U. S. Army Corps of Engineers

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

July 2019

Appendix A
Coordination

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK

1. COOPERATING AGENCY COORDINATION 9 FEBRUARY 2016

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Missouri Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0057
Phone: (573) 234-2132 Fax: (573) 234-2181

February 9, 2016

Mr. Brian Johnson
Environmental Compliance Branch Chief
Regional Planning and Environmental Division North
St. Louis Army Corps of Engineers
1222 Spruce Street
St. Louis, MO 63103-2833

Dear Mr. Johnson:

Thank you for your letter requesting participation of the U.S. Fish and Wildlife Service (Service) as a cooperating agency in preparing an Integrated Environmental Assessment (EA) on the Meramec and Big Rivers Ecosystem Restoration Feasibility Study (Study) in St. Louis and Jefferson Counties, Missouri. The Service supports the U.S. Army Corps of Engineers' (Corps) efforts to prepare this Study and EA and agrees to be a cooperating agency in accordance with our responsibilities under the National Environmental Policy Act of 1969 (42 U.S.C. 4321-4327), Fish and Wildlife Coordination Act (16 U.S.C. 661-667), Migratory Bird Treaty Act (16 U.S.C. 703-712), the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c), and the Endangered Species Act (16 U.S.C. 1531-1543), as amended.

The Service has and will continue to support the Corps during agency coordination meetings and provide input on the overall scope of the project, relevant technical studies that will be required for the project, assessment methodologies, range of alternatives, and important issues and impacts requiring evaluation during the environmental review process. Further, we look forward to the outputs of the Study that will inform ecological restoration efforts designed to improve fish and wildlife resources in the Meramec and Big Rivers.

The points of contact for the Service on the Study and EA are Jane Ledwin, Fish and Wildlife Biologist (jane_ledwin@fws.gov), and Dave Mosby, Environmental Contaminants Specialist (dave_mosby@fws.gov). Please feel free to contact me, Ms. Ledwin or Mr. Mosby by phone at (573) 234-2132 extensions 166, 109 and 113, respectively.

Sincerely,

Amy Salveter
Field Supervisor

cc: MO Dept. of Natural Resources (Mr. Robert Stout)

2. DRAFT FWCAR MAY 2018

Draft Fish and Wildlife Coordination Act Report
for the
Meramec River Basin Ecosystem Restoration Feasibility Study

Prepared by:

U.S. Fish and Wildlife Service
Missouri Ecological Services Field Office
Columbia, Missouri

May 2018

Table of Contents — Page

Preliminary Draft Fish and Wildlife Coordination Act Report
Meramec River Basin Ecosystem Restoration Feasibility Study (MRFS)

INTRODUCTION

The St. Louis District of the U.S. Army Corps of Engineers (USACE) and non-federal sponsor, the Missouri Department of Natural Resources (MDNR) are currently planning an ecosystem restoration feasibility study within the Meramec River Basin in Jefferson and St. Louis counties, Missouri. The study purpose is to investigate natural resource concerns, consider and evaluate viable restoration alternatives, develop a tentatively selected plan (TSP), and pursue a series of ecological restoration projects.

The U.S. Fish and Wildlife Service's (Service) involvement in this study is authorized by the Fish and Wildlife Coordination Act (FWCA; 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). The FWCA specifies that fish and wildlife resource conservation be equally considered as part of federally funded or permitted water development proposals or projects which impact any jurisdictional stream or body of water. For relevant projects, the FWCA requires that federal action agencies consult with the Service and state wildlife agencies during project planning, development, and maintenance activities. A required product of this FWCA consultation is the Draft Fish and Wildlife Coordination Act Report (DFWCAR). This report outlines the anticipated impacts to fish and wildlife resources as well as problems and opportunities as they pertain to the proposed project planning objectives and alternatives. Section 2(b) of the FWCA requires that the Service and state wildlife agency reports and recommendations be given full consideration and be included in project reports provided to Congress or to any other relevant agency or person for approval or authorization. The purpose of this report is to identify and evaluate existing fish and wildlife resources and habitats, outline the Service's concerns and planning objectives, as well as indicate specific recommendations and conservation measures to help ensure those resources receive equal consideration with the associated project purposes.

This DFWCAR does not constitute the Final report of the Secretary of the Interior as required by Section 2(b) of the FWCA. Upon USACE endorsement of a TSP and final project plans, the Service will revise this DFWCAR and provide a final FWCAR to the USACE in fulfillment with Section 2(b) of the FWCA.

FWCA Agency Coordination

This report is based on numerous meetings and discussions between participating agencies, resource documentation, historical evaluations, and recent studies of both fish and wildlife resources and landscape issues within/near the study area. Information has been received and collated from USACE staff as well as Service and state biologists whom include regional species experts. The Service has provided a preliminary draft of this report to the Missouri Department of Conservation (MDC) for their comment and input. Comments received are indicated in Appendix 4 and will be incorporated into the final report. A concurrence letter from MDC will also be provided with the final FWCA Report when completed.

Project Authority
The USACE indicated that the Meramec River Basin Ecosystem Restoration Feasibility Study was authorized by a 21 June 2000 Resolution by the Committee on Transportation and Infrastructure, U.S. House of Representatives, Docket 2642:

> *Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on the Mississippi River, 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.*

STUDY AREA
The Meramec River Basin is situated entirely within the Ozark Highlands in the State of Missouri. The watershed is approximately 6400 square kilometers (3980 square miles) and collectively drains a predominately forested region comprised of moderately rugged terrain overlying a karst (limestone/dolomite) geology. Beginning near Salem, the Meramec River flows approximately 370 kilometers (230 miles) to its confluence with the Mississippi River near St. Louis. The Meramec's two largest tributaries are the Big and Bourbeuse rivers. The Meramec and its tributaries are characterized as Ozark streams typically being clear and moderately swift, flowing over substrates consisting of various amounts of sand, gravel, cobble, and boulders amongst scenic bluff features along their course. The watershed is largely dominated by sinuous, single thread channels which alternate between shallow riffles, runs, pools, and glides varying in depth often forming sequences of depositional areas (gravel bars and islands) in which additional side-channel habitats, backwater sloughs, and wetlands can also provide unique habitats within this riverine/floodplain ecosystem. Historically, the floodplain/riparian lands were diverse native forest communities. However, during the 1800s most of the old growth forests were harvested and floodplains cleared to convert these areas to either cropland or pastureland. Also during this period, a finite number of small historic mill dams were constructed in the Big and Bourbeuse rivers. Later, during the 1960s and 1970s, the USACE planned but did not construct the Meramec Park Lake near Sullivan, Missouri. All other ponds, small lakes, and impoundments developed within the basin are currently confined to tributary streams situated in the upper watershed areas. Despite these features, the Meramec River Basin remains largely free-flowing, its hydrology principally determined by regular precipitation events and groundwater inputs including large springs and seeps. The study area is a portion of the Meramec Basin which includes the Meramec and Big rivers and their tributaries within St. Louis and Jefferson counties, Missouri (Figure 1). The primary water uses within the

study area are public and private recreation, municipal and industrial uses, livestock watering, and fish and wildlife habitat. Streams and springs throughout the Meramec River Basin and elsewhere in the Ozark Region are a primary destination for many outdoor recreational activities including: canoeing, kayaking, fishing, and camping. Furthermore, numerous Missouri state parks are situated directly adjacent to the Meramec River (i.e., Onondaga Cave State Park, Meramec State Park, Robertsville State Park, Route 66 State Park, and Castlewood State Park) and the Big River (i.e., St. Francois State Park and Washington State Park).

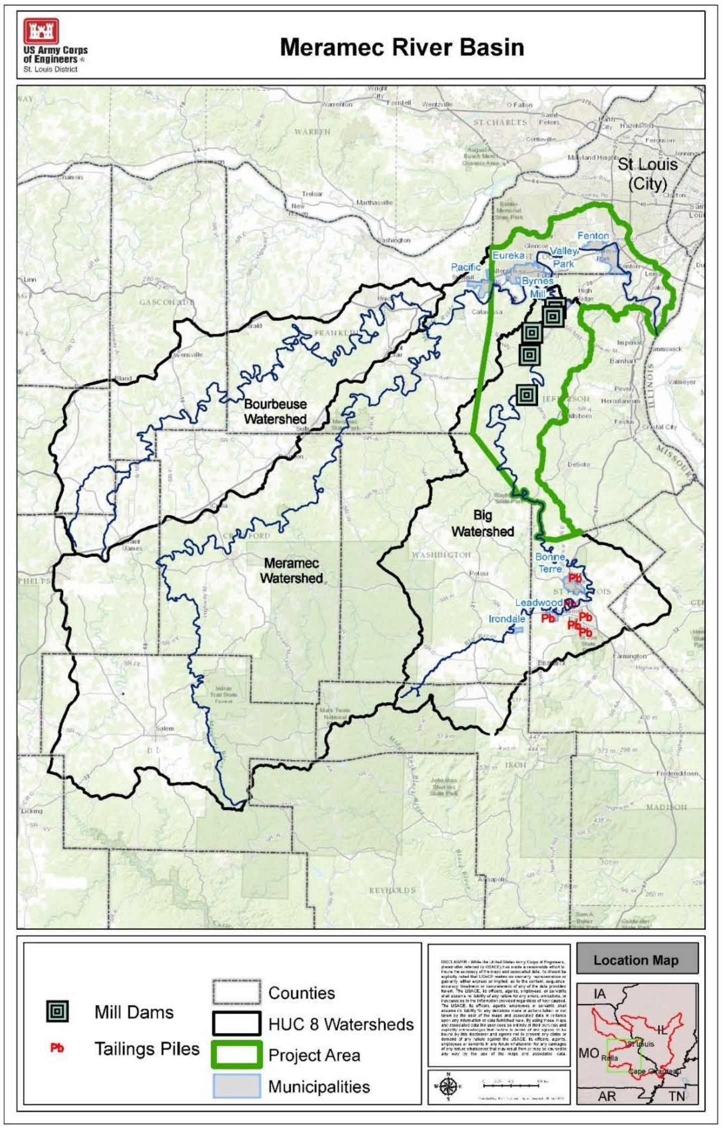


Figure 1. Meramec Feasibility Study Area as indicated by the USACE.
Project Description

4

The MRFS is a focused study to conduct ecosystem restoration within the Meramec River Basin in Jefferson and St. Louis counties, Missouri. The USACE and the MDNR identified a project need due to a significantly degraded condition of the aquatic environment throughout the study area. This environmental degradation resulted from historical heavy metal mining within the upper reaches of the Big River (~175 to 135 km upstream of the mouth). The purpose of the MRFS, as provided by the USACE, is "to restore significant ecosystem function, structure, and dynamic processes that have been degraded within the Meramec River Basin." If approved, the USACE would plan, construct, monitor, and adaptively manage a suite of actions that are expected to preserve, restore and improve aquatic and riparian habitat conditions for resident and migratory wildlife, including federally listed species. These actions are also intended to maximize fish and wildlife habitat benefits while minimizing environmental, cultural, and socioeconomic impacts. These measures, if completed, should reduce/prevent downstream wildlife impacts attributed to contaminated sediments present within the streambed and floodplain soils from entering/migrating downstream into lower segments of the Big River and then into the Meramec River. Doing so, the actions will also protect/enhance habitat for several species of federal and state listed mussels, bats, as well as state listed crayfish. These species and their habitat preferences will be detailed within later sections of this document. The project period, if approved, will last 50 years from the first construction season, and may include aquatic and terrestrial habitat improvement measures for future construction actions in the study area within the Meramec River Basin.

FISH and WILDLIFE RESOURCE PROBLEMS and OPPORTUNITIES

Human activity within the study area during the past two centuries has significantly impacted and reduced the natural biotic community, ecosystem functions, and physical characteristics of the riverine environment within the Big River compared to historical conditions. The Meramec River and its tributaries have been referenced as one of the most ecologically important tributaries to the Upper Mississippi River, with 292 aquatic-dependent species recorded from the basin (Nigh and Sowa 2005 and TNC 2014). This intersection of diverse biologic communities with toxic exposure to heavy metals elevates the need for timely habitat improvement measures by agencies and highlights the challenges facing restoration efforts. Numerous studies have identified the following key environmental problems contributing to fish and wildlife resource impacts in the Meramec River Basin:

Contaminated Streambed Sediments/Streambank Erosion

The most significant resource problem within and throughout the study area is attributed to effects resulting from contaminated sediments associated with historical lead (Pb) and zinc (Zn) mining in the upper Big River watershed in St. Francois County. Barite mining in Washington and Jefferson counties also has the potential to contribute contaminated sediments to the watershed. However, the source of the vast majority of the toxic heavy metal sediment contamination demonstrated to date has been identified as originating from St. Francois County (Pavlowsky et al. 2010 and USEPA 2017). This mining activity was substantial and spanned over two centuries (1740-present). The majority of Pb and Zn production and resource impacts occurred during the early to mid-20th century from industrial scale subterranean mining. The metal ore was extracted from a dolomite host-rock which required milling to be obtained. The

5

waste materials from this crushing process are referred to as mine tailings which still contain residual amounts of Pb and Zn ore. It is estimated that at least 30 million cubic meters of mine tailings are currently stored within six material waste sites (Pavlowsky et al. 2010). These sites are depicted in Figure 1. As direct result of those mining activities, immense influxes of Pb and Zn and lesser amounts of cadmium originally entered the upper Big River from source locations and subsequently contaminated the entire Big River floodplain and over 150 km of its stream length. In 1977, a mine tailings dam failed during a flood event. This single event was reported to have introduced 63,000 cubic meters of contaminated mill waste into the Big River (Roberts and Bruenderman 2000). All six tailing piles have been or are currently being stabilized to limit/prevent mine tailings from continuing to enter waterways. However, Pb contaminated materials already within the river system continue to negatively impact the environment to various degrees throughout the study area. A majority of the mine tailings within the river system are less than 8mm in size. The finest fraction (<250μm) are largely present within floodplain deposits. These small, distinct fluvial mine wastes are now migrating downstream episodically by natural stream forces/processes typically associated with regular flooding events. Depending on their size and forces acting upon them, contaminated sediments are either redeposited within the stream channel, on adjacent gravel bars/islands, in back/side channels, or on floodplain surfaces. Pavlowsky et al. (2010) studied the degree of contamination within the Big River channel and floodplain and reported that an estimated 3.7 million cubic meters of contaminated sediment is stored in the Big River stream channel and 86.8 million cubic meters was deposited in the Big River floodplain. Pavlowsky et al. (2010) also indicated that concentrations and sizes of these contaminated sediments vary within the streambed in the Big River and floodplain within the Big and Meramec rivers. The distribution of contamination is complex. Generally, the highest heavy metal concentrations for both instream sediments (about 500 to 1,500 mg Pb/kg) and floodplain soils (about 1,000 to 3,000 mg Pb/kg) are closest to the tailing sources in the upstream/middle reaches of the Big River (~170-100 km from the mouth) and a number of tributaries upstream of the study area. Furthermore, because floodplain sediments are typically small (less than 1 mm), these materials were/are more readily mobilized and thus able to be transported farther distances during large flood events compared to larger instream materials. This has resulted in a greater degree/distribution of floodplain contamination extending farther downstream than for the instream contamination. Also, the largest contaminated sediments (2-8mm) are generally confined to the stream channel and transported downstream at a much slower rate. Despite this, contaminated sediments in the streambed and/or within floodplain sediments, which re-enter the active channel via streambank erosion sources, are certain to continue to migrate downstream from their points of origin and impact additional habitats and resources far into the future. Similarly, the largest aquatic and terrestrial wildlife resource impacts also have a similar distribution, the most impacted locations being nearest these mine waste source areas. Impacts to the freshwater mussel community in the study area resulting from mining were initially noted by the Missouri Water Pollution Board (1964). The magnitude and effects of these contaminated sediments to the mussel community have only recently been documented (Roberts et al. 2009 and 2016). A separate study by Albers et al. (2016) using the Roberts et al. (2016) field data indicate that Pb concentrations above 136 mg/kg in <2mm streambed sediment negatively impacted mussel density. The Albers et al. (2016) analysis found very similar sediment Pb concentrations demonstrating negative effects to mussels as was also indicated by the Consensus Based Probable Effects Concentration (PEC) for Pb of 128 mg/kg based on laboratory testing of a variety of benthic organisms (MacDonald et al. 2000). Other laboratory based studies have demonstrated various impacts and relatively high sensitivity to life functions in mussels resulting from exposure to heavy metals (Besser et al. 2009 and Wang et al. 2010). Roberts et al. (2016) and Albers et al. (2016) both concluded that the Pb contaminated sediment concentration was the most highly correlated factor to the reduction of mussel densities and species distribution in the Big River compared to other habitat metrics. The Service believes that without direct actions to stop the downstream progression of Pb contaminated streambed sediments and/or remove/reduce these contaminated sediments to concentrations below the PEC value, the remaining aquatic environments throughout the study area are expected to degrade to the current levels mentioned for the upper Big River into the distant future. This is especially problematic due to the very important freshwater mussel and crayfish communities residing in the lower Big and Meramec rivers that are at risk due to this contaminated sediment migration. These wildlife communities include several federal and state listed and unique endemic species, discussed later.

Pavlowsky and Owen (2013) identified numerous areas of channel migration throughout the Big River spanning a 70-year period (1937-2007). Within the study area, the USACE identified approximately 30 locations where accelerated streambank erosion is occurring. Considering that a majority of the Big River floodplain soils are contaminated with mine wastes and because of the enormous quantities involved, the Service supports the USACE's pursuit of actions which can stabilize actively eroding streambanks in order to restrict/prevent the re-introduction of these contaminated materials back into the stream channel. Such actions would help reduce further degradation of downstream environments and their potential impacts to the extremely important mussel communities in the lower Big and Meramec rivers. In addition to these measures, we also support actions which can most efficiently remove substantial quantities of contaminated streambed sediments from the Big River where applicable. We believe this dual strategy, if conducted correctly, is the best approach to effectively prevent/reduce these contaminated sediments from continuing to significantly degrade downstream environments as well as potentially improve impaired habitats. The current streambank protection and streambed sediment removal measures being considered include: longitudinal peak stone toe protection (LPSTP), bendway weirs, rock vanes, channel relocation, streambank slope modification, bioengineering, toe-wood, riparian plantings, in-channel streambed sediment collectors, gravel bar restoration, rock archways, sediment removal from within mill dam impoundments, and passive floodplain/side channel sediment traps. Apart from the USACE alternatives, the U.S. Environmental Protection Agency (USEPA) may also develop and undergo separate or similar remedial actions in the study area and/or upstream at a future date. However, no actions or plans are known at this time. The USACE has considered this issue during the future without project alternative analysis. This information is discussed in the **EVALUATION and COMPARISON of ALTERNATIVES** section to follow. Furthermore, the USACE also considered a project alternative that limited restoration activities to only the Meramec River because of the need to work with contaminated materials. In addition to the list of identified proposed actions, the Service will recommend the USACE consider bank stabilization measures which can incorporate natural and biological elements such as: logs, differential flow gradients, structures with available interstitial spaces, and overlying shade from the sun to promote/enhance aquatic wildlife habitat diversity within each design feature. We anticipate the Service will be able to provide additional input regarding those project details in the future.

Altered Aquatic Connectivity

Large, unnatural, vertical structures such as dams and road crossings can often act as barriers to aquatic organism passage (AOP). Originally constructed in the mid-19th Century, four mill dams (Rockford Beach Dam, Byrnesville Dam, Byrnes Mill Dam, and Cedar Hill Dam) remain in the lower Big River. An additional mill dam (Morse Mill) was the most upstream mill dam but has since degraded to a height nearly at-grade within the stream channel. It has been suggested that these mill dams are a primary reason for negative impacts to the Big River mussel population. However, as indicated in the mussel section below, native mussels require a fish host in order to successfully complete their life cycle. Based on an analysis of MDC creel data (unpublished), the Big River fish species richness and diversity did not differ upstream and downstream of mill dams. This may be because of their relatively low structure height (less than 2 meters), general state of disrepair, and frequent overtopping. Furthermore, Roberts et al. (2009 and 2016) reported a high incidence of numerous species of subfossil mussel shells found either within physical mussel habitat or on depositional surfaces (e.g., gravel bars and islands) throughout the stream reaches upstream of all mill dams. As discussed later, mussels can live a very long time; however, none are known to live as long as the period of time in which the Big River mill dams have been in place (approximately 170 years). Since the mussel population is directly reliant upon the fish community for sustainable mussel recruitment, the presence and quantities of the subfossil mussel shells in addition to these fish data suggests that both fish and mussel populations were far more robust than current levels long after these mill dams were constructed. Furthermore, the small, remnant mussel population in the upper Big River, also upstream of known Pb contamination, may be indicative that the remaining mill dams, given their current condition, are likely only causing minor, local, short-term disruptions to AOP. Lastly, the Bourbeuse River, the second largest tributary to the Meramec and a reference stream for various Big River mussel studies, also has similar mill dams but does not exhibit similar mussel population reductions.

Nonetheless, we support additional actions which could further reduce the downstream bed slope directly below each dam to potentially provide additional passage benefits to local native fish communities. Another important component of these mill dams is that, like most impoundments, they serve as a trap for fine instream bed sediment. The mill dams therefore, have likely prevented a significant fraction of contaminated sediments from being transported into downstream environments. Pavlowsky et al. (2010) found the maximum volume of instream sediment stored in segments immediately above Rockford Beach and Byrnesville mill dams, which are the most intact structures. Because of this sediment trapping mechanism, the Service also supports investigating opportunities to utilize/maintain/modify these structures to enhance the capture and removal of contaminated instream sediment to a point when those materials are no longer accumulating or affecting the environment. We support designs that consider adequate

AOP as well as recreational user passage to also provide habitat and public use benefits into the future.

Altered Floodplain/Riparian Corridor
Riparian areas throughout the Ozark Region were historically a forested environment. Alluvial floodplains are well known to provide productive farmland. Because of this, lands were often cleared of native forests and understory vegetation. Established riparian corridors are known to significantly reduce erosional forces from flooding by functioning as roughness elements which promote sediment and debris capture/retention on the floodplain surface in addition to protecting stream banks by way of a dense root system. Riparian vegetation typically provides substantial food and habitat for various terrestrial wildlife and buffers adjacent land uses and other natural environmental factors from the adjacent waterway (e.g., elevated water temperatures from the sun). Wetland areas within the riparian area can also provide many additional physical and biotic benefits. In many reaches of the study area, the riparian vegetation is absent altogether or significantly reduced. Areas where the riparian forests are less than 30 meters wide are prone to natural channel evolution processes such as bank erosion/channel migration and associated habitat impacts as previously mentioned. The Service believes the riparian area should be no less than 30 meters in width and comprised of a diverse index of native species to function adequately. From a terrestrial habitat perspective, riparian areas as wide as 100 meters would be the most beneficial for bottomland forest interior birds. A wider riparian forest would tend to prevent nest predation from other species adapted to edge environments. Many migratory birds that depend on this type of habitat are in decline due to habitat fragmentation and agricultural development.

Beyer et al. (2013) documented Pb exposure to songbirds collected in the Big River floodplains and demonstrated tissues concentrations that have been linked to detrimental effects. Therefore, we believe floodplain restoration should also include measures that reduce exposure to Pb contaminated soils, such as high phosphate fertilizers or other high phosphate composted soil amendments. Beyer et al. (2016) showed reduced Pb bioavailability to birds dosed with phosphate treated soils. The Service would caution that the use of high phosphate soil amendments should be employed only with adequate off sets and specific Best Management Practices (BMPs) to ensure excess nutrients are not transported into waterways.

Loss of Wetlands
Similar to riparian corridors, wetlands have been significantly reduced across the landscape and within the study area. Losses of additional floodplain wetlands could reduce potential sediment capture/storage areas and allow contaminated sediments to travel downstream and impact additional aquatic habitats. Because of elevated Pb concentrations throughout the floodplain, wetland development should be limited to either the Meramec River floodplain and the downstream areas within the Big River to prevent the possibility of the habitat acting as an attractive nuisance where Pb concentration levels could pose further risk of injury to wildlife; or additional protective measures such as soil/sediment capping or soil treatment amendments should be implemented to reduce potential Pb exposure. Increasing the number of floodplain

wetlands in uncontaminated areas and/or treated wetlands in the Big River could serve to multiply additional benefits already described (e.g., increasing amphibian diversity).

Altered Hydrology
Natural stream hydrology within the study area is dependent on precipitation and ground water inputs. Recent rapid changes to the landscape associated with development and urbanization (e.g., increased groundwater withdrawals, sewer outfalls, and watershed detention features) can have direct, indirect, and cumulative impacts to basin hydrology. Furthermore, vegetation reduction/removal, addition of impervious materials, and infrastructure expansion (e.g., roads, bridges, and pipeline crossings) could accelerate the magnitude, frequency, timing, force, and flow declination rates of river hydrology/levels. As a result, the sediment transport rate could also be accelerated which would increase the potential for the instream contaminated sediments to be carried into sensitive downstream environments and also potentially affect the stream's dimension/pattern/profile which in turn would likely induce secondary impacts such as streambank erosion as previously discussed.

Mussel Habitat Degradation
Refer to the **Fish and Wildlife Resources** section below.

Excess Bedload/Sediment Contributions
Tributary streams are normal sediment contributors to alluvial systems. However, due to the tremendous amounts of contaminated mine waste introduced within the Big River, we expect the sediment budget to have likely exceeded the historical sediment transport capacity. This is supported by many instances of large mid-channel islands and gravel bars forming beyond their typical levels in the upper Big River in St. Francois County. These features can be exacerbated at tributary confluences, in wide areas, and stretches with a low streambed slope. As a result, these features can/do directly disrupt physical habitat stability and often lead to secondary channel planform changes and accelerated bank erosion (as mentioned above). The latter situations are of importance as they continue to introduce Pb contaminated soils from within floodplain deposits and impact local and downstream benthic habitats. Thus, we believe to maximize local and downstream habitat benefits, the USACE should consider thorough investigations to determine the proper sediment budget within the Big River. This, in addition to the proposed designs and activities described in the **Contaminated Sediments/Streambank Erosion** section will help to prevent additional erosional source areas and excess contributions of contaminated materials.

Gravel Harvest
Stream gravel is a large commodity regularly mined throughout the Ozarks due to the material being easily accessible, being comprised of largely erosion-resistant chert material, naturally rounded, and dust-free. However, improper gravel removal from within streams can have significant negative effects to both the physical condition of the stream as well as the local and downstream environments. Commercial gravel harvest is regulated by the State of Missouri via the MDNR Land Reclamation Program pursuant to 444.760 RSMo. This regulatory oversight provides covenants and BMPs related to gravel removal activities. However, gravel harvest for

personal use is not currently regulated. It is unclear to what level gravel harvest for either use is occurring within the study area. The Service can agree that gravel removal activities can be allowed in controlled situations in areas where the bedload has exceeded the stream's transport capacity. As mentioned earlier, we believe appropriate areas could be identified and habitat benefits could result by removing these contaminated sediments as well as excess bedload materials in controlled/monitored situations.

Nuisance Species

The following invasive exotic animal and plant species have been reported or likely occur within the Meramec Basin. These include: Asian Clam (*Corbicula fluminea*), Zebra Mussel (*Dreissena polymorpha*), Bighead Carp (*Hypophthalmichthys nobilis*), Silver Carp (*Hypophthalmichthys molitrix*), Grass Carp (*Ctenopharyngodon idella*), Common Carp (*Cyprinus carpio*), Eurasia Water-milfoil (*Myriophyllum spictatum*), Japanese Hops (*Humulus japonicus*), Garlic Mustard (*Alliaria petiolata*), Multiflora Rose (*Rosa multiflora*), Wintercreeper (*Euonymus fortunei*), Reed Canary Grass (*Phalaris arundinacea*), Johnson Grass (*Sorghum halepense*), Honeysuckle (*Lonicera sp.*), and likely many others. Some of these species may have an enormous impact to the health and longevity of aquatic systems into the future. For example, Asian carp have dramatically increased their range throughout the Mississippi and Ohio River basins just within the past two decades, which includes the study area. The presence of these species may require additional resource management considerations into the future. We believe the presence of these species helps support the need to pursue this project. Restoration of native habitats and water quality improvements would help native species compete with these exotic species which are better able to withstand the existing marginal habitat quality. As such, we believe a better understanding of the potential impacts and risks these exotic species pose should be investigated as this project develops and proceeds into design phases.

Urbanization

A large area near and within the downstream segments of the study area have been/are being influenced by the expansion of an urbanizing landscape within a number of different municipalities around greater St. Louis. Conversion of the largely rural area into an urban setting coupled with additional water resource needs/impacts are being realized throughout the region. There are also synergistic effects of urbanization on water quality, quantity, and influence drainage timing that can impact/exacerbate flooding, erosion, and mobilization of contaminated sediments similar to impacts discussed for climate change below. Furthermore, floodplain development or conversion has the potential to impact existing infrastructure and further reduces options to mitigate past and foreseeable habitat losses. Despite this, there has been a long standing interest throughout this area to protect the natural resources indicated below. As mentioned earlier, a large federal impoundment was planned and approved but was not completed because of substantial local opposition. In addition, other entities, such as area citizens, non-government organizations, recreational outfitters, land trusts, and mitigation banking instruments continue to express a strong interest to protect the Meramec River ecosystem.

Climate Change

Climate change is and will continue to be a primary issue for fish and wildlife conservation into the future. Dramatic changes in temperature and precipitation are predicted to affect the Midwest region and, consequently, the Meramec River Basin. Climate change will likely be a significant stressor to wildlife and plant resources. However, when combined with other human-related stresses will likely exacerbate the vulnerability of ecosystems resulting from rapid/extreme environmental changes/fluctuations, invasive species, and loss of native species. Average temperatures have risen consistently throughout the Midwest over the last few decades, and are currently projected to continue to increase in the future (Staudinger et al. 2015). Consequently, even slight temperature changes could result in large, detrimental life history impacts such as condition/availability of and competition for water, food and habitat, as well as lack/loss of recruitment because of minor but cumulative changes in breeding patterns. The projected precipitation changes are expected to include more frequent stochastic events such as severe droughts and heavy rainfall/flooding. Climate change will also likely impact the magnitude and duration of those events. As a result, larger than normal mean discharges and temperatures could drastically impact wildlife, their habitats and possibly affect the management of projects proposed within the study area. Potential examples include two large flood events which exceeded the 100-year probability occurred in the study area between 2015 and 2017. If these situations continue or increase, the rate at which Pb contaminated sediments enter/migrate downstream is amplified which will directly increase the magnitude of cumulative impacts to habitats and sensitive wildlife throughout the study area and beyond. In addition, the possible increase of human populations in both rural and urban areas will likely increase water demands as well and potentially impact the Meramec River Basin hydrology as discussed above. These increased rural, municipal, and industrial needs for water coupled with decreased groundwater supplies could very likely and expectedly impact additional fish and wildlife resources beyond our current evaluation. We recommend the USACE consider the potential impacts resulting from climate change to the best possible ability during the planning phases of this study as this project proceeds into the future.

As mentioned in the introduction to this section, the Meramec and its tributaries provide ecologically robust habitats of national significance. The following section provides more detailed information on the unique opportunities for fish and wildlife conservation available in the Meramec River.

FISH and WILDLIFE RESOURCE CONDITIONS and HABITATS

This section will summarize and briefly describe the primary habitat types, fish and wildlife resources, and their relationships along the uncontaminated areas of the Meramec and Big rivers. As a general concept, the daily, seasonal, annual, and long-term flow fluctuations within a naturally flowing river encompass many dynamic riverine and floodplain environments. This situation helps promote successional habitat changes necessary to support habitat diversity. Natural seasonal river flow patterns regularly flood adjacent, river-bottom areas and fill/maintain ephemeral and perennial wetlands present in the floodplain as well as deliver important nutrients such as decomposing leaf fall materials to the aquatic ecosystem. During these high flows, erosive forces also act to constantly transport sediment down the river, creating and modifying habitat via removing terrestrial vegetation from some areas while creating suitable conditions for new plants to grow in other areas. These flows also provide important wildlife breeding and foraging habitat and are used by some species to make vital migratory journeys into sometimes specific habitats. Streams and rivers, including their ephemeral tributaries, are known to provide essential spawning and nursery habitat for countless Missouri wildlife. Combinations and transitional zones of open water, floodplain wetlands, and riparian vegetation are particularly important for the large number of migratory species including fish, amphibians, reptiles, and birds which use the Meramec River watershed to various degrees during their cyclic migrations. This wildlife seeks and utilizes a wide assortment and sometimes specific variations of supportive habitat. However, when habitats are composed of or influenced by toxic materials, as in the case of the upper Big River, the numbers of species and associated beneficial ecosystem services also become impaired. The current quantity, concentration, and distribution of Pb contamination throughout the study area coupled with the toxic impacts to the associated habitats and species substantiates the immediate need for the proposed actions to protect uncontaminated areas as well as treat and rehabilitate contaminated areas throughout the study area.

Available Habitats

The study area contains a very high number of differing aquatic and terrestrial habitat types. Variations of flows, substrate/streambank stability and composition, sediment deposition, sheer stress, riparian protection and species relationships are only a few of the many variables that can influence/determine suitability for specific species occupation. If suitable, many aquatic and terrestrial wildlife including microorganisms, macroinvertebrates, crustaceans, snails, mussels, fish, reptiles, birds and mammals occupy and utilize available resources within available habitat types. Some habitats may contain a high number and high diversity of many different groups, while other habitats may be unique or specific to a few or even one species which may have adapted to such an environment to prevent competition for resources. The aquatic environment can be categorized as either riverine (lotic) or backwater (lentic) habitat. The terrestrial environment can be categorized as either floodplain or upland habitat. To summarize, habitat importance and fish and wildlife success is largely dependent on having and maintaining a wide range of interconnected diverse to specific habitat types over a large area. These elements are critical to ensure that the associated species have sufficient resources to successfully complete necessary life history functions and produce sufficient offspring to sustain long-term populations. If uncontaminated, aquatic ecosystems are typically extremely complex and dynamic. Their function is entirely dependent on many variations of flows, depths, substrate materials, and nutrient inputs from surrounding lands to allow wildlife to thrive. Due to a large number of differing habitats, specific habitat elements within each of the four categories listed above will be defined and described in Appendix 1.

Fish and Wildlife Resources

An extensive number of fish and wildlife species within many taxonomic groups permanently or temporarily reside within many of the listed habitats (Appendix 1) in this very diverse ecosystem. The MDC maintains a Natural Heritage Database for which wildlife and rare plants are documented to help manage fish and wildlife resources within Missouri. A diverse assemblage of resident and migratory wildlife still utilize many aquatic and terrestrial habitats within the lower Big River and Meramec River sections of the study area despite the historical and residual Pb impacts from mine wastes. However, these communities are typically depressed when compared to historical and similar habitats elsewhere in the watershed and outside the influences of residual heavy metal mining impacts. We believe this situation helps identify the importance of the resource at risk as well as the need for the proposed ecological restoration project. The Meramec Basin is noted to have one of the largest aquatic diversity indices compared to other Midwestern rivers (TNC 2014) as well as one of the most diverse mussel faunas in the central U.S. (Hinck et al. 2012). Due to the large size of this watershed and its proximity to the Mississippi River, there may also be undocumented species within this watershed but not known simply because of their rarity. For instance, the Pallid Sturgeon (*Scaphirhynchus albus*) is a federally listed fish species which has been documented in the Mississippi and Missouri rivers but has not been reported within the Meramec River. However, the aquatic habitat within the lower Meramec is not that dissimilar to either the Missouri or Mississippi rivers where the species is known. Also, the wildlife resources indicated below does not preclude an overriding ecological importance and interdependence with that of other taxonomic groups in the study area. For example, many associated wildlife species such as phytoplankton are extremely important food resources for mussels and crayfish. Thus, for simplicity, we will expand on only the most pertinent wildlife potentially impacted by this study.

<u>Invertebrates</u>
A countless number of macroinvertebrate species such as worms, aquatic and terrestrial insects, spiders, and snails, etc. are within this area and are particularly important animals as either a food source and/or due to performing ecological functions (e.g., decomposition, pollination, etc.). Because of the enormous number of species in this assemblage, we will refine our focus to two of the larger groups, mussels and crayfish, which also have particular ecological and regulatory significance and are described in more detail below.

<u>Freshwater Mussels</u>
Mussels are an extremely important animal group recognized within this ecosystem. They act as natural biological filters, perform essential nutrient cycling, represent food for many fish and wildlife groups, and are often considered as indicators of water quality. Mussels also denote the largest biomass compared with other invertebrate taxa. However, during the past century, mussel populations represent only a fraction of their original state. These animals now rank as one of the largest groups of imperiled organisms in North America (Williams et al. 1993). During the last 100 years it is presumed that 30-40 species have gone extinct and many more species nearly so (Haag 2012). Mussel declines have been generally attributed to many factors which include: degradation and loss of habitat by chemical or physical influences such as poor water quality, sedimentation, streambed instability, nutrient loading, loss of host fish, impacts from invasive species, urbanization, and overharvest for production of buttons, cultured pearl blanks, and the occasional discovery of a natural pearl. The Meramec River is reported to have one of the most diverse freshwater mussel faunas in the Midwest when compared with the number of species known within the upper Mississippi River Basin (Buchanan 1980, Roberts and Bruenderman 2000, McMurray et al. 2012). Currently at least 45 mussel species are represented in the Meramec Basin (McMurray et al. 2012). Roberts and Bruenderman (2000) conducted a

comprehensive study throughout the Meramec Basin, which included the Big River, and compared results with an earlier, similar study by Buchanan (1979). Although this comparison indicated a similar species index, a decline of mussel numbers was reported. This situation suggests the mussel community within the Meramec River Basin has also experienced a similar negative population trend as noted in many river systems (Haag 2012). In addition to general mussel reductions, several state and federal endangered species were noted to also have declined in the number of sites where they had been previously reported in earlier surveys. Roberts and Bruenderman (2000) also noted that some sites sampled by Buchanan (1979) no longer contained suitable mussel habitat.

Mussels are benthic organisms which can have very specific and complex habitat needs. They occupy a wide variety of habitats ranging from wetlands and sluggish backwaters/oxbows to high-flow riffles areas. A majority of mussels found in the Meramec River Basin are long-lived, riverine, sedentary creatures which typically require lotic conditions to persist. These riverine mussels are often found in dense aggregations comprised of many different species (i.e., mussel beds) due to having similar habitat requirements. However, mussel habitat is not widespread within lotic systems and can also vary significantly for specific species. An entire mussel's adult life is often spent in a small area most often comprised of permanent flow over very stable substrate. Individuals sometimes move only a few meters during an entire lifespan. Some mussels, such as the Scaleshell (*Leptodea leptodon*), can live as few as a 5-10 years (USFWS 2007) while others, such as the Spectaclecase (*Margaritifera monodonta*) are reported to live over 50 years (Baird 2000). Freshwater mussel beds are most analogous to the sensitive coral reefs found in the ocean environment. Because of their benthic lifestyle and limited range of movement, mussels are extremely vulnerable to many stressors but most particularly those that reflect very drastic and rapid changes to their environment. Roberts and Bruenderman (2000) and Hinck et al. (2012) attributed the mussel decline in the Meramec Basin to channel and streambank degradation resulting from activities such as gravel mining, riparian removal, increased hydrology from urban development, and most pertinent to this study, heavy metal mining activities in the Big River.

As discussed, mining activities directly led to the introduction of substantial concentrations of Pb contaminated mine wastes into the Big River. These contaminated sediments are believed to be the major factor that have caused declines in mussel abundance and diversity in the Big River compared to reference sections in the Meramec, Bourbeuse, and upper Big rivers. Roberts et al. (2016) reported significant declines in mussel density between Big River kms 113 and 67 and significant declines in mussel richness between kms 113 and 16.5. These values are relative to the distance upstream from the Big River confluence with the Meramec River. Mussels are known to accumulate Pb within their tissues and skeletal structures (Angelo et al. 2007). Laboratory studies have also identified chronic effects by Pb concentration on juvenile mussels (Besser et al. 2009). Roberts et al. (2016) and Albers et al. (2016) documented negative correlations between mussel density and species richness compared with Pb concentrations in sediment in the Big River. The sampling efforts by Roberts et al. (2016) were specifically limited to sites which contained live mussels and had stable substrate conditions to eliminate complicating factors related to habitat quality, which would potentially negatively affect mussel presence. When toxic conditions are present within mussel habitat, these animals are not able to subsist or recolonize those environments despite ample amounts of stable physical habitat being present. As a result, the once diverse mussel fauna within the Big River has been significantly reduced to only residual populations occurring in the most upstream and downstream stream segments where the Pb concentrations are currently lower than or within 10% of the PEC (128 mg Pb/kg) as defined by MacDonald et al. (2000). The distribution of Pb contamination in the Big River is complex. Both the floodplain and significant lengths of instream sediments within the upper and middle segments are presently contaminated and impacting the mussel habitat to varying degrees (Figure 2). The instream fraction of contaminated sediment is progressively migrating downstream through natural processes degrading the stream channel and likely also influencing its geomorphic characteristics and functions. These geomorphic processes were discussed in the **Excess Bedload/Sediment Contributions** section above and have applied to the development of all alluvial systems over time and are not unique to the study area. Pavlowsky and Owen (2013) identified many unstable areas throughout the Big River. In these reaches, changes to the channel have resulted in significant amounts of bank erosion. Although bank erosion is a natural phenomenon, these sites are of particular concern specifically due to the elevated levels of Pb contaminated soils contained within them. As these materials re-enter the stream, depending on their relative downstream location, they can induce additional primary chemical impacts to instream habitat quality and a lesser degree of secondary impacts to the physical stability of the channel (i.e., sedimentation, aggradation, development of transverse bars, and mid-channel islands). These erosional areas are expected to be actively contributing substantial volumes of additional Pb contaminated sediments into the stream as they erode. While some of these sediments may be suspended and redeposited on the floodplain, some remaining fraction will likely accumulate in the channel. Thus, as long as these contaminated materials are allowed to enter or remain in the river, a large portion of the Big River will continue to be unsuitable for nearly all mussel species. An even more severe impact would be to the remaining habitat in the lower Big and Meramec rivers which supports a very significant mussel community which could eventually become unsuitable for native mussels without a significant level of intervention. We do believe however, that many of the proposed actions have great potential to stabilize and limit/prevent Pb contamination from bank erosion sources as well as slow the downstream migration of these contaminated instream sediments. If the project can reduce the instream Pb concentration to near or below 135 mg/kg, indicated by Albers et al. (2016), we believe:

- Existing mussel resources present in the downstream environments will be preserved.
- Mussel habitats within impaired reaches of the Big River will be improved.
- Mussels will be able to successfully recolonize the vacated habitats within the Big River by either natural recruitment from upstream and downstream populations in uncontaminated reaches and/or through restocking efforts.
- The upstream mussel population will no longer be isolated.
- Threatened and endangered mussel species populations will be able to expand into the significant length of restored habitat and enhance their recovery potential.

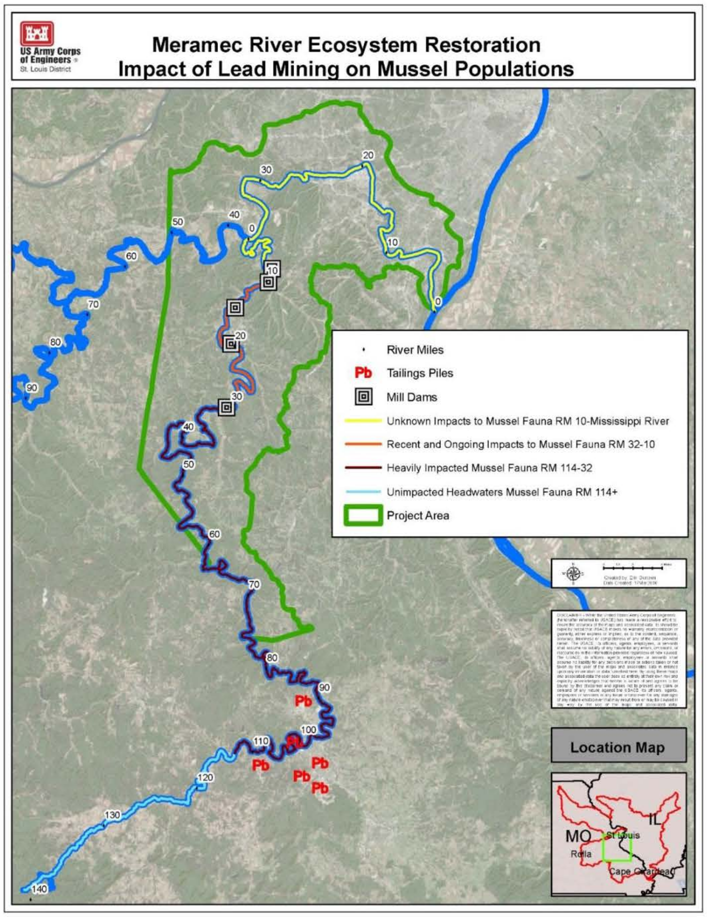


Figure 2. Big River Mussel Impacts as indicated by the USACE.

The mussel species assemblage of the Meramec Basin includes six federally listed mussel species: the Spectaclecase, Scaleshell, Snuffbox (*Epioblasma triquetra*), Pink Mucket (*Lampsilis abrupta*), Sheepnose (*Plethobasus cyphyus*), and Winged Mapleleaf (*Quadrula fragosa*); as well as four state listed mussels: the Slippershell (*Alasmidonta viridis*), Elephantear (*Elliptio crassidens*), Ebonyshell (*Fusconaia ebena*), and Salamander Mussel (*Simpsonaias ambigua*). The Winged Mapleleaf was found subsequent to the comprehensive Meramec Basin mussel studies by Buchanan (1979) and Roberts and Bruenderman (2000). An important note to clarify is that due to specific mussel habitat requirements not being well understood, we cannot simply recreate mussel habitat at this time. Therefore, considering the number of state and federally

17

listed species in the study area, continuing mussel declines, and significant time elapsed since previous comprehensive mussel studies in the watershed, underscore the importance and urgency of the proposed restoration activities. We believe additional status investigations throughout the entire Meramec River Basin for future population comparisons should also be considered to help protect this nationally significant freshwater mussel community. The threatened and endangered taxa and their habitat requirements will be summarized below within the **Threatened, Endangered, and At Risk Species** section.

Crayfish

Crayfish belong to a very diverse animal group. They make up one of the most dominant aquatic animal groups throughout North America with 400 of the more than 500 species known world-wide. Missouri contains nine percent of this fauna with 36 species. The Meramec River Basin is the most crayfish-diverse in Missouri with nine species. Two of these are state listed, the Salem Cave Crayfish (*Cambarus hubrichti*) and the Belted Crayfish (*Faxonius harrisoni*), and have an extremely limited range and distribution outside the basin within Missouri. Two others, the state listed Freckled Crayfish (*Cambarus maculatus*) and Saddleback Crayfish (*Faxonius medius*) are endemic to the Meramec Basin and found nowhere else (Pflieger 1996). Crayfish can occur in large numbers in both lotic and lentic environments and similar to mussels, can have a large influence on functions involving the transfer of energy and nutrients within the food chain. They are opportunistic omnivores that consume a variety of organic matter such as detritus (i.e., leaves) and a myriad of smaller organisms (e.g., worms, macroinvertebrates, juvenile mussels, other crayfish and small or dead fish). Stream crayfish convert more detritus into usable energy for animals in higher trophic levels than all other invertebrates combined (Montemarano et al. 2007). They are also considered "ecosystem engineers" that provide habitat for many other members of the aquatic community (Jones et al. 1994 and 1997) and represent a primary food source for hundreds of fish and wildlife species such as: Smallmouth Bass (*Micropterus dolomieu*), Rock Bass (*Ambloplites rupestris*), Largemouth Bass (*Micropterus salmoides*), catfishes, Eastern Hellbender(*Cryptobranchus alleganiensis*), Bullfrog (*Lithobates catesbeianus*), Common Snapping Turtle (*Chelydra serpentina*), Great Blue Heron (*Ardea herodias*), Belted Kingfisher (*Megaceryle alcyon*), River Otter (*Lontra canadensis*) and American Mink (*Neovison vision*) (DiStefano 2005). Crayfish are of commercial importance in the southern U.S. and were noted by Pflieger (1996) as a recreational fishery in Missouri outside of the basin.

Allert et al. (2009b and 2013) studied crayfish distribution and in-situ toxicity at eight locations in the Big River, characterized as either reference, mine impacted, or distant from mining. Like the Roberts et al. (2009 and 2016) mussel studies, crayfish densities were reduced in over 140 km of the Big River and were lowest in areas with elevated concentrations of Pb contaminated sediment. Likewise, in-situ toxicity tests with caged crayfish also showed elevated Pb in crayfish and reduced survival in contaminated areas. Reduced crayfish abundance alters ecosystem function by decreasing 1) organic matter processing, 2) nutrient recycling, 3) energy transfer to higher trophic levels, including limiting available prey abundance for fish and wildlife inhabiting the river, and 4) habitat for other community members.

Fish

Missouri has a tremendous fisheries resource with at least 200 species known to occur within the state and at least 20 species endemic to the Ozark Region (Pflieger 1997). The Meramec Basin has a notably high species diversity index with approximately 128 species and one endemic specific to this system, the Meramec River Saddled Darter (*Etheostoma erythrozonum*) (TNC 2014). The Meramec Saddled Darter was recently recognized as a valid species (Switzer and Wood 2009). It was separated from the Missouri Saddled Darter (*Etheostoma tetrazonum*) classification which still occurs in neighboring drainages of the Missouri River.

Nearly every fish species has a particular habitat association and specific life history requirements. For the purpose of this report, we will separate the fish into the following three composites (sportfish, preyfish, and other fish) and summarize each. Of note, all three groups have many species which are very important fish hosts for resident mussel species and may also have a wide range of variation within their tolerance of water quality and habitat locations. For example, some fish may prefer to live in swift pelagic environments while others are more limited by preferring specific small microhabitats (i.e., benthic locations near submerged structures in slow flows). Similar to other wildlife groups, the fish indexes were also reduced within the Big River.

- Sportfish – this fish group primarily consists of larger, predatory species which are targeted by recreational anglers. A variety of fishing related purchases for recreational fishing activities generates hundreds of millions of dollars annually in Missouri (Pflieger 1997). The Meramec River has good populations of Smallmouth Bass, Rock Bass Channel Catfish (*Ictalurus punctatus*), and Flathead Catfish (*Pylodictis olivaris*).

- Preyfish – this fish group is largely comprised of many species of minnows, darters, herrings, and young-age fish within the other groups which are targeted by larger predatory fishes, turtles, and birds. These fish occupy a wide-variety of habitats and are found in nearly every aquatic environment indicated in Appendix 1. These environments range from no-flow areas and backwaters to high-flow pelagic areas. The continued presence of this fish group is extremely important for a large variety of ecosystem functions.

- Other fish – many other fish species also inhabit the Meramec River Basin including: Freshwater Drum (*Aplodinotus grunniens*), lampreys, gars, suckers, sculpins, and madtoms. Each having important roles within the freshwater ecosystem. Some additional uncommon and noteworthy species within the basin include the Alabama Shad (*Alosa alabamae*), Highfin Carpsucker (*Carpiodes velifer*), Crystal Darter (*Crystallaria asprella*), River Darter (*Percina shumardi*), and Western Sand Darter (*Ammocrypta clara*). Non-indigenous fish species and impacts were mentioned earlier for Nuisance Species within the **FISH and WILDLIFE RESOURCE PROBLEMS and OPPORTUNITIES** section.

Fish have been reported to accumulate Pb in their tissues in the Big River (Schmitt and Finger 1982, Czarnezki 1985 and MDC 2010, Schmitt and McKee 2016). Pb concentrations in redhorse suckers (*Moxostoma sp.*), sunfish (*Lepomis sp.*), and carp (*Cyprinus sp.*) have tissue Pb concentrations that exceed the Missouri Department of Health and Senior Services (MDHSS; http://health.mo.gov/living/environment/fishadvisory/pdf/fishadvisory.pdf website) action levels for fish consumption (0.3 mg Pb/kg) and MDHSS has recommended that humans do not consume these fish species from the Big River (MDHSS 2017).

Pb concentrations in fish fillets were positively related to concentrations of Pb in sediments of the Big River (Gale 2004 and MDC, unpublished). Pb concentrations in sunfish and redhorse suckers were highest (50% exceeding 0.3 mg Pb/kg, the level that may trigger consumption advisories in Missouri) closest to the mining areas, at intermediate concentrations (0.03-0.1 mg Pb/kg) within 10 miles of the Meramec River, and below 0.03 mg Pb/kg in fish collected from the Meramec River (Schmitt and McKee 2016). Population densities were lower and the concentration of Pb was greater in riffle-dwelling benthic prey fish (Missouri Saddled Darter[1] and stonerollers) near mining sites on the Big River than at reference and downstream sites (Allert et al. 2013).

Schmitt et al. (2002 and 2005), which included fish collected from the Big River, also reported that elevated concentrations of Pb in fish muscle and blood were associated with physiological impairment as indicated by an inhibition of enzymes involved in heme synthesis. These and other studies suggest that Pb concentrations could be detrimental to growth and recruitment of fish, thereby negatively impacting the ecological and recreational value of the Big River watershed.

<u>Amphibians and Reptiles</u>

This combined animal group is comprised of 108 species found in Missouri compared to the approximately 460 known species within the U.S. (Johnson 2000). Approximately 66 species are known to occur in the Ozarks and within the study area. Those include many species of salamanders, frogs, toads, turtles, lizards, and snakes. These animals are typically very secretive in their habits and can be found in both the aquatic and terrestrial environments throughout the study area. They are cold-blooded creatures which remain inactive during the colder portions of the year. Animals from both groups residing within the study area are largely reliant on mature riparian woodlands for deadfall and woody debris that are delivered by flooding to provide sufficient food supply and cover. Amphibians also have an important connection to the water resources due to their reliance upon available predator-free habitat such as ephemeral floodplain wetlands for reproduction success. Frogs are a well-recognized group due to their presence being announced by loud, vocal breeding calls. Of note, the Eastern Hellbender is a large, long-lived, benthic, riverine salamander which was recently proposed for federal listing. The Eastern Hellbender occupies similar deep pool habitat as described for the Spectaclecase Mussel. This species occurs in the Meramec River and has also been recently documented in the Big River.

---

[1] The Missouri Saddled Darter in the Meramec Basin has been reclassified as the Meramec Saddled Darter.

Additional uncommon species reported in this region include the Wood Frog (*Lithobates sylvaticus*), Four-toed Salamander (*Hemidactylium scutatum*), Ringed Salamander (*Ambystoma annulatum*), Alligator Snapping Turtle (*Macrochelys temminckii*), and Eastern Collared Lizard (*Crotaphytus collaris*).

Birds

The terrestrial community and riparian lands found throughout the Ozarks are functionally important for feeding and/or nesting habitat for a vast array of migratory song birds, shorebirds, game birds, waterfowl, herons, and raptors (Jacobs 2003). The Meramec Basin in particular, being situated in the Mississippi flyway, acts as a very important habitat for many noteworthy populations of neotropical songbirds such as warblers, swallows, and martins.

During a benthic fish evaluation conducted by MDC (2010), it was noted that herons are particularly susceptible to Pb exposure due to their diet consisting primarily of various aquatic organisms and fishes having high Pb levels within their whole-body tissues as referenced by a previous study (Allert et al. 2009a and 2013). The Missouri Saddled Darter[2] and Largescale Stoneroller (*Campostoma oligolepis*) were found to have a mean value of 66.8 mg Pb/kg and 175 mg Pb/kg respectably at two locations within the Big River. Crayfish concentrations found by Allert et al. (2009b) contained similar concentrations (122 to 58 mg Pb/kg) at sites near and distant from mining respectively. Both riffle fish and crayfish tissues exceed concentrations found to be a risk to herons using an ecological risk assessment model. The no-effect hazard concentration (NEHC) of herons was reported as 45.3 mg Pb/kg dry weight within food items. Because of these studies, other aquatic-related birds, specifically piscivorous species, may also be prone to similar effects.

Beyer et al. (2013) studied Pb exposure to songbirds in several locations within the Southeast Missouri Pb Mining District (SEMO), including one location in the Big River floodplain. This study demonstrated blood, liver, and kidney tissue concentrations of Pb that correspond to adverse effects to birds found in the literature, Pb related pathological changes to kidneys, and inhibition of enzymes associated with Pb exposure. Songbirds accumulate Pb from the consumption of earthworms and other soil organisms from contaminated sites. Gamebirds (i.e. quail, doves, ducks, and geese) that inhabit this area are also expected to accumulate Pb when foraging and when using Pb contaminated floodplain soils for grit. There is currently an ongoing study of songbirds in SEMO that includes two sites in the Big River floodplain that will give additional information on tissue concentrations and potentially reproductive effects from Pb exposure to soil. The MDHSS (unpublished) has detected Pb in eggs collected from domestic chickens and ducks that have consumed soils from the Big River floodplain. This finding supports the belief that maternal transfer of Pb to eggs is a route of Pb exposure to developing embryos of wild birds which has the potential to negatively impact reproductive success.

The Service is responsible for protection of several bird species via the Migratory Bird Treaty

[2] The Missouri Saddled Darter in the Meramec Basin has been reclassified as the Meramec Saddled Darter.

Act and Bald and Golden Eagle Act. Through project development, the USACE is expecting to avoid and minimize woodland impacts and habitat losses during construction as well as increase riparian habitats through restoration activities. Thus, pending study approval, the Service plans to continue coordinating with the USACE on future project design, potential riparian impacts, and habitat development throughout the study area.

Mammals – A large variety of mammals inhabit the Ozark Region. The study area contains many species of herbivorous, carnivorous, and omnivorous mammals. Small mammals comprised of numerous species of mice, rats, voles, rabbits, and squirrels constitute primary food sources for larger carnivorous mammals and birds of prey. The Ozarks karst geology also provides extremely important hibernacula for many Midwestern and migratory bat species. Bats are extremely important wildlife as they consume a large volume of night flying insects including agriculture pest species. Bats may become exposed to Pb through ingestion of emergent aquatic insects that are contaminated through contact with Big River sediments. However, this route of Pb exposure to bats has not been documented. Three federally listed bat species occur within the Ozarks and are expected to be present within the study area and also likely utilize the riparian woodlands during their active season. Other mammals present in the study area that may also be considered economically important are the furbearers. These mammals include muskrat, mink, otter, opossum, beaver, raccoon, skunk, fox, coyote, and bobcat. Other important, larger mammals are: deer, possibly elk (reintroduced just outside the study area) and non-native pigs which are known to cause devastating, localized landscape impacts. Feral pig populations occur in Missouri and are rapidly expanding. If feral pigs are not currently within the study area, they may likely occur within the 50-year project period and will require management consideration on potential impacts to riparian projects. Of other importance, many of the smaller mammals mentioned that occur in the Big River floodplain are also likely burrowing into Pb contaminated soils. Beyer et al. (in press) collected white-footed mice to assess exposure of Pb contaminated soil in southeast Missouri. One of the sites was located in the Big River floodplain. Beyer's study indicated elevated concentrations of Pb in tissues and reduced enzyme activity specific to Pb exposure.

In summary, the identified wildlife studies have indicated a decline in density and potential physiological effects of many taxa throughout the Big River. This topic exemplifies the need to protect the remaining habitats by reducing the amount of Pb exposure within the benthic and floodplain environments. Restoration efforts can help prevent continued habitat degradation and reduce the amount of Pb contaminated sediments progressing into downstream environments. By improving aquatic and riparian habitat conditions, the resulting ecosystem benefits are expected to be elevated and expand through the upper trophic levels and positively impact the fish and wildlife species mentioned throughout the Meramec Basin.

Threatened, Endangered and At-Risk Species

A major emphasis of this project is to protect and restore aquatic and riparian habitats within the study area. This section will focus on the federally listed and at-risk species that are known to occur in and along the Meramec and Big rivers which will likely benefit from the proposed actions. Each federally listed species, its status, and its habitats will be discussed in detail within this section.

Plants

Decurrent False Aster (*Boltonia decurrens*), Threatened

This plant species is typically found in open, muddy bottomland areas where regular flooding and disturbance creates persistent, wet, sandy floodplain and prairie wetlands soil conditions. In the Missouri portion of its range, it is currently only known to occur along the Mississippi River north of St. Louis. Because of the close proximity to the study area, the potential occurrence of the species should be investigated as this project develops.

Running Buffalo Clover (*Trifolium stoloniferum*), Endangered

This plant typically occurs in open areas of rich soils of forest and prairies. Similar to Decurrent False Aster, it prefers disturbed areas such as those impacted by mowing, trampling, and grazing. The potential occurrence of this species should also be investigated as this project develops.

Animals

Earlier, we indicated that six federally listed mussels occur within the Meramec River Basin, four of which occur within the study area:

Spectaclecase (*Margaritifera monodonta*), Endangered
Pink Mucket (*Lampsilis abrupta*), Endangered
Scaleshell (*Leptodea leptodon*), Endangered
Sheepnose (*Plethobasus cyphyus*), Endangered

Mussel habitat, although difficult to explain, can be generalized for a majority of mussel species found in Ozark streams, including the species listed above. These mussels are typically associated within lotic environments and most often found in areas of permanent flow and stable substrate that is composed of a consolidated mixture of sand/gravel/cobble/boulders not overlain with excessive amounts of fine sediments. Many malacologists believe the largest factor influencing mussel habitat is the long-term persistence of firm substrate with moderate current draining an uncontaminated landscape. Haag (2012) supports this opinion and also mentions that depth, flow and substrate can vary greatly in microhabitats within a lotic environment. These variations do not seem to limit mussel colonization/persistence unless the substrate becomes unstable. All four federally listed mussel species indicated typically reside in this habitat type. The Spectaclecase's habitat varies slightly from that of the others in that it is most often found in deeper stream segments in association with large boulders most often along bluffs. Of particular note, Buchanan (1980) and Butler (2002) have indicated the Meramec River contains one of the largest Spectaclecase populations in the U.S. It was also reported as the most abundant species in the Meramec River (Roberts and Bruenderman 2000). Baird (2000) indicated Spectaclecase densities of up to 3.15 per 1/4 meter^2 (approximately 22,697 individuals) residing with 17 other species in one mussel bed within the Meramec River. Comprehensive evaluations of the mussel community have been conducted within the study area (Buchanan 1979, Roberts and Bruenderman 2000, Roberts et al. 2009 and 2016). The latter two were specific studies to understand the relationship between mussel habitat and impacts resulting from heavy metals within the study area. Sampling data from these reports and other Service efforts indicate several significant mussel beds remain on the lower reaches of the Big River and throughout the lower Meramec River. These mussel beds harbor some of the best populations known range-wide for these federally listed species.

The evidence indicates the largest factor degrading the Big River aquatic environment and associated wildlife communities has directly and indirectly resulted from Pb mining activities. Additional evidence supports the notion that the lack of AOP caused by mill dams is only of minor concern on the Big River compared to impacts associated with contaminated sediments. We believe the existing Big River mill dams are not causing major negative AOP impacts. This statement is supported by the existing condition of all the remaining dams being very dilapidated and/or breached such that all are also regularly inundated by slightly higher than normal flows. Roberts et al. (2016) indicate that a diverse mussel community has persisted upstream of two similar-sized, mill dams in the Bourbeuse River in the Meramec Basin outside the study area. This situation doesn't preclude the possibility for AOP improvement. Despite this, we recognize these instream impoundments have served to capture/contain significant amounts of Pb contaminated sediments and thus likely have helped to minimize possible impairment/loss of additional downstream environments in the lower Big and Meramec Rivers.

The following federally listed bats have been recently documented within the study area:

Indiana Bat *(Myotis sodalis)*, Endangered
In Missouri, the Indiana Bat hibernates in caves in the Ozarks and Ozark Border Natural Divisions from late fall through winter months (November 1 to March 31). During the spring and summer, the Indiana Bat utilizes living, injured (i.e., split trunks and broken limbs from lightning strikes or wind), dead or dying trees for roosting. Indiana Bat roost trees tend to be greater than nine inches diameter at breast height (dbh) (optimally greater than 20 inches dbh) with loose or exfoliating bark. Most important are structural characteristics that provide adequate space for bats to roost. Preferred roost sites are located in forest openings, at the forest edge, or where the overstory canopy allows some sunlight exposure to the roost tree, which is usually within one km (0.6 mi.) of water. The Indiana Bat forages for flying insects (particularly moths) in and around the tree canopy of floodplain, riparian, and upland forests.

Northern Long-eared Bat (*Myotis septentrionalis*), Threatened
The Northern Long-eared Bat occurs throughout Missouri and similar to the Indiana Bat, roosts in caves (or habitats similar to caves) during the winter and under loose tree bark or in tree cracks or crevices during the summer.

Gray Bat *(Myotis grisescens)*, Endangered
The Gray Bat occupies a limited geographic range in limestone karst areas of the southeastern United States, including Missouri. With rare exception, the Gray Bat roosts in caves year-round. In winter, most Gray Bats hibernate in vertical (pit) caves with cool, stable temperatures below 10 degrees Celsius. Summer caves, especially those used by maternity colonies, are nearly

always located within a kilometer (0.6 mile) of rivers or reservoirs over which bats feed. The summer caves are warm with dome ceilings that trap body heat. Most Gray Bats migrate seasonally between hibernating and maternity caves, and both types of caves are located in Missouri. Gray Bats are active at night, foraging for insects over water or along shorelines, and they need a corridor of forest riparian cover between roosting caves and foraging areas. They can travel as much as 20 kilometers (12 miles) from their roost caves to forage.

The greatest current threat to all three species of bats is white-nose syndrome (WNS). WNS is named for the white fungus that appears on the muzzle and other parts of infected hibernating bats. WNS is associated with extensive mortality of bats in eastern North America and has spread rapidly across the eastern United States and Canada. The fungus that causes WNS has been detected as far south as Mississippi and as far west as the state of Washington. Bats with WNS act strangely during cold winter months, including flying outside in the day and clustering near the entrances of hibernacula (caves and mines where bats hibernate). Bats have been found sick and dying in unprecedented numbers in and around caves and mines. WNS has killed more than an estimated 5.7 million bats in eastern North America. In some hibernacula, 90 to 100 percent of bats have died.

The study area contains suitable habitat for all three bat species. In fact, areas in and along the Meramec River floodplain support maternity and winter bat hibernacula, potential swarming habitat, and maternity colonies. However, recent surveys have failed to detect Northern Long-eared Bats in many areas where they had occurred just a few years previous. Because data indicate Northern Long-eared Bats are short distance migrants, it is likely that they are using the Big River floodplain in the summer and also may have winter hibernacula nearby. Limiting woodland removal and increasing protection during construction during riparian restoration will likely help these bats resist other environmental threats and provide meaningful benefits towards recovery.

The following two species have been proposed for federal listing. They are either known or are likely to occur within the study area.

Monarch Butterfly (*Danaus plexippus plexippus*), Proposed
The project lies within the range of the Monarch Butterfly. The Service has determined that listing under the ESA may be warranted for the Monarch and is currently conducting a status review of the species. Monarchs are found throughout Missouri and some populations migrate vast distances across multiple generations each year. Many fly between the U.S., Mexico, and Canada – a journey of over 4,500 km. This journey has become more perilous because of increasing threats along their migratory path as well as impacts to their breeding and wintering grounds. Monarch populations have declined over 90% during the last 20 years. Primary threats to the species are attributed to loss of primary host-plants (i.e., milkweeds) and increased use of pesticides. Similar to bats, riparian restoration which includes planting of milkweeds and other nectar producers will be beneficial to this species as well as other pollinator species.

Eastern Hellbender (*Cryptobranchus alleganiensis*), Proposed

The Eastern Hellbender is a large, long-lived benthic riverine salamander which is restricted to 13 states in North America. Missouri is the only state where the species occurs west of the Mississippi River. In Missouri, it is restricted to the Ozark Region (Johnson 2000). It is known to occur in the Meramec Basin and has been recently reported from the Big River. The Eastern Hellbender occupies similar habitats as those described for the Spectaclecase Mussel. This species has been proposed for federal listing and the Service is currently conducting a status review of the species. Efforts to improve benthic habitat for riverine mussel species will likely also improve habitat for the Eastern Hellbender.

PLANNING OBJECTIVES

A collective planning team for the MRFS was comprised of biologists and engineers from the USACE, Service, MDNR, MDC, and TNC. Represented as Trustees, the Service and MDNR also provided input as it pertains to the Natural Resources Damage Assessment (NRDA) program. Numerous meetings, workshops, and field visits throughout the study area were conducted to identify and discuss the most prominent and relevant issues (negative environmental impacts) as well as collaboratively provide/discuss potential evaluation and restoration opportunities which could provide measurable wildlife habitat improvements within the study area. The Service believes completing the following large-scale planning objectives can potentially preserve and protect the existing aquatic habitats currently supporting unique wildlife species in the lower Big and Meramec rivers. Furthermore, this project is expected to reverse habitat degradation induced by chemical contamination upstream and significantly improve habitat quality within the study area. Without additional intervention in the upper Big River, riverine and terrestrial habitats upstream of the study area will continue to be impacted by these contaminated materials into the future.

- **Primary objective:**
  - **Reduce the Pb concentration within the benthic environment to 128 mg/kg throughout the study area to prevent continued impacts to mussels and their habitat.**

- **Additional objectives:**
  - **Remove Pb contaminated sediment from the benthic environment to repair and restore degraded aquatic habitats throughout the study area.**
  - **Reduce/prevent the downstream migration of Pb contaminated sediment throughout the study area to protect remaining mussel habitat in the lower Big River and Meramec River.**
  - **Locate and correct Pb input at eroding banks with willing landowners to reduce contaminated sediment contributions within the study area.**
  - **Maintain a proper sediment budget needed to support benthic aquatic habitat.**
  - **Establish/increase riparian buffer widths and habitat connectivity, quantity, diversity and complexity within the project area with willing landowners.**

- **Reduce risks from Pb exposure within the project area with willing landowners.**
- **Restore/create functional habitat for fish, mussel, and terrestrial species throughout the study area.**
- **Adopt design and construction principles and practices that maximize fish and wildlife habitat functionality.**
- **Improve aquatic organism and recreational user passage where feasible throughout the study area.**

Ecological Habitat Assessment and Quantification

The USACE is currently planning large-scale habitat restoration using a variety of specific techniques targeted to remove/reduce/contain Pb contaminated sediments and total suspended solids (TSS) which are currently above concentration levels known to impair aquatic life. These contaminated sediments have/are originating from either existing streambed sources and/or accelerated streambank erosion within the Big River. During the course of the study's development the USACE, MDNR, Service, and MDC representatives worked collaboratively to the extent possible to develop various preliminary preferred project alternatives for comparison purposes per federal requirements and the goal to restore ecological functions within this impaired system. The USACE attempted to quantify the baseline conditions, potential impacts and investigate possible design alternatives to the best of their ability using available field evaluations, review of watershed hydrology gauge data, aerial photography review, literature review, and input from subject matter professionals. The USACE investigated many preliminary designs and evaluated elements within the seven various project alternatives described below. The proposed construction actions within each alternative included singular or combinations of the following measures depending on the site complexity and existing habitat conditions/circumstances: streambank/channel stabilization, grade control structures, streambank re-sloping, floodplain benching, LPSTP, bendway weirs, vane/barb placement within the streambank, bioengineering techniques, toe wood installation, channel reconfiguration, riparian plantings, mechanical or passive floodplain sediment capture/containment features either instream or within side channels, gravel bar restoration, in-channel bedload collectors, and mill dam/impoundment modification.

Habitat Suitability Index (HSI) Models

To equally compare the effectiveness of each of the project alternatives considered, the USACE employs internally certified models to evaluate, quantify, and compute any potential relative benefits (indicated as habitat units (HUs)) resulting from various projects within/among the proposed alternatives. To forecast expected benefits, calculations must be able to consider/compare existing (baseline) conditions with, the future without project and future with project conditions. The development of a HSI model typically involves collection and evaluation of pertinent peer reviewed literature, datasets, site visits, and expert opinion. Once known, the HUs for a given alternative are then compared with the project cost to help measure/inform the cost/benefit for each alternative which helps direct decisions to select the TSP from the group of alternatives. Two HSI models were used to evaluate the potential aquatic and terrestrial HUs within the current study area. The Black-capped Chickadee HSI model (USFWS 1983) was pre-certified for regional and national use and used to evaluate the floodplain forest habitat. The mussel model was developed and approved as a single-use model in collaboration with competent experts representing the USACE, Service, MDNR, and MDC to be used to evaluate mussel (riverine) habitat (USACE 2017). The primary habitat suitability variables consisted of six equally-weighted parameters: total suspended solids (TSS) levels, Pb concentration levels, substrate composition, percentage of available aquatic cover, fish species richness, and riparian width/amount of channel migration.

The threshold values indicated for the TSS variable in the mussel model were largely based on available literature indicating that elevated levels of TSS can cause feeding or reproductive difficulties in mussels. Subsequent to the HSI mussel model development and approval, the Service obtained additional data from the Kansas Department of Health and Environment (KDHE) water quality monitoring program which appear to indicate the upper threshold value (20 mg/L) may be conservative. For example, median values for TSS and temperature that were collected between 2006-2017 (Table 1) from streams which currently harbor a high number of long-term, diverse mussel communities, including many of the mussel species found within the Meramec Basin. The median TSS (mg/L) and temperature values reported in these streams were summarized from a high number of samples collected throughout the mussels' most physiologically active periods (spring, summer and fall months). Apart from occurring in a different ecoregion, mussel physiology and nutrition are not expected to be vastly different between the streams indicated compared to the Meramec River.

Basin	Spring	Summer	Fall
Marais des Cynges	42 mg/L, 20°C (N=207)	34 mg/L, 25°C (N=207)	15 mg/L, 13°C (N=184)
Neosho	30 mg/L, 20°C (N=461)	23.5 mg/L, 26°C (N=429)	12 mg/L, 15°C (N=390)
Verdigris	21 mg/L, 19°C (N=291)	20 mg/L, 27°C (N=239)	14 mg/L, 15°C (N=263)

Table 1. KDHE Median TSS Values indicated for Basin and Season.

Therefore, mussels appear to have a higher level of tolerance to TSS than the values indicated in the USACE mussel model. Despite this specific discrepancy, high levels of TSS in the Big River remain a considerable resource concern due to the chemical attributes of Pb binding to fine sediment particles, resulting in TSS being the primary vector for Pb mobilization. Therefore, a reduction of TSS levels throughout the study area would directly reduce the transport rate of Pb. As the model is used to quantify and compare the HUs generated for pertinent projects involving relative habitat types over the project time periods, we do not anticipate any concern using the mussel model in its existing state as it calculated the same variables for all project alternatives.

DESCRIPTION of MRFS ALTERNATIVES

To best address the **Fish and Wildlife Resource Concerns** and **Planning Objectives** described above, the USACE, in cooperation with the interested parties, developed seven independent alternatives. Each alternative considered the impact of various individual actions along different sections of the Meramec and Big rivers. The proposed actions within each of the alternatives are largely composed of streambank stabilization projects, passive sediment capture structures, direct mechanical sediment removal activities (i.e., gravel bar restoration, instream collection by mechanical collectors and directly upstream of (behind) existing mill dams), and riparian corridor enhancement. These projects are described below.

Streambank stabilization: These projects will be located at sites exhibiting accelerated bank erosion with a primary purpose to protect each site from scour and redirect stream flows away from existing erosional areas to limit/prevent additional contributions of Pb contaminated sediments contained within the floodplain. Current designs may include LPSTP, bioengineering, and river training structures such as vanes, weirs, barbs, toe wood, and channel realignment.

Passive sediment capture: These projects will be located at sites within the floodplain. Sites will require the excavation of a large basin to enhance the depositional potential in order to receive and capture contaminated sediments (<2mm) that are being transported overland during high-discharge events. The operation and maintenance activities (i.e., regularly remove deposited materials or allow the features to fill and be capped) will be determined at a later date by project sponsors. If materials will be removed, there will likely be associated removal, transport, and disposal costs.

Direct mechanical sediment removal: These projects will be located at sites within the active stream channel below the floodplain elevation. These projects will remove a larger size fraction and volume of contaminated sediment currently impacting the aquatic environment by the following means:

Bedload collectors – These projects are constructed traps located within the wetted channel at a grade below the existing streambed and will capture sediment during large discharge events at a time when streambed sediment is mobilized. The collectors can target particular-sized sediments depending on their design. The resulting material can either be mechanically or hydraulically removed and transported to an approved disposal location.

Gravel bar restoration – These projects will occur at existing, large depositional features above the base flow elevation. The sediment removed will be mechanically collected, screened, and the contaminated fraction transported to an approved disposal location. The sediment removal process will consist of repeated excavation activities at each gravel bar location throughout the project period. The resulting bar morphology will be lowered to an elevation sufficient to encourage additional sediment deposition during future high flow events followed by repeated excavation. Many of the existing large gravel bars throughout the study area have existing private access points. We expect that some roads and access improvements may be necessary to support large excavation equipment which may include some minor riparian impacts. Nevertheless, similar to bedload collectors, particular-sized sediments can be targeted to remove a large volume of Pb concentration from the Big River channel. These practices will follow the regulating guidelines provided by the MDNR Land Reclamation Program and USACE General Permit (GP) 34M. These regulations implement particular measures to avoid and minimize impacts to the environment. The Service provides input to each agency during the permit review/reissuance periods.

Instream dredging – These projects will occur directly from existing mill dam impoundments or from behind an established grade control structure. Big River mill dam impoundments have historically acted as sediment capture devices by processes similar to those described for passive sediment capture above. Projects will require the excavation of existing instream substrate materials directly behind existing mill dams. The level of excavation will depend on the depth of contamination within each impoundment. These actions will allow the stream to re-create additional deposition potential. As mentioned for passive sediment capture, actions to regularly remove these sediments or allow the features to fill will be determined by project sponsors. If materials will be removed there will likely be associated removal/transport/disposal costs.

Riparian Corridor Enhancement: These projects will be located at various locations either in association with other restoration project or singular actions within the floodplain on lands adjacent to the stream channel. The purpose is to create/enhance a riparian buffer, streambank protection and create wildlife habitat. Some projects may include additional preparation such as re-sloping of streambanks and floodplain benching to ensure riparian vegetation development. Furthermore, discussions regarding floodplain soil treatment, such as adding phosphate to contaminated surface soils to reduce Pb concentrations and exposure risks are currently being discussed as additional potential restoration measures.

The habitat evaluation calculations within the seven study alternatives included the following general and site specific assumptions as provided by the USACE (2018):

General Assumptions

- The period of analysis was determined to be 50 years based on the prediction that some project features (e.g., development of key ecological processes needed to restore ecosystem structure and function) would need a longer period of time to reach maximum benefits; and the accrual of benefits were predicted to level off after 50 years. Target years of 0 (existing condition), 1, 5, 25, and 50 (future without and future with project conditions) were used to analyze HUs and characterize habitat changes over the estimated period of analysis.
- No major land-use changes are expected to occur within the watershed that would greatly change the existing land-use. Land cover types may shift but the overall quantity would remain relatively the same.
- Anticipated climate changes are not expected to greatly change the existing hydrology of the Big or Meramec rivers.

Site specific Assumptions

- Riverine Habitat
  - TSS median baseline values (Big River 16mg/L, Meramec River 17mg/L).
    - TSS values are expected to be slightly higher in Meramec River compared to Big River due to the former being a larger stream and the latter being a tributary.
    - TSS values >20 mg/L are a limiting factor for mussel habitat.
    - No expected changes to existing TSS values into the future without the project.
  - Channel Change baseline values (Big River - high, Meramec River - low).
    - Big River contains several areas of channel change from the historical channel position throughout study area.
    - Meramec River has a relatively intact riparian corridor throughout study area. No drastic historic channel change identified, minus a few problem areas.
    - Lack of riparian corridor increases probability of channel change in the Big River.
    - Areas with known historical channel change are still prone to future channel change.
    - Areas considered high probability of channel change will continue or worsen into future. Low probability areas will remain low probability into future.
  - Substrate baseline values (Big River - marginal, Meramec River - suboptimal) from field observation averages.
    - Values could be used to generalize overall condition in each river.
    - Each reach of Big River had similar substrate composition.
    - Localized substrate variability exists but does not drastically influence overall general conditions in each river.
    - Impacts from Pb may occur from downstream substrate migration.
  - Available Aquatic Cover baseline values (Big River – 51%, Meramec River – 64%) from field observation averages.
    - Each reach of Big River had similar available aquatic cover.
    - Localized variability exists but does not drastically influence overall general conditions in each river.
    - Meramec River – conditions expected to remain the same as existing.
    - Big River – conditions expected to worsen from bank erosion and trees falling into channel without project. Areas with vertical banks would continue to erode and limit aquatic cover without project.
  - Fish Species Richness baseline values (Big River (mile 0-10.2) – 48, Big River (mile 10.2 +) – 26, Meramec River – 48).
    - Thirty-year old dataset is accurate and reflects species potential within study area.
    - Average species richness from Big River 0-10.2 is suitable for Meramec River.
    - Lower Big River reaches should have a greater number of species than headwater reaches.
    - The value of 48 species represents the optimal number within the watershed.
    - Greater richness is important for mussel species composition and distribution.

31

- Sensitive species would be gone from system without project by year 25 in Meramec River.
- Loss of species would occur in Big River without project due to aquatic habitat impacts from homogenous substrate, limited aquatic cover, and Pb migration.

- Pb concentration baseline values obtained from Roberts et al. (2016) and USEPA (2017) as referenced in Table 3 within USACE (2018).
  - One of the following future without project (FWOP) scenarios will be conducted.
    - FWOP 1: No Action by the USACE or USEPA within Study Area.
    - FWOP 2: No Action by the USACE, USEPA will remediate sediment and soil to 1200 ppm Pb.
    - FWOP 3: No Action by the USACE, USEPA will remediate sediment and soil to 400ppm Pb.
  - The USEPA data for habitat evaluation due to being more robust sampling effort.
  - Pb concentration values are appropriate to provide a longitudinal gradient in the <2mm sediment fraction. These data were from averaged sampling sites within each reach.
  - Single sampling location in Meramec is applicable for entire Meramec River.
  - Using the proportion of each river reach to the total study area for the Big River would help determine the existing baseline condition for each alternative that spanned more than one reach due to the model being limited to only include one baseline value per alternative.
  - Rate of Pb effects being equal to 1.7 miles/year.
    - Negative effects would move into Meramec and Mississippi rivers in 50 years.
    - Some dilution to effects would occur due to mixing of waters without Pb.
  - Rate of Pb contaminated bedload movement within Big River being equal to 0.62 miles/year (1 km/year).
  - Pb would migrate into the study area during period of analysis in FWOP1 and FWOP2.
  - The maximum Pb concentrations would be no greater than 400 ppm for the FWOP3 scenario.

- <u>Riparian Habitat</u>
  - Tree planting locations/riparian corridor widths were in areas less than 300 feet and 1500 feet in length along the river corridor.
  - Existing conditions were expected to have little or no tree cover throughout the study period.

<u>List of Alternatives</u>
As defined by the USACE (2018), Alternatives 2, 3, and 4 were formulated based upon geographic location. Alternative 5 was formulated based upon sites/projects meeting efficiency criteria. Alternative 6 was formulated to include all sites/projects along the Big River. Alternative 7 was formulated to include all sites/projects along both the Big and Meramec rivers.

Alternative 1 – No Action Alternative – FWOP
This alternative is specifically meant to provide conditions if the project were not to occur within the study area and is also used for comparison purposes in order to assess restoration benefits and project impacts for all alternatives considered. The USEPA will also likely have involvement in remediation of Pb within and upstream of the study area. However, because no Record of Decision (ROD) has been indicated, the USACE also considered three FWOP alternatives assumptions (identified above). Once the USEPA provides its ROD the TSP may be impacted to some degree by potential measures pursued by the USEPA.

Alternative 2 – Big River RM 0-10.2 (RKM 0-16.4)
This alternative represents actions conducted only on the lower 16.4 river kilometers (10.2 river miles) within the Big River. The alternative was considered assuming the USEPA would be doing remediation activities upstream of RKM 16.4. The following actions were evaluated at six sites:

- Three bank stabilization projects
- An off-channel sediment capture project
- Grade control at an existing mill dam
- A riparian planting project greater than 4 hectares (10 acres)
- Monitoring, research, and adaptive management

Alternative 3 – Big River RM 0-35 (RKM 0-56)
This alternative represents actions conducted only on the lower 56 river kilometers (35 river miles) within the Big River. The alternative was considered assuming the USEPA would conduct remediation activities upstream of RKM 56. The following actions were evaluated at 25 sites:

- Twelve bank stabilization projects
- Five off-channel sediment capture projects
- Three grade control projects at existing mill dams
- Two excavation projects behind grade control structures
- Three riparian planting projects greater than 4 hectares
- Monitoring, research, and adaptive management

Alternative 4 – Meramec River Only
This alternative was considered due to the concern of the USACE working with hazardous materials. Actions would be limited to only the Meramec River to limit this interaction. It should be mentioned that this alternative will not address either the primary planning objective or many of the additional objectives discussed previously. The following actions were evaluated at six sites:

- Six bank stabilization projects
- Monitoring, research, and adaptive management

Alternative 5 – Efficient Alternative
The following actions were evaluated at 54 sites throughout the Big River within the study area:

- Twelve bank stabilization projects

- Six off-channel sediment capture projects
- Four sediment removal projects (gravel bars, natural sediment collection points)
- A sediment removal project in association with bank stabilization activities
- Six instream bed sediment collectors
- Three grade control projects at existing mill dams
- Four excavation projects behind grade control structures
- Eight riparian planting projects greater than 4 hectares
- Ten riparian plantings in lieu of bank stabilization actions
- Monitoring, research, and adaptive management

Alternative 6 – Maximum Ecosystem - Big River
The following actions were evaluated at 69 sites throughout the Big River within the study area:

- Twenty-four bank stabilization projects
- Six off-channel sediment capture projects
- Fourteen sediment removal projects (gravel bars, natural sediment collection points)
- Two sediment removal projects in association with bank stabilization activities
- Six instream bed sediment collectors
- Three grade control projects at existing mill dams
- Six excavation projects behind grade control structures
- Eight riparian planting projects greater than 4 hectares
- Monitoring, research, and adaptive management

Alternative 7 – Maximum Ecosystem – Project Area
The following actions were evaluated at 75 sites throughout the entire study area:

- Thirty bank stabilization projects
- Six off-channel sediment capture projects
- Fourteen sediment removal projects (gravel bars, natural sediment collection points)
- Two sediment removal projects in association with bank stabilization activities
- Six instream bed sediment collectors
- Three grade control projects at existing mill dams
- Six excavation projects behind grade control structures
- Eight riparian planting projects greater than 4 hectares
- Monitoring, research, and adaptive management

EVALUATION METHODOLOGY
The Service, MDC, and MDNR contributed to the USACE planning process by collectively suggesting particular project actions which were believed as actions which would best address the stated project objectives (indicated earlier), prevent/limit fish and wildlife resource impacts, as well as attempt to maximize fish and wildlife resource benefits. The Service has relied upon the expertise and best professional judgment of USACE staff and biologists to estimate and evaluate project-related habitat changes for the study period (50 years). To do so, the USACE conducted the model computations and performed the quality control necessary to evaluate all projects within each of the seven alternatives. Based on the best available information, the following three main elements were considered during the evaluation process: the amount of Pb

that could be removed by element of time and cost of project for the resulting HUs. The resulting values were also used to form the basis of other USACE evaluations such as project costs/benefits in order to compare and rank each alternative in order to select the TSP. The following sections rely on the information and calculations provided by the USACE.

EVALUATION and COMPARISON of ALTERNATIVES
Collective computations from the HSI models allowed the USACE to quantify, compare and evaluate potential habitat benefits. The Cost Effective and Incremental Cost Analysis (CE/ICA) was conducted by the USACE for each project alternative within all three FWOP scenarios. As result of the full evaluation, the USACE project delivery team determined that FWOP2 was the most realistic and reasonable scenario. The HUs indicated in Table 2 represent the values for both FWOP1 and FWOP2 scenarios. The Service emphasizes the finding that the FWOP2 scenario, USEPA 1200 ppm Pb remediation clean-up level, will not provide detectible wildlife benefits.

Alternative	Description	Floodplain Net AAHUs	Riverine Net AAHUs	Total Net AAHUs
1	**No Action**	**0**	**0**	**0**
2	**Big River RM 0-10.2**	**122**	**75**	**197**
3	**Big River RM 0-35**	**361**	**384**	**745**
4	**Meramec River Only**	**16**	**11**	**26**
5	**Big River – Efficient**	**553**	**1011**	**1565**
6	**Maximum Ecosystem – Big River**	**557**	**1010**	**1567**
7	**Maximum Ecosystem – Study Area**	**573**	**1053**	**1625**

Table 2. Net average annualized HUs (AAHUs) for each project alternative for FWOP1 and FWOP2 scenarios.

Assessment of Individual Alternatives
For this draft report, the Service will use a programmatic approach for project alternative analysis. We will provide more detailed evaluation once specific project design information is received from the USACE. At this time, we will assess each alternative as it pertains to potential fish and wildlife restoration. Based up the results of the USACE evaluation and our own expertise, we anticipate that no alternative can completely remove all the Pb contamination or its associated impacts from within the Big River.

Alternative 1 – No Federal Action = 0 total AAHUs
The no action alternative is the least desired alternative as it will not provide any potential HUs and will be the least effective in preventing additional/cumulative impacts to the current benthic aquatic community throughout the entire study area and possibly beyond. As mentioned elsewhere, the downstream reaches of the Big and Meramec rivers are currently largely un-impacted by Pb contaminated sediments. These stream segments contain several unique species

and a nationally significant freshwater mussel community also containing numerous locations and numbers of federally listed species. Although the no action alternative may involve future remediation activities conducted by the USEPA, this agency has not indicated the location/degree/level at which possible remediation actions will occur. Thus, our current assumption is that if the USEPA would remediate, their clean-up actions would not be to the degree needed to restore mussel habitat (128 mg Pb/kg) within the Big River. As a result, downstream reaches of the Big and Meramec rivers will not be protected from migrating Pb contamination and therefore, existing wildlife resources/habitats would likely be impacted and degrade into the distance future.

Alternative 2 – Big River RM 0-10.2 (RKM 0-16.4) = 197 total AAHUs
This alternative is a low ranking alternative due to the limited type and number of habitat restoration projects. As mentioned, the downstream reaches of the Big River and Meramec River are currently largely un-impacted by Pb contaminated instream sediment. This particular stream reach contains the best population of freshwater mussels remaining in the Big River which includes federally listed species. This alternative will be one of the least effective to protect this population, will not substantially reduce instream Pb contamination, or prevent contaminated sediments from migrating into additional important downstream environments.

Alternative 3 – Big River RM 0-35 (RKM 0-56) = 745 total AAHUs
Similar to Alternative 2, this alternative is also a low ranking alternative for similar reasoning: limited type and number of habitat restoration projects and expected HUs will provide limited protection of downstream environments compared to several other alternatives.

Alternative 4 – Meramec River Only = 26 total AAHUs
This alternative will be considered the second lowest ranking alternative proposed due to no restoration projects considered within the Big River. As mentioned, all of the deleterious materials impacting the environment discussed in this study occur and are actively migrating downstream from the Big River to the Meramec River. By restricting the projects to only the Meramec, migration and impacts of Pb contaminated sediments will not be addressed. The benthic environment within the Meramec River segment of the study area is currently un-impacted by Pb contamination. This alternative will do very little to either dilute or prevent deleterious impacts to the remaining mussel community or rehabilitate habitat elsewhere. As a result, we anticipate future habitats will be similar to those mentioned for FWOP conditions.

Alternative 5 – Efficient Alternative = 1565 total AAHUs
This alternative will be considered the highest ranking alternative. We believe that when compared with all other alternatives, Alternative 5 produces the most cost-effective approach to protect the downstream environments as well as rehabilitate and restore a significant reach of the Big River for numerous fish and wildlife species as well the public interest. Based on the USACE's calculations, this alternative potentially removes the maximum quantity of Pb contamination per dollar expended.

Alternative 6 – Maximum Ecosystem – Big River = 1567 total AAHUs

This alternative generates a nearly identical number of AAHUs as Alternative 5. However, this alternative received the second highest ranking alternative due to the higher level of operation and maintenance (O&M) involvement/costs necessary. Another difference between the two was Alternative 6 could potentially decrease the amount of time necessary to remove Pb contaminated materials from the study area, but at a significantly higher cost per HU.

Alternative 7 – Maximum Ecosystem – Study Area = 1625 total AAHUs
This alternative generates the highest number of AAHUs. However, it was considered the third highest priority due to both the significantly higher project cost and sponsor cost-share needed to obtain the additional 60 HUs.

Generally, alternatives 5, 6, and 7 all present similar ecological benefits, but are vastly different in cost of construction, as well as cost expected to be incurred by the project sponsor. Therefore, as a result of the comparison, the USACE and the study partners plan to pursue **Alternative 5 – Efficient Alternative** as the TSP.

Adaptive Management (AM)
The USACE provided a proposed work schedule and has indicated that principles of AM will be incorporated once projects have been constructed. During AM, the USACE plans to regularly monitor/evaluate all restoration measures in order to ensure they 1) function as intended and 2) meet the intended project objectives during the project period. For example, a bank stabilization project may require slight design modifications pending project condition in response to unexpected outcomes following a high-flow event. The Service anticipates that innovative design criteria may be developed over the project period and possibly included if project maintenance is necessary. As previously mentioned, the Big and Meramec rivers are represented by a natural hydrograph with their high-flows being dominated by precipitation events. As the science of fluvial geomorphology improves, we foresee a potential to develop/use evaluation metrics to better understand how channel dimension, pattern, and profile, bedform, streamflow, and sediment transport variables interact in response to these events to help influence development and persistence of aquatic habitat(s). If adequately understood, applicable restoration opportunities within projects could further enhance the potential ecological function and increase the resulting habitat value. For example, if the proper sediment budget and transport rate were understood the potential to remove the contaminated bedload fraction within specific reaches could be maximized. Furthermore, completing projects using relevant/accurate natural channel design principles can utilize stream functions and processes to promote/enhance habitat development and expedite anticipated results. These design strategies allow the use of readily available, natural construction materials, such as large woody debris to not only help reduce project costs but also create/increase local habitat diversity potential. Additional design concepts able to combine/develop/maintain side channel or back channel habitat or can emulate any of the habitats mentioned in Appendix 1 should be considered. As indicated, the lower Big and Meramec rivers currently support intact diverse wildlife populations. While some of this diversity is simply due to the size of the river, much of it is a result of a variety of river flows and the amount of stable habitat over multiple seasons and years. Therefore, in creating habitat, we would stress that these "reference" environments should be carefully studied to not only ensure

they persist but to also develop the evaluation criteria needed to make accurate habitat variable comparisons within the project areas to ensure they meet the project objectives. In doing, the Service considers future collaboration an important component within the AM approach to implement fish and wildlife conservation. Collaborative efforts will provide opportunities to improve current habitat conditions in the impacted reaches of the Big River and protect the downstream habitats in the lower Big and Meramec rivers. The Service will include more specific comments regarding AM planning in the FWCAR.

ALTERNATIVE IMPACTS ANALYSIS and DISCUSSION

Potential Project Impacts

Many of the projects within each alternative were comprised of similar types of project actions. Each mainly differed by the number of actions and/or their site location within the study area. Due to the primary study purpose of restoring wildlife habitat, nearly all project actions will occur within currently degraded areas/environments. All proposed project types were either vetted or proposed by the Service and MDC. Most of those, as for the Big River, are either directly impacted from contaminated bed sediments or are directly contributing to additional habitat degradation (i.e., accelerated streambank erosion) in the study area. Due to existing habitat conditions, we currently only anticipate minor, local, short-term impacts to result from/near each projects completion. That said, all authorized projects should receive a full impact evaluation based upon the type, location and timing of the proposed actions which may include additional less obvious cumulative impacts likely to result from project implementation. The Service recommends this evaluation begin as soon as possible once project designs are finalized and be coordinated with the Service and MDC. We believe our agencies could help the USACE define sound biological monitoring metrics to evaluate ecological impacts and assess habitat improvement for non-listed native fish and wildlife species as they pertain to the projects throughout the study area. These monitoring efforts and assays could then be included within the USACE (AM) planning described above. To help this facilitation, the Service provided the USACE specific conservation measures meant to address potential negative impacts to federally listed mussel and bat species (Appendix 2).

Potential Project Benefits

Overall, the proposed USACE actions and AM plans are expected to remove an enormous fraction of the existing Pb contaminated bedload from within the Big River during the project period as well as help ensure the planned restoration actions function as intended. Altogether, as planned, these proposed actions are currently the most feasible benefits for this impaired aquatic community. However, because the adjacent floodplain will remain significantly contaminated throughout the Big River into the future, any additional actions to ensure this largest fraction of hazardous materials, (approximately 86.8 million cubic meters) remains contained in the floodplain to prevent future instream contamination would be extremely beneficial.

Instream Benefits

Habitat is a key variable to a healthy ecosystem as it can provide the needs of all fish and wildlife within the study area. Mussels also require habitat stability in order to subsist in the benthic environment. There are numerous variables and existing unknowns surrounding the topic. A primary component of mussel habitat is sediment. Much of the Big River is currently unsuitable for mussels because the current instream sediment Pb concentration levels exceed their tolerance level despite stable habitat being present in those areas (Roberts et al. 2016). Therefore, our best expectation to improve/restore the impacted zones to a historical condition would be a large-scale project to attempt to remove/reduce/contain the Pb contamination by the proposed measures. These actions are expected to collectively remove Pb contaminated sediments from within the Big River over time to concentrations near/below deleterious levels and should then allow mussels to recolonize those already stable habitats.

Reducing Pb concentrations in instream sediment will also benefit fish and crayfish populations. A reduction in sediment Pb concentrations that are protective of mussels would reduce Pb concentrations in sportfish and could result in removal of current fish consumption advisories. Furthermore, fish and crayfish densities could recover to more historic levels, and provide a more dense and uncontaminated prey base for sportfish and piscivorous birds. Lowering concentrations of Pb in sediment would restore ecosystem function, structure, and stability and therefore, increase both the ecological and recreational value of the Meramec River Basin.

However, because streambed stability and proposed Pb removal activities both involve sediment transport processes, additional sediment management calculations may be required for project design refinement to not create negative habitat impacts. The Service believes the best approach to formulate the proposed projects is one that would focus natural fluvial processes to perform a majority of this work. In doing, the USACE should develop a good understanding of the channel-forming streamflow and sediment transport indices to effectively incorporate proper channel dimension, physical pattern, and profile which will then in turn help to efficiently promote the creation, maintenance, and function of the resulting habitat(s) in addition to helping ensure project longevity. As a result, we believe these geomorphic elements would also allow the associated habitat(s) and functions to respond positively and naturally improve the impaired reaches throughout the Big River.

The smaller TSS fraction is readily mobilized during many lower flows. Because Pb readily binds to fine sediment, the TSS is directly associated with elevated Pb levels in the Big River. Therefore, the proposed actions to reduce TSS in the Big River are expected to have beneficial effects to both the instream and floodplain environments throughout the study area but largest benefits would be to prevent these hazardous materials from passing into/through the Meramec River.

Riparian Benefits

As a result of the proposed actions, we initially expect that the containment/reduction/removal of contaminated sediments from the instream portions of the study area to directly reduce/prevent contaminated levels of TSS from being continually delivered to the floodplain surface by overland flows. This will, in turn, eventually result in reduced concentrations of Pb to levels below toxicity thresholds throughout the study area. Secondly, the planned riparian buffer enhancement and plantings will not only create woodland habitat for a variety of terrestrial wildlife into the future, but it will also help minimize flood damages by shielding susceptible adjacent land areas from erosional forces and additional sources of Pb contaminated soils. This protection is also expected to promote/improve additional edge habitat and increase associated benefits for many additional native wildlife species such as pollinators (i.e., Monarch Butterfly), migratory birds, and bats which includes three federally listed species. Apart from the planned activities, the Service encourages land treatment techniques which may be considered as additional floodplain restoration opportunities that reduce Pb exposure to contaminated soils, such as high phosphate fertilizers or composted manure or biochar amendments.

Additional Benefits

In addition to the expected instream and riparian benefits, the intermediate areas connecting these two environments may also benefit as a result of the activities. Floodplain connectivity is very important component of the overall health and productivity of the aquatic system. Proper bank height ratios compared with the channel-forming water surface cannot only help reduce flood damages but also connect the instream aquatic habitat to the terrestrial riparian habitat for an overall, healthy functioning riparian ecosystem. The stream can do this by normal channel evolution processes but doing so may come at the cost of unexpected negative changes to either environment (i.e., streambank erosion). Adequate floodplain connectivity throughout the study area could not only help provide necessary nutrients which are needed to drive biological functions and promote wildlife movements within the aquatic ecosystem but also help maintain the physical stability of the waterway. Therefore, this important topic and the geomorphic calculations, mentioned earlier, should not be overlooked during project and riparian restoration design phases.

In addition to the wildlife (mussels, crayfish, fish, amphibians, reptiles, birds, and mammals) and habitat diversity increases mentioned, the Service also believes the public will also receive benefits from the proposed activities. Considering the negative health effects typically associated with Pb exposure, especially children, the completion of the project is expected to reduce the potential contact with Pb contaminated materials by substantially removing Pb from areas typically frequented by people (i.e., gravel bars). Furthermore, these sediments will also be prevented from eroding, traveling downstream, and accumulating on currently uncontaminated surfaces in the lower Big and Meramec rivers (i.e., croplands). Additionally, improved resource values could increase public perception and could also potentially increase the recreational use in the region (discussed below).

Cultural and Economic Significance and Fish and Wildlife Recreation

Many significant archeological locations are situated near and within the study area. This supports the notion that this region has been an extremely important economic region for thousands of years. This was possibly because of the availability of natural resources and the close proximity to the nation's largest inland waterways. The City of St. Louis was initially sited among numerous extremely large earthen mounds which were constructed by earlier cultures (Marshall 1992). Little is known about their significance as they were destroyed during the early expansion of St. Louis before they could be studied. However, investigations at the Cahokia Mound complex help portray the early economic importance of the region. Many stone sources used to make prehistoric tools (e.g., projectile points, knives, axes, and celts) were presumed to have originated from areas along the Meramec River and the St. Francois Mountains located in the upper Big River and transported to this large cultural center (Kelly 2010 and Koldehoff and Wilson 2010). During the 1700s, early European trappers and settlers speculating for natural resources in the region began obtaining Pb from the surface deposits. It has been suggested that the 1804 Lewis and Clark expedition obtained Pb to make their musket bullets from southeast Missouri deposits. Since that time, this region went on to become the world's largest producer of Pb for nearly two centuries. During the last century, numerous towns and cities have relied on this mining industry as a primary economy.

Similarly, the fish and wildlife resources within the region must have also played an extremely important role prior to modern agriculture. Although the Pb mines within the Big River watershed are no longer active, their residual effects, as described, have significantly degraded the environment. Currently, the recreational use of the Big River appears to be limited to finite number of recreational users and individuals from local communities and adjacent landowners. This may be attributed to the knowledge regarding the contamination level and fish consumption advisory. As mentioned by Plieger (1997), a variety of fishing related purchases for recreational fishing activities generates hundreds of millions of dollars annually in Missouri. This number is expected to have risen in the 20 years since this estimate. Nonetheless, the Service suggests that this project represents not only an opportunity for protection of numerous federally and state listed species and rehabilitation of lost habitat for fish and wildlife, but also a great potential opportunity to stimulate and boost the region's economic growth. It has been documented that with the initial construction of restoration projects that there will likely also be additional economic benefits to the local economy through needs for materials, laborers, sub-contractors, and businesses such as hotels and restaurants, etc. Furthermore, the actions to improve natural resources at the landscape level will very likely also improve the perception and awareness of the Big River which in turn could then lead to additional economic benefits resulting from increased number of recreational users traveling to the region. The Big River presents a wide variety of recreational opportunities for the public such as swimming, canoeing, kayaking, camping, and fishing. Currently, many anglers utilize the Meramec and Big rivers by fishing specifically for sportfish species such as: Smallmouth Bass, Rock Bass, Channel Catfish and Flathead Catfish. Gigging and snagging are additional fishing practices conducted in the Ozarks which target non-game species such as redhorse suckers. Members of the sunfish family (including Rock Bass) and suckers (e.g., redhorse) are included in the fish consumption advisory. Other economies on other Ozark streams but currently under represented on the Big River include canoe outfitters, private campgrounds, and fishing guide services.

The State of Missouri contains abundant amounts of public lands and natural resources. Outdoor activities such as fishing, hunting, or other wildlife-associated recreation are enjoyed by over two million Missouri residents and visitors. A large fraction of the population support efforts to restore rare and extirpated animals in the state. The MDC funds fish, forest and wildlife conservation throughout Missouri via a 1/8 of 1% state sales tax. Wildlife-related recreation and forest products industries contribute over $12 billion in Missouri. These industries also support over 99,000 jobs. This information helps to illustrate that fish and wildlife can have incredible economic benefits as well as provide additional reasoning to protect the natural resources within

41

this region by completing the proposed actions.

Recommended Fish and Wildlife Conservation Measures

Through the initial project coordination, the Service has reviewed various USACE draft project proposals. Prior to this report, we have provided our best recommendations regarding wildlife considerations throughout the preliminary stages of the MRFS. If the study is approved, the Service requests the USACE continue to provide us an opportunity to coordinate in the future to help project design formulation as well as ensure that conservation planning objectives can be realized throughout the study area. We offer the following specific recommendations to help promote resource recovery and fish and wildlife habitat rehabilitation:

1) Use the overarching Principles and Requirements for Federal Investments in Water Resources" while completing the MRFS (Appendix 3).
2) Consider involvement of stakeholders to continue planning specific projects into the future and collaboratively author/develop/approve the AM plan as well as set a formalized process to establish/assess performance and success criteria with appropriate definitions for project adjustment needs.
3) The Service believes habitat diversity is extremely important. Future projects should consider design strategies that can promote streambed stability while also increasing habitat diversity through creating variations in stream depths, velocities, and substrate composition. A large variety of habitat characteristics within many different habitats would provide the greatest benefits to a range of wildlife species.
4) Adopt design and construction practices and principles that develop fish and wildlife habitat functionality.
5) Consider all project designs as they pertain to the resulting fish and wildlife habitat beyond their engineering function.
6) Consider how each project's resulting habitats could be potentially impacted by exotic species such as honeysuckle, Asian carp, feral pigs, etc.
7) Consider including various bioengineering structures and plantings (toe wood, large boulders, submerged logs, willow staking) to increase habitat variability and maximize aquatic habitat potential in addition to standard engineering elements (LPSTP) and ensure all designs also consider and prevent boating hazards.
8) Consider bank stabilization measures which can incorporate biological elements such as: logs, differential flow gradients, structures with interstitial spaces, and shade to promote/enhance aquatic wildlife habitat diversity within each design feature.
9) Consider streambank benching elements in association with proposed projects to help maximize riparian establishment, reduce erosional stressors to the project, improve floodplain connectivity as well as provide additional habitat diversity.
10) Continue to investigate the most practical and efficient bedload collector devices/designs which can maximize reduction of instream Pb contaminated sediments and potentially reduce time needed to rehabilitate degraded downstream environments.
11) Consider field investigations to determine the proper sediment budget needed to model bedload removal practices and prevent stream degradation.

12) Coordinate design and construction activities with the Service and MDC where projects may occur near known mussel bed locations.
13) Consider a full risk and impact analysis for a FWOP scenario during planning phase to define the potential wildlife and natural resources losses throughout the study area.
14) Develop an AM plan which considers a monitoring plan for both project and ecosystem level response as result of collective project actions in coordination with the Service and MDC. As mentioned above, this plan should make sure to include specific project performance standards for each action with a defined set of outcomes to ensure what threshold limits would trigger a future need for additional project involvement.
15) Maintain a willingness to modify, improve, redesign, or refine project features as the understanding of environmental conditions (i.e., flow) as they pertain/relate to particular habitat conditions, needs, and opportunities become apparent within the study area.
16) Develop and include comprehensive monitoring parameters (i.e., Pb concentration, bank erosion rates, biological indices and status of river resources) in coordination with the Service and MDC such that all pertinent findings can be utilized to update design models, adapt and modify management actions, and refine target objectives. If desired objectives are ultimately unsatisfactory, the AM plan should also have contingencies to expedite remedial actions which capture uncertainties within particular designs (i.e., change bedload collector flow/material transport criteria) which could improve designs. This AM strategy could potentially reduce federal investments by avoiding repeated, costly, and long-term project repairs.
17) Evaluate completed grade control projects for adequate AOP and implement corrective measures as part of the AM contingency planning.
18) Include AM contingency plans that ensure future erosion doesn't occur at non-project locations which may negate current restoration activities.
19) Consider implementing an AM plan which applies a comprehensive approach to river management in the context of a fully-functioning river system such as stable river form and function. This strategy may help interpret impacts/changes of habitat conditions as a result of the actions.
20) A primary objective is to create functional habitat. A large fraction of the bank stabilization projects involves structural modification using hard points such as large quarry stone. Therefore, to quantify and understand the kinds of physical and biological responses incurred to these immediate habitats, we recommend a long-term comparative impact analysis to assess the quality of habitat produced by the various structures. We also recommend an analysis of what impacts these modifications will have on other native species.
21) Because freshwater mussels were identified as a primary index model for successful ecological restoration, consider including a supplementary mussel survey using similar methods as indicated in Roberts et al. (2016) during habitat monitoring/AM planning. A comparative evaluation would help inform changes and direct future management decisions regarding restoration objectives.
22) Develop a suite of monitoring metrics to effectively identify the type and quantity of habitats as well as evaluate both the biological response and physical habitat changes resulting from project actions.

23) Evaluate habitats during many river stages to interpret site-specific results as many species such as small/young fish may have slightly different habitat requirements in response to project.
24) Consider AM plans which allow unique habitat diversity elements to remain or become included (e.g., connectivity to bank channels, nursery environments, in-stream deposition/retention of large woody debris).
25) Because a large number of proposed actions occur on private lands, the success of the overall project largely depends on the availability of many willing landowners. Early discussions with all pertinent landowners within the study area are recommended to inform/discuss objectives and outcomes as well as advise them about land-use practices or treatments which may help contain/reduce the exposure of contaminated soils within the floodplain.
26) If the project includes land acquisition or conservation easements from willing landowners, we recommend a priority be provided to lands immediately adjacent to the Big River. Within this area, preferred habitat types would also include poorly drained lands, tributary confluences, lands with backwaters and side channels, and lands with unique habitats such as perennial wetlands and mature bottomland forests.
27) Coordinate with the USEPA to locate an acceptable sediment disposal/repository site.
28) Consider including high phosphate fertilizer or other organic amendments designed to reduce the bioavailability of Pb in riparian and floodplain areas in a manner which does not result in eutrophication in adjacent aquatic environments.
29) Consider expanding the study area boundary upstream into additional degraded environments in Washington and St. Francois counties, and potentially upper Meramec River tributary counties.
30) Coordinate with the USEPA remedial actions to promote efficiencies, and/or to maximize the effectiveness of the restoration opportunities within the study area.
31) Consider the potential impacts to project actions resulting from climate change, flooding, and changes in precipitation.
32) Evaluate the accuracy of the current TSS values within the HSI Mussel Model prior to future use.

SUMMARY of FINDINGS

The heavy metal mining activities within the Big River watershed have led to the introduction and episodic movement of toxic sediment throughout an extensive portion of the Big River. This contamination has now resulted in the significant reduction of fish and wildlife resources compared to historical levels as well as a direct impairment of approximately 150 km of stream and 86.8 million cubic meters covering adjacent floodplain habitats. In the study context, toxic sediment and soils persist in the Big River and continually pose imminent danger to additional downstream environments as they are transported by natural processes. Due to the vast area and enormous level of contamination, the task to restore lost ecological functions within the Big River seems daunting. However, the Service believes the proposed MRFS study is a sound approach to not only preserve the extremely important remaining wildlife resources and habitats within the lower portions of the Big and Meramec rivers, but also presents a variety of logical, cost-effective measures which can significantly improve and rehabilitate the highly degraded

44

aquatic and floodplain environments and their associated habitats in the upper portions of the study area. The results of these actions are expected to provide extremely meaningful benefits to a diverse range of wildlife and endangered species as well as the public over a large length of stream. To achieve the low concentrations of Pb found to be non-toxic to mussels and other aquatic animals will be a monumental challenge; one that the project may not holistically achieve in the defined 50-year project period. USEPA remedial actions may address short-term ecological risks, but are not designed to restore lost ecological services. It is unrealistic to believe that all Pb contamination will be removed during this limited time frame. We emphasize that although the actions may not reach the concentrations desired for ecological restoration throughout the entire study area, the proposed restoration benefits will likely occur in a longitudinal direction as the contaminated sediments are contained/removed. As a result, the objective to improve habitat in the lower Big and Meramec rivers will be achieved in a downstream to upstream progression over time. Within the project timeframe, we expect a considerable amount of the currently impaired habitat will likely achieve the desired concentration with the only possible exception being the upper limits of the study area. Based on the small difference needed to achieve the desired objective, we expect success throughout the defined study area within several more years. Under the no action alternative, it is expected that Pb contaminated sediments will continue to migrate downstream and impair a substantial amount of extremely important aquatic habitats in both the lower Big and Meramec rivers in the near future. The Service requests the USACE to also consider possibly expanding the study area upstream into the most contaminated reaches of the St. Francois and Washington counties, if not the entire Meramec Basin. This project expansion would then address the most impacted segments of the Big River and its tributaries and likely promote a quicker restoration response. The Service considers this study as the beginning step toward a sound restoration approach and feasible path forward to address fish and wildlife needs, ultimately protect the lower Big and Meramec rivers, as well as potentially fully rehabilitate the Big River to be able to support historical wildlife species.

After working diligently with the USACE toward this study's development, we support the USACE plans to pursue Alternative 5 as the TSP. We believe this alternative represents the most cost effective, comprehensive, holistic river-wide ecosystem approach to benefit the unique resources and fish and wildlife species mentioned throughout this report.

The Service position and recommendations are based on the best available information which includes most recent studies and monitoring data and expertise provided by the USACE design engineers. We realize that due to the limited planning time, the large spatial area, magnitude of contamination and their impacts on this resource, many assumptions had to be drawn to make decisions. Because of this, if the project is funded, the Service expects to continue coordinating with the USACE to work collaboratively to resolve many of the current design uncertainties and habitat evaluation metrics. The Service appreciates that the USACE is committing to an AM process. As recommended, the Service wishes to remain engaged with project monitoring, design, and implementation to contribute science-based analysis. Such a process will likely be a critical component in successfully evaluating the many varying conditions and uncertainties, and develop the best measures and tools to address the fish and wildlife needs in the study area.

In conclusion, we hope that this report has effectively described the significance of the natural resources and habitats currently being impacted within the Meramec River Basin. In addition, we would like to express our full support for the USACE and MDNR efforts to pursue this project to restore and enhance fish and wildlife resources and serve the public interest.

LITERATURE CITED

Albers, J.L., J.M. Besser, C.J. Schmitt, and M.L. Wildhaber. 2016. Mussel community associations and substrate characteristics in the Big River, Missouri, U.S.A. U.S. Geological Survey Natural Resource Damage Assessment and Restoration Administrative Report.

Allert, A.L., J.F. Fairchild, C.J. Schmitt, J.M. Besser, W.G. Brumbaugh, and S.J. Olson. 2009a. Effects of mining-derived metals on riffle-dwelling benthic fishes in southeast Missouri, USA. Ecotox. Environ. Saf. 72:1642-1651.

Allert, A.L., R.J. DiStefano, J.F. Fairchild, C.J. Schmitt, and W.G. Brumbaugh. 2009b. Impacts 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. U.S. Geological Survey Natural Resource Damage Assessment and Restoration. Administrative Report to U.S. Fish and Wildlife Service, Columbia Ecological Services Office, Columbia, Missouri.

Allert, A.L., R.J. DiStefano, J.F. Fairchild, C.J. Schmitt, M.J. McKee, J.A. Girondo, W.G. Brumbaugh, and T.W. May. 2013. Effects of historical lead-zinc mining on riffle-dwelling benthic fish and crayfish in the Big River of southeastern Missouri, USA. Ecotoxicology 22(3):506-21. DOI 10.1007/s10646-013-1043-3.

Angelo, R.T., M.S. Cringan, D.L. Chamberlain, A.J. Stahl, S.G. Haslouer, and C.A. Goodrich. 2007. Residual effects of lead and zinc mining on freshwater mussels in the Spring River Basin (Kansas, Missouri, and Oklahoma, USA). Science of the Total Environment 384:467-496.

Baird, M.S. 2000. Life history of the spectaclecase, *Cumberlandia monodonta*, Say, 1829 (Bivalvia, Unionoidea, Margaritiferidae). Master's Thesis, Southwest Missouri State University, Springfield, Missouri. 108pp.

Besser, J.M., W.G. Brumbraugh, D.K. Hardesty, J.P. Hughes, and C.G. Ingersoll. 2009. Assessment of metal-contaminated sediments from the southeast Missouri (SEMO) mining district using sediment toxicity tests with amphipods and freshwater mussels. Administrative Report 08-NRDAR-02, U.S. Fish and Wildlife Service, Columbia Ecological Services Office, Columbia, Missouri.

Beyer, W.N., J.C. Franson, J.B. French, T. May, B.A. Rattner, V.I. Shearn-Bochsler, S.E. Warner, J. Weber, and D. Mosby. 2013. Toxic exposure of songbirds to lead in the Southeast Missouri Lead Mining District. Arch. Environ. Toxicol. DOI 10.1007/s00244-013-9923-3.

Beyer, W.N., N.T. Basta, R.L. Chaney, P.F.P. Henry, D.E. Mosby, B.A. Rattner, K.G. Scheckel, D. Sprague, and J. Weber. 2016. Bioaccessibility tests accurately estimate bioavailability of lead to quail. Environ. Toxicol. Chem. DOI 10.1002/etc.3399.

Buchanan, A.C. 1979. Mussels (Naiades) of the Meramec River Basin, Missouri. Final Report prepared for U.S. Army Corps of Engineers, St. Louis District, St. Louis, Missouri. 224pp.

Buchanan, A.C. 1980. Mussels (Naiades) of the Meramec River Basin, Missouri. Missouri Department of Conservation Aquatic Series No. 17. 76pp.

Butler, B. 2002. Status Assessment Report for the spectaclecase, *Cumberlandia monodonta*, occurring in the Mississippi River system (U.S. Fish and Wildlife Service Regions 3, 4, 5, and 6). 66pp.

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.

DiStefano, R. J. 2005. Trophic interactions between Missouri Ozarks stream crayfish communities and sport fish predators: increased abundance and size structure of predators cause little change in crayfish community densities. Missouri Department of Conservation, Dingell-Johnson Project F-1-R-054, Study S-41, Job 4, Final Report. Columbia, MO. 127 p.

Gale, N.L., C.D. Adams, B.G. Wixson, A.K. Loftin, and Y. Huang. 2004. Lead, zinc, copper, and cadmium in fish and sediments from the Big River and Flat River Creek of Missouri's Old Lead Belt. Environmental Geochemistry and Health 26: 37-49.

Haag, W.R. 2012. North American Freshwater Mussels Natural History, Ecology, and Conservation. Cambridge University Press. New York, New York. 505pp.

Hinck, J.E., S.E. McMurray, A.D. Roberts, M.C. Barnhart, C.G. Ingersoll, N. Wang, T. Augspurger. 2012. Spatial and Temporal Trends of Freshwater Mussel Assemblages in the Meramec River Basin, Missouri, USA. Journal of Fish and Wildlife Management 3(2): 319-331.

Jacobs, B. 2003. Birds in Missouri. Missouri Department of Conservation, Jefferson City. 375pp.

Johnson, T.R. 2000. Amphibians and Reptiles of Missouri 2nd Edition. Missouri Department of Conservation, Jefferson City. 400pp.

Jones, C. G., J. H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69:373-386.

Jones, C. G., J. H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78:1946-1957.

Kelly, J.E. 2010. The Geological and Cultural Contexts of Basalt from Late Emergent Mississippian and Early Mississippian Sites in the St. Louis Region. The Missouri Archeologist Volume 71:199-215.

Koldehoff, B. and G.D. Wilson. 2010. Mississippian Celt Production and Resource Extraction in the Upper Big River Valley of St. Francois County, Missouri. Volume 71:217-248.

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

Marshall, J.B. 1992. The St. Louis Mound Group: Historical Accounts and Pictorial Depictions. The Missouri Archeologist Volume 53:43-79.

McMurray, S.E., J.S. Faiman, A. Roberts, B. Simmons, and M.C. Barnhart. 2012. A guide to Missouri's freshwater mussels. Missouri Department of Conservation, Jefferson City. 94pp.

Missouri Department of Conservation (MDC). 2010. Effects of Lead-Zinc Mining on Benthic Fish Density in Riffles of the Big River (Southeast Missouri). Final Report. 39pp.

Missouri Department of Health and Senior Services (MDHSS). 2017. Missouri Fish Advisory. A Guide to Eating Missouri Fish. 25pp.

Missouri Water Pollution Board. 1964. Water quality of Big, Bourbeuse, Meramec River basins. Department of Public Health and Welfare of Missouri. Jefferson City. 65pp.

Montemarano, J. J., M. W. Kershner, and L. G. Leff. 2007. Crayfish effects on fine particulate organic matter quality and quantity. Fundamental and Applied Limnology/Archiv für Hydrobiologie 168(3):223-229.

Nelson, P.W. 2005. The terrestrial natural communities of Missouri. Revised edition. Missouri Natural Areas Committee. Missouri Department of Natural Resources, Jefferson City, Missouri. 550 pp.

Nigh, T.A. and S.P. Sowa. 2005. An aquatic biodiversity assessment for Missouri. Missouri Resource Assessment Partnership. Final Report, submitted to the Missouri Department of Conservation, Jefferson City, MO.

Pavlowsky, R.T., M.R. Owen, and D.J. Martin. 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. Final Report for the U.S. Fish and Wildlife Service, Cooperative Ecosystems Study Unit, Columbia Missouri Field Office, Columbia, Missouri. 141pp.

Pavlowsky, R.T. and M.R. Owen. 2013. Historic channel change maps for the Big River System in St. Francois, Washington, and Jefferson counties, Missouri. Final report prepared for the U.S. Fish and Wildlife Service, Columbia Missouri. 23pp.

Pflieger, W.L. 1996. The crayfishes of Missouri. Missouri Department of Conservation, Jefferson City. 152pp.

Pflieger, W.L. 1997. The fishes of Missouri. Revised edition. Missouri Department of Conservation, Jefferson City. 372pp.

Roberts, A. and S. Bruenderman. 2000. A reassessment of the status of freshwater mussels in the Meramec River Basin, Missouri. Report prepared for the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota 55111-4056. 141pp.

Roberts A.D., D. Mosby, J. Weber, J. Besser, J. Hundley, S. McMurray, and S. Faiman. 2009. An assessment of freshwater mussel (Bivalvia: Margaritiferidae and Unionidae) populations and heavy metal sediment contamination in the Big River, Missouri. Final Report for U.S. Fish and Wildlife Service Natural Resource Damage Assessment. 110pp.

Roberts A., J. Hundley, D. Mosby, A. Rosenberger, K.L. Bouska, B. Simmons, and G. Lindner. 2016. Quantitative survey of freshwater mussels (Unionoidea) and assessment of sediment contamination in the Big River, Missouri. Final Report for U.S. Fish and Wildlife Service Natural Resource Damage Assessment, Columbia Missouri Ecological Services Field Office, Columbia, Missouri. 69pp.

Rosgen, D., L. Silvey, and D. Frantila. 2006. Watershed assessment of river stability and sediment supply (WARSSS). Wildland Hydrology. Ft. Collins Colorado.

Schmitt, C.J. and S.E. Finger. 1982. The dynamics of metals from past and present mining activities in the Big and Black River watersheds, southeastern Missouri. U.S. Fish and Wildlife Service, Columbia National Fisheries Research Laboratory. Final Report for the U.S. Army Corps of Engineers, St. Louis District, Project No. DACW43-80-A-0109.

Schmitt C.J., C.A. Caldwell, B. Olsen, D. Serdar, and M. Coffey. 2002. Inhibition of erythrocyte d-aminolevulinic acid dehydratase (ALAD) activity in fish from waters affected by lead smelters. Environmental Monitoring and Assessment 77: 99-119.

Schmitt C.J., J.J. Whytte, W.G. Brumbaugh, and D.E. Tillitt. 2005. Biochemical effects of lead, zinc, and cadmium from mining on fish in the tri-states district of Northeastern Oklahoma, USA. Environmental Toxicology and Chemistry 24: 1483-1495.

Schmitt C.J. and M.J. McKee. 2016. Concentration trends for lead and calcium-normalized lead in fish fillets from the Big River, a mining-contaminated stream in Southeast Missouri USA. Bull Environ Contam Toxicol. Volume 97, Issue 5, pp 593–600 Doi. 10.1007/s00128-016-1850-2.

Staudinger, M.D., T.L. Morelli, and A.M. Bryan. 2015. Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Massachusetts. 52pp.

Switzer, J.F. and R.M. Wood. 2009. *Etheostoma erythrozonum*, a new species of darter (Teleostei:Percidae) from the Meramec River drainage, Missouri. Zootaxa 2095:1-7.

The Nature Conservancy (TNC). 2014. Meramec River Conservation Action Plan. The Nature Conservancy. Missouri Chapter, St. Louis, MO. 140pp.

USACE. 2017. Meramec River freshwater mussel habitat suitability index model. Engineering Research and Development Center (ERDC) for St. Louis District U.S. Army Corps of Engineers. 23p.

USACE. 2018. Draft Meramec River Ecosystem Restoration Feasibility Study. Appendix B Habitat Evaluation and Quantification. St. Louis District U.S. Army Corps of Engineers.

USEPA. 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. EPA/600/X-17/303. August 22, 2017.

USFWS. 1983. Habitat Suitability Index Model: Black-capped chickadee. U.S. Fish and Wildlife Service.

USFWS. 2007. Scaleshell Mussel Recovery Plan (*Leptodea leptodon*). U.S. Department of Interior. 118pp.

Wang, N., C.G. Ingersoll, C.D. Ivey, D.K. Hardesty, T.W. May, T. Augspurger, A.D. Roberts, E. Van Genderen, and M.C. Barnhart. 2010. Sensitivity of early life stages of freshwater mussels (Unionidae) to acute and chronic toxicity of lead, cadmium, and zinc in water. Environ. Toxicol. and Chem. Vol 29, No. 9, pp. 2053-2063.

Williams, J.D., M.L. Warren, K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9): 6-22.

APPENDIX 1

Wildlife Habitats within the Study Area

Aquatic Habitat

Riverine

- Thalweg/Main-channel: This habitat is described as the region of maximum depth and velocity in the river channel and its adjacent areas. It can occur either along the bank margin or in the mid-channel depending on the stream channel pattern and profile. The thalweg is best described as the location in which the majority of streamflow and sediment transport maintain longitudinal connectivity in the river system. The thalweg can be further divided into features such as riffles, runs, pools and glide habitat based on topography, contour, depth, velocity, substrate, flow structure, and sediment regime of the stream. Connecting areas known as channel crossovers should also be mentioned as they often connect similar environments on opposite sides of the stream channel such as two pools and are generally associated with riffle features. Crossovers within the thalweg can provide important habitat diversity elements needed for many fish and invertebrate species.

- Streambank/Cut Bank: This habitat is described as the area which forms the outside (terrestrial) boundary of the stream channel. Streambanks are most often composed of fine alluvial soils deposited by previous flood events. They typically build vertically over time depending on watershed conditions. Streambanks are subject to erosive forces if rapid local or system changes have occurred (e.g., increased amounts of impervious materials to the upstream landscape). If a streambank can maintain an adequate slope and be protected with deeply rooted vegetation while near bank sheer stresses remain low, they are less prone to erosive forces and both aquatic and terrestrial habitats can become established/persist. Conversely, cut banks are streambanks not considered in a stable condition where their slopes often become vertical and/or undercut can lead to sediment and often riparian vegetation contributions until equilibrium is reestablished. Erosion to cut banks are often a major contributing source of sediment and cause for channel meandering which can have indirect effects to other stream habitats. However, while in this condition, they can still provide forage, refuge, and nesting habitat by numerous species (i.e., bank swallows). Another streambank type in the Meramec Basin, are bluffs and rocky outcrops. This habitat type is most often is associated with a pool feature with the substrate being composed of coarser materials such as boulders, cobbles, and gravels and sometimes entrained woody debris. This environment is referred as a bluff pool and if in the thalweg, often possess a high species diversity index due to the persistence of stable habitat.

- Channel Margin: This habitat is the area of the stream channel between the streambank and the thalweg. Typically in stable areas, it is generally shallow water habitat of low energy and low velocity. Fine sediments often accumulate in these areas and emergent vegetation such as water willow (*Justicia sp.*) can develop and persist. This habitat type often serves as refugia and nursery habitat for many aquatic species.

- Pool: This habitat is the stream feature that most frequently occur along the outside bends of the stream thalweg and along rock outcrops and bluffs as described above. Pools are generally areas of greater depth and slower velocity and function to reduce stream energy between riffle features. Pools most frequently occur in the channel at outside bends, downstream of riffle/runs. They can also occur around large objects such as logs and debris jams and other channel obstructions such as bridge piers due to local erosion as result of channel constriction. Pools provide critical overwintering habitat for fish and serve as refugia and water sources for many species during drought conditions.

- Secondary Channel: This habitat is a location where streamflow becomes disconnected from the thalweg (main channel) and can be a result of channel evolution processes such as aggradation or degradation. The secondary channel often contains less streamflow and depth compared to the main channel. In some instances and depending on conditions, these channels may only flow partially or only during high-flow events. Secondary channel can possess the same stream features as the main channel particularly if the main channel migrated from the secondary channel location. In the Meramec Basin, these habitats are often associated with mid channel island features or chute cutoffs. In braided systems with a high bedload they can be very short-term in persistence.

- Gravel bar: This habitat is a raised depositional feature resulting from geomorphic processes within the stream. In the Meramec Basin, gravel bars are typically composed of sand/gravel/cobble mixtures are found within and along the channel margins and can be either vegetated or unvegetated. Gravel bars can either be wet/dry, temporary or long-lasting depending upon stream condition and location. Also, depending on system geomorphic stability, depositional patterns can form a variety of arrangements such as: point bars, mid-channel bars, side bars, diagonal bars, delta bars, transverse bars, and islands, as illustrated in Rosgen (2006). Each type may also have secondary affects to the habitats within their vicinity over time. Habitats associated with gravel bars are dependent on associated variables such as sediment size, stream stability, rate of bedload deposition, movement or loss, vegetation type and size, adjacent stream environments and stream flow. A wide range of species (insects, fish, amphibians, reptiles, birds, and mammals) utilize this habitat type.

- Island (This habitat can overlap with the floodplain and gravel bar types): This habitat is typically an area of elevated substrate within the channel which generally forms as result of accumulation of alluvial materials from bedload deposition or by rapid channel migration such as channel avulsion. They are typically lower in elevation than that of the floodplain and located within the active river channel. Similar to gravel bars, islands may be long-lasting or temporary. If long-lasting they may also contain successional stages of vegetation and an increased diversity ranging from emergent plants to large trees. Also similar to gravel bars, habitats associated with islands are dependent on associated variables such as sediment size, stream stability, rate of bedload deposition, movement or loss, vegetation type and size, adjacent stream environments and stream flow. Islands, like floodplains, can act to capture or contribute organic materials within the system when flooding occurs. Depending on the rate of inundation, islands are important wildlife habitat and transitional areas for many species and often bridge local environments for most stream wildlife because of a wide range of associated habitat diversity.

- Spring/Seep: This habitat is associated with the underlying karst geology of the Ozark Region. The hydrology within this habitat originates from either a deep aquifer/groundwater source within a specific recharge area. Some aquifers within the study area are known to span different overlying watersheds. These features areas are important because of their water contributions and thermal benefits during periods of extreme temperatures. Because of this, these areas are important summer and winter refuge habitat for resident aquatic species.

Backchannel

- Backwater/Slough (this habitat can overlap with the secondary channel type): Backwater habitat is an area that is hydrologically connected to the stream channel but separated from the thalweg with very little to no flow. They are most often located on the downstream areas of islands and form as a result of island development or channel avulsion. Backwaters are not considered riverine because of the associated lentic environment. Due to a lack of streamflow, backchannels often function to collect and trap fine sediments such as silt and organic matter from the riverine channel, often becoming consolidated to support a high diversity of submerged and emergent vegetation. Environmental conditions such as water chemistry, temperature, and dissolved oxygen are influenced by frequency of flooding, amount of riparian canopy cover, water surface elevation, depth and period of inundation. Depending on sediment supply, backchannel areas can transition and possibly develop into wetlands and eventually floodplain habitat. These areas can be extremely important for plants, fish and amphibian nursery habitat, reptiles, waterfowl, and mussels adapted to this environment.

- Oxbow: This habitat is formed by channel migration of primary (thalweg) or secondary channels. It is an environment completely isolated from the stream channel base flow. Oxbow hydrology is maintained either by groundwater, surface runoff and/or high-flow events. Oxbows are similar to the backwater habitat. Their conditions can vary depending upon level of water input, depth, frequency of flooding, and amount of riparian canopy cover. Oxbow areas typically transition and develop into emergent wetlands and eventually floodplain habitat. They are important areas for plants, fish and amphibian refuges and nursery habitat, waterfowl, and a few mussels adapted to this environment.

- Fringe Wetland: This habitat may overlap with many habitats. Fringe areas consist of wetlands along areas of flow. They are typically transitional areas of other habitats described. They provide ecological link between lotic and lentic environments. This habitat best characterized by reduction of stream flow and associated minor sediment accumulation. Typically these are areas along the margins of stable channels. The reduction of flow and sediment accumulation promotes development of emergent vegetation such as water willow. This habitat is very important for protection of juvenile and small fish and reptiles from fish and bird predation.

- Emergent Wetland/Marsh: This habitat is generally associated with or resulting from successional backwaters and oxbow habitats. They have a high level of organic matter and are typically dominated by perennial submerged and/or emergent vegetation and macrophytes. Habitat condition and species composition is dependent upon water depth, level of canopy cover, inundation frequency, and potential disturbance from adjacent land-use. Similar to backwaters and oxbows, alluvial sediment deposition can occur within the environment with high-flow events.

Terrestrial Habitat
There are a vast number of terrestrial habitats within the study area (Nelson 2005). Terrestrial habitats have many levels of variation. For the purpose of this report, only the riparian area and upland habitat directly associated with the stream environment will be described. Within these, the important habitat composition elements and wildlife species occupation potential are dependent on watershed position, hydrology, stream stability, upstream and adjacent land-use and climate. The wildlife within this focused terrestrial habitat is composed of countless species within nearly every taxonomic group (bacteria, fungi, lichen, worms, insects, crustaceans, spiders, snails, amphibians, reptiles, resident and migratory birds, and mammals). The focused terrestrial environment includes the following specific habitats:

<u>Floodplain</u>:
- Forested Floodplain: This habitat consists of riparian lands directly adjacent to the stream course which are naturally formed and modified by riverine processes resulting from flooding. Floodplain size, composition and conditions are largely dependent on the historical and present hydrology and geology within the watershed. Generally, the floodplain elevation is associated with a stage near the mean annual discharge. The floodplain is primarily composed of alluvial materials received from upland areas which were previously deposited during floods. During flooding events, the stream moves its bedload, erodes and deposits subsequent materials throughout the riverine system. If the floodplain elevation is low compared to the adjacent streambed, flow is reduced allowing suspended particles (i.e., sediment, nutrients, and organic debris) to accumulate on the floodplain surface. If streambank erosion is occurring, floodplains will contribute those materials to downstream environments. Forested floodplains provide many very important habitat elements adjacent to stream channels. They form transitional relationships and bridge aquatic and terrestrial environments. Floodplain forests are also a primary source of woody debris which can enter the stream and create additional habitat diversity elements (e.g., log-jams) used by various fish species: minnows, sunfish, and basses as well as provide the seed bank necessary for maintaining riparian plant diversity.

- Cropland/Sod Farms/Pastureland Floodplain: Although not a native environment, this floodplain type is a prominent feature throughout the study area and deserves inclusion for comparison. Although, the planting of crops can have direct benefits as a food source for various wildlife, pasturelands and sod farms are typically composed of non-native grasses which are either significantly grazed by livestock, hayed for winter livestock forage or in the case of sod farming, removed all together and replanted. These latter activities have limited wildlife values. As a result, the potential conversion of this habitat back to a native environment, where possible, would extend many other life history benefits such as shelter or nesting habitat and benefit a majority of plant and wildlife species and habitat diversity conditions throughout the study area.

Upland:
In the Ozarks, upland topography can also repeatedly occur adjacent to stream channels. This habitat is associated either with a cut bank or more often as an erosive resistant geology such as limestone/sandstone bluffs. The latter can influence the pattern and profile of the water course and often contribute to streambed stability. In some instances, bluff features can have caves and direct connections to subterranean environments such as springs, seeps (described above). Because of their permanence, bluffs often form stable environments such as deep pools with large boulders for mussels, fish, and long-lived amphibians such as the Eastern Hellbender. Caves are also important for troglophytic wildlife such as insects, crustaceans, fish, amphibians, as well as bats. Upland forests are extremely important sources for organic material contributions such as leaf litter which form one of the primary food sources for countless aquatic species.

APPENDIX 2

Conservation Measures

Conservation measures are actions that benefit or promote the recovery of a listed species that a Federal agency includes as an integral part of its proposed action and that are intended to avoid, minimize or compensate for potential adverse effects of the action on the listed species. As such, mandatory measures below will be incorporated into every USACE action that falls within this consultation framework. The following guidelines are provided for federally listed mussel and bat species.

Mussels

- If a project action occurs at or within 0.5 miles downstream of a known mussel bed location consultation with the Service will be initiated.
    - Consultation may require additional habitat evaluation/survey prior to the project initiation.

Bats

- All tree clearing resulting from the USACE action will occur during the inactive season from November 1 to March 31 unless negative presence/probable absence survey results were obtained for the action area through appropriate surveys approved by the Service.

- The USACE will require a habitat assessment if the project will occur in Zone 1 (defined below) and includes more than 10 acres of tree clearing. If the results indicate that more than 10 acres of suitable bat-roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.

- The USACE will require a habitat assessment if the project will occur in Zone 2 and includes more than 5 acres of tree clearing. If the results indicate that more than 5 acres of suitable roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.

- If located in Zone 1, the project will not remove more than 10 acres of suitable roosting habitat during the inactive season.

- If located in Zone 2, the project will not remove more than 5 acres of suitable roosting habitat during the inactive season.

- A USACE action will not result in the removal of trees in Zone 3.

- Tree clearing associated with the project and the USACE action will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage.

- If the project is located in a karst area and will involve construction methods that may cause deep ground disturbance, the USACE will require a cave search be conducted to determine if any caves are present in the action area that would be considered suitable habitat for bats and/or are currently or formerly used by listed bats.

- If the demolition of an existing building or structure will occur as a result of the project in Zones 2 or 3, the USACE will require bat use surveys in collaboration with the USFWS. If during the course of demolition, bats of any species are discovered, then all work must cease and USFWS must be immediately contacted. If the structure is safe to leave as is, then it will be left until after November 1, or until bats have stopped using the structure. If the structure is unsafe and poses a risk to human health and safety, the USACE will request the assistance of the USFWS in determining reasonable measures to exclude the bats.
    - Zone 1 = Conservation measures apply to actions within the State of Missouri excluding Zones 2 and 3.
    - Zone 2 = Conservation measures apply to actions within 5.0 miles (radius) of a known capture of a listed bat.
    - Zone 3 = Conservation measures apply to actions that occur within 0.25 miles (radius) of a known roost tree or hibernacula.

APPENDIX 3

Pursuant to the Water Resources Planning Act of 1965, the March 2013 "Principles and Requirements for Federal Investments in Water Resources" updated the national framework for water development projects across the country. That framework identifies the following six guiding principles which we believe are directly relevant to this effort.

1. Healthy and Resilient Ecosystems – Federal investments in water resources should protect and restore the functions of ecosystems and mitigate any unavoidable damage to these natural systems.

2. Sustainable Economic Development – Federal investments in water resources should encourage sustainable economic development through the sustainable use and management of water resources ensuring both water supply and water quality.

3. Floodplains – Federal investments in water resources should avoid the unwise use of floodplains and flood-prone areas and minimize adverse impacts and vulnerabilities in any case in which a floodplain/flood-prone area must be used. Unwise use includes actions or changes that have unreasonable adverse effects on public health and safety, or are incompatible with or adversely affect one or more floodplain functions that lead to a floodplain that is no longer self-sustaining.

4. Public Safety – Threats to people from natural events should be assessed in both existing and future conditions, and ultimately in the decision-making process. Alternative solutions must avoid, reduce, and mitigate risks to the extent practicable and include measures to manage and communicate these risks.

5. Environmental Justice – Agencies should ensure that Federal actions identify any disproportionately high and adverse public safety, human health, or environmental burdens of projects on minority, Tribal and low-income populations. In implementation, agencies should seek solutions that would eliminate or avoid disproportionate adverse effects on these communities, and include effective public participation throughout both project planning and decision-making processes.

6. Watershed Approach – A watershed approach to analysis and decision-making facilitates evaluation of a more complete range of potential solutions and is more likely to identify the best means to achieve multiple goals over the entire watershed. A watershed approach facilitates the proper framing of a problem by evaluating it on a system level to identify root causes and their interconnectedness to problem symptoms.

APPENDIX 4

The following comments were received from the Missouri Department of Conservation:

The Missouri Department of Conservation appreciates the opportunity to consult on the Meramec River Feasibility Study. Our comments are to participate in consultation with the United States Fish and Wildlife Service on federal projects that may affect fish and wildlife resources in the State of Missouri. The complexity and extent of the Big River's mining legacy will require continuous agency input as new science and technology will inform future actions of the federal and state agencies. The Department will make additional comments besides this official consultation between our agencies.

For your consideration:

- The Department supports restoring habitat within the Big River system because of water quality impairments associated with legacy mining impacts.
- The Department supports enhancing fish passage and recreational use at mill dams and any other channel trapping locations.
- The Department has not reviewed studies relate to reducing lead bioavailability via phosphate treatments of soil, therefore cannot make informed comments related to these treatments.
- The Department appreciates the Service reporting on the recently discovered data indicating that the TSS relationship in the habitat model may be unduly conservative. This may not affect the TSP, but may be important for prioritization of efforts during the restoration construction phase.
- The Department supports the development and use of an adaptive management plan, likely well into the future, due to the complexity of the environmental conditions, future EPA actions regarding remediation of mining wastes, the recruitment of willing landowners to participate in various remediation and restoration actions, and the inherent dynamics of the river.

3. SHPO COORDINATION 9 MAY 2018

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

REPLY TO
ATTENTION OF:

May 9, 2018

Engineering and Construction Division
Curation and Archives Analysis Branch

Dr. Toni M. Prawl
Missouri State Historic Preservation Office
P.O. Box 176
Jefferson City, MO 65102

SUBJECT: Big River Eco-System Restoration Project, Missouri.

Dear Dr. Prawl:

We are contacting you to formally initiate consultation for a proposed undertaking for an environmental restoration project on the Big River, Jefferson and St. Louis Counties, Missouri, in accordance with Section 106 of the National Historic Preservation Act of 1966, as amended. The Saint Louis District, U.S. Army Corps of Engineers (Corps) is proposing measures to address erosion and sedimentation issues that degrade the habitat of endangered species in the Big River. Currently, the Corps is completing a Feasibility Study that proposes specific features at work sites along the river.

The enclosed information paper outlines the authority and the general nature of the proposed features, as well as the known cultural resources that might be impacted. The project will include work sites located along 80 miles of the Big River. The features are primarily concentrated within the river itself and on immediately adjacent riverbanks. However, reforestation is being recommended in some locations and each work site will require access by equipment and vehicles from nearby roads.

Because the Corps anticipates changes in the project conditions that will affect the type and location of features between completion of the Feasibility Study and the receipt of authorization and funding to proceed to the Design and Specifications stage of the project, we are proposing the execution of a Programmatic Agreement (PA) that will specify future actions and responsibilities for the participating parties. We are concurrently contacting the federally-recognized tribes with which we regularly consult to determine if any wish to participate as a concurring party to the PA. Once we have determined who the participating parties, we will be provide more detailed information regarding the project.

If you have any questions or comments, please feel free to contact me, or Jim Barnes at telephone number (314) 331-8830, or e-mail at james.e.barnes@usace.army.mil.

Thank you,

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

Enclosure

2

SHPO RESPONSE INITIATION LETTER 31 MAY 2018

Missouri Department of NATURAL RESOURCES
dnr.mo.gov
Eric R. Greitens, Governor
Carol S. Comer, Director

May 31, 2018

Mr. Michael K. Trimble
Department of the Army
St. Louis District Corps of Engineers
1222 Spruce Street
St. Louis, MO 63103-2833

Re: **SHPO Project No. 030-MLT-18** – Big River Ecosystem Restoration Project (COE), Missouri

Dear Mr. Trimble:

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

We have reviewed the information provided concerning the above referenced project. Thank you for initiating the Section 106 review and comment process. We have no additional comments at this time.

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

If you have any questions, please write Heather Gibb at State Historic Preservation Office, P.O. Box 176, Jefferson City, Missouri 65102 or call 573/751-7862.

Recycled paper

Mr. Trimble
Page 2

Please be sure to include the SHPO Log Number (**030-MLT-18**) on all future correspondence or inquiries relating to this project.

Sincerely,

STATE HISTORIC PRESERVATION OFFICE

Toni M. Prawl

Toni M. Prawl, Ph.D.
Director and Deputy State
Historic Preservation Officer

TMP:jd

c Ms. Amber Tilley, EPA
Mr. Jim Barnes, USCOE

Hello Brian,

I received the Feasibility Study and have been able to read most of it. I did note that the historic/cultural resource review portion included reference to the need for further consideration and Programmatic Agreement. Would you like a formal letter of comment concurring with that or will this email suffice?

Thank you,
Heather

Heather Gibb
Review, Compliance, Records Coordinator
Missouri SHPO
PO Box 176
Jefferson City, MO 65102
573-751-7862

4. TRIBAL COORDINATION

DISTRIBUTION LIST

The example letter was sent to the following tribal leaders and cultural representatives:

Title	Name (First, Middle, Last)	Tribe	Street Address	Street Address 2	St	Zipc
Governor	Edwina Butler-Wolfe	Absentee-Shawnee Tribe	2025 S. Gordon Cooper Drive		OK	74810-
Chairman	John Barret	Citizen Potawatomi Nation	1601 S. Gordon Cooper Drive		OK	74801
President	Deborah Dotson	Delaware Nation of Oklahoma	P.O. Box 825		OK	73005
Chief	Chester Brooks	Delaware Tribe of Indians	5100 Tuxedo Boulevard		OK	74006
Chief	Glenna J. Wallace	Eastern Shawnee Tribe of Oklahoma	P.O. Box 350		MO	64865
Chairman	Harold Frank	Forest County Potawatomi	P.O. Box 340		WI	54520
Chairman	Kenneth Meshigaud	Hannahville Indian Community	N 14911 Hannahville B-1 Road		MI	49896-9
President	Wilford Cleveland	Ho-Chunk Nation of Wisconsin	P.O. Box 667		WI	54675
Chairman	Tim Rhodd	Iowa Tribe of Kansas and Nebraska	3345 Thrasher Road, #8		KS	66094
Chairman	Bobby Walkup	Iowa Tribe of Oklahoma	Route 1, Box 721		OK	74059
Chairman	Lester Randall	Kickapoo Tribe of Indians of Kansas	P.O. Box 271		KS	66439
Chairman	David Pacheco	Kickapoo Tribe of Oklahoma	P.O. Box 70		OK	74851
Chairman	D.K. Sprague	Match-e-be-nash-she-wish Potawatomi	2872 Mission Dr.		MI	49344
Chief	Douglas Lankford	Miami Tribe of Oklahoma	202 S. Eight Tribes Trail	P.O. Box 1326	OK	74355
Chairman	Jaime Stuck	Nottawaseppi Band of Huron Potawatomi	2221—1 & 1/2 Mile Road		MI	49052
Chief	Craig Harper	Peoria Tribe of Indians of Oklahoma	118 S. Eight Tribes Trail	P.O. Box 1527	OK	74355
Chairman	John P. Warren	Pokagon Band of Potawatomi	P.O. Box 180	58620 Sink Road	MI	49047
Chairwoman	Liana Onnen	Prairie Band Potawatomi Nation	Government Center	16281 Q Road	KS	66509
Chairman	Edmore Green	Sac & Fox Nation of Missouri in Kansas and Nebraska	305 N. Main Street		KS	66434
Principal Chief	Kay Rhoads	Sac & Fox Nation of Oklahoma	920883 S Highway 99	Building A	OK	74079
Chairman	Anthony Waseskuk	Sac & Fox Tribe of the Mississippi in Iowa	349 Meskwaki Road		IA	52339
Chairman	Ron Sparkman	Shawnee Tribe	P.O. Box 189		OK	74355
Principal Chief	Geoffrey Standing Bear	The Osage Nation	P.O. Box 779		OK	74056
Chairman	John Berrey	The Quapaw Tribe of Indians	P.O. Box 765		OK	74363
Chief	Joe Bunch	United Keetoowah Band of Cherokee of Oklahoma	P.O. Box 746		OK	74464
Chairman	Frank White	Winnebago Tribe of Nebraska	P.O. Box 687		NE	68071

Name (First, Middle, Last)	Position	Tribe	Street Address	Street Address 2	City	State	Zipcode
Suhaila Nease	Tribal Historic Preservation Officer	Absentee-Shawnee Tribe	2025 S. Gordon Cooper Drive		Shawnee	OK	74810-9381
Kelli Mosteller	Tribal Historic Preservation Officer	Citizen Potawatomi Nation	Cultural Heritage Center	1601 S. Gordon Cooper Drive	Shawnee	OK	74801
Kim Penrod	Director Cultural and Historic Preservation Departmen	Delaware Nation of Oklahoma	P.O. Box 825		Anardarko	OK	73005
Larry Heady	THPO Special Assistant	Delaware Tribe of Indians	1929 E. 6th ST		Duluth	MN	55812
Brett Barnes	Historic Preservation Office	Eastern Shawnee Tribe of Oklahoma	12705 E. 705 Road		Wyandotte	OK	74370
Melissa Cook	Tribal Historic Preservation Officer	Forest County Potawatomi	Cultural Center, Library & Museum	8130 Mishkoswen Drive, P.O. Box 340	Crandon	WI	54520
Earl Meshigaud	Historic Preservation Office	Hannahville Indian Community	P.O. Box 351, Highway 2 & 41		Harris	MI	49845
William Quackenbush	Tribal Historic Preservation Officer	Ho-Chunk Nation of Wisconsin	P.O. Box 667		Black River Falls	WI	54675
Lance Foster	Tribal Historic Preservation Officer	Iowa Tribe of Kansas and Nebraska	3345 Thrasher Road		White Cloud	KS	66094
Robert Field	Historic Preservation Office	Iowa Tribe of Oklahoma	Route 1, Box 721		Perkins	OK	74059
Fred Thomas	Vice Chair	Kickapoo Tribe of Indians of Kansas	P.O. Box 271		Horton	KS	66439
Kent Collier	Historic Preservation Office	Kickapoo Tribe of Oklahoma	P.O. Box 70		McCloud	OK	74851
Sydney Martin	Historic Preservation Office	Match-e-be-nash-she-wish Potawatomi	2872 Mission Drive		Shelbyville	MI	49344
Diane Hunter	Tribal Historic Preservation Officer	Miami Tribe of Oklahoma	202 S. Eight Tribes Trail	P.O. Box 1326	Miami	OK	74355
Douglas Taylor	Interim Tribal Historic Preservation Officer	Nottawaseppi Band of Huron Potawatomi	2221—1 1/2 Mile Road		Fulton	MI	49052
Logan Pappenfort	Historic Preservation Office	Peoria Tribe of Indians of Oklahoma	118 S. Eight Tribes Trail	P.O. Box 1527	Miami	OK	74355
Jason Scott Wesaw	Tribal Historic Preservation Officer	Pokagon Band of Potawatomi	P.O. Box 180	58620 Sink Road	Dowagiac	MI	49047
Warren Wahweotten	Tribal Council Member	Prairie Band Potawatomi Nation	Government Center	16281 Q Road	Mayetta	KS	66509
Gary Bahr	NAGPRA/Historic Preservation Office	Sac & Fox Nation of Missouri in Kansas and Nebraska	305 N. Main Street		Reserve	KS	66434
Sandra Massey	NAGPRA/Historic Preservation Office	Sac & Fox Nation of Oklahoma	920883 S. Highway 99	Building A	Stroud	OK	74079
Johnathan Buffalo	Historic Preservation Office	Sac & Fox Tribe of the Mississippi in Iowa	349 Meskwaki Road		Tama	IA	52339
Nicky Smith	Historic Preservation Office	Shawnee Tribe	P.O. Box 189		Miami	OK	74355
Andrea Hunter	Historic Preservation Office	The Osage Nation	627 Grandview Avenue		Pawhuska	OK	74056
Everett Brandy	Tribal Historic Preservation Officer	The Quapaw Tribe of Indians	P.O. Box 765		Quapaw	OK	74363
Eric Oosahwee-Voss	Tribal Historic Preservation Officer	United Keetoowah Band of Cherokee of Oklahoma	P.O. Box 746		Tahlequah	OK	74464
Henry Payer	Tribal Historic Preservation Officer	Winnebago Tribe of Nebraska	P.O. Box 687		Winnebago	NE	68071

EXAMPLE LETTER 9 MAY 2018

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

May 9, 2018

Engineering and Construction Division
Curation and Archives Analysis Branch

SUBJECT: Big River Eco-System Restoration Project, Missouri.

Dear :

We are contacting your tribe to formally initiate consultation for a proposed undertaking for an environmental restoration project on the Big River in Jefferson and St. Louis Counties, Missouri, in accordance with Section 106 of the National Historic Preservation Act of 1966, as amended. The Saint Louis District, U.S. Army Corps of Engineers (Corps) is proposing measures to address erosion and sedimentation issues that degrade the habitat of endangered species in the Big River. Currently, the Corps is completing a Feasibility Study that proposes specific features at work sites along the river.

The enclosed information paper outlines the authority and the general nature of the proposed features, as well as the known cultural resources that might be impacted. The project will include work sites located along 80 miles of the Big River. The features are primarily concentrated within the river itself and on immediately adjacent riverbanks. However, reforestation is being recommended in some locations and each work site will require access by equipment and vehicles from nearby roads.

Because the Corps anticipates changes in the project conditions that will affect the type and location of features between completion of the Feasibility Study and the receipt of authorization and funding to proceed to the Design and Specifications stage of the project, we are proposing the execution of a Programmatic Agreement (PA) that will specify future actions and responsibilities for participating parties. Therefore, we are contacting federally-recognized tribes with which the St. Louis District regularly consult to determine if your tribe would like to participate as a concurring party to the PA. Once we have determined the participating parties, we will provide more detailed information regarding the project.

If you have any questions or comments, please feel free to contact me, or Chris Koenig at telephone number (314) 331-8151, or e-mail at chris.j.koenig@usace.army.mil.

Thank you,

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

Enclosure

2

TRIBAL COMMENTS RECEIVED – JUNE 2018

Brian,
I left a voice mail message for you today. Please call me at your earliest convenience regarding this project.
I have deep concerns regarding this project.
Kim

Respectfully,

Kim Penrod
Delaware Nation
Director, Cultural Resources/106
Archives, Library and Museum
31064 State Highway 281
PO Box 825
Anadarko, OK 73005
(405)-247-2448 Ext. 1403 Office
(405)-924-9485 Cell
kpenrod@delawarenation.com

Dear Dr. McCain,

The Osage Nation Historic Preservation Office is currently reviewing the draft report, titled "St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment." The Osage Nation will be providing comments on the proposed action documented in the report as soon as our office has finished reviewing the document.

In accordance with the National Historic Preservation Act, (NHPA) [16 U.S.C. 470 §§ 470-470w-6] 1966, undertakings subject to the review process are referred in S101 (d)(6)(A), which clarifies that historic properties may have religious and cultural significance to Indian tribes. Additionally, Section 106 of NHPA requires Federal agencies to consider the effects of their actions on historic properties (36 CFR Part 800) as does the National Environmental Policy Act (43 U.S.C. 4321 and 4331-35 and 40 CFR 1501.7(a) of 1969).

The Osage Nation has a vital interest in protecting its historic and ancestral cultural resources.

Should you have any questions or need any additional information, please feel free to contact me at the number listed below.

Respectfully,

Jess G. Hendrix
Archaeologist, MA, RPA

Osage Nation Historic Preservation Office

627 Grandview Avenue, Pawhuska, OK 74056

Office:918-287-5427 | Fax: 918-287-5376

jess.hendrix@osagenation-nsn.gov <mailto:jess.hendrix@osagenation-nsn.gov>

Blockedhttps://www.osagenation-nsn.gov/who-we-are/historic-preservation

Received 22 June 2018

Osage Nation Historic Preservation Office

Date: June 19, 2018 **File: 1718-2810MO-5**

RE: USACE, St. Louis District, Big River Eco-System Restoration Project, Jefferson and St. Louis Counties, Missouri

USACE, St. Louis District
Chris Koenig
1222 Spruce Street
St. Louis, MO 63103-2833

Dear Mr. Koenig,

The Osage Nation Historic Preservation Office has received the St. Louis District's proposed Big River Eco-System Restoration Project in Missouri. The Osage Nation agrees that this is an important project, and this is a significant area for the Osage Nation. **We request Consulting Party Status as an Invited Signatory on the proposed Programmatic Agreement**. Please keep us notified regarding this project.

In accordance with the National Historic Preservation Act, (NHPA) [54 U.S.C. § 300101 et seq.] 1966, undertakings subject to the review process are referred in 54 U.S.C. § 302706 (a), which clarifies that historic properties may have religious and cultural significance to Indian tribes. Additionally, Section 106 of NHPA requires Federal agencies to consider the effects of their actions on historic properties (36 CFR Part 800) as does the National Environmental Policy Act (43 U.S.C. 4321 and 4331-35 and 40 CFR 1501.7(a) of 1969).

Should you have any questions or need any additional information, please feel free to contact me at the number listed below. Thank you for consulting with the Osage Nation on this matter.

John Fox
Archaeologist

627 Grandview * Pawhuska, OK 74056 Telephone 918-287-5328 * Fax 918-287-5376

Miami Tribe of Oklahoma
3410 P St. NW, Miami, OK 74354 • P.O. Box 1326, Miami, OK 74355
Ph: (918) 541-1300 • Fax: (918) 542-7260
www.miamination.com

June 8, 2018

Michael K. Trimble
Chief, Curation and Archives Analysis Branch
Department of the Army
St. Louis District Corps of Engineers
1222 Spruce Street
St. Louis, MO 63101-2833

Re: Big River Eco-System Restoration Project Programmatic Agreement – Comments of the Miami Tribe of Oklahoma

Dear Mr. Trimble:

Aya, kikwehsitoole – I show you respect. My name is Diane Hunter, and I am the Tribal Historic Preservation Officer for the Federally Recognized Miami Tribe of Oklahoma. In this capacity, I am the Miami Tribe's point of contact for all Section 106 issues.

The Miami Tribe of Oklahoma does not choose to be a signatory to the Big River Eco-System Restoration Project Programmatic Agreement; however, we reserve the legal right to be notified and consulted regarding any unanticipated discoveries that are determined to have Native American affiliation. This includes the ability to be consulted within a timely manner regarding identification and evaluation of discovered properties to determine if they are properties to which the tribe attaches religious or cultural significance. Additionally, if a discovered property is one to which the Tribe attaches religious or cultural significance, the Tribe maintains the full array of rights regarding consultation and involvement in the Section 106 process.

To the extent that any applicable state law is contrary to, inconsistent with, or would frustrate the purposes of the Native American Graves Protection and Repatriation Act (NAGPRA), federal law preempts such state law. Further, should human remains or cultural items be discovered, the obligation following law enforcement clearance is to notify the appropriate Federally Recognized Indian Tribes to begin the consultation process.

2

In the case of an unanticipated discovery, please contact me at 918-541-8966 or by email at dhunter@miamination.com to initiate consultation.

Respectfully,

Diane Hunter

Diane Hunter
Tribal Historic Preservation Officer

FORMAL GOVERNMENT TO GOVERNMENT TRIBAL CONSULTATION MEETING WITH DELAWARE AND OSAGE NATIONS

Date: 14 November, 2018

Location: Delaware Nation Law Building in Anadarko, Oklahoma

Attendees:

COL Bryan K. Sizemore, Commander, St. Louis District
Dr. Kat McCain, Supervisory Ecologist, St. Louis District
Chris Koenig, Archaeologist and Tribal Liaison, St. Louis District
President Dotson, Delaware Nation
Kim Penrod, Historic Preservation Director, Delaware Nation
Terry Williams, Committee Member, Delaware Nation
Dr. Andrea Hunter, Tribal Historic Preservation Officer, Osage Nation
James Munkres, Archaeologist, Osage Nation
Jess Hendrix, Archaeologist, Osage Nation

Purpose: Improved understanding of the Nations' concerns with this project and information to bring back to the District to guide how best to move forward.

Topics discussed, as related to the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study included:

- Tribal consultation procedures. The Osage and Delaware Nations stated just sending project notification letters and not calling tribes is not enough. The Osage Nation stated there must be more outreach at beginning stages of projects, particularly projects of the size and magnitude of the Meramec River Feasibility Study – these projects require more communication. The Osage Nation stated tribes are stakeholders and that only four tribes responded to the Districts' letters is a red flag. The Osage Nation stated the lack of communication and consultation is alarming and that tribes cannot be engaged last as the clock is always ticking. The Osage Nation stated tribes want to be engaged in each step of the process from the beginning. The Osage Nation requested a flow chart with POCs and jurisdictional areas that outlines the District's processes and procedures for 106, NEPA, Appendix C, and NAGPRA. The Delaware Nation stated they were disappointed in Chris' consultation efforts for this large project. The Delaware Nation stated the District needs to ensure their POC list is updated. The Delaware Nation stated Missouri is a highly sensitive area for the tribe and that we need to start over and rebuild the trust relationship. COL Sizemore responded by stating the District and Nations can better streamline the communication process and embrace technology because we are all constituents.
- Project Specific. The Osage Nation stated the online website report link was inaccessible. The Osage Nation stated that tribes must be allowed to contribute their significant locations and sites during the assessment phase and that tribes are the cultural component. The Osage Nation stated that PM and Planning needs to be better informed of tribes and the consultation process. The Osage Nation asked when would a PA be signed for this project and Chris responded that the PA would be ready for review once the project was appropriated and the NEPA and 106 process was better defined. The Osage Nation stated that Pocketbook Mussels are a sacred animal/resource and if they were engaged earlier they could have expressed this prior to any study (in regards to the Czarneki 1987 conducted by the Missouri Department of Conservation). The Delaware Nation requested to be an invited signatory not a concurring party and the District agreed. The Delaware Nation stated they need to provide their tribal buffer zones

within the project footprint, be notified of all ground disturbance (including haul roads and staging areas), and requested the project KMZ files so they could provide their feedback. The Delaware Nation stated their sacred sites and archaeological sites of importance must be kept confidential and the District concurred. The Delaware Nation asked what happens to archaeological sites with contaminated material and the District stated they would be further investigated as to the most appropriate mitigation method with EPA. Both Nations requested to re-review the report once additional information has been added and the District concurred. Project schedule will be updated to include an additional 30 days and submittal to Headquarters would be updated to April rather than in March.

TRIBAL COMMENTS RECEIVED – OSAGE NATION 7 DEC 2018

From: Koenig, Christopher J Jr CIV (US)
To: McCain, Kathryn N CIV USARMY CEMVP (US)
Subject: FW: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)
Date: Thursday, December 13, 2018 7:37:28 AM
Attachments: ONHPO Survey Standards 2019.pdf

-----Original Message-----
From: Jess Hendrix [mailto:Jess.Hendrix@osagenation-nsn.gov]
Sent: Friday, December 07, 2018 3:43 PM
To: Koenig, Christopher J Jr CIV (US) <Christopher.J.Koenig@usace.army.mil>
Subject: [Non-DoD Source] RE: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)

Good afternoon Chris,

The KMZ files for the project have been reviewed. The Big River is intrinsically connected to the St. Louis Trail, one of the major historic trails of the Osage. The river itself, as well as the landscape and area around the river, are extremely significant to the Osage Nation. Those areas around the river also possess an extremely high likelihood of containing archaeological sites, including burials, of great significance to the Osage Nation. All of the tentatively selected project areas provided in the KMZ will need to be surveyed in a sufficient manor appropriate to the significance of the area. The cultural resources surveys (CRS) will need to meet the standards of the ONHPO, which have just recently been updated. Attached you will find a copy of the new ONHPO survey standards. In an effort to ensure understanding and concurrence between our office and the District in executing the CRS, the ONHPO requests to review the draft scope of work for the CRS prior to its finalization and the hiring of a contractor. Additionally, the ONHPO requests to be consulted in the selection of the cultural resources contractor to access the appropriateness of their qualifications and experience to conduct such an extremely important survey in an area of such great significance to the Osage Nation. Lastly, we will be providing some specific source material to be included for review by the CRS contractor for inclusion in the literature review of the CRS.

At this time, the Osage Nation does not have an objection with the tentatively planned location of any of the project specific locations identified in the KMZ files, provided: 1) a sufficient cultural resources survey is conducted, as discussed above, 2) the CRS meets the approval of the OHNPO as determined through review of the CRS report, 3) the final selection of the project specific locations are pending the final review/approval of the ONHPO, and 4) appropriate mitigation actions, determined in consultation with the ONHPO, will be taken at each of the project locations, dependent upon the results of the planned cultural resources survey.

With regard to reception of the planned February report. Please send both a hard copy and an electric copy to Dr. Hunter. The electric copy can be sent via CD, thumb drive, or email. We very much look forward to reviewing the report. And on a personal note, I hope your surgery goes well and you recover quickly.

Thank you,

Jess G. Hendrix
Archaeologist, MA, RPA
Osage Nation Historic Preservation Office
627 Grandview Avenue, Pawhuska, OK 74056
Office:918-287-5427 | Fax: 918-287-5376
Blockedhttps://www.osagenation-nsn.gov/who-we-are/historic-preservation

-----Original Message-----
From: Koenig, Christopher J Jr CIV (US) [mailto:Christopher.J.Koenig@usace.army.mil]
Sent: Friday, December 7, 2018 11:44 AM
To: Jess Hendrix <Jess.Hendrix@osagenation-nsn.gov>
Cc: Andrea Hunter <ahunter@osagenation-nsn.gov>
Subject: RE: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)

CLASSIFICATION: UNCLASSIFIED

Jess - thanks for all the helpful information. I will ensure you are cc'd on all future emails regarding St. Louis District.

Look forward to hearing from you soon. Just as an FYI - I will be out next week for surgery and teleworking the week after.

Chris Koenig, M.A., RPA
Archaeologist and Tribal Liaison
USACE St. Louis District
MCX-CMAC-EC-Z
1222 Spruce Street
St. Louis, MO 63103
Office: 314-331-8151
Work Cell: 314-356-0483
Chris.J.Koenig@usace.army.mil

-----Original Message-----
From: Jess Hendrix [mailto:Jess.Hendrix@osagenation-nsn.gov]
Sent: Friday, December 07, 2018 8:57 AM
To: Koenig, Christopher J Jr CIV (US) <Christopher.J.Koenig@usace.army.mil>
Cc: Andrea Hunter <ahunter@osagenation-nsn.gov>
Subject: [Non-DoD Source] RE: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)
Importance: High

Good morning Chris,

I can confirm that we received your first email and that the KMZs open just fine. I cannot confirm receipt of the second email. I handle all of the St. Louis District projects that some into the office, so you can cc me on emails to Dr. Hunter. It's almost a guarantee every time that I'll see it before she does. She receives so many emails a day that incoming emails very quickly get pushed down the chain. Certainly, if something is urgent, cc me and I can at least tell her she needs to look at it.

With regard to review of the KMZ files, let me try to get you something by the end of the day. I'll Also confirm to whom the report should be sent and how.

Lastly, and unfortunately, Kim Penrod is no longer with the Delaware Nation in her capacity as the Director of Cultural Resources/106. I would suggest addressing all future correspondence for the Delaware Nation to Deborah Dotson.

Thank you,

Jess G. Hendrix
Archaeologist, MA, RPA
Osage Nation Historic Preservation Office
627 Grandview Avenue, Pawhuska, OK 74056
Office:918-287-5427 | Fax: 918-287-5376
BlockedBlockedhttps://www.osagenation-nsn.gov/who-we-are/historic-preservation

-----Original Message-----
From: Koenig, Christopher J Jr CIV (US) [mailto:Christopher.J.Koenig@usace.army.mil]
Sent: Thursday, December 6, 2018 9:39 PM
To: Jess Hendrix <Jess.Hendrix@osagenation-nsn.gov>
Subject: FW: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)
Importance: High

CLASSIFICATION: UNCLASSIFIED

Jess,

Wanted to verify the Nation is receiving my emails?

Thank you,

Chris Koenig, M.A., RPA
Archaeologist and Tribal Liaison
USACE St. Louis District
MCX-CMAC-EC-Z
1222 Spruce Street
St. Louis, MO 63103
Office: 314-331-8151
Work Cell: 314-356-0483
Chris.J.Koenig@usace.army.mil

-----Original Message-----
From: Koenig, Christopher J Jr CIV (US)
Sent: Tuesday, November 27, 2018 2:40 PM
To: Hunter, Andrea MVS External Stakeholder <ahunter@osagetribe.org>; kpenrod <kpenrod@delawarenation.com>
Cc: 'Deborah Dotson' <ddotson@delawarenation.com>; McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Subject: RE: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)
Importance: High

CLASSIFICATION: UNCLASSIFIED

Good Afternoon Dr. Hunter and Kim,

I wanted to follow up with you to ensure you received the KMZ files and were able to open them successfully? Are both Nations still on track to provide the District any tribal information by close of next week? Also, I was informed the report will be available for tribal review beginning February 11, 2018 through March 12, 2018. This report will not be posted publically. Therefore, the District would like to know who each Nation wants it to go to directly and the best way we can transmit it to those identified.

Thank you in advance and talk soon,

Chris Koenig, M.A., RPA
Archaeologist and Tribal Liaison
USACE St. Louis District
MCX-CMAC-EC-Z
1222 Spruce Street
St. Louis, MO 63103
Office: 314-331-8151
Work Cell: 314-356-0483
Chris.J.Koenig@usace.army.mil

-----Original Message-----
From: Koenig, Christopher J Jr CIV (US)
Sent: Thursday, November 15, 2018 11:00 AM
To: Hunter, Andrea MVS External Stakeholder <ahunter@osagetribe.org>; kpenrod <kpenrod@delawarenation.com>
Cc: Deborah Dotson <ddotson@delawarenation.com>; McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Subject: KMZ files for Meramec Feasibility Project (UNCLASSIFIED)
Importance: High

CLASSIFICATION: UNCLASSIFIED

Good Morning Dr. Hunter and Kim,

As discussed yesterday, attached are the KMZ files for the Nations' review for the Meramec Feasibility Study. I have also cc'd Kat so you can review and provide the Nations' general areas of concern or tribal resources of concerns within the study area. I will be the first to admit I am not GIS/tech savvy so if you have any issues opening the files please let me know.

Thank you again for the productive meeting yesterday,

Chris Koenig, M.A., RPA
Archaeologist and Tribal Liaison
USACE St. Louis District
MCX-CMAC-EC-Z
1222 Spruce Street
St. Louis, MO 63103
Office: 314-331-8151
Work Cell: 314-356-0483
Chris.J.Koenig@usace.army.mil

ADDITIONAL TRIBAL CORRESPONDENCE

The following email was sent to Dr. Andrea Hunter and Jesse Hendrix of the Osage Nation and President Dotson and Nekole Alligood of the Delaware Nation. Response confirmation emails were received on 28 January 2019 from the Ms. Alligood, and on 29 January 2019 from Dr. Hunter.

From:	Koenig, Christopher J Jr CIV (US)
To:	Hunter, Andrea MVS External Stakeholder; Jess Hendrix; kpenrod; Nekole Alligood
Cc:	McCain, Kathryn N CIV USARMY CEMVP (US); Savage, Monique E CIV USARMY CEMVP (US); Vielhaber, Matthew R CIV USARMY CEMVS (USA)
Subject:	Final Draft of the St. Louis Riverfront- Meramec River Basin Ecosystem Restoration Feasibility Study
Date:	Monday, January 28, 2019 11:15:55 AM

Good Morning,

The draft final of the St. Louis Riverfront- Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment has been updated per comments received during public review and due to WRDA 2018 study area expansion. Per the Delaware and Osage Nations request during our government-to-government meeting in November 2018, we will be mailing you a hard copy of the final draft report and appendices for a final review concurrently with our internal technical review and sponsor review. The scheduled review will occur Feb 11- March 12, 2019. All tribal comments received by March 12, 2019 will be responded to and addressed prior to final report recommendation and submittal for endorsement. Comments received after March 12, 2019 will become part of the administrative record for the feasibility study. Can the tribes please provide the contact of whom we should send the hard copy to so we can ensure prompt delivery to the appropriate reviewer?

Thank you in advance,

Christopher Koenig, M.A., RPA
Archaeologist and Tribal Liaison
USACE St. Louis District
MCX-CMAC-EC-Z
1222 Spruce Street
St. Louis, MO 63103
Office: 314-331-8151
Work Cell: 314-356-0483
Christopher.J.Koenig@usace.army.mil

Osage Nation Historic Preservation Office

Date: February 28, 2019 **File: 1819-1070MO-10**

RE: USACE, St. Louis District, St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment, Jefferson and St. Louis Counties, Missouri

St. Louis District, USACE
Chris Koenig
1222 Spruce Street
St. Louis, MO 63103-2833

Dear Mr. Koenig,

The Osage Nation Historic Preservation Office has reviewed the draft St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment (hence for referred to as the document) provided to the Osage Nation for the proposed project listed as USACE, St. Louis District, St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment, Jefferson and St. Louis Counties, Missouri. An electronic Word version of the document containing ONHPO edits and additional comments has been submitted to you via AMERDEC SAFE. The ONHPO understands that consultation regarding impacts of the project to cultural resources is not complete, but will continue if the project is approved and funded. The Osage Nation would like to reiterate its requests to be an Invited Signatory on the Programmatic Agreement that is expected to be executed if the project is approved. The Osage Nation requests to be updated with any progress or changes in status of the pending project.

Additionally, the document states that the proposed project will have no effect on some species and may affect, but will likely not adversely affect a number of other species. The Osage Nation would like to take this opportunity to inform the St. Louis District that the following animals are sacred species: lake sturgeon, all dragonflies, and all clams and freshwater mussels listed. The Osage Nation understands that the project will likely not adversely affect these species, however, given the sacred nature of the species to the Osage people, the Nation requests to be informed of any adverse effects to these species which may result from the proposed project. Likewise, the Nation requests to be informed of the results of any future population studies which may be conducted to measure the health status of these species populations in the project area.

In accordance with the National Historic Preservation Act, (NHPA) [54 U.S.C. § 300101 et seq.] 1966, undertakings subject to the review process are referred to in 54 U.S.C. § 302706 (a), which clarifies that historic properties may have religious and cultural significance to Indian tribes. Additionally, Section 106 of NHPA requires Federal agencies to consider the effects of their actions on historic properties (36 CFR Part 800) as does the National Environmental Policy Act (43 U.S.C. 4321 and 4331-35 and 40 CFR 1501.7(a) of 1969).

The Osage Nation has a vital interest in protecting its historic and ancestral cultural resources. **The Osage Nation anticipates continued consultation for the proposed USACE, St. Louis District, St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment, Jefferson and St. Louis Counties, Missouri.**

627 Grandview * Pawhuska, OK 74056 Telephone 918-287-5328 * Fax 918-287-5376

OSAGE NATION HISTORIC PRESERVATION OFFICE

Should you have any questions or need any additional information please feel free to contact me at the number listed below. Thank you for consulting with the Osage Nation on this matter.

Andrea A. Hunter, Ph.D.
Director/Tribal Historic Preservation Officer

Jess G. Hendrix
Archaeologist

5. KEY MEETINGS

- 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

6. FARMLAND PROTECTION POLICY ACT COMPLIANCE JUNE 2018

Introduction

This appendix outlines the regulatory background and documentation requirements to be National Environmental Policy Act (NEPA) documentation compliant with the Farmland Protection Policy Act (FPPA) of 1981. The Natural Resources Conservation Service (NRCS), a U.S. Department of Agriculture (USDA) agency, policies govern compliance with the FFPA. FFPA applies only to Federal assistance and actions that would convert important farmland to nonagricultural uses. It does not authorize the Federal government in any way to regulate the use of private or nonfederal land or in any way affect the private property rights of owners of private land.

Purpose

The purpose of the Farmland Protection Policy Act (FFPA) is to:

(1) Minimize the extent to which Federal programs, including technical assistance or financial assistance, contribute to the unnecessary and irreversible conversion of important farmland to nonagricultural uses;
(2) Encourage alternative actions, if appropriate, that could lessen the adverse effect on farmland; and
(3) Assure that Federal programs are operated in a manner that, to the extent practicable, will be compatible with State, local government, and private programs that protect farmland.

Lands Subject to Provisions of FPPA

Important farmlands, including lands identified with soils that are prime, unique, or statewide or locally important farmland, are subject to the provisions of the FPPA.

Designating Important Farmland Soils

In accordance with the 1981 Act (Public Law 97-98), important farmland includes all land that is defined as prime, unique, or statewide or locally important. U.S. Code – Title 7 – Part 657 (7 CFR 657), Section 657.5 defines these farmlands based on soil types.

Designating Prime Farmland Soils

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops and is also available for these uses. The land could be cropland, pastureland, rangeland, forestland or other land but not urban built-up land or water.

Designating Unique Farmland Soils

Unique farmland is land other than prime farmland that is used for the production of specific high-value food and fiber crops. It has the special combination of soil quality, growing season and moisture supply needed to economically produce sustained high-quality and/or high yields of a specific crop when treated and managed according to acceptable farming methods and other conditions that favor the growth of a specific food or fiber crop.

Designating Farmland of Statewide Importance

This is land, in addition to prime and unique farmlands, that is of statewide importance for the production of food, feed, fiber, forage or oilseed crops (7CFR 657.5).

Designating Farmland of Local Importance

In some local areas, certain additional farmlands are important for the production of food, feed, fiber, forage and oilseed crops even though these lands are not identified as having national or statewide importance. Where appropriate, these lands are to be identified by the local agencies concerned. A local unit of government, as defined in 7CFR 657.5, must designate farmland of local importance.

Paths for Compliance

Projects that are subject to FPPA regulations must fall within one of the following categories:

(1) Non-Applicable – Project not subject to provisions of the FPPA
(2) Conversion Causes Non-Adverse Effects – The project would convert farmland subject to the FPPA to a non-agricultural, transportation use, but the combination scores of the relative value of the farmland and the site assessment, as documented, are such that the site need not be given further consideration for protection and no additional sites need to be evaluated.
(3) Conversion Causes Adverse Effects

St. Louis Riverfront - Meramec River Basin Feasibility Study Compliance

The procedural requirements for compliance with FPPA was followed. The Corps determined the project activities are subject to FPPA protection. The Corps used online resources (web soil survey, US Census Maps, etc.) to determine whether the proposed project area is comprised of unprotected farmland, prime, unique and statewide or locally important farmland. The proposed project does propose to convert protected farmland to a non-agricultural use through reforestation and construction of off-channel sediment basins. Form AD-1006 (Encl 1) is to determine the Farmland Conversion Impact rating to compare among Alternatives 4, 5 and 7. NRCS completed the AD-1006 Evaluation (Enclosure 2) and no further action was required with selection of Alternative 5. Table 1 summarizes the site assessment criteria for the considered action alternatives.

Table 1. Site Assessment Criteria for Considered Action Alternatives

	Max Points	Alternative 4 - Maximizes Ecosystem Benefits in Meramec River	Alternative 5 - Maximizes Efficiency in Big River	Alternative 7 - Maximizes Ecosystem Benefits in Study Area
1. Area in non-urban use	15	10	12	12
2. Perimeter in non-urban use	10	8	9	9
3. % of site being farmed	20	15	15	15
4. Protection provided by Govt	20	0	0	0
5. Distance from urban built-up area	15	5	10	10
6. Distance to urban support services	15	0	10	10
7. Size of present farm unit compared to average	10	5	5	5
8. Creation of non-farmable farmland	10	10	10	10
9. Availability of farm support services	5	5	5	5
10. On-farm investments	20	1	1	1
11. Effects of conversion on farm support services	10	0	0	0
12. Compatibility with existing agricultural use	10	0	0	0
TOTAL SITE ASSESSEMENT POINTS	**160**	**59**	**77**	**77**

U.S. Department of Agriculture

FARMLAND CONVERSION IMPACT RATING

PART I *(To be completed by Federal Agency)*	Date Of Land Evaluation Request 14 March 2018
Name of Project Meramec River Basin Ecosystem Restora	Federal Agency Involved USACE, USFWS
Proposed Land Use Ecosystem Restoration	County and State St. Louis & Jefferson Counties, Missouri
PART II *(To be completed by NRCS)*	Date Request Received By NRCS / Person Completing Form:
Does the site contain Prime, Unique, Statewide or Local Important Farmland? *(If no, the FPPA does not apply - do not complete additional parts of this form)* YES ✓ NO ☐	Acres Irrigated / Average Farm Size
Major Crop(s) / Farmable Land In Govt. Jurisdiction Acres: %	Amount of Farmland As Defined in FPPA Acres: %
Name of Land Evaluation System Used / Name of State or Local Site Assessment System	Date Land Evaluation Returned by NRCS

PART III *(To be completed by Federal Agency)*	Maximum Points	No Action	Alt 4	Alt 5 - TSP	Alt 7
		Alternative Site Rating			
A. Total Acres To Be Converted Directly			28.3	857.1	850.9
B. Total Acres To Be Converted Indirectly			0	0	0
C. Total Acres In Site			28.3	857.1	850.9
PART IV *(To be completed by NRCS)* Land Evaluation Information					
A. Total Acres Prime And Unique Farmland			4.8	123.1	130.9
B. Total Acres Statewide Important or Local Important Farmland			0	1	1
C. Percentage Of Farmland in County Or Local Govt. Unit To Be Converted					
D. Percentage Of Farmland in Govt. Jurisdiction With Same Or Higher Relative Value					
PART V (To be completed by NRCS) Land Evaluation Criterion Relative Value of Farmland To Be Converted (Scale of 0 to 100 Points)					
PART VI *(To be completed by Federal Agency)* Site Assessment Criteria *(Criteria are explained in 7 CFR 658.5 b. For Corridor project use form NRCS-CPA-106)*	**Maximum Points**	Site A	Site B	Site C	Site D
1. Area In Non-urban Use	(15)		10	12	12
2. Perimeter In Non-urban Use	(10)		8	9	9
3. Percent Of Site Being Farmed	(20)		15	15	15
4. Protection Provided By State and Local Government	(20)		0	0	0
5. Distance From Urban Built-up Area	(15)		5	10	10
6. Distance To Urban Support Services	(15)		0	10	10
7. Size Of Present Farm Unit Compared To Average	(10)		5	5	5
8. Creation Of Non-farmable Farmland	(10)		10	10	10
9. Availability Of Farm Support Services	(5)		5	5	5
10. On-Farm Investments	(20)		1	1	1
11. Effects Of Conversion On Farm Support Services	(10)		0	0	0
12. Compatibility With Existing Agricultural Use	(10)		0	0	0
TOTAL SITE ASSESSMENT POINTS	160	0	59	77	77
PART VII ***(To be completed by Federal Agency)***					
Relative Value Of Farmland *(From Part V)*	100	0	0	0	0
Total Site Assessment *(From Part VI above or local site assessment)*	160	0	59	77	77
TOTAL POINTS *(Total of above 2 lines)*	260	0	59	77	77

Site Selected:	Date Of Selection	Was A Local Site Assessment Used? YES ☐ NO ✓

Reason For Selection:

Name of Federal agency representative completing this form: U.S. Army Corps of Engineers — Date: 14 March 2018

(See Instructions on reverse side) **Form AD-1006 (03-02)**

ENCLOSURE 1: USDA Farmland Conversion Impact Rating (AD-1006), Submitted 14 March 2018

U.S. Department of Agriculture

FARMLAND CONVERSION IMPACT RATING

PART I *(To be completed by Federal Agency)*	Date Of Land Evaluation Request 14 March 2018
Name of Project Meramec River Basin Ecosystem Restora	Federal Agency Involved USACE, USFWS
Proposed Land Use Ecosystem Restoration	County and State Jefferson Counties, Missouri

PART II *(To be completed by NRCS)*		Date Request Received By NRCS 6/21/18	Person Completing Form: Rod Taylor	
Does the site contain Prime, Unique, Statewide or Local Important Farmland? *(If no, the FPPA does not apply - do not complete additional parts of this form)*	YES ☑ NO ☐	Acres Irrigated	Average Farm Size	
Major Crop(s) corn	Farmable Land In Govt. Jurisdiction Acres: 406552 % 95.6		Amount of Farmland As Defined in FPPA Acres: 152886 % 35.9	
Name of Land Evaluation System Used LESA	Name of State or Local Site Assessment System		Date Land Evaluation Returned by NRCS 6/25/18	

PART III *(To be completed by Federal Agency)*		Alternative Site Rating		
	No Action	Alt 4	Alt 5 - TSP	Alt 7
A. Total Acres To Be Converted Directly		28.3	857.1	850.9
B. Total Acres To Be Converted Indirectly		0	0	0
C. Total Acres In Site		28.3	857.1	850.9
PART IV *(To be completed by NRCS)* Land Evaluation Information				
A. Total Acres Prime And Unique Farmland		4.8	123.1	130.9
B. Total Acres Statewide Important or Local Important Farmland		0	1	1
C. Percentage Of Farmland in County Or Local Govt. Unit To Be Converted		.003	.081	.086
D. Percentage Of Farmland in Govt. Jurisdiction With Same Or Higher Relative Value		4.7	4.7	4.7
PART V (To be completed by NRCS) Land Evaluation Criterion Relative Value of Farmland To Be Converted (Scale of 0 to 100 Points)		100	100	100

PART VI *(To be completed by Federal Agency)* Site Assessment Criteria *(Criteria are explained in 7 CFR 658.5 b. For Corridor project use form NRCS-CPA-106)*	Maximum Points	Site A	Site B	Site C	Site D
1. Area In Non-urban Use	(15)		10	12	12
2. Perimeter In Non-urban Use	(10)		8	9	9
3. Percent Of Site Being Farmed	(20)		15	15	15
4. Protection Provided By State and Local Government	(20)		0	0	0
5. Distance From Urban Built-up Area	(15)		5	10	10
6. Distance To Urban Support Services	(15)		0	10	10
7. Size Of Present Farm Unit Compared To Average	(10)		5	5	5
8. Creation Of Non-farmable Farmland	(10)		10	10	10
9. Availability Of Farm Support Services	(5)		5	5	5
10. On-Farm Investments	(20)		1	1	1
11. Effects Of Conversion On Farm Support Services	(10)		0	0	0
12. Compatibility With Existing Agricultural Use	(10)		0	0	0
TOTAL SITE ASSESSMENT POINTS	160	0	59	77	77
PART VII *(To be completed by Federal Agency)*					
Relative Value Of Farmland *(From Part V)*	100	0	100	100	100
Total Site Assessment *(From Part VI above or local site assessment)*	160	0	59	77	77
TOTAL POINTS *(Total of above 2 lines)*	260	0	159	177	177

Site Selected:	Date Of Selection	Was A Local Site Assessment Used? YES ☐ NO ☑

Reason For Selection:

Name of Federal agency representative completing this form: U.S. Army Corps of Engineers | Date: 14 March 2018

(See Instructions on reverse side) **Form AD-1006 (03-02)**

ENCLOSURE 2. USDA Farmland Conversion Impact Rating (AD-1006) Completed Evaluation

Additional Email Communication Regarding Compliance with the Farmland Protection Policy Act

-----Original Message-----
From: McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Sent: Friday, September 28, 2018 9:46 AM
To: Taylor, Rodney - NRCS, Jackson, MO <Rod.Taylor@mo.usda.gov>; tim.rielly@dnr.mo.gov
Cc: Lugo-Camacho, Jorge - NRCS, Columbia, MO <Jorge.Lugo-Camacho@mo.usda.gov>; Savage, Monique E CIV USARMY CEMVP (US) <Monique.E.Savage@usace.army.mil>; Vielhaber, Matthew R CIV USARMY CEMVS (US) <Matthew.R.Vielhaber@usace.army.mil>
Subject: RE: Farmland Protection Policy Act question

Rod,

I'm just circling back around to ensure that with the attached completed AD-1006 we are in full compliance with the Farmland Protection Policy Act for the St. Louis Riverfront Meramec River Basin Ecosystem Restoration Feasibility Study. Is there any further documentation/action required at this time?

Thanks

Cheers,

Kat McCain, Ph.D.
Chief, Environmental Planning Section
Water Resources Certified Planner
Regional Planning and Environmental Division North

-----Original Message-----
From: Taylor, Rodney - NRCS, Jackson, MO [mailto:Rod.Taylor@mo.usda.gov]
Sent: Monday, October 1, 2018 2:33 PM
To: McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Subject: [Non-DoD Source] RE: Farmland Protection Policy Act question

Kat

I'm not aware of any further documentation needed.

Rod Taylor
USDA/NRCS
www.nrcs.usda.gov

-----Original Message-----
From: McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Sent: Thursday, November 15, 2018 3:01 PM
To: Taylor, Rodney - NRCS, Jackson, MO <Rod.Taylor@mo.usda.gov>
Subject: RE: Farmland Protection Policy Act question

Rod,

In regards to the St. Louis Riverfront- Meramec River Ecosystem Restoration Feasibility study, the recent Water Resources Development Act of 2018, signed on 23 October, expanded the authorized study area to the entire Meramec River Basin (previous authority limited the Corps to only looking at Jefferson and St. Louis Counties). After talking with the project sponsor, MO DNR, the study team has decided to expand the study area to include all of the Big River Watershed (St. Louis, Jefferson, St. Francois, and Washington Counties); however, the proposed alternatives will not change. So in terms of being in compliance with the Farmland Protection Policy Act, would you like me to update my request to include the new study area, or is the previous application still be sufficient since the proposed actions are not changing?

Thanks you

Cheers,

Kat McCain, Ph.D.
Chief, Environmental Planning Section
Water Resources Certified Planner
Regional Planning and Environmental Division North
-----Original Message-----
From: Taylor, Rodney - NRCS, Jackson, MO [mailto:Rod.Taylor@mo.usda.gov]
Sent: Monday, November 19, 2018 10:57 AM
To: McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Subject: [Non-DoD Source] RE: Farmland Protection Policy Act question

Kat,

If the proposed acres of converted farmland are not changing, the previous AD-1006 will still be valid. Let me know if you have any questions.

Thanks
Rod

7. PUBLIC COMMENTS RECEIVED

GENERAL PUBLIC

Less study of rivers and more action to keep water flow moving.

Private land owners need more help to maintain stream banks as they see fit on their property (as long as good practices are maintained).

Permitting process needs to be one stop shopping – eliminating extra government bureaucracy that costs private landowners more money and does nothing to help restoration or ecosystem

Received 8 June 2018 by C. Groeteke

It gave me an outlook of what may work to eliminate some of the issues that could affect public health. Gave me an idea of how heated the public can be.

Received 7 June 2018 by C. Colson (Jefferson County Health Department)

Brian,

Thank you for forwarding the information on Feasibility Study.

On another issue, I have a concern about losing a public access point on the Bourbeuse River, but not sure if this is something your office can do anything about. Mayers Landing Access used to be a good access about 10 years ago, but since then the river has cut through at a point about a quarter mile away (cutting off about a half mile of river). I had raised this concerned to MDC about 6 years ago when it started to cut through, but I guess they decided to let nature take its course. Its sort of sad to lose a public access point, especially one that is easy to get to. Any thoughts?

https://nature.mdc.mo.gov/discover-nature/places/mayers-landing-access
Received 20 June 2018 by B. Arnold

Brian,

Thanks for releasing the feasibility study for review. I was wondering if there is an email list we could sign up for to find out about other similar types of projects/regulatory items? Nora Estopare and I work in the Metropolitan St. Louis Sewer District's Environmental Compliance division and we were thinking it would help us stay in the loop on things.

If so, could you please refer me to someone I could contact to get us signed up?

Received 19 June 2018 by J. Peterein

Thank you very much for this notification. I have quickly reviewed this report and am very impressed with the content. What a gigantic and comprehensive effort! I look forward to studying the details.

The reason I asked to be included as a recipient is based primarily on my interest concerning the Bourbeuse River. I own some property that is right on the Bourbeuse River. The referenced study seems to focus mostly on the Big River.

Could you also include me on any efforts that specifically concern the Bourbeuse River?

Also, I have noticed the recent installation of some signs (which are currently covered) on land where Highway 185 crosses over the Bourbeuse River. There are signs on both sides of the river on the east side of the bridge and it appears as if this area is preparing to be opened as a public use area. I believe that the Corp of Engineers used to own the land under the bridge. Is there any way that you could tell me if this land is now managed by MDC or DNR and who I might be able to contact with regard to this area?

Thank you very much!

Received 26 May 2018 by K. Crist

THE DOE RUN COMPANY

THE DOE RUN COMPANY

1801 Park 270 Drive
Suite 300
St. Louis, Missouri 63146

June 12, 2018

VIA E-MAIL (Kathryn.McCain@usace.army.mil) and US FIRST CLASS MAIL, RETURN RECEIPT REQUESTED

US Army Corps of Engineers, St. Louis District
ATTN: Environmental Planning PD-P (McCain)
1222 Spruce St.
St. Louis, MO 63103-2833

Re: Draft Report: "St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment"—Request for Sixty (60) Day Extension of Comment Period

Dear Ms. McCain,

The Doe Run Resources Company (DRRC) hereby requests a sixty (60) day extension of the comment period for the recently issued Draft Report: "St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment" ("Draft Report"). The initial comment period is from the date of the Draft Report was issued, May 23, 2018, through June 23, 2018. We now request that this period be extended by sixty days (60), so as to run through Wednesday, August 22, 2018.

This request is based upon the complexity of the subject matter and the unique position of DRRC to provide critical, quality comments. For several years DRRC has been working on a CERCLA Focused Feasibility Study (FFS) to address lead contamination in the St. Francois County portion of the Big River. This work is being carried out in a co-operative effort with US EPA ("EPA") under an Agreed Order on Consent. Given that the St. Francois County portion of the Big River is immediately upstream of the Draft Report study area, it seems appropriate to study all portions of the watershed in depth, not just the lower portion.

Based on our initial review of the Draft Report, we can provide a substantial volume of quality information for the improvement of this project. The Big River can only benefit from a cooperative approach by which all interested parties are allowed to contribute. This is too important a matter to be decided without all the facts being laid out and all parties being heard. We look forward to a productive relationship on this project.

If you have any questions or comments, please call me at 314-453-7132.

Sincerely,

Chris C. Neaville

Chris C. Neaville
Asset Development Director

[Type here]

From: McCain, Kathryn N CIV USARMY CEMVP (US)
To: "Neaville, Chris"
Bcc: Vielhaber, Matthew R CIV USARMY CEMVS (US); Kohler, Gregory W CIV USARMY CEMVS (US); Savage, Monique E CIV USARMY CEMVP (US); Rielly, Tim
Subject: RE: Ecosystem Restoration Feasibility Study Draft Report comments extension request
Date: Friday, June 15, 2018 10:28:00 AM

Mr. Neaville,

Thank you for your interest in the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study. We have received the Doe Run Resource Company's request for a sixty (60) day extension to the public review period. Because of schedule requirements that need to be met in order to transmit a final report to Congress in Fiscal Year 2019, we are unable to accommodate the full 60 day request. However, we have extended the public review period an additional fifteen (15) days. The public review period now ends 8 July 2018.

All comments provided within the public review period will become part of the public record. However, comments, data, and other information can be submitted and considered at any time during our study process. We would appreciate any information that you all could provide that will improve our project.

We would be happy to discuss any potential data or information that you have. Please let us know if you would like to set up a teleconference to discuss further.

Regards,

Kat McCain, Ph.D.
Chief, Environmental Planning Section
Water Resources Certified Planner
Regional Planning and Environmental Division North
1222 Spruce Street
St. Louis MO 63012
Phone: 314-331-8047
Email: Kathryn.mccain@usace.army.mil

-----Original Message-----
From: Neaville, Chris [mailto:cneaville@doerun.com]
Sent: Tuesday, June 12, 2018 1:02 PM
To: McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>
Subject: [Non-DoD Source] Ecosystem Restoration Feasibility Study Draft Report comments extension request

Kathryn,

Please see the attached and confirm that you have received.

Regards,

Chris Neaville, Asset Development Director

The Doe Run Company

1801 Park 270 Drive | St. Louis, MO 63146

T 314 453 7132 | C 919 757 3313 | cneaville@doerun.com <mailto:cneaville@doerun.com> | Blockedwww.doerun.com <Blockedhttp://www.doerun.com/>

Please consider the environment before printing this email.

This email contains information that is confidential and privileged, the contents of this email are intended only for the recipient(s) listed above. If you are not the intended recipient, you are directed not to read, disclose, distribute or otherwise use this transmission. If you have received this email in error, please notify the sender immediately and delete the transmission. Delivery of this message is not intended to waive any applicable privileges

---

This message is intended solely for the designated recipient and may contain confidential, privileged or proprietary information. If you have received it in error, please notify the sender immediately and delete the original and any copy or printout. Please note that any views or opinions presented in this e-mail are solely those of the author and do not necessarily represent those of The Doe Run Company. Finally, the recipient should check this message and any attachments for the presence of viruses or malware. The Doe Run Company accepts no liability for any loss or damage caused through the transmission of this e-mail.

THE DOE RUN COMPANY
1801 Park 270 Drive
Suite 300
St. Louis, Missouri 63146

July 9, 2018

Dr. Kathryn McCain
US Army Corps of Engineers, St. Louis District
Environmental Planning PD-P
1222 Spruce Street
St. Louis, Missouri 63103-2833

Re: Meramec River Basin Ecosystem Restoration Feasibility Study - Draft Report Comments

Dear Dr. McCain:

The purpose of this letter is to provide comments on the above referenced draft report in response to the May 23, 2018 announcement regarding this Feasibility Study (FS). Doe Run supports the Corps of Engineers' initiative to implement ecosystem restoration in the Meramec River Basin. However, we have several concerns about the approach and supporting studies that were incorporated into the FS. Our greatest concerns are highlighted below:

Conceptual Site Model (CSM): There are several critical flaws in the CSM, but the most significant problem is how the study area was constructed. We strongly believe that the entire watershed needs to be considered in order for the CSM to be valid. Thus, the boundary should include the headwaters of the Big River which lies mostly within St. Francois County. Also, in order for restoration activities to be effective, they should be implemented upstream to downstream which would necessitate incorporating St. Francois County.

Sources of Lead: The FS cites studies indicating that the lead in sediments in the lower Big River has migrated from underground mining areas in St. Francois County. There are extensive studies on the sources of lead in the Big River documenting numerous other sources including naturally occurring, historic surface lead mining in St. Francois, Washington, and Jefferson County, and barite mining in Washington and Jefferson County. In order for restoration activities to be effective, the various sources and background conditions need to be understood to a much greater extent than the simplistic version described in the FS. Enclosed with this letter is a CD containing a compilation of in-depth studies on these topics conducted by Doe Run, its consultants and other experts on the Big River. These studies have been previously submitted to the National Academy of Science, the US Environmental Protection Agency and the Missouri Natural Resource Trustees.

MDNR Funding: The FS states that MDNR's funding contribution as the non-Federal sponsor is $27,602,000. The actual source of that proposed funding is not identified in the FS, but at public meetings it has been stated several times by the government partners that the source of funding will be the ASARCO Trust Funds collected from an NRD settlement for the Big River Mine Tailings Site (BRMTS). If this is the case, Doe Run's position is that the BRMTS NRD funds should be dedicated to restoration activities at or related to the Site which lies in St. Francois County. If St. Francois County is added to the Ecosystem Restoration project area, then the ASARCO Trust Fund would be an appropriate source of cost-matching for projects in that County. Doe Run objects to the use of the ASARCO funds for restoration activities far removed and unrelated to releases of hazardous substances at or from the BRMTS.

In addition to the general comments above, we have also attached detailed technical comments with regard to the May 2018 Draft FS document prepared by our consultant, Wood Environment and Infrastructure Solutions.

We hope that these comments provide constructive content for improving the Ecosystem Restoration in the Meramec River Basin. Again, we greatly support these efforts and are willing to collaborate to provide expertise and assistance. If you have any questions or comments, please call me at 314-453-7658.

Sincerely,

Mark R. Yingling

Mark Yingling
Vice President – EH&S

Enclosures:
Attachment 1 – Wood Environment and Infrastructure Solutions- Technical Comments letter

INDEX TO ATTACHMENT 2
MERAMEC RIVER BASIN ECOSYSTEM RESTORATION FEASIBILITY STUDY
DRAFT REPORT COMMENTS
The Doe Run Resources Company (DRRC)
July 9, 2018

2016-2017 DRRC Submittals to the National Academy of Science

- PbSS-1 Natural and Anthropogenic Sources of Lead in the Big River Watershed
- PbSS-3 Historical References and Consultant Studies on Sources of Lead
- PbSS-8 Mining, Milling, and Waste Handling Procedures at Southeast Missouri Lead Mining Sites
- PBSS-17 Bibliography of Reference Papers for NAS Study of Lead in the Old Lead Belt
- PbSS-24 AMEC Comments to Draft Southeast Missouri Ozarks Regional Restoration Plan and Environmental Assessment
- PbSS-25 2016 Draft SFCMA OU-2 Feasibility Study, River and Non-Residential Areas, St. Francois County Mining Area, St. Francois County, Missouri
- PbSS-26 AMEC Naturally Occurring Lead in Mined Areas

Page **1** of **1**

INDEX TO ATTACHMENT 2

MERAMEC RIVER BASIN ECOSYSTEM RESTORATION FEASIBILITY STUDY
DRAFT REPORT COMMENTS
The Doe Run Resources Company (DRRC)
July 9, 2018

2016-2017 DRRC Submittals to the National Academy of Science

- PbSS-1 Natural and Anthropogenic Sources of Lead in the Big River Watershed
- PbSS-3 Historical References and Consultant Studies on Sources of Lead
- PbSS-8 Mining, Milling, and Waste Handling Procedures at Southeast Missouri Lead Mining Sites
- PBSS-17 Bibliography of Reference Papers for NAS Study of Lead in the Old Lead Belt
- PbSS-24 AMEC Comments to Draft Southeast Missouri Ozarks Regional Restoration Plan and Environmental Assessment
- PbSS-25 2016-10 Draft SFCMA OU-2 Feasibility Study, River and Non-Residential Areas, St. Francois County Mining Area, St. Francois County, Missouri
- PbSS-26 AMEC Naturally Occurring Lead in Mined Areas

Page **1** of **1**

wood.

July 9, 2018

Mr. Chris Neaville
Asset Development Director
The Doe Run Company
881 Main Street
Herculaneum, MO 63048

Subject: St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment, May 23, 2018, US Army Corps of Engineers

Dear Mr. Neaville:

This document provides comments by Wood Environment and Infrastructure Solutions, Inc. (Wood) on the above referenced Feasibility Study (FS) and certain appendices to the document. Broad comments are initially provided both on the FS and Environmental Assessment, followed by comments on certain appendices to the FS.

Poorly Defined Study Goals Will Undermine Success

The general goal of ecological restoration in this river system is admirable and important. The study goal as stated in Section 3.7 is:

> *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.*

Alternatives were developed and evaluated in the study, and federal participation in restoring habitat functionality was considered justified. However, the study goal includes another statement that indicates an overly simplistic notion for ecological restoration:

> *A fundamental component of meeting this (study) goal is to reestablish, in measurable terms, the dynamic balance between the physical, chemical and biological habitat components that formerly existed in the watershed.*

There are several problems with this statement. First, the reference time period for "formerly existed' (assumed to be the base condition) is not referenced. If this reference period is immediately prior to the underground mining era, there is no measure of the characteristics of the environment under the base condition. Assumptions regarding lead in sediments and floodplains under the base condition cannot be evaluated independently of other potential stressors that may include the expansive influences of surface mining, legacy and ongoing effects of prior mill dams, deforestation, agriculture, and other development pressures. If the reference period is prehistory (i.e., prior to European settlement of the region), the background should include natural, geological sources for lead in the Big River system including that attributable to the expansive presence of galena at the surface. In any case, as part of

wood.

the CSM more information on the reference condition should be provided – and that reference condition should not ignore presence of lead or other metals. In other words, a natural, prehistory state for the Big River would have been one of elevated lead concentrations.

Second, given changes in climate, regional environmental conditions, and environmental stressors, the "dynamic balance" from prior conditions may not be relevant to current or restored conditions – so a more realistic and achievable "fundamental component" should be considered. We recommend that the plan focus on acceptable endpoints in the ecological restoration (such as improved density of mussels, stable banks in particular reaches), with consideration of realistic background conditions. This will generally improve the plan.

Problems with Statement of Objectives and Measures of Effectiveness

A summary of the USACE ecosystem restoration plan objectives, related goals, and measures for ranking effective alternatives is provided in Table 1. We are unsure how the objectives are unique. Specifically, Objectives 1, 2, and 3 and their related goals include reducing sediment loads. Greater clarity on downstream migration could be:

Objective 1 – Protect and restore mussel and fish habitat

Objective 2 – Reduce bank erosion and downstream migration of contaminated sediments

Objective 3 – Improve connectivity and diversity of riparian habitat

For objective 1, the goal for restoring habitat should emphasize those locations in which there is good potential for restoration. The primary measures of success would be increased species populations (or density) and diversity. Monitoring of species, water and sediment quality, and aquatic vegetation should be used to characterize whether habitat has been improved. Related studies on habitat improvements, perhaps to provide more specific measures expected to provide effective habitat could be cited. Rankings of alternatives are useful and are assumed to be relevant to USFWS, USGS, and USACE experience. However, measures of what constitutes good habitat (lead standards, sediment substrate conditions, vegetation, water quality, stream connectivity) are left subjective and amorphous.

For objective 2, it is unclear whether sediment loadings are to be reduced primarily from reducing bank erosion, or whether this objective also requires reduced fine sediment loads to the Big River (including from tributaries). Clarity is also needed on the size fractions of sediment to be assessed, is it all sediment or just the < 2 mm or < 0.25 mm fraction? If the goal is to greatly reduce the loadings from upstream sediments, from mining-impacted sediments with higher lead concentrations, more discussion is needed on the timing of restoration plans relative to sediment and floodplain soil cleanup measures in upstream and neighboring areas – and from potential loadings from former lead and barite mining sites along Mineral Fork, Mill Creek, and other downstream mines.

For objective 3, restoring riparian habitat is somewhat dependent on urbanization, agricultural land use practices, and slopes. The goal here seems to be reduction of bank erosion and sediment loadings from runoff – as well as to add habitat improvements to the Meramec River floodplains, in general. However, additional definition on the objective would be welcome.

wood.

Table 1 – Restoration objectives, related goals and measures for effective alternatives

Objective	Related goals	Measures / Effectiveness Rating for Alternatives
1. Reduce downstream migration of excess mining derived sediment	Protect and restore degraded aquatic and freshwater mussel habitat (enhance aquatic complexity and diversity to support mussels and fish)	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.
2. Reduce quantity of contaminated sediment entering Big R. and Meramec R for 50 years	Reduce bank erosion to reduce sources (influx) of lead to Big River Reduction of sediment loads to increase channel stability	Alternatives that produced aquatic habitat units over 1,000 AAHU and included 5 or more bank stabilization sites were given a high score, alternatives that contributed over 100 AAHU and included 5 or more bank stabilization sites were given a medium score, and all other alternatives were given a low score.
3. Increase riparian habitat connectivity, quantity, diversity and complexity for 50 years	Restore riparian vegetation that has been removed, narrowed. Plant trees. Reduce contaminated sediment loadings into Meramec R and its tributaries	...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.

Notes:

1. AAHU – average annual habitat units
2. Ratings for alternatives were discussed in Section 6.3.2.1. Ratings were made on the basis of completeness (all proposed alternatives scored high), effectiveness (see table above), efficiency (cost-effectiveness as high/medium/low), and acceptability. Acceptability ranked high for alternatives that were independent of an US EPA ROD, and low for alternatives that required a ROD to be compliant with federal law and policy.

The objectives should be based on a good conceptual site model (CSM). It is apparent that the CSM is overly simplistic – that ecological deficits are due solely to the toxicity of lead contaminated sediments from a set of upstream, St. Francois County mines from the underground mining era. Such a simplistic CSM, if wrong or more complex, reduces the chances for successful restoration: lead is not the only stressor, background and natural conditions are not understood, multiple sources and sediment loads are important, mill dams and other structures limit recovery, and other ecological stressors exist. However, if the toxicity of sediments containing lead is so critical, the success of the ecological restoration objectives would also seem to depend on upstream control of toxic loadings from significant sources, from runoff and erosion, Mill Creek, Mineral Fork, and the Big River.

Below, we identify major elements that should be part of CSM, including mining history, Washington County sources, sediment transport and deposition details, background lead levels, and other stressors besides lead. We would encourage that the objectives come from a more complete CSM, and that remedies are developed from a process of integrated environmental assessment.

Incomplete Understanding of Mining History

Section 2.1.2 addresses historic mining, emphasizing mines far upstream along the Big River and generally downplaying or failing to discuss the mining that occurred within the study area. This section should include additional detail on historical mining, including surface mining and barite mining. In the second paragraph of this section (p. 12), surface diggings are called small, but they were the major

wood.

form of mining up until the underground mining era, and they were numerous and vast in overall geographic scale. Furthermore, the early, smaller production of finished lead does not equate to less lead contamination than that of underground mines. On the contrary, the historical mining and smelting practices were so crude that well over 50% of the lead mined would be left in loose soil or smelting wastes on the ground to be washed into streams at the next rain. Often, miners would even wash the lead ore itself directly in the streams.

Next, when the wide-spread nature of this historic mining region is considered, the identified lead surface mine areas of St. Francois County and the lead and barite surface mine areas of Washington and Jefferson counties are extensive and account for an approximate 560 sq. mi area that was largely denuded, uncontrolled, and resulted in historical (and on-going) runoff to lands and tributary streams that drain to the Big River. By comparison, lands associated with mine sites of the underground lead mining era in St. Francois County were notably more limited and comprise an approximate 4-sq. mi area. It should also be noted that surface mining activities expanded in the region due to the abundance of naturally occurring lead at the surface over widespread areas within St. Francois and Washington counties. Consequently, natural mineralization along the river from surface geologic formations, and the more expansive scope of surface mine areas within the region should be included as part of the CSM. In particular, background lead levels should be set to an appropriate level, perhaps for expected soil residuum conditions prior to underground mining (not simply areas outside the Old Lead Belt).

The Big River and its tributaries have also been eroding the lead-bearing Bonneterre and Potosi dolomite formations and the overlying lead-bearing residuum since the drainage basin was formed, creating the naturally elevated lead concentrations. Early accounts of the occurrence of lead within the residuum by Austin (1804) and Lewis (1936) have reported that lead minerals were commonly present in near surface soils and in close association with stream channels of the region:

> *"The mineral existed in great abundance. It was commonly found on slopes near the creeks in a clay of deep red color. Frequently it was found but a few feet below the surface and in huge masses of sometimes a thousand and two thousand pounds, but generally it was in lumps of from one to fifty pounds in weight" (account of Henry Brackenridge in Lewis 1936)*[1].
>
> and,
>
> *"The greatest part or the workings at Mine a Burton are in an open prairie, which rises nearly a hundred feet above the level of the Creek [a tributary of the Big River]. The mines may be said to extend over two thousand acres of land...The mineral is found within two feet of the surface of the earth, and it is seldom the miners dig deeper than ten feet; not that the mineral discontinues, but because they find it troublesome to raise it out of the ground..." (Austin 1804)*[2].

Given the vast scale and centuries of mining activities in the broader region, addressing a more rational background condition is essential.

---

[1] Lewis, D. F. 1936. Economic and Social Life in the French Villages of Missouri. Master's Thesis, University of Missouri.

[2] Austin, Moses. 1804. Description of the Lead Mines in Upper Louisiana. Appendix B in Report of the Geological Survey of the Status of Missouri Including Field Work of 1873-1874, by Garland Broadhead, State Geologist, Bureau of Geology and Mines, Jefferson City, MO, 1874.

wood.

During the underground mining era wastes were handled in many ways, including extensive use of chat for construction, fill and other uses. The brief summary of the mining wastes indicates a biased view that fines were selectively generated by the underground mining operations, and selectively deposited in sensitive habitats. In fact, chat and other mining materials were used heavily by rail operations, road construction, and in agriculture.

Additionally, information within the document and on Figure 2-10 indicates direct discharge of mine wastes to the Big River. Perhaps the most thorough discussion of early milling in St. Francois County is from Watt (1917)[3]. Watt actually says that tailings were NOT discharged into streams, in order "to prevent pollution" (p. 396) and were either impounded or filtered through chat piles. Any theory of routine, continuing slime discharges to the Big River, which supposedly ended only when mining stopped in 1972, fails to reflect the mining practices evident within the Big River.

There is an extensive history of the OLB and other Missouri mining practices described in the literature. Consideration of mining industry sources for matters of mining, mine processing, waste management, and regional geology are critical for the development of the CSM.

Contributions from Mining Districts in Washington County

The FS and its supporting analyses and studies repeatedly reflect a flawed CSM by diminishing the contributing effects of mining districts outside of St. François County. As indicated in Figure 1, other mining districts are recognized by EPA (notably in Washington and Jefferson County) that have made extensive contributions to the sediments of the lower Big River, including the Washington County Lead District (WCLD), the Washington County Barite District (WCBD), Valles Mines, and the Southwest Jefferson County District. In fact the FS suggests that tributaries draining the Washington County Barite District have high concentrations of barite but are low in lead. As such, they are not considered to be important contributors of lead to the Big River.

[3] Watt, A.P., 1917. Concentration Practice in Southeast Missouri, Transactions of the American Institute of Mining Engineers, Vol. LVII p. 309, at 370-371 and Figures 4, 27-30, (Paper Presented at St. Louis Meeting, October 1917).

wood.

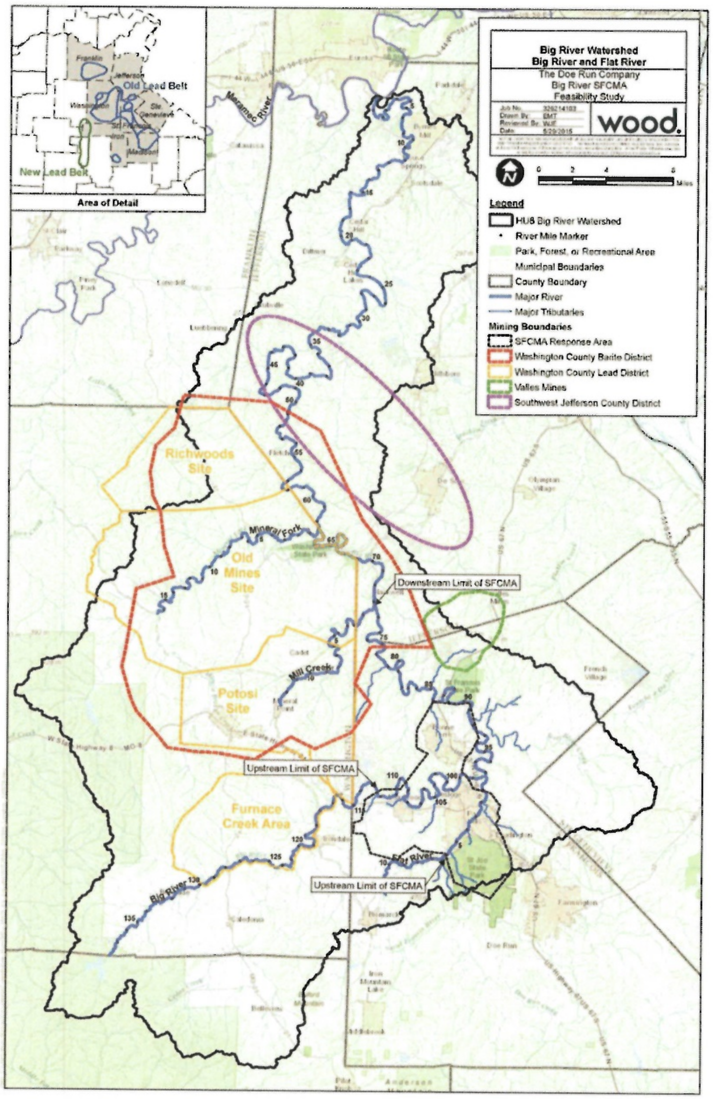


Figure 1. Historical Mining Districts within the Big River Watershed

Lead has been recognized as a contaminant in barite mill effluent since at least 1979 (USEPA 1979)[4]. Indeed, lead is often co-located with barite (see inset) and in recent sampling of sediments downstream of the Star Mine tailings impoundment were found to contain 570 to 1,000 mg/kg lead years after mining ceased (Integral 2014) confirming that these facilities are an important source of lead to receiving streams that drain to the Big River downstream of the SFCMA.

Barite/Galena Specimen from Washington County, MO
(Photo taken of specimen from Missouri Mines Historical Site)

The importance of WCBD contributions of mining related metals to sediments and floodplains of the Big River is significant. As described in Section 1.8, distinct differences in geochemistry and mining history between St. Francois and Washington counties is evident in floodplain soil composition from sites above and below Mill Creek. Because very little barite mining occurred in St. Francois County and the SFCMA, the presence of barium in floodplain soils demonstrates the important contribution of runoff from uncontrolled mine sites within Washington County to the sediments and floodplains of the Big River (MDNR 2010)[5].

In order to evaluate the potential differences and contributions from mining sites within the watershed, a geo-archaeological investigation of selected floodplains of the Big River (Amec 2014)[6] was performed by Wood (formerly Amec) to establish a temporal geo-stratigraphy of selected areas of the Big River floodplain. The purpose of this investigation was to evaluate the geochemical characteristics of floodplain soils as they relate to the periods of historical land use and mining. The approach used a combination of geological and archaeological investigation techniques to characterize floodplain soil composition at two sites along the Big River (St. Francois State Park and Washington State Park) relative to different periods of human use and settlement. Specific objectives were to identify soils associated with the pre-European settlement period (i.e., pre-1720s pre-mining background era), the early surficial lead mining period (i.e., 1720s to 1860s), the underground lead mining era (i.e., 1870 to 1970s) and the barite mining era (1860s to 1999).

The study results were used to evaluate the extent to which lead in floodplain soils originated from natural weathering of parent material (i.e., naturally occurring background lead), and that which is attributable to human activities within the landscape before and approximately after the advent of hard rock mining. Key findings that are important to a complete CSM of the Big River include the following:

1. Much of the floodplain soils examined were found to have been deposited prior to the European settlement of the region in the 1720s.

[4] United States Environmental Protection Agency (USEPA). 1979. Development document for effluent limitation guidelines and new source performance standards for the mineral mining and processing point source category. USEPA, Office of Water and Hazardous Materials. Washington DC. July 1979.

[5] Missouri Department of Natural Resources (MDNR), Water Protection Program. 2010a. Total Maximum Daily Loads (TMDL) for Big River, Flat River Creek, and Shaw Branch, Jefferson, St. Francois and Washington Counties, Missouri. Approved March 24, 2010. Retrieved from http://dnr.mo.gov/env/wpp/tmdl/2074-2080-2168-2170-big-r-tmdl.pdf (accessed November 2014).

[6] Amec. 2014. Geo-Archaeological Analysis of Big River Floodplains, Report prepared for The Doe Run Company, St. Louis, MO

wood.

2. Elevated lead concentrations were observed to occur in deeper floodplain soils, which reflect the presence of naturally occurring lead in floodplain soils. Indeed, accounts from Schoolcraft (1821) include the following which demonstrates clearly that naturally occurring lead occurred in floodplain soils:

   > *"The ore worked is galena, or sulphuret of lead, which is found in abundance, and smelts very easily, yielding from sixty to seventy per cent, of metallick lead in the large way. It is found in* ***alluvial soil*** [emphasis added]*, along with sulphate of barytes, radiated quartz, and pyrites, and also veins in primitive limestone*." (Schoolcraft 1821, page 4).

3. Elevated soil lead concentrations as noted by Pavlowsky et al. (2010) exceeded 10,000 mg/kg in some locations at depth in soils that predated European settlement of the region. Such isolated and naturally occurring lead deposits within the weathered residuum are consistent with the "nugget" effect described by Integral (2014)[7].Effects of widespread land disturbances from Surface Lead Mining Era and the inefficient recovery rates of the period, were demonstrated to correspond to elevated concentrations of lead and zinc in floodplain sediment deposits that preceded the advent of hard rock mining in the St. Francois County Mine Area (SFCMA).

4. Results of floodplain core sampling at St. Francois State Park reflect a notable reduction of lead in soils near the surface that likely reflects a change in watershed land use and mining practices that are distinctly different from those evident during the Surface Lead Mining Era. The shift from surface mining practices to the hard rock mining practices (post 1869), coupled with general revegetation and reduced erosion of highly disturbed landscapes dramatically reduced the contribution of lead to the Big River and its associated floodplains, and points to the benefits of natural recovery mechanisms.

5. Within St. Francois State Park, core sample values of barium ranged from 47 to 228 mg/kg whereas barium values in similar samples from Washington State Park exceeded 1,600 mg/kg. Barite mining within the region has been shown to be primarily associated with mines within Washington and Jefferson County and few St. Francois County mines downstream of St. Francois State Park. This result reflects the landscape position of the sampling location of the geo-archaeology study within Washington State Park as being downstream of Mill Creek and, therefore, subject to the contributing influences related to the barite mining. Because lead mineralization is co-located in surface soils along with barite, and patterns of lead concentrations in floodplain soils at Washington State Park parallel those of barium, it is clear that mining-related effects on soils and sediments downstream of Mill Creek are dominated by activities within the Washington County Barite District (WCBD) and Washington County Lead District (WCLD).

6. Outside the SFCMA, geochemical signatures that correlate to influences from barite mining within Washington County reflect a notable increase of barium and lead in shallower floodplain sediments from Washington State Park. Clearly, sediment chemistry within floodplain soils in Washington State Park has been strongly influenced by inputs from extensive barite and lead mining in the WCBD. Key characteristics of sediment geochemistry include:

[7] Integral. 2014. Background Soil Lead Concentrations in the Big River Watershed, Report prepared for The Doe Run Company, St. Louis, MO.

wood.

- Notable decreases in lead concentrations within the Big River within the SFCMA downstream to the confluence with Mill Creek,
- Increased lead concentrations downstream of Mill Creek, and
- Corresponding increased concentrations of barite downstream of Mill Creek.

The fact that the increase in elevated lead levels in cores from Washington State Park are paralleled by increases in barium, strongly indicates that barite surface mining activities within Washington County are therefore, expected to have been important contributors of lead concentrations in floodplains below Mill Creek. Historic mining within Washington and St. Francois County, coupled with naturally occurring lead associated with the unique geology of this region have combined to shape a complex floodplain geochemistry within Washington State Park and other floodplains of the Big River.

The following findings from the geo-archaeological investigation have important implications for formulating a comprehensive CSM for the Big River:

- Floodplains of the Big River within St. Francois County contain COCs that originate from both natural and anthropogenic sources.
- Concentrations of COCs vary spatially within floodplain soils.
- Notably concentrations of lead in near surface floodplain core samples demonstrate:
  - Near surface floodplain soils contain lower concentrations of COCs.
  - Potential benefits of natural recovery mechanisms in which soils with low COC concentrations are burying deeper floodplain soils.
- Sediment and floodplain soil contamination downstream of Mill Creek may be appropriately considered in conjunction with potential sources from barite and lead mining within the WCBD as they are not characteristic of the conditions considered within St. Francois County.

Unfortunately it is noted that the FS and its supporting documents do not recognize or consider the effects of contributions from other mining districts in Washington and Jefferson County. All evidence, correlations, and conclusions seem to reflect an unbalanced perspective that points singularly to the underground mining activities in St. Francois County. This is troublesome as data offered by Roberts et al (2016)[8] are particularly useful in pointing to a different conclusion. For example, while Roberts et al (2016) only offers analyses and correlations between mussel and Corbicula studies and lead, they do report sediment chemistry data that includes barium. For example, Table 2 below (extracted from Roberts et al, Table C1) summarizes the barium concentrations identified in sediments from the Big River. Data from this table clearly support the conclusions of the geo-archaeological analysis and point to the importance of sediment contributions from Washington County where barite was extensively mined. For example, in all sediment fractions the average concentration of barium in sediments was higher in the Big River as compared to reference locations. Notably the results of the finer sediment fraction reflects an average concentration of more than 1,100 ppm, which is six times that of the average from reference locations. It is also noted that no attempt is made by Roberts et al to assess

[8] Roberts, A, J. Hundley, D. Mosby, A. Rosenberger, K. Bouska, B. Simmons and G. Lindner. 2016. Quantitative Survey of Freshwater Mussels (Unionoidea) and Assessment of Sediment Contamination in the Big River, Missouri

wood.

the correlational relationship between barium in sediments and unionid mussel distribution and composition.

Table 2. Summary of Big River Sediment Barium Concentration

	Barium Concentration (ppm)		
Site Name¶	<0.25 mm	<2 mm	Bulk
Reference Sites			
Mer75.6	265	244	239
Big194	68	307	323
Mean	**166.5**	**275.5**	**281**
Big River Sites			
Big2.5	324	319	279
Big16.5	282	371	360
Big20.5	472	276	258
Big30.7	380	337	336
Big41	605	422	316
Big47	414	317	370
Big67.5	1131	1455	502
Big68	1444	550	573
Big86	728	499	449
Big91	1374	370	304
Big105.7	624	531	475
Big106.5	4026	798	1004
Big107.5	1189	366	451
Big108	797	369	363
Big113	2463	461	476
Big113.5	1541	452	470
Mean	**1112.1**	**493.3**	**436.6**

Source: Roberts, et al, 2016

Sediment Transport and Deposition

Broad Comments

The report provides a description of mine-related sediments, which include chat (4 – 16 mm, fine gravel), tailings (0.06 – 0.2 mm, sand), and slime (<63 µm, smaller than fine clay). The report appropriately describes the general relationship between particle size and relative transport distances: chat—larger sized particles with a relatively short transport distance closer to the source; tailings – medium sized particles with a somewhat longer transport distance but still relatively close to the source and finer grained materials, slimes, that may be transported longer distances as suspended or wash load.

However, without significant explanation, the report hypothesizes that slimes would be transported as a larger mass. Specifically, the first paragraph of p. 13 contains two sentences that are problematic:

wood.

These fine grained materials are transported more rapidly within the Big River and have been transported and deposited downstream. As described above, mine wastes and associated heavy metals have been transported en masse from the releases in St. Francois County and are completely incorporated into floodplain soils and in-stream sediments from Leadwood to the Meramec River Confluence.

There is no description above detailing how there was "en masse" transport and how the materials are "completely incorporated into floodplain soils and in-stream sediments". River and floodplain sediments come from multiple sources, varied events, mix and are transported differently depending on sediment load and particle sizes, and are typically well distributed to downstream load, floodplain storage, and in-river sediments. The idea for selective erosion from the St. Francois County mining areas, followed by selective deposition, is faulty. The argument is largely unscientific, based mainly on evidence that lead is present in the floodplain sediments, extensively and at depth.

Slimes are simply finer materials and lead concentrations can vary widely. Slimes might accumulate in quiescent areas during low flow and be flushed down-river during high flow events, but based on fundamental sediment transport processes, fine sediments would remain suspended and disperse over very large distances (tens to hundreds of miles), rather than be transported as a larger mass. Fine sediments suspended during these events would be mixed with sediments from upstream sources.

Further, the mass balance that needs be considered if the deposition occurred as hypothesized by Pavlowsky (2010) suffers from serious flaws. In addition to other issues, in order to rectify a mass balance considering the hypothesis propounded by Pavlowsky, one would have to assume that chat and tailings comprised nearly 100% of the sediment load for more than 100 years and it all was deposited in the floodplain. Considering the recent study regarding sediment transport and loading in the Big River, as well as other reported mining investigations and sediment transport [Swanson et al. (2008)[9]; Walling & Owens (2003)[10]], these assumptions are unrealistic. The FS should recognize these limitations in its development of an appropriate CSM.

Specific Comments

- The document states (Section 2.3.5) that failure of one or more old mill dams is assumed releasing stored sediments. It is not certain if this assumption has any significant consequences to the EA / FS, but no explanation is given as to why there would not be dam removal or structure stabilization action taken to preclude this potential.
- Section 2.4.3. Reference to "31.2 million tons per year of sediment from eroding banks". Where did this number come from? Seems extremely high considering paragraph immediately preceding this paragraph indicates 33,700 tons eroded from floodplain (banks) annually. A total of 31.2 million tons/year would be equivalent to 78.8 tons/LF of river. Is this an estimate for all streams within the Big River watershed? Note that it exceeds the estimated SSL at Byrnesville (227,103 tons/year) by a factor of 137. Even considering delivery ratio, this number must be an error.

[9] Swanson, K. M., E. Watson, R Aalto, J. W. Lauer, M. T. Bera, A. Marshall, M. P. Taylor, S. C. Apte, and W. E. Dietrich (2008), Sediment Load and Floodplain Deposition Rates: Comparison of the Fly and Strickland Rivers, Papua New Guinea, J. Geophys. Res., 113, F01S03, doi: 10.1029/2006JF000623.

[10] Walling, D. E., and P. N. Owens (2003), The Role of Overbank Floodplain Sedimentation in Catchment Contaminant Budgets, Hydrobiologica 494: 83-91.

wood.

- Similar to Appendix H, there are various statements made that are not supported by a reference or explanation. There is reference to work completed and apparently considered for the FS that is not provided in the EA-FS (i.e., the SWAT analysis referenced in Appendix H and stated in this document to be work done by St. Louis University). But there is no discussion of findings. While tributary loadings are apparently considered work to be addressed by the sponsor (MDNR), there is no statement about assumptions made or expectations for those tributary loadings.
- There is no clear explanation regarding grade control structures. Specifically, there does not appear to be a description of the stream reaches that are degrading that may be subject to improvement by grade control structures. We suggest a more thorough analysis and presentation of system needs that can be used to support the basis for proposed restoration measures and their benefits.
- Section 2.2.5.1. Statement indicating "accelerated changes" seems to imply an interpretation of increasing stream instability. It is not clear what the source of this is. Table 2-1 of the FS indicates increased "lateral movement" in 2007 – 2016 than during 1990 – 2007. However, the average bank erosion volume during those periods was very similar. The geometric parameters for bank failure/erosion areas is likely very difficult to define and subjective (i.e., "top" of bank, "bottom" of bank). Sporadic nature of large bank failures, relationship to conditions prior to a high flow event resulting from one or more preceding high flow events, all make bank erosion difficult to assign to a specific cause and are not just an annual phenomenon (i.e., affected by or have an influence on conditions greater than one year).
- The concentrations of lead and other metals in the bedload sediments and suspended sediments has decreased and will continue to decrease over time due to natural processes. The FS states the following:

  "*Migration of contaminated sediments downstream threaten the health of the lower Big River and Meramec River. It is estimated that the plume of contaminated bedload would continue to migrate downstream and would adversely affect the remaining viable mussel beds and aquatic biota in the Big River and Meramec River into the future.*"(page 29).

  However, this statement is misleading and suggests that unless action is take immediately, a large plume of contaminated bedload (presumably previously historically unsurpassed) is in the process of migrating downstream. In contrast, data from multiple sources suggests that in fact, that conditions are actually improving within the Big River:

  1. Lead concentrations in sediments such as those near Brown's Ford (River km 79) demonstrate improvement from historical levels that ranged from 1,800 to 3,900 mg/kg in pools (Schmitt and Finger 1982)[11], to 245 mg/kg (Pavlowsky, et al 2010).
  2. Lead concentrations in vertical cores from floodplains of the Big River reflect a trend in which prior sediments containing elevated lead concentrations have been buried by cleaner sediments with lower lead concentrations (see Pavlowsky et al 2010, Figure 26 and similar figures from Amec 2014 geo-archaeology study).

[11] C. Schmitt and S Finger. 1982. The dynamics of metals from past and present mining activities in the Big and Black River watersheds, southeastern Missouri. Final Report for the U.S. Army Corps of Engineers, St. Louis District. Project No. DACW43-80-0109.

wood.

3. Bivalve (unionid mussels and *Corbicula fluminea*) tissue lead concentrations have demonstrated improvement from historical levels that ranged from 386 and 245 ug/g dry weight at the Browns Ford and Washington State Park locations (Schmitt and Finger 1982), to a mean of 74 ug/g (Roberts et al 2016).

These and other data not only point to improving conditions within the Big River but also cast real doubt on the veracity of the claim that a "plume" of contaminated sediments that is poised for transport to the lower Big River demands urgency in restoration measures to protect the aquatic ecosystems of the lower Big River. Instead, this points more clearly to the need for a CSM that looks at the system more comprehensively and recognizes the effectiveness of remedial actions coupled with ongoing natural recovery processes.

Trends in Freshwater Mussel Communities

The FS presents in Sections 2.7.2 and 3.3.2.5 a narrow characterization of the factors that may be contributing to the distribution and composition of unionid mussel communities within the Big River. Specifically, based upon the work of Roberts et al (2016), it is suggested that freshwater mussel abundance and distribution is based solely on lead concentrations.

- The effect of other environmental stressors on mussel abundance and distribution is not recognized or considered by the USACE (e.g., dams, low water crossings, land use, agriculture, other point source and non-point source discharges). Both of the cited studies (Roberts et al., 2010; Roberts et al., 2016) fail to evaluate the effect of other important environmental factors that are known to control unionid mussel populations. For example, the adverse effect of dams on mussels is well documented in the scientific literature and referenced at high level in the FS, but not truly evaluated. As summarized by Williams et al (1993)[12], the decline of freshwater mussels during the past century has involved a variety of threats, the single most important being the destruction of habitat. Mussels are sessile organisms and are considered good indicators of the health of aquatic ecosystems. They are dependent on good water quality and physical habitat conditions and an environment that will support populations of host fish. Destruction of mussel habitat has ranged from the obvious-dams, dredging, and channelization- to the more subtle- siltation and contaminants. Dams change the physical, chemical, and biological environment of streams, both upstream and downstream of the structure, to the point that approximately 30% to 60% of the mussel fauna is destroyed.

  There is little consideration given to the presence of five mill dams and numerous low water crossings on the Big River and the potential deleterious impacts that they may have had on mussel communities. Figure 2 provides the locations of mill dams and low water crossings superimposed on the mussel results of Roberts et al 2008 studies and appears to reflect a continuing residual effect on unionid mussels due to mill dam legacy effects. Roberts et al (2016) however, only include the following reference to mill dams:

  > *"Potential impacts (unrelated to heavy metal contamination) that are common to these watersheds are bank and channel degradation, other contaminants, sedimentation, and indirect effects from mill dams."* (Roberts et al, 2016, p. 10)

[12] Williams, James D., Melvin L. Warren, Jr., Kevin S. Cummings, John L. Harris, and Richard J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries Vol 18, No. 9.

wood.

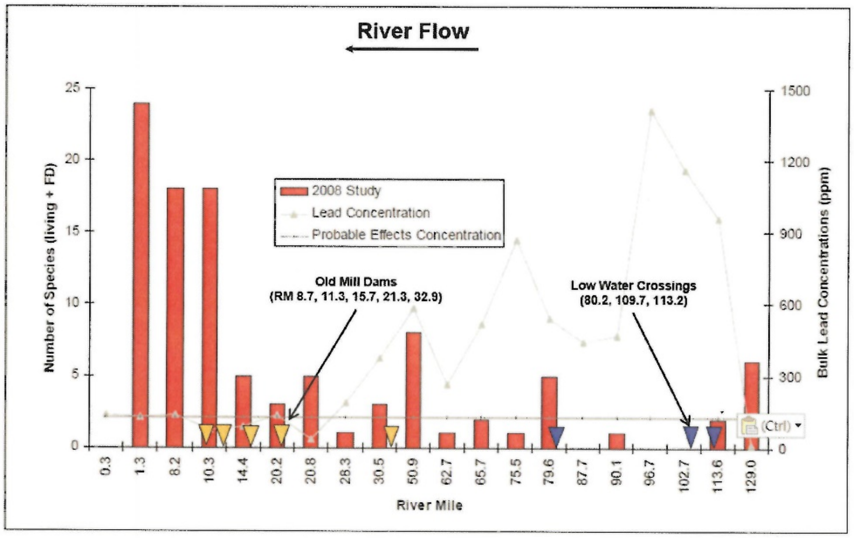


Figure 2. Relationship Between Old Mill Dams and Low Water Crossings and Mussel Species Richness

Effects of mill dams on unionid mussels should be further evaluated to develop a more comprehensive CSM that would inform restoration measures appropriate to the Big River system.

Correlations suggested between sediment lead concentration and unionid mussel density and/or species richness are overly simplistic and do not recognize the full range of factors that may influence mussel populations in the Big River. For example, Figure 3 demonstrates that stream gradient is equally inversely correlated with trends in mussel populations in the Big River from 2008. Observations in the upper reaches of the Big River demonstrate that substrates are highly unstable (loose gravel) in many locations or dominated by bedrock—neither of which are suitable for unionid mussel establishment.

wood.

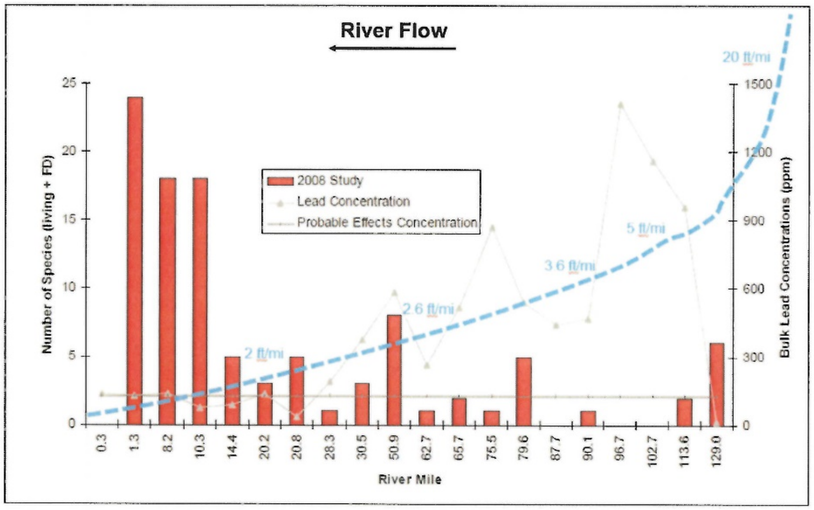


Figure 3. Relationship Between Big River Gradient and Unionid Mussel Species Richness

Further, Roberts et al (2016) do not provide an adequate explanation of the contributing effect of sediment grain size on the apparent precipitous decline in unionid density at Site Big20.5 (see Figure 11 below). This site is clearly dominated by fine-grained sediments that apparently has exerted a notable influence on mussel density. This relationship is recognized by the authors as suggested in the following text:

> *"Site Big20.5 is an outlier among the lower Big River sites (sites downstream of Big67.5), with an average mussel density of 0.02. This site is located in an atypical, predominately sandy reach of the Big River, which may have affected mussel density and distribution. Other Missouri streams with primarily sand substrate tend to naturally have low mussel densities (Andy Roberts pers. obs. and Roberts et al. 1997)." (Roberts et al, 2016, p. 18)*

The FS repeatedly conflates the multiple factors that may be impacting the mussel communities, such as the physical effects of fine sedimentation, yet points incorrectly to toxicity of metals contamination as the primary factor. In order that the benefits associated with the proposed restoration activities can be properly evaluated, recognition of these physical limitations of the stream need to be properly assessed.

wood.

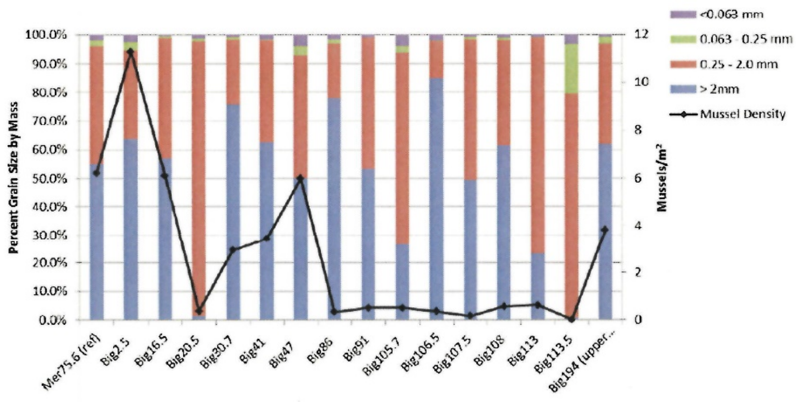


Figure 11: Grain size distribution of sediments by percent mass and mussel density collected in the Big River and Meramec Rivers. The USGS grain size fraction analysis does not subdivide size classes > 2mm.

(Source: Roberts et al 2016)

- Nationwide declines of freshwater mussel species, including many of the federally listed endangered species (e.g. *Leptodea leptodon, Plethobasus cyphyus, Cumberlandia monodonta*) occurring within the study area, have occurred as a result of numerous non-mining activities. The referenced studies (Roberts et al., 2010; Roberts et al., 2016), however, attribute all variability in species abundance to metals from releases resulting from mining activities. Other non-mining stressors should also be considered before concluding that mining activities are solely responsible for observed mussel distributions. Similarly, no consideration was given to historical baseline conditions associated with naturally occurring metals in the Big River Watershed.
- Reference sites selected by Roberts et al. 2010 on the Bourbeuse and Meramec Rivers are characterized as being located in river reaches having lower channel slopes relative to the middle and upper portions of the Big River. While they do allow comparison to Big River sampling locations near the mouth of the Big River, they are not appropriate for comparisons to other reaches of the Big River. Physical conditions such as substrate coarseness, water depth, and current velocity were different at the reference sites when compared to the mining and downstream locations. Lack of consistency in physical conditions between reference sites and study sites is the likely explanation for varying species composition and density, a factor not considered in the study. Roberts et al. 2016 used additional sites from the Gasconade River and compared relationships of species richness with drainage area for each river system, yet many of the same issues regarding differences in physical conditions between reference and sampling locations still exists.

Several of the assumptions (page B-10 of Appendix B) related to the rate of lead effects on mussel communities rely on conclusions from Roberts et al. 2009 that are unreliable due to the main issues raised above. A variety of other factors (e.g. stream gradient, discharge, velocity, embeddedness) besides lead concentrations influence mussel distributions and were not addressed by Roberts et al.

wood.

2009. Applying a rate of movement downstream for lead effects based on the results of Roberts et al. 2009 could be misleading and overestimate negative effects.

Accounting for Background Lead

The report failed to properly estimate or account for background lead concentrations in the Big River watershed given the area's prior geologic and anthropomorphic history. Section 1.6.3 states "contaminated sediment ... has been defined by the Trustees as concentrations over the ... PEC." This does not take into account site specific risks or background lead concentrations which may be above 128 mg/kg.

Section 2.2.3, presents background lead concentration to be 53 mg/kg in St. Francois County and 62 mg/kg in Jefferson County as calculated using USGS PLUTO database (2018). There is insufficient detail to understand how this value was calculated or what it represents (e.g., floodplain soils vs. upland soils vs. sediments). Additional sources of data are available to better define background and should be considered.[13]

Appropriate and representative background threshold values (BTV) are critical in determining many things at a contaminated site. These include the level of risk not associated with site activities, delineation of site contamination extent, and confirmation of site remediation or source removal activities. The following from USEPA guidance[14] is particularly relevant in understanding a proper definition of background:

> "For the purposes of this guidance, background refers to substances or locations that are not influenced by the releases from a site, and are usually described as naturally occurring or anthropogenic:
>
> - *Naturally occurring* - substances present in the environment in forms that have not been influenced by human activity; and,
> - *Anthropogenic* - natural and human-made substances present in the environment as a result of human activities (not specifically related to the CERCLA site in question)."

To better understand the factors affecting site characteristics under these two points, a summary of both natural and anthropogenic aspects in play at the site is useful:

Naturally Occurring:

- The region was extensively mineralized with typical sulfide minerals (especially lead, but also copper, zinc, cadmium) about 250-300 million years ago. The original carbonate rock probably had around 10 ppm lead (Goldschmidt 1954[15]) and mineralization that over time introduced

[13] Existing data sets from the U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey indicate that background soil lead concentrations in the Big River watershed are elevated and variable, with 20 to 35 percent of the samples exceeding 400 mg/kg lead. A formal background soil lead study produced similar results, with 39 percent of samples exceeding 400 mg/kg lead. See Sources of Lead, Background Soil Lead Concentrations In The Big River Watershed, Ver.2, Integral Consulting, Inc. (2014)

[14] U.S. Environmental Protection Agency, 2002. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites, Office of Emergency and Remedial Response Washington, DC 20460, EPA 540-R-01-003 OSWER 9285.7-41.

[15] Goldschmidt, V.M. 1954. Geochemistry. Edited by Alex Muir, Clarendon Press.

wood.

various amounts of galena (87% lead by weight). Mineralization was not uniform but depended on the availability of mineralizing fluids, appropriate geologic conditions, and available flow paths.

- Once erosion exposed the carbonate rock, further weathering left in-place residual soils at the surface and near surface soils that were greatly enriched with the less-soluble lead minerals, oftentimes resulting in ore bodies.

Anthropogenic:

- Surface mining era activities that were initiated in the early 1720s (perhaps earlier by Native Americans, but definitely by 1721 by French explorer Philippe Francois Renault) (Anthropogenic)
- Underground hard-rock mining era activities that began in 1869 (beginning of any non-background effects)

This BTV value is an important factor in understanding the complexity of the site and has particular relevance as a check-point in the ecological risk assessment and the development of an appropriate and achievable restoration. Key inputs of this value to the alternative development process include establishment of threshold values against which aquatic habitats are measured and the development of appropriate restoration strategies for floodplain, sediments and water quality.

Isolation of Lead as a Primary Stressor

Section 1.6.3 cites the Probable Effects Concentration (PEC) for lead at 128 ppm. The PEC is derived as guidance for triggering other evaluations, not for setting a harmful level. Site-specific criteria are most helpful, especially when lead is often unavailable (when present in sulfide minerals and with hard, alkaline waters). From the US EPA BERA (2006), USGS (2009), and Amec (2013), site-specific bioassays of *Hyallela azteca* on Big River sediments showed no evidence of toxicity relative to controls at 128 ppm and limited toxicity at levels of 1280 ppm (10 times the PEC). Lead effects on *Hyallela azteca* are often pronounced (a sensitive species for metals contamination), but the lack of a toxic response indicates poor bioavailability. In addition, other metals, such as zinc and cadmium, also have effects only at several times their respective PEC's.

When stating lead concentrations, it's important to note that these determinations are made only on the fractions of sediments less than 2 mm. For many sediment areas in this gravel bed river, extensive sieving is required to generate enough sediment needed for the test and the more coarse granular portions of sediment are ignored.

The FS, in Section 2.7, states that the Meramec River Basin is considered to be in relatively good health and acknowledges "a number of factors, along with metals toxicity, that have contributed to the degradation of aquatic habitats and have affected fish and wildlife resources in the lower Big River". In spite of this admission, the FS identifies lead/metals contamination as the sole primary stressor. Land use and ecological disturbance are generically mentioned as "drivers" in Section 3.3.1 but the FS does not attempt to quantify impacts from these drivers. As stated above in "Poor or Incomplete Summary of Mining History" large scale land cover alteration has historically occurred in conjunction with the surface mining era and in conjunction with agricultural practices that has had dramatic effects on sediment transport to the Big River. Furthermore, Section 2.3.4.1 references historic mill dams as it relates to sediment transport, but no mention is made regarding their recognized impact on aquatic biota (notably unionid mussel species). Please see additional notes on this subject below under "Appendix B—Habitat Evaluation and Quantification".

wood.

Lack of Details on Alternatives

The following items made review and evaluation of the alternatives difficult:

- Section 3.9 Management Measures lists a variety of technologies but does not provide details. Additional details for each measure, including pros/cons and the rationale for screening would be helpful. It is unclear why BMPs were not retained. Bioengineering measures should be evaluated carefully with consideration of the hydraulic conditions of the Big River. Due to the flashy nature of the system (>20 ft stage increases), some bioengineering measures may be inappropriate and screened out prior to developing alternatives.
- Section 3.10 Formulation Strategies would benefit significantly with a presentation of details of each alternative, including listing management measures, rationale for selecting, maps, quantities, and costs.
- Section 3.12 requires additional narrative describing rationale for ranking of each alternative.
- Table 3-3 requires a narrative outlining how quantities were scoped for each alternative
- There is no discussion regarding length of construction for each alternative. Some alternatives could take years or decades to complete.
- Section 4.0 "Long-term benefits to area habitats would far outweigh the short-term impacts." This is conjecture and could be potentially a significant oversight. Large scale construction would require years and significant disturbance to complete.
- Table 4-1 cannot be reviewed without a description of alternatives
- Appendix I: Details related to cost estimates are not available. It is unclear how costs were estimated, what unit rates were used, or what the time scale and discount rate for each alternative was. Uncertainties associated with these costs would impact the cost/benefit analysis presented in the main document.

Elements of the Integrated Environmental Assessment

Chapter 1.0 Introduction

Section 1.6. Purpose and Need.

- The Draft Restoration Feasibility Study includes an Environmental Assessment and therefore serves as an integrated document that is intended to meet the requirements of the National Environmental Policy Act of 1969 (NEPA). As required by NEPA and its implementing regulations (40 C.F.R. Part 1500 and 43 C.F.R. Part 46) the project Purpose and Need must be established to justify the action under consideration. The document states the purpose of the draft feasibility study with integrated Environmental Assessment (EA) is to "assess the environmental effects of a reasonable range of alternatives or actions taken by the USACE, including the no action plan, prior to making decisions." The Purpose and Need statement guides the alternatives screening and development process that is used to determine the range of reasonable alternatives to be studied. The Purpose and Need should be established for the action and not for the document.
- The document states that the purpose of the Restoration Feasibility Study is "to determine a National Ecosystem Restoration (NER) plan that addressed the degradation of the aquatic ecosystem and altered geomorphic characteristics within the study area caused by human-induced modifications." The need for the project is not clearly stated. Is the project needed to

wood.

address environmental problems occurring in the Meramec River Basin? In the Study Area? Is the project needed to develop a comprehensive plan for the Meramec River Basin? Additionally, the Need for the Federal Action as described in Chapter 3 does not address the need for the project under NEPA.

Section 1.7. Resources of National Significance

- This is not a standard section in an EA. These considerations are inherent in the determination of severity of impact (i.e. context and intensity). Significance should be determined for all resources evaluated.

Section 1.8. Scoping and Coordination

- Scoping input is not summarized in the document or Appendix A. Therefore it cannot be determined if comments received during scoping assisted the USACE with informed decision-making.

Chapter 2.0 Existing and Future without Project Conditions.

The text notes that this chapter is not a comprehensive discussion of every resource within the study area, but rather focuses on those aspects of the environment that were identified as relevant issues during scoping or may be affected by the considered alternative. It would be helpful to identify those resources not impacted and give a short summary of justification for removing them from detailed review.

Description of Affected Environment (Existing Project Conditions) does not contain a complete description of the Project Area (defined as those portions of the Meramec River Basin located in Jefferson and St. Louis Counties). Specifically the Meramec River portion of the study area is incomplete in the following sections and as such there is no substantive and quantifiable assessment that provides the basis for the project evaluation of impacts:

- Chapter 2.4. Sediment. The introduction to this section describes the impact of sediment to ecological health. However it also includes specific reference to the Big River watershed. Further, there is no recognition that naturally occurring lead and other metals, as well as surface materials left behind by two centuries of early mining, are present in the surficial geology and associated residuum within that have in turn, become part of the terrestrial and aquatic environment.
- Chapter 2.5.3. Big River Water Quality. Text in this section summarizes water quality information collected for the Big River. However, only the last sentence provides a general overview of actions in the watershed which affect the Meramec River water quality. Water quality data for both rivers should be evaluated with similar level of detail to characterize the setting of the study area.
- Chapter 2.7.3. Other Aquatic Organisms fails to identify the invertebrate fauna in the Meramec River Basin only providing detail regarding organisms in the Big River.

Chapter 2.10.2 Economics and Environmental Justice. Table 2-6 Population estimates reported for Jefferson County and St. Louis County differ from those shown in Table 2-5. Both cite the same source.

Chapter 3.0 Alternative Analysis

Chapter 3.12. Screening Evaluation of Initial Array of Alternatives. The assigned ranking in Table 3-2 does not appear to represent the quantitative metrics as described in the text. Each alternative is assigned a ranking, and five of the original 10 alternatives are dismissed from further evaluation. The assigned ranking does not justify this decision as the alternative "Maximize ecosystem befits in the Meramec River" should have been dismissed as it received a ranking of 8 out of 10.

Chapter 3.13. Final Array of Alternatives. Alternatives evaluated in the EA include the following:

- Alternative 1: No Action
- Alternative 2 Subset: Maximize Ecosystem Restoration in the Big River RM 0-10.2
- Alternative 3 Subset: Maximize Ecosystem Restoration in the Big River RM 0-35
- Alternative 4. Maximized Ecosystem Benefits in the Meramec River
- Alternative 5. Maximized Efficiency in the Big River
- Alternative 6 Maximizes Ecosystem Benefits in the Big River
- Alternative 7 Maximized Ecosystem Benefits in the Study Area

The description of the alternatives are supported with superficial narrative that does not effectively distinguish one alternative from another. A summary table that identifies general measures that may be considered as part of each alternative is provided. However there is no description of where proposed bank stabilization or sediment removal features would be established. As such the impacts of these features cannot be effectively analyzed. In addition, the ability of the alternatives to satisfy the project Purpose and Need is not identified or evaluated.

Chapter 4.0 Environmental Effects

This chapter does not evaluate the impacts of all alternatives. The EA states that measures in Alternatives 2, 3 and 6 are included in other alternatives evaluated, and as such it is assumed the effects would be similar to those described for alternatives 4, 5 and 7. There is not enough detail provided for the alternatives to support this conclusion. Therefore there is no way to differentiate the impacts of implementation of these alternatives.

The text states the purpose of characterizing environmental consequences is to determine cumulative effects. Although a cumulative effect analysis is an important part of NEPA, the analysis of environmental effects of each alternative is used to provide a relative comparison of the impact of the alternatives considered to assist with the decision-making process

Environmental Consequences Analysis Not Supported. The technical evaluation of alternatives does not follow established practices for demonstration of reasonable basis for conclusion of the environmental effects. General narrative is provided for many resources that provides a high level description of the environmental consequences, but there is no supported basis to the conclusions given. As per appropriate NEPA practice, the assessment of environmental impacts should be supported by an analysis of "cause and effect" associated with each alternative and each resource under consideration. Rather the analysis provides conclusions that impacts are "expected to be positive" or "expected to have no impact" with no evidence provided to support these conclusions. Where impacts are identified, general statements such as "impacts would be minimized through implementation of best management practices. None of these practices are identified.

Chapter 4.17. Socioeconomics. This section only identifies the quantifiable economic impact of Alternative 5 (later identified as the Tentatively Selected Plan) and concludes that all action alternatives would have a positive effect on socioeconomics. This statement is not supported by the analysis presented.

The impact to recreational, ecological, scenic, or aesthetic resources indicates that some features may change local aesthetics, however minimizing the impact to aesthetic features would be taken into consideration. This statement indicates the alternatives are poorly defined and as such impacts cannot be effectively evaluated.

The summary of impacts presented in Table 4-1 is not supported in the analysis of impacts.

Chapter 5 Cumulative Effects Analysis

This chapter is incomplete. While it is appropriate to include a discussion of cumulative effects, the analysis presented is unsupported and incomplete. For example, the potential for construction related impacts of the proposed alternatives to overlap with impacts of the foreseeable future projects is not identified.

Summary of Technical Deficiencies:

- Purpose and Need is not adequately established.
- Issues identified during scoping are not presented.
- NEPA Alternatives are Undefined and Do Not Support Evaluation of Environmental Consequences.
- Baseline conditions of the affected environment are not accurately or effectively characterized.
- Alternatives under consideration are not clearly defined.
- Environmental Consequences Analysis Not Supported
- Cumulative Effects analysis is not supported.

Additional Editorial Comments:

- References are incomplete in the main document or completely absent in the appendices.
- Section 2.2.6 discusses land cover and land use changes between 1992 and 2011, but does not discuss changes prior to 1992, when significant deforestation, surface mining, and development occurred. For example, the Big River watershed in Washington County was subjected to wide-spread industrialized barite strip mining for over a half-century from before WWII to 1999.[16] Please consider including additional information during this period.
- Climate change (Section 2.14.2) is presented without site specific or regional data. Studies and "consensus" are mentioned but no specific references are presented. It is unclear how this review influenced the alternatives presented in the FS.
- Assumptions of converting floodplains from agriculture to forest may be overly optimistic (hundreds of acres). Have land owners expressed interest in supporting this?

[16] As noted in a Missouri Department of Natural Resources publication, the Washington County Barite Mining Area was "a landscape laid open as if lashed by a ship's cat-o-nine-tails". Hawker, Jon L., 1992, Missouri Landscapes: A Tour through Time, MDNR, Division of Geology and Land Survey.

wood.

- Section 6.1.3 Management of Uncertainty in Benefits Analysis requires additional detail. Please provide in main text or in supporting appendix.
- For the underground mining era, the cultural impacts on the area should be mentioned. The population and community growth was largely driven by mining activities, and mining was one of Missouri's largest industries. There are multiple references available on the cultural history of the area, and these should be summarized and cited. The US and state benefitted materially and culturally from mining activities. Roads, rail, electrical and other utilities, and other major regional infrastructure was built to support mining.
- Information on the USACE Sediment Trap monitoring is valuable, but additional information may be available. Pavlowsky (2016) notes that the Year 2 contracted work was between Aug 1, 2016 and July 31, 2017. Have the results of the Year 2 monitoring affected the conclusions of the sediment trap?

Appendix B – Habitat Evaluation and Quantification

Initial Summary of Document Findings:

- To assess the effects of heavy metals on fishery resources in the Big River Watershed, USACE relies on and cites the study by McKee, Vining, & Sheriff (2010) (see Section 2.7.1). Findings from this study indicate that benthic riffle fish density is negatively correlated with mining-related heavy metals in sediments and surface water from the Big River (McKee et al. 2010).
- USACE suggests that the limiting factor to the abundance and distribution of freshwater mussels in the Big River is high concentrations of lead found in the sediment (see Section 2.7.2). Two studies (Roberts et al., 2010; Roberts et al., 2016) are cited as supporting evidence and several figures (Figures 2-11 and 2-12) are presented to illustrate the findings of these studies. In addition, several key assumptions used in calculating the baseline (existing conditions) and future without project for the Meramec River Freshwater Mussel model relied on conclusions from these studies (see page B-11 of Appendix B).
- USACE summary of other aquatic organisms (i.e. crayfish) point to heavy metals related to previous mining activities that negatively affected populations in the Big River (Allert et al. 2009; see Section 2.7.3).
- Appendix B (Habitat Evaluation and Quantification) and Section 4.11 of the FS attempts to quantify, to the extent possible, aquatic and floodplain ecological benefits resulting from the proposed ecosystem restoration FS. Ecological/habitat benefits within Meramec River floodplains are modeled using the habitat suitability index (HSI) for the black-capped chickadee (BCC). While restoration of floodplain forest in areas where it is currently lacking will benefit BCC, this would be true along any river within the range of BCC. It is not unique to the Meramec River. Section 2.7.4 of the FS points out that 24% of the Big River sites lack a riparian floodplain forest as a result of timber harvest, agriculture, urbanization and other similar land use. It is worth noting that the lack of forested riparian corridors within the Big River sites is not a result of lead contamination from mining activities and should be properly characterized as a stressor on aquatic ecosystems as part of the CSM.

Identified Technical Deficiencies:

Deficiencies with relying on McKee et al. 2010 for determining effects of heavy metals on fisheries resources in the Big River Watershed:

wood.

- The study by McKee et al. 2010 is based on correlations only, and does not show a direct cause and effect. Additionally, there are major interpretive errors associated with this study due to the fact that sediment and water metal concentration data was not collected as part of the study, and instead relied on these data from other studies. As a result, heavy metal concentrations in the sediment samples that were used may not have been collocated with riffle habitats sampled and instead may have been from habitats with different hydrologic regimes that are dissimilar from those sampled, thereby confounding results and conclusions.
- The study by McKee et al. 2010 does not account for multiple determining factors that create inaccurate interpretations of correlations with metals. For example, the study does not account for the significant impacts caused by mill dams on the benthic fish communities or other stressors (e.g. sewage effluent, agriculture, forestry, livestock use) that may significantly impact riffle dwelling fishes at specific sampling locations.

Deficiencies with Allert et al. 2009 for determining effects of heavy metals on crayfish populations in the Big River:

- The study by Allert et al. 2009 has several deficiencies, namely employing inappropriate reference sites for comparison with study sites. Physical conditions such as substrate coarseness, water depth, and current velocity were different at reference sites when compared to the mining and downstream sampling locations. Mining sites had less favorable substrate conditions with smaller particle class size, more homogeneous substrate and higher flow velocities. Lack of consistency in physical conditions between reference sites and study sites could explain the varying species composition and density observed, a factor not considered in the study.

Appendix G – Engineering Design

Initial Summary of Document Findings

- This document is basically a summary of stabilization measures with standard technical standards, guidance, limitations, etc. and there is not much project specific information to assess.
- Generally the information associated with each measure is from established guidance for the type of measure.
- Statements regarding performance (e.g. tons/year capture) may be somewhat arbitrary and not supported due to lack of site-specific information and analysis.

Identified Technical Deficiencies

- The measures in this report appear to be oriented to streambank stabilization, grade control, and sediment capture. It is unclear where grade stabilization enters into use as no indications of stream degradation or aggradation have been identified and reported.
- Appendix H – Hydraulics and Hydrology Analysis, indicates that tributary loads to Big River will be controlled through BMPs. However, no discussion of BMPs is provided. The measures discussed in Appendix G appear to be primarily appropriate for larger streams and do not include BMPs that would be expected in general for smaller streams and watersheds.

wood.

Appendix H – Hydraulics and Hydrology Analysis

Initial Summary of Document Findings

- There is limited information and data developed by the St. Louis District that has significant ramifications to the EA-FS. Most significant information related to hydraulics and hydrology is based on information from other references, most or all of which are generated by, or associated with, Pavlowsky and the Ozarks Environmental and Water Resources Institute (OEWRI), Missouri State University (MSU).
- Appendix H includes numerous statements of fact that are not supported by source or reference.

Appendix H references extensively information provided by Pavlowsky, Owen and Martin (2010) that has been questioned with respect to its reliability. In addition to specific references, it appears that the conclusions made by Pavlowsky, Owen and Martin (2010) has been adopted as a fundamental basis defining the creation of existing conditions. In earlier discussions of the Big River with Federal Agencies, the Pavlowsky et al. (2010) study has been severely critiqued on, but not limited to the following:

- ▶ General unsupported and contradicted assumptions
- ▶ Poor or incomplete summary of mining history
- ▶ Conclusory statements regarding sources without investigation
- ▶ Incorrect assumptions regarding background lead
- ▶ Unsupported and contradicted conclusions regarding age of soils
- ▶ Untested hypotheses regarding sediment transport and deposition
- ▶ Questionable estimation techniques for sediment deposition volumes
- ▶ Dismissal of contradictory evidence
- ▶ Improper application of lead : zinc ratio

- Given the present deadline for these comments and the US Army Corps of Engineers' assurances that further discussions and submissions will be considered, we look forward to providing additional in-depth reviews, not only of the Pavlowsky et al. (2010) study, but of other cited studies, at least one of which was only recently made publically available.
- Appendix H provides a summary of mills, existing and historic, but the significance of this is not clearly described in Appendix H. A study of similar mill dams on a similar stream (not confirmed) suggests that such mill dams can and do evolve to pass sediment and upstream sediment storage is variable and may not be large (especially for mill dams that have degraded and have less hydraulic effect than in the original condition. The information is good, but specific relevance is not clearly stated.
- There is extensive hydrologic data available for Big River and Meramec River, but there is only limited information analyzed and discussed; relevant information from streamflow stations outside of the project area is not referenced or used.
- There is some information discussed that is not strictly hydrology or hydraulic in nature. Bank migration is briefly discussed, followed by calculation of lead loading from bank erosion volumes inferred from the migration. There is little information provided actually summarizing the bank migration locations, rates, etc.
- There is virtually no information provided regarding stream profile/gradient other than the "specific gage" analysis at 2 locations at USGS streamflow stations on Big River. Appendix H does not address the issue of the effect such a large sedimentation depth on the Big River floodplain (as much as 8 -10 feet deposition) would have on stream stability. This deposition

wood.

Suspended sediment transport monitoring was performed at two locations on Big River during 2011 – 2013 (Barr 2016)[17]. The suspended sediment loads from that monitoring were compared to the regional data described above and found to be consistent. A power equation was fitted to the data and the Big River data was found to be slightly higher than the composite data set from the other three rivers in the region.

Sediment transport also provides clean sediments to the SFCMA, which may reduce concentrations over time. With total sediment volume of approximately 50,000 CY per mile, an annual bedload transport of approximately 1,500 CY per year equates to an exchange rate of approximately 3 percent per year. Assuming incoming sediments are clean, the average rates of reduction in sediment lead concentrations could be up to 3 percent per year (16 percent reduction in 5 years). However, because the Big River within the SFCMA flows for approximately 18 miles wherein it is in close contact with the Bonnterre-Davis contact zone (demonstrated to be a geologic feature with elevated naturally occurring lead, Integra, 2014), incoming sediments may contain naturally occurring lead within bedrock and un-mined soils of the contact zone. This would result in a lower rate of reduction in sediment lead concentrations. Additional measures to remove or stabilize contaminated sediments and bank materials may increase the rate of reduction.

Detailed studies may be needed to formulate a more comprehensive watershed CSM to develop site-specific estimates of sediment transport. Development of a properly calibrated, mass balance based sediment transport model would significantly reduce uncertainties related to sediment erosion, transport, and deposition.

Application of the above principles with respect to sediment transport must also be integrated into other elements of the CSM to form a comprehensive and cohesive view of not only the movement of sediments within the Big River, but also an informed understanding of the transport of COCs. The following represents a summary of key elements of sediment transport within the framework of the CSM:

1. Sediment transport and depositional processes that carry lead and other COCs have been at work over long periods of time. Naturally occurring lead within the residuum of surface soils and the Bonne Terre formation have been mobilized to the sediments and floodplains of the Big River for eons prior to European settlement of the region. During the surface mining era, sediments containing lead were mobilized to the river due to the wide scale land disturbance and inefficient lead recovery methods. Additional materials were transported to the river by releases from the underground hard rock mining era. However, much of the mining-related materials from the hard rock mining activities were stored in upland locations (chat piles and tailings impoundments).

2. Attenuation of lead and other COCs in sediments in the upper Big River (below Flat River extending to Mill Creek) is evident, reflecting a similar attenuation of transport of mining-related sediments. Notably, a secondary peak of lead in sediments below Mill Creek (Integral 2014) points to other key contributors (barite mining, etc.) that have a more pronounced effect downstream.

3. Based on regional differences in geochemistry, demonstrated contributions of barium and associated lead from lead and barite mining in Washington County (both surface mining

[17] Barr, M.N. 2016. Surface-water quality and suspended-sediment quantity and quality within the Big River Basin, southeastern Missouri, 2011–13: U.S. Geological Survey Scientific Investigations Report 2015–5171, 39 p., http://dx.doi.org/10.3133/sir20155171.

wood.

and underground mining eras) point to important sediment transport processes from these sources (e.g., Washington County lead mines, Star Mine, Dresser Mine) on the receiving sediments and floodplains of the Big River downstream of the SFCMA. Inputs from these sources are likely to have had significant effects on sediment/floodplain characteristics downstream of Mill Creek. (Note: this is further substantiated by the presence of elevated barium in sediments in the lower Big River as described in Poor or Incomplete Summary of Mining History, above.)

4. Use of regional sediment transport data demonstrate that wide scale sedimentation and resultant floodplain building processes are not supported.

5. Far-reaching inferences by others about slime contributions to floodplain sediments of the Big River appear to be made from a single sample at the Bone Hole and as such, are not substantiated[18].

6. Transport of new sediments into the system is considerable and is capable of supporting remedies dependent upon natural recovery processes.

Additional point

Reference: *The Rivers of Missouri*, Dan Saults, c 1949. Section "The Meramec – St. Louis Playground". By Bill T. Crawford.

Mr. Crawford, Missouri Department of Conservation. Mr. Crawford wrote primarily about the Meramec in general, but explicitly mentioned and characterized the Big River in discussion of problems. He identified logging and agriculture activities as causing sedimentation and geomorphic problems. He, correctly or incorrectly, diagnosed river geomorphic changes and causes. However, he never mentioned the lead mining activities in the upper Big River watershed and releases of waste to the river as a problem. Mr. Crawford was a conservationist and was clearly quite well informed about the Meramec River watershed and tributaries. It seems unexpected that, if the lead mining activities in St. Francois County was a major problem of the scale that would produce the conditions leading to the result described by Pavlowsky et al (2010), he would not have mentioned mining activities as a problem.

Additionally, Jacobson and Primm (1997) (Historical land-use changes and potential effects on stream disturbance in the Ozark Plateaus, Missouri / by Robert B. Jacobson and Alexander T. Primm, U.S. Geological Survey water-supply paper; 2484, Prepared in cooperation with the Missouri Department of Conservation) mention lead mining near Potosi, but do not mention mining impacts on stream disturbance in the Big River, which is included in the study area.

Summary

We appreciate the effort and intent in developing a plan to guide ecosystem restoration initiatives on the Big River. Clearly there are many opportunities for restoration that may be undertaken to enhance Big River habitat and provide benefits to both aquatic and terrestrial ecosystems. However, as described in the preceding observations and comments, the ecosystem restoration FS appears to be

[18] Slimes have been hypothesized to contribute significant amounts of lead to floodplain soils and sediments within the Big River watershed (Pavlowsky et al. 2010). The hypothesis suggests large volumes of slime have been deposited in the river and transported via slug flow during large storm events, a process that has not been documented in the Big River. This theory however, is based upon a single data point at the Bone Hole and wide scale application of this single analytical data point to inferences about significant transport mechanisms within the Big River are not warranted and are not supported on a mass balance basis.

wood.

founded on an overly simplistic CSM. This CSM presumes that ecological deficits are due to lead contaminated sediments originating from a set of upstream mines (exclusively located in St. Francois County) associated with the underground mining era. Such a simplistic CSM, reduces the chances for successful restoration as it does not recognize background and natural conditions or the importance of multiple sources. Further, the importance of mill dams and other structures that limit recovery is not sufficiently addressed.

We recommend that other major elements should be included as part of CSM, including a more comprehensive treatment of mining history, Washington County sources, sediment transport and deposition details, background lead levels, and other stressors besides lead. We would encourage that the objectives come from a more complete CSM, and that remedies are from a process of integrated environmental assessment that factors in the on-going work to formulate remedies for the Big River within St. Francois County.

We sincerely appreciated the opportunity to provide comments on this important project. Should you have any questions regarding these comments, please do not hesitate to contact us.

Sincerely,

Wood Environment & Infrastructure Solutions, Inc.

William J. Elzinga, MS
Sr. Associate Scientist
Wood Environment & Infrastructure Solutions, Inc.
St. Louis, MO

MISSOURI FARM BUREAU FEDERATION

MISSOURI FARM BUREAU FEDERATION
P.O. Box 658, 701 South Country Club Drive, Jefferson City, MO 65102 / (573) 893-1400

June 21, 2018

Comments Regarding "St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment" Draft Report

The following comments are submitted on behalf of Missouri Farm Bureau, the state's largest farm membership organization.

In the draft report, the USACE sets forth several project objectives involving "willing landowners." During the public meeting in Eureka, agency officials confirmed 35 landowners have been identified from whom land would be acquired under the Tentatively Selected Plan (TSP). Cost estimates for these acquisitions as well as easements and related expenditures total $5.3 million.

According to the Cumulative Effects Analysis, also envisioned are commitments by willing landowners to implement best management practices for bank stabilization, gravel excavation, riparian corridor health and reforestation.

The Nature Conservancy (TNC) is the only nongovernmental organization serving with state and federal agencies on the "interagency study team." TNC's *Meramec River Conservation Action Plan* is cited throughout the draft report. It is unclear how TNC's plan and recommendations fit within the context of the TSP as well as the "larger effort in the entire Meramec River Basin," of which the TSP is described as "one component."

Appendix F of TNC's plan is a compilation of recommendations by various entities from which TNC derived 87 "unified objectives," including the following:

- By 2023 reduce existing livestock access to springs, streams, and rivers by X% (from X% currently);
- By 2023 reduce the rate of new dam construction to X% (from X% in a given catchment/watershed/sub-basin) and ensure minimal degradation of key ecological attributes;
- By 2023 restrict all in-stream gravel mining in specific (i.e., sensitive) areas of a given catchment/watershed/sub-basin;
- By 2023 increase non-urban/non-agricultural riparian corridor habitats (e.g., forested) to X% (from X% currently) within 100 feet of rivers and streams throughout the Meramec River Basin;
- By 2023 increase non-urban/non-agricultural floodplain and wetland habitats (e.g., forested) to X% (from X% currently) throughout the Meramec River Basin;
- By 2023 establish basin- or statewide policies or statutory laws that reduce the impacts of in-stream, riparian and/or floodplain construction; and

- By 2023 establish basin- or statewide policies or statutory laws that reduce or eliminate the practice or impacts of in-stream gravel mining and/or reaming.

Noting discussion during the Eureka public meeting regarding expanding the scope of the study to encompass the entire basin, we seek further clarification regarding implications for private landowners in terms of (a) the TSP for the authorized study area; (b) alternative plans yet to be assessed for the entire basin; and (c) the status of TNC's plan and related recommendations within the context of these scenarios.

Thank you for the opportunity to provide comment.

Sincerely,

Blake Hurst
President

USGS

USGS provided in-text comments to the draft report. The comments received are documented below and were taken into consideration and the draft report was revised accordingly:

- "Additional" to Acknowledgements Page
- Section 1.5: Wondering why USGS logo on report if USGS was not part of the study team??
- Section 2.1.2: Not sure what is meant by "low" there are Pb and Zn levels above the PECs in some barite district tributaries…
- Section 2.2.2: Not sure this is the "best reference" as not much glacial loess in the Ozarks. This might be appropriate for extreme downstream end of the Meramec basin but not most of it
- Section 2.2.2: Also not sure about "shale" being the predominate rock in the lower Big River Watershed. Geologic map shows mostly Plattin Group which is limestone with lesser amount of shale. Yes there is more shale in downstream end of the Big River watershed but its not the predominate rock type.
- Section 2.3.2: Please clarify, as Pb and other metal contamination has been found in the solid phase of the alluvial aquifer via floodplain cores by MSU and USGS. Perhaps the writer intends to indicate metal impacts have not been found in GW within the alluvial aquifer.
- Section 2.3.3: Reference for the stremgage data? Is this published somewhere? Reference for highest stage, also is this an instantaneous, daily, etc, value?
- Section 2.3.4: Again, published reference for these values?
- Section 2.4.2: Need consistent use of terms, paragraph above says "chat and tailings piles", then next sentence says "mine waste piles".
- Section 2.4.2: Barr (2015) provided actual measurements of tons of suspended sediment transported at two locations on Big River. Unclear how this 33,750 tons was estimated (it is for a particular year?), and how does this compare to the 2015 report?
- Section 2.4.3: Confused as section above indicates 33,750 tons of sediment/yr eroded from floodplains, so are streambanks not part of the floodplain?
- Section 2.5.4: Do not believe there is sufficient evidence presented in current studies to say the floodplain sediment in the Big River floodplain are almost "wholly comprised of impacted sediment". The referenced report does not state this – the report suggests that the average depth of Pb contamination in the floodplain is about 2-3 meters of sediment and does not estimate the amount/volume of metal contaminated sediment but does not provide that as a proportion of the entire estimated floodplain sediment volume. Also what is "impacted sediment", perhaps "metal contaminated sediment"? Also, what is the abundance of metal contaminated sediment upstream from the OLB. (a) the sediment volume is obviously much smaller than DS but the depth of contamination is probably much smaller. Do not see data in the 2010 report appendices from this reach of Big River so perhaps the text should be modified here and elsewhere to indicate Big River floodplain within and downstream from the OLB to be more accurate.

USEPA REGION 7

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219

06 JUL 2018

Dr. Katheryn McCain
U.S. Army Corps of Engineers
St. Louis District
ATTN: Environmental Planning PD-P (McCain)
1222 Spruce Street
St. Louis, Missouri 63103-2833

Dear Dr. McCain:

The U.S. Environmental Protection Agency has reviewed the draft report titled "St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment." Our review is provided pursuant to the National Environmental Policy Act 42 U.S.C. 4231, Council on Environmental Quality regulations on 40 C.F.R. Parts 1500-1508 and Section 309 of the Clean Air Act.

This Integrated FS/EA evaluates and documents the decision-making process for the proposed U.S. Army Corps of Engineers ecosystem restoration plan for the lower 75 miles of the Big River and the lower 50 miles of the Meramec River within the study area of Jefferson and St. Louis Counties in Missouri. The plan identifies a tentatively selected restoration plan for the study area which is intended to address impacts associated with a river system burdened with lead-contaminated sediment, bank instability and reduced riparian corridor. The EPA is developing plans for the remediation of contamination at the Southwest Jefferson County Mining Site under the Comprehensive Environmental Response, Compensation and Liability Act specific to eight Operable Units. Operable Unit 4 is upstream of the Corps' project study area within the Big River basin. We understand that the Corps is working closely with the EPA's personnel to coordinate the selection of its preferred alternative with the EPA's proposed plan for OU 4 under the CERCLA. A Feasibility Study is to be completed and a Record of Decision for Operable Unit 4 issued in 2019.

We are enclosing comments regarding the structure and clarity of the Integrated EA, which documents both the assessment of current environmental condition within the study area and the process by which restorative actions will be selected by the Corps. We encourage you to continue close coordination with the EPA's staff working under authority of the CERCLA on the Operational Units within the upper portions of the Meramec River basin above the study area as the Corps proceeds through final project design and construction.

Printed on Recycled Paper

Thank you for the opportunity to review and provide comments for this project and your Integrated FS/EA. If you have any questions or concerns regarding these comments, please feel free to contact me at 913-551-7606 or tapp.joshua@epa.gov.

Sincerely,

Josh Tapp, Deputy Director
Environmental Sciences and Technology Division

DETAILED COMMENTS

Purpose and Need

The Integrated Environmental Assessment provides the purpose of the study rather than the actual project purpose. While the purpose of the draft feasibility study is "to assess the environmental effects of a reasonable range of alternatives or actions taken by the USACE, including the no action plan, prior to making decisions", the project purpose is generally "to provide water-resources solutions to restore the ecosystem structure and function of the Meramec River Basin." The project, in truth, has two specific purposes underlying the overall broader basin-based purpose: restore the ecosystem structure and function of the Big River and its floodplain and to prevent the movement of contaminated sediment from the Big River into the Meramec River. The document identifies in Section 1.6 a 'need for action' which is linked directly to the project's purpose of the "restoration of ecosystem structure and function" in the larger basin. Project 'need' is characterized as a river and floodplain "overburdened with contaminated sediment from historic mining practices, altered hydrology, altered riparian corridor, and degradation of aquatic habitat." We suggest that the EA would be clearer regarding the nexus between project 'need' and 'purpose' if it did not confuse study purpose with project purpose and was more precise about its two-pronged purpose specific each to the Big River and the Meramec River.

Existing and Future Without Project Conditions

The project study area is identified as the Meramec River basin within Jefferson and St. Louis Counties, including the 50 miles of the Meramec River itself. However, in reviewing the EA, we noted the lack of information on the chemical and biological condition of the Meramec River, in comparison to the characterization of the Big River. The EA briefly notes, and we confirmed with our Superfund staff, that, while there is abundant data for the Big River, there is very little data available regarding sediment and water contamination for the Meramec River. In general, the EA references the condition of the Meramec River basin without much information on Meramec River resources specifically. We recommend that the Corps begin collecting water quality, sediment and biological data for the Meramec River prior to initiating construction and project development to establish a proper baseline condition of the river itself.

Range of Alternatives

The characterization of the Corps' "formulation strategies" in Section 3.10, which underlies the identification of the initial array of alternatives, is confusing and makes the comparison of alternatives difficult. Table 3-3 provides the detail necessary to compare and contrast alternatives. In the end, it seems that the alternatives fundamentally differ by where and what type of structures are placed and excavations conducted, the number of sites placed on either or both rivers, and the amount of stream length and floodplain area affected. In staff-to-staff telephone conversations, it appears that you are already taking measures to clarify the document's organization regarding the nature of the individual alternatives which would allow a proper comparison.

Sustainability of Alternatives

In characterizing the hydrology of the Big River, the EA states that "only low discharges were used due to much fewer actual discharge measurements being taken during higher [precipitation] events" for the three gages at Eureka, Byrnesville and Richwoods. Section 2.14.2 references projections of increasing annual precipitation and the frequency of large storm events. Given the condition of the watershed and the most recent precipitation record for the basin, we recommend you take into consideration the special challenges of designing structures for placement in streams characterized by a short lag time, high peak discharge, and steep rising and falling limbs. Structure design and placement should consider the unique stresses created by extreme flows and high stages and the likely effect on design performance.

Mitigation of Short-Term Impacts

The EA provides references regarding the presence of mussel beds within the Big and Meramec Rivers in Section 3.3.2.5. Without reviewing those references, we assume that there is some information regarding the locations of individual mussel beds within both rivers. We recommend the Corps perform surveys confirming the locations of individual sites on the Big River and downstream of areas targeted for in-stream sediment removal or structure placement. Mussel beds possibly located in the Meramec River might also be affected by dredging and construction in the Big River under certain circumstances in a fashion like those short-term impacts identified in Section 4.10 of the EA. The Corps has, in the past, completed mussel bed removals and re-placement as part of dredging activities and pool drawdowns in the Upper Mississippi River.

8. PUBLIC REVIEW EXTENSION ANNOUNCEMENT

From: Johnson, Brian L CIV USARMY CEMVS (US)
Bcc: [redacted]
Subject: Draft Meramec Feasibility Study Report - public review extension to July 8, 2018
Date: Friday, June 15, 2018 9:13:00 AM

Dear Sir or Madam:

Please note that the Corps of Engineers has extended the public review period for the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment. The feasibility report is now available for public review until July 8th, 2018, extended from the previously announced date of June 23rd, 2018.

For additional information please contact:

Dr. Kat McCain
US Army Corps of Engineers, St. Louis District
ATTN: Environmental Planning PD-P
1222 Spruce Street
St. Louis, MO 63103-2833
Email: Kathryn.McCain@usace.army.mil

Sincerely,

Brian Johnson

Environmental Compliance Branch Chief
St. Louis District Corps of Engineers
1222 Spruce St.
St. Louis, MO 63103-2833

-----Original Message-----
From: Johnson, Brian L CIV USARMY CEMVS (US)
Sent: Friday, May 25, 2018 7:29 AM
Subject: Draft Meramec Feasibility Study Report Available for Review

Dear Sir or Madam:

The U.S. Army Corps of Engineers St. Louis District has prepared a draft report titled "St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment". You are receiving this notification because you may be interested in this project. However, no action is required on your part. The project area includes portions of the Meramec River Basin located in Jefferson and St. Louis Counties, Missouri. The area includes the lower 75 miles of the Big River, a major tributary of the Meramec River, and the lower 50 miles of the Meramec River. The draft report evaluates and documents the decision-making process for the proposed U.S. Army Corps of Engineers (USACE) ecosystem restoration study in the St. Louis Riverfront – Meramec River Basin, Missouri. The report describes alternative solutions and presents a tentatively selected restoration plan. The report also serves to notify the public of the environmental effects of the project as required by law. These environmental effects are summarized in the report's Draft Finding of No Significant Impact(s) (FONSI), which is unsigned. A signed FONSI is required before project construction can occur. The FONSI will not be signed into effect until all comments received as a result of this public review have been carefully considered.

An electronic version of the draft report, titled "St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment" is available online at:
http://www.mvs.usace.army.mil/Portals/54/docs/pm/Reports/EA/STLRFMRBER/MeramecDraftFSwEA.pdf

You are welcome to comment on the content of the draft report. To submit a public comment please contact Dr. Kat McCain of our Environmental Planning Section, telephone 314-331-8047, or email at Kathryn.McCain@usace.army.mil. For general project inquiries, please contact Mr. Matthew Vielhaber of our Project Management Branch, telephone 314-331-8052, or email at Matthew.R.Vielhaber@usace.army.mil. Written comments may be sent to our address below:

US Army Corps of Engineers, St. Louis District
ATTN: Environmental Planning PD-P (McCain)
1222 Spruce Street
St. Louis, MO 63103-2833

The comment period runs from May 23, 2018 through June 23, 2018. Two public open houses will be held on 6 and 7 June 2018.

When: Wednesday, June 6, 2018, 6:30 to 8 p.m.
Where: The Timbers, 1 Coffey Park Lane, Eureka, MO 63025

When: Thursday, June 7, 2018, 6:30 to 8 p.m.
Where: Hillsboro City Hall, 101 Main St. P.O. Box 19, Hillsboro, MO 63050

Sincerely,

Brian Johnson
Environmental Compliance Branch Chief
RPEDN- St Louis
Business Line Manager - Ecosystem Restoration Mississippi Valley Division
314-331-8146

9. FINAL FWCAR JAN 2019

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Missouri Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0057
Phone: (573) 234-2132 Fax: (573) 234-2181

January 31, 2019

Ms. Kat McCain, Ph.D.
Chief, Environmental Planning Section
U.S. Army Corps of Engineers
Regional Planning and Environmental Division North
1222 Spruce Street
St. Louis, MO 63012

Dear Ms. McCain:

The U.S. Fish and Wildlife Service (Service) is submitting the Final Fish and Wildlife Coordination Act Report (FWCAR) for the U.S. Army Corps of Engineers (USACE) St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study (MRFS). The current phase of the proposed MRFS involves the development and comparison of various ecosystem restoration actions within the aquatic and adjacent terrestrial environments in the Big River in Jefferson and St. Louis counties in order to select a primary project alternative to pursue approval. The study area has been expanded and now includes Washington, St. Francois, Jefferson, and St. Louis counties, Missouri.

The FWCAR identifies the biological and ecological significance of the Meramec River Basin as well as outlines the existing problems, potential threats, and anticipated impacts in the study area. Furthermore, it also indicates resource opportunities and provides the USACE with specific recommendations to help protect and restore fish and wildlife resources. To summarize, the most noteworthy resource threats throughout the study area are impacts associated with historical mining in the Big River watershed. These impacts, if not adequately corrected, are expected to expand downstream and degrade additional aquatic and riparian habitats, which currently includes sensitive freshwater mussel communities including several federally listed species. Thus, the Service strongly supports the approval and completion of this ecological restoration project. The extensive length of Big River, if restored, would not only protect these sensitive downstream environments but also improve a significant length of habitat to help these species recover.

If approved, we believe this proposal would not only protect and enhance important aquatic resources and benefit federally endangered species but would also increase the awareness of these resources as well as reinforce the collaboration between many federal, state, NGOs, and private landowners within this region, many whom have expressed interest in attaining similar conservation goals.

Thank you for the opportunity to participate in this ecological restoration proposal. We look forward to continued collaboration on this much needed project to help support USACE planning efforts. Please contact our office if you need any additional information or have questions regarding information within the FWCAR.

Sincerely,

Karen Herrington
Field Supervisor

Enclosure

Cc via email: USACE, CEMVS-PM-N, Matthew Vielhaber
USACE, CEMVP, Monique Savage

Fish and Wildlife Coordination Act Report
for the
Meramec River Basin Ecosystem Restoration Feasibility Study

Prepared by:

U.S. Fish and Wildlife Service
Missouri Ecological Services Field Office
Columbia, Missouri

January 2019

Table of Contents

Page

Fish and Wildlife Coordination Act Report
Meramec River Basin Ecosystem Restoration Feasibility Study (MRFS)

INTRODUCTION

The St. Louis District of the U.S. Army Corps of Engineers (USACE) and non-federal sponsor, the Missouri Department of Natural Resources (MDNR) are currently planning an ecosystem restoration feasibility study within portions of the Meramec River Basin in Washington, St. Francois, Jefferson, and St. Louis counties, Missouri. The study area has been expanded beyond Jefferson and St. Louis counties since the Draft Fish and Wildlife Coordination Act Report completion. The study purpose is to investigate natural resource concerns including habitat degradation from historic mining practices, consider and evaluate viable restoration alternatives, develop a tentatively selected plan (TSP), and pursue a series of ecological restoration projects.

The U.S. Fish and Wildlife Service's (Service) involvement in this study is authorized by the Fish and Wildlife Coordination Act (FWCA; 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). The FWCA specifies that fish and wildlife resource conservation be equally considered as part of federally funded or permitted water development proposals or projects which impact any jurisdictional stream or body of water. For relevant projects, the FWCA requires that federal action agencies consult with the Service and state wildlife agencies during project planning, development, and maintenance activities. A required product of this FWCA consultation is the Fish and Wildlife Coordination Act Report. This report outlines the anticipated impacts to fish and wildlife resources as well as problems and opportunities as they pertain to the proposed project planning objectives and alternatives. Section 2(b) of the FWCA requires that the Service and state wildlife agency reports and recommendations be given full consideration and be included in project reports provided to Congress or to any other relevant agency or person for approval or authorization. The purpose of this report is to identify and evaluate existing fish and wildlife resources and habitats, outline the Service's concerns and planning objectives, as well as indicate specific recommendations and conservation measures to help ensure those resources receive equal consideration with the associated project purposes. This document will constitute the Secretary of the Interior's final report as required by Section 2(b) of the FWCA.

FWCA Agency Coordination

This report is based on numerous meetings and discussions between participating agencies, resource documentation, historical evaluations, recent studies of both fish and wildlife resources, and landscape issues within/near the study area. Information has been received and collated from USACE staff as well as Service and state biologists including regional species experts. The Service provided preliminary drafts of this report to the Missouri Department of Conservation (MDC) for their review and input. Comments received were incorporated into this report and a concurrence letter from MDC is attached.

Project Authority
The USACE indicated that the Meramec River Basin Ecosystem Restoration Feasibility Study was authorized by a 21 June 2000 Resolution by the Committee on Transportation and Infrastructure, U.S. House of Representatives, Docket 2642:

> *"Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on the Mississippi River, 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."*

and was expanded in Section 202 of the 2018 Water Resources Development Act (WRDA):

> *"(b) ST. LOUIS RIVERFRONT, MERAMEC RIVER BASIN, MISSOURI AND ILLINOIS.—*
> *(1) IN GENERAL.—The Secretary is authorized 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.*
> *(2) CONTINUATION OF EXISTING STUDY.—Any study carried out under paragraph (1) shall be considered a continuation of the study being carried out under Committee Resolution 2642 of the Committee on Transportation and Infrastructure of the House of Representatives, adopted June 21, 2000."*

STUDY AREA
The Meramec River Basin is situated entirely within the Ozark Highlands in the State of Missouri. The watershed is approximately 6400 square kilometers (3980 square miles) and collectively drains a predominately forested region comprised of moderately rugged terrain overlying a karst (limestone/dolomite) geology. Beginning near Salem, the Meramec River flows approximately 370 kilometers (230 miles) to its confluence with the Mississippi River near St. Louis. The Meramec's two largest tributaries are the Big and Bourbeuse rivers. The Meramec and its tributaries are characterized as Ozark streams typically being clear and moderately swift, flowing over substrates consisting of various amounts of sand, gravel, cobble, and boulders amongst scenic bluff features along their course. The watershed is largely dominated by sinuous, single thread channels which alternate between shallow riffles, runs, pools, and glides varying in depth often forming sequences of depositional areas (gravel bars and islands) in which additional side-channel habitats, backwater sloughs, and wetlands can also

2

provide unique habitats within this riverine/floodplain ecosystem. Historically, the floodplain/riparian lands were diverse native forest communities. However, during the 1800s most of the old growth forests were harvested and floodplains cleared to convert these areas to either cropland or pastureland. Also during this period, a finite number of small historic mill dams were constructed in the Big and Bourbeuse rivers. Later, during the 1960s and 1970s, the USACE planned but did not construct the Meramec Park Lake near Sullivan, Missouri. All other ponds, small lakes, and impoundments developed within the basin are currently confined to tributary streams situated in the upper watershed areas. Despite these features, the Meramec River Basin remains largely free-flowing, its hydrology principally determined by regular precipitation events and groundwater inputs including large springs and seeps. The study area is a portion of the Meramec Basin which includes the Meramec and Big rivers and their tributaries within Washington, St. Francois, Jefferson, and St. Louis counties, Missouri (Figure 1). The primary water uses within the study area are public and private recreation, municipal and industrial uses, livestock watering, and fish and wildlife habitat. Streams and springs throughout the Meramec River Basin and elsewhere in the Ozark Region are a primary destination for many outdoor recreational activities including: canoeing, kayaking, fishing, and camping. Furthermore, numerous Missouri state parks are situated directly adjacent to the Meramec River (i.e., Onondaga Cave State Park, Meramec State Park, Robertsville State Park, Route 66 State Park, and Castlewood State Park) and the Big River (i.e., St. Francois State Park and Washington State Park).

Project Description

The MRFS is a focused study to conduct ecosystem restoration within the Meramec River Basin in Washington, St. Francois, Jefferson, and St. Louis counties, Missouri. The USACE and the MDNR identified a project need due to a significantly degraded condition of the aquatic environment throughout the study area. This environmental degradation resulted from historical heavy metal mining within the upper reaches of the Big River (~175 to 135 km upstream of the mouth). The purpose of ecosystem restoration, as provided by the USACE, is "to restore significant ecosystem function, structure, and dynamic processes that have been degraded within the Meramec River Basin." If approved, the USACE would plan, construct, monitor, and adaptively manage a suite of actions that are expected to preserve, restore, and improve aquatic and riparian habitat conditions for resident and migratory wildlife, including federally listed species. These actions are also intended to maximize fish and wildlife habitat benefits while minimizing environmental, cultural, and socioeconomic impacts. These measures, if completed, should reduce downstream wildlife impacts attributed to contaminated sediments present within the streambed and floodplain soils from migrating downstream into lower segments of the Big River and then into the Meramec River. Doing so, the actions will also protect/enhance habitat for several species of federal and state listed mussels, bats, as well as state listed crayfish. These species and their habitat preferences will be detailed within later sections of this document. The project, if approved, will last 50 years from the first construction season, and may include aquatic and terrestrial habitat improvement measures for future construction actions in the study area within the Meramec River Basin.

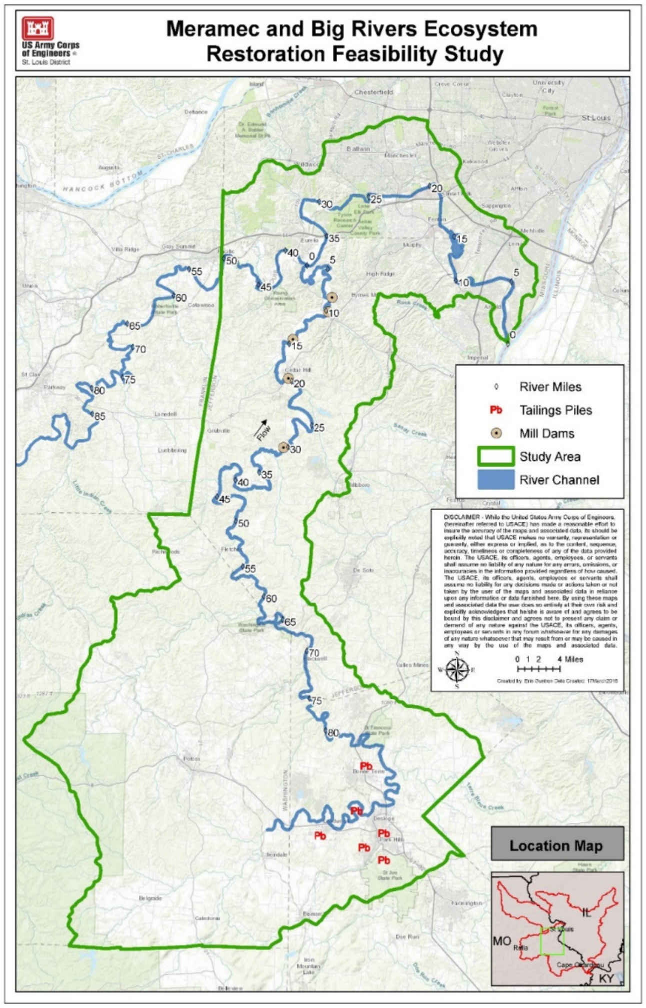


Figure 1. Meramec Feasibility Study Area as indicated by the USACE.

FISH and WILDLIFE RESOURCE PROBLEMS and OPPORTUNITIES
Human activity within the study area during the past two centuries has significantly impacted and reduced the natural biotic community, ecosystem functions, and physical characteristics of the riverine environment within the Big River compared to historical conditions. The Meramec River and its tributaries have been referenced as one of the most ecologically important

4

tributaries to the Upper Mississippi River, with 292 aquatic-dependent species recorded from the basin (Nigh and Sowa 2005 and TNC 2014). This intersection of diverse biologic communities with toxic exposure to heavy metals elevates the need for timely habitat improvement measures by agencies and highlights the challenges facing restoration efforts. Numerous studies have identified the following key environmental problems contributing to fish and wildlife resource impacts in the Meramec River Basin:

Contaminated Streambed Sediments/Streambank Erosion

The most significant resource problem within and throughout the study area is attributed to effects resulting from contaminated sediments associated with historical lead (Pb) and zinc (Zn) mining in the upper Big River watershed in St. Francois County. Barite mining in Washington and Jefferson counties also has the potential to contribute contaminated sediments to the watershed. However, the source of the vast majority of the toxic heavy metal sediment contamination demonstrated to date has been identified as originating from St. Francois County (Pavlowsky et al. 2010 and USEPA 2017). This mining activity was substantial and spanned over two centuries (1740-present). The majority of Pb and Zn production and resource impacts occurred during the early to mid-20th century from industrial scale subterranean mining. The metal ore was extracted from a dolomite host-rock which required milling to be obtained. The waste materials from this crushing process are referred to as mine tailings which still contain residual amounts of Pb and Zn ore. It is estimated that at least 30 million cubic meters of mine tailings are currently stored within six material waste sites (Pavlowsky et al. 2010). These sites are depicted in Figure 1. As direct result of those mining activities, immense influxes of Pb and Zn and lesser amounts of cadmium originally entered the upper Big River from source locations and subsequently contaminated the entire Big River floodplain and over 150 km of its stream length. In 1977, a mine tailings dam failed during a flood event. This single event was reported to have introduced 63,000 cubic meters of contaminated mill waste into the Big River (Roberts and Bruenderman 2000). All six tailing piles have been or are currently being stabilized to limit/prevent mine tailings from continuing to enter waterways. However, Pb contaminated materials already within the river system continue to negatively impact the environment to various degrees throughout the study area. A majority of the mine tailings within the river system are less than 8mm in size. The finest fraction (<250μm) are largely present within floodplain deposits. These small, distinct fluvial mine wastes are now migrating downstream episodically by natural stream forces/processes typically associated with regular flooding events. Depending on their size and forces acting upon them, contaminated sediments are either redeposited within the stream channel, on adjacent gravel bars/islands, in back/side channels, or on floodplain surfaces. Pavlowsky et al. (2010) studied the degree of contamination within the Big River channel and floodplain and reported that an estimated 3.7 million cubic meters of contaminated sediment is stored in the Big River stream channel and 86.8 million cubic meters was deposited in the Big River floodplain. Pavlowsky et al. (2010) also indicated that concentrations and sizes of these contaminated sediments vary within the streambed in the Big River and floodplain within the Big and Meramec rivers. The distribution of contamination is complex. Generally, the highest heavy metal concentrations for both instream sediments (about 500 to 1,500 mg Pb/kg) and floodplain soils (about 1,000 to 3,000 mg Pb/kg) are closest to the tailing sources in the upstream/middle reaches of the Big River (~170-100 km from the mouth)

5

and a number of tributaries in the study area. Furthermore, because floodplain sediments are typically small (less than 1 mm), these materials were/are more readily mobilized and thus able to be transported farther distances during large flood events compared to larger instream materials. This has resulted in a greater degree/distribution of floodplain contamination extending farther downstream than for the instream contamination. Also, the largest contaminated sediments (2-8mm) are generally confined to the stream channel and transported downstream at a much slower rate. Despite this, contaminated sediments in the streambed and/or within floodplain sediments, which re-enter the active channel via streambank erosion sources, are certain to continue to migrate downstream from their points of origin and impact additional habitats and resources far into the future. Similarly, the largest aquatic and terrestrial wildlife resource impacts also have a similar distribution, the most impacted locations being nearest these mine waste source areas. Impacts to the freshwater mussel community in the study area resulting from mining were initially noted by the Missouri Water Pollution Board (1964). The magnitude and effects of these contaminated sediments to the mussel community have only recently been documented (Roberts et al. 2009 and 2016). A separate study by Albers et al. (2016) using the Roberts et al. (2016) field data indicate that Pb concentrations above 136 mg/kg in <2mm streambed sediment negatively impacted mussel density. The Albers et al. (2016) analysis found very similar sediment Pb concentrations demonstrating negative effects to mussels as was also indicated by the Consensus Based Probable Effects Concentration (PEC) for Pb of 128 mg/kg based on laboratory testing of a variety of benthic organisms (MacDonald et al. 2000). Other laboratory based studies have demonstrated various impacts and relatively high sensitivity to life functions in mussels resulting from exposure to heavy metals (Besser et al. 2009 and Wang et al. 2010). Roberts et al. (2016) and Albers et al. (2016) both concluded that the Pb contaminated sediment concentration was the most highly correlated factor to the reduction of mussel densities and species distribution in the Big River compared to other habitat metrics. The Service believes that without direct actions to stop the downstream progression of Pb contaminated streambed sediments and/or remove/reduce these contaminated sediments to concentrations below the PEC value, the remaining aquatic environments throughout the study area are expected to degrade to the current levels mentioned for the upper Big River into the distant future. This is especially problematic due to the very important freshwater mussel and crayfish communities residing in the lower Big and Meramec rivers that are at risk due to this contaminated sediment migration. These wildlife communities include several federal and state listed and unique endemic species, discussed later.

Despite expanding the study area into St. Francois and Washington counties, the current USACE analysis doesn't explicitly propose additional projects in either county. As a result, the Service will specifically recommend the USACE consider and pursue additional study phases in the future to evaluate similar project proposals throughout the expanded study area. Pavlowsky and Owen (2013) identified numerous areas of channel migration throughout the Big River spanning a 70-year period (1937-2007). The USACE identified approximately 30 locations within Jefferson and St. Louis counties where accelerated streambank erosion is occurring. Considering that a majority of the Big River floodplain soils are contaminated with mine wastes and because of the enormous quantities involved, the Service supports the USACE's pursuit of actions which can stabilize actively eroding streambanks in order to restrict/prevent the re-introduction of these contaminated materials back into the stream channel. Such actions would help reduce further degradation of downstream environments and their potential impacts to the extremely important mussel communities in the lower Big and Meramec rivers. In addition to these measures, we also support actions which can most efficiently remove substantial quantities of contaminated streambed sediments from the Big River where applicable. We believe this dual strategy, if conducted correctly, is the best approach to effectively prevent/reduce these contaminated sediments from continuing to significantly degrade downstream environments as well as potentially improve impaired habitats. The current streambank protection and streambed sediment removal measures being considered include: longitudinal peak stone toe protection (LPSTP), rootwad revetment, weirs, barbs, channel relocation, streambank slope modification, bioengineering, toe-wood, riparian plantings, in-channel streambed sediment collectors, gravel bar restoration, rock archways, sediment removal from within mill dam impoundments, and passive floodplain/side channel sediment traps. Apart from the USACE alternatives, the U.S. Environmental Protection Agency (USEPA) may also develop and undergo separate or similar remedial actions in the study area at a future date. However, no actions or plans are known at this time. The USACE has considered this issue during the future without project alternative analysis. This information is discussed in the **EVALUATION and COMPARISON of ALTERNATIVES** section to follow. Furthermore, the USACE also considered a project alternative that limited restoration activities to only the Meramec River because of the need to work with contaminated materials. In addition to the list of identified proposed actions, the Service will recommend the USACE consider bank stabilization measures which can incorporate natural and biological elements such as: logs, differential flow gradients, structures with available interstitial spaces, and overlying shade from the sun to promote/enhance aquatic wildlife habitat diversity within each design feature. Once selected projects are designed, we anticipate the Service and MDC will be able to provide additional input regarding those project details in the future.

Altered Aquatic Connectivity

Large, unnatural, vertical structures such as dams and road crossings can often act as barriers to aquatic organism passage (AOP). Originally constructed in the mid-19th Century, four mill dams (Rockford Beach Dam, Byrnesville Dam, Byrnes Mill Dam, and Cedar Hill Dam) remain in the lower Big River. An additional mill dam (Morse Mill) was the most upstream mill dam but has since degraded to a height nearly at-grade within the stream channel. It has been suggested that these mill dams are a primary reason for negative impacts to the Big River mussel population. However, as indicated in the mussel section below, native mussels require a fish host in order to successfully complete their life cycle. Based on an analysis of MDC creel data (unpublished), the Big River fish species richness and diversity did not differ upstream and downstream of mill dams. This may be because of their relatively low structure height (less than 2 meters), general state of disrepair, and frequent overtopping. Furthermore, Roberts et al. (2009 and 2016) reported a high incidence of numerous species of subfossil mussel shells found either within physical mussel habitat or on depositional surfaces (e.g., gravel bars and islands) throughout the stream reaches upstream of all mill dams. As discussed later, mussels can live a very long time; however, none are known to live as long as the period of time in which the Big River mill dams have been in place (approximately 170 years). Since the mussel population is directly reliant upon the fish community for sustainable mussel recruitment, the presence and quantities of the subfossil mussel shells in addition to these fish data suggests that both fish and mussel populations were far more robust than current levels long after these mill dams were constructed. Furthermore, the small, remnant mussel population in the upper Big River, also upstream of known Pb contamination, may be indicative that the remaining mill dams, given their current condition, are likely only causing minor, local, short-term disruptions to AOP. Lastly, the Bourbeuse River, the second largest tributary to the Meramec and a reference stream for various Big River mussel studies, also has similar mill dams but does not exhibit similar mussel population reductions.

Nonetheless, we support additional actions which could further reduce the downstream bed slope directly below each dam to potentially provide additional passage benefits to local native fish communities. Another important component of these mill dams is that, like most impoundments, they serve as a trap for fine instream bed sediment. The mill dams therefore, have likely prevented a significant fraction of contaminated sediments from being transported into downstream environments. Pavlowsky et al. (2010) found the maximum volume of instream sediment stored in segments immediately above Rockford Beach and Byrnesville mill dams, which are the most intact structures. Because of this sediment trapping mechanism, the Service also supports investigating opportunities to utilize/maintain/modify these structures to enhance the capture and removal of contaminated instream sediment to a point when those materials are no longer accumulating or affecting the environment. We support designs that consider adequate AOP as well as recreational user passage to also provide habitat and public use benefits into the future.

Altered Floodplain/Riparian Corridor

Riparian areas throughout the Ozark Region were historically a forested environment. Alluvial floodplains are well known to provide productive farmland. Because of this, lands were often cleared of native forests and understory vegetation. Established riparian corridors are known to significantly reduce erosional forces from flooding by functioning as roughness elements which promote sediment and debris capture/retention on the floodplain surface in addition to protecting stream banks by way of a dense root system. Riparian vegetation typically provides substantial food and habitat for various terrestrial wildlife and buffers adjacent land uses and other natural environmental factors from the adjacent waterway (e.g., elevated water temperatures from the sun). Wetland areas within the riparian area can also provide many additional physical and biotic benefits. In many reaches of the study area, the riparian vegetation is absent altogether or significantly reduced. Areas where the riparian forests are less than 30 meters wide are prone to natural channel evolution processes such as bank erosion/channel migration and associated habitat impacts as previously mentioned. The Service believes the riparian area should be no less than 30 meters in width and comprised of a diverse index of native species to function adequately. From a terrestrial habitat perspective, riparian areas as wide as 100 meters would be the most beneficial for bottomland forest interior birds. A wider riparian forest would tend to prevent nest predation from other species adapted to edge environments. Many migratory birds that depend on this type of habitat are in decline due to habitat fragmentation and agricultural development.

Beyer et al. (2013) documented Pb exposure to songbirds collected in the Big River floodplains and demonstrated tissues concentrations that have been linked to detrimental effects. Therefore, we believe floodplain restoration should also include measures that reduce exposure to Pb contaminated soils, such as high phosphate fertilizers or other high phosphate composted soil amendments. Beyer et al. (2016) showed reduced Pb bioavailability to birds dosed with phosphate treated soils. The Service would caution that the use of high phosphate soil amendments should be employed only with adequate off sets and specific Best Management Practices (BMPs) to ensure excess nutrients are not transported into waterways.

Loss of Wetlands
Similar to riparian corridors, wetlands have been significantly reduced across the landscape and within the study area. Losses of additional floodplain wetlands could reduce potential sediment capture/storage areas and allow contaminated sediments to travel downstream and impact additional aquatic habitats. Because of elevated Pb concentrations throughout the floodplain, wetland development should be limited to either the Meramec River floodplain and the downstream areas within the Big River to prevent the possibility of the habitat acting as an attractive nuisance where Pb concentration levels could pose further risk of injury to wildlife; or additional protective measures such as soil/sediment capping or soil treatment amendments should be implemented to reduce potential Pb exposure. Increasing the number of floodplain wetlands in uncontaminated areas and/or treated wetlands in the Big River could serve to multiply additional benefits already described (e.g., increasing amphibian diversity).

Altered Hydrology
Natural stream hydrology within the study area is dependent on precipitation and ground water inputs. Recent rapid changes to the landscape associated with development and urbanization (e.g., increased groundwater withdrawals, sewer outfalls, and watershed detention features) can have direct, indirect, and cumulative impacts to basin hydrology. Furthermore, vegetation reduction/removal, addition of impervious materials, and infrastructure expansion (e.g., roads, bridges, and pipeline crossings) could accelerate the magnitude, frequency, timing, force, and flow declination rates of river hydrology/levels. As a result, the sediment transport rate could also be accelerated which would increase the potential for the instream contaminated sediments to be carried into sensitive downstream environments and also potentially affect the stream's dimension/pattern/profile which in turn would likely induce secondary impacts such as streambank erosion as previously discussed.

Mussel Habitat Degradation
Refer to the **Fish and Wildlife Resources** section below.

Excess Bedload/Sediment Contributions
Tributary streams are normal sediment contributors to alluvial systems. However, due to the tremendous amounts of contaminated mine waste introduced within the Big River, we expect the sediment budget to have likely exceeded the historical sediment transport capacity. This is supported by many instances of large mid-channel islands and gravel bars forming beyond their typical levels in the upper Big River in St. Francois County. These features can be exacerbated

at tributary confluences, in wide areas, and stretches with a low streambed slope. As a result, these features can/do directly disrupt physical habitat stability and often lead to secondary channel planform changes and accelerated bank erosion (as mentioned above). The latter situations are of importance as they continue to introduce Pb contaminated soils from within floodplain deposits and impact local and downstream benthic habitats. Thus, we believe to maximize local and downstream habitat benefits, the USACE should consider thorough investigations to determine the proper sediment budget within the Big River. This, in addition to the proposed designs and activities described in the **Contaminated Sediments/Streambank Erosion** section will help to prevent additional erosional source areas and excess contributions of contaminated materials.

Gravel Harvest
Stream gravel is a large commodity regularly mined throughout the Ozarks due to the material being easily accessible, being largely comprised of erosion-resistant chert material, naturally rounded, and dust-free. However, improper gravel removal from within streams can have significant negative effects to both the physical condition of the stream as well as the local and downstream environments. Commercial gravel harvest is regulated by the State of Missouri via the MDNR Land Reclamation Program pursuant to 444.760 RSMo. This regulatory oversight provides covenants and BMPs related to gravel removal activities. However, gravel harvest for personal use is not currently regulated. It is unclear to what level gravel harvest for either use is occurring within the study area. The Service can agree that gravel removal activities can be allowed in controlled situations in areas where the bedload has exceeded the stream's transport capacity. As mentioned earlier, we believe appropriate areas could be identified and habitat benefits could result by removing these contaminated sediments as well as excess bedload materials in controlled/monitored situations.

Nuisance Species
The following invasive exotic animal and plant species have been reported or likely occur within the Meramec Basin. These include: Asian Clam (*Corbicula fluminea*), Zebra Mussel (*Dreissena polymorpha*), Bighead Carp (*Hypophthalmichthys nobilis*), Silver Carp (*Hypophthalmichthys molitrix*), Grass Carp (*Ctenopharyngodon idella*), Common Carp (*Cyprinus carpio*), Eurasia Water-milfoil (*Myriophyllum spictatum*), Japanese Hops (*Humulus japonicus*), Garlic Mustard (*Alliaria petiolata*), Multiflora Rose (*Rosa multiflora*), Wintercreeper (*Euonymus fortunei*), Reed Canary Grass (*Phalaris arundinacea*), Johnson Grass (*Sorghum halepense*), Honeysuckle (*Lonicera sp.*), and likely many others. Some of these species may have an enormous impact to the health and longevity of aquatic systems into the future. For example, Asian carp have dramatically increased their range throughout the Mississippi and Ohio River basins just within the past two decades, which includes the study area. The presence of these species may require additional resource management considerations into the future. We believe the presence of these species helps support the need to pursue this project. Restoration of native habitats and water quality improvements would help native species compete with these exotic species which are better able to withstand the existing marginal habitat quality. As such, we believe a better understanding of the potential impacts and risks these exotic species pose should be investigated as this project develops and proceeds into design phases.

10

Urbanization

A large area near and within the downstream segments of the study area have been/are being influenced by the expansion of an urbanizing landscape within a number of different municipalities around greater St. Louis. Conversion of the largely rural area into an urban setting coupled with additional water resource needs/impacts are being realized throughout the region. There are also synergistic effects of urbanization on water quality, quantity, and drainage timing that can impact/exacerbate flooding, erosion, and mobilization of contaminated sediments similar to impacts discussed for climate change below. Furthermore, floodplain development or conversion has the potential to impact existing infrastructure and further reduces options to mitigate past and foreseeable habitat losses. Despite this, there has been a long standing interest throughout this area to protect the natural resources indicated below. As mentioned earlier, a large federal impoundment was planned and approved but was not completed because of substantial local opposition. In addition, other entities, such as area citizens, non-government organizations, recreational outfitters, land trusts, and mitigation banking instruments continue to express a strong interest to protect the Meramec River ecosystem.

Climate Change

Climate change is and will continue to be a primary issue for fish and wildlife conservation into the future. Dramatic changes in temperature and precipitation are predicted to affect the Midwest and, consequently, the Meramec River Basin. Climate change will likely be a significant stressor to wildlife and plant resources. However, when combined with other human-related stresses will likely exacerbate the vulnerability of ecosystems resulting from rapid/extreme environmental changes/fluctuations, invasive species, and loss of native species. Average temperatures have risen consistently throughout the Midwest over the last few decades, and are currently projected to continue to increase in the future (Staudinger et al. 2015). Consequently, even slight temperature changes could result in large, detrimental life history impacts such as condition/availability of and competition for water, food and habitat, as well as lack/loss of recruitment because of minor but cumulative changes in breeding patterns. The projected precipitation changes are expected to include more frequent stochastic events such as severe droughts and heavy rainfall/flooding. Climate change will also likely impact the magnitude and duration of those events. As a result, larger than normal mean discharges and temperatures could drastically impact wildlife, their habitats and possibly affect the management of projects proposed within the study area. Potential examples include two large flood events which exceeded the 100-year probability occurred in the study area between 2015 and 2017. If these situations continue or increase, the rate at which Pb contaminated sediments enter/migrate downstream is amplified which will directly increase the magnitude of cumulative impacts to habitats and sensitive wildlife throughout the study area and beyond. In addition, the possible increase of human populations in both rural and urban areas will likely increase water demands as well and potentially impact the Meramec River Basin hydrology as discussed above. These increased rural, municipal, and industrial needs for water coupled with decreased groundwater supplies could very likely and expectedly impact additional fish and wildlife resources beyond our current evaluation. We recommend the USACE consider the potential impacts resulting from climate change to the best possible ability during the planning phases of this study as this project proceeds into the future.

As mentioned in the introduction to this section, the Meramec and its tributaries provide ecologically robust habitats of national significance. The following section provides more detailed information on the unique opportunities for fish and wildlife conservation available in the Meramec River.

FISH and WILDLIFE RESOURCE CONDITIONS and HABITATS

This section will summarize and briefly describe the primary habitat types, fish and wildlife resources, and their relationships along the uncontaminated areas of the Meramec and Big rivers. As a general concept, the daily, seasonal, annual, and long-term flow fluctuations within a naturally flowing river encompass many dynamic riverine and floodplain environments. This situation helps promote successional habitat changes necessary to support habitat diversity. Natural seasonal river flow patterns regularly flood adjacent, river-bottom areas and fill/maintain ephemeral and perennial wetlands present in the floodplain as well as deliver important nutrients such as decomposing leaf fall materials to the aquatic ecosystem. During these high flows, erosive forces also act to constantly transport sediment down the river, creating and modifying habitat via removing terrestrial vegetation from some areas while creating suitable conditions for new plants to grow in other areas. These flows also provide important wildlife breeding and foraging habitat and are used by some species to make vital migratory journeys into sometimes specific habitats. Streams and rivers, including their ephemeral tributaries, are known to provide essential spawning and nursery habitat for countless Missouri wildlife. Combinations and transitional zones of open water, floodplain wetlands, and riparian vegetation are particularly important for the large number of migratory species including fish, amphibians, reptiles, and birds which use the Meramec River watershed to various degrees during their cyclic migrations. This wildlife seeks and utilizes a wide assortment and sometimes specific variations of supportive habitat. However, when habitats are composed of or influenced by toxic materials, as in the case of the upper Big River, the numbers of species and associated beneficial ecosystem services also become impaired. The current quantity, concentration, and distribution of Pb contamination throughout the study area coupled with the toxic impacts to the associated habitats and species substantiates the immediate need for the proposed actions to protect uncontaminated areas as well as treat and rehabilitate contaminated areas throughout the study area.

Available Habitats

The study area contains a very high number of differing aquatic and terrestrial habitat types. Variations of flows, substrate/streambank stability and composition, sediment deposition, sheer stress, riparian protection and species relationships are only a few of the many variables that can influence/determine suitability for specific species occupation. If suitable, many aquatic and terrestrial wildlife including microorganisms, macroinvertebrates, crustaceans, snails, mussels, fish, reptiles, birds, and mammals occupy and utilize available resources within available habitat types. Some habitats may contain a high number and high diversity of many different groups, while other habitats may be unique or specific to a few or even one species which may have adapted to such an environment to prevent competition for resources. The aquatic environment can be categorized as either riverine (lotic) or backwater (lentic) habitat. The terrestrial environment can be categorized as either floodplain or upland habitat. To summarize, habitat importance and fish and wildlife success is largely dependent on having and maintaining a wide range of interconnected diverse to specific habitat types over a large area. These elements are critical to ensure that the associated species have sufficient resources to successfully complete necessary life history functions and produce sufficient offspring to sustain long-term populations. If uncontaminated, aquatic ecosystems are typically extremely complex and dynamic. Their function is entirely dependent on many variations of flows, depths, substrate materials, and nutrient inputs from surrounding lands to allow wildlife to thrive. Due to a large number of differing habitats, specific habitat elements within each of the four categories listed above will be defined and described in Appendix 1.

Fish and Wildlife Resources

An extensive number of fish and wildlife species within many taxonomic groups permanently or temporarily reside within many of the listed habitats (Appendix 1) in this very diverse ecosystem. The MDC maintains a Natural Heritage Database for which wildlife and rare plants are documented to help manage fish and wildlife resources within Missouri. A diverse assemblage of resident and migratory wildlife still utilize many aquatic and terrestrial habitats within the lower Big River and Meramec River sections of the study area despite the historical and residual Pb impacts from mine wastes. However, these communities are typically depressed when compared to historical and similar habitats elsewhere in the watershed and outside the influences of residual heavy metal mining impacts. We believe this situation helps identify the importance of the resource at risk as well as the need for the proposed ecological restoration project. The Meramec Basin is noted to have one of the largest aquatic diversity indices compared to other Midwestern rivers (TNC 2014) as well as one of the most diverse mussel faunas in the central U.S. (Hinck et al. 2012). Due to the large size of this watershed and its proximity to the Mississippi River, there may also be undocumented species within this watershed but not known simply because of their rarity. For instance, the Pallid Sturgeon (*Scaphirhynchus albus*) is a federally listed fish species which has been documented in the Mississippi and Missouri rivers but has not been reported within the Meramec River. However, the aquatic habitat within the lower Meramec is not that dissimilar to either the Missouri or Mississippi rivers where the species is known. Also, the wildlife resources indicated below does not preclude an overriding ecological importance and interdependence with that of other taxonomic groups in the study area. For example, many associated wildlife species such as phytoplankton are extremely important food resources for mussels and crayfish. Thus, for simplicity, we will expand on only the most pertinent wildlife potentially impacted by this study.

Invertebrates

A countless number of macroinvertebrate species such as worms, aquatic and terrestrial insects, spiders, and snails, etc. are within this area and are particularly important animals as either a food source and/or due to performing ecological functions (e.g., decomposition, pollination, etc.). Because of the enormous number of species in this assemblage, we will refine our focus to two of the larger groups, mussels and crayfish, which also have particular ecological and regulatory significance and are described in more detail below.

Freshwater Mussels

Mussels are an extremely important animal group recognized within this ecosystem. They act as natural biological filters, perform essential nutrient cycling, represent food for many fish and wildlife groups, and are often considered as indicators of water quality. Mussels also denote the largest biomass compared with other invertebrate taxa. However, during the past century, mussel populations represent only a fraction of their original state. These animals now rank as one of the largest groups of imperiled organisms in North America (Williams et al. 1993). During the last 100 years it is presumed that 30-40 species have gone extinct and many more species nearly so (Haag 2012). Mussel declines have been generally attributed to many factors which include: degradation and loss of habitat by chemical or physical influences such as poor water quality, sedimentation, streambed instability, nutrient loading, loss of host fish, impacts from invasive species, urbanization, and overharvest for production of buttons, cultured pearl blanks, and the occasional discovery of a natural pearl. The Meramec River is reported to have one of the most diverse freshwater mussel faunas in the Midwest when compared with the number of species known within the upper Mississippi River Basin (Buchanan 1980, Roberts and Bruenderman 2000, McMurray et al. 2012). Currently at least 45 mussel species are represented in the Meramec Basin (McMurray et al. 2012). Roberts and Bruenderman (2000) conducted a comprehensive study throughout the Meramec Basin, which included the Big River, and compared results with an earlier, similar study by Buchanan (1979). Although this comparison indicated a similar species index, a decline of mussel numbers was reported. This situation suggests the mussel community within the Meramec River Basin has also experienced a similar negative population trend as noted in many river systems (Haag 2012). In addition to general mussel reductions, several state and federal endangered species were noted to also have declined in the number of sites where they had been previously reported in earlier surveys. Roberts and Bruenderman (2000) also noted that some sites sampled by Buchanan (1979) no longer contained suitable mussel habitat.

Mussels are benthic organisms which can have very specific and complex habitat needs. They occupy a wide variety of habitats ranging from wetlands and sluggish backwaters/oxbows to high-flow riffles areas. A majority of mussels found in the Meramec River Basin are long-lived, riverine, sedentary creatures which typically require lotic conditions to persist. These riverine mussels are often found in dense aggregations comprised of many different species (i.e., mussel beds) due to having similar habitat requirements. However, mussel habitat is not widespread within lotic systems and can also vary significantly for specific species. An entire mussel's adult life is often spent in a small area most often comprised of permanent flow over very stable substrate. Individuals sometimes move only a few meters during an entire lifespan. Some mussels, such as the Scaleshell (*Leptodea leptodon*), can live as few as a 5-10 years (USFWS 2007) while others, such as the Spectaclecase (*Margaritifera monodonta*) are reported to live over 50 years (Baird 2000). Freshwater mussel beds are most analogous to the sensitive coral reefs found in the ocean environment. Because of their benthic lifestyle and limited range of movement, mussels are extremely vulnerable to many stressors but most particularly those that reflect very drastic and rapid changes to their environment. Roberts and Bruenderman (2000) and Hinck et al. (2012) attributed the mussel decline in the Meramec Basin to channel and streambank degradation resulting from activities such as gravel mining, riparian removal, increased hydrology from urban development, and most pertinent to this study, heavy metal mining activities in the Big River.

As discussed, mining activities directly led to the introduction of substantial concentrations of Pb contaminated mine wastes into the Big River. These contaminated sediments are believed to be the major factor that have caused declines in mussel abundance and diversity in the Big River compared to reference sections in the Meramec, Bourbeuse, and upper Big rivers. Roberts et al. (2016) reported significant declines in mussel density between Big River kms 113 and 67 and significant declines in mussel richness between kms 113 and 16.5. These values are relative to the distance upstream from the Big River confluence with the Meramec River. Mussels are known to accumulate Pb within their tissues and skeletal structures (Angelo et al. 2007). Laboratory studies have also identified chronic effects by Pb concentration on juvenile mussels (Besser et al. 2009). Roberts et al. (2016) and Albers et al. (2016) documented negative correlations between mussel density and species richness compared with Pb concentrations in sediment in the Big River. The sampling efforts by Roberts et al. (2016) were specifically limited to sites which contained live mussels and had stable substrate conditions to eliminate complicating factors related to habitat quality, which would potentially negatively affect mussel presence. When toxic conditions are present within mussel habitat, these animals are not able to subsist or recolonize those environments despite ample amounts of stable physical habitat being present. As a result, the once diverse mussel fauna within the Big River has been significantly reduced to only residual populations occurring in the most upstream and downstream stream segments where the Pb concentrations are currently lower than or within 10% of the PEC (128 mg Pb/kg) as defined by MacDonald et al. (2000). The distribution of Pb contamination in the Big River is complex. Both the floodplain and significant lengths of instream sediments within the upper and middle segments are presently contaminated and impacting the mussel habitat to varying degrees (Figure 2). The instream fraction of contaminated sediment is progressively migrating downstream through natural processes degrading the stream channel and likely also influencing its geomorphic characteristics and functions. These geomorphic processes were discussed in the **Excess Bedload/Sediment Contributions** section above and have applied to the development of all alluvial systems over time and are not unique to the study area. Pavlowsky and Owen (2013) identified many unstable areas throughout the Big River. In these reaches, changes to the channel have resulted in significant amounts of bank erosion. Although bank erosion is a natural phenomenon, these sites are of particular concern specifically due to the elevated levels of Pb contaminated soils contained within them. As these materials re-enter the stream, depending on their relative downstream location, they can induce additional primary chemical impacts to instream habitat quality and a lesser degree of secondary impacts to the physical stability of the channel (i.e., sedimentation, aggradation, development of transverse bars, and mid-channel islands). These erosional areas are expected to be actively contributing substantial volumes of additional Pb contaminated sediments into the stream as they erode. While some of these sediments may be suspended and redeposited on the floodplain, some remaining fraction will likely accumulate in the channel. Thus, as long as these contaminated materials are allowed to enter or remain in the river, a large portion of the Big River will continue to be unsuitable for nearly all mussel species.

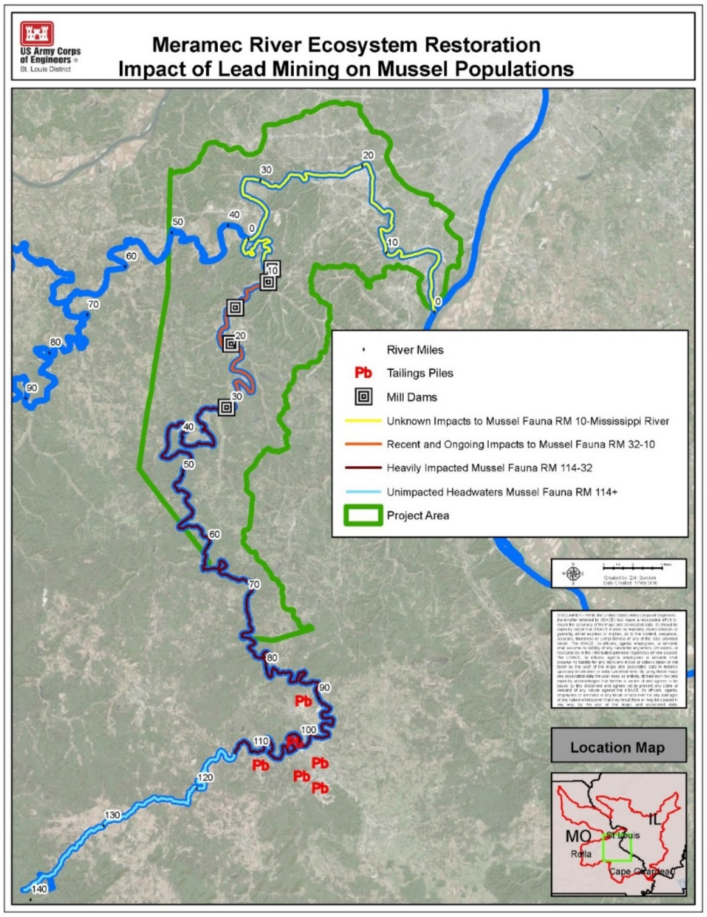


Figure 2. Big River Mussel Impacts as indicated by the USACE.

An even more severe impact would be to the remaining habitat in the lower Big and Meramec rivers which supports a very significant mussel community which could eventually become unsuitable for native mussels without a significant level of intervention. We do believe however, that many of the proposed actions have great potential to stabilize and limit/prevent Pb contamination from bank erosion sources as well as slow the downstream migration of these contaminated instream sediments. If the project can reduce the instream Pb concentration to near or below 135 mg/kg, indicated by Albers et al. (2016), we believe:

- Existing mussel resources present in the downstream environments will be preserved.
- Mussel habitats within impaired reaches of the Big River will be improved.

16

- Mussels will be able to successfully recolonize the vacated habitats within the Big River by either natural recruitment from upstream and downstream populations in uncontaminated reaches and/or through restocking efforts.
- The upstream mussel population will no longer be isolated.
- Threatened and endangered mussel species populations will be able to expand into the significant length of restored habitat and enhance their recovery potential.

The mussel species assemblage of the Meramec Basin includes six federally listed mussel species: the Spectaclecase, Scaleshell, Snuffbox (*Epioblasma triquetra*), Pink Mucket (*Lampsilis abrupta*), Sheepnose (*Plethobasus cyphyus*), and Winged Mapleleaf (*Quadrula fragosa*); as well as four state listed mussels: the Slippershell (*Alasmidonta viridis*), Elephantear (*Elliptio crassidens*), Ebonyshell (*Fusconaia ebena*), and Salamander Mussel (*Simpsonaias ambigua*). The Winged Mapleleaf was found subsequent to the comprehensive Meramec Basin mussel studies by Buchanan (1979) and Roberts and Bruenderman (2000). An important note to clarify is that due to specific mussel habitat requirements not being well understood, we cannot simply recreate mussel habitat at this time. Therefore, considering the number of state and federally listed species in the study area, continuing mussel declines, and significant time elapsed since previous comprehensive mussel studies in the watershed, underscore the importance and urgency of the proposed restoration activities. We believe additional status investigations throughout the entire Meramec River Basin for future population comparisons should also be considered to help protect this nationally significant freshwater mussel community. The threatened and endangered taxa and their habitat requirements will be summarized below within the **Threatened, Endangered, and At Risk Species** section.

<u>Crayfish</u>
Crayfish belong to a very diverse animal group. They make up one of the most dominant aquatic animal groups throughout North America with 400 of the more than 500 species known world-wide. Missouri contains nine percent of this fauna with 36 species. The Meramec River Basin is the most crayfish-diverse in Missouri with nine species. Two of these are state listed, the Salem Cave Crayfish (*Cambarus hubrichti*) and the Belted Crayfish (*Faxonius harrisoni*), and have an extremely limited range and distribution outside the basin within Missouri. Two others, the state listed Freckled Crayfish (*Cambarus maculatus*) and Saddleback Crayfish (*Faxonius medius*) are endemic to the Meramec Basin and found nowhere else (Pflieger 1996). Crayfish can occur in large numbers in both lotic and lentic environments and similar to mussels, can have a large influence on functions involving the transfer of energy and nutrients within the food chain. They are opportunistic omnivores that consume a variety of organic matter such as detritus (i.e., leaves) and a myriad of smaller organisms (e.g., worms, macroinvertebrates, juvenile mussels, other crayfish, and small or dead fish). Stream crayfish convert more detritus into usable energy for animals in higher trophic levels than all other invertebrates combined (Montemarano et al. 2007). They are also considered “ecosystem engineers” that provide habitat for many other members of the aquatic community (Jones et al. 1994 and 1997) and represent a primary food source for hundreds of fish and wildlife species such as: Smallmouth Bass (*Micropterus dolomieu*), Rock Bass (*Ambloplites rupestris*), Largemouth Bass (*Micropterus salmoides*), catfishes, Eastern Hellbender (*Cryptobranchus alleganiensis*), Bullfrog (*Lithobates*

catesbeianus), Common Snapping Turtle (*Chelydra serpentina*), Great Blue Heron (*Ardea herodias*), Belted Kingfisher (*Megaceryle alcyon*), River Otter (*Lontra canadensis*) and American Mink (*Neovison vision*) (DiStefano 2005). Crayfish are of commercial importance in the southern U.S. and were noted by Pflieger (1996) as a recreational fishery in Missouri outside of the Meramec Basin.

Allert et al. (2010 and 2013) studied crayfish distribution and in-situ toxicity at eight locations in the Big River, characterized as either reference, mine impacted, or distant from mining. Like the Roberts et al. (2009 and 2016) mussel studies, crayfish densities were reduced in over 140 km of the Big River and were lowest in areas with elevated concentrations of Pb contaminated sediment. Likewise, in-situ toxicity tests with caged crayfish also showed elevated Pb in crayfish and reduced survival in contaminated areas. Reduced crayfish abundance alters ecosystem function by decreasing 1) organic matter processing, 2) nutrient recycling, 3) energy transfer to higher trophic levels, including limiting available prey abundance for fish and wildlife inhabiting the river, and 4) habitat for other community members.

<u>Fish</u>

Missouri has a tremendous fisheries resource with at least 200 species known to occur within the state and at least 20 species endemic to the Ozark Region (Pflieger 1997). The Meramec Basin has a notably high species diversity index with approximately 128 species and one endemic specific to this system, the Meramec Saddled Darter (*Etheostoma erythrozonum*) (TNC 2014). The Meramec Saddled Darter was recently recognized as a valid species (Switzer and Wood 2009). It was separated from the Missouri Saddled Darter (*Etheostoma tetrazonum*) classification which still occurs in neighboring drainages of the Missouri River.

Nearly every fish species has a particular habitat association and specific life history requirements. For the purpose of this report, we will separate the fish into the following three composites (sportfish, preyfish, and other fish) and summarize each. Of note, all three groups have many species which are very important fish hosts for resident mussel species and may also have a wide range of variation within their tolerance of water quality and habitat locations. For example, some fish may prefer to live in swift pelagic environments while others are more limited by preferring specific small microhabitats (i.e., benthic locations near submerged structures in slow flows). Similar to other wildlife groups, the fish indexes were also reduced within the Big River.

- Sportfish – this fish group primarily consists of larger, predatory species which are targeted by recreational anglers. A variety of fishing related purchases for recreational fishing activities generates hundreds of millions of dollars annually in Missouri (Pflieger 1997). The Meramec River has good populations of Smallmouth Bass, Rock Bass, Channel Catfish (*Ictalurus punctatus*), and Flathead Catfish (*Pylodictis olivaris*).

- Preyfish – this fish group is largely comprised of many species of minnows, darters, herrings, and young-age fish within the other groups which are targeted by larger predatory fishes, turtles, and birds. These fish occupy a wide-variety of habitats and are found in nearly every aquatic environment indicated in Appendix 1. These environments range from no-flow areas and backwaters to high-flow pelagic areas. The continued presence of this fish group is extremely important for a large variety of ecosystem functions.

- Other fish – many other fish species also inhabit the Meramec River Basin including: Freshwater Drum (*Aplodinotus grunniens*), lampreys, gars, suckers, sculpins, and madtoms. Each species has an important role within the freshwater ecosystem. Some additional uncommon and noteworthy species within the basin include the Alabama Shad (*Alosa alabamae*), Highfin Carpsucker (*Carpiodes velifer*), River Darter (*Percina shumardi*), Western Sand Darter (*Ammocrypta clara*), and the state listed Crystal Darter (*Crystallaria asprella*). The USACE indicated the state listed Lake Sturgeon (*Acipenser fulvescens*) occurring in the study area. However, this species is not currently reflected in the Natural Heritage Database for the Meramec Basin (MDC 2018). Non-indigenous fish species and impacts were mentioned earlier for Nuisance Species within the **FISH and WILDLIFE RESOURCE PROBLEMS and OPPORTUNITIES** section.

Fish have been reported to accumulate Pb in their tissues in the Big River (Schmitt and Finger 1982, Czarnezki 1985, McKee et al. 2010, Schmitt and McKee 2016). Pb concentrations in redhorse suckers (*Moxostoma sp.*), sunfish (*Lepomis sp.*), and carp (*Cyprinus sp.*) have tissue Pb concentrations that exceed the Missouri Department of Health and Senior Services (MDHSS; http://health.mo.gov/living/environment/fishadvisory/pdf/fishadvisory.pdf website) action levels for fish consumption (0.3 mg Pb/kg) and MDHSS has recommended that humans do not consume these fish species from the Big River (MDHSS 2017).

Pb concentrations in fish fillets were positively related to concentrations of Pb in sediments of the Big River (Gale et al. 2004 and MDC, unpublished). Pb concentrations in sunfish and redhorse suckers were highest (50% exceeding 0.3 mg Pb/kg, the level that may trigger consumption advisories in Missouri) closest to the mining areas, at intermediate concentrations (0.03-0.1 mg Pb/kg) within 10 miles of the Meramec River, and below 0.03 mg Pb/kg in fish collected from the Meramec River (Schmitt and McKee 2016). Population densities were lower and the concentration of Pb was greater in riffle-dwelling benthic prey fish (Missouri Saddled Darter[1] and stonerollers) near mining sites on the Big River than at reference and downstream sites (Allert et al. 2013). The MDHSS fish consumption advisory pertains to Flat River Creek and the Big River beginning at Desloge, Missouri to the confluence of the Meramec River.

Schmitt et al. (2002 and 2005), which included fish collected from the Big River, also reported that elevated concentrations of Pb in fish muscle and blood were associated with physiological impairment as indicated by an inhibition of enzymes involved in heme synthesis. These and other studies suggest that Pb concentrations could be detrimental to growth and recruitment of fish, thereby negatively impacting ecological and recreational values of the Big River watershed.

[1] The Missouri Saddled Darter in the Meramec Basin has been reclassified as the Meramec Saddled Darter.

Amphibians and Reptiles
This combined animal group is comprised of 108 species found in Missouri compared to the approximately 460 known species within the U.S. (Johnson 2000). Approximately 66 species are known to occur in the Ozarks and within the study area. Those include many species of salamanders, frogs, toads, turtles, lizards, and snakes. These animals are typically very secretive in their habits and can be found in both the aquatic and terrestrial environments throughout the study area. They are cold-blooded creatures which remain inactive during the colder portions of the year. Animals from both groups residing within the study area are largely reliant on mature riparian woodlands for deadfall and woody debris that are delivered by flooding to provide sufficient food supply and cover. Amphibians also have an important connection to the water resources due to their reliance upon available predator-free habitat such as ephemeral floodplain wetlands for reproduction success. Frogs are a well-recognized group due to their presence being announced by loud, vocal breeding calls. Of note, the Eastern Hellbender is a large, long-lived, benthic, riverine salamander which was recently proposed for federal listing. The Eastern Hellbender occupies similar deep pool habitat as described for the Spectaclecase Mussel. This species occurs in the Meramec River and has also been recently documented in the Big River. Additional uncommon species reported in this region include the Wood Frog (*Lithobates sylvaticus*), Four-toed Salamander (*Hemidactylium scutatum*), Ringed Salamander (*Ambystoma annulatum*), Alligator Snapping Turtle (*Macrochelys temminckii*), and Eastern Collared Lizard (*Crotaphytus collaris*).

Birds
The terrestrial community and riparian lands found throughout the Ozarks are functionally important for feeding and/or nesting habitat for a vast array of migratory song birds, shorebirds, game birds, waterfowl, herons, and raptors (Jacobs 2003). The Meramec Basin in particular, being situated in the Mississippi flyway, acts as a very important habitat for many noteworthy populations of neotropical songbirds such as warblers, swallows, and martins.

During a benthic fish evaluation conducted by McKee et al. (2010), it was noted that herons are particularly susceptible to Pb exposure due to their diet consisting primarily of various aquatic organisms and fishes having high Pb levels within their whole-body tissues as referenced by a previous study (Allert et al. 2009 and 2013). The Missouri Saddled Darter[2] and Largescale Stoneroller (*Campostoma oligolepis*) were found to have a mean value of 66.8 mg Pb/kg and 175 mg Pb/kg respectably at two locations within the Big River. Crayfish concentrations found by Allert et al. (2010) contained similar concentrations (122 to 58 mg Pb/kg) at sites near and distant from mining respectively. Both riffle fish and crayfish tissues exceed concentrations found to be a risk to herons using an ecological risk assessment model. The no-effect hazard concentration (NEHC) of herons was reported as 45.3 mg Pb/kg dry weight within food items. Because of these studies, other aquatic-related birds, specifically piscivorous species, may also be prone to similar effects.

---

[2] The Missouri Saddled Darter in the Meramec Basin has been reclassified as the Meramec Saddled Darter.

Beyer et al. (2013) studied Pb exposure to songbirds in several locations within the Southeast Missouri Pb Mining District (SEMO), including one location in the Big River floodplain. This study demonstrated blood, liver, and kidney tissue concentrations of Pb that correspond to adverse effects to birds found in the literature, Pb related pathological changes to kidneys, and inhibition of enzymes associated with Pb exposure. Songbirds accumulate Pb from the consumption of earthworms and other soil organisms from contaminated sites. Gamebirds (i.e. quail, doves, ducks, and geese) that inhabit this area are also expected to accumulate Pb when foraging and when using Pb contaminated floodplain soils for grit. There is currently an ongoing study of songbirds in SEMO that includes two sites in the Big River floodplain that will give additional information on tissue concentrations and potentially reproductive effects from Pb exposure to soil. The MDHSS (unpublished) has detected Pb in eggs collected from domestic chickens and ducks that have consumed soils from the Big River floodplain. This finding supports the belief that maternal transfer of Pb to eggs is a route of Pb exposure to developing embryos of wild birds which has the potential to negatively impact reproductive success.

The Service is responsible for protection of several bird species via the Migratory Bird Treaty Act and Bald and Golden Eagle Act. Through project development, the USACE is expecting to avoid and minimize woodland impacts and habitat losses during construction as well as increase riparian habitats through restoration activities. Thus, pending study approval, the Service plans to continue coordinating with the USACE on future project design, potential riparian impacts, and habitat development throughout the study area.

Mammals – A large variety of mammals inhabit the Ozark Region. The study area contains many species of herbivorous, carnivorous, and omnivorous mammals. Small mammals comprised of numerous species of mice, rats, voles, rabbits, and squirrels constitute primary food sources for larger carnivorous mammals and birds of prey. The Ozarks karst geology also provides extremely important hibernacula for many Midwestern and migratory bat species. Bats are extremely important wildlife as they consume a large volume of night flying insects including agriculture pest species. Bats may become exposed to Pb through ingestion of emergent aquatic insects that are contaminated through contact with Big River sediments. However, this route of Pb exposure to bats has not been documented. Three federally listed bat species occur within the Ozarks and are expected to be present within the study area and also likely utilize the riparian woodlands during their active season. Other mammals present in the study area that may also be considered economically important are the furbearers. These mammals include muskrat, mink, otter, opossum, beaver, raccoon, skunk, fox, coyote, and bobcat. Other important, larger mammals are: deer, possibly elk (reintroduced near the study area) and non-native pigs. Feral pig populations are rapidly expanding and known to cause devastating, localized landscape impacts. If feral pigs are not currently in the study area, they may likely occur within the 50-year project period and will require management consideration on potential impacts to riparian projects. Of other importance, many of the smaller mammals occurring in the Big River floodplain are also likely burrowing into Pb contaminated soils. Beyer et al. (in press) collected white-footed mice to assess exposure of Pb contaminated soil in southeast Missouri. One site was located in the Big River floodplain. Beyer's study indicated elevated Pb concentrations in tissues and reduced enzyme activity specific to Pb exposure.

In summary, the identified wildlife studies have indicated a decline in density and potential physiological effects of many taxa throughout the Big River. This topic exemplifies the need to protect the remaining habitats by reducing the amount of Pb exposure within the benthic and floodplain environments. Restoration efforts can help prevent continued habitat degradation and reduce the amount of Pb contaminated sediments progressing into downstream environments. By improving aquatic and riparian habitat conditions, the resulting ecosystem benefits are expected to be elevated and expand through the upper trophic levels and positively impact the fish and wildlife species mentioned throughout the Meramec Basin.

Threatened, Endangered, and At-Risk Species

A major emphasis of this project is to protect and restore aquatic and riparian habitats within the study area. This section will focus on the federally listed and at-risk species that are known to occur in and along the Meramec and Big rivers which will likely benefit from the proposed actions. Each federally listed species, its status, and its habitats will be discussed in detail within this section.

Plants

Decurrent False Aster (*Boltonia decurrens*), Threatened

This plant species is typically found in open, muddy bottomland areas where regular flooding and disturbance creates persistent, wet, sandy floodplain, and prairie wetland soil conditions. In the Missouri portion of its range, it is currently only known to occur along the Mississippi River north of St. Louis. Because of the close proximity to the study area, the potential occurrence of the species should be investigated as this project develops.

Running Buffalo Clover (*Trifolium stoloniferum*), Endangered

This plant typically occurs in open areas of rich soils of forest and prairies. Similar to Decurrent False Aster, it prefers disturbed areas such as those impacted by mowing, trampling, and grazing. The potential occurrence of this species should also be investigated as this project develops.

Animals

Earlier, we indicated that six federally listed mussels occur within the Meramec River Basin, four of which occur within the study area:

Spectaclecase (*Margaritifera monodonta*), Endangered
Pink Mucket (*Lampsilis abrupta*), Endangered
Scaleshell (*Leptodea leptodon*), Endangered
Sheepnose (*Plethobasus cyphyus*), Endangered

Mussel habitat, although difficult to explain, can be generalized for a majority of mussel species found in Ozark streams, including the species listed above. These mussels are typically associated within lotic environments and most often found in areas of permanent flow and stable substrate that is composed of a consolidated mixture of sand/gravel/cobble/boulders not overlain with excessive amounts of fine sediments. Many malacologists believe the largest factor influencing mussel habitat is the long-term persistence of firm substrate with moderate current draining an uncontaminated landscape. Haag (2012) supports this opinion and also mentions that depth, flow, and substrate can vary greatly in microhabitats within a lotic environment. These variations do not seem to limit mussel colonization/persistence unless the substrate becomes unstable. All four federally listed mussel species indicated typically reside in this habitat type. The Spectaclecase's habitat varies slightly from that of the others in that it is most often found in deeper stream segments in association with large boulders most often along bluffs. Of particular note, Buchanan (1980) and Butler (2002) have indicated the Meramec River contains one of the largest Spectaclecase populations in the U.S. It was also reported as the most abundant species in the Meramec River (Roberts and Bruenderman 2000). Baird (2000) indicated Spectaclecase densities of up to 3.15 per 1/4 meter^2 (approximately 22,697 individuals) residing with 17 other species in one mussel bed within the Meramec River. Comprehensive evaluations of the mussel community have been conducted within the study area (Buchanan 1979, Roberts and Bruenderman 2000, Roberts et al. 2009 and 2016). The latter two were specific studies to understand the relationship between mussel habitat and impacts resulting from heavy metals within the study area. Sampling data from these reports and other Service efforts indicate several significant mussel beds remain on the lower reaches of the Big River and throughout the lower Meramec River. These mussel beds harbor some of the best populations known range-wide for these federally listed species.

The evidence indicates the largest factor degrading the Big River aquatic environment and associated wildlife communities has directly and indirectly resulted from Pb mining activities. Additional evidence supports the notion that the lack of AOP caused by mill dams is only of minor concern on the Big River compared to impacts associated with contaminated sediments. We believe the existing Big River mill dams are not causing major negative AOP impacts. This statement is supported by the existing condition of all the remaining dams being very dilapidated and/or breached such that all are also regularly inundated by slightly higher than normal flows. Roberts et al. (2016) indicated that a diverse mussel community has persisted upstream of two similar-sized, mill dams in the Bourbeuse River in the Meramec Basin outside the study area. This situation doesn't preclude the possibility for AOP improvement. Despite this, we recognize these instream impoundments have served to capture/contain significant amounts of Pb contaminated sediments and thus likely have helped to minimize possible impairment/loss of additional downstream environments in the lower Big and Meramec Rivers.

The following federally listed bats have been recently documented within the study area:

Indiana Bat *(Myotis sodalis)*, Endangered

In Missouri, the Indiana Bat hibernates in caves in the Ozarks and Ozark Border Natural Divisions from late fall through winter months (November 1 to March 31). During the spring and summer, the Indiana Bat utilizes living, injured (i.e., split trunks and broken limbs from lightning strikes or wind), dead or dying trees for roosting. Indiana Bat roost trees tend to be greater than nine inches diameter at breast height (dbh) (optimally greater than 20 inches dbh) with loose or exfoliating bark. Most important are structural characteristics that provide adequate space for bats to roost. Preferred roost sites are located in forest openings, at the forest edge, or where the overstory canopy allows some sunlight exposure to the roost tree, which is usually within one km (0.6 mi.) of water. The Indiana Bat forages for flying insects (particularly moths) in and around the tree canopy of floodplain, riparian, and upland forests.

Northern Long-eared Bat (*Myotis septentrionalis*), Threatened
The Northern Long-eared Bat occurs throughout Missouri and similar to the Indiana Bat, hibernates in caves (or habitats similar to caves) during the winter and roosts under loose tree bark or in tree cracks or crevices during the summer.

Gray Bat *(Myotis grisescens)*, Endangered
The Gray Bat occupies a limited geographic range in limestone karst areas of the southeastern United States, including Missouri. With rare exception, the Gray Bat roosts in caves year-round. In winter, most Gray Bats hibernate in vertical (pit) caves with cool, stable temperatures below 10 degrees Celsius. Summer caves, especially those used by maternity colonies, are nearly always located within a kilometer (0.6 mile) of rivers or reservoirs over which bats feed. The summer caves are warm with dome ceilings that trap body heat. Most Gray Bats migrate seasonally between hibernating and maternity caves, and both types of caves are located in Missouri. Gray Bats are active at night where they forage for insects over water or along shorelines. They need a corridor of forest riparian cover between roosting caves and foraging areas. Gray Bats can travel as much as 20 kilometers (12 miles) from their roost caves to forage.

The greatest current threat to all three species of bats is white-nose syndrome (WNS). WNS is named for the white fungus that appears on the muzzle and other parts of infected hibernating bats. WNS is associated with extensive mortality of bats in eastern North America and has spread rapidly across the eastern United States and Canada. The fungus that causes WNS has been detected as far south as Mississippi and as far west as Washington. Bats with WNS act strangely during cold winter months, including flying outside in the day and clustering near the entrances of hibernacula (caves and mines where bats hibernate). Bats have been found sick and dying in unprecedented numbers in and around caves and mines. WNS has killed more than an estimated 5.7 million bats in eastern North America. In some hibernacula, 90 to 100 percent of bats have died.

The study area contains suitable habitat for all three bat species. In fact, areas in and along the Meramec River floodplain support maternity and winter bat hibernacula, potential swarming habitat, and maternity colonies. However, recent surveys have failed to detect Northern Long-eared Bats in many areas where they had occurred just a few years previous. Because data indicate Northern Long-eared Bats are short distance migrants, it is likely that they are using the Big River floodplain in the summer and also may have winter hibernacula nearby. Limiting woodland removal and increasing protection during construction during riparian restoration will likely help these bats resist other environmental threats and provide meaningful benefits towards recovery.

The following species have been proposed for federal listing. They are either known or are likely to occur within the study area.

Monarch Butterfly (*Danaus plexippus plexippus*), Proposed
The project lies within the range of the Monarch Butterfly. The Service has determined that listing under the ESA may be warranted for the Monarch and is currently conducting a status review of the species. Monarchs are found throughout Missouri and some populations migrate vast distances across multiple generations each year. Many fly between the U.S., Mexico, and Canada – a journey of over 4,500 km. This journey has become more perilous because of increasing threats along their migratory path as well as impacts to their breeding and wintering grounds. Monarch populations have declined over 90% during the last 20 years. Primary threats to the species are attributed to loss of primary host-plants (i.e., milkweeds) and increased use of pesticides. Similar to bats, riparian restoration which includes planting of milkweeds and other nectar producers will be beneficial to this species as well as other pollinator species.

Eastern Hellbender (*Cryptobranchus alleganiensis*), Proposed
The Eastern Hellbender is a large, long-lived, benthic, riverine salamander which is restricted to 13 states in North America. Missouri is the only state where the species occurs west of the Mississippi River. In Missouri, it is restricted to the Ozark Region (Johnson 2000). It is known to occur in the Meramec Basin and has been recently reported from the Big River. The Eastern Hellbender occupies similar habitats as those described for the Spectaclecase Mussel. This species has been proposed for federal listing and the Service is currently conducting a status review of the species. Efforts to improve benthic habitat for riverine mussel species will likely also improve habitat for the Eastern Hellbender.

PLANNING OBJECTIVES
A collective planning team for the MRFS was comprised of biologists and engineers from the USACE, Service, MDNR, MDC, and TNC. Represented as Trustees, the Service and MDNR also provided input as it pertains to the Natural Resources Damage Assessment (NRDA) program. Numerous meetings, workshops, and field visits throughout the study area were conducted to identify and discuss the most prominent and relevant issues (negative environmental impacts) as well as collaboratively provide/discuss potential evaluation and restoration opportunities which could provide measurable wildlife habitat improvements within the study area. The Service believes completing the following large-scale planning objectives can potentially preserve and protect the existing aquatic habitats currently supporting unique wildlife species in the lower Big and Meramec rivers. Furthermore, this project is expected to reverse habitat degradation induced by chemical contamination and significantly improve habitat quality in the Big River beginning near the Jefferson/St. Francois County line. However, without additional intervention in the upper Big River, riverine and terrestrial habitats upstream of proposed activities will continue to be impacted by contaminated materials into the future.

- **Primary objective:**
  - Reduce the Pb concentration within the benthic environment to 128 mg/kg throughout the study area to prevent continued impacts to mussels and their habitat.

- **Additional objectives:**
  - Remove Pb contaminated sediment from the benthic environment to repair and restore degraded aquatic habitats throughout the study area.

- Reduce/prevent the downstream migration of Pb contaminated sediment throughout the study area to protect remaining mussel habitat in the lower Big and Meramec rivers.
- Locate and correct Pb input at eroding banks with willing landowners within the study area to reduce contaminated sediment contributions.
- Maintain a proper sediment budget needed to support benthic aquatic habitat.
- Establish/increase riparian buffer widths and habitat connectivity, quantity, diversity, and complexity with willing landowners within the project area.
- Reduce risks from Pb exposure with willing landowners within the project area.
- Restore/create functional habitat for fish, mussel, and terrestrial species throughout the study area.
- Adopt design and construction principles and practices that maximize fish and wildlife habitat functionality.
- Improve aquatic organism and recreational user passage where feasible in the study area.

Ecological Habitat Assessment and Quantification

The USACE is currently planning large-scale habitat restoration using a variety of specific techniques targeted to remove/reduce/contain Pb contaminated sediments and total suspended solids (TSS) which are currently above concentration levels known to impair aquatic life. These contaminated sediments have/are originating from either existing streambed sources and/or accelerated streambank erosion within the Big River. During the course of the study's development the USACE, MDNR, Service, and MDC representatives worked collaboratively to the extent possible to develop various preliminary preferred project alternatives for comparison purposes per federal requirements with the primary goal to restore ecological functions within this impaired system. The USACE attempted to quantify the baseline conditions, potential impacts, and investigate possible design alternatives to the best of their ability using available field evaluations, review of watershed hydrology gauge data, aerial photography review, literature review, and input from subject matter professionals. The USACE investigated many preliminary designs and evaluated elements within the seven various project alternatives described below. The proposed construction actions within each alternative included singular or combinations of the following measures depending on the site complexity and existing habitat conditions/circumstances: streambank/channel stabilization, grade control structures, streambank re-sloping, floodplain benching, LPSTP, rootwad revetment, weir and barb placement within the streambank, bioengineering techniques, toe wood installation, channel reconfiguration, riparian plantings, mechanical or passive floodplain sediment capture/containment features either instream or within side channels, gravel bar restoration, in-channel bedload collectors, and mill dam/impoundment modification.

Habitat Suitability Index (HSI) Models

To equally compare the effectiveness of each of the project alternatives considered, the USACE employs internally certified models to evaluate, quantify, and compute any potential relative benefits (indicated as habitat units (HUs)) resulting from various projects within/among the proposed alternatives. To forecast expected benefits, calculations must be able to consider/compare existing (baseline) conditions with, the future without project and future with project conditions. The development of a HSI model typically involves collection and evaluation of pertinent peer reviewed literature, datasets, site visits, and expert opinion. Once known, the HUs for a given alternative are then compared with the project cost to help measure/inform the cost/benefit for each alternative which helps direct decisions to select the TSP from the group of alternatives. Two HSI models were used to evaluate the potential aquatic and terrestrial HUs within the project study area (Jefferson and St. Louis counties). The Black-capped Chickadee HSI model (USFWS 1983) was pre-certified for regional and national use and used to evaluate the floodplain forest habitat. The mussel model was developed and approved as a single-use model in collaboration with competent experts representing the USACE, Service, MDNR, and MDC to be used to evaluate mussel (riverine) habitat (USACE 2017). The primary habitat suitability variables consisted of six equally-weighted parameters: total suspended solids (TSS) levels, Pb concentration levels, substrate composition, percentage of available aquatic cover, fish species richness, and riparian width/amount of channel migration.

The threshold values indicated for the TSS variable in the mussel model were largely based on available literature indicating that elevated levels of TSS can cause feeding or reproductive difficulties in mussels. Subsequent to the HSI mussel model development and approval, the Service obtained additional data from the Kansas Department of Health and Environment (KDHE) water quality monitoring program which appear to indicate the upper threshold value (20 mg/L) may be conservative. For example, median values for TSS and temperature that were collected between 2006-2017 (Table 1) from streams which currently harbor a high number of long-term, diverse mussel communities, including many of the mussel species found within the Meramec Basin. The median TSS (mg/L) and temperature values reported in these streams were summarized from a high number of samples collected throughout the mussels' most physiologically active periods (spring, summer, and fall months). Apart from occurring in a different ecoregion, mussel physiology and nutrition are not expected to be vastly different between the streams indicated compared to the Meramec River.

Basin	**Spring**	**Summer**	**Fall**
Marais des Cynges	42 mg/L, 20°C (N=207)	34 mg/L, 25°C (N=207)	15 mg/L, 13°C (N=184)
Neosho	30 mg/L, 20°C (N=461)	23.5 mg/L, 26°C (N=429)	12 mg/L, 15°C (N=390)
Verdigris	21 mg/L, 19°C (N=291)	20 mg/L, 27°C (N=239)	14 mg/L, 15°C (N=263)

Table 1. KDHE Median TSS Values indicated for Basin and Season.

Therefore, mussels appear to have a higher level of tolerance to TSS than the values indicated in the USACE mussel model. Despite this specific discrepancy, high levels of TSS in the Big River remain a considerable resource concern due to the chemical attributes of Pb binding to fine sediment particles, resulting in TSS being the primary vector for Pb mobilization. Therefore, a reduction of TSS levels throughout the study area would directly reduce the transport rate of Pb. As the model is used to quantify and compare the HUs generated for pertinent projects involving relative habitat types over the project time periods, we do not anticipate any concern using the mussel model in its existing state as it calculated the same variables for all project alternatives.

DESCRIPTION of MRFS ALTERNATIVES

To best address the **Fish and Wildlife Resource Concerns** and **Planning Objectives** described above, the USACE, in cooperation with the interested parties, developed seven independent alternatives. Each alternative considered the impact of various individual actions along different sections of the Meramec and Big rivers. The proposed actions within each of the alternatives are largely composed of streambank stabilization projects, passive sediment capture structures, direct mechanical sediment removal activities (i.e., gravel bar restoration, instream collection by mechanical collectors and directly upstream of (behind) existing mill dams), and riparian corridor enhancement. These projects are described below.

Streambank stabilization: These projects will be located at sites exhibiting accelerated bank erosion with a primary purpose to protect each site from scour and redirect stream flows away from existing erosional areas to limit/prevent additional contributions of Pb contaminated sediments contained within the floodplain. Current designs may include LPSTP, bioengineering, and river training structures such as weirs, barbs, rootwad revetments, toe wood, and channel realignment.

Passive sediment capture: These projects will be located at sites within the floodplain. Sites will require the excavation of a large basin to enhance the depositional potential in order to receive and capture contaminated sediments (<2mm) that are being transported overland during high-discharge events. The operation and maintenance activities (i.e., regularly remove deposited materials or allow the features to fill and be capped) will be determined at a later date by project sponsors. If materials will be removed, there will likely be associated removal, transport, and disposal costs.

Direct mechanical sediment removal: These projects will be located at sites within the active stream channel below the floodplain elevation. These projects will remove a larger size fraction and volume of contaminated sediment currently impacting the aquatic environment by the following means:

Bedload collectors – These projects are constructed traps located within the wetted channel at a grade below the existing streambed and will capture sediment during large discharge events at a time when streambed sediment is mobilized. The collectors can target particular-sized sediments depending on their design. The resulting material can either be mechanically or hydraulically removed and transported to an approved disposal location.

Gravel bar excavation – These projects will occur at existing, large depositional features above the base flow elevation. The sediment removed will be mechanically collected, screened, and the contaminated fraction transported to an approved disposal location. The sediment removal process will consist of repeated excavation activities at each gravel bar location throughout the project period. The resulting bar morphology will be lowered to an elevation sufficient to encourage additional sediment deposition during future high flow events followed by repeated excavation. Many of the existing large gravel bars throughout the study area have existing private access points. We expect that some roads and access improvements may be necessary to support large excavation equipment which may include some minor riparian impacts. Nevertheless, similar to bedload collectors, particular-sized sediments can be targeted to remove a large volume of Pb concentration from the Big River channel. These practices will follow the regulating guidelines provided by the MDNR Land Reclamation Program and USACE General Permit (GP) 34M. These regulations implement particular measures to avoid and minimize impacts to the environment. The Service provides input to each agency during the permit review/reissuance periods.

Instream excavation – These projects will occur directly from existing mill dam impoundments or from behind an established grade control structure. Big River mill dam impoundments have historically acted as sediment capture devices by processes similar to those described for passive sediment capture above. Projects will require the excavation of existing instream substrate materials directly behind existing mill dams. The level of excavation will depend on the depth of contamination within each impoundment. These actions will allow the stream to re-create additional deposition potential. As mentioned for passive sediment capture, actions to regularly remove these sediments or allow the features to fill will be determined by project sponsors. If materials will be removed there will likely be associated removal/transport/disposal costs.

Riparian Corridor Enhancement: These projects will be located at various locations either in association with other restoration project or singular actions within the floodplain on lands adjacent to the stream channel. The purpose is to create/enhance a riparian buffer, streambank protection, and create wildlife habitat. Some projects may include additional preparation such as re-sloping of streambanks and floodplain benching to ensure riparian vegetation development. Furthermore, discussions regarding floodplain soil treatment, such as adding phosphate to contaminated surface soils to reduce Pb concentrations and exposure risks are currently being discussed as additional potential restoration measures.

The habitat evaluation calculations within the seven study alternatives included the following general and site specific assumptions provided by the USACE (2018):

General Assumptions

- Target years of 0 (existing condition), 1, 5, 25 and 50 (future without and future with project conditions) are sufficient to analyze HUs and characterize habitat changes over the estimated period of analysis. The period of analysis was determined to be 50 years based on the prediction that some project features (e.g., development of key ecological processes needed to restore ecosystem structure and function) would need a longer period of time to reach maximum benefits and the accrual of benefits were predicted to level off after 50 years.
- No major land use changes are expected to occur within the watershed that would greatly change the existing land use. Land cover types may shift but the overall quantity would remain relatively the same.
- Anticipated changes in climate are not expected to greatly change the existing hydrology of the Big or Meramec Rivers.

Site Specific Assumptions

- Riverine Habitat
  - **TSS** baseline values for Year 0 (Big River 16mg/L, Meramec River 17mg/L).
    - Used median value from the available data sets to determine an overall existing condition for each river.
    - Due to limited number of gages collecting TSS, the use of the one gage for each river is adequate to provide a generalization of the condition of TSS in study area.
    - Meramec River should be higher than Big River since it is a higher order stream, and TSS from the Big River enters the Meramec River.
    - Based on published literature, TSS > 20 mg/L with water temperatures greater than 65°F would be a limiting factor for mussel habitat.
    - Future without project, no expected changes in TSS over the baseline into the future.
  - **Channel Change** baseline values for Year 0 (Big River - High, Meramec River - Low).
    - Overall, the Big River has several known areas of channel change throughout the study area; therefore, the existing conditions were determined to be High.
    - The Meramec River existing riparian corridor will substantially remain in place within the study area. Excepting the few recognized channel change areas, no obvious historic channel change was identified by the aerial imagery analysis; therefore, the existing conditions were determine to be Low.
    - That lack of or minimal riparian corridor (<100 foot wide) increases probability of channel change.
    - Vegetative plantings (turf and tree screens) associated with bank stability would be captured in this parameter.
    - Areas with known historic channel change are still prone to channel change.
    - Future without project, areas considered to have high probability of change would continue to have high probability of channel change into the future or get worst. Areas of low channel change are expected to remain in the low probability category into the future.
  - **Substrate** baseline values for Year 0 (Big River - Marginal, Meramec River - Suboptimal) from field observation averages.
    - The field observations taken at specific sites on a given river could be used to generalize the overall condition of that river.
    - Each reach of the Big River currently had similar substrate composition.
    - Localized substrate variability does exist; however, these localized "hot spots" are local and do not drastically influence the overall general condition of each river.
    - See discussion under Pb in USACE (2018) for potential changes in substrate as related to the movement of bed material through the system into the future.

30

- **Available Aquatic Cover** baseline values for Year 0 (Big River – 51%, Meramec River – 64%) from field observation averages.
  - Each reach of the Big River had similar aquatic available cover.
  - Localized variability does exist; however, these localized "hot spots" are local and do not drastically influence the overall general condition of each river.
  - Future without project, Meramec River expected to remain the same as current existence.
  - Future without project, Big River expected to get worst due to continual bank erosion and trees falling into the river. Areas with vertical banks would continue to erode and provide limited aquatic cover.

- **Fish Species Richness** baseline values for Year 0 (Big River (mile 0-10.2) = 48, Big River (mile 10.2+) = 26, Meramec River = 48).
  - 30+ year old data set is still accurate and represents the existing potential for species richness within the study area.
  - Average species richness from the Big River 0-10.2 is appropriate to use for the Meramec River.
  - Lower river reaches should have greater number of species due to mix of headwater species, big river species, and generalists.
  - 48 was the optimal number of species within the watershed.
  - Greater fish species richness important for mussel community composition and distribution since mussel species require varying hosts to complete their life cycle.
  - Future without Project, Meramec River, assumed that by year 25 at least some sensitive species would be gone from system; Pb impacts not as great due to dilution.
  - Future without Project, Big River, assumed loss of species during the period of analysis due to decrease in aquatic habitat related to migration of Pb, homogenous substrate, and limited aquatic cover. Reduction rate in fish richness determined subject matter expertise and published literature of how Pb affects prey/food sources for riffle fishes.

- **Pb Concentration** baseline values were obtained from Roberts et al. (2016) and USEPA (2017) as referenced in Table 3 within USACE (2018).
  - Use of 2017 samples from the more robust sampling effort are the data to use for the habitat evaluation.
  - Averaged sampling sites within each reach to provide a longitudinal gradient in Pb concentration in <2 mm size class is appropriate.
  - Determined baseline conditions for the Meramec and Big River separately.
  - One Meramec River sampling site is applicable to use for entire study area.
  - Model is limited to only include one baseline value per alternative. Assumed that using the proportion of each river reach to the total study area for the Big River would help determine the existing baseline for each alternative that spanned more than one reach.
  - It was determined that multiple future without project (FWOP) scenarios would be

beneficial to assess to better inform decision-making. These various FWOP scenarios are geared at better understanding the Pb parameter in the model, and include the following scenarios:

- FWOP1: No Action from the USACE and USEPA within Jefferson County, but continue their current work in upstream counties of the Project Area.
- FWOP2: No Action from the USACE but USEPA will do work in areas > 1200 ppm Pb within Jefferson County and would continue to work in upstream areas outside of Project Area.
- FWOP3: No Action from the USACE but USEPA will do work in areas >400 ppm Pb within Jefferson County and would continue to work in upstream areas outside of the Project Area.

- Based on the high uncertainty in regards to reasonable and foreseeable work to be undertaken by the USEPA or others within Jefferson County, the USACE is proposing the FWOP1 as the most appropriate future without project scenario; however, the team did evaluate the other scenarios targeting the differences in the Pb parameter for comparison. The differences in the Pb parameter will be discussed for each of these scenarios. The FWOP assumptions for the other parameters are included above in each parameter discussion.

References for additional USACE assumptions related to rate of Pb effects on mussel communities and rate of contaminated bedload with the Big River were indicated for all FWOP scenarios USACE (2018). The summary of this information includes:

- The negative effects of Pb to mussel species richness has migrated 48.3 miles in the Big River over 29 years, equaling 1.7 miles/year.
- Using this rate, the negative effects from Pb are currently expected to be at the Big River confluence of the Meramec River.
- Using this rate, the negative effects from Pb would move into the Meramec and Mississippi rivers in 50 years.
- Some dilution effect within the Meramec and Mississippi rivers would occur due to mixing of waters from these larger watersheds containing negligible Pb concentrations.
- In 2017, a large amount of contaminated bedload (>2mm) was noted at RM 75 in the Big River.
- Rate of Pb contaminated bedload movement within Big River is approximately one km/year (0.62 miles/year).
- Using this rate, the contaminated bedload is expected to move approximately 36 miles near RM 39 in the Big River by the end of the project period of analysis (2025-2075).
- This material is expected to negatively affect the substrate composition, potentially altering hydraulics and lead to increased probability of channel change and negative impacts to benthic organisms, such as mussels.
- The average Pb concentrations from RM 75-97 in the Big River is 1137 ppm. This value of Pb would migrate into the project area during period of analysis in FWOP1 and FWOP2 scenarios. For FWOP3, the maximum Pb concentration would be no greater than 400 ppm since areas greater than 400 ppm would be remediated by the USEPA.

32

- Riparian Habitat
  - Tree planting locations/riparian corridor widths were in areas less than 300 feet and 1500 feet in length along the river corridor.
  - Existing conditions were expected to have little or no tree cover throughout the study period.

List of Alternatives
As defined by the USACE (2018), Alternatives 2, 3, and 4 were formulated based upon geographic location. Alternative 5 was formulated based upon sites/projects meeting efficiency criteria. Alternative 6 was formulated to include all sites/projects along the Big River. Alternative 7 was formulated to include all sites/projects along both the Big and Meramec rivers.

Alternative 1 – No Action Alternative – FWOP
This alternative is specifically meant to provide conditions if the project were not to occur within the study area and is also used for comparison purposes in order to assess restoration benefits and project impacts for all alternatives considered. The USEPA will also likely have involvement in remediation of Pb within the study area. However, because no Record of Decision (ROD) has been indicated, the USACE also considered three FWOP alternatives assumptions (identified above). Once the USEPA provides its ROD the TSP may be impacted to some degree by potential measures pursued by the USEPA.

Alternative 2 – Big River RM 0-10.2 (RKM 0-16.4)
This alternative represents actions conducted only on the lower 16.4 river kilometers (10.2 river miles) within the Big River. The alternative was considered assuming the USEPA would be doing remediation activities upstream of RKM 16.4. The following actions were evaluated at six sites:

- Three bank stabilization projects
- An off-channel sediment capture project
- Grade control at an existing mill dam
- A riparian planting project greater than 4 hectares (10 acres)
- Monitoring, research, and adaptive management

Alternative 3 – Big River RM 0-35 (RKM 0-56)
This alternative represents actions conducted only on the lower 56 river kilometers (35 river miles) within the Big River. The alternative was considered assuming the USEPA would conduct remediation activities upstream of RKM 56. The following actions were evaluated at 25 sites:

- Twelve bank stabilization projects
- Five off-channel sediment capture projects
- Three grade control projects at existing mill dams
- Two excavation projects behind grade control structures
- Three riparian planting projects greater than 4 hectares
- Monitoring, research, and adaptive management

Alternative 4 – Meramec River Only
This alternative was considered due to the concern of the USACE working with hazardous materials. Actions would be limited to only the Meramec River to limit this interaction. It should be mentioned that this alternative will not address either the primary planning objective or many of the additional objectives discussed previously. These actions were evaluated at six sites:
- Six bank stabilization projects
- Monitoring, research, and adaptive management

Alternative 5 – Efficient Alternative
The following actions were evaluated at 54 sites within the Big River:
- Twelve bank stabilization projects
- Six off-channel sediment capture projects
- Four sediment removal projects (gravel bars, natural sediment collection points)
- A sediment removal project in association with bank stabilization activities
- Six instream bed sediment collectors
- Three grade control projects at existing mill dams
- Four excavation projects behind grade control structures
- Eight riparian planting projects greater than 4 hectares
- Ten riparian plantings in lieu of bank stabilization actions
- Monitoring, research, and adaptive management

Alternative 6 – Maximum Ecosystem - Big River
The following actions were evaluated at 69 sites within the Big River:
- Twenty-four bank stabilization projects
- Six off-channel sediment capture projects
- Fourteen sediment removal projects (gravel bars, natural sediment collection points)
- Two sediment removal projects in association with bank stabilization activities
- Six instream bed sediment collectors
- Three grade control projects at existing mill dams
- Six excavation projects behind grade control structures
- Eight riparian planting projects greater than 4 hectares
- Monitoring, research, and adaptive management

Alternative 7 – Maximum Ecosystem – Project Area
The following actions were evaluated at 75 sites within the Big and Meramec rivers:
- Thirty bank stabilization projects
- Six off-channel sediment capture projects
- Fourteen sediment removal projects (gravel bars, natural sediment collection points)
- Two sediment removal projects in association with bank stabilization activities
- Six instream bed sediment collectors
- Three grade control projects at existing mill dams
- Six excavation projects behind grade control structures
- Eight riparian planting projects greater than 4 hectares
- Monitoring, research, and adaptive management

EVALUATION METHODOLOGY

The Service, MDC, and MDNR contributed to the USACE planning process by collectively suggesting particular project actions which were believed as actions which would best address the stated project objectives (indicated earlier), prevent/limit fish and wildlife resource impacts, as well as attempt to maximize fish and wildlife resource benefits. The Service has relied upon the expertise and best professional judgment of USACE staff and biologists to estimate and evaluate project-related habitat changes for the study period (50 years). To do so, the USACE conducted the model computations and performed the quality control necessary to evaluate all projects within each of the seven alternatives. Based on the best available information, the following three main elements were considered during the evaluation process: the amount of Pb that could be removed by element of time and cost of project for the resulting HUs. The resulting values were also used to form the basis of other USACE evaluations such as project costs/benefits in order to compare and rank each alternative in order to select the TSP. The following sections rely on the information and calculations provided by the USACE.

EVALUATION and COMPARISON of ALTERNATIVES

Collective computations from the HSI models allowed the USACE to quantify, compare, and evaluate potential habitat benefits. The Cost Effective and Incremental Cost Analysis (CE/ICA) was conducted by the USACE for each project alternative within all three FWOP scenarios. As result of the full evaluation, the USACE project delivery team determined that FWOP2 was the most realistic and reasonable scenario. The HUs indicated in Table 2 represent the values for both FWOP1 and FWOP2 scenarios. The Service emphasizes the finding for the FWOP2 scenario, USEPA 1200 ppm Pb remediation clean-up level, will not provide detectible wildlife benefits.

Alternative	Description	Floodplain Net AAHUs	Riverine Net AAHUs	Total Net AAHUs
1	No Action	0	0	0
2	Big River RM 0-10.2	122	75	197
3	Big River RM 0-35	361	384	745
4	Meramec River Only	16	11	26
5	Big River – Efficient	553	1011	1565
6	Maximum Ecosystem – Big River	557	1010	1567
7	Maximum Ecosystem – Project Area	573	1053	1625

Table 2. Net average annualized HUs (AAHUs) for each project alternative for FWOP1 and FWOP2 scenarios.

Assessment of Individual Alternatives

The Service has used a programmatic approach for the project alternative analysis. We will provide more detailed evaluation once specific project design information is received from the USACE. At this time, we will assess each alternative as it pertains to potential fish and wildlife restoration. Based up the results of the USACE evaluation and our own expertise, we anticipate that no alternative can completely remove all the Pb contamination or its associated impacts from within the Big River.

Alternative 1 – No Federal Action = 0 total AAHUs
The no action alternative is the least desired alternative as it will not provide any potential HUs and will be the least effective in preventing additional/cumulative impacts to the current benthic aquatic community throughout the study area and possibly beyond. As mentioned elsewhere, the downstream reaches of the Big and Meramec rivers are currently largely un-impacted by Pb contaminated sediments. These stream segments contain several unique species and a nationally significant freshwater mussel community also containing numerous locations and numbers of federally listed species. Although the no action alternative may involve future remediation activities conducted by the USEPA, this agency has not indicated the location/degree/level at which possible remediation actions will occur. Thus, our current assumption is that if the USEPA would remediate, their clean-up actions would not be to the degree needed to restore mussel habitat (128 mg Pb/kg) within the Big River. As a result, downstream reaches of the Big and Meramec rivers will not be protected from migrating Pb contamination and therefore, existing wildlife resources/habitats would likely be impacted and degrade into the distant future.

Alternative 2 – Big River RM 0-10.2 (RKM 0-16.4) = 197 total AAHUs
This alternative is a low ranking alternative due to the limited type and number of habitat restoration projects. As mentioned, the downstream reaches of the Big River and Meramec River are currently largely un-impacted by Pb contaminated instream sediment. This particular stream reach contains the best population of freshwater mussels remaining in the Big River which includes federally listed species. This alternative will be one of the least effective to protect this population, will not substantially reduce instream Pb contamination, or prevent contaminated sediments from migrating into additional important downstream environments.

Alternative 3 – Big River RM 0-35 (RKM 0-56) = 745 total AAHUs
Similar to Alternative 2, this alternative is also a low ranking alternative for similar reasoning: limited type and number of habitat restoration projects and expected HUs will provide limited protection of downstream environments compared to several other alternatives.

Alternative 4 – Meramec River Only = 26 total AAHUs
This alternative will be considered the second lowest ranking alternative proposed due to no restoration projects considered within the Big River. As mentioned, all of the deleterious materials impacting the environment discussed in this study occur and are actively migrating downstream from the Big River to the Meramec River. By restricting the projects to only the Meramec, migration and impacts of Pb contaminated sediments will not be addressed. The benthic environment within the Meramec River segment of the study area is currently un-impacted by Pb contamination. This alternative will do very little to either dilute or prevent deleterious impacts to the remaining mussel community or rehabilitate habitat elsewhere. As a result, we anticipate future habitats will be similar to those mentioned for FWOP conditions.

Alternative 5 – Efficient Alternative = 1565 total AAHUs
This alternative will be considered the highest ranking alternative. We believe that when compared with all other alternatives, Alternative 5 produces the most cost-effective approach to protect the downstream environments as well as rehabilitate and restore a significant reach of the Big River for numerous fish and wildlife species as well the public interest. Based on the USACE's calculations, this alternative potentially removes the maximum quantity of Pb contamination per dollar expended.

Alternative 6 – Maximum Ecosystem – Big River = 1567 total AAHUs
This alternative generates a nearly identical number of AAHUs as Alternative 5. However, this alternative received the second highest ranking alternative due to the higher level of operation and maintenance (O&M) involvement/costs necessary. Another difference between the two was Alternative 6 could potentially decrease the amount of time necessary to remove Pb contaminated materials from the study area, but at a significantly higher cost per HU.

Alternative 7 – Maximum Ecosystem – Project Area = 1625 total AAHUs
This alternative generates the highest number of AAHUs. However, it was considered the third highest priority due to both the significantly higher project cost and sponsor cost-share needed to obtain the additional 60 HUs.

Generally, alternatives 5, 6, and 7 all present similar ecological benefits, but are vastly different in cost of construction, as well as cost expected to be incurred by the project sponsor. Therefore, as a result of the comparison, the USACE and the study partners plan to pursue **Alternative 5 – Efficient Alternative** as the TSP.

Adaptive Management (AM)
The USACE provided a proposed work schedule and has indicated that principles of AM will be incorporated once projects have been constructed. During AM, the USACE plans to regularly monitor/evaluate all restoration measures in order to ensure they 1) function as intended and 2) meet the intended project objectives during the project period. For example, a bank stabilization project may require slight design modifications pending project condition in response to unexpected outcomes following a high-flow event. The Service anticipates that innovative design criteria may be developed over the project period and possibly included if project maintenance is necessary. As previously mentioned, the Big and Meramec rivers are represented by a natural hydrograph with their high-flows being dominated by precipitation events. As the science of fluvial geomorphology improves, we foresee a potential to develop/use evaluation metrics to better understand how channel dimension, pattern, profile, bedform, streamflow, and sediment transport variables interact in response to these events to help influence development and persistence of aquatic habitat(s). If adequately understood, applicable restoration opportunities within projects could further enhance the potential ecological function and increase the resulting habitat value. For example, if the proper sediment budget and transport rate were understood the potential to remove the contaminated bedload fraction within specific reaches could be maximized. Furthermore, completing projects using relevant/accurate natural channel design principles can utilize stream functions and processes to promote/enhance habitat

development and expedite anticipated results. These design strategies allow the use of readily available, natural construction materials, such as large woody debris to not only help reduce project costs but also create/increase local habitat diversity potential. Additional design concepts able to combine/develop/maintain side channel or back channel habitat or can emulate any of the habitats mentioned in Appendix 1 should be considered. As indicated, the lower Big and Meramec rivers currently support intact diverse wildlife populations. While some of this diversity is simply due to the size of the river, much of it is a result of a variety of river flows and the amount of stable habitat over multiple seasons and years. Therefore, in creating habitat, we would stress that these "reference" environments should be carefully studied to not only ensure they persist but to also develop the evaluation criteria needed to make accurate habitat variable comparisons within the project areas to ensure they meet the project objectives. In doing, the Service considers future collaboration an important component within the AM approach to implement fish and wildlife conservation. Collaborative efforts will provide opportunities to improve current habitat conditions in the impacted reaches of the Big River and protect the downstream habitats in the lower Big and Meramec rivers.

ALTERNATIVE IMPACTS ANALYSIS and DISCUSSION

Potential Project Impacts

Many of the projects within each alternative were comprised of similar types of project actions. Each mainly differed by the number of actions and/or their site location within the study area. Due to the primary study purpose of restoring wildlife habitat, nearly all project actions will occur within currently degraded areas/environments. All proposed project types were either vetted or proposed by the Service and MDC. Most of those, as for the Big River, are either directly impacted from contaminated bed sediments or are directly contributing to additional habitat degradation (i.e., accelerated streambank erosion) in the study area. Due to existing habitat conditions, we currently only anticipate minor, local, short-term impacts to result from/near each projects completion. That said, all authorized projects should receive a full impact evaluation based upon the type, location, and timing of the proposed actions which may include additional less obvious cumulative impacts likely to result from project implementation. The Service recommends this evaluation begin as soon as possible once project designs are finalized and be coordinated with the Service and MDC. We believe our agencies could help the USACE define sound biological monitoring metrics to evaluate ecological impacts and assess habitat improvement for non-listed, native fish and wildlife species as they pertain to the projects throughout the study area. These monitoring efforts and assays could then be included within the USACE (AM) planning described above. To help this facilitation, the Service provided the USACE specific conservation measures meant to address potential negative impacts to federally listed mussel and bat species (Appendix 2).

Potential Project Benefits

Overall, the proposed USACE actions and AM plans are expected to remove an enormous fraction of the existing Pb contaminated bedload from within the Big River during the project period as well as help ensure the planned restoration actions function as intended. Altogether, as planned, these proposed actions are currently the most feasible benefits for this impaired aquatic community. However, because the adjacent floodplain will remain significantly contaminated throughout the Big River into the future, any additional actions to ensure this largest fraction of hazardous materials, (approximately 86.8 million cubic meters) remains contained in the floodplain to prevent future instream contamination would be extremely beneficial.

Instream Benefits

Habitat is a key variable to a healthy ecosystem as it can provide the needs of all fish and wildlife within the study area. Mussels also require habitat stability in order to subsist in the benthic environment. There are numerous variables and existing unknowns surrounding the topic. A primary component of mussel habitat is sediment. Much of the Big River is currently unsuitable for mussels because the current instream sediment Pb concentration levels exceed their tolerance level despite stable habitat being present in those areas (Roberts et al. 2016). Therefore, our best expectation to improve/restore the impacted zones to a historical condition would be a large-scale project to attempt to remove/reduce/contain the Pb contamination by the proposed measures. These actions are expected to collectively remove Pb contaminated sediments from within the Big River over time to concentrations near/below deleterious levels and should then allow mussels to recolonize those already stable habitats.

Reducing Pb concentrations in instream sediment will also benefit fish and crayfish populations. A reduction in sediment Pb concentrations that are protective of mussels would reduce Pb concentrations in sportfish and could result in removal of current fish consumption advisories. Furthermore, fish and crayfish densities could recover to more historic levels and provide a more dense and uncontaminated prey base for sportfish and piscivorous birds. Lowering concentrations of Pb in sediment would restore ecosystem function, structure, and stability and therefore, increase both the ecological and recreational value of the Meramec River Basin.

However, because streambed stability and proposed Pb removal activities both involve sediment transport processes, additional sediment management calculations may be required for project design refinement to not create negative habitat impacts. The Service believes the best approach to formulate the proposed projects is one that would focus natural fluvial processes to perform a majority of this work. In doing, the USACE should develop a good understanding of the channel-forming streamflow and sediment transport indices to effectively incorporate proper channel dimension, physical pattern, and profile which will then in turn help to efficiently promote the creation, maintenance, and function of the resulting habitat(s) in addition to helping ensure project longevity. As a result, we believe these geomorphic elements would also allow the associated habitat(s) and functions to respond positively and naturally improve the impaired reaches throughout the Big River.

The smaller TSS fraction is readily mobilized during many lower flows. Because Pb readily binds to fine sediment, the TSS is directly associated with elevated Pb levels in the Big River. Therefore, the proposed actions to reduce TSS in the Big River are expected to have beneficial effects to both the instream and floodplain environments in the study area but the largest benefits would be to prevent these hazardous materials from passing into/through the Meramec River.

Riparian Benefits
As a result of the proposed actions, we initially expect that the containment/reduction/removal of contaminated sediments from the instream portions of the study area to directly reduce/prevent contaminated levels of TSS from being continually delivered to the floodplain surface by overland flows. This will, in turn, eventually result in reduced concentrations of Pb to levels below toxicity thresholds downstream of the project actions in the study area. Secondly, the planned riparian buffer enhancement and plantings will not only create woodland habitat for a variety of terrestrial wildlife into the future, but it will also help minimize flood damages by shielding susceptible adjacent land areas from erosional forces and additional sources of Pb contaminated soils. This protection is also expected to promote/improve additional edge habitat and increase associated benefits for many additional native wildlife species such as pollinators (i.e., Monarch Butterfly), migratory birds, and bats which includes three federally listed species. Apart from the planned activities, the Service encourages the USACE to evaluate land treatment techniques (high phosphate fertilizers, composted manure, or biochar amendments) prior to reforestation as additional restoration opportunities to reduce Pb exposure to contaminated soils.

Additional Benefits
In addition to the expected instream and riparian benefits, the intermediate areas connecting these two environments may also benefit as a result of the activities. Floodplain connectivity is very important component of the overall health and productivity of the aquatic system. Proper bank height ratios compared with the channel-forming water surface cannot only help reduce flood damages but also connect the instream aquatic habitat to the terrestrial riparian habitat for an overall, healthy functioning riparian ecosystem. The stream can do this by normal channel evolution processes but doing so may come at the cost of unexpected negative changes to either environment (i.e., streambank erosion). Adequate floodplain connectivity throughout the study area could not only help provide necessary nutrients which are needed to drive biological functions and promote wildlife movements within the aquatic ecosystem but also help maintain the physical stability of the waterway. Therefore, designs including streambank benching and geomorphic calculations, mentioned earlier, should not be overlooked during project and riparian restoration design phases.

In addition to the wildlife (mussels, crayfish, fish, amphibians, reptiles, birds, and mammals) and habitat diversity increases mentioned, the Service also believes the public will also receive benefits from the proposed activities. Considering the negative health effects typically associated with Pb exposure, especially children, the completion of the project is expected to reduce the potential contact with Pb contaminated materials by substantially removing Pb from areas typically frequented by people (i.e., gravel bars). Furthermore, these sediments will also be prevented from eroding, traveling downstream, and accumulating on currently uncontaminated surfaces in the lower Big and Meramec rivers (i.e., croplands). Additionally, improved resource values could increase public perception and could also potentially increase the recreational use in the region (discussed below).

Cultural and Economic Significance and Fish and Wildlife Recreation
Many significant archeological locations are situated near and within the study area. This

supports the notion that this region has been an extremely important economic region for thousands of years. This was possibly because of the availability of natural resources and the close proximity to the nation's largest inland waterways. The City of St. Louis was initially sited among numerous extremely large earthen mounds which were constructed by earlier cultures (Marshall 1992). Little is known about their significance as they were destroyed during the early expansion of St. Louis before they could be studied. However, investigations at the Cahokia Mound complex help portray the early economic importance of the region. Many stone sources used to make prehistoric tools (e.g., projectile points, knives, axes, and celts) were presumed to have originated from areas along the Meramec River and the St. Francois Mountains located in the upper Big River and transported to this large cultural center (Kelly 2010 and Koldehoff and Wilson 2010). During the 1700s, trappers and settlers speculating for natural resources in the region began obtaining Pb from the surface deposits. It has been suggested that the 1804 Lewis and Clark expedition obtained Pb to produce bullets from southeast Missouri deposits. Since that time, this region went on to become the world's largest producer of Pb for nearly two centuries. During the last century, numerous towns and cities have relied on this mining industry as a primary economy.

Similarly, the fish and wildlife resources within the region must have also played an extremely important role prior to modern agriculture. Although the Pb mines within the Big River watershed are no longer active, their residual effects, as described, have significantly degraded the environment. Currently, the recreational use of the Big River appears to be limited to finite number of recreational users and individuals from local communities and adjacent landowners. This may be attributed to the knowledge regarding the contamination level and fish consumption advisory. As mentioned by Plieger (1997), a variety of fishing related purchases for recreational fishing activities generates hundreds of millions of dollars annually in Missouri. This number is expected to have risen in the 20 years since this estimate. Nonetheless, the Service suggests that this project represents not only an opportunity for protection of numerous federally and state listed species and rehabilitation of lost habitat for fish and wildlife, but also a great potential opportunity to stimulate and boost the region's economic growth. It has been documented that with the initial construction of restoration projects that there will likely also be additional economic benefits to the local economy through needs for materials, laborers, sub-contractors, and businesses such as hotels and restaurants, etc. Furthermore, the actions to improve natural resources at the landscape level will very likely also improve the perception and awareness of the Big River which in turn could then lead to additional economic benefits resulting from increased number of recreational users traveling to the region. The Big River presents a wide variety of recreational opportunities for the public such as swimming, canoeing, kayaking, camping, and fishing. Currently, many anglers utilize the Meramec and Big rivers by fishing specifically for sportfish species such as: Smallmouth Bass, Rock Bass, Channel Catfish, and Flathead Catfish. Gigging and snagging are additional fishing practices conducted in the Ozarks which target non-game species such as redhorse suckers. Members of the sunfish family (including Rock Bass) and suckers (e.g., redhorse) are included in the fish consumption advisory. Other economies on other Ozark streams but currently under represented on the Big River include canoe outfitters, private campgrounds, and fishing guide services.

The State of Missouri contains abundant amounts of public lands and natural resources. Outdoor activities such as fishing, hunting, or other wildlife-associated recreation are enjoyed by over two million Missouri residents and visitors. A large fraction of the population support efforts to restore rare and extirpated animals in the state. The MDC funds forest, fish, and wildlife conservation throughout Missouri via a 1/8 of 1% state sales tax. Wildlife-related recreation and forest products industries contribute over $12 billion in Missouri. These industries also support over 99,000 jobs. This information helps to illustrate that fish and wildlife can have incredible economic benefits as well as provide additional reasoning to protect the natural resources within this region by completing the proposed actions.

Recommended Fish and Wildlife Conservation Measures

Through the initial project coordination, the Service has reviewed various USACE draft project proposals. Prior to this report, we have provided our best recommendations regarding wildlife considerations throughout the preliminary stages of the MRFS. If the project is approved, the Service requests the USACE continue to provide us an opportunity to coordinate in the future to help project design formulation as well as ensure that conservation planning objectives can be realized throughout the study area. We offer the following specific recommendations to help promote resource recovery and fish and wildlife habitat rehabilitation:

1) Use the overarching Principles and Requirements for Federal Investments in Water Resources" while completing the MRFS (Appendix 3).
2) Continue coordinating with project stakeholders for all future project design, planning, and implementation activities. This includes collaborating to author/develop/approve the AM plan as well as set a formalized process to establish/assess performance and success criteria with appropriate definitions for project adjustment needs.
3) Add future study phases to investigate and implement similar restoration projects throughout the expanded study area in Washington and St. Francois counties.
4) The Service believes habitat diversity is extremely important. Future projects should incorporate design strategies that can promote streambed stability while also increasing habitat diversity through creating variations in stream depths, velocities, and substrate composition. A large variety of habitat characteristics within many different habitats would provide the greatest benefits to a range of wildlife species.
5) Adopt design and construction practices and principles that develop/enhance fish and wildlife habitat functionality.
6) Evaluate all project designs as they pertain to the resulting fish and wildlife habitat beyond their engineering function.
7) Investigate and develop BMPs during project planning to help minimize the potential for exotic/invasive species encroachment.
8) Increase habitat variability and maximize aquatic habitat potential by including various bioengineering structures and plantings (toe wood, large boulders, submerged logs, willow staking) in addition to standard engineering elements (LPSTP) and ensure all designs also consider and prevent boating hazards.
9) Include bank stabilization measures which can incorporate additional biological elements such as: logs, differential flow gradients, structures with interstitial spaces, and shade to promote/enhance aquatic wildlife habitat diversity within each design feature.

10) Incorporate streambank benching elements in association with proposed projects to help maximize riparian establishment, reduce erosional stressors to the project, improve floodplain connectivity, as well as provide additional habitat diversity.
11) Continue to investigate the most practical and efficient bedload collector devices/designs which can maximize reduction of instream Pb contaminated sediments and potentially reduce time needed to rehabilitate degraded downstream environments.
12) Include field investigations to determine the proper sediment budget needed to model bedload removal practices and prevent stream degradation.
13) Coordinate design and construction activities with the Service and MDC where projects may occur near known mussel bed locations.
14) Conduct a full risk and impact analysis for a FWOP scenario during planning phases to define potential wildlife and natural resources losses throughout the expanded study area.
15) Develop an AM plan which considers a monitoring plan for both project and ecosystem level response as result of collective project actions in coordination with the Service and MDC. As mentioned above, this plan should make sure to include specific project performance standards for each action with a defined set of outcomes to ensure what threshold limits would trigger a future need for additional project involvement.
16) Maintain a willingness to modify, improve, redesign, or refine project features as the understanding of environmental conditions (i.e., flow) as they pertain/relate to particular habitat conditions, needs, and opportunities become apparent.
17) Develop and include comprehensive monitoring parameters (i.e., Pb concentration, bank erosion rates, biological indices and status of river resources) in coordination with the Service and MDC such that all pertinent findings can be utilized to update design models, adapt and modify management actions, and refine target objectives. If desired objectives are ultimately unsatisfactory, the AM plan should also have contingencies to expedite remedial actions which capture uncertainties within particular designs (i.e., change bedload collector flow/material transport criteria) which could improve designs. This AM strategy could potentially reduce federal investments by avoiding repeated, costly, and long-term project repairs.
18) Evaluate completed grade control projects for adequate AOP and implement corrective measures as part of the AM contingency planning.
19) Include AM contingency plans that ensure future erosion doesn't occur at non-project locations which may negate current restoration activities.
20) Develop and implement an AM plan which applies a comprehensive approach to river management in the context of a fully-functioning river system such as stable river form and function. This strategy may help interpret impacts/changes of habitat conditions as a result of the actions.
21) A primary objective is to create functional habitat. A large fraction of the bank stabilization projects involves structural modification using hard points such as large quarry stone. Therefore, to quantify and understand the kinds of physical and biological responses incurred to these immediate habitats, we recommend a long-term comparative impact analysis to assess the quality of habitat produced by the various structures. We also recommend an analysis of what impacts these modifications will have on other native species.

22) Because freshwater mussels were identified as a primary index model for successful ecological restoration, consider including a supplementary mussel survey using similar methods as indicated in Roberts et al. (2016) during habitat monitoring/AM planning. A comparative evaluation would help inform changes and direct future management decisions regarding restoration objectives.
23) Develop a suite of monitoring metrics to effectively identify the type and quantity of habitats as well as evaluate both the biological response and physical habitat changes resulting from project actions.
24) Evaluate habitats during many river stages to interpret site-specific results as many species such as small/young fish may have slightly different habitat requirements in response to the project.
25) Include AM activities which allow unique habitat diversity elements to remain or develop (e.g., connectivity to bank channels, nursery environments, in-stream deposition/retention of large woody debris).
26) Because a large number of proposed actions occur on private lands, the success of the overall project largely depends on the availability of many willing landowners. Early discussions with all pertinent landowners are recommended to inform/discuss objectives and outcomes as well as advise them about land-use practices or treatments which may help contain/reduce the exposure of contaminated soils within the floodplain.
27) If the project includes land acquisition or conservation easements from willing landowners, we recommend a priority be provided to lands immediately adjacent to the Big River. Within this area, preferred habitat types would also include poorly drained lands, tributary confluences, lands with backwaters and side channels, and lands with unique habitats such as perennial wetlands and mature bottomland forests.
28) Coordinate with the USEPA to locate an acceptable sediment disposal/repository site.
29) Evaluate the potential habitat benefits associated with including high phosphate fertilizer or other organic amendments designed to reduce the bioavailability of Pb in riparian and floodplain areas in a manner which does not result in eutrophication in adjacent aquatic environments.
30) Consider expanding the study area boundary to include the upper Meramec River and its primary tributaries to help address additional degraded environments in the watershed.
31) Coordinate with the USEPA remedial actions to promote efficiencies and/or to maximize the effectiveness of the restoration opportunities within the study area.
32) Assess the potential impacts to project actions resulting from climate change, flooding, and changes in precipitation.
33) Evaluate the accuracy of the current TSS values within the HSI Mussel Model prior to future use.

SUMMARY of FINDINGS

The heavy metal mining activities within the Big River watershed have led to the introduction and episodic movement of toxic sediment throughout an extensive portion of the Big River. This contamination has now resulted in the significant reduction of fish and wildlife resources compared to historical levels as well as a direct impairment of approximately 150 km of stream and 86.8 million cubic meters covering adjacent floodplain habitats. In the study context, toxic sediment and soils persist in the Big River and continually pose imminent danger to additional downstream environments as they are transported by natural processes. Due to the vast area and enormous level of contamination, the task to restore lost ecological functions within the Big River seems daunting. However, the Service believes the proposed MRFS study is a sound approach to not only preserve the extremely important remaining wildlife resources and habitats within the lower portions of the Big and Meramec rivers, but also presents a variety of logical, cost-effective measures which can significantly improve and rehabilitate the highly degraded aquatic and floodplain environments and their associated habitats in a large portion of the Big River. The results of these actions are expected to provide extremely meaningful benefits to a diverse range of wildlife and endangered species as well as the public over a large length of stream. To achieve the low concentrations of Pb found to be non-toxic to mussels and other aquatic animals will be a monumental challenge; one that the project may not holistically achieve in the defined 50-year project period. USEPA remedial actions may address short-term ecological risks, but are not designed to restore lost ecological services. It is unrealistic to believe that all Pb contamination will be removed during this limited time frame. We emphasize that although the actions may not reach the concentrations desired for ecological restoration in the entire study area, the proposed restoration benefits will likely occur in a longitudinal direction as the contaminated sediments are contained/removed. As a result, the objective to improve habitat in the lower Big and Meramec rivers will be achieved in a downstream to upstream progression over time. Within the project timeframe, we expect a considerable amount of the currently impaired habitat will likely achieve the desired concentration with the possible exception being the portion of the Big River near the Jefferson/St. Francois County line. Based on the small difference needed to achieve the desired objective, we expect success throughout the defined study area within several more years. Under the no action alternative, it is expected that Pb contaminated sediments will continue to migrate downstream and impair a substantial amount of extremely important aquatic habitats in both the lower Big and Meramec rivers in the near future. The Service requests the USACE include future project phases and similar restoration activities within the expanded study area in the most contaminated Big River reaches in St. Francois and Washington counties. We also recommend the USACE also consider an additional study area expansion to include the upper Meramec River and its primary tributaries. The Service believes these additions would not only promote a quicker restoration response by addressing the most impacted segments of the Big River and its tributaries but also preserve and restore their core biotic communities and habitats.

After working diligently with the USACE during this study's development, we support the USACE plans to pursue Alternative 5 as the TSP. We believe this alternative represents the most cost effective, comprehensive, holistic river-wide ecosystem approach to benefit the unique resources and fish and wildlife species mentioned throughout this report. The Service considers this study as the beginning step toward a sound restoration approach and feasible path forward to address fish and wildlife needs, ultimately protect the lower Big and Meramec rivers, as well as potentially fully rehabilitate the Big River to support historical wildlife species.

The Service position and recommendations are based on the best available information which includes the most recent studies, monitoring data, and expertise provided by the USACE design engineers. We realize that due to the limited planning time, the large spatial area, magnitude of contamination and its impacts on this resource, many assumptions had to be drawn to make decisions. Because of this, if the project is authorized/funded, the Service commits to continue coordinating with the USACE and project partners to work collaboratively to resolve many of the current design uncertainties and habitat evaluation metrics as well as contribute to the AM process. This collaboration will likely be critical to develop the best measures and tools to successfully rehabilitate and restore the vast amounts of fish and wildlife habitat throughout the study area.

In conclusion, we believe that this report has effectively described the significance of the natural resources and habitats currently being impacted within the Meramec River Basin. In addition, we would like to express our full support for the USACE and MDNR efforts to pursue this project to restore and enhance fish and wildlife resources and serve the public interest.

REFERENCES

Albers, J.L., J.M. Besser, C.J. Schmitt, and M.L. Wildhaber. 2016. Mussel community associations with sediment metal concentrations and substrate characteristics in the Big River, Missouri, U.S.A. Natural Resource Damage Assessment and Restoration Administrative Report. U.S. Geological Survey Columbia Environmental Research Center, Columbia, Missouri.

Allert, A.L., J.F. Fairchild, C.J. Schmitt, J.M. Besser, W.G. Brumbaugh, and S.J. Olson. 2009. Effects of mining-derived metals on riffle-dwelling benthic fishes in Southeast Missouri, USA. Ecotoxicology and Environmental Safety. 72:1642-1651.

Allert, A.L., R.J. DiStefano, J.F. Fairchild, C.J. Schmitt, and W.G. Brumbaugh. 2010. 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. Final Report to the U.S. Fish and Wildlife Service, Missouri Ecological Services Field Office, Columbia, Missouri. U.S. Geological Survey, Columbia Environmental Research Center, Columbia, Missouri.

Allert, A.L., R.J. DiStefano, J.F. Fairchild, C.J. Schmitt, M.J. McKee, J.A. Girondo, W.G. Brumbaugh, and T.W. May. 2013. Effects of historical lead-zinc mining on riffle-dwelling benthic fish and crayfish in the Big River of southeastern Missouri, USA. Ecotoxicology 22(3):506-521. DOI 10.1007/s10646-013-1043-3.

Angelo, R.T., M.S. Cringan, D.L. Chamberlain, A.J. Stahl, S.G. Haslouer, and C.A. Goodrich. 2007. Residual effects of lead and zinc mining on freshwater mussels in the Spring River Basin (Kansas, Missouri, and Oklahoma, USA). Science of the Total Environment 384:467-496.

Baird, M.S. 2000. Life History of the Spectaclecase, *Cumberlandia monodonta*, Say, 1829 (Bivalvia, Unionoidea, Margaritiferidae). Master's Thesis, Southwest Missouri State University, Springfield, Missouri. 108pp.

Besser, J.M., W.G. Brumbaugh, D.K. Hardesty, J.P. Hughes, and C.G. Ingersoll. 2009. Assessment of metal-contaminated sediments from the Southeast Missouri (SEMO) mining district using sediment toxicity tests with amphipods and freshwater mussels. Administrative Report 08-NRDAR-02 submitted to the U.S. Fish and Wildlife Service, Missouri Ecological Services Office, Columbia, Missouri. U.S. Geological Survey, Columbia, Missouri.

Beyer, W.N., J.C. Franson, J.B. French, T. May, B.A. Rattner, V.I. Shearn-Bochsler, S.E. Warner, J. Weber, and D. Mosby. 2013. Toxic exposure of songbirds to lead in the Southeast Missouri Lead Mining District. Arch. Environ. Toxicol. DOI 10.1007/s00244-013-9923-3.

Beyer, W.N., N.T. Basta, R.L. Chaney, P.F.P. Henry, D.E. Mosby, B.A. Rattner, K.G. Scheckel, D. Sprague, and J. Weber. 2016. Bioaccessibility tests accurately estimate bioavailability of lead to quail. Environmental Toxicology and Chemisty. DOI 10.1002/etc.3399.

Buchanan, A.C. 1979. Mussels (Naiades) of the Meramec River Basin, Missouri. Final Report prepared for U.S. Army Corps of Engineers, St. Louis District. Missouri Department of Conservation, Jefferson City.

Buchanan, A.C. 1980. Mussels (Naiades) of the Meramec River Basin, Missouri. Missouri Department of Conservation Aquatic Series No. 17. Missouri Department of Conservation, Jefferson City. 76pp.

Butler, R.S. 2002. Status Assessment Report for the spectaclecase, *Cumberlandia monodonta*, occurring in the Mississippi River system (U.S. Fish and Wildlife Service Regions 3, 4, 5, and 6). Ohio River Valley Ecosystem Team, Mollusk Subgroup. 67pp.

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.

DiStefano, R. J. 2005. Trophic interactions between Missouri Ozarks stream crayfish communities and sport fish predators: increased abundance and size structure of predators cause little change in crayfish community densities. Dingell-Johnson Project F-1-R-054, Study S-41, Job 4, Final Report. Missouri Department of Conservation, Columbia. 127pp.

Gale, N.L., C.D. Adams, B.G. Wixson, K.A. Loftin, and Y. Huang. 2004. Lead, zinc, copper, and cadmium in fish and sediments from the Big River and Flat River Creek of Missouri's Old Lead Belt. Environmental Geochemistry and Health 26: 37-49.

Haag, W.R. 2012. North American Freshwater Mussels Natural History, Ecology, and Conservation. Cambridge University Press. New York, New York. 505pp.

Hinck, J.E., S.E. McMurray, A.D. Roberts, M.C. Barnhart, C.G. Ingersoll, N. Wang, and T. Augspurger. 2012. Spatial and Temporal Trends of Freshwater Mussel Assemblages in the Meramec River Basin, Missouri, USA. Journal of Fish and Wildlife Management 3(2): 319-331.

Jacobs, B. 2003. Birds in Missouri. Missouri Department of Conservation, Jefferson City. 375pp.

Johnson, T.R. 2000. Amphibians and Reptiles of Missouri 2nd Edition. Missouri Department of Conservation, Jefferson City. 400pp.

Jones, C. G., J. H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69:373-386.

Jones, C. G., J. H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78:1946-1957.

Kelly, J.E. 2010. The Geological and Cultural Contexts of Basalt from Late Emergent Mississippian and Early Mississippian Sites in the St. Louis Region. The Missouri Archeologist Volume 71:199-215.

Koldehoff, B. and G.D. Wilson. 2010. Mississippian Celt Production and Resource Extraction in the Upper Big River Valley of St. Francois County, Missouri. The Missouri Archeologist Volume 71:217-248.

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

Marshall, J.B. 1992. The St. Louis Mound Group: Historical Accounts and Pictorial Depictions. The Missouri Archeologist Volume 53:43-79.

McMurray, S.E., J.S. Faiman, A. Roberts, B. Simmons, and M.C. Barnhart. 2012. A guide to Missouri's freshwater mussels. Missouri Department of Conservation, Jefferson City. 94pp.

McKee, M., I. Vining, S. Sheriff, J. Girondo, K. Meneau, M. Reed, D. Brown, S. Kluesner. 2010. Effects of Lead-Zinc Mining on Benthic Fish Density in Riffles of the Big River (Southeast Missouri). Missouri Department of Conservation. 39pp.

Missouri Department of Conservation (MDC). 2018. Missouri Natural Heritage Program Database. Missouri Department of Conservation, Jefferson City.

Missouri Department of Health and Senior Services (MDHSS). 2017. Missouri Fish Advisory. A Guide to Eating Missouri Fish.

Missouri Water Pollution Board. 1964. Water quality of Big, Bourbeuse, Meramec River basins. Department of Public Health and Welfare of Missouri, Jefferson City. 65pp.

Montemarano, J. J., M. W. Kershner, and L. G. Leff. 2007. Crayfish effects on fine particulate organic matter quality and quantity. Fundamental and Applied Limnology/Archiv für Hydrobiologie 168(3):223-229.

Nelson, P.W. 2005. The terrestrial natural communities of Missouri. Revised edition. Missouri Natural Areas Committee. Missouri Department of Natural Resources, Jefferson City. 550pp.

Nigh, T.A. and S.P. Sowa. 2005. An aquatic biodiversity assessment for Missouri. Missouri Resource Assessment Partnership. Final Report, submitted to the Missouri Department of Conservation, Jefferson City.

Pavlowsky, R.T., M.R. Owen, and D.J. Martin. 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. Final Report submitted to the U.S. Fish and Wildlife Service, Missouri Ecological Services Field Office, Columbia, Missouri. Ozarks Environmental and Water Resources Institute (OEWRI) and Missouri State University, Springfield. 141pp.

Pavlowsky, R.T. and M.R. Owen. 2013. Historic channel change maps for the Big River System in St. Francois, Washington, and Jefferson counties, Missouri. Final report prepared for the U.S. Fish and Wildlife Service, Missouri Ecological Services Field Office, Columbia, Missouri. 23pp.

Pflieger, W.L. 1996. The Crayfishes of Missouri. Missouri Department of Conservation, Jefferson City. 152pp.

Pflieger, W.L. 1997. The Fishes of Missouri. Revised edition. Missouri Department of Conservation, Jefferson City. 372pp.

Roberts, A. and S. Bruenderman. 2000. A reassessment of the status of freshwater mussels in the Meramec River Basin, Missouri. Report prepared for the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. Missouri Department of Conservation, Jefferson City. 141pp.

Roberts A.D., D. Mosby, J. Weber, J. Besser, J. Hundley, S. McMurray, and S. Faiman. 2009. An assessment of freshwater mussel (Bivalvia: Margaritiferidae and Unionidae) populations and heavy metal sediment contamination in the Big River, Missouri. U.S. Fish and Wildlife Service Natural Resource Damage Assessment Final Report, U.S. Fish and Wildlife Service Missouri Ecological Services Field Office, U.S. Geological Survey, and Missouri Department of Conservation, Columbia, Missouri. 110pp.

Roberts A., J. Hundley, D. Mosby, A. Rosenberger, K.L. Bouska, B. Simmons, and G. Lindner. 2016. Quantitative Survey of Freshwater Mussels (Unionoidea) and Assessment of Sediment Contamination in the Big River, Missouri. Natural Resource Damage Assessment Final Report, U.S. Fish and Wildlife Service Missouri Ecological Services Field Office, U.S. Geological Survey, and University of Missouri Cooperative Fish and Wildlife Research Unit, Columbia, Missouri. 69pp.

Rosgen, D., L. Silvey, and D. Frantila. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology. Ft. Collins, Colorado.

Schmitt, C.J. and S.E. Finger. 1982. The dynamics of metals from past and present mining activities in the Big and Black River watersheds, southeastern Missouri. Final Report to the U.S. Army Corps of Engineers, St. Louis District, Project No. DACW43-80-A-0109. U.S. Fish and Wildlife Service, Columbia.

Schmitt C.J., C.A. Caldwell, B. Olsen, D. Serdar, and M. Coffey. 2002. Inhibition of erythrocyte d-aminolevulinic acid dehydratase (ALAD) activity in fish from waters affected by lead smelters. Environmental Monitoring and Assessment 77: 99-119.

Schmitt C.J., J.J. Whytte, W.G. Brumbaugh, and D.E. Tillitt. 2005. Biochemical effects of lead, zinc, and cadmium from mining on fish in the tri-states district of Northeastern Oklahoma, USA. Environmental Toxicology and Chemistry 24: 1483-1495.

Schmitt C.J. and M.J. McKee. 2016. Concentration trends for lead and calcium-normalized lead in fish fillets from the Big River, a mining-contaminated stream in Southeast Missouri, USA. Bull. Environ. Contam. Toxicol. Volume 97, Issue 5, pp 593–600 DOI. 10.1007/s00128-016-1850-2.

Staudinger, M.D., T.L. Morelli, and A.M. Bryan. 2015. Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Massachusetts. 52pp.

Switzer, J.F. and R.M. Wood. 2009. *Etheostoma erythrozonum*, a new species of darter (Teleostei:Percidae) from the Meramec River drainage, Missouri. Zootaxa 2095:1-7.

The Nature Conservancy (TNC). 2014. Meramec River Conservation Action Plan. The Nature Conservancy. Missouri Chapter, St. Louis. 140pp.

USACE. 2017. Meramec River freshwater mussel habitat suitability index model. Engineering Research and Development Center (ERDC) for the U.S. Army Corps of Engineers, St. Louis District. 23pp.

USACE. 2018. St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment. Draft – 2018. Appendix B. Habitat Evaluation and Quantification. U.S. Army Corps of Engineers, St. Louis District. Dated November, 2018.

USEPA. 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. EPA/600/X-17/303. August 22, 2017.

USFWS. 1983. Habitat Suitability Index Model: Black-capped chickadee. U.S. Fish and Wildlife Service.

USFWS. 2007. Scaleshell Mussel Recovery Plan (*Leptodea leptodon*). U.S. Department of Interior. U.S. Fish and Wildlife Service. 118pp.

Wang, N., C.G. Ingersoll, C.D. Ivey, D.K. Hardesty, T.W. May, T. Augspurger, A.D. Roberts, E. Van Genderen, and M.C. Barnhart. 2010. Sensitivity of early life stages of freshwater mussels (Unionidae) to acute and chronic toxicity of lead, cadmium, and zinc in water. Environmental Toxicology and Chemisty 29: 2053-2063.

Williams, J.D., M.L. Warren, K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9): 6-22.

APPENDIX 1

Wildlife Habitats within the Study Area

Aquatic Habitat

Riverine

- Thalweg/Main-channel: This habitat is described as the region of maximum depth and velocity in the river channel and its adjacent areas. It can occur either along the bank margin or in the mid-channel depending on the stream channel pattern and profile. The thalweg is best described as the location in which the majority of streamflow and sediment transport maintain longitudinal connectivity in the river system. The thalweg can be further divided into features such as riffles, runs, pools, and glide habitat based on topography, contour, depth, velocity, substrate, flow structure, and sediment regime of the stream. Connecting areas known as channel crossovers should also be mentioned as they often connect similar environments on opposite sides of the stream channel such as two pools and are generally associated with riffle features. Crossovers within the thalweg can provide important habitat diversity elements needed for many fish and invertebrate species.

- Streambank/Cut Bank: This habitat is described as the area which forms the outside (terrestrial) boundary of the stream channel. Streambanks are most often composed of fine alluvial soils deposited by previous flood events. They typically build vertically over time depending on watershed conditions. Streambanks are subject to erosive forces if rapid local or system changes have occurred (e.g., increased amounts of impervious materials to the upstream landscape). If a streambank can maintain an adequate slope and be protected with deeply rooted vegetation while near bank sheer stresses remain low, they are less prone to erosive forces and both aquatic and terrestrial habitats can become established/persist. Conversely, cut banks are streambanks not considered in a stable condition where their slopes often become vertical and/or undercut can lead to sediment and often riparian vegetation contributions until equilibrium is reestablished. Erosion to cut banks are often a major contributing source of sediment and cause for channel meandering which can have indirect effects to other stream habitats. However, while in this condition, they can still provide forage, refuge, and nesting habitat by numerous species (i.e., bank swallows). Another streambank type in the Meramec Basin, are bluffs and rocky outcrops. This habitat type is most often is associated with a pool feature with the substrate being composed of coarser materials such as boulders, cobbles, and gravels and sometimes entrained woody debris. This environment is referred as a bluff pool and if in the thalweg, often possess a high species diversity index due to the persistence of stable habitat.

- Channel Margin: This habitat is the area of the stream channel between the streambank and the thalweg. Typically in stable areas, it is generally shallow water habitat of low energy and low velocity. Fine sediments often accumulate in these areas and emergent vegetation such as water willow (*Justicia sp.*) can develop and persist. This habitat type often serves as refugia and nursery habitat for many aquatic species.

- Pool: This habitat is the stream feature that most frequently occur along the outside bends of the stream thalweg and along rock outcrops and bluffs as described above. Pools are generally areas of greater depth and slower velocity and function to reduce stream energy between riffle features. Pools most frequently occur in the channel at outside bends, downstream of riffle/runs. They can also occur around large objects such as logs and debris jams and other channel obstructions such as bridge piers due to local erosion as result of channel constriction. Pools provide critical overwintering habitat for fish and serve as refugia and water sources for many species during drought conditions.

- Secondary Channel: This habitat is a location where streamflow becomes disconnected from the thalweg (main channel) and can be a result of channel evolution processes such as aggradation or degradation. The secondary channel often contains less streamflow and depth compared to the main channel. In some instances and depending on conditions, these channels may only flow partially or only during high-flow events. Secondary channel can possess the same stream features as the main channel particularly if the main channel migrated from the secondary channel location. In the Meramec Basin, these habitats are often associated with mid channel island features or chute cutoffs. In braided systems with a high bedload they can be very short-term in persistence.

- Gravel bar: This habitat is a raised depositional feature resulting from geomorphic processes within the stream. In the Meramec Basin, gravel bars are typically composed of sand/gravel/cobble mixtures are found within and along the channel margins and can be either vegetated or unvegetated. Gravel bars can either be wet/dry, temporary or long-lasting depending upon stream condition and location. Also, depending on system geomorphic stability, depositional patterns can form a variety of arrangements such as: point bars, mid-channel bars, side bars, diagonal bars, delta bars, transverse bars, and islands as illustrated in Rosgen et al. (2006). Each type may also have secondary affects to the habitats within their vicinity over time. Habitats associated with gravel bars are dependent on associated variables such as sediment size, stream stability, rate of bedload deposition, movement or loss, vegetation type and size, adjacent stream environments, and stream flow. A wide range of species (insects, fish, amphibians, reptiles, birds, and mammals) utilize this habitat type.

- Island (This habitat can overlap with the floodplain and gravel bar types): This habitat is typically an area of elevated substrate within the channel which generally forms as result of accumulation of alluvial materials from bedload deposition or by rapid channel migration such as channel avulsion. They are typically lower in elevation than that of the floodplain and located within the active river channel. Similar to gravel bars, islands may be long-lasting or temporary. If long-lasting they may also contain successional stages of vegetation and an increased diversity ranging from emergent plants to large trees. Also similar to gravel bars, habitats associated with islands are dependent on associated variables such as sediment size, stream stability, rate of bedload deposition, movement or loss, vegetation type and size, adjacent stream environments and stream flow. Islands, like floodplains, can act to capture or contribute organic materials within the system when flooding occurs. Depending on the rate of inundation, islands are important wildlife habitat and transitional areas for many species and often bridge local environments for most stream wildlife because of a wide range of associated habitat diversity.

- Spring/Seep: This habitat is associated with the underlying karst geology of the Ozark Region. The hydrology within this habitat originates from either a deep aquifer/groundwater source within a specific recharge area. Some aquifers within the study area are known to span different overlying watersheds. These features are important because of their water contributions and thermal benefits during periods of extreme temperatures. Because of this, these areas are important summer and winter refuge habitat for resident aquatic species.

Backchannel

- Backwater/Slough (this habitat can overlap with the secondary channel type): Backwater habitat is an area that is hydrologically connected to the stream channel but separated from the thalweg with very little to no flow. They are most often located on the downstream areas of islands and form as a result of island development or channel avulsion. Backwaters are not considered riverine because of the associated lentic environment. Due to a lack of streamflow, backchannels often function to collect and trap fine sediments such as silt and organic matter from the riverine channel, often becoming consolidated to support a high diversity of submerged and emergent vegetation. Environmental conditions such as water chemistry, temperature, and dissolved oxygen are influenced by frequency of flooding, amount of riparian canopy cover, water surface elevation, depth, and period of inundation. Depending on sediment supply, backchannel areas can transition and possibly develop into wetlands and eventually floodplain habitat. These areas can be extremely important for plants, fish and amphibian nursery habitat, reptiles, waterfowl, and mussels adapted to this environment.

- Oxbow: This habitat is formed by channel migration of primary (thalweg) or secondary channels. It is an environment completely isolated from the stream channel base flow. Oxbow hydrology is maintained either by groundwater, surface runoff, and/or high-flow events. Oxbows are similar to the backwater habitat. Their conditions can vary depending upon level of water input, depth, frequency of flooding, and amount of riparian canopy cover. Oxbow areas typically transition and develop into emergent wetlands and eventually floodplain habitat. They are important areas for plants, fish and amphibian refuges and nursery habitat, waterfowl, and a few mussels adapted to this environment.

- Fringe Wetland: This habitat may overlap with many habitats. Fringe areas consist of wetlands along areas of flow. They are typically transitional areas of other habitats described. They provide an ecological link between lotic and lentic environments. This habitat is best characterized by reduction of stream flow and associated minor sediment accumulation. Typically these are areas along the margins of stable channels. The reduction of flow and sediment accumulation promotes development of emergent vegetation such as water willow. This habitat is very important for protection of juvenile/small fish and reptiles from fish and bird predation.

- Emergent Wetland/Marsh: This habitat is generally associated with or resulting from successional backwaters and oxbow habitats. They have a high level of organic matter and are typically dominated by perennial submerged and/or emergent vegetation and macrophytes. Habitat condition and species composition is dependent upon water depth, level of canopy cover, inundation frequency, and potential disturbance from adjacent land-use. Similar to backwaters and oxbows, alluvial sediment deposition can occur within the environment with high-flow events.

Terrestrial Habitat
There are a vast number of terrestrial habitats within the study area (Nelson 2005). Terrestrial habitats have many levels of variation. For the purpose of this report, only the riparian area and upland habitat directly associated with the stream environment will be described. Within these, the important habitat composition elements and wildlife species occupation potential are dependent on watershed position, hydrology, stream stability, upstream and adjacent land-use, and climate. The wildlife within this focused terrestrial habitat is composed of countless species within nearly every taxonomic group (bacteria, fungi, lichen, worms, insects, crustaceans, spiders, snails, amphibians, reptiles, resident and migratory birds, and mammals). The focused terrestrial environment includes the following specific habitats:

<u>Floodplain</u>:

- Forested Floodplain: This habitat consists of riparian lands directly adjacent to the stream course which are naturally formed and modified by riverine processes resulting from flooding. Floodplain size, composition, and conditions are largely dependent on the historical and present hydrology and geology within the watershed. Generally, the floodplain elevation is associated with a stage near the mean annual discharge. The floodplain is primarily composed of alluvial materials received from upland areas which were previously deposited during floods. During flooding events, the stream moves its bedload, erodes and deposits subsequent materials throughout the riverine system. If the floodplain elevation is low compared to the adjacent streambed, flow is reduced allowing suspended particles (i.e., sediment, nutrients, and organic debris) to accumulate on the floodplain surface. If streambank erosion is occurring, floodplains will contribute those materials to downstream environments. Forested floodplains provide many very important habitat elements adjacent to stream channels. They form transitional relationships and bridge aquatic and terrestrial environments. Floodplain forests are also a primary source of woody debris which can enter the stream and create additional habitat diversity elements (e.g., log-jams) used by various fish species: minnows, sunfish, and basses as well as provide the seed bank necessary for maintaining riparian plant diversity.

- Cropland/Sod Farms/Pastureland Floodplain: Although not a native environment, this floodplain type is a prominent feature throughout the study area and deserves inclusion for comparison. Although, the planting of crops can have direct benefits as a food source for various wildlife, pasturelands and sod farms are typically composed of non-native grasses which are either significantly grazed by livestock, hayed for winter livestock forage or in the case of sod farming, removed all together and replanted. These latter activities have limited wildlife values. As a result, the potential conversion of this habitat back to a native environment, where possible, would extend many other life history benefits such as shelter or nesting habitat and benefit a majority of plant and wildlife species and habitat diversity conditions throughout the study area.

Upland:
In the Ozarks, upland topography can also repeatedly occur adjacent to stream channels. This habitat is associated either with a cut bank or more often as an erosive resistant geology such as limestone/sandstone bluffs. The latter can influence the pattern and profile of the water course and often contribute to streambed stability. In some instances, bluff features can have caves and direct connections to subterranean environments such as springs, seeps (described above). Because of their permanence, bluffs often form stable environments such as deep pools with large boulders for mussels, fish, and long-lived amphibians such as the Eastern Hellbender. Caves are also important for troglophytic wildlife such as insects, crustaceans, fish, amphibians, as well as bats. Upland forests are extremely important sources for organic material contributions such as leaf litter which form one of the primary food sources for countless aquatic species.

APPENDIX 2

Conservation Measures
Conservation measures are actions that benefit or promote the recovery of a listed species that a Federal agency includes as an integral part of its proposed action and that are intended to avoid, minimize, or compensate for potential adverse effects of the action on the listed species. The USACE specified that sites/activities near known mussel beds would be avoided and indicated the following mandatory measures would be incorporated to help reduce potential direct, indirect, and cumulative impacts to federally listed mussels and/or bats:

Mussels

- Quantitative mussel surveys will be completed for pre-project and post-project years 2, 5, and 8 following previous mussel surveys within the study area conducted by the USACE, the Service, the non-Federal sponsor, or an entity approved by the Service. A more detailed monitoring plan for freshwater mussels will be developed in cooperation with the Service and other resource agencies during the Planning, Engineering, and Design Phase for the project.

- If pre-project surveys identify mussel beds within the construction footprint of a given site or in proximity downstream, then re-evaluation of that site would occur to determine if adverse effects could be avoided. If adverse effects cannot be avoided, separate site specific Section 7 consultation would be conducted.

- Best management practices to reduce siltation during construction activities would be implemented to minimize impacts to water quality.

Bats

- All tree clearing resulting from the USACE action will occur during the inactive season from November 1 to March 31 unless negative presence/probable absence survey results were obtained for the action area through appropriate surveys approved by the Service.

- The USACE will require a habitat assessment if the project will occur in Zone 1 (defined below) and includes more than 10 acres of tree clearing. If the results indicate that more than 10 acres of suitable bat-roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.

- The USACE will require a habitat assessment if the project will occur in Zone 2 and includes more than 5 acres of tree clearing. If the results indicate that more than 5 acres of suitable roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.

- If located in Zone 1, the project will not remove more than 10 acres of suitable roosting habitat during the inactive season.

- If located in Zone 2, the project will not remove more than 5 acres of suitable roosting habitat during the inactive season.

- A USACE action will not result in the removal of trees in Zone 3.

- Tree clearing associated with the project and the USACE action will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage.

- If the project is located in a karst area and will involve construction methods that may cause deep ground disturbance, the USACE will require a cave search be conducted to determine if any caves are present in the action area that would be considered suitable habitat for bats and/or are currently or formerly used by listed bats.

- If the demolition of an existing building or structure will occur as a result of the project in Zones 2 or 3, the USACE will require bat use surveys in collaboration with the Service. If during the course of demolition, bats of any species are discovered, then all work must cease and the Service must be immediately contacted. If the structure is safe to leave as is, then it will be left until after November 1, or until bats have stopped using the structure. If the structure is unsafe and poses a risk to human health and safety, the USACE will request the assistance of the Service in determining reasonable measures to exclude the bats.
    - Zone 1 = Conservation measures apply to actions within the State of Missouri excluding Zones 2 and 3.
    - Zone 2 = Conservation measures apply to actions within 5.0 miles (radius) of a known capture of a listed bat.
    - Zone 3 = Conservation measures apply to actions that occur within 0.25 miles (radius) of a known roost tree or hibernacula.

APPENDIX 3

Pursuant to the Water Resources Planning Act of 1965, the March 2013 "Principles and Requirements for Federal Investments in Water Resources" updated the national framework for water development projects across the country. That framework identifies the following six guiding principles which we believe are directly relevant to this effort.

1. Healthy and Resilient Ecosystems – Federal investments in water resources should protect and restore the functions of ecosystems and mitigate any unavoidable damage to these natural systems.

2. Sustainable Economic Development – Federal investments in water resources should encourage sustainable economic development through the sustainable use and management of water resources ensuring both water supply and water quality.

3. Floodplains – Federal investments in water resources should avoid the unwise use of floodplains and flood-prone areas and minimize adverse impacts and vulnerabilities in any case in which a floodplain/flood-prone area must be used. Unwise use includes actions or changes that have unreasonable adverse effects on public health and safety, or are incompatible with or adversely affect one or more floodplain functions that lead to a floodplain that is no longer self-sustaining.

4. Public Safety – Threats to people from natural events should be assessed in both existing and future conditions, and ultimately in the decision-making process. Alternative solutions must avoid, reduce, and mitigate risks to the extent practicable and include measures to manage and communicate these risks.

5. Environmental Justice – Agencies should ensure that Federal actions identify any disproportionately high and adverse public safety, human health, or environmental burdens of projects on minority, Tribal, and low-income populations. In implementation, agencies should seek solutions that would eliminate or avoid disproportionate adverse effects on these communities, and include effective public participation throughout both project planning and decision-making processes.

6. Watershed Approach – A watershed approach to analysis and decision-making facilitates evaluation of a more complete range of potential solutions and is more likely to identify the best means to achieve multiple goals over the entire watershed. A watershed approach facilitates the proper framing of a problem by evaluating it on a system level to identify root causes and their interconnectedness to problem symptoms.

MISSOURI DEPARTMENT OF CONSERVATION

Headquarters

2901 West Truman Boulevard, P.O. Box 180, Jefferson City, Missouri 65102-0180

Telephone: 573-751-4115 ▲ www.MissouriConservation.org

SARA PARKER PAULEY, Director

January 22, 2019

Karen Herrington
U.S. Fish and Wildlife Service
Missouri Ecological Field Service
101 Park DeVille Drive Suite A
Columbia, MO 65203-0057

RE: Consultation: Fish and Wildlife Coordination Act Report: Meramec River Ecosystem Restoration Feasibility Study, January 2019

Dear Ms. Herrington:

The Missouri Department of Conservation (the Department) holds in public trust the protection of forest, fish and wildlife resources of the State of Missouri and therefore provides consultation and coordination with the United States Fish and Wildlife Service (the Service) as required by Congress.

The Department has reviewed the Service's report on the Meramec River Ecosystem Restoration Feasibility Study, January 2019.

Department staff have long been active participants in the Meramec River study and offer these comments to the Service:

- Restoration efforts in the Big River Watershed will directly improve fish and wildlife habitats by reducing the level of contaminants, which will in turn reduce exposure to wildlife and to Missourians and visitors enjoying outdoor opportunities in the region.
- Improvements described in this report to the Meramec River, the Big River and tributaries are needed to restore the recreational value and enjoyment of the Big River watershed.
- The Department supports the enhancement of fish passage and supports agencies performing restoration and recovery work to also construct contaminant removal projects which allow recreational boat passage at various flow levels throughout the year.
- Contaminants in the streams and sediments continue to move in the basin. The Department recommends ongoing adaptive management as projects are designed and constructed to reflect this movement of contaminants within the larger Meramec basin.

COMMISSION

DON C. BEDELL, Sikeston | MARILYNN J. BRADFORD, Jefferson City | DAVID W. MURPHY, Columbia | NICOLE E. WOOD, Bonne Terre

Ms. Herrington
January 22, 2019
Page 2

Upon consultation and review, it appears Alternative 5 provides significant opportunities in recovery and restoration while being the most cost-effective approach. It also matches the recommendation of the Meramec River Feasibility Study partners team.

The Department will continue to work with partners for the protection and management of forest, fish and wildlife resources in the Meramec River/ Big River feasibility study area. Future restoration and recovery projects will improve the health and diversity of wildlife and must reflect the importance of people's quality of life and enjoying natural resources of the Meramec and Big River basin.

If you have any questions, please contact me.

Sincerely,

STUART MILLER
POLICY COORDINATOR

U.S. Army Corps of Engineers

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

July 2019

Appendix B

Habitat Evaluation and Quantification

Intentionally Left Blank

TABLE OF CONTENTS

LIST OF TABLES

INTENTIONALLY LEFT BLANK

1. INTRODUCTION

This appendix presents an ecological habitat assessment of the study area and quantification, to the extent possible, of the aquatic and floodplain ecological benefits resulting from the proposed alternatives for the *Meramec River Ecosystem Restoration Feasibility Study*. This assessment includes a summary of the existing biological conditions used in the evaluation as well as the forecast for future conditions under the No Action Alternative and each considered action alternatives. Three different future without project (FWOP) scenarios were included for consideration:

FWOP1: No Action by the Corps or USEPA within Jefferson County

FWOP2: No Action by the Corps, but USEPA will remediate to 1200ppm [Pb]

FWOP3: No action by the Corps, but USEPA will remediate to 400 ppm [Pb]

The evaluation was conducted by a multi-agency team of biologists, malacologists, geomorphologists, engineers, and heavy metal experts from the U.S. Fish and Wildlife Service (USFWS), the Missouri Department of Natural Resources (MoDNR), the Missouri Department of Conservation (MDC), Natural Resources Damage Assessment Trustees (NRDA), and the U.S. Army Corps of Engineers (USACE), St. Louis and St. Paul Districts.

2. HABITAT BENEFIT EVALUATION METHODS

The purpose of the habitat benefit evaluation is to evaluate and quantify, to the extent possible, environmental benefits of alternative plans for the aquatic and floodplain habitat improvements within the study area. Aquatic and floodplain benefits were quantified through the use of Engineering Circular 1105-2-412, *Assuring Quality of Planning Models,* and Habitat Suitability Index (HIS) models for the Black-Capped Chickadee HSI model (floodplain forest; (USFWS, 1983)) and Meramec River Freshwater Mussel HSI model (aquatic-riverine). The Black-Capped Chickadee model is approved for regional and nationwide use and the HSI calculator was reviewed by the Ecosystem Restoration Planning Center of Expertise and was recommended for regional use (see Section 4, Memorandum for CECW-MVD; 15 September 2016; Enclosure 1). The USACE Model Certification Panel concurred and the spreadsheet calculator was approved for use (see Section 4, email dated 5 October 2016; Enclosure 2).

The Meramec River Freshwater Mussel Model was recommended for single-use approval for this study by the USACE Ecosystem Planning Center of Expertise (see Section 4, Memorandum for CECW-MVD; 15 August 2017; Enclosure 3). The USACE Model Certification Panel concurred and the model was approved for single use (see Section 4, email dated 3 October 2017; Enclosure 4). Consistent with guidance from the USACE Ecosystem Planning Center of Expertise, the Agency Technical Review (ATR) Team for the Meramec River Ecosystem Restoration Feasibility Study conducted an assessment of the models used for this study. This process evaluated the technical quality and appropriateness of the models utilized.

2.1 QUANTITY COMPONENT

Traditionally, the USACE has used the quantity and quality of habitat jointly, in the form of habit units, to measure benefits provided by ecosystem restoration projects. The quantity portion is often measured as area (acres of habitat, landform, etc.) or number of species. In some systems, it is measured as length (feet of stream bank). The evaluation conducted for this study uses acres, delineated by polygons, to represent the quantity. The area associated with each proposed measure must have a clear definition for use as guidance in estimating the area component of the ecosystem output model, and must be applied consistently to all actions evaluated.

For this study, different scales of area were considered to determine which would be the most suitable area metric to use in the analysis. Table 1 summarizes the capabilities and limitations of each. It was determined of the three scales considered, using “Area of Restored Process” scale is the optimal approach for this study to estimate ecological benefits beyond the specific action footprint with the least amount of uncertainty. The team determined that the “Action Footprint” scale would grossly underestimate the spatial extent of habitat benefits provided by the considered actions. Estimating the “Potential Area of Influence” scale was considered too uncertain and speculative.

Table 2 provides the acres proposed for use for each alternative by habitat cover type (Floodplain Forest; Aquatic - Riverine). For the “Floodplain Forest” habitat cover type, the area of restored process boundary included the area of reforestation (aka action footprint). For the “Aquatic-Riverine” habitat cover type, the area of restored process boundary included the area from the most upstream measure to the confluence with the Meramec (for measures along the Big River) or to the confluence with the Mississippi (for measures within the Meramec). If alternatives included sites along the Big and Meramec Rivers, the area of restored process included all areas from the most upstream measures on the Big River and the Meramec River to the confluence of the Mississippi River.

Table 1. Different Scales of Areas Considered For Use

Scale	Description	Capability	Limitation
Action Footprint	Measurement of physical footprint of the project measure	Accurately quantified with a high degree of certainty	Grossly underestimates the spatial extent of ecological benefit
Area of Restored Process	Area directly affected by the restoration process; includes footprint + processes	Accurately quantified with high level of certainty for some measures and more fully captures the area that would experience ecological benefits	Difficult to quantify with certainty for some measures
Potential Area of Influence	Area that could benefit from the process restoration provided by the action; could extend beyond the area of restored process to the greater ecosystem	Fully captures the area of ecological benefits of a given measure	Not feasible to estimate with any degree of certainty and consistency

Table 2. Acres Used by Alternative (Rounded to the nearest 10th acre)

Habitat Cover Type	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7
	No Action	Subset of Maximizes Ecosystem Benefits in the Big River, River Mile 0-10.2	Subset of Maximizes Ecosystem Benefits in the Big River, River Mile 0-35	Maximizes Ecosystem Benefits in the Meramec River	Maximizes Efficiency in the Big River	Maximizes Ecosystem Benefits in the Big River	Maximize Ecosystem Restoration in the Study Area
Floodplain Forest		149.1	443.3	19.1	674.8	679.4	698.5 (679.4 Big) (19.1 Meramec)
Aquatic – Riverine		182.0	645.4	2128.6	1310.0	1310.0	3438.6

2.2 QUALITY BENEFITS

The methodology utilized for evaluating benefits to aquatic and terrestrial habitat incorporates the Habitat Evaluation Procedures (HEP) format, which was developed by the USFWS. HEP is a habitat-based evaluation methodology used in project planning. The procedure documents the quality and quantity of available habitat for selected fish and wildlife species. The qualitative component of the analysis is known as the habitat suitability index (HSI) and is rated on a 0.0 to 1.0 scale, with higher values indicating better habitat for that species.

The HSI for a particular habitat type is determined by selecting values that reflect present and future project area conditions from a series of abiotic and biotic metrics. Each value corresponds to a suitability index for each species. Future values are determined using management plans, historical conditions and best professional judgment. The quantitative component is the number of acres of the habitat being evaluated. The standard unit of measure from the calculated qualitative and quantitative values, the habitat unit (HU), is calculated using the formula (HSI × Acres = HUs). Habitat units are calculated for specific target years to forecast changes in habitat values over the life of the project with- and without-project conditions.

For the purpose of planning, design and impact analysis, the period of analysis was established as 50 years. To facilitate comparison, target years were established at 0 (existing conditions), 1, 5, 25 and 50 years. When HSI scores are not available for each year of analysis, a formula that requires only target year HSI and area estimates is used (USFWS, Habitat Evaluation Procedures, 1980). This formula is:

$$\int_{0}^{T} HU\ dt \equiv (T_2 - T_1)\left[\left(\frac{A_1H_1 + A_2H_2}{3}\right) + \left(\frac{A_2H_1 + A_1H_2}{6}\right)\right]$$

Where:

$$\int_0^T HU\ dt = CumulativeHUs$$

T_1= first target year of time interval

T_2 = last target year of time interval

A_1 = area of available habitat at beginning of time interval

A_2 = area of available habitat at end of time interval

H_1 = habitat suitability index at the beginning of time interval

H_2 = habitat suitability index at end of the time interval

3 and 6 = constants derived from integration of HSI × Area for the interval between any two target years

This formula was used to annualize habitat units over the life of the project to derive Average Annual Habitat Units (AAHUs; (USFWS, 1980)). This formula was developed to precisely calculate cumulative HUs when either HSI scores, area or both, change over a time interval, which is common when dealing with the unpredictable fluctuations found in nature. Habitat Unit gains or losses are annualized by summing the cumulative HUs calculated using the above equation across all target years in the period of analysis and dividing the total (cumulative HU) by the number of years in the period of analysis (i.e., 50 years).

AAHUs are used as the output measurement to compare alternatives for the study. The benefits of each proposed project alternative (net AAHUs) are then determined by subtracting with-project benefits from without-project benefits. The effects of various project alternatives can then be evaluated by comparing the net AAHUs and costs for each alternative considered.

In preparation of using the HSI models, the evaluation team conducted site visits, reviewed aerial photography, published data and topographic maps. Results from engineering models as well as the long-term data sets and published data were used to develop HSI models. During the evaluation, assumptions were developed regarding existing conditions and forecasted with-project conditions relative to habitat changes over time and management practices. It is important to note these assumptions are meant to capture general habitat benefits with best available data and are not robust outputs from in depth scientific investigations.

2.2.1 GENERAL ASSUMPTIONS

- It was assumed that target years of 0 (existing condition), 1, 5, 25 and 50 (future without and future with project conditions) are sufficient to analyze HUs and characterize habitat changes over the estimated period of analysis. The period of analysis was determined to be 50 years based on the prediction that some project features (e.g., development of key ecological processes needed to restore ecosystem structure and function) would need a longer period of time to reach maximum benefits and the accrual of benefits were predicted to level off after 50 years.

- It was assumed no major land use changes are expected to occur within the watershed that would greatly change the existing land use. Land cover types may shift but the overall quantity would remain relatively the same.
- Anticipated changes in climate are not expected to greatly change the existing hydrology of the Big or Meramec Rivers.

2.2.2 ASSUMPTIONS BY HABITAT MODEL

2.2.2.1 FLOODPLAIN FOREST HABITAT COVER TYPE

The USACE approved (per EC 1105-2-412) Black-Capped Chickadee HSI Model (USFWS, 1983) was used to assess the terrestrial benefits of reforestation/riparian tree plantings. The Black-Capped Chickadee HSI Model is relatively simple with only three parameters: average height of overstory trees, tree canopy cover and density of snags (the 4th parameter in the model related to tree canopy volume/area of ground surface, which is difficult to calculate and does not influence the output model, was not used). It is acknowledged that one of the purposes of tree planting for this project is to improve bank stability and reduce additional floodplain sediments introduction into the river channel within the watershed, but these trees were not evaluated with the Black-Capped Chickadee HSI Model since there benefit is tied more directly to the parameters in the Freshwater Mussel HSI Model (see below). The Black-Capped Chickadee HSI Model was used to evaluate reforestation only. The areas of proposed reforestation currently offer little or no habitat due to current land uses (e.g., sod farming, row-crop agriculture, etc.). A change from very poor habitat to high quality habitat leads to big changes in HSI scores (0.0 - 1.0 wherever applied), this coupled with the acreage of reforestation (Table 2) results in a net gain in habitat units for any alternative that includes reforestation.

The following assumptions were made when determining the *baseline* (existing conditions) and *future without project condition* for the Black-Capped Chickadee HSI Model:

1) Areas proposed for reforestation met these criteria (delineated through ArcGIS with 2016 aerial photography):
    a. Less than 300 foot wide riparian corridor; AND
    b. 1500 feet or greater linear length along the river corridor
2) Assumed existing conditions for all proposed reforestation sites have little or no tree cover and will continue to have little or no tree cover throughout the period of analysis.

2.2.2.2 AQUATIC – RIVERINE HABITAT COVER TYPE

The Corps approved and certified the Meramec River Freshwater Mussel Habitat Suitability Index model (see Section 4, certified for use on 3 October 2017; Enclosure 4) to assess the aquatic benefits in the main channel of both the Big and Meramec Rivers related to the proposed project alternatives. This model was built through an interagency team of malacologists, modeling experts, engineers and biologists, as well as experts with experience with lead (Pb) toxicity. The model was also vetted through the Upper Mississippi River System Mussel Coordination Team, received guidance during model development through the Engineering Research and Design Center of the USACE and underwent outside agency review for technical and ecological appropriateness. The model is comprised of 6 parameters, equally weighted, with lead (Pb) concentrations and total suspended solids acting as limiting factors if certain values are realized. The suitability index for each parameter were developed through the use of published literature and subject matter experts (full report on model documentation can be provided upon request).

The following assumptions were made when determining the *baseline* (existing conditions) and *future without project* for the Meramec River Freshwater Mussel model:

1) *Total Suspended Solids* (*TSS*) (mg/L when water temps > 65°F):
    a. Data Source:
        i. Big River: Byrnesville gage (1990-2007)
        ii. Meramec River: Eureka gage (1996-2007)
    b. Baseline Value (Year 0)
        i. Big River: 16 mg/L
        ii. Meramec River: 17 mg/L
    c. Assumptions
        i. Used median value from the available data sets to determine an overall existing condition for each river
        ii. Due to limited number of gages collecting TSS, the use of the 1 gage for each river is adequate to provide a generalization of the condition of TSS in study area
        iii. Meramec River should be higher than Big River since it is a higher order stream, and TSS from the Big River enters the Meramec River
        iv. Based on published literature (Way, Hornbach, Millerway, Payne, & Miller, 1990) (Hornbach, Way, Wissing, & Burky, 1984) (Landis, Haag, & Stoeckle, 2013) >20 mg/L TSS has resulted in reduced reproduction and feeding in freshwater mussels with water temperatures greater than 65°F. This value was used strictly as a guide to be able to quantify habitat units, and that we acknowledge that freshwater mussels exist in dense, recruiting beds in streams with TSS > 20mg/L. Based on this published literature, we assumed TSS > 20 mg/L with water temperatures greater than 65°F would be a limiting factor for mussel habitat. In other words, if TSS > 20 mg/L the habitat suitability would be 0. The team recognizes that TSS is only one habitat variable that can negatively affect freshwater mussels and we recommend that others look at all factors when assessing the adverse effects to freshwater mussels in the study area, including lead contamination.
        v. Future without project, no expected changes in TSS over the baseline into the future.
2) *Channel Change* (probability for channel to shift; categorical of either low or high)
    a. Data Source
        i. Big River: channel change maps 1937 - 2007 (Pavlowsky & Owen, 2013); visual observations; ArcGIS aerial imagery analysis
        ii. Meramec River: visual observations; ArcGIS aerial imagery analysis; targeted channel change analysis 2007-2017
    b. Baseline Value (Year 0)
        i. Big River: High
        ii. Meramec River: Low
    c. Assumptions

i. Assumed overall the Big River has several known areas of channel change throughout the study area; therefore, the existing conditions were determined to be High
ii. Assumed the Meramec River existing riparian corridor will substantially remain in place within our study area. Excepting the few recognized channel change areas, no obvious historic channel change was identified by the aerial imagery analysis; therefore, the existing conditions were determine to be Low
iii. Assumed that lack of or minimal riparian corridor (<100 foot wide) increases probability of channel change
iv. Assumed vegetative plantings (turf and tree screens) associated with bank stability would be captured in this parameter
v. Assumed areas with known historic channel change are still prone to channel change
vi. Future without Project, areas considered to have high probability of change would continue to have high probability of channel change into the future or get worst. Areas of low channel change are expected to remain in the low probability category into the future.

3) *Substrate* (composition of sand/fine gravel, silt and gravel/cobble/boulder; categorical parameter)
   a. Data Source
      i. Big River: Based on field observations conducted by 3 biologists at 13 sites in fall of 2016, averaged observers' scores for each site, averaged all sites
      ii. Meramec River: Based on field observations conducted by 3 biologists at 5 sites in fall of 2016, averaged observers' scores for each site, averaged all sites
   b. Baseline Value (Year 0)
      i. Big River: Marginal
      ii. Meramec River: Suboptimal
   c. Assumptions
      i. Assumed that the field observations taken at specific sites on a given river could be used to generalize the overall condition of that river
      ii. Assumed that each reach of the Big River currently had similar substrate composition
      iii. Localized substrate variability does exist; however, these localized "hot spots" are local and do not drastically influence the overall general condition of each river
      iv. See discussion under lead (Pb) for potential changes in substrate as related to the movement of bed material through the system into the future.

4) *Aquatic Available Cover* (% favorable aquatic available cover)
   a. Data Source
      i. Big River: Based on field observations conducted by 3 biologists, averaged observers' scores for each site, averaged all sites
      ii. Meramec River: Based on field observations conducted by 3 biologists, averaged observers' scores for each site, averaged all sites
   b. Baseline Value (Year 0)

i. Big River: 51%
ii. Meramec River: 64%

c. Assumptions
i. Assumed that each reach of the Big River had similar aquatic available cover
ii. Localized variability does exist; however, these localized "hot spots" are local and do not drastically influence the overall general condition of each river
iii. Future without project, Meramec River expected to remain the same as current existence.
iv. Future without project, Big River expected to get worse due to continual bank erosion and trees falling into the river. Areas with vertical banks would continue to erode and provide limited aquatic cover.

5) *Fish Species Richness* (number of fish species)
a. Data Source: (Mills, 1978); average species richness from published data with geographic locations throughout the Big River.
b. Baseline Value (Year 0)
i. Big River (0-10.2 RM) - 48
ii. Big River (10.2+ RM) - 26
iii. Meramec River - 48
c. Assumptions
i. Assumed 30+ year old data set is still accurate and represents the existing potential for species richness within the study area
ii. Assumed average species richness from the Big River 0-10.2 is appropriate to use for the Meramec
iii. Lower river reaches should have greater number of species due to mix of headwater species, big river species and generalists
iv. Assumed 48 was the optimal number of species within the watershed
v. Assumed greater fish species richness important for mussel community composition and distribution since mussel species require varying hosts to complete their life cycle
vi. Future without Project, Meramec River, assumed that by year 25 at least some sensitive species would be gone from system; lead (Pb) impacts not as great due to dilution
vii. Future without Project, Big River, assumed loss of species during the period of analysis due to decrease in aquatic habitat related to migration of lead (Pb), homogenous substrate and limited aquatic cover. Reduction rate in fish richness determined subject matter expertise and published literature of how lead affects prey/food sources for riffle fishes

6) *Lead (Pb) concentrations* (parts per million in grain size <2 mm)
a. Data Sources
i. Roberts, et al. (2016) published data (<2mm collected from mussel beds)
ii. River Sediment bulk average < 2mm (samples collected 2017)
b. Baseline Value (Year 0) (Table 3)

Table 3. River Sediment Bulk average (<2 mm) Lead (Pb) Concentration by River Reach for 2016 and 2017 Used to Determine Baseline Conditions for the Evaluation

River	River Miles applied to	2016		2017	
		Pb ppm	Number of sample sites (n)	Pb ppm	Number of sample sites (n)
Meramec (St. Louis County)	0-38	2	1	n/a	n/a
Big (Jefferson County)	0-10.2	78	2	256	21
	10.2-35	207	4	275	87
	35-75	351	10	456	93
Big – (Washington & St. Francois Counties)	75-97	n/a	n/a	1137	9

c. Assumptions for *baseline conditions*
   i. Assumed use of 2017 samples from the more robust sampling effort are the data to use for the habitat evaluation.
   ii. Averaged sampling sites within each reach to provide a longitudinal gradient in lead (Pb) concentration in <2 mm size class is appropriate to do.
   iii. Determined baseline conditions for the Meramec and Big River separately.
   iv. Assumed one sampling site on the Meramec is applicable to use for entire Meramec River study area.
   v. Model is limited to only include one baseline value per alternative. Assumed that using the proportion of each river reach to the total study area for the Big River would help determine the existing baseline for each alternative that spanned more than one reach.

d. Assumptions for *future without project conditions*
   i. It was determined that multiple future without project scenarios would be beneficial to assess to better inform decision-making. These various future without project scenarios are geared at better understanding the lead (Pb) parameter in the model, and include the following scenarios:
      - FWOP1: No Action from the USACE AND USEPA within Jefferson County, but continue their current work in upstream counties of the Project Area
      - FWOP2: No Action from the U.S. Army Corps of Engineers but USEPA will do work in areas > 1200 ppm lead within Jefferson County and would continue to work in upstream areas outside of Project Area
      - FWOP3: No Action from the U.S. Army Corps of Engineers but USEPA will do work in areas >400 ppm lead within Jefferson County and would continue to work in upstream areas outside of the Project Area.
   ii. Based on the high uncertainty in regards to reasonable and foreseeable work to be undertaken by the USEPA or others within Jefferson County, the USACE Project Delivery Team is proposing the FWOP1 as the most appropriate future without

project scenario; however, the team did evaluate the other scenarios targeting the differences in the lead parameter for comparison. The differences in the lead parameter will be discussed for each of these scenarios. The future without project assumptions for the other parameters are included above in each parameter discussion.

2.2.2 ASSUMPTIONS RELATED TO LEAD (PB), APPLICABLE TO ALL FWOP SCENARIOS

1) Rate of lead *effects* on mussel communities: A 1979 mussel survey (Buchanan, 1979) identified a “dead zone” in the mussel community related to the toxic effects of lead, with the leading edge of impact at RM 62.7 on the Big River. In 2008, a mussel survey (Roberts, et al., 2009) estimated the leading edge of this “dead zone” to be at RM 14.4 (Byrnesville). So over 29 years, the negative effects of lead to mussel species richness has moved approximately 48.3 river miles, which equates to 1.7 river miles/year. Applying this rate, we assumed that present day (2017; 9 years x 1.7 = 15.3 river miles) the negative effects from the lead are now to the confluence of the Meramec. The 2017 data also support higher lead values in the lower reach of the Big River. Applying this rate to our period of analysis we are assuming that in 50 years, the negative effects of the lead would move into the Meramec and to the Mississippi River. We assumed there will be some dilution effect within the Meramec River and Mississippi River due to mixing of waters from the larger watersheds which have negligible concentrations of lead.
2) Rate of contaminated bedload movement within Big River: Besides the negative effects of lead within the suspended sediment, the bedload also poses a direct risk to mussels and other benthic aquatic organisms. The movement of contaminated bedload (>2mm size class) has been observed to be moving from the source mine tailings piles from Washington and St. Francois Counties. Presently (2017), this “slug” of contaminated bedload is located at approximately RM 75 in the Big River. It is estimated by subject matter experts working in this watershed that this contaminated bedload is migrating downstream at approximately 1 km/year (0.62 miles/year). So, applying this rate of migration downstream, it is assumed that by end of our period of analysis (2025-2075), the contaminated bedload would have moved approximately 36 miles (2017-2075), or to approximately RM 39 within the Big River. It is expected that this slug of material would negatively affect the substrate composition of the river, potentially alter hydraulics leading to increased probability of channel change, and, most importantly, negatively affect benthic organisms, including mussels.
3) Outside Project Area Influence: Based on 2017 data, the average lead (Pb) concentrations from RM 75-97 from 9 sites is 1137 ppm. It is assumed that for FWOP1 and FWOP2, this value would migrate into the study area during the period of analysis. For FWOP3 scenario, it is assumed that the max Pb concentration would be no greater than 400 ppm since areas greater than 400 ppm would be remediated by USEPA.

3. HABITAT BENEFIT EVALUATION RESULTS

Section 3.9 of the main report, *Management Measures*, describes each potential measure in detail. After a lengthy process involving preliminary analysis, identification of compatibility, dependencies and input from our resource agencies, the study planning team identified a list of measures and sites to be formulated into alternatives before this habitat quantification exercise. Formulation strategies were used to combine measures into alternatives. For a detailed description of the formulation strategies, see Section 3.10 of the main report, *Formulation Strategies*. Alternatives 2, 3 and 4 are formulated based on geographic location. Alternative 5 was formulated based on including sites/measures that met our efficiency screening criteria. Alternative 6 was formulated based on including all sites/measures along the Big River; and Alternative 7 was formulated based on including all sites/measures along both the Big and Meramec Rivers.

3.1 FLOODPLAIN FOREST BENEFITS.

Table 4 provides the final suitability index (SI), acres for each considered alternative, habitat units, gross AAHUs and net AAHUs (ecological lift) for each target year (1, 5, 25 and 50) under consideration.

3.2 AQUATIC –RIVERINE BENEFITS.

Table 5 provides the final suitability index (SI), acres for each considered alternative, habitat units, gross AAHUs, and net AAHUs (ecological lift) for each target year (1, 5, 25, and 50) under consideration for the FWOP1 and FWOP2 scenarios. FWOP1 scenario values are the same as FWOP2. FWOP3 values are not presented here but are available upon request.

Table 4. Floodplain Forest Benefit Evaluation Results for Each Considered Alternative Under the FWOP2 Scenario (1200 ppm).

Values are rounded

Alt.	Description	Condition	Year	SI[1]	Acres	Cumulative HUs B=Big/M=Meramec	AAHUs	Net AAHUs
1	No Action – Big River	Existing	0	0.0	0	0	0	0
		FWOP	1	0.0		0		
			5	0.0		0		
			25	0.0		0		
			50	0.0		0		
	No Action – Meramec River	Existing	0	0.0	0	0	0	0
		FWOP	1	0.0		0		
			5	0.0		0		
			25	0.0		0		
			50	0.0		0		
2	Big River RM 0-10.2	FWP	1	0.0	149	0	122	122
			5	0.5		149		
			25	1.0		2237		
			50	1.0		3728		
3	Big River RM 0-35	FWP	1	0.0	440	0	361	361
			5	0.5		440		
			25	1.0		6605		
			50	1.0		11008		
4	Meramec River Only	FWP	1	0.0	19	0	15	15
			5	0.5		19		
			25	1.0		287		
			50	1.0		478		
5	Big River - Efficiency	FWP	1	0.0	675	0	553	553
			5	0.5		675		
			25	1.0		10122		
			50	1.0		16870		
6	Big River- Enviro Max	FWP	1	0.0	679	0	557	557
			5	0.5		679		
			25	1.0		10191		

			50	1.0		16985		
7	Big River + Meramec River- Enviro Max	FWP	1	0.0	679B 19M	0	572 (556B) (16M)	572
			5	0.5		679B/19M		
			25	1.0		10191B/287M		
			50	1.0		16985B/478M		

[1]using the Black-Capped Chickadee Habitat Suitability Index Model

Table 5. Aquatic Riverine Benefit Evaluation Results for Each Considered Alternative under the FWOP2 scenario (1200 ppm).

Values are rounded

Alt.	Description	Condition	Year	Suitability Index[1]	Acres	Cumulative HUs	AAHUs	Net AAHUs
1	No Action – Big River (RM 0-75)	Existing	0	0.5	1310	--	7	0
		FWOP	1	0.0		332		
			5	0.0		0		
			25	0.0		0		
			50	0.0		0		
	No Action Big River (RM 0-10.2)	Existing	0	0.6	182	--	63	0
		FWOP	1	0.6		108		
			5	0.6		427		
			25	0.4		1753		
			50	0.0		866		
	No Action Big River (RM 0-35)	Existing	0	0.6	645	--	97	0
		FWOP	1	0.5		358		
			5	0.5		1321		
			25	0.0		3158		
			50	0.0		0		
	No Action – Meramec River	Existing	0	0.9	2129	--	1785	0
		FWOP	1	0.9		1818		
			5	0.9		7242		
			25	0.8		35967		
			50	0.8		44215		
2	Big River RM 0-10.2	FWP	1	0.8	182	123	138	75
			5	0.8		578		
			25	0.7		2798		
			50	0.7		3380		
3	Big River RM 0-35	FWP	1	0.8	645	413	481	384
			5	0.8		1965		
			25	0.8		9715		
			50	0.8		11958		
4		FWP	1	0.9	2129	1824	1796	11

Alt.	Description	Condition	Year	Suitability Index[1]	Acres	Cumulative HUs	AAHUs	Net AAHUs
	Meramec River Only		5	0.9		7286		
			25	0.8		36185		
			50	0.8		44484		
5	Big River - Efficiency	FWP	1	0.5	1310	663	1018	1012
			5	0.7		3258		
			25	0.8		19769		
			50	0.9		27202		

6	Big River- Enviro Max	FWP	1	0.7	1310	761	1016	1010
			5	0.7		3686		
			25	0.8		19684		
			50	0.9		26684		
7	Big River + Meramec River- Enviro Max	FWP- Big	1	0.7	1310	761	1016	1053
			5	0.7		3686		
			25	0.8		19684		
			50	0.9		26684		
		FWP- Meramec	1	0.9	2129	1830	1828	
			5	0.9		7342		
			25	0.9		36601		
			50	0.9		45613		

[1]using the Meramec Freshwater Mussel Habitat Suitability Index Model

3.3 TOTAL HABITAT BENEFITS.

Tables 6 and 7 provide a summary of the total net AAHUs for each considered alternative at each considered future without project scenario:

FWOP1: No Action by the USACE or USEPA within Jefferson County

FWOP2: No Action by the USACE, but USEPA will remediate to 1200ppm [Pb]

FWOP3: No action by the USACE, but USEPA will remediate to 400 ppm [Pb]

The Cost Effective and Incremental Cost Analysis (CE/ICA) was conducted on all 3 scenarios which produced the same results to help inform in selecting a plan (see Section 6.3 of the main report, *Cost Effective and Incremental Cost Analysis*). The project delivery team determined that FWOP2 was the most realistic and reasonable and was used in determining cost per AAHU.

Table 6. Net Average Annualized Habitat Units (AAHUs) For Each Considered Alternative for FWOP1 and FWOP2 Scenarios

Alt	Description	Floodplain Forest Net AAHUs	Aquatic – Riverine Net AAHUs	Total Net AAHUs
1	No Action	0	0	0
2	Subset of Maximizes Ecosystem Benefits in the Big River, River Mile 0-10.2	122	75	197
3	Subset of Maximizes Ecosystem Benefits in the Big River, River Mile 0-35	361	384	745
4	Maximizes Ecosystem Benefits in the Meramec River	15	11	26
5	Maximizes Efficiency in the Big River	553	1012	1565
6	Maximizes Ecosystem Benefits in the Big River	557	1010	1567
7	Maximize Ecosystem Restoration in the Study Area	572	1053	1625

Table 7. Net Average Annualized Habitat Units (AAHUs) For Each Considered Action Alternative for FWOP3 (USEPA remediating to 400 ppm [Pb])

Alt	Description	Floodplain Forest Net AAHUs	Aquatic – Riverine Net AAHUs	Total Net AAHUs
1	No Action	0	0	0
2	Subset of Maximizes Ecosystem Benefits in the Big River, River Mile 0-10.2	51	122	173

3	Subset of Maximizes Ecosystem Benefits in the Big River, River Mile 0-35	194	361	555
4	Maximizes Ecosystem Benefits in the Meramec River	11	16	26
5	Maximizes Efficiency in the Big River	452	553	1006
6	Maximizes Ecosystem Benefits in the Big River	451	557	1008
7	Maximize Ecosystem Restoration in the Study Area	494	573	1067

4. REFERENCES

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

Hornbach, D. J., Way, C. M., Wissing, T. E., & Burky, A. J. (1984). Effects of particle concentration and season on the filtration rates of the freshwater clam, Spaherium striatinum Lamarck (Bivalvia, Pisidiidae). *Hydrobiologia, 108*, 83-96.

Landis, A., Haag, W., & Stoeckle, J. (2013). High suspended soilds as a factor in reproductive failure of a freshwater mussel. *Freshwater Science, 32*, 70-81.

Mills, P. A. (1978). The pre-impoundment fish fauna of Big River (Meramec Drainage, Missouri). *Transactions of the Missouri Academy of Science, 12*, 25-35.

Pavlowsky, R. T., & Owen, M. R. (2013). *Historic Channel Change Maps for the Big River System in St. Francois, Washington, and Jefferson Counties, Missouri.* Springfield MO: Ozark Environmental and Water Resources Institute Missouri State University.

Roberts, A. D., Mosby, D., Weber, J., Besser, J., Hundley, J., McMurray, S., & Faiman, S. (2009). *An assessment of freshwater mussel (bivalvia: margaritiferidae and unionidae) populations and heavy metal contamination in the Big River, Missouri.* Columbia, MO: USFWS, USGS, and MDC.

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.

USFWS. (1980). *Habitat Evaluation Procedures.* Washington, D.C.: USFWS. Retrieved November 9, 2016, from http://www.fws.gov/policy/ESM102.pdf

USFWS. (1983). *Habitat Suitability Index Model: Black-capped chickadee.* USFWS.

Way, C. M., Hornbach, D. J., Millerway, C. A., Payne, B. S., & Miller, A. C. (1990). Dynamics of filter feeding in Corbicula fluminea (Bivalvia, Corbiculidae). *Canadian Journal of Zoology, 68*, 115-120.

ENCLOSURE 1

DEPARTMENT OF THE ARMY
MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080

REPLY TO
ATTENTION OF:

CEMVD-PD-L 15 September 2016

MEMORANDUM FOR CECW-MVD (Redican)

SUBJECT: Recommendation for Regional Use Approval of 11 Spreadsheet Calculators for Application of Regionally Approved Habitat Suitability Index Models

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2011.
   b. Final Planning Model Quality Assurance Review Comment Response Record for 11 Habitat Suitability Index Model Calculators, USACE (Encl 1).
   c. Ecosystem Restoration Model Library, Habitat Suitability Index Models

2. The National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated spreadsheet calculators for the black capped chickadee, bullfrog, creek chub, fox squirrel, gray squirrel, least tern, smallmouth bass, smallmouth buffalo, striped bass, white bass, and wood duck habitat suitability index models following reference 1.a. Based on the review results (Encl 1), the ECO-PCX recommends Regional Use Approval of all spreadsheet calculators for use in the geographic area defined for each model. Please log in this recommendation with the Office of Water Project Review for the Model Certification Team to consider.

3. The black capped chickadee, bullfrog, creek chub, fox squirrel, gray squirrel, least tern, smallmouth bass, smallmouth buffalo, striped bass, white bass, and wood duck habitat suitability index models are approved for regional use per EC 1105-2-412 (Reference 1.c.). However, software was lacking which would allow planners to apply the models in a computational correct fashion for individual projects. Consequently, MVP, MVR, and MVS collaborated to develop a library of Microsoft Excel spreadsheet calculators. Each spreadsheet calculator is an independent spreadsheet built using the same variables, habitat suitability index curves, aggregation equations, and habitat cover types as displayed in the approved model documentation. Furthermore, all spreadsheet calculators employed a similar development scheme to include consistent use of formatting, input requirements, and output display. Each calculator includes user documentation or a link to a user's guide, and employs best spreadsheet practices.

4. The ECO-PCX and biologists from MVP, MVR, and MVS reviewed each spreadsheet calculator independently to assess the degree to which the spreadsheets meet the system quality and usability criteria in accordance with EC 1105-2-412. The spreadsheet development team and the spreadsheet reviewers included individuals with expertise in habitat benefit evaluations, Habitat Evaluation Procedures, plan formulation policies, and software/spreadsheet programming and auditing. Review results are found in the Final Planning Model Quality Assurance Review Comment Response Record for 11 Habitat Suitability Index Model Calculators, USACE (Encl 1).

Review of the spreadsheet calculators resulted in 72 total comments. All comments were related to the system quality and usability of the model, all were of low to medium significance, and all evaluations resulted in concurrence with the comments. The ECO-PCX reviewed the comments, evaluations, and revisions made to the model. All were made to the satisfaction of the ECO-PCX and are in alignment with the requirements of assuring the quality of planning models. The following summarizes the overall review and modifications made to the spreadsheets to improve system quality and usability.

SUBJECT: Recommendation for Regional Use Approval of 11 Spreadsheet Calculators for Application of Regionally Approved Habitat Suitability Index Models

Overall, the calculators were found to function well and included simple and easy-to-use interfaces. Most importantly, the variables, suitability index curves, aggregation equations, and habitat cover types match the technical model documentation. The review resulted in several minor to moderate revisions to improve clarity for the user, reduce potential calculation errors, and improve the quality of the spreadsheets.

- All spreadsheets are locked so only identified input cells are available for modification.
- Requirement to include all inputs prior to population of an overall HSI score.
- Model documentation was made available to the user within the spreadsheet.
- Data validation was included for all input cells.
- HSI curves were added to the user documentation to increase transparency.
- Discrepancies between the variables in the model documentation and those in the calculators were identified and fixed.

5. The spreadsheet calculators have sufficient system quality and usability. The models are all encoded in MS Excel. The spreadsheets are computationally correct and employ best spreadsheet practices including cell locking, highlighting input/calculation/output cells, and data validation. Error messages display appropriately when erroneous inputs are attempted and final scoring is displayed and easy to understand. The models are transparent and would allow for verification of inputs and outputs. User documentation is available and sufficient to implement the technique and use the spreadsheets. The spreadsheets will be maintained by the ECO-PCX on the Ecosystem Restoration Model Library. During application input and output scores should be documented and ATR teams charged with review to ensure the application of the model and its associated parts is appropriate.

6. The ECO-PCX finds the spreadsheet calculators for the black capped chickadee, bullfrog, creek chub, fox squirrel, gray squirrel, least tern, smallmouth bass, smallmouth buffalo, striped bass, white bass, and wood duck habitat suitability index models has sufficient system quality, meets usability criteria, and maintains the already approved technical quality of the models. The ECO-PCX recommends Regional Use Approval of all spreadsheet calculators for use in the geographic area defined for each model. Please notify the ECO-PCX of the Model Certification Panel's findings.

Gregory Miller

Encls (1)

Gregory Miller
Operating Director
National Ecosystem Restoration
Planning Center of Expertise

CF (without enclosures)
CECW-PC (Paynes, Coleman, Matusiak, Trulick, Bee)
CECW-MVD (Brown, Hanneken, Turner)
CEMVD-PD (Chewning, Lachney, Miller, Young)
CEMVP-PD-C (Johnson, Clark, Allen, Jordan, Popkin, McFarlane)
CEMVP-PD-P (Barr, McCain, Herzog, McGuire, Simmons, Ingvalson)
CEMVP-PD-F (Knollenberg, Richards, Opsahl, Savage)

ENCLOSURE 2

From: Richards, Nathan S MVR
To: Redican, Joseph H HQ02; Hanneken, Charles D HQ; Chewning, Brian MVD; Lachney, Fay V MVD; Young, Gary L MVD; Johnson, Brian L MVS; McFarlane, Aaron M MVP; Knollenberg, Camie A MVP @ MVR; Opsahl, Katie MVP; Savage, Monique E MVR; Barr, Kenneth A MVP @ MVR; Mccain, Kathryn MVP @ MVS; Herzog, Kathryn MVP @ MVR; McGuire, Benjamin MVP; Simmons, Shane M MVP @ MVS; Ingvalson, Derek MVP; Turner, Matthew E MVD; Allen, Teri C MVS; Clark, Steven J MVP; Jordan, Joseph W MVP @ MVR; Popkin, Breann; Miller, Gregory B MVD; Hubbell, Marvin E MVR
Subject: RE: Model Recommendation - MVD - 11 HSI Spreadsheet Calculators - Regional Use Approval
Date: Wednesday, October 05, 2016 10:42:31 AM

All --

Good news! The HSI spreadsheet calculators recommended for regional use in the RPEDN were approved by the HQ Model Certification Team. Thank you to all of you in MVP, MVR, and MVS who contributed to the development, review, and documentation of the models. Also, thank you to the MVD RIT for getting the recommendation routed, logged, and on the agenda. This is a significant addition to our model library!

The HQ memo outlining the recommendation is being prepared and will be routed as soon as we receive it. In the meantime, please use October 4, 2016, as the approval date for all official documentation.

Nate

Nathan Richards
U.S. Army Corps of Engineers
Mississippi Valley Division
Regional Technical Specialist
ECO-PCX Model Review Manager
Office: 309-794-5286
Cell: 309-230-3804

-----Original Message-----
From: Miller, Gregory B MVD
Sent: Monday, September 19, 2016 2:27 PM
To: Redican, Joseph H HQ02 <Joseph.H.Redican@usace.army.mil>
Cc: Paynes, Wilbert V HQ <Wilbert.V.Paynes@usace.army.mil>; Coleman, Wesley E Jr HQ02 <Wesley.E.ColemanJr@usace.army.mil>; Matusiak, Mark HQ02 <Mark.Matusiak@usace.army.mil>; Trulick, Jeff HQ02 <Jeff.Trulick@usace.army.mil>; Bee, Patricia L HQ02 <Patricia.L.Bee@usace.army.mil>; Brown, Theodore A SES HQ02 <Theodore.A.Brown@usace.army.mil>; Hanneken, Charles D HQ <Charles.D.Hanneken@usace.army.mil>; Chewning, Brian MVD <Brian.Chewning@usace.army.mil>; Lachney, Fay V MVD <Fay.V.Lachney@usace.army.mil>; Young, Gary L MVD <Gary.L.Young@usace.army.mil>; Johnson, Brian L MVS <Brian.L.Johnson@usace.army.mil>; McFarlane, Aaron M MVP <Aaron.M.McFarlane@usace.army.mil>; Knollenberg, Camie A MVP @ MVR <Camie.A.Knollenberg@usace.army.mil>; Richards, Nathan S MVR <Nathan.S.Richards@usace.army.mil>; Opsahl, Katie MVP <Katie.M.Opsahl@usace.army.mil>; Savage, Monique E MVR <Monique.E.Savage@usace.army.mil>; Barr, Kenneth A MVP @ MVR <Kenneth.A.Barr@usace.army.mil>; Mccain, Kathryn MVP @ MVS <Kathryn.Mccain@usace.army.mil>; Herzog, Kathryn MVP @ MVR <Kathryn.Herzog@usace.army.mil>; McGuire, Benjamin MVP <Benjamin.M.Mcguire@usace.army.mil>; Simmons, Shane M MVP @ MVS <Shane.M.Simmons@usace.army.mil>; Ingvalson, Derek MVP <Derek.S.Ingvalson@usace.army.mil>; Turner, Matthew E MVD <Matthew.E.Turner@usace.army.mil>; Allen, Teri C MVS <Teri.C.Allen@usace.army.mil>; Clark, Steven J MVP <Steven.J.Clark@usace.army.mil>; Jordan, Joseph W MVP @ MVR <Joseph.W.Jordan@usace.army.mil>; Popkin, Breann <Breann.K.Popkin@usace.army.mil>
Subject: Model Recommendation - MVD - 11 HSI Spreadsheet Calculators - Regional Use Approval

ENCLOSURE 3

DEPARTMENT OF THE ARMY
MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080

REPLY TO
ATTENTION OF:

CEMVD-PD-L 15 August 2017

MEMORANDUM FOR CECW-MVD (Redican)

SUBJECT: Recommend Single-Use Approval of the Meramec River Freshwater Mussel Habitat Suitability Index Model

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. February 2012.

   c. Model Review Plan, Meramec River Freshwater Mussel Habitat Suitability Index Model, dated 16 May 2017. (Encl 1).

   d. Model Documentation, Meramec River Freshwater Mussel Habitat Suitability Index Model, dated 23 June 2017. (Encl 2).

   e. Final Model Review Comment Record, Meramec River Freshwater Mussel Habitat Suitability Index Model, dated 23 June 2017 (Encl 3).

   f. Application Calculator, Meramec River Freshwater Mussel Habitat Suitability Index Model, dated 23 June 2017 (Encl 4).

2. The National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the Meramec River Freshwater Mussel Habitat Suitability Index Model (Meramec HSI) using references 1.a., 1.b., and 1.c. Based on the evaluation results, the ECO-PCX recommends single-use approval of the model for the Meramec River Ecosystem Restoration Study. Please log in this recommendation with the Office of Water Project Review for the Model Certification Panel to consider.

3. The development of the Meramec HSI (Encl 2) was led by the St. Louis District and researchers from the U.S. Army Engineer Research and Development Center – Environmental Laboratory to support planning of the Meramec River Ecosystem Restoration Study. Model development followed a common ecological modeling process of conceptualization, quantification, evaluation, and application. This process was iterative and involved participants from the Missouri Department of Conservation, the Missouri Department of Natural Resources, U.S. Fish and Wildlife Service (FWS), and St. Paul District (MVP). The model structure was developed during an Ecological Modeling Workshop held at the St. Louis District office on April 12-14, 2016, and further refined by the interagency field team and project delivery team. The model was quantified based on empirical data from the project location and established peer-reviewed literature. Finally, the model was coded as a Microsoft Excel spreadsheet calculator (Encl 4), tested and reviewed (Encl 3), and documented.

   The model consists of HSI curves for the habitat variables: total suspended solids, lead (Pb), pool substrate, aquatic available cover, fish species richness, and channel change. These are key variables in determining mussel habitat that are directly influenced by the implementation of proposed ecosystem restoration measures. Each variable is assigned a dimensionless suitability index value that

CEMVD-PD-L
SUBJECT: Recommendation for Single-Use Approval of the Meramec River Freshwater Mussel Habitat Suitability Index Model

represents the relationship between an environmental variable and freshwater mussel suitability (noted as *MSIn*). Each *MSI* is represented quantitatively as a series of linear suitability curves, with a value of 0.0 for unsuitable to 1.0 for optimal habitat. When combined, the model provides an overarching assessment of freshwater mussel habitat integrity in the Meramec River Basin.

4. The current Meramec HSI has completed two levels of peer-review. The first review was conducted by the Upper Mississippi River Mussel Coordination Team (MCT). The MCT is an interagency team of malacologists, researchers, and state and federal agency representatives, which coordinate all mussel propagation, restoration, and research in the Upper Mississippi River System. The second review was an intermediate level of review managed by the ECO-PCX in accordance with References 1.a., 1.b., and 1.c. The review team possessed extensive experience and knowledge of USACE planning policy, alternative evaluation and comparison, and freshwater mussel ecology. Reviewers included Mr. Joseph Jordan (Biologist Regional Technical Specialist, MVP), Mr. Dan Kelner (Senior Biologist, MVP), and Bryan Simmons (Senior Ecologist and Malacologist, FWS). The reviewers received electronic versions of the model review documents and a charge that solicited comments on 20 questions developed to assess the technical quality, system quality, usability, and conformance with USACE policy (Encl 1).

   In summary, the reviewers agreed the model is a well-documented and established tool which assists users in formulating and evaluating alternative restoration plans for the Meramec River Ecosystem Restoration Study. The review resulted in 26 comments (nine high significance, 10 medium significance and seven low significance). The high significant issues and related updates are summarized below. The full text of the comments, evaluations, and resolutions can be found in the Final Model Comment Review Record (Encl 3). All comments were addressed and incorporated to the satisfaction of the reviewers and the ECO-PCX.

   a. All reviewers were concerned with the original functionality and description of the substrate variable. The original variable was a categorical variable and lacked good definitions for each variable. The model development team refined the model by first developing a linear function and then expanding the linear function to a three-axis relationship (i.e., ternary diagram), whereby four substrate quality categories are defined by the ratio of fine to coarse substrate composition. This relationship improves fidelity and resolution of the model, and more accurately captures the system being represented.

   b. Reviewers recommended improving the model documentation by expanding the assumptions and limitations of the model, improving definitions, and better defining the model's intended use. The resulting model documentation includes better definitions for submerged structure, the importance of mussel habitat, field data collection methodologies, channel change suitability scores, and the importance of substrate heterogeneity.

   c. Reviewers reinforced the impacts of elevated total suspended solids to freshwater mussel feeding, growth, and reproduction under elevated temperatures. The model documentation was improved to clarify this threshold response.

   d. Spreadsheet errors and omissions were identified and fixed. The final version incorporates best spreadsheet practices (i.e., cell locking, highlight input/output cells, cell validation).

5. The Meramec HSI has sufficient technical quality. The model structure and relationships are based on research established in relevant, peer-reviewed literature and on field data collected within the project area. The model operates on the premise that key environmental characteristics affect freshwater mussel community distribution and abundance. It offers a robust, defensible and

2

CEMVD-PD-L
SUBJECT: Recommendation for Single-Use Approval of the Meramec River Freshwater Mussel Habitat Suitability Index Model

quantifiable relationship of freshwater mussel habitat integrity across a gradient of environmental conditions through consideration of reference conditions. The documentation provides a clear understanding of the model's intended use, its theoretical basis, and its application to the Meramec River. Assumptions and limitations of the model are clearly documented. Formulas and calculation routines forming the basis of the model are logical and ecologically correct.

6. The Meramec HSI has sufficient system quality. The model is coded within a Microsoft Excel spreadsheet, which was found to be computationally correct and functions well. The spreadsheet incorporates best spreadsheet management practices and is locked for editing. The ECO-PCX will keep the password and will maintain the spreadsheet on the Ecosystem Restoration Model Library. The model developers documented the computational scheme for the model and implemented system quality testing procedures utilized during model development. The implemented Q/A practices, model testing, and validation procedures ensures the model functions as intended.

7. The Meramec HSI has sufficient usability. The model is well-suited to the tasks for which it was designed. Input requirements are well-specified in the model documentation and require a nominal level of expertise and some field time. Model outputs are transparent, easy to understand, and facilitate the evaluation and comparison of alternatives in the planning process. The model has more than adequate functionality and usability for the Meramec River Ecosystem Restoration Study.

8. The Meramec HSI model and methodology are consistent with USACE policies and accepted procedures for ecosystem restoration planning and is at an appropriate level of detail for the study needs. The model does not incorporate, facilitate, or encourage the use of non-ecosystem parameters or values. The model uses established principles of alternative evaluation and facilitates trade-off analyses used in identifying the National Ecosystem Restoration plan.

9. The ECO-PCX finds the Meramec River Freshwater Mussel Habitat Suitability Index Model has sufficient technical and system quality, meets usability criteria, and complies with USACE policy. The ECO-PCX recommends the model be approved for single use for the Meramec River Ecosystem Restoration Study. Please notify the ECO-PCX of the Model Certification Panel's findings.

Gregory Miller

Encls (4)

Gregory Miller
Operating Director
National Ecosystem Restoration
Planning Center of Expertise

CF (without enclosures)
CECW-P (Paynes)
CECW-PC (Coleman, Matusiak, Trulick, Bee)
CECW-MVD (Brown, Hanneken, Varisco)
CEMVD-PD-L (Chewning, Mallard, Young)
CEMVP-PD-P (Creswell, Kelner, McCain)
CEMVP-PD-C (Johnson, Jordan, Simmons)
CEMVP-PD-F (Knollenberg, Richards, Savage)
CEMVS-PM-F (Kohler)
CEERD-EEC (Reif, Saltus)
CEERD-EEW (Swannack)
CENAO-WRP-E (Conner)

ENCLOSURE 4

From: Richards, Nathaniel S CIV USARMY CEMVR (US)
Sent: Tuesday, October 03, 2017 11:25 AM
To: Hanneken, Charles D CIV USARMY CEHQ (US) <Charles.D.Hanneken@usace.army.mil>; Varisco, Jeffrey J CIV USARMY CEMVN (US) <Jeffrey.J.Varisco@usace.army.mil>; Chewning, Daniel B (Brian) CIV USARMY CEMVD (US) <Brian.Chewning@usace.army.mil>; Mallard, Matthew S CIV USARMY CEMVD (US) <Matthew.S.Mallard@usace.army.mil>; Young, Gary L CIV USARMY CEMVD (US) <Gary.L.Young@usace.army.mil>; Jordan, Joseph W CIV (US) <Joseph.W.Jordan@usace.army.mil>; Kelner, Daniel E CIV USARMY CEMVP (US) <Daniel.E.Kelner@usace.army.mil>; McCain, Kathryn N CIV USARMY CEMVP (US) <Kathryn.Mccain@usace.army.mil>; Savage, Monique E CIV USARMY CEMVP (US) <Monique.E.Savage@usace.army.mil>; Simmons, Shane M CIV USARMY CEMVP (US) <Shane.M.Simmons@usace.army.mil>; Kohler, Gregory W CIV USARMY CEMVS (US) <Greg.Kohler@usace.army.mil>; Reif, Molly K CIV (US) <Molly.K.Reif@usace.army.mil>; Saltus, Christina L CIV USARMY CEERD-EL (US) <Christina.L.Saltus@usace.army.mil>; Swannack, Todd M CIV USARMY CEERD-EL (US) <Todd.M.Swannack@usace.army.mil>; Conner, Susan L CIV (US) <Susan.L.Conner@usace.army.mil>; Redican, Joseph H CIV USARMY CEHQ (US) <Joseph.H.Redican@usace.army.mil>
Cc: Miller, Gregory B CIV USARMY CEMVD (US) <Gregory.B.Miller@usace.army.mil>; Trulick, Jeffrey L CIV USARMY CEHQ (US) <Jeff.Trulick@usace.army.mil>; Richards, Nathaniel S CIV USARMY CEMVR (US) <Nathaniel.S.Richards@usace.army.mil>

Subject: RE: Model Recommendation - Meramec River Freshwater Mussel Habitat Suitability Index (for use in Meramec Feasibility Study) (UNCLASSIFIED)

CLASSIFICATION: UNCLASSIFIED

More good news for MVS! Today the HQ model certification team approved the Meramec River Mussel model for use in the Meramec River Feasibility Study. Please reference today's date and this email in your correspondence. We will forward the HQ approval memo once delivered.

Thanks again to all for contributing to the development, review, and approval of the model. This model would not be possible without the great work of ERDC, RPEDN and contributions by our partner agencies.

Have a great week!

Nate

Nathan Richards
U.S. Army Corps of Engineers
Mississippi Valley Division
Regional Technical Specialist
ECO-PCX Model Review Manager
Office: 309-794-5286
Cell: 309-230-3804

U.S. Army Corps of Engineers

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

July 2019

Appendix C

Biological Assessment

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK

1. INTRODUCTION

1.1. PURPOSE

The purpose of the St. Louis Riverfront, Missouri and Illinois, Meramec River Ecosystem Restoration Feasibility Study (Study) is to determine the National Ecosystem Restoration (NER) plan that addresses the degradation of the aquatic ecosystem and altered geomorphic characteristics within the authorized portion of the Meramec River Basin caused by human-induced modifications. The purpose of this feasibility study with integrated environmental assessment (EA), including the unsigned Finding of No Significant Impact (FONSI), is to assess the environmental effects of a reasonable range of alternatives or actions taken by the U.S. Army Corps of Engineers (USACE), including the No Action Plan, prior to making decisions.

The need for this Study is demonstrated by the large number of local, state and Federal activities taking place in the study area. Coordination of this feasibility study with larger Meramec River Basin planning efforts allows for a more comprehensive and complete Federal ecosystem restoration plan. The need for 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 excess contaminated sediment from historic mining practices, altered hydrology, altered riparian corridor and degradation of aquatic habitat, including ecologically significant freshwater mussel habitat. This feasibility study is being closely coordinated with the agencies involved with the remediation and restoration efforts described below. These interagency partnerships and collaboration are 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 USACE and the Missouri Department of Natural Resources (MoDNR) to leverage resources with the other partners (Natural Resource Damage Assessment and Restoration (NRDAR) trustees, The Nature Conservancy (TNC), U.S. Environmental Protection Agency (USEPA), and the U.S. Fish and Wildlife Service (USFWS)) to provide the water-resources solutions to restore the ecosystem structure and function of the Meramec River Basin.

The purpose of this Biological Assessment (BA) is to review the Meramec River Ecosystem Restoration Feasibility Study in sufficient detail to evaluate whether the proposed actions may affect any Federally threatened, endangered, proposed or candidate species identified by the U.S. Fish and Wildlife Service (USFWS). This BA is prepared in accordance with legal requirements set forth under Section 7 of the Endangered Species Act (15 U.S.C. 1536 (c)) and applicable guidance documents. The BA includes the description of the study area, proposed actions, species accounts and status, effects of the proposed actions and effects determinations.

1.2. PROPOSED ACTION

The proposed Federal action involves selecting and recommending one of the alternatives for implementation to restore the ecosystem structure and function of the Meramec River Basin within Jefferson, St. Francois, Washington and St. Louis Counties, Missouri.

2. PROJECT DESCRIPTION

The U.S. Army Corps of Engineers, St. Louis District, is preparing to implement aquatic ecosystem restoration within the Meramec River Basin, including portions of the lower 50 river miles of Meramec River in St. Louis County, and the Big River Watershed located in Jefferson, St. Francois, and Washington Counties, Missouri (Figure 1).

The proposed project involves a combination of constructing bank stabilization measures, channel realignment, grade control structures, bed sediment collectors, in-stream excavation (including bed sediment removal), floodplain reforestation and sediment basins in high priority areas identified through an interagency partnership of Federal, state, and non-governmental organizations. For detailed descriptions of proposed restoration measures (including where, when and how the action will be accomplished) please refer to the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment. Figure 2 depicts approximate potential sites with proposed measures; however, the final plan may be a subset of the ones shown pending further analyses.

2.1. STUDY OBJECTIVES

The overarching goal of this study is to formulate an alternative that can restore the aquatic ecosystem and determine if Federal participation in repairing habitat functionality within the authorized study area is justified.

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

- 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;
- Reduce the quantity of contaminated sediment entering the Big River and Meramec River; and
- Increase riparian habitat connectivity, quantity, diversity and complexity within the study area.

The proposed plan would include a combination of measures at various locations within the study area. The final plan may include a subset of the measures upon further detailed analyses.

2.1.1. 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

Specific restoration measures that have been developed to help accomplish this objective may include:

- Establish sediment basins to collect the excessive contaminated bedload moving downstream in the Big River.
- In-channel rock riffles or similar structures to collect sediments and provide in-stream structural diversity and grade control.
- Excavation to remove excessive contaminated sediment
- Collectors placed in-channel to capture excessive contaminated sediment

2.1.2. OBJECTIVE 2: RESTORE IMPACTED CHANNELS AND FLOODPLAINS IN THE BIG RIVER AND MERAMEC RIVER SYSTEMS TO EMULATE A MORE NATURAL STATE OVER THE 50 YEAR PERIOD OF ANALYSIS

Within the Big River, areas susceptible to bank erosion and are a source of sediment entering the system have been identified (Pavlowsky & Owen, 2013). Targeting restoration measures at these locations provides an opportunity to stabilize the system and reduce the influx of sediments entering the river channel. Sediments arising from bank erosion are usually “fines”. Fine sediments are problematic to the aquatic ecosystem by reducing the ability of filter feeders (e.g., mussels) to feed, by increasing total suspended solids which reduces water clarity and by filling in the crevices of the bottom substrate which reduces the diversity of the river bottom habitat. In the case of the Big River, fine sediment is problematic in that it is the most likely to be highly contaminated with heavy metals and adversely affects aquatic organisms.

Specific restoration measures that have been developed to help accomplish this objective may include:

- Use bioengineering methods for bank stabilization where possible
- Re-slope steepened banks to a gentler slope
- Use rock structure and toe wood methods for bank stabilization
- Re-vegetate riparian zones with an appropriate mix of native species
- Traditional bank stabilization

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

Specific restoration measures that have been developed to help accomplish this objective include:

- Riparian tree plantings
- Restore hydrologic aspects to encourage survival of appropriate plant communities
- Use bioengineering methods for bank stabilization where possible

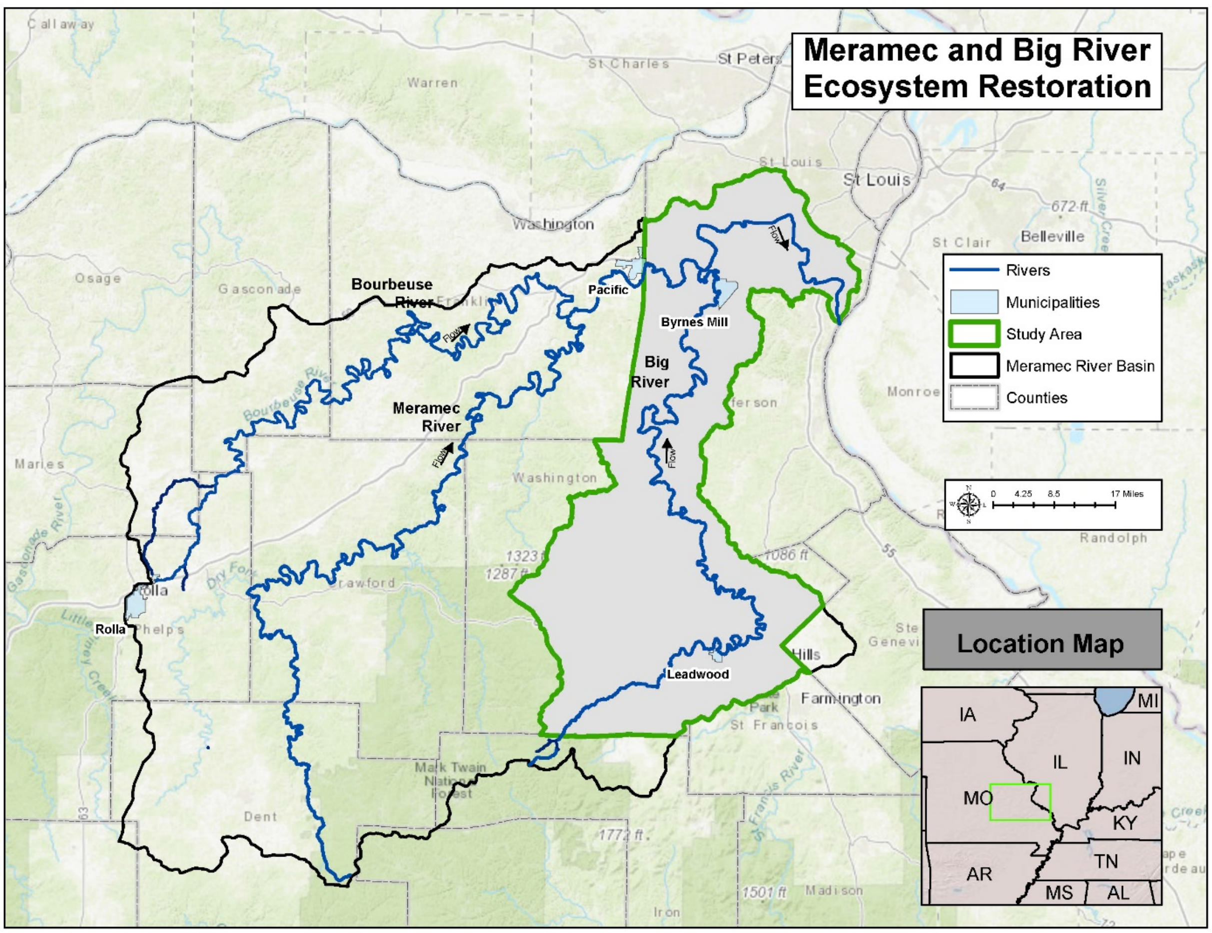


Figure 1. Meramec River Basin Ecosystem Restoration Study Area (highlighted in grey) and Vicinity

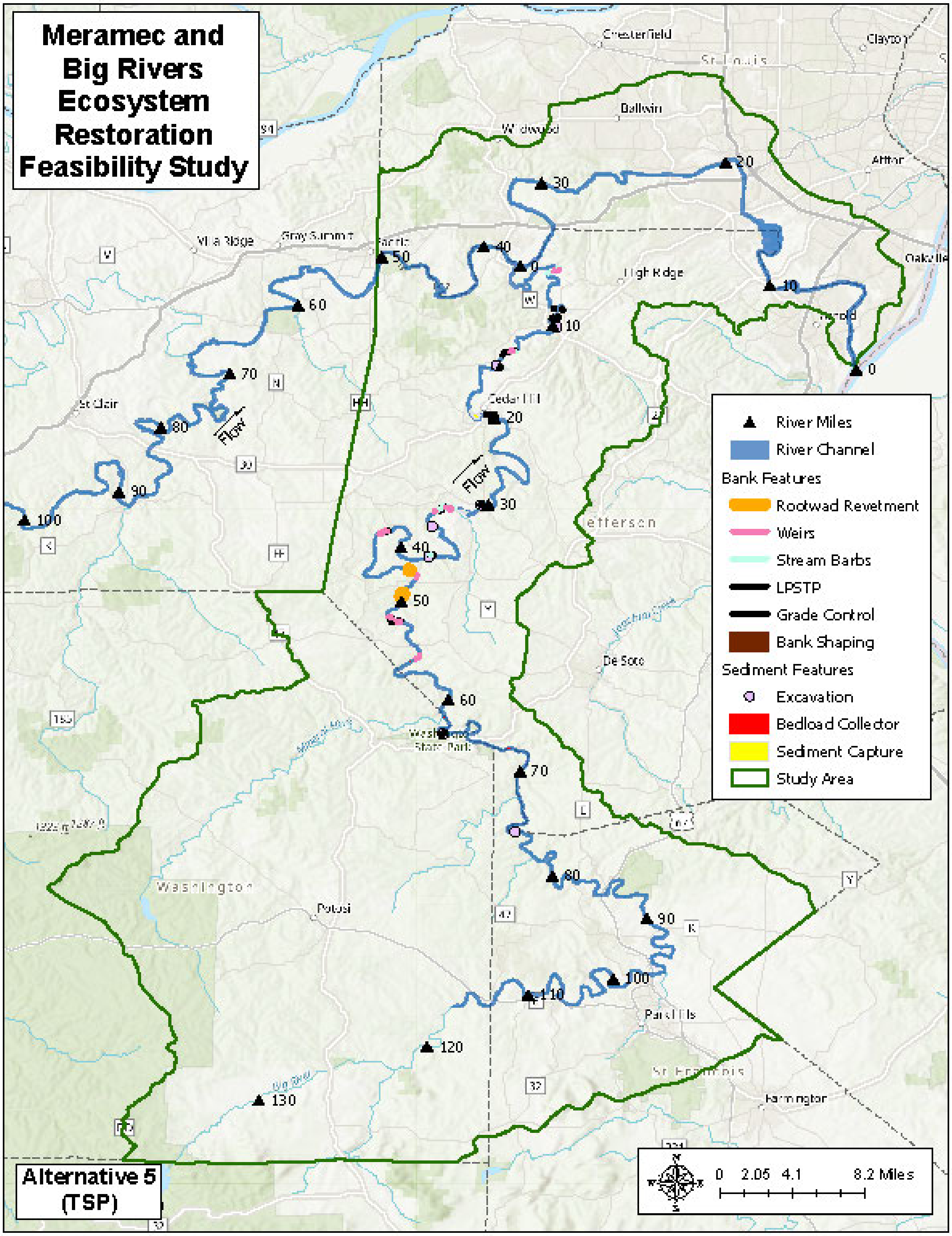


Figure 2. Proposed Site Location for the Meramec River Basin Ecosystem Restoration Feasibility Study

3. SPECIES/HABITAT CONSIDERED IN THIS CONSULTATION

3.1. BIOLOGICAL SURVEY DATA

The mussels within the Big and Meramec River watershed have been well studied (Buchanan, 1979) (Buchanan, Mussels (Naiades) of the Meramec River Basin, 1980) (Roberts, et al., 2016) (Roberts, et al., 2009) (Hinck, et al., 2012) (Besser, Brumbaugh, Hardesty, Hughes, & Ingersoll, 2009) (Roberts & Bruenderman, 2000). Overall, the mussel assemblage within the Meramec River Basin is diverse and six federally listed species are known to occur within the Basin. Forty-six mussel species occur within the Meramec River Basin and 30 species occur within the Big River watershed (Buchanan, 1980).

3.2. SPECIES COVERED IN THIS CONSULTATION

The Corps requested the official species via the ECOS-IPaC website (http://ecos.fws.gov/ipac/), dated 15 November 2018. U.S. Fish and Wildlife Service provided a list of 13 Federally threatened and endangered species that could potentially be found in the study area (Meramec River within St. Louis county, and Big River Watershed, Missouri). The 13 species, Federal protection status and habitat can be found in Table 1. Critical habitat for the Indiana Bat (*Myotis sodalis*) is located within the study area.

Table 1. Federally Listed Threatened and Endangered 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
CLAMS		
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

4. MEASURES TAKEN TO AVOID IMPACT TO LISTED SPECIES

During the planning process for the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study, the planning team considered how project features could impact listed species. Efforts have been made to reduce direct, indirect and cumulative impacts to freshwater mussels and other listed species. Surveys previously conducted by the U.S. Fish and Wildlife Service were used and known mussel beds were avoided during site selection and preliminary design. In most cases, features were moved or completely eliminated if in the vicinity of a known bed.

4.1.1. CONSERVATION MEASURES FOR LISTED SPECIES

Conservation measures are actions to benefit or promote the recovery of a listed species that a Federal agency includes as an integral part of the proposed action and that are intended to avoid, minimize or compensate for potential adverse effects of the action on the listed species. As such, mandatory measures below will be incorporated into every USACE action that falls within this consultation framework.

The following bat conservation measures are proposed for the Proposed Action Alternative to help minimize effects to currently listed bats within the study area.

1. All tree clearing resulting from the USACE action will occur during the inactive season from November 1 to March 31 unless negative presence/probable absence survey results were obtained for the action area through appropriate surveys approved by the U.S. Fish and Wildlife Service.
2. The USACE will require a habitat assessment if the project will occur in Zone 1 (defined below) and includes more than 10 acres of tree clearing. If the results indicate that more than 10 acres of suitable roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.
3. The USACE will require a habitat assessment if the project will occur in Zone 2 (defined below) and includes more than 5 acres of tree clearing. If the results indicate that more than 5 acres of suitable roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.
4. If located in Zone 1, the project will not remove more than 10 acres of suitable roosting habitat during the inactive season.
5. If located in Zone 2, the project will not remove more than 5 acres of suitable roosting habitat during the inactive season.
6. The project and the Corps action will not result in the removal of trees in Zone 3 (defined below).

7. Tree clearing associated with the project and the Corps action will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage.
8. If the project is located in a karst area and will involve construction methods that may cause deep ground disturbance, the USACE will require a cave search be conducted to determine if any caves are present in the action area that would be considered suitable habitat for bats and/or are currently or formerly used by listed bats.
9. If the demolition of an existing building or structure will occur as a result of the project in Zones 2 or 3, the USACE will require bat use surveys in collaboration with the USFWS. If during the course of demolition, bats of any species are discovered, then all work must cease and USFWS must be immediately contacted. If the structure is safe to leave as is, then it will be left until after November 1, or until bats have stopped using the structure. If the structure is unsafe and poses a risk to human health and safety, the USACE will request the assistance of the USFWS in determining reasonable measures to exclude the bats.

*Zone 1 = Conservation measures apply to actions within the State of Missouri excluding Zones 2 and 3.

*Zone 2 = Conservation measures apply to actions within 5.0 miles (radius) of a known capture of a listed bat.

*Zone 3 = Conservation measures apply to actions that occur within 0.25 miles (radius) of a known roost tree or hibernacula.

The following conservation measures are proposed for the Proposed Action Alternative to help minimize effects to currently listed freshwater mussels within the study area.

1. Quantitative mussel surveys will be completed for pre-project and post-project years 2, 5 and 8 following previous mussel surveys within the study area conducted by the Corps, the U.S. Fish and Wildlife Service, the non-Federal sponsor or an entity approved by the U.S. Fish and Wildlife Service. A more detailed monitoring plan for freshwater mussels will be developed in cooperation with the U.S. Fish and Wildlife Service and other resource agencies during the Planning, Engineering and Design Phase for the project.
2. If pre-project surveys identify mussel beds within the construction footprint of a given site or in proximity downstream, then re-evaluation of that site would occur to determine if adverse effects could be avoided. If adverse effects cannot be avoided, separate site-specific Section 7 consultation would be conducted.
3. Best management practices to reduce siltation during construction activities would be implemented to minimize impacts to water quality.

5. IMPACT ASSESSMENT

The following section includes a status description of each species and how it will be affected by project elements as well as the determination of effects for each species. The effects determination took into account implementation of the conservation measures listed above.

5.1. GRAY BAT (MYOTIS GRISESCENS)

5.1.1. STATUS

The gray bat is listed as federally endangered and inhabits caves during both summer and winter. This species forages over rivers and reservoirs adjacent to forests. During the winter, gray bats hibernate in deep, vertical caves. In the summer, they roost in caves which are scattered along rivers. These caves are in limestone karst areas (USFWS, 2015c). The study area does provide bat roosting and foraging habitat. The karst topography and abandoned mines provide roosting cave habitat and the forested streams and riparian corridor provide foraging habitat.

5.1.2. EFFECTS DETERMINATION

Direct adverse effects from implementing the proposed project are not anticipated. Tree clearing may be involved for construction access; however, the above conservation measure would be followed to minimize effects to bats. No known winter habitat is located within any of the proposed restoration sites. There is minimal chance for indirect effects to gray bats through short-term noise disturbance. Indirect adverse effects that could result from foraging habitat loss are avoided because tree clearing associated with the project will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage. We conclude the proposed St. Louis Riverfront - Meramec River Ecosystem Restoration Feasibility Study ***may affect, but is not likely to adversely affect gray bats.***

5.2. INDIANA BAT (*MYOTIS SODALIS*)

5.2.1. STATUS

The Indiana bat is a federally listed, endangered mammal species (USFWS, 2016). The range of the Indiana bat includes much of the eastern half of the United States, including Missouri. Indiana bats migrate seasonally between winter hibernacula and summer roosting habitats. Winter hibernacula include caves and abandoned mines. Females emerge from hibernation in late March or early April to migrate to summer roosts. During the summer, the Indiana bat frequents the corridors of small streams with well-developed riparian woods as well as mature upland forests. It forages for insects in many habitats including along stream corridors, within the canopy of floodplain and upland forest, over clearings with early successional vegetation (old fields), along the borders of croplands, along wooded fencerows and over farm ponds in pastures.

Females form nursery colonies under the loose bark of trees (dead or alive) and/or cavities, where each female gives birth to a single young in June or July. A maternity colony may include from one to 100 individuals. A single colony may utilize a number of roost trees during the summer, typically a primary roost tree and several alternates. Some males remain in the area near the winter hibernacula during summer months, but others disperse throughout the range of the species and roost individually or in small numbers in the same types of trees as females.

Disturbance and vandalism of caves, improper cave gates and structures, natural hazards, microclimate changes, land use changes in maternity range, chemical contamination and white-nose syndrome are the leading causes of population decline in the Indiana bat (USFWS, 2000) (USFWS, 2004). To avoid impacting this species, tree clearing activities should not occur during the period of 1 April to 31 October.

The study area does provide bat roosting and foraging habitat. The karst topography and abandoned mines provide roosting cave habitat and the forested streams and riparian corridor provide foraging habitat.

5.2.2. EFFECTS DETERMINATION

Direct adverse effects from implementing the proposed project are not anticipated. Some tree clearing will be involved for construction access; however, the above conservation measures would be followed to minimize effects to bats. There is minimal chance for indirect effects to Indiana bats through short-term noise disturbance. Indirect adverse effects that could result from foraging habitat loss are avoided because tree clearing associated with the project will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage. Previous actions of deforestation, urbanization and land use changes have adversely altered both foraging and roosting habitat. The proposed project would result in substantial beneficial impacts to Indiana bats due to restored riparian corridor with a diverse tree species mix which, in turn, will provide necessary roosting habitat into the future. We conclude the proposed St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but is not likely to adversely affect Indiana bats.***

5.3. NORTHERN LONG-EARED BAT (*MYOTIS SEPTENTRIONALIS*)

5.3.1. STATUS

The northern long-eared bat is a federally listed, threatened mammal species (Federal Register 4 May 2015). The northern long-eared bat is sparsely found across much of the eastern and north central United States and spends winter hibernating in caves and mines. They typically use large caves or mines with large passages and entrances; constant temperatures; and high humidity with no air currents. Within hibernacula, they are found in small crevices or cracks (USFWS, 2016a). During summer, northern long-eared bats roost singly or in colonies underneath bark, in cavities, or in crevices of both live and dead trees. Males and non-reproductive females may also roost in cooler places like caves and mines. This bat seems opportunistic in selecting roosts, using tree species based on suitability to retain bark or provide cavities or crevices. They have also been found, rarely, roosting in structures like barns and sheds (USFWS, 2016a). Foraging occurs in floodplain and upland forests. Forest fragmentation, logging and forest conversion are major threats to the species. One of the primary threats to the northern long-eared bat is the fungal disease, white-nose syndrome, which has killed an estimated 5.5 million cave-hibernating bats in the Northeast, Southeast, Midwest and Canada.

The study area does provide bat roosting and foraging habitat. The karst topography and abandoned mines provide roosting cave habitat and the forested streams and riparian corridor provide foraging habitat.

5.3.2. EFFECTS DETERMINATION

Direct adverse effects from implementing the proposed project are not anticipated. Tree clearing may be involved for construction access; however, the above conservation measures would be followed to minimize effects to bats. There is minimal chance for indirect effects to northern long-eared bats through short-term noise disturbance. Indirect adverse effects that could result from foraging habitat loss are avoided because tree clearing associated with the project will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage. Previous actions of deforestation, urbanization and land use changes have adversely altered both foraging and roosting habitat. The proposed project would result in substantial beneficial impacts to Northern long-eared bats due to restored riparian corridor with a diverse tree species mix, which in turn will provide necessary roosting habitat into the future. We conclude the proposed St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but is not likely to adversely affect Northern long-eared bats.***

5.4. PALLID STURGEON (*SCAPHIRHYNCHUS ALBUS*)

Pallid sturgeon are a federally listed endangered large river fish species that is found in the Mississippi River and Missouri River. They are bottom dwelling, slow growing fish that that feed primarily on small fish and immature aquatic insects. Their preferred habitat has a diversity of depths and velocities formed by braided channels, sand bars, sand flats and gravel bar of large rivers (USFWS, 2018a). The riverine habitat for the pallid sturgeon has been altered due to impoundment, channelization, and environmental contamination leading to species decline.

The counties within the study area that border the Mississippi River do provide suitable habitat for the pallid sturgeon; however, the focused study along the Big River does not. It is likely pallid sturgeon may enter the lower Meramec River near the confluence with the Mississippi River. Based on fisheries data available during this study, pallid sturgeon have not been observed in the Big River.

5.4.1. EFFECTS DETERMINATION

Direct adverse effects from implementing the proposed project are not anticipated. The proposed actions along the Big River are not expected to effect the Pallid Sturgeon due to lack of suitable habitat. The proposed actions considered along the Meramec River (not part of the recommended plan) involving bank stabilization and tree plantings may result in temporary short-term effects due to increases in turbidity during construction; therefore, we conclude the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration feasibility study ***may affect, but not likely to adversely affect Pallid Sturgeon.***

5.5. PINK MUCKET (*LAMPSILIS ABRUPTA)*

5.5.1. STATUS

Pink Mucket is a federally listed endangered mussel species (USFWS, 2015d) that is found in mud and sand and in shallow riffles and shoals in large rivers and tributaries. Erosion and excessive sedimentation related to land use practices are major threats to this species since the added suspended sediment clog the mussel's feeding siphons and/or burial. The major threat is loss of suitable habitat.

Pink Mucket is known to occur in the lower reaches of the Big River and lower 55 miles of the Meramec River (Buchanan, 1980). Pink Mucket was found in a variety of substrate from silt to cobble, but most commonly found in the gravel and cobble substrate in 1-5 feet of water in standing to moderately flowing (1.2 ft/sec) water.

5.5.2. EFFECTS DETERMINATION

Suitable habitat does exist within the study area and project measures seek to reduce sediment and channel instability which should enhance mussel habitat. The placement of in-stream measures (i.e., collectors, river training structures, excavation) would seek to avoid and minimize effects to mussels. Existing mussel data have been used to inform placement location of in-stream measures during the feasibility study, and a mussel survey would be conducted during project design to avoid and minimize effects to mussel beds. If adverse effects cannot be avoided, separate site-specific Section 7 consultation would be conducted. Ultimately, the proposed project would result in substantial beneficial impacts to endangered mussel species due to reduction in contaminated sediment (suspended and bedded), improved channel stability and substrate, and enhanced aquatic habitat; therefore, we conclude the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but not likely to adversely affect Pink Muckets.***

5.6. SCALESHELL (*LEPTODEA LEPTODON*)

5.6.1. STATUS

Scaleshell is a federally listed endangered mussel species (USFWS, 2016a) and is a relatively small freshwater mussel with a thin, fragile shell and faint green rays. Scaleshell live in medium-sized and large rivers with stable channels and good water quality.

Scaleshell is known to occur in the Meramec and Big Rivers (Buchanan, 1980). Specimens were found in gravel and cobble substrate.

5.6.2. EFFECTS DETERMINATION

Suitable habitat does exist within the study area and project measures seek to reduce sediment and channel instability which should enhance mussel habitat. The placement of in-stream measures (i.e., collectors, river training structures, excavation) would seek to avoid and minimize effects to mussels. Existing mussel data have been used to inform placement location of in-stream measures during the feasibility study, and a mussel survey would be conducted during project design to avoid and minimize effects to mussel beds. If adverse effects cannot be avoided, separate site-specific Section 7 consultation would be conducted. Ultimately, the proposed project would result in substantial beneficial impacts to endangered mussel species due to reduction in contaminated sediment (suspended and bedded), improved channel stability and substrate and enhanced aquatic habitat; therefore, we conclude the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but not likely to adversely affect Scaleshell.***

5.7. SHEEPNOSE (*PLETHOBASUS CYPHYUS)*

5.7.1. STATUS

Sheepnose is a federally listed endangered mussel species (USFWS, 2016e) found in large rivers and streams with moderate to swift currents flowing over coarse sand and gravel. Historically, the species is known from the Meramec and Big Rivers; however, sheepnose has extirpated throughout much of its former range or reduced to isolated populations.

The Meramec River harbors one of the best Sheepnose populations remaining range-wide (Butler, 2002). Buchanan (1980) describes that the species is generally distributed in the downstream 140 miles of the Meramec. The maximum number of live species were recorded near river mile 40 on the Meramec River, which is within the study area.

5.7.2. EFFECTS DETERMINATION

Suitable habitat does exist within the study area; and project measures seek to reduce sediment and channel instability which should enhance mussel habitat. The placement of in-stream measures (i.e., collectors, river training structures, excavation) would seek to avoid and minimize effects to mussels. Existing mussel data have been used to inform placement location of in-stream measures during the feasibility study, and a mussel survey would be conducted during project design to avoid and minimize effects to mussel beds. If adverse effects cannot be avoided, separate site-specific Section 7 consultation would be conducted. Ultimately, the proposed project would result in substantial beneficial impacts to endangered mussel species due to reduction in contaminated sediment (suspended and bedded), improved channel stability and substrate and enhanced aquatic habitat; therefore, we conclude the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but not likely to adversely affect Sheepnose.***

5.8. SNUFFBOX (*EPIOBLASMA TRIQUETRA*)

5.8.1. STATUS

Snuffbox is a federally listed endangered mussel species ((USFWS, 2016f) found in small- to medium-sized creeks, inhabiting areas with swift current with sand, gravel or cobble substrates. It is a small- to medium-sized freshwater mussel with a yellow, green or brown shell interrupted by green rays, blotches or chevron-shaped lines. Shell shape is usually triangular.

Snuffbox is known to occur in the Meramec River (Buchanan, 1980) and found in gravel and cobble, cobble, or gravel, cobble and boulder substrates, often entirely buried beneath the substrate.

5.8.2. EFFECTS DETERMINATION

Suitable habitat does exist within the study area and project measures seek to reduce sediment and channel instability which should enhance mussel habitat. The placement of in-stream measures (i.e., collectors, river training structures, excavation) would seek to avoid and minimize effects to mussels. Existing mussel data have been used to inform placement location of in-stream measures during the feasibility study, and a mussel survey would be conducted during project design to avoid and minimize effects to mussel beds. If adverse effects cannot be avoided, separate site-specific Section 7 consultation would be conducted. Ultimately, the proposed project would result in substantial beneficial impacts to endangered mussel species due to reduction in contaminated sediment (suspended and bedded), improved channel stability and substrate and enhanced aquatic habitat; therefore, we conclude the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but not likely to adversely affect Snuffbox.***

5.9. SPECTACLECASE (*CUMBERLANDIA MONODONTA*)

5.9.1. STATUS

Spectaclecase is a federally listed, endangered mussel species (USFWS, 2016b). This mussel lives in large rivers in sheltered areas (e.g., beneath rock slabs). Historically, this large mussel was found in at least 44 streams of the Mississippi, Ohio and Missouri river basins in 14 states; however, today it is found only in 20 streams, with the populations fragmented and restricted to short stream reaches.

Spectaclecase is known to occur within the project area. Living specimens have been collected in the Meramec River while shell material and live specimens have been found in the lower Big River (Buchanan, 1980). The largest populations of spectaclecase in the world may be found in the Meramec River (Buchanan, 1980).

5.9.2. EFFECTS DETERMINATION

Suitable habitat does exist within the study area and project measures seek to reduce sediment and channel instability which should enhance mussel habitat. The placement of in-stream measures (i.e., collectors, river training structures, excavation) would seek to avoid and minimize effects to mussels. Existing mussel data have been used to inform placement location of in-stream measures during the feasibility study, and a mussel survey would be conducted during project design to avoid and minimize effects to mussel beds. If adverse effects cannot be avoided, separate site-specific Section 7 consultation would be conducted. Ultimately, the proposed project would result in substantial beneficial impacts to endangered mussel species due to reduction in contaminated sediment (suspended and bedded), improved channel stability and substrate and enhanced aquatic habitat; therefore, we conclude the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study ***may affect, but not likely to adversely affect Spectaclecase.***

5.10. HINE'S EMERALD DRAGONFLY (*SOMATOCHLORA HINEANA*)

5.10.1. STATUS

The Hine's emerald dragonfly, listed as endangered, is found in Illinois, Missouri, Michigan and Wisconsin. Adults lay their eggs in small streams in fens and sedge meadows. After hatching, the aquatic larvae spend up to five years in wetlands before completely maturing and emerging as adult dragonflies (USFWS, 2018b). The greatest threat to the Hine's emerald dragonfly is habitat destruction. Most of the wetland habitat that this dragonfly depends on for survival has been drained and filled to make way for urban and industrial development (USFWS, 2018b).

5.10.2. EFFECTS DETERMINATION

The study area is outside the designated critical habitat for the Hine’s Emerald Dragonfly. This species is known to occur or believed to occur in St. Francois and Washington Counties, Missouri within the study area (USFWS, 2018). No actions are proposed for the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study in St. Francois and Washington counties; therefore, we conclude this study would have ***no effect on the Hine’s Emerald Dragonfly.***

5.11. DECURRENT FALSE ASTER (*BOLTONIA DECURRENS*)

5.11.1. STATUS

Decurrent false aster is a federally listed, threatened floodplain perennial plant species that may be found on moist, sandy floodplains and non-forested wetlands along the Mississippi and Illinois Rivers. It requires either natural or human disturbance to create and maintain suitable habitat and remove other plants competing for the same habitat. Without disturbance, other plant species can out-compete decurrent false aster and eliminate it in 3 to 5 years from any given area. Species decline is due to several factors including excessive silting of habitat due to topsoil run-off, conversion of natural habitat to agriculture, drainage/development of wetlands, altered flooding patterns and herbicide use. No critical habitat rules have been published for the decurrent false aster. This species has not been found within the project area, but has been found along the Mississippi River in Madison County, Illinois and St. Charles County, Missouri.

5.11.2. EFFECTS DETERMINATION

Suitable habitat does not exist within the study area; therefore, we conclude the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study would have ***no effect on decurrent false aster*.**

5.12. MEAD’S MILKWEED (*ASCLEPIAS MEADII*)

5.12.1. STATUS

Mead’s milkweed is a federally threatened perennial plant of the tallgrass prairies. This milkweed formerly occurred throughout the eastern tallgrass prairie region of the central United States, from Kansas through Missouri and Illinois and north to southern Iowa and northwest Indiana. It currently is known from 171 sites in 34 counties in eastern Kansas, Missouri, south-central Iowa, and southern Illinois. This milkweed requires moderately wet (mesic) to moderately dry (dry mesic) upland tallgrass prairie or glade/barren habitat characterized by vegetation adapted for drought and fire. It persists in stable late-successional prairie (USFWS, 2018c)

Mead's milkweed is threatened by the destruction and alteration of tallgrass prairie due to farming along with residential and commercial development. Sites known to have Mead's milkweed were destroyed by plowing and land development.

5.12.2. EFFECTS DETERMINATION

Mead's Milkweed is known to occur or likely to occur in St. Louis county; however no proposed actions would effect tallgrass prairie habitat; therefore, we conclude the proposed St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study would have ***no effect on Mead's milkweed.***

5.13. RUNNING BUFFALO CLOVER (*TRIFOLIUM STOLONIFERUM*)

5.13.1. STATUS

Running buffalo clover is a federally endangered plant species which requires periodic disturbance and a somewhat open habitat to successfully flourish. The plant cannot tolerate full-sun, full-shade or severe disturbance. Historically, running buffalo clover was found in rich soils in the ecotone between open forest and prairie. Those areas were probably maintained by the disturbance caused by bison. Today, the species is found in partially shaded woodlots, mowed areas (lawns, parks, cemeteries), and along streams and trails (USFWS, 2015b).

5.13.2. EFFECTS DETERMINATION

Suitable habitat does exist within the study area; therefore, we conclude the proposed St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study would have ***no effect on running buffalo clover***.

6. LITERATURE CITED

Anderson, E. A. (1983). *Nesting productivity of the interior or Least Tern of Illinois.* Carbondale, IL: Cooperative Wildlife Research Laboratory, Southern Illinois University.

Besser, J., Brumbaugh, W., Hardesty, D., Hughes, J., & Ingersoll, C. (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.

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

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

Butler, R. (2002). *Status Assessment Report for the sheepnose, occurring in the Mississippi River System (USFWS Regions 3,4,and 5).* Asheville, NC: U.S. Fish and Wildlife Service. Retrieved April 19, 2017, from https://www.fws.gov/Midwest/endangered/clams/pdf/sheepnose-sa.pdf

Constant, G. C., Kelso, W. E., Rutherford, D. A., & Bryan, C. F. (1997). *Habitat, movement, and reproductive status of pallid strugeon (Scaphirhunchus albus) in the Mississippi and Atchafalaya Rivers.* New Orleans, LA: U.S. Army Corps of Engineers, New Orleans District.

Ecological Specialist Inc. (2014). *Final Report, Freshwater Mussel Survey for the Piasa and Eagle's Nest Islands Habitat Rehabilitation and Enhancement Project, Mississippi River Miles 207.5-211.5.* St. Louis, MO: Prepared for U.S. Army Corps of Engineers, St. Louis District.

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

Moseley, L. J. (1976). *Behavior and communication in the Least Tern (Sterna albifrons).* Chapel Hill, TN: University of North Carolina.

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.

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

Roberts, A., Hundley, J., Rosenberger, A., Bouska, K., Mosby, D., Simmons, B., & Lindner, G. (2016). *Quantitative Survey of Freshwater Mussels (Unionoidea) and Assessment of Sediment Contamination in the Big River, Missouri.* Columbia, MO: U.S. Fish and Wildlife Service, U.S. Geological Survey, and Missouri Cooperative Research Unit.

Roberts, A., Mosby, D., Weber, J., Besser, J., Hundley, J., McMurray, S., & Faiman, S. (2009). *An Assessment of Freshwater Mussel (Bivalvia: Margartiferidae and Unionidae) Populations and Heavy Metal Sediment Contamination in the Big River, Missouri.* Columbia, MO: U.S. Fish and Wildlife Service, U.S. Geological Survey, and Missouri Department of Conservation.

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

Simons, D. B., Simons, R. K., Ghaboosi, M., & Chen, Y. H. (1988). *Physical impacts of navigation on the Upper Mississippi River System.* Ft. Collins, CO: Simons & Associates, Inc.

Smith, J. W., & Renken, R. B. (1991). Least tern nesting habitat in the Mississippi River valley adjacent to Missouri. *Journal of Field Ornithology, 62*, 497-504.

Theiling, C. H., Korschgen, C., DeHaan, H., Fox, T., Rohweder, J., & Robinson, L. (2000). *Habitat Needs Assessment for the Upper Mississippi River System Technical Report.* La Crosse, WI: U.S. Geological Survey, Upper Midwest Environmental Sciences Center.

USACE. (1999). *Biological Assessment, Interior Population of the Least Tern, Sterna Antillarum, Regulating Works Project, Upper Mississippi River (River Miles 0-195), and Mississippi River and Tributaries Project, Channel Improvement Feature, Lower Mississippi River.* Vicksburg, MS: U.S. Army Corps of Engineers, Mississippi Valley Division/Mississippi River Commission.

USACE. (2012). *Summer bat mist net surveys and acoustic monitoring, Mississippi River Complex, Illinois and Missouri.* St. Louis, MO: U.S. Army Corps of Engineers, St. Louis District.

USFWS. (2000). *Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System.* U.S. Fish and Wildlife Service.

USFWS. (2004). *Final Biological Opinion for the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study.* U.S. Fish and Wildlife Service.

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, April 4). *USFWS Endangered Species*. Retrieved April 19, 2017, from Pink Mucket Fact Sheet: https://www.fws.gov/midwest/endangered/clams/pinkm_fc.html

USFWS. (2016, July 19). *Species Profile: Indiana bat (Myotis sodalis)*. Retrieved from USWFW Endangered Species: https://www.fws.gov/midwest/Endangered/mammals/inba/index.html

USFWS. (2016a, September 2). *Northern long-eared bat fact sheet*. Retrieved March 26, 2015, from USFWS Endangered Species: https://www.fws.gov/Midwest/Endangered/mammals/nleb/nlebFactSheet.html

USFWS. (2016a, September 21). *Scaleshell Mussel Fact Sheet*. Retrieved April 19, 2017, from U.S. Fish and Wildlife Service Endangered Species: https://www.fws.gov/midwest/endangered/clams/scmu_fct.html

USFWS. (2016b, Sept 21). *Spectacelcase*. Retrieved from USFWS Endangered Species: https://www.fws.gov/midwest/Endangered/clams/spectaclecase/index.html

USFWS. (2016e, September 21). *USFWS Endangered Species*. Retrieved April 19, 2017, from Sheepnose Fact Sheet: https://www.fws.gov/Midwest/endangered/clams/sheepnose/index.html

USFWS. (2016f, September 21). *USFWS Endangered Species*. Retrieved April 19, 2017, from Snuffbox Fact Sheet: https://www.fws.gov/midwest/endangered/clams/snuffbox/SnuffboxFactSheet.html

USFWS. (2018a, October 10). *Pallid Sturgeon*. Retrieved November 15, 2018, from U.S. Fish and Wildlife Service: https://www.fws.gov/midwest/endangered/fishes/pallidsturgeon/index.html

USFWS. (2018b, March 12). *Hine's Emerald Dragonfly*. Retrieved November 15, 2018, from U.S. Fish and Wildlife Service: https://www.fws.gov/midwest/endangered/insects/hed/hins_fct.html

USFWS. (2018c, March 12). *Mead's Milkweed*. Retrieved November 15, 2018, from U.S. Fish and WIldlife Service: https://www.fws.gov/midwest/endangered/plants/meads/meadsmil.html

Whitman, P. L. (1988). *Biology and Conservation of the Endangered Interior Least Tern: A Literature Review.* Twin Cities, MN: U.S. Fish and Wildlife Service, Division of Endangered Species.

7. LIST OF PREPARERS

Dr. Kat McCain

Chief, Environmental Planning Section

U.S. Army Corps of Engineers

Regional Planning and Environmental Division North

St. Louis MO 63012

8. OFFICIAL SPECIES LIST – 15 NOVEMBER 2018

Consultation Technical Assistance

Refer to the Midwest Region S7 Technical Assistance website for step-by-step instructions for making species determinations and for specific guidance on the following types of projects: projects in developed areas, HUD, pipelines, buried utilities, telecommunications, and requests for a Conditional Letter of Map Revision (CLOMR) from FEMA.

Federally Listed Bat Species

Indiana bats, gray bats, and northern long-eared bats occur throughout Missouri and the information below may help in determining if your project may affect these species.

Gray bats - Gray bats roost in caves or mines year-round and use water features and forested riparian corridors for foraging and travel. If your project will impact caves, mines, associated riparian areas, or will involve tree removal around these features particularly within stream corridors, riparian areas, or associated upland woodlots gray bats could be affected.

Indiana and northern long-eared bats - These species hibernate in caves or mines only during the winter. In Missouri the hibernation season is considered to be November 1 to March 31. During the active season in Missouri (April 1 to October 31) they roost in forest and woodland habitats. Suitable summer habitat for Indiana bats and northern long-eared bats consists of a wide variety of forested/wooded habitats where they roost, forage, and travel and may also include some adjacent and interspersed non-forested habitats such as emergent wetlands and adjacent edges of agricultural fields, old fields and pastures. This includes forests and woodlots containing potential roosts (i.e., live trees and/or snags 5 inches diameter at breast height (dbh) for Indiana bat, and 3 inches dbh for northern long-eared bat, that have exfoliating bark, cracks, crevices, and/or hollows), as well as linear features such as fencerows, riparian forests, and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Tree species often include, but are not limited to, shellbark or shagbark hickory, white oak, cottonwood, and maple. Individual trees may be considered suitable habitat when they exhibit the characteristics of a potential roost tree and are located within 1,000 feet (305 meters) of other forested/wooded habitat. Northern long-eared bats have also been observed roosting in human-made structures, such as buildings, barns, bridges, and bat houses; therefore, these structures should also be considered potential summer habitat and evaluated for use by bats. If your project will impact caves or mines or will involve clearing forest or woodland habitat containing suitable roosting habitat, Indiana bats or northern long-eared bats could be affected.

Examples of unsuitable habitat include:

- Individual trees that are greater than 1,000 feet from forested or wooded areas;
- Trees found in highly-developed urban areas (e.g., street trees, downtown areas);
- A pure stand of less than 3-inch dbh trees that are not mixed with larger trees; and
- A stand of eastern red cedar shrubby vegetation with no potential roost trees.

Using the IPaC Official Species List to Make No Effect and May Affect Determinations for Listed Species

1. If IPaC returns a result of "There are no listed species found within the vicinity of the project," then project proponents can conclude the proposed activities will have **no effect** on any federally listed species under Service jurisdiction. Concurrence from the Service is not required for **No Effect** determinations. No further consultation or coordination is required. Attach this letter to the dated IPaC species list report for your records. An example "No Effect" document also can be found on the S7 Technical Assistance website.

2. If IPaC returns one or more federally listed, proposed, or candidate species as potentially present in the action area of the proposed project other than bats (see #3 below) then project proponents can conclude the proposed activities **may affect** those species. For assistance in determining if suitable habitat for listed, candidate, or proposed species occurs within your project area or if species may be affected by project activities, you can obtain Life History Information for Listed and Candidate Species through the S7 Technical Assistance website.

3. If IPac returns a result that one or more federally listed bat species (Indiana bat, northern long-eared bat, or gray bat) are potentially present in the action area of the proposed project, project proponents can conclude the proposed activities **may affect** these bat species **IF** one or more of the following activities are proposed:

a. Clearing or disturbing suitable roosting habitat, as defined above, at any time of year;
b. Any activity in or near the entrance to a cave or mine;
c. Mining, deep excavation, or underground work within 0.25 miles of a cave or mine;
d. Construction of one or more wind turbines; or
e. Demolition or reconstruction of human-made structures that are known to be used by bats based on observations of roosting bats, bats emerging at dusk, or guano deposits or stains.

If none of the above activities are proposed, project proponents can conclude the proposed activities will have **no effect** on listed bat species. Concurrence from the Service is not required for **No Effect** determinations. No further consultation or coordination is required. Attach this letter to the dated IPaC species list report for your records. An example "No Effect" document also can be found on the S7 Technical Assistance website.

If any of the above activities are proposed in areas where one or more bat species may be present, project proponents can conclude the proposed activities **may affect** one or more bat species. We recommend coordinating with the Service as early as possible during project planning. If your project will involve removal of over 5 acres of suitable forest or woodland habitat, we recommend you complete a Summer Habitat Assessment prior to contacting our office to expedite the consultation process. The Summer Habitat Assessment Form is available in Appendix A of the most recent version of the Range-wide Indiana Bat Summer Survey Guidelines.

Other Trust Resources and Activities

Bald and Golden Eagles - Although the bald eagle has been removed from the endangered species list, this species and the golden eagle are protected by the Bald and Golden Eagle Act and the Migratory Bird Treaty Act. Should bald or golden eagles occur within or near the project area please contact our office for further coordination. For communication and wind energy projects, please refer to additional guidelines below.

Migratory Birds - The Migratory Bird Treaty Act (MBTA) prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Service. The Service has the responsibility under the MBTA to proactively prevent the mortality of migratory birds whenever possible and we encourage implementation of recommendations that minimize potential impacts to migratory birds. Such measures include clearing forested habitat outside the nesting season (generally March 1 to August 31) or conducting nest surveys prior to clearing to avoid injury to eggs or nestlings.

Communication Towers - Construction of new communications towers (including radio, television, cellular, and microwave) creates a potentially significant impact on migratory birds, especially some 350 species of night-migrating birds. However, the Service has developed voluntary guidelines for minimizing impacts.

Transmission Lines - Migratory birds, especially large species with long wingspans, heavy bodies, and poor maneuverability can also collide with power lines. In addition, mortality can occur when birds, particularly hawks, eagles, kites, falcons, and owls, attempt to perch on uninsulated or unguarded power poles. To minimize these risks, please refer to guidelines developed by the Avian Power Line Interaction Committee and the Service. Implementation of these measures is especially important along sections of lines adjacent to wetlands or other areas that support large numbers of raptors and migratory birds.

Wind Energy - To minimize impacts to migratory birds and bats, wind energy projects should follow the Service's Wind Energy Guidelines. In addition, please refer to the Service's Eagle Conservation Plan Guidance, which provides guidance for conserving bald and golden eagles in the course of siting, constructing, and operating wind energy facilities.

Next Steps

Should you determine that project activities **may affect** any federally listed species or trust resources described herein, please contact our office for further coordination. Letters with requests for consultation or correspondence about your project should include the Consultation Tracking Number in the header. Electronic submission is preferred.

If you have not already done so, please contact the Missouri Department of Conservation (Policy Coordination, P. O. Box 180, Jefferson City, MO 65102) for information concerning Missouri Natural Communities and Species of Conservation Concern.

We appreciate your concern for threatened and endangered species. Please feel free to contact our office with questions or for additional information.

Karen Herrington

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Wetlands

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Missouri Ecological Services Field Office
101 Park Deville Drive
Suite A
Columbia, MO 65203-0057
(573) 234-2132

Project Summary

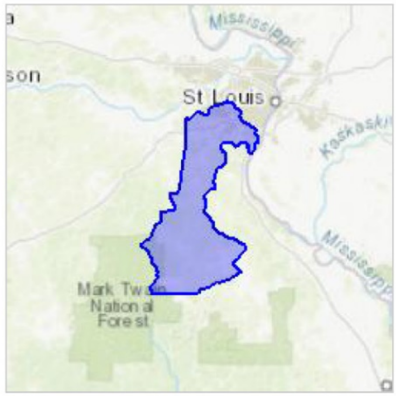
Consultation Code:	03E14000-2019-SLI-0287
Event Code:	03E14000-2019-E-00700
Project Name:	St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study - WRDA 2018
Project Type:	LAND - RESTORATION / ENHANCEMENT
Project Description:	Updating previous study area based on WRDA 2018 Section 2012. Expanded to include the Big River Watershed

The Meramec River Basin Ecosystem Restoration study is authorized by a June 2000 Resolution by the House Committee on Transportation and Infrastructure. This authorization called for a study of improvements along the Mississippi River and its tributaries in the St. Louis area, which is why "St. Louis Riverfront" is included in the official project name. The authority language limits the study area to St. Louis City, St. Louis County, and Jefferson County in Missouri. A Reconnaissance Study (Recon) was completed in 2004 and recommended that an addendum to the Recon Report should be completed to investigate ecosystem restoration opportunities in the Meramec River Basin. This Recon addendum was completed in 2013 and recommended proceeding into the feasibility phase because of high ecosystem restoration potential along the Big River, a primary tributary to the Meramec in Jefferson County.

The primary goal of this ecosystem restoration feasibility study is to evaluate and identify cost effective projects that will protect and restore the degraded aquatic ecosystem structure and function of the Big River and Lower Meramec within Jefferson and St. Louis Counties. Specific objectives include protecting and restoring degraded mussel habitat, increasing aquatic connectivity, and restoring degraded riparian corridor habitat. Industrial and agricultural practices, land use changes, and the presence of mill dams along the river have led to excessive sedimentation, a loss of riparian habitat, and the loss of in-stream and floodplain connectivity along the rivers. The presence of lead has exacerbated these problems. This study will evaluate potential solutions to these problems, which will include typical features that the Corps considers for ecosystem restoration: bank stabilization, riparian improvements and plantings, fish passage, etc.

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/38.18250480270453N90.72369226048195W



Counties: Franklin, MO | Iron, MO | Jefferson, MO | St. Francois, MO | St. Louis, MO | Ste. Genevieve, MO | Washington, MO

Endangered Species Act Species

There is a total of 13 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

---

1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Mammals

NAME	STATUS
Gray Bat *Myotis grisescens* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6329	Endangered
Indiana Bat *Myotis sodalis* There is **final** critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/5949	Endangered
Northern Long-eared Bat *Myotis septentrionalis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9045	Threatened

Fishes

NAME	STATUS
Pallid Sturgeon *Scaphirhynchus albus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7162	Endangered

Clams

NAME	STATUS
Pink Mucket (pearlymussel) *Lampsilis abrupta* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7829	Endangered
Scaleshell Mussel *Leptodea leptodon* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/5881	Endangered
Sheepnose Mussel *Plethobasus cyphyus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6903	Endangered
Snuffbox Mussel *Epioblasma triquetra* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4135	Endangered
Spectaclecase (mussel) *Cumberlandia monodonta* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7867	Endangered

Insects

NAME	STATUS
Hine's Emerald Dragonfly *Somatochlora hineana* There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/7877	Endangered

Flowering Plants

NAME	STATUS
Decurrent False Aster *Boltonia decurrens* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7705	Threatened
Mead's Milkweed *Asclepias meadii* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/8204	Threatened
Running Buffalo Clover *Trifolium stoloniferum* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2529	Endangered

Critical habitats

There is 1 critical habitat wholly or partially within your project area under this office's jurisdiction.

NAME	STATUS
Indiana Bat *Myotis sodalis* https://ecos.fws.gov/ecp/species/5949#crithab	Final

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

REFUGE INFORMATION WAS NOT AVAILABLE WHEN THIS SPECIES LIST WAS GENERATED. PLEASE CONTACT THE FIELD OFFICE FOR FURTHER INFORMATION.

Wetlands

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

Please note that the NWI data being shown may be out of date. We are currently working to update our NWI data set. We recommend you verify these results with a site visit to determine the actual extent of wetlands on site.

Due to your project's size, the list below may be incomplete, or the acreages reported may be inaccurate. For a full list, please contact the local U.S. Fish and Wildlife office or visit https://www.fws.gov/wetlands/data/mapper.HTML

FRESHWATER EMERGENT WETLAND

- PEM1A
- PEM1/FO1A
- PEM1/FO1Fx
- PEM1/USCh
- PEM1Ad
- PEM1Ah
- PEM1Ax
- PEM1B
- PEM1C
- PEM1Ch
- PEM1Cd
- PEM1Cx
- PEM1Fh
- PEM1F
- PEM1Fx
- PEM1K
- PEM1Kx

FRESHWATER FORESTED/SHRUB WETLAND

- PFO1A

FRESHWATER POND

- PAB3Gh
- PABF

- PABFh
- PABGh
- PABGx

LAKE

- L1UBGh
- L1UBH
- L1UBHh
- L1UBHx
- L1UBK
- L1UBKx
- L2UBGx
- L2USAh
- L2USCh
- L2USK

9. RESPONSE LETTER FROM USFWS TO USACE 30 JANUARY 2019

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Missouri Ecological Services Field Office
101 Park Deville Drive
Suite A
Columbia, MO 65203-0057
Phone: (573) 234-2132 Fax: (573) 234-2181

In Reply Refer To: November 15, 2018
Consultation Code: 03E14000-2019-SLI-0287
Event Code: 03E14000-2019-E-00700
Project Name: St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study - WRDA 2018

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

To Whom It May Concern:

This response has been generated by the Information, Planning, and Conservation (IPaC) system to provide information on natural resources that could be affected by your project. The U.S. Fish and Wildlife Service (Service) provides this response under the authority of the Endangered Species Act of 1973 (16 U.S.C. 1531-1543), the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d), the Migratory Bird Treaty Act (16 U.S.C. 703-712), and the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.).

Threatened and Endangered Species

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and may be affected by your proposed project. The species list fulfills the requirement for obtaining a Technical Assistance Letter from the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. **Note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days.** The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Missouri Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0057
Phone: (573) 234-2132 Fax: (573) 234-2181

January 30, 2019

Kat McCain, Ph.D.
Chief, Environmental Planning Section
U.S. Army Corps of Engineers
Regional Planning and Environmental Division North
1222 Spruce Street
St. Louis, MO 63012

Dear Ms. McCain:

The U.S. Fish and Wildlife Service (Service) has reviewed the U.S. Army Corps of Engineers (USACE) Biological Assessment (BA) for the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study (MRFS) dated November 15, 2018. The study area includes Washington, St. Francois, Jefferson, and St. Louis counties, Missouri.
The following comments are provided in accordance with the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.). The current phase of the MRFS involves the USACE's consideration and comparison of various ecosystem restoration activities in the study area in order to select a primary project alternative and pursue additional approval. The following main MRFS planning objectives were listed for the 50 year period of analysis:

- Reduce the quantity of contaminated sediment entering the Big River and Meramec River.
- 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.
- Restore impacted channels and floodplains in the Big River and Meramec River Systems to emulate a more natural state.
- Increase riparian habitat connectivity, quantity, diversity, and complexity within the study area.

The activities currently being evaluated include: bank stabilization measures (e.g., bioengineering, toe wood, longitudinal peak stone toe protection, bank modification to a gentler slope, revegetating riparian zones, etc.), extraction and disposal of heavy-metal contaminated sediments, installation of grade control structures or similar structures to collect sediments, and riparian corridor enhancements within the Big River in Jefferson and St. Louis counties.

1

The USACE was provided a list of federally listed species, via the Information for Planning and Consultation program (IPaC) (Consultation Code: 03E14000-2019-SLI-0287), which are potentially affected by the activities associated with the tentatively selected plan. The USACE has requested the Service's concurrence with a "may affect, but not likely to adversely affect" (NLAA) determination for the following species: Gray Bat (*Myotis grisescens*), Indiana Bat (*Myotis sodalis*), Northern-long eared Bat (*Myotis septentrionalis*), Pallid Sturgeon (*Scaphirhynchus albus*), Pink Mucket (*Lampsilis abrupta*), Scaleshell (*Leptodea, leptodon*), Sheepnose (*Plethobasus cyphyus*), Snuffbox (*Epioblasma triquetra*), and Spectaclecase (*Margaritifera monodonta*).

As part of MRFS coordination, the Service provided the USACE with known mussel bed locations to be considered during the site selection and preliminary design phases. As a result, the USACE specified that sites/activities near known mussel beds would be avoided and indicated the following mandatory measures would be incorporated to help reduce potential direct, indirect, and cumulative impacts to federally listed mussels and/or bats:

Mussels

1. Quantitative mussel surveys will be completed for pre-project and post-project years 2, 5, and 8 following previous mussel surveys within the study area conducted by the USACE, the Service, the non-Federal sponsor, or an entity approved by the Service. A more detailed monitoring plan for freshwater mussels will be developed in cooperation with the Service and other resource agencies during the Planning, Engineering, and Design Phase for the project.

2. If pre-project surveys identify mussel beds within the construction footprint of a given site or in proximity downstream, then re-evaluation of that site would occur to determine if adverse effects could be avoided. If adverse effects cannot be avoided, separate site specific Section 7 consultation would be conducted.

3. Best management practices to reduce siltation during construction activities would be implemented to minimize impacts to water quality.

Bats

1. All tree clearing resulting from the USACE action will occur during the inactive season from November 1 to March 31 unless negative presence/probable absence survey results were obtained for the action area through appropriate surveys approved by the Service.

2. The USACE will require a habitat assessment if the project will occur in Zone 1[1] and includes more than 10 acres of tree clearing. If the results indicate that more than 10 acres of suitable roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.

[1] Zone 1 = Conservation measures apply to actions within the State of Missouri excluding Zones 2 and 3.

3. The USACE will require a habitat assessment if the project will occur in Zone 2[2] and includes more than 5 acres of tree clearing. If the results indicate that more than 5 acres of suitable roosting habitat will be cleared, the USACE will require presence/probable absence surveys to determine if additional consultation is necessary or the project will not affect listed bats.

4. If located in Zone 1, the project will not remove more than 10 acres of suitable roosting habitat during the inactive season.

5. If located in Zone 2, the project will not remove more than 5 acres of suitable roosting habitat during the inactive season.

6. The project and the USACE action will not result in the removal of trees in Zone 3[3].

7. Tree clearing associated with the project and the USACE action will not result in a cumulative loss of more than 5% of the baseline (2005) forested acreage.

8. If the project is located in a karst area and will involve construction methods that may cause deep ground disturbance, the USACE will require a cave search be conducted to determine if any caves are present in the action area that would be considered suitable habitat for bats and/or are currently or formerly used by listed bats.

9. If the demolition of an existing building or structure will occur as a result of the project in Zones 2 or 3, the USACE will require bat use surveys in collaboration with the Service. If during the course of demolition, bats of any species are discovered, then all work must cease and the Service must be immediately contacted. If the structure is safe to leave as is, then it will be left until after November 1, or until bats have stopped using the structure. If the structure is unsafe and poses a risk to human health and safety, the USACE will request the assistance of the Service in determining reasonable measures to exclude the bats.

Upon reviewing the BA, project information, the proposed planning and conservation measures, the Service agrees with the no effect determination for the Hine's Emerald Dragonfly (*Somatochlora hineana*), Decurrent False Aster (*Boltonia decurrens*), Mead's Milkweed (*Asclepias meadii*), and Running Buffalo Clover (*Trifolium stoloniferum*) and also concurs with the USACE's NLAA determination for the Gray Bat, Indiana Bat, and Northern-long eared Bat, Pallid Sturgeon, Pink Mucket, Scaleshell, Sheepnose, Snuffbox, and Spectaclecase. As a reminder, the species list provided to the USACE is valid for 90 days. Therefore, a new species list should be obtained and reviewed by the USACE prior to construction activities. Also, please contact the Service for additional consultation if there are any changes in project scope, timing, or manner of activity.

[2] Zone 2 = Conservation measures apply to actions within 5.0 miles (radius) of a known capture of a listed bat.
[3] Zone 3 = Conservation measures apply to actions that occur within 0.25 miles (radius) of a known roost tree or hibernacula

Thank you for your consideration of threatened and endangered species. The Service looks forward to the completion of the MRFS. If you have any questions, please contact Bryan Simmons at (417) 836-5302 or bryan_simmons@fws.gov.

Sincerely,

Karen J. Herrington
Field Supervisor

Cc via email: USACE, CEMVS-PM-N, Matthew Vielhaber
USACE, CEMVP, Monique Savage

U. S. Army Corps of Engineers

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

July 2019

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

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLES

INTENTIONALLY LEFT BLANK

1. PROJECT DESCRIPTION

1.1. LOCATION

The Meramec River Basin is located in east-central Missouri, southwest of St. Louis. The study area for the *St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study* is defined as that portion of the Meramec River and its watershed, including the Big River, located within Washington, St. Francois, Jefferson and St. Louis Counties of Missouri, highlighted in gray on Figure 1.

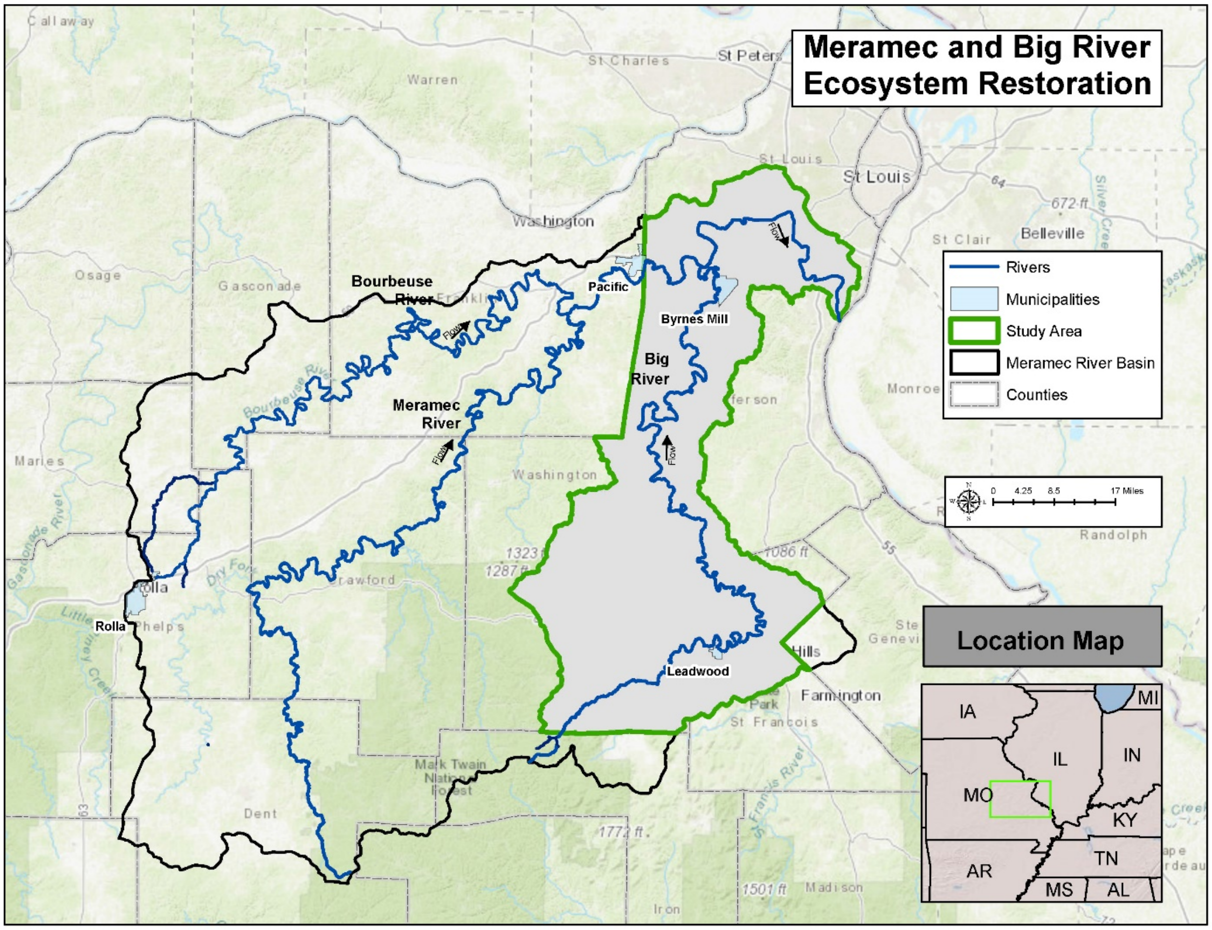


Figure 1. Study area and vicinity

1.2. GENERAL DESCRIPTION

Human-induced modifications within the Meramec River Basin degraded the aquatic ecosystem. The purpose of the *St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study* (Study) is to determine the National Ecosystem Restoration (NER) plan addressing degradation of the aquatic ecosystem.

The purpose of this feasibility 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 alternatives or actions taken by the U.S. Army Corps of Engineers (USACE), including the No Action Plan, prior to making decisions.

A large number of local, State, and Federal agencies and activities addressing a variety of water resources problems with the Meramec River Basin demonstrates the need for this Study and allows for a more comprehensive and complete federal ecosystem restoration plan. Concurrently working these efforts allows USACE and the Missouri Department of Natural Resources (MoDNR) to leverage resources with the other partners (Natural Resource Damage Assessment and Restoration (NRDAR) trustees, The Nature Conservancy (TNC), U.S. Environmental Protection Agency (USEPA), and the U.S. Fish and Wildlife Service (USFWS)), and ultimately provide the water-resources solutions to restore the ecosystem structure and function of the Meramec River Basin.

The need for Federal action stems from the variety of environmental problems impacting the Meramec River Basin. Several of these problems are interrelated and indirectly affect each other. The primary problems identified negatively affecting the structure and function of the Meramec River Basin include its rivers and floodplains overburdened with contaminated sediment from past mining practices, altered hydrology, altered riparian corridor and degraded aquatic habitat, including ecologically significant freshwater mussel habitat.

1.3. AUTHORITY AND PURPOSE

The objective of USACE feasibility studies is to investigate and recommend solutions to water resources problems. Prior to the USACE launching a civil works feasibility study, it must be authorized by Congress and subsequently Federal money appropriated.

The *St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study* was authorized by a 21 June 2000 Resolution by the Committee on Transportation and Infrastructure, U.S. House of Representatives, Docket 2642:

> *Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on the Mississippi River, 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 authority allows the Corps to investigate and recommend solutions in the portions of the Meramec River Basin that lie within the designated geographical scope.

The Water Resources Development Act of 2018, signed into law on 23 October, expanded the authority to study all Missouri counties within the Meramec River Basin. The *St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study* area of interest for this current effort includes portions of the Meramec River watershed and the Big River watershed located in St. Louis, Jefferson, Washington and St. Francois Counties, Missouri.

1.4. GENERAL DESCRIPTION OF DREDGED AND FILL MATERIAL

The construction of the recommended plan would require the mechanical excavation of an estimated 624,800 cubic yards of material within the study area; 337,200 cubic yards would remain on site (Table 1; Excavation & Earthwork) and be incorporated into constructed management measures (e.g., fill, bank sloping). The remaining 287,700 cubic yards would be permanently hauled off site (Table 1; Excavation & Hauling). Substrate samples within the study area indicate the material is a silt-sand mixture. Clean Water Act, Section 401 guidelines do not require elutriate testing or sieve analyses where mechanical excavation is used for sediment removal; therefore, the Corps has not included these in this study.

The recommended plan would also require an estimated total of 158,800 tons of clean riprap to construct management measures. The recommended plan would result in 33.5 acres of tree clearing for construction access. The excavated material from tree clearing would be disposed off-site. Refer to Table 1 for further details on the quantities for excavation and tree clearing. During the feasibility study, the USACE planning team avoided and minimized impacts to wetlands with placement of management measures. This 404(b)1 evaluation covers the management measures included in the recommended plan.

Table 1. Excavation, Riprap and Tree Clearing Data Summary for the Recommended Plan*

Management Measure	Location* Big River River Mile	Excavation & Earthwork (cubic yards) Material kept on-site	Excavation & Hauling (cubic yards) Material disposed off-site	Riprap (tons)	Tree Clearing (acres)
Bed Sediment Collectors	71.5	-	589.4	43.0	1.3
	55.2	-	268.6	43.0	-
	19.8	-	-	-	-
Bank Stabilization	62.5	3,232.3	-	8,957.7	-
	52.0	34,320.5	-	26,792.1	6.3
	49.8	4,470.8	-	5,488.2	9.5
	48.5	9,560.7	-	607.9	3.3
	42.5	1,707.4	-	7,082.3	0.1
	38.0	8,620.3	-	2,410.5	3.1
	34.0	-	-	7,552.4	0.2
	32.2	14,419.9	-	565.9	3.8
	14.5	6,285.9	-	4,027.9	1.3
	13.5	20,132.8	-	2,445.8	0.1
	9.2	30,384.8	-	6,668.8	-
	5.0	562.3	-	1,662.1	0.1
Excavation	30.2	-	29,501.1	-	-
	19.9	-	29,501.1	-	-
	14.5	-	29,501.1	-	-
	10.2	-	29,501.1	-	-
Grade Control	30.2	-	800.5	5,266.5	-
	19.8	-	1,591.6	10,471.1	0.1
	8.5	-	1,438.7	9,465.2	0.6

Management Measure	Location* Big River River Mile	Excavation & Earthwork (cubic yards) Material kept on-site	Excavation & Hauling (cubic yards) Material disposed off-site	Riprap (tons)	Tree Clearing (acres)
Reforestation & Vegetative Plantings **use of vegetation for bank stabilization	61.0	-	-	-	-
	58.0	-	-	-	-
	56.0	-	-	-	-
	54.0	-	-	-	-
	49.0	-	-	-	-
	47.0	-	-	-	-
	46.0	-	-	-	-
	45.0	-	-	-	-
	44.5	-	-	-	-
	39.0	-	-	-	-
	34.9	-	-	-	-
	33.2**	7,961.3	-	-	-
	31.0**	1,188.4	-	-	-
	22.0**	138.7	-	410.7	-
	21.0**	208.0	-	668.5	-
	18.0	-	-	-	-
	14.0	-	-	-	-
	8.0	-	-	-	-
	2.5	-	-	-	-
Sediment Basins	62.5	-	102,000.0	-	-
	31.0	79,088.8	-	15,235.0	3.0
	25.5	38,539.8	37,373.4	2,162.0	-
	19.0	21,848.8	-	30,566.0	-
	14.5	44,540.6	-	8,451.0	-
	9.2	9,974.3	8,317.8	1,749.0	0.9
In-Stream Excavation - Sediment Removal Bars	74.5	-	4,161.2	-	-
	62.5	-	1,943.4	-	-
	38.1	-	7,471.1	-	-
	34.0	-	3,686.7	-	-
Totals:		337,186.6	287,646.8	158,792.5	33.5

*refer to main report for description of site locations

1.5. DESCRIPTION OF THE PROPOSED PLACEMENT SITES

All excavated material would either be transported off-site for disposal or re-used in conjunction with riprap and trees to construct site-specific management measures; therefore, USACE does not anticipate any discharge into waters of the U.S. During plans and specifications, exact placement of constructed measures and disposal locations will be refined. Off-site placement locations will be selected based on the following:

- Avoidance of threatened and/or endangered bat roosting habitat
- Avoid and minimize impacts to wetlands
- Avoidance of cultural and historic resources
- Avoidance of utilities
- Following natural contours
- Minimize footprint for clearing
- No impact to the floodplain
- No impact to adjacent landowners
- Concurrence from State and Federal sponsors
- Approved USEPA facility, if applicable

1.6. DESCRIPTION OF THE PLACEMENT METHOD

Mechanically excavated material would be reused on-site and incorporated into project construction or placed onto trucks and hauled off-site. Riprap placement for the rock structures would be transported via truck then mechanically placed.

2. FACTUAL DETERMINATIONS

2.1. PHYSICAL DETERMINATIONS

2.1.1. SUBSTRATE ELEVATION AND SLOPE

The study area is one of the most rugged regions of the Midwest. The Meramec River Basin lies primarily within the Salem Plateau subdivision of the Ozark Plateau, with the lower Meramec River located within the Central Lowland Region. The study area includes the Big River Watershed with land elevations ranging from 435 feet above sea level at the confluence with the Meramec River to 1,740 feet in the headwaters at Buford Mountain, Missouri. Topography varies from wide ridges and gentle slopes to natural ridges, steep slopes and bluffs.

2.1.2. SOIL TYPE

Within the Big River Watershed, soils on ridge tops and slopes are highly erodible, especially when disturbed, while upland soils are moderately shallow and consist of combination of loess and residuum derived from in-place weathering of dolomite. The higher elevations of these soils tend to be clayey with high chert content, thin, droughty, infertile and stony. In the river bottoms, very fertile silt-loam (0-2% slope) developed from alluvium has been deposited over cherty gravel. These soils are deep to very deep (greater than 60 inches), well drained and prone to occasional or frequent flooding. On foot slopes, side slopes and sloping point ridges, the soils are also silt loams (5-14%) and moderately well-drained. Two hundred seventeen (217) different soil series are located within the study area, with the most common soil series being Sonsac (10% of the entire study area).

Sonsac gravelly silt loam, 15 to 40 percent slopes, very stony (73201): This soil type 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 with low organic matter content (USDA 1999).

2.1.3. EXCAVATED/FILL MATERIAL MOVEMENT

As part of its operation, maintenance, repair, rehabilitation and replacement (OMRRR) responsibilities, the Non-Federal Sponsor would transport hauling material to disposal facilities located in Missouri that are approved by USEPA, if applicable. Earthwork material would be reused at the site specific work location from which it is excavated; it would not be transported and used at different sites. In general, earthwork material would be placed on land in conjunction with riprap and trees to form the specific management measures (e.g., stabilize riprap, re-fill excavated areas, bank sloping, etc.), and would not be discharged into the open water. Rock placement should experience minimal material movement. Adequate rock size is proposed to reduce settling and material movement during high flow events.

2.1.4. PHYSICAL EFFECTS ON BENTHOS

Some of the long-term effects of the recommended plan (e.g., reduced sedimentation, improved substrate composition) are expected to enhance benthic habitat and increase the abundance and diversity of benthic organisms; however, during construction activities, some disturbed solids may settle within the substrate in the adjacent aquatic habitat temporarily altering substrate composition and smothering benthos in these areas. Direct discharge into open water would not occur during construction activities and Best Management Practices (BMPs) would be implemented to reduce the disturbance of solids in aquatic areas; therefore, any benthic smothering is expected to be minimal and temporary. Substrate conditions would return to normal after construction activities, and the re-colonization of benthic organisms should quickly occur. Furthermore, quantitative mussel surveys would be completed for pre-project and post-project years 2, 5 and 8 following the protocol of previous mussel surveys completed within the study area. A more detailed monitoring plan for freshwater mussels would be developed in cooperation with the USFWS and other resource agencies during the Planning, Engineering and Design Phase for the project. If pre-project surveys identify freshwater mussel beds within the construction footprint of a given site or in proximity downstream, then re-evaluation of that site would occur to determine if adverse effects could be avoided.

2.1.5. ACTIONS TAKEN TO MINIMIZE IMPACTS

The construction footprint was kept as small as possible to minimize impacts to the benthic community. Construction materials to be used are physically stable and clean, reducing the chances for impacting the river. Mechanical excavation prevents excess water runoff back into the river and reduces instability by keeping the material consolidated. Tree plantings, ground cover and erosion control materials would be installed following dirt work. Additionally, BMPs for construction would be enforced.

2.2. WATER CIRCULATION, FLUCTUATION, AND SALINITY DETERMINATIONSWATER

USACE does not expect any significant differences in water chemistry following recommended plan construction, and does not anticipate any violations of applicable state water standards. The rock materials are inert material having little effect on water chemistry. Odor, taste, pH, temperature and dissolved gas changes would not be affected. Turbidity (as measured by total suspended solids) is expected to temporarily increase during construction; however, in the long-term turbidity is expected to improve with constructed measures by reducing bank line inputs of suspended sediments. Best management practices would be implemented during construction. The construction should not impair the aquatic ecosystem's capability to sustain life or reduce the suitability of the Big River for aquatic organisms, human consumption, recreation or aesthetics.

2.2.1. CURRENT PATTERNS AND CIRCULATION

Shallow water placement of rock and willow stakings may have a minor effect on flow patterns in the immediate vicinity of the structures. River training structures and grade control structures were designed to improve the hydraulics of the river. USACE expects the construction of these management measures to improve water movement throughout the study area.

2.2.2. NORMAL WATER LEVEL FLUCTUATION

The USACE anticipates no changes in normal water level fluctuations as a result from the recommended plan.

2.2.3. SALIENT GRADIENT

This consideration is not applicable in the study area of the recommended plan.

2.2.4. ACTIONS TAKEN TO MINIMIZE IMPACTS

The construction footprint was kept as small as possible and design of river training structures and alignment were informed through hydraulic modeling to minimize any potential for adverse effects to water circulation and fluctuation. Best management practices for construction would be enforced.

2.3. SUSPENDED PARTICULATE/TURBIDITY DETERMINATIONS

2.3.1. EXPECTED CHANGES IN SUSPENDED PARTICLES AND TURBIDITY LEVELS IN VICINITY OF PLACEMENT SITE

Suspended solids and turbidity values would be expected to temporarily increase during excavation and placement; however, BMPs would be implemented. A return to ambient conditions should occur shortly after construction completion. The USACE designed management measures to reduce suspended sediments, so the recommended plan should result in long-term beneficial reductions to suspended solids and turbidity. Best management practices would be implemented during construction.

2.3.2. EFFECTS ON PHYSICAL AND CHEMICAL PROPERTIES OF THE WATER COLUMN

2.3.3. LIGHT PENETRATION

The study area may have short-term adverse impacts during construction due to turbidity plumes. Following construction, turbidity and associated light penetration should return to pre-construction or improved levels as a result of the constructed measures' intended purpose to reduce suspended sediments.

2.3.4. DISSOLVED OXYGEN (DO)

Placement of excavated material should have no short- or long-term adverse impacts to DO levels. The recommended plan should help to maintain DO in the study area at levels (5mg/l minimum) suitable for year-round fish habitat.

2.3.5. TOXIC METALS AND ORGANICS

The recommended plan is specifically designed to reduce the concentration of heavy metal contaminants within aquatic areas. Through the direct removal of contaminants and the reduction of future inputs, the recommended plan would reduce heavy metal concentrations over time. As such, no increase in contaminants in the aquatic environment are anticipated from the placement of fill material. Material placed as part of the recommended plan would comply with the Missouri Water Quality Standards defined within 10 CSR 20-7.031. Excavated material would either be transported and disposed off-site (Hauling) or placed on land in the immediate vicinity from which it was excavated (Earthwork).

2.3.6. AESTHETICS

Temporary increases in suspended sediments would have a minor short-term impact on aesthetics in the study area. Changes to aesthetics as related to placement of rock structures, sediment basins and operation and maintenance of bed collectors may result in minimal adverse effects to aesthetics. In some cases, the placement of rock and revegetation of eroding banks would likely enhance site-specific aesthetic value, especially compared to existing raw and eroded bank conditions. The USACE would consider site-specific strategies for minimizing impacts to aesthetics during final design and placement of these management measures.

2.3.7. EFFECTS ON BIOTA

Minor disturbances to organisms present in the construction zone may occur as a result of fill activity and excavating. These disturbances are short-term and are off-set by the overall functional lift to the local aquatic and riparian ecological communities. The overall long-term benefits to biota and function in the study area and the river system are demonstrated in Table 2. Refer to Chapter 4-*Environmental Effects*, and Chapter 5-*Cumulative Effects* of the Feasibility Study with Integrated Environmental Assessment for more details.

Table 2. Management Measures that Restore Process and Area of Restored Process

Management Measure	Process Restored	Area of Restored Process
Bankline Restoration	Stream geomorphology; suspended sediment reduction	Footprint plus area in which the measure has influence downstream
Reforestation	Habitat connectivity, forest structure and structure	Footprint plus area in which the measure has an influence on forest canopy cover, species or composition; or reproduction, rearing and foraging habitat.
Grade Control	Hydraulics; stream geomorphology	Footprint plus area in which the measure has influence downstream
Sediment Basin	Sediment budget, contaminated sediment reduction	Footprint plus area in which the measure has influence downstream
Bed Sediment Collector	Sediment budget, contaminated sediment reduction	Footprint plus area in which the measure has influence downstream

Management Measure	Process Restored	Area of Restored Process
In-Stream Excavation	Contaminated sediment reduction; stream geomorphology	Footprint plus area in which the measure has influence downstream

2.4. CONTAMINANT DETERMINATIONS

No contaminants would be excavated exceeding the USEPA standards in identified substrates. Possible introduction by equipment or construction-related contaminants would be controlled by adherence to runoff monitoring plans during construction activity. No additional toxic material would be introduced to the area over ambient conditions as a result of construction activities. Rock riprap would be clean, uncontaminated stone from an approved source in compliance with the Clean Water Act, Section 404 Missouri Regional Condition #4 and Section 401 Water Quality Certification Condition #5.

2.5. AQUATIC ECOSYSTEM AND ORGANISM DETERMINATIONS

2.5.1. EFFECTS ON PLANKTON

Only short-term and minimal effects are anticipated to occur as a result of excavated and fill activity. No significant impacts to plankton are expected.

2.5.2. EFFECTS ON BENTHOS

Only short-term and minimal effects to benthic organisms are anticipated to occur as a result of excavated and fill activity; these are discussed above (see Section B. d.). The long-term effects of the recommended plan would improve the local benthic aquatic habitat and are expected to increase the abundance and diversity of benthic aquatic organisms, such as freshwater mussels.

2.5.3. EFFECTS ON NEKTON

No adverse impacts to nekton are expected and the recommended plan would substantially improve the quality of the aquatic habitat in the study area. The recommended plan would reduce suspended sediment, bedded sediment and, in turn, reduce contaminated sediments. Constructed measures would also restore hydraulics of the river improving the overall aquatic habitat into the future.

2.5.4. EFFECTS ON AQUATIC FOOD WEB

The loss of the benthic organisms within the footprint of the riprap bankline production and river training structures should not cause significant impact to any level/segment of the aquatic food web or disrupt the flow of energy between trophic levels. This small benthic loss should not cause any decrease in the overall productivity and nutrient export capability of the ecosystem.

Improvements in the aquatic habitat through reduction of suspended and bedded sediments, channel stability and vegetation plantings should increase primary and secondary production in the study area. This increase in production should lead to an increased forage base for fish and wildlife.

2.6. EFFECTS ON SPECIAL AQUATIC SITES

2.6.1. SANCTUARIES AND REFUGES

The study area is not located in any sanctuaries or refuges; therefore, the recommended plan would not impede any sanctuaries or refuges.

2.6.2. WETLANDS, MUD FLATS, AND VEGETATED SHALLOWS

Wetlands within the study area may be impacted with the construction of some management measures (e.g., sediment collection basins) which would account for approximately 154 acres; however, the impacts would be offset by reforestation of approximately 675 acres of forested wetlands. Overall, the wetland impacts would be outweighed by the benefits to not only the aquatic habitat but the entire ecosystem within the study area.

2.6.3. THREATENED AND ENDANGERED SPECIES

Presence of, or use by, endangered and threatened species is discussed in the Feasibility Study with Integrated Environmental Assessment. No adverse impacts are expected to result from the recommended plan. Refer to Chapter 4-*Environmental Effects* and Chapter 5-*Cumulative Effects* of the Feasibility Study with Integrated Environmental Assessment as well as the Biological Assessment (Appendix C) for more details. In accordance with Section 7 Endangered Species Act (ESA) guidelines, USACE concluded a determination of "*May Affect, Not Likely to Adversely Affect"* for the following species: gray bat (*Myotis grisescens*), Indiana bat (*M. sodalis*), northern long-eared bat (*M. septentrionalis*), pink mucket (*Lampsilis abrupta*), scaleshell (*Leptodea leptodon*), sheepnose mussel (*Plethobasus cyphyus*), snuffbox mussel (*Epioblasma triquetra*), spectaclecase (*Cumberlandia monodonta*) and pallid sturgeon (*Schaphirhynchus albus*). This determination includes implementation of conservation measures currently being coordinated between USFWS and the USACE. The recommended plan would have *No Effect* on Mead's milkweed (*Asclepias meadii*), decurrent false aster (*Boltonia decurrens*), Hine's emerald dragonfly (*Somatochlora hineana*) and running buffalo clover (*Trifolium stoloniferum*). Full compliance with ESA would occur prior to construction.

OTHER WILDLIFE

Some short-term displacement of wildlife in the immediate vicinity of construction activities is anticipated. Wildlife species which utilize forested and non-forested wetland habitats should benefit from the recommended plan in the long-term.

2.7. PROPOSED PLACEMENT SITE DETERMINATIONS

2.7.1. MIXING ZONE DETERMINATIONS

Discussions pertaining to turbidity and suspended particulates are summarized above, as well as contaminants. A small amount of fine-grained material may migrate from the placement sites and become diluted with adjacent main channel border flow. Placement of material to help re-slope banklines and around river training structure anchor points would result in temporary localized increases in suspended material. The use of mechanical excavating should help to minimize these effects.

2.7.2. DETERMINATION OF COMPLIANCE WITH APPLICABLE WATER QUALITY STANDARDS

This Clean Water Act Section 404(b)(1) provides the necessary compliance required by law. If applicable, Section 401 Water Quality certification in compliance with the Clean Water Act and all other permits necessary for the completion of the project would be obtained prior to project construction.

2.7.3. POTENTIAL EFFECTS ON HUMAN USE CHARACTERISTICS

Implementation of the recommended plan would have no significant adverse effects on municipal or private water supplies, recreational or commercial fisheries, water-related recreation or aesthetics, parks, national monuments or other similar preserves. Potential impacts to recreational opportunities were specifically considered during the feasibility study and the comparison of alternatives. The ability to enhance recreational opportunities was identified as one of the overall opportunities during the study, and avoidance of measures that would impact recreation along the river was identified as a planning constraint. As such, measures that could potentially impact recreation were ultimately screened out, and it was determined that other measures would be designed to avoid negative impacts to recreation (e.g., grade control structures allowing canoe/kayak passage).

2.8. DETERMINATION OF CUMULATIVE EFFECTS ON THE AQUATIC ENVIRONMENT

Although minor short-term construction-related impacts are anticipated to local fish and wildlife populations, no negative cumulative impacts to fish and wildlife have been identified. From a systemic approach, the recommended plan would result in positive long-term benefits to riverine and riparian forest habitats located within the study area and would benefit the restoration of the Big River watershed. Refer to Chapter 5-*Cumulative Effects* in the Feasibility Study with Integrated Environmental Assessment for more details.

2.9. DETERMINATION OF SECONDARY EFFECTS ON THE AQUATIC ECOSYSTEM

The recommended plan would directly improve water clarity. Potential secondary effects would include improved river health and overall water quality.

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

The District's Project Delivery Team concludes that the recommended plan meets the conditions of Section 404 of the Clean Water Act (CWA). No significant adaptations of the 404(b)1 guidelines were made relative to this evaluation. An array of alternatives, including the No Action Plan, were evaluated for habitat benefits and costs, meeting project objectives and for completeness, effectiveness, efficiency and acceptability.

1. If applicable, certification under Section 401 of the Clean Water Act would be obtained from the Missouri Department of Natural Resources.
2. The proposed fill activity is in compliance with the Applicable Toxic Effluent Standards of Prohibition under Section 307 of the Clean Water Act.
3. Prior to construction, full compliance with the Endangered Species Act would be documented.
4. The project is situated along an inland freshwater river system. No marine sanctuaries are involved or would be affected by the recommended plan.
5. No municipal or private water supplies would be affected by the recommended plan, and no degradation of waters of the United States is anticipated to result from the proposed action. The proposed construction activity would not have a significant adverse effect on human health and welfare, recreation and commercial fisheries, plankton, fish, shellfish, wildlife or special aquatic sites.

No significant adverse effects on life stages of aquatic life and other wildlife dependent on aquatic ecosystems are expected to result. The proposed construction activity would have no significant adverse effects on aquatic ecosystem diversity, productivity and stability. No significant adverse effects on recreational, aesthetic, and economic values would occur.

6. The materials used for construction would be chemically and physically stable and non-contaminating.
7. The proposed action is in compliance with Section 404(b)(1) of the Clean Water Act, as amended. The proposed action would not significantly impact water quality.

If construction activities are not completed within the allotted time, the team would then re-evaluate the project's Section 404 compliance status and would coordinate the project with the District's Regulatory Branch. The recommended plan would be in full compliance with the current Clean Water Act regulations prior to any construction and activities.

_________________________ _____________________________________

(Date)

Bryan K. Sizemore
Colonel, U.S. Army
District Commander

U. S. Army Corps of Engineers

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

July 2019

Appendix E

Hazardous, Toxic, and Radioactive Waste Analysis

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTENTIONALLY LEFT BLANK

1. INTRODUCTION

1.1. OVERVIEW

The Southeast Missouri Lead Mining District is a large area of historic and current lead and other heavy metal mining that is comprised of two main sub districts: the Old Lead Belt and the Viburnum Trend (also known as the New Lead Belt). The study area overlaps with portions of the Old Lead Belt (OLB), including Jefferson, Washington and St. Francois Counties. The Big River drains the OLB, which covers 280km² of St. Francois County with its center about 100km south of St. Louis.

Lead was probably first mined in the Big River watershed between 1742 and 1762 near Potosi where relatively large galena crystals were extracted by hand from shallow pits or diggings (Pavlowsky R. T., 2017). Industrial mining and smelting practices were prevalent from 1864 to 1972, during which approximately 10 million tons of Lead (Pb) and two million tons of Zinc (Zn) (USBM, 1972) were reportedly produced from the estimated 250 million tons of mine waste produced (Pavlowsky 2017). The mining and smelting processes left large quantities of mine waste that were either stockpiled in mountainous uncapped piles or directly released into the Big River. Wind, rain and floods led to hundreds of uncontrolled releases of mine waste contaminated by lead, cadmium and other toxic metals. The released materials have deposited in the channels and floodplains and continue to migrate through the Big River watershed.

The U.S. Environmental Protection Agency (USEPA) Superfund Region 7 (SUPR VII) is currently in the Remedial Investigation/Feasibility Study (RI/FS) phase of the Superfund Process dictated by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) for most Operable Units (OU) related to these mining activities. The result of this process is expected to be a conceptual plan for remediating mine waste and establishing acceptable benchmarks and final target concentrations through Records of Decision (ROD), which will also establish the concentration at which soils and sediment are considered Hazardous, Toxic, and Radioactive Waste (HTRW) per U.S. Army Corps of Engineers (USACE) policy. These RODs may affect USACE potential to construct at sites with concentrations at or above target levels due to USACE policy to avoid HTRW where practicable.

Table 1-1 shows a comparison of standard soil sieve sizes vs. estimated grain size of typical mining and smelting waste products found in the Big River sediments and floodplain. This table represents a compilation from investigations of mining practices and tailings piles by approximate timeframe (Pavlowsky R. T., 2017).

Table 1-1: Sieve and Grain Sizes of Mine Waste and Smelting Byproducts

Grain Type:	Gravel								Coarse Sand
Sieve Size (Imp.):	2.000"	1.500"	1.000"	0.750"		0.375"	0.004"		10
(mm):	53.9	33.1	26.9	17.0	16.0	9.52	4.76	4.0	2.00
Byproduct:					4-16mm, Coarse Tailings, ≤1860s				
Grain Type:	Medium and Fine Sands								Fines
	Medium		Fine Sand						
Sieve Size (Imp.):	20	40	60		80	100	200	230	>230
(mm):	0.840	0.420	0.250	0.200	0.177	0.149	0.074	0.063	<0.063
Byproduct:				0.06-0.20 mm, Fine Tailings, 1860s to 1972					Effluent/Slimes
Note: Concentration of lead (Pb) is typically inversely related to grain size; finer grain sediments carry higher metal content									

1.2. PURPOSE

The USACE, St. Louis District, performed a historic and current records review search for the study area, which includes the Big River within the St. Francois, Washington and Jefferson Counties and the Meramec River within St. Louis County. The purpose was to identify recognized environmental conditions (RECs) involving HTRW within the study area. For the purpose of this study, RECs are defined as a past, present or likely future release of hazardous substances into the soil of a site.

The record search included Federal, State, tribal and local databases to identify sites where the presence or likely presence of heavy metals, primarily lead (Pb), have been previously documented.

The ultimate goal is to provide a reasonable assessment of areas of concern (i.e., RECs) so that project management and local sponsors can make decisions on property projects or future testing requirements.

METHODOLOGY

This following report was prepared in accordance with the applicable requirements contained in the following references:

U.S. Army Corps of Engineers Regulation ER 1165-2-132, Water Resources Policies, and Authorities for Hazardous, Toxic, and Radioactive Waste Guidance for Civil Works Projects, 26 June 1992;

U.S. Army Corps of Engineers, Lower Mississippi Valley Regulation 1165-2-9, Water Resources Policies and Authorities for Hazardous, Toxic, and Radioactive Waste Guidance for Civil Works Projects, 14 June 1996

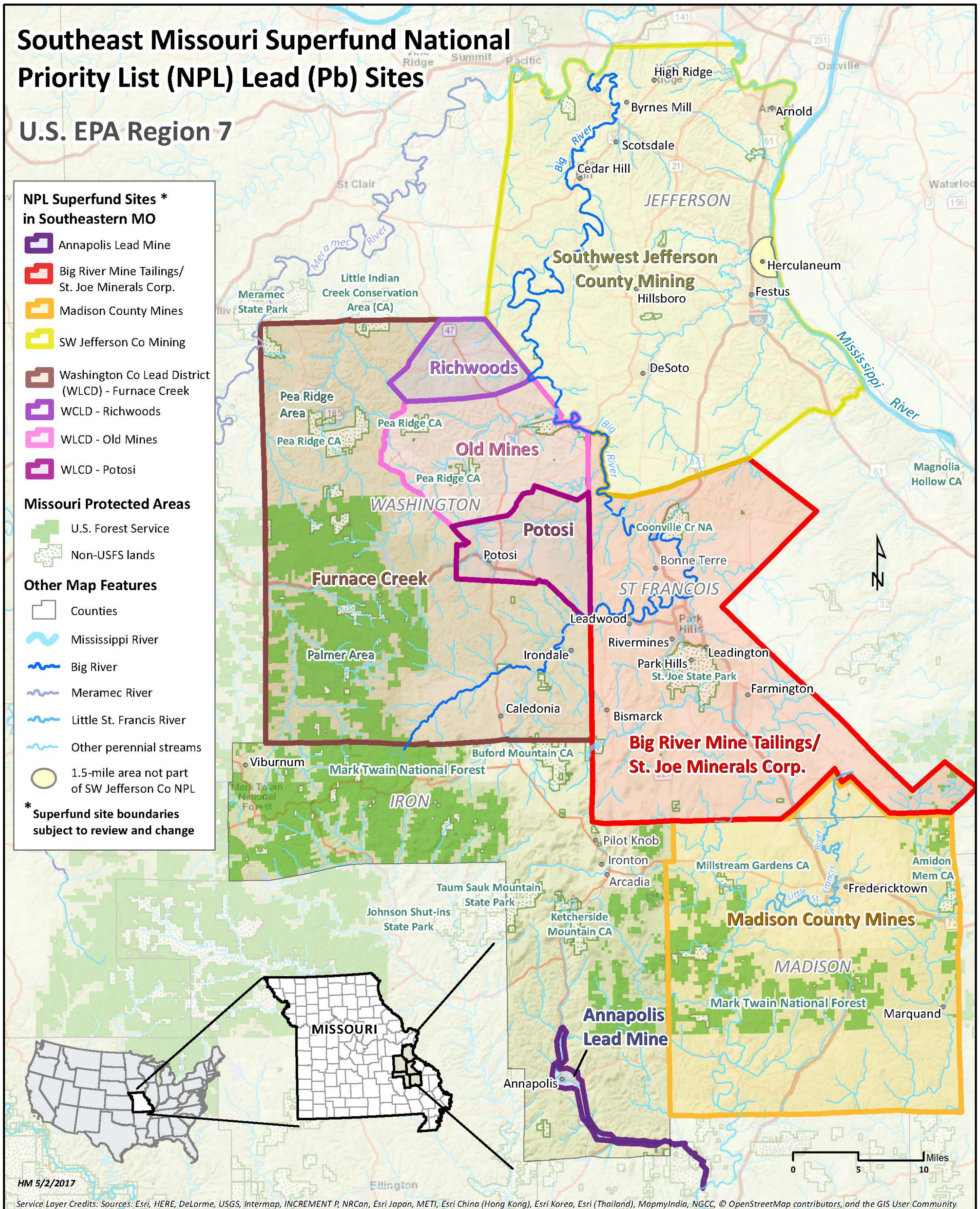
HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE (HTRW)

Hazardous waste is defined as a waste either that is listed as such in regulations issued by the USEPA or that exhibits one or more of the following characteristics: corrosive, ignitable, reactive or toxic constituents. Contaminated sediment as it is used throughout the body of the main report is not the same as USEPA's definition of contaminants of concern. Contaminants of concern are chemicals addressed by a cleanup action because they pose a threat to human health or the environment. The USEPAs cleanup (remedial) action level will determine the USACE HTRW levels.

The National Priorities List (NPL) is the list of national priorities among the known releases or threatened releases of hazardous substances, pollutants or contaminants throughout the United States and its territories. The NPL is intended to guide the USEPA in determining which sites warrant further investigation. Our study area is within the

Southeast Missouri (SEMO) Superfund NPL Lead Sites shown in Figure 2-1, which are composed of the following sub-sites:

1. Annapolis Lead Mine
2. Big River Mine Tailings/St. Joe Mineral Corp.
3. Madison County Mines,
4. Southwest Jefferson County Mining
5. Washington County Lead District
    a. Richwoods Site
    b. Old Mines Site
    c. Potosi Site



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, opinion, or interpretation, 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 2-1. Southeast Missouri (SEMO) Superfund NPL Lead Sites and Study Area

Tables 2-1, 2-2, and 2-3 show the status of relevant Superfund sites, black text are the operating units that affect the study area.

Table 2-1: Big River Mine Tailings/ St. Joe Mineral Corp.

Operable Unit(OU) 00 - All of the sources areas	Five of the source areas have been addressed through PRP actions.
OU 01 - Residential Yards	To date, over 5,000 residential properties have been sampled for lead contamination. To date, over 1,300 residential yards have been remediated along with all contaminated schools, daycares and head starts. This work is ongoing and EPA will continue to sample and remediate properties that are greater than 400 parts per million lead. This work is being done both through enforcement and EPA actions.
OU 02 - The Big River	The Remedial Investigation and Feasibility Study of the River is ongoing. An Interim Record of Decision was proposed in 2018 but not finalized. EPA scheduled to complete a final ROD in 2020.

Table 2-2: Southwest Jefferson County Unit

OU 01 - Residential Yards	As of September 2018, EPA has sampled over 4,550 residential properties and remediated more than 978 properties. Sampling and remediation work is ongoing and is expected to continue until the remedial action objectives are met. These totals include residential yards addressed under OU2 and OU3. Both OU2 and OU3 remedial actions were completed in September 2015.
OU 04 - Big River and Floodplain	EPA has completed pilot projects along the Big River. A Remedial Investigation (RI) for the river and the floodplain is anticipated to be completed during the summer of 2019. Additional eco-risk sampling will be conducted during the 2018-2019 winter.
OU 05 - Groundwater	EPA continues to work on the Remedial Investigation/Feasibility Study (RI/FS). As of September 2018, over 1,100 private drinking water wells have been sampled with 101 wells exceeding 15 parts per billion lead. Bottled water is currently being offered to affected residents until a final remedy can be implemented. Sampling of private residential groundwater wells will continue in conjunction with residential yard sampling.
OU 06 - Valley Mines Area	Work on the Valles Mines Site is currently on hold as the site represents a relatively low risk due to few receptors and generally localized contamination on the property. Direct exposure and the higher risks present in other OUs has taken priority at this time.
OU 07 - Rail Lines	EPA has collected samples along the southern rail line in places where the rail line was deeded out to the property owner. EPA will attempt to gain access in other locations and contact the rail line owners through site counsel; however, this work is currently on hold. This OU represents a relatively low risk due to few receptors and generally localized contamination along the rail lines. Direct exposure and the higher risks present in other OUs has taken priority at this time.
OU 08 - Mine Waste Areas	An RI was initiated in September 2013 for the mine waste piles and a draft report was received in July 2017. A total of three barite mining areas were characterized during the RI sampling and no previous investigations have focused on these locations. Work remains on both the ERA and HHRA and the RI will remain draft until these studies are complete.

Table 2-3: Washington County Lead District (WCLD)

WCLD-Potosi Site	OU 01-Residential Yard Removal	ROD on 29 September 2011
WCLD -Furnace Creek	OU 01-Soil	ROD on 26 September 2017
WCLD -Old Mines	OU 01-Residential Yard Removal	ROD on 29 September 2011
WCLD -Richwoods	OU 01-Residential Yard Removal	ROD on 29 September 2011

NATURE OF HTRW

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 (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 industrial 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 in St. Francois County. These six piles, known as the Bonne Terre, Desloge, Leadwood, Elvins, Federal, and National sites cover over four (4) square miles (Pavlowsky, Owen, & Martin, 2010.

Later ore processing and beneficiation methods resulted in the production of sand, generally known as tailings, and finer grained materials (“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.

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 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.

Based on USEPA, the following tailings piles have been stabilized or are undergoing construction stabilization under the regulatory framework of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as “Superfund”.

- Desloge Pile (Big River Pile): Stabilization work on the Desloge Pile (Big River Pile) was mostly completed by 2000. The Desloge mine source pile is currently being used as an on-site soil repository for lead contaminated residential soil. Upon completion, the areas used as repository will be capped with clean soil/rock.
- Bonne Terre Pile: Chat pile stabilized in 2007. The Bonne Terre East Tailings Flat is currently being used as an on-site soil repository for lead-contaminated soils. Upon completion, this area will be capped with clean soil/rock.
- Elvins Pile: Area was stabilized in 2009.
- Leadwood Pile: Area was stabilized in 2010.
- National Pile: Area was stabilized in 2012.
- Federal Pile (St. Joe State Park): Cleanup is ongoing and construction completion should occur by September 30, 2018.
- Hayden Creek Pile: Area was partially stabilized in 2012.
- Doe Run Pile: Not yet addressed and located outside of the study area.

CERCLA REGULATED MATERIAL

NATURE OF CERCLA REGULATED MATERIAL IN BIG RIVER WATERSHED

The USEPA ROD for Big River Mine Tailings Superfund Site, St. Francois County, Missouri Operable Unit (OU) 1 (USEPA, 2011) estimates that over 100 years of lead mining produced over 250 million tons of mine waste (see Section 1.1). OU1 consists of the stabilization of the Desloge Pile (stabilized in 2000) and remediation of residential properties and high child exposure areas exceeding lead levels in residential soil of 400 ppm in St. Francois County and focuses on properties in the towns of Park Hills, Desloge, Bonne Terre, Leadwood, Leadington and Doe Run, including the rural residential properties surrounding these communities (USEPA, 2011). The USEPA ROD for Southwest Jefferson County Mining Site estimates that over three million pounds of lead were shipped out of Jefferson County annually during the 1800's. The USEPA RODs for Southwest Jefferson County Mining Site (USEPA, 2012) and Big River Mine Tailings Superfund Site, St. Francois County, Missouri Operable Unit (OU) 1 (USEPA, 2011) set a remediation level of 400 ppm for residential soils based on site specific health risk assessments.

A significant portion of the mining waste is located in the eight major piles, identified above. These piles were predominately barren of vegetation, access to the waste piles was unrestricted before the USEPA removal actions, and stabilization of the mine waste piles started in the early 2000's. The general magnitude of the piles as described in the USEPA ROD (2011) prior to USEPA efforts are defined as: Desloge Pile - 600 acres in size and up to 100 feet deep; Elvins Pile - 149 acres and 170 feet higher than surrounding area; Bonne Terre Pile (eastern portion) - 306 acres and up to 50 feet deep, Bonne Terre Pile (western portion) - approximately 39 acres and about 160 feet higher than the surrounding area; the Federal Pile - over 1,000 acres; and the Leadwood Pile - approximately 563 acres in size.

The mine waste contains elevated levels of lead and other heavy metals, which pose a threat to human health and the environment. The mine waste has contaminated soils, sediments, surface water, and groundwater. These materials also may have been transported by wind and water erosion or manually relocated to other areas.

EXTENT OF HEAVY METALS IN THE BIG RIVER WATERSHED

This section briefly summarizes the extent of CERCLA related materials in and around the study area. For further information, please refer to the documents listed below.

- 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 (Pavlowsky), 2010
- Mussel Community Associations with Sediment Metal Concentration and Substrate Characteristics in the Big River, Missouri, USA, (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,
- Analysis of Soil and Sediment in the Big River Watershed Utilizing Pb Isotopes for Source Distribution, Synchrotron Speciation for Phase Identification, and In-Vitro Bio accessibility for Risk Assessment (USEPA), 2017
- Channel bar feature extraction for a mining contaminated river using high-spatial multispectral remote sensing imagery (Wang et al), 2016
- Legacy Sediment, lead, and zinc storage in channel and floodplain deposits of the Big River, Old Led Belt Mining district, Missouri (Pavlowsky, Lecce, Owen Martin), 2017
- Historical Channel Change and Mining-Contaminated Sediment Remobilization in the Lower big River (Young), 2011

Almost all of the contaminated sediment came from the historical mining operations in St. Francois County (USEPA, 2017), which have been selectively transported downstream in association with channel sediment according to size. Floodplain contamination is generally more severe and extends further downstream compared to channel sediments. Floodplain surface soils less than two decades old contain between 1,000 ppm and 2,000 ppm of lead. In these layers, lead concentrations decrease downstream from the mining areas in St. Francois County due to the influence of dilution and upstream deposition. It is estimated (Pavlowsky, 2010) that of the 227 million Mg (250 million tons) of contaminated sediment produced as mine waste, currently 3,700,000 m^3 (8 million tons[1]) is stored in the channel and 86,800,000 m^3 (192 million tons[1]) is stored in the floodplain. Of that, about 63% of the contaminated sediment is stored in Jefferson County. It is also estimated in total (Pavlowsky, 2010) for the Big River 3,800 Mg (4,188 tons) of lead is stored in channel bed and bar deposits and 226,000 Mg (249,000 tons) lead is stored in the floodplain. USEPA (2017) analysis of soil and sediment in the Big River Watershed utilizing lead isotopes for source distribution confirms that the source of contamination in the Big River watershed correspond to the piles in St. Francois County, Missouri.

[1] Imperial tonnage was calculated using Pavlowsky 2010 bulk density of 2 g/cm^3

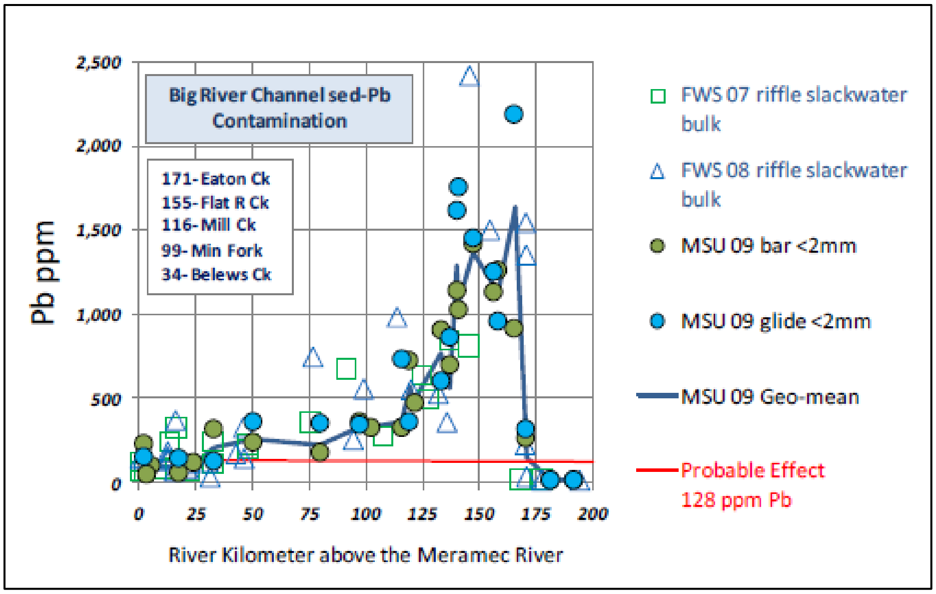


Figure 2-2. Pavlowsky Big River Lead Concentrations Per River Kilometer

Table 2-4: Bulk Lead Concentrations Averaged

	Meramec River	Big River RM 0-10	Big River RM 10-35	Big River RM 35-75	Big River RM 75-113
In-Stream Average Lead (ppm)	2	256	275	456	1,137
Floodplain Average Lead (ppm)		506	648	1,452	1,443

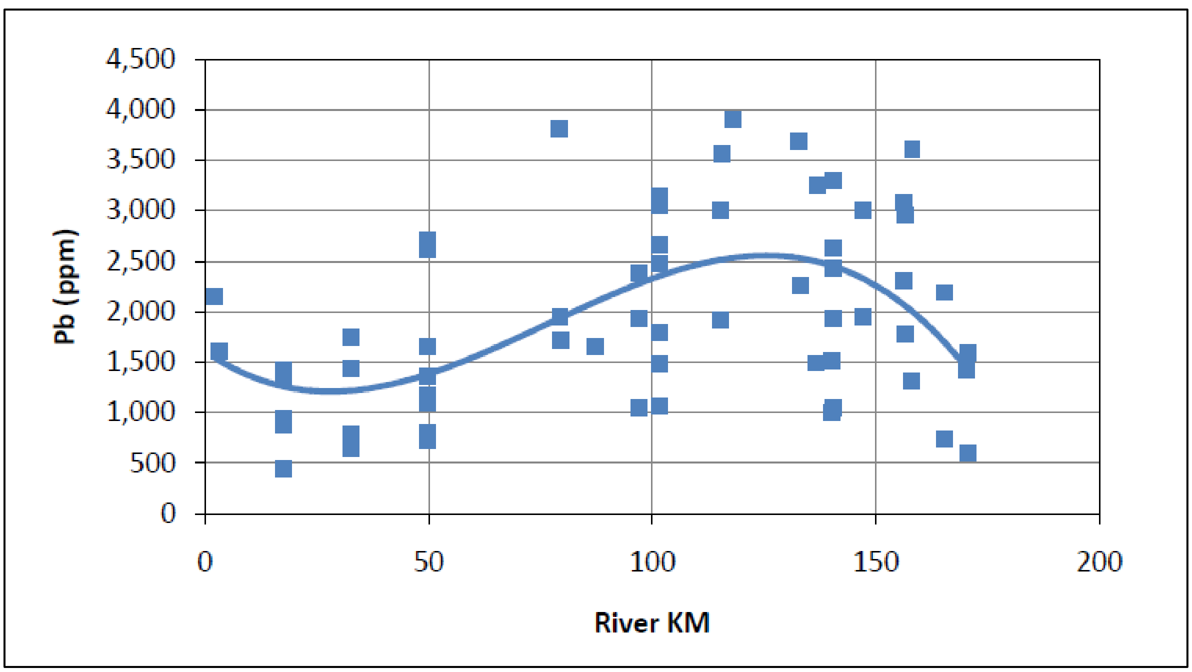


Figure 2-3. Pavlowsky (2010) Mean Floodplain Lead Concentrations

Additional review of soil samples was done by the USACE to ascertain the extent of CERCLA regulated material. Based on the results of these data sets, it was determined that barium (i.e. barite "tiff"), cadmium and zinc are not considered an HTRW concern since their average concentrations are not found above the regional screening levels (RSLs)[2]. However, in 2009 the USEPA conducted a Human Health Risk Assessment (HHRA) and identified cadmium and zinc in nonresidential soil and stream sediment and considered them as contaminants of concern (COC) for Big River Mine Tailings Superfund Site, St. Francois County, Missouri OU 1 (USEPA, 2011). It was also confirmed that lead is a contaminant of concern but it cannot be ascertained whether it is an HTRW concern until the USEPA identifies a remedial action level; therefore, to manage that risk it is imperative to obtain soil samples during design activities. Final site selection during preconstruction engineering and design (PED) will not occur until the USEPA issues their ROD.

RESIDENTIAL USEPA SOIL SAMPLES

Results of sampling completed during the Pre-Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) Site Screening Assessment for Jefferson County conducted by Tetra Tech in 2007 and 2008 were used for USEPA to identify multiple residential properties exhibiting lead levels greater than the TCRA level of 1,200 ppm, and numerous other properties at levels greater than the non-TCRA level of 400 ppm (Tetra Tech, 2007 and 2008).

Metal	Chemical of Potential Concern		
	Soil	Groundwater	Surface Water[1]
Arsenic	X	X	X
Barium	-	X	X
Cadmium	-	X	X
Lead	X	X	X
Zinc	-	X	X

Notes:
[1] COPCs for surface water have not yet been established and will include all Target Analyte List metals, excluding mercury, until the Human Health and Ecological Risk Assessments are complete.

Figure 2-4. Chemicals of Potential Concern

As of September 2018, USEPA has sampled over 4,550 residential properties and remediated more than 978 properties. Sampling and remediation work is ongoing and is expected to continue until the remedial action objectives are met.

Tributary inputs, such as the Flat River Creek, remain a source of tailings to the Big River; however, the piles that erode into Flat River Creek have been capped. Mill Creek and Mineral Fork Creek both contain elevated lead and zinc concentrations in channel sediments, but these are usually below the PEC. Floodplain deposits in these creeks are also elevated in both lead and zinc concentrations, but that appears related to Big River floodplain deposition. The release of contaminated sediment from Mill Creek and Mineral Fork Creek to the Big River does not appear to influence the sediment contamination along the main stem of the Big River.

MEASURES

[2] Per USEPA, RSLs are used for site "screening" and as initial cleanup goals, if applicable. RSLs are considered to be protective to humans over a lifetime and are not always applicable to a particular site and do not address non-human health endpoints, such as ecological impacts. RSLs are not cleanup standards; however, they help identify areas, contaminants and conditions that require further federal attention at a particular site.

RESUSPENSION OF SEDIMENT

The USACE planning team identified alternatives comprised of various potential sites and management measures that meet the Study objectives. Alternative 5 - *Maximize Efficiency in the Big River* was selected and consists of stabilizing sediment in place through bed stabilization (grade control structures), bank stabilization (longitudinal peak stone toe protection, root wad revetment, weirs, barbs and riparian plantings), in channel sediment removal using sediment capture basins, bed sediment collectors and direct excavation. Sediment resuspension and the resulting unwanted release and transport of lead in the water body are a concern when dredging a channel. While USACE will minimize the disturbance of excavated material during construction, there is a high likelihood of temporary resuspension of sediment. Table 3-1 shows the Best Management Practices (BMPs) to minimize and control resuspension of sediment. Barriers include oil booms, silt curtains, silt screens, sheet pile walls, cofferdams and bubble curtains. Under favorable conditions, use of those barriers or channel diversions will help limit the areal extent of particle-bound contaminant migration resulting from dredging resuspension and enhance the long-term benefits gained by the removal process (USEPA , 2005).

Table 3-1: BMPs Used to Minimize the Risk of Resuspension of Sediment

MEASURES	RISK	BMPs	POTENTIAL TO REINTRODUCE CERCLA MATERIAL ABOVE USEPA ROD
Longitudinal peak stone toe protection (LPSTP)	High	Floodplain silt fences will stabilize the bank and further reduce erosion to the stream. In-stream barriers will reduce and contain the spread of sediment in the surrounding water column. In-stream peninsulas in order to reduce the development of wind waves and resuspension of deposited sediments.	Low
Root wad Revetment	High	Floodplain silt fences will stabilize the bank and further reduce erosion to the stream. In-stream barriers will reduce and contain the spread of sediment in the surrounding water column.	Low
Weirs	High	In-stream barriers will reduce and contain the spread of sediment in the surrounding water column.	Low
Barbs	High	In-stream barriers will reduce and contain the spread of sediment in the surrounding water column. In-stream peninsulas in order to reduce the development of wind waves and resuspension of deposited sediments.	Low
Riparian Plantings	Low	Floodplain silt fences will stabilize the bank and further reduce erosion to the stream.	Low
Sediment Capture Basins	High	In-stream barriers will reduce and contain the spread of sediment in the surrounding water column.	Low
Sediment Bed Collectors	High	In-stream barriers will reduce and contain the spread of sediment in the surrounding water column.	Low
Grade Control Structures	High	In-stream barriers will reduce and contain the spread of sediment in the surrounding water column.	Low
Excavation	Low to High	In-stream barriers parallel to riverbanks will reduce and contain the spread of sediment in the surrounding water column.	Low

Excavation techniques can generally accommodate excavated material without an increase in resuspension, release[3], and residual[4] (ITRC (Interstate Technology & Regulatory Council), 2014) sediment. Table 3-2 shows the

[3] Release is defined as the transport of dissolved constituents of disturbed pore water or constituents desorbed from sediment particles.
[4] Residual is defined as disturbed sediments remaining after cessation of dredging.

different excavation equipment and the risk associated with resuspension of sediment. The equipment selection factors reflect the potential performance of a given dredge type, and are a function of both the capability of the equipment type and the site and/or sediment conditions.

Table 3-2: Excavation Overview in Resuspension of Sediments

EQUIPMENT TYPE	EQUIPMENT SELECTION FACTORS	RISK	CONTROL CONTAMINANT RELEASE OF EQUIPMENT TYPE	BMPS
Mechanical Dredges (2 to 8 cubic meter buckets)	Conventional Clamshell (Wire)[5]	High	Low	Can be operated such that the excavation and water column exposure of the bucket is within an in-stream barrier or enclosure; however, high-suspended solids within an in-stream barrier may be released if it is moved.
	Enclosed Bucket (Wire)[i]	Low	High	Can be operated such that the excavation and water column exposure of the dredge is within an in-stream barrier.
	Articulated Mechanical (Fixed Arm)[ii]	Low	High	
Hydraulic/ Pneumatic Dredges (15 to 30 cm pump sizes)	Cutterheads[iii]	Medium	Medium	Capable of transporting the material directly by pipeline, minimizing exposure to the water column and to volatilization. Can be operated within enclosures, but the footprint of such enclosures would be larger than that for mechanical dredges.
	Horizontal Auger[iv]	Medium	Medium	
	Plain Suction[v]	Low	Medium	
	Pneumatic[vi]	Low	Medium	
	Specialty[vii]	Low	Medium	
	Divers[viii]	Low	High	Scale of diver-assisted dredging would seldom require contaminant release controls.
Dry Excavation	Various Mechanical Excavators[ix]	Low	High	Dewatering of the dredging area effectively eliminates dissolved releases.

Control contaminant release is the inherent ability to control sediment resuspension, dissolved and volatile releases for the given equipment type and associated operation. The use of BMPS such as dredge operations within the in-stream barrier will minimize the potential to reintroduce CERCLA material above the USEPA remedial action level.

DISPOSITION OF EXCAVATED, CAPTURED, OR COLLECTED MATERIAL

During construction, USACE will avoid the disturbance of CERCLA materials above HTRW levels of concern. Material excavated at bank stabilization, tree planting and off site sediment basins will remain in place. Material excavated in stream and captured at bed sediment collector sites will be disposed of at a USEPA approved

[5] Clamshell – conventional clamshell dredges, wire supported, conventional open clam bucket.

repository. Disposal of material will be in accordance with applicable state and federal laws. Use of disposal material will be in accordance with the record of decision for the Big River and floodplain.

CONCLUSIONS

Based on the data reviewed and information gathered during this and previous assessments, it appears there is evidence of CERCLA regulated material within the study area.

Currently, USEPA is working to finish the Remedial Investigation (RI). This RI phase is primarily concerned with site characterization and includes data collection, risk assessments, evaluation of the nature and extent of contamination, and will identify Remedial Action Objectives. In late 2019, the USEPA is scheduled to finalize a remedial action level in the ROD for the Big River and its floodplain. Because the USEPA has not yet issued a ROD for this site, the extent of HTRW concern is uncertain.

Based upon sediment samples, the average lead concentrations within the study area are within 100 ppm and 1,000 ppm, with a general downward trend from upstream in St. Francois County to Big River's confluence with the Meramec River. The restoration alternatives proposed for the Meramec River Basin Ecosystem Restoration project have been managed so that disturbance of CERCLA materials above HTRW levels of concern will be avoided. These management measures may impact the number of sites, reducing cost and benefits alike, but not the identified measures. Final site selection during preconstruction engineering and design will not occur until the USEPA issues their ROD.

Best management practices will be employed during construction at the study areas to avoid the suspension of sediment and the release of any contamination into the water column.

- An erosion control plan will be created and implemented to control the entry of sediments into the Big River and / or tributaries and their migration downstream of the work area.
- Construction will occur during low water levels to avoid the introduction of sediment into the water column.

Material that is excavated from the study area will be below the remedial action levels identified in the USEPA ROD. Once excavated, materials will be handled in accordance with applicable Federal and state requirements and cost shared appropriately (Section 10).

---

[i] Enclosed Bucket – wire supported, near watertight or sealed bucket usually incorporating a level cut capability
[ii] Articulated Mechanical – backhoe designs, clam-type enclosed buckets, hydraulic closing mechanisms, all supported by articulated fixed-arm.
[iii] Cutterhead – conventional hydraulic pipeline dredge, with conventional cutterhead.
[iv] Horizontal Auger – hydraulic pipeline dredge with horizontal auger dredgehead.
[v] Plain Suction – hydraulic pipeline dredge using dredgehead design with no cutting action.
[vi] Pneumatic – air operated submersible pump, pipeline transport, either wire supported or fixed-arm supported.
[vii] Specialty Dredgeheads – other hydraulic pipeline dredges with specialty dredgeheads or pumping systems.
[viii] Diver Assisted – hand-held hydraulic suction with pipeline transport.
[ix] Dry Excavation – conventional excavation equipment operating within dewatered containments such as sheet-pile enclosures or cofferdams.

U. S. Army Corps of Engineers

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

July 2019

Appendix F

Water Quality

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTENTIONALLY LEFT BLANK

1. IMPAIRED WATERS

1.1. TOTAL MAXIMUM DAILY LOADS (TMDL) WITHIN THE STUDY AREA (JEFFERSON,ST. FRANCOIS, ST. LOUIS, AND WASHINGTON COUNTIES), 2001-2010

USEPA's 303(d) Program assists states, territories and authorized tribes in submitting lists of impaired waters and developing total maximum daily loads (TMDLs). A TMDL establishes the maximum amount of a pollutant allowed in a waterbody and serves as the starting point for restoring water quality. Each pollutant causing a waterbody to be impaired or threatened is referred to as a waterbody/pollutant combination, and typically a TMDL is developed for each waterbody/pollutant combination. Neither the Clean Water Act nor USEPA's regulations define or limit the scale of TMDLs.

The TMDL process is important as it develops a framework for water quality standards that improves water quality and implements control actions to attain those standards.

The USEPA suggests the following approach, which consists of five (5) activities to develop a TMDL for a particular waterbody or watershed.

- Selection of the pollutant(s) to consider.
- Estimation of the waterbody's assimilative capacity (i.e., loading capacity).
- Estimation of the pollutant loading from all sources to the waterbody.
- Analysis of current pollutant load and determination of needed reductions to meet assimilative capacity.
- Allocation (with a margin of safety) of the allowable pollutant load among the different pollutant sources in a manner such that water quality standards are achieved.

Within the study area, TMDLs have been developed for the Big River, Flat River Creek, Pond Creek, Shaw Branch and Shibboleth Creek to address impairments to the protection of aquatic life caused by sediments and heavy metals in the stream attributed to past mining activities. A TMDL was also written for Turkey Creek in St. Francois County to address aquatic life impairments caused by excessive biochemical oxygen demand (BOD) and organic sediment. Pollutant reductions and implementation plans for the metals and sediment TMDLs target former mining and milling activities, while the Turkey Creek TMDL assigns pollutant allocations and load reductions to a specific wastewater treatment facility. Implementation of these TMDLs are intended to restore these waters to a level that attains water quality standards and protects beneficial uses. The TMDLs for Big River, Flat River Creek, Shaw Branch, Turkey Creek, Shibboleth Creek, Saline Creek and Fishpot Creek were approved by the USEPA.

Water quality targets for metals are based on chronic criteria and thus aquatic life protected from acute and chronic toxicity. Current lead and zinc standards are expressed in dissolved form; those numbers are 5 µg/L for lead and 193 µg/L for zinc. Missouri has no numeric standard for nonvolatile suspended solids. Excessive deposits of sediment, in particular nonvolatile suspended solids, in waters of the State are interpreted as violations to the general criteria of the Water Quality Standards. Nonvolatile suspended solids data is not available; therefore, total suspended solids (TSS) was used as a surrogate with a calculated target of 5 mg/L. This target represents suspended clean sediment free of pollutants including metals. Table 1-1 summarizes the water bodies within the study area that are listed on Missouri's 303(d) List of Impaired Waterways for 2016. Currently 81.3 miles of Big River is impaired for lead, zinc and cadmium in sediment and lead in fish tissue. Big River and Meramec River are identified as impaired waters and are discussed in the draft MDNR 2018 TMDL Prioritization and Development Schedule. TMDL for cadmium and zinc located in sediment for the Big River, and lead and E. coli for the Meramec River is currently scheduled for 2023.

Table 1-1. 2016 Missouri 303(d) Impaired Waters within the Study Area

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

NOTE: (W) pollutant is in the water, (S) pollutant is in the sediment, and (T) pollutant is in fish tissue.

Designation as an impaired water indicates that the waterway does not meet the water quality standards established by the State for protection of beneficial uses of water including whole body contact (such as swimming), maintaining fish and other aquatic life and providing drinking water for people, livestock and wildlife. The following figures show the water bodies within the study area that are listed on Missouri's 303(d) List of Impaired Waterways and contain a TMDL for 2016.

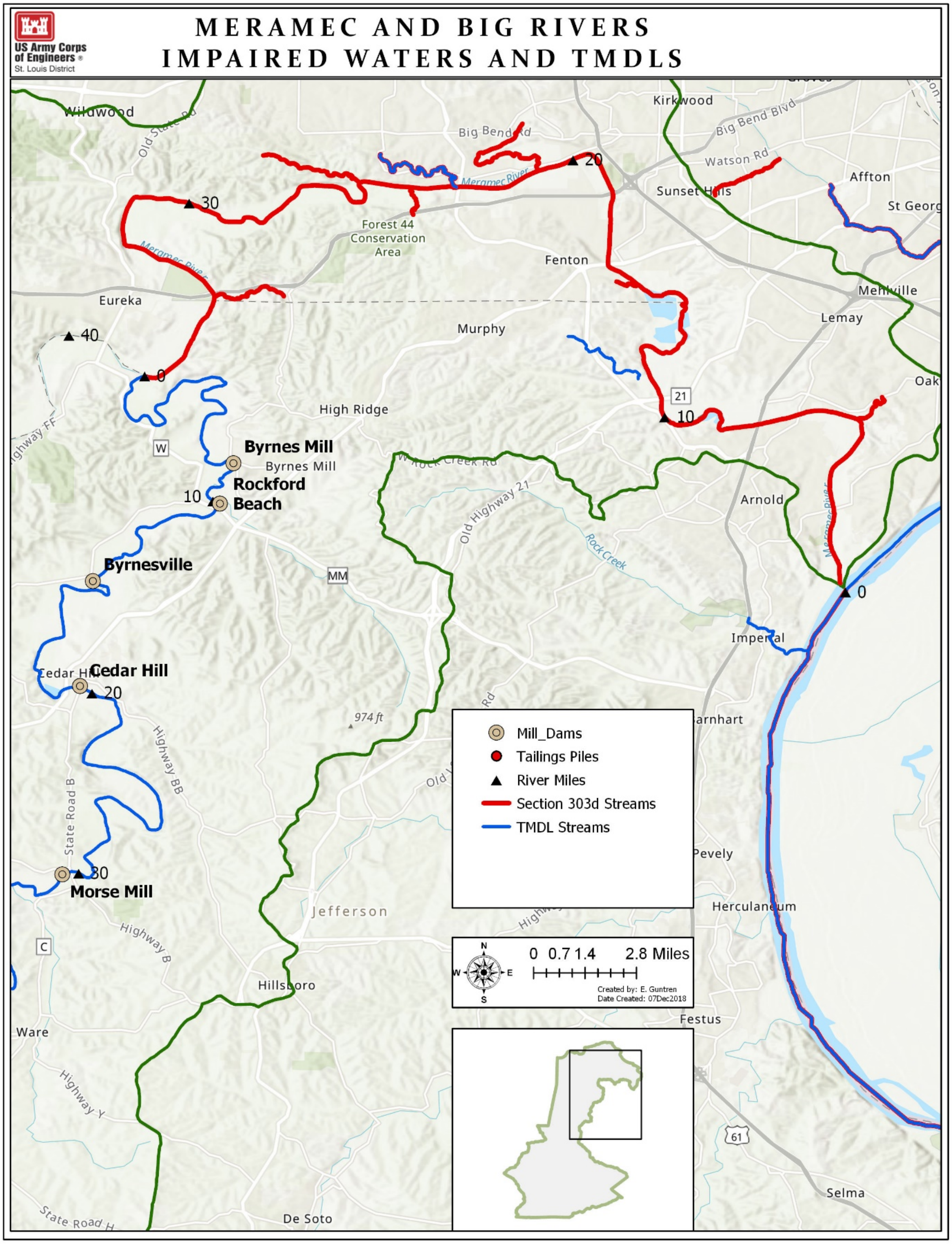


Figure 1-1. Impaired Water and TMDLs within the Study Area (Upper Section)

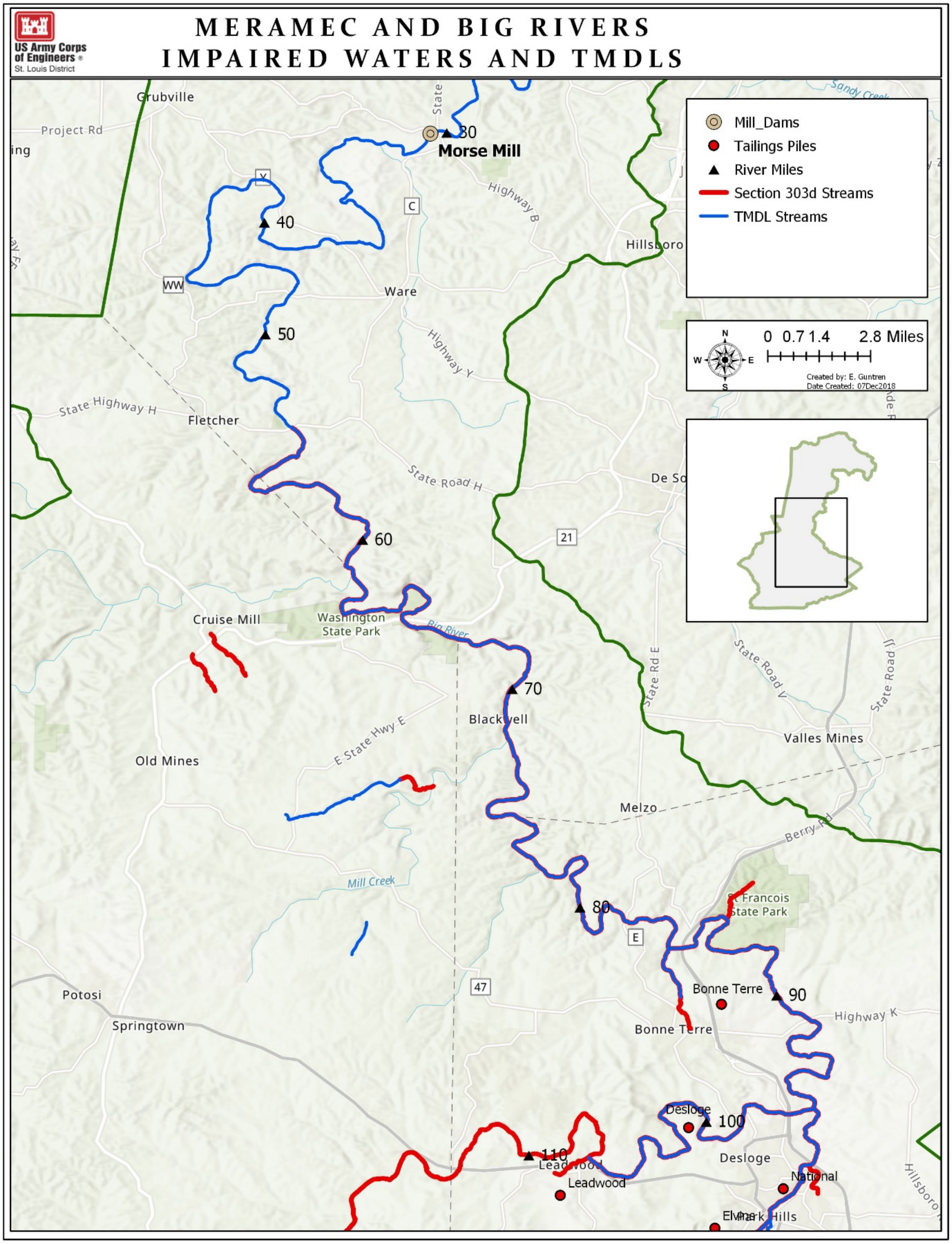


Figure 1-2. Impaired Water and TMDLs for the Study Area (Middle Section)

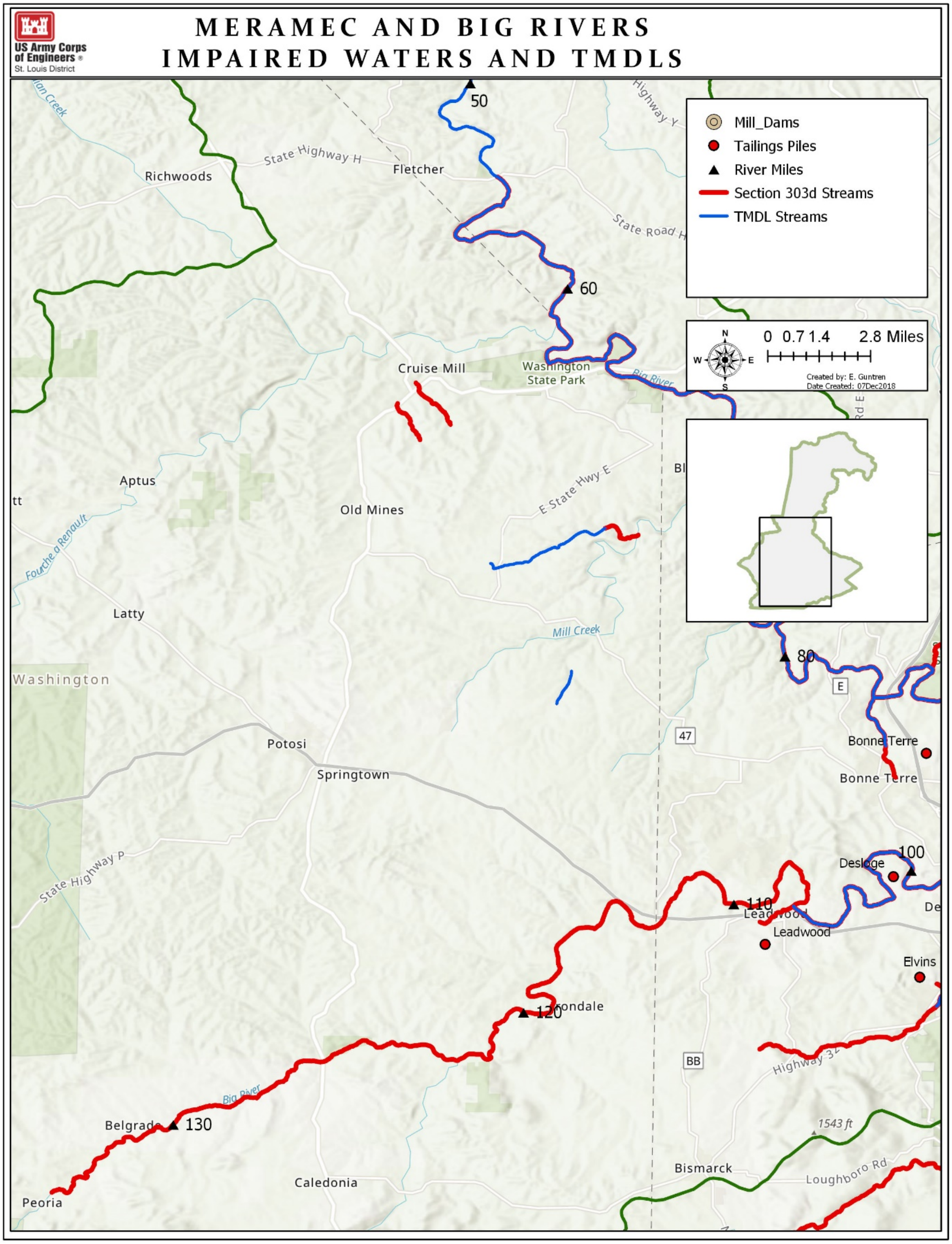


Figure 1-3. Impaired Water and TMDLs for the Study Area (Lower Section)

2. WATER QUALITY STANDARD

2.1. SPECIFIC CRITERIA

2.1.1. DISSOLVED LEAD AND ZINC

The Code of State Regulations of Missouri, Title 10 CSR 20-7.031 Water Quality Standards (WQS) purpose is to identify the uses of waters of the State, criteria to protect those uses and defines the anti-degradation policy. It is developed in response to the Missouri Clean Water Law and the federal Clean Water Act, Section 303(c) (1) and (2) which requires that state water quality standards be reviewed at least once every three (3) years. These revisions are pursuant to the national goal of protecting fish, shellfish and wildlife and recreation as outlined in Section 101(a) (2) of the Act. Dissolved metals toxicity is based on 25th percentile of hardness according the Missouri's Water Quality Standards. Table 2-1 shows the dissolved lead and zinc toxicity if the hardness is 200mg/L.

Table 2-1. Dissolved Lead and Zinc WQS for the Protection of Aquatic Life Use

Metals	Acute (µg/L)	Chronic (µg/L)	Hardness
Lead	136	5	200
Zinc	211	193	200

2.1.2. NON-VOLATILE SUSPENDED SOLIDS (NVSS)

Missouri has no numeric sediment for NVSS. Excessive deposits of sediment in waters of Missouri are interpreted as violations of the general criteria of the WQS. The general criteria states that:

- Waters shall be free from substances in sufficient amount to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
- Water shall be free from substances in sufficient amounts to cause unsightly color, turbidity, offensive odor or prevent full maintenance of beneficial uses.
- Water shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

2.2. BIG RIVER WATERSHED TREND ANALYSIS

The findings below reflect the trend analysis from the following reports:

- Water Quality Sampling Big River, Jefferson County (2014-2015)
- 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

2.2.1. WATER QUALITY SAMPLING BIG RIVER (JEFFERSON COUNTY)

Table 2-2 summarizes water quality parameters measured from samples acquired in 2014 and 2015 from the Big River within Jefferson County, Missouri.

Parameters	Mean	Units

Conductivity	314	umhos/cm
Hardness as CaCO3	204	mg/L
Oxidation-Reduction Potential	127	mV
pH	8	SU
Temperature	16	Deg C
Dissolved Oxygen	8	mg/L

2.2.2. ASSESSMENT OF METAL-CONTAMINATED SEDIMENTS FROM THE SOUTHEAST MISSOURRI (SEMOA) MINING DISTRICT USING SEDIMENT TOXICITY TESTS WITH AMPHIPODS AND FRESHWATER MUSSELS, 2009.

The USGS assessed sediment and water quality in the following locations of the Big River (Figure 2-1, Table 2-3):

- 15 sites downstream of the St. Francois County mining area
- One site in Mineral Fork (a Big River tributary that drains the Washington County mining area)
- Two sites in the Meramec River (upstream and downstream of the mouth of the Big River)
- One site in the Bourbeuse River (unaffected by mining activity)

Pore waters extracted from bulk sediment samples by centrifugation were filtered and analyzed for dissolved metals, nickel(Ni), copper(Cu), zinc(Zn), cadmium(Cd), and lead(Pb), by semi-quantitative inductively-coupled plasma-mass spectrometry and routine water quality parameters.

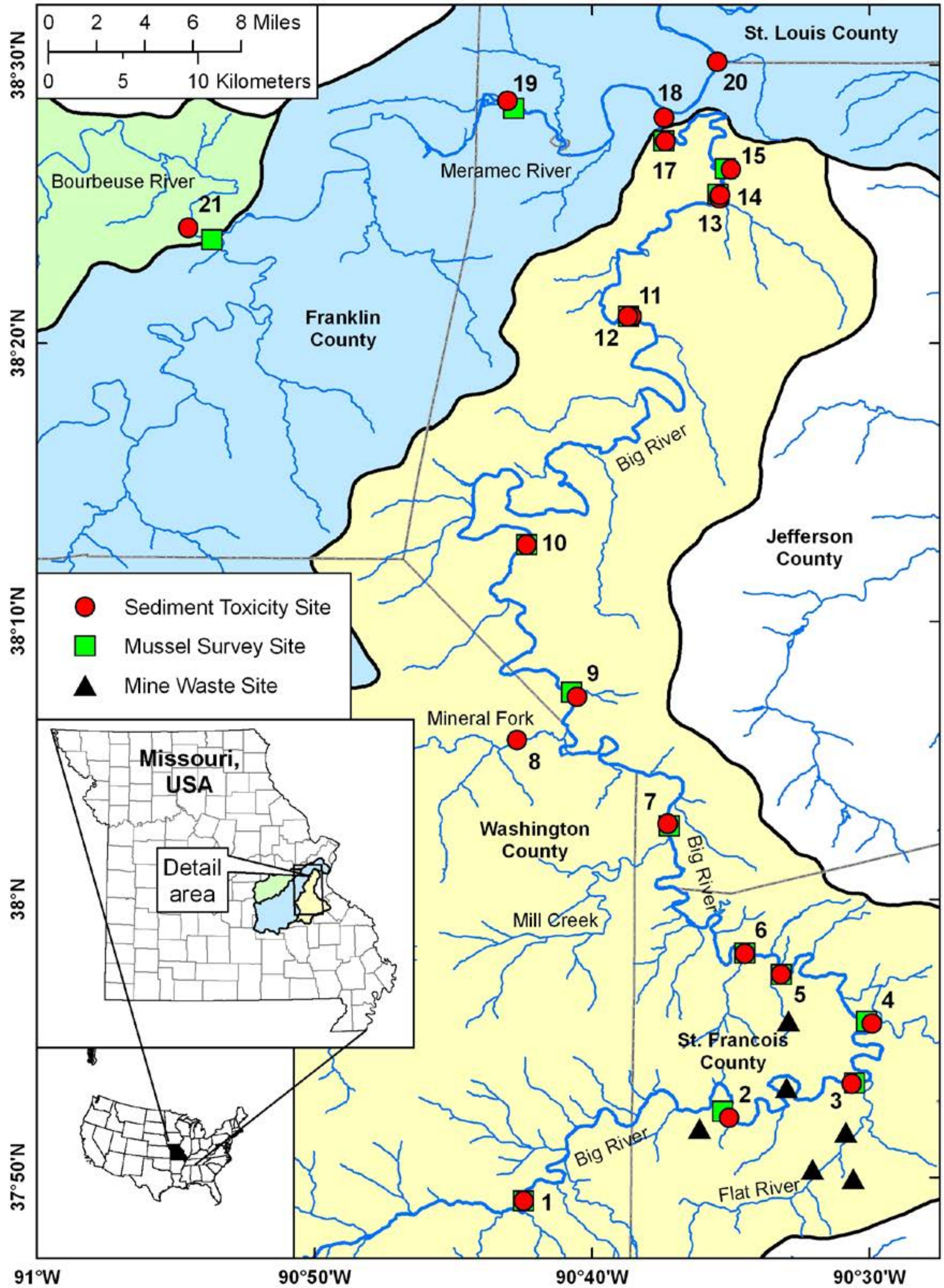


Figure 2-1. USGS SEMO Sample Location Map

Table 2-2. USGS SEMO Sample Location Sites

Site ID	Site Description	Date Sampled	River Mile
SEMO-1	Big River above Irondale	9-Sep-08	129
SEMO-2	Big River at MDC Leadwood access	9-Sep-08	113
SEMO-3	Big River at Hwy 67	9-Sep-08	103
SEMO-4	Big River at Hwy K	9-Sep-08	97
SEMO-5	Big River at Cherokee Landing	9-Sep-08	90
SEMO-6	Big River at Hwy EE	9-Sep-08	88
SEMO-7	Big River at Hwy CC	9-Sep-08	76
SEMO-8	Mineral Fork Creek near mouth	10-Sep-08	--
SEMO-9	Big River at Mammoth MDC Access	9-Sep-08	63
SEMO-10	Big River at Brown's Ford MDC Access	9-Sep-08	51
SEMO-11	Big River above Cedar Hill Dam	9-Sep-08	21
SEMO-12	Big River below Cedar Hill Dam	9-Sep-08	20
SEMO-13	Big River above Rockford Beach Dam	10-Sep-08	11
SEMO-14	Big River below Rockford Beach Dam	10-Sep-08	10
SEMO-15	Big River at Byrne's Mill Dam	10-Sep-08	8.2
SEMO-17	Big River at Hwy W	10-Sep-08	1.3
SEMO-18	Big River above confluence w/ Meramec	10-Sep-08	0.3
SEMO-19	Meramec River upstream; Pacific Palisades	10-Sep-08	--
SEMO-20	Meramec River downstream; Route 66 State Park	10-Sep-08	--
SEMO-21	Bourbeuse River near Choteau access	11-Sep-08	--

Table 2-3. Water Quality of Centrifuged and Filtered Pore Waters from SEMO Sediments

Site ID	pH	Conductivity (µS/cm)	Hardness (as CaCO3)	Alkalinity	Ammonia (mg N/L)	Dissolved Organic Compound
FL (Control)	6.23	2340	200	68	1.7	115
SEMO-1	7.53	319	180	156	0.3	7.1
SEMO-2	7.9	390	230	184	0.33	6.3
SEMO-3	7.76	468	300	268	1.16	20.8
SEMO-4	7.9	474	288	208	ND	9.2
SEMO-5	7.82	522	300	270	0.9	11.5
SEMO-6	7.41	556	320	324	0.5	21.6
SEMO-7	7.51	534	320	300	0.9	16.1
SEMO-8	7.68	410	250	230	0.46	5.4
SEMO-9	7.63	527	322	302	1.22	14.3
SEMO-10	7.71	421	260	222	0.41	16.2
SEMO-11	7.79	474	284	270	0.68	24
SEMO-12	7.88	574	350	340	0.39	20.1
SEMO-13	7.74	558	330	320	1.62	22.2
SEMO-14	7.75	542	300	290	0.66	18.2
SEMO-15	7.93	408	230	200	0.46	12
SEMO-17	7.77	384	250	202	0.35	7.6
SEMO-18	7.93	633	390	370	ND	26.5
SEMO-19	7.73	446	280	260	0.55	21.4
SEMO-20	8.02	443	ND	ND	0.39	15.2
SEMO-21	7.46	348	224	190	0.54	18.9
SEMO-22	7.95	347	226	183	0.26	7.9
SEMO-23	7.71	381	240	200	0.3	4.8

Table 2-4. Metal Concentrations (µg/L) in Pore Waters of SEMO Sediments Prepared by Centrifuged and Filtered Samples

Site ID	Ni	Cu	Zn	Cd	Pb
FL Control	4	9	20	<0.1	1
SEMO-1	3	<1	<1	<0.1	1
SEMO-2	3	<1	20	0.1	20
SEMO-3	10	2	100	1	100
SEMO-4	10	4	60	0.5	60
SEMO-5	8	2	20	0.2	50
SEMO-6	9	<1	8	<0.1	20
SEMO-7	4	<1	5	<0.1	20
SEMO-8	2	<1	9.5	<0.1	5
SEMO-9	6	6	20	0.2	100
SEMO-10	6	10	30	0.6	100
SEMO-11	5	10	60	1	400
SEMO-12	7	9	40	0.8	300
SEMO-13	8	8	40	0.8	300
SEMO-14	9	9	20	0.5	100
SEMO-15	4	10	30	1	200
SEMO-17	4	2	10	0.1	70
SEMO-18	10	10	40	1	300
SEMO-19	7	10	20	0.3	30
SEMO-20	6	3	9	0.1	30
SEMO-21	7	8	10	0.1	20

SUMMARY OF RESULTS

Table 2-4 (shown above) displays the outputs from the routine water quality parameters collected in the pore water samples. Table 2-5 (shown above) displays the metal concentrations found in the collected pore water samples. Lead was above the USEPA regional screening level in almost all samples.

2.2.3. BIG RIVER (LOWER) IRONDALE TO WASHINGTON STATE PARK (MODNR), 2002-2003

Water quality samples were collected upstream of the USACE study area. These samples were used to identify dissolved metals and nutrients from nine Big River and two Courtois Creek stations. From September to October of 2002, dissolved barium, lead and zinc were found. Dissolved barium was more than two-fold higher downstream at Courtois Creek as was found at all stations upstream. Dissolved lead was below detectable levels at the controls and Leadwood but increased more than three-fold downstream of Desloge. Dissolved zinc increased at Leadwood and quadrupled at Desloge before declining. Zinc declined to less than detectable levels just upstream of Washington State Park. In April 2003, samples of dissolved barium, lead, and zinc were found in water quality samples. Dissolved barium was high in Courtois Creek and downstream of Washington State Park. Between Irondale to upstream of Mill Creek concentration levels of barium were low and stable. Dissolved lead increased downstream from the Flat River confluence and was its highest concentration downstream of Washington State Park. Dissolved zinc increased downstream of Leadwood and reached a high downstream of Bonne Terre, St. Francois County, Missouri.

Although there were substantial increases in dissolved barium, lead and zinc from the controls to test stations, water quality samples for dissolved metals concentrations from 2002 and 2003 did not exceed WQS.

2.3. MERAMEC WATERSHED TREND ANALYSIS

The finding below summarizes the following reports:

- Meramec River Watershed Demonstration Project, (EPA), 1998

2.3.1. MERAMEC RIVER WATERSHED DEMONSTRATION PROJECT, 1998

According to MDNR Water Quality Standards, all streams within the basin are designated for aquatic life protection, fishing, and livestock and wildlife watering. From the mouth of Big River to Meramec State Park, residents use the Meramec River for drinking water supply and industrial uses. Drinking water is considered adequate. Current threats to beneficial uses are:

- Excessive discharge from sewage treatment plants,
- Cattle in streams, and
- Dioxin and chlordane

3. CONCLUSIONS

Based on the data reviewed and information gathered, the Big River is affected by the historical mining activities and erosion of tailing piles, as it poses a potential threat to stream water quality as it flows downstream to the Meramec River. Cattle grazing, urbanization, land disturbance and runoff, in general, affect the Meramec River.

Best management practices will be employed during construction at the project area to avoid the suspension of sediment and the release of any contamination into the water column.

- An erosion control plan will be created and implemented to control the entry of sediments into the Big River and/or tributaries and their migration downstream of the work area.

- Construction will occur during low water level to avoid the introduction of sediment into the water column.

U. S. Army Corps of Engineers

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

July 2019

Appendix G
Engineering Design

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLES

FIGURES

1. EXISTING CONDITIONS

1.1. STUDY AREA

The study area includes portions of the Meramec River Basin located in Jefferson, St. Louis, St. Francois and Washington counties of Missouri, located in east-central Missouri, southwest of St. Louis. The Recommended Plan focuses on the Big River, one of the primary tributaries to the Meramec River.

1.2. TOPOGRAPHIC DATA

Topographic surveys were not conducted for this study due to the large study area and dynamism of the associated streams reducing the long-term reliability of survey data. The data used for the majority of the analysis was collected or gathered by the Missouri Spatial Data Information Service (MSDIS). Most of the data was collected for planning purposes from 2007 to 2010 and is publicly available at *http://www.msdis.missouri.edu/data/lidar/index.html*. The data was collected in various datum and units and was converted to the design datum for this and parallel studies: Missouri State Plane East (FIPS 2401) in units of U.S. Survey Foot, Horizontal and Vertical Datum NAD83, NAVD88.

Surveys for use in design should be taken as close to the time of construction as possible to account for changes occurring in the interim and changes which may occur during design. Survey control requirements will vary from site to site as determined in preconstruction engineering design (PED) to achieve adequate precision in construction, but will utilize NGS Control Stations where available and appropriate. Design effort should be simplified as much as possible to reduce changes in site conditions during the intervening time between survey and construction.

1.3. EXISTING STRUCTURES

During the Civil War and Reconstruction Era, several mills were constructed and powered by the Big River, which were powered using the head differential afforded by low-head dams. The portions of these that remain are of interest to the public for a variety of reasons, including aesthetics, historical significance and conversely the hazards they can pose.

Little or no information on the construction methods and materials has been found, but research on similar structures elsewhere, coupled by observation of the remnant structures suggests that they were likely built using timber cribbing filled with rough quarried stone and capped with cut trapezoidal stone.

Additional structures have been found near the sites identified in Feasibility Level Design (FLD) and material estimation. These structures typically are formed of stone and appear to have been placed for the purposes of bank stabilization, but were inadequately or inappropriately implemented and have failed in that purpose. These structures will be removed during the construction of the adjacent stabilization projects and the materials reused to the extent practicable to reduce hauling costs.

1.4. CERCLA REGULATED MATERIALS – LEAD, CADMIUM, ZINC

The Old Lead Belt, which includes Jefferson, Washington, St. Francois and Madison Counties in Missouri were found to be rich in the mineral galena, amongst others, and were mined for lead ore and zinc from as early as 1720 (NAS, 2017; USBM, 1972). The mining and smelting processes left large quantities of waste that were stockpiled in mountainous uncapped piles. Wind, rain and floods have led to hundreds of uncontrolled releases of waste minerals contaminated by heavy metals, as well as refined lead materials from flooding of the mining and smelting works. The released materials have deposited in the channels and floodplains and continue to migrate through the Big River watershed and have a toxic effect on aquatic organisms.

The U.S. Environmental Protection Agency (USEPA) Superfund Region 7 (SUPR VII) is currently in the Remedial Investigation/Feasibility Study phase of the Superfund Process dictated by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) for most Operable Units (OU) related to these mining activities. The result of this process is expected to be a conceptual plan for remediating mine waste and establishing acceptable benchmarks and final target concentrations through Records of Decision (ROD), which will also establish the concentration at which soils and sediment are considered to be Hazardous, Toxic, and/or Radioactive Waste (HTRW) per USACE policy. These RODs may affect USACE ability to construct at sites with concentrations found to be at or above target levels due to USACE policy of avoiding HTRW. Sediment and soils containing lead concentrations within the study area that are above the Probable Effects Concentrations (PEC) for aquatic species (128ppm) will be referred to as “contaminated” materials, while those above the EPA ROD will be considered HTRW.

USACE is designing measures in the Big River for the USEPA through interagency agreements (IAs) to pilot and study innovative methods of removing and preventing reintroduction of contaminated sediment. Many of the existing and proposed pilot projects are similar to the measures identified in the Recommended Plan.

Table 1-1 shows a comparison of standard soil sieve sizes vs. estimated grain size of typical mining and smelting waste products found in the Big River sediments and floodplain. This table represents a compilation from investigations of mining practices and tailings piles by approximate timeframe (Pavlowsky R. T., 2017).

Table 1-1: Sieve and Grain Sizes of Mine Waste and Smelting Byproducts

Grain Type:	Gravel								Coarse Sand
Sieve Size (Imp.):	2.000"	1.500"	1.000"	0.750"		0.375"	0.004"		10
(mm):	53.9	33.1	26.9	17.0	16.0	9.52	4.76	4.0	2.00
Byproduct:					4-16mm, Coarse Tailings, ≤1860s				
Grain Type:	Medium and Fine Sands								Fines
	Medium		Fine Sand						
Sieve Size (Imp.):	20	40	60		80	100	200	230	>230
(mm):	0.840	0.420	0.250	0.200	0.177	0.149	0.074	0.063	<0.063
Byproduct:				0.06-0.20 mm, Fine Tailings, 1860s to 1972					Effluent/Slimes
Note: Concentration of lead (Pb) is typically inversely related to grain size; finer grain sediments carry higher metal content									

2. MEASURES

A suite of measures were developed during the Scoping Charrette to determine what improvements could be made to the aquatic habitat of the study area. The full list of measures and screening information is included in Chapter 3 of the Main Report. These measures are discussed in the following paragraphs, while specific hydraulic and hydrologic information is included in Appendix H-*Hydraulics and Hydrology Analysis*.

2.1. BANK STABILIZATION

2.1.1. MEASURE INTENT

In the unstable reaches of the Big and Meramec Rivers, caving banks are introducing excessive suspended sediment to the stream. These suspended solids are primarily fine soil particles that are contaminated and detrimental to mussels and many fish communities. Measures are considered successful in bank stabilization if the rate at which erosion occurs is reduced to those found in stable reaches, with small releases primarily occurring during high-flow events.

2.1.2. GENERAL DESIGN DISCUSSION

Two primary methodologies are utilized in bank stabilization which can be combined and include a wide variety of techniques and materials. These methodologies are to train the channel meander to a more stable configuration (i.e., river training structures) or to directly armor the toe of the bank. Each method, and the various techniques used to achieve them have limitations and potential adverse effects that can be unpredictable.

Bank instability is a difficult and dynamic problem to remedy. Streams with destabilizing stressors will continue to alter over time and an accurate estimate of the shear stress, velocity and spatial location (vertically, as well as horizontally) of the driving stress is difficult to achieve. Additionally, unstable reaches lend themselves to being “locked in” to configurations which are hydraulically inefficient and have the possibility of finding an alternative configuration by flanking the stabilization. Alternatively, moving the stream to develop a more efficient configuration is often expensive and could cause an increase in gradient of the stream (a reduction in stream length for the same relative drop in elevation) that can lead to head cuts, destabilization of adjacent reaches or other forms of migrating instability.

Using a variety of publications, a multitude of stabilization techniques were proposed for this measure, primarily using crushed stone structures and biotechnical stabilization constructions – using natural and biodegradable materials to provide temporary stabilization until natural stabilization of the bank can reoccur through vegetation establishment (often referred to as “bioengineering”). There are a multitude of these techniques which have varying degrees of applicability as stand-alone methods, but can be used in concert with other methods (Eubanks & Meadows, 2002; Li & Eddleman, 2002). Stone structures are generally simpler to construct, can make large changes to the local planform of the stream with little in-channel work, but can cause flow-reflection into adjacent banks, are expensive, and can also alter the local ecology. Biotechnical stabilization methods are thought to better mimic natural stream stabilization processes to create a more self-sustaining alternative to stone structures, while also enhancing the local habitat by providing organic inputs and cover for aquatic species. Biotechnical stabilization techniques have limits in terms of shear and velocity resistance (particularly during the first few years prior to vegetation development), are labor intensive and often require multiple specialized tasks and materials to achieve a functional product.

For alternatives development, biotechnical methods were selected where visual evaluation suggested they would be acceptable based on need for toe stabilization and stability thresholds (Frothingham, 2008; Fischenich, 2001). For FLD, a 1-dimensional (1D) 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. This process is discussed in greater detail in Appendix H-*Hydraulics and Hydrology Analysis*.

In more turbulent areas where stone structures must be used, a partially hybridized approach is assumed to be implemented for most locations by incorporating in-stream or harvested timber (referred to as “locked logs”) into the structure. These timbers will be placed on a foundation of stone beneath the estimated base-flow water surface elevation to preserve them from degradation and then locked in place by the remaining stone structure. Joint planting of willow stakes and similar vegetation will also be used at many locations to provide additional stabilization while providing additional riparian corridor habitat following the concept of live siltation and similar biotechnical stabilization techniques (Eubanks & Meadows, 2002). Where bank shaping or upper floodplain stabilization is also implicated, biotechnical soil stabilization methods such as live fascines and live brush layering (LBL) will also be considered. For FLD, all upper banks receiving bank shaping are assumed to implement LBL to provide additional temporary resilience until the vegetation is established.

2.1.3. QUANTIFICATION AND CONSTRUCTION OF BANK STABILIZATION FEATURES

For the purposes of the alternatives milestone, a simplified end-area-method of volume estimation is used throughout, excepting area features like tree planting, grass seed and mulch, etc., which were spatially estimated, and individual (“each”) items or complex constructions like grade control structures. The standard equation for this method is as follows:

$$V = \frac{1}{2}L(A_1 + A_2)$$

The variables used include Volume (V), Length (L) and cross-sectional Areas (A) at each of the two points considered. For features with a single cross-section throughout, the equation simplifies to:

$$V = LA$$

The following sub-sections are discussions for each measure and component feature with associated design and construction methods, along with the method and equations used to quantify them.

LONGITUDINAL PEAK STONE TOE PROTECTION (LPSTP)

Longitudinal Peak Stone Toe Protection (LPSTP) is a linear stone structure built of a riprap gradation stone. It is used when there is very little room to re-align the channel and when water velocity and stresses are high.

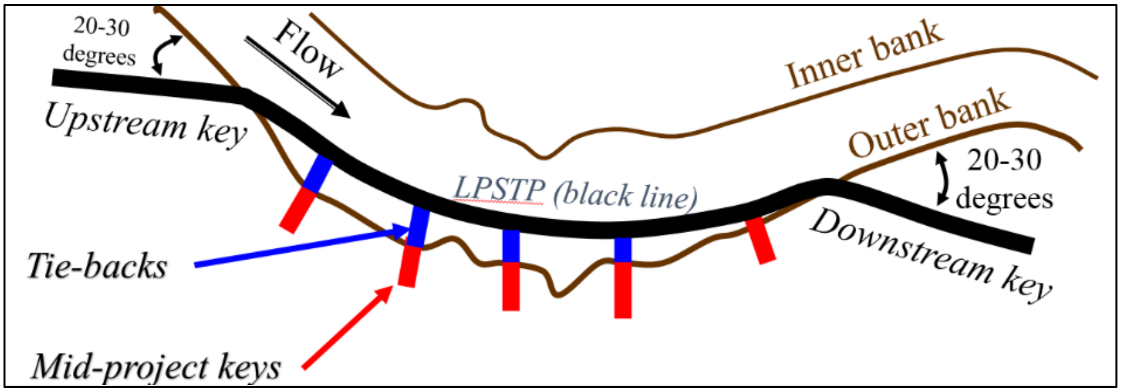


Figure 2-1: LPSTP Overview (Courtesy of Dave Derrick)

The LPSTP structure is composed of three sub-structures: the stone toe protection, the tie-in keys (upstream and downstream) and the tie-backs. Each of these sub-structures has a slightly different cross-section in reality due to where they are placed, how they are constructed and the composition of their foundation soil or sediment, but idealized cross-sections were assumed throughout to simplify quantification of materials. The stone toe protection is a peaked trapezoidal section of stone laid on a foundation key dug into the channel sediment. The sediment removed for this operation is typically backfilled behind (or landward of) the LPSTP and forms the foundation of the tie-backs, which are shorter peaked trapezoidal sections. The tie backs are keyed back into the caving bank, or, when the bank is shaped, will follow the new bankline up to tie in at the crest to prevent flanking of the LPSTP system. Where possible, live-siltation between these keys will be further encouraged by planting live cuttings or posts.

The tie-in keys are used to tie the protection into the stable portions of the existing bank, creating a continuous, stable line and preventing the river from flanking the LPSTP. They are constructed by excavating a trench which is nearly rectangular and placing geotextile on the soil beneath a bedding gravel before placing the riprap stone. The riprap is then often covered with soil that is packed down and planted with vegetation to create a hybridized structure. For the purposes of the alternatives milestone, all three sub-structures are considered to have the same cross-section, excepting that the foundation key is not included in the tie-backs.

The main cross-section is a simple trapezoidal section, calculated as a function of height (h) and length (L) with crown width (W_c) and sideslope-run (x_s) as constants:

$$V = L(W_c h + x_s h^2)$$

Where $Sideslope = \frac{1}{x_s}$

The crown height should be based on the height of the point bar opposite to it, which is approximately the flow height for the 66.7% annual chance exceedance (ACE) flood, still often referred to as the 1.5-year flow height. The foundation key volume is a function of length multiplied by a constant rectangular section. The volume calculations are multiplied by a typical conversion factor for in-situ unit weight to estimate tonnage of stone to be purchased. The number of locked logs, which are used to dissipate reflected velocity from the stone and provide ancillary habitat benefits, are calculated by dividing the length of the LPSTP by a constant spacing and rounded to the nearest piece of timber. Locked logs are not used at locations where swimming or wading are common due to a public safety consideration, as there are anecdotal reports of individuals being swept under such structures and unable to surface for air.

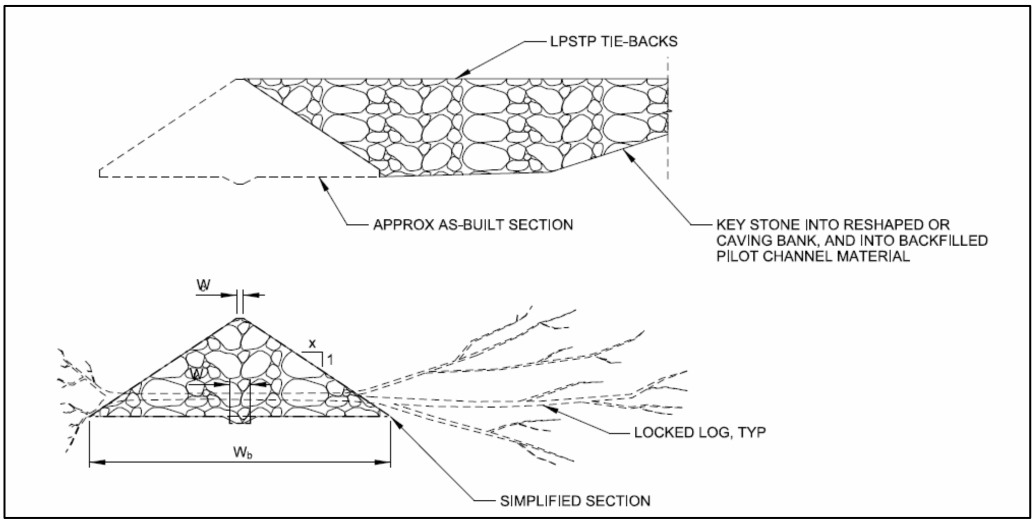


Figure 2-2: LPSTP Details

BENDWAY WEIRS

Bendway weirs (weirs) are low elevation stone structures used to re-direct the channel alignment and reduce the river's width to depth ratio. Bendway weirs protect the bank by reducing near bank velocity, re-directing flow away from the bank and interrupting secondary helical currents. These weirs are used on relatively gentle bends when there is plenty of space available to re-align the channel.

Bendway weirs were quantified using the same fundamental equations as the LPSTP, but are located at an angle approximately 10 to 15 degrees from perpendicular to flow, angled upstream from the bank to the thalweg. They are then keyed into the bank, or, when used in conjunction with LPSTP, are placed on the same spacing as tie-backs. These keys should have a length equal to 1.5 times the bank height, and a height equal to the elevation of the top of the opposite point bar. The crown width, (W_c) is typically larger than that of LPSTP, usually around 2 feet instead of an approximate peak.

The design elevation of the crest is one foot above base flow (much lower than stream barbs and LPSTP), with one half foot of tolerance up or down. Weirs have a foundation key similar to LPSTP, which is estimated as a constant, rectangular cross-section.

Figure 2-3: Bendway Weirs in Physical, Movable Bed Model (Courtesy of Dave Derrick)

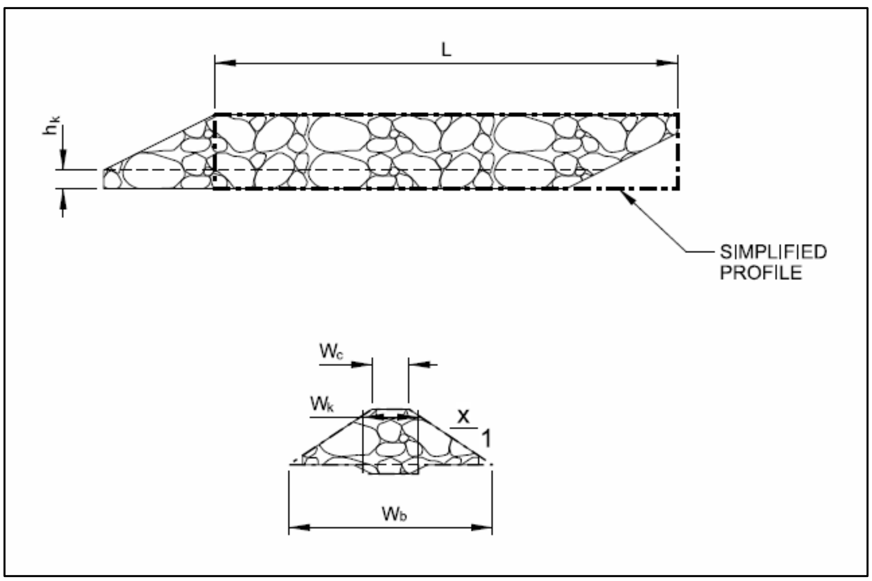


Figure 2-4: Weir Details

STREAM BARBS

Stream-barbs (sometimes referred to simply as "barbs"), are utilized similarly to weirs, but are angled more sharply upstream. Unlike weirs and LPSP, barbs have a sloped crest tapering from the top elevation down to a minimal section as the structure moves from bank down toward the stream thalweg.

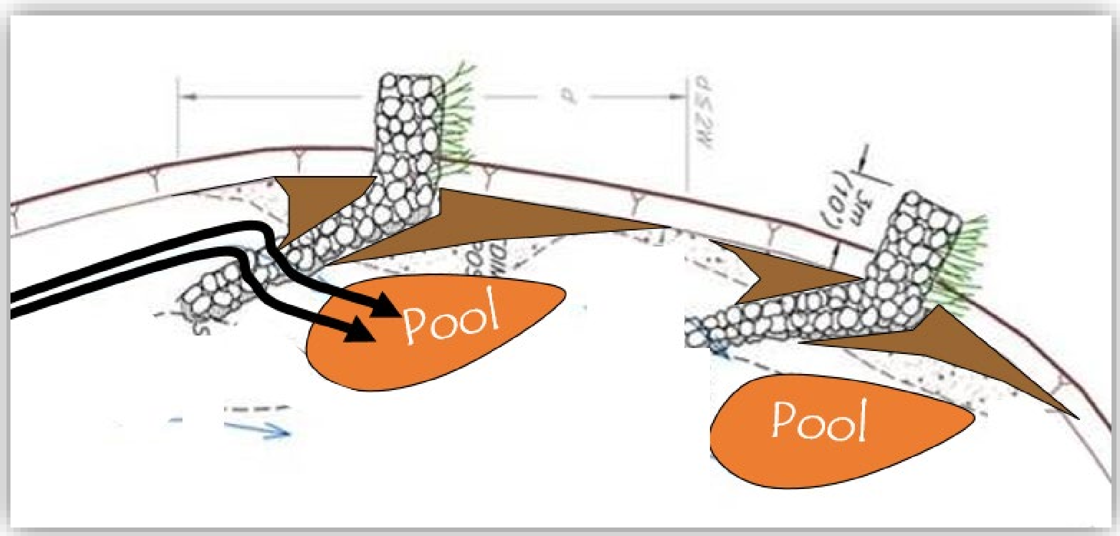


Figure 2-5: Plan View of Stream Barbs (Courtesy of Dave Derrick)

The stream barbs are keyed into the bank a standard length, a portion of which is trapezoidal, while the portion that is located in the trench cut from the bank is approximately rectangular. The barb keys are assumed to be a trapezoidal section throughout using the same equation provided previously, using a constant proportion of the maximum height of the barb. The top of the crest of the barbs at the bank should be the same elevation as the opposite point bar. The key length should be 1.5x bank height, and the key height should be the same as the crest height. The sloped portion of the barb should be sloped at approximately 10% to 15%.

The volume is calculated using the average end-area method, with A_1 being considered negligible, simplifying to the following:

$$V = \frac{1}{2}L(W_c h + x_s h^2) + L(d_k W_k)$$

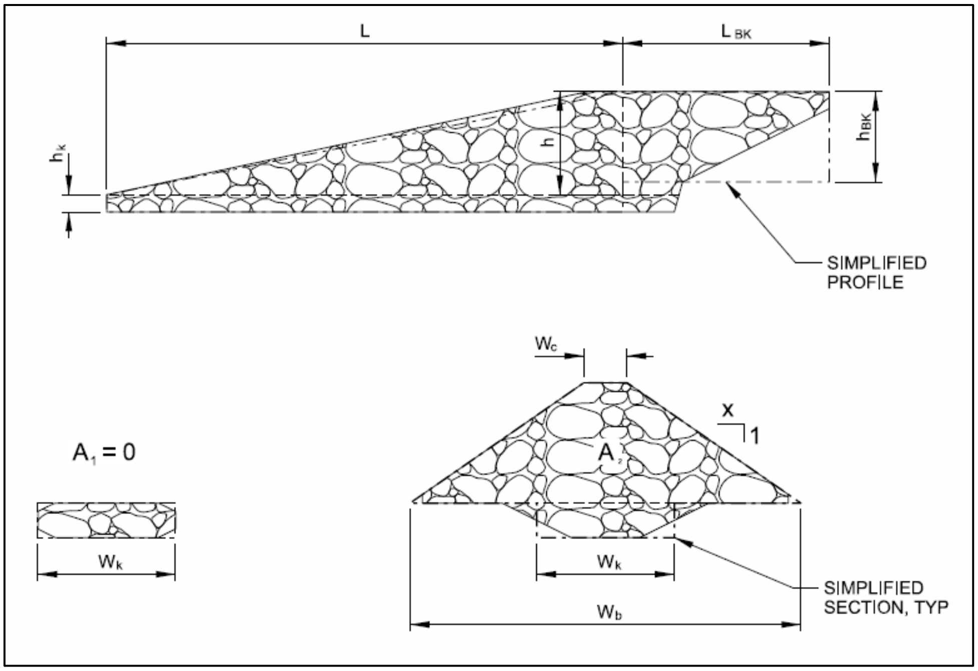


Figure 2-6: Stream Barb Details

ROOTWAD REVETMENT

Rootwad Revetment is a broad term for biotechnical stabilization using intact tree roots and trunks in a configuration to protect or restore a failing bank. The specific configuration of rootwad revetment is assumed to follow the Toe Wood Structure (Rosgen), which is formed by placing harvested timbers on footer logs or stone foundation, then backfilling with soil, sod and a natural fabric like jute. This multi-layer soil system is planted with live willow poles, floodway plant seeds, etc., to create a low floodway bench next to the re-shaped bank.

This stabilization technique requires that the bank be excavated back enough to allow for placement of toe wood and backfill. It is preferable to use this in locations where the river has already removed a sufficient portion of the bank to make space

Figure 2-7: Toe Wood Immediately after Construction, LaBarque Creek, Coastal Hydrology, Inc.

for placement of the logs. Rootwad revetment is also best suited for lower stream velocities than LPSTP, though hybridized approaches are experimentally showing higher resistance capacities.

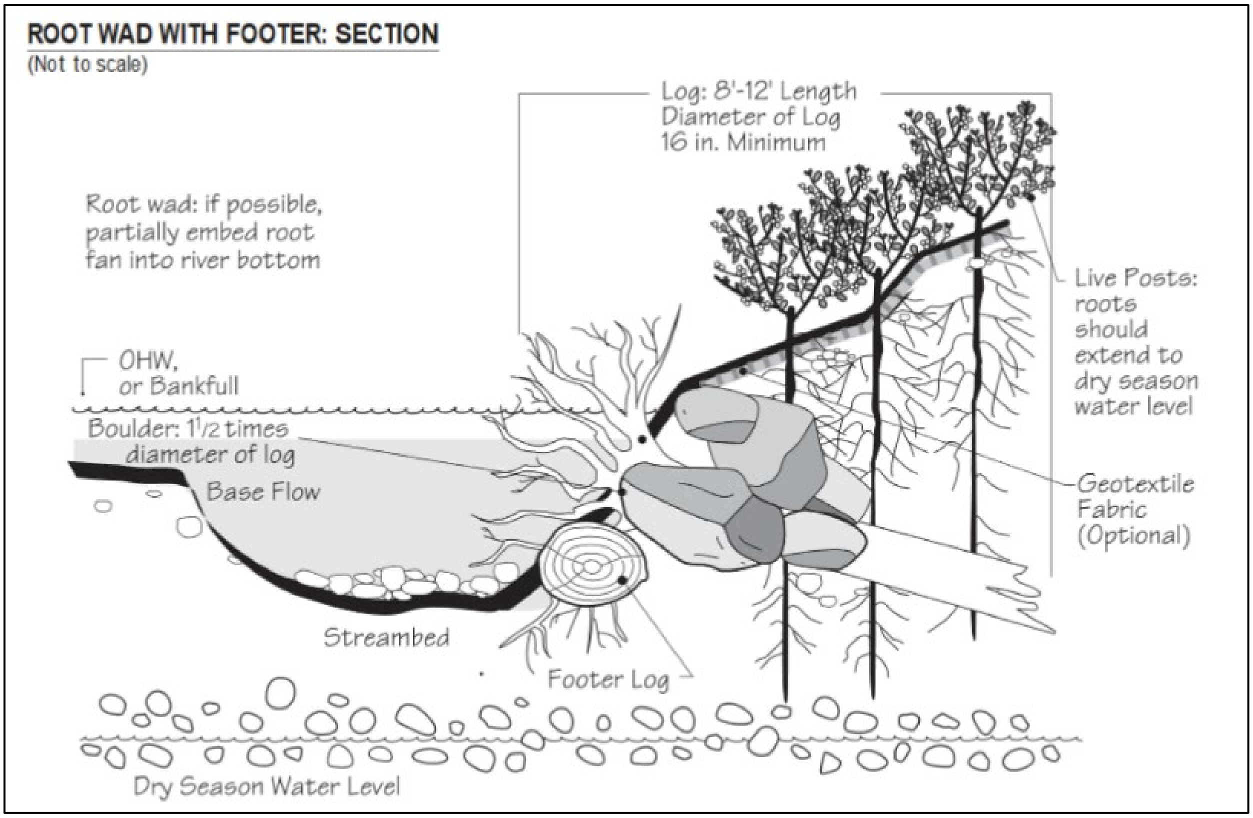


Figure 2-8: Cross-Section View of Rootwad Revetment (Eubanks & Meadows, 2002)

The quantities are calculated using the same procedure as the locked logs in LPSTP, though the spacing between pieces is much smaller. Since toe wood structures typically are not able to induce channel change ("train the river"), a pilot channel and other manual re-shaping of the bank and stream are necessary. This material is considered to be reused on site, either locked between the individual pieces to form the toe-wood itself, or cut and backfilled into a new bank at a shallower and more stable angle of repose. The toe-wood timbers use a sequence to alternate between timbers with intact rootwads and those that do not. This sequence can vary between 1:1 and 1:3 depending on the relative width of rootwad and trunks, and is dependent on the harvest source. Ideally, all materials (excepting fabric, seeds, and stone, if any) will be harvested on site. The quantity of soil is calculated separately as pilot channel excavation and/or bank shaping. Willow poles and seed are quantified by an estimated area of floodway plantings, and fabric and harvested sod are considered incidental to the timber harvest and placement costs.

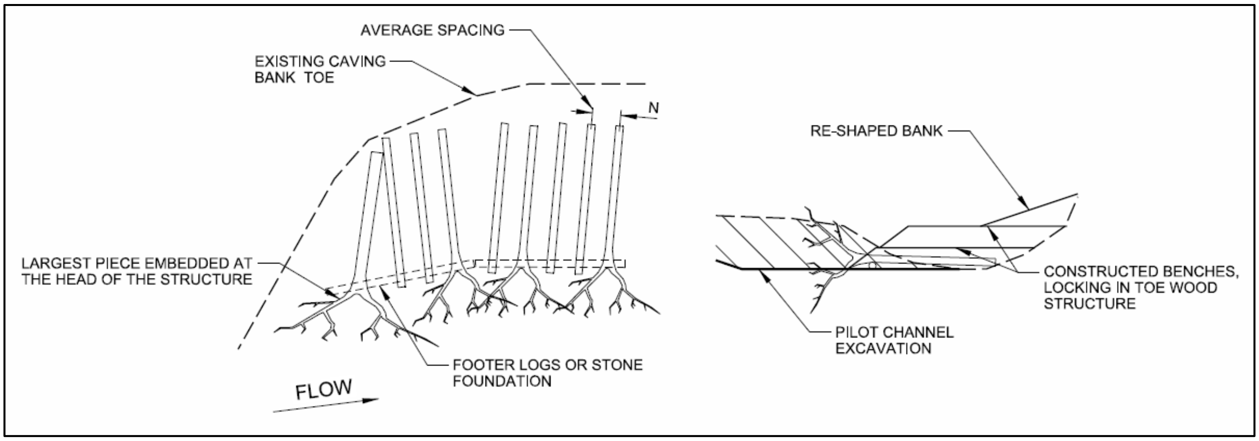


Figure 2-9: Toe Wood Structure Typical Details

A simple alternative similar to rootwad revetment is tree revetment. This method requires minimal excavation – just anchor trees along the bank of the river to absorb the river's energy. Cedar trees are recommended in this application due to their ability to resist decay, and their multitude of branches disrupt velocities. The Missouri Department of Conservation (MDC) Stream Management Guide recommends this method be limited to caved banks shorter than 10 feet in height, and that the revetment cover the lower two-thirds of the bank. Larger banks are not able to be adequately covered by this form of revetment and are likely subject to greater velocity and shear than they are able to withstand.

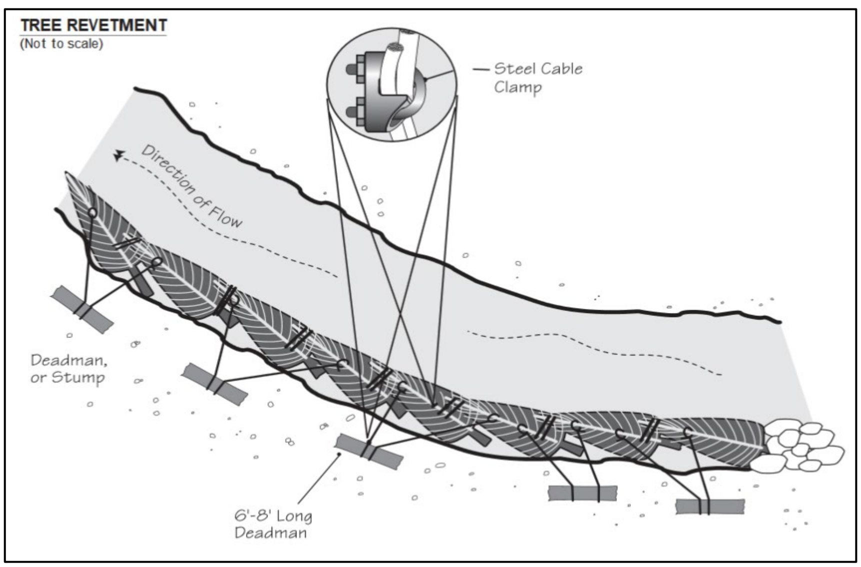


Figure 2-10: Plan View of Tree Revetment (Eubanks & Meadows, 2002)

While this method will be considered during PED wherever applicable within the above limitations, but for the purposes of this study, they have been assumed infeasible and not been used.

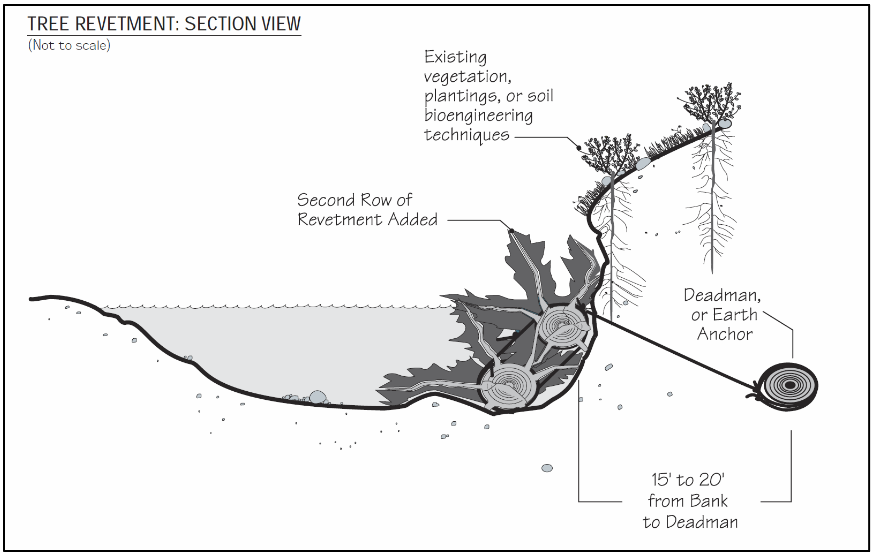


Figure 2-11: Tree Revetment Section view (Eubanks & Meadows, 2002)

BANK SHAPING AND PILOT CHANNELS

For the purposes of FLD, all bank shaping locations are assumed to incorporate the biotechnical stabilization feature Live Brush Layering (LBL). This approach uses live vegetation cuttings (likely sycamore and willow) harvested nearby and a biodegradable temporary erosion control fabric (TECF) to provide roughness and soil protection, respectively, until the vegetation can establish. Figure 2-12 shows an example project which utilized LBL above a buried stone toe protection system in Noel, Missouri that was implemented under management by The Nature Conservancy (TNC) in cooperation

Figure 2-12: LBL immediately and several months post-construction (Courtesy TNC)

with the landowners. To construct LBL, the bank is cut into terraces of a set height, and TECF, usually coir or jute, is laid out above a layer of live cuttings to width much larger than the width of the terrace. The TECF is usually staked down with untreated wood stakes, then filled with soil that is blended with a native seed mix. The excess fabric is then wrapped around the soil and onto the next terrace, where live cuttings are again placed, and the process is repeated until the design elevation is reached. The number of LBL rows or terraces is estimated by dividing the total bank height by a standard row height. A schematic of idealized fabric placement is shown in Figure 2-13, and quantified by using the following equation:

$$A_{TECF} = L\,\{\sqrt{(1 + {x_s}^2)(h_{Row})} + 2(x_s h_{Row} + x_L)\}$$

Live cuttings and stakes are estimated by dividing the total length (L) by a standard spacing for each, then multiplying it by the number of rows of LBL. More precise methods may be incorporated into PED to take into account changes in the bank height between the stable reaches to which the LBL will tie in. The soil volume is calculated using the bank shaping methodology below.

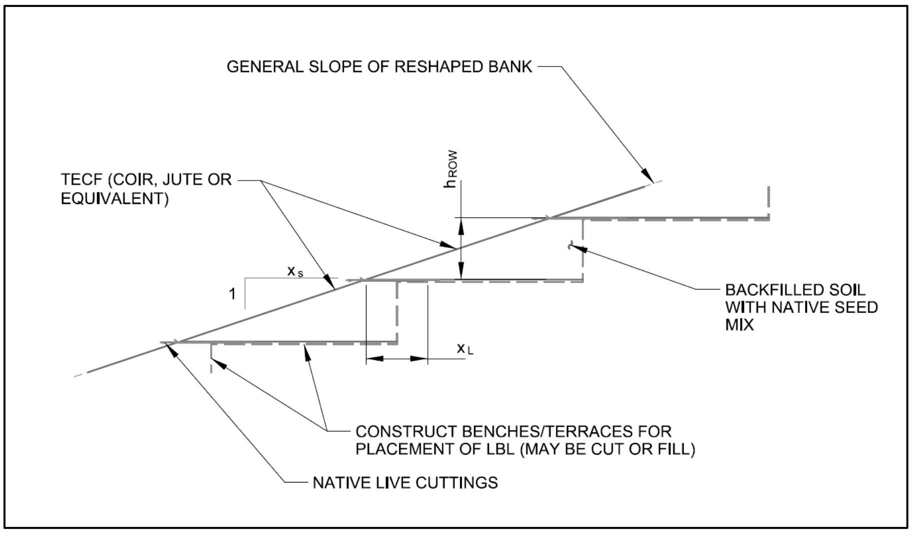


Figure 2-13: Live-Brush Layering (LBL) Typical Details

Bank shaping is assumed to be a uniform triangular section along the length of the bank providing some conservativity to the calculation. The section calculation is a function of height and side-slope, much in the same method as the trapezoidal sections for stone features.

$$V = \frac{1}{2} L x_s h^2$$

The height of cut is reduced from the total bank height to match any adjacent Toe Wood or LPSTP structures, when applicable.

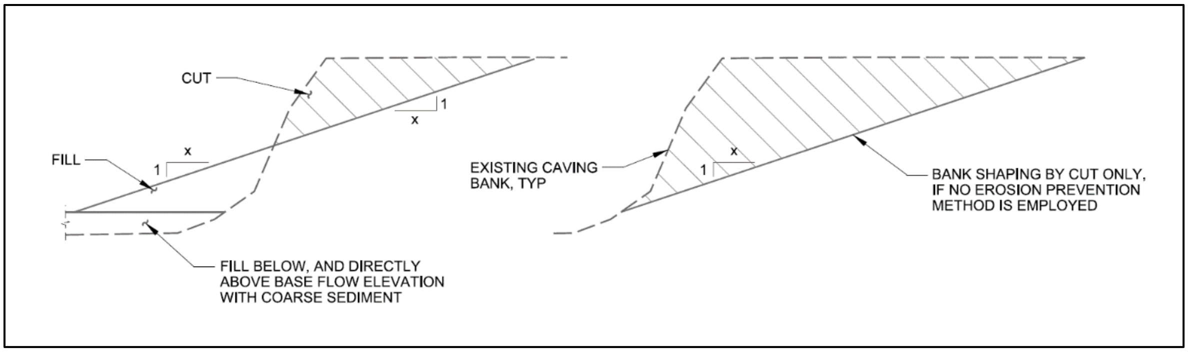


Figure 2-14: Bank Shaping Details

Pilot Channel Excavation is used to manually adjust the stream thalweg to reduce pressure on the constructed stabilization. It is a highly invasive process that disturbs bedded sediment and can cause adverse effects to the bed and bank stability at and near the site, but is often necessary for biotechnical techniques, and where bank stabilization requires channel migration to a new location while attempting to minimize the adverse response potential. It is also a common method of flow diversion, improving constructability and reducing storm water pollution from the bank. It is calculated using a measured area estimate multiplied by the depth of cut, with a reduction for side-slopes calculated in the same manner as bank shaping.

$$V = A_s d - L x_s d^2$$

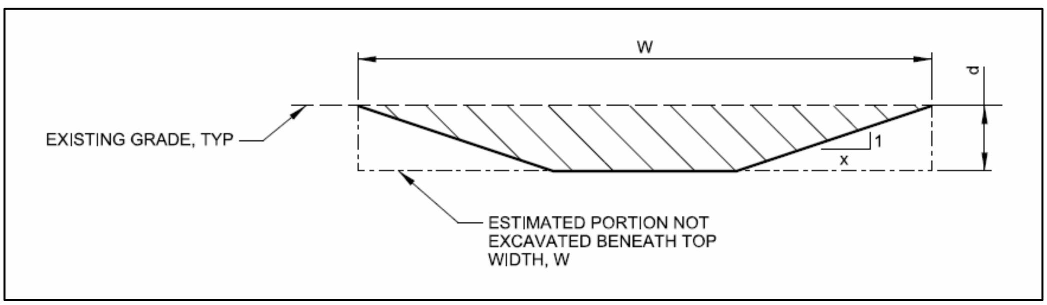


Figure 2-15: Pilot Channel Details

Material excavated for bank shaping and pilot channel excavation is assumed to be reused on site when incorporated into a LBL or similar system. Any site that does not implement a soil protection system is assumed to be unable to prevent the material from uncontrolled release back into the river, thereby negating or reducing the benefits and possibly increasing liability. This material would be required to be hauled off for disposal to avoid reintroduction/release. For FLD, all sites are assumed to incorporate live brush layering or similar protective systems, and it is assumed that soil and sediment materials to be reused to backfill/construct those features will have minimal likelihood of reintroduction. Coarse material (gravel and sand with minimal fines) excavated from the channel will be placed beneath, and immediately above, the base flow elevation. Material used in the upper terrace of toe wood structures and in the majority of bank shaping will be fine grained soils, typically clayey silt with sand based on adjacent geotechnical information, discussed in Chapter 4 of this appendix. This is expected to mimic the native bank soil structures common in the Big River, thereby improving survivability of native plantings and subsequent riparian habitat.

TREE SCREENS AND OTHER RIPARIAN PLANTINGS

Tree screens and riparian corridor plantings are used in conjunction with bank stabilization to improve hydraulics and provide ancillary habitat, as discussed in Section 2.2, and quantified in the same way. In highly unstable reaches where a configuration that is both hydraulically efficient and cost-effective could not be found, a standalone riparian tree planting zone is recommended in lieu of more-structured techniques. This is considered to have less benefit (and a reduction factor was assumed for bank stabilization benefit inputs from those sites for comparing Alternatives) than the more direct approaches, but may eventually be successful in helping the system reach a new equilibrium with minimal cost and disturbance.

Floodway plantings have been incorporated into many of the bank stabilization measures included in this report. These include brushy and other fast-growing native vegetation plantings by a variety of techniques, including bare-root planting, seed and mulch, and live staking or live-post installation.

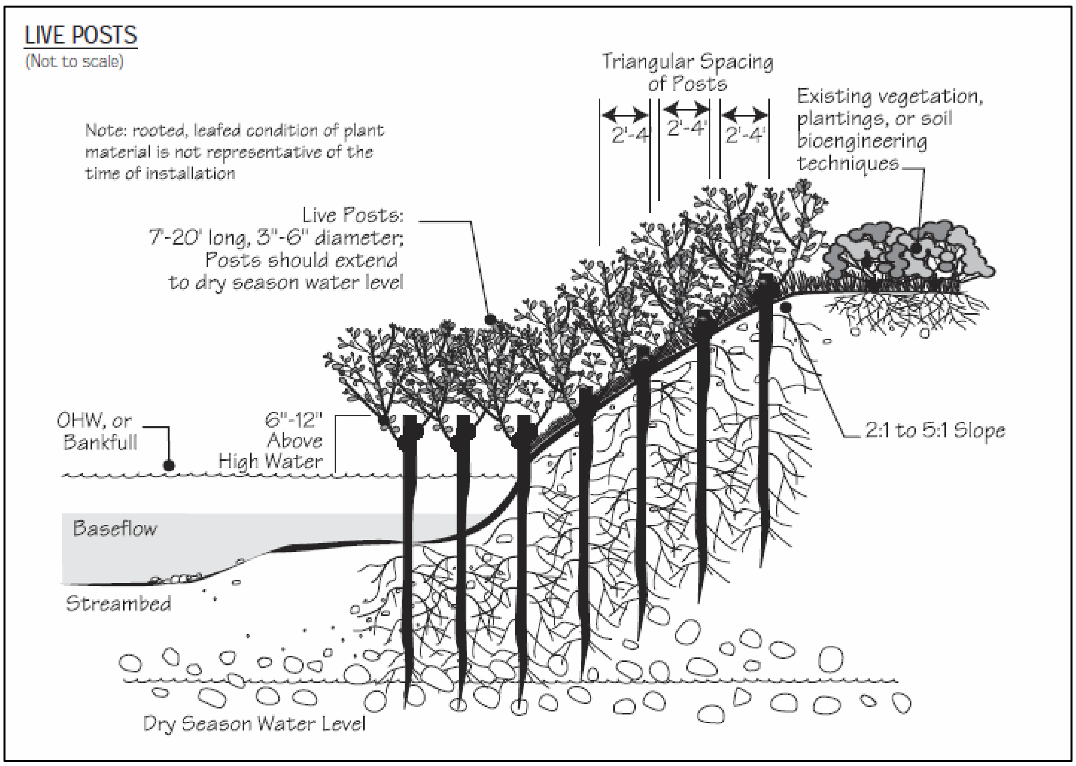


Figure 2-16: Cross section view of live posts (Eubanks & Meadows, 2002)

Live posts are sometimes implemented as a form of permeable revetment for a stream bank. Consisting of vegetation such as willows and poplars, live posts root strongly into the bank, reduce water velocity and cause sediment to deposit near the posts. This measure has the potential to quickly establish riparian vegetation in a natural way, but should not be used in actively-eroding areas, limiting its applicability for this study.

Live post revetment, along with other biotechnical stabilization techniques, including brush mattresses, branch-packing, cedar tree revetment (as previously discussed), etc., may be considered in PED, where appropriate, but were not quantified at this early stage of design, except as discussed in LBL.

2.1.4. DESIGN RISK

Stabilized banks may experience forces greater than expected and designed for that will cause the stabilized bank to deteriorate and/or fail. Conservative design practices including use of nature-based stabilization systems, floodplain bench enhancements to increase cross-sectional flow area, active adaptive management, and sufficient OMRRR mitigate this risk. Use of calibrated hydraulic models to further mitigates this risk, since design parameters can be closely estimated.

Stabilized banks may experience flow that travels around the constructed structure, a process known as flanking which can render the stabilization useless. Best-practice design of keys and tie-backs, along with proper vegetative plantings, mitigates this risk.

2.1.5. OPERATION, MAINTENANCE, REPAIR, REHABILITATION AND REPLACMENT (OMRRR)

Stone features may require a small quantity of additional stone to repair sections locally affected by high-velocities, human disturbance, etc., and weathering. Weathering effects are typically greater than the 50 year project life before rehabilitation or replacement is necessary. Stone features will also require lifecycle analysis long after implementation to determine if they are still necessary. Partial or complete removal of stone structures may be necessary to allow the river to return to a natural meander, particularly if adjacent areas have adjusted to such an extent that the stone structures are causing more harm than benefit.

Tree revetment, whether rootwad revetment, cedar tree revetment or toe wood structures, have limited documentation of their ability to withstand the wear and tear of repeated flooding and decay of the timbers over similar durations to the 50-year period of analysis. It is theorized the tree revetment will become self-sustaining natural systems and not need to be replaced. To error on the conservative side for cost purposes, the revetments are assumed to require replacement at some point before the end of the 50-year period of analysis.

Plantings will require OMRRR as discussed in Section 2.2 and similar general care until they are established.

2.2. REFORESTATION

2.2.1. MEASURE INTENT

A well-vegetated riparian corridor, defined as the few hundred feet of bank and floodplain directly adjacent to the stream, is a primary indicator and requirement of a healthy stream. The trees adjacent to the stream break up flood velocities, hold soil, detain runoff (a primary source of turbidity and increases in hydrograph peak discharges) and provide shade and nutrient inputs to the stream. Reforestation is the portion of tree plantings intended to create floodplain forest habitat, with these other benefits considered ancillary. The tree plantings intended solely for the purposes of hydraulic and hydrologic risk reduction is discussed in Section 2.3.3.

2.2.2. DESIGN DISCUSSION

Tree plantings will require tilling of grassy vegetation in most instances, as corridor is commonly cleared for use as sod farms, pasture, or domestic yards. After tilling, the bare-root seedlings will be installed either by use of seed drill or by excavation and backfill, then surrounded by leaf-litter and wood chip mulch, creating a ring around the tree for retaining moisture around the roots. A cover-crop of native-mixed grassy vegetation will be seeded and mulched with straw in between the trees to reduce likelihood of becoming an attractive nuisance area for invasive plants, as well as providing localized root stabilization of floodplain soil. A phosphate-based fertilizer will be used throughout the area to assist in plant development while also reducing the bio-availability of lead within the soil for foraging animals that are attracted to the site. All portions of construction for riparian plantings are included in a per-acre cost, the acreage measured from the footprint developed in ArcGIS or Computer Aided Design (CAD) software.

Figure 2-17: Riparian Corridor Plantings and Cover Crop

2.2.3. OMRRR

The cover crop will be mowed for the first five years after tree planting to ensure adequate sunlight for the juvenile trees, and trees that die after the one-year warranty period will be replaced by the sponsor at their cost.

2.3. GRADE-CONTROL STRUCTURES

2.3.1. MEASURE INTENT

Grade control is a bed stabilization measure. These structures control the overall slope of the river (also referred to as grade or gradient), particularly in instances where the length of the channel has been reduced by a natural or anthropomorphic cut-off. A drop can also occur if the bed is destabilized by in-stream excavation. In locations where a drop or cut-off has occurred, these structures absorb and direct the kinetic energy with larger materials than are available to that reach of the river, preventing or arresting a headcut condition, such as that shown in Figure 2-18. Headcuts typically migrate upstream, as the flow continues to erode the bed until dynamic equilibrium is reestablished.

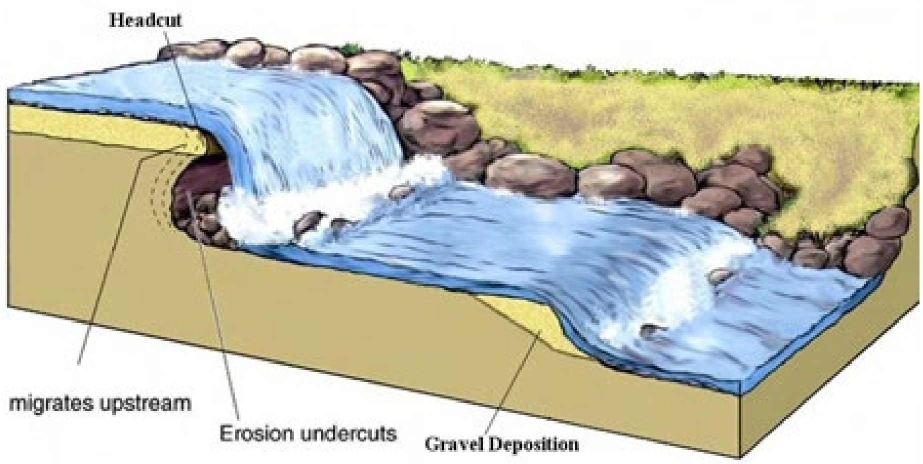


Figure 2-18: Diagram of a Head-Cut (NYDEC, 2014)

In most streams, grade control structures are generally designed with less than two feet of head differential to reduce the risk of failure and subsequent headcut, as well as impacts to aquatic species passage. In the case of the Big River, these structures may be designed at higher head differentials to slow and sometimes stop migration of sediment downstream, protecting downstream mussel communities from inundation by contaminated materials. Some measure of grade control was (and in certain cases, still is) provided by each of the mill dams, making these locations the primary focal area for applying this measure. Smaller grade control structures than those used for dam replacement and sediment detention may be implemented as part of, or in lieu of bank stabilization using more traditional sill or very low-head designs.

2.3.2. DESIGN DISCUSSION

These structures will be generally designed as engineered rock riffles. In many cases, these designs will be larger in scale than typical structures. As such, they will require that fish- and recreation-passage is incorporated, as with the structure replacing the Frankenmuth Dam constructed by USACE Detroit District (CELRE) in 2014-2015. Most design guides recommend building these structures with a backslope (downstream) of 1:20 (USDA, 2007) as was used in 2014 to construct a structure in St. Francois County as part of a USEPA pilot project to detain lead contaminated sediment and mine tailings runoff from a nearby pile; however, more recent performance data recommends a shallower slope of approximately 1:30 yields better results for aquatic species passage (CELRE, 2013).

Figure 2-19: Frankenmuth, MI, Engineered Rock Riffle with Integrated Weirs, Google Earth 2016

Additionally, since the construction of the St. Francois County structure at river mile 96 was installed, the USEPA has received multiple complaints from resource agencies and interest groups about its weirs forming a barrier to benthic species as well as canoe and kayak passage. The Frankenmuth ramp designed the integrated weirs to leave a central channel for larger fish and benthic species, and to allow passage of canoes and kayaks, while leaving slackwater pools along the edges for smaller fish to rest while migrating upstream.

The crest of these structures must be keyed into the banks on either side in much the same way as LPSTP to ensure the structure is not flanked, and a foundation key is recommended beneath the upstream and downstream toes to account for localized scour effects. With the exception of the weirs which are constructed of individually graded stones, the foundation stones must be well graded riprap to allow for the structure to self-adjust under loading as well as potentially changing bathymetry resulting from the profile changes. Water surface head differentials of more than three feet but less than six feet may require the use of a cutoff wall to prevent seepage. Loose stone rock riffles should only be used if the head differential is less than three feet. If a large head differential exists, then multiple structures spaced appropriately can take the place of a single, taller structure.

For FLD, design values completed using Computer Aided Design-Civil Information Modelling (CAD-CIM) for similar structures at Rockford Beach, RM 10 (under a USEPA IA) were used as the basis for quantity development. The quantity of stone and that of excavation were divided by the area footprint of the structures, providing a coefficient against which other structures could be quantified. This is an inexact method, and will require refinement during PED using CAD-CIM.

Figure 2-20: USEPA Engineered Rock Riffle Pilot Project, Big River Mile 96

Figure 2-21: Very low head grade control structure (Photo Courtesy Trout Unlimited Canada)

Small grade control structures may be used in tributaries or as localized bed stabilization without increasing the existing or native head differential. These structures will ideally be placed within existing riffles by excavation, placement of bedding material and riprap up to the existing grade, commonly referred to as sill-structures. These structures will be keyed into the banks in much the same way as the larger versions. Where used, the volume of stone and excavation to be used was estimated by a footprint drawn in CAD and a typical depth of stone. Figure 2-21 shows an example of a very low head grade control structure (Photo found at http://brontecreekrenewal.blogspot.com/, accessed 11/23/2018).

2.3.3. DESIGN RISK

Grade control structures may experience forces greater than expected and designed for that will cause the grade control structure to deteriorate and/or fail. Resilient design practices including stone size and gradation, shallow constructed slopes, active adaptive management, and OMRRR mitigate this risk. Use of calibrated hydraulic models further mitigates this risk, since design parameters can be closely estimated.

Grade control structures may experience flow that goes around the constructed structure, flanking it and rendering it useless. Conservative and best-practice design of keys, self-launching stone to arrest bed instability and proper vegetative plantings mitigate this risk.

Additionally, those structures intended for sediment detention will require close monitoring of the bed profile to determine to what extent they are providing storage. Sediment detention in low-head dams has been found to be episodic and difficult to predict (Csiki & Rhoads, 2010; 2014; Pearson & Pizzuto, 2015), and thus adaptive management of these systems and the sediment management program as a whole will be key to long term success.

2.3.4. OMRRR

As with other stone features, these may require a small quantity of additional stone to repair sections locally affected by high-velocities, human disturbance, etc., and will weather over time. Weathering effects are typically greater than the 50-year project life before rehabilitation or replacement is necessary. Companion plantings as a biotechnical stabilization approach may also be necessary along the banks and keys to ensure longevity of these structures. Woody vegetation should be prevented from establishing in the central portions of the structure, as roots may cause damage to the stone foundation and prevent launching of graded riprap.

2.4. SEDIMENT BASINS (OFF-CHANNEL SEDIMENT COLLECTION SYSTEMS)

2.4.1. MEASURE INTENT

Excessive and lead-contaminated sediment is considered the primary driver of habitat loss for mussels in the Big River, and as the contaminated sediment continues to migrate, will also significantly affect aquatic communities in the Meramec River. Reduction of excessive sediment is best accomplished by prevention, changing land-use and farming and construction practices to prevent stormwater pollution. Once in stream, however, traditional options are limited to direct excavation (mechanical or hydraulic dredging), which carry a high cost, both monetarily and to the adjacent habitat as discussed in Section 2.6. Alternative methods of removing sediment from the system are being developed, and are included in the suite of measures recommended by this study. One of these methods is establishing off-channel sediment collection systems, referred to as Sediment Basins (or Traps or Sediment Capture features).

Sediment basins collect sediment carried by high flow events within the floodplain. These systems are thought to have reduced (potentially negligible) hydraulic and ecological impacts than those often caused by direct excavation or dredging. Sediment basins reduce the likelihood of head cuts, material reintroduction into the water column and uncontrolled releases from cutting equipment, as well as alleviate the cost of mobilization and difficult working conditions.

2.4.2. DESIGN DISCUSSION

Sediment collection basins are constructed so that flow from the main river channel is diverted to a large area in the floodplain where flow velocity will decrease and sediment is allowed to deposit. After the basin has filled with sediment it can be capped in place or the captured sediment can be excavated and the basin can fill again.

Sediment basins have highly specific site conditions that must be met, as they need to be positioned where the river will bring the maximum amount of sediment. Additionally, a great deal of hydraulic analysis will be required to estimate the optimal height and depth of both the basin and control structures to facilitate capture of the target sediment sizes.

Basins placed low in the floodplain, particularly those located in existing high-flow channels, are expected to capture fine sands. Basins placed in floodplain terraces, or which are only accessed by

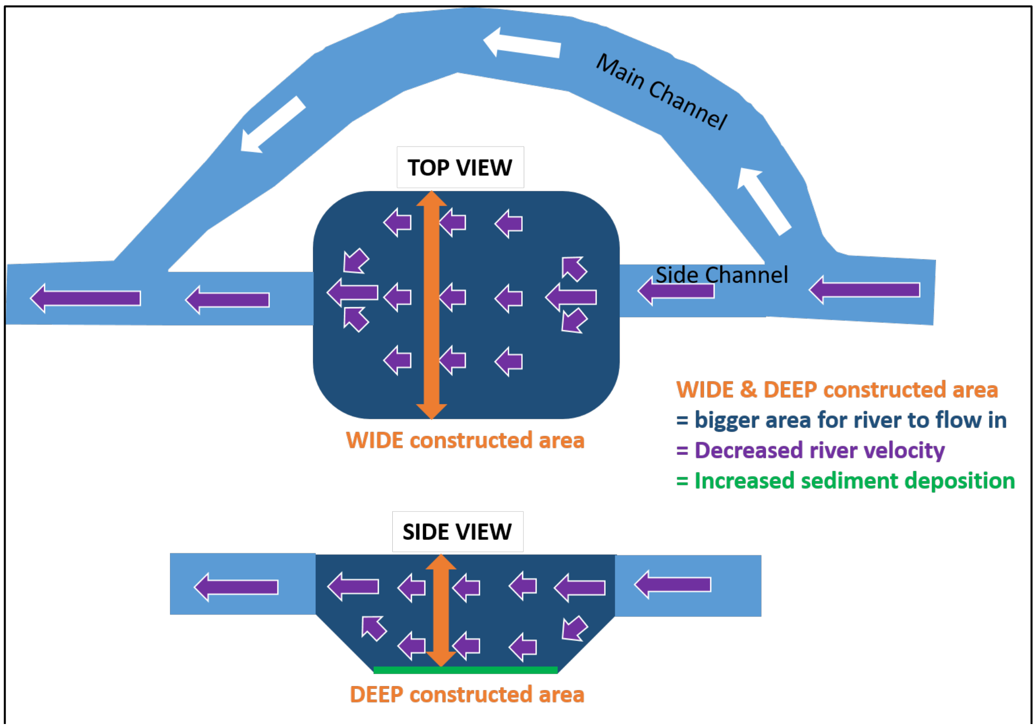


Figure 2-22: Sediment Collection Basin Conceptual Diagram

floodwaters backing into the trap, are likely to collect fine sediment with minimal coarse load. The water detained within the trap will then drop fine-grained sediment from suspension, after evaporation and/or after infiltration through soil or filter structures. A combination of each of both basin types is recommended.

In the case of all but two of the sites selected for this measure, previous land-use can drastically reduce the cost of construction. Sale of soil for construction fill, commercial sod farms and sand and gravel for aggregate and decorative stone is prevalent in this watershed. These land-use practices require careful design and management to prevent potential damage to the streambed and banks and uncontrolled stormwater sediment pollution. Conversely, such land-use creates low-lying areas in the floodplain which may be modified through minimal construction of berms and control structures to become effective traps. Establishing berms and vegetation to improve hydraulic trapping efficiency would also result in ancillary forest habitat benefits and localized Total Suspended Solids (TSS) reduction.

Figure 2-23: USEPA Pilot Sediment Basin at Big River Mile 59.6

In the case of the basin at river mile 25.5, the landform provides a natural location for a trap targeting fine sediment, as the upstream flank is protected by a bluff, while the floodplain of a small stream creates a low-lying area in which a bermed area could be established. Berms would be established to collect sediment and prevent erosion into the Big River and adjacent tributaries and create conditions in which fine-sediment will likely deposit over time. In the case of the series of basins outlined in the site at river mile 62.5, the selected area is flat farm land, and thus no existing landform is available for establishing a collection basin. This site will require wholesale removal of sediment from the floodplain terrace which will then be disposed of in a landfill or repository legally capable of storing CERCLA regulated material.

The construction quantities and capacity estimates for the sediment basins were developed using rudimentary models drafted with InRoads CAD-CIM software. The inlet and outlets of the sediment basins include overtopping control structures (designed similarly to and often referred to as small grade control structures) to protect the embankment and provide a path for water egress. Quantities for grade control structures were determined using area calculations in the same manner as those discussed in Section 2.3. In some cases, these structures are intended to prevent a shift in the river thalweg by scouring through the basin. The control structures should be designed to allow the river to begin accessing the sediment basin at median flow, with design benefits occurring near and above bankfull flow. The basin itself should be deep enough to efficiently capture sediment – generally greater than 5 feet. In many cases, the core of these structures will be designed with filtration in mind, with the core composed of gravel and sometimes sand and geotextile to retain sediments within the basin but allow water to seep through. Each of these structures is generally based on structures constructed for the USEPA Pilot Sediment Basin at Big River Mile 59.6, in Jefferson County, Missouri (Figure 2-23) in 2017. The lessons learned from this system are expected to inform future design and adaptive management of these structures and collection systems, in general.

In nearly all cases, tree screens and turf grasses are recommended to control erosion, direct flow and reduce noise and visual pollution to the nearby residents.

2.4.3. DESIGN RISK

See Section 2.3.3 for risks to sediment capture basins at high flows as it pertains to their grade control structures.

Sediment capture basins may experience moderate to severe scour at very high flows, depending on local conditions: location with respect to main flow line and geometric configuration (primarily depth, but also sharpness of slopes and imposed flow radius of curvature).

Sediment capture basins may experience high levels of sediment deposition in unexpected areas, which could hinder lower design flows from reaching the basin. This is because high flows can contain larger volumes of sediment that may behave in unexpected ways not originally designed for. Additional performance information from the EPA Pilot Basin at Mammoth Road will be utilized in final design, and these innovative systems will be closely monitored during the Adaptive Management phase for performance concerns and recommendations.

2.4.4. OMRRR

This report assumes the basins will be operated “passively,” meaning that the material collected in the current set of basins is not expected to be excavated during the project life; however, some amount of earthwork may be necessary to ensure they continue to operate as efficiently as possible, that they do not release collected sediment and that adequate vegetation is in place to maintain bank stability of what will essentially become a landfill. Additionally, the overflow and filter structures may need repair over time, generally with small quantities of additional stone.

Actively managed traps will require material be disposed of in accordance with applicable laws. Depending on the Toxicity Characteristic Leaching Procedure (TCLP) testing results (USEPA, 1992), this material may or may not be considered Resource Conservation and Recovery Act (RCRA) Class C or Hazardous Waste. This material is generally termed “Special Waste” to differentiate it from Class D, general municipal waste. The material removed from other systems (see Sections 2.5 and 2.6) will fall under these same limitations. Soil repositories managed by the USEPA or Potentially Responsible Parties (PRPs, as defined by CERCLA) are the preferred method of disposal when necessary, as the disposal costs are substantially less than those of landfills, and the material is often able to be used by the repository for altering gradations of other materials, capping, etc. Hauling costs may be higher, depending on the distance to the repository compared to a landfill.

2.5. BED SEDIMENT COLLECTORS

2.5.1. MEASURE INTENT

To supplement the efforts of the sediment basins, in-stream collection systems will be necessary to reduce degradation of existing habitat and restore communities already inundated by excessive and contaminated sediment. Bed sediment collectors (also called bedload collectors) are an innovative methodology developed to reduce dredging needs in navigable channels, ports, etc., and show promise in sediment removal for restoration with minimal modification to the common operations.

2.5.2. DESIGN DISCUSSION

These systems are typically prefabricated steel sediment-collection structures embedded into the river bed at or slightly above the existing bed grade or incorporated into grade control structures, and utilize a series of pumps for operation. The main component is known as the "interceptor", and is composed of a ramp that uses the river's current to push bedload up or over and into a screened collection slot that runs perpendicular to the river's flow. This screen allows bedload sediment smaller than the screen to enter the collection slot, while the opening is designed to alter the stream velocity above it to allow coarse material to drop out of suspension and into the collector hopper. As the sediment and turbid water enters the collection slot, water is injected into the hopper to stir up the collected sediment. Separately, a pipe within the collection slot pulls the collected sediment from the collection slot and into a processing system on the shore. While the sediment collected by these systems is typically sand size, upstream collector systems may be designed with larger grating to allow older (and larger) tailings materials to be collected. Downstream collectors may be able to implement what are now experimental models of these systems that incorporate a silt bubbler system (Figure 2-24) to also remove fine sediment, more likely to be encountered in the lowest reaches of the Big River.

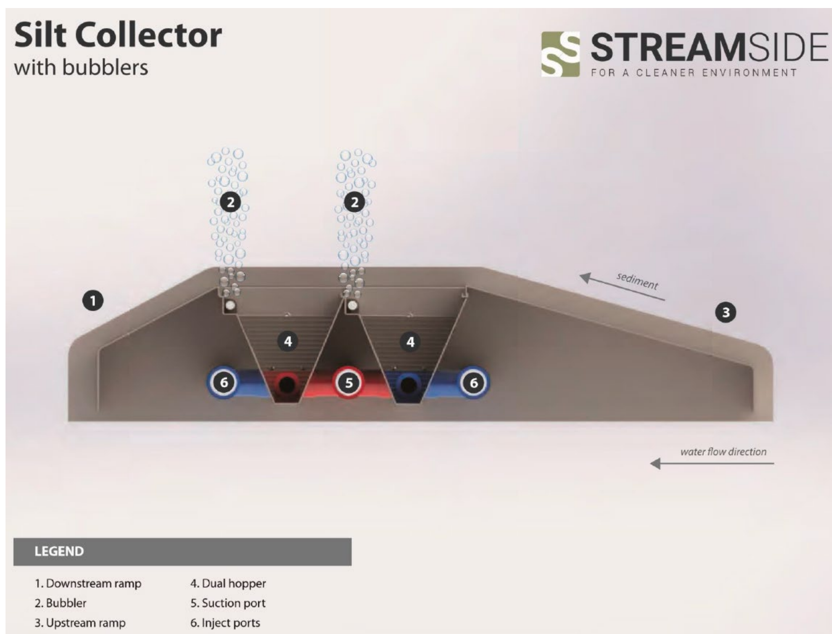


Figure 2-24: Stream Side Bed Sediment Collector with Silt

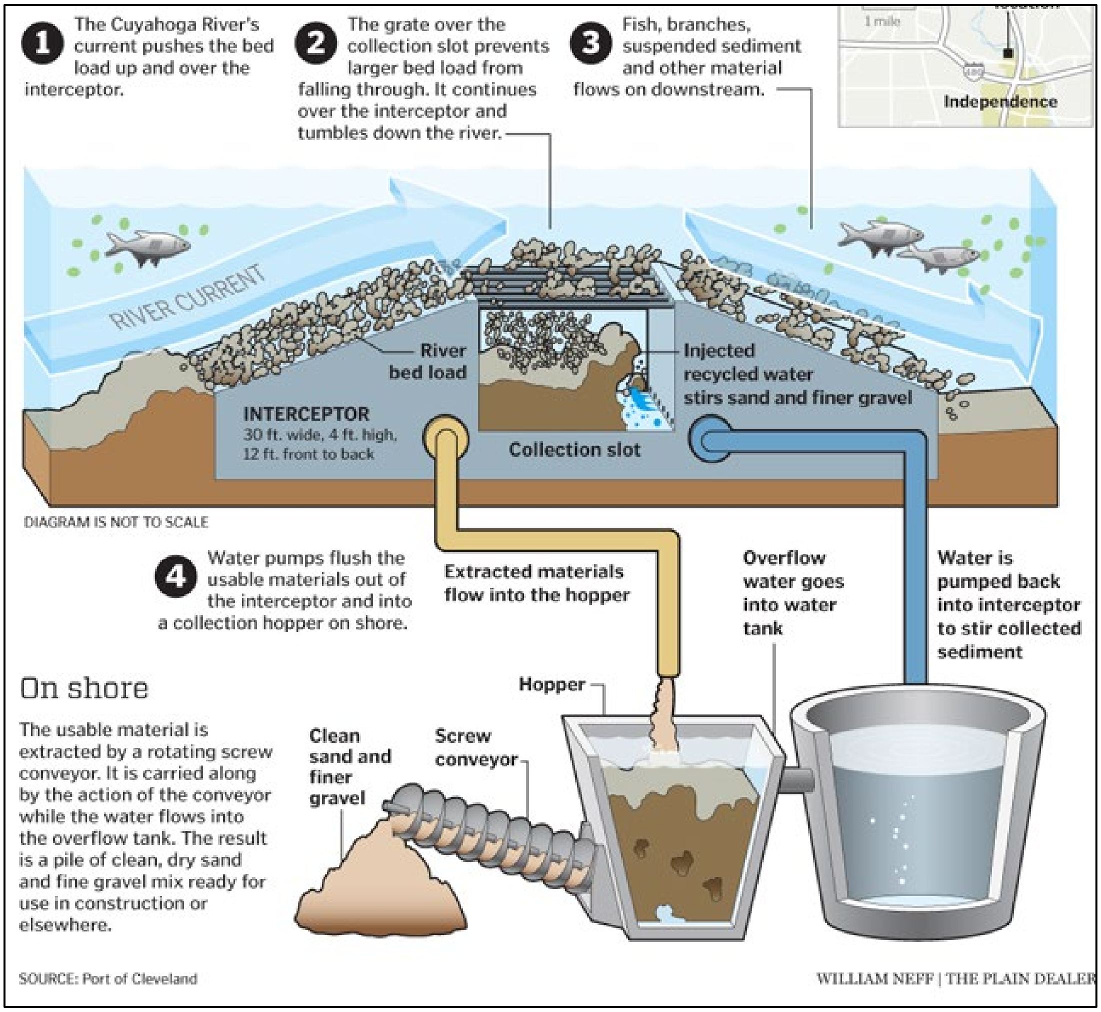


Figure 2-25: Conceptual Diagram of How a Bedload Collector Works

For most dredging reduction applications, a secondary screening system is used to sort the sand and gravel materials by size for resale as aggregate, while the turbid water is returned to the river, usually in jets to assist with cleaning debris from the screens. In the case of sites on the Big River, however, the sediment concentrations of lead and other heavy metals are expected to be above the PEC levels, and thus a filtration or other suspended sediment capture system will be required so that only clean water is returned to the system.

Depending on the availability of real estate, operations capabilities of the Sponsor and other considerations, this could be achieved through the use of geotextile dewatering tubes (such as those used in sanitary dredging applications) which would contain nearly all sediment within them until the material is dewatered for transportation. Alternatively, containment areas designed similarly to sediment basins or confined disposal facilities (CDF), a dredging management practice) could also be developed to receive the material directly, allowing the discharge water to infiltrate or seep through filter structures, after which the dried sediment is graded, scarified and compacted in preparation for the next operation. Centrifugal separators may also be considered to improve capture without the need for a CDF or similar system.

Figure 2-26: Sediment Collector During Installation, Fountain Creek, CO (Thomas, 2017)

These systems are advantageous when compared to direct in-stream excavation because they capture sediment at or below the river's natural rate of sediment transport, so that there is minimal risk of bed or bank destabilization or system sediment starvation. They also operate only when the pump systems are activated, such that operations can be scheduled and otherwise automated to ensure minimal impact to aquatic species that would pass over the structure when elevated flows are not present.

2.5.3. CONSTRUCTION/INSTALLATION

Many components of these collector systems will likely be manufactured and procured instead of constructed on site. Construction will be focused on installation of the interceptor within the channel itself, the effluent reception system (stockpile area, geotubes, CDF, etc.), and utility extension and transformation to run the pumps and control systems (Section 2.5.4). To increase lifespan of the collector systems, the study estimate assumes the interceptor will be cast-in-place concrete instead of steel, with the interior components cast into it. This will require additional construction dewatering and management processes. The construction estimate assumes a conservative dewatering approach, including sheetpile cutoff and pumping systems. A prism of crushed stone is assumed to help anchor the collector and provide any needed grade control. The estimate assumes the stone will occupy a space of approximately 20% of the collector footprint at an average thickness of three feet. This value will require refinement in Preconstruction Engineering Design (PED). The anchoring system estimate is assumed to include any base rock stone required as bedding for the interceptor. The pumps, hoses and effluent reception system will then require operational testing, analysis and optimization.

2.5.4. ELECTRICAL REQUIREMENTS

Electrical requirements were analyzed based on the following three phase 480 V components needed for a bedload collector system: 50 horsepower (hp) dredge pump, 50 hp return water pump, 15 hp flush pump, and a 25 hp dewatering pump. These components were listed in an estimate provided for the procurement of a 30 foot sediment collector system. Analysis is based on the assumption that the system will only operate during high water events, estimated at an average of 80 hours of operation per year.

The following sections discuss the methods of powering the collector pump and control systems considered for this analysis. While this will require additional consideration in PED, utility extension was assumed for development of the cost estimate.

UTILITY POWER EXTENSION TO SITE

Six locations were originally identified as ideal for a bed sediment collector system as detailed in Table 2-1. Additional analysis suggests that three or fewer of these locations would be necessary to achieve the benefits calculated during Alternatives Analysis. The proximity to existing three phase utility power is a large cost driver. Based on the above electrical requirements, each site will require a 225 kVA utility-owned three phase step-down transformer at a cost of approximately $20,000.

Table 2-1: Utility Extension Information and Cost Estimates

Recommended Plan Sites Used			
Site River Mile	*Current Power Source Location (Intersection)*	*Extension Length (miles)*	*Extension Cost Estimate*
19.6*	Cedar Hill Rd & Stovesand Rd	0.3	$ 200,000
55.1	Ware Rd & Highway H	2.4	$ 720,000
71.5	Vineland Rd & Highway CC	2.5	$ 750,000
Additional Sites from TSP			
Site River Mile	*Current Power Source Location (Intersection)*	*Extension Length (miles)*	*Extension Cost Estimate*
30.2*	Riverview Dr & Hillsboro Rd	0.6	$ 300,000
61.5	Folage Rd & Highway 21	2.6	$ 780,000
74.8	Newbery Rd & Tiff Rd	3.3	$ 990,000
*Cost estimate provided by Ameren includes conversion of existing power to three-phase requirements.			

ONSITE GENERATOR

The construction cost for each bedload collector site increases significantly when not located in close proximity to existing three phase utility power. An onsite three phase generator has been considered as an alternative power source for these remote project sites with a quoted cost of $130,000, which will require additional analysis and consideration in PED. The following generator specifications were used in the analysis:

- Generator size: 180 kVA Prime Rating
- Diesel Fuel Capacity: 320 gallon sub-base fuel tank with additional 500 gallon external tank
- Diesel Fuel Consumption Rate: 10 gallons/hour
- Diesel Exhaust Fluid (DEF) Capacity: 30 gallon sub-base fuel tank with additional 30 gallon external tank
- DEF Consumption Rate: 0.5 gallons/hour
- Continuous Runtime: 80 hours without refueling
- Emissions: EPA Tier 4 Compliant

A secondary power source is needed to provide continuous power for the bedload collector control system. The control system will monitor conditions and automatically start the generator and pumps when needed. A solar panel and battery bank can be used for this small power requirement for an estimated cost of $5,000.

2.5.5. DESIGN RISK

Bedload collectors may be damaged or removed from their foundations during high flows when struck by debris, or foundation material could be undermined by bed instability. Foundations and anchoring will be designed to anchor the system and underlying substrate, and monitored after construction for stability. Bedload collector equipment (i.e., generator, screening system, etc.) may be washed away if it is staged in a way that does not consider high flows, or effluent from bedload collection operations may be eroded if placed in the floodway or without regard to best-management practices (BMPs). Risks to these peripheral systems, including generators, pumps, Confined Disposal Facilities, and other dewatering systems will be addressed in site design during PED. Conservative design practices, active adaptive management and proper OMRRR mitigate this risk.

2.5.6. OMRRR

OPERATION

Operation of these systems will require multiple pumps to draw the material from the collector and place it in the stilling basin, geotextile dewatering tube or other collection basin. This plan should consider utility availability for providing power and likelihood of theft or vandalism, as well as operations efficiency. Specific pump capacity and power requirements have been analyzed based on the assumption of a 30 foot bedload collector system. Final requirements will likely change during PED. Each bedload collector will require electrical power for operations, as discussed previously; if using grid power, the estimated cost is a little more than $4,000 per average year, while generator systems will be significantly more expensive to operate.

While beyond the scope of the current design, it is recommended that a repository designed similar to a CDF be established in which each collector can pump material directly to its final disposal site, with overtopping control and filter structures allowing the material to dewater over time and eliminate the high expense and disruption of hauling material for disposal elsewhere. Options for material handling are discussed in section 2.5.2. An estimate of annual average sediment that could be collected was developed during Alternatives Analysis for each of the six selected collector sites. During FLD, this analysis was expanded to incorporate additional analytical tools and newly-available information (see appendix H); this analysis suggests that the earlier analysis underestimated the material that would be available to each collector under current river conditions. As such, the benefits used in determining the Recommended Plan (a removal of 1.1 tons per average year of Pb from the river) could theoretically be achieved by fewer collectors. To target where contaminated sediments currently are, and thereby provide benefits throughout the river system, a minimum of three collectors is theoretically required.

The collectors would have to remove a total of approximately 2,150 cubic yards of sediment to achieve the benefits to meet the operations recommended by the Federal Project, and incorporated in the Recommended Plan; however, three collectors could potentially remove up to 19,000 cubic yards of additional sediment (assuming pre-construction testing demonstrates maximum collector efficiency), providing an unknown amount of additional benefits (the ecological model is not sensitive enough to estimate the ecological lift). Removal of large quantities of sediment has the potential to create a sediment starvation condition detrimental to mussels and other aquatic species. As such, the actual amount removed would require a detailed sediment mass balance to estimate the limit of removal, which will require field-verification (monitoring) to confirm that no damage is occurring. The additional sediment removal would also carry additional operation costs, which could theoretically be offset or reduced by sale of portions of the collected material for approved beneficial reuse and/or by establishment of a CDF or similar on-site disposal as discussed above.

MAINTENANCE, REPAIR, REHABILITATION, AND REPLACEMENT

These systems have not been in operation for extended periods of time from which detailed schedules of OMRRR can be developed for the project life. More detailed review of these requirements will be necessary as part of OMRRR manual development during and after PED. General maintenance for pumping systems and hydraulic structures are assumed to be a reasonable approximation until that time. The Sponsor will be responsible for periodically replacing fittings and hoses, conducting preventive and periodic maintenance on the pump engine and automation systems and ensuring all effluent reception systems can be quickly prepared for flood operations. A flood risk management plan will also be necessary, depending on the elevation at which the equipment is housed to ensure that it can be removed when a flood inundation risk is greater than acceptable levels. The equipment will also need to be secured, protected from weather, theft, and vandalism.

At some point in the life of a steel collector, the body of the interceptor will need to be removed from the river for blasting and repainting, with any corroded components replaced or repaired. For this estimate, a concrete body is expected to be utilized to meet the 50-year design life, though sub-components will require replacement.

Utility power extended to the site would be more reliable and require less maintenance effort as the transmission lines and transformer are the responsibility of the utility company; however, due to high construction costs for some remote sites, an onsite generator may be more cost effective. The maintenance effort for project staff can be minimized with a maintenance subscription service for a yearly oil change and inspection provided by the generator manufacturer. Fuel tanks shall be sized accordingly during PED to ensure the site can operate for the duration of a flood event without refueling. A generator will likely need replaced once during the 50 year design life of the system. During PED, it may be worthwhile to identify alternative bedload collector sites that are closer to existing three phase utility power to lessen or eliminate the need for onsite generators.

2.6. IN-STREAM (DIRECT) EXCAVATION

While attempts to establish a reasonable hydraulic mass balance of sediment are underway in the entire Big River by the USEPA, preliminary estimates suggest that the less-invasive methods of sediment reduction (e.g., Sediment Basins, Bedload Collectors and Bank Stabilization) will not fully restore the system to a stable equilibrium. As such, direct excavation, or removing sediment directly from the stream or gravel bars by mechanical or hydraulic means may be necessary to restore the structure and function of the aquatic ecosystem. These excavations will require careful layout, control and coordination to ensure that the potential negative impacts are not incurred (as discussed in Section 2.3.1). As a potential cost savings, it is recommended that coarse gravel material be screened from the excavated material and returned or sold. This material has limited potential to cause negative impacts, particularly compared to the finer materials which are more heavily impacted by mining waste, as was demonstrated in Table 1-1. Returning this material to the stream will require careful management and monitoring to ensure it does not cause harm during resuspension.

2.6.1. AT GRAVEL BARS (BED SEDIMENT REMOVAL)

Design work will require establishing limits in order to comply with Permit GP-34M requirements (MDNR, 2013), which generally creates an offset of 20 feet horizontally from either the water's edge or established vegetation, whichever is closest, and limits excavation to those portions above the water line. This limits the available volume of material, reducing the efficiency of this method of sediment reduction. The construction quantities reflect a single excavation event at each bar selected for the alternative, with two additional excavations included as Adaptive Management contingency actions.

An additional measure the Sponsor may choose to pursue in lieu of, or in conjunction with, the USACE direct excavation is to pursue institutional controls. By advertising technical (and potentially monetary) assistance to landowners who may wish to conduct surface mining on gravel bars adjacent to their properties, there is a potential that the state could achieve a substantial savings to remove bed sediment. In this way, the State would not have to purchase additional real estate interests or pay the costs of excavation, handling and screening equipment mobilization and operation. The landowner would be able to sell the gravel commercially, and the state could transport the remaining material to a landfill or repository for disposal. The trucking and tipping costs for transportation and disposal would still be incurred by this method.

2.6.2. AT GRADE CONTROL (IN-STREAM EXCAVATION)

The grade control structures provide a potential collection point for large quantities of sediment, up to the newly established bed profile. Excavation at these points limits the risk of bed destabilization so long as the original bed is not excavated. There is, however, the risk that fine material will be reintroduced into the water column causing temporary impacts to aquatic species during construction. Dredging best-management-practices for collecting plumes of disturbed sediment (namely silt curtains) are unlikely to be implementable in a swiftly flowing current like those present in most of these sites, though bubbler systems may provide some risk reduction. Additionally, equipment selection will be a driving force behind how much material can be feasibly removed in each excavation event (of which, only one is included in this study recommendation). More information on BMPs and equipment selection for reducing resuspension and residuals is provided in Appendix E.

The potential for sediment removal will require extremely tight monitoring and flexible contracting methodologies. Because the floodplain is not blocked by these "run-of-river" dams, sediment transport is able to continue during some high-flow events in episodic deposition and scour.

3. OMRRR SUMMARY

The sequencing of OMRRR events by measure type have been estimated for use by the Sponsor in initial planning are presented in Table 3-1. These are recommended to be updated throughout the project life as additional information on actual operations becomes available.

Table 3-1: Estimated OMRRR Events Sequences

M. Type	Feature	OMRRR Event Year														
		A	1	2	3	4	5	10	15	20	25	30	35	40	45	50
All	Stone Replacement											X				
	Turfing (Mortality)						X									
	Reforestation (Mortality)						X									
	Mowing		X	X	X	X	X									
Bedload Collector (BC)	Roads						X	X	X	X	X	X	X	X	X	X
	Utility Usage	X														
	Pump replacement / rehabilitation							X		X		X		X		
	Pipe replacement / rehabilitation							X		X		X		X		
	Hopper replacement / rehabilitation							X		X		X		X		
	Control Systems Replacement										X					
	Sediment Removal (Hauling)	X														
Bank Stabilization (BI)	Roads							X								X
	Timbers															X
	Harvest															X
	Replace / Extend LBL - TECF							X								X
	Replace / Extend LBL - Stakes							X								X
	Replace / Extend LBL - Earthwork							X								X
	Replace / Extend LBL - Live poles							X								X
GC	Stone Replacement (Additional)							X				X				
Exc	Sediment Removal (Hauling)															
SC	Roads							X		X		X		X		
	Basin Adjustment (Earthwork)							X		X		X		X		
SRB	Roads						X									
	Sediment Removal (Hauling)						X									

The return-period estimates are rounded to the nearest 5-year block, excepting the first 5 years of maintenance. Measure (M.) Types in the table include Bedload Collector (BC), Bank Stabilization (BI), Grade Control (GC), Excavation (Exc), Sediment Capture (SC), and Bed Sediment Removal at Bar formations (SRB); features that are included in multiple measure types (e.g., Reforestation) are included in "All." Event Year "A" refers to those components that are completed on an Annual basis.

4. MATERIALS AND GEOTECHNICAL CONSIDERATIONS

4.1. GENERAL

Site-specific geotechnical sampling and testing was not conducted as part of this study due to the large study area and few geotechnical concerns related to the various measures. No Federal levees or similar projects are currently located near enough to any proposed project location to be negatively affected by proposed features.

4.2. SOIL AND SEDIMENT

Sampling and testing data was collected throughout the Old Lead Belt along the Big River in 2016 and 2017 by HydroGeoLogic, Inc. (HydroGeoLogic, Inc., 2018) under contract with the USEPA Superfund Region VII. The average values in the study area from this data were used to inform the quantity and benefit analyses (Table 4-1).

Table 4-1: Averaged Sediment and Soil Sample Values

	Density / Unit Weight		Particle Size Fraction		
Location	*g/cm^3*	*Lbs./ft^3*	*Gravel*	*Sand*	*Fines*
Gravel Bars	1.62	101	33%	59%	9%
Banks	1.31	82	2%	74%	24%

All earthwork features will be composed of semi-compacted fill; compaction will be reached using a prescriptive (rather than performance-based) specification expected to achieve a minimum of native compaction acceptable for the development of vegetation for long-term stability.

4.3. STONE

Stone features are currently included in the recommended set of measures. The majority of these features will use a standard riprap gradation specified by the top-size stone weight which will allow for self-adjustment under high-flow and variable stream-bed conditions. Features such as weirs and barbs, however, will likely use a graded stone to reduce the likelihood of movement over time. Land-based stone features will be placed over geotextile and bedding material for foundation stability and filtration of seep-water, excepting some water-based features, namely LPSTP. Size of stone will be based on hydraulic characterization of each site in terms of expected velocity and turbulence, using CEMVD guidance for stone quarried in the St. Louis area.

For all types of stone, rough volume calculations were developed based on idealized cross-sections and estimated length and height information. A unit weight of 1.6 tons per cubic yard (TN/CY) was applied to calculate quantities of stone, which is assumed to be the same for all gradations of stone. This weight is also assumed to include any bedding stone with geotextile incidental to those costs.

5. CONSTRUCTION SEQUENCE, METHODS AND CONSIDERATIONS

5.1. CONTRACT STRUCTURE

Contracts will be issued as funding becomes available and will likely be issued by measure type with multiple sites in the same contract. The contracts covering Bank Stabilization and Direct Excavation measures will likely be issued as indefinite delivery indefinite quantity (IDIQ) contracts to assist the project delivery team (PDT) in adjusting the design to match the ever-changing site conditions. Larger, single-site measures like grade control structures and sediment basins may be issued as individual contracts, either Lump Sum or IDIQ. Bedload collectors as specialty items will require procurement either directly or as a subcontract item to the construction contractor installing them.

5.2. PRIORITIZATION

The highest priority will likely be placed on bed stability and passive collection measures, namely grade control structures and sediment basin construction. The grade control structures will assist in re-establishing a stable bed, reducing the cost and increasing the likelihood of success for follow-on bank stabilization projects upstream. Sediment basins will require site alteration in advance of high-flow events to begin capturing material, and may require adaptive management or operational adjustments to the heights of overflow structures if actual operations suggest a change is needed to achieve expected performance.

5.3. ENVIRONMENTAL PROTECTION DURING CONSTRUCTION

Each contract will include USACE- and industry-standard specification sections and submittal requirements for care of water and environmental protection plans, including storm-water pollution prevention plans (SWPPP), requiring that these plans be developed, implemented and maintained by the contractor. Preparation of these is beyond the scope of Feasibility Level Design, but the same design principles used in their successful development will be incorporated into Preconstruction Engineering Design (PED).

5.4. SECURITY AND TRAFFIC CONTROL CONSIDERATIONS

By standard USACE specifications, the contractor will be required to establish security of the site throughout construction, to include background checks of their employees prior to construction. After construction is complete, the sponsor will be responsible for maintaining security of the site under the auspices of their own regulations, which are separate from Army Regulations.

A traffic control plan will be developed by the prime contractor for each site per state and Federal regulations and standard USACE specifications to accommodate common traffic patterns along with trucks hauling materials to or from the site. The sponsor will utilize this plan as the basis for establishing and refining their own traffic control during OMRRR.

6. REFERENCES

CELRE. (2013). *Frankenmuth, Michigan Fish Passage Design Documentation Report.* U.S. Army Corps of Engineers - Detroit District.

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.

Eubanks, C. E., & Meadows, D. (2002). *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization.* San Dimas, CA: U.S. Department of Agriculture Forest Service, Technology and Development Program.

Farrah, H., Hatton, D., & Pickering, W. F. (1979). *The Affinity of Metal Ions for Clay Surfaces.* Amsterdam, Netherlands: Elsevier - Chemical Geolgoy.

Fischenich, C. (2001). Stability Thresholds for Stream Restoration Materials. *EMRRP Technical Notes Collection. ERDC TN-EMRRP-SR-29 (US Army Research and Development Center)*.

Frothingham, K. M. (2008). Evaluation of stability threshold analysis as a cursory method of screening potential streambank stabilization techniques. *Elsevier Applied Geography 28*.

HydroGeoLogic, Inc. (2015). *Draft Hydraulic and Sediment Transport Modeling Report Remedial Investigation Southwest Jefferson County Mining Site Operable Unit 4 Jefferson County, Missouri.*

HydroGeoLogic, Inc. (2018, May). Draft Hydraulic and Sediment Transport Modeling Report Southwest Jefferson County Mining Site Operable Unit 4, Jefferson County, Missouri. Overland Park, KS.

Li, M., & Eddleman, K. E. (2002). A biotechnical streambank stabilization design approach. *Elsevier Landscape and Urban Planning 60*.

MDNR. (2013). *Pollution Prevention and Compliance Guide for Sand and Gravel Removal.* Jefferson City, MO: Missouri Department of Natural Resources (MDNR).

Naimo, T. J. (1995). A review on the effects of heavy metals on freshwater mussels. *Ecotoxicology*, 4: 341-362.

NAS. (2017). *Investigative Strategies for Lead-Source Attribution at Superfund Sites Associated with Mining Activities.* National Academies of Sciences, Engineering, and Medicine (NAS). Washington, DC: The National Academies Press. Retrieved from https://doi.org/10.17226/24898

NYDEC. (2014). *Post-Flood Emergency Stream Intervention Training Manual.* New York, NY: New York Department of Environmental Conservation. Retrieved from http://www.dec.ny.gov/docs/administration_pdf/streammnll.pdf

Pavlowsky, R. T. (2017). Legacy sediment, lead, and zinc storage in channel and floodplain deposits of the Big River, Old Lead Belt Mining District, Missouri, USA. *Elsevier Geomorphology 299*.

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.* Springfield, MO: Ozarks Environmental and Water Resources Institute, Missouri State University.

Pearson, A. J., & Pizzuto, J. (2015). Bedload transport over run-of-river dams, Delaware, U.S.A. *Geomorphology*, 382-395.

Roberts, A. D., Mosby, D., Weber, J., Besser, J., Hundley, J., McMurray, S., & Fairman, S. (2009). *An Assessment of Freshwater Mussel (Bivalvia: Margaritiferidae and Unionidae) Populations and Heavy Metal Sediment Contamination in the Big River, Missouri.* Columbia, Missouri: US Fish & Wildlife Service.

Rosgen, D. L. (n.d.). The Toe Wood Structure. Pagosa Springs, Colorado: Wildland Hydrology. Retrieved from Oneida County: http://www.ocgov.net/oneida/sites/default/files/planning/SCBIC/MapsDocuments/Documents/Toe%20Wood%20Structures.pdf

Thomas, R. J. (2017, April). Sediment management methods to reduce dredging: Part 2, sediment collector technology. *DOER Technical Notes Collection. ERDC TN-DOER-T13 (US Army Research and Development Center)*. Retrieved from www.wes.army.mil/el/dots/doer

University of Missouri Department of Geography. (n.d.). Retrieved from Missouri Spatial Data Information Service: http://www.msdis.missouri.edu/data/lidar/index.html

USBM. (1972). *Minerals Yearbook.* United States Bureau of Mines (USBM). Retrieved from https://minerals.usgs.gov/minerals/pubs/usbmmyb.html

USDA. (2007). *Technical Supplement 14G, "Grade Stabilization Techniques".* United States Department of Agriculture (USDA).

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

U. S. Army Corps of Engineers

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

July 2019

Appendix H
Hydraulics and Hydrology Analysis

INTENTIONALLY LEFT BLANK

1 TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 PROJECT INFORMATION

The Meramec River watershed, including its two major tributaries, the Big River and the Bourbeuse River, are located in east-central Missouri, southwest of St. Louis. The Meramec River watershed drains approximately 3,950 square miles, with the Big River and Bourbeuse River accounting for 970 square miles and 840 square miles of that total, respectively. The study area is defined as that portion of the Meramec River's watershed located within St. Louis, Jefferson, Washington and St. Francois counties of Missouri (Figure 1-1).

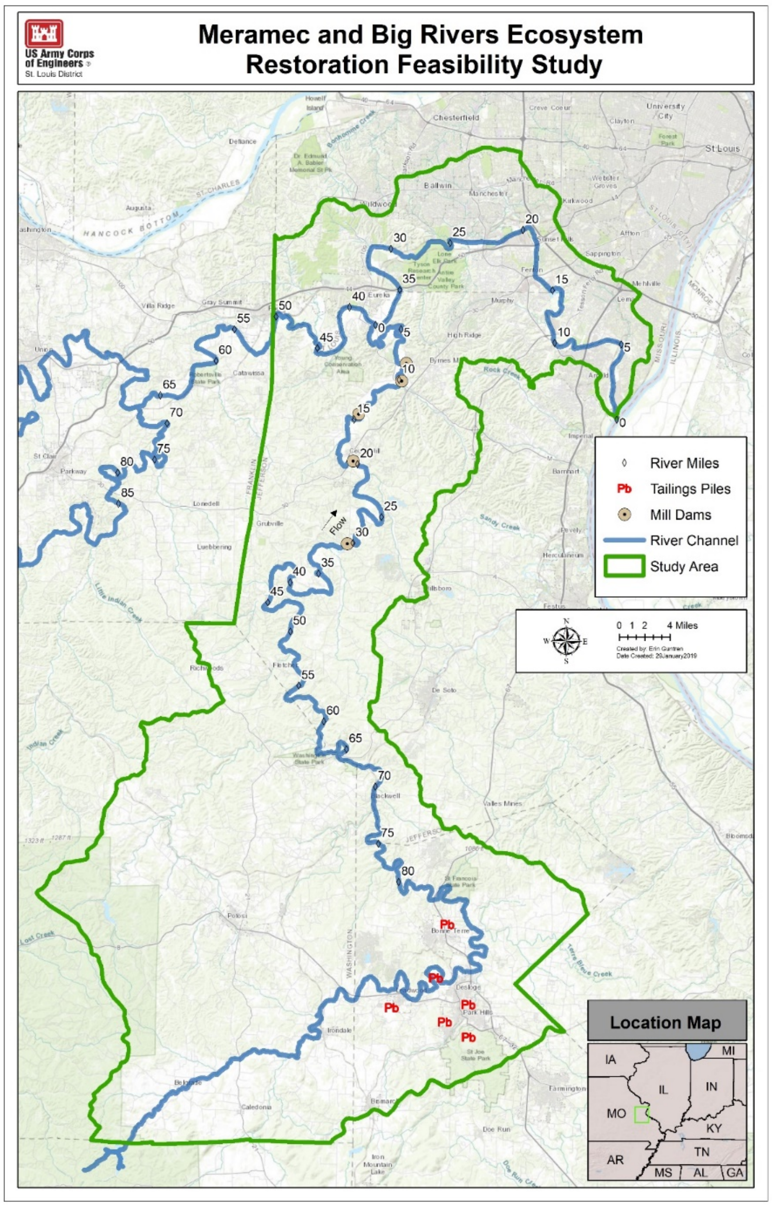


Figure 1-1. Study Area

The Big River has been significantly affected by mining activities in the region. Lead and zinc are plentiful in the region, and historic mining activities unearthed millions of tons of ore. As the ore was processed, much of that mine waste found its way into streams and rivers. Over time, the streams and rivers have distributed the waste, and much of it is now settled into the bed, banks and floodplain of the Big River. Although the sources of the waste are or have been addressed, the waste continues to cycle into and through the system.

1.1 HYDROLOGY

Hydrology within the Meramec River Watershed is driven by rainfall runoff. Sustained flows are attributed to adequate precipitation, evaporation, 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. The Big River has five mill dams located within 30 miles of its confluence with the Meramec River. Low water crossings are found throughout the watershed and depending on the design, can act as local gradient controls (MDC, 1998).

1.2 GAGE DATA

Five river gaging stations are located within the study area on the Big River:

1. The Irondale Gage (07017200) is located at River Mile (RM) 119.7, with a drainage area of 175 sq. mi. This station is operated by U.S. Geological Survey (USGS) in cooperation with U.S. Army Corps of Engineers (USACE) – St. Louis District. Current/historical precipitation, discharge and gage height are available at this station.
2. The Desloge Gage (07017260) is located at RM 96.9, with a drainage area of 264 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District. Current/historical precipitation, discharge and gage height are available at this station.
3. The Bonne Terre Gage (07017610) is located at RM 82.4, with a drainage area of 409 sq. mi. This station is operated by USGS in cooperation with U.S. Environmental Protection Agency (USEPA). Current/historical water temperature, discharge, gage height and turbidity are available at this station.
4. The Richwoods Gage (07018100) is located at RM 53.7, with a drainage area of 735 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District. Current/historical precipitation, discharge and gage height are available at this station.
5. The Byrnesville (07018500) gage is located at RM 14.1, with a drainage area of 917 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District and the USGS National Streamflow Information Program. Current/historical precipitation, discharge and gage height are available at this station.

Flow data for the Byrnesville and Richwoods gages were downloaded from the USGS National Water Information System (USGS, 2017). The data was analyzed and basic statistics were computed on discharge using USACE's Hydrologic Engineering Center-Data Storage System (HEC-DSS)Vue software. The events and their corresponding stages, as approximated using the most updated stage-discharge rating curve, are summarized in Table 1-1. The basic analysis was conducted for screening purposes, and more detailed hydrologic analysis will be conducted during preconstruction engineering design (PED) phase. It is recommended that full Bulletin 17C analysis is performed to inform final design of features in this project.

Table 1-1. Selected Flow Events and Stages at Richwoods and Byrnesville Gages

	Annual Exceedance Probability (%)	Richwoods Flow (cfs)	Richwoods Approximate Stage (ft)	Byrnesville Flow (cfs)	Byrnesville Approximate Stage (ft)
Min	100%	25	1.8	25	0.9
Median	100%	290	3	341	3.2
Mean	100%	726	4.2	875	5
1.2 Year	83%	7,040	12.6	7,590	14.6
2 Year	50%	14,200	17.7	14,600	19
10 Year	10%	33,800	24.9	34,200	24.9

Figure 1-2 shows the average, minimum and P95 flows at Byrnesville, as outputted from HEC-DSSVue. The graph shows a four month window from March – June where elevated flows occur most often. P95 flow is similar to maximum flow, but excludes the top 5% of flows (i.e., 95th percentile); it's a useful metric because including the top 5% of flows in this watershed would greatly expand the scale of the graph, making it harder to read.

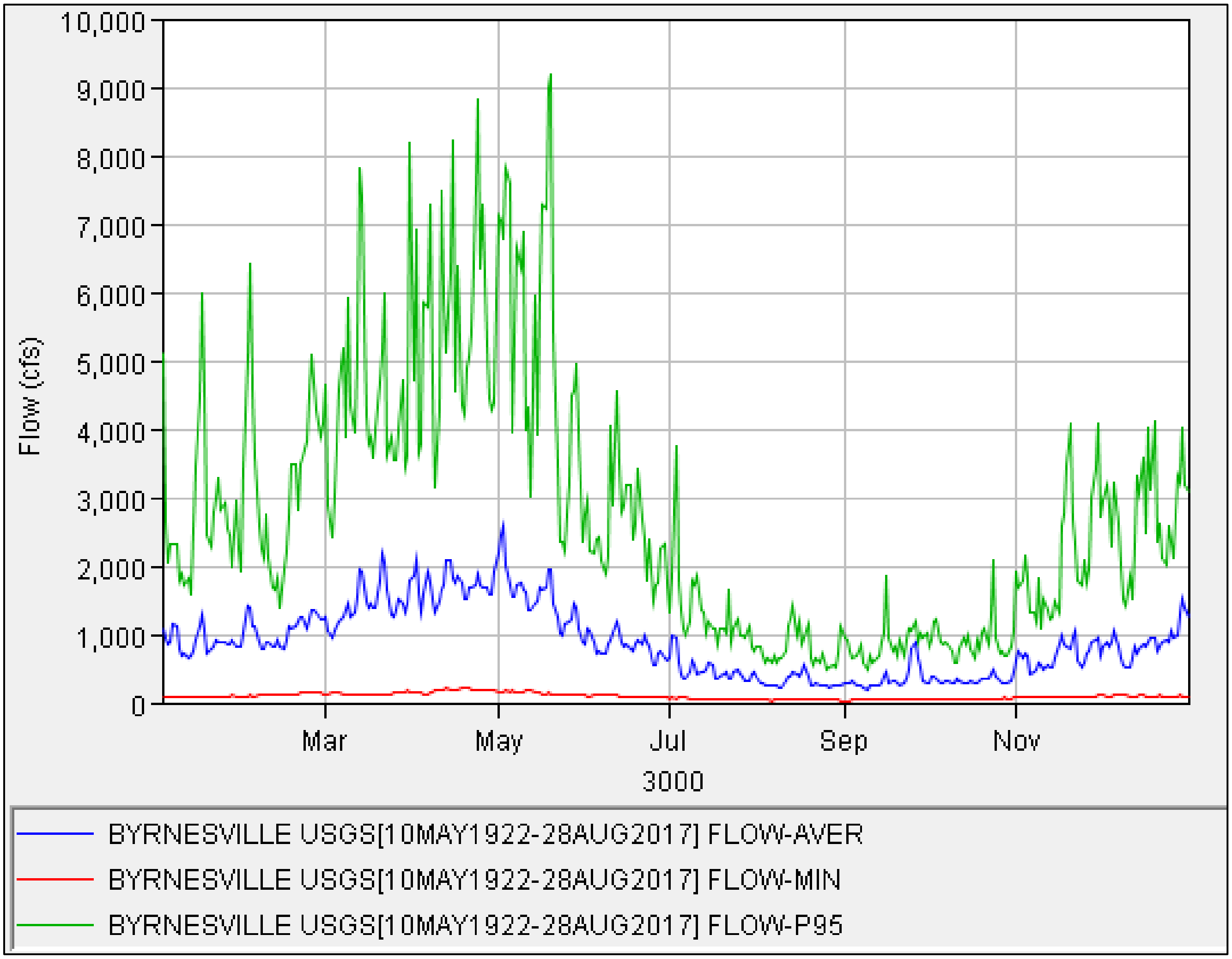


Figure 1-2. Average, Minimum and P95 Flows For Each Day of the Month at Byrnesville, from 1922-2017; Analysis Completed Using DSSVue

Five river gaging stations are located within the authorized study area on the Meramec River:

1. The Pacific Gage (07017020) is located at RM 50.9, with a drainage area of 2,740 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District. Current/historical precipitation, discharge and gage height are available at this station.
2. The Eureka Gage (07019000) is located at RM 35.0, with a drainage area of 3,788 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District. Current/historical precipitation, discharge and gage height are available at this station.
3. The Valley Park Gage (07019130) is located at RM 22.2, with a drainage area of 3,850 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District. Current/historical precipitation, discharge and gage height are available at this station.

4. The Fenton Gage (07019210) is located at RM 16.1, with a drainage area of 3,880 sq. mi. This station is operated by USGS in cooperation with Metropolitan St. Louis Sewer District. Current/historical precipitation and gage height are available at this station.
5. The Arnold Gage (07019300) is located at RM 6.3, with a drainage area of 3,950 sq. mi. This station is operated by USGS in cooperation with USACE – St. Louis District. Current/historical precipitation and gage height are available at this station.

Data for the Eureka gage was downloaded from the USGS National Water Information System (USGS, 2017) and analyzed using USACE's HEC-DSSVue software. Flow and stage statistics at Eureka gage are summarized in Table 1-2. Flows, and therefore sediment loading, in this river are highly seasonal and variable. Figure 1-3 shows the average, minimum and P95 flows at Eureka, as outputted from HEC-DSSVue. This graph shows that there is a five month window from March – July where elevated flows occur most often.

Table 1-2. Selected Flow Events and Stages at the Eureka Gage

	Annual Exceedance Probability (%)	Flow (cfs)	Approximate Stage (ft)
Min	100%	196	2.7
Median	100%	1,440	3.7
Mean	100%	3,318	4.8
1.2 Year	83%	21,100	13.1
2 Year	50%	37,800	20.2
10 Year	10%	89,900	35.1

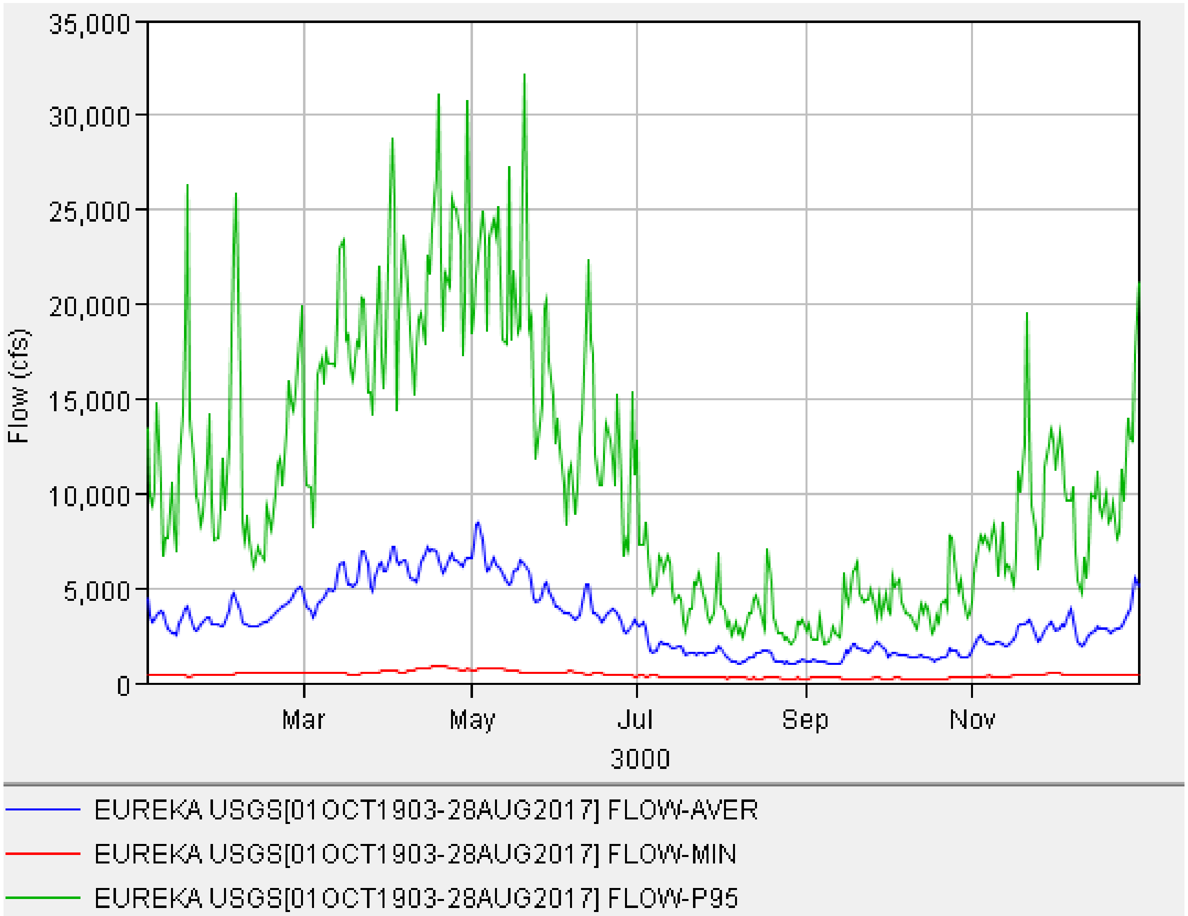


Figure 1-3. Average, Minimum and P95 Flows For Each Day of the Month at Eureka, from 1903-2017; Analysis Completed Using HEC-DSSVue

2 EXISTING CONDITIONS

2.1 TRIBUTARY INPUTS

Sediment inputs from tributaries is understood to aggravate bank instability at and near tributary confluences in the Big River. Tributary sediment is carried to the confluence of the tributary and the Big River. Since the Big River is not capable of moving larger sediment from within the tributaries, gravel bar "tails" (similar to deltas) often form at tributary confluences. This "pile" of tributary sediment often forces the river into the opposing bank and incites lateral channel instability. It also creates a backwater effect upstream of the confluence. This process is shown at Ditch Creek in Figure 2-1 and Figure 2-2. It is also shown at Calico Creek in Figure 2-3 and Figure 2-4.

Sediment contributed to the Big River from tributaries is generally considered to be cleaner than what is already in the Big River; however, some tributaries continue to contribute contaminated sediment to the Big River, like the Flat River.

Figure 2-1. Channel Instability Into Right Descending Bank Due to Delta Formed Confluence of Ditch Creek and Big River at RM 44.5 (Flow From Bottom to Top)

Figure 2-2. Lateral Instability Due to Ditch Creek Sediment Dropping at Confluence with Big River, Looking Downstream at Moderate Flow (Pic: Apr. 2017)

Figure 2-3. Channel Instability Into Right Descending Bank Due to Delta Formed Confluence of Calico Creek and Big River at RM 52 (Flow From Right to Left)

Figure 2-4. Lateral Instability Due to Calico Creek Sediment Dropping at Confluence with Big River, Looking Upstream at Low Flow (Pic: Mar. 2017)

2.2 IN-STREAM GRAVEL MINING

Gravel is periodically removed from streams and floodplains within the study area by unpermitted and undocumented small operators (MDC, Missouri Watershed Inventory and Assessment: Big River, 1997). Disturbances resulting from in-stream gravel mining might be impacting the study area.

In-stream gravel mining can cause environmental and geomorphic issues unless carefully managed. In-stream gravel mining can disrupt the river's sediment balance and preferred flow path. If gravel mining is not carefully managed, it can cause the river to become unstable, potentially leading to streambank erosion and/or the cutoff of a meander bend. An example of in-stream gravel mining is shown in Figure 2-5. The changes to the landscape near the middle of each photo are a result of gravel mining. Notice the gravel bar that formed on the far left side of the 2005 photo. Based on aerial photos, it appears that mining stopped in or around 2009, and the river has slowly started to heal itself.

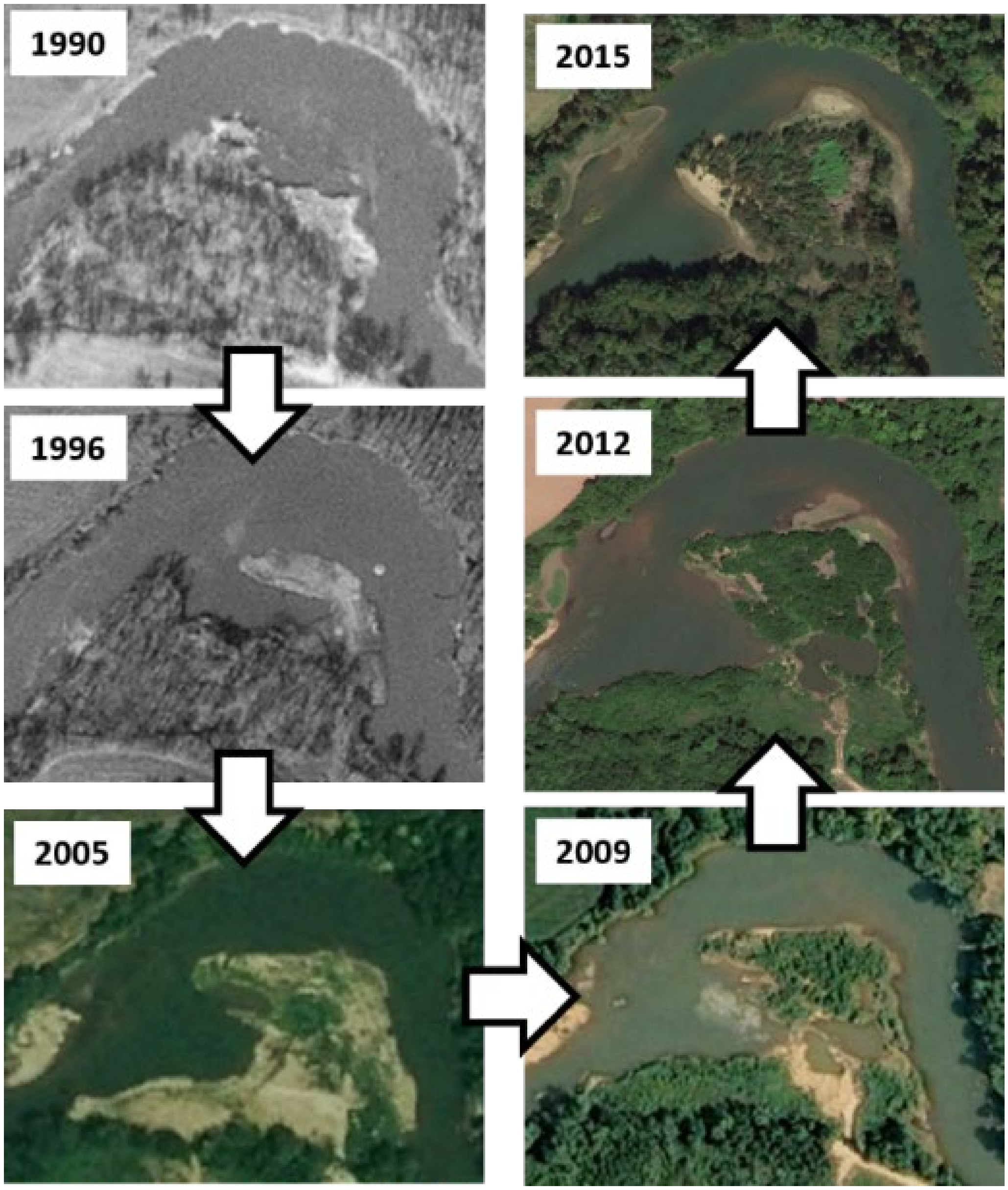


Figure 2-5. Recent Gravel Mining near RM 31.5; River Flows From Left to Right

2.3 MILL DAMS

Records show that seven mill dams have been constructed within study area. It is likely that more have been constructed which no longer exist and have gone undocumented. Vandercruyssen Mill was constructed somewhere in the lower part of Head's Creek, while the other six known mill dams were constructed on the Big River. The only mill dam that is currently fully intact is Byrnesville Mill (RM 14.4). All others are either partially breached, partially degraded or fully degraded.

No construction records for Big River mill dams were found; however, mill dams built on the Big River during the Civil War era likely had a timber cribbing foundation that was backfilled with quarry stone. It's likely they were capped with trapezoidal-shaped quarry stone to provide resistance to flow. Figure 2-6 shows a typical Civil War era foundation and historic Rockford Dam (From: *http://www.crt.state.la.us/dataprojects/archaeology/virtualbooks/BAILEYS/dam.htm*).

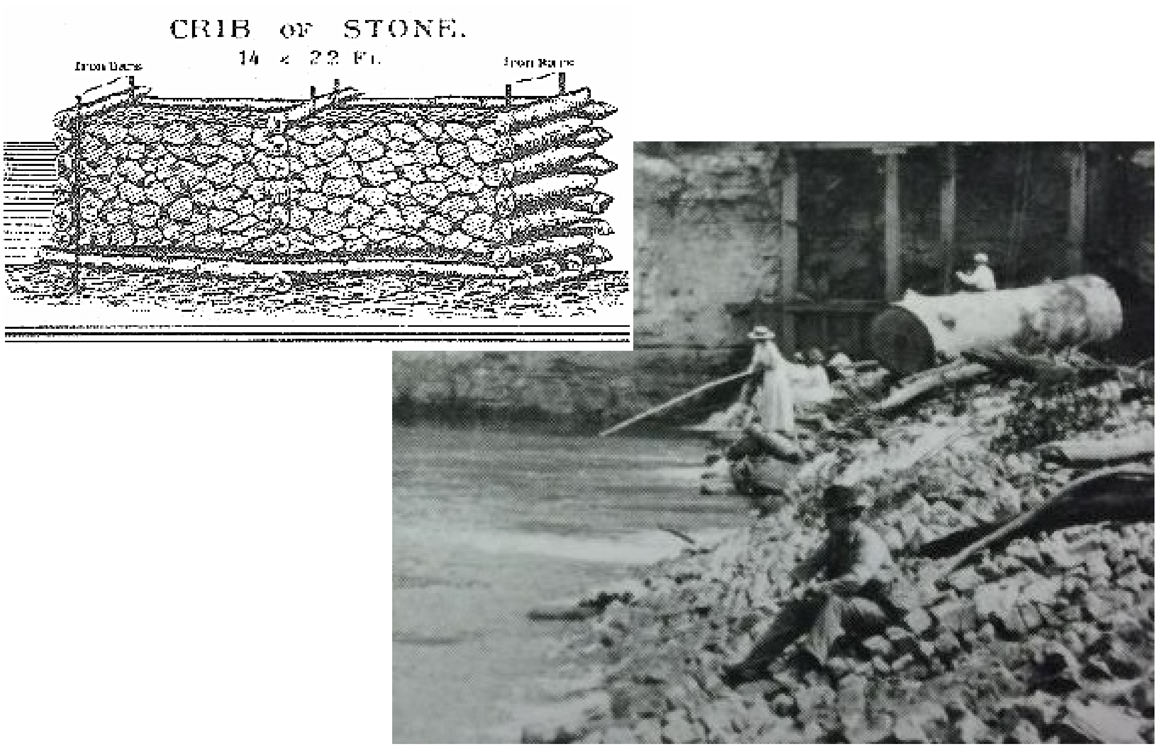


Figure 2-6. Typical Foundation Sketch, U.S. War Department 1891-1895 (left); Historic Photo of Rockford Mill dam (right)

These mill dams have been in place for over 100 years and the river has adjusted to their presence. Pearson and Pizzuto (2015) studied sediment storage behind similar-type mill dams on a similar river system and concluded that all sediment load (fine and coarse) can be transported over mill dams because the grain size and bed elevation of the river has been forcibly altered to transport the supplied sediment as it approaches the dam structure. If this were not the case, the impoundment would fill with sediment, which does not seem to be the case.

This process is shown in Figure 2-7, which shows that after a sediment ramp forms, a relatively small amount of sediment can be transiently stored immediately upstream of such structures. The process and extent of sediment impoundment is still being studied. It is difficult to precisely quantify the amount of transiently stored sediment because its presence is highly dependent upon recent flow. It is currently assumed that sediment is stored episodically and transported over Big River mill dams during highly variable flows, and then deposited at some point downstream of the structures (Pearson & Pizzuto, 2015).

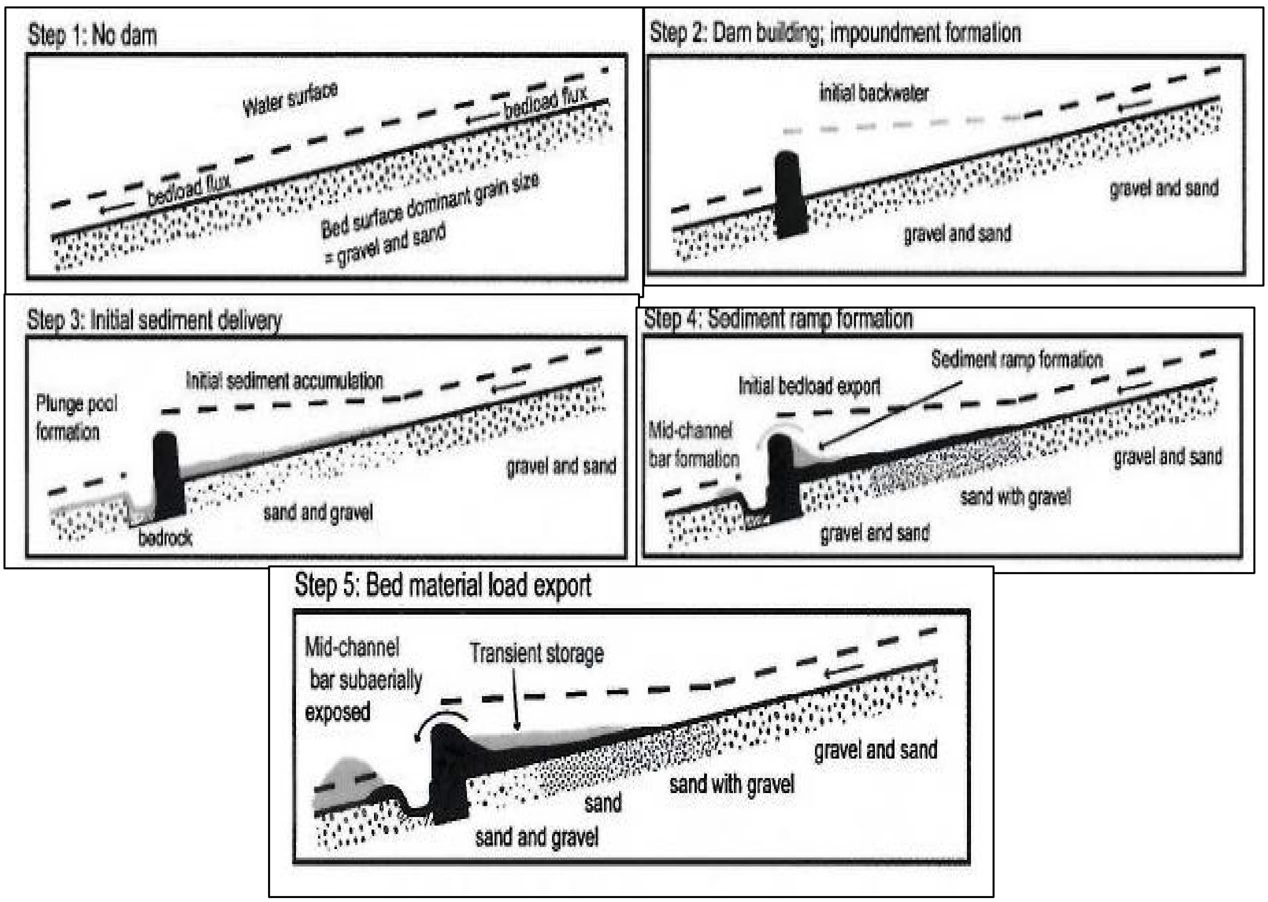


Figure 2-7. The Effects of Mill Dam Construction on Bed and Sediment-Storage Conditions

The failure of a mill dam can cause a few negative geomorphic effects in the surrounding river system. The magnitude of these effects are dependent upon a few factors, including rate of failure and height of dam. Some of the negative geomorphic effects include:

- The release of transient contaminated sediment storage from upstream of the dam (identified in Step 5 of Figure 2-7), which would be transported downstream. Larger contaminated sediments would likely be deposited nearby, potentially fueling localized bank instability.
- A reduction in bank stability due to the change in backwater elevation. Vegetative roots help stabilize banks, but they cannot immediately adjust to a rapid decrease in water surface elevation. Banks that do not have adequate armoring from roots are more susceptible to erosion during elevated flows.
- The initiation of a headcut, which reduces bed elevation locally and can propagate upstream. This process causes further deterioration of banks by undermining the foundation of the banks (this process is discussed in detail later, in Figure 3-5).

2.3.1 BYRNES MILL – RM 8.5

Patrick Byrnes, not to be confused with Patrick P. Byrnes of Byrnesville, constructed Byrnes Mill in the late 1800’s. The dam breached on its left descending bank, which now creates gentle rapids at low flows. The remaining structure is in poor condition and is capped with concrete which has significant open cracks. The concrete cap can also hide large voids which are not readily seen. The historic mill is shown in Figure 2-8 and the current condition is shown in Figure 2-9.

USACE entered into an interagency agreement to remove contaminated sediment from the floodplain at Byrnes Mill Park. Twelve inches of floodplain soil was removed and replaced with clean soil. Within a few years, floods have re-deposited several inches of contaminated soil. A better understanding of sediment dynamics in this area of the river is currently being studied under this agreement. It is understood that sediment deposits on and near Byrnes Mill park during high flows.

Figure 2-8. Byrnes Mill Historic Photos

Figure 2-9. Byrnes Mill 2016-2017

2.3.2 ROCKFORD MILL – RM 10.2

Rockford Mill, also known to some as Bonacker's Mill, was built by Henry Vandercruyssen in 1882 on a bluff outcrop just upstream of the confluence of Head's Creek (Figure 2-10). This was the second mill he constructed after the Vandercruyssen's Mill on Head's Creek. Between 1882 and 1929, Rockford Mill changed ownership. The new owner, Mr. Froshe, was arrested for operating it as a large still during prohibition. The Rockford Mill house went through many modifications through the years of its operation as a gristmill. By 1946, the mill fell into a state of disrepair, and not much was done to the dam structure (Bruce, 2016) (Jefferson County (Missouri) Library, n.d.).

The dam structure breached on its right descending bank creating steep rapids at low flows. The date of the breach is unknown. The remaining dam structure fell into such disrepair (Figure 2-11) that the USEPA became concerned that it might fail and release stored sediment with elevated lead and heavy metal content. USACE entered into an interagency agreement with the USEPA to temporarily stabilize the dam, and a temporary stabilization effort was completed in June 2016 (Figure 2-12 and Figure 2-13). A more permanent solution is still being studied.

Figure 2-10. Rockford Beach Mill historic photo

Figure 2-11. Rockford Beach Mill March 2016, Pre-stabilization

Figure 2-12. Rockford Beach Mill June 2016, Post-stabilization

Figure 2-13. Rockford Beach Google Earth Aerial Photo 2017

2.3.3 VANDERCRUYSSEN MILL – HEADS CREEK

In the late 1800's, Henry Vanderscruyssen built his first water mill on what is now known as Head's Creek, about one mile west of House Springs (Figure 2-14). Records do not indicate the exact location of the mill. By May 26, 1891, the Vandercruyssen Mill did the grinding for the surrounding township and had "a large patronage from other localities." The Vandercruyssen Mill stood on Head's Creek until the late 1950's.

Figure 2-14. Vandercruyssen Mill Historic Photo

2.3.4 BYRNESVILLE MILL – RM 14.4

Byrnesville Mill, also known to some as Gherke's Mill, Yerkey or Yerkes Mill, was built in the mid-1800's. An undated photo of the mill is shown in Figure 2-15. The exact construction date of the Byrnesville Mill dam is unknown but records show that in 1847, a man by the name of David Manchester applied for a Missouri state permit to construct the dam. At the time of completion, the dam was nearly twice as long as any other mill dam on the Big River. The mill dam had a rafting chute constructed to accommodate the timber cutters and the milling process was powered by a waterwheel. The chute was heavily used during the post-Civil War era when Missouri became a major supplier of railroad ties. The mill dam was constructed using timber cribbing with a stone cap.

The mill changed ownership about every two years until 1865, when Patrick P. Byrnes took ownership. Patrick P. Byrnes completely rebuilt most of the mill in order to accommodate the post-Civil War era automated milling process. In 1887, a full roller system was added which allowed the mill to produce a brand of flour called "Lilly White." The mill was operated by the Byrne family until 1903. In 1936, the milling operation permanently ceased and the mill changed ownership several times. The milling machinery was sold as scrap iron during World War II. In 1976, James Lalumondiere bought the mill and turned it into a residence.

Byrnesville Mill Dam is currently the only fully intact dam structure across the Big River in the study area, as shown in Figure 2-16. No in-depth structural assessment of the dam has been completed, but it appears to be in good condition and is maintained by the current owner. While the dam is in good repair, it is placed on a sharp bend and disrupts the natural riffle pool regime.

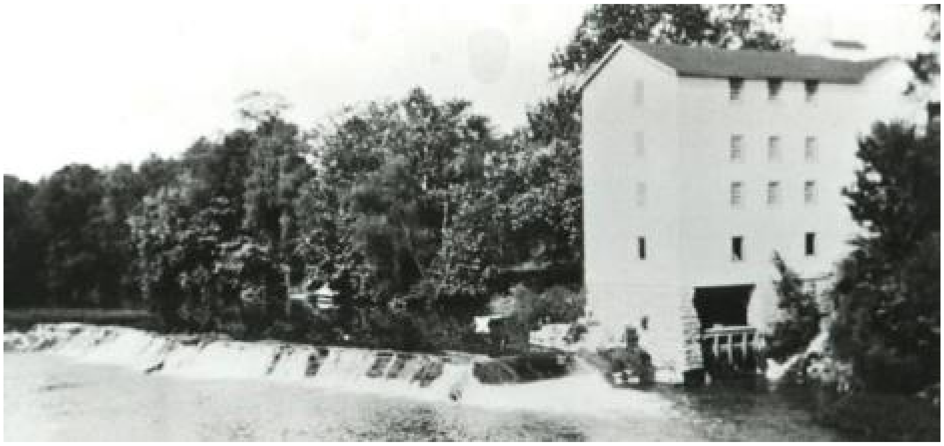


Figure 2-15. Byrnesville Mill Historic Photo

Figure 2-16. Byrnesville Mill 2017

2.3.5 CEDAR HILL MILL – RM 19.7

Cedar Hill Mill, also known to some as Maddox Mill, was built in the mid-1800's. The exact construction date of the Cedar Hill Mill Dam is unknown but records show that in 1847, Thomas Maddox petitioned to build a dam across the Big River in order to operate a water powered gristmill and sawmill.

Over the years, Cedar Hill Mill was used to mill meal and flour for livestock feeds and pet food. In the 1940s, Cedar Hill Mill started producing block ice. Ice production continued through the 1990s, peaking in the 1950s and 1960s. By the mid-1980s, milled pet food made up 50% of the mill's production.

It's unclear when the dam structure substantially breached, but aerial photos suggest it happened in the early 1990's. What remains of the dam appears to be unstable (Figure 2-17). At some point, a concrete cap was placed on the dam to help prevent further deterioration. The concrete cap has several gaping cracks as a result of being undermined, and it continues to deteriorate.

The dam was constructed in a leftward bend, so the mill was designed to take advantage of high flow velocity along the right bank. Since the dam has breached, water rushes through the breach towards the left descending bank, which is showing signs of erosion from the misaligned flow. There is strong evidence of head cuts upstream of this structure as a result of its vertical degradation thus far. Further degradation of the dam could cause further vertical and lateral instability upstream. The reach containing this mill dam structure should be stabilized by one or more grade control structures placed strategically to have minimal impact on the rivers natural riffle pool regime. If Cedar Hill Mill Dam is replaced by grade control structures, there is an excellent opportunity to use a bed sediment collector to collect bed material load.

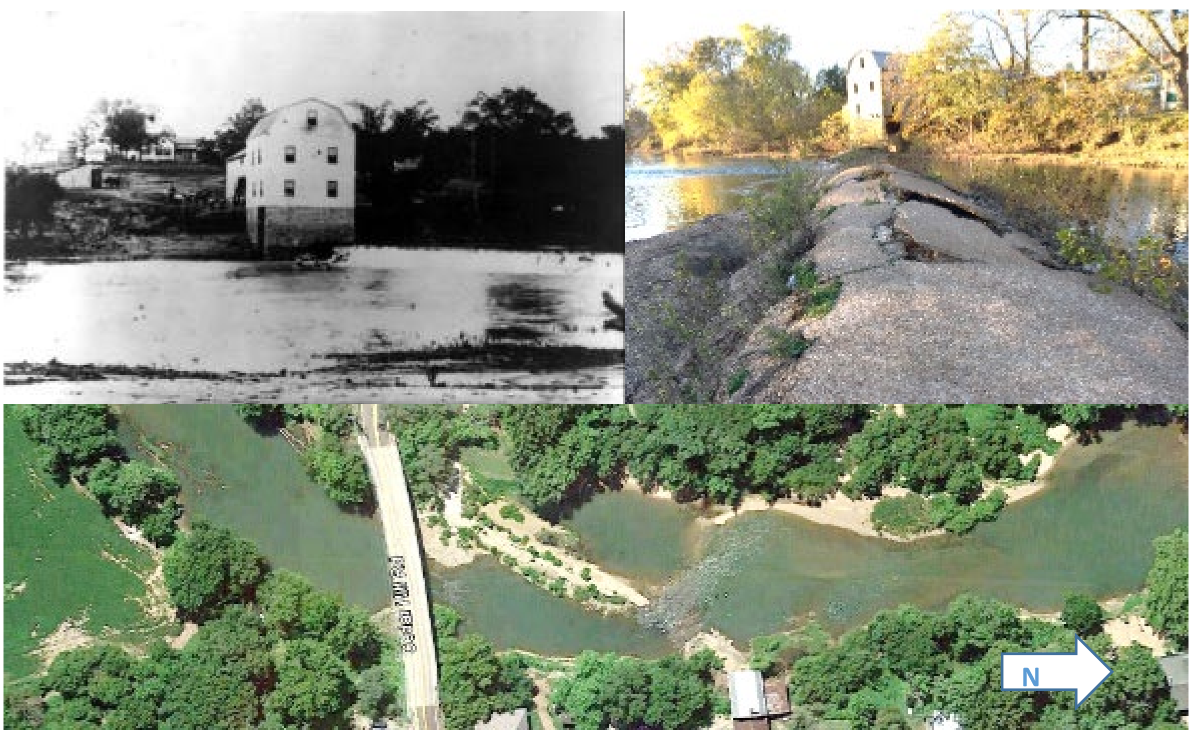


Figure 2-17. Cedar Hill Current and Historic Photos

2.3.6 MORSE MILL – RM 30.2

Morse Mill was built in 1851 by Madison Graham and John H. Morse and was permitted with an act from the state of Missouri. The mill closed down during the great depression, but it was not torn down until the 1940's. The dam structure has degraded to the point where the only visible evidence is a gentle rock riffle across the river (Figure 2-18). Morse Mill is the only known Big River mill dam that was built on a straight reach of river.

Figure 2-18. Morse Mill Current and Historic Photos

2.3.7 WIDEMAN MILL – RM 30.7

Completed in 1802, Wideman Mill is the earliest known water mill on the Big River. Wideman Mill was built by Francis Wideman approximately three quarters of a mile upstream of Morse Mill on a plot of land provided by the Spanish Government. Wideman Mill shut down on May 16, 1845 mainly because of the construction of Byrnesville and Cedar Hill Mills. These two mills took business from Wideman Mill, which milled corn and flour.

2.4 LOW WATER CROSSINGS

Low water crossings are defined as roads or bridges that significantly intrude into the river channel and disrupt the natural flow of water and sediment. Some low water crossings impede the upstream passage of fish at certain flows. Low water crossings can be constructed in ways to allow low flow and bedload to pass relatively uninhibited. The presence of a continuous structure spanning a river bed also affects hydraulics at higher flows. Depending on the size of the crossing, the disrupted hydraulics at high flows can encourage the development of a sediment ramp and downstream point bars, as described by (Pearson & Pizzuto, 2015).

There are six identified low-water crossings between RM 132 and RM 0 of the Big River. Four of these crossings appear to be constructed using box-culverts, which allow low flows to pass through with relatively little disruption. These crossings are located at RM 72.8, RM 74.4, RM 113.8 and RM 115.7. One of the crossings appears to have no accommodation for passing low-flow and acts as a continuous weir across the river bed, similar to a mill dam. This crossing is located at RM 102.7. Another of the crossings appears to have a low-flow metal culvert to prevent overtopping during baseline low flows. It is located at RM 106.0. These low water crossings are all shown with context in Figure 2-19 through Figure 2-24.

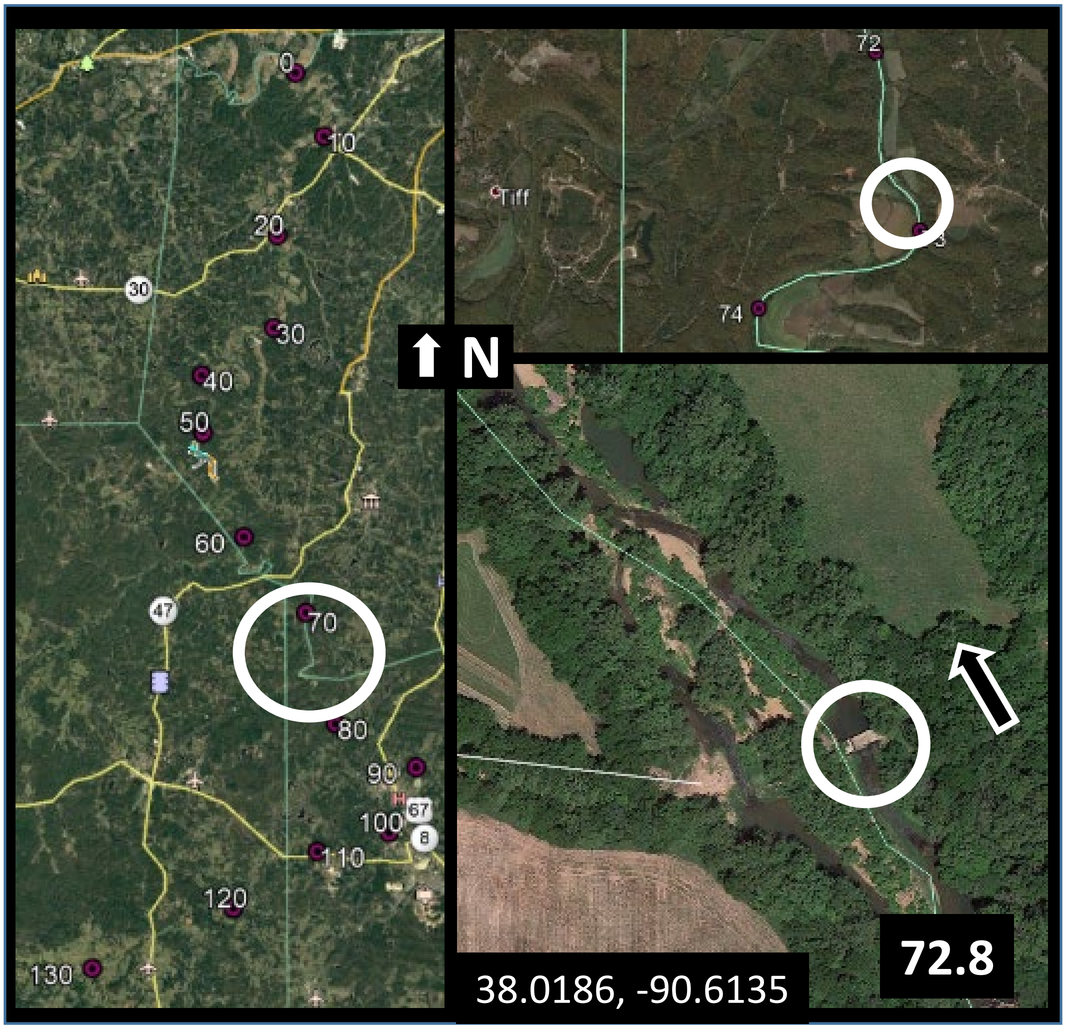


Figure 2-19. Box-culvert low water crossing at RM 72.8 – structure appears to be degraded and flanked

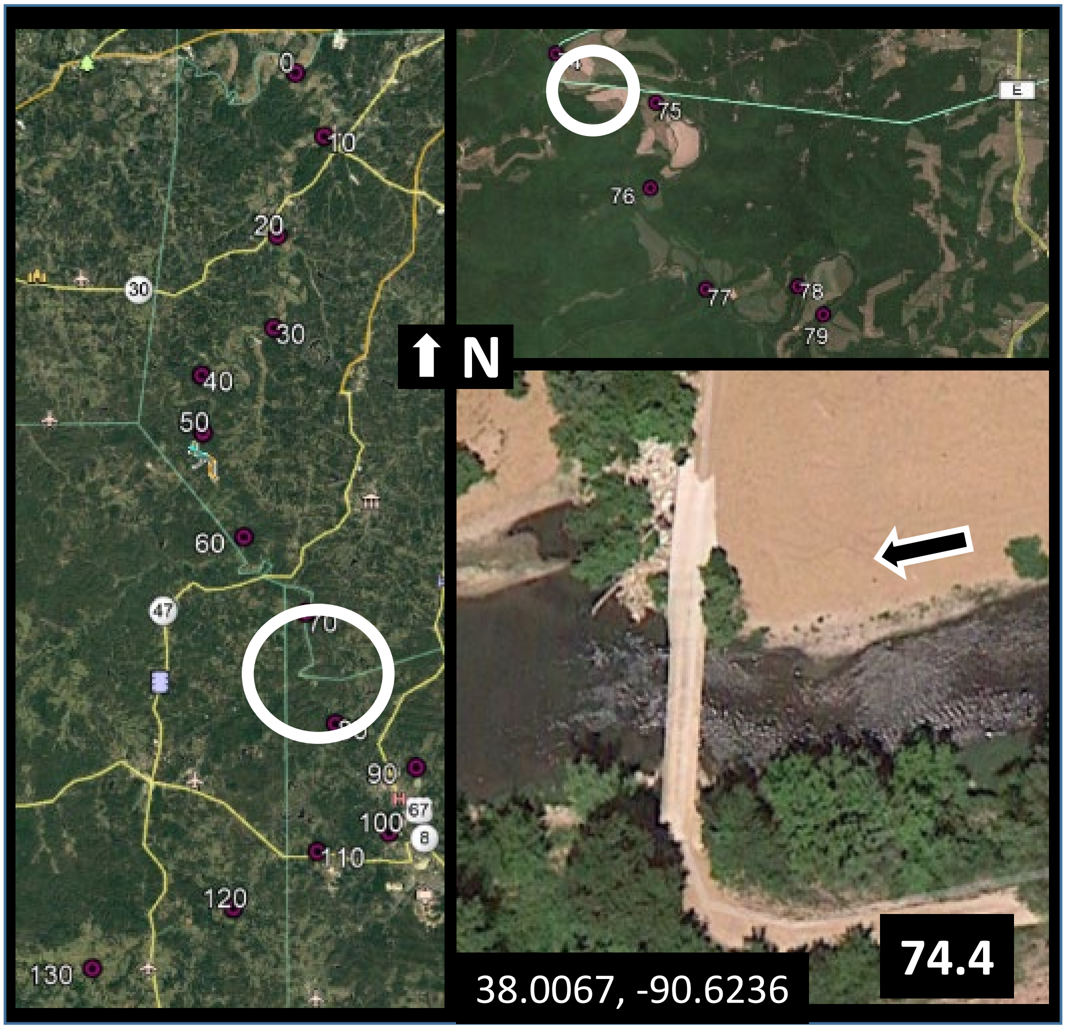


Figure 2-20. Box-culvert low water crossing at RM 74.4

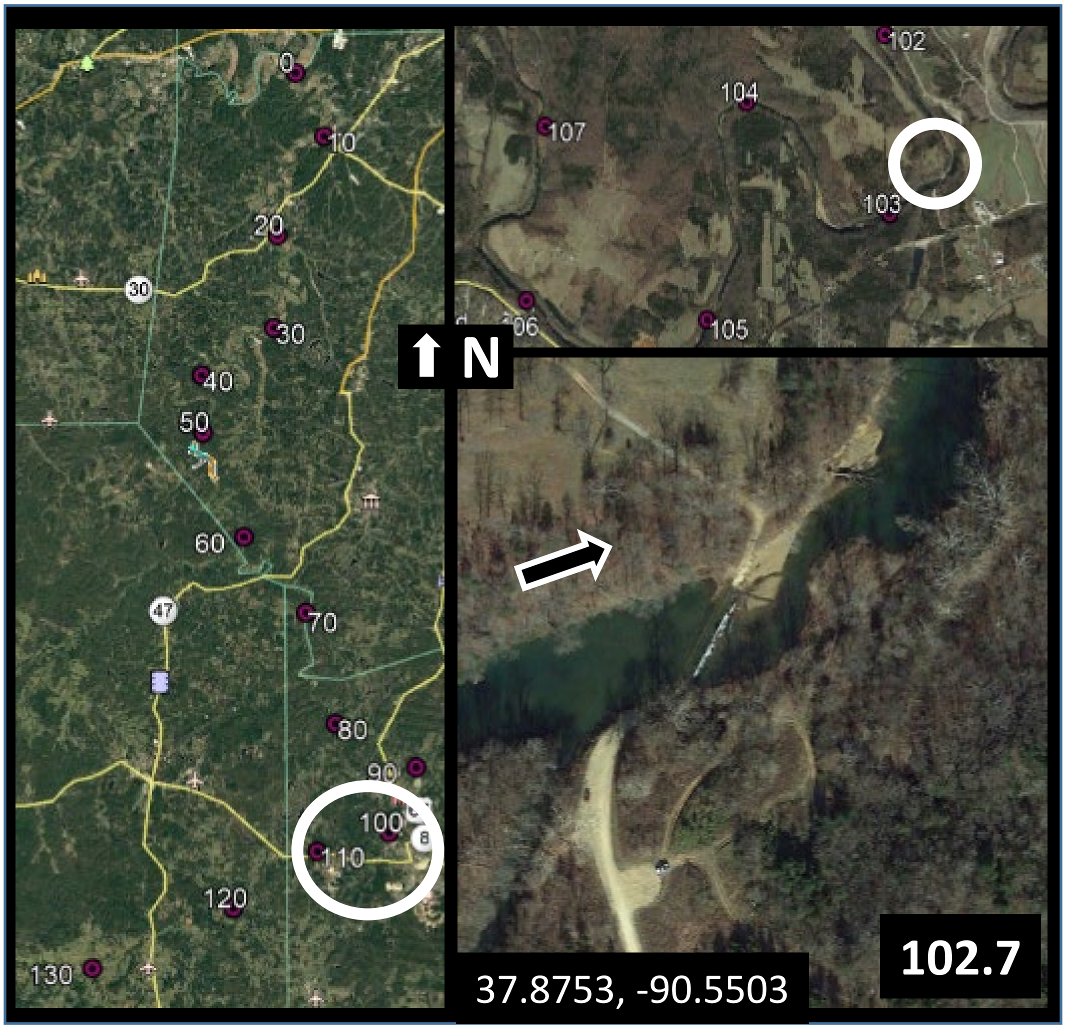


Figure 2-21. Low water crossing at RM 102.7

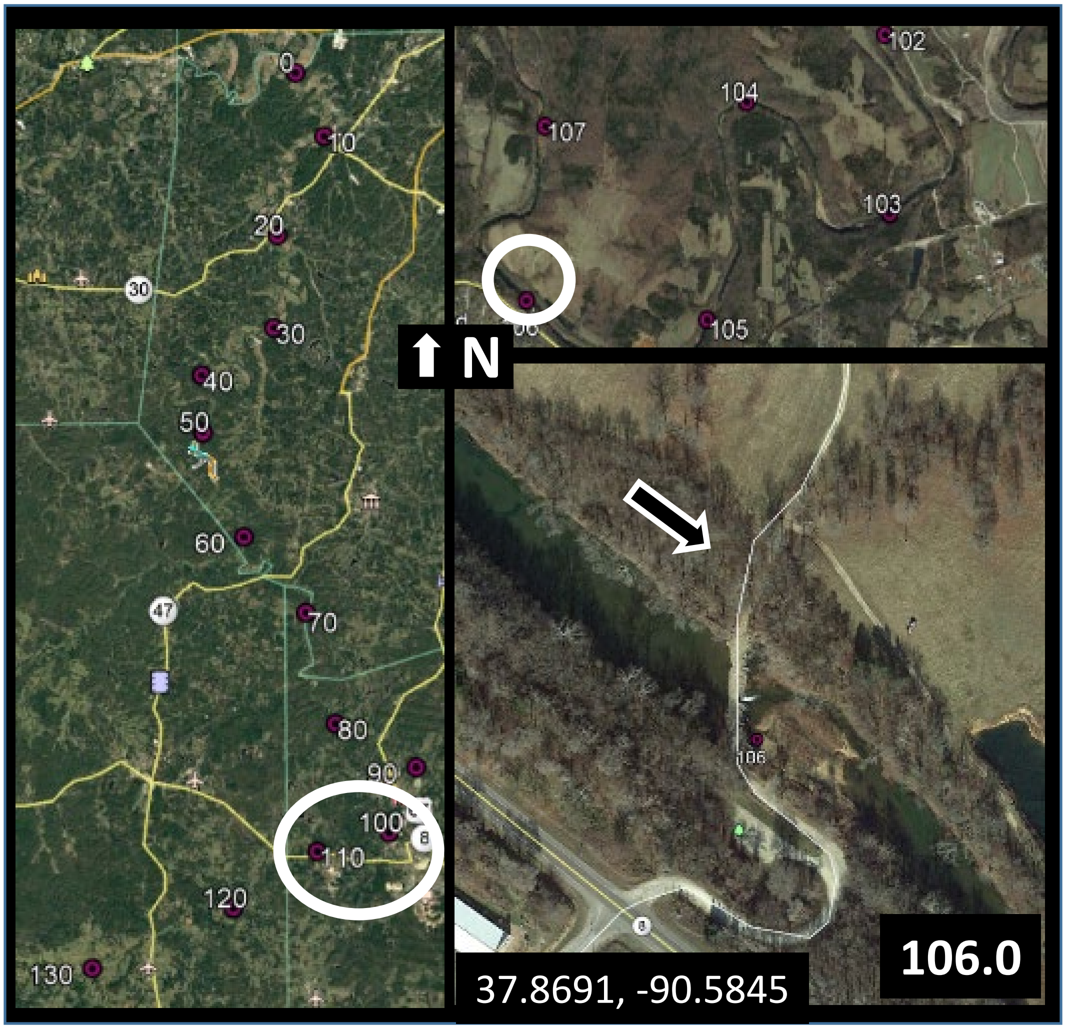


Figure 2-22. Low water crossing at RM 106.0 (AKA: Leadwood Access)

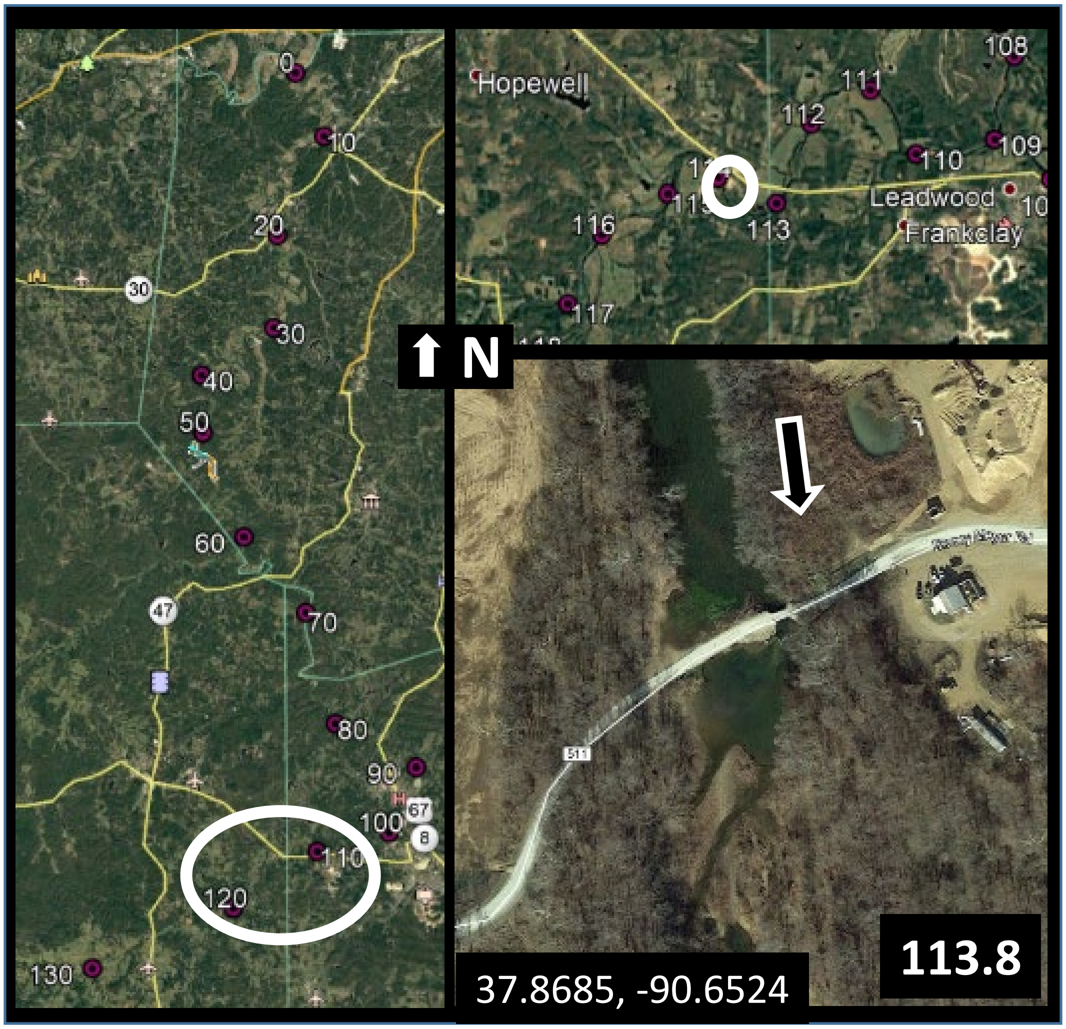


Figure 2-23. Box-culvert low water crossing at RM 113.8 (AKA: The Mounts Swimming Hole)

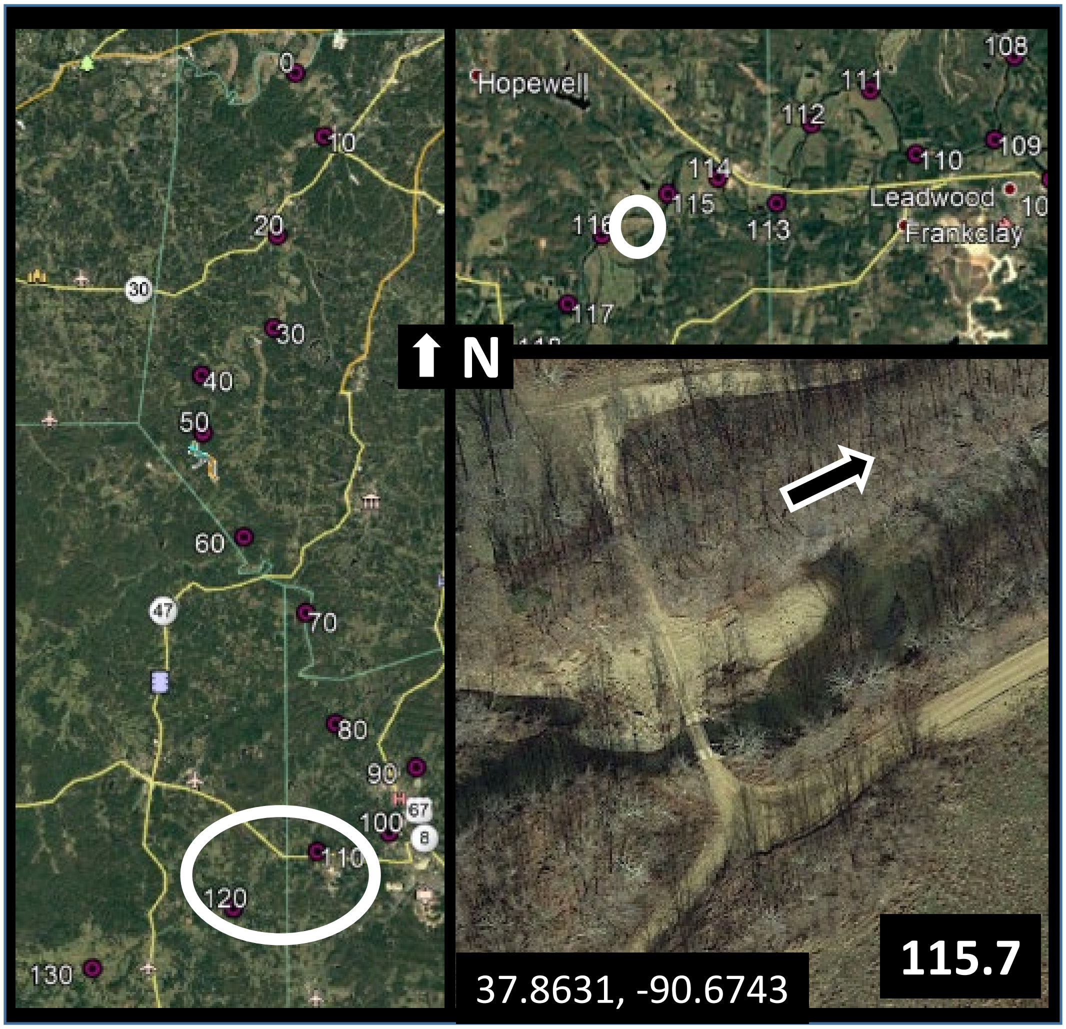


Figure 2-24. Box-culvert low water crossing at RM 115.7

3 DISCUSSION

The Big River can be characterized as an Ozarkian stream with a sandy gravel bed. There are two types of reaches within this river: disturbance and stable. Disturbance reaches actively erode and deposit sediment and have high lateral channel migration, actively changing gravel bars and/or no bank vegetation. Stable reaches tend to neither aggrade nor degrade, and generally exist in the presence of bluffs, bedrock controls, and/or forested floodplains.

3.1 SEDIMENT INTERACTIONS

Figure 3-1 conceptually outlines the inputs and interfaces for sediment and lead in the Big River. There are three main sources of lead and sediment: tailings piles, historic direct milling discharge and overland flow. Tailings piles have historically contributed excessive, heavy-metal-contaminated sediment into the Big River. Presently, the tailing piles have largely been mitigated by the USEPA. Contributions from tailings piles range in grain size. Milling discharge (slimes) were exclusively in the finest fraction (<0.063mm), and it is this input that has caused such excessive contamination in some parts of the floodplain in Jefferson and St. Francois Counties (Pavlowsky, Owen, & Martin, 2010). Slimes no longer directly contribute to the Big River, but were exceptionally toxic.

Overland flow continually contributes sediment into the Big River by means of surface erosion. Eroded sediment originating from upland portions of the basin has a much lower concentration of lead than sediment that erodes from the floodplain. 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. The only difference between these two pathways is the gradation or quantity of sediment that they tend to individually carry – a major tributary will generally carry more sediment while a minor tributary will generally carry less sediment.

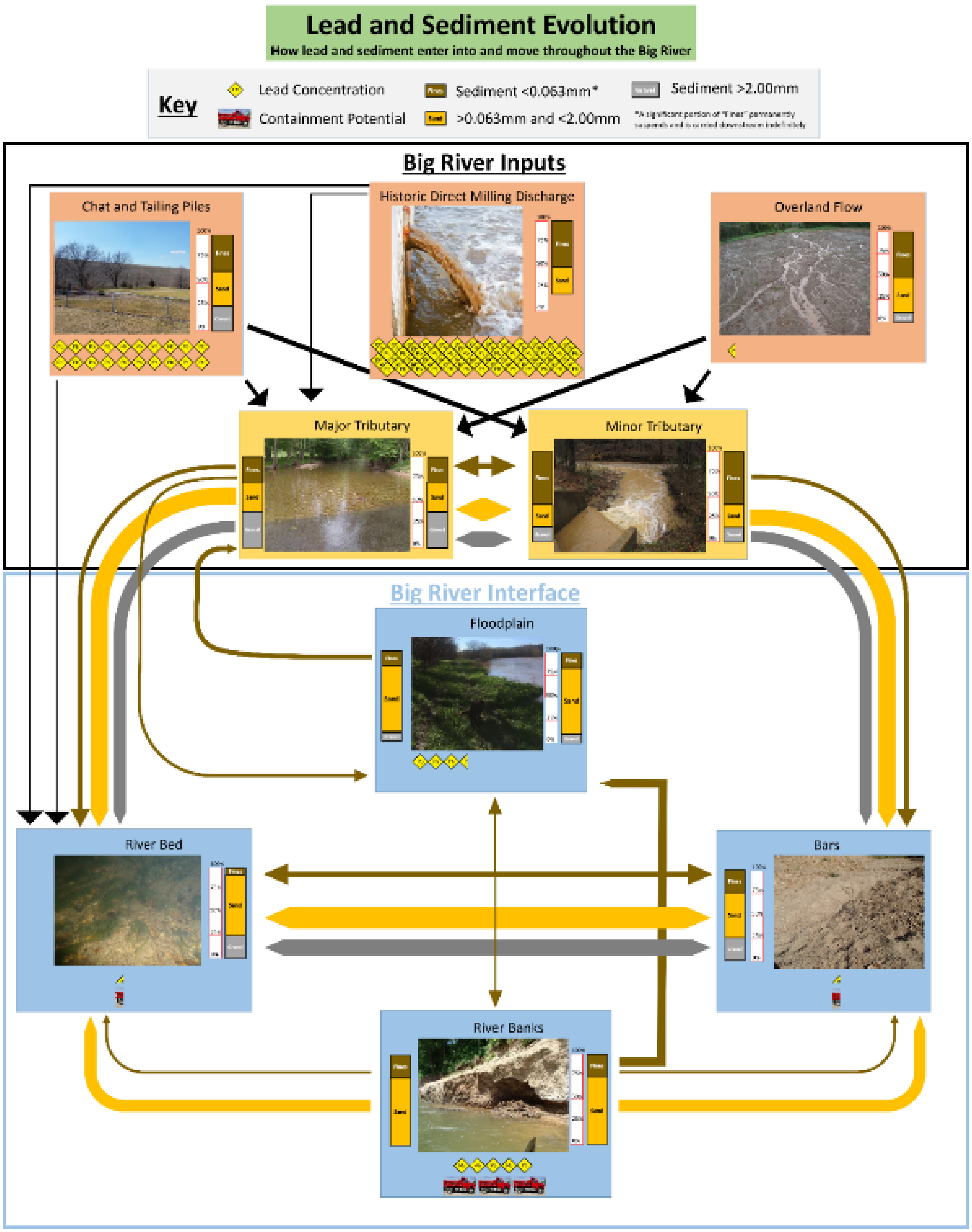


Figure 3-1. System-level Conceptual Diagram of Interactions With Lead and Sediment in the Big River

Prior to stabilization, tailing piles regularly contributed significant amounts of contaminated material to the Big River and its tributaries. Stabilized tailing piles no longer actively contribute substantial material to the river; however, tributaries that used to drain tailings piles remain highly contaminated. It is material from tailings piles that has choked the bed of the Big River in St Francois County and is moving downstream towards and through Jefferson County.

As described in (Pavlowsky, Owen, & Martin, 2010), "…mining chat (2-16mm) deposits are largely limited to channel segments in St. Francois County … finer tailings sediment fractions (<2mm) are present further downstream…"

Once the inputs have traversed the pathways, they then interface with and between four main areas in the Big River: floodplain, river bed, river banks and bars. Banks are just vertically exposed floodplain, but are separated here because samples indicate that exposed bank grain size compositions and lead contamination levels vary slightly from floodplain soil.

Larger sediment is usually transported as bedload and can be found in the bed and bars. Larger sediment can occasionally be found in the floodplain and banks. Smaller sediment is usually transported in suspension and can be carried through much of the system. Some smaller sediment will settle in the floodplain during overbank flooding and some smaller sediment will settle in-between the spaces of larger sediment in the bed, bar and banks as floods recede or during smaller events.

Larger sediment, such as chat from tailings piles, does not suspend or transport as readily as smaller sediment, such as from river banks. This material is bed material, which is transported only a short distance during sufficiently high energy flow events. When bed material moves, it unlocks smaller sediment from in-between it, which is transported downstream as a function of its size. Larger sediment is transported more slowly than smaller sediment because more energy is required to move it. In this watershed, events with high energy occur naturally and tend to move through the watershed relatively quickly. As a result, larger sediment does not move very far before it comes to rest. Larger sediment generally remains in the river bed and bars.

In contrast to larger sediment, smaller sediment (such as mining slimes are incorporated into the sediment load) can remain in suspension for longer. This is because smaller sediment can suspend and transport in lower energy flow conditions, which occur more often than high energy flow conditions. Thus, smaller sediment can be transported greater distances than larger sediment, even within a single flood; however, energy in a river varies spatially and temporally. When the energy is no longer sufficient to maintain smaller sediment in suspension, it will move more slowly as bedload or deposit and remain in place. Once smaller sediment is transported to lower reaches of the river, the energy required to move it may occur less frequently since lower reaches of a river see lower energy levels relative to upper reaches. Smaller sediment that was once primarily suspended in upper reaches may primarily be transported as bedload in lower reaches as evidenced by the vast areas of contaminated floodplain and in-stream sediments in the lower Big River.

3.2 SPECIFIC GAGE ANALYSIS

Specific gage analysis was performed at Eureka, Byrnesville and Richwoods gages in order to assess bed stability. A specific gage analysis considers how river stages have changed for a given flow. A river channel is considered to be vertically stable if the specific gage record shows no consistent increasing or decreasing trends over time for a given flow. An increasing or decreasing trend indicates an aggrading or degrading condition, respectively. Vertical bed stability is important to consider when selecting and designing river features. For example, a degrading bed could undermine a bank stabilization site; similarly, an aggrading bed could flank a bank stabilization site. Two key drawbacks of a specific gage analysis are that it does not provide a reason for an increasing or decreasing trend and it does not forecast future conditions; however, future stability is dependent upon factors including land use changes, climate trends, and changes in the stream condition upstream or downstream of the gage.

For all three gages analyzed, median, mean, 1.2-year, and 2-year flows were considered, if data allowed. Because median, mean, and 1.2-year flows are generally in-bank (or close), the chosen flows are lower than the river banks and the stages tend to reflect the bed of the river, but not the overbanks. As flows and stages increase, they are increasingly affected by overbank conditions. River beds are naturally dynamic due to sediment transport that occurs during flooding, so minor variances in stage for a given flow is not necessarily bad. During large flood events, significant geomorphic changes can occur. These changes may be noticed in specific gage analysis.

3.2.1 MERAMEC RIVER

The specific gage analysis at Eureka is shown in Figure 3-2. The bed of the river has degraded at this gage; stages have changed significantly since the inception of this gage. Median and mean flows from inception until the mid-1940’s, have increased slightly. From the mid-1940’s until the mid-1950’s, the stages remained fairly stable, with a slight decrease in the late 1950’s sharply diving into a pronounced decline in the early 1960’s. This decline persisted for upwards of four decades until the 1990’s. In the early 2000’s, stages began to level out. The trendlines show that stages in the median flow are beginning to increase. The final two points in the median flow are increased by about one foot. It is unwise to make assumptions about future trends based only upon these two points.

Considering only the higher flows, there is a strong and constant downward trend. These higher flows are measured less often, hence the reduced number of measurement points. Because of this, it is important to understand that errors in measurement and nuances in the river, gage and equipment conditions at the time of measurement can have a greater effect on the shown trend. Because the trend is a plot of stages at flows that are +/- 10% of the target flow, data can be unintentionally skewed upward or downward if not enough data points exist. If those data points are, for example, mostly in the +10% or -10% range instead of representative of entire +/- 10% range, then data can be skewed.

It appears that the Meramec River at Eureka has had an unstable past, but stage changes can be affected by a variety of factors including changes in vegetation, variance in water viscosity and density due to water temperature, measurement error and effects of nearby structures such as bridges. If, in fact, the bed at Eureka is unstable, the risk is low of this instability adversely affecting the Tentatively Selected Plan (TSP). On the Meramec River, instability could partially explain the lateral erosion that has occurred 10 miles (discussed later in Figure 3-13) and 13 miles upstream of the gage. Meanwhile, there are no obvious signs that bed instability at the Eureka gage has adversely affected the planform of the Big River. Even if bed instability found its way up the Big River, Byrnes Mill is located 11.5 miles upstream of the Eureka gage and would presumably arrest any instability and prevent it from continuing further upstream. Further, grade control features are considered in the TSP and would be applied as needed to prevent potential instability from continuing upstream. In addition, features will be adequately designed with consideration for potential bed instability; therefore, it is reasonable to assume that any potential vertical bed instability at the Eureka gage would not adversely affect the features proposed in the TSP.

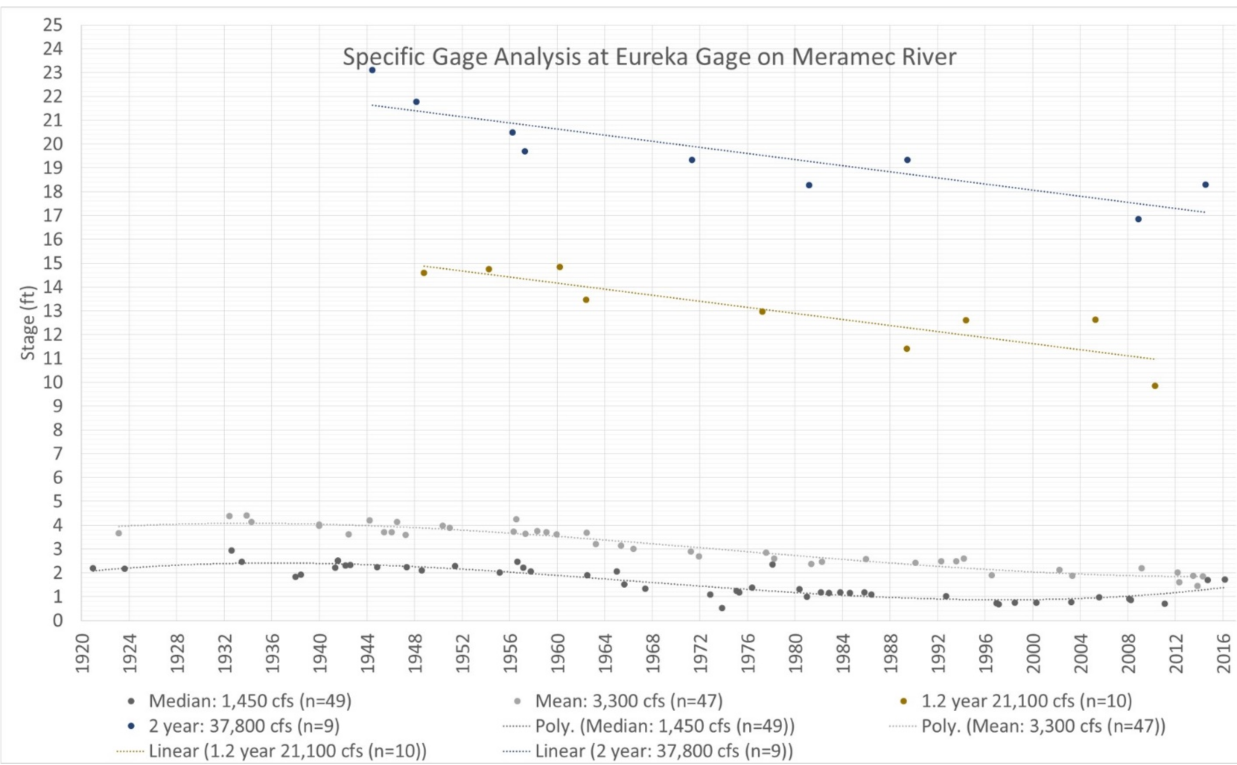


Figure 3-2. Specific Gage Analysis at Eureka

3.2.2 BIG RIVER

The specific gage analyses at Byrnesville and Richwoods are shown in Figure 3-3 and Figure 3-4, respectively. There is less data available at these gages, but still enough to complete a specific gage analysis with some certainty.

The Byrnesville mill dam is located just upstream of the Byrnesville gaging station. The presence of the mill dam could have affected bed material load patterns and thus hidden trends at this gage. The mean river stage appears quite stable over the almost 100-year history of the gage. The 1.2- and 2-year flow stages are also quite stable over time, although the 1.2-year stage seems to have declined slightly in the past couple of decades. The slight decline in stages at median flow near Byrnesville are likely affected by the in-stream gravel bar nearby, which can adjust and cause changes to the stage over time. These effects are dampened at higher flows, as is evident when comparing median flow stages to mean flow stages.

Future stability at this gage site depends on many factors including land use changes, changes in the stream condition upstream or downstream of the study area, specifically including the current/potential deterioration of mill dams in the lower Big River.

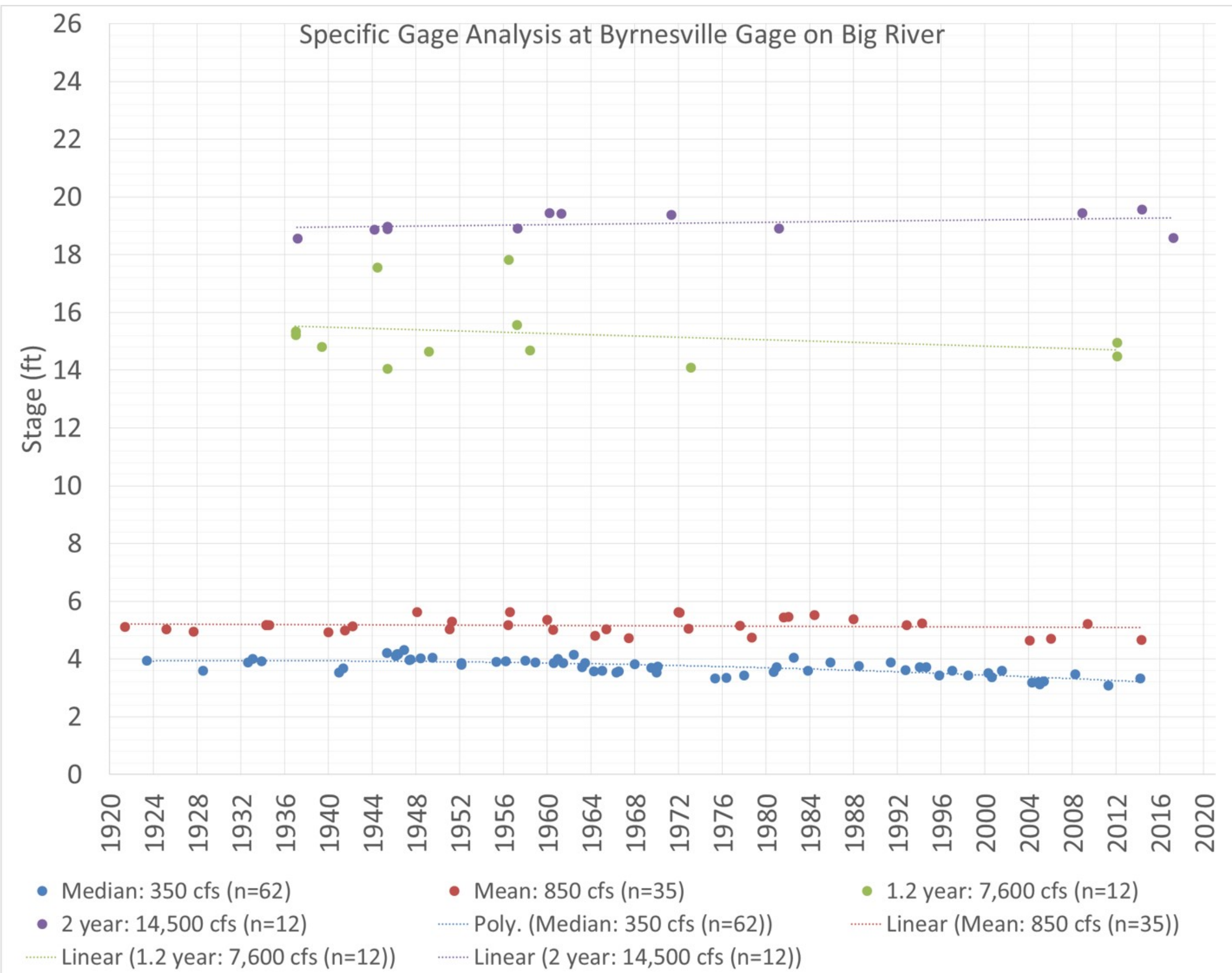


Figure 3-3. Specific Gage Analysis at Byrnesville

Richwoods gage does not have as much historic data available for analysis compared to Byrnesville – Figure 3-4 is sized equally to Figure 3-3 to illustrate the relative lack of historic data. Two-year flow was not considered in this analysis because there were not enough measurements. Also, a lower flow (200 cfs) was used instead of median flow (290 cfs), because nearly twice as many measurements were available. As is evident by the trendlines in Figure 3-4, stages at this gage have remained quite stable over the last 30+ years.

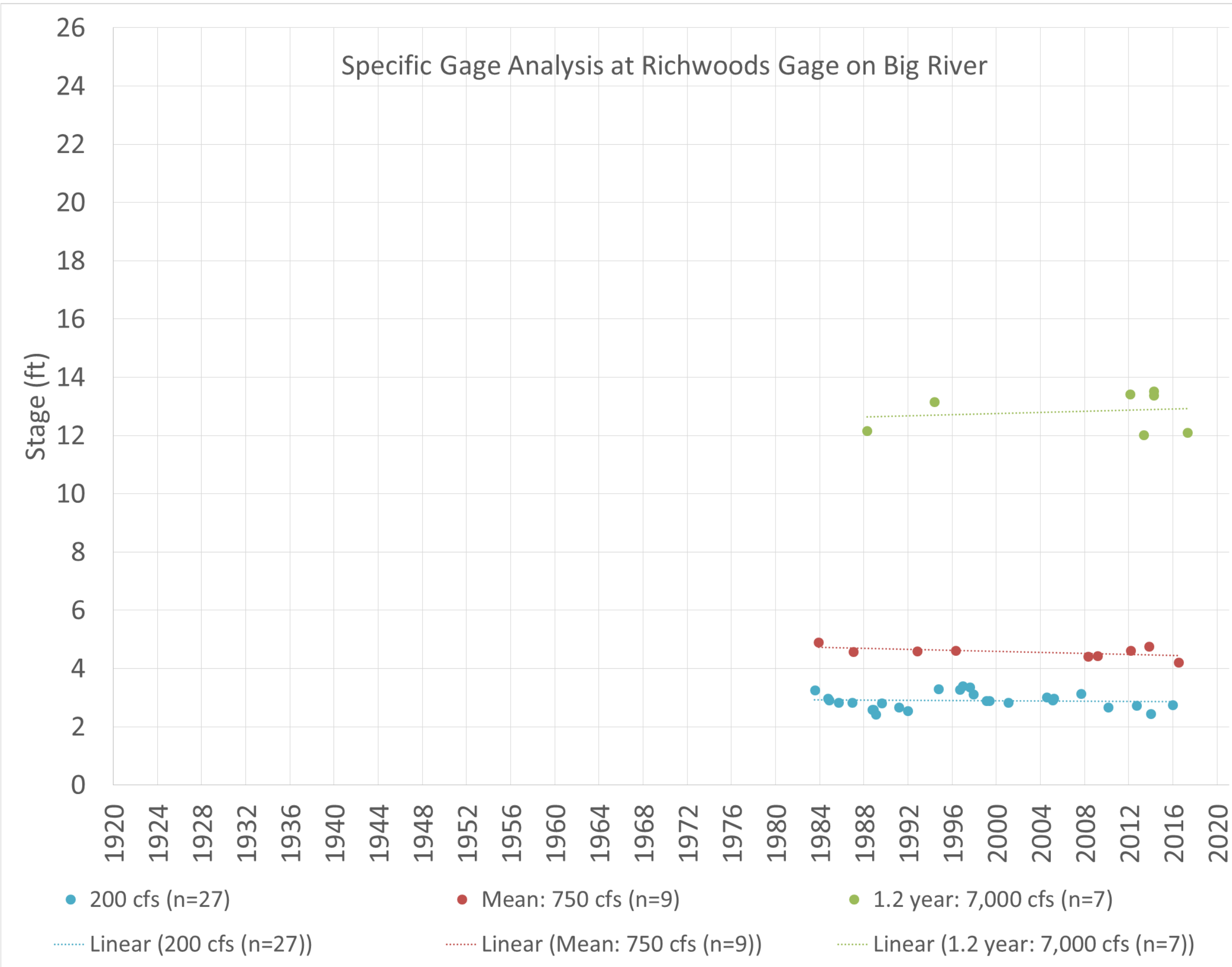


Figure 3-4. Specific Gage Analysis at Richwoods

3.3 SUSPENDED SEDIMENT ANALYSIS

Suspended sediment is important to this study because it is of a finer gradation. Previous studies and samples have shown that finer gradation sediment has higher levels of contamination than coarser gradations (Pavlowsky, Owen, & Martin, , 2010), (Young, 2011).

Suspended Sediment Concentration (SSC) is a common metric that is used to quantify sediment that is transported in suspension by a river – that is, without touching the river bed. SSC is not representative of the entire sediment load in the river because it excludes bedload. Bedload is not suspended, but instead translates (slides) and/or saltates (skips/bounces) along the bed of the river. While SSC is a great metric to quantify suspended sediment in a river, it must be related to Total Suspended Solids (TSS) in order to properly relate to mussel health in this ecosystem study. TSS is a common metric used in ecosystem studies involving mussels because literature generally correlates TSS to mussel health and habits.

TSS and SSC are similar, but the sampling method to reach each is slightly different. This is described in (Glysson, Gray, & Schwarz, 2001), which also states: "SSC values tend to exceed TSS values … when the percentage of sand-size material exceeds about a quarter of the sample sediment mass." The mass of sand in a sediment sample from the Big River easily exceeds a quarter of the total sample in most locations. Because SSC data was the basis for the USGS analysis at Byrnesville, a reduction of 20% was applied to SSC values as a conservative estimate to estimate TSS (Glysson, Gray, & Schwarz, 2001). With the reduction factor in place, TSS can be approximated by using a discharge-SSC relationship, followed by the reduction percentage.

The existing TSS conditions in the study area were estimated using the analysis described in this section.

3.3.1 SOURCES

Suspended sediment comes from a few primary sources, as described previously in Figure 3-1. This section focuses on river-bank erosion and discusses overland flow. Finer bed material is another source of suspended sediment, although it is composed mostly of sediment that has been sourced from river bank erosion, overland flow, or tributary inputs.

Overland flow generally contributes mostly silt/clay-sized sediment, which remains in suspension indefinitely. Overland flow sediment inputs can be quantified using the Soil and Water Assessment Tool (SWAT). This tool considers land use, basin size and slope and hydrology. The user calibrates the model using stream gages and the model produces estimates of past discharge and sediment contributions from each watershed. The parameters of a SWAT model can be adjusted to investigate the effects of changing land use and hydrology.

SWAT highlighted some of the best and worst tributaries. Some tributaries have experienced significant bank erosion, as well. Some tributaries have high turbidity (looks like "chocolate milk") during rain events, while others have much lower turbidity (can see channel bottom through flow). This difference can likely be attributed to a combination of land management practices, drainage basin size and/or basin steepness. Tributaries with high sediment load can be managed with Best Management Practices (BMPs) to reduce sediment loading.

3.3.2 SIMULATION

Sediment data is intermittent within the study area. USGS collected some suspended sediment data at Eureka from 1982-1986 and at Byrnesville and Bonne Terre from 2011-2013 and has written a report on the sediment data from Byrnesville and Bonne Terre gages (Barr, 2016). USGS provides an equation that relates discharge to SSC at the Byrnesville and Bonne Terre gages. This study applied USGS's equation at

Byrnesville gage to extrapolate back in time to represent suspended sediment transport at Byrnesville based on daily discharge. The resulting simulated suspended sediment totals are summarized in Table 3-1, which shows total flow and simulated total suspended sediment load from 1990–2007. The results in Table 3-1 are statically tied to the relationship developed by USGS at the Byrnesville gage with sediment data from 2011 to 2013; therefore, the extrapolated results shown in Table 3-1 represent sediment estimates as if geomorphological, climatological, land management, land use and other factors in the watershed were the same as 2011-2013 data.

One output of this simulation is a frequency analysis of discharges and their associated estimated suspended sediment load (SSL). The analysis can be further refined by year and month to get statistics for timeframes of interest. Loading during specific periods is important when bank erosion rates are considered, as a portion of eroded banks become suspended sediment.

Median flows were considered separately from TSS at median flows during seasons when water temperatures exceed 65˚F (April – September). High flows are intermittent in this watershed and median flow is more representative of conditions during the majority of the year. It is during these conditions that malacologists expect mussels to be most active. Once the median flow was isolated, it was used to look up the typical simulated TSS value at that flow and water temperature.

At Byrnesville, the TSS value at median flow between April and September is 18 mg/L.

Table 3-1. Annual Flow and Simulated Annual Suspended Sediment Load at Byrnesville Gage on Big River, Jefferson County, Missouri; 1990 to 2007

Big River at Byrnesville		
Year	Cumulative Flow (cubic feet)	Cumulative Sediment (tons)
1990	40,668,048,000	362,465
1991	22,245,840,000	61,308
1992	19,212,317,115	94,027
1993	66,920,515,200	1,195,312
1994	38,699,251,200	598,448
1995	30,280,348,800	218,782
1996	31,248,901,770	243,822
1997	31,780,339,200	187,047
1998	31,916,073,600	179,268
1999	23,631,177,600	114,509
2000	8,979,574,426	34,441
2001	12,807,763,200	44,950
2002	30,600,633,600	237,067
2003	25,873,430,400	125,437
2004	28,335,268,328	100,462
2005	23,966,841,600	135,403
2006	20,164,464,000	109,055
AVERAGE	28,666,516,943	237,753
MEDIAN	28,335,268,328	135,403
TOTAL	487,330,788,039	4,041,804

In order to understand discharge and suspended sediment transport on the Big River and Meramec Rivers in the same context, the results of the simulation at Byrnesville gage on Big River were integrated into another simulation. A regression was developed for suspended sediment at Eureka gage using discharge and intermittent suspended sediment concentration data from 1982-1986. The regression was applied to discharges at Eureka dating from 1922 to 2017. Separately, the USGS-developed regression at Byrnesville was applied to the Byrnesville discharges dating from 1922 to 2017. It should be understood that applying these regressions to historic and/or future discharges on the Big and Meramec Rivers flows will not yield actual suspended sediment load (SSL); however, these regressions can be used to extrapolate SSL on the Big and Meramec Rivers simultaneously for a better conceptual understanding of system-wide sediment trends and order of magnitude estimates.

At Eureka, this median TSS value is approximately 18 mg/L between April and September.

Upon analysis of the system-wide simulation, average daily SSL at Byrnesville and Eureka are around 600 tons/day and 1,600 tons/day, respectively. These averages are severely skewed by high flow events –

SSL at baseflow is over an order of magnitude smaller at <30 tons/day and <80 tons/day at Byrnesville and Eureka, respectively. By subtracting Byrnesville's daily SSL from Eureka's SSL, it is possible to estimate the SSL from the Meramec upstream of Big River's confluence with Meramec River. These contributions are associated with the Pacific gage, which is just upstream of the Big River's confluence with Meramec River. The average daily SSL at Pacific is estimated to be around 1,100 tons/day. As with Eureka and Byrnesville, this average is severely skewed by high flow events – SSL at baseflow is over an order of magnitude smaller (<60 tons/day).

When considering averages, the Big River contributes 25% of the flow to the Meramec, and 39% of the suspended sediment load in the Meramec. That's 0.7 tons of sediment per day per cubic foot of discharge from the Big River and 0.4 tons of sediment per day per cubic foot of discharge from the Meramec River.

This simulation does not account for changes in hydrology, land use, land management, geomorphology or other factors that were beyond the scope of this analysis. Despite these limitations, it provided valuable conceptual insight to the suspended sediment loadings on the Big and Meramec Rivers.

3.3.3 CHANNEL CHANGE ANALYSIS

Bank erosion is a natural process that can be exacerbated by human actions such as deforestation, urbanization, surface mining, gravel mining and farming/grazing to the bank's edge. After a period of instability at one location, a bank will begin to heal itself and begin to slow or stop its lateral migration. This process is summarized in the Channel Evolution Model (CEM), which is shown in Figure 3-5. Bank material eroded from the Big River main stem contributes sediment to the river and increases total suspended solids (TSS) levels. Within most of this study area, sediment eroded from banks also contains high levels of lead contamination.

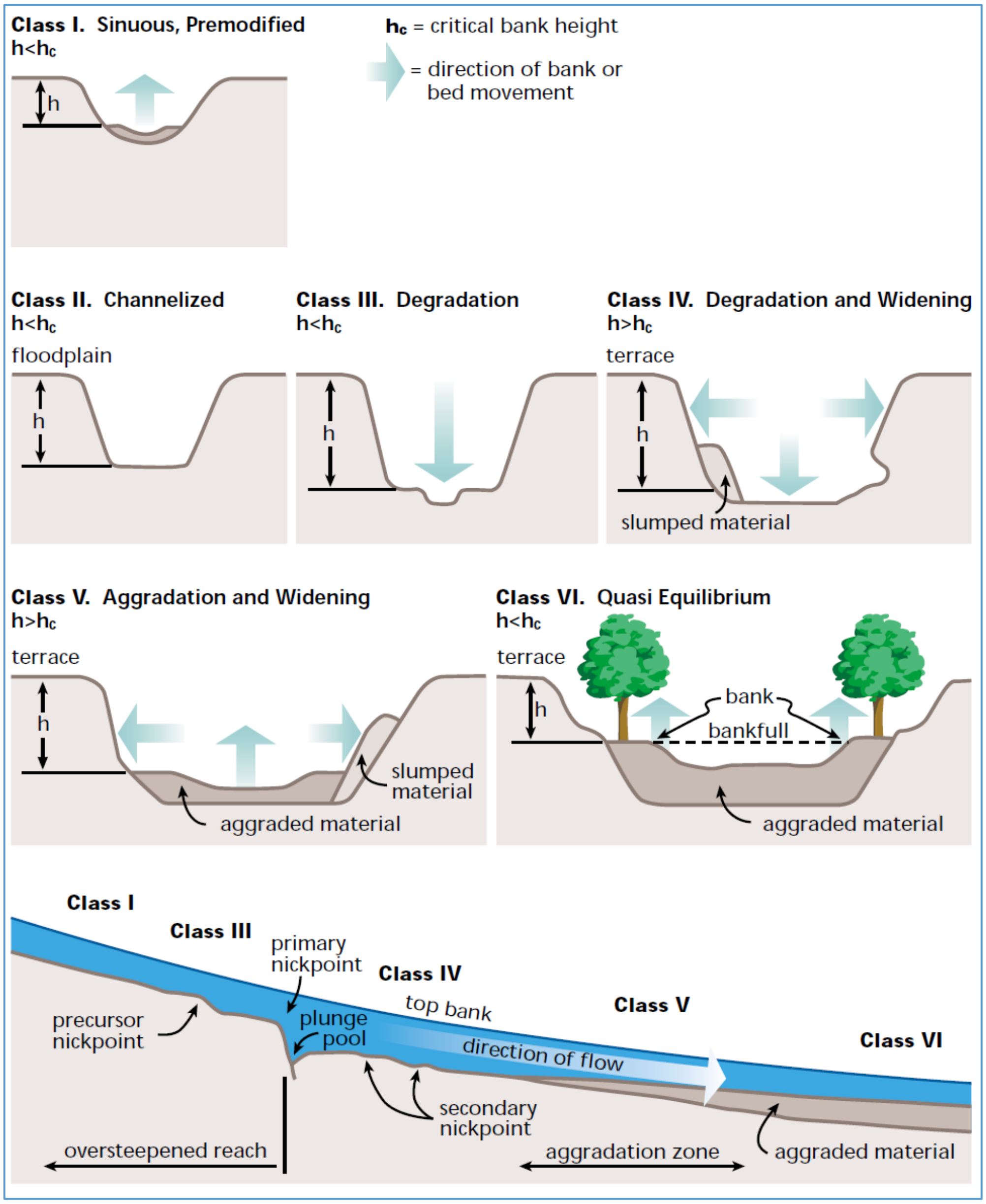


Figure 3-5. Channel Evolution Model (CEM); Source: Simon 1989

Pavlowsky and Young visually assessed channel migration throughout the Big River due to bank erosion over time by drawing banklines from 1937, 1954, 1970, 1990 and 2007 imagery (Pavlowsky & Owen, 2013). This analysis clearly marked areas of significant channel change and areas where channel change has persisted for many decades. An example of that assessment is shown in Figure 3-6 - “disturbance” reaches in Figure 3-6 include at River Kilometers 53 and 57; “stable” reaches include at River Kilometers 50, 58, and 61.

USACE used 2016 imagery to update Pavlowsky’s channel change map with 2016 banklines on the Big River. Banklines were traced and compared to previous banklines to identify and quantify lateral movement by measuring the distance that the banklines moved since 2007 and since 1990. Further, the eroded bank volume was estimated by using Light Detection and Ranging (LiDAR) data from 2007 (MSDIS: http://www.msdis.missouri.edu/data/lidar/index.html). This method assumed a similar bank geometry as the bank continued to erode. The process is summarized on the next few pages in Figure 3-7 through Figure 3-10.

The study area encompasses about 136 miles of the Big River, extending from Jefferson County to the edge of Iron County. This analysis focuses on a 65 mile stretch of the Big River in Jefferson County, which is assumed to be typical of the lateral instability and contamination that exists in most of the Big River.

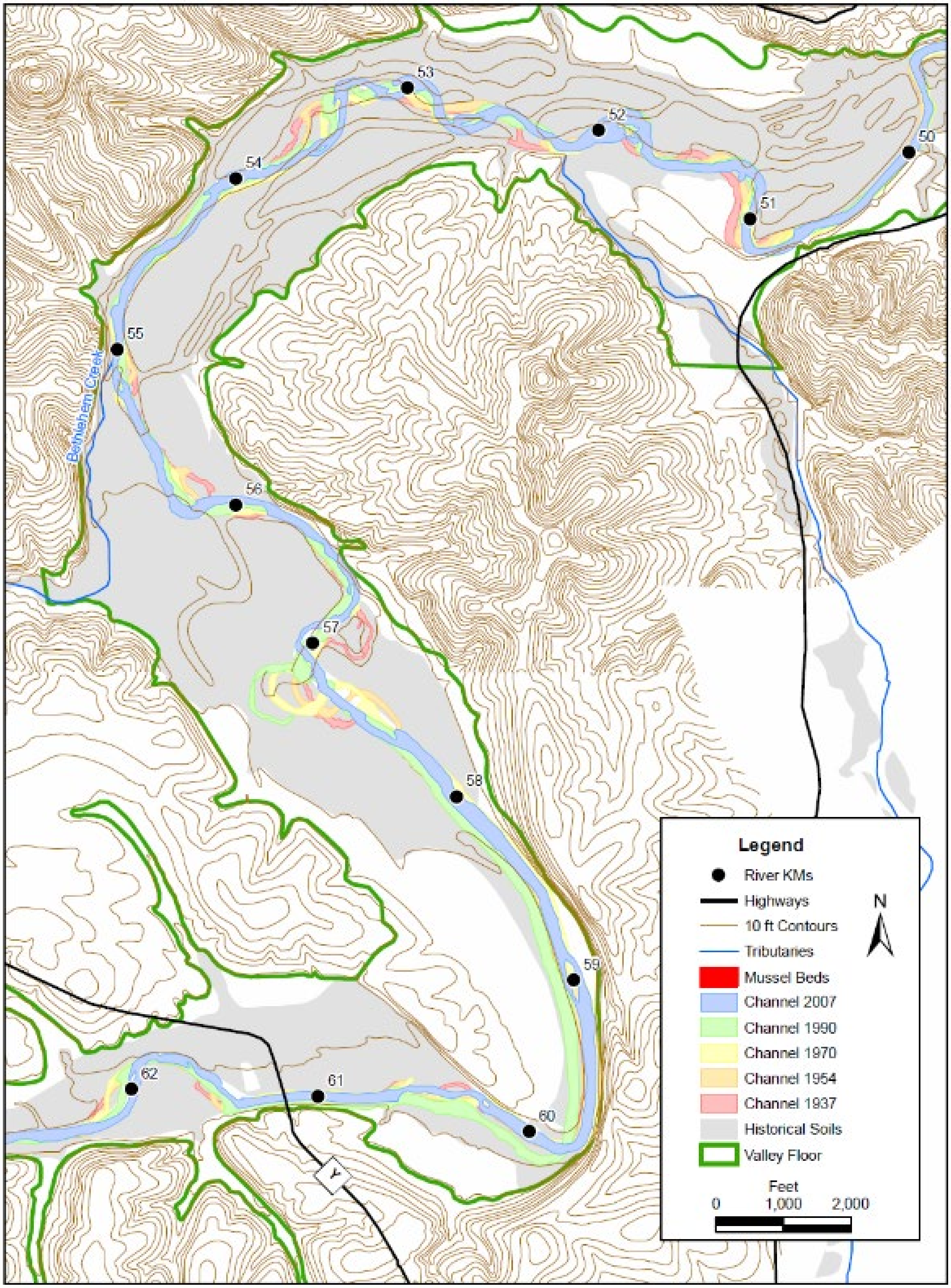


Figure 3-6. Example of Pavlowsky Channel Change Map

Figure 3-7. Step 1: Identify Eroded Area.
Yellow is old channel; purple is new channel + area through which the old channel eroded

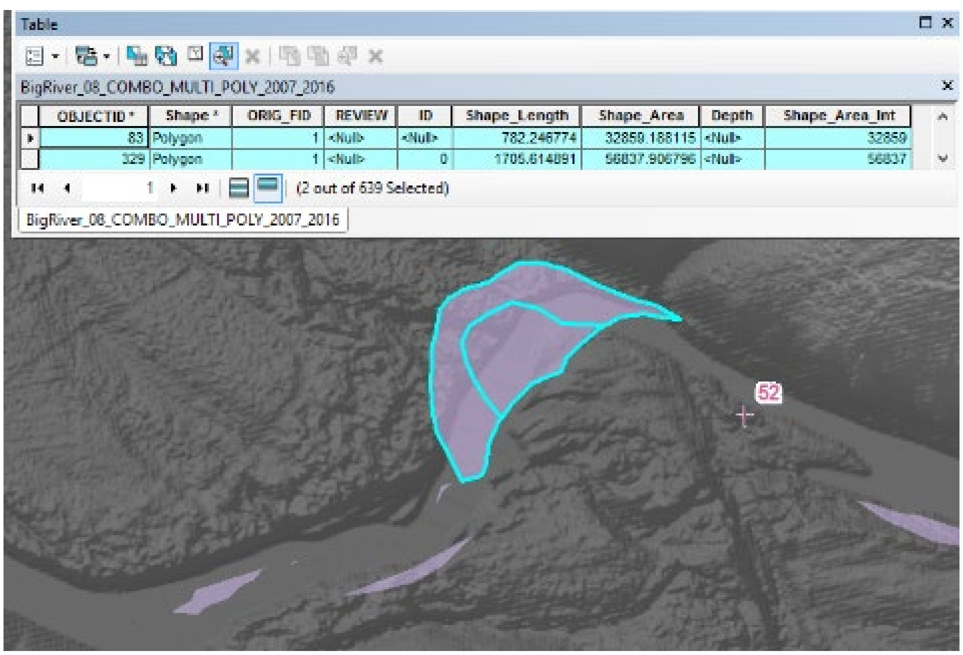
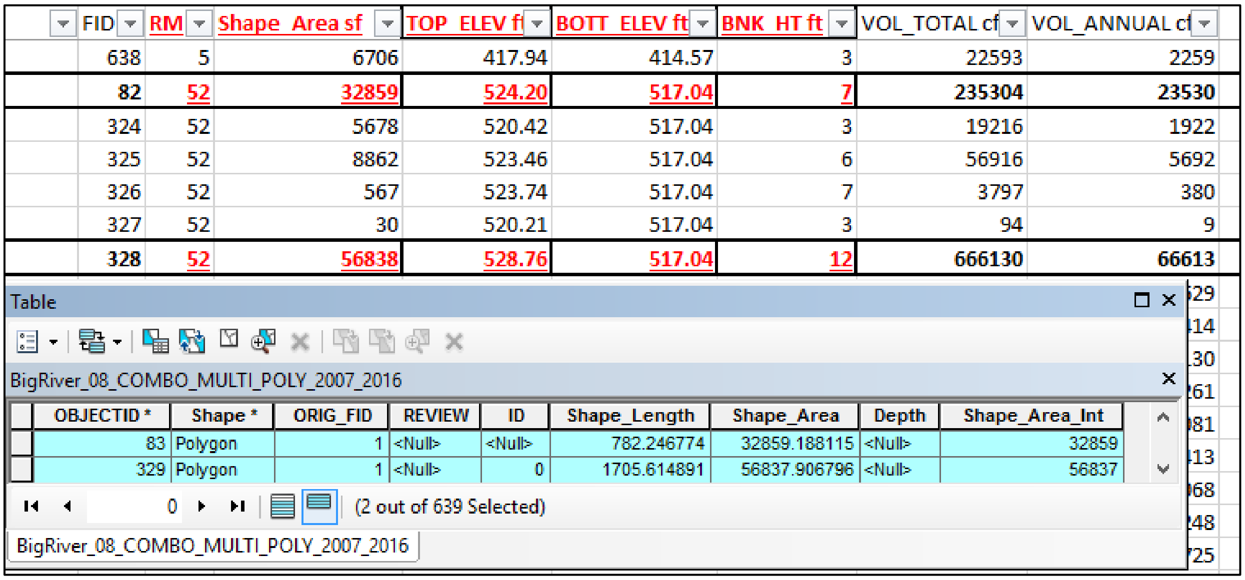


Figure 3-8. Step 2: Obtain Attributes and Get Bank Height From LiDAR.



FID	RM	Shape_Area sf	TOP_ELEV ft	BOTT_ELEV ft	BNK_HT ft	VOL_TOTAL cf	VOL_ANNUAL cf
638	5	6706	417.94	414.57	3	22593	2259
82	52	32859	524.20	517.04	7	235304	23530
324	52	5678	520.42	517.04	3	19216	1922
325	52	8862	523.46	517.04	6	56916	5692
326	52	567	523.74	517.04	7	3797	380
327	52	30	520.21	517.04	3	94	9
328	52	56838	528.76	517.04	12	666130	66613

Table

BigRiver_08_COMBO_MULTI_POLY_2007_2016

OBJECTID *	Shape *	ORIG_FID	REVIEW	ID	Shape_Length	Shape_Area	Depth	Shape_Area_Int
83	Polygon	1	<Null>	<Null>	782.246774	32859.188115	<Null>	32859
329	Polygon	1	<Null>	0	1705.614891	56837.906796	<Null>	56837

(2 out of 639 Selected)

BigRiver_08_COMBO_MULTI_POLY_2007_2016

Figure 3-9. Step 3: Export Attributes to Aggregate and Summarized Metadata in a Spreadsheet

Figure 3-10 summarizes the outputs of this analysis. Only selected columns are shown to save space.

Rankings of Lateral Movement, Volume Eroded and Lead Released are shown in columns 1, 2 and 3. These rankings were used to highlight the worst sites based on multiple criteria.

Lateral Movement (column 5) was calculated by using the shape's perimeter and area under the simplified approximation that all lateral erosion is rectangular-shaped. This is an inexact method, but the lateral migration metric was not considered in final site selection. Annualized values are simply an average of total lateral movement over the time period.

Bank Statistics (columns 6, 7 and 8) are included because a bank's contaminated depth (Pavlowsky, Owen, & Martin, , 2010) could be less than the bank's total height; thus, a portion of the eroded material would not contain elevated lead levels. This is an intermediate calculation that is referenced in the next calculation (column 15).

Bank Volume Eroded (column 10) is a simple volumetric calculation based on bank height and area eroded. This calculated volume assumes that the bank maintains a constant geometry as it erodes. Annualized values are simply an average of total erosion over the time period.

Bank Mass Eroded (column 12) relies on a specific weight of soil (pounds per cubic foot, or PCF) and converts the volume based on that specific weight. The USEPA samples in this study area indicated that the bank has a specific weight of 82 PCF.

Bank Lead Eroded (columns 13 and 15) considers the percentage of bank that is contaminated (column 8), the mass of bank that has eroded (column 12), and the contamination level of the bank. On average, a cubic yard of eroded bank sediment contains 1.3 - 1.8 pounds of lead, with values increasing further upstream in the study area, as shown in Figure 3-11.

Bank Suspended Sediment Contribution (columns 17 and 18) is a metric that represents the ratio of average annual mass of eroded bank to the estimated average annual mass of suspended sediment that passed through the river during the period of analysis with respect to median flow.

Bank Stabilization (1990-2007)

column # --->		1	2	3	5	6	7	8	10	12	13	14	15	17	18
		SITE RANK (Green cell = bad; red cell = worst)			Average Lateral	Bank Statistics			Bank Volume Eroded	Bank Mass Eroded (soil	Bank Lead Eroded			Bank Suspended Sediment	
Kilometer	Mile	Lateral Movement	Volume Eroded	Lead Released	Movement (annual) ft/yr	Avg Bank Height ft	Clean Bank Fraction ft	% of Bank w/High Lead Concentration	Volume (annual) cy/yr	1990-2007 tons/yr	Concentr mg/kg (rounded)	[1]Lead (total) ton	[1]Lead (annual) tons/yr	TSS Reduced (mg/L)	Rank
4.0	2.5	20	14	20	1.2	21	13	35%	4,052	4,485	510	14	0.8	0.3	14
8.0	5.0	22	19	21	0.9	11	4	66%	1,917	2,122	510	12	0.7	0.1	19
14.8	9.2	12	5	13	1.9	16	9	46%	8,640	9,565	404	30	1.8	0.6	5
21.7	13.5	18	10	18	1.3	16	9	44%	4,822	5,338	404	16	1.0	0.4	10
23.3	14.5	13	12	12	1.7	16	9	44%	4,333	4,797	1,210	44	2.6	0.3	12
29.0	18.0	14	8	10	1.6	13	6	55%	5,223	5,782	1,210	66	3.9	0.4	8
35.4	22.0	15	16	22	1.5	14	7	50%	2,699	2,988	371	9	0.6	0.2	16
49.9	31.0	19	17	14	1.2	13	6	56%	2,619	2,899	1,000	28	1.6	0.2	17
51.8	32.2	4	2	3	2.5	13	5	58%	11,429	12,652	1,000	124	7.3	0.9	2
53.4	33.2	17	22	23	1.4	16	9	45%	793	878	1,000	7	0.4	0.1	22
54.7	34.0	9	6	6	2.0	12	4	63%	7,132	7,895	1,000	84	4.9	0.5	6
56.2	34.9	6	3	4	2.4	15	8	47%	11,253	12,457	900	90	5.3	0.8	3
61.2	38.0	3	7	9	2.6	12	5	61%	6,594	7,300	900	68	4.0	0.5	7
68.4	42.5	1	1	2	4.8	14	6	53%	20,119	22,272	950	191	11.2	1.5	1
71.6	44.5	11	18	16	1.9	13	5	58%	2,252	2,493	950	23	1.4	0.2	18
77.2	48.0	8	9	5	2.2	9	2	78%	5,122	5,670	1,200	90	5.3	0.4	9
80.1	49.8	7	13	7	2.4	10	3	70%	4,216	4,667	1,470	82	4.8	0.3	13
83.7	**52.0**	**5**	**4**	**1**	**2.5**	**8**	**1**	**85%**	**10,810**	**11,967**	**1,470**	**255**	**15.0**	**0.8**	**4**
86.9	54.0	16	15	11	1.5	12	5	61%	3,164	3,502	1,400	51	3.0	0.2	15
88.2	54.8	2	11	8	3.2	10	3	73%	4,436	4,911	1,150	70	4.1	0.3	11
95.3	59.2	23	23	19	0.8	10	3	71%	564	624	1,830	14	0.8	0.0	23
96.2	59.8	24	24	24	0.0	11	3		0	-	1,800	-	-	-	24
98.2	61.0	21	21	17	0.9	16	9	45%	1,350	1,495	1,790	20	1.2	0.1	21
100.6	62.5	10	20	15	1.9	15	8	47%	1,493	1,653	1,790	24	1.4	0.1	20
AVERAGE			**AVERAGE**		**1.9**	**13.1**	**5.9**	**57%**	**5,210**	**5,767**	**1,092**	**58.8**	**3.5**	**0.39**	
MEDIAN			**MEDIAN**		**1.8**	**12.7**	**5.5**	**56%**	**4,274**	**4,732**	**1,000**	**36.8**	**2.2**	**0.32**	
TOTAL			**TOTAL**		**44**				**125,034**	**138,413**		**1,410**	**83**	**9.3**	

Figure 3-10. Step 4: Analyze and Summarize All Sites (selected columns shown from 1990-2007 analysis)

This analysis was performed on two periods: 1990-2007 and 2007-2016. The results of all 24 analyzed banks are summarized in Table 3-2. As shown in Table 3-2, the average annual volume of bank eroded during both periods of analysis remained nearly constant, while annual lateral movement and lead reintroduced increased. The reason these two periods are both similar and different is because bank instability simultaneously worsens and heals throughout the entire system. The rate at which a site becomes unstable and subsequently heals itself is difficult to generalize because it partially depends on year-to-year hydrology and local site characteristics. Analysis showed that sites with poor riparian vegetation tended to have higher rates of erosion than sites with good riparian vegetation. Variance in discharge between the two periods could account for part of the drop in TSS contribution from banks.

Table 3-2. Big River – Averaged Bank Erosion Findings

Timeframe	Lateral Movement	Volume Eroded	Lead Reintroduced	TSS Contribution
(years)	(ft/yr)	(cy/yr)	(tons/yr)	(mg/L)
1990-2007	1.9	125,000	83	9.3
2007-2016	3.2	123,000	100	6.7

As mentioned previously, Figure 3-11 shows lead reintroduction due to bank erosion as a function of river miles. Clearly, more lead is reintroduced by bank erosion upstream in the study area than downstream. In contrast to a hypothetical graph of lead reintroduced as a function of river mile, the points on this graph are normalized by taking the ratio of lead reintroduced per cubic yard of bank eroded.

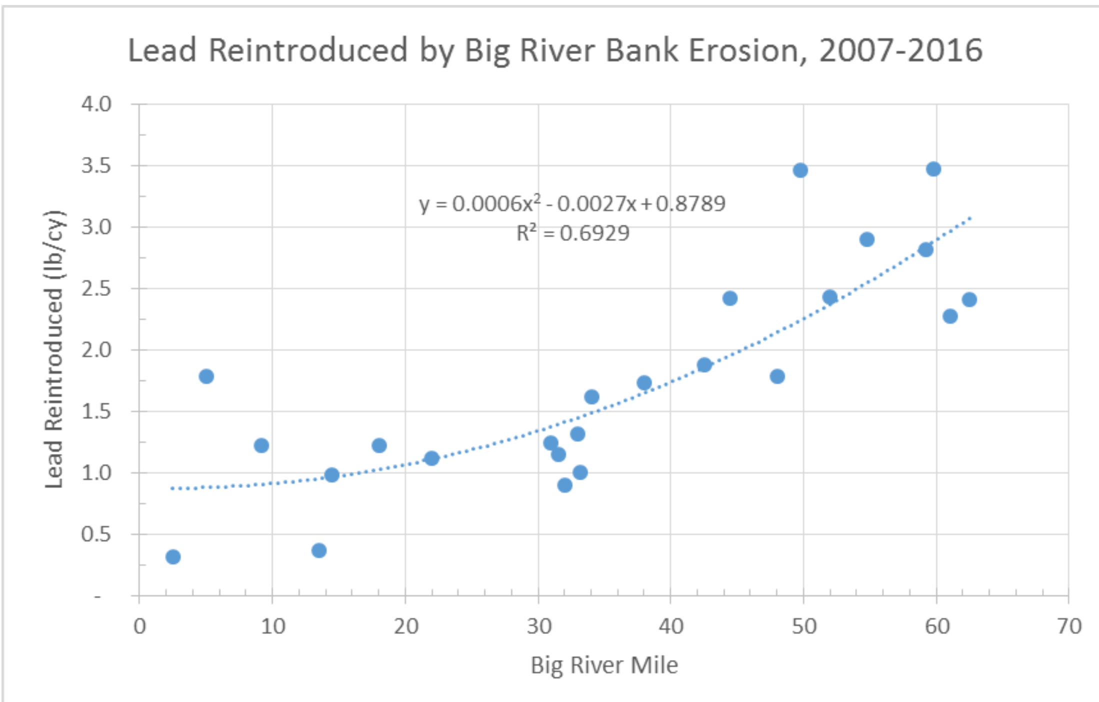


Figure 3-11. Lead Reintroduced Per Cubic Yard of Bank Erosion in the Big River, From 2007-2016

Sediment data in the Meramec River in Jefferson and St Louis Counties, Missouri, is limited compared to the Big River. Pavlowsky's channel change analysis did not extend into the Meramec River, so this study analyzed portions of the Meramec River using Pavlowsky's method. Calculations for the Meramec River are less robust than those for the Big River because there is less sediment data available in the Meramec River than in the Big River; however, Meramec River banks are laterally stable in comparison to Big River banks. Two of the most visible examples of bank erosion from each river are included for comparison purposes in Figure 3-12 and Figure 3-13.

These examples are both isolated cases. While the Big River tends to have more of this sort of horizontal instability, the Meramec River in the study area (lower 50 miles) is largely stable or at least not migrating laterally at a rapid pace. Using channel change analysis described in this section, the worst offending Meramec River bank (shown in Figure 3-13) contributes about 2,300 cy/yr. Each of the other lower Meramec River banks within the study area contribute no more than 200-300 cy/yr. In comparison, about 70% of Big River bank instability sites exceed 2,300 cy/yr, and all Big River sites exceed 300 cy/yr. Some Big River banks are an order of magnitude larger than the lower Meramec River's worst offending bank.

For the purpose of estimating suspended load in the Meramec River resulting from bank erosion, the grain size distributions samples from lower Big River were applied to the Meramec River. Table 3-3 summarizes the assumed sediment grain size distribution in the Meramec River near the confluence with the Big River.

Table 3-3. Meramec River Bank and Bed Sediment Size (Lower Big River Samples Applied to Meramec)

Sediment Size Distribution		
Size (mm)	**Bank %**	**Bed %**
<0.063	21%	11%
0.063-0.25	45%	41%

About 66% of Meramec River banks contribute to suspended load and the rest to bedload. Meramec River banks are not contaminated like the Big River banks. Additionally, Meramec River banks are not as actively eroding as Big River banks; thus, bank stabilization efforts on the Meramec River would be a less efficient use of resources in comparison to efforts on the Big River.

Figure 3-12. Big River Bank Instability at RM 51-52; yellow = 2016, pink = 1990

Figure 3-13. Meramec River Bank Instability RM 44-45; pink = 2016, yellow = 1979

3.3.4 BANK MATERIAL

The USEPA took sediment samples in 2017 in the Big River watershed. These samples included measurements of sediment sizes and lead contamination levels in the river, bar, floodplain and bank. Over 2,200 samples were aggregated and analyzed. Bank sediment findings within the study area are summarized in Table 3-4. Nearly 1,200 samples throughout this stretch indicate that 98% of bank material is less than 2mm in diameter; that is, only 2% of bank material is larger than sand (>2mm). Further, 97% is less than 0.84mm in diameter. Finally, 66% is less than 0.25mm in diameter. It is the 66% that is considered to remain in suspension once eroded, and the remaining 34% that is considered to eventually settle into the bed, bar or floodplain at some place downstream of the bank it was eroded from.

Table 3-4. Bank Material Summary

Sample Count	% Gravel	% Sand	% Fines	Lead (ppm)	
1191	2%	74%	24%	997	Bulk
Density (g/cc)		// \\		969	0.25-2 mm
1.31	// Sand Fraction \\			907	0.063-0.25 mm
% <2mm	% Coarse	% Med	% Fine	1,292	< 0.063 mm
98%	1%	30%	42%	Avg Sample Depth	5.3 ft

Lead concentrations are fairly similar in coarse sand (2 - 0.25mm) and medium sand (0.25mm – 0.063mm) fractions, at 969 ppm and 907 ppm, respectively. The fines fraction (<0.063mm) has a higher relative lead concentration - 1,292 ppm. Sediment size fractions are broken down in Table 3-5.

Table 3-5. Characterization of Bank Material; C = Coarse, M = Medium, F = Fine

Grain Type		Sieve Size	mm
Gravel		2.000"	53.9
		1.500"	33.1
		1.000"	26.9
		0.750"	17.0
		0.375"	9.52
		0.004"	4.76
Sand	C	10	2.00
	M	20	0.840
		40	0.420
	F	60	0.250
		80	0.177
		100	0.149
		200	0.074
		230	0.063
Fines		>230	<0.063

Based on multiple field observations, it is reasonable to assume that at least up to 0.25mm sediment mostly suspends during median flow, especially when considered in the context of the Hjulström-Sundborg diagram, as shown in Figure 3-14.

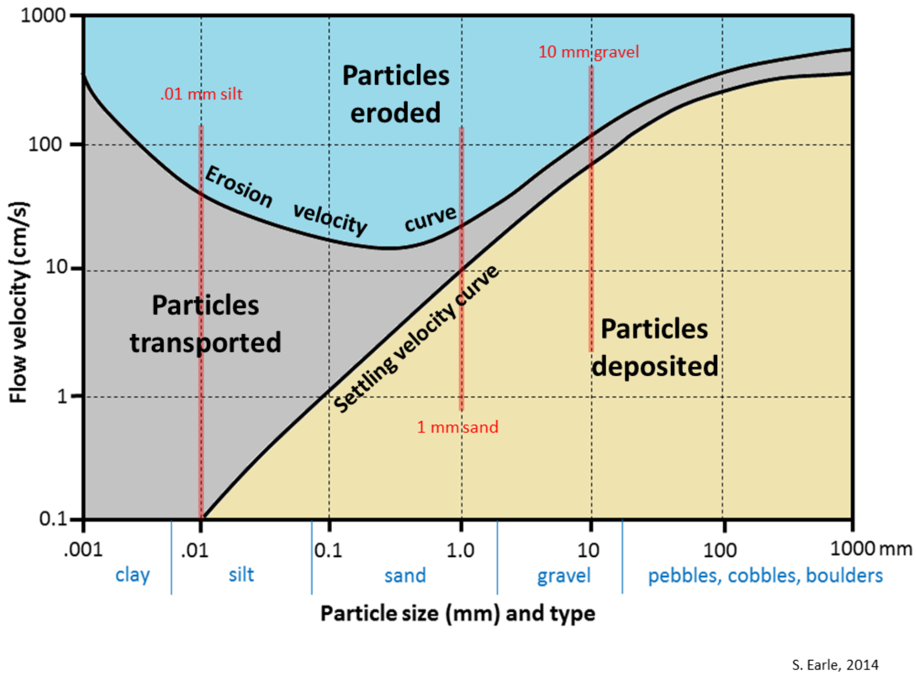


Figure 3-14. Hjulström-Sundborg Diagram Shows the Effect of Sediment Size and Flow Velocity on a Sediment Particle's Ability to be Eroded. 1 cm/s = 0.03 ft/s; 10 cm/s = 0.3 ft/s; 100 cm/s = 3 ft/s

The sediment in the banks is very fine, as summarized in Table 3-4. It is likely that much of the coarser sediment eroded from the banks (2 - 0.25mm) transitions between bedload and suspended load during median flow, as local hydraulic conditions vary.

Considering eroded bank material during median flow and greater:

- If 66% is purely wash load (<0.25mm), then 34% is transitional between bedload and suspended load (>0.25mm).
- Therefore, if 125,000 cy/yr is eroded (138,000 tons/yr), then 66%, or 82,500 cy/yr (91,000 tons/yr) is purely wash load.
- Therefore, the remaining 34%, or 42,500 cy/yr (47,000 tons/yr), finds its way into the bed, bars and/or floodplain.

Pavlowsky channel change maps, which extend to RM 106 (Pavlowsky & Owen, 2013), indicate that there is also lateral instability in portions of St. Francois County. Additionally, sample data from EPA (2017 Sample Data), which extends from RM 0 to RM 96, indicates that contamination is even higher in St. Francois County than in Jefferson County.

3.4 BED MATERIAL ANALYSIS

Bed material is important to this study because it is where mussels live, and it composes most of the river bed and many of the bars. The transport of bed material is a complicated and inexact science. By definition, bedload is not suspended, but instead translates (slides) and/or saltates (skips/bounces) along the bed of the river. But bedload material is redefined as flows change; what may be bedload in low flows can suspend in high flows. Generally, bed material is of a relatively coarse gradation, but traps relatively finer gradation sediment within its interstices, which is released whenever the bed material is transported. Generally, bed material transport becomes substantial during floods with 66% - 91% exceedance flows (1.1 - 1.5 year events). It is at and above these flow levels that the river has enough energy to move significant amounts of bed material frequently. Bed material transport capacity correlates directly to flow levels – higher flow equals higher transport capacity. However, a river may not transport bedload at its capacity if not enough bedload material is supplied for transport.

A bed material capacity load calculation was completed at the Richwoods gaging site on the Big River at River Mile (RM) 53.7. Bed load transport was calculated using the Bedload Assessment for Gravel-bed Streams (BAGS) software developed by the U.S. Forest Service (http://www.stream.fs.fed.us/publications/bags.html) (Wilcock, Pitlick, & Cui, 2009). The program implements six bed material load transport equations developed specifically for gravel-bed rivers. Transport capacities are calculated on the basis of field measurements of channel geometry, reach-average slope, bed material grain size and flow characteristics. Bedload transport was calculated using the Wilcock/Crowe equation because it is the only bedload equation available in BAGS that accounts for the nonlinear effect of sand content on gravel transport rates. Additionally, the equation accommodates the full grain size distribution of the bed surface, including sand (Wilcock, Pitlick, & Cui, 2009). Importantly, this analysis computes bedload capacity, and is not necessarily predictive of actual load.

3.4.1 INPUTS

Discharge data was obtained for the USGS gage 07018100 Big River near Richwoods, Missouri. The data is available online to the public at https://waterdata.usgs.gov/nwis/. The period of record used was April 28, 1949 to August 18, 2017. HEC-SSP was used to calculate the flow duration values input into the BAGS software, shown in 10%).

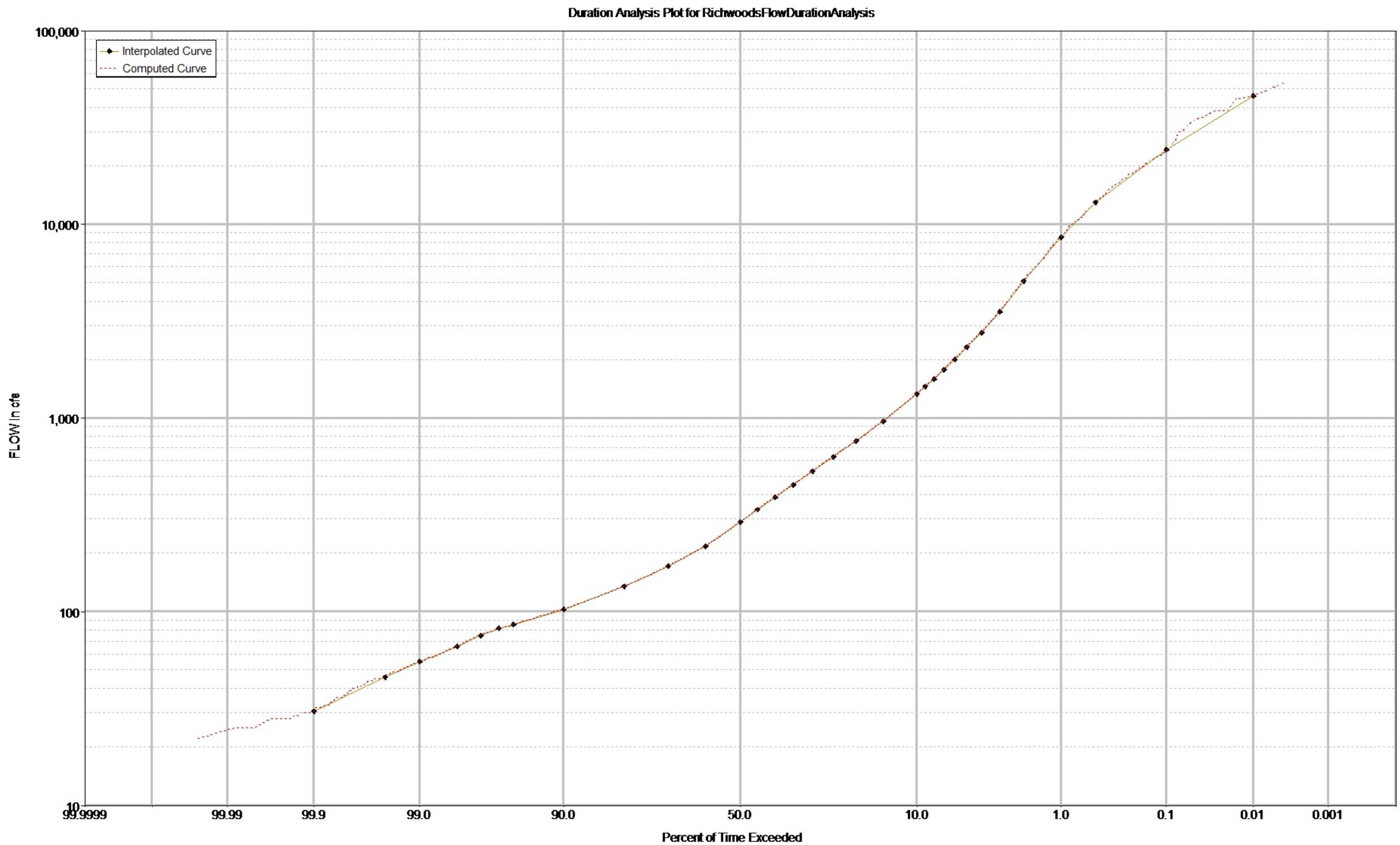


Figure 3-15. Flow Duration Analysis Plot At Richwoods. Computed Using HEC-SSP. Data From 1947-2017

Table 3-6. Flow duration analysis considers what percentage of days a river exceeds a specific flow each year. The flow duration chart computed by HEC-SSP is shown in Figure 3-15; flow exceeds 103 cfs 90% of the year, and about 1,330 cfs 50% of the year. Importantly, percent of time exceeded is not relatable in any way to annual exceedance probability (AEP), as presented previously in Table 1-1. BAGS software requires the user to set a flows associated with 100% and 0% of time exceeded. Setting such values is unconventional, but reasonable extreme values were chosen. A brief sensitivity analysis where the 100% and 0% of time exceeded values were adjusted revealed negligible changes to bedload outputs.

Grain size strongly affects bed sediment transport. Grain sizes used to estimate sediment transport were from river bar and bed sediment between River Miles 35 and 40. The samples used were several miles downstream of Richwoods gage at RM 53.7, as no samples were available near the gage. There were six river sediment samples and nine bar samples. The grain size distribution input into BAGS is shown in Table **3**-**7**. Table 3-8 shows the statistics on the grain size distribution output from BAGS.

The Wilcox/Crow sediment transport equation specifies that the sediment samples should be taken from the surface armor, as opposed to the substrate. These samples were taken anywhere from 0 to 12 inches in depth, which is probably a mix of natural surface armor layer and some substrate.

The energy slope was obtained from a HEC-RAS model created by AMEC Foster Wheeler. The model was upgraded from an HEC-2 flood model created in the 1980's. No new cross sections were collected, but bridge information was updated. The energy slope used was 0.00036 ft/ft and was taken from the 10-year flow (AEP 10%).

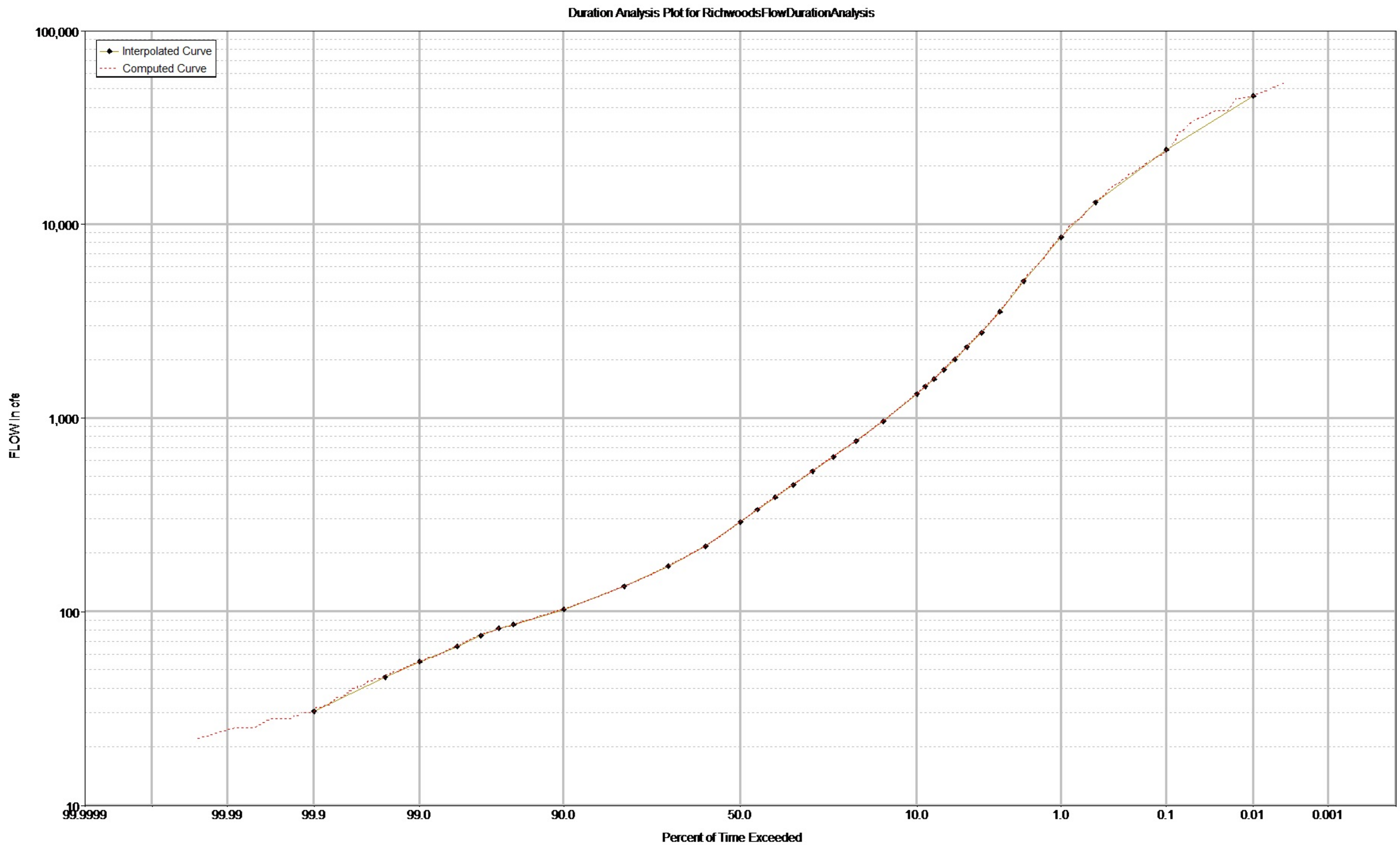


Figure 3-15. Flow Duration Analysis Plot At Richwoods. Computed Using HEC-SSP. Data From 1947-2017

Table 3-6. Flow Duration Analysis at Richwoods Gage. Computed Using HEC-SSP and Input Into BAGS. Data from 1947-2017.

Flow (cfs)	% of Time Exceeded
20	100
103	90
135	80
172	70
218	60
290	50
337	45
390	40
453	35
531	30
630	25
761	20
963	15
1330	10
1460	9
1590	8
1780	7
2010	6
2330	5
2762	4
3540	3
5090	2
8591	1
13002	0.5
24201	0.1
65000	0

Table 3-7. Sediment Grain Sizes Input Into BAGS

Size (mm)	% Finer
0.063	0
0.074	11
0.149	15
0.177	16
0.25	19
0.42	31
0.84	46
2	59
4.76	71
9.52	83
17	95
26.9	99
33.1	100
53.9	100

Table 3-8. Statistics of the Grain Size Distribution Input Into BAGS

Geometric mean (mm)	1.22
Geometric std deviation	5.85
D10 (mm)	0.07
D16 (mm)	0.18
D25 (mm)	0.32
D50 (mm)	1.10
D65 (mm)	3.09
D75 (mm)	6.00
D84 (mm)	9.99
D90 (mm)	13.35

3.4.2 OUTPUTS

BAGS provides a variety of outputs, including average bedload transport capacity, bedload grain size distribution and statistics, and a large table that breaks down transport capacity by grain size at various flows. First and foremost, Figure 3-16 shows the bed material load rating curve which was created using the outputs of the BAGS analysis. As is evident, the river has only negligible bedload transport capacity during low, common/median flows. Considering all flow since 1949, BAGS estimates that the average bedload transport capacity is 79 tons/day. The flow duration plot in Figure 3-15 shows that only about

10% of days have flows exceeding 1,000 cfs since 1947, which has a bedload transport capacity of about 40 tons/day. So 79 tons/day does not represent median flow, or 50% of time exceeded (290 cfs), which yields closer to 2 tons/day; nor does it represent the 50% Annual Exceedance Probability (AEP), or 2-year flow (33,800 cfs), which yields closer to 2,800 tons/day.

Despite the caveats of the average bedload transport capacity of 79 tons/day, it can be used to estimate the average annual bedload transport capacity by multiplying it by 365 days/year. The total bedload transported in a year is 28,800 tons. For reference, the suspended sediment (excludes bedload) at Byrnesville gage from 1980-2016 is around 243,900 tons/year, or 670 tons/day. That means annual bedload capacity at Richwoods makes up about 11% of total sediment transport at Byrnesville, which seems reasonable.

Since the transport capacity of bedload transport is so closely tied to discharge, it is useful to understand the patterns of flow within an average year. Figure 3-17 shows the average flow for each day of the year, using flow data from 1947-2017. This figure shows that Big River has strong seasonal flow tendencies. In the late winter and early spring, flow picks up; in the early summer and late fall, flow is much lower. Thus, bedload transport and geomorphic work mostly occurs during late winter and early spring.

BAGS also provides details and statistics about the grain size distribution of bedload, as shown in Table 3-9 and Table 3-10.

Figure 3-18 charts the bedload and bed material grain size distribution in a familiar format – cumulative percent passing. This chart shows that bedload is smaller than bed material; while 75% of bedload is composed of grains smaller than 2 mm, 40% of bed material is composed of grains larger than 2 mm.

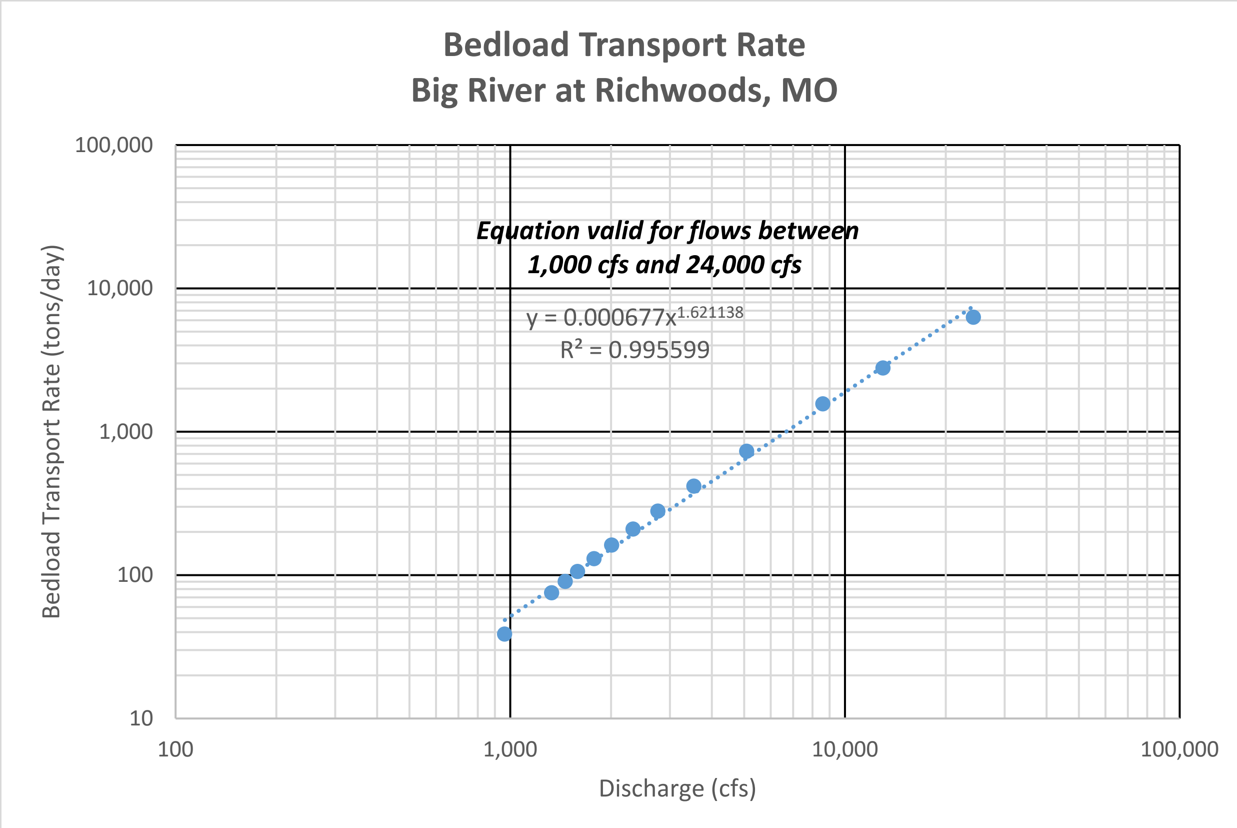


Figure 3-16. Bed Material Load Rating Curve Output From BAGS

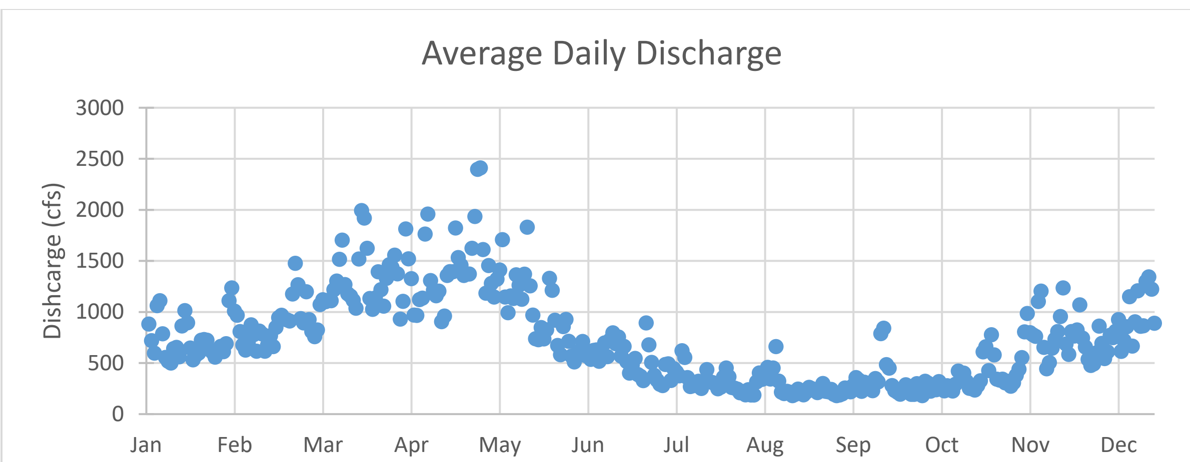


Figure 3-17. Average Daily Discharge at Richwoods From 1949-2017

Table 3-9. Sediment Grain Sizes for Bedload

Size (mm)	% Finer
0.063	0
0.074	15
0.149	21
0.177	22
0.25	26
0.42	42
0.84	61
2.00	77
4.76	88
9.52	95
17.0	99
26.9	100
33.1	100
53.9	100

Table 3-10. Statistics of the Grain Size Distribution for Bedload

Geometric mean (mm)	0.63
Geometric standard deviation	4.57
D10 (mm)	0.07
D16 (mm)	0.08
D25 (mm)	0.23
D50 (mm)	0.56
D65 (mm)	1.04
D75 (mm)	1.79
D84 (mm)	3.47
D90 (mm)	5.8

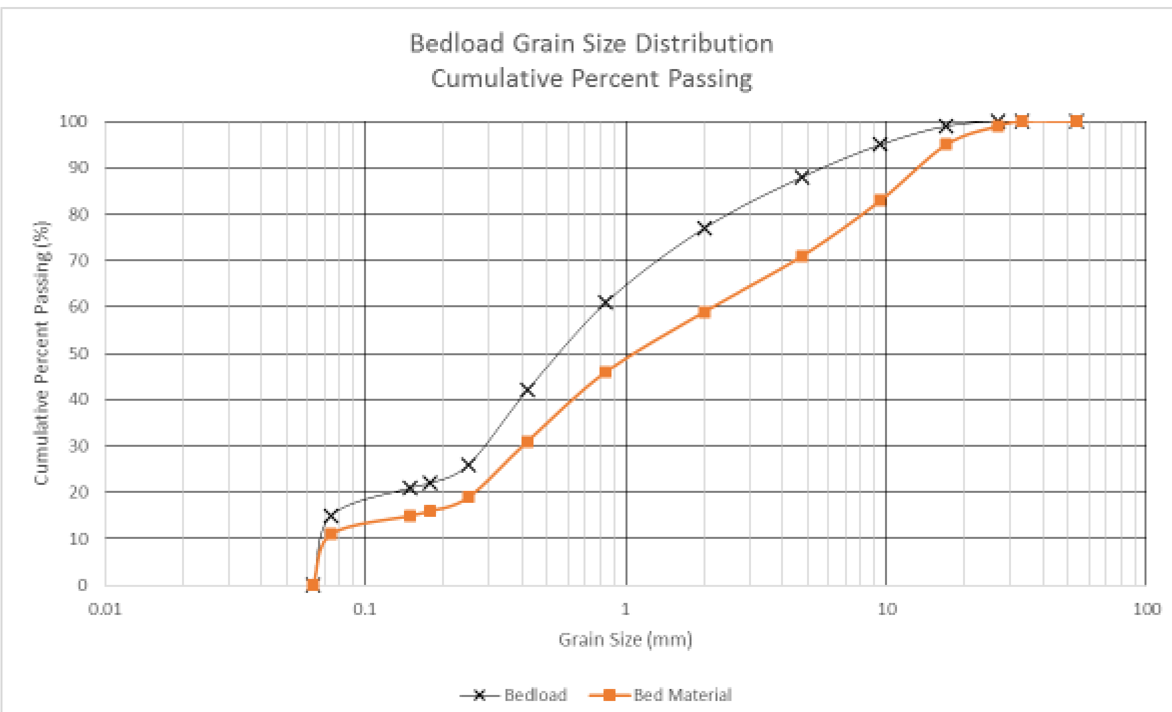


Figure 3-18. Bedload Grain Size Distribution - Cumulative Percent Passing

3.4.3 SENSITIVITY AND LIMITATIONS

All bed load transport relations are sensitive to estimates of the available grain sizes and the available shear stress. Small differences in those two variables can lead to large (order-of-magnitude) differences in calculated transport capacities. Sediment grain sizes can vary widely throughout the river system and even within a single cross section, and is therefore a source of uncertainty.

Another source of uncertainty is the sediment from Mineral Fork Creek. Mineral Fork is a major tributary which enters the Big River at RM 60. According to aerial photography, Mineral Fork appears to have experienced significant bank erosion in recent years. There is a strong presence of current and/or historical surface mining and gravel mining in the Mineral Fork watershed. These variables can cause substantial fluxes in sediment supply which can lead to variations in actual sediment transport yields. Transport equations focus on sediment transport capacity and do not take into account variations in sediment supply, which can cause bedload supply to be lesser or greater than the calculated transport capacity.

HEC-DSSVue was used to calculate Annual Exceedance Probability (AEP) of flows in Table 1-1. Analysis using HEC-DSSVue is quick and simple, but it is blind to certain factors that can have a minor effect on flows; therefore, HEC-SSP duration analysis was performed in order to assess the sensitivity of BAGS analysis to slight adjustments in flow using differing computation methodologies. The flows in 10%).

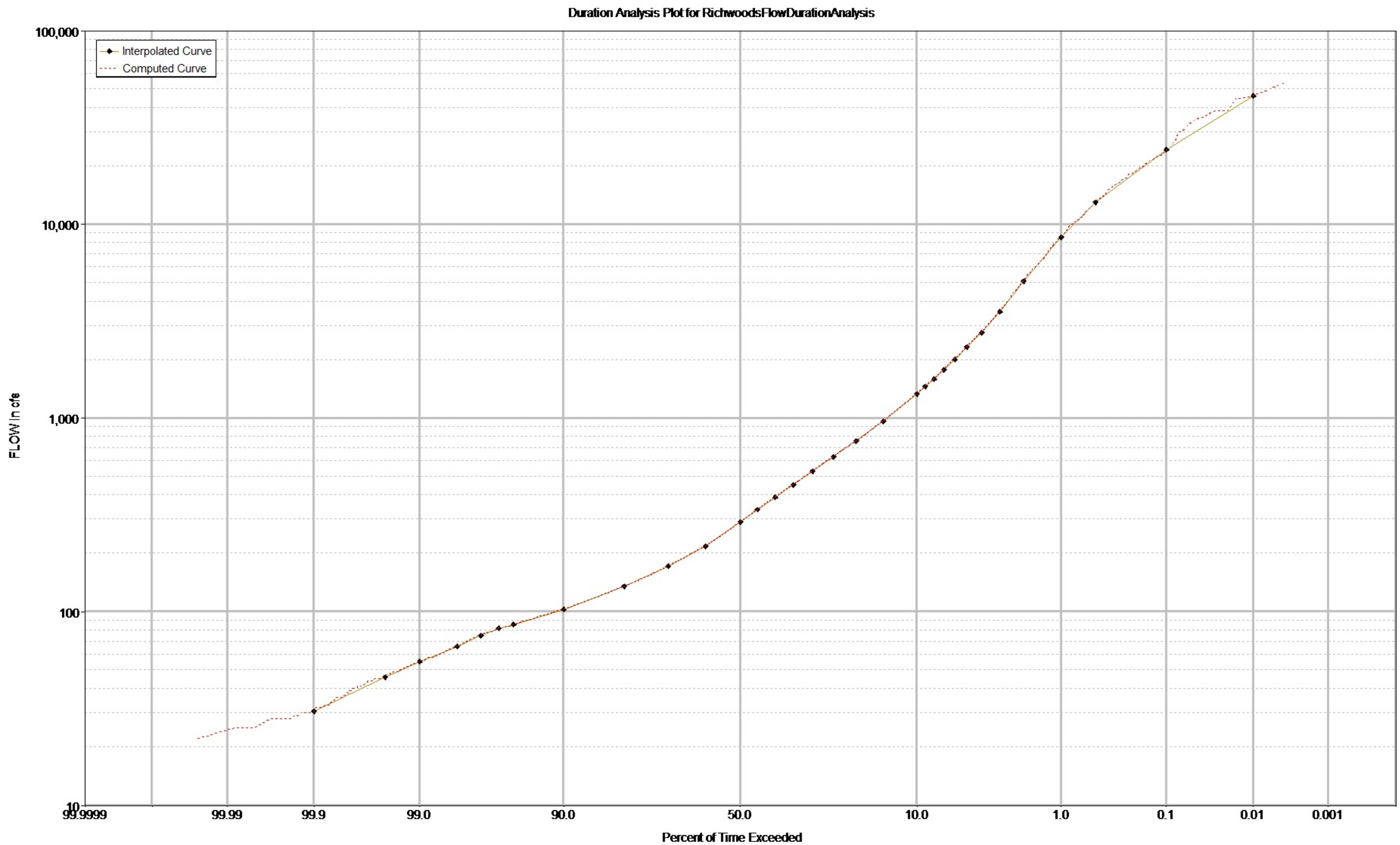


Figure 3-15. Flow Duration Analysis Plot At Richwoods. Computed Using HEC-SSP. Data From 1947-2017

Table 3-6 differ by a few percent from flows outputted by HEC-DSSVue. Only negligible changes in bedload capacity were observed as a result.

The BAGS analysis is predictive of the order of magnitude of bed material load capacity as a function of flow. As shown in Figure 3-17, the temporal pattern of average discharge is distinct, with higher discharges (and thus bed material transport capacity) occurring primarily in the spring. The results of this analysis are not directly used in the selection or design of features in this study. Instead, this analysis serves as another corroborative estimate of sediment transport. Design decisions will be made using a HEC-RAS model and other Corps-approved methods.

3.5 HEC-RAS MODEL

In July 2018, HydroGeologic (HGL) completed a one-dimensional HEC-RAS river model. This model covers about 75 miles of Big River, from the confluence with Mill Creek at the edge of Jefferson County to the confluence with Meramec. The structure of the model is one-dimensional with quasi-unsteady flow. Sediment transport and bed scour are also analyzed in this model. The two primary purposes of this model are to:

1. "Update the preliminary sediment transport model using the additional data collected … for use as an analytical tool for assessing remediation strategies" and
2. "Locate zones of significant riverbed aggradation or degradation…"

Model results that directly informed selection, placement and/or design of specific measures include:

1. Hydraulic Results (Water surface elevations and reach-averaged shear and velocity)
2. Geomorphic Results (Aggradation and degradation zones)

This model is not intended to precisely predict flood elevations, although such data can be extracted and used as a point of reference for design purposes.

3.5.1 MODEL SELECTION AND DESCRIPTION

(HGL, May 2018) states:

"The USACE HEC-RAS Version 5.0 program was used to develop the sediment transport model of Big River. The HEC-RAS software has the capability to perform one-dimensional steady and unsteady flow river hydraulic calculations, and sediment transport mobile bed modeling."

"HEC-RAS sediment transport-mobile bed capabilities are intended to simulate long-term trends of scour and deposition within a river system, but it can be also applied to a single flood event. HEC-RAS 5.0 has the capabilities to simulate the hydrodynamics as quasi-unsteady or unsteady flow. A quasi-unsteady approach was used for this study [because] there is insufficient data to support the use of the more complex unsteady flow approach."

"The calibrated model was then utilized to estimate the scour and deposition of lead material for four flow conditions:

1. Average annual flood hydrograph,
2. 50% annual exceedance event,
3. 10% annual exceedance event, and
4. 1% annual exceedance event.

More information about the development and results of the HEC-RAS sediment transport model [can be found in (HGL, May 2018)]."

3.5.2 MODEL RESULTS

Pertinent hydraulic results include flood elevations and reach-averaged shear and velocity. The flow elevations summarized graphically in Figure 3-19 are 1%, 10%, bankfull and base flows. Elevations from these flows along the river inform the design heights of bank stabilization, sediment capture basins, and bedload collection infrastructure. Figure 3-20 includes bar elevation, which is an important factor when designing bank stabilization infrastructure.

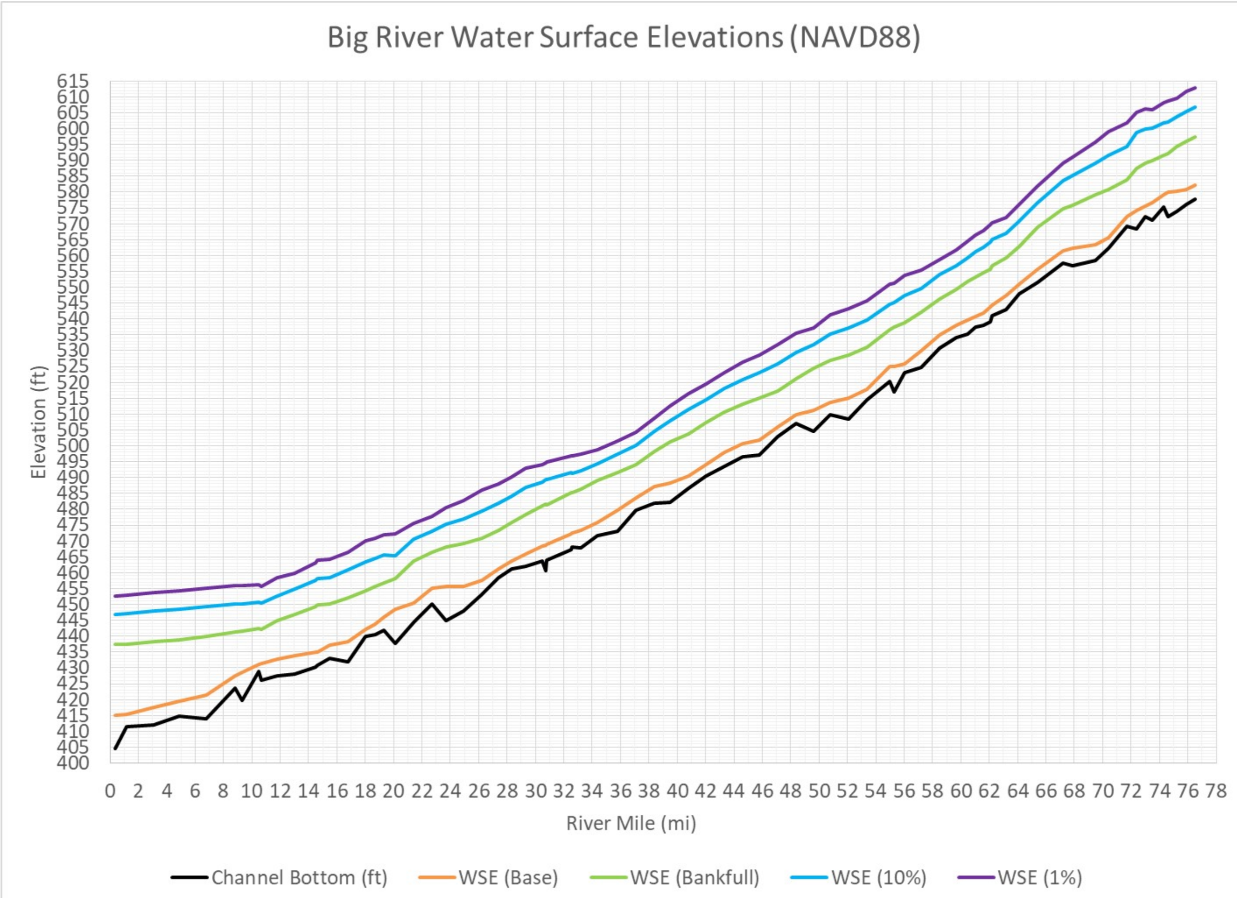


Figure 3-19. Water Surface Elevations (WSE) at Bankfull (1.2-year), 10% (10-year), and 1% (100-year) flows on Big River

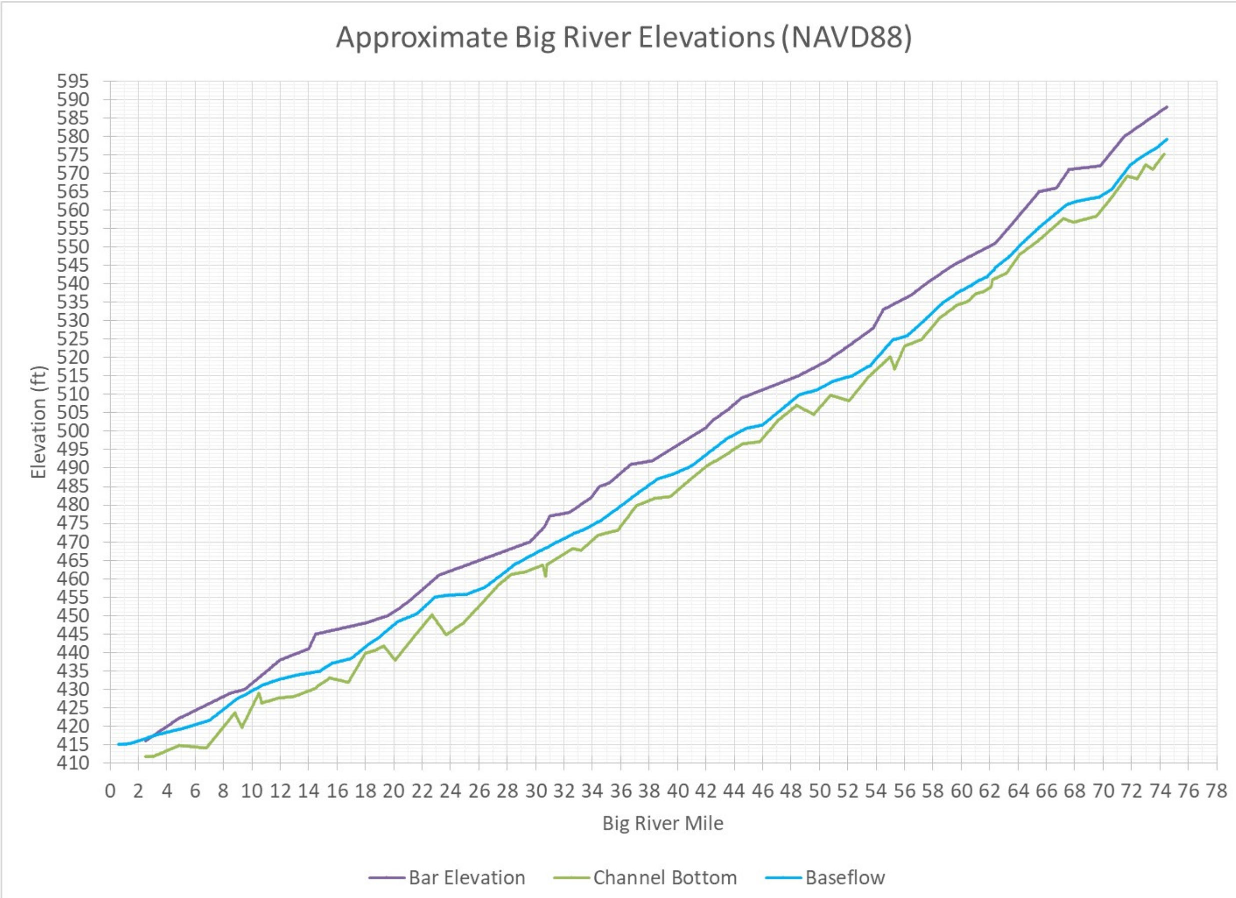


Figure 3-20. Elevations of Channel Bottom, Baseflow, and Bars along Big River

HGL summarized average velocity and average bed shear stress in Table B.6 of their model report (HGL, May 2018).

Table 3-11. Average Velocity and Bed Shear on Big River from Downstream (DS) to Upstream (US)

DS RM	US RM	Average Velocity (ft/s)			Average Bed Shear (lb/sf)		
		1.2-yr	10-yr	100-yr	1.2-yr	10-yr	100-yr
0.3	6.4	3.5	4.0	4.3	0.28	0.32	0.36
6.6	9.9	2.9	3.1	3.6	0.21	0.21	0.27
10.2	12.0	4.1	5.1	5.5	0.42	0.58	0.69
12.5	14.5	2.9	3.5	4.4	0.21	0.27	0.40
14.6	19.7	3.6	4.4	5.1	0.32	0.48	0.59
19.8	27.7	3.7	5.0	5.8	0.32	0.56	0.71
28.8	32.8	3.0	3.1	3.4	0.24	0.21	0.24
33.4	37.1	4.2	5.5	6.3	0.46	0.79	1.06
37.4	46.3	4.1	5.5	6.0	0.42	0.67	0.79
46.8	61.5	4.1	5.1	5.8	0.41	0.58	0.71
62.0	68.6	4.6	6.3	7.0	0.52	0.85	0.97
68.7	73.4	4.0	5.4	6.3	0.40	0.66	0.86
73.7	76.5	4.8	6.7	7.9	0.56	0.93	1.19

Figure 3-21 indicates areas where the bed elevation changed by greater than 0.5 feet during a 1% exceedance flow simulation. It is useful to understand portions of the river that aggrade and degrade. Of the 125 km (77.7 miles) of river modeled, 19.1 km (11.9 miles) consistently aggraded and 22.7 km (14.1 miles) consistently degraded. As stated by HGL (HGL, May 2018):

> "The aggradation zones present opportunities to apply remedial technologies that remove contaminated sediment from the riverbed. Effective remedies within deposition zones may include sediment dredging, engineered sediment cap, and engineered sediment trap and removal facilities. For locations that experience the highest sediment deposition rates, natural recovery may be viable after source control and other elements of the remedy ensure that future sediment in transport would have sufficiently low lead concentrations."

> "The degradation zones identify portions of the river where ongoing sediment transport will reliably transport sediments downstream. Sediment does not accumulate within these zones, therefore remedial technologies that focus on removing sediment from the riverbed generally would not be necessary or effective. Degradation zones occur in locations where the river has a slightly steeper gradient or is confined resulting in higher local flow velocity. These relatively high energy zones have the potential to produce more riverbank erosion and channel migration compared to lower energy channel segments. Bank stabilization would be an effective remedial technology for channel segments that have higher potential to erode river banks."

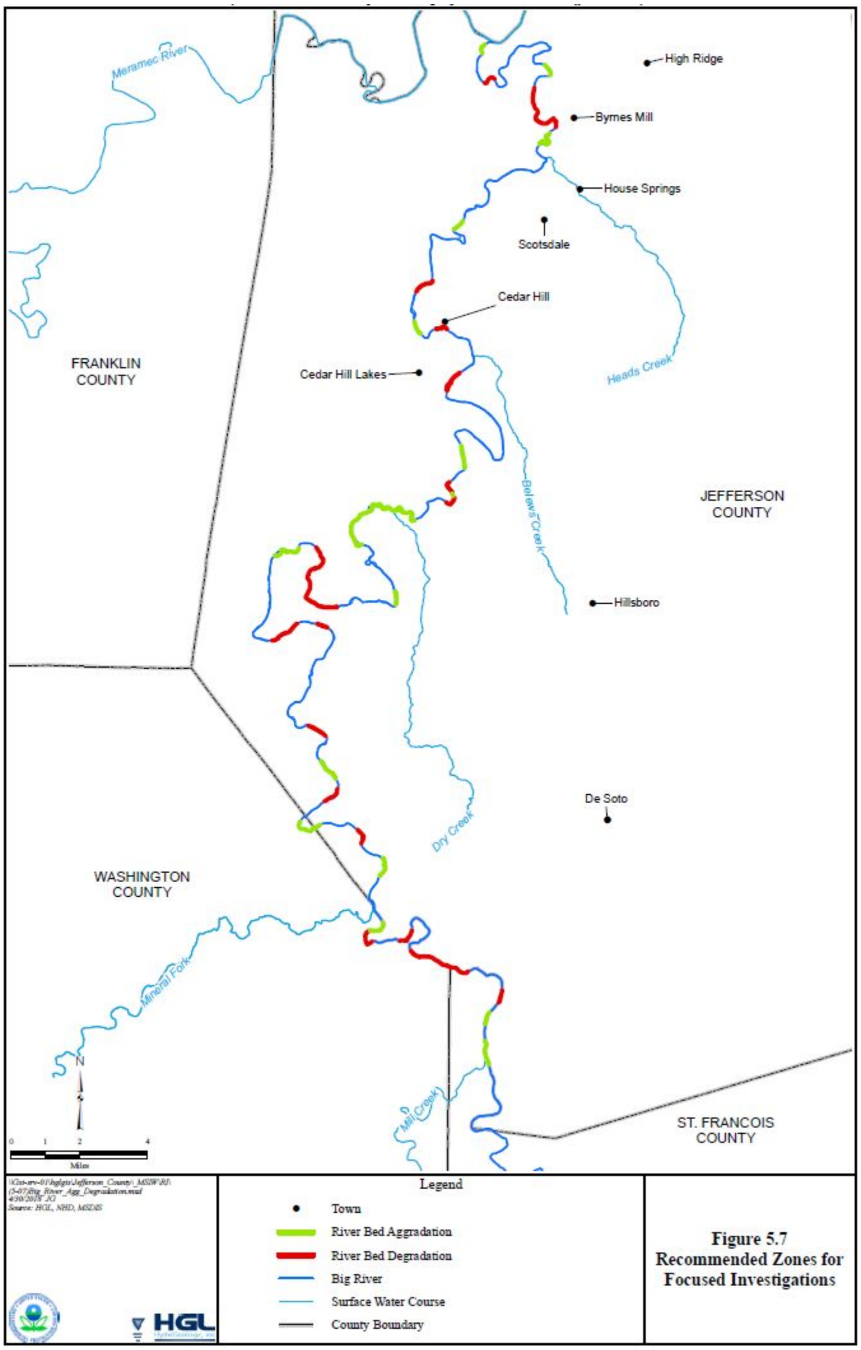


Figure 3-21. Aggradation and Degradation Zones Identified By the HEC-RAS Model

Figure 3-22 shows the estimated sediment inflow at the upstream boundary of the model. The blue diamond represents total load, while the green circles represent bed material load. The data points represent measured data which was taken from the Bonne Terre gage (07017610) between 2011 and 2013.

HGL—Hydraulic and Sediment Transport Modeling Report, SJCM Site OU4 —Jefferson County, MO

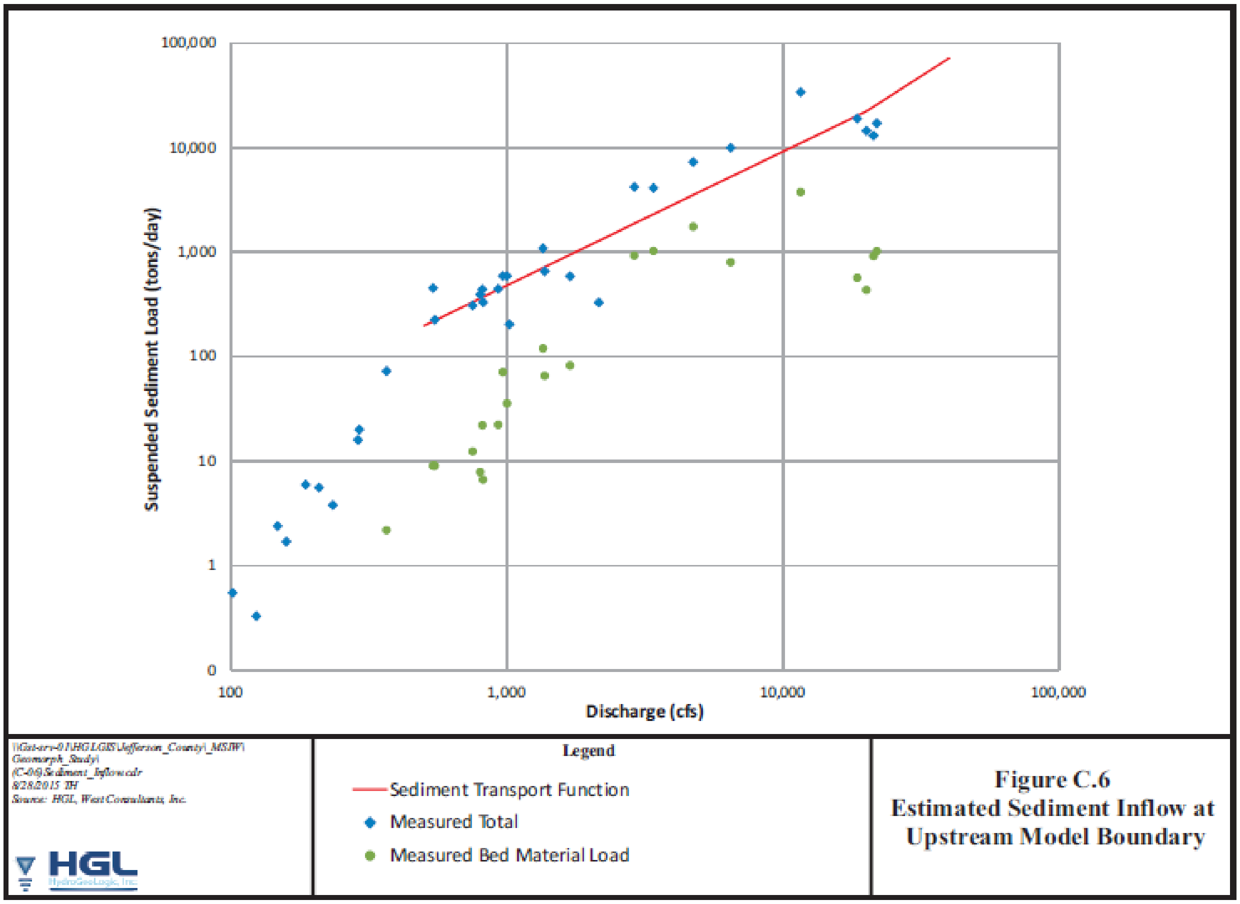


Figure 3-22. Estimated Sediment Inflow at Upstream Model Boundary

4 PROPOSED MEASURES

This section briefly describes benefits and assumptions, site selection criteria and suggestions for feasibility level of design of measures proposed for this project. Please refer to Appendix G-*Engineering Design* for further discussion and greater detail about these measures.

4.1 BANK STABILIZATION

4.1.1 BENEFITS AND ASSUMPTIONS

Benefits* – per foot of stabilization per year of operation

- 3.1 tons of sediment prevented from eroding
- 4.1 pounds of lead prevented from reintroduction

Assumptions*

- Bank sediment is 66% <0.25mm
- Soil unit weight: 82 lbs/ft^3
- Bank contamination depth: 7.2 feet (Pavlowsky, Owen, & Martin, , 2010)
- Bank contamination concentration: varies by RM from 400-1800
- All calculations are based on historic analysis and are not predictive
- Erosion at the site stops upon stabilization

*These benefits and assumptions are from preliminary analysis for the Tentatively Selected Plan (TSP).

4.1.2 SITE SELECTION CRITERIA

Careful site selection is important for the success of each bank stabilization measure (USDOI, 2015). All bank stabilization measures should start and end in stable areas. Consider how the river might react upstream and downstream of stabilization areas. The primary bank failure driver (geotechnical vs hydraulic forces) should also be considered.

Longitudinal Peak Stone Toe Protection (LPSTP)

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Use in sharp bends where high velocities would overwhelm efforts to redirect flow
- Use this method if bank failure would endanger human life or critical infrastructure
- Use when channel must be realigned or when bank alignment varies abruptly

Weirs

- Appropriate at channel evolution model (CEM) stage 4 or 5
- Use when potential for scalloping between weirs is acceptable
- Use only when minor energy redirection is needed
- Use when ratio of width to depth is greater than ten
- Use when ratio of radius of curvature to bankfull width is greater than six
- Use when opposite point bar is unvegetated at less than 50% bankfull depth and the material can be moved by flow
- Use only when channel bed is at least 20 feet wide

Stream Barbs

- Appropriate at channel evolution model (CEM) stage 4 or 5
- Use when moderate to major energy redirection is needed
- Use when ratio of width to depth is greater than ten
- Use when ratio of radius of curvature to bankfull width is greater than two

- Use when opposite point bar is unvegetated at less than 50% bankfull depth, and the material can be moved by flow
- Use only when channel bed is at least 20 feet wide

Rootwad Revetment

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Do not use if failure would endanger human life or critical infrastructure
- Use when toe erosion is primary bank failure driver
- Use only when stream velocities are not expected to exceed 9 ft/s
- Use when site has good access for maintenance

Tree Revetment

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Do not use if failure would endanger human life or critical infrastructure
- Use as a short-term measure to protect bank and encourage it to self-heal
- Use only when stream velocities are not expected to exceed 9 ft/s
- Use when site has good access for maintenance

Riparian Plantings

- Appropriate at channel evolution model (CEM) stage 4 or 5 (relatively stable system)
- Do not use if failure would endanger human life or critical infrastructure
- Use as a long-term measure to protect meander belt
- Use to reduce floodway velocities during high flows

Live Posts

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Use in conjunction with other stabilization methods
- Use to speed the growth of riparian vegetation

4.1.3 FEASIBILITY LEVEL OF DESIGN

Feasibility Level of Design (FLD) of bank stabilization measures primarily focused understanding which of the many bank stabilization methods is/are appropriate to use given the hydraulic conditions at each site.

A literature review indicated that certain bank stabilization measures could withstand varying levels of local shear stress and local flow velocity (USDOI, 2015) (NEH Part 654, 2007) (NEH Part 654, Use of Large Woody Material for Habitat and Bank Protection Technical Supplement 14j, 2007). The ranges of allowable shear stress and velocity are summarized in Table 4-1. These ranges are an attempt to mediate the variability between sources.

Table 4-1. Ranges of Allowable Shear Stress and Velocity by Bank Stabilization Measure Type

Measure Type	Max Shear Stress		Max Velocity	
	Low (A)	High (B)	Low (A)	High (B)
Vegetation	0.4	2.5	3.0	6.0
Live Poles in Coir	2.0	2.5	3.0	5.0
Brush Mattress	0.2	6.0	1.0	10.0
Fascine	1.2	3.1	5.0	8.0
Live Willow Stakes	2.1	3.1	3.0	10.0
Temporary Degradable RECP	0.5	2.3	1.0	7.0
Woody Structure	N/A	N/A	8.9	12.1
Riprap	2.5	10.1	5.0	18.0

Average velocity and bed shear, as extracted from the HEC-RAS model, are summarized by reach in Table 4-2. Average velocity represents average channel velocity, and is denoted in HEC-RAS as "Vel Chnl." Average bed shear is denoted in HEC-RAS as "Shear Chan." The average values were isolated by freezing the quasi-unsteady flow at time steps that corresponded to when flows approximately equaled 1.2-yr, 10-yr, and 100-yr flows. Once these time steps were isolated, the data at cross sections along the entire river was exported to an Excel spreadsheet and statistics were computed and summarized. The data in Table 4-2 serves as a groundwork for selecting specific bank stabilization measures and materials.

Table 4-2. Summary of Cross-Sectional Average Shear Stress and Velocity, on Big River, by Reach

Reach	DS RM	US RM	Average Velocity (ft/s)			Average Bed Shear (lb/sf)		
			1.2-yr	10-yr	100-yr	1.2-yr	10-yr	100-yr
1	0.3	6.4	3.0	3.7	4.0	0.09	0.12	0.13
2	6.6	9.9	4.0	3.4	3.5	0.29	0.19	0.19
3	10.2	12.0	4.2	5.5	6.2	0.23	0.34	0.42
4	12.5	14.5	6.0	6.9	7.9	0.36	0.42	0.52
5	14.6	19.7	5.2	5.7	6.8	0.33	0.34	0.44
6	19.8	27.7	5.1	6.7	7.4	0.31	0.46	0.52
7	28.8	32.8	5.0	5.0	5.7	0.28	0.26	0.31
8	33.4	37.1	4.8	6.3	7.1	0.26	0.40	0.49
9	37.4	46.3	5.7	7.7	9.3	0.35	0.56	0.76
10	46.8	61.5	5.8	7.8	8.8	0.45	0.70	0.83
11	62.0	68.6	6.9	8.6	10.2	0.53	0.69	0.92
12	68.7	73.4	5.8	6.9	7.9	0.37	0.46	0.59
13	73.7	76.5	6.1	8.0	9.1	0.42	0.59	0.71

These values can't be directly compared to permissible local shear stress and maximum local velocity because the model can't consider local hydraulic effects, which can substantially elevate shear and velocity. Results from a 2D model could be applied more directly, but it is not feasible or cost-effective to create a 2D model of 75 miles of the Big River at this time. Instead, local shear and velocity can be estimated at specific sites of interest with a moderate level of confidence using established literature, as summarized below.

Local shear can be estimated using methodology outlined in (Sin, Thornton, Cox, & Abt, 2012), and shown in Equation 4-1:

Equation 4-1. Convert Cross-Sectional Average Shear to Local Maximum Shear

$$K_b = 2.4992 * \left(\frac{R_c}{T_w}\right)^{-0.321}$$

Where:

K_b = ratio of maximum shear stress and average shear stress from HEC-RAS modeling (dimensionless)

R_c = radius of curvature of meandering channel (ft); and

T_w = top width of channel (ft).

Once K_b is calculated, it is then multiplied by average shear stress to obtain the maximum shear, in pounds per square foot (lb/sf).

Local velocity can be estimated using methodology outlined in Computation Design Tool for Evaluating the Stability of Large Wood Structures (Rafferty, 2017), and shown in Equation 4-2:

Equation 4-2. Convert Cross-Sectional Average Velocity to Local Maximum Velocity

$$u_m = u_{avg} * (1.74 - 0.52 * \log\left(\frac{R_C}{W_{BF}}\right))$$

$$[\frac{R_C}{W_{BF}} \leq 26]$$

Where:

u_m = local maximum flow velocity (ft/s),

u_{avg} = average cross-sectional velocity (ft/s),

R_c = radius of curvature of centerline of meandering channel (ft); and

W_{BF} = top width of bankfull channel (ft).

Equation 4-1 and Equation 4-2 provide tools for adjusting cross-section-averaged shear and velocity to estimate local shear and velocity given specific site conditions. An updated version of Table 4-2 showing adjusted shear and velocity would be inappropriate. Instead, each site of interest was listed in a spreadsheet, and the following parameters and variables were filled in:

- Radius of curvature *(from aerial imagery)*
- Top width *(from HEC-RAS model, at various flow events)*
- Bankfull width *(from HEC-RAS model, at various flow events)*
- Reach-averaged shear *(from HEC-RAS model, at various flow events)*
- Reach-averaged velocity *(from HEC-RAS model, at various flow events)*.

Given the parameters and variables at each site, the adjusted (local) shear and velocity were calculated. Those adjusted values were then compared against each type of bank stabilization method, and their respective allowable values, as provided in Table 4-1. The output provides three signals:

1. "Yes" – the adjusted velocity (or shear) is below the "Low (A)" velocity (or shear) value, as referenced in Table 4-2. Measures that receive this signal may be applied at that site using normal engineering practice. Most recommended measures received this signal.
2. "Maybe" - the adjusted velocity (or shear) is within the range of "Low (A)" to "High (B)" velocity (or shear) values, as referenced in Table 4-2. Measures that receive this signal may or may not be applied at that site after further analysis, using cautious engineering practice and expert judgment.
3. "No" - the adjusted velocity (or shear) is above the "High (B)" velocity (or shear) value, as referenced in Table 4-2. Measures that receive this signal are not appropriate for application at that site.

The reach-averaged cross-section-averaged values extracted from the RAS model do vary slightly from the values presented by HGL in their report. A sensitivity analysis was performed to compare the resulting adjusted (local) data, between the extracted from HEC-RAS (Table 4-2) and the data pulled directly from HGL's report (Table 3-11). The sensitivity analysis entailed determining if the signals, as calculated from both tables separately, matched at each selected bank stabilization site. This analysis revealed that some signals changed on certain measures, but the signals for selected measures were not meaningfully different.

The selection, layout and design of bank stabilization measures was a joint-effort between the Civil-Design and Hydraulic Design branches. Representatives from these branches sat down together to identify appropriate measures, to orient and scale them on a map and to adjust their dimensions. Throughout this effort, various sources and guidelines were consulted, including:

- Previous recommendations for Feasibility Level of Design
- Historic aerial imagery,
- Site visit photos,

- HGL's HEC-RAS model,
- The bank stabilization screening criteria spreadsheet, and
- Expert opinion.

In the preconstruction engineering design (PED) phase, emphasis should be placed on ensuring the design of the selected measures is in line with recommendations put forth in 4.1.4 and opinions from bank stabilization experts.

4.1.4 PRECONSTRUCTION ENGINEERING DESIGN

These design recommendations are not all-inclusive, but should serve as a foundation for preconstruction engineering design (PED) for bank stabilization measures. All bank stabilization attempts should account for the local and nearby channel evolution classes, as mentioned in Figure 3-5. Stabilization efforts applied in the wrong way can worsen a system and waste time, money, and materials. While each site should be assessed individually, many of the sites identified for bank stabilization are class IV (Degradation and widening) or V (aggradation and widening). The Channel Evolution Model (CEM) does not necessarily terminate once stage VI is reached – the river can work through the CEM multiple times until it reaches equilibrium. The most important stage to prevent or arrest is stage III (Degradation), because it will lead to stage IV and V, which have significant consequences for bank instability.

Longitudinal Peak Stone Toe Protection (LPSTP)

- Calculate or estimate scour depth in bend
- Design upstream and downstream key dimensions and angles
- Design tieback dimensions
- Crown height is based on professional judgment – consult experienced LPSTP designers; if opposite point bar exists, generally build crown at or above opposite point bar top elevation
- Crown width should be designed to compensate for self-launching stone, which will reduce the crown height (and thus reduce protection) if the width is not sufficient
- Design stone gradation to self-launch, entrap suspended sediment, and withstand flow velocity
- Incorporate woody debris whenever possible to create habitat

Weirs

- Appropriate at channel evolution model (CEM) stage 4 or 5
- Design key dimensions – length at least 1.5x bank height; height at same elevation of opposite point bar elevation
- Angle weir 10-30 degrees upstream, as measured from perpendicular with flow
- Weir crest should be one foot above baseflow
- Use downstream weir to aim flow exiting the stabilized bank
- Design stone gradation to self-launch and withstand flow velocity

Stream Barbs

- Appropriate at channel evolution model (CEM) stage 4 or 5
- Design key dimensions – length at least 1.5x bank height; height at same elevation as crest
- Length should be less than 25-33% of bankfull width
- Design barb slope (3-7%) to balance length
- Design angle to intercept 33-50% of base flow width
- Design barb angle to be 20-30 degrees from tangent with bank
- Design bar crest height; max height should be height of opposing point bar; min height should be 33% bankfull depth, as measured from downstream riffle
- Design stone gradation to self-launch and withstand flow velocity

Rootwad Revetment

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Consult with experienced bioengineering designers
- Design size of toe wood and rootwads based on bankfull height, scour potential, and flow velocities
- Design rootwad trunks tie-in length
- Determine source of rootwads and toe logs

Tree Revetment

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Consult with experienced bioengineering designers
- Design type, size, and density of trees
- Determine anchor positions and depths

Riparian Plantings

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Consult with a biologist that has experience planting riparian zones in nearby riverine systems
- Determine type of plantings (seed mix vs live plantings)
- Determine protective measures that reduce mortality during first few years

Live Posts

- Appropriate at channel evolution model (CEM) stage 3 or 4
- Consult with experienced bioengineering designers
- Ensure roots will extend to dry season water level

4.2 GRADE CONTROL

4.2.1 BENEFITS AND ASSUMPTIONS

Benefits* – per location of grade control structure per year of operation

- 470 tons of sediment arrested and removed
- 380 pounds of lead arrested and removed

Assumptions*

- Soil unit weight: 97 lbs/ft^3
- 1.5 events per year contribute material (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016)
- 675 cubic yards of material is deposited with each design event
  - 500 cy/yr; ~470 tons/yr available for removal (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016)
- Regular cleanout allows grade control to continue capturing material
- 75% of deposited material is available for recovery
- 100% of recovered material is retained during removal and hauling
- Only <2mm sediment is removed
- The furthest upstream samples available can be applied to reaches of Big River up to RM 97

*These benefits and assumptions are from preliminary analysis for the Tentatively Selected Plan (TSP).

4.2.2 SITE SELECTION CRITERIA

Engineered Rock Riffles

- Appropriate at channel evolution model (CEM) stage 2 or 3
- Use upstream of degrading river bed to prevent degradation from continuing upstream
- Use in degraded river bed to encourage aggradation in degraded area behind structure
- Strongly consider the rivers natural riffle-pool sequence; locate on riffles
- Use above and/or below mill dams to mitigate effects of further structure degradation

4.2.3 FEASIBILITY LEVEL OF DESIGN

For Feasibility Level of Design (FLD), grade controls were designed and placed as appropriate. Most grade control structures that were designed are to be built below the water surface, with no part of it visible except during extreme low flow. This design is intended provide protection against future degradation, should it occur.

The grade controls were designed using feasibility level of design (FLD) recommendations. The structures are limited in height because taller structures require additional considerations, such as a sheet-pile cutoff wall to prevent seepage. The stone gradation is designed to allow the structure to adjust and settle in as the river changes. Slopes adhere to FLD recommended 1V:20H for downstream slope and 1V:5H for upstream slope. These slopes are hydraulically and geotechnically stable, and fish can pass up through a 1:20 slope in the event of low flow.

4.2.4 PRECONSTRUCTION ENGINEERING DESIGN

These design recommendations are not all-inclusive, but should serve as a foundation for preconstruction engineering design (PED) for grade control structures.

Engineered Rock Riffles

- Appropriate at channel evolution model (CEM) stage 2 or 3
- Head differential should be no more than 3 feet per structure (greater heights necessitates a cutoff wall)
- Downstream slope should be no steeper than 1V:20H
- Upstream slope should be no steeper than 1V:5H
- Design stone gradation to be stable and withstand flow velocity
- Design upstream and/or downstream self-launching keys to automatically adjust to scour holes or incision working upstream
- If multiple structures are required, determine spacing and locations to complement natural riffle-pool regime
- Design to allow fish passage

4.3 SEDIMENT BASINS (OFF-CHANNEL SEDIMENT COLLECTION SYSTEMS)

4.3.1 BENEFITS AND ASSUMPTIONS

Benefits – per acre of sediment basin per year of operation

- 319 tons of sediment captured
- 295 pounds of lead captured

Assumptions

- Variable fillable depth ranging from 4.5 to 16 feet
- Soil unit weight: 97 lbs/ft^3
- Fill rate of 1-2 inches per year (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016)
  - A rough watershed-wide approximation; but it is the best available data at the time of analysis
- Captured sediment is similar to fine-gradation floodplain deposits, with some coarser material mixed in as well

- Captured sediment contamination level between 300-1700 ppm
- Basin efficiency 85-100%, depending on depth

4.3.2 SITE SELECTION CRITERIA

Off-channel sediment collection basins require particular site conditions in order to properly function.

- Site is adjacent to river
- Site is low in elevation, like a high-flow channel
    - Design flow reached frequently but not too frequently (average of 1-3 times per year)
- Excellent access to river for monitoring and/or cleanout activities

4.3.3 FEASIBILITY LEVEL OF DESIGN

In Feasibility Level of Design (FLD), the primary focus was inlet/outlet crest elevations and basin capacity. In practice, inlet/outlet crest elevations can only be designed to allow river access at or near average flow when the basin is placed in a side channel. However, backwater collection basins can be optimized to only receive and discharge flow at certain elevations. In the initial design of the inlet and outlet elevations, the HEC-RAS model was consulted to compare flow elevations to event frequency.

Preconstruction engineering design (PED) should focus on optimizing activation elevations and design of the inlet and outlet structures. A few recommendations for PED are listed in 4.3.4.

4.3.4 PRECONSTRUCTION ENGINEERING DESIGN

These design recommendations are not all-inclusive, but should serve as a foundation for preconstruction engineering design (PED) for off-channel sediment collection basins. The inlet and outlet should be carefully designed to target the most appropriate grain size and to not induce deposition in the main channel due to reduced main channel stream power.

- Inlet and outlet crest elevations allow river to access basin beginning at median to average flow
- Inlet and outlet lateral keys should be designed to resist permanent flanking after floods
- Inlet and outlet bed keys designed to self-launch in the event of head cutting
- Design benefits are calculated based on near-bankfull flow
- Basins should be deep enough to efficiently capture sediment – generally no less than 5 feet
- Basin cross section designed to amply reduce flow velocity to allow deposition of finest target sediment size

4.4 BED SEDIMENT COLLECTORS

4.4.1 BENEFITS AND ASSUMPTIONS

Benefits* – total collected by bed sediment collector per year of operation

- 2,800 tons of sediment collected
- 2,300 pounds of lead collected

Assumptions*

- Soil unit weight: 97 lbs/ft^3
- 1.5 events per year contribute material (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016)
- 675 cubic yards of material passes by a collector during each design event (Pavlowsky, Pierson, Owen, Voss, & Weedman, 2016)
- 75% of transported material is available for recovery
- 70% of material available for recovery is <2 mm
- 100% of recovered material is retained during removal and hauling
- Sample data came from a sampling event in 2016 by HGL. Not all bedload collection sites had sample data, so some interpolations and limited extrapolations were performed. Assume this creates negligible error.

*These benefits and assumptions are from preliminary analysis for the Tentatively Selected Plan (TSP), and updated benefits for Feasibility Level Design (FLD) can be found in 4.4.3.

4.4.2 SITE SELECTION CRITERIA

Bed sediment collectors require particular site conditions in order to properly and efficiently function.

- Excellent site access for monitoring, operation, and maintenance
  - Electricity or diesel power source; removal of equipment during very high flows; removal of stockpiled material
- Adequate stockpile area for removed material
- River stretch should be laterally stable
- Vertical river profile should be stable to aggrading

4.4.3 FEASIBILITY LEVEL OF DESIGN

For Feasibility Level of Design (FLD), the focus was set on a few primary factors that guide the design and operation of the bed sediment collectors. For a bedload collection operation to be efficient, the collector should run for as little time as possible, and collect as much bedload as possible. Optimizing this problem requires an understanding of hydrology, sediment transport, and other site-specific limitations. The following questions should be answered:

1) How are flow events defined?
2) How often do flow events occur?
3) How long do flow events last?
4) How much bedload is transported during flow events?

Multiple iterations are required in order to reach an optimal solution. First, a flow event must be arbitrarily defined. Then, the flow statistics must be analyzed. Lastly, the bedload transport during the defined flow events must be quantified. In order to reach an optimal solution, the flow event is then adjusted to encompass slightly different flows, and the flow and bedload data is compared. Significantly more bedload is transported during very large flows; however, large flows occur less frequently. An optimum flow event will maximize bedload collection while minimizing operating time, while staying within site-specific constraints and equipment limitations.

A flow event must be defined by a low and high threshold. Thresholds are used to define the operating timeframe of bed sediment collectors. Bed sediment collectors begin running at and above a low flow threshold and they cease running at and above a high flow threshold. Existing hydrology data (USGS, 2017) and sediment transport data (HGL, May 2018) can be combined and studied to optimize how flow events are defined. Daily flow data was taken from Richwoods Gage (07018100). The selected low and high flow thresholds are 1,200 cfs and 12,000 cfs, respectively. Bedload begins to non-trivially mobilize at 1,200 cfs, and 12,000 cfs is a bit above bankfull, and a bit below a 50% exceedance event (2-yr return).

Bedload transport was estimated at each daily flow using a bedload equation derived from the HEC-RAS model by HGL (HGL, May 2018). Since bedload is truly difficult to predict, the bedload transport capacity was estimated at each daily flow value based on BAGS analysis (as discussed in Bed Material Analysis) in order to corroborate the magnitude of the transport estimate from the model.

The equation for actual bedload transported, as assumed by HGL for the HEC-RAS model inputs, is shown in Equation 4-3. The equation for bedload transport capacity, as calculated using BAGS, is shown in Equation 4-4.

Equation 4-3. Estimated Bedload Transported (tons/day)

$$b_t = 0.000677 * Q^{1.6211}$$

Equation 4-4. Bedload Transport Capacity (tons/day)

$$b_c = 0.0018 * Q^{1.4168}$$

Where:

b_t = estimated bedload transported, per HGL model (tons/day),

b_c = estimated bedload transport capacity, per BAGS analysis (tons/day), and

Q = river discharge (cfs).

As expected, the transport estimate never exceeds the capacity estimate.

Equation 4-3 and Equation 4-4 can be used with daily discharge data to estimate how much bedload passes a bed sediment collector.

Historic (1950-2018) averages associated with flow thresholds of 1,200 cfs – 12,000 cfs are listed below:

- Assuming active flow days/events are defined as 1,200 – 12,000 cfs, bed sediment collectors will activate 12 times each year for a total of 39 days each year (11% of the year).
- Those activations will vary in length, with 54% lasting 4 days or less; 75% lasting 6 days or less; and 90% lasting 10 days or less.
- Flow will exceed 12,000 cfs for 2.4 days each year, or 6.2% of active flow days.
- On average, 150 tons/day of bedload is transported during active flow days.
- On average, 6,300 tons/year or bedload is transported during active flow days.

Figure 4-1 shows the average number of flow event occurrences per year, and their relative frequency of occurrence, for each flow event duration. For example, an event with a flow duration of three days occurs an average of two times each year, and its relative frequency of occurrence is about 25%.

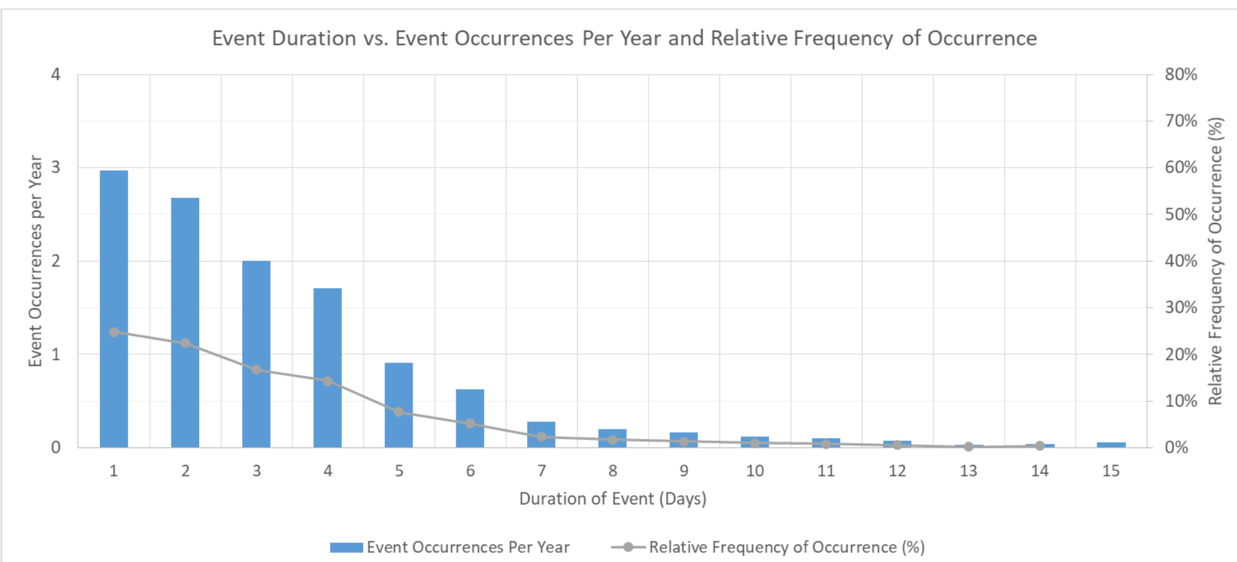


Figure 4-1. Event Duration vs. Event Occurrences Per Year and Relative Frequency of Occurrence

Figure 4-2 compares the estimated bedload transported each year to the number of flow event days between 1,200 cfs and 12,000 cfs. For example, in 1964 there were nine flow event days and the estimated bedload transported was 314 tons/day.

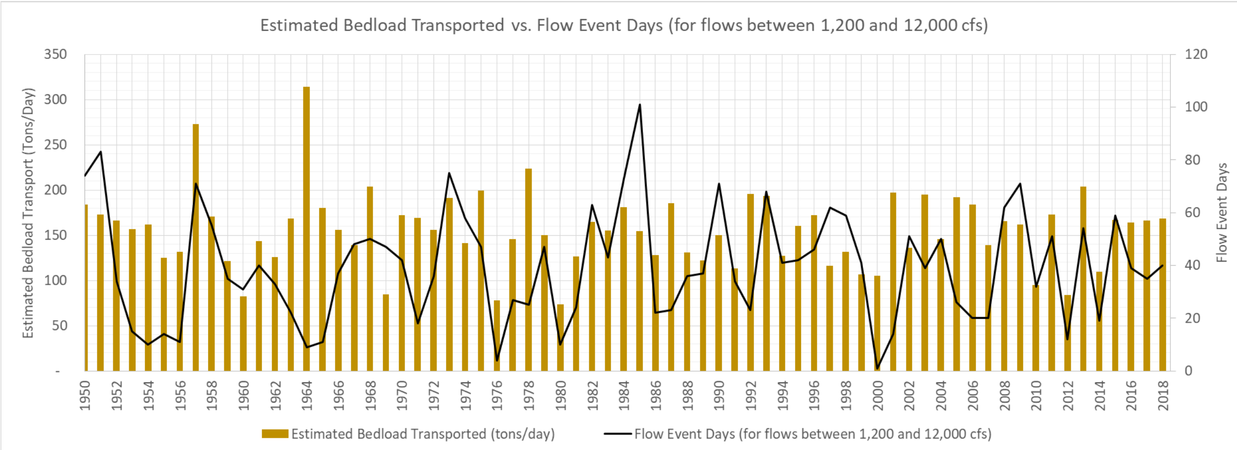


Figure 4-2. Estimated Bedload Transported vs. Flow Event Days (for flows between 1,200 and 12,000 cfs)

4.4.4 PRECONSTRUCTION ENGINEERING DESIGN

These design recommendations are not all-inclusive, but should serve as a foundation for preconstruction engineering design (PED) for bed sediment collectors.

- Begin operating at or above median flow
- Placement should enable the collection of target grain sizes
- Grate size should exclude non-target grain sizes
- Equipment should be placed in a way that optimizes the cost to operate, effort to protect against high flows, and benefit of collected sediment
- Staging piles should not impede flood flows
- In-stream footprint should be optimized to minimize disturbance, yet still accommodate bedload collection rate
- Use hydrology data to further optimize the required operation and maintenance
- Use bedload mass balance to optimize the quantity of collected sediment to minimize adverse impacts from taking too much sediment out of the system
    - Calculate/compare: 1) Bedload supply capability of river, 2) Removal capability of collector; and 3) Appropriate removal quantity – via detailed bedload mass balance
- Bedload transport will vary from reach to reach, as the physical characteristics of the river channel vary. This is quantified by the HEC-RAS model.
- Provide consideration to the level of separation between bedload collectors throughout the project. The benefits of collecting bedload are not simple and vary by location and as collector density increases. For example, three collectors placed three miles apart near the downstream end of the project will not provide the same project-wide benefit that three collectors placed twenty miles apart starting at RM 90 would. This is not well quantified and it would be extremely difficult to predict the exact benefit associated with various collector densities and collection rates.

4.5 IN-STREAM EXCAVATION

4.5.1 BENEFITS AND ASSUMPTIONS

Benefits* – per removal location per year

- 669 tons of sediment removed
- 333 pounds of lead removed

Assumptions*

- Annual benefits assume a discrete number of removal events; varies by site
- Depositional area upstream of grade control reaches up to 2000 feet upstream of structures
- Bed storage rate varies: 2570 +/- 14% m^3/100m for River Kilometer (RKM) 171-90; 1580 +/- 12% m^3/100m from RKM 90-15 (Pavlowsky, Owen, & Martin, , 2010)
- Only <2mm sediment retained and removed

*These benefits and assumptions are from preliminary analysis for the Tentatively Selected Plan (TSP).

4.5.2 SITE SELECTION CRITERIA

In-stream excavation is possible behind grade control structures. These excavation sites should meet the following criteria:

- Excavation can occur behind structures that have backwater, and that have potential to cause sediment to deposit behind or near them
- Excavation can occur between grade control structures if there is no pooled backwater, in such a way that any instability caused by excavation is substantially contained between them

In-stream excavation is also possible at select gravel bars. Missouri Department of Natural Resources has published Chapter 10 – Permit and Performance Requirements for Industrial Mineral Open Pit and In-Stream Sand and Gravel Operations. Missouri Department of Conservation has published a guide for sand and gravel removal from streams in "A Landowners Guide for Sand and Gravel Removal." Major requirements and criteria include:

- Remove sand and gravel only from loosely packed bars with little to no vegetation present
- Remove sand and gravel only above the water line
- Allow a 20-ft buffer of undisturbed material between the normal water line and the excavation area
- Avoid areas that contain threatened and endangered species
- Excavation of sand or gravel deposits shall be limited to deposits in unconsolidated areas containing primarily smaller material (at least eighty-five percent (85%) of the material is less than three inches (3") in diameter) that is loosely packed and contains no woody perennial

vegetation greater than one and one-half inches (1 1/2") in diameter, measured at breast height four and one-half feet (4.5').

- An undisturbed buffer of ten foot (10') width shall be left between the excavation area and the water's edge of the flowing stream at the time of excavation. A buffer zone of adequate width to protect bank integrity should be left between the excavation area and the base.
- An undisturbed buffer of twenty-five feet (25') wide shall be maintained in an undisturbed condition landward of the high bank for the length of the gravel removal site. Disturbed areas in this riparian zone shall be limited to maintained access road(s) for ingress and egress only. No clearing within this riparian area is authorized in association with work authorized by this permit.
- Sand or gravel shall not be excavated below water elevation at the time of removal, except: A. If the stream is dry at the time of excavation, excavation shall not occur deeper than the lowest undisturbed elevation of the stream bottom adjacent to the site. Upon request of the applicant, excavation depth restriction may be modified if the staff director determines that a variance would not significantly impact the stream resource. B. For wet stream reaches, excavation depth restriction may be modified if it is determined by the staff director that a variance would not significantly impact the stream resource based on the presence of bedrock to prevent head cutting, excessive bedload, gravel rich areas or any other appropriate reason.
- Stream channels shall not be relocated, straightened, cut off, shortened, widened, or otherwise modified. A stream channel is defined as that area between the high banks of the creek where water is flowing, or in the case of a dry stream, where water would flow after a rain event.
- Within thirty (30) days of the removal of excavation equipment from the site, streambank areas disturbed by the removal operation shall be revegetated or otherwise protected from erosion. For long-term operations (longer than thirty (30) days) or for sites that will be periodically revisited as gravel is deposited, access points shall be appropriately constructed and maintained such that streambanks and access roads are designed and constructed to minimize erosion.
- Any aggregate, fines, or oversized material removed from the site shall be placed beyond the high bank, on a non-wetland site that has been approved by the landowner. No material, including oversized material, that results from excavation activity may be stockpiled or otherwise placed into flowing water or placed against streambanks as bank stabilization unless specifically authorized by a state or federal permit.
- All sand or gravel washing, gravel crushing, and gravel sorting shall be conducted beyond the high bank, in a non-wetland area and away from areas that frequently flood, such that gravel, silt, and wash water that is warm, stagnant, or contains silty material cannot enter the stream or any wetland.
- Vehicles and other equipment shall be limited to removal sites and existing crossings. Water shall be crossed as perpendicular to the direction of the stream flow as possible.

- Fuel, oil and other wastes and equipment containing such wastes shall not be stored or released at any location between the high banks or in a manner that would enter the stream channel. Such materials shall be disposed of at authorized locations.

4.5.3 PRECONSTRUCTION ENGINEERING DESIGN

These design recommendations are not all-inclusive, but should serve as a foundation for preconstruction engineering design (PED) for in-stream excavation operations.

For in-stream excavation behind grade control structures:

- Survey and sample sites to confirm presence and extent of contaminated sediment that has been deposited
- Optimize removal and screening process to balance natural sediment supply and lead contaminated sediment removed; do not make the water "sediment-hungry"
- Remove in a fashion that does not propagate vertical bed instability
- Minimize terrestrial disturbance for accessing and servicing the site; especially minimize near-bank disturbance, and/or mitigate by reinforcing or hardening weakened near-bank areas

For in-stream excavation of gravel bars:

- Identify gravel bars that pass screening criteria and guidelines set forth in 4.5.2 and meet the performance requirements laid out in CSR 40-10.050 in Chapter 10 of the Missouri Department of Natural Resources Chapter 10 – Permit and Performance Requirements for Industrial Mineral Open Pit and In-Stream Sand and Gravel Operations (MoDNR 2018).

5 CLIMATE

It is important to understand the climate for ecosystem restoration projects. Changes in climate could cause the life of ecosystem restoration features to be cut short. Considering existing climate, trends, and projections reduces risk and allows features to be designed resiliently.

Mussels are most active within a certain temperature range, so a dramatic, consistent, and rapid change in temperature could affect their ability to adapt and thrive. The Big River is spring-fed, so water temperatures and base-flows are fairly consistent. 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.

Bank stabilization features integrate self-launching rip-rap and bio-engineered banks. The rip-rap can react to an increase in water velocity and shear forces by self-launching to situate and stabilize itself. Meanwhile, bio-engineered banks are constructed using flood-tolerant methods and species that recover quickly after being inundated. Grade control features will be constructed using self-launching rip-rap, and will be conservatively designed to react to changes in flow. Sediment basins are indifferent to modest changes in median, mean, or peak flows; if mean streamflow were expected to trend extremely downwards, then their benefits would be overstated, as they would not function as often. Bed sediment collectors use algorithms to self-optimize their operation to maximize their benefit, no matter how flows change; a generally wetter trend would increase benefits, while a generally drier trend would decrease benefits. In-stream excavation is a manual process that relies on coordination of efforts during low water – a significantly increasing trend in median flow would slightly increase the complexity of this operation by reducing the window of opportunity during which to excavate deposited sediments.

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 the ecosystem, it hinges on means and medians not maximums and minimums. Extremes data is presented and discussed within this section, with the context of ecosystem restoration in mind. Data relating to means and medians is also presented and discussed.

Data for annual peak streamflow shows an increasing trend of borderline statistical significance on Meramec River at Eureka, a statistically significant increasing trend on Big River at Byrnesville (105 cfs per year), and a statistically insignificant increasing trend on the Big River at Richwoods. Meanwhile, data for both annual mean and annual median flows on Big River at Byrnesville show no statistically significant increasing or decreasing trends. The only strong nonstationarity among the analyses was relating to an increasing trend for annual mean flow on the Meramec River at Eureka. This nonstationarity had consensus, robustness, and non-trivial magnitude.

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. A literature review reveals a general consensus that there has been a moderate increase in temperature, precipitation, and streamflow in the Upper Mississippi Region over the past century. Some evidence also points towards an increased frequency of extreme storm events.

5.1 OBSERVED LOCAL WEATHER

Monthly precipitation and temperature data were obtained from the National Weather Service's Global Historical Climatology Network (GHCN). The data is from the Farmington, Missouri gage (Network ID GHCND: USC00232809, Latitude 37.7922°, Longitude -90.4102°, Elevation 282.9 m). Table 5-1 shows precipitation statistics and Table 5-2 shows temperature statistics for the period of January 1907 to July 2017. The average, maximum and minimum yearly temperature and precipitation from the Farmington gage for the period of 1893-2017 are graphed in Figure 5-1.

A cursory review of the 30-year moving averages does not yield any immediately alarming trends over the period of 1893-2017. The following are observations about the 30-year moving average trendlines for each temperature and precipitation graph shown in Figure 5-1: Average annual temperature appears to have just completed an 80-year-long sin-wave-like cycle; however, this does not necessarily indicate the direction or magnitude of future trends. Minimum annual temperature dropped by 3 to 4 degrees F in the early 1970's, but has since recovered to pre-1970's levels. Maximum annual temperature shows constancy since the early 1970's. Average annual precipitation seems to be increasing slightly since the early 1970's. Minimum annual precipitation has remained steady with only small and lethargic adjustments. Maximum annual precipitation has varied within a range of 2 inches.

Table 5-1. Precipitation Data at Farmington, Missouri

Month	Precipitation			Snowfall		
	Average (in)	Minimum (in)	Maximum (in)	Average (in)	Minimum (in)	Maximum (in)
Jan	2.4	0.0	10.9	3.0	0.0	14.8
Feb	2.5	0.2	6.4	3.2	0.0	15.5
Mar	3.8	0.5	10.4	2.5	0.0	20.4
Apr	4.6	1.0	14.5	0.1	0.0	3.0
May	4.9	0.5	13.4	0.0	0.0	0.8
Jun	3.8	0.2	17.7	0.0	0.0	0.0
Jul	3.7	0.2	9.4	0.0	0.0	0.0
Aug	3.7	0.1	9.0	0.0	0.0	0.0
Sep	3.4	0.1	15.1	0.0	0.0	0.0
Oct	3.1	0.2	12.2	0.0	0.0	2.0
Nov	3.6	0.3	11.3	0.7	0.0	17.5
Dec	3.0	0.2	13.0	2.4	0.0	17.2
Annual	42.6			12.0		

Table 5-2. Temperature Data at Farmington, Missouri

Month	Temperature		
	Average (°F)	Minimum (°F)	Maximum (°F)
Jan	32.3	4.0	54.0
Feb	36.2	12.5	57.4
Mar	45.4	20.2	73.6
Apr	56.1	36.4	77.1
May	64.2	45.0	86.4
Jun	73.1	53.1	95.9
Jul	77.1	58.9	103.2
Aug	75.7	56.6	101.5
Sep	68.1	47.7	89.5
Oct	57.3	35.1	82.8
Nov	45.1	23.9	65.3
Dec	35.5	11.3	54.6
Annual	55.5		

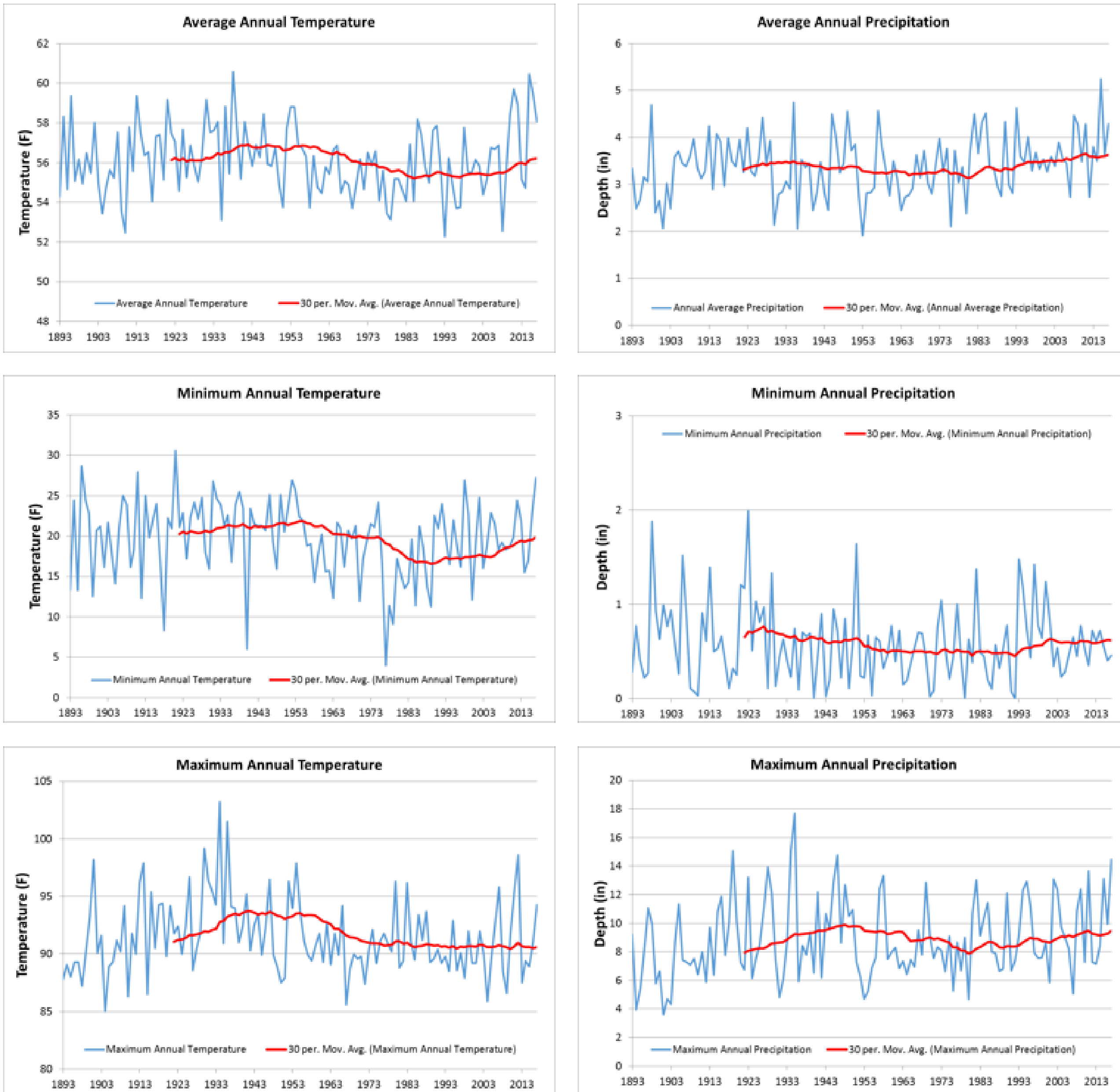


Figure 5-1. Average, Maximum, and Minimum Yearly Temperature and Precipitation at Farmington, Missouri

5.2 OBSERVED LOCAL TRENDS

The USACE Climate Hydrology Assessment Tool, created by USACE, was used to examine observed streamflow trends in the vicinity of the study area. The tool only has capability to assess the annual peak instantaneous streamflow. The hydrologic time series of annual peak instantaneous streamflow was generated at Richwoods, Byrnesville and Eureka gages. These gages all exhibit an increasing trend in annual peak instantaneous streamflow. The analysis from the Big River gage near Richwoods (07018100) has a p-value of 0.492, which indicates that the trend is not statistically significant ($p>0.05$). The analysis from the Big River gage near Byrnesville (7018500), shown in Figure 5-2, has a p-value of 0.015, which indicates that the trend is statistically significant ($p<0.05$). The analysis from the Meramec River gage near Eureka (07019000) has a p-value of 0.052, which is a borderline value for determining the statistical significance of the trend ($p \approx 0.05$).

The increasing annual peak streamflow trend may be attributable to land use change, climate change, and/or watershed development. All of these potentially attributable factors are being researched further through a SWAT model, as previously discussed in section 3.3.1.

An increasing trend in peak annual streamflow has only a small impact on this project because mussels are not active during high flows anyway, and measures are designed to withstand certain physical forces (shear and velocity), which will be affected only slightly by an increase in peak flow magnitude. Over the 50-year lifespan of the project, an increase in annual peak streamflow of 5,250 cfs (104.9 cfs per year * 50 years) would have only a small impact on the associated forces. To understand why, let's consider the highest flow at Byrnesville – 65,000 cfs – which occurred in 1993. If this flow were to increase to 70,000 cfs, the 8% increase in flow would generally equate to a lesser increase in forces. An increase of even 8% in velocity is well-within the error and uncertainty of a river model, and measures are not so precisely designed that a small fluctuation in velocity or shear would prove catastrophic to their function.

The Climate Hydrology Assessment tool can be found here:
https://maps.crrel.usace.army.mil/projects/rcc/portal.html.

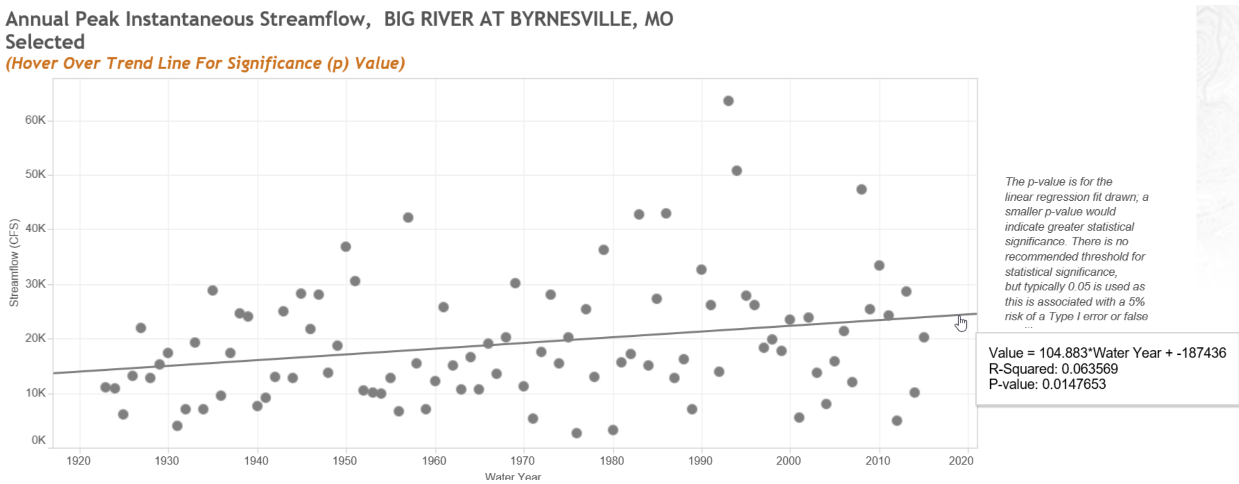


Figure 5-2. Annual Peak Instantaneous Streamflow, Big River at Byrnesville, Trendline Equation: Q = 104.9 * (Water Year) + -187436, p = 0.015.

Stationarity is the assumption that streamflow and runoff function within a fixed envelope of natural variability, in such a way that their past behavior can be used to represent future conditions. Data that is nonstationary has means, variances, and/or co-variances that change over time, and thus its past behavior does not necessarily represent future conditions, but may indicate long-term trends and cycles.

The Nonstationarity Detection Tool, created by USACE, was used to examine the time series for annual peak streamflow at Richwoods, Byrnesville and Eureka gages. The tool uses twelve statistical tests to detect three types of nonstationarities: mean, variance, and distribution. A strong nonstationarity has consensus, robustness and magnitude, as outlined in Appendix B-5 of ETL 1100-2-3. Consensus means that the nonstationarity was detected by two or more tests of the same type (mean, variance, and distribution). Robustness means that the nonstationarity was detected by two or more different types of tests. Nonstationarities are associated with a change in mean or variance, so the magnitude of that change is also important in determining whether or not a nonstationarity is strong and of significance.

A nonstationarity was detected at the Richwoods gage in 1983 using a timeframe of 1953-2015. This nonstationarity lacks consensus, robustness, and magnitude. A nonstationarity was also detected at the Byrnesville gage in 1983 using a timeframe of 1923-2015, but it also lacks consensus, robustness, and magnitude. A nonstationarity was detected at the Eureka gage between 1979 and 1981 using a timeframe of 1922-2015. Example results from the Eureka gage are shown in Figure 5-3. This is a strong nonstationarity because it has consensus, robustness, and magnitude. Four statistical tests were triggered, indicating a nonstationarity. Two tests – Kolmogorov-Smimov (CPM) and Energy Divisive Method – indicate a change in distribution; two tests – Lombard Wilcoxon and Pettitt – indicate a change in mean. Since the tests checking for a change in distribution agree with the tests checking for a change in mean, the nonstationarity has consensus and robustness. Meanwhile, the magnitude of the increase in segment mean for annual peak flow is non-trivial.

The largest flow event observed in the continuous period of record occurred in 1983 and likely played a role in triggering the nonstationarity detected in the early 1980s. This nonstationarity shows an increase in mean annual flow, which is in agreement with the CHAT analysis. Additionally, the nonstationarity at Eureka occurs at approximately the same time as the nonstationarities at the Byrnesville and Richwoods gages, which raises their credibility.

The Nonstationarity Detection Tool (NSD) can be found here:
https://maps.crrel.usace.army.mil/projects/rcc/portal.html

The USACE Timeseries Toolbox, created by USACE, was used to examine both the mean and median streamflow trends on the Big River at the Byrnesville gage. The toolbox provides a variety of tools that are helpful in assessing long-term trends hidden within the data. If annual median or mean flow were changing, then annual sediment transport could also be affected, since sediment transport is correlated closely with flow.

The Timeseries Toolbox can be found here: https://maps.crrel.usace.army.mil/projects/rcc/portal.html

For monthly median flows, there were no statistically significant ($p<0.05$) trends detected by either the Mann-Kendall ($p=0.113$) or the Spearman Rank-Order ($p=0.111$) tests, which check for consistent increasing/decreasing trends and an association between time and drought condition. This is also true of monthly mean flows, with these two tests returning p-values of 0.367 and 0.364, respectively. In other words, both median and mean flows show no statistically significant increasing or decreasing trends. In addition, median and mean flows did not show an increasing or decreasing trend at all. This suggests that an annual change in sediment transport would not be driven by a change in mean or median flow.

For annual median flows, three nonstationarities were detected, but they all lack consensus, robustness and magnitude; however, the tests did highlight two short periods during which annual median flow was significantly higher than usual, as shown in Figure 5-4. The nonstationarity detection tests were also performed on annual mean flow, as shown in Figure 5-5, with no nonstationarities detected. Annual median flow was significantly elevated from 1927 to 1929, and in 1957. This is worth noting because median flows are not strongly influenced by short high flows, which are common on the Big River. Therefore, a significantly elevated annual median flow indicates that flow for the entire year was significantly higher than usual.

In contrast to annual median flow, annual mean flow can be strongly affected by short high flows. In the early 1990's, the annual mean flow was relatively high while the annual median flow appeared within its normal range. The elevated annual mean flow suggests that there were more high flows than in a typical year, which pulled the annual mean upward; but the normal annual median flow suggests that there was a typical number of lower (normal) flows as well.

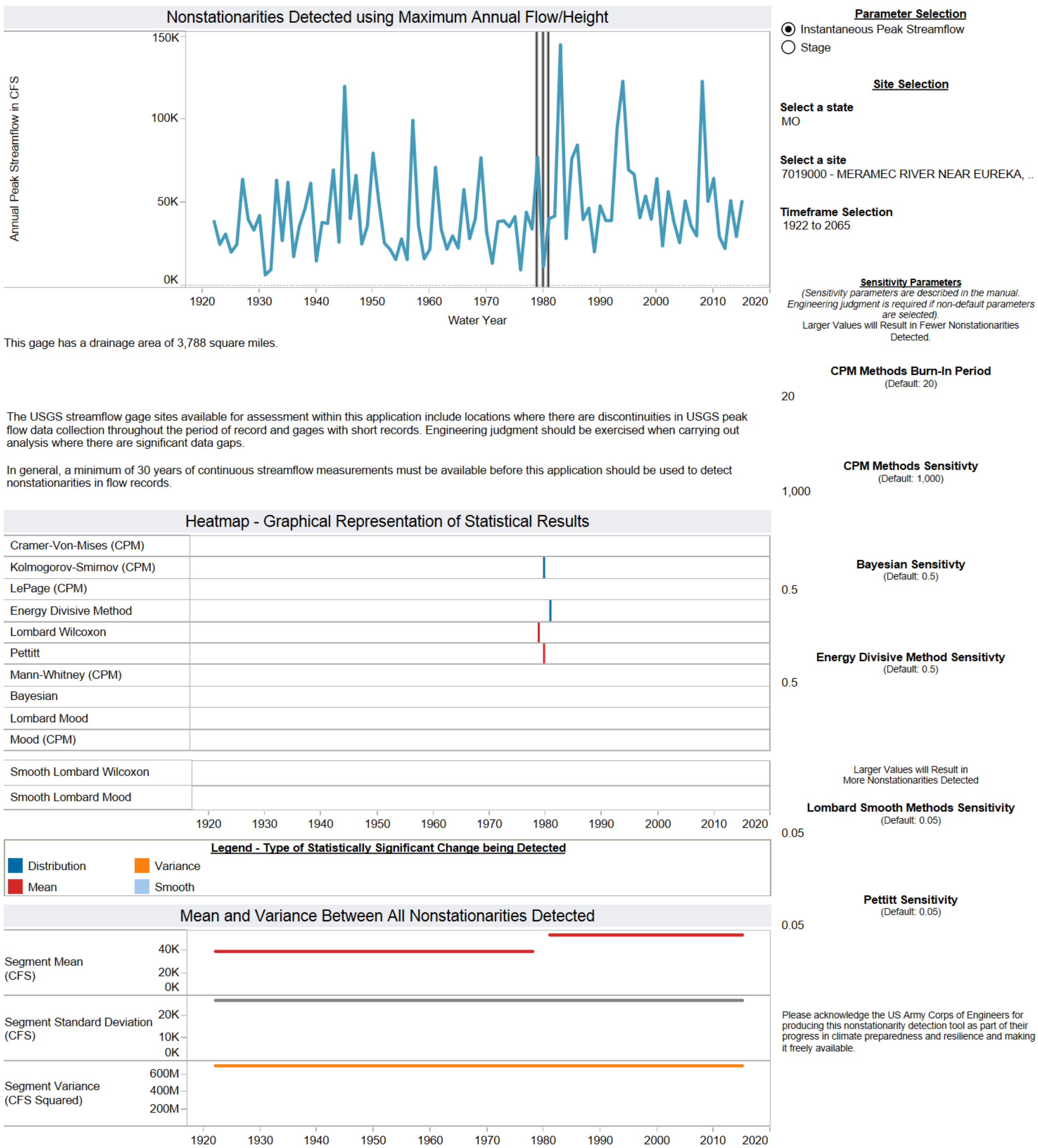


Figure 5-3. Nonstationarity Analysis of Maximum Annual Flow, Meramec River near Eureka, MO.

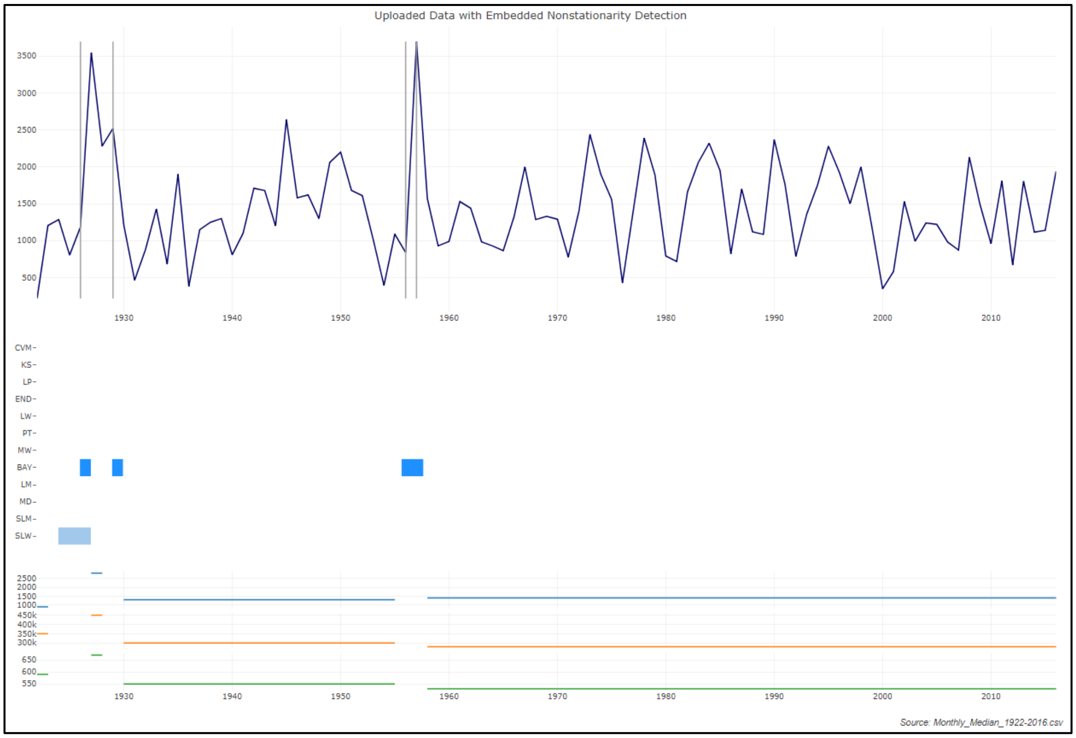


Figure 5-4. Nonstationarity Analysis of Annual Median Flow, Big River near Byrnesville, MO

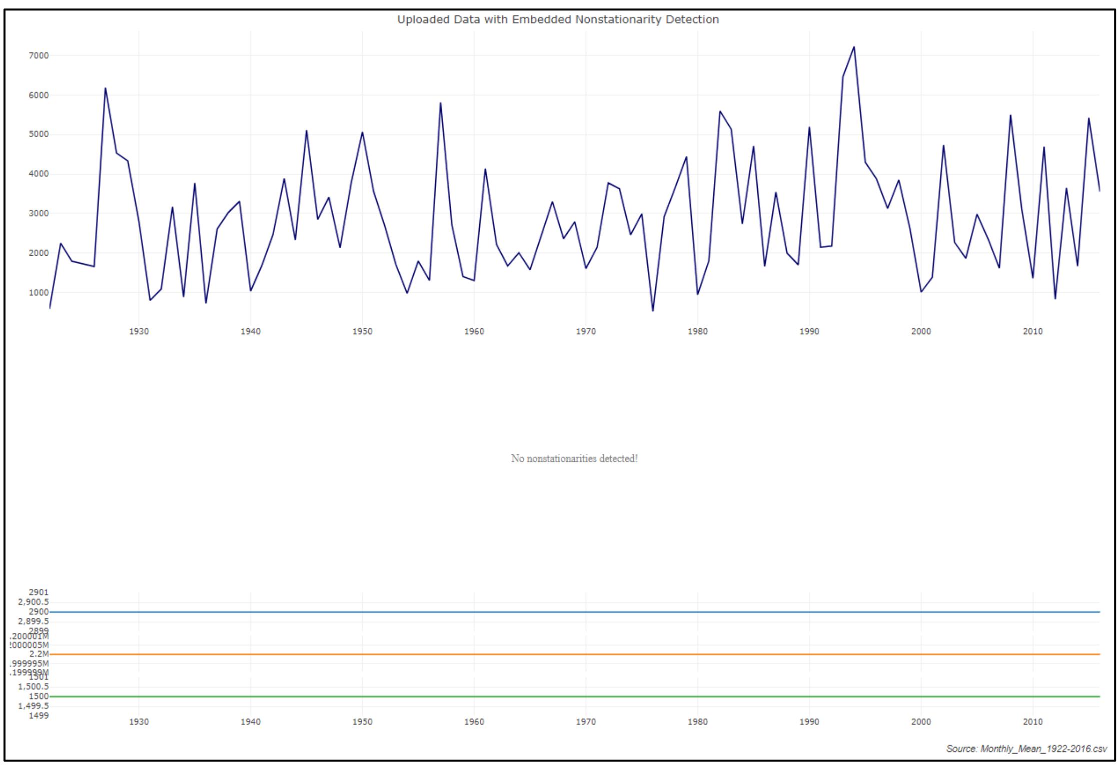


Figure 5-5. Nonstationarity Analysis of Annual Mean Flow, Big River near Byrnesville, MO

5.3 LITERATURE REVIEW

U.S. Army Corps of Engineers personnel have authored regional reports summarizing available scientific literature available to meet the Corps' goal of addressing potential climate change impacts in planning and decision making. The Meramec and Big River Watersheds fall within Region 7 – the Upper Mississippi Region (USACE, 2015). A graphical summary of observed and projected trends and literature consensus is shown in Figure 5-6. From those reports, the following was summarized:

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

There is strong consensus in the literature that air temperatures will increase in the study region and throughout this country over the next century. The studies reviewed generally agree on an increase in mean annual air temperature of approximately 2 to 6 ºC (3.6 to 10.8 ºF) by the latter half of the 21st century in the Upper Mississippi Region. Reasonable consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer and more intense summer heat waves in the long term future compared to the recent past.

Increased air temperatures and increased frequencies of drought, particularly in the summer months, will probably result in increased water temperatures. This may lead to changes in dissolved oxygen levels which is an important water quality parameter for aquatic life. Increased air temperatures are associated with the growth of nuisance algal blooms and influence wildlife and supporting food supplies; however, since the Big River is spring-fed and free-flowing, dissolved oxygen levels and algal blooms should not be an issue.

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

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

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.

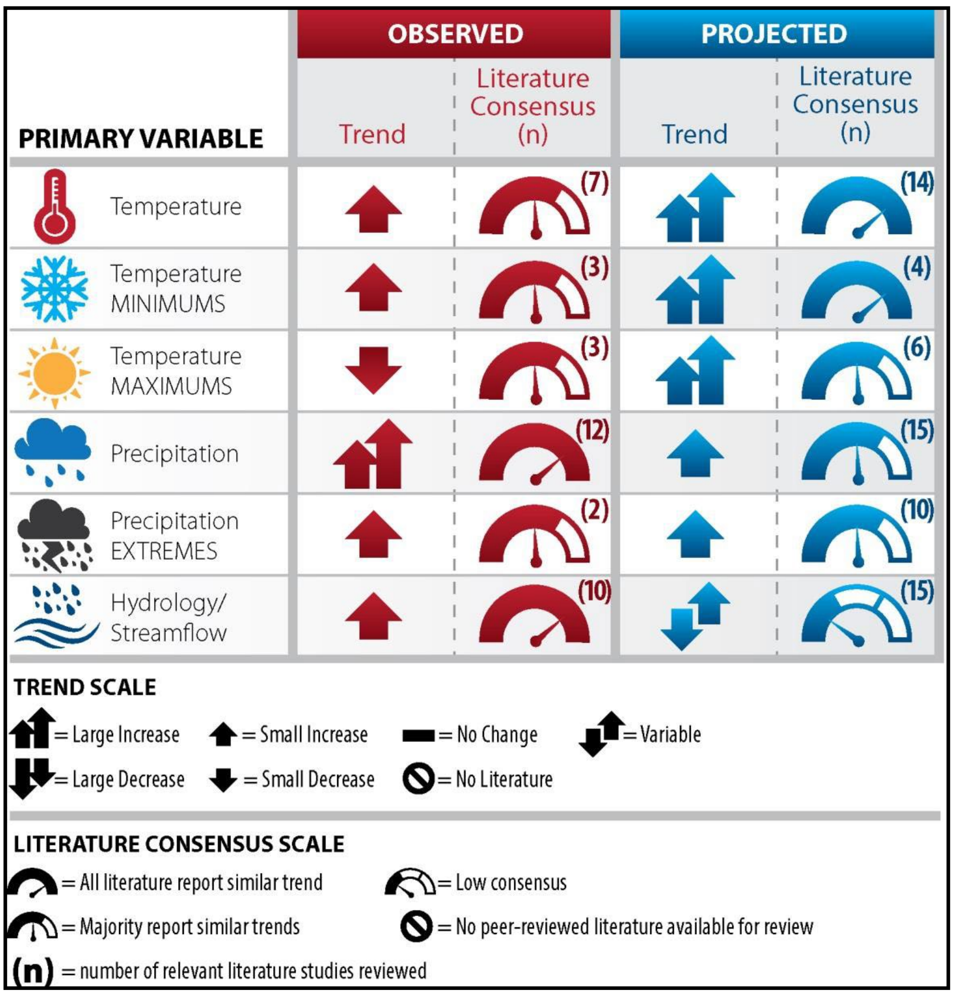


Figure 5-6. Graphical Summary of Observed and Projected Regional Climate Trends and Literature Consensus (USACE, 2015)

*Note: Literature review was conducted in late 2016, and does not consider literature that has been published since then.

5.4 REGIONAL TRENDS

The USACE Climate Hydrology Assessment Tool was used to examine observed and projected trends in watershed hydrology. This tool was used on the greater upper Mississippi-Kaskaskia-Meramec Rivers. As expected for this type of analysis, there is considerable but consistent spread in the projected annual maximum monthly flows (Figure 5-7). The overall projected trend in annual maximum instantaneous streamflow increases over time (Figure 5-8). This increase is statistically-significant (p-value <0.05) and suggests that there may be potential for higher peak streamflows in the future; this is consistent with the CHAT analysis presented in Section 5.2. Features are designed to withstand peak flows, and relatively small increases to peak flow have little effect on their survival.

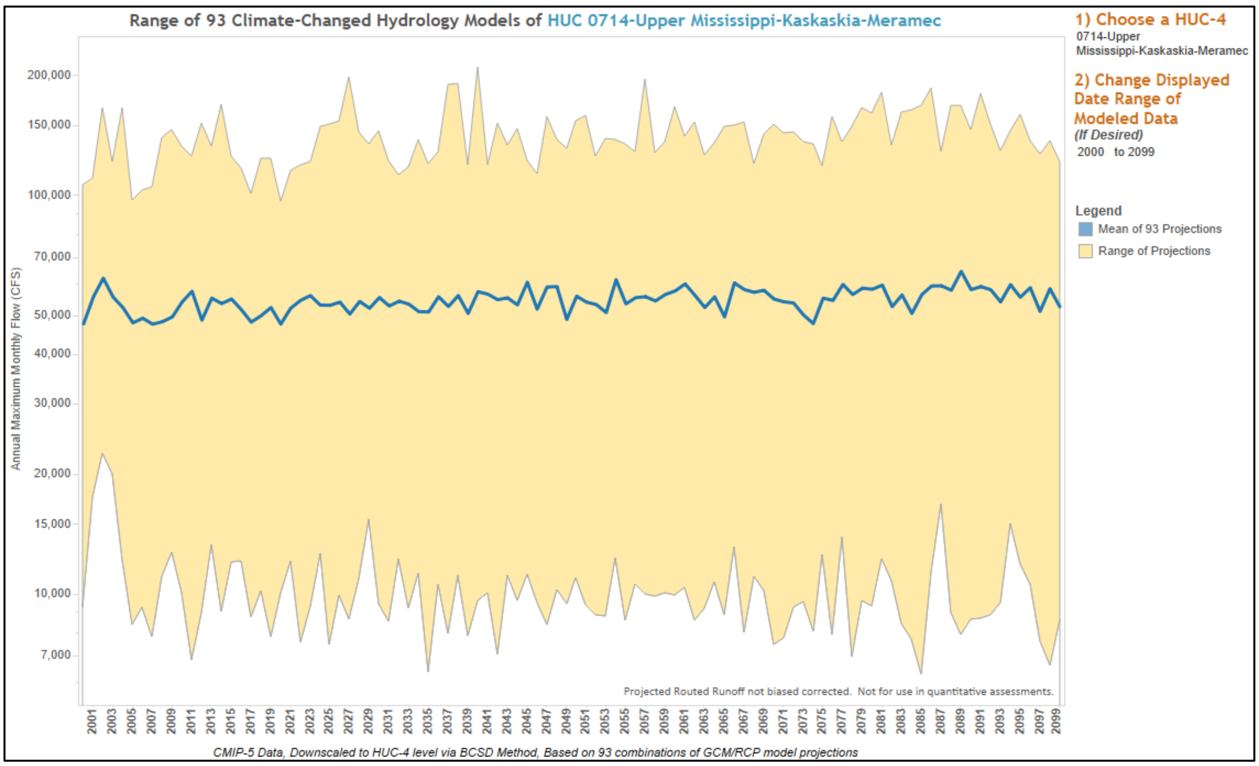


Figure 5-7. Range in the Projected Annual Maximum Monthly Flows, HUC 0714 Upper Mississippi-Kaskaskia-Meramec

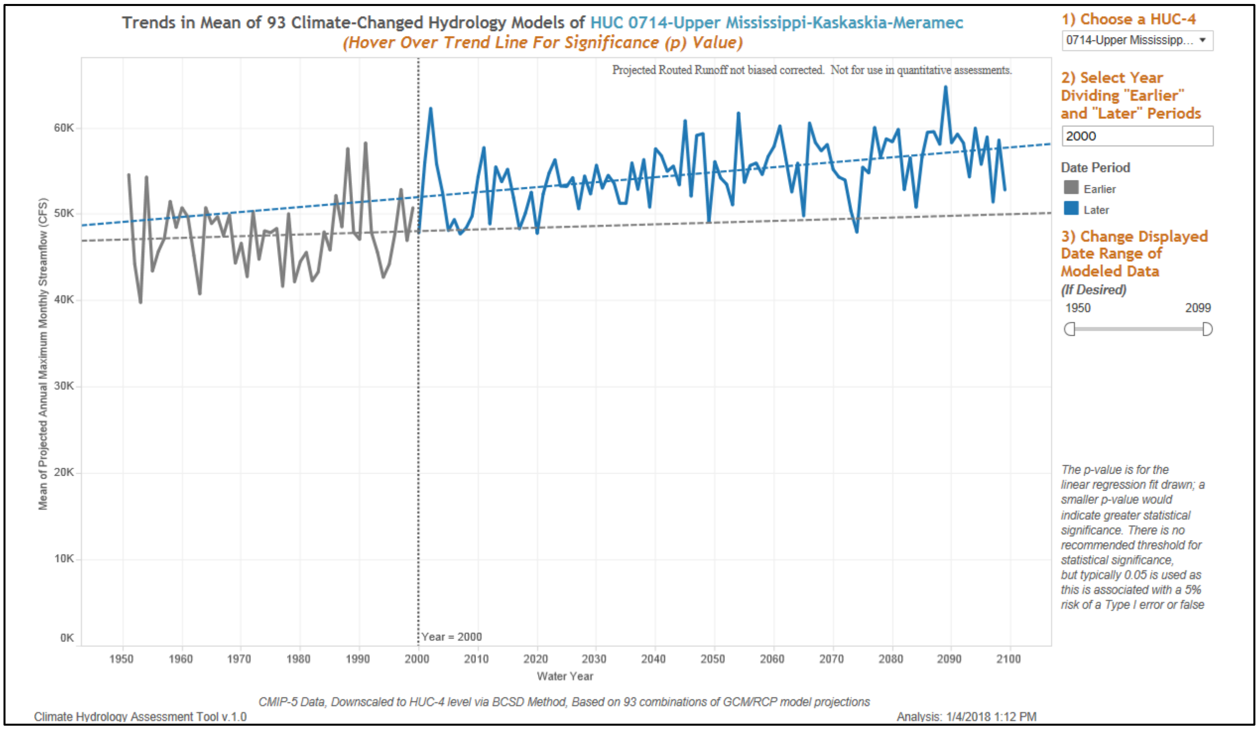


Figure 5-8. Mean Projected Annual Maximum Monthly Streamflow, HUC 0714 Upper Mississippi-Kaskaskia-Meramec. Trendline Equation: Q = 57.5719 * (Water Year) – 63194.8, $p < 0.0001$

The USACE Watershed Vulnerablility Assessment Tool was used to examine the vulnerability of the study area to ecosystem decline (Figure 5-9). The tool operates by Hydrologic Unit Codes (HUC), codes up to eight digits in length that uniquely identify every single drainage basin in the U.S. Shorter codes indicate a larger region, while longer codes indicate smaller watersheds. Various indicators are considered to determine the vulnerability of a HUC for ecosystem decline. Below are the names and a brief explanation of the primary indicators for ecosystem restoration:

- Indicator 8 – Percent of Freshwater Plant Communities at Risk
  - Measures: percentage of wetland and riparian plant communities that are at relative risk of extinction, compared to other watersheds
  - Importance to ecosystem restoration: very important, with a weight of 2 (out of 2)
  - Value: high values suggest higher vulnerability relative to other watersheds
  - Application: a low score indicates a natural stream with healthy plant ecosystem
- Indicator 221C – Monthly CV of Runoff
  - Measures: short-term variability in regional hydrology
  - Importance to ecosystem restoration: very important, with a weight of 1.75 (out of 2)
  - Value: high values suggest higher vulnerability relative to other watersheds
  - Application: a high score suggests a higher occurrence of flash floods
- Indicator 277 – Percent Change in Runoff divided by Percent Change in Precipitation
  - Measures: how runoff will change if precipitation trends change

- Importance to ecosystem restoration: very important, with a weight of 1.75 (out of 2)
- Value: high values suggest higher vulnerability relative to other watersheds
- Application: a high score indicates that small changes in precipitation will result in large changes in runoff

- Indicator 297 – Macroinvertebrate Index of Biotic Condition
  - Measures an aggregation of: richness, composition, diversity, groups, habits, and pollution tolerance of macroinvertebrate assemblages
  - Importance to ecosystem restoration: very important, with a weight of 2 (out of 2)
  - Value: low values suggest higher vulnerability relative to other watersheds
  - Application: a higher score suggests a good overall stream ecosystem health

The Upper Mississippi-Kaskaskia-Meramec Watershed (HUC 0714) is not among the top 20% of HUCs at greatest risk for ecosystem decline under either a wet or dry climate scenario (Figure 5-9); however, this watershed still has vulnerability as identified by the tool by way of Indicator 8 – Percent of Freshwater Plant Communities at Risk. This indicator makes up nearly half of the watersheds vulnerability to the Corps Ecosystem Restoration business line. To minimize this vulnerability, species used in plantings will be carefully chosen to ensure mixed species diversity that are appropriate for expected changes in climate.

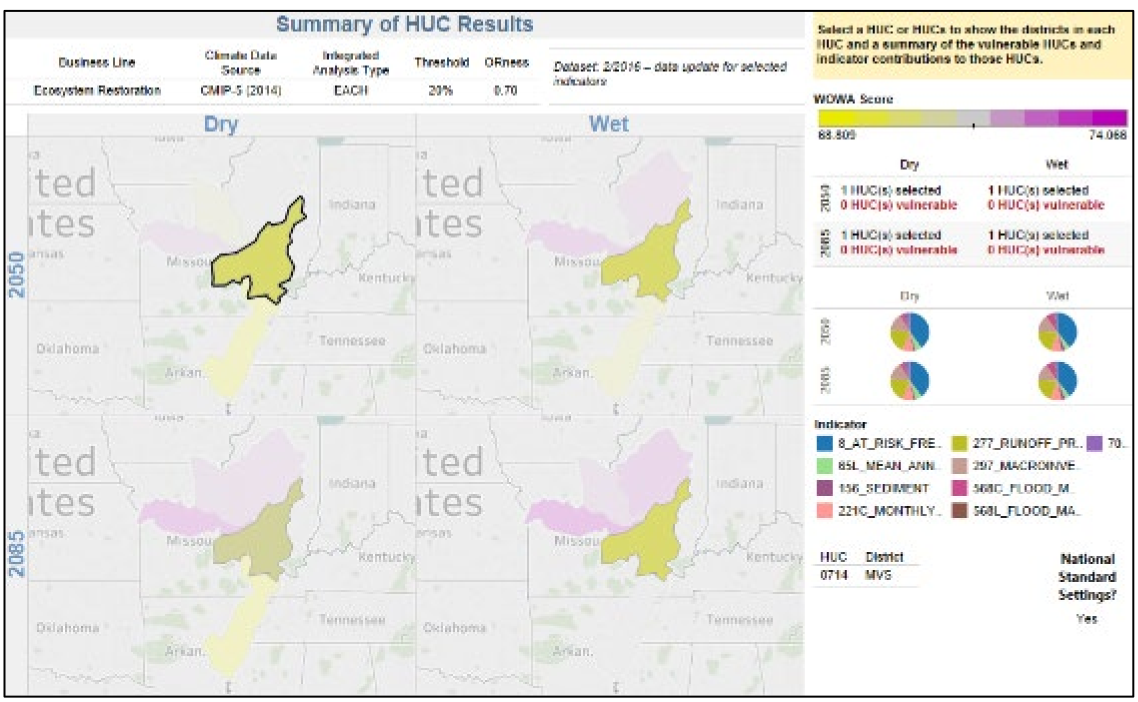


Figure 5-9. Projected Vulnerability for the Upper Mississippi-Kaskaskia-Meramec (HUC 0714) with Respect to Ecosystem Restoration

6 REFERENCES

Barr, M. N. (2016). *Surface-Water Quality and Suspended-Sediment Quantity and Quality within the Big River Basin, Southeastern Missouri, 2011-13: U.S. Geological Survey Scienfitic Investigations Report 2015-5171, 39 p., http://dx.doi.org/10.3133/sir20155171.*

Bruce, T. (2016, June 23). *Looking back – To Rockford Beach*. Retrieved from Leader: http://www.myleaderpaper.com/features/looking_back/looking-back-to-rockford-beach/article_d2ee5aba-3962-11e6-936f-f75d946f98ec.html

Glysson, D. G., Gray, J. R., & Schwarz, G. E. (2001). *A Comparison of Load Estimates Using Total Suspended Solids and Suspended-Sediment Concentration Data.* World Water Congress.

HGL. (May 2018). *Draft Hydraulic and Sediment Transport Modeling Report.*

Jefferson County (Missouri) Library, N. B. (n.d.). *Rockford Mill and Covered Bridge (House Springs, Missouri) # 2008.008.001*. Retrieved from Flickr: https://www.flickr.com/photos/jeffersoncountylibrary/6629119091/in/photostream/

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

MoDNR. (2018). *CODE OF STATE REGULATIONS.*

NEH Part 654. (2007). *Streambank Soil Bioengineering Technical Supplement 14i.*

NEH Part 654. (2007). *Use of Large Woody Material for Habitat and Bank Protection Technical Supplement 14j.*

Pavlowsky, R. T., & Owen, M. R. (2013). *Historic Channel Change Maps for the Big River System in St. Francois, Washington, and Jefferson Counties, Missouri.* OEWRI.

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.*

Pavlowsky, R. T., Pierson, M. C., Owen, M. R., Voss, J. C., & Weedman, N. R. (2016). *Big River Lead Remediation Structure (BRLRS) Monitoring Project.* Ozark Environmental and Water Resources Institute (OEWRI).

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

Rafferty, M. (2017). *Computational Design Tool for Evaluating the Stability of Large Wood Structures.* U.S. Department of Agriculture.

Sin, K.-S., Thornton, C. I., Cox, A. L., & Abt, S. R. (2012). *Methodology for Calculating Shear Stress in a Meandering Channel.* Fort Collins, CO: Colorado State University.

US Department of Agriculture Forest Service. (n.d.). *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization.*

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

USDOI. (2015). *Bank Stabilization Design Guidelines.* Denver, Colorado: Report No. SRH-2015-25.

USGS. (2017, August). *National Water Information System*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/

Wilcock, P., Pitlick, J., & Cui, Y. (2009, May). Sediment Transport Primer - Estimating Bed-Material Transport in Gravel Bed Streams. *United States Department of Agriculture Forest Service*.

Young, B. M. (2011). *Historical Channel Change and Mining-Contaminated Sediment Remobilization in the Lower Big River, Eastern Missouri.* Missouri State University.

U. S. Army Corps of Engineers

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

July 2019

Appendix I

Cost Estimate

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK

1. INTRODUCTION

This ecosystem restoration project consists of the Big River (RM62.5-RM2.5). The Big River is a tributary of the Meramec River and the Meramec River is a tributary of the Mississippi River. The rivers stretch throughout St. Francois, Washington, Jefferson and St Louis Counties in the state of Missouri.

2. GENERAL

Construction crews and production rates were developed for 11 features of work including Mobilization, Tree Clearing, Cut and Backfill, Excavation and Hauling, Placing Timbers, Stone, Tree Planting, Establishment of Turf, Sediment Collectors, Removals and Demobilization. The production rates assumed were either based on the rates of similar projects or developed by estimating equipment size, speed and efficiency. The same production rates are used for each site; however, the features of work and the quantities will vary at each site. The Excavation and Hauling rates were calculated based on a midpoint along the Big River. A midpoint was used because the repository location is likely to change depending on contractor means and methods.

3. CONSTRUCTION CONTINGENCIES

A contingency of 27% was applied to construction based on the output of the Cost and Schedule Risk Analysis. A 17% contingency was applied to AM, PED, and S&A based discussions with PDT. The overall contingency comes to 24.4%.

4. ESCALATION

An escalation rate of 2.5% was applied to construction costs and to Lands and Damages. An escalation rate of 3.9% was applied to PED and S&A based on the assumption that the program year will start in October 2019.

Inflation costs were developed on the assumption of an eight year construction schedule based on contracts ranging from $5M-$8M each. A total rate of 18.7% was used to inflate Project First Costs up to the midpoint of construction using the indexes from the Civil Works Construction Cost Index System issued March 2018; however, the inflation costs are not a part of the Project First Costs.

5. ENGINEERING AND DESIGN

A standard 13% for engineering and design was applied to the estimate based on discussion with PDT. This includes Program Management, Planning and Environmental Compliance, Engineering and Design, Reviews, Life Cycle Updates, Engineering during Construction and Planning during Construction.

6. CONSTRUCTION SUPERVISION AND ADMINISTRATION

A standard 8% was applied to each estimate based on the St. Louis District's average expenditures for construction management on a typical contract of this magnitude. An additional 1.5% was included for program and project management on the side of USACE.

7. OPERATION, MAINTENANCE, REPAIR, REHABILITATION, RESTORATION

Details on estimated OMRRR cost can be found in Appendix G-*Engineering Design* and *Section 7.3 of the Main Report*. OMRRR costs are included in the economic feasibility of the study but are not included in the project first cost because OMRRR is the responsibility of the NFS.

8. ADAPTIVE MANAGEMENT AND MONITORING

Costs for adaptive management were supplied by the USACE Environmental Planning and Civil Design department and includes monitoring, inspections, analysis, and rework of failed designs. Further details can be found in Appendix J - *Monitoring and Adaptive Management Plan* and Appendix G-*Engineering Design*.

9. MITIGATION

There are no cultural mitigation or fish and wildlife mitigation costs associated with this project.

10. REAL ESTATE

Real Estate costs and contingencies are discussed in Appendix K - *Real Estate Plan*.

11. TOTAL PROJECT FIRST COST

Table 1 is a summary of the estimated project first cost. This cost estimate will serve as the the cost of the project for which authorization will be sought.

Table 1. Project First Cost

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**

U. S. Army Corps of Engineers

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

July 2019

Appendix J

Monitoring and Adaptive Management Plan

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

This appendix presents the feasibility level monitoring and adaptive management plan for the St. Louis Riverfront - Meramec River Basin Feasibility Study. This plan identifies and describes the monitoring and adaptive management activities proposed for the considered action alternatives and estimates associated costs and duration. This appendix outlines how the results of the study-specific monitoring plan would be used to adaptively manage each of the action alternatives, including monitoring targets which demonstrate success in meeting study objectives. This plan was developed through an interagency working group of Federal and state agencies and The Nature Conservancy, and included a workshop facilitated by the Corps' Engineering Research and Design Center (ERDC) Adaptive Management Working Group which was held in June 2017. The interagency working group's intent was to develop monitoring and adaptive management actions appropriate for the study's goal and objectives. This plan will be further developed in the planning, engineering and design (PED) phase as specific details are made available for the preferred alternative.

1.1 AUTHORIZATION

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.

1.2 FRAMEWORK

Section 1161 of WRDA 2016 requires that when conducting a feasibility study for ecosystem restoration, the proposed study 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. Adaptive management "prescribes a process wherein management actions can be changed in response to monitored system response, so as to maximize restoration efficacy or achieve a desired ecological state" (Fischenich et al. 2012). The St. Louis Riverfront - Meramec River Basin

Ecosystem Restoration Feasibility Study adaptive management framework follows the two phased approached for set-up and implementation (Figure 1).

1.3 GOVERNANCE STRUCTURE

To execute an adaptive management framework for the St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study, a communication structure has been identified (Figure 2). The structure establishes clear lines of communication and data exchange between the USACE, the non-Federal sponsor, the executive board, technical committee, Project Delivery Team (PDT) and stakeholders. Successful implementation will require the right resources being coupled at the right time to support the framework components.

2. ADAPTIVE MANAGEMENT PLANNING

The resulting adaptive management plan for the Meramec River Basin Ecosystem Restoration Feasibility Study describes and discusses whether adaptive management is needed in relation to the considered action alternatives identified in the Feasibility Study. The plan also identifies how adaptive management would be conducted and who would be responsible for specific adaptive management actions. The developed plan outlines how the results of study-specific monitoring would be used to adaptively manage the considered action alternatives, including specifications that will define success.

The Adaptive Management Plan reflects a level of detail consistent with the feasibility study. The primary intent was to develop monitoring and adaptive management actions appropriate for the study's restoration goal and objectives. The specified management actions permit estimation of the adaptive management plan costs and duration. The Adaptive Management Plan:

- identifies the restoration goal and objectives;
- presents a conceptual model that relates management actions to desired study outcomes; and
- lists sources of uncertainty that would lend themselves to adaptive management.

Following the discussion of the above, the subsequent sections of this appendix describe monitoring, assessment and decision-making in support of adaptive management. The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the Feasibility Study. Uncertainties remain concerning the exact restoration measures, monitoring elements and adaptive management opportunities. Components of the monitoring and adaptive management plan, including costs, were similarly estimated using currently available information.

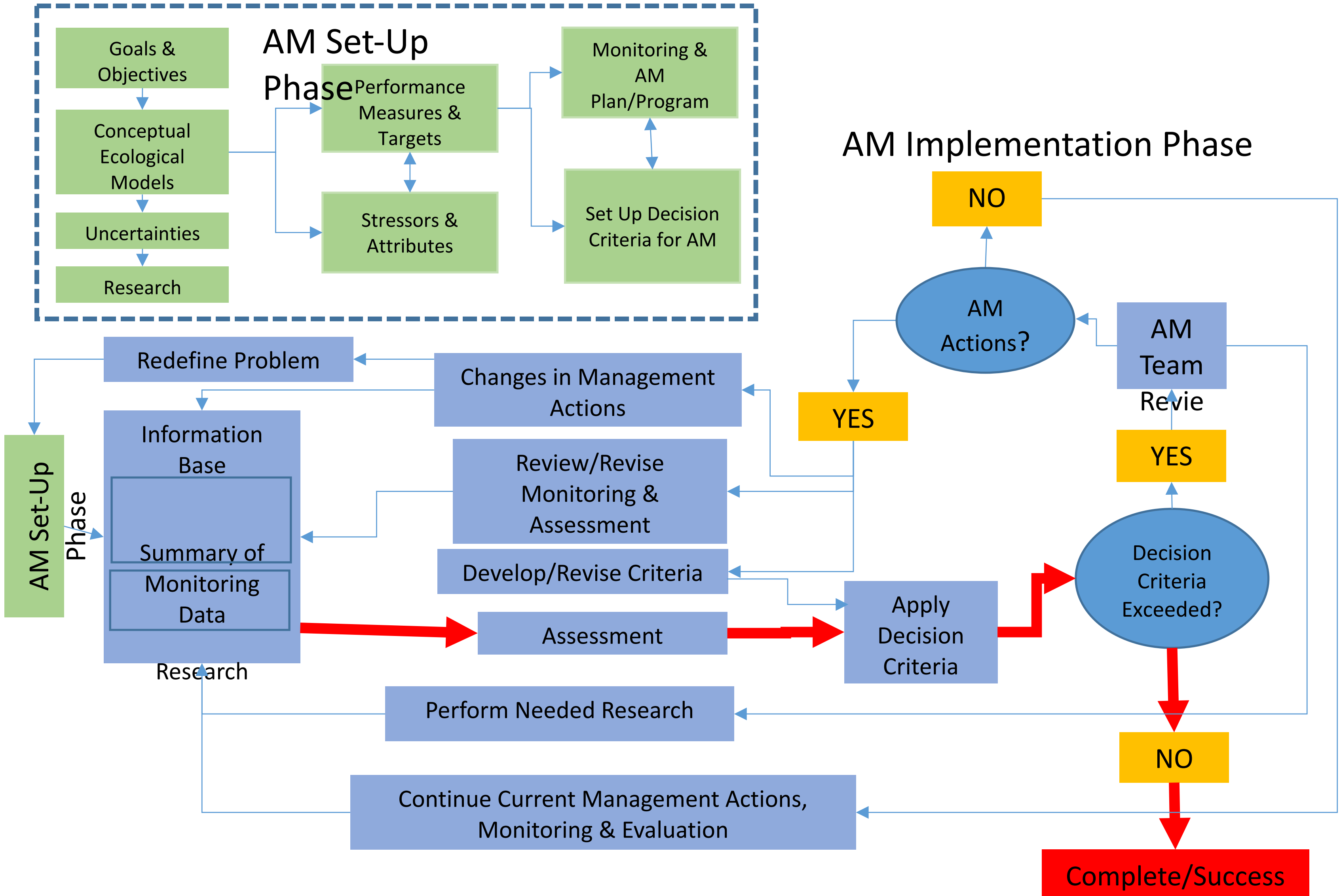


Figure 1. Adaptive Management (AM) Planning Flow Chart

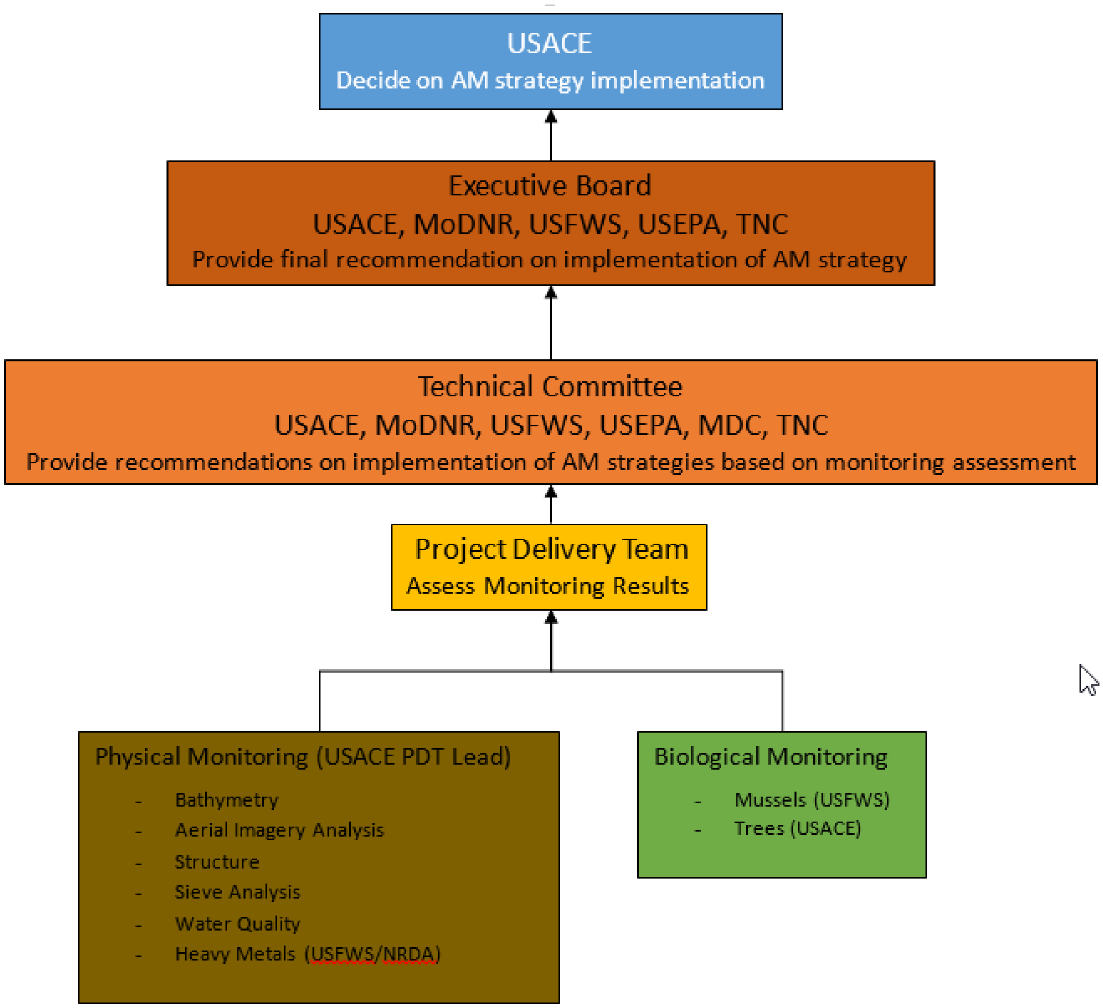


Figure 2. Monitoring and Adaptive Management (AM) Governance Structure

2.1 STUDY GOALS AND OBJECTIVES

The overarching goal of this study is to formulate an alternative that can restore the aquatic ecosystem and determine if Federal participation in repairing habitat functionality within the authorized study area is justified.

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

- 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 (OBJECTIVE 1)
- Restore impacted channels and floodplains in the Big River and Meramec River systems to emulate a more natural, stable river over the 50-year period of analysis (OBJECTIVE 2)
- Increase riparian habitat connectivity, quantity, diversity and complexity within the study area over the 50-year period of analysis (OBJECTIVE 3)

2.2 SOURCES OF UNCERTAINTY

Adaptive management provides a coherent process for making decisions in the face of uncertainty. Scientific uncertainties and technological challenges are inherent with any ecosystem restoration study. Following is a list of uncertainties identified by the PDT associated with the restoration of the aquatic ecosystem in the Meramec River Basin Ecosystem Restoration Feasibility Study for the considered action alternatives. The considered action alternatives all have some amount of the below proposed measures; therefore, the uncertainty is similar across all considered action alternatives. The alternatives differ in the amount of each type of restoration measure and the location within the study area. With the similarity across alternatives, the considered action alternatives will be discussed collectively unless otherwise noted.

2.2.1 FLOODPLAIN FOREST

The interagency adaptive management planning team evaluated the level of uncertainty and risk in the floodplain forest measure and determined it did not require using Adaptive Management to address the potential of the measure to meet performance criteria. Furthermore, other ecosystem restoration projects through the Upper Mississippi River Restoration (UMRR) Program has extensively evaluated adaptive management and monitoring designs for forestry and these lessons learned have been applied in the design of the floodplain forest measure. Monitoring will be conducted to determine success (see Section 3.1 below). Information gained from the UMRR Program will be used to guide floodplain forest restoration.

2.2.2 BANKLINE RESTORATION

The District evaluated the level of uncertainty and risk in the bank stabilization measures of either hard structure, soft structure (e.g., bio-engineering plantings) or a combination of and determined that bank movement would be reduced as a result of whichever bank stabilization method is implemented. Associated with the bank stabilization are the use of pilot channels to aid in the new river alignment and reduce the likelihood that high flow events from outflanking any of the bank stabilization measures. The main sources of uncertainty involved with bank stabilization and pilot channels include:

- Longevity of the soft structures and the potential for excessive scour particularly before any bio-engineering plantings develop.
- Placement of keys where the structures tie into the bankline since they are of high importance for any bankline measure.
- Unanticipated in-channel sediment depositing post pilot-channel excavation leading to bank stabilization measures being outflanked or to fail.

2.2.3 SEDIMENT COLLECTION

Collection of suspended and bedded sediments within the study area are of importance for study success; however, bedded and suspended sediments have unique uncertainties associated with them and will be discussed separately.

2.2.3.1 BEDDED SEDIMENT COLLECTION

The District evaluated the level of uncertainty and risk in the bedded sediment capture measures including the use of bed sediment collectors and in-stream excavation (e.g., bedded sediment and excavation behind existing mill dams). It is expected these measures will capture the target grain size of 4-16 mm. The sources of uncertainty with these measures are the following:

- Bed sediment collectors: amount of bedded sediment that this measure will collect; constructability, operation and maintenance and ability to withstand extreme flood events
- Bedded sediment excavation: state permit guidelines will be followed; however, there is still uncertainty on unanticipated hydraulic changes that may result by removing the bars from the system
- Excavation behind mill dams: amount of bedded material currently captured and the estimated fill rate of filling in post excavation
- Grade control structure: existing location of head-cut and unforeseen new head cut if existing mill dams fail between now and implementation of the proposed plan

2.2.3.2 SUSPENDED SEDIMENT CAPTURE

The District evaluated the level of uncertainty and risk in the suspended sediment capture measures including the use of sediment basins. It is expected this measure will capture the target grain size of <2mm. The sources of uncertainty with this measure include:

- Ability to capture the target grain size
- Potential of structures to be outflanked or experience erosion
- Estimated fill rate of basins

2.2.3.3 FRESHWATER MUSSEL HABITAT

It is expected that implementation of the bank stabilization measures, bedded and suspended sediment measures and reforestation will not significantly alter hydraulic forces within existing mussel beds and would continue to provide stabilization of the stream. If monitoring demonstrates a significant negative impact to mussels of existing mussel beds as related to implemented structures, then modification of structures would be required.

2.3 CONCEPTUAL MODEL

Figure 3 shows the conceptual ecological model. This model identifies the drivers and stressors of the system and how they relate to the five essential ecosystem characteristics. This model was developed through an interagency and interdisciplinary partnership and aids in identifying the problems and potential management actions that could be implemented to counter the stressors that are degrading the ecosystem.

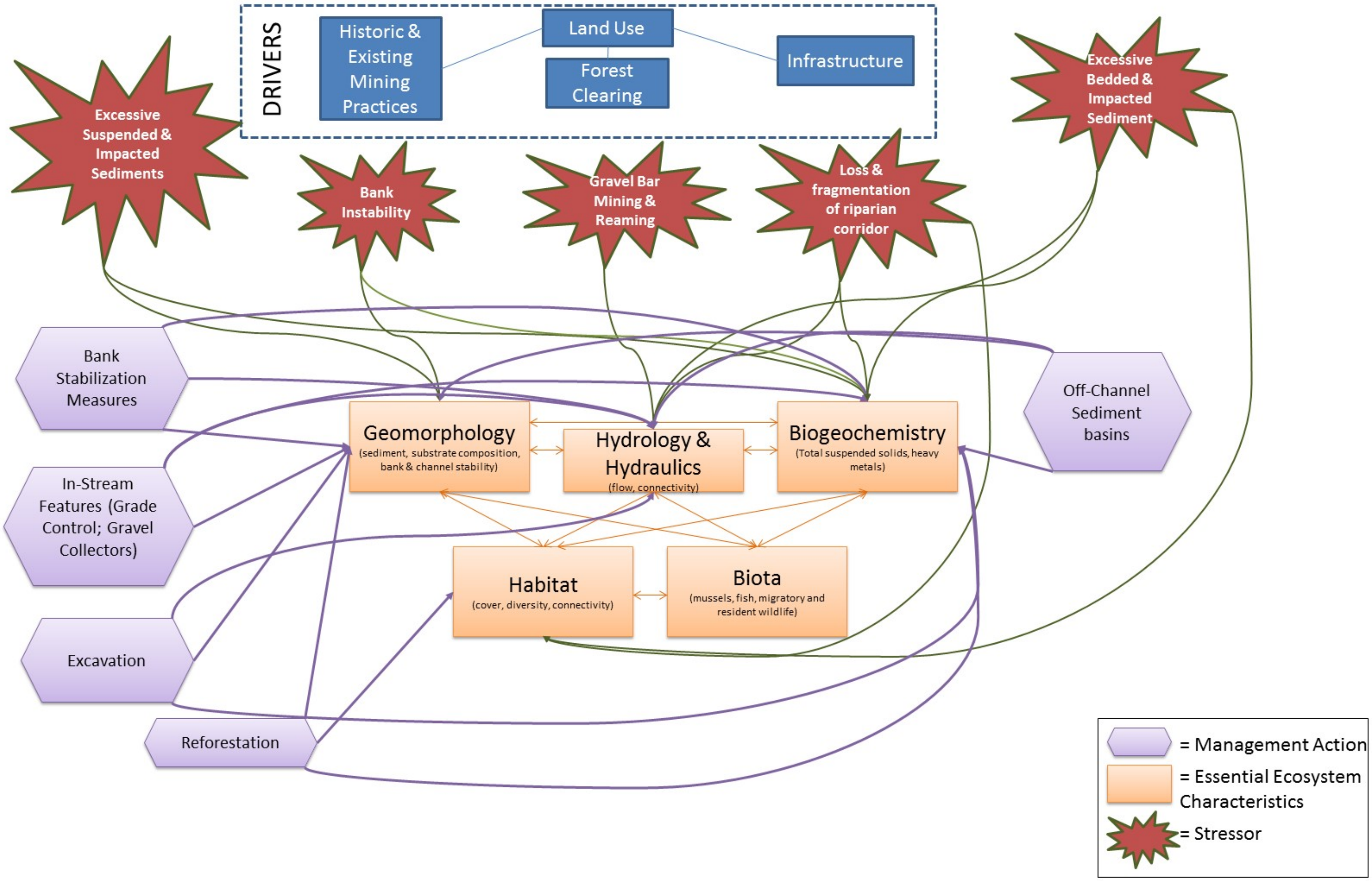


Figure 3. Conceptual Ecological Model

3. MONITORING OF OBJECTIVES TO DETERMINE SUCCESS AND ADAPTIVE MANAGEMENT MEASURES

The power of a monitoring program developed to support determinations of success and inform adaptive management lies in the establishment of feedback between continued monitoring and corresponding project management. The considered action alternatives all have some amount of the proposed measures (reforestation, bankline stabilization and suspended and bedded sediment collection); therefore, the monitoring plans are similar. The alternatives differ in the amount of each type of restoration measure and the location within the study area; however, the monitoring plans would be similar with minor differences due to amount or location within the study area. With the similarity across alternatives, considered action alternatives will be discussed collectively unless otherwise noted. The main differences among alternatives are provided in Table 1. Table 2 provides the generalized monitoring schedule for each monitoring component and how each monitoring component links to study objective(s). Table 3 provides the monitoring and adaptive management costs for the final array of alternatives. These costs were included as part the cost effective incremental cost analysis.

Table 1. Quantity of Types of Restoration Measures Within the Final Array of Alternatives

			Bank Stabilization								Sediment Removal					
#	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 (#)	**Reforestation (acres)**
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

Table 2. Generalized Monitoring Schedule, Applicable For Considered Action Alternatives

Linking to Study Objectives	Measures	Work Category	Activity	*PED	Post-construction Years									
					1	2	3	4	5	6	7	8	9	10
All	Site Visits	Monitoring & Analysis	Site Visits	x		x			x				x	
All	Reforestation	Monitoring & Analysis	Forest surveys		x				x					x
Objectives 1 & 2	Bankline Restoration	Monitoring & Analysis	Aerial Imagery Analysis			x			x			x		
Objective 1	Suspended Sediment Collection	Monitoring & Analysis	Sieve Analysis	x					x					x
			Inspection						x					x
Objective 1	Bedded Sediment Collection	Monitoring & Analysis	Cross Section Survey	x					x				x	
Objective 1	In-Stream Excavation – Bedded Sediment Removal													
Objective 1 and 2	In-Stream Excavation													
Objective 2	Grade Control Structures													
All	Freshwater Mussel Habitat	Monitoring & Analysis	Survey	x		x			x			x		

Table 3. Estimated Costs (rounded to the nearest $1000) for Monitoring and Adaptive Management For Final Array of Alternatives

	Estimated Monitoring Cost by Year per Considered Alternative ($)												AM Cost ($)
Alt	**PED**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**	**+8**	**+9**	**+10**	**TOTAL**	**Years 1-10**
1	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2	61,200	5,000	53,200			76,200			50,000	15,200	11,000	**211,000**	**687,000**
3	86,800	15,000	66,800			154,800			50,000	61,800	46,800	**395,000**	**2,638,000**
4	62,800	0	54,800			72,800			50,000	22,800	0	**200,000**	**1,184,000**
5	179,800	60,000	78,800			255,800			50,000	109,000	96,000	**650,000**	**4,697,000**
6	273,200	40,000	97,200			323,200			50,000	197,200	76,000	**784,000**	**8,196,000**
7	296,000	40,000	102,000			346,000			50,000	220,000	76,000	**834,000**	**9,308,000**

3.1 REFORESTATION

1) Objective: All

2) Methodology: Forest monitoring will follow the sampling design as outlined in the *Upper Mississippi River Restoration Habitat Rehabilitation and Enhancement Project Monitoring Design Handbook* (McCain 2012). The nested fix plot design as described in this monitoring design will be used to establish 3-5 plots randomly within the reforestation area (depending on size of site). Success of planted trees will be monitored 1, 5 and 10 years post-planting to determine basal diameter and % seedling survivorship (tree count). To determine long-term success, periodic monitoring (every 5 years, with possible monitoring after large hydrologic events) of trees planted will be used to monitor trees through time. In addition, based on Henderson et al. (2009), relative growth rate (RGR) will also be calculated to determine success (where RGR > 0 equals positive level of production, while <0 equals loss of production) using the following equation:

$$r = \frac{\ln(D_2) - \ln(D_1)}{t_2 - t_1}$$

D_1 and D_2 refer to growth measurements (height or diameter) at times t_1 and t_2.

3) Success Criteria (Desired Outcome): The amount of floodplain forest due to reforestation would be increased by a total number of acres for each alternative (see Table 1 for acres per alternative). The monitoring target for initial (1-year post planting) and longer term (years 5 and 10) monitoring is 70% survivorship of planted trees. Additionally, a target of increasing basal diameter (positive RGR) would be used as an indicator of forest health.

3.2 BANKLINE RESTORATION

1) Objectives: 1 & 2

2) Methodology: Bathymetric and topographic cross section surveys of sites will be completed pre-construction and post-construction to determine base conditions and construction compliance. Repeated cross section surveys, or surveys using the same cross section line, will be conducted at years 5 and 10. Analysis of the survey data will be performed to determine movement and bank slopes. In addition, site visits to each site will occur annually the first 3 years and then corresponding with cross-section surveys conducted at year 2, 5 and 9, as well as after meaningful large hydrological events to determine condition of implemented structures. Aerial imagery analysis will also be performed using publicly available images to estimate bank movement.

3) Success Criteria (Desired Outcome):

Criterion 1. Bank stabilization measures will be considered successful if after 3 years, bank location post-construction is within the following limits:

- Toe Zone: very limited erosion
- Mid Bank Zone: 1-2 feet of the as-built design
- High Bank Zone: 5-10 feet of the as-built design

Criterion 2. Bank stabilization measures with rock structures will be considered successful if sagging/settling is < 15% of design height within first 3 years of construction.

Criterion 3. Bank stabilization measures will be considered successful if after 3 years based on aerial imagery analysis, estimated erosion rate be less than 2 feet per year.

Criterion 4. Bank stabilization measures with rock or soft structures will be considered successful if no visible scour that undermines the constructed measures within first 3 years of construction.

Criterion 5. Bank stabilization measures with rock or soft structures will be considered successful if measures are not outflanked during high water events.

Criterion 6: Bank stabilization measures with soft structures will be considered successful if greater than 80% of these structures are retained within 5 years of construction.

4) Adaptive Management Trigger and Measures: If monitoring results indicate an inability to reach success criteria within two observations, then adaptive management may be warranted. If any of the items below begin to occur within one monitoring observation, then adaptive management would be implemented.

- Excessive erosion between weirs, stream barbs, or other measures.
- Keys of the structure are outflanked.
- Excessive erosion above the toe at the mid or high bank area is discovered.

If monitoring results indicate an inability to reach success criteria after two observations, modification to the bank stabilization measures will be implemented to increase protection of the bank, improve bank slope geometry, reduce upstream/downstream scour or a combination. If monitoring results indicate an inability to reach success criteria within two observations, then adaptive management may be warranted.

Preliminary information suggests additional rock on sites primarily implemented with soft structures or modify elevation of rock structures or alignment would be warranted to better direct flow.

3.3 SEDIMENT BASIN

1) Objective: Objective 1

2) Methodology: Within each sediment basin, a sieve analysis will be performed of sediment collected at years 5 and 10 post-construction and when sediment basins are filled and material is removed.

3) Success Criterion (Desired Outcome): An assumed success criterion of grain size <2 mm will be used. The success criterion will be verified by sampling during Planning, Engineering and Design. Targets will be calibrated and validated based on other sediment basins currently in operation within the watershed.

4) Adaptive Management Trigger and Measures: If any of the items below begin to occur within one monitoring observation, then adaptive management would be implemented to restore the structure:

- The inflow and outflow channel has excessive erosion or deposition.
- The inlet structure or overflow structure has excessive scour or is outflanked.

If monitoring results indicate an inability to capture the <2mm grain size for two observations, modification to the inlet structure of the sediment basin will be implemented to better capture the target desired grain size in the water column. Preliminary information suggest that if >2mm, then raising of the inlet would be required to allow only particles in the higher portions of the water column to enter the basin.

3.4 BED SEDIMENT COLLECTOR, IN-STREAMEXCAVATION, GRADE CONTROL STRUCTURES

1) Objectives: 1 & 2

2) Methodology: Cross-section repeated surveys will be performed throughout the study area at years 5 and 10 in conjunction with the surveys collected for bankline restoration described above.

3) Success Criterion (Desired Outcome):

- Reduction in bedded system migration downstream
- Constructed measures are maintained during high water events
- Constructed measures and excavation do not result in bed or bank instability elsewhere

4) Adaptive Management Trigger and Measures: If after construction of measures and/or excavation bank instability tied to these measures result, then adaptive management actions would be taken to correct any concerns. The exact action would be evaluated by the interagency team based on the site specific concerns.

3.5 FRESHWATER MUSSEL HABITAT

1) Objectives: All

2) Methodology: A series of mussel survey methodologies including dive surveys, timed searches and randomized quadrat surveys will be used to survey the existing known mussel beds within the study area. This will occur with a multi-agency team pre-and post-construction at years 2, 5 and 8. Surveys will be conducted in partnership with the USFWS to determine species diversity, age structure, substrate relationships and density. If Federally-listed species are encountered during surveys, further coordination will occur with USFWS. Data analysis will include simple analyses of mussel diversity, density, age structure and relationships to implemented measures or location. Collection of habitat characteristics would occur at each survey site, including, but not limited to substrate, velocity and water depth. Results of the analyses will be used to inform success.

3) Success Criteria (Desired Outcome):

> *Criterion 1.* Persistence of existing mussel beds and or increase in species diversity and density over pre-constructions surveys will determine success of the overall study components.
>
> *Criterion 2.* Desirable physical habitat characteristics related to substrate and velocity within the survey sites remain suitable for mussel habitat.

4) Adaptive Management Trigger and Measures: If species diversity and density decrease significantly and conditions become unsuitable to mussel habitat, then further investigation would be needed to determine the source of the change. If investigations show that a constructed measure is the source, then adaptive management to that measure would be needed to restore the physical conditions for suitable mussel habitat.

4. DOCUMENTATION, IMPLEMENTATION COSTS, RESPONSIBILITIES, AND PROJECT CLOSE-OUT

4.1 DOCUMENTATION, REPORTING AND COORDINATION

The Project Delivery Team will document each of the performed assessments and communicate the results to the Project Manager and Technical Steering Committee designed for the study. Periodic reports will be produced to measure progress towards the study goals and objectives as characterized by the selected performance measures.

4.2 COSTS

The costs associated with implementing monitoring and adaptive management measures were estimated based on current available data and information developed during plan formulation as part of the feasibility study. Because uncertainties remain as to the exact project measures, monitoring elements and adaptive management opportunities, the estimate costs in Table 3 will need refinement during PED during the development of the Detailed Monitoring and Adaptive Management Plan.

4.3 RESPONSIBILITIES

Reforestation. Feasibility and PED activities are limited to one pre-construction evaluation of the proposed sites for reforestation. Currently, these areas lack tree cover. Post-planting monitoring would be conducted at years 1, 5 and 10. Responsibility of these measures will be a coordinated effort between the Corps, MoDNR and USFWS.

Bankline Restoration. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, measure performance will be evaluated at years 2, 5 and 8. Responsibility of these measures will be a coordinated effort between the Corps, MoDNR and USFWS.

Bed Sediment Collector. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, measure will be evaluated at years 5 and 9. Responsibility of these measures will be coordinated between the Corps, MoDNR and USFWS.

Sediment Basin. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, measure performance will be evaluated at years 3 and 8. Responsibility of these measures will be a coordinated effort between the Corps, MoDNR and USFWS.

Grade Control Structure. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, measure performance will be evaluated at years 5 and 9. Responsibility of these measures will be a coordinated effort between the Corps, MoDNR and USFWS.

In-Stream Excavation. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, measure performance will be evaluated at years 5 and 9. Responsibility of these measures will be a coordinated effort between the Corps, MoDNR and USFWS.

Freshwater Mussel Habitat. Feasibility and PED data collection will consist of pre-construction data collection and analyses. Following construction, mussel surveys will be conducted at years 2, 5 and 8. Responsibility for these efforts will be a coordinated effort between the Corps, MoDNR and USFWS.

4.4 PROJECT CLOSE-OUT

Close-out would occur when it is determined that the restoration project has successfully met the success criteria as described within this appendix. Success would be considered to have been achieved when the study objectives have been met or when it is clear that they will be met based upon the trends for the site conditions and processes. Success would be based on the following:

- success criteria met;
- continued site inspections to determine continued Project status; and
- continued operation, maintenance, repair, rehabilitation and replacement (OMRRR).

5. REFERENCES

Fischenich, C., C. Vogt, and others. 2012. The application of adaptive management to ecosystem restoration projects. ERDC TN-EMRRP-EBA-10 April 2012, Vicksburg, MS: U.S. Army Corps of Engineers Ecological Management and Restoration Research Program.

Henderson, D., P. Botch, J. Cussimanio, D. Ryan, J. Kabrick, and D. Dey. 2009. Growth and Mortality of Pin Oak and Pecan Reforestation in a Constructed Wetland: Analysis with Management Implications. Missouri Conservation Technical Report Series: 2009, Number. Missouri Department of Conservation, Jefferson City, MO.

McCain, K.N.S., editor. 2012. Upper Mississippi River Restoration-Environmental Management Program Monitoring Design Handbook Section 1: Vegetation. U.S. Army Corps of Engineers, Rock Island, Illinois.

U. S. Army Corps of Engineers

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

July 2019

Appendix K
Real Estate Plan

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK

1. PURPOSE

The purpose of this Real Estate Plan (REP) is to support the Final Report for the St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Feasibility Study. This REP identifies Lands, Easements, and Rights-of-Way (LER) necessary to complete the project. The Non-Federal Sponsor (NFS) for this project is the Missouri Department of Natural Resources (MoDNR). The Meramec River Basin Ecosystem Restoration Feasibility Study was authorized by a 21 June 2000 Resolution by the Committee on Transportation and Infrastructure, U.S. House of Representatives, Docket 2642.

The study area is the Meramec River watershed, including its two major tributaries, the Big River and the Bourbeuse River. Within the study area, the Meramec River flows west to east generally along the Jefferson and St. Louis County boundary to its confluence at the Mississippi River. The Big River flows south to north generally from the St. Francis County boundary approximately 75 miles north to its confluence with the Meramec River near Eureka, Missouri (St. Louis County). The Meramec River watershed drains approximately 3,950 square miles, with Big River and Bourbeuse River accounting for roughly 970 square miles and 840 square miles, respectively. The study area is confined as that portion of the Meramec River and its watershed located within Jefferson and St. Louis Counties; this would include small meanders into St. Francois and Washington Counties to the south. The study area is entirely within the state of Missouri. See Exhibit A.

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. 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. These processes have overburdened the system with sediment (both bedded and suspended) that is contaminated with lead and 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 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) regulated material which falls below the U.S. Environmental Protection Agency's (USEPA's) remedial action levels as finalized in the USEPA's Record of Decision (ROD) and/or a regulator-approved remediation response has occurred.

As part of the U.S. Army Corps of Engineers (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.

Project features are located on privately owned lands within the study area. The NFS, the MoDNR, is responsible for acquiring the necessary real estate for the project and also the Operation, Maintenance, Repair, Rehabilitation, and Replacement (OMRRR) costs in accordance with Section 107(b) of WRDA 1992, Public Law 102-580.

This Real Estate Plan will document the recommended plan. The recommended plan includes numerous sites throughout 75 miles of the Big River. Features of the Recommended Plan include:

- 6 sediment basins will be constructed along the Big River and associated excavation, earthwork and hauling.
- Construction of 5 grade control structures and associated excavation and hauling.
- Installation of 3 bedload sediment collectors and associated excavation and hauling.
- 8 in-stream excavation sites
- Construction of 12 bank stabilization sites:
    - 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 rootwad revetment
    - 219 acres of vegetative plantings
    - 134,000 cubic yards of associated excavation and earthwork
- Reforestation of 675 acres

2. LANDS, EASEMENTS, AND RIGHTS-OF-WAY (LER)

The recommended plan provides for the construction of features to restore the aquatic ecosystem of the study portion of the Meramec River Basin. Fee simple acquisition (1526 acres) will be required for Sediment Capture Basins, Grade Control Structures, Bed Collectors, Reforestation and Bank Stabilization features. Permanent Easements (83 acres) are required for Road Access. Temporary Easements (117 acres) will be required for Bed Sediment Removal, Staging Areas, and Access. The duration of temporary staging areas and access is estimated to be 2 years. USACE approved Standard Estates are included as Exhibit B.

Total LER required for the Recommended Plan is as follows:

TABLE 2.1

MANAGEMENT MEASURES	ACRES		
	FEE	PERMANENT EASEMENTS	TEMPORARY EASEMENTS
		Roads	Work Area & Access
Bedload Collector	11	2	
Sediment Capture Basin	272	6	6
Grade Control Structure	13	7	4
Bank Stabilization	555	29	59
Excavation			2
Sediment Removal			11
Reforestation	675	39	35
TOTAL	**1526**	**83**	**117**

The NFS will secure and facilitate all lands, easements and rights-of-way necessary to construct the management measures. The recommended plan will take place on privately-owned lands located predominantly in Jefferson County with some minimal requirements occurring in St. Francois and Washington Counties. These lands are predominantly vacant and are located in the floodway of the river. Individual ownerships are estimated to be 152 owners covering portions of 213 parcels. The primary land use is agricultural (crop production). Other uses include recreation and residential. No improvements are located within the preliminary right-of-way. See Exhibit C (Site Maps).

3. SPONSOR-OWNED LER

The NFS does not own any property within the currently identified project sites. The MoDNR, is responsible for acquiring the necessary real estate for the project and also the Operation, Maintenance, Repair, Rehabilitation, and Replacement (OMRRR) costs in accordance with Section 107(b) of WRDA 1992, Public Law 102-580.

4. NON STANDARD ESTATES

No non-standard estates are required for the project; however, the USACE is evaluating whether a rationale exists for less than fee for ecosystem restoration where appropriate.

5. EXISTING FEDERAL PROJECTS

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 sources areas, release mechanisms, exposure routes, potentially exposed populations and potential health risks associated with the CERCLA regulated material in the study area. 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-alone document but will be finalized in a ROD, which are scheduled to be completed in 2020. Because the ROD is not complete, it is unknown what USEPA will set as a clean-up level within the study area. 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 Hazardous, Toxic and Radioactive Waste (HTRW) within the study area cannot be identified at this time. Any proposed project by the USACE will avoid HTRW by finalizing site selection in areas below the final USEPA ROD remedial action level and/or a regulator-approved remediation response is completed by the NFS such that the USACE project can be constructed without triggering remedial liability. Any remedial response by the NFS is not considered part of the USACE project and not cost shared with the Federal Government.

6. FEDERALLY-OWNED LANDS

No federally-owned lands are being utilized for this project.

7. NAVIGATION SERVITUDE

Federal, Navigation Servitude does not apply to this project.

8. MAPPING

Mapping for each site location is included as Exhibit C.

9. INDUCED FLOODING

There will be no induced flooding as part of this project.

10. BASELINE COST ESTIMATE

See Exhibit D. Total estimated Land, Easements, Rights of Way, Relocation and Disposal (LERRD) costs for the project is **$9,278,000**.

11. RELOCATION ASSISTANCE BENEFITS

No persons, farms or businesses will be displaced as part of this project.

12. MINERAL ACTIVITY

There are no known present or anticipated mineral activity or timber harvesting in the project area. All ore or other minerals mined in the state is the property of the owner or lessee of the land where it was mined, except in cases where ownership is modified or transferred by express contract (Mo. Ann. Stat. Sec. 444.050). The area has been heavily mined for over 100 years for lead and zinc with the majority of it occurring on the Big River upstream of the identified project sites; therefore, it is assumed mineral rights will not complicate the acquisition process. See Section 2.1.2 of the Main Report for more information.

13. SPONSOR ASSESSMENT

The MoDNR is the NFS for this project. The NFS possesses the necessary authority and capability to acquire all lands required for this project. A copy of the Sponsor's Capability Checklist is included as Exhibit E.

14. ZONING

There will be no zoning ordinances enacted to facilitate acquisition of land for this project.

15. SCHEDULE OF LAND ACQUISITION MILESTONES

A project schedule was developed based upon the assumption that this report will be approved in the last quarter of Federal fiscal year (FY) 2019. The Project schedule sequences design and construction activities are 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.

16. FACILITY OR UTILITY RELOCATIONS

No facility or utility relocations are anticipated as part of this project.

17. HTRW

Section 5, Existing Federal Projects, discusses the progress of current USEPA superfund site studies. Since the USEPA has not yet issued RODs, the extent of Hazardous, Toxic and Radioactive Waste (HTRW) within the study area cannot be identified at this time. Any proposed project by the USACE will avoid HTRW by finalizing site selection in areas below the final USEPA ROD remedial action level and/or a regulator-approved remediation response is completed by the NFS such that the USACE project can be constructed without triggering remedial liability.

This Feasibility Report includes an Integrated Environment Assessment. A Finding of No Significant Impact (FONSI) was prepared and is awaiting signature. It was determined that an Environmental Impact Statement is not required. The proposed project is in compliance with all other environmental statutes. See Section 2.6.1 of the Main Report for more information.

18. LANDOWNER ATTITUDE

The NFS is in favor of the proposed project. A majority of the affected landowners have been made aware of the tentative plan through mailers, public meetings and direct contact from the Sponsor. Currently, there are no known landowner opposition to this project. The sites are at the feasibility level of design and therefore subject to change once the USEPA finalizes the Southwest Jefferson County Operating Unit 4, Big River Floodplain Record of Decision, and a final design package can be completed.

19. NOTIFICATION TO THE SPONSOR REGARDING THE RISKS ASSOCIATED WITH LAND ACQUISITION BEFORE EXECUTION OF THE PROJECT PARTNERSHIP AGREEMENT (PPA)

The sponsor does not intend to acquire any real estate for this project prior to the execution of the PPA. A Risk Assessment memo has been sent to the Sponsor and a copy is included as Exhibit F.

20. OTHER RELEVANT REAL ESTATE ISSUES

None are known to exist.

Melissa Lynn Hoerner
Real Estate Contracting Officer
St. Louis District - MVS

James T. Lovelace
Realty Specialist
St. Louis District - MVS

Exhibit A - Project Map

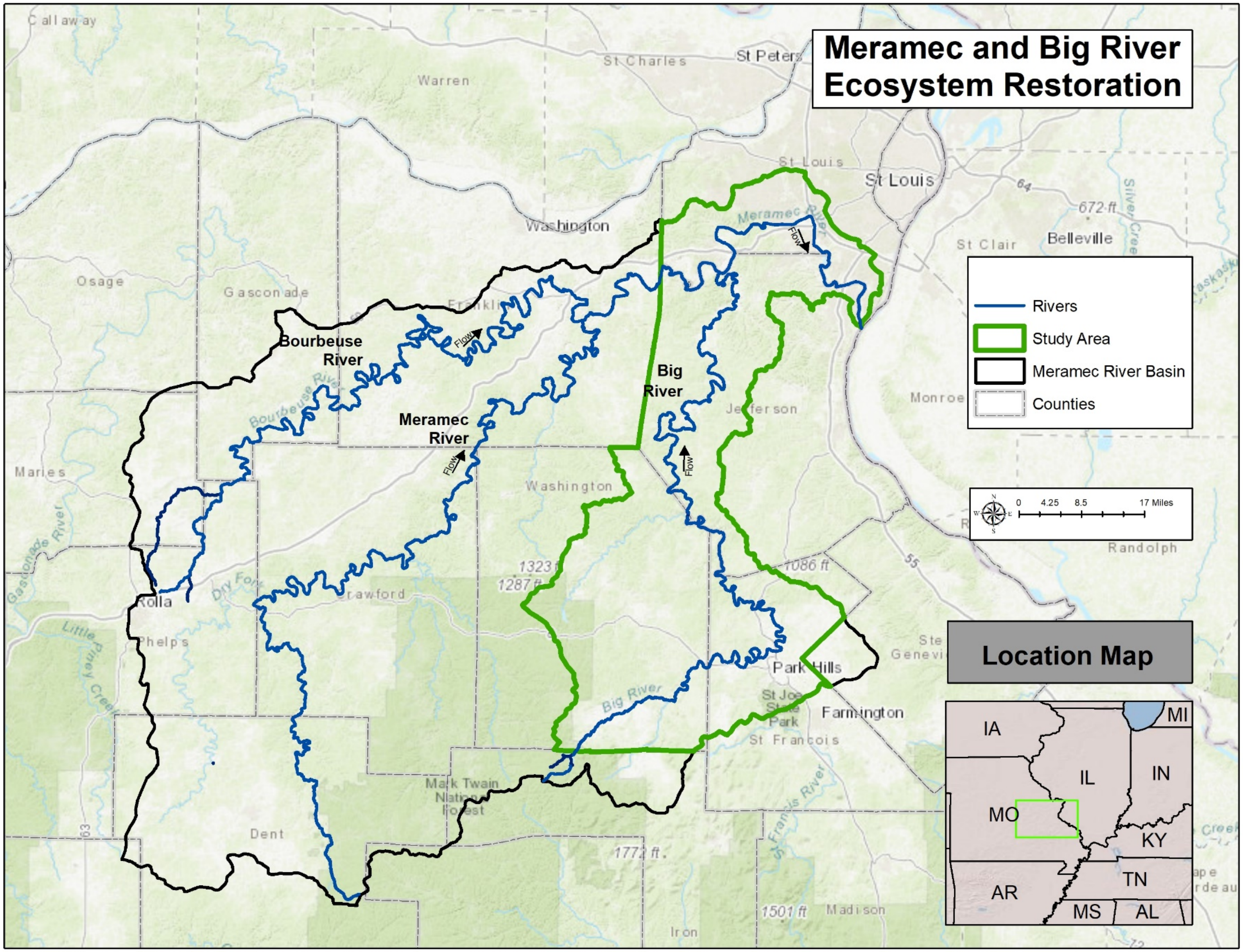


Exhibit B – Standard Estates

FEE.
The fee simple title to (the and described in Schedule A) (Tracts Nos. , and), Subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

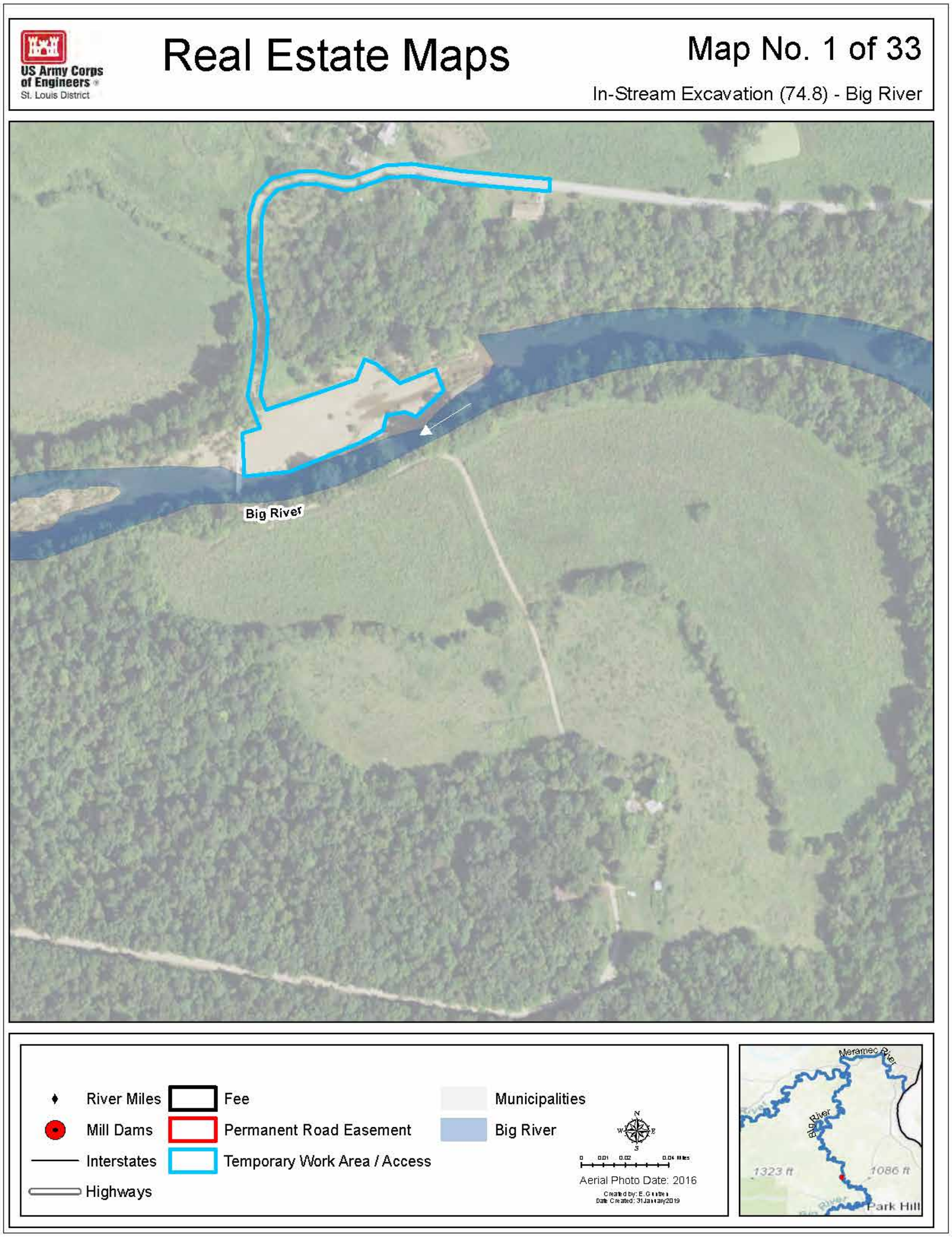
PERMANENT ROAD EASEMENT.
A perpetual easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos. _____, _____ and _____) for the location, construction, operation, maintenance, alteration replacement of (a) road(s) and appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; (reserving, however, to the owners, their heirs and assigns, the right to cross over or under the right-of-way as access to their adjoining land at the locations indicated in Schedule B); [1] subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

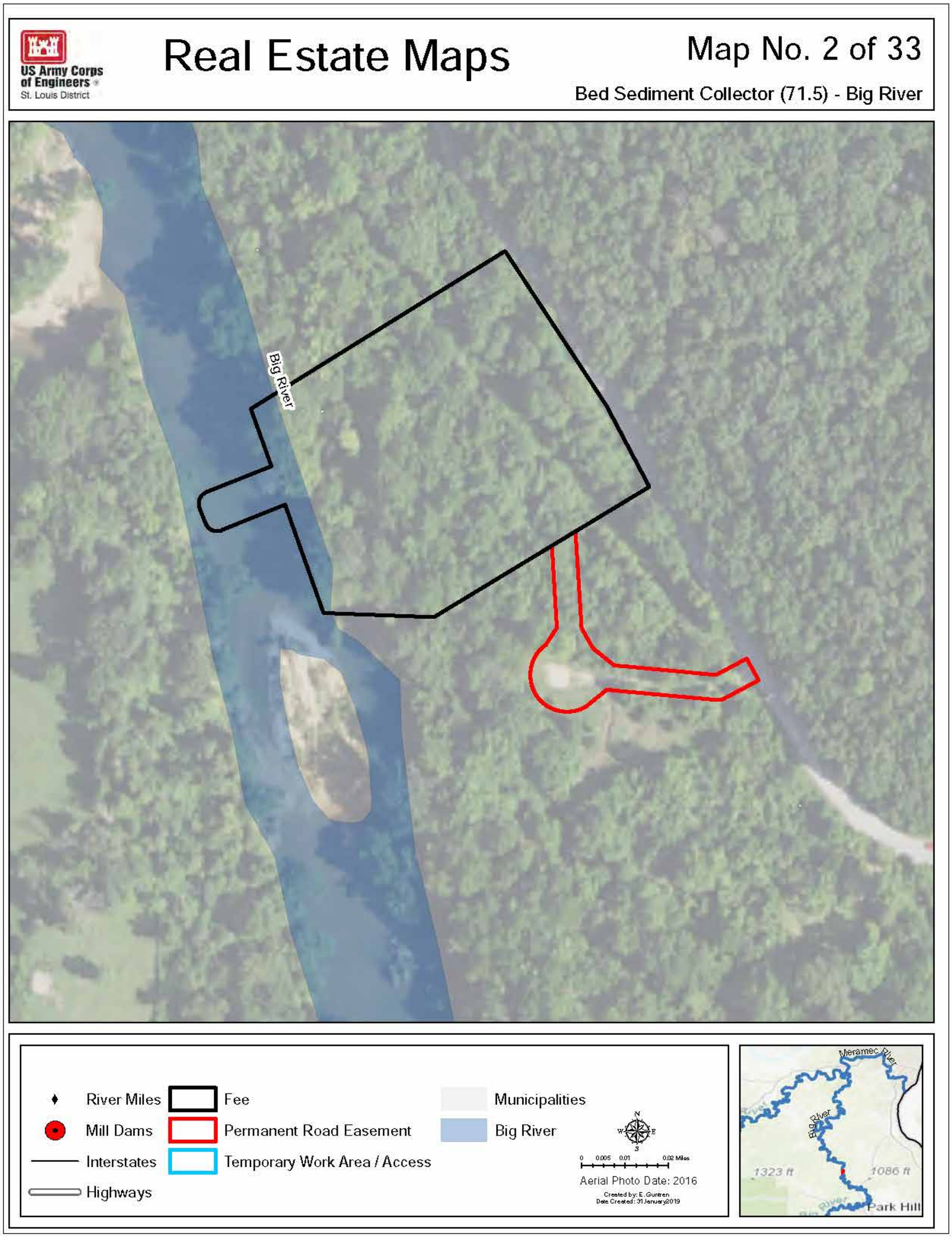
TEMPORARY WORK AREA EASEMENT.

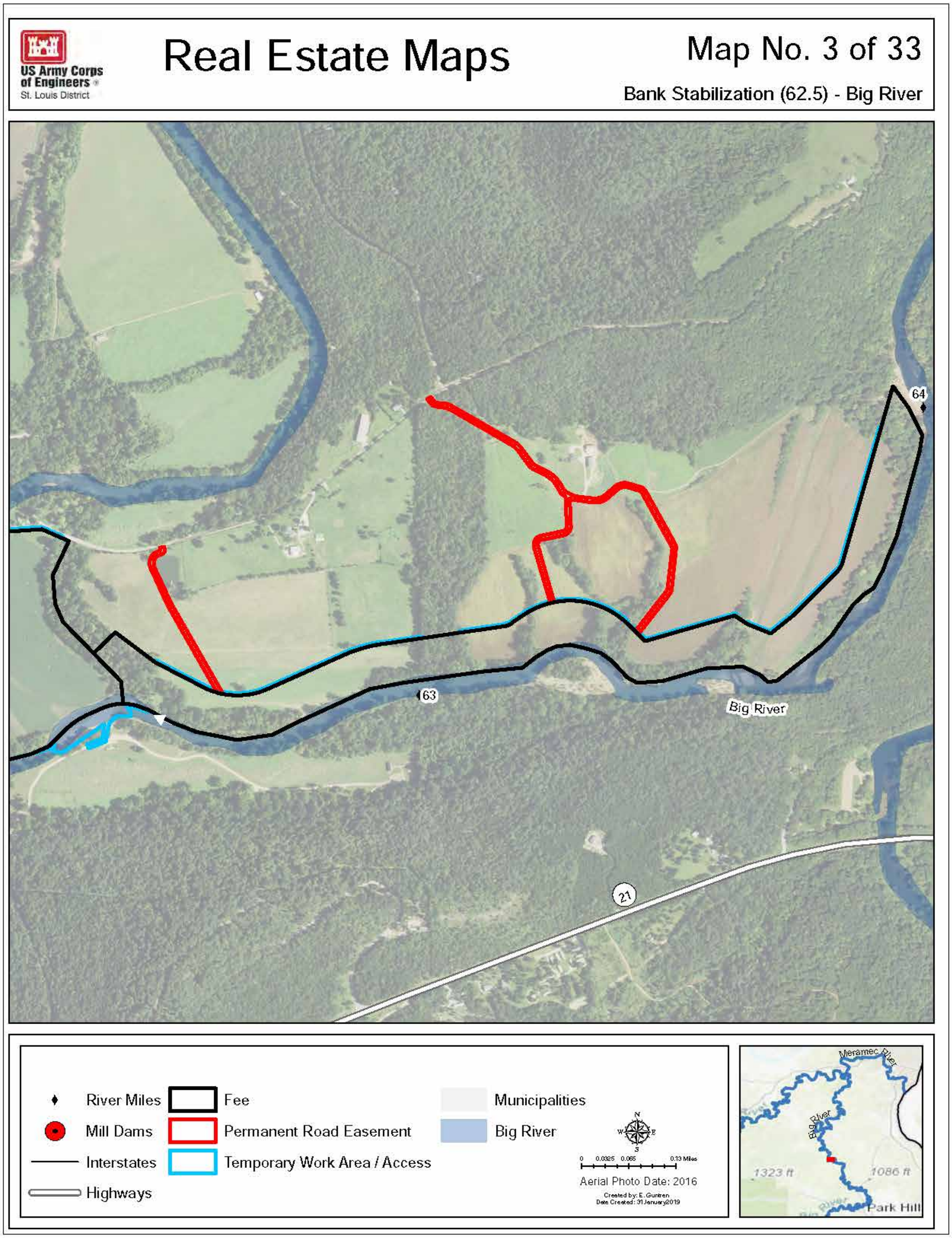
A temporary easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos. _____, _____ and _____), for a period not to exceed __________________, beginning with date possession of the land is granted to the State of Missouri, for use by the State of Missouri, its representatives, agents, and contractors as a (borrow area) (work area), including the right to (borrow and/or deposit fill, spoil and waste material thereon) (move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the ____________________ Project, together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

TEMPORARY ROAD EASEMENT.
A temporary easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos. _____, _____ and _____) for the location, construction, operation, maintenance, alteration replacement of (a) road(s) and appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; (reserving, however, to the owners, their heirs and assigns, the right to cross over or under the right-of-way as access to their adjoining land at the locations indicated in Schedule B); [2] subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

Exhibit C – Site Maps
(33 Site Maps)




US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 2 of 33
Bed Sediment Collector (71.5) - Big River
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
N
W
E
S
0 0.005 0.01 0.02 Miles
Aerial Photo Date: 2016
Created by: E. Guntren
Date Created: 31 January 2019
Meramec River
Big River
1323 ft
1086 ft
Park Hill

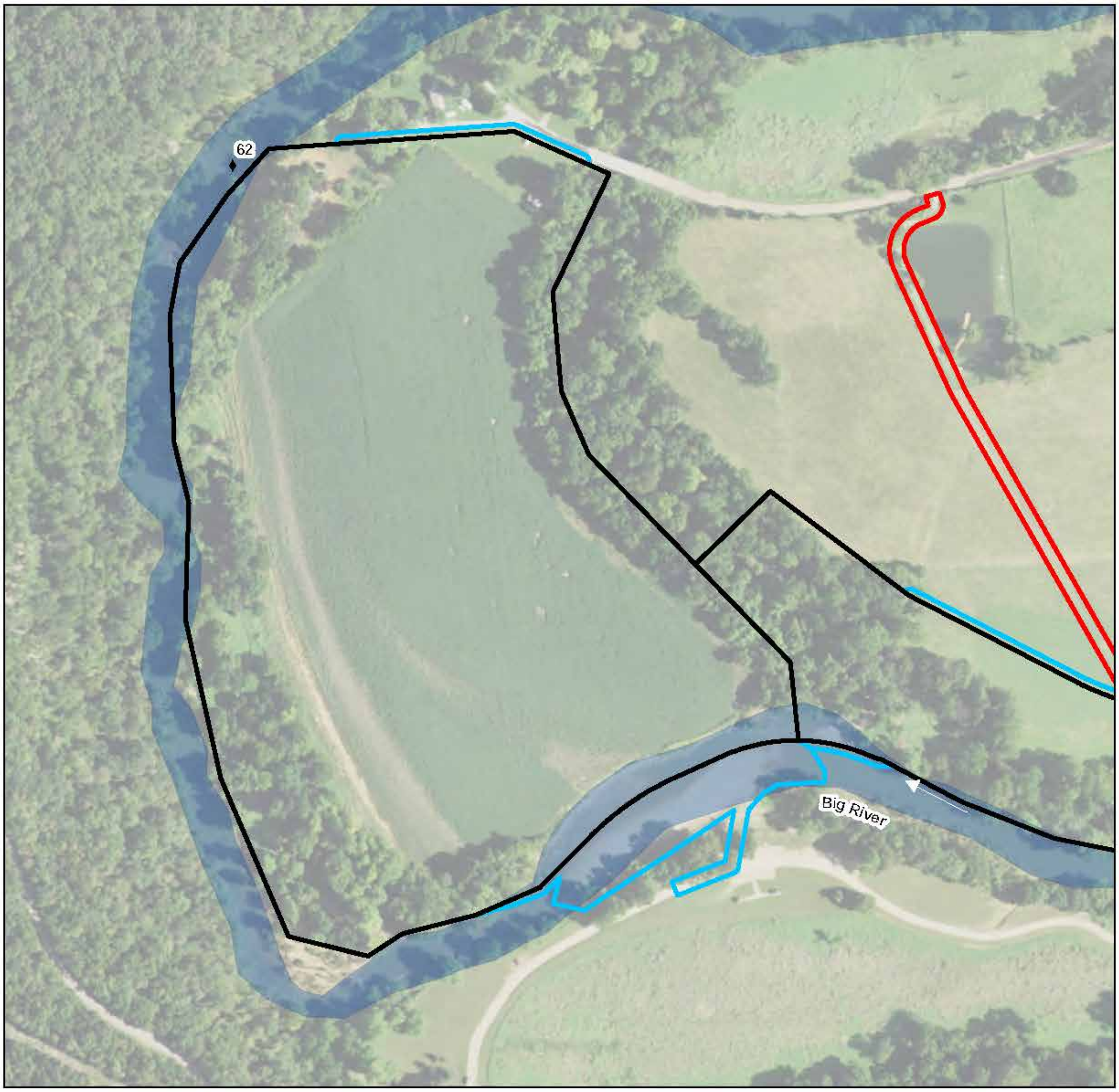

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 3 of 33
Bank Stabilization (62.5) - Big River
64
63
Big River
21
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
0 0.0325 0.065 0.13 Miles
Aerial Photo Date: 2016
Created by: E. Guntren
Date Created: 31January2019
Meramec River
Big River
1323 ft
1086 ft
Park Hill

US Army Corps of Engineers®
St. Louis District

Real Estate Maps

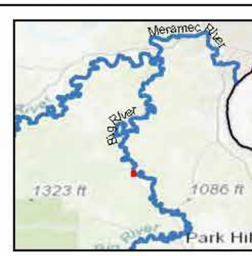
Map No. 4 of 33

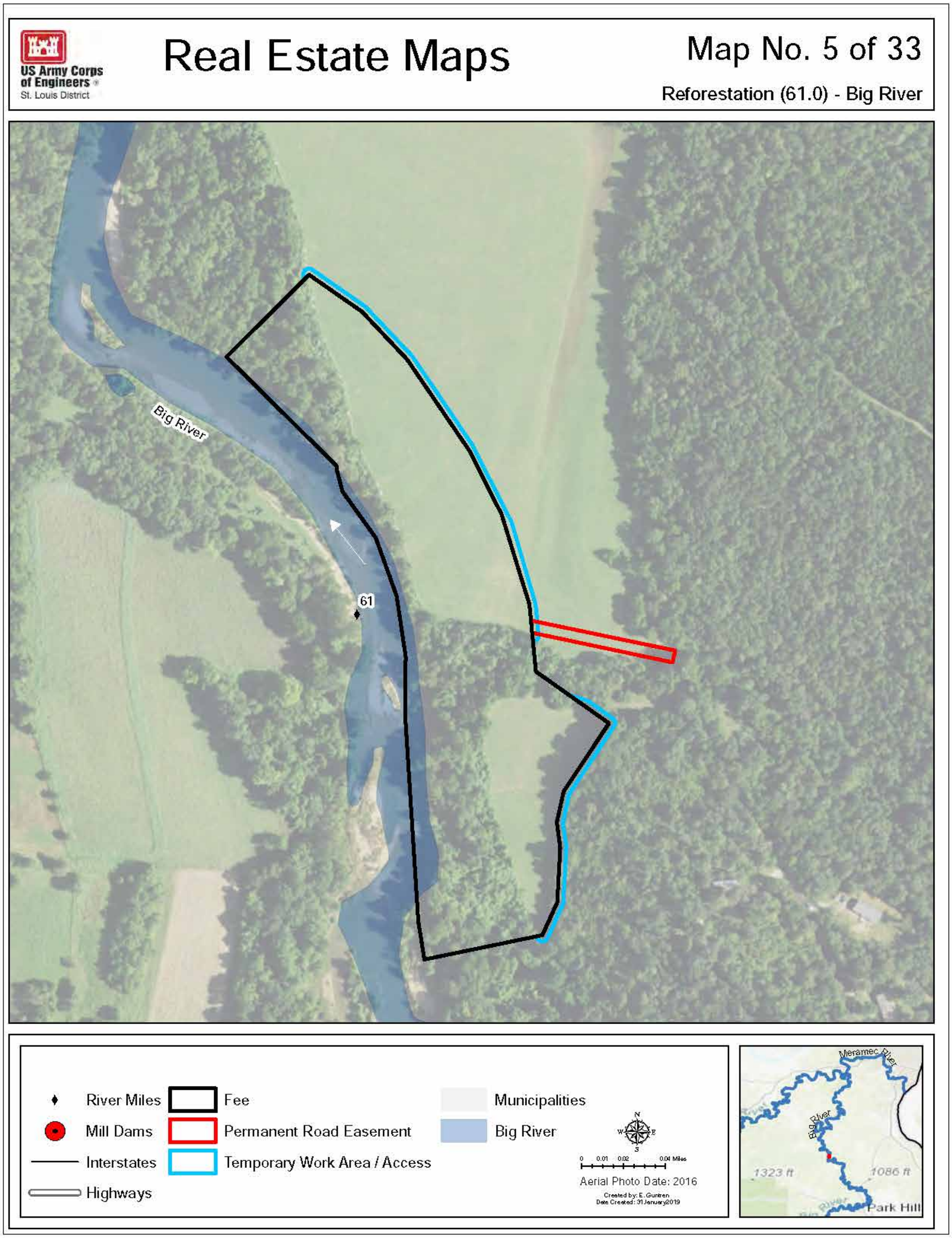
Sediment Basin and In-Stream Excavation (62.5) - Big River

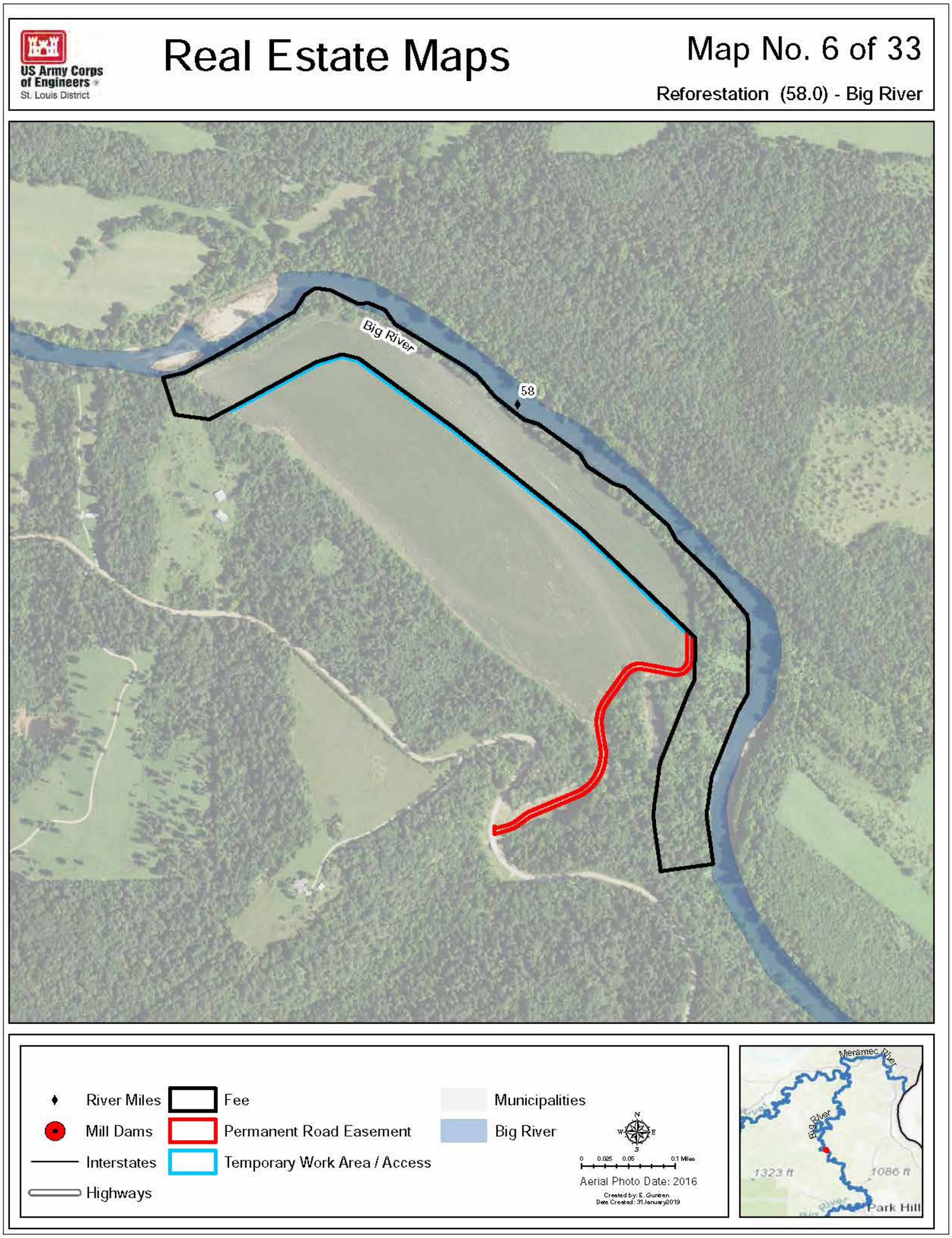


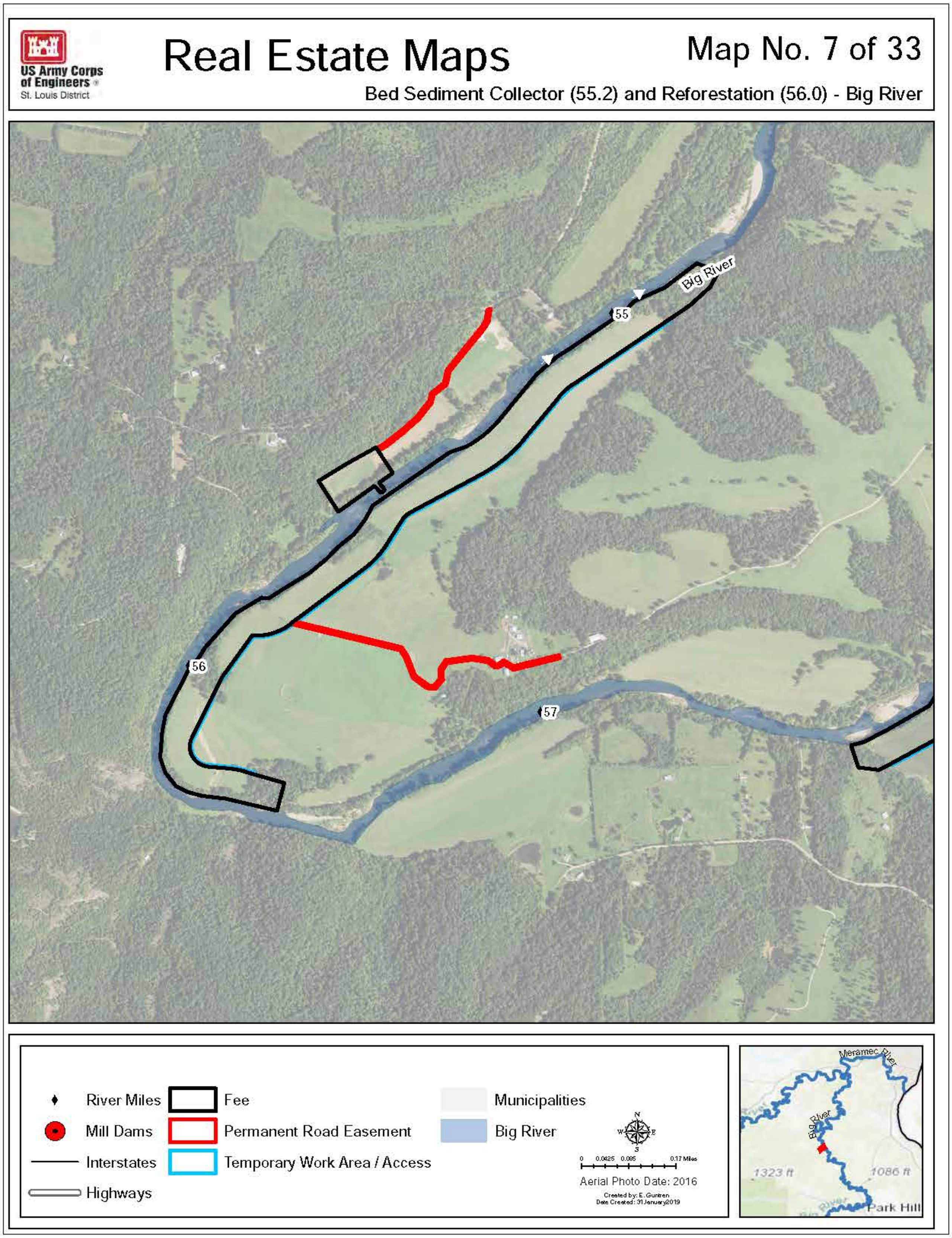
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River

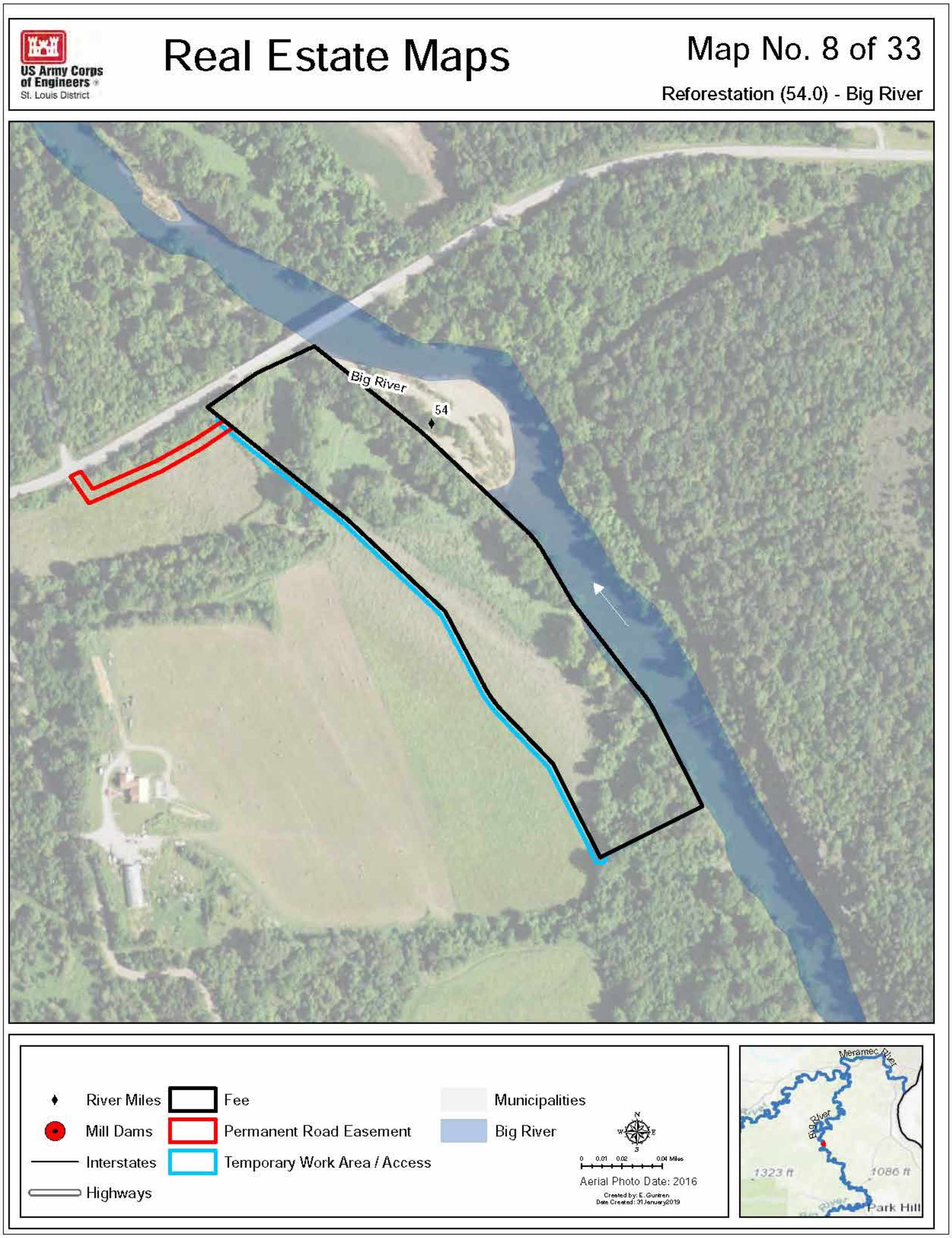
Aerial Photo Date: 2016
Created by: E. Guntren
Date Created: 31January2019

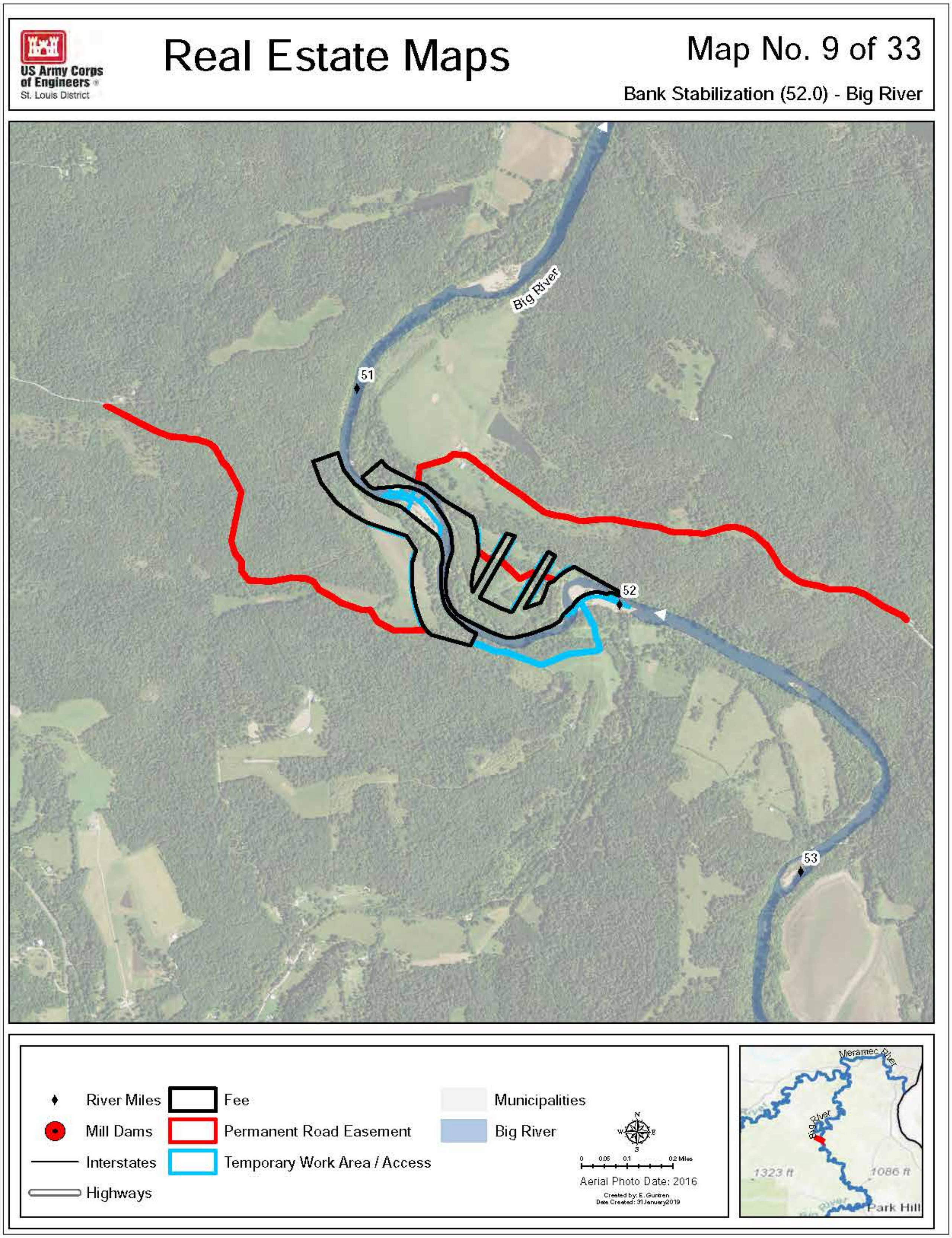


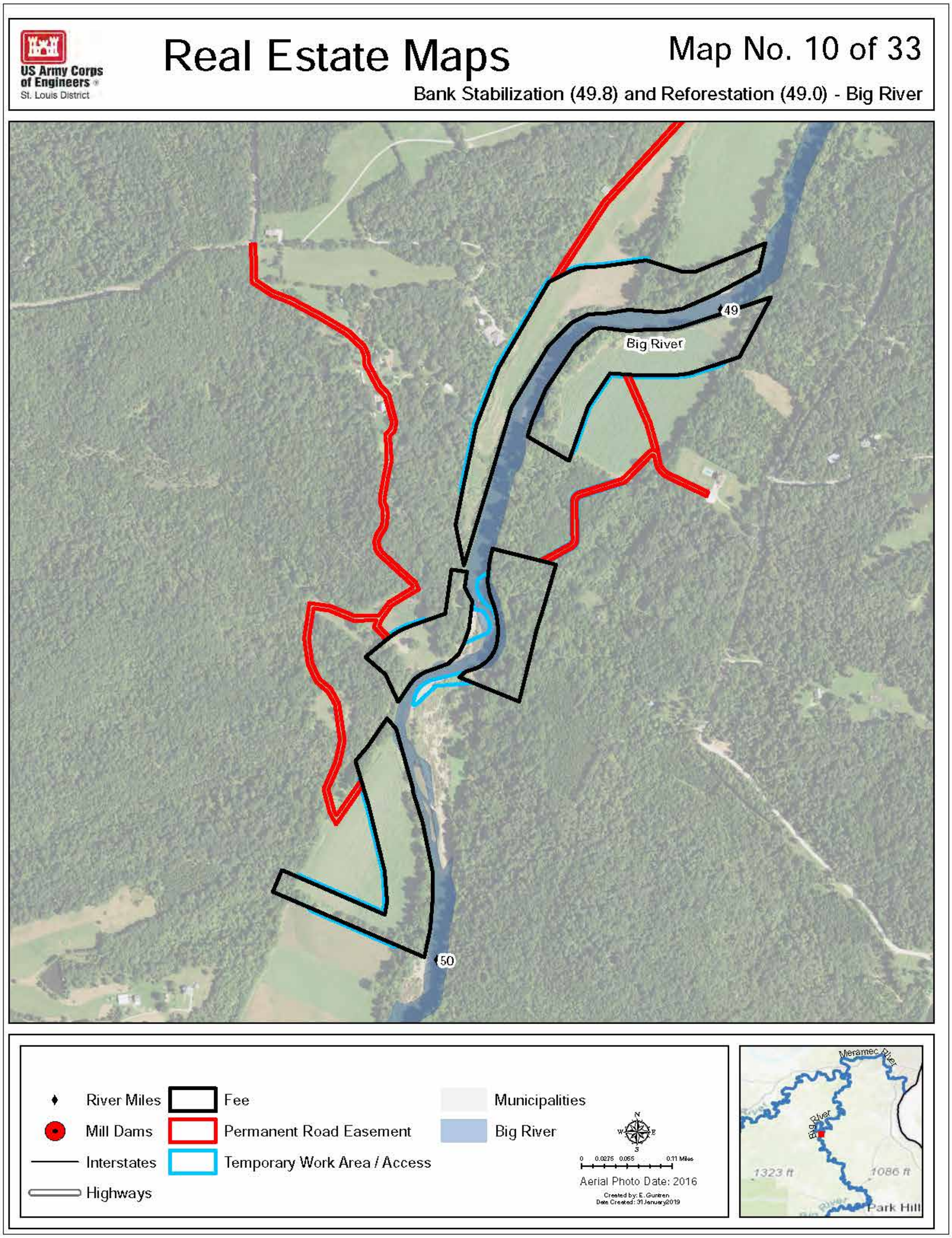

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 5 of 33
Reforestation (61.0) - Big River
Big River
61
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 6 of 33
Reforestation (58.0) - Big River
Big River
58
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
0 0.025 0.05 0.1 Miles
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 7 of 33
Bed Sediment Collector (55.2) and Reforestation (56.0) - Big River
Big River
55
56
57
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
N
W
E
S
0 0.0425 0.085 0.17 Miles
Aerial Photo Date: 2016
Created by: E. Guntren
Date Created: 31 January2019
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 8 of 33
Reforestation (54.0) - Big River
Big River
54
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 9 of 33
Bank Stabilization (52.0) - Big River
Big River
51
52
53
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

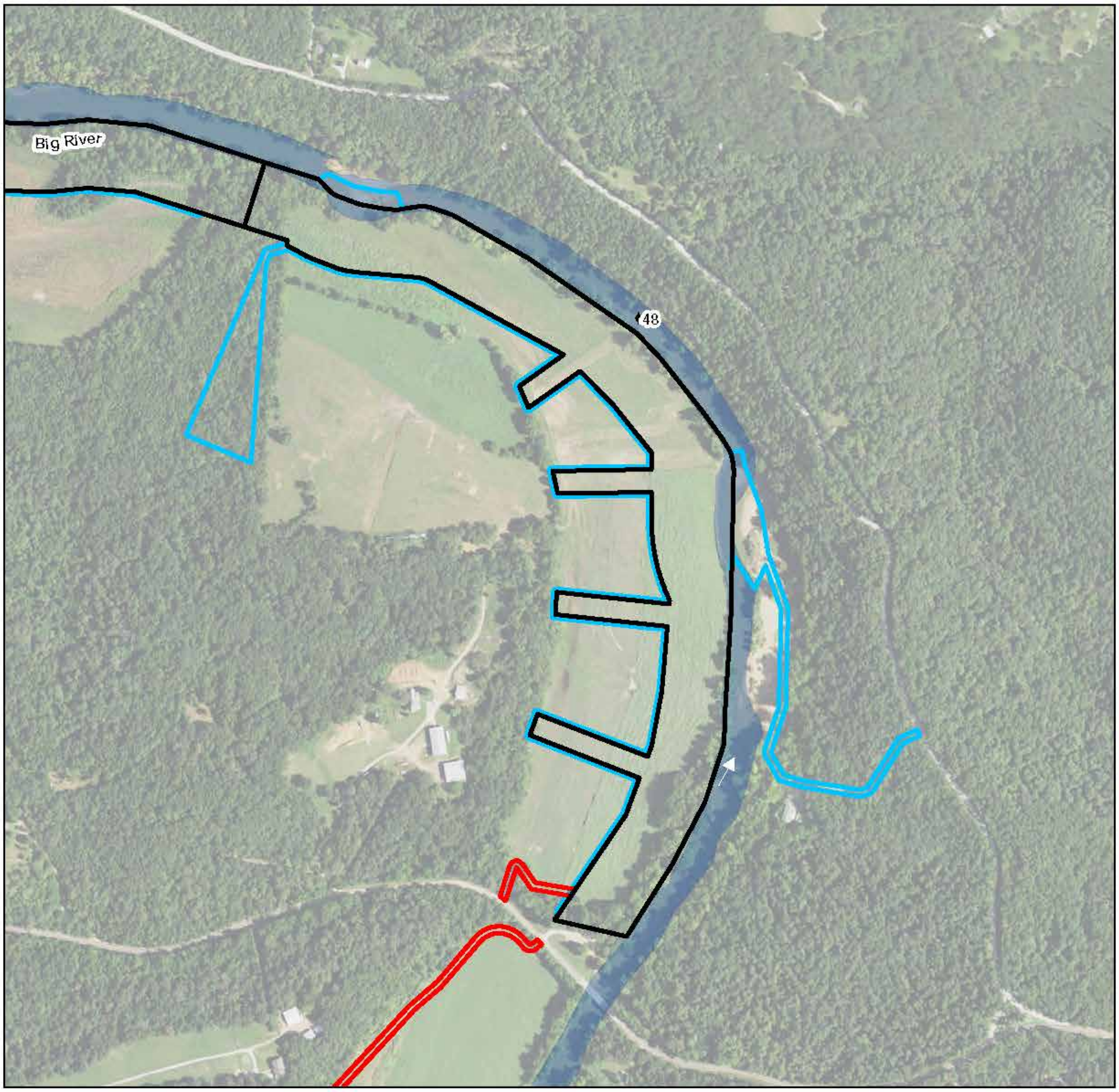

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 10 of 33
Bank Stabilization (49.8) and Reforestation (49.0) - Big River
49
Big River
50
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

US Army Corps of Engineers
St. Louis District

Real Estate Maps

Map No. 11 of 33

Bank Stabilization (48.0) - Big River

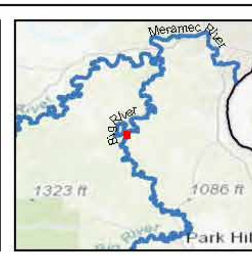


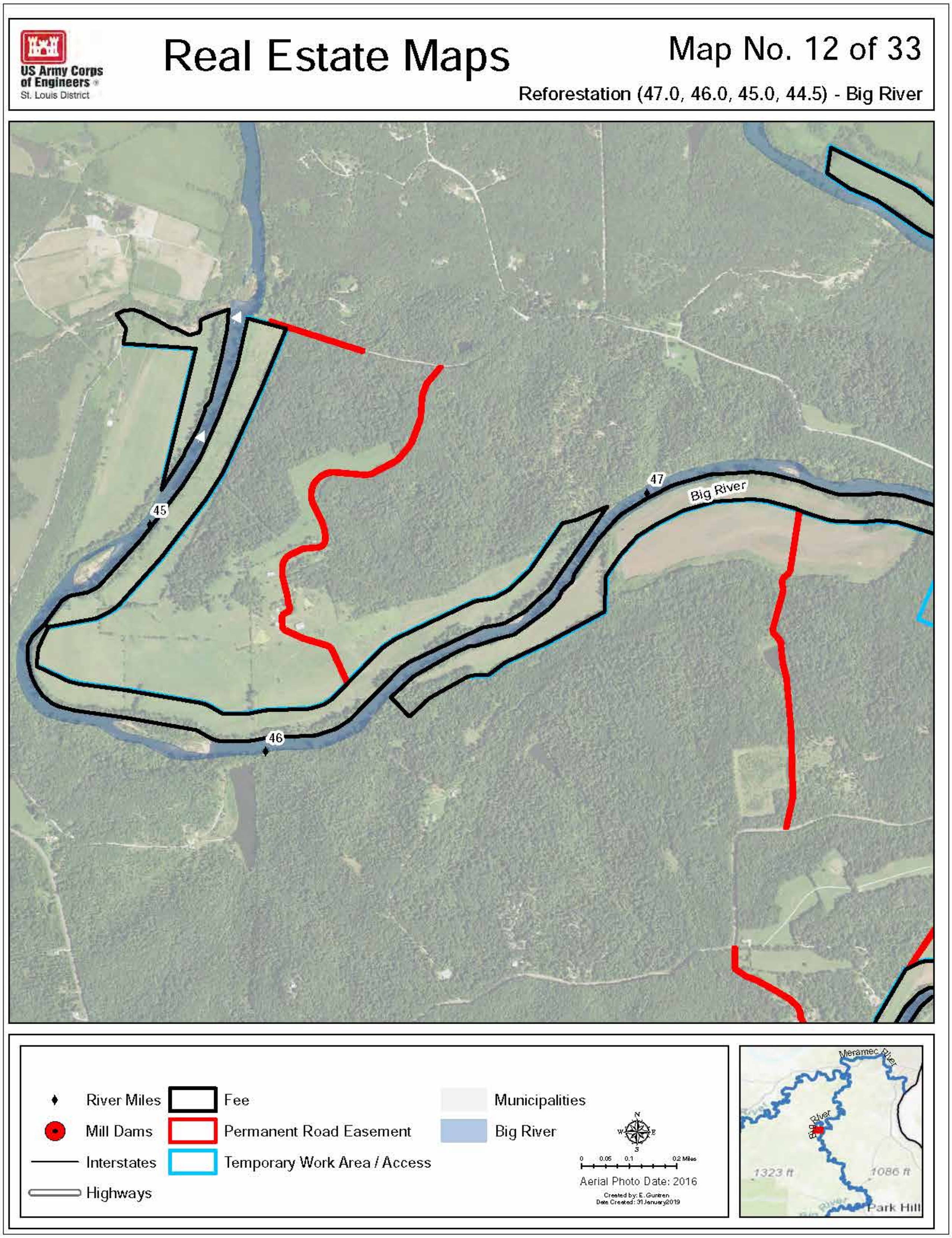
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River

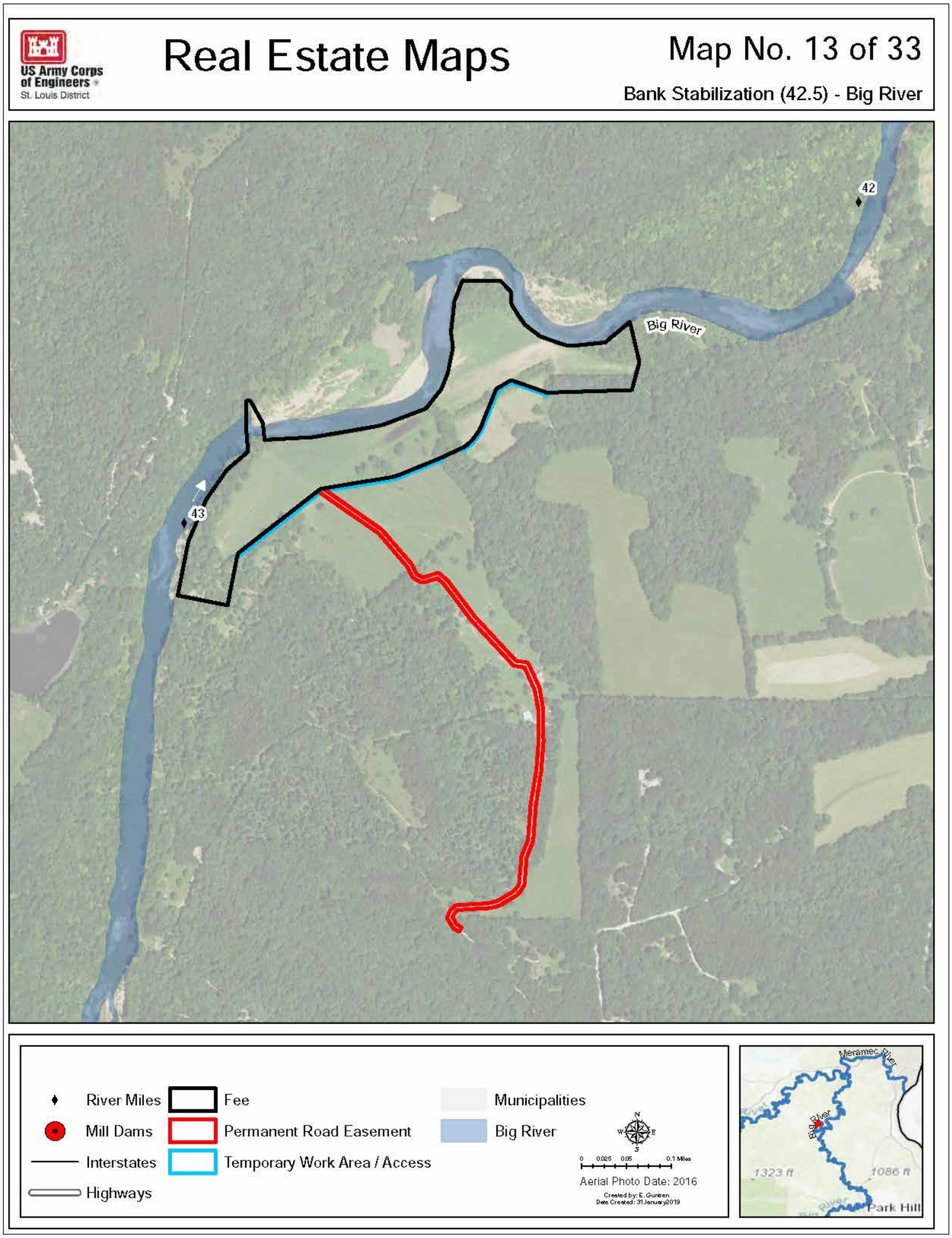
0 0.0225 0.045 0.09 Miles

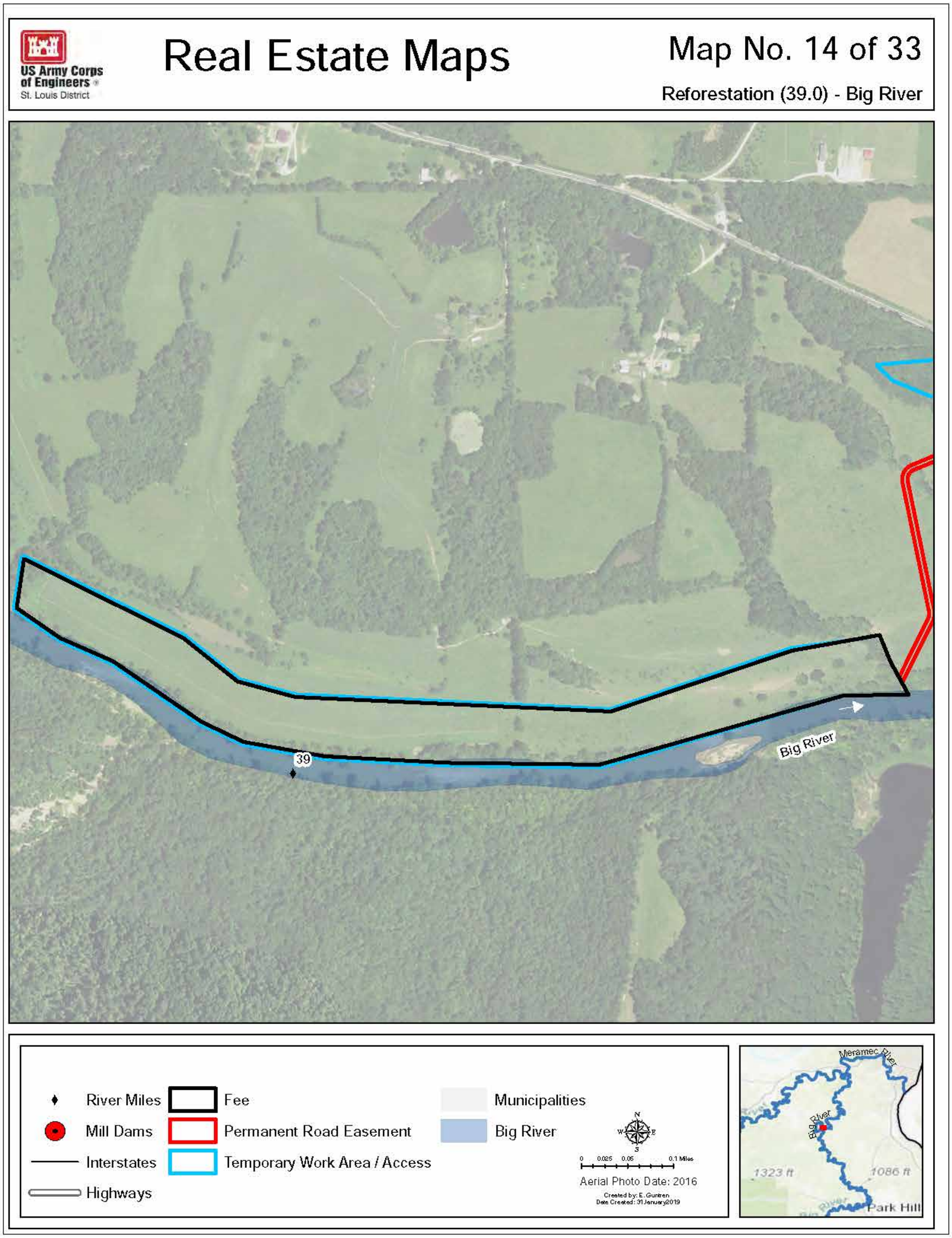
Aerial Photo Date: 2016

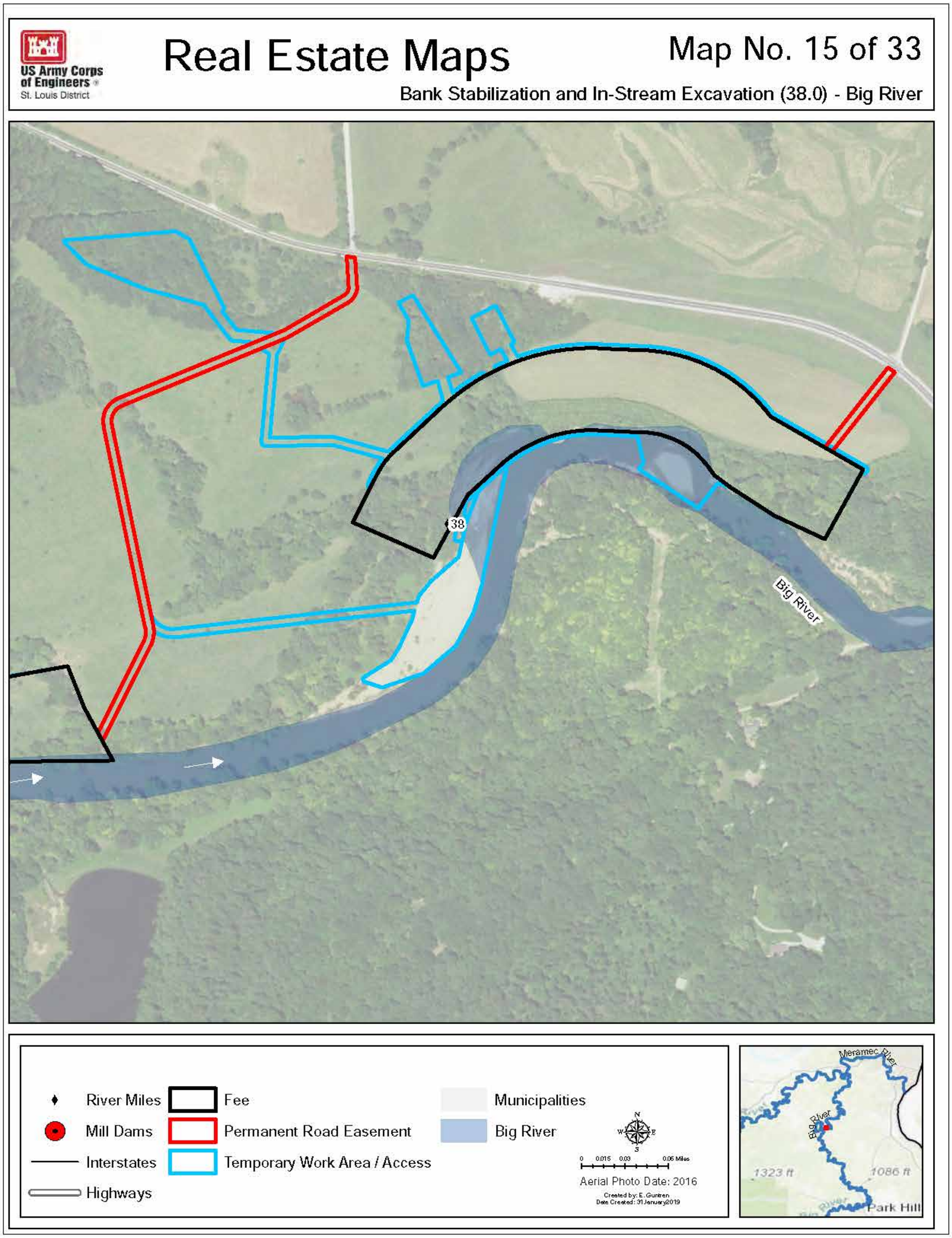
Created by: E. Guntren
Date Created: 31January2019




US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 12 of 33
Reforestation (47.0, 46.0, 45.0, 44.5) - Big River
47
Big River
45
46
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 13 of 33
Bank Stabilization (42.5) - Big River
42
43
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 14 of 33
Reforestation (39.0) - Big River
39
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

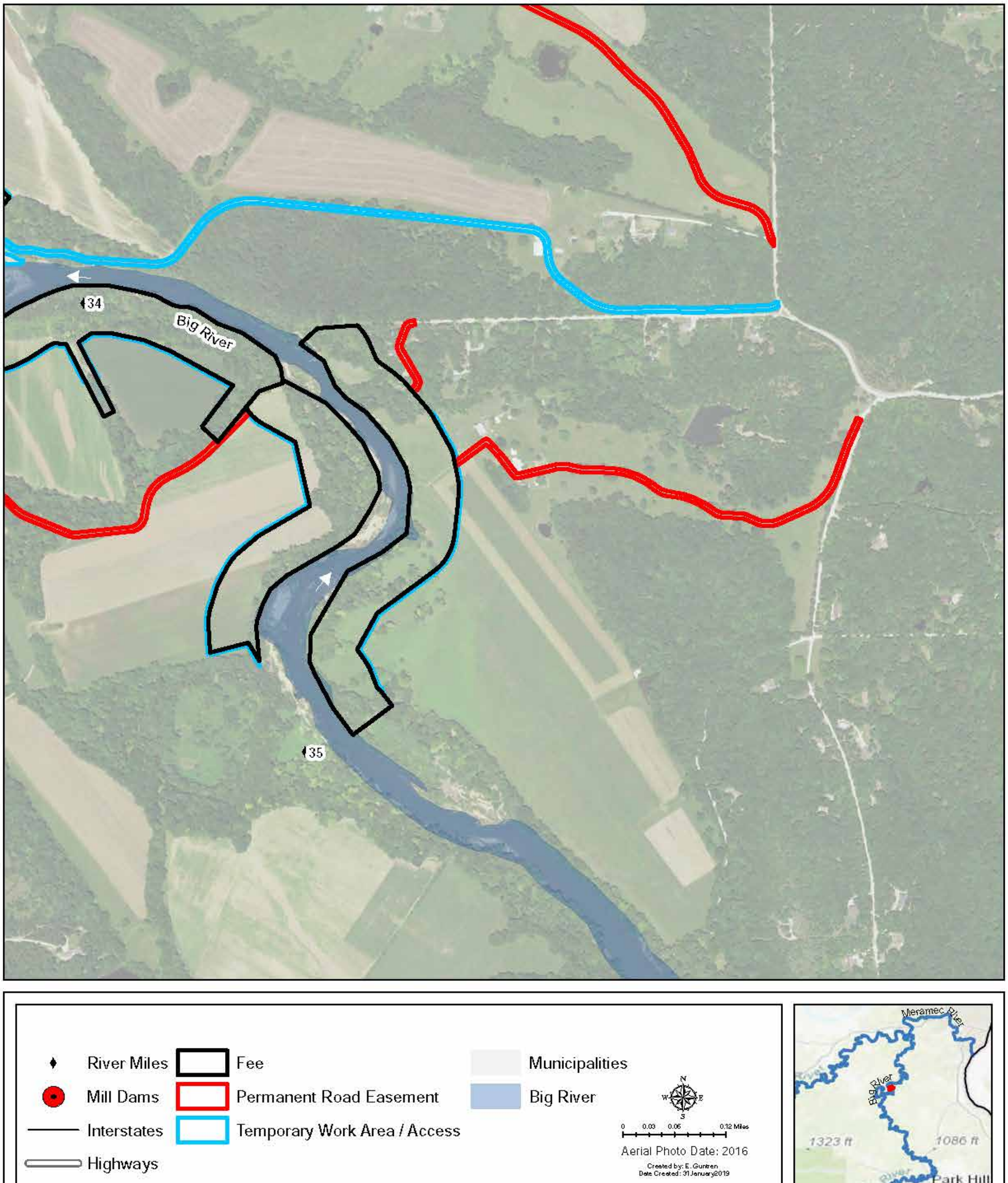

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 15 of 33
Bank Stabilization and In-Stream Excavation (38.0) - Big River
38
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

US Army Corps of Engineers
St. Louis District

Real Estate Maps

Map No. 16 of 33

Reforestation (34.9) - Big River

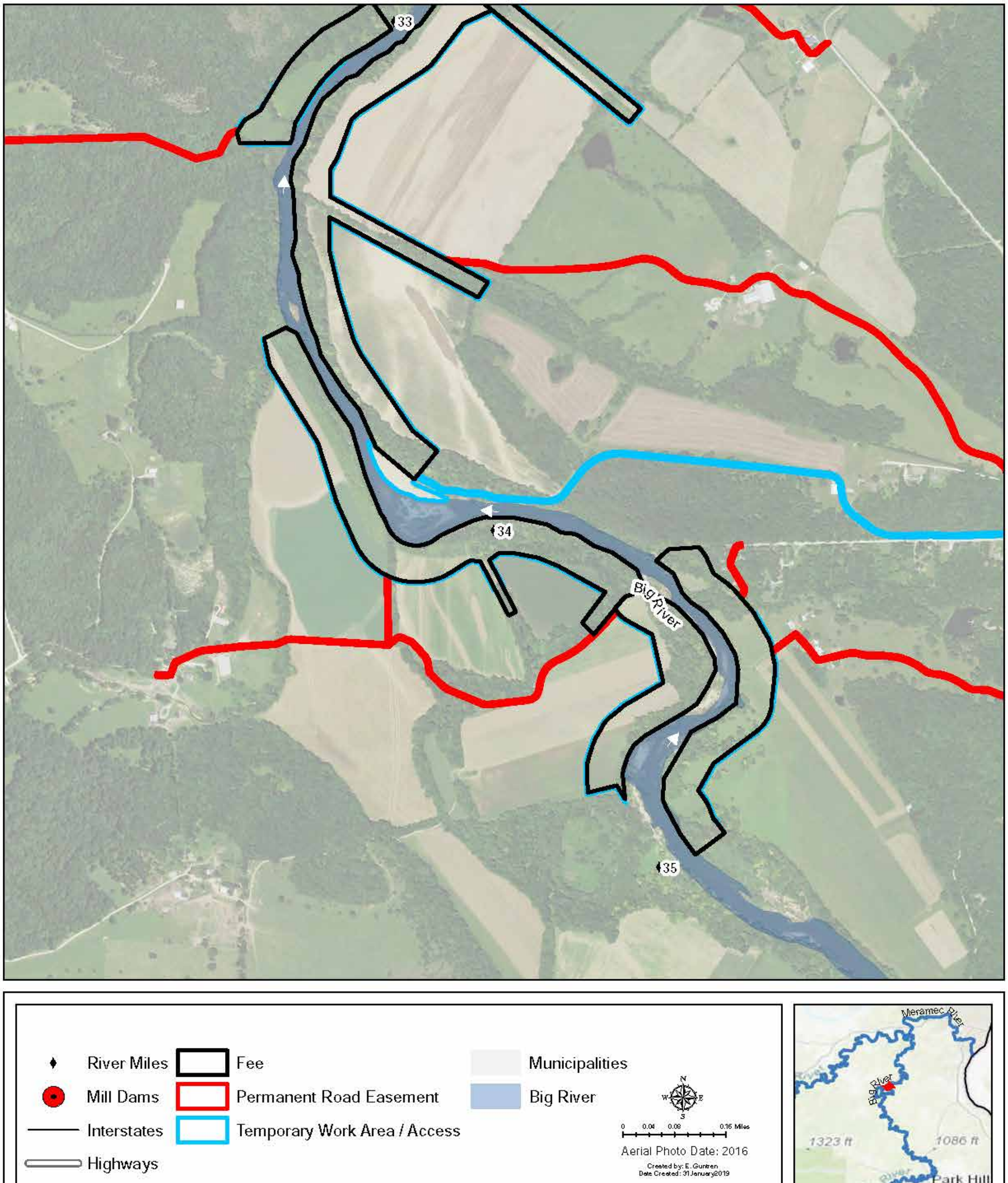


US Army Corps of Engineers
St. Louis District

Real Estate Maps

Map No. 17 of 33

Bank Stabilization and In-Stream Excavation (34.0) - Big River

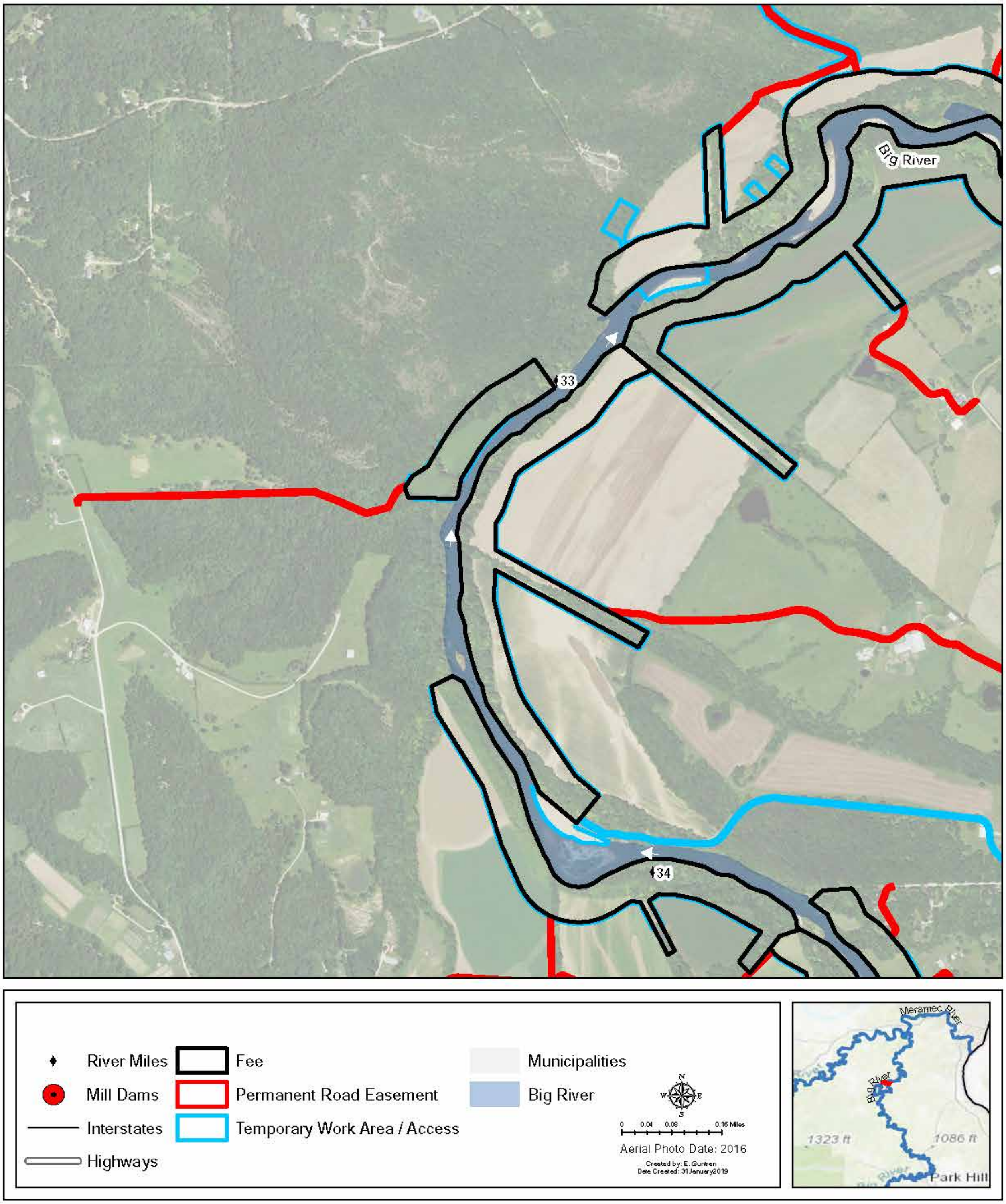


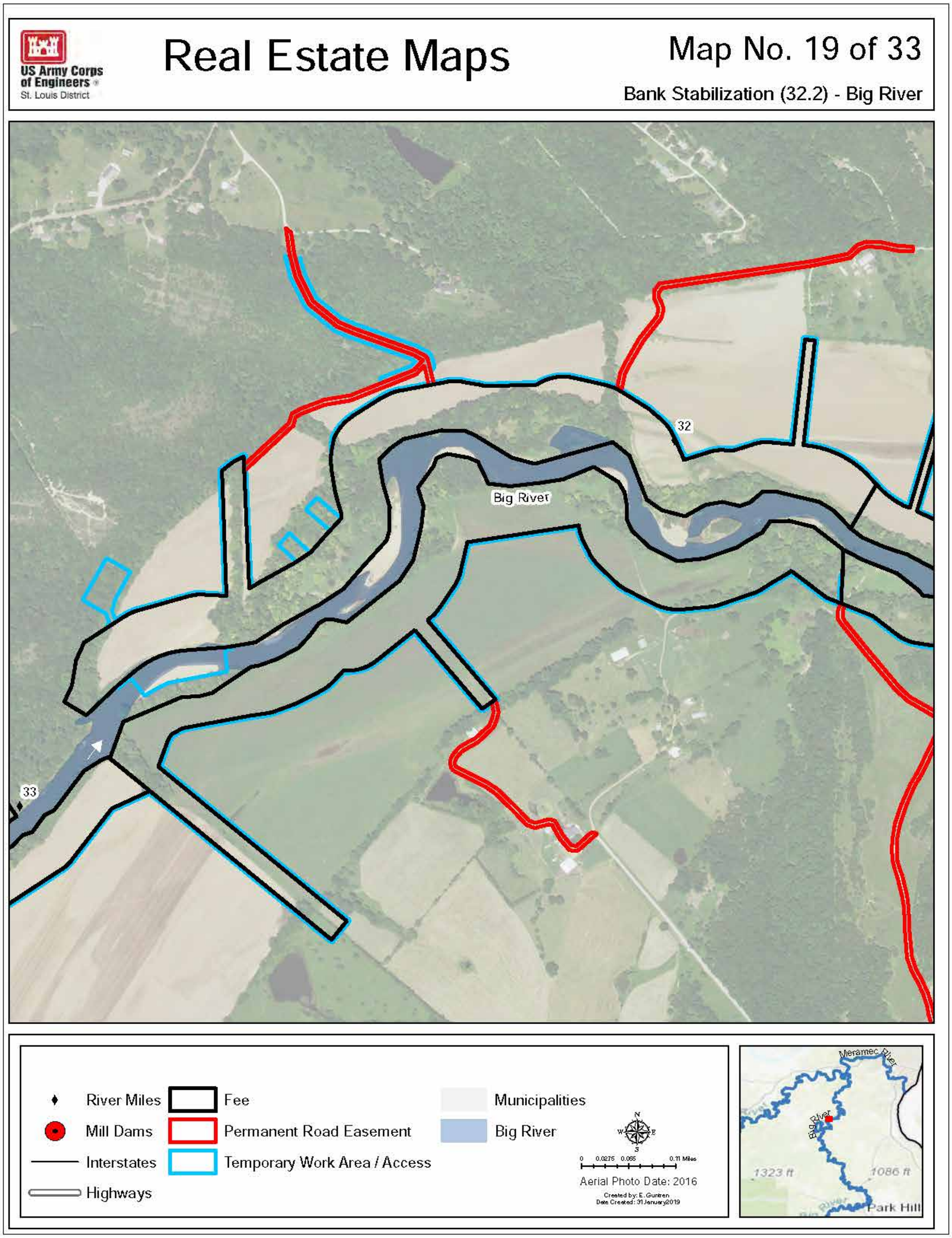
US Army Corps of Engineers
St. Louis District

Real Estate Maps

Map No. 18 of 33

Reforestation (33.2) - Big River



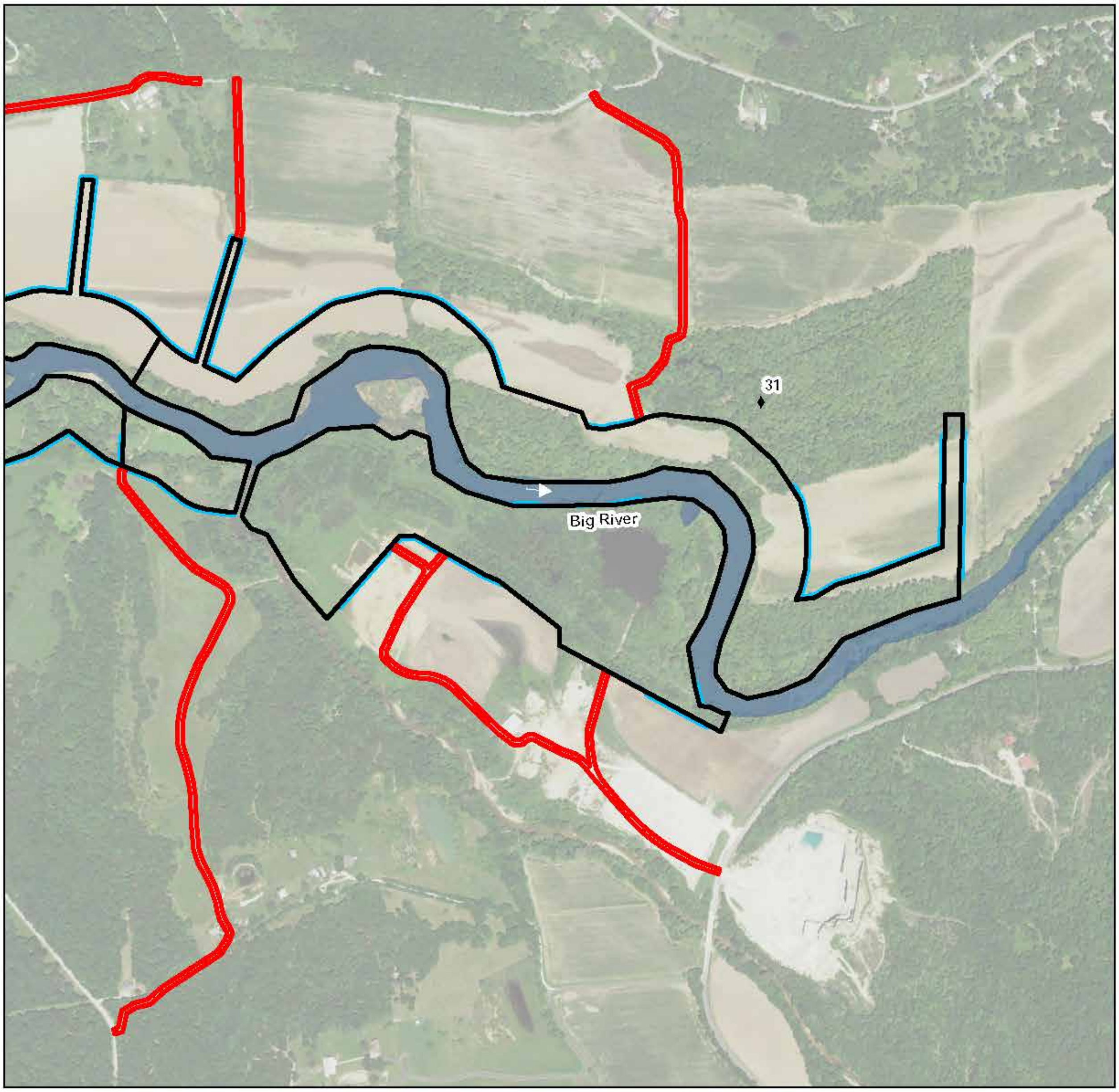

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 19 of 33
Bank Stabilization (32.2) - Big River
32
Big River
33
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
N
W
E
S
0 0.0275 0.055 0.11 Miles
Aerial Photo Date: 2016
Created by: E. Guntren
Date Created: 31 January2019
Meramec River
Big River
1323 ft
1086 ft
Park Hill

US Army Corps of Engineers®
St. Louis District

Real Estate Maps

Map No. 20 of 33

Sediment Basin (31.0) and Reforestation (31.0) - Big River

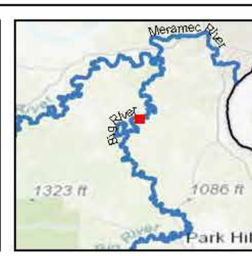


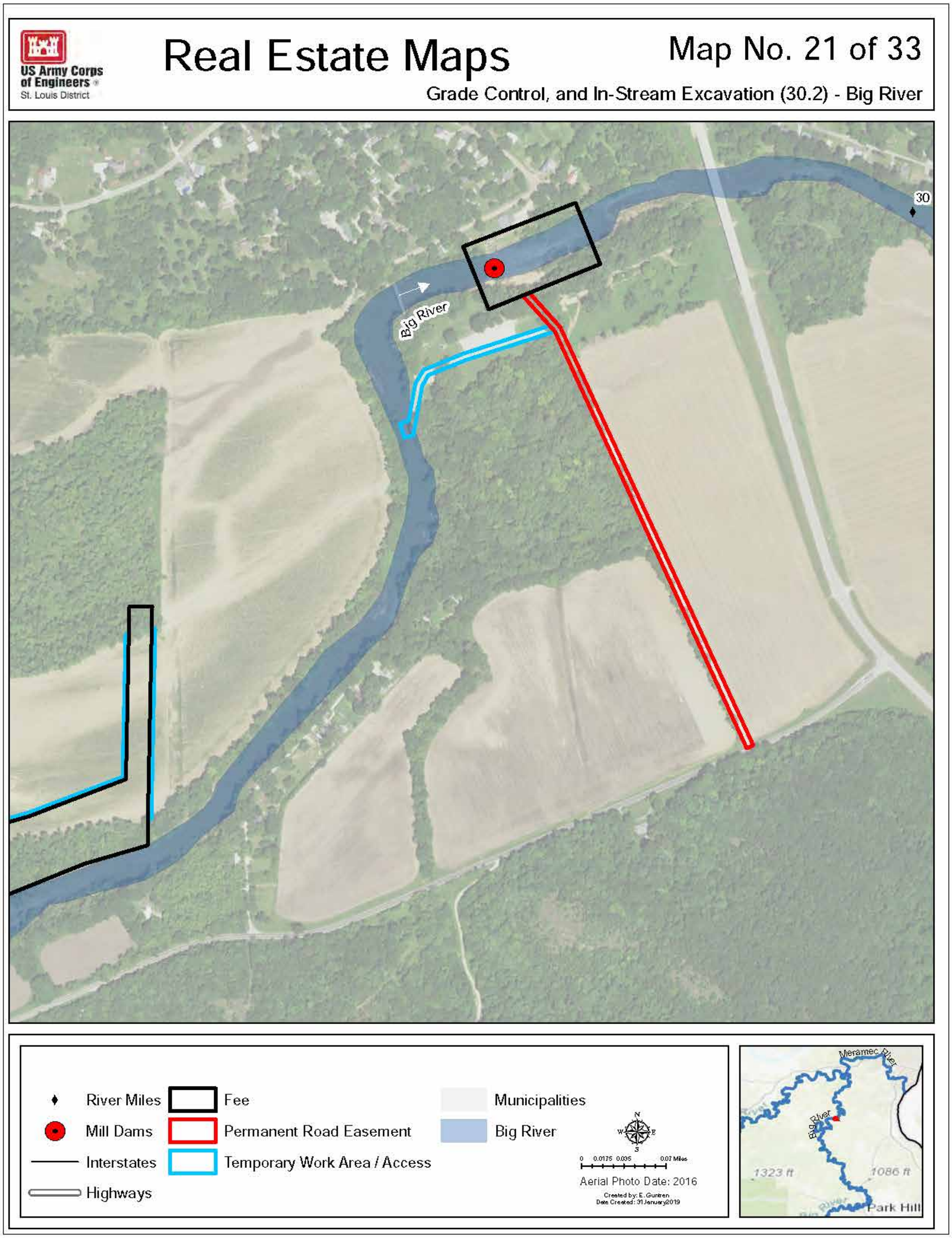
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River

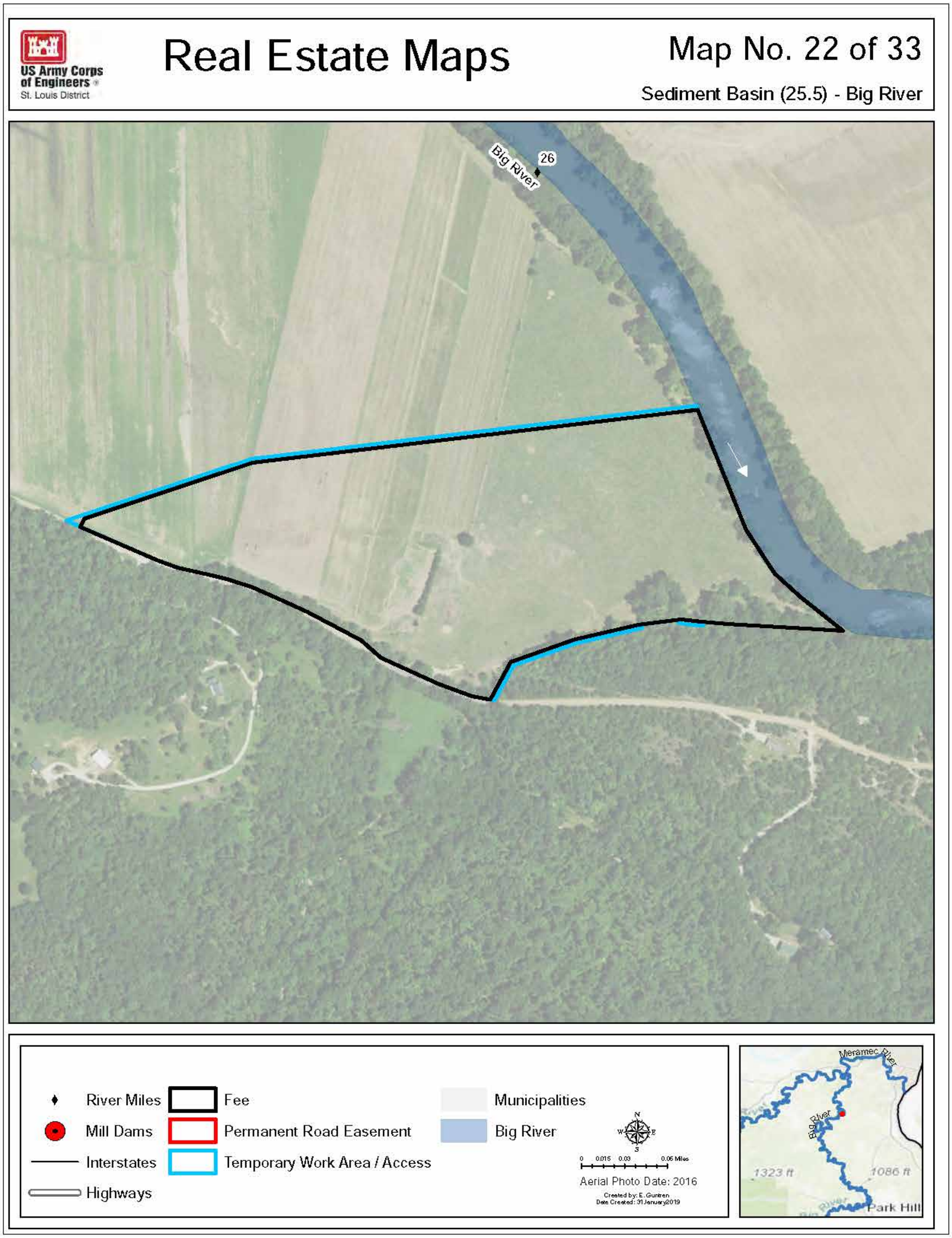
0 0.03 0.06 0.12 Miles

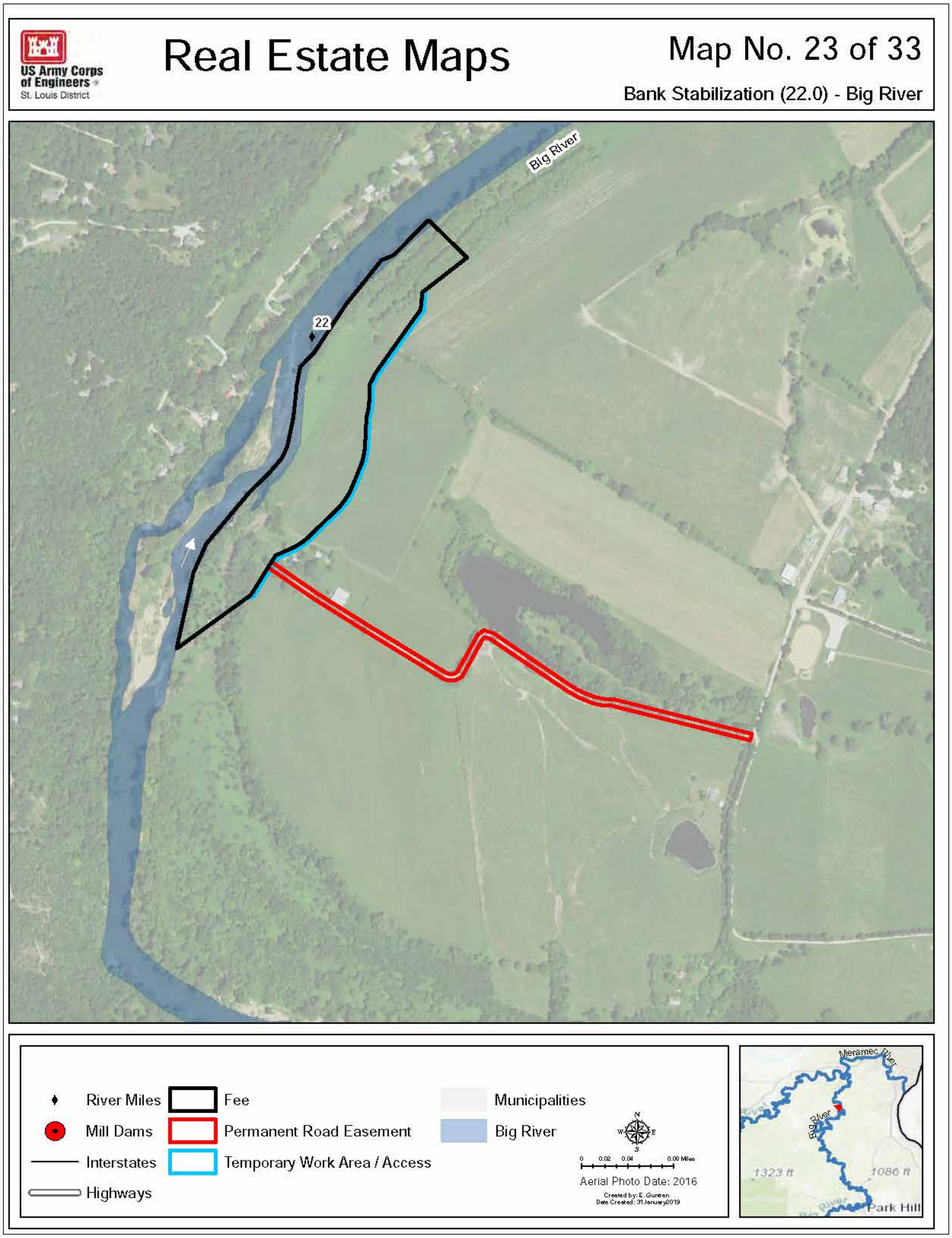
Aerial Photo Date: 2016

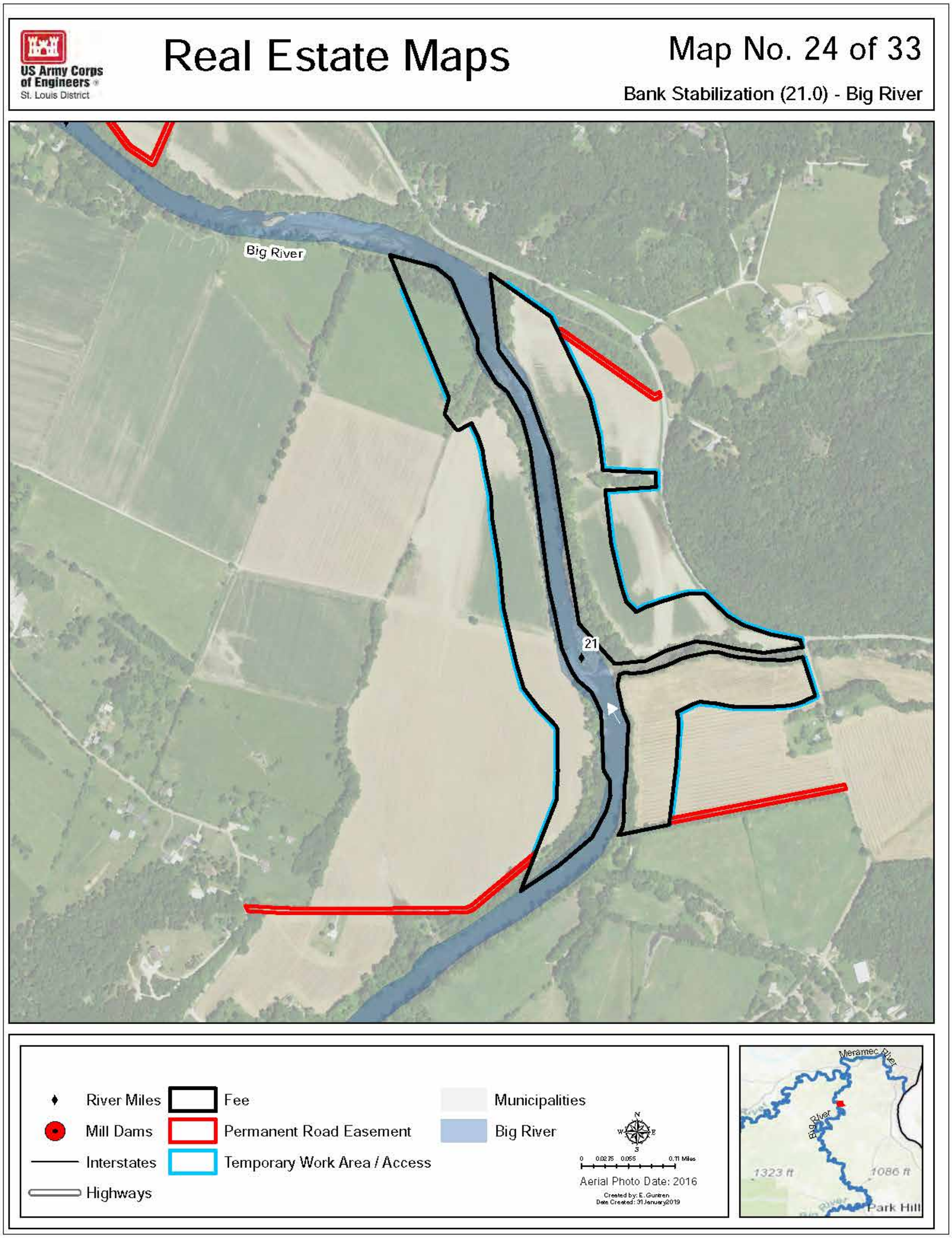
Created by: E. Guntren
Date Created: 31January2019




US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 21 of 33
Grade Control, and In-Stream Excavation (30.2) - Big River
30
Big River
River Miles
Fee
Mill Dams
Permanent Road Easement
Interstates
Temporary Work Area / Access
Highways
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 22 of 33
Sediment Basin (25.5) - Big River
Big River
26
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 23 of 33
Bank Stabilization (22.0) - Big River
Big River
22
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

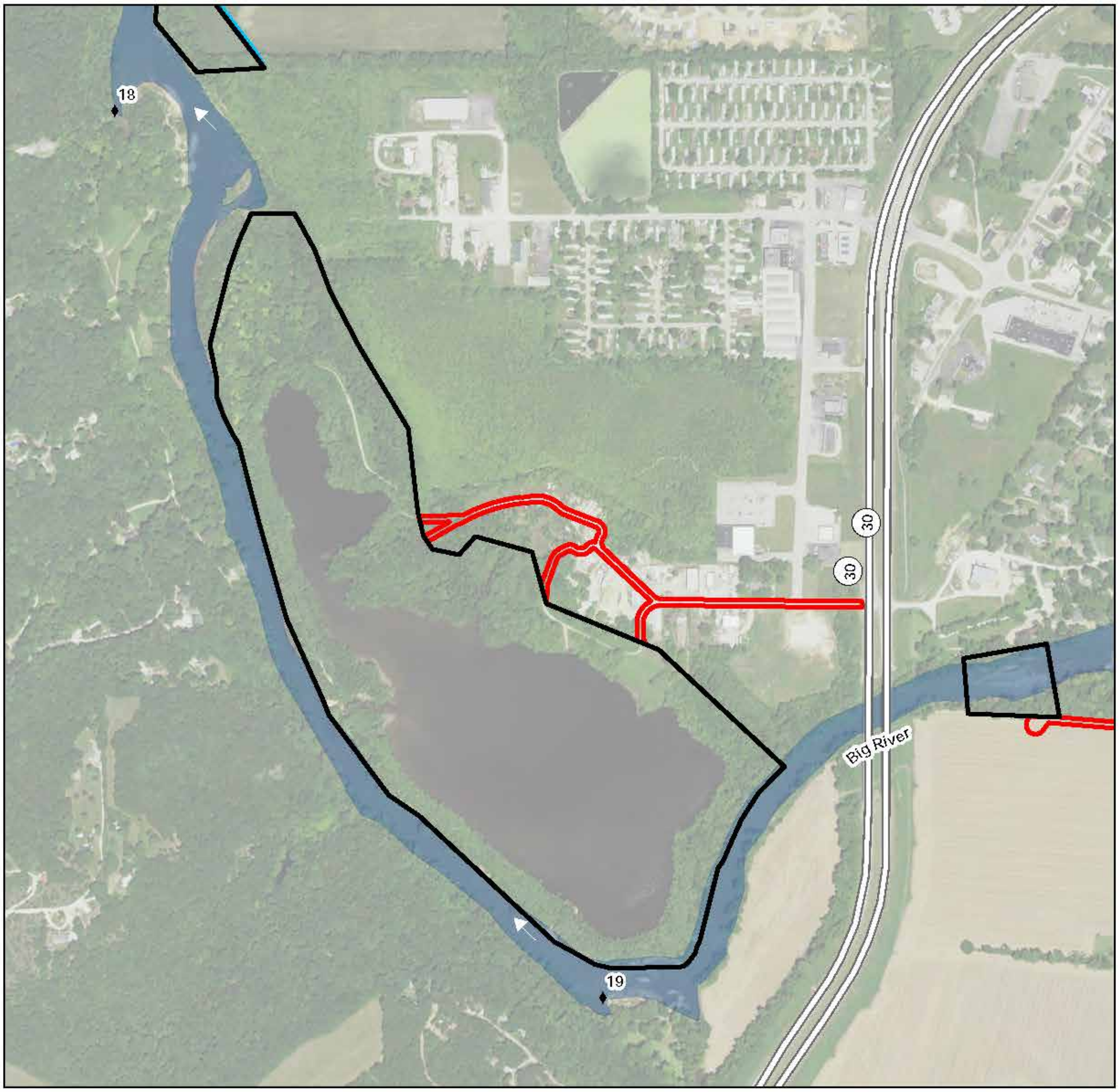

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 24 of 33
Bank Stabilization (21.0) - Big River
Big River
21
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

US Army Corps of Engineers
St. Louis District

Real Estate Maps

Map No. 26of 33

Sediment Basin (18.6) - Big River

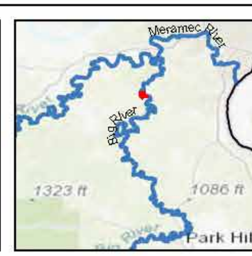


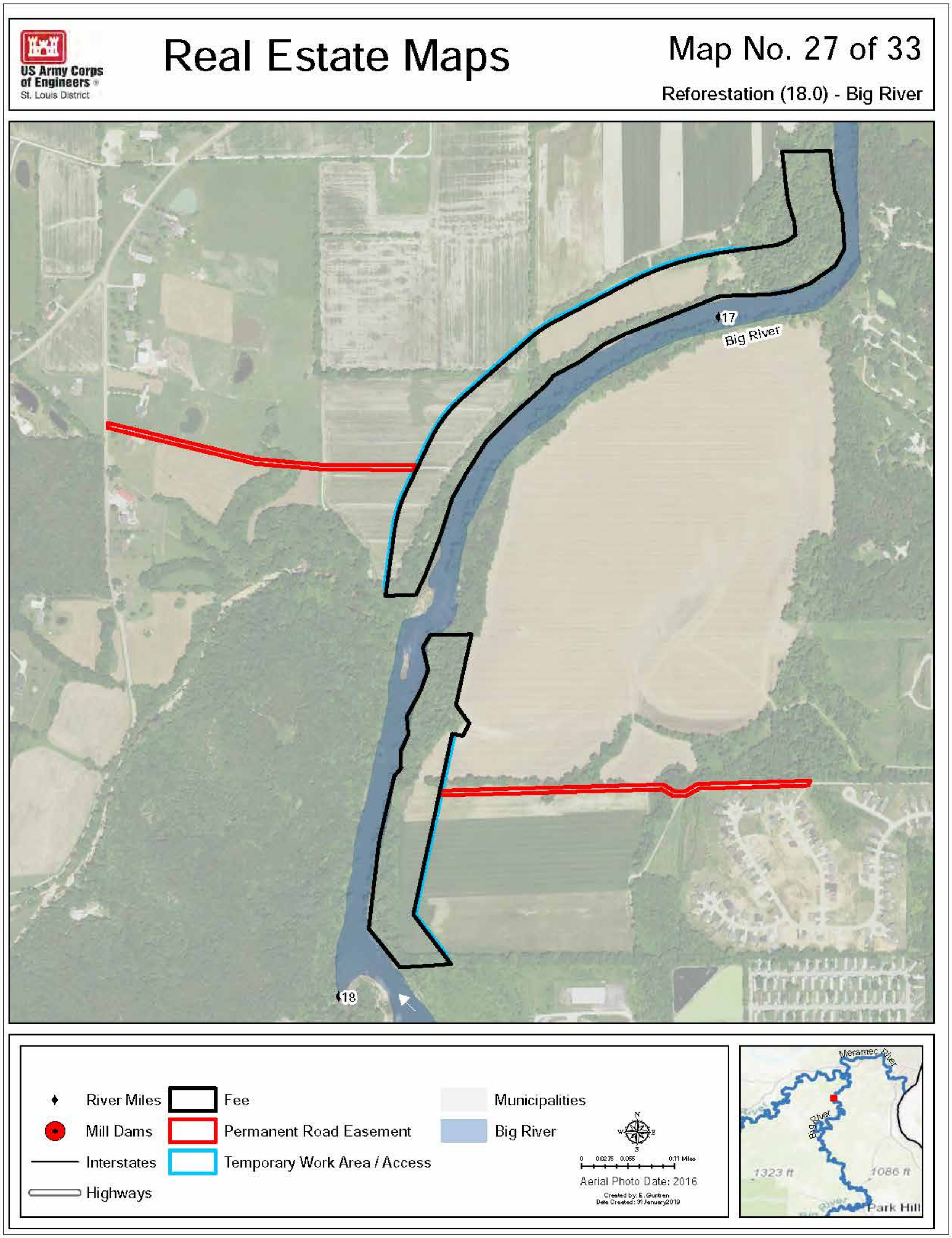
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River

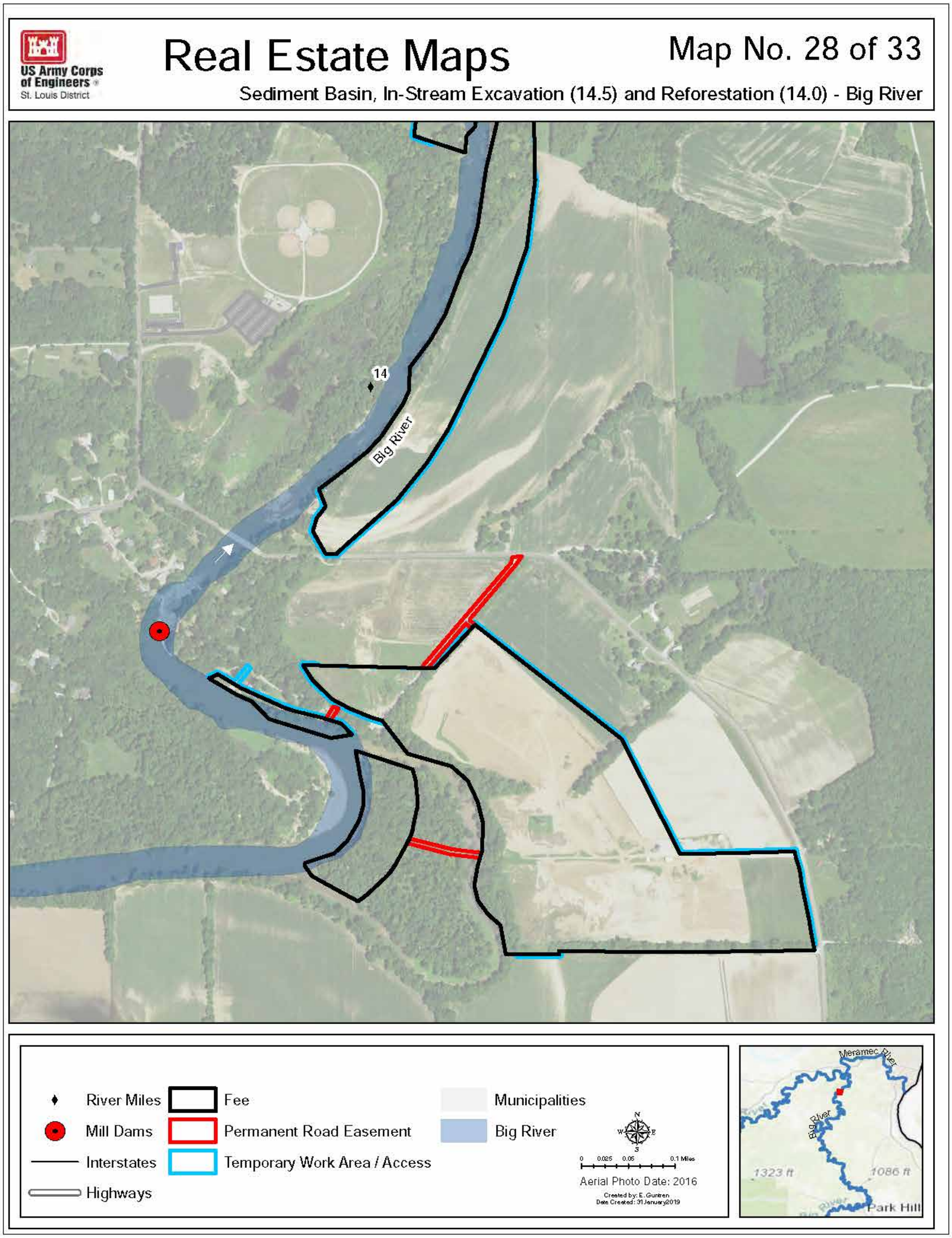
0 0.025 0.05 0.1 Miles

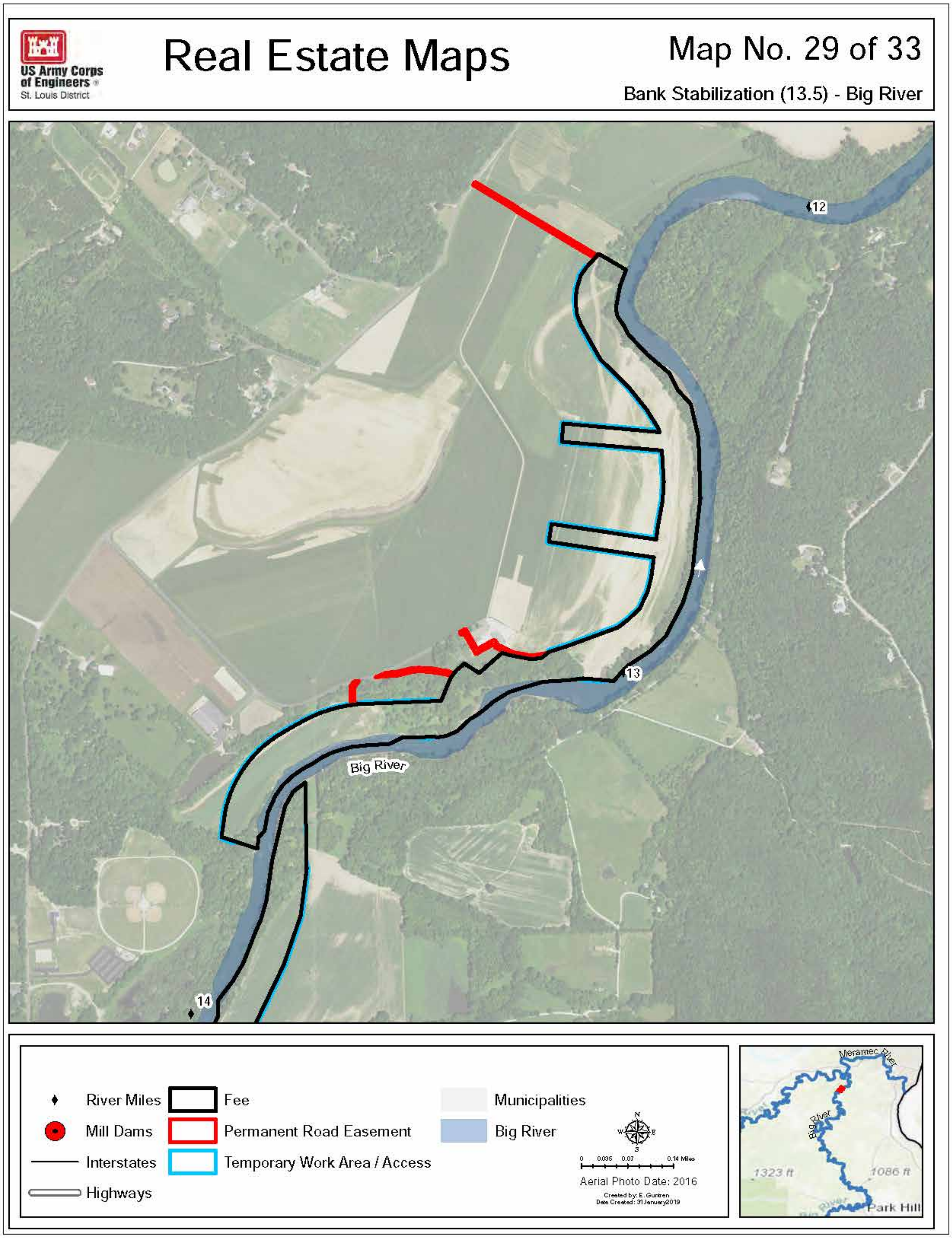
Aerial Photo Date: 2016

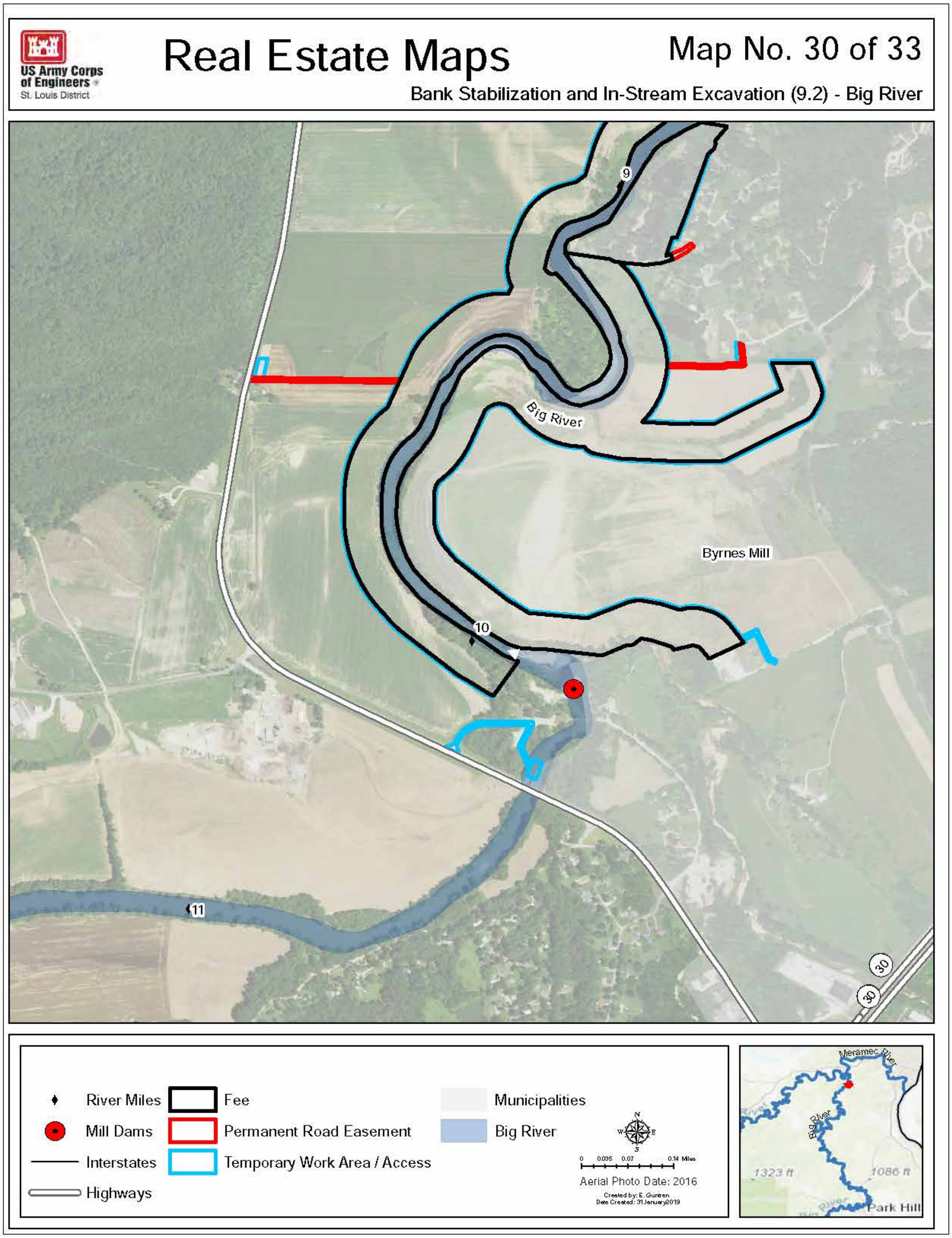
Created by: E. Guntren
Date Created: 31January2019

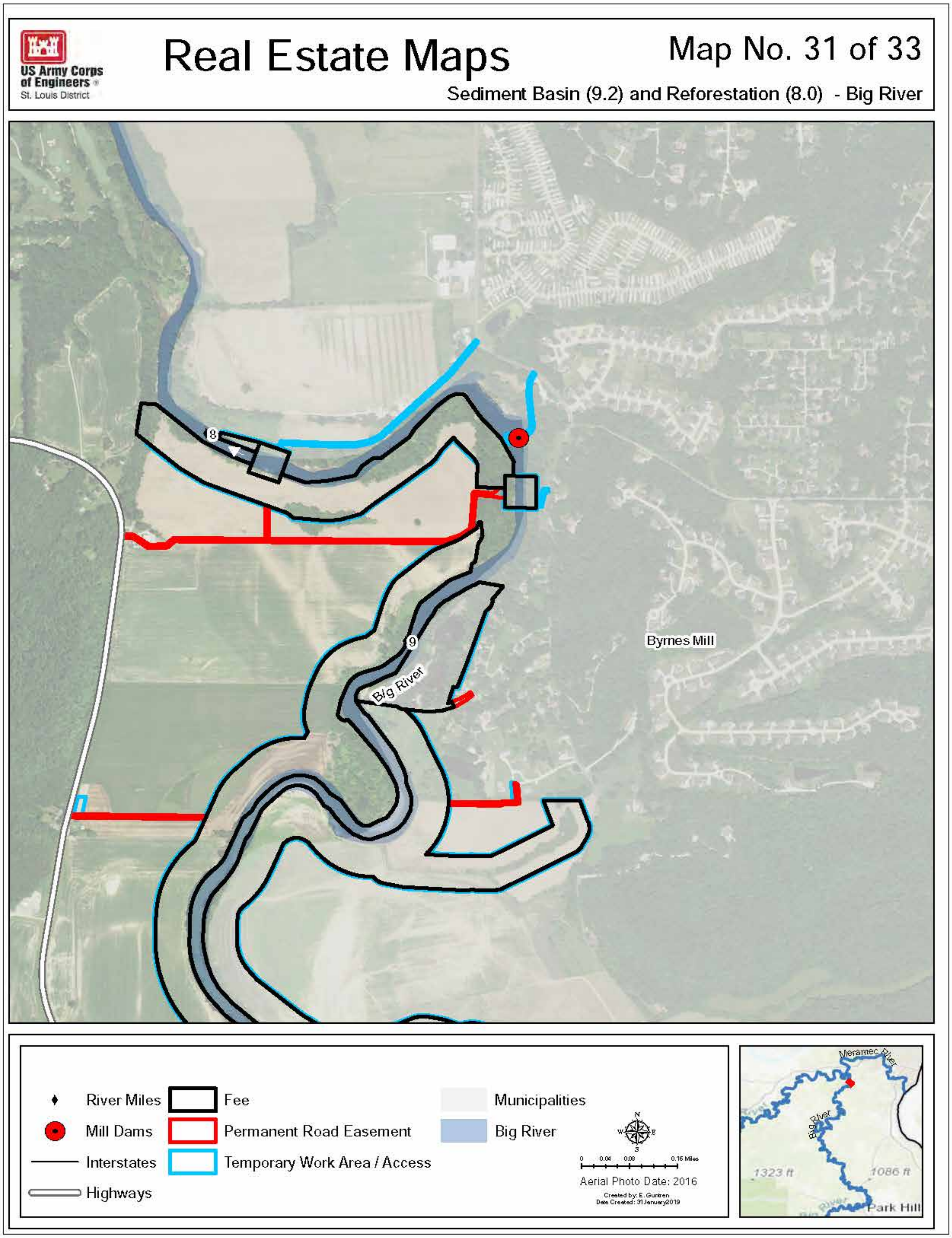


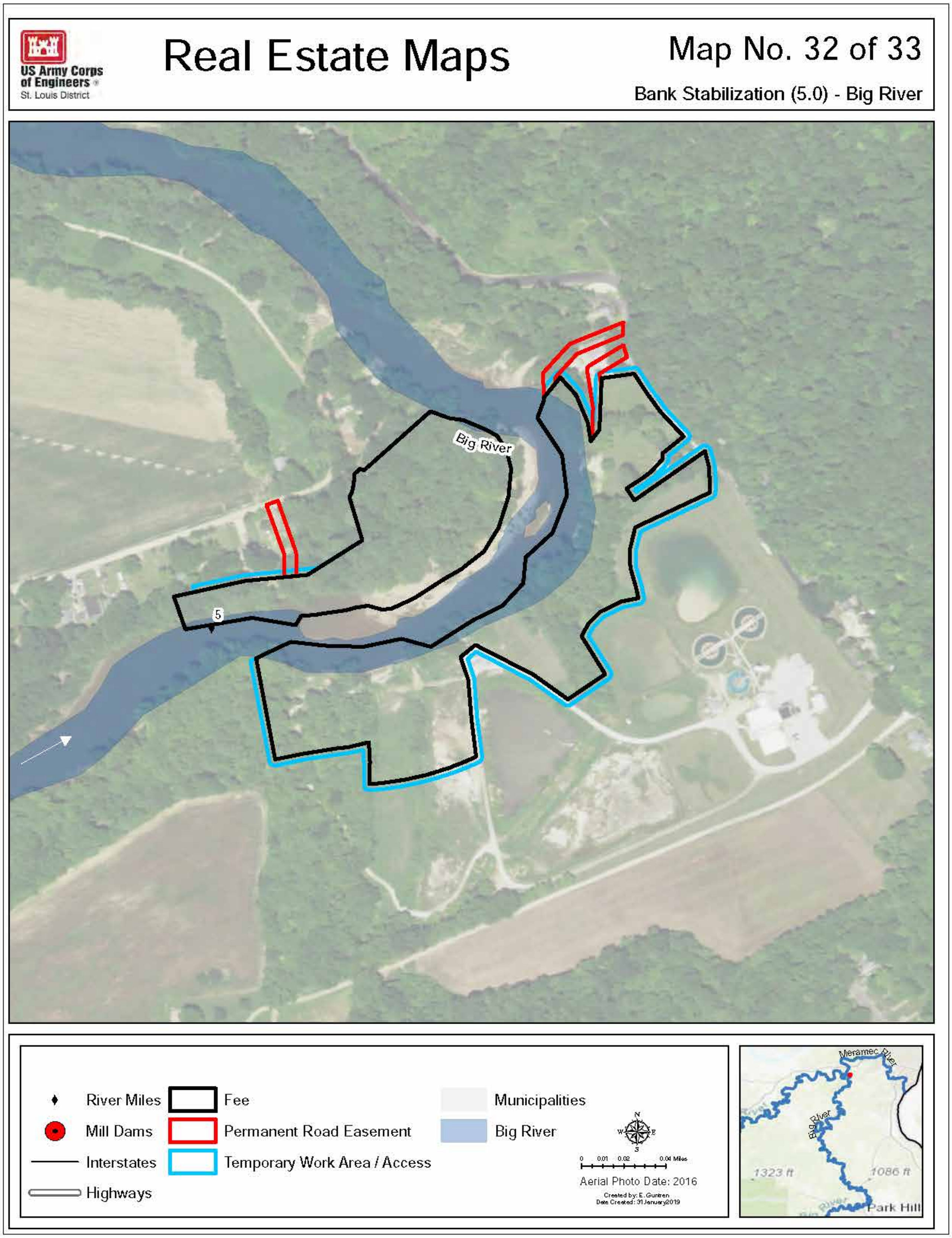

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 27 of 33
Reforestation (18.0) - Big River
17
Big River
18
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

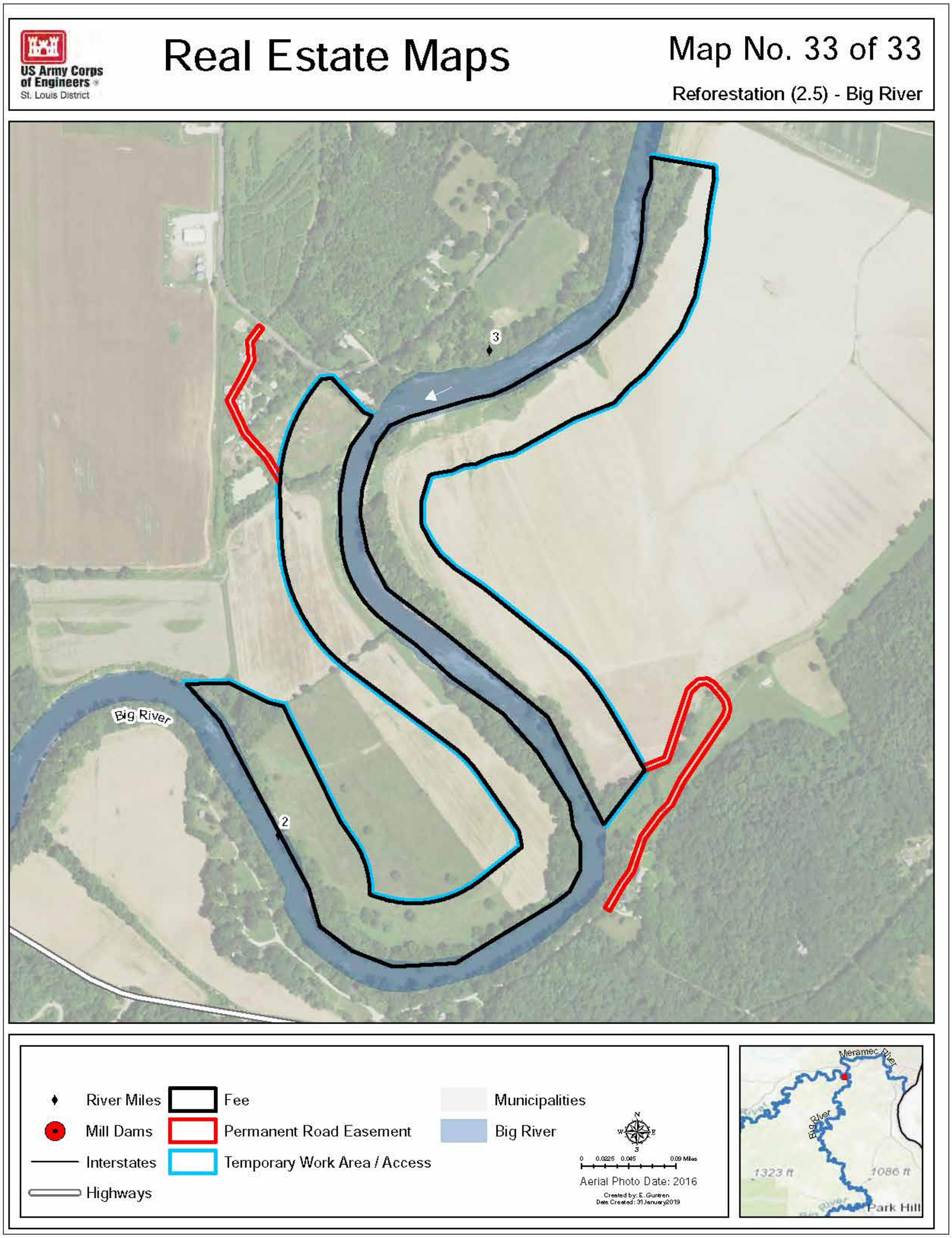

US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 28 of 33
Sediment Basin, In-Stream Excavation (14.5) and Reforestation (14.0) - Big River
14
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 29 of 33
Bank Stabilization (13.5) - Big River
12
13
14
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
0 0.035 0.07 0.14 Miles
Aerial Photo Date: 2016
Created by: E. Guntren
Date Created: 31January2019
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 30 of 33
Bank Stabilization and In-Stream Excavation (9.2) - Big River
9
Big River
10
Byrnes Mill
11
30
30
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 31 of 33
Sediment Basin (9.2) and Reforestation (8.0) - Big River
8
9
Big River
Byrnes Mill
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 32 of 33
Bank Stabilization (5.0) - Big River
Big River
5
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill


US Army Corps of Engineers
St. Louis District
Real Estate Maps
Map No. 33 of 33
Reforestation (2.5) - Big River
3
2
Big River
River Miles
Mill Dams
Interstates
Highways
Fee
Permanent Road Easement
Temporary Work Area / Access
Municipalities
Big River
Aerial Photo Date: 2016
Meramec River
Big River
1323 ft
1086 ft
Park Hill

DISCLAIMER – THIS DISCLAIMER MUST APPEAR IN THE REAL ESTATE PLAN

Cost Estimates are not appraisals, value conclusions from Cost Estimates are not intended to be utilized in approval decision, project authorization, or funding documents, except CAP projects. If Cost Estimates are used in decision or funding documents, the Project Managers, Realty Specialists, or other decision makers doing so need to confirm in writing that they understand the increased risks associated with using Cost Estimates in this manner.[1]

Allocated Cost Estimate - Summary Table[2]

RECONCILIATION		
Land Value		**Sum (Rounded)**
	Fee	$4,575,000
	Permanent Easements	$211,000
	Temporary Easements	$27,000
	Total Land Value	$4,813,000
Severence Damage (5% of Total Land Value rounded to nearest K)		$241,000
Incremental Costs (32.5% of Total Land Value rounded to nearest K)		$1,564,000
Total Land, Easements, Rights-of-Way		$1,805,000
Allocation of Acquisition Costs		
NFS - 152 landowners @ $12,500		$1,900,000
Federal - Administrative Costs (152 land owners @ $5,0000/owner)		$760,000
Total Acquisition Costs		**$2,660,000**
Total Non-Federal Project Costs		**$9,278,000**

Based on my sales analysis, the project locations and my understanding of the recommended plan, the final concluded cost estimate of the total project cost (TPC) is:

$9,278,000

[1] ER 405-1-04; Real Estate, Appraisal, 29 January 2016, Paragraph 4-17, Page 4-10

[2] The Summary Table of the Cost Estimate was updated to break-out (allocate) federal administrative costs and non-federal administrative costs per an 18 June 2019 email from James L Cole regarding HQ RE team comments of the Meramec Feasibility Study. The update of the table portrayed in this report is 2 July, 2019. For purposed of clarification, there is no change in value, no change in the date of value, and no change in date of the report.

EXHIBIT E
(ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE CAPABILITY)

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? Yes.
b. Does the sponsor have the power of eminent domain for this project? Yes
c. Does the sponsor have "quick-take" authority for this project? Yes
d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? No.

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of the Federal project including P.L. 91-646, as amended? No
b. If the answer to II.a. is "yes," has a reasonable plan been developed to provided such training?
c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? Yes
d. Is the sponsor's projected in-house staffing level sufficient considering its other workload, if any, and the project schedule? Yes
e. Can the sponsor obtain contractor support, if required in a timely fashion? Yes
f. Will the sponsor likely request USACE assistance in acquiring real estate? No

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? Yes
b. Has the sponsor approved project/real estate schedule/milestones? Yes

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? Yes
b. With regard to this project, the sponsor is anticipated to be fully capable. Yes

James T. Lovelace
James T. Lovelace
Realty Specialist

EXHIBIT F
(Risk Assessment Letter)

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

REPLY TO
ATTENTION OF

July 17, 2018

Real Estate Division
Acquisition and Planning Branch

SUBJECT: St. Louis Riverfront – Meramec River Basin Ecosystem Restoration Project – Project Real Estate Acquisition

Attn: Tim Rielly, Water Quality Coordinator
Division of Environmental Quality
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO
65102-0176

Dear Mr. Rielly:

The purpose of this letter is to inform the non-federal partner, Missouri Department of Natural Resources (MDNR), about the real estate requirements and the risks involved in acquiring real estate before the Project Partnership Agreement (PPA) is signed by the MDNR Ecosystem Restoration Project.

This project will require the acquisition of various real estate interests to support the design features. The procedures for acquiring real estate right-of-way in conjunction with Federal Programs are outlined in the Uniform Real Property Acquisition and Relocation Assistance Act, Public Law 91-646, as amended. The requirements for acquisition under this law have been discussed with the MDNR during the Feasibility Phase of the project. Detailed discussions will be held with the MDNR when final right-of-way requirements for the project are identified by the U. S. Army, Corps of Engineers, St. Louis District, Real Estate Division.

The St. Louis District is advising the MDNR of the potential risks associated with starting an acquisition program before execution of the PPA. Generally, these risks include but are not limited to, the following:

1. Congress may not appropriate funds to construct the proposed project.

2. The proposed project may otherwise not be funded or approved for construction.

3. A PPA mutually agreeable to the non-Federal partner and the Government may not be executed and implemented.

4. The non-Federal Partner may incur liability and expense by virtue of its ownership of contaminated lands, or interests therein, whether such liability should arise out of local, state, or Federal laws or regulations including liability arising out of the Comprehensive Environmental Response, Compensation, and Liability ACT of 1980, as amended (CERCLA).

5. The non-Federal Partner may acquire interests or estates that are later determined by the Government to be inappropriate, insufficient, or otherwise not required for the project.

6. The non-Federal Partner may initially acquire insufficient or excessive real property acreage which may result in additional negotiations and/or benefit payments under P.L. 91-646, as well as the payment of additional fair market value to affected landowners which could have been avoided by delaying acquisition until after PPA execution and the Government's notice to commence acquisition and performance of the Lands, Easements, Rights-of-Way, Relocations and Disposals (LERRDS).

7. The non-Federal Partner may incur costs or expenses in connection with its decision to acquire or perform LERRDS in advance of the executed PPA and the Government's notice to proceed which may not be creditable under the provisions of Public Law 99-662 or the PPA.

We look forward to working closely with you on this important project. If you have questions regarding this information, please contact James Lovelace at 314-331-8175.

Sincerely,

Jaclyn C. Wittenborn
Chief, Real Estate Division

U.S. Army Corps of Engineers

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

July 2019

Appendix L
Distribution List

(used for Public Review June 2018)

Intentionally Left Blank

Jefferson County Executive
Ken Waller
PO Box 100
Hillsboro, MO 63050

City of Eureka
The Honorable Mayor
Kevin Coffey
100 City Hall Drive
PO Box 125
Eureka, Missouri 63025-0125

City of Valley Park
The Honorable Mayor
Mike Pennise
320 Benton St.
Valley Park, MO 63088

City of Fenton
The Honorable Mayor
Josh Voyles
625 New Smizer Mill Road
Fenton, MO 63026

City of Kirkwood
The Honorable Mayor
Timothy E. Griffin
139 S. Kirkwood Road
Kirkwood, Missouri 63122

City of Arnold
The Honorable Mayor
Ron Counts
2101 Jeffco Blvd.
Arnold, Missouri 63010

City of Pacific
The Honorable Mayor
Jeffrey M. Palmore
300 Hoven Drive
Pacific, MO 63069

U.S. Environmental Protection Agency, Region 7
NEPA Implementation Section

U.S. Environmental Protection Agency, Region 7
Superfund Branch Chief
Gene Gunn
11201 Renner Blvd.
Lenexa, KS 66219
gunn.gene@epa.gov

U.S. Fish & Wildlife Service
Kevin Sommerland
5600 American Blvd. West
Suite 990
Minneapolis, MN 55437

U.S. Fish & Wildlife Service
Matt Mangan
8588 Route 148
Marion, IL 62959

U.S. Fish & Wildlife Service
Columbia, MO Ecological Services Field Station
c/o Dave Mosby
101 Park DeVille Drive, Suite A
Columbia, MO 65203-0057
Dave_mosby@fws.gov

U.S. Fish & Wildlife Service
c/o Bryan Simmons
bryan_simmons@fws.gov

USDA-NRCS
Karen Brinkman
Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, MO 65203-2546
karen.brinkman@mo.usda.gov

USDA Rural Development
Mike Hartman
michael.hartman@mo.usda.gov

USDA Forest Service

U.S. Economic Development Administration
Steve Castaner
1244 Speer Boulevard, Suite 431
Denver, CO 80204
scastaner@eda.gov

HUD Region VII
Bradley Streeter
bradley.e.streeter@hud.gov

National Park Service

ASTDR Region 7
c/o USEPA Region 7, Erin Evans
11201 Renner Blvd.
Lenexa, KS 66219
isb5@cdc.gov

U.S. Geological Survey
Missouri Water Science Center
Amy Beussink, Director
1400 Independence Road, MS-100
Rolla, MO 65401

Missouri Department of Natural Resources
St. Louis Regional Office
c/o Tracy Haag
7545 Lindbergh Blvd # 210, St. Louis, MO 63125
tracy.haag@dnr.mo.gov

Missouri Department of Natural Resources
CERCLA/OPA NRDAR
Eric Gramlich
P.O. Box 176
Jefferson City, MO 65102
eric.gramlich@dnr.mo.gov

Missouri Department of Natural Resources
Tim Rielly
Tim.rielly@dnr.mo.gov

Jefferson County Highway Division
Maple Street Annex
725 Maple Street, Room 104
Hillsboro, MO 63050
pworks@jeffcomo.org

Missouri Department of Transportation
St Louis Area District
1590 Woodlake Drive
Chesterfield, MO 63017

Missouri Department of Conservation
Matt Vitello
2901 W. Truman Blvd.
Jefferson City, MO 65109

Missouri Department of Conservation
Stuart Miller
PO Box 180
Jefferson City, MO 65102-0180
stuart.miller@mdc.mo.gov

United States Congress
The Honorable Senator
Claire McCaskill
503 Hart Senate Office Building
Washington, D.C. 20510

United States Congress
The Honorable Senator
Roy Blunt
260 Russell Senate Office Building
Washington, DC 20510

United States Congress
The Honorable Congresswoman
Ann Wagner
435 Cannon House Office Building
Washington, DC 20515

United States Congress
The Honorable Congressman
Blaine Luetkemeyer
2230 Rayburn HOB
Washington, DC 20515

Missouri Legislature
The Honorable Senator
Andrew Koenig
201 W Capitol Ave., Rm. 220
Jefferson City, Missouri 65101

Missouri Legislature
The Honorable Representative
Jean Evans
201 West Capitol Avenue, Room 405-A
Jefferson City MO 65101

Missouri Legislature
The Honorable Representative
David Gregory
201 West Capitol Avenue, Room 116-5
Jefferson City MO 65101

Missouri Legislature
The Honorable Representative
Shamed Dogan
201 West Capitol Avenue, Room 412-B
Jefferson City MO 65101

Mary Grace Lewandowski
East-West Gateway Council of Governments
1 Memorial Dr # 1600,
St. Louis, MO 63102
marygrace.lewandowski@ewgateway.org

Meramec Regional Planning Commission
c/o Tamara Snodgrass
4 Industrial Drive
St. James, MO 65559
tsnodgrass@meramecregion.org

Meramec River Restoration Association
David Wilson
david4wilson@gmail.com

Open Space Council
Kat Dockery
3115 S Grand Blvd #600
St. Louis, MO 63118
katherine@openspacestl.org

Great Rivers Greenway
Patrick Owens
6174 Delmar Blvd.
St. Louis, MO 63112
powens@grgstl.org

The Nature Conservancy
c/o Barbara Charry
Missouri Chapter Office
P.O. Box 440400
St. Louis, MO 63144

Sierra Club
Eastern Missouri Chapter
2818 Sutton Ave,
St. Louis, MO 63143

Izaak Walton League of America
President Illinois Division
55 Ridgecrest Drive
Decatur, IL 62521

Heartlands Conservancy
406 E. Main Street
Mascoutah, IL 62258

Audubon Center at Riverlands
Ken Buchholz
Center Director
301 Riverlands Way
West Alton, MO 63386

Great Rivers Habitat Alliance
PO Box 50014
Saint Louis, MO 63105

Missouri Coalition for the Environment
c/o Heather Navarro
3115 S. Grand Blvd., Ste. 650
St. Louis, MO 63118

World Bird Sanctuary
125 Bald Eagle Ridge Rd.
Valley Park, MO 63088

Washington University Tyson Research Center
6750 Tyson Valley Rd.
Eureka, MO 63025

St. Louis University
Jason Knouft
jason.knouft@slu.edu

City of Arnold
Jason Fulbright

City of Pacific
Alderman Ward II
Steve Myers
2102 Peace Pipe Road
Arnold, Missouri 63010
smyers@pacificmissouri.com

Doe Run Company
Jay Doty
jdoty@doerun.com

Metropolitan Sewer District

Missouri History Museum
David Lobbig
dl@mohistory.org

Missouri State Parks

Meramec Caverns
Judy Turilli
jat@fidnet.com

Jefferson County Water Supply #2
Steve Ratliff, Plant Manager
steve@pwsd2.con

Missouri American Water
Ed Bolden
eddie.bolden@amwater.com

St. Louis Post-Dispatch
900 N. Tucker Blvd.
St. Louis, MO 63101

Tribal Leaders and cultural representatives:
See Appendix A for distribution List

Private Citizens:
Available upon request

Residents:
Available upon request