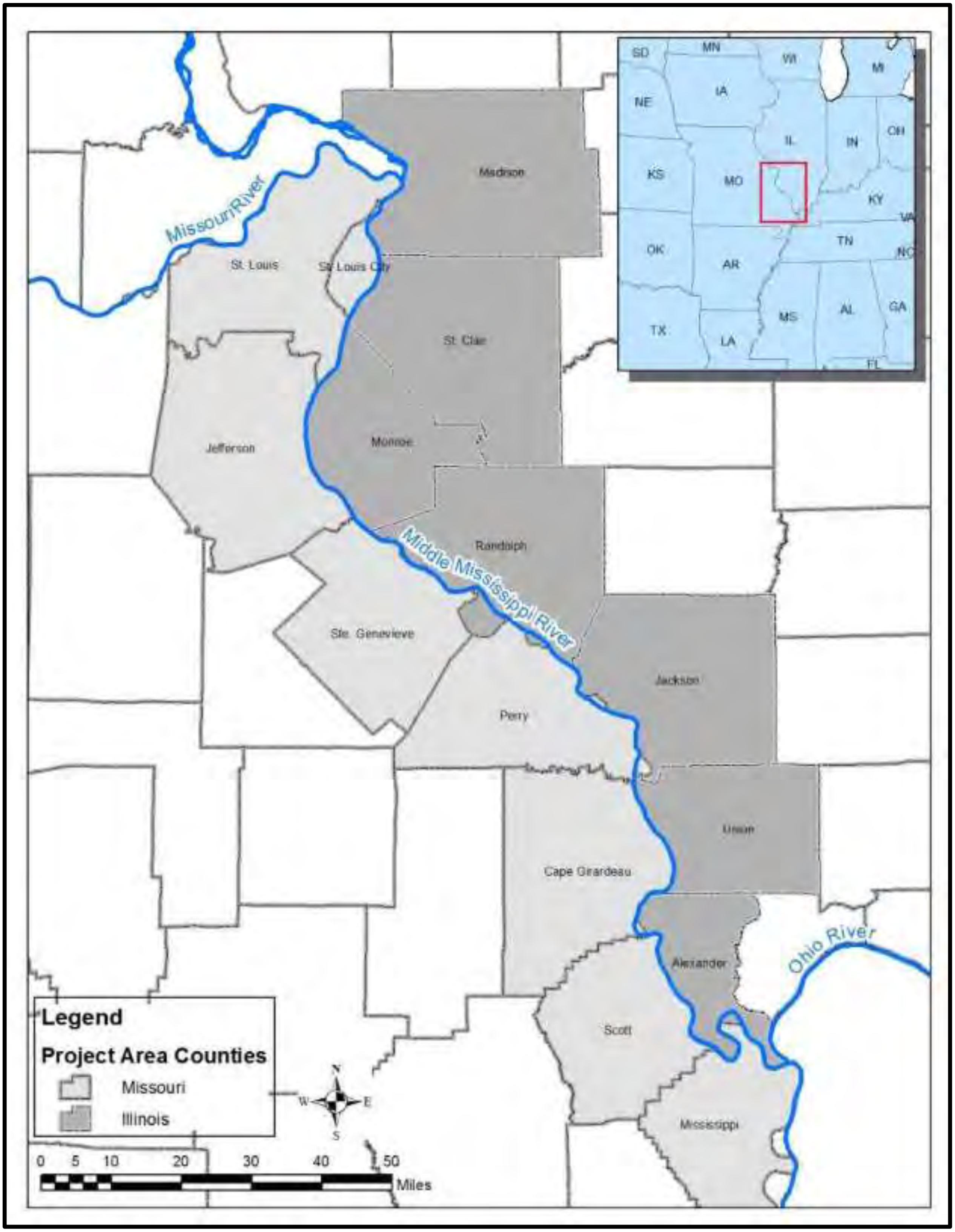


Figure 3-33. Missouri and Illinois counties adjacent to the Middle Mississippi River.

Table 3-11. Population statistics for Project Area counties.

Area	2000 Population	2014 Population	2000 to 2014 % Change in Population
Missouri			
St. Louis County	1,016,315	1,000,423	-1.6
St. Louis City	348,189	318,727	-8.5
Jefferson County	198,099	220,558	11.3
St. Genevieve County	17,842	18,017	1.0
Perry County	18,132	19,042	5.0
Cape Girardeau County	68,693	77,031	12.1
Scott County	40,422	39,137	-3.2
Mississippi County	13,427	14,276	6.3
State of Missouri	5,595,211	6,028,076	7.7
Illinois			
Madison County	258,941	267,937	3.5
St. Clair County	256,082	268,415	4.8
Monroe County	27,619	33,373	20.8
Randolph County	33,893	33,091	-2.4
Jackson County	59,612	60,125	0.9
Union County	18,293	17,620	-3.7
Alexander County	9,590	7,821	-18.4
State of Illinois	12,419,293	12,868,747	3.6

Source: U.S. Census Bureau 2014.

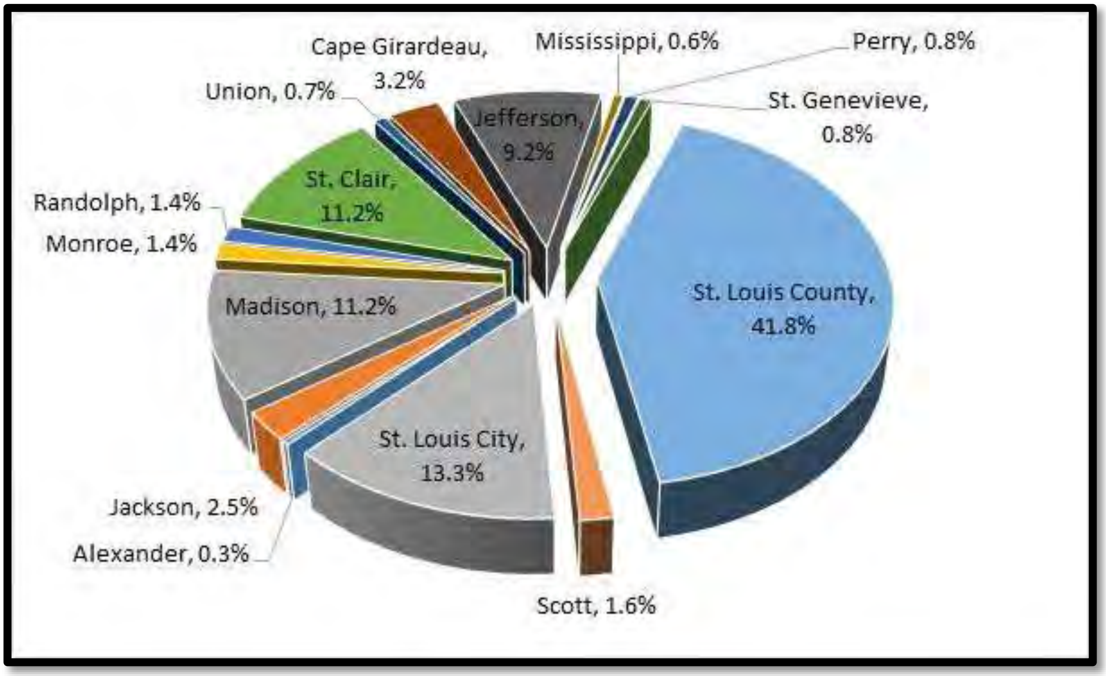


Figure 3-34. 2014 population statistics for Project Area counties – percent of total Project Area population. Source: U.S. Census Bureau 2014.

Table 3-12. Employment statistics for Project Area counties (in percent of total employment).

	Missouri										**Illinois**								
Occupation	St. Louis County	St. Louis City	Jefferson County	St. Genevieve County	Perry County	Cape Girardeau County	Scott County	Mississippi County	Project Area	State of Missouri	Madison County	St. Clair County	Monroe County	Randolph County	Jackson County	Union County	Alexander County	Project Area	State of Illinois
Agriculture, Forestry, Fishing and Hunting, and Mining	0.5	0.3	0.5	6.6	4.7	1.3	3.8	8.9	**0.7**	**1.8**	0.7	0.7	1.8	5.1	2.2	4.0	2.6	**1.2**	**1.1**
Construction	4.2	3.6	9.3	10.2	9.0	6.1	6.3	5.4	**5.0**	**5.9**	5.7	5.2	7.9	8.3	4.7	7.7	4.7	**5.7**	**5.1**
Manufacturing	10.0	7.8	11.7	22.8	25.1	10.7	15.4	9.5	**10.3**	**11.3**	12.9	8.5	10.8	19.3	5.5	10.2	10.5	**10.7**	**12.5**
Wholesale Trade	3.0	2.6	3.0	1.6	0.8	2.8	2.3	3.0	**2.9**	**2.7**	2.4	2.3	4.2	1.8	1.0	0.9	2.5	**2.3**	**3.0**
Retail Trade	11.4	9.0	12.4	9.4	12.4	12.8	13.8	12.6	**11.2**	**12.1**	11.7	11.3	11.3	10.1	13.2	10.5	11.7	**11.5**	**11.0**
Transportation and Warehousing and Utilities	4.3	4.2	5.2	6.0	4.4	3.9	7.7	6.8	**4.5**	**5.0**	6.3	6.7	5.6	7.3	3.1	6.9	7.2	**6.2**	**5.9**
Information	2.5	2.6	1.7	1.8	1.0	2.0	2.3	0.3	**2.3**	**2.1**	1.7	1.3	2.8	1.8	1.6	1.7	0.7	**1.6**	**2.1**
Finance and Insurance and Real Estate, Rental, and Leasing	9.2	6.4	7.6	3.4	3.4	5.9	4.4	4.4	**8.1**	**6.8**	6.6	6.7	8.9	3.4	3.2	3.9	4.7	**6.3**	**7.3**
Professional, Scientific, Management, and Administrative	12.2	11.4	10.1	4.3	4.9	6.5	4.7	5.1	**11.2**	**9.2**	10.0	10.6	10.0	5.2	4.8	5.8	5.3	**9.4**	**11.3**
Educational Services, Health Care, and Social Assistance	25.7	27.6	21.1	22.0	20.2	29.5	24.5	24.1	**25.5**	**24.4**	22.9	25.5	22.2	22.9	41.0	30.4	22.5	**25.5**	**23.1**
Arts, Entertainment, and Recreation, and Accommodation and Food Services	9.3	13.7	8.4	6.2	6.4	10.7	7.3	5.8	**9.9**	**9.3**	10.0	9.1	6.6	5.6	9.7	5.3	11.7	**9.1**	**9.0**
Public Administration	2.9	5.7	3.5	3.2	3.2	3.3	4.6	9.6	**3.6**	**4.6**	4.3	7.7	3.4	5.3	5.5	8.9	10.9	**5.8**	**3.9**
Other	4.8	5.0	5.5	2.6	4.5	4.5	2.8	4.4	**4.9**	**4.8**	4.8	4.7	4.5	3.8	4.6	3.8	4.9	**4.7**	**4.8**
Unemployed	8.2	14.1	9.2	6.4	4.1	7.3	7.4	13.9	**10.3**	**8.4**	8.9	9.0	5.4	6.5	10.3	9.7	16.7	**9.7**	**10.0**

Source: U.S. Census Bureau 2014.

Median household income and per capita income data for the Project Area show most income levels to be below statewide averages (Table 3-13; U.S. Census Bureau 2014). Median household incomes for Project Area counties were below statewide averages for all counties except St. Louis County, Jefferson County, Perry County, and Monroe County. Per capita incomes were below statewide averages for all counties except St. Louis County and Monroe County.

Table 3-13. Income statistics for Project Area counties.

Area	Median Household Income	Per Capita Income
Missouri		
St. Louis County	$59,520	$35,388
St. Louis City	$34,800	$23,244
Jefferson County	$55,563	$25,034
St. Genevieve County	$46,244	$23,780
Perry County	$50,817	$23,539
Cape Girardeau County	$45,849	$23,684
Scott County	$39,076	$20,637
Mississippi County	$28,436	$15,032
State of Missouri	**$47,764**	**$26,006**
Illinois		
Madison County	$53,912	$28,093
St. Clair County	$50,728	$26,459
Monroe County	$69,592	$33,059
Randolph County	$48,901	$22,771
Jackson County	$32,681	$20,729
Union County	$41,849	$22,430
Alexander County	$25,495	$14,052
State of Illinois	**$57,166**	**$30,019**

Source: U.S. Census Bureau 2014.

Environmental Justice (EO 12898)

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs federal agencies to identify and address any disproportionately high adverse human health or environmental effects of federal actions to minority and/or low-income populations. CEQ guidance on conducting Environmental Justice analyses in NEPA documents (CEQ 1997) indicates that a minority population exists where the percentage of minorities in an affected area either exceeds 50 percent or is meaningfully greater than in the general population or other appropriate unit of geographic analysis. The CEQ guidance also recommends utilizing the Census Bureau's statistical poverty thresholds in determining low-income populations. The Census Bureau defines a "poverty area" as a Census tract with 20 percent or more of its residents below the poverty threshold.

Accordingly, a potential disproportionate impact could occur anywhere the percent minority and/or percent low-income population in a project area is greater than the recommended threshold percentages and/or is meaningfully greater than those in the reference community. For purposes of this analysis, minority and low income population information for the states of Missouri and Illinois, all Project Area counties, and all Census Block Groups[15] immediately adjacent to the MMR was acquired.

The most recent minority and low-income data available for this analysis (U.S. Census Bureau 2014) can be found in Table 3-14. The demographic profile records indicate that the minority population in the Missouri Project Area counties (32.0%) is lower than the 50% threshold but is significantly higher than the general population in the state of Missouri (21.0%). St. Louis County (32.6%), St. Louis City (58.2%), and Mississippi County (27.7%) have minority population densities higher than the state average. The minority population in the Illinois Project Area counties (24.5%) is lower than the 50% threshold and is lower than the general population in the state of Illinois (43.8%). No Illinois counties in the Project Area have minority population densities higher than the state average. The low-income populations in the Missouri Project Area counties (14.3%) and the Illinois Project Area counties (16.3%) are both below the 20% threshold and are similar to the general populations of Missouri (15.6%) and Illinois (14.4%). St. Louis City, Missouri (27.8%), Mississippi County, Missouri (29.7%), Jackson County, Illinois (32.3%), and Alexander County, Illinois (36.8%), have low-income populations above the 20% threshold.

To further refine the Environmental Justice analysis, Census Block Group information was analyzed to determine the status of minority and low-income populations immediately adjacent to the MMR. By utilizing Census Block Group data, minority or low-income populations that may not have been revealed when looking at the broader county-wide information could be analyzed. In addition, comparisons of minority and low-income populations among different parts of the Project Area could more accurately be conducted to ensure that potential disproportionate impacts within the Project Area itself were considered.

[15] Census Block Groups are small geographical population units used by the U.S. Census Bureau that typically contain 600 to 3,000 people. Census Block Groups were the smallest population unit for the Project Area for which the most up to date population information was available.

Seventy-four Census Block Groups exist adjacent to the MMR, 50 in Missouri and 24 in Illinois (Figure 3-35). Of those 74, 30 in Missouri and 11 in Illinois contain populations that meet the minority and/or low-income criteria (Figure 3-35). Potential impacts to minority and low-income populations in the Project Area will be discussed in Chapter 4, Environmental Consequences.

Table 3-14. Minority and low-income populations in Project Area counties.

Area	Total Population	Total Minority Population (%)	African American (%)	American Indian and Alaska Native (%)	Asian (%)	Native Hawaiian and other Pacific Islander (%)	Other (%)	Multi-Race (%)	Hispanic or Latino (%)	Low-Income (%)
Missouri										
St. Louis	1,000423	32.6	23.3	0.1	3.6	0.0	0.6	2.4	2.6	10.8
St. Louis City	318,727	58.2	48.1	0.2	2.8	0.0	0.8	2.6	3.7	27.8
Jefferson	220,558	5.2	0.9	0.2	0.6	0.1	0.3	1.4	1.7	11.1
St. Genevieve	18,017	3.9	0.5	0.0	0.0	1.6	0.1	0.8	0.9	14.6
Perry	19,042	4.7	0.4	0.2	0.1	0.0	0.5	1.5	2.0	11.7
Cape Girardeau	77,031	13.4	7.4	0.2	1.3	0.2	0.4	1.8	2.1	17.3
Scott	39,137	16.0	11.1	0.3	0.5	0.0	0.2	1.9	2.0	19.4
Mississippi	14,276	27.7	24.0	0.2	0.0	0.0	0.0	1.7	1.8	29.7
Project Area	**1,707,211**	**32.0**	**23.5**	**0.2**	**2.8**	**0.0**	**0.6**	**2.3**	**2.6**	**14.3**
State of Missouri	**6,028,076**	**21.0**	**11.5**	**0.4**	**1.7**	**0.1**	**1.1**	**2.4**	**3.8**	**15.6**
Illinois										
Madison	267,937	14.4	8.0	0.2	0.8	0.0	0.4	2.1	2.9	13.9
St. Clair	268,415	38.5	30.1	0.2	1.2	0.0	0.8	2.6	3.6	17.8
Monroe	33,373	3.4	0.3	0.0	0.8	0.0	0.0	0.8	1.5	5.4
Randolph	33,091	14.5	10.2	0.1	0.3	0.0	0.5	0.7	2.7	12.3
Jackson	60,125	26.6	14.6	0.4	3.3	0.0	0.8	3.3	4.2	32.3
Union	17,620	10.0	1.6	0.1	0.5	0.0	1.5	1.3	5.0	18.0
Alexander	7,821	41.1	35.9	0.4	0.3	0.0	0.0	2.4	2.1	36.8
Project Area	**688,382**	**24.5**	**17.1**	**0.2**	**1.2**	**0.0**	**0.6**	**2.2**	**3.2**	**16.3**
State of Illinois	**12,868,747**	**43.8**	**14.4**	**0.2**	**4.9**	**0.0**	**5.8**	**2.2**	**16.3**	**14.4**

Source: U.S. Census Bureau 2014.

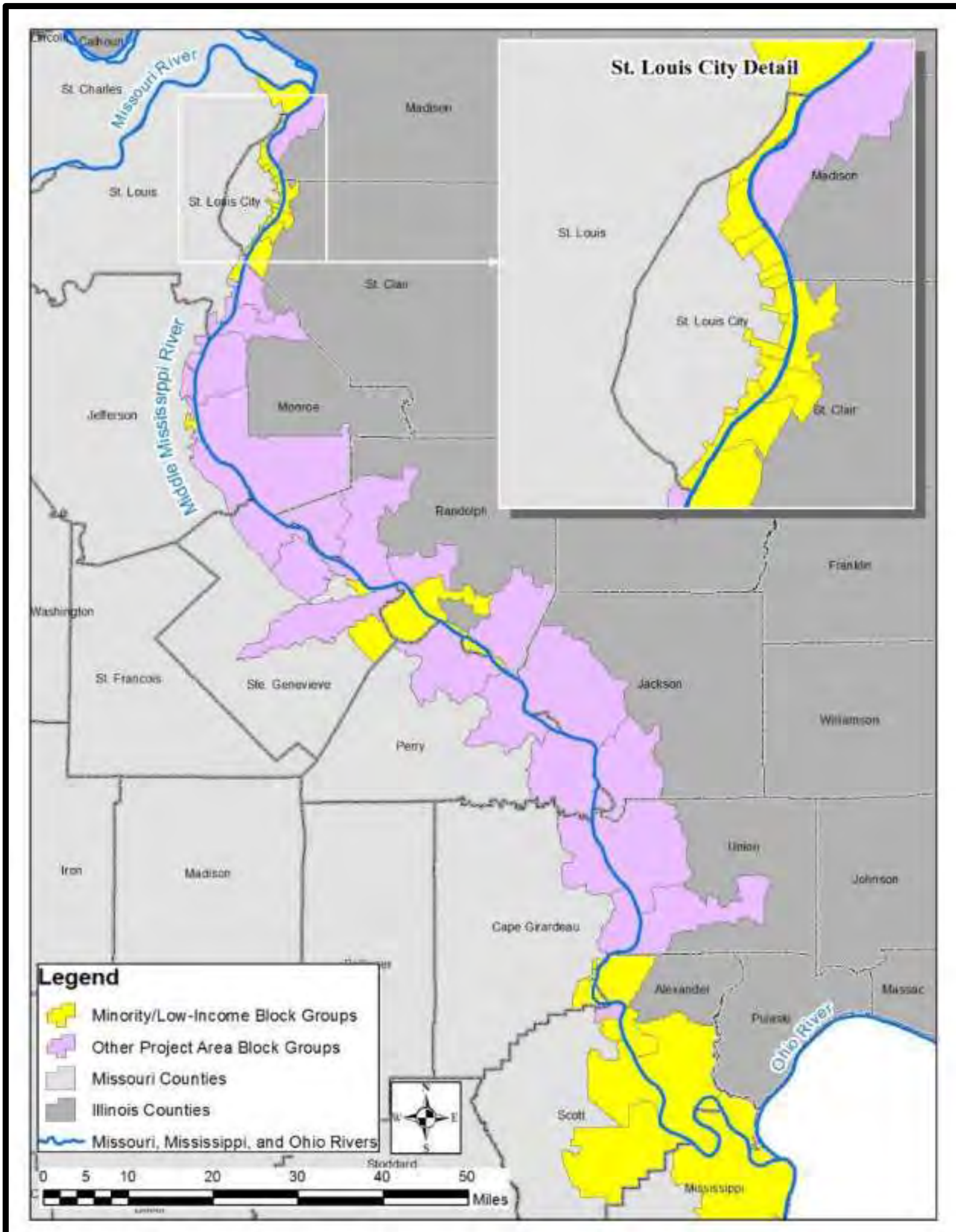


Figure 3-35. Minority and low-income population Census Block Groups within the Project Area.

Land Cover/Land Use

The Middle Mississippi River floodplain area encompasses approximately 670,000 acres (Table 3-15). The majority of the land in the floodplain can be generally categorized as rural and agrarian in nature with isolated areas of highly developed industrialized urban pockets, the St. Louis metropolitan area being by far the largest among them (Figure 3-36). Approximately 50 percent of the floodplain is currently used for agriculture. These areas are generally protected by an extensive levee and drainage system. Forest is the second most abundant land cover class, occupying 18 percent of the area. Open water and developed lands occupy 12 and 9 percent of the area, respectively. The remaining three categories, marsh, grass/forbs, and sand/mud, each account for less than 5 percent of the area.

Comparisons of current land cover distribution to that of past years can be difficult due to differing data coverage. Datasets from the 1800s frequently have large areas where no land cover delineation exists. The only available land cover datasets for the time period around 1976 cover only the portion of the MMR that lay riverward of the levee system at the time instead of covering the entire bluff to bluff floodplain as current analyses do. For these reasons, comparisons of land cover classifications between time periods necessarily cover only the portions of the MMR and its floodplain common to both dates being compared. When comparing current land cover to that of 1890 (Table 3-16), general trends that can be seen are large increases in agriculture and developed areas and large decreases in forested land. When comparing current land cover to that of 1975 (Table 3-17), there are large decreases in agriculture acreage and increases in open water, forest, and marsh.

Table 3-15. MMR floodplain land cover categories, acreages, and percentages (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014b).

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 3-16. MMR land cover categories, acreages, and percentages for 1890 and 2011 (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014b).

Land Cover Category	1890 Acreage (% of Total)	2011 Acreage* (% of Total)
Agriculture	136,638 (38.2%)	157,568 (44.1%)
Forest	110,062 (30.8%)	68,857 (19.3%)
Open Water	71,935 (20.1%)	67,539 (18.9%)
Developed	3,909 (1.1%)	25,440 (7.1%)
Marsh	6,757 (1.9%)	20,769 (5.8%)
Grass/Forbs	Not delineated	15,452 (4.3%)
Sand/Mud	27,958 (7.8%)	1,634 (0.5%)
Total	357,259	357,259

* 1890 dataset did not contain complete coverage of the floodplain. Therefore, acreage covers only the portions of the MMR and its floodplain common to both dates.

Table 3-17. MMR land cover categories, acreages, and percentages for 1975 and 2011 (based on Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element data; USGS 2014b).

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

* 1975 dataset did not contain complete coverage of the floodplain. Therefore, acreage covers only the portions of the MMR and its floodplain common to both dates.

Outdoor recreation

The Middle Mississippi River provides opportunities for a variety of recreational activities including fishing, hunting, boating, birdwatching, sightseeing, etc. and there are public and private boat ramps throughout the 195-mile area affording access opportunities. There are also several state and federal properties on the MMR that facilitate land-based access to the river. However, very little quantitative information is available on the number of users who take advantage of MMR recreational opportunities. Compared to the pooled areas of the Upper Mississippi River which are more conducive to boating related activities, the MMR sees relatively little recreational pressure. Sport fishing is the most popular recreational activity with catfish being the most frequently targeted species.

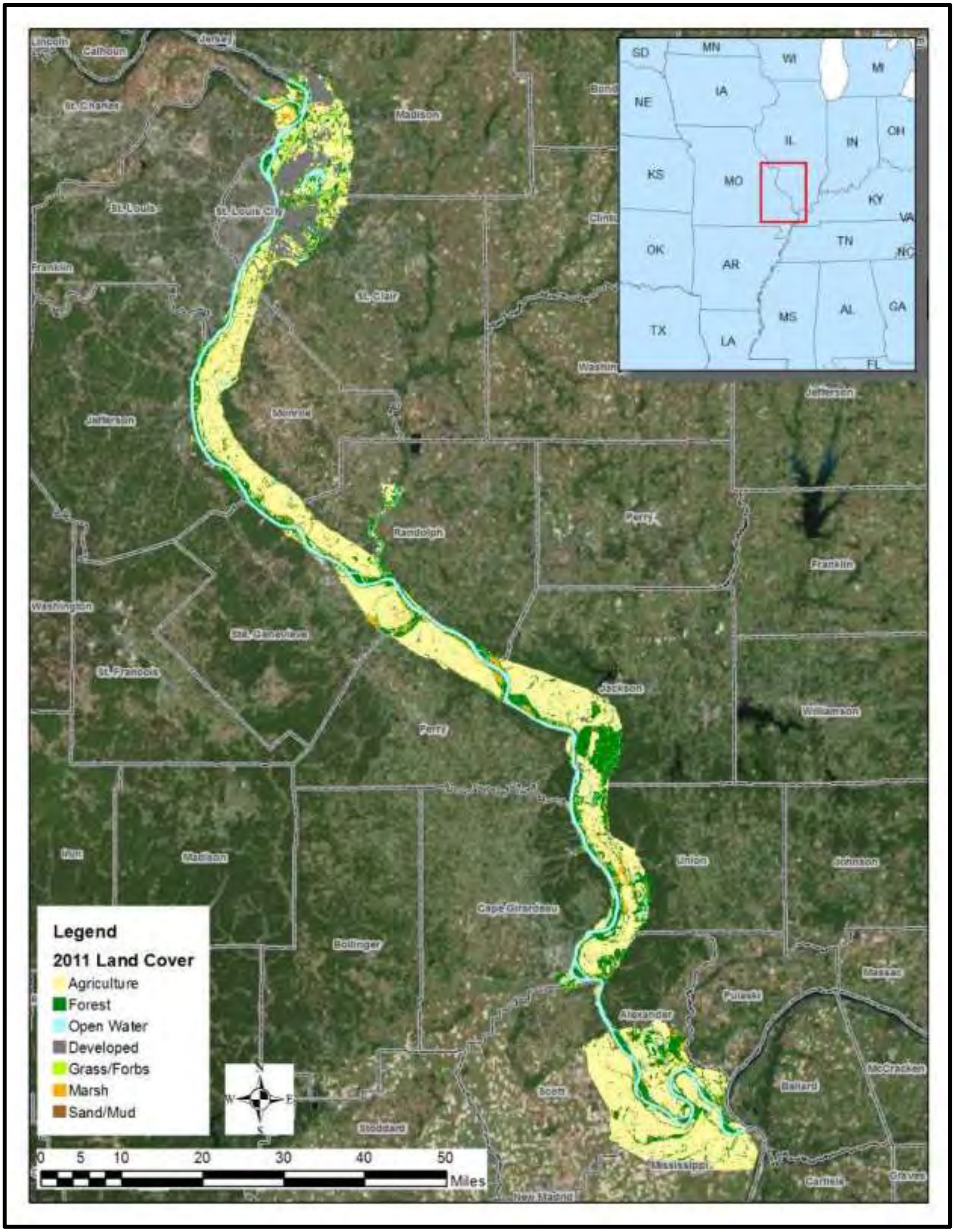


Figure 3-36. 2011 land cover classification for the MMR and its floodplain.

3.4.2 Navigation

The Port of Metropolitan St. Louis plays a key role in meeting the bulk transportation needs of Greater St. Louis and the Midwest with a competitive advantage over other regions because of its central location on the U.S. Inland Waterways System. St. Louis is the third largest inland port in the U.S. by tonnage (USACE 2014e).

The Port is the northernmost ice-free port on the Mississippi River remaining open throughout the year and provides a direct avenue to the Gulf of Mexico and other world markets. The Port is centrally located on the 25,000-mile U.S. Inland Waterway System connecting the markets and industrial centers located along the St. Lawrence Seaway; the Missouri, Ohio, Illinois and Tennessee Rivers; the Gulf of Mexico; and beyond to international markets. Intermodal transportation facilities provide industrial and agricultural users within Greater St. Louis cost effective and competitively priced transportation access to and from the U.S. Inland Waterway System and world markets. Because of its location within the agricultural and industrial Midwest, the Port is a major shipper of grain, coal, petroleum products and chemicals (Table 3-18). It provides dependable, efficient, environmentally sound, low-cost transportation particularly for the shippers of bulk commodities where rates and freight cost considerations are the critical ingredient in the competitiveness of their operations.

The Port spans 70 miles and includes five public Port Authorities and dozens of private independent company docks and wharves. Of the five Port Authorities within the Port of St. Louis, only two have active harbor operations. America's Central Port (Tri-City) and St. Louis Port Authority are the operating ports. Jefferson County Port Authority, St. Louis County Port Authority and Southwest Regional Port District are primarily involved in economic development activities and do not have waterside operations. America's Central Port (Tri-City) on the Chain of Rocks Canal typically moves the most tonnage from a single port location. The St. Louis Port Authority leases city-owned land to private companies along the port's 19-mile stretch of the Mississippi River.

Table 3-18 displays the waterborne tonnage that passed through the MMR from 2005 to 2014. During this 10-year period an average of approximately 104 million tons traversed the MMR, with the maximum tonnage (110.3 million tons) in 2006 and the minimum tonnage (89.7 million tons) in 2013. Since the onset of the most recent economic recession in 2008, waterborne shipments on the MMR have settled in around 104 million tons per year. 80% of this tonnage has been in the downstream direction. Of the eight major commodity groups, only three – chemicals, non-metallic ores and minerals, and iron ore and iron and steel products – have seen the majority of shipments head upstream.

Table 3-18. Tonnage of commodities passing through the Middle Mississippi River over the last ten years.

Middle Mississippi River Waterborne Tonnage 2005 to 2014 (millions of tons)

Commodity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Last 10 Years (avg)	Last 5 Years (avg)
COAL	22.91	26.34	26.43	26.23	27.13	22.26	25.59	22.41	17.35	15.54	23.22	20.63
PETROLEUM PRODUCTS	7.25	8.28	8.48	7.20	7.34	6.99	7.07	7.79	8.23	9.35	7.80	7.89
CRUDE PETROLEUM	0.02	0.10	0.37	0.73	0.68	0.89	3.23	4.83	5.75	4.80	2.14	3.90
AGGREGATES	7.14	10.34	9.74	8.70	8.43	8.34	7.95	9.79	10.90	11.48	9.28	9.69
GRAINS & GRAIN PRODUCTS	39.11	40.56	41.68	32.53	40.01	41.52	36.26	33.82	23.11	38.04	36.66	34.55
CHEMICALS	8.22	7.42	9.20	8.64	8.58	10.37	11.59	11.16	10.38	12.39	9.80	11.18
NON-METALLIC ORES & MINERALS	3.63	3.58	3.13	4.87	4.80	2.81	3.58	2.56	2.66	4.88	3.65	3.30
IRON ORE & IRON & STEEL PRODUCTS	6.66	6.69	5.04	4.93	3.21	3.31	3.99	4.24	3.43	4.55	4.61	3.90
OTHERS	7.24	6.96	5.75	4.85	4.16	6.47	7.37	8.18	7.85	8.35	6.72	7.64
TOTAL	102.17	110.26	109.81	98.67	104.32	102.97	106.63	104.77	89.67	109.37	103.86	102.68

Source: Waterborne Commerce Statistics Center (USACE 2014e)

On a commodity level, the distribution of goods on the MMR has held fairly steady since 2005. The emergence of crude petroleum shipments has provided the largest single gain in volume shipped of any commodity. Crude shipments have increased from zero tons in 2005 to almost 5 million tons in 2014. The largest decrease in volume occurred in coal shipments, which have generally been declining since 2009. While some of these commodity fluctuations are quite significant, it is important to note the total tons shipped has remained relatively steady as the maximum and minimum are both within 9 percent of the 10 year average.

Of all of the shipments made on the MMR, grains and grain products accounted for between 26 and 40 percent of the total tonnage. From 2005 to 2014, corn led all other grains with 55% of the tonnage, followed by soybeans (27%), wheat (5%), and oil seeds or oleaginous fruits (5%). Roughly 18% of all corn and soy beans produced in the U.S. are shipped using the MMR.

Commodities by Draft[16]

Draft depth is driven by the demand for waterborne shipping and river conditions. Table 3-19 shows the 10-year distribution of commodities shipped by draft depth. The vast majority of

[16] The draft of a vessel is defined as the vertical distance between the water line and the lowest point on the vessel, or the depth of water to which a vessel sinks based on its load.

tonnage is shipped on barges with a draft of 8-9 feet. During favorable river conditions, high demand can be met by loading barges in excess of 9 feet, resulting in fewer trips and a lower shipping cost. If there is low demand or unfavorable river conditions, the carrier may be forced to partially load a barge, resulting in draft depths of less than 9 feet. During this period, 95% of the MMR tonnage was shipped on barges with at least 8 feet of draft.

Table 3-19. MMR Commodities by Draft.

Commodities by Draft Depth
2005 to 2014
(thousands of tons)

DRAFT (ft)	COAL	PETROLEUM PRODUCTS & CRUDE PETROLEUM	AGGREGATES	GRAINS & GRAIN PRODUCTS	CHEMICALS	NON-METALLIC ORES & MINERALS	IRON ORE & IRON & STEEL PRODUCTS	OTHERS	Total
Less than 5	72	92	8	47	525	165	54	121	1,083
6	85	104	12	532	213	79	17	81	1,122
7	412	450	22	686	693	373	92	339	3,067
8	4,549	1,260	218	2,623	13,852	4,760	1,837	2,101	31,202
9	15,518	3,785	1,068	4,019	14,852	3,340	1,024	1,684	45,289
10	802	1,565	501	818	1,871	565	210	120	6,452
11 or more	1,031	544	310	539	4,505	494	403	155	7,980
All Drafts	**22,469**	**7,800**	**2,139**	**9,263**	**36,511**	**9,775**	**3,638**	**4,601**	**96,195**

Source: Waterborne Commerce Statistics Center

Value of Commodities

The U.S. Department of Transportation Commodity Flow Survey for 2012 estimated that a total of 374.2 million tons of goods were shipped by inland waterways, valued at approximately $202.3 billion. The MMR accounted for almost 28% of this tonnage and roughly 10% of the value. The low MMR value, compared to the total inland waterway tonnage, is driven by the relatively low cost of grains.

Using current prices for the commodities, the total estimated value for the commodities shipped on the MMR is $20.9 billion per year, with agricultural products ($8.2 billion) and chemicals ($8.1 billion) making up 78% of the total value. The sources for the unit prices for these commodity groups were found on the U.S. Geological Survey, U.S. Department of Agriculture, Platts (futures), Energy Information Agency, and CME Group (futures) websites. This represents a rough estimate based on approximations for the value of a wide range of products within each commodity type.

3.5 Historic and Cultural Resources

3.5.1 Cultural Resources Policy

The National Historic Preservation Act of 1966 (NHPA) directs that federal agencies consider an undertaking’s effects on cultural resources. Section 106 of the act requires that federal agencies assess the effects of the undertaking on historical properties and consult with the relevant State Historic Preservation Officer (SHPO), affected Tribes, and other interested parties. The regulation implementing Section 106, 36 CFR Part 800, encourages coordination with the environmental review process required by NEPA and other statutes. This Section 106 compliance procedure has been discussed with both the IL and MO SHPOs during consultations begun in 2014 regarding this document. Additionally, twenty-eight federally recognized tribes affiliated with the St. Louis District were notified during the development of the SEIS and no objections were raised.

Properties protected under Section 106 are those that are listed, or are eligible to be listed, on the National Register of Historic Places (NRHP). Eligible properties must be, generally, fifty years old and considered to have integrity of location, design, setting, materials, workmanship, feeling, and association. They must be significant under one or more specified criteria:

(a) They must be associated with events that have made a significant contribution to the broad patterns of our history; or
(b) They are associated with the lives of persons significant in our past; or
(c) They embody distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
(d) They have yielded, or may be likely to yield, information important in prehistory or history.

3.5.2 Cultural and Historical Setting

Documentation of the Mississippi River Valley prehistoric and historical sequence is extensive and only a brief outline is presented here. Prehistoric human occupation of the area is generally broken into four inclusive periods: Paleo-Indian, Archaic, Woodland, and Mississippian. Each period is characterized by differing degrees of social complexity and changes in subsistence technologies and pursuits. The Paleo-Indian period represents the first populating of North America. The earliest evidence for the occupation of mid-continental United States are fluted points made around 13,500 to 12,700 years ago (Morrow 2014; Fiedel 1999). Paleo-Indians are generally characterized as consisting of smaller groups of hunter and gatherers following migrating herds of large game. The period lasted until the end of the Wisconsin glaciation around 8000 B.C. when the stabilizing climate led to the different ecological adaptations of the Archaic period. While hunting and gathering continued, there was some cultivation of native plants. Larger communities formed as a more sedentary culture developed. The subsequent Woodland culture (1000 B.C. to 900 A.D.) is characterized by the widespread use of pottery, increasing use of agriculture, and development of long-distance trade. The sociocultural traits generally ascribed to the following Mississippian period (900 to 1400 A.D.) include intensive agricultural adaptations, increasingly large fortified towns, pyramidal mounds, increased interregional trade, and highly stratified sociopolitical organization. The most elaborate and famous expression of the culture is the extensive settlement of Cahokia Mounds located on the American Bottom near modern Collinsville, Illinois.

European exploration of the Middle Mississippi began with the voyage of Jacques Marquette and Louis Joliet down the river in 1673. A trading establishment and mission were built at "Grand Village of the Illinois" in 1675. Kaskaskia was established in 1703, Sainte Genevieve around 1750, and St. Louis in 1764. For much of the 18th and 19th centuries commerce on the river was driven by the fur trade, while there was some limited trade in salt and lead. The introduction of steamboats in the early 19th century, along with the increasing development of the region, greatly expanded the volume of the trade in general commodities and the transportation of people. The number of vessels engaged in river traffic increased yearly along with their size and the number of round trips each took in a given year (Haites and Mak 1971).

3.5.3 Area of Potential Effect

36 CFR Part 800.16 defines area of potential effect (APE) as "the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character of use of historic properties, if any such properties exist." For cultural resources, the APE for the Middle Mississippi River Regulating Works Project is from bankline (mean high water) to bankline of the river between the Ohio and Missouri River confluences (RM 0 and RM 195, respectively).

3.5.4 Shipwreck Background

Before contact with Europeans, Native American communities used the Mississippi as a means of transportation by several types of watercraft. Many descriptions are readily available from early European documents and illustrations, while archaeology provides more limited evidence.

Many of the native forms of water transport are now known as canoes; the term is derived from the Arawakan word *canot*, first borrowed by the Spanish and later Anglicized. It is a general term used for many structurally different types of watercraft including those with bark, sewn-plank, skin, and dugout construction styles. From ethno-historical sources, however, it appears that throughout much of North America by that time bark canoes were the most widely used rivercraft (Gamble 2002).

After the arrival of Euroamericans a number of smaller vessel types were introduced. The terms used, such as pirogue, bateau and skiff, are often ambiguously applied and should not be taken to describe a single and unique style of construction.

By the late 18th century, however, two general classes of vessels dominated navigation on the Middle Mississippi River: flatboats and keelboats. Both classes incorporated many sub-varieties and were known by different names. Flatboats, for example, were also known as arks, flats, Kentucky boats, and broadhorns.

Flatboats were, in essence, floating rectangular boxes. Flat bottomed and usually roofed for protection from inclement weather, they were generally around sixty feet long and twenty feet wide (Hoagland 1911). A unique archaeological example was recorded on the Ohio just above the confluence with the Mississippi in 2002 (Wagner 2003). The remains consisted of a shell-built edge-joined flat bottomed structure, and probably dated to the first quarter of the 19th century.

Flatboats were ungainly vessels only partially guided by long broad sweeps. Carrying any number of different bulk goods, flatboats were only used for downstream commerce and were generally broken up as lumber once at their destination. Due to the dangers resulting from being only controlled to a degree during their descent, flatboat traffic was limited to a few months of the year during high water, except on the Lower Mississippi (Hoagland 1911). Even then insurance companies generally refused to insure this type of vessel (Mak and Walton 1973).

Keelboats were generally long, narrow, and shallow craft with pointed ends, a planked deck, and a cabin which covered the majority of the boat. The key difference from the earlier bateau was the introduction of a keel either added externally or, more usually, as part of its interior construction (Baldwin 1941). Made of plank construction with interior frames, they generally were from forty to sixty feet long and seven to ten feet wide (Hoagland 1911). They drew about two feet of water when loaded. Traveling downstream they were rowed, but to travel upstream they were generally poled at the rate of eight to ten miles per day. If the water was too deep for poling, the crew would tow the boat from the shoreline.

The use of steamboats on the western rivers was inaugurated when the *Orleans* traveled from Pittsburg down the Ohio and Mississippi and arrived in New Orleans in January of 1812. The advantages of steam propulsion are as obvious as they are revolutionary. Trips took a fraction of the time, allowing for more tonnage to be carried by a vessel, or fleet, in a given period. Moreover, steam power reduced navigational risks compared to floated, rowed, or sailed vessels. The vessel loss rate, however, continued to be high compared with modern standards. The combination of advantages cut the cost of transportation in half (Landon 1960).

Steamboats rapidly replaced keelboats and flatboats. By the beginning of the 1820s some 70 steam vessels were in operation on the Mississippi River system and by the middle of the century the number had risen to over 700 (Tuttle and James 2005). The introduction of steamboat technology made the Mississippi River system one of the most heavily trafficked in the world. In the 1840s the tonnage of its boats accounted for half the register amount of the nation as a whole, and during the 1850s it was greater than all transported by the merchant ships of the British Empire at that time (Landon 1960).

The earliest steamboats were side-wheelers, but by 1880 stern-wheelers outnumbered them (Landon 1960). The latter had several advantages. On the Ohio, stern-wheelers were almost a necessity after the opening of the Louisville canal in 1830. The canal was only 82 feet wide and while the larger stern-wheelers could slip through the channel, wider side-wheel boats of the same tonnage were shut out from trade above Louisville. Moreover, when the river was low boats could not carry full cargos and found it useful to lay freight barges along each side of the steamer (Hall 1884). One would carry cargo and the other would carry fuel. On such a "light water trip" on the Ohio, when the vessel arrived in Cairo, the cargo was transferred to the steamer for the remaining voyage down the Mississippi (Figure 3-37). The use of lighters was a common way to reduce a vessel's draft on all the rivers. Screw (i.e., propeller) propulsion was introduced on maritime vessels in the 1840s and 1850s, but was not used on the rivers until 1930. The shallow river depths made the equipment more vulnerable and less efficient. The introduction of the more powerful and cost efficient diesel engines hastened their adoption as they could not be used to advantage with a paddle wheel (Landon 1960).

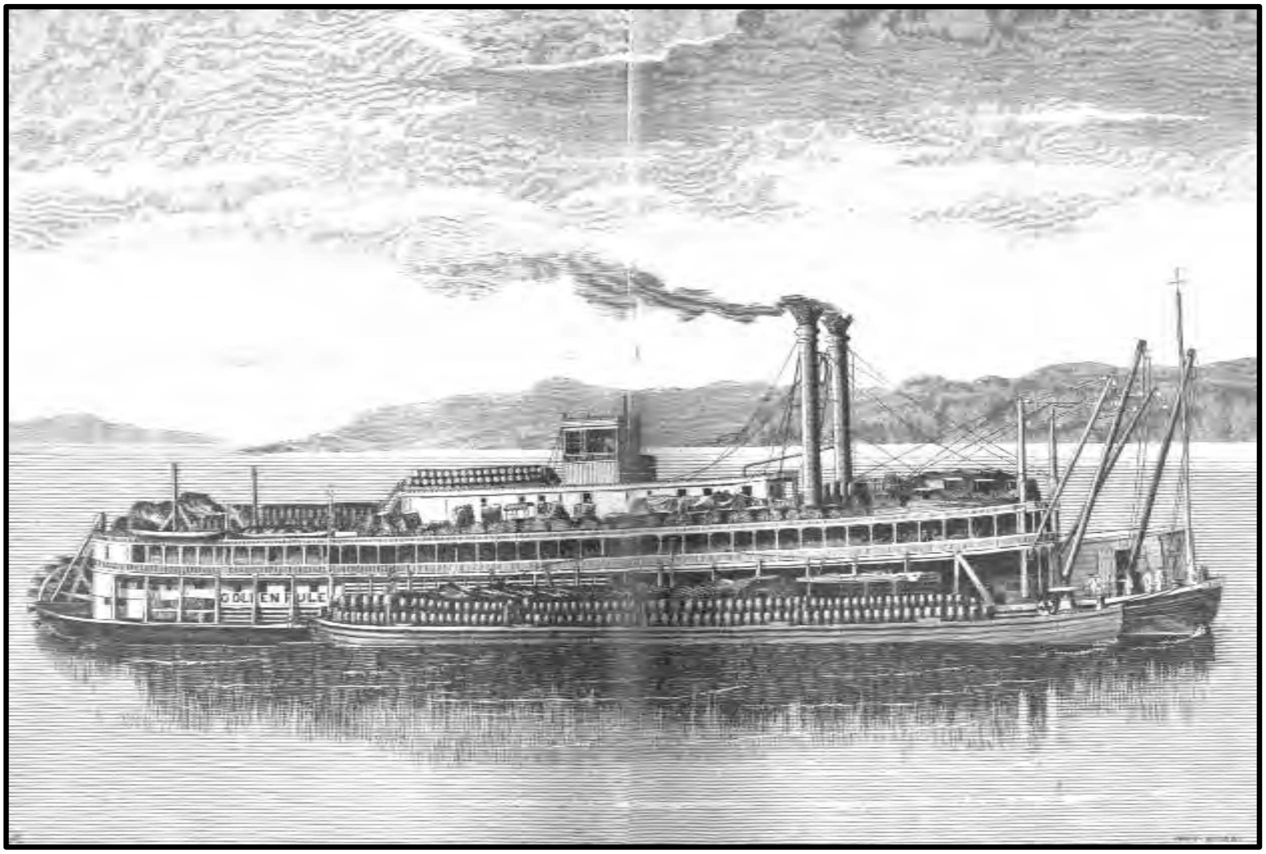


Figure 3-37. Stern-wheel freight boat Golden Rule with barge lashed alongside (from Hall 1885, Figure 53).

The number of steamboats arriving at New Orleans reached a high of 3566 in 1860 (Landon 1960) before the Civil War disrupted commerce (Landon 1960). After the war the trade quickly recovered and was profitable until about 1875. In 1882 there were 1198 vessels on the western rivers for a total of 251,793 tons (Hall 1885). Additionally there were 5397 flat boats and barges measuring 1,251,529 tons. A long term danger to the industry, however, was the rise in competition from the railways. After 1890 there was a rapid decline in the number of vessels engaged in trade. The nadir of Mississippi River commerce came in 1918 when about five-and-a-half million tons were shipped (Landon 1960).

From their inception, steamboats were used to tow non-powered craft. Indeed, in maritime settings their earliest use was to tow sailing vessels in and out of harbors when the wind was not advantageous. It was common for steam vessels on the Mississippi to tow a barge or two alongside, either as lighters (as outlined above), or simply for extra cargo.

By 1880 there were four recognized classes of barges (Hall 1884). The smallest was the flatboat. Related in function to the earlier flatboat, they were the smallest barge being 90 feet long by 16 feet wide and registering about 75 tons. They were square and box-like with a raking bow and stern. Unlike their earlier namesakes they were undecked and not intended to be disposable. They were generally used for short trips on small streams. The second type was the coal barge, another open boat, about 130 feet long, 24 feet wide, and registering around 225 tons. Most of these were employed on the Ohio River bringing coal from Pennsylvania and West Virginia to locations south. The main difference between them and the flatboats was their size and higher construction standards. The third type, also found on the Ohio, was a smaller cheaper version of the coal barge. Produce boats were around 122 feet long by 22 feet wide and were designed to be broken up upon reaching their destination. After its introduction in the 1860s, the pride of the barge fleet was the model barge. There were four sizes carrying 600, 800, 1000, and 1200 tons respectively. The 1200 ton version was 225 feet long, 36 feet wide and with a depth of nine-and-a-half feet. Their defining hull characteristic was their "pinkie stern," which made them double-ended (Figure 3-38). After the introduction of the towing knee in 1865, barges were generally pushed in the western rivers (Landon 1960). By 1880 it was not uncommon for fleets of eight barges wide and four barges long to be lashed together ahead and alongside the bow of a steamer (Hall 1884). Until the 1930s the typical towboat was a steam stern-wheeler of 600 to 1000 horse power. Since then they have been replaced by diesel powered screw propeller vessels.

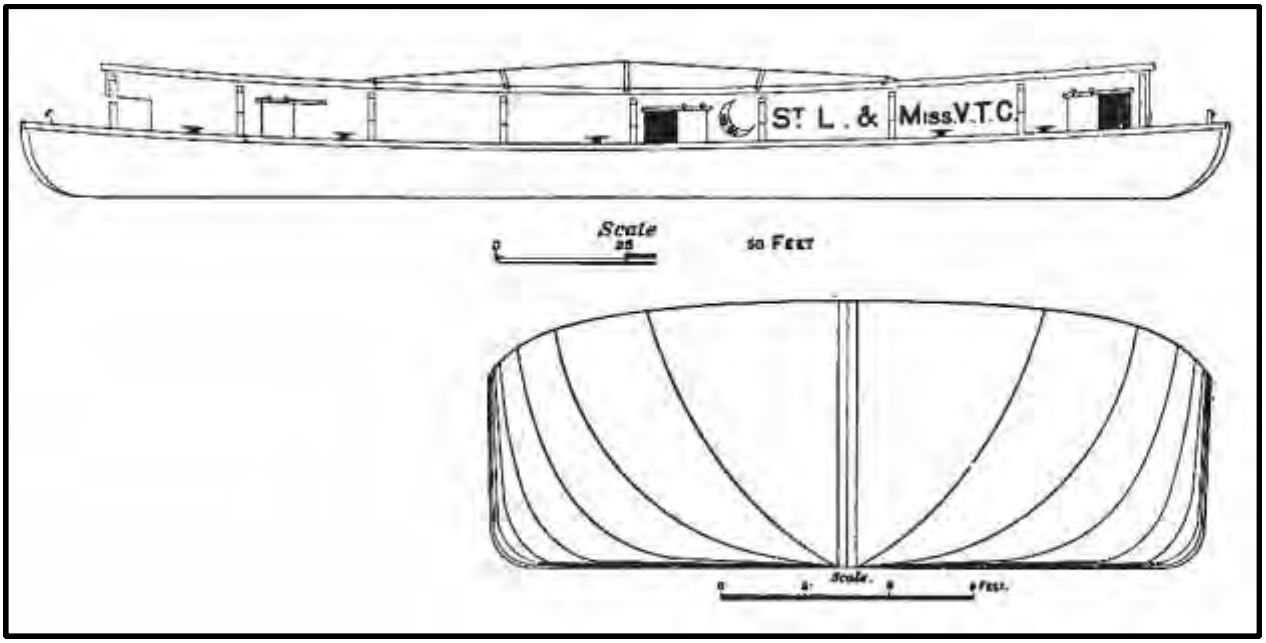


Figure 3-38. 1200 ton class model barge (from Hall 1885, Figures 56 and 57).

3.5.5 Shipwreck Inventory

Losses among steamboats were high. Primary reasons for their destruction were snags, fires, and explosions. Indeed, the average longevity for steamboats has been calculated to be only six (Haites and Mak 1971) or seven (Hall 1884) years. For this reason insurance rates were high and many operators carried none; those that did typically only did so for two-thirds or three-quarters the value of the boat (Haites and Mak 1971).

As part of a 2003 Corps study, archival research documented six hundred and eighty seven (687) ships abandoned or reported lost prior to 1940 between Saverton, Missouri, and the confluence of the Mississippi and Ohio Rivers. The information was obtained by James V. Swift from a variety of sources, including unsigned, undated wreck data in the files of the Waterways Journal (St. Louis), nineteenth century correspondence and newspaper accounts, insurance records, official government surveys and reports, private accounts, and published research (Norris 2003). Generally, most losses were reported with a general location (e.g., Scudder Towhead, Brewer Point), which was researched and when possible converted to approximate river miles (Figure 3-39). The yearly mean for reported losses is just over five-and-a-half (5.5) with a peak in the 1850s to 1860s (Figure 3-40). A number of individual historic events, such as the St. Louis Fire of 1849, are responsible for some of the peak years.

Figure 3-39. Approximate locations of documented vessel losses on the Middle Mississippi River.

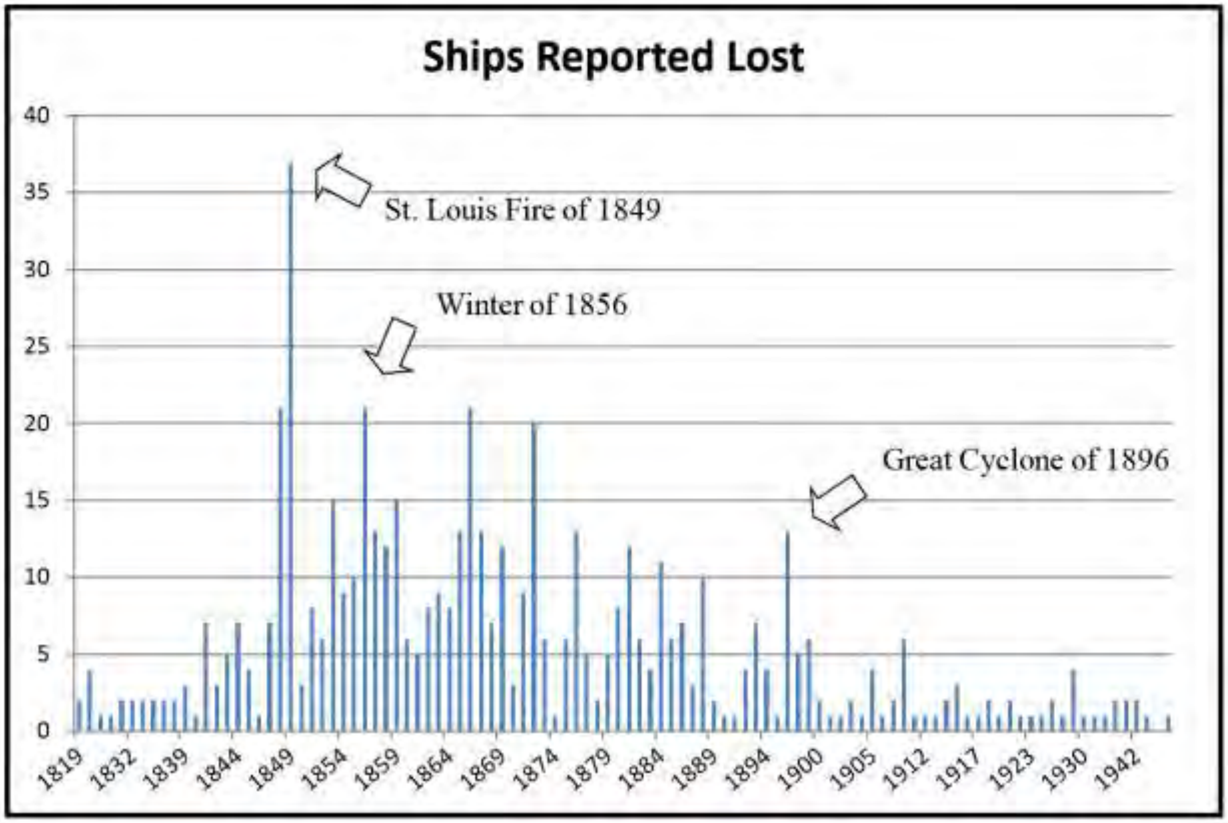


Figure 3-40. Recorded ship losses per year.

The database should not be considered exhaustive of all watercraft losses, however, as smaller vessels and the more numerous barges were less likely to make accounts. Indeed, only forty nine (49) of the entries are identified as barges, or groups of barges, even though we know from archival records they were more numerous than steamboats by a considerable margin. No keelboats or other early vessel types are identified. The descriptions are a mix of functions and forms (Table 3-20).

Table 3-20. Vessel descriptions in losses database.

Vessel Description	Count	Vessel Description	Count
Barge	49	Stern-wheel boat	49
Canal boat	2	Stern-wheel towboat	2
Dredge	1	Tinclad	1
Excursion boat	2	Towboat	15
Ferry	9	Transfer boat	3
Gunboat	1	Tug	1
Recessed-wheel boat	1	Wharf boat	4
Side-wheel boat	119	Wrecking boat	1
Side-wheel ferry	1	None Given	425
Side-wheel snagboat	1		

The most frequent cause of loss was burning, especially if one includes explosions within that category (Table 3-21). The second most frequent cause was ice damage, followed by snags.

Table 3-21. Vessel cause of loss in loss database.

Cause	Count
Abandoned	25
Burned	184
Capsized	5
Collision	12
Dismantled	1
Exploded	13
Hit bridge/tower	6
Hit obstruction/wreck/rocks	7
Ice	85
Sank (unspecific)	75
Snagged	81
Stranded	18
Tornado	15
Wind	5

3.5.6 Known Shipwrecks

The St. Louis District maintains two databases of shipwrecks which are updated periodically as new wrecks are discovered by the Corps, other government agencies, or independent research groups (Figure 3-41). The first is comprised of historical shipwrecks, most of which are relatively insubstantial and located in normally shallow water outside of the navigation channel. The second documents more significant, and generally more recent, wrecks that may pose a risk to navigation.

The nucleus of the historical wreck database was created during a 1988 aerial survey of the Mississippi River, between Saverton, Missouri and the mouth of the Ohio River, when it was at a particularly low level (Norris 2003). Since then surveying techniques have improved with the use of a variety of sonographic tools, such as single and multi-beam surveys, as appropriate. The district conducts bathymetric surveys on the MMR bi-annually and in conjunction with dredging cycles and/or other Regulating Works Project activities. As outlined in Section 4.5, as part of the Tier II SSEAs multi-beam sonar surveys are conducted before the construction of structures associated with the Regulating Works Project. To date, no wrecks have been discovered by the latter surveys.

In total, approximately 90 wreck locations have been identified, and while few shipwrecks have been discovered in recent years, if discovered during the above mentioned surveys consultation with the appropriate SHPO and other interested parties would be undertaken to determine appropriate measures for their documentation and/or preservation.

Of the known wrecks in the Middle Mississippi River only one was on the National Register of Historic Places. The USS Inaugural (AM-242), an Admirable class fleet minesweeper, was listed on 14 January 1986 with NPS Reference Number 86000091. The vessel was berthed at the northern leg of the Gateway Arch in St. Louis. During the 1993 flood, she broke loose from her moorings, suffered a breach, and sank on the Missouri side of the river at approximately RM 178.75. Determined a total loss, her Landmark designation was withdrawn on 7 August 2001. Scrapping efforts began in 2013.

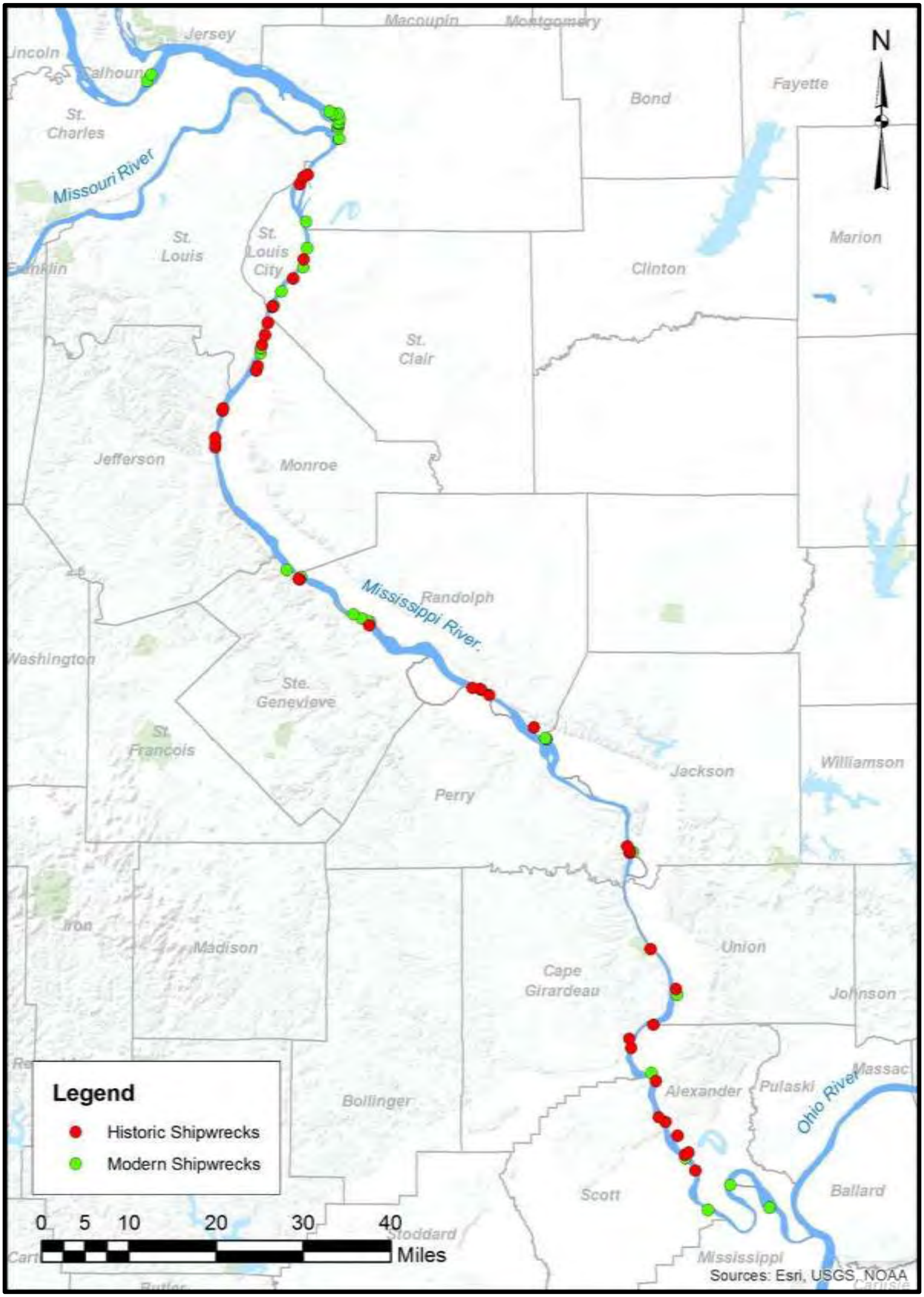


Figure 3-41. Known shipwrecks on the Middle Mississippi River.

3.5.7 Regulating Works Project

The District, in consultation with the Missouri and Illinois State Historic Preservation Offices (SHPOs), prepared a National Register of Historic Places (National Register) Determination of Eligibility (DOE) Study for the Middle Mississippi River Regulating Works Project. Given that the Project contains structures of sufficient age to be considered for the National Register, and that some of these structures may be modified or removed by future engineering efforts, it was considered appropriate to address the Project's National Register eligibility (See full report as Appendix F).

The DOE assesses the historic and engineering significance of the Project and its associated built features. It includes a narrative history and physical description of the Project and an evaluation of National Register eligibility within its historic and engineering context. Key sources included Corps annual reports; authorizing legislation concerning the MMR; and a wide variety of published works and scholarly articles pertinent to the history of the Project, navigation on the Mississippi River in general, and development of river-training technology in the United States. Historic maps, photographs, and design drawings were also consulted, along with the MMR features catalog, providing location data from 1881 to the present for dikes constructed as part of the Project.

The Project is recommended, due to a loss of integrity, as *not eligible* for the National Register. The study indicates that the Project has been a constant engineering effort involving the construction, reconstruction, modification, and upgrading of various river training structures. With direct national influence on agriculture, commerce, engineering, industry, and transportation, the navigability of the MMR is demonstrated to be immeasurably important, and the Project continues to be promoted and implemented today. For these reasons, the Project, evaluated as a district, is historically significant under National Register *Criterion A*. To be eligible for the National Register, however, a property must also possess integrity, i.e., the ability of a property to convey significance. The study demonstrates that due to continual, but necessary, modifications of various river training structures, the Project no longer retains integrity of materials and workmanship from its period of significance (1881-1965). With most, if not all, of its associated structures constructed or modified since 1965, the Project is unable to convey its considerable national significance as necessary to be considered eligible for the National Register.

3.5.8 Other Cultural and Historic Resources

Other anthropogenic structures within the project APE may include remnants of historic mooring piles, quays, railroad inclines, and river training structures. Prehistoric sites and their features are not expected to survive in the reworked underwater environment, except for on occasions when a feature is non-perishable (i.e., not likely to decay or breakdown). A unique example of such a feature is a periodically submerged boulder with a petroglyph panel at the Commerce Quarry and Petroglyph site (23ST255) (Norris and Pauketat 2008).

While the Middle Mississippi alluvial plain is the location of literally thousands of known archaeological sites, only a relatively few are within the project APE. In the Missouri SHPO database there are nine (9) sites mapped within 100 feet of the Mississippi River bankline. In the

Illinois equivalent database there are fifteen (15) such sites. Of the combined twenty four sites (24), one is a wreck recorded in the Corps database (Table 3-22).

Table 3-22. Known archaeological sites within 100 feet of Project APE.

Period	Type	Number
Prehistoric	Habitation/Scatter	10
	Habitation (Rock Shelter)	3
	Mound	1
Historic	Habitation/Scatter	6
	Cemetery	1
	Industrial	1
	Wreck	1
Multi-component	Habitation	1

Twelve (12) districts or locations on the National Register of Historic Places are within 100 feet of the project APE (Table 3-23; Figure 3-42). Two of these sites, Eads Bridge and Fort de Chartres, are also National Historic Landmarks.

Table 3-23. National Register sites within 100 feet of Project APE.

Item	NPS Reference
Chain of Rocks Bridge	06001091
Eads Bridge	66000946
Fort de Chartres	66000329
Grand Tower Mining, Manufacturing and Transportation Company Site	79000839
Green's Ferry (Cherokee Trail of Tears MPS)	07000571
Greystone-Meissner, Gustave House	74001078
Jefferson Barracks Historic District	72001492
Jefferson National Expansion Memorial National Historic Site	66000941
Laclede's Landing	76002262
North Riverfront Industrial Historic District	70000344
Steins Street District	64000390
Tower Rock	70000344

Figure 3-42. Locations of NRHP sites/districts within 100 feet of APE.

Chapter 4. Environmental Consequences

4.1 Introduction

This chapter describes the potential environmental consequences of implementing the alternative plans considered. A comparison of direct, indirect, and cumulative impacts of alternatives is presented. Direct impacts are those that are caused by the action taken and occur at the same time and place (40 CFR §1508.8(a)). For example, an increase in turbidity associated with dredging would be a direct impact on water quality. Indirect impacts are those that are caused by the action but are later in time or further removed in distance, but are still reasonably foreseeable (40 CFR §1508.8(b)). For example, the increase in macroinvertebrates as a food source due to colonization of rock surfaces would be an indirect impact of river training structure construction on fish. Cumulative impacts are impacts that result 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 actions (40 CFR §1508.7). Cumulative impacts would be the aggregate of impacts to the environment resulting from the proposed action in combination with other ongoing actions, and actions being considered within the reasonably foreseeable future. Cumulative impacts can result from actions that are individually minor but collectively significant over time (40 CFR 1508.7). For example, the construction of one dike in the MMR might have little impact when considered by itself, but the combined construction of all dikes in the MMR since the 1800s, and the resultant narrowing of the river channel, would be a cumulative impact. Cumulative impacts are more readily conveyed and understood when considered together rather than separately by resource category. Therefore, the cumulative impacts discussion for all resources can be found in Section 4.6 Cumulative Impacts at the end of this chapter.

As with Chapter 3, this chapter is organized by general resource categories: Physical Resources, Biological Resources, Socioeconomic Resources, and Historic and Cultural Resources. The impacts of both alternatives are combined under each resource heading. The impacts of implementation of each Alternative are evaluated relative to the baseline condition of each resource category. The baseline conditions of all resources are discussed in Chapter 3, Affected Environment, and reflect the current environmental and socioeconomic condition of the Middle Mississippi River.

Summary of Alternatives:

Continue Construction Alternative (No Action Alternative): The Continue Construction Alternative for this SEIS represents no change in the current implementation of the Regulating Works Project, with the addition of analyzing the potential consideration of and implementation of compensatory mitigation. Under a normal feasibility study seeking authorization for a new project, the No Action Alternative would mean that no action is to be taken. However, in the instance of an ongoing program, the No Action Alternative refers to no change in program direction (CEQ 1981). Accordingly, the No Action Alternative for this SEIS represents continuing with implementation of the Regulating Works Project as it is currently being implemented. The potential addition of compensatory mitigation measures to this Alternative does not change the basic features associated with the Alternative, how the features address the problems in the Project Area, or how they are constructed, operated, and maintained. Therefore, this Alternative is still considered to be the No Action Alternative. Truly taking "no action" in this case and, thereby, not maintaining the navigation channel on the MMR, is not a viable option and will not be considered, as discussed in Chapter 2.

Based on current estimates, the Continue Construction Alternative would entail placement of an estimated 4.4 million tons (2.9 million cubic yards) of rock at a rate of approximately 260,000 tons per year. This estimate is based on assumptions of Congressional funding levels, rock prices, dredging costs, potential mitigation costs, etc. and could differ markedly from actual implementation. The Continue Construction Alternative would also involve continuing to dredge as necessary, completing known bankline stabilization projects to reduce the risk of a channel cutoff, placing additional revetment, and continuing to maintain existing structures. Dredge quantities would be expected to decrease from their current average annual quantity of approximately 4 million cubic yards to approximately 2.4 million cubic yards after construction of new river training structures is complete.

No New Construction Alternative: The No New Construction Alternative consists of not constructing any new river training structures for navigation purposes, but continuing to maintain the navigation channel by dredging and by maintaining existing river training structures and bankline stabilization to ensure they continue to perform their intended functions. Maintenance dredging would continue at roughly the current level of approximately 4 million cubic yards per year. Maintenance of river training structures and revetment would be completed based upon need and annual funding received.

Both alternatives would continue to be in compliance with the Endangered Species Act as legally required. Actions as part of this compliance are not specifically discussed in this SEIS.

4.2 Impacts on Physical Resources

4.2.1 Impacts on Stages

Impacts of the Continue Construction Alternative on Stages

With implementation of the Continue Construction alternative, stages at average and high flows 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. Some of this research purports that river training structures raise flood heights. A summary of all of the available 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.

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. Current observations and analyses do not support this conclusion. See Section 3.2.2 Geomorphology above and Section 4.2.2 Impacts on Geomorphology below for results of side channel analyses. 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.

Impacts of the No New Construction Alternative on Stages

Stages for high flows are expected to be similar to current conditions under the No New Construction Alternative. The stages at low flows are less straightforward. The decreasing trend in stages for low flows can be attributed to a number of factors potentially including the construction of regulating works structures. It is expected that there would continue to be a decrease in stage for lower flows in the future even without any additional regulating works construction. However, the magnitude of this change attributable to regulating works cannot be determined.

4.2.2 Impacts on Geomorphology

The following discussion of the impacts on geomorphology is broken into three broad habitat categories: main channel/main channel border, side channels, and islands. For reference, the relative abundance of these habitats is provided in Table 4-1.

Table 4-1. Acreage of main channel, main channel border, side channel, and island habitat in the MMR in 1976 and 2014.

	1976 Acreage	2014 Acreage
Main Channel	20,834	25,134
Main Channel Border	29,911	24,592
Side Channels	3,893	4,128
Islands	11,465	11,375

Impacts of the Continue Construction Alternative on Geomorphology

Main Channel / Main Channel Border

Through the period of structure construction from the 1960s to present very little change has occurred to the planform. It is expected that this would continue moving forward with the Continue Construction Alternative. It is also expected that the average planform width, planform surface area and channel surface area would continue to be in a state of dynamic equilibrium.

Changes to channel bathymetry include an increase in cross sectional area, hydraulic depth, channel volume and channel conveyance due to continued construction of river training structures. This is the result of the changes in channel cross section to a narrower, deeper and more efficient shape due to the construction of river training structures. The magnitude of these changes is uncertain due to the other factors that can impact the channel geometry.

Local velocity increases following the construction of river training structures are due to the constriction of the channel. Increased velocities cause an increase in bed sheer stresses resulting in an increase in sediment transport, bed erosion, and changes in channel geometry. As the channel geometry changes the local velocities decrease to values consistent with the pre-construction scenario (Watson et al. 2009, USACE 2016). An evaluation of velocity trends at the rated gages on the MMR (Huizinga 2009) has shown that velocity has remained relatively constant over the period of record. It is expected that the observed velocity trends would continue with the continue construction alternative.

Substrate changes in the dike field fluctuate seasonally and are dependent on the configuration of the structures, spacing of the structures, and the hydrograph. Generally, when the dike field is emerged finer sediment is entrained in to the dike field, picked up by secondary eddies and deposited (Henning and Hentschel 2013). When the dike field is submerged, flow velocities within the field are much higher than when emerged, leading to increased sediment transport. Eroded sediment from the dike field can be transported and deposited directly downstream or washed downstream. At higher flows, coarser grains may be deposited within the dike field (Henning and Hentschel 2013). Large regions of sand and gravel are found within dike fields during and immediately after high flows (Shields 1995).

A channel cutoff similar to the capture of the Kaskaskia River in 1881 could result in major changes to channel geomorphology. However, one of the objectives of the Regulating Works Project is to prevent a channel cutoff from occurring. See Section 1.1.6 for further discussion on past and current channel cutoff issues. It is expected that there will be other locations on the MMR that will need to be addressed to prevent a channel cutoff. Future projects will be addressed with SSEAs.

Side Channels

Chapter 3, Section 3.2.2 Geomorphology, presents information on the historic and existing conditions of MMR side channels. As detailed there, in order to predict Project impacts on, and future conditions of, MMR side channels, the District conducted multiple analyses on the depth and area characteristics of the side channels. In general the analyses showed that there is a high degree of natural variability in conditions from year to year within individual side channels and between side channels. However, side channel habitat in the MMR appears to be maintaining at a relatively stable level. Side channel planform widths have remained relatively stable since the 1960s. Side channel depths are highly variable both within and between side channels, but on the whole are stable or improving. With implementation of the RPAs, RPMs, and Terms & Conditions of the Project's Biological Opinion discussed in Section 3.3.4 Threatened and Endangered Species, and other restoration authorities, the District would continue to restore

MMR side channels that exhibit deteriorating conditions in habitat, contingent upon available funding and continued authority.

Despite the anticipated stability in the overall acreage, depth, and volume of side channel habitat in the future, another area of potential adverse effect to MMR side channel habitat from the Regulating Works Project is decreasing river stages at low flows associated with river training structure placement. As detailed in Section 4.2.1 Impacts on Stages, no changes in river stages are anticipated from river training structure placement at higher flows; however, at flows below 425,000 cfs, analysis of the St. Louis gage data shows a trend of decreasing stages over time while the trends at the Chester gage are less clear (Figure 3-7). Huizinga (2009) summarized the trends in St. Louis and Chester gage data as follows:

> *The apparent decrease in stage with time for lower discharges (less than one-half bankfull) at the St. Louis streamgage ... appears to be linked to the general lowering of the average bed elevation ... The top widths and average velocities from measurements have remained relatively constant at each of the measurement locations at the St. Louis streamgage ... so the lowering of the average bed elevation with time results in a lowering of the stage with time for in-channel flows. The lowering of the average bed elevation with time likely is caused by a combination of dikes in the channel, which cause channel deepening in the thalweg of the channel at the end of the dikes, and a general decrease in sediment flux into the MMR, which results in less incoming sediment to replace outgoing sediment in the MMR...*
>
> *...The apparent decrease in stage with time for lower discharges is less pronounced at the Chester streamgage ... than at the St. Louis streamgage, because there is less lowering in average bed elevations with time at the Chester streamgage ... However, the average velocities from measurements increase slightly with time for in-channel flows ... and this offsets the relatively constant top widths and average bed elevations from measurements ... resulting in a decrease in measured and rated stages with time for in-channel flows.*

As mentioned above by Huizinga (2009), the observed decreases in stages at low flows is likely a result of a combination of river training structures deepening the channel and a decrease in the sediment load in the river. It is not possible to determine the relative contributions of these two likely causes of stage decreases.

Regardless of the cause, the decrease in stages could result in loss of side channel habitat by reducing side channel stages. A reduction in stage at any given side channel, assuming a constant side channel bottom elevation, would result in less side channel depth and volume available as aquatic habitat. In order to determine the magnitude of potential impacts of decreasing stages to side channels, the District analyzed trends in stages for various flows at the St. Louis and Chester gages. Scatter plots for flows and stages at the St. Louis and Chester gages from the early 1900s to present can be found in Figure 3-7. Table 4-2 summarizes the projected changes in stage, by discharge, which are anticipated over the course of the remaining Regulating Works construction, estimated to be approximately 17 years[17]. The projections are based on differences between the current and year 2000 rating curves for St. Louis and Chester. In addition to a potential reduction in the quantity of side channel habitat, a reduction in stage could also result in decreased availability of that habitat to fish due to the loss of connectivity to the main channel at lower flows.

The quantity of side channel habitat in the MMR appears to be stable or improving based on current analyses of trends in side channel depth, width, and volume. River training structures constructed as part of the Regulating Works Project going forward are not anticipated to directly affect the quantity or quality of aquatic habitat provided by MMR side channels as they did prior to the 1970s. The current methods of construction used by the District, in consultation with natural resource agency partners, are specifically implemented in ways that avoid and minimize impacts to side channels. In addition, contingent upon available funding and continued authority, it is expected that the District will continue to plan and implement MMR side channel restoration projects. Discussion of potential adverse effects to individual side channels as a result of specific Regulating Works construction sites and any avoidance, minimization, and/or compensatory mitigation measures necessary to address adverse effects would continue to be covered on a case by case basis in SSEAs.

With respect to the indirect impact that river training structures may have on side channels by way of reduction of river stages, based on the assumption that construction of new river training structures would continue for approximately 17 years, stage changes are expected to remain similar to past trends over that period of time. Based on current projections (Table 4-2), decreases in stage of 0.24 to 0.94 feet can be anticipated at St. Louis across the range of non-flood flows (less than 500,000 cfs). Stages at Chester are anticipated to decrease 0.34 to 1.10 feet at flows between 50,000 and 100,000 cfs, increase 0.11 feet at 150,000 cfs, remain stable at 200,000 cfs, and decrease 0.40 to 0.63 feet at flows between 300,000 and 500,000 cfs. These projections are based on the assumption that the trends would continue at a pace similar to what they have in the past and that the trends are linear. It is not possible to determine what portion of the past or projected future decreases in stage are the result of river training structures versus a reduction in tributary sediment load, or other geomorphological factors including response to the 1881 shortening of the channel due to a channel cutoff at the Kaskaskia River. Therefore, it is not possible to project how much the effect might decrease after construction of river training structures ends. Analysis of dike systems on the Lower Mississippi River has shown that following the initial response period (10 – 15 years) the annual percentage rate of change in scour or fill approaches zero indicating that the systems are approaching an equilibrium condition (Biedenharn et al. 2000).

In light of the quantity of additional stone to be placed on the MMR being less than 5% of what currently exists and the degree of variability in side channel depths and associated choke points (see 3.2.2 Geomorphology), whatever proportion of the small reduction in stage that future river training structures are responsible for is anticipated to be minor and inconsequential. In addition,

[17] This estimate of the number of years of construction remaining is based on assumptions of future congressional funding levels per year, rock prices, dredging costs, mitigation costs, etc. Actual values for these variables are likely to differ from the assumptions made, thereby affecting the actual duration of remaining construction. See Appendix C for a full discussion of the assumptions associated with the remaining quantity of construction.

any compensatory mitigation implemented to address potential future adverse effects to MMR main channel border habitat would be anticipated to reduce the magnitude of any stage reductions that additional river training structures cause (see 4.3.2 and Appendix C).

Maintenance dredging activities associated with the Continue Construction Alternative are not anticipated to have any adverse effects on MMR side channel habitat.

Table 4-2. Projected reductions/increases in stages through the projected end of new construction for the Regulating Works Project (17 years) for discharges up to 500,000 cfs at St. Louis and Chester gages. Red shading indicates a projected reduction in stage and green shading indicates a projected increase in stage*.

Gage Location	Discharge	Projected Change in Stage over 17 years
St. Louis	50,000	-0.94
	70,000	-0.79
	100,000	-0.59
	150,000	-0.50
	200,000	-0.39
	300,000	-0.31
	400,000	-0.24
	500,000	-0.24
Chester	50,000	-1.10
	70,000	-0.68
	100,000	-0.34
	150,000	0.11
	200,000	0.00
	300,000	-0.40
	400,000	-0.63
	500,000	-0.40

* Projected stage change was calculated using the difference between the current rating curve and the rating curve from 2000 for St. Louis and Chester. Current stage data from USGS rating curve 17 for St. Louis (07010000) and 19 for Chester (07020500) . Year 2000 stage data from USGS rating curve 13 for St. Louis (07010000) and 16 for Chester (07020500).

Impacts of the No New Construction Alternative on Geomorphology

Main Channel / Main Channel Border

It is expected that under the No New Construction Alternative there would be no changes to the planform dimensions. Due to the other factors impacting channel geometry, channel cross sectional area, hydraulic depth, channel volume and channel conveyance would continue to increase. The magnitude of these changes is uncertain due to the other factors that can impact the channel geometry.

Similar to the Continue Construction Alternative, if the threat of a channel cutoff were to occur, it would be addressed by the Regulating Works Project and addressed with SSEAs. However, once the construction portion of the Regulating Works Project is closed out, any new construction necessary after that point would require a formal request for additional construction funding for the Project.

Side Channels

No new construction of river training structures would occur with implementation of the No New Construction Alternative. Consequently, any future reduction in stages would likely be due to a reduction in tributary sediment load, residual effect from past river training structure construction, or other geomorphological factors including response to the 1881 shortening of the channel due to a channel cutoff at the Kaskaskia River. Maintenance dredging activities are not anticipated to have any adverse effects on MMR side channel habitat.

Impacts of both Alternatives on Islands

Chapter 3, Section 3.2.2 Geomorphology, presents information on the historic and existing conditions of MMR island habitat. As detailed there, the total area of islands in the MMR has been relatively stable since the mid-1900s. This trend is expected to continue and neither Alternative would be expected to have an adverse effect on MMR island habitat. Any potential site-specific impacts to individual islands would be covered in SSEAs, as necessary. Ephemeral island creation with the flexible dredge pipe is expected to continue.

4.2.3 Impacts on Water Quality

Impacts of the Continue Construction Alternative on Water Quality

Construction activities associated with placement of all future river training structures and with maintenance of existing structures would cause temporary increases in turbidity and suspended sediment concentrations in the immediate vicinity of the structure locations. The impacts would be localized and would dissipate quickly. Sediments 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.

River training structures are designed to change sedimentation patterns and would, therefore, cause some minor temporary changes in the suspended sediment concentration in the immediate vicinity of placement locations as the river bed adjusts to the altered flow patterns. When compared to the typical sediment load in the MMR, this increase in suspended sediment concentration from all future river training structure construction and maintenance is expected to be negligible.

Revetment is designed to reduce bankline erosion and would, therefore, reduce suspended sediment concentration in the immediate vicinity of placement locations indefinitely. When compared to the typical sediment load in the MMR, this reduction in suspended sediment associated with reduced bankline erosion from all future revetment construction is considered negligible.

Limestone material used for construction and maintenance of structures 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 expected to be negligible.

Maintenance dredging activities would be expected to temporarily increase suspended sediment concentrations in the immediate vicinity of the dredge and disposal locations and for a short distance downstream. However, the degree of increase in turbidity is directly related to the proportion of fine-grained sediment in the material to be dredged (Herbich and Brahme 1991). Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. Given that the vast majority of dredged material is sand and not fine-grained material that would stay in suspension longer, the impact would be localized and would dissipate quickly. Turbidity plumes from dredging operations in the Upper Mississippi River are generally undetectable one-half mile downstream from the dredging location (WEST 2000). The Corps' St. Paul District monitored dredging operations in the main channel of the Mississippi River in the 1970s (Anderson et al. 1981a; Anderson et al. 1981b) and found that dredging operations had only minor, localized effects on turbidity. The Corps' Kansas City District monitored dredging operations on the Lower Missouri River in the 1980s (USACE 1990) and found that the plume from dredging operations returned to background levels within approximately 1,300 feet.

The impacts of such short-term changes in turbidity are further diminished when compared to the variability in background suspended sediment levels in a river such as the MMR that naturally experiences dramatic fluctuations in turbidity. Water quality measurements taken in the main channel of the MMR from 1991 to 2013 (Upper Mississippi River Restoration Program Long Term Resource Monitoring element) show that turbidity averages approximately 99 NTUs[18] but ranges between 6 NTUs and 755 NTUs. The average annual minimum value during that time period was 21 NTUs and the average annual maximum was 396 NTUs.

There is also potential for mobilization of contaminants in the dredged material due to the ability of contaminants to attach to silt and clay particles that may be present. However, IEPA and MDNR water quality certification conditions require analyses of the composition of dredged material to ensure that materials do not exceed 20% silt and clay material. As noted above, sediments in dredge and disposal areas in the MMR are predominantly sand and gravel. If material to be dredged is found to be greater than 20% fine-grained, further chemical testing is required to ensure contaminants are not present in quantities that would exceed water quality

[18] Nephelometric Turbidity Units (NTUs) are a standard unit of measure for quantifying the turbidity or cloudiness of water. Higher values indicate more turbidity. As a point of reference, USEPA generally requires drinking water turbidity to be less than 1 NTU.

standards. All testing to evaluate dredged material is done in accordance with the Inland Testing Manual (USEPA and USACE 1998).

Maintenance dredging activities would gradually decrease over the life of the Project but would never be completely eliminated. Likewise, the short-term increases in turbidity associated with dredging activities would decrease over the life of the Project. Dredging effort would fluctuate from year to year based on a range of factors, but is estimated to decrease from a current average of approximately 4 million cubic yards per year to an average of approximately 2.4 million cubic yards per year after completion of river training structure construction.

Programmatic authorization for construction, maintenance, and dredging activities under Section 404 of the Clean Water Act would be sought as part of the Continue Construction Alternative. In addition, authorization for construction activities under Sections 404 and 401 of the Clean Water Act would be sought on a site-specific basis as work areas are planned and implemented. Authorization for dredging activities under Section 401 of the Clean Water Act is sought on a programmatic basis every 5 years from the states of Illinois and Missouri. All permits and approvals necessary for completion of work would be obtained prior to implementation. See Appendix D for the Programmatic 404(b)(1) Evaluation.

Impacts of the No New Construction Alternative on Water Quality

Since no new construction would occur with implementation of this Alternative, there would be no construction-related water quality impacts beyond those associated with maintenance of existing structures. As with construction of new river training structures, maintenance of existing structures would cause temporary increases in turbidity and suspended sediment concentrations in the immediate vicinity of the structure locations. The impacts would be localized and would dissipate quickly. Sediments 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 associated with maintenance dredging activities under the No New Construction Alternative would be similar to those outlined above under the Continue Construction Alternative. However, maintenance dredging under the No New Construction Alternative would be required at approximately the same rate as is currently necessary and would not be expected to decrease in the future as under the Continue Construction Alternative since no new river training structures would be constructed to reduce dredging. Dredging effort under the No New Construction Alternative would fluctuate from year to year based on a range of factors, river stage being foremost among them, but would average approximately 4 million cubic yards per year based on average dredge quantities over the last 10 years.

4.2.4 Impacts on HTRW

Impacts of both Alternatives on HTRW

All future construction and maintenance activities associated with both Alternatives would avoid impacts to the known HTRW locations outlined in Section 3.2.4 HTRW. In addition, site-specific work areas would be screened for potential HTRW issues in accordance with standard practices for conducting Phase I Environmental Site Assessments (ESA) as outlined in Section 3.2.4 HTRW. As such, no impacts to HTRW from river training structure construction or maintenance activities are anticipated.

Likewise, future dredging activities associated with both Alternatives are not anticipated to impact the known HTRW locations outlined in Section 3.2.4 HTRW. Dredging could, however, mobilize unknown contaminants associated with fine sediments in dredged material or disposal locations. However, as outlined in Section 4.2.3 Impacts on Water Quality, sediments in dredge and disposal areas in the MMR are typically sand and gravel with very little fine sediment. Permit conditions require analysis of the composition of dredged material to ensure that materials do not exceed 20% silt and clay material. Sediments with higher proportions of silt and clay are more likely to contain contaminants. If material in dredge or disposal locations is found to be greater than 20% fine-grained, further chemical testing is required. All testing is done in accordance with the Inland Testing Manual (USEPA and USACE 1998). As such, no impacts to HTRW from dredging activities are anticipated.

4.2.5 Impacts on Air Quality and Climate Change

Impacts of both Alternatives on Air Quality

When a federal action is being undertaken in a nonattainment area, the federal agency responsible for the action is required to determine if its action conforms to the applicable State Implementation Plan (SIP). An SIP is a plan that provides for implementation, maintenance, and enforcement of the NAAQS and includes emission limitations and control measures to attain and maintain the NAAQS. As outlined in Section 3.2.5 Air Quality and Climate Change, there are several counties on both the Missouri and Illinois sides of the MMR designated as nonattainment areas for multiple criteria pollutants. Excluding Randolph County, Illinois, these counties are known collectively as the Metropolitan St. Louis Interstate Air Quality Control Region (AQCR). In accordance with the final rule of the EPA, *Determining Conformity of General Federal Actions to State or Federal Implementation Plans* (final rule), a conformity determination has been prepared for the Metropolitan St. Louis Interstate AQCR and Randolph County, Illinois.

Federal actions occurring in air basins that are in attainment for criteria pollutants are not subject to the conformity rule, except for those basins that recently met attainment and are being managed through a maintenance plan. As such, this conformity determination only addresses emissions of the criteria pollutants for which attainment is not being met within the Metropolitan St. Louis Interstate AQCR (RM 136-195) and Randolph County, Illinois (RM 98.4-136). The specific criteria pollutants included in this analysis are ozone, particulate matter (PM), and sulfur dioxide (SO_2). Although parts of the Metropolitan St. Louis Interstate AQCR are currently designated as being in nonattainment for lead, this criteria pollutant was omitted from this analysis under the assumption that the Regulating Works Project will not produce lead emissions.

To focus conformity requirements on those Federal actions with the potential to have significant air quality impacts, threshold (*de minimis*) rates of emissions were established in the final rule (Table 4-3). With the exception of lead, the *de minimis* levels are based on the Clean Air Act's major stationary source definitions for the criteria pollutants (and precursors of criteria pollutants) and vary by the severity of the nonattainment area. If annual direct and indirect emissions resulting from a federal action within a nonattainment or maintenance area are below the *de minimis* levels set by the EPA, the federal action is considered in conformity with the SIP. However, when a federal action equals or exceeds the annual *de minimis* levels, a more rigorous analysis of emissions from the federal action and conformity to the applicable SIP must be demonstrated.

A federal action that does not exceed the *de minimis* levels of criteria pollutants may still be subject to a general conformity determination. The direct and indirect emissions from the action must not exceed 10 percent of the total emissions inventory for a particular criteria pollutant in a nonattainment or maintenance area. If the emissions exceed this 10 percent *de minimis*, the federal action is considered to be a "regionally significant" activity, and thus, general conformity rules apply. The concept of regionally significant is to capture those federal actions that fall below the *de minimis* levels but have the potential to impact the air quality of a region.

The analysis described herein will demonstrate that emissions from both Alternatives would be well below the annual *de minimis* levels set by the EPA for the aforementioned criteria pollutants, and would not represent a regionally significant source of pollutants for the Metropolitan St. Louis Interstate AQCR and Randolph County, Illinois.

The methodology for the general conformity analysis consists of the following steps: 1) determine pollutants of concern based on attainment status of the AQCR; 2) define the scope of the federal action to include timing and location; 3) calculate emissions based on the scope; 4) review net emission changes for threshold levels and regional significance; and 5) determine conformity for applicable criteria pollutants.

Table 4-3. Annual Emissions threshold (*de minimis*) levels for Criteria Pollutants (40 CFR 93.153).

Criteria Pollutant	Designation	Tons per Year
Ozone*	Serious nonattainment	50
	Severe nonattainment	25
	Extreme nonattainment	10
	Other nonattainment areas outside ozone transport region	100
	Marginal and moderate nonattainment areas inside ozone transport region	50/100**
Carbon Monoxide	All nonattainment areas	100
Sulfur Dioxide	All nonattainment areas	100
Lead	All nonattainment areas	25
Nitrogen Dioxide	All nonattainment areas	100
Particulate Matter	Moderate nonattainment	100
	Serious nonattainment	70

* Includes precursors of volatile organic compounds (VOCs) and nitrogen oxides (NOx).
** VOCs / NOx

The Project consists of river training structure construction and maintenance, as well as channel maintenance dredging. Given the process that is utilized by the District in determining where construction of new project features are needed, what the exact features will be, and what methods will be used to construct the features, site-specific impacts in nonattainment areas would not be known until projects are developed. Since the exact designs of such projects are not known at this time, the analysis relied on estimates of average annual emissions based on past dredging quantities and the amount of rock projected to be used for future construction of river training structures.

To estimate the emission levels from future dredging, the District utilized records of dredging activities from the years 2002-2013, which include the location and duration of each dredging event. Dredging that occurred at river miles adjacent to Randolph County, Illinois, were separated from those that occurred in the Metropolitan St. Louis Interstate AQCR, and were analyzed independently because this area is designated as being in nonattainment only for particulate matter. Average annual durations of dredging activities were calculated for each of the nonattainment areas. Estimates of future annual emissions from dredging were based on these average durations. It was assumed that all future dredging events for the Regulating Works Project would be completed with the District-owned dredge, the Potter, which is equipped with three Caterpillar 3516B diesel engines. Two of the engines are active during dredging events, and the third is in reserve.

Regarding construction and maintenance of river training structures and revetment, the District projects that an average of 260,000 tons of rock would be used annually for new construction, and 90,000 tons would be used annually for maintenance of existing structures. Because the specific locations of future construction and maintenance activity have not yet been identified, it was assumed that the 350,000 tons of rock would be dispersed evenly across river miles and that rock placement would occur at an average production rate of 350 tons/hr. Furthermore, the majority of construction and maintenance activity completed under the Regulating Works Project is done by contractors, and the District does not have access to the details of contractors' operations (e.g., equipment, activity duration, fuel consumption, etc.), which can also vary from year to year. Therefore, in order to fully calculate the emissions from new construction or maintenance of river training structures and revetment, equipment generally used for construction and maintenance of river training structures was selected from the Corps document *Construction Equipment Ownership and Operating Expense Schedule Region V*. This equipment used in the analysis consisted of a dragline crane, 40 ft. inland tug, and a 22 ft. inland tug, all with diesel engines.

Details of the equipment used for new construction or maintenance of river training structures and revetment were used in conjunction with exhaust emissions factors taken from U.S. EPA sources. The primary source used was the *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling-Compression-Ignition, Report No. NR-009d* (2010), which describes the exhaust emission factors used in the EPA's NONROAD2008a emission inventory model, as well as a *Compilation of Air Pollutant Emission Factors AP-42 Fifth Edition* (1995). Annual emissions from the Regulating Works Project were calculated based on equations and instructions outlined in the former document.

It should be noted that ozone emissions were not calculated directly. Rather, the primary precursor compounds for ozone were calculated, those being volatile organic compounds (VOCs) and nitrogen oxides (NOx), and then the *de minimis* level for ozone was applied to each precursor. Furthermore, rather than calculate the emissions of specific VOCs, the District calculated annual emissions of the total organic compounds (TOCs), which include the VOCs. The Regulating Works Project is located in areas designated as moderate and marginal nonattainment for ozone (outside an ozone transport region).

Table 4-4 summarizes the results of the analysis. Average annual emissions of the criteria pollutants within the nonattainment areas, Metropolitan St. Louis Interstate AQCR, and Randolph County, Illinois, are well below the *de minimis* levels set by the EPA. Furthermore, these emission levels do not represent a regionally significant source of criteria pollutants. The calculated average annual emissions were compared to recent emissions inventories for both the Missouri portion and the Illinois portion of the Metropolitan St. Louis Interstate AQCR, as well as Randolph County, Illinois, and are well below ten percent of the total emissions for any of the criteria pollutants. The results of this analysis demonstrate that emissions of this magnitude would not be in violation of the Clean Air Act, and further analysis to demonstrate conformity to the Missouri and Illinois SIPs is not required. This analysis was conducted using current average annual dredging quantities. Emissions associated with the Continue Construction Alternative would be expected to gradually decrease in the future as average annual dredging requirements decrease. Emissions associated with the No New Construction Alternative would be less than those calculated due to reduced construction emissions.

Table 4-4. Summary of average annual emissions from the Regulating Works Project (tons/year).

Activity	TOC	NOx	SO2	PM*
Channel Maintenance Dredging	3.45	20.44	2.46	1.52
Dike Construction and Maintenance	0.34	1.45	0.24	0.08
Total	**3.79**	**21.89**	**2.70**	**1.60**

* Includes emissions occurring in Randolph County, Illinois.

Climate Change. The following analysis summarizes information on the anticipated impacts of GHG emissions from the best available climate science literature and provides an estimate of GHG emissions for the Regulating Works Project.

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 Corps 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 2015b). A graphical summary of the findings can be found in Figure 4-1.

Summary of Observed Climate Findings (USACE 2015b):

> *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.

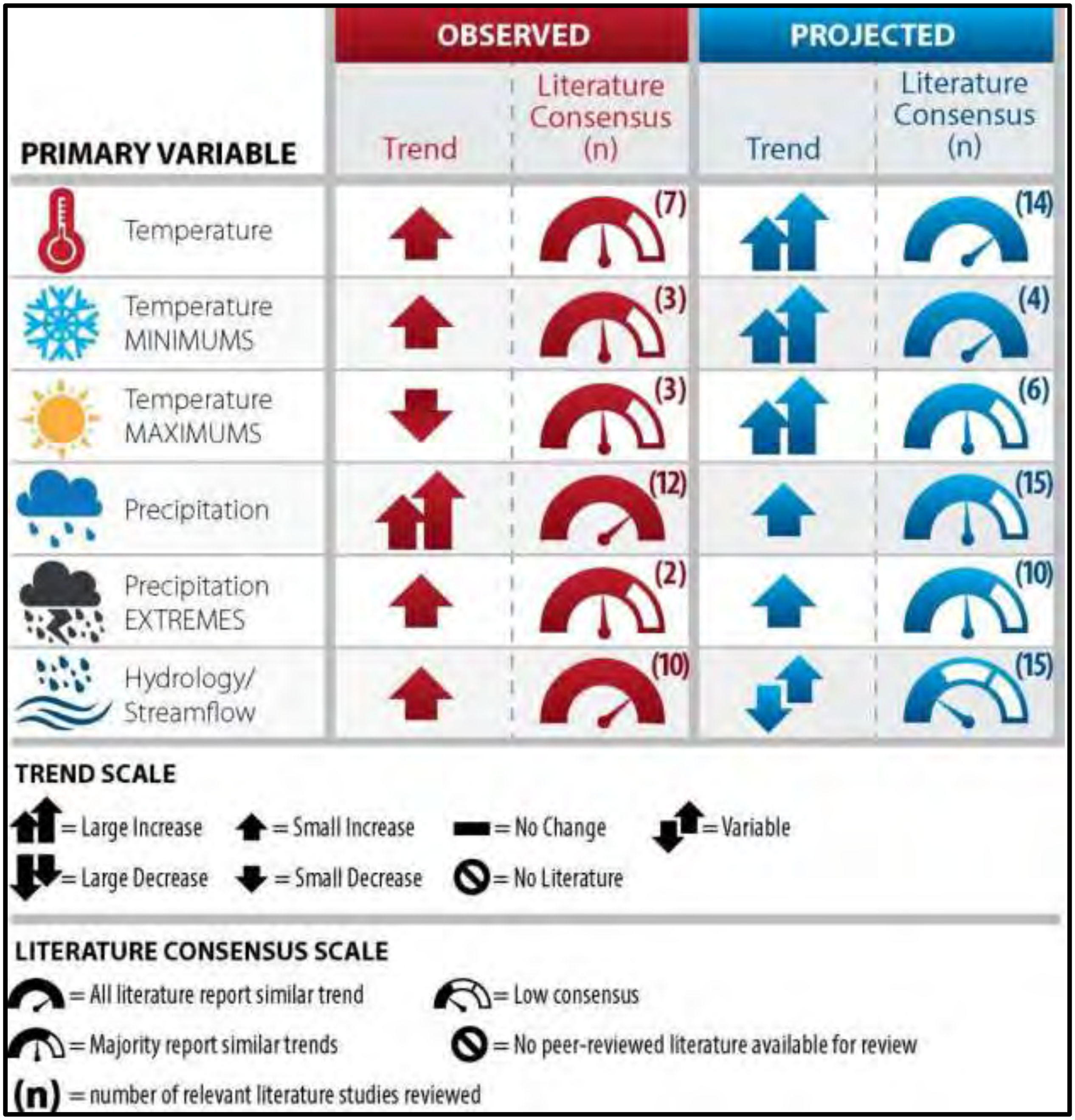


Figure 4-1. Summary matrix of observed and projected regional climate trends and literature consensus (from USACE 2015b).

Summary of Future Climate Projection Findings (USACE 2015b):

> *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.*

In summary, based on the best available climate science literature, the following changes can be expected in the MMR:

- Increase in air temperatures
- Increase in frequency and magnitude of extreme temperature events such as summer heat waves
- Increase in precipitation and frequency of large storm events
- Increase in frequency of droughts
- Potential increase or decrease in streamflow

Based on these projected changes, the District analyzed the potential effects of climate change on the resources in the Project Area and the potential changes to Project impacts and the resilience and adaptability of the Alternatives to those changes (Table 4-5).

Table 4-5. Effects of climate change on MMR resources and associated Project impacts.

Resource	Potential Effects of Climate Change on Resources in the Project Area	Expected Impacts to Project and Resilience and Adaptability of Alternatives
Stages	Potential increase in frequency and magnitude of low water and high water events.	Potential increase in need for revetment and repairs to structures due to increase in frequency and magnitude of high water events. Impacts from the unknown amount of reduction in stages at low flows associated with the Continue Construction Alternative could become more frequent. Neither Alternative expected to impact stages at average and high flows – no change expected with climate change.

Resource	Potential Effects of Climate Change on Resources in the Project Area	Expected Impacts to Project and Resilience and Adaptability of Alternatives
Geomorphology	Potential changes to sedimentation rates from changes in storm intensity, depth, duration, and seasonality may change sedimentation characteristics and patterns in the MMR; potential changes in sedimentation patterns may also affect side channel depth/volume/connectivity; potential increase in frequency and magnitude of low water and high water events may affect side channel connectivity.	Basic functionality of river training structures and their ability to change sedimentation patterns should not be affected. Unknown amount of reductions in stage at low flows associated with the Continue Construction Alternative may become more frequent due to potential increase in frequency of low water events, thereby increasing the minor reduction in quantity and connectivity of side channel habitat. Continued side channel monitoring and restoration efforts would enhance the adaptability to this potential change.
Water Quality	Potential changes in turbidity and pollutant loads from changes in frequency and magnitude of low water and high water events; potential increase in frequency of low dissolved oxygen concentrations, particularly in backwater areas when not connected to the main river channel, due to higher water temperatures.	Potential increase in frequency of low dissolved oxygen concentrations in side channels due to minor decrease in connectivity associated with the Continue Construction Alternative. Continued side channel monitoring and restoration efforts would enhance the adaptability to this potential change.
Air Quality	Potential increases in particulate matter concentrations are possible as a result of increased incidence of extreme weather events and wildfires.	Continue Construction Alternative expected to reduce future emissions, including particulate matter, due to dredging reduction and should enhance resilience of Project to air quality changes.
Fish and Wildlife (including threatened and endangered species)	Potential shifts in ranges of fish and wildlife species due to shifts in precipitation and temperature patterns. Effects may be more evident in sensitive populations such as threatened and endangered species that have reduced abilities to withstand further changes to habitat conditions. Potential increases in frequency and magnitude of low water events could further reduce connectivity of MMR to important off-channel habitats. Potential increases in frequency and magnitude of high water events could improve connectivity of MMR to important off-channel habitats.	Unknown amount of reductions in stage at low flows associated with the Continue Construction Alternative may become more frequent due to potential increase in frequency of low water events, thereby increasing the reduction in quantity and connectivity of side channel habitat. Continued side channel monitoring and restoration efforts would enhance the adaptability to this potential change.

Resource	Potential Effects of Climate Change on Resources in the Project Area	Expected Impacts to Project and Resilience and Adaptability of Alternatives
Navigation	Potential increase in frequency and magnitude of low water and high water events may affect navigation channel reliability/channel closures and may increase barge grounding rates.	Requirement for periodic maintenance dredging may increase if frequency and/or magnitude of low water events increase; increase in frequency and/or magnitude of low water and high water events may reduce reliability of navigation channel; potential general increase in cross-sectional area, hydraulic depth, conveyance, and channel volume associated with the Continue Construction Alternative should increase the resilience of the navigation channel to potential changes in sedimentation rates and patterns and should reduce barge grounding rates and increase channel reliability; Project is inherently resilient and adaptable due to the fundamental variability and unpredictability of the MMR.
Environmental Justice	Potential increase in frequency and magnitude of high water events may increase exposure of minority and low income populations to flooding.	Neither Alternative expected to impact stages at average and high flows. Both Alternatives resilient to this potential change.
Historic and Cultural Resources	Potential increase in frequency and magnitude of high water may increase exposure of known and unknown historic and cultural resources to flooding; potential increase in frequency and duration of low water may increase exposure of known and unknown submerged historic and cultural resources due to de-watering.	No appreciable changes to Project impacts anticipated. Both Alternatives resilient to this potential change.

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 4.2.1 Impacts on Stages 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). Therefore, this could also affect the assumptions on the future construction needed for cost-effective dredging reduction for the Regulating Works Project discussed in Chapter 2.

The potential increase in frequency and magnitude of low water events in the MMR could increase the frequency of the reduction in stage at low flows associated with the Continue Construction Alternative, thereby reducing the quantity and connectivity of MMR side channel habitat. Continued side channel monitoring and restoration efforts would enhance the adaptability of the Project to this potential change.

Relating to changes in sediment, any change in climatic conditions can result in one or two principal changes in basin hydrology. First, storm intensity, depth and duration may be different than indicated in past data which will directly impact sediment yield computations. Changes in sediment yield impacts the quantity and characteristics of sediment entering streams which directly affects in-channel sedimentation. Second, the seasonality of storms may be different than indicated by past data. This change in seasons of when storms occur may also impact sediment yield calculations and in-channel sedimentation rates.

The significance of climate change on sedimentation investigations is related to various thresholds that pertain to sediment mobility and movement. If climate change produces sufficient change in hydrologic inputs to exceed threshold values, the Regulating Works Project may fail to perform as expected. Similarly, climate change effects on basin hydrology may alter land cover by changing vegetation density and species composition which impacts sediment mobility.

There is no actionable science or formal consensus across the Federal agencies with responsibility for water-resource management at this time on how to assess quantitative changes to sediment yield, in-channel sediment routing, or reservoir sedimentation from climate change. Several water resources management agencies are working together using observed data and model outputs to assess possible future effects from climate change on the runoff and streamflow inputs necessary to compute changes to sediment. Corps guidance for incorporating climate change impacts to inland hydrology in Civil Work studies, designs, and projects describes how to assess potential changes in streamflow at the appropriate level of effort and provides links to Corps web tools for assessing past trends, examining change points in historical data, and analyzing future streamflow based on statistically downscaled general circulation model output. The Climate Preparedness and Resilience Community of Practice is developing additional guidance and web tools to assist in the analysis of climate change impacts to sediment yield, and these can be found at https://maps.crrel.usace.army.mil/projects/rcc/portal.html for Corps staff and externally at http://www.corpsclimate.us/pubtools.cfm. The latest available methods should be used in evaluating quantitative changes to sediment yield, in-channel sediment routing, or reservoir sedimentation due to changing climate.

Future sediment yield is also likely to be heavily influenced by non-climate changes (such as urbanization and changes in land use and land cover), as well as to indirect climate-change effects (such as changes in frequency, duration, intensity, location, seasonality of wild land and prescribed fire in the basin). Even less is agreed about how to incorporate non-climate and indirect climate change effects into analyses of future sedimentation rates. Factors that cannot be accounted for in modeling efforts should be discussed in the risk register.

As climate change science continues to improve and agency guidance evolves, the District will continue to evaluate the Project and its impacts in accordance with new information and guidance.

With respect to impacts of Project-related emissions on climate change, the District conducted an analysis of the GHG emissions of the Regulating Works Project and the alternatives under consideration. The analysis was completed with the same methodology used to calculate average annual emissions of criteria pollutants previously discussed. However, the geographic scope of the analysis was not limited strictly to the nonattainment areas, but was expanded to encompass the entire MMR. The GHG equivalents analyzed were carbon dioxide (CO2), methane (CH4), and nitrous oxides (NOx).

Table 4-6 summarizes the results of the analysis. Based on the average annual operation time and the equipment used to complete project activities discussed above, the Continue Construction Alternative would be expected to produce an average of approximately 29,400 tons of CO_2 Eq per year currently, gradually decreasing to approximately 16,970 tons per year after construction is complete. The vast majority of these annual emissions would be produced by the Potter during dredging activities and the reduced dredging requirement expected with the Continue Construction Alternative accounts for the decrease in emissions after completion of construction. Conversely, emissions associated with the No New Construction Alternative, while slightly lower than the Continue Construction Alternative initially due to a lack of emissions from construction of new dikes, would not be expected to decrease in the future due to dredging requirements remaining stable.

Table 4-6. Summary of the average annual GHG emissions projected for the Regulating Works Project (tons of CO_2 Eq/year).

Time Period	Activity	GHG	Continue Construction Alternative	No New Construction Alternative
Current	Dredging	Carbon Dioxide	5,724.77	5,724.77
		Methane	7.75	7.75
		Nitrous Oxide	21,715.26	21,715.26
	Dike Construction and Maintenance	Carbon Dioxide	523.23	134.52
		Methane	2.50	0.64
		Nitrous Oxide	1,427.42	366.99
		Total	**29,400.93**	**27,949.93**
After Completion of Construction	Dredging	Carbon Dioxide	3,434.86	5,724.77
		Methane	4.65	7.75
		Nitrous Oxide	13,029.16	21,715.26
	Dike Maintenance	Carbon Dioxide	134.52	134.52
		Methane	0.64	0.64
		Nitrous Oxide	366.99	366.99
		Total	**16,970.82**	**27,949.93**

4.3 Impacts on Biological Resources

4.3.1 Impacts on Benthic Macroinvertebrate Resources

The benthic macroinvertebrate resources impact analysis addresses direct and indirect impacts to benthic macroinvertebrates and their habitat that would occur as a result of dredging and river training structure placement. The analysis provides the basis for understanding the context and intensity of the impacts of each of the Alternatives considered.

Impacts of the Continue Construction Alternative on Benthic Macroinvertebrate Resources

Dredging Impacts on Benthic Macroinvertebrate Resources

Periodic maintenance dredging and dredged material disposal operations would have the potential to affect benthic macroinvertebrate resources through direct removal of individual organisms (entrainment) at the dredging site and by burying organisms at the disposal site. The degree to which macroinvertebrate resources are impacted is largely a factor of the density of the organisms in the area of the dredge cut and disposal location at the time of dredging operations. Benthic 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.

The majority of dredging and dredge placement in the MMR takes place within repetitive dredging areas and placement areas that are located in the main channel, where low densities of benthic organisms are found. Based on the current average annual dredge quantity of approximately 4 million cubic yards associated with the Continue Construction Alternative, approximately 550 acres of main channel habitat are dredged each year and another 550 acres of main channel habitat are impacted by dredged material disposal. These are anticipated to decrease to approximately 330 acres each after completion of construction associated with implementation of the Continue Construction Alternative. Given the naturally dynamic nature of the main channel areas impacted by dredging and disposal, the low densities of macroinvertebrates found in these habitats, and the fact that these areas only represent, on average, approximately 2 % of the riverine habitat in the MMR today, decreasing to 1% after completion of river training structure construction, adverse effects to benthic macroinvertebrates associated with dredging are anticipated to be minor.

River Training Structure Impacts on Benthic Macroinvertebrate Resources

Although there are areas of rock outcrops, rock bottoms, and gravel bars in the MMR, the natural (without river training structures) main channel border substrate is predominantly sand with some finer depositional materials. As described above in Section 3.3.1 Benthic Macroinvertebrate Resources, the rock material that is used for construction of river training structures provides an excellent substrate for colonization by benthic macroinvertebrates.

Although a relatively small number of benthic macroinvertebrates in the footprint of river training structure locations would be lost during construction or maintenance activities, this loss would be offset by the benefits of increased substrate for colonization associated with new rock placed in the river. This exchange of habitat types could be reversed in areas where river training structures are removed for any future compensatory mitigation purposes (see Section 4.3.2 Impacts on Fishery Resources below). Areas of high concentrations of benthic macroinvertebrates could be modified and replaced by areas of low concentrations. Overall, the impact on benthic macroinvertebrates from construction, maintenance, and removal of river training structures associated with the Continue Construction Alternative is anticipated to be negligible, but detailed analysis of this impact would be provided in future Tier II site-specific EAs.

Impacts of the No New Construction Alternative on Benthic Macroinvertebrate Resources

Dredging Impacts – Periodic maintenance dredging and dredged material disposal operations associated with the No New Construction Alternative would be similar to those associated with the Continue Construction Alternative but would remain at a relatively stable level over the remainder of the Project. Based on the current average annual dredge quantity of approximately 4 million cubic yards, roughly 1,100 acres of main channel habitat would be impacted each year. Due to the low concentration of benthic macroinvertebrates in these areas, adverse effects are anticipated to be minor.

Dike Impacts – No new construction of river training structures under the Regulating Works Project would occur with this Alternative with the exception of potential construction pursuant to implementation of the Biological Opinion. No removal of structures for compensatory mitigation would be considered. However, maintenance and repair of existing river training structures would continue for the remainder of the Project. Maintenance and repair activities are anticipated to have a negligible effect on benthic macroinvertebrates.

4.3.2 Impacts on Fishery Resources

The fishery resources impact analysis addresses direct and indirect impacts to fish and to the quality and quantity of fish habitat that would occur as a result of dredging and river training structure placement. The analysis provides the basis for understanding the context and intensity of the impacts of each of the Alternatives considered. General impacts of dredging on fishery resources are discussed first, followed by specific impacts of the two Alternatives considered. General impacts of river training structures are then discussed, followed by specific impacts of the two Alternatives considered.

Dredging Impacts on Fishery Resources

Potential impacts of dredging on fish include entrainment[19] of individual fish into the dredge head, behavioral changes of individual fish due to increased turbidity and noise at the dredge and

[19] Dredge entrainment is defined as the direct uptake of organisms by the suction field generated at the dredge intake (Reine and Clarke 1998).

disposal locations, and habitat changes due to river bed elevation changes at the dredge or disposal locations (LaSalle et al. 1991).

Dredge Entrainment – Due to the amount of suction needed by the dredge head to remove sediment from the river channel and transport it to the disposal site, fish in the vicinity of the dredge head may be entrained into the dredge pipe and be transported, along with the sediment/water slurry, to the disposal location. Fish exposed to these physical stresses are at a high risk of mortality; however, entrainment may vary based on the species, size and age of the fish in question (Ault et al. 1998). The degree to which fish populations are impacted by dredging entrainment is largely a factor of the density of fish in the area of the dredge cut at the time of dredging operations. For fish that are in the vicinity of the dredge cut, intake water velocity is the primary determinant for likelihood of entrainment, but other factors such as fish size, water temperature, light cycles, feeding regime, and attraction or avoidance of dredge noise could affect entrainment susceptibility of individual fish or species of fish (Hoover et al. 2005; Boysen and Hoover 2009).

Accurate estimates of the number of fish present or the number of fish entrained through maintenance dredging operations on the MMR do not exist. As covered in Section 3.3.2 Fishery Resources, limited fish sampling has been conducted in the main channel of the MMR where maintenance dredging occurs. Sampling conducted in the MMR in support of the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element showed adult and/or juvenile Blue Catfish, Channel Catfish, Freshwater Drum, Shovelnose Sturgeon, and Gizzard Shad as the most common species caught in the main channel of the MMR.

Although not specifically related to channel maintenance dredging, the St. Louis District recently contracted a dredge entrainment monitoring study for the Chain of Rocks East Canal Levee Project (Ecological Specialists 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. Fish entrainment monitoring at the outflow of the dredged material settling area was conducted during approximately 15% of the operation. Forty-seven individual fish were captured during the sampling. Based on the number of cubic yards of material dredged during sampling (171,263), the entrainment rate was calculated to be .00027 fish/cubic yard of material dredged, or approximately 1 fish entrained for every 4,000 cubic yards of material dredged.

The estimated entrainment rate for the Chain of Rocks East Canal Levee Project is at the lower end of other published dredging entrainment rates. 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, with the vast majority of entrainment rates being near the lower end of this range. In general, the authors concluded that, although the assessment of entrainment impacts poses serious technical challenges and precise estimates and consequences of entrainment rates have been difficult to determine, much of the evidence suggests that entrainment is not a significant problem for many species of fish in many bodies of water that are dredged periodically (Reine and Clarke 1998).

In addition to larger fish, fish eggs and larvae are also susceptible to entrainment by dredges. No estimates of entrainment rates of fish eggs or larvae exist for the MMR. However, estimates of larval fish densities in the main channel of the MMR range from 0.12 to 6.17 fish per cubic yard of water (UEC 1979; Foley and Dunn 2014). These estimates are based on sampling conducted during the peak larval fish months in spring and summer when densities are typically highest. The volume of water entrained with each cubic yard of substrate can vary considerably based on the specific dredging conditions at each dredge location, but, on average, approximately 80 percent of the dredge slurry is water. Based on this information, estimates of the number of larval fish entrained by maintenance dredging can be achieved by extrapolating from the number of cubic yards of material dredged. It should be noted that maintenance dredging operations on the MMR normally only take place from July through January each year and larvae are generally only present in appreciable numbers in the water column April through August (Bartell and Campbell 2000). Accordingly, larval fish entrainment estimates for the MMR should be calculated using July and August average dredge quantity and larval fish density data (see entrainment estimates in Alternatives impact assessment below).

Dredging Related Habitat Impacts – Channel maintenance dredging in the MMR generally occurs in channel crossover areas, areas where the thalweg shifts from one side of the channel to the other. These areas, and most other areas in the main channel of the MMR, are areas with a high degree of variability in habitat conditions. River bottom habitat in these areas is in a constant state of flux as waves of bed load sand are transported down river. The more naturally variable the impacted habitat, the less the anticipated effect that dredging would be expected to have on the organisms that utilize that habitat (USACE 1978). Organisms utilizing these naturally unstable areas are more adapted to unstable conditions and would be expected to better withstand the stresses imposed by dredging and recover more quickly (USACE 1978; USACE 1983). In addition, as discussed in Section 4.3.1 Impacts on Benthic Macroinvertebrate Resources, fish prey resources such as macroinvertebrates are generally expected to be present at low densities in dredge and disposal areas due to the unstable substrate conditions.

While the exact depth of material removed from a dredge cut varies with each dredging event and also varies across an individual dredge cut based on natural riverbed elevation variations, the average amount of material removed from dredge cuts in the MMR is approximately 4.5 feet. In other words, a dredged area is, on average, 4.5 feet deeper immediately after a dredging event. Assuming hydraulic conditions remain unchanged, this deeper area typically fills back in with sediment gradually and requires dredging again at some point in the future. The purpose of river training structures is to alter the hydraulic patterns of the river channel in these chronic dredging locations, thereby reducing the need for repetitive dredging.

Dredge disposal areas generally become shallower to approximately the same degree that the associated dredged areas become deeper. Material is typically deposited through a rigid pipeline with a disposal location that moves up and down the river as the dredge moves up and down the dredge cut. This results in a disposal area that is similar in size and shape to the dredge cut. Disposal of dredged material in the MMR typically takes place adjacent to the dredge cut, in the main channel of the river, but outside of the navigation channel and riverward of existing river training structures, if present (Figure 4-2). Due to specific conditions at each dredging location, e.g. the presence of barge fleeting areas, there are instances when dredged material cannot be placed in the main channel and must be placed in main channel border areas. Some of the District's dredging is accomplished with a floating flexible dredge pipe which allows for more adaptability in disposal area location, elevation, and size (see Section 1.1.4 Process for Dredging under the Regulating Works Project for more information on the flexible dredge pipe). Regardless of the disposal technique or placement location, all dredging is coordinated with natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits.

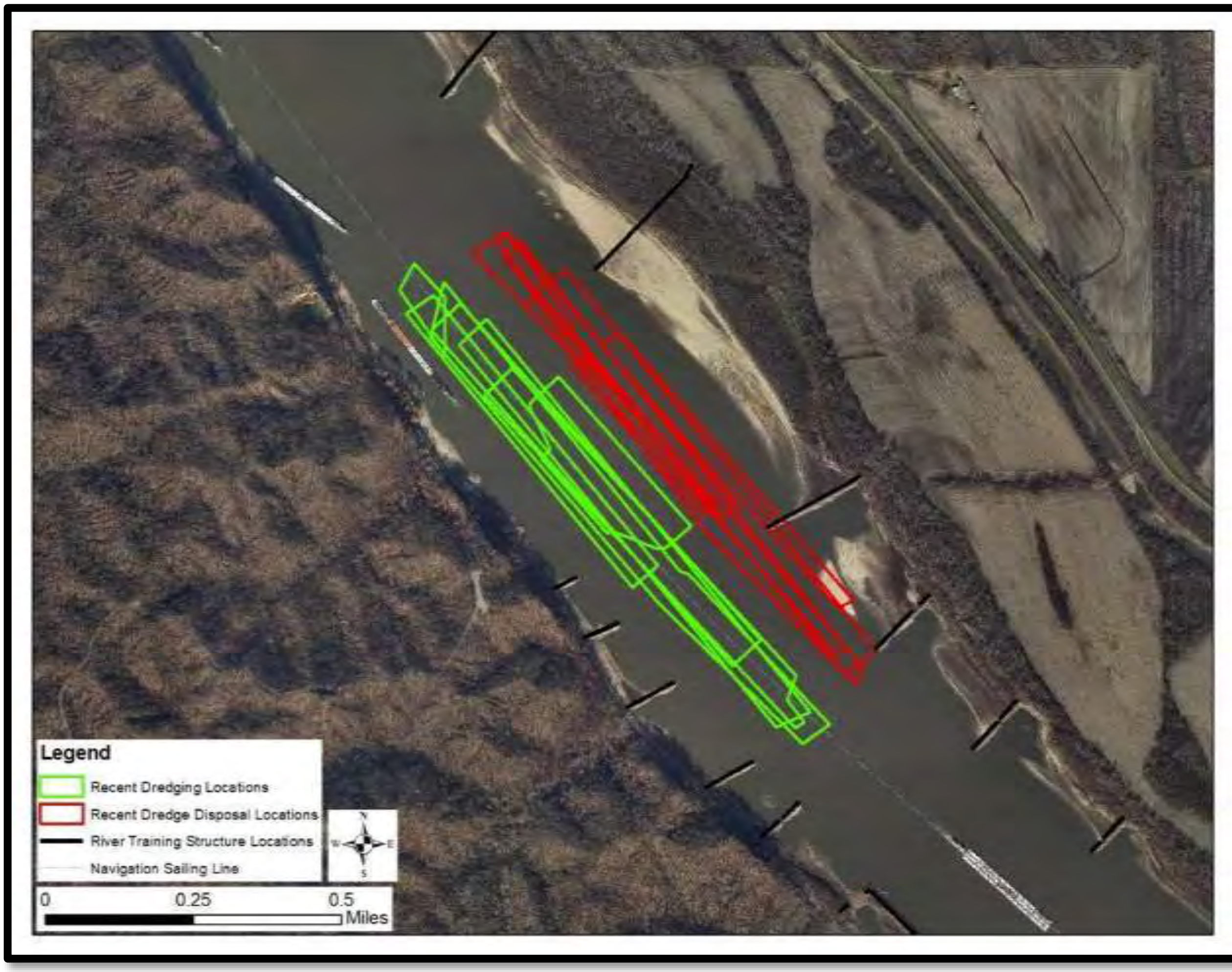


Figure 4-2. Example of recent dredging (green boxes) and dredge disposal (red boxes) locations on the MMR (2010 through 2014 dredging at river mile 68).

Dredging Related Noise - Much of the sound produced during hydraulic dustpan or cutterhead dredging is associated with pumps and generators, with additional sounds from the injection of water into the substrate by the dustpan dredge or the rotation of the cutterhead in the substrate and movement of material through the pipeline. Sounds emitted are dependent on substrate type.

For example, movement of sand/gravel through the pipeline would produce more intense sounds than slurry comprised of mostly water and sandy dredged material that would be expected on the MMR. These sounds are omnidirectional and continuous in nature during dredging operations.

Although there have been a number of studies of sound production by a variety of dredge types dredging a variety of materials (e.g., Reine and Dickerson 2014; Reine et al. 2014a; Reine et al. 2014b), there have been no studies of hydraulic pipeline dredges (dustpan or cutterhead dredges) currently operating on the Mississippi River. The *Veracious*, although a cutterhead dredge, provides sound pressure level (SPL) data for pumps used for suction with horse power ratings closest to the *Potter* (2,500 hp), the St. Louis District's dredge. Sound production by the *Veracious* (Reine and Dickerson 2014), with a 1,000 hp main pump, ranged from 151.48 to 157.43 dB[20] re 1 µPa at 1m from the noise source. These SPLs at the dredge (1 meter) are well below the levels responsible for fish mortality (228.9 dB re 1 µPa) cited in the literature (Hubbs and Rechnitzer 1952) or 180 dB re 1 µPa shown to cause temporary or permanent hearing loss due to sensory epithelia damage (Hastings et al. 1996; McCauley et al. 2003). SPLs are also below levels (160–170 dB re 1 µPa) responsible for temporary threshold shifts in hearing and stress responses (increased cortisol levels; Smith et al. 2004). It should be noted that these impact metrics would attenuate relatively quickly in water – at short distances from the dredge, SPLs would be reduced considerably.

Dredging Related Turbidity - Information on the potential impacts of dredging on water quality is provided above in Section 4.2.3 Impacts on Water Quality. As detailed there, dredging has the potential to increase turbidity at the dredge location and the disposal location, and, therefore, could impact fish behavior in the vicinity. However, given that dredging-related turbidity dissipates quickly and that the MMR naturally experiences dramatic fluctuations in turbidity, impacts to fish are anticipated to be minor and short-term.

Impacts of Dredging associated with the Continue Construction Alternative on Fishery Resources

Under the Continue Construction Alternative, maintenance dredging effort would fluctuate from year to year based on a range of factors, river stage being foremost among them, but would decrease from a current average of approximately 4 million cubic yards per year based on dredge quantities over the last 10 years to an average of approximately 2.4 million cubic yards per year after new construction completion associated with the Regulating Works Project. These figures are based on the best available information on forecasted reductions in dredging associated with river training structure placement and assumptions on funding levels for program implementation, rock prices, fuel prices, etc. All dredging activities would continue to be coordinated with resource agency partners to avoid and minimize potential adverse effects on fish and wildlife resources. Section 1.1.4 Process for Dredging under the Regulating Works Project describes the coordination process.

[20] The decibel (dB) is the typical system used to describe the relative loudness of sound. Sounds in water have different reference levels than sounds in air due to differing behavior characteristics of sound in water vs. air. Therefore, it is important to know if a dB reference is for a sound in water or air. For sounds in water, the reference level is expressed as dB re 1 µPa (IAGC 2016).

Dredge Entrainment Impacts – Direct measurements of the number of adult and juvenile fish entrained through maintenance dredging operations on the MMR do not exist. However, estimates have been developed based on the amount of dredging anticipated in the future and the number of fish entrained by other dredging conducted on the MMR as discussed above. Based on this information, the number of adult and juvenile fish lost to dredge entrainment would gradually decrease from a current level of approximately 1,080 fish per year to approximately 650 fish per year after new construction completion associated with the Regulating Works Project. Entrainment levels would remain at approximately this level indefinitely. These numbers are only approximations based on the best available information specific to the MMR. However, impacts on this order of magnitude are extremely small in relation to the total number of fish existing in the MMR. Estimates of fish densities for the Middle and Upper Mississippi River vary widely but range from 35 fish per acre to 24,000 fish per acre with an average of approximately 3,500 fish per acre (Christenson and Smith 1965; Dettmers et al. 2001b; Pitlo 1987). Even at the extreme lower end of this density range, the loss of 1,080 fish per year would represent less than 0.06% of the total number of MMR fish. If the average density is used, the impact declines to less than 0.0006%. Impacts of this magnitude would be considered minor and would not be anticipated to appreciably adversely affect the viability of the MMR fish community.

Similar to adult and juvenile fish, direct measurements of the number of larval fish entrained through maintenance dredging on the MMR do not exist. However, estimates have been developed based on measurements of larval fish densities in the main channel of the MMR. Based on these densities, the number of larval fish currently lost to dredge entrainment per year is estimated to be between 366 thousand and 19 million. These estimates decrease to 220 thousand and 11 million based on the predicted dredging reduction associated with the Continue Construction Alternative. These are very broad ranges due to the fact that the two available larval density estimates for the MMR are so different. Regardless of the total number of larval fish entrained, the potential impact needs to be considered in the context of the total number of larval fish in the MMR as a whole. This can be estimated by contrasting the amount of water dredged versus the overall amount of water passing through the MMR.

In comparison to the amount of water flowing through the MMR at any given point in time, the amount that actually passes through the dredge is minute. The average river discharge of the MMR at St. Louis in July and August is approximately 193,000 cfs, or approximately one trillion cubic feet of water in the two-month period. An average of approximately 83 million cubic feet of water passes through the dredge in July and August, or approximately 0.01% of the total volume of water carried by the river. This would decrease to approximately 50 million cubic feet of water passing through the dredge in July and August if dredging decreases to 2.4 million cubic yards per year with the Continue Construction Alternative. This would represent approximately 0.006% of the total volume of water carried by the river. The average amount of water passing through the MMR during months when larval fish are typically present is approximately 3.4 trillion cubic feet. Approximately 0.002% of that flow passes through the dredge in an average year. In other words, in an average year roughly 1 of every 50,000 larval fish might be entrained by maintenance dredging in the MMR. This would decrease to approximately 1 of every 80,000 after new construction completion associated with the Regulating Works Project. It must also be recognized that the reproductive strategy of fish involves producing large numbers of young, an extremely small percentage of which are expected to reach adulthood (Bartell and Campbell 2000). In addition, fish populations appear to exhibit density-dependent population response processes that increase survivorship of remaining individuals in the population when individuals are removed (Bartell and Campbell 2000). The potential impacts of larval entrainment associated with the Continue Construction Alternative are anticipated to be negligible.

Dredging Related Habitat Impacts – Based on the current average annual dredge quantity of approximately 4 million cubic yards associated with the Continue Construction Alternative, approximately 550 acres of main channel habitat are dredged each year and another 550 acres of main channel and main channel border habitat are impacted by dredged material disposal. These are anticipated to decrease to approximately 330 acres each with the Continue Construction Alternative. Given the naturally dynamic nature of the main channel areas impacted by dredging and disposal, the fact that the areas almost immediately return to a state that is available as fish habitat subsequent to dredging and disposal, the fact that macroinvertebrate densities are likely already low, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, decreasing to 1.3% with the Continue Construction Alternative, adverse habitat impacts associated with dredging are anticipated to be minor. In addition, beneficial use of dredged material through use of the District's floating flexible dredge pipe is expected to increase the quantity of shallow sandbar and ephemeral island habitat available in the MMR. The exact locations and quantities associated with flex pipe projects on the MMR vary from year to year as dredging requirements fluctuate and as the District begins to fully implement the flex pipe's use.

Dredging Related Noise Impacts – There are no known studies of underwater sound production associated with hydraulic pipeline dredges (dustpan or cutterhead dredges) currently operating on the Mississippi River. Based on information from a similar hydraulic dredge (Reine and Dickerson 2014), dredges used on the MMR are not anticipated to produce sound levels that would kill, injure, or cause stress in fish. Dredging related sound may disturb fish in the immediate vicinity of dredging operations, but this disturbance is anticipated to be short-term and localized in nature.

Dredging Related Turbidity Impacts – Information on the potential impacts of dredging on water quality is provided above in Section 4.2.3 Impacts on Water Quality. As detailed there, dredging has the potential to increase turbidity at the dredge location and the disposal location, and, therefore, could impact fish behavior in the vicinity. However, given that dredging-related turbidity dissipates quickly and that the MMR naturally experiences dramatic fluctuations in turbidity, impacts to fish are anticipated to be minor and short-term.

Impacts of Dredging associated with the No New Construction Alternative on Fishery Resources

Under the No New Construction Alternative, maintenance dredging effort would fluctuate from year to year based on a range of factors, river stage being foremost among them, but would remain indefinitely at the current average of approximately 4 million cubic yards per year based on dredge quantities over the last 10 years. All dredging activities would continue to be coordinated with resource agency partners to avoid and minimize potential adverse effects on fish and wildlife resources. Section 1.1.4 Process for Dredging under the Regulating Works Project describes the coordination process.

Dredge Entrainment Impacts – The number of adult and juvenile fish lost to entrainment per year under the No New Construction Alternative would be expected to remain similar to the current level which is estimated to be approximately 1,080 fish per year. This is estimated to represent less than 0.06% of the total number of MMR fish. This number would be expected to remain unchanged, on average, over the entire Project life. Impacts of this magnitude would be considered minor and would not be anticipated to appreciably adversely affect the viability of the MMR fish community.

The number of larval fish lost to entrainment under the No New Construction Alternative would be expected to remain similar to the current level which is estimated to be 1 of every 50,000 larval fish. This number would be expected to remain unchanged, on average, over the entire Project life. Impacts of this magnitude are anticipated to be negligible.

Dredging Related Habitat Impacts – Based on the current average annual dredge quantity of approximately 4 million cubic yards associated with the No New Construction Alternative, approximately 550 acres of main channel habitat are dredged each year and another 550 acres of main channel habitat are impacted by dredged material disposal. Given the naturally dynamic nature of the main channel areas impacted by dredging and disposal, the fact that the areas almost immediately return to a state that is available as fish habitat subsequent to dredging and disposal, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, adverse habitat impacts associated with dredging are anticipated to be minor. In addition, beneficial use of dredged material through use of the District's floating flexible dredge pipe is expected to increase the quantity of shallow sandbar and island habitat available in the MMR. The exact locations and quantities associated with flex pipe projects on the MMR vary from year to year as dredging requirements fluctuate and as the District begins to fully implement the flex pipe's use.

Dredging Related Noise Impacts – There are no known studies of underwater sound production associated with hydraulic pipeline dredges (dustpan or cutterhead dredges) currently operating on the Mississippi River. Based on information from a similar hydraulic dredge (Reine and Dickerson 2014), dredges used on the MMR are not anticipated to produce sound levels that would kill, injure, or cause stress in fish. Dredging related sound may disturb fish in the immediate vicinity of dredging operations, but this disturbance is anticipated to be short-term and localized in nature.

Dredging Related Turbidity Impacts – Information on the potential impacts of dredging on water quality is provided above in Section 4.2.3 Impacts on Water Quality. As detailed there, dredging has the potential to increase turbidity at the dredge location and the disposal location, and, therefore, could impact fish behavior in the vicinity. However, given that dredging-related turbidity dissipates quickly and that the MMR naturally experiences dramatic fluctuations in turbidity, impacts to fish are anticipated to be minor and short-term.

River Training Structure Impacts on Fishery Resources

Dike Effects – The hydrodynamics around training structures are complex and vary greatly depending upon the type of training structure in question, location within the river channel, height and length, and the river stage. 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. Traditional wing dikes cause both increased velocities and turbulent flow patterns near the tip of the dike and shear flows extending downstream (Yossef and de Vriend 2011). When river levels are below the top elevation of dikes, a complex flow pattern forms within the dike field (Maynord 2000d; Uijttewaal et al. 2001; Yossef and de Vriend 2011; Figure 4-3). The flow is characterized by: 1) a primary eddy that forms in the downstream part of the dike field, rotates in a counter clockwise direction to the channel flow on the left descending bank (or clockwise on the right descending bank), covers approximately 2/3 of the area between dikes, and has a circulation velocity approximately 30-40% of the main channel mean velocity; 2) A secondary eddy driven by the primary eddy with the opposite rotation and a much smaller flow velocity; and 3) A dynamic eddy that sheds regularly from the tip of the upstream dike. The dynamic eddy migrates in a downstream direction and merges with the primary eddy, which in return changes in size due to the interaction with the migrating eddy. During high flows, when wing dikes are submerged, the eddies disappear when dikes reach a high enough submergence level (Maynord 2000d; Yossef 2002).

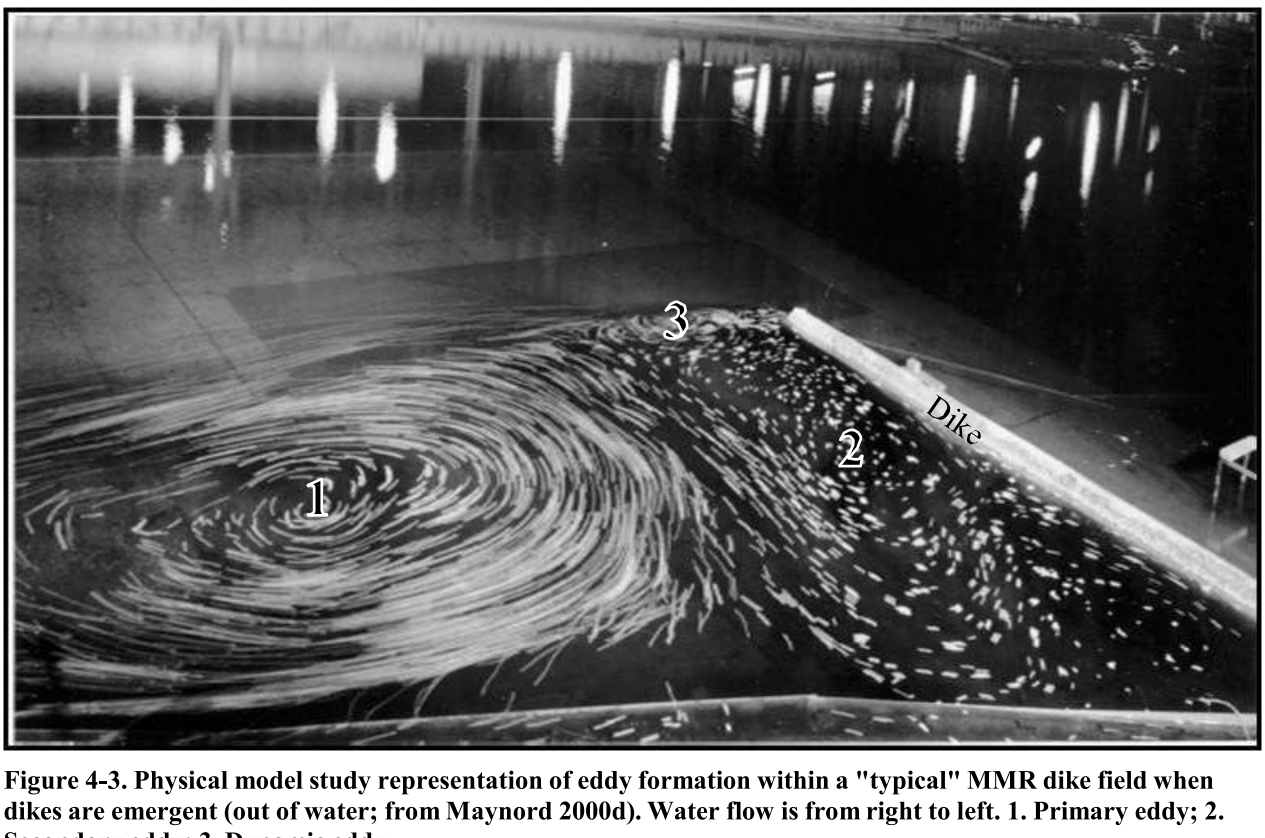


Figure 4-3. Physical model study representation of eddy formation within a "typical" MMR dike field when dikes are emergent (out of water; from Maynord 2000d). Water flow is from right to left. 1. Primary eddy; 2. Secondary eddy; 3. Dynamic eddy

Yossef and de Vriend (2011) modeled sediment exchange mechanisms and sediment transport patterns in dike fields. They found that under all flow conditions (submerged and emergent wing dikes) there is a net import of sediment into a dike field. So, traditional dike fields accumulate sediment and are generally shallower than the adjacent river (Uijttewaal et al. 2001). 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, after placement of the structures. 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 3.2.2 Geomorphology 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, the suite of innovative river training structures currently used by the District is intended to provide bathymetric diversity, flow refuge, and split flow conditions that differ from traditional wing dikes.

As described above, traditional wing dikes cause increased velocities and turbulent flow patterns near the tips of dikes; shear flows extending downstream; and eddies within the dike field with flows moving in a reverse direction to the channel flows along the shoreline. Fish making short-distance movements for feeding or long-distance spawning migrations have to navigate these anthropogenic flow fields. It has been suggested that fish select migration pathways to minimize energy expenditure during migrations. McElroy et al. (2012) telemetrically tracked a federally endangered pallid sturgeon (*Scaphirhynchus albus*) migrating upstream in the Missouri River. They found that the pathway taken by the sturgeon had a lower energy cost than one hundred thousand randomly generated paths through the study reach. Fish migrating upstream to spawn or making shorter upstream feeding movements must navigate natural complex flow fields. The modification of flow fields by training structures, especially typical wing dikes, makes the choice of a pathway with the least energy expenditure difficult and may impede movement along routes that would normally minimize energy expenditure. This is a relatively new area of scientific study and the implications for MMR fish populations are unknown, but it is possible that species may currently be impacted at some unknown level.

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 (see 4.3.1 Impacts on Benthic Macroinvertebrate Resources above). Barko et al. (2004a) found that species richness was greatest at wing dikes in the Middle Mississippi River for both adult and age-0 fishes when compared with main channel borders. However, they did find differences in species composition. At the family level, Cyprinidae, Clupeidae, and Centrarchidae were more abundant in wing dike physical habitat, while Catostomidae and Ictaluridae were more abundant in main-channel border habitat. Individual species and life stages also showed preferences for dike vs. natural main channel border habitat.

Madejczyk et al. (1998) studied differences in fish assemblages among various artificial and natural habits within the main channel border of Pool 6 in the Upper Mississippi River. In their study, nine species of fish preferred specific types of near-shore habitat. Fish abundance and diversity measures differed little among habitat types, but significantly larger fish were present at locations with structure (wing dikes and woody snags) than at sites without (bare shoreline). They found that ten fish species showed nonrandom distributions among the three habitats sampled. Redhorses (*Moxostoma*) and Channel Catfish (*Ictalurus punctatus*), were significantly more common at wing dike habitats. In addition to providing habitat for redhorses and Channel Catfish, Madejczyk et al. (1998) suggested that they may be important for other fish species (i.e., Flathead Catfish (*Pylodictis olivaris*), Walleye (*Sander vitreus*), and Sauger (*Sander canadensis*)) because wing dikes provide rocky substrates, higher current velocities, and shallow depths relative to the adjacent main channel areas. Other species such as Paddlefish (*Polyodon spathula)* and Pallid Sturgeon may frequent areas near wing dikes because of scour holes, sand bars, or eddies created by these structures (Southall and Hubert 1984; Koch et al. 2012). Similarly, Bischoff and Wolter (2001) found that groyne-heads (the tips of wing dikes) were an important habitat for both age 0+ and age 1+ juvenile rheophilic fish (fish species adapted to current) in the River Oder in Germany during the summer, but habitat use was limited by stochastic availability due to varying discharges. On a negative note, Calkins et al. (2012) found that the Silver Carp (*Hypophthalmichthys molitrix*), an exotic Asian carp species, actively selected wing dike areas with moderate flow (about 0.3 m/s) and elevated chlorophyll a (about 7 μg/L) in Pool 26 of the UMR, relative to random sites. Wing dikes were preferred while the main channel was avoided.

Hartman and Titus (2010) 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. The study results suggest that dike habitat favors some taxa and certain taxa benefited more from those habitats than others. Members of the Catostomidae and Cyprinidae were more abundant at dikes and high-quality references areas than in low-quality reference areas. They conclude that dikes "appear to provide comparable habitat for these groups as high-quality reference areas." Wing dike use was most important among Centrarchidae species, especially juveniles, including black bass and several species of *Lepomis*. Centrarchids are important sport fish as adults and are foraged upon by larger fish when small. Poizat and Pont (1996) found dike use was highest by centrarchids in the *Rhône River, France (exotic species in France),* and Barko et al. (2004b) found slightly more centrarchids at wing dikes than main channel borders on the MMR.

A study of larval fish use of dike structures on the Kanawha River (Niles and Hartman 2009) found that overall taxonomic composition did not differ between dike sites and reference sites. However, larval fish were captured at significantly higher capture rates at dike sites than at high- and low-quality reference sites. Water velocities were significantly lower at dike sites than at reference areas, suggesting that greater larval fish use of dike sites may be attributed to reduced velocity provided by the structures. Niles and Hartman (2011) found that catch per unit effort (CPUE) of larval fish along dike structures was higher than CPUE along other shoreline sites. Percidae CPUE was significantly higher on artificial dike structures than reference sites. Niles and Hartman (2009; 2011) suggest that dikes can serve as shelters and retention areas for larval fish and provide habitats that increase larval fish diversity in rivers impacted by commercial navigation traffic.

Braun et al. (2015) compared standardized CPUE and overall community structure for 50 fish species among un-notched wing dikes, notched wing dikes, and L-dikes in the MMR, sampled as part of the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring element. There were no differences in standardized CPUE for 64% of the fish species examined. Five species known to be associated with lotic habitats were most abundant near L-head dikes. Seven species were more abundant at un-notched dikes than notched dikes, while six species were more abundant at notched dikes than un-notched dikes.

Schloesser et al. (2012) compared species occupancy and fish community composition at natural sandbars and at notched and un-notched rock dikes along the lower Missouri River to determine if notching dikes increases species diversity or occupancy of fish. Few differences in species richness and diversity were evident among engineered dike structures and natural sandbars. Notching a dike structure had no effect on abundance of proportional fluvial dependents, fluvial specialists, and macrohabitat generalists. Occupancy at notched dikes increased for two species but did not differ for the other 17 species (81%). The authors suggest that dike structures may provide suitable habitats for fluvial species compared with channel sand bars, but notching of dikes did not increase abundance or occupancy of most Missouri River species.

Limited sampling conducted by the St. Louis District at an offset dike field in the MMR at RM 60.0 to 57.5 (USACE 2012a) 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.

Chevron Dike Effects - Remo et al. (2013) studied habitat diversity (depth and water velocities) in a series of three chevron dikes for pre- and post-construction conditions in the MMR's St. Louis Harbor. A comparison of pre- and post-construction conditions revealed an increase in deep to very deep (> 3.0 m), slow (<0.6 m/s) water downstream of the chevrons during emergent flow conditions. Chevrons added approximately 7.6 ha of potential over-wintering habitat (deep, > 3.0 m with low velocity, <0.6 m/s). Chevrons also created 0.8-3.8 ha of shallow-water habitat (0-1.5 m depth with a 0-0.6 m/s) for flows ≤ 2.0 times mean annual flow and contributed to an 8-35% increase in physical-aquatic habitat diversity compared to pre-construction conditions.

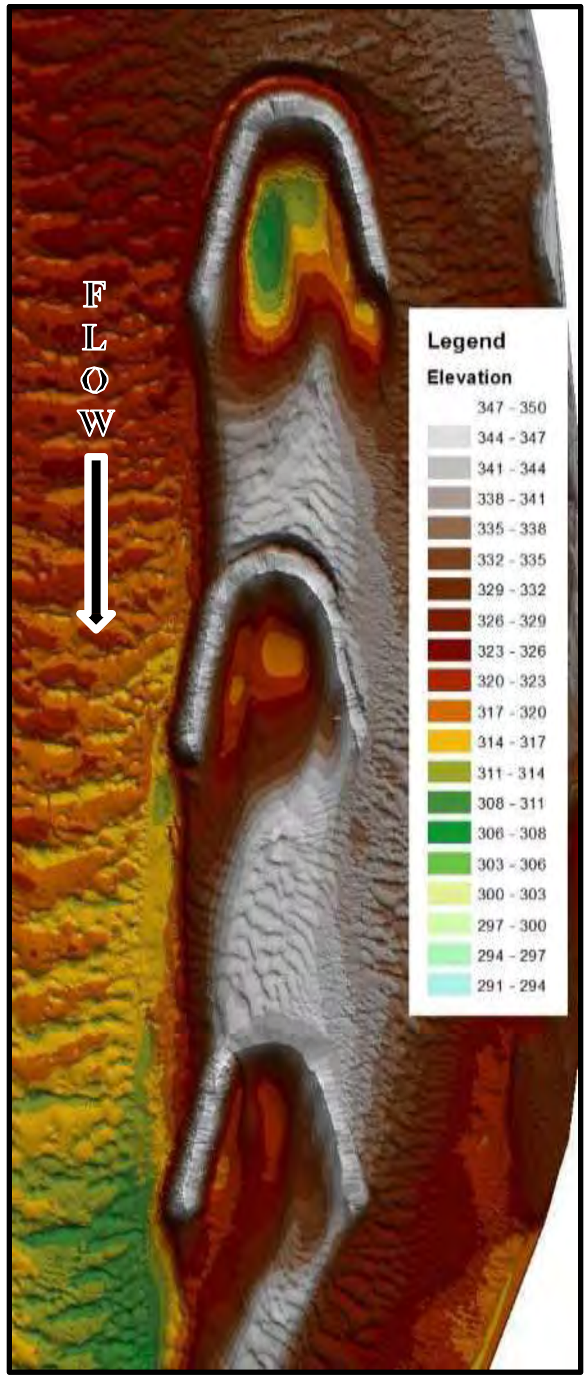


Figure 4-4. Example of bathymetry around MMR chevron dikes.

Schneider (2012) tracked the habitat changes in the same chevrons as the Remo et al. (2013) study from pre-construction bathymetry in 2007 to changes seen in 2008, 2009, and 2010. Immediately following construction, a deep scour hole formed behind each of the three chevron dikes creating ephemeral islands downstream at all dike locations. The right descending bank (RDB) maintained a large portion of its shallow water habitat. In 2008, as a result of high flows, the scour holes grew larger, but the flows nearly completely removed the ephemeral islands. A large portion of shallow water habitat on the RDB was lost, moving downstream. In early 2009, during lower flows, the islands started to reform and the scour holes shrank. Shallow water habitat again formed on the RDB. Another high water event occurred in 2009 reducing islands and the shallow-water habitat on the RDB was again reduced. In 2010, another high water event removed islands and shallow water habitat still occurred further downstream on the RDB. It is obvious that the chevrons create greater habitat diversity when compared to pre-construction bathymetry and habitat type and availability is stage dependent. Schneider (2012) also investigated fish communities associated with chevron dikes and found increased fish diversity as compared to pre-construction conditions and open water control sites. Only 11 fish species were caught at the chevron construction site during two years of pre-construction sampling, while 33 species were collected during post-construction sampling. There was a reduction of benthic chubs after chevron construction. Schneider (2012) suggests that this was due to the reduction of shallow water areas with strong currents along the RDB. He indicates that suitable habitat may have shifted downstream of the chevrons as demonstrated by bathymetric surveys, but this area was outside his pre- and post-construction fish sampling areas.

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 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 macroinvertebrates (Ecological Specialists, Inc. 1997a, 1997b).

Hydroacoustic surveys of fishes were conducted by Kasul and Baker (1996) in four river bends of the Middle Mississippi River between Cairo, Illinois, and Cape Girardeau, Missouri (RM 2-50). Comparisons of fish density based on the hydroacoustic surveys suggest that bendway weirs increase the local abundance of fishes in affected areas of the river channel more than two-fold when compared to bends without weirs. Keevin et al. (2002) sampled fish in a 152-meter section over a bendway weir (RM 30.0) at Price Towhead weir field using explosives to document fish use. In total, 217 fish were captured representing 12 different species. Freshwater Drum (*Aplodinotus grunniens*) dominated the catch comprising 35.5% of the total, followed by Gizzard Shad (*Dorosoma cepedianum*) (27.2%), and Blue Catfish (*Ictalurus furcatus*) (16.6%). The small section of rock dike supported a fairly diverse species assemblage and a large number of fish.

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 (*Hiodon alosoides*), 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 (*Dorosoma petenense*), 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)[21] 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.

Revetment Effects – Revetment is designed to prevent erosion of the underlying river bank, thereby preventing migration of the river channel and potential disruption of commercial navigation. Prevention of channel migration also eliminates the formation of new habitats including side channels. Florsheim et al. (2008) argue that bank erosion, which is obviously restricted by revetment, is a desirable ecological attribute of rivers and is integral to the functioning of river ecosystems. Their argument focuses on four principles that illustrate the significance of bank erosion:

1. Bank erosion provides a sediment source that creates riparian habitat.
2. Active banks create and maintain diverse structure and habitat functions.
3. Riparian vegetation promotes bank stability and contributes large woody debris.
4. Bank erosion modulates changes in channel morphology and pattern.

Fischenich (2003) summarized the existing literature on the impacts of revetment on five general functions of riverine systems: evolution through morphological processes, maintenance of

[21] 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 LWRP was also calculated in reference to the North American Vertical Datum 88 (NAVD 88).

hydrologic balance, continuity of sediment processes, provision of habitat, and maintenance of chemical processes and pathways. Revetment was determined to most likely affect morphological evolution, sediment processes, and habitat. Morphological evolution is impacted by prevention of lateral migration and interruption of riparian succession processes. Sediment processes are affected in the reduced overall bank erosion with some increased local scour at the toe of the revetment. Habitat impacts tend to favor species that use interstitial spaces between rocks which can result in population shifts and usually result in increased macroinvertebrate biomass and density.

Bank erosion may be desirable from an ecological perspective, and channel migration was an integral part of the historic condition of the MMR (Heitmeyer 2008), but current social and economic factors provide hard constraints on the acceptability of bankline migration (Jacobson and Galat 2006). Allowing bankline erosion and migration in today's MMR would have the potential to adversely affect agricultural areas, levees protecting agriculture as well as residential and business developments, water supplies, and the location and reliability of the navigation channel.

Similar to other rock river training structures, revetment can improve fish habitat by providing substrate diversity, additional cover, and more 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 of the Mississippi River over a 3-year period. Although the number of species at each bankline type were similar, total fish collected was greater on banklines with revetment, especially where larger stone was present. On the Lower Mississippi River, Pennington et al. (1983) sampled fish populations using hoop nets and electroshocking along two natural and two revetted banks near Greenville, MS. They found that the numbers of fish species taken from natural and revetted banks were similar. Twenty-four species were collected from natural banks and 27 from revetted banks. 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. Mean catch per unit effort (CPUE) in numbers and weight were greater on natural banks during one of four sampling periods (June), but greater on revetted banks during the other sampling periods (April, September, and November). In a similar study on the Lower Mississippi River, Pennington et al. (1985) sampled fish populations using hoop nets along natural and revetted banks near Eudora, AR. During months prior to revetment placement Freshwater Drum was the most abundant species (32% of total catch), followed in abundance by Flathead Catfish (9.6%), Common Carp (*Cyprinus carpio*, 7.8%), and Blue Catfish (3.3%). After revetment placement Freshwater Drum remained the most abundant species (9.7% of the catch), followed by Gizzard Shad (*Dorosoma cepedianum*, 8.9%), Flathead Catfish (4.1%), and Blue Catfish (3.4%). There was no significant difference in CPUE between natural and revetted banks.

White et al. (2010) compared fish assemblage structure in engineered (revetment) and natural habitat in the Kansas River. They found that mean species diversity and richness were significantly higher in revetment than log jams and mud banks. Mean relative abundance (CPUE, number of fish collected per hour electrofishing) of six of the 15 most abundant fishes were most abundant in revetment, two were most abundant in log jams, and none in mud banks.

Revetment had the highest relative abundance of fluvial specialists and macrohabitat generalists, whereas mean CPUE of fluvial dependents was highest in log jams. There was a high degree of fish assemblage overlap among habitats.

Construction and Maintenance Effects – In addition to the potential broad scale impacts of river training structures and revetment discussed above, construction and maintenance activities associated with river training structures and revetment also have the potential to impact fishery resources. Construction and maintenance activities would typically consist of placement of limestone rock using barge mounted track hoes or dragline cranes. Most construction would be accomplished from the river and would be performed below ordinary high water. Potential impacts to fishery resources include displacement from the construction site due to temporary decreases in water quality and disturbance by construction equipment. Entrainment of fish in the propellers of motor vessels during construction and during travel to and from construction sites could also occur.

3-D Numerical Hydraulic Model

As outlined above, there is a reasonable amount of information available in the scientific literature on the potential impacts of river training structures on fishery resources. Existing information adequately characterizes the qualitative changes in fish community structure that might be anticipated with further construction of river training structures. However, in order to properly characterize the programmatic physical impacts of future river training structure construction on fishery resources, the District needed to develop a quantitative methodology. Previous analyses of physical aquatic habitat have been conducted using two-dimensional hydraulic models (e.g., Jacobsen et al. 2009, Remo et al. 2013). Such models can provide a good approximation of two-dimensional flow fields around traditional river training structures but are unable to replicate the three dimensional flow patterns around complex innovative structures[22] used extensively on the MMR. The District determined that a three-dimensional numerical hydraulic model would be the most appropriate tool for quantifying changes in velocity distribution throughout the water column.

Modeled Reach. Since it was not feasible to model the entire MMR due to budget, time, and technological constraints, the District had to determine which section of the 195-mile MMR should be modeled in order to adequately characterize impacts of future river training structure construction. Factors taken into consideration included:

- Locations of rated gages (locations where both discharge and stage are collected) – proximity to a rated gage was important in order to ensure proper model calibration.
- Number of different types of river training structures and habitats in the area (e.g. traditional dikes, chevron dikes, notched dikes, offset dikes, bendway weirs, point bars,

[22] Innovative structures are river training structures designed in unique configurations to achieve the primary objective of deepening the navigation channel while also increasing depth and flow diversity for fish and wildlife when compared to traditional wing dikes. The District has designed and implemented many different configurations of innovative structures including notched dikes, rootless dikes, L-dikes, W-dikes, chevron dikes, multiple roundpoint structures, etc.

side channels, etc.) – a variety of structure and habitat types was necessary to ensure that an adequate range of future construction scenarios would be covered by the model

- Length of the modeled area – the size of the modeled area needed to be large enough to cover an adequate range of habitats and structure types but small enough to make analysis of multiple scenarios realistically feasible given computing power and time required.
- Available bathymetric datasets – model velocity calculations around structures are dependent on bathymetry. To get the most accurate velocity patterns around structures it is critical to have the most dense and detailed bathymetric data available.

A 19-mile stretch of the MMR from river mile 110 near Chester, IL, to river mile 92 was selected for analysis (Figure 4-5). This stretch of river includes a rated gage at the upstream end (allowing the model to be calibrated to observed water surface and velocity data), contains the majority of structure and habitat types in the MMR, has good coverage of bathymetric data, and is of an appropriate length for maximizing data output and minimizing computation requirements.

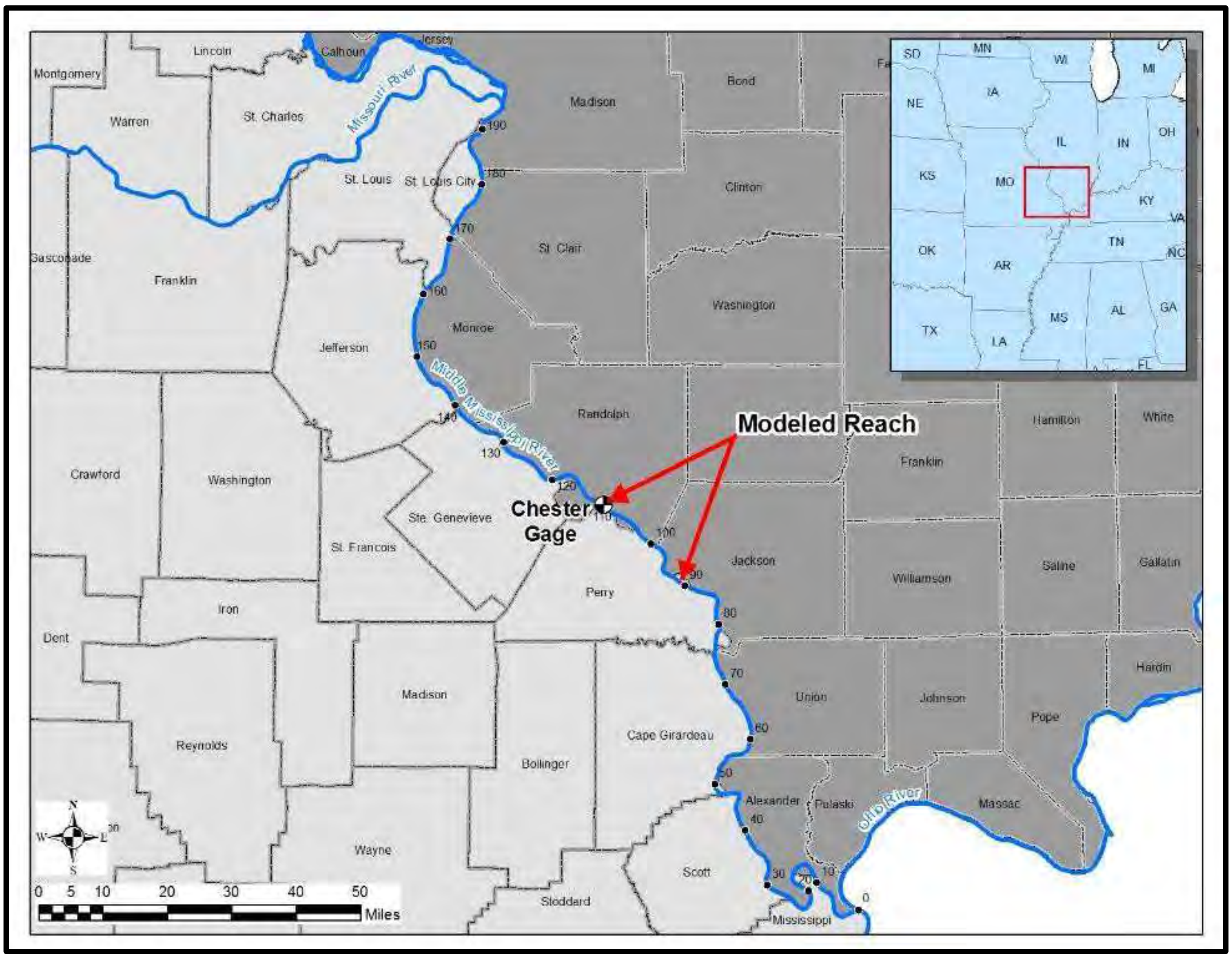


Figure 4-5. Location of the modeled portion of the MMR.

Analysis Methodology. The model was used to analyze velocities for three separate discharges: average annual low discharge (111,000 cfs), average annual discharge (213,000 cfs), and average annual high discharge (303,000 cfs). These discharges correspond to structures being emerged by 10 feet, emerged by 2 feet, and submerged by 4 feet, respectively. These discharges were chosen because they cover the full range of flows occurring in a typical year and cover a broad enough range to adequately capture the full range of velocity and depth profiles in the modeled reach. They were also chosen because they correspond to flows for which recent field measurements of water surface and velocity have been collected, thereby increasing model accuracy.

For each of the discharges, 6 depth categories and 5 velocity categories were computed. Depth and velocity categories were assigned to 1-m by 1-m by 1-m volumes within the modeled area. Depth categories were assigned based on the total water depth of the location, not by the depth of the cube within the water column. In other words, all individual $1m^3$ volumes at a particular point in the river were assigned the same depth category, irrespective of where they fell within the water column at that location. This was done to avoid classifying, for example, surface waters over shallow sandbars the same as surface waters over deep water in the main channel.

The depth and velocity classifications were developed with input from natural resource agency partners. The number of depth and velocity categories had to be limited to a reasonable number so that processing of model data did not become exceedingly time consuming. The chosen depth and velocity categories are skewed toward higher resolution at shallower and lower velocity habitat due to the fact that those areas are, in general, considered more likely to provide better fish habitat in the MMR. The following categories were used:

Depths (meters)

- 0-1.0
- 1.0-2.0
- 2.0-3.0
- 3.0-5.0
- 5.0-10.0
- >10.0

Velocities (m/s)

- 0.0-0.1
- 0.11-0.25
- 0.26-0.5
- 0.51-1.0
- >1.0

One of the recurring challenges with determining the future impacts of implementation of the Regulating Works Project on the human environment is the fact that the exact locations of future work sites and the exact set of structures to be used are not known. Given the dynamic nature of the MMR, work sites are developed on an ongoing basis as dredging issues arise and the set of structures to be used to address dredging issues at each location is developed based on the unique characteristics of each site. Because of these uncertainties in location and configuration of future structures, it was necessary to use existing dike fields within the modeled reach to serve as surrogates for work sites to estimate future impacts. Groups of dikes were selected as work sites based on typical Regulating Works construction site configurations and sizes. In selecting areas of the modeled reach to use as work sites, it was also necessary to select areas that could serve as surrogate control sites so that a before and after comparison could be conducted to quantify impacts. Due to the fact that detailed bathymetry for previous years did not exist for most of the modeled reach, the model could not be used to analyze true before construction and after construction conditions for work sites. Therefore, areas of the modeled reach that were representative of likely future work sites before construction were used as surrogate control sites. Eight areas were selected as control sites and nine were selected as work sites. Depth and velocity information for each site for all three discharges was calculated. This resulted in a dataset of volumes of the various combinations of depth and velocity occurring in each area for each discharge. These volumes were then converted to percentages to account for differing acres and volumes of each site and to allow for direct comparison.

Results. The overall quantities of the different combinations of depth and velocity habitat classifications for the entire modeled reach can be seen in Figure 4-6. The overall quantities of the different combinations of depth and velocity habitat classifications for just the main channel border portion of the modeled reach and the relative percent of each category when compared to the entire modeled reach can be seen in Figure 4-7. Analysis of the 3D model outputs resulted in a few key conclusions:

1. **Use of innovative structures is accomplishing the intended goal of avoiding and minimizing habitat impacts by increasing habitat diversity.** The analysis of model results for areas with innovative structures compared to areas with traditional dikes shows an increase in diversity of depth and velocity categories. In the modeled reach, innovative structures consist of chevrons, offset dikes, and notched dikes. As can be seen in Figure 4-8, the innovative structure fields tend to provide a more even distribution of habitat categories, particularly on the shallow end of the habitat scale. Another way to consider this is by comparing the gains in relative habitat percentage of innovative vs. traditional dikes. This can be done by comparing the amount of each habitat category in the work site or control site to the total amount of that habitat type in the entire modeled reach. Using this method highlights differences based on scarcity – small increases in scarce habitat categories show up as large relative percent increases. This comparison can be seen in Figure 4-9. Again, innovative structures appear to increase habitat diversity when compared to traditional dikes. This is an important validation that the use of innovative structures yields the desired habitat benefits as intended to avoid and minimize the Project impacts to habitat.

2. **Construction of river training structures generally results in an increase in shallow, low-velocity habitat which is generally regarded as important fish habitat.** When comparing model results for work sites to control sites (Figure 4-10), a general increase in the relative percent of low-velocity habitat can be seen, particularly shallow, low-velocity habitat. This is intuitively reasonable given that river training structure construction, whether traditional or innovative, generally results in some sediment accretion downstream of the structures in an area of low current velocity.

3. **Construction of river training structures generally results in a decrease in shallow to moderate-depth, moderate- to high-velocity habitat which is important habitat to some MMR fish guilds.** While there is a gain in low-velocity habitat as discussed in conclusion 2 above, model results indicate that river training structure construction causes a loss in

shallow to moderate-depth, moderate- to high-velocity habitat (Figure 4-10). The loss appears to be relatively small, but given the limited quantity of habitat of this type in the MMR, the relative loss is more meaningful. The depth and velocity characteristics of this loss are reasonable given the locations in which river training structures are generally constructed – shallow to moderate-depth unstructured main channel border habitat. This habitat would typically be expected to exhibit moderate to high velocities given its location in the river channel and presumed lack of river training structures to act as current breaks. Indeed, modeled depth and velocity profiles for such unstructured main channel border areas mimic the depth and velocity profiles of this habitat loss.

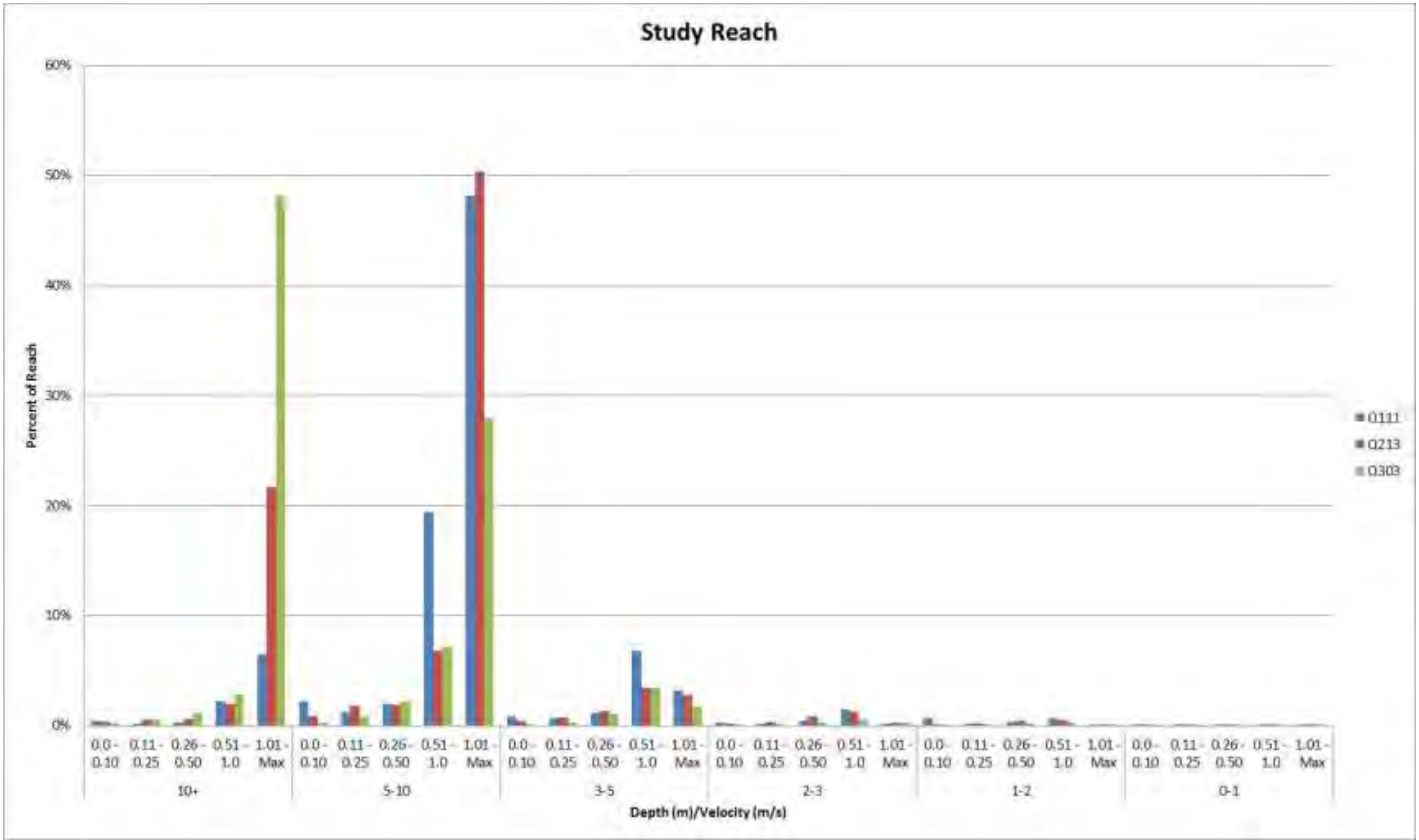


Figure 4-6. Quantity of each habitat category in the entire modeled reach expressed as a percent. Three discharges analyzed represented by three colors.

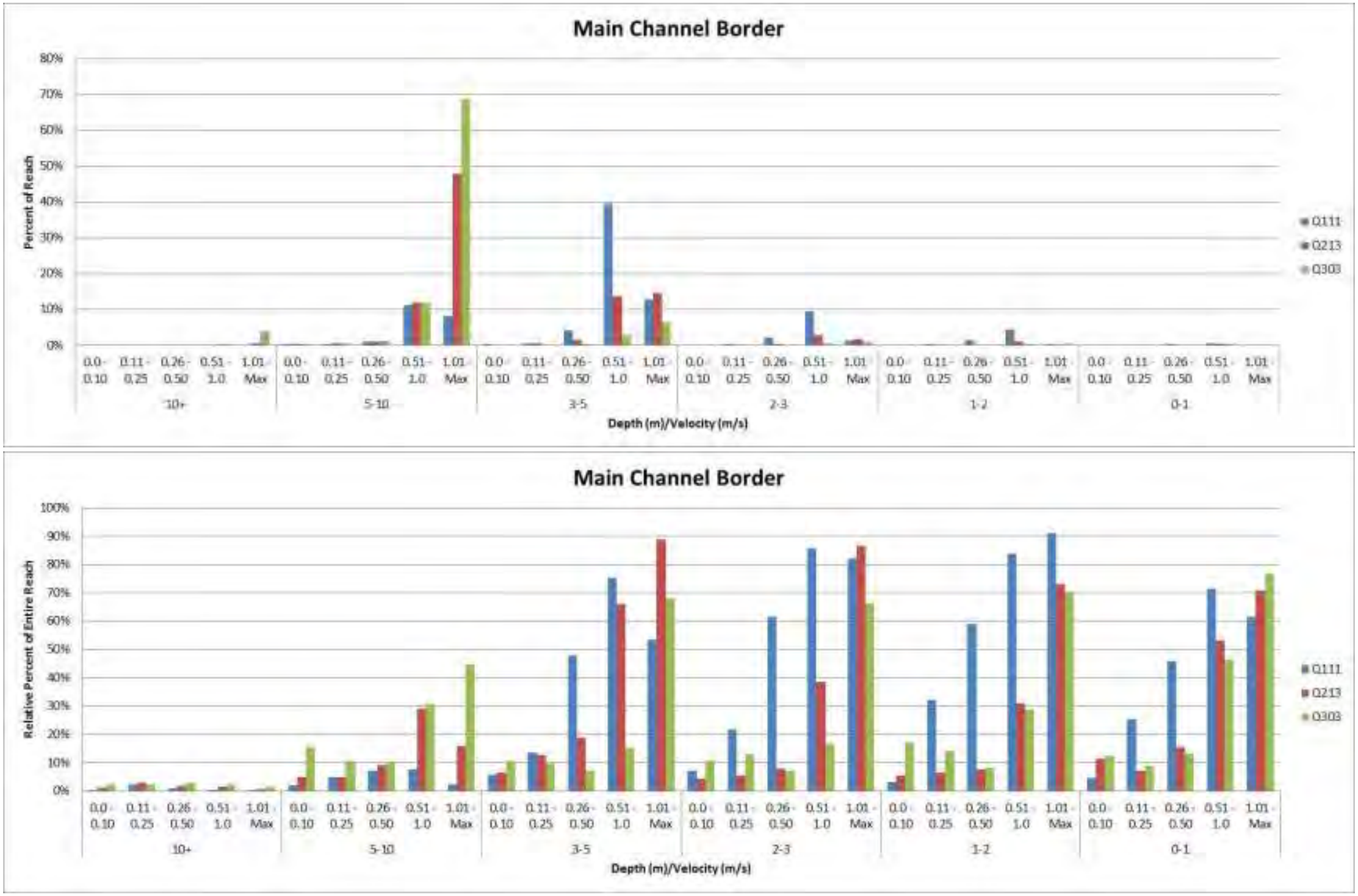


Figure 4-7. Quantity of each habitat category in the main channel border area of the modeled reach expressed as a percent (top) and expressed as a relative percent when compared to the entire modeled reach (bottom). Three discharges analyzed represented by three colors.

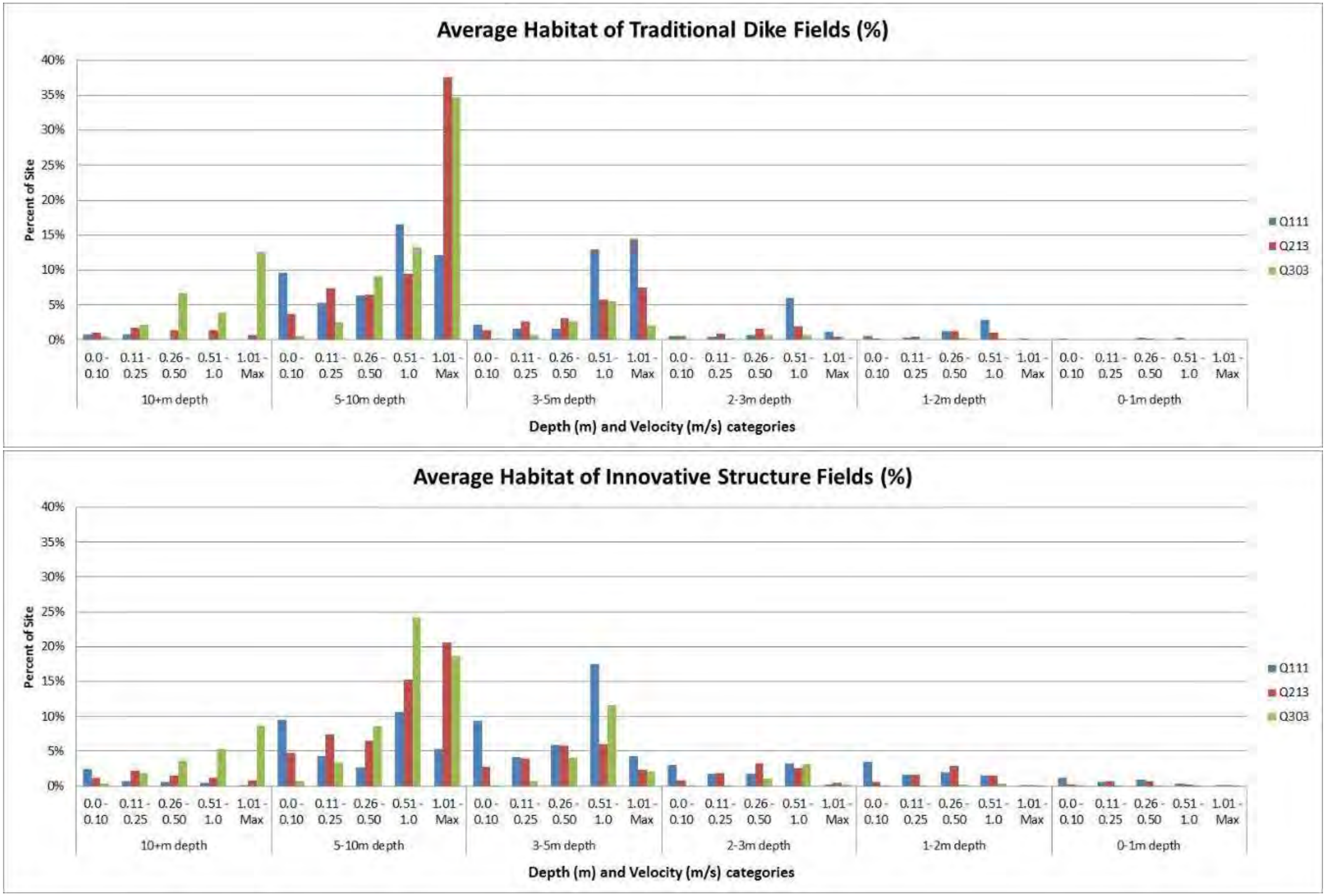


Figure 4-8. Comparison of habitat categories provided by traditional dikes (top) vs. innovative structures (bottom) expressed as a percent of the site. Three discharges analyzed represented by three colors.

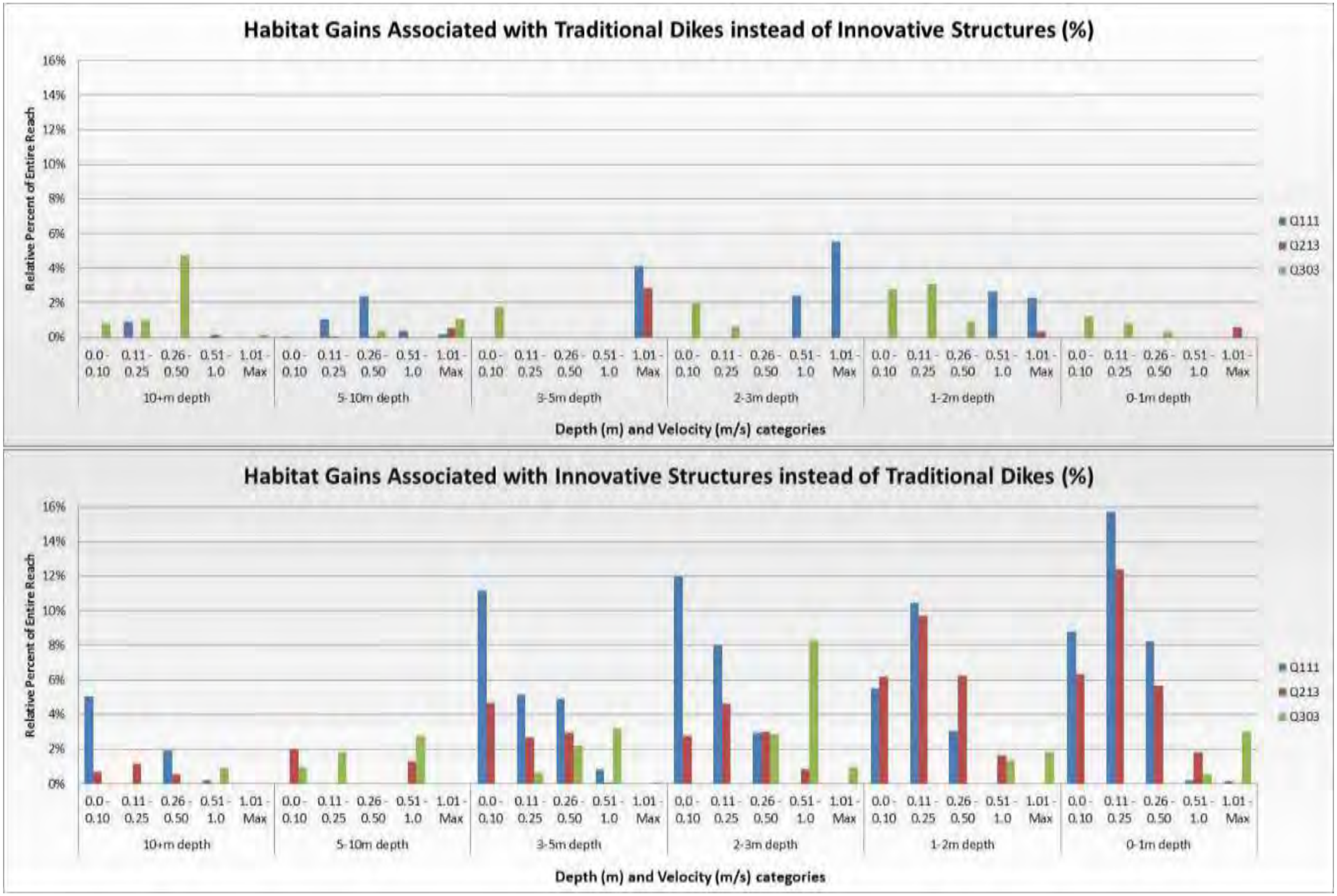


Figure 4-9. Comparison of habitat gains associated with construction of traditional dikes (top) vs. innovative structures (bottom) expressed as a relative percent of each habitat category.

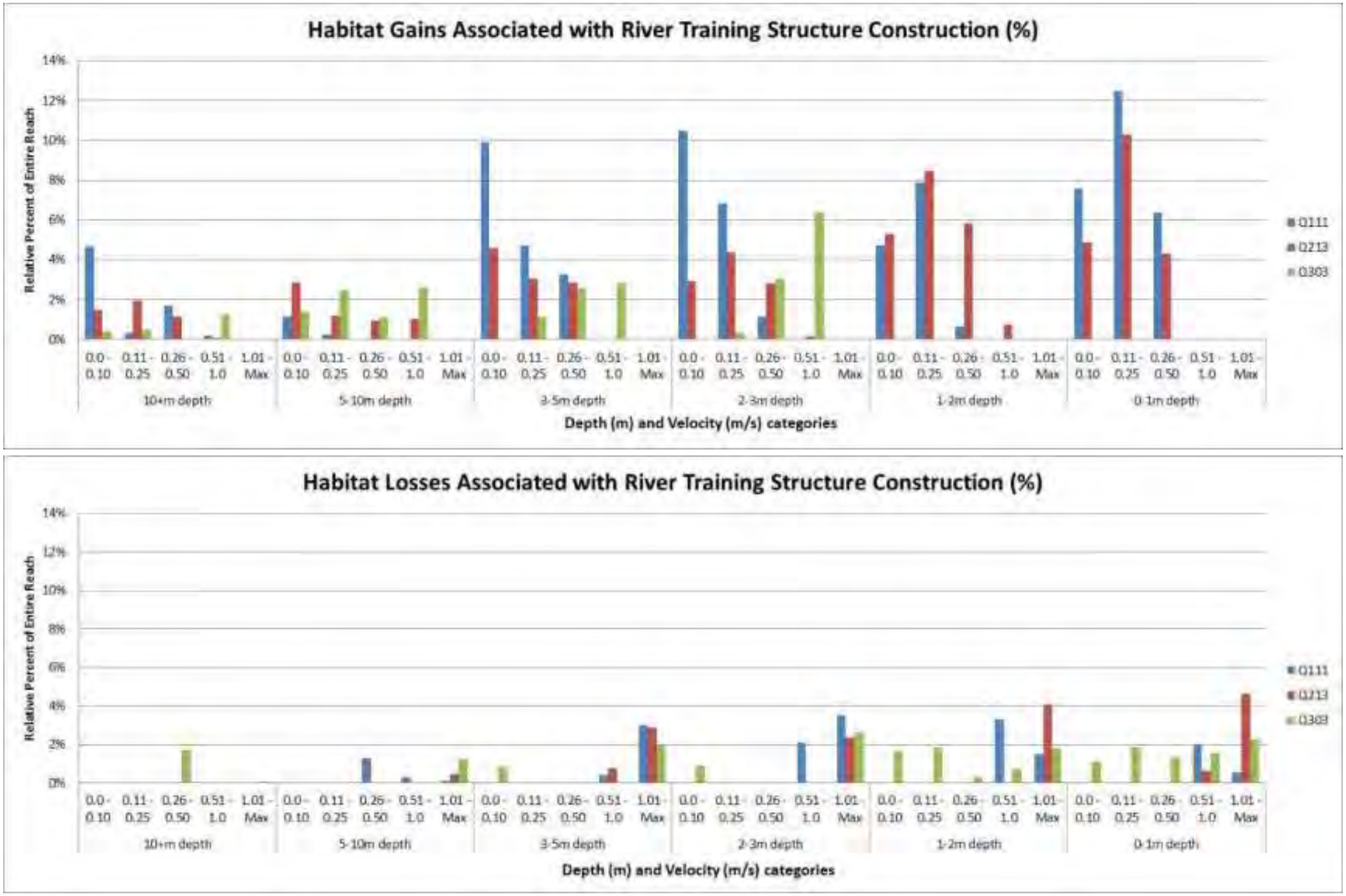


Figure 4-10. Habitat gains (top) and losses (bottom) associated with construction of river training structures expressed as a relative percent of each habitat category.

Impacts of River Training Structure Construction associated with the Continue Construction Alternative on Fishery Resources

Under the Continue Construction Alternative, an estimated 4.4 million tons of rock is expected to be placed for construction of river training structures to address repetitive dredging areas. The exact locations, configurations, and types of river training structures are not known at this time and would not be known until planning is conducted work area by work area over the remainder of the construction phase of the Project. The specific impacts associated with each work area would be covered in Tier II site specific Environmental Assessments. However, the generalized, programmatic impacts that can reasonably be anticipated to occur as a result of all future construction activities are summarized herein. To quantify the programmatic impacts of future river training structure construction on fish habitat, the assumption was made that for the remaining work areas in the MMR, impacts would be comparable to those in the modeled reach.

As a result of river training structure placement in future work areas, the adjacent navigation channel is expected to deepen and the main channel border area is expected to become shallower, on average. However, based on river planform trends over the past 50 years, very little conversion of the main channel border area to terrestrial habitat is expected to occur. River planform area is expected to remain similar to what it is today, with some variation from year to year. Future placement of river training structures is expected to increase areas of shallow, low-velocity main channel border habitat important to a wide variety of MMR fish species. Continued use of innovative river training structure designs is expected to increase depth and velocity diversity in main channel border areas to continue to avoid and minimize Project impacts to this habitat. Continued construction of bendway weirs is anticipated to improve habitat on outside bends for many fish species. The impacts on fish habitat on inside bends opposite the bendway weirs are uncertain. Studies to date do not provide conclusive results for predicting fish community response to bendway weir placement at adjacent inside bends, but the District will continue to evaluate any new information to this habitat and impacts from the Project. Continued construction of revetment on areas of MMR bankline is expected to prevent erosion of any adjacent riparian corridor, thereby reducing woody debris inputs. Approximately 60% of the MMR bankline has already been revetted to date. This revetment covers the vast majority of MMR bankline areas that might require revetment to prevent bankline erosion. The precise amount of revetment required going forward is unknown but is not anticipated to have an appreciable adverse effect on the MMR fish community. All rock material used for construction of river training structures and revetment is expected to increase habitat diversity, flow complexity, and the quantity of stable substrate available for macroinvertebrate colonization, thereby improving the overall quality of fish habitat. Further, the District will continue to coordinate with Federal and state resource agencies to insure proper avoidance and minimization measures are taken with respect to future river training structures and revetment construction, operation, and maintenance.

Despite any apparent increase in overall habitat diversity associated with river training structures, there are potential adverse effects anticipated with future construction. One area of potential adverse effect is the modification of flow fields by training structures and the potential implications for fish movement patterns either for migration or as part of daily foraging patterns. The velocity and turbulence patterns around river training structures may impede fish movement along routes that would normally minimize energy expenditure. There are also potential adverse effects to fishery resources from river training structure construction and maintenance activities. These include displacement from the construction site due to temporary decreases in water quality and disturbance by construction equipment. Entrainment of fish in the propellers of motor vessels during construction and during travel to and from construction sites could also occur.

Another area of potential adverse effect is the loss of shallow to moderate-depth, moderate- to high-velocity habitat. Habitat with these depth and velocity combinations is important habitat for some MMR fluvial specialists, or species that are found almost exclusively in flowing water throughout their life cycles. Some species of fluvial specialists in the MMR have seen declines in abundance since the mid-1900s. For example, Sturgeon Chub (*Macrhybopsis gelida*) and Sicklefin Chub (*Macrhybopsis meeki*) are typically found in medium- to high-velocity sand and gravel bar habitat in the MMR and have declined in abundance over time in the MMR (Pflieger 1997). Remnant habitats with these depth and velocity attributes are important biologically for the continued existence of the chub species (USFWS 2008).

In order to determine the magnitude of this potential adverse effect, the District conducted an analysis of MMR habitat classifications. Results of the 3-D numerical hydraulic model indicated that the depth and velocity profile of the shallow to moderate-depth, moderate- to high-velocity habitat that is lost with placement of river training structures is very similar to the depth and velocity profile of unstructured main channel border habitat in the modeled reach. Accordingly, the District analyzed the past and present quantities of unstructured main channel border habitat and projected future quantities. The analysis showed that the amount of unstructured main channel border habitat in the MMR (defined as areas shallower than LWRP -10 without river training structures) decreased from approximately 19,800 acres in 1976 to approximately 12,900 acres in 2014. In other words, river training structure construction affected approximately 6,900 acres of main channel border habitat from 1976 to 2014. Based on the current programmatic estimate of the amount of remaining construction, it is anticipated that river training structure construction could potentially affect another 1,100 acres of unstructured main channel border habitat[23]. This represents approximately 8% of the remaining unstructured main channel border habitat in the MMR, presumably with the depth and velocity identified as lost in the 3-D numerical hydraulic model. Although these unstructured main channel border habitats are part of a river system that is highly modified compared to its original state, they likely more closely resemble some of the habitats of the historic MMR. The continued conversion to structured habitat is expected to result in the continued functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high-velocity habitat of the main channel surrounded by structured main channel border habitat. This analysis also provides insight into the magnitude of the potential adverse effect to fish movement described above. Areas of unstructured main channel border habitat are more likely to provide the necessary movement and migration pathways required by the MMR fish community. Overall, the continued conversion to structured main channel border habitat is expected to have a significant adverse effect on the MMR fish community, and the District has concluded that this may warrant compensatory mitigation.

[23] Actual acreages affected would not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis. See Appendix C for a full discussion of the assumptions associated with the remaining quantity of construction.

This impact is considered potentially significant on technical, institutional, and public merits. The impact is potentially technically significant due to the magnitude of the potential adverse effect to unstructured main channel border habitat in comparison to the amount of that habitat remaining and the amount of similar habitat that has been lost in the past. Likewise, it is technically significant due to the decline in abundance of the species of fish that utilize the habitat and the fact that remnant habitats with these depth and velocity attributes are important biologically for the continued existence of these species. The impact is considered potentially significant on institutional grounds due to the importance that the Corps, through its Environmental Operating Principles, places on environmental sustainability, proactive consideration of the environmental consequences of Corps activities, and the creation of mutually supporting economic and environmental solutions. Congress recognized the Upper Mississippi River System as a "…nationally significant ecosystem and a nationally significant commercial navigation system" in Section 1103 of the Water Resources Development Act of 1986. Natural resource agency partners place high priority on protecting and sustaining the aquatic resources of the Mississippi River. The State of Illinois recognizes the Sturgeon Chub as significant in listing it as a state endangered species. The State of Missouri recognizes the Sturgeon Chub as a vulnerable species due to a restricted range, relatively few populations or occurrences, recent and widespread declines, or other factors making it vulnerable to extirpation. The impact is considered potentially significant to the public due to the intrinsic value the public places on the environment and its continued protection. Specific public interest in the Sturgeon Chub and the Sicklefin Chub is demonstrated by formal petitions by the public in 1994 and in 2016 to list the species as threatened or endangered under the Endangered Species Act.

Potential Compensatory Mitigation Measures
In order to compensate for the projected future unavoidable adverse effects of future river training structure placement associated with the Continue Construction Alternative, potential mitigation measures may include, but are not limited to: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, or other activities. Removal, shortening, notching, etc. of existing river training structures would facilitate the replacement of lost function with a similar amount of habitat function. This could be accomplished by restoring the amount of unstructured main channel border habitat that is lost by future placement of river training structures. An evaluation of current channel bathymetry on the MMR reveals opportunities where existing river training structures could be removed, shortened, and/or notched without adversely affecting the current dredging requirements of the adjacent navigation channel.

Dikes on the MMR have been added and extended over time to reduce dredging, increase safety, and add environmental diversity throughout the Regulating Works Project. Initially these structures were designed using design criteria that specified dike spacing as a function of dike length. Early river engineering practice was to extend existing structures to achieve greater channel contraction when necessary (see Appendixes F and K). The result of extending existing dikes is that the structure spacing is no longer optimized, resulting in structures that have little or no effect on maintaining navigation channel depths.

In addition, many of the structures on the MMR were designed by engineers without the assistance of modern numerical and physical model studies that are now used to optimize structure locations, configurations, spacing, etc. Adaptive management was used in cases when there was a need for additional constriction from what was initially designed; however, in cases where constructed projects deepened the navigation channel by more than what was needed or expected, structures were not normally removed.

These factors have created a situation where opportunities now exist within the MMR to remove, shorten, notch, or otherwise alter the configuration of existing river training structures without adversely affecting the adjacent navigation channel to potentially compensate for the 1,100 acres of main channel border habitat estimated to be impacted. The St. Louis District has, in fact, successfully altered existing dike configurations in multiple locations in the MMR to provide environmental benefits pursuant to the Avoid and Minimize Program (discussed in detail in Appendix K) and the RPAs, RPMs, and Terms and Conditions of the Biological Opinion. A preliminary evaluation of where further opportunities exist to remove, shorten, and/or notch existing structures could be done by comparing current main channel depth profiles to the profile for a navigation channel of nine-foot depth below LWRP. Once potential sites are identified, more detailed H&H modeling or analysis would be used to develop a recommended plan and verify that there would be no impact to the adjacent navigation channel, providing identified areas that could be used if necessary for potential compensatory mitigation for future construction.

Impacts of River Training Structure Construction associated with the No New Construction Alternative on Fishery Resources

The only Regulating Works Project construction activities associated with the No New Construction Alternative would be for maintenance of existing structures and for any construction associated with implementation of the Biological Opinion. Potential impacts to fishery resources include displacement from the construction site due to temporary decreases in water quality and disturbance by construction equipment. Entrainment of fish in the propellers of motor vessels during construction and during travel to and from construction sites could also occur. Further, as described, in Chapter 1, coordination with Federal and state resource agencies would proceed for these activities to avoid and/or minimize any identified or potential impacts to fishery resources. Therefore, fishery resources impacts associated with the No New Construction Alternative are anticipated to be minor and short-term in nature.

4.3.3 Impacts on Threatened and Endangered Species

As discussed in Section 3.3.4 Threatened and Endangered Species above, due to the existing Biological Assessment and Biological Opinion that cover the Regulating Works Project, a Biological Assessment was not prepared in conjunction with this SEIS for the species covered by the previous consultation process. However, for new threatened and endangered species that have been listed since issuance of the 2000 Biological Opinion (Table 4-7), a Biological Assessment has been prepared in conjunction with this SEIS. USFWS concurrence with the determinations in the Biological Assessment can be found in Appendix E. The 1999 Biological Assessment and 2000 Biological Opinion can be found on the District's web site at:

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

The Biological Assessment for this SEIS covering recently listed species can be found in Appendix B. Site-specific Tier II Biological Assessments for all appropriate species are currently prepared and would continue to be prepared for construction of specific work areas in the MMR.

Table 4-7. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area that have been listed since issuance of the 2000 Biological Opinion (based on USFWS Information, Planning, and Conservation (IPaC) website: https://ecos.fws.gov/ipac/; accessed 6 February 2017).

Species	Federal Status	Consultation Status and District Determination of Effect
Red Knot (*Calidris canutus rufa*)*	Threatened – listed in 2015	Covered in this document; May affect but not likely to adversely affect (see Appendix B);
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013	Covered in this document; No effect (see Appendix B)
Scaleshell Mussel (*Leptodon leptodon*)	Endangered – listed in 2001	Covered in this document; No effect (see Appendix B)
Sheepnose Mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012	Covered in this document; No effect (see Appendix B)
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered – listed in 2012	Covered in this document; No effect (see Appendix B)
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012	Covered in this document; No effect (see Appendix B)
Grotto Sculpin (*Cottus specus*)	Endangered – listed in 2013	Habitat not found in Project Area. No further analysis required.
Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened – listed in 2015	Covered in this document; May affect but not likely to adversely affect (see Appendix B)
Eastern Massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016	Habitat not found in Project Area. No further analysis required.

* The Red Knot was not listed as potentially occurring in the Project area in the most recent IPaC consultation but is listed here due to inclusion in previous consultations.

Although the Bald Eagle was removed from the federal list of threatened and endangered species in 2007, it continues to be protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (BGEPA). The BGEPA prohibits unregulated take of Bald Eagles, including disturbance. The U.S. Fish and Wildlife Service developed the National Bald Eagle Management Guidelines (USFWS 2007) to provide landowners, land managers, and others with information and recommendations regarding how to minimize potential project impacts to Bald Eagles, particularly where such impacts may constitute disturbance. Tiered site-specific Environmental Assessments prepared for specific work areas would address any potential impacts to Bald Eagles. If any nest trees were identified in specific work areas, the National Bald

Eagle Management Guidelines would be implemented to minimize potential impacts and appropriate coordination with the U.S. Fish and Wildlife Service would be conducted.

4.4 Impacts on Socioeconomic Resources

4.4.1 Impacts on Human Resources

Environmental Justice

Impacts of the Continue Construction Alternative and the No New Construction Alternative

As outlined above in Section 3.4.1 Human Resources, parts of the Project Area have minority or low-income populations that meet the defined thresholds and/or are meaningfully greater than the general population. St. Louis County, St. Louis City, and Mississippi County have minority population densities higher than the state average in Missouri. No Illinois counties in the Project Area have minority population densities higher than the state average. St. Louis City, Missouri, Mississippi County, Missouri, Jackson County, Illinois, and Alexander County, Illinois, have low-income populations above the 20% threshold.

In addition to county information, Census Block Group information was utilized to refine minority and low-income information for populations immediately adjacent to the MMR. Of the 74 Census Block Groups in Missouri and Illinois that are adjacent to the MMR, 30 in Missouri and 11 in Illinois have populations that meet the minority and/or low-income criteria (Figure 3-35).

Given that the population statistics for the Project Area counties and Census Block Groups indicate that certain areas within the Project Area do contain minority and/or low-income population groups, the possibility exists for the Project to disproportionately affect those populations. Accordingly, the Environmental Justice analysis looked at the locations of Project actions in relation to minority and low-income populations to determine if disproportionately high adverse human health or environmental effects would occur to those populations.

River training structure construction and dredging activities have historically occurred throughout the entire 195-mile Project Area. While dredging has been reduced by placement of river training structures, dredging still occurs throughout the Project Area and future river training structure construction is expected to be distributed throughout the entire length of the Project Area. Given that river training structure construction activities as well as dredging operations are anticipated to occur at locations along the entire length of the Project Area, no one area is expected to be impacted more than any other, and, as a result, minority and low-income populations are not expected to be impacted disproportionately by either of the alternatives considered. Any potential impacts are also minimized by the fact that residential areas are not generally located immediately adjacent to the river channel. Therefore, construction and dredging activities associated with the alternatives considered, and any associated disturbances, would not generally be in close proximity to residences. Likewise, given that the District has concluded that river training structures do not impact flood heights, the Project is not expected to impact areas in the floodplain. Further, most work occurs within the river, so no minority or low income population real estate would be impacted. For any work that did require obtaining real estate interests, proper analysis would take place in a Tier II site-specific EA to insure that these rights were not disproportionately impacted.

Outdoor Recreation

Impacts of the Continue Construction Alternative on Outdoor Recreation

As described in Section 3.2.2 Geomorphology and Section 4.2.2 Impacts on Geomorphology above, no further loss of surface area of the MMR would be anticipated with implementation of the Continue Construction Alternative. Likewise, the amount of side channel habitat available is anticipated to remain stable or increase going forward. Accordingly, no loss of aquatic habitat suitable for recreation would be anticipated.

Continued construction of river training structures would be expected to result in increased availability of shallow and deep low-velocity habitat which would provide areas for recreational fishing. Some loss of shallow to moderate-depth, moderate- to high-velocity habitat would also be anticipated. However, this potential adverse effect would be offset by the proposed compensatory mitigation (see Section 4.3.2 Impacts on Fishery Resources above).

Maintenance dredging, construction, and structure maintenance activities associated with this Alternative could lead to disturbance of fish in the immediate vicinity of work locations. These actions could also directly interfere with recreational activities by interfering with access and/or by detracting from the aesthetic value of the experience. However, these impacts would be considered very localized, temporary, and minor in nature.

Impacts of the No New Construction Alternative on Outdoor Recreation

Insofar as maintenance dredging and structure maintenance activities associated with the No New Construction Alternative could lead to disturbance of fish in the immediate vicinity of work locations, there could be a small adverse effect on recreational fishing activities. Dredging and structure maintenance activities could also directly interfere with recreational activities by interfering with access and/or by detracting from the aesthetic value of the experience. However, these impacts would be considered very localized, temporary, and minor in nature.

4.4.2 Impacts on Navigation

The Continue Construction Alternative would be expected to reduce average annual dredging quantities from approximately 4 million cubic yards to approximately 2.4 million cubic yards. This anticipated reduction in dredging would be expected to reduce barge grounding rates and result in a safer and more reliable navigation channel.

The reduction in dredging needs would result in increased channel reliability and a decrease in the risk of channel closures due to reduced frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages. The reduction in need for just-in-time dredging would reduce the likelihood of a failure to find problematic locations and get the dredge to the location when needed.

The District's ability to respond to extreme dredging situations would also be improved with implementation of the Continue Construction Alternative. During the recent low-water event of 2012/2013, the Corps had to redirect O&M funding from other O&M needs as well as bring on an additional dredge boat to meet dredging demands. The availability of additional funding and dredging resources cannot be assumed for future low-water events. Implementation of the Continue Construction Alternative would be expected to reduce the dredging requirements during any such future events and would increase the likelihood of avoiding adverse effects to navigation.

Any potential adverse effects to navigation associated with new river training structure construction or dredging would be avoided to the greatest extent practicable by coordination with navigation industry stakeholders.

4.5 Impacts on Historic and Cultural Resources

Impacts of the Continue Construction Alternative on Historic and Cultural Resources

Terrestrial Resources

The construction of revetment can potentially have adverse effects on terrestrial cultural resources. As with other river training structures, most placement of revetment 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 surface. Dredged material is deposited in the river thalweg and not in upland disposal areas and therefore has no impact on terrestrial resources.

The initial step in reviewing potential impacts to terrestrial cultural resources is to determine the age of the landforms where any new revetment would be placed by examining historic maps and written accounts. Landforms which have formed in historic times have little to no chance of possessing prehistoric cultural resources whereas older landforms do.

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). Prior to the introduction of bankline stabilization efforts, the Middle Mississippi River meandered across the landscape causing both the erosion and accretion of land. Rarer, but more dramatic, than this slow lateral migration across the landscape, was the occurrence of major avulsions, or shifts in course. These could take the form of river capture when one river migrated into and diverted the waters of another. The most dramatic example of the latter in historical times was the capture of the lower Kaskaskia by the Mississippi during the great flood of 1881, which resulted in the creation of Kaskaskia Island between two branches of the river.

The former lower Kaskaskia River ultimately became the main course of the Mississippi, and after the closing of the latter's western branch (i.e., the Doolan Slough), the only course.

Anthropogenic changes to the MMR system have also impacted historic and cultural 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. Before stabilization efforts, islands tended to shift downstream over time as their upstream head eroded and newly deposited alluvium accumulated downstream. Thus, many islands, as they are currently situated, are relatively recent landforms. 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 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 have been 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. Historically, river regulating structures and practices led to a significant narrowing of the MMR with accretion of land, largely along the Illinois bank. While early dikes and other structures had site-specific functions and goals (e.g., Lt. Robert Lee's project to improve St. Louis harbor in 1830s), after the formation of the MRC, more systematic efforts were made to use structures to aid navigation. In order to procure a navigation channel with a minimum depth of eight feet, it was a stated project of the District Engineer approved by the Chief of Engineers on March 31, 1881:

> *To make the improvement continuous, working downstream from St. Louis, by reclaiming land and building up new banks (using for the purpose preamble dikes of hurdles of piling to collect and hold the solid matter carried in suspension or rolled on the bottom of the river), thus reducing the width of the river to the uniform width of 2,500 feet* (Annual Report of the Chief 1881:1536).

The construction of dikes and revetment has greatly reduced bankline erosion and halted river migration, thereby protecting cultural resources, both known and unknown, from destruction by erosion. The current Regulating Works Project continues this mission with similar generally positive impacts to cultural resources.

To address the potential adverse effects to cultural and historic resources, and in compliance with Section 106 of the National Historic Preservation Act, as part of site-specific Tier II Environmental Assessments the following measures would be undertaken in consultation with the appropriate state and federal agencies:

- If the project design includes the placement of revetment, historic maps and aerial photographs would be consulted to attempt to identify any former or current structures and features that are in the project footprint.
- SHPO databases would be consulted for the presence of known archaeological or historic sites and to see if the area has previously been surveyed and, if so, by what means.

- If necessary, pedestrian surveys would be undertaken to further determine if any visible structures would be adversely affected by the placement of rock.
- If any grading would be necessary, an archaeological survey would be undertaken to determine if any archaeological site would be adversely affected.

Submerged Resources

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. However, it is possible that isolated and less-perishable prehistoric cultural items such as petroglyphs could be located within the Area of Potential Effect.

Potential site-specific effects on submerged historic and cultural resources would be addressed in Tier II Environmental Assessments in consultation with the appropriate state and federal agencies:

- As outlined in Section 3.5 Historic and Cultural Resources, the St. Louis District maintains databases of known and historically recorded shipwrecks. Both would be consulted to determine if the construction of dikes, chevrons, or other in-river structures may impact wreck sites.
- Recent high resolution multi-beam bathymetric surveys undertaken in the normal course of pre-construction planning would be examined for the presence of any anomalies that suggest the presence of a wreck. If it is determined that a prehistoric or historic resource would be adversely affected by proposed construction, consultation with the appropriate SHPO would be undertaken to determine appropriate measures.
- If cultural resources are encountered during construction, all work would stop in the affected area and appropriate consultation would take place.

Maintenance dredging is undertaken in the navigation channel where there is minimal chance any wreck would survive in-situ without having been removed by salvagers, dispersed by channel flow, or destroyed in historical dredging efforts. All known historical wrecks are located outside the navigation channel. Consequently, no adverse effects to historic and cultural resources are anticipated from maintenance dredging activities.

Bathymetric surveys are conducted before and after each dredging operation. They are, however, single-beam sonar surveys typically with a standard 200-foot distance between cross section lines and therefore do not produce a model with a resolution high enough to likely identify unknown historical wrecks. Dredge spoil is placed back in the river outside the navigation channel and not on the riverbanks or upland.

Impacts of the No New Construction Alternative on Historic and Cultural Resources

Maintenance of river training structures and revetment would occur in previously disturbed areas and consequently no adverse effects to historic and cultural resources are anticipated. Maintenance dredging activities under the No New Construction Alternative would be undertaken in the navigation channel where there is very little chance any wreck would survive in-situ without having been removed by salvagers, dispersed by channel flow, or destroyed in historical dredging efforts. Consequently, no adverse effects to historic and cultural resources are anticipated from maintenance dredging activities.

4.6 Cumulative Impacts

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).

4.6.1 Prior Studies

Cumulative impact analyses were recently conducted for Environmental Assessments with signed Findings of No Significant Impact for the Regulating Works Project (USACE 2014a, 2014b, 2014c, 2015c). 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. 2000) 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. (2000) provided a geomorphic assessment of the cumulative effects on geomorphology, sediment transport, and dredging. West Consultants, Inc. (2000) also 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 the UMRS, fish entrainment and impingement at electrical generating plants, and exotic and nuisance species. In addition, the UMR-IWW System Navigation Feasibility Study and Integrated Programmatic EIS (USACE 2004) contains a comprehensive description of the environmental impacts of navigation traffic.

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 the 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.

As detailed in section 3.2.1, channel degradation has occurred on the MMR as revealed by a decrease in stages for low flows. As shown in Table 4-1, the stage for a flow of 50,000 cfs is expected to decrease by 0.94 feet at St. Louis and 1.10 feet at Chester over the next 17 years. This degradation has been attributed to the placement of river training structures and a decrease in sediment load in the river due to construction of reservoirs on the Mississippi River tributaries.

Channel degradation has been observed on the lower 498 miles of the Missouri river from Rulo, Nebraska, to the mouth, located north of St. Louis, Missouri. Over ten feet of degradation has been observed since 1987 near Kansas City, Missouri, which has led to costly repairs and/or upgrades to infrastructure.

As part of the 2009 Missouri River Bed Degradation Reconnaissance Study (USACE 2009), the Kansas City District evaluated causes of bed degradation and the magnitude of their impact on the Missouri River. These causes included the construction of river training structures, major flood events, Missouri River dam construction, flow modification by regulation, river cutoffs, and dredging. After an evaluation of each of the potential causes for degradation it was determined that the bed degradation was the result of commercial sand and gravel mining (dredging) (USACE 2015e). The Kansas City District is evaluating the effectiveness of altering river training structures to slow bed degradation.

The magnitude of degradation on the MMR is small compared to what has been observed on the Missouri River. This is mostly due to limited commercial sand and gravel mining (less than a third of the quantity mined on the Missouri river) and thalweg dredge disposal which does not remove sediment from the system.

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

In determining the cumulative impact of the SEIS Alternatives on resources in the Project Area, information from the above documents was considered in addition to the information provided below. As with the impact analysis presented in Chapter 4 above, the cumulative impacts analysis is presented under four general resource categories: physical resources, biological resources, socioeconomic resources, and historic and cultural resources. In general, the geographic scope of the cumulative impacts analysis encompassed the 195-mile length of the MMR from its confluence with the Missouri River to its confluence with the Ohio River, from tree line to tree line. Depending on the resource at issue, however, the analysis required extending beyond the physical limits of the MMR. For example, the water quality discussion includes information on the Missouri River basin due to its influence on MMR water quality concerns. Likewise, the discussion of biological resources extends into the MMR floodplain to incorporate the influences of floodplain access, or lack thereof, on MMR biological resources. The temporal scope of the cumulative impacts analysis is generally from the 1800s to the mid-2000s.

4.6.2 Impacts to Physical Resources

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 determine the level and type of sediment, nutrient, and contaminant inputs into the Mississippi River and its tributaries. The Mississippi River, especially below metropolitan areas, has a long history of water quality impairment due to contamination from industrial, residential, municipal, and agricultural sources. Prior to the implementation of the Clean Water Act in 1972, the MMR acted as 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 directly into the MMR. In 1952, approximately 212 tons/day of garbage (animal and vegetable waste) were collected in St. Louis, ground, and discharged. The disposal of ground garbage into the MMR continued into the 1970s. These water quality stressors 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 1934; Platner 1946; Bi-State Development Agency 1954; U.S. Public Health Service 1958). 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 implementation of the Clean Water Act in 1972. Water quality monitoring has been conducted in the MMR through the Corps' Upper Mississippi River Restoration Program Long Term Resource Monitoring (LTRM) element since 1991. Analysis of LTRM data (Johnson and Hagerty 2008) shows that 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). During major storm events, raw sewage still enters the river because of sewage treatment plant overloads due to combined (sewage/stormwater) sewage systems in the St. Louis Metropolitan area. Johnson and Hagerty (2008) indicated that future changes in nutrient inputs to the river are difficult to predict and are 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 (wastewater and stormwater) sewage systems. These efforts should improve nutrient loading and eventually eliminate raw sewage overflow events. In 2013, the Metropolitan St. Louis Sewer District (MSD) launched Project Clear as part of a consent decree agreement between MSD, the EPA, and the Missouri Coalition for the Environment that went into effect on April 27, 2012. Project Clear is a 23-year, $4.7 billion initiative to plan, design, and build system-wide improvements to address water quality and alleviate many wastewater concerns in the St. Louis area. Throughout MSD's service area, there are hundreds of points where a combination of stormwater and wastewater discharges into local waterways from the wastewater sewer system during moderate to heavy rainstorms. These sewage overflow points act as relief valves when too much stormwater enters the sewer system (MSD 2013). Unfortunately, this means that untreated sewage, high in fecal coliform, nutrients, and other untreated wastes, either enter the MMR directly or indirectly from tributary streams. Stormwater runoff, or urban runoff, also contributes to a laundry list of problems where there are no storm sewer systems or where there are combined sewage systems. Additionally, rainwater and melting snow also carry sediment, pet waste, and chemicals from roads, parking lots, and lawns into streams that feed the MMR. It is anticipated that Project Clear will help alleviate these problems over the next two decades and these efforts should improve nutrient loading to the MMR and eventually eliminate MSD raw sewage overflow events. It is not anticipated that nutrients from agriculture will rise; however, this is driven by agricultural economics.

Although the USEPA has oversight authority, particularly with regard to interstate water quality, it is the responsibility of the individual states to implement most of the Clean Water Act, including the establishment of water quality standards. 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. However, there are inconsistencies among state water quality standards and specific water quality criteria for individual pollutants may vary depending on the designated use for a specific segment of the Mississippi River. The MMR was included on the 2014 state of Missouri 303(d) list for St. Louis City, St. Louis County and St. Genevieve County due to fecal coliform contamination from point and non-point sources of wastewater treatment plant effluent and urban storm water. The 2014 state of Illinois 303(d) list places use restrictions for human contact-recreation due to fecal coliform contamination and fish consumption due to mercury and PCB contamination along the length of the Middle Mississippi River.

There are also fish consumption advisories for the MMR for both Missouri and Illinois. Missouri has fish consumption advisories for the Mississippi River for Shovelnose Sturgeon (one meal per month) and for Flathead Catfish, Blue Catfish, Channel Catfish, and Common Carp (one meal per week) due to PCB, chlordane, and mercury contamination (MDHSS 2015). 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 (IDPH 2014).

High suspended sediment loads coming out of the Missouri River and flowing into the MMR was the natural condition prior to the construction of large reservoirs on the Missouri River (Kesel 1988; Meade and Moody 2010; Heimann et al. 2011). The highly turbid Missouri River earned its' nickname "Big Muddy" due to these naturally high suspended sediment loads. Large reservoirs on the Missouri River trap approximately 100-150 million metric tons of sediment per year, which represents approximately half of the current decrease in sediment discharge at the mouth of the Mississippi River (Meade and Moody 2010). The completion of Fort Randall Dam in the upper Missouri River in 1952 was the single largest event in the recorded historical decline of suspended sediment loads in the Mississippi River Basin (Heimann et al. 2011). In addition, reduced peak streamflows and construction of reservoirs on the UMR, river training structures, bank revetment, and soil erosion controls have trapped sediment, eliminated sediment sources, or protected sediment that was once available for transport episodically throughout the year (Meade and Moody 2010). Although suspended sediment loads from the Missouri have been tremendously reduced, the suspended sediment levels of the Missouri River still remain much higher than the MMR as shown in Figure 4-11.

Figure 4-11. A 2012 photo of the mouth of the Missouri River showing the heavy suspended sediment load entering the Middle Mississippi River.

The aquatic fauna of the MMR is highly adapted to high turbidity levels which is reflected in their distribution patterns. A number of fish species (e.g., Sicklefin Chub [*Macrhybopsis meeki*], Flathead Chub [*Platygobio gracilis*] Pallid Sturgeon [*Scaphirhynchus albus*]) occur in the Missouri River and in the Mississippi River below the mouth of the Missouri, but not above the mouth of the Missouri (Pflieger 1997) where the suspended sediments are much lower. These fish species have evolved specialized characteristics as adaptations to turbid conditions and all have experienced declining populations during historic times. For example, the Sicklefin Chub, which shows a strong preference for turbid water (Everett et al. 2004), has reduced eye size and reduced optic lobes (Davis and Miller 1967), as well as numerous cutaneous sensory papillae ventrally, within their buccal cavities and on their heads and fins (Davis and Miller 1967; Pflieger 1997). Conversely, the high MMR turbidity levels, as well as the downstream movement of sand waves, are historically responsible for the low diversity and extremely low density of freshwater mussels in the MMR. The high turbidity levels not only control aquatic organism distributions, such as freshwater mussels and fish in the MMR, but recent reductions in suspended sediment levels may be partially responsible for the decline of some fish species. There is too little information to speculate on the effects of turbidity reductions on other aquatic organisms such as phytoplankton, zooplankton, and benthic invertebrates (e.g., aquatic worms, immature insect larvae, etc.).

Project related impacts to MMR water quality fall into three broad categories: 1. Operation and maintenance of the 9-ft. navigation project which includes dredging and related increases in suspended sediment; 2. Construction impacts that could result in increased suspended sediment suspension; and 3. Navigation traffic related suspended sediment. Dredging results in a temporary and localized increase in downstream suspended solids concentration. However, dredging does not add significantly to ambient suspended solids concentrations in the MMR (WEST 2000). Over 90% of the material dredged from main channel dredge cuts on the MMR is sand-sized material or larger, carrying very small concentrations of contaminants (e.g., heavy metals and organics). Contaminants are primarily attached to finer silt and clay sized particles that typically are found in lower velocity areas downstream of metropolitan areas. Construction of river training structures in the MMR (bank protection and dikes) no longer involves bank or river bed recontouring, so the resuspension of bank or bed material would result in minor, short-term, localized, increases in suspended sediment from rock placement.

Navigation traffic can result in a suspended sediment plume downstream of a moving tow. The level of suspended sediment depends on such factors as the river depth, type of bed sediment, and towboat speed (Copeland et al. 2001). Towboat generated waves can also suspend sediments along the shoreline (Parchure et al. 2000). Again, the level and duration of suspended sediment depends on a number of factors including: the wave height, type of shoreline sediments, depth of water along the shoreline, and the ambient suspended sediment levels. Pokrefke et al. (2003) analyzed the potential impact (e.g., loss of habitat) of towboat induced suspended sediment movement into MMR backwaters/side channels. They determined that all suspended sediment levels would have negligible potential for impacts to MMR backwaters/side channels from towboats for the without project and proposed alternatives evaluated as part of the UMR-IWW System Navigation Study (USACE 2004). So other than short-term, minor effects of suspended sediments, long-term impacts or impacts on important habitat types are not anticipated.

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(s). The purpose of closing structures is to shunt water to the main channel to support navigation flows. Of the existing side channels, only one (Cottonwood Side Channel) does not have a closing structure. 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 (see 3.2.2). The level of connectivity between side channels and the river affects the water quality of the side channel and subsequently its biota (Barko and Herzog 2003;

Crites et al. 2012). Crites et al. (2012) found that water quality conditions in Buffalo Chute (River Mile 26) during isolation from the river channel (mid-June through March during their study) 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. The St. Louis District has conducted side channel restoration planning (USACE 1999a; Nestler et al. 2016) and has been restoring side channels under various authorities which should help alleviate this problem.

Stages – See Section 3.2.1 River Stages, Section 4.2.1 Impacts on Stages, and Appendix A for a complete analysis.

Geomorphology – See Section 3.2.2 Geomorphology and Section 4.2.2 Impacts on Geomorphology for a complete analysis.

Air Quality and Climate Change – See Section 3.2.5 Air Quality and Climate Change and Section 4.2.5 Impacts on Air Quality and Climate Change for a complete analysis.

4.6.3 Impacts to Biological Resources

Restoration Efforts

The District has undertaken a variety of ecosystem restoration activities in the MMR aimed at offsetting the adverse effects from a range of stressors that have impacted fish and wildlife species in the area. Numerous projects have been accomplished through implementation of the District's 2000 Biological Opinion. Details of activities associated with the Biological Opinion can be found in Table 3-9. In addition, several other restoration authorities or potential restoration authorities exist that have been used or have potential to be used in the MMR. Projects or potential projects of the Avoid and Minimize Program, Upper Mississippi River Restoration Program, and Navigation and Ecosystem Sustainability Program can be found in Table 4-8. The Avoid and Minimize Program was created in 1992 and seven projects in the MMR have been completed under the program. No projects have been constructed in the MMR under the UMRR Program to date but several are anticipated in the near future. Likewise, no projects have been constructed under NESP in the MMR but planning of some restoration projects has occurred. Funding for NESP has not been provided in recent years, and it is currently not expected to be funded. Detailed information on the history of these authorities can be found in Appendix K.

Table 4-8. MMR ecosystem restoration projects through the Avoid and Minimize Program, Upper Mississippi River Restoration Program, and Navigation and Ecosystem Sustainability Program. For details on restoration activities through the Biological Opinion, see Table 3-9.

Project Name	Purpose	Year(s)
Avoid and Minimize		
Santa Fe Chute	Hardpoint construction to improve habitat diversity	1997-1999
Owl Creek	Hardpoint construction to isolate sandbar habitat	1997
Marquette Chute	Closure structure notching to improve side channel connectivity	1998
Jefferson Barracks	Notched dike construction to improve habitat diversity	2006
Union Point/Wilson Landing	Dike notching to improve habitat diversity	2007-2009
Jones Chute	Dike notching, hardpoint placement to improve side channel connectivity and habitat diversity	2008
Cliff Cave-Kimmswick	Chevron construction/dike shortening to improve habitat diversity	2010-2011
Upper Mississippi River Restoration		
Crains Island Habitat Rehabilitation & Enhancement Project	Restoration of forest, wetland, and side channel habitat for fish and wildlife	2018
Harlow Island Habitat Rehabilitation & Enhancement Project	Restoration of forest, wetland, and back water habitat for fish and wildlife	2020
Oakwood Bottoms Habitat Rehabilitation & Enhancement Project	Restoration of forest and wetland habitat for fish and wildlife	2022
Wilkinson Island Habitat Rehabilitation & Enhancement Project	Restoration of forest, wetland, and back water habitat for fish and wildlife	2021
Horseshoe Lake Habitat Rehabilitation & Enhancement Project	Potential restoration of forest and wetland (beginning stages of development)	TBD
Schenimann Chute Habitat Rehabilitation & Enhancement Project	Potential restoration of side channel habitat (in beginning stages of development; formerly a NESP project now being considered under UMRR due to lack of funding for NESP).	TBD
Navigation and Ecosystem Sustainability Program		
Herculaneum Wing Dike Alteration	Placement of innovative river training structures for the purpose of creating secondary channels and improving habitat diversity	N/A

Project Name	Purpose	Year(s)
Buffalo Chute Side Channel Restoration	Dike notching, construction, placement of woody structure for side channel habitat enhancement	N/A
Schenimann Chute Side Channel Restoration	Side channel restoration (now under consideration as UMRR project due to lack of funding for NESP)	N/A
Harlow Island Reach Planning	Restoration of forest, wetland, and side channel habitat for fish and wildlife (now under consideration as UMRR project due to lack of funding for NESP)	N/A

Loss of 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 adequately 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 (*Atractosteus 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 2016). 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, 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 encompasses approximately 660,000 acres (Table 4-9), with approximately 202,000 acres (Table 4-10) 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 floodplain 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. 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 4-9), while 28% of the batture is in agriculture (Table 4-10). The only available land cover dataset 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 4-9) and approximately 27% of the batture lands (Table 4-10). 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 4-9. MMR floodplain land cover categories, acreages, and percentages (based on Corps' 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 4-10. 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' 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; 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. As part of the U.S. Fish & Wildlife Service's plans for managing the refuge, modifications to man-made structures such as levees are proposed to promote healthy and diverse fish habitat for native Mississippi River fishes. Where possible, old river channels and swales 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 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 benefit from the habitat restoration, and the public has increased opportunities for wildlife-dependent outdoor recreation.

Impacts from Navigation Traffic
The movement of commercial navigation traffic produces both physical and biological effects (

Table 4-11) that affect the ecosystem health of the MMR. These impacts are summarized in great detail in USACE (2004) and Söhngen et al. (2008). A considerable number of original research studies on the physical and biological impacts of commercial navigation traffic were conducted as part of the UMR-IWW System Navigation Feasibility Study (USACE 2004) and can be found at http://www2.mvr.usace.army.mil/UMRS/NESP/. In addition, there are a growing number of navigation effects studies, much of it conducted in the United States and Europe, that have been published in the scientific literature.

Table 4-11. 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. 2011
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; Holland 1986; 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. 2004a, 2004b; Wolter & Arlinghaus 2003; Wolter et al. 2004; Kucera-Hirzinger et al. 2009; Gabel et al. 2011b
Invertebrates	Bishop & Chapman 2004; Gabel et al. 2008, 2011a, 2011b, 2012
Shoreline Drawdown/Dewatering	Adams et al. 1999; Maynord 2005; Maynord & Keevin 2005
Towboat Induced Turbidity	
Channel	Smart et al. 1985; Savino et al. 1994; In addition, there are numerous publications on the adverse effects of turbidity on benthic invertebrates and fish.
Phytoplankton	Munawar et al. 1991
Side Channels/Backwaters	Pokrefke et al. 2003
Hull Sheer	
Larval Fish	Morgan II et al. 1976; Maynord 2000b, 2000c; 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 2000a; Sheehan et al. 2004a; Sheehan et al. 2004b

The Effects of Pressure Changes

Commercial navigation traffic is responsible for rapid mixing of the water column (Stefan and Riley 1985). Both drifting invertebrates and fish can be drawn from the surface and transported to the river bottom resulting in increased ambient pressure or drawn from the river bottom and moved to the surface, resulting in decreased ambient pressure. There are no studies on the effects of navigation related pressure changes on phytoplankton, zooplankton, or benthic invertebrates (drifting), but since they lack air-containing organs it is anticipated that they are relatively immune to major pressure changes when compared to fish. In a controlled laboratory study (Keevin et al. 2000), mortality of fish early life stages was measured in a pressure vessel to simulate three pressure change scenarios (simulating both pressure decreases and increases) associated with entrainment in the propwash of a towboat and subsequent vertical displacement within the water column. Mortality was measured for five fish species: larval Bigmouth Buffalo (*Ictiobus cyprinellus*), larval Blue Catfish (*Ictalurus furcatus*), larval Walleye (*Sander vitreus*), juvenile Bluegill, and juvenile Largemouth Bass (*Micropterus salmoides*).

There was no significant difference between fish exposed to any of the three pressure regimes and controls. The maximum pressure change tested, 344.8 kPa, equivalent to a 35.2 m displacement of fish within the water column, did not cause significant mortality of larval or juvenile fish. Since 35.2 m exceeds depths in the MMR navigation channel, the range of pressure changes that could be experienced by early life stages during towboat mixing of the water column would not result in significant mortality.

The Effects of Hull Shear

It has been suggested that the fluid shear field adjacent to the hull of a tow may impact aquatic organisms. Shear force is the force per unit area that results from differences in velocity from one point in the water to an adjacent point. Shear is defined as the velocity difference between two adjacent points divided by their distance.

In a controlled laboratory study (Keevin et al. 2002), mortality of fish early life stages was measured in a Couette cell for three shear stress levels at three exposure times for five fish species: larval Shovelnose Sturgeon (*Scaphirhynchus platorynchus*), larval Bigmouth Buffalo, larval Blue Catfish, juvenile Bluegill, and juvenile Largemouth Bass. Larval fish mortality values (Keevin et al. 2002) were then compared with calculated barge hull shear stress levels (Maynord 2000b) to determine the potential for mortality of fish early life stages due to commercial navigation traffic. There was no significant mortality of Shovelnose Sturgeon, Blue Catfish, Bluegill and Largemouth Bass at shear stress levels produced by barges in the MMR. However, the hull of a high-speed tow (4.0 m/sec) with a 1.22 depth/draft ratio would produce a shear stress of 250 dynes/cm^2 in 5% of the zone beneath the tow. This is the only area in the water column where hull shear stress values approached, but did not exceed, levels causing significant ($P<0.05$) mortality of bigmouth buffalo larvae. Therefore, it is unlikely that barge hull shear stress would result in substantial mortality of larval or juvenile fishes. There are no studies on the effects of hull shear stress on phytoplankton, zooplankton, or benthic invertebrates (drifting).

The Effects of Shoreline Drawdown

Water flow dynamics associated with moving commercial navigation vessels results in shoreline drawdown (water recedes from the shoreline; Bhowmik et al. 1993). These brief dewatering periods generally last 2-3 min (Holland 1987). The magnitude of drawdown depends on vessel speed, submerged cross-sectional area of the vessel, and channel cross-section. Shallow and constricted channels increase drawdown. If a vessel travels close to the riverbank, drawdown would be higher in the region between the vessel and bank than it would have been if the vessel were in the middle of the channel (Bouwmeester et al. 1977). Bhowmik et al. (1981) measured vertical drawdown for eight tow passage events during 1980-81 on the UMR. Drawdown elevation averaged 0.06 m (range 0.02-0.10 m) on the UMR. The drawdown resulting from vessel passage is followed by a rise in water level back to ambient levels. Typical rates of drawdown (vertical fall of water level per unit time) for channel sizes, tow sizes, and tow speeds found on the UMR are about 0.25-0.5 cm/sec based on field data presented in Bhowmik et al. (1998). Higher speed tows closer to the shoreline produce values around 0.75 cm/sec.

Maynord and Keevin (2005) determined that the average shoreline area exposed or dewatered decreases in a downstream direction as the UMR channel becomes larger. The MMR was not evaluated during this study, but results would be expected to approximate those experienced in the smaller channel of the upper pools in the UMR. Peak larval density and diversity occur during the months of May and June. During May, there was a 90% probability that 3.9 hectares or less of shoreline would be dewatered by a passing towboat in Pool 4, 5.5 hectares or less in Pool 8, 4.4 hectares or less in Pool 13, and 0.5 hectares or less in the portion of Pool 26 above the IWW confluence. During the month of June, there was a 90% probability that 4.4 hectares or less of shoreline would be dewatered in Pool 4, 5.8 hectares or less in Pool 8, 4.5 hectares or less in Pool 13, and 0.6 hectares or less in Pool 26. Typical values decrease from 0.49 m in Pool 8 (May, 90% exceedance tow) to 0.05 m in Pool 26 (May, 90% exceedance tow). The width of the dewatered zone is less in May than in July. The higher flows in May cause larger cross sections which result in less drawdown.

Commercial vessel passage may strand young fishes during drawdown and subsequent dewatering of littoral areas (Holland and Sylvester 1983; Nielsen et al. 1986), but actual field observations of stranding are sparse. In laboratory studies, Holland (1987) evaluated the effects of experimental dewatering on eggs and larvae of walleye and Northern Pike (*Esox lucius*). Eggs and larvae were exposed to air for 2 min at intervals of either 12, 6, 3, or 1 hr. (representing 2-24 tows/day) from the time just after fertilization to 10-14 days post-hatch. A single dewatering event (2 min air exposure) did not cause mortality of eggs of walleye or northern pike, but significant mortality of larvae of both species occurred at dewatering frequencies of 1 and 3 hours, the latter being equivalent to mean passage of eight tows per day. Holland (1987) used a flow-through aquarium system that prevented fish from moving out of the dewatered zone as water receded. Adams et al. (1999) evaluated the potential for stranding during simulated shoreline drawdown in a laboratory flume for larval Shovelnose Sturgeon, Paddlefish (*Polyodon spathula*), Bigmouth Buffalo, Largemouth Bass, and Bluegill. Stranding was measured at three vertical drawdown rates (0.76, 0.46, and 0.21 cm/s) and two bank slopes (1:5 and 1:10). Blue Catfish, Shovelnose Sturgeon, and Paddlefish were not tested at both bank slopes. Susceptibility to stranding varied among species and was independent of drawdown rate. At a slope of 1:5, Shovelnose Sturgeons had the highest stranding percentage (66.7%), followed by Paddlefish (38.0%), Bluegill (20.0%) Bigmouth Buffalo (2.2%), and Largemouth Bass (0.0%). At 1:10, Blue Catfish had the highest stranding percentage (26.7%), followed by Largemouth Bass (15.3%), Bluegills (5.3%), and Bigmouth Buffalo (0.0%).

Holland (1987) found significant mortality of larval walleye and northern pike using a flow-through aquarium system that prevented fish from moving out of the dewatered zone as water receded. Under natural conditions, it is not known if individual larvae or eggs would be subject to repeated dewatering. Adams et al. (1999) found that the likelihood of stranding was related to the behavioral response of fishes to drawdown. Species that typically occur in littoral and backwater areas swam with the current or passively drifted; whereas, the young of main-channel fishes, such as sturgeons and paddlefish, exhibit positive rheotaxis (i.e., movement into flowing water) and were more likely to become stranded. Adams et al. (1999) suggested that main-channel species such as Shovelnose Sturgeon and Paddlefish larvae that were highly vulnerable to stranding in their study are usually found in the main channel and not in the littoral zone where they would be susceptible to stranding. In addition, the dewatered zone itself is very narrow possibly limiting repeated stranding. During May and June, the peak larval fish density period, the dewatering zone ranges from 0.05 m (Pool 26, May) to 0.53 m (Pool 8, June) for 90% of tow passages. With the exception of Pool 8, the average width of dewatered shoreline during May and June is less than 0.4 m for 90% of tow passages.

The Effects of Shoreline Currents and Wave Wash

The passage of commercial navigation traffic results in changes in river flow patterns especially along the shoreline which is exposed to wave wash, changes in flow directions and velocities, and drawdown (Söhngen et al. 2008).

Invertebrates: Gabel et al. (2008) conducted a study in a wave tank to evaluate ship-induced wave disturbance of benthic invertebrates. They studied five benthic invertebrates and found that detachment of invertebrates was significantly related to shear stress. Detachment was lower in habitats with a high degree of structural complexity, decreasing in the habitat sequence: sand, coarse woody debris, stones, reeds, and tree roots. In the MMR, sheer would be greater for a fully loaded towboat, moving at high speed, and close to the shore-line. Gabel et al. (2012) found that waves from recreational boats had similar invertebrate detachment impacts. Both Gabel et al. (2008) and Gabel et al. (2012) conclude that management and protection of complex shoreline habitats is important in the maintenance of a littoral invertebrate community in navigated waters.

Gabel et al. (2011a) conducted a series of wave exposure tests in treatment flumes comparing physiological and behavioral response variables of two native (Rhine River) invertebrates (*Gammarus roeselii* and *Bithynia tentaculata*) and two non-native invertebrates (*Dikerogammarus villosus* and *Physella acuta*). Growth and energy storage were significantly reduced after exposure to waves in native invertebrates, but not in non-native invertebrates. They suggested that the differing vulnerability of native and non-native invertebrates to wave-stress was expected to shift community composition toward domination by non-native species.

This study points out that changes in hydrodynamic wave stress can cause invertebrate community shifts that would not be anticipated by casual impact analysis. In a second wave-tank study, Gabel et al. (2011b) studied the differential effects of ship- and wind-induced waves on the foraging success of littoral fish on benthic invertebrates. They found that the number of invertebrates suspended in the water column was higher in the wave treatment test compared to a no-wave control treatment. This was especially true during pulse waves mimicking ship-induced waves in comparison to continuous waves mimicking wind-induced waves. They found differences in how different fish species exploited the invertebrates during wave exposure. Waves influenced predator (fish) -prey (invertebrates) interactions differently depending on wave type and fish type.

Fishes: With respect to fish, Kucera-Hizinger et al. (2009) suggested that ship-induced wave wash resulted in the following impacts on fish during their early life history stages: 1) Short-term dislocation of suitable larval and juvenile fish habitats due to wake and splash; 2) Water velocities during ship passages frequently exceeding maximum swimming performance of age 0+ fish; and, 3) Suspended solids concentrations increasing dramatically in the inshore habitats and limiting the foraging efficiency of young-of-the-year (YOY) fish. Wolter et al. (2004) compared computed navigation traffic current velocities and compared those values with maximum fish swimming performance to determine the impact of commercial navigation on freshwater fish. They found that the "absolute magnitude of navigation-induced current limits the availability of littoral habitats for small fish." Wolter and Arlinghaus (2003) suggested that swimming performance of juvenile freshwater fish is the major bottleneck for fish recruitment in German waterways, as a result of their inability to withstand bank-directed navigation-induced physical forces.

Many MMR fishes, especially YOY, require low-velocity habitats for overwintering due to their diminished swimming ability at low water temperatures. Low-velocity habitats in river channels include the downstream side of wing dams and scour holes at the distal ends of wing dams, scour holes or sand ridges in channels, and downstream of any structures which obstruct water currents. During Navigation and Ecosystem Sustainability Program studies (USACE 2004), natural resource agencies expressed concern that hydraulic disturbances resulting from increased navigation traffic might cause fish displacement from these low-velocity habitats during cold-water periods. Displaced fish would continue to drift with the river current or they would actively or passively find and utilize another low-velocity habitat. If fish continue to drift, survival is doubtful. Loss of volitional control over swimming is the standard endpoint used in acute temperature tolerance tests. Risks to vessel propeller entrainment, predation, and other lethal factors would greatly increase. If fish find and utilize another low-velocity habitat after displacement, then increases in traffic levels may have little additional effect on over wintering fish (Sheehan et al. 2004a).

Studies were designed to determine if navigation traffic was capable of displacing fish from protected near-shore areas (Sheehan et al. 2004a). Studies were conducted to determine the velocities required to move YOY Channel Catfish and Bluegill from protected areas under cold-water conditions (Sheehan et al. 2004b). Physical force studies were then conducted in a laboratory flume to determine velocity conditions behind a wingdam with and without towboat traffic.

In laboratory studies, Sheehan et al. (2004a) determined the following median displacement velocities (DV50) for Channel Catfish and Bluegill.

Table 4-12. DV50 (Displacement Velocity) determinations at 1, 2 and 4°C for Channel Catfish and Bluegill. DV50's are the peak velocity (m/s) of a velocity change profile, similar to that of a passing barge, necessary to displace 50% of fish from their position within a test chamber. DV50s determined using Probit analysis, p=probability of Pearson's Chi-square test of goodness-of-fit.

Species	Temperature (°C)	DV 50 (m/s)	95% C.I.	p
Channel Catfish	1	0.08	0.01-0.36	0.33
	2	0.18	0.11-0.23	0.25
	4	0.30	0.25-0.35	095
Bluegill	1	0.09	0.06-0.95	0.38
	2	0.09	0.00-0.17	0.11
	4	0.16	0.13-0.20	0.04

Maynord (2000d) conducted a physical model study to measure velocity downstream of a typical UMR dike before and during passage of a model tow for typical winter flow conditions. Up bound versus down bound tows near the dike and far from the dike were evaluated. The results of Maynord's study, when compared to Sheehan's displacement velocities, indicate that large areas existing behind the study wing dike currently experience velocities that exceed displacement velocities under ambient conditions without navigation traffic for YOY Channel Catfish and Bluegill during periods when the water is in the 1-2°C range. With the exception of an area immediately behind the wingdam, close to the shoreline, all ambient velocities exceeded 0.10 m/sec and ranged from 0.10-0.50 m/sec. Maynord (2000d) found that upbound tows near the dike (77 m from the centerline of the tow to the waterline on the dike) produced only minor changes with large areas near the bankline showing no velocity changes. Downbound tows in the thalweg produced little effect with large areas showing no velocity change.

If ambient velocities are great enough to displace YOY Channel Catfish and Bluegill under existing conditions (without navigation traffic) it is quite possible that fish seek out low-velocity microhabitat behind wing dikes during cold-water conditions. Because fish are continuously exposed to navigation traffic-induced velocity changes, they may also seek out low-velocity habitats protected from navigation-related velocities.

Sheehan's displacement values were established for small YOY fish. Larger fishes may not be affected by what amounts to minor velocity changes under worst case conditions (upbound tows near the dike). It is known that scour holes at wingdam tips and areas behind wingdams are "packed" with fish during the winter months. It is assumed that fish use these low-velocity habitats during the winter as their swimming abilities decrease with decreasing water temperatures (Beamish 1978).

The Effects of Backwater and Side Channel Drawdown

During passage of commercial tow traffic in navigation channels, the water level is lowered alongside the tow, which is commonly referred to as drawdown. Drawdown magnitude increases with increasing tow speed, increasing tow size, and decreasing channel size. Drawdown duration is about twice the time required for a tow to pass a fixed location. This duration relationship results in a large fast tow producing a large but short-lived drawdown while the same large tow traveling at a lesser speed would produce a lesser maximum drawdown but having a longer duration.

Drawdown from tow traffic is one of the few physical effects of tows that can propagate large distances from the main navigation channel. Drawdown can extend up backwaters, side channels, and tributaries entering the main channel. Maynord (2005) measured drawdown at ten backwaters and side channels in the La Grange Pool of the IWW. Drawdown decayed with distance from the entrance channel within the backwater/chute but could be measured at considerable distances from the entrance. At the longest channel, Bath Chute, drawdown could be clearly detected at ll.6 km from the point of origin, although the magnitude was significantly reduced. Sangamon River measurements provide an example of the decay rate. At the entrance to the Sangamon River the drawdown was 0.138 m, at 600 m from the entrance it was 0.042 m, and at 1,350 m from the entrance it was 0.013 m.

Drawdown along the length of backwaters and side channels has the potential to make otherwise suitable habitat unavailable for nesting and to strand larval and juvenile fishes during drawdown events. The amount of habitat within side channels and backwaters that would otherwise have been suitable for spawning but is impacted by repeated drawdowns is unknown due to the lack of adequate bathymetric survey data for those habitats on the UMR-IWW. However, spawning fish, especially centrarchids, generally tend to spawn at water depths greater than the navigation induced drawdowns observed on the UMR-IWW (Maynord 2005) and they generally avoid spawning in areas that are repeatedly dewatered. As previously noted in the shoreline dewatering discussion, larval and juveniles of typical backwater fish species have behavioral adaptations to avoid being stranded by receding water levels (Adams et al. 1999), thus minimizing adverse effects.

The Effects of Towboat Propeller Entrainment

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 4-11, the impact of greatest concern in the MMR is larval and adult fish mortality associated with towboat propeller entrainment.

Existing (2000) traffic in the MMR 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 MMR 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 UMR. 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. Based on the value of 1 fish/km injured or killed (this would overestimate mortality because 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 MMR 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 estimated to be killed per year locking through Locks 27 (4.5125 average fish mortality per lockage x 7,750 commercial lockages in 2001) (Keevin et al. 2005). Entrainment mortality of some fish species, for example the Shovelnose Sturgeon, combined with other mortality factors (commercial fishing) may be responsible for unsustainable population levels in the Upper Mississippi River (Miranda and Killgore 2013).

In addition to the above projected mortality numbers, an unknown number of fish would be killed due to egg mortality from propeller entrainment (Holland and Sylvester 1983; Odum et al., 1992), shoreline dewatering (Adams et al 1999; Maynord & Keevin 2005), hull shear (Morgan II et al. 1976; Maynord 2000b; Keevin et al. 2002), and fish being washed out of protected areas (especially during the winter) due to wave wash (Sheehan et al. 2004a, 2004b; Wolter and Arlinghaus 2003; Wolter et al. 2004; Kucera-Hirzinger et al. 2009).

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 continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase navigation traffic beyond the existing or projected future conditions, there are no incremental impacts associated with either of the Alternatives. In other words, only an action that increased future navigation traffic levels would increase impacts beyond baseline levels.

The Effects of Fleeting

A fleeting area is defined as "Facilities where the barges are dropped off for loading, unloading, or awaiting other vessels, including barge warehousing whether a temporary or permanent barge location. This type of facility is an origin or destination and economic activity is taking place." Barge fleeting is a vital component of commercial river navigation on the Upper Mississippi River. Its role in commercial river traffic is very similar to that of a switching yard in a railroad system. Typically, barges are placed in fleeting areas to await loading or unloading at nearby terminals. Sometimes fleeting areas are merely used as staging areas where towboats leave full barges heading one direction on the river and take empties back in the other direction or vice versa. Without the use of fleeting areas, commercial river navigation would be much less efficient, if possible at all. In the St. Louis vicinity, where there is the highest concentration of fleeting areas on the UMR (Figure 4-12), the majority of the fleeting areas are engaged in staging operations. There are two major reasons that such extensive staging takes place in St. Louis: The region is centrally located on the river, and towboats below St. Louis commonly push 25 barges, while above St. Louis the largest typical tow size is only 15. Fleeting areas operating north of St. Louis rarely, if ever, engage in staging. These areas are mainly used for the servicing of terminals.

Figure 4-12. Aerial photograph of MMR showing a high concentration of fleeting areas within the St. Louis Harbor used for both staging of towboats and terminal loading and unloading.

The U.S. Fish and Wildlife Service listed 72 fleeting areas between Melvin Price Locks and Dam and the Ohio River (Miller and Mahaffy 1989) while unpublished data collected by the Corps in

1994 as part of the Upper Mississippi River-Illinois Waterway System Navigation Study listed 93 fleeting areas for this same reach. In 2015, there were 157 permitted fleeting areas in the MMR covering 894.83 acres.

To the best of the District's knowledge, there is only one primary scientific study (Sparks and Blodgett 1985), with acknowledged study problems, on the impacts of fleeting on aquatic organisms (i.e., benthic invertebrates, fishes, etc.). Impact assessments (USACE 1985) and literature reviews of potential impacts (Miller and Mahaffy 1989) of fleeting in the UMR have been based on observed impacts, knowledge of construction techniques, or known physical impacts (i.e., movement of the fleet by towboats, "parking" the barge fleet, deadmen construction, etc.) and their perceived environmental impacts. For example on the UMR, a major concern of resource agencies has been the potential development of fleeting areas over mussel beds. This concern developed because of the importance of freshwater mussels to riverine ecosystems and the occurrence of the federally endangered Higgins' Eye Pearly Mussel (*Lampsilis higginsii*). This concern is based on the observation by commercial mussel fishermen and researchers of crushed/broken shells resulting from fleeting in shallow water over mussel beds.

Potential impacts associated with fleeting fall into seven general categories: aesthetic issues associated with the fleet; how the towboat fleet is moored; fleeting areas utilizing space that would be used for other activities; fleeting areas moored in too shallow of water (i.e., crushing invertebrates/fish); physical forces associated with moving the fleet; dredging areas during extremely low flow conditions, especially those associated with terminals/docks; and potential water quality issues (barge cleaning, accidental spills).

Aesthetics: Aesthetics is a matter of human perception. One person viewing barges being moved in a fleeting area might view the scene as the wheel of industry turning, while another would see rusting barges "parked" in the river that obscure their view of the natural world. In addition, the assembly and disassembly of tow fleets produces sounds of barges banging into each other. The noise would be perceived by some people as unwanted.

Towboat Mooring: Properly permitted (Section 10 of the Rivers & Harbors Act/Section 404 of the Clean Water Act) barge fleeting areas are required to moor their barges to either deadmen, usually constructed on the shore, or anchored barges. Impacts would be restricted to minor short-term construction impacts. Deadmen placement could require a small amount of vegetation removal and excavation (less than one tenth of an acre per site). Loss of vegetation potentially impacts food/cover and reproductive requirements of various wildlife species, and excavation potentially affects subsurface dwellers. Permitted fleets do not tie off their barges to trees.

Alternative Use of Space: Stationary barge fleets would eliminate light passage into the water; this affects the food chain via reduced phytoplankton production (although this is a very minor impact in turbid river systems like the MMR), and in addition, sight feeding fish may have problems securing food in these darkened waters. The placement of fleeting in prime sport fishing and commercial fishing areas would reduce access to these areas and thus have adverse effects on their use. Fleeting areas are also not conducive to pleasure boating.

Fleeting in Shallow Water: Fleeting areas are generally chosen in deep water where barges would normally not be grounded. The major impact of grounding would be the potential to kill benthic invertebrates. As previously noted, freshwater mussel damage and mortality was a major concern in the UMR. However, there are no mussel beds in the MMR and mussel density is extremely low (Keevin et al. 2016).

Physical Forces Generated while Moving the Fleet: Some of the physical forces associated with commercial navigation traffic (i.e., drawdown, wavewash, turbulence and propeller entrainment of fish) would also be associated with movement of towboats and barges within a fleeting area. The impacts would occur to a lesser degree because fleeting activities typically use harbor boats with less horse power, moving at much slower speeds, and with fewer barges (2-3 barges) than typical line-haul tow traffic. The impacts of tow physical forces have been fully discussed above.

Dredging (terminals/docks) During Low Water: Fleeting areas are normally in deep-water habitats where dredging is normally not an issue. During low flows dredging may be necessary at terminals/docks or their approaches. The impacts of dredging have been fully discussed above.

Water Quality Issues: Water pollution related to boat sewage and barge cleaning is not believed to be a significant effect. Harbor boats have their own sewage collection systems and discharges from barge cleaning activity would be minimal. There is always the potential for toxic spills, but the probability is small.

With respect to cumulative impacts (past, present, and future actions), the impacts of fleeting 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 continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase navigation traffic and associated fleeting sites beyond the existing or projected future conditions, there are no incremental impacts associated with either of the Alternatives. In other words, only an action that increased future navigation traffic levels would increase impacts beyond baseline levels.

The Effects of Commercial Dredging and Dredged Material Disposal

The historic trend in MMR dredging and dredged material disposal is fully discussed in Chapter 1 of the SEIS. Chapter 4 addresses in detail the environmental impacts of existing and future levels of MMR dredging. As such, Corps dredging will not be discussed again in the cumulative impact analysis. There is currently private sector (commercial) sand dredging taking place in the MMR to provide sand for construction related activities.

Commercial sand dredgers within the St. Louis District use suction type dredges. Suction dredging removes sand materials from naturally replenishing deposits like a vacuum cleaner. The size of each company's suction pipe and dredge pump varies. One end of the suction pipe is attached to the dredge vessel with a pivot mount while the opposite end is attached to a cabled winch system that raises and lowers the intake pipe. Bars are welded in a grid pattern on the end of the flared suction pipe to minimize intake of debris and other materials that could damage the dredge pump.

When the dredge vessel reaches the work area it spuds or anchors into a stationary position. The winch holding the suction pipe lowers it into the water. The suction pipe then free-falls and buries the intake head beneath the surface into the sand deposit. A small auxiliary pump is turned on to prime water into the suction pipe. A larger dredge pump is then activated to initiate dredging. There are no rotating cutter heads or other mechanized excavation attachments associated with suction dredging. Suction dredging causes negligible turbidity at the subsurface work area due to the clean, coarse characteristics of sand. In addition, turbidity remains minimally altered as the intake pipe sucks itself deeper into the subsurface sand deposit.

Dredged materials travel up the intake pipe and pass over screens sized with maximum 3/8-inch openings. Materials larger than 3/8-inch (rock, debris…) pass over the screen and are returned to the river. Smaller sized sand particles fall through the screen openings and land in attached hopper barges. Suction dredging continues until the intake pipe encounters undesirable materials, reaches its maximum depth based on the pipe length or when the hopper barge is full. The larger dredge pump is turned off just before the winch raises the suction pipe's intake out of the sand deposit. If enough sand has not been collected, the dredge vessel relocates to repeat the process.

When the attached hopper barge is full, a workboat is dispatched to transfer the barge to existing unloading docks. The sand is unloaded using machinery equipped with a swing arm and clamshell bucket. Conveyor systems transfer the sand to stockpiles at the existing river terminal facilities. The stockpiled sand is typically sold to the construction industry for use in ready-mix concrete, asphalt and fill material.

The following river reaches and dredged material quantities have been permitted by the Corps in the main channel of the MMR under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. Most operators generally dredge within a five mile reach of their terminal and conveyor to save fuel and time. It is very rare for the commercial dredgers to actually reach the maximum allowed annual dredged material quantities.

RM 48-75, 135,000 cubic yards annual quantity. Permit abandoned within past 5 years.
RM 78-155, maximum permitted annual quantity 200,000 cubic yards.
RM 154-170, max permitted annual quantity 333,000 cubic yards.
RM 166-171, max permitted annual quantity 400,000 cubic yards.
RM 172-177, max permitted annual quantity 66,666 cubic yards.
RM 182-188, max permitted annual quantity 50,000 cubic yards.
RM 195-218, max permitted annual quantity 500,000 cubic yards.
RM 280-282, max permitted annual quantity 100,000 cubic yards.

The environmental effects of commercial dredging operations are similar to those described above for the Regulating Works Project, but at a smaller scale. Each dredging permit has special conditions which were developed in coordination with the U.S. Fish and Wildlife Service and state natural resource agencies in the state(s) where the dredging was permitted. These special conditions are provided to the dredger to protect the natural environment (e.g., No dredging or placement of dredged material shall be conducted within ¼ mile upstream or downstream of any chute, tributary mouth, park or refuge area, plus others) and to protect the human (constructed) environment (e.g., No dredging shall be conducted within 200 feet of any structure built or authorized by the Federal Government, nor within 500 feet of any bridge, pier or abutment, plus others).

With respect to cumulative impacts (past, present, and future actions), none of the actions associated with continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase dredging beyond the existing conditions. The Continue Construction Alternative would be expected to reduce dredging requirements and the No New Construction Alternative would be expected to have no impact on dredging requirements. Commercial dredging operations are not anticipated to grow dramatically. Currently, there are no known plans for new commercial dredging operations in the MMR.

Boat-Generated & Navigation Infrastructure Related Anthropogenic Sound

There is a very recent awareness and growing concern in the scientific community over the effects of man-made noise in the aquatic environment (e.g., Popper and Hastings 2009a, 2009b; Slabbekoorn et al. 2010). These noise sources in the MMR include, but are certainly not limited to, pleasure boating, commercial navigation traffic, fishing, dredging for channel and harbor maintenance, construction of bridges and navigation infrastructure, and demolition of structures. Currently, the biggest contributor to anthropogenic noise in the MMR is navigation traffic and work associated with operation and maintenance of the navigation channel. There is a growing concern that these sound sources may be impacting aquatic life, especially fish.

The Effects of Boat Traffic Noise

Anthropogenic sound from all types of boat traffic (e.g., canoes, pleasure boats, and commercial navigation traffic) have been shown to cause subtle physiological responses in fish such as increased cortisol (endocrinological stress response) levels in a number of European freshwater fishes studied (Wysocki et al. 2006), an increase in cardiac output in Largemouth Bass (*Micropterus salmoides*), associated with a dramatic increase in heart rate and a slight decrease in stroke volume (Graham and Cooke 2008), and increased auditory thresholds (an auditory threshold is the sound level at which an organism can first hear a sound)(Scholik and Yan 2002). Fish behavioral responses include disrupted auditory communication by decreasing the ability to detect conspecific acoustic signals (Vasconcelos et al. 2007); changes in schooling behavior (Sarà et al. 2007) which may be important in feeding, predator avoidance, and spawning; reduced foraging success (Voellmy et al. 2014); compromised antipredator behavior (Simpson et al. 2014); and diminished ability of resident fish to maintain territories (Sebastianutto et al. 2011).

It has been suggested that navigation traffic causes disturbance and side channels may be used as a refuge for fish escaping navigation related disturbances. Although the causes of these movements were not noted, it is possible that noise, in addition to physical disturbances (e.g., drawdown, wave wash, turbulence, etc.) may be partially responsible for displacement of fish. Galat and Zweimuller (2001) and Wolter and Bischoff (2001) hypothesize that commercial navigation traffic may push fish toward the littoral zone or into side 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 side channels. They found the presence of some species was unaffected by traffic disturbances, whereas, the presence of others was reduced.

As previously noted, the study of the impacts of boat-generated noise, or anthropogenic noise in the aquatic environment in general, and its effect on aquatic organisms is a very recent area of study and there are large data gaps in the knowledge base (Hawkins et al. 2015). For example, to the best of the District's knowledge there are no publications on the Sound Pressure Level (SPL) of operating tows similar to those operating on the MMR and there have been no studies of biological effects on aquatic organisms at those SPLs and durations. So our brief, potential "generic" impact analysis is based on the best available information from a variety of boat types.

With respect to cumulative impacts (past, present, and future actions), because none of the actions associated with continued Regulating Works construction or operation and maintenance of the Project are anticipated to increase navigation traffic and associated anthropogenic noise levels beyond the existing or projected future conditions, there are no incremental impacts associated with either of the Alternatives. In other words, only an action that increased future navigation traffic levels would increase impacts beyond baseline levels.

The Effects of Construction Noise

Future in-water construction activities by the Corps would involve the construction of additional river training structures and could involve construction activities associated with operation and maintenance of Lock and Dam 27 and the Chain-of-Rocks low-water structure. Private sector development could involve construction related to barge fleeting areas, harbor maintenance and development, and docks/piers. Most of these activities would produce low-level, short-term noise that would have minimal, localized impacts. Activities that involve pile-driving related impulse sounds have the greatest potential to affect aquatic resources. The level of impact depends on the size of the pile, size of pile-driver (energy being delivered to the pile), depth to which the pile is being driven, and the substrate. In addition, fish size, condition factor, reproductive condition, depth during exposure, distance from the sound source, type of airbladder (i.e., species lacking an airbladder, physostomous vs. physoclistous, and thickness of the airbladder, etc.) are additional biological conditions that can affect mortality. Impacts could range from no effect, minor behavioral effects, minor injury, to mortality (Bolle et al. 2012; Halvorsen et al. 2012a; Halvorsen et al. 2012b). There are potential mitigation measures that have been developed (e.g., warning sounds, seasonal or hourly schedule adjustments, bubble curtains) to reduce pile-driving effects that could be utilized for projects with a potential to have high impact levels (e.g., very large diameter piles with large pile-drivers) (Würsig et al. 2000).

With respect to cumulative impacts (past, present, and future actions) of construction noise, under the No New Construction Alternative, impacts would remain the same. Under the

Continue Construction Alternative additional training structures would be constructed which would result in construction related noise. However, construction noise is generally short-term and transitory in nature. For example, noise generated by rock placement during construction of training structures might move fish from the construction site, but they would return after the noise stopped. Even if sound pressure levels are high enough to injure or kill fish (e.g., pile driving with high-energy pile drivers), the impact zone would be relatively small and impacts would be to individual fish and would have little or no impact on MMR fish populations.

4.6.4 Impacts to 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.

4.6.5 Impacts to 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. Sedimentation within dike fields also contributed to the narrowing of the river (see Section 3.2.2 for full discussion). In areas where the river's planform width was narrowed, archaeological and historical sites on or near the riverbank that might have been subject to erosion from high water events, wave action (or other effects) from increased commercial navigation, or river migration, were essentially insulated by the newly formed land. Wrecked riverine vessels originally located on the river bankline or in side channels were also essentially buried under a protective blanket of sediment. The river's planform width has stabilized since the 1960s, but long term impacts of the Regulating Works Project include continued bankline stability, reducing the likelihood of cultural resources being damaged or destroyed by erosion.

4.6.6 Cumulative Impacts Analysis Conclusion

The Regulating Works Project, in combination with other past actions throughout the watershed, has had significant impacts, both positive and negative, on the resources, ecosystem and human environment of the MMR. However, this analysis is meant to characterize the incremental impacts of the current action in the broader context of other past, present, and future actions affecting the same resources. Although past actions associated with the Regulating Works Project likely significantly adversely affected some segments of the MMR environment as discussed in the 1976 EIS, the current practices employed in obtaining and maintaining a navigation channel integrate lessons learned from past experience and emphasize avoiding and minimizing environmental impacts to the greatest extent practicable. The additional analyses as part of this SEIS show that these measures have had the intended effect of avoiding and minimizing the impacts that were identified in the 1976 EIS. The District works closely with natural resource agency and navigation industry stakeholders throughout the project development process to ensure that all potential issues are addressed appropriately. This process, in conjunction with innovative river training structure designs and District restoration efforts, has contributed to a substantial reduction in adverse effects and equilibrium in many habitat conditions. Construction of river training structures is expected to continue to increase important low velocity habitat and increase bathymetric, flow, and substrate diversity. These improvements in Project implementation notwithstanding, the District has concluded that the adverse effects to shallow to medium-depth, moderate- to high-velocity main channel border habitat, as discussed in Section 4.3.2 Impacts on Fishery Resources above, are potentially significant and warrant consideration of compensatory mitigation. No other impacts associated with the Alternatives analyzed, in the context of other past, present, and reasonably foreseeable future actions, are anticipated to rise to a level of significance. See Table 4-13 below for a summary of cumulative impacts.

Table 4-13. Summary of Cumulative Impacts.

Resource	Past Actions	Present Actions	Future Actions	No New Construction Alternative	Proposed Action (Continue Construction Alternative)
Stages	Flows and stages impacted by watershed land use changes, levee construction, mainline and watershed dam construction, river training structure construction (low flow stage impacts), consumptive water use, climate change.	Continued impacts due to land use changes in watershed, continued operation of mainline and watershed dams, river training structure construction (low flow stage impacts), consumptive water use, levee construction, climate change.	Continued impacts due to land use changes in watershed, continued operation of mainline and watershed dams, river training structure construction (low flow stage impacts), consumptive water use, levee construction, climate change.	No impacts on stages anticipated, but trend of decreasing stages at low flows expected to continue.	No impacts on stages anticipated at average and high flows. At low flows, current trend of decreasing stages expected to continue.
Geomorphology	Widening of overall river planform and side channel planform from early 1800s to late 1800s due to floodplain land use changes; narrowing of overall river planform and side channel planform from late 1800s to mid-1900s due to river training structure construction for navigation; loss of side channels due to river training structure construction; stabilization of overall river planform and side channels mid-1900s to present; general increase in cross-sectional area, hydraulic depth, conveyance, channel volume since 1950s; restoration of side channel	General stabilization of overall river planform and side channel planform; continued general increase in cross-sectional area, hydraulic depth, conveyance, channel volume; continued provision of 9-foot navigation channel; continued restoration of side channels through Corps authorities.	Maintenance of stable overall planform and side channel planform; continued general increase in cross-sectional area, hydraulic depth, conveyance, channel volume; continued provision of 9-foot navigation channel; continued restoration of side channels through Corps authorities.	No impacts to geomorphology anticipated beyond continued provision of 9-foot navigation channel.	Continued general increase in cross-sectional area, hydraulic depth, conveyance, channel volume; continued provision of 9-foot navigation channel.

	habitat through Corps authorities.				
Resource	**Past Actions**	**Present Actions**	**Future Actions**	**No New Construction Alternative**	**Proposed Action (Continue Construction Alternative)**
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 population growth and development result in increased potential for water quality impacts; continued regulation enforcement and societal recognition prevent water quality degradation.	Localized, temporary increase in suspended sediment concentrations at dredged material discharge sites.	Localized, temporary increase in suspended sediment concentrations during construction activities.
Air Quality and Climate Change	Increasing human populations and industrialization result in deterioration of air quality; establishment of Clean Air Act, NEPA, USEPA, air quality standards improve conditions; non-attainment status in parts of Project Area; increasing global greenhouse gas emissions lead to climate change.	Continued population growth and development result in increased potential for air quality impacts; continued non-attainment status in parts of Project Area; continued regulation enforcement; increasing societal recognition of climate change causes and consequences; global greenhouse gas emissions continue to increase	Continued population growth and development result in increased potential for air quality impacts; continued non-attainment status in parts of Project Area; continued regulation enforcement potentially results in improvements in non-attainment areas; increasing societal recognition of climate change causes and consequences; possible stabilization/reduction in global greenhouse gas emissions through societal recognition and regulation.	Minor and local impacts to air quality due to use of dredging equipment and equipment used for maintenance of existing structures; greenhouse gas emissions approximately 27,950 tons per year from dredging and maintenance activities.	Temporary, minor, local impacts to air quality due to one-time use of construction equipment; reduction in future emissions due to dredging reduction.

Resource	Past Actions	Present Actions	Future Actions	No New Construction Alternative	Proposed Action (Continue Construction Alternative)
Fish and Wildlife (including threatened and endangered species)	Transformation of river system from natural condition to pooled lock and dam system above Chain of Rocks; in MMR, loss of floodplain habitat due to levees, agriculture, urbanization; loss of natural river habitat – loss of dynamic habitat due to river channel stabilization with dikes/ revetment; loss of side channel habitat; dredging impacts; navigation impacts; Corps, 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.	Maintenance of current habitat conditions due to maintenance of lock and dam system above Chain of Rocks and existing dikes/revetment; continued implementation of Regulating Works Project; continued use of innovative river training structures to provide habitat diversity; habitat restoration and land mgmt through Corps, 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; 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 Corps, 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; 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; creation of islands/sandbars with flexible dredge pipe; impacts to threatened and endangered species consistent with 2000 Biological Opinion; no effect or may affect but not likely to adversely affect for species listed since 2000.	Avoidance of sites during construction; no conversion of aquatic habitat to terrestrial; increased fish and macroinvertebrate use of structure locations due to increased low-velocity habitat and increased bathymetric, flow, and substrate diversity; loss of shallow to moderate-depth, medium- to high-velocity main channel border habitat potentially resulting in compensatory mitigation; creation of islands/sandbars with flexible dredge pipe; impacts to threatened and endangered species consistent with 2000 Biological Opinion; no effect or may affect but not likely to adversely affect for species listed since 2000.

Resource	Past Actions	Present Actions	Future Actions	No New Construction Alternative	Proposed Action (Continue Construction Alternative)
Navigation	1927 River and Harbor Act authorized the Corps to provide a 9-foot channel on MMR; Corps 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 obtain and maintain the navigation channel; navigation continues to be an important part of local, national, and 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 obtain and maintain the navigation channel; navigation continues to be an important part of local, national, and international transportation and commerce activities.	Continued requirement for periodic maintenance dredging at rates similar to recent history; potential reduction in reliability of navigation channel during extreme low water events.	Reduction in the amount and frequency of repetitive maintenance dredging in the Project Area; reduction in barge grounding rates; safer and more reliable navigation channel.
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.	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.

4.7 Relationship of short-term uses and long-term productivity

40 CFR 1502.16 requires that an EIS include a discussion of the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity. The intent of this analysis is to outline tradeoffs in the relationship between short-term uses of the environment and maintenance and enhancement of long-term productivity of resources. An important consideration when analyzing the effects of an action is whether it would result in short-term environmental effects to the detriment of achieving long-term productivity.

Implementation of the Proposed Action would specifically be implemented to benefit the long-term productivity of the District's navigation mission by facilitating commercial navigation in the most cost-effective fashion possible while continuing to avoid and minimize impacts to the environment. This would come at the expense of some minor, short-term effects to water quality, air quality, and fish and wildlife associated with construction activities necessary to achieve the Project objectives. These construction-related effects are not expected to alter the long-term productivity of the environment. The Proposed Action would also result in long-term adverse effects to main channel border fish habitat that would potentially result in the consideration of compensatory mitigation measures.

4.8 Irreversible and irretrievable commitments of resources

40 CFR 1502.16 requires that an EIS include a discussion of the irreversible or irretrievable commitment of resources associated with an action. An irreversible or irretrievable commitment of resources refers to an adverse effect to the human environment which cannot be recovered or reversed. Irreversible impacts are those that cause, through direct or indirect effects, use or consumption of nonrenewable resources in such a way that they cannot be restored or returned to their original condition despite mitigation. Irretrievable impacts refers to the loss of production or use of natural resources for a period of time. The production or use of the resource could return in the future if the action is reversed, but the production lost is irretrievable.

Irreversible commitments of resources associated with the Proposed Action would include such things as consumption of fossil fuels necessary for construction and operation and maintenance activities. If unknown historic or cultural resources were impacted by implementation of the Proposed Action, this would also be considered an irreversible effect. Most of the impacts (both positive and negative) to fish and wildlife associated with placement of river training structures would be considered irretrievable impacts. These impacts would be incurred for the period of time that the structure existed, but would return to normal if the structure were removed.

Chapter 5. Consultation, Coordination, and Compliance

National Environmental Policy Act. This SEIS, in conjunction with the 1976 EIS, is meant to satisfy the programmatic NEPA requirements of the Regulating Works Project. Tiered site-specific Environmental Assessments are prepared for specific work areas as they are implemented. See Section 1.1.2 Interagency Coordination, Section 1.1.3 Process for New Construction under the Regulating Works Project, Section 1.1.4 Process for Dredging under the Regulating Works Project, 1.1.6 Process for Bank Stabilization, Section 2.5 Future Implementation of the Regulating Works Project, and Appendix K for discussion on how the Regulating Works Project is implemented. Whereas this SEIS covers the programmatic impacts of the Regulating Works Project across the entire MMR, site-specific EAs contain information on the specific configuration of river training structures to be implemented, quantities of fill material required, amount of compensatory mitigation to be considered, as applicable, specific biological resources of concern in the area, and other such information relevant to the particular work area that could not be covered in this programmatic document. Site-specific impacts can only be determined subsequent to detailed planning, modeling, analysis, etc. to address the unique issues at each work area. Site-specific EAs will be prepared on an ongoing, as-needed basis as dictated by Congressional appropriation levels, Project priorities, etc.

Clean Water Act. Under Section 404 of the Clean Water Act of 1972, authorization is required to excavate in or discharge dredged or fill material into the Waters of the United States. Accordingly, the District has prepared a programmatic Section 404(b)(1) evaluation as part of this SEIS (see Appendix D) and is seeking programmatic Section 404 authorization for the Regulating Works Project. In addition, the District will continue to seek site-specific authorization for individual Regulating Works Project work areas under Section 404 of the Clean Water Act as part of the tiered NEPA document process.

Under Section 401 of the Clean Water Act of 1972, any applicant for a federal license or permit for an activity that may result in discharge into the Waters of the United States must seek certification from the appropriate state that the discharge will not violate applicable water quality standards. Accordingly, programmatic Clean Water Act Section 401 water quality certifications are sought from Illinois EPA and Missouri DNR for District dredging operations every five years. In addition, the District will continue to seek site-specific water quality certifications for individual Regulating Works Project work areas under Section 401 of the Clean Water Act as part of the tiered NEPA document process.

Rivers and Harbors Act. Under Section 10 of the Rivers and Harbors Act of 1899, authorization is required for construction of any structure in or over any navigable water of the United States, or the accomplishment of any other work affecting the course, location, condition, or physical capacity of such waters. Accordingly, the District is seeking programmatic authorization for the Regulating Works Project under Section 10 of the Rivers and Harbors Act as part of this SEIS. In addition, the District will continue to seek site-specific authorization for individual Regulating Works Project work areas under Section 10 of the Rivers and Harbors Act as part of the tiered NEPA document process.

Agency and Tribal Government Views. The District received comments on the Draft SEIS from USFWS, USGS, USEPA, MDC, IDNR, and the Osage Nation. Agency and tribal government comments and District responses can be found in Appendix E.

Federal Laws[1]	**Compliance Status**
Abandoned Shipwreck Act of 1987, as amended, 43 USC § 2101, et seq.	Full
American Indian Religious Freedom Act, as amended, 42 USC § 1996	Full
Archaeological and Historic Preservation Act, as amended, 54 USC § 312501, et seq.	Full
Bald and Golden Eagle Protection Act, as amended, 16 USC § 668, et seq.	Full
Clean Air Act, as amended, 42 USC § 7401, et seq.	Full
Clean Water Act, as amended, 33 USC § 1251, et seq.	Partial[2]
Comprehensive Environmental Response, Compensation, and Liability Act, as amended, 42 USC § 9601, et seq.	Full
Endangered Species Act, as amended, 16 USC § 1531, et seq.	Full
Farmland Protection Policy Act, as amended, 7 USC § 4201, et seq.	Full
Federal Water Project Recreation Act, as amended, 16 USC §460l-12, et seq. and 16 USC § 662	Full
Fish and Wildlife Coordination Act, as amended, 16 USC § 661, et seq.	Full[3]
Flood Control Act of 1944, as amended, 16 USC § 460d, et seq. and 33 USC § 701, et seq.	Full
Food Security Act of 1985, as amended, 16 USC § 3801, et seq.	Full
Land and Water Conservation Fund Act of 1965, as amended, 16 USC § 460l-4, et seq.	Full
Migratory Bird Treaty Act of 1918, as amended, 16 USC § 703, et seq.	Full
National Environmental Policy Act, as amended, 42 USC § 4321, et seq.	Partial[4]
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[5]	
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 laws, regulations, policies, and guidance have been complied with but not listed fully here.
[2] Full compliance will be obtained on a site by site basis prior to construction activities.
[3] Notice of Intent indicated that a Fish and Wildlife Coordination Act Report (CAR) would be obtained from the U.S. Fish and Wildlife Service. However, per the Fish and Wildlife Coordination Act of 1958 (Section 662.g) a CAR is not required for projects when sixty percent or more of the estimated construction cost has been obligated for expenditure as of the date the Act was passed. Therefore, a CAR was not required for this SEIS (see Appendix K and Response to USFWS Comment No. 13 in Appendix E for additional details). However, coordination with the Service was conducted and all Fish and Wildlife Coordination Act requirements are being fulfilled.
[4] Full compliance after submission for public comment and signing of Record of Decision.
[5] This list of Executive Orders is not exhaustive and other Executive Orders not listed may be applicable.

Chapter 6. Areas of Controversy

Flood Heights. There is research claiming that the construction of river training structures affects flood heights. The Corps takes these claims very seriously, so the Corps conducted several studies on the issue, completed a thorough analysis of all available research (see Appendix A), and concluded that river training structures do not affect water surface elevations at higher flows.

Mitigation. In both scoping and public review comments, Federal and state natural resource agency partners have stated that the Corps should mitigate for adverse effects going back to at least 1976. The authority for mitigation of the Regulating Works Project is discretionary, and in general, the Corps plans for and implements mitigation associated with proposed actions (see Appendix K, response to USFWS Comment No. 13 in Appendix E, and response to National Wildlife Federation Comment No. 10 in Appendix H for detailed explanation of the Project's mitigation authority). The impact identified in the SEIS that may result in the consideration of compensatory mitigation was not a known negative, potentially significant impact until the completion of additional analyses to obtain unknown and unavailable information as part of the SEIS. Therefore, potential compensatory mitigation for the Regulating Works Project would be conducted for adverse effects that have occurred or will occur since publication of the Notice of Intent to prepare this SEIS in the Federal Register in December 2013 as committed to in the SSEAs for that work. However, the Corps' standing ecosystem restoration mission and associated authorities, outside of the Regulating Works Project authority, could be used to restore ecological resources affected by past activities of the Corps and others (see Appendix K and response to USFWS Comment No. 13 in Appendix E for more details on these other authorities).

1976 Post Authorization Change Alternative. Federal and state natural resource agency partners have continued to ask that the Corps seek the Post Authorization Change (PAC) referenced in the 1976 EIS to add fish and wildlife as a Project purpose. The District fulfilled the commitments made in the 1976 EIS; however, this purpose was never added to the Project by Congress to utilize Regulating Works Project construction funding for ecosystem restoration or enhancement measures. However, all of the activities described in the 1976 EIS for the PAC can now be accomplished through other authorities. See Appendix K for details.

Geographic Scope of Analysis. The District received scoping comments indicating that the SEIS should address all of the navigation channel operation and maintenance activities in the Upper Mississippi River – Illinois Waterway System (UMR-IWW) instead of focusing only on the MMR. Recognizing the dynamic nature of the river in certain regions, Congress authorized many different navigation projects throughout the UMR-IWW. The Congressional authority for and management of the navigation channel on the MMR is very different from other projects within the UMR-IWW, primarily because the MMR is open river and the rest of the UMR-IWW consists of a series of pools created and managed through locks and dams. As such, the District concluded that a separate analysis for the MMR is appropriate.

Chapter 7. List of Preparers

Name	Role	Experience
Greg Kohler	Project Manager	6 years planning/project management
Edward Brauer	Engineering Lead	14 years, hydraulic engineering, Regional Technical Specialist - River Engineering
Keli Broadstock	Legal Review	4 years Corps, 6 years private sector law
Elliott Stefanik	Mitigation Planning	19 years, biology
Kip Runyon	Environmental Lead	18 years, biology
Thomas Keevin	Cumulative Impacts and Aquatic Resources	35 years, aquatic ecology
Shane Simmons	Air Quality and Climate Change	4 years, biology
Michelle Kniep	Planning	20 years, water resources planning, Regional Technical Specialist - Plan Formulation
Mike King	HTRW	25 years, environmental engineering
Mark Smith	Historic and Cultural Resources	22 years, archaeology
Erin Guntren	GIS	7 years, geography
Diane Karnish	Economics	27 years, economics
Danny McClendon	Regulatory	29 years, regulatory compliance and biology
Brian Rentfro	History	10 years, history

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Appendix A: Effects of RTS 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 stages for 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 in stage.

After a closer examination of the specific gage trends it was apparent that the long term stage 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 in stage were observed. Prior to 1973 at all gages studied, there were no increasing stage 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 in stage (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

IIHR-Hydroscience & Engineering 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.

In contrast to the above, there is research concluding that the construction of river training structures affects flood heights. 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.
Some of the analyses reaching this conclusion 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 concluding there is 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

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 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 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.

However, upon review and analysis, Pinter (2010) did not analyze a data set sufficient to prove this 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 by many experts, including ones from academia and other federal agencies, 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 include 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).

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 (Dyhouse 1995).

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. Upon review and analysis, the Corps concludes 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. To further verify model results and gain a full understanding of the physical processes driving the concluded increase in flood stage in Remo and Pinter (2007), the Corps has requested the authors provide the model, data or any other supporting materials, but the authors have refused to share this information with the Corps. Therefore, due to the concerns described above, the Corps does not support the conclusions in Remo and Pinter (2007).

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" (which extends from St. Louis just below the Eads Bridge to Commerce, MO) 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 for Remo and Pinter (2007) 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. The Middle Mississippi River is wider with smaller structures that are spaced further from each other. 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 to which it was calibrated. 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 with geometry and structures 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).

3.2.4 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 and 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.

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

Criss and Luo (2016) is an 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 paper was submitted for publication within days after floodwaters had receded. The authors detail preliminary observations and do not present any analysis on instream structures and how they impact flood levels.

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 December 29, 2015 was 41.0 feet. The stages for similar discharges on July 14, 1993 (824,000 cfs) and on May 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 feet above the previous record for this day set in 1982. The authors also use incorrect information in their analysis. For instance, the authors state that the stage on the Meramec at Pacific was slightly lower in 2015 than in 1982. This is not true; the stage at Pacific hit a new record of 33.42 on December 30, 2015, which surpassed the previous record of 32.71 on December 6, 1982.

The authors claim that it was "remarkable" 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". Every flood event on the middle Mississippi River is unique. Volume, timing, and duration of the event depends on the spatial and temporal distribution of the precipitation that caused the event, as well as the antecedent conditions prior to the event. The December 2015/January 2016 flood was very similar to the December 1982 event in both duration and peak discharge. In 2015/2016, there was a larger volume of runoff over a slightly longer period of time, resulting in a higher peak stage and flow, as well as a slightly longer duration. The peak discharge in December 1982 at St. Louis was 728,000 cfs with a peak stage just under major flood stage at 38.6 feet. The river was above flood stage for only 9 days during this event. Both events were caused by extreme precipitation in a short time period that fell over relatively small watersheds that drain directly into the Missouri, Mississippi, and Illinois Rivers just upstream of St. Louis. As pointed out by the authors, only a small fraction of the Mississippi River watershed above St. Louis received extraordinary rainfall and therefore once the peak flows passed through the MMR there was not additional flow to sustain the high flows.

A majority of Criss and Luo (2016) is focused on the Meramec River. Relating to the MMR, the authors make unsubstantiated claims that the flood of December 2015/January 2016 is "remarkable" and "unnatural" and attempt to attribute it to channelization of the middle Mississippi River and its isolation from its floodplain by levees. There is no analysis on the impact of river training structure construction on the MMR on flood levels.

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 at various times by the public, claiming to conclude that instream structures increase flood levels. However, the Corps has reviewed and analyzed these references and concluded that 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 (2007b) 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.

15. Clifford et al. (2002) evaluates the use of the SSIMM 3-D numerical model to simulate flow velocities for eco-hydraulic design and evaluation of river rehabilitation projects. There is no discussion or analysis by Clifford et al. (2002) on how the construction of river training structures impacts flow levels.

5. Conclusion

Based upon all of the 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 current research finding a link between river training structures and an increase in flood heights is based off 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). Therefore, the Corps has concluded that there is no impact to flood heights from the construction of river training structures, and thus, no impact from the Regulating Works Project outside of the MMR banks to warrant further study or analysis on this issue.

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Appendix B: Biological Assessment

Appendix B. Biological Assessment

This Biological Assessment, prepared for the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project, only covers newly listed threatened and endangered species potentially occurring in the Project Area that were not covered by the Endangered Species Act consultation process for the 1999 Biological Assessment and associated 2000 Biological Opinion for the Upper Mississippi River System which addressed multiple projects, including the Regulating Works Project (see Table 1 below). The 1999 Biological Assessment and 2000 Biological Opinion can be found on the District's web site at:

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

Table 1. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area that have been listed since issuance of the 2000 Biological Opinion (based on USFWS Information, Planning, and Conservation (IPaC) website: https://ecos.fws.gov/ipac/; accessed 6 February 2017).

Species	Federal Status	Consultation Status
Red Knot (*Calidris canutus rufa*)*	Threatened – listed in 2015	Covered in this document
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013	Covered in this document
Scaleshell Mussel (*Leptodon leptodon*)	Endangered – listed in 2001	Covered in this document
Sheepnose Mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012	Covered in this document
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered – listed in 2012	Covered in this document
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012	Covered in this document
Grotto Sculpin (*Cottus specus*)	Endangered – listed in 2013	Habitat not found in Project Area. No further analysis required.
Northern Long-Eared Bat (*Myotis septentrionalis*)	Threatened – listed in 2015	Covered in this document
Eastern Massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016	Habitat not found in Project Area. No further analysis required.

* The Red Knot was not listed as potentially occurring in the Project area in the most recent IPaC consultation but is listed here due to inclusion in previous consultations.

Red Knot. The Red Knot was listed as a federally threatened species in 2015 (Federal Register, Volume 79, Number 238, pp. 73706-73748). The following information comes from the information contained in the final rule (USFWS 2014a).

The Red Knot is a medium-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 Red 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.

There is no known 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 likely provide temporary feeding habitat. The Project would not eliminate or substantially reduce exposed substrates or shallow water within the Project Area. There is the remote possibility that river training structure construction, dredging, or other Project-related activities could disturb migrating Red Knots, but this impact would be minor and short-term in nature and would not significantly disrupt normal behavior patterns.

Determination. Project actions could have minor site-specific impacts on the Red Knot or Red Knot habitat, but are not anticipated to individually or cumulatively have an adverse impact on the population as a whole. Tier II Biological Assessments will be considered through coordination with the Service for future site-specific actions that may impact Red Knot habitat. It is our determination that the Project may affect but is not likely to adversely affect the Red Knot.

Rabbitsfoot. The Rabbitsfoot was listed as a federally threatened species in 2013 (Federal Register, Volume 78, Number 180, pp. 57076-57097). The following habitat information comes from the U.S. Fish and Wildlife Service's Rabbitsfoot Species Assessment (USFWS 2009):

> *Parmalee and Bogan (1998, pp. 211-212) described the following habitat requirements for the rabbitsfoot. The rabbitsfoot is primarily an inhabitant of small to medium-sized streams and some larger rivers. It usually occurs in shallow areas along the bank and adjacent runs and shoals where the water velocity is reduced. Specimens may also occupy deep water runs, having been reported in 9-12 feet of water. Bottom substrates generally include sand and gravel. This species seldom burrows but lies on its side (Watters 1988, p. 13; Fobian 2007, p. 24).*

The Rabbitsfoot historically occurred in 39 streams and rivers within the lower Great Lakes Sub-basin and Mississippi River Basin, including some streams and rivers in eastern Illinois and southern Missouri (USFWS 2009). Although the county threatened and endangered species lists include this species as potentially occurring in the Project Area, this is due to the fact that it is known to occur in Alexander County, IL. However, the records of occurrence for the Rabbitsfoot in Alexander County, Illinois are historical records for the Ohio River. This species is considered extirpated from Alexander County, IL and no records exist of the Rabbitsfoot occurring in the Mississippi River portion of Alexander County or any other part of the Middle Mississippi River (USFWS 2009).

Determination. It is our determination that the Project will have no effect on the Rabbitsfoot.

Scaleshell Mussel. The Scaleshell Mussel was listed as a federally endangered species in 2001 (Federal Register, Volume 66, Number 195, pp. 51322-51339). The following habitat information comes from the U.S. Fish and Wildlife Service's Scaleshell Mussel Recovery Plan (USFWS 2010):

> *The scaleshell occurs in medium to large rivers with low to medium gradients. It inhabits a variety of substrate types, but is primarily found in stable riffles and runs with slow to moderate current velocity. Buchanan (1979, 1980, 1994) and Gordon (1991) reported it from riffle areas with substrate consisting of gravel, cobble, boulder, and occasionally mud or sand. Call (1900), Goodrich and Van der Schalie (1944), and Cummings and Mayer (1992) reported collections from muddy bottoms of medium-sized and large rivers. Oesch (1995) considered the scaleshell a typical riffle species, occurring only in clear, unpolluted water with good current. Oesch also noted that it frequently buries itself in gravel to a depth of four to five inches.*

The Scaleshell historically occurred in 56 rivers in 13 states within the Mississippi River Drainage including the States of Illinois and Missouri. The Scaleshell is believed to be extirpated from Illinois. In Missouri, the Scaleshell can be found consistently in the Meramec, Bourbeuse, and Gasconade Rivers (USFWS 2010). The threatened and endangered species lists for counties in the Project Area indicate the presence of the Scaleshell in Jefferson and St. Louis Counties. However, these are due to its occurrence in the Meramec River basin. No records of occurrence in the Middle Mississippi River exist for the Scaleshell.

Determination. It is our determination that the Project will have no effect on the Scaleshell Mussel.

Sheepnose Mussel. The Sheepnose Mussel was listed as a federally endangered species in 2012 (Federal Register, Volume 77, Number 49, pp. 14914-14949). The following habitat information comes from the U.S. Fish and Wildlife Service's Sheepnose Status Assessment Report (USFWS 2002a):

> *The following habitat requirements of the sheepnose are generally summarized from Oesch (1984) and Parmalee and Bogan (1998). The sheepnose is primarily a larger-stream species. It occurs primarily in shallow shoal habitats with moderate to swift currents over coarse sand and gravel (Oesch 1984). Habitats with sheepnose may also have mud, cobble, and boulders. Specimens in larger rivers may occur in deep runs (Parmalee and Bogan 1998). Strayer (1999a) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives.*

The Sheepnose historically occurred throughout much of the Mississippi River system with the exception of the upper Missouri River system and most lowland tributaries in the lower Mississippi River system. The species is known from the Mississippi, Ohio, Cumberland, and Tennessee main stems, as well as many tributary streams throughout its range (USFWS 2002a). Recent sampling shows the Sheepnose to be extremely rare in the Mississippi River main stem and is thought to be extant in very low numbers only in pools 3, 7, 15, 20, and 22. Recent records also show the Sheepnose to be extant in the Meramec River and Ohio River basins (USFWS 2002a). The threatened and endangered species lists for counties in the Project Area indicate the presence of the Sheepnose in Jefferson and St. Louis Counties in Missouri and Alexander

County in Illinois. However, the Jefferson and St. Louis County records are due to its occurrence in the Meramec River basin and the Alexander County records are due to its occurrence in the Ohio River. No records of occurrence in the Middle Mississippi River exist for the Sheepnose (USFWS 2002a).

Determination. It is our determination that the Project will have no effect on the Sheepnose Mussel.

Snuffbox Mussel. The Snuffbox Mussel was listed as a federally endangered species in 2012 (Federal Register, Volume 77, Number 30, pp. 8632-8665). The following comes from information contained in the final rule (USFWS 2012).

Historically the Snuffbox Mussel was widespread, occurring in 210 streams and lakes in 18 U.S. states and Ontario, Canada. The population has been reduced to 79 streams and lakes in 141 states and Ontario, representing a 62 percent range wide decline. The Snuffbox is currently found in Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, Minnesota, Missouri, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, Wisconsin, and Ontario, Canada. Most populations are small and geographically isolated from one another, further increasing their risk of extinction (USFWS 2012). The Snuffbox is found in small- to medium- sized creeks, to larger rivers, and in Missouri it is known in the Meramec River, Bourbeuse River, St. Francis River, and Black River.

The threatened and endangered species lists for counties in the Project Area indicate the presence of the Snuffbox in Jefferson and St. Louis Counties in Missouri. However, these records are due to its occurrence in the Meramec River basin. There are no recent records of the Snuffbox in the MMR.

Determination. It is our determination that the Project will have no effect on the Snuffbox Mussel.

Spectaclecase. The Spectaclecase mussel was listed as a federally endangered species in 2012 (Federal Register, Volume 77, Number 49, pp. 14914-14949). The following habitat information comes from the U.S. Fish and Wildlife Service's Spectaclecase Status Assessment Report (USFWS 2002b):

> *Primarily a large-river species, Baird (2000) noted its occurrence on outside river bends below bluff lines. It appears to most often inhabit riverine microhabitats sheltered from the main force of current... It occurs in substrates from mud and sand to gravel, cobble, and boulders in relatively shallow riffles and shoals with slow to swift current (Buchanan 1980, Parmalee and Bogan 1998, Baird 2000). According to Stansbery (1967), this species is usually found in firm mud between large rocks in quiet water very near the interface with swift currents. Specimens have also been reported in tree stumps, root masses, and in beds of rooted vegetation (Stansbery 1967, Oesch 1984). Similar to other margaritiferids, spectaclecase occurrences throughout much of its range tend to be aggregated (Gordon and Layzer 1989), particularly under slab boulders or under bedrock shelves (Call 1900, Hinkley 1906, Buchanan 1980, Parmalee and Bogan 1998,*

> *Baird 2000), where they are protected from the current...Unlike most species that move about to some degree, the spectaclecase may seldom if ever move except to burrow deeper, and may die from stranding during droughts (Oesch 1984).*

The Spectaclecase historically occurred throughout much of the Mississippi River system with the exception of the upper Missouri River system, the uppermost Ohio River system, the Cumberland and Tennessee River systems, and some lowland tributaries in the Mississippi Delta region of Mississippi and Louisiana. The species is known from the Mississippi, Ohio, and Missouri main stems, as well as many other tributary streams throughout its range (USFWS 2002b). Recent sampling shows the Spectaclecase to be extremely rare in the Mississippi River main stem and is thought to be extant in very low numbers only in pools 15, 16, 19, 22, 24, and 25. There is one recent record of the Spectaclecase being found in the Mississippi River just above the confluence with the Missouri River (ESI 2014) and at least one historic record of the Spectaclecase being found in the MMR (Tiemann 2014). A weathered, relict Spectaclecase shell was recently found in the MMR (Keevin et al. 2016); however, the shell was found downstream of the Meramec River and may have originated there. Recent records show the Spectaclecase to be extant in the Meramec River basin (USFWS 2002b). The threatened and endangered species lists for counties in the Project Area indicate the presence of the Spectaclecase in Jefferson and St. Louis Counties in Missouri and Madison County in Illinois. The Jefferson and St. Louis County records are due to its occurrence in the Meramec River basin. The Madison County record is due to its occurrence in the Mississippi River just above the confluence with the Missouri River.

Most mussels that are found in the MMR are scattered and of very low density and may not represent viable populations (Keevin et al. 2016). Individual mussels may have been transported to the MMR as glochidia by host fishes from other water bodies in the surrounding watershed that do support viable mussel populations (e.g. the Meramec, Big Muddy, Kaskaskia, Upper Mississippi, and Ohio Rivers; Keevin et al. 2016). Due to the influx of sediment from the Missouri River and associated unstable sand substrates and high turbidity levels, the MMR does not generally provide the stable habitats required by most mussel species and no permanent mussel beds have been reported in the MMR (ESI 2014; Keevin et al. 2016).

Determination. It is our determination that the Project will have no effect on the Spectaclecase.

Northern Long-Eared Bat. The Northern Long-Eared Bat (NLEB) was listed as a federally threatened species throughout its range in 2015 (Federal Register, Volume 80, Number 63, pp. 17974-18033).

The following information on NLEB habitat and ecology comes from the U.S. Fish and Wildlife Service's Northern Long-Eared Bat Interim Conference and Planning Guidance (USFWS 2014b):

> ***NLEB Species Range***
> *The NLEB is found in the United States from Maine to North Carolina on the Atlantic Coast, westward to eastern Oklahoma and north through the Dakotas, extending southward to parts of southern states from Georgia to Louisiana, even reaching into eastern Montana and Wyoming. In Canada it is found from the Atlantic Coast westward to the southern Yukon*

Territory and eastern British Columbia. Historically, the species has been found in greater abundance in the northeast and portions of the Midwest and Southeast, and has been more rarely encountered along the western edge of the range.

NLEB Winter Habitat and Ecology

Suitable winter habitat (hibernacula) for the NLEB includes underground caves and cave-like structures (e.g. abandoned or active mines, railroad tunnels). These hibernacula typically have large passages with significant cracks and crevices for roosting; relatively constant, cool temperatures (0-9 degrees Celsius) and with high humidity and minimal air currents. Specific areas where they hibernate have very high humidity, so much so that droplets of water are often seen on their fur. Within hibernacula, surveyors find them in small crevices or cracks, often with only the nose and ears visible. NLEBs will typically hibernate between mid-fall through mid-spring each year. NOTE: there may be other landscape features being used by NLEB during the winter that have yet to be documented.

NLEB Summer Habitat and Ecology

During summer NLEBs roost singly or in colonies in cavities, underneath bark, crevices, or hollows of both live and dead trees and/or snags (typically ≥3 inches dbh). 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 presence of cavities or crevices or presence of peeling bark. NLEBs has also been occasionally found roosting in structures like barns and sheds (particularly when suitable tree roosts are unavailable). NLEB emerge at dusk to forage in upland and lowland woodlots and tree-lined corridors, feeding on insects, which they catch while in flight using echolocation. This species also feeds by gleaning insects from vegetation and water surfaces.

Suitable summer habitat for NLEB consists of a wide variety of forested/wooded habitats where they roost, forage, and travel and may also include some adjacent and interspersed non-forested habitats such as emergent wetlands and adjacent edges of agricultural fields, old fields and pastures. This includes forests and woodlots containing potential roosts (i.e., live trees and/or snags ≥3 inches dbh that have exfoliating bark, cracks, crevices, and/or cavities), as well as linear features such as fencerows, riparian forests, and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Individual trees may be considered suitable habitat when they exhibit characteristics of suitable roost trees and are within 1000 feet of other forested/wooded habitat. NLEB has also been observed roosting in human-made structures, such as buildings, barns, bridges, and bat houses; therefore, these structures should also be considered potential summer habitat. NLEBs typically occupy their summer habitat from mid-May through mid-August each year and the species may arrive or leave some time before or after this period.

NLEB maternity habitat is defined as suitable summer habitat used by juveniles and reproductive (pregnant, lactating, or post-lactating) females. NLEB home ranges, consisting of maternity, foraging, roosting, and commuting habitat, typically occur within three miles of a documented capture record or a positive identification of NLEB from properly deployed acoustic devices, or within 1.5 miles of a known suitable roost tree...

Suitable NLEB Roost Trees
Suitable NLEB roosts are trees (live, dying, dead, or snag) with a diameter at breast height (DBH) of three inches or greater that exhibits any of the following characteristics: exfoliating bark, crevices, cavity, or cracks. Isolated trees are considered suitable habitat when they exhibit the characteristics of a suitable roost tree and are less than 1000 feet from the next nearest suitable roost tree within a woodlot, or wooded fencerow.

NLEB Spring Staging/Fall Swarming Habitat and Ecology
Suitable spring staging/fall swarming habitat for the NLEB consists of the variety of forested/wooded habitats where they roost, forage, and travel, which is most typically within 5 miles of a hibernaculum. This includes forested patches as well as linear features such as fencerows, riparian forests and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Isolated trees are considered suitable habitat when they exhibit the characteristics of a suitable roost tree and are less than 1000 feet from the next nearest suitable roost tree, woodlot, or wooded fencerow. NLEBs typically occupy their spring staging/fall swarming habitat from early April to mid-May and mid- August to mid-November, respectively.

NLEB Migration
As with many other bat species, NLEBs migrate between their winter hibernacula and summer habitat. The spring migration period likely runs from mid-March to mid-May, with fall migration likely between mid-August and mid-October. Overall, NLEB is not considered to be a long-distance migrant (typically 40-50 miles) although known migratory distances vary greatly between 5 and 168 miles.

Potential Threats and Impacts to NLEB
No other threat is as severe and immediate for the NLEB as the disease, white-nose syndrome (WNS). If this disease had not emerged, it is unlikely the northern long-eared population would be declining so dramatically. Since symptoms were first observed in New York in 2006, WNS has spread rapidly in bat populations from the Northeast to the Midwest and the Southeast. Population numbers of NLEB have declined by 99 percent in the Northeast, which along with Canada, has been considered the core of the species' range. The degree of mortality attributed to WNS in the Midwest and Southeast is currently undetermined. Although there is uncertainty about how WNS will spread through the remaining portions of the species' range, it is expected to spread throughout the United States. In general, the FWS believes that WNS has reduced the redundancy and resiliency of the species.

Recent Bat Surveys. The St. Louis District's Rivers Project Office recently conducted bat surveys on Corps lands in Calhoun, Jersey, and Madison Counties in Illinois and St. Charles and Pike Counties in Missouri. The surveys were conducted to inventory bat species utilizing Corps lands, document any threatened and endangered species encountered, and to better inform management decisions that may impact bat species on Corps lands. The majority of the surveyed areas were outside of the Regulating Works Project Area in the pooled portion of the Upper

Mississippi River but did include the Chain of Rocks area located at the northern end of the Project Area.

The surveys were conducted in 2010, 2012, and 2014 (Walters et al. 2010; USACE 2012; SCI Engineering, Inc. 2014) and utilized both mist nets for capturing live bats and acoustic receivers for recording and identifying bat echolocation calls. Two individual NLEBs were captured during the surveys, although neither was within the Project Area. Thirty-two NLEB echolocation calls were identified during the surveys, including two within the Project Area at the Chain of Rocks location.

Given that NLEBs were captured in riparian corridor habitat in relatively close proximity to the Project Area, that NLEBs were acoustically located in the Chain of Rocks area within the Project Area, and that similar suitable NLEB habitat exists at many locations along the MMR corridor which lies within the NLEB range, it is reasonable to assume that NLEBs utilize or at least have the potential to utilize the riparian corridor throughout the Project Area.

Potential Impacts to the NLEB from Project Actions
Direct Effects
Dredging and Dredged Material Placement. Due to the fact that dredging and dredged material placement in the MMR take place within the main channel and main channel border areas of the river and do not impact adjacent bottomland forest areas, there is very little opportunity for impacts to the NLEB. Every dredging and dredged material placement location is coordinated with resource agency partners including the Service. Should disposal in adjacent bottomland forest habitat ever be required, a Tier II assessment would be considered through coordination with the Service. There is the remote possibility that dredging or disposal activities could disturb bats foraging or roosting in the vicinity of dredging operations, but this impact would be minor and short-term in nature and would not significantly disrupt normal behavior patterns. Dredging and dredged material placement may affect but are not likely to adversely affect the NLEB.

River Training Structure/Revetment Construction. There is the potential to affect roosting or nursery trees through bankline grading or placement of stone for river training structures and revetment. Maintenance of existing structures could also affect habitat if it requires shoreline modification. Current construction practices typically include placing stone from the river without the need for terrestrial staging areas and without the need for clearing or grading of bankline areas. In cases where shoreline modification is required, it is usually minor, and the long-term effect is preservation of the shoreline and reduction in erosion and tree loss. In most cases, construction of river training structures and revetment would not affect potential NLEB roost trees. In instances where clearing might be required, clearing should occur outside the roosting season and surveys may be necessary if work is conducted during the roosting season. The planning and design of all river training structures and revetment includes close coordination with resource agency partners including the Service. Close coordination helps to ensure that potential impacts are avoided. Should grading or clearing of banklines be required or there is a need for terrestrial staging areas, a Tier II assessment would be considered through coordination with the Service. There is also the remote possibility that river training structure or revetment construction could disturb bats foraging or roosting in the vicinity of construction activities, but this impact would be minor and short-term in nature and would not significantly disrupt normal behavior patterns.

Indirect Effects
Tow Traffic. The movement of tow traffic up and down the MMR may affect the foraging or roosting behavior of an occasional individual NLEB. However, this impact would be minor and short-term in nature and would not significantly disrupt normal NLEB behavior patterns.

Fleeting/Terminal Facilities. Barge fleeting areas are those areas where barges are continuously moved in and out for loading and unloading, or stored. They are generally located in close proximity to terminal facilities. Terminal or port facilities are usually within urban or industrial areas, and since their purpose is to provide river access, they are constructed in areas that were once floodplain habitat. Since the majority of fleeting and terminal facilities are in developed areas, it is likely that the amount of potential habitat affected is small.

Under Section 10 of the Rivers and Harbors Act of March 3, 1899, the placement of any permanent structure below the ordinary high water mark on navigable waterways requires a permit. Where installation involves the discharge of dredged or fill materials, permits are required under Sections 401, 402, and 404 of the Clean Water Act of 1977. Future expansion of fleeting areas or terminals will be subject to regulation and environmental review. Therefore, if expansion should occur in the future, evaluation of potential endangered species impacts will be assessed through the permit process. The States of Illinois and Missouri regulate barge fleeting through review of the Federal permitting process. In addition, trespass laws may be enforced on Federal property should inappropriate fleeting occur there.

Fleeting and terminal facilities may affect individual NLEBs through disturbance or minor habitat alteration but should not significantly disrupt normal behavior patterns.

Contaminants. Although contaminants may be a possible cause of insectivorous bat decline due to direct impacts to bats or due to impacts to their food supply (Clark 1981), the discussion here is focused on navigation-related contaminants. Environmental contaminants from accidental spills on the MMR could potentially affect the NLEB by affecting its food supply or by direct toxic affects to individual bats. However, this impact is considered negligible due to the low likelihood of occurrence.

Interrelated Effects
Management of Corps Lands. Corps lands in the MMR consist of the Chain of Rocks Management Area and the Thompson Bend Riparian Corridor Project. The Chain of Rocks Management Area encompasses 17 distinct management areas as shown in Table 2 below. Management of these areas varies depending on the intended use of the land with some forest management occurring in the vegetative management and mitigation areas.

Table 2. Chain of Rocks Management Area lands.

Management Area Classification	Number of Areas	Acres
Project Operations	2	1926
Low Density Recreation Areas	4	8
Mitigation Areas	2	234
Vegetative Management Areas	6	990
Easements	5	222
Total	**17**	**3380**

The Thompson Bend Riparian Corridor Project is located between river miles 32 and 19 on the right descending bank of the MMR. The project consists of a 300-foot-wide continuous permanent easement adjacent to the river channel, isolated blocks and strips of perpetual easement land off the main river corridor, river training structures, blew holes, and revetments. The purpose of the project is to maintain top bank control and to minimize over bank scour, which could lead to a channel cut-off, which would effectively close this reach of river to navigation, threaten the integrity of the Birds Point to Commerce levee, and affect thousands of acres of valuable agricultural land. The main feature of this project is a 300-foot-wide, 11-mile-long tree screen along the top bank of the river. Tree species selected for this feature are water-tolerant, fast-growing species. Where appropriate, tree species are selected that supply greater wildlife benefits.

Although some land management practices may cause temporary adverse impacts, there will be long-term benefits to the habitat. Prior to carrying out management actions, sites are evaluated for presence of threatened or endangered species and other natural resources of concern, and actions are taken to avoid impacts to these species. This includes designating special management zones, observing seasonal restrictions, and providing buffers. Forest management is carried out through close coordination with State and Federal resource agencies, including the U.S. Fish and Wildlife Service. Forestry practices diversify the habitat and strive to maintain size class diversity. Specific actions are described in the Rivers Project Master Plan (USACE 2014). Forest management practices that maintain forest age class and diversity contribute to the conservation of the species through providing and maintaining suitable future habitat.

Recreation on Corps Lands. Recreational activities on Corps lands have the potential to disturb roosting bats. However, these impacts are expected to be minor and would not significantly disrupt normal behavior patterns.

Section 4(d) Rule

In conjunction with the listing of the NLEB as threatened, the U.S. Fish and Wildlife Service (Service) published a 4(d) rule in 2016 (Federal Register, Volume 81, Number 9, pp. 1900-1922). Section 4(d) of the Endangered Species Act allows the Service to implement special rules for threatened (not endangered) species that provide flexibility in implementing the Act. Section 4(d) rules are used to reduce Endangered Species Act conflicts by allowing some activities that do not harm the species to continue, while focusing efforts on the threats that make a difference to the species' recovery.

In the case of the NLEB, the Service determined that white-nose syndrome is such an overwhelming threat to the species that regulating most other sources of harm or mortality would not help conserve the species. The NLEB 4(d) rule focuses prohibitions on protecting bats when and where they are most vulnerable: maternity roost trees during June and July pup-rearing and at hibernation sites.

For Federal agencies seeking Section 7 consultation on their actions, the Service provided an optional framework to streamline the NLEB consultation process. The framework requires the agency to notify the Service 30 days prior to implementing an action that may affect the NLEB. The notification is to include a determination that the action would not cause prohibited incidental take. Prohibited incidental take under the NLEB 4(d) rule consists of take within a hibernaculum or certain tree removal activities near a known hibernaculum or maternity roost tree. Service concurrence is not required, but the Service may advise the agency whether additional information indicates project-level consultation is required. If prohibited take may occur as a result of the agency action, standard Section 7 consultation procedures should be followed. The optional framework is not required and agencies can choose to follow standard Section 7 procedures.

Determination
Several components of the Project could have site-specific impacts on NLEBs and NLEB habitat, but are not anticipated to individually or cumulatively have an adverse impact on the population as a whole. Tier II Biological Assessments will be considered through coordination with the Service for future site-specific actions that may impact NLEB habitat. Use of the Section 4(d) rule optional framework will also be considered for future site-specific actions. It is our determination that the Project may affect but is not likely to adversely affect the NLEB.

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Appendix C: Mitigation Plan

1. OVERVIEW

In the Water Resources and Development Act of 1986 (WRDA 1986), Section 906(b), Congress gave the Corps the discretionary authority to mitigate for fish and wildlife damages for any water resources project that was completed or under construction at the time of the passing of WRDA 1986. This authority is in contrast to Section 906(a) of WRDA 1986, which made mitigation mandatory for any newly authorized projects or those where construction had not started. Because the Regulating Works Project was already under construction at the time WRDA 1986 passed, it fell under 906(b). Therefore, since 1986, efforts have been made to avoid and minimize project impacts by modifying designs of river training structures. This has included various designs such as chevron dikes, notched dikes, offset dikes, W-dikes, L-dikes, multiple roundpoint structures, and bendway weirs. Compared to only using traditional dikes, these designs generally create more diverse main channel border habitat for the benefit of aquatic biota.

However, even with these alternative designs, recent analyses suggest that river training structures would still result in the losses of main channel border habitat with certain depth, velocity, slope, and other functional characteristics. While the severity of these effects to biota is difficult to pinpoint, the losses are concerning given the cumulative condition of main channel border habitat and the lack of specific habitat areas that meet these various conditions. For these reasons, the Corps has decided that mitigation will be considered to offset losses to the greatest extent practicable in accordance with Section 906(b) of WRDA 1986, subject to the availability of future funding.

Corps regulations (Engineering Regulation 1105-2-100) guide the process for mitigation planning. Changes to habitat must be assessed as a function of improvement or degradation in habitat quality and quantity, as expressed quantitatively in physical units or indexes (but not monetary units). In the case of mitigation for significant environmental impacts, ecosystem restoration actions must be formulated and evaluated in terms of their net contributions to increases in ecosystem value, expressed in non-monetary units. Various mitigation actions also should be compared to each other through a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) to ensure benefits are optimized relative to cost.

Corps regulations also require an adaptive approach be taken to implementing, monitoring and modifying mitigation actions to ensure they are offsetting significant project impacts (USACE Implementation Guidance for Section 2036(a) of WRDA 2007, Aug 2009). This guidance requires mitigation plans include: 1) a description of the mitigation action; 2) a description of the type and amount of habitat to be restored; 3) ecological success criteria including specific metrics to quantify success; 4) a monitoring plan; 5) a Contingency Plan; and 6) a Real Estate Plan. The mitigation plan also will establish a consultation process with appropriate federal and State agencies to evaluate mitigation effectiveness, including monitoring and determining the success of mitigation.

This appendix provides a broad, programmatic discussion on habitat impacts quantification, mitigation and adaptive management, all of which are intended to ensure adverse effects from the project are offset. As outlined in the SEIS, specific project impacts cannot be definitively identified until specific future plans are developed. These future designs will allow planners to verify where, when and to what extent project features will alter river habitat. These details will be outlined within future Tier II site specific Environmental Assessments that will address future construction and mitigation for new river training structures and detailed mitigation planning. However, this appendix will outline the general programmatic approach for assessing impacts and mitigation in the future, including how an adaptive approach will be followed.

It should be noted that the District has completed site specific Environmental Assessments for Regulating Works construction sites since publication of the Notice of Intent for the SEIS. In these site-specific EAs, the District has committed to implementing measures in the future to avoid, minimize, and/or compensate for any new significant impacts revealed through preparation of the SEIS. For these work areas, impacts will be reviewed by the methods outlined below and compensatory mitigation will be reconsidered. NEPA documents will be updated, as appropriate, and any warranted mitigation plans will be developed and coordinated through the adaptive approach. Any compensatory mitigation will be implemented concurrent with construction to the extent practicable.

2. ASSESSMENT OF IMPACTS AND HABITAT LOSS

Future Conditions Under the Recommended Action

Future Regulating Works Project work areas will potentially have various effects to physical habitat. These changes to river habitat are complex. Based on the hydraulic analysis, use of innovative structures vs. traditional dikes is accomplishing the intended goal of increasing habitat diversity. In general, construction of river training structures results in an increase in shallow, low-velocity habitat which is generally regarded as important fish habitat. However, model output also suggests a decrease in shallow to moderate depth, moderate to high velocity habitat (Figure 1) which is important to some MMR fish guilds. This type of habitat would often be similar to “unstructured” sand bar habitat given that it’s typically found in main channel border locations with a lack of river training structures to act as current breaks. Indeed, modeled depth and velocity profiles for such unstructured main channel border areas mimic the depth and velocity profiles of this habitat loss.

The analysis detailed in the SEIS suggests that approximately 1,100 acres[1] of unstructured main channel border habitat in the MMR (defined as areas shallower than LWRP -10 without river training structures) could be affected as a result of future construction which is estimated to require placement of approximately 4.4 million tons of rock. This estimate includes the work areas that have already been constructed since publishing the Notice of Intent for the SEIS.

[1] The stated impact of 1,100 acres is a programmatic estimate based on the best available information (see Attachment 1 below). Actual impact acreages and potential mitigation will not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.

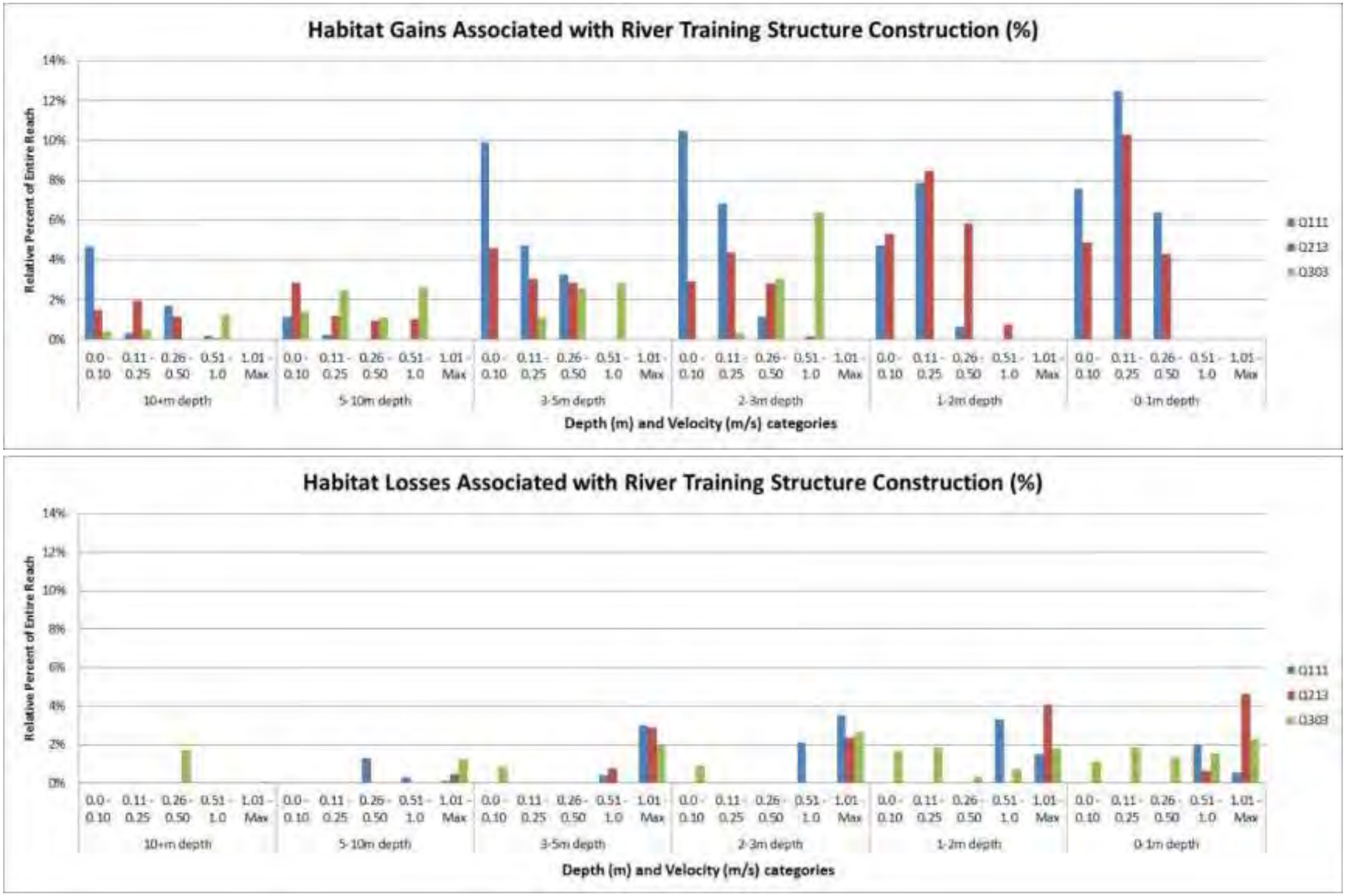


Figure 1. Habitat gains (top) and losses (bottom) associated with construction of river training structures expressed as a relative percent of each habitat category.

Resulting changes to these 1,100 acres of habitat are complex. Based on the hydraulic analysis, use of innovative structures vs. traditional dikes is accomplishing the intended goal of increasing habitat diversity. In general, construction of river training structures results in an increase in shallow, low-velocity habitat which is generally regarded as important fish habitat. However, model results suggest that river training structure construction causes a decrease in shallow to moderate depth, moderate to high velocity habitat which is important habitat to some MMR fish guilds (Figure 1). This habitat would typically be expected to exhibit moderate to high velocities given its location in the river channel and presumed lack of river training structures to act as current breaks. Indeed, modeled depth and velocity profiles for such unstructured main channel border areas mimic the depth and velocity profiles of this habitat loss.

An area of 1,100 acres represents approximately 8% of the remaining unstructured main channel border habitat in the MMR. Although these unstructured main channel border habitats are part of a river system that is highly modified compared to its original state, they may more closely resemble some of the historic habitats of the MMR. The continued conversion to structured habitat is expected to result in the functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high-velocity habitat of the main channel surrounded by structured main channel border habitat. Overall, this conversion is expected to have a potentially significant adverse effect on the MMR fish community and consideration of compensatory mitigation may be warranted. The level of significant adverse effect and amount of mitigation will be verified, as outlined below, within future Tier II site specific Environmental Assessments.

Detailed Future Assessment of Habitat Loss and Mitigation

Forecast conditions above are based on a "best guess" of likely impacts resulting from additional river training structures. Unfortunately specific locations and design of structures are not known at this time due to the changing nature of the river (the exception being the work areas already constructed). Future site-specific NEPA documents will be developed that outline in detail the plans for additional training structures within a certain river reach, including the anticipated changes in terms of depth, velocity and substrate that will result. This will be related to changes in aquatic habitat with impacts quantified as follows.

First, the quantity of habitat impacted will be determined in terms of its area, likely measured in acres. This measurement will be based on actual future work area designs and estimated resulting hydraulic conditions. The total amount of impacted future habitat will likely differ from the 1,100 acres estimated. Moreover, the adverse effects may not occur over the entire area of main channel border habitat influenced by future structures. The specific location and amounts of habitat with significant adverse project-related effects will be updated with detailed future plans and tracked to ensure accurate accounting of both impacts and potential mitigation.

After the location and quantity of aerial impact is identified, the quality of that habitat will be determined. Pursuant to Corps policy, habitat quality will be assessed through some type of ecological habitat model. Typically this has been done with tools such as the USFWS Habitat Evaluation Procedures (HEP) Habitat Suitability Index models (HSI). These HSI models generate a general habitat quality score between 0 and 1. This HSI score is then multiplied by the acres impacted to derive a total number of Habitat Units (HUs) lost. Those HUs lost that are determined to be a "significant" impact could result in mitigation. It should be noted that what level of loss is significant is a judgment determined by the Corps after collaboration with resource agencies and utilizing all information that is readily available. The simple loss of HUs does not in and of itself constitute a significant impact to consider mitigation to offset an equal amount of HUs. However, the Corps does anticipate pursuing mitigation for the types of habitat change forecasted within the SEIS. The levels of impact, impact significance and mitigation (including the type and amount and a detailed mitigation plan) would be developed and documented in these future Tier II site specific Environmental Assessments.

Main Channel Border Habitat Model and Future Work Areas

The above approach is how habitat losses will be calculated. However, no appropriate habitat model(s) currently exists to capture the unique aspects of Middle Mississippi main channel border aquatic habitat. To assist future impact assessment and mitigation planning, the Corps is attempting to develop a new main channel border habitat model. This model will focus on the specific aspects of main channel border habitat that this Project impacts. The model will function much like an HSI model to quantify habitat quality, and will be created collaboratively with input from natural resource agency partners. Model development was initiated early in 2016 with the bulk of preparation during spring and early summer. The model will go through the Corps model review process and is scheduled to be approved for regional use in 2017. This model could be used not only for future work areas under the Regulating Works Project, but other projects that could impact main channel border habitat on the Middle Mississippi River.

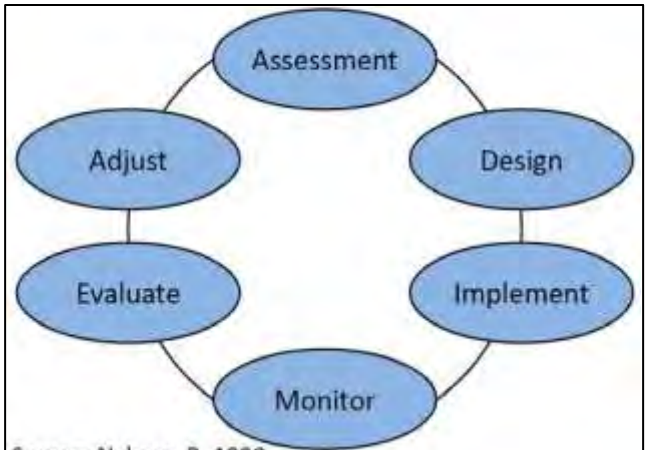
3. ASSESSMENT OF MITIGATION ALTERNATIVES

Once the specific amount of significant adverse future impact that warrants consideration of mitigation has been identified, the Corps must consider multiple alternatives to mitigate these impacts. This includes consideration of the cost for different mitigation alternatives, and the amount of mitigation benefits generated by each alternative. Mitigation benefits will be estimated and quantified using the main channel border habitat model that is under development. Mitigation costs and benefits will be annualized and a Cost Effectiveness/Incremental Cost Analysis performed to compare the alternatives. This helps ensure the Corps is making an informed selection on the most cost-effective mitigation approach.

Potential mitigation actions may include, but are not limited to, the following: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. Mitigation will be tailored toward the specific habitat features that are significantly impacted. This habitat likely includes shallow to moderate depth, moderate to high velocity main channel border habitat. Such habitat may be challenging to design and effectively implement. The ability to design for such habitat, including the associated costs, may need to be carefully considered within the context of the impacts. Impacts will be mitigated to the extent practicable.

4. MONITORING AND ADAPTIVE MANAGEMENT

Adaptive Management Approach



Source: Nyberg, B. 1999.

The purpose of this section is to begin laying out an adaptive strategy for a successful monitoring program in support of the project. Adaptive management (AM) is a "learning by doing" management approach which promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (National Academy of Sciences 2004). It is used to address the uncertainties often associated with complex, large-scale projects. In AM, a structured process is used so that the "learning by doing" is not simply a "trial and error" process.

Source: Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007

The basic elements of an AM process are: (1) Assess; (2) Design; (3) Implement; (4) Monitor; (5) Evaluate; and (6) Adjust. In practice, AM is implemented in a non-linear sequence, in an iterative way, starting at various points in the process and repeating steps based on improved knowledge.

Application of AM should occur in two phases as suggested by the *Adaptive Management: U.S. Department of the Interior Technical Guide (2007)*. A setup phase would involve the development of key components and an iterative phase would link these components in a sequential decision process.

Elements of the set-up phase include: stakeholder involvement, defining management or mitigation objectives, identifying potential management or mitigation actions, identifying or building predictive modeling or assessment tools, specifying performance measures and/or risk endpoints, and creating monitoring plans. In addition, values for the monitored measures that would trigger AM should be determined in this phase. The iterative phase uses these elements in an ongoing cycle of learning about system structure and function, and managing based on what is learned. The elements of the iterative phase include decision making, follow-up monitoring, and assessment.

Adaptive Management Team

An Adaptive Management Team (AMT) would provide essential support to meeting goals and objectives through the application of a systemic approach to evaluating project impacts, mitigation and mitigation effectiveness. The AMT would consist of a multi-agency (State and Federal) staff from the appropriate disciplines, including engineering, planning, environmental science and resource management. As the project sponsor, the Corps serves as the AMT leader. The exact members of the AMT will be determined during development of detailed project plans, but would likely include: the Corps, U.S. Fish and Wildlife Service (FWS), Missouri Department of Conservation (MDC), and Illinois Department of Natural Resources (ILDNR). The AMT would oversee the decision–making processes to plan and evaluate project features and mitigation.

Goals, Objectives and Performance Standards/Metrics

Clearly focused and quantitative goals and objectives are essential to AM. They should be logically linked to mitigation actions, action agencies, indicators/metrics, monitoring activities, and ecosystem values. Goals and objectives will be specifically identified during detailed mitigation planning. These goals and objectives will be critical elements of the project, with implementation concurrent with overall project construction.

Performance metrics would be used during two AM processes: planning mitigation actions (evaluating mitigation actions and metrics like those described above to predict project impacts) and assessment of actual mitigation performance following implementation. In many cases, these processes would be the same, allowing predictions to be compared to actual responses.

Performance standards/metrics include potential metrics for quantifying impacts following project construction, and measuring mitigation effectiveness. These standards/metrics will be fully developed based on input from the AMT during future Tier II site specific Environmental Assessments, which will include detailed mitigation plans. Ideally, these metrics will line up with the Main Channel Border habitat model that is under development (e.g., the model would serve to both plan for and help measure mitigation effectiveness). The general goal of mitigation will be to replace the habitat value lost through significant project impacts. Performance standards/metrics will allow for evaluation of mitigation effectiveness.

Develop and Implement Monitoring Plans

The CEQ NEPA Task Force (CEQ 2003) suggests that the effectiveness of adaptive management hinges upon an effective monitoring program to establish objectives, thresholds, and baseline conditions. This will be achieved through a stepwise process that includes pre- and post-construction studies of physical habitat. These studies would likely occur for both impact and mitigation sites, allowing impacts to be verified, and for mitigation effectiveness to be evaluated.

Monitoring programs are a key component of AM. Monitoring provides feedback between decision making and system response relative to management goals and objectives. An essential element of AM is the development and execution of scientifically rigorous monitoring and assessment to analyze and understand system response to project implementation. It is recognized that project level monitoring would be limited by cost and duration based on current regulations and that project level AM plans would need to be designed to reflect this constraint. However, post project monitoring would be a part of project implementation.

Following the adaptive framework of this document, impacts would be monitored over time and performance of measures would be assessed to determine whether additional avoidance, minimization, or compensatory mitigation measures should be considered. Future monitoring will provide information on the accuracy of the conclusions reached on the extent of impacts from the project features and evaluate the effectiveness of mitigation. Monitoring activities, including review of results, will be performed collaboratively with the AMT.

Future Tier II site specific Environmental Assessments will include the specific plan for monitoring and evaluation of the effectiveness of associated mitigation. The monitoring plan will need to outline the specific methodologies and frequencies for monitoring, as well as a cost estimate for all monitoring activities. The St. Louis District would be responsible for funding and executing this monitoring. Potential monitoring activities will be directly tied to the performance standards/metrics discussed above to measure mitigation effectiveness. Possible monitoring activities might include (but are not limited to) bathymetry observations, hydraulic measurements and/or modeling, and other measurements of physical habitat.

5. CONTINGENCY PLANS

Post-project monitoring will include an evaluation of mitigation effectiveness. Should mitigation prove ineffective, or should impacts prove more significant than previously anticipated, then additional mitigation may be considered.

The AMT must first identify which resources still have remaining impacts. This remaining impact should be quantified. Potential mitigation can then be identified to offset this remaining impact.

Funding mechanisms for implementing additional mitigation must then be identified. Depending on the amount of mitigation, funds may be available through the Regulating Works Project. This is especially the case for smaller activities. However, if large levels of funding are needed to address failed mitigation implemented in association with this SEIS, it may require additional action by Congress for either appropriation, or possibly even authorization. Thus, funding would be provided for construction of planned mitigation projects, and post-project monitoring. It cannot be guaranteed that federal funds would be available, specific to this project, for contingency mitigation.

6. REAL ESTATE PLANS

Real Estate needs are not applicable to mitigation associated with this project. The only proposed mitigation is for impacts in main channel border aquatic habitat. Mitigation would almost certainly be located in similar habitat areas. All land in main channel border habitat is under federal jurisdiction. As such all real estate would be available. Should work outside the Federal jurisdiction be considered, cooperation from real estate owners would be necessary since the mitigation authority under 906(b) does not allow for condemnation.

Literature Cited

Council on Environmental Quality (CEQ). 2003. Considering Cumulative Effects Under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, DC.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Attachment 1

Methodology to Estimate Remaining Construction and Associated Impacts

Methodology to Estimate Remaining Construction and Associated Impacts

To estimate the quantity and cost of potential compensatory mitigation for future dike construction, it was necessary to estimate the amount of future construction, estimate the impact of future construction, assume and evaluate possible mitigation measures, estimate the quality of mitigation measures and estimate a construction cost. Due to the dynamic nature of the Middle Mississippi River (MMR), the quantity, location and types of structures to be used for the remainder of the project are unknown. These specifics are dependent on future sediment load into the system, future dredging locations, impacts of climate change and other natural factors. Since an environmental planning model has not been certified for use yet, programmatic estimates of impacts and anticipated mitigation were developed for this SEIS. The actual amount of environmental impact of future construction and the quality of future mitigation measures will be defined in future site-specific environmental assessments (SSEAs).

Estimation of future construction

To estimate the amount of future construction that would be necessary to address chronic dredging sites in the MMR, generic designs were developed for all locations where recent dredging has occurred or where main channel depths were less than ten feet below the low water reverence plane (-10 LWRP[2]). Two sets of designs were developed – one using traditional dikes perpendicular to the bankline and another using chevron-shaped dikes. Generic, typical structure designs were used to determine the spacing of the structures. The quantity of material was estimated using length of structure, recent hydrographic surveys, and an assumed standard dike cross section with a crown width of 6 ft and an elevation of +18.5 ft LWRP. The quantity of material necessary to construct enough dikes on the MMR to reduce dredging to a minimum

[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 LWRP was also calculated in reference to the North American Vertical Datum 88 (NAVD 88).

(there will always be a residual amount of dredging due to the dynamics of the hydrograph and fluctuation of sediment load) was calculated to be approximately 6.5 million tons if traditional perpendicular dikes are used and 8.5 million tons if chevrons are used. The average quantity if an equal distribution of chevrons and traditional dikes are used is 7.5 million tons of stone. This equates to approximately 106,000 linear feet of structure.

To develop the dredging assumptions used in the Continue Construction Alternative, the District conducted an expert opinion elicitation (USACE 2015). A panel of District, regional, national and academic river engineering experts evaluated all available data to determine the current dredging requirements on the MMR, dike efficiency in reducing dredging, the relationship between dike construction and dredging and time considerations related to the dredging and dike efficiency values. The relationship between dredging and structure construction can be found Figure 1. This figure was derived by a cumulative comparison of existing dredging locations and the quantity of stone necessary to reduce dredging in these locations.

Through the evaluation of previous work areas, dredging records, and the prototype reach[3], it was determined that the 'efficiency' of Regulating Works to decrease dredging is 85%. This estimate means that, on average, after the completion of a Regulating Works project there is still a residual dredging requirement of 15% due to the natural variability of the channel and dynamic nature of the hydrograph.

The Continue Construction Alternative assumes that there is very little structure construction in the St. Louis Harbor reach of the MMR which spans from RM 184.0 to 168.5. Construction in St. Louis Harbor is difficult because of limited access due to high river traffic, fleeting, narrow channel width, and facilities along the banklines. The annual average dredging requirement in this reach will not likely change from the current quantity of 800,000 cubic yards/year. The dredging requirement for the remainder of the MMR can be reduced from the current amount of 3.2 million cubic yards/year to as low as 500,000 cubic yards/year depending on the amount of future construction. If maximum dredging reduction is achieved through the placement of approximately 7.5 million tons of material, a remaining dredging amount of 1.3 million cubic yards/year would exist on the MMR.

[3] The prototype reach is a formerly troublesome portion of the Middle Mississippi River between RM 154.0-140.0 in which a channel with a 1,200-foot constriction width between dike ends was constructed for the purpose of developing additional empirical design criteria which would assure successful implementation of the 9-ft channel project. The prototype reach was approved in 1966 and construction was initiated in July 1967 and completed in March 1969. Limited dredging has been necessary within the prototype reach since its completion.

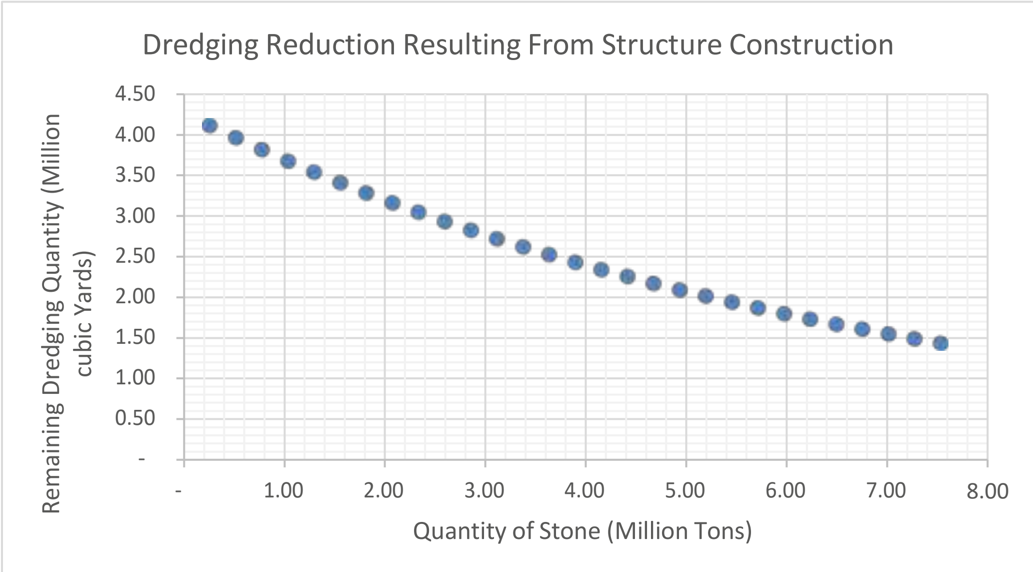


Figure 1. Relationship between dredging and structure construction.

Estimation of Impacted Habitat

The footprint of proposed structures was delineated using Cobb classification rules. If a structure already existed directly upstream or downstream, the footprint of the new structures would extend to that structure. If no structure existed, the footprint was assumed to extend to the bankline or adjacent dike field at a forty-five degree angle as seen in Figure 2. The intersection of the dike footprint with the existing habitat types was evaluated to determine how much main channel border was impacted by the proposed structures.

Using the process described in the paragraph above, the impact of all of the generic structures developed as part of the expert elicitation was calculated. This value represents the maximum potential impact of future regulating works construction. It was calculated that the impact of all construction necessary to achieve the maximum dredging reduction as determined by the Expert Elicitation was 1774 acres of main channel border. The process for estimating the impact of new construction was also applied to existing structure designs. The evaluation of six designed work locations allowed for the comparison of the percent of the footprint that impacted channel border and a comparison of the relationship between structure length and impact to channel border. See Table 1 and Figure 3.

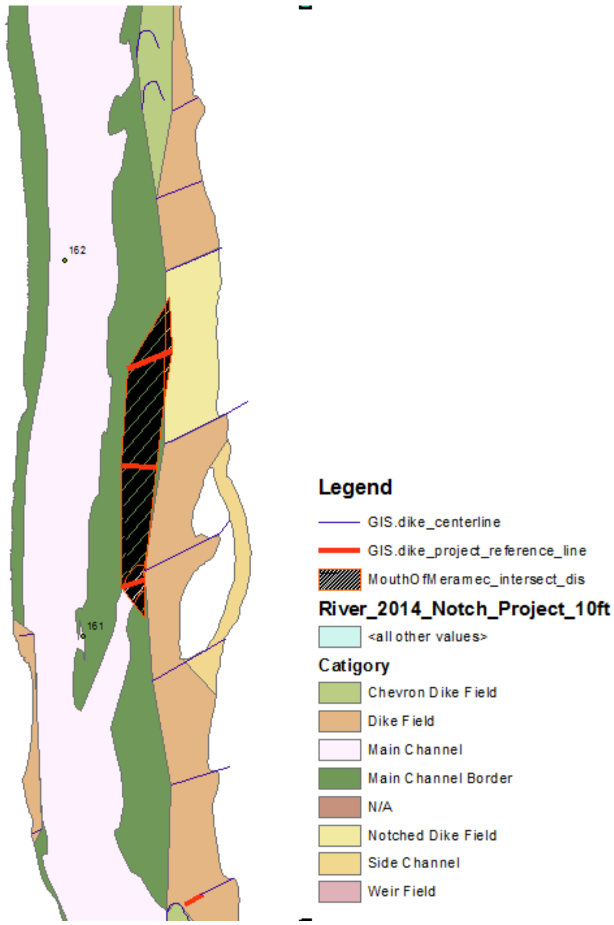


Figure 2

		Habitat Type Impacted (Acre)				Channel Border/ Total Impacted Area	Structure Length (ft)	Structure Length/ Channel Border Impacted
		Channel Border	Main Channel	Dike Field	Total			
Work Locations With SSEA's	Mosenthein- Ivory Landing Phase 4	7.16	-	-	7.16	1.00	488	68.18
	Dogtooth Bend Phase 5	1.65	0.53	-	2.18	0.76	295	178.80
	Grand Tower Phase 5	63.70	8.95	4.66	77.31	0.82	4,039	63.41
	Eliza Point/Greenfield Bend Phase 3	7.93	-	-	7.93	1.00	606	76.45
	Mosenthein- Ivory Landing Phase 5	35.06	2.29	2.08	39.43	0.89	1,442	41.13
Estimate For Remaining Construction		1,774.00	784.96	345.95	2,904.91	0.61	106,097	59.81

Table 1:Habitat Types Impacted

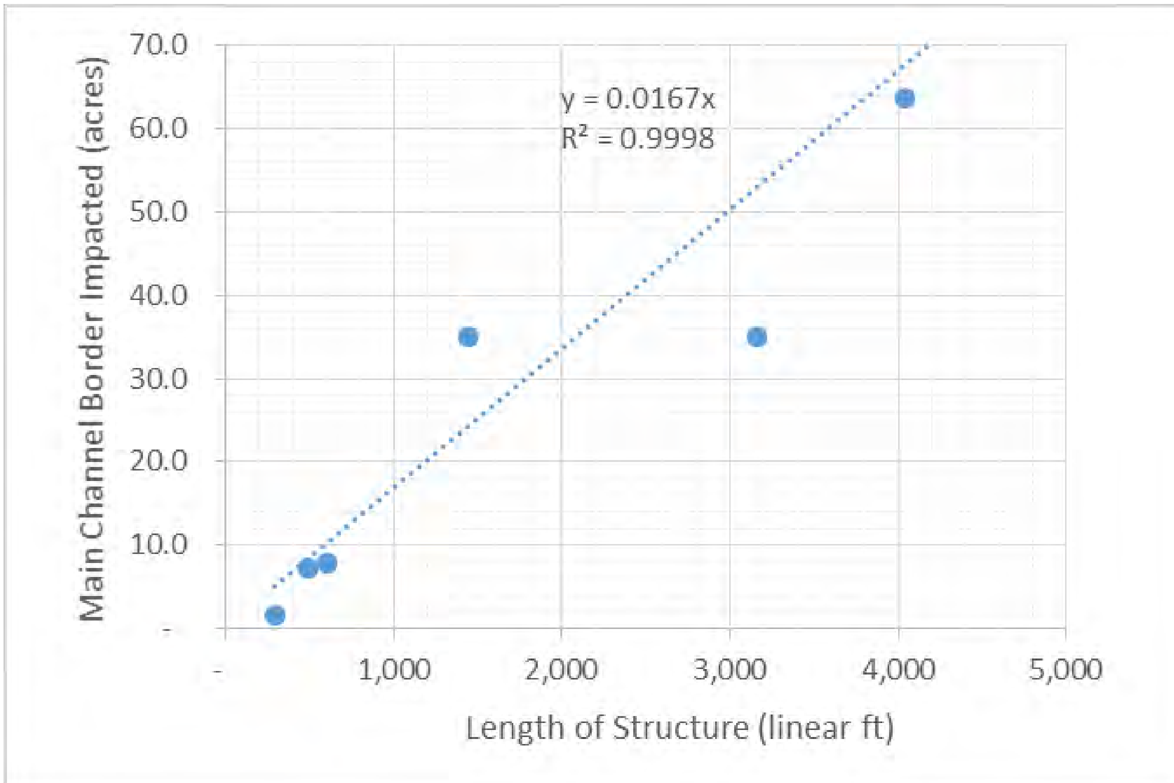


Figure 3: Relationship Between length of structure and channel border habitat impacted
Estimation of Quantity of Stone removed for Mitigation

For the purposes of this programmatic analysis, it was assumed that mitigation will be accomplished through the partial or complete removal of existing river training structures.

The average spacing and length of river training structures on the MMR was calculated to be 1200 ft and 680 ft respectively. For this analysis it is assumed that the depth at the river side of the structure is -10 ft LWRP with a constant slope to the crown elevation of +18 ft LWRP. The average height of the structure based off of the generic geometry is 14 ft. Based off of established quantity estimate information, the multiplier for a structure with an average height of 14 ft and a crown width of 6 ft is 20.9 Tons/lf. The amount of stone for a dike of average dimensions detailed in figure 4 is 14,212 Tons.

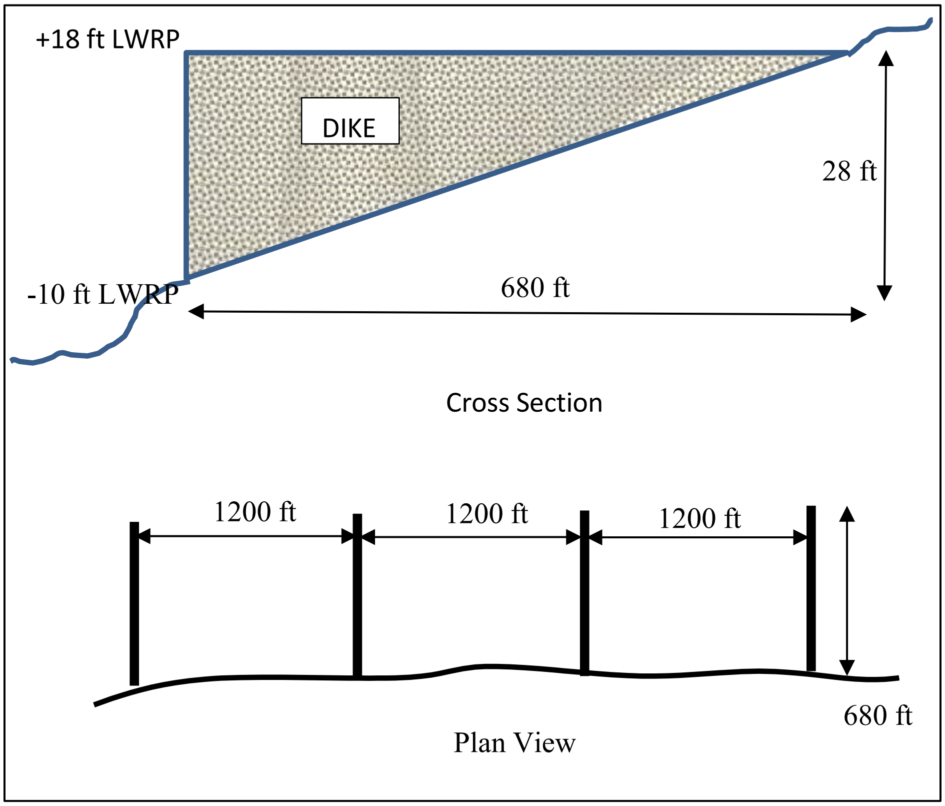


Figure 4: Generic dike cross section and spacing

The quantity of stone in a dike notch is dependent on the length of the notch and the average depth of the notch which is related to the notch location (i.e., river side, center, bankline) (see Figure 5). To estimate the average quantity of stone, the average structure dimensions were divided into three and stone quantity was calculated. It was assumed that all notches would be to the riverbed. The quantity of each notch is detailed in Table 2.

Type of Notch	Rock Quantity (Tons)
Full Structure	14,212
Bank side (rootless)	739
Middle	3,780
River Side	9,693

Table 2: Quantity of Rock required to remove to notch a dike 226.7 ft to the bed

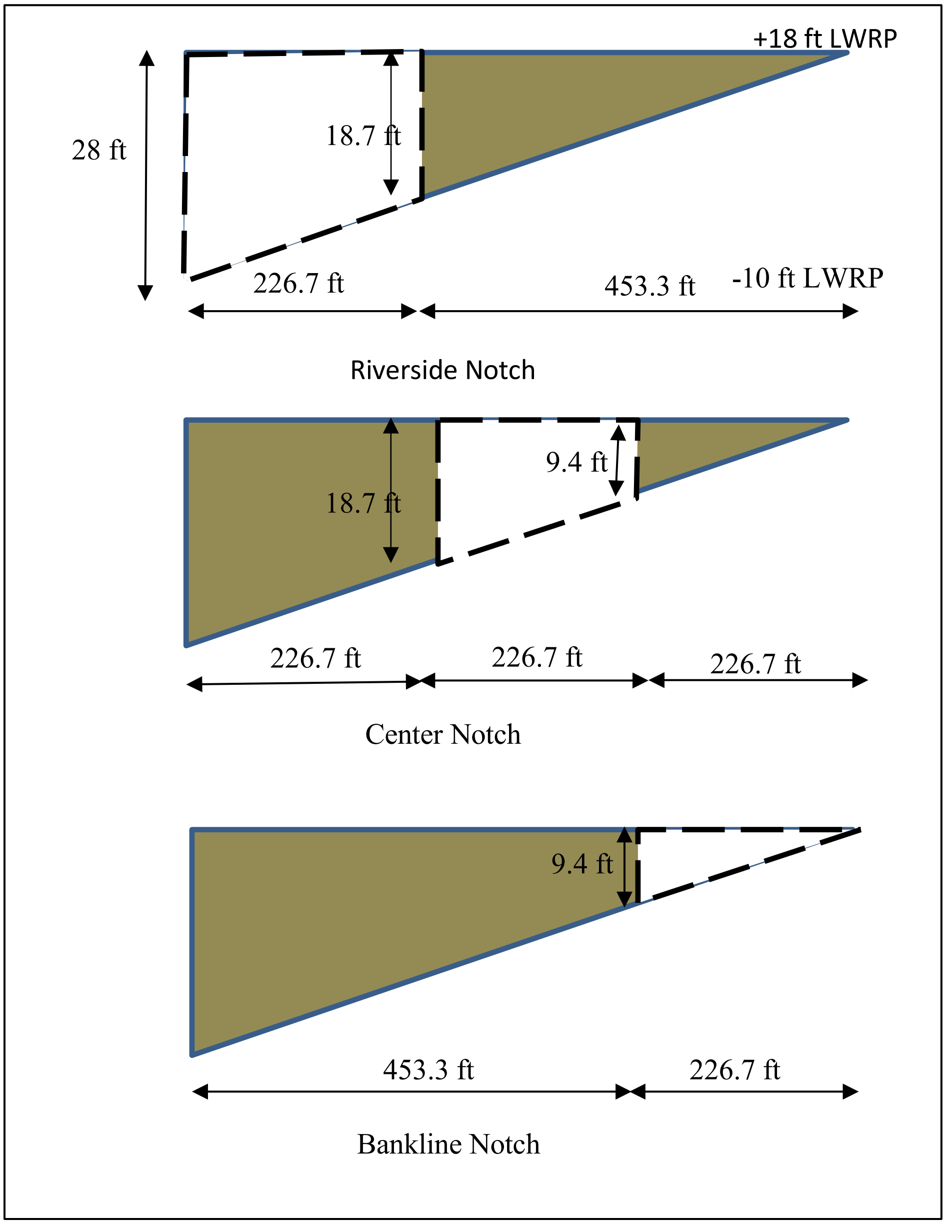


Figure 5

Estimation of Quantity of Habitat Created by Mitigation

The area of mitigation resulting from the removal of parts or all of a structure was defined as the additional unstructured area created by the structure removal as shown in Figure 6.

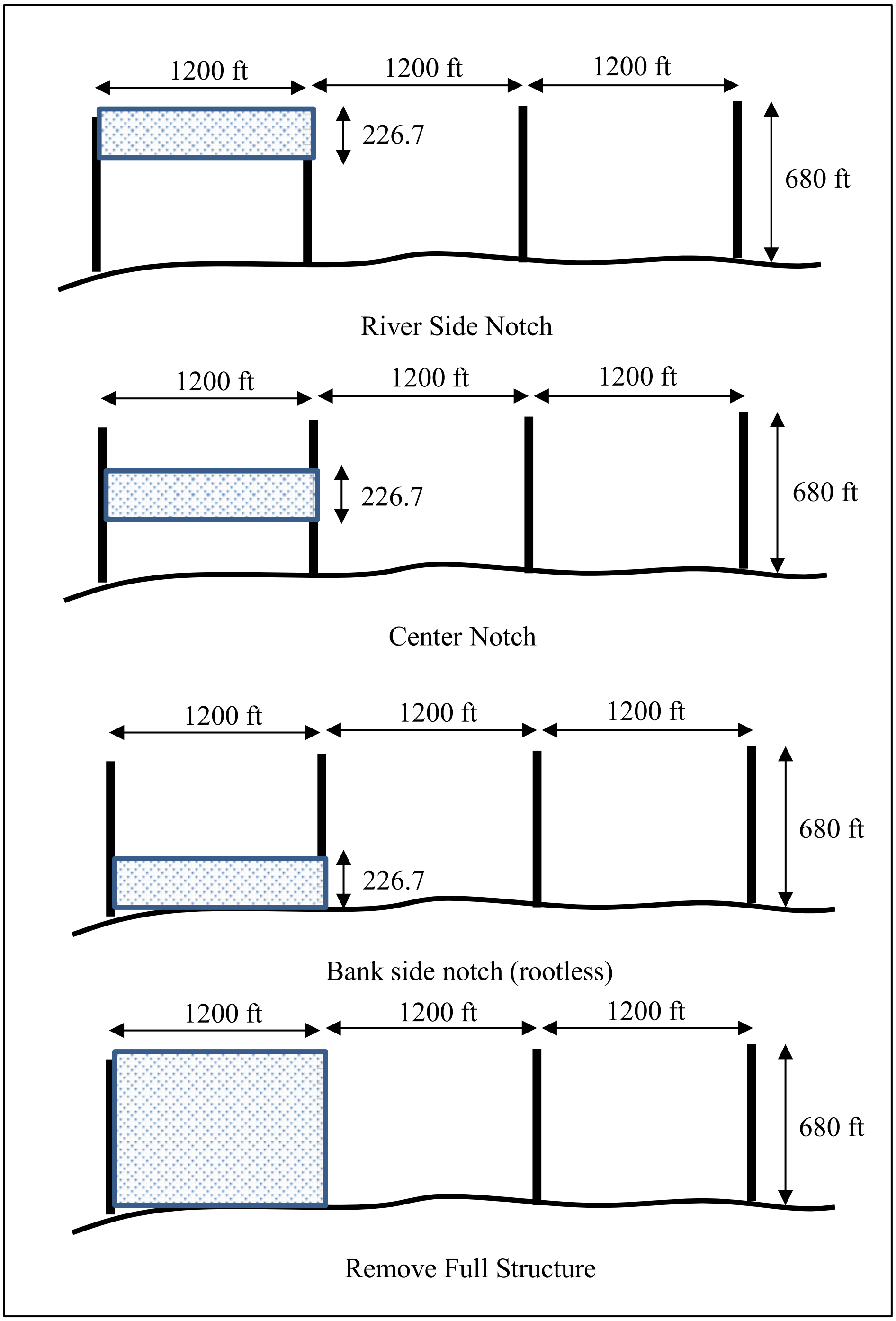


Figure 6: Amount of habitat created by notching or removing a structure

Since the amount of created habitat was equal for each type of notch (bankline, riverside, center) a relationship was developed between the quantity of rock removed and the amount of habitat created by each notch type (see Figure 7). This relationship was used for each notch type to calculate the amount of habitat created for the equivalent amount of stone removed when removing a typical structure.

Estimation of Average Mitigation Costs

To calculate the average cost of mitigation, a cost of $15.40 per ton of stone removed was assumed and the relationship between mitigation cost and amount of habitat created was developed. The four methods of creating habitat were averaged and a habitat suitability index (HIS) of 0.5 was applied. See Figure 8. In the average mitigation cost calculation it was assumed that the costs to make a dike rootless is the same as a center notch. This assumption was made to account for the uncertainty in the height of the structure in this location and the potential additional cost of construction dredging which may be required to access the structure. The cost of revetment to prevent bank erosion after a structure is removed was also added into the mitigation cost estimate. It was assumed that revetment was placed on the banks adjacent to the removed or notched structure for 50 ft upstream and 100 ft downstream. The average cost of 17 tons/linear ft was used to estimate revetment cost.

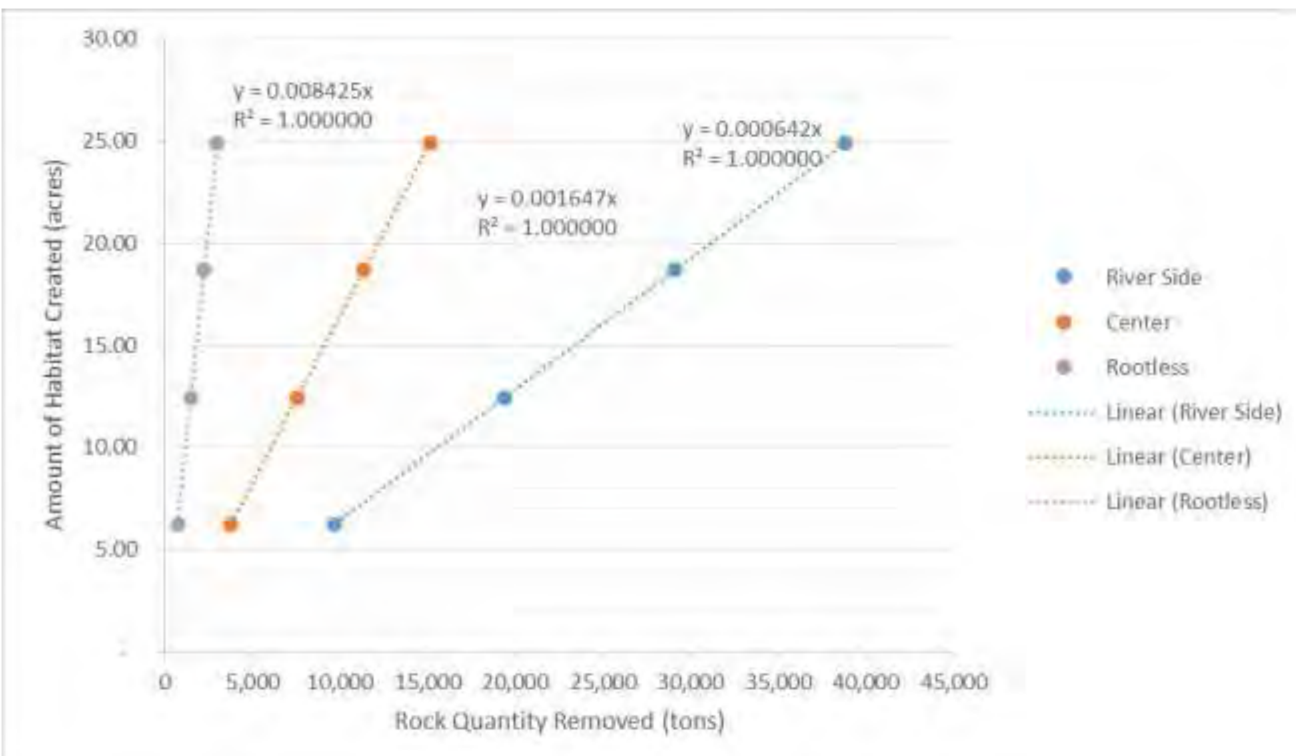


Figure 7: Amount of habitat created by notching dikes in different locations

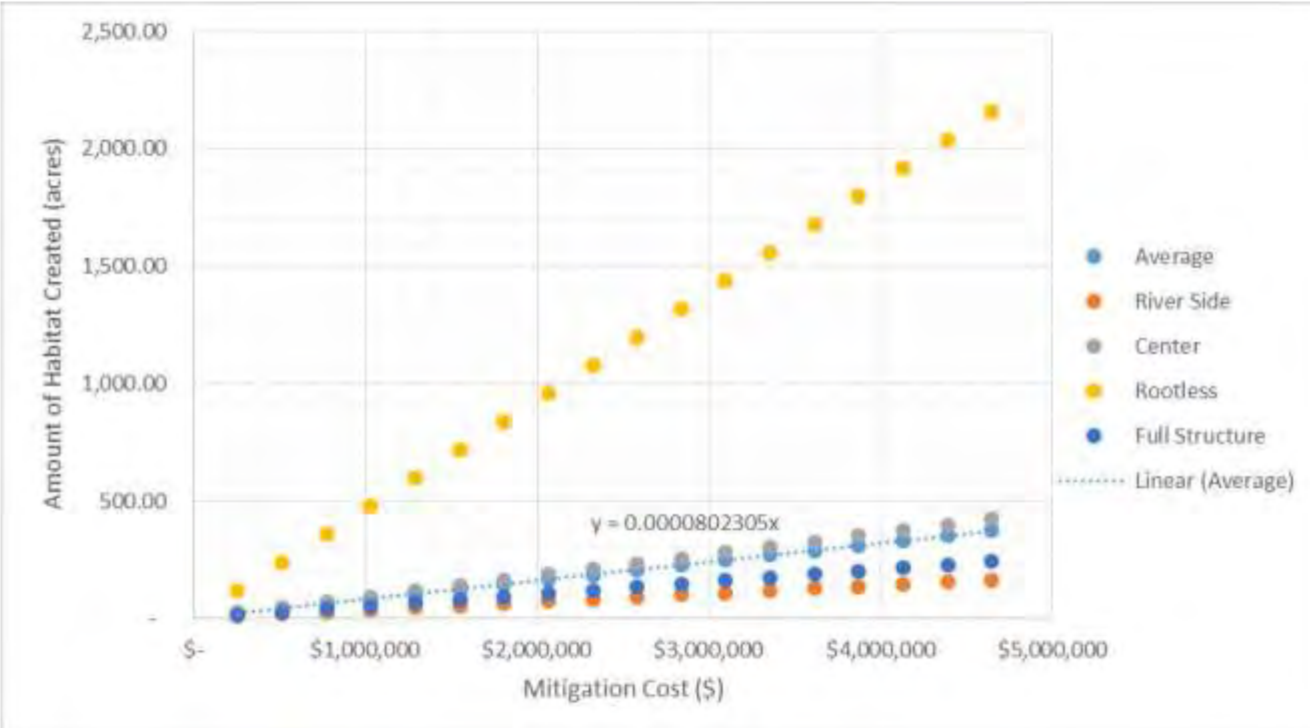


Figure 8: Cost of Mitigation by removing full dikes and different notch types

From the generic design analysis developed in the expert elicitation, a relationship between structure length and structure quantity was developed as shown in figure 9.

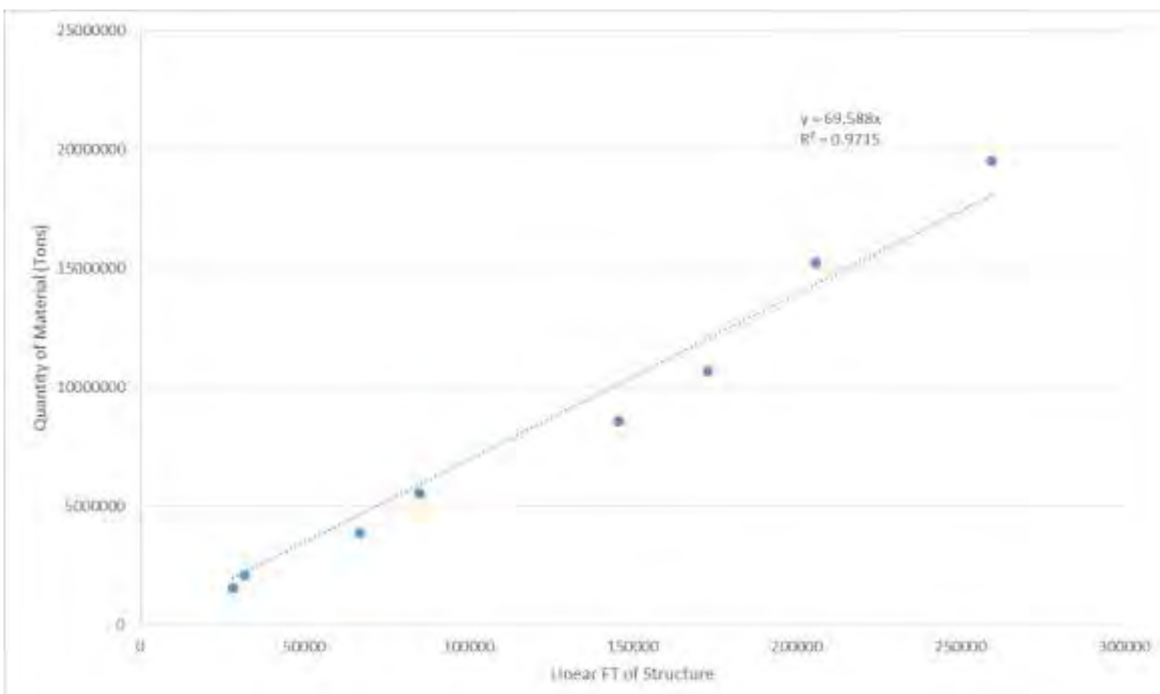


Figure 9: Relationship between strucutre quantity and length

Using the relationships above, a mitigation cost vs new structure construction cost could be developed. This relationship is shown in figure 10. This relationship is dependent on the cost of stone, habitat suitability index, footprint of constructed structures and length, depth and spacing of existing structures being removed and new structures being constructed. This cost only represents construction cost and does not account for costs associated with design, review, contracting, monitoring etc.

Figure 10: Cost of mitigation per dollar of dike construction

Estimation of remaining Regulating Works Dike Construction and Associated Mitigation

While reducing dredging to 1.3 million cubic yards per year is technically feasible, there will be a point where it is no longer economical to build additional structures. To estimate this approximate point, recent dredging costs and structure construction costs along with estimated mitigation costs were used to analyze the dredging reduction benefits of various increments of additional construction (up to 7.5 million tons). Using a 50-year period of analysis, a 3.125% discount rate, and FY16 price level, the increment of construction with the greatest net benefits is estimated to be 4.4 million tons.

Using the analysis presented in the previous sections, this quantity of construction would result in approximately 1,100 acres of mitigation for main channel border habitat impacts and would reduce dredging to an estimated average annual requirement of 2.4 million cubic yards. While these programmatic estimates utilized the best available information and assumptions at this time, the actual quantity and design of structures that are constructed, the impacts of that construction with associated mitigation, and the remaining average annual dredging requirements will depend on actual future conditions. As future work areas are identified with specific construction sites, designs and cost estimates, SSEAs will detail the impacts to main channel border habitat of those work areas along with the proposed mitigation. The cost of those work areas, the quantity and cost of the associated mitigation, and the future cost of dredging will be incorporated into future economic updates of the Regulating Works Project. Updated information will also be included in tiered SSEAs.

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

CLEAN WATER ACT
SECTION 404(b)(1) EVALUATION
MIDDLE MISSISSIPPI RIVER REGULATING WORKS PROJECT

I. INTRODUCTION

A. Authority, Purpose, Location, and General Description.

The St. Louis District (District) of the U.S. Army Corps of Engineers (Corps) is charged with operating and maintaining a nine-foot navigation channel on the Middle Mississippi River (MMR). The MMR is defined as that portion of the Mississippi River that lies between its confluence with the Ohio and Missouri Rivers (Figure 1 and Figure 2). This ongoing Project is also commonly referred to as the Regulating Works Project. As authorized by Congress in 1910, the Regulating Works Project utilizes bank stabilization, rock removal, 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. The Regulating Works Project is maintained through dredging and any needed maintenance to already constructed features. The long-term goal of the Project, as authorized by Congress, is to provide a sustainable and safe navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging and the occurrence of vessel accidents through the construction of regulating works. Therefore, pursuant to the Congressionally authorized purpose of the Project, the District continually monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable, and the District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel.

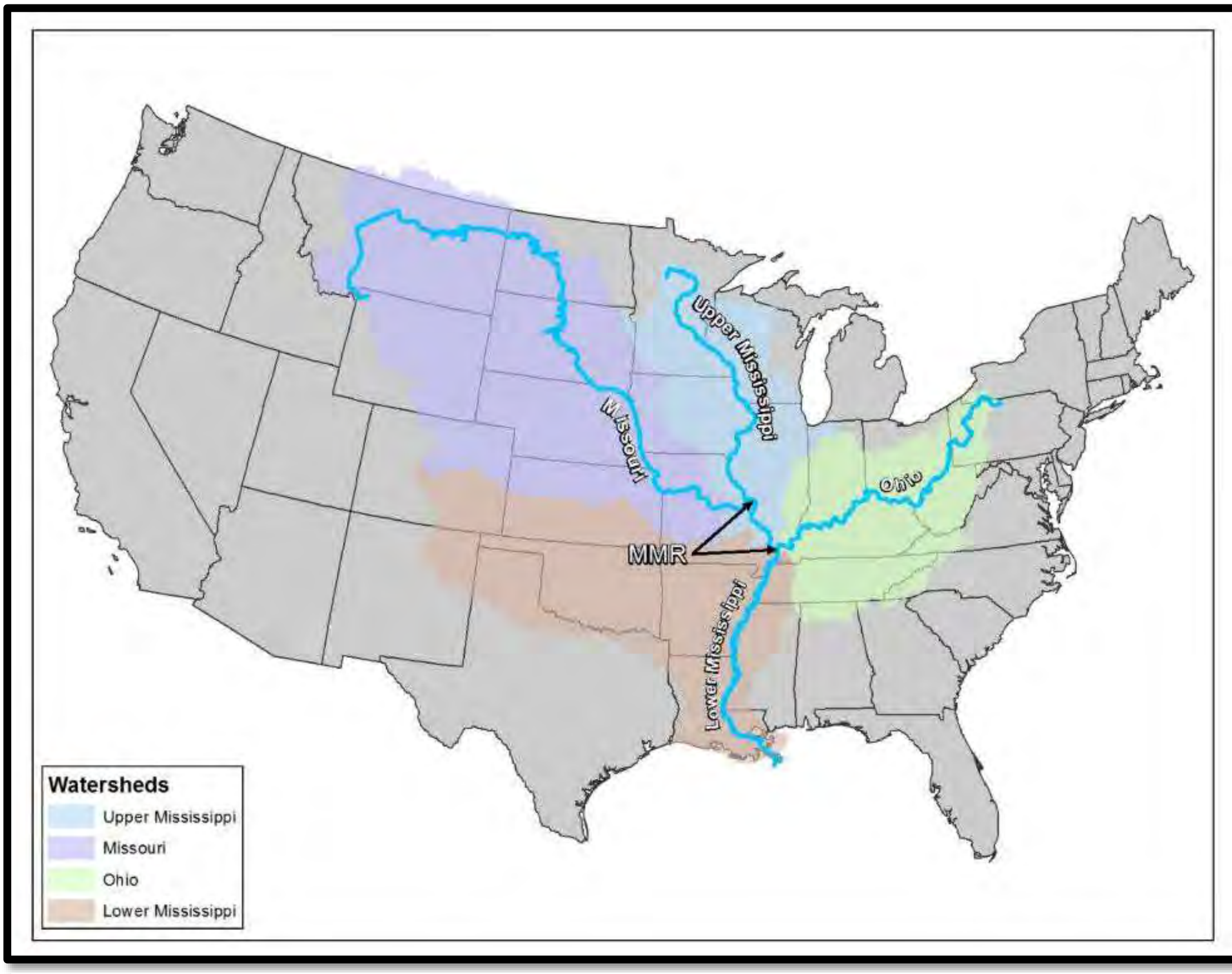


Figure 1. Location of the MMR within the Upper Mississippi River watershed.

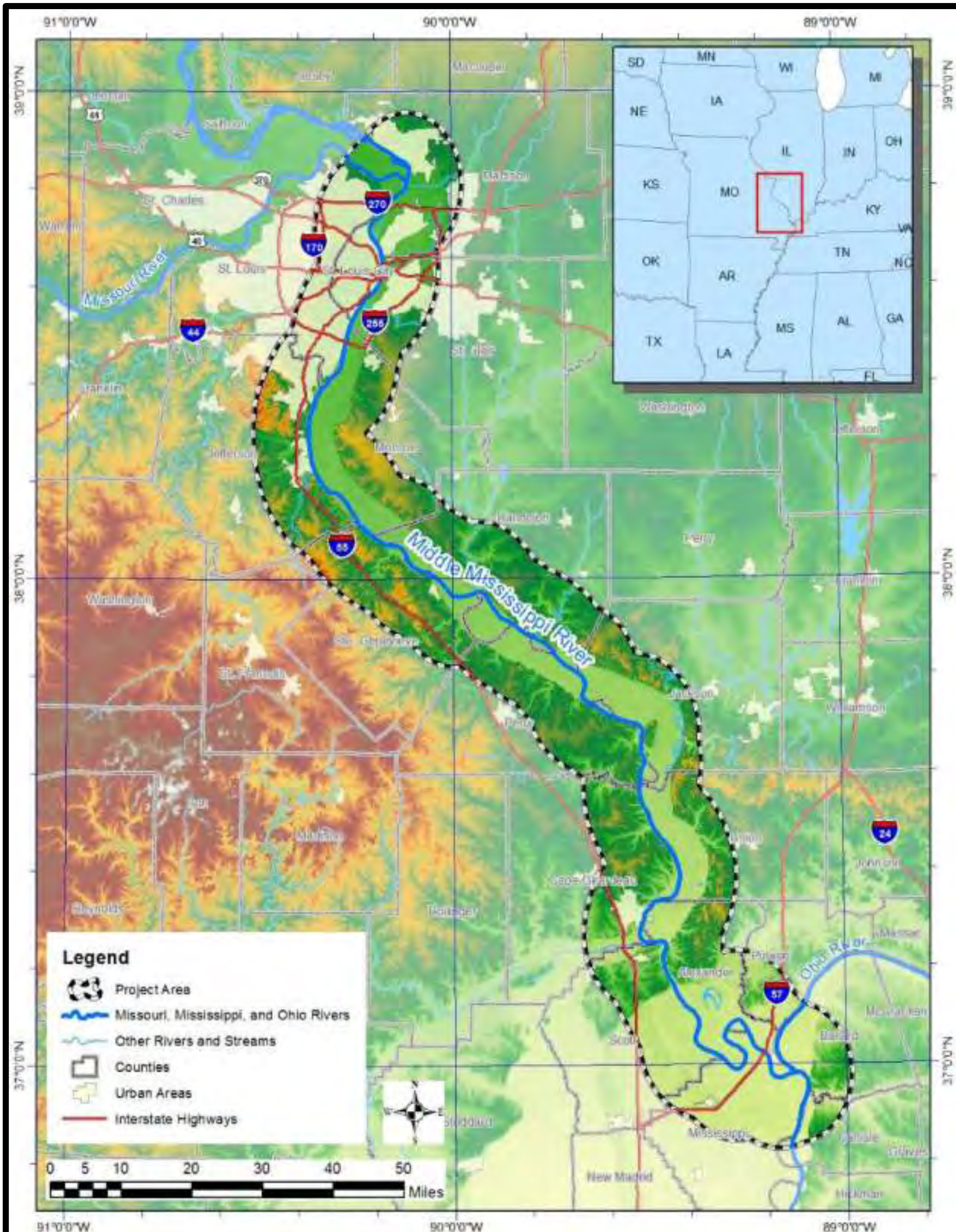


Figure 2. General location of the Project Area.

Dredging. The District currently dredges an average of approximately 4 million cubic yards of material per year from the MMR in order to maintain adequate navigation channel depths. This quantity is expected to decrease to approximately 2.4 million cubic yards per year, on average, after completion of construction of the remaining river training structures. The dredged material is generally placed in relatively close proximity to the dredge cut, outside of the navigation channel, riverward of existing river training structures, if present. Due to specific conditions at each dredging location, there are instances when dredged material cannot be placed in the main channel and must be placed closer to the bankline in main channel border areas. The District has also recently begun using a floating flexible dredge pipe to facilitate construction of sandbar/island habitat in association with dredging activities. Floating flexible dredge pipe is advantageous over typical rigid dredge pipe because the discharge end of the pipe can be kept in a fixed location instead of moving parallel to the dredge cut. With flexible pipe, as long as the discharge location is within a certain distance of the dredge, the position of the discharge can be fixed irrespective of the location of the dredge. Fixed-point discharge allows the buildup of material to higher elevations than is normally possible with rigid discharge pipe. This technique can be used to discharge "piles" of material to create expanses of shallow sandbar and/or ephemeral island habitat. Sandbar and island habitat is considered to be important fish habitat that is less abundant in the MMR than historically.

Dikes. The District utilizes various configurations of rock dikes to address repetitive dredging issues in the MMR. Dikes concentrate flows in the navigation channel, thereby inducing scour and reducing dredging. In response to natural resource agency partner concerns about the potential impacts of traditional dikes on fish and wildlife habitat, the St. Louis District developed innovative dike configurations that provide depth and flow diversity while still maintaining the primary function of deepening the navigation channel. The District has designed and implemented many different dike configurations including notched dikes, rootless dikes, L-dikes, W-dikes (see Figure 3), chevron dikes, multiple roundpoint structures (see Figure 3), etc. The District currently builds very few traditional wing dike structures in the MMR and continues to develop new configurations of innovative structures through coordination with natural resource agency partners.

Figure 3. Multiple roundpoint structure and W-dike on the MMR (River Mile 4 near Cairo, IL).

Bendway Weirs. Bendway weirs are low-level, submerged rock structures positioned from the outside bankline of a riverbend, angled upstream toward the flow. These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's secondary currents in a manner which controls excessive channel deepening, reduces adjacent riverbank erosion on the outside bendway and aligns the thalweg toward the center of the channel away from the outside of the bend. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging.

Revetment. Rock revetment is primarily used to prevent bank erosion and channel migration on the banks of the river and to establish or maintain a desired channel alignment.

B. General Description of Dredged and Fill Material.

(1) General Characteristics of Material

Dredged Material. Material dredged from the main channel of the MMR is predominately sand. As a requirement associated with Clean Water Act Section 401 Water Quality Certification, the District conducts grain size analysis on all dredge locations to ensure that less than 20 percent of the material is silt and clay. Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. If any sample contains more than 20 percent silt and clay, further chemical testing is required to analyze for potential contaminants.

Rock. Rock used for construction and maintenance of dikes, weirs, and revetment consists of quarry run limestone consisting of graded “A” stone. Size requirements for graded “A” stone are shown below in Table 1.

Table 1. Composition of graded "A" stone.

Stone Weight (pounds)	Cumulative % Finer by Weight
5,000	100
2,500	70-100
500	40-65
100	20-45
5	0-15
1	0-5

(2) Quantity of Material.

Dredged Material. The amount of material dredged in the MMR to maintain the navigation channel fluctuates greatly from year to year based on a range of factors, river stage being foremost among them. The average quantity currently dredged is approximately 4 million cubic yards per year. This quantity is expected to decrease to approximately 2.4 million cubic yards per year, on average, after the remaining construction of river training structures at chronic dredging sites is completed.

Rock. The amount of stone used each year for construction of dikes, weirs, and revetment will be specified in future site specific Environmental Assessments and associated 404(b)(1) analyses. An average of approximately 260,000 tons (175,000 cubic yards) of rock placed per year is anticipated over the remaining period of construction, for a total of 4.4 million tons (2.9 million cubic yards). The amount of stone used each year for maintenance of existing structures is anticipated to be approximately 90,000 tons (60,000 cubic yards).

(3) Source of Material.

Dredged Material. The main channel of the MMR is the source of all material dredged for maintenance of the navigation channel.

Rock. Rock required for construction and maintenance is obtained from commercial stone quarries in the vicinity of the work sites capable of producing stone which meets USACE specifications (see Table 1 above).

C. Description of the Proposed Discharge Sites.

(1) Location and Size.

Dredged Material. Dredged material is generally placed in the main channel of the MMR adjacent to the location of the dredge cut. Placement in main channel border areas is occasionally necessary based on specific site conditions. Dredging and disposal has the potential to take place anywhere in the 195 miles of the MMR, but typically occurs repeatedly in the same locations. Dredging and placement locations for 2006 through 2015 can be found below in Plate 1 through Plate 13. Based on an average dredge quantity of 4 million cubic yards per year, approximately 550 acres of main channel and main channel border habitat are impacted by dredged material placement. This is expected to decrease to approximately 330 acres after completion of new construction of river training structures. When using the floating flexible dredge pipe for disposal, the placement sites would be similar in location, but would be smaller in aerial extent than sites using rigid pipe.

Rock. The exact locations and sizes of future river training structures are determined on a site by site basis and will be specified in future Environmental Assessments and associated 404(b)(1) analyses. The typical elevations, slopes, configurations, etc. of MMR river training structures can be found in the typical section drawings at Plate 14.

(2) Type of Habitat.

Habitats affected by dredged material placement and by dike and weir placement are main channel and main channel border riverine habitats. Impacts to side channel habitat are avoided and minimized to the greatest extent possible. Revetment is typically placed on the bankline of the river up to the ordinary high water line. No grading of river bank habitat is required. All dredging and river training structure placement activities are coordinated with natural resource agency partners in order to minimize adverse effects.

(3) Timing and Duration of Discharge.

Dredged Material. Any dredging that occurs in any given year typically occurs during the period of July through December; however, the actual start and end dates and the total number of days dredged varies considerably from year to year depending on water levels and sedimentation patterns. The average number of days of dredging over the last 10 dredging seasons is approximately 115. Likewise, the duration of activity at each dredge and discharge location varies considerably based on site conditions, but the average number of days spent dredging at a location over the last 10 dredging seasons is approximately 5.

Rock. Placement of rock material for river training structure construction and maintenance is highly dependent on water levels and can occur at any time of year. The duration of each construction activity is highly variable as it is dependent on the size and configuration of the structure(s) being constructed and site conditions at the time of construction.

D. Description of Disposal Method.

Dredged Material. Two methods are used for placement of dredged material in the MMR: traditional side casting of material with rigid pipeline (see Figure 4 below), and fixed location disposal with floating flexible dredge pipe (see Figure 5 below). With traditional side casting, dredged material is placed in rows parallel to the dredge cut. As the dredge moves up and down the dredge cut, the discharge pipe moves up and down the placement area resulting in long, narrow disposal areas similar in size and shape to the dredged area. The majority of dredged material disposal conducted in the District still utilizes traditional rigid pipeline. Since its first use in 2011, the floating flexible dredge pipe has been utilized for approximately 8% of the District's dredging, based on total cubic yards dredged. Dredged material placement using the floating flexible dredge pipe allows disposal at a fixed location. This allows flexibility in the height and shape of the disposal location, providing opportunity to improve fish and wildlife habitat. The percentage of dredged material disposal in the MMR using the floating flexible dredge pipe is expected to increase as the District fully implements its use; however, it is unknown what percentage of the District's dredged material disposal will be conducted with the floating flexible pipe going forward and the percentage will likely vary considerably from year to year depending on river levels, dredge requirements, etc. All dredging is coordinated with natural resource agency partners to avoid and minimize adverse effects to fish and wildlife.

Figure 4. MMR side-cast dredging using rigid disposal pipe.

Figure 5. MMR fixed-point discharge dredging using floating flexible disposal pipe.

Rock. Placement of rock material for dike, weir, and revetment construction and maintenance is accomplished by track hoe (see Figure 6 below) and/or dragline crane (see Figure 7 below). Stone is transported to placement sites by barges. All construction is accomplished from the river and all work is performed below the ordinary high water elevation. All placement of rock is coordinated with natural resource agency partners to avoid and minimize adverse effects to fish and wildlife.

Figure 6. Construction of MMR dike with barge-mounted track hoe.

Figure 7. Construction of MMR dike with barge-mounted dragline crane.

II. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations.

(1) Comparison to Existing Substrate and Fill.

Dredged Material. Dredged material placed in main channel and main channel border areas is very similar in composition to the existing substrate, consisting primarily of sand with little gravel, silt, or clay content.

Rock. Rock fill material used in construction and maintenance of dikes, weirs, and revetment is graded limestone from local quarries. Rock fill material is placed on existing substrate that consists largely of sand with little gravel, silt, or clay content. Rock fill material used in future construction and maintenance operations will be similar in size and composition to existing dike, weir, and revetment material in the MMR.

(2) Changes to Disposal Area Elevation.

Dredged Material. Placement of dredged material using traditional rigid discharge pipeline generally results in a disposal area that is shallower to approximately the same degree that the associated dredged area is deeper. While the exact depth of material placed in a disposal area varies with each dredging event and also varies across an individual placement site based on natural riverbed elevation variations, the average amount of material removed from dredge cuts and placed in disposal areas in the MMR is approximately 4.5 feet. When floating flexible dredge pipe is used, the change in elevation of the disposal area will vary greatly from site to site but will generally be greater than if traditional rigid pipe were used.

Rock. Placement of stone associated with dike, weir, and revetment construction and maintenance will cause an immediate change in elevation over the aerial extent of the structure from the pre-construction condition to the design elevation of the structure. Design elevations of structures will vary from site to site based on local conditions and the intended purpose of the structures. Typical structure designs can be found at Plate 14.

In addition to the change in elevation in the footprint of the structure, dikes and weirs will also likely cause permanent changes in elevation of adjacent areas. Structures typically cause varying patterns of scour and deposition in the immediate vicinity of the area of placement and are designed to induce scour in the adjacent navigation channel. The degree of elevation changes both in the area of placement and the adjacent navigation channel will vary based on local conditions and the configuration of each structure.

(3) Migration of Fill.

Dredged Material. Dredged material placement sites generally return to their pre-placement elevation over time, with fill gradually eroding and migrating downstream. How quickly this occurs is largely dependent on the configuration of the river channel at the placement site and river stages subsequent to placement.

Rock. Rock fill material used in construction and maintenance of dikes, weirs, and revetment is intended to be very stable and resistant to the erosive forces of the river.

Nonetheless, some erosion of stone does occur, particularly during high flow events and winter ice conditions.

(4) Changes to Environmental Quality and Value.

Dredged Material. The dredged material placed in disposal areas is of similar composition to the existing material and is, therefore, anticipated to be of equivalent environmental quality and value.

Rock. The rock fill material used in construction of dikes, weirs, and revetment is expected to provide improved substrate for colonization by a wide variety of macroinvertebrates. The environmental quality and value of the substrate is anticipated to be of equal or greater value in relation to the existing material.

The changes in elevation of adjacent areas associated with placement of rock structures, in combination with the changes in current patterns discussed in Section II.B.(1) below, are anticipated to have an adverse effect on some segments of the MMR fish community. This adverse effect and proposed mitigation measures are discussed further in Section II.E.(3) below.

(5) Actions to Minimize Impacts.

All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas.

B. <u>Water Circulation, Fluctuation, and Salinity Determinations.</u>

(1) Alteration of Current Patterns and Water Circulation.

Dredged Material. Some minor changes in current patterns are expected at placement sites due to changes in elevation. These changes are expected to gradually subside as the disposal site elevations return to normal over time.

Rock. Dikes and weirs are specifically designed to alter current and sedimentation patterns to improve the depth and/or alignment of the navigation channel. Dike placement alters current patterns in main channel border areas downstream by creating diverse areas of slack water, eddies, and current breaks, particularly at river stages when structures are not overtopped. The exact pattern of circulation depends on the type of dike constructed and the location within the river channel. Dike placement also alters current patterns in the adjacent navigation channel. Velocities in the navigation channel initially increase in response to dike placement, resulting in channel deepening. Velocities gradually return to pre-construction levels as the channel deepens.

Weirs are placed on outside river bends to shift current patterns away from the outside bend, thereby controlling excessive channel deepening, reducing adjacent riverbank erosion on the outside bendway, and shifting the navigation channel toward the center of the river. This results in a wider, more evenly distributed current pattern across the bend, and, consequently, a safer navigation channel.

Revetment has little impact on current patterns and water circulation.

(2) Interference with Water Level Fluctuation.

Analysis of river stage data over time from gages on the MMR indicates that there appears to be a trend of decreasing river stages at lower flows on the MMR. This is likely caused by a combination of river training structures deepening the channel and a decrease in the sediment load entering the MMR from upstream tributaries. Based on current projections, decreases in stage of 0.13 to 0.88 feet can be anticipated at St. Louis across the range of non-flood flows (less than 425,000 cfs). Stages at Chester are anticipated to decrease 0.08 to 0.30 feet only at flows between 75,000 and 150,000 cfs and are anticipated to increase at all other flows. It is not possible to differentiate what portion of this effect is attributable to river training structure construction versus a reduction in sediment load from tributaries.

(3) Salinity Gradient Alteration. No effect.

(4) Cumulative Effects on Water Quality.

a. Salinity. No effect.
b. Clarity. See suspended particulate / turbidity determinations below.
c. Color. No effect.
d. Water Chemistry and Dissolved Gasses. Limestone material used for construction and maintenance of structures 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 expected to be negligible.
e. Temperature. No effect.
f. Nutrients. No effect.

(5) Changes to Environmental Quality and Value.

The changes in current patterns associated with placement of rock structures, in combination with the changes in elevation discussed in Section II.A.(2) above, are anticipated to have an adverse effect on some segments of the MMR fish community. This adverse effect and proposed mitigation measures are discussed further in Section II.E.(3) below.

(6) Actions Taken to Minimize Impacts.

All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas.

C. Suspended Particulate / Turbidity Determinations.

(1) Alteration of Suspended Particulate Type and Concentration.

Disposal of dredged material is likely to result in increased turbidity in the immediate vicinity of the placement area and for a short distance downstream. However, given the general lack of fine-grained sediments in dredged material, the similarity of dredged material to placement area material, and the degree of natural variability in MMR turbidity, this effect is expected to be short-term and minor.

Construction and maintenance of dikes, weirs, and revetment is likely to result in a slight increase in turbidity in the vicinity of construction activities. However, given the degree of natural variability in MMR turbidity, this effect is expected to minor.

Dikes and weirs are designed to change current and sedimentation patterns and would, therefore, cause some minor temporary changes in the suspended sediment concentration in the immediate vicinity of placement locations as the river bed adjusts to the altered flow patterns. When compared to the typical sediment load in the MMR, this increase in suspended sediment concentration from all future river training structure construction and maintenance is expected to be negligible.

Revetment is designed to reduce bankline erosion and would, therefore, reduce suspended sediment concentration in the immediate vicinity of placement locations indefinitely. When compared to the typical sediment load in the MMR, this reduction in suspended sediment associated with reduced bankline erosion from all future revetment construction is considered negligible.

(2) Particulate Plumes Associated with Discharge.

Discharge of dredged material is expected to result in some degree of particulate plume in the vicinity of the placement area. The degree of increase in turbidity is directly related to the proportion of fine-grained sediment in the material to be dredged (Herbich and Brahme 1991). Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. Given that the vast majority of dredged material is sand and not fine-grained material that would stay in suspension longer, the impact would be localized and would dissipate quickly. Turbidity plumes from dredging operations in the Upper Mississippi River are generally undetectable one-half mile downstream from the dredging location (WEST 2000). The Corps' St. Paul District monitored dredging operations in the main channel of the Mississippi River in the 1970s (Anderson et al. 1981a; Anderson et al. 1981b) and found that dredging operations had only minor, localized effects on turbidity. The Corps' Kansas City District monitored dredging operations on the Lower Missouri River in the 1980s (USACE 1990) and found that the plume from dredging operations returned to background levels within approximately 1,300 feet.

Construction and maintenance of dikes, weirs, and revetment is likely to result in minor particulate plumes in the immediate vicinity of construction activities. However, this effect is expected to be minor given its highly localized nature and the natural variability in background turbidity levels on the MMR.

(3) State Water Quality Standards. No violations of state water quality standards are anticipated. The District obtains Clean Water Act Section 401 Water Quality Certification for all dredging and river training structure construction activities on the MMR as required.

(4) Changes to Environmental Quality and Value. No effect.

(5) Actions to Minimize Impacts. No actions to minimize impacts necessary.

D. Contaminant Determinations.

As a requirement associated with Clean Water Act Section 401 Water Quality Certification, the District conducts grain size analysis on all dredge locations to ensure that less than 20 percent of the material is silt and clay. Grain size data collected from dredge and disposal sites in the MMR from 2007 to 2013 indicate that the average composition of sediments was more than 99% sand and gravel and less than 1% fine-grained. If any samples contain more than 20 percent silt and clay, further chemical testing is required to analyze for potential contaminants. In addition, all potential river training structure placement sites are screened to facilitate early identification of potential hazardous, toxic, and radioactive waste in accordance with USACE regulations (ER 1165-2-132 and ER 200-2-3). Accordingly, no adverse effects from contaminants are anticipated.

E. Aquatic Ecosystem and Organism Determinations.

(1) Effects on Plankton. No effect.

(2) Effects on Benthos.

Dredged Material. Due to the shifting nature of main channel sediments and the lack of fine organic particulate matter, main channel disposal areas generally provide poor habitat for macroinvertebrate colonization. Nonetheless, these areas do typically hold low densities of benthic macroinvertebrates that are likely lost through burying at the disposal site. Losses of benthic macroinvertebrates at main channel border disposal sites are likely much greater due to greater densities of organisms. Based on the current average annual dredge quantity of approximately 4 million cubic yards, approximately 550 acres of habitat are impacted by dredged material disposal each year. Given the naturally dynamic nature of the largely main channel areas impacted by dredged material disposal, the low densities of macroinvertebrates found in these habitats, and the fact that these areas only represent, on average, approximately 2 percent of the riverine habitat in the MMR today, adverse effects to benthic macroinvertebrates associated with dredging are anticipated to be minor. These adverse effects are expected to decrease gradually as chronic dredging locations are addressed through construction of new river training structures.

Rock. Placement of stone for dike, weir, and revetment construction and maintenance likely eliminates those benthic organisms utilizing the habitat and largely precludes future re-colonization. However, the rock used for river training structure construction generally provides habitat that results in greater densities of macroinvertebrates than the native sediments it replaces. Future construction of river training structures is expected to increase benthic macroinvertebrate numbers.

(3) Effects on Nekton.

Dredged Material. Placement of dredged material in main channel and main channel border areas likely temporarily causes avoidance of the areas by fish due to disturbance. This effect is short-term with dredge placement areas being usable by fish soon after completion of dredging. The floating flexible dredge pipe is specifically used to improve habitat diversity of dredge placement sites. Based on the current average annual dredge quantity of approximately 4 million cubic yards, approximately 550 acres of habitat are impacted by dredged material disposal each year, which represents approximately 2 percent of the riverine habitat in the MMR. This is expected to decrease to approximately 2.4 million cubic yards and 330 acres of habitat over the course of the remaining period of construction. Adverse effects to the MMR fish community from dredged material placement is anticipated to be minor.

Rock. Direct impacts from placement of rock for dike, weir, and revetment construction and maintenance activities on the MMR fish community are expected to be minor as fish likely avoid sites during construction. Placement of river training structures is expected to indirectly benefit the MMR fish community by increasing habitat diversity and by increasing the amount of shallow low velocity main channel border habitat which is generally regarded as important habitat to a large segment of the fish community. However, along with these benefits, there are adverse effects to fish that are anticipated with future construction of river training structures. Three-dimensional modeling conducted by the District indicates that construction of river training structures generally results in a decrease in shallow to moderate-depth, moderate- to high-velocity habitat which is important habitat to some MMR fluvial specialists, or species that are found almost exclusively in flowing water throughout their life cycles. This habitat is characteristic of MMR unstructured main channel border areas. Based on the amount of remaining construction anticipated, it is estimated that river training structure construction could affect another 1,100 acres[1] of unstructured main channel border habitat. This represents approximately 8% of the remaining unstructured main channel

[1] The stated impact of 1,100 acres is a programmatic estimate based on the best available information. Actual impact acreages and compensatory mitigation to be considered will not be known until a main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.

border habitat in the MMR. This conversion is expected to have a significant adverse effect on the MMR fish community and the District has concluded that this may warrant consideration of compensatory mitigation.

Compensatory Mitigation. In order to compensate for the projected adverse effects of future river training structure placement, potential mitigation measures may include, but are not limited to, wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. Removal, shortening, notching, etc. of existing obsolete river training structures would facilitate the replacement of lost function with an equivalent amount of habitat function. This could be accomplished by restoring the amount of unstructured main channel border habitat that is lost by future placement of river training structures. An evaluation of current channel bathymetry on the Middle Mississippi River reveals opportunities where existing river training structures could be removed, shortened, and/or notched without adversely affecting the current dredging requirements of the adjacent navigation channel. Detailed mitigation planning will be handled on a site by site basis and will be covered in site-specific Environmental Assessments and associated 404(b)(1) analyses.

(4) Effects on the Aquatic Food Web. No effects on the aquatic food web, beyond those effects on the constituent organisms delineated above, are anticipated.

(5) Effects on Special Aquatic Sites.
   a. Sanctuaries and refuges. No effect.
   b. Wetlands. No effect.
   c. Mud Flats. No effect.
   d. Vegetated shallows. No effect.
   e. Coral reefs. No effect.
   f. Riffle and pool complexes. No effect.

(6) Effects on Threatened and Endangered Species.

In 1999 the Corps prepared a Tier I Biological Assessment for the Operation and Maintenance of the Upper Mississippi River Navigation Project within the St. Paul, Rock Island, and St. Louis Districts to determine the impacts of operation and maintenance of the 9-foot navigation channel on threatened and endangered species. Subsequently, the U.S. Fish and Wildlife Service prepared a Biological Opinion on the O&M of the 9-foot navigation channel. In their Biological Opinion, the Service concluded that continued operation and maintenance of the 9-foot navigation channel

- would jeopardize the continued existence of the pallid sturgeon (*Scaphirhynchus albus*),
- would not jeopardize the continued existence of the least tern (*Sterna antillarum*), but would result in incidental take,

- would likely adversely affect the Indiana bat (*Myotis sodalis*), but impacts would be offset by management actions or would be negligible and would not rise to the level of incidental take, and
- would adversely affect the decurrent false aster (*Boltonia decurrens*), but would not jeopardize its continued existence.

Based on these determinations, the Service recommended appropriate actions for the Corps to take in order to avoid impacts to pallid sturgeon and least terns. The Corps initiated implementation of these actions subsequent to the issuance of the Biological Opinion and currently continues to implement them. Implementation of the recommendations of the Biological Opinion is coordinated extensively and continually with the Service and other natural resource agencies. Implementation of the District's Biological Opinion activities is expected to continue until such time as the species are considered recovered or it is determined that the District's actions are no longer jeopardizing the species or resulting in incidental take.

In addition to the species covered by the 2000 Biological Opinion, nine new species have been listed for counties in the Project Area since that time (see Table 2 below). The District has concluded that the Project may affect but is not likely to adversely affect the Northern long-eared bat and will have no effect on the remaining species.

Table 2. Federally threatened or endangered species potentially found in Missouri and Illinois counties in the Project Area that have been listed since issuance of the 2000 Biological Opinion.

Species	Federal Status
Red knot (*Calidris canutus rufa*)	Threatened – listed in 2015
Rabbitsfoot (*Quadrula cylindrica cylindrica*)	Threatened – listed in 2013
Scaleshell mussel (*Leptodon leptodon*)	Endangered – listed in 2001
Sheepnose mussel (*Plethobasus cyphyus*)	Endangered – listed in 2012
Snuffbox mussel (*Epioblasma triquetra*)	Endangered – listed in 2012
Spectaclecase (*Cumberlandia monodonta*)	Endangered – listed in 2012
Grotto sculpin (*Cottus specus*)	Endangered – listed in 2013
Northern long-eared bat (*Myotis septentrionalis*)	Threatened – listed in 2015
Eastern massasauga (*Sistrurus catenatus*)	Threatened – listed in 2016

(7) Effects on Other Wildlife. No effect.

(8) Actions to Minimize Impacts.

All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas. Compensatory mitigation will be considered to offset adverse effects to the MMR fish community based on ongoing site-specific analysis of impacts.

F. Proposed Disposal Site Determinations.

Discussions pertaining to turbidity and suspended particulates are covered under Section II.C above. Discussions pertaining to contaminants are covered under Section II.D above. Implementation of the proposed project will have no significant adverse effects on municipal or private water supplies; recreational or commercial fisheries; water-related recreation or aesthetics; parks; national monuments; or other similar preserves. Any adverse effects not covered by compensatory mitigation measures will be minor and of short-term duration.

G. Determination of Cumulative Effects on the Aquatic Ecosystem.

No significant adverse cumulative effects are anticipated beyond those outlined in Section II.E.(3) above.

H. Determination of Secondary Effects on the Aquatic Ecosystem.

No significant adverse secondary effects are anticipated beyond those outlined in Section II.E.(3) above.

III. FINDINGS OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS ON DISCHARGE

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

B. Alternatives. No practicable alternatives to the proposed discharges could be identified that would have less adverse effect on the aquatic ecosystem.

C. Compliance with State Water Quality Standards. Chemical constituents of the materials released during disposal operations are not expected to exceed Missouri or Illinois Water Quality Standards. The District obtains Clean Water Act Section 401 Water Quality Certification for all dredging and river training structure construction activities on the MMR as required.

D. Compliance with Endangered Species Act. The proposed action is compliant with the Endangered Species Act of 1973, as amended.

E. Evaluation of Extent of Degradation of the Waters of the United States. The proposed dredging and placement activities would not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing. The proposed activities would not adversely affect plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic life and other wildlife would not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability and on recreational, aesthetic, and economic values would not occur.

F. Appropriate and Practicable Steps Taken to Minimize Potential Adverse Impacts of the Discharge on the Aquatic Ecosystem. All dredging, disposal, construction, and maintenance activities are coordinated with natural resource agency partners to avoid and minimize any potential adverse effects to the greatest extent practicable. In addition, the District utilizes innovative river training structure designs and floating flexible dredge pipe whenever feasible in order to increase habitat diversity in and around placement areas. Compensatory mitigation will be considered on a site-specific basis to offset adverse effects to the MMR fish community. Accordingly, the project as proposed is specified as complying with the requirements of these guidelines.

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PLATES

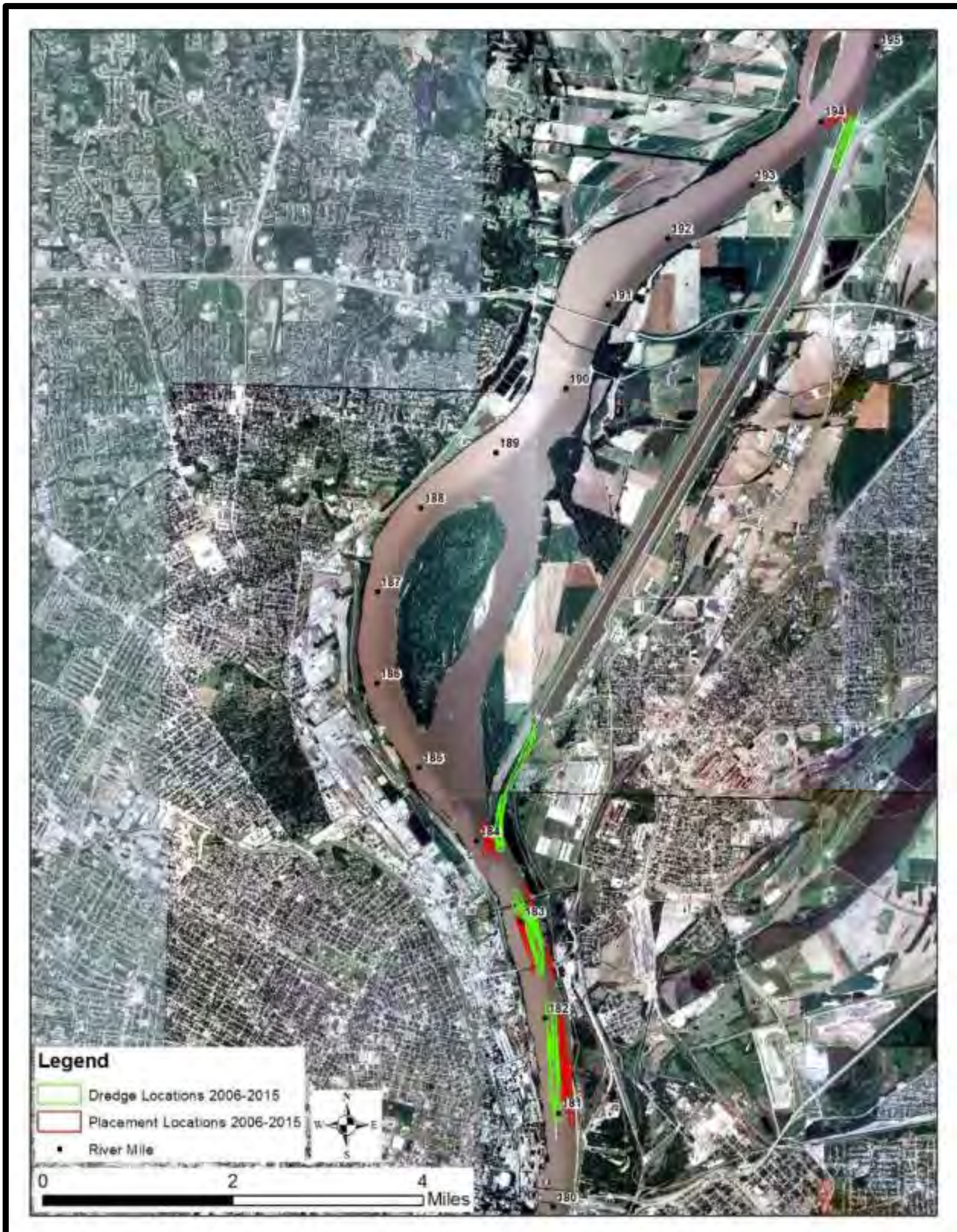

Plate 1. MMR dredge and placement locations, 2006 to 2015, river miles 195 to 180

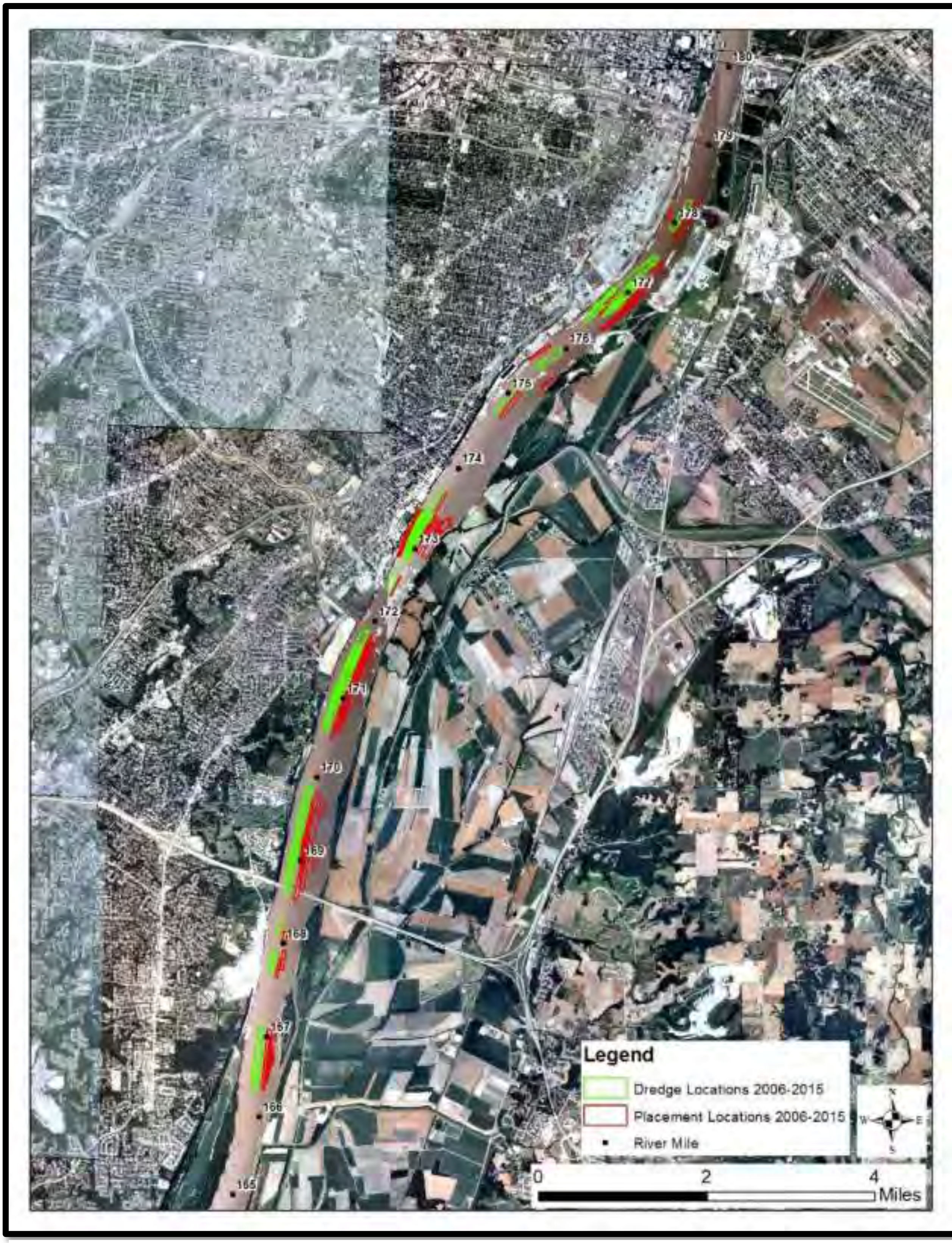

Plate 2. MMR dredge and placement locations, 2006 to 2015, river miles 180 to 165.

Plate 3. MMR dredge and placement locations, 2006 to 2015, river miles 165 to 150.

Plate 4. MMR dredge and placement locations, 2006 to 2015, river miles 150 to 135.

Plate 5. MMR dredge and placement locations, 2006 to 2015, river miles 135 to 120.

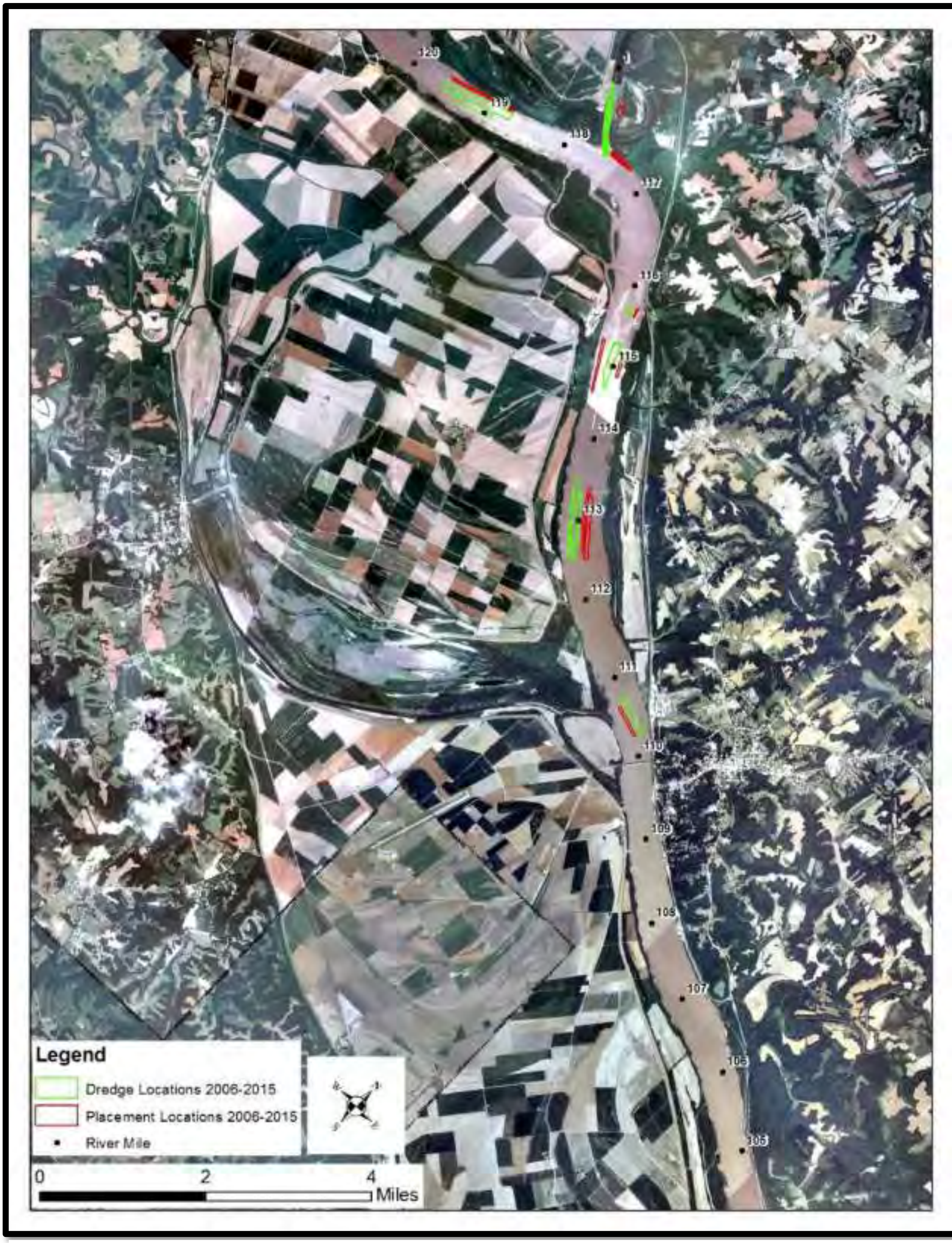

Plate 6. MMR dredge and placement locations, 2006 to 2015, river miles 120 to 105.

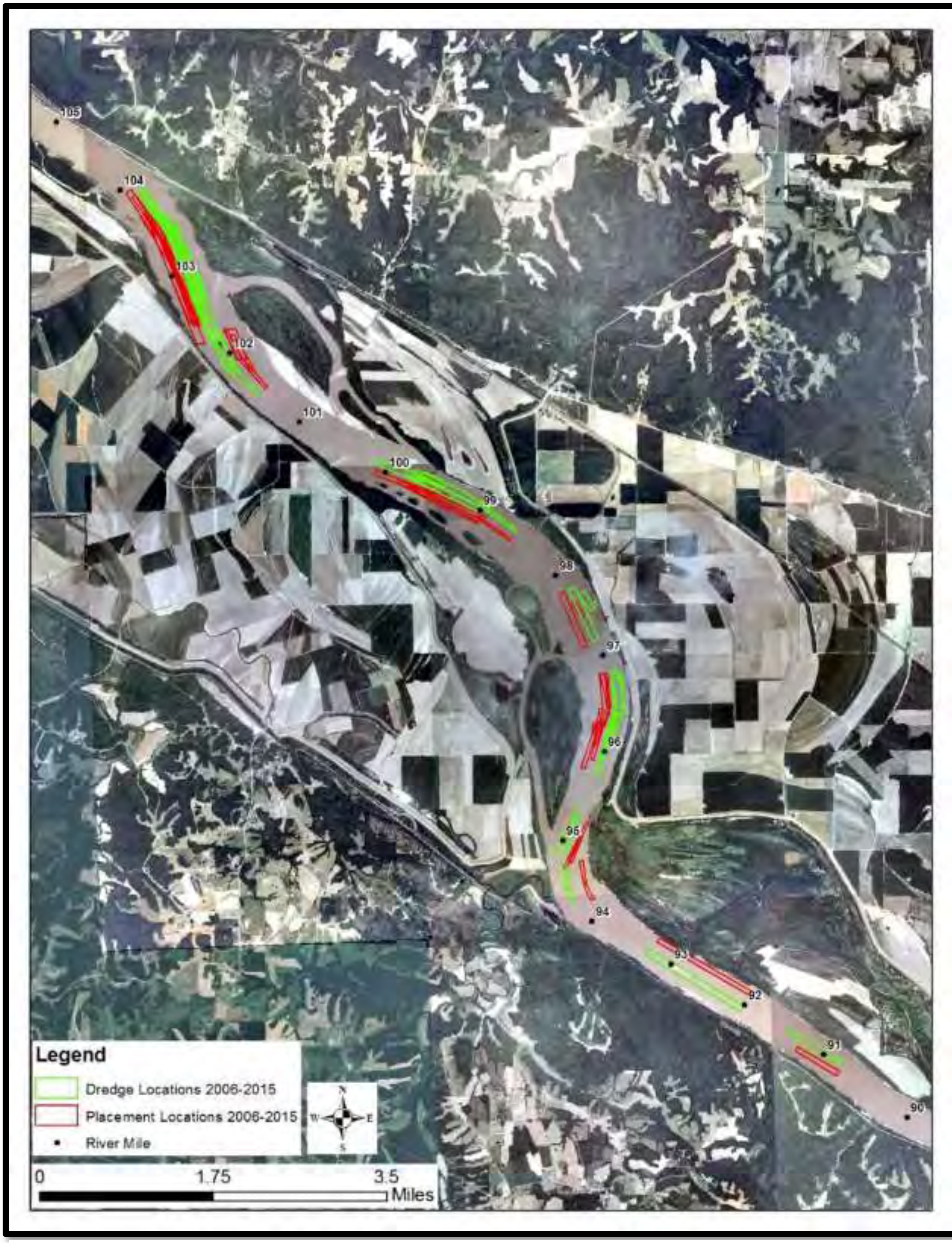

Plate 7. MMR dredge and placement locations, 2006 to 2015, river miles 105 to 90.

Plate 8. MMR dredge and placement locations, 2006 to 2015, river miles 90 to 75.

Plate 9. MMR dredge and placement locations, 2006 to 2015, river miles 75 to 60.

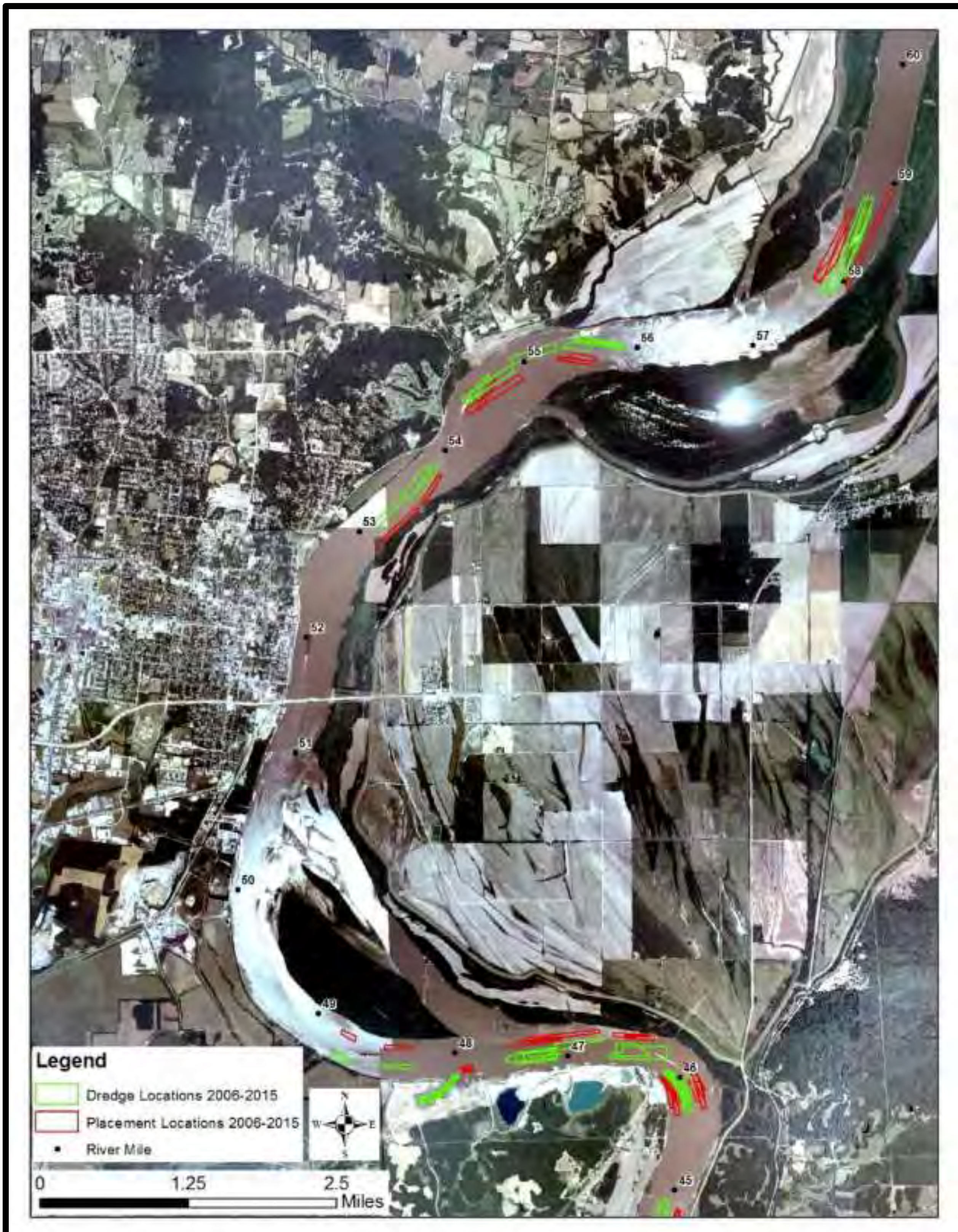

Plate 10. MMR dredge and placement locations, 2006 to 2015, river miles 60 to 45.

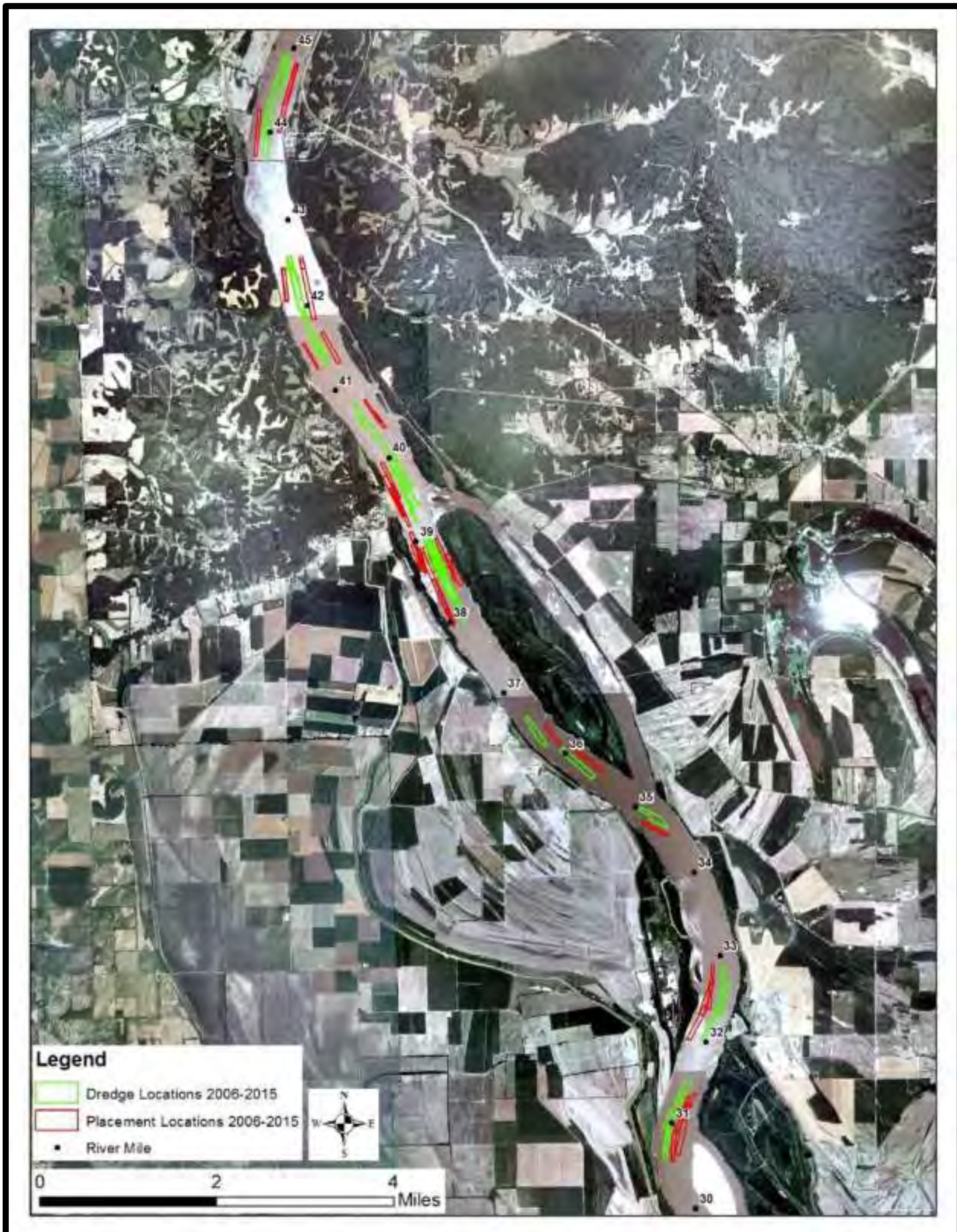

Plate 11. MMR dredge and placement locations, 2006 to 2015, river miles 45 to 30.

Plate 12. MMR dredge and placement locations, 2006 to 2015, river miles 30 to 15.

Plate 13. MMR dredge and placement locations, 2006 to 2015, river miles 15 to 0.

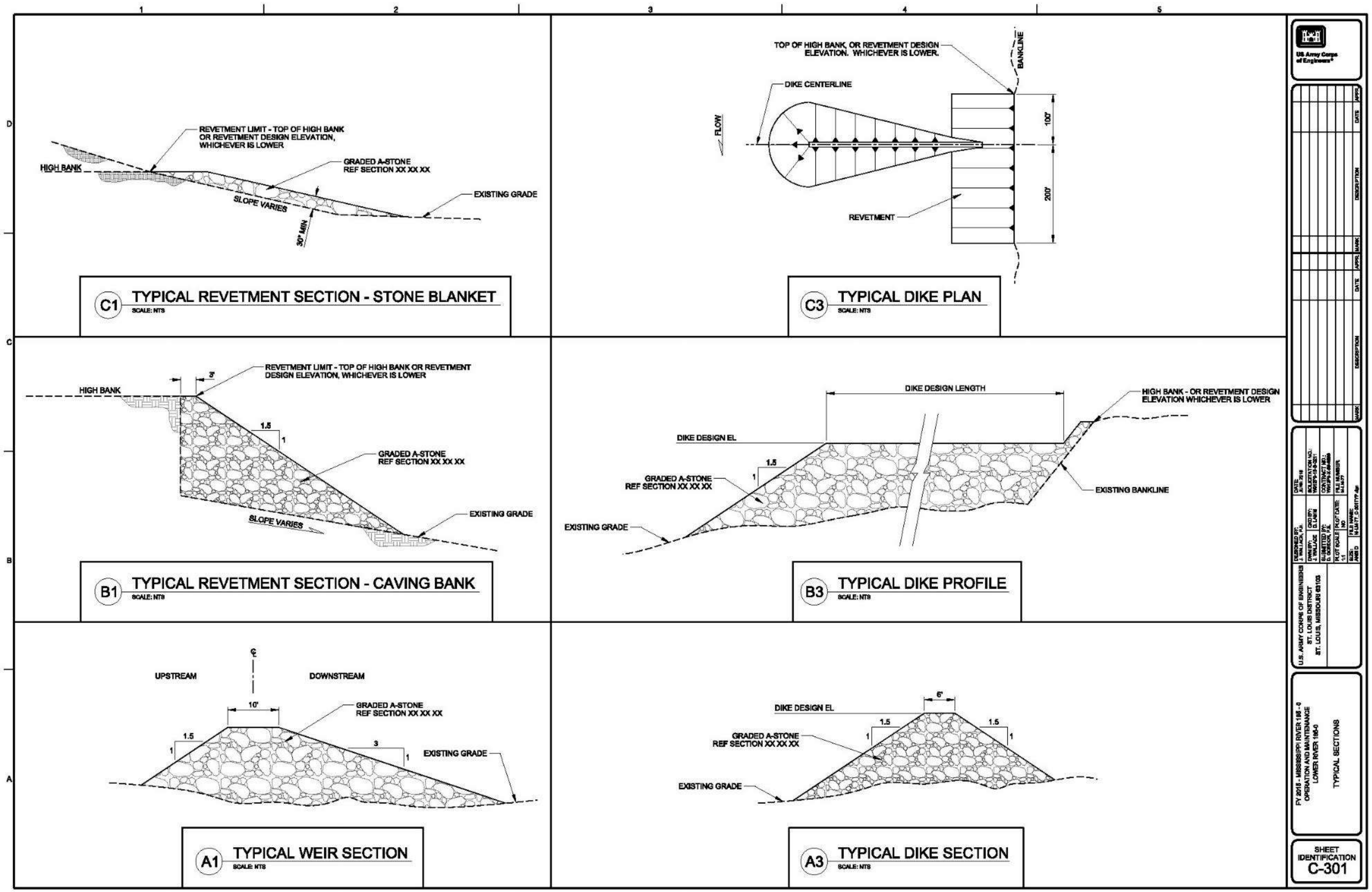

Plate 14. Typical structure sections.

Appendix E: Agency and Tribal Government Coordination including Comments and Responses

Appendix E: Agency and Tribal Government Coordination including Comments and Responses

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United States Department of the Interior

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

FWS/MISO

April 28, 2017

Colonel Anthony P. Mitchell
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103-2833

Attn: Mr. Brian Johnson

Dear Colonel Mitchell:

Thank you for the opportunity to review and comment on the revised Biological Assessment (BA) prepared for the Regulating Works Project Supplemental Environmental Impact Statement (SEIS). These comments are prepared under the authority of and in accordance with the provisions of 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.).

Threatened and Endangered Species

The Biological Assessment (BA) was prepared to address newly listed species that were not included in the 1999 Biological Assessment and 2000 Biological Opinion for the Operation and Maintenance of the 9-foot Navigation Channel on the Upper Mississippi River System. The species include the federally endangered grotto sculpin (*Cottus specus*), endangered scaleshell mussel (*Leptodea leptodon*), endangered sheepnose mussel (*Plethobasus cyphyus*), endangered snuffbox mussel (*Epioblasma triquetra*), endangered spectaclecase mussel (*Cumberlandia monodonta*), threatened eastern massasauga rattlesnake (*Sistrurus catenatus*), threatened northern long-eared bat (*Myotis septentrionalis*), threatened rabbitsfoot mussel (*Quadrula cylindrical cylindrica*), and threatened rufa red knot (*Calidris canutus rufa*).

Information provided in the BA indicates that habitat for the grotto sculpin and eastern massasauga is not found within the project area; therefore, the Corps has determined the proposed project will have no effect on these species. In addition, there are no records of occurrence in the Middle Mississippi River for the rabbitsfoot, scaleshell, sheepnose, snuffbox, and spectaclecase mussels, thus the Corps has determined the proposed project will have no effect on these species. 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 these species.

Information in the BA indicates that the rufa red knot is a rare migrant along this portion of the Mississippi River and that habitat for this species will not be substantially impacted by the proposed project; therefore, the Corps has determined that the proposed project is not likely to adversely affect the rufa red knot. Based on the information provided in the BA, the Service concurs that the proposed project is not likely to adversely affect the rufa red knot. Information in the BA indicates that suitable habitat for the northern long-eared bat occurs within the project area and past surveys indicate likely presence within the project area. The Corps has determined that components of the proposed project may impact habitat of the northern long-eared bat, but that with implementation of avoidance and minimization measures established during subsequent tiered consultation the proposed impacts are not likely to adversely affect the northern long-eared bat. Based on this information, the Service concurs that the proposed project is not likely to adversely affect the northern long-eared bat. 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 revised BA. For additional coordination, please contact me at (618) 997-3344, ext. 345.

Sincerely,

/s/ Matthew T. Mangan

Matthew T. Mangan
Fish and Wildlife Biologist

United States Department of the Interior

OFFICE OF THE SECRETARY
Office of Environmental Policy and Compliance
Denver Federal Center, Building 67, Room 118
Post Office Box 25007 (D-108)
Denver, Colorado 80225-0007

January 12, 2017

In Reply Refer To:
9043.1
ER 16/0636

Major General Michael C. Wehr
Commanding General, Mississippi Valley Division, U.S. Army Corps of Engineers
President, Mississippi River Commission
1400 Walnut Street, Vicksburg, MS 39181

Attn: Kip Runyon
1222 Spruce Street
St. Louis, MO, 63103-2833
RegWorksSEIS@usace.army.mil

Re: Draft Supplemental Environmental Impact Statement (SEIS) for Middle Mississippi River (Between the Ohio and Missouri Rivers) Regulating Works, Missouri and Illinois

Dear General Wehr:

The U.S. Department of the Interior (Department) has reviewed the referenced document and offers the following comments. This response is provided in accordance with provisions of the National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. 4321 et seq.), the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.), the Bald and Golden Eagle Protection Act (BGEPA) (54 Stat. 250, as amended, 16 U.S.C. 668a-d), the Migratory Bird Treaty Act (MBTA) (40 Stat. 755, as amended; 16 U.S.C. 703 et seq.), the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and Executive Order 13186: Responsibilities of Federal Agencies to Protect Migratory Birds (E.O. 13186, January, 2001).

Project Summary

The St. Louis District (District) of the U.S. Army Corps of Engineers (USACE) is charged with operating and maintaining a navigation channel on the Middle Mississippi River (MMR) that is nine feet deep, 300 feet wide with additional width in bends as necessary. The MMR is defined as the portion of the Mississippi River that lies between its confluence with the Ohio and the Missouri Rivers. This ongoing project is also commonly referred to as the Regulating Works Project (Project). The Project utilizes bank stabilization, rock removal, and sediment management to maintain bank stability and ensure adequate navigation depth and width. Bank stabilization is achieved by revetment and river training structures, while sediment management is achieved by river training structures. The Project is maintained through dredging and any needed maintenance to already constructed features. The environmental impacts of the Project were originally documented in the 1976 Environmental Impact Statement (1976 EIS).

The SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward since issuance of the Notice of Intent (NOI) to prepare the draft SEIS as published in the Federal Register (December 2013). Alternatives considered for the project include the Continue Construction Alternative (preferred alternative) and the No New Construction Alternative. The Continue Construction Alternative or No Action Alternative includes continuing with construction of new river training structures or revetment for navigation purposes until such time as the cost of placing more structures is no longer justified by the resultant reduction in repetitive dredging quantities and associated costs. This is currently estimated to require approximately 4.4 million tons (2.9 million cubic yards) of rock and construction would continue for approximately 17 years. This alternative would also involve continuing to dredge as necessary, completing known bankline stabilization projects to reduce the risk of a channel cutoff, placing additional revetment, and continuing to maintain existing structures. Dredge quantities would be expected to decrease from their current average annual quantity of approximately 4 million cubic yards to approximately 2.4 million cubic yards after construction of new river training structures is complete. Analysis of the impacts of the Continue Construction Alternative to main channel border habitat suggests that future construction of river training structures will potentially result in the need for compensatory mitigation measures. The No New Construction Alternative would involve not constructing any new river training structures for navigation purposes, but continuing to maintain the navigation channel only by dredging and maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Under this alternative, maintenance dredging would continue at roughly the current average rate of approximately 4 million cubic yards per year.

Consultation

The U.S. Fish and Wildlife Service (USFWS), a Bureau of the Department, is the federal agency primarily responsible for the management of the nation's fish and wildlife resources. The USFWS has broad, delegated responsibilities to protect and enhance fish and wildlife and related public resources and interests throughout the nation. These include conservation of fish and wildlife resources; maintenance and improvement of water quality in the interest of these resources; preservation, restoration, and maintenance of naturally functioning ecosystems on which these resources depend; and the enhancement of opportunities for human uses of these resources. Thus, the USFWS is directed by statute to be the national advocate for fish and wildlife interests that could be affected by water resource development. Intervention in this proceeding is authorized by the Fish and Wildlife Act of 1956, 16 U.S.C. § 742f(a)(4), which directs the Secretary of the Interior to "take such steps as may be required for the development, advancement, management, conservation, and protection of fish and wildlife resources."

The National Park Service (NPS) should be consulted on all river related projects, not just those with the potential to affect units of the National Park System. The NPS provides technical assistance about outdoor recreation resources pursuant to the Outdoor Recreation Act of 1963

(16 U.S.C. § 4601-1), the NPS Organic Act (16 U.S.C. § 1 et seq.), the Wild and Scenic Rivers Act of 1968 (Public Law 90-542), and the National Trails System Act of 1968 (16 U.S.C. § 1246(a)). In addition, the NPS is required under the NPS Organic Act to preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this generation and future generations.

General Comments

1.1.2 Process for New Construction under the Regulating Works Project

- This section does not clearly describe coordination with partners and how partner comments are addressed and documented during the process. The USFWS recommends that the USACE more clearly define the role of partners in the project development process and how that coordination is being documented.

- Figure 1-3 – In order for Federal and State stakeholders and individuals or groups to fully understand the effects of the Project(s), the completion of post project evaluation reports and additional coordination with partners is required. These additional steps would help the stakeholders understand if the project objectives have been met and inform future project decisions. These steps would also allow for potential changes to be made if the desired outcome was not achieved. We therefore recommend that steps be added to the development process to incorporate project functionality into the decision making framework.

1.1.3 Process for Dredging under the Regulating Works Project

- The SEIS indicates that disposal is typically accomplished with unconfined, in-river placement and that upland disposal is cost-prohibitive and is generally only considered when in-channel disposal would violate water quality conditions. In addition, all dredging is coordinated with state and Federal natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits. The USFWS has been involved with developing initial general dredge disposal guidelines for the MMR (1996) and has been involved with ongoing dredge coordination including the recent development of dredging master plans for the MMR; however, the process and management strategy is generally unclear. The Rock Island and St. Paul USACE Districts have dredged material placement coordination processes in place and have worked with their partners to develop channel maintenance and dredge material management plans that help guide the placement of material on the Upper Mississippi River. The USFWS recommends that the St. Louis USACE District more clearly define the dredge material placement coordination process and consider developing a dredged material management plan the MMR as described in the USACE Planning Guidance Notebook (ER 1105-2-100).

- Specifically the USFWS is interested in evaluating all potential measures, including upland disposal, to avoid and minimize potential impacts to sensitive fish and wildlife habitats from dredge material placement. The USFWS also believes there is significant value in identifying additional areas for beneficial uses of dredged material. Since 2011, the flexible dredge pipe has been utilized for approximately 8% of the St. Louis USACE District dredging workload and the USFWS believes there are additional opportunities for utilizing the flexible dredge pipe as described in the USACE Technical Report M57 "*Engineering Considerations for Island and Sandbar Creation Using Flexible Floating Dredge Disposal Pipe Middle Mississippi River, Miles 200.0 to 0.0*". The USFWS recommends that these measures be incorporated into the dredged material management plan if developed.

- Figure 1-4 - The USFWS recommends that additional coordination occur with partners following the post-dredge survey and that this step be added to the dredging development process. Currently the USACE must provide the USFWS an annual dredge material management report that includes information concerning dredging/disposal locations, quantities of material, the results of sediment size analysis and methods of disposal. This reporting should be described in the process and implemented accordingly.

1.1.4 Dredging Reduction under the Regulating Works Project

- The described purpose of the Project is to obtain and maintain the authorized navigation channel through regulating work structures and dredging, with a goal of reducing costly dredging to a minimum. Figure 1-6 describes the quantity of material dredged from the MMR from 1964 to 2014. It is unclear from this figure what affect the regulating works program has had on reducing dredging over the specified time period. Information included in this section indicates that the amount of dredging is dependent on a number of independent factors and that it is difficult to develop trends solely from the dredging data set. Additional information is provided; however, the information appears to be insufficient to justify the continued construction of regulating work structures.

- This section is critical to describing the purpose of and need for the Project. The Purpose and Need statement is among the most important chapters in a NEPA document, because it provides the basis for determining the range of alternatives considered in detail. A strong Purpose and Need statement should (1) clearly describe each of the purposes and needs; and (2) provide specific factual information that supports the existence of those needs.

- The USFWS recommends that additional information be provided to show specifically how regulating work structures have reduced dredging in the MMR and/or how other factors have influenced the effectiveness of the Project. This could include a greater discussion on the amount sediment entering the system from the Missouri River, Upper Mississippi River, and other tributaries to the system and the transport of that sediment through the system. **Note** - This comment was previously mentioned in the Final Independent External Peer Review Report on the SEIS.

1.1.5 Process for Bank Stabilization

- This section does not clearly describe how bankline erosion is being evaluated to determine if the erosion is having an impact on the navigation channel and if bank stabilization may or may not be needed. The USFWS recommends that the USACE further describe the evaluation and project selection process for bank stabilization.

- This section does not clearly describe coordination with partners and how partner comments are addressed and documented during the process. The USFWS recommends that the USACE more clearly define the role of partners in the development process and how that coordination is being documented.

1.1.6 Rock Removal

- This section does not clearly describe the removal of rock pinnacles and outcroppings in the lower MMR and the coordination that occurred for the project. The USFWS recommends that USACE provide additional information in this section to describe the work and the coordination process for this project including coordination for any future work.

1.4 Scoping/Public Involvement

- The NOI to prepare the SEIS was published on December 20, 2013. The USFWS provided formal comments in response to the NOI in a letter dated January 17, 2014, and participated in the scoping process during a meeting of the River Resources Action Team (RRAT) Executive Board on February 20, 2014. The USACE has not provided a direct response to these comments; however, they describe in the Draft Scoping Report (April 2014) where these comments would likely be addressed in the draft SEIS. The USFWS continues to request a direct response from the USACE regarding their comments and how they were/are being addressed in the draft SEIS.

2.1 Alternatives Considered

- Alternatives considered include the Continue Construction Alternative or No Action Alternative and the No New Construction Alternative. Under the Continue Construction Alternative construction, operation, and maintenance of the Project would continue as it is currently being implemented with the addition of analyzing the potential need for and implementation of compensatory mitigation on a site-specific basis. The No New Construction Alternative consists of not constructing any new river training structures for navigation purposes but continuing to maintain the navigation channel by dredging and by maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Any alternatives outside of the Project authorization would require a planning study for either modification of the Project or new authorization from Congress on how to obtain and maintain navigation within the MMR. During the evaluation process for the SEIS the USACE did not discover any reasonable or feasible alternatives that warranted transitioning the SEIS to a planning document.

- In their January 17, 2014, letter responding to the NOI to prepare the DSEIS for the Project, the USFWS recommended the USACE consider an additional alternative that would provide a greater emphasis on the avoidance and minimization of sensitive fish and wildlife resources. This alternative would also allow for additional habitat measures for fish and wildlife resources. In addition, the USFWS requested that the USACE consult with the USFWS and state conservation agencies early in the planning process to ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. Similar comments were made by the Missouri Department of Conservation, the agency responsible for Missouri's forest, fish and wildlife resources. Currently there are very few areas in the MMR that haven't been developed or greatly impacted by the Project and most of the few remaining areas contain sensitive fish and wildlife resources. There has been increased pressure in recent years to implement Regulating Works Projects in these areas which has raised concerns with the resource agencies. The FWCA of 1958 provides that "*wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation…*" and that "*The reporting officers in project reports of the Federal agencies shall give full consideration to the report and recommendations of the Secretary of the Interior and to any report of the State agency on wildlife aspects of such projects, and the project plan shall include such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits.*" Further, the 2003 Agreement between the USFWS and the USACE for conducting FWCA activities was developed to ensure that the USFWS is involved with USACE projects to help find solutions to water resources development problems that avoid, minimize, or mitigate impacts to fish and wildlife. A major goal of the Agreement is to ensure the USFWS is invited to participate early in throughout the planning process to facilitate the FWCA's equal consideration provision. The USFWS has not been contacted about the specific recommendations provided in response to the NOI and it doesn't appear that their concerns were addressed in the SEIS. The USFWS recommends that the USACE consider their original comments and recommendations and work with the USFWS and state natural resource agencies to develop an alternative that ensures adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources.

- The 1976 EIS included a post-authorization change that would include fish and wildlife habitat restoration as a project purpose to allow the USACE to compensate for adverse effects of the project. In the 1976 EIS, the USACE recognized that the overall effects of attaining the nine-foot navigation channel have not been beneficial upon the riverine ecosystem and that a significant amount of fish and wildlife habitat has been affected. Changes proposed under the post-authorization included dredging of side channel areas to prolong and enhance the fish and wildlife attributes they possess, beneficial use of dredged material, maintenance and construction of pile dikes to enhance fish habitat, notching and/or lowering of existing dikes, and altering stone dikes to provide access to islands. The intent of this change was to preserve and enhance fish and wildlife habitat associated with the riverine system, while continuing to utilize the river for navigational purposes. The USFWS has routinely expressed their support of the USACE's efforts to effect a post-authorization change to include fish and wildlife conservation measures as a project purpose on the MMR. The USFWS believes this change would lead to preservation of existing fish and wildlife habitat, potential modifications to current construction, operation and maintenance procedures, and compensation for past project damages to fish and wildlife habitat. The USACE indicates in the SEIS that the components considered as part of the post-authorization change have been incorporated over time as components of the Project or have been addressed under other authorities that have the purpose of ecosystem restoration, thus the USACE is not considering a post-authorization change alternative in the SEIS.

- Section 3(a) of the FWCA of 1958, Section 906 of the Water Resources Development Act (WRDA) of 1986, and Section 5099 of the WRDA of 2007 authorize the protection, restoration, enhancement, and mitigation of fish and wildlife resources to occur under the Regulating Works Project.

    - Section 3(a) of the FWCA of 1958 states as follows; "*whenever the waters of any stream or other body of water are impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, adequate provision, consistent with the primary purposes of such control, shall be made for the use thereof, together with any areas of land, water, or interests therein, acquired or administered by a Federal agency, in connection therewith, for the* ***conservation***, ***maintenance****, and* ***management*** *of wildlife resources thereof, and its habitat theron, including the* ***development*** *and* ***improvement*** *of such wildlife resources pursuant to the provisions of section 2 of this Act.*"

    - Section 906(b)(1) of WRDA 1986 states as follows; "*After consultation with appropriate Federal and non-Federal agencies, the Secretary is authorized to* ***mitigate damages*** *to fish and wildlife resulting from any water resources project under his jurisdiction, whether completed, under construction, or to be constructed. Such mitigation may include the acquisition of lands or interests therein...*"

    - Section 5099 of WRDA 2007 states as follows; "*As a part of the operation and maintenance of the project for the Mississippi River (Regulating Works), between the Ohio and Missouri Rivers, Missouri and Illinois, authorized by the first section of an Act entitled ''Making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes'', approved June 25, 1910 (36 Stat. 630), the Secretary may carry out activities necessary to* ***restore*** *and* ***protect*** *fish and wildlife habitat in the middle Mississippi River system. Such activities may include modification of navigation training structures, modification and creation of side channels, modification and creation of islands, and studies and analysis necessary to apply adaptive management principles in design of future work.*" The USFWS understands that the USACE via a memorandum for commander dated May 12, 2008, has been directed to not pursue further activities under the authority of section 5099 unless funds are specifically appropriated by Congress for such work. However, given this authorization exists; this authority should be included with the existing alternatives and/or included with an additional recommended alternative.

- The USFWS recommends that an additional alternative be developed that provides greater emphasis on protection of existing fish and wildlife resources, includes restoration of fish and wildlife habitat as described in Section 5009 of WRDA 2007, and provides compensation for past Project damages to fish and wildlife habitats.

2.2 Evaluation of Alternatives

- The Continue Construction Alternative involves river training structure construction that is equivalent to approximately 4.4 million tons of additional rock being placed in the MMR and a reduction of average maintenance dredging from the current level of approximately 4 million cubic yards per year to approximately 2.4 million cubic yards per year. This construction estimate is based on the expected quantity of reduced dredging per increment of river training structure construction which was derived by comparing existing dredging locations and the quantity of stone necessary to reduce dredging in those locations. It is unclear how much consideration was given to the cumulative impact of all the river training structures on the total quantity of dredged material in the MMR as shown in Figure 1-6 and while river training structures may initially reduce localized dredging amounts. It is also unclear what effect that the structures may have over an extended length of time and across the entire system. As mentioned above, the USFWS recommends that additional information be provided to specifically explain how regulating works structures have reduced dredging in the MMR and will continue to reduce dredging in the MMR in the future. This information should also explain how other factors have influenced the effectiveness of the Project. At this time, there is insufficient information provided to support the conclusion that the proposed river training structure construction will have the intended results.

- Information in the SEIS indicates that the exact location and quantity of future dredging needs as well as the future regulating works structure locations and designs are unknown; however, the programmatic analysis was used to estimate the remaining construction and associated impacts. Based on that analysis, the continued construction of regulating training structures would be expected to have a significant impact on main channel border habitat due to the potential loss of approximately 1,100 acres (8%) of the remaining unstructured main channel border habitat in the MMR. USACE indicates that this potential loss of habitat would result in the need for compensatory mitigation. While the USFWS agrees that unavoidable impacts should receive compensatory mitigation, the USFWS's mitigation policy places emphasis on avoidance and minimization of project impacts. It is not clear if any avoidance and minimization measures were utilized in the development of the alternatives for the proposed Project. The USFWS recommends that the USACE more clearly describe the avoidance and minimization measures that were utilized to develop the alternatives included in the SEIS and develop an additional alternative that provides greater emphasis on protection of existing fish and wildlife resources through avoidance and minimization.

2.4 Identification of the Preferred Alternative

- The preferred alternative is the Continue Construction Alternative with the potential for compensatory mitigation. As previously discussed, there is a lack of information included in the SEIS to accept that the proposed river training structure construction will have the intended results and there appears to be a lack of consideration for fish and wildlife resources; therefore, the USFWS does not concur with the preferred alternative at this time. The USFWS recommends that the USACE consider their original comments (provided January 2014) and recommendations and work with the USFWS and State natural resource agencies to develop an alternative that ensures adequate and equitable protection, mitigation, and enhancement of fish and wildlife resources.

2.5 Future Implementation of the Regulating Works Project

- The SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward and under the preferred alternative. The Project would continue as it is currently being implemented with the addition of analyzing the potential need for and implementation of compensatory mitigation on a site-specific basis. As previously discussed, there is a lack of information in the SEIS regarding protection (avoidance and minimization) of fish and wildlife resources and a lack of information on how site-specific EAs will address protection (avoidance and minimization) of fish and wildlife resources. The USFWS recommends that the USACE provide additional information on how protection (avoidance and minimization) of fish and wildlife resources is being achieved at the Project level and will be achieved at the site-specific level.

- Information in the SEIS indicates that dredging activities and revetment construction are not anticipated to require site-specific EAs. It is unclear how these types of activities will be implemented in the future and what process will be followed to coordinate and consult with the agencies and to ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. The USFWS recommends that this process be more clearly described and that the USACE consider our previous comments regarding dredge coordination and consider site-specific EAs for revetment.

3.1 Introduction

- Figure 3-4 – An additional figure showing annual dike construction since development of the 1976 EIS would provide for better understanding of recent trends in dike construction and provide a better basis for understanding the potential impact of dike construction since 1976.

3.2.2 Geomorphology

- Information in the SEIS indicates that the Project has contributed to an increase in cross sectional area, hydraulic depth, conveyance, and channel volume, although it is uncertain to what extent. The USFWS recommends that additional information be provided in the SEIS or additional studies be conducted to more clearly describe the changes in geomorphology and planform since the 1976 EIS and what role the Project has had in these changes. This should include a discussion of how these changes have impacted habitats of fish and wildlife resources. Table 3-6 highlights the broad impact of the Project since the 1976 EIS. Of specific concern is the conversion or loss of 5,319 acres of main channel border habitat.

3.2.3 Side Channels

- According to the SEIS, when evaluating side channels based on geomorphology, bathymetry, and connectivity, most MMR side channels appear to be stable or improving and that has been aided by side channel restoration efforts that began in 1990's under the MMR Side Channels Habitat Rehabilitation and Conservation Initiative. However, there continue to be instances where side channels are filling and connectivity is decreasing or has been lost and a majority of side channels continue to be regulated or impacted by closing structures, upstream dike fields, and associated sediment deposition. Information in the SEIS indicates that only one of the existing thirty-two side channels does not have a closing structure and that the original purpose of the closing structures was to direct flow to the main channel to support navigation flows. The continued operation and maintenance of these structures and upstream dike fields will continue to limit flows to side channels and restrict fish use of these extremely important habitats. And while there are efforts being undertaken by the District to implement side channel restoration under different authorities, little to no restoration efforts have been implemented under the Project and this has hindered restoration efforts. Thus, the USFWS recommends that the USACE include side channel protection, maintenance, and restoration in the alternatives to be considered.

3.2.6 Air Quality and Climate Change

- There is a lack of information in the climate change section regarding potential changes in temperature, changes in precipitation patterns, and increases in the frequency and intensity of severe weather events that may impact the MMR and how those potential changes are being incorporated or evaluated in the SEIS. Some information is provided in Section 4.2.6 of the SEIS but may be more appropriate to locate in this section.

3.3 Biological Resources

- Table 3-6 – This table highlights the impact of the Project since the 1976 EIS. Of specific concern is the conversion or loss of 5,319 acres of main channel border habitat. As described in the SEIS, the proposed additional impact from the Project to main channel border habitat is technically significant due to the magnitude of the potential adverse effect to unstructured main channel border habitat in comparison to the amount of that habitat remaining and the amount of similar habitat that has been lost in the past. The USFWS is concerned that the loss and continued degradation of this habitat will reduce substrate diversity and riverine productivity, thereby, reducing the natural forage base, and will reduce the availability of fish spawning substrate, larval and juvenile fish rearing habitat, and seasonal refugia. Thus, the USFWS recommends that the USACE include main channel border habitat protection, maintenance, and restoration in the alternatives to be considered.

3.3.1 Benthic Macroinvertebrate Resources

- Information in the SEIS indicates that rock training structures have been shown to support high densities of aquatic macroinvertebrates when compared to the natural substrate of the main channel border. However, much of the described "natural substrate" has been altered due to construction of regulating works structures, dredging and dredge disposal, and clearing of woody debris. Similar results have also been found when woody debris or woody structures have been added to the system. The addition of woody structure has been shown to support higher invertebrate densities and species riches, and contained a different species composition than the surrounding substrates (Ecological Specialists, Inc., 2004). Incorporation of woody debris and use of woody structures have been identified as habitat restoration and enhancement measures in the USFWS's 2000 BO. This section should include a discussion of woody debris, including a discussion of the Woody Structure Pilot Project and invertebrate results described in the report below.

- Ecological Specialists, Inc. 2004. Final Report: Evaluation of Macroinvertebrate use of Woody Structure and Surrounding Substrate in the Open Portion of the Upper Mississippi River. Prepared for U.S. Army Corps of Engineers, St. Louis District. 71 pp.

3.3.2 Fishery Resources

- There is a lack of information in the Main Channel Border section describing fish use and the importance of this habitat to aquatic resources. The publications below contain information relevant to the importance of this habitat.

  - Barko, VA, Herzog DP, Hrabik RA, Scheibe JS. 2004. Relationship among fish assemblages and main-channel-border physical habitats in the unimpounded Upper Mississippi River. Transactions of the American Fisheries Society 133:371-384.

  - Barko VA, Palmer MW, Herzog DP, Ickes BS. 2004. Influential environmental gradients and spatiotemporal patterns of fish assemblages in the unimpounded Upper Mississippi River. American Midland Naturalist 152(2): 369–385.

  - Phelps QE, Tripp SJ, Garvey JE, Herzog DP, Ostendorf DE, Ridings JW, Hrabik RA. 2010. Habitat use during early life history infers recovery needs for shovelnose sturgeon and pallid sturgeon in the Middle Mississippi River.

Transactions of the American Fisheries Society 139(4): 1060–1068. DOI:10.1577/T09-199.1.

- Hintz WD, Porreca AP, Garvey JE, Phelps QE, Tripp SJ, Hrabik RA, Herzog DP. 2015. Abiotic attributes surrounding alluvial islands generate critical fish habitat. River Research and Applications 31:1218-1226. DOI:10.1002/rra.2829.

- Love SA, Phelps QE, Tripp SJ, Herzog DP. 2016. The importance of shallow-low velocity habitats to juvenile fish in the Middle Mississippi River. River Research and Applications DOI:10.1002/rra.3075.

3.3.3 Terrestrial Communities

- Information in the SEIS indicates that the potential impacts of the Project on terrestrial communities are minimal and that no further analysis is being conducted in the SEIS. The USFWS has expressed concern about the impacts of the Project on sandbars and islands in the MMR and the importance of these habitats to fish and wildlife resources including the least tern and pallid sturgeon. These habitats tend to fall in the transition between the aquatic and terrestrial environment. The USFWS recommends that additional information be provided in the SEIS to describe these habitats, changes in these habitats over time including changes due to the Project, and the importance of these habitats.

3.3.4 Threatened and Endangered Species

- The USACE is utilizing the ESA Section 7 consultation for the Operation and Maintenance of the Mississippi River Navigation Project to address species listed under that consultation, and any newly listed species since that consultation are being addressed in a separate biological assessment included with the SEIS. The 2000 Biological Opinion (BO) for the Operation and Maintenance of the 9-foot Navigation Channel on the Upper Mississippi River System addressed channel maintenance dredging and river regulatory structures. In addition, a separate Tier II consultation was completed in 2002 to address Emergency Dredging for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. This document should be incorporated or referenced in the SEIS.

- To facilitate compliance with Section 7(c) of the Endangered Species Act of 1973, as amended, Federal agencies are required to obtain from the USFWS information concerning any species, listed or proposed to be listed, which may be present in the area of a proposed action. You can visit the USFWS's Information, Planning, and Conservation System (IPaC, https://ecos.fws.gov/ipac/) to obtain an updated species list for inclusion in the Final SEIS.

4.1 Environmental Consequences Introduction

- The impact from Navigation Traffic is an indirect effect of the Project and not a cumulative effect. As described in the SEIS, if all operation and maintenance activities on the MMR would cease then navigation in general would eventually cease to exist. Thus, navigation is dependent upon the Project and should be addressed accordingly in the SEIS. This should include a discussion of impacts to fish and wildlife resources including entrainment and a discussion of compensatory mitigation for those impacts.

4.2.1 Impacts on Stages

- Under the Continue Construction Alternative the analysis of water surface elevations at low flows indicate that stages are decreasing over time and this is the same conclusion that was reached in the 1976 EIS. The USFWS is concerned that continued river training structure construction will further decrease the stages at low flows and impact connectivity of and sedimentation within side channels. The USACE indicates that an evaluation on the impacts of river training structures at low flow has not been conducted. The USFWS recommends that additional research be conducted to evaluate the effect of various river training structures on stages at low flow and what if any measures can be developed to reduce this trend.

4.2.2 Impacts on Geomorphology

- Under the Continue Construction Alternative, the USACE expects that the average planform width, planform surface area, and channel surface area would continue to be in a state of dynamic equilibrium; however, it is expected that the cross sectional area, hydraulic depth, channel volume, and channel conveyance would continue to increase. Thus, the channel is expected to become narrower, deeper, and more efficient. There is a lack of discussion in this section on the impacts of river training structures on bathymetry, water velocity, and substrate composition within the main channel and off-channel areas from past and potential future actions. There is also a lack of discussion regarding the conversion of main channel border areas to main channel habitats. These changes are necessary to evaluate the impact of the proposed alternatives on fish and wildlife resources. The USFWS recommends that additional information be provided in this section to clearly describe the effects of river training structures on bathymetry, water velocity, and substrate composition and the conversion of main channel border habitat to main channel habitat. This discussion should also include the potential impacts of maintenance dredging on main channel and off-channel habitat.

4.2.3 Impacts on Side Channels

- According to the SEIS, side channel habitat in the MMR appears to be maintaining at a relatively stable level; however, there is concern that the Regulating Works Project is decreasing river stages at low flows by deepening the channel and decreasing sediment load in the river. This could result in a loss of side channel habitat and reduced connectivity at lower river flows. Based on the anticipated future construction of river training structures, the USACE believes that the effect on river stages would be minor and inconsequential. In addition, any potential future adverse impacts would be addressed with compensatory mitigation. The USFWS remains concerned that the continued operation and maintenance of existing river training structures and construction of new river training structures will continue to limit flows to side channels and restrict fish use of these extremely important fish habitats. And while there are efforts being undertaken by the District to implement side channel restoration under different authorities little to no restoration efforts have been implemented under the Regulating Works Project and this has hindered restoration efforts. Thus, the USFWS recommends that the USACE include side channel protection, maintenance, and restoration in the alternatives to be considered.

- Information in the SEIS indicates that maintenance dredging activities associated with the Continue Construction Alternative are not anticipated to have any adverse effects on MMR side channel habitat. The USFWS has expressed concerns about the potential impacts of dredge material placement on side channels including filling and/or restricting access. Thus, the USFWS recommends that the USACE consider the potential impacts to side channels from dredge material placement in the SEIS.

4.2.4 Impacts on Water Quality

- There is a lack of discussion in this section on the impacts of new river training structures on water quality. The USFWS recommends that additional information be provided in this section to clearly describe the effects of river training structures on water quality metrics and this could include a discussion on changes in water depth and velocity in the habitat surrounding the structures. The publication below contains information relevant to this section.

    - Sobotka MJ, Phelps, QE. 2016. A comparison of main and side channel physical and water quality metrics and habitat complexity in the Middle Mississippi River. River Research and Applications. DOI:10.1002/rra.3061.

4.2.6 Impacts on Air Quality and Climate Change

- There is a lack of information in the climate change section regarding the potential effects of climate change on the system and what impacts that may have on fish and wildlife resources with implementation of the Project. The USFWS has expressed concerns that the continued operation and maintenance of existing river training structures and construction of new river training structures will continue to limit flows to side channels and restrict fish use of these extremely important fish habitats. For example, if climate change within the basin were to result in more frequent or severe droughts than this could further exacerbate the effects of the river training structures on side channel connectivity. The USFWS recommends that additional consideration be given in the section to the impact on fish and wildlife resources and their habitats.

4.3.1 Impacts on Benthic Macroinvertebrate Resources

- Information in the SEIS indicates that impacts associated with dredging on macroinvertebrates are anticipated to be minor. The USFWS previously expressed interest in evaluating all potential measures, including upland disposal of dredge material, to avoid and minimize potential impacts to sensitive fish and wildlife habitats from dredge material placement. Coordinated development of a dredged material management plan or similar plan for the MMR would further reduce risk to macroinvertebrates from dredging and dredge material placement.

- There is a lack of discussion regarding the effects various regulating work structures can have on the factors that may influence abundance and diversity of macroinvertebrate resources. Such factors could include water depth, water velocity, substrate diversity, substrate stability, etc. (Ecological Specialists, Inc., 2004). The USFWS recommends that additional information be provided in the SEIS or additional studies be conducted to more clearly describe the impact of regulating work structures on macroinvertebrate resources. This should include a discussion of incorporating woody debris and/or use of woody structures in projects.

4.3.2 Impacts on Fishery Resources

- Dredging Impacts on Fishery Resources - There is a lack of discussion in this section regarding the avoidance and minimization measures for dredging including restrictions on the timing of dredging and coordination of dredged material placement as described in the USFWS's 2000 BO. There is also a lack of discussion regarding impacts of dredging and dredge disposal on the forage base of fishery resources. This information should be incorporated into this section.

- Dike Effects - Information in this section indicates that the river training structures currently used by the District can provide improved habitat for fish by providing areas of reduced flow, a more diverse substrate, and additional cover. While this may be true, some caution should be utilized in evaluating the results of habitat preference studies conducted in the highly altered river environments of today. As described in the USFWS's 2000 BO, "*the natural meandering processes of the MMR have been altered through channelization. Wingdams, revetments, closing structures and bendway weirs have fixed the channel in place, disrupting the dynamic processes that create and maintain pallid sturgeon habitat. As a result, the diverse habitats to which pallid sturgeon are adapted (e.g., braided channels, irregular flow patterns, flood cycles, extensive microhabitat diversity and turbid waters) continue to decline in quality and quantity*" and "*Continued maintenance of the 9-Foot Channel Project will result in further homogenization of the river environment, and thus, cause further declines in habitat quality, quantity and diversity*". It is unclear whether the river training structure modifications currently utilized today can fully compensate for past and current Project impacts and truly mimic what would have existed in an unaltered system. In addition, operation and maintenance of existing structures will continue to impact habitat quality, quantity and diversity. Further studies may be necessary in order to truly understand the potential impact of these new river training structures and to help develop additional mitigation measures.

- River Training Structure on Fishery Resources - This section describes the effects of traditional dike structures, chevron dikes, bendway weirs, and revetment; however, there is not a description of the effects of notched dikes, rootless dikes, offset dikes, W-dikes, L-dikes, and multiple roundpoint structures (MRS), all of which are currently utilized for the Project. Additional information should be provided on the effects of these alternative structures. In addition, information in this section indicates that a USACE 2011 study concluded that bendway weirs are not having a serious detrimental effect on inside bar slopes. Prior to and during this study the USFWS expressed concerns about loss of main channel border habitat from bendway weir construction and the lack of consideration in the study. The study did conclude that main channel width increased which the USFWS believes results in a corresponding loss of main channel border habitat. This loss should be accounted for and included in the compensatory mitigation for Project impacts.

- Construction and Maintenance Effects - There is a lack of discussion regarding the ongoing effects of maintaining existing structures in their current state. Additional information should be provided to describe the continued effect of these structures throughout this section.

- 3-D Numerical Hydraulic Model Analysis Methodology – Detailed bathymetry for previous years did not exist in the modeled reach and therefore true before and after construction results could not be analyzed. This highlights the need to collect detailed bathymetry before and following any construction to validate the results of the model. This methodology should be included in project development and monitoring plans.

- 3-D Numerical Hydraulic Model Results - The analysis indicates that innovative structures improve habitat diversity when compared to traditional dikes and results in an increase in shallow, low-velocity habitat. While this may be true, the USFWS recommends that caution be taken in evaluating these results given the highly altered river environments that exist today. As stated above, it is unclear whether the river training structure modifications currently utilized today can fully compensate for past and current Project impacts and truly mimic what would have existed in an unaltered system.

- 3-D Numerical Hydraulic Model Results - Additional information should be included in this section to describe the overall quantity of each habitat type or category in the main channel border to fully understand how limited these habitats are within the study reach. Also, there is a lack of discussion regarding the ongoing effects of maintaining existing structures in their current state. This effect should be further evaluated to determine how much mitigation may be needed to compensate for past and ongoing impacts of existing structures.

- Impacts of Continue Construction Alternative - There is a lack of discussion in this section regarding the ongoing effects of maintaining existing structures in their current state. According to the information provided, approximately 6,900 acres (~35%) of main channel border habitat have been altered or affected by river training structure construction since 1976. Maintenance of these existing structures has and will continue to have an effect on these 6,900 acres and the fisheries resources that may be or could be utilizing them. Additional information should be provided in this section to describe the continued effect of these structures on fish access to, use of and movement through these habitats. Similar information should be provided for the maintenance of revetment that has been placed on approximately 60% of the MMR bankline.

- Compensatory Mitigation - The USFWS recommends that the USACE include side channel maintenance and restoration and incorporation of woody debris and/or use of woody structures as additional potential mitigation measures. Also, consideration should be given to measures that would restore or improve shoreline and floodplain functionality and connectivity.

4.3.3 Impacts on Threatened and Endangered Species

- Information in the SEIS addresses potential impacts to bald eagles and their habitats. In addition to habitat for bald eagles, habitat for a variety of other migratory birds species also occur within and adjacent to the project area. E.O. 13186 directs federal agencies to: "(1) support the conservation intent of the migratory bird conventions by integrating bird conservation principles, measures, and practices into agency activities and by avoiding or minimizing, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; (2) restore and enhance the habitat of migratory birds, as practicable."

- The USFWS considers three elements (avoiding, minimizing, and restoring/enhancing) necessary to adequately mitigate for impacts to migratory bird and listed species habitat. To the extent practicable, they recommend avoiding construction in areas that will negatively impact migratory bird and listed species habitat. Where impacts cannot be avoided, they recommend minimizing impacts to the extent practicable. If negative impacts to habitat occur, they will seek compensatory mitigation for impacted habitat that was used by migratory birds (under E.O. 13186) or by listed species (under the ESA)

4.6 Cumulative Impacts

- As stated previously, the impact from Navigation Traffic is an indirect effect of the Project and not a cumulative effect. As described in the SEIS, if all operation and maintenance activities on the MMR would cease then navigation in general would eventually cease to exist. Thus, navigation is dependent upon the Project and should be addressed accordingly in the SEIS. This would include a discussion of impacts to fish and wildlife resources including entrainment and a discussion of compensatory mitigation for those impacts.

4.7 Relationship of Short-Term Uses and Long-Term Productivity

- Information in the SEIS indicates the Project would result in some minor, short-term effects to water quality, air quality, and fish and wildlife associated with construction activities and that these effects are not expected to alter the long-term productivity of the environment. The maintenance of existing structures, construction of new structures, and continued operation of the navigation channel under the Project has and will continue to have long-term effects on the fish and wildlife resources and associated habitats within the MMR. Thus, the USFWS recommends that the USACE develop a plan for mitigating for past and current impacts of the Project.

5.1 Consultation, Coordination and Compliance

- This section focuses on the development and implementation of the Projects and potential compensatory mitigation required; however, this section does not identify how the SEIS or site-specific EAs will address protection (avoidance and minimization) of fish and wildlife resources which is a necessary component of the NEPA, ESA, and FWCA. The FWCA of 1958 provides that "*wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation…"* and that "*whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, or by any public or private agency under Federal permit or license, such department or agency first shall consult with the United States Fish and Wildlife Service Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular State wherein the impoundment, diversion, or other control facility is to be constructed, with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water-resource development."*. The USFWS recommends that the USACE provide additional information on how consultation, coordination, and compliance is being fully achieved or will be achieved under the NEPA, ESA, and FWCA at the SEIS and site-specific levels. This should include a discussion of how wildlife conservation is receiving equal consideration and what measures are being implemented to conserve wildlife resources.

- The USACE indicates that a Fish and Wildlife Coordination Act Report is not required for the Project since sixty percent or more of the estimated construction cost has been obligated for expenditure. The reference to sixty percent completion in the FWCA is based on the date of enactment of the FWCA (The Act of August 12, 1958; Section 5g). It is unclear if the USACE is correctly applying this section of the FWCA.

- The USACE indicates that coordination with the USFWS has been conducted, and all Fish and Wildlife Coordination Act requirements are being fulfilled. As previously discussed, the USFWS provided comments in a letter dated January 17, 2014, on the NOI to prepare a DSEIS for the Regulating Works Project. In that letter they recommended that the DSEIS include an alternative in which execution of the existing project would incorporate appropriate NEPA compliance and a process for avoidance, minimization, and additional improvement measures for fish and wildlife resources. In addition, USFWS requested that the USACE consult with the USFWS and State conservation agencies early in the planning process to ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. The FWCA of 1958 provides that "*The reporting officers in project reports of the Federal agencies shall give full consideration to the report and recommendations of the Secretary of the Interior and to any report of the State agency on wildlife aspects of such projects, and the project plan shall include such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits.*" Further, the 2003 Agreement between the USFWS and the USACE for conducting FWCA activities was developed to ensure that the USFWS is involved with USACE projects to help find solutions to water resources development problems that avoid, minimize, or mitigate impacts to fish and wildlife. A major goal of the Agreement is to ensure that the USFWS is invited to participate early in throughout the planning process to facilitate the FWCA's equal consideration provision. The USFWS has not been contacted about the specific recommendations described above and it doesn't appear that our concerns were addressed in the SEIS. The USFWS recommends that the USACE consider these original comments and recommendations and work with the USFWS and State natural resource agencies to ensure full compliance with the NEPA, ESA, and FWCA.

6.1 Areas of Controversy

- The USFWS and State natural resource agencies have recommended that the USACE mitigate for adverse impacts going back to the 1976 EIS and seek the Post Authorization Change described in the 1976 EIS; however, the USACE indicates they will only consider compensatory mitigation for adverse impacts occurring since publication of the Notice of Intent in December, 2013, and that the Post Authorization Change was never added to the Project by Congress. In addition, the USACE indicates that they only plan for and implement mitigation associated with future actions because of budgetary constraints and that the USACE has other authorities outside of the Regulating Works Project authority that could be used to mitigate for past adverse impacts. As previously discussed, the USFWS contends that the USACE has the authority to implement these types of actions under the Project. If the actions are implemented under other authorities there should be an evaluation of past impacts to determine the amount of mitigation that may be necessary and a mitigation plan developed to guide mitigation efforts. This would aid in the delivery of funds if they were to become available under the Project authority or other authorities.

Appendix B. Biological Assessment

- The Biological Assessment (BA) was prepared to address newly listed threatened and endangered species not covered by the USFWS's 2000 BO. Information in the BA indicates that the Rufa red knot (*Calidris canutus rufa*) is a rare migrant along the MMR and utilizes exposed substrates and shallow water that are present in the Project area; however, the Project would not eliminate or substantially reduce these habitats thus the USACE has determined the Project will have no effect on the red knot. The USFWS cannot support a no effect determination for this species given that the species may present within the project area, habitat for the species is present in the project area, and the implementation of the Project will impact those habitats. The USFWS recommends that additional information be included in the BA to describe the potential effects of the Project on this species.

Appendix C: Mitigation Plan

- The USACE indicates that efforts have been made to avoid and minimize project impacts by modifying the design of river training structures; however, even with the modifications recent analysis suggest that river training structures would still result in losses of specific main channel border habitat. Therefore, the USACE is proposing that mitigation be implemented for projects constructed since publication of the NOI to offset losses to the greatest extent practicable in accordance with Section 906(b) of WRDA 1986, subject to the availability of future funding. The USFWS is a member of the adaptive management team and coordinating with the USACE on development of the mitigation plan. While they concur with the proposed development of a mitigation plan, the USFWS recommends that mitigation for Project impacts be evaluated going back to the 1976 SEIS. At a minimum, mitigation for Project impacts should be evaluated going back to the enactment of the WRDA of 1986.

U.S. Geological Survey Comments

The U.S. Geological Survey (USGS) has reviewed the USACE Draft SEIS for the Middle Mississippi River Regulating Works. These comments are intended to address potential disturbance of USGS streamgages and also water quality concerns.

The USGS operates streamgages along streams throughout the US to collect water quantity and quality data for a variety of purposes. Continuous operation of USGS streamgages is essential for our stakeholders. These streamgages have permanent infrastructure and are vulnerable to disruption when nearby construction occurs in the vicinity of these stations. Several active USGS streamgages fall within the Middle Mississippi River project area. Streamgage site descriptions are:

Review Table 1: Active USGS sites on Mississippi river in project area							
Agency	USGS site number	Station Name	Latitide DD	Longitude DD	Datum	State	County fips code
USGS	7010000	Mississippi River at St. Louis, MO	38.629	-90.179778	NAD83	Missouri	510
USGS	7020850	Mississippi River at Cape Girardeau, MO	37.301889	-89.518	NAD83	Missouri	31
USGS	5587498	Mississippi River Pool Lock and Dam 26 at	38.886444	-90.182547	NAD83	Illinois	119
USGS	7020500	Mississippi River at Chester, IL	37.900742	-89.830211	NAD83	Illinois	157
USGS	7022000	Mississippi River at Thebes, IL	37.2216	-89.462975	NAD83	Illinois	3

The final SEIS should list USGS structures as sites to be safeguarded. The USGS Missouri Water Science Center (WSC) and Illinois WSC should be contacted and given sufficient advance notice before any project activities occur near the USGS streamgages. Efforts should be made both to preserve the streamgages and minimize impacts to the data integrity collected at those sites. Changes to floodplain geometries by the modification of channels may affect USGS reported discharges and water surface elevations.

Water quality impacts from sediment mobilization due to construction in the river is addressed within the DSEIS on page 118. Safeguards should be considered within the final SEIS to protect water supply intakes from project activities. It is widely documented that river bottom sediments in the United States are potential reservoirs for hydrophobic compounds (Nowell and others, 2013; Wilson, 2016; Wilson and Bonin, 2007). It is also widely documented that both natural and anthropogenic activities can remobilize contaminated sediments and release contaminants to the water column (Eggleton and Thomas, 2004).

USGS strongly encourages the documentation within the final SEIS of the USGS streamgage infrastructure on the Middle Mississippi River in the project area and description of the protection and coordination to occur during the project. Additionally, they encourage the protection of water supply intakes from increased sediment and contaminant loads caused by the project.

Consultation

Questions or comments for the USFWS can be directed to Mr. Matt Mangan at the Marion Illinois Ecological Services Sub-Office, 8588 Route 148, Marion, Illinois 62959-4555; telephone (618) 997-3344, ext. 345; matthew_mangan@fws.gov. If you have any questions concerning U.S. Geological Survey comments, please contact J. Michael Norris, USGS Coordinator for Environmental Assessment Reviews, at (603) 226-7847 or at mnorris@usgs.gov.

Summary

The USFWS believes there is a lack of information included in the SEIS to support that the proposed Project will have the intended results and that there appears to be a lack of consideration for fish and wildlife resources. The USFWS recommends that the USACE consider our original comments and recommendations (January 2014) and work with the USFWS and State natural resource agencies to develop an alternative that ensures adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources.

Conclusion

The USFWS looks forward to additional coordination and consultation with the USACE regarding protection and enhancement of fish and wildlife resources and appreciate the opportunity to review the draft SEIS and provide these comments.

Sincerely,

Robert F. Stewart
Regional Environmental Officer

cc: Kip Runyon

REFERENCES:
Eggleton, J. and Thomas, K.V. A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. Environment International 30 (2004) 973-980.

Nowell, L.H., Moran, P.W., Gilliom, R.J. et al. Arch Environ Contam Toxicol (2013) 64: 32. doi:10.1007/s00244-012-9813-0

Wilson, J.T., 2016, Occurrence and concentrations of selected trace elements and halogenated organic compounds in stream sediments and potential sources of polychlorinated biphenyls, Leon Creek, San Antonio, Texas, 2012–14: U.S. Geological Survey Scientific Investigations Report 2016–5039, 99 p., http://dx.doi.org/10.3133/sir20165039.

Wilson, T.P. and Bonin, J.L., 2007, Concentrations and Loads of Organic Compounds and Trace Elements in Tributaries to Newark and Raritan Bays, New Jersey: U.S. Geological Survey Scientific Investigations Report 2007-5059, 176 p.

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SARA PARKER PAULEY, Director

January 18, 2017

Mr. Kip Runyon
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO 63102-2833
RegWorksSEIS@usace.army.mil

RE: Comments for Public Notice on Draft Supplemental Environmental Statement (SEIS) for Middle Mississippi River (Between the Ohio and Missouri Rivers) Regulating Works, Missouri and Illinois

Dear Mr. Runyon:

Thank you for the opportunity to review and provide comments on the above referenced document. The Missouri Department of Conservation (Department) is the agency responsible for fish, forest, and wildlife resources in Missouri. As such, the Department actively participates in the review of National Environmental Policy Act (NEPA) documents when the project might affect those resources. The Department also provides comments under the Fish and Wildlife Coordination Act. However, we have no regulatory authority over development projects and do not issue permits for project construction. Our questions, comments and technical recommendations in this response are for your consideration and are offered to help ensure that potential impacts to the fish and wildlife resources are identified and considered in the SEIS, and that adverse impacts are avoided and minimized, and where necessary, mitigation occurs.

The U.S. Army Corps of Engineers (USACE) is charged with operating and maintaining the 300 feet wide, 9 feet deep navigation channel in the Middle Mississippi River (MMR) through the Regulating Works Project (Project). This Project relies on placement of river training structures, rock revetments, rock removal and sediment management to maintain bank stability and ensure adequate navigation channel depth and width. In 2014, the USACE determined that there had been sufficient new circumstances and information relevant to the Project's environmental concerns to warrant completion of an SEIS to update the 1976 Environmental Impact Statement. The Department commends the USACE in recognizing that these changed circumstances could affect natural resources, and in moving forward on the SEIS.

The U.S. Fish and Wildlife Service (Service) submitted comments on the SEIS in its letter dated January 12, 2017. In general, the Department concurs with the Service's response. We also offer the following comments for your consideration.

SEIS Scope and Mitigation: The Department was hopeful that this evaluation would result in identification and quantification of habitat loss, by type and acreage, and at both sites specific and Project scales, from 1976 to the projected completion of the Project, and provide options for compensatory mitigation. However, we understand that it includes only the projects that have not been completed since the Notice of Intent was published in December 2013. Because the USACE in 1976 clearly identified future habitat and functional changes, and agreed that impacts should be mitigated, we encourage the USACE to include in the SEIS all projects completed since 1976 along with future projects, and fully calculate habitat changes in the MMR since 1976 due to Project implementation. An appropriate mitigation plan should be developed with federal and state partners.

While it may be difficult to again seek a post-authorization and funding appropriation to fund mitigation needs for significant past habitat loss and cumulative impacts, the Department believes there are existing authorities that could be used to allow ongoing and future projects and operation and maintenance projects to help address some of the lost habitat. For example, as noted on Page 7 of the U.S. Department of Interior comment letter dated January 12, 2017, Section 3(a) of the FWCA of 1958, Section 906 of the Water Resources Development Act (WRDA) of 1986, and Section 5099 of WRDA 2007, authorize the protection, restoration, enhancement, and mitigation of fish and wildlife resources to occur under the Regulating Works Project. In addition, precedent was set by the Navigation and Ecosystem Sustainability Program that was authorized by WRDA 2007 to fully consider fish and wildlife impacts as part of channel maintenance activities, because this Program was to be a dual-purpose program, addressing habitat impacts as part of navigation management. Allowing operations and maintenance activities and funding to address past and future project habitat impacts would also provide a means to restore lost habitat in certain locations.

Alternatives: The USACE's alternatives were limited to 1) continue with existing practices and mitigate for adverse impacts when necessary (i.e., Continue Construction Alternative – CCA), or 2) stop new construction of river training structures and manage navigation channel depth by dredging (i.e., No New Construction Alternative – NNCA). In both alternatives bank stabilization through revetment and all rock structure/revetment maintenance will continue. The goal of the Project is to minimize dredging costs and create a self-maintaining system, to the extent it is cost effective.

The expected amount of future habitat impacts under the CCA is estimated at 8% (i.e., about 1,100 acres) of the remaining unstructured main channel border habitat. There would be no additional permanent loss to the remaining unstructured main channel border habitat under the NNCA. In 1976, unstructured main channel border habitat was estimated at 19,800 acres, and by 2014 the acreage had declined by 6,900 acres to 12,900 acres. This is an approximate 35% decline in unstructured main channel border habitat for which no compensatory mitigation was completed. The Department agrees that a loss of 8% of the remaining habitat of this type is important and should be mitigated; we also contend that a loss of 35% of this habitat is also critically important and should be mitigated.

Because actual locations of future project sites are unknown, under the CCA, an estimate was made that approximately 4.4 million tons of rock would be placed over the next 17 years, and dredge quantities would decrease from 4 million cubic yards per year to approximately 2.4 million cubic yards per year. Under the NNCA, maintenance dredging is expected to be 4 million cubic yards per year. Thus, the difference in dredging between the two Alternatives is approximately 1.6 million cubic yards per year.

A general description of the ongoing habitat changes on Page 156 notes that managing the river with river training structures produces a "continued functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high-velocity habitat of the main channel surrounded by structured main channel border habitat." The unstructured main channel border habitat is thought to provide an important and necessary movement and migration pathways used by fish.

In the Department's comment letter of April 2, 2012, we suggested that that an additional alternative be considered, one that would allow for greater consideration of fish and wildlife resources, and which might require a greater level of annual dredging then the stated goal of reducing dredging to the lowest amount economically feasible. Because habitat conditions have been greatly altered, any method that will reduce habitat losses though continued creation of a deeper, faster flowing channel will be beneficial and may be the best environmental alternative. This is consistent with the additional alternative suggested by the Service that would ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. For example, a potential outcome of an alternative that incorporates more fish and wildlife resource needs, is an alternative that maintains the nine foot navigation channel while also maintaining river elevation, letting the channel widen in certain places when there is excess water. This would help increase connectivity and fish and wildlife habitat, although locations would have to be carefully identified and accepted by willing landowners.

Bankline Revetments: Lateral movement of the river is greatly altered with approximately 60% of the bankline revetted as of 2014 (see Page 155), and there is an unknown amount of additional revetment needed to complete and maintain the Project as currently operated. The SEIS notes that this additional amount of revetment will not have an "appreciable adverse effect on the MMR fishery." However, adverse impacts from further modifying lateral river migration have not been calculated. Restricted lateral movement reduces input of woody vegetation and sediments to the river. A healthy river has some level of lateral movement, and this movement helps to further create diverse aquatic habitat. These impacts should be identified and avoided and minimized to the extent practicable, and functional loss to river habitat conditions addressed through restoration projects.

The USACE should also examine the success the USACE – Memphis District has had with treed riparian corridors on the Lower Mississippi River. Rather than relying on rock revetments entirely to maintain bank stability, it has experienced success with reducing bank erosion and flood events on portions of its banks and floodplains by using forested riparian corridors of sufficient width and tree density to increase roughness coefficients and reduce high flow events that scour sediments.

Cumulative Impacts: This section should consider the cumulative impacts from construction of the Project since at least 1976. With over 6,900 acres of unstructured main channel border habitat eliminated, it is likely that the multiple changes to the river have resulted in changes to aquatic organisms and their habitats. The construction of one structure will result in local impacts, but what is unknown is the effect of nearly 40 years of regulating works on the river and the fish community. Additionally, while greater emphasis has been placed on new rock structure configurations (e.g., chevrons, w-dikes, multiple rock sites/piles) and hydraulic

sediment transport modeling has demonstrated that these structures will create different scour patterns and thus different depths and flow conditions, very few studies have been completed to evaluate if they are better or worse for the river environment than a regular straight dike. This evaluation is a current and future need of the project.
Another consideration to habitat impacts, as the river incises it is not just the side channels that are perched, but also islands themselves and the more shallowly sloping banks that could provide off-channel habitat when the river is high. This is another loss in important habitat that should be quantified.

Side Channel Habitats: Recognizing the importance of side channel habitats in a portion of the river where there is little floodplain connectivity, the river partners have identified the need to ensure side channels are connected to the river channel with suitable flows and that there is a diversity of aquatic habitats. The Department appreciates the efforts of the USACE to restore side channels and encourages continued efforts to ensure that restoration projects are not impacted by the predicted decrease in river stage during low flows. This could result in loss of side channel connectivity, possibly negating some restoration efforts. For example, in Section 2.3.2, the SEIS notes that side channels are a refuge from navigation disturbances; but if the side channels are becoming more and more isolated through reduced connectivity, they aren't going to be very useful to river organisms. Department researchers have also noted that the MMR has lost over half of side channel area in width. An increase in side channel volume is not equivalent to more habitat being added to the system. Restoration practices need more functional evaluation as well; for example we have little understanding of how or if the more benthic organisms move through notches. What notch elevation is necessary to allow passage of these organisms? These questions and others are important to understand as side channels are restored.

Additionally, to help estimate decreases in connectivity to side channels, the projected stage reduction values could be used. This would give a quantitative estimate of impact.

Please add the following citation to the SEIS:
Sobotka, M. J., & Phelps, Q. E. (2016). A Comparison of Main and Side Channel Physical and Water Quality Metrics and Habitat Complexity in the Middle Mississippi River. *River Research and Applications*, https://doi.org/10.1002/rra.3061

Other Comments
Dike Shape - Although studies have been completed demonstrating that fish and other aquatic organisms have been found in the vicinity of river training structures, we do not know if these areas are creating habitat that increases aquatic organism populations in a stretch of the river. It is possible that these sites are just displacing animals from other areas, without population gain. Further studies are required at both the project and cumulative scales to fully evaluate fish benefits of different shaped dikes.

Benthic Macroinvertebrate Resources and Freshwater Mussels:
Page 71- An additional resource is the UMRR's LTRM invertebrate collections. This component was discontinued approximately 10 to 12 years ago, due to lack of funding and concerns for sampling design. However, some information is available that should be considered in the analyses.

Page 72- Although it is thought that the MMR is not a historic place for freshwater mussel beds, there have been no recent studies to support this contention. Freshwater mussels have been found in certain rock dikes in the Lower Mississippi River, and they could exist in areas with similar conditions in the MMR. Areas with unstable, shifting sediments are not likely to provide good conditions, but areas that are more stable, perhaps in dike structures, or side channels, might harbor mussel life. As dike fields or side channels are altered, impacts to mussel resources should receive consideration.

Macroinvertebrate habitat has likely declined due to the reduction in woody debris and snags entering the river. While rock piles may provide some structure that macroinvertebrates can utilize, organic debris provides better conditions.

Fishery Resources:
Page 75 – Please define use of the term "stragglers." We do not know if changes in river management means that some species are now not as abundant due to intolerance to changing river conditions. Or if the species was never very abundant in the MMR>
Page 76 - Some of the main channel fish mentioned will also frequent the side channels.

Terrestrial Communities:
Page 78 - Terrestrial communities still can be impacted due to the fact that the aquatic community they depend on is being manipulated. Bottomland hardwood communities benefit by a certain level of flooded conditions; lack of floodplain connectivity may affect the hydrology of some of these wetland communities.

Impacts on Water Quality:
Page 118 - Continuing to narrow and deepen the channel will reduce potential for primary production. Higher velocities result in more turbidity (also because of added rock), leading to less light penetration and more turbulence that inhibits phytoplankton growth.

Lower water retention times and less water/sediment interface means less nutrient capture. We can't estimate reduction in nutrient capture, but it is likely occurring and will continue to do so as the channel deepens and narrows.

Impacts on Fishery Resources:
Page 132 – Dredging in July and August may have fewer impacts on fish, because many species will have already completed spawning or be out of larval stage. However, certain catfish and sunfish species and freshwater drum have been found spawning during these months.

Page 135 to 136 – Dredge Entrainment Impacts - We have questions regarding the estimate of larval fish entrainment during dredging. The SEIS notes that it is likely to be minimal, however, this is based on calculations that have not been verified. Additional information is needed to demonstrate that larval entrainment will be minimal, and if it is not, further avoidance and minimization measures should be followed, and resulting impacts should be mitigated.

Page 131 to 133 – Dredging Related Impacts - Fishes and other aquatic organisms are adapted to natural abrupt changes in turbidity. But a dredge is more abrupt and may instantly cover eggs or spawning areas of certain fishes. Whereas in natural conditions, the fish are otherwise in an ideal location with water chemistry that would gradually change. Impacts would be greater with the abrupt change in conditions.

Page 146 - Revetment Effects on Fish - Revetment can be good current refuge and even habitat for some fish species, but this is not true with all fish species. Life history of fishes show that habitat preference is extremely variable among species.

Agency Coordination
While we have a general idea of how future coordination on individual projects will occur and how and to what level fish and wildlife resources would be incorporated, it would be helpful to further describe the process and seek input from stakeholders.

Summary
The Department appreciates the efforts of the USACE to address environmental concerns while it constructs, operates and maintains the navigation channel. However, as noted in the 1976 EIS and this draft SEIS, management of the river for navigation purposes has resulted in loss of habitat diversity, habitat quality and quantity, none of which have been mitigated. Additionally, opportunity for habitat enhancement in the MMR through existing authorities has been limited. Fully evaluating resource impacts in the NEPA documents is important to identify mitigation and restoration needs, and identify opportunities to further avoid and minimize impacts.

Thank you for the opportunity to review and provide input on the SEIS. The USACE staff in the St. Louis District have often incorporated certain considerations for fish and wildlife habitat on Regulating Works Projects and operations and maintenance activities. However, we believe there are situations when habitat considerations should receive greater consideration in individual project development, and a modification of the Project can assist in this effort while not impacting the navigation channel itself, just modifying its management.

The Department requests that the our comments and recommendations be addressed in the final SEIS. Please let us know if you have questions on these comments. I may be reached at 573-522-4115 Extension 3372 or by e-mail at janet.sternburg@mdc.mo.gov.

Sincerely,

JANET E. STERNBURG
RESOURCE SCIENCE SUPERVISOR/MMR SEIS COORDINATOR

c: USFWS: Matt Mangan
IDNR: Nathan Grider, Butch Atwood

Illinois Department of
Natural Resources
One Natural Resources Way Springfield, Illinois 62702-1271
www.dnr.illinois.gov

Bruce Rauner, Governor
Wayne A. Rosenthal, Director

January 18, 2017

Kip Runyon
ST. Louis District, Army Corps
1222 Spruce St.
St. Louis, MO 63103

RE: Notice of Availability of Draft Supplemental Environmental Impact Statement (SEIS) For Middle Mississippi River Regulation Works from Missouri to Ohio Rivers

Dear Mr. Runyon:

The Illinois Department of Natural Resources (Department) has reviewed the Draft Supplemental Environmental Impact Statement (DSEIS) for the Middle Mississippi River (MMR) Regulating Works Project (Project). The Project area stretches from the confluence of the Missouri River to the confluence of the Ohio River. The area includes seven Illinois' counties, from Madison through Alexander.

The purpose of the Project is to maintain a nine feet deep, 300 feet wide channel, with additional width at river bends as necessary, to facilitate navigation. The project is maintained through dredging, bank stabilization, rock removal, and river training structures.

In general, the Department concurs with the comments provided by the U.S. Fish and Wildlife Service (USFWS) dated January 12, 2017. Pursuant to the Fish & Wildlife Coordination Act, the Department provides the following comments for your consideration:

Threatened and Endangered Species
The MMR contains records for nine state-listed fish species (including the federally-endangered pallid sturgeon (*Scaphirhynchus albus*), three state-listed bird species (including federally-endangered least tern (*Sternula antillarum*) and federally-threatened rufa red knot (*calidris canutus rufa*)), and many other floodplain adapted state-listed species are known to occur in the MMR, such as the Illinois chorus frog (*Pseudacris illinoensis*). A more comprehensive list can be found at the following link and individual records can be discussed with our staff: https://www.dnr.illinois.gov/ESPB/Documents/ET_by_County.pdf

While the Department understands that the U.S. Army Corps of Engineers (USACE) has no legal responsibilities to comply with the *Illinois Endangered Species Protection Act* regarding the congressionally mandated Project and invokes sovereign immunity, it has been customary for some of the USACE districts operating in Illinois to consider state-listed species and avoid or minimize impacts when possible. There is no discussion in the DSEIS regarding state-listed species and lands protected under the *Illinois Natural Areas Preservation Act*. While it may not be necessary to include a detailed discussion of these resources to comply with the National Environmental Policy Act (NEPA), the Department recommends increased coordination with our staff regarding these state natural resources to help fulfill our missions and ensure their continued existence within Illinois. You may already be aware of the Department's Ecological Compliance Assessment Tool (EcoCAT), which can be accessed at http://dnr.illinois.gov/EcoPublic/. We invite you to submit individual projects in EcoCAT and engage with our staff as necessary to further coordination between the agencies. Please contact Nathan Grider (217-524-0501) if you have any questions regarding EcoCAT and consultation with the Department.

Fish and Mussels

Page 131 and 132 discusses entrainment rates of fish from maintenance dredging activities in the MMR. It is stated that no data exists on actual entrainment rates from these dredging operations and estimates are made based on fish density per known volume and the amount of water taken in by the dredge. The Department acknowledges the difficulty in estimating entrainment rates given the wide range of estimates in the literature and seasonal, as well as site specific variability. The Department is concerned that fishery impacts related to dredge entrainment remains largely unknown and recommends the USACE more directly address the issue through field study and propose options to avoid, minimize, and mitigate the impacts in coordination with the USFWS and state agencies.

The DSEIS indicates disposal of dredged material typically occurs in-river as opposed to upland disposal to avoid increased costs. Adverse impacts to sensitive fish and wildlife habitats can be significant in some locations from in-river sediment disposal. The process of coordinating these events with the state agencies and USFWS is unclear. The Department regularly coordinates with the Rock Island District on these projects to minimize adverse impacts through the On Site Inspection Team (OSIT). The Department recommends the St. Louis District develop a coordination plan for dredging that more closely resembles the Rock Island District and develop a dredged material management plan for the MMR. The Department also recommends the district evaluate more areas for beneficial uses of the sediment using the flexible dredge pipe in coordination with the states and USFWS.

It has been generally agreed the freshwater mussel populations are sparse in the MMR due to unstable substrate conditions (page 71-72). As discussed on page 42 of the DSEIS, the river channel has reached stability over the last several decades through the use of river training structures and erosion has been reduced through the use of bank protection. Due to significant changes undergone in the MMR from implementation of the Project that may facilitate the development of mussel beds, the Department recommends the mussel community be monitored on a regular basis for changes with efforts focused in dike fields and other areas with stable substrates. The SEIS should include further discussion in this regard on impacts to mussels from regulating structures. The Department recommends proposed new river training structures or significant alterations to existing structures include an assessment of potential mussel impacts. This assessment should not be necessary in areas of frequent dredging in the main channel.

Habitat and Mitigation
The Department commends the USACE for the efforts to restore side channel habitats beginning in the 1990's. However, the Department recognizes there are still significant issues with sedimentation and disconnection of side channels in the MMR. Further, the construction of river training structures has resulted in significant impacts to main channel border habitats. The USACE is currently focused on improving the channel for commercial navigation with habitat enhancement as an important, yet secondary objective. The Department recommends the USACE pursue dedicated funding and increase habitat restoration and mitigation efforts for impacts resulting from the Project in the MMR. This initiative should include dredging of side channels to achieve small boat year around navigation and fish access, beneficial use of dredge material, construction of wooden pile dikes (wood cribbing and or LUNKER structures could be substituted) and dike alteration to benefit fish and wildlife resources. The states and USFWS have requested that these efforts be included as a post-authorization change by Congress to include fish and wildlife conservation measures as a Project purpose.

The states and USFWS have also requested that Project mitigation should be evaluated going back to the 1976 EIS. The USACE is proposing that mitigation be implemented for projects constructed since publication of the Notice of Intent (NOI) to develop the SEIS in December, 2013. The Department still believes that mitigation should be implemented going back to the 1975 EIS, or at least the enactment of the Water Resources Development Act of 1986. The Department recommends the USACE develop a dedicated planning effort for mitigating past and future impacts of the Project.

The Department notes that increased efforts in reconnecting side channels and floodplain habitats as a primary mission of the Project will greatly benefit species that have seen significant decline over the last half century. As mentioned on page 172, the alligator gar (*Atractosteus spatula)* was extirpated from the MMR for reasons partly associated with implementation of the Project, which resulted in a decrease in critical side channel and backwater habitats. The Department, along with the USFWS and other states in the historic range of the alligator gar, has initiated recovery efforts for this species. An increase in habitat restoration and mitigation work as part of the Project would greatly enhance these efforts, along with conservation benefit to other important riverine species that rely on lateral connection of aquatic habitats.

The Department notes an error on page 172 with the taxonomy of alligator gar; the species was moved from the genus *Lepisosteus* to *Atractosteus* in 1976 by E.O. Wiley to recognize two taxon of extant *Lepisosteidae* (gars).

Summary
The Department requests the above concerns and recommendations be addressed in the final SEIS. The Department looks forward to further coordination with the USACE, St. Louis District on the Regulatory Works Project in the MMR and addressing the ongoing challenges of managing both navigation needs and conservation of our critical fish and wildlife resources.

Thank you for the opportunity to comment. Please contact me if you have any questions regarding this review.

Nathan Grider
Division of Ecosystems and Environment
217-524-0501

cc: IDNR, Butch Atwood
USFWS, Matt Mangan
MDC, Janet Sternburg

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

JAN 18 2017

REPLY TO THE ATTENTION OF:
E-19J

Mr. Kip Runyon
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103-2833

Re: Mississippi River Between the Ohio and Missouri Rivers Regulating Works
Draft Supplemental Environmental Impact Statement; CEQ No. 20160256

Dear Mr. Runyon:

The U.S. Environmental Protection Agency has reviewed the U.S. Army Corps of Engineers' (Corps) Draft Supplemental Environmental Impact Statement (DSEIS) pursuant to our authorities under the National Environmental Policy Act, Council on Environmental Quality regulations (40 CFR Parts 1500-1508), Section 309 of the Clean Air Act, and Section 404 of the Clean Water Act. These comments reflect collaboration by EPA Regions 5 (Chicago office) and 7 (Kansas City office).

The Corps' Regulating Works Project utilizes bank stabilization, rock removal, and sediment management to maintain bank stability and ensure adequate navigation depth and width, as authorized by Congress. The Project's long-term goal is to maintain a navigation channel and reduce federal expenditures by minimizing the amount of annual maintenance dredging of the channel. This DSEIS updates the 1976 EIS "Mississippi River between the Ohio and Missouri Rivers (Regulating Works)." The Corps intends to use this document programmatically to describe the broad impacts of the Project on the environment while characterizing future site-specific impacts of individual projects in environmental assessments tiered from this DSEIS.

The DSEIS evaluates two alternative actions consisting of the continuing construction of new river training structures or revetments ('no action') and the continued maintenance of existing structures without new construction ('no new construction'). Both alternatives include continuing some maintenance dredging of the navigation channel. The Corps' 'preferred alternative' is the 'no action' alternative, which would continue the construction of new river training structures. This alternative would require less maintenance dredging quantities than the 'no new construction' alternative.

EPA has rated this alternative as LO (Lack of Objection). Detailed comments and a copy of EPA's rating descriptions are included as enclosures to this letter. We recommend that the Corps not proceed with further river training structure construction until the planned "main channel border habitat model" is finalized and can be utilized to quantify habitat loss and to guide compensatory mitigation.

We also concur with the Corps' assessment of the potential effects of the Regulatory Works Project on flood levels. The Corps concludes that placement of structures constricting flow and reducing conveyance within the floodplain during higher river stages, specifically the construction of levees, is primarily responsible for stage increases at overbank flows.

If you have any questions regarding these comments, please contact me at (312) 886-2910 or westlake.kenneth@epa.gov or Mr. Josh Tapp, Deputy Division Director, Environmental Sciences and Technology Division, Region 7, at (913) 551-7606 or tapp.joshua@epa.gov.

Sincerely,

Kenneth A. Westlake, Chief
NEPA Implementation Section
Office of Enforcement and Compliance Assurance

Enclosure – Summary of Rating Definitions
Draft Supplemental EIS Detailed Comments, dated January 18, 2017

SUMMARY OF RATING DEFINITIONS AND FOLLOW UP ACTION

Environmental Impact of the Action

LO-Lack of Objections
The EPA review has not identified any potential environmental impacts requiring substantive changes to the proposal. The review may have disclosed opportunities for application of mitigation measures that could be accomplished with no more than minor changes to the proposal.

EC-Environmental Concerns
The EPA review has identified environmental impacts that should be avoided in order to fully protect the environment. Corrective measures may require changes to the preferred alternative or application of mitigation measures that can reduce the environmental impacts. EPA would like to work with the lead agency to reduce these impacts.

EO-Environmental Objections
The EPA review has identified significant environmental impacts that must be avoided in order to provide adequate protection for the environment. Corrective measures may require substantial changes to the preferred alternative or consideration of some other project alternative (including the no action alternative or a new alternative). EPA intends to work with the lead agency to reduce these impacts.

EU-Environmentally Unsatisfactory
The EPA review has identified adverse environmental impacts that are of sufficient magnitude that they are unsatisfactory from the standpoint of public health or welfare or environmental quality. EPA intends to work with the lead agency to reduce these impacts. If the potential unsatisfactory impacts are not corrected at the final EIS sate, this proposal will be recommended for referral to the CEQ.

Adequacy of the Impact Statement

Category 1-Adequate
The EPA believes the draft EIS adequately sets forth the environmental impact(s) of the preferred alterative and those of the alternatives reasonably available to the project or action. No further analysis or data collecting is necessary, but the reviewer may suggest the addition of clarifying language or information.

Category 2-Insufficient Information
The draft EIS does not contain sufficient information for the EPA to fully assess the environmental impacts that should be avoided in order to fully protect the environment, or the EPA reviewer has identified new reasonably available alternatives that are within the spectrum of alternatives analyzed in the draft EIS, which could reduce the environmental impacts of the action. The identified additional information, data, analyses, or discussion should be included in the final EIS.

Category 3-Inadequate
EPA does not believe that the draft EIS adequately assesses potentially significant environmental impacts of the action, or the EPA reviewer has identified new, reasonably available alternatives that are outside of the spectrum of alternatives analyzed in the draft EIS, which should be analyzed in order to reduce the potentially significant environmental impacts. EPA believes that the identified additional information, data analyses, or discussions are of such a magnitude that they should have full public review at a draft stage. EPA does not believe that the draft EIS is adequate for the purposes of the NEPA and/or Section 309 review, and thus should be formally revised and made available for public comment in a supplemental or revised draft EIS. On the basis of the potential significant impacts involved, this proposal could be a candidate for referral to the CEQ.

*From EPA Manual 1640 Policy and Procedures for the Review of the Federal Actions Impacting the Environment

Mississippi River Between the Ohio and Missouri Rivers (Regulating Works) Draft Supplemental EIS Detailed Comments
January 18, 2017

General Comments

The DSEIS would be improved with an inventory and prioritization of reach locations where the Corps expects greater need for either new structure construction, mitigating structure modifications or mitigation projects. This could include locations with a past history of repeated dredging needs, a high potential for avulsion, bank erosion or failure, or a higher potential for damage to sensitive aquatic life or critical habitat from continual dredging. These circumstances all suggest the need for new or modified training structures or revetments.

Treatment of the DSEIS as a Programmatic NEPA Compliance Document

In reviewing the DSEIS, EPA assumes that planning for each site-specific project will also include a Tier II site-specific Environmental Assessment in addition (SSEA) to the NEPA coverage provided by the SEIS. If this is not the case, the Final SEIS should identify the protocol by which the Corps will determine whether a SSEA is required for individual projects.

Affected Environment

The DSEIS extensively characterizes channel, main channel border, backwater, side channel, and floodplain habitat in various locations throughout the document. Section 3.2.3 separately inventories and characterizes side channels and side channel environment under Section 3.2, Physical Resources. The DSEIS would be improved if the characterization of these other riverine habitats were similarly contained and organized within Chapter 3. Main channel, main channel border, and side channel biological resources are organized and characterized in Section 3.3 as biological resources. Similar treatment of these resources in Section 3.2, Physical Resources, would be useful.

The DSEIS includes multiple references to existing research which attributes stage rise to the constriction of the floodplain by levees and other infrastructure. In debunking claims that Corps regulatory works in the Middle Mississippi River raise river stage in Appendix A, the DSEIS diverts responsibility toward historic floodplain constriction as the overwhelming cause of past, and presumably future, river stage elevation. We agree with this assessment and support the Corps in its efforts to limit floodplain development and all efforts to realign existing levees to provide increased exposure of floodplains to elevated river flows.

Table 3-6, comparing the acreage of main channel, main channel border and side channel habitat in the MMR in 1976 with 2014, illustrates habitat changes within the River since the last EIS. EPA recommends the Corps consider repeating that table elsewhere in the document as it supplements text on important riverine habitat, impacts on that habitat, and restoration/mitigation priorities.

The DSEIS characterizes mussel populations within the main-channel border and the main channel of the MMR as insubstantial due to limited habitat. What populations are present within the MMR are likely limited to the floodplain and side channels. The document does not provide an assessment of project impacts on mussels given their limited presence. The Missouri Department of Conservation generally confirms the Corps' assessment of the MMR's mussel population. However, we strongly suggest that Federal and state natural resource agencies should be consulted as part of each site-specific project to confirm mussel status in each local instance.

Environmental Consequences
As identified earlier, organizing impacts on physical resources by component habitat types would improve the readability of the analysis of these impacts. Currently, the DSEIS includes a detailed habitat impact discussion within sections addressing biological resources.

The document characterizes river training structure impacts on various riverine habitat as generally providing an increase in low-velocity habitats, particularly shallow, low velocity habitat, while decreasing shallow to moderate-depth, high velocity habitat. This moderate-depth, high velocity habitat resembles the unstructured main channel border habitat which has decreased in the MMR with the placement of training structures since 1976. The DSEIS notes that these changes affect the fish species utilizing these different habitat types. In addition, migrating fish species could experience difficulty traversing complex flow patterns created by training structures along the main channel border. This shift in habitat types significantly affects the MMR fish community, and the DSEIS acknowledges that compensatory mitigation is warranted. The planned main channel border habitat model is intended to both characterize habitat loss and guide mitigation of damaged and lost habitat. We strongly recommend that the Corps not proceed with the construction of additional regulating structures until the main channel border habitat model is completed and site-specific structure design and mitigation needs can be identified for each site.

The DSEIS indicates that the Corps does not expect implementation of the preferred alternative to result in an increase in commercial traffic within the MMR. We recommend that the Corps revisit its NEPA compliance for the Regulatory Works Project should the transportation profile of the System change with the expansion of the project's structure coverage.

If a Biological Assessment (BA) has been prepared in conjunction with the preparation of the DSEIS, EPA recommends the Final SEIS provide an analysis of species impacts, rather than defer completely to successive SSEAs. We also recommend any correspondence received from USFWS pertaining to the BA should be incorporated into the Final SEIS.

Mitigation, Restoration and Endangered Species Act Efforts
The explanation on page 24 of the DSEIS that compensatory mitigation for project impacts is intended in the NEPA sense rather than as used under Section 404 of the Clean Water Act (CWA) is confusing. As mitigation for adverse impacts associated with regulating structures is critical to the NEPA analysis, additional explanation of this distinction would better support the overall impacts assessment.

The DSEIS would be improved with an inventory of all efforts to date to construct and restore habitat within the MMR under multiple authorizations (e.g., Upper Mississippi River Restoration Program (UMRR), Endangered Species Act, and CWA). A table listing the number, locations, and purpose of projects since the 1976 EIS would provide the reader with an important gauge of the restoration efforts to date in the MMR (e.g., sturgeon habitat mitigation, compliance with 1990 Biological Opinion, etc.). The 1976 EIS predates most, if not all, of the restoration programs currently implemented on the Upper Mississippi River (e.g., UMRR, formerly known as the Environmental Management Program, was authorized in 1986). It is our understanding that very few projects implemented as part of the UMRR have been conducted within the MMR.

The Corps' explanation that mitigation would only be considered for adverse project effects occurring since the Notice of Intent is not compelling. As a supplement to the 1976 EIS, the SEIS should identify any mitigation deficit from past projects as part of its cumulative impacts analysis. The adverse impacts of the entire Regulatory Works Project should be identified along with any mitigation efforts occurring as part of the Regulatory Works Project or the UMRR.

The Corps' position regarding discretionary mitigation for fish and wildlife damages arising from project actions under Section 906(b) of the Water Resources Development Act of 1986, based on the project construction prior to 1986, does not seem logical. With the construction of new structures and features as part of an expanding Regulatory Works Project, mitigation for natural resource damages should be mandatory. Later text in the Mitigation Plan states that Habitat Units "lost that are determined to be a 'significant' impact would require mitigation." EPA recommends that no project construction move forward without detailed, site-specific mitigation plans in place. As we recommended in earlier comments, project implementation should not proceed without finalization and implementation of the Corps' planned main channel border habitat model.

Air Quality and Construction Emission Control Efforts

EPA recognizes that diesel emissions and fugitive dust from project construction may pose environmental and human health risks and should be minimized.[1] We recommend the Corps consider the following protective measures, discuss emissions reduction measures regularly employed on construction/dredging equipment, and commit to applicable measures from the following list in the Final SEIS and Record of Decision.

Mobile and Stationary Source Diesel Controls

Purchase or solicit bids that require the use of vehicles that are equipped with zero-emission technologies or the most advanced emission control systems available. Commit to the best available emissions control technologies for project equipment in order to meet the following standards.

- On-Highway Vehicles: On-highway vehicles should meet, or exceed, the EPA exhaust emissions standards for model year 2010 and newer heavy-duty, on-highway compression-ignition engines (e.g., long-haul trucks, refuse haulers, shuttle buses, etc.).[2]
- Non-road Vehicles and Equipment: Non-road vehicles and equipment should meet, or exceed, the EPA Tier 4 exhaust emissions standards for heavy-duty, non-road compression-ignition engines (e.g., construction equipment, non-road trucks, etc.).[3]

[1] In 2002, EPA classified diesel emissions as a likely human carcinogen, and in 2012 the International Agency for Research on Cancer concluded that diesel exhaust is carcinogenic to humans. Acute exposures can lead to other health problems, such as eye and nose irritation, headaches, nausea, asthma, and other respiratory system issues. Longer term exposure may worsen heart and lung disease. See: https://www3.epa.gov/region1/eco/diesel/health_effects.html

[2] http://www.epa.gov/otaq/standards/heavy-duty/hdci-exhaust.htm

[3] http://www.epa.gov/otaq/standards/nonroad/nonroadci.htm

- Marine Vessels: Marine vessels servicing infrastructure sites should meet, or exceed, the latest EPA exhaust emissions standards for marine compression-ignition engines (e.g., Tier 4 for Category 1 & 2 vessels, and Tier 3 for Category 3 vessels).[4]
- Low Emission Equipment Exemptions: The equipment specifications outlined above should be met unless: 1) a piece of specialized equipment is not available for purchase or lease within the United States; or 2) the relevant project contractor has been awarded funds to retrofit existing equipment, or purchase/lease new equipment, but the funds are not yet available

Consider requiring the following best practices through the construction contracting or oversight process:

- Use onsite renewable electricity generation and/or grid-based electricity rather than diesel-powered generators or other equipment.
- Use ultra-low sulfur diesel fuel (15 ppm maximum) in construction vehicles and equipment.
- Use catalytic converters to reduce carbon monoxide, aldehydes, and hydrocarbons in diesel fumes. These devices must be used with low sulfur fuels.
- Use electric starting aids such as block heaters with older vehicles to warm the engine.
- Regularly maintain diesel engines to keep exhaust emissions low. Follow the manufacturer's recommended maintenance schedule and procedures. Smoke color can signal the need for maintenance (e.g., blue/black smoke indicates that an engine requires servicing or tuning).
- Retrofit engines with an exhaust filtration device to capture diesel particulate matter before it enters the construction site.
- Repower older vehicles and/or equipment with diesel- or alternatively-fueled engines certified to meet newer, more stringent emissions standards (e.g., plug-in hybrid-electric vehicles, battery-electric vehicles, fuel cell electric vehicles, advanced technology locomotives, etc.).
- Retire older vehicles, given the significant contribution of vehicle emissions to the poor air quality conditions. Implement programs to encourage the voluntary removal from use and the marketplace of pre-2010 model year on-highway vehicles (e.g., scrappage rebates) and replace them with newer vehicles that meet or exceed the latest EPA exhaust emissions standards.

Fugitive Dust Source Controls

- Stabilize open storage piles and disturbed areas by covering and/or applying water or chemical/organic dust palliative, where appropriate. This applies to both inactive and active sites, during workdays, weekends, holidays, and windy conditions.
- Install wind fencing and phase grading operations where appropriate, and operate water trucks for stabilization of surfaces under windy conditions.
- When hauling material and operating non-earthmoving equipment, prevent spillage and limit speeds to 15 miles per hour (mph). Limit speed of earth-moving equipment to 10 mph.

[4] http://www.epa.gov/otaq/standards/nonroad/marineci.htm

Occupational Health

- Reduce exposure through work practices and training, such as turning off engines when vehicles are stopped for more than a few minutes, training diesel-equipment operators to perform routine inspection, and maintaining filtration devices.
- Position the exhaust pipe so that diesel fumes are directed away from the operator and nearby workers, reducing the fume concentration to which personnel are exposed.
- Use enclosed, climate-controlled cabs pressurized and equipped with high-efficiency particulate air (HEPA) filters to reduce the operators' exposure to diesel fumes. Pressurization ensures that air moves from inside to outside. HEPA filters ensure that any incoming air is filtered first.
- Use respirators, which are only an interim measure to control exposure to diesel emissions. In most cases, an N95 respirator is adequate. Workers must be trained and fit-tested before they wear respirators. Depending on the type of work being conducted, and if oil is present, concentrations of particulates present will determine the efficiency and type of mask and respirator. Personnel familiar with the selection, care, and use of respirators must perform the fit testing. Respirators must bear a NIOSH approval number.

Cumulative Impact Analysis

The DSEIS concludes, in Section 4.6.6, that the cumulative impacts of the project in combination with other past, present and future actions affecting the Upper Mississippi River System do not "rise to a level of significance." The historical impact of creating and maintaining a system of navigation on the Mississippi River has resulted in significant changes to hydrology and ecology of the River and its floodplain. The purpose of the NEPA document is to characterize the impacts of a proposed Federal action and, by definition, an EIS is required when the project has significant impacts. The Corps has already determined that there are significant impacts resulting from continuing operation of the Regulating Works Project warranting an EIS. It is not clear why the Corps would make such a statement in this document. The Corps' reference to the significance level of "incremental impacts" is contrary to the concept of cumulative impact analysis.

The DSEIS does not adequately address the potential for excessive river bed scouring or bed loss. Combined with commercial dredging, the placement of dams on tributary rivers, and bank revetments, the continuing placement of river training structures could contribute to excessive sediment scouring in portions of the navigation channel. Bed loss affects floodplain ecology by lowering the groundwater level in the floodplain, could result in head cutting in tributary rivers, isolates backwaters and side channels, and could also threaten infrastructure within the main channel and channel margin. With the narrow exception of the impacts of bed lowering on side channel habitat, the DSEIS does not address the potential for unintended bed loss in select reaches resulting from continued training structure placement. Appendix A, Effects of RTS on Flood Levels, acknowledges the impact of training structures on bed and surface water elevations in multiple document locations. The Kansas City District of the Corps is presently investigating the impacts of and solutions to bed loss, within the navigable portion of the Missouri River, particularly in the St. Joseph to Kansas City reaches. River training structure modification is being considered as a potential remedy to slowing continuing bed loss. Consequently, EPA recommends the Final SEIS include a more robust cumulative impacts analysis incorporating the above.

Climate Adaptation

The DSEIS characterizes projected changes to regional climate within the MMR watershed based on its 2015 Civil Works Technical Report. However, it is not clear within the DSEIS that an analysis was conducted of projected changes in precipitation levels and subsequent shifts in hydrology and sediment movement as related to project performance, particularly under extreme high and low flows. This analysis is critical as changes in the hydrology in these watersheds could affect the navigational capability of and demands on the project.

EPA recommends the Corps provide a more robust discussion of its analysis to include the anticipated effect of projected changes in flow regime and consideration of extreme high and low flows on the project.

Editorial Comments

Terms such as "river forecast," "river cutoff," and "placement of hard points" may not be readily understood by reviewers. EPA recommends these terms be explained in the Final SEIS (e.g., as a footnote).

Reference to Table 4-3 in the section entitled "Interrelated Effects" (page 280) appears to be incorrect. EPA recommends this section refer to Table 4-1.

TRIBAL HISTORIC PRESERVATION OFFICE

Date: December 2, 2016 **File: 1617-1431MO-11**

RE: USACE, St. Louis District, Middle Mississippi River Regulating Works Project, Multiple Counties, Missouri and Illinois

USACE – St. Louis District
Kip Runyon
1222 Spruce St.
St. Louis, MO 63103-2833

Dear Mr. Runyon,

The Osage Nation Historic Preservation Office has received notification and accompanying information for the proposed project listed as USACE, St. Louis District, Middle Mississippi River Regulating Works Project, Multiple Counties, Missouri and Illinois. **After reviewing the available information for the project, the Osage Nation requests that a cultural resources survey be conducted for areas that have not been previously disturbed that are subject to rock placement for the 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 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).

The Osage Nation has a vital interest in protecting its historic and ancestral cultural resources. **The Osage Nation anticipates reviewing and commenting on the planned Phase I cultural resources survey report for the proposed USACE, St. Louis District, Middle Mississippi River Regulating Works Project, Multiple Counties, Missouri and Illinois.**

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.

Jackie Rodgers
Archaeologist

627 Grandview. Pawhuska, OK 74056, (918) 287-5328, Fax (918) 287-5376

<u>Responses to U.S. Fish and Wildlife Service Comments</u>

General Comments

1.1.2 Process for New Construction under the Regulating Works Project

Comment 1: *This section does not clearly describe coordination with partners and how partner comments are addressed and documented during the process. The USFWS recommends that the USACE more clearly define the role of partners in the project development process and how that coordination is being documented.*

Response: Specific information on interagency coordination through the River Resources Action Team has been added to Chapter 1 and more detail on the coordination that takes place for new construction and operation and maintenance has also been added to Chapter 1.

Comment 2: *Figure 1-3 – In order for Federal and State stakeholders and individuals or groups to fully understand the effects of the Project(s), the completion of post project evaluation reports and additional coordination with partners is required. These additional steps would help the stakeholders understand if the project objectives have been met and inform future project decisions. These steps would also allow for potential changes to be made if the desired outcome was not achieved. We therefore recommend that steps be added to the development process to incorporate project functionality into the decision making framework.*

Response: Project monitoring and adaptive management will be part of the mitigation planning efforts associated with site-specific EAs, providing opportunity for potential changes to the work area and/or mitigation measures. Mitigation plans associated with site-specific EAs will establish a consultation process with appropriate agencies to evaluate mitigation effectiveness.

1.1.3 Process for Dredging under the Regulating Works Project

Comment 3: *The SEIS indicates that disposal is typically accomplished with unconfined, in-river placement and that upland disposal is cost-prohibitive and is generally only considered when in-channel disposal would violate water quality conditions. In addition, all dredging is coordinated with state and Federal natural resource agency partners to avoid and minimize potential impacts to sensitive fish and wildlife habitats and to maximize potential benefits. The USFWS has been involved with developing initial general dredge disposal guidelines for the MMR (1996) and has been involved with ongoing dredge coordination including the recent development of dredging master plans for the MMR; however, the process and management strategy is generally unclear. The Rock Island and St. Paul USACE Districts have dredged material placement coordination processes in place and have worked with their partners to develop channel maintenance and dredge material management plans that help guide the placement of material on the Upper Mississippi River. The USFWS recommends that the St. Louis USACE District more* *clearly define the dredge material placement coordination process and consider developing a dredged material management plan the MMR as described in the USACE Planning Guidance Notebook (ER 1105-2-100).*

Response: Dredged Material Management Plans are only required for projects that do not have a 20-year dredged material disposal capacity, which is not applicable to the Regulating Works Project. However, the District has made improvements over the last several years with planning for dredged material placement locations for the Project. A Dredge Master Plan showing dredging areas and placement locations was developed in 2014. The Dredge Master Plan is used for coordination efforts and is updated at the end of each dredge season. Section 1.1.4, Process for Dredging under the Regulating Works Project, has been expanded to include more information on the dredge coordination process, including the Dredge Master Plan.

Comment 4: *Specifically the USFWS is interested in evaluating all potential measures, including upland disposal, to avoid and minimize potential impacts to sensitive fish and wildlife habitats from dredge material placement. The USFWS also believes there is significant value in identifying additional areas for beneficial uses of dredged material. Since 2011, the flexible dredge pipe has been utilized for approximately 8% of the St. Louis USACE District dredging workload and the USFWS believes there are additional opportunities for utilizing the flexible dredge pipe as described in the USACE Technical Report M57 "Engineering Considerations for Island and Sandbar Creation Using Flexible Floating Dredge Disposal Pipe Middle Mississippi River, Miles 200.0 to 0.0". The USFWS recommends that these measures be incorporated into the dredged material management plan if developed.*

Response: See response to Comment 3 above regarding dredged material management plans. The District will continue to coordinate all dredging with the Service to avoid and minimize potential impacts to sensitive fish and wildlife habitat and to plan the use of the flexible dredge pipe. With respect to upland disposal, the District is required to conduct dredge disposal practices consistent with the Federal Standard (33 CFR §335-338), requiring "...the least costly alternatives consistent with sound engineering practices and meeting the environmental standards established by the 404(b)(1) evaluation process..." Upland disposal would not meet the federal standard due to being cost-prohibitive except in the rare circumstances when in-channel disposal would not meet Clean Water Act requirements.

Comment 5: *Figure 1-4 - The USFWS recommends that additional coordination occur with partners following the post-dredge survey and that this step be added to the dredging development process. Currently the USACE must provide the USFWS an annual dredge material management report that includes information concerning dredging/disposal locations, quantities of material, the results of sediment size analysis and methods of disposal. This reporting should be described in the process and implemented accordingly.*

Response: Section 1.1.4, Process for Dredging under the Regulating Works Project, has been expanded to include more information on the dredge coordination process, the Dredge Master Plan, and information to be provided through the coordination process.

1.1.4 Dredging Reduction under the Regulating Works Project

Comment 6: *The described purpose of the Project is to obtain and maintain the authorized navigation channel through regulating work structures and dredging, with a goal of reducing costly dredging to a minimum. Figure 1-6 describes the quantity of material dredged from the MMR from 1964 to 2014. It is unclear from this figure what affect the regulating works program has had on reducing dredging over the specified time period. Information included in this section indicates that the amount of dredging is dependent on a number of independent factors and that it is difficult to develop trends solely from the dredging data set. Additional information is provided; however, the information appears to be insufficient to justify the continued construction of regulating work structures.*

Response: Additional information and analysis on dredging reduction on the MMR resulting from river training structure construction has been added to section 1.1.5, Dredging Reduction under the Regulating Works Project.

Comment 7: *This section is critical to describing the purpose of and need for the Project. The Purpose and Need statement is among the most important chapters in a NEPA document, because it provides the basis for determining the range of alternatives considered in detail. A strong Purpose and Need statement should (1) clearly describe each of the purposes and needs; and (2) provide specific factual information that supports the existence of those needs.*

The USFWS recommends that additional information be provided to show specifically how regulating work structures have reduced dredging in the MMR and/or how other factors have influenced the effectiveness of the Project. This could include a greater discussion on the amount sediment entering the system from the Missouri River, Upper Mississippi River, and other tributaries to the system and the transport of that sediment through the system. ***Note*** *- This comment was previously mentioned in the Final Independent External Peer Review Report on the SEIS.*

Response: Additional information and analysis on dredging reduction on the MMR resulting from river training structure construction has been added to section 1.1.5, Dredging Reduction under the Regulating Works Project. Additional information on sediment in the MMR has been added to section 3.2.2, Geomorphology.

1.1.5 Process for Bank Stabilization

Comment 8: *This section does not clearly describe how bankline erosion is being evaluated to determine if the erosion is having an impact on the navigation channel and if bank stabilization may or may not be needed. The USFWS recommends that the USACE further describe the evaluation and project selection process for bank stabilization.*

Response: See revised section 1.1.6, Process for Bank Stabilization, for additional details on identification, design and coordination of bank stabilization.

Comment 9: *This section does not clearly describe coordination with partners and how partner comments are addressed and documented during the process. The USFWS recommends that the USACE more clearly define the role of partners in the development process and how that coordination is being documented.*

Response: See revised section 1.1.6, Process for Bank Stabilization, for additional details on identification, design and coordination of bank stabilization.

1.1.6 Rock Removal

Comment 10: *This section does not clearly describe the removal of rock pinnacles and outcroppings in the lower MMR and the coordination that occurred for the project. The USFWS recommends that USACE provide additional information in this section to describe the work and the coordination process for this project including coordination for any future work.*

Response: More information on rock removal activities has been added to the Section and the reader has been directed to the Rock Removal SSEAs on the SEIS Library web site for more information. Specific information on the coordination process for any future rock removal activities cannot be provided due to the unique circumstances of each project location.

1.4 Scoping/Public Involvement

Comment 11: *The NOI to prepare the SEIS was published on December 20, 2013. The USFWS provided formal comments in response to the NOI in a letter dated January 17, 2014, and participated in the scoping process during a meeting of the River Resources Action Team (RRAT) Executive Board on February 20, 2014. The USACE has not provided a direct response to these comments; however, they describe in the Draft Scoping Report (April 2014) where these comments would likely be addressed in the draft SEIS. The USFWS continues to request a direct response from the USACE regarding their comments and how they were/are being addressed in the draft SEIS.*

Response: Comments received during scoping meetings are used to inform and guide the scope of issues to be addressed and identify the significant issues to be considered during document preparation. It is not standard procedure, nor is it required by USACE regulations, for USACE to respond directly to scoping comments. Rather, the resulting documentation should acknowledge and reflect consideration of those comments.

2.1 Alternatives Considered

Comment 12: *Alternatives considered include the Continue Construction Alternative or No Action Alternative and the No New Construction Alternative. Under the Continue Construction Alternative construction, operation, and maintenance of the Project would continue as it is currently being implemented with the addition of analyzing the potential need for and implementation of compensatory mitigation on a site-specific basis. The No New Construction Alternative consists of not constructing any new river training structures for navigation purposes but continuing to maintain the navigation channel by dredging and by maintaining existing river training structures and bankline stabilization to ensure they continue to achieve their intended functions. Any alternatives outside of the Project authorization would require a planning study for either modification of the Project or new authorization from Congress on how to obtain and maintain navigation within the MMR. During the evaluation process for the SEIS the USACE did not discover any reasonable or feasible alternatives that warranted transitioning the SEIS to a planning document.*

In their January 17, 2014, letter responding to the NOI to prepare the DSEIS for the Project, the USFWS recommended the USACE consider an additional alternative that would provide a greater emphasis on the avoidance and minimization of sensitive fish and wildlife resources. This alternative would also allow for additional habitat measures for fish and wildlife resources. In addition, the USFWS requested that the USACE consult with the USFWS and state conservation agencies early in the planning process to ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. Similar comments were made by the Missouri Department of Conservation, the agency responsible for Missouri's forest, fish and wildlife resources. Currently there are very few areas in the MMR that haven't been developed or greatly impacted by the Project and most of the few remaining areas contain sensitive fish and wildlife resources. There has been increased pressure in recent years to implement Regulating Works Projects in these areas which has raised concerns with the resource agencies. The FWCA of 1958 provides that "wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation…" and that "The reporting officers in project reports of the Federal agencies shall give full consideration to the report and recommendations of the Secretary of the Interior and to any report of the State agency on wildlife aspects of such projects, and the project plan shall include such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits." Further, the 2003 Agreement between the USFWS and the USACE for conducting FWCA activities was developed to ensure that the USFWS is involved with USACE projects to help find solutions to water resources development problems that avoid, minimize, or mitigate impacts to fish and *wildlife. A major goal of the Agreement is to ensure the USFWS is invited to participate early in throughout the planning process to facilitate the FWCA's equal consideration provision. The USFWS has not been contacted about the specific recommendations provided in response to the NOI and it doesn't appear that their concerns were addressed in the SEIS. The USFWS recommends that the USACE consider their original comments and recommendations and work with the USFWS and state natural resource agencies to develop an alternative that ensures adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources.*

Response: Information has been added to Section 1.1.2, Interagency Coordination, on the incorporation of avoid and minimize measures into the Project through interagency coordination. Information has also been added to Chapter 2 on the alternative development process detailing how incorporation of avoid, minimize, and potential compensatory mitigation measures resulted in development of a middle ground alternative as requested. Further, see response to Comment 13 below regarding information in Appendix K detailing the lack of authority for the District to use Regulating Works Project construction funding for ecosystem restoration matters.

Comment 13: *The 1976 EIS included a post-authorization change that would include fish and wildlife habitat restoration as a project purpose to allow the USACE to compensate for adverse effects of the project. In the 1976 EIS, the USACE recognized that the overall effects of attaining the nine-foot navigation channel have not been beneficial upon the riverine ecosystem and that a significant amount of fish and wildlife habitat has been affected. Changes proposed under the post-authorization included dredging of side channel areas to prolong and enhance the fish and wildlife attributes they possess, beneficial use of dredged material, maintenance and construction of pile dikes to enhance fish habitat, notching and/or lowering of existing dikes, and altering stone dikes to provide access to islands. The intent of this change was to preserve and enhance fish and wildlife habitat associated with the riverine system, while continuing to utilize the river for navigational purposes. The USFWS has routinely expressed their support of the USACE's efforts to effect a post-authorization change to include fish and wildlife conservation measures as a project purpose on the MMR. The USFWS believes this change would lead to preservation of existing fish and wildlife habitat, potential modifications to current construction, operation and maintenance procedures, and compensation for past project damages to fish and wildlife habitat. The USACE indicates in the SEIS that the components considered as part of the post-authorization change have been incorporated over time as components of the Project or have been addressed under other authorities that have the purpose of ecosystem restoration, thus the USACE is not considering a post-authorization change alternative in the SEIS.*

Section 3(a) of the FWCA of 1958, Section 906 of the Water Resources Development Act (WRDA) of 1986, and Section 5099 of the WRDA of 2007 authorize the protection, restoration, enhancement, and mitigation of fish and wildlife resources to occur under the Regulating Works Project.

- *Section 3(a) of the FWCA of 1958 states as follows; "whenever the waters of any stream or other body of water are impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, adequate provision, consistent with the primary purposes of such control, shall be made for the use thereof, together with any areas of land, water, or interests therein, acquired or administered by a Federal agency, in connection therewith, for the* ***conservation****,* ***maintenance****, and* ***management*** *of wildlife resources thereof, and its habitat theron, including the* ***development*** *and* ***improvement*** *of such wildlife resources pursuant to the provisions of section 2 of this Act."*

- *Section 906(b)(1) of WRDA 1986 states as follows; "After consultation with appropriate Federal and non-Federal agencies, the Secretary is authorized to* ***mitigate damages*** *to fish and wildlife resulting from any water resources project under his jurisdiction, whether completed, under construction, or to be constructed. Such mitigation may include the acquisition of lands or interests therein..."*

- *Section 5099 of WRDA 2007 states as follows; "As a part of the operation and maintenance of the project for the Mississippi River (Regulating Works), between the Ohio and Missouri Rivers, Missouri and Illinois, authorized by the first section of an Act entitled ''Making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes'', approved June 25, 1910 (36 Stat. 630), the Secretary may carry out activities necessary to* ***restore*** *and* ***protect*** *fish and wildlife habitat in the middle Mississippi River system. Such activities may include modification of navigation training structures, modification and creation of side channels, modification and creation of islands, and studies and analysis necessary to apply adaptive management principles in design of future work." The USFWS understands thatthe USACE via a memorandum for commander dated May 12, 2008, has been directed to not pursue further activities under the authority of section 5099 unless funds are specifically appropriated by Congress for such work. However, given this authorization exists; this authority should be included with the existing alternatives and/or included with an additional recommended alternative.*

Response: See Appendix K, Regulating Works Project History, which is a revised version of the Supplement to Appendix F in the Draft SEIS for additional details about the history of the project, including the actions taken by the Corps and Congress following the 1976 EIS as well as Corps decisions and analysis on the above-referenced legislation and authority. Since the original EIS in 1976, the District has taken actions to seek a Post Authorization Change and/or the measures described in the 1976 EIS. As discussed in Appendix K and Chapter 1, the District has acted upon the ability to do this within the Project's authority. However, to date, there has not been legislation enacted to allow the District use of

Regulating Works Project construction funding for ecosystem restoration. Further, any authority for ecosystem restoration has limitations such as requiring a cost-share sponsor, a feasibility/planning study or report (depending on which authority would be utilized), and funding appropriated for the study and construction of such project (e.g., the UMRR Program, Section 5099 of WRDA 2007, Section 4002(b) of WRRDA 2014, NESP, Beneficial Uses of Dredged Material (Section 204 of WRDA 1992), and Project Modification for Improvement of the Environment (Section 1135 of WRDA 1986) – all described in detail in Appendix K). Any actions taken under these authorities would have their own NEPA documentation separate from the Regulating Works Project since it would be for project purposes and actions taken outside of the ongoing project as it is currently being carried out. Therefore, due to this and the analysis below, it is not reasonable to expect separate, specific funding for such ecosystem restoration or enhancement projects to be carried out with Regulating Works Project funding since the ability to do this through other authorities already exists. Therefore, a Post-Authorization Change alternative to the Regulating Works Project is not a reasonable alternative. Also, see Chapter 2 for the addition of an Alternatives Development Process section.

Actions Taken from 1976 EIS Commitments

The 1976 EIS Statement of Findings indicated that the District would continue to pursue a post-authorization change for fish and wildlife purposes to the extent acted upon separately or integrated into the comprehensive river management plan that was in the process of being authorized at the time. As described in greater detail in Appendix K, the commitments made in the 1976 EIS resulted in Congress granting the Corps the authority for the Upper Mississippi River Restoration Program (UMRR Program) in 1986, which has been extremely successful in both monitoring and obtaining information as well as constructing projects to restore habitat lost due to various human activities in the Upper Mississippi River as defined by that legislation. The UMRR Program is separate and distinct from all of the navigation projects in the Upper Mississippi River watershed, and any work completed under this program has its own study/report and NEPA documentation. While there has not been a project yet constructed in the MMR under this program, the District has been working with various potential project sponsors to utilize this authority more in this area of the Mississippi River, and there are currently six projects being studied or considered, three of which USFWS is the sponsor (see information added in Section 4.6, Cumulative Impacts, and Appendix K on these projects). As USFWS is aware, there are constraints in the MMR for these projects, including the need for a project cost-share sponsor and availability of land for the projects. The District will continue to work under this authority to provide ecosystem restoration benefits within the MMR.

After the establishment of the UMRR Program, the District spent most of the 1990's working on the Navigation and Ecosystem Sustainability Program (NESP) study. Implementation of this program was authorized in 2007 but to date has not received substantial funding. The environmental projects under this program include restoration of the river habitat to benefit the ecosystem, with some of those projects being in the MMR.

Again, this program is separate and distinct from the Regulating Works Project and has its own report and NEPA documentation (See also Section 4.6, Cumulative Impacts, and Appendix K which have been revised to provide more details about NESP). Also, as noted in Section 4.6, Cumulative Impacts, and Appendix K, some of the projects identified for NESP are now being considered under UMRR since NESP funding does not seem likely in the near future.

Fish and Wildlife Coordination Act

As described in Appendix K, the Project was considered 82% complete in 1958, so pursuant to the FWCA, it is not applicable to the Regulating Works Project. The FWCA does not provide for subsequent applicability due to increased price levels or additional work requirements that are not a modification to the project. Further, pursuant to ER 1105-2-100, Appendix C-3(f)(1), the initial threshold for FWCA applicability is when the authorized plan is modified or supplemented. The Regulating Works Project is being carried out as authorized. The purpose of the SEIS was merely to update the original EIS with significant new information and circumstances to evaluate the impacts of the currently authorized project – not due to any substantial change in the project. Again, had it been determined that the Project should be modified or a post-authorization change report prepared, this would have required a new project planning study, which possibly would have made the FWCA applicable to such study. However, see Chapter 1 and Appendix K of the SEIS for more detail added with respect to informal coordination with the USFWS and state resource agencies with respect to new construction and operation and maintenance of the Regulating Works Project. This coordination will continue with future work, as well as consultation on activities for Endangered Species Act compliance. The District recognizes the expertise of these agencies as well as their ability to explain localized or specific concerns, so the District values the input and continues to coordinate with these agencies on the Regulating Works Project.

WRDA 2007, Section 5099

Appendix K has been revised to include a discussion of Section 5099 of the 2007 Water Resources Development Act (WRDA). Section 5099 provides discretionary authority for the Secretary to carry out activities to restore and protect fish and wildlife as part of the "operations and maintenance" of the Regulating Works Project. The statute does not provide the authority for such activities as part of "construction." It should be noted that Section 5099, as enacted, specifically changed "construction" to "operation and maintenance" from the earlier draft versions of the bill. Further, the Corps implementation guidance provides that the activities listed in Section 5099 may be considered under the authority of UMRR and NESP and no further activities will be pursued unless funds are specifically appropriated by Congress for such work. Pursuant to 33 USC § 2213, a cost share sponsor will be required for any environmental restoration project purpose. Therefore, utilizing the UMRR Program would probably serve as a more feasible and likely to be funded, approved, and constructed ecosystem restoration project. Should funding ever be appropriated specifically under this authority, the proper study and documentation would be completed for such project(s), but at this time considering this work as a viable alternative for the Regulating Works Project is not reasonable or feasible.

WRDA 1986, Section 906(b) - Mitigation
WRDA 1986, Section 906(b) (33 USC § 2283(b)) does provide the Corps the discretionary authority to mitigate for projects already under construction when this legislation was passed. The District has been mitigating known impacts of the Regulating Works Project through avoidance and minimization measures since 1986, and Chapter 1 of the SEIS has been updated to provide more details and clarification on these measures and their success, as well as providing additional explanation on USFWS and state resource agency participation in the process of work area designs and avoidance and minimization measures. While the purpose of the SEIS was to update the Regulating Works Project 1976 EIS with the new and significant information currently existing, the District realized early on through review of this information and discussions with USFWS and state resource agencies, that while there was general information about impacts of river training structure construction, there was not enough information to quantify those impacts for assessing the significance of those impacts on river habitat. Therefore, pursuant to 40 CFR § 1502.22, the District sought to obtain this incomplete and unavailable information within a reasonable cost (See new section in Chapter 2 on the Alternative Development Process). USFWS as well as state resource agencies were involved in providing information and insight into the most effective and efficient way to obtain this information. The results from the additional engineering model and analyses of information and data indicated that the modified structures to avoid and minimize impacts to shallow, low velocity habitat and side channels have been successful. The only loss of river habitat due to the construction of river training structures identified from this additional information and analysis done by the District for the SEIS was to shallow to moderate depth, moderate to high velocity habitat. Upon review and analysis of this newly identified impact by the District and discussions with Corps experts outside the District, USFWS, and state resource agencies, it was determined that this negative impact due to future construction of river training structures may be significant. Therefore, as provided in Appendix C of the SEIS, a broad, programmatic mitigation plan was prepared explaining the plan for considering compensatory mitigation in future, tiered site-specific EAs. The District has been and will continue to consult and work with USFWS and state resource agencies in proceeding with any future compensatory mitigation.

Comment 14: *The USFWS recommends that an additional alternative be developed that provides greater emphasis on protection of existing fish and wildlife resources, includes restoration of fish and wildlife habitat as described in Section 5009 of WRDA 2007, and provides compensation for past Project damages to fish and wildlife habitats.*

Response: See the added Alternative Development Process section in Chapter 2 and the response to Comment 13 above that there is no authority as part of the Regulating Works Project to complete additional measures outside of mitigation and/or Endangered Species Act compliance for the enhancement or restoration of fish and wildlife habitat. Therefore, an alternative to consider these measures is not reasonable or feasible at this time. Should this become a reasonable possibility in the future, the proper documentation will be prepared. The work that the District already does as part of the Regulating Works Project within its authority to emphasize protection of fish and wildlife resources has been documented in the SEIS as part of the Continue Construction Alternative plus the possible addition of compensatory mitigation as discussed in Appendix C of the SEIS. Further, additional details on actions taken under O&M funding for Endangered Species Act compliance have been added to the SEIS. The known potentially significant impacts from the construction of river training structure construction identified in the 1976 EIS are already being avoided and minimized, and the new engineering model and analysis of information done as part of the SEIS process showed that those avoidance and minimization measures, along with projects pursuant to other authorities or for Endangered Species Act compliance, have been effective. The potentially negative impact identified in the SEIS that may result in the recommendation for compensatory mitigation was not a known negative, potentially significant impact until after the District developed the engineering model and conducted additional analyses while completing the SEIS.

2.2 Evaluation of Alternatives

Comment 15: *The Continue Construction Alternative involves river training structure construction that is equivalent to approximately 4.4 million tons of additional rock being placed in the MMR and a reduction of average maintenance dredging from the current level of approximately 4 million cubic yards per year to approximately 2.4 million cubic yards per year. This construction estimate is based on the expected quantity of reduced dredging per increment of river training structure construction which was derived by comparing existing dredging locations and the quantity of stone necessary to reduce dredging in those locations. It is unclear how much consideration was given to the cumulative impact of all the river training structures on the total quantity of dredged material in the MMR as shown in Figure 1-6 and while river training structures may initially reduce localized dredging amounts. It is also unclear what effect that the structures may have over an extended length of time and across the entire system. As mentioned above, the USFWS recommends that additional information be provided to specifically explain how regulating works structures have reduced dredging in the MMR and will continue to reduce dredging in the MMR in the future. This information should also explain how other factors have influenced the effectiveness of the Project. At this time, there is insufficient information provided to support the conclusion that the proposed river training structure construction will have the intended results.*

Response: Additional information and analysis on dredging reduction on the MMR resulting from river training structure construction has been added to section 1.1.5, Dredging Reduction under the Regulating Works Project.

Comment 16: *Information in the SEIS indicates that the exact location and quantity of future dredging needs as well as the future regulating works structure locations and designs are unknown; however, the programmatic analysis was used to estimate the remaining* *construction and associated impacts. Based on that analysis, the continued construction of regulating training structures would be expected to have a significant impact on main channel border habitat due to the potential loss of approximately 1,100 acres (8%) of the remaining unstructured main channel border habitat in the MMR. USACE indicates that this potential loss of habitat would result in the need for compensatory mitigation. While the USFWS agrees that unavoidable impacts should receive compensatory mitigation, the USFWS's mitigation policy places emphasis on avoidance and minimization of project impacts. It is not clear if any avoidance and minimization measures were utilized in the development of the alternatives for the proposed Project. The USFWS recommends that the USACE more clearly describe the avoidance and minimization measures that were utilized to develop the alternatives included in the SEIS and develop an additional alternative that provides greater emphasis on protection of existing fish and wildlife resources through avoidance and minimization.*

Response: See responses to Comments 13 and 14 above. Also see the Alternative Development Process section added to Chapter 2.

2.4 Identification of the Preferred Alternative

Comment 17: *The preferred alternative is the Continue Construction Alternative with the potential for compensatory mitigation. As previously discussed, there is a lack of information included in the SEIS to accept that the proposed river training structure construction will have the intended results and there appears to be a lack of consideration for fish and wildlife resources; therefore, the USFWS does not concur with the preferred alternative at this time. The USFWS recommends that the USACE consider their original comments (provided January 2014) and recommendations and work with the USFWS and State natural resource agencies to develop an alternative that ensures adequate and equitable protection, mitigation, and enhancement of fish and wildlife resources.*

Response: See responses to Comments 13, 14, and 16 above. Also see the Alternative Development Process section added to Chapter 2.

2.5 Future Implementation of the Regulating Works Project

Comment 18: *The SEIS covers the programmatic impacts that can reasonably be anticipated to occur going forward and under the preferred alternative. The Project would continue as it is currently being implemented with the addition of analyzing the potential need for and implementation of compensatory mitigation on a site-specific basis. As previously discussed, there is a lack of information in the SEIS regarding protection (avoidance and minimization) of fish and wildlife resources and a lack of information on how site-specific EAs will address protection (avoidance and minimization) of fish and wildlife resources. The USFWS recommends that the USACE provide additional information on how protection (avoidance and minimization) of fish and wildlife resources is being* *achieved at the Project level and will be achieved at the site-specific level.*

Response: See responses to Comments 13, 14, and 16 above. Also see the Alternative Development Process section added to Chapter 2.

Comment 19: *Information in the SEIS indicates that dredging activities and revetment construction are not anticipated to require site-specific EAs. It is unclear how these types of activities will be implemented in the future and what process will be followed to coordinate and consult with the agencies and to ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. The USFWS recommends that this process be more clearly described and that the USACE consider our previous comments regarding dredge coordination and consider site-specific EAs for revetment.*

Response: The coordination processes used by the District have been more clearly described in Chapter 1. Revetment will continue to be coordinated on a site by site basis and will be covered in SSEAs as necessary.

3.1 Introduction

Comment 20: *Figure 3-4 – An additional figure showing annual dike construction since development of the 1976 EIS would provide for better understanding of recent trends in dike construction and provide a better basis for understanding the potential impact of dike construction since 1976.*

Response: A figure has been added to Section 3.1 with the quantity of stone placed on the MMR since 1976.

3.2.2 Geomorphology

Comment 21: *Information in the SEIS indicates that the Project has contributed to an increase in cross sectional area, hydraulic depth, conveyance, and channel volume, although it is uncertain to what extent. The USFWS recommends that additional information be provided in the SEIS or additional studies be conducted to more clearly describe the changes in geomorphology and planform since the 1976 EIS and what role the Project has had in these changes. This should include a discussion of how these changes have impacted habitats of fish and wildlife resources. Table 3-6 highlights the broad impact of the Project since the 1976 EIS. Of specific concern is the conversion or loss of 5,319 acres of main channel border habitat.*

Response: Additional information on changes in geomorphology is incorporated by reference and can be found in Little et al. 2015. The District believes that the analyses of impacts to MMR main channel border habitat and associated fish and wildlife resources presented in the SEIS adequately characterize the impacts of continued construction of river training structures. The District will continue to incorporate new information in future SSEAs as it becomes available and will continue to work with the Service and other partner agencies to avoid and minimize impacts.

3.2.3 Side Channels

Comment 22: *According to the SEIS, when evaluating side channels based on geomorphology, bathymetry, and connectivity, most MMR side channels appear to be stable or improving and that has been aided by side channel restoration efforts that began in 1990's under the MMR Side Channels Habitat Rehabilitation and Conservation Initiative. However, there continue to be instances where side channels are filling and connectivity is decreasing or has been lost and a majority of side channels continue to be regulated or impacted by closing structures, upstream dike fields, and associated sediment deposition. Information in the SEIS indicates that only one of the existing thirty-two side channels does not have a closing structure and that the original purpose of the closing structures was to direct flow to the main channel to support navigation flows. The continued operation and maintenance of these structures and upstream dike fields will continue to limit flows to side channels and restrict fish use of these extremely important habitats. And while there are efforts being undertaken by the District to implement side channel restoration under different authorities, little to no restoration efforts have been implemented under the Project and this has hindered restoration efforts. Thus, the USFWS recommends that the USACE include side channel protection, maintenance, and restoration in the alternatives to be considered.*

Response: See responses to Comments 13, 14, and 16 above. The District will continue to avoid and minimize impacts to side channels through close coordination with the Service and other partner resource agencies.

3.2.6 Air Quality and Climate Change

Comment 23: *There is a lack of information in the climate change section regarding potential changes in temperature, changes in precipitation patterns, and increases in the frequency and intensity of severe weather events that may impact the MMR and how those potential changes are being incorporated or evaluated in the SEIS. Some information is provided in Section 4.2.6 of the SEIS but may be more appropriate to locate in this section.*

Response: Additional information on anticipated changes in climate and associated impacts to the Project has been added to Section 4.2.5, Impacts on Air Quality and Climate Change. The decision was made to keep information on recent climate trends and future climate projections together in Chapter 4 to make the discussion clearer.

3.3 Biological Resources

Comment 24: *Table 3-6 – This table highlights the impact of the Project since the 1976 EIS. Of specific concern is the conversion or loss of 5,319 acres of main channel border habitat. As described in the SEIS, the proposed additional impact from the Project to main channel border habitat is technically significant due to the magnitude of the potential adverse effect to unstructured main channel border habitat in comparison to the amount of that habitat remaining and the amount of similar habitat that has been lost in the past. The USFWS is concerned that the loss and continued degradation of this habitat will reduce substrate diversity and riverine productivity, thereby, reducing the natural forage base, and will reduce the availability of fish spawning substrate, larval and juvenile fish rearing habitat, and seasonal refugia. Thus, the USFWS recommends that the USACE include main channel border habitat protection, maintenance, and restoration in the alternatives to be considered.*

Response: The District concluded that the anticipated impacts to main channel border habitat associated with the Continue Construction Alternative going forward may warrant consideration of compensatory mitigation. Accordingly, the Continue Construction Alternative includes this consideration of compensatory mitigation for main channel border habitat. The main channel border habitat model that is currently being developed will be used to quantify impacts to and restoration of this habitat on work areas completed since 2013 and future work areas to assess the potential for compensatory mitigation. See Comment 13 above for information on Project authority for alternatives to be considered.

3.3.1 Benthic Macroinvertebrate Resources

Comment 25: *Information in the SEIS indicates that rock training structures have been shown to support high densities of aquatic macroinvertebrates when compared to the natural substrate of the main channel border. However, much of the described "natural substrate" has been altered due to construction of regulating works structures, dredging and dredge disposal, and clearing of woody debris. Similar results have also been found when woody debris or woody structures have been added to the system. The addition of woody structure has been shown to support higher invertebrate densities and species riches, and contained a different species composition than the surrounding substrates (Ecological Specialists, Inc., 2004). Incorporation of woody debris and use of woody structures have been identified as habitat restoration and enhancement measures in the USFWS's 2000 BO. This section should include a discussion of woody debris, including a discussion of the Woody Structure Pilot Project and invertebrate results described in the report below.*

Ecological Specialists, Inc. 2004. Final Report: Evaluation of Macroinvertebrate use of Woody Structure and Surrounding Substrate in the Open Portion of the Upper Mississippi River. Prepared for U.S. Army Corps of Engineers, St. Louis District. 71 pp.

Response: A discussion of woody debris and information from the referenced report have been added to Section 3.3.1, Benthic Macroinvertebrate Resources, and further details about work done in the MMR under the 2000 Biological Opinion as well as other environmental restoration programs have been added to Section 3.3.4, Threatened and Endangered Species, and Section 4.6, Cumulative Impacts.

3.3.2 Fishery Resources

Comment 26: *There is a lack of information in the Main Channel Border section describing fish use and the importance of this habitat to aquatic resources. The publications below contain information relevant to the importance of this habitat.*

- *Barko, VA, Herzog DP, Hrabik RA, Scheibe JS. 2004. Relationship among fish assemblages and main-channel-border physical habitats in the unimpounded Upper Mississippi River. Transactions of the American Fisheries Society 133:371-384.*
- *Barko VA, Palmer MW, Herzog DP, Ickes BS. 2004. Influential environmental gradients and spatiotemporal patterns of fish assemblages in the unimpounded Upper Mississippi River. American Midland Naturalist 152(2): 369–385.*
- *Phelps QE, Tripp SJ, Garvey JE, Herzog DP, Ostendorf DE, Ridings JW, Hrabik RA. 2010. Habitat use during early life history infers recovery needs for shovelnose sturgeon and pallid sturgeon in the Middle Mississippi River. Transactions of the American Fisheries Society 139(4): 1060–1068. DOI:10.1577/T09-199.1.*
- *Hintz WD, Porreca AP, Garvey JE, Phelps QE, Tripp SJ, Hrabik RA, Herzog DP. 2015. Abiotic attributes surrounding alluvial islands generate critical fish habitat. River Research and Applications 31:1218-1226. DOI:10.1002/rra.2829.*
- *Love SA, Phelps QE, Tripp SJ, Herzog DP. 2016. The importance of shallow-low velocity habitats to juvenile fish in the Middle Mississippi River. River Research and Applications DOI:10.1002/rra.3075.*

Response: Much of the information on main channel border habitat and its characteristics and importance is included in Chapter 4 so that it can be considered in the context of environmental consequences. Information from the two Barko references can be found in Section 4.3.2. Information from the other publications was added to Section 3.3.2 as appropriate.

3.3.3 Terrestrial Communities

Comment 27: *Information in the SEIS indicates that the potential impacts of the Project on terrestrial communities are minimal and that no further analysis is being conducted in the SEIS. The USFWS has expressed concern about the impacts of the Project on sandbars and islands in the MMR and the importance of these habitats to fish and wildlife resources including the least tern and pallid sturgeon. These habitats tend to fall in the transition between the aquatic and terrestrial environment. The USFWS recommends that additional information be provided in the SEIS to describe these habitats, changes in these habitats over time including changes due to the Project, and the importance of these habitats.*

Response: Information on islands has been added to chapters 3 and 4. With respect to sandbars and impacts to sandbars due to the Project, the analyses that the District conducted on main channel border habitat and the potential significant impacts to main channel border habitat include the impacts of the Project on sandbars.

3.3.4 Threatened and Endangered Species

Comment 28: *The USACE is utilizing the ESA Section 7 consultation for the Operation and Maintenance of the Mississippi River Navigation Project to address species listed under that consultation, and any newly listed species since that consultation are being addressed in a separate biological assessment included with the SEIS. The 2000 Biological Opinion (BO) for the Operation and Maintenance of the 9-foot Navigation Channel on the Upper Mississippi River System addressed channel maintenance dredging and river regulatory structures. In addition, a separate Tier II consultation was completed in 2002 to address Emergency Dredging for Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System. This document should be incorporated or referenced in the SEIS.*

Response: Information on the Emergency Dredging consultation has been added to Section 3.3.4.

Comment 29: *To facilitate compliance with Section 7(c) of the Endangered Species Act of 1973, as amended, Federal agencies are required to obtain from the USFWS information concerning any species, listed or proposed to be listed, which may be present in the area of a proposed action. You can visit the USFWS's Information, Planning, and Conservation System (IPaC, https://ecos.fws.gov/ipac/) to obtain an updated species list for inclusion in the Final SEIS.*

Response: The species list in the SEIS has been updated.

4.1 Environmental Consequences Introduction

Comment 30: *The impact from Navigation Traffic is an indirect effect of the Project and not a* *cumulative effect. As described in the SEIS, if all operation and maintenance activities on the MMR would cease then navigation in general would eventually cease to exist. Thus, navigation is dependent upon the Project and should be addressed accordingly in the SEIS. This should include a discussion of impacts to fish and wildlife resources including entrainment and a discussion of compensatory mitigation for those impacts.*

Response: The ceasing of all construction, operation and maintenance activities alternative was analyzed in the 1976 EIS with the conclusion that doing so would eventually cause navigation to cease to exist. Due to the purpose of the Project and the purpose of the SEIS, this alternative was not evaluated any further. However, it would be presumed that presently even if all construction, operation, and maintenance were to stop, there would still be some navigation traffic for some future period – if not forever without a catastrophic event. As described in the SEIS, the purpose of the project is to provide a safe and dependable navigation channel and to do so in a way that reduces dredging to a minimum. If all activities of the Regulating Works Project were to stop, eventually the navigation channel would no longer be safe or dependable, but at this point, it does not mean that navigation traffic would cease to exist. For example, there would be more groundings, banklines would erode or possibly fail, and at low water periods, navigation traffic would probably have to halt until the river stage rose again. However, presuming no catastrophic bankline failures, channel cutoff, or long-term drought occurred, navigation traffic could still operate – although the channel would not be as safe and dependable without the Regulating Works Project. Therefore, for the purpose of the SEIS in updating the Regulating Works Project impacts, navigation is considered a cumulative effect rather than an indirect effect.

4.2.1 Impacts on Stages

Comment 31: *Under the Continue Construction Alternative the analysis of water surface elevations at low flows indicate that stages are decreasing over time and this is the same conclusion that was reached in the 1976 EIS. The USFWS is concerned that continued river training structure construction will further decrease the stages at low flows and impact connectivity of and sedimentation within side channels. The USACE indicates that an evaluation on the impacts of river training structures at low flow has not been conducted. The USFWS recommends that additional research be conducted to evaluate the effect of various river training structures on stages at low flow and what if any measures can be developed to reduce this trend.*

Response: Analyses of the causes of channel degradation, including the impact of the construction of river training structures, has been conducted by the U.S. Army Corps of Engineers, Kansas City District. A summary of this analysis and its applicability to the MMR has been added to section 4.6.1, Prior Studies.

4.2.2 Impacts on Geomorphology

Comment 32: *Under the Continue Construction Alternative, the USACE expects that the average planform width, planform surface area, and channel surface area would continue to be in a state of dynamic equilibrium; however, it is expected that the cross sectional area, hydraulic depth, channel volume, and channel conveyance would continue to increase. Thus, the channel is expected to become narrower, deeper, and more efficient. There is a lack of discussion in this section on the impacts of river training structures on bathymetry, water velocity, and substrate composition within the main channel and off- channel areas from past and potential future actions. There is also a lack of discussion regarding the conversion of main channel border areas to main channel habitats. These changes are necessary to evaluate the impact of the proposed alternatives on fish and wildlife resources. The USFWS recommends that additional information be provided in this section to clearly describe the effects of river training structures on bathymetry, water velocity, and substrate composition and the conversion of main channel border habitat to main channel habitat. This discussion should also include the potential impacts of maintenance dredging on main channel and off-channel habitat.*

Response: Additional discussion on the effects of river training structures on bathymetry, water velocity, substrate composition and the conversion of main channel border habitat to main channel habitat has been added to section 4.2.2, Impacts on Geomorphology.

4.2.3 Impacts on Side Channels

Comment 33: *According to the SEIS, side channel habitat in the MMR appears to be maintaining at a relatively stable level; however, there is concern that the Regulating Works Project is decreasing river stages at low flows by deepening the channel and decreasing sediment load in the river. This could result in a loss of side channel habitat and reduced connectivity at lower river flows. Based on the anticipated future construction of river training structures, the USACE believes that the effect on river stages would be minor and inconsequential. In addition, any potential future adverse impacts would be addressed with compensatory mitigation. The USFWS remains concerned that the continued operation and maintenance of existing river training structures and construction of new river training structures will continue to limit flows to side channels and restrict fish use of these extremely important fish habitats. And while there are efforts being undertaken by the District to implement side channel restoration under different authorities little to no restoration efforts have been implemented under the Regulating Works Project and this has hindered restoration efforts. Thus, the USFWS recommends that the USACE include side channel protection, maintenance, and restoration in the alternatives to be considered.*

Response: See responses to Comments 13, 14, and 16 above. The District will continue to avoid and minimize impacts to side channels through close coordination with the Service and other partner resource agencies.

Comment 34: *Information in the SEIS indicates that maintenance dredging activities associated with the Continue Construction Alternative are not anticipated to have any adverse effects on MMR side channel habitat. The USFWS has expressed concerns about the potential impacts of dredge material placement on side channels including filling and/or restricting access. Thus, the USFWS recommends that the USACE consider the potential impacts to side channels from dredge material placement in the SEIS.*

Response: Chapter 1 has been updated to better explain the dredge coordination process. The District will continue to coordinate all dredging activities with the Service and other resource agency partners to avoid and minimize impacts to side channels.

4.2.4 Impacts on Water Quality

Comment 35: *There is a lack of discussion in this section on the impacts of new river training structures on water quality. The USFWS recommends that additional information be provided in this section to clearly describe the effects of river training structures on water quality metrics and this could include a discussion on changes in water depth and velocity in the habitat surrounding the structures. The publication below contains information relevant to this section.*

- *Sobotka MJ, Phelps, QE. 2016. A comparison of main and side channel physical and water quality metrics and habitat complexity in the Middle Mississippi River. River Research and Applications. DOI:10.1002/rra.3061.*

Response: The discussion of depth and velocity changes associated with river training structures can be found in Section 4.3.2, Impacts on Fishery Resources. For brevity the information is not repeated in the Water Quality Section. Information from the referenced publication has been added to the document as appropriate.

4.2.6 Impacts on Air Quality and Climate Change

Comment 36: *There is a lack of information in the climate change section regarding the potential effects of climate change on the system and what impacts that may have on fish and wildlife resources with implementation of the Project. The USFWS has expressed concerns that the continued operation and maintenance of existing river training structures and construction of new river training structures will continue to limit flows to side channels and restrict fish use of these extremely important fish habitats. For example, if climate change within the basin were to result in more frequent or severe droughts than this could further exacerbate the effects of the river training structures on side channel connectivity. The USFWS recommends that additional consideration be given in the section to the impact on fish and wildlife resources and their habitats.*

Response: Information has been added to Section 4.2.6 accordingly.

4.3.1 Impacts on Benthic Macroinvertebrate Resources

Comment 37: *Information in the SEIS indicates that impacts associated with dredging on macroinvertebrates are anticipated to be minor. The USFWS previously expressed interest in evaluating all potential measures, including upland disposal of dredge material, to avoid and minimize potential impacts to sensitive fish and wildlife habitats from dredge material placement. Coordinated development of a dredged material management plan or similar plan for the MMR would further reduce risk to macroinvertebrates from dredging and dredge material placement.*

Response: See responses to Comments 3, 4, and 5 above regarding dredged material management plans and coordination.

Comment 38: *There is a lack of discussion regarding the effects various regulating work structures can have on the factors that may influence abundance and diversity of macroinvertebrate resources. Such factors could include water depth, water velocity, substrate diversity, substrate stability, etc. (Ecological Specialists, Inc., 2004). The USFWS recommends that additional information be provided in the SEIS or additional studies be conducted to more clearly describe the impact of regulating work structures on macroinvertebrate resources. This should include a discussion of incorporating woody debris and/or use of woody structures in projects.*

Response: The District believes that the available information presented in the SEIS is adequate to support the conclusion that the Project's impacts on macroinvertebrates are not significant. The District will consider studies in the future as necessary. Additional information on woody debris has been added to Section 3.3.1, Benthic Macroinvertebrate Resources.

4.3.2 Impacts on Fishery Resources

Comment 39: *Dredging Impacts on Fishery Resources - There is a lack of discussion in this section regarding the avoidance and minimization measures for dredging including restrictions on the timing of dredging and coordination of dredged material placement as described in the USFWS's 2000 BO. There is also a lack of discussion regarding impacts of dredging and dredge disposal on the forage base of fishery resources. This information should be incorporated into this section.*

Response: Reference added to section directing reader to information on avoidance and minimization coordination for dredging in Section 1.1.4. Information on fishery resources impacts as they relate to macroinvertebrates added to section.

Comment 40: *Dike Effects - Information in this section indicates that the river training* *structures currently used by the District can provide improved habitat for fish by providing areas of reduced flow, a more diverse substrate, and additional cover. While this may be true, some caution should be utilized in evaluating the results of habitat preference studies conducted in the highly altered river environments of today. As described in the USFWS's 2000 BO, "the natural meandering processes of the MMR have been altered through channelization. Wingdams, revetments, closing structures and bendway weirs have fixed the channel in place, disrupting the dynamic processes that create and maintain pallid sturgeon habitat. As a result, the diverse habitats to which pallid sturgeon are adapted (e.g., braided channels, irregular flow patterns, flood cycles, extensive microhabitat diversity and turbid waters) continue to decline in quality and quantity" and "Continued maintenance of the 9-Foot Channel Project will result in further homogenization of the river environment, and thus, cause further declines in habitat quality, quantity and diversity". It is unclear whether the river training structure modifications currently utilized today can fully compensate for past and current Project impacts and truly mimic what would have existed in an unaltered system. In addition, operation and maintenance of existing structures will continue to impact habitat quality, quantity and diversity. Further studies may be necessary in order to truly understand the potential impact of these new river training structures and to help develop additional mitigation measures.*

Response: The SEIS updated the original EIS with all of the existing new information and circumstances, and analyses, modeling, and studies were completed as part of the SEIS to help in providing unknown or unavailable information as to the Project's impacts within economic feasibility (see Alternative Development Process Section added in Chapter 2). Future tiered site-specific EAs will assess any new studies not considered in the SEIS.

Comment 41: *River Training Structure on Fishery Resources - This section describes the effects of traditional dike structures, chevron dikes, bendway weirs, and revetment; however, there is not a description of the effects of notched dikes, rootless dikes, offset dikes, W-dikes, L-dikes, and multiple roundpoint structures (MRS), all of which are currently utilized for the Project. Additional information should be provided on the effects of these alternative structures. In addition, information in this section indicates that a USACE 2011 study concluded that bendway weirs are not having a serious detrimental effect on inside bar slopes. Prior to and during this study the USFWS expressed concerns about loss of main channel border habitat from bendway weir construction and the lack of consideration in the study. The study did conclude that main channel width increased which the USFWS believes results in a corresponding loss of main channel border habitat. This loss should be accounted for and included in the compensatory mitigation for Project impacts.*

Response: More information on the different types of river training structures used in the MMR has been added to Section 3.2.2, Geomorphology. The impacts of specific structure types and configurations, along with any mitigation measures, will be considered on a site-specific basis.

Comment 42: *Construction and Maintenance Effects - There is a lack of discussion regarding the ongoing effects of maintaining existing structures in their current state. Additional information should be provided to describe the continued effect of these structures throughout this section.*

Response: Information has been added to Chapter 1 to better explain District coordination processes. The District will continue to coordinate structure maintenance activities with the Service and other resource agency partners and will consider allowing structures to degrade as part of our mitigation strategy should there be opportunity to do so without adversely affecting the navigation channel.

Comment 43: *3-D Numerical Hydraulic Model Analysis Methodology – Detailed bathymetry for previous years did not exist in the modeled reach and therefore true before and after construction results could not be analyzed. This highlights the need to collect detailed bathymetry before and following any construction to validate the results of the model. This methodology should be included in project development and monitoring plans.*

Response: SSEA mitigation plans will include adaptive management and monitoring plans.

Comment 44: *3-D Numerical Hydraulic Model Results - The analysis indicates that innovative structures improve habitat diversity when compared to traditional dikes and results in an increase in shallow, low-velocity habitat. While this may be true, the USFWS recommends that caution be taken in evaluating these results given the highly altered river environments that exist today. As stated above, it is unclear whether the river training structure modifications currently utilized today can fully compensate for past and current Project impacts and truly mimic what would have existed in an unaltered system.*

Response: As indicated in the SEIS, the purpose of the document is to update the original 1976 EIS with the new information and circumstances since 1976. The SEIS updated the original EIS with all of the existing new information and circumstances, and analyses, modeling, and studies were completed as part of the SEIS to help in providing unknown or unavailable information as to the Project's impacts within economic feasibility. The District believes that the information presented in the SEIS as a result of this information is adequate to support the conclusions drawn.

Comment 45: *3-D Numerical Hydraulic Model Results - Additional information should be included in this section to describe the overall quantity of each habitat type or category in the main channel border to fully understand how limited these habitats are within the study reach. Also, there is a lack of discussion regarding the ongoing effects of maintaining existing structures in their current state. This effect should be further evaluated to determine how much mitigation may be needed to compensate for past and ongoing impacts of existing structures.*

Response: The requested information has been added to Section 4.3.2, Impacts on Fishery

Resources. The identification of this habitat as being potentially significant was a result of the overall current availability of this habitat in the MMR. See response to Comment 13 above regarding the Project's mitigation authority. Also see the Alternative Development Process section added to Chapter 2.

Comment 46: *Impacts of Continue Construction Alternative - There is a lack of discussion in this section regarding the ongoing effects of maintaining existing structures in their current state. According to the information provided, approximately 6,900 acres (~35%) of main channel border habitat have been altered or affected by river training structure construction since 1976. Maintenance of these existing structures has and will continue to have an effect on these 6,900 acres and the fisheries resources that may be or could be utilizing them. Additional information should be provided in this section to describe the continued effect of these structures on fish access to, use of and movement through these habitats. Similar information should be provided for the maintenance of revetment that has been placed on approximately 60% of the MMR bankline.*

Response: See response to Comment 13 above regarding the Project's mitigation authority. Also see the Alternative Development Process section added to Chapter 2.

Comment 47: *Compensatory Mitigation - The USFWS recommends that the USACE include side channel maintenance and restoration and incorporation of woody debris and/or use of woody structures as additional potential mitigation measures. Also, consideration should be given to measures that would restore or improve shoreline and floodplain functionality and connectivity.*

Response: The District recognizes the importance of side channels, floodplains, and other habitats on the MMR and will continue to seek restoration of such important fish and wildlife habitat through other authorities as appropriate. More detail has been provided in Chapter 1 explaining the avoidance and minimization measures that are part of the Regulating Works Project. As discussed in Chapter 4, these habitats are not significantly impacted by the Project to warrant consideration of compensatory mitigation since the avoidance and minimization measures are performing as expected. With respect to compensatory mitigation for the Regulating Works Project, as detailed in the SEIS, the potential significant impact is to unstructured main channel border habitat. The ecological model under development will be sensitive to such impacts and any compensatory mitigation considered will be focused on similar habitat.

4.3.3 Impacts on Threatened and Endangered Species

Comment 48: *Information in the SEIS addresses potential impacts to bald eagles and their habitats. In addition to habitat for bald eagles, habitat for a variety of other migratory birds species also occur within and adjacent to the project area. E.O. 13186 directs federal agencies to: "(1) support the conservation intent of the migratory bird conventions by integrating bird conservation principles, measures, and practices into agency activities* *and by avoiding or minimizing, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; (2) restore and enhance the habitat of migratory birds, as practicable."*

The USFWS considers three elements (avoiding, minimizing, and restoring/enhancing) necessary to adequately mitigate for impacts to migratory bird and listed species habitat. To the extent practicable, they recommend avoiding construction in areas that will negatively impact migratory bird and listed species habitat. Where impacts cannot be avoided, they recommend minimizing impacts to the extent practicable. If negative impacts to habitat occur, they will seek compensatory mitigation for impacted habitat that was used by migratory birds (under E.O. 13186) or by listed species (under the ESA)

Response: The District will continue to coordinate with the Service to avoid and minimize impacts to fish and wildlife species, including migratory birds and listed species, and will evaluate impacts and potential compensatory mitigation on a site by site basis in SSEAs.

4.6 Cumulative Impacts

Comment 49: *As stated previously, the impact from Navigation Traffic is an indirect effect of the Project and not a cumulative effect. As described in the SEIS, if all operation and maintenance activities on the MMR would cease then navigation in general would eventually cease to exist. Thus, navigation is dependent upon the Project and should be addressed accordingly in the SEIS. This would include a discussion of impacts to fish and wildlife resources including entrainment and a discussion of compensatory mitigation for those impacts.*

Response: See response to Comment 30 above.

4.7 Relationship of Short-Term Uses and Long-Term Productivity

Comment 50: *Information in the SEIS indicates the Project would result in some minor, short-term effects to water quality, air quality, and fish and wildlife associated with construction activities and that these effects are not expected to alter the long-term productivity of the environment. The maintenance of existing structures, construction of new structures, and continued operation of the navigation channel under the Project has and will continue to have long-term effects on the fish and wildlife resources and associated habitats within the MMR. Thus, the USFWS recommends that the USACE develop a plan for mitigating for past and current impacts of the Project.*

Response: See response to Comment 13 above regarding the Project's mitigation authority. Also see the Alternative Development Process section added to Chapter 2.

5.1 Consultation, Coordination and Compliance

Comment 51: *This section focuses on the development and implementation of the Projects and potential compensatory mitigation required; however, this section does not identify how the SEIS or site-specific EAs will address protection (avoidance and minimization) of fish and wildlife resources which is a necessary component of the NEPA, ESA, and FWCA. The FWCA of 1958 provides that "wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation…" and that "whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, or by any public or private agency under Federal permit or license, such department or agency first shall consult with the United States Fish and Wildlife Service Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular State wherein the impoundment, diversion, or other control facility is to be constructed, with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water-resource development.". The USFWS recommends that the USACE provide additional information on how consultation, coordination, and compliance is being fully achieved or will be achieved under the NEPA, ESA, and FWCA at the SEIS and site- specific levels. This should include a discussion of how wildlife conservation is receiving equal consideration and what measures are being implemented to conserve wildlife resources.*

Response: Information on interagency coordination has been added to Chapter 1 and information on avoid and minimize measures has been added to Chapter 1, Chapter 2, and Appendix K.

Comment 52: *The USACE indicates that a Fish and Wildlife Coordination Act Report is not required for the Project since sixty percent or more of the estimated construction cost has been obligated for expenditure. The reference to sixty percent completion in the FWCA is based on the date of enactment of the FWCA (The Act of August 12, 1958; Section 5g). It is unclear if the USACE is correctly applying this section of the FWCA.*

Response: – See response to Comment 13 above.

Comment 53: *The USACE indicates that coordination with the USFWS has been conducted, and all Fish and Wildlife Coordination Act requirements are being fulfilled. As previously discussed, the USFWS provided comments in a letter dated January 17, 2014, on the NOI to prepare a DSEIS for the Regulating Works Project. In that letter they recommended that the DSEIS include an alternative in which execution of the existing project would incorporate appropriate NEPA compliance and a process for avoidance, minimization, and additional improvement measures for fish and wildlife resources. In addition, USFWS* *requested that the USACE consult with the USFWS and State conservation agencies early in the planning process to ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. The FWCA of 1958 provides that "The reporting officers in project reports of the Federal agencies shall give full consideration to the report and recommendations of the Secretary of the Interior and to any report of the State agency on wildlife aspects of such projects, and the project plan shall include such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits." Further, the 2003 Agreement between the USFWS and the USACE for conducting FWCA activities was developed to ensure that the USFWS is involved with USACE projects to help find solutions to water resources development problems that avoid, minimize, or mitigate impacts to fish and wildlife. A major goal of the Agreement is to ensure that the USFWS is invited to participate early in throughout the planning process to facilitate the FWCA's equal consideration provision. The USFWS has not been contacted about the specific recommendations described above and it doesn't appear that our concerns were addressed in the SEIS. The USFWS recommends that the USACE consider these original comments and recommendations and work with the USFWS and State natural resource agencies to ensure full compliance with the NEPA, ESA, and FWCA.*

Response: See information on the Alternative Development Process added to Chapter 2.

6.1 Areas of Controversy

Comment 54: *The USFWS and State natural resource agencies have recommended that the USACE mitigate for adverse impacts going back to the 1976 EIS and seek the Post Authorization Change described in the 1976 EIS; however, the USACE indicates they will only consider compensatory mitigation for adverse impacts occurring since publication of the Notice of Intent in December, 2013, and that the Post Authorization Change was never added to the Project by Congress. In addition, the USACE indicates that they only plan for and implement mitigation associated with future actions because of budgetary constraints and that the USACE has other authorities outside of the Regulating Works Project authority that could be used to mitigate for past adverse impacts. As previously discussed, the USFWS contends that the USACE has the authority to implement these types of actions under the Project. If the actions are implemented under other authorities there should be an evaluation of past impacts to determine the amount of mitigation that may be necessary and a mitigation plan developed to guide mitigation efforts. This would aid in the delivery of funds if they were to become available under the Project authority or other authorities.*

Response: See response to Comment 13 above.

Appendix B. Biological Assessment

Comment 55: *The Biological Assessment (BA) was prepared to address newly listed threatened and endangered species not covered by the USFWS's 2000 BO. Information in the BA indicates that the Rufa red knot (Calidris canutus rufa) is a rare migrant along the MMR and utilizes exposed substrates and shallow water that are present in the Project area; however, the Project would not eliminate or substantially reduce these habitats thus the USACE has determined the Project will have no effect on the red knot. The USFWS cannot support a no effect determination for this species given that the species may present within the project area, habitat for the species is present in the project area, and the implementation of the Project will impact those habitats. The USFWS recommends that additional information be included in the BA to describe the potential effects of the Project on this species.*

Response: The Biological Assessment has been updated to reflect a 'not likely to adversely affect' determination for the Rufa Red Knot.

Appendix C: Mitigation Plan

Comment 56: *The USACE indicates that efforts have been made to avoid and minimize project impacts by modifying the design of river training structures; however, even with the modifications recent analysis suggest that river training structures would still result in losses of specific main channel border habitat. Therefore, the USACE is proposing that mitigation be implemented for projects constructed since publication of the NOI to offset losses to the greatest extent practicable in accordance with Section 906(b) of WRDA 1986, subject to the availability of future funding. The USFWS is a member of the adaptive management team and coordinating with the USACE on development of the mitigation plan. While they concur with the proposed development of a mitigation plan, the USFWS recommends that mitigation for Project impacts be evaluated going back to the 1976 SEIS. At a minimum, mitigation for Project impacts should be evaluated going back to the enactment of the WRDA of 1986.*

Response: See response to Comment 13 above regarding the Project's mitigation authority.

Summary

Comment 57: *The USFWS believes there is a lack of information included in the SEIS to support that the proposed Project will have the intended results and that there appears to be a lack of consideration for fish and wildlife resources. The USFWS recommends that the USACE consider our original comments and recommendations (January 2014) and work with the USFWS and State natural resource agencies to develop an alternative that ensures adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources.*

Response: See responses to Comments 13, 14, and 16 above. Also see the Alternative Development

Process section added to Chapter 2 and information in Appendix K, Regulating Works Project History.

Responses to U.S. Geological Survey Comments

U.S.**Geological Survey Comments**

Comment 58: *The U.S. Geological Survey (USGS) has reviewed the USACE Draft SEIS for the Middle Mississippi River Regulating Works. These comments are intended to address potential disturbance of USGS streamgages and also water quality concerns.*

The USGS operates streamgages along streams throughout the US to collect water quantity and quality data for a variety of purposes. Continuous operation of USGS streamgages is essential for our stakeholders. These streamgages have permanent infrastructure and are vulnerable to disruption when nearby construction occurs in the vicinity of these stations. Several active USGS streamgages fall within the Middle Mississippi River project area. Streamgage site descriptions are:

Review Table 1: Active USGS sites on Mississippi river in project area

Agency	USGS site number	Station Name	Latitide DD	Longitude DD	Datum	State	County fips code
USGS	7010000	Mississippi River at St. Louis, MO	38.629	-90.179778	NAD83	Missouri	510
USGS	7020850	Mississippi River at Cape Girardeau, MO	37.301889	-89.518	NAD83	Missouri	31
USGS	5587498	Mississippi River Pool Lock and Dam 26 at	38.886444	-90.182547	NAD83	Illinois	119
USGS	7020500	Mississippi River at Chester, IL	37.900742	-89.830211	NAD83	Illinois	157
USGS	7022000	Mississippi River at Thebes, IL	37.2216	-89.462975	NAD83	Illinois	3

The final SEIS should list USGS structures as sites to be safeguarded. The USGS Missouri Water Science Center (WSC) and Illinois WSC should be contacted and given sufficient advance notice before any project activities occur near the USGS streamgages. Efforts should be made both to preserve the streamgages and minimize impacts to the data integrity collected at those sites. Changes to floodplain geometries by the modification of channels may affect USGS reported discharges and water surface elevations.

Water quality impacts from sediment mobilization due to construction in the river is addressed within the DSEIS on page 118. Safeguards should be considered within the final SEIS to protect water supply intakes from project activities. It is widely documented that river bottom sediments in the United States are potential reservoirs for hydrophobic compounds (Nowell and others, 2013; Wilson, 2016; Wilson and Bonin, 2007). It is also widely documented that both natural and anthropogenic activities can remobilize contaminated sediments and release contaminants to the water column (Eggleton and Thomas, 2004).

USGS strongly encourages the documentation within the final SEIS of the USGS streamgage infrastructure on the Middle Mississippi River in the project area and description of the protection and coordination to occur during the project. Additionally, they encourage the protection of water supply intakes from increased sediment and contaminant loads caused by the project.

Response: As a partner in the Cooperative Streamgaging Program, the Corps will continue to coordinate with the USGS on structure construction and modifications near streamgages owned and/or operated by the Corps or USGS on the MMR. The Corps will continue to coordinate with stakeholders to ensure that water supply intakes are protected from increased sediment and contaminant loads to the greatest extent possible.

Responses to Missouri Department of Conservation Comments

Comment 59: ***SEIS Scope and Mitigation:*** *The Department was hopeful that this evaluation would result in identification and quantification of habitat loss, by type and acreage, and at both sites specific and Project scales, from 1976 to the projected completion of the Project, and provide options for compensatory mitigation. However, we understand that it includes only the projects that have not been completed since the Notice of Intent was published in December 2013. Because the USACE in 1976 clearly identified future habitat and functional changes, and agreed that impacts should be mitigated, we encourage the USACE to include in the SEIS all projects completed since 1976 along with future projects, and fully calculate habitat changes in the MMR since 1976 due to Project implementation. An appropriate mitigation plan should be developed with federal and state partners.*

Response: See response to Comment 13 above regarding the Project's mitigation authority.

Comment 60: *While it may be difficult to again seek a post-authorization and funding appropriation to fund mitigation needs for significant past habitat loss and cumulative impacts, the Department believes there are existing authorities that could be used to allow ongoing and future projects and operation and maintenance projects to help address some of the lost habitat. For example, as noted on Page 7 of the U.S. Department of Interior comment letter dated January 12, 2017, Section 3(a) of the FWCA of 1958, Section 906 of the Water Resources Development Act (WRDA) of 1986, and Section 5099 of WRDA 2007, authorize the protection, restoration, enhancement, and mitigation of fish and wildlife resources to occur under the Regulating Works Project. In addition, precedent was set by the Navigation and Ecosystem Sustainability Program that was authorized by WRDA 2007 to fully consider fish and wildlife impacts as part of channel maintenance activities, because this Program was to be a dual-purpose program, addressing habitat impacts as part of navigation management. Allowing operations and maintenance activities and funding to address past and future project habitat impacts would also provide a means to restore lost habitat in certain locations.*

Response: See response to Comment 13 above regarding the referenced authorities.

Comment 61: ***Alternatives:*** *The USACE's alternatives were limited to 1) continue with existing practices and mitigate for adverse impacts when necessary (i.e., Continue Construction Alternative -CCA), or 2) stop new construction of river training structures and manage navigation channel depth by dredging (i.e., No New Construction Alternative -NNCA). In both alternatives bank stabilization through revetment and all rock structure/revetment maintenance will continue. The goal of the Project is to minimize dredging costs and create a self-maintaining system, to the extent it is cost effective.*

The expected amount of future habitat impacts under the CCA is estimated at 8% (i.e., about 1,100 acres) of the remaining unstructured main channel border habitat. There would be no additional permanent loss to the remaining unstructured main channel border habitat under the NNCA. In 1976, unstructured main channel border habitat was estimated at 19,800 acres, and by 2014 the acreage had declined by 6,900 acres *to 12,900 acres. This is an approximate 35% decline in unstructured main channel border habitat for which no compensatory mitigation was completed. The Department agrees that a loss of 8% of the remaining habitat of this type is important and should be mitigated; we also contend that a loss of 35% of this habitat is also critically important and should be mitigated.*

Response: See response to Comment 13 above regarding the Project's mitigation authority.

Comment 62: *Because actual locations of future project sites are unknown, under the CCA, an estimate was made that approximately 4.4 million tons of rock would be placed over the next 17 years, and dredge quantities would decrease from 4 million cubic yards per year to approximately 2.4 million cubic yards per year. Under the NNCA, maintenance dredging is expected to be 4 million cubic yards per year. Thus, the difference in dredging between the two Alternatives is approximately 1.6 million cubic yards per year.*

A general description of the ongoing habitat changes on Page 156 notes that managing the river with river training structures produces a "continued functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high-velocity habitat of the main channel surrounded by structured main channel border habitat." The unstructured main channel border habitat is thought to provide an important and necessary movement and migration pathways used by fish.

In the Department's comment letter of April 2, 2012, we suggested that that an additional alternative be considered, one that would allow for greater consideration of fish and wildlife resources, and which might require a greater level of annual dredging then the stated goal of reducing dredging to the lowest amount economically feasible. Because habitat conditions have been greatly altered, any method that will reduce habitat losses though continued creation of a deeper, faster flowing channel will be beneficial and may be the best environmental alternative. This is consistent with the additional alternative suggested by the Service that would ensure adequate and equitable protection, mitigation of damages to, and enhancement of fish and wildlife resources. For example, a potential outcome of an alternative that incorporates more fish and wildlife resource needs, is an alternative that maintains the nine foot navigation channel while also maintaining river elevation, letting the channel widen in certain places when there is excess water. This would help increase connectivity and fish and wildlife habitat, although locations would have to be carefully identified and accepted by willing landowners.

Response: An Alternatives Development Process section has been added to Chapter 2 to explain how the Continue Construction Alternative does allow for a greater level of dredging through the consideration of compensatory mitigation.

Comment 63: ***Bankline Revetments:*** *Lateral movement of the river is greatly altered with approximately 60% of the bankline revetted as of 2014 (see Page 155), and there is an* *unknown amount of additional revetment needed to complete and maintain the Project as currently operated. The SEIS notes that this additional amount of revetment will not have an "appreciable adverse effect on the MMR fishery." However, adverse impacts from further modifying lateral river migration have not been calculated. Restricted lateral movement reduces input of woody vegetation and sediments to the river. A healthy river has some level of lateral movement, and this movement helps to further create diverse aquatic habitat. These impacts should be identified and avoided and minimized to the extent practicable, and functional loss to river habitat conditions addressed through restoration projects.*

Response: The District will continue to avoid and minimize impacts to the extent practicable in close coordination with the Department and other resource agencies. More information on the interagency coordination process for bank stabilization has been added to Chapter 1.

Comment 64: *The USACE should also examine the success the USACE -Memphis District has had with treed riparian corridors on the Lower Mississippi River. Rather than relying on rock revetments entirely to maintain bank stability, it has experienced success with reducing bank erosion and flood events on portions of its banks and floodplains by using forested riparian corridors of sufficient width and tree density to increase roughness coefficients and reduce high flow events that scour sediments.*

Response: Additional information on coordination has been included in Chapter 1. The Memphis District has used treed riparian corridors in combination with rock and articulated concrete mat (ACM) revetment to maintain bank stability. The treed riparian corridors are used in areas of overbank flows to reduce velocities and minimize scour. There are no locations on the Lower Mississippi River where treed riparian corridor is the sole form of bank stabilization. Information from partner agencies will be considered for design of new construction or repair and maintenance of revetment.

Comment 65: ***Cumulative Impacts:*** *This section should consider the cumulative impacts from construction of the Project since at least 1976. With over 6,900 acres of unstructured main channel border habitat eliminated, it is likely that the multiple changes to the river have resulted in changes to aquatic organisms and their habitats. The construction of one structure will result in local impacts, but what is unknown is the effect of nearly 40 years of regulating works on the river and the fish community. Additionally, while greater emphasis has been placed on new rock structure configurations (e.g., chevrons, w-dikes, multiple rock sites/piles) and hydraulic sediment transport modeling has demonstrated that these structures will create different scour patterns and thus different depths and flow conditions, very few studies have been completed to evaluate if they are better or worse for the river environment than a regular straight dike. This evaluation is a current and future need of the project.*

Response: In the process of preparation of the SEIS, the District evaluated all applicable information on impacts to fish and wildlife resources. Further, the District conducted additional evaluation and analyses to better understand potential Project impacts within economically reasonable limitations. These evaluations led to the conclusion that innovative river training structures produce results as anticipated.

Comment 66: *Another consideration to habitat impacts, as the river incises it is not just the side channels that are perched, but also islands themselves and the more shallowly sloping banks that could provide off-channel habitat when the river is high. This is another loss in important habitat that should be quantified.*

Response: Information on MMR island habitat has been added to Section 3.2.2, Geomorphology, and Section 4.2.2, Impacts on Geomorphology. With respect to sandbars and impacts to sandbars due to the Project, the analyses that the District conducted on main channel border habitat and the potential significant impacts to main channel border habitat include the impacts of the Project on sandbars.

Comment 67: ***Side Channel Habitats:*** *Recognizing the importance of side channel habitats in a portion of the river where there is little floodplain connectivity, the river partners have identified the need to ensure side channels are connected to the river channel with suitable flows and that there is a diversity of aquatic habitats. The Department appreciates the efforts of the USACE to restore side channels and encourages continued efforts to ensure that restoration projects are not impacted by the predicted decrease in river stage during low flows. This could result in loss of side channel connectivity, possibly negating some restoration efforts. For example, in Section 2.3.2, the SEIS notes that side channels are a refuge from navigation disturbances; but if the side channels are becoming more and more isolated through reduced connectivity, they aren't going to be very useful to river organisms. Department researchers have also noted that the MMR has lost over half of side channel area in width. An increase in side channel volume is not equivalent to more habitat being added to the system. Restoration practices need more functional evaluation as well; for example we have little understanding of how or if the more benthic organisms move through notches. What notch elevation is necessary to allow passage of these organisms? These questions and others are important to understand as side channels are restored.*

Additionally, to help estimate decreases in connectivity to side channels, the projected stage reduction values could be used. This would give a quantitative estimate of impact.

Please add the following citation to the SEIS:
Sobotka, M. J., & Phelps, Q. E. (2016). A Comparison of Main and Side Channel Physical and Water Quality Metrics and Habitat Complexity in the Middle Mississippi River. River Research and Applications, *https://doi.org/10.1002/rra.3061*

Response: The District's analysis on side channel geomorphology (see Section 3.2.3, Side Channels) corroborates the Department's findings on loss of side channel width. The analysis shows large reductions in width from the 1800s to the mid-1900s. The analysis shows relative stability in side channel width since the 1960s. The District will continue to work with the Department on side channel restoration projects and will continue to monitor side channel habitat. Information from the referenced publication has been added to the document in Section 3.2.3 as appropriate.

Other Comments

Comment 68: ***Dike Shape*** *- Although studies have been completed demonstrating that fish and other aquatic organisms have been found in the vicinity of river training structures, we do not know if these areas are creating habitat that increases aquatic organism populations in a stretch of the river. It is possible that these sites are just displacing animals from other areas, without population gain. Further studies are required at both the project and cumulative scales to fully evaluate fish benefits of different shaped dikes.*

Response: In the process of preparation of the SEIS, the District evaluated all applicable information on impacts to fish and wildlife resources. Further the District conducted additional evaluation and analyses to better understand potential Project impacts within economically reasonable limitations. These evaluations led to the conclusion that innovative river training structures produce results as anticipated. The District believes that the analyses and information presented in the SEIS are adequate to support the conclusions drawn.

Benthic Macroinvertebrate Resources and Freshwater Mussels:

Comment 69: *Page 71- An additional resource is the UMRR's LTRM invertebrate collections. This component was discontinued approximately 10 to 12 years ago, due to lack of funding and concerns for sampling design. However, some information is available that should be considered in the analyses.*

Response: LTRM invertebrate data was considered. Due to limitations of the LTRM data, other datasets were used in the document to summarize MMR macroinvertebrate resources.

Comment 70: *Page 72 - Although it is thought that the MMR is not a historic place for freshwater mussel beds, there have been no recent studies to support this contention. Freshwater mussels have been found in certain rock dikes in the Lower Mississippi River, and they could exist in areas with similar conditions in the MMR. Areas with unstable, shifting sediments are not likely to provide good conditions, but areas that are more stable, perhaps in dike structures, or side channels, might harbor mussel life. As dike fields or side channels are altered, impacts to mussel resources should receive consideration.*

Response: As outlined in the SEIS, two recent MMR mussel surveys (Tiemann 2014 and Keevin 2016) found limited mussels and no mussel beds in the Project Area. The District will continue to work with the Department to avoid and minimize impacts to fish and wildlife, including mussels, for all Project activities.

Comment 71: *Macroinvertebrate habitat has likely declined due to the reduction in woody debris and snags entering the river. While rock piles may provide some structure that macroinvertebrates can utilize, organic debris provides better conditions.*

Response: Information on concerns about reductions in woody debris in the MMR and macroinvertebrate use of woody structure has been added to Section 3.3.1, Benthic Macroinvertebrate Resources.

Fishery Resources:

Comment 72: *Page 75 -Please define use of the term "stragglers." We do not know if changes in river management means that some species are now not as abundant due to intolerance to changing river conditions. Or if the species was never very abundant in the MMR.*

Response: Footnote definition added at first use of the term.

Comment 73: *Page 76 - Some of the main channel fish mentioned will also frequent the side channels.*

Response: List of most commonly encountered side channel species added to Section 3.3.2, Fishery Resources.

Terrestrial Communities:

Comment 74: *Page 78 - Terrestrial communities still can be impacted due to the fact that the aquatic community they depend on is being manipulated. Bottomland hardwood communities benefit by a certain level of flooded conditions; lack of floodplain connectivity may affect the hydrology of some of these wetland communities.*

Response: The District concluded that the discussion on terrestrial communities in the 1976 EIS did not need to be updated and that the potential impacts to terrestrial species were not sufficient to warrant further analysis in the SEIS.

Impacts on Water Quality:

Comment 75: *Page 118 - Continuing to narrow and deepen the channel will reduce potential for primary production. Higher velocities result in more turbidity (also because of added rock), leading to less light penetration and more turbulence that inhibits phytoplankton growth.*

Lower water retention times and less water/sediment interface means less nutrient capture. We can't estimate reduction in nutrient capture, but it is likely occurring and will continue to do so as the channel deepens and narrows.

Response: It is not anticipated that there will be an increase in channel velocity. See the additional information on velocity added to section 4.2.2, Impacts on Geomorphology.

Impacts on Fishery Resources:

Comment 76: *Page 132 -Dredging in July and August may have fewer impacts on fish, because many species will have already completed spawning or be out of larval stage. However, certain catfish and sunfish species and freshwater drum have been found spawning during these months.*

Response: The presented analysis assumes that there would still be appreciable numbers of larval fish present in July and August.

Comment 77: *Page 135 to 136 -Dredge Entrainment Impacts - We have questions regarding the estimate of larval fish entrainment during dredging. The SEIS notes that it is likely to be minimal, however, this is based on calculations that have not been verified. Additional information is needed to demonstrate that larval entrainment will be minimal, and if it is not, further avoidance and minimization measures should be followed, and resulting impacts should be mitigated.*

Response: The District believes that the analysis provided is adequate to determine that the impact is not significant.

Comment 78: *Page 131 to 133 -Dredging Related Impacts - Fishes and other aquatic organisms are adapted to natural abrupt changes in turbidity. But a dredge is more abrupt and may instantly cover eggs or spawning areas of certain fishes. Whereas in natural conditions, the fish are otherwise in an ideal location with water chemistry that would gradually change. Impacts would be greater with the abrupt change in conditions.*

Response: The analysis presented assumes such abrupt changes would occur in dredge disposal areas but that these areas do not represent a significant percentage of the available habitat in the MMR.

Comment 79: *Page 146 - Revetment Effects on Fish - Revetment can be good current refuge and even habitat for some fish species, but this is not true with all fish species. Life history of fishes show that habitat preference is extremely variable among species.*

Response: The information provided acknowledges different species assemblages in natural and revetted banks.

Agency Coordination

Comment 80: *While we have a general idea of how future coordination on individual projects will occur and how and to what level fish and wildlife resources would be incorporated, it would be helpful to further describe the process and seek input from stakeholders.*

Response: Information on interagency coordination has been expanded in Chapter 1.

<u>Responses to Illinois Department of Natural Resources Comments</u>

Threatened and Endangered Species

Comment 81: *The MMR contains records for nine state-listed fish species (including the federally-endangered pallid sturgeon (Scaphirhynchus albus), three state-listed bird species (including federally- endangered least tern (Sternula antillarum) and federally-threatened rufa red knot (calidris canutus rufa)), and many other floodplain adapted state-listed species are known to occur in the MMR, such as the Illinois chorus frog (Pseudacris illinoensis). A more comprehensive list can be found at the following link and individual records can be discussed with our staff: https://www.dnr.illinois.gov/ESPB/Documents/ET_by_County.pdf*

While the Department understands that the U.S. Army Corps of Engineers (USACE) has no legal responsibilities to comply with the Illinois Endangered Species Protection Act regarding the congressionally mandated Project and invokes sovereign immunity, it has been customary for some of the USACE districts operating in Illinois to consider state-listed species and avoid or minimize impacts when possible. There is no discussion in the DSEIS regarding state-listed species and lands protected under the Illinois Natural Areas Preservation Act. While it may not be necessary to include a detailed discussion of these resources to comply with the National Environmental Policy Act (NEPA), the Department recommends increased coordination with our staff regarding these state natural resources to help fulfill our missions and ensure their continued existence within Illinois. You may already be aware of the Department's Ecological Compliance Assessment Tool (EcoCAT), which can be accessed at http://dnr.illinois.gov/EcoPublic/. We invite you to submit individual projects in EcoCAT and engage with our staff as necessary to further coordination between the agencies. Please contact Nathan Grider (217-524-0501) if you have any questions regarding EcoCAT and consultation with the Department.

Response: The District will continue to submit individual projects in EcoCAT and coordinate with IDNR staff as part of the SSEA process.

Fish and Mussels

Comment 82: *Page 131 and 132 discusses entrainment rates of fish from maintenance dredging activities in the MMR. It is stated that no data exists on actual entrainment rates from these dredging operations and estimates are made based on fish density per known volume and the amount of water taken in by the dredge. The Department acknowledges the difficulty in estimating entrainment rates given the wide range of estimates in the literature and seasonal, as well as site specific variability. The Department is concerned that fishery impacts related to dredge entrainment remains largely unknown and recommends the USACE more directly address the issue through field study and propose options to avoid, minimize, and mitigate the impacts in coordination with the USFWS and state agencies.*

Response: In the process of preparing the SEIS, the District evaluated all applicable information on impacts to fish and wildlife resources. Further, the District conducted additional evaluation and analyses to better understand potential Project impacts within economically reasonable limitations. These evaluations led to the conclusion that the magnitude of dredge entrainment impacts would not appreciably adversely affect the MMR fish community. The District believes that the scope of the information and analyses presented in the SEIS is adequate to support the conclusions drawn. The District will continue to coordinate with the Department to avoid and minimize impacts and will continue to utilize new information as it becomes available.

Comment 83: *The DSEIS indicates disposal of dredged material typically occurs in-river as opposed to upland disposal to avoid increased costs. Adverse impacts to sensitive fish and wildlife habitats can be significant in some locations from in-river sediment disposal. The process of coordinating these events with the state agencies and USFWS is unclear. The Department regularly coordinates with the Rock Island District on these projects to minimize adverse impacts through the On Site Inspection Team (OSIT). The Department recommends the St. Louis District develop a coordination plan for dredging that more closely resembles the Rock Island District and develop a dredged material management plan for the MMR. The Department also recommends the district evaluate more areas for beneficial uses of the sediment using the flexible dredge pipe in coordination with the states and USFWS.*

Response: The District will continue to coordinate all dredging with the Department and other partner agencies to avoid and minimize potential impacts to sensitive fish and wildlife habitat and to plan the use of the flexible dredge pipe. Dredged Material Management Plans are only required for projects that do not have a 20-year dredged material disposal capacity, which is not applicable to the Regulating Works Project. However, the District has made improvements over the last several years with planning for dredged material placement locations in the MMR. A Dredge Master Plan showing dredging areas and placement locations was developed in 2014. The Dredge Master Plan is used for coordination efforts and is updated at the end of each dredge season. Section 1.1.4, Process for Dredging under the Regulating Works Project, has been expanded to include more information on the dredge coordination process, the Dredge Master Plan, and information to be provided through the coordination process.

Comment 84: *It has been generally agreed the freshwater mussel populations are sparse in the MMR due to unstable substrate conditions (page 71-72). As discussed on page 42 of the DSEIS, the river channel has reached stability over the last several decades through the use of river training structures and erosion has been reduced through the use of bank protection. Due to significant changes undergone in the MMR from implementation of the Project that may facilitate the development of mussel beds, the Department recommends the mussel community be monitored on a regular basis for changes with efforts focused in dike fields and other areas with stable substrates. The SEIS should include further discussion in this regard on impacts to mussels from regulating structures. The Department recommends proposed new river training structures or significant alterations to existing structures include an assessment of potential mussel impacts. This assessment should not be necessary in areas of frequent dredging in the main channel.*

Response: As outlined in the SEIS, two recent MMR mussel surveys (Tiemann 2014 and Keevin 2016) found limited mussels and no mussel beds in the Project Area. Due to these recent surveys and the historic lack of mussel resources in the MMR, the District does not believe it would be prudent to commit to funding MMR mussel community monitoring. The District will continue to work with the Department to avoid and minimize fish and wildlife impacts for all Project activities, and, if it becomes apparent that there are mussel resources at risk at a given work site, mussel surveys will be considered on a site-specific basis.

Habitat and Mitigation

Comment 85: *The Department commends the USACE for the efforts to restore side channel habitats beginning in the 1990's. However, the Department recognizes there are still significant issues with sedimentation and disconnection of side channels in the MMR. Further, the construction of river training structures has resulted in significant impacts to main channel border habitats. The USACE is currently focused on improving the channel for commercial navigation with habitat enhancement as an important, yet secondary objective. The Department recommends the USACE pursue dedicated funding and increase habitat restoration and mitigation efforts for impacts resulting from the Project in the MMR. This initiative should include dredging of side channels to achieve small boat year around navigation and fish access, beneficial use of dredge material, construction of wooden pile dikes (wood cribbing and or LUNKER structures could be substituted) and dike alteration to benefit fish and wildlife resources. The states and USFWS have requested that these efforts be included as a post-authorization change by Congress to include fish and wildlife conservation measures as a Project purpose.*

Response: See response to Comment 13 above.

Comment 86: *The states and USFWS have also requested that Project mitigation should be evaluated going back to the 1976 EIS. The USACE is proposing that mitigation be implemented for projects constructed since publication of the Notice of Intent (NOI) to develop the SEIS in December, 2013. The Department still believes that mitigation should be implemented going back to the 1975 EIS, or at least the enactment of the Water Resources Development Act of 1986. The Department recommends the USACE develop a dedicated planning effort for mitigating past and future impacts of the Project.*

Response: See responses to Comments 13 and 14 above.

Comment 87: *The Department notes that increased efforts in reconnecting side channels and floodplain habitats as a primary mission of the Project will greatly benefit species that have seen significant decline over the last half century. As mentioned on page 172, the alligator gar (Atractosteus spatula) was extirpated from the MMR for reasons partly associated with implementation of the Project, which resulted in a decrease in critical* *side channel and backwater habitats. The Department, along with the USFWS and other states in the historic range of the alligator gar, has initiated recovery efforts for this species. An increase in habitat restoration and mitigation work as part of the Project would greatly enhance these efforts, along with conservation benefit to other important riverine species that rely on lateral connection of aquatic habitats.*

The Department notes an error on page 172 with the taxonomy of alligator gar; the species was moved from the genus Lepisosteus to Atractosteus in 1976 by E.O. Wiley to recognize two taxon of extant Lepisosteidae (gars).

Response: Change made accordingly.

Responses to U.S. Environmental Protection Agency Comments

General Comments

Comment 88: *The DSEIS would be improved with an inventory and prioritization of reach locations where the Corps expects greater need for either new structure construction, mitigating structure modifications or mitigation projects. This could include locations with a past history of repeated dredging needs, a high potential for avulsion, bank erosion or failure, or a higher potential for damage to sensitive aquatic life or critical habitat from continual dredging. These circumstances all suggest the need for new or modified training structures or revetments.*

Response: The 2017 Channel Improvement Masterplan has been added to the SEIS as Appendix I. The masterplan includes recent channel surveys, dredging cut and disposal locations, existing and proposed river training structure and revetment locations, observed locations of pallid sturgeon and mussels, observed least tern nesting sites and high priority reach locations where the Corps expects greater need for new structure construction. Potential mitigation locations have not yet been determined.

Treatment of the DSEIS as a Programmatic NEPA Compliance Document

Comment 89: *In reviewing the DSEIS, EPA assumes that planning for each site-specific project will also include a Tier II site-specific Environmental Assessment in addition (SSEA) to the NEPA coverage provided by the SEIS. If this is not the case, the Final SEIS should identify the protocol by which the Corps will determine whether a SSEA is required for individual projects.*

Response: All new construction and O&M work will be appropriately evaluated to determine if it falls within the coverage of the SEIS, requires an SSEA, or is covered by a categorical exclusion.

Affected Environment

Comment 90: *The DSEIS extensively characterizes channel, main channel border, backwater, side channel, and floodplain habitat in various locations throughout the document. Section 3.2.3 separately inventories and characterizes side channels and side channel environment under Section 3.2, Physical Resources. The DSEIS would be improved if the characterization of these other riverine habitats were similarly contained and organized within Chapter 3. Main channel, main channel border, and side channel biological resources are organized and characterized in Section 3.3 as biological resources. Similar treatment of these resources in Section 3.2, Physical Resources, would be useful.*

Response: Certain sections of the document lend themselves to discussion broken out by individual resource category while others require a more general discussion. Section 3.2.2, Geomorphology, has been re-organized to discuss Main Channel and Main

Channel Border geomorphology, Side Channel geomorphology, and Island geomorphology.

Comment 91: *The DSEIS includes multiple references to existing research which attributes stage rise to the constriction of the floodplain by levees and other infrastructure. In debunking claims that Corps regulatory works in the Middle Mississippi River raise river stage in Appendix A, the DSEIS diverts responsibility toward historic floodplain constriction as the overwhelming cause of past, and presumably future, river stage elevation. We agree with this assessment and support the Corps in its efforts to limit floodplain development and all efforts to realign existing levees to provide increased exposure of floodplains to elevated river flows.*

Table 3-6, comparing the acreage of main channel, main channel border and side channel habitat in the MMR in 1976 with 2014, illustrates habitat changes within the River since the last EIS. EPA recommends the Corps consider repeating that table elsewhere in the document as it supplements text on important riverine habitat, impacts on that habitat, and restoration/mitigation priorities.

Response: A similar table was added to Section 3.2.2, Geomorphology, and Section 4.2.2, Impacts on Geomorphology.

Comment 92: *The DSEIS characterizes mussel populations within the main-channel border and the main channel of the MMR as insubstantial due to limited habitat. What populations are present within the MMR are likely limited to the floodplain and side channels. The document does not provide an assessment of project impacts on mussels given their limited presence. The Missouri Department of Conservation generally confirms the Corps' assessment of the MMR's mussel population. However, we strongly suggest that Federal and state natural resource agencies should be consulted as part of each site-specific project to confirm mussel status in each local instance.*

Response: The District will continue to closely coordinate site-specific actions with natural resource agency partners and will address potential mussel impacts on a site-by-site basis as necessary. Additional information on current coordination with natural resource agency partners has been added to Chapter 1.

Environmental Consequences

Comment 93: *As identified earlier, organizing impacts on physical resources by component habitat types would improve the readability of the analysis of these impacts. Currently, the DSEIS includes a detailed habitat impact discussion within sections addressing biological resources.*

Response: See response to Comment 90 above. Section 4.2.2, Impacts on Geomorphology, has been re-organized to discuss impacts to Main Channel and Main Channel Border geomorphology, Side Channel geomorphology, and Island geomorphology.

Comment 94: *The document characterizes river training structure impacts on various riverine habitat as generally providing an increase in low-velocity habitats, particularly shallow, low velocity habitat, while decreasing shallow to moderate-depth, high velocity habitat. This moderate-depth, high velocity habitat resembles the unstructured main channel border habitat which has decreased in the MMR with the placement of training structures since 1976. The DSEIS notes that these changes affect the fish species utilizing these different habitat types. In addition, migrating fish species could experience difficulty traversing complex flow patterns created by training structures along the main channel border. This shift in habitat types significantly affects the MMR fish community, and the DSEIS acknowledges that compensatory mitigation is warranted. The planned main channel border habitat model is intended to both characterize habitat loss and guide mitigation of damaged and lost habitat. We strongly recommend that the Corps not proceed with the construction of additional regulating structures until the main channel border habitat model is completed and site-specific structure design and mitigation needs can be identified for each site.*

Response: No new construction contracts will be awarded until specific project impacts can be evaluated and any compensatory mitigation can be considered.

Comment 95: *The DSEIS indicates that the Corps does not expect implementation of the preferred alternative to result in an increase in commercial traffic within the MMR. We recommend that the Corps revisit its NEPA compliance for the Regulatory Works Project should the transportation profile of the System change with the expansion of the project's structure coverage.*

Response: We will continue to evaluate the Project and its current NEPA compliance to determine if any additional NEPA documentation is necessary for any new information or circumstances or change to the Project.

Comment 96: *If a Biological Assessment (BA) has been prepared in conjunction with the preparation of the DSEIS, EPA recommends the Final SEIS provide an analysis of species impacts, rather than defer completely to successive SSEAs. We also recommend any correspondence received from USFWS pertaining to the BA should be incorporated into the Final SEIS.*

Response: Concur. The Biological Assessment can be found at Appendix B. USFWS correspondence can be found at Appendix E.

Mitigation, Restoration and Endangered Species Act Efforts

Comment 97: *The explanation on page 24 of the DSEIS that compensatory mitigation for project impacts is intended in the NEPA sense rather than as used under Section 404 of* *the Clean Water Act (CWA) is confusing. As mitigation for adverse impacts associated with regulating structures is critical to the NEPA analysis, additional explanation of this distinction would better support the overall impacts assessment.*

Response: The footnote in question unnecessarily complicated the issue. The footnote has been removed.

Comment 98: *The DSEIS would be improved with an inventory of all efforts to date to construct and restore habitat within the MMR under multiple authorizations (e.g., Upper Mississippi River Restoration Program (UMRR), Endangered Species Act, and CWA). A table listing the number, locations, and purpose of projects since the 1976 EIS would provide the reader with an important gauge of the restoration efforts to date in the MMR (e.g., sturgeon habitat mitigation, compliance with 1990 Biological Opinion, etc.). The 1976 EIS predates most, if not all, of the restoration programs currently implemented on the Upper Mississippi River (e.g., UMRR, formerly known as the Environmental Management Program, was authorized in 1986). It is our understanding that very few projects implemented as part of the UMRR have been conducted within the MMR.*

Response: Information has been added accordingly to Section 3.3.4, Threatened and Endangered Species, Section 4.6, Cumulative Impacts, and Appendix K, Regulating Works Project History.

Comment 99: *The Corps' explanation that mitigation would only be considered for adverse project effects occurring since the Notice of Intent is not compelling. As a supplement to the 1976 EIS, the SEIS should identify any mitigation deficit from past projects as part of its cumulative impacts analysis. The adverse impacts of the entire Regulatory Works Project should be identified along with any mitigation efforts occurring as part of the Regulatory Works Project or the UMRR.*

Response: See responses to Comments 12 and 13 above that the District has been effectively mitigating by avoiding and minimizing impacts through the design process and construction of innovative, environmentally friendly structure design. Further, more detail about activities that have benefited the environment beyond the Regulating Works Project have been added as well as the relevant authorities and policies with respect to mitigation under the Regulating Works Project. The potential for compensatory mitigation was not a known impact until an additional engineering model and analysis was completed as part of the SEIS process. The adverse impacts from past, present, and foreseeable future actions have been identified with the information analyzed and gathered as part of the SEIS process.

Comment 100: *The Corps' position regarding discretionary mitigation for fish and wildlife damages arising from project actions under Section 906(b) of the Water Resources Development Act of 1986, based on the project construction prior to 1986, does not seem logical. With the construction of new structures and features as part of an expanding Regulatory Works Project, mitigation for natural resource damages should* *be mandatory. Later text in the Mitigation Plan states that Habitat Units "lost that are determined to be a 'significant' impact would require mitigation." EPA recommends that no project construction move forward without detailed, site-specific mitigation plans in place. As we recommended in earlier comments, project implementation should not proceed without finalization and implementation of the Corps' planned main channel border habitat model.*

Response: See response to Comment 13 above and to National Wildlife Federation Comment Nos. 10 and 55 regarding the Project's mitigation authority. No new construction contracts will be awarded until specific project impacts can be evaluated and compensatory mitigation can be considered.

<u>*Air Quality and Construction Emission Control Efforts*</u>

Comment 101: *EPA recognizes that diesel emissions and fugitive dust from project construction may pose environmental and human health risks and should be minimized. We recommend the Corps consider the following protective measures, discuss emissions reduction measures regularly employed on construction/dredging equipment, and commit to applicable measures from the following list in the Final SEIS and Record of Decision.*

Mobile and Stationary Source Diesel Controls
Purchase or solicit bids that require the use of vehicles that are equipped with zero-emission technologies or the most advanced emission control systems available. Commit to the best available emissions control technologies for project equipment in order to meet the following standards.

- *On-Highway Vehicles: On-highway vehicles should meet, or exceed, the EPA exhaust emissions standards for model year 2010 and newer heavy-duty, on-highway compression-ignition engines (e.g., long-haul trucks, refuse haulers, shuttle buses, etc.).*
- *Non-road Vehicles and Equipment: Non-road vehicles and equipment should meet, or exceed, the EPA Tier 4 exhaust emissions standards for heavy-duty, non-road compression-ignition engines (e.g., construction equipment, non-road trucks, etc.).*
- *Marine Vessels: Marine vessels servicing infrastructure sites should meet, or exceed, the latest EPA exhaust emissions standards for marine compression-ignition engines (e.g., Tier 4 for Category 1 & 2 vessels, and Tier 3 for Category 3 vessels). 4*
- *Low Emission Equipment Exemptions: The equipment specifications outlined above should be met unless: 1) a piece of specialized equipment is not available for purchase or lease within the United States; or 2) the relevant project contractor has been awarded funds to retrofit existing equipment, or purchase/lease new equipment, but the funds are not yet available*

Consider requiring the following best practices through the construction contracting or oversight process:

- *Use onsite renewable electricity generation and/or grid-based electricity rather than diesel-powered generators or other equipment.*
- *Use ultra-low sulfur diesel fuel (15 ppm maximum) in construction vehicles and equipment.*
- *Use catalytic converters to reduce carbon monoxide, aldehydes, and hydrocarbons in diesel fumes. These devices must be used with low sulfur fuels.*
- *Use electric starting aids such as block heaters with older vehicles to warm the engine.*
- *Regularly maintain diesel engines to keep exhaust emissions low. Follow the manufacturer's recommended maintenance schedule and procedures. Smoke color can signal the need for maintenance (e.g., blue/black smoke indicates that an engine requires servicing or tuning).*
- *Retrofit engines with an exhaust filtration device to capture diesel particulate matter before it enters the construction site.*
- *Repower older vehicles and/or equipment with diesel- or alternatively-fueled engines certified to meet newer, more stringent emissions standards (e.g., plug-in hybrid-electric vehicles, battery-electric vehicles, fuel cell electric vehicles, advanced technology locomotives, etc.).*
- *Retire older vehicles, given the significant contribution of vehicle emissions to the poor air quality conditions. Implement programs to encourage the voluntary removal from use and the marketplace of pre-2010 model year on-highway vehicles (e.g., scrappage rebates) and replace them with newer vehicles that meet or exceed the latest EPA exhaust emissions standards.*

Fugitive Dust Source Controls

- *Stabilize open storage piles and disturbed areas by covering and/or applying water or chemical/organic dust palliative, where appropriate. This applies to both inactive and active sites, during workdays, weekends, holidays, and windy conditions.*
- *Install wind fencing and phase grading operations where appropriate, and operate water trucks for stabilization of surfaces under windy conditions.*
- *When hauling material and operating non-earthmoving equipment, prevent spillage and limit speeds to 15 miles per hour (mph). Limit speed of earth-moving equipment to 10 mph.*

Occupational Health

- *Reduce exposure through work practices and training, such as turning off engines when vehicles are stopped for more than a few minutes, training diesel-equipment operators to perform routine inspection, and maintaining filtration devices.*
- *Position the exhaust pipe so that diesel fumes are directed away from the operator and nearby workers, reducing the fume concentration to which personnel are exposed.*
- *Use enclosed, climate-controlled cabs pressurized and equipped with high-*

efficiency particulate air (HEPA) filters to reduce the operators' exposure to diesel fumes. Pressurization ensures that air moves from inside to outside. HEPA filters ensure that any incoming air is filtered first.

- *Use respirators, which are only an interim measure to control exposure to diesel emissions. In most cases, an N95 respirator is adequate. Workers must be trained and fit- tested before they wear respirators. Depending on the type of work being conducted, and if oil is present, concentrations of particulates present will determine the efficiency and type of mask and respirator. Personnel familiar with the selection, care, and use of respirators must perform the fit testing. Respirators must bear a NIOSH approval number.*

Response: The Corps attempts to account for the environment in all stages of the Regulating Works Project, including implementation and construction. All required Federal and state laws and regulations are followed by the Corps as well as its contractors with respect to air quality and construction emission control efforts in constructing and maintaining the Regulating Works Project. The Corps has and will continue to consider reasonable and efficient ways to minimize environmental and human health risks with respect to air quality and construction emission control efforts. Specifically, Engineering Manual 385-1-1 is required to be followed at all times by Corps employees and its contractors. The Corps also includes applicable Federal Acquisition Regulation clauses in its contracts and requires that contractors provide an Environmental Protection Plan specifically explaining the steps they will take to be in compliance with EM 385-1-1 and work to prevent any environmental harm.

Cumulative Impact Analysis

Comment 102: *The DSEIS concludes, in Section 4.6.6, that the cumulative impacts of the project in combination with other past, present and future actions affecting the Upper Mississippi River System do not "rise to a level of significance." The historical impact of creating and maintaining a system of navigation on the Mississippi River has resulted in significant changes to hydrology and ecology of the River and its floodplain. The purpose of the NEPA document is to characterize the impacts of a proposed Federal action and, by definition, an EIS is required when the project has significant impacts. The Corps has already determined that there are significant impacts resulting from continuing operation of the Regulating Works Project warranting an EIS. It is not clear why the Corps would make such a statement in this document. The Corps' reference to the significance level of "incremental impacts" is contrary to the concept of cumulative impact analysis.*

Response: Per CEQ regulations (40 CFR 1508.7) the cumulative impacts analysis in the SEIS considered "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions." The intent of the referenced paragraph was to convey the District's conclusion that, despite the impacts from past actions, the only significant incremental impacts of the Alternatives analyzed moving forward would be to shallow to medium-depth, moderate- to high-velocity main channel border habitat.

Comment 103: *The DSEIS does not adequately address the potential for excessive river bed scouring or bed loss. Combined with commercial dredging, the placement of dams on tributary rivers, and bank revetments, the continuing placement of river training structures could contribute to excessive sediment scouring in portions of the navigation channel. Bed loss affects floodplain ecology by lowering the groundwater level in the floodplain, could result in head cutting in tributary rivers, isolates backwaters and side channels, and could also threaten infrastructure within the main channel and channel margin. With the narrow exception of the impacts of bed lowering on side channel habitat, the DSEIS does not address the potential for unintended bed loss in select reaches resulting from continued training structure placement. Appendix A, Effects of RTS on Flood Levels, acknowledges the impact of training structures on bed and surface water elevations in multiple document locations. The Kansas City District of the Corps is presently investigating the impacts of and solutions to bed loss, within the navigable portion of the Missouri River, particularly in the St. Joseph to Kansas City reaches. River training structure modification is being considered as a potential remedy to slowing continuing bed loss. Consequently, EPA recommends the Final SEIS include a more robust cumulative impacts analysis incorporating the above.*

Response: Information on the Missouri River Channel Degradation Study and a discussion on why a similar condition will not occur on the MMR has been added to section 4.6.1, Prior Studies.

Climate Adaptation

Comment 104: *The DSEIS characterizes projected changes to regional climate within the MMR watershed based on its 2015 Civil Works Technical Report. However, it is not clear within the DSEIS that an analysis was conducted of projected changes in precipitation levels and subsequent shifts in hydrology and sediment movement as related to project performance, particularly under extreme high and low flows. This analysis is critical as changes in the hydrology in these watersheds could affect the navigational capability of and demands on the project.*

EPA recommends the Corps provide a more robust discussion of its analysis to include the anticipated effect of projected changes in flow regime and consideration of extreme high and low flows on the project.

Response: A more robust discussion of the impacts of climate change on sediment yield and sediment transport has been added to section 4.2.5, Impacts on Air Quality and Climate Change. In addition, more information on the effects of climate change on MMR resources and associated Project impacts has been added to section 4.2.5.

Editorial Comments

Comment 105: *Terms such as "river forecast," "river cutoff," and "placement of hard points" may not be readily understood by reviewers. EPA recommends these terms be explained in the Final SEIS (e.g., as a footnote).*

Response: Footnotes added as suggested for river forecast and river cutoff. Hard point definition is now provided in Table 3-3.

Comment 106: *Reference to Table 4-3 in the section entitled "Interrelated Effects" (page 280) appears to be incorrect. EPA recommends this section refer to Table 4-1.*

Response: Reference corrected.

Responses to Osage Nation Comments

Comment 107: *The Osage Nation Historic Preservation Office has received notification and accompanying information for the proposed project listed as USACE, St. Louis District, Middle Mississippi River Regulating Works Project, Multiple Counties, Missouri and Illinois. After reviewing the available information for the project, the Osage Nation requests that a cultural resources survey be conducted for areas that have not been previously disturbed that are subject to rock placement for the 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 in S l 0 I (d)(6)(A), which clarifies that historic properties may have religious and cultural significance to Indian tribes. Additionally, Section l 06 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 J5 01 .7(a) of 1969).

The Osage Nation has a vital interest in protecting its historic and ancestral cultural resources. The Osage Nation anticipates reviewing and commenting on the planned Phase I cultural resources survey report for the proposed USACE, St. Louis District, Middle Mississippi River Regulating Works Project, Multiple Counties, Missouri and Illinois.

Response: Cultural resources surveys will be conducted, as necessary, as part of site-specific Environmental Assessments. The District will coordinate any necessary surveys and share the findings of the surveys with the Osage Nation as requested.

Appendix F: Determination of National Register Eligibility

Determination of National Register Eligibility (DOE) Study
Middle Mississippi River Regulating Works Project
Missouri and Illinois

(Agreement No. W912P9-13-D-0502, Delivery Order No. 0010)

prepared for
U.S. Army Corps of Engineers,
St. Louis District

prepared by
Commonwealth Heritage Group, Inc.
West Chester, Pennsylvania

January 2016

DETERMINATION OF NATIONAL REGISTER ELIGIBILITY (DOE) STUDY

MIDDLE MISSISSIPPI RIVER REGULATING WORKS PROJECT MISSOURI AND ILLINOIS

Agreement No. W912P9-13-D-0502
Delivery Order No. 0010

prepared for

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January 2016

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers, St. Louis District (USACE), in consultation with the Missouri and Illinois State Historic Preservation Offices (SHPOs), prepared a National Register of Historic Places (National Register) Determination of Eligibility (DOE) Study for the Middle Mississippi River (MMR) Regulating Works Project (Project). The purpose of the DOE was to assess the historic and engineering significance of the Project and its associated built features. The DOE includes a narrative history and physical description of the Project and an evaluation of National Register eligibility within its historic and engineering context. Key sources included USACE annual reports; authorizing legislation concerning the MMR; and a wide variety of published works and scholarly articles pertinent to the history of the Project, navigation on the Mississippi River in general, and development of river-training technology in the United States. Historic maps, photographs, and design drawings were also consulted, along with the MMR features catalog, providing location data from 1881 to the present for dikes constructed as part of the Project.

The study indicates that the Project has been a constant engineering effort involving the construction, reconstruction, modification, and upgrading of various river training structures. With direct national influence on agriculture, commerce, engineering, industry, and transportation, the navigability of the MMR is demonstrated to be immeasurably important, and the Project continues to be promoted and implemented today. For these reasons, the Project, evaluated as a district, is historically significant under National Register *Criterion A*. However, to be eligible for the National Register, a property must also possess integrity, i.e., the ability of a property to convey significance. With most, if not all, of its associated structures post-dating the period of significance (1881-1965), the Project is unable to convey its considerable national significance. Therefore, due to a loss of integrity, the Project is recommended *not eligible* for the National Register.

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LIST OF FIGURES

1.0 INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District (USACE), in consultation with the Missouri and Illinois State Historic Preservation Offices (SHPOs), contracted with Commonwealth Heritage Group, Inc. (Commonwealth) to prepare a National Register of Historic Places (National Register) Determination of Eligibility (DOE) Study for the Middle Mississippi River (MMR) Regulating Works Project (Project). The MMR is defined as the 190-mile section of the Mississippi River between its confluence with the Missouri River above St. Louis, Missouri, and its confluence with the Ohio River at Cairo, Illinois (Figures 3.1 and 3.2). This DOE is intended to support the preparation of a Supplemental Environmental Impact Statement (SEIS) for the Project by the USACE. The original Environmental Impact Statement (EIS) was prepared in April 1976.

The purpose of this DOE is to assess the historic and engineering significance of the Project and its associated built features. Historically, the objective of the Project has been to ensure a safe and dependable navigation channel through bank stabilization and sediment management. Continuous implementation of the Project has been achieved primarily through dredging and the construction and calculated placement of river-training structures, namely dikes and revetments, along the length of the MMR. This DOE includes a narrative history and physical description of the Project and an evaluation of National Register eligibility within its historic and engineering context. As an ever-evolving system composed of many adaptable, functionally-related built features, the Project was evaluated for the National Register as a district.

2.0 METHODOLOGY

Commonwealth conducted extensive historical research to gain a comprehensive understanding of the Project and prepare an appropriate historic context for assessing its National Register eligibility. Various primary and secondary resources were utilized in conjunction with USACE staff having expert knowledge of the Project. Specifically, development of the historic context was a joint effort between Commonwealth and Brian Rentfro, a USACE contractor who co-authored *Engineers Far From Ordinary: The U.S. Army Corps of Engineers in St. Louis.*[1] Key sources included USACE annual reports, authorizing legislation concerning the MMR, and a wide variety of published works and scholarly articles pertinent to the history of the Project, navigation on the Mississippi River in general, and development of river-training technology in the United States. Historic maps, photographs, and design drawings were also provided by the USACE, along with a features catalog with location data from 1881 to the present for dikes constructed on the MMR as part of the Project. A field examination was not included in the scope of work for this DOE study, so the features catalog helped Commonwealth staff to visualize the distribution of the river-training structures, quantify changes to the MMR over time, and determine overall integrity of the Project.

This DOE was prepared in accordance with guidance provided by the National Park Service (NPS) on evaluating and documenting the eligibility of historic properties, specifically *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation* and *The Components of a Historic Context.*[2] These publications formed the basis for analyzing the applicability of the National Register evaluation criteria to the Project and identifying the physical characteristics of the Project and its associated built features that are needed to convey historic and/or engineering significance.

[1] Damon Manders and Brian Rentfro, *Engineers Far From Ordinary: The U.S. Army Corps of Engineers in St. Louis* (St. Louis: USACE, 2011).

[2] National Park Service, *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation* (Washington, D.C.: U.S. Department of the Interior, NPS, 1991); Barbara Wyatt, *The Components of a Historic Context* (National Register White Paper Series, 2009), accessed August 13, 2015, http://nps.gov/nr/publications/policy.htm.

3.0 HISTORICAL OVERVIEW

3.1 THE MISSISSIPPI RIVER

The Mississippi River begins near Lake Itasca in northern Minnesota and meanders south for approximately 2,320 miles. The river either passes through or borders Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana. The Mississippi River Watershed covers more than 1,245,000 square miles and drains 41 percent of the continental United States, including all or parts of 31 states and two Canadian provinces. The most significant tributaries of the Mississippi River are the Illinois, Missouri, Ohio, Arkansas, and Red rivers.

The Mississippi River can be divided into three sections. The Upper Mississippi River (UMR) stretches from the river's source at Lake Itasca in Minnesota to the confluence of the Mississippi and the Missouri rivers just above (north of) St. Louis, Missouri. The MMR is an approximately 190-mile section of river that extends from the mouth of the Missouri River to the mouth of the Ohio River. The section from the mouth of the Ohio River to where the Mississippi flows into the Gulf of Mexico is known as the Lower Mississippi River (LMR).

Congress has authorized the USACE to maintain a minimum navigation channel depth and width for the entire Mississippi River. Each section of the river is unique and presents its own set of challenges for engineers attempting to maintain the channel. On the UMR, flows are relatively low when the river is in its free-flowing, natural state without dams. The sediment load carried by the UMR is also much lower than on the MMR and LMR. Consequently, the construction of river regulating works (various types of dikes and bank stabilization structures) and channel contraction are not an effective means of maintaining the navigation channel. The USACE originally attempted to maintain a navigable channel on the UMR through the construction of regulating works and channel contraction, but ultimately this method proved ineffective. By 1940 the UMR had been canalized through the construction of locks and dams.

Flows on the MMR are much more substantial due to its merging with the Illinois and Missouri rivers. In addition, the sediment load in the MMR is much higher than on the UMR because the Missouri River transports a large amount of material. As a result, the MMR requires no locks or dams, and engineers can maintain the authorized navigation channel through the construction of regulating works to contract the channel, stabilization of riverbanks to prevent meandering and collapsing riverbanks, and dredging (the Project). The regulating works slow the flow of the river near dike fields, thereby causing sediment to be deposited and new riverbanks to be built up. This creates a narrower river that allows the energy of the river's flow to be directed into the navigation channel. The natural energy of the river scours the riverbed and flushes much of the sediment out of the channel, pushing it downstream.

On the LMR, regulating works are used less extensively because flows are typically substantial enough, and dredging alone can be used as the primary means of maintaining the authorized navigation channel.

The Mississippi River and its commercially navigable tributaries cut through the largest piece of contiguous farmland in the world. A great majority of America's prime agricultural lands lie within about 120 miles of a navigable river. Farmers and industries in the nation's interior depend on river transportation to move their goods to national and global markets. Because of this extensive river commerce, numerous cities and ports have been established along the Mississippi

River and they depend, or have depended in the past, on this commerce for their economic livelihood.[3]

The most important port of the Mississippi River system is the Port of South Louisiana, which stretches 54 miles along the Mississippi River between Baton Rouge and New Orleans. It is the largest tonnage port district in the Western Hemisphere and one of the largest in the world. The majority of agricultural products in the Midwest pass through the UMR and MMR and their tributaries on their way to the Port of South Louisiana. This port possesses global significance, as approximately 60 percent of product reaching it is exported.[4]

The MMR is especially important because it is the linchpin of the river system. Commercial vessels carrying bulk goods from the upper and lower Mississippi, Illinois, Missouri, and Ohio rivers often must traverse the MMR in order to reach their destinations. Should the MMR close or become a less safe and reliable navigable waterway, commerce and industry on both a national global scale would suffer greatly. For commercial navigation to thrive, each part of the system must function as designed. On the MMR commercial navigation needs are met by the Project, through the construction of regulating works and channel contraction.

3.2 EARLIEST SURVEY AND NAVIGATION IMPROVEMENTS

Europeans began establishing permanent settlements along the Mississippi River as early as 1716. Two years later, New Orleans was founded and the city became the capital of the region known as the Louisiana Territory. The city's growth occurred in large part because of its position near the mouth of the Mississippi River, as goods from the lower Mississippi valley and its tributaries were sent downriver to New Orleans. Because the river was the primary means of shipping goods from the Mississippi valley, most of the earliest settlements along the river were trading posts where goods from the interior could be shipped to New Orleans.[5]

The purchase of the Louisiana Territory by the United States from France in 1803 opened up the fertile lands west of the Mississippi River for settlement. Just sixteen years earlier Congress had passed the Northwest Ordinance, which established the Northwest Territory and allowed for the settlement of lands northwest of the Ohio River and east of the UMR. Thus, in a span of less than two decades, the nation had expanded to include nearly all the lands in the Mississippi River watershed.

In the early 1800s the vast majority of land in the upper Mississippi valley was still raw and uncultivated wilderness. When Thomas Jefferson authorized the Louisiana Purchase, he envisioned these western lands as a place where settlers could cultivate the land and establish small farms. It was in these lands, Jefferson believed, that the future greatness of America lay. Many Americans shared his vision and ventured westward. By 1840 around 40 percent of the nation's population lived west of the Appalachian Mountains. But for these settlers to get their goods from the Midwest's interior to markets, a dependable form of transportation was needed.[6]

[3] Stratfor, Inc., *The Geopolitics of the United States, Part 1: The Inevitable Empire* (Austin, Texas: Stratfor, Inc., 2012).

[4] Stratfor, *The Geopolitics of the United States*; Port of South Louisiana, "Overview of the Port," accessed July 10, 2015, http://www.portsl.com/overview.htm.

[5] Fredrick J. Dobney, *River Engineers on the Middle Mississippi* (Washington, D.C.: GPO, 1978), 1-15.

[6] Stephen Ambrose, *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West* (New York: Simon and Schuster, 1996), 68-79; Ronald D. Tweet, *History of Transportation on the Upper Mississippi and Illinois Rivers* (USACE Water Resources Support Center, National Waterways Study, 1983), 13-18.

Before the invention of the steamboat, river commerce mostly consisted of floating timber logs downstream or transporting furs and minerals (mostly lead) downstream via flatboat (Figure 3.3). The introduction of the steamboat completely transformed the course of history for the Mississippi River and the Midwest. The first steamboat to arrive in St. Louis was the *Zebulon Pike* in 1817. Within a decade river traffic was bustling around St. Louis and other towns such as St. Genevieve, Cape Girardeau, and New Madrid, Missouri (Figure 3.4). This increase in river commerce facilitated population growth in these towns, especially in St. Louis, where the population rose from around 925 in 1800 to nearly 5,000 in 1830, over 16,000 in 1840, nearly 78,000 in 1850, and just over 160,000 by 1860. During this same period, annual steamboat arrivals at St. Louis grew from 3 to over 3,600. By the 1850s St. Louis was the largest city west of Pittsburgh and would continue to grow at a torrid pace until the 1870s.[7]

Westward expansion and the arrival of the steamboat in 1817 necessitated survey of the MMR, which was first completed the same year. Settlement occurred along the river prior to this, so the survey did not represent the river in a completely "natural" state, but it was the earliest accurate survey and thus a close approximation to the "natural" river. At that time, the average width of the river was 3,358 feet. The river also included numerous chutes and side channels, fords and shallows, islands, snags, and numerous other obstructions to navigation. The Federal Government showed interest in removing these obstructions, as was indicated by the 1821 report of the Board of Engineers for Rivers and Harbors, which recommended the removal of snags, but it was not yet decided if the government had the constitutional authority to approve or fund such improvements.[8]

Commercial river navigation was a major challenge with the UMR and MMR in their "natural" state. If St. Louis was to continue to grow and if Midwest farmers were going to be able to ship their harvests to markets, then a dependable form of transportation was needed. At that time, transporting by river was by far the most practical means of moving goods from the nation's interior, but improvements were required to make the rivers dependably safe and navigable. While it was undecided if the Federal Government had the constitutional authority to fund river improvements, a landmark case *Gibbons v. Ogden* (1824) served as precedent. With this decision the U.S. Supreme Court ruled that the Federal Government had the power to regulate interstate commerce and river navigation "so far as that navigation may be in any manner connected with commerce." This gave Congress the legal authority to fund river improvements that promoted commercial navigation.[9]

The 1824 General Survey Act authorized the president to employ civil engineers and officers of the USACE to make surveys, plans, and estimates for "routes of such roads and canals as he may deem of national importance." The Act also, for the first time, provided for internal improvements on a national scale, including the first Rivers and Harbors Act, also passed in 1824. The Rivers and Harbors Act gave the USACE responsibility for improvement of internal waterways and contained the first appropriation for the improvement of the Mississippi River. The Rivers and Harbors Act of 1826 combined the authorities of the two 1824 Acts into a single Act that gave the USACE responsibility for surveys and projects, in turn setting the stage for river

[7] Dobney, 17-37; Tweet, 13-25; Charles E. Landon, "Technological Progress in Transportation on the Mississippi River System," *The Journal of Business* 33, no. 1 (1960): 43-62.

[8] E. J. Brauer et al., *Supplement to Geomorphology Study of the Middle Mississippi River* (St. Louis: USACE, 2013); *U.S. Congress, Report of the Board of Engineers on the Ohio and Mississippi Rivers*, House Doc. No. 35 (17th Cong. 2d sess.).

[9] *Thomas Gibbons vs. Aaron Ogden*. 22 U.S. 9 Wheat. 1 (1824).

engineering projects for the next two centuries. The USACE would carry out surveys and studies and make recommendations, while Congress would be responsible for approving and funding improvement projects. Once approved and funded, the USACE would oversee construction.[10]

The first improvements on the MMR consisted of removing snags (Figure 3.5). In 1828 the Secretary of War appointed Henry Shreve to the post of Superintendent of Western Rivers and asked him to carry out the task. Shreve constructed the first steam snagboat, the *Heliopolis*, in 1828 and by 1830 he had cleared the worst snag obstructions from the Mississippi River between St. Louis and New Orleans.[11]

The next task was to improve the St. Louis Harbor (Figure 3.6). Thanks to the removal of snags from the MMR and the arrival of the steamboat, river commerce was increasing dramatically at St. Louis, and the population was increasing accordingly. When the snag removal project first began in 1828, less than 300 steamboats arrived at the Port of St. Louis, but by 1838 this total increased to approximately 1,600. This trade made St. Louis the most important commercial city on the MMR and an essential port through which the goods from the Midwest's interior passed. The MMR, however, was naturally beginning to meander to the east, a serious threat to the city that would leave it landlocked if not corrected. The City lacked the financial means and engineering knowledge to do so, so City officials looked to the Federal Government for aid.[12]

In 1836 General Charles Gratiot, the Chief of Engineers of the USACE, proposed building a wing dam and a dike opposite St. Louis near Bloody Island to force the current back west toward the sandbar. He appointed a young Lieutenant name Robert E. Lee to carry out the effort. Although Lee would begin the work in 1837, it would take decades to complete, but it eventually saved the vital St. Louis Harbor. It also represented the first attempt to construct river regulating works to permanently improve a section of the MMR.[13] However, owing to the expansion of railroads, the growth of Chicago, and the Civil War, it was not until 1872 that Congress appropriated funds for additional permanent river navigation improvements on the MMR. Permanent improvements of the entire MMR were not authorized until 1881.[14]

The country's network of railroads began expanding west toward the Mississippi River during the 1850s, but there were few railroads that reached into western Iowa and the Dakotas prior to the 1870s (Figure 3.7). Most of the railroads that were constructed east of the Mississippi terminated at Chicago. Moreover, the completion of the Illinois-Michigan Canal in 1848 connected the Illinois River to Lake Michigan at Chicago. These two developments allowed goods from the eastern portion of the upper Mississippi valley and the Illinois River valley to be shipped to New York via Chicago instead of to New Orleans via St. Louis. Thus began the rise of Chicago as the commercial rival of St. Louis.[15]

[10] Damon Manders and Brian Rentfro, 16-23.

[11] Dobney, 17-34; Tweet, 13-25.

[12] Dobney, 17-34; Tweet, 13-25; U.S. Congress, *Harbor of St. Louis*, House Doc. 25-298 (25th Cong., 2d sess.).

[13] Dobney, 17-34; Tweet, 13-25; U.S. Congress, *Harbor of St. Louis*, House Doc. 25-298 (25th Cong., 2d sess.).

[14] Dobney, 39-62; U.S. Congress, *Letter from the Secretary of War Transmitting a Progress Report of the Mississippi River Commission, dated November 25, 1881*, Senate Executive Doc. No. 10 (47th Cong., 1st sess.). This is the report on which the original 1881 navigation project on the middle Mississippi River is based. Hereafter cited as Senate Executive Doc. No. 10.

[15] Frank Haigh Dixon, *A Traffic History of the Mississippi River System* (Washington, D.C.: GPO, 1909); James H. Lemly, "The Mississippi River: St. Louis' Friend or Foe?" *The Business History Review* 39, no. 1 (1965): 7-15; Lewis F. Thomas, "Decline of St. Louis as Midwest Metropolis," *Economic Geography* 25, no. 2 (1949): 118-127.

St. Louis and the MMR still dominated commerce in the Midwest because the railroads had not expanded sufficiently into the Missouri River basin and the western portion of the upper Mississippi valley, but the Civil War severed the LMR from the MMR and the commerce that ran through it. Many of the steamboats once used for commerce were now used to support the war effort and were badly damaged or sunk. On July 1, 1862, Congress further facilitated the growth of Chicago and rail transportation by chartering the Union Pacific Railroad. When construction of the railroad was completed in 1869, it connected the Pacific Coast to Council Bluffs, Iowa. Railroads began expanding rapidly southwest from Chicago and redirecting much of the Missouri River valley commerce, which otherwise would have passed through St. Louis and the MMR. During the 1870s and 1880s the Illinois Central Railroad began expanding into the south with a rail line near the eastern banks of the Mississippi River that terminated at New Orleans.[16]

The impact of railroad expansion on St. Louis and Chicago is clearly shown by the population growth of each city. In 1860 St. Louis had a population of 160,773 and Chicago 112,172, but by 1890 the population of Chicago was 1,099,850 and St. Louis had just 451,770 residents. The annual commercial tonnage on the MMR declined along with the population, peaking in 1869 at 2,243,499 tons, the same year that the Union Pacific Railroad was completed. By 1890 the annual tonnage was just 1,299,679. The annual tonnage declined to an average of around 500,000 by the first decade of the twentieth century, and it further declined to an average of less than 300,000 in the decade that followed.[17]

The decline of river commerce was as much due to unreliable and un-navigable waterways as it was to the expansion of railroads. Navigation of the Mississippi River and its tributaries above the Ohio River was often difficult if not impossible for long periods of time, either because of ice or low water. Even when there was sufficient flow in the channel, the rivers had shoals and other obstructions that grounded, delayed, or damaged vessels (Figure 3.8). A large part of the problem was that the MMR's channel was growing wider. In 1817 the river had an average width of 3,358 feet, but by 1881 the average width had increased to 3,743 feet, leading to a shallower channel that made navigation increasingly more dangerous and challenging. In contrast, the railroads were expanding and becoming more and more dependable. The rivers had the potential to be dependable, but ensuring this would require years of effort and significant financial investment.[18]

Many in Congress showed little support for river projects because they were believed to produce only local benefits or were considered pork barrel appropriations. The other problem was that there was not sufficient river commerce to justify the investment of large sums in projects. The supporters of river improvements argued that if a dependable channel could be obtained and maintained, then river commerce would return, but this was merely speculation. Moreover, because the Mississippi River and its tributaries act as a system, for improvements to be effective, they needed to be system-wide. It would matter little if the UMR, for example, was improved and saw an increase in river commerce if vessels could not pass through the MMR and reach New Orleans. Similarly, navigation improvements on the MMR would only provide a full return on investment if river commerce was also increased on the UMR and elsewhere.[19]

[16] Dixon; Lemly, 7-15, Thomas, 118-127.

[17] Dixon; Lemly, 7-15, Thomas, 118-127; Dobney, 39-63; Tweet, 21-41.

[18] Brauer et al., *Supplement to Geomorphology Study of the Middle Mississippi River*; Edward J. Brauer et al., *Geomorphology Study of the Middle Mississippi River* (St. Louis: USACE, 2005).

[19] John O. Anfinson, *The River We Have Wrought: A History of the Upper Mississippi River* (Minneapolis: University of Minnesota Press, 2003), 29-80.

Following the Civil War, river navigation supporters held conventions in St. Louis in 1867, 1872, and 1873; in New Orleans in 1869 and 1876; in St. Paul in 1875 and 1877; and in Prairie du Chien in 1868, to discuss how to increase river commerce and to pressure Congress to expand the work of the USACE. They believed that railroads were becoming monopolies and charging exploitative rates, and that the best way to lower rail rates was to increase competition by promoting river commerce. The farmers and navigation supporters argued that the Midwest was the nation's granary, and an affordable and efficient means of transportation was needed to transport the product of the fertile lands to markets. In 1864 the Midwest produced more than one-quarter of the value of all crops in the nation, including nearly one-half of all wheat and corn, one-quarter of all livestock, and between one-third and one-half of the country's leading food staples. For navigation boosters, this was a national, not a regional, issue.[20]

Congress responded by passing the Rivers and Harbors Act of 1866, which signaled the beginning of permanent navigation improvements on the UMR (Figure 3.9). The act appropriated $400,000 for channel improvements and surveys north of St. Louis. For the improvement of the MMR, Congress authorized $100,000 in the 1872 Rivers and Harbors Act. The USACE was to expend these funds on the improvement of the MMR just between the mouths of the Missouri and Meramec rivers.[21]

These projects were hardly enough to maintain the dependable navigation channel required for river commerce to compete with railroads. At that time, the MMR was divided by numerous islands and bars, which distributed large portions of the flow through chutes, sloughs, and secondary channels to the detriment of navigation. At many locations, the width of the river was one to one-and-one-half miles wide and the maximum usable channel depth was only three-and-one-half to four feet. If a dependable navigation channel was going to be obtained and maintained, a comprehensive river improvement project on a considerably larger scale would be necessary. By the 1870s the USACE recognized this and began planning for such a project.[22]

In 1873 the USACE established a permanent engineering office in St. Louis to oversee the improvement of the MMR. Under the leadership of Col. James Simpson, the St. Louis District Engineer, the district spent the next seven years studying the MMR to determine the best means to maintain a dependable navigation channel, which he recommended should be at least eight-feet-deep between St. Louis and the mouth of the Ohio River. To accomplish this, he recommended a policy of permanent river improvement structures based on the principle that the river itself should be used to do the work of channel maintenance wherever possible. In other words, the channel should be contracted through the construction of dikes and the stabilization of riverbanks so that the energy of the river would be directed into the main channel to scour the riverbed and reduce the accumulation of sediment and the need for dredging.[23]

In 1879 Congress established the Mississippi River Commission, with its headquarters in St. Louis, to oversee the implementation of plans for flood control and navigation improvements on the Mississippi River. The commander of the USACE Mississippi Valley Division, which included all the engineering districts in the Mississippi River valley, would serve as the commission's president, and the USACE became responsible for implementing the commission's

[20] Anfinson, 53-80; Tweet, 47-53.

[21] Anfinson, 53-80.

[22] USACE, *Annual Report of the Chief of Engineers* (1921), 1197. All subsequent references to Annual Reports refer specifically to those sections of the reports covering the section of the Mississippi River between the mouths of the Missouri and Ohio rivers.

[23] Dobney, 48-56; Manders and Rentfro, 47-59.

plans. The creation of the commission represented the first federal attempt to develop a coordinated plan for the development of the Mississippi River.[24]

In 1881 the commission adopted the plan proposed by Col. Simpson and included it in a report to Congress, which Congress then used as the basis for its authorization of the Project. The master plan recommended making "the improvement continuous, working downstream from St. Louis, by reclaiming land and building up new banks, thus reducing the width of the river to the uniform width of about 2,500 feet." The objective of the contraction was to maintain a minimum navigation channel depth of eight feet during low water. This plan was based on the premise, observed by Captain O.H. Ernst – the St. Louis District Engineer – and Col. Simpson before him, that all of the construction was intended to use the energy of the river "simply to restore what once existed and to do it in such a way that the restoration shall be permanent."[25]

The authorization of the projects for permanent navigation improvements on the UMR and MMR must also be understood within the context of the economic and political developments of the 1870s. Between 1873 and 1879 the United States was in the midst of a major economic depression. Midwest farmers were especially impacted by the depression because their profit margins were so slim. Often times the cost of transporting goods determined whether or not farmers made a profit. The expansion of the railroads had initially benefitted farmers west of the Mississippi River, but with the decline of river commerce, railroads began raising their rates. Farmers complained of a railroad monopoly and exploitative shipping rates. These complaints eventually led to what became known as the Granger Movement, which consisted of a union of farmers who came together to promote navigation improvements and oppose the railroad industry. They believed that the railroads needed to be regulated to keep rates low, and the best means to regulate rail rates naturally was through promoting commercial river navigation to provide more competition.[26]

Minnesota Senator William Windom, who was the chairman of the Senate Select Committee on Transportation to the Seaboard, shared many of the sentiments of the Granger Movement, especially the idea that river navigation improvements could be used to combat high rail rates. Windom's committee presented a report to the Senate in 1874 that recommended navigation improvements as a means to control rail rates. The report also recommended navigation improvements as a means to increase the export of grain between New Orleans and British ports so that the United States could challenge Russia and Europe for the British grain trade and develop its trade in Central and South America.[27]

In the Rivers and Harbors Act of 1878, Congress authorized a four-and-one-half foot navigation channel on the UMR. Although these improvements were not on the MMR, they nonetheless impacted its future development because any goods originating in the upper Mississippi valley had to traverse the MMR on their way to New Orleans. Thus the fate of the UMR and MMR were, and would continue to be, closely linked to one another.[28]

[24] Charles A. Camillo and Matthew T. Pearcy, *Upon Their Shoulders: A History of the Mississippi River Commission from its Inception Through the Advent of the Modern Mississippi River and Tributaries Project* (Vicksburg, Miss.: Mississippi River Commission, 2004), 25-35.

[25] USACE, *Annual Report of the Chief of Engineers* (1975), 471-495; Senate Executive Doc. No. 10.

[26] Anfinson, 56-80; U.S. Congress, Senate, *Senate Report of the Select Committee on Transportation-Routes to the Seaboard*, Report No. 307, Part 1 (43d Cong., 1st sess.): 79-240.

[27] Anfinson, 56-80; U.S. Congress, Senate, *Senate Report of the Select Committee on Transportation-Routes to the Seaboard*, Report No. 307, Part 1 (43d Cong., 1st sess.): 79-240.

[28] Anfinson, 56-80; U.S. Congress, Senate, *Senate Report of the Select Committee on Transportation-Routes to the Seaboard*, Report No. 307, Part 1 (43d Cong., 1st sess.): 79-240.

3.3 FIRST DECADES OF THE MMR PROJECT (1881-1910)

The general plan of the Project was to methodically build river training structures downstream from St. Louis rather than piecemeal at various locations. The river training structures consisted primarily of permeable wooden pile dikes and jetties, which slowed the flow in-between the structures and caused sediment to accumulate, thereby forming new banks and contracting the river. With the distance between riverbanks decreased, the river's energy would be directed into the navigation channel, in turn scouring the riverbed and reducing sedimentation and the need for dredging. The riverbanks were stabilized through the construction of hurdles and willow weave mattresses. Lastly, river training structures were constructed to close side channels so that the majority of the river's flow would remain in the navigation channel.[29]

At first, the greatest impediment to the Project was the lack of appropriations from Congress. At the end of his tenure as district engineer, Col. Simpson lamented that based on the rate of appropriations, the project would take a century to complete. The other major impediment was that the early pile dikes were not very durable and were often damaged or destroyed because of floods or because of ice, vessels, or debris crashing into them. Much of the earliest work consisted of as much repairing of damaged dikes as construction of new dikes.[30]

The first two decades of the project saw construction at Horsetail Bar, Sawyer Bend, Rush Tower, Cahokia Chute, Arsenal, Fort Chartres, Turkey, Liberty, Devil's, Dickey, Widow Beard's, Carroll's Island, Twin Hollows, Jim Smith's, Kaskaskia and Hat islands; Herculaneum and St. Genevieve, Mo, Platin Rock, Fish Bend, and Jones's Point. Nearly all of the improvements between 1881 and 1900 occurred no more than 80 miles downriver of St. Louis. By 1890 the St. Louis District reported that an eight-foot channel was being consistently maintained from St. Louis to Lucas Crossing, 30 miles downstream. By 1900 the USACE had constructed over 350,000 linear feet of dikes and 300,000 linear feet of revetment on the MMR.[31]

By the end of the century engineers were starting to consider other means of maintaining the authorized channel. In the Rivers and Harbors Act of 1896 Congress authorized the USACE to use dredges and temporary regulating works to maintain the channel. Consequently, nearly all work stopped on permanent navigation improvements, and for over a decade the USACE experimented with maintaining the authorized navigation channel through dredging.[32]

The Rivers and Harbors Act of 1902 established the Board of Engineers for Rivers and Harbors to compile a report on whether or not dredging was a more effective and cost efficient means of maintaining the navigation channel. The board determined that dredging could be more cost efficient, but to be certain, nearly all work on river training structures would have to cease and dredging would have to be used almost exclusively. Once enough data were gathered on the

[29] Senate Executive Doc. No. 10; USACE, *Annual Report of the Chief of Engineers*, 1881 to 1896, sections covering the Mississippi River between the mouths of the Missouri and Ohio rivers.

[30] USACE, *Annual Report of the Chief of Engineers* (1879), 1032.

[31] Brauer et al., *Geomorphology Study of the Middle Mississippi River*; USACE, *Annual Report of the Chief of Engineers*, 1881 to 1900, 1921.

[32] River and Harbor Act of 1896, (29 Stat. 202), passed June 3, 1896; U.S. Congress, *Report by a Special Board of Engineers on Survey of the Mississippi River from St. Louis, MO, to Its Mouth with a View to Obtaining a Channel 14 Feet Deep and of Suitable Width*, House Doc. No. 50 (61st Cong., 1st sess.).

efficacy of dredging, the board would make its final recommendation. The Rivers and Harbors acts of 1905 and 1907 reaffirmed the commitment to dredging.[33]

By 1910 the dredging experiment had run its course, and after an evaluation of the use of dredging exclusively, the board determined that the authorized channel could best be maintained through the construction of river training works, with dredging used as a supplement. Congress authorized the board's recommendations in the Rivers and Harbors Act of 1910, thereby restoring the original 1881 Project. The Act also authorized the construction of new permanent river training structures.[34]

3.4 THE DECLINE OF RIVER NAVIGATION (1910-1925)

Even though the 1910 River and Harbors Act restored the Project, actual construction of regulating works depended on Congress's willingness to authorize appropriations. Between 1911 and 1924 Congress appropriated just over $8 million for the Project. However, these funds had to cover not only the construction of new regulating works, but also the maintenance and repair of existing works and dredging costs. Consequently, only about 60 percent of funds were applied to the construction of new regulating works. The remaining 40 percent went mostly to the repair and maintenance of existing works, many of which were deteriorating so quickly that more old dikes were lost each year than there were new dikes constructed. In fact, between 1881 and 1924, almost as much money had been expended on maintenance and repair as had been expended on the construction of new regulating works. The 1921 Annual Report of the Chief of Engineers estimated that 40 percent of dikes constructed before 1910 had already been destroyed. The report also stated that between 1914 and 1921, funds were insufficient to even cover the repair of seasonal damages. The USACE estimated that between 1881 and 1921, 403,116 linear feet of dikes had been constructed, but 188,131 linear feet of dikes had been lost due to damage or deterioration.[35]

To continue the project Congress needed to appropriate funds, but the dramatic decline in river commerce did not justify the investment. When Congress first authorized the project, traffic on the MMR was just over 2 million tons annually. By the turn of the century, the total had fallen to around 800,000 tons. Between 1900 and 1910, the MMR averaged just 500,000 tons annually, and in 1910 just 191,965 tons traversed this stretch of river. Between 1911 and 1921 the average annual tonnage declined to just 200,000. It was not until the late 1920s and 1930s that commercial river traffic finally began to return to the MMR in considerable numbers.[36]

3.5 NATIONAL DEVELOPMENTS IMPACTING RIVER NAVIGATION

The population, economy, and agricultural production of the Midwest had continued to grow even though river commerce was in decline. Expanding railroads now controlled most of commercial transportation. Between 1900 and 1930, however, several developments occurred that increased commercial traffic on the Mississippi River and heightened the significance of the Project.

[33] U.S. Congress, *Report of the Board of Engineers for Rivers and Harbors Submitted November 12, 1903*, House Doc. No. 168 (58th Cong. 2d sess.).

[34] U.S. Congress, *Report by a Special Board of Engineers on Survey of the Mississippi River from St. Louis, MO, to Its Mouth with a View to Obtaining a Channel 14 Feet Deep and of Suitable Width*, House Doc. No. 50 (61st Cong., 1st sess.).

[35] USACE, *Annual Report of the Chief of Engineers*, 1910 to 1924.

[36] Tweet, Appendix A.

The first of these was the Panama Canal Project, which the United States had taken over in 1904 (Figure 3.10). When completed in 1914, the canal would provide a cheap means of transporting Midwest goods to the West Coast by water. However, to get the goods from the UMR and MMR to New Orleans, significant river improvements were needed. Politicians, farmers, and business interests in the region understood this and formed the Upper Mississippi River Improvement Association (UMRIA) to lobby for a six-foot channel for the UMR. In a 1905 speech the UMRIA president said that "the building of the Panama Canal makes the improvement of the Mississippi and Ohio rivers imperative, as the natural trend of commerce will then be along these highways to the Gulf and thence to and from the markets of the world." Even Chicago, he noted, sought to tie itself to the canal through the Mississippi River. Not only did Midwesterners need the canal, the canal needed goods from the Mississippi and Ohio rivers to be successful. Col. John L. Vance, president of the Ohio River Improvement Association, predicted that with the canal completed, "the products of the Ohio and Mississippi Valleys will control the markets of the world."[37]

The other reason why farmers and commercial interests called for navigation improvements was the same reason they called for them in the 1870s and 1880s: to lower rail rates and promote competition. Moreover, the rail shortage of 1906-1907 exposed the inadequacy of the railroads to support the growing transportation needs of the Midwest economy. Building enough railroads to support the commercial needs of the Midwest and West would take decades and billions of dollars. Instead of expanding railroads, river commerce boosters called for navigation improvements and a deeper channel on the UMR. Many congressmen still did not support navigation improvements, believing they were merely pork barrel appropriations that produced only local benefits, but Midwestern congressmen continued to show strong support for navigation improvements. More importantly, Teddy Roosevelt's administration was a strong supporter of water resource projects. This support was enough for Congress to authorize a six-foot channel in the Rivers and Harbors Act of 1907. However, the six-foot channel authorization had no impact on commercial river traffic, which did not begin to rebound until the late 1920s.[38]

Another development that led to increased funding for navigation improvements was the rise of the corporate farmer. When navigation improvements for the MMR were first authorized in the nineteenth century, most of the beneficiaries were small farmers and businessmen. By the 1920s many of the small yeoman farmers had been supplanted by large plantations, and the smaller farms that still existed had banded together to form corporate bodies. Consequently, a powerful farm lobby emerged. The influence of the farm lobby combined with the growing influence of commercial barge lines were enough to pique congressional interest in a possible a nine-foot navigation channel above the mouth of the Ohio River.[39]

3.6 BIRTH OF THE MODERN MMR PROJECT (1924-1927)

In 1924 the House Committee on Rivers and Harbors requested that the Board of Engineers for Rivers and Harbors study the feasibility and advisability of obtaining and maintaining a nine-foot-deep and 300-foot wide channel on the MMR. The report, submitted to Congress in December of 1926, cited "interruptions to the work of contraction, due to reliance upon dredging, [and] meager appropriations" as the reason why just one-third of the necessary works had been completed (between 1910 and 1925, only $2,592,920 had been appropriated for new work). USACE St. Louis District Engineer Maj. John Gotwals explained that the nature of the bed of the

[37] Anfinson, 130-144.
[38] Anfinson, 130-144.
[39] Anfinson, 125-144, 175-195.

river is such that maintaining a navigable depth is especially difficult in stretches only partially improved or not improved at all. Without sufficient permanent improvements, navigation could only be maintained by dredging and "it is impracticable to maintain a dredging fleet sufficient in number of dredges to safeguard the required depth at each bar." Maj. Gotwals recommended the modification of the Project to maintain a nine-foot-deep, 300-foot-wide channel, and insisted that continued contraction of the river through regulating works and revetment was essential to achieve this end. Congress approved the recommendations of the report, modifying the Project to provide for a nine-foot-deep, 300-foot-wide channel on the MMR in the Rivers and Harbors Act of 1927.[40]

3.7 NAVIGATION IMPROVEMENTS ON INTERRELATED RIVERS

The authorization of a nine-foot channel on the MMR was just the first in a series of navigation improvement authorizations between 1927 and 1930 that would completely transform the entire Mississippi River navigation system and dramatically increase the importance of the MMR and the Project. In 1927 Congress approved a nine-foot channel for a portion of the Illinois River and expanded the nine-foot channel authorization to include the entire river in 1930. Construction of the Illinois River nine-foot channel project was completed by the mid-1930s. The impact of the project is exemplified by the increase in commercial traffic between 1940 and 1975. In 1940 the annual tonnage on the Illinois River was 3.745 million; in 1950 it rose to 13.7 million; in 1960 it rose to 22.8 million; and by 1975, it was 43.6 million. The significance of this increase in relation to the MMR is that Chicago and New Orleans are linked via the MMR, as it connects the LMR and Illinois River. Thus, without a navigable channel on the MMR, which is maintained by the Project, the inland navigation channel between Chicago and New Orleans would be severed, as well as the link between the Great Lakes and the Gulf of Mexico.[41]

Congress also authorized the study of a nine-foot channel project for the UMR in 1927 and in 1930 approved a project for canalizing the UMR through the construction of 26 locks and dams. By the end of 1940 the USACE had completed the nine-foot channel project, and for the first time, farmers, businessmen, and the barge industry had a dependable navigation channel that would allow river commerce to compete with rail transport. As a result, commercial traffic dramatically increased on the UMR between 1940 and 1975. In 1940, 3.5 million tons passed through the UMR; by 1950, the total was over 11 million; by 1960 it was 27.3 million; and by 1975, it was over 63 million. The significance of the UMR nine-foot channel project in relation to the MMR is obvious, as the MMR served to connect the goods from the UMR to the ports on the LMR. This is exemplified by the fact that the increase in commerce on the MMR occurred in tandem with that on the UMR.[42]

Authorization of river navigation improvements of course meant nothing without appropriations for construction. The Great Depression, combined with the Franklin Roosevelt administration's philosophy on Federal spending and civil works projects, ensured congressional support in the form of massive civil works appropriations that allowed the UMR and Illinois River to be transformed in a little over a decade (Figure 3.11). These improvements also impacted the

[40] U.S. Congress, *Report of the Board of Engineers for Rivers and Harbors on Review of Reports Heretofore Made on Mississippi River Between the Mouth of the Ohio River and the Northern Boundary of the City of St. Louis*, House Doc. No. 9 (69th Cong., 2d sess.); U.S. Cong., *Report of the Board of Engineers for Rivers and Harbors on Review of Reports Heretofore Submitted on Illinois and Mississippi Rivers*, House Committee on Rivers and Harbors, House Committee Doc. 12 (70th Cong., 1st sess.).

[41] Tweet, 64-74 and Appendix B.

[42] Tweet, 75-95.

Project, as it made little sense to make such massive investments in the other sections of the river system without also investing in the critical linchpin where all of these rivers converged.

3.8 THE GOLDEN AGE OF REGULATING WORKS CONSTRUCTION (1926-1950)

The period from 1926 until around 1950 was the golden age of construction for the Project for several reasons. First, there was a large amount of money available for construction during the period due to the Great Depression and the Roosevelt Administration's investment in public works projects. Secondly, the authorization of other navigation projects on the UMR and Illinois River made a dependable navigation channel on the MMR a necessity. Lastly, in the early 1930s engineers completed a study of the original regulating works design plan and concluded that the project design should be modified to contract the river to 1,800 feet instead of 2,500 feet, as initially recommended in 1881.[43]

Between 1926 and 1950 Congress appropriated approximately $68 million for the Project, around 75 percent of which was used for the construction of new regulating works; the remainder was put toward the repair and maintenance of existing structures. As a point of reference, Congress had appropriated around $24 million for the Project over the previous 45 years, and nearly half of that was used for repair and maintenance.[44]

Between 1926 and 1950, the USACE oversaw construction of around 633,000 linear feet of dikes on the MMR. The types of dikes constructed remained mostly the same as they had been since the start of the Project: permeable wooden pile dikes. Although all of these dikes were categorized as new construction, what equated to "new construction" was very broad and varied depending on the needs of a particular section of river. In some cases new work consisted of building an entirely new single dike or dike field, but often the work consisted of extending an existing dike or dike field, slightly modifying it in some way, or replacing a dike or dike field that was completely destroyed. Other new work consisted of building a new dike to contract or close a side channel. None of the dike designs or methods of construction was particularly unique but was rather in line with the standard river engineering techniques and structures used at that time.[45]

The Project also included bank stabilization. The USACE still used the same method to stabilize banks that it had since the beginning of the Project, which was to place wooden willow weave and brush mattresses along sections of the riverbank that were susceptible to erosion and caving, and also along the new riverbanks built up by the sediment accumulated in dike fields. However, by the 1940s, and especially by the 1950s, hand-placed stone revetment, which was much more durable, began to be used for bank revetment. Neither the use of brush mattresses nor stone revetment was unique in respect to river engineering methods used at that time but was the standard means to stabilize banks.[46]

Between 1928 and 1956 the Project had successfully contracted the average planform width of the river (which extends from tree line to tree line and includes all channels, side channels, sandbars and islands) from 4,662 feet to 3,502 feet. When the Project first began, the average

[43] USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154* (St. Louis: USACE, May 1971).
[44] USACE, *Annual Report of the Chief of Engineers*, 1926-1950.
[45] USACE, *Annual Report of the Chief of Engineers*, 1926-1950.
[46] USACE, *Annual Report of the Chief of Engineers*, 1926-1950.

planform width was 6,085 feet. Much of the work that occurred between 1881 and 1927 had focused on eliminating side channels and sandbars and thus had a dramatic effect on the planform width of the river. However, the main channel is what commercial vessels use for navigation, a simple fact that is critical to understanding the impact of dike and revetment construction. At the beginning of the Project the average main channel width was 3,743 feet. By 1928, through the construction of dikes and revetment, engineers had contracted the channel to 3,160 feet. By 1956 the average width of the main channel was 2,667 feet. The closure of side channels had directed more flow into the main channel, and the contraction of the main channel directed the energy of this flow into the riverbed so that it could scour the bed and reduce sedimentation. The result was a deeper, more dependable navigation channel.[47]

The successful contraction of the MMR allowed for year-round commercial navigation by the 1940s. Prior to this, a nine-foot channel was only possible for around two-thirds of the year at best, and between December and February the river was closed completely. By the 1940s the investment in river navigation improvements was beginning to pay dividends. In 1927 just 1.1 million tons passed through the MMR, but by 1945 this total increased to 4.5 million tons. By 1950 it reached 11.5 million tons. Most of this tonnage originated on the UMR, with lesser amounts coming from the Missouri and Illinois rivers. The majority of the tonnage passing through the MMR was bound for the LMR for exportation to global markets.[48]

The golden age of construction for the Project was also the period when St. Louis saw its population grow to over 800,000, peaking at 856,796 in 1950.[49]

3.9 MMR PROJECT MODIFICATIONS (1950-1970)

The 1950s saw nearly a complete halt to construction of dikes and revetment on the MMR. During the decade only 10,000 linear feet of dikes were constructed, and between 1953 and 1956 specifically, only one new dike and no new revetment were constructed. The reason for the decline was the Korean War and later the conservative fiscal policies of the Eisenhower Administration. Even when Congress began appropriating funds for the Project again in 1957, the amount was meager at less than $200,000 per year. Because of heavy ice flows in the winters of 1950-1951, 1957-1958, and 1962-1963, and because of floods in 1951, many regulating works were destroyed or damaged. Consequently, most of what little money Congress appropriated went to maintenance and repair of existing structures.[50]

In the 1960s appropriations began to return to the levels that had existed in the 1940s. Because of the high cost of timber pile dikes and the meager appropriations of the 1950s, engineers began looking for a way to reduce the cost of dike construction. By the late 1950s they began experimenting with stone dikes because of the abundance of stone in the region. The St. Louis District was the first USACE district in the country to experiment with the use of stone dikes. The dikes performed the same function as pile dikes, but they were more durable and had greater longevity. This had been one of the major problems with the pile dikes: they simply were not durable enough and limited the efficacy of the project.[51]

[47] Brauer et al., *Supplement to Geomorphology Study of the Middle Mississippi River.*
[48] USACE, *Annual Report of the Chief of Engineers*, 1927-1950; Dobney, 113-122.
[49] "Historical Census Browser," University of Virginia Library, Retrieved June 22, 2015.
[50] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963.
[51] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963.

The other reason for converting to stone dikes was the completion of the Missouri River reservoir system, which reduced sediment flow in the Missouri River and, in turn, reduced the sediment load on the MMR. The reduction of sediment in the MMR made timber pile dikes less effective because they depended on sediment deposition. Impermeable stone dikes depended less on sediment deposition than pile dikes, so it made engineering sense to convert to them.[52]

At first the district used stones to construct new dikes or to repair existing dikes, but by the early 1960s, the district began building only stone dikes and replacing existing dikes with stone dikes. By 1965, 25 percent of pile dikes had already been converted to stone-fill dikes, and this trend of converting timber dikes to stone dikes continued in the decades that followed.[53]

Prior to the conversion to stone dikes, the methods of constructing dikes had been largely unchanged since the Project began in 1881. The only changes in the project prior to the 1960s had been in respect to how many dikes needed to be constructed and how much the river needed to be contracted to maintain the nine-foot channel.[54]

In 1966 the district began a study to determine whether the Project criteria needed to be revised in order to assure a dependable nine-foot channel. Severe droughts between 1963 and 1965 exposed the inadequacy of the project for maintaining the navigation channel during extreme low-water conditions. Engineers had hoped that converting pile dikes to stone dikes and contracting the river to 1,800 feet would be enough to maintain the authorized channel and the river would not require further contraction, but this was not the case. The study evaluated whether the river needed to be further contracted through the extension of existing dikes and construction of new dikes.[55]

Engineers studied a prototype reach of the river between River Mile 55 and 68, the Devil's Island reach, which was one of the most difficult stretches of river to maintain. The study used stone dikes to contract the river to 1,200 feet between 1967 and 1969. The study revealed that contraction to 1,200 feet produced a deeper channel than was required at low-water. The study concluded that a contraction to 1,500 feet would be sufficient to maintain the navigation channel. Further experiments were conducted at the Waterways Experiment Station, which confirmed the district's conclusions. St. Louis District river engineers adopted the 1,500 foot contraction plan in 1974, and all future work on the Project followed this plan.[56]

3.10 REBIRTH OF RIVER COMMERCE ON THE MISSISSIPPI RIVER (1950-1970)

After peaking in 1950, the population of St. Louis began to decline in the 1950s and has continued this decline until the present day. In 1960 the population declined to 750,026, and in 1970 it was 622,236. Much of the loss of population was due to economic stagnation, residential

[52] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963.

[53] Dobney, 113-122; USACE, *Annual Report of the Chief of Engineers*, 1950-1963; USACE*, Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*.

[54] USACE, *Annual Report of the Chief of Engineers*, 1950-1963; USACE*, Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154*.

[55] USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154;* USACE, *Progress Report, 1500 foot Contraction Plan Middle Mississippi River, Mile 168 to 154, SLD Potamology Study (S-4)* (St. Louis: MVS, June 1977).

[56] USACE, *Prototype Reach River Regulating Works Middle Mississippi River Mile 140 to 154;* USACE, *Progress Report, 1500 foot Contraction Plan Middle Mississippi River, Mile 168 to 154, SLD Potamology Study (S-4)* (St. Louis: MVS, June 1977).

deterioration, and suburbanization. Not a single new office building was constructed between 1930 and the late 1950s, and unemployment reached 71,800 people by 1958. Many people fled the city to live in the suburbs, leading to a decline in the city's population but a rise in the population of the county and metro area, a trend common to many of the country's major metropolitan areas.[57]

One of the few exceptions for St. Louis's dismal economy during this period was the growth of river commerce at the Port of St. Louis, which increased from 2,259,894 tons in 1947 to 7,408,279 in 1956, over 9 million in 1960, and 10.4 million in 1970. Traffic at the port had increased so much that the port limits had to be expanded in 1972, and with the expanded port limits, tonnage increased to 21.7 million by 1974, making it by far the busiest port above Baton Rouge.[58] This reflected an overall increase in the use of inland waterways in general during the period. In 1950, 11.5 million tons passed through the MMR; by 1960 the total increased to 30 million tons; by 1970 it was 58.3 million tons; and by 1975 the total was 71.6 million tons. The increase in traffic on the MMR was largely due to increased traffic on the UMR, which saw its annual tonnage increase from 11 million in 1950 to 27.4 million in 1960 and 54 million in 1970. The Illinois River also saw substantial increases in annual tonnage, rising from 11 million tons in 1950 to 34.3 million in 1970. Tonnage also increased on the Missouri River, but not as substantially as on the other rivers in the system. Taken together, this increased tonnage dramatically increased the regional and national importance of the MMR and the Project. By 1974, 193.4 million tons were carried between New Orleans and the Gulf of Mexico, over a third of which passed through the MMR. The systematic improvement of the Mississippi River and its tributaries had allowed the Port of South New Orleans to become the busiest port in the Western Hemisphere and a vital part of the nation's economy.[59]

3.11 THE MMR PROJECT FROM 1970 TO PRESENT

Since 1970 Project construction activities have largely been limited to maintenance and repair, replacing existing pile dikes with stone dikes, and extending existing dikes and dike fields to further contract the channel in troublesome areas prone to sedimentation. About two-thirds of the Project's dikes had been converted to stone by 1976. The remaining one-third remained timber pile dikes, many of which were in a state of disrepair and needed to be replaced with stone dikes. The Project has also included extensive work to remove natural rock formations that protrude from the riverbed and impede navigation. Engineers also developed new innovative regulating works such as chevron dikes, L-dikes, wing dikes, and bendway weirs, but construction of these did not begin until the 1980s and 1990s.[60]

The major development in the modern period was the passing of the National Environmental Policy Act and the formation of the Environmental Protection Agency. Environmental laws required the district to coordinate with local, state, and federal environmental agencies to assess the environmental impact of projects and to modify regulating works to create greater habitat diversity and limit their environmental impact. In the 1970s the St. Louis District began

[57] Dobney, 113.

[58] Dobney, 113.; Mississippi River Commission, *Mississippi River Navigation* (Vicksburg, Miss.: Mississippi River Commission, 1975), 17.

[59] Tweet, 75-98; Mississippi River Commission, 17; Port of South Louisiana; Stratfor, Inc., *The Geopolitics of the United States*.

[60] USACE, *Environmental River Engineering on the Mississippi* (St. Louis: USACE, 1995); U.S. Government Accountability Office, *Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures*, GAO-12-41 (Washington, D.C.: GPO, 2012), 6-10.

experimenting with new designs and modifications for regulating works. Many of the modifications were minor, such as placing notches in dikes to allow flow to pass through them, thereby creating side channels and greater habitat diversity. Some dikes were lowered; others used stone of various sizes; some revetments were placed off the riverbanks to allow channels between the banks and revetment. The purpose of these modifications was to allow for a greater diversity of habitats, which would thereby allow for a greater diversity of riverine ecology, while at the same time allowing the project to perform its intended purpose of maintaining the congressionally authorized navigation channel.[61]

[61] USACE, *Environmental River Engineering on the Mississippi* (St. Louis: USACE, 1995); U.S. Government Accountability Office, *Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures*, GAO-12-41 (Washington, D.C.: GPO, 2012), 6-10; USACE, *EIS, Mississippi River Between the Ohio and Missouri Rivers Regulating Works* (St. Louis: USACE, April 1976).

4.0 DESCRIPTION OF RESOURCES

4.1 THE MMR PROJECT

The MMR is defined as the 190-mile section of the Mississippi River between its confluence with the Missouri River at St. Louis, Missouri, and its confluence with the Ohio River at Cairo, Illinois. It is a relatively small reach of river compared to the UMR and LMR, yet serves as the hub of a vast interconnected inland waterway system. In its natural, pre-Project state, the MMR was obstructed by countless snags and split into separate channels or chutes in many places. The river was also progressively widening, which was consequently decreasing the depth of the navigation channel.

The Project, as initially authorized in the 1881 Rivers and Harbors Act, called for the construction of bankline revetments and permeable dikes to contract the river to a uniform width of 2,500 feet between dike ends and develop and maintain an eight-feet-deep and 200-feet-wide low-water navigation channel. The purpose of the Project—to provide a safe and dependable navigation channel on the MMR—has not changed since 1881, though the specifications were modified in 1927 and 1930 due to increased river traffic and a demand for deeper draft vessels. Since that time the Project has been authorized to maintain a nine-feet-deep and 300-feet-wide navigation channel. To do so, the width of the MMR between dike ends was reduced to 1,800 feet, then further to 1,500 feet in the 1970s.

The USACE has ensured adequate navigation depth and width through bank stabilization and sediment management, which has been achieved by the use of river training structures (dikes), revetments, and dredging. This has allowed for "open river" navigation on the MMR, as opposed to the UMR, for example, with its comprehensively engineered system of locks and dams. As a result, the MMR maintains a comparatively more natural appearance.

Since its inception, the Project has involved constructing new dikes and extending, modifying, or replacing existing dikes to maintain the authorized navigation channel. There are currently more than one thousand structures on the MMR and, in general, similar structures have been used since the nineteenth century. The specific types of river training structures associated with the Project are discussed in detail below.

4.2 ASSOCIATED BUILT FEATURES

There are two main types of river training structures on the MMR: redirective and resistive. Redirective structures, as the name implies, direct a river's flow into the main channel to use the river's energy to enhance and maintain the navigation channel. A resistive structure acts to maintain the system by preventing bank erosion and channel migration.

Redirective structures are usually a series of dikes that extend from the riverbank. The major function of dikes for navigation projects is to concentrate the river's energy into a single channel, control the location and increase the depth of the channel, and prevent the accumulation of sediment to reduce the need for dredging. Redirective structures are also used in environmental applications to create more environmental diversity by change flow velocity and scour patterns.

Resistive structures, also known as revetment, are used to prevent bank erosion and channel migration on the outside of a river bend and to establish or maintain a desired channel alignment.

Revetment historically consisted of brush and timber mattresses, but since the 1940s has primarily been constructed of stone.

4.2.1 Dikes

Dikes are structures placed in a river to redirect the river's energy to provide a variety of effects, such as preventing erosion and protecting structures along the bank; realigning a reach of river; constricting the channel and scouring the riverbed to increase depth; cutting off side channels and chutes; reducing sedimentation and the need for dredging; and creating environmental habitat.

4.2.1.1 Dike Types

The most common type of dike is a ***spur dike***, also called a ***wing dam*** or ***jetty*** (Figure 4.1). This type of dike typically extends perpendicularly from the riverbank toward the main river channel, or it extends across a side channel or chute to act as a dam to close the side channel and concentrate the river's flow into a single channel. This is the most common type of dike and has been constructed on the MMR since the nineteenth century. Other less-common types of dikes come in a variety of shapes and configurations, but they still perform the same basic function.

A ***rootless dike*** is one that is offset from the river bank, meaning the structure starts some distance off the bank. The typical offset distance is 100 feet or more. The rootless section provides environmental diversity by altering flow and sediment transportation. Many times, multiple dikes are left rootless and positioned in a line to create a secondary channel for environmental enhancement. Construction of these structures did not begin until after 1970.

L-head dikes, also called ***trail dikes***, extend from the riverbank like a spur dike but also have a section at the dike end that extends downstream (Figure 4.2). The L-head section spreads the energy of the flow over a larger area and can be used to increase the spacing between dikes, to reduce scour on the stream end of the dike, or to extend the effects of the dike system further downstream. The L-head also tends to block the movement of sediment behind the dike by reducing the formation of eddies downstream. This type of dike did not become common on the MMR until after 1970.

Closure dikes are built in side channels, or chutes, to reduce or eliminate the flow through these secondary channels, thereby allowing more flow to be concentrated in the main channel (Figure 4.3). Spur dikes divert sediment into the side channel and closure dikes reduce the velocity of the flow in the side channel, leading to increased sediment deposition and potentially the eventual closure of the side channel or a reduction in its size. Closure dikes have been constructed on the MMR since the nineteenth century.

Side channels are not used for navigation, but are valuable environmental areas. Traditionally these side channels were closed with rock structures to divert the flow into the main channel. While improving navigation, this process tends to fill the side channels with sediment and convert aquatic habitat to terrestrial habitat. Notching a closure structure can prevent the side channels from filling with sedimentation. ***Notched closure dikes*** form areas of deep water and shallow water, creating a diversity of habitat and attracting different species of fish. Construction of these structures did not begin until after 1970.

A ***bendway weir*** is a low-level, fully submerged rock structure that is positioned from the outside bankline of a river bend and angled upstream toward the flow (Figure 4.4). These underwater structures extend directly into the navigation channel underneath passing tows. Their unique position and alignment alter the river's secondary currents in a manner which controls excessive channel deepening and reduces adjacent riverbank erosion on the outside bendway. Because excessive river depths are controlled, the opposite side of the riverbank is widened naturally. This results in a wider and safer navigation channel through the bend without the need for periodic maintenance dredging. The first bendway weirs were constructed on the MMR in 1989.

Chevrons are dike structures designed with a blunt-nosed, arch shape (Figure 4.5). They are constructed parallel to flow and like regular dikes utilize the energy of the river to redistribute flow and sediment. They are usually placed adjacent to the river bank to allow flow separation and create both channel deepening, side channel development, and middle bar formation. Chevrons were first constructed on the MMR in 2001.

Hard points are very short rock dikes that are used to stabilize side channel river banks (Figure 4.6). These navigation structures extend from the riverbank into the river and do not cause a significant buildup of sediment. Their contribution to habitat improvement is the creation of scour holes under the hard points. These deep plunge holes attract catfish that flourish in this environment. Hard points were first constructed after 1970.

Notched dikes are simply dikes with notches added (Figure 4.7). The notches allow the river to move in and out between them, thus creating a greater diversity of river habitats while still allowing the dike to perform its primary function of directing flow into the main channel for navigation. River engineers first began experimenting with notched dikes in the late 1960s and they became much more prevalent on the MMR after the 1970s. In some cases, new dikes were designed with notches, and in other cases, notches were added to existing dikes.

Multiple roundpoints structures (MRSs) are alternating rows of rock mounds within the footprint of a typical dike (Figure 4.8). They are used like a dike to maintain the navigation channel and to create flow and bathymetric diversity within a dike field. The main benefit of these structures is to create diverse flow and scour patterns for aquatic improvement. MRSs were not constructed on the MMR until after the 1970s. Currently, there is only one MRS field on the MMR.

W-dikes are dikes that have four legs and are shaped like the letter “W,” with the apex of two legs facing upstream. Flows are directed toward the apexes, forming two scour holes and one depositional bar downstream. The tips of the W-dikes behave like traditional dike structures, constricting the channel and increasing sediment transport through an area. The landward side of a W-dike can be attached to the bankline. Construction on these structures did not begin until after 1970.

Dike extensions are used when a dike is not performing adequately and additional channel constriction is needed. The extension may incorporate a gap between the existing structure and new construction, which performs like a notch and can provide a dynamic system for environmental enhancement.

4.2.1.2 Dike Design and Construction

While most dikes are very similar in their basic design, there are numerous variations. Dike design can vary by type of material, length, crest height and width, slope, angle, and spacing.

Stone and timber are the two most common materials in the construction of dikes. Prior to the 1960s, timber piles were constructed almost exclusively on the MMR, but in the late 1950s, engineers began experimenting with stone dikes. By the early 1960s all new dikes were built with stone, and timber pile dikes were being replaced with stone dikes. About two-thirds of the Project's dikes were converted to stone by 1976.

Timber pile dikes were constructed by driving timber piles vertically into the riverbed and then filling the area between the vertical piles with material, usually brush, and placing a horizontal spreader between the vertical piles (Figure 4.9). Stone was then placed on the shore end of the dike. To construct a stone dike, stone is placed onto a barge and dumped into the river. The construction is carried out in accordance with design specifics, such as length, angle, width, height, slope, etc.

Prior to the late 1960s all dikes constructed were spur dikes. But in the 1990s and 2000s, new structures such as bendway weirs, MRSs, chevron, and L-dikes (see Section 4.2.1.1 above) have been constructed. In the 1970s engineers began modifying the design of structures for environmental purposes. Some of the stone dikes built in the 1960s were later modified, usually through adding notches or an L-head or other extension.

The length of dikes is determined by the desired contraction width of a specific section of river. If engineers determine that a particular section of river needs to be contracted to a specific width to maintain the congressionally authorized navigation channel, then they will design dikes of the necessary length to contract the river to this width. Engineers may also extend the length of existing dikes if this is deemed necessary to further contract the river to provide for a dependable navigation channel. Typically, dikes will initially be constructed to a specific length and then engineers will gather data and observe the response of the river. Once the river has responded to the dikes, engineers will gather these data to determine if any design modifications are necessary.

When the Project first began in 1881, dikes were constructed to such a length as to contract the river to an average width of 2,500 feet. Since that time, engineers have observed the response of the river to the construction of dikes and have determined that the river required further contraction in order to maintain the navigation channel. In the 1930s engineers developed design guidelines that advised contraction of the MMR to 1,800 feet between dike ends, and in the late 1960s, engineers modified the guidelines to a width of 1,500 feet. Since the 1970s engineers have designed dikes to be of such a length as to contract the river to an average width of 1,500 feet. Extension of existing dikes was sometimes necessary.

The height or top elevation of dikes is normally associated with the reference plane associated with the Project (Figure 4.10). The elevation of dikes relative to the water surface can have an important bearing on the structures' performance, their impact on the stream, and their impact on the areas within the dike field. On open river portions of the Mississippi River the top elevation of dikes typically varies from about 10 to 18 feet above the Low Water Reference Plane.

The width of the crest of a stone dike is generally determined by the method of construction, but with a minimum design width of 5 feet. Dikes constructed from a barge usually have a crest width of 6 to 10 feet, while those constructed by truck have a crest width of 10 to 14 feet to accommodate movement of the truck/backhoes and other equipment on the dike structure. In river reaches susceptible to ice flows, dikes with crest widths of less than 6 feet may have their top portion sheared off as the ice moves downstream. One other method for determining dike crest width is to design the dikes based on the size of stone used and the height of the dike. In this case the crest width is allowed to vary so long as the minimum width of 5 feet is maintained.

Summarizing, there is some variation in the crest widths used for dikes, but virtually all dikes fit within the range of 5 to 20 feet with the majority of dikes constructed with a crest width of 5 to 10 feet.

Dike angling and spacing vary based on the needs of a particular stretch of river. The angle of a dike is an important factor in determining where and how much scour occurs at the stream end of the dike and the location of the channel that develops adjacent to the dike. Historically, dikes have been constructed normal to the adjacent bank line or angled slightly downstream.

4.2.2 Revetment

Revetment includes resistive structures placed on or near a river bank, usually on the outside of a river bend and on banks around new structures. They are primarily used to prevent bank erosion and channel migration and to establish or maintain a desired channel alignment.

4.2.2.1 Revetment Types

The majority of stone revetment consists of a layer of non-uniform size stone, or rip rap, laid on a sloping river bank. ***Traditional stone revetment*** has been the most common type of revetment on the MMR since the 1930s (Figure 4.11).

Willow/board mattresses were the earliest and most common type of revetment used on the MMR prior to the 1930s when cheap stone became available (Figures 4.12 and 4.13). Board mattresses consist of wooden boards woven together; similarly, willow mattresses consist of willow brush woven together or formed together using wire. The mattresses are then placed along the riverbank to prevent erosion. They continue to be employed in combination, such as stone above the flow line and mattress below.

Off-bankline revetment is revetment built slightly off the riverbank and sometimes notched to allow for flow to pass between the riverbank and the revetment, thereby allowing for a greater diversity of habitats (Figure 4.14). This modified type of revetment was not constructed on the MMR until after 1970.

4.2.2.2 Revetment Design and Construction

On the MMR, revetment must consist of a minimum of a 30-inch rock blanket of “A” stone (a well-graded stone with a maximum size of 5,000 pounds) on the existing bank grade. Stone is placed in such a way as to meet the necessary bank grade. Stones are typically block-like and angular. Since the 1970s, engineers have used stones of non-uniform size to allow for a greater diversity of habitats. Prior to the 1930s, willow weave mattresses were the more common type of revetment. These are constructed by weaving together willow brush and/or timber and placing the mattresses along the river bank at the appropriate grade. During the early decades of the Project, mattresses were used to protect the portion of the banks below the low–water stage, and stone was used to protect the portion of the banks above the low-water stage. The design and construction of both stone revetment and willow weave mattresses were standard for the time and had been widely used on other rivers.

Off-bankline revetment is constructed by placing stone on a barge and dropping the stone into the river just off the bankline to form a long, dike-like structure between the riverbank and the revetment. These structures were not first constructed until after the 1970s. Much of the earliest revetment remains in place on the MMR.

5.0 EVALUATION OF SIGNIFICANCE

5.1 APPLICABILITY OF NATIONAL REGISTER CRITERIA

Four criteria are used to evaluate the eligibility of properties (buildings, structures, objects, sites, and districts) for the National Register. To be eligible, a property must be associated with significant historic events or trends (*Criterion A*) or the lives of significant persons (*Criterion B*), possess significant design or construction value (*Criterion C*), or yield information important in history or prehistory (*Criterion D*). Below are summaries of how each criterion may be applied to the Project and its associated built features.

5.1.1 Criterion A: Event

To be eligible for the National Register under *Criterion A* a property must be significantly associated with a specific event, pattern of events, or trend important to history. River navigation projects are inherently important, especially those concerning principal navigable waterways, such as the Mississippi River. The need for safe and dependable navigation channels is immense and widespread, and since 1824 almost every Congress has passed one or more Rivers and Harbors acts to authorize the maintenance and improvement of the nation's rivers and harbors for the benefit of navigation.[62] Navigation projects on the Mississippi River, specifically, have played a critical role in the nation's economy. Commercial navigation on the largest river system in the United States has opened the country's agriculturally-rich interior to global markets and has had a profound impact on growth and development in the region.

A river navigation project may be found eligible for the National Register under *Criterion A: History* if it has a demonstrably important association with historically significant events or trends. Mere coexistence or speculative association would not equate to National Register eligibility under this criterion. For example, a specific project may be eligible if it represents the first successful attempt to construct regulating works to permanently improve a section of river for navigation purposes. Conversely, a project that successfully maintained a navigation channel as designed but otherwise had no momentous historical influence on river commerce and possessed no other associations would not be eligible.

5.1.2 Criterion B: Person

For eligibility under *Criterion B* a property must be closely associated with a significant person and illustrate that person's important achievements and/or his or her productive life better than any other extant property. River navigation projects would rarely be found eligible under this criterion, primarily because an association with a prominent engineer or other significant individual would apply more to *Criterion C*, discussed below. These projects also generally represent the work of many people, rather than specific individuals. A project could be eligible under *Criterion B* if it best represents a person's significant contributions to river engineering and navigation history.

[62] American Public Works Association, *History of Public Works in the United States, 1776-1976* (Chicago: American Public Works Association, 1976), 30-31.

5.1.3 Criterion C: Design/Construction

Properties eligible for the National Register under *Criterion C* are notable for their design and/or construction qualities. They may embody distinctive characteristics of a type, period, or method of construction; exemplify the work of a master; possess high artistic merit; or represent a significant unified entity (a district) whose component resources lack individual distinction. A river navigation project or any one of its individual structural elements may have unique engineering values, represent a specific navigation improvement, or illustrate trends in engineering as a design innovation. These projects may also be noteworthy for the way they were adapted over time to continuously meet their objectives. In any case, it must be demonstrated that the project or individual engineering resource is important within its engineering context.

It is unlikely that a river navigation project, as a whole, would be eligible under *Criterion C* as the work of a master, since these types of undertakings are typically conceived and executed by numerous people across many disciplines and as the result of various factors. Certainly, an individual component of a designed river system, such as a lock and dam, could be a good example of a single important engineer's work. To be eligible for its artistic value, a project or any one of its engineering features must express an aesthetic ideal or particular design concept more fully than other examples of its type.

5.1.4 Criterion D: Information Potential

Properties that have yielded, or are likely to yield, important information regarding history may be eligible for the National Register under *Criterion D*. This criterion most often applies to archaeological sites, as they can serve as principal sources of data. Information regarding the history of extant aboveground resources, on the other hand, is generally well documented or obtainable from other sources. For a river navigation project to be eligible under *Criterion D*, it must possess significant research value. For example, early built features of a project that have been buried by sediment may be able to provide important information regarding river engineering practices that is otherwise not known or available, such as the modification of dike placement and construction methods in reaction to previously unencountered site conditions. Projects with an especially long history with gaps in its historical record certainly have the potential to supply new insights. Once the research potential of a property has been realized, it is no longer eligible for the National Register under *Criterion D*.

5.2 NATIONAL REGISTER ELIGIBILITY OF THE MMR PROJECT

River navigation projects are undertaken to fulfill a specific navigational need and generally involve the design and implementation of various engineering works intended to work together to achieve desired outcomes. This is exemplified by the Project, an enterprise of the USACE representing more than 130 years of river engineering dedicated to maintaining a safe and dependable navigation channel on the MMR. Specifically, the Project has primarily involved the use of river training structures to sustain its singular goal. Although there are more than a thousand of these structures, the Project is a unified entity reflecting one principal activity (see Feature Catalogue Maps). As a result, it is most appropriate to evaluate the Project for National Register eligibility as a district.

Unlike the navigation channel project on the UMR, which consists of a system of individually distinctive locks and dams, the built features on the MMR are undistinguished and do not act as focal points. Similar structures have been constructed as part of the Project since the nineteenth century, and they are not unique to this river system. The types of dikes and revetment that have been used are common river-training structures, employ relatively simple engineering principles and construction methods, and were built in large numbers. There is no indication that any have the potential to possess exceptional design qualities or important historical associations on their own. Consequently, none of the Project's structures was evaluated individually for National Register eligibility.

5.2.1 Criterion A: Event

The Project represents a long-standing, concentrated effort by the USACE to ensure a safe and dependable navigational channel on the MMR, a vital section of the nation's largest river system. The significance of the Project from its outset in 1881 is undeniable. No river has influenced the development and expansion of the United States more than the Mississippi River, and the Mississippi River could not have attained its current place in history without the sustained navigability of the MMR.

The Project is directly associated with defining periods in the country's agricultural, commercial, engineering, industrial, and transportation histories, and maintaining the navigation channel on the MMR has certainly contributed to the furtherance of these themes. The Project was a reaction to the decline of river commerce in the Midwest caused by rapid railroad expansion and the Mississippi River's unreliability and sometimes completely un-navigable conditions. The navigational improvements on the MMR helped to combat the exploitative shipping rates of the railroads that were hampering the agricultural industry and the country's ability to compete in the global trade market. In addition, the Project essentially marked the beginning of the USACE's St. Louis District and has since remained one of the agency's primary missions.

The significance of the Project was heightened in the twentieth century. After the opening of the Panama Canal in 1914, the most efficient shipping route between the East and Midwest regions of the United States and Asia was by water. The safe and dependable transportation of goods down the Mississippi River was critical to the success of the canal and the country gaining a global foothold. The Project is also associated with the "Golden Age" of the USACE, when the agency achieved its greatest influence and completed its greatest volume of work. Substantial navigational improvements were made to the MMR during that period, roughly defined as 1930 to 1950, and annual tonnage on the river increased exponentially.

Given its vast historical impact and its continued importance on a national scale, the Project possesses significance under *Criterion A*. The period of significance is 1881, the year the Project was first congressionally authorized, to 1965, the National Register's 50-year threshold. Any structures built prior to 1966 should be considered as contributing resources of the district.

5.2.2 Criterion B: Person

The Project is associated with notable people, such as engineers Col. James Simpson and O.H. Ernst, but ultimately represents the work of many over the course of more than 130 years. It does not appear that any individuals achieved historical significance specifically through their contributions to the Project. As a result, the Project is recommended not eligible for the National Register under *Criterion B*.

5.2.3 Criterion C: Design/Construction

The Project is a functioning, ever- evolving engineered system that is embodied by the physical form and properties of the MMR and the various river-training structures constructed, reconstructed, modified, and upgraded by the USACE since 1881. It does not necessarily represent a specific type of river-engineering project, method of obtaining and maintaining a navigation channel, or period of construction. Rather, it has been an ongoing, dynamic process that has been directed by shifting riverine conditions, changes in economics and attitudes, and modern technological advancements. The Project does not possess distinctive characteristics with unique engineering values or that could be considered design innovations. The various dikes and revetment used on the MMR are typical examples of their respective types and are not distinctly interrelated within the context of river engineering. Also, the need for constant engineering on the MMR to continuously meet the objectives of the Project does not represent a significant achievement. In essence, similar structures have been used since the Project's inception, and additions and modifications to the Project have been made for maintenance purposes or simply because newer, better ways have been found to achieve comparable results. Without any discernible significant design or construction value, the Project is recommended not eligible for the National Register under *Criterion C*.

5.2.4 Criterion D: Information Potential

It does not appear that the Project is a likely source of information important to history. Research indicated that the Project, and permanent navigation improvements on the MMR in general, is well documented through USACE annual reports, historic maps and design drawings, and construction records. Remnants of early timber pile dikes constructed as part of the Project are presumably present in the MMR, buried by sediment, but such archaeological material would provide little research value considering what is already known regarding construction methods and materials of the time. There are no other apparent important research questions that only in depth study and analysis of the Project would answer. The Project is, therefore, recommended not eligible for the National Register under *Criterion D*.

5.3 INTEGRITY

In addition to eligibility under one or more evaluation criteria, a property must also possess integrity, or the ability to convey its significance. There are seven aspects of integrity to consider—*location, design, setting, materials, workmanship, feeling, and association*—and a property must retain at least several, and usually most, of these qualities. The evaluation of integrity for a river navigation project essentially consists of determining if it retains the identity for which it is significant.

Arguably, the Project retains integrity with regard to five of the aspects of integrity. Since its initial authorization in 1881 the objective of the Project has been the same—to ensure a safe and dependable navigation channel on the 190-mile reach of the Mississippi River known as the MMR (*location*). The navigation channel was obtained and has been maintained for over 130 years through bank stabilization and sediment management measures, which have been limited to the use of dikes, revetment, and dredging (*design*). Although the appearance of the MMR has changed quite perceptibly as it has been narrowed over time, its position within its environment and its basic physical conditions as a free-flowing river with "open river" navigation have been consistent (*setting*). And the use of similar river-training structures since the nineteenth century and the sustained commercial traffic on the MMR are expressions of the Project's permanence and provide a direct link between present day and its nineteenth-century beginnings (*feeling* and *association*).

The nature of the Project requires that it continually evolve to meet its objectives and react to any changing needs. Ongoing maintenance, improvements, and upgrades have been, and will continue to be, necessary for it to uphold its purpose of maintaining a safe and dependable navigation channel on the MMR. As a result, relative to its period of significance (1881-1965), the Project fails to retain integrity with regard to the two remaining aspects of integrity, *materials* and *workmanship*. With few, if any, associated structures that date from the historic period, the Project is not a truly tangible historic resource. Continuous engineering of the Project to keep it current and functional has led to the loss of the essential physical features that would enable it to convey its historic identity and significance. In its current physical state, the Project can no longer be identified as a historic regulating works project. Without an ample number of components that contribute to its significance the Project does not possess sufficient integrity to be eligible for the National Register as a district.

5.4 CONCLUSION

National Register eligibility is dependent upon two major factors: significance and integrity. *Significance* is the ability of a property to meet one or more of the criteria for evaluation; *integrity* is the ability of a property to convey significance. This study demonstrates that the Project clearly meets the significance test, but not the integrity test. The criteria for evaluation allow that a property can be eligible if it possesses specific important associations with events that have made a significant contribution to the broad patterns of history. Documentary research indicates that since 1881 the USACE has undertaken the mission of ensuring that a safe and dependable navigation channel exists on the MMR. The Project has been a constant engineering effort involving the construction, reconstruction, modification, and upgrading of various river training structures. With direct national influence on agriculture, commerce, engineering, industry, and transportation, the navigability of the MMR has been immeasurably important, and the Project continues to be promoted and implemented today. For these reasons, the Project, evaluated as a district, is historically significant under National Register *Criterion A*. However, the study also demonstrates that due to continual, but necessary, modifications of various river training structures, the Project no longer retains integrity of materials and workmanship from its period of significance (1881-1965). With most, if not all, of its associated structures post-dating 1965, the Project is unable to convey its considerable national significance. Therefore, the project is recommended *not eligible* for the National Register.

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FIGURES

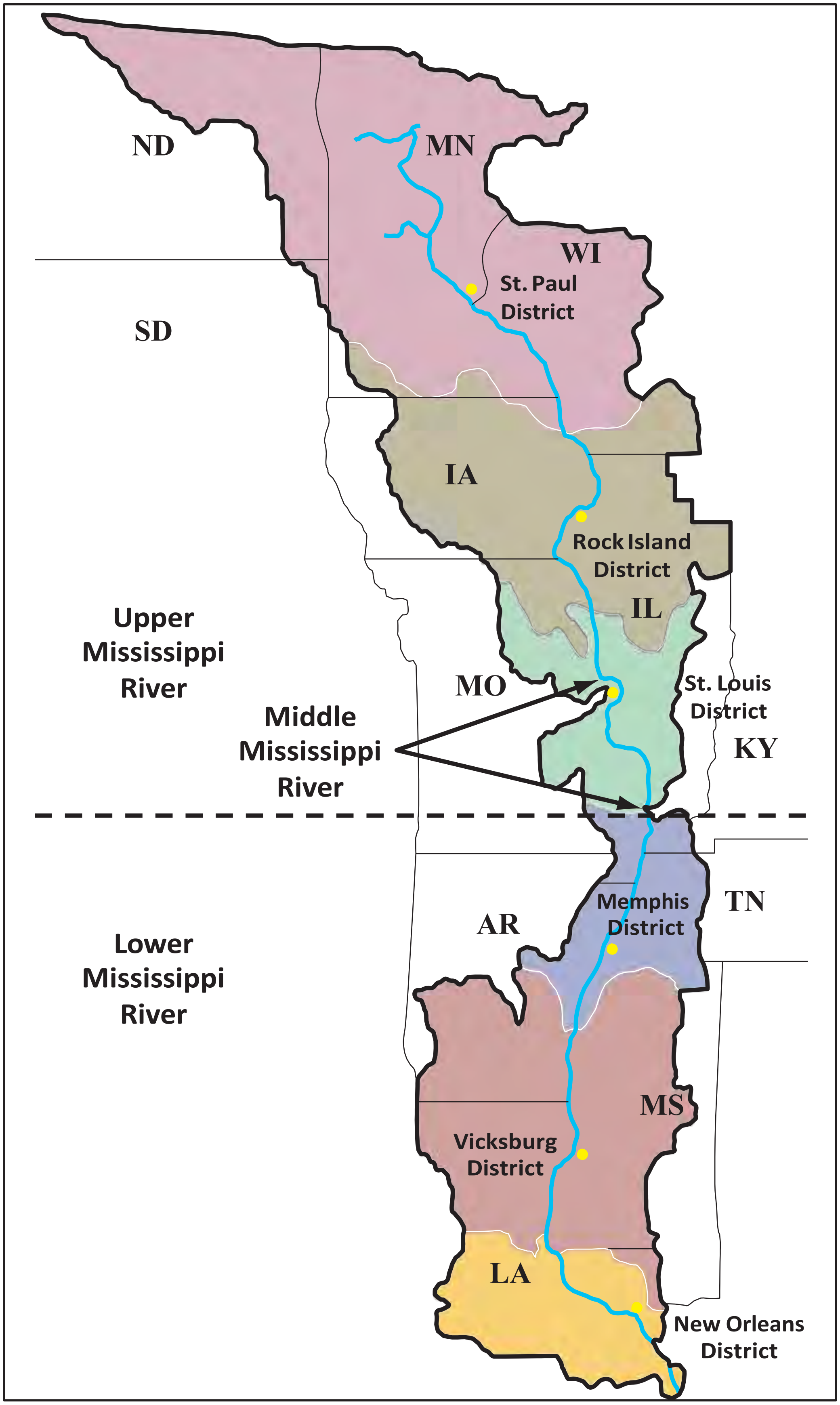

Figure 3.1. The Three Sections of the Mississippi River (USACE).

Figure 3.2. The Middle Mississippi River (Google Earth).

Figure 3.3. A Flatboat (Dobney, 21).

Figure 3.4. Steamboats on the Mississippi River (Manders and Rentfro, 33).

Figure 3.5. The Removal of Snags on the Middle Mississippi River via Snagboat (Manders and Rentfro, 33).

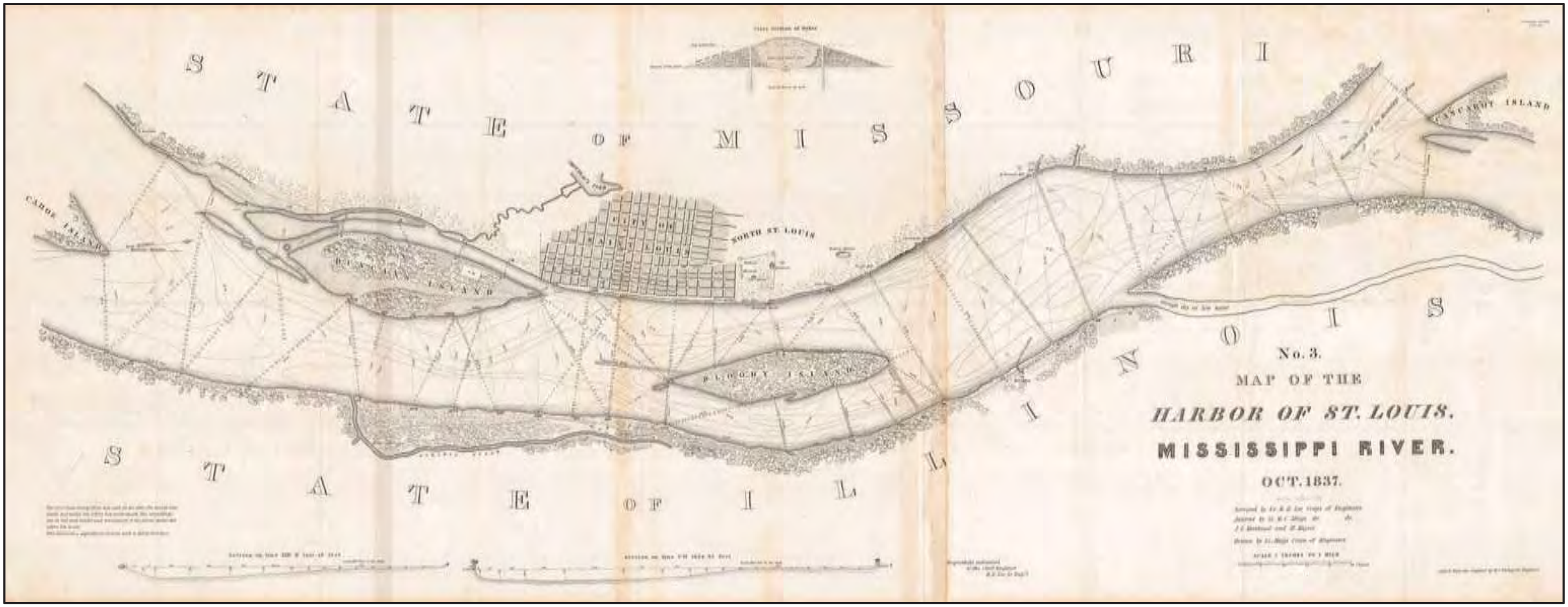

Figure 3.6. The St. Louis Harbor Project (Lee and Meigs).

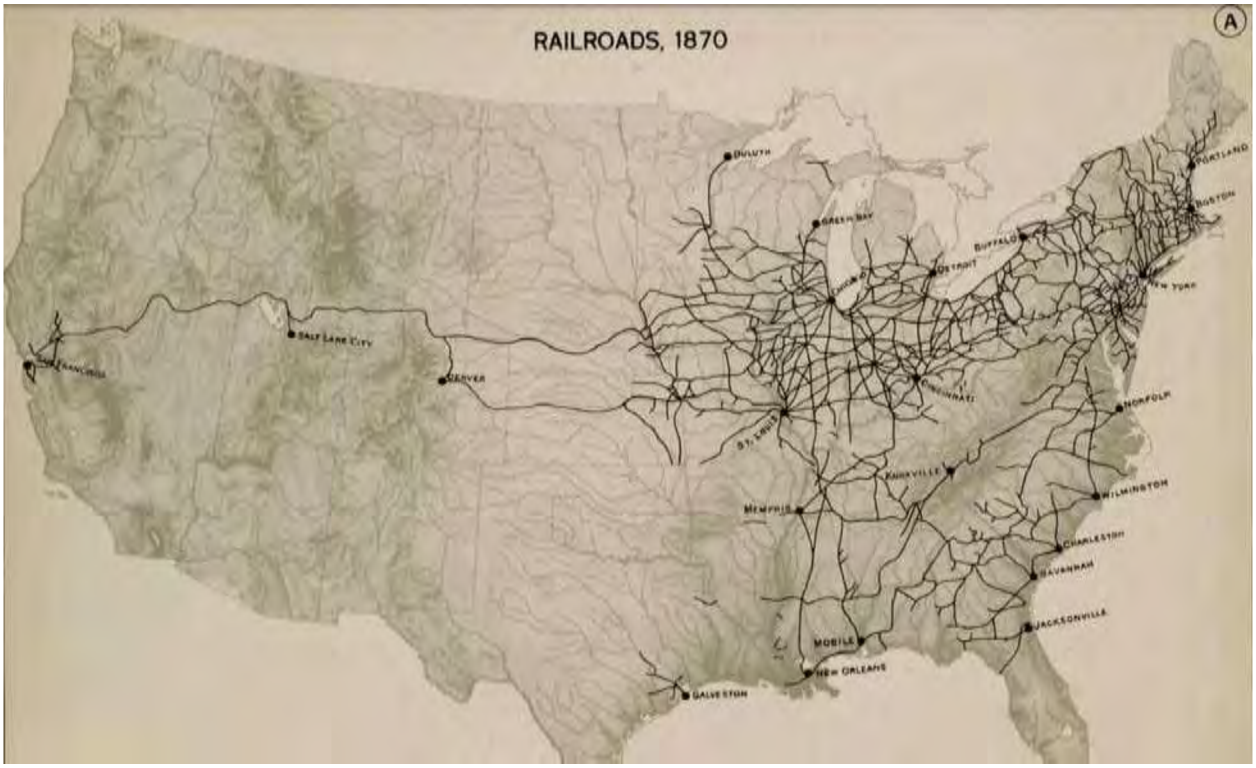

Figure 3.7. Railroads in the United States in 1870 (Paullin and Wright, 140).

Figure 3.8. Shipwreck on the Middle Mississippi River (Manders and Rentfro, 106).

Figure 3.9. Dredging on the Middle Mississippi River (Manders and Rentfro, 67).

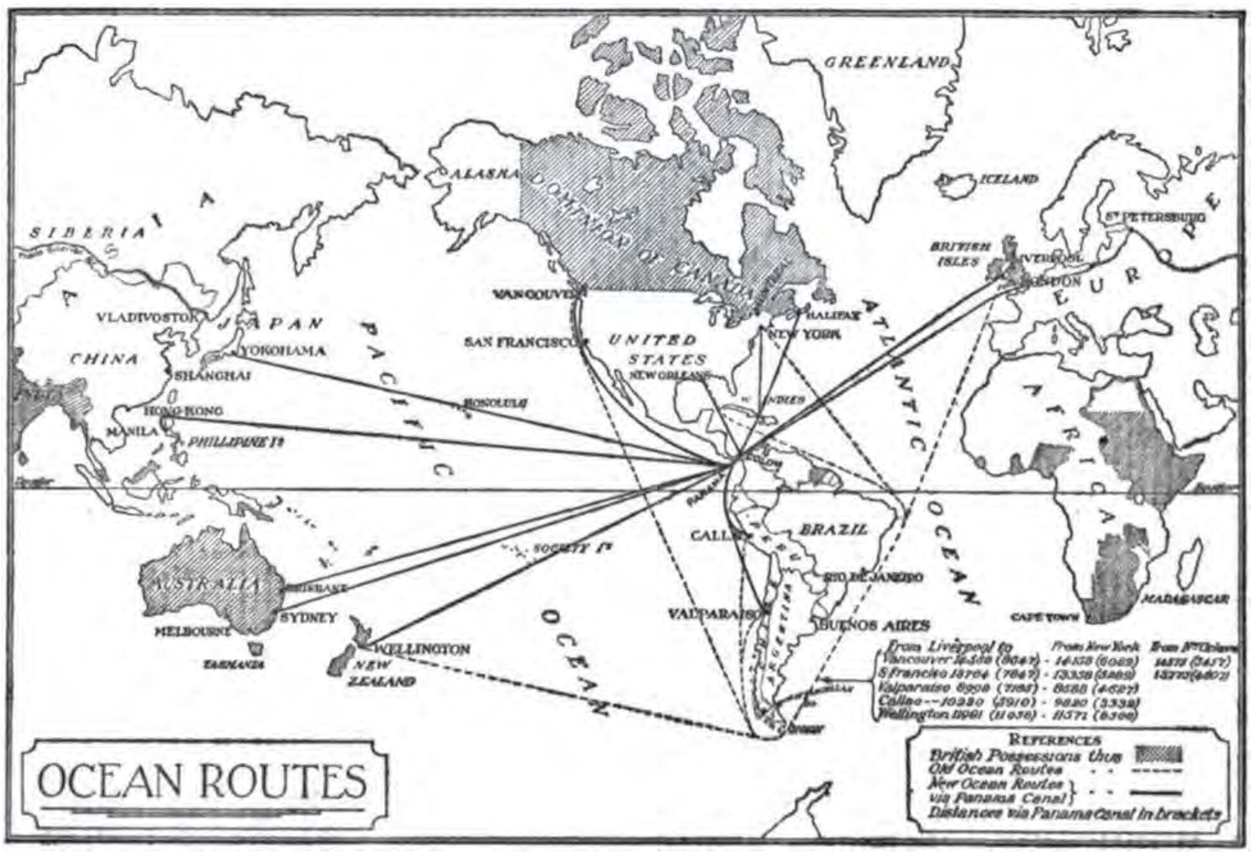

Figure 3.10. The Panama Canal (Mills, 245).

Figure 3.11. The Upper Mississippi River and Illinois River Locks and Dams (Manders and Rentfro, 93).

Figure 4.1. Spur Dike/Wing Dam Field (USACE).

Figure 4.2. L-Head Dike (USACE).

Figure 4.3. Closure Dike (USACE).

Figure 4.4. Artist's Conception of Bendway Weirs (USACE).

Figure 4.5. Chevrons (USACE).

Figure 4.6. Hard Points (USACE).

Figure 4.7. Notched Dikes (USACE, top; U.S. Fish and Wildlife Service, bottom).

Figure 4.8. Multiple Roundpoint Structures (USACE).

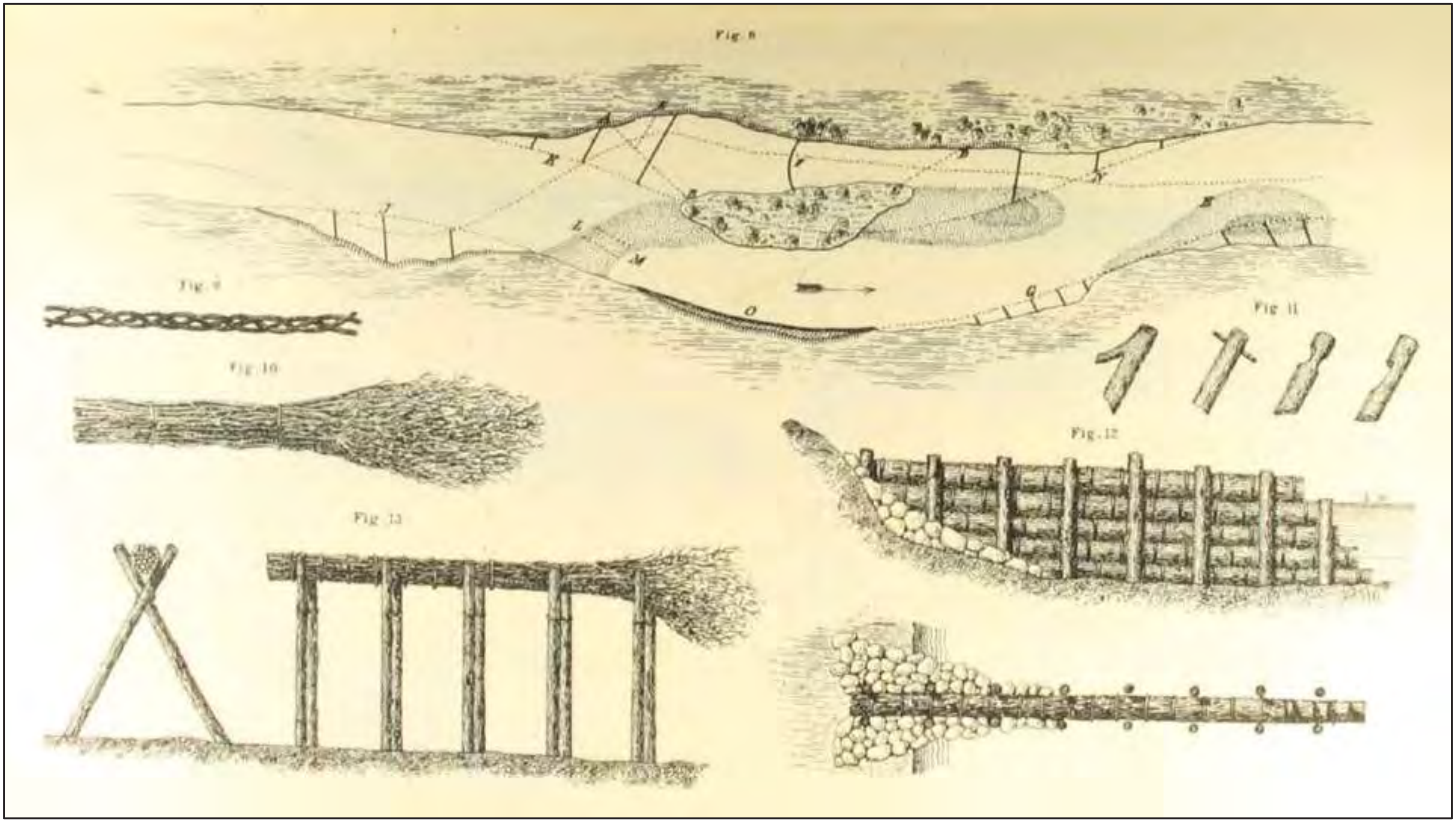

Figure 4.9. Illustrations of Early Timber Pile Dikes (USACE, *Annual Report* [1875], follows 466).

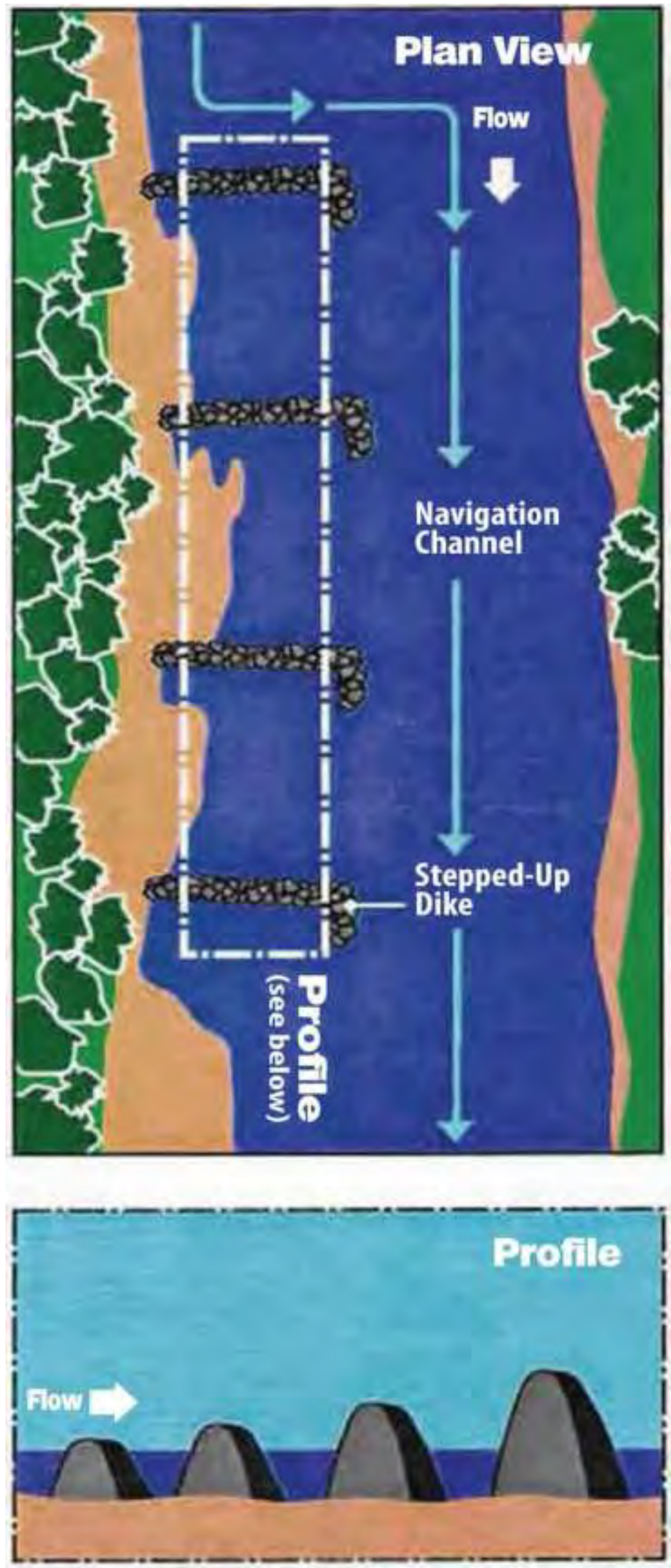

Figure 4.10. Artist's Conception of a Stepped-up Dike Field (USACE).

Figure 4.11. Stone Revetment (USACE).

Figure 4.12. Board Mattress (USACE).

Figure 4.13. Timber Mattress (USACE).

Figure 4.14. Off-Bankline Revetment (USACE).

Appendix G: Distribution List

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

Adrian, D
Alexander County Highway Department
Amato, Joel
Andria, Kathy
Atwood, Butch
Baldera, Patrick
Banner Press
Barnes, Robert
Bax, Stacia
Beardslee, Thomas
Bellville, Colette
Beres, Audrey
Berland, Paul
Boaz, Tracy
Boehm, Gerry
Brescia, Chris
Brinkman, Elliot
Brown, Doyle
Buan, Steve
Buffalo, Jonathan
Burlingame, Chuck
Caito, J
Campbell-Allison, Jennifer
Caneff, Denny
Carney, Doug
Ceorst MVS External Stakeholder
Chicago Commodities
Chief John Red
City of Portage des Sioux
Clements, Mark
Clover-Hill, Shelly
Coder, Justin
Congressman Clay
Congressman Graves
Corker, Ashley
Crowley, S
Cruse, Lester
Curran, Michael
Davis, Dave
Deel, Judith
Dewey, Dave

Diedrichsen, Mike
District Director Senator Blunt
Docks
Dodd, Harold
Dorothy, Olivia
Dotts, Glenn
Dougherty, Mark
Duncan, Cecil
Ebey, Mike
Elmestad, Gary
Enos, Tim
Escudero, Marisa
Fabrizio, Christi
Favilla, Christine
Foster, Bill
Fretz, Eileen
Fung, Jenny
Genz, Greg
Glenn, S
Goode, Peter
Great Lakes Dredge & Dock
Grider, Nathan
Hall, Mike
Hammond, Cheryl
Hanke Terminals
Hanneman, M
Hansens Harbor
Harding, Scott
Held, Eric
Henleben, Ed
Henry, Donovan
Heroff, Bernard
Herschler, Mike
Herzog, Dave
Hilburn, Craig
HMT Bell South
Hoppies Marine
Howard, Chuck
Hubertz, Elizabeth
Hughes, Shannon
Hunt, Henry
Hussell, B
IL SHPO

Jamison, Larry
JBS Chief
Jefferson Port Authority
Jochim, Christine
Johnson, Frank
Knowles, Kim
Knuth, Dave
Kowal, Kathy
Kovarovics, Scott
Kristen, John
Lange, James
Larson, Robert
Lauer, Steve
Lavalle, Tricia; Senator Blunt
Leary, Alan
Lipeles, Maxie
Logicplus
Lorberg, Jerry
Louis Marine
Malone, Pat
Manders, Jon
Mangan, Matthew
Mannion, Clare
Marrs, T. Bruce
Mauer, Paul
McGinnis, Kelly
McPeek, Kraig
MDNR
Medina, Santita
Melgin, Wendy
Menees, Bob
Middleton, Joeana; Senator McCaskill
Miller, Jeff
Miller, Kenneth
Miller, M
Missouri Corn Growers Association
Morgan, Justin
Morrison, Bruce
Muench, Lynn
Muir, T
Nash-Mayberry, Jamie
Nelson, Lee
Niquette, Charles

Novak, Ron
O'Carroll, J
Paurus, Tim
Pehler, Kent
Peper, Sarah
Pinter, Nicholas
Popplewell, Mickey
Porter, Jason
Randolph, Anita
Reitz, Paul
Roark, Bev
Rowe, Kelly
Salveter, Amy
Samet, Melissa
Sauer, Randy
Schranz, Joseph Standing Bear
Schulte, Rose
SEMO Port
Senator Blunt's Office
Shepard, Larry
Shoulberg, J
Skrukrud, Cindy
Slay, Glen
Smith, David
Southern Illinois Transfer
Spoth, Robert
Stahlman, Bill
Staten, Shane
Sternburg, Janet
Stewart, Robert
Stout, Robert
Strole, Todd
SUMR Waterways
Taylor, Susan
Teah, Philip
Todd, Brian
Tow Inc
Tyson, J
Urban, David
U.S. Salt
USEPA Region 5
USEPA Region 7
Walker, Brad

Welge, Owen
Werner, Paul
Westlake, Ken
Wilmsmeyer, Dennis
Winship, Jaci
York Bridge Co.
Zupan, T

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

Bighorse, Scott
Blankenship, Tina
Bradley, Russell
Campbell, Leon
Congressman Bost
Congressman Luetkemeyer
Congressman Smith
Congresswoman Wagner
Damptz, Amanda
Governor Greitens
Governor Rauner
Keo, Nellie
Knupp, Virgil
Korando, David
Houghton, Fay
Houston, Elena
Mezo, Braden
Schranz, Joseph Standing Bear
Senator Durbin
Senator Duckworth
Shepard, Ron
Spurlock, Jessica
Taflinger, Jim
Verble, Kenneth
Verble-Whitaker, LaRae

Appendix H: Public Comments and Responses

Appendix H: Public Comments and Responses

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Comments on the
Regulating Works Project
Draft Supplemental Environmental Impact Statement
November 2016

Submitted by

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

January 18, 2017

Submitted by email to: RegWorksSEIS@usace.army.mil

Table of Contents

The National Wildlife Federation, American Rivers, Missouri Coalition for the Environment, and Prairie Rivers Network (collectively, the Conservation Organizations) appreciate the opportunity to submit these comments on the Regulating Works Project Draft Supplemental Environmental Impact Statement (November 2016) (the "DSEIS"). The Conservation Organizations strongly oppose the preferred alternative in the DSEIS and urge the Corps of Engineers to develop and select an alternative that will protect communities and the ecological health of the Middle Mississippi River.

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 forty-nine states and territories. NWF has a long history of advocating for the protection, restoration, and ecologically sound management of the Mississippi River. NWF also has a long history of working to modernize federal water resources planning to protect the nation's rivers, wetlands, floodplains, and coasts and the fish and wildlife that depend on those vital resources.

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 works to protect and restore the environment through education, public engagement, and legal action.

Prairie Rivers Network (PRN) is Illinois' advocate for clean water and healthy rivers. PRN champions clean, healthy rivers and lakes and safe drinking water to benefit the people and wildlife of Illinois. Drawing upon sound science and working cooperatively with others, PRN advocates public policies and cultural values that sustain the ecological health and biological diversity of water resources and aquatic ecosystems.

General Comments

The Regulating Works Project is a massive, ongoing federal civil works project that imposes enormous financial costs on federal taxpayers, significantly increases flood risks for communities, and destroys vital fish and wildlife habitat and the free services that habitat provides to all of us.

The National Environmental Policy Act (NEPA) provides an important framework for developing and selecting alternatives that would reduce these significant burdens. However, rather than taking advantage of NEPA to do this, the DSEIS appears to have been formulated to justify continuation of the status quo. As discussed in detail in these comments, the DSEIS: fails to comply with longstanding legal requirements; fails to evaluate a host of highly reasonable alternatives; fails to evaluate the project's adverse impacts to a wide range of fish and wildlife species and vital habitats; and is scientifically unsound.

The end result of this flawed study is the selection of a preferred alternative that is bad for both people and wildlife. The preferred alternative will significantly increase flood risks and the associated costs of flood insurance payments; federal emergency assistance; and state, local, and private recovery efforts. The preferred alternative will cause wide-spread, highly significant harm to the Middle Mississippi River and the fish and wildlife that rely on that vital resource. The preferred alternative will also undermine extensive taxpayer investments in flood risk reduction and habitat protection and restoration.

NEPA and its public participation process provide a much needed framework to ensure that federal investments are both environmentally sound and cost-effective. To achieve these goals, and ensure the highest level of protection to the public, the Conservation Organizations once again urge the Corps to:

1. 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.

2. Impose a moratorium on the construction of new river training structures pending completion of the National Academy of Sciences Study and the SEIS. As discussed in these comments, 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, the National Academy of Sciences study and comprehensive SEIS establish that such construction will not contribute to increased flood risks to communities.

3. Fully evaluate the impacts of all reasonable alternatives—including those alternatives outlined in these comments—and select an alternative that protects people and wildlife. To comply with longstanding Congressional directives, including the National Water Resources Policy, the SEIS must ultimately select an alternative that will protect and restore the natural functions of the Mississippi River system and mitigate any unavoidable damage.

4. Appoint a new and fully independent external peer review panel to evaluate the adequacy and appropriateness of the models, science, and methodology used in the SEIS and to evaluate whether the selected alternative will in fact protect communities and protect and restore the natural functions of the Mississippi River system.

5. Expand the SEIS to evaluate the full suite of operations and maintenance activities for the Upper Mississippi River – Illinois Waterway (IWR-IWW) navigation system. As the Corps is well aware, the Regulating Works Project is just one of a number of activities carried out by the Corps to maintain navigation on the UMR-IWW. Other activities include water level regulation; operation and maintenance of the system's 37 locks and dams; and dredging, dredged spoil disposal, and construction of revetment in other portions of the UMR-IWW. Since all of these activities are designed to maintain a single navigation project, individual activities may not be evaluated in isolation, but should instead be evaluated in a single environmental impact statement.

Specific Comments

I. The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment

The Conservation Organizations strongly oppose the preferred alternative because it will lead to increased flooding and will further degrade the ecological conditions in the Mississippi River. The flood risks created by the preferred alternative's continuation of river training structure are discussed in Section II.C.4 of these comments. The DSEIS recognizes that the preferred alternative will cause significant environmental harm, and as outlined throughout these comments, the Conservation Organizations believe that the adverse impacts will be far greater than acknowledged in the DSEIS.

The preferred alternative is also at odds with longstanding federal policy directing the protection of the nation's rivers, floodplains, and wetlands, including the National Water Resources Planning Policy established by Congress in 2007:

> "It is the policy of the United States that all water resources projects" are to, among other things, "protect[] and restor[e] the functions of natural systems and mitigat[e] any unavoidable damage to natural systems."[1]

The preferred alternative violates this policy because it would harm, not protect and restore, the functions of the Middle Mississippi River and its floodplain.

To comply with NEPA, the DSEIS should be substantially revised to fully consider the alternatives outlined below in light of an appropriate project purpose, a clear demonstration of project need, and a comprehensive and meaningful assessment of potential impacts that is directed by a National Academy of Sciences study on the effect of river training structures on flood heights and flooding:[2]

(1) The No New Construction Alternative, which should be reexamined in light of an appropriate project purpose, a clear demonstration of need, and a comprehensive and meaningful assessment of potential impacts.

(2) An alternative that includes removing and/or modifying existing river training structures in the Project area to restore backwater, side channel, and braided river habitat; and reduce flood risks.

    Importantly, the DSEIS acknowledges that such actions can be carried out without adversely affecting navigation. According to the DSEIS (pages 157-158):

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[1] 42 USC § 1962–3.

[2] These alternatives, and the critical need for a National Academy of Sciences study, were also identified in the Scoping Comments for the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project, Public Notice 2013-744, submitted by the National Wildlife Federation, American Rivers, Great Rivers Environmental Law Center, Missouri Coalition for the Environment, Prairie Rivers Network, River Alliance of Wisconsin (February 14, 2014).

> "Removal, shortening, notching, etc. of existing river training structures would facilitate the replacement of lost function with a similar amount of habitat function. This could be accomplished by restoring the amount of unstructured main channel border habitat that is lost by future placement of river training structures. An evaluation of current channel bathymetry on the MMR reveals opportunities where existing river training structures could be removed, shortened, and/or notched without adversely affecting the current dredging requirements of the adjacent navigation channel."
>
> ***
>
> "The result of extending existing dikes is that the structure spacing is no longer optimized, resulting in structures that have little or no effect on maintaining navigation channel depths."
>
> "In addition, many of the structures on the MMR were designed by engineers without the assistance of modern numerical and physical model studies that are now used to optimize structure locations, configurations, spacing, etc. Adaptive management was used in cases when there was a need for additional constriction from what was initially designed; however, in cases where constructed projects deepened the navigation channel by more than what was needed or expected, structures were not normally removed."
>
> "These factors have created a situation where opportunities now exist within the MMR to remove, shorten, notch, or otherwise alter the configuration of existing river training structures without adversely affecting the adjacent navigation channel to compensate for the 1,100 acres of main channel border habitat estimated to be impacted."

(3) An alternative that minimizes the use of new river training structures, including by placing restrictions on the number and/or types of structures that can be utilized in a given reach based on a robust scientific assessment of the cumulative impacts of the various types of river training structures.

(4) An alternative that maintains the authorized navigation channel through other approaches, including such things as alternative upstream water level management regimes, alternative dredging and dredged spoil disposal activities, and the development of new, innovative techniques.

(5) An alternative that evaluates restoration activities that would improve the ecological health and resiliency of the Mississippi River and its floodplain and the fish and wildlife species that rely on those resources. This alternative should include formally adopting restoration, and fish and wildlife conservation, as authorized Project Purposes.[3]

To comply with the National Water Resources Planning Policy, and to protect communities and taxpayers, the final SEIS should select an alternative that will reduce flood risks to communities, and protect and restore the Mississippi River.

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[3] That restoration activities can be carried out under other authorities does not obviate the need for developing, evaluating, and selecting an alternative that would improve the health and resiliency of the Mississippi River.

II. The DSEIS Fails to Comply with the National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires that an environmental impact statement identify the full scope of direct, indirect, and cumulative impacts of a proposed action and determine whether there are less environmentally damaging ways to achieve the project purpose. As discussed throughout these comments, the DSEIS is inadequate as a matter of law because it fails to satisfy these fundamental requirements.

A. The DSEIS Purpose and Need Statement Fails to Comply with NEPA

The DSEIS utilizes the following statement of Purpose and Need:

> "As authorized by Congress, the Regulating Works Project utilizes bank stabilization, rock removal, and sediment management to maintain bank stability and ensure adequate navigation depth and width. Bank stabilization is achieved by revetment and river training structures, while sediment management is achieved by river training structures. The Regulating Works Project is maintained through dredging and any needed maintenance to already constructed features. The long-term goal of the Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of regulating works. Therefore, pursuant to the Congressionally authorized purpose of the Project, the District continually identifies and monitors areas of the MMR that require frequent and costly dredging to determine if a long-term sustainable solution through regulating works is reasonable. The District also monitors bank stabilization areas to determine if additional work or re-enforcement of existing work is needed to ensure the dependability of the navigation channel." DSEIS at ES-1.

This DSEIS Purpose and Need statement violates NEPA because it: (1) is drawn so narrowly that it effectively limits the analysis of alternatives to only those that will continue the status quo approach to carrying out the Regulating Works project; (2) fails to account for a host of Congressional directives that require and/or promote the protection and restoration of the nation's water resources; and (3) fails to establish an actual need for the Project, including the need to construct new river training structures. The problems created by this legally inadequate Purpose and Need statement are compounded by the Corps' explicit refusal to evaluate alternatives that may require additional or changed Congressional authorization, in direct violation of NEPA.[4] *See* DSEIS at ES-1.

To correct these failings, the Conservation Organizations urge the Corps to adopt the following, legally appropriate, Project and Need statement that would help ensure consideration of important and fully reasonable alternatives:

> **The purpose of the Project is to maintain navigation in the Middle Mississippi River while protecting and restoring the ecological health of the river and its floodplain and minimizing flood risks to communities.**
>
> The need for this Project includes, the critical need to:

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[4] 42 C.F.R. § 1502.14, §1506.2(d); CEQ, Forty Most Asked Questions Concerning CEQ's NEPA Regulations (reasonable alternatives that are outside the legal jurisdiction of the lead agency or outside the scope of what Congress has approved or funded must be analyzed).

(1) Improve the degraded conditions of the Middle Mississippi River;
(2) Protect and restore important and diverse in-stream, channel border, and side channel habitats;
(3) Restore as much of the natural functions of the Middle Mississippi River as possible;
(4) Conserve and restore populations of fish and wildlife species affected by the Project;
(5) Reduce the risks of flooding created by the extensive construction of river training structures;
(6) Maintain a viable navigation system; and
(7) Ensure full compliance with Federal laws and policies.

1. The Purpose and Need Statement Improperly Limits the Alternatives Analysis

An appropriate statement of Purpose and Need is crucially important to the adequacy of the DSEIS because the Purpose and Need statement "delimit[s] the universe of the action's reasonable alternatives."[5] This is because "[o]nly alternatives that accomplish the purposes of the proposed action are considered reasonable, and only reasonable alternatives require detailed study. . . ."[6]

As the Courts have long acknowledged:

> "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). . . . 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)."[7]

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[5] *Citizens Against Burlington v. Busey*, 938 F.2d 190, 195 (D.C. Cir. 1991). *See also Wyoming v. U.S. Dep't of Agric.*, 661 F.3d 1209, 1244 (10th Cir. 2011) ("how the agency defines the purpose of the proposed action sets the contours for its exploration of available alternatives."); *Sierra Club v. U.S. Dep't of Transp.*, 310 F.Supp.2d 1168, 1192 (D. Nev. 2004) (citing *City of Carmel-By-The-Sea v. U.S. Dep't of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997)).
[6] Webster v. U.S. Department of Agriculture, 685 F.3d 411, 422 (4th Cir. 2012); Methow Valley Citizens Council v. Regional Forester, 833 F.2d 810, 815-16 (9th Cir. 1987).
[7] *Simmons v. United States Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997). *See also City of Bridgeton v. FAA*, 212 F.3d 448, 458 (8th Cir. 2000); *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"); *Methow Valley Citizens Council v. Regional Forester*, 833 F.2d 810, 815-16 (9th Cir. 1987) (impact statements must consider all reasonable alternatives that accomplish project purpose, but need not consider alternatives not reasonably related to purpose).

Accordingly, the Courts have made it clear that an agency may not define a project so narrowly that it "forecloses a reasonable consideration of alternatives"[8] or makes the final EIS "a foreordained formality."[9]

The DSEIS Purpose and Need statement violates each of these mandates because it is so narrowly drawn that it dictates continuation of the status quo approach to the Project, severely limiting the analysis of alternatives. For example, the DSEIS Purpose and Need statement effectively mandates continuation of river training structure construction to reduce dredging costs regardless of public safety impacts, ecological impacts, or national priorities. The Purpose and Need statement similarly suggests that the Project must also continue to stabilize the river banks with revetment and remove rocks that may affect navigation. As a result, the Purpose and Need statement precludes meaningful consideration of alternatives that do not include each of these features.

Notably, while the DSEIS states repeatedly that Congress has dictated the approach that the Corps must take in carrying out the Project, the DSEIS does not provide the full text of either the legislation or supporting Chief of Engineers' reports that set forth those approaches. As a result, the public is precluded from assessing the accuracy of the Corps' claims with respect to the alleged dictates of the authorizing legislation. The public is also precluded from determining whether the Project authorization included limitations on appropriations or included a Project expiration date. For example:

(a) The DSEIS provides only a one sentence excerpt from the 1881 report that forms the basis of the Regulating Works Project authorization.[10] DSEIS at 3; *see* DSEIS Appendix F at F-9 to F-13. This limited excerpt makes it impossible to evaluate the full suite of actions suggested by the plan and any limitations that the plan may have placed on recommended activities, funding, or length of authorization. The 1881 plan is not readily accessible to the public.

(b) The DSEIS does not provide any text from the Chief of Engineers Report that accompanied the Rivers and Harbors Act of 1910, and provides only a short excerpt from the Chief of

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[8] *Fuel Safe Washington v. Fed. Energy Regulatory Comm'n*, 389 F.3d 1313, 1324 (10th Cir. 2004) (quoting *Davis v. Mineta*, 302 F.3d 1104, 1119 (10th Cir. 2002); *Citizens' Comm. To Save Our Canyons v. U.S. Forest Serv.*, 297 F.3d 1012, 1030 (10th Cir. 2002); *Friends of Southeast's Future v. Morrison*, 153 F.3d 1059, 1066 (9th Cir. 1998) ("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".); *Simmons v. United States Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997); *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) ((holding that "an agency may not narrow the objective of its action artificially and thereby circumvent the requirement that relevant alternatives be considered); *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991), *cert. denied* 502 U.S. 994 (1991).

[9] *City of Bridgeton v. FAA*, 212 F.3d 448, 458 (8th Cir. 2000) (quoting *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991), *cert. denied* 502 U.S. 994 (1991); citing *Simmons v. U.S. Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997)).

[10] DSEIS at 3 ("the system to be pursued is that of contraction, thus compelling the river to scour out its bed; this process being aided, if necessary by dredging. Wherever the river is causing any serious caving of its banks, the improvement will not be permanent until the bank has been protected and the caving has been stopped" and that "it may be advisable to remove some bowlders [sic] and perhaps to cut off some points of rocks, which at low-water hamper navigation" (Senate Executive Doc. No. 10 (47th Congress, 1st Session) (hereinafter referred to as the 1881 Report))."

Engineers Report that accompanied the Rivers and Harbors Act of 1927.[11] This limited excerpt makes it impossible to evaluate the full suite of actions suggested by the plan and any limitations on the recommended activities, funding, or length of authorization. Neither of these reports are readily accessible to the public.

In addition, the strict limitations on the Project approaches outlined in the DSEIS do not appear to be supported by the limited excerpts from the 1881 plan and the Chief of Engineers Report that accompanied the Rivers and Harbors Act of 1927 provided in the DSEIS. The Corps' own actions also appear to contradict the strict Project approach limitations established by the DSEIS. As set forth in DSEIS Appendix F, the Corps made numerous and significant changes to the techniques it has used to carry out the Project **after** the 1910 and 1927 authorizations. DSEIS Appendix F at F-9 to F-13. Indeed, the significant changes to the Project over time demonstrate that the Corps believes it is readily able to change the methods and techniques used to carry out the Project.

The Corps should provide the full text of the applicable sections of the Rivers and Harbors Acts, and the full text of the sections of the Chief of Engineers' Reports relied on in those Acts so that the public and decision makers can assess: (1) the full extent of any limitations on techniques authorized under those provisions; and (2) whether Congress imposed any limitations on the length of time the Project authorization would remain in effect or imposed a limitation on the amount of appropriations that could be spent on the Project. This information is essential to understanding the full extent of any constraints that may have been established in the authorizing legislation.

The ability to review this information is particularly important given the length of time that has passed since the Project was authorized. While it is of course possible that the Chief of Engineers recommended a Project with no time limitation or appropriations ceiling, or that the Chief of Engineers authorized continuous construction of new river training structures and revetment for well over 100 years, it is far more likely that the Chief of Engineers reports recommend a far more limited scope of construction. Under such a scenario, new Congressional authorization would likely be required to carry out any additional construction of river training structures that might be recommended in the final EIS.[12] This would have important implications for the DSEIS.

The DSEIS should provide the full text of the applicable sections of the Chief of Engineers' reports to assist the public and decision makers in evaluating the precise activities currently authorized (including any limitations on those activities) and whether new authorization would be required.

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[11] DSEIS at 3. ("The Congressionally authorized modification to the Project in the Rivers and Harbors Act of 1927, changing the depth and width of the authorized navigation channel, was based upon the Chief of Engineers' report dated December 17, 1926. This Chief of Engineers report described the current and future status of the Project as follows: "Although great benefits have resulted from the work already done, it is essential that additional regulating works and bank protection be carried to a point where a minimum of dredging is required and a stable channel is available at all times... [The Chief of Engineers also concurred in the District Engineers' recommendation that] the regulating works and revetment be completed and that dredging, which affords only temporary relief, be resorted to only when and to the extent that the needs of navigation then existing require" (House Committee Doc. No. 12 (70th Cong., 1st Session)).")

[12] It is also possible that the numerous river training structure projects currently being proposed by the Corps also exceed the existing authorization, and thus cannot be constructed without new Congressional authorization.

2. The Purpose and Need Statement Fails to Account for Clear Congressional Directives

The Purpose and Need statement fails to account for the full suite of laws and policies applicable to Corps projects. A proper statement of Purpose and Need 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**."[13]

Congress has established a host of post-authorization directives that must be incorporated into the Purpose and Need statement for the Project, including many directives that require and/or promote the protection and restoration of the nation's waters and fish and wildlife resources, and that require the Corps to minimize flood risks. These directives include:

a. The National Water Resources Planning Policy established by Congress in 2007. This policy 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. This policy requires the Corps to operate the Regulating Works Project to protect the Mississippi River and its floodplain.

b. The National Environmental Policy Act enacted in 1970. NEPA directs the "Federal Government to use all practicable means" to, among other things: (i) "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;" (ii) ensure "safe, healthful, productive" surroundings for all Americans; and (iii) "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences." 42 U.S.C. § 4331(b). NEPA states explicitly that the policies, regulations and laws of the United States "**shall** be interpreted and administered in accordance with the policies set forth in this Act." 42 U.S.C. § 4332(1) (emphasis added). NEPA also explicitly states that "policies and goals set forth in this Act are supplementary to those set forth in existing authorizations of Federal agencies." 42 U.S.C. § 4335.

c. The many statutory directives to protect the environment and fish and wildlife contained in the Clean Water Act, the Endangered Species Act, the Clean Air Act, the Corps' civil works mitigation requirements (33 U.S.C. § 2283(d)), and the Water Resources Development Act of 1990 that changed the Corps' fundamental mission to "include environmental protection as one of the primary missions of the Corps of Engineers in planning, designing, constructing, operating, and maintaining water resources projects." 33 U.S.C. § 2316.

d. The Fish and Wildlife Coordination Act enacted in 1958. The Fish and Wildlife Coordination Act 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. *See* Section IV of these comments for a more detailed discussion of the Fish and Wildlife Coordination Act and its applicability to the Project.

Corps regulations in place since 1980 state that:

[13] *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991) (emphasis added).

> "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 DSEIS fails to incorporate these critically important post-project authorization Congressional directives, and longstanding Corps' policy objectives, into the project purpose as required by law.[14]

3. The Purpose and Need Statement Fails to Demonstrate Project Need

The DSEIS Purpose and Need Statement fails to demonstrate Project need, and notably fails to establish that there is in fact a need for new river training structures (*e.g.*, dikes, weirs, chevrons, and revetment) or additional revetment.

New navigation structures are clearly not required to maintain the navigation channel as the current dredging regime has a long history of effectively maintaining navigation in the Middle Mississippi River. To the contrary, the Corps acknowledges that the actual purpose of the river training structures is simply to reduce the costs associated with dredging certain sections of the navigation channel. Notably, however, the DSEIS does not provide any type of meaningful cost information or a benefit-cost assessment that could assist in determining whether new river training structure construction might actually achieve even this limited goal.

Instead of providing meaningful information demonstrating the need for new river training structure construction, the DSEIS contends that new river training structures should be constructed to fend off vague and unsubstantiated risks of barge groundings, channel closures, and lack of sufficient funding for dredging under certain extreme conditions that may (or may not) occur at some point in the future. According to the DSEIS:

> "The Continue Construction Alternative would be expected to reduce average annual dredging quantities from approximately 4 million cubic yards to approximately 2.4 million cubic yards. This anticipated reduction in dredging would be expected to reduce barge grounding rates and result in a safer and more reliable navigation channel.
>
> The reduction in dredging needs would result in increased channel reliability and a decrease in the risk of channel closures due to reduced frequency of groundings and the formation of mid channel sandbars that could impact navigation at low stages. The reduction in need for just-in time dredging would reduce the likelihood of a failure to find problematic locations and get the dredge to the location when needed.

[14] See Citizens Against Burlington, Inc. v. Busey, 938 F.2d 190, 196 (D.C. Cir. 1991).

> The District's ability to respond to extreme dredging situations would also be improved with implementation of the Continue Construction Alternative. During the recent low-water event of 2012/2013, the Corps had to redirect O&M funding from other O&M needs as well as bring on an additional dredge boat to meet dredging demands. The availability of additional funding and dredging resources cannot be assumed for future low-water events. Implementation of the Continue Construction Alternative would be expected to reduce the dredging requirements during any such future events and would increase the likelihood of avoiding adverse effects to navigation."

DSEIS at 161-162.

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."[15]

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."[16]

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. Moreover, the DSEIS fails to provide any estimate of future costs with and without new river training structure construction, and fails to identify those areas likely to require continued dredging even if additional structures are constructed.

As discussed in Section II.C.2 of these comments, the DSEIS also fails to provide critical information on sediment loads and sediment transport in the Middle Mississippi River, making it impossible for the public and decision makers to assess the need for additional river training structures.

Properly demonstrating a need for construction of new river training structures – on the basis of legitimate, scientifically sound, and detailed factual information – is fundamental to an adequate NEPA analysis and is absolutely critical for this Project as the river training structures create a significant risk of increased flooding for river communities and, by the Corps' own acknowledgement, will lead to significant adverse impacts to the environment.

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[15] USACE, Event Study 2012 Low-Water and Mississippi River Lock 27 Closures, August 2013 at 15.

[16] 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. The DSEIS Alternatives Analysis Fails to Comply with NEPA

The DSEIS alternatives analysis is inadequate as a matter of law because it: (1) fails to review highly reasonable alternatives, including alternatives that would reduce flood risks and improve the health and resiliency of the Middle Mississippi River; (2) fails to evaluate a reasonable range of alternatives; and (3) fails to provide an informed and meaningful consideration of alternatives. The DSEIS also fails to identify the environmentally preferable alternative. As discussed in Section II.C of these comments, the DSEIS alternatives analysis is also inadequate as a matter of law because it is based on a fundamentally flawed analysis of direct, indirect, and cumulative impacts.

NEPA requires that each EIS "[r]igorously explore and objectively evaluate all reasonable alternatives."[17] This requires a "**thorough consideration of all appropriate methods of accomplishing the aim of the action**" and an "**intense consideration of other more ecologically sound courses of action**."[18] The rigorous and objective evaluation of all reasonable alternatives is the "heart of the environmental impact statement."[19] Importantly, "the discussion of alternatives must be undertaken in good faith; it is not to be employed to justify a decision already reached."[20]

While an EIS need not explore every conceivable alternative, it must rigorously explore all reasonable alternatives that are consistent with its basic policy objective and that are not remote or speculative. A viable but unexamined alternative renders an EIS inadequate.[21] An alternative may not be disregarded merely because it does not offer a complete solution to the problem.[22] Importantly, an alternative also may not be disregarded because it would require additional Congressional authorization. To the contrary, the alternatives analysis must "[i]nclude reasonable alternatives not within the jurisdiction of the lead agency."[23]

Failure to look at an appropriate range of alternatives likewise renders an alternatives analysis inadequate.[24] The range of alternatives that must be considered is determined by the nature and scope of the proposed action. The greater the impacts and scope of the proposed action, the greater the

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[17] 40 C.F.R. § 1502.14.
[18] Environmental Defense Fund, Inc. v. Corps of Engineers of U.S. Army, 492 F.2d 1123, 1135 (5th Cir. 1974) (emphasis added).
[19] 40 C.F.R § 1502.14.
[20] Citizens Against Toxic Sprays, Inc. v. Bergland, 428 F.Supp. 908, 933 (D.Or. 1977).
[21] E.g. Muckleshoot Indian Tribe v. U.S. Forest Service, 177 F.3d 800, 810, 814 (9th Cir. 1999).
[22] Natural Resources Defense Council, Inc. v. Morton, 458 F.2d 827, 836 (D.C. Cir. 1972).
[23] 40 C.F.R. § 1502.14(c); *Natural Resources Defense Council v. Morton*, 458 F.2d 827, 834-36 (D.C. Cir. 1972) (alternative sources of energy had to be discussed, despite federal legislation indicating an urgent need for offshore leasing and mandating import quotas; Department of Interior had to consider reasonable alternatives to offshore oil lease which would reduce or eliminate the need for offshore exploration, such as increased nuclear energy development and changing natural gas pricing, even though that would require Congressional action); *Environmental Defense Fund v. Froehlke*, 473 F.2d 346 (8th Cir. 1974) (acquisition of land to mitigate loss of land from river channel project must be considered even though it would require legislative action).
[24] *E.g. Resources Ltd., Inc. v. Robertson*, 35 F.3d 1300, 1307 (9th Cir. 1993).

range of alternatives that must be considered.[25] The range of alternatives considered is not sufficient if each alternative has the same end result.[26]

In comparing and analyzing potential alternatives, the DSEIS must examine, among other things, the direct, indirect, and cumulative environmental impacts of the flow regimes in the different alternatives, the conservation potential of those alternatives, and the means to mitigate adverse environmental impacts. 40 C.F.R. § 1502.16. A robust analysis of project impacts is essential for determining whether less environmentally damaging alternatives are available.

Direct impacts are caused by the action and occur at the same time and place as the action. Indirect impacts are also caused by the action, but are later in time or farther removed from the location of the action. 40 C.F.R. § 1508.8. Cumulative impacts are:

> "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 C.F.R. § 1508.7. A cumulative impact analysis ensures that the agency will not "treat the identified environmental concern in a vacuum."[27]

1. The Alternatives Analysis Violates NEPA as a Matter of Law

The DSEIS clearly violates NEPA as a matter of law, because it has explicitly and intentionally failed to evaluate reasonable alternatives to determine whether there are less damaging ways to achieve the project purpose. To the contrary, the DSEIS states that it has not examined any alternatives that the Corps currently deems to be outside of the existing authorization, or that do not specifically track approaches identified by Congress more than 100 years ago. *See* DSEIS at ES-2 and 23.

NEPA requires that the DSEIS "[r]igorously explore and objectively evaluate all reasonable alternatives."[28] This requires a "**thorough consideration of all appropriate methods of accomplishing the aim of the action**" and an "**intense consideration of other more ecologically sound courses of action**."[29] The alternatives analysis must "[i]nclude reasonable alternatives not within the jurisdiction of the lead agency,"[30] which means that an alternative may not be disregarded merely because it would require additional Congressional authorization. An alternative also may not be disregarded merely

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[25] *Alaska Wilderness Recreation and Tourism v. Morrison*, 67 F.3d 723, 729 (9th Cir. 1995); *see Sierra Club v. Espy*, 38 F.3d 792, 803 (5th Cir. 1994) (the range of alternatives that must be considered in an environmental assessment decreases as the environmental impact of the proposed action becomes less and less substantial).
[26] *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).
[27] *Grand Canyon Trust v. FAA*, 290 F.3d 339, 346 (D.C. Cir. 2002).
[28] 40 C.F.R. § 1502.14.
[29] Environmental Defense Fund, Inc. v. Corps of Engineers of U.S. Army, 492 F.2d 1123, 1135 (5th Cir. 1974) (emphasis added).
[30] 40 C.F.R. § 1502.14(c).

because it does not offer a complete solution to the problem.[31] A viable but unexamined alternative renders an EIS inadequate.[32]

Despite these well-settled legal requirements, and the fundamental importance of identifying less environmentally damaging alternatives, the DSEIS explicitly and intentionally refuses to examine alternative approaches to achieving the goals of the project. The Corps attempts to justify this untenable position by claiming that it must continue to use the techniques for carrying out the Project that Congress approved 107 years ago based on a Corps studied developed 136 years ago.[33] DSEIS at 3 and Appendix F.

According to the DSEIS:

> "Alternatives. Congress provided the manner in which the navigation channel for the MMR should be obtained and maintained via the original Regulating Works Project authorization in 1910 and a modification to the authorization in 1927. The purpose of this SEIS is not to consider a change to that authorization through reevaluating the need for the Regulating Works Project or the methods to be used to accomplish the goals of the project. Rather, this document analyzes the impacts of the Regulating Works Project as it is currently constructed, operated, and maintained with current information that has become available since the completion of the 1976 EIS." DSEIS at ES-2.

* * *

> "As described in Section 1.2 Purpose of and Need for NEPA Supplement, this SEIS is not a study or re-evaluation of how a project should be carried out, but an updated analysis of the impacts of an already authorized, on-going project; Congress has already provided the manner in which the navigation channel for the MMR is to be obtained and maintained via the Regulating Works Project authorization. Any alternatives outside of this authorization to be considered in detail would require a planning study for either modification of the Project or new authorization from Congress on how to obtain and maintain navigation within the MMR. While alternatives outside of this authorization were not immediately dismissed, the analysis and evaluation of the new information and circumstances during the process of supplementing the 1976 EIS did not lead to a reasonable or feasible alternative that warranted transitioning this SEIS to such a planning document. Therefore, alternatives outside of the scope of this authorization are not evaluated in detail for purposes of this document." [34] DSEIS at 23.

The Corps' explicit refusal to examine any alternatives that the Corps currently deems to be outside of the existing authorization, or that do not specifically track approaches identified by Congress more than 100 years ago, renders the DSEIS inadequate as a matter of law. Common sense and modern science also clearly dictate a fundamentally different approach to evaluating alternatives.

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[31] Natural Resources Defense Council, Inc. v. Morton, 458 F.2d 827, 836 (D.C. Cir. 1972).

[32] E.g. Muckleshoot Indian Tribe v. U.S. Forest Service, 177 F.3d 800, 810, 814 (9th Cir. 1999).

[33] DSEIS at 3 ("In the Rivers and Harbors Act of 1910, Congress authorized obtaining and maintaining the MMR to be carried out in accordance with the plan in 1881.")

[34] The DSEIS states that "[i]n the Rivers and Harbors Act of 1910, Congress authorized obtaining and maintaining the MMR to be carried out in accordance with the plan in 1881." DSEIS at 3.

2. The DSEIS Fails to Evaluate Highly Reasonable Alternatives

The DSEIS violates NEPA because it fails to evaluate highly reasonable alternatives, as required by NEPA. *See* discussion above. To comply with NEPA, the DSEIS must rigorously explore and objectively evaluate at least the following alternatives (which are also set forth in Section I of these comments) in light of an appropriate project purpose, a clear demonstration of project need, and a comprehensive and meaningful assessment of potential impacts that is directed by a National Academy of Sciences study on the effect of river training structures on flood heights and flooding:[35]

(6) The No New Construction Alternative, which should be reexamined in light of an appropriate project purpose, a clear demonstration of need, and a comprehensive and meaningful assessment of potential impacts.

(7) An alternative that includes removing and/or modifying existing river training structures in the Project area to restore backwater, side channel, and braided river habitat; and reduce flood risks.

Importantly, the DSEIS acknowledges that such actions can be carried out without adversely affecting navigation. According to the DSEIS (pages 157-158):

> "Removal, shortening, notching, etc. of existing river training structures would facilitate the replacement of lost function with a similar amount of habitat function. This could be accomplished by restoring the amount of unstructured main channel border habitat that is lost by future placement of river training structures. An evaluation of current channel bathymetry on the MMR reveals opportunities where existing river training structures could be removed, shortened, and/or notched without adversely affecting the current dredging requirements of the adjacent navigation channel."
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> ***
>
> "The result of extending existing dikes is that the structure spacing is no longer optimized, resulting in structures that have little or no effect on maintaining navigation channel depths."
>
> "In addition, many of the structures on the MMR were designed by engineers without the assistance of modern numerical and physical model studies that are now used to optimize structure locations, configurations, spacing, etc. Adaptive management was used in cases when there was a need for additional constriction from what was initially designed; however, in cases where constructed projects deepened the navigation channel by more than what was needed or expected, structures were not normally removed."

[35] These alternatives, and the critical need for a National Academy of Sciences study, were also identified in the Scoping Comments for the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project, Public Notice 2013-744, submitted by the National Wildlife Federation, American Rivers, Great Rivers Environmental Law Center, Missouri Coalition for the Environment, Prairie Rivers Network, River Alliance of Wisconsin (February 14, 2014).

"These factors have created a situation where opportunities now exist within the MMR to remove, shorten, notch, or otherwise alter the configuration of existing river training structures without adversely affecting the adjacent navigation channel to compensate for the 1,100 acres of main channel border habitat estimated to be impacted."

(8) An alternative that minimizes the use of new river training structures, including by placing restrictions on the number and/or types of structures that can be utilized in a given reach based on a robust scientific assessment of the cumulative impacts of the various types of river training structures.

(9) An alternative that maintains the authorized navigation channel through other approaches, including such things as alternative upstream water level management regimes, alternative dredging and dredged spoil disposal activities, and the development of new, innovative techniques.

An alternative that evaluates restoration activities that would improve the ecological health and resiliency of the Mississippi River and its floodplain and the fish and wildlife species that rely on those resources. This alternative should include formally adopting restoration, and fish and wildlife conservation, as authorized Project Purposes.[36]

3. The DSEIS Fails to Evaluate an Appropriate Range of Alternatives

The DSEIS examines only two alternatives, the Continue Construction Alternative and the No New Construction alternative. This cannot satisfy NEPA's requirement to evaluate an appropriate range of alternatives for at least three reasons.

First, as discussed above, there are other highly reasonable alternatives that must be examined.

Second, the scope and impacts of the Project mandate evaluation of a much broader range of alternatives.[37] The range of alternatives that must be considered is determined by the nature and scope of the proposed action. The greater the impacts and scope of the proposed action, the greater the range of alternatives that must be considered.[38] Both the scope and the impacts of the Project are enormous. For example:

(a) The Project has caused, and will continue to cause, direct, indirect, and cumulative impacts to 195 miles of the Mississippi River and its floodplain, and the hundreds of species that rely on those vital resources.

(b) The Project is well documented as causing significant adverse impacts to the Middle Mississippi River, including as documented in the 2000 Biological Opinion and in the numerous studies incorporated by reference in the DSEIS cumulative impact analysis. The DSEIS also

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[36] That these types of activities could be carried out under other authorities does not obviate the need for this approach.

[37] *E.g. Resources Ltd., Inc. v. Robertson*, 35 F.3d 1300, 1307 (9th Cir. 1993).

[38] *Alaska Wilderness Recreation and Tourism v. Morrison*, 67 F.3d 723, 729 (9th Cir. 1995); *see Sierra Club v. Espy*, 38 F.3d 792, 803 (5th Cir. 1994) (the range of alternatives that must be considered in an environmental assessment decreases as the environmental impact of the proposed action becomes less and less substantial).

acknowledges that the Corps' preferred alternative will cause significant adverse impacts through the destruction of at least an additional 1,100 acres of vitally important main channel border habitat.

(c) Independent scientists, conservation organizations, and river communities remain deeply concerned about the Project's impacts to flood stages. Extensive peer-reviewed science demonstrates that river training structures have caused significant increases in flood heights in broad stretches of the Mississippi River, and a 2016 peer-reviewed study demonstrates that the excessive constriction caused by river training structures (and to a lesser extent, levees) has led to fundamental changes in the way the Middle Mississippi River responds to flood events. *See* Section II.C.4 of these comments.

(d) The DSEIS states that preferred alternative will result in "constructing future river training structures that equate to approximately 4.4 million tons of rock" and continued dredging of an average of approximately 2.4 million cubic yards per year.[39]

This Project's significant scope and extensive impacts require the Corps to evaluate a far greater range of alternatives that the two evaluated in the DSEIS, including at least those additional alternatives identified in these comments.

Third, Federal courts have routinely found that NEPA "prevents federal agencies from effectively reducing the discussion of environmentally sound alternatives to a binary choice between granting and denying an application."[40] The DSEIS provides just such an improper binary choice; one alternative would continue construction of river training structures along with all other current Regulating Works activities, while the second alternative would stop construction of river training structures while still carrying out all other current Regulating Works activities.

To satisfy NEPA, the DSEIS must evaluate a full range of alternatives, including the alternatives outlined above that will improve ecological conditions and/or reduce flood risks.

4. The DSEIS Fails to Provide an Informed and Meaningful Consideration of Alternatives

NEPA requires an "informed and meaningful" consideration of 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

[39] DSEIS at 32.

[40] *Save Our Cumberland Mountains v. Kempthorne*, 453 F. 3d 334, 345 (6th Cir. 2006), *citing Davis v. Mineta,* 302 F.3d 1104, 1122 (10th Cir.2002) ("[O]nly two alternatives were studied in detail: the no build alternative, and the preferred alternative. [The agency] acted arbitrarily and capriciously in approving an [environmental assessment] that does not provide an adequate discussion of [p]roject alternatives."); *Colo. Envtl. Coal. v. Dombeck,* 185 F.3d 1162, 1174 (10th Cir.1999) ("[T]he National Environmental Policy Act and Council on Environmental Quality Regulations require [an agency] to study in detail all `reasonable' alternatives [in an environmental impact statement].... [Courts] have interpreted this requirement to preclude agencies from defining the objectives of their actions in terms so unreasonably narrow they can be accomplished by only one alternative.").

> alternatives – including the no action alternative – is . . . an integral part of the statutory scheme.[41]

As documented throughout these comments, the DSEIS fails to satisfy this requirement because it fails to properly evaluate impacts, fails to analyze highly reasonable alternatives, and fails to analyze an appropriate range of reasonable alternatives.

The DSEIS also fails to satisfy the "informed and meaningful" review requirement for the two alternatives that it does evaluate because it fails to provide meaningful information on the actions that will be carried out under those alternatives. Neither alternative provides criteria for the triggering of future dredging, revetment, or river training structure construction. Neither alternative provides information concerning the likely locations of such future actions. Neither alternative provides any information on the economic costs or impacts of the likely future actions. The Continue Construction Alternative does not provide any information on the types of river training structures that will be used, and does not provide any information on the projected linear feet of river training structures that will be constructed. As discussed in Section II.C.4 of these comments, the total linear feet of river training structures has a significant impact on flood heights.

The Independent Peer Review (IEPR) panel for the Project highlights a number of these failings. The IEPR panel concludes, among other things, that:

1. "It is not clear why impacts of future river training structure construction and the associated compensatory mitigation requirements were not evaluated in more detail with respect to specific locations in the MMR."

2. "The project description for the proposed action does not describe the decision-making process that will be employed for identifying new river training structure construction sites."

3. "The SEIS does not clearly describe the project construction features within the main report such that a link between the project and the level of impacts can be easily compared."[42]

See Section II.C.2 of these comments for an additional discussion of the IEPR Panel and its findings.

Because the Corps has been implementing the Project since 1910, the agency should have information on likely future dredging needs and dredged spoil disposal sites, river training structure construction needs, and locations where the Corps contends that new revetment may be needed. Without this type of information it is not possible to meaningfully evaluate the impacts of the proposed alternatives.

The DSEIS also fails to satisfy the "informed and meaningful" review requirement for the two alternatives that it does evaluate because that analysis has been conducted in light of an improperly narrow project purpose. Indeed, this improperly narrow project purpose appears to be the determining

[41] *Bob Marshall Alliance v Hodel*, 852 F.2d 1223, 1228 (9th Cir. 1988) (internal citations omitted).
[42] Final Independent External Peer Review Report on the Supplemental Environmental Impact Statement (SEIS) for the Mississippi River between the Ohio and Missouri Rivers (Regulating Works), October 13, 2016 ("Final IEPR Report").

factor in the DSEIS selection of the Continue Construction Alternative even though that alternative will, according to the DSEIS, cause far more harm than the No New Construction Alternative.[43]

5. The DSEIS Fails to Identify the Environmentally Preferable Alternative

The Record of Decision for the final SEIS must identify the "environmentally preferable" alternative[44] and agencies are encouraged to identify the environmentally preferable alternative in the EIS.[45] The environmentally preferable alternative is "the alternative that will promote the national environmental policy as expressed in NEPA's Section 101. Ordinarily, this means the alternative that causes the least damage to the biological and physical environment; it also means the alternative which best protects, preserves, and enhances historic, cultural, and natural resources."[46]

Identification of the environmentally preferable alternative is critical so that the public and decision makers can fully assess the appropriateness of the preferred alternative:

> "Through the identification of the environmentally preferable alternative, the decisionmaker is clearly faced with a choice between that alternative and others, and must consider whether the decision accords with the Congressionally declared policies of the [National Environmental Policy] Act."[47]

On the basis of the information provided in the DSEIS, the No New Construction alternative is clearly the environmentally preferable alternative since the Corps contends that it would not cause a significant loss of channel border habitat and would not otherwise require compensatory mitigation. The Corps should clearly identify the environmentally preferable alternative in the DSEIS.

C. The DSEIS Fails to Properly Evaluate Project Impacts

The DSEIS fails to properly evaluate project impacts, leading to a dangerously false picture of the potential impacts of the Project.

NEPA requires agencies to analyze all "reasonably foreseeable" direct, indirect and cumulative environmental impacts.[48] "If it is reasonably possible to analyze the environmental consequences in an EIS...the agency is required to perform that analysis."[49] This mandate applies to both site-specific and programmatic NEPA documents.[50]

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[43] Compare DSEIS at 29 (The No New Construction Alternative "Does not achieve Congressionally authorized project objective of reducing federal expenditures by reducing dredging to a minimum") with DSEIS at 32 ("Based on the Project's Congressional authority and the continued benefit of the remaining construction, the Continue Construction Alternative with the described potential compensatory mitigation is the Preferred Alternative.")
[44] 40 C.F.R. § 1505.2.
[45] *Id*.
[46] CEQ Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 Fed. Reg. 18026 (March 23, 1981), as amended, Question 6.
[47] *Id*.
[48] 40 C.F.R. § 1508.8.
[49] *Kern v. U.S. Bureau of Land Mgmt.,* 284 F.3d 1062, 1072 (9t hCir.2002).
[50] See, e.g., Kern v. U.S. Bureau of Land Mgmt., 284 F.3d at 1072.

Where site-specific impacts are "reasonably foreseeable" at the program planning stage, they must be evaluated in the programmatic EIS.[51] The Corps may not evade its obligation to analyze the reasonably foreseeable, site-specific environmental consequences of a larger program merely by saying that those consequences will be analyzed later.[52] Indeed, such procrastination is antithetical to NEPA's basic charge to undertake analysis and integrate it into agency decision making as early as possible.[53]

The DSEIS impacts analysis must be based on, and present, "quantified or detailed information."[54] "General discussion of an environmental problem over a large area" is not sufficient and cannot satisfy NEPA.[55] Unsupported conclusory statements likewise cannot satisfy NEPA:

> "A conclusory statement unsupported by empirical or experimental data, scientific authorities, or explanatory information of any kind not only fails to crystalize the issues, but affords no basis for a comparison of the problems involved with the proposed project and the difficulties involved in the alternatives."[56]

The DSEIS also must be based on "high quality" science and information and the Corps must "insure professional integrity, including scientific integrity, of the discussions and analysis in environmental impact statements."[57] Importantly, if information that is essential for making a reasoned choice among

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[51] *Colorado Environmental Coalition v. Office of Legacy Management*, 819 F. Supp. 2d. 1193, 1209 (D. Colo. 2011), reconsideration granted in part on other grounds, 2012 U.S. Dist. LEXIS 24126 (D. Colo. Feb. 27, 2012) (concluding that future site-specific mining activity was reasonably foreseeable at the lease stage because mining had previously taken place on the same public lands and thus must be reviewed at the programmatic leasing stage.)
[52] Kern v. U.S. Bureau of Land Mgmt., 284 F.3d at 1072.
[53] *See* 40 C.F.R. §§ 1501.2, 1502.5; *Save Our Ecosystems v. Clark*, 747 F.2d 1240, 1246 n. 9 (9th Cir.1984) ("Reasonable forecasting and speculation is . . . implicit in NEPA, and we must reject any attempt by agencies to shirk their responsibilities under NEPA by labeling any and all discussion of future environmental effects as 'crystal ball inquiry,'" *quoting Scientists' Inst. for Pub. Info., Inc. v. Atomic Energy Comm'n*, 481 F.2d 1079, 1092 (D.C. Cir.1973)); *City of Davis v. Coleman*, 521 F.2d 661, 676 (9th Cir. 1975) ("the purpose of an [EIS] is to evaluate the possibilities in light of current and **contemplated** plans and to produce an informed estimate of the environmental consequences. . . . Drafting an [EIS] necessarily involves some degree of forecasting." (emphasis added)).
[54] *Neighbors of Cuddy Mountain v. U. S. Forest Service*, 137 F.3d 1372, 1379 (9th Cir. 1998); *Ecology Center v. Castaneda*, 574 F.3d 652, 666 (9th Cir. 2009) (requiring "quantified or detailed data"); *Natural Resources Defense Council v. Callaway*, 524 F.2d 79, 87 (2d Cir. 1975).
[55] South Fork Band Council v. U.S. Dept. of Interior, 588 F.3d 718 (9th Cir. 2009); Neighbors of Cuddy Mountain v. U.S. Forest Service, 137 F.3d 1372, 1379-80 (9th Cir. 1998).
[56] *Seattle Audubon Society v. Moseley*, 798 F. Supp. 1473, 1479 (W.D. Wash. 1992), *aff'd* 998 F.2d (9th Cir. 1993); *see also, e.g.*, *Klamath-Siskiyou Wildlands Ctr. v. BLM*, 387 F.3d 989,995-996 (9th Cir. 2004) ("generalized or conclusory statements" in cumulative effects analyses do not satisfy NEPA); *Friends of the Earth v. Army Corps of Engineers*, 109 F. Supp. 2d 30, 38 (D.D.C. 2000) (ruling that the Corps must "provide further analysis" to satisfy NEPA because the Corps did not provide "the basis for any" of its claims that the project would have an insignificant impact or that fish and other organisms would simply move to other areas); *Sierra Club v. Norton*, 207 F. Supp. 2d 1310, 1335 (S.D. Ala. 2002) (stating "Defendant's argument in this case would turn NEPA on its head, making ignorance into a powerful factor in favor of immediate action where the agency lacks sufficient data to conclusively show not only that proposed action would harm an endangered species, but that the harm would prove to be 'significant'").
[57] 40 C.F.R. § 1502.24 ("Agencies shall insure professional integrity, including scientific integrity, of the discussions and analysis in environmental impact statements"); *Earth Island Inst. v. U.S. Forest Service*, 442 F.3d 1147, 1159-60 (9th Cir. 2006) (quoting 40 CFR §1502.24).

alternatives is not available, the Corps **must** obtain that information unless the costs of doing so would be "exorbitant."[58]

As discussed throughout these comments, the DSEIS violates these fundamental NEPA requirements, including by relying extensively on unsupported conclusory statements and generalizations, failing to include necessary information, and failing to ensure the scientific integrity of its analyses. Because of the many failings, the DSEIS profoundly understates the adverse impacts of the alternatives assessed in the DSEIS.

At the most fundamental level, key problems with the DSEIS can be traced to its excessive focus on engineering outcomes and acres of physical habitat affected, while ignoring critical biological implications of the Project and the preferred alternative. Moreover, the extremely limited assessments of biological impacts in the DSEIS are poorly tied to the claimed environmental benefits of the Project and the vaguely defined mitigation. The claimed positive environmental actions that may be carried out under the preferred alternative, such as notching dikes, will not result in meaningful ecological benefits. For example, a 2012 study found that single feature restoration projects, such as the placement of weirs to increase habitat heterogeneity, are not effective at achieving biodiversity goals. That study recommends "baseline attributes and historic conditions be assessed and integrated into project design and implementation" to ensure the restoration strategy is truly site appropriate.[59] Similarly, a 2009 study found that almost all restoration projects that focused exclusively on rehabilitated physical habitat failed to restore invertebrate biodiversity.[60] The DSEIS should carefully evaluate these studies.

The Conservation Organizations also note that the DSEIS fails to analyze how the Project may affect the broader restoration goals for, and efforts on, the Middle Mississippi River. The DSEIS should include this evaluation and identify and explain how the Project will affect the Corps' other missions and projects along the Middle Mississippi River, including restoration and flood damage reduction efforts. The Corps should also work with the full array of resource agencies, and the public, to improve management of the Mississippi River, including by implementing a robust monitoring plan to evaluate the effectiveness of those efforts. These efforts would be greatly facilitated through the development of an environmental impact statement for the entire Upper Mississippi River-Illinois Waterway navigation system

1. The DSEIS Fails to Examine Reasonably Foreseeable Site-Specific Impacts

The DSEIS violates NEPA because it fails to examine reasonably foreseeable site-specific impacts.

As discussed above, where, site-specific impacts are "reasonably foreseeable" at the program planning stage, they must be evaluated in the programmatic EIS.[61] The Corps may not evade this requirement by saying these impacts will be examined through later environmental reviews.[62]

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58 40 C.F.R. § 1502.22.

59 Salant, NL, JC Schmidt, P Budy, and PR Wilcock. 2012. Unintended consequences of restoration: loss of riffles and gravel substrates following weir installation. *J Environ Manage* 109:154-63.

60 Palmer, MA, HL Minninger, E Bernhardt. 2010. River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? *Freshwater Biology* 55 (Suppl. 1), 205–222.

61 *Colorado Environmental Coalition v. Office of Legacy Management*, 819 F. Supp. 2d. 1193, 1209 (D. Colo. 2011), reconsideration granted in part on other grounds, 2012 U.S. Dist. LEXIS 24126 (D. Colo. Feb. 27, 2012) (concluding that future site-specific mining activity was reasonably foreseeable at the lease stage because mining had previously taken place on the same public lands and thus must be reviewed at the programmatic leasing stage.)

62 Kern v. U.S. Bureau of Land Mgmt., 284 F.3d at 1072.

Site-specific impacts are reasonably foreseeable for the Project because the Corps has seen the impacts of the Project for more than a century. During the past 100 years, the Corps has seen the impacts of: constructing an extensive array of river training structures; repeated and extensive dredging and dredged spoil disposal; and placing revetment on some 60 percent of the banks of the Middle Mississippi River. The Corps also has extensive experience with those areas in the Middle Mississippi River that require repeated dredging. The Corps also has extensive experience with the way in which river training structures can shift the locations where repetitive dredging may be required.

Because site specific impacts of the Project are reasonably foreseeable, the DSEIS is required to analyze those impacts.

2. The DSEIS Lacks Scientific Integrity

The DSEIS violates NEPA because it lacks scientific integrity.

"Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA."[63] Accordingly, the DSEIS must be based on "high quality" science and information and the Corps must "insure professional integrity, including scientific integrity, of the discussions and analysis in environmental impact statements."[64] Importantly, if information that is essential for making a reasoned choice among alternatives is not available, the Corps **must** obtain that information unless the costs of doing so would be "exorbitant."[65]

An EIS must utilize "quantified or detailed information" when analyzing impacts.[66] The DSEIS may not rely "on conclusory statements unsupported by data, authorities, or explanatory information."[67] Accordingly, the DSEIS must supply supporting data and authorities, and explain how and why it has drawn the conclusion it has reached.

The Corps must also candidly disclose the risks of its proposed action and respond to adverse opinions held by respected scientists:[68]

> "'Where scientists disagree about possible adverse environmental effect, the EIS must inform decision-makers of the full range of responsible opinion on the environmental effects.' Where the agency fails to acknowledge the opinions held by well respected scientists concerning the hazards of the proposed action, the EIS is fatally deficient."[69]

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[63] 40 C.F.R. § 1500.1(b).

[64] 40 C.F.R. § 1502.24 ("Agencies shall insure professional integrity, including scientific integrity, of the discussions and analysis in environmental impact statements"); *Earth Island Inst. v. U.S. Forest Service*, 442 F.3d 1147, 1159-60 (9th Cir. 2006) (quoting 40 CFR §1502.24).

[65] 40 C.F.R. § 1502.22.

[66] *Neighbors of Cuddy Mountain v. U. S. Forest Service*, 137 F.3d 1372, 1379 (9th Cir. 1998); *Ecology Center v. Castaneda*, 574 F.3d 652, 666 (9th Cir. 2009) (requiring "quantified or detailed data"); *Natural Resources Defense Council v. Callaway*, 524 F.2d 79, 87 (2d Cir. 1975).

[67] *Id*.

[68] *Seattle Audubon Soc'y v. Mosely*, 798 F.Supp. 1473, 1482 (W.D. Wash. 1992) (citing *Friends of the Earth v. Hall*, 693 F.Supp. 904, 934, 937 (W.D.Wash. 1988).

[69] *Friends of the Earth v. Hall*, 693 F. Supp. 904, 934 (W.D. Wash. 1988) (citations omitted).

It is not sufficient to include the statements of independent experts, including the Independent External Peer Review panel, in an Appendix or some other document. The expert comments must be included and appropriately responded to in the impacts section of the DSEIS.[70]

The DSEIS fails to meet these important and longstanding NEPA requirements, including by lacking scientific credibility across the board, as discussed below. The DSEIS also lacks scientific integrity because it fails to evaluate critical information discussed throughout Section II.C of these comments.

(a) Flood Heights and Flood Response

As discussed extensively in Section II.C.4 of these comments, the DSEIS' contention that river training structures do not increase flood heights lacks scientific credibility.

(b) Sediment Loading, Sediment Transport, Hydrology and Hydraulics

The DSEIS lacks fundamental information on sediment loading, sediment transport, hydrology and hydraulics in the Middle Mississippi River despite the fundamental purpose of the Regulating Works Project. The purpose of the Regulating Works Project is to maintain navigation on the Middle Mississippi River, which historically has been carried out through the sediment management practices of dredging and river training structure construction.

Despite the fact that sediment loads drive the Project, the DSEIS fails to provide sufficient data regarding the sediment load of the Middle Mississippi River or the River's sediment transport capabilities. This failing was identified by the IEPR panel, which concluded that the panel could not "judge whether structures and dredging designs are based on robust science, data and engineering" because the DSEIS does not provide meaningful information on sediment load and transport in the DSEIS.[71] The IEPR Panel recommends that the DSEIS be revised to include the following information:

- "Annual percentages and load from Missouri River and Upper Mississippi River."
- "Sediment properties for both bed load and suspended load – particle size, settling velocity, specific gravity, and fraction distribution within each particle size."
- "Annual volumes entering the MMR, temporarily and permanently deposited in the MMR, and exiting the MMR as compared to annual dredging load."
- "Relationship between channel conveyance, flood hydrographs (i.e., rising leg and falling leg), bed load, suspended sediment load, and sediment transportation."
- "Percentage of total bed load and suspended sediment load that is dredged."[72]

The Conservation Organizations note that there have been significant advancements in the understanding of large river sediment transport and deposition documented in hundreds of published

[70] *Id*.
[71] IEPR Final Report at 9
[72] *Id*.

scientific studies since the 1976 EIS was finalized.[73] This extensive body of science should be evaluated by the Corps and addressed in the DSEIS. As the IEPR panel notes, a "[s]trong working knowledge of sediment characteristics is necessary to design and construct effective regulating structures and conduct annual dredging programs."[74]

The IEPR Report also concluded that "the SEIS has little information on the hydraulic and hydrologic engineering data for the MMR."[75] While the IEPR panel concluded that the 1976 EIS contained sufficient data for this review, this finding is contradicted by the DSEIS and common sense. According to the DSEIS, the hydraulic and hydrology of the Middle Mississippi River has changed significantly since 1976:

> "Generally there has been an increase in cross sectional area, hydraulic depth, conveyance and volume throughout the period of record (Little et al. 2016). The Regulating Works Project has contributed to these changes, although it is uncertain to what extent." DSEIS at 44.

The DSEIS lacks scientific credibility because it fails to include fundamentally important data and information on sediment loading, sediment transport, hydrology, and hydraulics.

(c) Main Channel Border Habitat Model

The DSEIS assessment of main channel border habitat is based on an incomplete, and uncertified border habitat model. According to the DSEIS:

> "Actual acreages affected would not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.[76]

This failing is particularly critical since the DSEIS recognizes that the preferred alternative will cause significant adverse impacts to main channel border habitat, and those impacts will add to the already extremely significant loss of 34.85% of this habitat in the Middle Mississippi River.[77] *See* Section II.C.5 of these comments for an additional discussion of problems with the DSEIS assessment of main channel border habitat.

This model should have been completed, certified, and used to assess impacts before the DSEIS was completed because it is essential for making a reasoned choice among alternatives. As a result, the Corps **must** obtain this information unless the costs of doing so would be "exorbitant."[78]

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[73] E.g., DeHaan, H.C. 1998, *Large River Sediment Transport and Deposition: An Annotated Bibliography,* U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, April 1998, LTRMP 98-T002. 85 pp. (identifying more than 250 scientific studies addressing large river sediment transport and deposition published since 1976): Pierre Y. Julien and Chad W. Vensel, Department of Civil and Environmental Engineering Colorado State University, *Review of Sedimentation Issues on the Mississippi River*, DRAFT Report Presented to the UNESCO: ISI, November 2005 (referencing more than 100 studies published between 1979 and 2005).
[74] IEPR Final Report at 9.
[75] IEPR Final Report at 5.
[76] DSEIS at 56, n.22
[77] *See* DSEIS at 156 (from 1976 to 2014, the amount of unstructured main channel border habitat in the MMR decreased from 19,800 acres to 12,900; "river training structure construction affected approximately 6,900 acres of main channel border habitat from 1976 to 2014).
[78] 40 C.F.R. § 1502.22.

The model also may not be used for planning purposes until it is finalized, independently reviewed, and certified. 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 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.

(d) Nineteen Mile Modeled Reach

The DSEIS lacks critical information on both the model used to assess the 19 mile reach of the Middle Mississippi River and on the characteristics of that modeled reach. The DSEIS also does not indicate whether the model has been independently reviewed and certified, as required by the Corps' internal guidelines EC 1105-2-412, EC 1105-2-408, and EC-1105-2-410. The accuracy and reliability of this model is particularly important because it forms the basis for the Corps' entire impacts analysis.

In addition to the potential lack of independent review and model certification, at least the following additional information must be provided in the DSEIS to assist the public and decision makers in assessing the adequacy, and potential accuracy, of the model:

1. The number and types of river training structures that are in the modeled reach.
2. The total length of river training structures in the modeled reach.
3. The height and widths of the river training structures in the modeled reach.
4. The information in 1-3 should also be provided for each different type of river training structure (*e.g.*, wing dike, bendway weir, chevron, other).

5. The linear feet and acreage of natural main channel border habitat in the modeled reach, and the linear feet and acreage of wetlands both in the main channel border habitat and in the adjacent floodplain.
6. The baseline depth data for the modeled reach.
7. The baseline flow patterns in the modeled reach.
8. The locations and areal extent of areas within the modeled reach that require repetitive dredging.
9. The length and width of revetment in the modeled reach.
10. Sufficient details concerning the model used to allow an independent reviewer to assess the adequacy of the model used.

In addition, the DSEIS should document that the length and characteristic of the modeled reach are statistically significant for assessing impacts to the entire Middle Mississippi River (the modeled reach accounts for just 9.75% of the length of the Middle Mississippi River). To properly analyze flood height impacts, the model should also **not be biased** towards shallower flows as river training structures have a greater impact on flood heights during high flow events.

The DSEIS should also provide detailed information on the cost and "time consuming" nature of modeling the full Middle Mississippi or multiple reaches of the Middle Mississppi. Because the modeled information is essential for making a reasoned choice among alternatives, the Corps must obtain the information unless the costs of doing so would be "exorbitant."[79] Without the cost and time data, it is not possible to assess whether the costs of addition modeling would in fact be "exorbitant" and thus, not required.

The DSEIS should also provide evidence demonstrating that this model was certified and independently reviewed pursuant to EC 1105-2-412, EC 1105-2-408, and EC-1105-2-410. These Engineering Regulations are discussed above.

(e) Independent External Peer Review Panel Comments

The DSEIS fails to include the concerns raised by the Independent External Peer Review Panel (IEPR Panel), and fails to address those concerns. Indeed, the DSEIS does not even mention the existence of the IEPR Panel. It is not sufficient to include the statements of the IEPR Panel in a separate report or Appendix, the expert comments must be included and appropriately responded to in body of the DSEIS.[80] This failure to address the concerns of the IEPR Panel renders the DSEIS "fatally deficient."[81]

The IEPR Panel made the following findings, each of which demonstrates that the DSEIS lacks the most basic and fundamental information needed to assess Project impacts:

1. "It is not clear why impacts of future river training structure construction and the associated compensatory mitigation requirements were not evaluated in more detail with respect to specific locations in the MMR."

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[79] 40 C.F.R. § 1502.22.
[80] *Friends of the Earth v. Hall*, 693 F. Supp. 904, 934 (W.D. Wash. 1988) (citations omitted).
[81] *Id*.

2. "The project description for the proposed action does not describe the decision-making process that will be employed for identifying new river training structure construction sites."

3. "The SEIS does not clearly describe the project construction features within the main report such that a link between the project and the level of impacts can be easily compared."

4. "A lack of detailed information on the sediment load entering the MMR limits the understanding of the overall effort needed to achieve the project's stated purpose of providing an economical, regulated, and dredged navigation channel."[82]

(f) Independent Peer Review Panel Report and Membership

The existence of the IEPR Panel has not ensured the scientific credibility of the DSEIS for at least three reasons. *First*, as noted above, the DSEIS does not address the issues raised by the IEPR Panel.

Second, the IEPR Panel conducted only an extremely limited review and was provided with only limited information on the highly controversial issue of the impact of river training structures on flood stages. As a result, the Panel did not meaningfully "assess the 'adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used' (EC 1165-2-214; p. D-4) for the MMR Regulating Works SEIS documents" as required by the Corps' stated Objectives for the IEPR Panel.[83] Contrary to the IEPR Panel charge, the Panel also did not: "identify, explain, and comment upon assumptions that underlie all the analyses"; "evaluate the soundness of models, surveys, investigations, and methods"; or "evaluate whether the interpretations of analysis and the conclusions based on analysis are reasonable." The Conservation Organizations also note that the Final IEPR Report contains just five partial pages of substantive results and discussion,[84] and cites only three references.[85]

Critically, the IEPR Panel was only provided with the Corps' views on river training structures and flood stage as set forth in the 30 page Appendix A (Effects of River Training Structures on Flood Levels) of the DSEIS.[86] The IEPR Panel did not receive the extensive array of information on this critical topic that the Conservation Organizations have provided to the Corps over the past 5 years in connection with previous comments on Environmental Assessments for river training structure projects, scoping comments on the DSEIS, and federal litigation. During this period, the Conservation Organizations provided the Corps with a list of scientific references that included approximately 500 pages of scientific research linking river training structures to flood risk in previous comments, copies of a number of those studies, and two critical Affidavits that lay out the scientific case demonstrating that river training structures affect flood heights and that provide a point-by-point rebuttal of the Corps' conclusions on this issue.

Appendix A does not provide a balanced assessment of the science and cannot support a meaningful independent review of the impact of river training structures on river and flood stages. The language in Appendix A is both biased and dismissive of the findings of other respected scientists, and demonstrates a significant degree of animosity between the St. Louis District and independent scientists. While

[82] Final IEPR Report.
[83] Final IEPR Report, Appendix C.
[84] Final IEPR Report at 5-9.
[85] Final IEPR Report at 10.
[86] Final IEPR Report, Appendix C at C-6.

Appendix A contends that the Corps' models and findings have been reviewed by "other external reviewers" Appendix A does not provide the identities or affiliations of these reviewers and does not discuss their qualifications.

Third, the IEPR Panel has, at a minimum, a strong appearance of lack of meaningful independence and, at worse, in fact lacks the independence required for a meaningful independent review. The IEPR Panel also included an inappropriately small number of reviewers.

Collectively, the members of the IEPR Panel have worked directly for the Corps for 63 years. Each IEPR Panel members has worked for the Corps for a significant portion of their professional lives: one panel member worked for the Corps for 31 years; one panel member worked for the Corps for 19 years; and one panel member worked for the Corps for 13 years. Each IEPR Panel member has worked on previous IEPR Panel reviews for Corps civil works projects. The Conservation Organizations are extremely concerned that this extensive history of working with and for the Corps biases Panel members towards agreeing with, or minimizing critique of, Corps methodologies, models, and evaluations. This problem is amplified by the fact that there were only three reviewers on the IEPR Panel – despite the significance of the scientific controversies surrounding the Project, the extensive scope of the Project, and the significant impacts of the Project. Such a small panel for such a large project calls into question whether the panel really had the full range of expertise needed to review the DSEIS. By comparison, the IEPR Panel for the St Johns Bayou New Madrid Floodway Project had eight panelists.

As discussed elsewhere in these comments, the Conservation Organizations urge the Corps to initiate a National Academy of Sciences study on river training structures and flood heights. The Corps should also convene a new, larger, and more Independent External Peer Review Panel to evaluate the DSEIS and the Final DSEIS.

(g) Economic Data and Analyses

The DSEIS provides only the most rudimentary, general, and unsupported analysis of the potential cost of future river training structure construction and mitigation. *See* DSEIS, Appendix C at 9-11. The DSEIS explicitly does not provide any economic analysis of the Regulating Works Project, despite the fact that the preferred alternative recommends extensive new, ongoing construction for at least 17 years:

> "The purpose of this document is to analyze the environmental impacts of the Regulating Works Project in the context of the new circumstances and information that has become available since the 1976 EIS was produced. Accordingly, this SEIS does not include a detailed economic evaluation of the Regulating Works Project. The future economic updates that are performed for the Project will include current information on construction costs, dredging costs, and any mitigation costs. These future economic updates may also result in an updated estimated quantity of construction and mitigation, which will be appropriately evaluated and assessed when completed." DSEIS at 27.

This lack of a meaningful economic analysis is particularly problematic since the DSEIS claims that new river training structure construction is needed to reduce the costs of maintaining the navigation channel. Without a detailed assessment of project costs **and** benefits, it is not possible to determine whether this stated goal would in fact be met. To assess the benefits and costs of the preferred alternative, the DSEIS should assess at least the following information:

(1) The projected future costs of required dredging for each alternative evaluated in the DSEIS, and each of the other highly reasonable alternatives identified in these comments, calculated for the life Project.
(2) The construction and full life cycle maintenance costs of river training structures that would be constructed under the New Construction Alternative;
(3) A meaningful assessment of mitigation costs for each alternative, including the costs associated with monitoring (as required by law), adaptive management and contingency planning should the mitigation not achieve ecological success criteria as required by law;
(4) The costs associated with increased risks of upstream or nearby levee failures should new river training structure construction increase flood heights.
(5) The value of the ecosystem services that will be lost under each alternative.

In addition, due to the extensive construction of new river training structure projects under the preferred alternative, the DSEIS should also include a National Economic Development (NED) analysis to compare alternatives. In this needed analysis, the DSEIS should evaluate the full range of ecosystem services that will be lost due to the construction of the preferred alternative.

The DSEIS lacks scientific credibility because it fails to include basic and necessary economic data.

3. The DSEIS Fails to Accurately Establish Baseline Conditions

The DSEIS violates NEPA because it fails to accurately establish and consider baseline conditions. It is well established that:

> "Without establishing the baseline conditions ... there is simply no way to determine what effect the [action] will have on the environment, and consequently, no way to comply with NEPA."[87]

Properly establishing baseline conditions requires accurate and comprehensive data on baseline conditions. Without baseline data, "an agency cannot carefully consider information about significant environment impacts. Thus, the agency fails to consider an important aspect of the problem, resulting in an arbitrary and capricious decision."[88] If information that is essential for making a reasoned choice among alternatives is not available, the Corps must obtain that information unless the costs of doing so would be "exorbitant."[89]

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[87] *Half Moon Bay Fisherman's Mktg. Ass'n. v. Carlucci,* 857 F.2d 505, 510 (9th Cir.1988). As a result, the entire DSEIS is inadequate as a matter of law. *E.g.*, *Friends of Back Bay v. U.S. Army Corps of Engineers*, 681 F.3d 581, 588 (4th Cir. 2012) (an EIS fails to comply with NEPA if it relies on a "material misapprehension of the baseline conditions.")

[88] *N. Plains Res. Council, Inc. v. Surface Transp. Bd.*, 668 F.3d 1067, 1083, 1085 (9th Cir. 2011) (the EIS did "not provide baseline data for many of the species" of concern and thus "did not take a sufficiently 'hard look'" to fulfill its NEPA-imposed obligations at the impacts as to these species).

[89] 40 C.F.R. § 1502.22. *See also*, *Half Moon Bay Fisherman's Mktg. Ass'n.* 857 F.2d 505; N. Plains Res. Council, 668 F.3d 1067; *Gifford Pinchot Task Force v. Perez*, No. 03:13-CV-00810-HZ, 2014 WL 3019165, at *27-29 (D. Or. July 3, 2014), *appeal dismissed* (Dec. 23, 2014), *appeal dismissed* (Dec. 29, 2014); *Idaho Conservation League v. U.S. Forest Serv.,* No. 1: 11 –CV–00341 -EJL, 2012 WL 3758161, at *16 (D.Idaho Aug. 29, 2012) (analyzing an EA, ruling that the agency needed to conduct a baseline study and actual investigation of groundwater before reaching a conclusion regarding the impacts of a mining project on groundwater).

Properly establishing baseline conditions also requires a clear description of "how conditions have changed over time and how they are likely to change in the future without the proposed action" to determine whether additional stresses will push this system over the edge.[90] This is particularly important in situations, like those in the Middle Mississippi River, where the environment has already been greatly modified by human activities because it "is often the case that when a large proportion of a resource is lost, the system nears collapse as the surviving portion is pressed into service to perform more functions."[91]

The DSEIS fails to meet these requirements because the DSEIS:

(a) Lacks fundamental baseline data on flood heights. Notably, the DSEIS improperly dismisses extensive and highly credible information on flood level increases and on fundamental changes to the way the Middle Mississippi River responds to flood events.[92] The Corps' refusal to acknowledge the validity of this information, and account for these changes—and the role of river training structures in creating these dangerous conditions—taints the entire DSEIS.

(a) Lacks fundamental baseline data on sedimentation rates.

(b) Lacks fundamental baseline data on fish and wildlife species, including migratory species, and their critical habitat needs. The DSEIS fails even to identify the vast majority of the many hundreds of individual species that rely on the Middle Mississippi River and its floodplain, including particularly those species that rely on diverse braided river habitats, slow moving river habitats, border channel habitats, and floodplain wetlands. Critically, the DSEIS also fails to provide any information on the various habitats needed throughout the full life cycles of those species, including habitat and flows needed to support breeding (including access to the floodplain), rearing, feeding, and resting.

(c) Lacks fundamental baseline data on plant species, including wetland plant species.

(d) Lacks fundamental baseline data on vitally important habitat types, including main channel border habitat, braided river habitat, wetland habitat, and floodplain habitat. Despite the significant losses of main channel border habitat from the preferred alternative, the DSEIS does not describe the ecological characteristics of this habitat, does not identify the full suite of fish and wildlife species that utilize this habitat, and does not provide information on the direct, indirect, and cumulative effects of the loss of this habitat.

(e) Fails to meaningfully evaluate the potential impacts of channel cutoffs. Channel cut offs can have significant consequences for conditions in the Middle Mississippi River. One location of particular concern is the potential for a channel cut off at Dogtooth Bend. For this location, the DSEIS states only that "[a]nother site that has shown the potential of a channel cutoff is at Dogtooth Bend at river mile 33. A cutoff at Dogtooth Bend would reduce the length of the MMR by approximately 16 – 18 miles. The consequences of a channel cutoff at Dogtooth Bend would be similar to those at Thompson Bend." DESIS at 13. The implications of such a change are

[90] Council on Environmental Quality, Considering Cumulative Effects Under the National Environmental Policy Act at 41 (January 1997).
[91] *Id*.
[92] *See* Section II.C.4 of these comments.

significant and should be analyzed in far more depth. Important information on this situation is included in a 2016 study by Olson and Morton. A copy of this study is provided at Attachment A. The DSEIs should fully assess the potential implications of a channel cutoff at this and other locations, and develop a comprehensive approach to the problem.

(f) The discussion of baseline conditions fails to discuss and account for the significant decline in the ecological health of the Mississippi River and the role of the Regulating Works Project in that decline. These issues must be addressed in the discussion of baseline conditions; it is not enough to simply incorporate by reference numerous past studies that document this significant decline.[93]

Because of these failings, the DSEIS fails to take the "hard look" at impacts required by NEPA and fails to comply with the Act.

4. The DSEIS Fails to Adequately Evaluate Impacts on Flooding

The DSEIS fails to adequately evaluate the impacts of the Regulating Works Project, and particularly the construction of river training structures, on flood heights. The DSEIS instead rejects the extensive body of scientific evidence demonstrating that such structures increase flood heights and that the extensive array of these structures has fundamentally changed the way the Middle Mississippi River responds to flood events.

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 study would cost far less than a single river training structure, and the costs of the study would be far outweighed by the public benefits of an NAS review. Importantly, an NAS study would increase the public's confidence in the decision making process. There currently is intense public opposition to constructing new river training structures, due to their flood risks.[94]

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.[95] 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

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[93] *See* DSEIS at 166.

[94] *See, e.g.*, the extensive public scoping comments for this Project, the extensive public comments on this DSEIS, and the strong opposition by local community members to the revised Grand Tower Environmental Assessment expressed at the March 9, 2016 and February 19, 2014 public hearings on the Grand Tower project.

[95] 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.

the DSEIS (*e.g.*, Watson et al., 2013a, DEIS at 40 and Appendix A) find statistically significant increases in water levels for flood flows.

Scientific evidence directly contradicting the Corps' findings on river training structures continues to accumulate. In his comments on the Regulating Works Project Grand Tower Amended Environmental Assessment, 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 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."[96]

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."[97]

A 2016 Journal of Earth Science study co-authored by Dr. Criss ("Criss and Luo 2016") highlights the cumulative impact 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":[98]

> "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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[96] Comments on Draft Environmental Assessment by Robert E Criss, Washington University, March 3, 2016 (emphasis added).
[97] *Id*.
[98] 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).

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 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).

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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."[99]

A copy of Criss and Luo 2016 is provided at Attachment B.

The critique of Criss and Luo 2016 in Appendix A to the DSEIS is fundamentally flawed. That critique does not address the content of the study, and instead focuses on a single locality (Chester) that was scarcely mentioned in the study. The DSEIS discussion of this single locality (Chester) inappropriately compares the recent winter flood with prior, warm weather floods, and rising limb data with falling limb data.

In addition, the DSEIS critique, does not—and cannot—explain away critical findings in Criss and Luo 2016, including the findings related to:

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[99] 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).

(1) The record high stages set during this recent flood just downstream at Cape Girardeau and Thebes, which as Criss and Luo point out would have been far higher but for the catastrophic failure of the Len Small levee.
(2) Why the recent peak stage at Chester was nearly 3 feet higher than it was on April 30, 1973, which at that time was the highest water level ever recorded at that site.
(3) The unusual winter timing of this recent flood and its short duration, both of which would not have caused a flood of this magnitude without constriction of the river.
(4) Why the site showing the greatest increase in stage over previous floods occurred adjacent to the Valley Park levee, built by the Corps in 2005.

Moreover, contrary to the assertions in the DSEIS critique, the Criss and Luo 2016 synopsis of weather conditions clearly acknowledges antecedent ground saturation, and all data used by Criss and Luo are identical to values reported by the cited federal agencies at the time of writing. Each of those values remains identical to the values reported today with the single exception that the 1982 stage at Pacific was revised subsequently by the National Weather Service. However, this change has no effect on the Criss and Luo 2016 conclusions.

The Corps' conclusion that river training structures do not affect flood heights has been conclusively 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 by the Corps. The series of exchanges between Dr. Pinter and Watson are provided at Attachment C. Dr. Pinter has also rebutted the Corps' conclusion in sworn affidavits submitted to the District Court for the Southern District of Illinois. These affidavits are provided at Attachment D.

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 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."[100]

The Conservation Organizations urge the Corps to fully consider the information provided by Dr. Pinter in these rebuttals.

The failure to acknowledge and account for the significant increases in flood heights and the fundamental changes to the way the Middle Mississippi River responds to floods caused by river training structures renders the DSEIS fundamentally, and dangerously flawed.

5. The DSEIS Fails to Adequately Evaluate Impacts to Main Channel Border Habitat

Despite recognizing that the preferred alternative will result in the loss of at least "1,100 acres (8%) of the remaining unstructured main channel border habitat,"[101] the DSEIS fails to meaningfully evaluate the full extent of main channel border habitat impacts, fails to meaningfully evaluate the ecological implications of those losses, and fails to evaluate the additive implications of those losses in light of the already highly significant losses of main channel border habitat to date

The Conservation Organizations note that based on the information provided in the DSEIS the 1,100 acre loss would actually constitute an 8.53% loss of existing main channel border habitat (1,100 acres of the remaining 12,900 acres), not 8% has indicated in the DSEIS. Given the 34.85% loss of main channel border habitat to date due to river training structures,[102] it is important to accurately state the additional percentage of habitat that might be lost.

The DSEIS fails to provide an accurate assessment of the areal extent and locations of adverse impacts to main channel border habitat for at least the following four reasons:

(1) The DSEIS assessment that 1,100 (8%) of the remaining unstructured main channel border habitat will be lost is based on an incomplete border habitat model. DSEIS at 56, n.22 ("Actual acreages affected would not be known until the main channel border habitat model is completed and is subsequently used to determine impacts on an ongoing site-by-site basis.) This model should have been completed, certified, and used to assess impacts before the DSEIS was completed.

(2) The incomplete main channel border habitat model appears to have been applied to the extremely limited and problematic analysis of the 19 Mile Modeled Reach. *See* Section II.C.2 of these comments for a discussion of problems with the Modeled Reach.

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[100] 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.

[101] DSEIS at 26.

[102] *See* DSEIS at 156 (from 1976 to 2014, the amount of unstructured main channel border habitat in the MMR decreased from 19,800 acres to 12,900; "river training structure construction affected approximately 6,900 acres of main channel border habitat from 1976 to 2014).

(3) The DSEIS does not meaningfully analyze the additive losses to main channel border habitat that will be caused by the disposal of dredged spoil. According to the DSEIS, “550 acres of main channel and main channel border habitat are impacted by dredged material disposal. These are anticipated to decrease to approximately 330 acres each with the Continue Construction.” DSEIS at 136. While the Corps presumably knows the precise locations of its dredged spoil disposal, the DSEIS does not provide information on dredged spoil disposal within the main channel border habitat alone.

Based on the information provided in the DSEIS, in a worse-case scenario, the Middle Mississippi River could be losing 550 acres of main channel border habitat each year from the disposal of dredged spoil alone. Under the preferred alternative, this could eventually drop to 330 acres of impact to main channel border habitat each year at the end of 17 years. Since the Corps appears to contemplate dredging in perpetuity, these losses would also continue into perpetuity. Even using a conservative estimate of 100 acres of side channel habitat impacted by dredged disposal for each of the next 17 years (when the Corps currently estimates an end to river training structure construction), dredged disposal would cause an additional 1,700 acre loss of main channel border habitat during this period, more than doubling the 1,100 acres of border habitat loss estimated from river training structure construction alone. The full extent of direct, indirect, and cumulative impacts to main channel border habitat from all aspects of the Project must be assessed and mitigated.

In addition, DSEIS Appendix C suggests that impacts to main channel border habitat from river training construction alone could be much higher than 1100 acres: “It was calculated that the impact of all construction necessary to achieve the maximum dredging reduction as determined by the Expert Elicitation was 1774 acres of main channel border.”[103]

(4) The assessment of impacts is limited to an estimate of acreage losses. While it is important to know the acreage losses, to assess impacts in a river system, it is equally important to know the total linear feet and likely locations of such losses. This information is essential for assessing the true extent of impacts, including assessing whether significant losses will occur in areas that are of particular importance to key species, or assessing whether such losses will occur in areas where natural main channel border habitat has already been significantly compromised.

The DSEIS also fails to meaningfully evaluate the ecological losses that will stem from the significant losses of main channel border habitat. For example:

(1) The DSEIS fails to provide even the most basic information on the ecological characteristics of main channel border habitat. Indeed, the DSEIS states only that main channel border habitat is “defined as areas shallower than LWRP -10 without river training structures.” DSEIS at 156. As the St. Louis District has recognized in the past, main channel border habitat has important ecological characteristics. For example, in 1998 the St. Louis District provided this definition of main channel border habitat in the Upper Mississippi River:

> “The zone lines between the 9-foot channel and the main riverbank, islands, or submerged definitions of the old main river channel. The bottom is mostly sand

[103] DSEIS, Appendix C at 3.

> along the main channel border in the upper sections of a pool and silt in the lower. On the MR there are 87,833 acres of main channel border habitat. . . . The main channel border is a primary habitat for freshwater mussels, and the basis for the commercial mussel industry. Furbearers use this area as they do side channels and backwaters for feeding, and the banks occasionally serve as den sites. Shore and wading birds use the shallow waters within the main channel border for feeding. Some waterfowl use can also be noted, mainly by wood ducks and mallards. . . . Main channel border is classified primarily as riverine unconsolidated shore, but may also include riverine aquatic bed and emergent wetlands."[104]

This 1998 definition for the Upper Mississippi River suggests that the loss of a significant portion of the remaining main border habitat would have ecological impacts far beyond benthic organisms and fisheries. *See* DSEIS at 74, 77. The DSEIS should evaluate impacts to the various habitat types located within the main channel border habitat, and assess the impacts to the fish and wildlife species that utilize those various habitats.

(2) The DSEIS also does not identify the vast array of fish and wildlife species that utilize the main channel border, and does not provide a meaningful assessment of the direct, indirect, and cumulative adverse impacts to the full array of fish and wildlife resources from the significant additional losses to main channel border habitat. The DSEIS does not examine any impacts at all to non-fish species that utilize main border channel habitat. While the DSEIS does identify some fish species that prefer main border channel habitat, it provides little information on the impacts to those species. The DSEIS instead focuses its fisheries impact analysis on changes in fish densities surrounding river training structures and impacts of entrainment during dredging.

For example, the DSEIS fails to discuss or reference an important 2004 study which shows that in the Middle Mississippi River, main channel border habitat is a preferred habitat for the federally endangered Pallid sturgeon.[105] A copy of this study is provided at Attachment E to these comments. The DSEIS fails to discuss impacts to reptiles at all, even though a 2016 study shows that "[s]hallow, low-velocity habitat seems most important to turtles" in the Middle Mississippi River and that "smooth softshell turtles used open side channels and unstructured main-channel borders most often."[106]

(3) As discussed in Section II.C.16 of these comments, the DSEIS fails to account for the cumulative impacts of the loss of an additional 8.53% of main channel border habitat on top of the already extremely significant loss of 34.85% of main channel border habitat in the Middle Mississippi River. As a result, the DSEIS cannot satisfy the fundamental requirement

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[104] Draft Environmental Impact Statement, Second Lock at Locks and Dam No. 26 (replacement) Mississippi River, Alton, Illinois and Missouri (St. Louis District) 1986 at DEIS-65.
[105] Hurley, Keith L., Sheehan, Robert J., Heidinger, Roy C., Wills, Paul S. and Clevenstine, Bob. "Habitat Use by Middle Mississippi River Pallid Sturgeon." (Jul 2004), published in Transactions of the American Fisheries Society, Vol. 133, Issue 4 (July 2004) at doi: 10.1577/T03-042.
[106] Braun, Andrew P., Phelps, Quinton E. "Habitat Use by Five Turtle Species in the Middle Mississippi River." Chelonian Conservation and Biology Jun 2016: Vol. 15, Issue 1, pg(s) 62-68 doi: 10.2744/CCB-1156.1 (available at http://www.bioone.org/doi/abs/10.2744/CCB-1156.1).

to “determine the magnitude and significance of the environmental consequences” of the preferred alternative in the context of the cumulative effects of other past, present, and future actions.[107]

Notably, however, even the minimal information provided in the DSEIS demonstrates that the Project induced losses are so significant that the Corps should select the No New Construction alternative, or one of the other alternatives recommended for review in these comments. According to the DSEIS:

> “Although these unstructured main channel border habitats are part of a river system that is highly modified compared to its original state, they likely more closely resemble some of the habitats of the historic MMR. The continued conversion to structured habitat is expected to result in the continued functional change of the river from the unconfined, shifting, meandering river that was the historic condition, toward a river dominated by the deep, high velocity habitat of the main channel surrounded by structured main channel border habitat. This analysis also provides insight into the magnitude of the potential adverse effect to fish movement described above. Areas of unstructured main channel border habitat are more likely to provide the necessary movement and migration pathways required by the MMR fish community. Overall, the continued conversion to structured main channel border habitat is expected to have a significant adverse effect on the MMR fish community and the District has concluded that this would warrant compensatory mitigation.”

DSEIS at 156-157.

As the DSEIS properly concludes, this level of impact to main channel border habitat is “significant on technical, institutional, and public merits.” DSEIS at ES-26. The full suite of adverse impacts from this significant loss of main channel border habitat must be assessed in the DSEIS.

6. The DSEIS Fails to Evaluate Key Information Concerning Side Channels

The DSEIS properly recognizes the importance of side channel habitat in the Middle Mississippi River, and provides information on the threat to these important habitats due to greater isolation from the main channel caused in part by the trend toward decreasing stages at low to moderate river discharges. See DSEIS at 171.

However, the DSEIS fails to meaningfully assess and recognize the extent of the threat of such disconnection caused by river training structures, which are well recognized as causing cause lower water levels during low flow conditions. The DSEIS also fails to evaluate how trends in extreme flows (due to the construction of river training structures and climate change), may create additional side channel disconnections by transporting and depositing excessive sediment into the side channels. In the absence of this information, the DSEIS conclusion that the quantity of side channel habitat is stable or improving and that the Corps intends to avoid and minimize impacts to side channels is not supported by evidence. See DSEIS at 116.

The Conservation Organizations appreciate the effort that went into the side channel connectivity analysis in the DSEIS. See DSEIS at 53-58. However, this analysis focuses solely on hydrologic

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[107] Council on Environmental Quality, *Considering Cumulative Effects Under the National Environmental Policy Act* (January 1997) at 41 (emphasis added).

connectivity. The entire side channel analysis fails to address the biological value of side channel connectivity in the Middle Mississippi River and the impacts of the Project on those biological values. The DSEIS also does not provide information the side channel conditions that would maximize their value for fish and wildlife.

The DSEIS also fails to evaluate the impacts of climate change on the Middle Mississippi River side channels at both low and high flow conditions. Because the Middle Mississippi River is influenced by the Illinois, Upper Mississippi, Missouri, and Ohio Rivers, climate change is likely to have an extremely significant impact on the Middle Mississippi River and its vital side channels.

The DSEIS should provide a significantly more robust analysis of impacts to essential side channel habitat.

7. The DSEIS Fails to Evaluate Impacts to Braided Channel Habitat

An accurate assessment of fish and wildlife impacts requires a meaningful and accurate assessment of impacts to the full range of habitats that these species rely on. In addition to main channel border habitat and side channel habitat, important fish and wildlife habitat includes braided channels, crossover habitat, mid-channel bars, backwater habitat, riverine wetlands, and floodplain wetlands.

Impacts to braided channel habitat were highlighted in the Draft Environmental Assessment with Unsigned Finding of No Significant Impact, Regulating Work Projects Eliza Point/Greenfield Bend Phase 3; Public Notice P-2852 (2013-618). In that draft environmental assessment, the Corps wrote that the tentatively selected plan would result in 272.2 average annual habitat units for the shovelnose sturgeon," a species closely related to the river's endangered Pallid sturgeon. Environmental Assessment at 57. According to the Environmental Assessment, pallid sturgeon "are adapted to braided channels, irregular flow patterns, flooding of terrestrial habitat, extensive microhabitat diversity, and turbid waters (Mayden and Kahajda 1997)." *Id*. However, the 2003 Rodgers Study does not describe creation of this type of habitat, and the limitations in the table-top physical model prevent any assessment of whether such habitat will in fact be created.

Braided channel habitat will certainly be affected by the construction of new river training structures, and the DSEIS must analyze impacts to this and other diverse river habitats.

8. The DSEIS Fails to Evaluate Impacts to Wetlands

The DSEIS violates NEPA because it fails to evaluate impacts to vegetated and forested wetlands, including wetlands located in main channel border habitat and in the Mississippi River floodplain. Indeed, despite noting that Middle Mississippi River side channels can function as wetlands and that the Middle Mississippi River National Wildlife Refuge is managed to provide wetlands for migratory birds, the DSEIS provides **<u>no analysis at all</u>** of wetland impacts.

Assessing the impacts to wetlands requires a scientifically sound assessment of the impacts of the proposed Project on wetland hydrology and wetland plant species. This is critically important because "[h]ydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes":

> "Hydrology affects the species composition and richness, primary productivity, organic accumulation, and nutrient cycling in wetlands. . . . Water depth flow patterns, and duration and frequency of flooding, which are the result of all the hydrologic inputs and outputs, influence the biochemistry of the soils and are major factors in the ultimate selection of the biota of wetlands. . . . Hydrologic conditions can directly modify or change chemical and physical properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties, and pH."[108]

Even "small changes in hydrology can result in significant biotic changes"[109] and produce ecosystem-wide changes:

> "**When hydrologic conditions in wetlands change even slightly, the biota may respond with massive changes in species composition and richness and in ecosystem productivity.**"[110]

As a result the impacts from even small changes in the duration and extent of inundation of wetlands in the Mississippi River system must be evaluated as such changes could create significant adverse impacts to the structure and function of those wetlands leading to adverse impacts to fisheries, wildlife habitat, plant communities, water quality, water quantity, soil moisture recharge, nutrient cycling, and flood pulse conditions.

As with all impacts analyses, the wetland assessment must look at the direct, indirect, and cumulative impacts to wetlands. The cumulative impacts assessment should look at the cumulative impacts to wetland resources and floodplain connectivity due to: river training structure construction and other channel modifications; dredging and dredged spoil disposal; the burying of at least 60 percent of the Middle Mississippi River banks under concrete and other types of revetment; construction of levees; and climate change.

9. The DSEIS Fails to Adequately Evaluate Impacts to Species Listed Under the Federal Endangered Species Act

The DSEIS violates NEPA because it fails to adequately evaluate the impacts to species listed under the Federal Endangered Species Act (ESA). As discussed in Section III of these comments, the Corps should also reinitiate Endangered Species Act consultation for the species evaluated in the 2000 Biological Opinion.

The only discussion of listed species in the DSEIS is a summary conclusion that there will be no impacts for species listed prior to 2000 other than those already contemplated in the 2000 Biological Opinion. A Biological Assessment for species listed after 2000 is provided at DSEIS Appendix B.

However, as a matter of law, past, present or future compliance with the ESA cannot satisfy the NEPA requirement to evaluate the impact of the proposed management alternatives on these species. This is because the Corps' legal obligations under the ESA and NEPA are entirely separate and apply fundamentally different standards. Compliance with the ESA Section 7 prohibition against jeopardizing the continued existence of a species does not satisfy NEPA's requirements to analyze significant impacts

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[108] William J. Mitsch and James G. Gosselink, *Wetlands* (2nd ed.) (1993) at 67-68.
[109] *Id*. at 68.
[110] *Id*. at 68 (emphasis added).

that fall short of the threat of extinction.[111] "Clearly, there can be a significant impact on a species even if its existence is not jeopardized."[112]

As a fundamental matter, the analysis of impacts to listed species suffers from the many problems with the analyses of impacts and alternatives identified throughout these comments. The flaws in the Corps' analysis of main channel border habitat are particularly problematic because an important 2004 study shows that in the Middle Mississippi River, main channel border habitat is a preferred habitat for the federally endangered Pallid sturgeon.[113] A copy of this study is provided at Attachment E to these comments. The DSEIS does not include or discuss this study. As noted in these comments, the DSEIS provides no assessment of the Project's impacts on birds, including the federally endangered least tern, other than discussing the terms of the 2000 Biological Assessment and discussing the red knot in the 2016 Biological Assessment.

10. The DSEIS Fails to Meaningfully Evaluate Impacts to Fisheries

The DSEIS violates NEPA because it fails to meaningfully evaluate impacts to the full range of fish species found in the Project area. This failure presents a fundamentally flawed image of the impacts of the preferred alternative that renders the DSEIS inadequate.

Some 144 species of fish representing 22 families are likely found in the Project area.[114] However, the DSEIS does not provide information on the full suite of species utilizing the Middle Mississippi River, and does not provide any life cycle information for those species that it does identify. The DSEIS does not provide any information on the impacts of river training structures on critical aspects of those life cycles.

Notably, despite recognizing that the preferred alternative would result in a significant loss of main channel border habitat, the DSEIS does not evaluate the impacts to fisheries resources from these losses. For example, the DSEIS fails to discuss or reference an important 2004 study which shows that in

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[111] *See Greater Yellowstone Coalition v. Flowers*, 359 F.3d 1257, 1275-76 (10th Cir. 2004) (recognizing that FWS' conclusion that the action is not likely to cause jeopardy does not necessarily mean the impacts are insignificant); *Makua v. Rumsfeld*, 163 F. Supp.2d 1202, 1218 (D. Haw. 2001) ("A FONSI . . . must be based on a review of the potential for significant impact, including impact short of extinction. Clearly, there can be a significant impact on a species even if its existence is not jeopardized."); *National Wildlife Federation v. Babbitt*, 128 F. Supp.2d 1274, 1302 (E.D. Cal. 2000) (requiring EIS under NEPA even though mitigation plan satisfied ESA); *Portland Audubon Society v. Lujan*, 795 F. Supp. 1489, 1509 (D. Or. 1992) (rejecting agency's request for the court to "accept that its consultation with [FWS under the ESA] constitutes a substitute for compliance with NEPA.").

[112] *Makua v. Rumsfeld*, 163 F. Supp.2d 1202, 1218 (D. Haw. 2001) ("A FONSI . . . must be based on a review of the potential for significant impact, including impact short of extinction. Clearly, there can be a significant impact on a species even if its existence is not jeopardized.")

[113] Hurley, Keith L., Sheehan, Robert J., Heidinger, Roy C., Wills, Paul S. and Clevenstine, Bob. "Habitat Use by Middle Mississippi River Pallid Sturgeon." (Jul 2004), published in Transactions of the American Fisheries Society, Vol. 133, Issue 4 (July 2004) at doi: 10.1577/T03-042.

[114] *See, e.g.*, November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers (providing these numbers for the nearby project area of the Corps' St. Johns Bayou New Madrid Floodway Project).

the Middle Mississippi River, main channel border habitat is a preferred habitat for the federally endangered Pallid sturgeon.[115] A copy of this study is provided at Attachment E to these comments.

We note that the Corps would have obtained important information on the fisheries in the Project Area and the likely impacts to those fisheries from the Project if the Corps had obtained a Fish and Wildlife Coordination Act Report for the Project, as required by law. *See* Section IV of these comments.

11. The DSEIS Fails to Evaluate Impacts to Birds and Waterfowl

The DSEIS violates NEPA because it fails to evaluate impacts to birds and waterfowl found in the Project area. This failure presents a fundamentally flawed image of the impacts of the preferred alternative that renders the DSEIS inadequate.

The only mention of migratory birds in the DSEIS is a comment that the Middle Mississippi River National Wildlife Refuge is managed for migratory birds.[116] The word "waterfowl" does not appear anywhere in the DSEIS or its appendices. The DSEIS does include the terms of the 2000 Biological Opinion that relate to the federally endangered least tern, and the red knot is discussed in the Biological Assessment. However, as noted above, impacts to these species must also be evaluated in the DSEIS because "[c]learly, there can be a significant impact on a species even if its existence is not jeopardized."[117]

The Middle Mississippi River is a central component of the Mississippi River Flyway, which is used by vast numbers of migratory birds. Nearly half of all migratory birds, and 40 percent of all waterfowl migrate through the Mississippi River Flyway. One estimate suggests that 326 different species use the flyway.[118] The Department of the Interior has documented 193 species of migratory birds near the Project area, and tens of thousands of migrating shorebirds and waterfowl."[119]

A meaningful assessment of impacts to migratory birds must account for direct, indirect, and cumulative impacts, including the cumulative impacts of climate change, which can significantly exacerbate the impacts on the many migratory species that utilize the Middle Mississippi River.

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

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[115] Hurley, Keith L., Sheehan, Robert J., Heidinger, Roy C., Wills, Paul S. and Clevenstine, Bob. "Habitat Use by Middle Mississippi River Pallid Sturgeon." (Jul 2004), published in Transactions of the American Fisheries Society, Vol. 133, Issue 4 (July 2004) at doi: 10.1577/T03-042.

[116] DSEIS at 174.

[117] *Makua v. Rumsfeld*, 163 F. Supp.2d 1202, 1218 (D. Haw. 2001) ("A FONSI . . . must be based on a review of the potential for significant impact, including impact short of extinction. Clearly, there can be a significant impact on a species even if its existence is not jeopardized.")

[118] http://www.couleeaudubon.org/festival06_checklist.html (visited January 15, 2017).

[119] November 18, 2013 Letter from the Office of Environmental Policy and Compliance, U.S. Department of the Interior to Col. Jeffery A. Anderson, Commander, Memphis District, U.S. Army Corps of Engineers (providing these numbers for the nearby project area of the Corps' St. Johns Bayou New Madrid Floodway Project).

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."[120]

Migratory birds are at particular risk from climate change. Migratory birds are affected by changes in water regime, mismatches with food supply, habitat shifts, changes in prey range, increased storm frequency, and sea level rise.[121]

We note that the Corps would have obtained important information on the birds and waterfowl that use the Project area, and the likely impacts to those species from the Project, if the Corps had obtained a Fish and Wildlife Coordination Act Report for the Project, as required by law. *See* Section IV of these comments.

12. The DSEIS Fails to Evaluate Impacts to Amphibians and Reptiles

The DSEIS violates NEPA because it fails to evaluate impacts to amphibians and reptiles. Indeed, the words "amphibian" and "reptile" are not found anywhere in the DSEIS or its appendices. This failure

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[120] 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).
[121] *Id*. at 42-43.

presents a fundamentally flawed image of the impacts of the preferred alternative and renders the DSEIS inadequate.

Notably, despite recognizing that the preferred alternative would result in a significant loss of main channel border habitat, the DSEIS does not evaluate the impacts to amphibian and reptile species that utilize that habitat. For example, a 2016 study shows that "[s]hallow, low-velocity habitat seems most important to turtles" in the Middle Mississippi River and that "smooth softshell turtles used open side channels and unstructured main-channel borders most often."[122]

Evaluating the impacts of the Project on amphibians and reptiles is particularly important because these species are facing unprecedented risks of extinction. In the United States, the IUCN Red List of Threatened Species lists 56 amphibian species and 37 reptile species as known to be critically endangered, endangered, or vulnerable.[123] Worldwide, at least 1,950 species of amphibians are threatened with extinction of which 520 species are critically endangered, 783 are endangered, and 647 species are vulnerable. This represents 30 percent of all known amphibian species.[124] In 2004, scientists estimated that most of 1,300 other amphibian species are also threatened though sufficient data are currently lacking to be able to accurately assess the status of those species.[125] The IUCN Red List of Threatened Species also lists 879 species of reptiles as threatened with extinction worldwide, which represents 21 percent of all evaluated reptile species.[126]

A recent study demonstrates the increasingly dire conditions of amphibians worldwide:

> "Current extinction rates are most likely 136–2707 times greater than the background amphibian extinction rate. These are staggering rates of extinction that are difficult to explain via natural processes. No previous extinction event approaches the rate since 1980 (Benton and King, 1989).
>
> Despite the catastrophic rates at which amphibians are currently going extinct, these are dwarfed by expectations for the next 50 yr (Fig. 1). If the figure provided by Stuart et al. (2004) is true (but see Pimenta et al., 2005; Stuart et al., 2005), one-third of the extant amphibians are in danger of extinction. This portends an extinction rate of 25,000–45,000 times the expected background rate. Episodes of this stature are unprecedented. Four previous mass extinctions could be tied to catastrophic events such as super volcanoes and extraterrestrial impacts that

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[122] Braun, Andrew P., Phelps, Quinton E. "Habitat Use by Five Turtle Species in the Middle Mississippi River." Chelonian Conservation and Biology Jun 2016: Vol. 15, Issue 1, pg(s) 62-68 doi: 10.2744/CCB-1156.1 (available at http://www.bioone.org/doi/abs/10.2744/CCB-1156.1).

[123] IUCN Red List version 2013:2, Table 5: Threatened species in each country (totals by taxonomic group), available at http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table5.pdf (visited on November 24, 2013.)

[124] IUCN Red List version 2013:2, Table 3a: Status category summary by major taxonomic group (animals), available at http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table3a.pdf (visited on November 24, 2013).

[125] Science Daily, Amphibians In Dramatic Decline; Study Finds Nearly One-Third Of Species Threatened With Extinction (October 15, 2004), available at http://www.sciencedaily.com/releases/2004/10/041015103700.htm (visited on November 24, 2013).

[126] IUCN Red List version 2013:2, Table 3a: Status category summary by major taxonomic group (animals), available at http://cmsdocs.s3.amazonaws.com/summarystats/2013_2_RL_Stats_Table3a.pdf (visited on November 24, 2013).

> occur every 10 million to 100 million years (Wilson, 1992). The other mass extinction seems to be tied to continental drift of Pangea into polar regions leading to mass glaciation, reduced sea levels, and lower global temperatures (Wilson, 1992). The current event far exceeds these earlier extinction rates suggesting a global stressor(s), with possible human ties."[127]

Amphibians thrive in cool wetland environments, and are found in all types of wetlands except more saline coastal environments. Small, isolated wetlands play especially important roles in amphibian productivity.[128] Amphibian populations thrive when there are a variety of small ecosystems within a regional landscape in which a "dynamic equilibrium" of different populations becomes established.[129] However, if the environment becomes overly fragmented, the dynamic equilibrium is disturbed because patterns of emigration and immigration may be disrupted.

Amphibians spend part of their life cycles in an aquatic environment and part in a terrestrial environment (typically returning to water to breed). For example, some salamanders undergo larval development within an aquatic environment, and then live along wet streamsides following metamorphosis into adult stages. Those that do not breed in water still need moist environments to prevent extreme dehydration.[130] The tadpoles of most frog species develop in ponds, lakes, wet prairies, and other still bodies of water, while others are known to breed in a wide variety of wetland habitats. As adults, toads, frogs and some salamanders can travel relatively great distances from water sources, but they return to water to reproduce.

Recent studies also point to the role of global climate change in promoting potentially catastrophic impacts to amphibian populations. For example:

- Global climate change will result in changes to weather and rainfall patterns that can have significant adverse effects on amphibians. Drought can lead to localized extirpation. Cold can induce winterkill in torpid amphibians. It is possible that the additional stress of climate change, on top of the stresses already created by severe loss of habitat and habitat fragmentation may jeopardize many amphibian species.[131]

- Recent studies suggest that climate change may be causing global mass extinctions of amphibian populations. Particularly alarming is the fact that many of these disappearances are occurring in

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[127] McCallum, M. L. (2007). "Amphibian Decline or Extinction? Current Declines Dwarf Background Extinction Rate. *Journal of Herpetology* 41 (3): 483–491. doi:10.1670/0022-1511(2007)41[483:ADOECD]2.0.CO;2.
[128] Gibbons, J. Whitfield, Christopher Winne, et. al. 2006. Remarkable Amphibian Biomass and Abundance in an Isolated Wetland: Implications for Wetland Conservation. Conservation Biology Volume 20, No. 5, 1457–1465.
[129] Mann, W., P. Dorn, and R. Brandl. 1991. Local distribution of amphibians: The importance of habitat fragmentation. Global Ecology and Biogeography Letters 1:36-41.
[130] Semlitsch, R. D. 1987. Relationship of pond drying to the reproductive success of the salamander Ambystoma talpoideum. Copeia 1987:61-69; Pechmann, J. H. K., D. E. Scott, J. W. Gibbons, and R. D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. Wetlands Ecology and Management 1:3-11.
[131] Sjogren, P. 1993a. Metapopulation dynamics and extinction in pristine habitats: A demographic explanation. Abstracts, Second World Congress of Herpetology, Adelaide, Australia, p. 244; Sjogren, P. 1993b. Applying metapopulation theory to amphibian conservation. Abstracts, Second World Congress of Herpetology, Adelaide, Australia, p. 244-245.

relatively pristine area such as wilderness areas and national parks.[132] One recent study suggests that climate change has allowed the spread of a disease known as chytridiomycosis which has led to extinctions and declines in amphibians. Climate change has allowed this disease to spread by tempering the climate extremes that previously kept the disease in check.[133] About two-thirds of the 110 known harlequin frog species are believed to have vanished during the 1980s and 1990s because of the chytrid fungus *Batrachochytrium dendrobatidis.* Other studies indicate that amphibians may be particularly sensitive to changes in temperature, humidity, and air and water quality because they have permeable skins, biphasic life cycles, and unshelled eggs.[134]

- Climate change may also affect amphibian breeding patterns.[135] Amphibians spend a significant part of the year protecting themselves from cold or shielding themselves from heat. They receive cues to emerge from their shelters and to migrate to ponds or streams to breed from subtle increases in temperature or moisture. As the earth warms, one potential effect on amphibians is a trend towards early breeding, which makes them more vulnerable to snowmelt-induced floods and freezes common in early springs. Some studies already indicate a trend towards earlier breeding in certain amphibian species.[136]

- Increases in UV-B radiation in the northern hemisphere due to ozone depletion is also having an adverse impact on amphibians.[137] One study suggests that ultraviolet-B (UV-B) radiation adversely affects the hatching success of amphibian larvae.[138] High levels of UV-B also induced higher rates of developmental abnormalities and increased mortality in certain species (*Rana clamitans* and *R. sylvatica*) than others that were shielded from UV-B.[139] UV-B also can have detrimental effects on embryo growth.

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[132] Pounds, J. A., and M. L. Crump. 1994. Amphibian declines and climate disturbance: The case of the golden toad and the harlequin frog. Conservation Biology 8:72-85; Lips, K. R. 1998. Decline of a Tropical Montane Amphibian Fauna. Conservation Biology 12:106-117; Lips, K., F.Brem, R. Brenes, J.D. Reeve, R.A. Alford, J. Voyles, C. Carey, L. Livo, A. P. Pessier, and J.P. Collins 2006. Emerging infectious disease and the loss of biodiversity. Proceedings of the National Academy of Sciences 103:3165-3170.
[133] Pounds, J.A., M.P.L. Fogden, J.H. Campbell. 2006. Biological response to climate change on a tropical mountain. Nature 398, 611-615.
[134] Carey, C., and M. A. Alexander. 2003. Climate change and amphibian declines: is there a link? Diversity and Distributions 9:111-121.
[135] Carey, C., and M. A. Alexander. 2003. Climate change and amphibian declines: is there a link? Diversity and Distributions 9:111-121.
[136] Beebee, T. J. C. 1995. Amphibian Breeding and Climate. Nature 374:219-220; Blaustein, A. R., L. K. Belden, D. H. Olson, D. M. Green, T. L. Root, and J. M. Kiesecker. 2001. Amphibian breeding and climate change. Conservation Biology 15:1804-1809; Gibbs, J. P., and A. R. Breisch. 2001. Climate warming and calling phenology of frogs near Ithaca, New York, 1900-1999. Conservation Biology 15:1175-1178.
[137] Blumthaler, M., and W. Ambach. 1990. Indication of increasing solar ultraviolet-B radiation flux in alpine regions. Science 248:206-208; Kerr, J. B., and C. T. McElroy. 1993. Evidence for large upward trends of ultraviolet-B radiation linked to ozone depletion. Science 262:1032-1034.
[138] Blaustein, A. R., P. D. Hoffman, D. G. Hokit, J. M. Kiesecker, S. C. Walls, and J. B. Hays. 1994a. UV repair and resistance to solar UV-B in amphibian eggs: A link to population declines? *Proceedings of the National Academy of Science* 91:1791-1795.
[139] Grant, K. P., and L. E. Licht. 1993. Effects of ultraviolet radiation on life history parameters of frogs from Ontario, Canada. Abstracts, Second World Congress of Herpetology, Adelaide, Australia, p. 101.

We note that the Corps would have obtained important information on the amphibians and reptiles that use the Project area, and the likely impacts to those species from the Project, if the Corps had obtained a Fish and Wildlife Coordination Act Report for the Project, as required by law. *See* Section IV of these comments.

13. The DSEIS Fails to Evaluate Impacts to Mammals

The DSEIS violates NEPA because it fails to evaluate impacts to mammals. Indeed, the word mammal is not included anywhere in the DSEIS. Bats are discussed only in the Biological Assessment, and impacts to bats in general are not discussed in the DSEIS.

Many mammal species are found in the Mississippi River Valley and many of those species utilize riparian areas. However, the DSEIS fails to provide any analysis whatsoever on the potential impacts to mammals from the Project, despite acknowledging a minimum loss of 1100 acres of channel border habitat. Because the Project will affect riparian and wetland areas, the DSEIS must evaluate impacts to the mammal species found in those areas.

We note that the Corps would have obtained important information on the mammals that use the Project area, and the likely impacts to those species from the Project, if the Corps had obtained a Fish and Wildlife Coordination Act Report for the Project, as required by law. *See* Section IV of these comments.

14. The DSEIS Fails to Evaluate Impacts to Plants

The DSEIS violates NEPA because it fails to evaluate impacts to plants, including wetland plant species. This failure presents a fundamentally flawed image of the impacts of the Project and renders the DSEIS inadequate. The impacts of the proposed alternatives on plant species, including wetland plant species in the main channel border habitat, must be analyzed.

15. The DSEIS Fails to Evaluate Key Information on Climate Change

The Conservation Organizations appreciate the work that the Corps put into the climate change analysis in the DSEIS. However, that analysis—and the related analysis of the cumulative impacts of climate change—fail to address key issues. See Section II.C.16 of these comments for a detailed discussion of problems with the DSEIS cumulative impacts analysis.

At the most fundamental level, the DSEIS fails to evaluate whether the impacts of climate change could exacerbate the adverse impacts of the preferred alternative or the No New Construction Alternative. The DSEIS also fails to assess whether the preferred alternative or the No New Construction Alternative would make the Middle Mississippi River and the species that rely on it less resilient to climate change. As discussed in Section II.C.16 of these comments, these issues must be examined.

Notably, because the DSEIS improperly rejects the comprehensive scientific evidence that demonstrates that river training structures increase flood heights, the DSEIS fails to address the additive effects of climate change on flood levels. As noted above, the Middle Mississippi is particularly susceptible to increased extreme weather from climate change because the river is influenced by multiple large river systems – the Illinois, Upper Mississippi, Missouri, and Ohio Rivers. The DSEIS climate change assessment should address the implications of this susceptibility.

16. The DSEIS Fails to Adequately Evaluate Cumulative Impacts

The DSEIS violates NEPA because it fails to meaningfully evaluate cumulative impacts. This failure renders the DSEIS grossly inadequate.

The cumulative impacts analysis is a critical component of NEPA review. It ensures that the reviewing agency will not "treat the identified environmental concern in a vacuum."[140] Cumulative impacts are defined 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."[141]

A meaningful assessment of cumulative impacts must identify:

> "(1) the area in which effects of the proposed project will be felt; (2) the impacts that are expected in that area from the proposed project; (3) other actions – past, present, and proposed, and reasonably foreseeable – that have had or are expected to have impacts in the same area; (4) the impacts or expected impacts from these other actions; and (5) the overall impact that can be expected if the individual impacts are allowed to accumulate."[142]

In conducting the cumulative impacts assessment, it is not enough to simply catalog past actions. The DSEIS instead must determine the specific impacts of those actions on the system. The DSEIS must also assess whether the past degradation of the system combined with the proposed alternative will significantly affect the ecological health and functioning of the Middle Mississippi River and its floodplain. Indeed, this is the primary goal of the cumulative impacts analysis:

> "The analyst's primary goal is to determine the magnitude and significance of the environmental consequences of the proposed action in the context of the cumulative effects of other past, present, and future actions. Much of the environment has been greatly modified by human activities, and most resources, ecosystems, and human communities are in the process of change as a result of cumulative effects. **The analyst must determine the realistic potential for the resource to sustain itself in the future and whether the proposed action will affect this potential; therefore, the baseline condition of the resource of concern should include a description of how conditions have changed over time and how they are likely to change in the future without the proposed action.** The potential for a resource, ecosystem, and human community to sustain its structure and function depends on its resistance to stress and its ability to recover (i.e., its resilience). Determining whether the condition of the resource is within the range of natural variability or is vulnerable to rapid degradation is frequently problematic.

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[140] *Grand Canyon Trust v. FAA*, 290 F.3d 339, 346 (D.C. Cir. 2002).
[141] 40 C.F.R. § 1508.7.
[142] *TOMAC, Taxpayers Of Michigan Against Casinos v. Norton*, 435 F.3d 852 (D.C. Cir. 2006) (quoting Grand Canyon Trust, 290 F.3d at 345); *Fritiofson v. Alexander*, 772 F.2d 1225, 1245 (5th Cir. 1985) (holding this level of detail necessary even at the less detailed review stage of an Environmental Assessment).

Ideally, the analyst can identify a threshold beyond which change in the resource condition is detrimental. More often, the analyst must review the history of that resource and evaluate whether past degradation may place it near such a threshold. For example, the loss of 50% of historical wetlands within a watershed may indicate that further losses would significantly affect the capacity of the watershed to withstand floods. **It is often the case that when a large proportion of a resource is lost, the system nears collapse as the surviving portion is pressed into service to perform more functions.**"[143]

The DSEIS completely fails to satisfy this primary goal of a cumulative impacts analysis. While the cumulative impacts analysis incorporates a number of studies that discuss the significant decline in the ecological health of the Mississippi River due in large part to the construction and operation of the river's navigation system, the DSEIS cumulative impacts discussion blatantly ignores that information. For example, despite providing an extremely general discussion of the Status and Trends Reports, the DSEIS does not state that those reports documented a significant decline in the health of the river. *See* DSEIS 166-167.

The lack of consideration given to the significant ecological decline of the Middle Mississippi River can be seen very clearly in the DSEIS Cumulative Impacts Analysis Conclusion:

"4.6.6 Cumulative Impacts Analysis Conclusion
The Regulating Works Project, in combination with other actions throughout the watershed, has had past impacts, both positive and negative, on the resources, ecosystem and human environment of the MMR. However, this analysis is meant to characterize the incremental impacts of the current action in the broader context of other past, present, and future actions affecting the same resources. Although past actions associated with the Regulating Works Project likely adversely affected some segments of the MMR environment, the current practices employed in obtaining and maintaining a navigation channel integrate lessons learned from past experience and emphasize avoiding and minimizing environmental impacts to the greatest extent practicable. The District works closely with natural resource agency and navigation industry stakeholders throughout the project development process to ensure that all potential issues are addressed appropriately. This process, in conjunction with innovative river training structure designs and District restoration efforts, has contributed to a substantial reduction in adverse effects and equilibrium in many habitat conditions. Construction of river training structures is expected to continue to increase important low velocity habitat and increase bathymetric, flow, and substrate diversity. These improvements in Project implementation notwithstanding, the District has concluded that the adverse effects to shallow to medium-depth, moderate- to high velocity main channel border habitat, as discussed in Section 4.3.2 Impacts on Fishery Resources above, are potentially significant and warrant compensatory mitigation. No further incremental impacts associated with the Alternatives analyzed, in the context of other past, present, and reasonably foreseeable future actions, are anticipated to rise to a level of significance. See Table 4-10 below for a summary of cumulative impacts."

DSEIS at 190.

[143] Council on Environmental Quality, *Considering Cumulative Effects Under the National Environmental Policy Act* (January 1997) at 41 (emphasis added).

This conclusion completely ignores the significant and fundamental changes to the ecological health, form, and function of the Middle Mississippi River caused by past activities. This conclusion fails to account for the adverse impacts to the Middle Mississippi from reasonably foreseeable future activities. This conclusion completely ignores the extensive numbers of river training structures already in the Middle Mississippi—estimated at 1.5 miles of river training structure for each mile of the Middle Mississippi. This conclusion completely ignores the significant body of science that demonstrates that the construction of river training structures has significantly increased flood heights and has fundamentally altered the way the Middle Mississippi River responds to flood events. This conclusion ignores the fact that 34.85% of main channel border habitat in the Middle Mississippi River has already been lost, and fails to assess the ecological significance of losing an additional 8.53% of main channel border habitat on top of this already extremely significant loss. This conclusion fails even to recognize the significant past and present activities carried out under the Regulating Works Program and the Mississippi River and Tributaries Program, and the impacts of those activities.

The DSEIS cumulative impacts analysis also fails to address the additive effects of climate change on increasing flood levels in the Middle Mississippi River, and on decreasing the resiliency of the Middle Mississippi. The DSEIS fails to evaluate whether the impacts of climate change could exacerbate the adverse impacts of the preferred alternative or the No New Construction Alternative. The DSEIS also fails to assess whether the preferred alternative or the No New Construction Alternative would make the Middle Mississippi River and the species that rely on it less resilient to climate change.

Council on Environmental Quality guidance makes clear that analyzing the impacts of climate change is not restricted to evaluating whether a project could itself exacerbate climate change. The magnifying and additive effects that climate change would cause on the resources affected by the project must also be evaluated.

> "Climate change can affect the environment of a proposed action in a variety of ways. Climate change can increase the vulnerability of a resource, ecosystem, human community, or structure, which would then be more susceptible to climate change and other effects and result in a proposed action's effects being more environmentally damaging. For example, a proposed action may require water from a stream that has diminishing quantities of available water because of decreased snow pack in the mountains, or add heat to a water body that is exposed to increasing atmospheric temperatures. Such considerations are squarely within the realm of NEPA, informing decisions on whether to proceed with and how to design the proposed action so as to minimize impacts on the environment, as well as informing possible adaptation measures to address these impacts, ultimately enabling the selection of smarter, more resilient actions.
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> * * *
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> Therefore, climate change adaptation and resilience — defined as adjustments to natural or human systems in response to actual or expected climate changes — are important considerations for agencies contemplating and planning actions with effects that will occur both at the time of implementation and into the future."[144]

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[144] Council on Environmental Quality, Revised Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions (December 2014) (internal citations omitted); *see Center for Biological Diversity v. Nat'l Hwy Traffic Safety Administration*, 538 F.3d 1172, 1217 (9th Cir. 2008) (holding that analyzing the

The Corps should fundamentally redo its cumulative impacts assessment to ensure that it provides a comprehensive, factually accurate, and realistic assessment of the magnitude and significance of the environmental consequences of the Project in the context of the cumulative effects of other past, present, and future actions. This assessment should determine how the preferred alternative will affect the ability of the Middle Mississippi River to sustain itself in the future.

17. The DSEIS Fails to Adequately Evaluate the Risk of Disproportionate Impacts to Low Income and Minority Communities

Executive Order 12898 requires that each Federal agency achieve environmental justice by identifying and addressing disproportionately high adverse human health or environmental effects of federal activities on minority and low-income populations. The DSEIS fails to comply with this Executive Order for at least three reasons.

First, the DSEIS fails to assess the potential for disproportionate effects on the health and safety of minority and low income populations from the significant risk of increased flooding created by construction of river training structures. See Section II.C.4 for a discussion of flood risks.

Second, the DSEIS environmental justice analysis looks only at county wide data to assess the potential for disproportionate impacts. DSEIS at 160. The DSEIS should also assess the potential for disproportionate impacts to individual communities (towns and cities) with large minority or low-income populations. This would provide a more accurate assessment of potential impacts.

Third, the DSEIS cannot conduct a meaningful environmental justice analysis without also assessing the reasonably foreseeable site-specific impacts, as required by law. See Section II.C.1 for a discussion of this requirement. The DSEIS conclusion that minority and low income communities will not be disproportionately impacted because "river training structure construction activities as well as dredging operations are anticipated to occur at locations along the entire length of the Project Area"[145] is not a meaningful assessment and is not supported by information in the DSEIS.

18. The DSEIS Fails to Evaluate Impacts to Ecosystem Services

The DSEIS fails to provide any assessment of the ecosystem services that will be lost as a result of the preferred alternative or of the No New Construction alternative. Ecosystem services valuations are well recognized as providing important information for decision makers. Understanding the impacts to these services is critical for assessing the full extent of Project impacts.

The importance of ecosystem services valuation is made clear in the 2013 *Principles and Requirements for Federal Investments in Water Resources* and *Interagency Guidelines* (collectively, the PR&G). The PR&G focus extensively on the importance of evaluating the value of ecosystem services lost and gained

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impacts of climate change is "precisely the kind of cumulative impacts analysis that NEPA requires agencies to conduct"); *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.").

[145] DSEIS at 160.

during project planning. While the Conservation Organizations recognize that the Corps is not yet utilizing the PR&G, the Corps should nevertheless evaluate the impacts on ecosystem services.

The Conservation Organizations urge the Corps to contract with an organization expert in conducting ecosystem services valuations to properly account for the ecosystem services that will be lost to the project.

19. The DSEIS Fails to Meaningfully Evaluate Mitigation and Fails to Comply With Federal Mitigation Requirements

The DSEIS violates NEPA because it fails to meaningfully evaluate mitigation. The DSEIS also fails to comply with federal mitigation requirements. Importantly, the DSEIS contention that mitigation for the Project is "discretionary"[146] is incorrect as a matter of law. Mitigation will be required as a matter of law for the entire Project upon completion of the DSEIS.[147] Mitigation is already required as a matter of law for any elements of the Project being carried out pursuant to an Environmental Assessment or "any report" where a project alternative was selected.[148]

NEPA requires that the DSEIS discuss mitigation measures with "sufficient detail to ensure that environmental consequences have been fairly evaluated."[149] A "perfunctory description" of the mitigating measures is not sufficient.[150]

The DSEIS also must discuss the effectiveness of the proposed mitigation:

> "An essential component of a reasonably complete mitigation discussion is an assessment of whether the proposed mitigation measures can be effective. The Supreme Court has required a mitigation discussion precisely for the purpose of evaluating whether anticipated environmental impacts can be avoided. A mitigation discussion without at least *some* evaluation of effectiveness is useless in making that determination."[151]

A bald assertion that mitigation will be successful is not sufficient. The effectiveness must instead be supported by "substantial evidence in the record."[152]

The Water Resources Development Acts require the Corps to mitigate the adverse impacts of the Project.[153] The Corps is required to mitigate all losses to fish and wildlife created by a project unless the

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[146] DSEIS, Appendix C at C-1.
[147] The Water Resources Development Act of 2007 requires the Corps to implement mitigation, and comply with mitigation planning requirements, for any project for which the Corps "select[s] a project alternative in any report." 33 U.S.C. § 2283(d). Thus, mitigation will be required for the Project as a matter of law upon issuance of the final SEIS, and mitigation is required as a matter of law for components of the Regulating Works Project that are proceeding under environmental assessments.
[148] *Id*.
[149] Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 352 (1989).
[150] Neighbors of Cuddy Mountain v. U.S. Forest Service, 137 F.3d 1372, 1380 (9th Cir.1998).
[151] *South Fork Band Council v. Dept. of Interior*, 588 F.3d 718, 727 (9th Cir. 2009) (internal citations omitted).
[152] Wyoming Outdoor Council v. U.S. Army Corps of Eng'rs, 351 F. Supp. 2d 1232, 1252 (D. Wyo. 2005).
[153] The Water Resources Development Act of 2007 requires the Corps to implement mitigation, and comply with mitigation planning requirements, for any project for which the Corps "select[s] a project alternative in any report." 33 U.S.C. § 2283(d). Thus, mitigation will be required for the Project as a matter of law upon issuance of

Secretary determines that the adverse impacts to fish and wildlife would be "negligible." 33 U.S.C. § 2283(d)(1). To ensure that this happens, the Corps is prohibited from selecting a "project alternative in any report" unless that report includes a "specific plan to mitigate fish and wildlife losses." *Id*. Accordingly, the DSEIS must include a specific mitigation plan.

Corps mitigation plans must ensure that "impacts to bottomland hardwood forests are mitigated in-kind and harm to other habitat types are mitigated to not less than in-kind conditions, to the extent possible." 33 U.S.C. § 2283(d)(1). Mitigation plans "shall include, at a minimum:"

1. The type, amount, and characteristics of the habitat being restored, a description of the physical actions to be taken to carry out the restoration, and the functions and values that will be achieved;
2. The ecological success criteria, based on replacement of lost functions and values, that will be evaluated and used to determine mitigation success;
3. A description of the lands and interest in lands to be acquired for mitigation, and the basis for determining that those lands will be available;
4. A mitigation monitoring plan that includes the cost and duration of monitoring, and identifies the entities responsible for monitoring if it is practicable to do so (if the responsible entity is not identified in the monitoring plan it must be identified in the project partnership agreement that is required for all Corps projects). Corps mitigation must be monitored until the monitoring demonstrates that the ecological success criteria established in the mitigation plan have been met; and
5. A contingency plan for taking corrective action in cases where monitoring shows that mitigation is not achieving ecological success as defined in the plan. 33 U.S.C. § 2283(d).

Corps mitigation plans must also comply with the "the mitigation standards and policies established pursuant to the regulatory programs" administered by the Corps. 33 U.S.C. § 2283(d).

Corps mitigation must be monitored until the monitoring demonstrates that the ecological success criteria established in the mitigation plan have been met. The Corps is also required to consult yearly on each project with the appropriate Federal agencies and the states on the status of the mitigation efforts. The consultation must address the status of ecological success on the date of the consultation, the likelihood that the ecological success criteria will be met, the projected timeline for achieving that success, and any recommendations for improving the likelihood of success. 33 U.S.C. § 2283(d).

In addition, mitigation lands for Corps civil works projects must be purchased before any construction begins. 33 U.S.C. § 2283(a). Any physical construction required for purposes of mitigation should also be undertaken prior to project construction but must, at the latest, be undertaken "concurrently with the physical construction of such project." *Id*.

The DSEIS fails to comply with these important mitigation requirements for at least the following reasons.

(1) The DSEIS does not discuss mitigation measures with "sufficient detail to ensure that environmental consequences have been fairly evaluated," and does not demonstrate that

the final SEIS, and mitigation is required as a matter of law for components of the Regulating Works Project that are proceeding under environmental assessments.

the proposed mitigation will be ecologically successful.[154] To the contrary, the DSEIS acknowledges that "no appropriate habitat model(s) currently exists to capture the unique aspects of Middle Mississippi main channel border aquatic habitat" so the "Corps is attempting to develop a new main channel border habitat model." DSEIS, Appendix C at C-5.

(2) In direct violation of the longstanding NEPA requirements discussed above, the DSEIS fails to provide a meaningful discussion of mitigation actions and mitigation effectiveness and instead simply provides a list of possible activities and says that mitigation will occur "to the extent practicable":

> "Potential mitigation actions may include, but are not limited to, the following: wing dike notching, dike removal, wing dike creation using alternative designs (e.g., rootless dikes), use of rock piles, dredging or material placement of sand, and other possible activities. Mitigation will be tailored toward the specific habitat features that are significantly impacted. This habitat likely includes shallow to moderate depth, moderate to high velocity main channel border habitat. Such habitat may be challenging to design and effectively implement. The ability to design for such habitat, including the associated costs, may need to be carefully considered within the context of the impacts. Impacts will be mitigated to the extent practicable." DSEIS Appendix C at C-5.

(3) The DSEIS does not propose mitigation for all fish and wildlife impact that are more than negligible, as required by law. The DSEIS instead states that impacts must be "significant" before they require mitigation. DSEIS, Appendix C at C-5.

(4) The DSEIS does not propose any mitigation for the impacts caused by revetment, dredging, and dredged spoil disposal.

(5) The DSEIS cannot determine the actual amount of mitigation needed because it has not meaningfully assessed the full extent of the harm to fish and wildlife as a result of the direct, indirect, and cumulative impacts of the Project.

(6) The DSEIS does not provide a specific plan to mitigate the adverse impacts of the Project that satisfies the requirements discussed above, including the requirement to monitor mitigation efforts until it can be demonstrated that the mitigation has been ecologically successful.

The DSEIS also violates the Corps' civil works mitigation requirements by concluding that the Corps may not carry out required mitigation if funds are not available through the Regulating Works Project:

> "Funding mechanisms for implementing additional mitigation must then be identified. Depending on the amount of mitigation needed, funds may be available through the Regulating Works Project. This is especially the case for smaller activities. However, if large levels of funding are needed to address failed mitigation implemented in association with this SEIS, it may require additional action by Congress for either appropriation, or possibly even authorization. Thus,

[154] Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 352 (1989).

> funding would be provided for construction of planned mitigation projects, and post-project monitoring. It cannot be guaranteed that federal funds would be available, specific to this project, for contingency mitigation." DSEIS, Appendix C at C-8.

This demonstrates a lack of understanding of the Corps' mitigation requirements. As discussed above, mitigation will be required as a matter of law for the entire Project upon completion of the DSEIS, and mitigation is already required as a matter of law for any elements of the Project being carried out pursuant to an Environmental Assessment or "any report" where a project alternative was selected.[155] The Corps must mitigate the adverse impacts of the Project and the cost of carrying out that mitigation is a Project cost.

III. The Corps Must Reinitiate Consultation on the 2000 Biological Opinion

The Corps is required to reinitiate consultation on the 2000 Biological Opinion because: (1) new information indicates that the Project may affect a listed species in a previously unforeseen way; and (2) the Project has been modified in a manner that causes an impact not considered in the 2000 Biological Opinion.[156]

Important information exists, including the information discussed throughout these comments, that demonstrate the ways in which the Project may affect a listed species in ways not foreseen in the 2000 Biological Opinion. For example:

(1) A 2004 study demonstrates that the precise type of habitat that would be significantly affected by the preferred alternative—main channel border habitat—is a preferred habitat type for federally endangered Pallid sturgeons in the Middle Mississippi River.[157] That study concludes:

> "Of the seven macrohabitats identified, pallid sturgeon were found most often in main-channel habitats (39% of all relocations) and main-channel border habitats (26%); the between-wing-dam habitats were used less often (14%)."
>
> "In the middle Mississippi River, pallid sturgeon were often found in the MCL and MCB habitats. The high use of these areas by pallid sturgeon makes any negative changes to these habitats potentially harmful to pallid sturgeon. Any changes in use of these habitats or alterations to them should be examined before future projects are undertaken. Conversely, the three of the four wingdam habitats represent the low-use habitats examined in this study. Any alterations or changes to these habitats would have a reduced chance of harming pallid sturgeon populations due to their infrequent use of these areas."
>
> "Although the MCL is the area of highest use by middle Mississippi River pallid sturgeon, the habitat selectivity analysis presented here indicates that the ITD, MCB, and WDB

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[155] 33 U.S.C. § 2283(d).
[156] 50 C.F.R. 402.16.
[157] Hurley, Keith L., Sheehan, Robert J., Heidinger, Roy C., Wills, Paul S. and Clevenstine, Bob. "Habitat Use by Middle Mississippi River Pallid Sturgeon." (Jul 2004), published in Transactions of the American Fisheries Society, Vol. 133, Issue 4 (July 2004) at doi: 10.1577/T03-042.

areas may actually represent preferred habitats. Much like results found in other studies (Bramblett and White 2001; Snook et al. 2002), habitats may be selected by pallid sturgeon to maximize forage opportunities. These habitats should be given consideration for any future projects aimed at creating pallid sturgeon habitat because they may be necessary for the recovery of this species. Enhancement and restoration of these habitats would represent an increase in habitat diversity, which could benefit many species in addition to the endangered pallid sturgeon."[158]

(2) The DSEIS discusses new science that shows that the modification of flow by river training structures may cause Pallid sturgeon to expend more energy during migration or when feeding. DSEIS at 140.

(3) The cumulative loss of main channel border habitat identified in the DSEIS, combined with other cumulative impacts including climate change, is also critical new information that indicates the Project may affect the listed species in previously unforeseen ways.

The Project has also been modified in a manner that causes an impact not considered in the 2000 Biological Opinion. For example, the Project is utilizing new forms of river training structures that cause different types of impacts to flow, and is constructing a significant number of new river training structures.

For at least these reasons, the Corps must reinitiate consultation on the 2000 Biological Opinion.

IV. The Corps Must Comply with the Fish and Wildlife Coordination Act

The Corps is required to obtain a Fish and Wildlife Coordination Act Report for the DSEIS.

The DSEIS contends that the Regulating Works Project is exempt from the Fish and Wildlife Coordination Act because "60 percent or more of the estimated construction cost has been obligated for expenditure", presumably as of 2016. DSEIS at 197. However, the Fish and Wildlife Coordination Act cost exemption must be measured as of 1958, when the Fish and Wildlife Coordination Act was signed into law. The U.S. Fish and Wildlife Service's Fish and Wildlife Coordination Act Handbook states:

> **"**The only class of projects exempted from the provisions of Section 2 of the FWCA, then, are those on which project construction was 60 percent or more completed (based on obligation of estimated construction costs) on August 12, 1958. Projects that are later modified or supplemented thus fall under the provisions of Section 2 of the FWCA, even if the original project modified or supplemented was more than 60 percent constructed at the time of enactment of the FWCA." [159]

The DSEIS fails to provide any information or supporting evidence that this spending requirement was met in 1958. In fact, the DSEIS does not provide any information on either historic or anticipated spending for the Regulating Works Project, or on the original authorized total Project cost or the

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[158] *Id*.
[159] U.S. Fish and Wildlife Service, Water Resources Development Under the Fish and Wildlife Coordination Act (November 2004) at I-38 (https://www.fws.gov/ecological-services/es-library/pdfs/fwca.pdf, visited January 17, 2017.)

currently projected total Project cost. Moreover, since the Corps appears to interpret the Regulating Works Project as a perpetual authority, it would be impossible to determine a final spending amount and therefore impossible to determine when 60 percent of that amount has been spent.

Notably, the DSEIS contention that this cost exemption is to be determined as of 2016 is inconsistent with previous Corps decisions. In 1984, the Corps' Chief of Engineers stated in writing that for an ongoing project, the Fish and Wildlife Coordination Act cost exemption must be measured as of the date of enactment of the Fish and Wildlife Coordination Act (August 12, 1958):

> "The Fish and Wildlife Coordination Act (FWCA) of 1958 is applicable to any project where less than 60 percent of the estimated construction cost had been obligated as of 12 August 1958, the date of enactment."[160]

The same conclusion was reached in 1980:

> "The 1912 project, as amended, has been determined to have been less than 60 percent complete as of 12 August 1958 and is eligible under the Coordination Act. Water and land use changes which have occurred and continue to occur within the natural river area are directly attributable to the 1912 project, as amended. In addition, the prevention of erosion in the natural river meander belt is also a direct effect of the project and was not addressed in your draft report."[161]

In 2011, the Government Accountability Office concluded that the Fish and Wildlife Coordination Act applies to the Regulating Works Project:

> "The Corps' authority to use river training structures in the Mississippi River comes from several Rivers and Harbors Acts, which collectively require the Corps to maintain a 9-foot navigation channel in the river, and several Water Resources Development Acts, which also authorize projects in the Corps' civil works program. In using these structures, the Corps must comply with federal environmental laws such as the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and the Fish and Wildlife Coordination Act, as well as applicable state requirements. The Corps also has its own guidance that district offices are to use when planning, designing, and building river training structures."[162]

The Corps did not object to, or otherwise disagree with, this finding.

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[160] April 24, 1984 Letter from the USACE Chief of Engineers to the Secretary of the Army at page 4, including with the Missouri River Bank Stabilization and Navigation Project Final Feasibility Report and Final EIS for the May 1981 Fish and Wildlife Mitigation Plan (file:///C:/Users/sametm/Downloads/MO%20River%20BSNP%20Feas%20%20Mit%201981.pdf, visited January 17, 2017).

[161] February 19, 1980 letter from Col. Walker C. Bell, USACE District Engineer, Kansas City District to Tom Saunders, Area Manager, U.S. Fish and Wildlife Service.

[162] Government Accountability Office, Mississippi River: Actions Are Needed to Help Resolve Environmental and Flooding Concerns about the Use of River Training Structures, GAO-12-41 (December 2011), at Summary Page, 16, 20.

The Conservation Organizations also note that the scope of the Project, the significance of the adverse impacts, and the importance of the Mississippi River to fish and wildlife conservation, clearly warrant preparation and full consideration of a Fish and Wildlife Coordination Act Report.

Conclusion

The Conservation Organizations strongly oppose the preferred alternative in the DSEIS and urge the Corps of Engineers to develop and select an alternative that will protect communities and the ecological health of the Middle Mississippi River. The Conservation Organizations 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 this alternative, and urge the Corps to fully address the many legal, scientific, and factual deficiencies discussed throughout these comments

Respectfully submitted,

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Attachments

Attachment A

Conservation Organization Comments
On The
Regulating Works Project
Draft Supplemental Environmental Impact Statement (November 2016)

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FEATURE

Mississippi River threatens to make Dogtooth Bend peninsula in Illinois an island

Kenneth R. Olson and Lois Wright Morton

The receding floodwaters of the Mississippi River in January of 2016 left behind barren sand dunes on southern Illinois farmland reminiscent of the windswept dunes of the movie *Lawrence of Arabia* (figure 1). Large sand deposits up to 1.3 m (4 ft) deep covered nearly 800 ha (2,000 ac) of farmland south of Miller City, Illinois, in the Dogtooth Bend peninsula. Rainfall almost three times above average in November and December of 2015 over Missouri set in motion record flooding with the Cape Girardeau river gage breaking the 1993 record at 14.89 m (48.86 ft) and led to the breaching of Len Small levee on January 2, 2016. Floodwaters cut deep craters and scoured the landscape as they poured through the breach at mile marker 34 and then followed an old meander channel across the narrow neck of Dogtooth Bend peninsula to reconnect with the Mississippi River at mile marker 15 (figure 2). Levee breaches and land scouring are not new events for this region, occurring in 1993, 2011, and 2016; and there is high likelihood these farmlands will experience similar events in the future. Each event deepens the meander channel when the floodwaters take a 4.6 km (3.5 mi) shortcut and threaten to permanently reroute the Mississippi River leaving Dogtooth Bend peninsula an island. This would result in landowners and farmers of 6,000 ha (15,000 ac) in the Dogtooth Bend area no longer having road access to their land if the Mississippi River realigns naturally. In some cases the land use would likely shift from agriculture to other uses.

Figure 1

Mississippi River floodwaters deposited many tons of sand on farmland and roads in Dogtooth Bend peninsula when the Len Small levee breached in January of 2016. The sand dunes left behind required graders and snow plows to open the road for local traffic.

HISTORY OF FLOODING OF THE DOGTOOTH BEND PENINSULA IN SOUTHWEST ILLINOIS

The Mississippi River has a long history of continually changing course. After the last glacier advance at the end of the Great Ice Age, the melting ice waters flooded and altered the flow of many channels and streams including the ancient Mississippi and ancient Ohio rivers. The middle Mississippi Indians in the fourteenth and fifteenth centuries built two ceremonial mounds and a village near Milligan Lake (Maruszak 1977) at an elevation of 100 m (328 ft) in the area of Dogtooth Bend peninsula (figure 2) along a waterway or meander channel of the Mississippi River (elevation approximately 90 m [295 ft]). This suggests that humans lived here for more than 700 years and the area was seldom flooded.

However, the farmers and homeowners who settled in early 1800s on the bottomlands of southwest Alexander County, locally known as Dogtooth Bend peninsula, have battled flooding from the Mississippi River for the last 200 years. Illinois became a state in 1818, and Alexander County was established on March 4, 1819. Farming of the Mississippi and Ohio bottomlands started in the 1840s and depending on location continues to present day. Flooding in those early years was less of a problem since only corn (*Zea mays* L.), oats (*Avena sativa* L.), and soybean (*Glycine max* [L.] Merr.; after 1930s) were grown during the summer growing season. There was very little winter wheat (*Triticum aestivum* L.) as it would be vulnerable to early spring or late fall flooding.

In the 1880s the Missouri farmers on the west side the Mississippi River south of Commerce, Missouri (figure 3), began constructing levees to protect their bottomlands. This redirected Mississippi River floodwaters toward southwest Alexander County, Illinois, where lands were not leveed. During this same period, Missouri farmers also built levees south of Cape Girardeau, Missouri, to block the Mississippi River during flood events from entering its ancient valley and flood-

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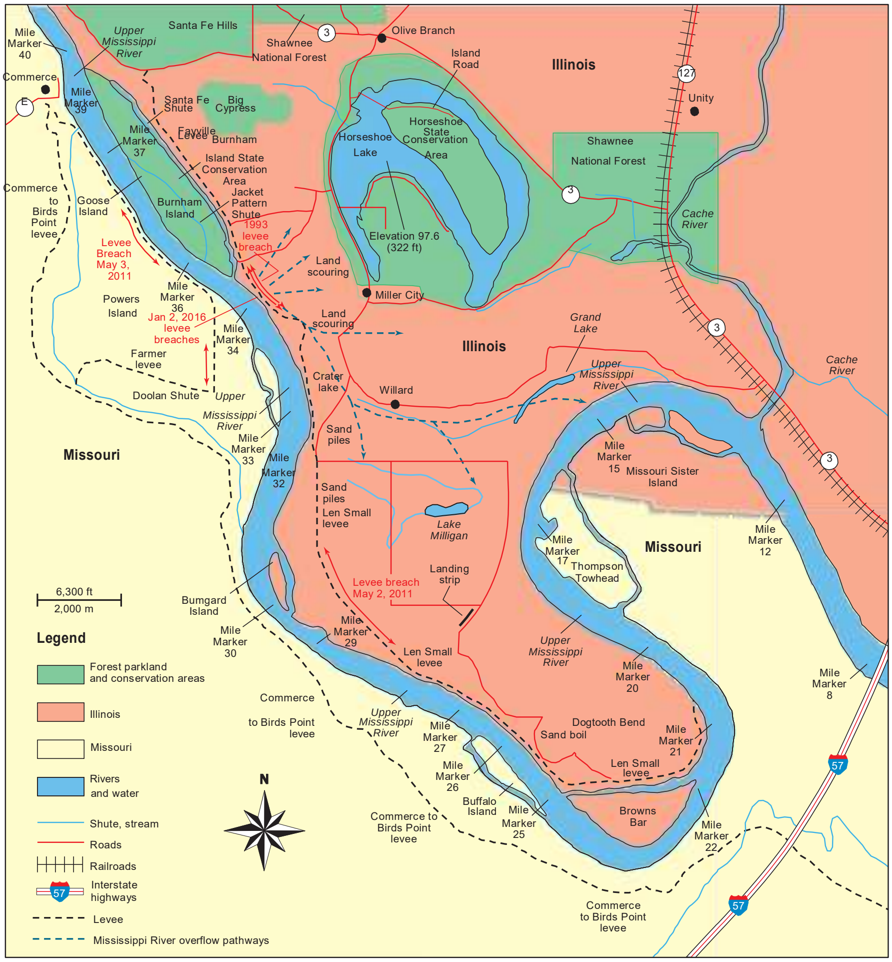
Figure 2

This map of the Dogtooth Bend area in southwest Illinois shows the 1993, 2011, and 2016 breach locations and the 2016 Mississippi River floodwater overland flow patterns. The blue dotted line represents a new channel cutting through southeast Alexander County and floodwaters flowing north of Lake Milligan and then exiting into the Mississippi River at mile marker 15.



ing lands around the Big Swamp. The Alexander County, Illinois, bottomland farmers were likely not aware of how the Missouri farmer levees built between 1880 and 1915 (shown in figure 3 by thick black lines on the west side of the river—one south of Cape Girardeau and the other south of Commerce) might affect the Illinois lands on the east side of the Mississippi River.

After the 74 km (46 mi) Little River Drainage District Headwaters project diversion levee and channel was constructed in 1916, the runoff from the 288,000 ha (720,000 ac) Ozark Plateau via the Castor and Whitewater rivers and Crooked Creek was diverted into the Mississippi River north of the Thebes Gap and south of Cape Girardeau (figure 3) (Olson and Morton 2016a). Prior to the creation of the diversion channel, the Ozark Plateau waters entered the Mississippi River north of Helena, Arkansas, more than 365 river miles to the south (Olson and Morton 2016b). The Little River Headwaters Diversion levee and channel effectively raised the floodwater peaks recorded on the river gages at Cape Girardeau, Missouri; Thebes in Alexander County, Illinois; Cairo, Illinois; and Hickman, Kentucky. New floodwalls and levee systems were built to address threats of urban flooding—Cairo, Illinois, in 1928; the New Madrid Floodway, Missouri, from 1928 to 1932; and Cape Girardeau, Missouri, between 1956 and 1964 (Olson and Morton 2016c). To reduce agricultural land flooding, the Hickman levee (Kentucky) was strengthened, the Missouri levees south of Commerce were aggressively maintained, and a new federal levee was created from Commerce to Birds Point, Missouri, which connected to the New Madrid Floodway setback levee (Olson and Morton 2012; Olson and Morton 2016b).

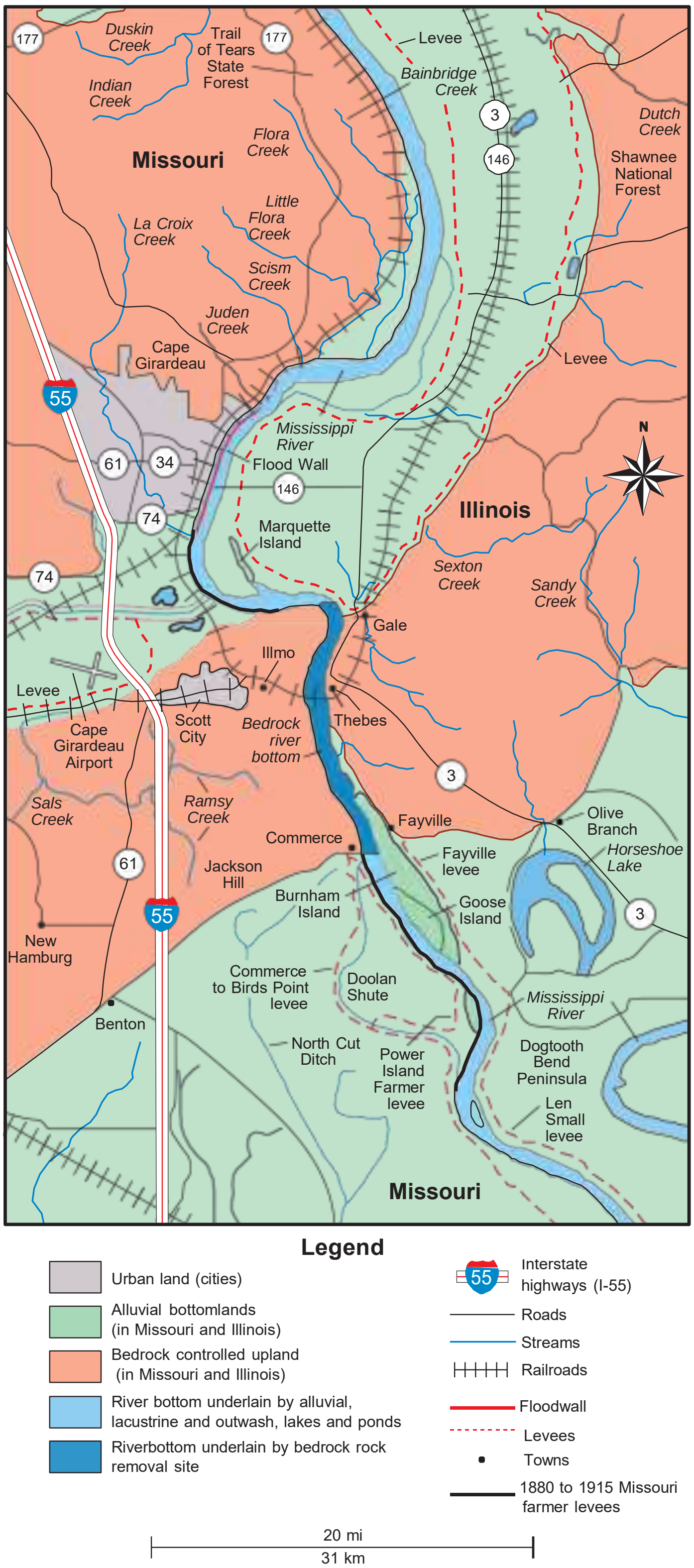
Between the 1840s and 1943 the Alexander County bottomland farmers were not protected from Mississippi River floodwaters. There is little historical evidence that the Illinois farmers and landowners were aware of the impact on river height from creating the 72 km (45 mi) Little River Drainage District Headwaters Diversion (in the year 1916) (Olson and Morton 2016a, 2016b, 2016c) or the construction of additional levees on the west side of the river. However, the Dogtooth Bend area at 10 m (33 ft) above the Mississippi River began to experience more frequent flooding and water flowing into old meander channels as the river reached greater peak heights during flood events.

LEN SMALL LEVEE AND DRAINAGE DISTRICT

By 1940, it was apparent to Illinois landowners that they needed to protect their farms and homes from river flooding, and they created the Len Small Levee and Drainage District (LSLDD) in the Dogtooth Bend area (1943) and later the Fayville levee extension in 1969 (figure 2). The new farmer drainage district built a sand core levee, which was lower and weaker than Missouri and Kentucky farmer and mainline federal levees near the confluence of the Mississippi and Ohio rivers. With the construction of LSLDD levees, the Mississippi River was now confined by levees on both sides to a less than 2.5 km (1.5 mi) wide corridor from Commerce, Missouri, at mile marker 39 to mile marker 15. This reduction in the original Mississippi River floodplain which was six times wider than the new corridor, meant the loss of considerable space for storing flood waters and resulted in increased peak heights during major flooding events (figure 2). However, during the first 50 years,

Figure 3

This map shows the location of the Missouri Little River Drainage District diversion channel outlet below Cape Girardeau and the Missouri and Illinois farmer levees south of the Thebes Gap and Commerce, Missouri, which narrowed the original 16 km wide Mississippi River floodplain to less than 2 km.



from 1943 to 1993, no documented Len Small breach occurred.

Then, in 1993, the Len Small–Fayville levee failed when the Mississippi River reached record heights and was repaired. It failed again in 2011, with breaches and craters in five places. The largest 2011 breach was repaired when LSLDD pushed sand into the levee hole, making a sand core barrier between the river and farmland, which the US Army Corps of Engineers (USACE) in 2012 covered with a clay cap at a cost of US$5 million. This was the second known federal involvement in building or repairing the Len Small farmer levee. The 1993 and 2011 levee breaches resulted in the flooding of 6,800 to 14,000 ha (17,000 to 35,000 ac) with an unknown number of buildings damaged and removed after the 1993 flood and 169 structures damaged during the 2011 flood. The Federal Emergency Management Agency awarded the State of Illinois an US$8.7 million grant that required a state match to purchase these structures beginning in April of 2015, but only a few homes were purchased before July 1, 2015. After the Illinois legislature failed to pass a state budget in July of 2015, the state matching funds were not available and the program could not be fully implement before the 2016 flood.

FLOOD OF 2016

The 2016 Len Small levee breach was much more severe than 2011 because of its location (figure 2). The fast moving river cut a 1.6 km (1 mi) long breach during late December of 2015 through early January of 2016 (figure 4) and scoured out a crater lake and deep gullies into adjacent agricultural lands. The southeast flow of the Mississippi River floodwaters through the breach created a new channel (figure 5) from river mile marker 34 through Alexander County, connected to an old meander channel, and then exited back into the main stem river at mile marker 15, a distance of 4.6 km (3.5 mi). This shortcut across Dogtooth Bend peninsula by-passed about 15 river miles (24 km) of the current Mississippi River path (figure 2). Approximately seven river lane-line buoys, hundreds of trees (figure 6), irrigation pivots, and other debris were carried onto the Dogtooth Bend bottomlands along with millions of tons of sand deposited on more than 600 ha (1,500 ac) of farmland. Another 800 ha (2,000 ac) were subjected to land scouring by the Mississippi floodwaters. The county lost 11 to 13 km (7 to 8 mi) of roads with others buried by sand (figure 1). After ditches and culverts filled with sand, drainage was nearly impossible.

The LSLDD staff members (Jim Taflinger, personal communication, April 15, 2016) were pessimistic that the district had sufficient resources to repair the levee, fill the crater lake extending 1 km (0.6 mi) through the levee, and fill and regrade the 2 km (1.3 mi) channel created by the 1993 levee breach and the 2011 deepening of the old meander channel north of Lake Milligan to mile marker 15. It is currently not clear what actions the USACE will take and what resources they have to support the LSLDD repair of the Len Small–Fayville levee. A damage assessment including both a land scouring and sand depositional survey and an updated soil survey (conducted by the USDA Natural Resource Conservation Service [NRCS]) of the 6,800 ha (17,000 ac) of LSLDD land and perhaps a total of 14,000 ha (35,000 ac) of southwest Alexander County covered by floodwaters is needed. This information is necessary to guide current repair decisions and evaluate alternative investments and activities in preparation for future flooding. Until repairs to the levee breach are made, the Alexander County bottomlands are totally exposed to the next Mississippi River flooding event.

Following the January of 2016 winter flood, the USACE moved a large amount of rock in front of the 1,200 m (4,000 ft) breach (figure 4) in anticipation of spring floods to keep the Mississippi River from extending the 4.6 km (3.5 mi) channel to the next downstream bend in the Mississippi River. If the channel were to permanently cross Dogtooth Bend peninsula, it would become an island cutting off more than 6,000 ha (15,000 ac), at least one hunting structure, and one home from the Illinois mainland. The USACE conducted a sonar survey of the 2016 Len Small levee breach to identify craters, holes, scouring and the extent of damage. The flooding took out tree lines and wiped out large chunks of the levee with sonar revealing scouring of soil and underlying parent material as deep as 9 m (30 ft) according to Alexander County engineer Jeff Denny (personal communication, April 20, 2016). However, the sonar survey showed the damage could have been much worse, finding the damaged area was not as large as in 1993.

Figure 4

The 2016 Len Small levee breach was 1.6 km long. US Army Corps of Engineer crews, working from barges in the Mississippi River channel, dropped rocks in front of and against levee banks in an attempt to stabilize them. This rock barrier covering a portion of the south end of the levee breach is shown in the right side of picture.

REPAIR AND RESTORATION EFFORTS POST-2016 LEN SMALL LEVEE BREACH

The USACE sonar survey helped the LSLDD to prioritize repairs and target restoration efforts. However local, state, and federal financial resources were limited, and many important repairs were put on hold until resources were available. After farmers, homeowners, and county crews worked to make sure their homes were safe, farmers turned to the spring work of preparing fields for planting. By April some landowners had begun removing the sand from their fields or incorporating it into the topsoil with a combination chisel plow and disk (figure 7). Some soybeans were planted by late April in fields with thin sediment deposits.

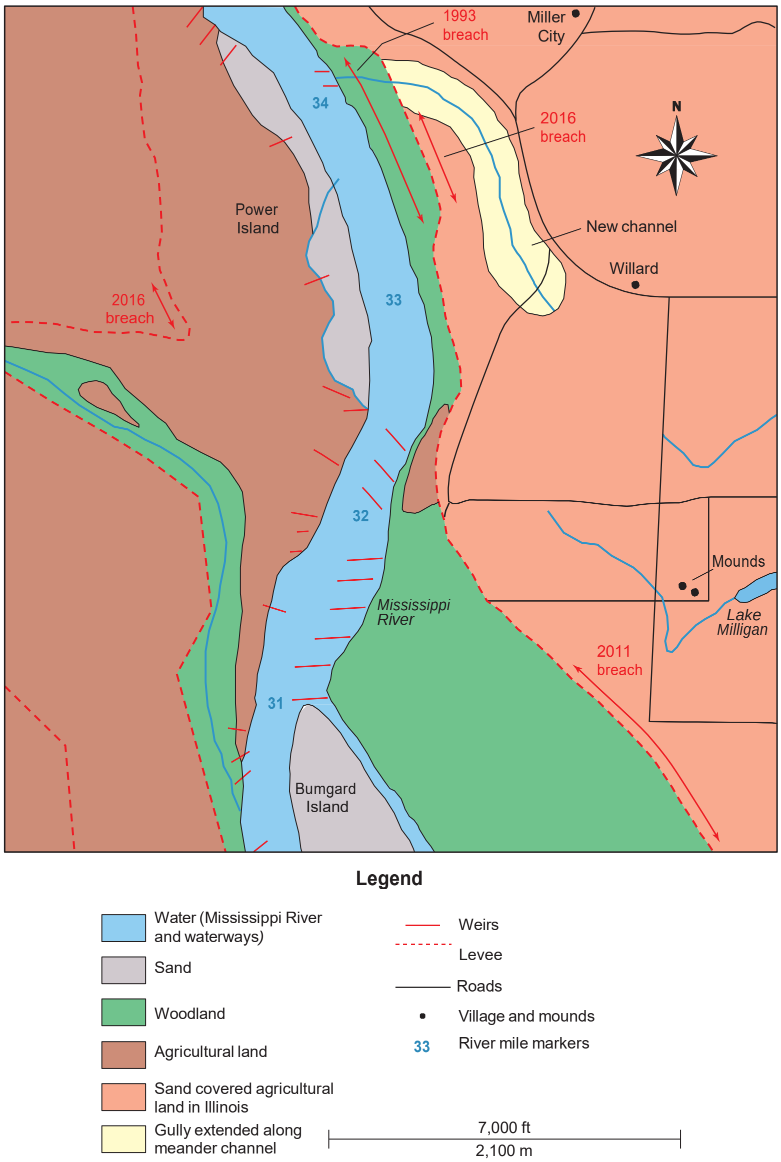
However, by August of 2016, nearly eight months after the breach, the levee still had a gaping hole, and many repairs had not yet occurred. Without repairs to the levee breach, there was little value in fixing the roads, in cleaning out the ditches, or moving the sand off fields; and planting crops was risky. Spring or summer floodwaters could again pour through the hole, drowning crops and covering roads, ditches, and fields with new sand and debris. Delayed planting reduced crop yield potential, and much of the 2016 harvest was at risk. This was not a new experience for farmers in the Mississippi and Ohio river confluence area. Back in 2011, New Madrid Floodway farmers (Missouri) planted 24,000 ha (90,000 ac) of soybeans from June 15 to July 7 and experienced modest yield reductions (Olson and Morton 2012, 2013). However, 12,000 ha (30,000 ac) were not planted that year (2011) in the New Madrid Floodway. The same year, 140 New Madrid Floodway farmers sued the USACE when major flooding damaged (land scouring, crater lake, gully fields, and sand deposition) their land. Alexander County farmers are part of this familiar debate about farmland in the floodplain and who is responsible for its protection.

POST-2016 AND FUTURE ALTERNATIVES

Dogtooth Bend farmers and landowners, members and staff of the LSLDD, community and state-level leaders, and the USACE have some difficult decisions ahead in repairing the current landscape and in preparing for future flood events that predispose the Mississippi River to

Figure 5

A close-up map of the 2016 Len Small levee breach on the Mississippi River from mile marker 34 to 30. Floodwaters poured through the breach depositing sand over a large part of the area and created the new channel shown on the map (yellow area).



realign and create a new flow path across Dogtooth Bend peninsula. These decisions affect future land uses, resource allocations, and the livelihoods of the people of southern Illinois.

Agriculture is currently the primary land use in this area. There is a need for an updated county soil survey by USDA NRCS that assesses gully formation locations, soil erosion, sediment deposition damages, and land uses. The most recent soil survey of Alexander County (Williams et al. 2007) is almost 10 years old, with two major levee breaches occurring since the last survey. Extensive land scouring and sand deposition can adversely impact soil productivity and crop yield. Many landowners removed sand from their fields after levee breaches in 2011 and 2016; others simply piled the sand up, taking land out of agricultural production. An unknown number of gullies have not been filled or regraded and are farmed around when tilling and planting occur, leaving the gullies to revert to wetland vegetation. Thus, long-term soil productivity has decreased (Olson and Morton 2015), and these changes in land use affect land values. Without an updated soil survey of the Dogtooth Bend area, the land continues to be taxed as if no land scouring or sand deposition had occurred because land productivity indices are not adjusted to reflect the soil degradation, land scouring, or sand deposition. Further, longer term planning for existing and new land uses is hindered without sufficient information to evaluate investments in reclamation of farmland or nonfarm uses.

The Mississippi River Commission (MRC)/USACE and the LSLDD are partners in managing the river landscape and need to develop and evaluate alternative strategies for addressing the river-land relationships in the Dogtooth Bend area. Several alternative courses of action are presented in this paper. While many of the details of each alternative would need to be evaluated and negotiated, they offer a start in visioning different scenarios to guide preparation for the future.

The first alternative is to continue, as in the past, to repair the Len Small levee. This could impede and delay the eventual and natural tendency of the Mississippi to take a shortcut and realign its downstream course. This alternative is a near-term fix. There is a high likelihood at some future date that another flood event will occur, and the Len Small levee will breach again, creating new craters and gullies and flooding farmland. Since 1993, major weirs and bank stabilizing efforts along the Mississippi River banks in this area have been put in place three times. Although these structures have slowed the water and bank erosion, they have not prevented the breaches of 2011 and 2016 and are likely inadequate to deter levee damage during future high water events.

A second alternative is to proactively construct a diversion channel, with embankments on both sides, where the old meander channel is currently located. During high water periods, the channel would temporarily redirect excess Mississippi River floodwaters across the neck of Dogtooth Bend peninsula and allow the water to exit back into the river at mile marker 15. The existing Mississippi River 3 m (9 ft) channel between mile

Figure 6

Hundreds of trees were transported by floodwaters and dropped on agricultural lands along with sand and lane line buoys like the red one shown here.

Figure 7

A combination chisel plow and disk is being used to incorporate the sand into the topsoil. The tillage equipment driver attempted to avoid the crater lake, gullies, and land scoured area.

markers 34 and 15 would be maintained for navigation. One or more bridges would need to be built over the diversion channel to allow access to farmland, agricultural structures, and homes; and to recreational hunting, fishing, birdwatching uses. Hydrologic studies and environmental, economic, and social acceptability analyses would be necessary to fully evaluate the investments needed and impacts on the region.

A third alternative is to assist the Mississippi River realignment tendency and construct a 1 km (0.6 mi) wide new Mississippi River channel through the 4.6 km (3.5 mi) shortcut between mile marker 34 and 15 where the Mississippi River is already cutting with each major flooding event. The USACE could accelerate this process even more by making this channel between mile markers 34 and 15 the main stem river navigation channel. This would also require thorough hydrologic, environmental, social, and economic assessments.

An elaboration of the third alternative is to create a new Mississippi River channel with low rise levees on each side of the navigation channel and set back about 1.1 km (0.7 mi). This would make Dogtooth Bend an island in Illinois and turn the current Mississippi River channel between mile markers 34 and 15 into an oxbow lake. Dogtooth Bend Island could be used for floodwater storage during major flooding events since it is 4,800 ha (12,000 ac) in size, which along with thousands more acres in the oxbow lake and other nearby islands and adjacent land not levee-protected within the current mainline federal and farmer levees, would enlarge flood storage capacity in the area. If the new Mississippi River channel is used for navigation, the current Mississippi River shipping channel length would be reduced by 24 km (15 mi). Landowners would need to be compensated if the Dogtooth Bend area is used for a new Mississippi River channel or for temporary flood storage during the nongrowing season.

Historically, the Mississippi River bottomlands have experienced hundreds of Mississippi River realignment events and course changes in the river. The large number of oxbow remnants and interior old meanders (e.g., nearby Horseshoe Lake area) are evidence of the past and harbingers of the future. Federal, state, and local managers of the Mississippi and Ohio river landscapes can impede or delay the Mississippi River realignment by attempts to maintain the status quo, but realignment will eventually happen. Over time, the mighty Mississippi River will eventually win, as it always has in the past.

CONCLUSIONS

Prior to the construction of the farmer (Len Small–Fayville) levee in Illinois and the farmer (Commerce to Birds Point) levee in Missouri, the Mississippi River was 16 km (10 mi) wide between mile markers 39 to 15 (figure 3). The creation of these two levees restricted the Mississippi River floodplain to less than 2 km (1.5 mi) and increased the peak height of the river during flooding events that occurred after 1943. The resulting increased river velocity and height place both levees, as well as downstream levees, at risk of failure.

The USACE/MRC mission includes the maintenance of the mainline levees that protect Cairo, Illinois, and the Illinois, Missouri, Kentucky, and Arkansas bottomlands and the maintenance of navigation on the Mississippi River. The USACE cannot strengthen the existing Len Small-Fayville levee without increasing the risk of losing their own mainline levees (Cairo levee and floodwall, the Commerce to Birds Point levee and the New Madrid Floodway setback levee). If the Cairo floodwall and levee were to fail, it would put nearly 3,000 residents and 400 structures at risk. If the Commerce to Birds Point levee or the New Madrid Floodway setback levee were to fail, 800,000 ha (2,000,000 ac) in Missouri, Kentucky, and Arkansas bottomlands could be flooded with both crops and soils damaged. The opening of the New Madrid Floodway can be used to reduce the pressure and peak height by as much as 1.2 m (4 ft) on confluence area levees (Olson and Morton 2012). The floodway was used in 1937 and 2011. There is a need for additional floodwater storage in the confluence area of the greater Ohio and Mississippi rivers (Olson and Morton 2016a, 2016b, 2016c). A regional effort on both sides of the Ohio and Mississippi rivers is needed to strategically identify floodplain areas that could provide temporary water storage and policy incentives for landowners of low-lying lands to profitably invest in crops and income alternatives.

Climate scientists predict a continued pattern of extreme rainfall events in the upper Mississippi River region (Olson and Morton 2016c). This suggests that unexpected above-average rainfall events in the Ohio and Mississippi river basins will continue to increase the frequency of extreme flooding events on these great rivers. As the frequency of intense precipitation events increase, the current Illinois and Missouri farmer levee systems are likely to repeatedly fail if repaired to existing height and strength. The current solution to prevent flooding in the Dogtooth Bend area is not working. Combinations of land use changes and new structures are needed to address the problem. Whatever solutions are chosen, there will need to be a significant investment of human and financial resources to prepare for the future.

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Attachment B

Conservation Organization Comments
On The
Regulating Works Project
Draft Supplemental Environmental Impact Statement (November 2016)

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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 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.

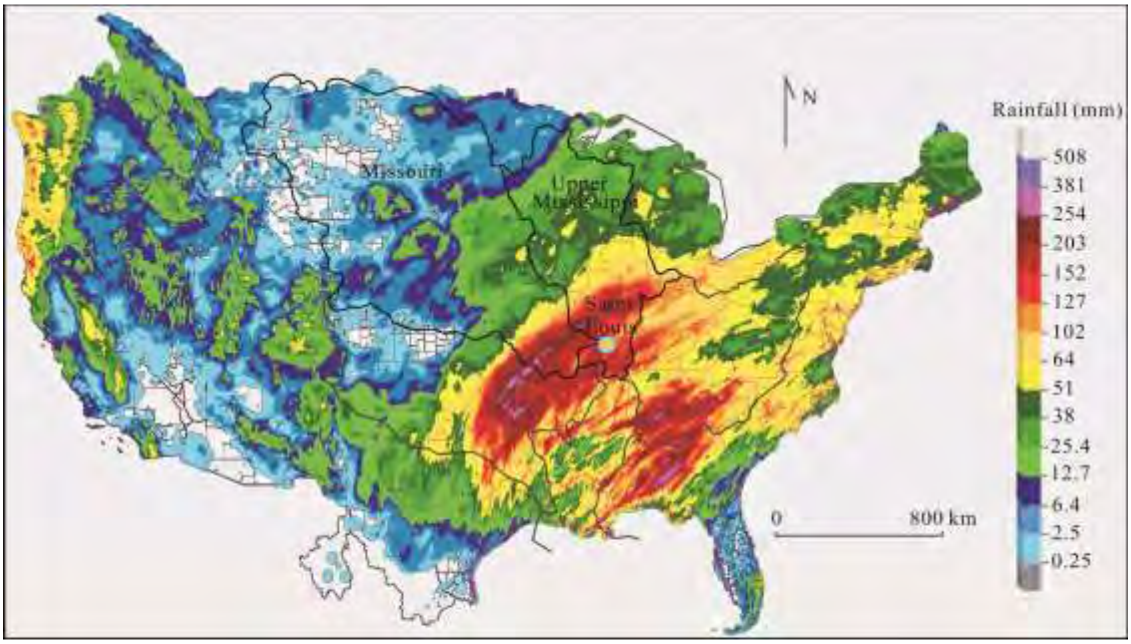

Figure 1. Map showing the observed, 7-day precipitation for December 22–29, 2015, according to NWS (2016a). Superimposed on this map are the boundaries of the upper Mississippi and Missouri watersheds (labeled) and other major river basins. Goliath delivered an average of 20 cm of rain to the entire 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).

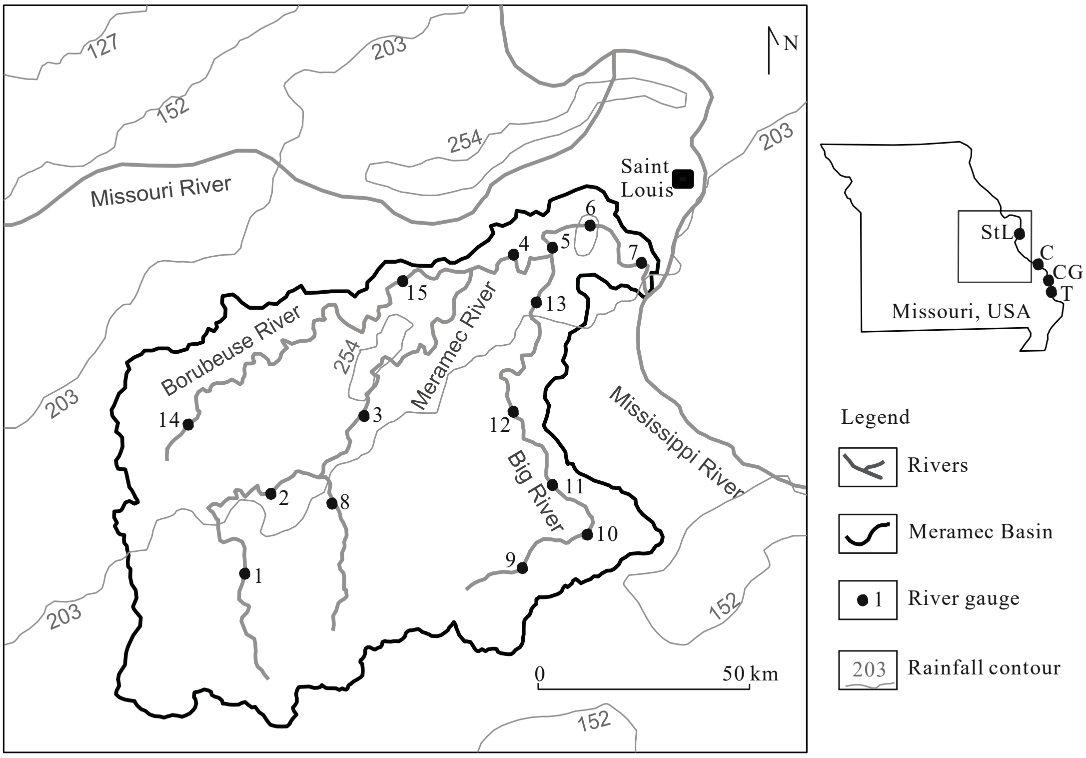

Figure 2. Map of East-Central Missouri showing the 10 300 km^2 Meramec River Basin (dark outline) and contours for precipitation delivered from December 22–29, 2015 according to NWS (2016a). Labeled dots are river gauging stations; stage hydrographs for the stations along the main stem of Meramec River (#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).

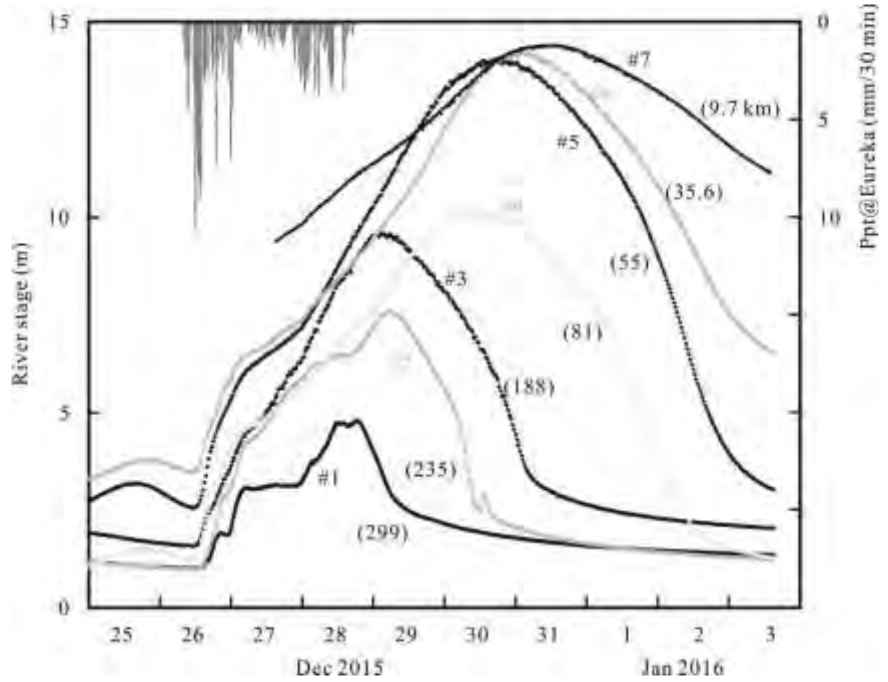

Figure 3. Stage hydrographs showing the propagation of the 2015 flood wave down the main stem of Meramec River, for sites #1 to #7 on Fig. 2. Numbers in parenthesis are the distance in km above the confluence with the Mississippi River to the south of St. Louis. Hydrographs for each site are plotted 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

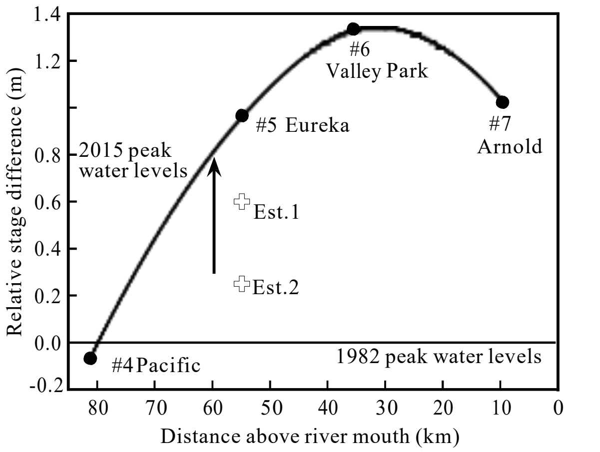

Figure 4. Relative difference between the peak water levels of December 30–31, 2015 and those of December 6, 1982 at different sites in the lower Meramec Basin (cf. Fig. 2). This difference was greatest close to Valley Park, where a large levee was built in 2005; this and other changes appear to have 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.

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.

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

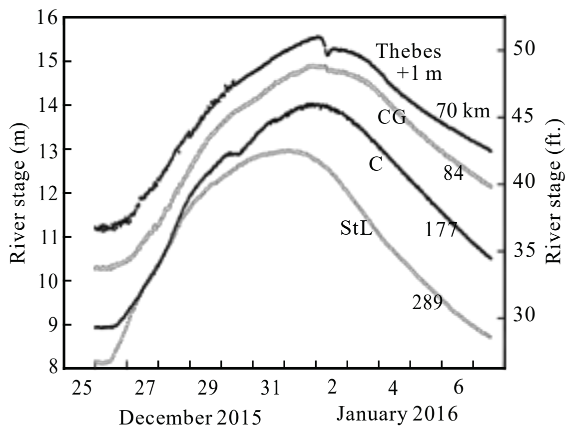

Figure 6. Stage hydrographs at St. Louis (StL), Chester (C), Cape Girardeau (CG) and Thebes, showing propagation of the 2015–2016 flood wave down the middle Mississippi River (cf. Fig. 2). The official stages depicted for each station are relative to its local datum, except that 1 m was added to the 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 C

Conservation Organization Comments
On The
Regulating Works Project
Draft Supplemental Environmental Impact Statement (November 2016)

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 $\sim 10\times$ 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 100þ 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

DOI: 10.1061/(ASCE)HY.1943-7900.0000752

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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.

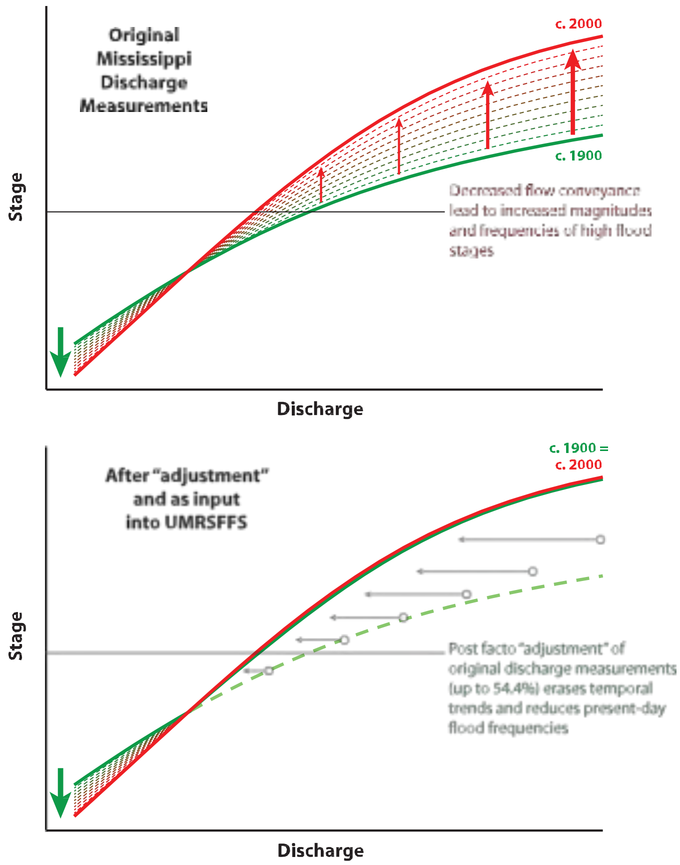

Fig. 1. (Color) Conceptual illustration showing how modification of historical discharge measurements (Dieckmann and Dyhouse 1998) erases temporal trends in MMR rating curves documented by previous researchers, including increases in flood stages for fixed discharges (red arrows); these modifications 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,

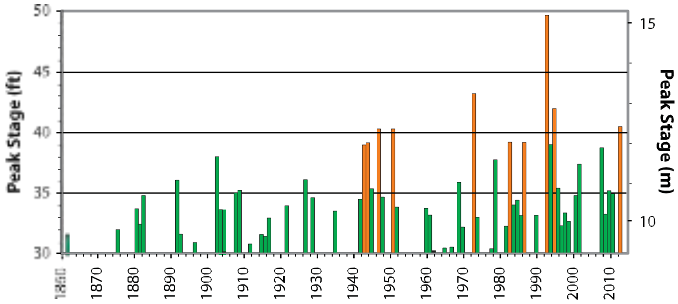

Fig. 2. (Color) Peak stages above flood level (30 ft above datum) for the Mississippi River at St. Louis; homogenous daily stages date back to 1861, and the 10 highest flood peaks (in orange) all occur in the latter half of the record; probability that this represents the random distribution of a stationary time-series is on the order of 0.00098

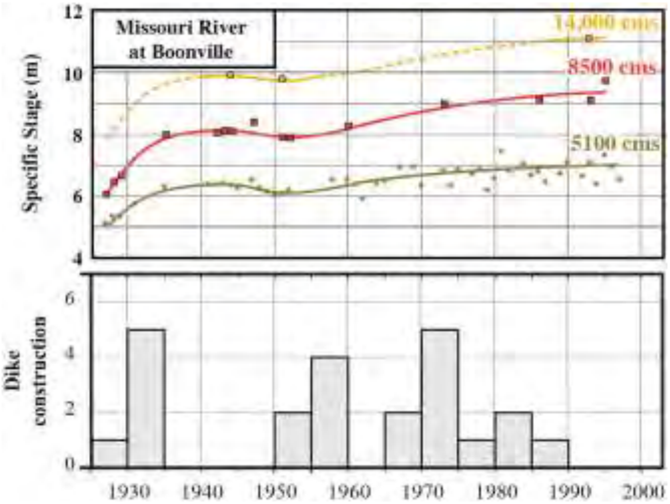

Fig. 3. (Color) Like most stations analyzed by Pinter et al. (2008, 2010), and others, discharges on the Missouri River at Boonville were developed exclusively by the USGS; flood stages increased when and where new navigational dikes were constructed (number of dike segments built within the 3.2 km of 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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J. Hydraul. Eng.

Closure to "Mississippi River Streamflow Measurement Techniques at St. Louis, Missouri" by Chester C. Watson, Robert R. Holmes Jr., and David S. Biedenharn

DOI: 10.1061/(ASCE)HY.1943-7900.0000752

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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 D

Conservation Organization Comments
On The
Regulating Works Project
Draft Supplemental Environmental Impact Statement (November 2016)

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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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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.

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Convener, Theme Session: N. Pinter, and D.W. Burbank, 1996. Feedbacks between tectonics and surface processes in orogenesis. Geological Society of America meeting, Denver.

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REFERENCES

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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 geomorph-ology, 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.

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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.

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ABSTRACTS AND PAPERS PRESENTED

Below + numerous invited talks at universities, agencies, and organizations

Paul, J.S., M.L. Books, B. Csányi, and N. Pinter, 2014. Chronic metal pollution in the Tisza River, Eastern Europe: Water quality, contaminants, and ecology. Joint Aquatic Sciences National Meeting, Abstract #15058, Portland, OR, May 18-23, 2014.

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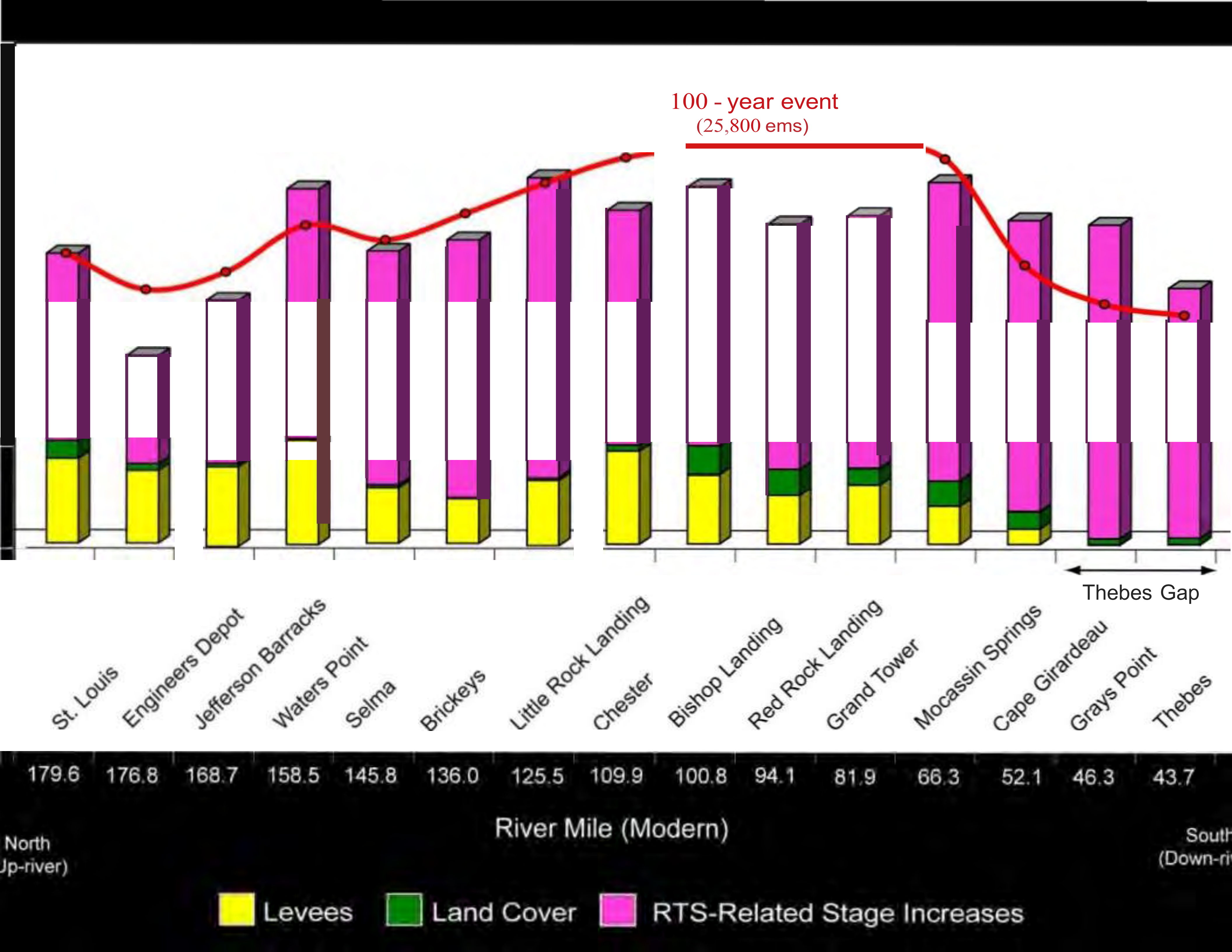
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FEATURE

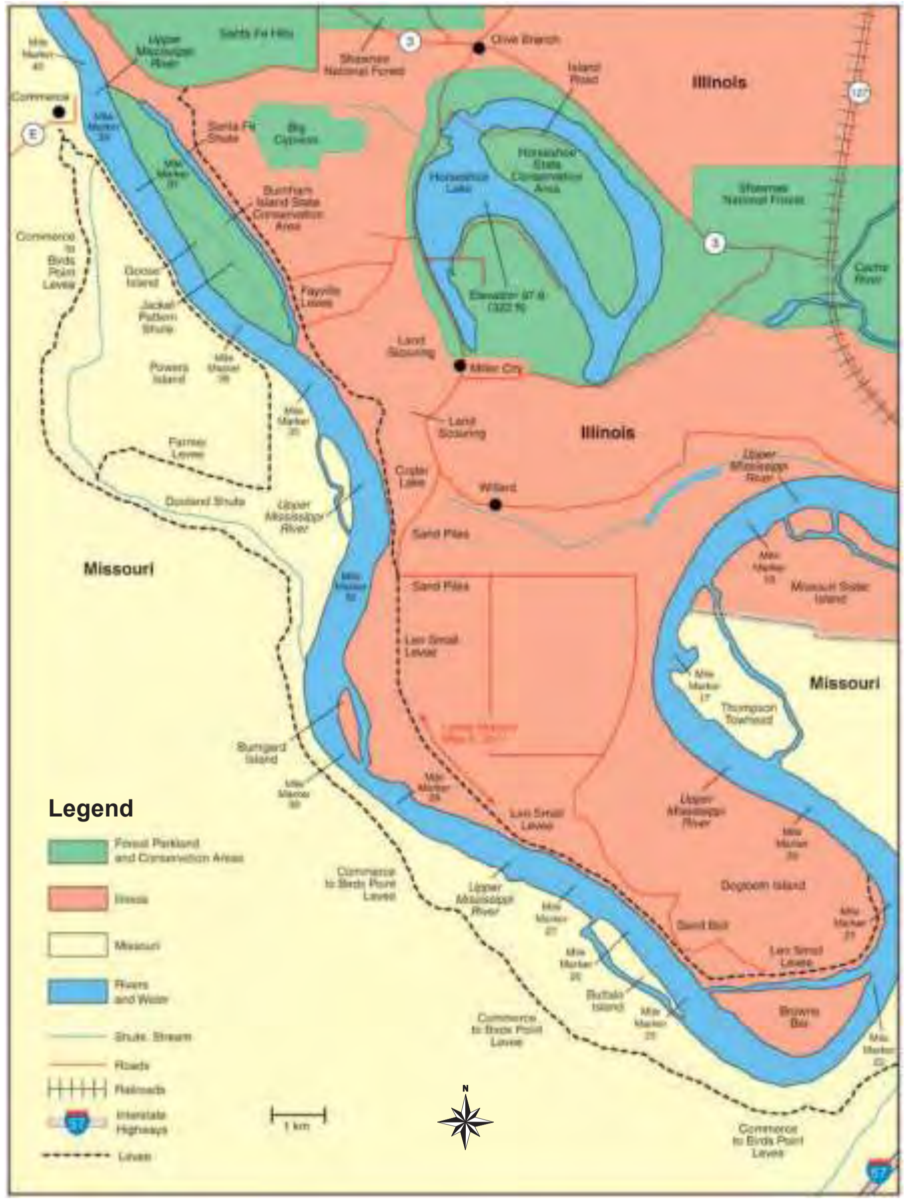
Impacts of 2011 Len Small levee breach on private and public Illinois lands

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.

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.



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

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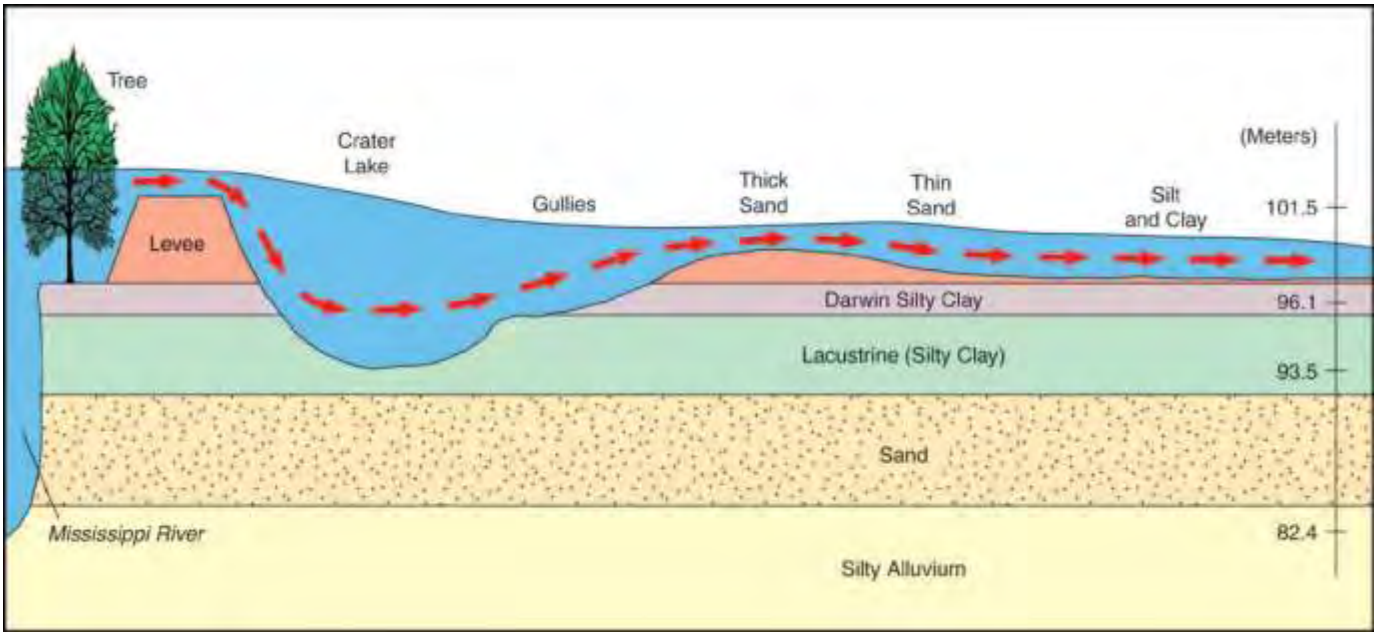
Figure 2

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

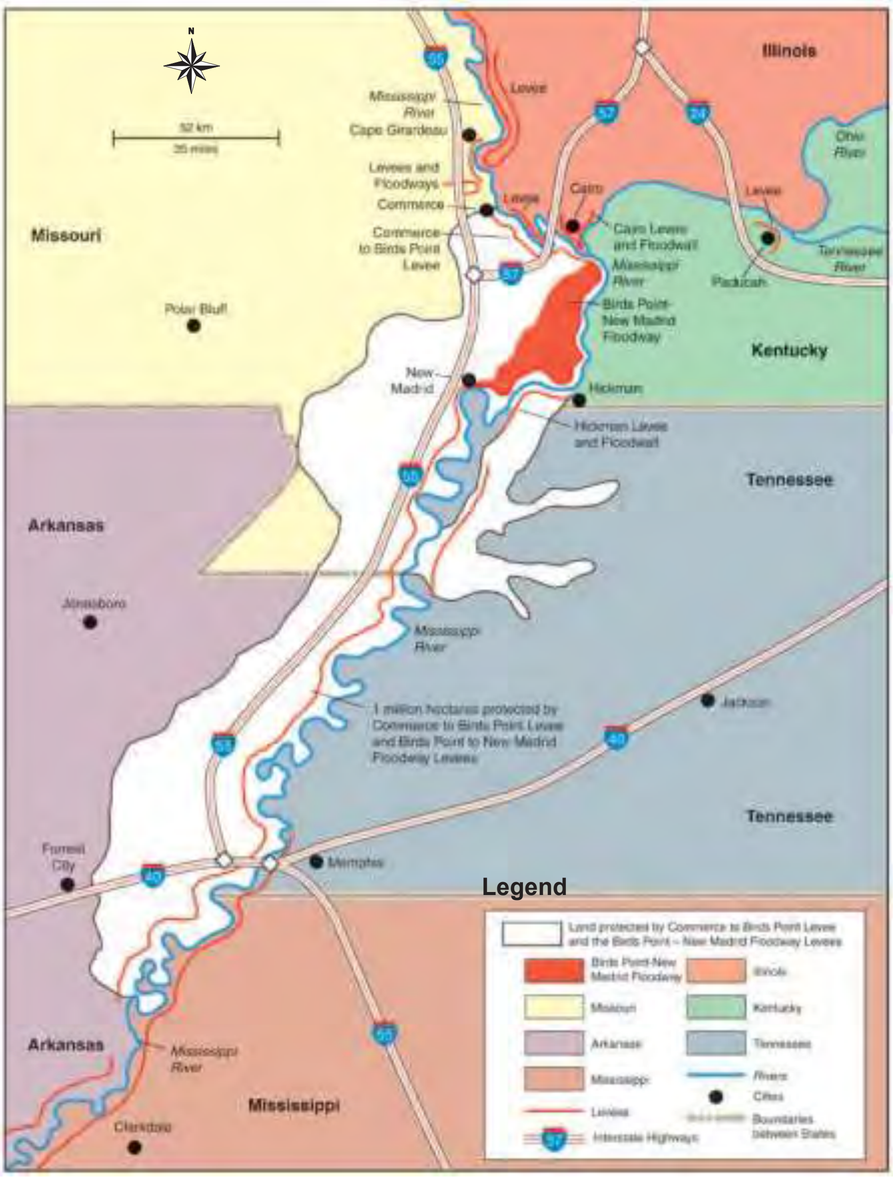
The Mississippi River Commission (MRC) was established by Congress in 1879 to combine the expertise of the USACE and civilian engineers to make the Mississippi River and tributaries a reliable shipping channel and to protect adjacent towns, cities, and agricultural lands from destructive floods (Camillo 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).

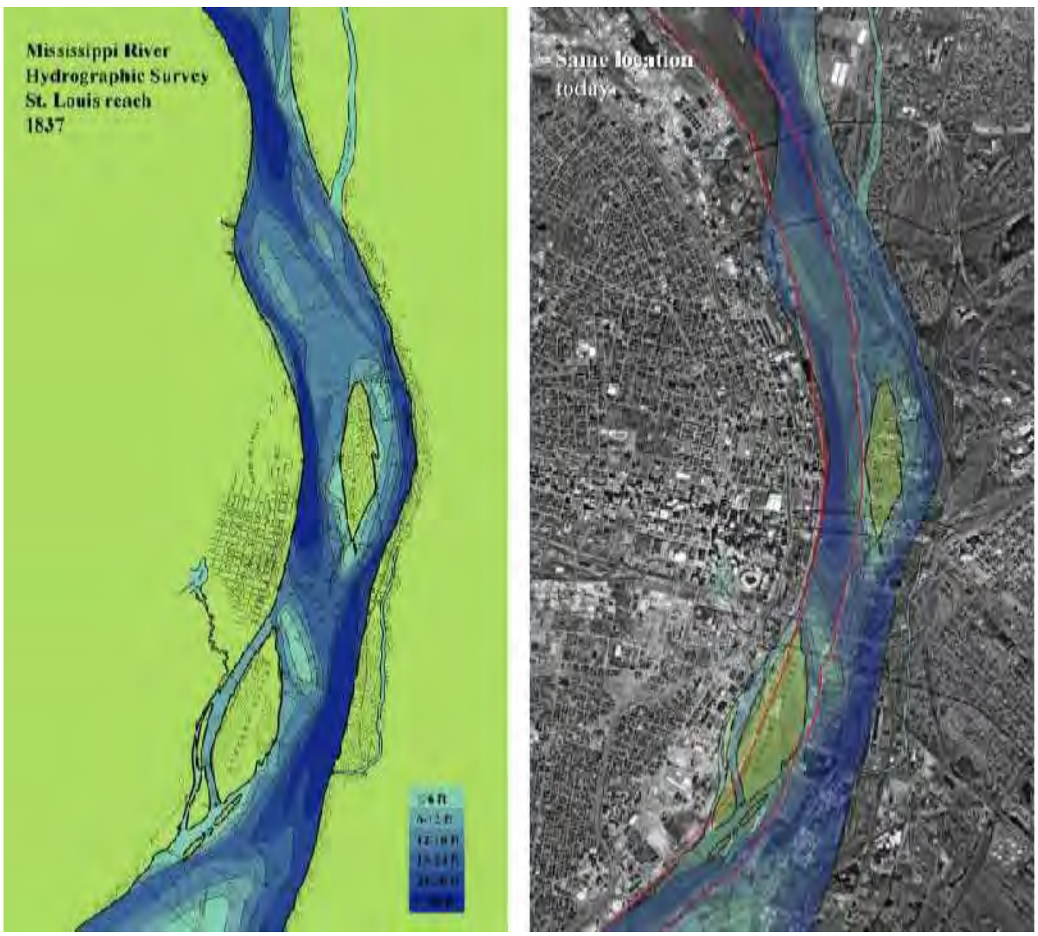
29. As I attested in paragraph 23 of my Original Declaration, many other studies confirm and corroborate these findings on the flow-dependent effects of river training structures. Particularly after the record-breaking floods on the Middle Mississippi, researchers sought to answer why such large increases 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 E

Conservation Organization Comments
On The
Regulating Works Project
Draft Supplemental Environmental Impact Statement (November 2016)

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Habitat Use by Middle Mississippi River Pallid Sturgeon

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Habitat Use by Middle Mississippi River Pallid Sturgeon

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Abstract.—Little is known about the habitat preferences and needs of pallid sturgeon *Scaphirhynchus albus*, which was federally listed as endangered in 1990. To learn more about habitat use and selection by pallid sturgeon, sonic transmitters were surgically implanted in 27 individuals from the middle Mississippi River. Study fi were located 184 times (1–23 times/individual) from November 1995 to December 1999. Of the seven macrohabitats identifi pallid sturgeon were found most often in main-channel habitats (39% of all relocations) and main-channel border habitats (26%); the between-wing-dam habitats were used less often (14%). Strauss's linear selectivity index (L_i) values indicated that study fi exhibited positive selection for the main-channel border, downstream island tips, between-wing-dam, and wing-dam-tip habitats; they showed negative selection for main-channel, downstream of wing dams, and upstream of wing dam habitats. Comparison of L_i values for four temperature ranges and three daily mean discharge ranges revealed little change in habitat selection due to temperature or discharge. Habitat use patterns also were similar across seasons and discharge regimes, except during spring months when between-wing-dam habitats saw greater use and main-channel and main-channel border habitat use declined. These changes may have been a response to high river stages associated with spring fl which may create favorable feeding areas in the between-wing-dam habitats. Enhancement and restoration of habitat diversity, particularly downstream island tip and between-wing-dam habitats, may be necessary for the recovery of pallid sturgeon in the middle Mississippi River.

The pallid sturgeon *Scaphirhynchus albus* is one of three river sturgeons of the genus *Scaphirhynchus* that is endemic to North America. Bailey and Cross (1954) characterized the pallid sturgeon as ''nowhere common.'' Pallid sturgeon numbers have since decline markedly (Kallemeyn 1983; Carlson et al. 1985; Dryer and Sandvol 1993), resulting in the species being federally listed as endangered in 1990. Management of pallid sturgeon populations has been hindered by the lack of scientifi information about their life history and habitat requirements (Kallemeyn 1983). This lack of biological information was identifi by the Pallid Sturgeon Recovery Plan (Dryer and Sandvol 1993), and the scientifi investigation of the life history and habitat needs of all life stages of the species was included in plan's objectives (Dryer and Sandvol 1993). A 1997 survey of biologists working on North American sturgeon and paddlefi also noted a lack of knowledge about the biology and life history of the pallid sturgeon and a need for additional research (Beamesderfer and Farr 1997).

The primary macrohabitat of pallid sturgeon is reported to be the main channels of the Missouri and Mississippi rivers and their largest tributaries (Bailey and Cross 1954; Carlson and Pfl 1981; Erickson 1992); pallid sturgeon were not found in backwater areas, submerged islands, or riparian areas (Erickson 1992). Little is known about the microhabitat needs of pallid sturgeon and almost no quantitative data are available on its habitat use (Bramblett and White 2001). Bramblett and White (2001) identifi individual home ranges for pallid sturgeon of up to 250 km. Large home ranges such as this increase the diffi of identifying microhabitat needs beyond general habitat use.

Modifi of the middle Mississippi River to maintain a 2.7-m navigation channel has resulted

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FIGURE 1.—Study area of the middle Mississippi River in which pallid sturgeon were radio-tagged; the area within the dotted outline is the area that received the most telemetry effort.

in longitudinal and cross-sectional changes in channel morphometry. These changes are suspected to have reduced habitat diversity, availability, and value for large river organisms, including the pallid sturgeon. The Pallid Sturgeon Recovery Plan suggested that destruction and alteration of habitats by human modifi were the primary threat to the species. However, these modifi have continued under a federal program to operate and maintain the navigation system. Information on habitat use and selection is necessary to evaluate the effect of this program on pallid sturgeon and to suggest modifi to support recovery of the species. The goal of this study was to examine the habitat use and selection of adult sturgeon in the middle Mississippi River. The middle Mississippi River stretches 314 km from the mouth of the Missouri River near St. Louis, Missouri, to the mouth of the Ohio River near Cairo, Illinois (Figure 1). This region of the river is highly channelized and has few secondary or abandoned channels, sandbars, or islands. The Pallid Sturgeon Recovery Plan identifi the middle Mississippi River as a recovery-priority area (Dryer and Sandvol 1993).

Methods

Pallid sturgeon were obtained from commercial fi the Missouri Department of Conservation, and by sampling conducted by Southern Illinois University at Carbondale (SIUC). Character index (CI) values (Wills et al. 2002) were calculated to quantify the strength of the pallid sturgeon characteristics exhibited by the fi Character index values with increasingly negative numbers represent fi with stronger pallid sturgeon characteristics, whereas increasingly positive numbers represent fi with stronger shovelnose characteristics.

Sonic transmitters were surgically implanted into their body cavity, and study fi were released as close to their capture site as logistically possible. Transmitters used for the study (18 mm in diameter, 90 mm long, and weighing 12 g) transmitted at 40 kHz, were uniquely pulse-coded, and had an estimated life of 13 months. Fish were located with a Sonotronics USR-91 receiver with a dual hydrophone array. Location coordinates were then taken using a differential global positioning system, and the position was recorded on U.S. Army Corps of Engineers navigation charts. Macrohabitat type was determined from a list of habitat classifi (Table 1; Figure 2) in reference to habitat structures such as islands, channels,

TABLE 1.—Standard distances used in delineating borders between different middle Mississippi River macrohabitats used in habitat availability analysis for pallid sturgeon.

Habitat	Standards for delineation
Wing dam upstream	74.9 m upstream and inside of tip of wing dam
Wing dam downstream	170.9 m downstream and inside of tip of wing dam
Wing dam tip	43.8-m radius around tip of wing dam
Between wing dams	All area between and inside tips of consecutive wing dams not otherwise delineated
Downstream island tip	163.6-m radius around downstream tip of islands
Main-channel border	253.2 m from shore lacking wing dams
Main channel	All area not otherwise delineated

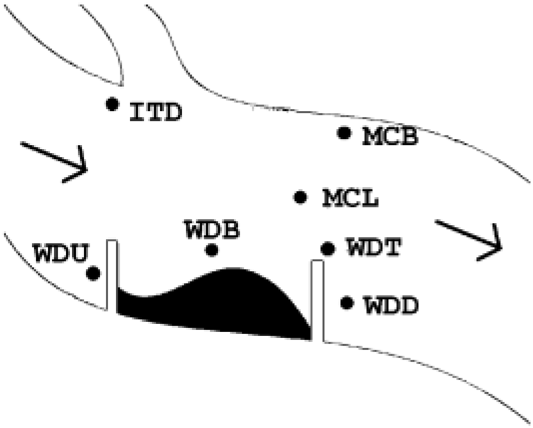

FIGURE 2.—Schematic of macrohabitat classifi of areas where radio-tracking effort for pallid sturgeon was focused. Abbreviations are as follows: MCL = main channel, MCB = main-channel border, WDU = wing dam upstream, WDD = wing dam downstream, WDT = wing dam tip, WDB = between wing dams, and ITD = downstream island tip.

shorelines, and wing dams (i.e., jetty-like rock structures extending laterally from the shore into the river that are used to redirect current from the shoreline to the main channel). These habitat classifi included main channel (MCL), main-channel border (MCB; i.e., any associated shoreline lacking current-obstructing features), immediate upstream of a wing dam (WDU), immediate downstream of a wing dam (WDD), the wing dam tip (WDT), between two consecutive wing dams (WDB), and the downstream side of an island tip (ITD).

Macrohabitat associations were expressed as a percentage of total relocations per habitat type. Additionally, habitat associations were characterized according to surface water temperature at point of relocation. Surface water temperature at point of contact was used to separate macrohabitat associations into four groups: less than 4°C, 4°C to 10°C, 10°C to 20°C (during both spring and fall months), and greater than 20°C. Increased mortality and decreased swimming ability have been shown in some fi at temperatures below 4°C (Sheehan et al. 1990; Bodensteiner and Lewis 1992). The other temperature ranges were chosen to represent the remainder of the winter season, spring and fall, and summer, respectively.

Habitat availability data were obtained from U.S. Army Corps of Engineers navigation charts. Twenty, 1.6-km stretches were randomly chosen from the river stretch occupied by the study fi To ensure up-to-date accuracy the navigation charts of these 20 stretches were ground-truthed (i.e., physical examination of each 1.6-km stretch to determine whether the habitats shown on the charts had been modifi added, or removed). Changes typically included the addition or removal of wing dams and the disappearance of small islands, presumably due to erosional processes. Changes were then corrected on the navigation charts, and charts were then enlarged to a scale of 89 mm = 914.4 m.

Each occurrence of a macrohabitat type in the 1.6-km stretch was outlined according to a predefi set of standards (Table 1). These standards were derived from a mean of fi measurements of representative habitat types via a prismatic rangefi . Three different sites of each macrohabitat were arbitrarily selected; at three arbitrary locations at each site, two measurements were taken from the edge of that particular habitat feature. The delineated areas on the charts were then measured three times using a planimeter and averaged. Results were summed by macrohabitat type, and the percentage of all available habitats was calculated for each macrohabitat. Strauss's (1979) linear selectivity index (L_i) was chosen to examine habitat selection by pallid sturgeon because it is not as susceptible to sampling bias when the habitat type represents a small or minute proportion of all available habitats (Lechowicz 1982). A chi-square goodness-of-fi test was used to determine whether signifi selection was occurring. To determine direction of selection for each habitat, L_i values were graphed with their 95% confi intervals.

To examine the effects of temperature, L_i values were calculated for each habitat for the four temperature ranges (0–4°C, 4–10°C, 10–20°C, and >20°C). A chi-square goodness-of-fi test was used to determine whether signifi selection was occurring within each temperature range. To examine changes in selection for individual habitats due to temperature, L_i values were grouped by temperature and habitat and graphed with their 95% confi intervals.

To examine the effects of discharge, L_i index values were calculated for each habitat for three daily mean discharge ranges: low (0–4,669 m^3/s), medium (4,670–7,641 m^3/s), and high (>7,641 m^3/s). These break points correspond to the 33.3% and 66.6% daily mean discharge for all days during the sampling period (Figure 3). All discharge data were obtained from the U.S. Geological Survey for the Chester, Illinois, gauging station at river kilometer

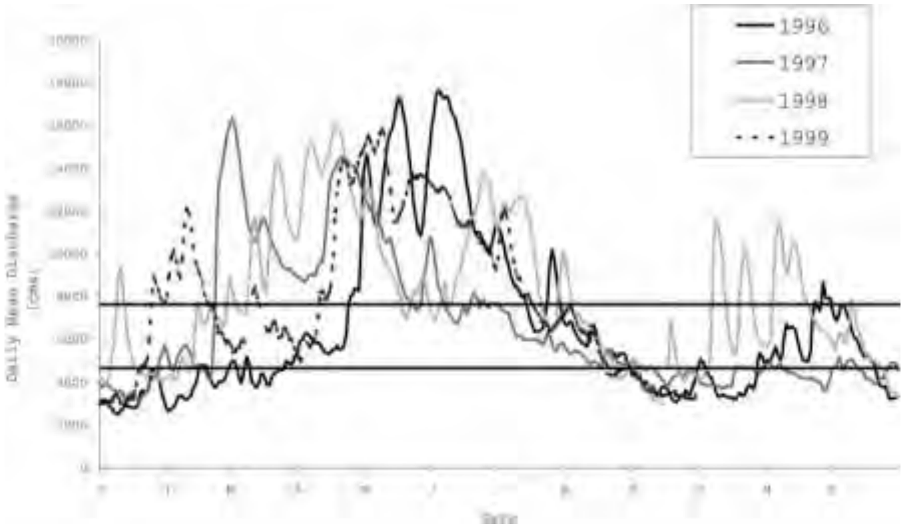

FIGURE 3.—Daily mean discharge values (m^3/s) obtained from the U.S. Geological Survey for the Chester, Illinois, gauging station on the Mississippi River from January 1, 1996, through September 30, 1999. Months are abbreviated by their fi letters; the solid horizontal lines represent the break points between the low-, middle-, and high-discharge regimes.

177. A chi-square goodness-of-fi test was used to determine if signifi selection was occurring within each discharge range. To examine changes in selection for individual habitats due to discharge, L_i values were grouped by discharge range and habitat and graphed with their 95% confi intervals.

TABLE 2.—Number of locations and days at large for pallid sturgeon implanted with sonic transmitters and released into the middle Mississippi River. Number of locations does not include initial capture or release location. Days at large is the time from date of release to date of last location.

Transmitter number	Number of locations	Days at large
7–8	1	5
2,273	1	20
239	1	8
276	1	24
456	2	43
5–10	2	200
3,334	3	263
339	5	106
2,264	6	337
384	6	217
2,237	8	588
348	9	170
465	10	228
375	12	395
267	15	519
2,588	18	417
366	19	1,488
294	20	499
249	22	527
357	23	506

Results

Twenty pallid sturgeon (614–888 mm standard length, 950–3,273 g) were surgically implanted with ultrasonic transmitters between November 1995 and December 1999. Percent weight of transmitters to body weight ranged from 0.4% to 1.3%. Character index values ranged from +0.1345 to -2.08. Although 6 of the 27 sturgeon exhibited characteristics of hybrid sturgeon, all but one of the CI values fell into the range that Carlson and Pfl (1981) identifi as pallid sturgeon, and all 27 values were below CI values of shovelnose sturgeon collected from the middle Mississippi River. Character index values for the radio-tagged fi were similar to those for other pallid sturgeon captured during the study period but not radio-tagged due to their small size or other considerations.

A total of 184 locations of study fi were made between November 1995 and December 1999. These 184 contacts were all made during daytime hours. Individual fi were located 1 to 23 times (Table 2). Approximately 4,273 km of tracking effort was exerted during the 3 years of this study. To maximize contact with the study fi tracking effort was mostly focused between river kilometers 130 and 243 (Figure 4) because that was the

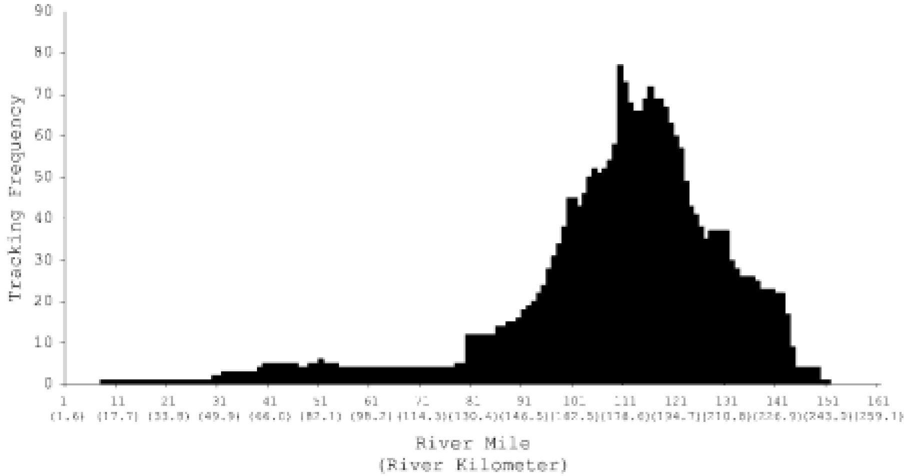

FIGURE 4.—Tracking frequency (the total number of days that a given river kilometer was radio-tracked divided by the total radio-tracking days conducted to locate radio-tagged pallid sturgeon in the middle Mississippi River), November 1995 to December 1999.

portion of the study area where fi were located most often. However, effort was also expended in other parts of the study area in attempts to fi missing study fi

Study sturgeon were located in MCL habitats 39% of the time. The MCB and WDB habitats made up 26% and 14% of all contacts, respectively (Table 3). Habitat associations for the winter season were broken down into two different temperature ranges: less than 4°C, and 4–10°C. At less than 4°C the study sturgeon were found in association with current-disrupting habitat features such as the ITD (12%) and WDD (10%) than at other times during the study. However, the MCL (49%) was still used most often. The diversity of habitat associations at less than 4°C were similar to other seasons, six of the seven habitats being used. Once winter temperatures rose above 4°C, habitat use became more restricted. The MCL (54%) and the MCB (28%) together composed 82% of all relocations in this temperature range.

Habitat associations during the spring months (10–20°C) deviated from those found during the rest of the year. The MCL habitat, which was used heavily during the rest of the year, contributed only 11% of the locations during spring, whereas spring use of the WDB habitats increased greatly (36%). It is notable, however, that the number of contacts during spring was low (*N* = 19) because of diffi in detecting fi during spring fl During fall months at the same temperatures, habitat associations were similar to those during the

TABLE 3.—Percentage occurrence and, in parentheses, number of pallid sturgeon occurrences or locations in each macrohabitat, by season (based on temperature) and relative availability of each habitat type within the middle Mississippi River study area (river kilometers 1.6 to 265.7), November 1995 to September 1998. Abbreviations are as follows: MCL = main channel, MCB = main-channel border, WDD = wing dam downstream, WDB = between wing dams, WDU = wing dam upstream, WDT = wing dam tip, and ITD = downstream island tip.

Habitat type	Percent of available habitat	Percent occurrence (number of locations)					
		All seasons	Extreme winter (<4°C)	Winter (2:4 to <10°C)	Spring (2:10 to <20°C)	Fall (2:10 to <20°C)	Summer (2:20°C)
MCL	64	39 (73)	49 (21)	54 (17)	11 (2)	56 (16)	27 (17)
MCB	11	26 (48)	14 (6)	28 (9)	26 (5)	28 (8)	32 (20)
WDD	9	4 (7)	10 (4)	3 (1)	11 (2)	0 (0)	0 (0)
WDB	8	14 (25)	10 (4)	9 (3)	36 (7)	3 (1)	16 (10)
WDU	4	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)
WDT	3	7 (13)	5 (2)	0 (0)	0 (0)	10 (3)	13 (8)
ITD	1	9 (17)	12 (5)	6 (2)	16 (3)	3 (1)	10 (6)
Total *N*		184	42	32	19	29	62

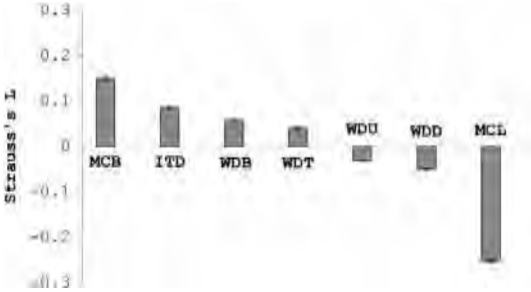

FIGURE 5.—Strauss's (1979) linear selectivity index (L_i) values for each macrohabitat radio-tracked for pallid sturgeon use in the middle Mississippi River. Positive values represent positive selection, negative values negative selection; error bars represent 95% confi in-tervals. Abbreviations are given in the caption to Figure 2.

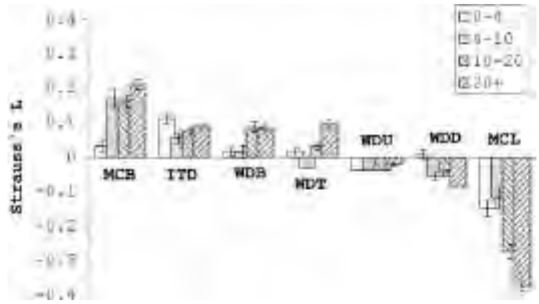

FIGURE 6.—Strauss's (1979) linear selectivity index (L_i) values by temperature regime (°C; four categories) for each macrohabitat radio-tracked for pallid sturgeon use in the middle Mississippi River. See the caption to Figure 5 for additional information.

rest of the year. The MCL contributed 56% of the fall contacts and the MCB contributed 28%, totaling 84% of the contacts for these two habitat types (Table 3).

Summer (surface water temperatures >20°C) habitat associations were diverse and closely resembled the overall habitat associations (Table 3). The use of WDT macrohabitats was heavier during the summer months than during other seasons.

Habitat availability analysis indicated that the study area was approximately 64% MCL and 11% MCB. The ITD habitat contributed the smallest amount of the study area at only 1%. The other macrohabitat types, WDD, WDB, WDU, and WDT, contributed 9%, 8%, 4%, and 3%, respectively (Table 3).

The L_i ranged from -0.22 to +0.15 (Figure 5). A chi-square goodness-of-fi test indicated that the distribution of habitat use differed signifi from habitat availability (χ^2 = 154.90, critical value with 6 df = 12.59). Radio-tagged sturgeon showed decreasingly positive selection for MCB, ITD, WDB, and WDT habitats; they exhibited increasingly negative selection for MCL, WDD, WDU (Figure 5).

Chi-square goodness-of-fi tests indicated that signifi habitat selection was occurring within temperature ranges (Table 4). However, only two habitats showed a change from positive to negative selection, or vise versa across temperatures. The WDT habitats were positively selected for during each temperature range except 4–10°C (Figure 6).

A chi-square goodness-of-fi test indicated that the distribution of habitat use was signifi different from the habitat availability at the low, medium, and high discharge regimes (Table 4). Selection direction did not change for any habitat across discharge regimes (Figure 7).

TABLE 4.—Chi-square goodness-of-fi results of Strauss's linear selectivity index values for pallid sturgeon habitat selection in the middle Mississippi River, by temperature range and discharge range. Low, medium, and high discharge ranges were 0–4,669; 4,670–7,641; and greater than 7,641 m^3/s, respectively. A χ^2 value greater than 12.59 indicates that significant selection occurred at c x 0.05, df = 6.

Variable	Range	χ^2
Temperature (°C)	0–4	187.96
	4–10	33.95
	10–20	230.80
	>20	194.99
Discharge	Low	99.08
	Medium	102.58
	High	297.18

Discussion

In the context of this study, the term ''habitat use'' refers to the habitats with which the study

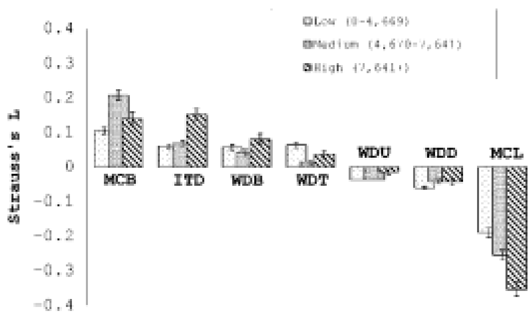

FIGURE 7.—Strauss's (1979) linear selectivity index (L_i) values by discharge regime (m^3/s) for each macrohabitat radio-tracked for pallid sturgeon use in the middle Mississippi River. See the caption to Figure 5 for additional information.

sturgeon were associated. High-use areas are important to pallid sturgeon because these are the habitats where they were most commonly found. Water-use changes or habitat modifi in these areas need to be carefully examined for their effects on pallid sturgeon. Habitat selection takes into account the availability of the habitat and compares that availability with the amount of use each habitat receives. Habitats that are negatively selected may represent areas that are undesired, unavailable, or simply used less frequently. Habitats that are positively selected may represent areas preferred by or important to pallid sturgeon and may represent the types of habitat that should be created, maintained, and protected for the benefi and recovery of the species.

Radio-tagged fi were found most often in the MCL habitat, followed by MCB and WDB habitats. However, MCB, ITD, BWD, and WDT were important areas of positive habitat selection. These areas would seem to be preferred by middle Mississippi River pallid sturgeon and may represent important pallid sturgeon habitat. Bramblett and White (2001) found that pallid sturgeon were more often located in reaches with diverse habitats, channels, and islands rather than single, uniform channels.

Although the radio-tagged sturgeon were found most often in the MCL, they exhibited stronger negative selection for MCL than for any other habitat. This is not surprising considering the MCL contributed 64% of available habitat. The MCL habitat would seem to be an area where pallid sturgeon are commonly found, yet it may not be a preferred habitat for the species. This may be explained by the fact that movement among different macrohabitat types would dictate movement through MCL habitats. Snook et al. (2002) never found sturgeon directly in the channel of the Platte River but often adjacent to it, along transitions from shallower, sandbar habitats. Similarly, pallid sturgeon in the middle Mississippi River during our study showed high use of MCB areas and positive selection for main-channel borders and ITD habitats.

The ITD represented less than 1% of the habitat available in the middle Mississippi River. Although this is not a common habitat, the radio-tagged fi did seem to positively select this area. Bramblett and White (2001) found that pallid sturgeon in the upper Missouri and lower Yellowstone rivers preferred reaches with a high density of islands and suggested these reaches provided better availability of prey fi and invertebrates. Snook et al. (2002) found pallid sturgeon to be associated with the sharp change in depths and transition areas between the downstream edges of sandbars and the main channel of the Platte River. Snook et al. (2002) noted that these areas were often just downstream from habitats that were ideally suited for a number of small prey species of fi In the middle Mississippi River fl cut away at the rich embankments of side channels releasing benthic macroinvertebrates that are swept back to the main stem in the ITD habitats. Macroinvertebrates were found to contribute a large part of pallid sturgeon diets (Carlson et al.1985). Sturgeon may use these habitats as breakwater structures that provide lower water velocities that facilitates feeding on invertebrates and small fi being swept out of the side channels.

Temperature and water velocity are two environmental factors that greatly affect behavior and habitat use of many riverine fi Extreme winter water temperatures (<4°C) can severely affect swimming ability and mortality of riverine fi (Sheehan et al. 1990). Habitat associations during winter (water temperature <4°C) did not differ from those found during the rest of the year. Habitat associations also were as diverse as those during any other season, the radio-tagged fi being found in six different habitats. Likewise, no shifts between habitat selection and avoidance were noticed during these temperatures, so it appears that winter temperatures did not have an effect on habitat selection and use.

In fact, habitat use and selection by pallid sturgeon did not seem to be affected by any temperature or discharge regime in the middle Mississippi River, except for spring months when the temperature ranged between 10°C and 20°C. During this period, the WDB areas composed the area of greatest habitat use, at the expense of MCL and MCB habitats. Pallid sturgeon are generally thought to be late spring spawners, and one conclusion is that the shift to using WDB habitats over MCL and MCB habitats may represent areas used for spawning or staging by pallid sturgeon. Although no direct information is known about pallid sturgeon reproductive biology (Dryer and Sandvol 1993), interpretation of certain data indicates that pallid sturgeon are hybridizing with shovelnose sturgeon (Carlson et al. 1985; Wills et al. 2002) such that similar areas are probably being used by both species for spawning. Examination of literature concerning shovelnose sturgeon reproductive biology indicates that the species typically spawn over rock, rubble, and gravel in the main channel or on rip-rap wing dams at water temperatures of 18–19°C (Helms 1974; Moos 1978). Shovelnose sturgeon spawning habitat seems to be distinctly different than that in the WDB areas, which consist of mostly sandy substrates. Additionally, no evidence was found during surgical implantation of the transmitters to suggest that the study specimens were sexually mature. The increased use of WDB habitats during the spring does not appear to be consistent with inferred spawning migrations.

An alternative explanation is that pallid sturgeon may have used the WDB habitats as feeding stations during the high spring fl Snook et al. (2002) found that pallid sturgeon were often located in the Platte River just downstream of shallow sandbar habitats favorable to possible sturgeon prey items. The WDB habitats in the middle Mississippi River may function in much the same manner during high spring fl when most of the sandbar depositions in the WDB areas are underwater. The water current cuts away at the sand substrate and this may help expose benthic invertebrates common in the pallid sturgeon diet (Carlson et al. 1985), creating favorable feeding areas in WDB habitats during the spring. Additionally, the WDB areas may provide lower velocities than the MCL and MCB areas, which were more commonly used than the WDB habitat during the other seasons at lower fl It should be noted, however, that if this is the case, radio-tagged fi were not seeking zero-current habitats, such as the WDD areas, but areas of reduced current. Other reduced-current habitats, such as the ITD (16%), were also being used to a greater extent during the spring.

With very little natural, unaltered habitat still available, it is diffi to determine critical habitat needs for pallid sturgeon. Therefore, habitat use and habitat selection by pallid sturgeon are both important pieces of information. Infrequent use does not indicate that a habitat is not important to pallid sturgeon because positive habitat selection may occur for habitats of low use. Areas of high use should therefore be viewed as areas to be protected for the benefi of pallid sturgeon commonly located there, and areas of positive habitat selection should be the type of areas considered for habitat enhancement and restoration projects.

In the middle Mississippi River, pallid sturgeon were often found in the MCL and MCB habitats. The high use of these areas by pallid sturgeon makes any negative changes to these habitats potentially harmful to pallid sturgeon. Any changes in use of these habitats or alterations to them should be examined before future projects are undertaken. Conversely, the three of the four wing-dam habitats represent the low-use habitats examined in this study. Any alterations or changes to these habitats would have a reduced chance of harming pallid sturgeon populations due to their infrequent use of these areas.

Although the MCL is the area of highest use by middle Mississippi River pallid sturgeon, the habitat selectivity analysis presented here indicates that the ITD, MCB, and WDB areas may actually represent preferred habitats. Much like results found in other studies (Bramblett and White 2001; Snook et al. 2002), habitats may be selected by pallid sturgeon to maximize forage opportunities. These habitats should be given consideration for any future projects aimed at creating pallid sturgeon habitat because they may be necessary for the recovery of this species. Enhancement and restoration of these habitats would represent an increase in habitat diversity, which could benefi many species in addition to the endangered pallid sturgeon.

Acknowledgments

I would like to thank Michael Schmidt, Joe Hennessy, Miguel Nuevo, Greg Conover, and others from the Fisheries and Illinois Aquaculture Center at Southern Illinois University Carbondale for their help in the fi All work done for this project was conducted under U.S. Fish and Wildlife Service Federal Fish and Wildlife Permit number PRT-697830A2, subpermit 98–01 and Illinois Natural Resource Permit number 95-12S. The U.S. Army Corp of Engineers and the U.S. Fish and Wildlife Service provided funding to conduct this research.

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Transactions of the American Fisheries Society 134:548, 2005

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Erratum: Habitat Use by Middle Mississippi River Pallid Sturgeon

K. L. Hurley, R. J. Sheehan, R. C. Heidinger, P. S. Wills, and B. Clevenstine

Volume 133(4), July 2004: 1033–1041.

Page 1039. Pallid sturgeon with sonic tags were incorrectly described as radio-tagged.

The first sentence of the second paragraph should read as follows:

Tagged fish were found most often in the MCL habitat, followed by MCB and WDB habitats.

The first sentence of the third paragraph should read as follows:

Although the tagged sturgeon were found most often in the MCL, they exhibited stronger negative selection for MCL than for any other habitat.

Kip Runyon, U.S. Army Corps of Engineers - St. Louis District,
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RE: Comments on the Draft SEIS for the Middle Mississippi River – Regulating Works Project

The Nature Conservancy appreciates the opportunity to comment on the Draft Supplemental Environmental Impact Statement (DSEIS) for the Middle Mississippi River Regulating Works Project. We understand that the mission of the U.S. Army Corps of Engineers St. Louis District (Corps) is to provide innovative solutions for delivering flood risk management, navigation, environmental stewardship, emergency operations, and other authorized civil works to benefit the region and the Nation.

Due to our organizational interests and overlap in mission areas, we partner extensively with the Corps nationally which has led to TNC-Corps MOU's at the national level and within the Mississippi Valley Division. We understand that the Corps has selected Continue Construction Alternative (no action) for achieving this mission under the DSEIS for the Project respectfully request that the Corps consider the following comments.

Project Management - We could not find any indication in the document that says when dredging levels are down to 2.4 M c/y that the installation of RTS will stop, be re-evaluated, or seek additional RTSs to reduce dredging even further. There is indication that the estimated level of RTSs in the preferred alternative is the point where cost effectiveness is lost. Will cost be the only or primary driver in this decision? Is this known, and if so, can it be addressed? The environment must be considered in the scenario, not just reduced dredging or cost. We believe information from historic dredging in the LMR could inform this question and it should be noted that RTSs are being removed in some LMR locations.

The DEIS has a fairly specific number of cubic yards of rock that will be needed and the footprint associated with the construction of these RTSs, yet the location and number of RTSs is unknown and identified through an ongoing process. There were the estimates for linear feet and volume of rock needed to minimize dredging all the way to 1.3 MCY/year. Analysis was then made of various increments of construction and the 4.4 million tons of rock for RTSs was identified as the option with the greatest Net Benefit (Appendix C, attachment 1, pg 11). However, information the other "increments of construction" were not presented. Can you provide that information, even if it is in a rough form?

Figure 1.6 and specifically Figure 1.7 (pgs 11-12) show the trend is progressing downward for dredging and it is important to ask if no additional structures were put in the river for a few years would the trend line level continue and actually adjust to something close to the desired 2.4 M c/yds. without additional RTS construction. A pause in construction may be warranted to let current conditions settle out to determine if more RTSs are actually needed. Figure 1.6 only goes back to 1964 and dredge volumes were likely much higher prior to 1964. Since the 6-foot channel was authorized in 1907, maybe that is the timeframe that should be used if data are available.

Fishery resources – The Recommended Alternative will cause another 8% loss of main channel border habitat or 1,100 acres. Estimates were provided indicating that 6,900 acres of main channel border have be lost since 1976. Combined with the additional 1,100 acres, main channel border habitat loss would total over 40% with additional losses prior to 1976 not accounted for in this analysis. It should be the policy of MVS to go beyond the mitigation of the 8% future losses. Page 158 of the SEIS indicates that there are opportunities to modify existing RTSs for compensatory mitigation for future impacts. Further, there is indication that an evaluation "could" be done to identify these opportunities. We suggest that a commitment be made to carry out this evaluation and continue modifications based on past impacts to this important habitat.

Geomorphology – With the Recommended Alternative additional RTS will be put into the system and continue to increase velocity and scour. This has been shown to have impact on tributary incising and headcutting up these tributary watersheds. This not only impacts the tributary stream but releases additional sediment that can cause additional main channel dredging, which is contrary to the value of the RTS structures. How are the current and additional RTSs destabilizing the tributaries? This issue should be acknowledged and addressed.

Based on the planform information in Figure 3.7 (pg 42) the floodplain is reduced to somewhere between 55% and 59% of the historic footprint. Although this only a planform metric, it likely represents a significant change in the floodplain depth diversity (shallow to deep), main channel depth (more incised), and significant shifts in the terrestrial floodplain topography. Additional loss is significant in context to the historic floodplain loss, however the SEIS only recognizes the loss in terms of the additional increment of this project work. This minimizes the environmental impact of this additional work on this already degraded portion of the river.

Figures 3.8 and 3.9 (pg 43) show a reduction of about 1/3 the original width of the Main Channel and Floodplain Planform, respectively. Although the rate of change has slowed, we would like to know if/how the additional RTSs will reduce the original width in the main channel and the floodplain.

The DEIS indicates that there are currently 32 side channels for the entire 200-mile reach of the MRR (pg 45). The regulating works project effectively eliminates the creation of new side channels. How many were present historically? Is the re-creation of side channels a possibility that is being considered?

Air Quality and Climate Change – The SEIS documents reduced GHG releases from the recommended alternative as compared to the No New Construction Alternative of 29, 400 down to 16,970. While The DEIS makes an effort to estimate the contributions of GHGs from the transport of rock to the site and actual construction of the RTS, it fails to account for the actual mining and processing of the rock which would be a significant contribution. We suggest that this be corrected.

Thank you,

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Floodplain Management, Mississippi River Basin Program
The Nature Conservancy
619 South Oregon Street
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Audubon MISSOURI

State Office Headquarters
301 Riverlands Way
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636.899.0090

January 18, 2017

Mr. Kip Runyon
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO 63103-2833

Re: Draft Supplemental Environmental Impact Statement (SEIS) for Middle Mississippi River Regulating Works, Missouri and Illinois

Dear Mr. Runyon:

Audubon Missouri would like to thank the U.S. Army Corps of Engineers for undertaking this important review of the operation and management of the Middle Mississippi River and associated impacts, and we appreciate the opportunity to offer the following comments.

Audubon Missouri is a division of the National Audubon Society, which places significant conservation emphasis on the Mississippi River Flyway and the importance of habitat maintenance and restoration to the vitality of bird populations and other wildlife. These conservation goals are furthered through a variety of Audubon research, education and policy programs and efforts carried out at numerous locations along the Mississippi River. One of the most notable focal points for this work is the Audubon Center at Riverlands, which is located on the Riverlands Migratory Bird Sanctuary in the St. Louis area.

Audubon Missouri has been on record in strong support of habitat restoration along our big rivers in Missouri by the Corps and its partners. Restoration is an important and essential purpose of Corps of Engineers' management of the rivers, but we believe the Corps has not undertaken sufficient habitat restoration commensurate with the loss of habitat, damage to riparian ecosystems, and detrimental effects upon fish and wildlife that have resulted from years of techniques employed in support of navigation and flood control.

We believe the Corps has ample sources of authority to increase significantly its habitat restoration projects and to confer upon restoration activities the priority and focus they deserve including authorities under the Fish and Wildlife Coordination Act of 1958 and the Water Resources Development Acts of 1986 and 2007. In addition, we believe these authorities allow the Corps to assess impacts going back to the original 1976 EIS and mitigate for negative impacts that have occurred since the original 1976 EIS.

The Corps of Engineers indicates that further loss of habitat caused by the preferred alternative described in the SEIS would require offsetting mitigation. Audubon Missouri calls upon the Corps to further analyze and undertake options and means to avoid and minimize detrimental project impacts on habitat and resulting effects upon fish and wildlife.

We respectfully ask that for any existing or future structures placed in the Middle Mississippi River or along its banks to support navigation and flood control you ensure that appropriate modifications or other mitigation measures to support fish and wildlife habitat are reviewed, considered, and undertaken.

We would be pleased to support you in these efforts. Thank you for your consideration.

Sincerely,

Anita C Randolph

Anita Randolph
President
Audubon Missouri

January 18, 2017

Mr. Kip Runyon
U.S. Army Corps of Engineers - St. Louis District
1222 Spruce St.
St. Louis, MO 63103-2833

RegWorksSEIS@usace.army.mil

Re: Draft Supplemental Environmental Impact Statement for US Army Corps of Engineers, St Louis District Middle Mississippi River Regulating Works Project

Dear Mr. Runyon,

The undersigned organizations, which are members of the Water Protection Network, appreciate the opportunity to comment on the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project. We respectfully urge the US Army Corps of Engineers St Louis District (the "District") to pursue the "No New Construction Alternative" for the Middle Mississippi River Regulating Works Project given the environmental consequences and increasing flood risk of the preferred alternative identified in the Draft Supplemental Environmental Impact Statement (DSEIS).

1. The District is violating NEPA by not considering more alternatives and by failing to meaningfully evaluate project impacts

The DSEIS violates the National Environmental Policy Act (NEPA) by refusing to examine alternative approaches to achieving the goals of the project. The District attempts to justify this untenable position by claiming that it must continue to use century-old techniques for carrying out this project. NEPA requires that an environmental impact statement identify the full scope of impacts (direct, indirect, and cumulative) from a proposed action and determine whether there are less environmentally damaging ways to achieve the project purpose. Maintaining navigation is the purpose of the Regulating Works Project, and river training structures and dredging are just potential tools not a pre-ordained end in themselves. The District must consider a full range of alternatives and consider abandoning outdated tools if they prove to be no longer be in the public interest.

The DSEIS violates NEPA by failing to meaningfully evaluate project impacts. For example, the DSEIS dismisses extensive and highly credible information on flood level increases and fundamental changes in the river's hydrology. The DSEIS also lacks fundamental and essential information needed to assess project impacts, including information on: flood levels; sedimentation rates; fish and wildlife species, including migratory species, and their critical habitat needs; plant species, including wetland plant species; and vitally important habitat types, including main channel border habitat, braided river habitat, wetland habitat, and floodplain habitat. The DSEIS also fails to recognize the severely degraded condition of the Middle Mississippi River.

2. The District does not have the data to support their preferred alternative

Maintaining the navigation channel through the Middle Mississippi River presumably requires the removal of sand from the channel. However, the District fails to provide sufficient data regarding the sediment load of the Middle Mississippi River, which is noted by the District's own Independent External Peer Review (IEPR). The IEPR panelists were not able to "judge whether structures and dredging designs are based on robust science, data and engineering" because the District does not provide information about the actual sediment load in the Middle Mississippi River. Also, none of the IEPR's specific recommendations to include sedimentation information were followed. Additionally, the IEPR found that "the SEIS has little information on the hydraulic and hydrologic engineering data for the MMR". The Middle Mississippi River has changed considerably since the 1976 data used in the report was collected. Critical economic information is missing from the DSEIS as well, calling into question the economic benefits of river training structures over dredging. The District does not provide any budget estimates of funds spent on the project to date or anticipated spending to complete the project. As the Regulating Works Project includes new construction, a National Economic Development analysis should be completed to compare alternatives. Included in this analysis, the District should also consider the full range of ecosystem services lost in the construction of their preferred alternative.

3. The preferred alternative may increase flood risk

Extensive peer-reviewed science demonstrates that river training structures have caused significant increases in flood heights in broad stretches of the Mississippi River. 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. 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 DSEIS establish that such construction will not contribute to increased flood risks for communities. The District attempted to review the link between flood risk and river training structures by commissioning an Independent External Peer Review (IEPR). However, several potential flaws are inherent in the IEPR findings. All the IEPR reviewers have worked for the US Army Corps of Engineers and giving the appearance of biasing them towards agreeing with Corps policies and protocols. Instead of relying on a panel selected by the District, the District should call on the National Academy of Sciences to do a truly independent review of the Regulating Works Project and the link between river training structures and flooding. A National Academy of Sciences review is critical for ensuring that 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. A National Academy of Sciences review would also provide valuable recommendations regarding construction of new river training structures to protect people and wildlife. Such a process will give the public improved confidence in the Corps' analyses and decisions.

4. An Environmental Impact Statement needs to be prepared for operations and maintenance on the entire Upper Mississippi River

The District should expand the DSEIS to evaluate the full suite of operations and maintenance activities for the Upper Mississippi River – Illinois Waterway (UMR-IWW) navigation system. The Regulating Works 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, Corps 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 operations and maintenance activities are designed to maintain a single project, individual activities should not be evaluated in isolation.

As members of the Water Protection Network, a coalition of over 230 members comprised of national, local, and regional organizations that work together to ensure water policies and projects are environmentally and economically sound. We ask the District to protect critical habitat on the Middle Mississippi River and select an alternative that abandons the use of new river training structures and that removes or modifies many of the existing river training structures to restore wildlife habitat and reduce flood risks to communities.

Please accept these comments for Draft Supplemental Environmental Impact Statement for US Army Corps of Engineers, St Louis District Middle Mississippi River Regulating Works Project. Should you have any questions or require additional information, please contact Marisa Escudero, Water Protection Network Manager, at 202-797-6644 or escuderom@nwf.org.

Sincerely,

Ellen McNulty
President
Arkansas Wildlife Federation

John Koeferl
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Citizens Against the Widening of the Industrial Canal

Clark Bullard
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Robert Eisenstadt
Treasurer
Friends of Black Bayou Lakes

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Executive Director
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January 18, 2017

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Dear Mr. Runyon,

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As members or partners of the Mississippi River Network, a coalition of 53 organizations and nearly 20,000 River Citizens working toward a healthier Mississippi River from the headwaters to the Gulf, the undersigned organizations recognize the difficulty of balancing many interests while protecting the land, water, wildlife and people of America's Greatest River. We ask the District to protect critical habitat on the Middle Mississippi River and select an alternative that abandons the use of new river training structures and that removes or modifies many of the existing river training structures to restore wildlife habitat and reduce flood risks to communities.

Re: Draft Supplemental Environmental Impact Statement for US Army Corps of Engineers, St Louis District Middle Mississippi River Regulating Works Project

Please accept these comments for Draft Supplemental Environmental Impact Statement for US Army Corps of Engineers, St Louis District Middle Mississippi River Regulating Works Project. Should you have any questions or require additional information, please contact Andy Kimmel, Network Policy Manager, at 847-417-8581 or akimmel@bluestemcommunications.org, or Olivia Dorothy, Network Policy Co-chair, at 217-390-3658 or odorothy@americanrivers.org.

Sincerely,

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Nicollet Island Coalition

January 18, 2017

Kip Runyon
U.S. Army Corps of Engineers - St. Louis District
1222 Spruce St.
St. Louis, MO 63103-2833

RegWorksSEIS@usace.army.mil

Re: Draft Supplemental Environmental Impact Statement for US Army Corps of Engineers, St Louis District Middle Mississippi River Regulating Works Project, EIS Number 20160256

Dear Mr. Runyon,

The Nicollet Island Coalition is a group of taxpayer, environmental, and conservation non-profits dedicating to protecting and restoring the Upper Mississippi River (UMR) by advocating for reforms to the navigation system to create a healthy, natural and sustainable UMR. The Coalition urges the U.S. Army Corps of Engineers St Louis District (the District) to pursue the "No New Construction Alternative" given the environmental consequences and increasing flood risk of the preferred alternative identified in the Draft Supplemental Environmental Impact Statement for the Regulating Works Project (DSEIS). Due to these concerns and others, the District should stop the construction of river training structures until the Regulating Works Project can be adequately evaluated and the District can complete a supplemental environmental impact statement. These steps are essential to protecting both the environment and taxpayer investment in operating and maintaining the navigation channel. The Coalition also urges the District to review and rectify the following concerns with the DSEIS.

1) Studies show river training structures increase flood stages.

The Coalition and its members have provided detailed comments in the past on the District's finding that river training structures do not cause flood stage increases. The Coalition continues to believe that the District's methods and findings are flawed. Please find the attached comment letters for the Middle Mississippi Regulating Works Project and Grand Tower Environmental Assessment for the Coalition's detailed response to the District's findings.

While the Coalition appreciates the District's attempt to review the link between flood risk and river training structures by commissioning an Independent External Peer Review (IEPR), the Coalition found several flaws with the IEPR and their findings. Instead of relying on a panel selected by the District, the District should call on the National Academy of Sciences to do a truly independent review of the Regulating Works Project and the link between river training structures and flooding.

The IEPR only had three reviewers on the panel. This is very small given the magnitude of the information under review. By comparison, the St Johns New Madrid Floodway Project IEPR had 8 panelists. Such a small panel for such a large project calls into question whether the panel really had the full range of expertise needed to review the DSEIS.

All the IEPR reviewers have worked for the US Army Corps of Engineers (the Corps) and the Coalition is concerned that this history biases them towards agreeing with Corps policies and protocols. The use of micro models have been cited by experts as a major flaw in the District's analysis of the link between flood risk and river training structures. Using micro models to evaluate the impacts of river training structures cannot be relied upon to provide accurate planning information as they lack "predictive capability." This includes the Corps' Hydraulic Sediment Response or HSR model which is a small-scale physical sediment transport model used by the St. Louis District. A 2006 study concluded that because of the "lack of predictive evidence, the micromodel should be limited to demonstration, education, and communication."[1] Unfortunately, despite their poor performance for planning purposes, micro models are an approved method for analyzing instream engineering challenges and methods within the Corps and it is possible that IEPR reviewers were not adequately able to provide the critical review needed of the methodology.

The District only provided the IEPR with Appendix A of the DSEIS. Appendix A is a 30-page analysis authored by the District themselves to defend their modeling methods and their finding that river training structures do not elevate flood stage. It is not an independent review of many studies on the link between river training structures and flood risk. The Coalition partners provided the District with a list of references that included approximately 500 pages of scientific research that linked river training structures to an increase flood risk in previous comments. While the District did provide the IEPR with this list of references, the District did not ask the IEPR to review these studies. The IEPR has the discretion to review material beyond what the District provides, but there is no discussion in the IEPR report that would indicate the panelists conducted such a review.

If the IEPR only reviewed Appendix A it would be hard not to support the District's methods given that it was written by the District with pre-conceived notions of findings favorable to the status quo. Appendix A is in no way an independent review of the academic dispute concerning the impact of river training structures on river and flood stages. The language in Appendix A is clearly biased and dismissive of the findings of other respected scientists and peer-reviewed research. While the District claims in several passages that their models and findings have been reviewed by "other external reviewers" to bolster

[1] Stephen T. Maynord, Journal of Hydraulic Engineering, Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model (April 2006).

their position, the District provides no information about the identity of these “other external reviewers” nor their qualifications. To adequately assess the value of opinions provided by other reviewers, the District must provide their identities, affiliations and qualifications.

The tone and language of Appendix A demonstrates the magnitude of animosity that has developed between the District and independent researchers. For example, the District complains on A-15 that scientists won’t share their data, models or other supporting materials, while at the same time, the District has removed their historical river gage data from the public access database, rivergages.com. If the District is indeed so confident in their data, it should be shared publicly as it is by every other district in the country. Scientists noticed the data went missing around 2012, when the dispute around the validity of the District’s data and methods really heated up in the media and journal articles. Unfortunately, some of the tone and language presented in Appendix A reads as though it were written in the letters to the editor section of a scholarly journal, not an environmental impact statement. This dispute underscores the need for a truly independent body such as the National Academies of Science to resolve the conflict.

Recommendation: The District needs to request a National Academy of Sciences review of river training structures and their impacts on flood stage to resolve the academic disagreement between the District and independent scientists.

2) The District’s review of alternatives violates the National Environmental Policy Act (NEPA)

The DSEIS violates the most fundamental purpose of NEPA by intentionally and explicitly refusing to examine alternative approaches to achieving the goals of the project. The Corps attempts to justify this untenable position by claiming that it must continue to use the techniques for carrying out this project approved by Congress 107 years ago:

> “Alternatives. Congress provided the manner in which the navigation channel for the MMR should be obtained and maintained via the original Regulating Works Project authorization in 1910 and a modification to the authorization in 1927. The purpose of this SEIS is not to consider a change to that authorization through reevaluating the need for the Regulating Works Project or the methods to be used to accomplish the goals of the project. Rather, this document analyzes the impacts of the Regulating Works Project as it is currently constructed, operated, and maintained with current information that has become available since the completion of the 1976 EIS.” DSEIS at ES-2.

NEPA requires that an environmental impact statement identify the full scope of impacts (direct, indirect, and cumulative) from a proposed action and determine whether there are less environmentally damaging ways to achieve the project purpose. The purpose of the Regulating Works Project is to maintain navigation; river training structures and dredging are tools to achieve this purpose. The District must consider a full range of alternatives and consider abandoning the tools authorized by Congress if they prove to no longer be in the public interest.

A striking example of this is at Dogtooth Bend where the Mississippi River is threatening to realign and turn the main channel into an oxbow. A recent study proposed a range of long-term engineering alternatives that need to be examined at this location.[2] However, in Section 1.1.5, the District identifies bank stabilization and revetment as the only option at this location. Instead of prescribing one and only one method to be applied where the Mississippi River threatens to realign itself, the District needs to evaluate a range of projects to ensure the most cost-effective, environmentally sustainable solution is used – including moving the navigation channel and permitting the river to migrate to reduce future damages. The project at Dogtooth Bend deserves its own environmental impact statement and should not be tiered off the Regulating Works Project Environmental Impact Statements.

Recommendation: The District needs to ensure NEPA procedures are followed and evaluate a full range of alternatives to maintain the navigation channel on the Middle Mississippi River, including strategies that may require initiating separate environmental impact statements to evaluate unique challenges like channel migration in certain areas.

3) The DSEIS violates the Fish and Wildlife Coordination Act

The District claims that the Regulating Works Project is exempt from the Fish and Wildlife Coordination Act because "60 percent or more of the estimated construction cost has been obligated for expenditure" (DSEIS at 197). However, this exemption applies to project spending in 1958, when the Fish and Wildlife Service Coordination Act was signed into law. The District does not provide any information or supporting evidence that spending met this requirement in 1958 and, in fact, does not provide any information on historic and anticipated spending for the Regulating Works Project. Given that the Regulating Works Project is a perpetual authority, it would be impossible to determine a final spending amount and therefore impossible to determine 60% of that amount.

Additionally, the DSEIS identifies the least tern and sturgeon as species that will be impacted by the proposed alternatives. As it has been 17 years since the Biological Opinion was completed and the District is proposing significant additional construction in the Middle Mississippi River, the District should reinitiate consultation on the 2000 Biological Opinion and obtain a Fish and Wildlife Coordination Act Report. Reinitiating consultation is needed to determine if changes must be made to the Biological Opinion based on the proposed new construction under the preferred alternative. While the District states that the Regulating Works Project will end in 17 years, the authority has no expiration date and the District could continue to use the authority for endless construction for another 100 years. Those issues should be explored fully with the U.S. Fish and Wildlife Service as part of the consultation process.

Recommendation: The District needs to reinitiate consultation with the U.S. Fish and Wildlife Service on the 2000 Biological Opinion and obtain a Fish and Wildlife Coordination Act Report.

4) The District lacks the data needed to evaluate and justify the Regulating Works Project

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[2] Olson, K.R. and L.W. Morton. 2016. Mississippi River Threatens to Make Dogtooth Bend Peninsula in Illinois an Island. *Journal of Soil and Water Conservation.* 71(6):140A-146A.

The purpose of the Regulating Works Project is to maintain the navigation channel through the Middle Mississippi River and presumably this primarily requires the removal of sand from the channel. However, the District fails to provide sufficient data regarding the sediment load of the Middle Mississippi River, which is noted by the IEPR. The IEPR panelists were not able to "judge whether structures and dredging designs are based on robust science, data and engineering" because the District does not provide information about the actual sediment load in the Middle Mississippi River (IEPR at 9). This is extremely concerning and the District failed to address the IEPR's specific recommendations to include sedimentation information in Chapter 3.2.2 and/or a dedicated appendix were followed. The failure of the District to provide such basic information to justify the need for the Regulating Works Project calls into question the appropriateness of the District's preferred alternative. It is impossible to adequately evaluate the effectiveness of the District's proposed actions when the underlying need for the action is not fully explained.

Additionally, the IEPR found that "the SEIS has little information on the hydraulic and hydrologic engineering data for the MMR" (page 5). While the IEPR concluded that the 1976 EIS contained sufficient data for review, this finding is not logical. According to the DSEIS, the Middle Mississippi River has changed significantly since 1976:

> "Generally there has been an increase in cross sectional area, hydraulic depth, conveyance and volume throughout the period of record (Little et al. 2016). The Regulating Works Project has contributed to these changes, although it is uncertain to what extent." DSEIS at 44.

Critical economic information is missing from the DSEIS as well, calling into question the economic benefits of river training structures over dredging. The District does not provide any budget estimates of funds spent on the project to date or anticipated spending to complete the project (supposedly in 17 years). As the Regulating Works Project includes new construction, a National Economic Development (NED) analysis should be completed to compare alternatives. Included in this analysis, the District should consider the full range of ecosystem services lost in the construction of their preferred alternative.

This missing information is critically problematic and indicates that the District neither understands the underlying need for their proposed alternative nor its environmental and economic impacts. This carelessness indicates that the District is not taking the SEIS process seriously and adequately evaluating potential alternatives for their existing and proposed work. If the District cannot provide basic information related to the need for the Regulating Works Project and its costs and impacts then the project must be suspended until such a time that the information can be gathered and analyzed to ensure the proposed alternatives meet the needs of the system with minimal environmental impacts.

Recommendation: Suspend the Regulating Works Project until the District has the economic information it needs to evaluate the impacts of the Regulating Works Project and conduct a thorough review of alternatives as required by the National Environmental Policy Act.

5) The DSEIS lacks the information needed to determine cumulative environmental impacts and needs to include a programmatic level mitigation plan.

The Coalition agrees with the opinion of natural resource agencies that the District must develop a mitigation plan to address cumulative impacts of the Regulating Works Project at least going back to the implementation of NEPA. The fact that the District delayed the development of the DSEIS, despite clear guidance that environmental impact statements should be reviewed more periodically, is not an excuse for disregarding mitigation requirements. NEPA itself,[3] agency guidance,[4] and court rulings[5] make it abundantly clear that environmental impact statements must be reviewed periodically when new information is available and at least every 5 years.[6]

The IEPR found that compensatory mitigation requirements should be evaluated and included in the DSEIS. The Coalition agrees. The District provides surprisingly specific details regarding the remaining work to be completed for the Regulating Works Project. Up to this point, having been initiated over 100 years ago, the Coalition had understood the Regulating Works Program to be an ongoing program. However, the District states that the Regulating Works Project will place an estimated 2.9 million cubic yards of rock over the next 17 years – the remaining life of the project (page 116). With this level of specificity regarding the remaining work, the District should be able to develop a mitigation plan for the preferred alternative that covers work completed since 1976 and future anticipated work.

As part of a mitigation plan, the District should include the following information, at least:

- The number of acres impacted by the Regulating Works Project to date. The DSEIS includes information on the miles of river training structures constructed to date and the cubic yards of rock to be placed, but these measures are not comparable. The District needs to provide information on historic and future work in the same units of measure, preferably in acres.
- Potential locations of future projects based on known areas of frequent dredging. Given the relatively short duration of time until project completion (17 years), the District must have some idea of the remaining locations in need of modifications. This information must be provided in the SEIS to understand the cumulative impacts.
- Location and scope of critical natural resource areas to be avoided, protected or restored, including the areas identified as part of the 8% of remaining unstructured main channel border habitat.
- Locations where fish and wildlife would most benefit from mitigation actions.

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[3] 40 C.F.R. § 1502.9(c)
[4] 33 C.F.R. § 230.11(b)
[5] *Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 374 (1989).
Louisiana Wildlife Federation v. York, 761 F.2d 1044, 1051 (5th Cir. 1985) (quoting *Wisconsin v. Weinberger*, 745 F.2d 412, 418 (7th Cir. 1984)).
[6] 46 Fed Reg. 18026 (March 23, 1981), as amended, 51 Fed. Reg. 15618 (April 25, 1986), Question 32; *see also Oregon Natural Resources Council v. U.S. Forest Serv*., 445 F. Supp. 2d 1211, 1232 (D. Or. 2006) (recognizing passage of time likely warrants supplemental NEPA analysis).

- A list of possible mitigation strategies or techniques that will be implemented as part of tiered projects, ideally strategies that, when taken collectively, will provide greater environmental benefits.
- A monitoring plan and ecological analysis.

The District proposes to mitigate the impacts of the Regulating Works Program with additional dredging, revetment and construction of river training structures (page C-5). Ironically, these are the same activities which require mitigation activities in the first place (Section 4.2). The Coalition finds it hard to believe that the mitigation for dredging, revetment and river training structure construction is more dredging, revetment and river training structure construction. Almost all the mitigation activities proposed by the District themselves have environmental impacts significant enough to require another environmental impact statement for the mitigation activities alone. This defeats the purpose of mitigation. The District needs to develop a mitigation plan using tools and activities that do not themselves require additional mitigation.

Recommendation: The District should properly mitigate the cumulative impacts of the Regulating Works Project going back to 1976 as part of the SEIS with methods that do not themselves have significant environmental impacts.

6) Environmental analysis too focused on engineering outcomes

The DSEIS includes limited studies on the impact of certain features on biodiversity and describes the historic conditions of the Middle Mississippi River. Unfortunately, this information is poorly tied to the claimed environmental benefits of mitigation and those components of the Regulating Works Project that may improve habitat. Namely, the District focuses almost exclusively on acres of physical habitat impacted and does not identify how potential ecosystem benefits relate to broader restoration goals for the Middle Mississippi River. A 2012 study by Salant, et al found that single feature restoration projects, such as the placement of weirs to increase habitat heterogeneity, are not effective at achieving biodiversity goals. The study recommends "baseline attributes and historic conditions be assessed and integrated into project design and implementation" to ensure the restoration strategy is truly site appropriate.[7] Further, a 2009 study by Palmer, et al found that almost all restoration projects that focused exclusively on rehabilitated physical habitat failed to restore invertebrate biodiversity.[8] These studies show that focusing exclusively engineering outcomes in isolation will not necessarily restore or protect biodiversity.

The District needs to work with natural resource agencies to identify the extent and magnitude of ecosystem stressors. The SEIS needs to identify and explain how projects will address those issues that fall within the Corps jurisdiction and provide context of broader management efforts to resolve critical issues impacting the health of the Middle Mississippi River. These efforts need to be followed up with a

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[7] Salant, NL, JC Schmidt, P Budy, and PR Wilcock. 2012. Unintended consequences of restoration: loss of riffles and gravel substrates following weir installation. *J Environ Manage* 109:154-63.
[8] Palmer, MA, HL Minninger, E Bernhardt. 2010. River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? *Freshwater Biology* 55 (Suppl. 1), 205–222.

robust monitoring plan to evaluate the effectiveness of the Corps efforts, such as should be included in a cumulative mitigation plan, as recommended in comment 5. This recommendation would be facilitated through the development of an environmental impact statement for the entire Upper Mississippi River-Illinois Waterway navigation system, as recommended in comment 7.

Recommendation: The District needs to explain how components of the Regulating Works Project and/or mitigation plan meet broader restoration and biodiversity objectives for the Middle Mississippi River.

7) Scope of SEIS should be expanded to include the entire Upper Mississippi River and Illinois Waterway System

The District refutes our previous comments that a full EIS needs to be completed for the Upper Mississippi River and Illinois Waterway System and states that this was completed as part of the NESP Programmatic EIS. However, the NESP Programmatic EIS did not include an analysis of operations and maintenance alternatives and it did not evaluate the Regulating Works Project. The District should 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, is just one of many 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.

Recommendation: Expand the scope of the DSEIS to include all O&M activities on the UMRR-IWW.

8) Conclusion

As discussed above, the Coalition strongly opposes the recommended alternative and urges the District to pursue the "No New Construction" alternative unless a more environmentally acceptable alternative can be developed that does not also increase flood risk for the region.

As the District works towards finalizing the SEIS, the District should carry out the scientific evaluations discussed throughout these comments, and address the legal and scientific deficiencies identified herein. The Coalition urges the Corps to respond to, and fully adopt, the recommendations made throughout these comments.

Respectfully submitted,

Olivia Dorothy, Facilitator
American Rivers

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.

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[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

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[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

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[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]

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[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.

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[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.

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[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.
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> * * *
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> 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

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[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
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> 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]

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[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."
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> * * *
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> "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]

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[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."
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> "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 . . . ."
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> "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

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[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]

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[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

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[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 sufficient 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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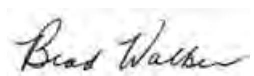

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Attachments

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

Danny D. McClendon
Chief, Regulatory Branch
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, Missouri 63103

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.

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[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.

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[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.

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[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]

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[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

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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.

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[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

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[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,

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[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]

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[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]

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[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.

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[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

$$\Pi_A = f_A\left[D\left(\frac{g(\rho_s-\rho)}{\rho\nu^2}\right)^{1/3}, \frac{\rho R i}{D(\rho_s-\rho)}, \frac{\rho_s}{\rho}, \frac{D}{R}, \frac{B}{R}, \frac{\sigma}{\rho g i R^2}\right] \quad (1)$$

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 $3 \times 3\ \mathrm{mm}^2$ 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

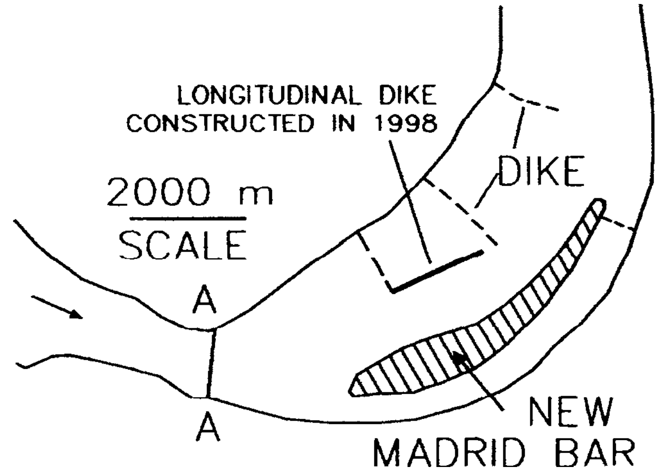

Fig. 2. Schematic of New Madrid, Mississippi River. Micromodel scale=1:19,000 horizontal, 1:1,200 vertical.

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

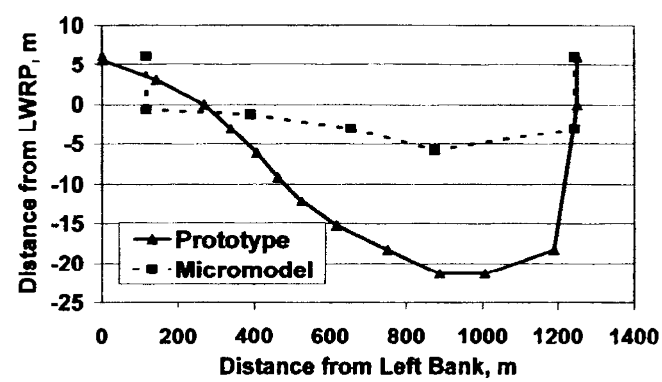

Fig. 3. Prototype and micromodel cross sections at New Madrid

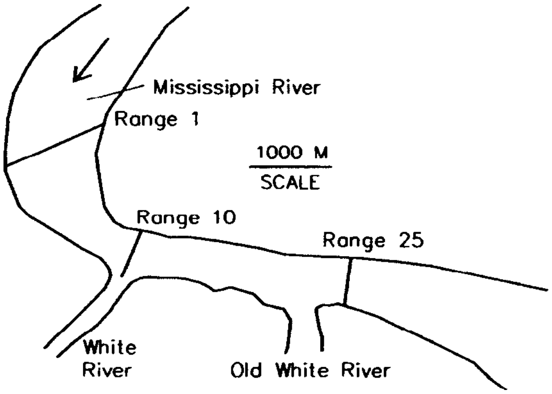

Fig. 4. Schematic of the Mouth of the White River, Mississippi River. Micromodel scale=1:12,000 horizontal, 1:1,200 vertical.

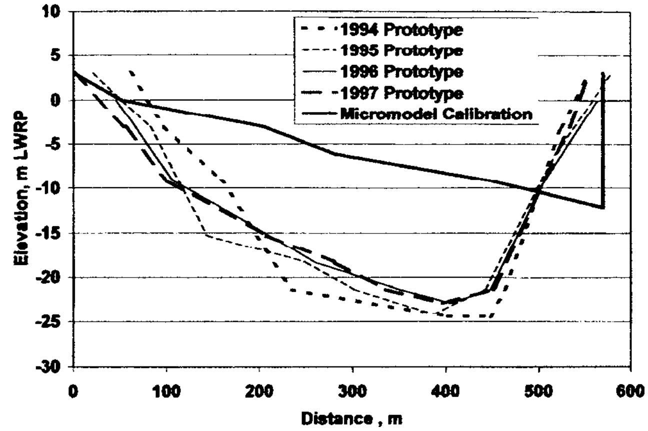

Fig. 6. Cross section at the Mouth of the White River, Range 17

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.

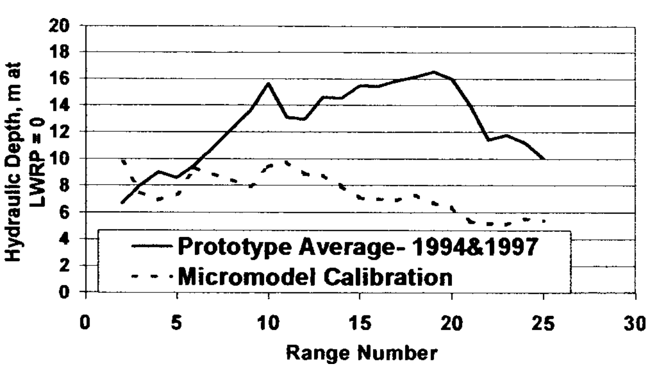

Fig. 5. Hydraulic depth at Mouth of the White River

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

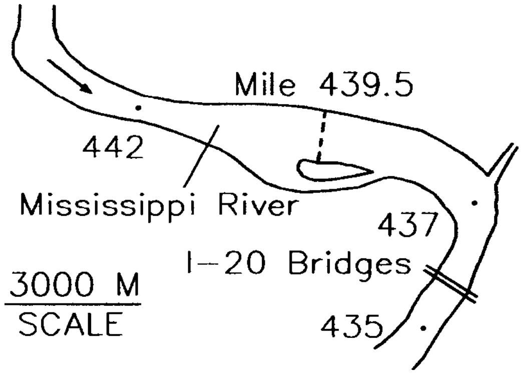

Fig. 7. Schematic of Vicksburg Front, Mississippi River. Micromodel scale=1:14,400 horizontal, 1:1,200 vertical.

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 (2X) 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.

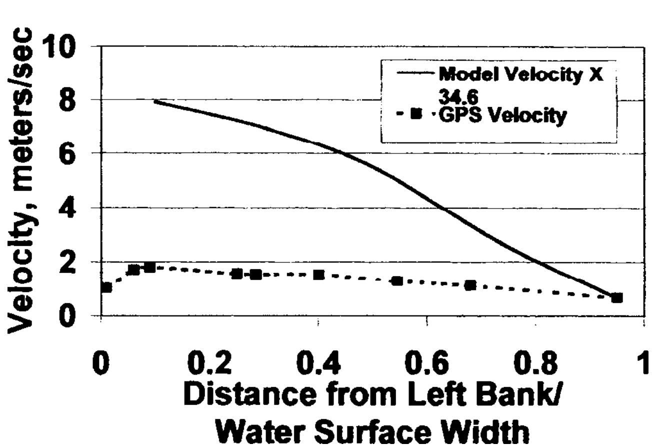

Fig. 8. Prototype GPS and micromodel velocities at Vicksburg Front

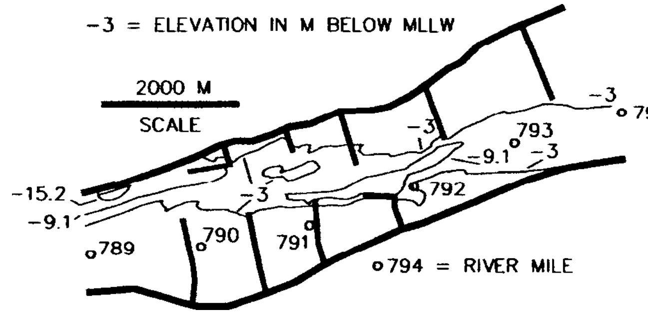

Fig. 9. Kate Aubrey, Mississippi River, 1998 prototype bathymetry. Flow from right to left.

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

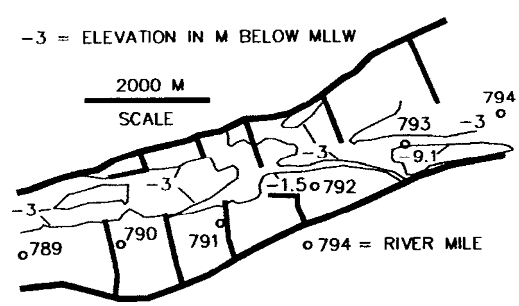

Fig. 10. Kate Aubrey, Mississippi River, 1:8,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

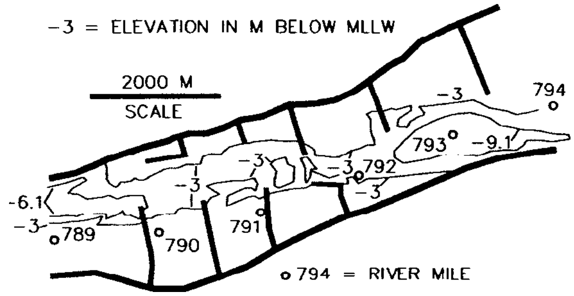

Fig. 11. Kate Aubrey, Mississippi River, 1:16,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

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

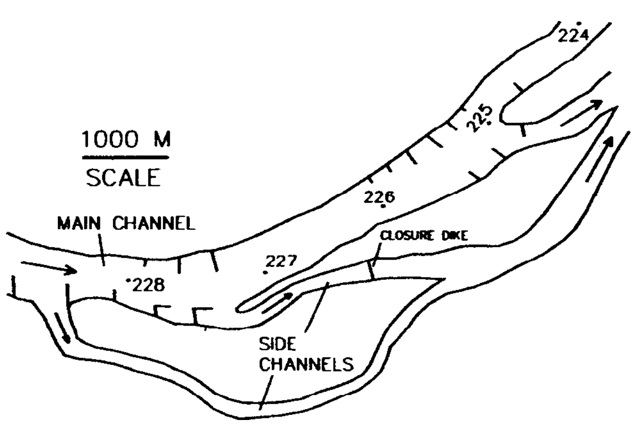

Fig. 12. Schematic of Bolter's Bar, Mississippi River, without project. Micromodel scale=1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

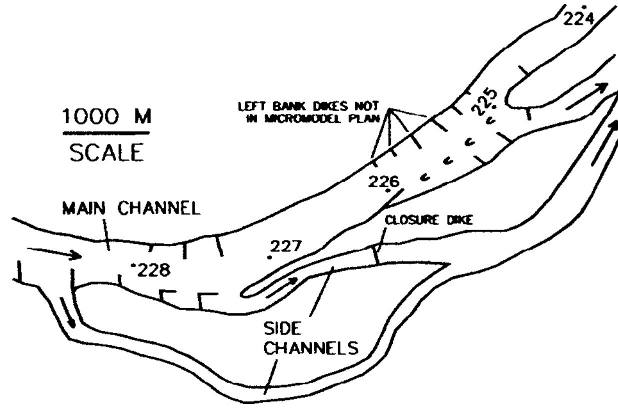

Fig. 13. Schematic of Bolter's Bar, Mississippi River, with project. Micromodel scale=1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

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

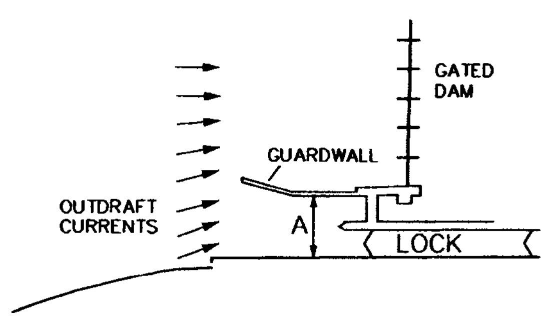

Fig. 14. Schematic of Lock 24 outdraft at upstream lock approach on Mississippi River. Micromodel scale= 1 : 9,600 horizontal, 1:600 vertical. Dimension "A" in micromodel is about 0.8 cm versus a prototype distance of about 80 m.

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;
- v kinematic viscosity;
- p water density;
- p_s particle density; and
- u 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

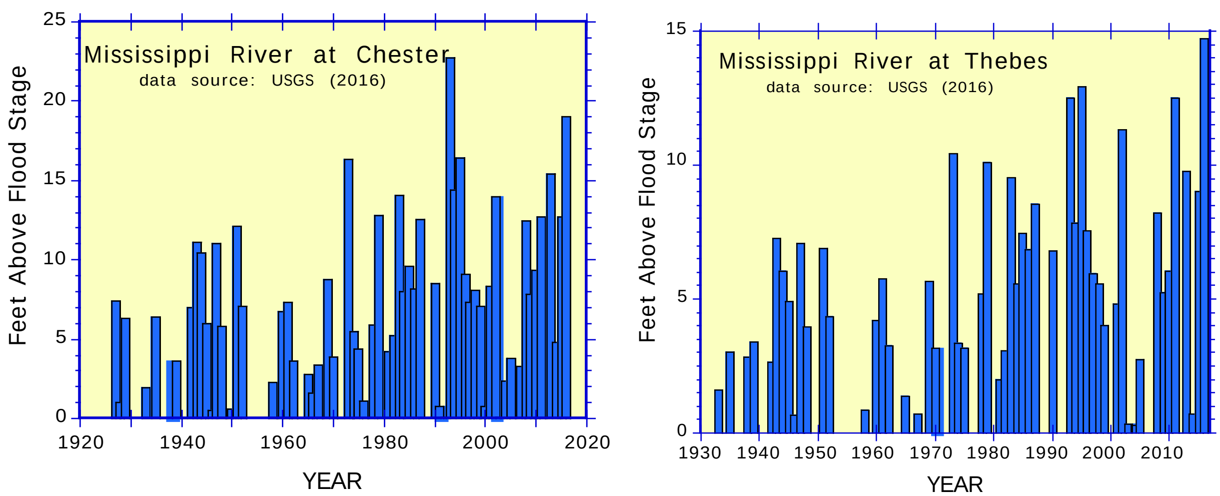
Comments of the Conservation Organizations on the Grand Tower EA

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 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.

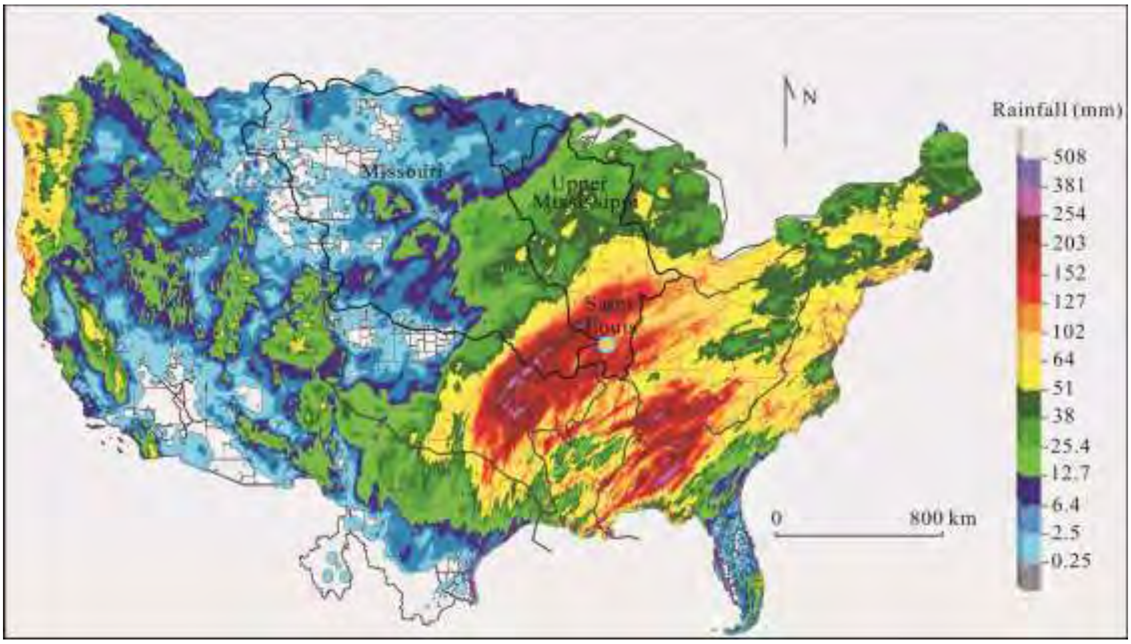

Figure 1. Map showing the observed, 7-day precipitation for December 22–29, 2015, according to NWS (2016a). Superimposed on this map are the boundaries of the upper Mississippi and Missouri watersheds (labeled) and other major river basins. Goliath delivered an average of 20 cm of rain to the entire 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).

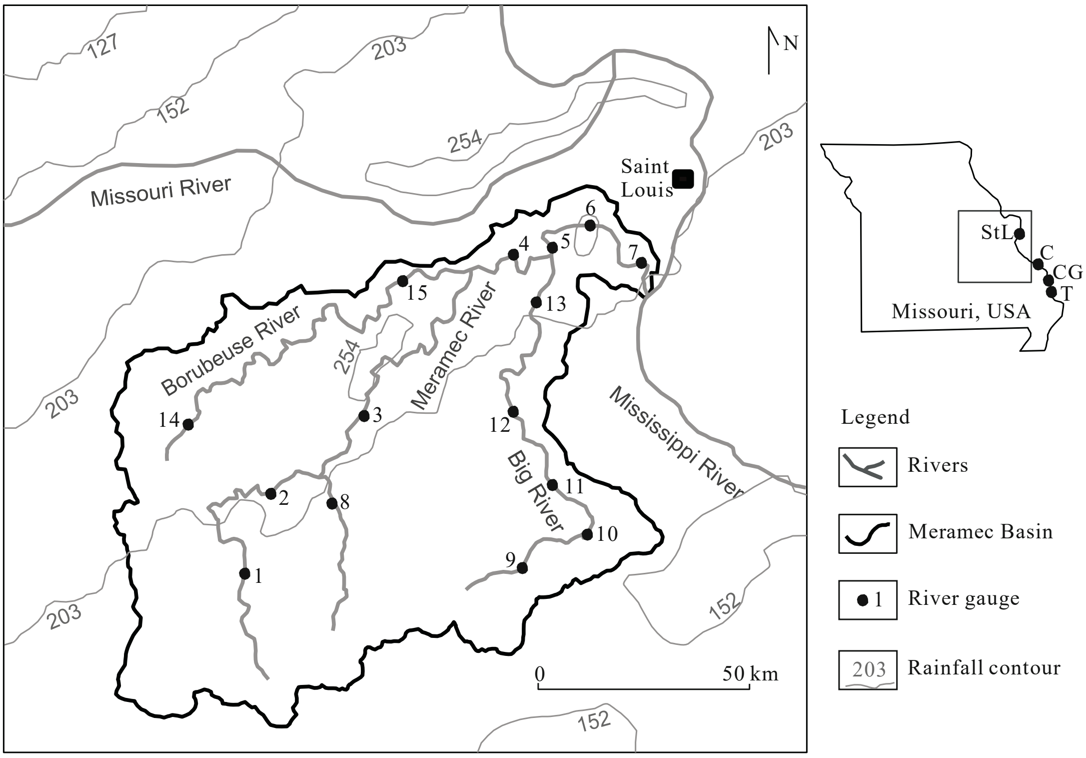

Figure 2. Map of East-Central Missouri showing the 10 300 km^2 Meramec River Basin (dark outline) and contours for precipitation delivered from December 22–29, 2015 according to NWS (2016a). Labeled dots are river gauging stations; stage hydrographs for the stations along the main stem of Meramec River (#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).

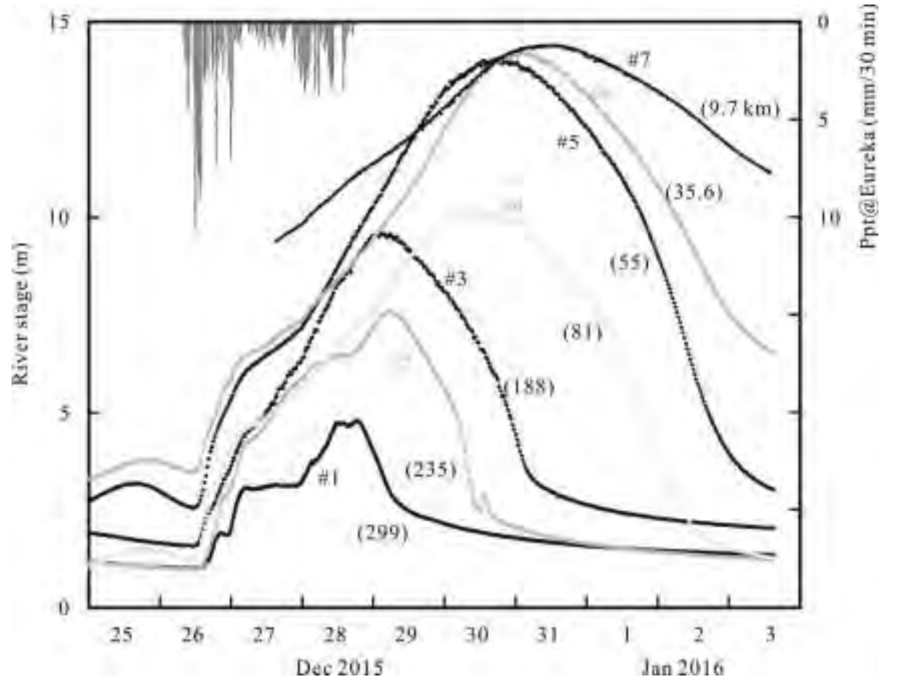

Figure 3. Stage hydrographs showing the propagation of the 2015 flood wave down the main stem of Meramec River, for sites #1 to #7 on Fig. 2. Numbers in parenthesis are the distance in km above the confluence with the Mississippi River to the south of St. Louis. Hydrographs for each site are plotted 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

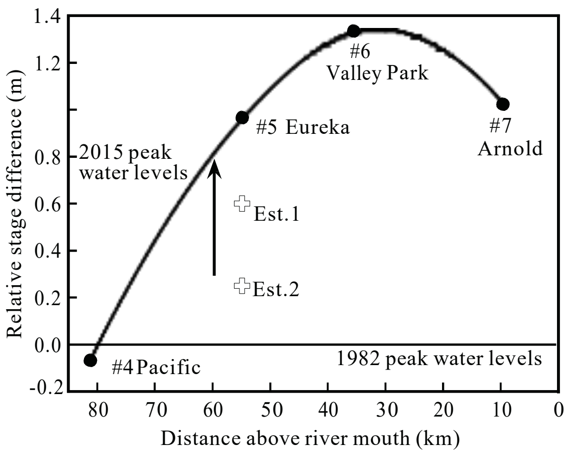

Figure 4. Relative difference between the peak water levels of December 30–31, 2015 and those of December 6, 1982 at different sites in the lower Meramec Basin (cf. Fig. 2). This difference was greatest close to Valley Park, where a large levee was built in 2005; this and other changes appear to have 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.

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.

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

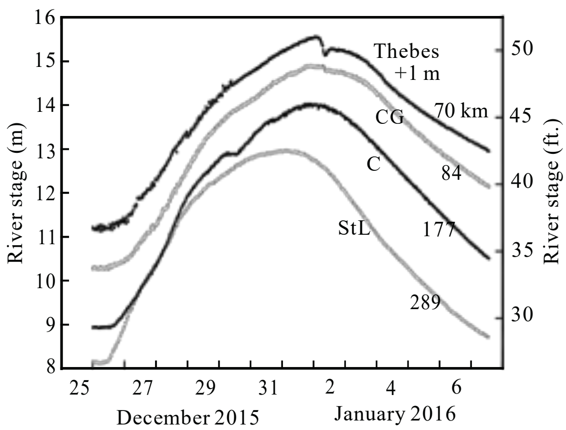

Figure 6. Stage hydrographs at St. Louis (StL), Chester (C), Cape Girardeau (CG) and Thebes, showing propagation of the 2015–2016 flood wave down the middle Mississippi River (cf. Fig. 2). The official stages depicted for each station are relative to its local datum, except that 1 m was added to the 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

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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 $\sim 10\times$ 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 100þ 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.

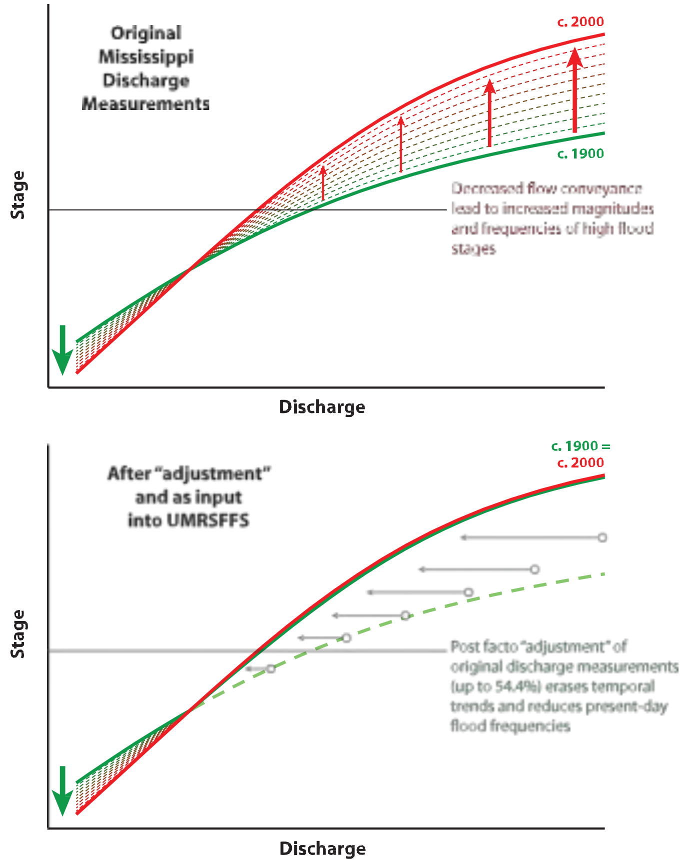

Fig. 1. (Color) Conceptual illustration showing how modification of historical discharge measurements (Dieckmann and Dyhouse 1998) erases temporal trends in MMR rating curves documented by previous researchers, including increases in flood stages for fixed discharges (red arrows); these modifications 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,

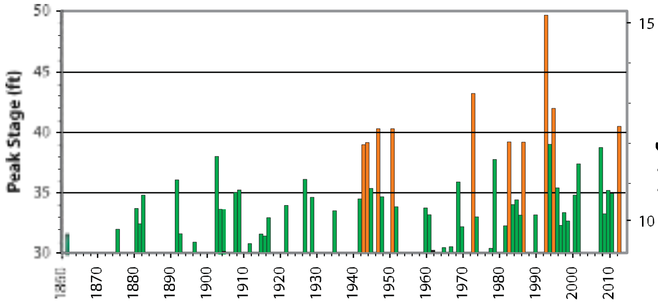

Fig. 2. (Color) Peak stages above flood level (30 ft above datum) for the Mississippi River at St. Louis; homogenous daily stages date back to 1861, and the 10 highest flood peaks (in orange) all occur in the latter half of the record; probability that this represents the random distribution of a stationary time-series is on the order of 0.00098

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

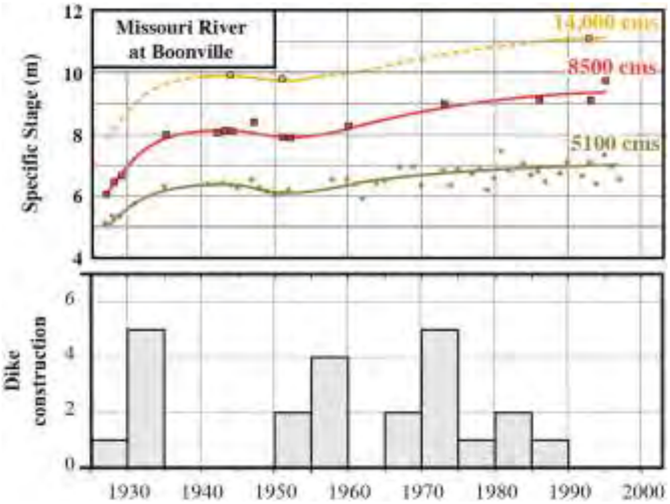

Fig. 3. (Color) Like most stations analyzed by Pinter et al. (2008, 2010), and others, discharges on the Missouri River at Boonville were developed exclusively by the USGS; flood stages increased when and where new navigational dikes were constructed (number of dike segments built within the 3.2 km of channel centered on the gage; data from Pinter and Heine 2005)

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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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 $\pm 10\%$ 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 $\pm 2\%$ of the true discharge and, furthermore, considers measurements that differ from the true discharge by more than $\pm 8\%$ 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 $\pm 10\%$ 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 $\pm$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 $\pm 5\%$ but less than $\pm 10\%$, while 7% were in error by more than $\pm 10\%$. 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, 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
Edward Keller	Univ. of California, Santa Barbara, CA 93106	keller@geol.ucsb.edu	805-893-4207
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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.

Keller, E.A. and N. Pinter, 1996. Active Tectonics: Earthquakes and Landscape. 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.

Huthoff, F., N. Pinter, and J.W.F. Remo, 2013. Theoretical analysis of stage magnification caused by wing dikes, Middle Mississippi River, USA. Journal of Hydraulic Engineering, 139: 550-556.

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.

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

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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.

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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.

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

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

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

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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.

Pinter, N., and C. Sorlien, 1991. Evidence for latest Pleistocene to Holocene movement on the Santa Cruz Island fault, California. Geology, 19: 909-912.

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
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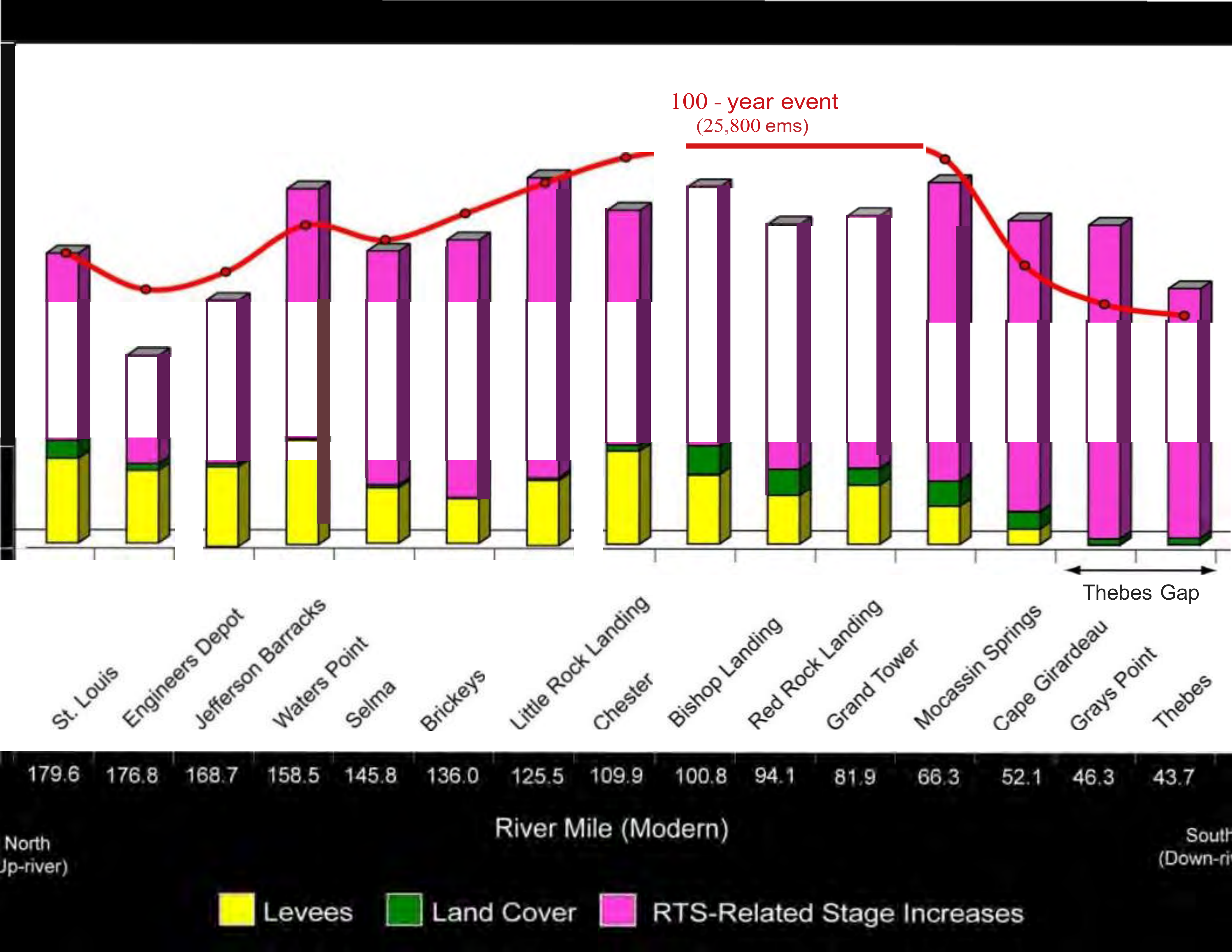
100 - year event
(25,800 cms)
Thebes Gap
St. Louis
Engineers Depot
Jefferson Barracks
Waters Point
Selma
Brickeys
Little Rock Landing
Chester
Bishop Landing
Red Rock Landing
Grand Tower
Mocassin Springs
Cape Girardeau
Grays Point
Thebes
179.6
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100.8
94.1
81.9
66.3
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43.7
River Mile (Modern)
North
(Up-river)
South
(Down-river)
Levees
Land Cover
RTS-Related Stage Increases

EXHIBIT
3

doi:10.2489/jswc.68.4.89A

FEATURE

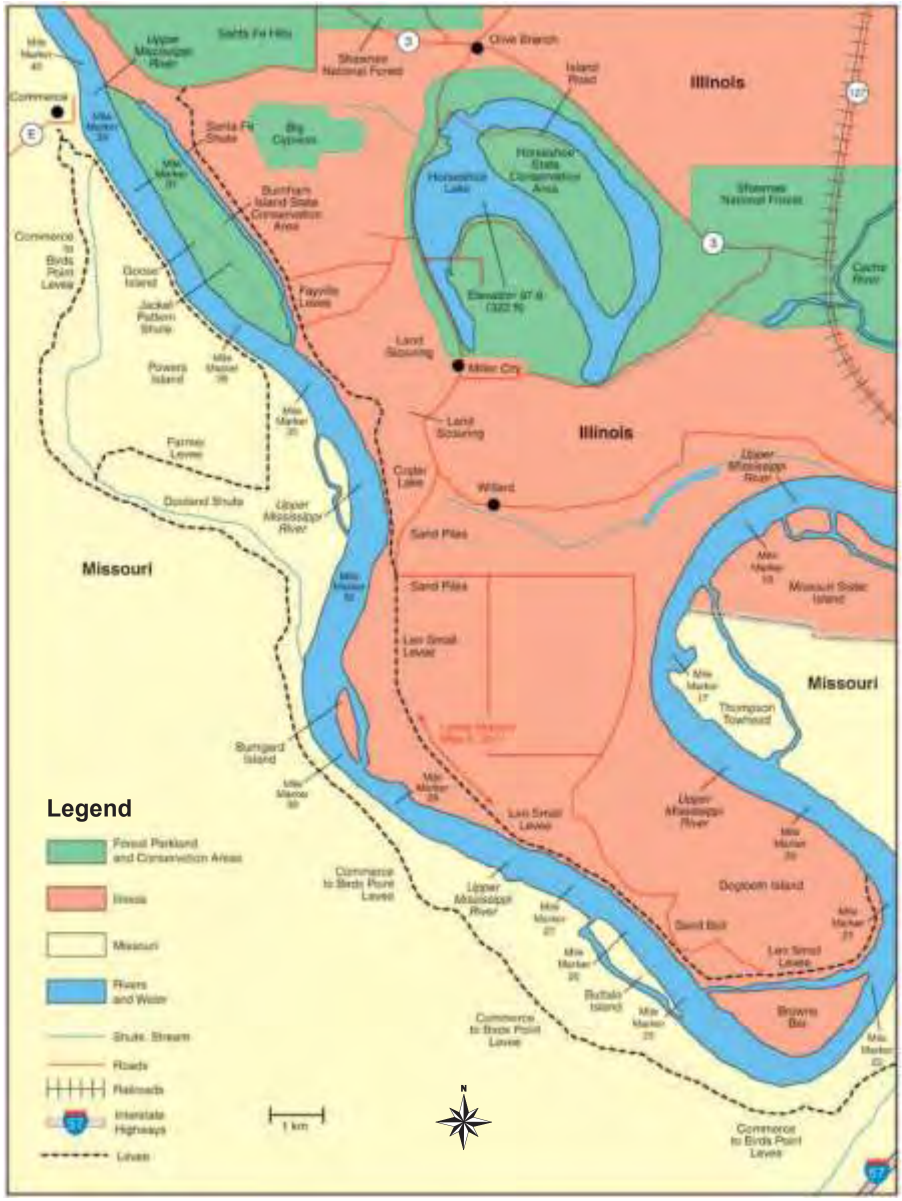
Impacts of 2011 Len Small levee breach on private and public Illinois lands

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.

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.



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

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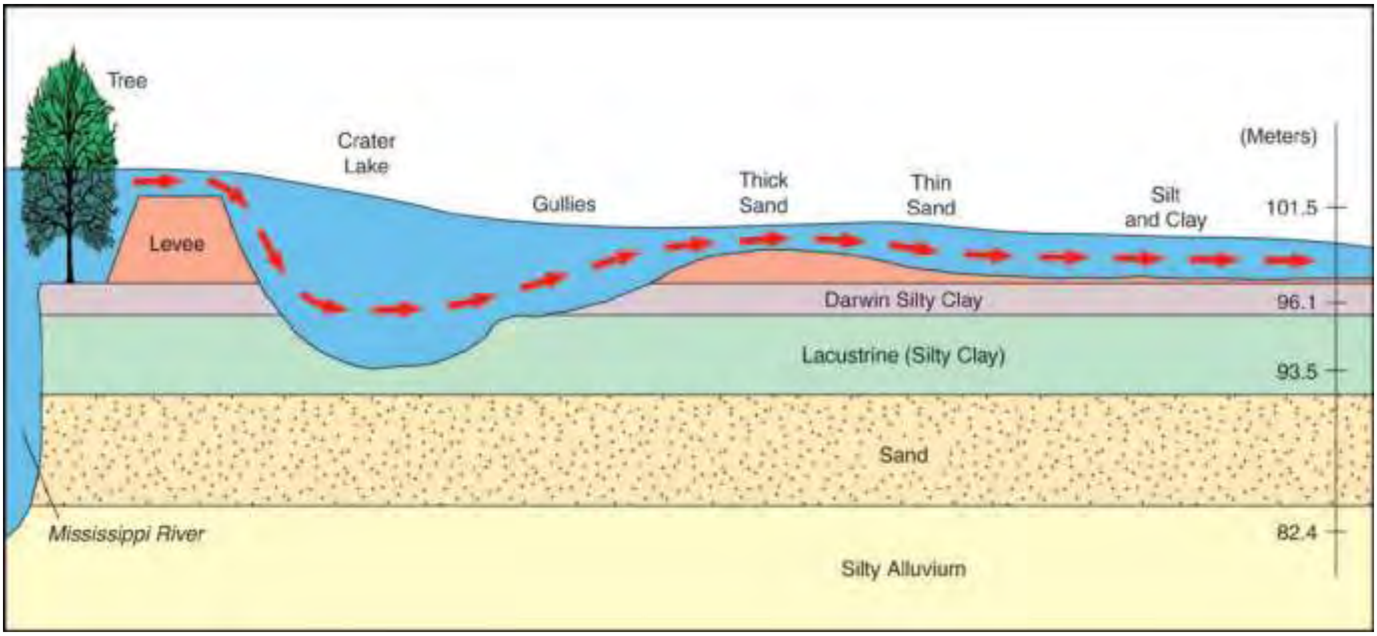
Figure 2

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.

Figure 3

The bald cypress trees and American lotus at Horseshoe Lake conservation area.

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.

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

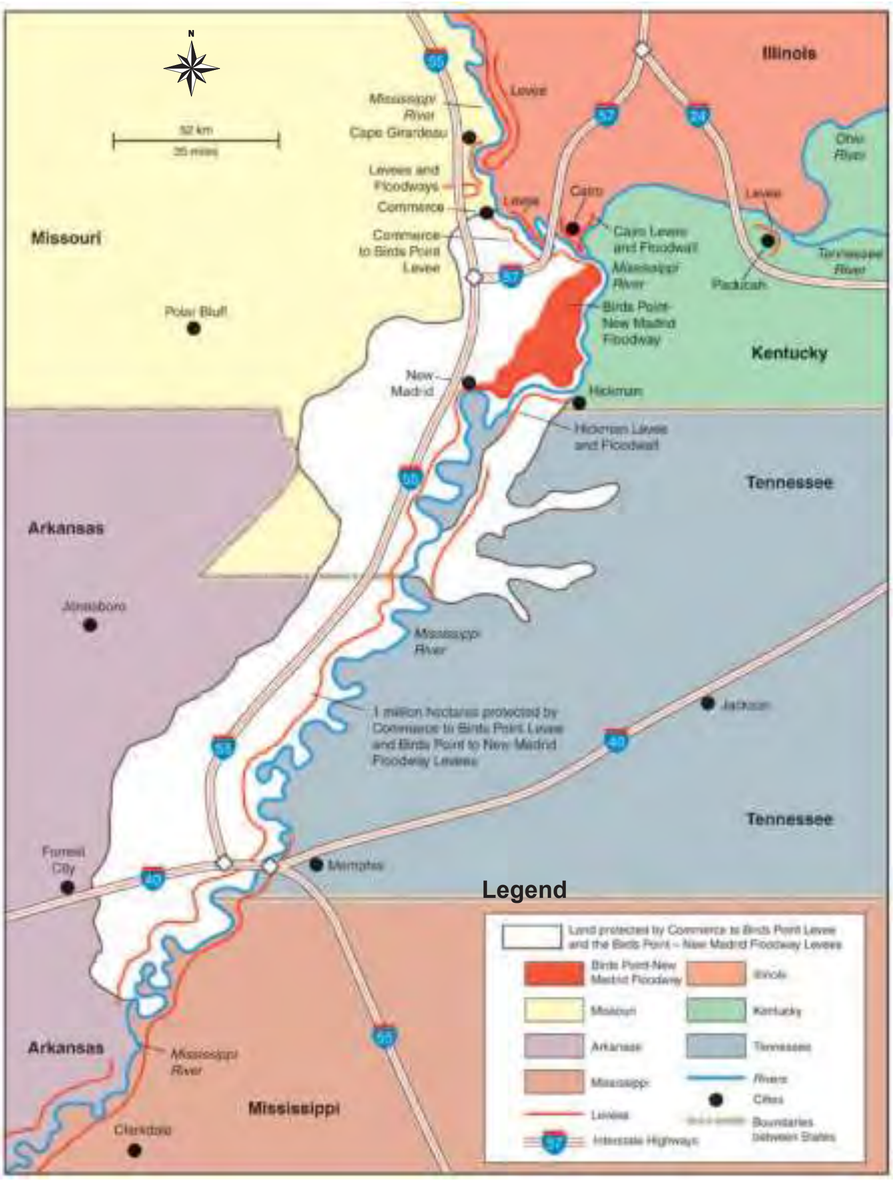
The Mississippi River Commission (MRC) was established by Congress in 1879 to combine the expertise of the USACE and civilian engineers to make the Mississippi River and tributaries a reliable shipping channel and to protect adjacent towns, cities, and agricultural lands from destructive floods (Camillo 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.

Documents Reviewed for this Declaration

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.

Analysis

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).

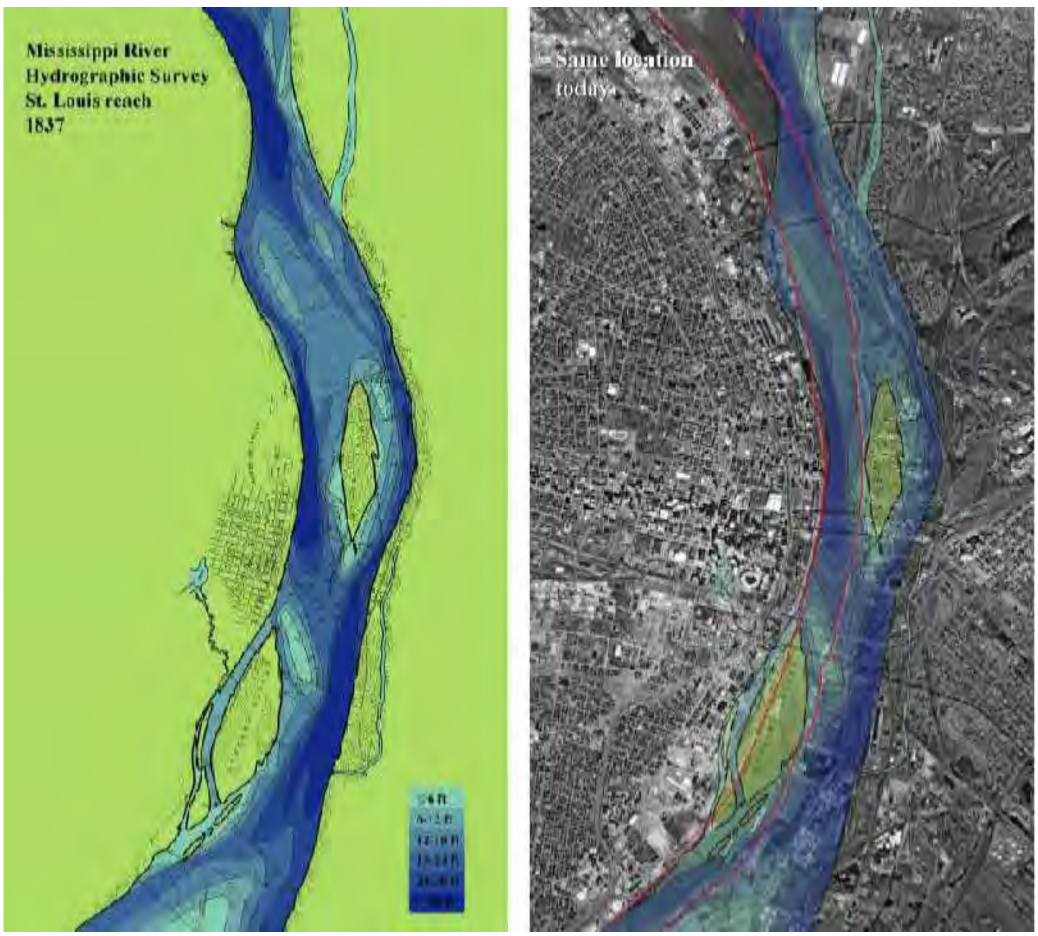
29. As I attested in paragraph 23 of my Original Declaration, many other studies confirm and corroborate these findings on the flow-dependent effects of river training structures. Particularly after the record-breaking floods on the Middle Mississippi, researchers sought to answer why such large increases 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 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 $3 \times 3\ \text{mm}^2$ 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 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.

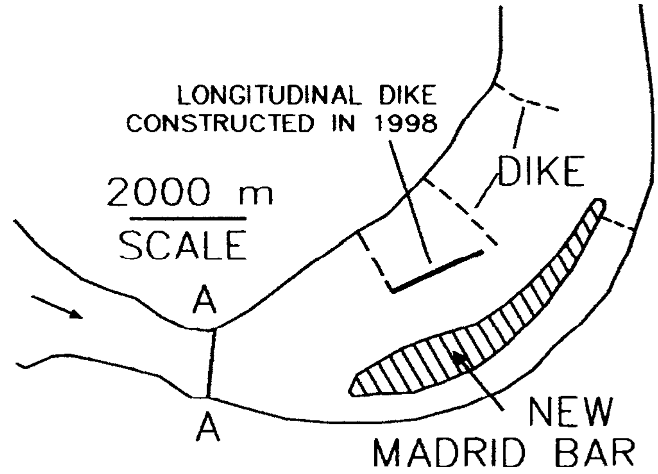

Fig. 2. Schematic of New Madrid, Mississippi River. Micromodel scale=1 : 19,000 horizontal, 1:1,200 vertical.

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

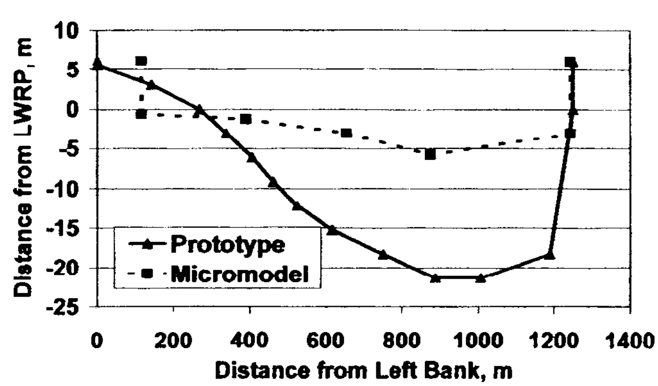

Fig. 3. Prototype and micromodel cross sections at New Madrid

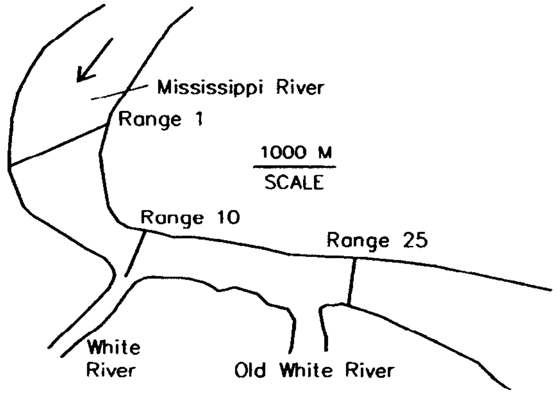

Fig. 4. Schematic of the Mouth of the White River, Mississippi River. Micromodel scale=1:12,000 horizontal, 1:1,200 vertical.

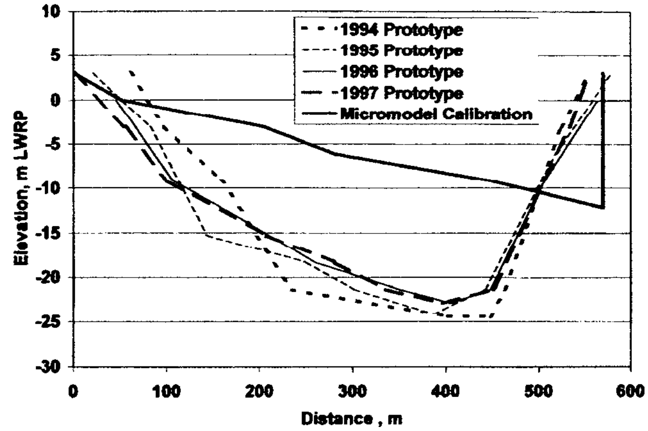

Fig. 6. Cross section at the Mouth of the White River, Range 17

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.

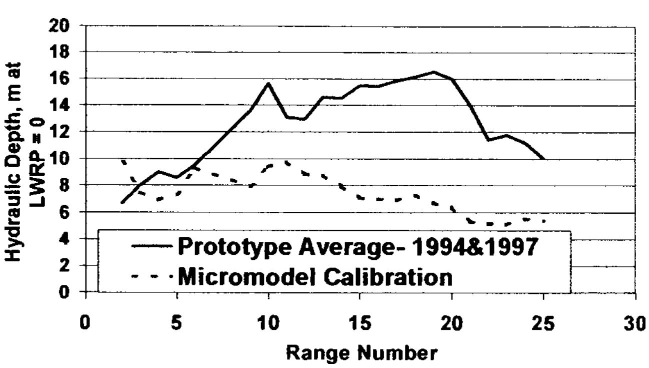

Fig. 5. Hydraulic depth at Mouth of the White River

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

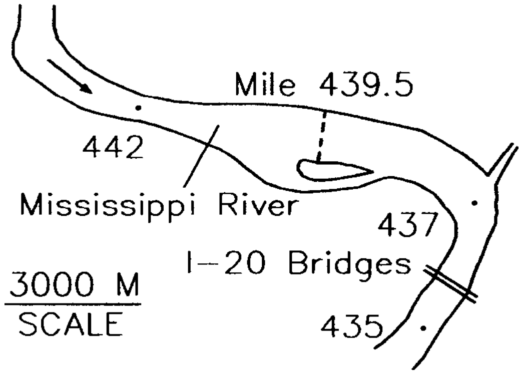

Fig. 7. Schematic of Vicksburg Front, Mississippi River. Micromodel scale=1:14,400 horizontal, 1:1,200 vertical.

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 (2X) 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.

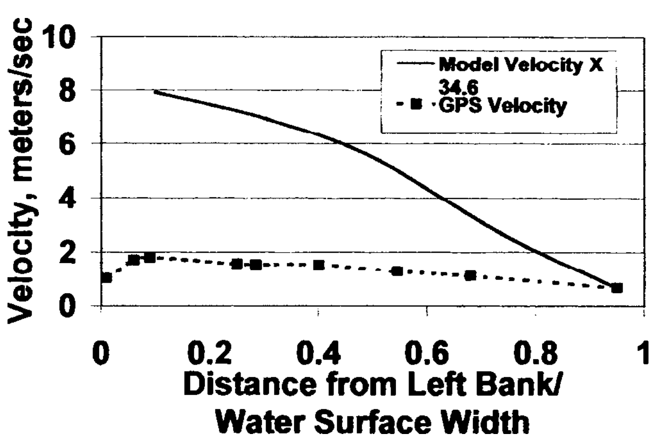

Fig. 8. Prototype GPS and micromodel velocities at Vicksburg Front

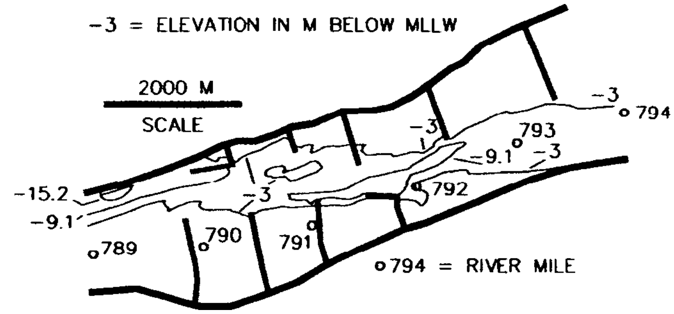

Fig. 9. Kate Aubrey, Mississippi River, 1998 prototype bathymetry. Flow from right to left.

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

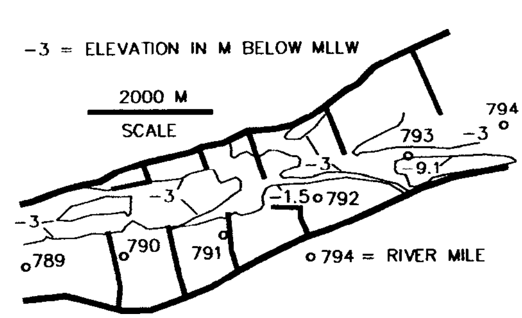

Fig. 10. Kate Aubrey, Mississippi River, 1:8,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

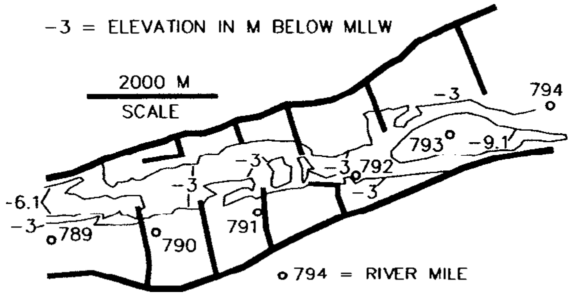

Fig. 11. Kate Aubrey, Mississippi River, 1:16,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

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

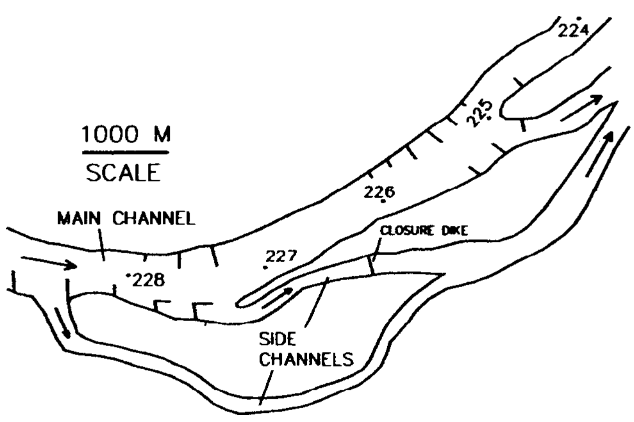

Fig. 12. Schematic of Bolter's Bar, Mississippi River, without project. Micromodel scale=1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

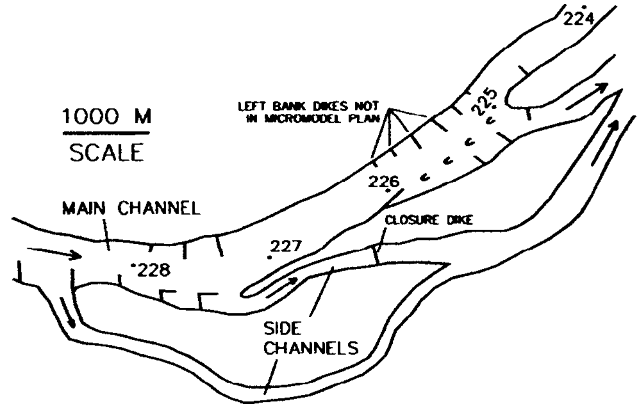

Fig. 13. Schematic of Bolter's Bar, Mississippi River, with project. Micromodel scale=1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

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

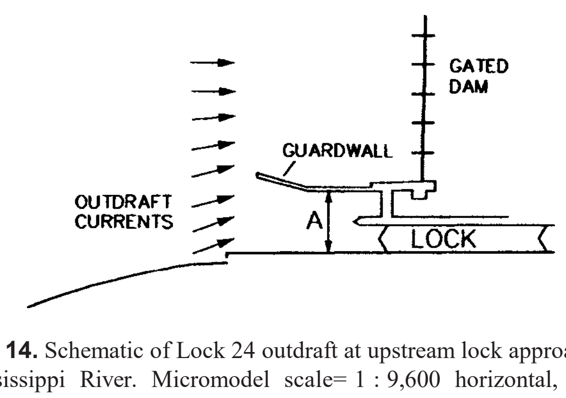

Fig. 14. Schematic of Lock 24 outdraft at upstream lock approach on Mississippi River. Micromodel scale= 1 : 9,600 horizontal, 1:600 vertical. Dimension "A" in micromodel is about 0.8 cm versus a prototype distance of about 80 m.

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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National Wildlife Federation
American Rivers
Great Rivers Environmental Law Center
Missouri Coalition for the Environment
Prairie Rivers Network
River Alliance of Wisconsin

February 14, 2014

Via Email: jasen.l.brown@usace.army.mil and RegWorksSEIS@usace.army.mil

U.S. Army Corps of Engineers
St. Louis District
CEMVS-EC-H
1222 Spruce St.
St. Louis, MO 63103-2833

RE: Scoping Comments for the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project, Public Notice 2013-744

Dear Mr. Brown:

The National Wildlife Federation, American Rivers, Great Rivers Environmental Law Center, Missouri Coalition for the Environment, Prairie Rivers Network, and River Alliance of Wisconsin (collectively, the Conservation Organizations") appreciate the opportunity to submit these comments on the scope of the Supplemental Environmental Impact Statement for the Middle Mississippi River Regulating Works Project (the SEIS).

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.

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. As the nation's leading river conservation organization, American Rivers has an interest in restoring and protecting the health of the Mississippi River Basin for people and wildlife.

Great Rivers Environmental Law Center is a nonprofit organization dedicated to providing free and reduced-fee public interest legal services to individuals and organizations working to protect and preserve Missouri's environment.

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.

The River Alliance of Wisconsin is a statewide nonprofit river conservation organization with 2,500 individual and over 200 business and organizational members. Its interest in the Mississippi stems from the fact that the river forms about half the state's western boundary with Minnesota. Thousands of Wisconsinites recreate on the river, and the more than two dozen cities and villages along the river are concerned with how the river's management affects water levels, especially flooding.

General Comments

The Conservation Organizations appreciate the Corps' decision to prepare a supplemental EIS for its Regulating Works Project. However, since this project is just one of many types of operations and maintenance (O&M) activities designed to maintain a 9 foot navigation channel in the Upper Mississippi River-Illinois Waterway Navigation System (UMR-IWW), evaluating just the Regulating Works Project would constitute an impermissible piecemeal assessment that cannot satisfy the requirements of the National Environmental Policy Act (NEPA). Instead, NEPA requires preparation of a supplemental Environmental Impact Statement that evaluates **all** O&M activities and identifies alternatives that could cause less harm to the environment.

As discussed in detail below, the Corps' O&M activities are causing significant harm to the environment, increasing flood risks for communities, and undermining the work carried out under the Corps' restoration and flood damage reduction authorities. For example, while the Corps is authorized to reduce flood damages along the river, extensive peer-reviewed science demonstrates that river training structures constructed under the Regulating Works Project 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.[1] The Corps, however, continues to deny the validity of this science.

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[1] 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-

To comply fully with NEPA and to ensure the highest level of protection to the public, the Conservation Organizations urge the Corps to:

I. Expand the SEIS to evaluate the full suite of O&M activities for the Upper Mississippi River – Illinois Waterway navigation system. As the Corps is well aware, the Regulating Works Project is just one of a number of activities carried out by the Corps to maintain navigation on the UMR-IWW. 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 may not be evaluated in isolation. A supplemental EIS for the full suite of O&M activities would help ensure that future O&M activities comply with current law, planning criteria and policies, including the requirements established by the Clean Water Act, the Endangered Species Act, the Water Resources Development Act of 2007, and the Fish and Wildlife Coordination Act.

II. 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.

III. Impose a moratorium on the construction of new river training structures pending completion of the National Academy of Sciences Study and 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, the National Academy of Sciences study and comprehensive SEIS establish that such construction will not contribute to increased flood risks to communities.

IV. Fully evaluate the impacts of all reasonable alternatives and select an alternative that protects and restores the Mississippi River. To comply with NEPA, the SEIS must (among other things) properly define the project purpose, fully evaluate project impacts, and fully review all reasonable alternatives. The project purpose is most properly defined as maintaining navigation. Impacts that must be examined include, direct, indirect, and cumulative impacts (including the cumulative impacts of climate change) of all O&M activities on the UMR-IWW

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).

ecosystems; the effect of those activities on flood heights and public safety; alternatives to those activities that could cause less harm to the environment, including alternative water level management regimes and removal and/or modification of river training structures; and mitigation for those impacts that cannot be avoided. To comply with the National Water Policy and the Corps' civil works mitigation requirements, the SEIS must ultimately select an alternative that will protect and restore the natural functions of the Mississippi River system and mitigate any unavoidable damage.

The independent external peer review that is clearly required for the SEIS should be conducted by the National Academy of Sciences, and the panel's task should explicitly include a charge to evaluate: the appropriateness of the alternative recommended by the Corps; whether the selected alternative will in fact protect and restore the functions of the Mississippi River system; whether the selected alternative includes a mitigation plan that is likely to produce ecologically successful mitigation; and whether the selected alternative includes appropriate and meaningful criteria for determining project success.

Specific Comments

I. The Corps Should Expand the SEIS to Evaluate the Full Suite of O&M Activities

The UMR-IWW navigation system includes 1,200 miles of 9-foot navigation channel, 37 lock and dam sites, and thousands of channel training structures. This system requires "continuous regular operations and maintenance" at a cost of more than $120 million each year.[2] These operations and maintenance (O&M) activities include: dredging and disposal of dredged material, water level regulation, construction of river training structures (wing dikes, bendway weirs, chevrons), construction of revetment, and operation and maintenance of the system's 37 locks and dams.

These actions must be examined in a single environmental impact statement because they are "connected actions."[3] Actions are connected if they:

(i) Automatically trigger other actions which may require environmental impact statements.
(ii) Cannot or will not proceed unless other actions are taken previously or simultaneously
(iii) Are interdependent parts of a larger action and depend on the larger action for their justification.[4]

Under these standards, the full suite of O&M activities are clearly "connected actions" that must be evaluated in a single environmental impact statement (EIS). Each O&M activity is an interdependent part of a larger action – maintaining the UMR-IWW navigation system – and will not proceed unless other actions that independently would require an environmental impact statement are undertaken (for

[2] 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.
[3] 40 C.F.R. § 1508.25; *e.g.*, *Thomas v. Peterson*, 753 F.2d 754, 758 (9th Cir. 1985).
[4] 40 C.F.R. § 1508.25(a).

example, dredging the Mississippi River, controlling water levels in the Mississippi River). There is no independent utility for constructing river training structures for navigation purposes absent the full suite of O&M activities that are required to maintain the UMR-IWW navigation system.[5]

All O&M activities must be reviewed under a comprehensive supplemental environmental impact statement for the same reasons that mandate preparation of the SEIS for the Regulating Works Project. A supplemental EIS must be prepared where, as here, there "are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts" or when the agency makes "substantial changes in the proposed action that are relevant to environmental concerns." 40 C.F.R. § 1502.9(c); 33 C.F.R. § 230.13(b).

The Supreme Court has ruled that:

> If there remains 'major Federal actio[n]' to occur, and if the new information is sufficient to show that the remaining action will 'affec[t] the quality of the human environment' in a significant manner or to a significant extent not already considered, a supplemental EIS <u>must</u> be prepared.[6]

New information requires preparation of a supplemental EIS if the information "'presents a picture of the likely environmental consequences associated with the proposed action not envisioned by the original EIS'" and "'raises new concerns of sufficient gravity such that another, formal in-depth look at the environmental consequences of the proposed action is necessary.'"[7]

The Corps is not free to ignore the possible significance of new information. The Corps must "take a hard look" at any new information (*i.e*., information that did not exist when the original environmental impact statement was prepared) to determine whether a supplemental environmental impact statement is required.[8] Where, as here, an EIS is "more than 5 years old," it should be "carefully reexamined" to determine if a supplement is required.[9]

Despite the significant changed circumstances discussed below, the Corps continues to rely on a series of five outdated and piecemeal environmental impact statements that do not satisfy the requirements of NEPA. Four of these EISs are more than 35 years old – two were written in 1974, one in 1975, and one in 1976.[10] Another assessment that reviews only a portion of O&M activities carried out in one

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[5] *See Save the Yaak Committee v. Block*, 840 F.2d 714, 720 (9th Cir. 1988) (agency must consider both the logging road project and timber sale together because they road would not proceed absent the timber sale); *Thomas v. Peterson*, 753 F.2d 754, 757 (9th Cir. 1985) (same).

[6] *Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 374 (1989) (emphasis added).

[7] *Louisiana Wildlife Federation v. York*, 761 F.2d 1044, 1051 (5th Cir. 1985) (quoting *Wisconsin v. Weinberger*, 745 F.2d 412, 418 (7th Cir. 1984) (a supplemental EIS must be prepared when "new information provides a *seriously* different picture of the environmental landscape such that another hard look is necessary")).

[8] *Marsh*, 490 U.S. at 385.

[9] 46 Fed Reg. 18026 (March 23, 1981), as amended, 51 Fed. Reg. 15618 (April 25, 1986), Question 32; *see also Oregon Natural Resources Council v. U.S. Forest Serv*., 445 F. Supp. 2d 1211, 1232 (D. Or. 2006) (recognizing passage of time likely warrants supplemental NEPA analysis).

[10] The St. Paul District prepared an EIS in 1974 for the operation and maintenance of a 9-foot channel on the Upper Mississippi River from the head of navigation to Guttenberg, Iowa. The Rock Island District prepared an EIS in 1974

Corps District was written in 1997, but that 17-year old EIS itself acknowledged a major shortcoming: "The major unresolved issue is the *cumulative impacts* of the continued operations and maintenance of the 9-foot navigation channel."[11]

None of these O&M EISs evaluate the cumulative impact of the more than 1,375 river training structures[12] constructed by the Corps in the middle Mississippi River on flood heights or on the safety of river communities.[13] The Corps has never prepared a single, comprehensive environmental impact statement evaluating the full range of impacts, including the cumulative impacts, of O&M activities on the UMR-IWW system.[14]

In addition to the changes mandating a supplemental EIS on all O&M activities discussed below, the Conservation Organizations also understand that the Corps is dredging the Mississippi River channel to at least 11.5 feet rather than the authorized depth of 9-feet. The original EISs do not evaluate the environmental impacts of dredging the channel 2.5 feet deeper than the authorized depth. The Corps must analyze the environmental impacts of the actual dredging that it is conducting.

The failure to supplement the out of date and piecemeal environmental reviews and to develop less environmentally damaging alternatives violates the clear requirements of NEPA. The failure to examine and adopt less damaging alternatives is extremely troubling since the Corps has long been aware that alternative methods exist for maintaining the system's navigational capacity while also improving the system's ecological health.[15]

A. Dramatic Decline in the Ecological Health of the System

Since the O&M EISs were completed there has been a dramatic decline in the ecological health of the UMR-IWW that triggers the need to prepare a supplemental EIS for all O&M activities. Moreover, it is well recognized – including by the Corps itself – that the Corps' O&M activities have completely altered

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for the operation and maintenance of a 9-foot navigation channel on the Upper Mississippi River. The St. Louis District prepared an EIS in 1975 and 1976 for the operation and maintenance of pools on the Mississippi and Illinois Rivers and the regulating works for the Mississippi River between the Ohio and Missouri River.

[11] The St. Paul District issued a fifth EIS in 1997 that evaluated navigation maintenance activities within that district. 1997 EIS at 1-4 (emphasis added). The 1997 EIS acknowledged that the document did not evaluate "operations" and did not examine cumulative impacts.

[12] GAO Study on River Training Structures.

[13] GAO Study on River Training Structures.

[14] The duty to discuss cumulative impacts in an EIS is mandatory and not within the agency's discretion. 40 C.F.R. §§ 1502.16, 1508.7; *see also Oregon Natural Resources Council v. Marsh*, 52 F.3d 1485 (9th Cir. 1995) (holding that the Corps violated NEPA by narrowly limiting the scope of the discussion of cumulative impacts).

[15] For example, in 1997, the Donald J. Barry, Deputy Assistant Secretary for Fish and Wildlife and Parks, U.S. Department of Interior wrote a letter to the Martin Lancaster, Assistant Secretary of the Army for Civil Works advising the Corps of the new information that has been developed by the Corps and FWS regarding the impacts of the Corps' O&M activities on the Upper Mississippi River System and that the Corps' activities "can be managed to achieve the goals of navigation and a healthy river system." (Letter dated April 12, 1997). Similarly, the Upper Mississippi Water Level Management Task Force advised the Corps in 1996 that "[w]ater level management experiences from around the world amply demonstrate that opportunity exists for improving the ecological conditions of the Upper Mississippi River." Upper Mississippi Water Level Management Task Force, Problem Appraisal Report for Water Level Management (1996) at 3-3.

the natural processes of the Upper Mississippi River and have played a major role in the dramatic decline in the ecological health of the Mississippi and Illinois Rivers and the species that rely on them.[16] Construction of river training structures has also resulted in significant increases in flood heights along the Mississippi River. These adverse impacts also undermine the effectiveness of work carried out under the Corps' restoration and flood protection authorities for the Mississippi River

For example, in December 1997, the Corps issued a report to Congress which concludes that "conditions at even the most healthy sites within the [Upper Mississippi River System] are at least partially artificial, non-sustainable, and in a recognized state of degradation."[17]

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.[18]

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.[19]
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.[20]

In May 2000, the U.S. Fish and Wildlife Service issued a Final Biological Opinion on the Corps' O&M activities which concludes that the "continued operation and maintenance of the 9-foot Navigation project will jeopardize the continued existence of the Higgins eye pearly mussel (*Lampsilis higginsi*) and the pallid sturgeon (*Sacphirhynchus albus*)."[21] The Biological Opinion also concludes that the Project will

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[16] 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).
[17] Rock Island District, U.S. Army Corps of Engineers, *Report to Congress, An Evaluation of the Upper Mississippi River System Environmental Management Program* (December 1997) at 2-3.
[18] *Id*.
[19] "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.
[20] 1999 Status *and Trends Report at* 16-1 to 16.-2.
[21] U.S. Fish and Wildlife Service, Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System at 1.

result in the incidental take of the least tern (*Sterna antillarum*) and winged mapleleaf mussel (*Quadrula fragosa*). The Biological Opinion also concludes that the Project will likely adversely affect the bald eagle (*Haliaeetus leucocephalus)*, the Indiana bat (*Myotis sodalis*), and the decurrent false aster (*Boltonia decurrens*).[22]

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.[23] 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.[24]

The 2008 Status and Trends report also recognized that there has been "a substantial loss of habitat diversity"[25] 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.[26]

These changed conditions, and the role of all the O&M practices in these changes, mandates preparation of a supplemental EIS that comprehensively examines all O&M activities.

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[22] *Id*.
[23] 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).
[24] *Id*. at 3.
[25] *Id*. at 6.
[26] *Id*. at 6.

B. Significant New Scientific Information

Since the O&M EISs were completed there has been a deluge of new scientific studies that bear directly on the environmental impacts of the Corps' O&M activities and that trigger the need to prepare a supplemental EIS for all O&M activities.

For example, since 1976, hundreds of studies have been published addressing large river sediment transport and deposition.[27] As discussed above, sedimentation in the navigation pools, side channels, and backwater areas is well recognized as one of the most critical ecological problems affecting the Upper Mississippi River ecosystem.

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 A.

Indeed, there is 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.[28]

As discussed below, new science also shows significant changes in precipitation in the Mississippi River basin triggered by climate change. New science also shows that climate change may significantly exacerbate the impacts on the many migratory species that utilize the Mississippi River, Mississippi River Flyway, and the project area. 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

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[27] E.g., DeHaan, H.C. 1998, *Large River Sediment Transport and Deposition: An Annotated Bibliography,* U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, April 1998, LTRMP 98-T002. 85 pp. (identifying more than 250 scientific studies addressing large river sediment transport and deposition published since 1976): Pierre Y. Julien and Chad W. Vensel, Department of Civil and Environmental Engineering Colorado State University, *Review of Sedimentation Issues on the Mississippi River*, DRAFT Report Presented to the UNESCO: ISI, November 2005 (referencing more than 100 studies published between 1979 and 2005).
[28] GAO Study on River Training Structures at 41.

> Change not only on their breeding and non-breeding grounds but also while on migration."
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> "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 . . . ."
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> * * *
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> "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."[29]

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.[30]

This new scientific information mandates preparation of a supplemental EIS that comprehensively examines all O&M activities.

C. Significant Changes in Precipitation and Stream Flow

Since the O&M EISs were completed there have been documented changes in precipitation and stream flow within the Mississippi River basin that trigger the need to prepare a supplemental EIS for all O&M activities.[31] For example:

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[29] 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).

[30] *Id*. at 42-43.

[31] The Corps is required as a matter of law to evaluate the cumulative impacts of climate change. *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

- In March 2005, the U.S. Geological Survey released a study showing upward trends in rainfall and stream flow for the Mississippi River.[32]

- In 2009, the U.S. Global Change Research Program issued a 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]

- In March 2012, Midwest regional assessments were issued that provide important technical input into the National Climate Assessment.[36]

- In 2013, Regional Climate Trends and Scenarios were issued 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%.[37]

Notably, climate change could significantly exacerbate the public safety impacts of O&M activities 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.

"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.").

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

[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*.

[36] The Midwest regional assessment can be accessed at http://glisa.msu.edu/great_lakes_climate/nca.php (visited January 22, 2014).

[37] 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).

These documented changes in precipitation and stream flow trigger the need to prepare a supplemental EIS for all O&M activities.

D. Significant Changes in Applicable Law and Policy

Since the O&M EISs were completed there have been significant changes to the laws and policies applicable to the Corps' O&M practices that trigger the need to prepare a supplemental EIS for all O&M activities. For example:

(1) New Executive Orders: Executive Orders issued in 1977 direct agencies to protect wetlands and floodplains. Executive Order 11990 (Protection of Wetlands) directs each federal agency to provide leadership and take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values in carrying out agency policy. Executive Order 11988 (Floodplain Management) directs each federal agency to avoid, to the extent possible, the long and short-term adverse impacts associated with the occupancy and modification of floodplains; to avoid direct and indirect support of floodplain development wherever there is a practicable alternative; and "to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

(2) NEPA Implementing Regulations: In 1978, the Council on Environmental Quality promulgated regulations for implementing NEPA. The Corps' own regulations implementing NEPA were promulgated in 1988.

(3) Clean Water Act Regulations: In 1980, the Clean Water Act's Section 404(b)(1) guidelines were promulgated. These guidelines must be followed for the Corps' civil works activities. In 1990 the Corps and EPA signed a Memorandum of Agreement on mitigation that establishes priorities and procedures to be used in implementing mitigation under the Clean Water Act § 404. In 2008, the Corps and EPA issued new mitigation requirements applicable to the Clean Water Act § 404 program. Corps civil works projects are subject to these new mitigation requirements (and to the mitigation requirements established by the Water Resources Development Act of 2007, discussed below). 33 U.S.C. § 2283(d). These mitigation requirements must be satisfied for both new projects and existing projects that are reevaluated under NEPA. *Id*.

(4) Water Resources Development Acts: The Water Resources Development Act (WRDA) of 1986 authorizes the Corps to modify existing water resources projects and operations to improve the quality of the environment. WRDA 1990 changed the Corps' fundamental mission to "include environmental protection as one of the primary missions of the Corps of Engineers in planning, designing, constructing, operating, and maintaining water resources projects." 33 U.S.C. § 2316. WRDA 2007 created a new federal water policy that requires all Corps projects to protect and restore the environment and imposes new and important mitigation requirements for Corps projects, including existing projects that are re-evaluated through an EIS or supplemental EIS. 33 U.S.C. § 2283(d).

These significant changes in law and policy trigger the need to prepare a supplemental EIS for all O&M activities.

II. The Corps Should Initiate A National Academy of Sciences Study on the Effect of River Training Structures on Flood Heights to Inform Development of the SEIS

The Conservation Organizations call on 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 study is needed to provide important guidance on this significant public safety issue, and to ensure that that the Corps fully accounts for the flood height inducing effects of river training structures when planning and carrying out future O&M activities. To date, the Corps has denied the existence of this flood-height inducing effect, ignoring extensive peer-reviewed science and global recognition of this impact.

As discussed in Section I.B. above, an extensive body of peer-reviewed scientific literature demonstrates that river training structures constructed by the Corps to help maintain the 9 foot navigation channel are significantly increasing the risks of floods for riverside communities and floodplain lands.[38] 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.[39] 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. Indeed, there is a global consensus that river training structures increase flood risks as evidenced by the costly work being carried out by the government of the Netherlands to modify hundreds of river training structures to reduce flood risks.[40]

In the face of the overwhelming scientific consensus on the role of river training structures in increasing flood levels and the resulting significant risks to public safety, the Corps should not construct new structures without a detailed and comprehensive analysis of this issue by the National Academy of Sciences. The costs associated with a National Academy study are far outweighed by the public benefits, including public confidence in a final decision regarding construction of new river training structures.

III. The Corps Should Impose A Moratorium on the Construction of New River Training Structures

In light of the public safety implications discussed above, and the fact that navigation can in fact continue without the construction of new river training structures, the Conservation Organizations urge the Corps to impose a moratorium on the construction of new river training structures pending completion of the requested National Academy of Sciences study and the SEIS. New river training structures should not be built unless the National Academy of Sciences study and a comprehensive and

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[38] See Attachment A listing 51 peer reviewed studies linking instream structures to increased flood heights.
[39] 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.
[40] GAO Study on River Training Structures at 41.

legally adequate SEIS establish that such construction will **not** contribute to increased flood risks to communities.

The moratorium should apply to all new river training structures in the Mississippi River, whether they are for navigation or other purposes, including the extensive field of chevrons proposed as a restoration project for the Herculaneum Reach of the Mississippi River. Absent such a moratorium, construction of new river training structures will certainly continue without the much-needed comprehensive assessment of public safety and environmental impacts. For example, the Corps is currently seeking approval for at least the following additional projects that would add a significant number of new training structures to the river:

- The Grand Tower project which would add 2 new chevrons, 3 new S-dikes, 3 new weirs, 1 dike extension, and additional new revetment.
- The Dogtooth Bend project would add 8 new bendway weirs and 1 new dike.
- The Eliza Point project which would add 4 new bendway weirs and 1 new rootless dike.
- The Moosenthein Ivory project which would add 1 new rootles dike and 2.2 miles of new revetment.
- The Herculaneum Reach project which would add 12 new chevrons in a narrow, 3.5 mile stretch of the Mississippi River (creating the River's largest concentration of chevrons).

These, and any other structures constructed by the Corps during the SEIS review period, would add to the more than 1,375 wing dikes, bendway weirs, chevrons, and similar structures already in the 195 miles that constitute the Middle Mississippi River.[41] Independent scientists who have studied the effects of river training structures report that as of 2001, the Corps had constructed 1.5 miles of river training structures for each mile of the Middle Mississippi River (river miles 180 to 37). 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 potentially significant risks to public safety, the fact that navigation can in fact continue without the construction of new river training structures, and the current lack of a legally adequate environmental review, warrant the adoption of a moratorium on the construction of new river training structures pending completion of the requested National Academy of Sciences study and the SEIS.

IV. The SEIS Must Fully Evaluate the Impacts of All Reasonable Alternatives and Select an Alternative that Protects and Restores the Mississippi River

To comply with NEPA, the SEIS must properly define the project purpose, fully evaluate project impacts, and fully review all reasonable alternatives. To comply with the National Water Policy and the Corps' civil works mitigation requirements, the SEIS must select an alternative that protects and restores the natural functions of the Mississippi River system and that mitigates any unavoidable damage.

The independent external peer review that is clearly required for the SEIS should be conducted by the National Academy of Sciences, and the panel's task should explicitly include a charge to evaluate: the

[41] GAO Study on River Training Structures at 9-10.

appropriateness of the alternative recommended by the Corps; whether the selected alternative will in fact protect and restore the functions of the Mississippi River system; whether the selected alternative includes a mitigation plan that is likely to produce ecologically successful mitigation; and whether the selected alternative includes appropriate and meaningful criteria for determining project success.

A. Properly Define Project Purpose

It is critical that the SEIS properly define the purpose and need for the proposed project as this determines the universe of reasonable alternatives that must be evaluated.[42] The project purpose drives the evaluation of alternatives because all reasonable alternatives that accomplish the project purpose must be examined in an environmental impact statement, while alternatives that are not reasonably related to the project purpose do not have to be examined.[43]

Because the evaluation of alternatives is "the heart of the environmental impact statement,"[44] 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). . . . 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)."[45]

As a result, the courts have made it clear that an agency may not define a project so narrowly that it "forecloses a reasonable consideration of alternatives."[46] An agency also may not define the project's purpose so narrowly that it makes the final EIS "'a foreordained formality.'"[47]

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[42] *Citizens Against Burlington v. Busey*, 938 F.2d 190, 195 (D.C. Cir. 1991) (the project purpose and need "delimit[s] the universe of the action's reasonable alternatives.") *See also Wyoming v. U.S. Dep't of Agric.*, 661 F.3d 1209, 1244 (10th Cir. 2011) ("how the agency defines the purpose of the proposed action sets the contours for its exploration of available alternatives.").

[43] Methow Valley Citizens Council v. Regional Forester, 833 F.2d 810, 815-16 (9th Cir. 1987).

[44] 40 C.F.R. § 1502.14.

[45] *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").

[46] *Fuel Safe Washington v. Fed. Energy Regulatory Comm'n*, 389 F.3d 1313, 1324 (10th Cir. 2004) (quoting *Davis v. Mineta*, 302 F.3d 1104, 1119 (10th Cir. 2002); *Citizens' Comm. To Save Our Canyons v. U.S. Forest Serv.*, 297 F.3d 1012, 1030 (10th Cir. 2002); *Simmons v. United States Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997); *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) ((holding that "an agency may not narrow the objective of its action artificially and thereby circumvent the requirement that relevant alternatives be considered); *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991), *cert. denied* 502 U.S. 994 (1991).

According to the Public Notice (Public Notice 2013-744), the long-term goal of the Regulating Works Project "is to reduce 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." Public Notice at 2. If the Corps were to adopt this stated goal as the project purpose, it would be too narrow to allow consideration of reasonable alternatives as it would preclude consideration of measures for maintaining channel depth that did not include additional river training structures. A more appropriate project purpose would be **"to maintain navigation in the Middle Mississippi River"** or for the expanded SEIS requested by the Conservation Organizations **"to maintain navigation in the UMR-IWW."** The Conservation Organizations urge the Corps to adopt this as the project purpose for the SEIS.

The SEIS should also evaluate, and demonstrate in the purpose and need statement, that there is in fact a need for new navigation structures (*e.g.*, dikes, weirs, chevrons, and revetment). This is critically important because the current O&M regime is clearly able to maintain a reliable navigation channel while projects constructed under the Regulating Works Project have been implicated in significant increases in flood risks for communities and floodplain lands.

The SEIS should also clearly document whether any actions proposed in the SEIS can be carried out under the existing authorization, or whether new authorization from Congress would be required. According to the 1976 EIS for the "Mississippi River Between the Ohio and Missouri Rivers (Regulating Works)", prepared by the Corps' St. Louis District, the Regulating Works Project is authorized by the Rivers and Harbors Act of 1910, the Rivers and Harbors Act of 1927 and the Rivers and Harbors Act of 1930. Each of these Acts authorizes activities recommended in a Chief of Engineers Report prepared prior to enactment of each Act. These Chief of Engineers Reports, however, are not readily accessible to the public and the text of the reports was not provided in the 1976 EIS.

It is of course possible that these Chief of Engineers reports recommend an ongoing program of river training structure construction, or authorize construction for a more than 100 year period. However if, as is more likely, these reports recommend a more limited scope of construction, new Congressional authorization would likely be required to carry out any additional construction of river training structures that might be recommended in the final SEIS.[48] The public and decision makers should have a clear understanding of the precise activities currently authorized (including any limitations on those activities) and whether new authorization would be required.

B. Rigorously Evaluate All Reasonable Alternatives and Ultimately Select an Alternative that Protects and Restores the Mississippi River

The consideration of alternatives is "the heart of the environmental impact statement" and to satisfy the requirements of NEPA, the SEIS must "[r]igorously explore and objectively evaluate all reasonable alternatives." 40 C.F.R. § 1502.14. "[T]he existence of reasonable but unexamined alternatives renders

[47] *City of Bridgeton v. FAA*, 212 F.3d 448, 458 (8th Cir. 2000) (quoting *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (D.C. Cir. 1991), *cert. denied* 502 U.S. 994 (1991); citing *Simmons v. U.S. Army Corps of Eng'rs*, 120 F.3d 664, 666 (7th Cir. 1997)).

[48] It is also possible that the numerous river training structure projects currently being proposed by the Corps also exceed the existing authorization, and thus cannot be constructed without new Congressional authorization.

an EIS inadequate."[49] "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."[50]

The National Water Policy established by Congress in 2007 requires the Corps to operate and maintain the UMR-IWW navigation system to protect the Mississippi River and its floodplain. That policy states that "all water resources projects" shall "protect[] and restor[e] the functions of natural systems and mitigat[e] any unavoidable damage to natural systems." 33 U.S.C 1962-3 (established by § 2031(a) of the Water Resources Development Act of 2007, and immediately applicable to all water resources projects).[51] As a result, the SEIS must evaluate alternatives that would protect and restore the natural functions of the Mississippi River, and must ultimately select an alternative that achieves these objectives.

Critically, the alternative ultimately recommended by the SEIS 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 that were established by § 2036(a) of the Water Resources Development Act of 2007. These mitigation requirements must be satisfied, among other times, whenever the Corps will be recommending a project alternative in an EIS. 33 U.S.C. § 2283(d). The alternative ultimately recommend by the SEIS must also obtain a Clean Water Act water quality certification from the appropriate Mississippi River states.

The Public Notice proposes the consideration of only two alternatives: (1) continuing with the Regulating Works Project at the current pace; and (2) not building new dikes, weirs, or revetments but maintaining existing structures. While we agree that these two alternatives should be evaluated, such a truncated alternatives analysis would violate the Corps' duty under NEPA to fully review "all reasonable alternatives."[52]

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[49] Ctr. for Biological Diversity v. United States Dep't of the Interior, 623 F.3d 633, 642 (9th Cir. 2010); Westlands Water Dist. v. U.S. Dep't of Interior, 376 F.3d 853, 868 (9th Cir. 2004); Morongo Band of Mission Indians v. Fed. Aviation Admin., 161 F.3d 569, 575 (9th Cir. 1998); Oregon Natural Desert Ass'n v. Bureau of Land Management, 531 F.3d 1114, 1121 (9th Cir. 2008).

[50] Forty Most asked Questions Concerning CEQ's NEPA Regulations, 46 Fed. Reg. 18,026 (March 23, 1981).

[51] 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).

[52] Evaluations of alternative configurations of river training structures cannot satisfy the requirement to evaluate all reasonable 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).

Additional alternatives that should be examined include, but are by no means limited to:

- Removing and/or modifying existing river training structures to reduce flood risks and restore backwater, side channel, and braided habitat.

- Maintaining the authorized navigation channel through alternative approaches, including such things as alternative water level management regimes, alternative dredging strategies, and/or removing sediment dredged from the river rather than pumping dredged sediment back into the river adjacent to the main channel.

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

Each alternative **must** include mitigation for any unavoidable adverse impacts as required by 33 U.S.C. § 2283(d) and the Clean Water Act.

The SEIS should also provide the construction and full life cycle maintenance costs of each alternative to assist the public and decision makers in assessing the full impact of each alternative.

C. Fully Analyze Direct, Indirect, and Cumulative Impacts

In comparing and analyzing potential alternatives, the SEIS must examine, among other things, the direct, indirect, and cumulative environmental impacts of alternatives, the conservation potential of those alternatives, and the means to mitigate adverse environmental impacts that cannot be avoided. 40 C.F.R. § 1502.16. This assessment is essential for determining whether less environmentally damaging alternatives are available.

Direct impacts are caused by the action and occur at the same time and place as the action. Indirect impacts are also caused by the action, but are later in time or farther removed from the location of the action. 40 C.F.R. § 1508.8. Cumulative impacts are:

> "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 C.F.R. § 1508.7. The cumulative impacts analysis ensures that the agency will not "treat the identified environmental concern in a vacuum."[53]

[53] *Grand Canyon Trust v. FAA*, 290 F.3d 339, 346 (D.C. Cir. 2002).

The cumulative impacts analysis must examine the cumulative effects of federal, state, and private projects and actions.[54] The cumulative impacts analysis must also evaluate the cumulative impacts of climate change.[55] 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."
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> * * *
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> "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, and the implications for the environment to adapt to the projected effects of climate change."[56]

Notably, climate change could significantly exacerbate the public safety impacts of the Regulating Works 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 studies and analyses referred to in Section I.C. above.

The SEIS must provide "quantified or detailed information" on the impacts, including the cumulative impacts, so that the courts and the public can be assured that the Corps has taken the mandated hard look at the environmental consequences of the Project.[57] **If information that is essential for making a reasoned choice among alternatives is not available, the Corps must obtain that information unless the costs of doing so would be "exorbitant."** 40 C.F.R. § 1502.22 (emphasis added).

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[54] The requirement to assess non-Federal actions is not "impossible to implement, unreasonable or oppressive: one does not need control over private land to be able to assess the impact that activities on private land may have" on the project area. *Resources Ltd., Inc. v. Robertson*, 35 F.3d 1300, 1306 (9th Cir. 1993).

[55] *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.").

[56] 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.

[57] Neighbors of Cuddy Mountain v. U. S. Forest Service, 137 F.3d 1372, 1379 (9th Cir. 1998); Natural Resources Defense Council v. Callaway, 524 F.2d 79, 87 (2d Cir. 1975).

Importantly, as CEQ has made clear, in situations like those in the Mississippi River where the environment has already been greatly modified by human activities, it is **not** sufficient to compare the impacts of the proposed alternative against the current conditions. Instead, the baseline must include a clear description of how the health of the resource has changed over time to determine whether additional stresses will push it over the edge.[58]

D. Types of Impacts That Must Be Examined

The SEIS should examine the direct, indirect, and cumulative impacts of all reasonable alternatives on at least the impacts discussed below. Importantly, the SEIS should also carefully examine such impacts for each different type (e.g., bendway weir, chevron, wing dike, S-dike, rootless dike) and configuration of structures that would be utilized in each alternative since different types and configurations of river training structures have different impacts on the environment.

- **Impacts on hydrology, including the impacts on flood heights; impacts on channel morphology; and impacts on stream flow (including deviations from the historical water levels and natural flood pulse).**

  As part of this analysis, the SEIS must review and incorporate the findings of the extensive body of peer-reviewed science demonstrating that river training structures are causing significant increases in flood heights in the Middle Mississippi River. As noted above, the Conservation Organizations urge the Corps to initiate a National Academy of Sciences study to evaluate this issue.

  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. Independent scientists have also 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. A list of the 51 studies assessing the role of instream structures on increasing flood heights is attached to these comments at Attachment A. We request that these studies be included in the record for this project.

  The SEIS should also evaluate and incorporate the 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.[59] In light of this global consensus on the potentially deadly impacts of river training structures, the Corps should be required to prove that such structures are safe and effective *before* building any additional structures.

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[58] Council on Environmental Quality, Considering Cumulative Effects Under the National Environmental Policy Act at 41 (January 1997).
[59] GAO Study on River Training Structures at 41.

As part of this analysis, the Corps should also analyze the potential increased risk of levee failures due to higher flood levels (both in terms of general risks due to overall higher flood levels, and in terms of risks to individual levees upstream or nearby specific fields of river training structure), including the cumulative impacts on such risks from climate-change induced increases in precipitation and extreme weather events.

In carrying out its hydrologic analysis the Corps must utilize the most up-to-date modeling to evaluate the potential impacts of each alternative 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. The Corps should abandon its use of micro models to evaluate the impacts of river training structures (including the Corps' Hydraulic Sediment Response or HSR model which is a small-scale physical sediment transport model used by the St. Louis District) as such models cannot be relied upon to provide accurate planning information as they lack "predictive capability".[60] A study published in the Journal of Hydraulic Engineering 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 B.

- **Impacts on fish and wildlife.** The SEIS must examine the impacts of the alternatives on the species that utilize the Mississippi River, including the impacts to fish, waterfowl, birds, mammals, reptiles, amphibians, and mussels. The Mississippi River is used by an astounding array of wildlife, including 360 species of birds, 260 species of fish, 145 species of amphibians and reptiles, 98 species of mussels, and 50 species of mammals.

  Forty percent of North America's waterfowl migrate through the Mississippi River flyway. The impacts on the critical array of migratory species that utilize the Mississippi River and Mississippi River flyway must also be analyzed, including the cumulative impacts of climate change on these species. As discussed in Section I.B. above, migratory wildlife is particularly vulnerable to the impacts of climate change.

  An accurate assessment of fish and wildlife impacts will require an accurate assessment of impacts to the full range of habitats that these species rely on. A meaningful assessment would also include an evaluation of the impacts of each alternative on the ability of the fish and wildlife that utilize the river and flyway to withstand the adverse impacts of climate change (*i.e.*, the species' resiliency to climate change).

- **Impacts on endangered species.** The SEIS should pay particular attention to the impacts on threatened and endangered species and any critical habitat. This should include an analysis of impacts to recently listed species (for which there currently is no biological opinion) and to species covered by the "Tier 1 Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel in the Upper Mississippi River System." The Conservation Organizations urge the Corps to reinitiate formal consultation under the Endangered Species Act and demonstrate full compliance with all conditions established in the Tier I biological opinion.

[60] Stephen T. Maynord, Journal of Hydraulic Engineering, Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model (April 2006).

- **Impacts on key habitats – including backwater, side channel, mid-channel bars, braided river habitat, riverine wetlands, and floodplain wetlands.** The large-scale loss of backwater and side channel habitat is one of the most significant problems caused by the O&M activities. The Mississippi River and its floodplain have also suffered astounding wetland losses. The loss of these vital habitats has cascading negative impacts on fish and wildlife, public safety, recreation, and economies that rely on healthy river and floodplain systems. The SEIS must carefully evaluate and quantify the potential for additional losses – or gains – of backwater areas, natural side channels, crossover habitat, mid-channel bars, riverine wetlands and floodplain wetlands. The cumulative impacts of historical losses to these key habitats must also be fully evaluated and accounted for in any final recommended alternative.

- **Impacts on sedimentation.** Sedimentation is one of the most significant problems caused by O&M activities. The SEIS must carefully evaluate and quantify the impacts of each alternative on: increasing sedimentation in vital habitats; relocating sedimentation problems (*i.e*., shifting the loci of sedimentation which could eventually lead to even more river training structure construction and dredging); and altering sediment transport downstream, including any resulting impacts on coastal wetland losses and/or coastal wetland restoration.

- **Impacts on water quality, including nutrient composition.** The Mississippi River remains plagued by water quality problems, including excess nutrients that have both local and ecosystem wide impacts (including, for example, yearly development of the Gulf of Mexico dead zone). The SEIS must carefully evaluate and quantify the impacts of each alternative on water quality in the river, including the potential water quality impacts caused by loss of backwater habitats and wetlands and increased sedimentation.

- **Cumulative impacts of climate change.** As discussed above, the SEIS must assess the cumulative impacts of climate change, including climate-change induced increases in precipitation and extreme weather events, on the direct and indirect impacts of each alternative. Of critical concern are the additive and magnifying effect of climate change on increased flood risks and on harm to migratory species.

- **Impacts on restoration and flood damage reduction efforts.** The Corps, other federal agencies, states, non-governmental organizations, and members of the public are engaged in significant efforts to restore the Mississippi River and its floodplain and to reduce flood damages to communities and floodplain lands. The Regulating Works Project and many of the Corps' other O&M activities work against these efforts, including through increasing flood levels and destroying vital habitats. The SEIS should carefully assess the impacts of each alternative on these other vital efforts. The SEIS should also evaluate the ability of each alternative to comply with the National Water Policy which requires that all water resources projects protect and restore the functions of natural systems and mitigate any unavoidable damage to natural systems. 33 U.S.C 1962-3.

- **Impacts on ecosystem services provided by a healthy Mississippi River and floodplain.** "Ecosystem services" are the goods and services produced by ecosystems that benefit humankind. These services include (but are by no means limited to) such things as carbon sequestration, wildlife habitat, nutrient retention, and erosion reduction. While these services have traditionally been undervalued because they often fall outside of conventional markets and pricing, society is increasingly recognizing the essential link between healthy ecosystems and human welfare and significant progress has been made in the science of ecosystem services evaluation. The SEIS should carefully assess the impacts of each alternative on ecosystem services. The Conservation Organizations refer the Corps to the three ecosystem services valuations attached at Attachment C of these comments for information on preparing a meaningful ecosystem services valuation and for examples of ecosystem services valuations carried out in the Mississippi River Valley.

- **Impacts on recreational fishing and tourism industries that rely on a healthy Mississippi River and floodplain.** Mississippi River tourism generates approximately $2 billion annually. Recreational opportunities, including recreational fishing, are vitally important to the public. The SEIS should fully evaluate the impacts of each alternative on these important activities.

- **Impacts on navigation.** The Conservation Organizations have been advised that river training structures can create difficulties for safe navigation. The SEIS should examine the impacts of each alternative on the ability of barges to safely navigate the Mississippi River and reaches within the Mississippi River that are particularly dangerous or that have large concentrations of river training structures.

E. Actions that Must be Evaluated in the Cumulative Impacts Analysis

The SEIS must meaningfully evaluate the cumulative impacts of past, present, and reasonably foreseeable future actions that affect the Mississippi River on each alternative evaluated in the SEIS. The actions that must be examined include those carried out by the Corps, other federal agencies, state agencies, and members of the public.

With respect to the Corps' activities, it is critical that the Corps evaluate the cumulative impacts of the full suite of past, present, and reasonably foreseeable future O&M activities for the Mississippi River navigation system. As the Corps is of course aware, O&M activities carried out by the Corps to maintain navigation on the 1,200 miles of the UMR-IWW, including dredging and disposal of dredged material, water level regulation, construction of revetment, construction of river training structures, and operation and maintenance of the system's 37 locks and dams. Impacts from major rehabilitation efforts and reasonably foreseeable new construction must also be evaluated.

As discussed above, the Corps has already constructed more than 1,375 wing dikes, bendway weirs, chevrons, and similar structures in the 195 miles that constitute the Middle Mississippi River. The Corps constructed at least 150 of the bendway weirs between 1990 and 2000, and constructed 23 chevrons in this portion of the river between 2003 and 2010.[61] Reasonably foreseeable future projects[62] include at least the following:

[61] GAO Study on River Training Structures at 9-10.

[62] These projects should not be constructed unless (and until) the SEIS and the requested National Academy of Sciences study demonstrate that they will not pose a threat to public safety and that they are otherwise in the public interest and appropriate for construction.

- The Grand Tower project which would add 2 new chevrons, 3 new S-dikes, 3 new weirs, 1 dike extension, and additional new revetment.
- The Eliza Point project which would add 4 new bendway weirs and 1 new rootless dike.
- The Moosenthein Ivory project which would add 1 new rootles dike and 2.2 miles of new revetment.
- The Herculaneum Reach project which would add 12 new chevrons in a narrow, 3.5 mile stretch of the Mississippi River (creating the River's largest concentration of chevrons).

The cumulative impacts analysis should incorporate the significant body of scientific evidence, much of which was prepared with the Corps' input, which 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. A number of these studies are discussed in Sections I.A. and I.B. above.

In addition, the cumulative impacts analysis must evaluate the cumulative impacts of work carried out by the Corps under its flood damage reduction authority, including the construction and maintenance of Mississippi River levees and reasonably foreseeable future flood damage reduction projects. The cumulative impacts analysis should also evaluate such things as past, present, and reasonably foreseeable future: (a) lock and dam construction; reservoir and dam operations that affect the Mississippi River and its floodplain – including for such facilities located in areas outside of the Mississippi River; (b) residential and commercial development, including road construction, that affects the Mississippi River and its floodplain; and (c) agricultural practices that have affected and will continue to affect floodplain wetlands and Mississippi River water quality.

In analyzing the cumulative effects of the activities discussed above, the Corps must compare the impacts to the historical, non-disturbed, Mississippi River and not compare the impacts to the current condition of the river. This includes both the historic ecological condition and the historical flow and flood level conditions. If this information is not currently available, the Corps must obtain this information unless the costs of doing so would be "exorbitant." 40 C.F.R. § 1502.22. To establish the proper baseline, the SEIS should document and evaluate the historical changes in the Mississippi River with respect to at least the following indicators:

- Historical flows and flood levels;
- Acres of river and floodplain wetlands lost;
- Acres of native upland habitats lost;
- Miles of streambed lost or modified;
- Changes in stream flows;
- Changes in ground water elevations;
- Changes in the concentrations of indicator water quality constituents;
- Changes in the abundance, distribution, and diversity of indicator fish, waterfowl, bird, mammal, reptile, amphibian, and mussel communities;
- Changes in rainfall, and reasonably foreseeable future changes.

Conclusion

The Conservation Organizations appreciate the opportunity to provide these comments and look forward to working with the Corps to ensure that the SEIS fully evaluates environmental impacts, complies with NEPA and the nation's other vitally important environmental laws, and identifies and selects an alternative that will protect and help restore the Mississippi River.

Sincerely,

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Attachments

Attachment A

To The

Scoping Comments of the Conservation Organizations
On the Middle Mississippi River Regulating Works Project SEIS

Studies Linking the Construction of Instream Structures to Increases in Flood Levels

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Attachment B

To The

Scoping Comments of the Conservation Organizations
On the Middle Mississippi River Regulating Works Project SEIS

Evaluation of the Micromodel: An Extremely Small-Scale Movable Bed Model

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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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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

$$\Pi_A = f_A\left[D\left(\frac{g(\rho_s-\rho)}{\rho\nu^2}\right)^{1/3}, \frac{\rho R i}{D(\rho_s-\rho)}, \frac{\rho_s}{\rho}, \frac{D}{R}, \frac{B}{R}, \frac{\sigma}{\rho g i R^2} \right] \quad (1)$$

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 $3 \times 3\ \mathrm{mm}^2$ 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 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.

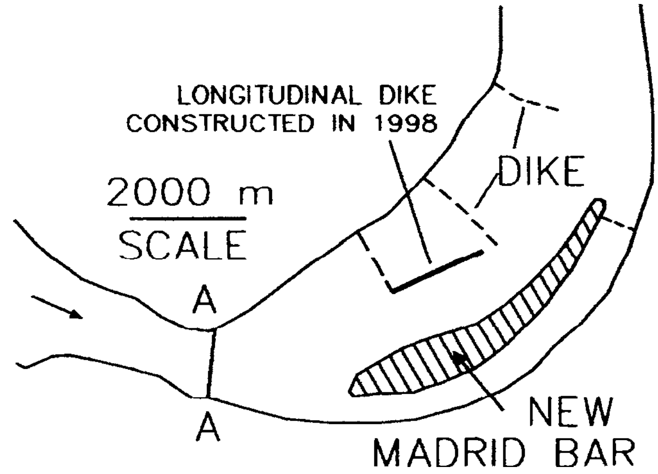

Fig. 2. Schematic of New Madrid, Mississippi River. Micromodel scale=1:19,000 horizontal, 1:1,200 vertical.

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

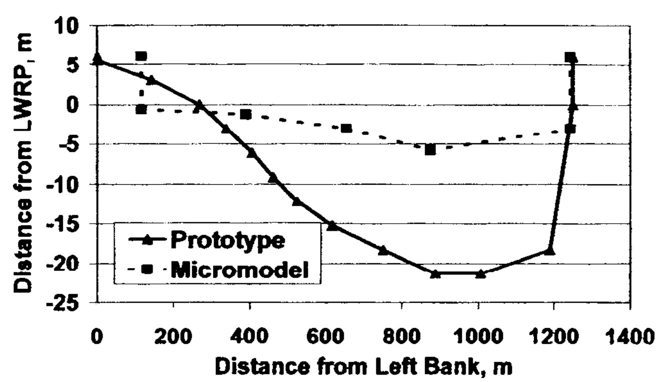

Fig. 3. Prototype and micromodel cross sections at New Madrid

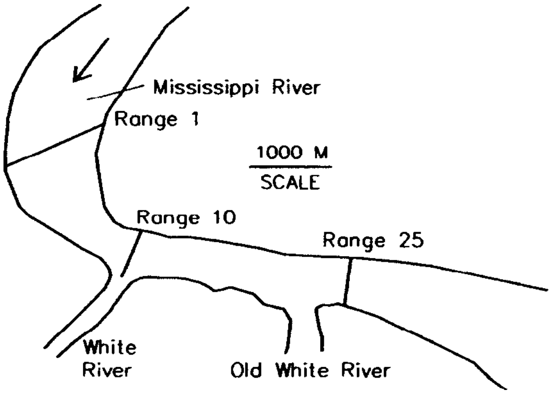

Fig. 4. Schematic of the Mouth of the White River, Mississippi River. Micromodel scale=1:12,000 horizontal, 1:1,200 vertical.

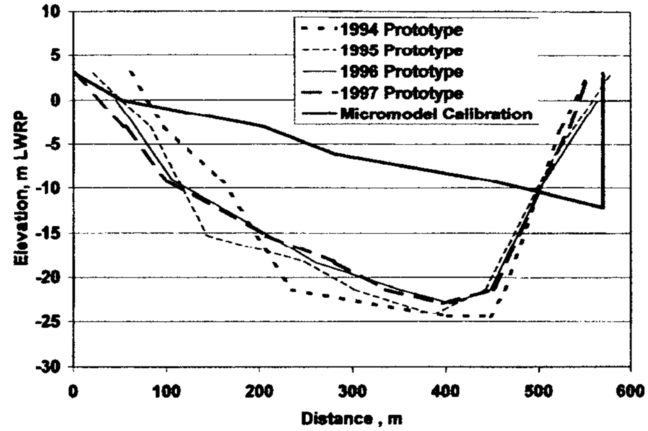

Fig. 6. Cross section at the Mouth of the White River, Range 17

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.

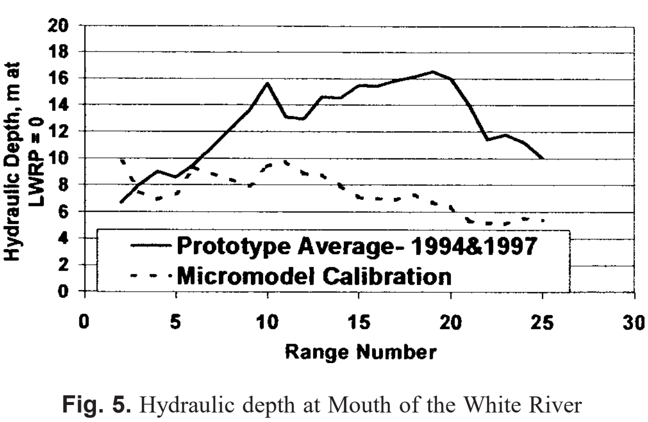

Fig. 5. Hydraulic depth at Mouth of the White River

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

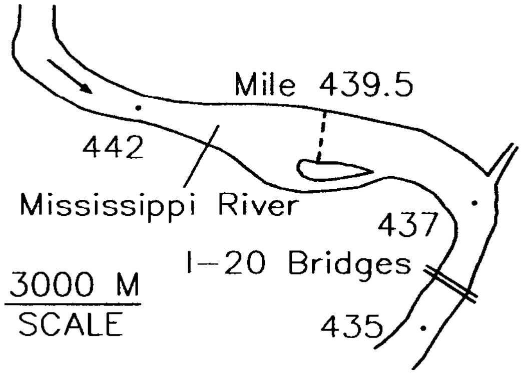

Fig. 7. Schematic of Vicksburg Front, Mississippi River. Micromodel scale=1:14,400 horizontal, 1:1,200 vertical.

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 (2X) 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.

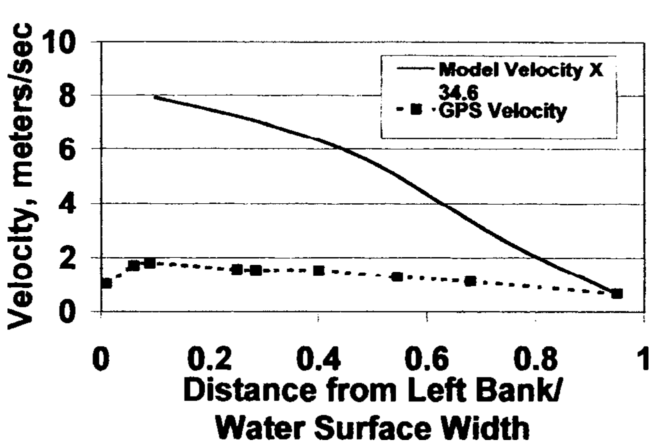

Fig. 8. Prototype GPS and micromodel velocities at Vicksburg Front

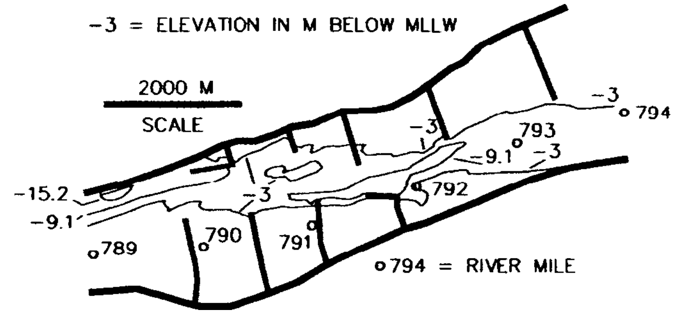

Fig. 9. Kate Aubrey, Mississippi River, 1998 prototype bathymetry. Flow from right to left.

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

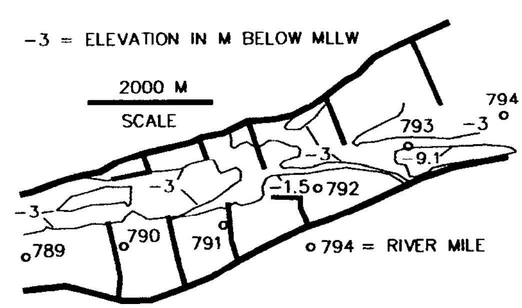

Fig. 10. Kate Aubrey, Mississippi River, 1:8,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

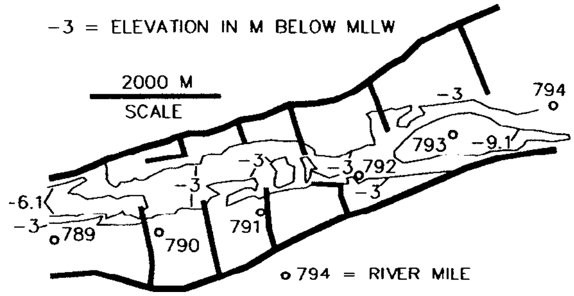

Fig. 11. Kate Aubrey, Mississippi River, 1:16,000 micromodel prediction of 1998 conditions. Flow from right to left. Upper end of model at mile 803.

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

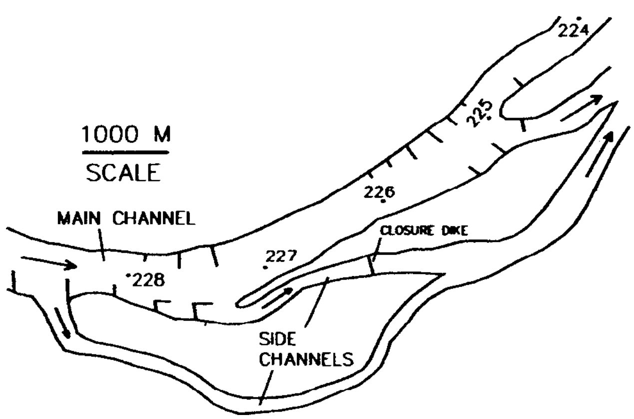

Fig. 12. Schematic of Bolter's Bar, Mississippi River, without project. Micromodel scale= 1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

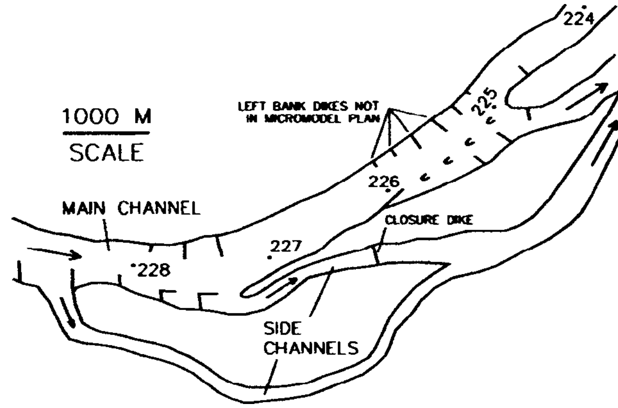

Fig. 13. Schematic of Bolter's Bar, Mississippi River, with project. Micromodel scale= 1 : 9,600 horizontal, 1:600 vertical. Upper end of model at mile 231.5.

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

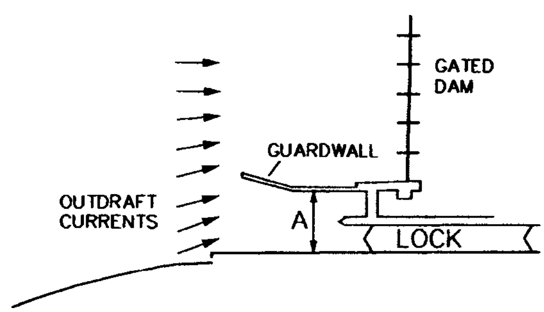

Fig. 14. Schematic of Lock 24 outdraft at upstream lock approach on Mississippi River. Micromodel scale= 1 : 9,600 horizontal, 1:600 vertical. Dimension "A" in micromodel is about 0.8 cm versus a prototype distance of about 80 m.

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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Attachment C

To The

Scoping Comments of the Conservation Organizations
On the Middle Mississippi River Regulating Works Project SEIS

Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley

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February 2009

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ECOSYSTEM SERVICES SERIES

    

Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley

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ABSTRACT

Under appropriate conditions, restoring wetlands on crop fields can result in a net increase of ecosystem services and therefore a net benefit to society. This study assesses the value of actions to restore wetlands via the Wetland Reserve Program (WRP) in the Mississippi Alluvial Valley (MAV) of the U.S. by quantifying and monetizing ecosystem services. Focusing on hardwood bottomland forest, a dominant wetland type of the MAV, *in situ* measurements of multiple ecosystem services are made on a land use continuum of agricultural land, wetlands restored via WRP, and mature bottomland forest. A subset of these services, namely greenhouse gas (GHG) mitigation, nutrient mitigation, and waterfowl recreation, are selected to be monetized with benefit transfer methods. Above- and belowground carbon estimates and changes in methane (CH_4) and nitrous oxide (N_2O) emissions are utilized to project GHG flows on the land. Denitrification potential and forgone agriculture-related losses are summed to estimate the amount of nitrogen prevented from entering water bodies. Increased Duck Energy Days (DEDs) on the landscape represent the WRP-induced expansion of waterfowl habitat. We adjust and transform these measures into per-hectare, valuation-ready units and then monetize them with prices from emerging markets (GHG) and environmental economic literature (GHG, nutrient, recreation).

Valuing all services produced by wetland restoration would yield the total ecosystem value of the change; however, due to data and model limitations we generate a partial estimate by monetizing three ecosystem services. Social welfare value is found to be between $1,446 and $1,497 per hectare per year, with GHG mitigation valued in the range of $162 to $213, nitrogen mitigation at $1,268, and waterfowl recreation at $16 per hectare. Limited to existing markets, the estimate for annual market value is merely $74 per hectare, but when fully accounting for potential markets, this estimate rises to $1,068 per hectare. The estimated social value surpasses the one-time public expenditure or social cost of wetlands restoration ($2,526 per hectare) in the MAV in only two years, indicating that the ecosystem service value return on public investment appears to be very attractive in the case of the WRP. Moreover, the finding that annual potential market value is substantially greater than landowner opportunity costs ($401–$411 per hectare) indicates that payments to private landowners to restore wetlands could be profitable for individual landowners in addition to being value-enhancing to society. This should help to motivate the development of ecosystem markets to more fully integrate societal values into land use decisions.

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INTRODUCTION

In recent decades, U.S. agricultural policy has implemented programs that offer financial incentives to private landowners to spur restoration of natural habitat and its attendant ecosystem services. A younger sibling of the Conservation Reserve Program (CRP), the Wetlands Reserve Program (WRP) focuses specifically on the restoration, protection, and enhancement of wetlands on marginal farmland. Originally authorized in 1985, the acreage cap for WRP was expanded to 2.275 million acres in the 2002 Farm Security and Rural Investment Bill (USDA-NRCS 2007).

Ecosystem services, a collective term for the goods and services produced by ecosystems that benefit humankind, have traditionally been undervalued as they often fall outside of conventional markets and pricing (NRC 2005). Without market prices, the incentive to provide them privately has been low relative to other competing land uses, such as crops, timber, or mining. Furnishing evidence for this idea, the Millennium Ecosystem Assessment reported in 2005 that about 60% of global ecosystem services are being degraded or used unsustainably (MEA 2005). Increasingly, society has recognized the essential link between healthy ecosystems and human welfare and seeks ways to increase the provision of ecosystem services. Programs such as the WRP aim to stimulate provision of ecosystem services on private lands through strategic public payments to landowners and increased collaboration between landowners and government agencies. Also, substantial effort has gone toward the formation of nascent markets to allow the trading of new environmental commodities such as carbon offset credits (to mitigate greenhouse gases causing climate change) or water quality credits for land use actions that mitigate the introduction of nutrients and sediment to waterways. Economic valuation attempts to estimate the monetary values of these nonmarket ecosystem services so that they may be more fully accounted for in natural resource management decisions, both public and private.

An important dichotomy in economic values is that between social welfare value and market value. The first represents the economic value to society of the flow of ecosystem services and is the type of value which would be used in social benefit-cost analyses of public policies or programs. These social welfare values may pertain to varying geographical scales, as recreation is local, water quality is regional, and climate protection is global. Market value embodies what value landowners can capture through the market system and can be used to inform the design of landowner incentive programs for ecosystem protection or for the development of markets for ecosystem services. Market values encompass the goods, services, and assets traded in markets, ranging from traditional agriculture or land leasing to emerging commodities such as greenhouse gas (GHG) offsets.

This study focuses on the restoration of wetland ecosystem services in the Mississippi Alluvial Valley (MAV). The MAV covers the floodplain area below the confluence of the Mississippi and Ohio Rivers, principally located in the states of Arkansas, Mississippi, and Louisiana. Once containing nearly 10 million hectares (Mha) of bottomland hardwood forest, the MAV had only 2.8 Mha remaining by the 1980s following many decades of hydrological alteration and agricultural expansion (King et al. 2006). The major land use of the region is now agriculture, dominated by cultivation of corn, cotton, rice, and soybeans (USDA-NASS). This landscape transformation has had profound ecological consequences, such as wildlife habitat loss and fragmentation, loss of flood storage, and water quality degradation due to nonpoint source runoff.

The objective of the WRP is to restore and protect the functions and values of wetlands in agricultural landscapes with an emphasis on habitat for migratory birds and wetland-dependent wildlife, protection and improvement of water quality, flood attenuation, groundwater recharge, protection of native flora and fauna, and educational and scientific scholarship (USDA-NRCS 2004). The CRP has similar goals and objectives including improving the quality of water, controlling soil erosion, and enhancing wildlife habitat. The effectiveness of these conservation programs in achieving their goals and objectives, and thereby restoring ecosystem services, is not known for wetlands in the MAV. The USDA Conservation Effects Assessment Project (CEAP) began in 2003 as a multi-agency effort to quantify the environmental benefits of conservation practices used by private landowners participating in selected U.S. Department of Agriculture (USDA) conservation programs (Duriancik et al. 2008). As part of this program, the USDA CEAP-Wetlands component in the MAV has funded research on both natural forested wetlands and forested wetlands restored through the WRP and CRP. This research effort provides site-specific data on the ecosystem services supplied by these wetlands as well as by existing cropland. This data is used in valuation approach reported here.

This study aims to assess the value to society of actions to restore wetlands in the MAV. This objective is accomplished principally by comparing the economic values of ecosystem services produced on two land use types, agricultural land and restored wetlands. Constructing values from the bottom up, this study exploits a unique link between field data and economic valuation. Although the flows of ecosystem services are myriad, we confine ourselves to the three most well defined goods for the region's wetlands: GHG regulation, nutrient retention, and waterfowl recreation. The findings of this analysis can provide valuable input into public and private decision making regarding natural resource management, including an assessment of the impact the WRP. Methodologies and values developed here will be available for use by other regional wetland assessments as well as more broadly for ecosystem service studies undertaken elsewhere.

RELATED LITERATURE

Advances in ecosystem sciences in recent years have increased our understanding of the critical importance that healthy ecosystems play in environmental sustainability. Because of human impact on ecosystems, efforts to maintain and restore ecosystems require an improved understanding of how humans benefit from ecosystems as well as how human behavior can be influenced through conservation payments and other policy tools (Heal 1991; Kramer 2008). A growing body of research has examined ecosystem services and their valuation, and government agencies are searching for ways to incentivize the provision of ecosystem services (U.S. EPA 2002; Ricketts et al. 2004; Barbier 2007).

Economists have been measuring ecosystem service values for years, for example, as part of legal proceedings to assess and assign natural resource damages from oil spills and other environmental accidents (Carson et al. 1994; NRC 2005). Enthusiasm for ecosystem services, however, expanded to the broader scientific and policy community due in part to two widely influential works published in the mid-90s by Daily (1997) and Costanza et al. (1997). Costanza's article sought to estimate the economic value of earth's ecosystems in their entirety. Most economists since then have followed the counsel of Toman (1998) to focus on changes in specific ecosystem service flows, as does this paper. In that vein, Loomis et al. (2000) measure the total economic value of the restoration of five ecosystem services for an impaired section of the South Platte River. Using contingent valuation, the authors find that households interviewed would be willing to pay $252 annually for this restoration and that scaling those values to all living along the river produces an aggregate benefit estimate that exceeds the water leasing costs and CRP easement costs needed to realize the restoration. Despite describing the environmental services in the survey, the WTP question treats them as a composite, making it impossible to decompose values for individual services. In contrast, Chan et al. (2006) implement a conservation-planning framework to examine trade-offs between biodiversity and six other ecosystem services, but do not attempt to value the services economically. Their approach reveals spatial correlations between biodiversity and the production of ecosystem services and provides information on the relative impacts of different conservation targets on those services.

Two recent articles have conducted statistical meta-analyses of wetland valuation studies, using wetland value per unit area as the dependent variable. Woodward and Wui (2001) draw data from 39 studies, predominantly of temperate wetlands, while Brander et al. (2006) use 80 studies from 25 countries representing all the continents. Updating to 2008 U.S. dollars, the former found a mean annual value per hectare of $567 among its constituent studies, whereas the latter computed a mean of over $4,000/ha/yr but a median of $215. Significant decreasing returns to scale are noted as wetland area grows in both analyses, though Woodward and Wui (2001) assert that area has a minimal impact on value per acre because this effect rapidly approaches zero with increasing wetland size. Regarding the values of different wetland services, only bird watching (Woodward and Wui) has significantly higher value than average, while bird hunting and amenity services (Woodward and Wui) and hunting, material, and fuelwood services (Brander et al.) are found to be significantly lower than average. In each meta-analysis, the service nutrient retention is classified under water quality and GHG mitigation is not included at all. Both studies conclude that benefit transfer still faces major challenges and that the need for more high-quality primary valuation studies continues to be great.

A few studies have examined the benefits associated by the Conservation Reserve Program (CRP). Feather and Hellerstein (1997) evaluate the national benefits of reduced soil erosion for recreation by estimating the benefits in four study areas and then extrapolating them to the nation as a whole with a calibration function that accounts for area-specific factors. The authors report that 11%, or about $40 million, of the nationwide benefits are attributable to the CRP. Surveying both nationally and in Iowa, Ahearn et al. (2006) find that a conservative non-use value of the Central Plains grassland birds that increase in numbers due to the CRP to be about $33 million per year.

Anderson and Parkhurst (2004) consider farmers' decisions to continue commodity crop production or to enroll in the Wetland Reserve Program (WRP) in the Mississippi delta region. In their study, land was more likely to be entered into WRP if its crop base was soybeans/soybeans or cotton/soybeans and if it had considerable recreational value. In a similar analysis, Ibendahl (2008) simulates the farmers' decisions for three counties in Mississippi using crop budgets for 2008 which reflect the historically high crop prices. He concludes that the 30-year stream of crop returns and government payments for cotton or soybean production exceeds the expected per-acre WRP payment.

ECOSYSTEM SERVICE CONCEPTUAL MODEL

We are interested in estimating the value of ecosystem services associated with a change in the use of a given unit of land. Land is an asset that generates a flow of different services.

Some of the flow is in biophysical outputs that are directly sold in the agricultural market and perhaps the timber market. Other flows work though a series of ecological and spatial processes before they become part of a service that can be valued. For instance, nutrient retention is not a valued service per se; it becomes a valued service only after working through the hydrological system to create a change in water quality. Likewise, there can be complex relationships between the existence of a unit of a particular habitat in the area of interest and its relationship to what people value either locally or at a distance.

To describe the valuation process, we start with basic hedonic model (Rosen 1974; Palmquist 1989) of value, *V*:

$$V = V(a) \qquad [1]$$

where *a* = a vector of site attributes (e.g., size, soil quality, elevation, infrastructure, population, proximity to markets).

The ecosystem service flows are reflected in a vector, *S*, that is a function of the underlying attributes

$$S = S(a) \qquad [2]$$

The service vector *S* has three subvectors:

S_M(a): goods and services that can be sold in markets, (e.g., agricultural and forest commodities, housing, marketed ecosystem services such as hunting)

S_C(a): in situ goods and services consumed by the owner of the land (e.g., residential space, nonmarketed products, amenity values)

S_P(a): services that generate public goods that do not (yet) have markets (e.g., nutrient retention, biodiversity)

It should be noted that some of these services can be produced simultaneously on the same plot of ground (e.g., commodities and certain ecosystem services), while others require explicit choices and cannot be co-produced.

Hence, the flow value of land is expressed as the sum of the value of market and nonmarket services generated:

$$V(S) = p^*S_M + v^*S_C + w^*S_P \qquad [3]$$

where *p* is a vector of market prices matched with the market good/service vector, *v* is a vector of implicit prices reflecting the values of each self-consumed good/service, and *w* is a vector of implicit prices reflecting the marginal value to society of the public good/service vector generated onsite.

The market value of the land (rental) should reflect the array of market services generated in highest and best use. In other words, the prices of market goods and services and self-consumed goods will determine how the landowner chooses the level of market/consumed services that will be generated by the land (how much of marketed commodity, how much residential space, etc.). Hedonic value, as a function of attributes, is a reduced-form version of that $V = V(a)$. In other words, the site attributes are deemed to dictate the choices that determine the "highest and best use."

Hedonic models usually try to capture the relationship between market data (property values, which are a capitalized expression of the value flow, *V*) and attributes (*a*) to give marginal values of each. But here, given that there are no markets for the ecosystem services except those that have a market price or are self-consumed (in vectors S_M and S_C), hedonic valuation cannot help us determine ecosystem service values generated by the land. Because the market value does not capture all value, the market does not allocate to highest and best use. If all ecosystem services were valued in the market, then in principle it could.

So we can examine comparative values across discrete uses and see how optimal land allocation might occur if the market valued it (or if there were government intervention with payments for ecosystem services).

We are specifically interested in testing the hypothesis that the change in total economic land value increases as one changes from agriculture to wetlands:

$$H_O: V_W(a) > V_A(a) \qquad [4]$$

where $V_W(a)$ is the total value of land, inclusive of all ecosystem services whether marketed or not, when it is in wetlands and $VA(a)$ is the total value of land in agriculture.

As an economic principle, we believe that if land is in agriculture, then the sum of all marketed and self-consumed services in agriculture must be higher than the sum of all marketed and self-consumed services in wetlands, or any other use. The real issue, then, is whether the difference in public goods value exceeds the difference in market value.

Before proceeding, we acknowledge there are criticisms leveled at this "total economic value" approach to ecosystem services stemming from the fact that the estimated value is the sum of all measured services times their shadow price (see Howarth and Farber 2002 for a review of the arguments). The critical issue is whether it is reasonable to assume the shadow price remains fixed when the ecosystem service quantity changes. In standard economics terms, it is a matter of using a partial equilibrium approach for a general equilibrium problem. This is clearly problematic when the stock value of entire ecosystems is being valued, as presumably large changes in these services are at issue and prices (marginal values) would have to change. We do not believe this is a significant problem for this study. First, we are looking at changes in ecosystem services brought about by marginal changes in land use, not at the existence of entire ecosystems. The WRP, while an important public program, does not change the landscape at a scale large enough to fundamentally alter demand for the various services, and therefore has not likely changed the shadow prices either, or if they have changed, the change is small. Therefore, in our view, a more general equilibrium approach is not needed. However, one should be careful in interpreting the implications of these results for changes of a larger magnitude.

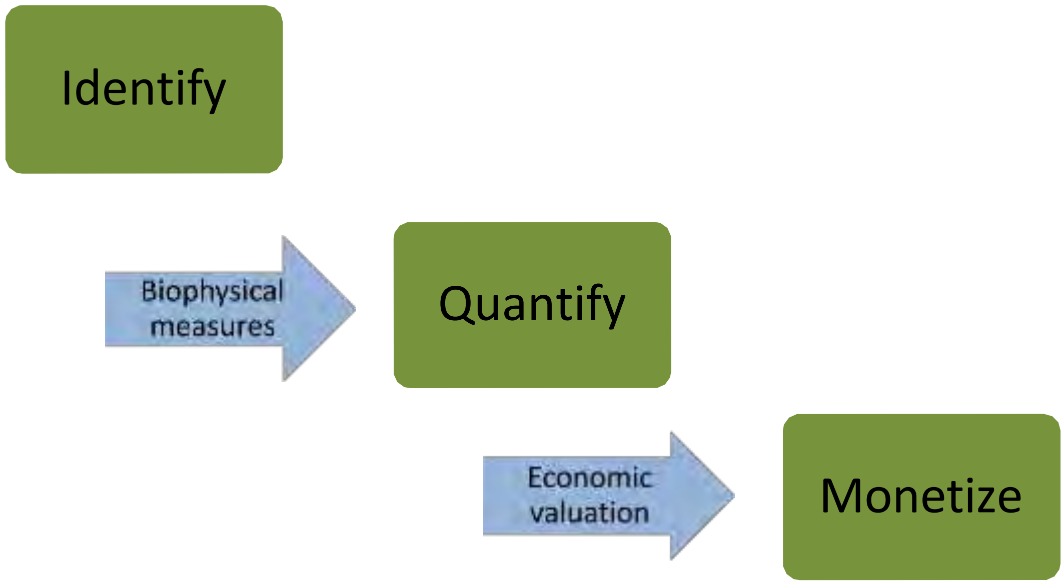
APPLICATION

Study Area

The Mississippi Alluvial Valley (MAV) is the nation's largest floodplain, extending from below the confluence of the Mississippi and Ohio Rivers to southern Louisiana (Figure 1). About three-quarters of the original bottomland hardwood forests have been converted, principally to row crop agriculture, while the remaining quarter is fragmented into over 38,000 discrete patches larger than 2 ha in size (Twedt and Loesch 1999). The study area encompasses all of the counties that intersect with the MAV, save for those in Louisiana bordering the Gulf of Mexico.

Figure 1. Extent of the Mississippi Alluvial Valley (MAV) and the locations of the 16 WRP sites sampled by USGS scientists.

Figure 2. Flow chart of ecosystem service valuation process.



Benefit Valuation Process

There are three essential steps in the ecosystem service valuation sequence: (1) identify the service, (2) quantify the service flows, and (3) monetize those flows (Figure 2). Disciplines that assess biophysical processes, such as ecology, biogeochemistry, and hydrology, play the central role in moving from identification to quantification. Economics then provides the link from service quantification to monetization. Critical to bridging the biophysical and human aspects of ecosystem services is to transform the service flow data into valuation-ready measures. This transformation may involve integrating field observations with existing process models and modeling the service through time. We standardize the service measures into per-hectare values to facilitate comparisons with economic returns from other land uses and the aggregation of benefits to broader scales. Using benefit transfer methods (Wilson and Hoehn 2006), we multiply biophysical values for services of interest by shadow prices for the services (see conceptual model discussion). These prices are obtained either through market price observations or from estimates of marginal willingness to pay for these services in the environmental economics literature. We focus on the monetization of three services: GHG mitigation, nitrogen mitigation, and waterfowl recreation, which prior information suggests are the dominant service flows for the MAV region in terms of economic value.

Although new ecosystem markets are emerging, ecosystem services can generally be considered public, nonmarket goods. When valuing a nonmarket good, total economic value (TEV) is the sum of use values, which are directly or indirectly derived from the use of an ecosystem, and nonuse values, which are related to the ecosystem's existence (Krutilla 1967; Young 2005). Thus, the TEV is equivalent to the monetization of the flow of the services from an ecosystem. In the conduct of primary research, nonmarket valuation approaches tend to be divided into two main categories: (1) stated preference and (2) revealed preference (Freeman 2003). Stated preference methods use data of intended behavior derived from survey questions directly asking respondents how they would value differing levels of an environmental good. Contingent valuation and conjoint analysis are two examples of stated preference methods. Revealed preference methods utilize observed market prices, travel costs, and purchase decisions that are correlated with changes in an environmental attribute as indicators of value for that attribute. Examples include observed market prices for some services (e.g., GHG reductions, hunting leases), travel cost method for recreation values, hedonic property value studies, and estimation of avoided expenditures to achieve a certain level of an environmental attribute (e.g., water quality).

Acknowledging that time and resources are scarce, the benefit transfer method builds on the previous methods by applying results from primary research to new contexts of interest (Rosenberger and Loomis 2003). For example, the benefits estimated for a water quality improvement in one region may be adapted to estimate the benefits of an improvement in another region. A proper benefit transfer requires that the original study site be comparable to the targeted policy site with respect to the ecosystem service definition, the market (i.e., human population) context, and the welfare measure employed (Loomis and Rosenberger 2006).

In each application in this analysis, agricultural land use is treated as the baseline, since it represents the dominant land use in the MAV, and thus the business-as-usual scenario prior to restoration. Seeking to value the action of restoring forested wetlands on cropland, we capture this economic value by calculating the difference in the values of ecosystem services provided by the two respective land use types.

Biophysical Measurement of Ecosystem Service Flows

Scientists at the USGS National Wetlands Research Center carried out the sampling design and the data collection for this study as part of the CEAP-Wetlands component (Faulkner et al. 2008). Initiated in 2003, CEAP is a multi-agency effort to evaluate the effectiveness of conservation practices used by private landowners participating in selected USDA conservation programs (USDA-NRCSa). A major element of CEAP is the National Assessment, whose objectives are to collect national estimates of benefits resulting from conservation practices and programs for croplands, wetlands, wildlife, and grazing lands and to weigh the potential of existing and future conservation programs to meet the nation's environmental goals. The wetlands component of the National Assessment measures the effects of conservation practices on ecosystem services provided by wetlands in agricultural landscapes and is being conducted in eleven regions throughout the coterminous U.S. These regional assessments will focus on one or more wetland hydrogeomorphic classes common to agricultural land in that region.

For the CEAP-Wetlands study in the MAV, a stratified random sampling design was used in the Lower White-Cache and Tensas river basins where eight replicate sites were selected for each of three treatments: restored to forested wetlands under the WRP, active cropland, and natural forested wetland sites. These sites are representative of the variability on the landscape and add up to 48 sites in total, 16 each of cropland, WRP, and natural forest. Site-level field data was collected between March and October 2006 for four ecosystem services, while soil samples for the denitrification measurements were taken in

2007. Three involve biogeochemical processes, namely, carbon sequestration, nutrient retention, and sediment retention, and the other two involve biological conservation, i.e., amphibian species richness and neotropical migrant bird species richness. Region-level data for migratory waterfowl habitat was calculated by estimating the extent of flooding based on Landsat Thematic Mapper (TM) classified image analysis for 2000–2005 and the estimated waterfowl foraging values of reforested areas (James et al., in review). Using the static chamber technique, methane and N_2O emissions were measured monthly from low- and high-elevation sites in both WRP and natural forested wetlands from 2005–2008 at 18 sites in the MAV different from the CEAP-WRP sites (Faulkner, unpublished data). Table 1 lists the relevant services with the metric measured and its spatial resolution.

Table 1. Ecosystem services measured by USGS National Wetlands Center and Ducks Unlimited.

Ecosystem Service	Definition/Metric	Spatial Resolution
Wildlife habitat – amphibians	Species richness (number/ha)	Site
Wildlife habitat – breeding birds	Species richness (number/ha)	Region
Wildlife habitat – waterfowl	Duck energy days/acre	Region
Nutrient retention	Denitrification potential (kg NO_3-N/ha/yr)	Site
Erosion reduction	Sediment (Mt/ha/yr)	Site
Carbon sequestration	Mg CO_2e/ha/yr	Site

ECOSYSTEM SERVICE VALUATION

Greenhouse Gas (GHG) Mitigation

Converting land from croplands to forested wetlands can affect the GHG balance in the atmosphere in several ways. First, carbon dioxide (CO_2), the most prevalent GHG, is removed from the atmosphere via photosynthesis and is sequestered in forest biomass and soils at levels typically well above the sequestration rate for crop systems. This creates a net carbon sink and reduces GHG concentrations, all else being equal. Second, crop production can be a significant source of non-CO_2 trace GHGs such as nitrous oxide (N_2O) and methane (CH_4), gases that are individually more potent than CO_2. Thus, discontinuation of agricultural practices reduces these emissions from the site. However, the anaerobic conditions of wetlands are ideal for the creation of methane and nitrous oxide and thus conversion can increase emissions accordingly. The net balance is determined by site conditions, as discussed below.

The process of converting GHG biophysical measures to monetary values is described below for carbon sequestration and non-CO_2 GHGs respectively.

Carbon sequestration

The biophysical data collected by the CEAP research team for this service are point estimates of aboveground and soil carbon in metric tons of carbon per hectare in the first few years after restoration. Because carbon accumulation in ecosystems is a dynamic process, these point estimate snapshots need to be transformed into GHG flux over time in order to be properly monetized. Carbon accumulation growth is tracked in three carbon pools—soil, live biomass, and other non-soil—and is projected for the future employing two different process models.

Soil carbon

For soil carbon sequestration, we average the soil carbon point estimates to create mean carbon values for all sites in each land use class (cropland, WRP land, and mature forest). Site soil carbon data are provided for the upper 15 cm of soil, where soil carbon is highest before decreasing dramatically with depth. These data are a fair proxy for one meter of soil depth, the standard used in soil carbon estimation. Next, we seed the WRP mean values, 20.83 Mg[1] C/ha/yr for Arkansas and 24.07 for Louisiana, into stand-level tables developed by the U.S. Forest Service as part of the federal 1605(b) GHG registry process. These tables are derived from the FORCARB2 forest carbon projection model (Smith et al. 2006). These tables contain data on carbon accumulation growth paths for afforested and reforested stands in 5-year increments by carbon pool, forest type, and U.S. region. To use the FORCARB2 soil model, WRP land in the MAV is proxied by afforested oak-gum-cypress forest in the south-central U.S. The growth paths are

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[1] The abbreviation *Mg* stands for *megagram*; 1 Mg is equivalent to 1 metric ton (tonne) or 10^6 grams. This paper uses Mg except in the context of the carbon credit trading market, in which the standard abbreviation *tCO₂e* is used to refer to "metric tons of CO_2 equivalent."

traced out in 5-year time steps for 90 years from the initial year of restoration (see Table 2). Soil organic carbon at WRP sites is assumed to follow the same growth path as reported in the FORCARB2 lookup tables, though the beginning value is that provided by the CEAP field data.

Table 2. Growth and net carbon flux over 90 years in soil organic carbon for agricultural and WRP sites in Arkansas and Louisiana.

	FORCARB2 table	CEAP Data – AR		CEAP Data – LA		AR		LA	
		Ag	WRP	Ag	WRP	Ag	WRP	Ag	WRP
Age	Soil Organic Carbon					Carbon Flux			
yrs	Mg C/ha					Mg C/ha			
0	29.00		–		–				
5	29.10	20.80	20.83	21.84	24.07	0.00	0.00	0.00	0.00
10	29.40	20.51	21.05	21.54	24.31	−0.29	0.21	−0.29	0.25
15	29.80	20.23	21.33	21.24	24.64	−0.28	0.29	−0.28	0.33
20	30.40	19.95	21.76	20.95	25.14	−0.28	0.43	−0.28	0.50
25	31.10	19.68	22.26	20.66	25.72	−0.27	0.50	−0.27	0.58
30	31.90	19.41	22.84	20.38	26.38	−0.27	0.57	−0.27	0.66
35	32.70	19.14	23.41	20.10	27.04	−0.27	0.57	−0.27	0.66
40	33.50	18.88	23.98	19.82	27.70	−0.26	0.57	−0.26	0.66
45	34.30	18.62	24.55	19.55	28.37	−0.26	0.57	−0.26	0.66
50	35.10	18.36	25.13	19.28	29.03	−0.26	0.57	−0.26	0.66
55	35.80	18.11	25.63	19.01	29.61	−0.25	0.50	−0.25	0.58
60	36.40	17.86	26.06	18.75	30.10	−0.25	0.43	−0.25	0.50
65	36.90	17.61	26.41	18.49	30.52	−0.25	0.36	−0.25	0.41
70	37.30	17.37	26.70	18.24	30.85	−0.24	0.29	−0.24	0.33
75	37.60	17.13	26.92	17.99	31.10	−0.24	0.21	−0.24	0.25
80	37.90	16.90	27.13	17.74	31.34	−0.24	0.21	−0.24	0.25
85	38.10	16.66	27.27	17.49	31.51	−0.23	0.14	−0.23	0.17
90	38.30	16.43	27.42	17.25	31.67	−0.23	0.14	−0.23	0.17

At the agricultural sites, the initial soil carbon values come directly from the agricultural sites paired with the WRP sites in Arkansas and Louisiana. Conventional tillage is the assumed agricultural practice. In contrast to the WRP sites, agricultural soil carbon levels tend to gradually decrease over time as they are oxidized and released into the atmosphere as a result of crop production (Potter el al. 2006a). A 2006 NRCS study simulates the change in soil carbon content for agricultural lands over a 30-year time period with the Environmental Policy Integrated Climate (EPIC) model (Williams et al. 1989; Potter et al. 2006b). The analysis provides soil organic carbon estimates, as well as those for soil and nutrient losses, by region and by crop type.

Live biomass carbon

The non-soil carbon data from CEAP represents aboveground and belowground (i.e., coarse roots) live carbon biomass plus standing dead, understory, and forest floor carbon. Across the WRP forested wetland sites that had been planted between 4 and 12 years prior to sampling, non-soil carbon measurements average 2.70 Mg/ha in Arkansas (1.69–6.33 Mg/ha range) and 3.06 Mg/ha in Louisiana (1.79–5.71 Mg/ha range).

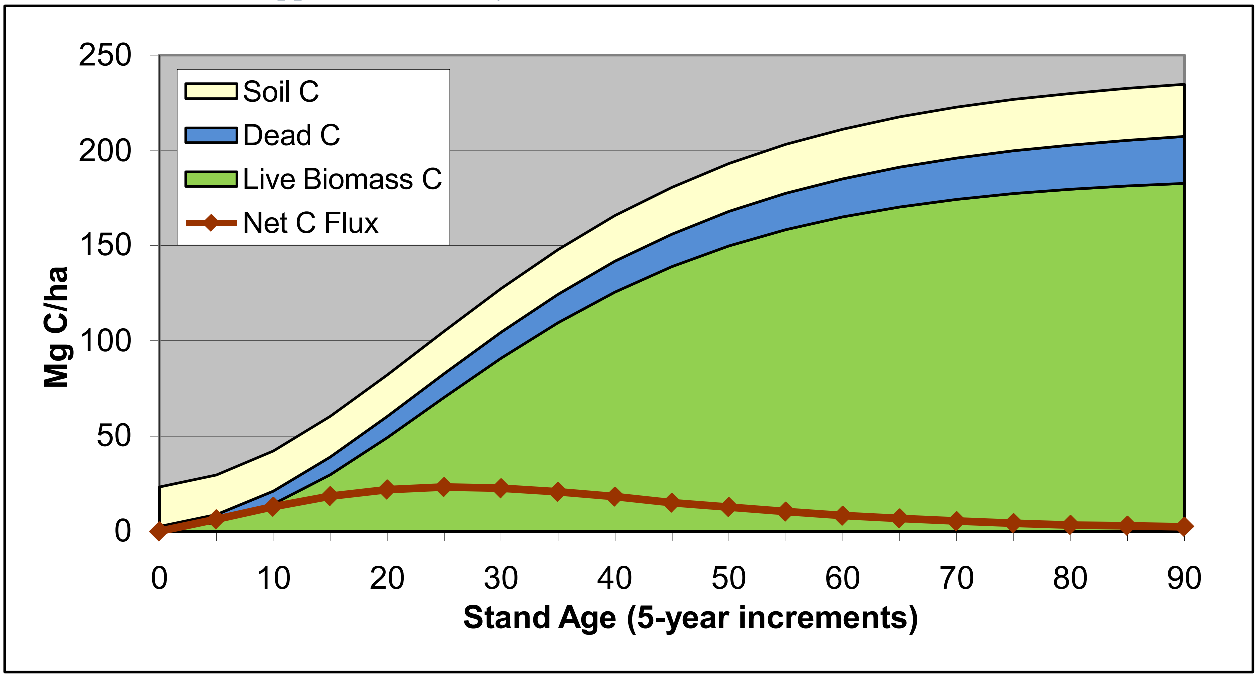
The majority of carbon sequestration potential resides in the growth of live carbon biomass (e.g., trees) through time, increasing from 72% at year 10 to over 86% in year 90 according to the USFS FORCARB2 tables (Smith et al. 2006). We estimate the carbon accumulation flows of this pool using the growth function from Shoch et al. (2008) who examine the carbon sequestration potential of bottomland hardwood afforestation in the MAV. The authors produce a chronosequence of even-aged plantations and naturally regenerated stands and statistically estimate a growth path that is markedly greater for years 20 to 90 than that derived from the USFS FORCARB2 tables for afforested oak-gum-cypress stands (Smith et al. 2006), which are commonly used for regional analysis.

This substantial difference between Shoch et al. and FORCARB2 is neither surprising nor a criticism of the FORCARB2, which is clearly defined as a model with large regional resolution. The estimated growth curve from Shoch et al. is specific to the MAV and is thus more appropriate for our study than the FORCARB2 tables whose estimates are for the south-central region in general. Dominated by bottomland red oaks, stem plantings in the WRP sites are very similar in species composition as the plantations surveyed by Shoch et al. (2008), further validating the use of their growth function. The CEAP field data for non-soil carbon falls approximately within the 95% confidence interval of and well within the prediction interval of the total live tree biomass carbon growth curve generated by Shoch et al. (2008). Therefore, it is appropriate to project future live tree carbon accumulation for the WRP sites with the Shoch et al. (2008) growth function.

Other carbon

MAV-specific estimates for carbon found in standing dead, understory, and forest floor (i.e., not found in live trees) are currently unavailable, so we utilize the USFS FORCARB2 tables as the best available source. Growth in carbon in those pools is projected in the same way as described above for the WRP soil organic carbon. In Figure 3, the carbon accumulation curve is depicted, with each major carbon pool represented by a different colored area.

Figure 3. Carbon growth and net carbon flux curves for afforested bottomland hardwood on WRP sites in Mississippi Alluvial Valley.



Carbon flux (Mg C/ha/time period) is the net change of carbon on the site from one period to the next so that positive carbon flux represents new carbon stored in addition to the existing carbon stock. This is the service flow of interest as it directly relates to the removal of CO_2 from the atmosphere, which provides the climate stabilization benefit. Flux often varies through time following the growth rate of the vegetation and soil carbon storage. The projected carbon flux for the WRP sites is represented by the red line in Figure 2. Agricultural sites (not shown here) have a slightly negative carbon flux, since soil carbon declines gradually from soil oxidation associated with crop production (Potter et al. 2006a) and the biomass grown in crops each year is also removed from the land on an annual basis. Once the carbon fluxes for total site carbon have been calculated for the agriculture and WRP sites, we then convert them into units of carbon dioxide equivalents (CO_2e) by simply multiplying by 3.67. CO_2e is the currency in which carbon service flows are monetized.

Non-CO_2 GHG emissions

The last step in quantifying the GHG sequestration potential is to account for the effect of emissions of trace GHGs, methane (CH_4), and nitrous oxide (N_2O). They have global warming potentials (GWP) much greater than CO_2 itself: 23 for CH_4 and 296 for N_2O (IPCC 2007). Both crop and wetland sites are net sources of CH_4 and N_2O emissions, though of different magnitudes. Accordingly, site N_2O and CH_4

fluxes are converted to their CO_2 equivalents using the GWP above, and are then subtracted from the CO_2 flux to determine the net GHG flux ($MgCO_2e$/ha/yr).[2]

For the agricultural sites in the region, CH_4 is emitted through rice production and residue burning and N_2O is emitted through the use of nitrogenous fertilizers and nitrogen fixation by soybeans. To find these GHG fluxes, we first determine the crop mixes for a representative agricultural hectare in the MAV for each state using data compiled by USDA National Agricultural Statistics Service (USDA-NASS). Then, we multiply the crop mixes by the corresponding state average estimates for agricultural CH_4 and N_2O emissions from the FASOMGHG model (Adams et al. 2005). Finally, weighted averages for the three MAV states are produced: −5.51 $MgCO_2e$ /ha/5 years for CH_4 and −3.14 $MgCO_2e$ /ha/5 years for N_2O.

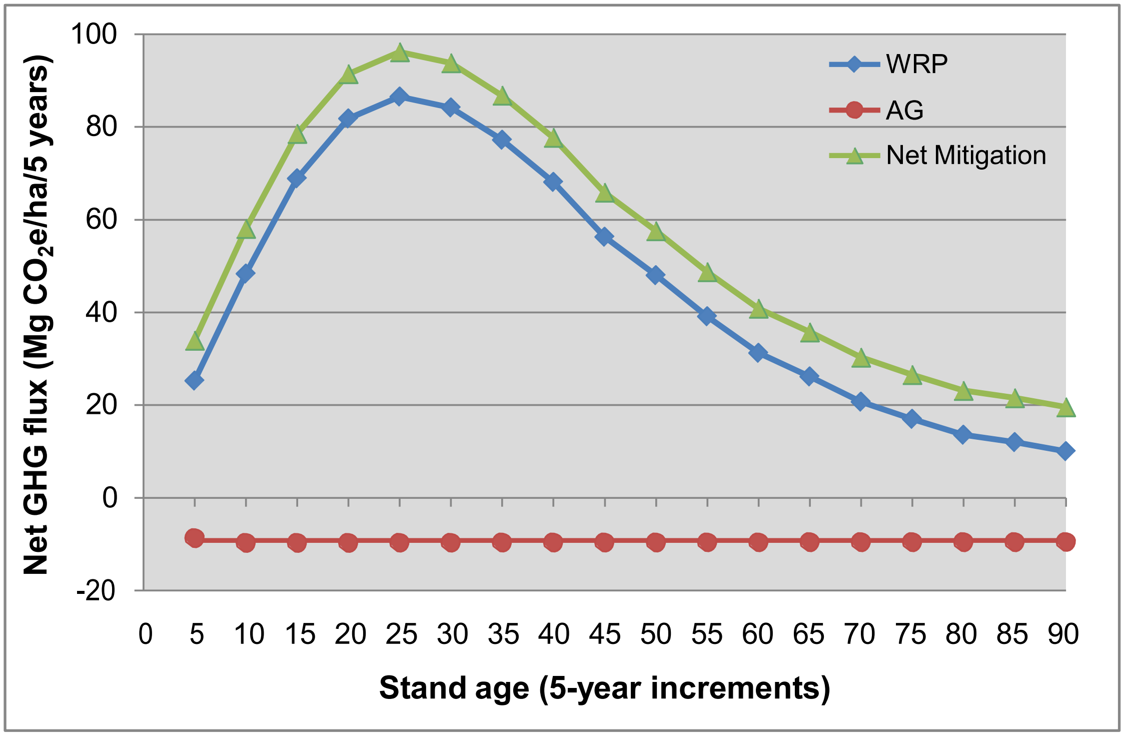
For both WRP and natural wetland sites, the levels of CH_4 and N_2O emissions vary by landscape position, i.e., whether the site is located in a low- or high-elevation position. Low-elevation sites flood more frequently and for longer duration than high-elevation sites and thus will experience longer periods with anoxic conditions in the soil. This anoxia is a prerequisite for the processes of methanogenesis and denitrification to produce gaseous methane and convert nitrate into gaseous dinitrogen (N_2) and nitrous oxide (N_2O) (Mitsch and Gosselink 2007). Since the goal of WRP is to remove frequently flooded, marginal croplands from commodity crop production, we estimate that approximately 80% of the WRP area is characterized by low elevation and the other 20% by high elevation. We multiply the CH_4 and N_2O emission rates for each landscape position by the corresponding proportion (0.8/0.2) and generate a weighted average of CH_4 and N_2O emissions for each 5-year increment between years 5 and 90 after the wetlands restoration. After converting to $MgCO_2$ equivalents, the mean CH_4 flux is −0.13 $MgCO_2e$/ha/5 years and the mean N_2O flux was −2.02 $MgCO_2e$/ha/5 years.

Total GHG flux change

Since a typical agricultural site candidate for restoration serves as the baseline, full GHG flux for restoring a hectare of wetland is the difference between the GHG fluxes for the average MAV agricultural and WRP sites. Figure 4 shows these three flux streams over the 90-year study period. Agricultural sites function as sources of GHG emissions and have a negative flux value for mitigation purposes (see footnote 2). In contrast, WRP sites serve as net sinks, have a positive mitigation flux value, and sequester up to 84 Mg of new CO_2 per hectare per 5-year period. Although non-CO_2 GHG gases are emitted in restored wetlands, their contribution is easily offset and exceeded by the carbon sequestration of the growing wetland forests. The net GHG mitigation value of restoring wetlands ranges between 19.6 and 96.2 Mg CO_2e/ha/5 years, with the peak coming at 25 years after planting the tree seedlings.

[2] We depart from some convention on the sign of the flux. We use the terrestrial ecosystem itself as the stock from which fluxes occur. Thus, a negative flux is an emission (e.g., release of CO_2 from oxidized soil carbon or the release of N_2O from denitrification), whereas carbon sequestration is a positive flux. We do this to highlight the notion that a positive number (increased sequestration or reduced emissions) is “mitigation” representing an environmental benefit that can receive a positive payment as discussed throughout.

Figure 4. Net greenhouse gas (GHG) mitigation from converting agricultural sites (AG) to WRP sites.



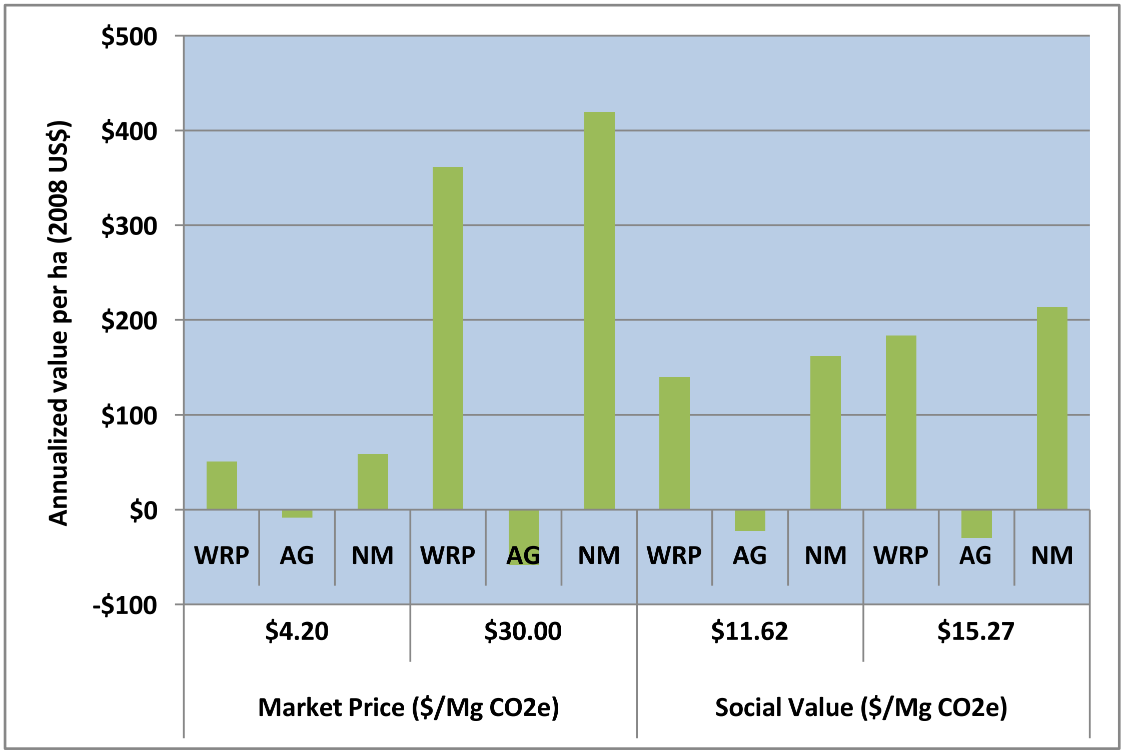
Monetizing GHG mitigation

The social welfare value of GHG mitigation captures the value of the damages avoided by mitigating the risks of climate change. This is typically estimated with the use of integrated assessment general equilibrium models to capture the *social cost of carbon,* or SCC. The IPCC Fourth Assessment Report (2007) reviews studies in the environmental economics literature that investigated the benefits of GHG mitigation and finds that mean estimates for SCC range from about \$12/MgCO_2 to \$15/MgCO_2. We use this as the shadow price for 1 Mg of GHG mitigated on our study sites.

Present value calculation

The stream of total GHG flux per hectare is multiplied by the market and social value prices and then discounted back to the present with a 4% real discount rate. The net present value of the GHG mitigation service is divided by the 90-year annuity factor to yield the annualized values per hectare that appear in Figure 5. Note that the discussion of how we determined the range of market prices used here is found further on in the Market Value section. The monetized net mitigation value is the difference between the WRP and agriculture sites. It ranges from \$59/ha/yr to \$419/ha/yr for the market prices of \$4.20 and \$30.00 respectively, while the social values are intermediate at \$162/ha/yr to \$213/ha/yr.

Figure 5. Annualized value per hectare in 2008 US$ for WRP, agricultural sites (AG), and net mitigation (NM) under market and social value prices for $MgCO_2e$.



Nitrogen Mitigation

Quantifying nitrogen service flows

Nitrogen is a major nutrient in agricultural runoff linked to water quality degradation in general (Carpenter et al. 1998) and, specifically, its increase in loading to the Mississippi River is considered a principal cause of the hypoxic "dead zone" in the Gulf of Mexico (Goolsby and Battaglin 2001). There are two principal ways in which wetlands restoration mitigates environmental damage from nitrogen releases: (1) forgone nitrogen (N) losses associated with runoff from crop cultivation and (2) removal of nitrate (NO_3) via denitrification.

When land is enrolled in a WRP easement, it is by definition taken out of agricultural production and thus the N losses driven by fertilizer application, fixation, and tilling cease. Because nitrate is the species of N most clearly correlated with the hypoxic zone size in the Gulf of Mexico, we focus on nitrate loading in our analysis (Mississippi River/Gulf of Mexico Water Nutrient Task Force 2007). We compute the nitrate prevented from entering the local waterways by applying average annual values for nitrate lost in surface water runoff, in lateral subsurface flow, and in leachate (N kg/ha/yr) from agricultural sites using output from the EPIC model (Potter et al. 2006b). These EPIC model estimates are available by U.S. region and by primary crop type within each region (Potter et al. 2006a). Knowing the counties in which the paired WRP and reference agricultural sites are located in the MAV but not their exact location due to privacy restrictions, we create representative crop sites for the MAV portion of each state with USDA data that details the crop mix for those counties (USDA-NASS). The nitrogen loss estimates for each crop type are combined with the crop type proportions to produce total nitrogen loss for a representative agricultural hectare in the MAV in that state. See Table 3 for an example calculation for Arkansas. Total nitrate ground- and surface-water losses for the MAV counties in Arkansas, Louisiana, and Mississippi are 41.3, 29.3, and 32.3 kg/ha/yr, respectively. Computed using the relative total hectares planted in crops in the MAV counties for each state, the weighted average of agriculture-related N loss for the MAV is 37.0 kg/ha/yr.

Table 3. Estimated nitrate loss by crop type from a representative agricultural hectare in the MAV in Arkansas.

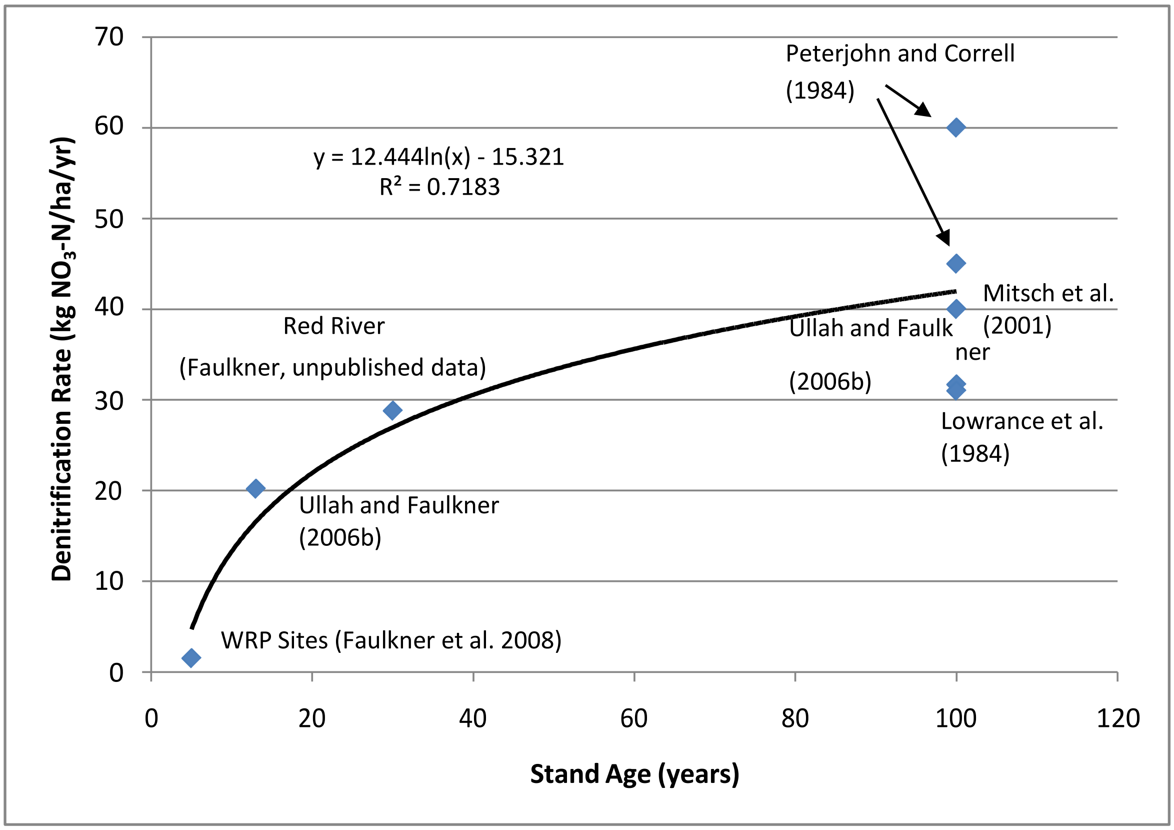
Crop Type	Estimated NO_3 Loss	Crop Type	Crop Contribution
	kg/ha	Proportion	kg/ha
Corn	24.9	0.031	0.8
Cotton	29.4	0.1	2.9
Rice	69.9	0.32	22.4
Sorghum	13.1	0.005	0.1
Soy	29.0	0.516	15.0
Winter Wheat	5.7	0.028	0.2
		Total	**41.3**

The second mitigation pathway is the removal of nitrate (NO_3) through the denitrification process, which is the primary N loss process in freshwater wetland ecosystems (Faulkner and Richardson 1989; Mitsch et al. 2001). The complex interactions of hydrology, soil type, nutrient loadings, and landscape position create the variability in specific ecosystem processes found in natural wetlands (even within a wetland type) and there is a wide range in reported nutrient retention rates due to differences in specific processes controlling those rates (Faulkner and Richardson 1989; Reddy et al. 1999; Novak et al. 2004; Lowrance et al. 2006). Reported denitrification rates in natural forested wetlands range from <1 to >800 kg N ha^{-1} y^{-1} (Mitsch et al. 2001, Lowrance et al. 2006). In addition, there is evidence that restored forested wetlands have different rates that change as the system ages and develops ecosystem characteristics more similar to forests than croplands (Hunter and Faulkner 2001; Ullah and Faulkner 2006a). This variability makes it difficult to predict N retention rates for WRP sites through time. We estimated denitrification potential (kg NO_3/ha/yr) with the denitrification enzyme assay (DEA) using field soil samples from both cropland and WRP CEAP sites. This denitrification potential approximates the rate at which nitrate is removed by the site. The DEA is a widely used approach (Groffman and Tiedje 1989; Clement et al. 2002; Ullah and Faulkner 2006a). We also reviewed published denitrification rates and found several studies that were similar to the WRP and natural sites evaluated here (Peterjohn and Correll 1984; Lowrance et al. 1984; Mitsch et al. 2001; Ullah and Faulkner 2006a, 2006b).

In order to capture the future denitrification potential of the restored wetlands, we modeled the relationship between the ages of forested wetland stands and the denitrification rates using the CEAP

WRP data; unpublished data from sites at Red River, Louisiana; and six point estimates from the literature. As can be seen in Figure 6, a log function fits the data well with a R^2 value of 0.7183. We use this curve to represent the age-dependent trajectory of denitrification through the 90-year study period at sites with a low landscape position. Since none of the published denitrification rates distinguish between low- and high-elevation sites in forested wetlands, we used experimental data which indicates that high-elevation sites display denitrification rates that are about 10% of those of low-elevation sites—low 28.8 kg N/ha/yr vs. high 2.88 kg N/ha/yr (Faulkner, unpublished data). Therefore, we assume that denitrification rates at high-elevation sites have the same trajectory as those at low-elevation sites, but with one-tenth of the value. Applying our assumption that 80% of the area of the WRP sites is low-elevation and 20% is high-elevation, we add together the proportional contribution of each site type to yield the combined N mitigated each year via the denitrification process.

Figure 6. Log function between measured denitrification rate and stand age of forested wetlands.



Nitrogen losses from agricultural land are a nitrogen source to the waterway, i.e., they have a negative mitigation value, while denitrification is considered a nitrogen sink, keeping N from entering the waterway and generating a positive mitigation benefit. Since restoring a wetland on cropland precludes additional agriculture-related N losses, those forgone losses are then seen as a positive mitigation value. We assume that forgone N losses from crop production remain constant through the study period so that annual N mitigated equals the forgone N losses (37.0 kg N/ha/yr) plus the current level of denitrification. Because the agricultural site functions as the baseline, the nitrogen eliminated through denitrification there must be netted out to arrive at the N mitigated due to WRP wetlands restoration. It is assumed that the denitrification rate on cropland does not "mature" through time and so the constant mean value for the 16 CEAP agricultural sites, 1.69 kg N/ha/yr, is subtracted annually.

Figure 7. Nitrogen (N) flux accounting for MAV counties over the 90-year study period. DP is denitrification potential, WRP is the WRP sites, and Ag is the agricultural sites. Low is low elevation, High is high elevation, and Wtd Avg is 80% low, 20% high.

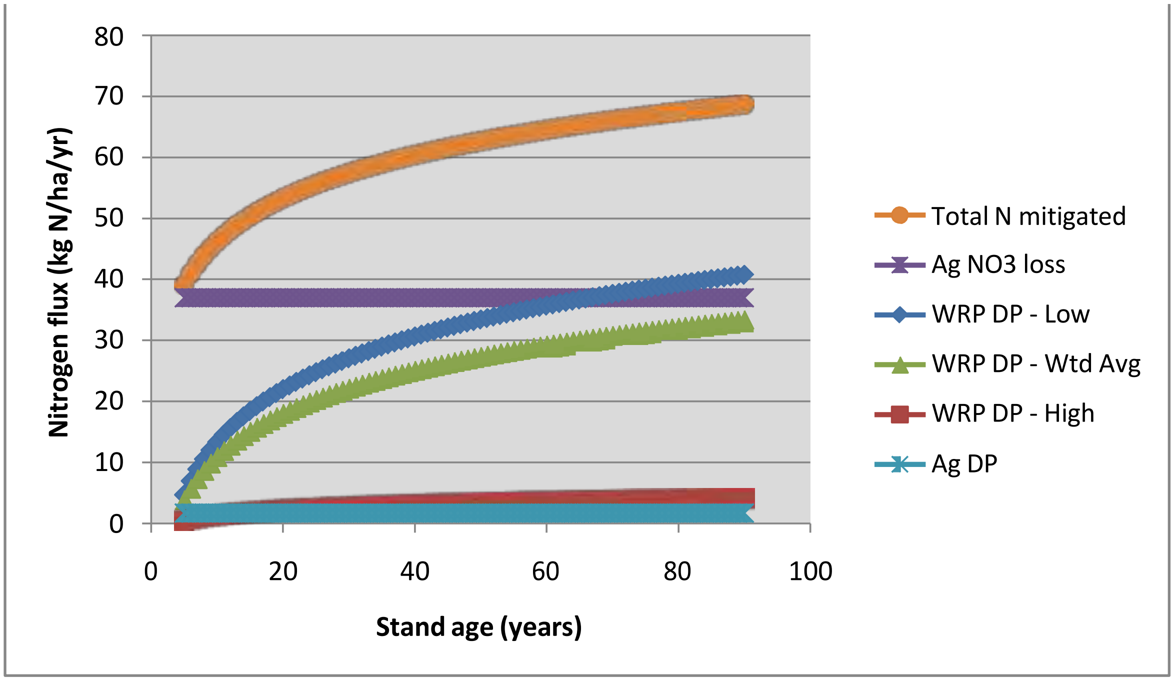


Figure 7 depicts the curves of denitrification rates for WRP low, high, weighted average, as well as for agriculture sites; the N losses associated with crop production; and the total N mitigated. Total N abatement is dominated by the cropland N loss pathway in the years immediately after a wetland restoration takes place. As the wetland grows, the contribution of denitrification to total N mitigated rises from 10% at year 5 to nearly 49% by year 90. Total N mitigated increases from about 37 kg N/ha/yr in the early years to almost 69 kg N/ha/yr by the end of the study period.

Monetizing nitrogen mitigation

Nitrogen mitigation is monetized using a price estimated for the Delta region (Arkansas, Louisiana, and Mississippi) of the U.S. South in Ribaudo et al. (2005). That study's results are selected for the benefit transfer because it is one of the few studies in the literature that produces a marginal price for nitrogen mitigation; moreover, its estimates are also specific to the MAV study area. Note that its values are only for the wastewater treatment industry.

Ribaudo et al. (2005) employ the U.S. Agricultural Sector Mathematical Programming (USMP) model to explore the potential for nitrogen credit trading in the entire Mississippi Basin by modeling the interaction between agricultural nonpoint sources and wastewater treatment plant point sources mandated to reduce nitrogen emissions. In the model, farmers are able to furnish nitrogen reduction credits via the following four methods: changing fertilizer application rates, changing production practices, growing different crops, or retiring cropland. Restoring wetlands is not included as a mitigation option because, in an earlier paper, Ribaudo et al. (2001) demonstrate that wetlands restoration is generally more expensive than fertilizer management and therefore a less attractive alternative for farmers. However, the cost of the alternative approaches does capture the avoided costs of achieving the given level of water quality improvements in another way when wetlands restoration is undertaken in the region, and thus provides a workable marginal value for wetland N mitigation outcomes.[3]

Table 4. Annualized value of N mitigation service and range of values depending on costs of marginal N credits in Ribaudo et al. (2005) (all values are in 2008 US$).

	Cost of marginal N credit ($/kg N)	Net Present Value	Annualized value ($/ha/yr)
Study area	$25.27	$30,773.76	$1,268.12
Lower bound	$22.82	$27,790.15	$1,145.17
Upper bound	$106.09	$129,196.20	$5,323.89

The cost of the marginal trade for the Delta region is estimated at $10.50/lb N, a result which we transform to $25.27/kg N by converting it to price per kilogram and then by inflating the price to 2008 dollars using the CPI Inflation Calculator (BLS 2008).[4] For the dynamic model of nitrogen mitigation developed here, the monetization step follows the same process as applied to the GHG mitigation service. Each year the amount of total nitrogen abated is multiplied by $25.27/kg N. Next, the 90-year stream of N mitigation values are discounted back to the present using a 4% discount rate and then converted to an annualized value. The result is over $1,268/ha/yr. A range of values for N mitigation is derived by using the lowest and highest N credit prices among all sub-regions in the Mississippi Basin generated by Ribaudo et al. (2005). In Table 4, the costs of a marginal N credit range from $22.82 to $106.09 kg N and the interval of annualized values is between $1,145 and $5,324. The costs to mitigate nitrogen in the MAV are clearly at the low end of the range and may therefore represent a relatively conservative estimate for the valuation of nitrogen mitigation service.

Wildlife Habitat Service

Converting row crop fields to wetlands results in additional habitat for many taxa of wildlife, including anurans (i.e., frogs), black bear, and neotropical migratory birds. Although habitat benefits accrue to a variety of wildlife in the MAV, our analysis focuses on the benefits from the expansion of migratory waterfowl habitat by WRP. This is in large part due to the widely recognized recreational value derived from waterfowl, which has generated values in the economics literature, enabling benefit transfer

[3] We recognize that replacement cost is conceptually a less-preferred shadow price than a directly estimated WTP value for the service, but unfortunately there are no direct estimates of WTP to draw from. We do believe replacement cost is an empirically valid measure for the region because policies are attempting to take a suite of approaches to achieving certain water quality targets for the region (Mississippi River/Gulf of Mexico Water Nutrient Task Force 2007).

[4] As a comparison, the Nutrient Offset Program run by North Carolina's Ecosystem Enhancement Program uses $21.67/lb N for the Tar-Pamlico River Basin and $28.35/lb N in the Neuse Basin ($47.77/kg N and $62.50/kg N) for offset payments to mitigate nitrogen (http://www.nceep.net/services/stratplan/Nutrient_Offset_Program.htm).

(Duffield and Neher 1991; Gan and Luzar 1993). Alternatively, marginal increases in anuran species or in black bear habitat have not been previously monetized.

Quantifying waterfowl habitat service flows

Flooded bottomland forests provide necessary forage for waterfowl that overwinter in the Mississippi Alluvial Valley as well as for those who stop over in the MAV en route to other wintering grounds such as Mexico (LMVJV Waterfowl Working Group 2007). Other benefits include protection from winter weather and pair isolation habitat (Baldassarre and Bolen 2006). We concentrate on the food provision aspect of these WRP wetlands which is captured by the metric Duck Energy Days (DEDs). A DED represents the amount of daily energy required by a duck supplied by a unit area of foraging habitat for a day (Reinecke and Kaminski 2007). The DED value of 294.35 kcal reflects the "average duck" wintering in the MAV, thus taking into account daily energy requirements of all dabbling ducks, of which mallards are the most common, and also of wood ducks (LMVJV Waterfowl Working Group 2007). The difference between DEDs produced on restored wetlands and on cropland is equivalent to the additional waterfowl habitat provided by WRP.

To calculate the net gain in waterfowl habitat, we first draw on the results of James et al. (in review). For the MAV areas of Arkansas, Louisiana, Mississippi, James et al. calculate the DEDs on post-restoration WRP lands, on the pre-restoration cropland, and the net DED increase for the 110-day wintering period. These calculations are based on an analysis of the flooding frequency of WRP acreage and the DED values per hectare for pertinent land use classes for WRP land (e.g., 677 DED/ha for naturally flooded restored wetland) and cropland (e.g., 89 DED/ha for harvested flooded soybean fields). In Table 5, we report the DED averages for each state over the 2001–2005 time period. The post-restoration net increase in DEDs is then divided by the total DEDs estimated to be produced in the MAV on all public and private land (LMVJV Waterfowl Working Group 2007). The quotient is the gain in DEDs in the MAV due to WRP-driven wetlands restoration, averaging 9.19% across the three states.

Table 5. Waterfowl habitat impact of wetlands conversion in duck energy days (DEDs).

State	Hectares WRP, avg 2001-2005	WRP: Post-restoration DEDs	Baseline: Pre-restoration DEDs	Net DED Increase post-restoration	Total DEDs in MAV, avg 2001-2005	DED Increase due to WRP in MAV
Arkansas	48,158	18,449,659	1,241,126	17,208,533	226,379,794	8.23%
Louisiana	65,673	10,923,441	804,859	10,118,582	132,498,674	8.27%
Mississippi	49,231	14,177,318	993,564	13,183,754	122,512,518	12.06%
Total	**163,062**	**43,550,418**	**3,039,549**	**40,510,869**	**481,390,986**	**9.19%**

The final step in this quantification process involves linking gains in waterfowl habitat to changes in hunting behavior. Increases in waterfowl habitat generally mean augmented hunting opportunities. That is, more habitat implies potentially more waterfowl in the MAV and thus a greater population to hunt. One caveat is that these waterfowl populations are migratory and thus dependent on habitat in more than one region to thrive. In particular, the prairie pothole region in the north-central U.S. and south-central

Canada serve as the most important breeding ground for North American ducks, producing 50% to 80% of the continent's duck population (Batt et al. 1989). The MAV is part of a waterfowl network called the Mississippi Flyway, whose duck populations principally originate in the prairie pothole region. Waterfowl habitat gains in the MAV represent greater resource flow in the region and create a positive network externality, though these benefits may be potentially moderated or even offset by changes in other components of the habitat network. Without modeling the entire breeding and migration network of North American ducks, our results will have to serve as a reasonable first order estimate of the region's contribution to hunting opportunity.

Greater waterfowl population numbers can result in increased harvest rates for hunters (a quality effect) as well as induce more waterfowl hunting trips (a quantity effect). More habitat provided by private land in WRP easements could also furnish additional destinations for hunting trips and thus potentially more trips (a quantity effect). We endeavor to capture these effects through a quantity measure, duck hunter days afield. A direct relationship is assumed between the percentage of increased waterfowl habitat created via WRP and the percentage increase in duck hunter days. Ideally, gains in hunter days are computed by multiplying the average numbers of duck hunter days in the MAV counties of each state for the five seasons between 2001 and 2005 by the percentage of waterfowl MAV habitat increase in the corresponding state over that same time period. Since duck hunter days are not available at the sub-state level, we use five-year averages of U.S. Fish & Wildlife Service county-level data on duck harvests to find the share of state harvest occurring in the MAV counties of the three states. These shares are then multiplied by the average number of duck hunter days in each state (2001 to 2005 seasons) to yield the number of duck hunter days in the MAV for each state (USFWS 2003; USFWS 2004; USFWS 2006). It should be noted that those percentage changes in duck hunter days, although not trivial (between 8% and 12%), are still marginal and thus appropriate for our economic valuation approach.

Table 6. The calculation of increase total surplus per hectare due to increase in waterfowl habitat in the MAV due to the Wetlands Reserve Program (WRP).

State	Increase in habitat due to WRP	Waterfowl Hunter Days in MAV, avg 2001-2005	Increase in Waterfowl Hunter Days	Total increase in consumer surplus	Consumer surplus gained per ha	Producer surplus gained per ha	Total surplus per hectare
Arkansas	8.23%	415,185	34,157	$1,655,944	$34.39	$15.00	$49.39
Louisiana	8.27%	109,383	9,044	$438,452	$6.68	$15.00	$21.68
Mississippi	12.06%	86,196	10,394	$503,910	$10.24	$15.00	$25.24
Total/Avg	**9.19%**	**610,764**	**53,595**	**$2,598,307**	**$15.93**	**$15.00**	**$32.10**

Monetizing waterfowl service flows

To monetize the change in the ecosystem service of waterfowl habitat, we consult the recreation economics literature for an appropriate value of an additional day of waterfowl hunting to be used as the transferred shadow price. For the per-day value of waterfowl hunting, we take the results of a meta-analytical study on outdoor recreation values conducted for the U.S. Forest Service (Rosenberger and

Loomis 2001). The value estimated for the southeast region was $34.72 in 1996 dollars, which we update to $48.48 in 2008 dollars by using the CPI calculator (Bureau of Labor Statistics 2008). Therefore, the total increase in consumer surplus resulting from WRP is the estimated increase in waterfowl hunter days multiplied by $48.48. Consumer surplus gained per hectare of restored wetland is simply the total increase divided by the number of hectares in WRP easements in each state. These values range from about $7/ha/yr to $34/ha/yr, with an average of $16 across the three basins. Using $15/ha/yr as the average producer surplus obtained (discussed below), that value can be added to the consumer surplus gains to yield total annual surplus values of between about $22 and $49 per hectare, with a mean of $32 across the MAV.

Total Social Value of Ecosystem Services: Partial Estimate

Summing the results from the preceding three ecosystem services valuation applications attains a partial estimate for the total ecosystem value of wetlands restoration (see Table 7). Although they were not monetized in this analysis, it is assumed that floodwater storage, sediment retention, and other habitat services also possess positive economic values. Therefore, the total social value estimated here, which ranges from $1,446/ha/yr to $1,497/ha/yr, is necessarily a lower bound on the full social value of restoring wetlands.

Table 7. Social Welfare Benefit estimates of individual ecosystem (estimates in 2008 US$/ha/yr).

Ecosystem Service	Social Value ($/ha/yr)
GHG mitigation	$162–$213
Nitrogen mitigation	$1,268
Wildlife recreation	$16
Total	**$1,446–$1,497**

As we will discuss below, the social value estimate for wetlands restoration dwarfs the market value that exists with current markets, being almost 20 times greater. However, we will first examine how it is that not all of these social welfare values can be captured in markets for the private landowner.

Market Value

The estimates in the section above are measures of social welfare value and are thus appropriate to use for social benefit-cost analysis to gauge the performance of public programs such as WRP. However, the emergence of ecosystem service markets raises the question of whether private markets can play a role in incentivizing socially beneficial landowner behavior. Thus, we turn to an assessment of market value with the potential to be captured by landowners in the region.

GHG mitigation

Market value for GHG mitigation is realized through the existence of carbon markets for GHG mitigation, wherein landowners can be compensated for sequestering carbon or reducing emissions below a baseline as part of an offset program in a cap-and-trade system. In 2008, carbon credits were traded as an environmental commodity on the voluntary Chicago Climate Exchange (CCX) in the range of $1.00 and $7.40/tCO$_2$e. We use the midpoint of this range, $4.20/tCO$_2$e, for the low market price in the analysis. Because voluntary demand is generally less binding than a mandatory system, this price is relatively small. Prices on the European Union Emissions Trading Scheme (EU ETS), part of the Kyoto Protocol compliance driven market have been much higher, near $35/tCO$_2$e in the summer of 2008, but we do not use its values because the ETS does not allow forest carbon in its trading. Instead, we draw upon the analysis of the recently proposed Lieberman-Warner climate change bill (S. 2191), which calls for a federal cap-and-trade program covering the energy, transportation, and industrial sectors with mitigation from the forest sector usable as offset credits for the capped sectors. Various estimates of the Lieberman-Warner bill estimated a carbon price of about $20/tCO$_2$e to $30/tCO$_2$e. We use $30/tonne as the upper end of the market price range. In Table 8, annualized values per hectare for GHG mitigation are calculated to be about $59 for the low market price and over $419 for the high market price.

GHG offset payments in forestry and agriculture typically have to be modified to account for permanence, additionality, and leakage (Murray et al. 2007). Permanence reflects the fact that stored carbon could be re-released due, for instance, to harvesting the timber after some time. Seeing that the majority of WRP easements in our study area are permanent, we assume that the converted wetlands will not be harvested and thus we make no adjustment for impermanence. Additionality adjusts for the fact that some of the activity getting credited may have happened anyway without the payment. This is unlikely in the case of hardwood restoration in the MAV, as afforestation rates are extremely low there without any kind of government inducement. So no further adjustment is made. Leakage means that GHG sequestration services gained in one area are partially compensated by loss in another. This can happen when restoring cropland to wetlands in one place could cause land clearing for agriculture in another. Leakage rates have been estimated at 43% for forest carbon sequestration programs in the south-central region (Murray et al. 2004). Studying 12 states in the central U.S., Wu (2000) found that about 20 acres of non-cropland was converted to cropland for every 100 acres enrolled in the Conservation Reserve Program (CRP). Nevertheless, although ecosystem service values determined here may be offset by leakage elsewhere of the system, perhaps by as much as 20% to 40%, the direct estimation of that leakage effect is outside the scope of this study. Therefore, following the protocol used by the Chicago Climate Exchange for Afforestation Offset projects(Chicago Climate Exchange 2007)., we present the calculated GHG flux values (and all other ES values estimated here) without adjusting for leakage.

Nitrogen mitigation

Although there are more than 40 nutrient trading programs on the books in the U.S., very few trades have taken place to date (Ribaudo et al. 2008). As such, the market value under existing markets is essentially zero for N mitigation. Nevertheless, given the substantial interest in nutrient trading and the degraded condition of many of the nation's waterways, it is not implausible that N abatement will gain a market value in the near future. It should be noted that the potential market value of the nitrogen mitigation service equals only half of the social value because we assume that a nutrient trading scheme would require a trading ratio of at least 2:1. The most common ratio for trading between point and nonpoint sources is 2:1 (Morgan and Wolverton 2005). That is, two kilograms of nitrogen needs to be mitigated by farmers for every one kilogram of nitrogen credit generated. Ratios are used in order to reduce the uncertainty involved with nutrient mitigation by nonpoint sources such as farms. Therefore, we estimate an annualized potential market value of $634/ha/yr for nitrogen mitigation.

Waterfowl recreation

In addition to the consumer surplus accruing to regional waterfowl hunters, private landowners who enroll in WRP may also potentially garner some level of producer surplus. Since easements necessarily occur on private land, WRP participants can be seen as producers of the waterfowl habitat and could capture a portion of the created value through hunting leases. Recent studies in Mississippi find that hunting lease prices range from $4 to $8 per acre per season, or about $10 to $20 per hectare (Hussain et al. 2007; Rhyne and Munn 2007). Using the mean of these findings, the annual market value for waterfowl recreation is $15 per hectare.

Table 8. Benefit estimates of individual ecosystem services for market value, assuming current markets, or considering potential markets (estimates in $2008/ha/yr).

Ecosystem Service	Market Value – Current markets	Market Value – Potential markets
GHG mitigation	$59	$419
Nitrogen mitigation	$0	$634
Wildlife recreation	$15	$15
Total	**$74**	**$1,068**

Market value summary

Given current markets, market value yields about $74/ha/yr and pales in comparison to the estimated social value of over $1,400/ha/yr. However, the gap closes to a large degree when one considers potential markets for ecosystem services. At $1,068/ha/yr, the potential market value is about three-quarters of the social value and over 14 times the market value under existing markets. Nitrogen mitigation is clearly the driver for both of the larger values, comprising 59% of the potential market value and almost 90% of the social value.

COMPARISONS WITH COSTS OF WETLAND RESTORATION

To provide context for the above estimates of ecosystem service benefits, we examine the two types of costs related to their provision. The first is the private cost borne by the landowner, and the second is the social cost of implementing WRP shouldered by the federal government. We do not attempt to conduct a full cost-benefit analysis, which would imply a complete accounting of all costs and benefits of wetlands restoration. For ease of comparison with the estimated benefits, costs are converted to per-hectare units.

Landowner Perspective

From the perspective of the MAV landowner, the main opportunity cost of wetland restoration is the forgone income from agricultural use of the land. We can estimate this cost by considering either annual cash rents for agricultural land or the net returns from crop production. For the three Delta states, average cash rents per hectare range from $138 to $209, with a mean of $169 (USDA-NASS 2006). Looking at crop production in the region, returns vary substantially by crop type and by year over the period of 1997 to 2006. After subtracting operating costs from the value of production, rice emerges as the most profitable at an average of $391 per hectare, while wheat is the least at an average of $141 per hectare (USDA ERS). Using the representative agricultural hectare approach described in Nitrogen Mitigation Service subsection, we find that the annual return for a hectare of crop production in the MAV is $277.

Another relevant source of income for agricultural producers is government payment programs. The 2002 Farm Bill furnishes three types of payments to farmers, of which only the direct payment is provided annually and is independent of the crop cultivated (Ibendahl 2004). The provision of the countercyclical and loan deficiency payments hinges on national and county crop prices and is not guaranteed each year. Focusing on the Mississippi Delta, Parkhurst and Anderson (2004) calculate that the sums of the direct and maximum countercyclical payments per base acre are $17 for soybeans, $156 for rice, and $139 for cotton. The corresponding values per hectare are $42, $385, and $343. Ibendahl (2008) finds that for three Mississippi counties, expected government payments for cotton and soybeans average $133 and $25 per acre, respectively ($329 and $62 per hectare). Applying these values to the representative agricultural hectare approach, we obtain a conservative estimate of about $91 per hectare.

Using $277 as the value of a hectare for crop production and $91 as the annual government payment subsidy, their sum of $368 represents the estimated annual per-hectare income forgone by a private landowner who opts to enroll acreage in the WRP. If the landowner wished to undertake a wetlands restoration on his property without enrolling in a conservation program, one-time costs for afforestation projects in the MAV may run around $680 to $900 per hectare.[5] Assuming that those restoration costs are

[5] NRCS costs for restoring a forested wetland in Arkansas are approximately $275 per acre ($680 per hectare) (personal communication, Andrew James 2009). A private firm specializing in afforestation projects may charge around $350–$375/acre ($865–$926/hectare) for a carbon offsets package that includes the basic site preparation and tree planting, as well as "long-term carbon monitoring plan, with initial funding price inclusive of permanent monitoring plot establishment, soil carbon measurement and baseline report, 100-year carbon reporting table, and survival analysis during the third growing season," plus "guidance on offset registration and standards" (personal communication, Carol Jordan 2009).

paid up front, a present value analysis combining foregone agricultural income with the restoration costs over a 90-year horizon yields an annualized value of $400 to $411. Currently the annual market value that could be captured from existing carbon and hunting markets amounts to $74 per hectare, only about a fifth of the net returns from agricultural production. In contrast, the potential market value of GHG mitigation, nitrogen mitigation, and wildlife habitat provision with emerging ecosystem markets is $1,068—over two and a half times greater than the restoration opportunity costs. Without the payments provided by WRP, landowners will not have sufficient economic incentive to undertake wetlands restoration on their properties until markets for environmental services become more fully developed.

Taxpayer Perspective

The principal costs to taxpayers of restoring wetlands via the WRP are the easement payments to landowners and the cost share of the restoration. Easement payments provide compensation to the landowner for forgoing agriculture and are made as a lump sum in the first year of the WRP contract. Under a 30-year easement, the USDA pays for 75% of the restoration cost, whereas it covers 100% of the cost for a permanent easement (USDA-NRCS 2007). The publically available cost data for the WRP aggregates the annual costs for all three contract options at the state level for 2003 to 2007 (USDA-NRCSb). From this data, we can derive per-hectare costs incurred by the USDA for each state. The 5-year average across the three Delta states is $2,617 per hectare in 2008 dollars. Since the government no longer is obligated to provide agricultural payments when a farmer enrolls land in WRP, the annual subsidy estimated above ($91) should be subtracted from the WRP cost. We use the remainder of $2,526 per hectare as the one-time public expenditure or social cost of wetlands restoration in the MAV.

Again considering the values reported in Table 8, it would only take two years for the social benefits of wetlands restoration (~$1800/ha/yr) to surpass the costs incurred by the government in paying for the WRP. Furthermore, the estimated social benefits represent a lower bound on the total ecosystem value since several ecosystem services are not accounted for in the analysis. The ecosystem service value return on public investment appears to be very attractive in the case of the WRP.

BENEFIT AGGREGATION FOR MAV

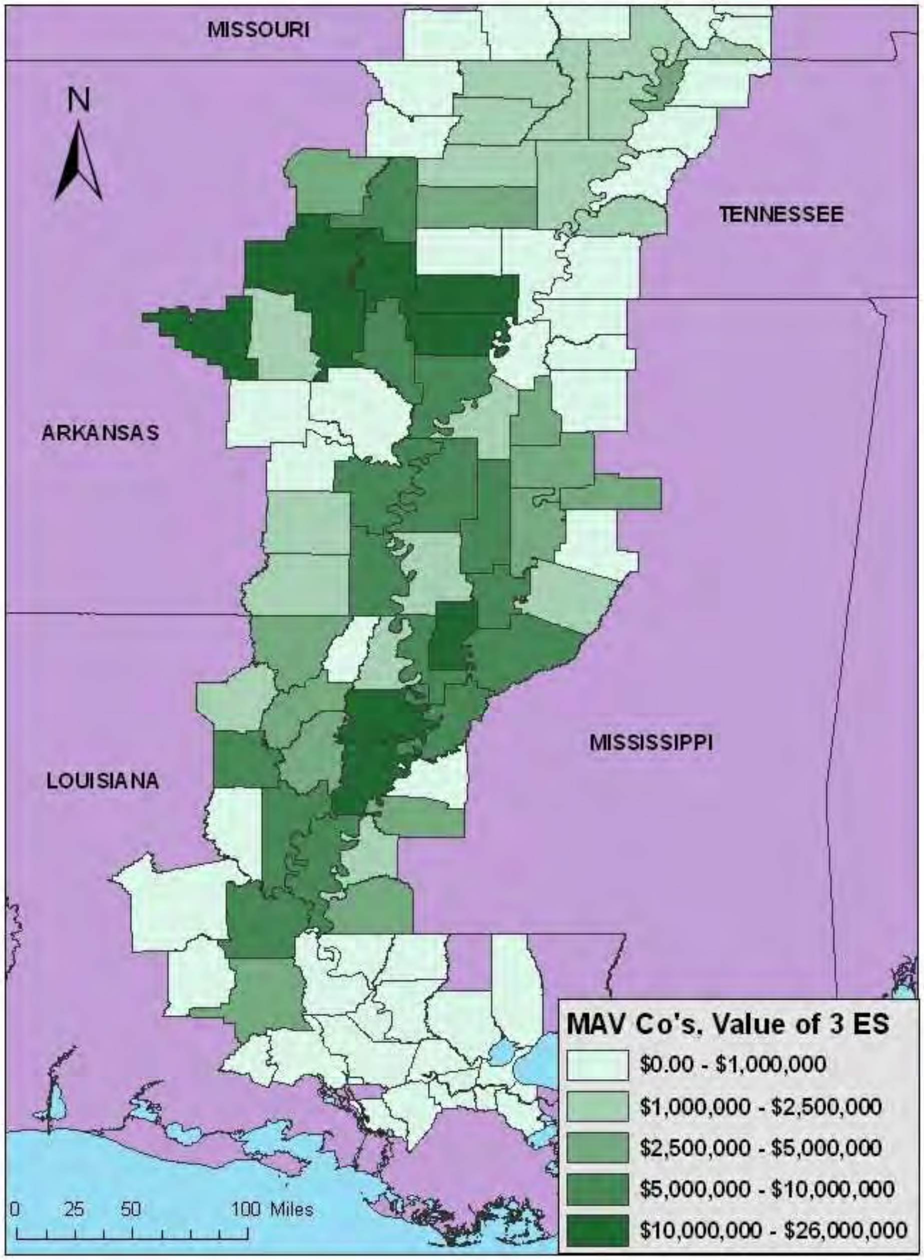
The measurement of aggregate benefits resulting from a program can be useful to policymakers by providing an estimate of the magnitude of program impacts. Using the per-hectare values for the three focal ecosystem services, we can scale them up to generate aggregate values for the study area, the three major river basins of the MAV. Examining the benefits associated with the land currently enrolled in WRP there, we observe that there are 226,522 hectares in WRP easements in the 104 counties in the MAV (as of 2005). With the assumption that the services are provided equally by each WRP hectare, we apply their social welfare values, which are \$213.40 per hectare for the GHG mitigation value (using \$15/tCO_2e), \$1268.12 for the nitrogen mitigation, and \$15.93 for waterfowl recreation. Multiplying these values by the number of WRP hectares located in each county, we calculate county-level estimates of the bundled values of the three services and then sum those to arrive at an aggregate value at the spatial scale of the MAV (see Table 9).

Table 9. Annual GHG mitigation, nitrogen mitigation, and waterfowl recreation values (2008 US\$) for WRP land combined at the MAV level.

	Extent (ha)	GHG mitigation	N mitigation	Waterfowl recreation	Aggregate value
WRP per hectare		\$213	\$1,268	\$16	\$1,497
All WRP land	226,522	\$48,339,795	\$287,257,079	\$3,608,495	\$339,205,369

The differential distributions of bundled ecosystem service values across the study area counties is reflected in Figure 8, a map displaying the value of the three ecosystem services on WRP land for each of the counties. Higher values are represented by progressively darker shades of green coloring the counties. Annual MAV-level benefits are approximately \$339 million, although 25 of the 104 counties supply almost 75% of the value.

Figure 8. Counties of the Mississippi Alluvial Valley (MAV) by annual aggregate social value of the three bundled ecosystem services generated on restored wetlands on WRP land.



CONCLUSIONS

As public goods, ecosystem services are underprovided because they are undervalued in the marketplace. Thus far, government programs such as WRP and CRP have sought to increase the flow of these services, and they have attained a certain level of success, as has been demonstrated by this analysis. However, with increasing public recognition of the importance of healthy ecosystems to human welfare also comes the potential for new economic opportunities in the form of private ecosystem markets. Policymakers and business entrepreneurs need good information on the economic value of ecosystem services to guide their programs and market development efforts. This paper addresses that need.

The Mississippi Alluvial Valley is a particularly rich ecosystem that has undergone massive change in the last 100 years. It has been a recent target of restoration efforts through WRP, CRP, and other programs. To examine ecosystem service values from WRP restoration in this region, we combined field data collection with secondary data collection and then linked these data with process models to calibrate expected change in those values. Unlike many other ecosystem service studies that have used top-down, landscape-level approaches, we implemented a bottom-up integration of ecosystem service function measurements, environmental modeling, and economic valuation.

Focusing on three services—GHG mitigation, nitrogen mitigation, and waterfowl habitat—we estimated a lower bound for the economic value to society of restoring wetlands in the MAV. With advances in methodologies and markets, that value will likely grow as currently unmonetized services, such as floodwater storage, gain their own price tags. Considering the lower bound estimate, this study's findings suggest that restoring wetlands in MAV has a total economic value to society well above the alternative use in agriculture. The largest benefits are found to flow from nitrogen mitigation, followed by GHG mitigation. Nevertheless, absent expanded public programs or new ecosystem service markets to deliver payments, landowners are being economically rational by keeping most of this land in agriculture, which currently has a higher market return. As a result, some mix of expanded payments from the public or private sector would appear to be warranted to incentivize continued wetlands restoration at a net benefit to society.

From the taxpayer perspective, the social benefits easily outstrip the social costs of restoring wetlands via WRP, as the public investment pays for itself in enhanced ecosystem services in only two years. Again, these benefit estimates do not include other services that do not presently have a clear monetary value, but may in the future. Given the considerable "surplus" in conservation effects generated by WRP payments, there could be substantial opportunity for mitigation markets in the region to supplement, or possibly even replace, conservation program payments.

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Ecosystem Service Analysis of the Yazoo Pumps Project

For submission to the EPA

in Support of a Veto on the proposed Yazoo Pumps Project

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Executive Summary

Earth Economics strongly supports an EPA veto of the Yazoo Pumps project. Army Corps analysis of the project is deeply flawed omitting entirely the loss of critical ecosystem functions and services. The Yazoo Pumps project will have a vast and long term impact on wetlands in the Yazoo Backwater area.

There is a great deal of uncertainty and debate concerning the actual area of wetlands to be impacted by this project. This analysis takes the most conservative Army Corps figures for complete draining of 26,300 acres of wetlands, 18,000 of which are forested wetlands, the rest area assumed to be herbaceous or shrub wetlands. With an additional 40,700 acres of wetlands being negatively impacted.

This report supports the consensus in the economic discipline that natural systems, including wetlands, are economic assets. They provide highly valuable economic goods and services including flood protection, drinking water provision, fisheries production, recreation and habitat among others. For some of these goods and services, dollar values can be established.

Using a benefit transfer methodology and the Army Corps' estimate of the wetlands impacted at 65,000 acres, Earth Economics estimated the range in value for 7 of 23 identified economically valuable ecosystem services between $22-90 million/year in this area with a net present value between $462 million and $1.9 billion dollars at a 5% discount rate.

This net present value is analogous to a capital asset value for the 65,000 acres impacted. These figures are large because the value of services the public receives as public goods and services is large. The public receives benefits from these vital natural assets, yet pays very little or nothing for their "capital construction" costs and maintenance. This means that these natural assets are more valuable because they do not require the costs associated with built capital.

By using the lowest and highest values in the academic peer reviewed literature this analysis compensates for inherent uncertainty. Though these figures are certainly underestimates of the true value of ecosystem services provided by this area, they are robust and far better estimates than the assumption of zero value, which the Army Corps has made in their economic analysis.

Ecosystems and particularly forested wetlands are economic assets providing a suite of 23 highly valuable ecosystem goods and services. Although rendered for free, these ecological goods and services are valuable. The Yazoo Backwater Area provides flood protection, natural storm mitigation, nutrient flows, biodiversity, wildlife habitat, fisheries, aesthetic value, and other public goods and services. Many of these services traverse large areas and a far larger population of US citizens than this project would benefit. For example, over 3 million people living downstream will be negatively impacted by the loss of water quality, natural water conveyance and backwater functions of the Yazoo area. Millions of Americans that enjoy the migratory wildlife passing through Yazoo along the Mississippi flyway will experience a reduction in wildlife viewing, harvest and enjoyment. Most of these highly valuable services are public services which are non-excludable, benefiting everyone. The Army Corps of Engineers has failed to account for any of these important values in their analysis. The Corps has basically counted the ecological services of this area as having zero value. This project is painfully similar to the Army Corps' failure to include the storm protection benefits of wetlands at the mouth of the Mississippi River.

Large infrastructure decisions which involve water or other ecosystem goods and services should be informed by the best available understanding and analysis of the relationships between watershed ecosystem health and the provision and value of watershed goods (like water) and services (including wildlife habitat, flood protection, water filtration, waste assimilation and other services).

Although rendered for free in terms of market price, these services have high economic value. The majority of economic value, or special benefits, provided by ecosystem services are produced as economically non-excludable services for landowners as well as members of the general public. This report estimates the economic value of forested wetlands in the Yazoo Backwater area. This case is made using ecosystem service valuation, the best available scientific method for quantitative analysis of the relationships between ecosystem health and economic benefit.

Earth Economics utilized the best economic methods currently available for estimating the value of ecological goods and services produced by Yazoo Backwater Area. We adopted a 65,000 acre figure using a benefit transfer methodology. This methodology is based on peer reviewed academic journal articles in order to estimate the high and low dollar value range of a list of 23 ecosystem services produced within the acreage of each vegetation type. These values were then summed for an initial rough-cut total valuation of ecosystem goods and services provided annually by each area. These values were then modified according to the particular area of Yazoo Backwater Area being examined. To get a sense of the asset value, the present value (PV) was then calculated to demonstrate the annual flow of ecosystem benefits.

Introduction

This economic analysis aims to demonstrate costs not included in the Army Corps analysis with a valuation of the ecological goods and services generated within Yazoo Backwater Area .

This study uses a natural capital approach to policy and asset management, identifying and estimating the value of those goods and services produced by natural capital. These ecosystem service valuations build off recent studies conducted by David Batker and others at Earth Economics in support of salmon habitat restoration for the Water Resource Inventory Area 9 (WRIA 9) Steering Committee and the King County Department of Natural Resources (Batker et al, 2005) and also for the Seattle Public Utilities Tolt River Watershed Asset Management Plan (Batker, 2005) as well as a General Technical Report for the United States Department of Agriculture, Forest Service Pacific Northwest Research Station (Batker, 2006).

While ecosystem and resource management decisions typically focus on "built capital" and financial assets, they are critically dependent on "natural capital" for provision of water, drainage, electricity, flood protection, and other benefits. Watersheds and other ecosystems are capable of providing a full range of 23 identified categories of ecological goods and services. An understanding of the relationships between watershed ecosystem health and the provision and value of these goods and services can better inform public investment decisions.

The next section describes the key concepts for including natural capital.

1. <u>Key Concepts</u>

The scientific field of Economics has advanced significantly in recent years in ways that improve our ability to quantify the value and impacts of resource management strategies. A great deal of research since 1985 has focused on developing and refining methods, tools, and techniques for measuring the value produced by natural systems. These include new concepts such as "natural capital" and new techniques including ecosystem service valuation.

1.1. Natural Capital and Asset Management

Ecosystems and natural resources, or natural capital, have previously been viewed as virtually limitless compared to human-built capital. In the past, they were considered as "free" and therefore of no value. Given the increasing scarcity of healthy ecosystems, the valuation of natural capital helps decision makers identify costs and benefits, evaluate alternatives, and make effective and efficient management decisions. Excluding natural capital in asset management can result in significant losses, increased costs, and decreases in efficiency and community benefit.

1.1.1. Understanding Natural Capital

Natural capital is comprised of geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continual return of valuable benefits (Daly and Farley, 2004). It contributes to our economy and quality of life in many ways that are not currently included in policy considerations. This includes provision of water, natural water filtration, energy production, flood control, recreation, natural storm water management, biodiversity, and education. Consideration of the Yazoo Backwater Area and other ecosystems as natural capital helps provide a more complete view of ecosystem health and the production of valuable benefits.

1.1.2. Economics of Natural Capital

Healthy ecosystems are self-maintaining, they have the potential to provide an ongoing output of valuable goods and services in perpetuity and to appreciate in value over time. In contrast, built structures and other man-made capital have a tendency to depreciate in value over time and require significant financial inputs for operations and maintenance. Without incorporating the ecological and economic value of natural capital affected by the Yazoo Pumps project the proposal cannot provide a clear understanding of the full costs and benefits. This is the case, thus the Yazoo Pumps project economic analysis provided by the Army Corps is catastrophically flawed. Investment of public funds in infrastructure projects must include the full impact on natural capital.

Public and private landowners have a unique opportunity to understand the full economic importance of ecosystems in services. Public agencies like the Department of Interior have put substantial investments into acquiring and improving natural assets in the Yazoo Backwater area. This project threatens to unravel these important public investments.

Natural systems are both ecological and economic assets. The provision and filtration of water is a good example. The city of New York accepted in 1997 the importance of ecosystem service valuation when considering long term supply options for a city that demanded a daily supply of more than one billion gallons of water. Facing degraded drinking water quality, New York City weighed the options of building a water filtration plant costing over $7 billion or of investing $1.5 billion to restore the health of the watershed and allow natural processes to filter the water and meet drinking water standards. The City decided to invest in watershed restoration that had a far higher rate of return, a less costly and less risky method for meeting standards.

Ecosystems in the Yazoo Backwater Area can be managed in a way that optimizes the aggregate value of goods and services with potential to benefit current and future generations. This is only possible if large infrastructure proposals thoroughly include analysis of the ecological and economic benefits of affected areas.

1.2. Ecosystems and Value Production

Ecosystems comprise of individual structural components (trees, forests, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, etc.) that generate ecological goods and services (salmon, timber, flood protection, recreation, etc.). **Figure 1** below summarizes these relationships in a simplified diagram. Ecosystem infrastructure has particular physical components within given boundaries of the ecosystem. The infrastructure itself is dynamic, as biotic structures migrate and abiotic components flow through the watershed, often via air or water. These functions vary widely in spatial boundaries (oxygen migrates globally, spawning habitat is locally confined). Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production). These structures, processes, and functions combine to produce economically valuable goods and services.

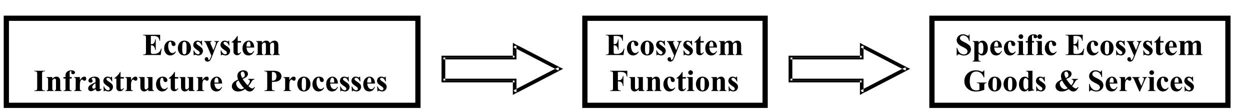

Figure 1. Relationship of Ecosystems to the Goods and Services Produced

Ecosystem service valuation assigns a dollar value on goods and services provided by a given ecosystem. This allows for proposed management policies to be considered in terms of their ability to improve ecological processes that produce the full diversity of valuable ecosystem goods and services. Often these ecosystem services are lost or gained as a full basket. As 2,000 square miles of wetlands in the Mississippi Delta have been lost, largely due to the Army Corps of Engineers levying of the Mississippi River, hurricane protection, water quality, wildlife habitat, recreation opportunities have all been lost. The retreat of the coastline now threatens the very inhabitability of the coast and major cities such as New Orleans. Restoring these ecological processes within a natural range of variability maintains structure and the ecological goods and services that follow. Further study will show the value of ecological goods and services contributed by all restoration sites, thereby showing the low estimate of the cumulative value brought in by these restorations sites to present and future generations.

1.2.1. Ecosystem Goods

Ecosystems provide a variety of useful goods like water, timber, and fish. Most goods are excludable; if one individual owns or uses a particular good, that individual can exclude others from owning or using the same, i.e., if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets. The production of goods can be measured by the physical quantity produced by an ecosystem over time, such as, the volume of water production per second, the board feet of timber production in a 40-year rotation, or the weight of fish harvested each year. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. This production creates a flow of ecosystem goods over time.

1.2.2. Ecosystem Services

Ecological services are defined as “the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life” (Daily et al., 1997). Ecosystems provide a variety of services that individuals and communities use and rely upon, not only for their quality of life, but also for economic production (Daily, 1997; Costanza et al., 1997). Ecosystem services are measurable benefits that people receive from ecosystems. Ecosystems produce goods and services as a result of ecosystem process, function, and structure.

The stream of services provided by an ecosystem is referred to as a “service flux.” A flow of goods can be measured in quantitative productivity over time while a service flux is generally more difficult to measure and value. Ecosystem services are in many cases non-excludable services. A healthy watershed provides aesthetic value to anyone who looks at it as well as the benefit of flood protection to all people downstream. As a result of this non-excludability, most ecosystem services are not sold in markets. Table 1 shows a list of ecosystem services.

Table 1. Examples of Ecosystem Services (from Dailly et. al., 1997)

Purification of the air and water
Mitigation of floods and droughts
Recreation
Detoxification and decomposition of wastes
Generation and renewal of soil and soil fertility
Pollination of crops and natural vegetation
Control of the vast majority of potential agricultural pests
Dispersal of seeds and translocation of nutrients
Maintenance of biodiversity
Protection from the sun’s harmful ultraviolet rays
Partial stabilization of climate
Moderation of temperature extremes and the force of wind and waves
Support of diverse human cultures

Provision of aesthetic beauty

1.2.3. The Value of Ecosystem Services Relative to Ecosystem Goods

While the value of a service flux may be more difficult to measure, its value may, in many cases, significantly exceed the value of the flow of goods. A study of Philippine mangroves showed that the services of storm protection and nursery functions (85% of commercial fish species are dependent on the mangroves for a period of time within their lifecycle) produced several times the value of shrimp aquaculture operations that replaced the mangrove ecosystems (Boumans et al., 2004).

1.2.4. Process, Function, Structure and Value Production

The quality, quantity, reliability, and combination of goods and services provided by the ecosystems within a watershed depend highly on the structure and health of the ecosystems within the watershed. Structure refers to a specific arrangement of ecosystem components. The importance of ecosystem structure can be understood by using the car as a metaphor. The steel, glass, plastic, and gasoline that comprise a car must retain a very particular structure to provide transportation service. Having a pile of the same constituent materials but absent a car's structure, this "car" cannot provide transportation service. Salmon require certain processes, structures, and conditions. Ecological service production is more dependent on structure than the flows of goods. A single species timber plantation may yield a flow of goods (timber) but it cannot provide the same service fluxes (biodiversity, recreation, and flood protection) as an intact natural forest.

1.2.5. Integrated Ecosystems

A heart or lungs cannot function outside the body. Neither can the human body cannot function without a heart and lungs. Good health requires organs to work as part of a coordinated system. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts. Each of the physical and biological components of the watershed, if they existed separately, would not be capable of generating the same goods and services provided by the processes and functions of an intact watershed system (EPA, 2004). Ecosystem services are systems of enormous complexity. Individual services influence and interact with each other, often in nonlinear ways (Limburg et al., 2002).

1.2.6. Value Production "In Perpetuity"

Healthy intact ecosystems are self-organizing (require no maintenance) and do not depreciate. They can provide valuable ecological goods and services on an ongoing basis "in perpetuity" and without cost to humans. A forest provides water control, flood protection, aesthetic and recreational values, slope stability, biodiversity and other services without maintenance costs. This differs from human-produced goods and services (cars, houses, energy, telecommunications, etc.) that require maintenance expenditures, dissipate, may depreciate, and usually end up discarded, requiring further energy inputs for disposal or recycling. Destruction of ecosystem functions disrupts an ongoing flux of valuable ecological services. Filling flood plains increases flooding. When an ecosystem's free natural flood prevention functions are destroyed, flood damage will exact continuing costs on individuals and communities who must either suffer flood damage or pay for engineering structures and storm water infrastructure to compensate for the loss. Without healthy ecosystems, taxpayers, businesses and governments incur damage or costs to repair or replace these ecosystem services. When ecological services are restored, the reverse dynamic can occur.

In the case of the Yazoo Pump project, natural capital, and self-maintaining natural water conveyance is being replaced with a highly capital intensive system that will require on-going maintenance and will eventually have to be rebuilt, requiring capital asset investments in the future. This locks taxpayers into an ongoing expense and threat to wildlife which is simply unnecessary.

2. Ecosystems Services Valuation Analysis Overview

The methodology for valuing ecosystem services involves the identification and categorization of ecological services, identification of the area and vegetation type of the affected lands and peer-reviewed studies of market and non-market values using direct use and indirect use valuation methods. Economic valuation data from peer reviewed academic journal articles were aggregated using a value transfer methodology to estimate a high and low dollar value range for a list of 23 ecosystem services (water purification, flood control, climate regulation, etc.). Economic modeling was used to integrate data on the health, age, and species diversity of the ecosystems on the study site. Initial analysis resulted in a rough-cut total valuation of ecosystem goods and services provided annually by each area. Long-term economic value was also calculated by calculating a 5% present value of the annual flow of ecosystem benefits. This is analogous to a natural capital asset value which can be used within an Army Corps economic framework to include the cost of lost natural assets. The next sections discuss the analysis process in more detail.

2.1. Ecosystem Service Categorization

De Groot et al. (2002) categorized 23 ecosystem processes and functions of ecosystem services (see Table S) based on a review and synthesis of the valuation literature on ecological services. These are grouped into four function categories: 1) regulation, 2) habitat, 3) production, and 4) information. Regulation and habitat functions are considered essential functions that are necessary before production and information functions can be active (De Groot et al., 2002). Table 2 provides a list of 23 ecosystem services, their functions, infrastructure and processes with examples.

Table 2. Ecosystem Functions, Processes, and Services (from De Groot et. al., 2002)

Functions		Infrastructure and Processes	Examples of Good and Service
Regulation Functions		*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles	Provides clean breathable air, disease prevention, and a habitable planet
2	Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favorable climate, promotes human health, crop productivity, recreation, and other services
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	Prevents and mitigates natural hazards and natural events generally associated with storms and other severe weather
4	Water regulation	Role of landcover in regulating runoff and river discharge	Provides natural irrigation, drainage, channel flow regulation, and navigable transportation
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers and snowpack)	Provision of water for consumptive use; includes both quality and quantity
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	Maintains arable land and prevents damage from erosion, and promotes agricultural productivity
7	Soil formation	Weathering of rock, accumulation of organic matter	Promotes agricultural productivity, and the integrity of natural ecosystems

8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients	Promotes health and productive soils, and gas, climate, and water regulations
9	Waste treatment	Role of vegetation and biota in the removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification, Filtering of dust particles through canopy services
10	Pollination	Role of biota in the movement of floral gametes	Pollination of wild plant species and harvested crops
11	Biological control	Population control through trophic-dynamic relations	Provides pest and disease control, reduces crop damage
Habitat Functions		*Providing habitat (suitable living space) for wild plant and animal species*	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity (thus the basis for most other functions)
13	Nursery function	Suitable reproduction habitat	Maintenance of commercially harvested species
Production Functions		*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	Hunting, gathering (fish, game, fruits, etc.) small scale subsistence farming, and aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing, fuel and energy, fodder and fertilizer
16	Genetic resources	Genetic material and evolution in wild plants and animals	Improve crop resistance to pathogens and pests
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs, pharmaceuticals, chemical models, tools, test and essay organisms
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs
Information Functions		*Providing opportunities for cognitive development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc., use of nature for scientific research

2.2. Value Transfer in Economic Valuation

The methodology of value transfer was used to conduct this economic valuation. Conducting original studies for every ecological service on every site for every vegetation type is cost and time prohibitive; researchers developed a technique called benefit or value transfer which is a widely accepted economic methodology wherein the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in other comparable locations.

This valuation is akin to a house appraisal where an appraiser considers the valuations (sales) of houses in different locations, the similar and different attributes, and specific aspects of the house and property being appraised. The number of bedrooms, condition of the roof, unfinished basement, and view are additive values for estimating the full value of the house. These additive values provide different services and contribute to the total value of a house.

The Gund Institute for Ecological Economics (GIEE), the leading national ecological economics institution, has compiled a database of published, peer-reviewed ecological service valuation studies. The database provides value transfer estimates based on land cover types and is updated as new literature becomes available. In addition, Earth Economics has recently completed a review of valuation studies in the Mississippi Delta including values for hardwood wetland forests very similar to those found in the Yazoo Backwater area.

The value of the ecosystem services described above is additive. An acre of forestland provides water regulation and filtration services and aesthetic, flood protection, and refugium benefits. One study may establish the value per acre of a watershed in water filtration for a drinking water supply. Another study may examine the value per acre of refugium for wildlife. To determine the full per acre value provided by a vegetation type, ecosystem service values are summed up and multiplied by the acreage.

The valuation techniques utilized to derive the values in the database were developed primarily within environmental and natural resource economics. As Table 3 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing, and contingent valuation.

- ***Direct use value*** involves interaction with the ecosystem itself rather than via the services it provides. It may be consumptive use such as the harvesting of trees or fish, or it may be non-consumptive such as hiking, bird watching, or educational activities.

- ***Indirect use value*** is derived from services provided by the ecosystem when direct values are not available. This may include the removal of nutrients, providing cleaner water downstream (water filtration), or the prevention of downstream flooding. Studies may derive values from associated market prices such as property values or travel costs. Values can also be derived from substitute costs like the cost of building a water filtration plant when natural ecosystem filtration services are disturbed and fail. Contingent valuation is an additional method that entails asking individuals or groups what they are willing to pay for a good or service.

Table 3. Methods for Primary Research in Ecosystem Service Valuation

Direct Use Values	
Market Price	Prices set in the marketplace appropriately reflect the value to the "marginal buyer." The price of a good tells us how much society would gain (or lose) if a little more (or less) of the good were made available.
Indirect Use Values	
Avoided Cost	Value of costs avoided by ecosystem services that would have been incurred in the absence of those services, e.g., flood control provided by barrier islands avoids property damages along the coast.
Replacement Cost	Cost of replacing ecosystem services with man-made systems, as when nutrient cycling waste treatment are replaced with costly treatment systems.
Factor Income	The enhancement of income by ecosystem service provision, e.g., water quality improvements increase commercial fisheries catch and incomes of fishermen.
Travel Cost	Cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service, e.g., recreation areas attract tourists whose value placed on that area must be at least what they were willing to pay to travel to it.
Hedonic Pricing	The reflection of service demand in the prices people will pay for associated goods, e.g., housing prices along the coastline tend to exceed the prices of inland homes.
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives, e.g., people would be willing to pay for increased preservation of beaches and shoreline.
Group Valuation	Discourse-based contingent valuation which is arrived at by bringing together a group of stakeholders to discuss values to depict society's willingness to pay.

2.2.1. Methodology for Comparison of Management Scenarios

Were time and resources permitting, the various project options could be compared with future scenarios. In such cases, this section would include individual ecosystem service valuation analysis for present state and/or management options with cost estimates for management changes in order to integrate valuation into full cost-benefit analysis. Time and resources did not allow this analysis to be conducted at this time.

2.2.2. Present Value Calculation and Discounting

The assessment and management of ecosystem service flows earned over generations is a difficult challenge. The stream of benefits can reflect current costs of capital or other financial opportunity costs but due to social discount rates, we tend to undervalue benefits that will be received in the future or by future generations. The discount rate assumes that the benefits we harvest in the present are worth more than the benefits that are provided for future generations, a view that those in the future may not share.

Discount rates that are used in public land management project appraisal can be based on a variety of rate sources including the prime rate of interest, the market rate of interest, and inferred social discount rate. Based on rates used for project appraisal by the Army Corps of Engineers, this report provides net present value (NPV) calculations with the three discount rates of 3.5%, 5%, and 7%. Since it is common for reduced discount rates to be applied to forestry projects, this also includes a zero discount rate analysis of long-term flows of ecosystem services.

The tendency of discounting for present value maximization encourage decision makers to select projects that pull short-term benefits into the present and push costs into the discounted future. Over the long-term, this increases the risk of amplifying intergenerational inequities. In economic terms, potentially unsustainable management practices will tend to liquidate renewable resources for short-term gain at much greater long-term expense or loss of value.

Economists solve this dilemma by defining a sustainable scale for the use of ecosystem services, one where basic ecosystem services within a watershed are kept intact. This ensures ecological sustainability where future generations are not left with an unviable set of ecological systems. The vast majority of value provided by a healthy ecosystem is held in the indefinite future. Today, we reap a thin annual slice of benefits from this continuous stream of the 23 categories of ecosystem goods and services.

Ecosystems are assets, a form of wealth. Many ecosystem services are necessary for our survival: oxygen production, waste decomposition, and storm protection. This asset of natural capital provides a stream of benefits that current and future generations require. This is unlike non-renewable resources, such as burning gasoline, or human-built capital like a new car. They burn up, are used up, or depreciate to eventually become waste, requiring further energy inputs for recycling. The primary benefits of non-renewable and human-built capital are held closer to the present. This is an important distinction between natural and human-built capital. In addition, value is not fixed in time; the values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al. 2002).

Healthy ecosystems are self-organizing, often not requiring maintenance. They do not depreciate, can provide goods and services potentially in perpetuity, and hold vast amounts of value in the distant future. As a result, it is important to illustrate the value of these ecosystem services by considering their value without discounting.

A calculation of value produced by Yazoo Backwater Area using a zero discount rate was used to provide a glimpse of how the people of [#Stakeholder, region] would see the stream of future ecosystem service benefits. Ecosystem services have, in fact, increased in value at an accelerating rate as they become increasingly scarce. This is expected to continue with current development projections in the area. Thus, the true value of these services may be much larger.

Critical Natural Capital

TheYazoo Backwater Area currently houses critical ecosystem processes and ecological services. These services cannot be transferred. A marginal increase in agricultural production, the primary benefit of this project can be provided in many areas in the State of Mississippi or within the United States. However, the unique ecological services, habitat, value for migrating wildlife, water quality and other benefits of the Yazoo wetlands cannot be marginally moved elsewhere in Mississippi or the US

The benefits of the Yazoo Backwater Area redound to the long-term interest of the public both local and national. The Yazoo Pumps project would result in ecological process changes that would degrade vast areas of wetlands and the ecological services they provide. This would likely result in a substantial loss of benefits and potentially substantial costs incurred by the public.

Study Limitations

This study provides a best-possible first estimate of the economic value of the ecological goods and services generated within Yazoo Backwater Area. The study, is based primarily on value transfer and not on original research of each ecosystem service within Yazoo Backwater Area, should be regarded as the best first estimate with the potential for improved accuracy from further research.

While a number of study limitations should be kept in mind when considering the results, these limitations do not detract from the fact that ecosystem services provide high value. EPA is better informed with fact-based estimates rather than an implicit assumption of zero value for the following reasons:

1. ***Limited ecosystem service studies.*** Although the field of ecosystem service valuation has expanded rapidly, regionally relevant studies are still extremely limited. The value of some ecosystem services has not been estimated. For example, the value to people of ecosystem processes the full wildlife benefits of Mississippi hardwood wetland forests have never been estimated. Where ecosystem services of value are identified and valuations have not been conducted, zero value is the default estimate. This contributes to values for both the low and high valuations that are underestimates. For this reason, the values calculated here should be considered underestimates.

2. ***Uncertainty and service identification.*** Some ecological services may not yet be identified. The dollar estimates of the value produced by natural systems are inherently underestimates. For example, while we may be able to place a dollar value on the water filtration services provided by a forest, we cannot fully capture the aesthetic pleasure that people gain from looking at the forest, nor every aspect of the forest's role in supporting the intricate web of life. Thus, most ecological service valuations serve as base markers somewhere below the minimum value of the true social, ecological, and economic value of an ecological service.

3. ***Lack of appropriate valuation studies.*** Medicinal, historic and spiritual values were identified within the area affected by the Yazoo Pump project, but eliminated from the study because existing studies were inappropriate for this area. However, assuming that Yazoo Backwater Area produces no value in these categories is incorrect and reduces its true value. Taxol, a breast cancer drug was discovered from the Northwest yew tree that occurs in all western Washington watersheds. No methodology on how to distribute this value to the ecosystem that produced it on a per acre basis has yet been developed. Historical values are site specific and resources were insufficient for a specific study of Yazoo Backwater Area. Similarly, there is no accepted method for monetizing cultural or spiritual value.

4. ***Static analysis.*** The values of goods and services, natural capital or otherwise, are dynamic. The current analysis provides a "snapshot" of value in Yazoo Backwater Area and for the project site. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al. 2002). This could give rise to a general tendency for value transfer based on studies performed over the past ten years to underestimate the value of ecological services produced by ecosystems today. Earth Economics is currently working under a National Science Foundation grant on a dynamic methodology for examining how changes in ecosystem processes change value over time.

5. ***GIS information.*** The GIS vegetation cover data used is coarse. For instance, it does not differentiate the quality of different wetlands. In other studies we have used the age of forest stands to provide an estimate of ecosystem health and services provided. A recently clear cut area will not yield the same flood protection, soil stabilization, or other services as an old growth forest. What is remarkable about the Yazoo area is the high quality of much of the habitat and the success of past restoration projects.

6. ***Process.*** Since this methodology is based on ecosystem services provided per acre of vegetation type, it does not pick up the full value of process changes. For example, the creation or occurrence of log-jams and barriers or restoring the natural processes of a watershed will have impacts beyond the project site because they are process changes. These are not captured in the geographical analysis of the site.

7. ***Irreversibility.*** Most economic modeling and analysis is a marginal analysis. Marginal analysis assumes a degree of reversibility that is not universally applicable to natural capital. Value changes

on the margins appear to be smooth, consistent, and continuous though this may not be the case in actual contexts.

8. ***Endangered species status.*** This report does not incorporate adequate analysis appropriate for consideration of endangered species as an element of critical natural capital. In particular, it overlooks any non-incremental impacts such as the potential for land management to contribute to a radical decline or even extinction in populations of endangered species.

3. Results of Ecosystem Service Valuation Analysis

3.1. Ecosystem Service Valuation of Yazoo Backwater Area

The ecological goods and services produced by each land cover type by Yazoo Backwater Area were estimated utilizing the methodological approach outlined in the previous section.

The total estimated value generated on the 65,000 acres of Yazoo Backwater Area in ecosystem services is estimated to be in the range of $22-90 million annually. The following sections and tables discuss this in more detail.

These estimates are based on the range of values for these land covers conducted outside Yazoo Backwater Area. As cursory estimates based on benefit transfer methodology they provide a ball-park range. A specific study or set of studies should be conducted to narrow the range in values.

3.1.1. Total Acreage of Yazoo Backwater Area by Landcover Class

Table 4 shows the acreages of GIS classification types that characterize Yazoo Backwater Area and were used for geo-spatial estimates for calculating ecosystem service valuation.

Table 4. Impacted Acreage (in hectares) of Yazoo Backwater Area by Landcover Class.

GIS Classification *	Acres
Wetland hardwood forests drained to non-jurisdictional	18,000
Wetlands, shrub and herbaceous drained to non-jurisdictional	8,300
Wetland hardwood forests negatively impacted	27,900
Wetlands, shrub and herbaceous negatively impacted	12,800
Total wetlands impacted	65,000

* The Army Corps provides few details on these impacted wetlands. For the 40,700 wetlands impacted, it is assumed that the same ratio of forested to non-forested wetlands is the same as the 26,300 acres where the Army Corps identifies the acres of wetland forest drained.

3.1.2. Valuation of Yazoo Backwater Area by Landcover Class

Tables 5 shows the estimates of ecological services produced by each GIS vegetation type within Yazoo Backwater Area. These estimates are all presented in $US. Because more valuation information was available for non-forested wetlands, they register a higher total per acre value. In fact, forested wetlands provide greater values for ecosystem services, however, valuation studies for hardwood bottom land Mississippi forests are not available for a range on aesthetic value or for wildlife habitat, refugium and nursery values. Because so many valuable ecosystem services have been identified but not valued, these dollar values should be considered underestimates of the true ranges in ecosystem service value. These values were derived from an ecosystem service database first developed by the University of Vermont Gund Institute for Ecological Economics later modified under a project for the State of New Jersey and further improved by Earth Economics. An excel spreadsheet linking each of the values in the table below to the corresponding published peer reviewed academic journal article is available upon request from Earth Economics.

Table 5. **Valuation of Yazoo Backwater Area Wetland Forest Ecosystem.**

Ecological Service	Impacted Yazoo Wetland Forests		Impacted Yazoo Non-forested Wetlands	
	Low	***High***	***Low***	***High***
Gas regulation	$21.11	$191.87	$29.43	$267.53
Climate regulation	$136.64	$136.64	$136.64	$136.64
Waste treatment	$3.13	$1,069.56	$3.13	$1,069.56
Water supply	$42.52	$113.39	$42.52	$113.39
Water regulation	$15.47	$15.47	$15.47	$15.47
Soil retention and formation	Not valued	Not Valued	Not valued	Not Valued
Fisheries	$25.80	$25.80	$53.37	$74.46
Nutrient regulation	Not valued	Not Valued	Not valued	Not Valued
Recreation	$134.44	$134.44	$134.44	$134.44
Pollination	Not valued	Not Valued	Not valued	Not Valued
Biological control	Not valued	Not Valued	Not valued	Not Valued
Refugium and Nursery function	Not valued	Not Valued	$185.51	$442.67
Food	Not valued	Not Valued	Not valued	Not Valued
Raw materials	Not valued	Not Valued	$4.26	$4.34
Genetic resources	Not valued	Not Valued	Not valued	Not Valued
Medical resources	Not valued	Not Valued	Not valued	Not Valued
Ornamental resources	Not valued	Not Valued	Not valued	Not Valued
Aesthetic information	Not valued	Not Valued	$68.09	$217.79
Cultural & artistic information	Not valued	Not Valued	Not valued	Not Valued
Spiritual & historic information	Not valued	Not Valued	Not valued	Not Valued
Science & education	Not valued	Not Valued	Not valued	Not Valued
Navigational services	Not valued	Not Valued	Not valued	Not Valued
Total	**$379.11**	**$1,687.17**	**$672.85**	**$2,476.29**

3.1.3.Present Value of the 65,000 acre portion of the Yazoo Backwater area

The present values of Yazoo Backwater Area ecosystem services are presented below in Table X. Under any calculation of PV, the ecosystem services provided by Yazoo Backwater Area are enormous and highly significant, ranging from a low of $462 million estimate at a 5% discount rate to $1.9 billion for the higher estimate boundary.

Table X. Present Value over 100 years with Various Discount Rates (in billion $US).

Discount Rate	Low Estimate	High Estimate
5 %	$462,000,000	$1,900,000,000

Conclusion

Earth Economics conducted this analysis by estimating the range of economic values for ecological goods and services produced annually by 65,000 acres of Yazoo Backwater Area. Of this, 18,000 acres are forested wetlands, 8,300 other wetlands with an additional 27,900 acres of forested wetlands and 12,800 acres of non-forest wetlands impaired. It was assumed that the impaired wetlands would produce half of the ecosystem services they previously provided.

Using USGS National Land Classification Data on vegetation types over these 65,000 acres, Earth Economics estimated the range of annual value provided by Yazoo Backwater Area ecosystem services $22-90 million. This results in a PV of $462 million to $1.3 billion at a 5% discount rate. A 3.5% discount rate, more commonly used for renewable, self-sustaining ecosystem services,

Most of the value provided by restoring healthy ecological processes in Yazoo Backwater Area will be garnered by future generations. The annual values calculated for Yazoo Backwater Area correspond to thin slices of the benefits that future generations will gain if Yazoo Backwater Area is maintained in an ecologically healthy condition. Unlike human-built capital, like cars and buildings, ecological capital appreciates and can be self-maintaining.

Both the high and low estimates of ecosystem services are likely underestimates of their true value. Most identified ecosystem services could not be valued. Other services that were valued are likely higher in Yazoo Backwater Area than in studied watersheds, for example, water purification and non-market valuations only captured partial values. The values of ecosystem services are rising rapidly due to increasing scarcity. In the case of recreation, the upper watershed is overvalued and lower watershed likely undervalued, with an ambiguous net result. The large ranges of value reflect the fact that benefit transfer methodology is an inexact science with significant uncertainty and variability. The ranges for these estimates will close with ongoing research. Nevertheless using inexact science for asset management is better than no science at all.

Recommendations

1. Eight ecosystem services, of 23 identified ecosystem services were valued for the 65,000 acres of wetlands potentially impacted by the Yazoo Pumps project. The range in value of these services is estimated to be between $22-90 million annually with a net present value range of $462 million to $1.9 billion.
2. The natural assets of the Yazoo Backwater Area are large and highly valuable. The value of these wetlands was not fully included in the US Army Corps of Engineers economic or environmental analysis.
3. **The EPA should veto the flawed Yazoo Pumps project.**
4. The Yazoo Backwater Area supplies sufficient ecosystem service benefits to justify significant restoration investments without the Yazoo Pumps project.
5. Because most of the benefits are held in the future, the estimate of value depends on how future value is weighted including what discount rate is used in this study we used a 5% discount rate, slightly higher than the Army Corps discount rate. The use of a lower discount rate would raise the net present value of the ecological services.
6. The EPA should partner with other organizations and agencies to increase the knowledge base on ecosystem services in the Yazoo area.
7. The public should be informed of the ecosystem services and their value, which Yazoo Backwater Area provides.

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Appendix A. Brief Descriptions of Some Ecosystem Services

A great number of studies examine the economic value of ecological services. These studies can be land use, vegetation type, or service based. A few services and valuation studies are discussed below.

Storm Protection and Flood Protection
Storm water management and flood protection provided by wetlands and other ecosystems are of vast value (Farber and Costanza 1987; Kenyon and Nevin 2001; Thibodeau and Ostro 1981). Wetlands between the Gulf States and the Gulf of Mexico, for example, provide buffer functions against hurricanes and tidal surges. As wetland buffers between the Gulf of Mexico and New Orleans have been lost, storm damage has increased dramatically. Existing wetlands prevent billions of dollars in storm damage from a single storm.

A Washington State wetlands study within WRIA 9 assessed the value of flood protection provided by wetlands in Renton, finding that Renton wetlands yielded flood protection benefits worth $41,300/acre to $48,200/acre (Leschine et al. 1997). Similarly, a draft study conducted in Portland, Oregon indicates that creation of a wetland to prevent flooding in a frequently flooded area of southeast Portland would prevent damage amounting to more than $500,000 per flood. This figure is based on actual damages to local homeowners in previous floods in the area (Rojas-Burke 2004).

Water Quality and Supply
Regulation of the quality and supply of water is perhaps the most recognized and studied ecosystem service. Studies have shown that the value of marginal improvements in water quality for specific areas range from $100 to over $1,000 per hectare (Bocksteal et al. 1988; Bouwes and Scheider 1979; Ribaudo and Epp 1984; d'Arge 1989; Desvousages et al. 1987; Cho 1990). Riparian forest buffers are estimated to reduce runoff nitrate levels by 84% and reduce sediment by more than 80% (Northeast Midwest Institute 2004).

Water purification services provided by natural ecosystems are far less expensive than water filtration and treatment facilities. New York City provided over $1.5 billion in watershed conservation measures to restore natural ecosystem filtration to meet water quality standards, rather than spend $8 billion (plus annual maintenance costs) to build a filtration plant (Krieger, 2001). Other jurisdictions have followed a similar pattern. To avoid the need to build a $200 million water filtration plant with additional maintenance and operating expenses, Portland, Oregon spends $920,000 annually to protect and restore the Bull Run watershed, maintaining the natural filtration of its drinking water supply (Krieger 2001). Annual operating costs of artificial water filtration vary. The estimated annual operating costs alone of water filtration facilities in Portland, Maine were $750,000, $3.2 million in Salem, Oregon, and $300 million in New York City (Krieger 2001). Healthy watershed ecosystems permanently provide filtration services, largely for free without capital, maintenance or operating costs.

Trees: Storm Water, Climate Regulation, and Atmospheric Pollutant Removal
Healthy ecosystems provide many bundles of services. Within these systems, trees provide a number of critical ecosystem services, and climate and air regulation have also been valued. One acre of forest can remove 40 tons of carbon from the air and produce 108 tons of oxygen annually (Northeast Midwest Institute 2004). Market values of carbon sequestration range from $10 – 100 per ton (Antle et al. 1999; McCarl et al. 2000; Haener and Adamowicz 2000) and $650 to $3,500 per hectare (Bishop and Landell-Mills 2002).

The level of service will differ based on the ecosystem structure (Bishop and Landell-Mills 2002). For example, a Douglas Fir forest plantation, planted ten years ago will not produce the same services as a natural old growth forest with a variety of tree sizes and species. Carbon sequestration in King County was estimated at about 56 million metric tons in 2000, and is predicted to average about 68 tons per acre in 2005, but the service varies significantly between types of growth (Turnblom et al. 2002).

The environmental purification and recovery of mobile nutrients – waste treatment services – provided by forests have been valued at $35 per acre (Loomis and Richardson 2000). Using land cover analysis, a 1998 report by American Forests related changes in the amount of vegetation and tree cover in the Puget Sound region to storm water management and air quality. The report placed an economic value on the ecology of the most urbanized parts of the Puget Sound watershed. The analysis valued the air quality by pollutants removed by the canopy cover at $166.5 million annually, and estimated storm water benefits amounting to $5.9 billion annually. Forestland is estimated to save about $21,000 per acre in storm water retention costs by capturing up to 50% of rainfall in the region (American Forests 1998).

Waste Treatment

Wetlands provide another important function for purifying water. A 1990 study found that the 11,000- acre Congaree Bottomland Hardwood Swamp in South Carolina removed the same amount of pollutants as the equivalent of a $5 million wastewater treatment plant (EPA 2003). A study in Georgia revealed that a 2,500-acre wetland saves taxpayers $1 million in water pollution abatement costs (EPA 2003).

Agricultural lands

One land use and policy based study (Ribaudo et al., 1989) estimated the following average benefit per acre of agricultural land under the US Conservation Reserve Program: soil productivity: $36; water quality: $79; air quality: $12; and wildlife: $86.

Pollination

Honeybees have been valued as natural pollinators for American cropland at $9 - $20 per hectare, and pollination services provided to US agriculture by all other pollinators are estimated at over $4 billion annually (Southwick and Southwick 1992).

Pest Control

Natural systems also provide pest control services. Estimates indicate that it would cost more than $7 per acre to replace the pest control services provided by birds in forests with chemical pesticides (Krieger 2001).

Recreational Value

Another valuable service that ecosystems provide is recreation. Uses such as fishing and hunting have been valued between $3 and $54 per trip (Adamowicz 1991). The fish and wildlife sector is a major economic force in Washington. Over $854 million was spent in 2002 on recreational fishing alone, while an additional $980 million was spent on wildlife viewing and $408 million on hunting (WDFW 2002). Commercial fishing added $140 million to the Washington economy in 2002 (WDFW 2002). Wildlife watching alone generates significantly more revenue for Washington's economy than the apple industry. It supports over 21,000 jobs in the state, more than any other Washington employer besides Boeing (WDFW 1997). Studies have found water quality for recreational purposes to be valued at $10 and $80 per year (Adamowicz 1991).

Aesthetic Value

Wetlands and other healthy ecosystems also provide aesthetic value, and the higher property prices around wetlands and forests reflect this phenomenon. A study in the Portland, Oregon area found that residential property values increased $436 for every 1,000 feet closer that a property was to a wetland (Mahan et al. 2000). Additional research has also assessed how other environmental amenities enhance property values (Crompton 2001; Anderson and Cordell 1988; Laverne and Winson-Geideman 2003; Dorfman et al. 1996).

Contingency Valuation, Restoration and Species Preservation
Contingency valuation establishes values for non-market goods by interviewing human stakeholders. Habitat valuations depend on the species that the habitat is for, and the use of those species for human demand. Many habitats are valued based on species used for consumption, such as oyster and other seafood production (Batie and Wilson 1978). Many other habitats are protected for valued megafauna (bear, elk, wolves) and protected endangered species. Studies of household values in the Pacific Northwest reflect strong preferences for protection of forests, fish and wildlife. In a study of estuarine function, residents of the Tillamook, Oregon area estimated the value of each additional acre of salmon habitat at approximately $5,000 (Gregory and Wellman 2001). Olsen and others (1991) found that households in the Pacific Northwest were willing to pay between $26-74 per year to double the size of the salmon and steelhead runs in the Columbia River (Quigley 1997). Another study found that Oregon households were willing to pay $2.50 to $7.00 per month to protect or restore salmon, a cumulative total of $2 million to $8.75 million dollars per month (ECONorthwest 1999). The mean annual value per household of river and fishery restoration on the Olympic Peninsula was $59 in Clallam County and $73 for the rest of Washington (Loomis 1996). Another study found Oregon households willing to pay $380 annually to increase preservation of old growth forests, $250 per year to increase endangered species protections, and $144 to increase protection for salmon habitat (Garber-Yonts et al. 2004).

Gaining Ground

Wetlands, Hurricanes and the Economy: The Value of Restoring the Mississippi River Delta

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Executive Summary

> ***"As the great Mississippi River Delta disappears, so do the ecosystems, economies and people that it holds. The Mississippi River is the solution. It has the water, sediment and energy to rebuild land, defend against hurricanes and again provide habitat, safety, livelihood, and prosperity. We must look to the natural functioning of the delta to guide us in restoration."***
>
> ***John Day, 2007***

Economies need nature. Natural systems provide foundational economic goods and services including oxygen, water, land, food, climate stability, storm and flood protection, recreation, aesthetic value, raw materials, minerals, and energy. All "built capital" is made of natural capital, including cars, buildings and food. An economy also requires hurricane protection, a stable climate, waste assimilation and other natural services. No economy can function without nature's provision of economic goods and services. This is most apparent in North America's largest river delta.

The Mississippi River Delta ecosystems provide at least $12-47 billion in benefits to people every year. If this natural capital were treated as an economic asset, **the delta's minimum asset value would be $330 billion to $1.3 trillion** (3.5% discount rate)**.** This study is the most comprehensive measure of the economic value of Mississippi River Delta natural systems to date. Marine waters, wetlands, swamps, agricultural lands and forests provide natural goods and services. The goods and ecosystem services valued in this study include hurricane and flood protection, water supply, water quality, recreation and fisheries. The Mississippi River Delta is a vast natural asset, a basis for national employment and economic productivity. It was built by literally gaining ground: building land with sediment, fresh water and the energy of the Mississippi River.

Yet, this vast national economic asset is being squandered at tremendous cost. The Mississippi Delta lost over 1.2 million acres of land in the last 80 years. In some areas, the coastline has retreated by as much as 30 miles. The lower Mississippi River has been constricted by levees since the 1930s, resulting in billions of tons of valuable sediment and trillions of gallons of valuable freshwater being channeled into deep water off the edge of the continental shelf. The Mississippi's energy to move vast amounts of sediment and water could have built additional land and provided hurricane protection and other economic benefits at no significant cost.

Without the input of sediment and water, wetland systems collapse. Land is lost to the waters of the Gulf of Mexico causing tremendous economic and human cost. Wetlands provide vital protection against hurricanes. When land disappears, so do the economies, homes and communities that depend on it. Solving this problem requires an accounting of and investment in the economic assets of nature – natural capital – as an integral component of hurricane damage prevention and as a critical foundation for healthy communities and economies.

Is this national investment worthwhile during a period of financial crisis? The results of this report point to an unequivocal "yes." Seventy years ago, investments in roads yielded high economic returns because the U.S. was transitioning from a horse and wagon road system to a motorized system. Today, roads are neither scarce nor a barrier for economic recovery. Hurricane protection is scarce and hurricanes hamper national economic productivity; the disruption of oil and gas supplies alone cost U.S. citizens dearly. Today, a major investment in natural capital is required for economic development. An investment in restoring the Mississippi River Delta is both a local and national investment that realizes local and national economic benefits.

This report discusses the value of investing in the restoration of the Mississippi River Delta. Part I introduces a new view on the value of natural capital as a critical and large part of the economy. It also introduces ecosystem services and goods that directly benefit people but have historically been overlooked. Part II presents a valuation of ecosystem services in the Mississippi Delta, calculates their present value to assess the flow of value over time. Part III of this study examines the dramatic dynamic physical changes affecting the Mississippi River Delta and the profound economic implications for the region and our nation. Part IV examines three investment/restoration scenarios for the Mississippi Delta.

The first scenario involves doing nothing new: invest nothing in natural capital and keep building costly levees that are repeatedly damaged by storms while land continues to wash away. Practiced for 80 years, this option has proven to be very costly. It results in a retreating coastline in the Mississippi Delta, causing a retreat of people, communities, industry, built capital and the economy. This report estimates losses associated with this option at $41 billion. This does not include estimates of damage from another major hurricane, which is certain to happen. Considering that Katrina caused $200 billion in damage and that with further land loss future damage may greatly increase, this is a significant underestimate. The nation breathed a sigh of relief when Hurricane Gustav's glancing blow did not destroy New Orleans in 2008. Had the hurricane struck slightly to the east, the impact could have been more damaging. Hurricane Ike was perhaps more powerful than hurricane Katrina. The resulting devastation along the Texas coast demonstrated that the entire U.S. Gulf Coast and Eastern Seaboard are now vulnerable to hurricanes and storm surges of increasing power. The contribution of natural capital in protecting people and economic assets need to be considered throughout the Gulf of Mexico and Southern Atlantic seaboard. Hurricanes Gustav and Ike caused tens of billions of dollars in damage, much of which would have been reduced had larger barrier islands and a greater wetland buffer been in place. This first scenario continues the path of reducing natural hurricane buffering. The less nature does its work, the more FEMA will be needed.

The second scenario covers a suite of projects that aim to maintain the current amount of land across the delta so as to "hold the line" and prevent net land loss. The U.S. Army Corps of Engineers adopted this scenario in the 2008 Louisiana Coastal Protection Technical Report (LACPTR). Holding the line provides greater benefits than the first do nothing new, let-it-deteriorate scenario. This option prevents further collapse of the Mississippi Delta and the loss of at least $41 billion in ecosystem services. However, it does not significantly secure greater natural hurricane buffering than what was available the day Hurricane Katrina hit. It will leave New Orleans and other populated areas no better protected by natural systems. This scenario depends on larger and more expensive levees that actually require wetlands as buffers. Hurricanes Katrina, Rita, Gustav and Ike provided an important lesson, recognized by the U.S. Army Corps of Engineers, that levees protected by wetlands perform better and fail less than levees directly exposed to hurricane storm surges. Although this scenario takes into account some lessons from recent hurricanes, it does not grapple with the scale of the problem and potential for success. Deltas on the scale of the Mississippi River Delta are tremendously dynamic, either expanding or shrinking depending on the allocation of vast quantities of water and sediment. Attempting to "hold the line" is not realistic in a deltaic system of this scale. It is more difficult and more costly than actually re-establishing deltaic processes and using the energy and water of the Mississippi River on a larger scale to reap far greater benefits. The "hold the line" scenario is a better strategy than doing nothing but it is not systemic and provides too little investment in the Mississippi Delta. It does not solve the problem at the needed delta-wide scale.

The final scenario, sustainable restoration, implements large-scale, controlled diversions of water and sediment from the Mississippi River to reconnect it to the delta. This will gain ground, restore deltaic processes at the scale that the delta requires to stop land loss and maintain a net expansion of land. It will build a larger natural asset base and yearly provide greater ecosystem services, such as, fisheries production and direct expansion of hurricane buffering before hurricanes hit the levees and inhabited areas. Studies show that diversions and plant growth are sufficient to outpace the expected sea level rise that the Intergovernmental Panel on Climate Change has predicted. This scenario offers the best economic investment in terms of producing the greatest benefits in safety, economic viability and habitability of the Mississippi River Delta. It is also the most resilient option to uncertainty in natural systems, such as climate change and economic uncertainty. Initial investments in diversion structures utilize the energy of the Mississippi River and are inexpensive to operate over the long run.

The lands gained from this scenario will avoid the $41 billion in damage under scenario 1 and produce benefits with an estimated present value of at least $21 billion, bringing in an annual net benefit of $62 billion. This includes partial values of 11 ecosystem services. It does not include the value of increased protection for levees, or avoided catastrophic impacts such as levee breaching. It does not include the benefit of reduced displacement of residents, reduced FEMA, relief and recovery costs, lower insurance rates, lower national oil and gas prices, less litigation, or the benefits of an expanding coastal economy, greater employment, and stability gained for existing communities and residents.

A comparison of the three scenarios - with 27 other criteria including contribution to coastal stability, capacity to expand economic development and protection of water quality and energy infrastructure - show scenario 3 to have the highest ranking by far.

With an expanded Mississippi Delta, prevention of damage from levee failure or the protection of an existing levee infrastructure can provide benefits on the level of tens of billions of dollars in a single hurricane event. These values are difficult to estimate. However, it is clear that a strategy of gaining ground will provide critical natural goods and services such as public safety, storm protection, oil and gas and thereby expand the economic base of the Mississippi Delta and the nation. This is not a cut-the-river-loose scenario, but a managed system of diversions to use sediment and water to provide for public safety and economic benefits.

The economics is clear: invest in the Mississippi River rebuilding the delta to gain ground, physically and economically. On the other hand, ground loss results in loss of nature's services, causing a hurricane-driven disorderly retreat inland and damaging people and businesses. This analysis strengthens ongoing planning by providing the economic justification for large-scale restoration. It complements efforts such as the State of Louisiana's Comprehensive Master Plan for a Sustainable Coast and the Multiple Lines of Defense strategy developed by the Lake Pontchartrain Basin Foundation and Coalition to Restore Coastal Louisiana.

Academics, non-profit organizations, state officials, residents and just about every person who studied this issue carefully support the restoration of the Mississippi Delta. Gaining ground provides economic benefits by:

1. Rebuilding land with more than half of the Mississippi River's peak flow water and sediment;
2. Adding economic value including hurricane protection and protection of existing levees;
3. Spurring wetland plant growth soaking up carbon, increasing fisheries production and other benefits;
4. Building land with plant growth that beats sea level rise and land subsidence;
5. Helping stabilize barrier islands increases hurricane protection and coastal stability;
6. Reducing the "dead zone" in the Gulf of Mexico which will increase fisheries and other benefits;
7. Yielding greater ecosystem services for better water quality, wildlife habitat and hurricane protection;
8. Securing the nation's energy infrastructure and inhabitable area of the Mississippi River Delta;
9. Providing a more sustainable, vibrant economy with a higher quality of life; and
10. Setting an example for the nation, Gulf Coast and Eastern Seaboard in natural hurricane buffering.

The use of diversions for restoration is a proven strategy, not an experimental approach. Over 30 years of experience in water and sediment diversion shows that this strategy is successful in building land area and restoring wetlands. The Old River Control Structure diverts water and sediment down the Atchafalaya River; this results in the formation of new deltas in Wax Lake. The diversion at Caernavon is another success for rapid wetland expansion. These examples can be replicated on a much broader scale.

With such a wide range of economic benefits, this report provides a starting point to inform investments in levees, restoration, land use, and economic development in the Mississippi River Delta. This study provides the most comprehensive valuation of natural capital assets in the Mississippi River Delta to date; however, it is still a partial valuation and an underestimate of the delta's total potential economic value. This valuation does not include economically valuable benefits such as navigation, protection of oil and gas infrastructure, and aesthetic value. Even with a wide range of estimates, it points to critical tools that can better inform investments in levees, restoration, land use and economic development in the Mississippi River Delta.

This report shows conclusively that physical sustainability and delta expansion secures vast economic benefits locally and nationally. Within the context of the current financial crisis, investment in restoration secures short-term benefits of employment, income generation, greater ecosystem services and other economic benefits, and the long term goals of increased storm protection, greater oil and gas supply reliability and other economic benefits. A sustainable restoration of the Mississippi River Delta is a good investment with a high rate of return. Gaining ground is the most successful economic strategy for securing hurricane defenses and economic development.

Main Points

1. Mississippi River Delta ecosystems provide economically valuable services including hurricane storm protection, water supply, climate stability, food, furs, habitat, waste treatment, and other benefits worth at least $12-47 billion/year. These annual benefits provide a vast amount of value to people across time.
2. Estimates of the present value of the benefits from 11 Mississippi Delta ecosystem goods and services are between $330 billion and $1.3 trillion (3.5% discount rate).
3. Wetlands – a product of Mississippi River deltaic processes – which include freshwater, saltwater, estuaries, tidal bays, and cypress swamps account for more than 90% of the estimated total value of ecosystem services provided in the Mississippi Delta.
4. Large-scale physical changes are affecting the Mississippi River Delta. These are known facts: hurricanes have become larger and more frequent in the last 30 years, sea level has risen, atmospheric temperatures have risen, and the delta is subsiding and has lost over 1.2 million acres of land since 1930.
5. Three scenarios show that a "do-nothing" approach will cost at least $41 billion in damages. A "hold the line" scenario avoids the $41 billion, without additional benefits. A third "sustainable restoration" option will avoid $41 billion in losses and secure $21 billion in benefits, providing $62 billion in present value.
6. Science has established that large diversions of water and sediment from the Mississippi River are required to rebuild the Mississippi Delta and secure economic benefits.
7. Many ecosystem services with clear economic value could not be estimated in this study. Work is critically needed to further understand the benefits that investments in diversions, levees, or other structures produce.
8. Restoration of the Mississippi River deltaic processes requires a major investment to maintain or expand the vast value of this natural asset. The movement of water and sediment and the maintenance and expansion of land underlies the production of many economic benefits, including protection against hurricanes. Without this investment, people and economic assets will be forced to retreat from the coast.
9. Delta restoration must be based on ecological engineering. High and rising energy costs will erode the economics of energy intensive options such as levees and sediment pumping. Water and sediment diversions utilize the Mississippi River's energy and can easily be maintained throughout many decades.
10. Within the context of the current financial crisis, investment in the restoration of the Mississippi River Delta provides high short and long-term returns. The Army Corps of Engineers, Federal, State and local governments should dramatically increase expenditures for the restoration of the Mississippi Delta.

List of Abbreviations

AC	Avoided Cost
CPRA	Coastal Protection and Restoration Authority
CV	Contingent Valuation
ESV	Ecosystem Services Valuation
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Product
GNP	Gross National Product
GV	Group Value
HP	Hedonic Pricing
IPCC	Intergovernmental Panel on Climate Change
LCA	Louisiana Coastal Area
LSU	Louisiana State University
MRGO	Mississippi River Gulf Outlet
NOAA	National Oceanic and Atmospheric Administration
NPV	Net Present Value
PV	Present Value
RC	Replacement Cost
TC	Travel Cost
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

Introduction

"We are living in a historic moment, one that presents us with a stark choice: either make the bold and difficult decisions that will preserve our state's future, or cling to the status quo and allow coastal Louisiana to wash away before our eyes. There is no longer any time to waste. We must act now or forfeit the possibility that our children and grandchildren will be able to share the life, culture, and resources that are so precious to us and so important to the nation."

Coastal Protection and Restoration Authority of Louisiana, May 2007

A Rich and Enriching Delta

Landscapes, rivers and ecosystems are integral natural capital assets that influence, house, build and shape economies. The greatest concentrations of people and economic productivity have thrived along rivers, especially by coastlines and river deltas. Practically all major US cities have settled by rivers. Mississippi River, the longest in North America, has a basin that comprises 41% of the continental United States covering 1.2 million square miles. The water and soil of the Mississippi Basin flow, as they have for millennia, to the Mississippi River Delta[1] and into the Gulf of Mexico. Engineering on the Mississippi River over the years has removed sediment and water which once expanded the Mississippi River Delta. This has degraded vast areas of the delta and resulted in massive land loss.

The 9,600 square-mile Mississippi River Delta, one of the most productive and expansive river deltas in the world, is an invaluable part of America. Over 2.2 million people live in the delta.[2] The history, music, literature, cuisine, Cajun and Creole culture, and folk songs and stories of the Mississippi River Delta form part of the heart and soul of our nation.

The geology, climate, biological systems, and movement of water and sediment within the Mississippi River Delta sustain its economy and communities. The Mississippi River Delta has 40% of the United States coastal wetlands. It has provided the US and the world a vital navigation route to the mid-western states, oil and gas resources, pipelines, refineries, chemical and fertilizer industries, fisheries, forestry and agricultural production.

Healthy communities and economies need a well-functioning "natural capital", the stock of natural and ecological systems that yield a flow of ecological services and natural resources that benefit people.[3] River deltas shaped the world's first economies. Economies on river deltas expand or shrink with the delta.

Understanding the economic importance of natural capital in the Mississippi Delta requires an assessment of its economic productivity. More importantly, decisions that impact the delta's viability require measurement of the

[1] Reference to the Mississippi River Delta in this report includes the Mississippi River deltaic and Chenier plains.
[2] U.S. Census, 2004
[3] Daly & Farley, 2004

value and benefits that this natural feature provides, such as storm protection, fisheries production, drinking water, recreation, wildlife habitat, and flood protection.

For the past eight decades, management of the Mississippi River Delta has had the primary goal of promoting shipping and the secondary goal of preventing flooding and storm damage. Today, an understanding of nature's contribution to the economy is fast emerging. A healthy economy requires the contributions that natural ecosystems provide, including oxygenated air, the protective ozone layer, a stable climate, clean water, land that does not sink, and protection from flood and storm. Forests, oceans, rivers, and land provide a vast array of benefits that are economically valuable assets.

Eighty years ago, the natural capital and benefits provided by the Mississippi River wetlands and barrier islands were so plentiful that they were viewed as limitless and deemed to be largely without value. Economic goals focused on the expansion of built capital, including roads, houses and levees. Today, built capital is abundant and more people have settled in coastal areas even as protective coastal features, such as wetlands and barrier islands have shrunk and hurricanes have grown stronger. Natural capital providing goods (fish, water) and services (storm protection, recreation) is now scarce and more valuable. The need to protect people and property against the destructive power of hurricanes, while increasing the stock of natural capital, has become more critical.

The barrier islands, coastal wetlands, swamps and uplands all provide buffering against hurricanes. Studies show that wetlands significantly reduce hurricane storm surge.[4] This and the value of other ecosystem services have not been counted as economic benefits. Neither were they included in flood and storm protection analyses that valued only built structures like levees. Valuable natural capital was then squandered. Land, barrier islands and wetlands were needlessly lost – as were the substantial benefits that these ecosystems provide, including hurricane protection.

The loss of valuable natural capital is a national trend, but change is afoot as new analyses and solutions are developed and applied. New Jersey became the first U.S. state to actually conduct a full economic analysis of its natural capital assets.[5] The Puget Sound basin was the first region with a valuation of 12 ecosystem services setting out a new vision of a local economy which includes the economic value of healthy natural systems.[6] On a local scale Earth Economics' recent study on the valuation of ecosystem services demonstrated that salmon restoration along the Green River in Puget Sound provides other ecosystem services, such as recreation and flood protection.[7] Six cities in the U.S., including Seattle, San Francisco and New York, filter drinking water through natural watersheds at costs that are far lower than what water filtration plants require. Most services that healthy ecosystems provide can be secured at far less cost compared to replacing these natural systems with built capital by incorporating these services (for instance, clean water or flood protection) in the management of utilities.[8] This study provides state of the art valuation methods to inform investment decisions.

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[4] Boesch et al. 2006, Day et al. 2007
[5] New Jersey Department of Environment Protection, 2007
[6] Batker et al. 2008
[7] Earth Economics, 2006
[8] Earth Economics, 2006

Knowledge of the Mississippi River Delta's economy is incomplete without measuring the economic productivity of the natural systems (natural capital) in providing hurricane storm protection, fisheries production, drinking water, recreation, wildlife habitat, flood protection and other benefits. Hurricanes Katrina and Rita demonstrated that natural, social and human capital have been undervalued in the decision making process and are now needed for economic analysis and for generating pragmatic and effective solutions.

Eyeing the Storms

Katrina first struck the U.S. near Florida's Broward/Miami-Dade County line as a category 1 hurricane on August 24, 2005. Fueled by the Gulf of Mexico's hot water, it quickly powered up into a massive category 5 hurricane. As Katrina moved inland, it crossed wetlands which then put more physical drag on the storm, slowed its progress, lowered the storm surge and reduced fetch (the area of open water where waves can gain in size and momentum). Figure 1 shows that as the hurricane hit the coastline, it quickly weakened to category 4 and then category 3 by the time it struck the Mississippi-Louisiana border on August 29, 2005 with sustained winds of 125 mph. The hurricane generated a storm surge that exceeded 30 ft along the Mississippi coast.[9] New Orleans experienced storm surges from 14-18 ft.

Figure 1. The track of Hurricane Katrina Showing Changes in Storm Intensity and Spatial Extent

Track of Hurricane Katrina, August 23-29, 2005, showing spatial extent and storm intensity along is path.

Source: NOAA

[9] NOAA, 2005; USACE, 2007

The hurricane storm surge flooding was most severe along the Mississippi coastline and in Louisiana communities where levees and floodwalls failed and wetland buffers had disappeared. Hurricane Katrina directly pummeled the Mississippi River Delta, affecting an area of over 90,000 square miles and over two million people. The communities most impacted include the Birdfoot Delta of the Mississippi River, the Mississippi coast, Slidell and surrounding areas, St. Bernard and Plaquemines parishes and New Orleans.[10]

Wetlands reduce hurricane impact. Hurricanes Katrina and Rita passed through areas of the Mississippi River Delta that had the greatest wetland loss between 1932 and 1990. This includes the Birdfoot Delta of the Mississippi River which lost 50% of its land area, St. Bernard Parish wetlands lost 17.0%, Plaquemines Parish lost 12.0% and the East Orleans land bridge lost 17.6%.[11] If the original wetlands still existed, they would have buffered the storm surge and both hurricanes would have caused far less damage.

Three weeks after Hurricane Katrina struck, category 5 Hurricane Rita cut a far larger swath of destruction, running parallel to the Gulf Coast stretching from Florida to Texas and again flooding parts of New Orleans. It made landfall near Sabine Pass at the Louisiana-Texas border with sustained wind speeds of 120 mph and a storm surge of at least 20 ft. Hurricane Rita's southeasterly approach resulted in a storm surge of at least nine ft that swept through the entire Louisiana coast.

In the 2008 hurricane season, Hurricane Gustav's faster speed in crossing the Gulf of Mexico fortunately prevented the storm from building up a larger storm surge. Had it moved more slowly, it would have generated and hauled a much larger storm surge across the gulf. Striking to the west of New Orleans, the storm surge of Hurricane Gustav was reduced by wetlands in its path. Gustav caused significant damage and again clearly demonstrated the importance of wetlands as barriers to hurricane storm surges.

The severity of hurricane damages in recent years have spurred a lively debate on the full impact of levees and built structures on storm surges. The Army Corps of Engineers now recognizes that the configuration of canals and levees can increase the damage caused by hurricane storm surges. For instance, the Mississippi River Gulf Outlet Canal (MRGO), dredged to provide an extra shipping canal for New Orleans, created a v-shaped funnel as wetlands in the center of the v-shape were lost due to salt water intrusion. Had these wetlands been intact, there would have been less flooding in southeastern New Orleans and St. Bernard Parish and the levee may have held and not been breached. However, as the storm surge waters of Katrina progressed from the wide-open mouth of the v-shape to its closed point, the levees constricted the storm surge waters and increased their height and destructive power. This flushed the storm surge's full force right into New Orleans, overtopping and demolishing the protective levees. This led the Louisiana Legislature and the U.S. Congress to order the permanent closure of the Mississippi River Gulf Outlet Canal. Plans to close the MRGO canal at the Bayou La Loutre ridge have been set.

Wetlands in the "land bridge" once provided a physical barrier to hurricane storm surge waters from the Gulf of Mexico entering Lake Pontchartrain. However, with the severe degradation of these wetlands, the storm surge

[10] Cole, 2005
[11] USGS, 2002

of Hurricanes Katrina and Rita engorged Lake Pontchartrain, levees and sea walls failed below their rating, causing catastrophic flooding and killing people.

Levees can reflect and amplify storm surge waves, unlike wetlands that absorb and resist storm waters without amplifying wave action. The levee along the Birdfoot portion of the Mississippi River may have actually reflected Katrina's storm surge back to the Mississippi coastline, creating an additive effect and increasing the size and power of storm surge waves that struck the coast. The Army Corps of Engineers initially contested this view but accepted it as true after studying the similar effects from Hurricane Gustav.[12]

It is a clear fact that intact natural wetland ecosystems and other natural features provide hurricane protection. It is undeniable that the loss of barrier islands, wetlands, and land over the past several decades has made coastal residents far more vulnerable to hurricanes and storm surge damage. Louisiana lost over 1,875 square miles of wetlands and many of its barrier islands between 1932 and 2000.[13] After the hurricane season of 2005, this number rose to over 2,000 square miles or about 25% of total wetland area that existed at the turn of the century.

Public investment in the restoration of the Mississippi River can restore natural processes which generate real economic value in the form of hurricane protection, recreation, safe land for housing and industry and other benefits. Ignoring the degradation of the Mississippi Delta entails tremendous economic, ecological and social costs.

The Hurricanes' Economic Impact

Hurricanes Katrina, Rita, Gustav and Ike wrought heavy havoc along the U.S. Gulf Coast. Although the damage to built capital can be monetized, the human cost is incalculable. Hurricanes Katrina and Rita alone caused 1,815 deaths in Louisiana and Mississippi[14] with 705 people still deemed missing.[15] FEMA estimated the displaced people at two million in January 2006.[16] The hurricanes exposed the harsh reality of poverty and racism.[17] Neighborhoods and communities that were poor or African American or both still lie in ruin. Some coastal towns remain virtually abandoned. Hundreds of thousands of people remain displaced. The social fabric of the Gulf Coast is yet reeling from the storms' effects. Impeded by physical, legal and economic obstacles, full recovery has been slow to come.

Hurricane Katrina, the most costly natural disaster in U.S. history, caused $200 billion in property damages and economic losses.[18] Both hurricanes damaged 150 miles of levees to the point of requiring reconstruction; wrecked 360,000 homes, 504 schools, 97 hospitals, 570,000 cars, and 70,000 boats;[19] destroyed roads, bridges,

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[12] USACE, 2007
[13] USGS, 2003, also Boesch et al. 2006, Day et al. 2007
[14] Louisiana Department of Health and Hospitals, 2006
[15] Krupa, 2006
[16] Hsu, 2006
[17] Brown University, 2006
[18] U.S. Government Accountability Office, 2006
[19] FEMA, 2006

electric posts, telecommunications, water supply, sewerage, industrial areas, and playgrounds; caused 99% mortality in oyster beds with $1.1 billion in fisheries losses;[20] damaged 365,000 acres in 16 federal wildlife refuges, $1 billion in cropland losses;[21] and spilled 6.5 million gallons of oil.[22]

Property prices fell across the U.S. Gulf of Mexico while insurance rates rose.[23] Katrina shut down over 95% of offshore gulf crude oil production, roughly 27 % of total U.S. crude oil production. It broke pipelines and forced the shutdown of nearly a dozen refineries in eastern Louisiana, Mississippi and Alabama. Hurricane Rita forced the closure of 20 Texas and Louisiana refineries, accounting for more than four million barrels a day or more than 26% of U.S. refining capacity.[24] The disruption of oil and gas pipelines and oil refining in Louisiana caused a spike in the prices of natural gas, gasoline and other petroleum product throughout the U.S. Americans had to pay for the increase in the transportation costs of goods and people.

The increase in construction in Louisiana increased the cost of labor and materials by 20-40 % of the pre-2005 hurricane season; the nationwide increase was 5-10%. This dramatically increased the cost of recovery for insurers and owners across the Gulf Coast.[25] It also increased the price of building materials throughout the South. The legal aftermath of Hurricane Katrina promises to be as costly as the hurricane damage. Katrina produced an unprecedented number of lawsuits involving, among others, FEMA, the U.S. Army Corps of Engineers, levee boards, States, local governments, insurance companies, banks and homeowners.

While experts expect the damage from hurricanes to increase in the coming years, they also agree that this can be mitigated. The costliest hurricanes in history offer lessons we need to heed, the most important of which is the need to rebuild the delta at the scale that significantly reverses land loss.

Restoration Plans and Recent Legislation in Louisiana

Louisiana has developed restoration plans for the Mississippi River Delta. However, Hurricanes Katrina and Rita revealed that because of their limited goals for halting land loss, restoration plans such as the 1998 Coast 2050 Plan and the 2004 Louisiana Coastal Area Plan did not meet the scale of the problem. The Mississippi Delta is dynamic. It has consistently swung between gaining and losing land, but not to the extent of the net land loss in the past century. Meeting the goal of stopping land loss cannot be accomplished through levees and small projects. It requires a fundamental shift toward large diversions – moving vast quantities of water and sediment into the delta and out of the Mississippi River where it would be dumped off the continental shelf. Models and analyses of the impacts of wetlands and Hurricanes Katrina and Rita on flooding and storm surges now stress the need[26] to build land, sequester carbon and secure hurricane buffering and other services.

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[20] Gaddis et al., 2005
[21] Center for the Study of Rural America, 2005
[22] EPA 2005
[23] Fletcher, 2005
[24] Federal Trade Commission, 2006
[25] McCormack, 2006
[26] Farley, Batker, & Pittman, 2006

In recognition of this weakness and in response to the 2005 storms, the Louisiana Legislature approved Act 8 creating the Louisiana Coastal Protection and Restoration Authority (CPRA) to develop and implement a comprehensive and integrated plan to restore the coastal wetlands and barrier islands. CPRA produced a master plan with the core objective to "Promote a sustainable coastal ecosystem by harnessing the processes of the natural system."[27] This plan outlines the need for a large-scale restoration of the Mississippi River Delta.

This objective includes the use of the Mississippi River's water and sediment to reestablish water flow and sediment delivery.[28] This comprehensive approach will provide a full basket of ecosystem service benefits including hurricane protection and flood protection, internationally significant fish and wildlife habitat, water quality, regionally and nationally important port facilities, navigable waterways, fuel processing capacity and the unique culture of the area.[29] Effective coastal restoration calls for a recognition of how the economy is dependent on a stable, healthy and expanding Mississippi Delta.

The State of Louisiana is moving forward with a new vision of restoration in the Mississippi Delta. In addition, citizen's organizations such as the Lake Pontchartrain Basin Foundation and Coalition to Restore Coastal Louisiana have outlined a Multiple Lines of Defense strategy, which also restores basic deltaic processes and is integrated with levees and built structures to provide effective hurricane protection.[30] However, the investment resources for implementing a comprehensive restoration are lacking. Understanding the importance of natural capital to the local and national economy is a relatively new revelation in economics. It provides a new view of the economy and a better insight into the local and national value of investing in natural capital.

Part I: A New View of Value in the Mississippi River Delta

The field of economics has advanced significantly in recent years improving our ability to quantify the value of goods and services provided by nature. These advances include new concepts and techniques such as "natural capital" and ecosystem service valuation. The sophistication and applicability of ecosystem service valuation has also rapidly expanded.[31] This section provides basic concepts and methods used for assessing the value of ecosystem services in the Mississippi River Delta.

Natural Capital

Natural Capital and Asset Management

In the 1930s, human-built capital was scarce; the expansive wetlands of the Mississippi River Delta were considered a wasteland. Natural goods sourced in the wetlands such as timber, fish and oil were viewed as limitless. Economic development was seen as the conversion of otherwise untapped natural resources into built capital or useful marketable goods. However, natural systems produce benefits and public goods – such as

[27] Coastal Protection and Restoration Authority, 2007a
[28] CPRA 2007a
[29] CPRA 2007a
[30] Lake Pontchartrain Basin Foundation, 2008
[31] Limburg, O'Neill, Costanza, & Farber, 2002

breathable air and hurricane protection – without human labor, fees or restriction (everyone can breathe the air and everyone living behind wetlands receives storm protection). Because these "public goods" cost nothing and could not be privatized or traded in markets, they were deemed to have no economic value. Today, however, markets produce a vast abundance of goods such as cloths, toys, asphalt and food for a lower real cost while nature's goods and services have become relatively scarcer and increasingly valuable. Given the loss of healthy ecosystems, the valuation of natural capital helps decision makers identify costs and benefits, evaluate alternatives and make effective and efficient management decisions. Excluding natural capital in investment decisions or asset management can result in significant losses, increased costs (public and private) and decreases in efficiency and community benefit.

Understanding Natural Capital

Natural capital is comprised of the geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continuing return of valuable benefits.[32] It contributes to our economy and quality of life in many ways that are not currently included in market transactions or policies. In fact, most decision makers and the citizens are not aware of the full economic value of natural systems. Natural capital contributes to the provision of water, natural water filtration, energy production, flood control, recreation, natural storm water management, biodiversity, discovery of new medicines, and education. Ecosystems are defined as all the interacting living and nonliving elements of an area of land or water. Ecosystem functions refer to the processes of transformation of matter and energy in ecosystems. Ecosystem goods and services are the benefits that humans directly and indirectly derive from naturally functioning ecological systems.[33] They are the flux of value provided from intact natural capital to people. For something to be classified as an ecosystem good or service, it must benefit people.

The Economics of Natural Capital

Healthy ecosystems are self-maintaining. They have the potential to appreciate in value over time and to provide an ongoing output of valuable goods and services in perpetuity. In contrast, built structures and other man-made capital depreciate in value over time and require capital investment, operations and maintenance. The provision and filtration of water is a good example.

The city of New York requires a daily supply of more than one billion gallons of water. Facing degraded drinking water quality, New York City weighed its options between building a water filtration plant costing over $6 billion and that of investing $1.5 billion to restore the health of the watershed thereby allowing natural processes to filter the water and meet drinking water standards. The city decided to invest in the watershed. Investment in restoration has proved to bring a far higher rate of return; it is less costly and less risky for meeting standards. The cities of Seattle, Tacoma, Portland and San Francisco have maintained forested watersheds that supply water at above drinking water standards. With forests filtering water for drinking, the cities of Seattle and Tacoma have avoided capital construction for water filtration plants that would have cost $250 million and $150 million respectively. In addition, filtration plants would require maintenance and replacement while the forest is essentially a self-maintaining water supply and filtration system. If the value of

[32] Daly & Farley, 2004
[33] Costanza et al., 1997; Daily, 1997; De Groot et al., 2002; Wilson, Troy & Costanza, 2004

these ecosystems is not recognized and they are degraded, we may well lose these critical benefits and be forced to replace least-cost natural systems with more costly built capital replacements.

Ecosystems and Value

Ecosystems and Value Production

Ecosystems are comprised of structural components (trees, wetland plants, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, reduced fetch, obstructions to hurricane storm surges, etc.) that generate ecological goods (fish, timber, water, oxygen) and services (hurricane and flood protection, water filtration, recreation, aesthetic value, etc.). Figure 2 below summarizes these relationships in a simplified diagram.

Ecosystem infrastructure has particular physical components such as the salt, brackish, intermediate and fresh marshes and swamps of the Mississippi Delta. The infrastructure itself is dynamic; biotic structures migrate and abiotic components flow through the delta, often via air or water. For example, the lobes of the Mississippi River Delta show great dynamism in the deposition of historical sediments. These functions vary widely in spatial boundaries (oxygen migrates globally while shrimp spawning and production are confined locally). Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production). These structures, processes and functions combine to produce economically valuable goods and services.

Figure 2. Relationship of Ecosystems to the Goods and Services Produced

Valuation of Ecosystem Services

Ecosystem service valuation assigns a dollar value to goods and services provided by a given ecosystem. This allows for proposed management policies to be considered in terms of their ability to improve ecological processes that produce the full diversity of valuable ecosystem goods and services. This study will provide the low and high value estimates for some of the goods and services provided in the Mississippi River Delta.

Ecosystem Goods and Their Valuation

Most goods that the Mississippi River Delta provides – such as water, timber, fish, and furs – are excludable. If one individual owns or uses a particular good, that individual can exclude others from owning or using the same. For instance, if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets.

The production of goods can be measured by the physical quantity produced by an ecosystem through time. This is known as a flow of benefits; for instance, the volume of water production per second, the board feet of timber production in a 40-year rotation, or the weight of fish harvested each year. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. This production creates a flow of economically valuable ecosystem goods over time.

Ecosystem Services and Their Valuation

Ecosystem Services Defined

Ecological services are defined as "the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life."[34] Ecosystems provide a variety of services that individuals and communities use and rely on, not only for their quality of life but also for economic production.[35] Ecosystem services are measurable benefits that people receive from ecosystems.

The stream of services provided by an ecosystem, referred to as a "service flux," cannot be measured as the physical quantity of a product produced, and is then far more difficult to measure and value. Examples of this are the hurricane buffering of wetlands, water filtration and recreational value.

Most ecosystem services are non-excludable. Wetlands provide hurricane buffering to all who live behind them, aesthetic value to anyone who looks at them, and flood protection for everyone living downstream. Due to this non-excludability, most ecosystem services cannot be traded or sold in markets.

Table 1. Examples of Ecosystem Services

Examples of Ecosystem Services
Purification of the air and water
Mitigation of hurricanes, floods and droughts
Recreation
Detoxification and decomposition of wastes
Generation and renewal of soil and soil fertility
Pollination of crops and natural vegetation
Control of the vast majority of potential agricultural pests
Dispersal of seeds and translocation of nutrients
Maintenance of biodiversity
Protection from the sun's harmful ultraviolet rays
Partial stabilization of climate
Moderation of temperature extremes and the force of wind and waves
Support of diverse human cultures
Provision of aesthetic beauty

Source: Daily et. al, 1997

[34] Modified from Daily et al., 1997
[35] Daily, 1997; Costanza et al., 1997

Structure and Value Production

The quality, quantity, reliability and combination of goods and services that the ecosystems in the Mississippi Delta provide depend on the structure and health of these ecosystems. Structure refers to a specific arrangement of ecosystem components. For instance, the steel, glass, plastic and gasoline that comprise a car must retain a very particular structure to provide transportation service. These very same components cannot provide transportation without a car's structure. Shrimp require certain ecological processes, structures and conditions. Ecological service production is more dependent on structure than the flows of goods. A single species timber plantation may yield a flow of goods (timber) but it cannot provide the same service fluxes (biodiversity, recreation and flood protection) as an intact natural forest.

Integrated Ecosystems and Multiple Benefits

A heart or lungs cannot function outside the body. Neither can the human body function without a heart and lungs. With all the organs functioning, a body can perform many tasks. Good bodily health requires organs to work as part of a coordinated system. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts. When separated, each of the physical and biological components of the Mississippi Delta would not be capable of generating the same goods and services that the processes and functions of an intact watershed system provide.[36] The sheet flow of water across the Mississippi Delta for example, maintains wetlands across salinity gradients. Intact ecosystems provide a full basket of goods and services. The Mississippi Delta provides fish, land for habitation and industry, storm protection, clean water, recreation and flood control. Built structures, such as levees or fish hatcheries, may replace only one function, but not the full basket of goods and services. Ecosystems are engines of economic productivity and systems of significant complexity. Individual services influence and interact with each other, often in nonlinear ways. They may collapse if they are stressed beyond critical thresholds. For example, the "dead zone" is an area the size of New Jersey, off the outlet of the Mississippi River created by the nutrient load, plankton bloom and oxygen depletion. This productive area has collapsed ecologically and economically.

Resilience

Resilience refers to the potential of a system to return to a previous state after disturbance. A system is assumed to be fragile when resilience is low. Fragile systems tend to be replaced after disturbance, for example wetlands are converted to open water which produce reduced amounts of ecosystem services and provide less economic value.[37] While symptoms of disturbance may appear when an ecosystem is on the verge of collapse, with the exception of a few well-studied systems,[38] there is little science available to show the minimum threshold of ecosystem infrastructure that is needed to stop the breakdown of services. Likewise, ecosystems have been shown to be quite resilient; in some cases, ecosystem health improves when restoration projects are initiated. Wetlands in coastal Louisiana provide a great example. Thresholds of stress cause loss of large areas of wetlands. Experience in rebuilding wetlands with renewed inputs of sediments and nutrients from the Mississippi River have secured greater resiliency.[39] Subsidence, a natural process, is a characteristic of the Mississippi Delta and all major deltas. It is the lowering of the surface of the land due to compaction,

[36] EPA, 2004
[37] Gunderson & Holling, 2002 also Day et al. 1997
[38] Carpenter & Gunderson, 2001
[39] Tibbets, 2006

consolidation and dewatering of sediments.[40] In order to survive subsidence, wetlands must build upwards at the same rate that the land is sinking and sea level is rising (this is called relative sea level rise or RSLR). Under natural conditions, the Mississippi Delta was highly dynamic and resilient. The delta loses wetlands in some areas and gains in others, but expanded overall despite subsidence and sea level rise. The elimination of sediment and water from the river to most of the delta (it was channeled by levees off the continental shelf) initiated the collapse of wetlands with pervasive changes in hydrology.

Value Production in Perpetuity

The Mississippi Delta has contributed to human economies for thousands of years. This is evidenced by numerous sites where Native Americans lived. Healthy intact ecosystems are self-organizing (require no maintenance) and do not depreciate. They can provide valuable ecological goods and services on an ongoing basis "in perpetuity." A forest can provide water control, flood protection, aesthetic and recreational values, slope stability, biodiversity, water filtration and other services without maintenance costs. This differs from human-produced goods and services (cars, houses, energy, telecommunications, etc.) that require maintenance expenditures, dissipate, may depreciate and usually end up discarded, requiring further energy inputs for disposal or recycling. The benefits that a natural capital provides can be quickly and permanently lost with mismanagement. The loss of an ecosystem's natural flood or storm prevention functions will result in large, long-term and accelerating costs to private individuals, businesses, communities and governments. They either suffer increased storm and flood damage or pay for expensive and often less effective engineering solutions. As the health of ecosystems decline, the natural and economically valuable services are lost. Taxpayers, businesses and governments then incur damage, repair or replacement costs and higher insurance premiums (or loss of access to insurance). When ecological services are restored, the reverse dynamic can occur.

Greatly altered or degraded ecosystems, like those in the Mississippi River Delta, require a combination of built structures, such as water and sediment diversion structures, to restore natural processes and provide the greatest benefits for people. Understanding the value of natural capital is important for all decision makers, from individual residents to corporations, and local and federal governments. All hold assets, earn income, or participate in the long-term economic planning for the region; all would be better off knowing the importance and value of Mississippi River Delta natural systems.

23 Ecosystem Services

De Groot et al. categorized ecosystem services based on the processes and functions they perform to the benefit of humans (see Table 2).[41] Grouped into four categories (regulation, habitat, production, and information), these functions amount to 23 ecological services. The regulation and habitat functions are considered essential before production and information functions can be active.[42] The following table defines and describes ecosystem services that flow from most ecosystems, including those in Coastal Louisiana. The next section gives a more detailed description of wetland ecosystem services.

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[40] Day et al. 1977
[41] De Groot et al. 2002
[42] De Groot et al. 2002; Wilson et al. 2006

Table 2. Categories of Ecosystem Dynamics with Corresponding Goods and Services

Functions		Ecosystem Infrastructure and Processes	Examples of Goods and Services
Regulation Functions		*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles	Provides clean, breathable air, disease prevention, and a habitable planet
2	Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favorable climate promotes human health, crop productivity, recreation, and other services
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	Prevents and mitigates natural hazards and natural events that are generally associated with storms and other severe weather
4	Water regulation	Role of land cover in regulating runoff and river discharge	Provides natural irrigation, drainage, channel flow regulation, and navigable transportation
5	Water supply	Filtering, retention, and storage of fresh water (e.g. in aquifers and snow pack)	Provision of water for consumptive use, includes both quality and quantity
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	Maintains arable land, prevents damage from erosion, and promotes agricultural productivity
7	Soil formation	Weathering of rock, accumulation of organic matter	Promotes agricultural productivity and the integrity of natural ecosystems
8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients	Promotes health and productive soils; gas, climate, and water regulations
9	Waste treatment	Role of vegetation and biota in removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification; filtering of dust particles through canopy services
10	Pollination	Role of biota in movement of floral gametes	Pollination of wild plant species and harvested crops
11	Biological control	Population control through trophic-dynamic relations	Provides pest and disease control, reduces crop damage
Habitat Functions		*Providing habitat (suitable living space) for wild plant and animal species*	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity; thus the basis for most other functions
13	Nursery function	Suitable reproduction habitat	Maintenance of commercially harvested species
Production Functions		*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits, etc.; small scale subsistence farming and aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing; fuel and energy; fodder and fertilizer
16	Genetic resources	Genetic material and evolution in wild plants and animals	Improves crop resistance to pathogens and pests
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs, pharmaceuticals, chemical models, tools, test and assay organisms

18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration and souvenirs
Information and Cultural Functions		*Providing opportunities for cognitive and spiritual development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Source: De Groot et al. 2002

Because decisions turn out to be very costly when the contributions of natural capital to economic activity are not counted,[43] interest in identifying, describing and quantifying the economic value of ecosystem services to improve decision making have increased through the years.[44] This is particularly relevant in coastal areas given that preliminary estimates of the global economic value of coastal (including large estuaries) and marine ecosystems show that are two-thirds of total ecosystem service value of all systems on earth.[45] It is crucial to understand how economic value shifts with changes in natural systems, especially along coastal systems with high development and extraction pressures.[46]

Deriving economic values for ecosystem services is a complex undertaking. Ecosystem services are different from private goods because they do not easily lend themselves to pricing and markets.

Ecosystem functions, and the services they produce, result from broad interactions across large landscapes (e.g., storm buffering) or, in some cases, the whole planet (e.g., climate and carbon sequestration). These interdependent systems make life possible; providing for climate, oxygen, nutrient cycles, water and energy flows, and the movements of seeds. This interdependence and tremendous scale of operation makes nature the best producer of these goods and services. It would be impractical and undesirable to attempt to set up human institutions, markets and factories to provide for global climate regulation, oxygen production and provision of water. [47] It is far better economics to avoid wrecking productive natural systems, or to restore them when damaged, than attempt to displace or do without them.

[43] Daly & Farley, 2004
[44] Daily, 1997; Costanza et al., 1997; Balmford et al., 2002
[45] Costanza et al., 1997; Costanza 1999
[46] UNEP, 2005
[47] Daly & Farley, 2004

Natural systems like the Mississippi Delta are part of our common wealth. Many are ***public goods and services***. Ascribing economic value to these ecosystem services helps policy makers and the public decide how to allocate public funds for the common good.[48]

Valuation Techniques

Ecosystem goods and services may be divided into two general categories: ***market*** and ***non-market***. Measuring market values simply requires monitoring market data for prices and quantities sold. This production creates a flow of ecosystem goods that have a market-defined economic value over time.

The non-market values of goods and services are more difficult to measure. When there are no explicit markets for services, the more indirect means of assessing values must be used. Table 3 identifies a spectrum of valuation techniques that are commonly used to establish values when market values do not exist. It also summarizes the appropriateness of each technique for different types of services.

Table 3. Valuation Methodologies

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; storm protection provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC): services can be replaced with man-made systems; nutrient cycling waste treatment provided by wetlands can be replaced with costly treatment systems.
Factor Income (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and the incomes of fisherfolk.
Travel Cost (TC): service demand may require travel whose costs can reflect the implied value of the service; recreation areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it, including the imputed value of their time.
Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods; for example, housing prices along the coastline tend to exceed the prices of inland homes.
Marginal Product Estimation (MP): service demand is generated in a dynamic modeling environment using a production function (Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.
Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay for increased preservation of beaches and shoreline.
Group Valuation (GV): this approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate.*

Source: Costanza et al. 2006

[48] Costanza, 2006

Table 4. Appropriateness of Valuation Methodologies for Ecosystem Service Type[49]

Ecosystem Service	Amenability to Economic Valuation	Most Appropriate Method for Valuation	Transferability Across Sites
Gas regulation	Medium	CV, AC, RC	High
Climate regulation	Low	CV, AC, RC	High
Disturbance regulation	High	AC	Medium
Biological regulation	Medium	AC, P	High
Water regulation	High	M, AC, RC, H, P, CV	Medium
Soil retention	Medium	AC, RC, H	Medium
Waste regulation	High	RC, AC, CV	Medium to high
Nutrient regulation	Medium	AC, RC, CV	Medium
Water supply	High	AC, RC, M, TC	Medium
Food	High	M, P	High
Raw materials	High	M, P	High
Genetic resources	Low	M, AC	Low
Medicinal resources	High	AC, RC, P	High
Ornamental resources	High	AC, RC, H	Medium
Recreation	High	TC, CV, ranking	Low
Aesthetics	High	H, TC, CV, ranking	Low
Science and education	Low	Ranking	High
Spiritual and historic	Low	CV, ranking	Low

Adapted from Farber et al. 2006

These tables show that each valuation methodology has its own strengths and limitations, often limiting its use to a select range of ecosystem goods and services within a given landscape. For instance, the value generated by a naturally functioning ecological system in the treatment of wastewater can be estimated by using the replacement cost (RC) method which is based on the price of the cheapest alternative for obtaining that service (the cost of chemical or mechanical alternatives). A related method, avoided cost (AC) can be used to estimate value based on the cost of damages due to lost services. This method was used to value the flood protection services provided by restored habitats and functions within the flood plain. Travel cost (TC) and contingent valuation (CV) surveys are useful for estimating recreation values while hedonic pricing (HP) is used for estimating property values associated with aesthetic qualities of natural ecosystems. Contingent valuation surveys and conjoint analysis can be used to measure existence value of ecosystems and charismatic animals. Marginal product (MP) estimation has generally been used in a dynamic modeling context; it helps examine how ecosystem service values change over time. Finally, group valuation (GV), a more recent addition to the

[49] This table is adapted from Farber et al. 2006. Some changes are based on our opinion on appropriateness of some techniques for some services.

valuation literature, directly addresses the need to measure social values in a group context. In many applications, the full suite of ecosystem valuation techniques will be required to account for the economic value of goods and services provided by a natural landscape.

Not all ecosystem services listed in Table 4 were readily valued; for some services no valuation studies have yet been conducted. Very important services such as climate regulation, genetic resources, and spiritual and historical significance have low valuation amenability. In addition, nutrient cycling usually receives relatively low values even though life on the planet would not be possible without it.[50]

The diverse structures and processes associated with the landscapes creating ecosystem goods and services that benefit people are linked together. Once valuable ecosystem services are identified, values for some of these goods and services can be assessed where valuation techniques exist. It is easier to note that a service is valuable to people than to attach a dollar value to it. In economic terms, the natural assets of the landscape can yield direct (fishing) and indirect (nutrient regulation) use values as well as non-use (preservation) values of the system. Once accounted for, these economic values can be aggregated to estimate a more complete value of benefits that the landscape provides.

Methodology

Value Transfer Method

A value transfer study appraises the value of ecosystem services in a geographic area based on previously conducted primary valuation studies. Individual primary valuation studies are generally conducted for one or a small number of services in one ecosystem or land-use type using the methods described above. These local studies are precise for individual ecosystem services, but are incomplete, lacking the scope across ecosystems and services necessary to be instructive for policy work at a landscape scale. Conducting primary research for the Mississippi River Delta and examining a wide number of ecosystem services across ecosystems would require over 50 primary studies to cover the full suite of ecosystem services across each vegetation type. It would require an enormous budget and take many years of research. Primary studies are required, and must proceed. The need for more comprehensive value estimates of these values, which can be useful for policy decisions, gave rise to the value transfer method.

Value transfer method involves using existing on-site or, if unavailable, off-site primary valuation studies or data to estimate the value of ecosystem services. Following Desvouges et al., this study uses the term 'value transfer,' instead of the more commonly used term 'benefit transfer,' to reflect the fact that the transfer method is not restricted to economic benefits and can include the analysis of potential economic costs as well as value functions themselves. The transfer method involves obtaining an economic estimate for the value of non-market services through the analysis of a single study, or group of studies, that have been previously carried out to value similar services. The transfer itself refers to the application of values and other information from the original 'study site' to a new 'policy site'.[51]

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[50] UNEP, 2005

[51] Desvouges et al., 1998; Loomis 1992; Smith 1992

This methodology is much like a house appraisal. An appraisal is conducted to provide an estimate of the house's value before the house is put up for sale. A very rough "appraisal" of the house's value can be provided by examining the values of similar houses in the neighborhood or other similar areas and by taking into account particular characteristics, such as an extra bedroom or a bad roof.

Public agencies are increasingly using the value transfer method to inform landscape management decisions.[52] Despite acknowledged limitations, such as context sensitivity of value estimates, existing studies provide a credible basis for policy decisions involving sites other than the study site for which the values were originally estimated. Using the studies that bound low and high values reflects the uncertainty that is implicit to using valuation studies that are older or from another site. The critical underlying assumption, just as in a house appraisal, is that a range in the economic value of ecosystem goods or services provided by existing valuation studies can encompass the site value with sufficient accuracy to be useful. Without this methodology, decision makers have in effect ascribed a zero value to natural services over the past decades.

The accuracy of the value transfer technique improves with increases in the richness, extent and detail of information of the source literature.[53] With the increasing sophistication and number of empirical economic valuation studies in peer-reviewed literature, the value transfer method has become a practical way to inform decisions when budget and time constraints preclude full primary data collection.[54] Although the literature is yet far from complete, the Mississippi River Delta has one of the world's richest collections of primary research on ecosystem service valuation for wetlands. The reference section includes studies by Day, Costanza, Farber, Boesch and others.

There are two parts to this economic analysis. The first part shows the value of ecosystem services from wetlands, with some of the data filled in with studies from wetlands other than the Mississippi River Delta. We also provide similar value transfer results from ecosystem services for non-wetland ecosystem types within the coastal zone that will be affected by loss of wetlands and will therefore be less habitable in the coming decades. Ecosystems and their services will be less valuable to people in the coastal areas if they can no longer live there. Many ecosystems are already less functional, as in the case of fresh water lakes, due to wetland loss and saltwater intrusion.

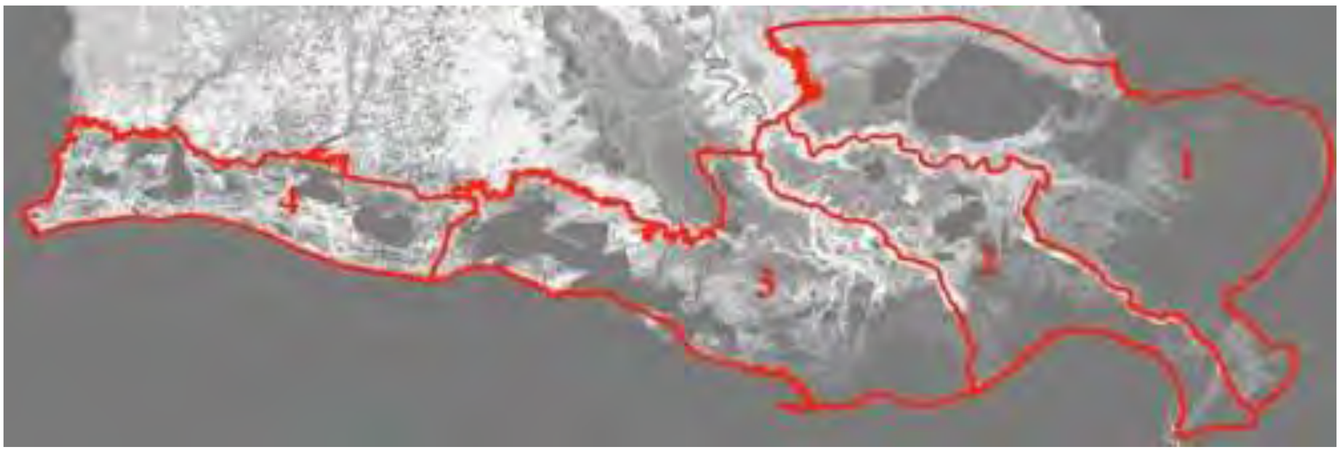
We then synthesize results and primary data on wetlands functions and values to come up with a value for the specific ecosystem services and functions for which there is Louisiana-specific information. This approach leads to a range of values that carry fewer uncertainties associated with economic results transferred from different sites. These results are underestimates; they provide a high quality "lower bound" set of values of ecosystem services for coastal wetlands in the Mississippi River Delta.

[52] Downing & Ozuna, 1996; Eade & Moran, 1996; Kirchoff et al., 1997; Smith, 1992, Troy and Wilson, 2006
[53] See Spash and Vatn, 2006 for an alternative perspective
[54] Kreuter et al. 2001; Moran 1999

Area of Study and GIS data

Figure 3 shows the geographic boundary of our study area. The Mississippi Deltaic Plain (Units 1-3) and the Chenier Plain (Unit 4) are divided into four subprovinces or units by the U.S. Geological Survey and the State of Louisiana. This includes the wetlands and upland ecosystems that are valued in this study.

Figure 3. Geographic Boundary of Study Area



Source: USGS

Units 1, 2 and 3 form part of the Mississippi River Delta while unit 4 holds the Chenier Plain. All four units comprise the Mississippi River Delta in this report.

Geographic Information Systems (GIS) data for six wetland types in the four subprovinces of the Mississippi Deltaic and the Chenier Plains were used based on 2000 data provided by the US Geological Service.[55] Table 5 shows acres of wetland type by subprovince.

Table 5. Acres of Wetland by Type and Subprovince

Subprovince	Fresh Wetlands	Intermediate Wetland	Brackish Wetlands	Saline Wetlands	Shrub/Scrub Wetlands	Wetland Forest
1	75,388	137,084	154,070	126,484	31,268	345,465
2	168754	78,650	63,603	123,327	22,260	286,864
3	337,266	277,118	134,583	31,032	16,915	10,416
4	295,690	168,080	195,189	140,717	50,823	388,815
Total	**877,099**	**660,933**	**547,445**	**421,561**	**172,106**	**10,311,561**

[55] Kreuter et al. 2001; Moran 1999

Ecosystem Service Valuation Studies

Ecosystem service values were derived from delta-specific data for eight ecosystem services. These are carbon sequestration (gas regulation, see Table 1), water quality (nutrient regulation), water supply, fisheries (food provisioning), fur and alligator production (raw materials production), recreation (cultural and information services), storm protection (disturbance regulation) and cultural value. Details of how we calculated service values or which ones we chose from the literature follow. Louisiana-specific data were not available for all ecosystem services. To provide a more complete estimate, the values for other ecosystem services were based on studies conducted outside Louisiana. Part II of this study discusses the valuation of ecosystem services.

PART II: The Value of Mississippi River Delta's Natural Capital

Mississippi River Delta Ecosystem Services

Below are descriptions of the subset of the ecosystem services identified in Table 2, which were considered in this study. The function of the ecosystem service and the economic value derived are discussed. Ecosystem services often have multiple benefits within each category; it may be possible to value only one or two of these multiple benefits. For example, while wetlands may provide recreation in the form of hunting, fishing, boating, birding and swimming, only one of these benefits may have actually been quantified. This is one reason economists typically view most valuation estimates as conservative.

Water Supply

While some rely on groundwater, most communities in southern Louisiana rely on fresh surface water for their water supplies. Wetlands protect the water supplies of coastal communities by preventing the intrusion of salt water into surface and groundwater supplies. As wetlands retreat, saltwater moves through open water areas where wetlands once existed or seeps into freshwater aquifers, contaminating surface and underground waters. Farber estimates the cost for groundwater-dependent communities to develop alternative sources under future wetland loss scenarios. Farber uses the replacement cost method for groundwater-dependent communities to develop pump and main infrastructure that would deliver water from other communities.[56]

Laska notes that communities that depend on surface water from rivers and bayous rely on coastal wetlands to prevent saltwater intrusion. Laska does not provide economic value estimates for this service. Wetland loss will mean increased salinity problems for these communities.[57] Figures for this service were derived from the replacement cost of desalinization plants for 19 coastal parishes in Louisiana and the population of 2.2 million people they serve. Desalinization of brackish water is less expensive than estuarine saltwater. Assuming that the average American uses 90 gallons of water per day, this amounts to an annual 72.3 billion gallons of water use in the Louisiana coast. Using figures from the American Water Works Association, a "low" cost of $1.50/1000

[56] Farber, 1996
[57] Laska, 2005

gallons and a "high" cost of $4/1,000 gallons were established. This gives values of $46.67 and $124.47 on a per acre-year basis in 2007 dollars.[58]

Some economists argue that replacement costs provide "upper bound" estimates of ecosystem services values. The replacement cost method is appropriate for valuing the water supply functions of the Mississippi River Delta's wetlands because there are no other alternatives except human-engineered replacements for the provision of freshwater to many communities. In addition, human-built systems, such as a desalinization plant, are more vulnerable to hurricanes damage. Thus the replacement costs may be considerable underestimates because a plant may be destroyed prior to the expected lifetime of the facility. Built replacement options, such as desalinization, are in fact more vulnerable to damage or destruction under conditions of wetland loss. Thus, replacement cost method for human-engineered systems may greatly underestimate the true costs of supplying drinking water.

Water Quality (Nutrient Regulation)

Excess nitrogen, phosphorous, bacteria such as fecal coliform, and other pollutants in water reduce the quality of water for drinking, recreation, agriculture and industrial purposes. Wetlands have a very high capacity to absorb and process excess nutrients as well as destroy harmful bacteria. The Mississippi Delta wetlands absorb nutrients and reduce the "dead zone" or hypoxic area in the Gulf of Mexico (further discussed below). Wetlands are eutrophic systems that are able to process large quantities of nitrogen and phosphorous and rapidly sequester carbon. These benefits are provided throughout the Mississippi Delta.

Many coastal Louisiana studies have examined nutrient removal, primarily as a substitute for tertiary sewerage treatment by towns and industries particularly using swamp forests.[59] Wetland-based filtration provides the benefit of being much less energy intensive than "traditional" wastewater treatment;[60] it can also increase the growth rates and carbon sequestration[61] by bald cypress.[62] More than 15 communities in coastal Louisiana have wetland assimilation systems. These systems proved to be far more resilient to hurricane damage than traditional systems. New Orleans is now pursuing what will be the largest wetland treatment system in the U.S.; it will use wastewater to fertilize 30,000 acres of bald cypress swamp that will in turn be a critical hurricane buffer for the city.

Economic values for wetlands depend on state and federally imposed water quality standards. Most rely on the replacement cost method. These regulatory water standards are attempts to internalize pollution costs and are related to the socially acceptable levels of health standards. Farber provided an extrapolation of the benefits of nutrient removal for all towns in the coastal wetland zone where treatment is a viable option.[63] This study did not include New Orleans, which is adopting wetland sewerage treatment. Rather than per-acre values, he used present value for the entire coastal wetland zone under different discount rates. In a literature review, Kazmierczak provided mean, median, upper and lower bound (the Farber paper) per-acre estimates of the value

[58] AWWA, 2007

[59] Breaux, Farber & Day, 1995; Cardoch, Day & Kemp, 2000; Kazmierczak, 2001; Day et al., 2004; Ko et al., 2004

[60] Ko et al., 2004

[61] Millennium Ecosystem Assessment, 2005

[62] Hesse Doyle & Day, 1998

[63] Farber, 1996

of wetlands for water quality ($2.85-$5,674/ac-yr range; $975 mean, $281 median for Louisiana 2000 dollars; 2007 are $3.44, $6,832.35, $1,217.96, and $338.37).[64]

Using wetland assimilation also reduces CO_2 release to the atmosphere because these systems are much more energy efficient. Thus wetland assimilation reduces CO_2 release because these systems are more energy efficient. It also enhances carbon sequestration through below and above ground plant growth.

The gulf hypoxic zone at the mouth of the Mississippi River is a related nutrient management problem for the Gulf Coast. Mitsch et al. estimate that reconnecting the Mississippi River to its floodplain would absorb 50,000-100,000 metric tons of nitrogen per year.[65] Nitrogen enrichment also enhances tree stem growth by 23-80%, increasing carbon sequestration.[66] Shrinking the hypoxic zone would also improve fisheries productivity. The complexity between weather and climate patterns, hypoxic zone size, wetland loss, individual species life cycles and habitat requirements make fisheries improvement difficult to estimate.[67] Thus, despite the high likelihood of an important economic linkage between hypoxia and fisheries an estimate on the value of shrinking the hypoxic zone to improvements in fisheries is not included here. This value is highly spatially dependent, with high-value areas for treatment concentrated around human settlements and industrial areas, and likely lower background values for hypoxia reduction throughout the wetlands.

This analysis uses the median $281/acre as a low value and $1,217.96/acre as a high value. There are studies that show far higher values for effluent treatment services. For instance, the $6,224.27 derived from a commercial potato chip plant for effluent treatment is too specific and too small a scale to extrapolate to the entire Louisiana coastal zone.

Fisheries Production

Costanza et al. use a production function developed by Lynne et al. for fisheries production in Louisiana where catch predictions are based on marsh acreage and catch in the previous year and harvesting effort in the current year.[68] Costanza et al. estimate that the per-acre wetland value for brown and white shrimp, menhaden fish, oyster and blue crab total to $25.36/acre/year using 1983 prices ($48.10 2004 dollars).[69] Farber estimates per-acre values of $36.93-$51.52 in 1990 dollars ($58.58 low, $81.73 high in 2007 dollars).[70] Since Farber's range of estimates includes those of Costanza et al., we used Farber's low value for the low value for this category. These figures do not include all of the fish and shellfish species and production from the Mississippi Delta nor the value of fish reared in the Mississippi Delta but caught elsewhere in the Gulf of Mexico. More recent fisheries data available from several sources[71] can be used to update the estimates from Costanza et al. and Farber. Thus, these provide good estimates of the lower boundary. For the high value, the meta analysis mean

[64] Kazmierczak, 2001
[65] Mitsch et al., 2001
[66] Day et al., 2003
[67] Chesney et al. 2000
[68] Lynne et al., 1981
[69] Costanza et al., 1989
[70] Farber, 1996
[71] See Chesney et al. 2000, Gramling and Hagelman 2005, Lindstedt 2005

for the fisheries production value of wetlands derived from an econometric analysis of 39 studies is adapted from Woodward and Wui at $1,233.49 in 2007 dollars.[72]

Raw Materials: Wild Fur and Alligator Production

Many raw materials produced in the Mississippi Delta, including timber, are not included in the value for this study. For this category, only fur and alligator production was included from the harvest estimates of the Louisiana Fur and Alligator Advisory Council that keeps annual harvest data by species. Assuming that muskrats come from brackish and intermediate marsh, nutria and raccoons from freshwater marsh, and alligators from fresh, intermediate and brackish marsh, harvests for these species can be valued on a per-acre basis. The 2004-2005 harvests and prices provide the low values for this category while the 10-year average values from 1995-1996 to 2004-2005 harvests and prices provide the high values.

Costanza et al. previously used estimates of 0.98 muskrat pelts/ac from brackish and intermediate marsh, and 0.88 nutria pelts/acre from freshwater marsh. They use 1980-1981 values of $6 per muskrat pelt and $7 per nutria pelt, for a total value per acre of $12.04.[73] However, the fur market collapsed in 1987-1988, making these values inappropriate for today's use. More recent data show values of over $1 million per year for trapping pelts and meat between 1993 and 2002 in Louisiana.[74] Of this harvest, 71% of commercial value came from nutria, 18% from raccoon, and 11% from other mammals, including muskrat. The low value used in this study is $4.74/acre/year and the high is $5.38/acre/year.

Carbon sequestration

Carbon sequestration as used in this study refers to the ability of vegetation to take up carbon dioxide through photosynthesis and store it for long periods of time in their woody tissues, in the soil, or in both. There are two parts to valuing carbon sequestration: establishing how much carbon is sequestered each year and establishing a dollar value for that sequestration service.

Herbaceous wetlands store large amounts of carbon in the soil while forested wetlands store it in both woody tissue and in the soil. Chmura et al. found median carbon uptake rates for all wetland types and the median carbon uptake rate to be 186 g/m^2/year. The uptake was greater in fresh to intermediate marsh than in brackish to salt marsh. Fresh and intermediate marsh had lower soil carbon density.[75] Choi et al. found far higher soil carbon sequestration rates than Chmura in salt marsh (2900 g/m^2) and in brackish to intermediate (1300-1500 g/m^2).[76] These results are specific to the Barataria Basin in coastal Louisiana. These marshes had the Net Primary Productivity (NPP) of 1,000-4,000 g C/m^2-year. This is much greater than that of the surrounding upland forests, which are estimated at 200-1,000 g C/m^2-year. Due to sulfate reduction, salt marshes do not generate significant methane. Yu et al. showed that mature Louisiana swamp forests accumulate

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[72] Woodward and Wui, 2001
[73] Costanza, Farber & Maxwell, 1998
[74] Lindstedt, 2005
[75] Chmura, 2003
[76] Trulio, 2007

carbon, but that atmospheric methane release offset these gains.[77] Sea level rise may cause upland forests to transition into swamp forests, affecting their greenhouse gas balance. Day et al. showed tree stem growth enhancement of 23-80% under enhanced nutrient conditions in swamp forests.[78] Day and Kemp[79] have produced more recent estimates of marsh and wetland forest carbon sequestration rates which show degraded marsh sequestering 4.5 tons CO_2/acre/year, healthy marshes sequestering 11 tons CO_2/acre/yr, and wetland forests sequestering 10 tons CO_2/acre/year with forests enhanced with waste assimilation sequestering up to 25 tons CO_2/acre/year including both above and belowground sequestration. Full analysis with methane production is not yet complete.

There is a significant range in carbon sequestration depending on the health of the wetland or forested wetland. For this study we use the Day et al. low value, which assume that all wetlands are in a degraded state of 4.5 tons CO_2/acre/year for the low value of all wetland types and shrub/scrub wetlands. This study uses 11 tons CO_2/acre for the marsh high value, which is also in line with the findings of Choi et al. We use the Day et al. value of 10 tons CO_2/acre/year for the high and low of wetland forest carbon sequestration as this includes both above and belowground sequestration.

For a dollar value per ton of CO_2 sequestered, a low value of this service inclusive of both a market and social cost is provided by Pearce & Pearce who recommend the use of $10/ton ($11.71 in 2007 dollars) of carbon sequestered as a conservative estimate.[80] Such a market does not exist yet.[81] The Stern Report, probably the most widely quoted economic report on climate change, established a social cost value of $85/ton. This value is used for the high value.[82]

Market prices for a ton of carbon based on voluntary markets fluctuate dramatically, making it difficult to determine a clear market value for CO_2. Being voluntary and without full participation of all CO_2 emitters, the market price of the Chicago and European trading systems do not reflect full market prices. Both markets have fluctuated greatly. At the European Union Emissions Trading Scheme, carbon prices rose to $36/ton early in 2006 and fell to under $3/ton by spring 2007.[83] The Chicago Climate Exchange priced carbon at $4/ton in 2007 and $8/ton in 2006.[84] Voluntary carbon markets in the United States have sold carbon "offsets" at prices ranging from $5-25/ton with an average of $10/ton.[85]

Although carbon markets are yet at early stages of development, the science is clear. Removing carbon from the atmosphere will reduce global warming and help secure the valuable ecosystem service of better climate stability reducing draught, floods, storms and broad climate shifts.

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[77] Yu & DeLaune, 2006
[78] Day et al., 2003
[79] Day and Kemp manuscript
[80] Pearce & Pearce, 2001
[81] Zhang (2000) provides similar estimates for an "ideal" global market - at $11.23-14.74/ton C.
[82] Stern Report
[83] Ecosystem Marketplace, 2007
[84] Chicago Climate Exchange, Mar. 2006; Chicago Climate Exchange, Sept. 2006
[85] Clean Air-Cool Planet, 2006

Recreation

Numerous studies have estimated the recreational benefits of coastal Louisiana's wetlands. Most of these studies give a present value for each acre of wetlands or the entire coast. Since Bergstrom et al. provide a per-acre-year value and the different studies find values to be similar, Bergstrom's value of $147.57/acre/year is used here.[86]

Bergstrom et al. similarly used TC and CV across seven parishes. They estimated a value of $224.21/ha-yr for marshland only in the study area ($147.57/acre/year in 2007 dollars). Bergstrom et al. stratified their sample for sites in fresh and saltwater marsh, at high and low-density recreation sites and across an east-west gradient. Unfortunately only total values were reported since these would be useful distinctions for recreational valuation across coastal Louisiana. Farber modeled recreational loss under wetland decline as a function of willingness to pay, quality of the experience and population, and projects declining values as fishing and hunting quality falls.[87] Bergstrom et al. found values for fishing on the lower Atchafalaya almost identical to Bergstrom et al. 1990, supporting the use of similar values for the entire Louisiana Coast.[88]

Storm Protection (Disturbance Regulation)

If there is one area that exemplifies the rapid increase in value of ecosystem services, it is storm protection value. It also shows how our understanding of ecosystem services improves with time as wind and storm surge damage area included in the most recent analysis. Storm protection refers to the function of wetlands in reducing storm energy and storm-generated water surges that cause flooding. This ecosystem service is very important to residents of the Mississippi Delta, the Gulf of Mexico and U.S. Eastern Seaboard.

Farber and Costanza first estimated wetland value for hurricane protection from wind damage at $63,676/mile strip of wetlands (1980 dollars), with a present value of $23/acre discounted at 3%.[89] Martinez et al. developed a study about the coasts of the world, estimating a value for the ecosystem services provided by terrestrial and aquatic ecosystems. They estimate in 2004 dollars $\$436.3*10^9$ per kilometer per year for permanent wetlands in terrestrial ecosystems and $\$24,364.72*10^9$ per kilometer per year for the whole aquatic ecosystem including coral reefs, mangroves, sea grass, coastal shelf, swamps-floodplains and estuaries.[90] Costanza et al. provide estimates for both wind and flood damage; Farber provided estimates for capital, land and maintenance costs associated with levee construction and property loss from wetland disintegration.[91]

In a 2008 study, Costanza et al[92] provide the most timely and accurate value estimates for storm protection values. Their analysis includes Hurricanes Katrina and Rita. They use estimates of spatially explicit GDP (flows of value from built capital at risk) along with storm probabilities to model value per hectare for gulf and Atlantic coast states. They estimate the value of wetlands for storm protection in Louisiana at $3,446/hectare/year (2007 dollars - $1,530.82/acre). It is highly probable that this figure will rise with Hurricane Gustav. Future

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[86] Bergstrom & Stahl, 1993; Bergstrom et al., 1990
[87] Farber, 1996
[88] Bergstrom et al., 2004; Bergstrom et al., 1990
[89] Farber & Costanza, 1987
[90] Martinez et al., 2007
[91] Costanza et al., 1989; Farber, 1996
[92] Costanza et al., 2008

estimates may refine values spatially by examining the differences in built capital across Louisiana's coast from east to west.[93] Given the importance of the 2008 Costanza et al. study, we appended their methods section to this report.

Our understanding of the storm protection value of wetlands is increasing rapidly. Wetlands tend to be most effective at reducing the storm surge of hurricanes where the storm surge is most intense. Thus, they likely provide a higher value than estimated here. In addition, the vegetation of wetlands reduce hurricane storm surge in three ways: they reduce the height of the storm surge directly with the drag of vegetation thus holding water back, they physically slow the movement of the storm surge forward thus allowing for greater dissipation of the storm surge, and they physically rob the hurricane of the ability to pull up water into the storm surge.

Wetlands reduce the wave action of the storm surge, thus protecting levees from pounding waves and increasing the effectiveness and lifespan of levees. The full value of these preventative and protective benefits has not been fully valued. Costanza's analysis provides a tremendous improvement and is the best estimate of the value of wetlands for reducing storm surge to date.

Other important ecosystem services for which adequate results or data from Louisiana could not be found include aesthetics, habitat for threatened and endangered species, and cultural values. Values from other studies on wetland ecosystems from other parts of the country and of the world were substituted to provide estimates for these services.

Other Wetland Ecosystem Values

Values for endangered species habitat[94] and aesthetics,[95] adjusted to 2007 dollars per acre per year, were adopted from original peer-reviewed studies. Values for gas regulation (distinct from carbon sequestration) and water flow regulation were adjusted to 2007 dollars per acre from 1994 dollars per hectare.

Water Flow Regulation: Flood Protection

Wetlands provide protection from the wind and storm surge of hurricanes from the Gulf of Mexico and flood protection from waters flowing from the Mississippi River Basin. Across a geographic area the physical functions provided by the wetlands may be similar. However, the valuable service provided to people varies with where people live and the value to them. Value is then distinct from function. This section discusses the flood protection value of the Mississippi Delta, which is unique in North America due to the size of its drainage area and the levees on the Mississippi River. Both built structures and natural ecosystems in the Mississippi Delta provide flood protection benefit for areas downstream and for the cities upstream in the Mississippi Basin by receiving floodwaters out of the Basin and effecting more rapid drainage.

The Mississippi River used to flood 50 miles wide on either side of the river. Over the decades the Army Corps of Engineers has leveed the main stem of the Mississippi River and separated the river from the wide flood

[93] Costanza & Farley, 2007
[94] Kazmierczak, 2001b
[95] Thibodeau, 1981; Mahan, 2000

plain. In addition the Corps corked rivers that distributed water out of the main stem of the river and into wetlands and the Gulf of Mexico. The 2008 record flooding along the Mississippi River in the Midwest was not caused from water rushing down and flooding cities from the upper watershed down, but from the Mississippi River backing up into tributaries to flood cities like Cedar Rapids, Iowa. This flooding results from engineering actions like confining the river too tightly within levees and separating the river from its floodplain. All the surface water that flows through the 1.2 million square miles of the Mississippi River Basin draining over 40% of the continental U.S. is funneled to the Old River Control Structure in Louisiana. Before the levees were built, the Red River and many other rivers branched off from the Mississippi River to distribute water across the Mississippi Delta. Tributaries are rivers that come together to form a larger river while distributaries are rivers branching out in the delta to distribute the river's waters and sediment across the delta.

The Old River Control Structure divides the waters of the Mississippi River sending them down two great distributaries, not yet cut off by levees, the lower Mississippi River and the Atchafalaya River. They finally enter the Gulf of Mexico at the Birdfoot outlet and Wax Lake Delta. River diversion structures act as controlled distributaries letting water and sediment flow into the deltaic plain and reducing flooding on the main stem upstream and downstream. Diversions increase the capacity of water and sediment to escape into wetlands, which then lowers the main stem water level allowing floodwaters further upstream to drain more quickly. Wetlands both absorb water and further move water in a sheet flow toward the Gulf of Mexico. This also reduces damage to levees and flood protection structures upstream and downstream.

During flood periods, the Old River Control Structure diverts far greater amounts of water and sediment down the Atchafalaya River and through a vast floodway and expanse of wetlands to relieve flooding pressure far upstream in the Mississippi River and to protect New Orleans and other cities downstream. Mississippi Delta wetlands provide high value flood protection by receiving these floodwaters. Without this "uncorked" area available to contain a tremendous quantity of floodwaters, flooding would be greater and longer lasting in the Midwestern U.S. Ultimately cities like Chicago are dependent on the Mississippi Delta as the outlet for water and some flood reduction benefits. Both in water quantity and the vastness of area served, the Mississippi Delta is absolutely unique in the provision of flood protection in North America.

In addition, although coastal areas are sparsely populated, the value of these wetlands may be more similar to wetlands providing benefits to urban areas. The Mississippi Delta houses extremely high value oil and gas infrastructure. Delta wetlands protect oil and gas production facilities, pipelines and refineries providing over a quarter of U.S. domestic oil and gas supplies. Wetlands provide flood and storm protection to oil infrastructure by reducing erosion and damage to pipes buried within the wetlands and by buffering other infrastructure from flood (and storm) waters. Hurricane Katrina revealed the vulnerability of both gas and oil pipelines by devastating enormous areas where oil and gas pipes had been exposed through wetland loss. Katrina caused 44 oil spill incidents with over seven million gallons of oil spilled.[96]

The full flood protection value of Mississippi Delta wetlands cannot easily be separated from the built structures, such as the Old River Control Structure and levees. There is great debate on how much local flood protection levees provide during low flood years and how much flooding they cause during peak flood years,

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[96] Llanos, 2005

like 2008 and 1993. Despite the critical importance of flood protection for safety and economic assets, few studies on wetland flood protection value exist.

There are no ecosystem service valuation studies in Louisiana that show the high value flood protection benefits of Mississippi Delta. In addition, there are no studies that examine flood protection over great landscapes such as the Mississippi River Delta or the extensive upstream flood protection benefits. There are no studies examining the value of these wetlands for protection of oil and gas infrastructure. The few studies that do exist primarily examine flood protection benefits provided by wetlands to nearby urban areas. The full flood protection that the Mississippi Delta provides upstream and downstream to public safety and economic assets such as oil and gas assets is perhaps one of the most important studies yet to be conducted.

The lack of local studies poses a problem in placing a dollar equivalent to the extensive flood protection value that the Mississippi Delta natural systems provide. This presents a difficult choice between excluding the value of a clearly high value ecosystem service the Mississippi Delta provides and using values from studies in other locations for comparison. How applicable these comparative studies are depends on the ecosystem service, the vegetation type and the site. Carbon sequestration provides a case of easy transferability. For instance, although they may be of different locales, similar forest ecosystems of similar structure and growth rates provide equal carbon sequestration functions. Carbon sequestration is of value in stabilizing the climate anywhere it takes place. The value is not dependent on the location. Here studies from distant but similar systems likely describe the value of carbon sequestration very well. Endangered species habitat, however, is more unique. The value of preserving one endangered species habitat on one continent may not transfer to another entirely unique species' habitat elsewhere.

The analysis in this paper is partial. More than a dozen ecosystem services identified as present and valuable in the Mississippi River Delta are not valued. This is largely due to a lack of local or comparable valuation studies. Overall, the study, analogous to a house appraisal, is an inexact approximation. In the authors' view, it is better to include an imperfect comparable value, than to simply give a highly valuable and clearly present asset a value of zero.

The flood benefit studies used in this analysis are for wetlands providing flood benefits to urban areas. These are wetlands in close proximity to urban areas with high value infrastructure. Although freshwater, intermediate and brackish wetlands all provide the function of flood protection, freshwater wetlands are most closely associated with urban areas. They also provide the greatest upstream flood relief, as in the case of the Atchafalaya basin. In this study, the greater values for flood protection are attributed only to freshwater wetlands and not to intermediate, brackish, or salt marshes.

A study by Thibodeau[97] values the flood protection of wetlands outside Boston at $6,539.19 per acre in 2007 dollars. Another study in Washington State examined two wetland areas (one near the city of Renton and the other near Lynnwood) establishing a per acre values with a low of $8,000/acre and a high of $51,000/acre.[98]

[97] Thibodeau et al., 1981
[98] Leschine et al., 1997

Flood and disturbance protection value is provided by all of the wetlands where they are protecting people, towns, oil and gas or other infrastructure. In this study, the mean value from Woodward and Wui was applied for the low value and the $6,539.19 value from Thibodeau was applied as high value for fresh marsh, shrub and forested wetlands. These wetlands are further inland and tend to be closer to cities and other built infrastructure; they contribute to the protection of cities further up the Mississippi Basin. Brackish and saline marsh still protect high value oil and gas infrastructure, towns and businesses on the coast; lower values based on the low values from Woodward and Wui were thus applied to these areas.[99]

Habitat Refugium
The Mississippi Delta is a tremendous area for aquatic and terrestrial wildlife. The area is a critical and irreplaceable stopover for migratory North American birds. The area provides valuable habitat to a number of endangered and threatened species. In addition, by providing sufficient habitat to keep other species off the threatened and endangered species lists, the Mississippi Delta relieves other jurisdictions in the continental U.S. of costly expenditures that would arise if these species were listed. No full study of the value per acre of provided by the Mississippi Delta exists. However, Kazmierczack provides the figures used here as the low and high values of $203.63/acre/year and $485.92/acre/year.

Upland Ecosystems

Despite the substantial number of economic valuation studies that have been completed for coastal Louisiana's wetlands, less work has been done for the region's upland ecosystems. As an initial effort to assess values for upland areas, the value coefficients from a project at the University of Vermont to estimate ecosystem service values for the state of New Jersey were utilized.[100] Although New Jersey has a different ecoregional and socioeconomic setting, it is a coastal U.S. state whose natural capital base faces pressure, albeit largely from development and not wholesale wetlands decline. The studies selected for the New Jersey value transfer exercise were selected from across the U.S. including some from the Mississippi Delta.

To round out our estimate of the value of Mississippi River Delta's natural capital when local data was not available and when other values were not present, the values from Costanza et al. were used[101] for the ecosystem services that more recent studies did not cover. Although these numbers are likely less accurate, we chose to use all available data to get a more complete picture and estimate. The greatest error of most valuation studies has been the omission of values for clearly valuable ecosystem services, thus significantly underestimating the value of benefits that ecosystem services provide to people. Further refinement of the value estimates for these upland ecosystems will improve the value estimates for the Mississippi River Delta. All values were converted into 2007 dollars using the Bureau of Labor Statistics' Consumer Price Index.

It is important to note that this study does not pick a single number as a value, it establishes a low and high value range. This helps us understand some of the inherent uncertainty held in this process. The most prevalent

[99] Woodward and Wui, 2001
[100] Costanza et al., 2006a
[101] Costanza et al. 1997

error is that of omission; for instance, agricultural land provides greater benefits but few studies examining them exist.

Although these express the range of possible values for each land cover type, each estimate is a composite value for all relevant ecosystem services where data is available; it is unlikely that a particular ecosystem would have the highest or lowest values for all ecosystem services.

Results and Discussion

Land cover Types, Ecosystem Services and Dollar Value Estimates

The next three tables provide an overview of results. Table 6 shows values per acre (in 2007 dollars) for all land cover types including wetlands and all ecosystem services for which data is available. It shows the dollar value per acre of each ecosystem service for each land cover type. The highest values per acre are provided by fresh water wetlands and forested wetlands at $3,200-12,000. All natural systems provide economic benefits. For some systems, there is far more valuation data available than for other systems. Generally, estuarine and open water systems are far less studied than wetlands and forested systems. Water regulation and storm protection benefits have the highest values per acre. Flood prevention and hurricane protection are two of the most important functions of coastal systems in the Mississippi Delta.

Forested wetlands provide the significant value for both low and high values in the Mississippi Delta. This is directly tied to the physical functions of these forests. Wetland forests provide strong hurricane protection value by slowing and reducing the storm surge and breaking up hurricane force winds at the surface where it is most important. Bald Cypress trees, for example, are excellent hurricane buffers because they are well buttressed by an extensive root system that provides tall, sturdy and highly resilient barriers to wind and water. They have evolved to withstand strong wind and water action. All of the marsh types provide hurricane buffering. Salt, brackish and intermediate marshes provide greater buffering value along the coastline. More research is needed to fully understand the mechanics of natural systems in buffering hurricanes.

The color codes in Table 6 correspond to the general source of academic valuation studies. Green indicates numbers derived from local Mississippi Delta data. We used other study references where there was no local data. Purple corresponds to figures used in the 2005 New Jersey study, most of which were derived outside New Jersey. Blue corresponds to the Kazmierczack 2001 wildlife value study. Pink corresponds to Costanza (1997) and yellow to studies from the Gund Institute for Ecological Economics database. Appendix A contains all of the references for the value transfer studies from which each of these figures is derived. Appendix B provides a table of the land cover type, authors, the type of valuation analysis conducted (one of seven valuation study types, avoided cost, contingent, etc.) and the high and low values in 2004 dollars which corresponds to the values in Table 6 (converted to 2007 dollars).

The greatest source of error is introduced by lack of data. Many of the boxes in the table are empty. In many cases, economically valuable services are clearly provided but no valuation studies have been conducted. This is the case for over 50 clearly valuable ecosystem service/land cover type combinations such as the value of wetlands for erosion control. Thus the high and low values are likely underestimates of the true high and low values of these systems. In a few cases, the service may not be provided, for example pollination in marine environments. Because there were no newer and better studies, many of the studies used here are over a decade old. Despite these shortcomings, this table to date provides the most comprehensive accounting of ecosystem services provided by the Mississippi Delta.

Table 6. Per Acre Values for Land Cover Types and Ecosystem Services in the Mississippi River Delta (2004 Dollars/Acre/Year)

	Fresh Wetland		**Intermediate Wetland**		**Brackish Wetland**		**Saline Wetland**		**Shrub-scrub Wetland**		**Forested Wetland**		**Open Fresh Water**		**Open Estuarine Water**		**Upland Shrub-Scrub**		**Upland Forest**		**Pasture/ Agriculture Land**	
Ecosystem Service Type	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Carbon Sequestration	35.14	382.52	35.14	382.52	35.14	382.52	35.14	382.52	52.71	382.52	117.12	850.05					5.81	7.32	11.60	14.63		
Atmospheric Composition Regulation	149.99	149.99	149.99	149.99	149.99	149.99			149.99	149.99	149.99	149.99					3.96	3.96				
Waste Treatment	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	308.45	1,174.05	376.70	376.70			49.28	49.28	49.28	49.28		
Water Supply	46.67	124.47	46.67	124.47	46.67	124.47	46.67	124.47	46.67	124.47	46.67	124.47	30.24	788.82	6.07	131.49			9.88	422.61		
Water Flow Regulation	612.14	6,539.19	141.27	612.14	141.27	612.14	141.27	612.14	612.14	6,539.19	612.14	6,539.19					1.70	1.70				
Storm Protection (Disturbance Regulation)	1,530.8	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82	1,530.82							1.13	1.13		
Food Production	58.59	1,354.00	58.58	1,354.00	58.58	1,354.00	58.59	1,354.00	58.58	1,354.00	58.58	1,354.00	23.23	23.23					28.32	28.32	34.28	34.28
Raw Materials Production	4.75	5.38	4.68	4.76	4.68	4.77			4.68	4.76									14.16	14.16		
Recreation	205.74	644.20	205.74	644.20	205.74	644.20	205.74	644.20	205.74	644.20	205.74	644.20	1.58	1,794.37	11.88	1,425.07	14.35	1,198.56	0.40	2,368.84	28.29	28.29
Aesthetic	74.74	239.07	74.74	239.07	74.74	239.07	74.74	239.06	74.74	239.07												
Pollination																	1.24	6.22	64.76	290.89	2.47	12.45
Soil Formation																	0.56	0.56	5.66	5.66	0.56	0.56
Nutrient Cycling																			204.49	204.49		
Erosion Control																	16.42	16.42	54.38	54.38		
Biological Control																	13.32	13.32	2.26	2.26	13.32	13.32
Genetic Resources																			9.08	9.08		
Habitat Refugium	203.63	485.92	203.63	485.92	203.63	485.92	203.63	485.92	203.63	485.92	203.63	485.92			1.39	365.30	0.60	298.26	1.15	596.51		
Cultural																						
Total	3,230.67	12,629.60	2,759.73	6,701.94	2,759.73	6,701.94	2,605.06	6,547.19	3,248.17	12,628.99	3,233.16	12,852.69	431.78	2,983.12	19.34	1,921.86	107.20	1,595.60	456.55	4,062.24	78.90	88.88

Table 7 shows the land cover types, acres of each land cover type, low and high value estimates per acre, and the sum of ranges in value these vegetation types provide on the Mississippi Delta. Thus, this study presents the low and high value estimates of ecosystem services that the Mississippi River Basin provides in one year. The range between the high and low total values – $25 billion – is substantial and reflects the uncertainty and differences in valuation studies. Both the low and high values are large and demonstrate that the natural systems in the Mississippi Delta provide valuable economic benefits. These natural systems are also highly efficient at providing this value. To replace them with built capital alternatives would be far more costly or impossible. In addition, if restored to health, these natural systems are self-maintaining and can, without charge, provide services, such as hurricane buffering.

The large values of wetlands and wetland forests in the Mississippi Delta primarily come from the water regulation and hurricane protection. These areas deserve further study. As is the case with all economic measures, this measure of value is not perfect. Like other aggregate economic measures such as the Gross Domestic Product, or total assessed property values, this analysis takes the marginal value per unit (dollars per acre) multiplied by the total number of units (acres) to estimate a "gross" total value. A better, far more difficult, and not yet developed measure would consider the dynamic nature of the change in value as trade-offs between these land cover types takes place. The Gund Institute for Ecological Economics is developing dynamic tools for this purpose.

The spatial distribution of services is another difficult issue. Not every acre of wetland provides equal amounts of storm protection value, as was assumed here. Because every storm differs in location, intensity, storm surge, wind speed, aspect to the coastline etc., the value of wetlands for storm protection will be different for every storm. With greater Geographic Information System data, and better predictive data on hurricane strength, location and occurrence as well as land cover types along the expected hurricane route and the lives and value of property protected would provide the basic information needed to improve this valuation. One advantage to increased coastal wetlands, as opposed to levees, is that a wide skirt of wetlands provides buffering against hurricanes approaching from any angle, speed, or storm surge height. The cumulative nature of wetland protection value is also not measured here.

Every individual acre of wetland provides differential benefits. As better techniques for valuation become available, this differential value will be better measured. However, most economic measures, such as the gross domestic product (GDP), are incapable of accounting for this individual difference in expressed value. Every new automobile of an identical make also provides differential benefits. For example, consider two new trucks of the same model sold for the same price, one performs poorly while the lasts for decades. They are valued identically in the GDP. A more useful economic measure of value would be based on the actual economic performance and benefit provided by each truck (analogous to the actual value an acre of wetland provides for hurricane protection). However, this would be impossible to calculate. Imperfect as it is, the GDP is a useful aggregate measure of value. Similarly, this report provides an aggregate value of natural systems in the Mississippi River Delta that can be improved upon. Although the values provided here are underestimates of the true value Mississippi Delta ecosystems provide, they meet the same basic standard of accepted economic measures and are certainly better than nothing.

Based on available data, the value of the services examined here and provided by the Mississippi Delta is estimated between $12-47 billion annually. Retaining and expanding this annual flow of benefits is good economics. Unfortunately, these benefits have been largely counted as zero for most of the last century.

Table 7. Total Value Based on Acreage for Each Ecosystem Type (2007 Dollars)

Land Cover Type	Acres	Low Value Estimate	High Estimate
Fresh Water Marsh	877,099	$2,833,616,569	$11,077,411,806.55
Intermediate Marsh	660,933	$1,823,993,642	$4,429,535,089.73
Brackish Marsh	547,445	$1,510,797,014	$3,668,942,825.58
Saline Marsh	421,561	$1,098,191,310	$2,760,038,549.65
Shrub-scrub wetland	172,106	$393,890,419	$1,531,460,185.19
Forested/Swamp Wetland	1,031,561	$3,335,203,387	$13,258,333,954.99
Open Fresh Water	992127	$428,346,204	$2,959,631,369.64
Open Estuarine Water	3,549,990	$68,661,717	$6,822,566,401.65
Upland Shrub-Scrub	84,799	$9,090,572	$135,305,795.41
Upland Forest	172,106	$78,575,469	$699,135,025.33
Pasture-Agriculture	481,575	$37,997,389	$42,802,567.96
Total	8,940,461	$11,953,060,333	$47,385,163,571.67

Table 8 shows the equivalent of an asset value for the economic benefits derived from Mississippi Delta's natural systems. This is the present value of the flow of benefits from these services in a 100-year period, shown for the four discount rates. The asset value of Mississippi Delta ecological systems (a partial value since not all ecosystem services were valued) varies from $237 billion at the low end using a 5% discount rate to $4.7 trillion if the benefits to people in the future are treated equally to the benefits we receive in the present over a 100-year period. This demonstrates that the natural capital asset value of the Mississippi River Delta is tremendous by any measure.

Since open water provides fewer benefits than land in this area, continued land loss will result in a decline in asset value. In addition, the dead zone reduces the value of estuarine waters within the area of study, thus providing a lower value. The reduced value on account of the dead zone was not included. The reality is that all ecosystems in the Mississippi Delta contribute value to citizens both within the delta and the nation. Local, state and national investment decisions should be informed by the value of natural capital.

Table 8. Present Value of Ecosystem Services over 100 years (2007 dollars).

Discount Rate	Low Estimate	High Estimate
0 %	1.2 trillion	4.7 trillion
2 %	513 billion	2.3 trillion
3.5%	330 billion	1.3 trillion
5%	237 billion	940 billion

The differences between these values depend on the discount rate chosen, as shown by Table 8. How value across time is treated, particularly in respect to renewable resources that provide value across vast amounts of time. A short discussion of how an "asset" value is calculated from the value of annual benefits that the Mississippi Delta provides and some of the implicit issues behind the choice of a discount rate follows.

The difference between an annual flow of benefits and an asset value is often not intuitive to non-economists. Consider first that ecosystems provide an annual flow of benefits, some of which can be expressed in dollar value as shown in Tables 6 and 7. From this annual flow of value, the value of the asset or the structure that produces that value can be estimated. This is analogous to comparing an annual mortgage payment for a house (the value of living in the house for a year) and the total "asset value" or price of the house.

A natural capital asset value is *analogous* to a built capital asset value because unlike a house or car, ecosystems the size of the Mississippi Delta cannot be bought or sold as a whole asset and because many of the most important benefits are public goods and services which by their physical nature (like oxygen in the air or hurricane buffering) cannot be bought or sold in markets. However, just as the value of a "built capital" asset can be calculated from the annual flow of net income it produces (annual flow of value) a "natural capital" asset value of the Mississippi Delta can also be calculated from the estimated annual flow of benefits that it provides.

Calculating the present value of an asset requires the use of a discount rate. Discount rates measure the extent to which people value benefits in the present versus benefits at a future date. Current environmental economics literature yields a healthy discussion about whether or not to use discount rates and what rate should be applied to calculate the value ecological assets over time;[102] there is a variety of alternatives to standard exponential discounting, including using declining rates[103] and "intergenerational" discounting which allows the assignment of different, lower discount rates for future generations versus the current generation.[104]

Renewable resources should be treated with lower discount rates than built capital assets because they provide a rate of return over a far longer period of time (potentially thousands of years or longer, for example, the ozone

[102] Azar and Sterner, 1996
[103] Newell and Pizer, 2003
[104] Sumaila and Walter, 2005

layer). It would be unwise and a tremendous economic blunder to treat value across time for the ozone layer's protection the same way we treat the useful life of a throwaway coffee cup. The discarded coffee cup provides no value to our grandchildren. Since the value of the ozone layer and a coffee cup are fundamentally different in importance and value to people across time, a coffee cop and the integrity of the ozone layer should be valued differently across time.

Natural capital, when healthy, is an appreciating and self-maintaining asset while built capital depreciates and requires active maintenance or it falls apart. This has profound implications for defining sustainability and how assets and investments are treated across time. The benefits that a natural asset provides are garnered across time, most in the distant future, whereas the benefits of built capital, such as a car or levee, are largely delivered in the immediate future, depreciating rapidly, with few or no benefits provided in the distant future. Both built and natural assets are necessary to maintain a high quality of life for people. What is more important now than at any time in the past, when natural capital was abundant, is how we balance investments in natural and built assets. In the past, investments in built capital have substituted for and damaged natural capital. In the future, wiser investments in both natural and built capital should be complementary. For example, wetland expansion protects levees and diversion structures enhance wetland restoration.

Discounting tilts valuation and decision making toward choices that pull the benefits into the present and push costs into the discounted future. High discount rates are biased toward investments that have a high and quick pay off, even though their value may quickly disappear and cause large and long lasting costs. Low discount rates give greater value to future benefits.

For simplicity, we use the four discount rates of 0, 2, 3.5 and 5 percent to underscore the difference in asset value depending on the value given to future benefits. A zero discount rate implies that we in the present hold future flows of ecosystem services to be just as important to people living in the future as the value of those assets are to us today. We limit the time horizon arbitrarily to 100 years for the zero discount rate. This is short sighted. Without limiting the time period the value of natural assets would be infinite, compared to any built capital asset that depreciates. This reflects the true nature of a potentially sustainable flow of value and an asset that falls apart and can only provide a finite flow of value. However, built capital provides important current benefits. A 2-3.5% discount rate implies that people today have a positive time preference so that what remains in the future is less important in meeting current needs than what we have today. It gives more value to the future than the 5% rate or greater, a range that is typically used to value built capital assets or to calculate expected rates of return on monetary investments.

The fact is that how we treat great amounts of value provided for long periods of time into the future is fundamentally an ethical decision; it cannot simply be left to a mathematical calculation based on today's prime interest rate or any other arbitrarily set discount rate.

To conclude this section, calculations of the present value of the flow of ecosystem services show that intact natural systems provide enormous value to society in the short and long term. While we currently need and enjoy the benefits, such as hurricane protection or the supply of drinking water, most of the benefits that healthy natural capital provides, like all renewable resources, will be gained in the future. The cumulative economic benefits from healthy, functioning natural capital across time and generations is tremendous.

At one time, we could assume that all natural capital was basically healthy and functioning well. This is no longer the case. For example, cypress trees cannot grow in saltwater. They will die off if saltwater intrudes through canals or coastal land loss in their area. The economic value that cypress trees provide, such as hurricane protection, will also be lost.

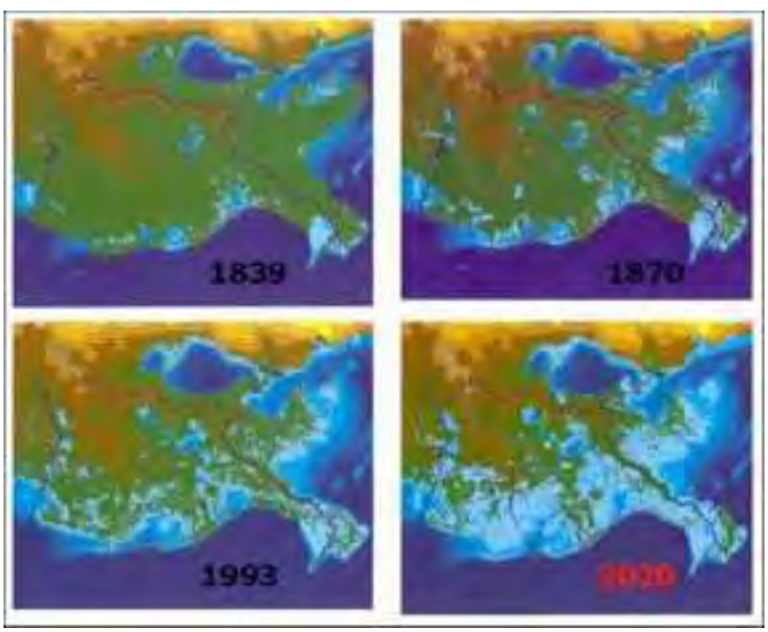
PART III: Lessons from the Delta's Physical Reality

This section examines the changing physical reality of the Mississippi Delta and its importance to the economy. It deals with observed and incontrovertible scientific facts which have very significant economic implications.

A Rapidly Shrinking Delta

After expanding for tens of thousands of years, the Mississippi River Delta started to shrink rapidly eight decades ago, losing over 1.2 million acres of land.[105] This trend continues. An increase in hurricane activity can accelerate this loss.[106] Without renewing the deltaic processes which built and maintained the Mississippi River Delta, land loss acceleration will continue. Land loss carries the loss of critical benefits, including hurricane protection. To understand the economics of the Mississippi Delta, it is important to understand the rates and patterns of land loss from the reduction of sediment and water, hydrological disruption, subsidence, how wetlands and barrier islands buffer against hurricanes, and the full suite of physical changes and their implications. Figure 5 shows the actual and projected loss of coastal wetlands between 1839 and 2020.

Figure 4. Loss of coastal wetlands: 1839 -2020



[105] CPRA, 2007b
[106] Barras et al., 2003

Rates and Patterns of Wetland loss

All deltas grow in some areas and deteriorate in others as the river deposits sediment in one lobe and then shifts sedimentation to another lobe. Sedimentation and wetland plant growth caused the Mississippi River Delta's net land expansion for thousands of years. However, its deterioration in the last 80 years showed a land loss as high as 24,710 acres per year[107] or a total wetland loss of over 1.2 million acres.[108] The land loss rates were highest in the 1960s and 1970s.[109] Current rates of loss were estimated before 2005 at 15,360 acres per year, still a high rate of loss, with a total expected loss of over 328,000 acres in the next 50 years.[110] However, hurricanes Katrina and Rita may have rewritten the estimates of potential land loss. The US Geological Survey stated in 2006:

> "Land transformed to water along the coast and on barrier islands further reduces Louisiana's natural protection from future storms. Louisiana had already lost 1,900 square miles of coastal lands, primarily marshes, from 1932 to 2000. The 217 square miles of potential land loss from the 2005 hurricanes represent 42 % of what scientists had predicted before Hurricanes Katrina and Rita would take place over a 50-year period from 2000 to 2050, even though they had factored storms into their model."

The USGS estimated that 138,000 acres of land were lost to open water due to the 2005 hurricanes.[111] Healthy wetlands are often horizontally compacted by hurricanes only to re-expand after the storm. Similarly, storms can actually benefit wetlands by bringing additional sediment in from the continental shelf. However, if wetlands are unhealthy, as is largely the situation along the coast, hurricanes can physically break them up or bring in saltwater.

As long as the landscape of the Mississippi Delta is deteriorating, the ecological services that are derived from that landscape and are vital to the economy and habitation will continue to deteriorate. A complex array of factors has led to land loss where there should have been a net gain. Human activities primarily caused land loss in the last 80 years.[112]

More than 1.2 million acres of land have been lost to open water with the coast receding 30 miles in some areas.[113] The main causes of this loss are the leveeing of the Mississippi River and the construction of oil, gas and shipping canals which allow saltwater to seep in from the coast thereby increasing salinity and killing freshwater wetlands. This introduced large interior open water areas. Waves attack and wash away land at the expanding land-water interface. Most land loss was in the interior for most part of the 20th century[114] but as wetlands opened up into large lakes, wave erosion has become more damaging.[115] Erosion and stress from the loss of fresh water and sediment inputs, combined with natural land subsidence and sea level rise, cause submergence and increase salinity, killing vegetation.

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[107] Gagliano et al., 1981
[108] Boesch et al., 1994
[109] Baumann & Turner, 1990; Britsch & Dunbar, 1993; National Biological Survey, 1994
[110] Barras et al., 2003
[111] USGS, 2006
[112] Boesch et al., 1994; Boesch et al., 2006; Day et al., 2000
[113] USGS, 2006
[114]Day et al., 2000
[115] Day et al., 2000; Barras et al., 1994

Reduction of Riverine Sediment and Water

The isolation of the Mississippi River from the deltaic plain was accomplished by levees that physically separate the river from the delta and severely damages the delta's health.[116] The Mississippi River is leveed up to its mouth to prevent overbank flooding and crevasse formation. The Old River Control Structure was designed to retain the main channel of the Mississippi River and prevent it from being captured down the Atchafalaya River, a shorter course to the Gulf of Mexico. Because of this, the Mississippi River runs to the edge of the continental shelf; most of the freshwater and sediment load that would have previously nourished the delta is now deposited in deep water. In addition, large quantities of freshwater and nutrients that would have once supplied marshes are lost to the Gulf of Mexico. The large amounts of nitrates that the Mississippi River has been discharging into the Gulf of Mexico has created another problem, a "dead zone" or oxygen-deprived "hypoxic" area which is about the size of New Jersey. Microorganisms use the nitrogen and remove the oxygen from the water. Wetlands are heavy nitrate consuming systems; increases in nitrates promote plant growth and carbon sequestration. Thus wetlands are far better recipients of nutrient-rich water than offshore marine ecosystems. There has also been a reduction of sediment in the river due to the construction of dams and reservoirs in the upper watershed.[117]

Hydrological Disruption of the Delta

There has been pervasive alteration of the Mississippi River Delta's hydrology; it has lost the familiar branching pattern of river deltas. Except for the Atchafalaya River, all the Mississippi River distributaries have been closed. More than 9,000 miles of canals have been dredged for navigation, drainage and logging, but mostly for oil and gas development.[118] These canals form a dense network that effectively changes hydrology and sediment transport in the coastal zone. Figure 6 shows an area, once completely composed of wetlands, crossed with canals and largely converted to open water. Spoil banks associated with canals also reduce the natural sheet flow of water.[119] Deep, straight navigation canals, stretching inland from the Gulf of Mexico to freshwater areas, have caused significant saltwater intrusion and killed vast areas of freshwater wetlands.[120] One of the most notable navigation canals, the Mississippi River Gulf Outlet which was dredged through the Breton Sound Basin in the late 1950s, has an average depth of 30 ft and width of 1,500 ft. Saltwater intrusion caused by MRGO has led to widespread land and freshwater wetland loss.

Katrina's path crossed Breton Sound and areas that were formerly wetlands and are now bounded by spoil banks (dirt accumulated from excavation) created by MRGO. This created a funnel effect for Hurricane Katrina's storm surge, further building it up in height and power and causing the catastrophic levee failure that flooded eastern New Orleans and St. Bernard parish. MRGO resulted in the death of over 10,000 acres of cypress forests in Orleans and St. Bernard Parishes. To prevent future funneling of hurricane storm surges, the U.S. Congress subsequently approved the closure of MRGO upon request by the Louisiana Legislature.

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[116] Day et al. 2000
[117] Kesel, 1989
[118] Day et al., 2000, and Day et al., 2007
[119] Swenson & Turner, 1987
[120] Day et al., 2000 and Day et al., 2007

Cypress forests are highly resistant to being blown down by hurricanes; they reduce storm surge and the wave generation on top of the surge. Had these forests been in place during Hurricane Katrina, the flooding would have been greatly reduced.

Figure 5. Network of Canals in the Mississippi Delta

Source: USGS

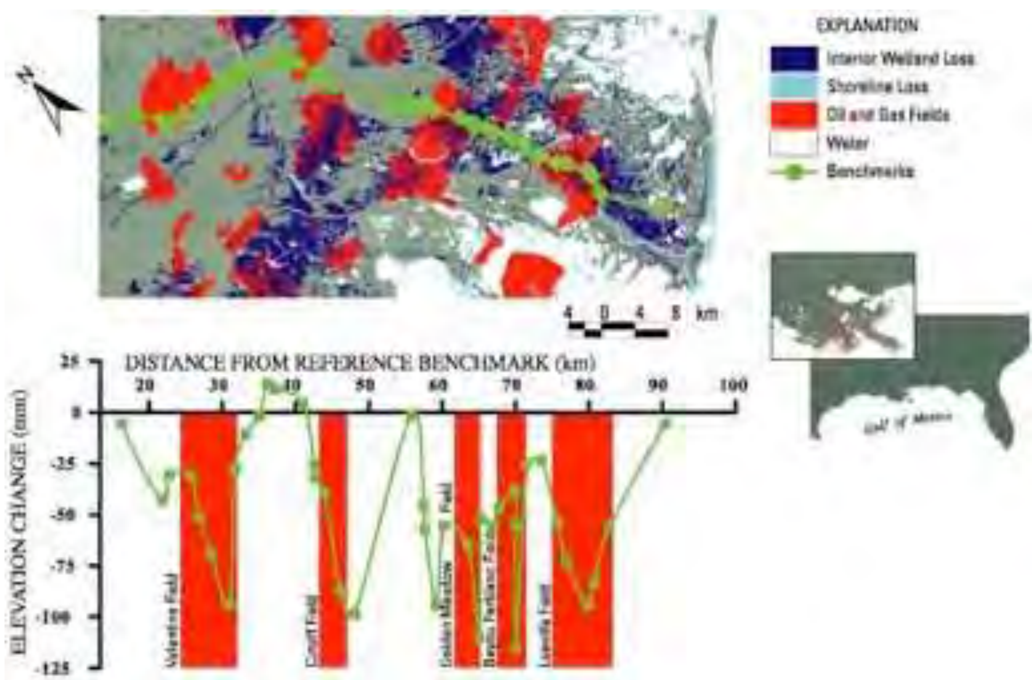
Subsidence

Natural subsidence of river deltas result from the compaction of loosely deposited sediments and dewatering. The Mississippi Delta, like other deltas, constantly subsides, sinking as sediment settles. However, the constant deposit of new sediments for thousands of years brought about a net gain of land and elevation.

Enhanced Subsidence from Oil and Natural Gas Production

Recent evidence from examining large areas of the coast shows that extraction of oil and natural gas increases the rate of land subsidence near oil and gas fields by two to three times, a critical factor contributing to land loss.[121] Morton, a former petroleum geologist who is now with the USGS, found that the highest rates of wetland loss occurred during or just after the period of peak oil and gas production in the 1970s and early 1980s. After much study, Morton concluded that the removal of millions of barrels of oil, trillions of cubic feet of natural gas, and tens of millions of barrels of saline formation water lying with the petroleum deposits caused a drop in subsurface pressure known as regional depressionism. That led nearby underground faults to slip and the land above them to slump downward. Morton does not give a percentage of wetland loss that can be attributed to oil and gas recovery.

Figure 6. Fossil Fuel Extraction and Subsidence



Source: Morton, Buster & Krohn, 2002

[121] Morton, Buster & Krohn, 2002

The upper area of Figure 6 shows the areas of oil and gas fields in a portion of the Mississippi Delta. Oil and gas fields are shown in red while shoreline and wetland loss are in blue. The graph along the transect shows the correspondence between areas of high elevation change (subsidence) and areas where oil and gas have been extracted.

Wetlands and Storm Surge Reduction

Hurricanes gain power over hot, open and deep water; they lose power over coastal barrier islands and wetlands. The Mississippi River Delta wetlands provide hurricane buffering, reducing storm surges. The storm surge of a hurricane is a circulating disk of water that is pulled up by the low pressure of the storm and moves with it. All storms are different but in a perfect storm, the highest point of the storm surge follows the hurricane's eye. As a hurricane approaches shore, the storm surge builds up enormous waves bringing in hundreds of billions of gallons of water.

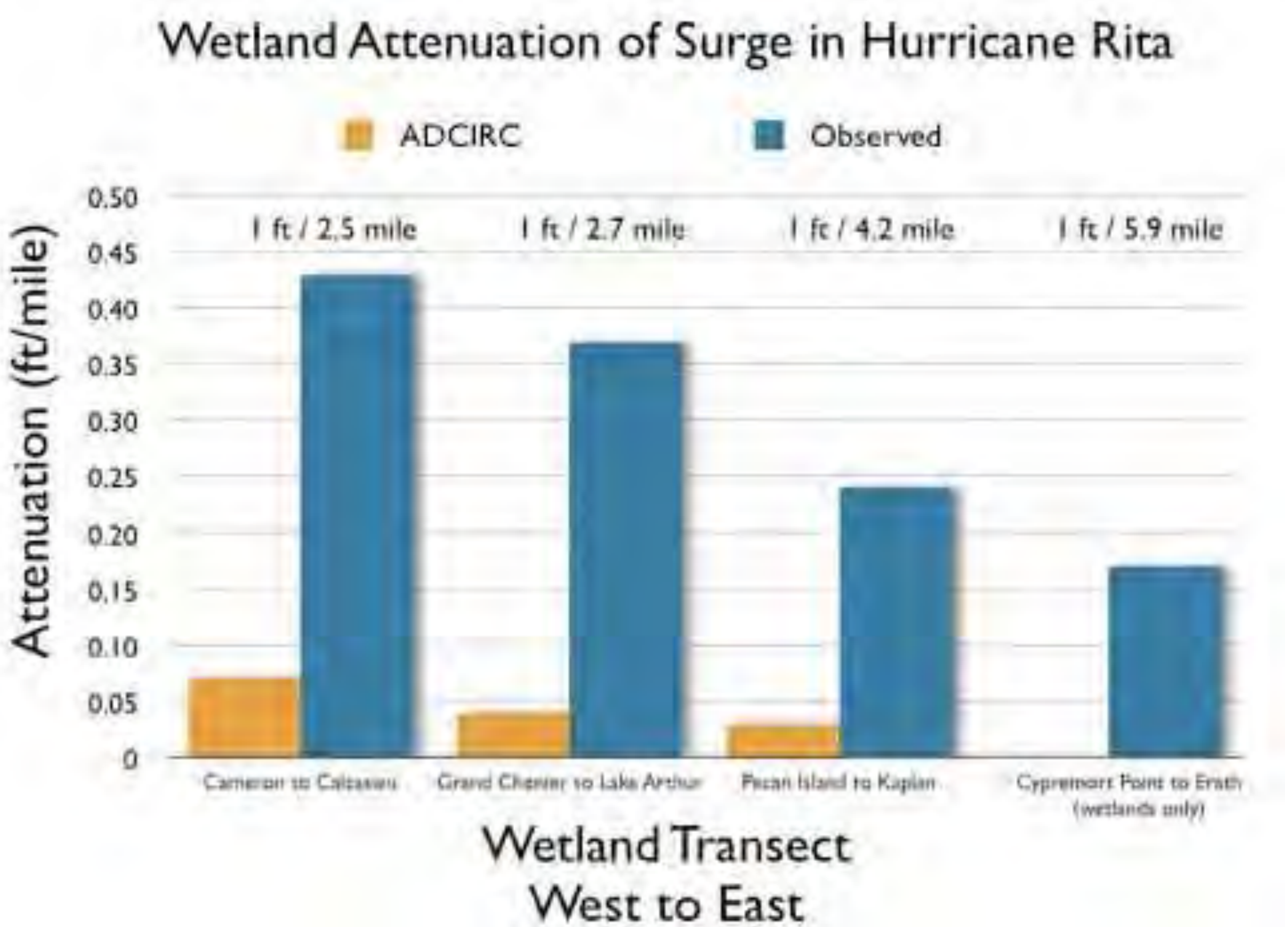
Wetlands reduce storm surge waters. Marshes provide drag and resistance to water movement, reducing the storm's ability to gather storm surge waters. This physically slows the progress of hurricanes and weakens their strength. Wetlands loss results in more open water and less capacity for buffering between land and the Gulf of Mexico where hurricanes develop. The loss of wetlands in the critically important area of the East Orleans land bridge exacerbated the damage that hurricane Katrina wrought because it allowed more storm surge waters to flood into Lake Pontchartrain, causing sea walls in New Orleans to fail and catastrophically flood the city. The receding of areas of the coastline by 20-30 miles since the 1930s removed a significant capacity to diminish the power of hurricanes in Southern Louisiana.

The U.S. Geological Survey (USGS) estimated that wetlands reduce hurricane storm surge by one foot for every 2.5 miles of wetlands. More recent measurements of the effects of wetlands on Hurricane Rita's storm surges indicate that the wetlands may be even more effective at reducing the height of the surges, depending on the storm, by as much as one foot for every 1.4 to 5.9 miles of wetlands. The storm surge models used by the Army Corps of Engineers did not include the wetland buffering function of wetlands.[122] A post-hurricane modeling effort predicted that if all the wetlands near New Orleans had been lost, storm surges from Katrina would have been up to six feet higher, causing far more substantial damage.[123] Other modeling indicates that the loss of barrier islands significantly increases the wave energy hitting the coast, even in mild weather.[124] The Army Corps of Engineers storm surge models do not yet include wetlands as features that reduce storm surge.

Figure 7 shows the expected attenuation (blue) based on modeling which did not include the storm surge weakening effects of wetlands and the observed attenuation (purple) for Hurricane Rita based on the physical measurement of water marks on trees and structures.

[122] Kemp & Mashriqui, 2006; pers com
[123] Working Group for Post-Hurricane Planning for the Louisiana Coast, 2006
[124] Stone, 2004

Figure 7. Kemp and Mashriqui's Wetland Attenuation of the Hurricane Rita Storm Surge



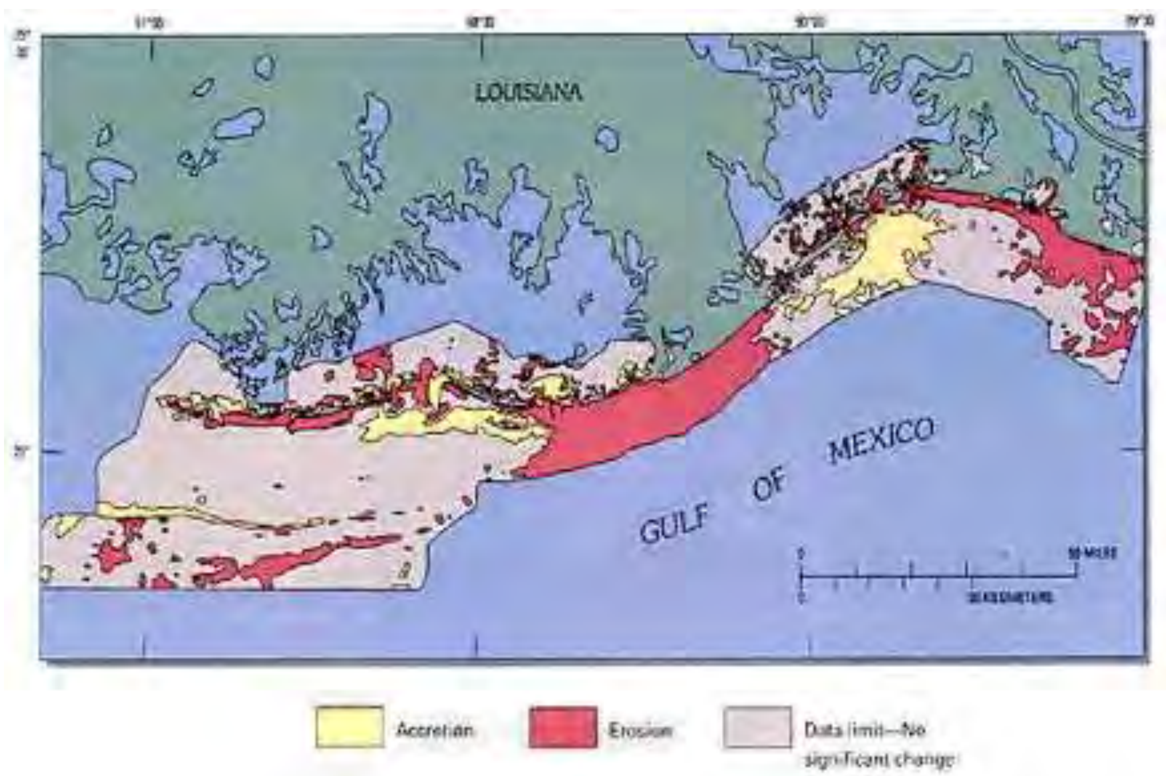
Source: Kemp and Masriqui, 2006

The Chenier Plain, which lies to the west of Mississippi River Deltaic Plain, has also lost wetlands and barrier islands. The Mississippi and the Atchafalaya Rivers influence the Chenier Plain over long periods, but its landforms are different from the Mississippi River Deltaic Plain. Ridge systems made of sand and shells give its coastal landscape a more forested character. No major rivers currently flow through the Chenier Plain. Sediment deposition and land loss mechanisms are also different in this area of coastal Louisiana. Saltwater intrusion from canals and navigation channels has caused the loss of freshwater marsh and forested wetlands. The diminution of the barrier islands have caused increased coastal erosion due to wave energy. Saltwater intrusion also threatens to alter freshwater lakes and reduce water supplies for agriculture. During Hurricane Rita, many levees surrounding freshwater and low salinity impoundments were overtopped by saltwater, leading to widespread death of these marshes and damaging agricultural fields because the saltwater could not retreat or be flushed out by natural processes. Unlike the more populated Deltaic plain, population is more dispersed in the Chenier Plain where agriculture is a mainstay of the local economy.

Wetlands and Barrier Islands

Barrier islands also provide considerable protection against hurricanes and storm surges. They absorb wave energy and provide a direct physical barrier to storm surges, helping protect people and structures from hurricane-generated waves. The Mississippi Coast had barrier islands, like Ship Island, as buffers. These provided important storm protection, reducing storm surges by three feet or more.[125] Construction and management of levees, reservoirs, and flood-control structures have reduced the input of coarse sands that are necessary to maintain barrier islands. As a result, all barrier islands in the delta, and most of the barrier islands in the Gulf of Mexico and along the Eastern seaboard, are deteriorating.[126] The deterioration phase of the barrier island cycle has accelerated while the building phase has stopped. Figure 8 shows the areas where barrier islands have deteriorated (red) and areas of barrier island building continues (yellow).

Figure 8. Areas of Barrier Island Accretion and Deterioration



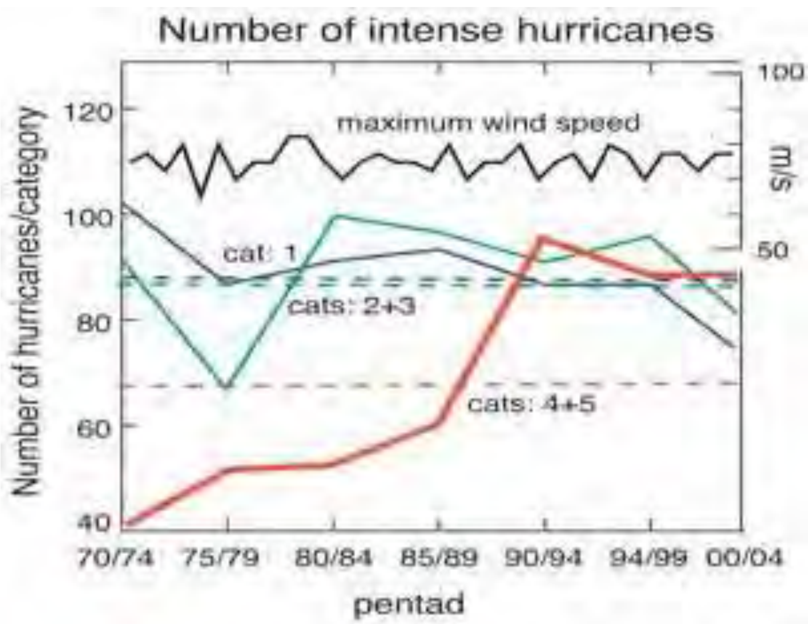
Source: USGS

[125] Farber & Costanza, 1987
[126] Pilkey, 2003

Bigger, Stronger, More Hurricanes

Hurricanes have increased in strength and duration of by 50% in the last 30 years.[127] Maximum wind speeds have increased by 60%, holding about twice the total amount of energy compared to hurricanes more than 30 years ago. The frequency of category 4 and 5 hurricanes, the most powerful and damaging hurricanes, have also risen sharply over the same period. Hurricanes that would have been within category 1-3 are encountering conditions that feed hurricane growth – especially warmer water – and are becoming more powerful category 4-5 hurricanes. There were 171 severe hurricanes 1975-1989, the number rose to 269 in 1990- 2004. Figure 9 from the journal *Science* demonstrates the increase in numbers of more powerful hurricanes.[128]

Figure 9. Increase in Category 4-5 Hurricanes and Reduction in Category 1-3 Hurricanes between 1970 and 2004



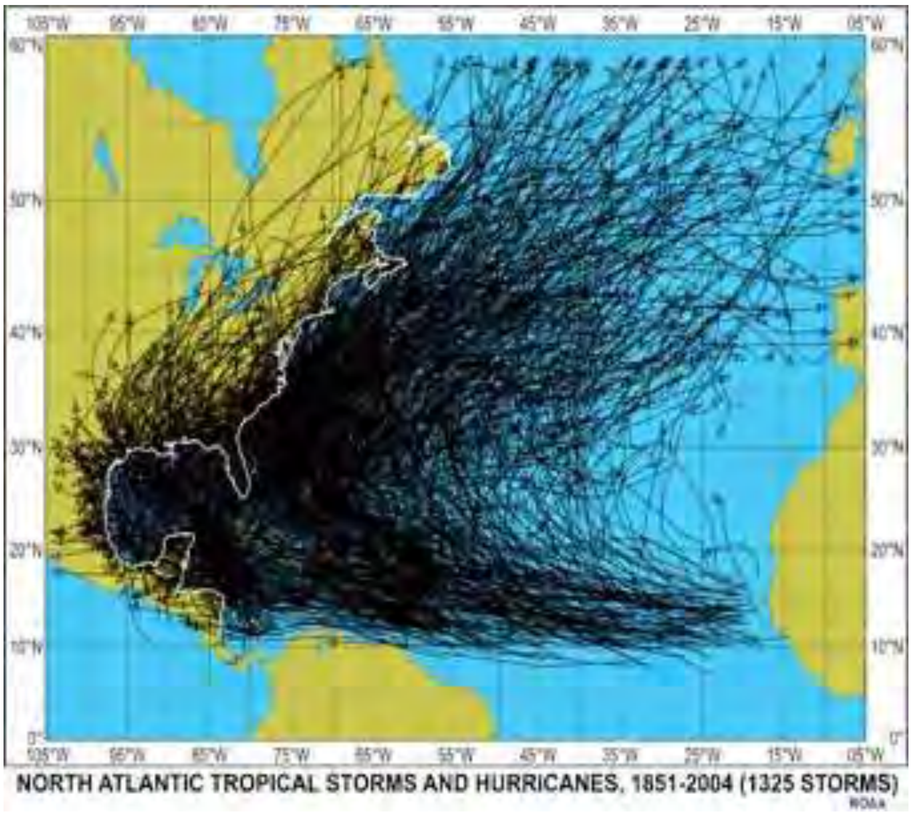
Source: Emanuel, 2005

NOAA's findings also show that the intensity of hurricanes has risen since 1980.[129] Hurricanes Katrina, Rita, and Wilma started out as tropical storms – all weaker than category 1 hurricanes when they were in the Atlantic but when they entered the Gulf of Mexico, the hot waters sparked these storms to massive category 5 hurricanes in just a few days.

[127] Emanuel, 2005
[128] Webster & Curry, *2005*
[129] Landsea, 2005

More storms will hit the U.S. Figure 10 shows the paths of Atlantic hurricanes in 1851-2004. The trend toward larger and more powerful hurricanes associated with increases in global and oceanic temperatures is a concern for the United States' entire eastern seaboard.

Figure 10. Atlantic Hurricane Paths, 1851-2004



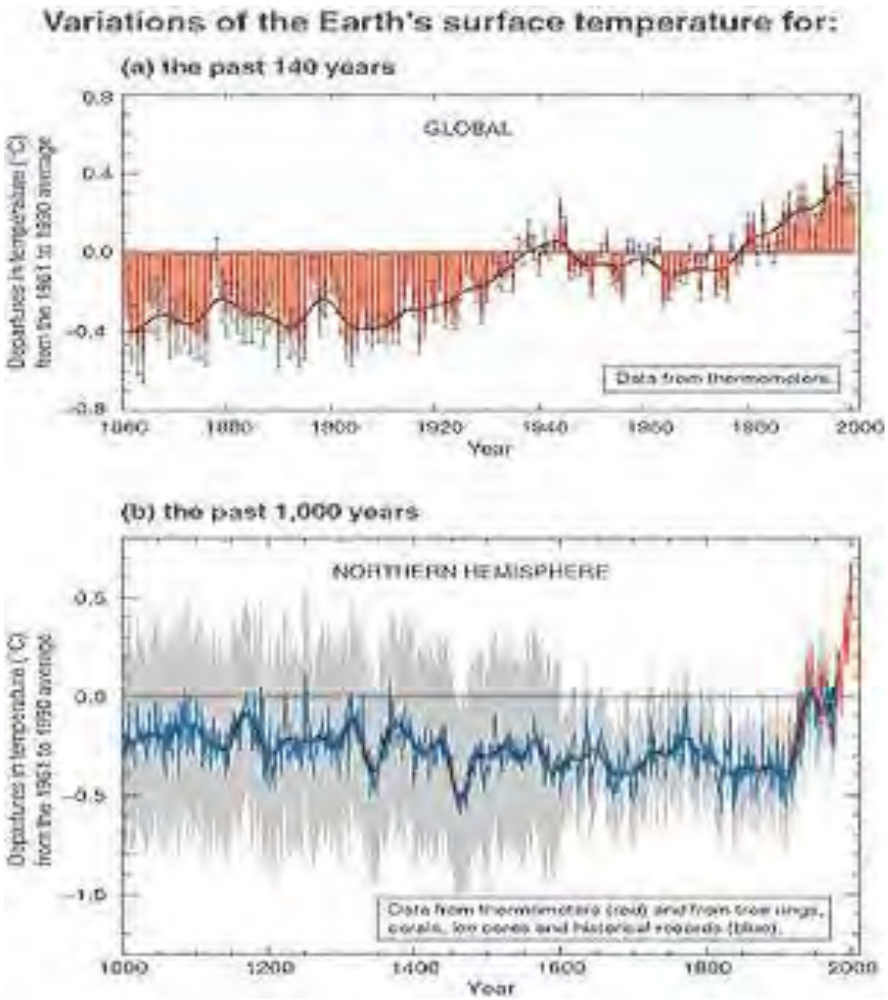
Source: NOAA

The Earth is Warming Up

Tens of thousands of temperature measurements over the last 150 years and geologic, plant and ice data that provide the earth's historical temperatures show that the earth's surface temperature has increased in the last century. Figure 11 shows increases in the earth's surface temperature.[130]

[130] Intergovernmental Panel on Climate Change, 2001

Figure 11. The Earth's Surface Temperature from 1860 to 2000



Source: IPCC, 2001

Two general theories explain this observed increase in temperature. A very small number of scientists, primarily without climate science training, contend that the burning of fossil fuels does not drive the observed increase in the earth's surface temperature. They assert that it is part of a natural cycle and predict that temperatures will again decline at some future time. On the other hand, more than 400 of the world's top climate scientists at the Intergovernmental Panel on Climate Change (IPCC) have ascertained that human activities, including the burning of fossil fuels, partially caused the observed increase in global temperatures.[131]

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[131] IPCC, 2001

IPCC scientists predict that global temperatures will rise by 1-5^{o}C within the 21st century. The increase in temperature will directly affect coastal areas, lead to changes in precipitation, increase the conditions for more powerful hurricanes, and accelerate sea level rise. It is predicted that as the tropics gain more heat, there will be a greater transport of water vapor toward higher latitudes.

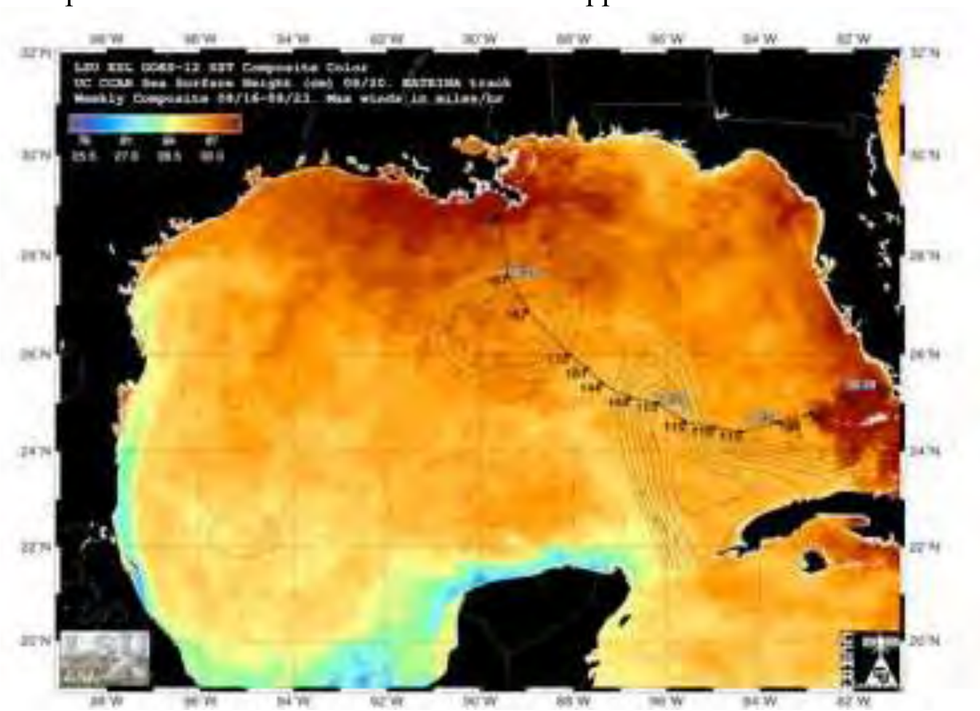
Sea Surface Temperatures

The transfer of heat from marine waters to the atmosphere creates hurricanes. The higher the sea surface temperature, the more quickly hurricanes gain power, the more powerful they become. Rising sea surface temperatures, half a degree globally,[132] are cause for great concern.

The 2005 Hurricane season saw tropical storms Katrina, Rita and Wilma explode from tropical storms into huge category 5 hurricanes upon entering the Gulf of Mexico.

Below is an image provided by the LSU Earth Scan Laboratory that shows the sea surface temperature in the Gulf of Mexico in August 2005. The darkest orange areas correspond to higher sea surface temperatures. The path of Hurricane Katrina and the sea surface height, building of the storm surge is also shown along the black tracking line.

Figure 12. Sea Temperature in the Gulf of Mexico and the Approach of Hurricane Katrina



Source: LSU ESL, 2008

[132] Elperin, 2005; Bart et al, 2007

Sea Level Rise

In low elevation coastlines like Louisiana's and much of the Gulf Coast's, a rise in sea level can profoundly impact wetlands and other ecosystems, particularly with the removal of historic sedimentary sources. Sea level and subsidence combine to increase the effective change in sea level in Mississippi River Delta. For about 3,000 years before 1900, sea levels did not change very much, perhaps rising very slightly. Since 1900 however, global sea levels rose by nearly 20 cm.[133] The IPCC predicted that by the year 2100, the sea level will rise another 11-88 cm.[134] Based on empirical relationships between temperature and sea level rise in the 20th century, Rhanstorf predicted that sea level rise may be one meter or more.[135] Despite these uncertainties, there is no doubt that coastal wetlands in Louisiana will see a high rate of relative sea level rise due to the combination of subsidence and eustatic sea level rise.

The Importance of Levees

The U.S. Army Corps of Engineers (USACE) found that wetlands and swamp forests provide storm buffering that helps protect levees. Heavy waves associated with storm surges force water into the pour structure of levees, weakens them, sometimes to the point of failure. Wetlands break up the wave action of hurricanes so that water rises with less force. Levee specialist Dr. Paul Kemp best described what wetlands do: level out waves so that rising water may overtop levees – not breach them – like water flowing over a bathtub lip, as opposed to a failure, which is like the whole side of the bathtub giving away. Overtopping allows far less water through with far less force, and results in far less damage. While levees are built to protect human safety and economic assets, the 2005 hurricane season showed that levees can also amplify hurricane storm damage.

The Issue with Levees

Tens of billions of dollars were invested in building levees in the Mississippi Delta without considering the land loss this would cause, or the increased vulnerability and economic costs associated with losing vast areas of land, wetlands and barrier islands. Canals for oil and gas drilling were dug, also without concern for the resulting land loss.

Despite having sufficient shipping channels in the Mississippi River, Congress appropriated funds to build and maintain the MRGO canal in the 1960s to shorten the shipping trip from the Gulf of Mexico to New Orleans to 76 miles. Saltwater came up the canal and killed thousands of acres of freshwater wetlands converting them to an open water area shaped like a funnel in St. Bernard Parish southeast of New Orleans.[136] Cypress trees are highly resistant to blow down even with hurricane intensity winds. The sturdy three-dimensional structure of cypress forests reduces surface winds, hurricane storm surge and wave heights on top of the surge. In the wake of Hurricane Katrina, experts and the public decried the "funnel" effect caused by MRGO and the wetland loss it caused which focused and piled up hurricane storm surge waters and demolished protective levees causing much of the destruction in New Orleans and St. Bernard Parish.[137] The USACE initially contested the assertion that the MRGO canal caused the vast loss of wetlands and increased the damage to New Orleans. However, the

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133 United Nations Environment Programme, 2007
134 IPCC, 2007
135 Rahmstorf et al, 2007
136 Day et al, 2006
137 Day et al, 2006

evidence that MR-GO both caused wetland destruction and substantially focused and increased the height of Hurricanes Katrina and Rita's storm surge is now widely accepted. The U.S. Congress, upon request of the Louisiana Legislature, directed the USACE to close MRGO. In 2007 the Army Corps settled on a plan and received funding to block the navigation canal. It is now clear that the design of the MRGO shipping canal for the promotion of shipping was at the expense of wetlands "natural capital" and the hurricane protection they provided. This investment in built capital caused greater overall damage than benefit to New Orleans. The substantial cost of closing the canal and restoring the protective wetlands is a good investment.

Levee Successes and Failures

Many levees protecting New Orleans and other areas of the Mississippi Delta performed well while some failed. The 17th Street and London Avenue Canals were lined with levees with seawalls atop, these structures failed because they simply did not meet their required engineering specifications. There is a great deal of research and discussion of these failed structures.[138]

Wetlands protect levees. The photo below shows a section of a levee where Hurricane Katrina storm surge hit from left to right. Notice the base of the photo where a wetland buffers the levee. Water overtopped the levee, flowed over it, scoured the other side, but did not breach or destroy the levee. Wetlands broke the wave action associated with the hurricane storm surge. This protected the levee and seawall from the pounding wave action of the storm surge; the storm surge rose more gently, like water filling up a bathtub. The structure was overtopped, but not destroyed. The top of the photo shows that where there was no wetland buffer, storm surge waves were unbroken. The full wave action pounded the levee and floodwall structure. The levee was breached, allowing a torrent of floodwaters to enter A levee breach lets in the full depth of floodwaters, causing catastrophic damage, like punching a large hole in the side of a bathtub. Where levees are overtopped, they allow some water to flow while yet holding most of the floodwaters back until the storm surge recedes, causing far less flooding and far less damage.

Figure 13. Levee Damage after Hurricane Katrina

Photo Credit: G. Kemp

[138] Louisiana Department of Transportation, 2007

Levees Can Amplify Hurricane Storm Surge and Damage

It now appears that the 29-foot storm surge from Hurricane Katrina that devastated the Mississippi coastline was partially created by levees along the Mississippi River. Hurricane storm surges move in a rotation around the eye of the storm. A northward arm of the storm surge struck the coastline directly, while a southern moving arm of the storm surge was reflected off the Mississippi River Levee and back toward the Mississippi coastline, creating an additive effect.

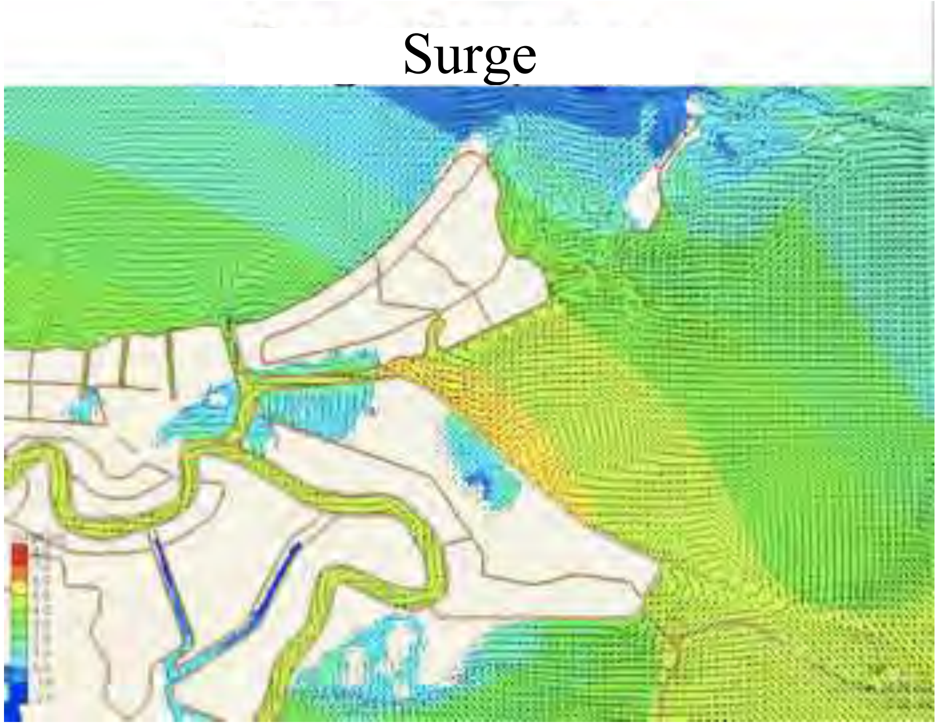
The levees that maintain the MRGO Canal on the northeast boundary of St. Bernard Parish and the shipping canal to the south of eastern Orleans Parish created a v-shaped funnel, leading storm surge waters directly into New Orleans. As storm surge waters moved west from the path of Katrina into this "V" created by the canals, the funneling effect increasingly confined the storm surge waters as they approached New Orleans, increasing the height of the storm surge and demolishing the levees that protected the southern part of the city.

Figure 14. The "Funnel" Exposing New Orleans to Increased Storm Surge Damage

Source: Dr. Paul Kemp, 2006

Dr. Hassan Mashriqui modeled the storm surge of hurricane Katrina showing the amplification of the storm surge in the funnel. This is just a "snap shot" of one point in time as the storm surge built up then overtopped or breached levees in St. Bernard Parish, East New Orleans, and New Orleans.

Figure 15. Katrina Storm Surge "Snap Shot"



Source: Dr. Hassan Mashriqui of Louisiana State University, 2006

Figure 16. Storm Surge of Hurricane Katrina Amplified by Levees in the "Funnel"

Picture taken by an automatic camera located at an electrical generating facility on the Gulf Intracoastal Waterway (GIWW) where the Route I-510 bridge crosses the GIWW. This is close to where the Mississippi River Gulf Outlet (MRGO) enters the GIWW. The shot clearly shows the storm surge, estimated to be 5.5-6m (18-20 ft.) in height.

An automatic camera from an electric-generating plant at the Interstate Bridge on Parish Road caught an image of the massive storm surge likely amplified by this funnel effect close to the end of the funnel. The levees' constricting effect amplified the storm surge to a height of 18-20 feet.

Figure 17. Flood Caused by the Breaching of New Orleans' Protective Levees

Source: National Systems Modeling Group, 2006

The Decline of Oil and Natural Gas Reserves and Production

One of the most profound global and local physical changes affecting energy prices and industrial society is the global decline in oil reserves. This has an important bearing on wetland restoration decisions. Some delta restoration and levee options are more energy intensive than others. Allowing the Mississippi River to move vast amounts of sediment and water is far less expensive than constructing levees and pumping sediment. With rising fossil fuel prices, restoration options that utilize the river's energy will continue to be less expensive than extensive levee works and other energy intensive options. Another critical fact to consider in levee/delta restoration is the depletion of oil and gas reserves in Louisiana, the U.S. and the world. Vast, easily accessible fossil fuel reserves have been depleted; cheap oil will not be available in the future.

In the past, if world demand for oil rose, supply could be easily expanded. This is no longer true today. Because the world's oil supply has become inelastic (the supply curve is close to vertical, and supply does not readily expand in response to increases in price), when demand is high, prices rise dramatically. When demand falls, prices fall dramatically. This was borne out in just the few months between the high demand period of the summer of 2008, where oil prices surpassed $140/barrel, and the fall of 2008 when global recession depressed demand and prices fell to less than $40/barrel.

U.S. oil production peaked in the early 1970s. Except for a brief smaller peak in production from Alaska's Prudhoe Bay, U.S. oil production has declined steadily. According to the Louisiana Department of Mineral Resources, "overall crude oil production in the state has fallen considerably from peak production levels attained in the mid 1960s (North Louisiana) to early 1970s (offshore and South Louisiana). Today, crude oil production is 17% of its 1965 peak production in North Louisiana, 12% of its 1970 peak in South Louisiana, and 12% of its 1972 peak in offshore Louisiana. Relative to their respective peaks, crude oil production in North Louisiana has experienced an annual average decline of almost 5%, with South Louisiana and offshore Louisiana each seeing a 6% average decrease per year."[139] Louisiana's oil production has been in decline for over 35 years and continues to decline.

Natural gas production in Louisiana has also peaked and is now declining. Offshore production will peak. Oil and gas have been a major part of Louisiana's economy for decades. With the decline oil and gas reserves, these non-renewable resources may play a smaller role in the state's economy. Production is expected to trail off considerably in another 10 years. These declines in production are critical; they signal a need for a post-oil economic strategy for the state and nation. Renewable resources will need to play a larger role in the future. As global oil reserves are depleted, oil prices as well as transportation and construction costs will rise in the long run despite temporary declines in price associated with demand reductions, as in the current recession. Energy prices have a dramatic effect on the cost of energy intensive projects, such as levees, and improve the overall economics of restoration projects, such as diversions, which utilize the Mississippi River's energy to transport water and sediment.

It is wise to now invest in large diversions to restore the Mississippi Delta. Diversions have upfront costs and provide employment opportunities in construction and very low operating costs. The upfront construction costs of diversions will most likely be less today than they will be in the future while the benefits will accrue in the future as oil and gas revenues decline. Energy intensive restoration techniques, such as piping dredged sediments, are likely to become less viable in the future.

Summary: Facing Physical Realities

Economies depend on ecosystems, natural resources and stable landscapes. Science has clearly shown that physical processes are driving larger hurricanes and destroying wetlands and barrier islands. The loss of land is reducing the valuable wetland and barrier island storm buffering endangering economic assets and people. If these trends continue unabated, viable economies may decline in many parts of the Mississippi Delta. These facts lay the groundwork for a better economic understanding of the Mississippi Delta and the profound

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[139] Dismukes et. al, 2004

implications of a very physically dynamic system for people, local governments, infrastructure, housing and industries, including the oil and gas industry.

These are measured scientific observations and physical facts, not theory:

- Hurricanes are getting larger, more destructive, and more costly.
- Land, wetlands and barrier islands (horizontal levees) reduce hurricane impact.
- Land, wetlands and barrier islands are being lost and converted to open water.
- Hurricanes gain power over deep, warm, open water.
- Some levee configurations magnify storm surge and storm surge damage.
- The Mississippi River Delta is subsiding (sinking).
- Land expands where water and sediment are provided.
- Sea level is rising.
- Global atmospheric and ocean temperatures, including the Gulf of Mexico, are rising.
- Oil and gas reserves are declining in Louisiana, the U.S. and the world. Energy intensive options will become more expensive and less feasible.

The physical reality of these dynamic changes holds tremendous economic implications for the United States, the Mississippi River Delta and the states along the Gulf of Mexico and Atlantic coastline. Part IV of this study examines three scenarios and their economic implications.

PART IV: Restoration Scenarios

This section examines three management scenarios of the Mississippi Delta and the economic implications of each scenario in 100 years. The values of ecosystem services provided by each scenario are calculated. Estimating the cost of each scenario is outside the scope of this study but should be examined.

The ecosystems of the Mississippi Delta provide benefits ranging from $330 billion to $1.3 trillion, contributing to the national economy and the quality of life. How much, where, and by whom should investments in restoration and levees be made? What should the balance be? These are critical questions arise with radically different alternatives being considered.

One thing is certain. The continued degradation of the Mississippi River Delta threatens public safety, economic productivity and ecosystem services. The damage to oil production, pipelines and refineries has national economic implications. Without wetland expansion hurricane damage will result in higher prices for gasoline, jet fuel, diesel, fuel oil and natural gas for the entire U.S. as it did after Hurricanes Katrina, Rita, Gustav and Ike. Better management of the Mississippi Delta is critical to the U.S.

Part 1 of this study introduced a "new view on value," and the critically important role of natural capital for the economy of the Mississippi River Delta. Part II provided a valuation of 11 ecosystem services and net present value calculations establishing that the delta is an enormously valuable natural capital asset. Part III of this study shows how the dramatic, dynamic physical changes affecting the Mississippi River Delta have profound economic implications. This section examines three scenarios for the Mississippi Delta: continued delta deterioration and land loss, a modest investment in delta restoration, and a more aggressive investment in the restoration of the Mississippi River and the delta.

Three Scenarios

Hurricanes Katrina, Rita, Gustav and Ike renewed wake-up calls for the large-scale physical and economic changes that have been taking place in the Mississippi Delta. Greater efforts need to be exerted toward determining how to best respond to the physical, economic and social dynamics of a changing delta.

The three scenarios considered here are: 1) do nothing new 2) hold the line and 3) restore the delta. These scenarios actually represent the three general suites of approaches to the problem of land loss in the Mississippi Delta. Each has a set of different possible actions, investments in built and natural infrastructure, and economic and social ramifications. This is not intended to be an exact analysis but a broad examination of three overarching approaches. It is intended to shed light on the set of alternatives currently being considered for the delta and to offer far more economically productive options.

The "do nothing new" scenario assumes the continuation of the past management of the Mississippi River. Large investments in levees and reconstruction of hurricane-damaged structures to keep water and sediment flowing off the continental shelf pertain to a management regime that has lead to the loss of 1.2 million acres in the delta. The Mississippi River will remain, as it does today, separated from the Mississippi Delta resulting in greater wetland losses, greater losses of ecosystem services, and the increased exposure of towns and cities to hurricanes.

This scenario is based on the U.S. Geological Society's estimate of wetlands loss of 328,000 acres in the next 50 years.[140] It is assumed that an additional 272,000 acres will be lost as the impact of subsidence and sea level rise intensify in the next 50 years. This may be a very conservative estimate since 42% of the predicted land loss for the next 50 years has already occurred with the loss of 138,000 acres from Hurricanes Katrina and Rita. Based on the pattern of land loss in the last 80 years and on the experience of hurricanes Katrina and Rita, wetland loss is not linear. Hurricanes may also abruptly increase the loss of wetlands where they are not healthy. Initially, high wetland loss rates decline as there are fewer wetlands to lose. Thus, the shape of the wetland loss curve adopted is concave, reflecting the history and nature of wetland loss.

The "hold the line" scenario carries the entire set of issues on coastal restoration presently considered by the U.S. Army Corps of Engineers. There are many potential project combinations to try to achieve this goal. If successful, it will result in no net land loss. The delta will lose land in some areas and gain land elsewhere with overall land coverage remaining the same. Although this scenario significantly improves on the first scenario with the use of some small diversions, it does not bring a fundamental management shift. The Mississippi River will remain disconnected to the delta and most of its water and sediment of the will continue to flow off the continental shelf.

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[140] U.S. Geological Survey, 2004

Questions persist whether this scenario can be achieved. Deltas involve large landscape processes that create and maintain them. They are either restored so that they shift toward sediment/water/land building balance or are not restored resulting in land loss. This analysis assumes the viability of holding the line. If the deltaic processes are not restored at the scale required, the Mississippi River Delta will continue to shrink and fall apart. Trying to hold the line through a combination of small projects or energy-intensive sediment pumping can be considerably costlier than a fundamental reworking of the system with large diversions that, once in place, move far more water and sediment per dollar spent.

The "sustainable restoration" scenario – rejoining the river and the delta – brings a fundamental shift in policy and action. This scenario includes large diversions and crevasse structures in the levees of the Mississippi River that can be opened, particularly during flood periods when the flow and sediment loads are high. This moves water and sediment into large wetland and open water areas to restore wetlands. Other restoration ideas also need to be considered, such as a structure in the bottom of the river to force bottom sediment up and into diversion channels when desired. Diversion and crevasse structures can always be closed to accommodate shipping or low water periods.

Most of the water and sediment would be taken out of the Mississippi River during peak flows when sediment and water levels are highest, thereby providing the greatest restoration value and the least conflict with navigation. During periods of low flow, the quantity of water diversion would be scaled back to allow continued navigation.

Restoration planning over longer periods and inclusive of a greater area of the Mississippi Basin dramatically improves results. Much of the larger grain sediment from the Mississippi Basin has been trapped behind dams for 80 years. These dams will be filled with sediment in coming decades. Upper Mississippi River dams will require decommissioning or sediments flushing in the next 100 years. If developed as part of a Mississippi River basin plan, this heavier sediment can be provided through a controlled release, adding very substantially to the quality and quantity of the river's sediment load and capacity for coastal restoration. Barrier Islands throughout the Atlantic and Gulf Coast have been deprived of sand from upstream rivers. Under this scenario, upper basin sediment will be managed to increase downstream benefits. Another option in the short term, prior to further reductions in oil production and increases in price, sediments can be pumped to promote rapid wetland recovery and expansion.

Like the "hold the line" scenario, there are many combinations of potential projects that can achieve this goal. Identifying the suite of projects to be implemented involves the use of spatially specific modeling which can account for multiple benefits, such as storm protection, land building, coastal economic recovery potential, recreation and carbon sequestration to set up and test different suites of river reconnection projects.

This excludes the cost of a sustainable restoration for lack of full project identification that can be used as basis of costs. Like the other two scenarios, this also needs to include the returns in avoided costs and a suite of sustainable and valuable economic goods and services gained. Trapping the water and sediment of the Mississippi River will bring significant co-benefits, including a reduction in the "dead zone" hypoxic area in the

Gulf of Mexico, as the nitrogen is trapped and utilized by wetland plants in the delta. These co-benefits are not included in this preliminary analysis.

Modeling has not included the eventual release of currently impounded sediments. Thus, there is no clear estimate of land restoration under a scenario that utilizes currently- impounded sediments, some sediment pumping, and release of as much of the water and sediment of the river as possible. The sustainable restoration scenario assumes that with the release of large sediment loads, wetland recovery and growth rates, increased release of silt and sand in coming decades, diversions and some sediment pumping, 500,000 acres of wetlands can be created or restored in the next 100 years. Data and modeling are not yet available for accuracy in estimating the acreage of wetlands restored from a long term, coast-wide restoration. This is intended to promote a wider analysis and the consideration of the general suite of restoration options and to recognize that economic analysis, which includes ecosystem services supports the implementation of restoration projects now.

It is important to consider this scenario. Academics, NGOs, businesses and coastal communities have been calling for restoration on a scale that would reestablish deltaic processes and result in a net gain in land in the long run. With the addition of wetlands, the ecosystem services these lands provide, especially hurricane buffering, would expand over time.

Costs and Scenario Details

No option is cheap. Under the "no action" scenario, the deterioration of the delta will continue along with the loss of nature's services and increasing damages to communities and economic assets. It will ensure a costly retreat of people and economic productivity. The "hold the line" scenario requires an unknown set of smaller projects to stop land loss without restoring the functions of the Mississippi River Delta. The third scenario entails large projects that reconnect the sediment, water and energy of the Mississippi River with the delta. All these options entail significant expenditures. Further analysis would refine the costs, benefits and net rate of return on restoration investments.

These three scenarios are meant to spur further research rather than present a detailed modeling effort. Economic analysis of changes in wetland values relies on the accuracy of the physical changes in each wetland type. This analysis is of three very broad scenarios with coarse physical estimates, thus the economic analysis is also coarse. Since the exact changes in wetland type for each scenario are unknown, single average values for wetland values were used. As the physical analysis of restoration alternatives becomes more robust, more refined economic analysis based on ecosystem-specific values can be produced.

The restoration of wetlands largely involves the conversion of estuarine open water to wetlands with a movement of the salt gradient toward the coast and conversion of salt marsh to brackish marsh, brackish to intermediate, and intermediate to fresh marsh.

The inland movement of the salt gradient and conversion of wetlands into estuarine open water results in wetland loss. The low value of estuarine wetlands was subtracted from the average low value per acre per year for all wetland types, excluding the highest wetland value for forested wetlands to derive a net loss or gain value of $4,515/acre with the conversion of wetlands to open water or open water to wetlands for the three scenarios.

- Land loss in the "do nothing new" scenario in 100 years is set at twice what the U.S. Geological Survey predicts to occur over the next 50 years. This adds up to a loss of 500,000 acres in the next 100 years.
- The "hold the line" scenario assumes there is no net gain or loss of land in the next 100 years.
- The "sustainable restoration" scenario assumes that with large-scale restoration over a 100-year period, roughly 40% of the wetlands lost in the last 80 years would be restored totaling 500,000 acres. This is a speculative scenario if short-term sediment pumping, long-term river restoration and release of basin sediments were secured.

Each scenario translates into a net loss or gain of ecosystem service values in the next 100 years. A larger time horizon would accentuate the differences between the scenarios. The net present value of benefits from ecosystem services, not total project costs, for each scenario was calculated. Cost projections for the various restoration scenarios are not included because they are difficult to ascertain without actual project identification.

The calculation of net present value of land loss or land gain depends on the discount rate chosen, which reflects how value received in the future is counted in the present. A lower discount rate implies giving greater weight to the benefits that storm protection, fisheries and other ecosystem services provide to people in the future. A vast majority of benefits from renewable resources are provided in the future. Healthy natural capital does not depreciate. Lower discount rates for natural capital restoration are justified – as opposed to built capital that depreciates. The choice of a discount rate is arbitrary. At times the US Prime rate is used as a marker. As of February 2009, the commercial bank prime rate of interest was 3.25%. In February 2009, the U.S. Federal Reserve Bank Open Market Committee in continued response to the financial crisis retained the remarkable fed funds rate of 0-0.25%[141]. This is the interest rate that banks lend cash to each other overnight in the Federal Funds Market.

Table 9 shows the Present Value of the conversion of wetlands and open water. It does not include the total cost of implementing each of the scenarios. This is a comparison of an estimated net gain or loss in ecosystem services associated with each scenario.

Table 9. Three Scenarios of Present Value of Wetland Ecosystem Services for 100 years (in billions, 2007 dollars).

Present Value of Scenario				
Scenario	**Discount Rate 0%**	**Discount Rate 2%**	**Discount Rate 3.5%**	**Discount Rate 5%**
Do Nothing New	-190	-72	-41	-26
Army Corps No Net Loss	0	0	0	0
Sustainable Restoration	132	41	21	12

[141] U.S. Federal Reserve Bank, 2009

Depending on the discount rate chosen, the "no action" scenario will result in losses of $26-190 billion in ecosystem services alone. This does not include losses such as the costs of future damage by hurricanes, retreat of economic infrastructure, or loss of life. Losing over 500,000 acres of wetlands would leave New Orleans and other coastal cities far more exposed to hurricanes. Hurricane Katrina showed that a single event can cause $200 billion in damage.

The "no change" scenario has no net increase or decrease in values. This scenario would avoid the negative costs associated with the "no action" scenario, but would not increase storm protection or other ecosystem services provided at higher levels in the past.

The "sustainable restoration" scenario will add over 500,000 acres of wetlands in a century and significantly add to the hurricane protection of New Orleans and other cities and communities on the Mississippi River Delta. Because this is a building process, the benefits will increase dramatically in the future. The benefits from the net gain in wetland area will be between $12-132 billion. In addition, the costs associated with the "no action" option will be avoided.

Table 10 shows the total present value of benefits in scenario 3, the sum of avoided costs associated with the "do nothing new" option, and the gains from the increase in additional wetlands.

Table 10. Total Present Value for Scenario 3, Avoided Losses and Gains Realized in $ Billions

Major Restoration Scenario	PV 0% Discount Rate	PV 2% Discount Rate	PV 3.5% Discount Rate	PV 5% Discount Rate
Total PV Avoided Costs and Direct Gains	322	113	62	38

Scenario 3 increases the area of land and avoids the costs associated with the current path of land loss. This provides a net benefit of $322 billion with a zero discount rate if future benefits to people are counted equally as benefits to people in the present or $38 billion at a 5% discount rate if renewable benefits provided in the future are rather steeply discounted and deemed as having little value. The US Prime Rate of Interest as of February 1, 2009 was 3.25%. The figure conservatively adopted here is $62 billion at a 3.5% discount rate. Not included in this analysis, these wetlands would also provide greater protection for any built structure, including levees. Adoption of a 2% discount rate, that is recognizing the greater benefits of restoration in the future, would show over $100 billion in benefits.

Restoration of the coastline would reduce levee maintenance and reconstruction costs substantially. A larger skirt of wetlands around the Mississippi Delta would provide greater hurricane buffering. This alone could reduce future damage to cities like New Orleans by tens or hundreds of billions of dollars.

Even though many of the most important cost and benefit outcomes of these scenarios are beyond the scope of this study or not easily expressed in dollar value (human safety, future FEMA relief costs or community stability), the direction of the outcomes for each scenario is clear. For this reason, we present two tables that examine the likely outcomes of each scenario rated simply "Up, Down, or Same".

Table 11 shows the direction of the cost/damage outcomes for each scenario. The list of costs and damages is not comprehensive. It includes: loss of life, displacement of people, loss of infrastructure, storm-associated national energy price increase, insurance costs, FEMA and other relief costs, storm damage costs, post storm litigation, loss of the coastal economy, and area of the hypoxic dead zone in the Gulf of Mexico.

Table 11. Likely Cost or Damage and Scenario Outcomes

Cost/Damage	Scenario Outcomes		
	"Do Nothing New"	Hold the Line	Sustainable Restoration
Loss of life	Up Greatly	Same	Down
Dislocation of People	Up Greatly	Same	Down
Loss of infrastructure	UP Greatly	Up	Down
Storm Associated Energy Price Rises	Up Greatly	Up	Down
Insurance costs	Up Greatly	Up	Down
FEMA and relief costs	Up Greatly	Same	Down
Storm Damage Costs	Up Greatly	Up	Down
Post Storm Litigation	Up Greatly	Up	Down
Loss of Coastal Economy	Up Greatly	Up	Down
Area of Dead Zone	Up	Same	Down

Table 12 shows the direction of the benefit outcomes for each scenario. The list of costs and damages is not comprehensive. It includes: coastal stability, land building, storm protection, community stability, protection of levees, protection of energy infrastructure, wetland expansion, economic development potential, food, furs and fiber, wildlife habitat, water quality, carbon sequestration, waste treatment, recreation, aesthetic value, people's sense of security and national pride.

Table 12. Likely Benefit Scenario Outcomes

Benefit	"Do Nothing New"	Hold the Line	Sustainable Restoration
Coastal Stability	Down	Same	Up
Land building	Down	Same	Up
Storm Protection	Down	Same	Up
Community Stability	Down	Same	Up
Protection of Levees	Down	Same	Up
Protection of Energy Infrastructure	Down	Down	Up
Wetland Expansion	Down	Same	Up
Coastal Economic Development Potential	Down	Same	Up
Food, Furs, Fiber	Down	Same	Up
Wildlife Habitat	Down	Same	Up
Water Quality	Down	Down	Up
Carbon Sequestration	Down	Same	Up
Waste Treatment	Down	Same	Up
Recreation	Down	Down	Up
Aesthetic Value	Down	Same	Up
People's Sense of Security	Down	Down	Up
National Pride	Down	Same	Up

Tables 11 and 12 provide the direction of impact of each scenario for each outcome area. The "do nothing new" scenario will increase costs in virtually every category over current costs.

The "hold the line" scenario stabilizes some of the outcomes. If the goal of no net land loss is attained, overall coastal stability and land building will not deteriorate further but it will not experience a net advance either. Stopping land loss will not stop the deterioration of water quality but it will likely result in a decline in the protection of energy infrastructure because land building in a hold the line scenario will be focused where it protects inhabited areas and land loss will likely continue to take place where important energy infrastructure exists more distant from population centers.

The "sustainable restoration" scenario provides greater benefits and fewer costs by providing a net gain in land and large diversions that enable controlled distribution of sediment and water across the Mississippi Delta. Overall, sediment pumping, barrier island reconstruction and other restoration methods all increase land and the suite of benefits they bring. The dollar calculation of benefits based on a few ecosystem services and a cursory examination of the direction of benefits for the three options clearly show that the "sustainable restoration" option provides the greatest benefits and least costs. Neither the full costs nor full benefits of the projects are included. For example, the "do nothing" option may entail the outstandingly costly relocation of the people and assets of New Orleans. The sustainable restoration option may ensure the viability of New Orleans and secure vast assets and less disruption for many people.

One of the most persistent political tragedies has been that while the scientists, academics, state officials and citizens have emphasized the importance of reconnecting the Mississippi River to the delta as proposed in the Louisiana Coastal Protection Restoration Draft Technical Report, this option has not been considered by decision makers, such as the Army Corps of Engineers, as an option for coastal restoration.[142] This scenario analysis indicates that investing in sustainable restoration at a larger scale is the best approach. It provides the greatest benefits under any discount rate. The sustainable restoration scenario provides far greater and more comprehensive hurricane protection and provides for greater economic productivity in the Mississippi Delta. The sustainable restoration option to reconnect the Mississippi River to the delta should be the basis for restoration investment in the Mississippi Delta.

The many different combinations of delta and levee restoration each produce a different land restoration or deterioration scenario. Human safety, the impact on economic assets and the overall dynamics and sustainability of the Mississippi River Delta are critical to determining which levee/coastal restoration option will provide the greatest public safety, protection of economic assets (including natural assets) and coastal restoration value. The current levee designs are not integrated with wetland restoration models. None of the economic analyses fully include the value of ecosystem services. Including ecosystem services and their value would provide a better understanding of the value of public investments in restoration.

The persistent pursuit of restoration projects that are too small compared to the scale of the Mississippi Delta and its land loss is another notable flaw in the current management. The Coastal Protection and Restoration Authority of Louisiana has recognized this and said that "Creating a sustainable deltaic system requires that we reestablish the processes that originally created the landscape." The plan specifically recommends "building very large diversions that will use the majority of the river's sediment and fresh water to both create new delta lobes and nourish existing wetlands."[143] The report does not identify the locations and size of these diversions, but has produced a list of projects that comprise a partial coastal restoration plan. This was an important step forward but it needs the set of projects for moving very large amounts of water and sediment out of the Mississippi River and into the deltaic plain.

The scientific and coastal communities as well as the State of Louisiana are calling for far larger diversion projects that will significantly restore the Mississippi Delta's natural sediment regime and provide a net increase in and more enduring maintenance of existing wetlands. The natural functioning of the delta must be a guide to restoration. Before the levees became widespread, there were many crevasses, often as large as or larger than the Bonnet Carre spillway. This scale of diversion must be considered especially with the increasing sea level rise. A primary concern has been maintaining navigation channels however this is relatively easily addressed by constructing locks or using peak flow periods which are the natural sediment load land building potential is greatest and where utilization of diversions does not interfere with navigation.

Larger restoration projects may be the only hope for a maintaining a sustainable landscape and economy as well as the long-term sustainability of ports and cities like New Orleans.

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[142] Army Corps of Engineers, 2008
[143] Executive Summary, CPRA, 2007a

CONCLUSIONS

Mississippi River Delta Ecosystems provide economically valuable services, including hurricane storm protection, water supply, climate stability, food, furs, waste treatment, wildlife habitat, recreation and other benefits. These services are valued at $12-47 billion/year.

This flow of annual benefits provides a vast amount of value to people across time. A "natural capital asset value" can be established from these annual benefits. The present value of the benefits from these ecosystem goods and services provided by the Mississippi Delta, analogous to an asset value, is worth at least $330 billion to $1.3 trillion.

Wetlands – a product of Mississippi River deltaic processes including freshwater, saltwater, estuaries/tidal bays and cypress swamps – account for more than 90% of the Mississippi Delta's estimated total value of ecosystem services.

These benefits are derived from "natural capital" which is self-maintaining and lasts for a long time; it is fundamentally different from "built capital" which depreciates quickly and requires capital and maintenance costs.

In the past, our natural capital was taken for granted. Although natural systems provide economic goods and services such as fish and hurricane protection, they have not been valued as economic assets and were excluded from economic analysis and investment decisions.

Large-scale physical changes are affecting the Mississippi River Delta. In the last 30 years, oil and energy costs have been increasing, hurricanes have become larger and more frequent, sea level has risen, atmospheric temperatures have risen, the delta has been subsiding and, since 1930, has lost 1.2 million acres of land. This loss has had tremendous economic implications, including exposing cities like New Orleans to greater threats from hurricanes.

Hurricanes Katrina and Rita triggered a warning that has been sounded several times before. The current management of the Mississippi River, moving the sediment and fresh water of the river off the continental shelf has damaging economic costs in terms of land loss. The river has been walled off from the Mississippi River Delta since the 1930s. The public, academics and the State of Louisiana have sought to reconnect the river to the delta and utilize its sediment, water and energy to renew the processes that added land to the delta for thousands of years.

It is clear that restoration of the deltaic processes and levees are needed to secure public safety, economic assets and valuable ecosystem services.

A "do-nothing" scenario will result in continued land loss costing the U.S. at least $41 billion. A "hold the line" scenario could avoid the $41 billion, but would provide no additional benefits at a 3.5% discount rate. A third "sustainable restoration" option would avoid $41 billion in losses and secure an additional $21 billion in benefits, providing $62 billion in net present value benefits.

This analysis does not include many ecosystem services with clear economic value. It is part of a series of efforts to understand the value of the natural capital in the Mississippi Delta. More work is critically needed to understand how and what investments in diversions, levees or other structures can produce the best and most long-lasting benefits.

A major investment to restore the deltaic processes of the Mississippi River Delta is required to maintain or expand the vast value of this natural asset. The movement of water and sediment and the maintenance and expansion of land underlies the production of many economic benefits, including protection against hurricanes. Without this investment, people and economic assets will be forced to retreat from the coastline.

Ecological engineering must form the basis of delta restoration. High and rising energy costs will erode the economics of energy intensive options, such as levees and sediment pumping while water and sediment diversions utilize the Mississippi River's energy and can be easily maintained over many decades.

The overarching solution is well understood: large diversions of water and sediment from the Mississippi River are required to rebuild the Mississippi Delta and to secure the many benefits, including the economic productivity that the river provides. Management of more coarse sediments in the Mississippi Basin, currently trapped behind dams, should also be considered as these sediments will eventually be released in the next 100 years and can contribute substantially to the delta's restoration.

Overall, this study shows that a major investment of $15-20 billion for restoring the Mississippi River Delta to significantly increase land building would return at least four to five times that amount in the order of $62 billion in net present value at a 3.5% discount rate.

Once restored in a manner that allows the maintenance of natural processes, these wetlands will continue to support the economic health of the Mississippi River Delta. With the river reconnected to the delta, the system will be closer to self-maintaining at the operating cost for diversion structures.

Without a large investment in restoration, hurricane damage will clearly increase and other ecosystem services will be lost. The economic viability and habitability of the Mississippi River Delta will be threatened. This could result in vast losses to the country in terms of irreplaceable cultural and natural resources.

Within the context of the current financial crisis, investment in the restoration of the Mississippi River Delta provides high short and long term returns. The Army Corps of Engineers, Federal, State and local governments should dramatically increase expenditures for the restoration of the Mississippi Delta.

The Mississippi River Delta, the largest delta in North America, houses oil and natural gas resources, refineries, fertilizer and chemical facilities and other industries that are vital to the country's economic health. It also comprises 40% of U.S. coastal wetlands, a crucial flyway for migratory birds. It is by far the most productive delta in the United States.

Economies need nature. This is very evident in the Mississippi River Delta. If the Mississippi River is not reconnected to the delta on a large-scale basis, the land, culture and economy of this vast and productive area will be lost. Effective hurricane defenses require wetland expansion. Reconnecting the river to the delta at the appropriate scale will accomplish restoration that is needed. This is in the best interest of the people of the United States.

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APPENDICES

APPENDIX A: List of Value-Transfer Studies Used for Data Sources

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APPENDIX B: Table of Land Cover Type, Ecosystem Services, Valuation Study Authors, Low and High Values

Land Cover/Ecosystem Service	Valuation Study Author	Method	Minimum Value	Maximum Value
Fresh Marsh				
Carbon sequestration	Chmura et al., 2003; Pearce, 2001; Tol, 2005	MP	$29.43	$267.53
Gas regulation	Costanza et al., 1997		136.64	136.64
Nutrient regulation	Kazmierczak, 2001	RC	$3.13	$1,069.56
Water supply	AWWA. 2007	RC	$42.52	$113.39
Flood protection	Thibodeau et al, 1981	AC	5,957.20	5,957.20
Hurricane protection	Costanza , 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber, 1996	PF	$53.37	$74.46
Fur & alligator production	Lindstedt, 2005	MP	$4.33	$4.90
Recreation	Bergstrom et al., 1990	TC, CV	$134.44	$134.44
Aesthetic				
Fresh Marsh Total			**$1,661**	**$3,059**
Intermediate Marsh				
Carbon sequestration	Chmura et al. 2003; Pearce 2001, Tol 2005	MP	$29.43	$118.59
Nutrient regulation	Kazmierczak, 2001	RC	$3.13	$1,069.56
Water supply	AWWA, 2007	RC	$42.52	$113.39
Hurricane protection	Costanza et al., 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber, 1996	PF	$53.37	$74.46
Fur and alligator production	Lindstedt, 2005	MP	$4.26	$4.34
Recreation	Bergstrom et al., 1990	TC, CV	$134.44	$134.44
Aesthetic				
Intermediate Marsh Total			**$1,656**	**$2,910**
Brackish Marsh				
Carbon sequestration	Chmura et al. 2003; Pearce 2001, Tol 2005	MP	$29.43	$118.59
Nutrient regulation	Kazmierczak 2001	RC	$3.13	$1,069.56
Water supply	AWWA 2007	RC	$42.52	$113.39
Hurricane protection	Costanza et al., 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber 1996	PF	$53.37	$74.46
Fur & alligator production	Lindstedt 2005	MP	$4.26	$4.34
Recreation	Bergstrom et al. 1990	TC, CV	$134.44	$134.44
Aesthetic				
Brackish Marsh Total			**$1,658**	**$2,910**
Saline Marsh				
Carbon sequestration	Chmura et al. 2003; Pearce 2001, Tol 2005	MP	$29.43	$118.59
Nutrient regulation	Kazmierczak 2001	RC	$3.13	$1,069.56
Water supply	AWWA 2007	RC	$42.52	$113.39
Hurricane protection	Costanza et al., 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber 1996	PF	$53.37	$74.46
Recreation	Bergstrom et al. 1990	TC, CV	$134.44	$134.44
Aesthetic				
Saline Marsh Total			**$1,653**	**$2,905**

Wetland Forest				
Carbon sequestration	CCX n.d., Pearce 2001, Tol 2005	MP	$21.11	$191.87
Nutrient regulation	Kazmierczak 2001	RC	$3.13	$1,069.56
Water supply	AWWA 2007	RC	$42.52	$113.39
Flood protection	Thibodeau et al, 1981	AC	5,957.20	5,957.20
Hurricane protection	Costanza et al. 2008	AC	$1,394.58	$1,394.58
Fisheries production	Farber 1996	PF	$53.37	$74.46
Wetland Forest Total			**$1,515**	**$2,844**
Beach				
Disturbance protection	Parsons et al. 2001, Pompe and Rinehart 1995	HP	$20,814	$33,738
Recreation & aesthetic	Edwards and Gable 1991, Kline and Swallow 1998	HP, CV	$131	$42,654
Cultural	Taylor and Smith 2000	HP	$24	$24
Beach total			**$20,969**	**$76,416**
Cropland				
Recreation & aesthetic	Alvarez-Farizo et al. 1999, Bergstrom et al. 1985	CV	$25.77	$25.77
Pollination	Southwick and Southwick 1992, Robinson et al. 1989	MP, AC	$2.25	$11.34
Cropland total			**$28**	**$37**
Forest				
Carbon sequestration	Reyes and Mates 2004, Pimentel 1998	AC	$10.57	$13.33
Recreation & aesthetic	Willis 1991, Bishop 1992	TC, CV	$0.15	$543.42
Habitat refugia	Haener and Adamowicz 2000, Amigues et al. 2002	CV	$1.05	$2,158.01
Forest Total			**$12**	**$2,715**
Open Water				
Water supply	Piper 1997, Ribaudo and Epp 1984	CV, TC	$27.55	$718.62
Recreation & aesthetic	Patrick et al. 1991, Ward et al. 1996	TC	$1.44	$1,634.67
Open Water Total			**$29**	**$2,353**
Riparian Buffer				
Water supply	Rich and Moffitt 1982, Matthews et al. 2002	HP, CV	$4.40	$11,088.93
Disturbance prevention	Rein 1999	TC	$6.44	$200.84
Recreation & aesthetic	Greenley et al. 1981, Bowker et al. 1996	CV, TC	$7.30	$9,051.84
Cultural	Greenley et al. 1981	CV	$3.98	$3.98
Riparian Buffer Total			**$22**	**$20,346**
Urban Open Space				
Climate regulation	McPherson et al. 1998, McPherson 1992	MP, AC	$25.12	$819.68
Recreation & aesthetic	Tyrvainen 2001	CV	$1,181.85	$3,464.50
Water regulation	McPherson 1992	AC	$5.63	$5.63
Urban Open Space Total			**$1,213**	**$4,290**

Wetland				
Water supply	Lant and Tobin 1989, Pate and Loomis 1997	CV	$169.64	$3,065.76
Recreation & aesthetic	Thibodeau and Ostro 1981, Doss and Tail 1996	CV, TC	$26.81	$3,942
Habitat refugia	Vankooten and Schmitz 1992	CV	$5.04	$5.04
Water regulation	Thibodeau and Ostro 1981	AC	$5,957.20	$5,957.20
Wetland Total			**$6,159**	**$12,970**

Estuary				
Water supply	Whitehead et al. 1997, Bockstael et al. 1989	CV	$5.53	$119.79
Recreation & aesthetic	Whitehead et al. 1997, Johnston et al. 2002	CV, TC	$1.27	$332.79
Habitat refugia	Farber and Costanza 1987, Johnston et al. 2002	PF	$10.82	$1,298.23
Estuary Total			**$18**	**$1,751**

Saltwater Wetland				
Nutrient regulation	Breaux et al. 1995	AC	$102.86	$16,560.46
Habitat refugia	Lynne et al. 1981, Bell 1997	PF, FI	$1.10	$953.01
Saltwater Wetland Total			**$104**	**$17,513**

APPENDIX C: Limitations of Approach

Transferred value analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem. Like any economic analysis, this methodology has strengths and weaknesses. Because this is a meta-study, it has greater opportunity or error, and as the numbers show, a very wide range between low and high estimates. Some have objected to this approach on the grounds that:

1. Every ecosystem is unique; per acre values derived from another part of the world may be irrelevant to the ecosystems being studied.
2. Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values). This remains to be an important issue even though this was partly addressed in the spatial modelling component of this project.
3. Gathering all the information needed to estimate the specific value for every ecosystem within the study area not feasible. Then the "true" value of all of the wetlands, forests, pastureland, etc. in a large geographic area; cannot be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.
4. To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of "exchange" value; we cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income accounts aggregates and not exchange values (Howarth & Farber, 2002). These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative that amounts to limiting valuation to a single ecosystem in a single location and only using data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. For an area with the size and landscape complexity of the Mississippi River Delta, this approach will make valuation extremely difficult and costly at this point in time.

In effect, these proponents would look at the problem of conducting a house appraisal as an impossible goal. The comps, other houses sold in the neighborhood, never match well enough to make an estimate. However, they would advocate an estimate the dollar value of a bathroom, stove or door knob with good precision.

Responses to these critiques can summarized as follows (See Costanza et al 1998 and Howarth and Farber 2002 for more detailed discussion):

1. While every wetland, forest, or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more and no less justified than their use in other "macroeconomic" contexts, e.g., developing economic

statistics such as Gross Domestic or Gross State Product. This study's estimate of the aggregate value of the Mississippi River Delta's ecosystem services is a valid and useful (albeit imperfect, as are all aggregate economic measures) basis for assessing and comparing these services with conventional economic goods and services.

2. The results of the spatial modelling analysis that were described in other studies do not support an across-the-board claim that the per-acre value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and probably other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, a major indicator of ecosystem health – and by implication of services tied to NPP – where each acre makes about the same contribution to the whole regardless of whether it is part of a large patch or a small one. This area of inquiry needs further research, but for the most part the assumption (that average value is a reasonable proxy for marginal value) seems appropriate as a first approximation.

3. As employed here, the prior studies we analyzed (most of which were peer-reviewed) encompass a wide variety of time periods, geographic areas, investigators, and analytic methods. Many of them provide a range of estimated values rather than single point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Limited sensitivity analyses were performed. The approach is similar to defining an asking price for a piece of land based on the prices for "comparable" parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure, even to the extent of publicizing a single asking price rather than a price range.

4. The objection as to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of *all* of the world's ecosystems. Leaving that debate aside, one can in fact conceive of an exchange transaction in which all or a large portion of, e.g., Louisiana's wetlands were sold for development, so that the basic technical requirement that economic value reflect exchange value could in principle be satisfied. But even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose more analogous to national income accounting than to estimating exchange values (cf. Howarth and Farber 2002).

In the last analysis, this report takes the position that "the proof is in the pudding", i.e., the possibility of plausibly estimating the value of an entire state's ecosystem services is best demonstrated by presenting the results of an attempt to do so. In this report we have tried to display our results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services it seems better to be approximately right than precisely wrong.

The estimated value of the world's ecosystems presented in Costanza et al. (1997) has been criticized as both (1) "a serious underestimate of infinity" and (2) impossibly exceeding the entire Gross World Product. These objections seem difficult to reconcile, but that may not be so. Just as a human life is "priceless" so are ecosystems, yet, people get paid for work. Thus Costanza's estimate of the work that ecosystem do, is an underestimate of the "infinity" of pricelessness because that is not what he estimated. That the value ecosystems provide to people exceeds the gross world product should, perhaps not be so surprising. Consider the value of one ecosystem service, photosynthesis, and the ecosystem good it produces, atmospheric oxygen, neither valued in Costanza's study. Given the choice between breathable air, and possessions, informal surveys have shown the choice of oxygen over stuff is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product. That is only a single ecosystem service and good.

In terms of more specific concerns, the value transfer methodology introduces an unknown level of error, because we usually do not know how well the original study site approximates conditions in the Mississippi River Delta, with the exception of some wetlands studies that were conducted in this area. Other potential sources of error in this type of analysis have been identified (Costanza et al. 1997) as follows:

1. Incomplete coverage is perhaps the most serious issue. Not all ecosystems have been well studied and some have not been studied at all as is evident from the gap analysis presented below. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of less than zero.
2. Distortions in current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of "true" values.
3. Most estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously been aware of.
4. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. If the Mississippi River Delta's ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in "supply" appear likely as land conversion and development proceed; climate change may also adversely affect the Mississippi River Delta's ecosystems (e.g., more intense hurricanes), although the precise impacts are harder to predict.
5. The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services (Limburg et al. 2002).
6. As noted above, the method used here assumes spatial homogeneity of services within ecosystems. The spatial modeling component of the project was intended to address this issue and showed that, indeed, the physical quantities of some services vary significantly with spatial patterns of land use and land cover. Whether this fact would increase or decrease valuations is unclear, and depends on the specific spatial patterns and services involved.
7. Our analysis uses a static, partial equilibrium framework that ignores interdependencies and dynamics. More elaborate systems dynamics studies of ecosystem services have shown that including

interdependencies and dynamics leads to significantly higher values (Boumans et al. 2002), as changes in ecosystem service levels ripple throughout the economy.

8. The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.
9. The approach does not fully include the "infrastructure" or "existence" value of ecosystems. It is well known that people value the "existence" of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.
10. There are great difficulties and imprecision in making inter-country comparisons on a global level. This problem was of limited relevance to the current project, since the majority of value transfer estimates were from the U.S. or other developed countries.
11. In the few cases where we needed to convert from stock values to annual flow values, the amortization procedure also creates significant uncertainty, both as to the method chosen and the specific amortization rate used. (In this context, amortization is the converse of discounting.)
12. All of these valuation methods use static snapshots of ecosystems with no dynamic interactions. The effect of this omission on valuations is difficult to assess.
13. Because the transferred value method is based on average rather than marginal cost, it cannot provide estimates consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

The result would most likely be significantly higher values if these problems and limitations were addressed. Unfortunately, it is impossible to know how much higher the values would be if these limitations were addressed. One example may be worth mentioning, however. Boumans et al. (2002) produced a dynamic global simulation model that estimated the value of global ecosystem services in a general equilibrium framework to be roughly twice of what Costanza et al estimated using a static, partial equilibrium analysis. Whether a similar result would obtain for the Mississippi River Delta is impossible to say, but it does give an indication of the potential range of values.

EARTH ECONOMICS

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National Wildlife Federation Action Center comment template (generated 14,610 comments):

I urge the Corps of Engineers to stop building river training structures in the Middle Mississippi River and to remove some existing structures to protect wildlife habitat and communities. The Corps has already built hundreds of miles of river structures in the Middle Mississippi and buried the river's banks under hundreds of miles of concrete, causing tremendous harm to wildlife and significantly increasing flood risks. Extensive peer-reviewed science shows that river training structures, built for the sole purpose of reducing navigation dredging costs, have already increased flood levels more than 10 feet in much of the Middle Mississippi. The Draft SEIS recommends using 4.4 million tons of rock to build even more river structures that will destroy 1100 acres of wildlife habitat. The Corps should go back to the drawing board and prepare a comprehensive, scientifically sound environmental impact statement that adopts less-damaging methods for maintaining navigation. As part of this process, it is imperative that the Corps initiate and listen to a National Academy of Sciences study on river training structures and flooding. Thank you.

From:	Jamie Nash-Mayberry
To:	RegWorksSEIS
Subject:	[EXTERNAL] river navigation structures
Date:	Monday, November 28, 2016 5:20:21 PM

Mr. Runyon,

In regards to the regulating works draft, I want it on the record that we, many of the citizens that live in the Shawnee School District 84, which stretches from Grand Tower, through Preston, Clear Creek, East Cape and Northern Alexander levee districts, continue to object to the building of more river navigational structures in the middle Mississippi. In fact, all of the levee district commissioners of those districts once signed letters objecting to them. We especially object to the experimental S dikes. I know that your studies do not show any connection to the wing dikes contributing to increased flood heights, but we can't deny that there are a number of sources who do feel it does, and there is no hidden agenda that we can uncover that would cause them to lie to us about the impact of dikes on flood heights. And as to an environmental improvement, the National Wildlife Federation and a number of other environmental groups do not feel these river structures are helpful to the environment. You should have their letters on file too. Thus, we feel the National Academy of Sciences needs to study this issue further. We have both spoken out and written letters over and over on this issue to the Corps. We do NOT want another public hearing. We've held multiple ones, and to no avail, you continue to pursue these projects and don't seem to hear us. Therefore, it seems public hearings are a waste of the public's time. What we do want is simple- put yourself in our shoes, and do what is right.

Sincerely,

Jamie Nash-Mayberry
Shawnee High School Social Science teacher

US Army Corps of Engineers
St. Louis District

Comment Form

Draft Supplemental Environmental Impact Statement (SEIS) for Regulating Works on the Middle Mississippi River

We need your comments. Please use this form to provide your thoughts or concerns on the Draft Supplemental Environmental Impact Statement for Regulating Works on the Middle Mississippi River. Your input will help us make an informed decision on the Project. Please complete this comment form today or mail to the address below. Comments will become part of the public record. Responses to your comments will be provided in the Final EIS. Comments must be received no later than January 18, 2017.

Comments may be mailed to:

U.S. Anny Corps of Engineers -St. Louis District
Attn: Kip Runyon (CEMVS-PD-P)
1222 Spruce St.
St. Louis, MO 63103-2833

If you prefer, you may email comments to RWorksSEIS@usacc.anny.mil

Please provide your comments below (Please print legibly):

The Mississippi River and it's harbors are very important to the economy of South East Missouri. Moving products by barge is not only important because of the significant savings on transportation costs, but also because it is environmental friendly. Less truck traffic on the highways also helps the economy by reducing the amount of road repair needed.

We appreciate very much the Corps concern for, interest in, and help with improvement projects in South East Missouri.

Signature: 9-l1flJ' ;in

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Thank you for your interest and participation.

US Army Corps of Engineers
St. Louis District

Comment Form

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1222 Spruce St.
St. Louis, MO 63103-2833

If you prefer, you may email comments to RegWorksSEIS@usace.arrny.mil

Please provide your comments below (Please print legibly):

please see attached letter

Signature: 2('

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Thank you for your interest and participation!

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PORT

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December 15, 2016

Comments
Draft Supplemental Environmental Impact Statement (SEIS)
For Regulating Works on the Middle Mississippi River

Dear Mr. Runyon:

Thank you for the opportunity to provide comments on the Regulating Works SEIS.

Transportation. For Semo Port and our customers, the Middle Mississippi River's navigation channel is an essential artery for transportation, both domestic and international. This year the companies located at Semo Port will ship and receive over 1.3 million tons of products by barge. These companies, in turn, buy and sell to many other companies, farmers, mines, and mills.

Based on 25 tons per truckload, the barge shipments equate to 52,000 truckloads. Allowing a return empty move for each loaded move, this represents 104,000 truck trips or 2,000 trips a week. These numbers are just for our Port, one facility of many on the river. By using river transportation, short haul truck trips are combined with long haul barge moves for greater fuel efficiency, lower cost, less pollution, and greater safety.

In reality, if the products did not move by barge, most would not move at all because they could not afford the higher cost of rail transportation or the much higher cost of truck transportation. The Mississippi River is a crucial advantage to United States agriculture and other industries as they compete in world markets.

River Navigation Channel. The Corps does an excellent job of maintaining the navigation channel, meeting budgetary requirements while balancing the needs of navigation with those of environmental habitat, flood control, water supply, recreation, and other uses.

Of the two alternatives, the Continue Construction Alternative is preferred for several reasons. First, it is needed to address changes in the river which occur over time. River training structures must be adjusted on occasion. The river does not exist in a vacuum – it is affected by many different factors within the watershed and other watersheds which feed into the Middle Mississippi River. As these change, the Corps' efforts must be adjusted.

One of these factors is the modification of structures and other elements to better accommodate habitat needs while meeting navigation requirements. The Corps has creatively found designs that can meet the needs of both and do so with an acceptable level of cost (investment).

Second, the Corps has a continuing effort to improve the effectiveness of the river structures while, as much as possible, reducing costs. Using the investment in permanent structures to reduce the annual operating costs of dredging and other maintenance work benefits the taxpayer and the environment. In these situations, the Corps uses the sustainable power of the river to replace or reduce man-made maintenance efforts.

Conclusion. The Continue Construction Alternative is preferred because it allows the Corps of Engineers to best meet the needs of the Middle Mississippi River and all those who depend on it.

Sincerely,

Daniel L. Overbey

Daniel L. Overbey
Executive Director

US Army Corps of Engineers
St. Louis District

Comment Form

Draft Supplemental Environmental Impact Statement (SEIS)
for Regulating Works on the Middle Mississippi River

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U.S. Army Corps of Engineers - St. Louis District
Attn: Kip Runyon (CEMVS-PD-P)
1222 Spruce St.
St. Louis, MO 63103-2833

If you prefer, you may email comments to RWorksSEIS@usace.army.mil

Please provide your comments below (Please print legibly):

I would like to [illegible] comment on the importance of the Mississippi River and barge service to our state and nation. The Corps, St. Louis District, is doing a great job in maintaining the river and I give you high marks on the priority you give to environmental matters. Millions of tons of many different commodities travel annually up and down the Mississippi River and the last statistic I read stated over 238 million cubic yards was removed through the Corps in maintaining channels. I also read that there was a 4.3% increase of cubic yards of material with a 7.6% decrease in cost. Keep up the good work and thank you.

Signature: [signature] Date: 12/19/16

Name: [illegible] Title: President - Cairo Marine Service

Mailing address: [illegible]

City, State, Zip code: [illegible]

Phone: [illegible] E-mail: [illegible] com

Responses to National Wildlife Federation, American Rivers, Missouri Coalition for the Environment, and Prairie Rivers Network Comments

Comment 1: *The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment . . . The No New Construction Alternative, which should be reexamined in light of an appropriate project purpose, a clear demonstration of need, and a comprehensive and meaningful assessment of potential impacts.*

Response: The Regulating Works Project purpose has been properly identified in light of the purpose of the SEIS to update the project's original EIS with new information and circumstances since 1976. See response to USFWS Comment 13 and Appendix K, Regulating Works Project History, for additional information on the project purpose and need. The SEIS has been updated with additional information and/or clarification as noted in other responses to comments with respect to assessment of potential impacts.

Comment 2: *The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment . . . An alternative that includes removing and/or modifying existing river training structures in the Project area to restore backwater, side channel, and braided river habitat; and reduce flood risks.*

Response: See response to USFWS Comment 13 and Appendix K with respect to the Regulating Works Project authorized purpose and authority. Further information has also been added to Chapter 2 to explain the alternatives development process and that alternatives outside of the existing authority are not reasonable or feasible at this time.

Comment 3: *The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment . . . An alternative that minimizes the use of new river training structures, including by placing restrictions on the number and/or types of structures that can be utilized in a given reach based on a robust scientific assessment of the cumulative impacts of the various types of river training structures.*

Response: See additional information added to Chapters 1 and 2 discussing the alternatives development process and the incorporation of avoid and minimize measures into the Continue Construction Alternative.

Comment 4: *The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment . . . An alternative that maintains the authorized navigation channel through other approaches, including such things as alternative upstream water level management regimes, alternative dredging and dredged spoil disposal activities, and the development of new, innovative techniques.*

Response: See additional information added to Chapters 1 and 2 and Appendix K providing more detail that the Continue Construction Alternative already incorporates some of these suggestions and that alternatives outside of the existing authorization are not reasonable or feasible at this time.

Comment 5: *The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment . . .An alternative that evaluates restoration activities that would improve the ecological health and resiliency of the Mississippi River and its* *floodplain and the fish and wildlife species that rely on those resources. This alternative should include formally adopting restoration, and fish and wildlife conservation, as authorized Project Purposes.*

Response: See response to USFWS Comment 13 and Appendix K explaining the lack of authority for ecosystem restoration activities to be completed as part of the Regulating Works Project. See also revised Chapter 2 detailing the alternative development process.

Comment 6: *The Corps Should Develop and Select a New Alternative that Will Protect People, Wildlife, and the Environment . . . To comply with the National Water Resources Planning Policy, and to protect communities and taxpayers, the final SEIS should select an alternative that will reduce flood risks to communities, and protect and restore the Mississippi River.*

Response: See response below to Comment 8 that the revised National Water Resources Planning Policy is not applicable to the SEIS because it is not a planning document. See also response to USFWS Comment 13 that there is no current authorization under the Regulating Works Project to protect and restore the Mississippi River through this particular project, but there are other authorities that can be utilized for these purposes. The SEIS evaluates the risk of flooding as a potential impact of the Regulating Works Project (see Appendix A). Also, see further information provided in Chapters 1 and 2 explaining what actions are taken as part of the Regulating Works Project to avoid and minimize impacts and coordinate with federal and state resource agencies.

Comment 7: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Improperly Limits the Alternatives Analysis . . . The DSEIS Purpose and Need statement violates each of these mandates because it is so narrowly drawn that it dictates continuation of the status quo approach to the Project, severely limiting the analysis of alternatives. . . . Notably, while the DSEIS states repeatedly that Congress has dictated the approach that the Corps must take in carrying out the Project, the DSEIS does not provide the full text of either the legislation or supporting Chief of Engineers' reports that set forth those approaches. . . . the significant changes to the Project over time demonstrate that the Corps believes it is readily able to change the methods and techniques used to carry out the Project.*

Response: All of the legislation and referenced Chief of Engineers' Reports as well as the portion of the Annual Chief's Reports relevant to the Regulating Works Project have been posted to the SEIS Library:
http://www.mvs.usace.army.mil/Missions/Navigation/SEIS/Library.aspx
Further, as seen through these reports and the description of the Regulating Works Project, there have not been significant changes to the Project over time. The Project has been carried out pursuant to the authority granted in 1910, referencing the 1881 plan, to obtain and maintain the navigation channel through the contraction of the river to scour out its bed, to be aided, if necessary by dredging; to protect eroding banklines; and to remove rock that may hamper low water navigation. See Appendix K for a history of the

project, which indicates that materials used, design of the structures, and the identified most efficient contraction width have changed over time as new information, techniques, and accounting for environmental impacts occurred. However, these have been minor design variations on the original authority as described in 1881 – the Regulating Works Project has always used the construction of river training structures to scour the river in an effort to reduce dredging to obtain the navigation channel, revetment for bankline protection, and rock removal where necessary. When situations existed through the years that required more than this authority to obtain and maintain a safe and dependable channel, additional authorization was sought (e.g., the Chain of Rocks Canal with Locks 27 and the low water dam at Chain of Rocks).

Comment 8: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Account for Clear Congressional Directives . . . The National Water Resources Planning Policy established by Congress in 2007. This policy 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. This policy requires the Corps to operate the Regulating Works Project to protect the Mississippi River and its floodplain.*

Response: The referenced statute is not applicable to the Regulating Works Project nor the SEIS. See 42 USC § 1962-3(7) for applicability of this statute:

After the date of issuance of the revisions to the principles and guidelines, the revisions shall apply-

(A) to all water resources projects carried out by the Secretary, other than projects for which the Secretary has commenced a feasibility study before the date of such issuance;

(B) at the request of a non-Federal interest, to a water resources project for which the Secretary has commenced a feasibility study before the date of such issuance; and

(C) to the reevaluation or modification of a water resources project, other than a reevaluation or modification that has been commenced by the Secretary before the date of such issuance.

(8) Existing studies

Revisions to the principles and guidelines issued under paragraph (2) shall not affect the validity of any completed study of a water resources project.

The most recent feasibility study, as that term is used today, for the overall Regulating Works Project was completed in 1926. Since that time, there has not been a substantial change or modification to the Project that warranted an additional feasibility study. As indicated in the SEIS, the purpose of the document is just to update the original 1976 EIS with the new information and circumstances since 1976 – it is not a reevaluation or modification of the project. And as explained in the revised Chapter 2, there was not a viable or reasonable alternative that suggested that the document should shift to a planning document for reevaluation or modification of the project.

Comment 9: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Account for Clear Congressional Directives . . . The National Environmental Policy Act enacted in 1970. NEPA directs the "Federal Government to use all practicable means" to, among other things: (i) "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;" (ii) ensure "safe, healthful, productive" surroundings for all Americans; and (iii) "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences." 42 U.S.C. § 4331(b). NEPA states explicitly that the policies, regulations and laws of the United States "**shall** be interpreted and administered in accordance with the policies set forth in this Act." 42 U.S.C. § 4332(1) (emphasis added). NEPA also explicitly states that "policies and goals set forth in this Act are supplementary to those set forth in existing authorizations of Federal agencies." 42 U.S.C. § 4335.*

Response: The SEIS fully accounts for the mandates of NEPA pursuant to the purpose of the Project and the purpose of the SEIS. More information and details have been added to the SEIS, primarily in Chapter 1, to better explain the environmental considerations and coordination with federal and state resource agencies that goes into the design, construction, and operation and maintenance of the Regulating Works Project, better detailing the compliance with the policies set forth in NEPA.

Comment 10: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Account for Clear Congressional Directives . . . The many statutory directives to protect the environment and fish and wildlife contained in the Clean Water Act, the Endangered Species Act, the Clean Air Act, the Corps' civil works mitigation requirements (33 U.S.C. § 2283(d)), and the Water Resources Development Act of 1990 that changed the Corps' fundamental mission to "include environmental protection as one of the primary missions of the Corps of Engineers in planning, designing, constructing, operating, and maintaining water resources projects." 33 U.S.C. § 2316.*

Response: See response to Comment 9 regarding additional details added to the SEIS to better explain the environmental considerations that go into the Regulating Works Project and will continue under either alternative. Further, the SEIS describes compliance with the Clean Water Act (Appendix D), the Endangered Species Act (Appendix B), and the Clean Air Act (See Sections 3.2.5 and 4.2.5). The reference to 33 USC § 2283(d)(1) is misplaced because it is not applicable to the SEIS since it is not a report being prepared for authorization by Congress. See USACE, Memorandum for Commanders, Major Subordinate Commands, subject: Implementation Guidance for Section 2036(a) of the Water Resources Development Act of 2007 (WRDA 07) – Mitigation for Fish and Wildlife and Wetlands Losses, Theodore Brown, P.E., Chief Planning and Policy Division, Directorate of Civil Works, 31 August 2009. The Regulating Works Project authority for mitigation of project impacts is pursuant to 33 USC § 2283(b), which is discretionary and subject to funding limitations. See response to USFWS Comment 13 and Appendix K for more information on the project authority. Appendix C and any future mitigation planning in tiered, site-specific EAs is and will be in accordance with current law, regulation, and guidance.

Comment 11: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Account for Clear Congressional Directives . . . The Fish and Wildlife Coordination Act enacted in 1958. The Fish and Wildlife Coordination Act 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. See Section IV of these comments for a more detailed discussion of the Fish and Wildlife Coordination Act and its applicability to the Project.*

Response: See response to USFWS Comment 13.

Comment 12: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Account for Clear Congressional Directives . . . "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).*

Response: The cited regulation is not applicable to the SEIS because it is not a water resource development plan. See 33 CFR § 236.1, stating that the purpose of 33 CFR Part 236 is to provide guidance for including Environmental Quality (EQ) measures in Corps of Engineers water resource development plans. However, the SEIS has been updated to include more information and detail about the environmental considerations and coordination with federal and state resource agencies that goes into the design, construction, and operation and maintenance of the Regulating Works Project.

Comment 13: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Demonstrate Project Need . . . the Corps acknowledges that the actual purpose of the river training structures is simply to reduce the costs associated with dredging certain sections of the navigation channel. Notably, however, the DSEIS does not provide any type of meaningful cost information or a benefit-cost assessment* *that could assist in determining whether new river training structure construction might actually achieve even this limited goal.*

Response: A simplified economic analysis was utilized to estimate the amount of remaining construction and is described in appendix C. This estimate was produced for the sole purpose of determining the significance of potential environmental impacts. Historical data was used to estimate the relationship between structure construction and dredging reduction and this relationship is displayed in Appx C Figure 1. This figure shows that structure construction reduces dredging. In addition, more information on dredging reduction has been added to Section 1.1.5. An economic update is completed periodically to support budget requests (i.e. determine if construction should continue to be funded).

Comment 14: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Demonstrate Project Need . . . Instead of providing meaningful information demonstrating the need for new river training structure construction, the DSEIS contends that new river training structures should be constructed to fend off vague and unsubstantiated risks of barge groundings, channel closures, and lack of sufficient funding for dredging under certain extreme conditions that may (or may not) occur at some point in the future. . . . 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."*

Response: See additional information added to Section 1.1.5 that details the effectiveness of the Regulating Works Project during low water conditions.

Comment 15: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Demonstrate Project Need . . . 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.*

Response: See additional information added to Section 1.1.5 that details the effectiveness of the Regulating Works Project during low water conditions. There is no reason to believe that a reduction in dredging achieved during average conditions would not lead to a reduction in low water conditions.

Comment 16: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Demonstrate Project Need . . . the DSEIS fails to provide any estimate of future costs with and without new river training structure construction, and* *fails to identify those areas likely to require continued dredging even if additional structures are constructed.*

Response: Estimates of future costs with and without new river training structure construction will be included in the ongoing economic analysis. Areas likely to require continued dredging can be found in the included masterplan in Appendix I.

Comment 17: *The DSEIS Fails to Comply with the National Environmental Policy Act . . . The DSEIS Purpose and Need Statement Fails to Comply with NEPA . . . The Purpose and Need Statement Fails to Demonstrate Project Need . . . the DSEIS also fails to provide critical information on sediment loads and sediment transport in the Middle Mississippi River, making it impossible for the public and decision makers to assess the need for additional river training structures.*

Response: See response to USFWS Comment 13 and Appendix K for information on Project purpose and need. Information on sediment has been added to Section 3.2.2, Geomorphology.

Comment 18: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The Alternatives Analysis Violates NEPA as a Matter of Law . . . because it has explicitly and intentionally failed to evaluate reasonable alternatives to determine whether there are less damaging ways to achieve the project purpose. . . . The Corps' explicit refusal to examine any alternatives that the Corps currently deems to be outside of the existing authorization, or that do not specifically track approaches identified by Congress more than 100 years ago, renders the DSEIS inadequate as a matter of law.*

Response: See response to USFWS Comment 13 and Appendix K for information on Project purpose. Information on the alternative development process has been added to Chapter 2.

Comment 19: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The DSEIS Fails to Evaluate an Appropriate Range of Alternatives . . . the scope and impacts of the Project mandate evaluation of a much broader range of alternatives. The range of alternatives that must be considered is determined by the nature and scope of the proposed action. The greater the impacts and scope of the proposed action, the greater the range of alternatives that must be considered. Both the scope and the impacts of the Project are enormous...*

Response: The District believes that an appropriate range of alternatives is considered in the SEIS and that the impacts of the Project are accurately and adequately analyzed. See responses to Comments 7 and 9 above that the proper purpose of the Project has been identified, which dictates the scope of the proposed action. See additional Alternative Development information added to Chapter 2.

Comment 20: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The DSEIS Fails to Evaluate an Appropriate Range of Alternatives . . . Federal courts have routinely* *found that NEPA "prevents federal agencies from effectively reducing the discussion of environmentally sound alternatives to a binary choice between granting and denying an application." The DSEIS provides just such an improper binary choice; one alternative would continue construction of river training structures along with all other current Regulating Works activities, while the second alternative would stop construction of river training structures while still carrying out all other current Regulating Works activities.*

Response: Additional information has been provided in Chapter 2 on the alternatives development process for the SEIS. See Appendix K for information on the authority and history of the Regulating Works Project to further explain that process and why certain alternatives are not reasonable or feasible. Also, as discussed in response to Comments 7 and 9 above, the proper purpose of both the Project and the SEIS have been identified, which sets the scope for the alternatives to be considered.

Comment 21: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The DSEIS Fails to Provide an Informed and Meaningful Consideration of Alternatives . . . for the two alternatives that it does evaluate because it fails to provide meaningful information on the actions that will be carried out under those alternatives. . . . Neither alternative provides criteria for the triggering of future dredging, revetment, or river training structure construction.*

Response: See additional information provided in Chapter 1 about the process for identifying, designing and coordinating additional dredging, revetment, or river training structure construction.

Comment 22: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The DSEIS Fails to Provide an Informed and Meaningful Consideration of Alternatives . . . for the two alternatives that it does evaluate because it fails to provide meaningful information on the actions that will be carried out under those alternatives. . . . Neither alternative provides information concerning the likely locations of such future actions.*

Response: See the Masterplan that has been added as Appendix I.

Comment 23: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The DSEIS Fails to Provide an Informed and Meaningful Consideration of Alternatives . . . for the two alternatives that it does evaluate because it fails to provide meaningful information on the actions that will be carried out under those alternatives. . . . Neither alternative provides any information on the economic costs or impacts of the likely future actions.*

Response: See response to Comment 13 above for information on the economic analysis associated with the SEIS. A programmatic evaluation of the general nature and estimated scale of impacts based on specific locations in the MMR was conducted for the SEIS to determine the magnitude of impacts. A programmatic approach was taken because, while some chronic dredging sites are known, it is not possible to predict the location of all future river training construction sites. Because of dynamic river conditions and constraints on annual funding, it is not reasonable to develop detailed site-specific plans for each potential future work area. Some of these areas could change and typical funding only allows for a limited number of site-specific planning efforts at any given time. However, the specific types of structures to be used at each location will be detailed in future, tiered site-specific EAs along with an accounting of the magnitude of impacts at the site-specific and cumulative level. More information on the specific decision-making process used in identifying potential construction sites has been added to Section 1.1.3, Process for New Construction under the Regulating Works Project, of the Main Report. Appendix C describes the process by which the amount of remaining construction was estimated, which includes mitigation as one of the cost parameters and utilizes a simplified economic analysis to support the conclusion. The descriptions of the types of river training structures originally found in Appendix F have been moved to a table in Section 3.2.2, Geomorphology, of the Main Report.

Comment 24: *The DSEIS Alternatives Analysis Fails to Comply with NEPA . . . The DSEIS Fails to Provide an Informed and Meaningful Consideration of Alternatives . . . for the two alternatives that it does evaluate because it fails to provide meaningful information on the actions that will be carried out under those alternatives. . . . The Continue Construction Alternative does not provide any information on the types of river training structures that will be used, and does not provide any information on the projected linear feet of river training structures that will be constructed.*

Response: Additional information has been added detailing the types of river training structures that have been used and see updated Chapter 1 for additional details on how future projects will be identified, designed, and coordinated. The masterplan which has been added as Appendix I details the locations of areas that are currently known. The District recognizes that due to the dynamic nature of the system new construction locations could be identified in the future. Using the estimated relationship developed in Appendix C, 4.4 million tons of material equates to approximately 64,000 linear feet of additional structure length. As is the case with the estimated quantity of material to be placed, the actual linear feet of river training structures to be constructed is dependent on the configuration of the structures used.

Comment 25: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Examine Reasonably Foreseeable Site-Specific Impacts*

Response: See response to Comment 24 above.

Comment 26: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Flood Heights and Flood Response*

Response: See response to Comment 36.

Comment 27: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Sediment Loading, Sediment Transport, Hydrology and Hydraulics*

Response: Information on sediment has been added to Section 3.2.2, Geomorphology.

Comment 28: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Main Channel Border Habitat Model*

Response: The main channel border habitat model was not used to assess the anticipated programmatic impacts of the Project. A numerical hydraulic engineering model and an estimate of the quantity of future construction were used to assess the programmatic impacts of the Project. The engineering model used in this assessment was reviewed in accordance with Engineer Regulation 1110-2-1150, Engineering and Design for Civil Work Projects. The main channel border habitat model will be used to assess impacts to the quality and/or quantity of habitat on a site-specific basis as site-specific Environmental Assessments are prepared and the model will be certified (per the requirements of EC 1105-2-412) prior to being used for this purpose.

Comment 29: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Nineteen Mile Modeled Reach*

Response: The 3-dimensional numerical hydraulic model is an engineering model and not a planning model and, therefore, is not required to go through the planning model certification process. The model has been validated for use by the Hydraulics and Coastal Community of Practice (HH&C CoP) as detailed in Enterprise Standard (ES)-08101. The model study results were evaluated as part of the Agency Technical Review Process. The model study report has been added as Appendix J.

Comment 30: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Independent External Peer Review Panel Comments*

Response: The IEPR panel review was performed concurrently with the public review, per standard Corps review procedures, and therefore, the changes made in response to the panel's comments were not complete at the time the SEIS was released to the public. Additionally, the IEPR process results in just two publicly-available documents – the first of which is the Final Report, which was included in the documents released to the public and never includes the responses to the panel's comments. The second document is the Agency Response, which summarizes and explains the changes made to the document in response to the panel's comments. This is prepared when the document is near completion so that it may accurately reflect what is in the final document.

Comment 31: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Independent Peer Review Panel Report and Membership*

Response: The Type I IEPR was conducted in full compliance with Corps guidance. Per EC 1165-2-214, the panel was selected by an Outside Eligible Organization (OEO) based on the technical disciplines which contributed to the development of the SEIS. Additionally, per that same guidance, the OEO must select the panel members in adherence with the National Academy of Sciences (NAS) Policy on Committee Composition and Balance and Conflicts of Interest. The District did not ask the panel to review the referenced documents because the panel's task is to review and comment on the product produced by the Corps (the SEIS). The documents were referenced in the SEIS in relation to one area of potential controversy. The panel was instructed that they could request any of the reference documents, but they did not request them.

Comment 32: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Lacks Scientific Integrity . . . Economic Data and Analyses*

Response: The project involves continuing construction (not "new" construction), which does not require an alternatives comparison with NED analysis, only a periodic update of the economics to support budget requests (i.e. determine if construction should continue to be funded). Because of the dynamic nature of the river, it is not possible to accurately predict how much construction is left on the project. An estimate of remaining construction was developed for the purpose of determining the significance of environmental impacts, which is sufficient to support the scope and purpose of the SEIS. Appendix C describes the process by which the amount of remaining construction was estimated, which includes mitigation as one of the cost parameters and utilizes a simplified economic analysis. Since the SEIS is not a planning document but merely an update to the 1976 EIS, there is no need to conduct a valuation of ecosystem services lost for this document.

Comment 33: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Accurately Establish Baseline Conditions ... on flood heights...*

Response: See response to Comment 36 below.

Comment 34: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Accurately Establish Baseline Conditions ... on sedimentation rates...*

Response: See additional information on sediment added to Section 3.2.2, Geomorphology.

Comment 35: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Accurately Establish Baseline Conditions ... on fish and wildlife species, including migratory species, and their critical habitat needs... on plant species, including wetland plant species... on vitally important habitat types, including main channel border habitat, braided river habitat, wetland habitat, and floodplain habitat...Fails to meaningfully evaluate the potential impacts of channel cutoffs...fails to discuss and account for the significant decline in the ecological health of the Mississippi River and the role of the Regulating Works Project in that decline...*

Response: The background information and analyses presented in the SEIS are commensurate with the scope of the anticipated impacts of the Project and the scope of the document to update the 1976 EIS with new information. The District believes that the scope of the information presented is adequate to support the conclusions drawn.

Comment 36: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts on Flooding*

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. This review included an analysis of all available gage records on the MMR. 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 SEIS, 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 additional analyses of Criss and Luo 2016. Appendix K also provides a historical narrative of the District's efforts in addressing this issue.

The Corps recognizes that some individuals in academia 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, there is not sufficient evidence to warrant funding costly and time consuming research efforts at this time. The Corps welcomes and will continue to 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.

The comment claims that Criss and Luo (2016) makes four critical findings that the DSEIS critique does not - and cannot - explain. Information on these four points has been added to Appendix A and direct responses are below.

(1) The record high stages set during this recent flood just downstream at Cape Girardeau and Thebes, which as Criss and Luo point out would have been far higher but for the catastrophic failure of the Len Small levee.

Response: As stated in Appendix A, the Corps agrees that levees can impact stages for flood events.

(2) Why the recent peak stage at Chester was nearly 3 feet higher than it was on April 30, 1973, which at that time was the highest water level ever recorded at that site.

Response: The peak stage at Chester was 2.67 feet higher in 2016 than 1973. This is due to the flood of December 2015/January 2016 having a peak flow that was 67,000 cfs higher than the flood of 1973. The peak flow and stage at Chester in 1973 was 886,000 cfs and 43.32 ft on the Chester gage. In 2016 the peak flow and stage were 953,000 cfs and 45.99 ft on the Chester gage.

(3) The unusual winter timing of this recent flood and its short duration, both of which would not have caused a flood of this magnitude without constriction of the river.

Response: The timing of the December 2015/January 2016 flood is not unusual. The flood of 1982 also occurred in December. Additional information has been added to Appendix A discussing the short duration of the December 2015/January 2016 flood. There is no analysis in Criss and Luo (2016) supporting the claim that constriction of the river was the cause of the January 2015/December 2016 flood rather than extreme precipitation.

(4) Why the site showing the greatest increase in stage over previous floods occurred adjacent to the Valley Park levee, built by the Corps in 2005.

Response: Any potential impact of the Valley Park levee on stages on the Meramec River is not relevant to the impact of river training structure construction on the MMR on flood levels.

Comment 37: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts to Main Channel Border Habitat ... The DSEIS assessment that 1,100 (8%) of the remaining unstructured main channel border habitat will be lost is based on an incomplete border habitat model...*

Response: See response to Comment 28 above.

Comment 38: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts to Main Channel Border Habitat ... The DSEIS does not meaningfully analyze the additive losses to main channel border habitat that will be caused by the disposal of dredged spoil...*

Response: As discussed in Section 4.3, Impacts on Biological Resources, the majority of dredge disposal takes place in the main channel of the MMR, not in the main channel border, and the impact is considered a temporary disturbance in that the disposal area almost immediately returns to a state that is available as habitat. This impact is not considered an additive loss compounded annually but a recurring temporary disturbance.

Comment 39: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts to Main Channel Border Habitat ... In addition, DSEIS Appendix C suggests that impacts to main channel border habitat from river training construction alone could be much higher than 1100 acres: "It was calculated that the* *impact of all construction necessary to achieve the maximum dredging reduction as determined by the Expert Elicitation was 1774 acres of main channel border."*

Response: The exact quantity of impacted Main Channel Border Habitat is unknown due to the fact that it is not possible to predict the location of all future river training structure construction sites; therefore, it was necessary to estimate the programmatic impacts. The quantification of the impacts to main channel border habitat will be detailed in site-specific EAs once the site-specific plans for each potential future work area are developed.

Comment 40: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts to Main Channel Border Habitat ... The assessment of impacts is limited to an estimate of acreage losses...it is equally important to know the total linear feet and likely locations of such losses...*

Response: The programmatic estimate of the number of acres impacted is necessary given that the locations of future site-specific impacts are not known. Site-specific impacts will be covered in future SSEAs.

Comment 41: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts to Main Channel Border Habitat ... The DSEIS also fails to meaningfully evaluate the ecological losses that will stem from the significant losses of main channel border habitat...The DSEIS fails to provide even the most basic information on the ecological characteristics of main channel border habitat...The DSEIS also does not identify the vast array of fish and wildlife species that utilize the main channel border, and does not provide a meaningful assessment of the direct, indirect, and cumulative adverse impacts...*

Response: The District appreciates that there is a wide variety of fish and wildlife species that use or could potentially use the various habitats provided by the MMR. However, the information and analyses presented in the SEIS focus on the scope of the anticipated impacts of the Project based upon the need for updating the 1976 EIS with new information. The District believes that the information presented in the SEIS on the direct, indirect, and cumulative impacts of the Project is adequate to support the conclusions drawn.

Comment 42: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Key Information Concerning Side Channels ...The DSEIS conclusion that the quantity of side channel habitat is stable or improving and that the Corps intends to avoid and minimize impacts to side channels is not supported by evidence.*

Response: The conclusion that the quantity of side channel habitat in the MMR is stable or improving is directly supported by field measurements of MMR side channels, as presented in the SEIS. The District will continue to avoid and minimize impacts to side channel habitat.

Comment 43: *The Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Key Information Concerning Side Channels ...The entire side channel analysis fails to address the biological value of side channel connectivity in the Middle Mississippi River and the impacts of the Project on those biological values.*

Response: The biological characteristics and importance of side channels and side channel connectivity are presented in Section 3.2.2, Geomorphology. The information provides the basis to support the need for the side channel analyses that follow as well as the impact analysis in Chapter 4.

Comment 44: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Key Information Concerning Side Channels ... The DSEIS also fails to evaluate the impacts of climate change on the Middle Mississippi River side channels at both low and high flow conditions.*

Response: Additional information on climate change impacts on MMR resources and associated Project impacts has been added to Section 4.2.5, Impacts on Air Quality and Climate Change.

Comment 45: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Impacts to Braided Channel Habitat ... Impacts to braided channel habitat were highlighted in the Draft Environmental Assessment with Unsigned Finding of No Significant Impact, Regulating Work Projects Eliza Point/Greenfield Bend Phase 3...*

Response: The material that is referenced in the comment as coming from the Draft Environmental Assessment for Eliza Point/Greenfield Bend Phase 3 instead appears to be from a Draft Environmental Assessment for a project under a separate authority - the Navigation and Ecosystem Sustainability Program (NESP) Herculaneum Side Channel Restoration Project. It is not anticipated that the Regulating Works Project will affect braided channel habitat. However, the District is sensitive to the importance of MMR side channels that may mimic braided channel habitat, and the SEIS presents detailed analyses of impacts to side channel habitat accordingly.

Comment 46: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Impacts to Wetlands*

Response: Except for the immediate wetted perimeter of the main channel border up to the Ordinary High Water Mark (OHWM), many of the forested and emergent areas between the top of bank and the first natural berm, or even to the riverside toe of agricultural and flood protection levees, do not meet the three criteria (hydrology, soils, hydrophitic plants) needed to qualify as jurisdictional wetlands in accordance with the 1987 Wetland Delineation Manual and supplements. Therefore, the Regulating Works Project is not considered to be a significant contributor to wetland losses in the Mississippi River floodplain. Site-specific Environmental Assessments would evaluate impacts to wetland resources should any be anticipated.

Comment 47: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Impacts to Species Listed Under the Federal Endangered Species Act*

Response: See response to Comment 56 below regarding the Project's ESA compliance.

Comment 48: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Meaningfully Evaluate Impacts to Fisheries...Fails to Evaluate Impacts to Birds and Waterfowl...Impacts to Amphibians and Reptiles...Impacts to Mammals...Impacts to Plants...*

Response: The District appreciates that there is a wide variety of fish, wildlife, and plant species that occur or could potentially occur in the various habitats in and around the MMR. However, the information and analyses presented in the SEIS focus on the scope of the anticipated impacts of the Project. The analyses presented in the document detail potential significant impacts to a specific segment of main channel border depth and velocity habitat and associated biota, not to all main channel border habitat or all main channel border fish and wildlife species. The District believes that the information presented in the SEIS on the direct, indirect, and cumulative impacts of the Project is adequate to support the conclusions drawn.

Comment 49: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Key Information on Climate Change*

Response: Additional information on climate change impacts on MMR resources and associated Project impacts has been added to Section 4.2.5, Impacts on Air Quality and Climate Change.

Comment 50: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate Cumulative Impacts*

Response: Per CEQ regulations (40 CFR 1508.7) the cumulative impacts analysis in the SEIS correctly considered "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions." As a result of this analysis, the District concluded that the potentially significant, incremental impact of the work to be completed would be to shallow to medium-depth, moderate- to high-velocity main channel border habitat. The District believes that the cumulative impacts analysis is adequate to support the conclusions drawn.

Comment 51: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate the Risk of Disproportionate Impacts to Low Income and Minority Communities ... First, the DSEIS fails to assess the potential for disproportionate effects on the health and safety of minority and low income populations from the significant risk of increased flooding created by construction of river training structures. See Section II.C.4 for a discussion of flood risks.*

Response: See response to Comment 36. The District has concluded that river training structures do not increase flood levels.

Comment 52: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate the Risk of Disproportionate Impacts to Low Income and Minority Communities ... Second, the DSEIS environmental justice analysis looks only at county wide data to assess the potential for disproportionate impacts. DSEIS at 160. The DSEIS should also assess the potential for disproportionate impacts to individual communities (towns and cities) with large minority or low-income populations. This would provide a more accurate assessment of potential impacts.*

Response: The Environmental Justice analysis in the SEIS takes into account more than just county wide data. As stated in the SEIS in Section 3.4.1, Human Resources...

"To further refine the Environmental Justice analysis, Census Block Group information was analyzed to determine the status of minority and low-income populations immediately adjacent to the MMR. By utilizing Census Block Group data, minority or low-income populations that may not have been revealed when looking at the broader county-wide information could be analyzed. In addition, comparisons of minority and low-income populations among different parts of the Project Area could more accurately be conducted to ensure that potential disproportionate impacts within the Project Area itself were considered."

Similarly, in Section 4.4.1, Impacts on Human Resources...

"In addition to county information, Census Block Group information was utilized to refine minority and low-income information for populations immediately adjacent to the MMR. Of the 74 Census Block Groups in Missouri and Illinois that are adjacent to the MMR, 30 in Missouri and 11 in Illinois have populations that meet the minority and/or low-income criteria..."

Comment 53: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Adequately Evaluate the Risk of Disproportionate Impacts to Low Income and Minority Communities ... Third, the DSEIS cannot conduct a meaningful environmental justice analysis without also assessing the reasonably foreseeable site-specific impacts, as required by law. See Section II.C.1 for a discussion of this requirement. The DSEIS conclusion that minority and low income communities will not be disproportionately impacted because "river training structure construction activities as well as dredging operations are anticipated to occur at locations along the entire length of the Project Area"145 is not a meaningful assessment and is not supported by information in the DSEIS.*

Response: The District believes that the Environmental Justice analysis adequately and accurately assesses potential disproportionate impacts to minority and low income populations in the Project Area.

Comment 54: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Evaluate Impacts to Ecosystem Services*

Response: See response to Comment 8 above that even if implemented by the Corps, the 2013 Principles and Requirements (created pursuant to 42 USC § 1962-3) will not be applicable to the Regulating Works Project without a reevaluation or modification of the project. Further, since the SEIS is not a planning document but merely an update to the 1976 EIS, there is no need to conduct a valuation of ecosystem services lost for this document.

Comment 55: *The DSEIS Fails to Properly Evaluate Project Impacts . . . The DSEIS Fails to Meaningfully Evaluate Mitigation and Fails to Comply with Federal Mitigation Requirements*

Response: See response to Comment 10 above that the Regulating Works Project authority for mitigation is pursuant to 33 USC § 2283(b), so mitigation for this project is discretionary and not required by law. The SEIS does contain a mitigation plan on a broad, programmatic level in accordance with current law, regulation, and guidance. As noted in the SEIS and more specifically in Appendix C, since there are no currently existing, identified plans for specific, future projects, it is impossible to develop a fully detailed programmatic mitigation plan since there is no way to know what impacts there might be nor any way to quantify or ascertain the significance of those impacts. Since the SEIS is a programmatic document for the entire Regulating Works Project, Appendix C provides a broad mitigation plan of how any future construction will analyze the impacts to shallow to moderate depth, moderate to high velocity habitat based upon that site-specific work as well as the overall programmatic impact as discussed in the SEIS. Detailed mitigation planning will be completed on a site-specific, tiered EA approach, which will also include further details regarding monitoring and adaptive management, all in accordance with current law, regulation, and guidance. This is in accordance with the following Council on Environmental Quality guidance: Memorandum for Heads of Federal Departments and Agencies, subject: Effective Use of Programmatic NEPA Reviews, 18 December 2014.

Comment 56: *The Corps Must Reinitiate Consultation on the 2000 Biological Opinion*

Response: See response to Comment 8 above and information in Section 1.2, Purpose of and Need for NEPA Supplement, indicating that the Regulating Works Project has not changed in a substantial way since 1976; therefore, there has not been a change to the Project that changes the impacts on the endangered species identified in the 2000 Biological Opinion. The cited study and many others have been funded and continue to be funded by the District under the Biological Opinion for the Regulating Works Project. Information obtained from these studies is incorporated into the Reasonable and Prudent Alternative and Reasonable and Prudent Measures of the Biological Opinion, as appropriate. Incorporation of the information is coordinated extensively with the U.S. Fish and Wildlife Service and other partner agencies. Further, the District is following the proper consultation process on a site-specific basis as described in the 2000 Biological

Opinion, and see Appendix B for newly listed species since the 2000 Biological Opinion. Information on Biological Opinion activities undertaken in the MMR since 2000 has been added to Section 3.3.4, Threatened and Endangered Species.

Comment 57: *The Corps Must Comply with the Fish and Wildlife Coordination Act*

Response: See response to USFWS Comment 13 on the applicability of the Fish and Wildlife Coordination Act to the Regulating Works Project.

Responses to Nature Conservancy Comments

Comment 58: *We could not find any indication in the document that says when dredging levels are down to 2.4 M c/y that the installation of RTS will stop, be re-evaluated, or seek additional RTSs to reduce dredging even further. There is indication that the estimated level of RTSs in the preferred alternative is the point where cost effectiveness is lost. Will cost be the only or primary driver in this decision? Is this known, and if so, can it be addressed? The environment must be considered in the scenario, not just reduced dredging or cost. We believe information from historic dredging in the LMR could inform this question and it should be noted that RTSs are being removed in some LMR locations.*

Response: See section 2.2 and Appendix C for the estimates provided for the end of new construction for the Regulating Works Project. Since the purpose of construction of river training structures is to reduce dredging to a minimum, it is expected that the project will continue until it is no longer economically beneficial. The estimates provided in Appendix C for completion of the Regulating Works Project include estimates for compensatory mitigation, so environmental impacts also play a role in determining economic feasibility. Information on avoid and minimize measures included in the Continue Construction Alternative has been expanded in Chapters 1and 2. Complete removal of river training structures is not occurring on the LMR. Portions of existing structures are being removed to create a notch for habitat creation purposes, which the Regulating Works Project has also been doing since the 1970s.

Comment 59: *The DEIS has a fairly specific number of cubic yards of rock that will be needed and the footprint associated with the construction of these RTSs, yet the location and number of RTSs is unknown and identified through an ongoing process. There were the estimates for linear feet and volume of rock needed to minimize dredging all the way to 1.3 MCY/year. Analysis was then made of various increments of construction and the 4.4 million tons of rock for RTSs was identified as the option with the greatest Net Benefit (Appendix C, attachment 1, pg 11). However, information the other "increments of construction" were not presented. Can you provide that information, even if it is in a rough form?*

Response: While specific numbers associated with construction and dredging are discussed, these numbers represent rough estimates that supported the programmatic analysis of the remaining construction. The remaining construction estimate was produced to determine the significance of potential environmental impacts. The actual remaining quantity of construction, the impacts of that construction, and the remaining annual dredging quantity will be based on actual future conditions. The information requested will be included in the next economic update of the project, which is currently in draft form. The information provided in the SEIS is the best estimates to date with existing information.

Comment 60: *Figure 1.6 and specifically Figure 1.7 (pgs 11-12) show the trend is progressing downward for dredging and it is important to ask if no additional structures were put in the river for a few years would the trend line level continue and actually adjust to something close to the desired 2.4 M c/yds. without additional RTS construction. A pause in construction may be warranted to let current conditions settle out to determine if more*

RTSs are actually needed. Figure 1.6 only goes back to 1964 and dredge volumes were likely much higher prior to 1964. Since the 6-foot channel was authorized in 1907, maybe that is the timeframe that should be used if data are available.

Response: It is not expected that the dredging trend would continue downward without additional river training structure construction unless major geomorphological changes were to occur on the MMR. Generally, repeated dredging occurs in locations on the MMR where the physical characteristics of the reach do not produce enough bed scour for sufficient navigation depth. Without changing the physical characteristics of the reach through the construction of RTSs dredging will continue. The Corps evaluates dredging for a number of years at potential work areas before developing structure alternatives. Even after alternatives are developed, the work area is monitored to ensure that dredging is recurring before construction takes place.

Comment 61: *The Recommended Alternative will cause another 8% loss of main channel border habitat or 1,100 acres. Estimates were provided indicating that 6,900 acres of main channel border have be lost since 1976. Combined with the additional 1,100 acres, main channel border habitat loss would total over 40% with additional losses prior to 1976 not accounted for in this analysis. It should be the policy of MVS to go beyond the mitigation of the 8% future losses. Page 158 of the SEIS indicates that there are opportunities to modify existing RTSs for compensatory mitigation for future impacts. Further, there is indication that an evaluation "could" be done to identify these opportunities. We suggest that a commitment be made to carry out this evaluation and continue modifications based on past impacts to this important habitat.*

Response: As indicated in Appendix C, site specific analysis will be completed for consideration of compensatory mitigation and site specific EAs will be completed. Analyses on areas of the MMR that could accommodate structure modification are being conducted. For mitigation for past actions see response to USFWS Comment 14.

Comment 62: *With the Recommended Alternative additional RTS will be put into the system and continue to increase velocity and scour. This has been shown to have impact on tributary incising and headcutting up these tributary watersheds. This not only impacts the tributary stream but releases additional sediment that can cause additional main channel dredging, which is contrary to the value of the RTS structures. How are the current and additional RTSs destabilizing the tributaries? This issue should be acknowledged and addressed.*

Response: The impact of RTS construction on headcutting and incision on tributaries is expected to be minor and similar to the impact on side channels as described in Section 4.2.2, Impacts on Geomorphology. The impact of RTS construction on velocities and bathymetry has been added to Section 4.2.2.

Comment 63: *Based on the planform information in Figure 3.7 (pg 42) the floodplain is reduced to somewhere between 55% and 59% of the historic footprint. Although this only a planform metric, it likely represents a significant change in the floodplain depth diversity* *(shallow to deep), main channel depth (more incised), and significant shifts in the terrestrial floodplain topography. Additional loss is significant in context to the historic floodplain loss, however the SEIS only recognizes the loss in terms of the additional increment of this project work. This minimizes the environmental impact of this additional work on this already degraded portion of the river.*

Response: The referenced information on planform width deals only with the river channel proper from tree line to tree line and does not consider the floodplain beyond. Information on changes in land cover in the floodplain can be found in Section 3.4, Socioeconomic Resources, and in Section 4.6, Cumulative Impacts. As detailed in Section 4.6, the cumulative impacts analysis must consider the incremental impacts of the Project in the context of all past, present, and reasonably foreseeable future actions. Based on this analysis, the District does not anticipate significant impacts to river planform width or floodplain resources from the Regulating Works Project.

Comment 64: *Figures 3.8 and 3.9 (pg 43) show a reduction of about 1/3 the original width of the Main Channel and Floodplain Planform, respectively. Although the rate of change has slowed, we would like to know if/how the additional RTSs will reduce the original width in the main channel and the floodplain.*

Response: As described in Section 3.2.2, Geomorphology, and Section 4.2.2, Impacts on Geomorphology, it is not expected that additional river training structures will reduce the original width in the main channel and floodplain.

Comment 65: *The DEIS indicates that there are currently 32 side channels for the entire 200-mile reach of the MRR (pg 45). The regulating works project effectively eliminates the creation of new side channels. How many were present historically? Is the re-creation of side channels a possibility that is being considered?*

Response: Based on information in a Colorado State University study associated with the 1976 EIS, there were 35 side channels present in the MMR in 1880. The significant impacts of the Regulating Works Project outlined in the SEIS are on shallow to moderate depth, moderate to high velocity main channel border habitat. Any compensatory mitigation will focus on similar habitat. However, other programs (e.g. Upper Mississippi River Restoration) have the authority to restore and/or re-create side channel habitat in the MMR. Also see response to USFWS Comment 13 and Appendix K for information on Project authority.

Comment 66: *The SEIS documents reduced GHG releases from the recommended alternative as compared to the No New Construction Alternative of 29, 400 down to 16,970. While The DEIS makes an effort to estimate the contributions of GHGs from the transport of rock to the site and actual construction of the RTS, it fails to account for the actual mining and processing of the rock which would be a significant contribution. We suggest that this be corrected.*

Response: While the District appreciates that there may be GHG releases from a variety of actions peripherally associated with all facets of Regulating Works Project actions, the analysis focuses on more direct actions to keep the scope reasonable.

Responses to Audubon Missouri Comments

Comment 67: *Audubon Missouri has been on record in strong support of habitat restoration along our big rivers in Missouri by the Corps and its partners. Restoration is an important and essential purpose of Corps of Engineers' management of the rivers, but we believe the Corps has not undertaken sufficient habitat restoration commensurate with the loss of habitat, damage to riparian ecosystems, and detrimental effects upon fish and wildlife that have resulted from years of techniques employed in support of navigation and flood control.*

We believe the Corps has ample sources of authority to increase significantly its habitat restoration projects and to confer upon restoration activities the priority and focus they deserve including authorities under the Fish and Wildlife Coordination Act of 1958 and the Water Resources Development Acts of 1986 and 2007. In addition, we believe these authorities allow the Corps to assess impacts going back to the original 1976 EIS and mitigate for negative impacts that have occurred since the original 1976 EIS.

Response: See response to USFWS Comment 13 and additional information about the Corps' habitat restoration authorities provided in Appendix K.

Comment 68: *The Corps of Engineers indicates that further loss of habitat caused by the preferred alternative described in the SEIS would require offsetting mitigation. Audubon Missouri calls upon the Corps to further analyze and undertake options and means to avoid and minimize detrimental project impacts on habitat and resulting effects upon fish and wildlife.*

Response: See additional information in Chapters 1 and 2 about avoid and minimize measures.

Comment 69: *We respectfully ask that for any existing or future structures placed in the Middle Mississippi River or along its banks to support navigation and flood control you ensure that appropriate modifications or other mitigation measures to support fish and wildlife habitat are reviewed, considered, and undertaken.*

Response: The District considers fish and wildlife impacts in all actions undertaken and avoids, minimizes, and considers compensatory mitigation as appropriate. With respect to the Regulating Works Project, navigation is the only authorized purpose, but the District will consider mitigation as described in Appendix C. Information has been added to Chapters 1 and 2 on avoid and minimize measures. See response to USFWS Comment 13 and Appendix K for information on Project authority.

Comment 70: *We would be pleased to support you in these efforts.*

Response: See Appendix K for information regarding ecosystem restoration authorities as well as the response to USFWS Comment 13. The District would be pleased to speak with any potential cost share partner to work on execution of those authorities.

<u>Responses to Comments of Organizations identifying themselves as members of the Water Protection Network (WPN) and/or members or partners of the Mississippi River Network (MRN):</u>

Comment 71: *The District is violating NEPA by not considering more alternatives . . . The District must consider a full range of alternatives and consider abandoning outdated tools if they prove to be no longer be in the public interest.*

Response: See response to USFWS Comment 13 for information on Project authority and the lack of a reasonable or feasible justification for transitioning the SEIS to a planning study.

Comment 72: *The District is violating NEPA by . . . failing to meaningfully evaluate project impacts. . . . The DSEIS violates NEPA by failing to meaningfully evaluate project impacts. For example, the DSEIS dismisses extensive and highly credible information on flood level increases and fundamental changes in the river's hydrology. The DSEIS also lacks fundamental and essential information needed to assess project impacts, including information on: flood levels; sedimentation rates; fish and wildlife species, including migratory species, and their critical habitat needs; plant species, including wetland plant species; and vitally important habitat types, including main channel border habitat, braided river habitat, wetland habitat, and floodplain habitat. The DSEIS also fails to recognize the severely degraded condition of the Middle Mississippi River.*

Response: See response to Comment 36 above for information on flood heights. Information on sediment has been added to Section 3.2.2, Geomorphology. The District appreciates that there is a wide variety of fish and wildlife species that use or could potentially use the various habitats provided by the MMR. However, the information and analyses presented in the SEIS focus on the scope of the anticipated impacts of the Project. The analyses presented in the document detail potential significant impacts for continued construction to a specific segment of main channel border depth and velocity habitat and associated biota, not to all main channel border habitat or all main channel border fish and wildlife species. The District believes that the information presented in the SEIS on the direct, indirect, and cumulative impacts of the Project is adequate to support the conclusions drawn.

Comment 73: *The District does not have the data to support their preferred alternative. . . . the District fails to provide sufficient data regarding the sediment load of the Middle Mississippi River . . . Also, none of the IEPR's specific recommendations to include sedimentation information were followed.*

Response: See response to Comment 30 above regarding the timing of IEPR. Information on sediment has been added to Section 3.2.2, Geomorphology.

Comment 74: *The District does not have the data to support their preferred alternative. . . . Critical economic information is missing from the DSEIS as well, calling into question the economic benefits of river training structures over dredging. The District does not provide any budget estimates of funds spent on the project to date or anticipated spending to complete the project. As the Regulating Works Project includes new construction, a National Economic Development analysis should be completed to* *compare alternatives. Included in this analysis, the District should also consider the full range of ecosystem services lost in the construction of their preferred alternative.*

Response: The Regulating Works project involves continuing construction (not "new" construction), which does not require an alternatives comparison with NED analysis, only a periodic update of the economics to support budget requests (i.e. determine if construction should continue to be funded). Because of the dynamic nature of the river, it is not possible to accurately predict how much construction is left on the project. An estimate of remaining construction was developed for the purpose of determining the significance of environmental impacts and is discussed in Appendix C. The amount of funds spent on the project to date is not relevant to the purpose and scope of the document. More information on dredging reduction has been added to Section 1.1.5, Dredging Reduction under the Regulating Works Project. See Appendix K for information on Project costs to date.

With respect to ecosystem services, see response to Comment 8 above that even if implemented by the Corps, the 2013 Principles and Requirements will not be applicable to the Regulating Works Project without a reevaluation or modification of the project because these were created in accordance with 42 USC § 1962-3. Further, since the SEIS is not a planning document but merely an update to the 1976 EIS, there is no need to conduct a valuation of ecosystem services lost for this document.

Comment 75: *The preferred alternative may increase flood risk.*

Response: See response to Comment 36 above.

Comment 76: *An Environmental Impact Statement needs to be prepared for operations and maintenance on the entire Upper Mississippi River.*

Response: While navigation activities may be carried out throughout the Upper Mississippi River under various authorities, the Regulating Works Project on the Middle Mississippi River has its own specific authority, separate from the rest of the Upper Mississippi River. The SEIS has been prepared in accordance with the authority for the Middle Mississippi River Regulating Works Project. See response to USFWS Comment 13 and Appendix K for more information on Project authority.

Comment 77: *We ask the District to protect critical habitat on the Middle Mississippi River and select an alternative that abandons the use of new river training structures and that removes or modifies many of the existing river training structures to restore wildlife habitat and reduce flood risks to communities.*

Response: See response to USFWS Comment 13 and Appendix K for details on the lack of authority to do environmental restoration activities as part of the Regulating Works Project. See response to Comment 36 above reiterating there is no impact on flood risks from the Regulating Works Project. As indicated in Appendix C, future tiered documents will consider the possibility of removing or modifying existing river training structures as potential compensatory mitigation. Also see information added to Section 3.3.4, Threatened and Endangered Species, detailing activities undertaken pursuant to the Biological Opinion that include removal and modification of structures.

Responses to Nicollet Island Coalition Comments

Comment 78: *Studies show river training structures increase flood stages. . . . the District provides no information about the identity of these "other external reviewers" nor their qualifications. . . . the District has removed their historical river gate data from the public access database, rivergages.com. If the District is indeed so confident in their data, it should be shared publicly as it is by every other district in the country. . . . Recommendation: The District needs to request a National Academy of Sciences review of river training structures and their impacts on flood stage to resolve the academic disagreement between the District and independent scientists.*

Response: All research detailed in Appendix A used to evaluate the impact of river training structures on flood risk is cited. Rivergages.com is not maintained by the St. Louis District and therefore the District has no control of its content. Historic data for the St. Louis District is published at http://mvs-wc.mvs.usace.army.mil/archive/archindex.html. See response to Comment 36 above regarding the need for a National Academy of Sciences review.

Comment 79: *The IEPR only had three reviewers on the panel. . . . Such a small panel for such a large project calls into question whether the panel really had the full range of expertise needed to review the DSEIS. . . . All the IEPR reviewers have worked for the US Army Corps of Engineers (the Corps) and the Coalition is concerned that this history biases them towards agreeing with Corps policies and protocols. . . . While the District did provide the IEPR with this list of references, the District did not ask the IEPR to review these studies. The IEPR has the discretion to review material beyond what the District provides, but there is no discussion in the IEPR report that would indicate the panelists conducted such a review.*

Response: The Type I IEPR was conducted in full compliance with Corps guidance. Per EC 1165-2-214, the panel was selected by an Outside Eligible Organization (OEO) based on the technical disciplines which contributed to the development of the SEIS. Additionally, per that same guidance, the OEO must select the panel members in adherence with the National Academy of Sciences (NAS) Policy on Committee Composition and Balance and Conflicts of Interest. The District did not ask the panel to review the referenced documents because the panel's task is to review and comment on the product produced by the Corps (the SEIS). The documents were referenced in the SEIS in relation to one area of potential controversy. The panel was instructed that they could request any of the referenced documents but they did not request them.

Comment 80: *The District's review of alternatives violates the National Environmental Policy Act (NEPA). . . . The District must consider a full range of alternatives and consider abandoning the tools authorized by Congress if they prove to no longer be in the public interest. . . . Recommendation: The District needs to ensure NEPA procedures are followed and evaluate a full range of alternatives to maintain the navigation channel on the Middle Mississippi River, including strategies that may require initiating separate environmental impact statements to evaluate unique challenges like channel migration in certain areas.*

Response: The District has complied with all requirements of NEPA for the SEIS. See additional information added to Chapters 1 and 2 and Appendix K providing more detail about the authority for the Regulating Works Project and the alternatives development process for the SEIS.

Comment 81: *The project at Dogtooth Bend deserves its own environmental impact statement and should not be tiered off the Regulating Works Project Environmental Impact Statements.*

Response: See
http://www.mvs.usace.army.mil/Portals/54/docs/pm/Reports/EA/RegWorksDogtoothBendPhase6FINALEABASIGNEDFONSI%20FINALPACKET20July2016.pdf?ver=2016-08-01-110955-103

for the Environmental Assessment with signed FONSI for the Regulating Works Project, addressing the work to be done to maintain the navigation channel in light of the breach of the Len Small Levee. As indicated in that EA, the Regulating Works Project can only focus on the authorized purpose of navigation and utilize the authorized tools of regulating works to maintain the channel without seeking additional authority. The District would gladly discuss with interested parties the process for additional studies to address the various issues at Dogtooth Bend.

Comment 82: *The DSEIS violates the Fish and Wildlife Coordination Act. . . . The District does not provide any information or supporting evidence that spending met this requirement in 1958 and, in fact, does not provide any information on historic and anticipated spending for the Regulating Works Project. . . . Recommendation: The District needs to reinitiate consultation with the U.S. Fish and Wildlife Service on the 2000 Biological Opinion and obtain a Fish and Wildlife Coordination Act Report.*

Response: See response to USFWS Comment 13 explaining that the Fish and Wildlife Coordination Act is not applicable to the Regulating Works Project. See Appendix K for information on Project spending. See response to Comment 56 above regarding reinitiating consultation with the USFWS.

Comment 83: *The District lacks the data needed to evaluate and justify the Regulating Works Project. . . . However, the District fails to provide sufficient data regarding the sediment load of the Middle Mississippi River, which is noted by the IEPR. . . . Critical economic information is missing from the DSEIS as well, calling into question the economic benefits of river training structures over dredging. . . . As the Regulating Works Project includes new construction, a National Economic Development (NED) analysis should be completed to compare alternatives. . . . Recommendation: Suspend the Regulating Works Project until the District has the economic information it needs to evaluate the impacts of the Regulating Works Project and conduct a thorough review of alternatives as required by the National Environmental Policy Act.*

Response: The Regulating Works Project involves continuing construction (not "new" construction), which does not require an alternatives comparison with NED analysis, only a periodic update of the economics to support budget requests (i.e. determine if construction should continue to be funded). An estimate of remaining construction was developed using a simplified economic analysis for the sole purpose of determining the significance of environmental impacts (discussed in Appendix C). Information on sediment has been added to Section 3.2.2, Geomorphology. See response to Comment 30 above regarding the timing of IEPR.

Comment 84: *The DSEIS lacks the information needed to determine cumulative environmental impacts and needs to include a programmatic level mitigation plan. . . . The fact that the District delayed the development of the DSEIS, despite clear guidance that environmental impact statements should be reviewed more periodically, is not an excuse for disregarding mitigation requirements. . . . The District proposes to mitigate the impacts of the Regulating Works Program with additional dredging, revetment and construction of river training structures (page C-5). . . . Recommendation: The District should properly mitigate the cumulative impacts of the Regulating Works Project going back to 1976 as part of the SEIS with methods that do not themselves have significant environmental impacts.*

Response: See response to USFWS Comment 13 and Appendix K for explanation on the Project's authority for mitigation as well as a detailed explanation that the impact identified for consideration of compensatory mitigation was a result of the additional analyses developed by the District for the SEIS. The District did not delay the development of an SEIS for this project – see Appendix K for more detail as to the history of the Project and its NEPA compliance. The compensatory mitigation being contemplated in the SEIS for potential impacts to a certain depth and velocity portion of main channel border habitat does not include additional dredging, revetment, or construction of river training structures. Page C-5 indicates that it is assumed that mitigation will be accomplished through the partial or complete removal of existing river training structures. See response to Comment 55 above regarding mitigation planning.

Comment 85: *Environmental analysis too focused on engineering outcomes. . . . Recommendation: The District needs to explain how components of the Regulating Works Project and/or mitigation plan meet broader restoration and biodiversity objectives for the Middle Mississippi River.*

Response: See response to USFWS Comment 13 and Appendix K for information on the lack of authority to carry out ecosystem restoration measures with Regulating Works Project funding. Also, see response to Comment 55 regarding the Project's mitigation plan.

The Regulating Works Project is and will continue to be coordinated with fish and wildlife partner agencies and all work will continue to avoid and minimize adverse effects to the extent practicable. See information added in Chapter 1 about current and future coordination. Compensatory mitigation planning will, likewise, be done in conjunction with fish and wildlife partner agencies and will include an adaptive management and monitoring plan as required to ensure the effectiveness of mitigation measures.

Comment 86: *Scope of SEIS should be expanded to include the entire Upper Mississippi River and Illinois Waterway System. . . . Recommendation: Expand the scope of the DSEIS to include all O&M activities on the UMRR-IWW.*

Response: While navigation activities may be implemented throughout the UMRR-IWW under various authorities, the Regulating Works Project on the Middle Mississippi River has its own specific authority, separate from the rest of the UMRR-IWW. The SEIS has been prepared in accordance with the authority for the Middle Mississippi River Regulating Works Project. See response to USFWS Comment 13 and Appendix K for more information on Project authority.

Responses to National Wildlife Federation Action Center Comments

The National Wildlife Federation's Action Center website allows users to submit comments using an automatically generated comment template. Users are also able to change the content of the comment if desired. Action Center users generated 14,610 comments on the Draft SEIS. The vast majority of the comments (14,275) consisted of the template wording found in Comment 87 below without modification. Substantive modifications of the template wording generally related to urging the District not to harm bald eagles or their habitat.

Comment 87: *I urge the Corps of Engineers to stop building river training structures in the Middle Mississippi River and to remove some existing structures to protect wildlife habitat and communities. The Corps has already built hundreds of miles of river structures in the Middle Mississippi and buried the river's banks under hundreds of miles of concrete, causing tremendous harm to wildlife and significantly increasing flood risks. Extensive peer-reviewed science shows that river training structures, built for the sole purpose of reducing navigation dredging costs, have already increased flood levels more than 10 feet in much of the Middle Mississippi. The Draft SEIS recommends using 4.4 million tons of rock to build even more river structures that will destroy 1100 acres of wildlife habitat. The Corps should go back to the drawing board and prepare a comprehensive, scientifically sound environmental impact statement that adopts less-damaging methods for maintaining navigation. As part of this process, it is imperative that the Corps initiate and listen to a National Academy of Sciences study on river training structures and flooding. Thank you.*

Response: The long-term goal of the Regulating Works Project, as authorized by Congress, is to obtain and maintain a navigation channel and reduce federal expenditures by alleviating the amount of annual maintenance dredging through the construction of river training structures. In implementing the Project the District avoids and minimizes impacts to fish and wildlife and to the human environment to the extent practicable. Due to the continued benefit of the remaining construction, the District anticipates continued implementation of the Project with the future potential addition of compensatory mitigation for unavoidable adverse effects to main channel border habitat on a site-by-site basis. The District has determined that river training structures do not increase flood heights. See response to Comment 36 above and Appendix A for further information. The District believes that the SEIS is comprehensive and scientifically sound and is adequate to support the conclusions drawn. Due to the extensive research supporting the conclusions of the Corps, there is not 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.

With respect to bald eagles and their habitat, the District does not anticipate adverse programmatic effects from the Project. Although the Bald Eagle was removed from the federal list of threatened and endangered species in 2007, it continues to be protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act (BGEPA). The BGEPA prohibits unregulated take of Bald Eagles, including disturbance.

The U.S. Fish and Wildlife Service developed the National Bald Eagle Management Guidelines 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. Tiered site-specific Environmental Assessments prepared for specific work areas would address any potential impacts to Bald Eagles. If any nest trees were identified in specific work areas, the National Bald Eagle Management Guidelines would be implemented to minimize potential impacts and appropriate coordination with the U.S. Fish and Wildlife Service would be conducted.

Responses to Jamie Nash-Mayberry Comments

Comment 88: *...we...continue to object to the building of more river navigational structures in the middle Mississippi... your studies do not show any connection to the wing dikes contributing to increased flood heights, but we can't deny that there are a number of sources who do feel it does...*

Response: See response to Comment 36 above and Appendix A for information on flood heights.

Comment 89: *...the National Wildlife Federation and a number of other environmental groups do not feel these river structures are helpful to the environment.*

Response: See comments of and responses to the National Wildlife Federation and other conservation organizations above.

Comment 90: *...we feel the National Academy of Sciences needs to study this issue further...*

Response: See response to Comment 87 above regarding the National Academy of Sciences.

Responses to SEMO Port Comments

Comments of Jerry Lorberg, SEMO Port Commissioner

Comment 91: *The Mississippi River and it's harbors are very important to the economy of South East Missouri. Moving products by barge is not only important because of the significant savings on transportation costs, but also because it is environmental friendly. Less truck traffic on the highways also helps the economy by reducing the amount of road repair needed. We appreciate very much the Corps concern for, interest in, and help with improvement projects in South East Missouri.*

Response: Comment noted.

Comments of Daniel Overbey, SEMO Port Executive Director

Comment 92: *Transportation. For Semo Port and our customers, the Middle Mississippi River's navigation channel is an essential artery for transportation, both domestic and international. This year the companies located at Semo Port will ship and receive over 1.3 million tons of products by barge. These companies, in turn, buy and sell to many other companies, farmers, mines, and mills.*

Based on 25 tons per truckload, the barge shipments equate to 52,000 truckloads. Allowing a return empty move for each loaded move, this represents 104,000 truck trips or 2,000 trips a week. These numbers are just for our Port, one facility of many on the river. By using river transportation, short haul truck trips are combined with long haul barge moves for greater fuel efficiency, lower cost, less pollution, and greater safety.

In reality, if the products did not move by barge, most would not move at all because they could not afford the higher cost of rail transportation or the much higher cost of truck transportation. The Mississippi River is a crucial advantage to United States agriculture and other industries as they compete in world markets.

River Navigation Channel. The Corps does an excellent job of maintaining the navigation channel, meeting budgetary requirements while balancing the needs of navigation with those of environmental habitat, flood control, water supply, recreation, and other uses.

Of the two alternatives, the Continue Construction Alternative is preferred for several reasons. First, it is needed to address changes in the river which occur over time. River training structures must be adjusted on occasion. The river does not exist in a vacuum - it is affected by many different factors within the watershed and other watersheds which feed into the Middle Mississippi River. As these change, the Corps' efforts must be adjusted.

One of these factors is the modification of structures and other elements to better accommodate habitat needs while meeting navigation requirements. The Corps has creatively found designs that can meet the needs of both and do so with an acceptable level of cost (investment).

Second, the Corps has a continuing effort to improve the effectiveness of the river structures while, as much as possible, reducing costs. Using the investment in permanent structures to reduce the annual operating costs of dredging and other maintenance work benefits the taxpayer and the environment. In these situations, the Corps uses the sustainable power of the river to replace or reduce man-made maintenance efforts.

Conclusion. The Continue Construction Alternative is preferred because it allows the Corps of Engineers to best meet the needs of the Middle Mississippi River and all those who depend on it.

Response: Comment noted.

Responses to Cairo Marine Service Comments

Comment 93: *I would like to briefly comment on the importance of the Mississippi River and barge service to our state and nation. The Corps, St. Louis District, is doing a great job in maintaining the river and I give you high marks on the priority you give to environmental matters. Millions of tons of many different commodities travel annually up and down the Mississippi River and the last statistic I read stated over 238 million cubic yards was removed through the Corps in maintaining channels. I also read that there was a 4.3% increase of cubic yards of material with a 7.6% decrease in cost. Keep up the good work and thank you.*

Response: Comment noted.