St. Louis Riverfront - Meramec River Basin Ecosystem Restoration

Feasibility Study with Integrated Environmental Assessment

Final

July 2019

US Army Corps of Engineers®
St. Louis District

ST. LOUIS, JEFFERSON,
ST. FRANCOIS, & WASHINGTON COUNTIES
MISSOURI

ACKNOWLEDGEMENTS

EXECUTIVE SUMMARY

Purpose of Report. The purpose of this integrated feasibility report with environmental assessment, including the Finding of No Significant Impact (FONSI), is to evaluate and document the decision-making process for the proposed U.S. Army Corps of Engineers (USACE) ecosystem restoration project in the St. Louis Riverfront – Meramec River Basin, Missouri. This report was developed by the USACE with the Missouri Department of Natural Resources (MoDNR) serving as the non-Federal study sponsor and the U.S. Fish and Wildlife Service (USFWS) serving as a Federal coordinating agency. This report provides planning (including National Environmental Policy Act compliance), engineering and sufficient construction details of the Recommended Plan to help inform the final recommendation of the Chief of Engineers (Chief's Report).

Study Area Location. The study area includes portions of the Meramec River Basin located in St. Louis, Jefferson, St. Francois and Washington Counties of Missouri. The study area includes the Big River, a major tributary of the Meramec River, and the lower 50 river miles of the Meramec River. The Meramec River is a tributary of the Mississippi River, with its confluence approximately 35 miles south of St. Louis, Missouri.

Problem Identification. Freshwater mussels are among the world's most endangered animals (Williams, Warren, Cummings, Harris, & Neves, 1993) making the Meramec River Basin a significant aquatic resource since it has one of the most diverse freshwater mussel communities in the central United States (Hinck, et al., 2012). While the Meramec River Basin appears more stable and healthy for mussel communities than other streams, researchers studying freshwater mussels in the Meramec River Basin report a downward trend in number and abundance of species (Roberts & Bruenderman, 2000) due to substrate instability, sedimentation, water quality and altered flow. Within the Big River, the main source of freshwater mussel decline is heavy metal toxicity. The Industrial Era heavy metal mining that occurred within the study area overburdened the Big River and its floodplain with contaminated sediments. The estimated 250 million tons of mine waste (Pavlowsky, Owen, & Martin, 2010) including lead, zinc and cadmium that was released over time into the Big River altered, and continues to alter, the natural sediment balance of the river. In addition, the contaminated sediments continue to move downstream extirpating aquatic animals in the area, including freshwater mussels. The past, ongoing and expected future movement of this sediment contributes to unstable banks downstream. This, in turn, causes a negative feedback loop of additional sediment entering the system. This significant issue, in conjunction with the additional aquatic habitat problem of fragmented riparian corridor, made the Meramec River Basin a prime location to study the feasibility of a Federal ecosystem restoration project. The Meramec River Basin has been identified as one of the most diverse and robust aquatic ecosystems in the Midwestern United States, despite the identified habitat degradation. Action is needed to maintain the existing habitat and restore the degraded. The proposed study seeks to do both.

Study Goal and Objectives. The overarching goal of this study is to formulate alternatives to restore the aquatic ecosystem within the Meramec River Basin. In addition, the study also documents if USACE participation is economically justified in restoring ecosystem structure and function within the study area.

As part of the USACE planning process, the following ecosystem restoration objectives were identified for the study:

- Reduce the downstream migration of excess mining-derived sediment from the Big River, over the 50-year period of analysis, in order to protect and restore degraded aquatic and freshwater mussel habitat;

- Restore impacted channels and floodplains in the Big River and Meramec River systems to mimic a more natural, stable river over the 50-year period of analysis; and
- Increase riparian habitat connectivity, quantity, diversity, and complexity within the study area over the 50-year period of analysis.

Plan Formulation, Evaluation, and Comparison. The interagency planning team, which includes biologists, engineers, and planners from USACE, MoDNR, USFWS, Missouri Department of Conservation (MDC), U.S. Environmental Protection Agency (USEPA), and The Nature Conservancy (TNC), developed a series of measures for consideration to address the identified problems. The measures were formulated based on data collection and analyses, as well as, by experts in the field of malacology, sedimentation, geomorphology, and toxicology. The final list of measures consisted of in-channel structures (i.e., longitudinal peak stone toe protection, weirs, barbs, grade control structures, bed sediment collectors, and in-stream excavation), off-channel structures (i.e., sediment basins), nature-based structures (i.e., root wad revetment), and non-structural measures (i.e., reforestation). Seventy three possible sites were identified to construct these measures.

Ten unique alternatives were initially developed using various formulation strategies, including the No Action Alternative. This initial array of alternatives was evaluated for completeness, effectiveness, efficiency, and acceptability. From this initial evaluation, six alternatives, including the No Action Alternative were retained for further analysis. Preliminary cost estimates and habitat benefits were calculated for the remaining six alternatives. Habitat benefits were calculated using the Black Capped Chickadee Habitat Suitability Index (HSI) Model and the Meramec River Freshwater Mussel HSI model. Outputs from these models are defined as habitat units. The habitat outputs were compared to the cost for each alternative through a cost effective and incremental cost analysis (CE/ICA). This analysis, along with an alternative's ability to meet project objectives, National Environmental Policy Act (NEPA) compliance, and USACE Planning and Guidance evaluation criteria (ER 1105-2-100) were used to compare and evaluate the alternatives. Ultimately, one alternative was identified as the National Ecosystem Restoration (NER) plan.

The Recommended NER Plan, *Maximize Efficiency in the Big River*, includes 51 sites, and yields 1,565 net average annual habitat units (AAHUs) for an average annual cost over the 50 year period of analysis of $4,185,000 for an average cost per AAHU of $2,674 in fiscal year (FY) 2019 using a federal discount rate of 2.875%. These sites include various measures such as longitudinal peak stone toe protection, root wad revetment, weirs, barbs, reforestation, sediment basins, bed sediment collectors, grade control structures, and in-stream excavation to restore and improve the aquatic ecosystem structure and function of approximately 1,600 acres of riverine and floodplain habitats. Implementation of the Recommended Plan would reduce downstream movement of contaminated sediments, improve river and floodplain structure and function, and restore quality and quantity of the riparian corridor leading to improved habitat for a variety of native animals, including freshwater mussels. The Recommended Plan is deemed acceptable by the non-Federal sponsor (MoDNR) and other federal and state partners.

Based on October 2018 price levels, the current estimated project first cost (i.e., cost to construct) is estimated at $89,953,000 which includes monitoring costs of $784,000 and adaptive management costs of $5,151,000. The current Federal portion of the cost is $58,469,000 and the non-Federal sponsor's portion is $31,484,000. The MoDNR would be responsible for operation, maintenance, repair, rehabilitation, and replacement (OMRRR) at an estimated average annual cost of $489,000. No compensatory mitigation is included in the proposed plan as none is required. During construction there could be temporary adverse effects to the environment including increases in turbidity and temporary clearing of vegetation. These effects would be minimized by the use of erosion and pollution control best management practices and conducting removal activities according to State and Federal requirements. Conservation measures would be implemented during construction to minimize effects to Federally-listed plants and animals.

Public review of the draft feasibility study with integrated environmental assessment was completed on 8 July 2018. All comments submitted during the public comment period were responded to in the final feasibility report. Comments received during this public review included requests to expand the study authority to the entire Big River Watershed and request for formal government to government consultation with two Tribal Nations. These comments were resolved by Congressional study area expansion and on-going tribal consultation.

The St. Louis District Engineer has reviewed the significance of the resources, estimated habitat benefits outputs, economic costs, identified risks and has determined that the implementation of the Recommended Plan is in the Federal interest; therefore, the District Engineer recommends construction approval for the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Recommended Plan. It is important to note the USACE Recommended Plan will complement the comprehensive restoration activities by others within the Big River to restore the aquatic ecosystem overburdened with sediment that is contaminated with lead.

INTENTIONALLY LEFT BLANK

ACRONYMS

AAHU – Average Annual Habitat Unit

AML – Abandoned Mine Lands

As – Arsenic

ATR – Agency Technical Review

Ba – Barium

BGEPA – Bald and Golden Eagle Protection Act

BMP – Best Management Practices

BRLRS – Big River Lead Removal Structure

CAP – Conservation Action Plan

Cd – Cadmium

CE/ICA – Cost Effective / Incremental Cost Analysis

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

CFR – Code of Federal Regulations

dB – Decibels

DQC – District Quality Control

EEC – Essential Ecosystem Characteristics

EIS – Environmental Impact Statement

EQ – Environmental Quality

ER – Engineer Regulation

ERDC – Engineering Research and Development Center

ESA – Endangered Species Act

FEMA – Federal Emergency Management Agency

FMP – Floodplain Management Plan

FONSI – Finding of No Significant Impact

FPMS – Flood Plain Management Services

FPPA – Farm Protection Policy Act

FWOP – Future without Project

FY – Fiscal Year

GIS – Geographic Information System

GMP – Gross Metropolitan Product

GRP – Gross regional product

HEP – Habitat Evaluation Procedures

HSI – Habitat Suitability Index

HTRW – Hazardous, Toxic, Radioactive Waste

IL – Illinois

IWR – Institute for Water Resources

LERRD – Land, Easements, Rights of Way, Relocation, and Disposal

LiDAR – Light Detection and Ranging

LPP – Locally Preferred Plan

LPSTP – Longitudinal Peak Stone Toe Protection

MBTA – Migratory Bird Treaty Act

MDC – Missouri Department of Conservation

MFC – Missouri Farmers Care

MO – Missouri

MoDNR – Missouri Department of Natural Resources

MSA – Metropolitan Statistical Area

MSDIS – Missouri Spatial Data Information Service

MSU – Missouri State University

NAAQS – National Ambient Air Quality Standards

NEPA – National Environmental Policy Act

NER – National Ecosystem Restoration

NGO – Non-Governmental Organization

NHPA – National Historic Preservation Act

NPL – National Priorities List

NRCS – Natural Resources Conservation Service

NRDAR – Natural Resources Damage Assessment and Restoration

NVSS – Non-Volatile Suspended Solids

OLB – Old Lead Belt

OM – Operation and Maintenance

OMRRR – Operation, Maintenance, Repair, Rehabilitation, and Replacement

OSE – Other Social Effects

OU – Operable Unit

P&G – Principles and Guidelines

PA – Programmatic Agreement

Pb – Lead

PEC – Probable Effects Concentration

PM – Particulate Matter

ppm – parts per million

RECONS – Regional Economics System

RED – Regional Economic Development

RI – Remedial Investigation

RI/FS – Remedial Investigation / Feasibility Study

RM – River Mile

ROD – Record of Decision

SEMO – Southeast Missouri

SEMORRP – Southeast Missouri Ozarks Regional Restoration Plan

SHPO – State Historic Preservation Office

SLU – St. Louis University

SWAT – Soil and Water Assessment Tool

T&E – Threatened and Endangered

TBD – To Be Determined

TMDL – Total Maximum Daily Load

TNC – The Nature Conservancy

TSS – Total Suspended Solids

USACE – United States Army Corps of Engineers

USDA – United States Department of Agriculture

USEPA – United States Environmental Protection Agency

USFWS – United States Fish and Wildlife Service

WRDA – Water Resources Development Act

Zn – Zinc

INTENTIONALLY LEFT BLANK

St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment

(* Denotes NEPA Requirement)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

INTENTIONALLY LEFT BLANK

1 INTRODUCTION

1.1 U.S. ARMY CORPS OF ENGINEERS CIVIL WORKS MISSION

The U.S. Army Corps of Engineers' (USACE) civil works mission is to deliver vital public engineering solutions, in collaboration with partners, to secure the Nation, energize the economy and reduce risk from disaster.

1.2 STUDY AUTHORITY

USACE feasibility studies investigate and recommend solutions to water resource problems in areas authorized by Congress.

The St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study (Study) is an interim response to the study authority contained in Section 1202 of the 2018 Water Resource Development Act (WRDA) which directed the Secretary of the Army to carry out studies to determine the feasibility of a project for ecosystem restoration and flood risk management in Madison, St. Clair and Monroe Counties, Illinois, St. Louis City, and St. Louis, Jefferson, Franklin, Gasconade, Maries, Phelps, Crawford, Dent, Washington, Iron, St. Francois, St. Genevieve, Osage, Reynolds and Texas Counties, Missouri. These studies are considered a continuation of the House Committee on Transportation and Infrastructure Resolution dated 21 June 2000, Docket 2642, which directed the Secretary of the Army to review the report of the Chief of Engineers on the Mississippi River and its Tributaries, between Coon Rapids Dam and the mouth of the Ohio River published as House Document 669, 76th Congress, 3rd Session, and other pertinent reports to determine if improvements along the Mississippi River and its tributaries in St. Louis City, St. Louis County, and Jefferson County, Missouri, and Madison County, St. Clair County, and Monroe County, Illinois, are advisable at the present time in the interest of public access, navigation, harbor safety, off-channel fleeting, intermodal facilities, water quality, environmental restoration and protection, and related purposes.

The Study did not investigate the entire authority scope but instead focused its efforts on ecosystem restoration in the Lower Meramec River and Big River which are geographically located in portions of Jefferson, St. Francois, St. Louis, and Washington Counties, Missouri. Future studies may be undertaken to further investigate problems in the larger geographic scope, and/or mission areas described in the study authority. This study is cost-shared 50/50 between the USACE and the non- federal sponsor, the Missouri Department of Natural Resources (MoDNR). Construction of the project will be cost-shared between the USACE (65%) and the MoDNR (35%). The operation, maintenance, rehabilitation, restoration, and replacement (OMRRR) cost is 100% MoDNR responsibility.

1.3 USACE ECOSYSTEM RESTORATION MISSION

This Study focuses on ecosystem restoration, a primary mission of the USACE. The purpose of the USACE ecosystem restoration mission is to restore significant ecosystem function, structure and dynamic processes that have been degraded. The USACE focuses on improving aquatic ecosystems' sustainability, resilience, and health under existing and future conditions. Ecosystem restoration involves identifying the problems degrading the ecosystem and developing solutions to those problems.

1.4 STUDY AREA

The Meramec River Basin (which refers to the whole watershed of the Meramec River and its two major tributaries, the Big River and Bourbeuse River) is located in east-central Missouri, southwest of St. Louis (Figure 1-1). The study area includes portions of the Meramec River Basin located in St. Louis, Jefferson, St. Francois and Washington Counties of Missouri (Figure 1-2). For clarity, the term "watershed" refers to the area drained by a given river. For example, Big River Watershed extends upstream and up-gradient to the entire area that drains into the start of the Big River and ends at its confluence with the Meramec River.

1.5 STUDY STAKEHOLDERS AND OTHER COORDINATING AGENCIES

The MoDNR, the U.S. Fish and Wildlife Service (USFWS), the U.S. Environmental Protection Agency (USEPA), the Missouri Department of Conservation (MDC) and The Nature Conservancy (TNC) were part of the interagency study team. The interagency study team provided data and subject matter expertise to identify problems, characterize existing and future conditions, develop measures, and formulate and evaluate alternatives.

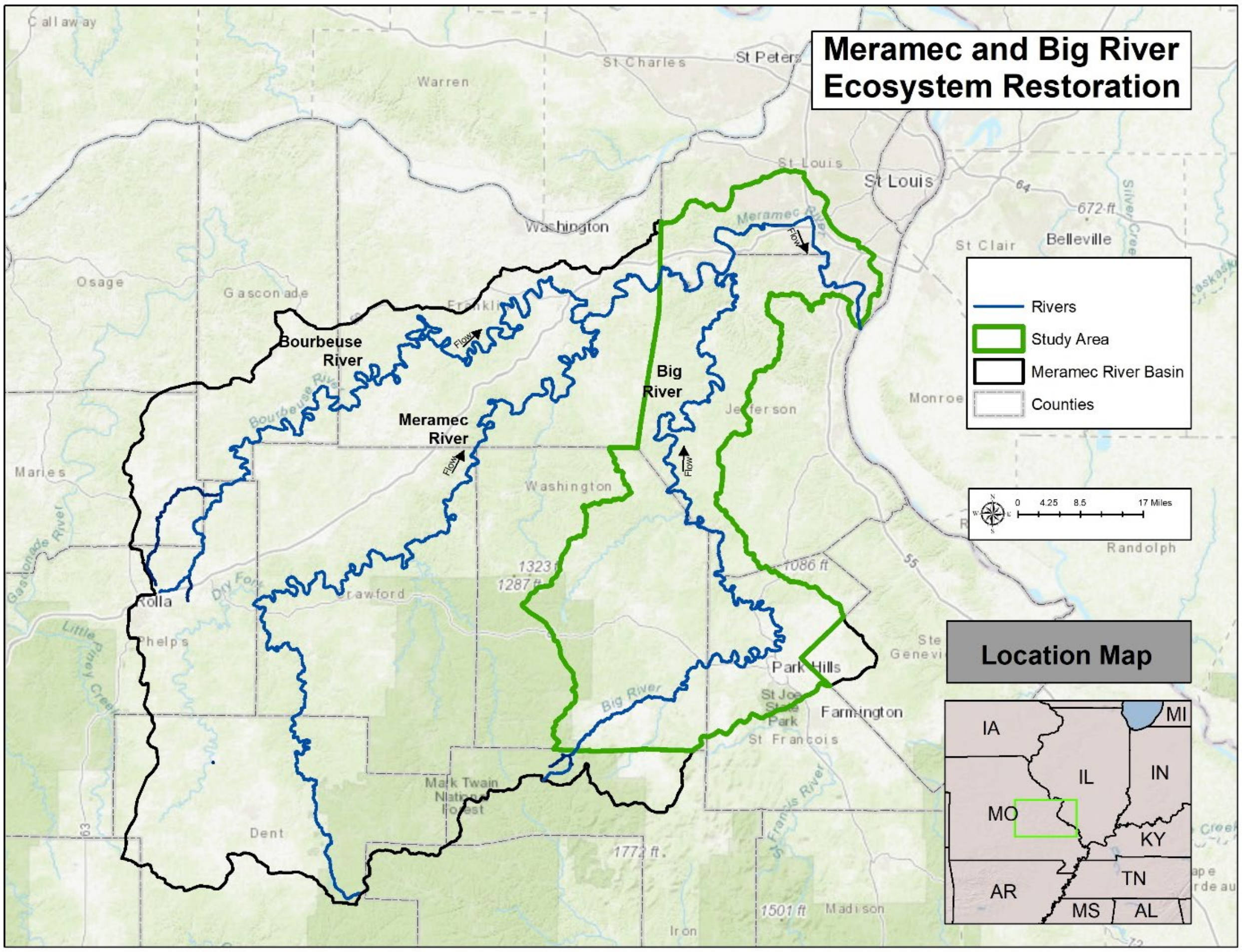


Figure 1-1. Meramec River Basin

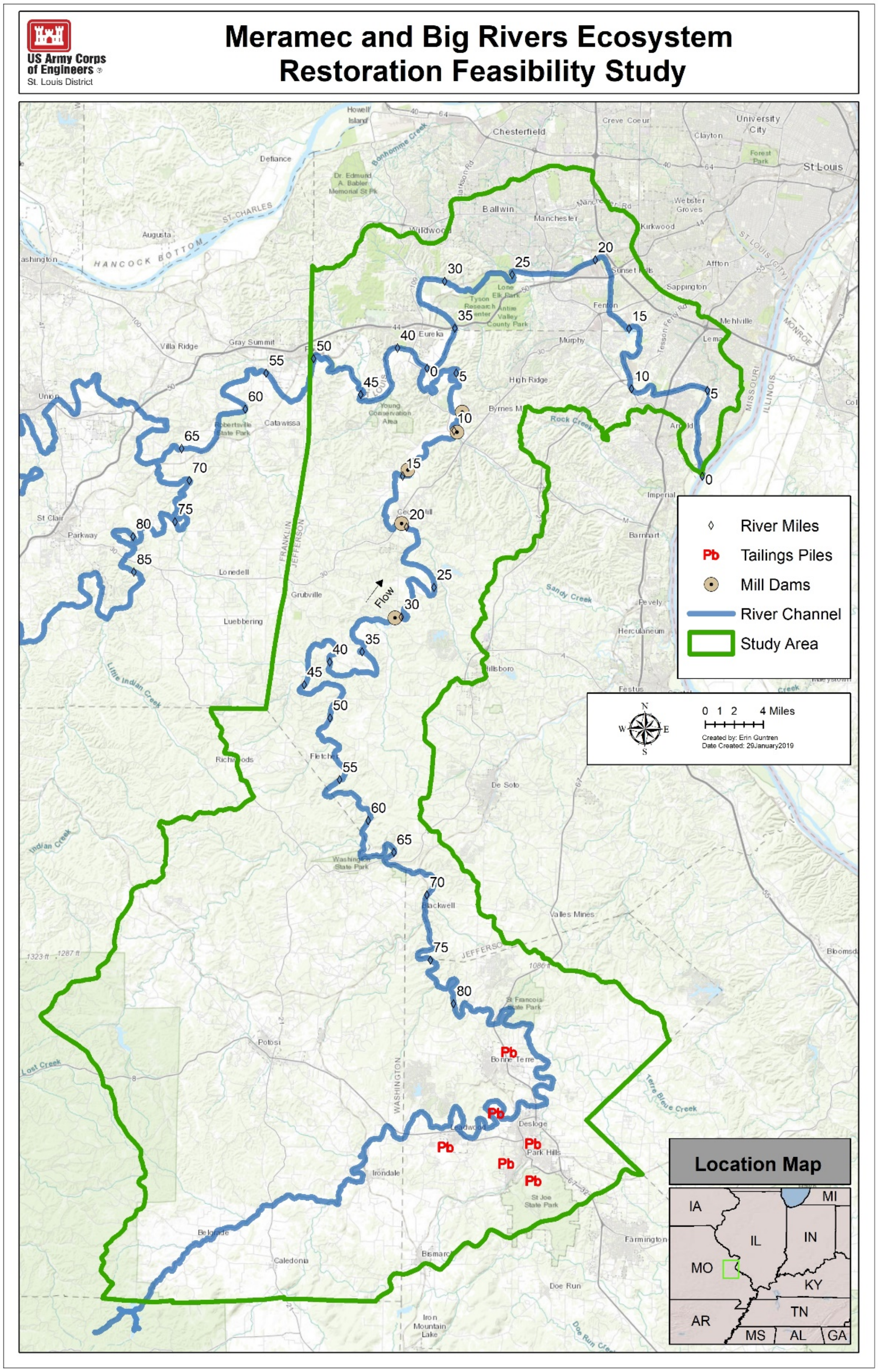


Figure 1-2. Study Area Location Map

1.6 PURPOSE AND NEED*

The purpose of the Study with integrated Environmental Assessment (EA), including the Finding of No Significant Impact (FONSI) is to assess the environmental effects of a reasonable range of potential alternatives or actions designed by the USACE, including the no action plan, prior to decision making. The study aims to provide enough information to federal and nonfederal decision makers to determine whether implementation of a proposed plan is a wise investment decision to address the aquatic ecosystem degradation. This plan will be identified as the National Ecosystem Restoration (NER) plan.

The need for this study is demonstrated by the large number of local, state, and federal activities taking place in the study area. Federal action stems from the variety of environmental problems that are impacting the Meramec River Basin. Several of these problems are interrelated and indirectly affect each other. The key factors identified as adversely affecting the Meramec River Basin's natural structure and function of its rivers and its floodplain are being overburdened with contaminated sediment from historic mining practices, altered hydrology, altered riparian corridor and degradation of aquatic habitat, including ecologically significant freshwater mussel habitat. Coordination of this feasibility study with larger Meramec River Basin planning efforts allows for a more comprehensive and complete federal ecosystem restoration plan. The interagency partnership is essential to developing and implementing a comprehensive plan to address the full suite of problems in the Big and Meramec River watersheds. Concurrently working these efforts allows the USACE and MoDNR to leverage resources with the other partners (TNC, USEPA and USFWS), and ultimately provide solutions to restore the ecosystem structure and function of the Meramec River Basin.

1.6.1 THE NATURE CONSERVANCY

The Meramec River Basin is a nationally significant watershed due to its high biodiversity. A collaborative effort of 29 partners, led by TNC, are working together to implement the *Meramec River Conservation Action Plan* (TNC, 2014). The *Meramec River Conservation Action Plan* (TNC, 2014) aimed to unify, clarify and intensify efforts to improve the overall health of the river. Key stressors are identified in Box 1-1. Currently, in partnership with the MoDNR, TNC is building on the *Meramec River Conservation Action Plan* to complete a Watershed Management Plan for the entire Meramec River Basin. As part of this effort, TNC contracted work to create a Soil Water Assessment Tool (SWAT). This tool models the quality and quantity of surface and ground water to predict the environmental impact of land use, land management practices and climate change within the Meramec River Basin. The USACE was involved with its development and utilized the results to help inform the Study.

Box 1-1. Conservation Action Plan: Key Stressors Affecting the Meramec River Basin

- Contaminated sediments
- Excessive bedded and suspended sediments
- Altered riparian corridor
- Altered stream geomorphology
- Altered connectivity
- In-stream habitat modification

1.6.2 USEPA REMEDIAL AND TRUSTEE RESTORATION COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT AUTHORITY

The USEPA is the lead Federal agency on Superfund under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The USEPA's Superfund program is responsible for cleaning up some of the Nation's most contaminated land. Numerous Superfund sites are located within the Big River Watershed related to the impacts of past lead mining activities (Figure 1-3). Since 1992, the USEPA has been working on developing remedial actions for Superfund sites located in St. Francois (e.g., Big River Mine Tailings/St. Joe Minerals Corp.), Jefferson (e.g., Southwest Jefferson County Mining Site), and Washington (e.g., Washington County Lead District) Counties, as well as, other National Priorities List (NPL) sites along the Big River[1].

In addition to empowering USEPA to effect clean-up actions at sites with releases of hazardous substances, the statutory framework of CERCLA provides natural resource trustees with a mechanism for obtaining monetary damages as compensation for natural resource injuries. CERCLA provides for the designation of public officials to act on behalf of the public as trustees for natural resources. The director of the MoDNR is the designated state trustee on Big River with USFWS acting on behalf of the Department of the Interior as the trustee (Trustees). The Trustees conduct Natural Resource Damage Assessment and Restoration (NRDAR) activities to address injury, destruction and/or loss of natural resources and their services. While remedial actions are focused on current and prospective risk to human health and the environment, NRDAR activities are focused on returning injured natural resources and their services as a result of releases of hazardous substances.

The USEPA remedial actions and NRDAR activities both use an iterative multi-step process to move from investigation and analysis to remedy or restoration. Both processes are designed to provide detailed information on site conditions to allow decision-makers to reach informed decisions on how to control risk to human health and the environment or to restore injured natural resources to baseline conditions. The NRDAR is residual to the clean-up, and may not perform remediation under CERCLA to clean-up hazardous substances at a site.

1.6.2.1 USEPA REMEDIAL ACTIVITIES IN THE STUDY AREA

The Big River Mine Tailings/St. Joe Minerals Corp. Site, located in St. Francois County, Missouri was added to the NPL in 1992. The Big River Mine Tailings Site is composed of eight large areas of mine waste, totaling approximately 110 square miles in size. The Big River Mine Tailings/St. Joe Minerals Corp. Site is separated into three Operable Units (OUs). OU2, which includes the Big River and its associated floodplain, overlaps with the study area of this Study. Currently, the USEPA is conducting a remedial investigation/feasibility study for OU2 that will characterize the nature and extent of contamination and assess potential threats to human health and the environment, the proposed plan will be documented in a Record of Decision (ROD). The current estimated date for a ROD in OU2 is late 2019, although the remedial process and schedule is uncertain. The USEPA contamination (clean-up) level for the Big River will be used to identify USACE hazardous, toxic, and radioactive waste (HTRW) levels.

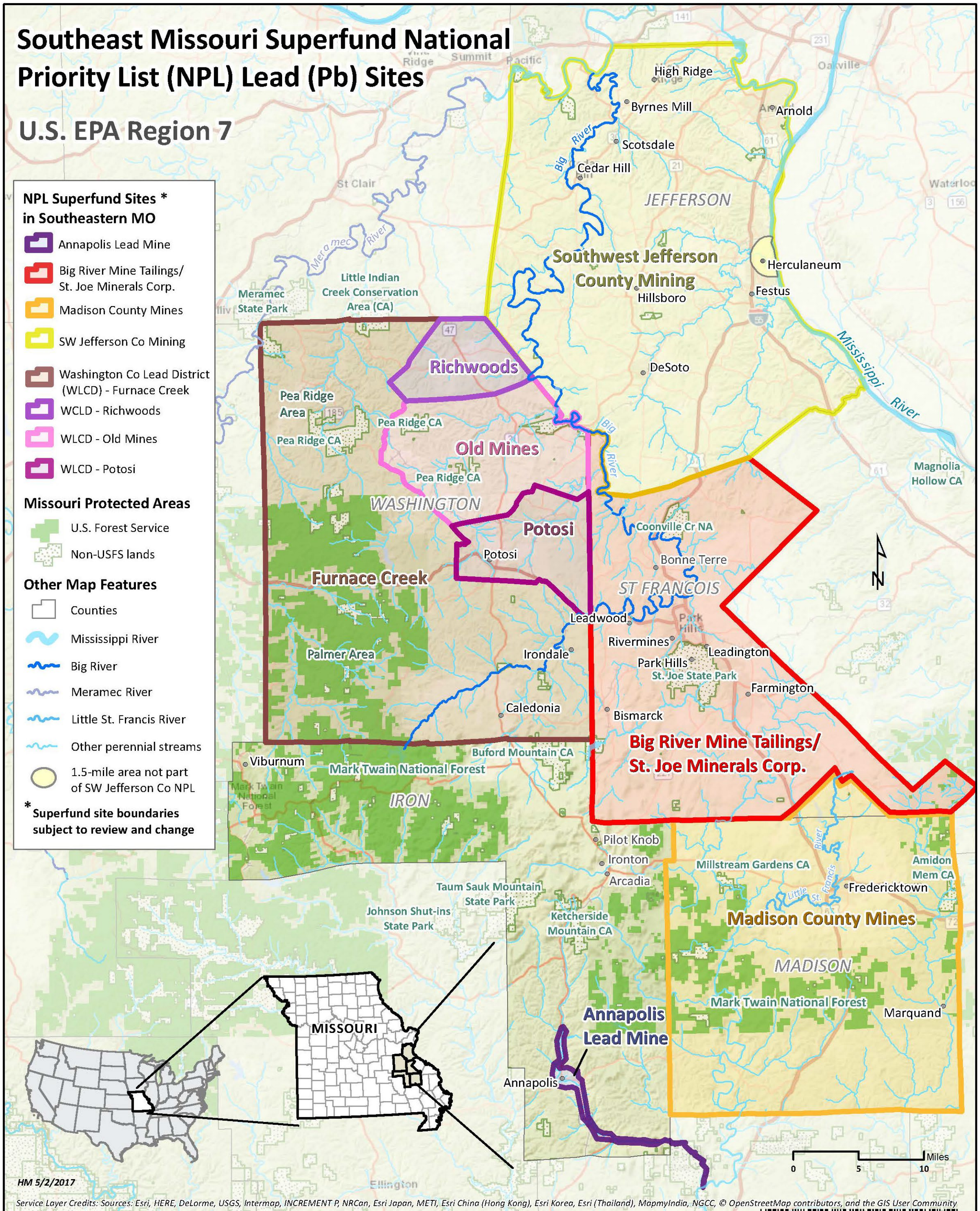
In 2009, the Southwest Jefferson County Mining Site was added to the NPL due to mine waste contaminating soil, sediment, surface water and groundwater with heavy metals (primarily lead). Heavy metal impacts to Jefferson County Big River Floodplain are primarily due to downstream migration from St. Francois County mine waste (USEPA, 2017). The Jefferson County site is separated into eight OUs. OU 4, which includes the Big River and its associated floodplain, overlaps with the study area of this Study. Currently, the USEPA is conducting a remedial investigation for OU4 that will characterize the nature and extent of contamination and assess potential threats to human health and the environment. After the remedial investigation phase, a USEPA feasibility study will be completed. The feasibility study

[1] See https://www.epa.gov/mo/missouri-cleanups for more information

will result in a proposed plan which will be documented in a ROD. The estimated date for a ROD in OU4 is late 2019 but, as noted above, the remedial process and schedule is uncertain.

Washington County is broken up into three separate Superfund sites: Old Mines, Potosi and Richwoods. Old Mines, Washington County includes soil, groundwater, surface water and sediment contaminated with associated historical mining practices in southeast Missouri. The site encompasses about 90 square miles in the northeastern portion of Washington County, Missouri and is broken up into four OUs. The portion of the Washington County Lead District Site that overlaps with this feasibility study area will be addressed in the Big River Mine Tailings/St. Joe Minerals Corp. RI/FS. The other two Washington County Sites, Potosi and Richwoods are not in the Big River floodplain. Both sites includes soil, groundwater, surface water and sediment contaminated with arsenic, barium, cadmium and lead associated with historical mining practices in southeast Missouri. Both sites encompass approximately 45 square miles in the northeastern part of Washington County.

It is important to note that the USEPA's role is to remediate uncontrolled hazardous waste, to protect human health and environment and *not* to restore ecological function. The NRDAR purpose is to restore natural resources and their services to pre-release conditions. The USEPA's remedial action is designed to address human health and risks to the environment represented by relatively short-term toxicity to aquatic organisms as demonstrated by laboratory tests. A clean-up remedial action level will be set to be protective against that risk. Residual injury occurs when natural resources and natural communities have been injured by residual contamination left following remediation. In the case of the Big River, the long-term viability, ecological function and services provided by mussel communities may continue to be injured after USEPA completes the remedy, depending on the cleanup remedial action level.



The Agency is providing this geospatial information as a public service and does not vouch for the accuracy, completeness, or currency of data. Data provided by external parties is not independently verified by EPA. This data is made available to the public strictly for informational purposes. Data does not represent EPA's official position or opinion, express or implied. This information is not intended for use in establishing liability or calculating Cost Recovery Statutes of Limitations and cannot be relied upon to create any rights, substantive or procedural, enforceable by any party in litigation with the United States or third parties. EPA reserves the right to change these data at any time without public notice.

30324628

Figure 1-3. Southeastern Missouri Superfund Lead Sites[2]

1.6.2.2 NRDAR RESTORATION ACTIVITIES IN THE STUDY AREA

The Trustees have initiated natural resource damage assessments at different sites throughout the Southeast Missouri Lead Mining District, which includes portions of the USACE study area. At the time of publication of this document, the Trustees have achieved several NRDAR settlements. The settlements provided the catalyst for the creation of the Southeast Missouri Ozarks Regional Restoration Plan (SEMORRP) to describe the restoration objectives and processes for programming existing restoration funds as well as potential future recoveries of restoration funds from the NRDAR process. It is important to note that NRDAR actions are intended to restore natural resources to the conditions that would have existed without the hazardous substance release. NRDAR projects could include those that restore resources at contaminated sites, which may involve mitigating the injurious effects caused by toxicity. However, NRDAR is not a program which will supplant the role of the response agencies; to clean-up sites to levels protective of human health and the environment.

1.6.2.3 CONTAMINATED SEDIMENT DEFINED

MacDonald (2000) calculated a 128 ppm Consensus-Based Probable Effects Concentration (PEC) for lead in sediment. The PEC is a sediment quality guideline that identifies concentrations above which harmful effects on aquatic sediment dwelling organisms are expected to occur frequently. Similarly, the Trustees determined that a 20% reduction in mussel density occurs at concentrations of 135 ppm lead in sediment, which approximates the MacDonald PEC. For the purposes of this study, the USACE uses the term contaminated sediment to describe sediment with concentrations of lead above the MacDonald PEC 128 ppm.

The characterization of contaminated sediment for lead harmful to aquatic organisms is not the same as the USEPA's characterization of contaminated sediment for lead associated with risk to human health and environment. Additionally, this Study assumes that the USEPA contaminated sediment (clean-up) level for the Big River and its associated floodplain will be significantly higher than the MacDonald PEC concentration of lead because the USEPA ROD for Residential Soils in Operable Unit 1 Southwest Jefferson County Mining Site (USEPA, 2012) was set at a 400 ppm contamination (clean-up) level.

Collaboration throughout the Study planning process ensured the USACE and the Trustees activities are consistent and compatible.

1.7 RESOURCES OF NATIONAL SIGNIFICANCE*

It is challenging to assign a monetary value to environmental resources; therefore, these resources are considered from a public, institutional and technical standpoint. These three categories are used to determine if the ecosystem is significant enough to warrant Federal investment. Table 1-1 summarizes the resource significance of the study area.

Institutional Recognition: Institutional recognition means the importance of an environmental resource is acknowledged in the laws, adopted plans and other policy statements of public agencies, tribes or private groups.

Public Recognition: Public recognition means some segment of the general public recognizes the importance of an environmental resource, as evidenced by people engaged in activities reflecting an interest or concern for that resource.

---

[2] https://semspub.epa.gov/work/07/30324628.pdf

Technical Recognition: Technical recognition means the resource qualifies as significant based on its "technical" merits, which are based on scientific knowledge or judgment of critical resource characteristics. Scarcity, representativeness, status and trends, connectivity, limiting habitat and biodiversity describe technical significance. Differences across geographical areas and spatial scales may determine whether a resource is significant.

- *Scarcity* is a measure of a resource's relative abundance within a specified geographic range.
- *Representativeness* is a measure of a resource's ability to depict the natural habitat or ecosystems within a specified range.
- *Status and Trend* measures the relationship between previous, current and future conditions.
- *Connectivity* is the measure of the potential for movement and dispersal of species throughout a given area or ecosystem.
- *Limiting Habitat* is the measure of resources present supporting significant species.
- *Biodiversity* is a measure of the variety of distinct species and the genetic variability within them.

Table 1-1. Resource Significance of Study Area

RESOURCE	LOCATION	SOURCES OF SIGNIFICANCE		
		Institutional	Public	Technical
Aquatic Habitat	Portions of Meramec River and Big River	President Reagan de-authorized the Meramec River Dam. Stream Reach Conservation Opportunity Area for Missouri State Fisheries Division Priority Watershed for Missouri Department of Conservation	TNC identifies Meramec River Basin as a top-ranked Midwest watershed. East-West Gateway Lower Meramec River Watershed Plan St. Louis Open Space Council Operation Clean Stream	***Representativeness:*** Representative of the Ozarks Highlands EcoSubregion.[3] ***Biodiversity:*** 125 fish species, 40 mussel species, 8 crayfish species and 107 aquatic insects.[4] ***Status and Trend:*** Several reports show a reduction in quality and quantity of aquatic organisms in the Meramec River Basin, particularly freshwater mussels.[5,6] **Connectivity:** Meramec River is one of the largest free flowing rivers in the US.[7]
Threatened and Endangered Species	Portions of Meramec River and Big River	Fish and Wildlife Coordination Act, as amended (16 U.S.C.§ 661) Endangered Species Act (ESA) of 1973, as amended	Stream Team initiatives Greenway Network Alliance	***Representativeness:*** Habitat suitable for federally-listed species similar to the region. ***Scarcity:*** 13 federally listed species and numerous state heritage species.[8] ***Status and Trend:*** Technical reports document a reduction in catch per unit effort of freshwater mussels from 1979 to present.[9]
Floodplain Forest	Riparian portion of the Meramec River Basin	WRDA 1986, as amended	Trust for Public Land currently reforesting areas of the Lower Meramec River. East-West Gateway Lower Meramec Watershed Plan Audubon Important Bird Area	***Representativeness:*** Representative of Upper Mississippi floodplain forest habitat. ***Status and Trend:*** Study area is likely to experience forest fragmentation over time. Consequently, neotropical and other migratory birds, Indiana bats and the other floodplain species relying on the forest resources will be severely impacted. ***Connectivity:*** The study area is included in the extensive contiguous forest of the Ozark Highlands, which provides suitable nesting habitat for forest-interior song birds.[10]

[3] (MDC, Missouri Watershed Inventory and Assessment: Big River, 1997)

[4] (MDC, Missouri Watershed Inventory and Assessment: Meramec River, 1998)

[5] (Roberts & Bruenderman, A reassessmentof the status of freshwater mussels in the Meramec River Basin, Missouri, 2000)

[6] (Besser, Brumbaugh, Hardesty, Hughes, & Ingersoll, 2009)

[7] (MDC, Missouri Watershed Inventory and Assessment: Meramec River, 1998)

[8] See https://mdc.mo.gov/property/responsible-construction/missouri-natural-heritage-program for St. Louis, Jefferson, St. François, and Washington counties heritage species lists.

[9] (Roberts & Bruenderman, A reassessmentof the status of freshwater mussels in the Meramec River Basin, Missouri, 2000)

[10] https://www.nrs.fs.fed.us/pubs/56525

1.8 SCOPING AND COORDINATION*

Scoping is an early and open process for determining the range of issues to be addressed and for identifying the significant concerns related to a proposed Federal action. During the planning process, a variety of communication methods with the affected public, agencies, and organization occurred.

The USACE conducted scoping and coordination with the following State and Federal agencies and other interested parties:

- Missouri Department of Natural Resources (non-Federal sponsor)
- U.S. Fish and Wildlife Service
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- Missouri Department of Conservation
- The Nature Conservancy
- East-West Gateway Council of Governments
- Big River Task Force
- Missouri Soil and Water Conservation
- Natural Resources Conservation Service
- St. Louis University
- State Historic Preservation Office
- Tribal Nations

The input received during scoping helped assist the USACE make holistic, informed decisions throughout the study process. Please see *Appendix A-Coordination*, for related documents.

1.8.1 COORDINATION MEETINGS

Study collaborators discussed problems, opportunities, and potential management measures through numerous coordination meetings. While not comprehensive, the following meetings are examples of ongoing coordination:

- Meramec River Watershed Workshop – Our Missouri Waters Meeting, 03 December 2015
- Pre-Charette Scoping Meeting, 15 December 2015
- Scoping Charette Meeting, 20-22 January 2016
- Ecological Model Development Workshop, 12-14 April 2016
- Big River Task Force Meetings, 28 February 2016, 12-13 April 2017, 24-25 October 2018
- Adaptive Management Workshop, 6-10 June 2017
- Habitat Model Evaluation Workshop, 26 July 2017
- Public Landowner Meeting, 07 February 2018
- Interagency Team Meetings

1.8.2 PUBLIC REVIEW AND COMMENTS

Public scoping occurred throughout the duration of the planning study. In 2015 and 2016, MoDNR led several meetings related to the Lower Meramec Watershed Plan development. This public scoping helped inform the Study. An initial stakeholder meeting held on 28 February 2016 occurred in conjunction with the Big River Task Force meeting. The general public could learn more about the Study through the USACE public website. Additional public meetings were held in June 2018 to encourage the public to provide comments on the proposed actions in the study area, see *Appendix A-Coordination*.

1.8.3 HISTORIC PRESERVATION COMPLIANCE AND TRIBAL CONSULTATION

The National Historic Preservation Act of 1966 (NHPA), as amended, requires federal agencies to consider the effects of "undertakings", or projects, on significant historical or archaeological sites ("historic properties"). To ensure agencies consider the effects, they are required to provide the State Historic Preservation Office (SHPO) an opportunity to review and comment on the plans and the agency's assessment of the potential risk to historic properties through the process of consultation.

Consultation is an on-going process during the life of a project. It begins with initial contact with the SHPO and continues through development of project alternatives, design and construction. Consultation ends when the project is complete.

Initial informal consultation with the Missouri SHPO began in January 2017 via telephone. The SHPO was informed of the general nature and location of the study area at that time. With the selection of the Recommended Plan, the St. Louis District is proceeding with formal consultation. The SHPO has been provided with details of the Recommended Plan as described in the Feasibility Study report. The next stage of consultation will occur during the development of the project design stage. As more definite details of potential impacts, their nature and their location are developed, the specific steps to identify historic properties that might be effected will be agreed in concert with the SHPO and Native American tribal representatives who have chosen to participate in consultation.

Due to the multi-year time span of the project and the potential changes in site-specific locations, it is possible that the Missouri SHPO and/or Tribes may wish to execute a Programmatic Agreement (PA) to formalize the consultation process. Such a PA would formally recognize the consultation procedures to be followed as project plans go forward.

The United States Government has a unique legal relationship with federally recognized Native American tribes based on recognition of inherent powers of Tribal sovereignty and self-government. Federal agencies are required to provide tribes the opportunity to comment on projects that may affect areas that hold significance for their tribe. The St. Louis District regularly consults with 28 Native American tribes. Each tribe was provided with the opportunity to participate in consultation regarding this project. A formal Government-to-Government consultation occurred on 14 November 2018 between the District and the Delaware and Osage Nations, who have elected to participate in further consultation with the St. Louis District and SHPO regarding compliance with Section 106 of the NHPA. Copies of all tribal correspondence are provided in Appendix A-*Coordination.*

1.9 PRIOR REPORTS AND EXISTING WATER PROJECTS

The following is a list of recent or ongoing programs and studies in the study area relevant to ecosystem restoration of the Meramec River Basin:

- USACE. Ongoing. *Lower Meramec Floodplain Management Plan*. This planning effort will produce a multi-jurisdictional Floodplain Management Plan (FMP) containing recommendations to be implemented by Jefferson, St. Louis and Franklin Counties.
- USACE. 2019. *Arnold, MO Flood Plain Management Services (FPMS).* Economic analysis of flood-prone structures in the floodplain within the City of Arnold. Completion of this economic analysis will allow the City of Arnold to prioritize mitigation actions in the future as funding becomes available.

- Pavlowsky, R.T. et. al. 2016. *Big River Lead Remediation Structure (BRLRS) Monitoring Project*. A case study on the effectiveness of an implemented and functioning sediment basin and impoundment structure on the Big River. In-depth analysis of what, where, how and when sediment was deposited as a result of this system. The results from this report helped inform the fill rates for sediment basins in this Study.
- The Nature Conservancy. May 2014. *Meramec River Conservation Action Plan*. This document utilized the TNC conservation action planning (CAP) process that identified target resources for conservation, the current health and problems affecting those resources, the source of the problems, and the best actions to maximize the benefit and long-term protection, restoration and conservation of the Meramec River and its aquatic resources.
- Jefferson County, Saint Francois County, and Washington County, Missouri. May 2014. *Big River Watershed Master Plan*. Prepared by URS Corporation. This Plan provides specific strategies for consideration by the agencies in the development of their management plans – those plans focused on the remediation and restoration alternatives that might be possible in the region.
- Natural Resources Damage Assessment and Restoration. 2014. *Southeast Missouri Ozarks Regional Restoration Plan and Environmental Assessment.* Internet. Retrieved from http://dnr.mo.gov/env/hwp/sfund/docs/nrd-final-semorrp.pdf on 17 December 2015. This document serves as a regional restoration plan and environmental assessment for the Southeast Missouri Lead Mining District which describes the restoration objectives and processes for existing funds as well as future recoveries derived from the NRDAR process.
- USACE. June 2013. *St. Louis Riverfront, Missouri and Illinois Addendum for Meramec River Basin Ecosystem Restoration Section 905(b) Reconnaissance Report.* This approved reconnaissance report identifies a Federal interest to study the feasibility of various solutions addressing ecosystem restoration in the Meramec River Basin and was the precursor to receiving Federal feasibility dollars.
- USEPA. September 2011. *Record of Decision Big River Operable Unit 1 – residential yards, USEPA.* The Big River Mine Tailings Site was put on the National Priority List (NPL) in 1997. The Record of Decision for Operable Unit 01 (Residential Yards) set a target clean up level of 400 ppm for residential properties. The ROD identifies that EPA generally selects a residential soil cleanup level within the range of 400 ppm to 1,200 ppm for lead (USEPA, 2011).
- USACE. August 2004. *St. Louis Riverfront, Missouri and Illinois Section 905(b) Reconnaissance Report.* The initial St. Louis Riverfront, Missouri and Illinois 905(b) Reconnaissance Report was approved in August 2004. As part of the findings of that study, it was determined that there was potential for ecosystem restoration in the Meramec River Basin, but that further study was needed and an addendum would be prepared accordingly.
- USACE. April 1988. *Meramec River Basin Reconnaissance Report.* The Meramec River Missouri Comprehensive Basin Study examined the opportunity for reservoir construction for flood risk management and identified five potential reservoir sites. No reservoir projects were found to be economically justified and worthy of Federal involvement so did not warrant further feasibility analysis.
- USACE. 1987. *Lower Meramec Flood Damage Reduction Report, Valley Park*. This report resulted in the construction of 3 miles of levee at a height of 20-25 feet around the city of Valley Park, located South of St. Louis on the Meramec River between river mile (RM) 21 and RM 22.

2 EXISTING AND FUTURE WITHOUT PROJECT CONDITIONS*

This chapter, organized by resource topic, assesses the existing conditions of resources within the study area. Per the Rivers and Harbors Act Section 122 (PL91-6110), the planning process considered 17 resources; however, this chapter is not a comprehensive discussion of every resource within the study area, but rather focuses on those aspects of the environment identified as relevant during scoping or had the potential of being affected by the considered alternatives. Information gathered in this step helped to describe the problems and opportunities and to forecast future conditions. The future without-project (FWOP) condition is also described which is the most likely condition of the study area without construction of a Federal project over the next 50 years. Chapters 4 and 5 describe the environmental consequences (direct, indirect and cumulative) on these resources.

2.1 HISTORIC SETTING

This section briefly highlights the history of the study area. For further details, see the *Missouri Watershed Inventory and Assessment* (MDC, 1997; MDC, 1998) and the *Meramec River Conservation Action Plan* (TNC, 2014) which describe the Meramec River and Big River extensively.

2.1.1 SETTLEMENT SETTING

Prior to settlement by Europeans, Native Americans, including the Delaware, Missouri, Osage and Shawnee tribes, inhabited the Meramec River Basin (Society, 1993). The Delaware, Missouri and Osage tribes lived and farmed along the river valleys and creek bottoms (Society, 1993). The King of Spain, Charles III, encouraged settlements by offering land grants to prospective tenants. The first European settler arrived in 1774 at Saline Creek, later known as the Meramec Settlement (Thomas, 1907).

2.1.2 HISTORIC MINING

Mining of rich deposits of lead, silica, zinc, barite, limestone and other minerals shaped the landscape of the Meramec River Basin. The Big River lies within "The Old Lead Belt" (OLB). The OLB was a leader in lead production within the U.S. and the world beginning in the 1700s through most of the 1800s. Mining activities in St. Francois and Washington Counties ranged from small-scale surface diggings to large-scale industrial mining using the diamond core drill to extract subsurface lead deposits (Buckley 1908).

Ore in the study area contains approximately 4 percent lead, 1 percent zinc and 0.15 percent copper (Doe Run, 2018). Massive quantities of lead mineral containing ore must be extracted from the mines, milled and processed to obtain the small proportion of lead concentrate which is then smelted to produce metallic lead. Industrial mining production from the late 1800s through the closure of the mines in 1972 resulted in the production of an estimated 250 million tons of mine waste. Pavlowsky, Owen and Martin (2010) estimated that 23% of mine waste still remains stored in the tailings piles located in St. Francois County, and 32% of the mine waste released is stored in channel sediments and floodplain deposits of the Big River throughout the study area.

The mining industry improved separation of metal concentrates from rock ores over its history. Early mine waste was produced in the form of gravel sized "chat". The study area contains six major "chat piles" on or near the Big River within the study area. These six piles, known as the Bonne Terre, Desloge, Leadwood, Elvins, Federal and National sites cover over four square miles ((Pavlowsky, Owen, & Martin, 2010) Figure 1-2).

Later, ore processing and beneficiation methods resulted in the production of sand, generally known as "tailings", and finer grained materials known as "slimes" that were pumped into impoundments as slurry for disposal. An example of this type of storage is the tailings impoundment at the massive dam at the Federal site. These fine-grained materials easily and rapidly move downstream and re-deposit within the Big River.

Massive amounts of mine waste were discharged directly or subsequently released into the Big River during active mining operations. Figure 2-1 depicts the failure of the Davis Creek (Federal) Tailings Dam during the 1940s, one of many events impacting local streams and the Big River (McHenry 2006). Even after mine closures, remaining tailings materials continued to enter streams and rivers through large precipitation events, ongoing erosion, slope failures and dam breaches. In 1977 at the Desloge Pile, (Newsfields, 2007) a steep slope failed resulting in approximately 50,000 cubic yards of mine waste sloughing directly into the Big River from a single event. The mine waste releases in St. Francois County are mixed with floodplain soils and in-stream sediments from the City of Leadwood to the Big River confluence with the Meramec River. Currently, the major tailings piles in St. Francois County have been mostly stabilized, but tributaries to the Big River continue to contribute contaminated sediment to the river system from prior releases.

Figure 2-1. Failure of Davis Creek (Federal) Tailings Dam (1940s)

Within Washington County, pre-industrial scale lead mining occurred near surface deposits. Early lead miners discarded large quantities of barite or "tiff" during the process. Barite was later discovered to be a marketable commodity used in oil and gas drilling mud, paints and ingested for medical radiology purposes. Barite is naturally deposited mainly as residuum in the soil/bedrock interface. As a result, mining of barite occurred largely as surface strip mining. Industrial scale mining for barite began at the turn of the century and peaked in 1957 with 13.4 million tons produced statewide (*dnr.mo.gov/geology/geosrv/imac/barite.htm* accessed May 3, 2018).

Tributaries draining the Washington County Barite District have high concentrations of barite, but low concentrations of lead and other toxic heavy metals. Barite or barium sulfate is considered non-toxic due to its very low solubility; whereas, other forms of barium do have some toxicity.

2.2 PHYSICAL SETTING

2.2.1 TOPOGRAPHY

Topography varies from wide ridges and gentle slopes to natural ridges, steep slopes and bluffs (MDC, 1998). The Meramec River Basin is considered one of the most rugged regions of the Midwest and drains nearly 4,000 square miles of east-central Missouri (MDC, 1998). The study area lies primarily within the Salem Plateau subdivision of the Ozark Plateau with portions of the Big River Watershed lying within the St. Francois Mountains subdivision (MDC, 1997). The Ozark Plateau is an asymmetrical, uplifted, dome-shaped landform lying in southern Missouri and portions of Arkansas, Kansas and Oklahoma. Strata dip gently northwestward and relief (elevation variance) through this area is moderately high (200-350 feet or more) (Nigh & Schroeder, 2002). Karst topography[11] losing streams (streams that lose water to groundwater as it flows downstream) and large springs (Nigh & Schroeder, 2002) characterize the study area. This diverse topography makes this region a wealth of habitats from narrow headwater streams to a larger floodplain river entering the Mississippi River.

For the main-stem Meramec River Watershed (which excludes the Big River and Bourbeuse River), land elevations range from 400 feet to 1,400 feet above sea level (MDC, 1998). For the Big River Watershed (955 square miles), land elevations range from 435 feet at the confluence of the Big River with the Meramec River to 1,740 feet in the headwaters at Buford Mountain (MDC, 1997).

2.2.2 GEOLOGY

The geology of the Meramec River Basin varies in age from Pennsylvanian to the Precambrian, with the majority underlain with limestone, dolomite[12], to cherty dolomite with minor sandstone from Ordovician Age rock of the Gasconade and Rubidoux formations (MDC, 1998). The Big River Watershed contains diverse representation of various geologic formations ranging in age from Mississippian to Precambrian which includes the Ordovician cherty dolomites, Cambrian age cherty dolomites and sandstones and the Precambrian igneous rock.

In the lower Meramec River Watershed, there is a mix of St. Louis limestone, Salem formation, Keokuk limestone and Burlington limestone (MDC, 1998). Permeable geologic material allows streams to lose water to bedrock aquifers. Several losing streams within the Meramec River Basin have been identified in Crawford, Phelps, Reynolds and Dent Counties, totaling approximately 160 miles of stream (MDC, 1998).

The headwaters of the Big River are in the St. Francois Mountains which are composed of igneous rocks; however, most of the Big River Watershed is underlain with dolomite with some limestone, shale and sandstone (Pavlowsky, Owen, & Martin, 2010). The majority of the Big River Watershed streams flow northward through the Salem Plateau (sedimentary rock topped by a thin layer of glacial loess and cuts through progressively younger limestone and dolomite forming a narrowly-cut river valley (MDC, 1997)).

In the southern and eastern portions of the Big River Watershed, Bonne Terre Dolomite (the host-rock of lead and zinc mineralization) outcrops at the surface, and mineral deposits occur hundreds of feet deep (Pavlowsky, Owen, & Martin, 2010).

2.2.3 SOILS

The Natural Resources Conservation Service (NRCS) Soil Survey characterizes the study area as an aggregate of soils known as the Deep Loess Hills area (MDC, 1998). Loess is a sediment formed by wind-

---

[11] Karst topography is a landscape formed from the dissolution of soluble rocks (e.g., limestone, dolomite); characterized by caves and sinkholes

[12] The dolomites are soluble and create impressive local karst, including some very large springs, extensive caverns, and numerous dry valleys (Nigh & Schroeder, 2002).

blown silt. A variety of separate soils can be found in this area due to the local variations in parent material, landforms and vegetation (MDC, 1998).

Within the Meramec River Watershed, the river bottom soils consist of the Hartville-Ashton-Cedargap-Nolin soil association paralleling the Meramec River channel (MDC, 1998). The soils on the side slopes and ridge tops consist of the Menfro-Winfield soil association, a deep, well-drained soil formed in loess (MDC, 1998).

Within the Big River Watershed, the floodplain soils are a very fertile silt-loam (0-2% slope) developed from alluvium over cherty gravel. They are deep to very deep (greater than 60 inches), well drained and prone to occasional or frequent flooding. These soils are suitable for row crops, bottomland forest and pasture (MDC, 1997). On foot slopes, side slopes and sloping point ridges the soils are also silt loams (5-14%) and are moderately well-drained. On ridge-tops and slopes, soils are highly erodible, especially when disturbed. The upland soils are moderately shallow and consist of a combination of loess and remnant weathered dolomite (MDC, 1997). In higher elevations, these soils tend to be clayey with high chert[13] content, thin, dry, infertile and stony, and are best suited for grasslands and forest (MDC, 1997).

Two hundred seventeen different soil series are located within the study area, with the most common soil series being Sonsac (10% of the study area). Sonsac gravelly silt loam is found on back slopes of hills with the parent material of gravelly colluvium over clayey residuum weathered from cherty limestone. It is moderately deep (20 to 40 inches), well drained and low organic matter content (USDA, 1999). Most of the other soil series make up less than 5% of the study area so are not discussed.

The U.S. Geological Survey (2018) PLUTO database characterizes background metal concentrations in soils by county. Background lead concentration in St. Francois County is 53 ppm and Jefferson County is 62 ppm.

2.2.4 PRIME FARMLAND

The U.S. Department of Agriculture (USDA) defines prime farmland as land with the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. Since the supply of high-quality farmland is limited, the USDA encourages responsible governments and individuals to use the Nation's prime farmland wisely. The USACE prepared an AD-1006 application to evaluate the prime farmland in the study area (See *Appendix A, Coordination*) for more details.

The study area contains prime farmland (10.7% of total area), farmland of statewide importance (17.8% of total area), and prime farmland if drained (2.7% of total area). These soils meet the prime farmland requirement and are found mainly on the floodplains and broad uplands affiliated with soil associations of Wrengart-Gross, Menfro-Gasconade, Minnith-Pevely and Haymond-Freeburg-Horsecreek-Bloomsdale. The USDA (1999) identifies the main uses of prime farmland in the study area to be pasture and cultivated crops (e.g., fescue, clover, corn and wheat).

2.2.5 STREAM GEOMORPHOLOGY

Geomorphology is the study of topographic and bathymetric features at or near the Earth's surface. These processes affect features by means of weathering, erosion, transportation, and/or deposition. The fluvial process describes the geomorphology of streams. It involves the mobilization,

[13] Chert is hard, fine-grained sedimentary rock composed of crystals of quartz (silica)

transportation, and deposition of sediment as bed load, suspended load, or dissolved load. As rainwater converges into concentrated flow, sediment may be mobilized if the shear stress caused by the water flowing past it is great enough. It is transported if the velocity remains high enough. It is deposited once the velocity is too low to continue to transport it. The rate of sediment transport is dependent upon the availability of sediment. Stream geomorphology creates a variety of habitats that native species depend on.[14]

The mainstem of the Meramec River meanders among rather steeply sloping hills. Massive limestone bluffs confine the river over much of its course, most notably in the headwaters. The floodplain varies in width from a few feet in the upper regions to nearly a mile in portions of the lower regions. Tributary floodplain areas are generally quite narrow (Ryckman, Edgerley, & Tomlinson, 1972). The stream gradient for the Meramec River ranges from 34.7 feet per mile in the Upper Meramec River (RM 218-166) to 1.0 feet per mile in the Lower Meramec (RM 42-0) (MDC, 1998).

The Big River's average stream gradient is 6.6 feet per mile with the steepest gradients at the headwaters in the St. Francois Mountain area (200 feet per mile at RM 137) to more gradual gradients starting at RM 85 to the confluence with the Meramec River (MDC, 1997). Removal of native vegetation and conversion to row crops, sod farming, grazing or urban landscapes diminish soil water retention, increase overland and instream flows and ultimately cause increased river bed erosion and channel degradation (Lyons & Beschta, 1983; Potter, 1991; Gangloff & Feminella, 2007).

2.2.5.1 GEOMORPHIC ASSESSMENT

Disturbance and stable river reaches define the study area. Disturbance reaches are portions of the river characterized by high levels of erosion, deposition, lateral channel migration, changing gravel bars, and often lack bank vegetation. Stable reaches are portions of the river with low levels of erosion and deposition, and often contain bluffs and forested floodplains. Stable reaches should provide suitable habitat for a variety of aquatic organisms, including freshwater mussels.

The channel of a river naturally moves, but human-induced modifications (e.g., deforestation, gravel mining, farming/grazing to the river bank's edge) to the river and floodplain often accelerate the channel movement and interfere with the river's natural geomorphic processes. Accelerated channel movement negatively affects aquatic organisms sensitive to channel change, including freshwater mussels.

In the Big River, studies (Pavlowsky & Owen, 2013; Young, 2011) tracked channel change through time and identified disturbance reaches (Figure 2-2). These disturbance reaches contribute excessive sediment from the banks and floodplain into the Big River. The problem is made worse because these sediments have elevated lead levels (Young, 2011). Several studies document the negative effects of elevated lead levels to aquatic life (Albers et al, 2016; Allert et al., 2009; Besser et al., 2009; Czarnezki 1985; Roberts et al. 2010, 2016). Roberts et.al. (2016) excluded the identified disturbance reaches and searched for freshwater mussels in stable reaches of the Big River that should support mussels; this study concluded the lack of freshwater mussels in stable reaches, otherwise suitable habitat, was strongly associated with the presence of contaminated sediments.

---

[14] Source: https://en.wikipedia.org/wiki/Geomorphology#Processes

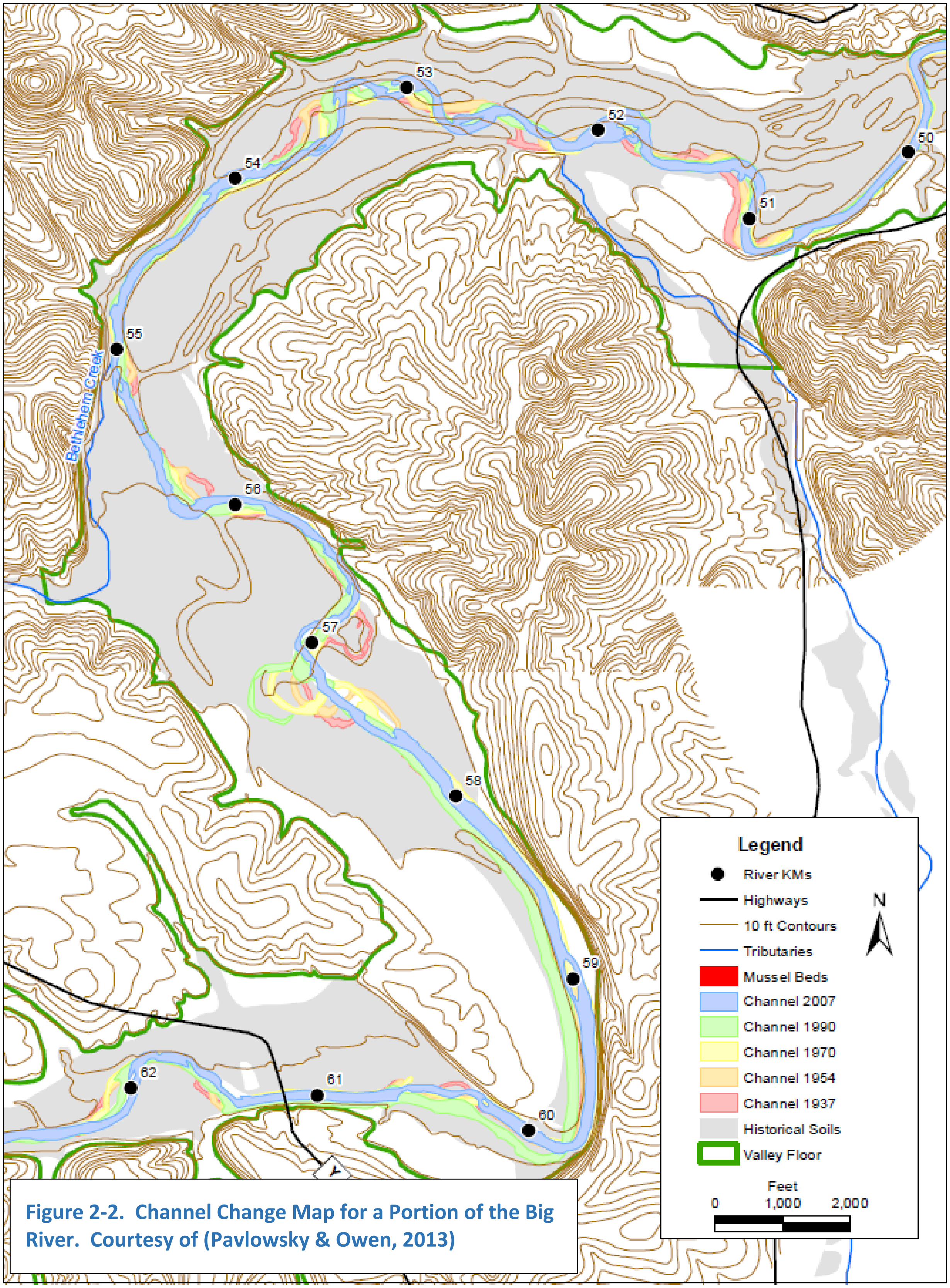


Figure 2-2. Channel Change Map for a Portion of the Big River. Courtesy of (Pavlowsky & Owen, 2013)

2.2.5.2 BANK EROSION

In the study area, a lack of a forest adjacent to the river (i.e., riparian corridor) contributes to accelerated bank erosion. Well-vegetated riparian corridors slow down bank erosion by making the banks more stable. Eroding banks are a main source for sediment being reintroduced into the river and carried downstream. This problem is compounded because the floodplain is contaminated with lead. Young (2011) determined approximately 32% of the banks in the lower 15 miles of the Big River are experiencing bank instability.

To better understand the rate and volume of bank erosion and to identify additional disturbance reaches in the Big River aerial imagery from 2016[15] was compared to previous channel change maps (Pavlowsky & Owen, 2013). Eroded bank volume was estimated using Light Detection and Ranging (LiDAR)[16] data from 2007, with the assumption that bank geometry remained similar as the bank continued to erode. The volume of bank erosion and lead reintroduction during both time periods was nearly the same, although the specific sites changed between the two timeframes (Table 2-1).

Table 2-1. Big River – Average Annual Bank Erosion Rate

Timeframe	***Volume of Bank Eroded*** (cubic yards per year)	***Lead Reintroduced*** (tons per year)
1990-2007	125,000	83
2007-2016	123,000	100

2.2.6 LAND COVER AND LAND USE

2.2.6.1 LAND COVER

Before European settlement, the Meramec River Basin was mainly timbered with oak savannahs and mixed forests with oak, pine and other deciduous trees. A mix of hardwood and riverfront sycamore-cottonwood trees dominated the river bottoms (Nigh & Schroeder, 2002). Figure 2-3 depicts the minimal changes in land cover among 2001, 2006, and 2011 (MRLC, 2012). The main land cover type is forest at approximately 60% of the study area; however, past clearing and land management altered the quality of the forests making them even-aged and dominated by a single or few tree species. Section 2.7.4-*Floodplain and Riparian Forest* contains additional information on the forest community.

[15]https://www.arcgis.com/home/group.html?owner=esri&title=NAIP%20Imagery&sortField=numviews&sortOrder=desc

[16] The LiDAR is a remote sensing method that uses light in the form of a pulsed laser to measure distances to the Earth.

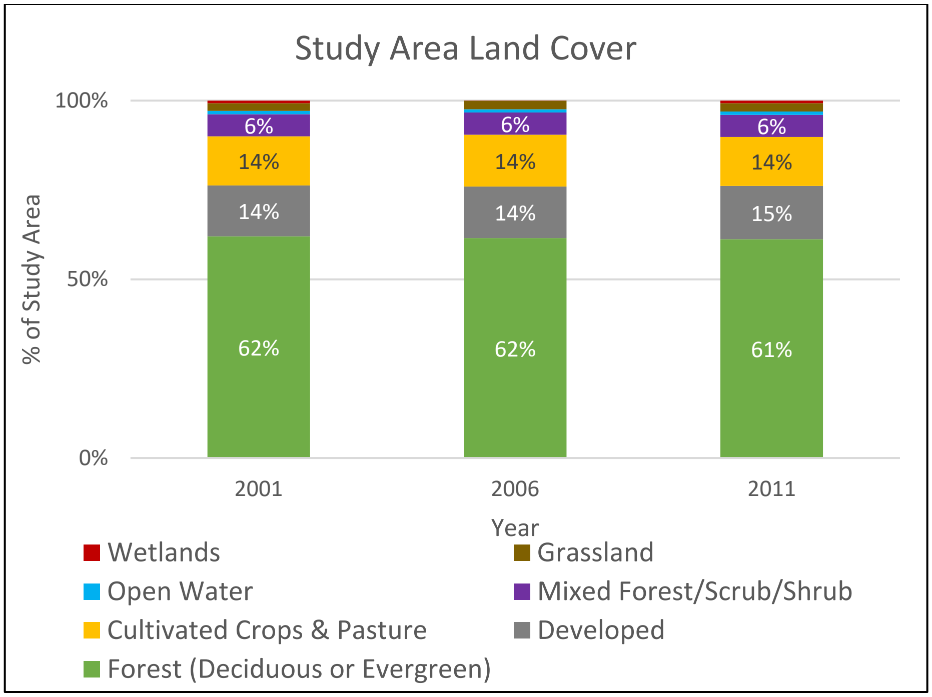


Figure 2-3. Recent Land Cover Changes within the Study Area (MRLC 2012)[17]

2.2.6.2 LAND USE & OTHER LAND USE PLANNING EFFORTS

Two commonly used indicators of projected land use change are population growth and the number of building permits issued. Section 2.10-*Socioeconomics Resources* discusses population growth and demographics. Overall, the study area, excluding the St. Louis Metropolitan Area, is rural with agriculture (e.g., sod farming, row crops and pasture) being the primary land use of non-forested areas.

Land use planning efforts within the study area have occurred or are ongoing. The following are the land use planning efforts most relevant and taken into consideration during this USACE planning study:

- The Meramec River Conservation Plan (TNC 2014)
- Big River Watershed Master Plan (prepared by URS Corporation)
- North American Waterfowl Management Plan
- The St. Louis County Strategic Plan 2013
- Jefferson County's Draft 5-Year Capital and Strategic Plan 2013-2017
- Southeast Missouri Regional Planning & Economic Development Commission (includes St. Francois County)
- Lower Meramec Multi-Jurisdictional Floodplain Management Plan

2.2.7 PHYSICAL SETTING FUTURE WITHOUT PROJECT CONDITIONS

It is assumed stream geomorphology changes due to the movement of mining waste will continue and more disturbances will occur as bed sediment moves downstream over the next 50 years (Section

[17] Data courtesy of the National Land Cover Database

2.2.5.2). It is also assumed overall bank erosion will continue at a similar rate, but recognizes the potential for localized variances.

Studies have shown various levels of projected urbanization within the study area. Substantial urban growth within the study area, excluding the St. Louis Metropolitan Area, is not projected. Urbanization estimates for St. Louis Metropolitan Area, ranged from 49% growth (1992-2001) to 5% growth (2001-2011) (Jordan, Ghulam, & Hartling, 2014). A 5% urban growth projection was assumed for the purposes of this study. If this assumption is incorrect and future urbanization rates are higher than the recent trends, then increased urbanization and its subsequent impacts on the watershed (e.g., altered hydrology and increased run-off) will be underestimated.

2.3 HYDROLOGY & HYDRAULICS

Hydrology generally refers to the study of rainfall and runoff in connection to topography and geology. Hydraulics is the mechanics of how water moves (e.g., flow, velocity, water depth and shear stress).

2.3.1 HYDROLOGY

2.3.1.1 SURFACE WATER

The mainstem of the Meramec River (218 linear miles) drains from lightly populated, forested, and agricultural upper watershed north-easterly to the heavily populated and urbanized lower watershed within St. Louis before entering directly into the Mississippi River. Meramec River base flows are well-sustained by artesian spring characteristics of the region's karst topography and by drainage from its two largest tributaries, the Big River and Bourbeuse River.

The Big River (138 linear miles) originates in Iron County and flows northward until it reaches the Meramec River near Eureka, Missouri (Meramec River RM 35.7). No natural lakes or ponds are present, except for sinkhole ponds.

2.3.1.2 GROUND WATER

The study area lies within the Ozark Plateau's aquifer system located throughout southern Missouri, southeastern Kansas, eastern Oklahoma and portions of Arkansas. The Big River Watershed is comprised of two aquifers, the Ozark aquifer and the deeper St. Francois aquifer. The aquifers are composed of limestones, dolomites, and sandstones separated by a shale confining unit of minimal permeability (Miller & Appel, 1997). Aquifer recharge occurs primarily through precipitation at outcrop areas and via fractures and bedding planes, resulting in the dissolution of carbonate rocks, enlarged byways and additional karst features (Miller & Appel, 1997). Water from the Ozark aquifer is primarily used for municipal, industrial, and domestic supplies (Miller & Appel, 1997).

Currently, the USEPA is investigating potential impacts to ground water as part of the Superfund efforts in the area under Operable Unit 5. EPA continues to work on the Remedial Investigation/Feasibility Study (RI/FS). Sampling of private residential groundwater wells will continue in conjunction with residential yard sampling.

2.3.1.3 MERAMEC RIVER HYDROLOGY

Hydrology within the Meramec River Watershed is driven by rainfall runoff. Sustained flows are attributed to adequate precipitation, runoff conditions, and ground water supply; sandstone and cavernous carbonate rocks rapidly transmit water from highland areas to deep river valleys where water emerges as springs (MDC, 1998). The Meramec River is the second longest free-flowing river (i.e., not channelized or impounded) in Missouri; however, there are several sites along the Meramec River that have been armored to reduce bank erosion. Four river gaging stations operated by USGS in cooperation with USACE – St. Louis District are located within the study area on the Meramec River near Pacific (USGS 07017020), Eureka (USGS 07019000), Valley Park (USGS 07019130) and Arnold (USGS 07019300).[18] The Eureka gages measures discharge for a drainage area of 3,788 square miles. The average discharge at Eureka during the period of record (January 1960 to 2016) is 2,970 cubic feet per second (cfs) and the average stage is 3.95 feet. Examining the average annual hydrograph over the period of record, elevated flows occur most often between March and July (figure 2.4). The 2[nd] highest instantaneous stage on record occurred on May 1, 2017 at 30.09 ft. (see Appendix H-*Hydraulics and Hydrology Analysis* for additional details).

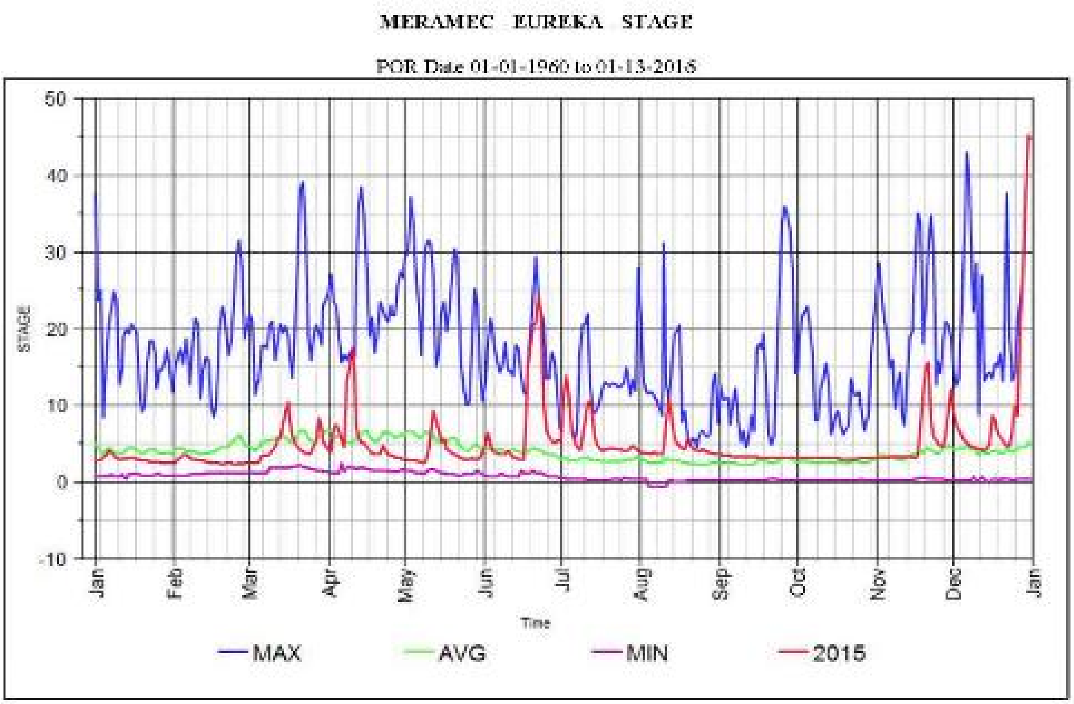


Figure 2-4. Annual Hydrograph for the Meramec River at Eureka, MO (1960-2016).

2.3.1.4 BIG RIVER HYDROLOGY

Four river gaging stations, operated by USGS in cooperation with USACE – St. Louis District, are located within the study area on the Big River: Desloge (USGS 07017260), Bonne Terre (07017610), Richwoods (USGS 07018100) and Byrnesville (USGS 07018500)[19]. At Byrnesville (drainage area of 917 square miles), the average discharge is 840 cfs (1970 to 2016) with an average river stage of 4.30 feet. Examining the average annual hydrograph over the period of record, elevated flows occur most often in April and lowest flows in August (Figure 2-5). During the planning study, the 5[th] highest instantaneous stage on record occurred on December 29, 2015 at 27.18 feet. Based on the flow data, the Big River can be highly variable and quickly cycle from low flows to high flows (Figure 2-6). On average, the Big River

[18] waterdata.usgs.gov

contributes 25% of the total flow of the Meramec (see Appendix H-*Hydraulics and Hydrology Analysis* for additional details).

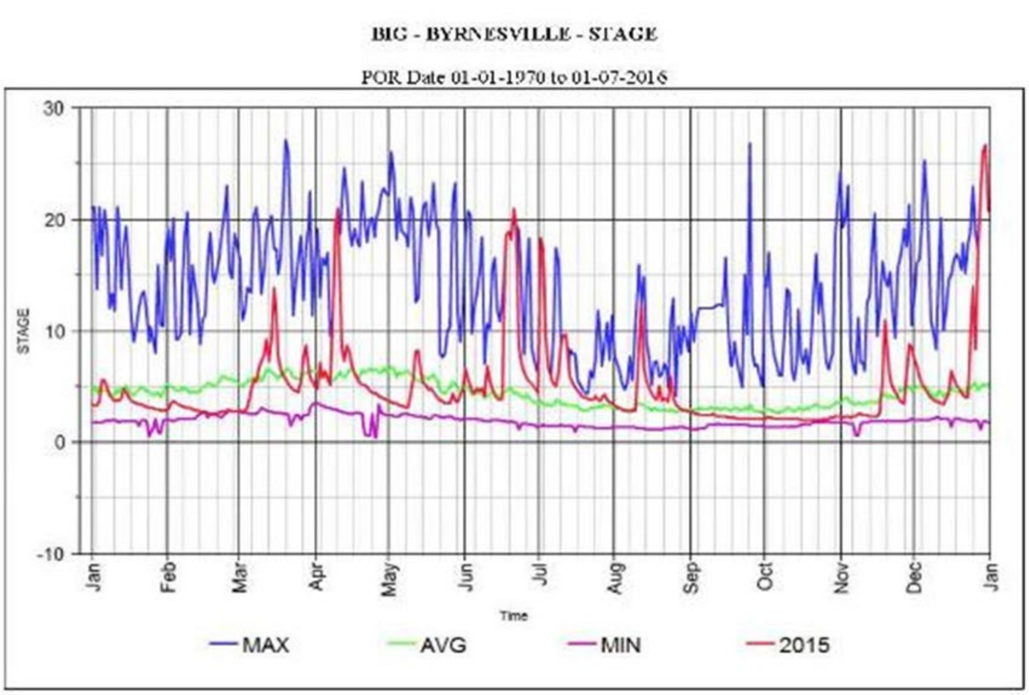


Figure 2-5. Annual Hydrograph for the Big River at Byrnesville, MO (1970-2016)

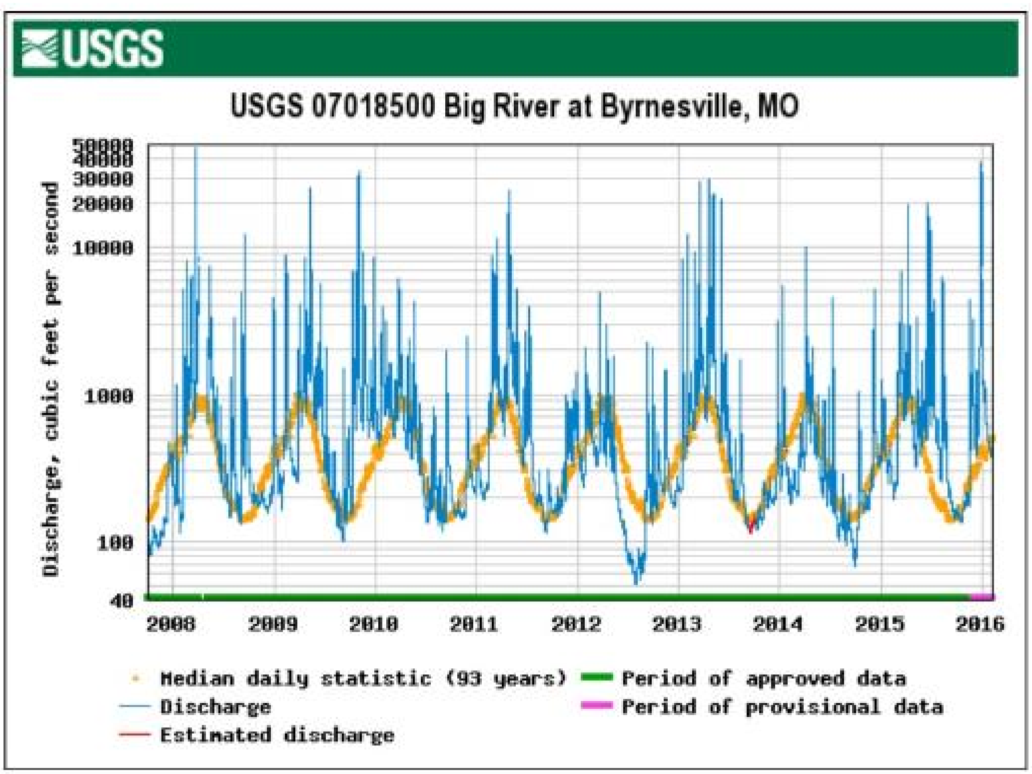


Figure 2-6. Discharge on the Big River at Byrnesville, MO (2008-2016). Data courtesy USGS.

2.3.2 HYDRAULICS

Today, five mill dams remain in the study area: Morse Mill, Cedar Hill, Byrnesville, Rockford Beach and Byrnes Mill (Figure 1-2). These mill dams have been in place for over 100 years. It was assumed that the mill dams have reached their sediment storage capacity. The dams are in varying degrees of disrepair with two (Rockford Beach and Byrnesville) intact. Pearson and Pizzuto (2015) studied sediment storage behind similar-type mill dams and concluded all sediment (bed material grain-sized fraction) can be transported over mill dams because the river has altered its grain size and elevation to transport the supplied sediment (Figure 2-7).

Mill dams impact the natural river morphology by acting as grade control structures and have the potential to retain contaminated sediment behind them. The study of the process and extent of sediment impoundment is ongoing within the study area. Based on the data available, it was assumed sediment is stored episodically and transported over Big River mill dams during highly variable flows (Pearson & Pizzuto, 2015; Csiki & Rhoads, 2014; Csiki & Rhoads, 2010). For more details about the dams refer to Appendix H-*Hydraulics and Hydrology Analysis.*

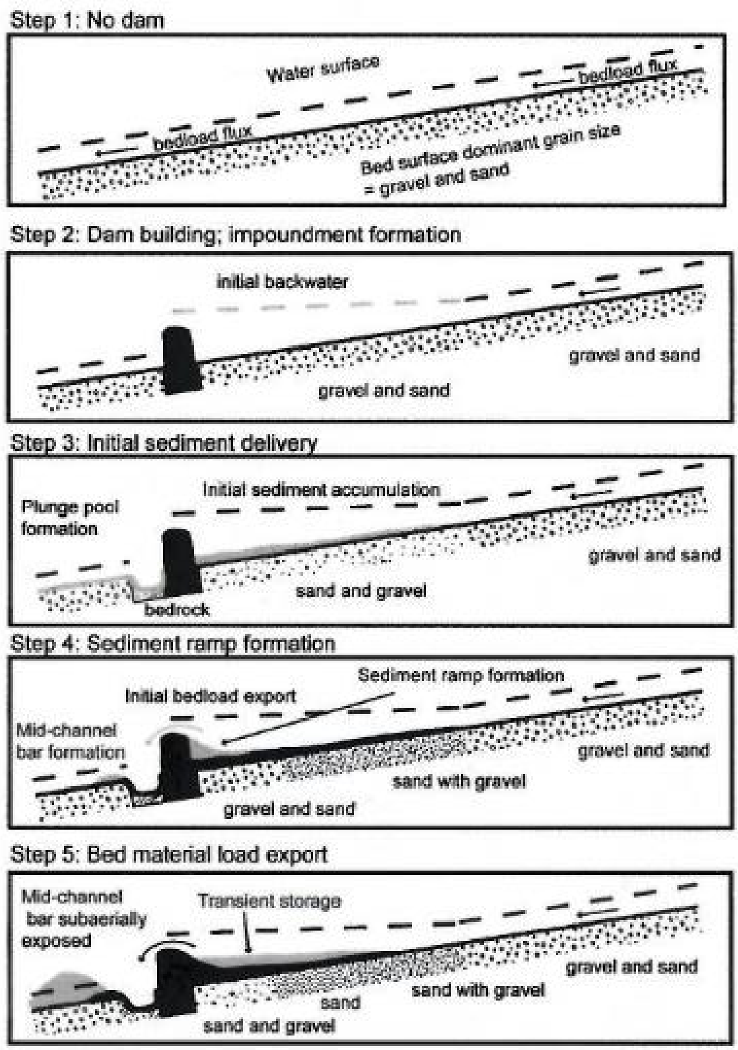


Figure 2-7. Conceptual Depiction of Bed Load Transport and Effects of Low-Head Dams. Graphic courtesy (Pearson & Pizzuto, 2015).

2.3.3 HYDROLOGY & HYDRAULICS FUTURE WITHOUT PROJECT CONDITIONS

Negligible changes were assumed to the current hydrology over the next 50 years based on minimal expected changes in future land use and climate change (discussed further in Section 2.14.2 and Appendix H-*Hydraulics and Hydrology Analysis)*. It was assumed that the Rockford Beach and Byrnesville mill dams will stay in place and sediment will be transported over them, while one or more of the less intact mills dams will fail without intervention. Failure would cause a head cut, which would mobilize, transport and deposit contaminated sediment stored in the upstream channel and floodplain near of the dam.

2.4 SEDIMENT

2.4.1 EXISTING SEDIMENT

Sediment movement occurs naturally within a river. A sign of a healthy river is a balance between erosion and deposition as well as a mix of sediment sizes (e.g., fine clays, silts, sand, and gravel). A healthy river provides the required habitat for aquatic organisms. The USEPA (2013) concludes the leading cause of degradation to rivers and streams nationwide is excess suspended and bedded sediments. When a river has excess sediment (i.e., an unbalanced sediment budget) the aquatic habitat becomes degraded (Box 2-1).

Box 2-1. Common Harmful Effects of Excess Sediment to Rivers

Biological

- Reduces feeding efficiency for sight-feeding fish (i.e., bass)
- Reduces aquatic plant growth due to decreased light availability
- Clogs gills of aquatic animals (e.g., fish, crayfish, and freshwater mussels)
- Reduces disease resistance
- Decreases growth and reproduction of aquatic organisms
- Physically smothers immobile organisms

Physical

- Alters flow
- Reduces water depth
- Changes slope and bedform

The Meramec River Conservation Action Plan (TNC, 2014) identifies excess suspended and bedded sediment as a primary stressor across the Meramec River Basin.

In the Big River, the excess suspended and bedded sediment is made worse because the sediment moving through the river is contaminated with heavy metals. During high water events, the contaminated sediments are transported and redistributed both spatially and temporally. This contamination is linked to loss of aquatic organisms (McKee, Vining, & Sheriff, 2010; Allert, et al., 2009; Besser, Brumbaugh, Hardesty, Hughes, & Ingersoll, 2009; Albers, Besser, Schmitt, & Wildhaber, 2016; Roberts, et al., 2016). As discussed in Section 1.6.5, a lead concentration higher than 128 parts per million negatively affects aquatic organisms (MacDonald, Ingersoll, & Berger, 2000). In 2008, the Trustees launched a series of multidisciplinary studies conducted by USFWS, the USGS and the MDC to assess potential adverse effects of mining on the aquatic organisms (i.e., freshwater mussels, invertebrates, and fish) of the Big River. Collectively, the studies demonstrated widespread heavy metal contamination of sediments from the city of Leadwood, Missouri to the confluence of the Big River with the Meramec River with ecological harm to aquatic organisms (Besser, Brumbaugh, Hardesty, Hughes, & Ingersoll, 2009; Allert, et al., 2009).

Pavlowsky, Owen, & Martin (2010) approximated of the 250 million tons (over 9 million dump trucks worth) of mining waste produced during the mining period, 23% of the lead produced remains in tailings piles and 32% is stored in the channel and floodplain. Figure 2-8 shows the “sand” bedform of contaminated material in the Big River. Pavlowsky and others (2010) estimated the Big River channel stores 4,828,000 cubic yards and the floodplain stores 114,200,000 cubic yards of contaminated sediment. Jefferson County alone stores roughly 63% of this contaminated sediment. It was estimated, on average, over 138,000 tons of sediment eroded annually, from 24 eroding Big River banks in Jefferson County from 1990-2007 and 2007-2016 (see Appendix H-*Hydraulics and Hydrology Analysis* for more detail).

The magnitude of basin-wide distribution of heavy metals in floodplain sediments ensures that remobilization by bank erosion will be a continuing problem into the future (Pavlowsky R.T., 2017).

Figure 2-8. Tailing “sand” bedform in the Big River. Photo courtesy of R. T. Pavlowsky

Figure 2-9 shows a graphical representation of the sediment budget in the Big River and outlines the inputs and interfaces for sediment and lead. Three main historic sources of lead and sediment are shown: (1) chat and tailing piles, (2) historic direct mill discharge, and (3) overland flow. Tailings piles and historic direct mill discharges contributed heavy metal contaminated sediment into the Big River and its tributaries. To date, these sources of lead have been greatly reduced by remedial actions. Contributions from chat and tailings piles range in grain size. Slimes, exclusively in the finest fraction (<0.063mm) and exceptionally toxic, are trapped in stored sediment within the channel and floodplain soils throughout the Big River Watershed. Overland flow continually contributes sediment into the Big River by means of surface erosion. Contributions from overland flow are almost exclusively in the finer fraction. These inputs reach the Big River interface via two pathways: major tributaries and minor tributaries.

2.4.2 SEDIMENT FUTURE WITHOUT PROJECT CONDITIONS

For the purpose of this study, it was assumed that the stabilized tailings piles would contribute little new sediment or heavy metals input into the Big River, and the existing contaminated sediment would continue to move downstream and negatively impact the health of the lower Big River and Meramec River into the future. It was also assumed the USEPA would remediate the heavy metal contamination, and the forecasted contribution from eroding banks (at least 138,000 tons of material) would continue to be released into the Big River annually without intervention (see Appendix H-*Hydraulics and Hydrology Analysis* for more detail). The magnitude of the heavy metal contamination in the Big River Watershed would continue into the future and negatively affect aquatic organisms, including freshwater mussels, in both the Big River and Meramec River.

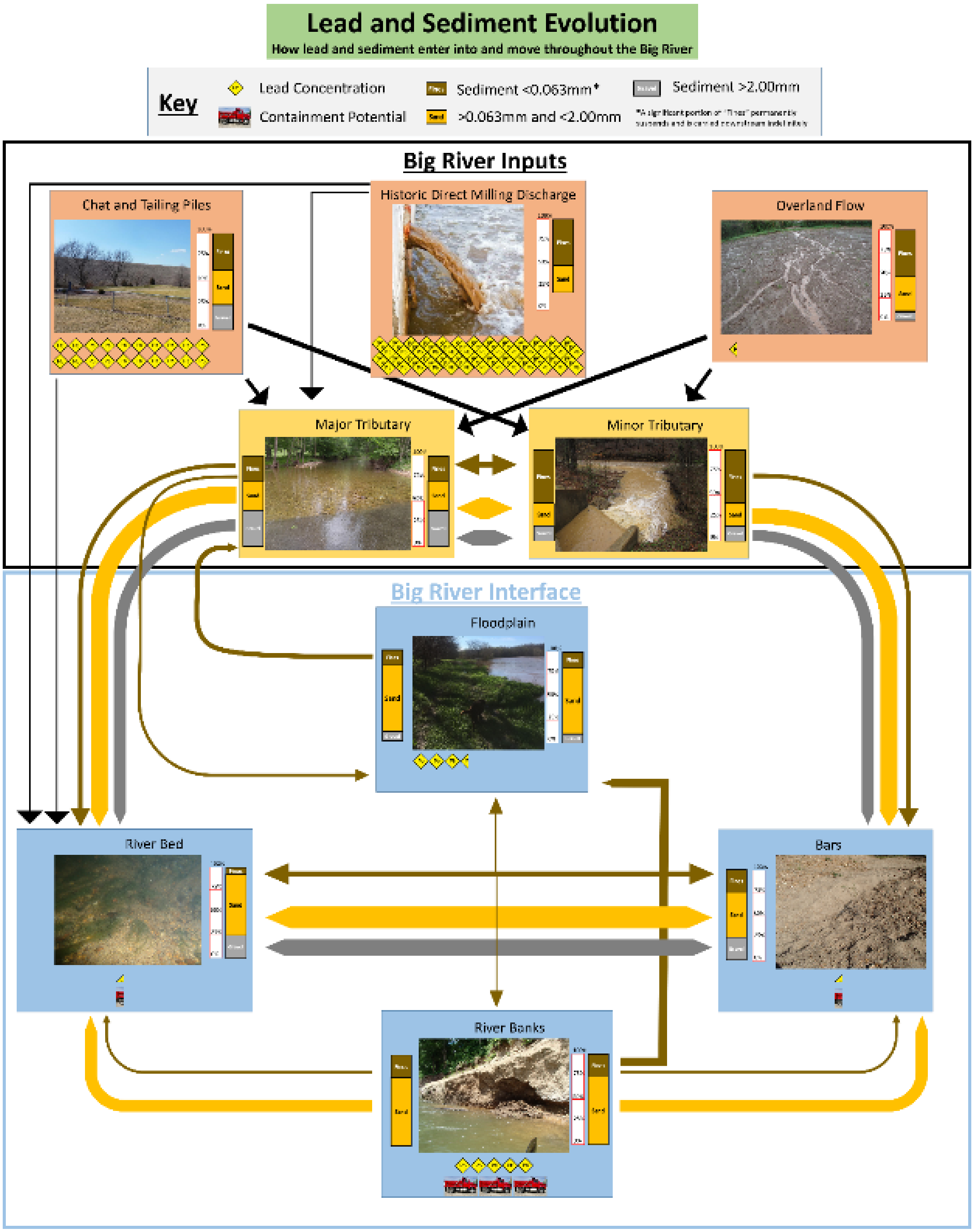


Figure 2-9. System-level Conceptual Diagram of Interactions with Lead and Sediment in the Big River

2.5 WATER QUALITY

Overall, the water quality within the Meramec River Basin is considered quite good (MDC, 1998); however, problems do exist. In the upper and middle portions of the Meramec River Watershed, cattle grazing and creek bottomland pastures are very common which lead to damage to riparian areas and excessive nutrient loading. In the lower Meramec River Watershed, urbanization poses other threats to water quality from sediment, land disturbance and pollution-laden runoff rapidly entering the river because of impervious surfaces from development and the channelization of tributaries (MDC, 1998).

In the Big River Watershed, the contaminated suspended and bedded sediment and floodplain soils threaten stream water quality. See Appendix F-*Water Quality* for more details and on the trend analysis from the following reports:

- Water Quality Sampling Big River, Jefferson County
- Assessment of Metal-Contaminated Sediments from the Southeast Missouri (SEMO) Mining District using Sediment Toxicity Tests with Amphipods and Freshwater Mussels, (USGS), 2009
- Big River (Lower) Irondale to Washington State Park (MoDNR), 2002-2003

Based on the data reviewed and information gathered, the entire Big River is affected by the historic mining activities and erosion of tailing piles. The contaminated sediments pose a potential threat to stream water quality as they move downstream to the Meramec River. Water samples from test sites have shown to be higher in dissolved metal concentrations compared to control sites, but these dissolved metals concentrations have not exceeded state water quality standards (MoDNR, 2001-2002) (MoDNR, 2002-2003); however, samples from sediment and pore water indicate a high risk of sediment toxicity in the Big River due to heavy metal concentrations. The following locations within the Big River Watershed have been identified due to high concentration levels of Lead (Pb), Zinc (Zn) and other heavy metal:

- 53 miles for Lead from Old Lead Belt Abandoned Mine Lands (AML)
- 40 miles for Lead and Non-Volatile Suspended Solids (NVSS) from Old Lead Belt AML

This toxicity negatively impacts aquatic habitat, growth and reproduction of aquatic organisms, including endangered species and other species of concern.

2.5.1 SECTION 303(D) OF THE FEDERAL CLEAN WATER ACT

Section 303(d) of the Clean Water Act requires each state to identify waters not meeting water quality standards and for which adequate water pollution controls are not in place. These identified waters are considered impaired. Water quality standards protect beneficial uses of water including whole body contact (e.g., swimming), maintaining fish and other aquatic life and providing drinking water for people, livestock and wildlife.

Table 2-2 summarizes the water bodies within the study area that are listed on Missouri's 303(d)[19] List of Impaired Waterways for 2016. Water bodies within the study area are impaired with lead, *E. coli*, pH, mercury in fish tissue, chloride, zinc and cadmium.

[19]MoDNR. 2016. Missouri Water Quality Report. http://dnr.mo.gov/env/wpp/waterquality/303d/303d.htm. Accessed 19 November 2018.

Table 2-2. 2016 Missouri 303(d) Impaired Waters Within the Study Area.

HUC 8 Watershed	Waterbody Name	Impairment
Meramec (07140102)	Antire Creek	E.coli, pH
	Bee Tree Lake	Mercury in fish tissue
	Burgher Branch	Dissolved oxygen
	Courtois Creek	Lead, Zinc
	Crooked Creek	Cadmium, Lead, Copper
	Dutro Carter Creek	Dissolved oxygen, E. Coli
	Fenton Creek	Chloride, E. Coli
	Fishpot Creek	Chloride, E. Coli
	Frisco Lake	Mercury in fish tissue
	Grand Glaize Creek	Chloride, E. Coli, Mercury in fish tissue
	Indian Creek	Zinc, Lead
	Keifer Creek	Chloride
	Little Dry Fork	Dissolved oxygen
	Mattese Creek	Chloride, E. Coli
	Meramec River	E. Coli, Lead
	Spring Branch	E. Coli
	Williams Creek	E. Coli
Big (07140104)	Big River	Cadmium, Lead, Lead in fish tissue
	Coonville Creek	Lead
	Eaton Branch	Cadmium, Lead, Zinc
	Flat River Creek	Cadmium
	Flat River Creek Tributary	Zinc
	Koen Creek	Lead
	Monsanto Lake	Total nitrogen, chlorophyll-a, Total Phosphorus
	Salt Pine Creek	Lead, Zinc
	Tributary to Old Mines Creek	Sedimentation, Lead
	Turkey Creek	Cadmium, Lead, Zinc, Copper, Nickel

2.5.2 TOTAL MAXIMUM DAILY LOADS

Total Maximum Daily Loads (TMDLs) is a regulatory term in the U.S. Clean Water Act describing a plan for restoring impaired waters by identifying the maximum amount of a pollutant a water body can receive while still meeting water quality standards. The USEPA approved TMDLs for Big River, Flat River

Creek, and Shaw Branch (Jefferson, St. Francois and Washington Counties[20]). To address the listed pollutants, TMDLs were calculated for dissolved lead, total suspended solids, and dissolved zinc. The Big River is impaired for lead, with 55% of observed lead data in the study area exceeding the TMDL target concentration of 5 micrograms per liter (µg/L).

2.5.3 WATER QUALITY FUTURE WITHOUT PROJECT CONDITIONS

Water quality conditions were assumed to remain similar to current conditions with elevated levels above aquatic life criteria for cadmium, lead and zinc in the Big River, and *E. coli* in the Meramec River. The State and local programs and stakeholder groups will continue to work in the study area to improve local water quality; however, based on the sheer magnitude of the heavy metal contamination it was assumed water quality related issues will continue into the future as the contaminated sediment moves downstream.

2.6 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

2.6.1 EXISTING HTRW

Hazardous, Toxic, and Radioactive Waste (HTRW) are materials listed as a hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act. Construction of USACE Civil Works projects in HTRW-contaminated areas is to be avoided where practicable and where it cannot response actions must be completed by the non-Federal sponsor prior to a federal project being constructed. The non-Federal sponsor and the USEPA are responsible for planning and accomplishing any HTRW response measures and those response efforts cannot be considered part of this Federal project.

Portions of the study area are located within the Southeast Missouri Lead Mining District, the largest lead production area in the Nation. Prior to environmental laws passed in the 1960s and 1970s, there were relatively few restrictions on mining activities and the associated waste (mine tailings) containing heavy metals (i.e., Arsenic (As), Barium (Ba), Cadmium (Cd) and Zinc (Zn)). The USEPA National Priority List (NPL) Superfund Sites applicable to the study area due to heavy metal contamination include:

- Big River Mine Tailings, St. Francois County
- Southwest Jefferson County, Jefferson County
- Old Mines, Washington County
- Potosi, Washington County
- Richwoods, Washington County

Currently, the USEPA is conducting a remedial investigation/feasibility study (RI/FS) for the Big River both in St. Francois County (Big River Mine Tailings Superfund Site) and Jefferson County (Southwest Jefferson County Superfund Site). These studies will be used to help the USACE determine the nature, extent, impacts, potential source areas, release mechanisms, exposure routes, potentially exposed populations, and potential health risks associated with the project. The USEPA RI/FS will also identify remedial action objectives for the Big River and its floodplain. The RI/FS(s) may be released as a stand-

[20] Available online at http://dnr.mo.gov/env/wpp/tmdl/docs/2074-2080-2168-2170-big-r-tmdl.pdf. TMDL document for the Big River (water body ID 2074, 2080), Flat River (water body ID 2168), and Shaw Branch (water body ID 2170). Accessed 27 Nov 2018

alone document but will be finalized in a ROD, which is scheduled to be completed in 2019. Because the ROD is not complete, it is unknown what USEPA will set as a clean-up level within the study area.

HTRW materials and their impact to the study are briefly described in Appendix E-*HTRW.* The following reports conducted by MoDNR, USEPA, USFWS and USGS contain additional information on the magnitude and effects of CERCLA-regulated heavy metals found within the study area.

- Quantitative survey of freshwater mussels (Unionoidea) and assessment of sediment contamination in the Big River, Missouri. Columbia, MO: USFWS, USGS, University of Missouri. (Roberts), 2016
- Distribution, Geochemistry, and Storage of Mining Sediment in Channel and Floodplain Deposits of the Big River System in St. Francois, Washington and Jefferson Counties, Missouri (OEWRI & MSU), 2008-2009
- Mussel Community Associations with Sediment Metal Concentration and Substrate Characteristics in the Big River, Missouri, USA, (USGS & USFWS), 2009
- Effects of Mining-Derived Metals on Riffle-Dwelling Crayfish and In-situ Toxicity to Juvenile *Orconectes hylas* and *Orconectes luteus* in the Big River of Southeast Missouri, USA (USGS), 2010
- Historical Channel Change and Mining-Contaminated Sediment Remobilization in the Lower Big River, Eastern Missouri (B. Young), 2011
- Surface water quality suspended-sediment quality and quantity with in Big River Basin, Southeastern MO, 2011-2013 (USGS), 2015
- Analysis of Soil and Sediment in the Big River Watershed Utilizing Pb Isotopes for Source Distribution, Synchrotron Speciation for Phase Identification, and In-Vitro Bioaccessibility for Risk Assessment (USEPA), 2017

2.6.2 HTRW FUTURE WITHOUT PROJECT CONDITIONS

The study area will continue to overlap with ongoing Superfund Sites. The USEPA's ROD for these sites will determine the remedial action level, or clean-up level. The USEPA clean-up level determines where the USEPA may implement remediation projects. Since the USEPA has not yet issued RODs, the extent of HTRW within the study area cannot be identified at this time. For comparison, other RODs issued in the vicinity of the study area have clean-up levels for residential yards ranging from 400 ppm to 1,200 ppm for lead. These numbers are identified through site-specific health risk assessment modeling (USEPA, 2012; USEPA, 2011). It was assumed the USEPA will not set a clean-up level for the Big River lower than what was established for residential soils (400 ppm). Based on the amount of recreation and local use occurring on Big River, it was also assumed that the USEPA will not set a clean-up goal higher than the 1200 ppm. Recent data collected in the Big River show variable lead concentrations generally ranging from 100 ppm to 1,000 ppm with a general descending trend in lead concentrations moving downstream. (Roberts, et al., 2010; Pavlowsky, Owen, & Martin, 2010; USEPA, 2017). With these data, it was assumed the USACE will be able to construct in a majority of Jefferson County with minimal potential of overlap with USEPA remediation projects.

Higher lead concentrations within the upper Big River Watershed were assumed to continue to move downstream through time and result in higher concentrations in the lower portions of the Big River and the Meramec River. In the next 50-years, lead concentrations in the floodplain soils and in-streams sediment within the Big River and Meramec River were assumed to remain a threat to the aquatic ecosystem without an USACE project.

2.7 BIOLOGICAL RESOURCES

The Meramec River Basin has been identified as one of the "most biologically significant river basins in mid-continental North America, with diverse and rare aquatic and terrestrial plants, animals, and natural communities" (TNC, 2014). The Meramec River Basin is part of the Southeast Missouri Ozarks, which is home to more rare and endangered species than any other region in Missouri (Nigh & Schroeder, 2002). Within the study area, 100 plants and animals have been identified as species of concern in the Natural Heritage Database maintained by the MDC. The following subsections describe the State-listed species based on the Wildlife Code of Missouri (Rule 3 CSR 10-4, 111 Endangered Species); whereas, Section 2.8 discusses Federally threatened and endangered species.

The Big River Watershed is unique in that it contains six sensitive aquatic natural communities including two examples of Ozark creeks and four examples of Ozark springs and spring branches (Grady, Corio, Elkington, Walker, & Hill, 2011), which helps explain the high species diversity found within this watershed.

TNC (2014) considered the Meramec River Basin in relatively good health, but a number of factors, including heavy metal toxicity, impact fish and wildlife resources within the study area. The *Meramec River Conservation Action Plan* (TNC, 2014) identified eight conservation targets for the whole basin with the assessment on the Lower Meramec River Watershed, Big River Watershed and freshwater mussel targets being of particular interest for this feasibility study. The TNC (2014) assessment ranked the Lower Meramec River Watershed as "poor" due to a combination of landscape level factors related to urban development and impervious surfaces which affect the hydrology and overall aquatic habitat. The TNC (2014) assessment ranked the Big River Watershed at the landscape level as "fair" and the aquatic habitat as "poor" due to the high levels of heavy metal contamination. The TNC (2014) assessment also ranked the freshwater mussel conservation target as "fair". See Section 2.7.2, *Freshwater Mussels* for more information.

2.7.1 FISH

A diverse assemblage of 125 fish species utilize the various habitats within the Meramec River Basin (MDC, 1998). Both large river fishes in the Lower Meramec and Ozark stream fishes found in the upper watershed and tributaries comprise the fish community of the study area. The Meramec River fish assemblage has distinct differences in fish species from the upper to lower Meramec River Basin (MDC, 1998). The Meramec River Basin is also home to a variety of game fish including smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivrais*), sunfish (*Lepomis* spp.), crappie (*Pomoxis* spp.) and suckers (Catostomidae) (Meneau, 1997). The MDC established a Smallmouth Bass Special Management Area on the lower Big River in 1992 (Meneau, 1997) which extends from the Leadwood Public Access in St. Francois County to the Big River's confluence with the Meramec River (Grady, Corio, Elkington, Walker, & Hill, 2011).

Two species of fish in the Meramec River are migratory: the Alabama Shad (*Alosa alabamae*) and American Eel (*Anguilla rostrata*). Alabama Shad, listed as rare in Missouri, migrate up the Mississippi River to spawn on the sand and gravel of the Lower Meramec Watershed, including the Big and Bourbeuse Rivers. The MDC has infrequently sampled Alabama Shad in the Lower Big River (RM 4-1) (Meneau, 1997). American Eel have also been collected in the Meramec River (MDC, 1998).

Within the study area, the following fish species are State-listed endangered species[21]:

- Crystal Darter (*Crystallaria asperella)* is a large darter (5-6 inches) that inhabits open channels of large, clear streams with low to moderate gradients and long stretches of silt-free sand and small gravel substrate. Populations have been found in the Meramec, St. Francis, Black and Big Rivers in Missouri. It is State-listed due to impacts from channelization, dredging and impoundments. Management should include: 1) the prohibition of dam construction and other impoundments in streams throughout the species range; 2) avoiding removal and altering the riparian corridor along streams; and/or 3) erosion and sediment controls (MDC, 2016).
- Lake Sturgeon (*Acipenser fulvescens*) is a large fish, up to eight-feet in length that inhabits areas with firm, silt-free bottoms of sand, gravel and rock of the Missouri and Mississippi Rivers and larger tributaries. It is known to occur in the Big River and Meramec River. It is State-listed in Missouri due to overharvest and alterations of river channels. Management should include protection from fishing, reestablishing self-sustaining populations, habitat improvement, river management, and artificial propagation (MDC, 2016).

Within the Big River Watershed, several studies have been performed to assess the effects of heavy metals on fishery resources. Below provides a brief summary of some key studies.

- Czarnezki (1985) studied the accumulation of lead in fish from the Big River to determine if elevated levels of lead occur in the edible tissue of fish inhabiting areas affected by lead mining. The study found fish collected from the Big River, located in the Old Lead Belt, contained the highest concentrations of lead found during the study and exceeded the World Health's Organization maximum safe level for human consumption. Other studies conducted along the Big River concluded that sediments contained high concentrations of lead contamination (1,400 – 2,200 ppm) (Schmitt & Fingers, 1982) and organic detritus (Whelan, 1983). Czarnezki (1985) found bottom-feeding fish (e.g., suckers) had the highest concentration of lead since they continually ingest sediment with elevated lead levels and detritus while feeding in the Big River. Smallmouth bass had the lowest levels of lead which Czarnezki (1985) related to the minimal contact these fish had while feeding on the stream bottom.
- The MDC (McKee, Vining, & Sheriff, 2010) conducted a study to determine the impacts of mining-related heavy metals on benthic riffle fish (e.g., darters, sculpins, madtoms and stonecats) within the Big River. Findings from this study indicate benthic riffle fish density is decreased with increased mining-related heavy metals in sediments and surface water from the Big River.

2.7.2 FRESHWATER MUSSELS

Freshwater mussels (Bivalvia: Unionoidea) are among the world's most endangered organisms (Williams, Warren, Cummings, Harris, & Neves, 1993). In general, freshwater mussels are sensitive to changes related to altered flow, substrate stability, sedimentation, water quality, and are highly sensitive to heavy metal toxicity. The degradation of freshwater mussels nationally is largely attributed to habitat loss, degraded water quality (which includes heavy metal toxicity), altered stream geomorphology, impoundments, exotic species and historic commercial overharvest for pearl buttons (Neves, 1993; Thiel & Fritz, 1993; Gangloff & Feminella, 2007). The Meramec River Basin has been identified as a stronghold for over 40 freshwater mussel species (Buchanan, 1980); however, the

[21] From Missouri Heritage Database available at https://mdc.mo.gov/property/greener-communities/heritage-program/results/county/Jefferson (accessed on 28 March 2018)

abundance and distribution of most species is declining. Within the Big River below Leadwood, Missouri, studies have shown the limiting factor to freshwater mussels is high concentrations of lead found in the sediment (Roberts, et al., 2010; Roberts, et al. 2016).

Figure 2-10 compares Big River mussel surveys conducted in 1979 and 2008 which looked at both catch-per-unit-effort (i.e., number of mussels collected per hour) and the number of species of live and fresh dead shells. This figure illustrates the "dead zone" of mussels within the Big River, and indicates that since 1979 the reduction in catch-per-unit-effort and number of species is extending downstream.

Figure 2-11 summarizes a third mussel survey conducted within the Big River and is overlaid with the lead concentration of smaller than 2mm sized sediment. It clearly shows with higher lead concentrations there are less live mussels and less diversity; and when the lead concentration is below the PEC of 128 ppm, the number of live individuals and the number of species is higher.

Within the Meramec River Basin, changes in stream geomorphology are contributing to aquatic habitat degradation. Mussel bed stability is affected by geomorphic processes within a given river reach. As the geomorphic processes change, mussel beds can migrate in response over time. Pavlowsky and others' (2013) historic channel change map comparisons highlight areas of increased channel movement along the Big River (Section 2.2.5-*Stream Geomorphology*, above for more information). These disturbance reaches are not likely suitable mussel habitat; therefore, mussels are not expected to be found there. In comparison, the remainder of the Big River does provide suitable physical characteristics that would constitute "good" mussel habitat; however, based on surveys by Roberts et al. (2016), mussels are not found in these areas. The conclusion for why they are not found in the Big River when the physical characteristics (e.g., substrate, flow, shear stress) supportive of mussel beds are present is due to the contaminated sediments from lead mining (Roberts et al., 2016).

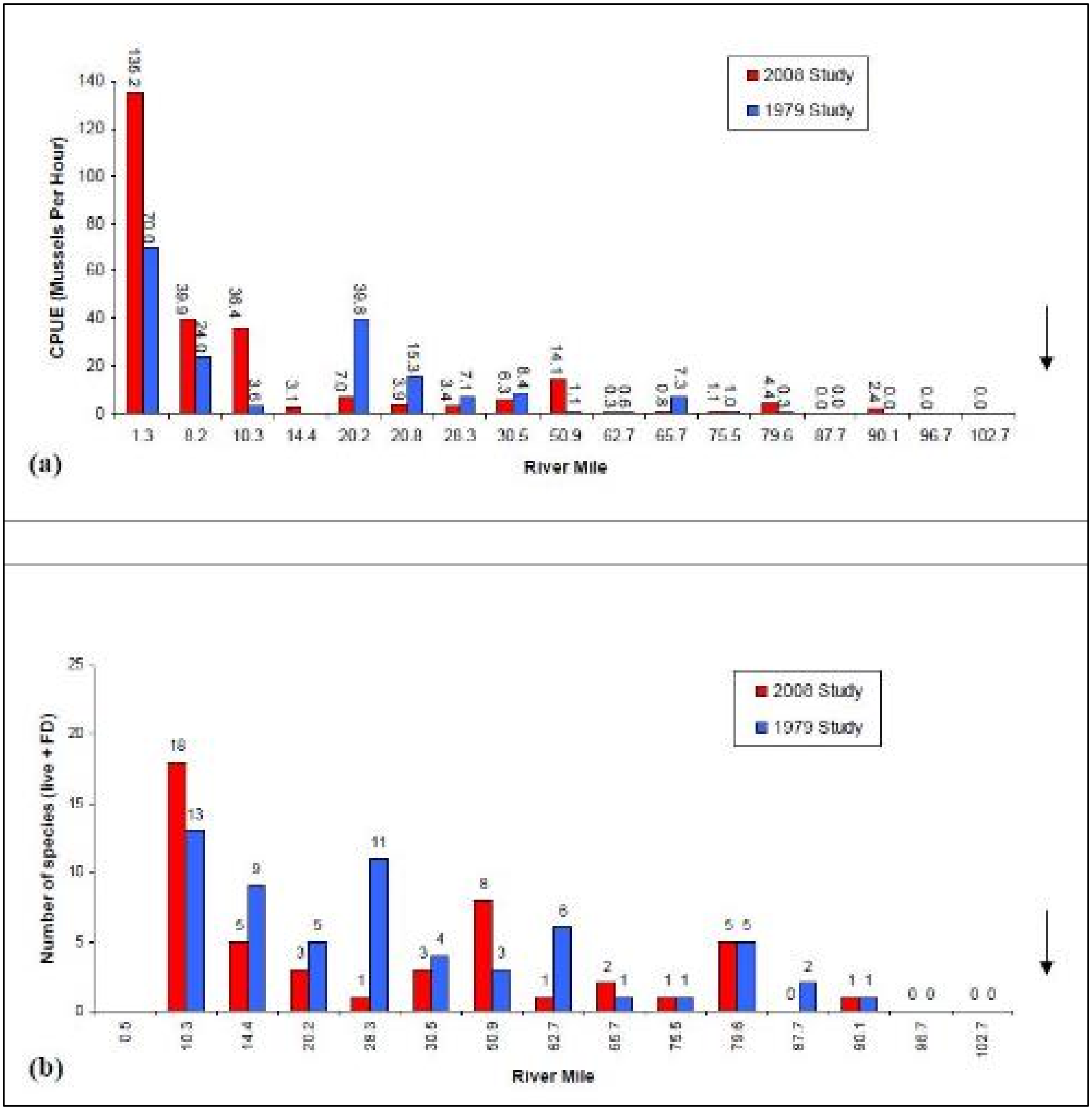


Figure 2-10. Comparison of 1979 (Buchanan, 1979) and (Roberts, et al., 2010) study of (a) catch per unit effort (mussels per person per hour) and (b) number of living species for common survey reaches. Arrow indicates upstream extent of mining. (Graph from Roberts, et al., 2010).

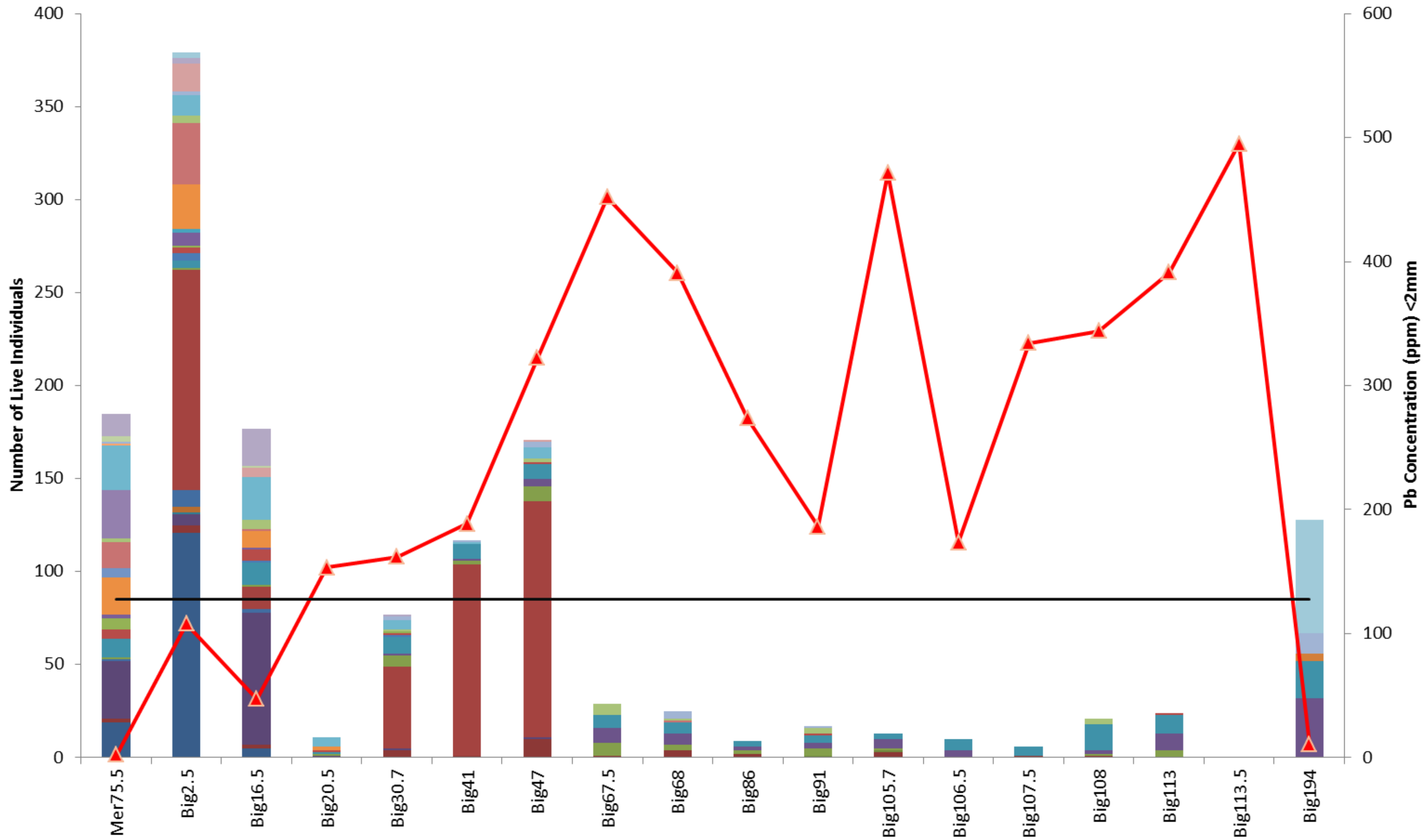


Figure 2-11. Number of individuals collected in the Big and Meramec Rivers and concentration of lead <2mm at each site. Each bar color represents a living freshwater mussel species found at the site. Site names are by river kilometer. Courtesy of (Roberts, et al., 2016).

Table 2-3 summarizes the state ranked freshwater mussels species historically found within the study area. Critically imperiled refers to extreme rarity or especially vulnerable to extirpation (<1,000 individuals remaining). Imperiled refers to rarity and very vulnerable to extirpation (1,000 to 3,000 individuals remaining). Vulnerable refers to rarity or uncommon or found in a restricted area (3,000 to 10,000 individuals remaining). Section 2.8, *Federally-Listed Threatened and Endangered Species*, further discusses Federally-listed species.

Table 2-3. Missouri Freshwater Mussel Species of Conservation Concern[22]

Name	State Rank	State Status	Federal Status
Black Sandshell (*Ligumia recta*)	Imperiled		
Ebonyshell (*Reginaia ebenus*)	Critically imperiled	Endangered	
Elephantear (*Elliptio crassidens*)	Critically imperiled	Endangered	
Elktoe (*Alasmidonta marginata*)	Imperiled		
Hickorynut (*Obovaria olivaria*)	Vulnerable		
Northern Brokenray (*Lampsilis brittsi*)	Vulnerable		
Pink Mucket (*Lampsilis abrupta*)	Imperiled	Endangered	Endangered
Rock Pocketbook (*Arcidens confragosus*)	Vulnerable		
Scaleshell (*Leptodea leptodon*)	Critically imperiled	Endangered	Endangered
Sheepnose (*Plethobasus cyphyus*)	Imperiled	Endangered	Endangered
Slippershell Mussel (*Alasmidonta viridis*)	Critically imperiled	Endangered	
Snuffbox (*Epioblasma triquertra*)	Critically imperiled	Endangered	Endangered
Spectaclecase (*Margaritifera monodonta*)	Vulnerable	Endangered	Endangered
Wartyback (*Cyclonaias nodulata*)	Vulnerable		

2.7.3 OTHER AQUATIC ORGANISMS

The Meramec River Basin has an aquatic invertebrate fauna similar to what is found in other Ozark streams. Many of the fauna are typical riffle-pool streams and have a wide geographical distribution (Ryckman, Edgerley, & Tomlinson, 1972). In addition to the diverse mussel community (more details above in Section 2.7.2-*Freshwater Mussels*), the Big River contains eight species of crayfish, including the belted crayfish (*Orconectes harrisoni*), which is only found in Missouri in the St. Francis and Big River Watersheds (Meneau, 1997). Crayfish are an important component of many freshwater ecosystems and play a crucial role in food web dynamics and nutrient processing. Negative effects of heavy metals on crayfish have a cascading effect on these important ecosystem processes. Allert and others (2009) studied riffle crayfish density, survival and growth upstream and downstream of mining activities in the Big River and determined how heavy metals harm crayfish (Box 2-2). Findings from this study indicate that heavy metals related to previous mining activities are negatively affecting crayfish populations in the Big River (Allert, et al., 2009).

Box 2-2. Impacts of heavy metal concentrations in sediment to crayfish:

- Reduced crayfish densities
- Reduced survivability
- Increased metal concentrations in body tissues (cascade effect into food web)

[22] Missouri Natural Heritage Database. Available online at https://mdc.mo.gov/property/greener-communities/heritage-program/results/county/Jefferson. https://mdc.mo.gov/property/greener-communities/heritage-program/results/county/St%20Louis Accessed 11 April 2018

2.7.4 FLOODPLAIN AND RIPARIAN FOREST

Floodplain forest refers to the forest community within the floodplain and common trees include sugar maple and butternut hickory (MDC, 1998). The riparian forest refers to the forest adjacent to the banks of the river, commonly referred to as the riparian corridor, and includes silver maple, sycamore and willow trees. Both of these forest communities are important for a healthy river ecosystem because they help prevent or lessen future stream bank erosion. Within the Meramec River Basin, upland forests are largely oak-hickory, having fewer maple, elm and black walnut (MDC, 1998).

Changes in the forest condition within the Meramec River Basin began with early settlement activities. In the mid-1800s and again in the 1920s, large tracts of forest were cleared and the understory burned to remove logging debris. This left extensive areas devoid of vegetation cover and subject to wind and rain erosion (Ryckman, Edgerley, & Tomlinson, 1972). The timber was used in lead smelting practices and along railroads that shipped mining products within the basin to St. Louis.

Removal of the riparian corridor can increase runoff, water temperatures, bed erosion and channel degradation which in turn disrupt aquatic habitat, including those essential for freshwater mussels. Morris and Corkum (1999) showed that distributions of freshwater mussel species can vary among riparian habitats.

The MDC assessed timbered riparian corridors within the Meramec River Watershed from 1991-1996 (MDC, 1998). Within the Lower Meramec watershed, corridors on the lower-order streams were poor and 9-15% of all stream corridors sampled had no woody vegetation in 25% of the corridor length (MDC, 1998).

Two decades ago, the MDC evaluated the stream habitat quality in the Big River Watershed and concluded the riparian corridor condition was fair to poor (Meneau, 1997). From this evaluation, 60% of Big River sample sites had a timbered stream corridor greater than 75 feet and 24% of the Big River sites had no timbered corridor (Meneau, 1997). The main causes for smaller portions of riparian corridor included row cropping and hay production adjacent to the Big River and increasing amounts of urbanization (Meneau, 1997).

Aerial imagery and outputs from the interagency rapid bio-assessment (Barbour, 1999) were used to identify areas lacking functional riparian corridor in the study area. Specifically, multiple biologists independently assessed and scored each of the habitat parameters (e.g., riparian zone width, bank stability). Scores were then averaged amongst assessors in order to rank sites based on overall habitat quality. Further, averaged scores were used as input into the habitat evaluation analysis, Appendix B-*Habitat Evaluation and Quantification.*

2.7.5 WILDLIFE

Common mammals found within the Meramec River Basin, which also occur state-wide, include white-tailed deer (*odocoileus virginianus*), gray squirrel (*Sciurus carolinensis*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), rabbit (*Oryctolagus cuniculus*), raccoon (*Procyon lotor*), beaver (*Castor canadensis*), river otter (*Lontra canadensis*), muskrat (*Onadtra zibethicus*), opossum (*Didelphis virginiana*), bobcat (*Lynx rufus)*, little brown bat (*Myotis lucifugus*), red bat (*Lasiurus borealis*) and big brown bat (*Eptesicus fuscus*).

The Meramec River Basin experienced an intensive wildlife harvest during the 1700s and 1800s for local food supplies and fur trade in Eastern markets. This occurred during the same time as logging, soil erosion, mining activities and cattle grazing, which intensified the negative effects to wildlife.

The Meramec River Basin provides suitable wildlife habitat. The karst topography provides bat cave habitat and the forested streams and riparian corridor provide bat roosting and foraging habitat. Gray bat, Indiana bat and Northern long-eared bat are both State- and Federally-listed as endangered. Section 2.8-*Federally-Listed Threatened and Endangered Species* discusses these species.

2.7.6 BIRDS

The Meramec River Basin provides mid-migration habitat for the Mississippi Flyway, one of the major migratory bird flight corridors in North America. The Meramec River is a tributary to the Mississippi River, which is the center of the flyway. The North American Waterfowl Management Plan recognized the mid-migration habitat as a habitat of major concern with more than 300 species of migratory birds using the flyway (MAS, 2016).

Within the riparian forest of the Meramec River Basin, characteristic species include Louisiana waterthrush (*Parkesia motacilla*) and prothontary warbler (*Protonotaria citrea*). Along streams and riparian corridor characteristic species included eastern wild turkey (*Meleagris gallopavo*), belted kingfisher (*Megaceryle alcyon*), solitary sandpiper (*Tringa solitaria*), wood duck *(Aix sponsa*) and other waterfowl.

The following are State-listed bird species of special concern for the State of Missouri:

- American bittern (*Botaurus lentignosus)* is a solitary medium-sized heron with a stocky build and stripes of brown, tan, and white. American bitterns prefer wetland marshes or extensive meadows mixed with areas of dense vegetation and open waters. It is a state-wide summer resident in Missouri and is listed as state endangered due to loss of wetland habitat (MDC, 2016).
- Peregrine falcon (*Falco peregrinus*) is a small to medium sized raptor which historically nested in the bluffs along the Mississippi, Missouri and Gasconade Rivers and is listed as endangered due to previous use of certain pesticides. Peregrine falcons have been reintroduced in major urban areas (MDC, 2016).

Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (BGEPA) protect migratory birds. Any activity resulting in the "take" of migratory birds or eagles is prohibited unless authorized by the U.S. Fish and Wildlife Service. Twenty-eight migratory birds of conservation concern may be found within the study area (MDC, 2016).

Although the Bald Eagle (*Haliaeetus leucocephalus)* 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 National Bald Eagle Management Guidelines (USFWS, 2007) 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.

2.7.7 AMPHIBIANS AND REPTILES

Common amphibians and reptiles utilize the Meramec River Basin including frogs, toads, salamanders, lizards and snakes. Of special concern is the State-listed endangered salamander, the Eastern Hellbender. The Eastern Hellbender (*Cryptobranchus a. alleganiensis*) is a large, aquatic salamander that grows to over 20 inches in length and occurs in the Ozark Plateau in rivers draining into the Missouri and Mississippi Rivers. They need cool, clear streams and rivers with many large rocks in waters usually less than four feet deep. The Eastern hellbender has experienced a 77% decline in population in the last 30 years related to herbicides, pesticides and insecticides, dredging and filling, stream channelization and gravel dredging in streams (MDC, 2016). Management efforts should include sedimentation control, pollution (thermal, physical, and chemical) prevention, and restriction of human disturbance (MDC, 2016).

2.7.8 INVASIVE SPECIES (EXECUTIVE ORDER 13112)

Presidential Executive Order 13112 addresses the prevention of the introduction of invasive species and provides for the control and minimization of the economic, ecological and human health impacts caused by invasive species. Within the Meramec River Basin, there are numerous terrestrial invasive species. For the purposes of this study, only those that pose a reasonable risk to the aquatic ecosystem were considered. Aquatic invasive species within the Meramec River Basin include Asian clams (*Corbicula* spp.), Asian carps (i.e., Grass, Silver, and Bighead), and zebra mussels (*Dreissena polymorpha*); however, TNC (2014) identified the threat of these species as low for the Lower Meramec and no rating was given for the Big River. Grass carp (*Ctenopharyngodon idella*) have been occasionally taken during sampling in the Big River and are suspected to originate from overflow of private ponds (Meneau, 1997). Silver carp (*Hypophthalmichthys molitrix*) and Bighead carp (*H. nobilis*) have also been observed in the Meramec River and the Big River. These invasive fishes are planktivores, which means they compete with native freshwater mussels for phytoplankton food. Zebra mussels, which are known to attach themselves to boats and native mussels, have been confirmed in the Lower Meramec River and were likely introduced when infested boats from the Mississippi River went upstream during high flows. Asian clams are widespread throughout the Meramec River Basin.

2.7.9 BIOLOGICAL RESOURCES FUTURE WITHOUT PROJECT CONDITIONS

The current conditions affecting the aquatic biological resources, specifically freshwater mussels, were assumed to continue in a similar fashion. It was also assumed freshwater mussel distribution and density will continue to decline as a result of downstream movement of contaminated sediments. The fragmentation and loss of floodplain forests are expected to continue resulting in the degradation of important foraging and roosting habitat for wildlife, including migratory birds and resident bats. While localized changes are a potential, it was assumed the lack of a riparian corridor within the Big River would be similar into the future, at approximately 25% remaining unvegetated without the USACE project. There is uncertainty relating to potential new invasive aquatic species introduced into the study area during the period of analysis and the unknown impacts of these species to the ecosystem in the future. For example, Black carp (*Mylopharyngodon piceus*), a mussel-eating fish species, has been detected in the Mississippi River; therefore, there is potential that this fish species may move into the Meramec River. The effects of this species on the freshwater mussel community is unknown at this time and unable to predict.

2.8 FEDERALLY-LISTED THREATENED AND ENDANGERED SPECIES

2.8.1 EXISTING THREATENED AND ENDANGERED SPECIES

The USFWS provided a list of 13 Federally threatened and endangered species that could potentially be found in the study area (St. Louis, Jefferson, St. Francois, and Washington Counties, Missouri) via a letter dated 15 November 2018 (Appendix C-*Biological Assessment*). Federally-listed species include any plant or animal listed as endangered or threated in the Endangered Species Act of 1973, as amended. *Endangered* species include any species that is in danger of becoming extinct. *Threatened* species include any species that is likely to become endangered in the foreseeable future. *Proposed* species include any species that is being reviewed by the USFWS for possible addition to the list of endangered and threatened species (see Appendix C-*Biological Assessment*, for more details).

Table 2-4 lists the 13 threatened or endangered species that may occur in St. Louis, Jefferson, St. Francois and Washington Counties within the Meramec River Basin. The study area contains critical habitat for the Indiana Bat (*Myotis sodalis*) as defined in the Endangered Species Act. Critical Habitat is a specific geographic area that contains features essential to the conservation of an endangered or threatened species and that may require special management and protection.

Table 2-4. Federally-Listed Species Potentially Occurring in the Study Area

SPECIES	STATUS	HABITAT
MAMMALS		
Gray Bat (*Myotis grisescens*)	Endangered	Caves; small stream corridors with well-developed riparian woods; bottomland forests; forages over open water.
Indiana bat (*Myotis sodalis)*	Endangered	Hibernates in caves and mines; maternity and foraging habitat: small stream corridors with well-developed riparian woods; upland and bottomland forests
Northern long-eared bat (*Myotis septentrionalis*	Threatened	Hibernates in caves and mines; swarming in surrounding wooded areas in autumn. Roosts and forages in upland forests during spring and summer.
FISHES		
Pallid Sturgeon (*Scaphirhynchus albus*)	Endangered	Large river obligate fish inhabiting the Missouri and Mississippi rivers and some tributaries.
MUSSELS		
Pink Mucket (*Lampsilis abrupta)*	Endangered	Medium to large sized rivers.
Scaleshell Mussel (*Leptodea leptodon*)	Endangered	Medium to large sized rivers.
Sheepnose Mussel (*Plethobasus cyphysu*)	Endangered	Large rivers.
Snuffbox Mussel (*Epioblasma triquetra*)	Endangered	Small to medium sized rivers.
Spectaclecase (*Cumberlandia monodonta*)	Endangered	Large rivers.
INSECTS		
Hine's Emerald Dragonfly (*Somatochlora hineana*)	Endangered	Lives in calcareous (high in calcium carbonate) spring-fed marshes and sedge meadows overlaying dolomite bedrock.
FLOWERING PLANTS		
Decurrent false aster (*Boltonia decurrens*)	Threatened	Disturbed alluvial soils.
Mead's Milkweed (*Asclepias meadii*)	Threatened	Prairies and rhyolite glades in Missouri.
Running Buffalo Clover (*Trifolium stoloniferum*)	Endangered	Open forest to prairie periodically disturbed.

2.8.2 THREATENED AND ENDANGERED FUTURE WITHOUT PROJECT CONDITIONS

It was assumed the 13 Federally-listed species would not be down-listed during the period of analysis. The listed freshwater mussel species are known to occur throughout the study area, both within and downstream of the existing contaminated material. Contaminated sediment moving downstream was assumed to negatively affect Federally-listed aquatic species into the future without the USACE project, and additional species may be added to the list over the next 50-years.

2.9 CULTURAL AND HISTORICAL RESOURCES

2.9.1 EXISTING CULTURAL AND HISTORICAL RESOURCES

A review of the Missouri State Historic Preservation Office's (SHPO) geographic information system (GIS) site data files indicate that there are 72 archaeological sites, either historic or prehistoric, recorded within 200 meters of the river channel (Ekberg, Smith, Walters, & Lange, 1981). Unfortunately, the areas that have been surveyed for sites are sparsely recorded. It is unknown at this time which areas have been surveyed with no sites found, which areas surveyed, and where unrecorded sites may exist; however, the largest archaeological investigation in the Big River drainage area was conducted in 1982 in anticipation of the construction of the Pine Ford Lake, which was never built (Ives, May, & Denman, 1982). The survey covered 3,356 acres within the proposed 15,000 acre reservoir. While the sites found are recorded in the SHPO database, the areas surveyed are not. The areas surveyed for the project have been transposed to GIS shape files and provided to the SHPO. The extent and adequacy of those surveys will be subject to continued consultation with the SHPO and tribal stakeholders during the development of final project plans.

2.9.2 CULTURAL AND HISTORICAL RESOURCES FUTURE WITHOUT PROJECT CONDITIONS

Under current conditions and without the project, existing archaeological sites adjacent to eroding stream banks are subject to destruction by natural processes.

2.10 SOCIOECONOMICS RESOURCES

2.10.1 TRANSPORTATION

In general, the study area is rural in nature, and becomes more urban in St. Louis County as you near the City of St. Louis. In Jefferson, Washington, and St. Francois Counties, the transportation corridors are comprised of 2-lane highways and county roads.

2.10.2 DEMOGRAPHIC TRENDS

Table 2-5 shows the 2016 U.S. Census Bureau population demographic estimates.

Table 2-6 provides further details from the U. S. Census Bureau on population demographics. In 2016, females made up 52.5%, 50.3%, 46.5%, and 48.6% of the population for St. Louis, Jefferson, St. Francois, and Washington Counties, respectively.

Table 2-5. Population Demographics for Study Area[23]

Population (2016)	St. Louis County	Jefferson County	St. Francois County	Washington County	State of Missouri
White (%)	68.6	92.6	93.1	95.4	82.5
African American (%)	24.7	1.1	4.7	2.4	11.6
Hispanic or Latino (%)	2.9	2.0	1.6	1.4	3.9
Asian (%)	4.4	0.8	0.4	0.3	1.8
American Indian or Alaskan Native (%)	0.2	0.3	0.2	0.5	0.4

Table 2-6. Race Demographics for the Study Area[24]

	St. Louis County	Jefferson County	St. Francois County	Washington County	State of Missouri
TOTAL	1,000,560	222,453	66,230	25,002	6,059,651
White	692,735	214,052	61,766	23,702	5,000,875
Black or African American	235,920	2,190	3,137	594	701,896
American Indian & Alaska Native	1,622	552	161	96	25,641
Asian	38,459	1,647	105	9	107,953
Native Hawaiian & Other Pacific Islander	222	37	0	13	6,479
Hispanic or Latino	27,008	3,954	950	79	237,284
Two or more races	22,720	2,958	900	538	131,246

2.10.3 ECONOMICS AND ENVIRONMENTAL JUSTICE

At the National level, environmental justice concerns have primarily focused on populations considered to be minority and/or low-income; however, since environmental justice is defined as the fair treatment and meaningful involvement of all people, the final decision should be whether the affected area is likely to, or is already impacted by greater adverse effects than a demographically similar reference community. In order to identify whether the potential alternatives may disproportionately affect minorities or impoverished citizens, an analysis was done utilizing census information provided from the U.S. Census Bureau 2010 Census. Due to the large geographic area of the study area, the data are summarized at the county level in Table 2-7.

[23] https://www.census.gov/quickfacts/fact/table/jeffersoncountymissouri,washingtoncountymissouri,stfrancoiscountymissouri,stlouiscountymissouri,mo/PST045217#PST045217. Accessed online 20 November 2018.

[24] U.S. Census Bureau Quick Facts. http://www.census.gov/quickfacts/table/PST045215/29099,29189,29. Accessed online 20 November 2018

Table 2-7. Population and Environmental Justice Characteristics within the Study Area[25]

	St. Louis County	Jefferson County	St. Francois County	Washington County	State of Missouri
POPULATION					
Population Estimate (July 1, 2017)	996,726	223,810	66,705	25,022	6,113,532
Population, Census (2010)	998,954	218,713	65,359	25,195	5,988,927
AGE & SEX (July 1, 2016)					
Persons under 18	22.0%	23.4%	21.3%	23.1%	22.6%
Persons over 65	17.7%	14.5%	16.0%	16.3%	16.5%
Female persons	52.5%	50.3%	46.5%	48.6%	50.9%
RACE & HISPANIC ORIGIN (July 1, 2017)					
White alone	68.6%	96.2%	93.1%	95.4%	83.1%
Black or African American alone	24.7%	1.1%	4.7%	2.4%	11.8%
Hispanic or Latino	2.9%	2.0%	1.6%	1.4%	4.2%
EDUCATION (2012-2016)					
High school graduate or higher	93.0%	87.5%	82.2%	77.0%	88.8%
Bachelor's degree or higher	42.4%	18.4%	13.8%	8.0%	27.6%
INCOME & POVERTY (2016 dollars)					
Median household income (2012-2016)	$61,103	$58,232	$41,461	$36,701	$49,593
Persons in poverty	9.2%	10.1%	16.3%	22.0%	13.5%
BUSINESSES					
Unemployment rate	4.4%	4.9%	3.8%	5.6%	4.1%

The Greater St. Louis Metropolitan Statistical Area spans the Mississippi River. This area includes St. Louis County, the independent City of St. Louis, the Missouri counties of St. Charles, Jefferson, Franklin, Lincoln and Warren, and the Illinois counties of Bond, Calhoun, Clinton, Jersey, Macoupin, Madison, Monroe and St. Clair. In 2012, the St. Louis Metropolitan Statistical Area had a population of 2,795,794 people and is the largest Metropolitan Statistical Area in Missouri (Cooke & Gascon, 2014). As measured by the Gross Metropolitan Product (GMP), the Greater St. Louis Metropolitan Statistical Area (MSA) was $116.5 billion in 2012, equivalent to approximately 50% of the gross state product in Missouri (Cooke & Gascon, 2014). The Greater St. Louis Metropolitan Statistical Area supports strong financial services and health care services sectors.

2.10.4 SOCIOECONOMIC FUTURE WITHOUT PROJECT CONDITIONS

The regional population has grown slower than the national average. The greatest change in population growth from 2002 to 2012 was in St. Charles, Lincoln and Warren Counties of Missouri; the greatest loss of population occurred in the City of St. Louis and St. Louis County of Missouri as well as Macoupin and Bond Counties of Illinois (Cooke & Gascon, 2014). After the recession ended in 2009, the St. Louis Metropolitan Statistical Area employment growth was positive in most industries; however, in 2011 the

[25] Data Sources: U.S. Census Bureau American Fact Finder. https://fred.stlouisfed.org/series/MOSLURN. Accessed online 20 November 2018.

recovery stalled with job losses in construction and retail trade unevenly distributed across the St. Louis Metropolitan Statistical Area, with Illinois being most affected. Future estimates of overall growth for the State of Missouri are between 6% per decade, while the Census Bureau models predict the Nation to grow 10% per decade. By year 2030, Missouri's population is estimated to grow by 21%[26]. Of particular interest to the study area, Jefferson County, Missouri, is projected to increase by over 30% from 2000 to 2030 while St. Louis County is expected to decrease by approximately 6% during the same time period.

The *Saint Louis County Strategic Plan 2013* indicates St. Louis County is implementing efforts to grow its population and plans to "retain and attract Millennials" because they are viewed as an important component of St. Louis County's future workforce. The plan also indicates plans to promote economic vitality and to "attract and integrate immigrants" into the community and is looking at ways to "reduce barriers to employment, ease transition into [the] broader community, [and to] develop a strong system of essential services" by communicating a "culture of inclusion" for immigrants.

St. Louis County also plans to "revitalize commercial areas for changing markets" by revitalizing obsolete commercial areas. Fortune Magazine (2013) wrote that "from healthcare to bioengineering and financial services, [St. Louis County] has companies that continue to rank among the top in the nation."

Jefferson County's *Draft Five-Year Capital and Strategic Plan 2013-2017* (dated July 31, 2012) identifies six developments designed to expand recreational services at existing park facilities, to include a new playground and concession stand as well as development of a new soccer park.

A 2003 report entitled *St. Francois County Economic Analysis and Baseline 2001-2011* summarizes the expected economic growth for the country during that time period. It was expected that St. Francois County would experience 1.1% population growth which would increase demand for approximately 2,480 housing units, a 1.8% per year increase to per capita income, an increase to the number of persons unemployed and the unemployment rate, increased retail sales and county revenues (Kovalyova 2003). The City of Farmington's *2008 Economic Development Brochure* corroborates that projected growth by displaying the annual increases to taxable sales throughout the 90's and early 2000's; furthermore, Farmington's *2011 Comprehensive Plan* outlines goals and strategies for housing, land use and commercial development. Examples include supporting residential development downtown, developing commercial traffic corridors and continue expansion of the Farmington Regional Airport.

Economic development in Washington County is spurred by the agricultural industry. Washington County was designated an Agri-Ready County Designation by Missouri Farmers Care (MFC), a coalition of 44 leading Missouri agricultural groups. MFC states that in 2016, Washington County's 531 farm and ranch families sold over $61.6 million in agricultural products and that wood container and pallet manufacturing alone contribute over $15 million in sales to the Washington County economy. Further, complementing agricultural industry is development in and around the city of Potosi, which boasts a newly established, fully certified 650-acre industrial park as well as a downtown revitalization effort.

---

[26] Office of Administration. https://oa.mo.gov/budget-planning/demographic-information/population-projections/population-trends. Accessed online 05 February 2016.

2.11 NOISE

2.11.1 EXISTING NOISE CONDITIONS

Throughout the study area, noise levels can vary widely. Ambient noise levels may be intermittently high in urban areas, particularly near industrial and commercial uses and highways, but consistently low or moderate elsewhere depending on suburban and rural population, wind levels, aircraft traffic, and recreational, agricultural and industrial activities. The common human activities causing elevated noise levels in the study area include cars, trucks, boats, rail, farm equipment, and other industrial machinery. The sound of firearms during hunting season may also be prevalent in certain portions of the study area. A typical car can produce 60-90 decibels (dB) at a distance of 50 feet while a pleasure boat may produce noise levels ranging from 65-115 dB (USEPA, 1974). Horn blasts from trains may be in excess of 120 dB at one foot. The noise from a typical 12-gauge shotgun is 130 dB. All of these may contribute to the noise levels within the study area.

2.11.2 NOISE FUTURE WITHOUT PROJECT CONDITIONS

Noise levels in the study area are not likely to change significantly from the existing conditions with no USACE Federal project.

2.12 RESOURCES OF RECREATIONAL, ECOLOGICAL, SCENIC OR AESTHETIC IMPORTANCE

2.12.1 EXISTING RECREATIONAL, ECOLOGICAL, SCENIC, OR AESTHETIC RESOURCES

The study area aesthetics are driven by a variety of factors within the basin including limestone bluffs, springs, forested hillsides and wildflowers. On a local scale, the Lower Meramec River flows through highly developed portions of the St. Louis Metropolitan area where urbanization and commercialization have dramatically changed the visual resources from their historic conditions. In the upper portions of the Meramec River, the rivers flow through rural landscapes where the visual resources of an Ozarkian river have remained more or less intact. In certain site-specific areas, the riparian corridor has been converted to agriculture and the banks are eroding making the waterway less attractive. On the contrary, the waterway in the metropolitan area near St. Louis is highly developed with little riparian zones. Within the study area, there are no waterways designated as wild and scenic per the Wild and Scenic Rivers Act of 1968.

Fish and wildlife in the Meramec River Basin provide hunting, fishing and wildlife watching opportunities for people living in or near the region, and result in significant annual revenue for the area. Fishing, hunting and wildlife watching expenditures in Missouri totaled nearly $2.5 billion in 2011, according to the most recent *National Survey of Fishing, Hunting, and Wildlife Associated Recreation* (USFWS, 2011). As a point of reference, the MDC (MDC, 1997) sites a 1988 survey that estimated the upper and lower Meramec River has more use (hours per acre) than any stream in Missouri.

Department of Health and Senior Services recommends that all consumers limit consumption of carp, sunfish, redhorse or other suckers due to lead in the Big River at St. Francis and Jefferson Counties (Department of Health and Senior Services, 2018).

The Big River Watershed contains 20 areas owned by governmental agencies equaling 5% of all land. Eighteen areas offer a combined 15.5 miles of stream frontage (74% on the Big River), including 14 access areas on floatable streams and four boat ramps (some of these are outside of the study area).

The study area contains over 2,000 acres of public lands that provide recreational opportunities such as hunting, fishing, swimming, boating, bird watching, camping and hiking. The Meramec River Basin has over 55,000 acres of state-owned land, 22 MDC Conservation Areas, 17 MDC river accesses and several other tracts of land that provide opportunities for recreational activities (some of these areas are located outside of the study area). Approximately 46 miles of land along the Meramec are MDC-owned. Although not considered public land, Meramec Spring Trout Park, owned by the James Foundation, offers year-round rainbow trout fishing.

Table 2-8 summarizes key resources of recreational, ecological, scenic or aesthetic importance located along the Meramec and Big Rivers within the study area.

Table 2-8. Key Resources of Recreational, Ecological, Scenic or Aesthetic Importance

Manager	Area Name	Stream
Missouri Department of Conservation	Brown's Ford Access	Big River
Byrnes Mill	Byrnes Mill City Park	Big River
Jefferson County	Cedar Hill Access	Big River
Jefferson County	House Springs Access	Big River
Missouri Department of Conservation	Mammoth Access	Big River
Missouri Department of Conservation	Merrill Horse Access	Big River
Jefferson County	Morse Mill Access	Big River
Missouri Department of Natural Resources	Washington State Park	Big River
Missouri Department of Natural Resources	Castlewood State Park	Meramec
St. Louis County	Sherman Beach Park	Meramec
St. Louis County	Buder Park	Meramec
St. Louis County	Simpson Park	Meramec
St. Louis County	Unger Park	Meramec
Kirkwood	Emmenegger Nature Park	Meramec
Sunset Hills	Minnie Ha Ha Park	Meramec
Jefferson County	George Winter Park	Meramec
Missouri Department of Conservation	Teszars Woods	Meramec

2.12.2 RESOURCES OF RECREATIONAL, ECOLOGICAL, SCENIC OR AESTHETIC IMPORTANCE FUTURE WITHOUT PROJECT CONDITIONS

Without the project, it was assumed recreational, ecological, scenic and aesthetic resources found within the study area would continue as they persist today. Localized areas of failing banks and lack of riparian corridor are expected to continue, but the aesthetic beauty of the Meramec River are expected to continue and support high recreational use.

2.13 AIR QUALITY

2.13.1 EXISTING AIR QUALITY

The USEPA sets national air quality standards for six common pollutants. These standards, known as National Ambient Air Quality Standards (NAAQS), include carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter (PM) 2.5, PM 10 and sulfur dioxide. Areas where air quality conditions violate these standards are classified as "non-attainment" and are subject to special air quality controls. Table 2-9 lists areas of non-attainment within the study area as of October 2018[27].

Table 2-9. Air Quality Non-Attainment Areas as of 2018

County	NAAQS	Area Name	Classification
Jefferson	Lead (1979)	Jefferson County; Herculaneum	None listed
	Lead (2008)	Jefferson County	None listed
	Sulfur Dioxide	Jefferson County	None listed
St. Louis	8-Hour Ozone (2015)	St. Louis, MO/IL	Marginal
St. Louis City	8-Hour Ozone (2015)	St. Louis, MO/IL	Marginal

In response to these NAAQS, the State of Missouri Plan for Implementation, Maintenance and Enforcement of National Ambient Air Quality Standards was adopted in 2007[28]. In addition, the St. Louis Region has developed *Connected 2045,* which outlines the major objectives of the East-West Gateway Council of Governments transportation planning process to ensure projects and policies help reduce and minimize air quality impacts in accordance with federal, state and local air quality standards, regulations and priorities[29].

2.13.2 AIR QUALITY FUTURE WITHOUT PROJECT CONDITIONS

Air quality in the study area was assumed not likely to change from the existing conditions in the future.

2.14 CLIMATE

2.14.1 EXISTING CLIMATE

The Meramec River Basin has a humid continental climate marked by strong seasonality with cold winters and hot, humid summers, which is characteristic of the Midwestern United States. Winter months are usually dry with most precipitation falling in the spring, early summer and fall months. For the St. Louis Region, the average annual temperature is 56°F. Average annual precipitation is approximately 43 inches, with spring typically being the wettest season[30] (for additional climate information, see Appendix H-*Hydraulics and Hydrology Analysis*, for more details).

2.14.2 CLIMATE CHANGE

There is strong consensus in the literature (USACE, 2015) that air temperatures will increase in the study region and throughout this country over the next century. The studies reviewed here generally agree on an increase in mean annual air temperature of approximately 2 to 6°C (3.6 to 10.8 °F) 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.

---

[27] USEPA. Green Book. https://www3.epa.gov/airquality/greenbook/anayo_mo.html. Accessed 28 November 2018.

[28] MoDNR. 2007. http://dnr.mo.gov/env/apcp/docs/sip-naaqs110.pdf. Accessed on 05 February 2016.

[29] East-West Gateway. 2015. http://www.ewgateway.org/trans/longrgplan/2015/AQConformDoc-2015.pdf. Accessed 05 February 2016.

[30] National Weather Service Forecast Office St. Louis, MO. http://www.weather.gov/lsx/?n=cli_archive. Accessed 05 February 2016.

Increased air temperatures and increased frequencies of drought, particularly in the summer months, will result in increased water temperatures. This may lead to water quality concerns, particularly for the dissolved oxygen levels which are an important water quality parameter for aquatic life (USACE, 2015). Increased air temperatures are associated with the growth of nuisance algal blooms and influence wildlife and supporting food supplies.

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 (see Appendix H-*Hydraulics and Hydrology Analysis* for additional details). 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.

Increased mean annual precipitation in the region may pose complications to planning for ecosystem needs and lead to variation in flows. This may be particularly true during dry years when water demands for conflicting uses may outweigh water supply. During wet years, flooding may raise particular ecological concerns and may threaten ecosystems.

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, although analysis of past data indicates a small upward trend in annual peak streamflow.

Most tools used to evaluate climate change focus on the extremes – maximums and minimums. These tools are often used to evaluate evolving peak flood and drought risks. Because this project focuses on ecosystem, it hinges on means and medians not maximums and minimums. Extremes data is presented and discussed with the context of ecosystem restoration in mind. Data relating to means and medians is also presented and discussed. Features proposed for this project are bio-engineered and/or self-healing; therefore, modest changes in extreme flows would not pose a challenge to this project, nor would modest changes in median or mean flows.

3 PLAN FORMULATION

3.1 NEED FOR FEDERAL ACTION*

This study focuses on proposed management measures that would improve aquatic ecosystem resources within the study area, including the Big River and lower portions of the Meramec River. The USACE, St. Louis District Engineer will select an alternative for potential implementation and determine, based on the facts and recommendations contained in this report, whether this Environmental Assessment (EA) is adequate to support a Finding of No Significant Impact (FONSI) or whether an Environmental Impact Statement (EIS) will need to be prepared.

3.2 PLAN FORMULATION RATIONALE

The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, established by the U.S. Water Resources Council on March 10, 1983, was developed to guide the formulation and evaluation studies of major Federal water resources agencies. These principles and guidelines are commonly referred to as the "P&G," and will be cited throughout the plan formulation sections of this study. To appropriately capture benefits, costs were amortized and benefits averaged for each alternative over a 50-year time frame. While benefits are anticipated beyond the period of analysis a 50-year time frame was used since it captures the significant beneficial impacts and minimizes inaccuracies associated with long range forecasts.

3.3 PROBLEMS

Problem identification was compiled through a combination of methods including interagency rapid bio-assessment, analysis of existing reports, consultation with state agencies, Federal agencies, and other non-Governmental organizations (NGOs) familiar within the study area. The identified problems and opportunities guided the study's inventory of current forecast of conditions and the development of the study objectives.

3.3.1 CONCEPTUAL MODEL

A conceptual model was developed to illustrate the interactions amongst drivers (i.e., climate, geology, ecological disturbance and land use), primary stressors (i.e., excessive and contaminated sediment) and essential ecosystem characteristics (EECs). Five EECs were identified for this study: geomorphology, hydrology and hydraulics, biogeochemistry, habitat and biota (Lubinski & Barko, 2003). The primary ongoing stressors for the study are a system overburdened with sediment (both bedded and suspended) highly contaminated with lead, bank instability and lost riparian corridor. These stressors directly affect the EECs of geomorphology, hydrology and hydraulics, and biogeochemistry. The changes in EECs and hydraulics then impact habitat (i.e., cover, diversity and connectivity), and biota (e.g., fish, mussels, wildlife, floodplain forest, emergent wetland) within the study area. The conceptual model aided the identification of resource problems, opportunities and constraints, development of study objectives and potential measures (Figure 3-1).

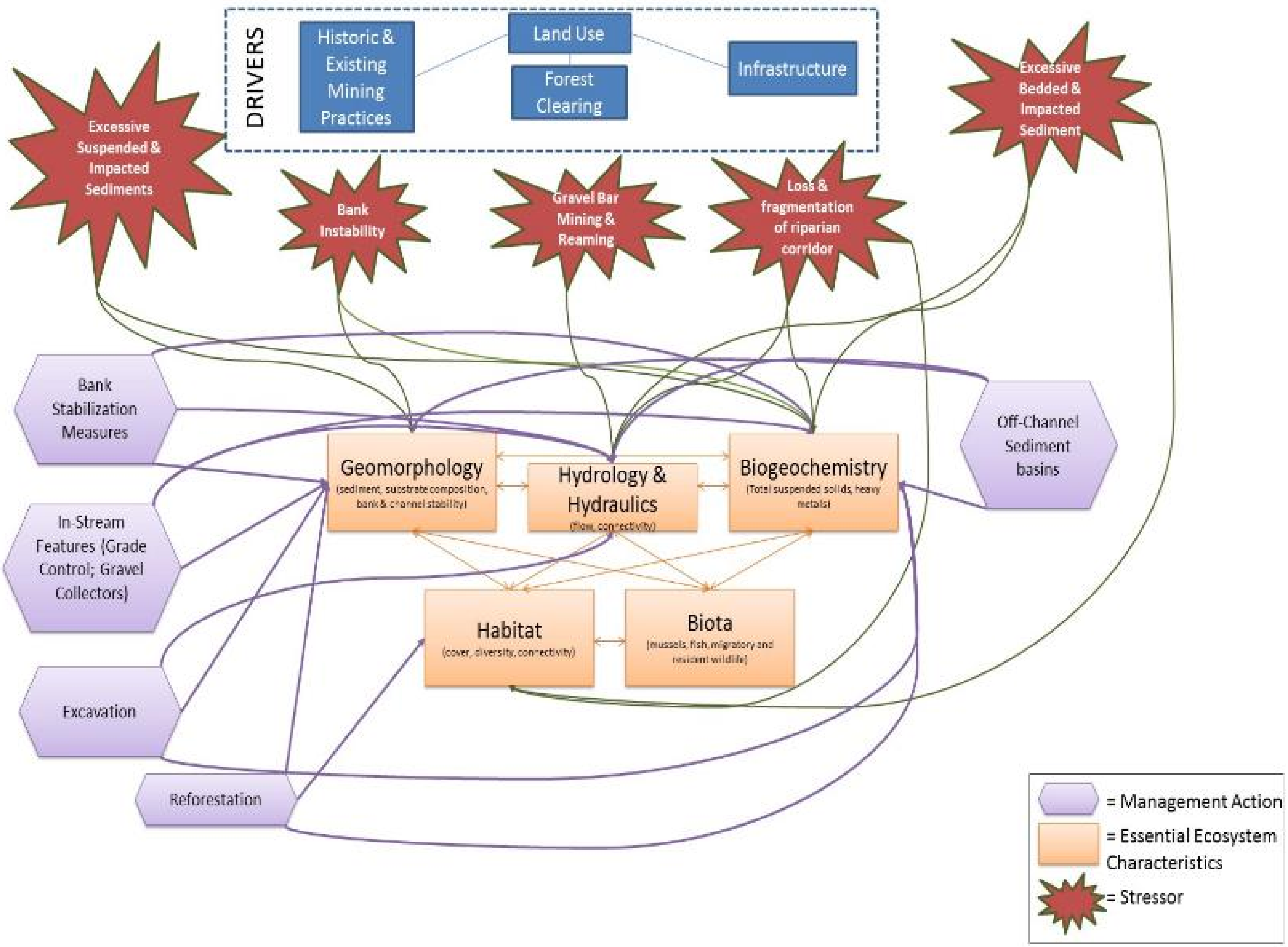


Figure 3-1. Conceptual Ecological Model

3.3.2 PROBLEM STATEMENT

Various land use changes, including historic lead mining efforts in the Big River and removal of riparian corridor, are responsible for modifying the geomorphic structure of the study area. These changes have led to an increase in soil erosion and long-term lead-laden sediment storage and movement. These processes have overburdened the system with sediment (both bedded and suspended) that is contaminated with lead which degrades aquatic ecosystem structure and function, specifically adversely affecting freshwater mussels. This restoration study will only address sediments that are contaminated with lead and other CERCLA regulated material below USEPA's remedial action levels as finalized in USEPA's ROD and/or a regulator-approved remediation response has occurred.

3.3.2.1 CONTAMINATED SEDIMENTS

Heavy metals such as lead, cadmium and zinc are present in sediments (suspended and bedded) at elevated levels. The metals concentrations exceed background levels within the Meramec River Basin, specifically within the Big River by orders of magnitude. The average concentrations in soils from St. Francois, Jefferson, and Washington Counties not impacted by industrial lead mining are predominantly less than 100 ppm (MoDNR 2013). The elevated heavy metal concentrations in the sediment are a result of industrial mining practices and are among the highest concentrations measured in rivers nationwide (Pavlowsky & Owen, 2013). Pavlowsky (2017) concludes from 1867 to 1972, mines discharged approximately 250 million tons of mine tailings waste in the Big River Watershed. Aquatic organisms, including freshwater mussels, crayfish and macroinvertebrates are particularly sensitive to heavy metal contamination and experience sub-lethal and lethal effects (Besser 2009, Allert et al. 2010). As contaminated sediments move downstream, the negative effects to remaining freshwater mussels and aquatic communities is expected to continue within the Big River, and eventually negatively affect the Meramec River and Mississippi River.

3.3.2.2 EXCESSIVE SUSPENDED AND BEDDED SEDIMENTS

Suspended and bedded sediments are naturally part of a healthy ecosystem and are required for an ecosystem to function properly; however, excessive amounts are considered the leading cause of impairment to rivers and streams nationwide (USEPA 2013) and result in impacts to stream function (e.g., destabilization of stream channels, degradation of spawning habitat, loss of species, respiration and feeding reduction). Suspended and bedded sediments originate from numerous sources within the study area and include mine waste inputs, streambank erosion, unpaved roads, livestock pastures and urban areas (TNC, 2014). These processes, coupled with the estimated 4,828,000 million cubic yards of contaminated channel sediment in the Big River (Pavlowsky, Owen, & Martin, 2010), upset the natural sediment budget in the study area. Influx and downstream transport of contaminated floodplain sediments during high water events is a particular concern within the Big River Watershed.

3.3.2.3 ALTERED HYDROLOGY & HYDRAULICS

Changes in water movement from the landscape to the stream channel have typically resulted in alteration of the natural flow regime, including the magnitude, frequency, duration, timing and rate of change in flow. Maintaining healthy riparian, floodplain, in-channel and off-channel habitats depend on this natural flow regime. Alterations to the natural flow regime can result in changes to stream hydraulics, geomorphology, physiochemical and biological processes. An example of altered hydrology and hydraulics within the Meramec River Basin by human-induced disturbances include intensification in water run-off (TNC 2014) from in-stream gravel mining and stream reaming (cutting the channel straight).

3.3.2.4 ALTERED RIPARIAN CORRIDOR

A riparian corridor, sometimes referred to as a "buffer", is the part of the floodplain closest to the stream and serves a variety of functions important to people and the environment as a whole. In general, intact riparian corridors help preserve water quality by filtering sediment from runoff before it enters rivers and streams, protect stream banks, provide a storage area for floodwaters, provide food and habitat for fish and wildlife, and preserve open space and surroundings. Within the Meramec River Basin, the riparian corridor has been altered by direct removal of vegetation from the streambank, narrowing of the riparian zone and conversion of deep rooted vegetation (e.g., trees) to shallow-rooted vegetation (e.g., fescue) (TNC, 2014). This alteration has destabilized the floodplain and the stream banks leading to degradation of the aquatic ecosystem.

3.3.2.5 DEGRADATION OF FRESHWATER MUSSEL HABITAT

The Meramec River Basin is home to a significant freshwater mussel community which is currently highly diverse and contains multiple Federally-listed species including Sheepnose, Spectaclecase, Snuffbox, Scaleshell and Pink Mucket. Since the Meramec River is nationally important to freshwater mussels, the need to protect this resource takes on national significance. Recent studies (Roberts, et al., 2010; Albers, Besser, Schmitt, & Wildhaber, 2016; Roberts, et al., 2016) compared freshwater mussels at Meramec and Bourbeuse River reference locations to Big River contaminated areas. These studies demonstrated that the Big River had greatly reduced freshwater mussel population metrics compared to the Bourbeuse and Meramec, which have similar threats except for lead mining. This comparison within the Meramec River Basin highlights the scale of impacts in the Big River and underscores the need to prioritize restoration projects related to mining impacts. Additionally, these studies not only demonstrate freshwater mussels are absent, less diverse and less abundant in locations downstream of mining impacts, but that the zone of decline continues to expand as lead contaminated sediment moves downstream (Zachritz 1978; Buchanan 1979; Gale et al. 1973; Schmitt and Finger 1987; Gale and Wixson 1986; Meneau 1997; Gale et al. 2002; MoDNR 2003; Besser et al. 2007; Mosby et al. 2008; Albers et al. 2016, Roberts 2016). Freshwater mussels are considered good indicators of ecological health and integrity. Their decline within the Meramec River Basin, and particularly within the Big River, represents both a current threat and future potential threat to the overall health and sustainability of the aquatic ecosystem of the Meramec River Basin.

3.3.2.6 ADDITIONAL PROBLEMS AND STRESSORS

Additional problems and stressors within the Meramec River Basin exist but will not be addressed within this USACE feasibility study. Potential problems not addressed include aquatic connectivity, chemical pollution, invasive species, nutrient pollution, organic pollution and other effects of urbanization, industry, farming, timber and ranching practices. These problems were briefly evaluated by the USACE and determined not to be the most significant problems affecting the study area. Initially, lack of connectivity was thought to be a factor affecting the aquatic community, but upon review of existing data (Mills et al. 1978), no statistically significant variation between fish assemblage or abundance above and below the mill dams was observed. Invasive species is a concern throughout the Nation, with several species known to occur within the study area, but existing information and visual observation shows invasive species are not a significant problem affecting the study area. MDC (1998) identified that overall water quality within the Meramec River Basin is considered quite good so was not evaluated further as a standalone problem in the study area.

3.4 OPPORTUNITIES

Opportunities are positive conditions in the study area that may result from implementation of a Federal project such as:

- Produce a more natural flow regime, with a more balanced sediment budget, in the Meramec River Basin.
- Increase the habitat for migratory birds in the Mississippi River by restoring the riparian corridor in the Meramec River Basin.
- Increase the population of highly diverse freshwater mussel communities consisting of multiple Federally-listed species including Sheepnose, Spectaclecase, Snuffbox, Scaleshell and Pink Mucket in the Meramec River Basin by reducing the influx of bedded and suspended sediment.
- Facilitate, to the greatest extent possible, other Federal and State agencies attaining their goals in the Meramec River Basin.
- Consideration of the alternatives' ability to provide incidental flood risk reduction benefits.
- Public outreach to increase public awareness of environmental issues within the Meramec River Basin.
- Consideration of the alternatives' ability to enhance recreational opportunities.

These opportunities may be realized by implementing a single management measure or a combination of management measures. Management measures, such as tree plantings, include additional opportunities to reduce flooding effects downstream by slowing down overland flow as well as enhance recreation aesthetics.

3.5 PLANNING CONSTRAINTS AND CONSIDERATIONS

A constraint limits the extent of the planning process. It is a statement of considerations that the alternative plans should avoid or minimize impacts. The criteria below were considered as constraints when formulating management measures:

- Study measures will not increase the distribution or migration rate of contaminated sediment by not finalizing site selection until USEPA issues a ROD.
- Avoid features that are not compatible with other restoration or remediation efforts.
- Avoid features that could permanently affect the function of surrounding infrastructure.
- Avoid features that could increase flood elevations or potential flood damages.
- Avoid features that would impact recreation along the river.
- Avoid and minimize features that would impact cultural and historic resources.
- Recreation designs on public property should avoid inadvertent access to private property.

3.6 NATIONAL OBJECTIVE

The USACE national objective for ecosystem restoration in response to legislation and administration policy is to contribute to the Nation's ecosystems by restoring degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition. Contributions to National Ecosystem Restoration (NER) are increases in ecosystem value and productivity and are measured in nonmonetary units. The NER Plan is the plan that reasonably maximizes ecosystem benefits relative to costs.

3.7 STUDY GOAL AND OBJECTIVES

The overarching goal of this study is to formulate an alternative for ecosystem restoration and determine if Federal participation in restoring habitat functionality within the study area is justified. Specific study objectives were to determine whether individual management measures are capable of solving the study area's problems while taking advantage of the opportunities identified and avoiding the constraints. The following study objectives were developed based on the study area problems, opportunities, and goals, as well as the Federal objective and regulations.

A fundamental component of meeting this goal is to reestablish, in measurable terms, the dynamic balance between the physical, chemical, and biological habitat components that formerly existed in the watershed. The objectives proposed to achieve this goal are described in Sections 3.7.1 through 3.7.3.

3.7.1 OBJECTIVE 1: REDUCE THE DOWNSTREAM MIGRATION OF EXCESS MINING DERIVED SEDIMENT FROM THE BIG RIVER IN ORDER TO PROTECT AND RESTORE DEGRADED AQUATIC AND FRESHWATER MUSSEL HABITAT OVER THE 50-YEAR PERIOD OF ANALYSIS

The primary ongoing stressor for the study is a system overburdened with sediment (both bedded and suspended) that is contaminated with lead from historic mining activities. Conditions show that the negative impacts to the habitat are correlated to the downstream movement of this sediment. Reduction of contaminated bedded and suspended sediment provides the opportunity to restore the aquatic complexity and diversity needed to support stable freshwater mussel, fish, and aquatic communities, including Federally-listed freshwater mussel species.

3.7.2 OBJECTIVE 2: RESTORE IMPACTED CHANNELS AND FLOODPLAINS IN THE BIG RIVER AND MERAMEC RIVER SYSTEMS TO MIMIC A MORE NATURAL, STABLE RIVER OVER THE 50-YEAR PERIOD OF ANALYSIS

Areas susceptible to bank erosion within the Big River are a significant source of sediment entering the system which are high in heavy metals (Pavlowsky & Owen, 2013). Targeting management measures at these locations provides an opportunity to stabilize the system and reduce the influx of sediments entering the river channel.

3.7.3 OBJECTIVE 3: INCREASE RIPARIAN HABITAT CONNECTIVITY, QUANTITY, DIVERSITY, AND COMPLEXITY WITHIN THE STUDY AREA OVER THE 50-YEAR PERIOD OF ANALYSIS

The riparian habitat within the study area support a variety of species once widespread throughout the Meramec River Basin; however, due to land use practice changes this habitat has been altered reducing its ability to provide the ecosystem functions. Restoring the riparian corridor within the study area will return much of these functions and reduce contaminated sediment entering into the rivers.

3.8 ENVIRONMENTAL OPERATING PRINCIPLES

Consistent with the National Environmental Policy Act (NEPA), USACE formalized its commitment to the environment by creating a set of "Environmental Operating Principles" applicable to all its decision making and programs (Box 3-1). These principles ensure environmental conservation and restoration are considered in all USACE activities.

Box 3-1. The USACE Environmental Operating Principles

1. Foster sustainability as a way of life throughout the organization.
2. Proactively consider environmental consequences of all Corps activities and act accordingly.
3. Create mutually supporting economic and environmentally sustainable solutions.
4. Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments.
5. Consider the environment in employing a risk management and systems approach throughout life cycles of projects and programs.
6. Leverage scientific, economic and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner.
7. Employ an open, transparent process that respects views of individuals and groups interested in Corps activities.

3.9 MANAGEMENT MEASURES

A management measure is a feature or activity that can be implemented at a specific geographic site to address one or more planning objectives. The USACE planning team, non-Federal sponsor and study partners participated in the study "*Scoping Charette*", *on* 20-22 January 2016, to brainstorm a list of management measures. Several times throughout the formulation process the list of management measures was refined. As an example, later in the formulation process bedload sediment collector was added since it's a fairly new technology.

1. Best management practices (BMP) – Best management practices are non-structural strategies to prevent or minimize the harmful effects of human-related activities on riparian resources, functions and values. This measure is considered non-structural.

2. Reforestation (Photo 3-1) – Planting of native vegetation for complexity and biodiversity along the riparian corridor. This measure is considered non-structural and is based in nature.

3. Gabion baskets (Photo 3-2) – Structural rectangular galvanized wire baskets filled with stones used as pervious, semi-flexible building blocks for slope and channel stabilization. Live rooting branches may be placed between the rock-filled baskets. Minimal disposal will be required since most material will be used on site. Disposal material will be hauled to an appropriate disposal site.

Photo 3-2. Reforestation (Rock Island District)

Photo 3-1. Gabion Baskets (Albuquerque District)

4. Rock riprap along surface (Photo 3-3) – Structural method of placing revetment along bankline. Minimal disposal required since most material will be used on site. Disposal material will be hauled to an appropriate disposal site.
5. Bendway weirs (Photo 3-4) – Structural method of sub-water surface stone structures used to re-direct the channel alignment and reduce the river's width to depth ratio.

Photo 3-3. Riprap (Nashville District)

Photo 3-4. Bendway Weirs (USEPA)

6. Longitudinal peak stone toe protection (LPSTP) (Photo 3-5) – Structural method of placing stone in a row along the toe of an eroding bank. It is used in situations where bank erosion is due to mass wasting from the toe of the bank. This measure is usually used in conjunction with "Reshape Bank" creating a stable and protected bank line. Minimal disposal will be required since most material will be used on site. Disposal material will be hauled to an appropriate disposal site.

Photo 3-3. LPSTP (ERDC)

7. Concrete channelization (Photo 3-6) – Structural method constructing a concrete trapezoid of the existing channel.
8. Reshape bank (Photo 3-7) – Non-structural method that removes soil to reduce the slope of very steep banks to a more stable angle. Minimal disposal will be required since most material will be used on site.

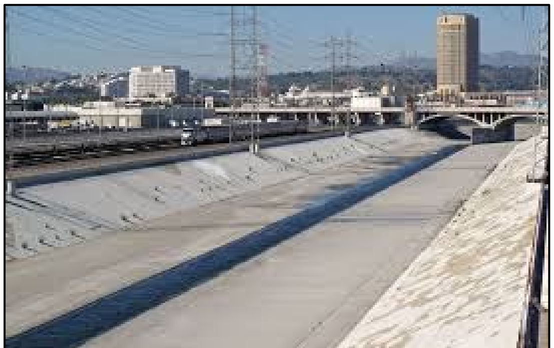


Photo 3-6. Concrete Channelization (LA District)

Photo 3-7. Reshape Bank (New England District)

9. Bioengineering
   a. Root wad revetment (Photo 3-8) – A nature based structural technique where the roots of large trees are used to protect the toes of an eroding stream bank. Minimal disposal will be required since most material will be used on site. Disposal material will be hauled to an appropriate disposal site.
   b. Live plantings (Photo 3-9) – A nature based structural method that consists of planting vegetation such as willows and poplars.
   c. Tree revetment (Photo 3-10) – A nature based structural technique where trees with all of their branches are placed parallel to the bankline and anchored using steel cables. Disposal material will be hauled to an appropriate disposal site.

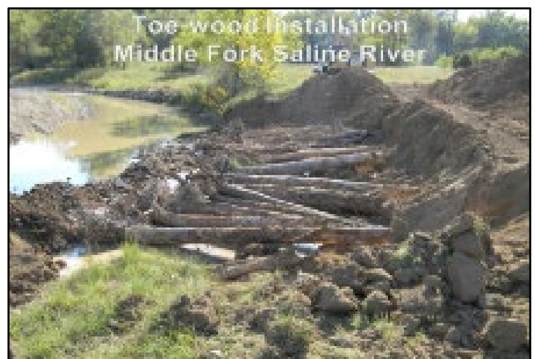


Photo 3-4. Root wad revetment (TNC)

Photo 3-9. Live Plantings (Rock Island District)

Photo 3-10. Tree Revetment (USEPA)

10. Stream barbs (Photo 3-11) – A structural method with stone structures that extend from the bank at a sharp upstream direction. Stream barbs protect the bank by re-directing flow away from the bank.
11. Rock ramp (Photo 3-12) – Type of structural method that provides a more stable grade at mill dams.

Photo 3-11. Stream Barbs (Rock Island District)

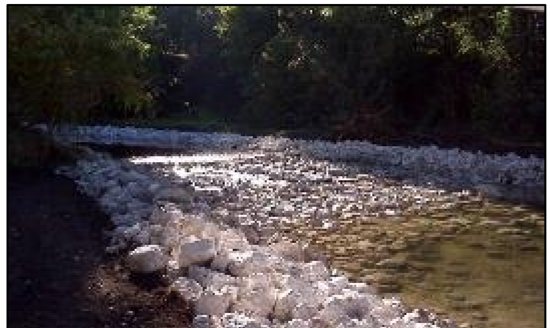


Photo 3-12. Rock Ramp (Rock Island District)

12. Removal of low head dams (Photo 3-13) – Natural method that removes existing infrastructure.
13. Grade control structure (Photo 3-14) – Type of structural method mainly used to stabilize the bed of the river.

Photo 3-13. Dam Removal (Nashville District)

Photo 3-14. Grade Control Structure (St. Louis District)

14. Sediment basins (Photo 3-15) – Structural method where flow from the main river channel is diverted to a large area where flow velocity will decrease and sediment is allowed to deposit. Disposal material will be hauled to an appropriate disposal site.
15. Construct new low head dam (Photo 3-16) – Structural method using concrete structure spanning the width of the river and tied into the adjacent banks.

Photo 3-15. Sediment Basin (St. Louis District)

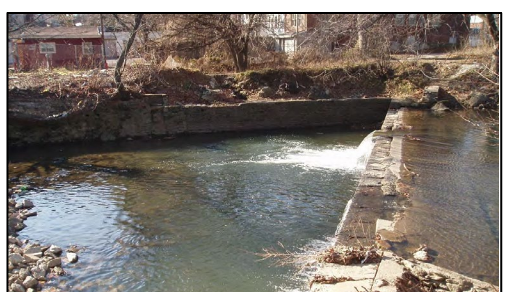


Photo 3-16. Low Head Dam (Pittsburgh District)

16. Excavation (Photo 3-17) – Structural using mechanical dredging either in-stream and/or at mill dam sites to remove sediment. Disposal material will be hauled to an appropriate disposal site.
17. Bedload sediment collector (Photo 3-18) – Structural method using a steel bin that is placed on the bottom of the river and is attached to a pump that redirects and collects bed load. Disposal material will be hauled to an appropriate disposal site.

Photo 3-17. Excavation (St. Louis District)

Photo 3-18. Bedload Sediment Collector (ERDC)

18. Conservation easements – Non-structural and natural method utilizing a legal agreement between a landowner and government agency that limits uses of land in order to protect its environmental value.

3.9.1 SCREENING OF MANAGEMENT MEASURES

Screening criteria was developed based on the planning objectives, constraints, opportunities and problems of the study area (Table 3-1). Management measures were screened and eliminated throughout the plan formulation process based on these criteria and the criteria described in the Principles and Guidelines (P&G) as shown in Box 3-2.

Box 3-2. Principles and Guidelines Criteria

Completeness: Extent to which the measure provides and accounts for all necessary investments or actions to ensure realization of the planning objectives.

Effectiveness: Extent to which the measure contributes to achieving the planning objectives.

Efficiency: Extent to which the measure is the most cost-effective means of addressing the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment.

Acceptability: Workability and viability of the alternative plan with respect to acceptance by Federal and non-Federal entities and the public, and compatibility with existing laws, regulations and public policies.

Table 3-1. Management Measure Screening Criteria

OBJECTIVES	MANAGEMENT MEASURE	RETAINED FOR EVALUATION	SCREENING CRITERIA/DESIGN CONSIDERATIONS
Riparian Corridor	Reforestation	Yes	Meets all criteria, retained
	BMPs	No	Recommended as Non-Federal Sponsor activity
Emulate a Natural and Stable River	Gabion baskets	No	High cost (not efficient due to higher costs than other measures) and not environmentally acceptable
	Rock riprap along surface (revetment)	No	High cost (not efficient due to higher costs than other measures
	Bendway weirs	Yes	Meets all criteria, retained
	Stream Barbs	Yes	Meets all criteria, retained
	Longitudinal peak stone toe protection (LPTSP)	Yes	Meets all criteria, retained
	Concrete channelization	No	High cost (not efficient due to higher costs than other measures) and environmentally unacceptable
	Reshape bank	Yes	Meets all criteria, retained
	Root wad revetment	Yes	Meets all criteria, retained
	Live plantings	Yes	Meets all criteria, retained
	Tree revetment	Yes	Meets all criteria, retained
Reduce Sediment	Sediment basin	Yes	Meets all criteria, retained
	Install new low head dam	No	High cost (not efficient due to higher costs than other measures) and environmentally unacceptable
	In-stream excavation	Yes	Meets all criteria, retained
	Grade control structure	Yes	Retained for bed stability
	Side channel with sediment trap	No	Similar to sediment basin
	Bed sediment collector	Yes	Meets all criteria, retained
	Conservation easements	No	Recommended as Non-Federal Sponsor activity

3.9.2 FORMULATION STRATEGIES

To narrow the focus of all possible combinations of the remaining management measures, formulation strategies were developed to create alternatives. The formulation strategies combine the management measure(s) together into alternatives based on the study goal, objectives, planning criteria and opportunies while avoiding constraints. Three main themes were used to formulate the initial array of alternatives:

1) *Geographic Area:* Because of the relatively large nature of the study area, alternatives were developed based on restoring the Meramec River, Big River or both.
2) *Level of Restoration Effort*: Additionally alternatives were developed based on various levels of restoration, identifying both the largest ecosystem restoration alternative possible (maximum) as well as alternatives that were designated as "efficient" meaning they could minimize redundant effort and/or expense.
3) *Meeting Study Objectives: A*lternatives were formulated to meet the specific study objectives described in Section 3.7.

3.9.3 INITIAL ARRAY OF ALTERNATIVES

No Action Plan - The National Environmental Policy Act (NEPA) requires Federal agencies to consider the option of no action as one of the alternatives. The No Action Plan assumed no action is taken by the USACE to achieve the planning objectives, and is synonymous with the future without project (FWOP) condition. The No Action Plan forms the basis against which all other alternative plans are measured.

Maximize Efficiency in the Big River - This alternative maximizes efficiency by selecting cost effective restoration solutions only along the Big River. Criteria used include: management measures must be combinable to reduce real estate and mobilization costs, construction access, willing landowner potential, riparian reforestation areas greater than 5 acres (large enough area to warrant mobilization) and bank stabilization areas that contributed greater than the estimated median annual total suspended solids (TSS) reduction.

Maximize Ecosystem Benefits in the Big River - This alternative combines all the possible restoration sites along the Big River only. Criteria used include: management measures must yield high ecosystem benefits, potential to have other secondary environmental benefits such as cover and in-stream complexity, and minimizes trade-offs between the potential losses and gains to the environment.

Maximize Ecosystem Benefits in the Meramec River - This alternative combines all the possible restoration sites along the Meramec River only. Criteria used include: management measures must yield high ecosystem benefits, potential to have other secondary environmental benefits such as cover and in-stream complexity, and minimizes trade-offs between the potential losses and gains to the environment.

Maximize Efficiency in the Meramec River - This alternative maximizes efficiency by selecting cost effective solutions along the Meramec River only. Criteria used include: management measures must be combinable to reduce real estate and mobilization costs, construction access, willing landowner potential, riparian reforestation areas greater than 5 acres (large enough area to warrant mobilization) and bank stabilization areas that contributed greater than the estimated median annual TSS reduction.

Minimize Impacts to Other Social Effects - This alternative achieves ecosystem restoration objectives along the Big River while minimizing the impact to stakeholders. Based on input from various public engagements, the general public does not want to see aesthetic/recreational changes to the study area; only management measures that would not impact the existing recreation, adjacent land users or aesthetics were included. Criteria used include: management measures must minimize impacts on other social effects, be combinable with other measures to reduce construction footprint, construction access and require minimal additions or changes to existing infrastructure.

Maximize Ecosystem Benefits in the Study Area - This alternative combines all the possible restoration sites within the study area using management measures that provide the highest ecosystem benefit. Criteria used include: management measures must yield high ecosystem benefits, potential to have other secondary environmental benefits such as cover and in-stream complexity and minimizes trade-offs between the potential losses and gains to the environment.

Maximize Bank Stabilization in the Study Area - This alternative combines all the possible ecosystem restoration sites within the study to optimize bank stabilization. Criteria used include: management measures must maximize bank stabilization benefits, yield high ecosystem benefits and potential to be cost effective.

Maximize Sediment Capture in the Big River - This alternative combined all the possible restoration sites to optimize sediment capture in the Big River. Criteria used include: management measures must maximize sediment capture, yield high ecosystem benefits, construction access, and willing landowner potential.

Sponsor Preferred - This alternative included the restoration sites and preferred managements which addressed the mission and goals of the sponsor (MoDNR). This alternative had the potential to become a locally preferred plan (LPP) at the recommended plan selection. A locally preferred plan is a variance from the National Ecosystem Restoration plan. Authorization to pursue an LPP is given by the Secretary of the Army.

3.10 SITE IDENTIFICATION

Site selection was completed through a combination of methods including interagency field assessments, aerial imagery analysis, topography, channel change analysis, existing infrastructure, and consultation with state agencies, Federal agencies and other non-Governmental organizations (NGOs) familiar within the study area (Table 3-2).

Table 3-2. Initial Site Identification with Existing and Future Without Project Description

RM	Existing Condition Site Description	Future Without Project Site Description
Big River		
74.8	River transports sediment through this point to be deposited downstream.	River will continue to transports sediment through this point to be deposited downstream.
74.5	River tends to deposit substantial sediment onto massive sediment aggregation area.	River will continue to deposit substantial sediment onto massive sediment aggregation area.
71.3	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit substantial sediment onto sediment aggregation area.
67.9	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit substantial sediment onto large sediment aggregation area.
67.9	River transports sediment through this reach to be deposited downstream.	River will continue to transports sediment through this point to be deposited downstream.
66.2	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit substantial sediment onto sediment aggregation area
63.5	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit substantial sediment onto sediment aggregation area
62.5	River tends to deposit some sediment onto sediment aggregation area. Bar is used for recreational purposes by park patrons.	River will continue to deposit some sediment onto large sediment aggregation area. Bar will continue to be used for recreational purposes by park patrons.
62.5	Medium-length high-height unvegetated bank is being eroded.	River will continue to erode into bank until river corrects itself in an unpredictable way at an unpredictable time.
62.5	Site is a field.	Site will presumably remain as a field.
61.5	River transports sediment through this reach to be deposited downstream.	River will continue to transport sediment through this reach to be deposited downstream.
61L	Medium-length medium-height moderately-vegetated bank is being eroded towards a bluff face.	River will continue to slowly erode the bank, but bluff will stop significant future erosion. Once bluff stops erosion, river may seek other nearby banks to erode in search of dynamic equilibrium.
61R	Medium-length medium-height moderate-to-sparsely-vegetated bank is being eroded.	River will continue to erode into bank until river corrects itself in an unpredictable way at an unpredictable time. Erosion at this site will be aggravated by sediment inputs from Mineral Fork tributary.
59.8	Medium-length medium-height moderate-to-sparsely-vegetated bank is being eroded.	River will continue to erode into bank until river corrects itself in an unpredictable way at an unpredictable time. Hydraulic changes associated with further erosion at this site may impair the function of EPA's sediment capture project, which is across the river from the eroding bank.

RM	Existing Condition Site Description	Future Without Project Site Description
59.2	Long-length low-height moderately-vegetated bank is being eroded.	River will continue to erode into bank until the river corrects itself in an unpredictable way at an unpredictable time.
57.7	River tends to deposit substantial sediment onto large sediment aggregation area.	River will continue to deposit substantial sediment onto large sediment aggregation area.
56.8	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
55.6	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
55.1	River transports sediment through this reach to be deposited downstream.	River will continue to transports sediment through this reach to be deposited downstream.
54.8	Medium-length high-height well-vegetated bank is being eroded towards a bluff face.	River will continue to slowly erode the bank, but bluff will stop significant future erosion. Once bluff stops erosion, river may seek other nearby banks to erode in search of dynamic equilibrium. Woody vegetation inputted by this process poses a threat to bridge piers <1 mile downstream.
54	Sediment aggregation area deposit, which is pushing water into bank, may be due to hydraulic effects of bridge <200 feet downstream.	River will likely continue to erode the bank. Eroded bank geometry directs redirects flow towards bridge piers. Woody vegetation inputted by this erosion poses a threat to bridge ~200 feet downstream.
52.5	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
52	Very long-length, high-height, variably-vegetated banks are being aggressively eroded. Landowner battled erosion with riparian plantings a decade ago, but is now actively seeking outside help and resources.	River will continue to aggressively erode the bank, cutting off the sole access road to a 30+ acre segment of land.
49.8	Long-length low-height moderately-vegetated banks are being eroded.	River will continue to erode into banks until river corrects itself in an unpredictable way at an unpredictable time.
49.3	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
49	Little to no riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
48.5	Medium-length medium-height unvegetated bank is being slowly eroded. Eroded bank is on inside of bend (left side), likely due to campground on opposing bank/bar, which pushes river in an un-natural way.	Uncertain due to unusual conditions. Inside (left) bank will likely continue to slowly erode.
47	Little riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
46	Little riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
45	Little riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.

RM	Existing Condition Site Description	Future Without Project Site Description
44.5	Short-length medium-height sparsely-vegetated bank is being eroded. This is presumably because of sediment load from Ditch Creek, which inputs at the upstream edge of the bank instability location.	Sediment load from Ditch Creek will likely continue to push river and erode bank.
42.5	Long-length, high-height, unvegetated bank is being aggressively eroded.	River will continue to erode into banks until river corrects itself in an unpredictable way at an unpredictable time. Meander bend will probably form a cutoff.
39	Little to no riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
38	Medium-length, medium-height, well-vegetated bank is eroding into a weak spot in the young vegetation.	River will continue to erode into weak spot. Young vegetation likely will not be able to stop the erosion that's occurring, and the erosion may break through the planted riparian strip.
38	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
38	Site is an in-stream sediment aggregation area.	In-stream sediment aggregation area will likely remain and may grow in size.
36.7	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
34.9	Enormous-length, high-height, variably-vegetated bank is slowly eroding. Area recently experienced a meander bend cutoff and may still be out of dynamic equilibrium.	River will continue to slowly erode into banks. Another near-term major correction is unlikely.
34	Long-length, high-height, well-vegetated bank is eroding. Bank is too tall and vertical for relatively young vegetation to resist erosion.	River will continue to slowly erode into banks. Another near-term major correction is unlikely.
33.9	River tends to deposit substantial sediment onto large sediment aggregation area.	River will continue to deposit substantial sediment onto large sediment aggregation area.
33.2	Short-length, medium-height, sparsely-vegetated bank is mostly exposed and slowly eroding.	Bank will continue to slowly erode. Since bank is not formally stabilized, this site has potential for major erosion in the future.
32.2	Enormous-length, high-height, variably-vegetated banks are eroding at variable rates. This stretch is very unstable, and has some localized revetment in place from landowners. This revetment has limited effectiveness (and perhaps exasperates the problem) when not applied programmatically.	Nearly 1 mile of river will remain unstable. Landowners will likely continue to apply localized "band-aid" solutions, ineffectively pushing the river around for a very long time. Where localized solutions are not applied, the river will likely continue to aggressively pursue dynamic equilibrium.

RM	Existing Condition Site Description	Future Without Project Site Description
31	Long-length, variable-height, variably-vegetated bank is moderately eroding. Area recently experienced the effects of gravel mining. This stretch is very disturbed.	River will continue to significantly erode. Landowners may apply localized "band-aid" solutions, ineffectively pushing the river around for a very long time. Where localized solutions are not applied, the river will likely continue to pursue dynamic equilibrium.
31	Current use unknown. Gravel from part of this site appears to have been harvested in the past.	Site will remain as is, or may be harvested further. Sediment will continue to deposit in this vicinity, as predicted by the HEC-RAS model.
30.2	Morse Mill dam is highly deteriorated, and pools <12 inches of water. The remnant structure that has constant flow acts as a grade control structure. The remaining portion of the dam restricts flow, especially during floods that remain within the river banks. The deterioration of this structure has likely contributed to vertical and/or lateral instability problems upstream.	Morse Mill dam will continue to deteriorate and pool may lessen to <6 inches. Further deterioration of the dam could cause further instability in the bed and banks upstream, if not arrested with supplemental grade control structures.
30.2	River transports sediment through this reach to be deposited downstream.	River will continue to transports sediment through this reach to be deposited downstream.
30.2	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
25.5	Site is a field.	Site will likely remain a field.
22	Short-length, moderate-height, unvegetated bank. Channel split likely caused by river flanking a historic grade control structure.	River will continue to slowly erode bank. Erosion may unexpectedly accelerate if bank remains unvegetated.
21	Little to no riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
19.6	River transports sediment through this reach to be deposited downstream.	River transports sediment through this reach to be deposited downstream.
19.5	River tends to deposit some sediment onto sediment aggregation area.	River tends to deposit some sediment onto sediment aggregation area.
19.5	Cedar Hill Mill dam is highly deteriorated, and pools <18 inches of water. The remnant structure that has constant flow acts as a grade control structure. The remaining portion of the dam restricts flow, especially during floods that remain within the river banks. The deterioration of this structure has likely contributed to vertical and/or lateral instability problems upstream.	Cedar Hill Mill dam will continue to deteriorate and pool may lessen to <6 inches. Further deterioration of the dam could cause further instability in the bed and banks upstream, if not arrested with supplemental grade control structures.
18.6	Large lake, previously dredged for commercial purposes.	Large lake, will slowly fill with sediment.
18	Short-length, medium-height, well-vegetated bank is being slowly eroded.	Bank will continue to slowly erode.
14.5	Tiny-length, medium-height, well-vegetated bank has been quickly eroded.	Bank will continue to erode and may begin to endanger nearby homes by redirecting river flow into banks near their homes.
14.5	Site functions as a dirt farm, which is naturally filled by sediment during high water.	Site will likely continue to function as a dirt farm.

RM	Existing Condition Site Description	Future Without Project Site Description
14.5	River tends to deposit some sediment onto sediment aggregation area.	River will continue to deposit some sediment onto sediment aggregation area.
14	Little to no riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
13.5	Long-length, medium-height, variably-vegetated bank has been slowly eroded.	Bank will continue to slowly erode.
10.2	River tends to deposit some sediment onto sediment aggregation area.	EPA project to stabilize dam structure may affect sediment deposition trends onto sediment aggregation area.
9.2	Site functions as a dirt farm, which is naturally filled by sediment during high water.	Site will likely continue to function as a dirt farm.
9.2	Long-length, high-height, unvegetated bank aggressively eroding.	Bank will continue to erode, and multiple cutoffs will likely form within the next few decades.
8.5	Byrnes Mill dam has deteriorated, and pools <18 inches of water. The remnant structure that has constant flow acts as a grade control structure. The remaining portion of the dam restricts flow, especially during floods that remain within the river banks. The deterioration of this structure has likely contributed to vertical and/or lateral instability problems upstream.	Morse Mill dam will continue to deteriorate and pool may lessen to <6 inches. Further deterioration of the dam could cause further instability in the bed and banks upstream, if not arrested with supplemental grade control structures.
8	Little to no riparian corridor exists here.	Future condition likely will not improve. Areas with insubstantial riparian corridor are at high risk of lateral bank instability.
5	Long-length, high-height, variably-vegetated bank slowly eroding.	Bank will continue to slowly erode.
2.5	Long-length, medium-height, unvegetated bank is very slowly eroding.	Bank will continue to very slowly erode.
Meramec River		
45	Long-length, high-height, variably-vegetated bank aggressively eroding.	Bank will continue to aggressively erode and may form one or more cutoffs.
41.5	Short-length, high-height, variably-vegetated bank aggressively eroding.	Unvegetated bank may continue to erode
38.3	Medium-length, high-height, unvegetated bank is being eroded.	Bank will continue to erode.
33.3	Short-length, high-height, variably-vegetated bank is being eroded. Erosion threatens rail infrastructure.	Bank will continue to erode. Private interests may protect
33	Medium-length, high-height, variably-vegetated bank is being eroded.	Bank will continue to erode.
18.5	Short-length, high-height, unvegetated bank is being eroded into a park.	Bank will continue to erode. Private interests may be protect

Once a site was identified as a possible restoration site, formulation strategy criteria discussed in Section 3.9.2 were used to determine which sites were added to an alternative (Table 3-3).

Table 3-3. Initial Array of Alternative – Number of Restoration Sites and Types of Management Measures Included

Alternative	Total Sites (#)	Bank Stabilization (LPSTP, Weir, Barb, Root wad, Live Plantings)	Sediment Basins	Grade Control Structures	In-stream Excavation	Bed Sediment Collector	Reforestation
No Action	0	0	0	0	0	0	0
Maximize Efficiency in the Big River	30	12	6	2	0	0	10
Maximize Ecosystem Benefits in the Big River	50	26	10	3	3	0	8
Maximizes Ecosystem Benefits in the Meramec River	6	6	0	0	0	0	0
Maximize Efficiency in the Meramec River	4	4	0	0	0	0	0
Minimize Impacts to Other Social Effects	29	10	6	0	3	0	10
Maximizes Ecosystem Benefits in the Study Area	56	32	10	3	3	0	8
Maximize Bank Stabilization in the Study Area	32	32	0	0	0	0	0
Maximize Sediment Capture in the Big River	10	0	10	0	0	0	0
Sponsor Preferred	50	26	4	3	9	0	8

3.11 INITIAL ARRAY OF ALTERNATIVE EVALUATION

The initial array of alternatives was based on completeness, effectiveness, efficiency, and acceptability (Table 3-4). A qualitative score of “high” signifies the metric was met considerably, a score of “medium” denotes the metric was met moderately, and a score of “low” indicates the metric was minimally met, if at all.

The metrics are described below for each of the four screenings. A qualitative metric was given a quantitative score for tallying. If the metric was high it was given a 3, medium a 2, and low a 1. For every alternative, the metric was averaged per screening criteria to weigh each criterion equally. Table 3-4 provides the ranking for each alternative based on the totals.

Effectiveness: In order to measure the effectiveness of each alternative metric were created for each of the project objectives:

> Sediment Capture Objective Metrics – This metric provides how well each alternative reduces the migration of sediment. It was assumed these measures could be designed to capture the equal amounts of sediment as well as require the same periodic Operation and Maintenance (OM) for removal.
>
> Sediment Reduction Objective Metrics - This metric provides how well each alternative reduces the quantity of sediment entering the streams. It was assumed all bioengineering and traditional structure measures could be designed to reduce equal amounts of sediment.
>
> Riparian Habitat Objective Metrics - This metric provides how well each alternative improves the riparian vegetation complexity and biodiversity. It was assumed these plantings will provide a diversity of tree species.

Efficiency: The efficiency metric used to compare the initial array included whether real estate, construction, and operation, maintenance, repair, replacement & rehabilitation (OMRRR) costs are anticipated to be high in comparison to the predicted benefits.

Acceptability: The acceptability metric used to compare the initial array was the viability of the alternative with respect to existing laws, regulations, and public policies. In order to measure the acceptability of each alternative, the metrics described below were created.

> USACE Policy Compliant – This metric evaluated the magnitude of potential policy concerns for each alternative. This metric assumed there are areas located in the Meramec River below the HTRW-threshold contamination levels.
>
> Complements the larger federal, state and local objectives - This metric provided how well each alternative complemented other state and federal agency efforts.
>
> Acceptable to stakeholders - This metric provided how well each alternative was accepted by various stakeholders and interest groups. This metric assumed the stakeholders that attended public meetings were representative of the larger public.

Completeness: Alternatives were evaluated for future potential USEPA investments, state investments, non-governmental investments, and land use changes to determine if these activities were necessary to or would prohibit achievement of this study's planning objectives. A determination was made that no additional investments were needed to obtain benefits so all alternatives are considered "complete".

Table 3-4. Evaluation of Initial Array of Alternatives

Alternative	EFFECTIVENESS			EFFICIENCY	ACCEPTABLE			COMPLETE	SCORE
	Reduces migration sediment	Increase Natural Channel	Increases riparian habitat	Minimizes cost relative to benefit	Minimizes USACE policy concern	Acceptable to State, local entities	Acceptable to community	All items considered	Equal weight per criteria
No Action	Low	Low	Low	Low	High	Low	Medium	High	13
Maximizes Efficiency in Big River	Medium	Medium	Medium	High	Medium	High	High	High	20
Maximizes Ecosystem Benefits in Big River	High	High	High	Medium	Medium	High	Medium	High	21
Maximizes Ecosystem Benefits in Meramec River	Medium	Medium	Medium	Medium	High	Low	Medium	High	17
Maximizes Efficiency in Meramec River	Low	Medium	Low	High	High	Low	Medium	High	16
Minimize Impacts to Other Social Effects	Low	Medium	Low	High	Medium	Medium	High	High	17
Maximizes Ecosystem Benefits in Study Area	High	High	High	Medium	Medium	High	Medium	High	21
Maximize Bank Stabilization in Study Area	Low	High	High	High	Medium	Medium	Medium	High	19
Maximize Sediment Capture in Big River	High	Medium	Low	Low	Low	Medium	Medium	High	15
Sponsor Preferred	High	High	High	Medium	Medium	High	Medium	High	21

Table 3-4 was used to evaluate and compare the initial array of alternatives. The alternatives that will not be evaluated further and the accompanying rationale are listed below.

Maximize Sediment Capture in the Big River: This alternative was not evaluated further since benefits would not be realized without also addressing inputs from unstable banks.

Maximize Bank Stabilization in the Study Area: This alternative was not evaluated further because it does not address multiple objectives, is not cost effective since benefits would not be realized without also addressing movement of bed sediment causing destabilization, and is not acceptable to the sponsor as a standalone measure.

Minimize Impacts to Other Social Effects: This alternative was not evaluated further since it is similar to the alternative Maximize Efficiency in the Big River. Based on guidance, alternatives are to be distinctly different from each other. To remediate this duplication, the final array included Maximize Efficiency, which ranked as high as other social effects, and if selected will utilized other social effect considerations during design.

Maximize Efficiency in the Meramec River: This alternative was not evaluated further since it scored among the lowest in meeting study objectives and included similar measures as Maximize Ecosystem Restoration in the Meramec River.

Sponsor Preferred: This alternative was not evaluated further since it is indistinguishable from Maximize Ecosystem Restoration in the Study Area. An approval by the Assistant Secretary to the Army (Civil Works) would be required if the Sponsor expressed interest in moving forward with a LPP.

3.12 FINAL ARRAY OF ALTERNATIVES

Five alternatives were carried forward to the final array of alternatives (Box 3-3), which were evaluated for consideration as the National Ecosystem Restoration (NER) plan (see Table 3-5). Section 1.6-*Purpose and Need*, discussed the potential for overlap with the USEPA Superfund Sites remedial actions. Initially there was uncertainty about the impacts of this overlap making it difficult to define the study area and sufficiently address the associated risks; therefore, two additional alternatives were added, both subsets of "Maximizes Ecosystem Benefits in the Big River", to evaluate the changes to potential benefits if a reduced geographic scope occurred as a result of a lower USEPA remedial action level than was assumed in Section 2.6.2 – *HTRW Future without Project Conditions*. The two additional alternatives were selected based on the assumption that USEPA will target project sites closer to historic mining sites (Big River RM 90-110) with higher lead concentrations.

Using current lead concentration data, areas upstream of RM 35 on the Big River have in-stream average lead concentrations higher than 400 ppm; therefore, RM 35 was set as a breakpoint and Alternative **Subset Maximize Ecosystem Benefits in the Big River, RM 0-35** was created to capture an alternative that reduced the risk of overlap with USEPA remediation efforts and potential for HTRW concerns.

As part of the remedial investigation process, USEPA is currently constructing several pilot projects in the Big River. The most downstream effort is located at Rockford Beach (RM 10.2) and is in close proximity to a robust freshwater mussel fauna. With this information, the risk of overlap with USEPA remediation efforts was further reduced. Alternative **Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2**, captures ecosystem restoration opportunities in the Big River between RM 10.2 and RM 0.

Alternatives in the final array were arranged from smallest to largest and given a number for clarity.

Box 3-3. Final Array of Alternatives

Alternative 1. No Action

Alternative 2: Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2

Alternative 3: Subset Maximize Ecosystem Benefits in the Big River, RM 0-35

Alternative 4: Maximizes Ecosystem Benefits in the Meramec River

Alternative 5: Maximizes Efficiency in the Big River

Alternative 6: Maximizes Ecosystem Benefits in the Big River

Alternative 7: Maximizes Ecosystem Benefits in the Study Area

Figure 3-2 through Figure 3-7 map each alternative in the final array.

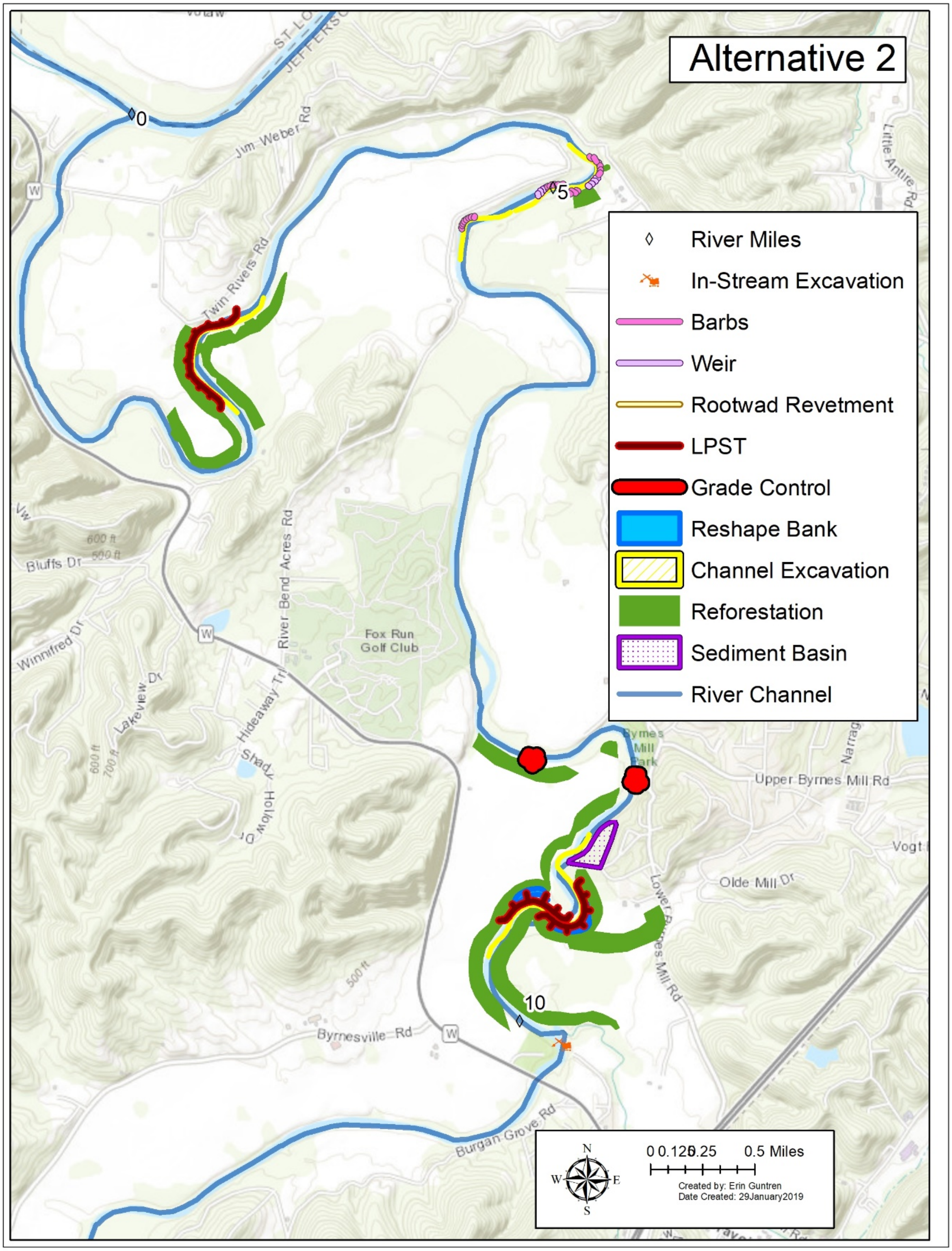


Figure 3-2. Alternative 2-Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2

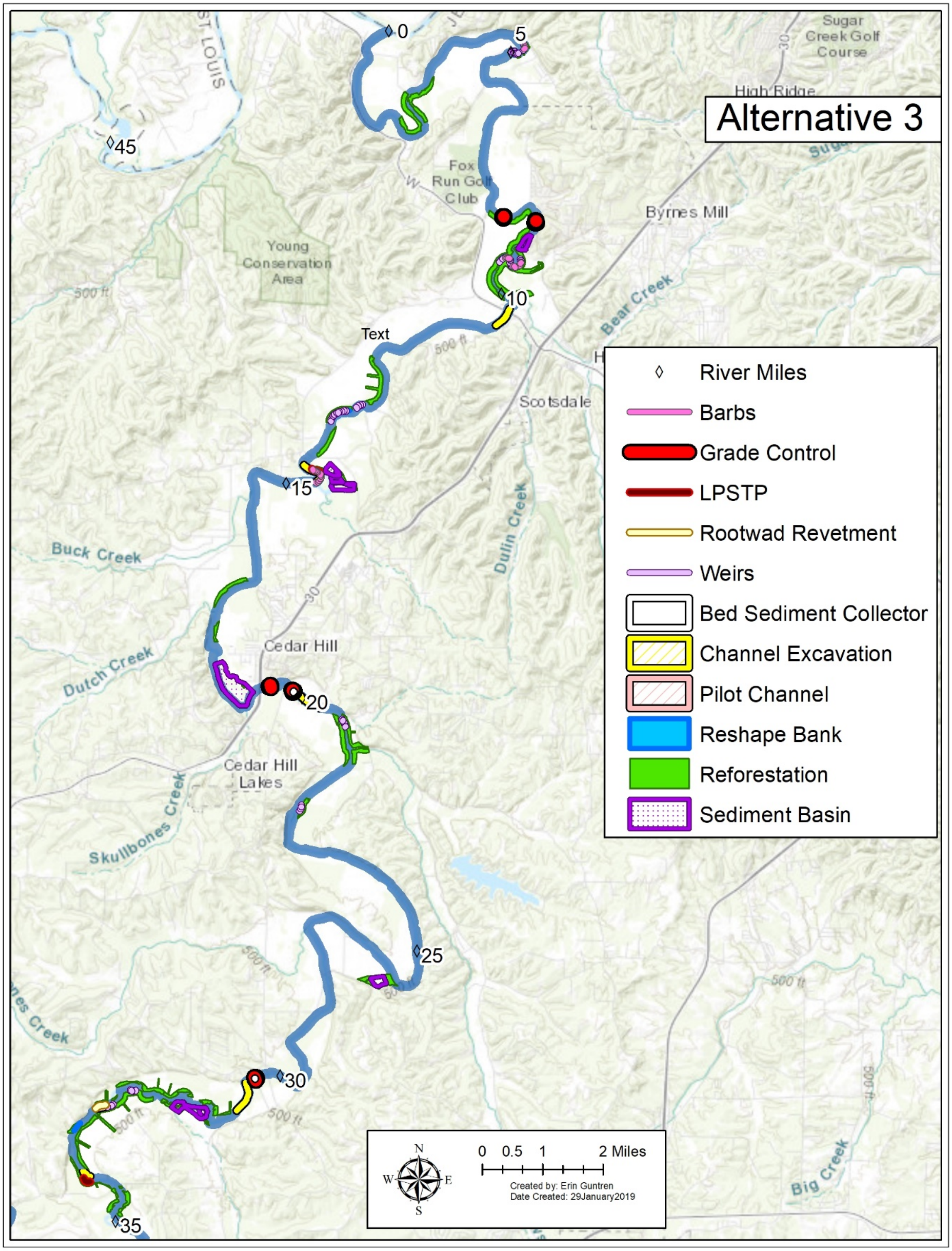


Figure 3-3. Alternative 3-Subset Maximize Ecosystem Benefits in the Big River, RM 0-35

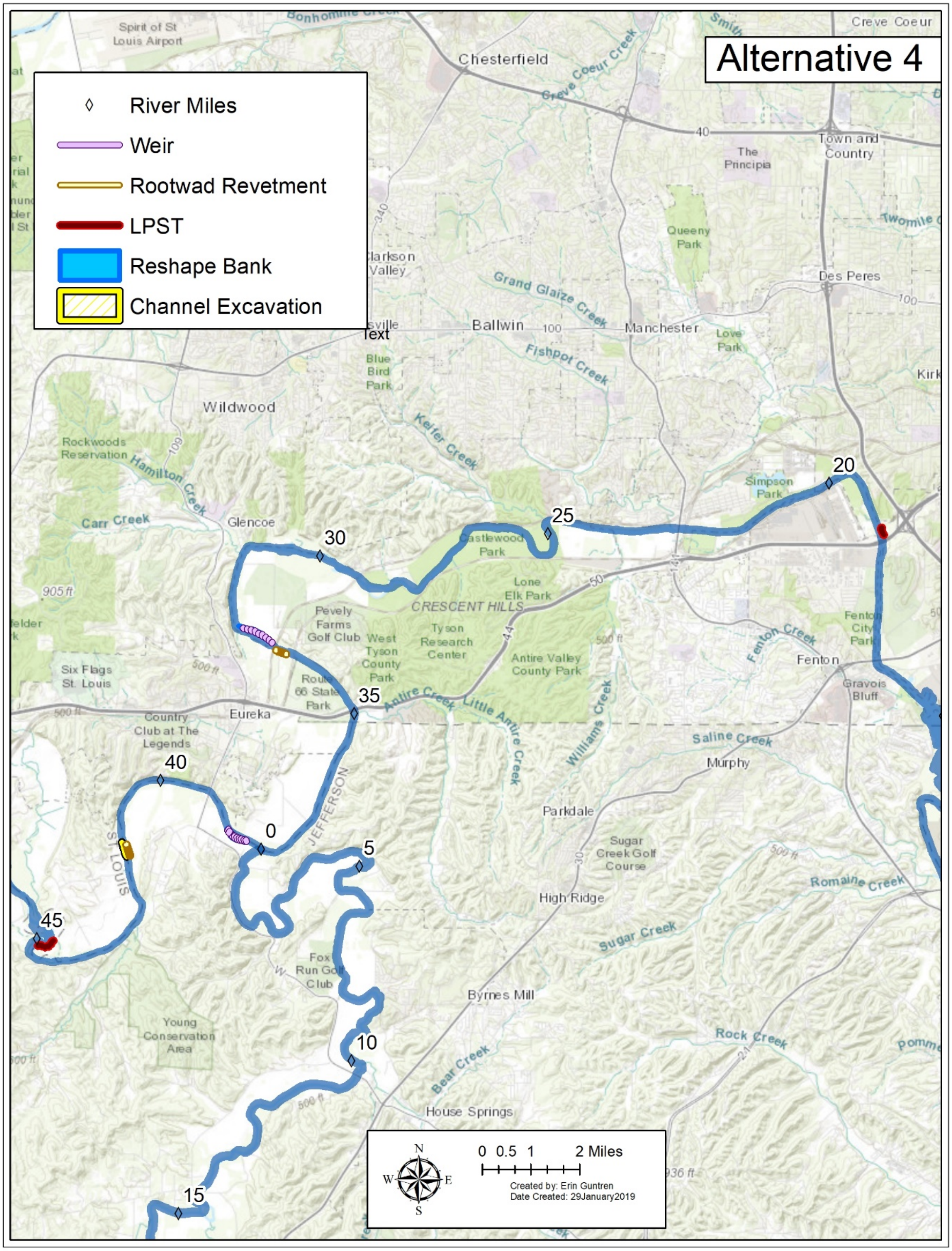


Figure 3-4. Alternative 4-Maximizes Ecosystem Benefits in the Meramec River

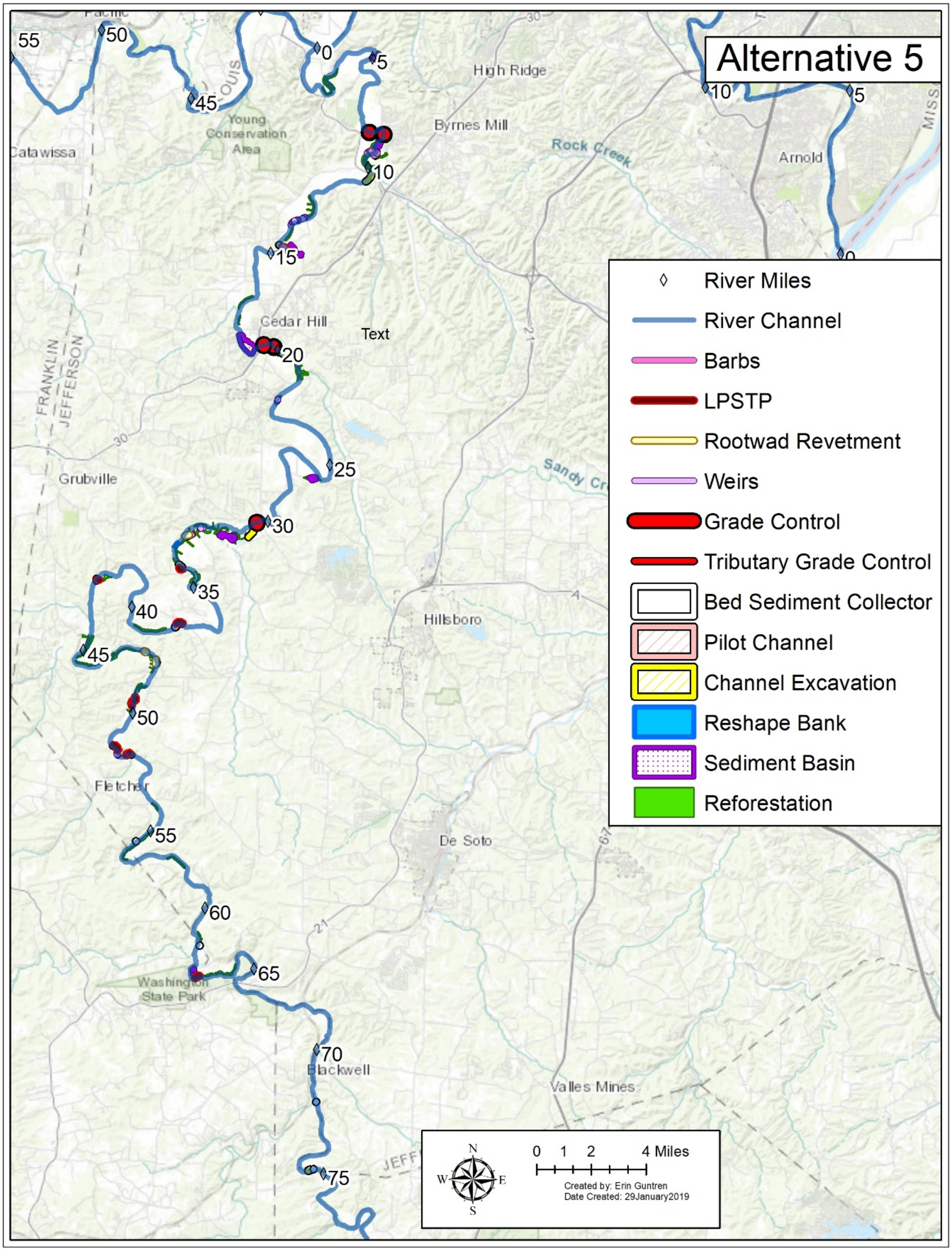


Figure 3-5. Alternative 5-Maximizes Efficiency in the Big River

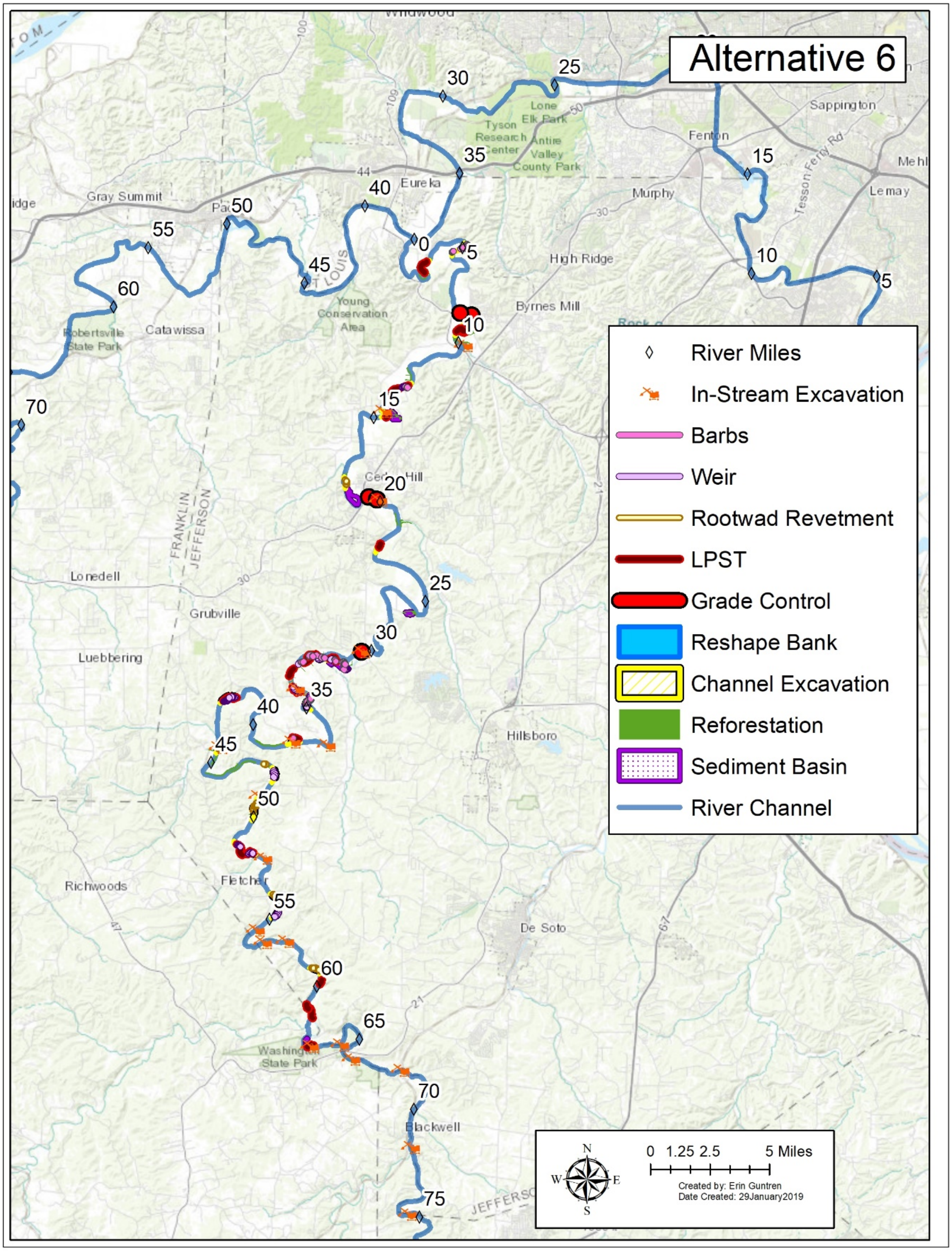


Figure 3-6. Alternative 6-Maximizes Ecosystem Benefits in the Big River

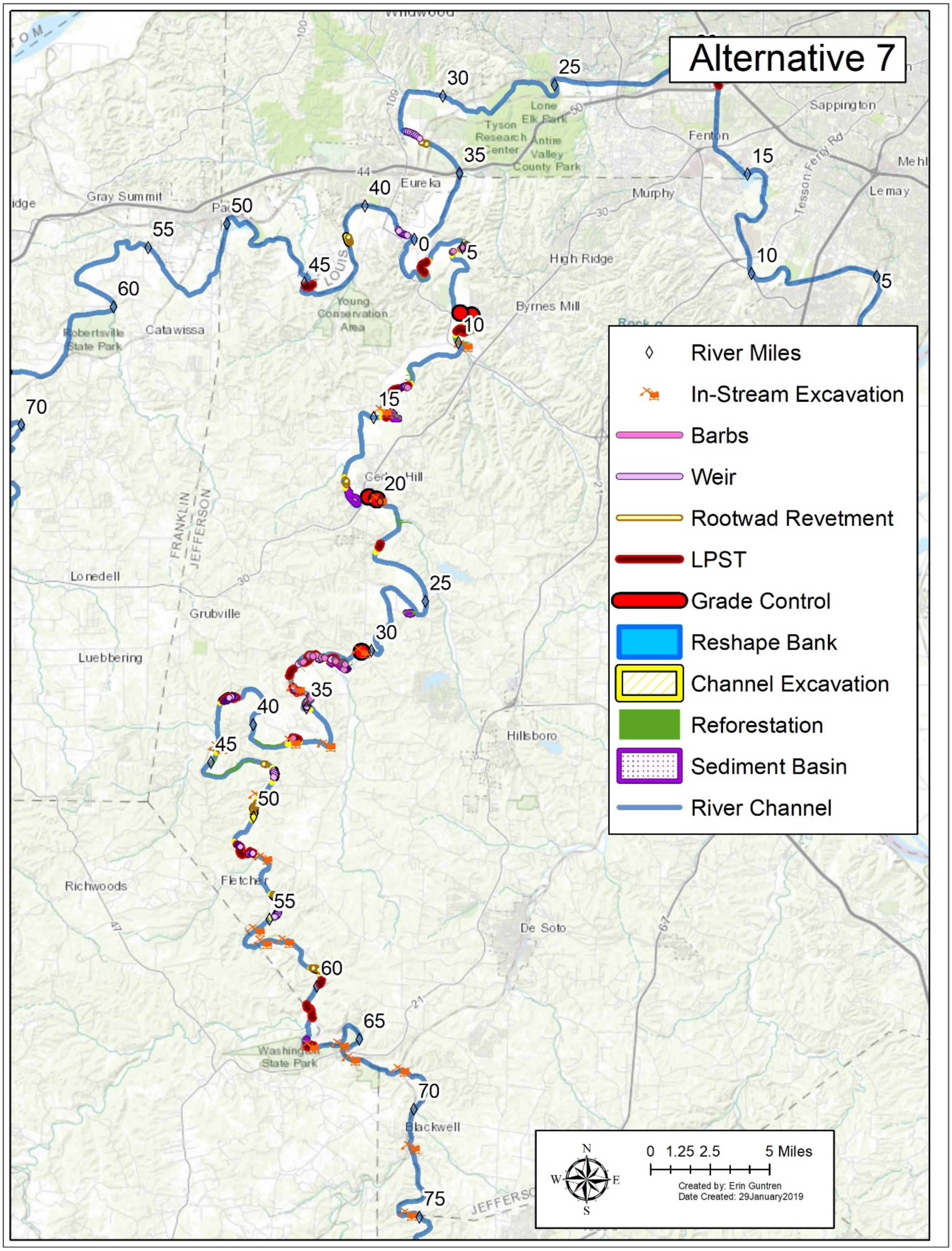


Figure 3-7. Alternative 7-Maximizes Ecosystem Benefits in the Study Area

Table 3-5. Final Array of Alternatives

			Bank Stabilization								**Sediment Removal**					**Reforestation (acres)**
#	Alternative	Total Sites (#)	LPSTP (Linear Feet)	Stream Barbs (#)	Weirs (#)	Bank Shaping (linear feet)	Root wad Revetment (linear feet)	Channel Excavation (acres)	Plantings (acres)	Grade Control Structure Sites (#)	#	Acres	In-stream Excavation Sites (#)	Bed Sediment Removal Sites (#)	Bed Collectors (#)	
1	No Action	0	0	0	0	0	0	0	0	0	0	0	0		0	0
2	Subset: Maximize Ecosystem Restoration in the Big River RM 0-10.2	3	5,899	22	8	2,012	0	0	3.6	1	1	5.9	2	0	0	149
3	Subset: Maximize Ecosystem Restoration in the Big River RM 0-35	17	19,068	60	52	11,559	929	6.7	21.6	3	5	143.2	4	1	2	440
4	Maximizes Ecosystem Benefits in the Meramec River	5	2,019	0	19	4,872	2,064	3.6	26.5	0	0	0	0	0	0	19
5	Maximizes Efficiency in the Big River	35	17,717	43	66	7,679	1,950	15.8	16.2	3	6	154.1	4	4	6	675
6	Maximizes Ecosystem Benefits in the Big River	51	29,447	61	102	16,052	5,590	28	38	3	6	154.1	4	16	6	679
7	Maximizes Ecosystem Benefits in the Study Area	56	33,041	61	112	21,434	7,654	28	64.5	3	6	154.1	4	16	6	698

4 ENVIRONMENTAL EFFECTS*

In accordance with National Environmental Policy Act (NEPA), this chapter evaluates the effects on social, economic, and natural environment that would result from implementation of the considered alternatives identified in Chapter 3-*Plan Formulation.* This chapter fulfills the NEPA requirements by evaluating the consequences of the considered alternatives, a subset of the final array of alternatives, including the No Action Alternative. Each resource from Chapter 2-*Existing Conditions* was evaluated for effects (also called impacts) on each considered alternative. Pursuant to NEPA, this chapter addresses the impacts in proportion to their significance (40 Code of Federal Regulations [CFR] § 1502[b]). Significance requires consideration of context and intensity[31] (40 CFR § 1508.27). The depth of analysis of the alternatives corresponds to the scope and magnitude of the potential environmental impact. This chapter provides the scientific and analytic basis for the comparisons of the alternatives and describes the probable consequences (impacts, effects) of each alternative on the selected environmental resources. The purpose of characterizing the environmental consequences is to determine whether the resources, ecosystems, and human communities of concern are approaching conditions where additional stresses will have an important cumulative effect (CEQ, 1997). Chapter 5 provides further discussion on cumulative effects.

The considered action alternatives would result in positive long-term ecosystem benefits for the study area (Table 4-1). The considered action alternatives would result in some conversion of land cover types (e.g., pasture to forest), but the resulting changes would provide improved ecosystem structure and function for a variety of species through time. During construction of any considered action alternative, short-term decreases in water quality, air quality, aesthetics, public use and temporarily disturb wildlife in the area are anticipated. Long-term benefits would far outweigh the short-term impacts. No long-term negative impacts to the Federally-listed species are anticipated with any of the considered action alternatives. No negative impacts to man-made resources, community resources, availability of public facilities and services, employment, tax income and value losses, property value losses, displacement of people, business and industrial growth, community growth or regional growth are expected. No impacts to life, health, safety or energy are expected. No impacts to historic and cultural resources are anticipated.

This chapter compares the effects of the following considered alternatives:

- Alternative 1: No Action Alternative
- Alternative 4: Maximizes Ecosystem Benefits in the Meramec River
- Alternative 5: Maximizes Efficiency in the Big River
- Alternative 7: Maximizes Ecosystem Benefits in the Study Area

This chapter does not explicitly discuss Alternatives 2 and 3 because Alternative 5 contains all the management measures included in Alternatives 2 and 3, and so it was assumed effects would be similar, just in a smaller area. This chapter discusses Alternative 4 because it covers only the Meramec River. Management measures in Alternative 6 are contained in Alternative 7; therefore, Alternative 6 is not discussed separately. When environmental effects of Alternatives 4, 5 and 7 are the same, they are discussed together.

[31] Context means the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Intensity refers to the severity of impact (CFR § 1508.27)

4.1 GEOLOGY AND SOILS

Impacts of No Action Alternative: Under this alternative, the USACE would not carry out any additional actions to restore the floodplain soils; therefore, this alternative would have no effect on geology and soils.

Impacts of Considered Action Alternatives: The USACE expects temporary, minor impacts to geology and soils due to construction activities from any considered action alternative. No long-term effects to geology are anticipated. The considered alternatives would have a positive effect on soils by reducing heavy metal contamination. In addition, increased forest cover would increase soil organic matter and fertility. Bank stabilization would directly affect floodplain soils by stabilizing and re-sloping banks providing opportunities for soils to collect among the in-stream structures. Sediment basins would also directly affect floodplain soils by first excavating and removal of material followed by depositing of finer material over time. The primary differences among the considered alternatives are the number of project sites. Alternative 4 would have marginal positive effect to soils along the Meramec River while Alternatives 5 and 7 have more sites providing more opportunities for benefits to soils within the study area.

Table 4-1. Environmental Effects Summary of Considered Alternatives for the Study Area

Resource	No Action	**Alternative 4** Maximizes Ecosystem Benefits in the Meramec River	**Alternative 5** Maximizes Efficiency in the Big River	**Alternative 7** Maximizes Ecosystem Benefits in the Study Area
Geology & Soils	No effect	Marginal positive	Positive	Positive
Prime Farmland	No effect	Marginal	Marginal	Marginal
Stream Geomorphology	Negative	Marginal positive	Positive	Positive
Land Cover/Land Use	No effect	Positive	Positive	Positive
Hydrology (surface & groundwater)	No effect	Positive	Positive	Positive
Hydraulics	Negative	Positive	Positive	Positive
Sediment	Negative	Marginal positive	Positive	Positive
Water Quality	Negative	Negative	Positive	Positive
HTRW	Negative	Negative	Positive	Positive
Biological (Fish, freshwater mussels and other aquatic organisms)	Negative	Marginal positive	Positive	Positive
Floodplain & Riparian Forest	No effect	Marginal positive	Positive	Positive
Wildlife & Birds	No effect	Marginal positive	Positive	Positive
Amphibians & Reptiles	No effect	Marginal positive	Positive	Positive
Invasive Species	No effect	No effect	No effect	No effect
Federally-Listed Threatened & Endangered Species	Negative	Positive	Positive	Positive
Cultural & Historic Resources	No effect	No effect	No effect	No effect
Socioeconomic Resources	No effect	Marginal positive	Positive	Positive
Resources of Recreational, Ecological, Scenic, or Aesthetic Importance	No effect	Positive	Positive	Positive
Environmental Justice	No effect	No effect	No effect	No effect
Noise	No effect	No effect	No effect	No effect
Air Quality	No effect	No effect	No effect	No effect
Climate Change	No effect	No effect	No effect	No effect
(See Sections 4.2 through 4.26 for an explanation of positive, negative, no effect)				

4.2 PRIME FARMLAND

Impacts of No Action Alternative: No prime farmland would be altered from existing conditions.

Impacts of Considered Alternatives: Table 4-2 summarizes the prime farmland acres in each considered alternative. Reforestation and sediment basins were identified as having a potential to effect prime farmland while other in-channel management measures would not. To comply with the Farm Protection Policy Act (FPPA) of 1981, the USACE coordinated with the Natural Resources Conservation Service and evaluated impacts of reforestation and sediments basins to existing prime farmland using Form AD-1006 (U.S. Department of Agriculture Farmland Conversion Impact Rating; see Appendix A-*Coordination* for more details). This evaluation determined the conversions of prime farmland due to reforestation and sediment basins would cause non-adverse effects.

Table 4-2. Prime Farmland Converted By Reforestation and Sediment Basin Construction

	Alternative 4	Alternative 5	Alternative 7
All areas in prime farmland (acres)	4.8	123.1	130.9
Not prime farmland (acres)	9.2	692.6	677.6
Prime farmland, if drained (acres)	14.3	40.4	41.4
Farmland of statewide importance (acres)	0.0	1.0	1.0

4.3 STREAM GEOMORPHOLOGY

Impacts of No Action: Under this alternative, disturbance reaches within the study area would continue. No large-scale aquatic modifications by other agencies are likely to restore ecosystem structure and function within the study area. Work by other agencies is unlikely to focus on disturbance reaches within the study area.

Impacts of Alternative 4: The bank stabilization management measures would have local impacts to stream geomorphology. These changes are expected to be positive at the local scale, but they will not provide large-scale benefits to the entire study area.

Impacts of Alternative 5: This alternative would have positive effects to stream geomorphology by stabilizing disturbance reaches, providing grade control, and restoring the riparian corridor along the Big River. In addition, this alternative uses soft structures (e.g., willow stakes, bioengineering solutions) to provide additional habitat benefits that traditional hard structures (e.g., rock) do not provide.

Impacts of Alternative 7: This alternative would have positive effects to stream geomorphology by stabilizing disturbance reaches, providing grade control and restoring the riparian corridor along the Big and Meramec Rivers; however, this alternative includes additional hard structures (e.g., rock) compared to Alternative 5, which does not provide as much additional habitat benefits as soft structures do. This alternative also includes the most bed sediment removal. Bed sediment removal would follow state guidance to reduce the potential for unintended consequences to the stream.

4.4 LAND COVER/LAND USE

Impacts of No Action Alternative: No changes to land cover and land use would be altered from existing conditions.

Impacts of Considered Action Alternatives: The considered action alternatives all propose tree plantings as a management measure, which directly changes land cover and land use by converting existing lands primarily used for agriculture to forest. Overall, this was viewed this as a positive effect to restore the riparian corridor, contain floodplain soils, reduce erosion, and improve habitat structure and diversity.

In regards to other land use plans, this USACE planning study would have a positive impact to some of the needs identified in the *Meramec River Conservation Action Plan* (TNC, 2014). All considered action alternatives would have no detrimental effect to any other agencies' ongoing planning efforts.

4.5 HYDROLOGY

Impacts of No Action Alternative: No changes to hydrology would be altered from existing conditions.

Impacts of Considered Action Alternatives: Due to construction activities, temporary minor impacts of surface water may occur related to erosion; however, construction would implement best management practices to reduce surface water erosion during and after construction. Slight positive effects to surface and groundwater are anticipated through increased riparian areas, decreased erosion and decreased contaminated floodplain metal sediments inputs. Changes to regional hydrology is not anticipated.

4.6 HYDRAULICS

Impacts of No Action Alternative: Under this alternative, no action by the USACE would be taken to restore the hydraulics of the study area. The study area would continue to have negative effects related to altered hydraulics. It is assumed some actions by others may continue locally at a small-scale, but no large-scale aquatic modifications to restore the aquatic ecosystem structure and function within the study area.

Impacts of Alternative 4: Alternative 4 would improve the hydraulics only along the Meramec River. Hydraulics are expected to improve in the Meramec River through reducing bank erosion and restoring the stream to a more natural state.

Impacts of Alternative 5: Alternative 5 would improve hydraulics only along the Big River. Hydraulics are expected to improve in the Big River through reducing bank erosion, stabilizing the bed and restoring natural sediment transport and channel function in the Big River.

Impacts of Alternative 7: Alternative 7 would improve the hydraulics throughout the entire study area. All restoration sites would provide the maximum benefit of restoring aquatic ecosystem function by reducing bank erosion, providing grade control and restoring natural sediment transport and channel function throughout the entire study area.

4.7 SEDIMENT

Impacts of No Action: Under this alternative, the USACE would not implement any action. It is assumed other agencies will continue to construct projects to reduce the contaminated sediment for human health; however, no large-scale restoration efforts would occur to address the contamination of heavy metals for aquatic ecosystem health. The contaminated sediment moving downstream in the Big River would continue.

Impacts of Alternative 4: Since Alternative 4 is limited to working in the Meramec River, this alternative is expected to have marginal effects to sediment throughout the study area. Local positive effects to sediment are expected in the Meramec River, but no direct reduction in contaminated sediment is anticipated throughout the entire study area. The existing contaminated sediment would continue as-is within the Big River, continue to move downstream, and negatively affect aquatic life within the Meramec River in the future.

Impacts of Alternative 5: Management measures included in Alternative 5 are designed to improve the condition of contaminated sediment within the Big River. Improved sediment conditions within the Big River are expected by addressing the sources of suspended and bedded contaminated material by stabilizing banks and reducing downstream migration of contaminated material. Improvements within the Big River would reduce risk of negative effects to the Meramec River in the future.

Impacts of Alternative 7: Alternative 7 would provide similar positive effects as described in Alternative 5, with the addition of management measures located within the Meramec River. Overall, this alternative would provide the maximum benefit of restoring aquatic ecosystem function by having the highest potential for reducing excessive contaminated sediments throughout the study area.

4.8 WATER QUALITY

Impacts of No Action Alternative: Water bodies currently on the 303(d) impaired water body list are expected to remain on that list into the future. Water quality issues related to lead contamination would continue into the future and move further downstream negatively effecting the study area.

Impacts of Alternative 4: Bank stabilization and tree plantings are expected to improve water clarity by reducing suspended sediment entering the river at a local level. This alternative contains a small number of sites (as compared to the overall size of the Meramec River), a detectable change in water quality data collected at gage stations is not anticipated. Overall, contaminated sediment within the Big River is expected to continue to move downstream and enter the Meramec River in the future which would negatively impact the water quality.

Impacts of Alternative 5: The combination of measures in this alternative along the Big River are expected to have a positive effect by improving water quality by reducing total suspended solids and bed sediments associated with contaminated sediments from mine waste (e.g., lead). Improvements in water quality are expected within the Big River to provide improvements to the Meramec River downstream as well.

Impacts of Alternative 7: It is expected that the combination of management measures in this alternative along the Big and Meramec Rivers will have a positive effect by improving water quality by reducing total suspended solids and heavy metal concentrations (i.e., lead). The improvements are expected to be similar as Alternative 5.

4.9 HTRW

Impacts of No Action: With this alternative, the USACE would not implement any action. Actions by other agencies within the Big River Watershed would continue with remediation work addressing heavy metal contamination as related to human health, but little work to restore the aquatic ecosystem. With no large-scale effort to restore the ecosystem, harm to aquatic life through the release of hazardous substances would continue under this alternative.

Impacts of Alternative 4: The Meramec River main stem has not been identified as a priority area for HTRW concerns. The existing conditions of HTRW within the Meramec River would not be altered from its current condition with this alternative; however, the contaminated sediment from the Big River is expected to continue to migrate downstream and may result in HTRW concerns and have a negative effect into the future.

Impacts of Alternatives 5 and 7: With these alternatives, ecosystem structure and function would be restored, which includes reducing HTRW concerns that harm aquatic life. These alternatives would leverage work by other agencies in restoring the overall ecosystem structure and function of the entire study area and have a positive effect in improving HTRW conditions (i.e., reducing lead contamination).

4.10 FISH, FRESHWATER MUSSELS AND OTHER AQUATIC ORGANISMS

Impacts of No Action: Fish, freshwater mussels, and other aquatic organisms would continue to be harmed by the release and movement of hazardous substances into the environment and the degraded aquatic habitat (e.g., accelerated channel change, suspended sediment, bedded sediment and lack of riparian corridor). The USACE planning anticipates the ongoing harm from heavy metal contamination to fish, freshwater mussels, and other aquatic organisms throughout the study area to continue. In particular, freshwater mussels would further decline as contaminated sediment moves downstream.

Impacts of Alternative 4: Marginal positive effect on fish, freshwater mussels, and other aquatic organisms are expected within the Meramec River as compared to the No Action Alternative. Contaminated sediment from the Big River will continue to move downstream and enter the Meramec River and potentially negatively impacting aquatic life there in the future. Within the Big River, fish, freshwater mussels and other aquatic organisms would be negatively impacted similar to the conditions described in the No Action Alternative.

Impacts of Alternatives 5 and 7: These alternatives would have positive effects to fish, freshwater mussels and other aquatic organisms within the study area. Overall, a proportionate increase in aquatic life is expected with the number of improvements constructed in the long-term. Short-term impacts during construction, especially bed collectors and bed sediment removal, may negatively impact aquatic organisms through direct smothering or removal via excavation. The bed collectors are designed to reduce potential incidental take of benthic organisms during operation. The removal of gravel from streams may result in loss of immobile aquatic life, including macroinvertebrates, during excavation. Alternative 7 has the maximum number of bed collectors and bed sediment removal; therefore, it has a higher potential to impact local aquatic organisms compared to Alternative 5. Local, minimal negative impacts during construction (i.e., physical smothering, reduced water clarity, noise) are expected, but these short-term impacts would be outweighed by the long-term benefits of a restored aquatic ecosystem within the study area.

4.11 FLOODPLAIN AND RIPARIAN FOREST

Impacts of No Action: Under this alternative, the existing conditions of the forest would continue, including the lack of riparian corridor.

Impacts of Alternative 4: Under this alternative, the forest resources within the study area would be minimally restored. Nineteen acres of restored floodplain forest along the Meramec River are estimated. Based on the habitat evaluation and quantification analysis (further described in Section 6.1.1.), a net gain of 16 average annual habitat units (AAHUS)[32] would be realized as compared to the No Action Alternative.

Impacts of Alternative 5: This alternative includes 675 acres of reforestation (net gain of 553 AAHUs over the No Action Alternative) along the Big River. Restoring the riparian corridor would improve the ecosystem structure and function throughout the study area benefiting a suite of wildlife resources.

Impacts of Alternative 7: This alternative includes 699 acres of reforestation (net gain of 573 AAHUs over the No Action Alternative) along the Big and Meramec Rivers. Restoring the riparian corridor would improve the ecosystem structure and function throughout the study area which would benefit a suite of wildlife resources.

---

[32] Floodplain forest benefits calculated using the Black-Capped Chickadee Habitat Suitability Index Model

4.12 WILDLIFE & BIRDS

Impacts of No Action: Wildlife, including Neotropical and migratory birds, harmed by the release of hazardous substances into the environment would continue. Local populations relying on streams, wetlands, floodplains and riparian corridor habitats would continue to be negatively affected by the degraded ecosystem. Residual injury is expected to continue within the study area. Work by other agencies would provide some local benefit to the wildlife resources, but no large-scale restoration efforts are anticipated.

Impacts of Alternative 4: Impacts to wildlife resources are expected to be similar to the No Action Alternative. Management measures along the Meramec River would benefit local populations, but the remaining study area would continue to be negatively affected by the continued release of hazardous substances, lack of riparian corridor, and degraded aquatic ecosystems that wildlife and birds depend on. Lead contamination from the Big River is assumed to continue to move downstream and enter the Meramec River negatively impacting wildlife and birds. To minimize impacts to bald eagles, the USFWS guidelines will be adhered to during construction if any nests are observed.

Impacts of Alternatives 5 and 7: These alternatives would benefit a wide variety of wildlife and birds within the study area. Proportionate increase in wildlife and birds with increased habitat improvements. During construction, short-term impacts to wildlife and birds are anticipated, but these short-term impacts would be outweighed by the long-term improvements of ecosystem structure and function. During construction, best management practices would be implemented to avoid and minimize impacts to wildlife resources. To minimize impacts to bald eagles, the USFWS guidelines will be adhered to during construction if any nests are observed.

4.13 AMPHIBIANS AND REPTILES

Impacts of No Action Alternative: Amphibian and reptile resources harmed by the release of hazardous substances into the environment would continue. Local populations relying on streams, wetlands, floodplains, and riparian corridor habitats would continue to be negatively affected by the degraded ecosystem. Ongoing residual injury is expected to continue within the study area. Work by other agencies would provide some local benefit to the amphibian and reptile resources; but no large-scale restoration efforts are anticipated.

Impacts of Alternative 4: The impacts to amphibian and reptile resources within the study area could potentially have marginal positive effects locally on the Meramec River as compared to the No Action Alternative; however, the remaining study area would continue to be negatively affected by the continued release of hazardous substances, lack of riparian corridor, and degraded aquatic ecosystems that amphibians and reptiles depend on.

Impacts of Alternatives 5 and 7: These alternatives would benefit a wide variety of amphibians and reptiles within the study area. A proportionate increase in amphibians and reptiles with increased habitat improvements is expected. During construction, short-term impacts to amphibians and reptiles are anticipated, but these short-term impacts would be outweighed by the long-term improvements of ecosystem structure and function. During construction, best management practices would be implemented to avoid and minimize impacts.

4.14 INVASIVE SPECIES

Impacts of No Action Alternative: Invasive species would not be altered from existing conditions.

Impacts of Considered Action Alternatives: All considered action alternatives seek to restore ecosystem structure and function for native species and habitats. With this, native plants and animals should be able to compete better with existing invasive species and make the ecosystem less susceptible to future invasions. During construction, best management practices would be implemented to reduce invasion while the sites are being disturbed.

4.15 FEDERALLY-LISTED THREATENED AND ENDANGERED SPECIES

Impacts of No Action Alternative: Negative impacts related to release of hazardous substances and degraded habitats would not be reduced under this alternative. Federally-listed species would be further adversely impacted as contaminated sediment moves downstream.

Impacts of Considered Action Alternatives: In accordance with the Endangered Species Act (ESA), the USACE obtained a list of Federally threatened and endangered animals and plants from the USFWS, satisfying the "request for species list requirements" for ESA Section 7 Consultation. The USACE prepared a Biological Assessment (Appendix C – *Biological Assessment*) documenting conservation measures and effects determination for the Federally-listed species in coordination with USFWS. Table 4-3 summarizes the USACE's effects determination for the Federally-listed species potentially occurring within the study area.

Table 4-3. Federally-Listed Species Effects Determination

Effects Determination	Category	Species
May Affect, Not Likely to Adversely	Mammals	Gray Bat Indiana Bat Northern long-eared Bat
	Fish	Pallid Sturgeon
	Clams	Pink Mucket Scaleshell Mussel Sheepnose Mussel Snuffbox Mussel Spectaclecase
No Effect	Insects	Hine's Emerald Dragonfly
	Flowering Plants	Decurrent False Aster Mead's Milkweed Running Buffalo Clover

4.16 CULTURAL AND HISTORICAL RESOURCES

Impacts of No Action Alternative: No cultural resources would be altered from their current condition, except by natural process.

Impacts of Considered Action Alternatives: During site selection and measure development, impacts of known cultural and historical resources were avoided or minimized.

The District received a letter from the Missouri SHPO on 31 May 2018 with no comments to the proposed project. Appendix A-*Coordination* includes a copy of the letter. If, however, cultural or historical resources were encountered during construction, all work would stop in the affected area and further consultation would take place per CFR 800-13. If adverse impacts to historic properties are unavoidable, per National Historic Preservation Act (NHPA) of 1966, as amended, it is possible to "mitigate" the effects of those impacts. If necessary, an archaeological site may be excavated and the information recovered. In terms of the NHPA, the excavation and data recovery mitigates the loss of the site. Moreover, should the proposed actions change from those discussed during initial consultation, consultations will be reinitiated.

Therefore, the considered action alternatives would have no effect on historic and cultural resources.

4.17 SOCIOECONOMICS

Impacts of No Action Alternative: No impacts to socioeconomics would be expected.

Impacts of Considered Action Alternatives: The considered alternatives have no measureable impacts on community cohesion, property values, industrial growth, life, health and safety, or privately owned farms. Increased recreational use within the study area is expected with the considered action alternatives which could increase community, regional, and business growth as well as tax revenues.

The USACE has not received any public opposition to the considered action alternatives. In the long-term, habitat improvement would increase wildlife and fish populations and diversity. Increased outdoor recreational opportunities including bird watching, hunting, fishing and boating with any of the considered action alternatives are expected. In the short-term, construction activities would likely disturb recreational activities within the study area, but could also create short-term employment opportunities.

Employment opportunities are evaluated using the USACE Institute for Water Resources and the Louis Berger Group regional economic impact modeling tool called RECONS (Regional ECONomic System).

RECONS estimates economic impacts/contribution of these alternatives to the economy by utilizing input-output (IO) modeling techniques to calculate the multiplier effects that USACE expenditures create through linkages to the industries, businesses, and households supplying the goods, services, and labor.

The analysis evaluated economic impacts at three levels of geography: region, state and nation. Table 4-4 provides the unit price estimates for Alternatives 4, 5, and 7 and how the total expenditures are captured by regional, state, and national impact areas. The expenditures made by the USACE for various services and products are expected to generate additional economic activity that can be measured in jobs, income, sales and gross regional products. Outputs show there are significant regional benefits, both directly and indirectly, for all evaluated alternatives.

Therefore, the considered action alternatives would have a positive effect on socioeconomics.

Table 4-4. Economic Impacts of Alternatives 4, 5, and 7 using unit price estimates (Jan 2018 pricing)

Alternative 4				
Impacts / Impact Areas		Regional	State	National
Total Spending		$16,953,650	$16,953,650	$16,953,650
Direct Impact				
	Output	$7,585,179	$13,373,598	$16,885,805
	Job	82.76	143.04	212.03
	Labor Income	$2,673,156	$5,055,404	$7,368,745
	Gross Regional Product	$3,192,795	$5,927,318	$8,375,268

Total Impact				
	Output	$10,063,401	$25,047,377	$48,708,674
	Job	104.86	230.63	396.46
	Labor Income	$3,411,499	$9,249,178	$17,620,725
	Gross Regional Product	$4,598,419	$12,839,622	$25,821,424
Alternative 5				
Impacts	**Impact Areas**	**Regional**	**State**	**National**
Total Spending		$79,192,620	$79,192,620	$79,192,620
Direct Impact				
	Output	$35,431,319	$62,469,749	$78,875,709
	Job	386.58	668.16	990.43
	Labor Income	$12,486,647	$23,614,427	$34,420,330
	Gross Regional Product	$14,913,944	$27,687,242	$39,121,923
Total Impact				
	Output	$47,007,404	$116,999,434	$227,524,310
	Job	489.83	1,077.29	1,851.90
	Labor Income	$15,935,539	$43,204,067	$82,308,610
	Gross Regional Product	$21,479,790	$59,975,479	$120,615,102
Alternative 7				
Impacts	**Impact Areas**	**Regional**	**State**	**National**
Total Spending		$105,762,400	$105,762,400	$105,762,400
Direct Impact				
	Output	$47,318,820	$83,428,867	$105,339,163
	Job	516.28	892.33	1,322.73
	Labor Income	$16,676,020	$31,537,262	$45,968,636
	Gross Regional Product	$19,917,696	$36,976,541	$52,247,652
Total Impact				
	Output	$62,778,777	$156,253,713	$303,860,601
	Job	654.17	1,438.73	2,473.23
	Labor Income	$21,282,044	$57,699,389	$109,923,830
	Gross Regional Product	$28,686,437	$80,097,749	$161,082,467

In terms of impacts to transportation, construction of any of the considered alternatives would increase short-term traffic on local roads as related to hauling of construction material and excavated material. Hauling of rock and excavated material would use existing roadways and would not adversely impact the roadways. For construction activities, using various sized trucks (10-18 cubic yard per load capacity) would equate to approximately 21,500-38,700 truckloads carrying excavated material or stone. Since the proposed construction sites are spaced out over 75 river miles, no one construction site would be impacted by that many trucks; therefore, the proposed construction of the considered action alternatives would produce short-term affects, but no long-term impacts to transportation.

4.18 RESOURCES OF RECREATIONAL, ECOLOGICAL, SCENIC OR AESTHETIC IMPORTANCE

Impacts of No Action Alternative: No resources of recreational, ecological, scenic or aesthetic importance would be altered from existing conditions.

Impacts of Considered Action Alternatives: Short-term impacts would occur with construction equipment. Alternatives including bed sediment collectors and sediment basins may have a local change to aesthetics due to the placement and footprint required for operation; however, minimizing the impact to the aesthetic of the scenic stream would be taken into consideration. In the long-term aesthetic resources throughout the study area would improve as a result of the enhanced riparian corridor and floodplain habitats. These improvements would make the study area more aesthetically pleasing to many visitors; therefore, the considered action alternatives would have a positive effect on scenic or aesthetic resources.

With habitat improvements, recreational opportunities including hunting and fishing may be enhanced within the study area. Improved riparian corridor and habitat structure may attract additional public use within the study area. Design of in-stream structures will take into consideration passage of watercraft, but slight passage barriers may occur during low water. Increased sport fisheries with reductions in fish consumption advisories are anticipated as the contamination is reduced; therefore, the considered action alternatives would have an overall positive effect on recreational resources.

4.19 ENVIRONMENTAL JUSTICE

Impacts of No Action Alternative: No change in environmental justice would be expected.

Impacts of Considered Action Alternatives: The USACE planning does not expect differential impacts to minority or low income populations with any of the action alternatives. Short-term increases in employment could be realized during construction. Improvements to the Big River would provide healthier natural resources for all residents.

4.20 NOISE

Impacts of No Action Alternative: No change in noise levels would be expected.

Impacts of Considered Action Alternatives: A temporary increase in noise levels during the construction are expected of any considered action alternative. This may lead to temporary displacement of some fish and wildlife species. No long-term impacts are expected. During construction, the contractor would be responsible to implement noise abatement measures if construction activity is in vicinity of a residence.

4.21 AIR QUALITY

Impacts of No Action Alternative: No change in air quality would be expected.

Impacts of Considered Action Alternatives: Minor, temporary increases in airborne particulates are expected as a result of mobilization and use of diesel construction equipment, but does not anticipate any long-term air quality standard violations or any adverse effects on air quality for any considered action alternative. Tree plantings are anticipated to improve air quality at the local scale, but when looking at the entire study area the slight local uplift may not be detectable; therefore, the considered action alternatives would have no effect on air quality.

4.22 CLIMATE CHANGE

Impacts of All Alternatives: The No Action and considered action alternatives should have no effect on climate change. For climate change, there is strong consensus that air temperature will increase within the study area and many projections forecast an increase in precipitation. In regards to impacts of climate change as related to hydrologic projection, a clear consensus is lacking within the study region (see Appendix H-*Hydraulics and Hydrology Analysis* for more details). Because most measures were designed to operate in low to moderate flows any of the considered action alternatives are anticipated to perform as designed regardless of hydrologic predictions.

4.23 PROBABLE UNAVOIDABLE ADVERSE IMPACTS (ON ALL RESOURCES)

Temporary, unavoidable adverse impacts including increased turbidity, noise, and clearing of vegetation would result from construction activities. Turbidity and noise levels would return to normal when construction is completed; however, benefits to natural resources would outweigh these unavoidable adverse impacts.

4.24 RELATIONSHIP TO SHORT-TERM USES AND LONG-TERM PRODUCTIVITY (ON ALL RESOURCES)

Construction activities would temporarily disrupt fish, wildlife, and human recreational use in the immediate vicinity of a given construction site. Construction activities would likely provide positive, short-term economic opportunities and a few jobs for the surrounding communities. Overall, the long-term health and productivity of the ecosystem is anticipated to increase with implementation of the proposed project. Additionally, the ecosystem benefits served within the study area would increase; therefore, short-term human use impacts would be offset by long-term increases in productivity.

4.25 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT TO RESOURCES (ON ALL RESOURCES)

Irreversible commitments are those that cannot be reversed, except perhaps in the extreme long run (Shipley 2010). Simply stated, once the resource is removed it can never be replaced. For the action alternatives considered, there are no irreversible commitments to natural resources. This study is in the planning stage. Money has been expended to complete this planning document and pre-project monitoring. No construction dollars, which are considered irreversible, have been expended for the study.

Irretrievable commitments are those that are lost for a period of time (Shipley 2010). Construction activities of any of the considered action alternatives will temporarily disrupt natural resource productivity. The construction activities signal an irretrievable loss in exchange for the benefits of the habitat improvements.

4.26 COMPLIANCE WITH ENVIRONMENTAL STATUTES*

All considered action alternatives were subject to compliance review with all applicable environmental regulations and guidelines.

<u>Aircraft-Wildlife Strikes</u>: There are a variety of land uses attracting wildlife and are, therefore, normally incompatible with airports. Accordingly, new, federally-funded airport construction or airport expansion project near habitats or other land uses that may attract hazardous wildlife must conform to the siting criteria established in the FAA Advisory Circular (AC) 150/5200-33, Section 1-3. Other federal agencies likewise are required to take airport operations and wildlife strikes into consideration during project

planning. The study is located approximately 30 miles from the Farmington Regional Airport. The distance and size of the study should not increase the presence of wildlife (avian or terrestrial) hazard to the airport.

Table 4-5. Relationship of the Considered Action Alternatives to Environmental Protection Statutes and Other Environmental Requirements

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

[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 USACE of Engineers laws, regulations, policies, and guidance have been complied with but not listed fully here.

[2] This list of Executive Orders is not exhaustive and other Executive Orders not listed may be applicable.

5 CUMULATIVE EFFECTS *

This chapter identifies possible cumulative effects of the considered alternatives when combined with past trends and other ongoing or expected future plans and projects.

5.1 CUMULATIVE EFFECTS OVERVIEW

Cumulative effects result from the proposed action when added to other past, present and reasonably foreseeable projects or actions. Cumulative effects are not caused by a single project, but include the effects of a particular project in conjunction with other projects (past, present and future) on the particular resource. Cumulative effects are studied to enable the public, decision-makers and project proponents to consider the "big picture" effects of a given project on the community and the environment. In a broad sense, all impacts on affected resources are probably cumulative; however, the role of the analyst is to narrow the focus of the cumulative effects analysis to important issues of national, regional and local significance (CEQ, 1997).

The Council of Environmental Quality (CEQ) issued a manual entitled *Cumulative Effects Under the National Environmental Policy Act* (CEQ, 1997). This manual presents an 11-step procedure for addressing cumulative impact analysis.

Box 5-1. Approach to Cumulative Effects

Scoping

1. Identify resources
2. Define the study area for each resource
3. Define time frame for analysis

Describing the Affected Environment

4. Identify other actions affecting the resources
5. Characterize resources in terms of its response to change and capacity to withstand stress
6. Characterize stresses in relation to thresholds
7. Define baseline conditions

Determining the Environmental Consequences

8. Identify cause-and-effect relationships
9. Determine magnitude and significance of cumulative effects
10. Assess the need for mitigation of significant cumulative effects
11. Monitor and adaptive management, accordingly

The cumulative effects analysis for the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study followed these 11 steps, shown in Box 5-1. The cumulative effects analysis concentrates on whether the actions proposed for this Study, combined with the impacts of other projects, would result in a significant cumulative impact, and if so, whether this Study's contribution to this impact would be *cumulatively considerable*.[33]

5.2 SCOPING FOR CUMULATIVE EFFECTS

5.2.1 BOUNDING CUMULATIVE EFFECTS ANALYSIS

Cumulative effects analysis requires expanding the geographic boundaries and extending the time frame to include additional effects on the resources, ecosystems, and human communities of concern.

[33] Cumulatively considerable means that the incremental effects of an individual action are significant when viewed in connection with the effects of past, present, and probable future actions.

5.2.1.1 IDENTIFYING GEOGRAPHIC BOUNDARIES

The USACE planning determined geographic boundaries for each resource by the distribution of the resource itself, and the area within that distribution where the resource could be affected by considered action alternatives in combination with other past, present and reasonably foreseeable actions. The primary area considered in the cumulative effects analysis is limited to the Meramec River Basin.

5.2.1.2 IDENTIFYING TIMEFRAME

The timeframe for the cumulative effects analysis for each considered resource begins when past actions began to change the status of the resource from its original condition, setting the long-term trend currently evident and likely to continue into the reasonably foreseeable future. The timeframe for this analysis began in the early 1800s when the region began to be altered by non-indigenous settlers and ends in 2073 (end of 50-year period of analysis for the study).

5.2.2 IDENTIFYING PAST, PRESENT AND REASONABLY FORESEEABLE FUTURE ACTIONS

Chapter 2 discussed the existing condition of each resource by describing the present condition and providing historical context (e.g., the past condition) for how the resource was altered to the current conditions. Field surveys, discussions with project sponsor and subject matter experts, scoping comments, and literature searches were used to assess the past and existing conditions of the resource and to identify present and reasonably foreseeable future actions.

“Reasonably foreseeable actions” were defined as actions or projects with a reasonable expectation of actually happening as opposed to potential developments expected only on the basis of speculation. Accordingly, the following criteria was applied when determining reasonably foreseeable actions:

- Actions on an agency’s list of proposed actions
- Actions where scoping has started
- Actions already permitted
- Actions where budgets have been requested

The St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study complements these present and future actions.

The cumulative effects analysis used the list-based approach, and considers the effects of the Study together with those of other past, present or probably future actions proposed by the USACE or others, as shown in Table 5-1. Study complements these past, present, and future actions.

Table 5-1. Projects Considered in Cumulative Effects Analysis

Project Name	Project Sponsor or Jurisdiction	Project Description	Status	Completion Dates
Lower Meramec Floodplain Management Plan	USACE, East-West Gateway Council of Governments, The Nature Conservancy, USGS, 3 counties, and 8 municipalities, MoDNR, FEMA	Partnership effort designed to assist in the development of a multi-jurisdictional floodplain management plan, identifying findings and the specific action items for non-structural measures, practices, and policies to reduce loss of life, injuries, damages to property and facilities, public expenditures, and other adverse impacts associated with flooding.	Planning/ Ongoing	Final Report 2019
Meramec River Project – Healthy Watershed Options for Floodplain Management	USEPA, Lower Meramec Floodplain Management Plan Partners, Witchita State University Environmental Finance Center	Supplement to the Lower Meramec FMP providing technical assistance in the form of a toolkit on healthy watershed practices communities may choose to implement to reduce localized flooding and impacts, including case studies, implementation processes, timing, cost-benefit information, funding options.	Planning/ Ongoing	TBD
Monitoring	Trustees, MoDNR, MDC	Biological & physical monitoring along the Big River and Meramec River	Ongoing	Ongoing
Local Stream Teams	MoDNR	Local stream teams led by the MoDNR would continue with local stream clean-ups and public outreach	Continual	Continual

Private Landowners regulatory permitting actions	Private landowners/ entities	Since 2015, the USACE Regulatory Program is currently working or has completed 55 permit applications along the Big River. Of these, 12 were Nationwide Permit 13 for bank stabilization, 7 were Nationwide Permit 14 for related to transportation crossings, and 28 were Nationwide Permit 3 related to maintenance. Even though applications are not guaranteed to result in construction, they are included here to provide a relative scope of the types of activities being pursued by others. Forecasting future permit activities is not well developed; therefore, it is assumed that future permit activities within the study area would be similar to the existing permit requests.	Continual	Continual
Big River – St. Francois County priority restoration areas	Trustees (USFWS and MoDNR), MDC, USGS, USACE, and USEPA	In June, September and October of 2017 representative of the Trustees and supporting agencies conducted a reconnaissance of the Big River in St. Francois County to identify potential restoration projects. USEPA's objective was also to identify potential remedial action projects. The agencies identified six areas with flowing boreholes, 12 eroding banks, 14 riparian corridors, and 24 gravel bars that could be priority areas for response actions/ or restoration depending on future decisions.	Under Evaluation	TBD; Funding Dependent

Big River – St. Francois County near Desloge, Missouri	Trustees	Upland and floodplain restoration and development of county park near Desloge, Missouri	Under Evaluation	TBD, Funding Dependent
Big River – Washington County Alternative water project	Trustees	Two small-scale bank stabilization projects using bioengineering measures and one cattle exclusion	Completed	2018
Byrnes Mill City Park	USEPA/USACE	Removal of contaminated soil and replacement of clean material at River Mile 8.5 along the Big River	Completed	2015-2016
Rockford Beach	USEPA/USACE	Dam stabilization project at River Mile 10.2 on the Big River	Interim Completed	2016
Rockford Beach	USEPA/USACE	Dam rehabilitation study/project at River Mile 10.2 on the Big River	Under Evaluation	Report in 2019
Calico Creek	USEPA/USACE/ in collaboration with the Trustees	Partnered contaminate stabilization and ecosystem restoration River Mile 52 on the Big River	In Design	Expected construction 2019-2020
Newbury Riffle Project	USEPA/USACE	In-stream sediment detention structure and off-channel sediment collection pilot project at River Mile 96 on the Big River	In Operation; Ongoing Monitoring	Constructed 2014-2015
Mammoth Road	USEPA/USACE	Off-channel sediment collection pilot project at River Mile 59 on the Big River	In Operation; Ongoing Monitoring	Constructed 2017

Mineral Fork/ Dug-Out Road	USEPA/USACE	Bank stabilization project on Mineral Fork Creek within the Big River floodplain (Big River Mile 61.3)	In Operation; Ongoing Monitoring	Constructed 2017
Meramec River Basin Watershed Management Plan and Soil Water Assessment Tool (SWAT)	St. Louis University, TNC	Basin-wide modeling effort that will be used to help identify sources of sediment and nutrients within the Meramec River Basin	Under Development	2019
Big River Watershed Master Plan	Prepared by the URS Corporation	This master plan provides specific strategies for consideration by agencies in the development of their management plans for remediation and restoration for Jefferson County, St. Francois, and Washington Counties.	Completed	2014
Southwest Jefferson County Mining Superfund Site, Operable Units 1-3, Residential Properties	USEPA	The Record of Decision Operable Unit 1 (Residential Yards) set a target clean up level of 400 ppm for lead for residential yards. The ROD identifies that the USEPA generally selects a residential soil cleanup level within the range of 400 ppm to 1,200 ppm	Ongoing	ROD for OU-1 2011

Southwest Jefferson County Mining Superfund Site, Operable Unit 4 – Big River and Floodplain, Jefferson County	USEPA	This site includes all of Jefferson County, Missouri (excluding the Herculaneum Site). The Remedial Investigation (RI) includes the Big River and floodplain to determine the full extent of mining-related metals contamination and to evaluate human health and ecological risk. Upon completion of the RI, the USEPA plans to initiate a Feasibility Study to evaluate remediation alternatives. The ROD for OU-4 would inform this Study's HTRW level.	Ongoing	TBD
Southwest Jefferson County Mining Superfund Site, Operable Unit 5 -8, includes groundwater, Valles Mines area, rail lines, and mine waste areas	USEPA	Ongoing Remedial Investigation activities. USEPA works on the various operable units on a priority basis, based on the potential for human health and environmental risk.	Ongoing	TBD
Historic Mining	Various Parties	Heavy metals mining throughout the study area altered the Big River.	1700-1970s	

5.2.3 CUMULATIVE EFFECTS BY RESOURCE

The remainder of this chapter describes the results of the cumulative effects analysis for each resource considered from Chapters 2 and 4. Table 5-2 is a checklist identifying potential incremental cumulative effects on the resources affected by the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study. Table 5-3 provides the cumulative effects analysis which includes the past, present and reasonably foreseeable actions that might impact each resource category identified to have an incremental cumulative effect. If a resource was not identified to have a cumulative effect then this resource was not discussed in detail. The cumulative effects analysis discusses future conditions of the no USACE Action (without project) and with the project (discussed in whole, as an alternative, unless otherwise noted).

Table 5-2. Checklist for Identifying Potential Cumulative Effects

Resource	Without Project	With Project		Past Actions	Other Present Action	Other Future Actions	Project's Incremental Cumulative Impact
		Construction	Operation				
Geology & Soils, including Prime Farmland	X	S1	X	S	S	S	X
Stream Geomorphology	M	X	+	M	S	X	+
LULC	X	S1	+	H	S	S	+
Hydrology	X	S1	X	X	X	X	X
Hydraulics	H	S1	+	H	X	X	+
Sediment	H	S1	+	H	X	X	+
Water Quality	S	S1	+	S	S	S	+
HTRW	H	X	+	H	+	+	+
Biological Resources (fish, freshwater mussels, other aquatic organisms, wildlife, birds, amphibians, reptiles, T&E species)	H	S1	+	H	X	X	+
Floodplain & Riparian Forest	M	S1	+	H	X	X	+
Invasive Species	+	X	S	+	+	X	X
Historic & Cultural Resources	X	X	X	X	X	X	X
Socioeconomics	X	+	X	X	X	X	X
Environmental Justice	X	X	X	X	X	X	X
Noise	X	X	X	X	X	X	X
Resources of Recreational, Ecological, Scenic, or Aesthetic Importance	X	X	X	X	X	X	X
Air Quality	X	X	X	X	X	X	X
Climate Change	X	X	X	X	X	X	X

KEY *X = no change* *S = slight adverse effect* *S1 = temporary, slight adverse effect*
M = moderate adverse effect *H = high adverse effect* *+ = beneficial effect*

Table 5-3. Cumulative Effects Analysis for Identified Resources

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Considered Action Alternatives
Stream Geomorphology	Improper gravel mining and reaming, mill dams, past mining activities	Continued improper gravel mining and reaming; continued mill dams on the Big River	Continued outreach by natural resource partners to educate landowners on proper gravel mining practices	Continued intermittent gravel mining and reaming practices; mill dams expected to remain or degrade further with potential to induce head cutting within Big River; existing identified disturbance reaches would continue to degrade stream geomorphology of the Big River	Project measures to help stabilize areas of high channel change and restore the stream geomorphology and provide grade control
Land Cover & Land Use	Deforestation, historic heavy metal mining, conversion to agriculture greatly altered the forested watershed	Continued fragmented floodplain forest, improper gravel mining and reaming, floodplain agriculture (e.g., sod farming), and urban growth	Continued outreach by natural resource partners to educate landowners on importance of a healthy riparian corridor and best farming practices. Expected future urban growth in the lower Meramec River watershed	Continued lack of connected riparian corridor, intermittent gravel mining and reaming practices, and floodplain sod farming, urban growth expansion	No negative impacts expected with reforestation. Some areas currently in agriculture would be converted to floodplain forest. Use of proper bed sediment removal practices would improve land use practices. No considered alternative expected to alter the projected urban growth

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Considered Action Alternatives
Hydraulics	Transformation of river system from natural condition to pooled areas from the historic mill dams; loss of natural river habitat function due to contamination; gravel mining and reaming; historic mining practices; USACE, other federal, state, and private habitat restoration and land management programs	Continued impacts due to land use changes in watershed; gravel mining and reaming; intact mill dam at Byrnesville; repair work by USEPA at Rockford Beach mill dam; continued restoration, flood risk management, and land management programs by the USACE, other Federal and state agencies; bank stabilization work by private landowners	Continued impacts due to land use changes in watershed, intact mill dam at Byrnesville and Rockford Beach; continued restoration, flood risk management, and land management programs by the USACE, other federal and state agencies; continued bank stabilization work by private landowners; continued gravel mining and reaming	Continued altered hydraulics	No negative impacts expected; improved hydraulics of the Big (Alternatives 5 and 7) and Meramec Rivers (Alternative 7) by reducing bank erosion, stabilizing the bed, and restoring natural sediment transport
Sediment	Historic heavy metal mining practices; failed tailings piles; movement of contaminated floodplain soil via sod farming; continued re-distribution of contaminated sediment during high flood events	Continued re-distribution of contaminated sediment during high flood events; USEPA remedial investigation and pilot studies within the study area; Trustees investigating how contaminated sediments result in injury to the mussels and other fish and wildlife. Continued land management programs by non-profits, Federal and state agencies	Potential for USEPA institutional controls; continued USEPA remedial investigation and potential future remedial actions within the study area; continued land management programs by non-profits, Federal and state agencies	Continued decline of the aquatic ecosystem as well as further degradation, as contaminated sediment migrates downstream	Reduction in contaminated sediments would provide a net benefit to aquatic life, reduce future impacts to downstream fauna and habitats, restore the ecosystem function within the study area and reduce future impacts to habitats downstream

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Considered Action Alternatives
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. Land use changes; historic heavy metal mining; deforestation; urbanization and run-off; localized areas of dumping into the river	Continued population growth and development result in increased potential for water quality impacts. Continued regulation enforcement and societal recognition help reduce water quality degradation. Programs by state and non-profit agencies as well as private citizens to improve water quality through stream teams and clean-ups; urbanization and run-off; continued localized dumping	Continued regulation enforcement and societal recognition. Continued population growth and development result in increased potential for water quality impacts related to urbanization, run-off, localized dumping. Programs by state and non-profit agencies as well as private citizens to improve water quality through stream teams and clean-ups	Continued degraded water quality (e.g., total suspended solids, dissolved oxygen, heavy metals)	Localized, temporary increase in suspended sediment concentrations during construction activities. In the long-term, the considered action alternatives would enhance the ongoing work by others restoring the water quality; these positive actions are expected to counter the continued pollution and past actions of others. No cumulative negative effects are expected.
HTRW	Historic industrial heavy metal mining practices generating very large piles of chat and slimes that are eroded by wind and water over time; failed tailings piles	USEPA remedial investigation determining HTRW levels for lead and other heavy metals; continued investigations by Trustees	USEPA record of decision for Jefferson County; continued assessment and restoration by Trustees	Continued downstream migration of contaminants into the lower Meramec Basin related to continued mine waste releases and migration of contaminated sediments downstream	Considered action alternatives seek to restore ecosystem structure and function within the study area by reducing transport of contaminated sediment and capture along with restoring the riparian corridor. Measures would avoid areas identified as HTRW unless a response action has been taken (as defined by USACE policy); however, measures would aid in the restoration of the aquatic environment by reducing sediments (including contaminated sediments) within the study area

Resource	Past Actions	Present Actions	Future Actions	No Action Alternative	Considered Action Alternatives
Biological Resources, including T&E Species	Land use changes; habitat fragmentation and conversion; loss of habitat both aquatic and floodplain; heavy metal contamination; USACE, other Federal, state, non-profit, and private habitat restoration and land management programs reduce habitat loss; recognition of T&E species through the Endangered Species Act (ESA); listing of multiple T&E species within the study area	Monitoring of fish and wildlife species, including T&E species, by Federal and state agencies; continued degradation of aquatic habitat related to heavy metal contamination; continuation of Federal, state, non-profit, and private habitat restoration and land management programs	Monitoring of fish and wildlife species, including T&E species, by Federal and state agencies; continued degradation of aquatic habitat related to heavy metal contamination; continuation of Federal, state, non-profit, and private habitat restoration and land management programs; continued negative impacts of heavy metal contamination; habitat loss; loss of riparian corridor	Decline of quality and quantity of ecosystem resources; continued loss of important habitat needed by fish and wildlife, including T&E species	The projects are designed to benefit biological resources, particularly T&E species. Temporary, minor, local impacts due to construction as well as operation and maintenance of some constructed features (e.g., bed collectors, sediment basins); long-term benefits expected that may affect, but not likely to adversely affect listed species. Conservation measures and best management practices would be implemented to avoid and minimize impacts to T&E species
Floodplain and Riparian Forest Resources	Increasing human populations and industrialization resulted in deforestation of the watershed; loss of riparian corridor; remaining forest fragmented	Continued population growth and development result in increased potential for forestry impacts. Federal, state, and non-profit agencies habitat restoration and land management programs; continued loss of riparian corridor	Continued population growth and development result in increased potential for forestry impacts. Federal, state, and non-profit agencies habitat restoration and land management programs; continued loss of riparian corridor	Decline of riparian corridor and degraded floodplain forest; loss of important forest habitat for T&E species	Some tree clearing during construction is anticipated with all considered action alternatives. Best management practices and conservations measures would be implemented to avoid and minimize forest habitat important to T&E species (i.e., bats). The loss of some existing trees would be off-set by reforestation of a larger area with each considered action alternative. Overall, a net positive cumulative impact to forest resources is expected with implementation of any of the considered action alternatives

6 ALTERNATIVE EVALUATION AND SELECTION

6.1 HABITAT BENEFITS

Further evaluation of the final array of alternatives was completed by quantifying habitat benefits through assessing existing conditions, forecasting future conditions, and comparing each alternative to the No Action Alternative. An interagency team (USACE, USFWS, MoDNR, MDC, and TNC) conducted the habitat evaluation. Aquatic and floodplain benefits were quantified using the Habitat Evaluation Procedures (HEP; USFWS 1980a). Two habitat cover types, riverine and floodplain, were evaluated to determine benefits since these two habitat cover types reflect the majority of the existing and future without project habitats and reasonably capture benefits.

6.1.1 HABITAT EVALUATION PROCEDURES

The habitat evaluation procedure (HEP) is a habitat-based evaluation methodology used in project planning. The evaluation documents the quality and quantity of available habitat for selected wildlife species. The HEP is based on the assumption that habitat for selected wildlife species can be described by a Habitat Suitability Index (HSI). This index value (from 0.0 to 1.0) is multiplied by the area of applicable habitat to obtain Habitat Units (HUs).

Changes in HUs will occur as a habitat matures naturally or is influenced by development. These changes influence the cumulative HUs derived over the life of the Project (50 years). Habitat units for select target years were calculated, and annualized for 50 years to derive net Average Annual Habitat Units (AAHUs). Net AAHUs were calculated by comparing each action alternative to the No Action Alternative. Net AAHUs were used as the output measurement to compare the considered action alternatives. Further details are provided in Appendix B-*Habitat Evaluation and Quantification*.

6.1.2 FRESHWATER MUSSEL HABITAT BENEFIT

HEP procedures were used to evaluate the effects of the considered alternatives on aquatic habitat quantity and quality. The Meramec River Basin Freshwater Mussel Habitat Suitability Index Model (certified for single-use per EC 1105-2-412) was used to assess the benefits of the individual alternatives to the freshwater mussel habitat. Freshwater mussel was selected as an indicator species to evaluate aquatic habitat benefits because freshwater mussels are prominent throughout the study area, are resources of concern, and are well known to be bio-indicators for aquatic habitat quality. An assessment of existing study area conditions, projected future conditions without the project, and expected impacts of proposed alternatives was completed. Appendix B-*Habitat Evaluation and Quantification* provides the detailed description of the habitat analysis.

6.1.3 RIPARIAN HABITAT BENEFIT

HEP procedures were used to evaluate the effects of the considered alternatives on floodplain habitat quantity and quality. The Black-Capped Chickadee Habitat Suitability Index Model (approved for regional and nationwide use per EC 1105-2-412) was used to assess the benefits of the individual alternatives to the riparian habitat. This model uses three parameters: average height of over-story trees, tree canopy cover, and density of snags. This model was selected to evaluate the riparian forest habitat because the model parameters indicate a forest structure the Study was seeking to restore. Restoring the forest structure would benefit numerous native wildlife and birds. An assessment of existing study area conditions, projected future conditions without the project and expected impacts of proposed project measures was completed. Appendix B-*Habitat Evaluation and Quantification* provides the detailed description of the habitat analysis.

6.1.4 KEY ASSUMPTIONS IN BENEFIT ANALYSIS

Future Without Project Lead Concentrations: As discussed in chapter 2, previous USEPA's RODs generally have determined clean up levels for lead in yards between 400 ppm and 1,200 ppm. Sampling has shown existing conditions of total lead are generally below 1,200 ppm. It is assumed USEPA will set a remedial action of 1,200 ppm. This level allows the widest array of alternatives to be evaluated and does not prematurely constrain the study. Due to the high uncertainty of the future clean-up levels, the USACE actively managed to reduce this risk by performing the habitat evaluation using three different scenarios for future without project lead concentrations: the USEPA would set it at 400 ppm, 1,200 ppm, or does nothing.

Bank Stabilization: Bank stabilization benefit calculation assumptions include (1) the material less than 0.25 mm is readily suspended (66% of bank material), (2) bank material has a density of 82 pounds per cubic foot (1.31 grams per cubic centimeter), (3) there is a fairly even distribution of bank stabilization sites along entirety of Big River, (4) median total suspended solids (TSS) of 16 mg/L, and (5) banks are impacted greater than 400 ppm to a depth of 7.2 feet (Pavlowsky 2010).

Sediment Basin: Sediment capture basins benefit calculation assumptions include 1) traps less than 2mm sediment; 2) the basin is active during an average of 4 events per year; 3) basin capture material is 102 pounds per cubic foot; and 4) capture efficiency remains constant throughout lifespan.

In-stream excavation (Removal): Sediment removal benefit calculation assumptions include 1) compliance with existing regulations on buffer distance and excavation depth; 2) 100% of deposited material is accessible for recovery; and 3) 100% of recovered material is retained during removal and handling.

Grade Control Structure: Grade control structure benefit calculation assumptions include 1) 1.5 events per year will contribute material; 2) assumes 450 cubic yards of material is deposited with each event (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016); 3) assumes 100% of deposited material is accessible for recovery; and 4) assumes 100% of recovered material is retained during removal and handling.

Bed Sediment Collectors: Bed load collector benefit calculation assumptions include 1) assumes 1.5 events per year pass material through collectors; 2) assumes 450 cubic yards of material is available to the collectors during each event (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016); 3) assumes 60% of available material is actually collected; 4) assumes 75% of collected material is less than 2mm; and 5) assumes 100% of collected material is retained during handling.

6.1.5 MANAGEMENT OF UNCERTAINTY IN BENEFIT ANALYSIS

Bank Erosion: Bank erosion was visually identified as occurring but the quantity or distribution of sediment size from those sites was unknown, which led to a high level of uncertainty about how much bank stabilization was needed to meet study objectives. Therefore, bank lines from three imagery sets were traced, spanning 26 years, to determine the eroded area. The eroded area, combined with bank heights from LiDAR, was used to estimate eroded bank volume and estimated average annual erosion. After performing sensitivity analysis between imagery sets, concluding that the intensity of erosion at different sites varies but the overall sediment input from the selected banks is relatively constant. Therefore, it was also concluded when bank stabilization sites are well-distributed throughout the study area there is no sizable change in benefits and thus parametric estimates are an accurate way to estimate future benefits regardless of specific bank stabilization sites chosen.

<u>Spatial Distribution of Mining Waste</u>: There was uncertainty about the spatial distribution of contaminated sediment throughout the study area, specifically the distribution between channel, bars, banks, and floodplain. This uncertainty made it difficult to assess the risk of migration and/or reintroduction of sediments into the system. It also made it difficult to confidently design efficient solutions to stabilize or capture that sediment. Multiple in-depth studies and sampling efforts that examined and interpreted the trends in sediment distribution throughout the study area were completed, then this knowledge was applied to models that quantified benefits and cost-benefit efficiencies to potential measures (e.g., bank stabilization, bed load collectors and sediment basins). This effort allowed the ratio of measures to be adjusted to optimize sediment removal, economics, and habitat units while maintaining a firm understanding of the upper benefit limits of each measure.

<u>Bedload Transport Rate and Frequency</u>: Downstream movement rates of bedload during higher flows was unknown. This uncertainty made it difficult to design a bedload solution that could adequately address the downstream migration of in-stream contaminated sediment. To reduce this uncertainty bed load capture rates were extrapolated from a case study within the Big River system by Pavlowsky (2016). This analysis allowed the bed load solution to be scaled within reason and with a greater level of confidence.

<u>Sediment Basin Fill Rate</u>: The quantity of contaminated sediment that would deposit within a sediment basin was unknown. Despite having a strong case conceptually, this uncertainty made it difficult to estimate the cost, benefits, and effectiveness of sediment basins. To reduce this uncertainty off-stream sediment basin capture rates were extrapolated from a case study within the Big River system by Pavlowsky (2016). This greatly reduced the uncertainties regarding sediment basin fill rates and target grain sizes.

<u>Tributary Sediment Contributions</u>: The quantity and quality of sediment contributions by minor tributaries to the Big River was unknown. This uncertainty affected the types and locations of bank stabilization and bed sediment collection measures. Consultation with outside experts and a simple confluence analysis was performed to conclude that tributary inputs helped the health of the sediment in the system but put pressure on banks at their confluence; therefore, bank stabilization measures must be robust at tributary confluences where bank failure is an issue.

<u>Land Use and Resulting Overland Flow</u>: The quantity of sediment contributed to the Big River by overland flow was unknown. The impact of land management practices on river sediment was uncertain. As a result, Saint Louis University (SLU) completed a Soil and Water Assessment Tool (SWAT) model for the TNC, which modeled the effects of land use on sediment contributions to the Big River. Results from this model highlight areas of greater sediment input and allowed watershed management recommendations to partners and local governments.

<u>Mill Dams</u>: The quantity of sediment stored behind mill dams was unknown. This uncertainty was important to address because a few of the mill dams are assumed to fail in the near future. Mill dam failures could release a significant amount of contaminated sediment into the system. To reduce the uncertainty of dam failure affects the USACE planning team consulted with experts, conducted a literature review, and reviewed USACE technical guidance. As a result, quantification of sediment behind mill dams is not possible with any amount of certainty since sediment is transient (Pearson & Pizzuto, 2015; Csiki & Rhoads, 2014; Csiki & Rhoads, 2010). However, sudden mill dam failure can lead

to head-cuts which will propagate upstream and cause bed and bank instability causing reintroduction of sediments. Mitigation for this high consequence includes grade control structures to account for dam failure effects.

Bed Stability: Long-term vertical stability of the Big River bed is unknown. Changes in elevation over time to the bed of the river at a specific location could indicate a system-wide issue. A specific gage analysis was conducted that showed the bed was relatively stable. As a result of this analysis, a better understanding of the natural stability of the Big River bed was realized and measures that are more sensitive to vertical bed movements were proposed.

Lead Reduction: The quantity of lead that could be removed as a result of proposed measures was unknown. A method, based on peer-reviewed research that tied sediment removal to lead removal was developed. This methodology was used to estimate the total lead removed as a result of individual measures and allowed lead concentration levels to be quantified for alternatives accordingly.

USEPA Future Conditions: It was uncertain how variances to the assumed USEPA remedial actions (discussed in Section 2.6.2 – HTRW Future without Project Conditions) affect alternative benefits. Benefits for the anticipated high and low future lead levels were developed (400 ppm and 1,200 ppm) to account for the greatest anticipated lead level variance. Institute for Water Resources (IWR) planning suite (defined in Section 6.3) shows that while there is an overall decrease in cost effectiveness for all alternatives on the Big River at 400 ppm, a change in lead concentrations does not affect whether a plan is cost effective (Figure 6-1). Reducing the risk of various lead levels on the cost effectiveness of an alternative.

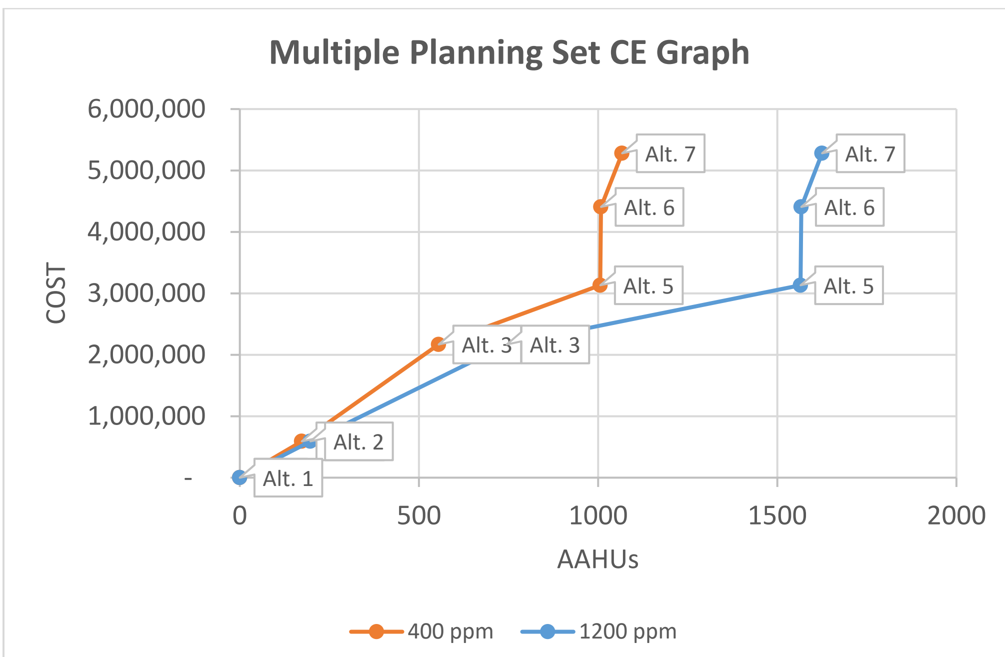


Figure 6-1. Benefit Variance between USEPA 400 ppm and 1200 ppm remedial action levels

Additionally, as discussed in Section 3.12 – *Final Array of Alternatives*, uncertainty of overlap between the USACE study and USEPA remedial action sites was actively managed by formulating and evaluating benefits of two alternatives in areas below the lowest assumed USEPA remediation levels of 400 ppm (Alternative 2 - Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2 and Alternative 3 - Subset Maximize Ecosystem Benefits in the Big River, RM 0-35). Figure 6-2- *Figure 6-2. Cost Effective*

Analysis of Final Array of Alternatives graphically displays that both subset alternatives 2 and 3 are cost effective, reducing the uncertainty of recommending a poor Federal investment if the actual USEPA remedial action level is lower than the lowest assumed USEPA remediation levels of 400 ppm.

More information on Future Without-Project (FWOP) scenarios can be found in Appendix B-*Habitat Evaluation and Quantification.*

6.1.6 BENEFITS OF FINAL ARRAY OF ALTERNATIVES

Table 6-1 lists the calculated net average annual habitat benefits for the final array of alternatives to be evaluated.

Table 6-1. Net Average Annualized Habitat Units (AAHUs) at 1,200 ppm FWOP Lead Levels

Alt #	Alterative Description	Floodplain Forest Net AAHUs	Aquatic – Riverine Net AAHUs	Total Net AAHUs
1	No Action	0	0	0
2	Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2	122	75	197
3	Subset Maximize Ecosystem Benefits in the Big River, RM 0-35	361	384	745
4	Maximizes Ecosystem Benefits in the Meramec River	15	11	26
5	Maximizes Efficiency in the Big River	553	1,012	1,565
6	Maximizes Ecosystem Benefits in the Big River	557	1,010	1,567
7	Maximizes Ecosystem Benefits in the Study Area	572	1,053	1,625

6.2 ALTERNATIVE COST ESTIMATE

Parametric costs, or rough order of magnitude costs, were used to estimate costs for construction, monitoring, adaptive management, and OMRRR. An abbreviated risk analysis was performed to inform the contingency for each alternative. This was paired with the anticipated schedule used to estimate annualized costs. Interest was calculated during the construction phase based on the construction schedule. The annualized economic cost of each alternative was also calculated using the 50-year period of analysis and FY 2018 discount rate of 2.75%. Table 6-2 provides a breakout of costs for each alterative.

Table 6-2. Final Array of Alternatives Cost and Habitat Benefits. (FY 2018 Price Level – 50 year period of analysis using 2.75% discount rate and 2 year construction schedule)

	Construction Cost	Monitoring Adaptive Management Measures	Planning Engineering Design/ Construction Oversight Costs	Contingency	Land, Easements, Rights of Way, Relocations, Disposal	Interest During Construction	Annualized Costs	Annualized Operation Maintenance, Repair, Replace, Rehabilitate	AAHUs
Alt 1	$0	$0	$0	$0	$0	$0	$0	$0	0
Alt 2	$8,241,000	$897,000	$1,978,000	$2,650,000	$1,282,000	$214,000	$578,000	$13,000	197
Alt 3	$29,980,000	$3,034,000	$7,195,000	$9,618,000	$5,132,000	$785,000	$2,059,000	$122,000	745
Alt 4	$11,837,000	$1,384,000	$2,841,000	$3,733,000	$634,000	$288,000	$758,000	$128,000	26
Alt 5	$43,694,000	$5,347,000	$10,487,000	$14,007,000	$5,328,000	$1,112,000	$ 2,921,000	$211,000	1,565
Alt 6	$60,527,000	$8,980,000	$14,527,000	$19,664,000	$5,967,000	$1,523,000	$4, 051,000	$356,000	1,567
Alt 7	$72,353,000	$10,143,000	$17,365,000	$23,267,000	$6,600,000	$1,809,000	$4,796,000	$484,000	1,625

6.3 COST EFFECTIVE/INCREMENTAL COST ANALYSIS

To determine the National Ecosystem Restoration Plan (alternative that reasonably maximizes habitat benefits compared to cost), the average annual habitat units and annualized costs from Table 6-2 of the considered alternatives (including the no action) were entered into the IWR-Planning Suite; a water resources investment decision support tool for evaluation of actions involving monetary and non-monetary cost and benefits. The purpose of entering the data was to analyze the cost effectiveness of each alternative and perform an incremental cost analysis on cost effective alternatives. Cost effective alternatives are plans that have the greatest benefit of all alternatives for that cost. A secondary analysis on the subset of cost-effective alternatives identifies superior financial investments, called "Best Buys," through analysis of incremental costs. Best Buys provide the greatest increase in AAHUs for the least increase in cost. The first Best Buy is the most efficient plan, producing benefits at the lowest incremental cost per unit. If a higher level of benefit is desired then the second Best Buy is the most efficient plan for producing additional benefit, and so on.

6.3.1 COST EFFECTIVE ALTERNATIVES

Figure 6-2 shows the considered alternatives and their cost per habitat unit. All but one alternative, Alternative 4 - Maximizes Ecosystem Benefits in the Meramec River, was considered cost effective. This is because more benefit, for less money, can be achieved by Alternative 2 - Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2. The remaining six alternatives were analyzed to determine which alternatives had the best cost for each additional increment of output (Table 6-3).

Table 6-3. Cost Effective Alternatives

#	Alternative	Outputs (AAHU) FWOP set by USEPA 1200 ppm	Outputs (AAHU) FWOP set by USEPA 400 ppm	Annualized Cost ($)	Average Cost ($) per AAHU FWOP set by USEPA 1200 ppm	Average Cost ($) per AAHU FWOP set by USEPA 400 ppm
1	No Action	0	0	$0	$0	$0
2	Subset Maximize Ecosystem Benefits in the Big River, RM 0-10.2	197	173	$591,000	$3,000	$3,416
3	Subset Maximize Ecosystem Benefits in the Big River, RM 0-35	745	555	$2,181,000	$2,928	$3,929
5	Maximizes Efficiency in the Big River	1,565	1,006	$3,132,000	$2,001	$3,113
6	Maximizes Ecosystem Benefits in the Big River	1,567	1,008	$4,407,000	$2,812	$4,372
7	Maximizes Ecosystem Benefits in Study Area	1,625	1,067	$5,280,000	$3,249	$4,948

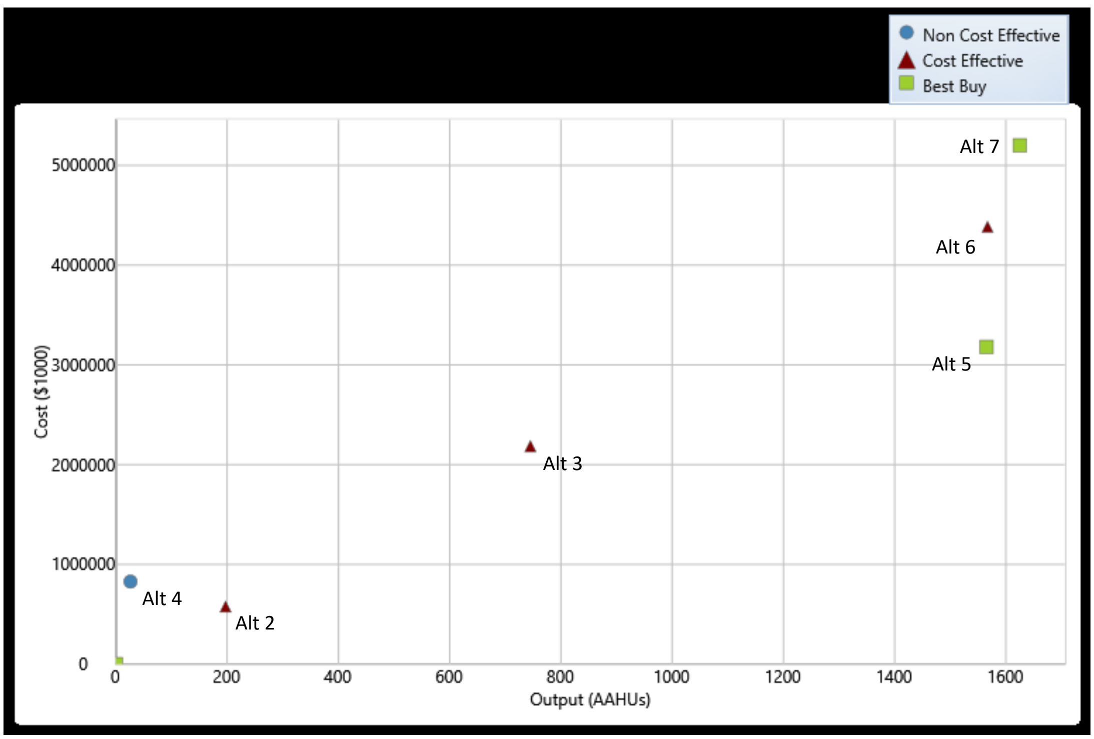


Figure 6-2. Cost Effective Analysis of Final Array of Alternatives

6.3.2 INCREMENTAL COST ANALYSIS

Three of the six cost effective alternatives were considered incrementally justified: No Action Plan, Alternative 5-*Maximizes Efficiency in the Big River,* and Alternative 7-*Maximizes Ecosystem Benefits in Study Area*. Table 6- 4 and Figure 6-3 present the best buy alternative incremental cost and benefit information. The first Best Buy, No Action Plan, is the lowest incremental cost but produces no benefit. The next Best Buy is Alternative 5-*Maximizes Efficiency in the Big River* at a cost of $2,032 per average annual habitat unit, or an incremental cost increase of $3,180,000 for 1,565 habitat units. The incremental cost increase for the additional 60 habitat units is Alternative 7, which provides $2,021,000, or a cost of $33,683 for each additional average annualized habitat unit.

Table 6- 4. "Best Buy" Alternatives

#	Alternative	Outputs (HU)	Annualized Cost ($)	Average Cost ($)	Incremental Cost ($)	Incremental Output (AAHU)	Incremental Cost/Output ($/AAHU)
1	No Action Plan	0	$0	$0	$0	0	$0
5	Maximizes Efficiency in the Big River	1,565	$3,180,000	$2,032	$3,180,000	1,565	$2,032
7	Maximizes Ecosystem Benefits in Study Area	1,625	$5,201,000	$3,201	$2,021,000	60	$33,683

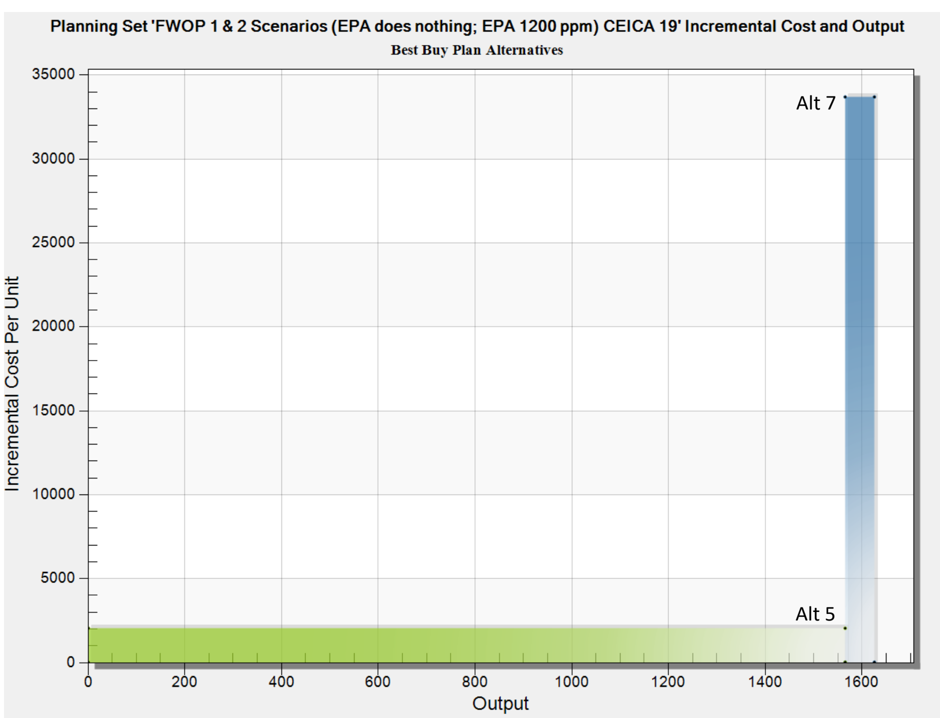


Figure 6-3. Graph Depicting "Best Buy" Alternatives

6.3.3 COMPARISON AND EVALUATION OF FINAL ARRAY OF ALTERNATIVES

The final array of alternatives were evaluated, defined in Section 3.12, using the four Principle & Guidelines criteria, four accounts, study opportunities, study constraints and environmental effects on identified resources. Table 6-5 displays the final array of alternatives evaluation.

The alternative evaluation was conducted with the supposition that a USEPA ROD is established and sites are below the remediation levels set by the USEPA.

6.3.3.1 PRINCIPLE & GUIDELINES CRITERIA

Each alternative in the final array was independently evaluated by metrics for each of the USACE four screening criteria: Completeness, Effectiveness, Efficiency, and Acceptability. A score of "high" signifies the metric was met considerably, a score of "medium" denotes the metric was met moderately, and a score of "low" indicates the metric was minimally met, if at all.

- Completeness. No additional investments, or actions, by others to realize the benefits were identified so all alternatives scored high.
- Effectiveness. All the alternatives in the final array provide some contribution to the study objectives.

  The efficacy in which alternatives met Objective 1, Reduce the downstream migration of excess mining derived sediment from the Big River, over the 50-year period of analysis, in order to protect and restore degraded aquatic and freshwater mussel habitat, was measured by the amount of aquatic habitat units achieved. If the alternative contributed over 1,000 AAHUs, it was given a high score, alternatives that contributed between 100-999 AAHUs were given a medium score, and all other alternatives were given a low score.

  The efficacy in which alternatives met Objective 2, Restore impacted channels and floodplains in the Big River and Meramec River systems to mimic a more natural, stable river over the 50-year period of analysis, was measured by the amount of aquatic habitat units achieved and whether the alternative included bank stabilization features. Alternatives that produced aquatic habitat units over 1,000 AAHU and included five or more bank stabilization sites were given a high score, alternatives that contributed over 100 AAHU and included five or more bank stabilization sites were given a medium score, and all other alternatives were given a low score.

  The efficacy in which alternatives met Objective 3, Increase riparian habitat connectivity, quantity, diversity, and complexity within the study area over the 50-year period of analysis, was measured by the amount of floodplain forest habitat units achieved. Alternatives that produced over 500 floodplain habitat units were given a high score, alternatives that contributed from 100–499 habitat units were given a medium score, and all other alternatives were given a low score.

- Efficiency. All alternatives in the final array provide net benefits. Outputs from the IWR Planning Suite CE/ICA were used to identify efficient alternatives. Best Buy alternatives were given a high efficiency, cost effective alternatives were given a medium efficiency, and inefficient alternatives were given a low efficiency.
- Acceptability. All the alternatives in the final array are in accordance with Federal law and policy so all alternatives scored high.

6.3.3.2 P&G ACCOUNTS

Principles and Guidelines (1983) established four accounts to facilitate evaluation and display of effects of alternative plans. Box 6-1 defines the four P&G accounts.

Box 6-1. P&G ACCOUNTS

The national economic development (NED) displays changes in the economic value of the national output of goods and services.

The environmental quality (EQ) account displays non-monetary effects on significant natural and cultural resources.

The regional economic development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output and population.

The other social effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts

In terms of National Economic Development (NED) effects of the alternatives, all action alternatives would have an economic cost to the nation to achieve the non-monetized environmental output of goods and services provided by the restoration of aquatic and riparian habitats described in section 6.1. Other effects in the NED account include small increases in recreation (due to projected increased fishing and hunting activity) and slight decreases in agricultural production (due to slight losses of agricultural land from conversion to riparian forest). These small changes in NED effects are described qualitatively in more detail in the environmental effects section 4.18 and 4.2 respectively, but were not quantified. While the non-monetized habitat benefits are captured in the EQ account, the NED effects are displayed as the annualized project cost and annualized projected OMRRR. NED ratings in Table 6-5 are: alternatives that are less than $1 million were considered low, alternatives more than $1 million but less than $5 million were considered medium, and alternatives above $5 million were considered high.

Regional Economic Development (RED) – All action alternatives would have a positive impact on the regional economy. A USACE regional economic model, ReCON, was run for all alternatives and while the amount of regional benefits varied, the percentage of Federal expenditure to regional benefits were equivalent and not useful as criteria for comparison.

Environmental Quality (EQ) – It is anticipated that all alternatives would have a positive effect on ecological resources. No known cultural sites have been identified and aesthetics are expected to be enhanced by all alternatives since they reduce sedimentation and increase riparian corridors. Potential temporary adverse effects could result from construction activities (e.g., land disturbance, emissions, tree clearing), but construction BMPs will be strictly adhered to, such that any and all adverse effects are temporary and minimal. Consequently, environmental quality of alternatives were ranked on AAHU output. Alternatives that had net benefits higher than 1,000 AAHU scored high, alternatives with net benefits from 500-999 scored medium, and all other alternatives ranked low.

Other Social Effects (OSE) - All alternatives assume positive social impacts; specifically reduced bank erosion for recreation and landowners, reforestation for aesthetics and roughness to help slow down overland waters coming into the system, and a reduction in contaminated sediments having an ancillary benefit to human health. Alternatives scored the same as for effectiveness for Objective 1.

6.3.3.3 OPPORTUNITIES AND CONSTRAINTS

Opportunities – Probable effect concentrations of lead on aquatic systems, above which adverse effects are expected to frequently occur in the Big River, was established at 128 ppm (MacDonald, Ingersoll, & Berger, 2000). No alternatives reduced lead levels below 128 ppm but there is still an ecological opportunity to reduce lead concentrations to the greatest extent possible. Therefore, alternatives that produced above 200 ppm were given a low score, alternatives that produced parts per million below 200 but above the 128 ppm were given a medium score, and alternatives that had a concentration level below 128 ppm probable effects were given a high score.

Constraints - It is not anticipated that any of the alternatives violate the study constraints. It is important to acknowledge the need to be mindful during plans and specifications, as well as construction, regarding affecting surrounding infrastructure, ensuring compatibility with other remediation efforts and not increasing the migration rate or distribution of contaminated sediments.

Table 6-5. Final Array of Alternatives Evaluation

#	Alternative	EFFECTIVENESS				EFFICIENCY	ACCEPTABLE	COMPLETE	NED	EQ	OSE	LEAD CONCENTRATION
		Reduces migration sedimentation	Restores natural channel	Increases riparian habitat	Reasonably maximizes benefits	Minimizes cost relative to benefit	Minimizes policy concern	Items considered complete	Estimated annualized cost	Positive effects on resources	Reasonably maximizes other perspectives	Reduces lead concentrations (ppm) after 50 years
1	No Action	LOW	LOW	LOW	LOW	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW
2	Maximizes Ecosystem Benefits RM 0-10.2	LOW	LOW	LOW	LOW	MEDIUM	HIGH	HIGH	LOW	LOW	MEDIUM	LOW
3	Maximizes Ecosystem Benefits RM 0-35	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	LOW
4	Maximizes Ecosystem Benefits in the Meramec River	LOW	LOW	LOW	LOW	LOW	HIGH	HIGH	LOW	LOW	LOW	LOW
5	Maximizes Efficiency in the Big River	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM
6	Maximizes Ecosystem Benefits in the Big River	HIGH	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM
7	Maximizes Ecosystem Benefits in Study Area	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MEDIUM

6.3.4 SELECTION OF THE RECOMMENDED PLAN

Federal planning for water resources development was conducted in accordance with the Principles and Guidelines (P&G) adopted by the U.S. Water Resources Council.

> *"For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be shown to be cost effective and justified to achieve the desired level of output. This plan shall be identified as the National Ecosystem Restoration (NER) Plan."*

Alternative 2 - Subset Maximizes Ecosystem Benefits in the Big River, RM 0-10.2(197 AAHUs and removes approximately 65,000 cubic yards of sediment) and Alternative 3 - Subset Maximizes Ecosystem Benefits in the Big River, RM 0-35 (427 AAHUs and removes approximately 1.9M cubic yards of sediment) are both cost effective alternatives that moderately contribute to the study objectives. Either of these two alternatives have the potential to become the NER plan if the (FWOP) lead remediation levels and/or the USEPA remedial site condition assumptions are incorrect and the USACE study area is constrained to a smaller geographic area.

Alternative 4 - Maximizes Ecosystem Benefits in the Meramec River not cost effective, nor did it sufficiently meet the Study objectives.

Alternative 5 - Maximizes Efficiency in the Big River ranked high in all evaluation criteria except lead reduction, in which it ranked moderately. It is the first iteration of best buy plans above the no action plan. Alternative 5 is worth the incremental investment above the no action plan since it provides an acceptable level of restoration (1,565 AAHUs) and removes approximately 2.1M cubic yards of sediment for an acceptable average annual cost of $3,180,000 while meeting the intent of the Federal objective through improved functionality of portions of the Big River through a more natural channel, reforestation, and improved aquatic habitat.

Alternative 6 - Maximizes Ecosystem Benefits in the Big River was not a best buy alternative but ranked high in the NER column and would meet the intent of the Federal objective by improving the functionality of the Meramec River Basin; however, Alternative 6 only offers two additional AAHUs (1,567) over Alternative 5 while increasing the average annual cost over one million dollars for a total average annual cost of $4,385,000. Additionally, Alternative 6 removes approximately 2.2M cubic yards of sediment.

Alternative 7 - Maximize Ecosystem Restoration in the Study Area is the second and last best buy alternative. Alternative 7 differs from Alternative 5 by adding 10 bank stabilization sites and 12 in-stream excavation sites. It provides 1,625 average annual habitat units over the no action plan at an incremental cost per unit of output of $3,201. The intent of the Federal objective would be met by improving the functionality of the Meramec River Basin through a more natural channel, reforestation, and improved aquatic habitat. After a lengthy comparison to Alternative 5, it was determined that although there would be additional benefits, this addition did not significantly increase the effectiveness of the project (60 AAHUs) while increasing the average annual cost by $2,000,000 for a total average annual cost of $5,201,000. Additionally, Alternative 7 removes approximately 2.2M cubic yards of sediment.

As a result of this discussion and review of the four accounts, Alternative 5 - Maximize Efficiency in the Big River is the NER alternative and the Recommended Plan since it reasonably maximizes ecosystem restoration benefits at an acceptable cost while meeting the Federal objective.

7 RECOMMENDED PLAN DESCRIPTION

The Recommended Plan description section describes additional design and detailed cost of Alternative 5 - Maximize Efficiency in the Big River. To achieve feasibility level design and cost additional analysis was conducted. A significant amount of time focused on the primary factors that guide the design and operation of the bed sediment collectors and required an understanding of hydrology, sediment transport, and other site-specific limitations. A one-dimensional HEC-RAS model provided by the USEPA was used to determine average shear and velocity values for the hydraulic reaches of the river, and adjusted using local geometries to estimate design stress and velocity values for each site. The HEC-RAS model was also consulted to compare flow elevations to event frequency for sediment basin design elevations. More information on analysis conducted during feasibility and recommendations prior to construction can be found in Appendix H-*Hydraulics and Hydrology Analysis.*

The Recommended Plan for feasibility includes:

- Construction of 6 sediment basins along the Big River and associated excavation, earthwork, stone, and hauling (378,000 cubic yards)
- Construction of 5 grade control structures (16,000 cubic yards) and associated excavation and hauling (4,000 cubic yards)
- Installation of 3 bed sediment collectors and associated excavation and hauling (1,000 cubic yards)
- In-stream excavation of 8 sites (135,000 cubic yards)
- Stabilization of 12 eroding banks by constructing:
    - 46,000 cubic yards of stone
        - 3,000 linear feet of longitudinal peak stone toe protection
        - 23 stream barbs
        - 69 weirs
        - 3 Tributary and sill grade control structures
    - 13,000 linear feet of bank shaping
    - 5,000 linear feet of root wad revetment
    - 219 acres of vegetative plantings
    - 134,000 cubic yards of associated excavation and earthwork
- Reforestation of 675 acres

Figures 7-1 to 7-34 shows a detailed plan layout of each measure identified in the Recommended Plan.

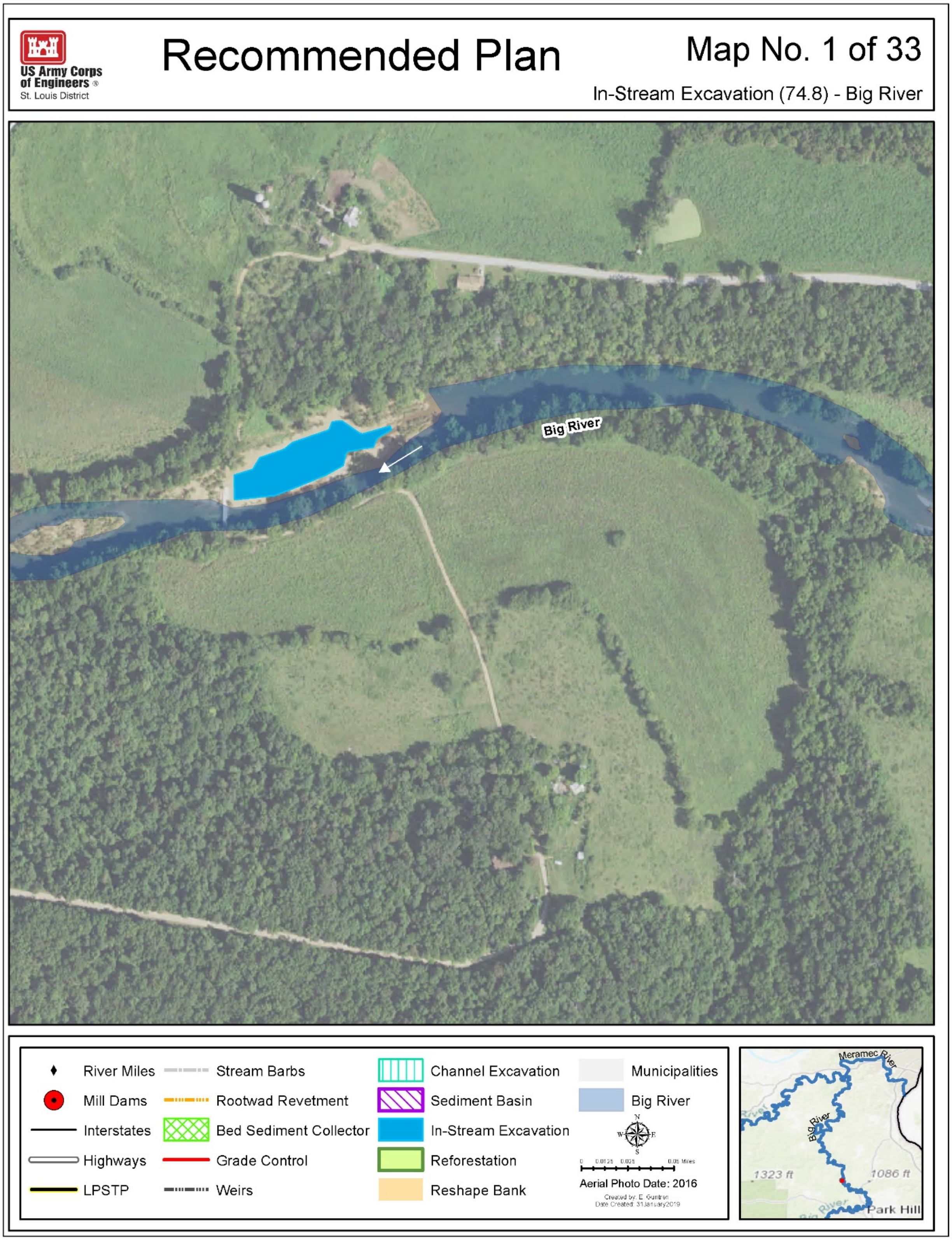


Figure 7-1. Recommended Plan River Mile 74.8

Figure 7-2. Recommended Plan River Mile 71.5

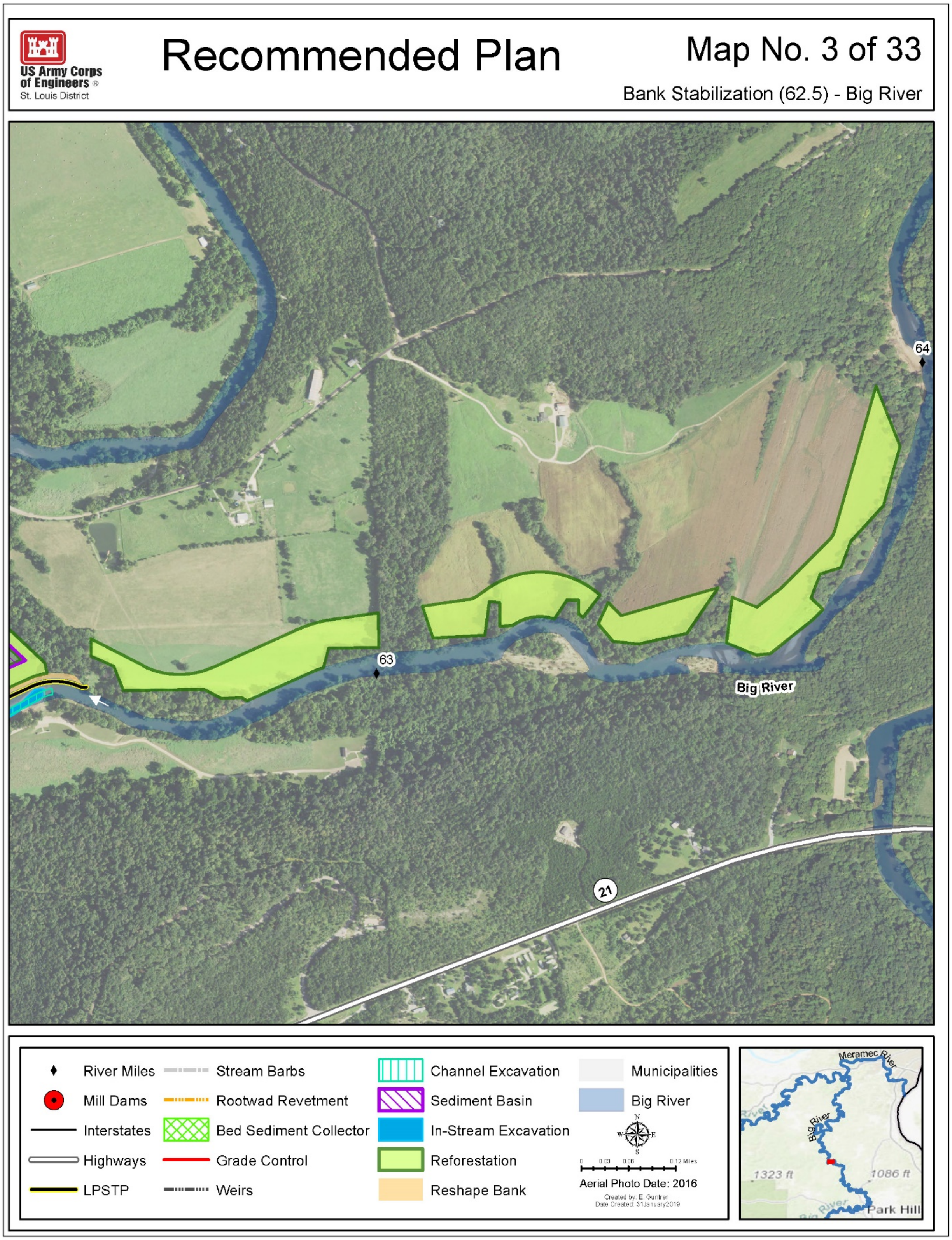


Figure 7-3. Recommended Plan River Mile 62.5 (1)

Figure 7-4. Recommended Plan River Mile 62.5 (2)

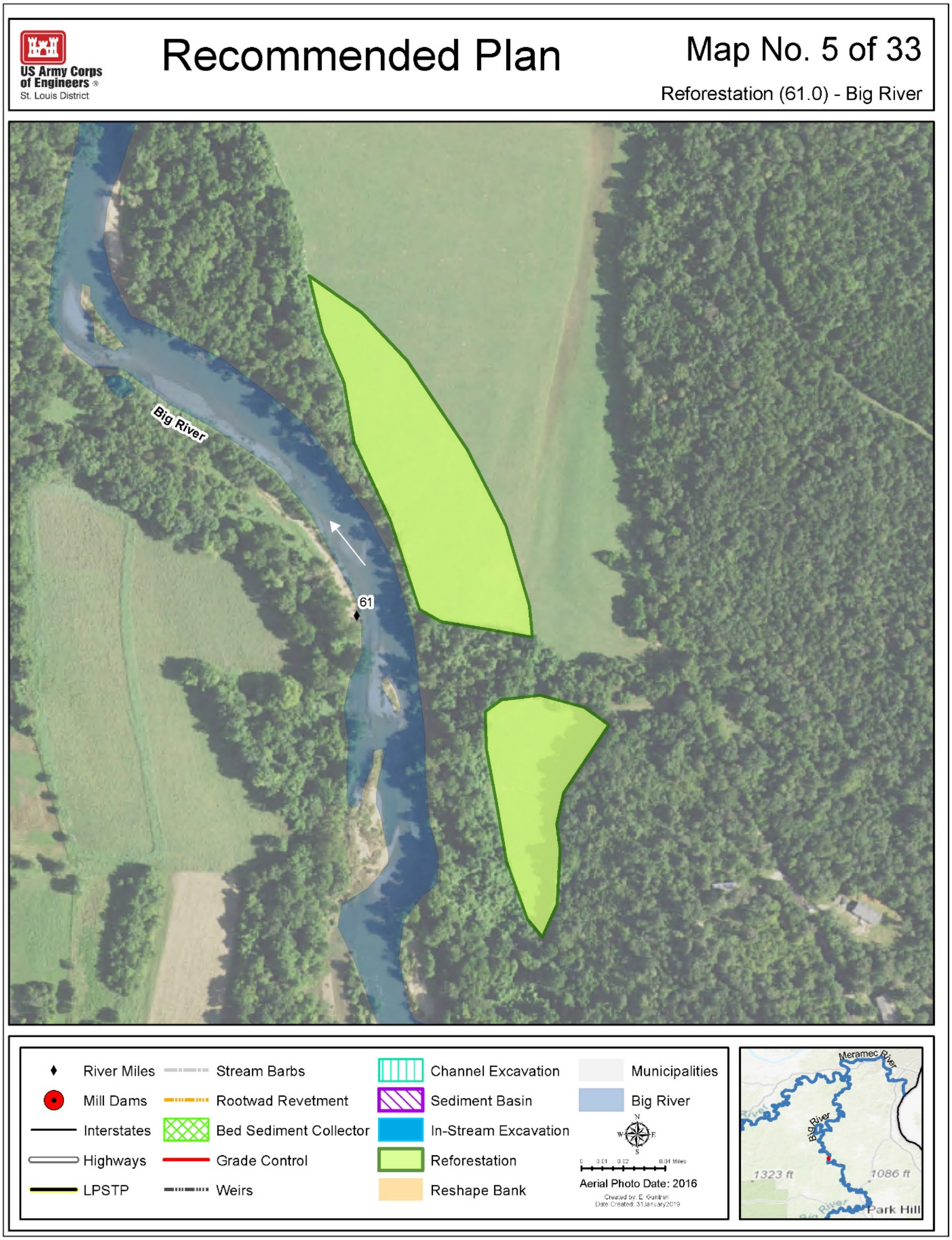


Figure 7-5. Recommended Plan River Mile 61.0

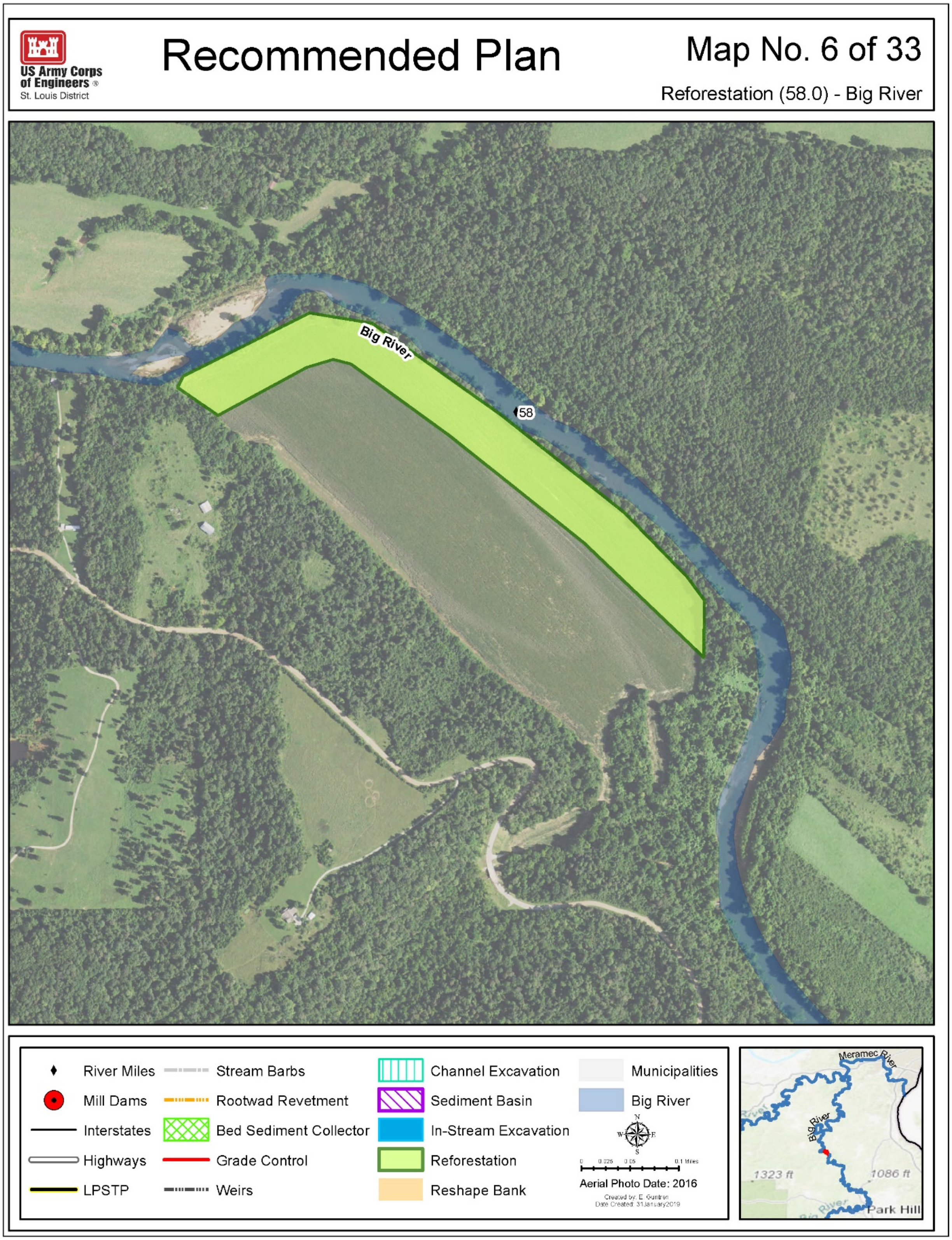


Figure 7-6. Recommended Plan River Mile 58.0

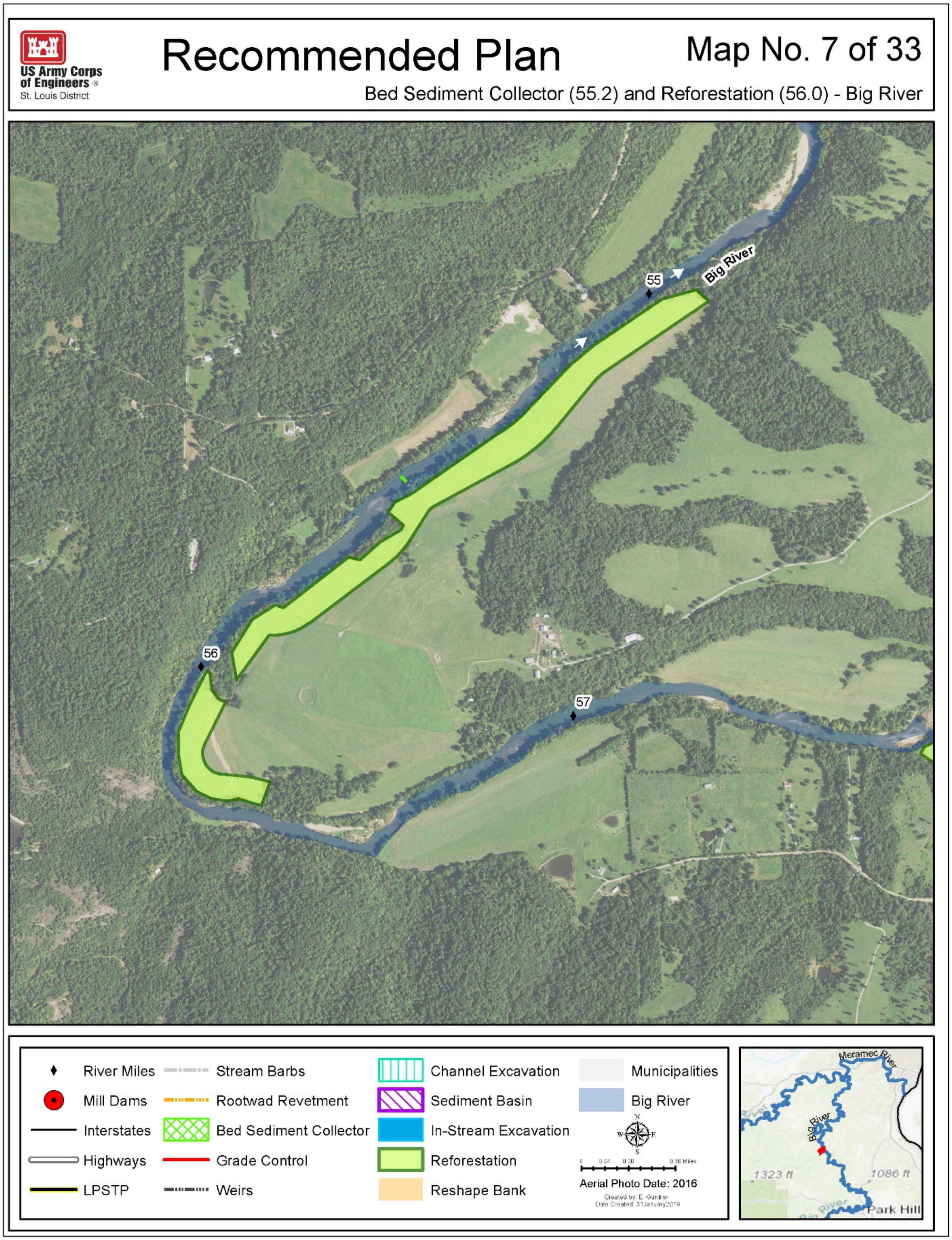


Figure 7-7. Recommended Plan River Mile 56.0

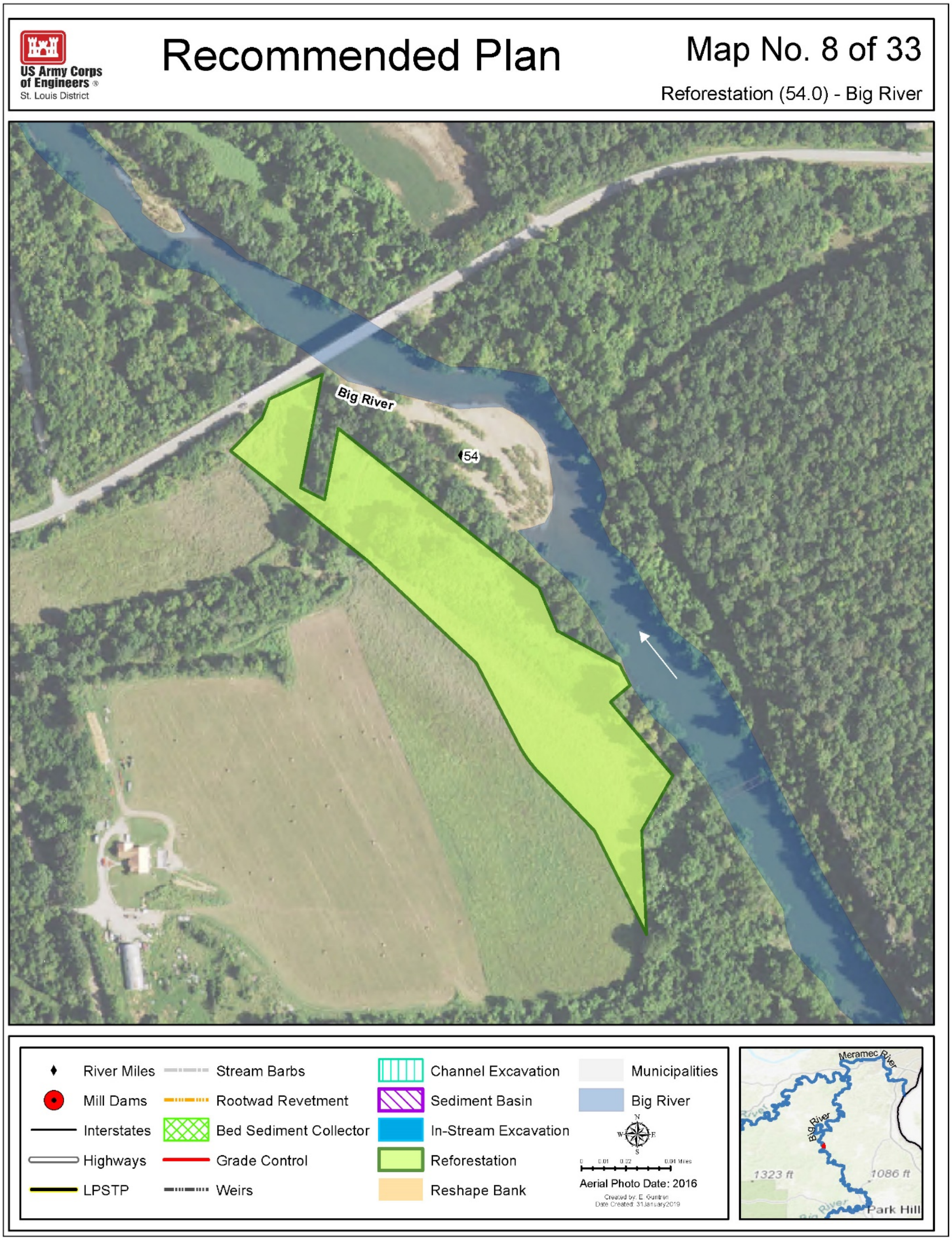


Figure 7-8. Recommended Plan River Mile 54.0

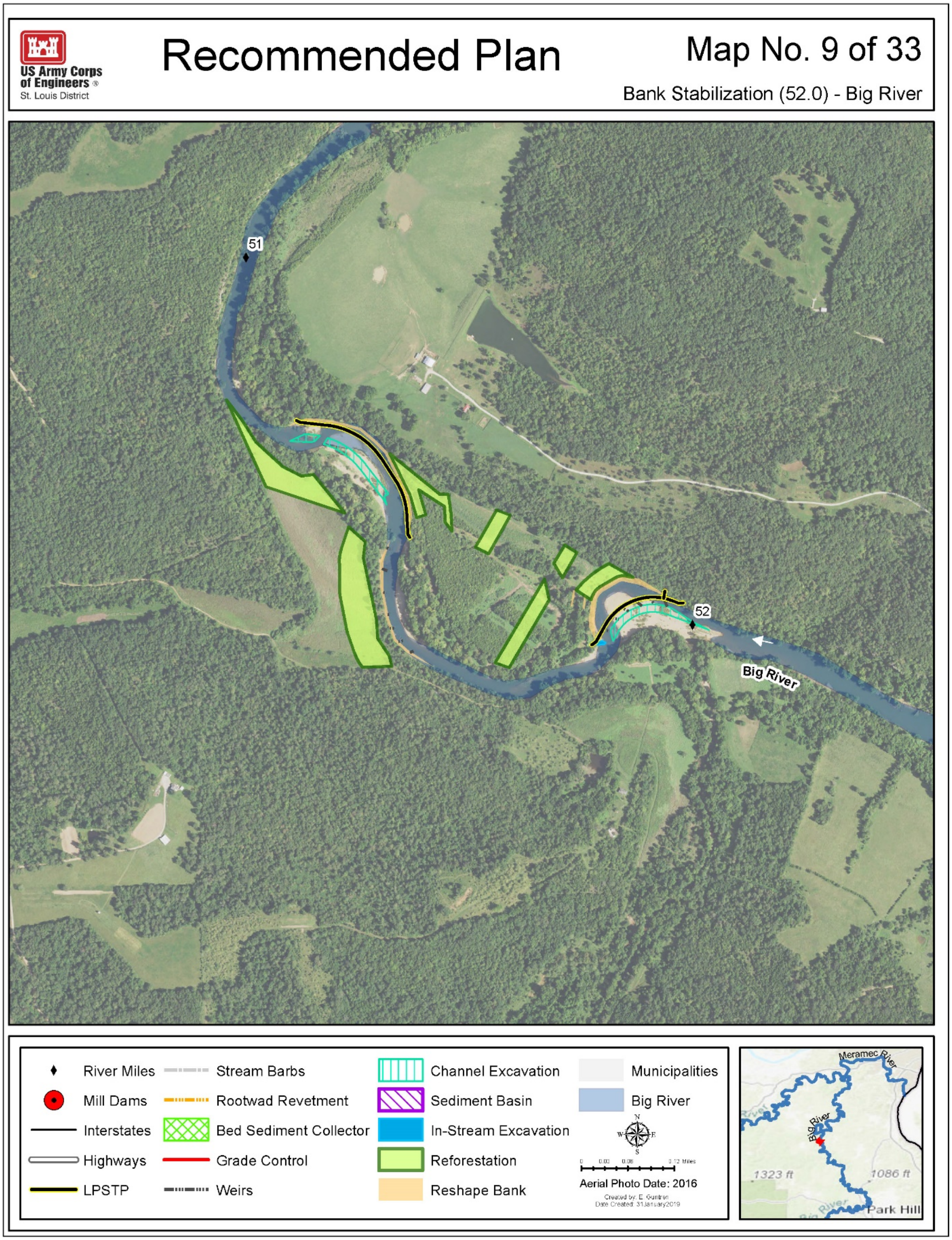


Figure 7-9. Recommended Plan River Mile 52.0

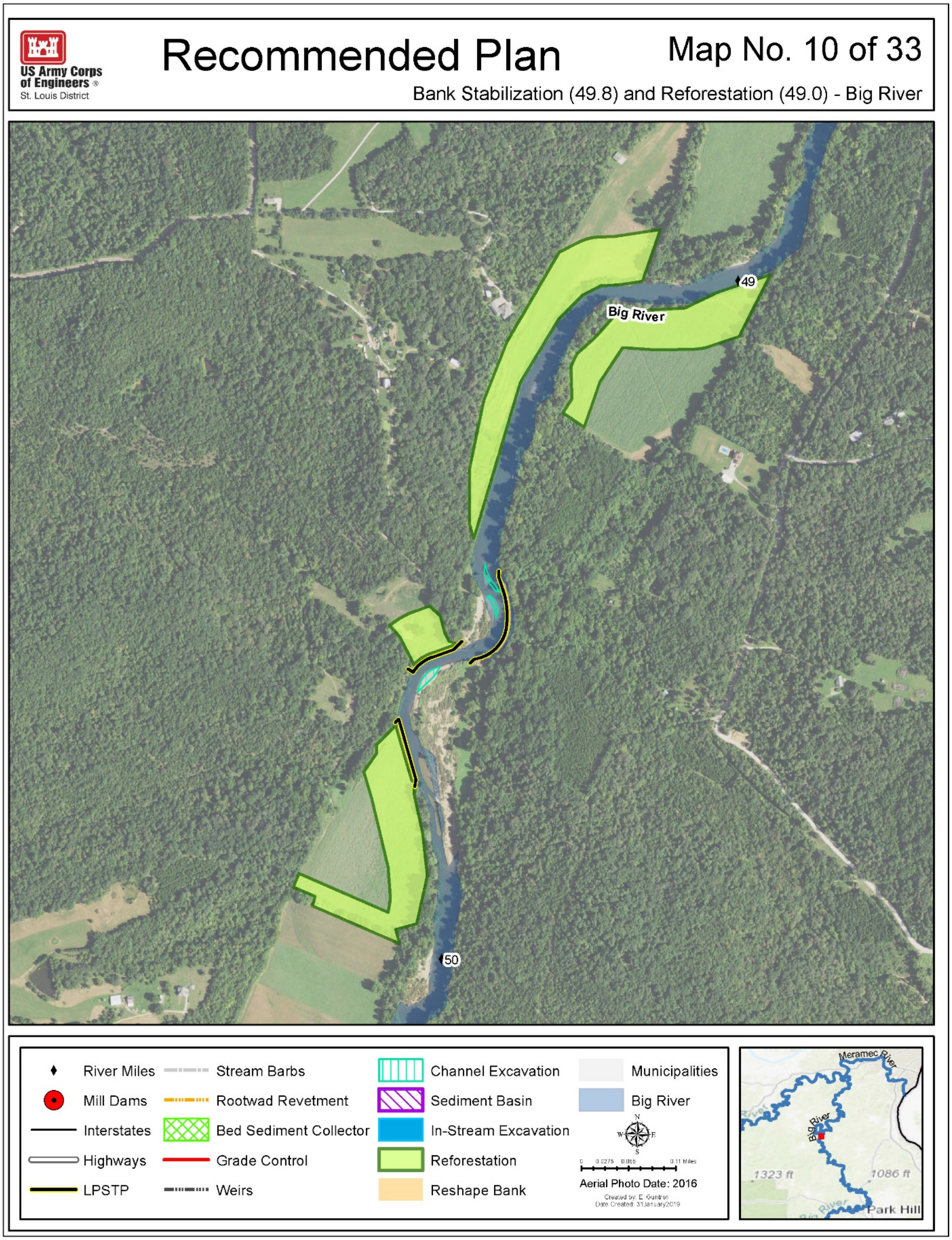


Figure 7-10. Recommended Plan River Mile 49.0

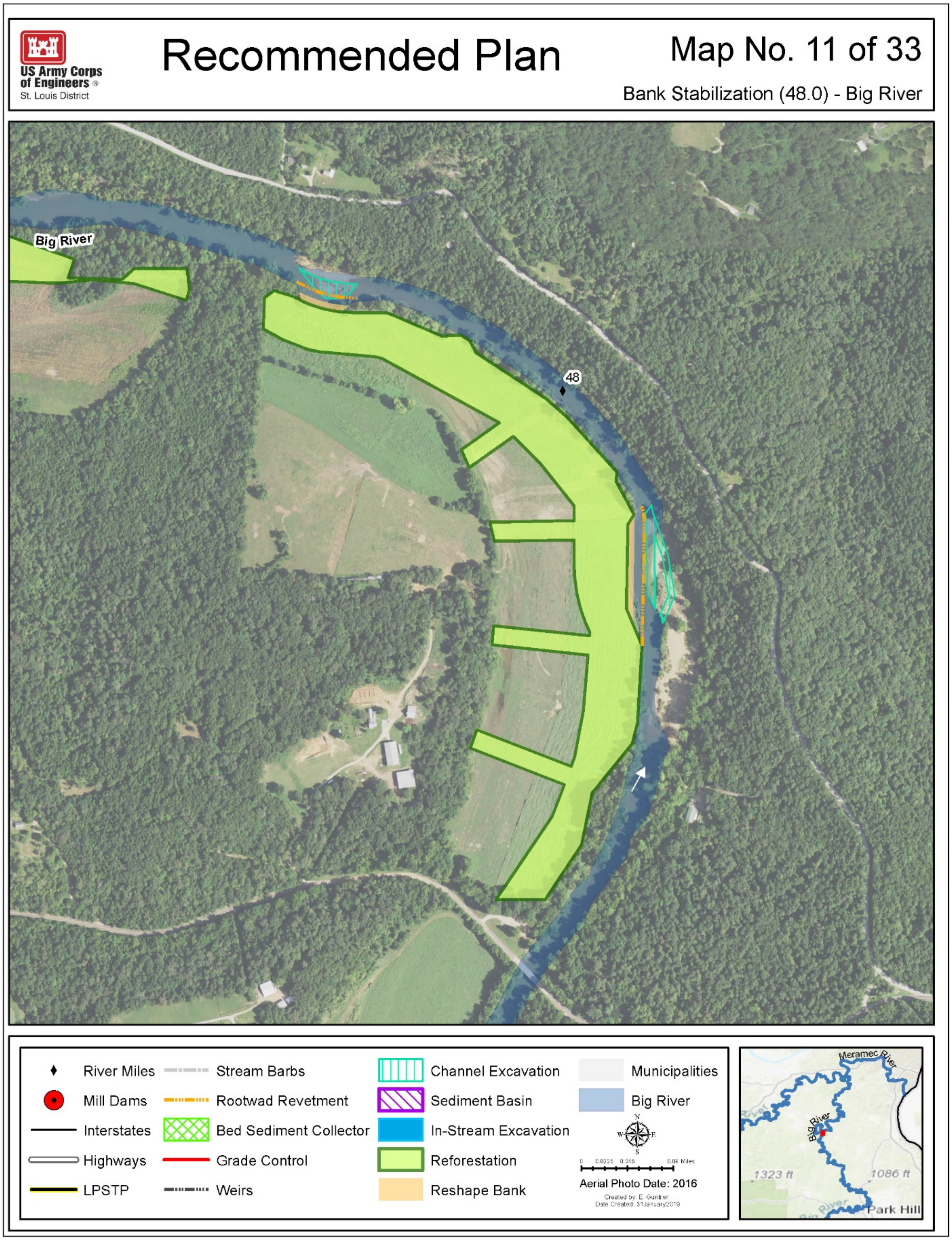


Figure 7-11. Recommended Plan River Mile 48.0

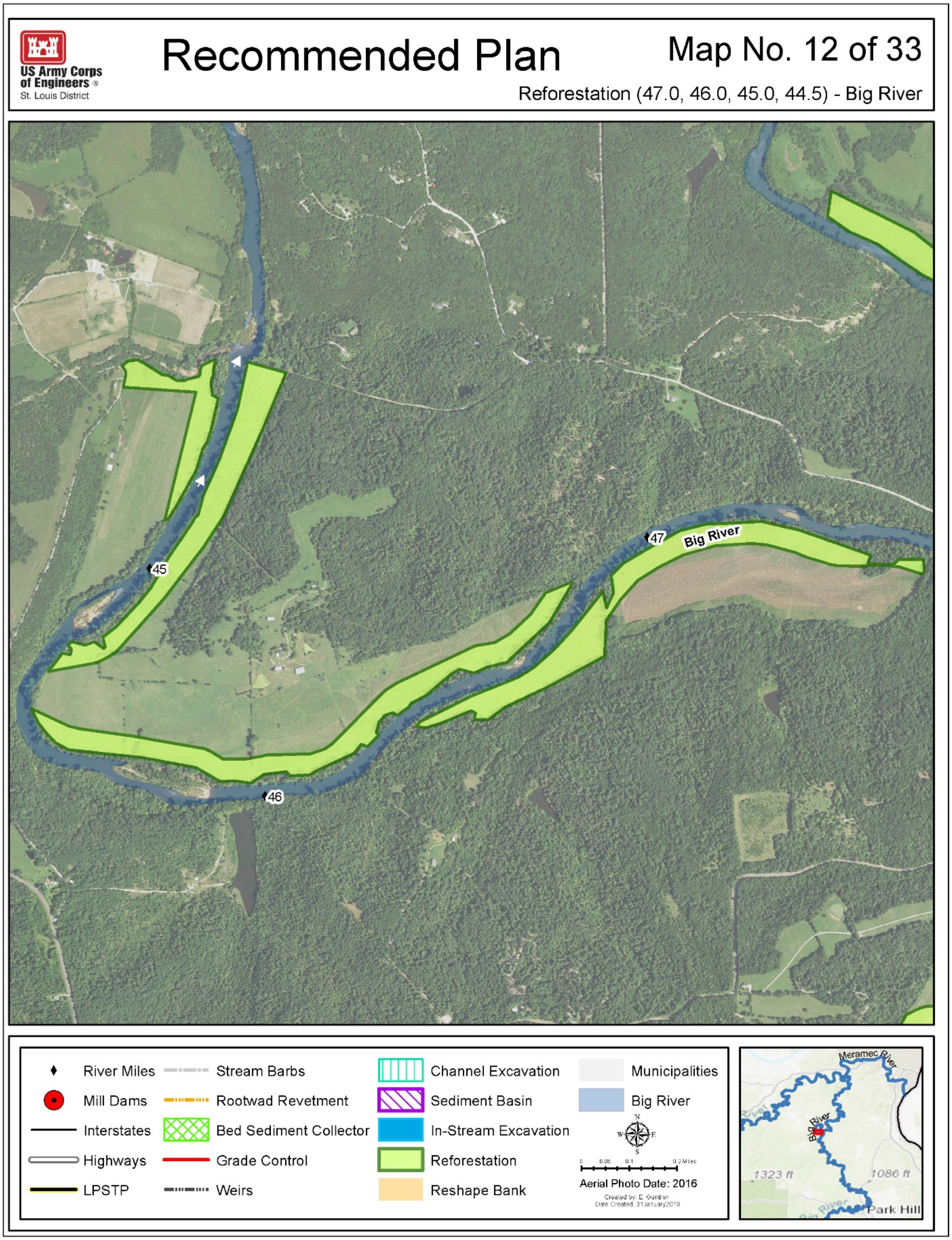


Figure 7-12. Recommended Plan River Mile 47.5-44.5

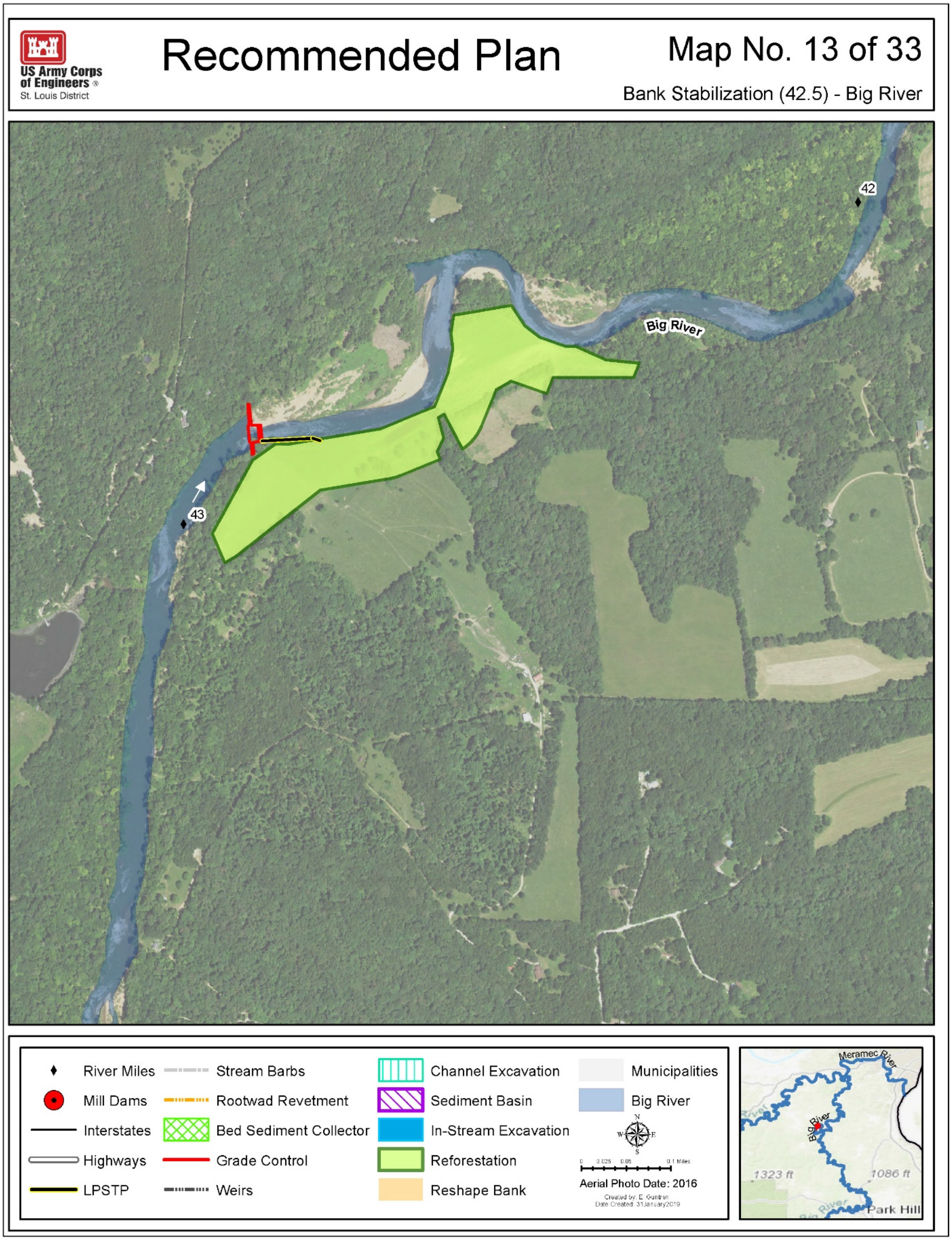


Figure 7-13. Recommended Plan River Mile 42.5

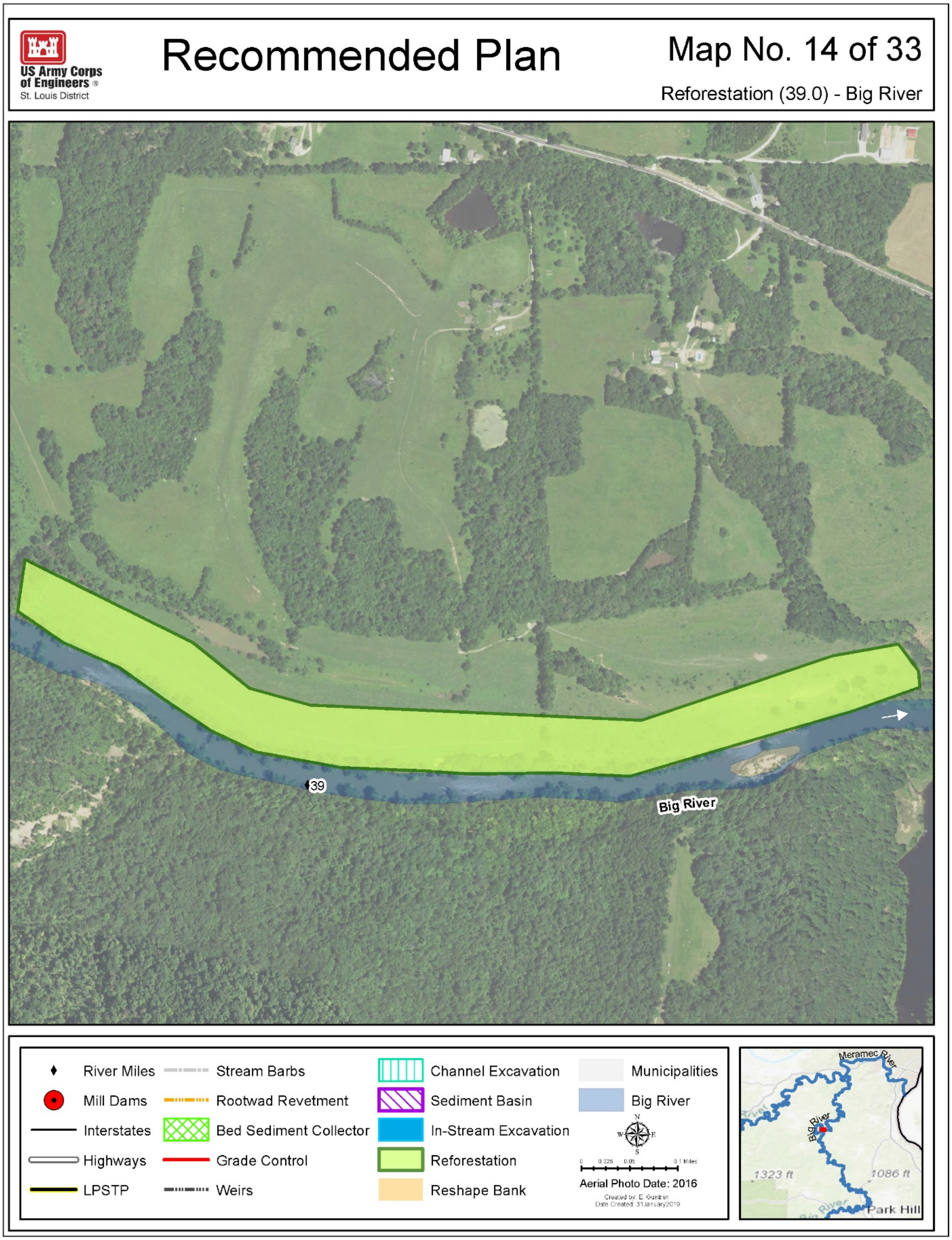


Figure 7-14. Recommended Plan River Mile 39.0

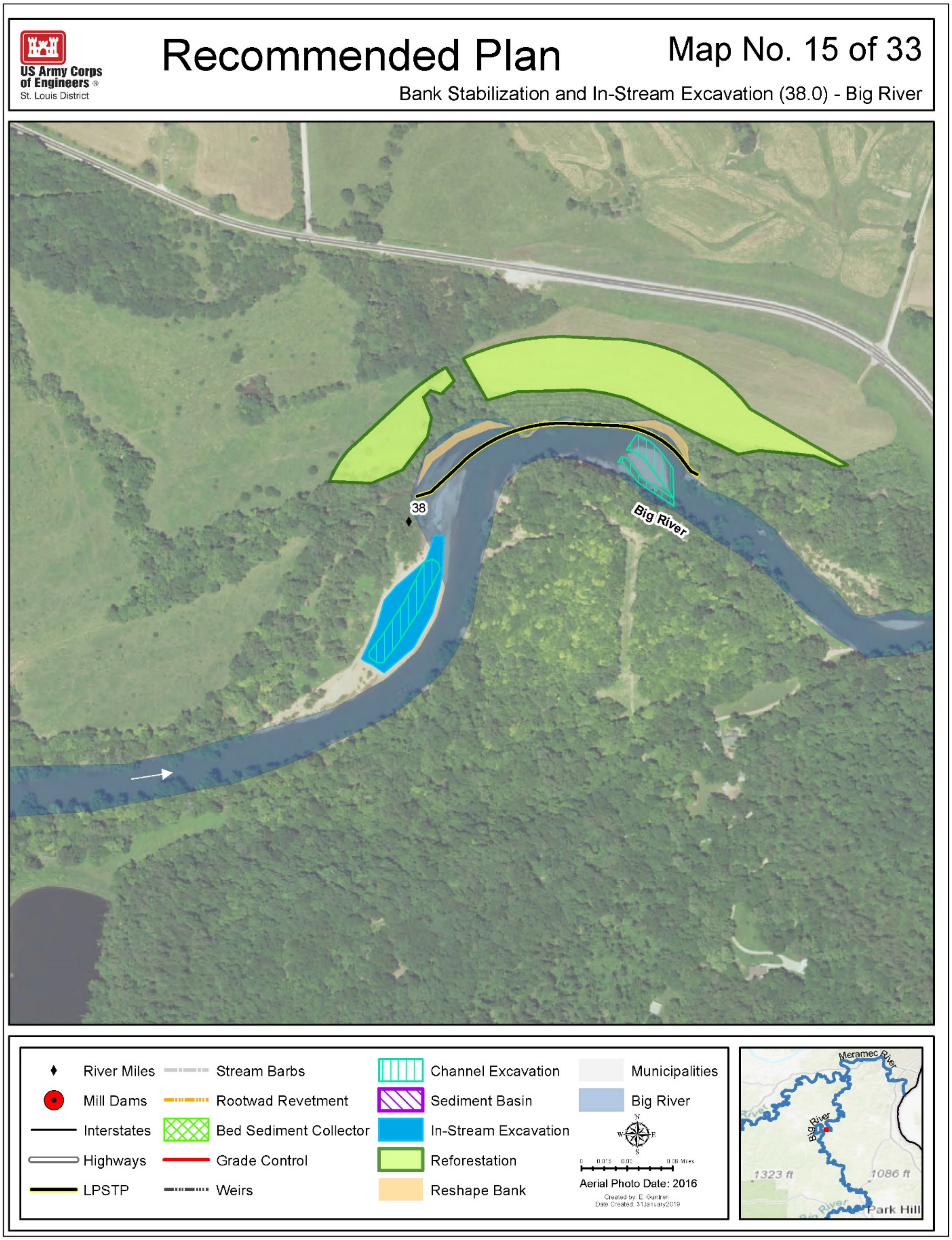


Figure 7-15. Recommended Plan River Mile 38.0

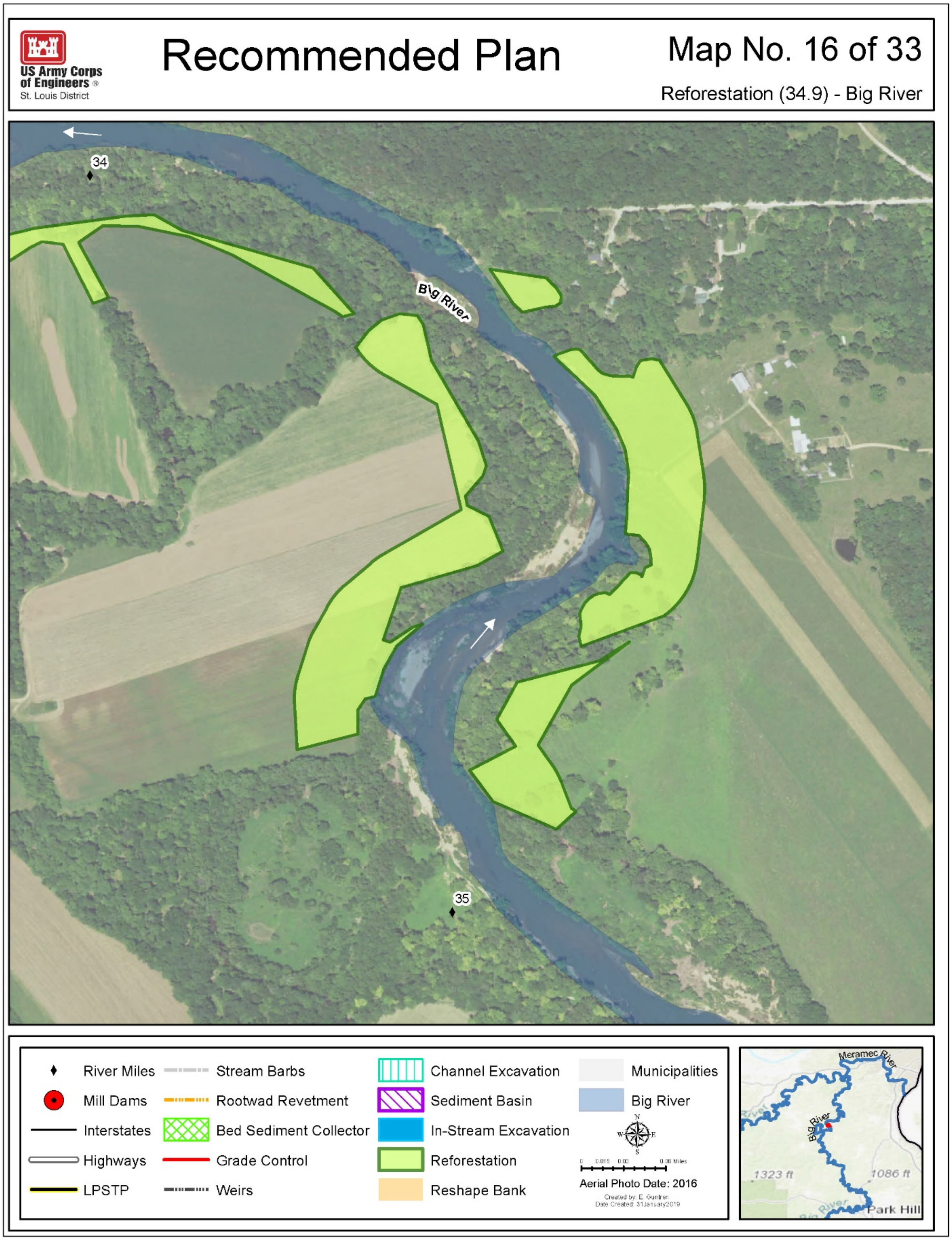


Figure 7-16. Recommended Plan River Mile 34.9

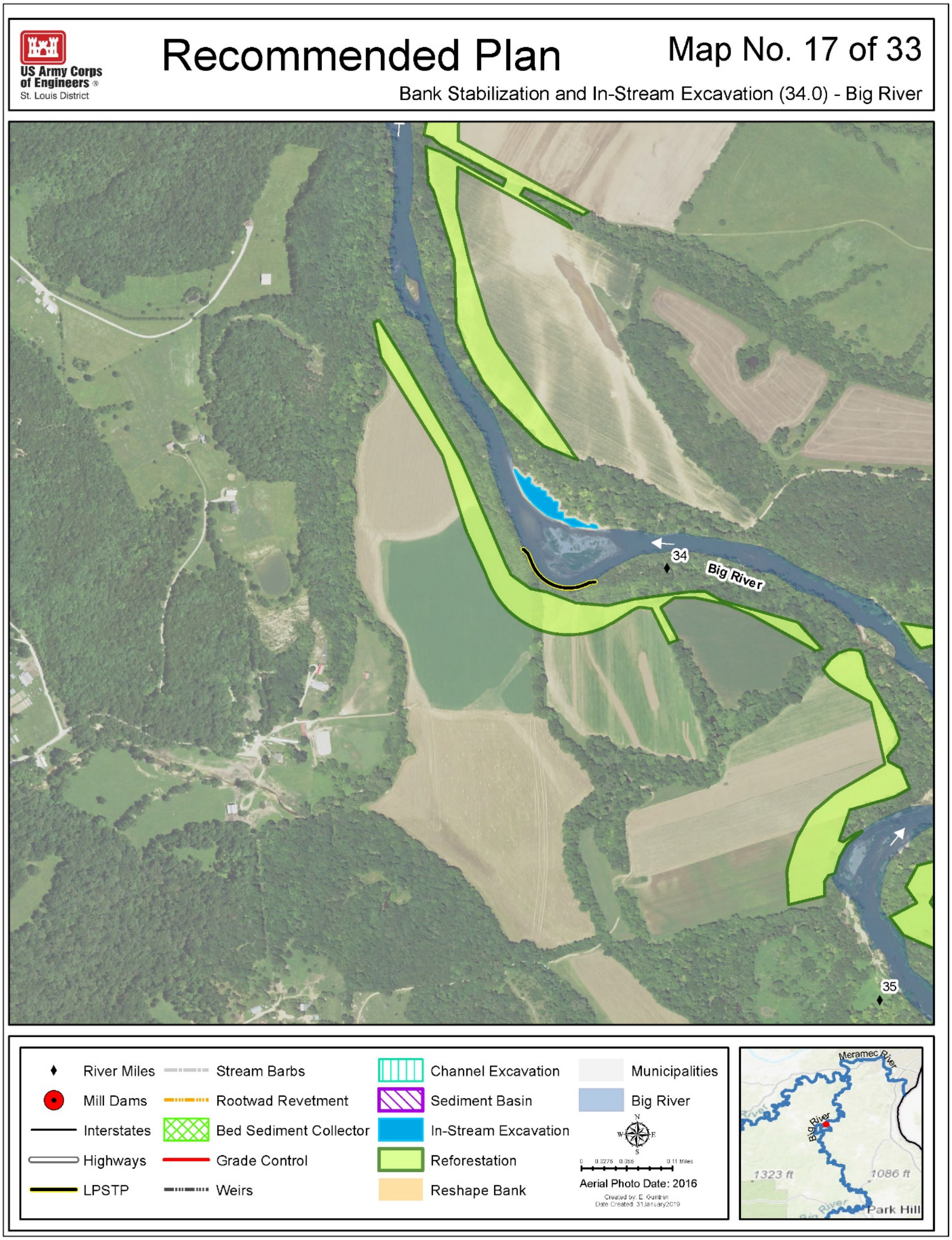


Figure 7-17. Recommended Plan River Mile 34.0

Figure 7-18. Recommended Plan River Mile 33.2

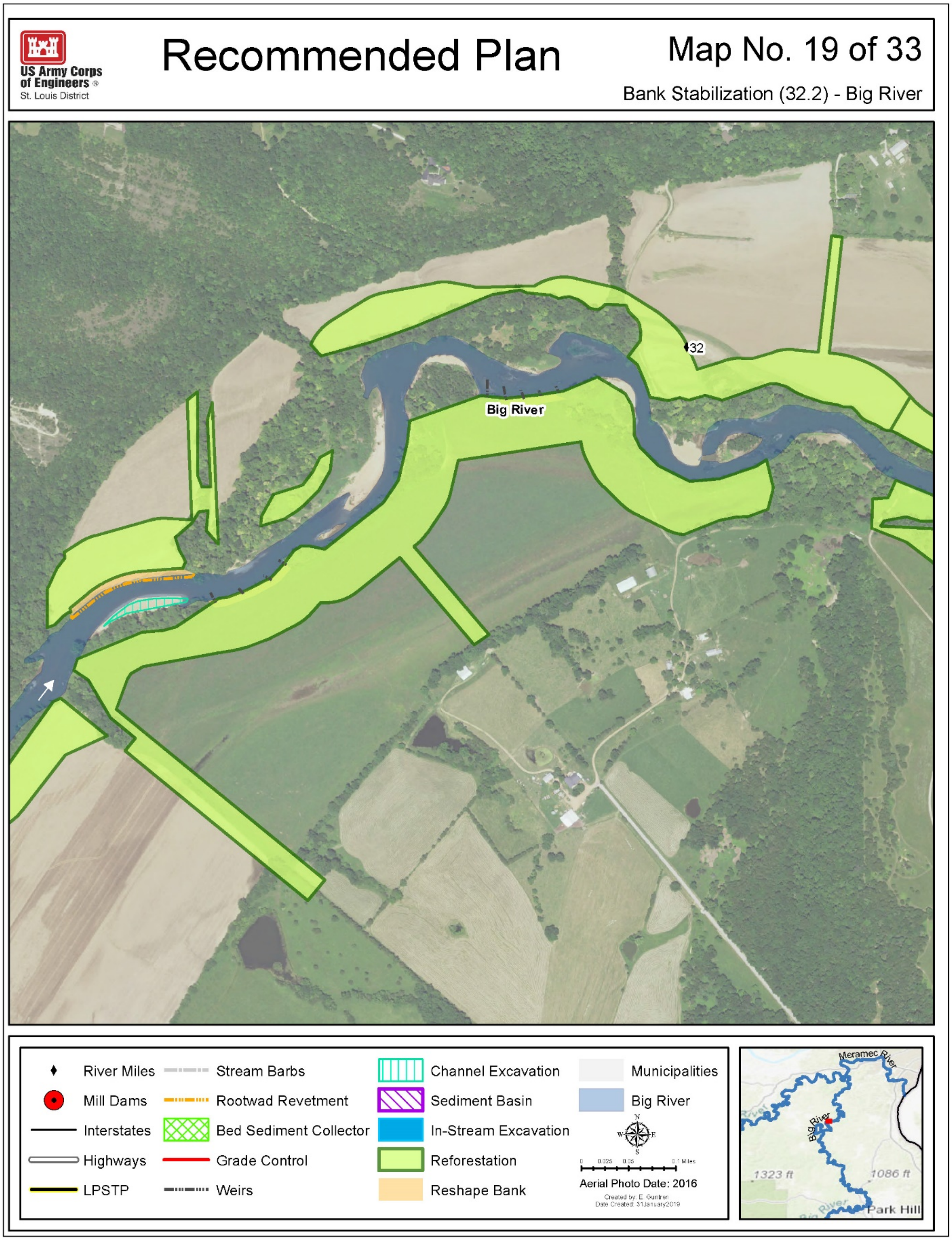


Figure 7-19. Recommended Plan River Mile 32.2

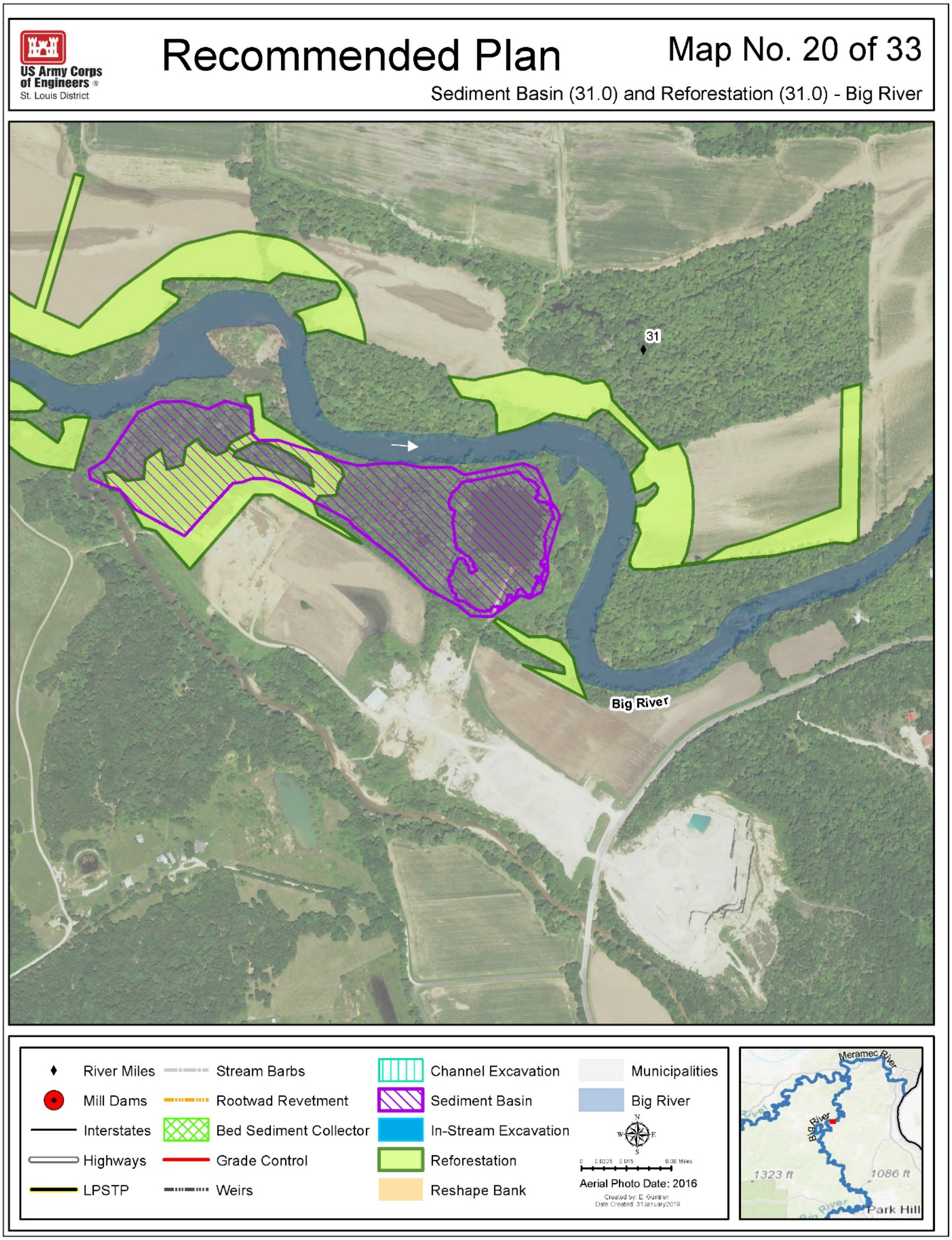


Figure 7-20. Recommended Plan River Mile 31.0

Figure 7-21. Recommended Plan River Mile 30.2

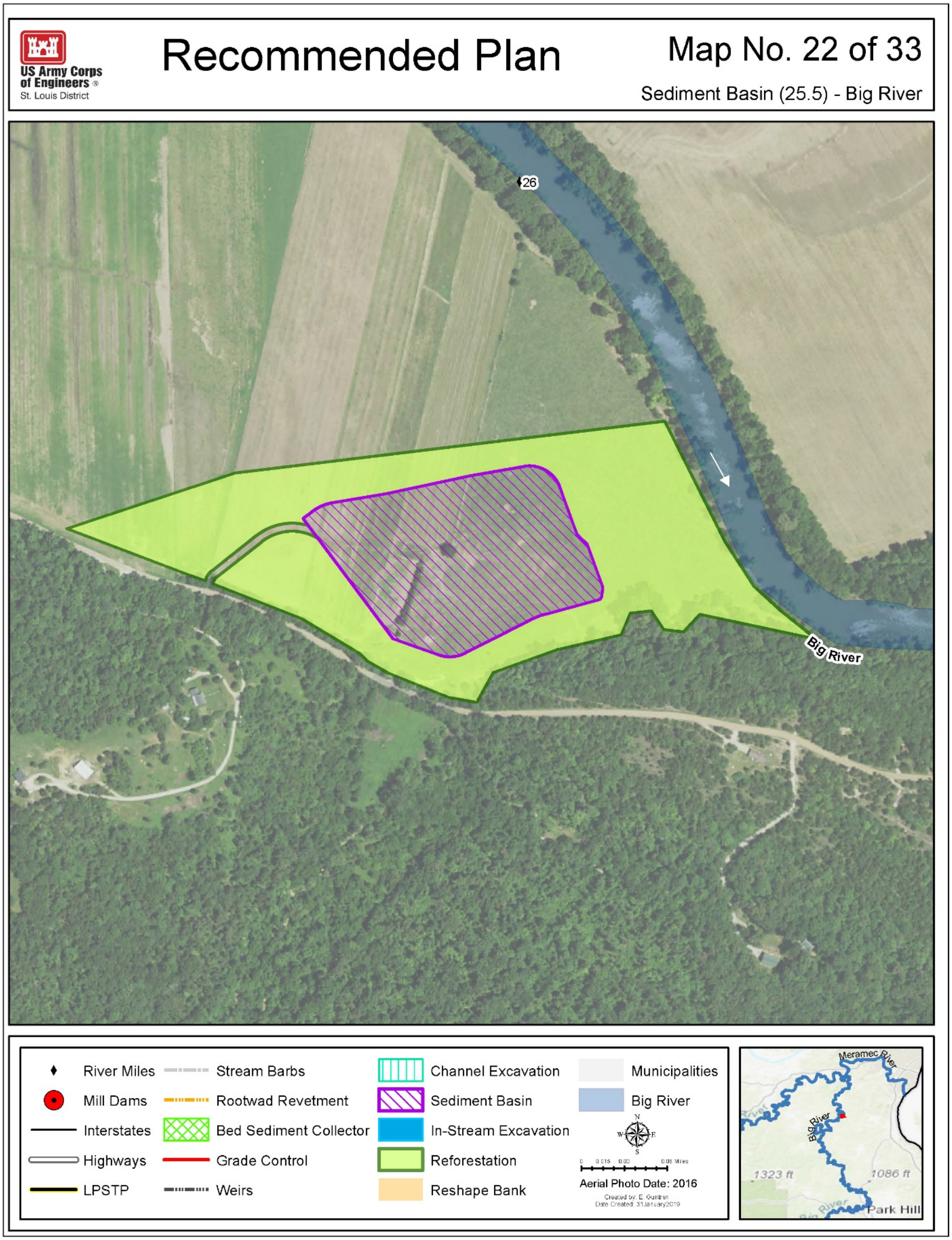


Figure 7-22. Recommended Plan River Mile 25.5

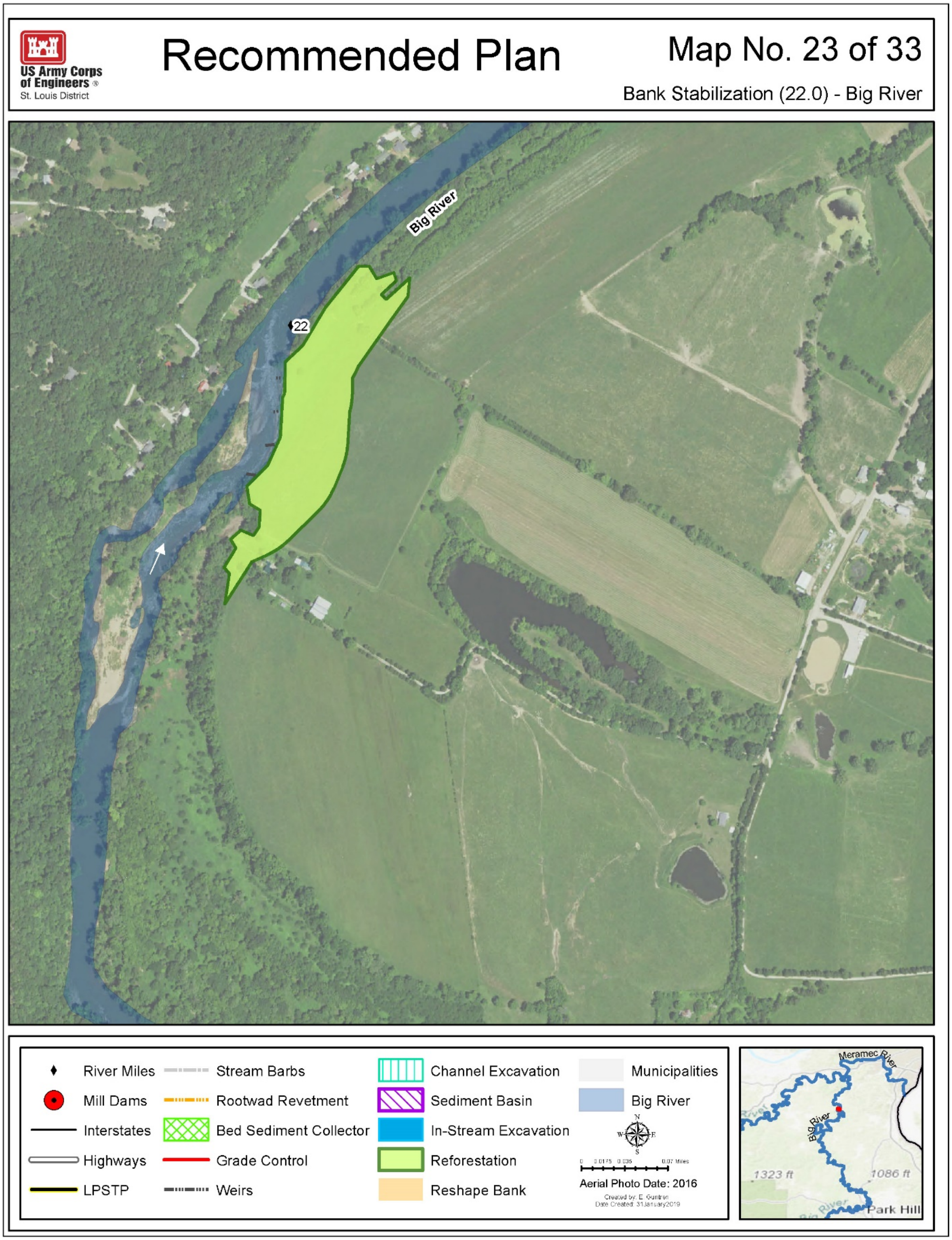


Figure 7-23. Recommended Plan River Mile 22.0

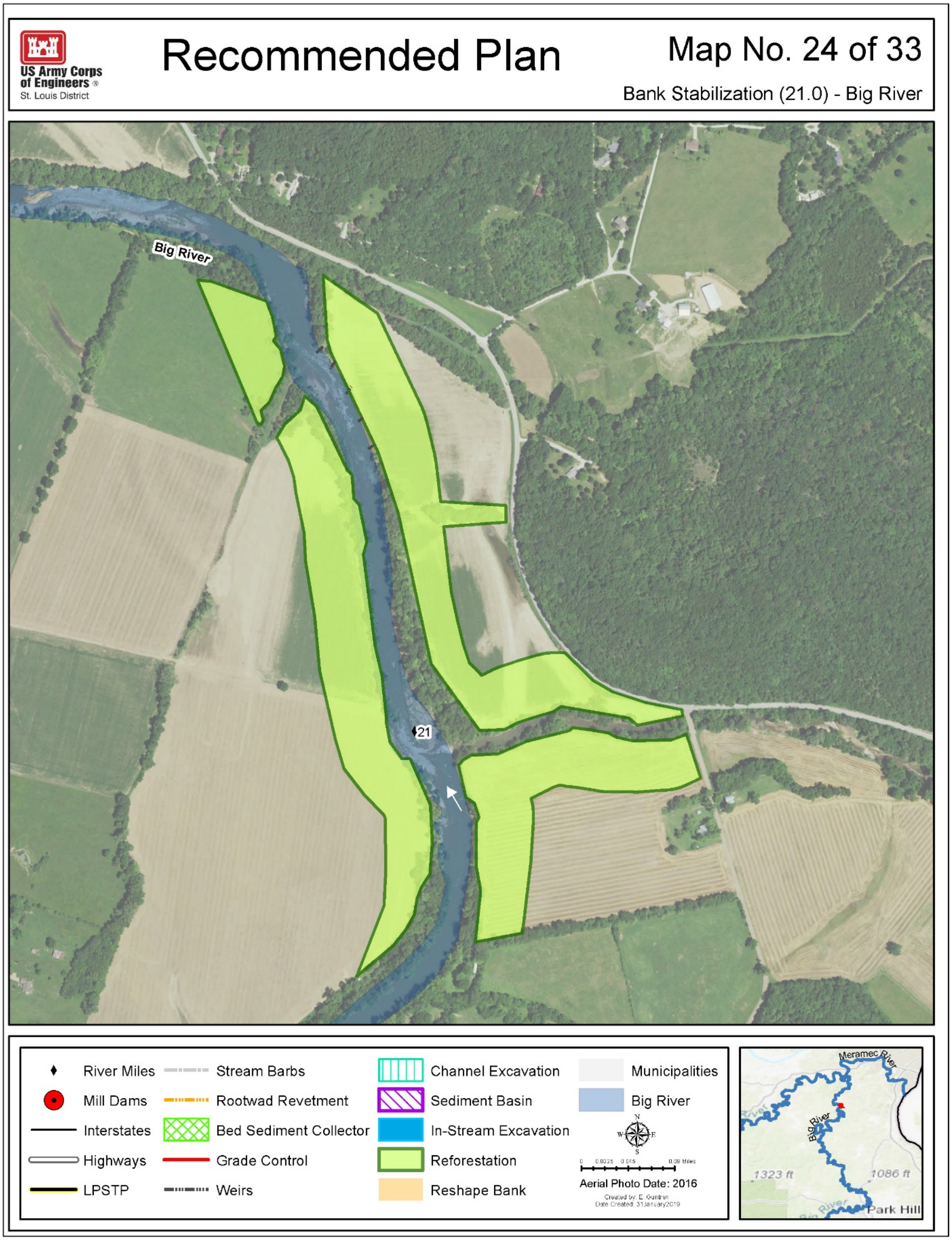


Figure 7-24. Recommended Plan River Mile 21.0

Figure 7-25. Recommended Plan River Mile 19.6

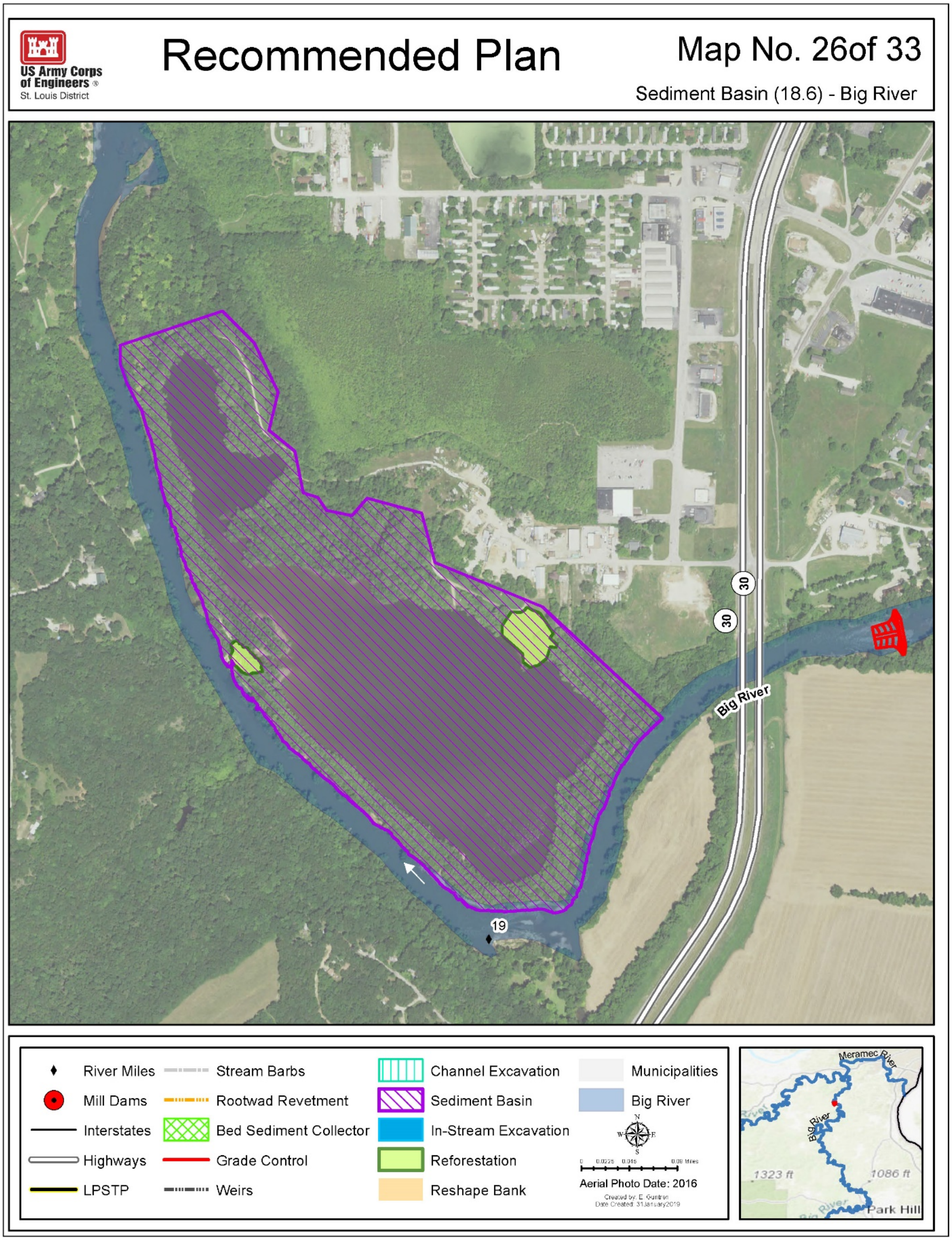


Figure 7-26. Recommended Plan River Mile 18.6

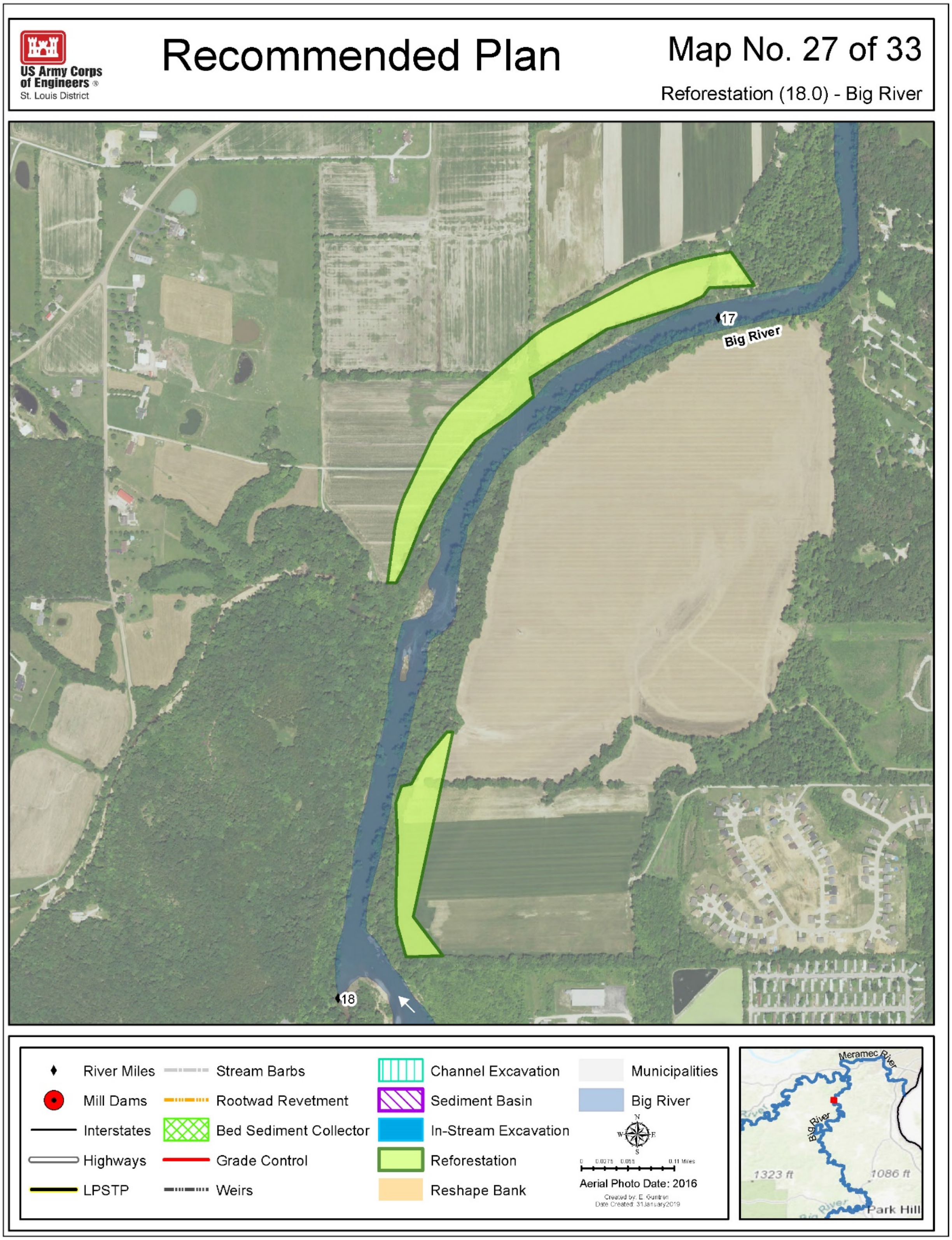


Figure 7-27. Recommended Plan River Mile 18.0

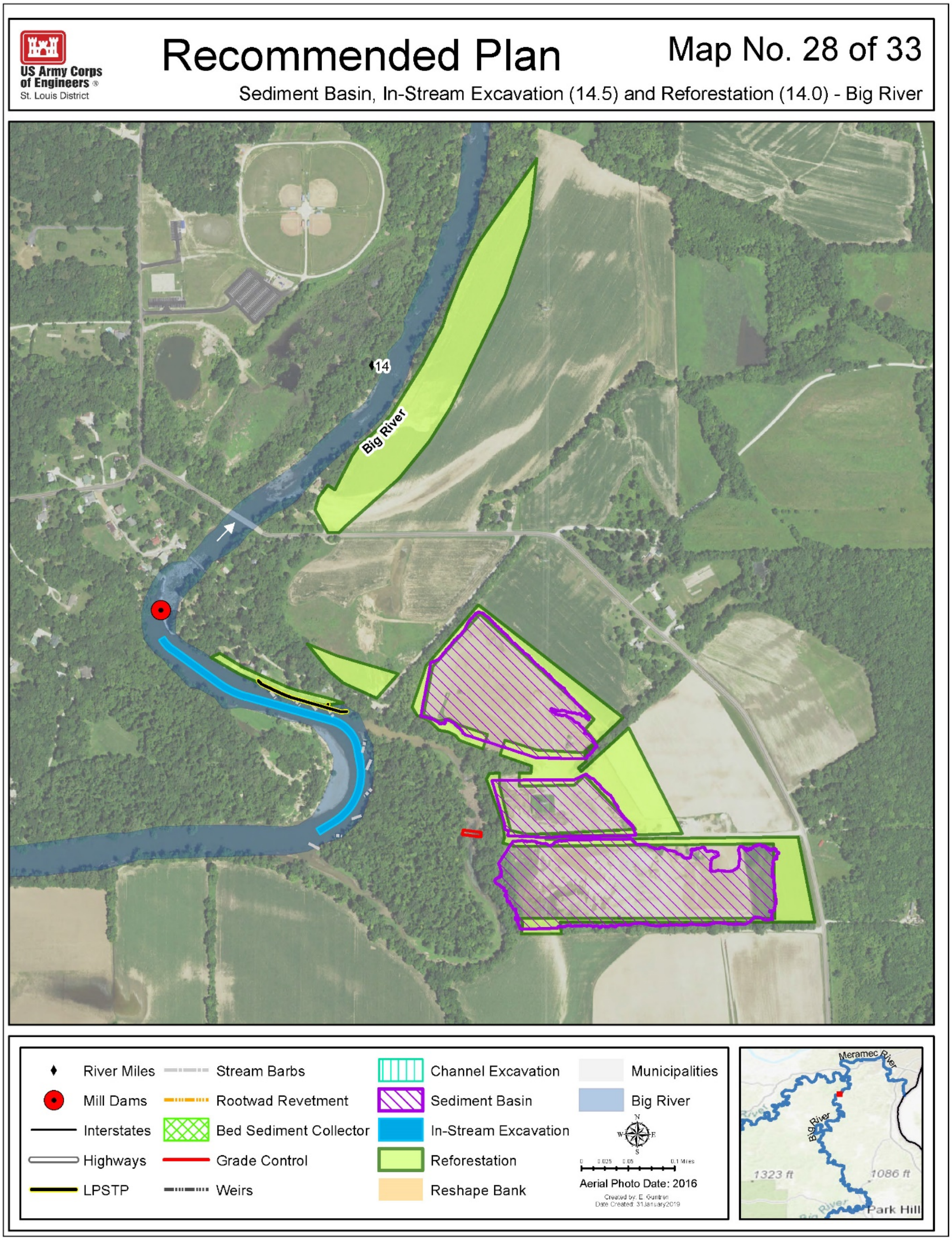


Figure 7-28. Recommended Plan River Mile 14.5-14

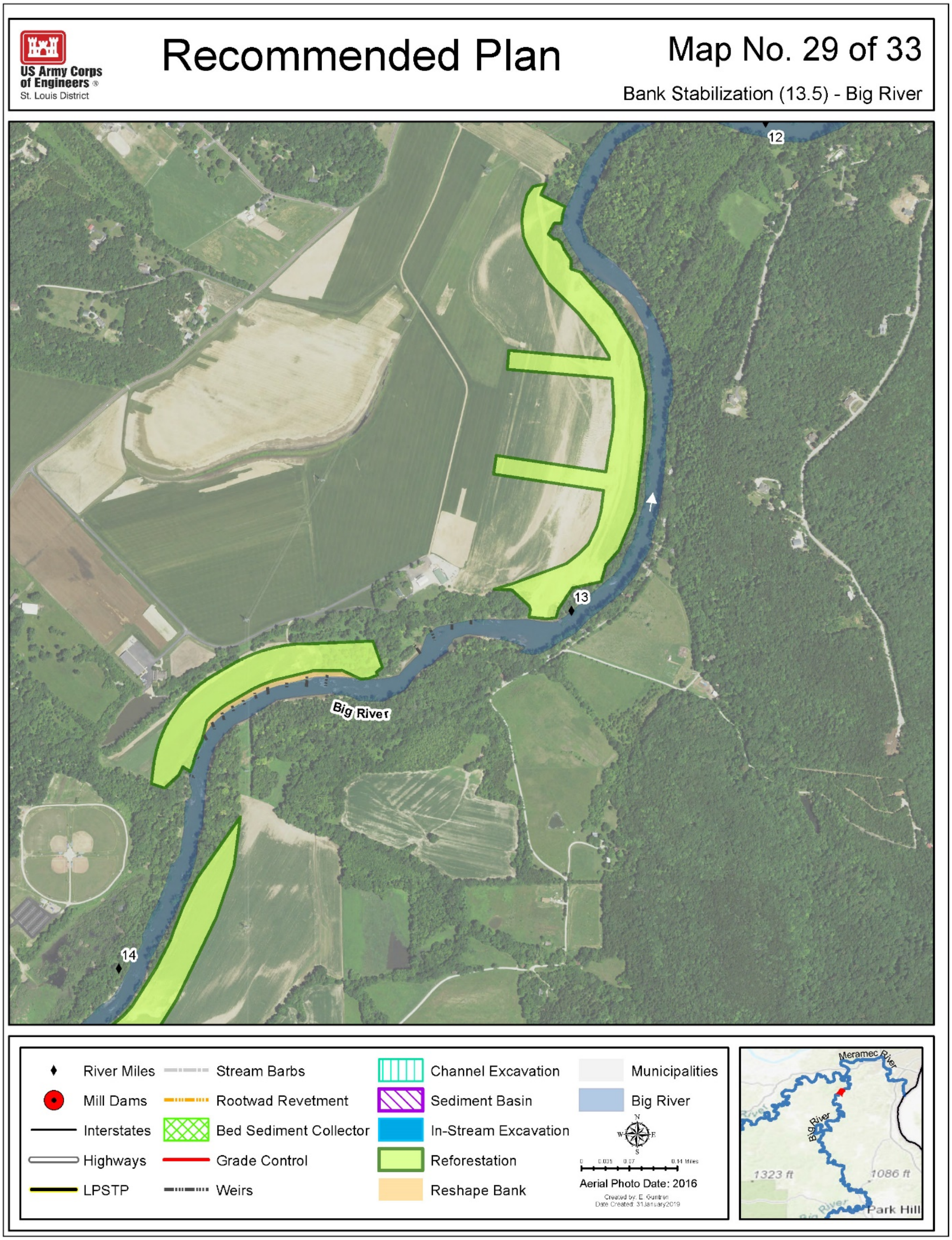


Figure 7-29. Recommended Plan River Mile 13.5

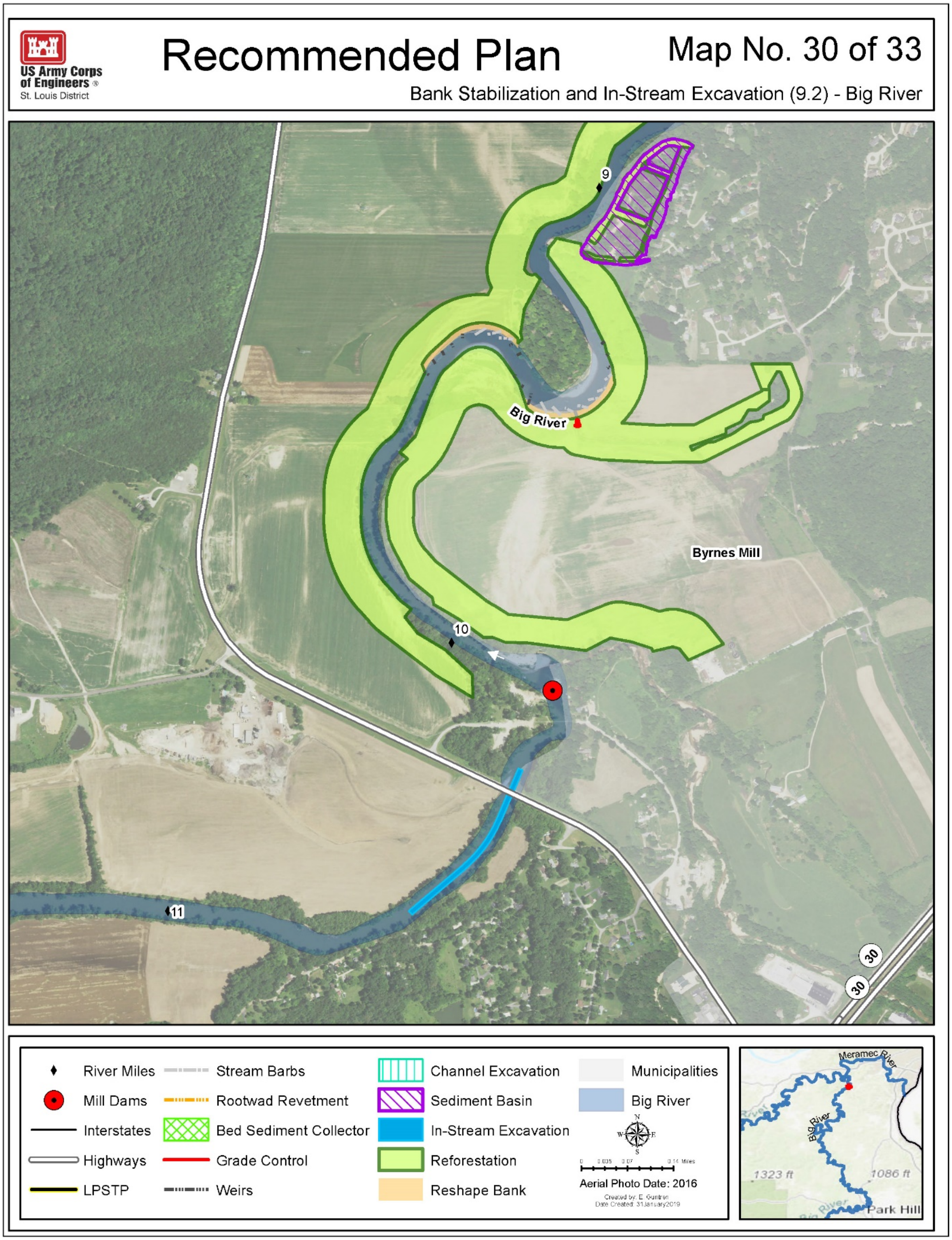


Figure 7-30. Recommended Plan River Mile 9.2

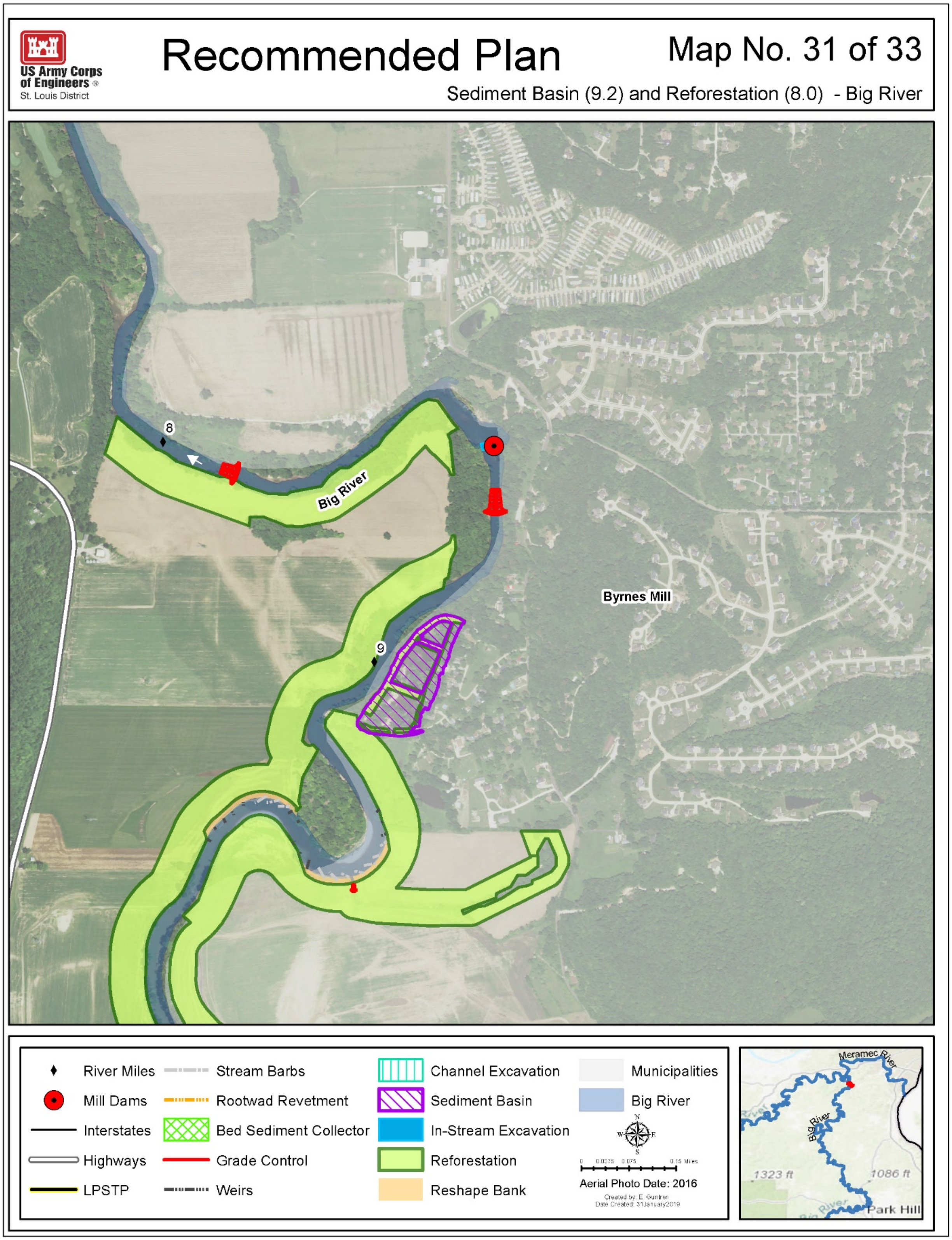


Figure 7-31. Recommended Plan River Mile 9.2-8.0

Figure 7-32. Recommended Plan River Mile 5.0

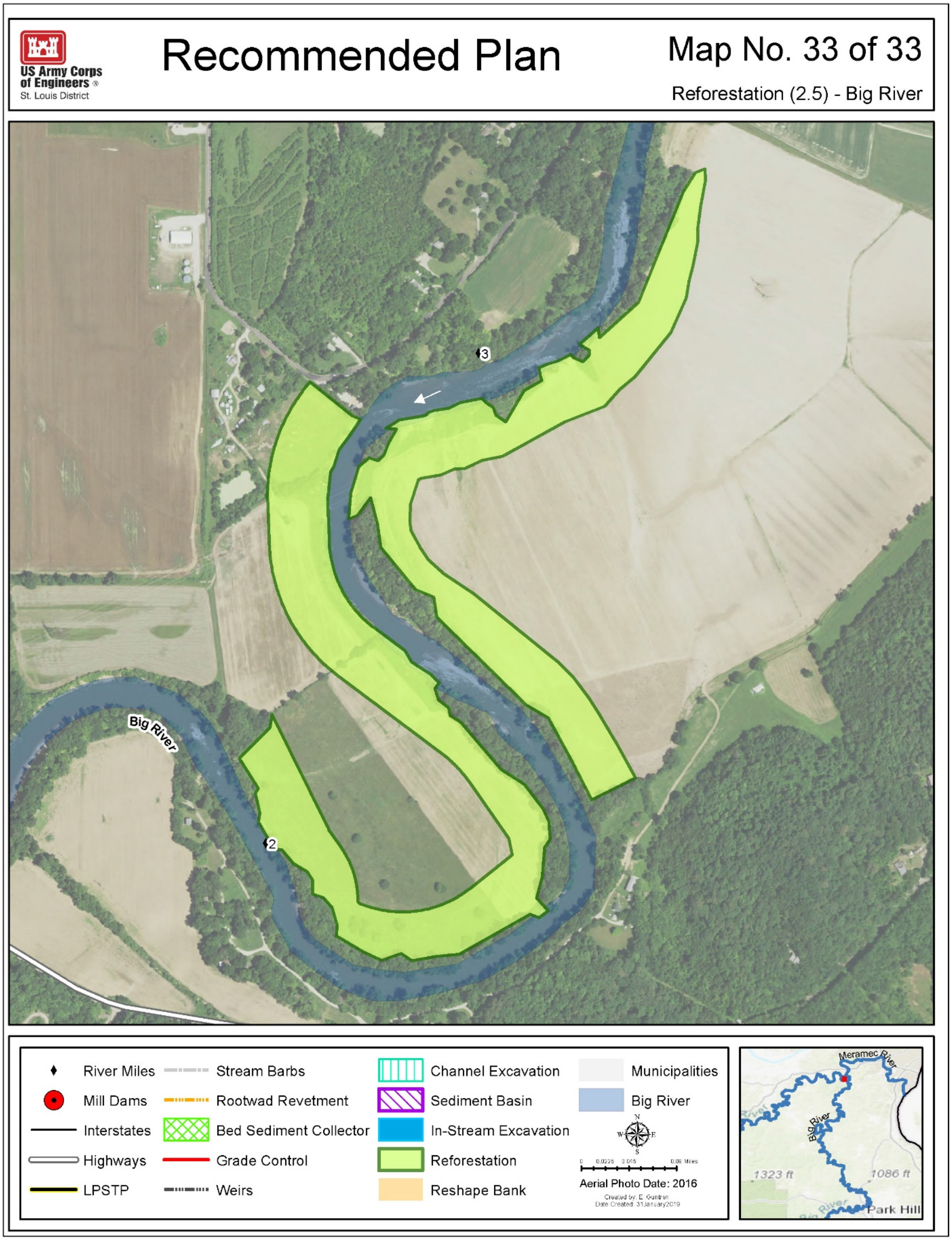


Figure 7-33. Recommended Plan River Mile 2.5

7.1 DESIGN CONSIDERATIONS

During pre-construction engineering and design (PED) the USACE and MoDNR will complete the detailed engineering & technical analysis needed to begin construction of the project as recommended in this decision document. This includes engineering design documentation and the plans and specifications of the first significant construction contract. Further refinement, and any necessary changes to the recommended plan will occur during this time. Recommended analysis during PED is discussed in Appendix H-*Hydraulics and Hydrology Analysis* and Appendix G- *Engineering Design.*

7.1.1 DATUM

Due to the large and dynamic study area, no new topographic surveys were conducted. The Missouri Spatial Data Information Service (MSDIS) during 2007 and 2008[34] collected or gathered data used for this study. These data required conversion to Missouri State Plane East (FIPS 2401) in units of U.S. Survey Foot, Horizontal and Vertical Datum NAD83, NAVD88 for design.

7.1.2 ACCESS

The project area is large and spread out so multiple access and staging areas will be necessary throughout construction of the Project. Final staging and access areas will not occur until the USEPA issues a ROD for the Big River.

7.1.3 EXCAVATED MATERIAL

Some portion of excavation material will not be able to be used on site create excess material. This material will be hauled to the nearest USEPA approved repository, the majority of which are located in St. Francois County.

7.1.4 HTRW

Final site selection and design will not occur until the USEPA issues a ROD the Big River. During construction, USACE will avoid the disturbance of CERCLA materials above HTRW levels of concern and is required to be disposed of in accordance with applicable laws. If any evidence of recognized environmental conditions is discovered during construction activities, operations should cease until an assessment is performed.

7.1.5 CULTURAL

The layout and design of measures was conducted to avoid impacts to known cultural sites. In an effort to avoid or minimize adverse effects to other cultural resources, final project site selection and design may be altered as a result of consultation with the SHPO and Tribes or as a result of any newly discovered cultural resources located by cultural resource surveys which may take place in the future. Design specifications will include requirements, developed in consultation with the SHPO and affiliated tribes, to the contractor for what to do in case culturally sensitive sites are encountered during construction.

---

[34] Data are publicly available at *http://www.msdis.missouri.edu/data/lidar/index.html*.

7.2 CONSTRUCTION CONSIDERATIONS

7.2.1 PROTECTED SPECIES

7.2.1.1 BALD EAGLES

Consideration (in coordination with the USFWS) will be given during design preparation sequencing construction activities in a manner that minimizes impacts. No clearing of trees where roosting or occupied nests exist shall be allowed when bald eagles are present in the area. If any nesting activity is observed, no construction activities within 660 feet of the nest shall be allowed.

7.2.1.2 INDIANA BAT AND NORTHERN LONG-EARED BAT

Construction work requiring tree clearing activities must be scheduled outside April 1 to September 30 when bats are known to inhabit summer habitat. Continued coordination with USFWS will occur through future project phases. At a minimum, a site visit by a team of biologists will be required to determine if any roost trees are among those trees proposed for removal. If removal of a roost tree is proposed, then the District must enter into Section 7 consultation with the USFWS. The consultation will determine if the proposed action is likely to jeopardize the continued existence of the Indiana Bat or Northern Long-Eared Bat.

7.2.1.3 MIGRATORY WILDLIFE

In accordance with Executive Order 13186, take of migratory birds protected under the Migratory Bird Treaty Act should be avoided or minimized, to the extent practicable, to avoid adverse impact on migratory bird resources. Proposed tree clearing during winter would also avoid nesting migratory wildlife.

7.2.2 AIR QUALITY

Diesel emissions and fugitive dust during project construction may pose environmental and human health risks and should be minimized. Applicable protective measures as outlined in USEPA's *Construction Emissions Control Checklist*[35] would be followed.

7.2.3 PERMITS

Laws of the United States and the State of Missouri have assigned the Corps and MoDNR with specific and different regulatory roles designed to protect the waters within and on the State's boundaries. Protecting Missouri' waters is a cooperative effort between the applicant and regulatory agencies.

7.2.3.1 SECTION 404 /401 COMPLIANCE

The District is compliant with Section 404 of the Clean Water Act based upon the 404(b)(1) evaluation (Appendix D-*404(b)1*). MoDNR Section 401 water quality certification is mandatory for all projects requiring a Federal Section 404 permit. Section 401 water quality certification is the MoDNR's concurrence that a project is consistent with the state's water quality standards. Short- and long-term

[35] Available online at: https://www3.epa.gov/ttn/scram/guidance/guide/Air_Quality_Analysis_Checklist-Revised_20161220.pdf. Accessed 19 December 2018.

impacts to water quality and water-related uses are evaluated in the Section 401 certification review. Section 401 water quality certification will be obtained from MoDNR prior to construction.

7.2.3.2 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

A storm discharge or NPDES permit for construction activities may be required. Effective March 10, 2003, the NPDES storm water discharge permit is required when a construction activity disturbs more than one acre. The construction contract for the study area may trigger the need for the contractor to apply for this permit. With or without the permit, the USACE requires an environmental plan that addresses contaminants as well as erosion control measures. The contractor would be required to prepare an erosion control plan to ensure that unprotected soil is not allowed to leave the study area work limits. The contractor would be required to comply with all local codes and permit requirements.

7.2.4 CONSTRUCTION SCHEDULE CONSTRAINTS

Scheduling of construction contracts would depend on availability of funds, and based on expected funding, it is likely that the contract would be awarded in at least 8 construction contracts. The following documents constraints related to construction:

- No clearing of trees shall be allowed between April 1 and September 30 to avoid impacts to bat roosting trees.
- During peak hunting weekends or peak harvest time construction activities may be required to cease for a short period of time.
- Trees and shrubs shall be planted during optimum times for each species. Final planting dates will be coordinated during the design phase.

7.2.5 PROJECT SCHEDULE

A Project schedule was developed based upon the assumption that this report will be approved in the last quarter of FY 2019. The Project schedule sequences design and construction activities to begin in FY 2021 once authority and appropriation to construct are acquired. The development of this schedule assumes Federal funding is available in the years required and that the real estate actions are completed on schedule.

The recommended schedule reflects the information currently available and the current departmental policies governing execution of projects. It does not reflect program and budgeting priorities inherent in either the formulation of a national civil works construction program or the perspective of higher review levels within the Executive Branch. Consequently, the schedule recommended may be modified before it is transmitted to higher authority. Under current plans, advertisement, and award of the first item of construction for work is scheduled in FY 2021, pending funding. Assuming funding availability, construction completion is planned for FY 2028.

7.3 OPERATION, MAINTENANCE, REHABILITATION, REPLACEMENT, AND REPAIR

Maintenance requirements would be further detailed in the Project's O&M manual published after construction completion. OMRRR life cycle costs include oversight, management, monitoring, debris and sediment removal, power, riprap repair, earthwork, timber, toe wood timber, tree clearing, plantings, periodically replacing fittings and hoses, conducting preventive and periodic maintenance on the pump engine and automation systems, ensuring reception systems are prepared for flood operations, protected from weather, theft, and vandalism, collector cell removal and repaint. The total annualized cost for OMRRR of the Recommended Plan is $489,000 using the FY 2019 2.875% discount rate. The annualized OMRRR amount went up from the alternative estimate of $217,628. A breakdown by year for the 50-year period of analysis is shown in Table 7-1 (see Appendix G-*Engineering Design* for additional details).

Table 7-1. Projected Total OMRRR Costs Over 50 Year Period of Analysis

Annual		$ 109,000
Year	1	$ 277,000
Year	2	$ 277,000
Year	3	$ 277,000
Year	4	$ 277,000
Year	5	$ 1,978,000
Year	10	$ 3,385,000
Year	15	$ 114,200
Year	20	$ 3,069,000
Year	25	$ 519,200
Year	30	$ 3,476,000
Year	35	$ 114,200
Year	40	$ 3,069,000
Year	45	$ 114,200
Year	50	$ 2,110,000
Total		**$ 23,008,000**
Annualized		**$ 489,000**

8 RISK AND UNCERTAINTY AT FEASIBILITY LEVEL

At the feasibility level of planning, there is always uncertainty about the extent to which the recommended plan will meet the planning objectives. Even when project performance uncertainty is negligible, there is some retained risks. In addition there can be new or transferred risks associated with the recommended plan. It is important to evaluate, communicate, and manage the risks prior to beginning PED.

8.1 COST RISK

A class three cost estimate was created for the recommended plan, meaning there was a fair level of scope and technical work done to generate a cost estimate. All measures, except bed sediment collectors, have been recently constructed in the study area by the interagency team so minimal uncertainty associated with cost was identified. Significant effort was performed to refine the bed sediment collector design and associated cost further reducing uncertainty.

Additionally, a detailed cost and schedule risk analysis was performed to include risk identification and sensitivity analysis using a Monte Carlo simulation method. The risk analysis documented the conditions, uncertainties, and evaluation methodology used to determine an overall contingency of 24 percent. This contingency will be used to cover unknowns, uncertainties, and/or unanticipated conditions that are not possible to evaluate from the data used in this study but must be accounted for to cover identified risks.

8.2 IMPLEMENTATION RISK

USEPA remediation levels remain the most significant area of uncertainty. This level will affect where the USACE and sponsor will be able to construct measures. The first significant construction contract will be completed in the lower portions of the Big River where lead levels are lowest. There is a risk that these levels may require redesign of the project or a delay in implementation.

8.3 PERFORMANCE RISK

While risks were reduced to a tolerable level by managing the uncertainty associated with project benefits, as discussed in Section 6.1.5, residual risks and the potential for new risks remain. To account for these risks a monitoring and adaptive management plan was created.

8.3.1 MONITORING AND ADAPTIVE MANAGEMENT

Section 1161 of WRDA 2016 requires that when conducting a feasibility study for ecosystem restoration, the proposed project includes a plan for monitoring the success of the ecosystem restoration. Additionally, paragraph (7)(d) of Section 1161 Implementation Guidance states that “an adaptive management plan will be developed for ecosystem restoration projects…appropriately scoped to the scale of the project.” The implementation guidance for Section 1161, in the form of a CECW-P Memo dated 19 October 2017, also requires that an adaptive management plan be developed for all ecosystem restoration projects. The primary incentive for implementing an adaptive management plan is to increase the likelihood of achieving desired project outcomes given the identified uncertainties which may include incomplete description and understanding of relevant ecosystem structure and function, imprecise relationships among project management actions and corresponding outcomes, engineering challenges in implementing project alternative, and ambiguous management and decision-making processes.

> ***The National Research Council defines Adaptive Management as:***
>
> *"Adaptive management promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a "trial and error" process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders."*

Bank stabilization measures may require adjustment to their design to include additional or adjustment of bioengineering methods. Additional alterations may include removing/replacing stone, supplementing with new stone. Toe wood alteration may include replacing key timbers, additional shaping, and intensive planting schedules. Tree screens alterations may include planting alternative species. Sediment basins may require adjustment to their design, particularly inlet and outlet structures. Direct excavation adaptive management response would involve actions to correct any bed or bank stability concerns occurring after project construction, which appear to be tied to the excavation.

This monitoring and adaptive management plan has been developed with input from the State and Federal resource agencies. The monitoring schedule is summarized in Table 8-1. Details on performance indicators, monitoring targets, time of effect, frequency of monitoring, adaptive management triggers, and responsibilities of monitoring and data collection are detailed in Appendix J- *Monitoring and Adaptive Management Plan.*

8.3.2 MONITORING AND ADAPTIVE MANAGEMENT COSTS

Per Section 1161 guidance, monitoring costs (not to exceed 10 years after project construction) were considered as part of project costs. Any monitoring conducted after 10 years would not be part of the total project cost and will be 100% non-Federal costs.

Table 8-1. Monitoring Schedule

Measure	Action	Year - Post Construction									
		1	2	3	4	5	6	7	8	9	10
Bed Sediment Collector	Site Inspection		$2,400			$2,400				$2,400	
	Cross-Section Survey					$9,000				$9,000	
Bank Stabilization	Site Inspection		$9,600			$9,600				$9,600	
	Cross-Section Survey					$36,000				$36,000	
In-stream Excavation	Site Inspection		$3,200			$3,200				$3,200	
	Cross-Section Survey					$12,000				$12,000	
	Site Inspection		$3,200			$3,200				$3,200	
	Cross-Section Survey					$12,000				$12,000	
	Site Inspection		$800			$800				$800	
	Cross-Section Survey					$3,000				$3,000	
Grade Control Structure	Site Inspection		$2,400			$2,400				$2,400	
	Cross-Section Survey					$9,000				$9,000	
Reforestation	Forest Plot Survey	$95,000				$95,000					$95,000
Sediment Basin	Site Inspection		$4,800			$4,800				$4,800	
	Cross-Section Survey					$18,000				$18,000	
	SC Trap Inspection					$6,000					$6,000
	SC Trap Geo-Analysis					$30,000					$30,000
All	Aerial Image Analysis		$10,000			$10,000			$10,000		
	Mussel Monitoring		$40,000			$40,000			$40,000		

* Baseline monitoring costs occurring in PED are not included in adaptive management totals.

Table 8-2 outlines the adaptive management costs.

Table 8-2. Projected Total Adaptive Management Cost Over 10 Year Adaptive Management Period

Adaptive Management Actions	Cost
Stone Structure Adjustments/Alterations	$ 1,409,000
Wood Structure Adjustments/Alterations	$ 940,000
Earthwork Feature Adjustments/Alterations	$ 1,874,000
Vegetation Adjustments/Alterations	$ 928,000
Total	**$ 5,151,000**

* Assume all Adjustments/Alterations will be conducted in Year 10

Foreseeable potential actions are discussed below and total anticipated monitoring and potential adaptive management costs are estimated to be $5,935,000.

9 LAND, EASEMENTS, RIGHTS OF WAY, RELOCATION, AND DISPOSAL (LERRD)

The non-federal sponsor is required to provide any lands, easements, right of ways, relocations and disposals (LERRD) necessary for project construction and OMRRR. Any LERRDs determined to be integral to the project will be credited to the project. Approximately 213 parcels of varying size of private ownership lie within the Recommended Plan footprint.

Based on a November 2018 cost estimate, the real estate values for the affected lands total approximately $9,278,000 (see Appendix K-*Real Estate Plan* for more details). The LERRD cost estimate was prepared by the St. Louis District Real Estate Office.

10 ESTIMATED PROJECT COST

Table 10-1. Cost Estimate of Recommended Plan

Account	Measure	Current Working Estimate
01	Lands and Damages	$ 9,278,000
06	Fish and Wildlife Activities	$ 48,088,000
09	Contingency	$ 15,833,000
16	Monitoring and Adaptive Management	$ 5,935,000
30	Planning, Engineering and Design	$ 6,251,000
31	Construction Management	$ 4,568,000
Project Cost Estimate		$ 89,953,000

Based on October 2018 price levels, the estimated project first cost, displayed in Table 10-1, is $89,953,000, which includes monitoring costs of $784,000 and adaptive management costs of $5,151,000. In accordance with the cost share provisions in Section 103(c) of the Water Resources Development Act (WRDA) of 1986, as amended {33 U.S.C. 2213(c)), the Federal share of the project first cost is estimated to be is $58,469,000 and the non-Federal sponsor's portion is $31,484,000, which equates to 65% Federal and 35% non-Federal. The non-Federal cost includes the LERRD value estimated to be $9,278,000. Per Engineering Regulation 1165-2-132, Hazardous, Toxic And Radioactive Waste (HTRW) Guidance For Civil Works Projects (1992) all CERCLA regulated response costs shall be a responsibility of the sponsor; therefore, any additional cost for special handling of CERCLA material will not be part of the total project cost and responsibility will solely fall to the non-Federal sponsor.

Table 10-2. St. Louis Riverfront Meramec River Basin Ecosystem Restoration Cost Sharing (October 2018 Price Level)

Item	Federal Cost	Non-Federal Cost	Total Cost
Ecosystem Restoration (ER)	$53,146,000	$21,278,000	$74,424,000
PED	$4,563,000	$1,688,000	$6,251,000
LERRD	$760,000	$8,518,000	$9,278,000
Total Project	$58,469,000	$31,484,000	$89,953,000
Associated Costs	$0	$0	$0
Total with Associated Costs	$58,469,000	$31,484,000	$89,953,000

A risk analysis was performed to determine the contingency for each alternative. Significant level of design and effort was completed to calculate the monitoring, adaptive management, and OMRRR items.

Further analysis from the alternative analysis cost estimate to feasibility level design increased the total project first cost from $78M to $90M. A sensitivity analysis was conducted, and confirmed, the cost increase did not affect which alternative is the NER plan.

11 RESPONSIBILITIES

11.1 USACE, ST. LOUIS DISTRICT

The St. Louis District, USACE is responsible for project management and coordination with the MoDNR and other affected agencies. The USACE will submit the feasibility report, program funds, finalize plans and specifications, complete all NEPA requirements, complete all NHPA requirements, advertise and award construction contracts, and perform construction contract supervision and administration.

11.2 MISSOURI DEPARTMENT OF NATURAL RESOURCES

Federal implementation of the recommended project would be subject to the non-Federal sponsor agreeing to comply with Federal laws and policies, including but not limited to:

a. Provide, during the periods of design and construction, funds necessary to make its total contribution for ecosystem restoration equal to 35 percent of the total project cost;

b. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material as determined by the Federal government to be required or to be necessary for the construction, operation, and maintenance of the project;

c. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

d. Operate, maintain, repair, rehabilitate, and replace the project at no cost to the Federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal government;

e. Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

f. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

g. Keep, and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, and other evidence are required, to the extent and in such detail as will properly reflect total cost of the project, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and local governments at 32 CFR, Section 33.20;

h. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under CERCLA, 42 USC 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be necessary for the construction or operation and maintenance of the project;

i. Assume, as between the Federal government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal government determines to be necessary for the construction, operation, maintenance, repair, rehabilitation, or replacement of the project;

j. Agree, as between the Federal government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA;

k. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, (42 U.S.C. 1962d-5b) and Section 101(e) of the WRDA 86, Public Law 99-662, as amended, (33 U.S.C. 2211(e)) which provide that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element;

l. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended, (42 U.S.C. 4601-4655) and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way necessary for construction, operation, and maintenance of the project including those necessary for relocations, the borrowing of material, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said act;

m. Comply with all applicable Federal and state laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d), and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (revising, codifying and enacting without substantive change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c));

n. Not use the project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project; and

o. Not use funds from other Federal programs, including any non-federal contribution required as a matching share therefore, to meet any of the non-Federal sponsor's obligations for the project unless the Federal agency providing the funds verifies in writing that such funds are authorized to be used to carry out the project.

12 LESSONS LEARNED DURING HURRICANES KATRINA AND RITA

The Recommended Plan is consistent with each of the Chief of Engineers' Actions for Change for Applying Lessons Learned during Hurricanes Katrina and Rita issued 24 August 2006. The twelve actions are grouped into four themes.

Actions in the first theme, Comprehensive Systems Approach, include: employing integrated, comprehensive systems-based approach; employing adaptive planning and engineering systems; and focusing on sustainability. A comprehensive systems approach was used through a collaborative interagency team with Federal and State agencies as well as NGO's and interested stakeholders.

Actions in the second theme, Risk Informed Decision Making, include: employing risk based concepts in planning, design, construction, operations, and major maintenance; and reviewing and inspecting completed works. The recommended plan for the Meramec River Basin Ecosystem Restoration was selected using a risk informed-decision making process in general. The unknown USEPA remedial action levels were identified as the highest level of risk and uncertainty, through interagency team coordination and various scenarios analysis the risks were managed and uncertainty minimized.

Actions in the third theme, Communication of Risk to the Public, include: effectively communicating risk; and establishing public involvement risk reduction strategies. The report establishes the current condition of the Meramec River Basin and also how this condition relates to public safety.

Actions in the fourth theme, Professional and Technical Expertise, include: continuously reassessing and updating policy for program development, planning guidance, design and construction standards; dynamic independent reviews; assessing and modifying organizational behavior; managing and enhancing technical expertise and professionalism; and investing in research. The report was continuously reassessed during its development. The analysis has undergone DQC (District Quality Control) and ATR (Agency Technical Review), legal, public and policy reviews. In addition sponsor and stakeholder reviews of the technical analysis is well documented. Technical experts were used throughout the life of the Study.

13 USACE CAMPAIGN PLAN

The USACE Campaign Plan provides goals, objectives, and actions for improving the USACE contribution to the nation in the areas of warfighting, civil works processes and delivery systems, risk reduction from natural events, and preparation for the future. The four primary goals are to 1) Support National Security, 2) Deliver Integrated Water Resource Solutions, 3) Reduce Disaster Risks, and 4) Prepare for Tomorrow. The Meramec River Basin Ecosystem Restoration Project supports the Campaign Plan with contributions to Goal 2, "Deliver Integrated Water Resource Solutions." The project does not make significant contributions to the other three goals.

Goal 2 (Deliver Integrated Water Resource Solutions) includes the following objectives: 2a - Deliver quality water resource solutions and services; 2b - Deliver the civil works program and innovative solutions; 2c - Develop the civil works program to meet the future needs of the Nation; and 2d - Manage the life-cycle of water resources infrastructure systems to consistently deliver reliable and sustainable performance. The Meramec River Basin Ecosystem Restoration Project supports Goal 2 by:

- Identification a plan to restore the function, structure, and process of the Meramec River Basin;
- Coordination with significant stakeholder groups throughout the study process; and
- Recommendation of a sustainable and resilient plan, with appropriate consideration of the long term operation and maintenance of the restoration features.

14 CONCLUSIONS

Management measures were designed to meet the study's objectives of protecting and restoring aquatic ecosystem structure and function and restoring floodplain forest habitat. The management measures identified as the NER plan for the Meramec River Basin (in-stream excavation, sediment basins, reforestation, bank stabilization, sediment bed collectors and grade control structures) would allow the study area to realize the highest benefit to freshwater mussels, fish, and wildlife.

The implementation of the *St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study* would reduce contaminated sediments, improve bank stability and enhance floodplain forest structure and diversity during the 50-year period of analysis. These restoration efforts would provide long-term benefits to aquatic organisms, including freshwater mussels, and resident and migratory wildlife. While improvements would occur at specific restoration sites, the collective effect would extend beyond an individual restoration site footprint and ultimately restore the ecosystem structure and function within the Meramec River Basin.

15 REFERENCES

Albers, j. L., Besser, J. M., Schmitt, C. J., & Wildhaber, M. L. (2016). *Mussel community associations with sediment metal concentrations and substrate characteristics in the Big River, Missouri, U.S.A.* Administrative Report U.S. Department of the Interior, U.S. Geological Survey.

Aldridge, D., Payne, B. S., & Miller, A. C. (1987). The effects of intermittent exposure to suspended soilids and turbulence on three species of freshwater mussels. *Environmental Pollution, 45*, 17-28.

Allert, A. L., DiStefano, R. J., Fairchild, J. F., Schmitt, C. J., Brumbaugh, W. G., & Besser, J. M. (2009). *Effects of mining-derived metals on riffle-dwelling crayfish and in-situ toxicity to juvenile Orconectes hylas and Orconectes luteus in the Big River of southeast Missouri, USA.* Columbia, MO: U.S. Fish and Wildlife Service Colubmia Ecological Services Office.

Barbour, M. J. (1999). *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, second edition.* Washington DC: EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water.

Benton, P. D., Ensign, W. E., & Freeman, B. J. (2008). The effect of road crossings on fish movements in small Etowah Basin streams. *Southeastern Naturalist, 7*(2), 301-310.

Besser, J. M., Brumbaugh, W. G., Hardesty, D. K., Hughes, J. P., & Ingersoll, C. G. (2009). *Assessment of metal-contaminated sediments from the Southeast Missouri (SEMO) mining district using sediment toxicity tests with amphipods and freshwater mussels.* Columbia, MO: U.S. Fish and Wildlife Service, Columbia Ecological Services Office.

Beussink, Z. S. (2007). *The effects of suspended sediment on the attachment and metamorphosis success of freshwater mussel parasitic life stages.* Springfield, MO: Missouri State University.

Box, J. B., & Mossa, J. (1999). Sediment, land use, and freshwater mussels: prospects and problems. *Journal of North American Benthological Society, 18*(1), 99-117.

Buchanan, A. C. (1979). *Mussels (Naiades) of the Meramec River Basin, Missouri.* St. Louis, MO: U.S. Army Corps of Engineers, St. Louis District.

Buchanan, A. C. (1980). *Mussels (Naiades) of the Meramec River Basin, Missouri.* Jefferson Citym Missouri: Missouri Department of Conservation.

Butler, R. S. (2002). *Status Assessment Report for the spectaclecase (Cumberlandia monodonta), occuring in the Mississippi River System.* Asheville, NC: U.S. Fish and Wildlife Service - Ohio River Valley Ecosystem Team, Mollusk Subgroup.

CAPF. (2016). *California Fish Passage Forum*. Retrieved April 21, 2016, from Why is Fish Passage Barrier Removal Important?: http://www.cafishpassageforum.org/why-is-fish-passage-barrier-removal-important

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

CEQ. (1997). *Considering Cumulative Effects Under the National Environmental Policy Act.* Retrieved from http://energy.gov/nepa/downloads/considering-cumulative-effects-under-national-environmental-policy-act-ceq-1997

Charbonneau, J. J., & Caudill, J. (2010). *Conserving America's Fisheries: An Assessment of Economic Contributions from Fisheries and Aquatic Resource Conservation.* U.S. Fish and Wildlife Service, Business Management and Operations, Division of Economics. Retrieved April 21, 2016, from http://www.fws.gov/midwest/fisheries/economicreport/documents/FishReportSept2010.pdf

Cooke, D. A., & Gascon, C. S. (2014). After stalling, recovery resumes in St. Louis. *The Regional Economist*, 16-19.

Csiki, S. J., & Rhoads, B. L. (2010). Hydraulic and geomorphological effects of run-of-river dams. *Progress in Physical Geography*, 34(6) 755-780.

Csiki, S. J., & Rhoads, B. L. (2014). Influence of four run-of-river dams on channel morphology and sediment characteristics in Illinois, USA. *Geomorphology*, 215-229.

Czarnezki, J. M. (1985). Accumulation of Lead in Fish from Missouri Streams Impacted by Lead Mining. *Bulletin of Environmental Contamination and Toxicology, 34*, 736-745.

Department of Health and Senior Services. (2018). *2018 MISSOURI FISH ADVISORY A GUIDE TO EATING MISSOURI FISH.*

Doe Run. (2018, February 23). *Milling and Mining*. Retrieved from http://www.doerun.com/what-we-do/mining-and-milling

Ekberg, C. J., Smith, C. R., Walters, W. D., & Lange, F. W. (1981). *A Cultural Geographical and Historical Study of the Pine Ford Lake Project Area, Washington, Jefferson, Franklin, and St. Francois Counties, Missouri.* Departemnt of Interior, Interagency Archaeological Services. Normal, IL: Illnois State University Archaeological Surveys.

Gangloff, M. M., & Feminella, J. W. (2007). Stream channel geomorphology influences mussel abundance in southern Applachian streams, USA. *Freshwater Biology, 52*, 64-74.

Grabarkiewicz, J., & Davis, W. (2008). *An introduction to freshwater mussels as biological indicators.* Washington, D.C.: EPA, Office of Environmental Information.

Grady, J., Corio, M., Elkington, B., Walker, A., & Hill, T. (2011). *Identification of Fish Passage Barriers through Inventory and Assessment of Road-Stream Crossings within the Big River Watershed Missouri.* Columbia, MO: U.S. Fish and Wildlife Service .

Henley, W. F., Patterson, M. A., Neves, R. J., & Lemly, A. D. (2000). Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. *Reviews in Fisheries Science, 8*, 125-139.

Hinck, J. E., Ingersoll, C. G., Wang, N., Augspurger, T., Barnhart, M. C., McMurray, S. E., . . . Schrader, L. (2011). *Threats to Habitat and Water-Quality Degradation to Mussel Diversity in the Meramec River Basin, Missouri, USA.* U.S Geological Survey Open File Report 2011-1125.

Hinck, J. E., McMurray, S. E., Roberts, A. D., Barnhart, M. C., Ingersoll, C. G., Wang, N., & Augspurger, T. (2012). Spatial and temporal trends in freshwater mussel assemblages in the Meramec River Basin, Missouri, USA. *Journal of Fish and Wildlife Management, 3*(2), 319-331.

Ives, D. J., May, J. A., & Denman, D. D. (1982). *Pine Ford Lake Phase I Archaeological Survey.* Department of Interior, Interagency Archaeological Services. Columbia, MO: American Archaeology Division, Department of Anthropology, University of MIssouri.

James, L. A. (1989). Sustained storage and transport of hydraulic gold mining sediment in the Bear River, California. *Annals of the Association of American Geographers, 79*, 570-592.

Jordan, Y. C., Ghulam, A., & Hartling, S. (2014). Traits of surface water pollution under climate and land use changes: a remote sensing and hydrological modeling approach. *Earth-Science Reviews, 128*, 181-195.

Knighton, A. D. (1989). River adjustments to changes in sediment load: the effects of Tin mining on the Ringarooma River, Tasmania, 1875-1984. *Earth Surfaces Processes and Landforms, 14*, 333-359.

Lubinski, K., & Barko, J. (2003). *Upper Mississippi River - Illinois Waterway System Navigation Feasibility Study: Environmental Science Panel Report.* Rock Island, Illinois, St. Louis, Missouri, and St. Paul, Minnesota: U.S. Army Corps of Engineers: Rock Island District, St. Louis District, St. Paul District.

Lyons, J. K., & Beschta, R. L. (1983). Land use, floods, and channel changes: upper Middle Fork Willamette River, Oregon (1936-1980). *Water Resources Research, 19*, 463-471.

MacDonald, D. D., Ingersoll, C. G., & Berger, T. A. (2000). Development of evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Archives of Environmental Contamination and Toxicology, 39*, 20-31.

MAS. (2016). *Missouri Audubon Society*. Retrieved April 4, 2016, from http://www.mobirds.org/listing/MOTopTen.pdf

McKee, M., Vining, I., & Sheriff, S. (2010). *Effects of Lead-Zinc Mining on Benthic Fish Density in Riffles of the Big River (Southeast Missouri).* Jeferson City, MO: Missouri Department of Conservation.

MDC. (1997). *Missouri Watershed Inventory and Assessment: Big River*. Retrieved April 21, 2016, from http://mdc.mo.gov/your-property/greener-communities/missouri-watershed-inventory-and-assessment/big-river.

MDC. (1998). *Missouri Watershed Inventory and Assessment: Meramec River*. Retrieved April 21, 2016, from http://mdc.mo.gov/your-property/greener-communities/missouri-watershed-inventory-and-assessment/meramec-river

MDC. (2009). *A Summary of Missouri Fishing Regulations. .* Jefferson City, MO: Missouri Department of Conservation.

MDC. (2016). *Missouri Fish and Wildlife Information System*. Retrieved April 4, 2016, from MOFWIS version 2.1: http://mdc7.mdc.mo.gov/applications/mofwis/mofwis_search1.aspx

MoDNR. (2001-2002). *Biological Assessment and Fine Sediment Survey, Big River (upper), Washington County, Missouri.* Jefferson City, MO: Missouri Department of Natural Resources.

MoDNR. (2002-2003). *Biological Assessement and Fine Sediment Study, Big River (lower) Irondale to Washington State Park - St Francois, Washington, and Jefferson Counties, Missouri.* Jefferson City, MO: Missouri Department of Natural Resources.

MoDNR. (2007). *The Estimated Volume of Mine-Related Benthic Sediment in Big River at Two Point Bars in St. Francois State Park using Ground Penetrating Radar and X-Ray Flourescence.* Jefferson City, MO: Missouri Department of Natural Resources, Water Quality Monitoring Unit, Environmental Services Program.

MoDNR. (2007, July). *Total Maximum Daily Load Information Sheet: Big River and Flat River Creek*. Retrieved May 11, 2016, from http://dnr.mo.gov/env/wpp/tmdl/docs/2074-2080-2168-big-r-info.pdf

Melillo, J. M., Richmond, T. C., & Yohe, G. W. (2014). *Climate Change Impacts in the United States: the Third National Climate Assessment.* U.S. Global Change Research Program. doi:10.7930/J0Z31WJ2

Meneau, K. J. (1997, 31 July). *Missouri Department of Conservation*. Retrieved 25 March, 2016, from Big River Watershed Inventoryh and Assessment: https://mdc.mo.gov/your-property/greener-communities/missouri-watershed-inventory-and-assessment/big-river

Miller, J. A., & Appel, C. L. (1997). *Ground Water Atlas of the United States: Kansas, Missouri, and Nebraska HA 730-D.* U.S. Geological Survey.

Morris, T. J., & Corkum, L. D. (1999). Unionid growth patterns in rivers of differing riparian vegetation. *Freshwater Biology, 42*, 59-68.

MRLC. (2012). *Multi-Resolution Land Characteristics Consortium*. Retrieved March 1, 2016, from National Land Cover Database: at http://www.mrlc.gov/nlcd01_data.php

Neves, R. J. (1993). A state-of-the-unionids address. In K. S. Cummings, A. C. Buchanan, & L. M. Koch, *Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC Symposium, 12-14 October 1992, St. Louis, Missouri* (pp. 1-10). Rock Island, IL: Upper Mississippi River Conservation Committee,.

Newsfields. (2007). *Volume of sediment in Big River, Flat River Creek, and Owl Creek - St. Francois County Mined Areas, Missouri. Addendum to the march 2006 Focused Remedial Investigation of Mined Areas in St. Francois, County, Missouri. .* Denver, CO : Newsfield.

Nigh, T. A., & Schroeder, W. A. (2002). *Atlas of Missouri Ecoregions.* Jefferson City, MO: Missouri Department of Conservation.

Pandolfo, T. J., Cope, W. G., & Arellano, C. (2010). Temperature tolerance of juvenile freshwater mussels (Unionidae) under the added stress of copper. *Environmental Toxicology and Chemistry, 29*, 691-699.

Pavlowsky R.T., L. S. (2017). Legacy sediment, lead, and zinc storage in channel and floodplain deposits of the Big River, Old Lead Belt Mining District, Missouri, USA. *Geomorphology*, 54-75.

Pavlowsky, R. T., & Owen, M. R. (2013). *Big River Mining Sediment Assessment Project: Historic Channel Change Maps for the Big River System in St. Francois, Washington, and Jefferson Counties, Missouri. Map Report.* Columbia, MO: Ozarks Environmental and Water Resources Institute for the U.S. Fish and Wildlife Service.

Pavlowsky, R. T., Owen, M. R., & Martin, D. J. (2010). *Distribution, Geochemistry, and Storage of Mining Sediment in Channel and Floodplain Deposits of the Big River System in St. Francois, Washington, and Jefferson Counties, Missouri.*

Pearson, A. J., & Pizzuto, J. (2015). Beadload transport of run-of-river dams, Deleware, U.S.A. *Elsevier*, 382-395.

Potter, K. W. (1991). Hydrological impacts of changing land management practices in a moderate-sized agricultural catchment. *Water Resources Research, 27*, 845-855.

Roberts, A. D., & Barnhart, M. C. (1999). Effects of temperature, pH, and CO2, on transformation of the glochidia of Anodonta suborbiculata on fish hosts and in vitro. *Journal of North American Benthological Society, 18*, 477-487.

Roberts, A. D., & Bruenderman, S. (2000). *A reassessmentof the status of freshwater mussels in the Meramec River Basin, Missouri.* Jefferson City, MO: Missouri Department of Conservation.

Roberts, A. D., Mosby, D., Weber, J., Besser, J., Hundley, J., McMurray, S., & Faiman, S. (2010). *An assessment of freshwater mussels (Bivalvia: Margaritiferidae and Unionidae) populations and heavy metal sediment contamination in the Big River, Missouri.* U.S. Fish and Wildlife Service, Natural Resource Damage Asssessment.

Roberts, A., Hundley, J., Mosby, D., Rosenberger, A., Bouska, K., Simmons, B., & Lindner, G. (2016). *Quantitative survey of freshwater mussels (Unionoidea) and assessment of sediment contamination in the Big River, Missouri.* Columbia, MO: USFWS, USGS, University of Missouri.

Ryckman, Edgerley, & Tomlinson. (1972). *Environmental Inventory of the Meramec River Basin Volume 6: Meramec Park Lake Biological Elements.*

Santucci Jr, V. J., Gephard, S. R., & Pescitelli, S. M. (2005). Effects of multiple low-head dams on fish, macroinvertebrates, habitat and water quality in the Fox River, Illinois. *North American Journal of Fisheries Management, 25*(3), 975-992.

Scheckel, & Noerpel. (2017). *Analysis of Soil and Sediment in the Big River Watershed Utilizing Pb Isotopes for Source Attribution, Synchrotron Speciation for Phase Identification, and In-Vitro Bioaccessibility for Risk Assessment.*

Schmitt, C. J., & Fingers, S. E. (1982). *The dynamics of metals from past and present mining activities in the Big and Black River watersheds, southeastern Missouri.* St. Louis, MO: U.S. Army Corps of Engineers, St. Louis District.

Society, J. H. (1993). Missouri Indian Tribes. *The Heritage News*(2), p. 3.

Strayer, D. L. (1983). The effects of surface geology and stream size on freshwater mussel (Bivalvia, Unionidae) distribution in southereastern Michigan, USA. *Freshwater Biology, 12*, 253-264.

Thiel, P. A., & Fritz, A. W. (1993). Mussel harvest and regulations in the Upper Mississippi River System. In K. S. Cummings, A. C. Buchanan, & L. M. Koch, *Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC Symposium, 12-14 October 1992, St. Louis, Missouri* (pp. 11-18). Rock Island, IL: Upper Mississippi River Conservation Committee.

Thomas, J. L. (1907). *Historic Landmarks of Jefferson County, report of the committee on landmarks.* Missouri Historic Review - Old Settlers Association of Jefferson County, 1900.

Tidball, R. (1984). Geochemical Survey of Missouri. *Geological Survey Professional Paper*, 954 - H, I.

TNC. (2014). *The Meramec River Conservation Action Plan.* The Nature Conservancy.

USACE. (1992). *Jefferson County and Vicinity, Missouri Reconnaissance Report.* St. Louis, MO: U.S. Army Corps of Engineers, St. Louis District.

USACE. (2015). *Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - Water Resources Region 07, Upper Mississippi.* Washington, D.C.: U.S. Army Corps of Engineers.

USACE. (2015). *Recent US Climate Change and Hydroloty Literature Apllicable to US Army Corps of Engineers Missions - Water Resources Region 07, Upper Mississippi.* Civil Works Technical Report, USACE, Washington, DC.

USEPA. (1974). *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety.* U.S. Environmental Protection Agency.

USEPA. (1992, July). *Toxicity Characteristic Leaching Procedure - Method 1311.* Retrieved from US Environmental Protection Agency (USEPA): https://www.epa.gov/sites/production/files/2015-12/documents/1311.pdf

USEPA. (2011). *BIG RIVER MINE TAILINGS SUPERFUND SITE RECORD OF DECISION.* Kansas City, KS: USEPA.

USEPA. (2012). Historical Mining - Residential Soils Operable Unit 1 Southwest Jefferson County Mining Site.

USEPA. (2012). *Record of Decision: Historical Mining - Residential Soils Operable Unit 1 Southwest Jefferson County Mining Site.* Kansas City: USEPA.

USEPA. (2013). *The National rivers and streams assessment 2008-2009: A collaborative survey.* Washington, DC: U.S. Environmental Protection Agency, Office of Water and Office of Science and Technology.

USEPA. (2017). *Analysis of Soil and Sediment in the Big River Watershed Utilizing Pb Isotopes for Source Attribution, Synchotron Speciation for Phase Identification, and In-Vitro Bioaccessibility for Risk Assessment.*

USFWS. (2007). Protection of Eagles: Definition of "Disturb". *Federal Register, 72*(107), 31132-31139.

USFWS. (2011). *2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Missouri.* U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. Retrieved from https://www2.census.gov/programs-surveys/fhwar/publications/2011/fhw11-mo.pdf

USFWS. (2015a, October 15). *USFWS Endangered Sepcies*. Retrieved March 24, 2016, from Mead's Milkweed Fact Sheet: http://www.fws.gov/midwest/endangered/plants/meads/meadsmil.html

USFWS. (2015b, October 15). *USFWS Endangered Species*. Retrieved March 24, 2016, from Running Buffalo Clover Fact Sheet: http://www.fws.gov/midwest/endangered/plants/runningb.html

USFWS. (2015c, October 15). *USFWS Endangered Species*. Retrieved from Gray Bat Fact Sheet: http://www.fws.gov/midwest/endangered/mammals/grbat_fc.html

USFWS. (2015d, October 15). *USFWS Endangered Species*. Retrieved March 24, 2016, from Indiana Bat Fact Sheet: http://www.fws.gov/midwest/Endangered/mammals/inba/inbafctsht.html

USFWS. (2015e, October 15). *USFWS Endangered Species*. Retrieved March 24, 2016, from Northern Long-Eared Bat Fact Sheet: http://www.fws.gov/Midwest/endangered/mammals/nleb/nlebFactSheet.html

USFWS. (2015f, April 14). *USFWS Endangered Species: Pallid Sturgeon*. Retrieved April 21, 2016, from http://www.fws.gov/Midwest/endangered/fishes/PallidSturgeon/index.html

USFWS. (2015g, April 14). *America's Mussels: Silent Sentinels*. Retrieved April 21, 2016, from http://www.fws.gov/midwest/endangered/clams/mussels.html

USFWS. (2015h, April 14). *Endangered Species Pink Mucket Fact Sheet*. Retrieved April 21, 2016, from http://www.fws.gov/midwest/endangered/clams/pinkm_fc.html

USFWS. (2015i, April 14). *Endangered Species Sheepnose Fact Sheet*. Retrieved April 21, 2016, from http://www.fws.gov/midwest/endangered/clams/sheepnose/SheepnoseFactSheetMarch2012.html

USFWS. (2015j, October 15). *Endangered Species: Decurrent False Aster Fact Sheet*. Retrieved April 21, 2016, from http://www.fws.gov/midwest/endangered/plants/decurrentfalseaster/decurrfa.html

USFWS, USDOI, USFS, & MoDNR. (2014). *Southeast Missouri Ozarks Regional Restoration Plan and Environmental Assessment*. Retrieved March 01, 2016, from http://dnr.mo.gov/env/hwp/sfund/docs/nrd-final-semorrp.pdf

USGS. (2018). *Geochemistry of soils from the PLUTO database.* Retrieved from USGS: https://mrdata.usgs.gov/pluto/soil/

Villarini, G., Smith, J. A., & Vecchi, G. A. (2013). Changing frequency of heavy rainfall over the central United States. *Journal of Climate, 26*, 351-357.

Warren, L. W. (1996). *The use of juvenile mussels, Utterbackia imbecillis Say (Bivalivia: Unionidae) as a standardized toxicity testing organisms.* Clemson, SC: Clemson Univesity.

Watters, G. T. (1993). Mussel diversity as a function of drainage area and fish diversity: management implications. *Conservation and management of freshwater mussels. Proceedings of a UMRCC Symposium, 12-14 October 1992* (pp. 113-116). St. Louis, MO: Upper Mississippi River Conservation Committee, Rock Island, IL.

Watters, G. T. (1996). Small dams as barriers to freshwater mussels (Bivalvia, Unionida) and their hosts. *Biological Conservation, 75*, 79-85.

Watters, T. G., & O'Dee, S. H. (1998). Metamorphosis of freshwater mussel glochidia (Bivalvia: Unionidea) on amphibians and exotic fishes. *The American Midland Naturalist, 139*, 49-57.

Whelan, G. E. (1983). *The distribution and accumulation of lead and cadmium within a lotic benthic community.* Colubmia, MO: University of Missouri.

Williams, J. D., Warren, M. L., Cummings, K. S., Harris, J. L., & Neves, R. J. (1993). Conservation status of freshwater mussels of the United States and Canda. *18*, 6-22.

Yoe, C. (2012). *Guide to Constructing the Without Project Scenario (Condition).* Institute of Water Resources 2012-R-03.

Young, B. M. (2011). *Historical channel change and mining-contaminated sediment remobilization in the Lower Big River, Eastern Missouri.* Missouri State University.

16 RECOMMENDATIONS

I have weighed the outputs to be obtained from the full implementation of the Meramec River Basin Ecosystem Restoration Project against its estimated cost and have considered the various alternatives proposed, impacts identified, and overall scope. In my judgment, this Project, as proposed, justifies expenditure of Federal funds. I recommend that the Chief of Engineers review and approve the proposed Meramec River Basin Ecosystem Restoration Report to include installation of bed sediment collectors, creation of sediment basins, in-stream excavation of sediment, construction of grade control structures, reforestation, and implementation of bank stabilization features through stone work, root wad revetment and bank shaping.

The total Federal estimated Project cost, including general design and construction management, is $89,953,000.

___________________________	____
Date	BRYAN K. SIZEMORE COL, EN Commanding