3.1 INTRODUCTION

Chapter 3 describes the environment potentially affected by the Proposed Action and alternatives, and provides the basis for the impact assessment documented in Chapter 4. It begins with an overview of the Project area, and a discussion of how the river has been segmented for analysis purposes. Detailed discussions of the affected environment for each resource area listed below then follow:

- Geology and Geomorphology;
- Infrastructure;
- Navigation and Transportation;
- Water Resources;
- Aquatic Resources;
- Wetlands, Floodplains, and Terrestrial Resources;
- Federally Listed Species;
- Land Use and Recreation;
- Economics and Demographics;
- Noise;
- Visual and Aesthetic Resources;
- Cultural Resources; and
- Air Quality and Climate Change.

3.2 OVERVIEW OF PROJECT AREA

3.2.1 Introduction

This section describes the geographic setting of the proposed project and background information on the Missouri River, including the major uses of the river and the history of river channel modification and management. It also presents information on river bed degradation in the LOMR.

3.2.2 Geographic Setting

The Missouri River originates at the confluence of the Madison, Jefferson, and Gallatin Rivers near the City of Three Forks, Montana, and is the longest river in the United States. It flows southeast through, or on the boundary of, seven states joining the Mississippi River north of St. Louis, Missouri. The river is approximately 2,540 miles long, with a drainage basin of 524,110-square-miles (one-sixth the size of the United States). Over 12 million people live in the Missouri River basin, which is shown in Figure 3.2-1. In modern times, the Missouri River is generally described in two segments: the Lower Missouri River and the Upper Missouri River.

3.2.2.1 Upper Missouri River Basin

The Upper Missouri River basin comprises that portion of the river from its headwaters in western Montana to the present-day Gavins Point Dam in Nebraska. The upper basin drains approximately one-half of the river's total drainage basin and overlaps the states of Montana, Wyoming, North Dakota, South Dakota, Colorado, and Nebraska. Most prominent in the upper basin are six dams and reservoirs that are located in Montana, North Dakota, South Dakota, and Nebraska. These dams control, store, and regulate water from the upper portion of the river to the LOMR.

3.2.2.2 Lower Missouri River Basin

The LOMR is that portion of the river from Gavins Point Dam in Nebraska to the river's confluence with the Mississippi River. The LOMR forms the boundary between Nebraska and Iowa, Nebraska and Missouri, and Missouri and Kansas. In Missouri, it traverses the width of the state in a west to east direction, from Kansas City to its confluence with the Mississippi River approximately 50 miles north of

St. Louis, Missouri. Throughout its length, the LOMR is joined by a number of major and minor tributaries.

Numerous towns and cities are located along the LOMR. They include Sioux City, Omaha, St. Joseph, Kansas City, Jefferson City, and St. Charles. St. Louis is the largest major city associated with the Missouri River. Uses along the LOMR include power plants, industrial and commercial businesses, rail yards, marinas, municipal utilities, sand and gravel excavation and processing plants, public parks, and floating casinos.

The floodplain of the LOMR extends well beyond the main channel banks in many locations and is predominantly used for agricultural production, especially row crops. Numerous levees have been built parallel to the river to partially contain the extent of flooding. Roadways and rail crossings cross the river sporadically along its length.

Between Sioux City, Iowa and the Mississippi River, there are no dams or other navigational impediments along the mainstem of the LOMR. Maximum flows vary depending on channel dimensional characteristics, slope, and the configuration of control structures such as revetments, dikes, and channel modifications installed to maintain the navigational channel.

The upper section of the LOMR, just below Gavins Point Dam, contains sand bars, islands, backwater marshes, and meandering channels. This section of the river has experienced some channel degradation due to the capture of sediments in the reservoirs upstream of Gavins Point Dam. In addition, fixed boat docks occasionally encroach into channel areas. Deterioration of the channel and flood capacity occurs variably downstream of Omaha. Water pumping for agricultural and industrial uses also occurs in the upper section of the LOMR. In some locations, channel degradation affects water withdrawal points during low winter river levels. In the upper section of the LOMR, as well as in some other portions of the river, periodic ice flows can cause flooding due to restrictions of channel capacity. USACE-operated water control facilities and reservoirs located on tributaries of the Missouri River also affect flows in the upper section of the LOMR.

Flooding occurs periodically in the upper section of the LOMR. Flood flows greater than the 25-year flood event can potentially interrupt navigation on the river. Installation of the dams and the levee systems in the upper Missouri River (upstream of Gavins Point Dam) have helped reduce flooding frequency, extent, and damage in the upper section of the LOMR.

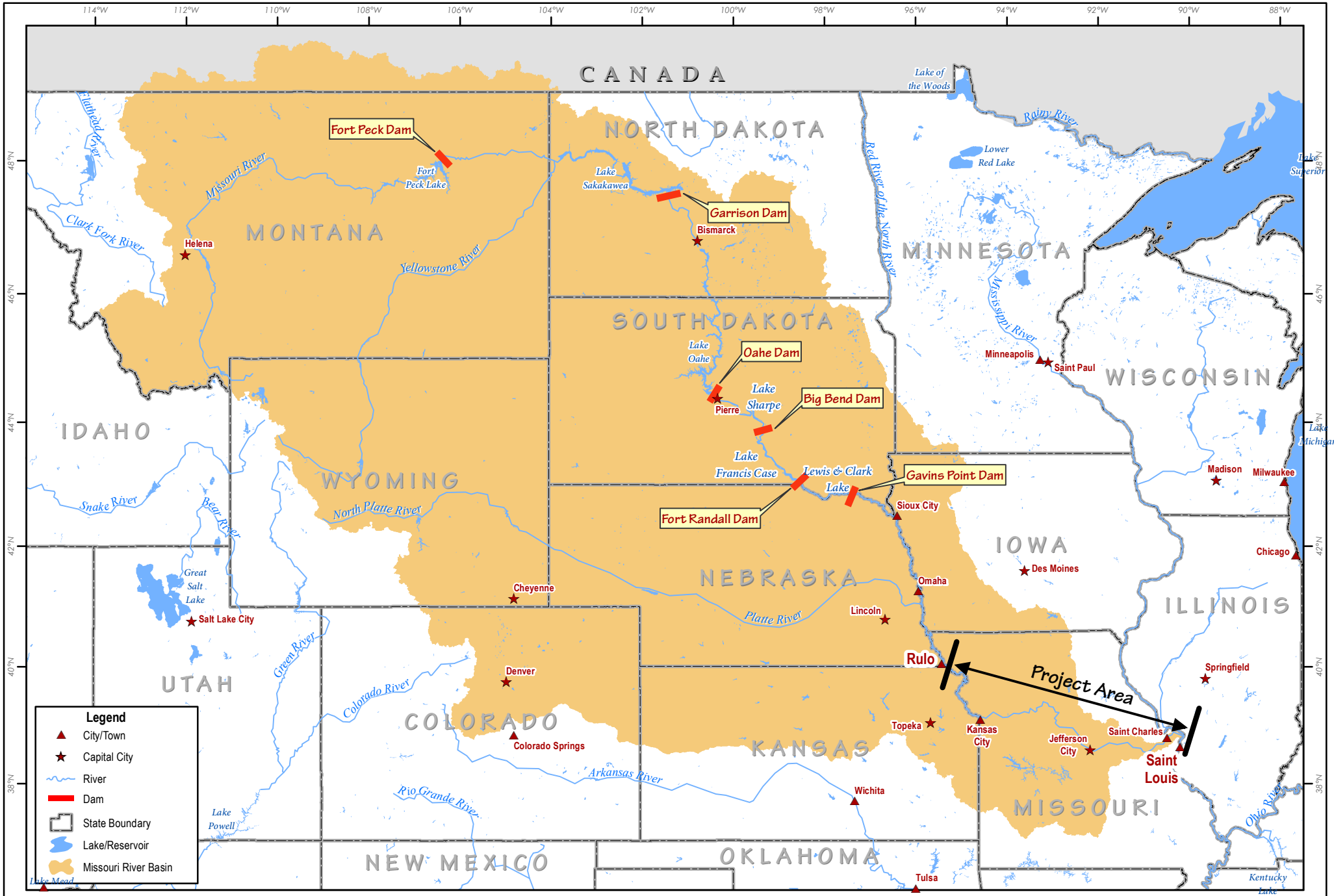

Figure 3.2-1
Missouri River Drainage Basin
Missouri River Commercial Dredging EIS

The lower section of the LOMR contains the BSNP, an extensive series of river control structures installed to maintain a self-scouring navigation channel that minimizes dredging as a necessary part of navigation channel maintenance (see Sections 1.5.1 and 3.2.4.2).

3.2.2.3 Tributaries to the Lower Missouri River

Major tributaries and their point of confluence with the LOMR include:

- Big Nemaha River (RM 495);
- Nodaway River (RM 462);
- Platte River (of Missouri, RM 391);
- Kansas River (RM 368);
- Big Blue River (RM 357);
- Little Blue River (RM 340);
- Grand River (RM 250);
- Chariton River (RM 239);
- Little Chariton River (RM 227);
- Lamine River (RM 203);
- Osage River (RM 130); and
- Gasconade River (RM 104).

Many other minor streams, rivers, and drainage channels connect to the river. Details of the major tributaries are provided in Section 3.4.3.

3.2.3 Major Uses of the Lower Missouri River

The LOMR is a major source of drinking water; industrial and agricultural irrigation water; commercial and recreational fishing, boating and other recreation; fish and wildlife habitat; and commercial sand and gravel production. In addition, the LOMR has been a major transportation network for passengers and freight, and is greatly affected by hydroelectric power production in the Upper Missouri River basin and in LOMR tributaries. The USACE must weigh each of these factors and others, including flood

control, when evaluating river management strategies or permit applications. The major uses of the LOMR include:

- Navigation, discussed in Section 3.6;
- Commercial sand and gravel production, discussed in Section 1.5.2;
- Recreation, discussed in Section 3.11; and
- Water supply, discussed in Sections 3.5 and 3.7.

3.2.4 Channel Modification

Since the 1930s, two major human-made modifications to the Missouri River have been constructed, resulting in significant change to the LOMR. These modifications include (1) construction of six dams on the upper river, which occurred between 1933 and 1963; and (2) construction of structures for the BSNP, which occurred between 1945 and 1981.

3.2.4.1 Upper Missouri River Dam and Reservoir Development

Dams were built on the upper portion of the river at six separate locations primarily to minimize flooding frequency and intensity. They were built in stages between 1933 and 1963 at the locations shown in Figure 3.2-1. In addition to providing flood storage, the dams include hydroelectric plants and produce electricity. The reservoirs above the dams are used for a variety of water uses (drinking water, crop irrigation, and industrial and commercial uses) and recreational purposes. Collectively, these six dam and reservoir projects comprise the Missouri River Mainstem Reservoir System and provide 73 million acre-feet of storage capacity. The hydroelectric power generating facilities located at each dam are operated by the USACE through the Missouri River Mainstem Reservoir System Master Water Control Manual (Master Manual) and, more specifically, the Missouri River Mainstem Reservoir Current Water Control Plan (CWCP), which is incorporated into the Master Manual.

The most upstream of the six dams, Fort Peck Dam, was authorized by executive order of President Roosevelt in 1933 and was later approved through the RHA of 1935. Fort Peck Dam was built first, with construction starting in 1933 and the embankment closing off the river in 1937. The Fort Peck Dam created Fort Peck Lake and is the largest hydraulically filled earthen dam embankment in the United States. The remaining five facilities were authorized and funded via the congressionally approved Flood Control Act of 1944 and are listed below:

- Garrison Dam (Lake Sakakawea): initiated in 1947, closure of the river occurred in 1953.
- Oahe Dam (Lake Oahe): initiated in 1948, closure of the river occurred in 1958.
- Big Bend Dam (Lake Sharp): initiated in 1959, closure of the river occurred in 1963.
- Fort Randall Dam (Lake Francis Case): initiated in 1946, closure of the river occurred in 1952.
- Gavins Point Dam (Lewis and Clark Lake): initiated in 1952, closure of the river occurred in 1955.

As with most major reservoir systems constructed and operated by the USACE, the reservoir system was designed and built to serve three purposes: flood control, hydropower production, and recreation.

- Flood control – The flood control capacity provided by the reservoir system's dams and lakes reduces the flow variability downstream and, therefore, the potential for damages due to floods that have historically occurred along the river. Flood control is accomplished by storing peak flows of the plains snowmelt and rainfall season from March through April, and the mountain snowmelt and rainfall period from May through July. In addition to lake storage and release, flood control mechanisms on the Missouri River include an extensive levee system (USACE 2004). A discussion of the change in historical flows that has occurred can be found in Section 3.4.4.
- Hydropower production – The greatest hydropower energy generation period extends from June through September, with peak load periods occurring in the winter heating season (December to mid-February) and the summer air-conditioning season (mid-June to early September) (USACE 2004). The reservoir system's 2.6 million kilowatts of hydroelectric generating capacity typically generates 10 billion kilowatt hours of electricity a year, although recent generation has been lower.
- Recreation – Recreational uses in the reservoirs include pleasure boating, fishing, water fowl hunting, riverbank hiking, and bird watching.

Operational practices for the reservoir system have always needed to balance the needs for flood protection, navigational reliability, hydropower generation, and industrial and municipal water uses with environmental concerns and maintenance of wildlife habitat. However, the passage of various federal laws such as NEPA, the ESA, and the NHPA, and various court rulings related to these laws has added additional factors to be considered and needs to be met in operating the reservoir system. The CWCP in the Master Manual sets specific guidelines for operation of the reservoir system (USACE 2006) and is discussed in further detail in Section 3.2.5.

3.2.4.2 Missouri River Bank Stabilization and Navigation Project

In 1912, the USACE began to construct the BSNP—a system of dikes to train and re-direct the river to an alignment engineered for the appropriate gradient for navigation and to prevent future channel movement; revetments to stabilize the banks; and other structures to direct flows in the LOMR, creating a self-scouring navigation channel. The BSNP structures were designed to direct river flows in order to prevent sediment accumulation in the main channel. The main goal of the BSNP was to provide a continuous open-river navigation channel, 9 feet deep and 300 feet wide, from Sioux City, Iowa to the Mississippi River—a distance of approximately 730 miles. The BSNP included substantial initial dredging; construction of over 2,000 dikes, revetments, and other structures; and shortening the river by closing off side oxbows and side channels. Although the channel was essentially completed in 1981, dredging to maintain navigational depths is occasionally still necessary when shoals develop, but the dredged material is generally not removed from the river system.

Water and ice flows can affect the river banks and flow channel. The BSNP also provides for the repair and stabilization of eroded or damaged banks in order to protect upland uses, water intakes, and other bank-located structures.

River Cutoffs

A number of projects to shorten the navigation distance in the LOMR were associated with construction of the BSNP. The extensive channel improvements in the river for navigational purposes resulted in numerous locations where new channels could be constructed to isolate meandering segments of the river into human-made oxbows or cutoff lakes. Many of these oxbows and lakes are cut off from the normal river flows by dikes on each end. The current hydrology of these areas differs substantially from historical conditions (USACE 2009a).

Navigational improvements also have resulted in isolation of side channels or smaller tributaries from the river. These areas essentially have become lakes. The contributions of water, nutrients, and sediments that were once sent to the Missouri River no longer occur, except during flood conditions.

Part of the recently implemented Missouri River Recovery Program (MRRP), discussed in Section 3.2.6.1, assesses the locations of cutoff areas and the potential benefits of reconnecting such areas into the normal flow of the river. These habitat restoration goals could contribute to improved fish and wildlife habitat.

River Bed Degradation in the Lower Missouri River

Construction of the BSNP facilities for navigational improvements has resulted in a deeper river with a single predominant channel. Flow is generally faster due to removal of meandering waterways and shallows. River banks contain more vegetation, and floodplains are primarily used for row crops.

Sediment loads in the LOMR have been substantially reduced due to upstream dams and reservoirs and stabilized banks. Upstream water capture in reservoirs also has changed the period and amounts of seasonal flows (USACE 2009a).

Construction and maintenance of the BSNP for barge traffic and navigational use has resulted in straighter and faster flows that tend to prevent sediment accumulation in the channel bottom. In addition, the dams and reservoirs in the upstream portion of the river trap large amounts of sediments that previously moved downstream with normal water flow. Commercial dredging operations have also removed sediment. As a result of these and other actions, degradation (lowering) of the river bed has occurred in the LOMR. Associated with bed degradation, average low-flow water surface elevations have dropped as much as 12 feet in some locations in the last 50 years. Dropping water levels have resulted in river bank erosion, impacts to operation of water withdrawals, tributary degradation and head-cutting, potential loss of stability of levees and bridges, and exposed navigational hazards. Erosion of stream banks can result in compromised use and value of adjacent riparian property; and the need to rebuild sophisticated intake structures at the river's edge belonging to municipal, commercial, and industrial water users.

Channel degradation also can affect fish and wildlife habitats. Receding sediments reduce nesting habitats for piping plover and least tern, and habitats suitable for various life stages of pallid sturgeon spawning (USACE 2009b, 2009c).

The USACE has identified several specific portions of the river with significant degradation. They include RM 50, RM 150, and RM 375. The USACE is considering specific actions to address the areas of most concern. A complete discussion of river bed degradation is included in Section 3.4.

3.2.5 River Operations and Management

Active management of the river by the USACE is associated with construction of the upper river dams and reservoirs, and the BSNP. This management includes plans for storage and release of water from the reservoirs and operation of flood control and BSNP structures to maintain navigation.

Prior to construction of the upstream dams and reservoirs, the typical annual flow regime would include a strong flood pulse beginning in March through April from rain and spring snowmelt from the Great Plains. A second pulse would normally occur from May through July from Rocky Mountain snowmelt and seasonal rainfall, which typically peaks in June. Flows then would decline through summer and fall. Lowest flows generally would occur in late December.

Active management of the river is guided by the CWCP. In enacting the 1944 Flood Control Act, Congress adopted the recommendations of the Pick-Sloan documents, which identified the purposes of the river management project (flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife). To study the balance of these functions for optimizing development and utilization of the river's water resources, the USACE prepared the Missouri River Master Water Control Manual Review and Update Study (Master Manual Study). The result of the Master Manual Study was identification of the CWCP. Chapter 7 of the current Master Manual (USACE 2006) describes the CWCP, which guides control and operation of the series of six dams in the upper river.

The CWCP specifies four zone designations for each dam and reservoir system, as follows:

- Permanent Pool Zones at each of the six reservoirs are intended to remain permanently filled with water and ensure the maintenance of minimum power heads, minimum irrigation diversion levels, and minimum reservoir elevations for water supply, recreation, and fish and wildlife purposes.
- Exclusive Flood Control Zones are reserved for regulating the largest floods and generally remain open and available for this purpose.
- Annual Flood Control and Multiple Use Zones are intermediate to the first two zones and provide (1) active storage for project purposes; (2) storage space for the control of moderate floods; and (3) when combined with the upper Exclusive Flood Control Zone, control of major floods.
- Carryover Multiple Use Zones are also intermediate to the first two zones and provide functions similar to those provided by the Annual Flood Control and Multiple Use Zones.

The CWCP attempts to restore some elements of natural variability of the pre-dam annual flow cycle by instituting pulsed flows in the spring. In approximately one out of every three years, the March pulse is designed to achieve as much as the 11th percentile of the pre-dam pulse magnitude and the May pulse is designed to achieve the 6-10th percentile of the pre-dam pulse magnitude (Jacobson and Galat 2008).

The reservoir system's water releases directly affect the LOMR flow rates and durations. The upper segment of the LOMR is more directly affected by the dam operations. The tributaries and side channel connections to the main river that flow into this upper segment of the LOMR lessen the effects of the reservoir system's release program the farther downstream one moves.

3.2.6 Environmental Evaluation and Restoration Projects/Programs

A number of major evaluation and restoration projects and programs have been completed or are in progress for the Missouri River, as described in the following subsections.

3.2.6.1 Missouri River Recovery Program

The MRRP is the most recent of a series of mitigation and habitat restoration efforts that have been implemented since construction and operation of the BSNP and mitigation projects that arose from the biological opinion for the Master Manual and its 2003 update (USFWS 2003). The USACE works in partnership with the USFWS and tribal nations, states, and other agencies to develop and implement recovery actions and recovery goals of the MRRP (MRRP 2010). These agencies define where changes or improvements might result in benefits to the river or the environment.

Missouri River Recovery Program Goals

The primary goals of the MRRP include creation of habitat (shallow-water habitat and emergent sandbar habitat), fish hatchery support, flow modifications, public involvement, and scientific studies (MRRP 2010). More than 50 sites for creation of shallow-water habitat or emergent sandbar habitat are currently under consideration (MRRP 2010). Sand bars and shallow-water, slow-velocity habitat is necessary for successful nesting, egg laying, hatching, and foraging for terns and plovers; and as nursery and refugia habitat for successful larval development of pallid sturgeon and other native fish (USFWS 2000).

The goal for the shallow-water habitat initiative is to establish 20–30 acres of shallow-water habitat per river mile prior to 2020 in order to support threatened and endangered, listed and candidate species, and other native species of concern (USFWS 2000). Shallow-water habitat is typically created by widening the river channel and restoring chutes and side channels. A portion of this work has already been completed, and habitat improvements have already shown positive biological results (USFWS 2000).

The goal for the emergent sandbar habitat initiative is to create 80 acres of sand bar per river mile by 2015. In January 2010, approximately 75 acres of sand bars per river mile had been constructed (MRRP 2010). Sand bars are generally not stable features but are formed, enlarged, moved, or eroded by the dynamic forces of the river. Stabilization of the Missouri River for navigation, hydropower, irrigation, and flood control has significantly increased stabilization in the river channel, resulting in stable sand bars that are unsuitable for nesting because of vegetation encroachment or are too low and subject to frequent inundation (USFWS 2000). Under the MRRP, sandbar habitat is typically created by mechanically building and maintaining sand bars and by clearing vegetation from existing sand bars.

Potential Sediment Contribution

The USGS has preliminarily estimated that, for a 700-mile stretch of river, approximately 37 million tons of sediment per year and 562 million tons of sediment over 15 years could be released through ongoing and reasonably foreseeable restoration projects (Jacobson et al. 2009). This estimate considers the different methods used to create the shallow-water habitat, the likelihood of projects to be carried out, and the goals set in the biological opinion for habitat restoration. The amount of sediment released from any particular restoration site would be small relative to current suspended sediment load over the duration of construction. The total sediment added to river from all sites over the projected 15-year time period of construction would be greater (as much as 62 percent of the current suspended-sediment load) but would be a transient pulse, diminishing after construction as the sites equilibrate to the prevailing sediment load of the river (Jacobson et al. 2009).

Missouri River Recovery Program Effects

Shallow-water habitat is created by mechanical excavation, which releases sediment into the river. Although sediment released into the river from restoration projects could potentially become available for dredging, the sediment contributed by such projects is unlikely to be predominately the size fraction that is desirable for dredging. Moreover, the addition of sediment to the river helps to create diverse aquatic habitats and to maintain sandbar and shallow-water habitat (USFWS 2000). Whereas sediment load resulting from construction of restoration projects may also increase turbidity, increased turbidity could benefit the pallid sturgeon and other turbid water specialized species (USFWS 2000).

Sediment releases into the Missouri River would likely benefit existing infrastructure, particularly in areas with high levels of degradation. Sediment aggradation enhances revetment protection and provides additional cover to near-exposed rock outcrops and buried pipelines.

The addition of large amounts of sediment into the Missouri River may negatively affect some biologic resources. Sediment aggradation in some areas may promote conversion of open-river habitat to undesirable lacustrine conditions and could eventually foster riparian forest growth if not maintained through continuing restoration efforts.

3.2.6.2 Biological Opinion

In 1989, the USACE initiated formal ESA Section 7 consultation with the USFWS on "Operations of the Missouri River Main Stem Reservoir System." In November 1990, USFWS issued a jeopardy biological opinion for the least tern (*Sterna antillarum*) and piping plover (*Charadrius melodus*) and a non-jeopardy opinion for the bald eagle (*Haliaeetus leucocephalus*). The pallid sturgeon (*Scaphirhynchus albus*), listed as endangered in late 1990, was not addressed by that biological opinion. In August 1994, the USFWS issued a draft biological opinion, which concluded jeopardy to the least tern, piping plover, and pallid sturgeon, and non-jeopardy to the bald eagle. Following the Flood of 1993, the USACE identified significant repair and maintenance work to flood-damaged training structures associated with the BSNP. Due to potential adverse effects on the pallid sturgeon in 1994, the USFWS requested that the USACE consult on the repair project. The USACE agreed to informal consultation on the project, including USFWS review and consultation on individual projects. In December 1998, the USACE provided the USFWS a biological assessment on the "Operations of the Missouri River Main Stem Reservoir System" and related "Operations of the Kansas River Tributary Reservoirs." In April 1999, the USACE also provided a biological assessment on "Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project." In a March 30, 2000 letter, the USACE requested that formal consultation on the three projects begin on April 3, 2000.

In 2002, the USFWS issued a biological opinion and amended it in 2003. The *USFWS 2003 Amendment to the 2000 Biological Opinion on the Operation of the Missouri River Mainstem Reservoir System Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project and Operation of the Kansas River Reservoir System* (2003 Biological Opinion) states that flora and fauna living in or along a river are often highly dependent on certain patterns of streamflow and habitat to ensure their sustainability. The USFWS believes that past management and regulation of the Missouri River, as well as changing hydrological patterns, have significantly adversely impacted the piping plover, the interior least tern, and the pallid sturgeon, as discussed above. The 2003 Biological Opinion outlined specific measures the USACE needed to take to recover these three endangered species (CDR Associates 2006).

3.2.6.3 Missouri River Fish and Wildlife Mitigation Project

The Missouri River Fish and Wildlife Mitigation Project was designed to mitigate fish and wildlife habitat losses that resulted from past channelization efforts on the Missouri River. Construction of the BSNP facilities and subsequent adaptation of the channel to increased flow rates and sediment deposition have impacted fish and wildlife habitat in the river corridor. Fish and wildlife populations have decreased, as well as the recreational opportunities they provide. In the early 1980s, the USACE Kansas City District completed a study of the feasibility of this mitigation project. The study was conducted under the authorization of the 1958 Fish and Wildlife Coordination Act (Public Law [PL] 85-624) and determined that mitigating fish and wildlife resources lost to construction of the BSNP project and enhancing fish and wildlife resources was economically feasible. In 1986, Congress authorized construction of the Missouri River Fish and Wildlife Mitigation Project (USACE 2003). The Missouri River Fish and Wildlife Mitigation Project has implemented numerous segment-specific mitigation and habitat enhancement measures within and along the river between Sioux City, Iowa and St. Louis (USACE 2003).

3.2.6.4 Missouri River Master Water Control Manual EIS

In March 2004, the USACE published the Missouri River Master Water Control Manual EIS. In 1990, the USACE undertook revision of the Master Manual, due in part to the ESA listings of the least tern, piping plover, and pallid sturgeon. The USACE objectives for the Master Manual have been to develop a CWCP that meets the contemporary needs of the basin; fulfills its responsibilities to Indian tribes; and complies with environmental laws, including the ESA. The Final EIS on the Master Manual stated that three features of the CWCP would be changed in the Master Manual to allow implementation of the Preferred Alternative identified in the Final EIS: drought conservation criteria, summer non-navigation service level, and reservoir system storage unbalancing (Kelly 2004).

3.2.6.5 Missouri River Recovery Implementation Committee

The USACE is exploring ways to encourage and support more collaborative approaches to water management challenges in the Missouri Basin. The USACE Record of Decision (ROD) on the Master Manual commits the USACE to initiate a comprehensive Missouri River Recovery Implementation Plan in order to restore the river's ecosystem and protect and recover threatened and endangered species. To explore the feasibility of implementing such a plan, the ROD specified that recovery actions will be implemented through coordination with a Missouri River Recovery Implementation Committee,

composed of a cross section of government entities and stakeholders, to ensure a comprehensive approach and broad-based support for recovery implementation (CDR Associates 2006).

3.2.6.6 Missouri River Ecosystem Restoration Plan and EIS

The USACE, in partnership with USFWS, is conducting a collaborative long-term study authorized by the Water Resources Development Act of 2007 (House of Representatives 2007). The study, known as the Missouri River Ecosystem Restoration Plan and EIS will identify the actions required to (1) mitigate losses of aquatic and terrestrial habitat; (2) recover federally listed species under the ESA; and (3) restore the ecosystem to prevent further declines among other native species. The intent of the study is to result in a plan that guides the USACE mitigation, restoration, and recovery efforts for the Missouri River for the next 30–50 years.

3.2.6.7 Federal Flood Risk Management Systems

The USACE established the Federal Flood Risk Management Program in 2006. Its purpose is to integrate USACE flood risk management programs and activities. The USACE coordinates with other agencies, such as the Federal Emergency Management Agency (FEMA); U.S. Department of Homeland Security; and other federal, state, and local agencies. The goal is to provide for comprehensive and sustainable national flood risk management, protect the public, and reduce flood damage.

As part of the program, the USACE performs several functions that relate to Missouri River floodplain management, including inventory and assessment of existing levees, assessment of potential public safety concerns related to deficient levee systems, assistance in flood mapping studies, participation in discussions relative to flood risk management, and development of policies (NFRMP 2010).

3.2.6.8 Missouri River Bed Degradation Study

The initial phase of the Missouri River Bed Degradation Study involved evaluation of the potential for federal interest in implementing solutions to water resources problems and opportunities related to river bed degradation in the lower 498 miles of the Missouri River. The necessary federal interest was demonstrated in the initial phase, allowing implementation of the reconnaissance phase.

The USACE Kansas City District prepared a Reconnaissance Report, which encompasses the geographic reach of the river from Rulo, Nebraska to the mouth of the river in St. Louis, Missouri. The purposes of the Reconnaissance Report were to examine existing data in order to determine the current condition and potential future condition of the river bed, and to look for opportunities to reduce river bed degradation and eliminate impacts. The USACE has determined through stream gage data and other physical data that the river bed has lowered. The river bed degradation has (1) affected public infrastructure, such as water intakes and pipeline crossings; (2) affected bank stability in certain areas; and (3) could potentially undermine dikes, revetments, and levees designed to support navigation and provide flood protection (USACE 2009a).

The Reconnaissance Report determined that there is a federal interest in implementing a feasibility study (USACE 2009a). Development of a project management plan and negotiating a feasibility cost-share agreement with non-federal partners for the next phase of study is currently ongoing.

3.2.6.9 Missouri River Authorized Purposes Study

Initiated in October 2009, the congressionally mandated Missouri River Authorized Purposes Study (MRAPS) co-led by the Omaha and Kansas City Districts of the USACE, will examine authorized purposes and current river infrastructure to identify options that may provide more multi-purpose benefits in terms of economic, ecosystem, socioeconomic and societal outputs. The study will analyze trade-offs and evaluate river management options within the context of current basin priorities. The result will be a comprehensive feasibility-type report and EIS for a USACE Chief's Report to Congress.

MRAPS also includes an extensive public involvement element. Involved stakeholders include the federal, state, and local agencies; tribal nations; businesses; interested stakeholder associations; farmers and landowners; environmental groups; recreation users; and others.

MRAPS will evaluate current interests and community values within the basin and identify opportunities for improvements to the Missouri River through research, analysis, and stakeholder input. MRAPS also will examine various alternatives and associated impacts on the following:

- Project infrastructure;
- Basin economics;
- Environmental quality;
- Public safety;

- Communities and social networks; and
- Other evaluation criteria that may be added during the study.

MRAPS will conclude with findings and recommendations, which will be provided to Congress (USACE 2009c).

3.2.6.10 Missouri River Recovery and Associated Sediment Management Study

The National Research Council (NRC) formed the Committee on Missouri River Recovery and Associated Sediment Management Issues to carry out the Missouri River Recovery and Associated Sediment Management Study. The committee members are scientific experts in water, ecology, chemistry, and soil, are not affiliated with the USACE and come from various universities, state agencies, federal agencies, and non-governmental organizations. The study is an independent, unbiased, and comprehensive study of sediment in and from the Missouri River basin. Issues associated with Missouri River basin sediment influence water management decisions throughout the greater Mississippi River watershed and extend as far as the Louisiana coast and the Gulf of Mexico. Effects also reach upstream to the river's headwaters in Montana and downstream to its mouth north of St. Louis. Specific questions addressed in this study include the following:

1. How and why is sediment a significant variable in the environmental restoration of a river system like the Missouri River?
2. What is the significance of the Missouri River sediments to the Gulf of Mexico hypoxia problem?
3. What is the significance of the Missouri River sediments to the restoration of Louisiana coastal wetlands?
4. What are the key environmental and economic considerations regarding nutrient loads and/or contaminants in Missouri River sediment? To what extent can such issues be addressed with management strategies?
5. Are there long-term consequences to the lack of sediment in the system to the human environment, either environmentally or economically?
6. Are there alternatives for reintroducing sediment into the system? What are they and what are the key constraints surrounding these alternatives?

7. Are current USACE management strategies, restoration tools (e.g. channel widening and creation of chutes and shallow-water habitat), and other activities adequate and sufficiently comprehensive to address issues associated with sediment and nutrients in the system? If not, how might such strategies and activities be improved?

Although the USACE is sponsoring the study, which began in March 2008, they are not directing or controlling it. Completed between the publication of the DEIS and the FEIS, key conclusions of the NRC (2010) Report are integrated in the following sections.

3.2.7 References

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3.3 SEGMENTATION OF THE LOWER MISSOURI RIVER

Due to the length of the river being considered for dredging permits, a means of dividing the river into manageable units was needed. The LOMR from Rulo, Nebraska to St. Louis, Missouri includes diverse environmental conditions and considerable variations in land uses encompassing rural and urban areas. In addition, there is considerable variation in historical dredging operations and in supply from major tributaries. Finally, there are limited locations where sufficient hydrologic and sediment data have been collected to allow computation of sediment bed load estimates.

Of primary importance in evaluating the Proposed Action and alternatives is the potential for contributing to or exacerbating river bed degradation and how that degradation may affect various aspects of the natural and human environment. The two most important factors for segmenting the LOMR were (1) the limited number of locations where data are available to calculate sediment loads in the river; and (2) the number and location of major tributaries contributing additional sediment load to the river. Segment boundaries were established at major tributaries: Kansas River (RM 367.5), Grand River (RM 249.9), and Osage River (RM 129.9). Physical parameters such as bedrock geology, slope breaks, tributaries, width of the alluvial floodplain, and USGS gage locations were reviewed to refine the segment boundaries.

During the river segmentation process, it was recognized that the confluence of the Kansas and Missouri Rivers at Kansas City created a special circumstance. The Kansas River joins the LOMR in the heart of Kansas City, bisecting both the urbanized area and the area with the most observed channel degradation within the Project area. To better analyze issues specific to the Kansas City area, an additional segment was created by selecting tributaries upstream and downstream from the Kansas River, creating the Kansas City segment. The upstream tributary is the Platte River (Missouri) at RM 391.1, and the downstream tributary is the Big Blue River at RM 356.9.

Five segments were used to compute sediment bed loads in the river, to describe the existing environment in those segments when possible, and as a basis for the impact analysis. The segments are described in Table 3.3-1 and are shown in Figure 1.3-1. Analysis segments were named after a major urban area within the segment.

Table 3.3-1 Description of River Segments Used in the Analysis

Segment	Upstream Boundary (river mile)[a]	Downstream Boundary (river mile)[a]	Length (miles)
St. Joseph	Rulo, Nebraska (498)	Platte River (391.1)	106.9
Kansas City	Platte River (391.1)	Big Blue River (356.9)	34.2
Waverly	Big Blue River (356.9)	Grand River (249.9)	107
Jefferson City	Grand River (249.9)	Osage River (129.9)	120
St. Charles	Osage River (129.9)	Confluence with Mississippi River (0)	129.9

[a] River miles are from USACE spreadsheet MissouriR_RM_1890_1930_1960.xls.

3.4 GEOLOGY AND GEOMORPHOLOGY

3.4.1 Introduction

The nature of the Missouri River system has changed dramatically during the 20th century. This change has resulted from many factors, including construction of upstream dams along the river system and construction of the BSNP by the USACE. Prior to these changes, the Missouri River comprised a wide, braided, sediment-laden river that at times extended up to 5 miles across the floodplain during flood events. After these physical changes, the river was converted to an approximately 600-foot-wide navigation channel designed to efficiently convey river traffic and require little maintenance dredging.

The USACE has permitted commercial dredging in select areas within the active river channel. In its 2006/2007 dredging permit decision (see Section 3.2.6), the USACE determined that geomorphologic river bed degradation has occurred along major portions of the LOMR. The river bed degradation identified by the USACE has lowered water levels, undermined certain revetments, and left some municipal water intakes above the waterline at low flows. While these and other impacts to infrastructure have not yet been widespread, evidence gathered to date indicates that river bed degradation has occurred over extensive portions of the river and that it may continue. River bed degradation can produce widespread effects on the ecology of the river by changing the water depths of in-river habitats and the water table and water surface elevations in adjacent floodplains. It has been determined that several tributaries to the Missouri River are experiencing headcuts and erosion due to river bed degradation in the mainstem LOMR (USACE 2009a).

This section of the EIS provides an assessment of the existing condition of river bed degradation in the LOMR based on the interaction of anthropogenic and natural factors. This assessment can be used to determine a sustainable level of annual river bed dredging in key river reaches. These sustainable dredging levels can be used to compare potential river bed degradation impacts associated with the Proposed Action and a set of alternatives to that action as determined by the USACE.

3.4.2 Geologic Setting

The geologic history of the Missouri River provides a framework for understanding the modern geomorphic characteristics of the river system. For much of the length of the LOMR, the present-day Missouri River flows in a bedrock valley that was initially carved by glacial-fed rivers and outburst floods, and subsequently filled by glacial till and outwash alluvium from successive episodes of glaciations (Colgan 1999). After the final glacial recession, the river naturally migrated between the

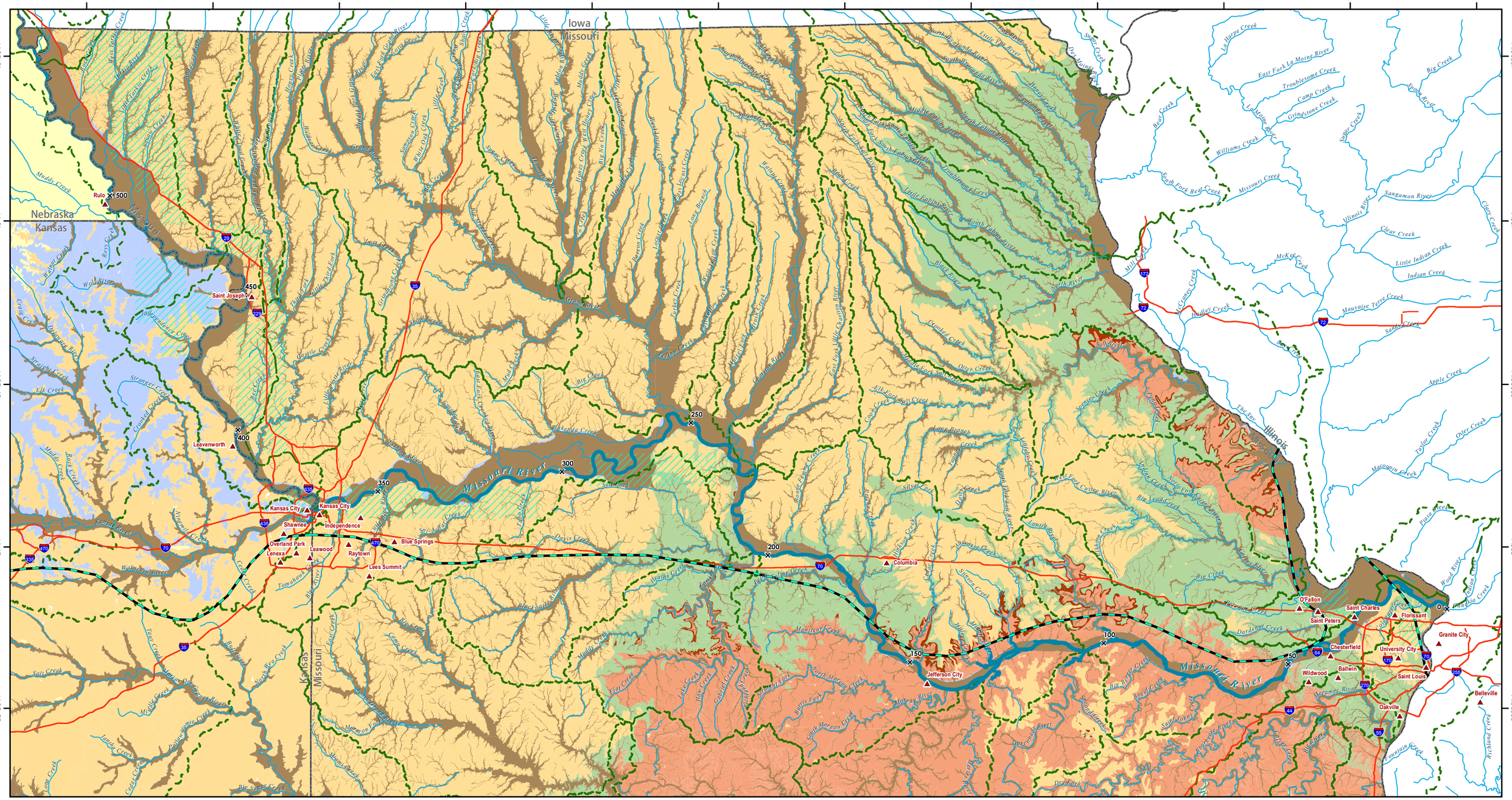
river valley walls with much less erosive power than when glacial melt waters carved the landscape. Although the modern LOMR no longer shifts its main channel side-to-side in the river valley because it is confined by engineering structures built over the past century, it still erodes the unconsolidated sand and gravel deposits that fill the river valley and make up the river bed.

3.4.2.1 Bedrock Geology and Valley Widths

Bedrock underlying the LOMR valley influences the width of the river valley bottom, the number of rock outcrops along the river, and the composition of coarse material found in the river. Key features of the LOMR valley geology relevant to river bed degradation are shown in Figure 3.4-1, including bedrock geology; the maximum extent of glaciations; post-glacial valley-bottom alluvial deposits; and glacially-derived, wind-deposited loess units. At approximately RM 250, a change in valley bedrock geology occurs, from softer and more erodible bedrock in upriver areas to harder and less erodible bedrock downriver from that point. This bedrock geology, in combination with the physical effects of past glaciations, influenced the width of the river valley and the dimensions of the natural floodplain prior to human modifications.

Bedrock Control on Valley and Floodplain Widths

Downriver from Rulo (RM 498), the bedrock transitions from Late Pennsylvanian-age (320 to 280 million years before present [BP]) and Mississippian-age (345 to 320 million years BP) limestones, cherts, and dolomites around RM 250 to Ordovician-age (500 to 425 million years BP) dolomites and sandstones near RM 226 (Figure 3.4-1). Outcrops near the river in the Jefferson City area consist of Ordovician-age dolomites and sandstones. Near the confluence of the Missouri and Mississippi Rivers, geologic outcrops consist of Pennsylvanian-age sandstone and limestone, Mississippian-age limestone and shales, and nearby occurrences of Ordovician-age dolomites and limestones (St. Louis County Department of Planning 2006). In general, the strata are not significantly deformed and dip gently to the north and west (Colgan 1999). Quaternary-age deposits consist of glacially deposited till, drift, and alluvium and extensive deposits of loess—a fine, wind-deposited silt (Gentile et al. n.d). The historical floodplain of the Missouri River has extensive fine sand and silt deposits.



1:1,600,000

0 10 20 30 40 50 Miles

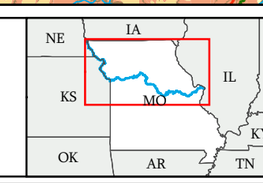
0 25 50 75 Kilometers

Legend

- River Mile
- City/Town
- Interstate Highway
- Southern Extent of Glaciation
- Watershed Boundary
- Alluvium
- Loess (>16' thick)
- Ordovician
- Silurian-Devonian
- Mississippian
- Pennsylvanian
- Permian/Mesozoic/Tertiary
- Quaternary

Figure 3.4-1
Geologic Setting

Missouri River Commercial Dredging EIS



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Map Projection: Mercator, WGS84

Table 3.4-1 lists the average valley widths, and Figure 3.4-2 shows the valley bottoms for each segment. (Figure 3.4-2 also shows other features that are discussed in later sections.) The upper end of the St. Joseph segment near Rulo, Nebraska is one of two areas where the river valley widens significantly. The other is in the Waverly segment. Below Rulo, Nebraska, the LOMR valley narrows toward the Kansas City segment (2.75 miles wide) and then widens downriver toward the Waverly segment (6.5 miles wide). Portions of the Kansas City metropolitan area lie in the valley bottom near the confluence of the Missouri and Kansas Rivers. An extensive system of federal levees and floodwalls protects this low-lying area from flooding (Figure 3.4-2, Kansas City Segment, Sheet 2).

Table 3.4-1 Average Valley Widths of the Lower Missouri River

Segment	Average Valley Width (miles)
St. Joseph	3.46
Kansas City	2.75
Waverly	6.50
Jefferson City	2.85
St. Charles	2.84

In the Waverly segment between the Little Blue River (RM 340) and Glasgow, Missouri (RM 266), the LOMR flows through softer bedrock; consequently, it has a comparatively wide valley (5–18 miles) (USACE 2004). Below Glasgow, in the Jefferson City segment, the LOMR enters more resistant bedrock, and the valley narrows to an average of 2.8 miles through the St. Charles segment until it emerges into the Mississippi River Valley at approximately RM 25. The more resistant bedrock below Glasgow tends to control the channel and valley morphology (Figure 3.4-1) (Spooner 2001). Because of the narrower river valley, more development occurred on the bluffs of the river valley rather than in the floodplain, therefore, less infrastructure and engineering structures such as federal levees are in the valley bottom below approximately RM 226.

Bedrock Outcrops and Coarse Substrate Patches

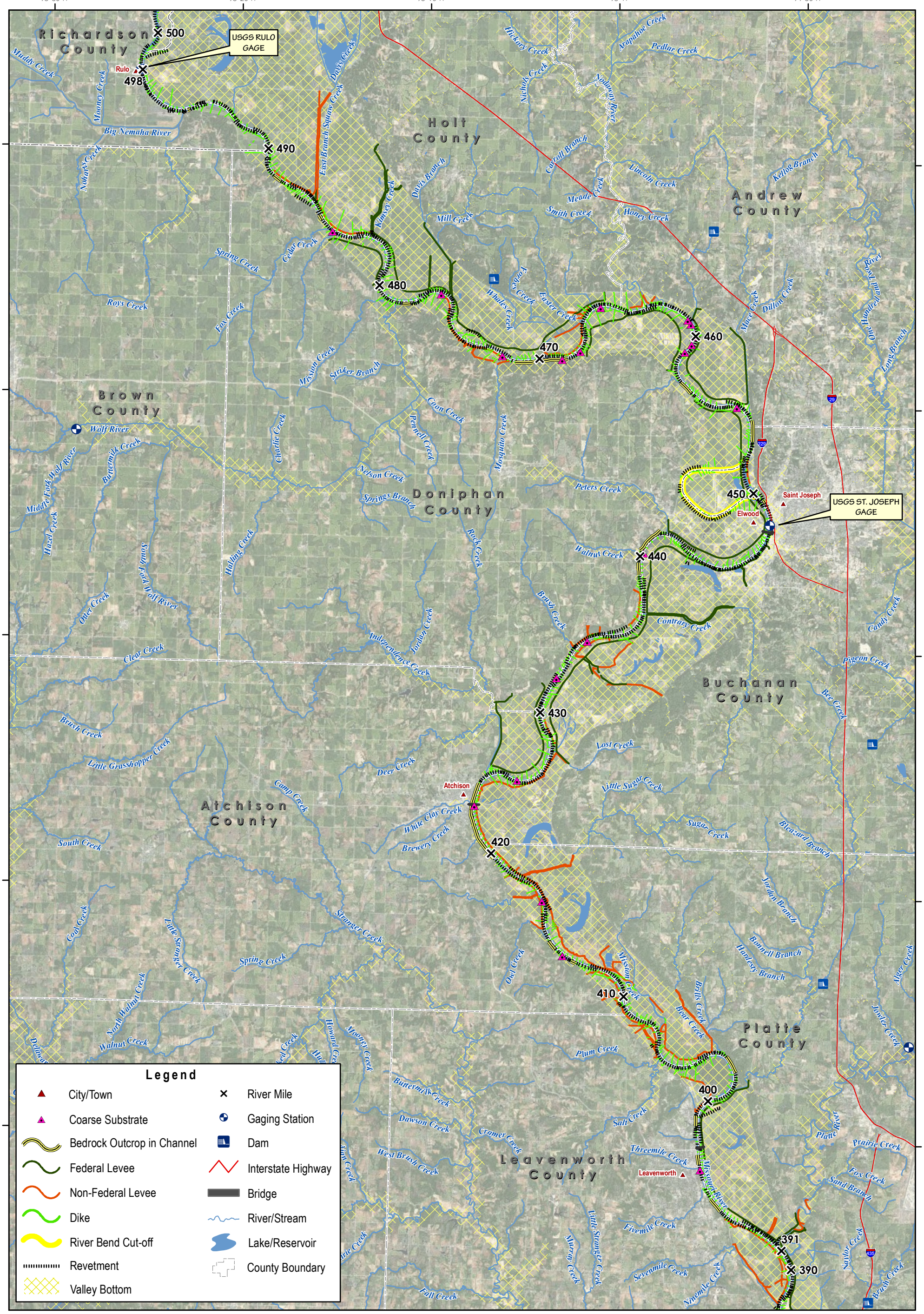
Figure 3.4-2 shows the locations of bedrock outcrops and coarse substrate patches in the river channel that were mapped as part of a study on pallid sturgeon habitat (Laustrup, Jacobson, and Simpkins 2007). Bedrock outcrops are solid bedrock exposures in the river bank that constrain the river. Coarse

substrate patches are areas greater than 1,076[1] square feet with coarse material (defined by the authors of the study as material ranging from 2 millimeters [mm] to 4 meters [m]). Coarse substrate patches are composed of colluvial deposits from hill slopes, alluvial fan deposits from tributary inputs, glacial drift or till deposits, channel bars formed from transported coarse sediment, and constructed enhancement projects (Laustrup, Jacobson, and Simpkins 2007). These areas may be important as aquatic habitat and resistant to erosion. Table 3.4-2 lists the length of bedrock outcrops and the number of coarse substrate patches by segment in the LOMR. The lower segments on the LOMR have more bedrock outcrops and coarse substrate patches than the higher segments. The increasing bedrock exposure and coarse material in the river are likely due to the constrained nature of the lower valley, the harder bedrock underlying the valley, and possibly inputs of coarse material from the Ozark Plateau from the south. Coarse substrate patches between Kansas City and Rulo are predominantly comprised of material originally placed as engineered structures, such as dikes, that subsequently eroded or were dismantled and left in the river (Laustrup, Jacobson, and Simpkins 2007). These substrate patches are identified as "engineered deposits."

Table 3.4-2 Bedrock Outcrops and Coarse Substrate Patches in the Lower Missouri River

Feature	St. Joseph	Kansas City	Waverly	Jefferson City	St. Charles
Bedrock Outcrops (miles)					
Left bank	2.3	0.4	0.1	7.6	15.1
Right bank	13.1	1.1	7.7	27	24.9
Average for segment (mile/mile)	0.14	0.04	0.07	0.29	0.31
Coarse Substrate Patches (count)					
Left bank	0	3	2	9	26
Channel bar	6	8	3	19	17
Right bank	14	1	2	19	28
Average for segment (count/mile)	0.19	0.35	0.07	0.39	0.55

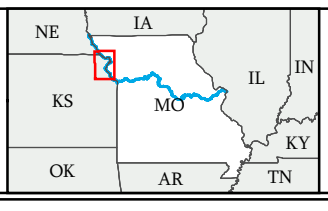
[1] The patch size was based on a minimum patch size of 100 square meters used in Laustrup, Jacobson, and Simpkins (2007).



0 5 Miles
0 5 Kilometers

Figure 3.4-2
Geomorphic Features of the
Lower Missouri River by Segment
Sheet 1 - St. Joseph Segment

Missouri River Commercial Dredging EIS



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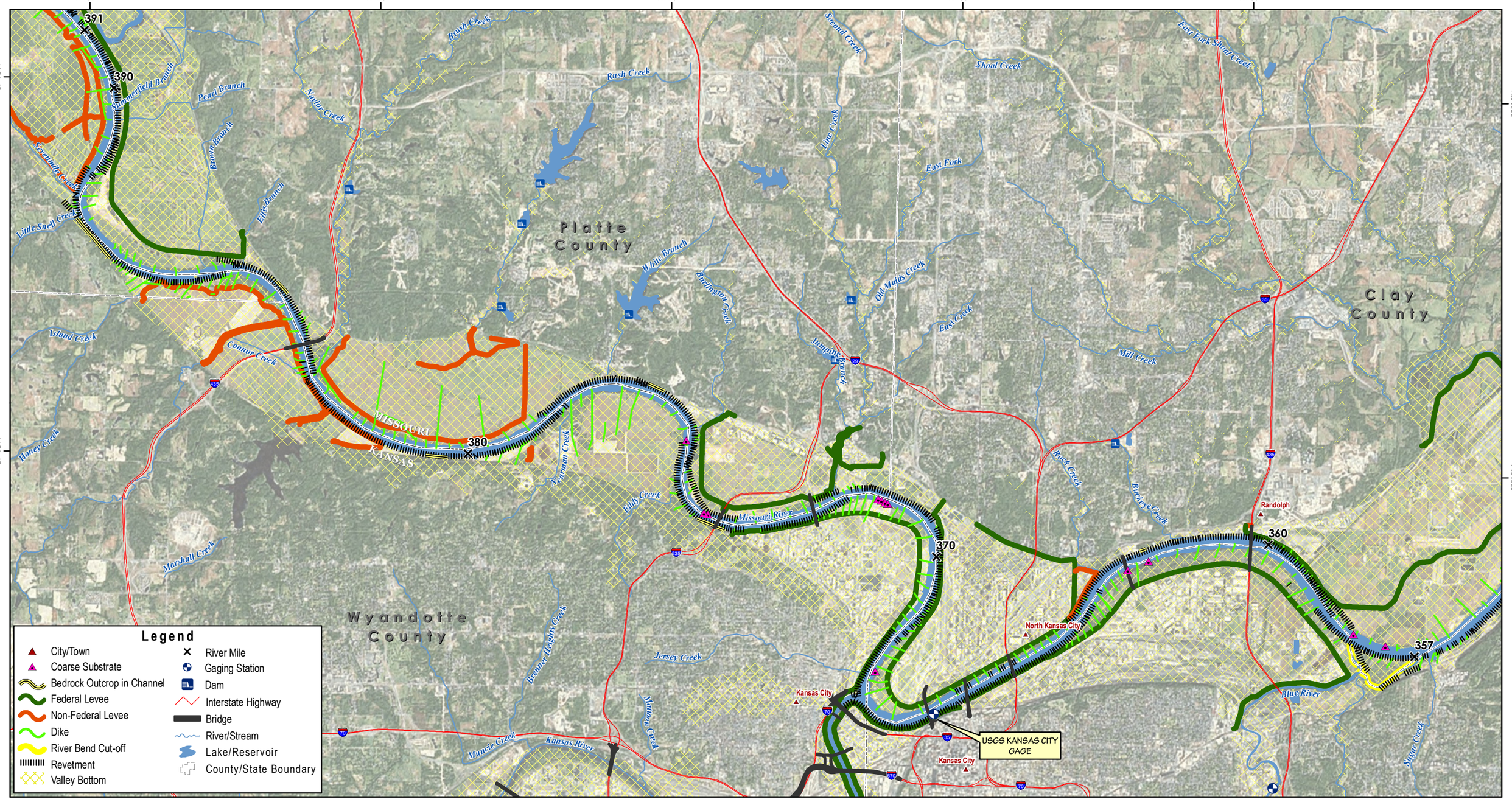
Map Projection: NAD83 UTM Zone15 North



0 2.5 5 Miles

0 2.5 5 Kilometers

Figure 3.4-2
Geomorphic Features of the Lower Missouri River by Segment
Sheet 2 - Kansas City Segment

Missouri River Commercial Dredging EIS

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Map Projection: NAD83 UTM Zone15 North

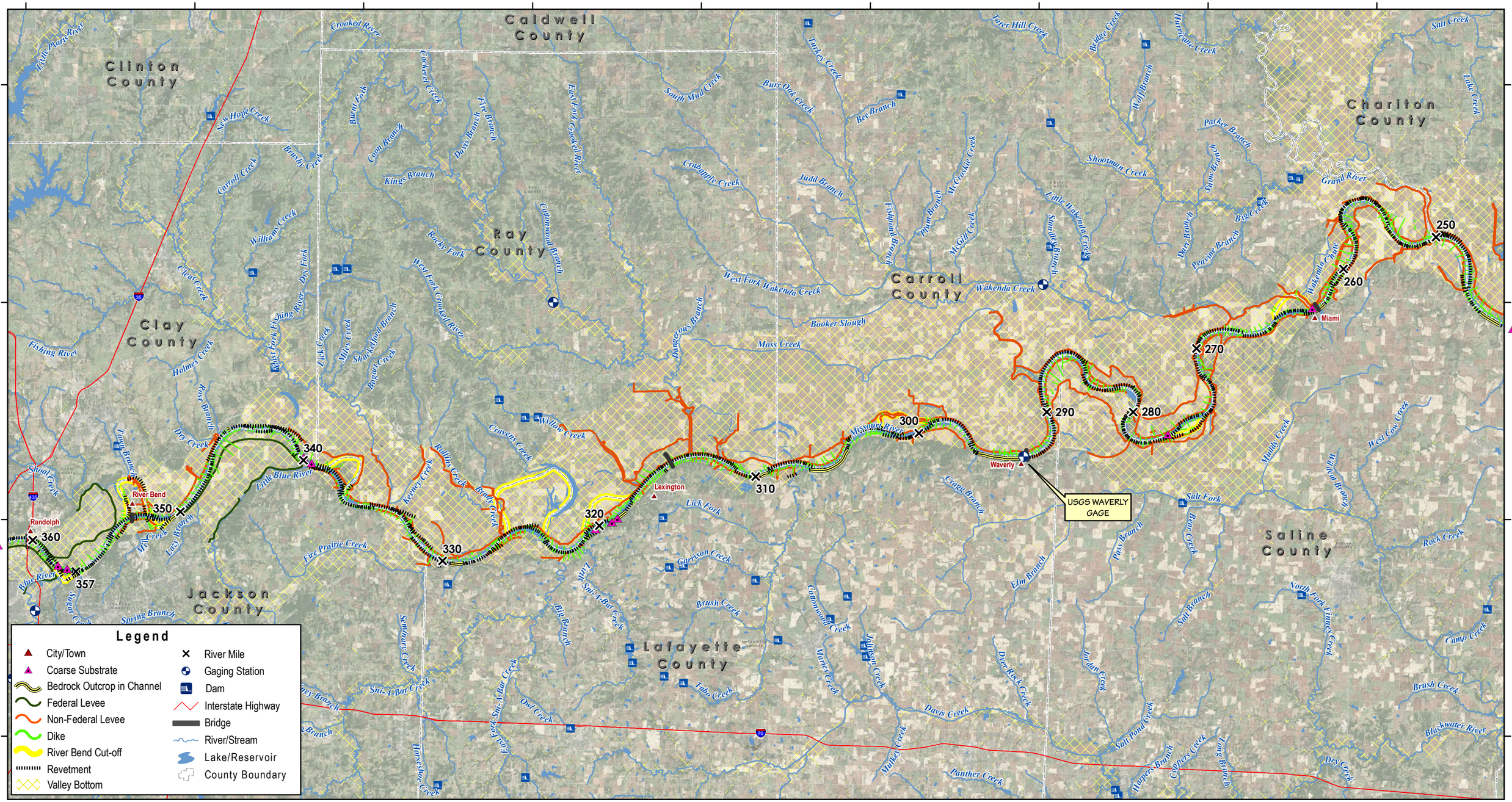
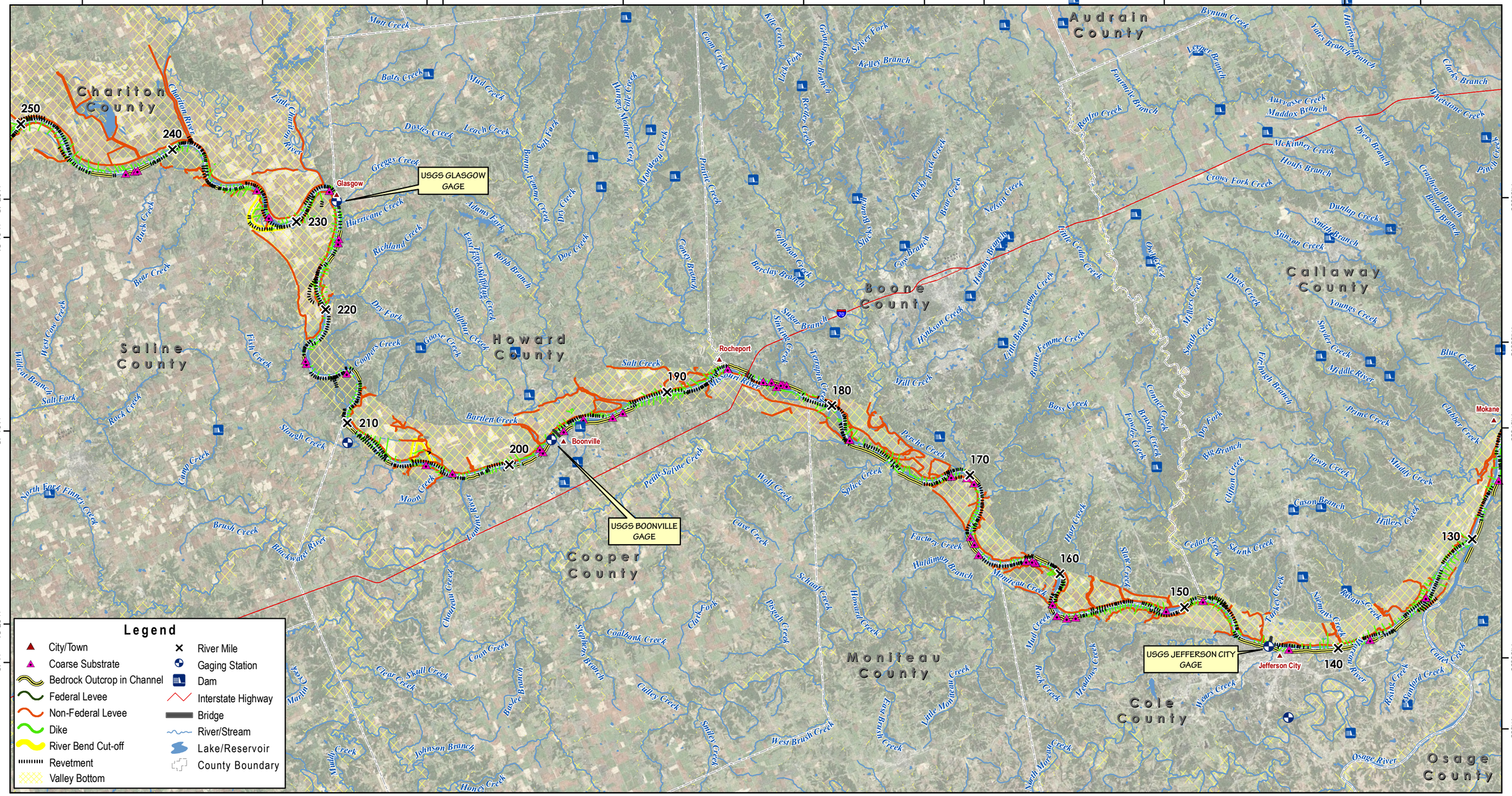


Figure 3.4-2
Geomorphic Features of the Lower Missouri River by Segment
Sheet 3 - Waverly Segment

Missouri River Commercial Dredging EIS



0 10 20 Miles

0 10 20 Kilometers

Figure 3.4-2
Geomorphic Features of the Lower Missouri River by Segment
Sheet 4 - Jefferson City Segment

Missouri River Commercial Dredging EIS

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Map Projection: NAD83, UTM Zone 15 North

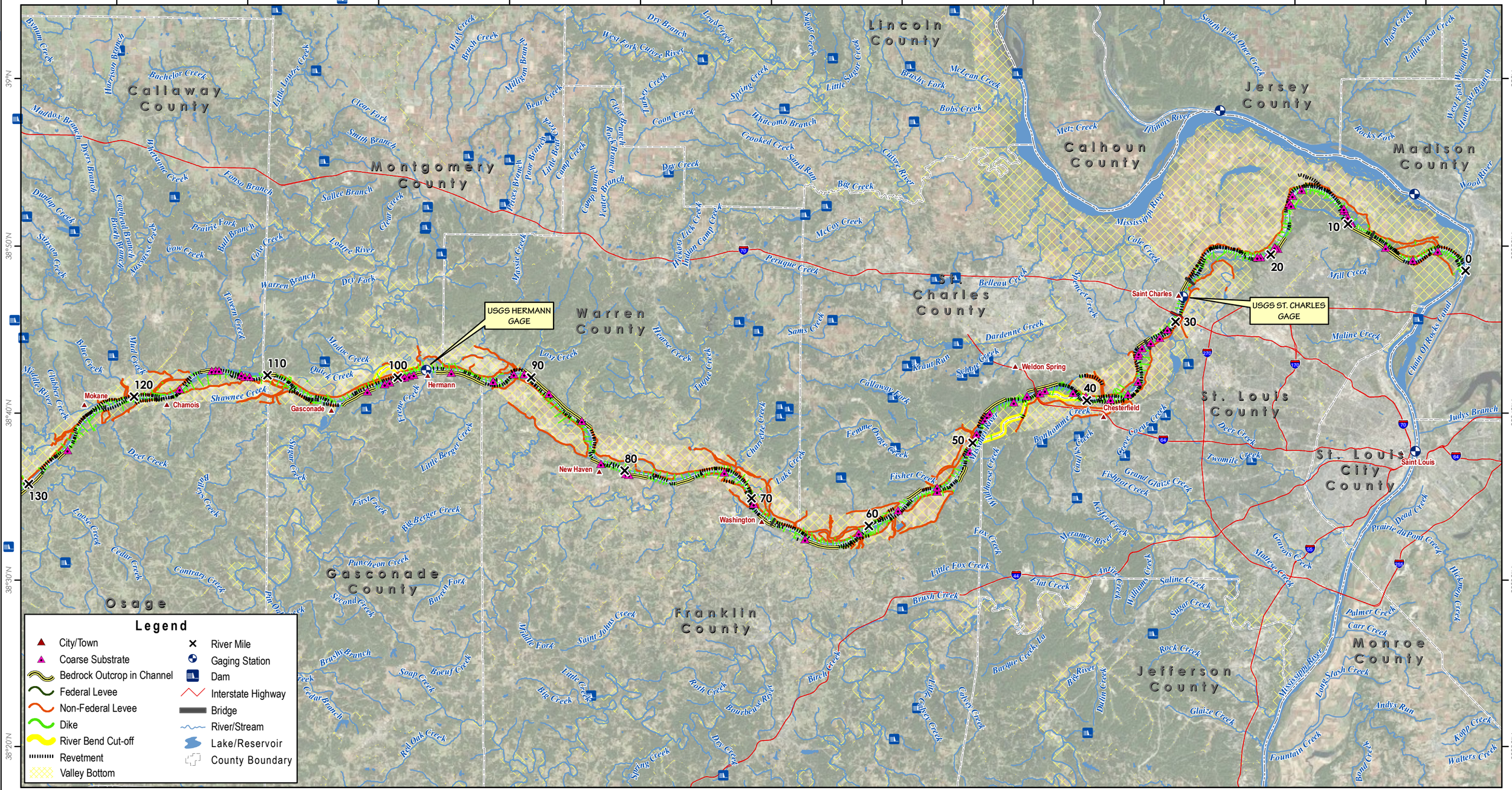


Figure 3.4-2
Geomorphic Features of the Lower Missouri River by Segment
Sheet 5 - St. Charles Segment

Missouri River Commercial Dredging EIS

3.4.2.2 Effects of Glaciation

Multiple episodes of glaciations occurred on the North American continent over the past 3 million years, but only a few glacial advances reached the present-day location of the Missouri River. The most extensive glaciation occurred between 780,000 and 620,000 years BP. Glaciation from this event significantly altered the drainage patterns of northwestern Missouri and northeastern Kansas. The advancing ice obliterated the existing drainage patterns, and a new course for the Missouri River was established in a post-glacial valley northwest of Kansas City and connected with the existing lower Kansas River valley between Kansas City and the confluence with the Grand River.

Glacial scour and melt water floods from this episode of glaciation over 600,000 years ago is evidenced in the deep valleys and trenches up to 240 feet deep in the bedrock underlying glacial deposits in the Kansas River and Missouri River Valleys in the Kansas City area. During glaciation and subsequent retreat, glacial lakes and spillways formed at the margin of the glacier, carving deep valleys in some areas and widening and deepening existing valleys such as the pre-glacial Kansas River (Colgan 1999). Figure 3.4-1 shows the maximum extent of this early episode of glaciation, which extended south of the LOMR above approximately RM 160 but did not reach the LOMR valley downriver of RM 160.

The most recent episode of glaciation, the Wisconsinian age (75,000 to 10,000 years BP), left extensive outwash deposits of sand and gravel alluvium in the river valleys—even though the glaciers did not extend as far south as Missouri. In a north-south cross section of the Missouri River near Kansas City, the thickness of surficial deposits varies depending on the depth to bedrock in the underlying bedrock valley. The upper 10–35 feet consist of recent (post-glacial) floodplain deposits of silt, clayey-silt, and fine-grained sand. The next 75–100 feet consist of sand and gravel deposited by the most recent Wisconsinian-age glaciers; and the deepest layer above bedrock consists of unsorted glacial till with boulders, sand, and clay likely deposited during the maximum extent of glaciation over 620,000 years ago (Gentile, Moberly, and Barnes n.d). The LOMR valley from approximately RM 226 to the confluence with the Mississippi River is also an alluvium-filled bedrock trench from 60 to 120 feet deep, with alluvium, sand and gravel, and sand, silt, and clay at shallower depths (Spooner 2001).

The Wisconsinian age episode of glaciation also left deposits up to 100 feet deep of wind-blown loess covering extensive portions of the state (Howe 1968) (Figure 3.4-1). These deposits occur in the northern part of Missouri and western Iowa. As they erode, they contribute to the high suspended sediment loads in the tributaries that drain that region and to the mainstem LOMR (USACE 2009a).

3.4.3 Geomorphic Character of the Lower Missouri River

The pre-contact geomorphologic character of the LOMR, the subsequent human alterations of the LOMR, and the resulting changes to the characteristics of the river channel and floodplain are discussed in this section.

3.4.3.1 The Missouri River prior to Development

Prior to European settlement of the region, the LOMR channel and floodplain were very different from the channel and floodplain of the modern Missouri River system. The pre-settlement river, while still constrained in most places to the floodplain between the bedrock bluffs carved by glacial-era flows, migrated back and forth between valley walls in as little as 70 years (Schlindwein pers. comm.). It transported approximately five times the amount of suspended sediment as the modern river and was often obstructed by snags and trees that had eroded from the river banks. Mean velocities of the river prior to development were slightly lower than modern velocities, while maximum velocities were higher (Blevins 2006).

> The pre-regulation river was characterized by log jams, snags, whirlpools, chutes, bars, cut-off channels, and secondary channels around bars. The main channel typically had a deep thalweg (the deepest part of the river) that contained the faster-moving flow and a shallower section(s) on one or both sides of the channel … The cross-sectional shape of the main channel often exhibited a highly nonuniform velocity distribution (Hesse 1993). The main river channel's width was variable, ranging from roughly 1,000 to 10,000 feet wide during normal flow periods to 25,000 to 35,000 feet wide during floods (Schneiders 1999). (NRC 2002)

Maps from the Lewis and Clark expedition in the early 1800s and mapping efforts in the late 1800s provide information on the geomorphology of the river prior to engineered efforts to create a navigation channel. Figure 3.4-3 shows an example of the movement of the main channel within the river valley at the confluence of the Missouri and Kansas Rivers. The figure shows the river channel location in 1804–1806 compared to the present river channel. Since construction of the BSNP, the wide somewhat braided channel has narrowed considerably. In the early 1800s, the Missouri River at Kansas City was still confined within the bedrock bluffs on either side, but was much wider and less sinuous than the modern channel form (Figure 3.4-1). The main channel was approximately 0.25 mile wide, with some areas including side channels around islands ranging up to 1 mile wide. In contrast, the modern channel is consistently approximately 0.125 mile wide and flows in a different location.

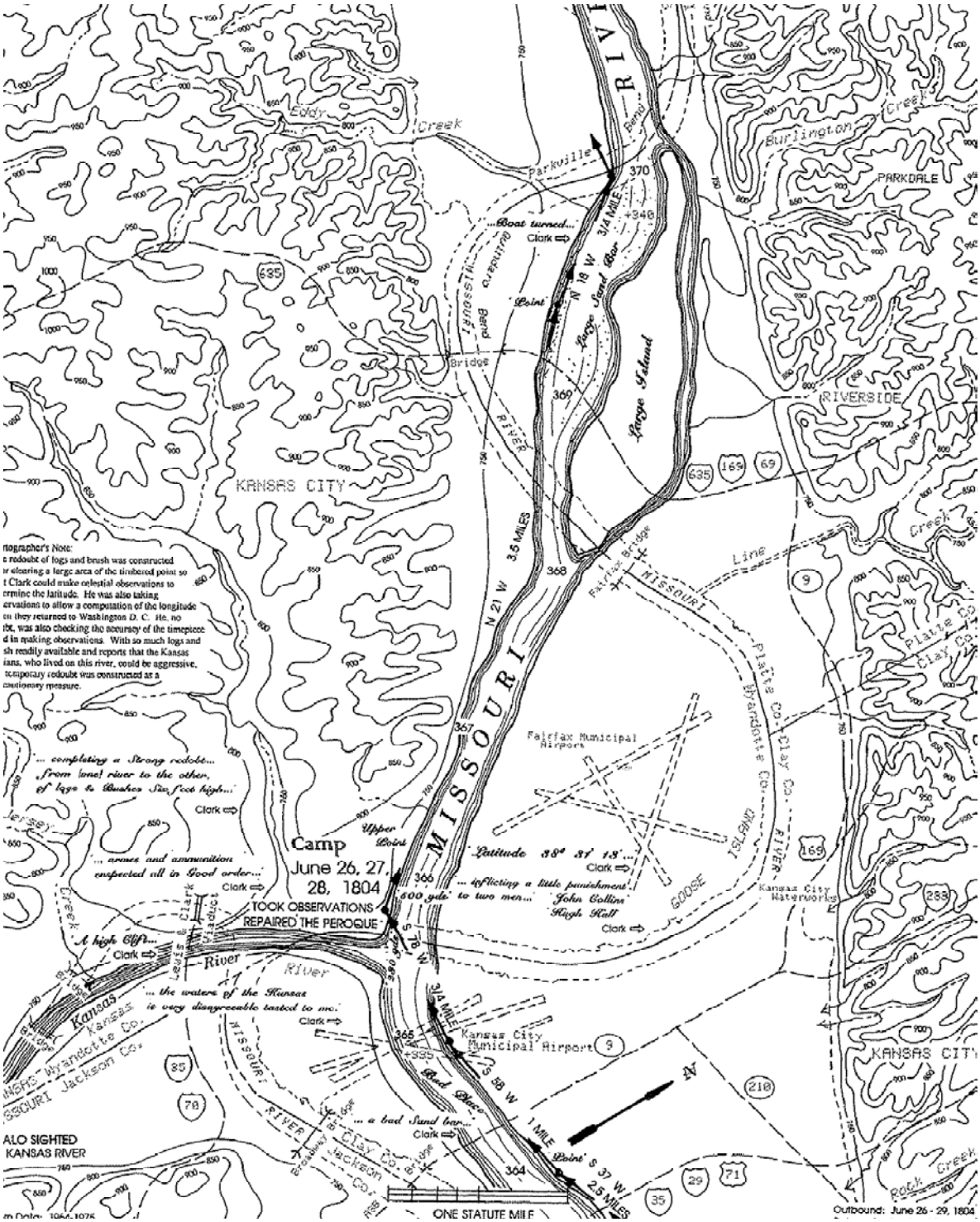


Figure 3.4-3 Map of the Missouri River at the Confluence with the Kansas River (RM 367.5) from the Time of the Lewis and Clark Expedition (1804–1806), with an Overlay of the Modern Missouri River

Source: Plamondon 2000.

3.4.3.2 Alterations of the Missouri River

As described in Section 3.2.4, six dams were constructed on the upper portion of the Missouri River, and the BSNP (consisting of dikes, revetments, and cutoffs) was constructed on the LOMR.

Dams

The construction of six mainstem dams significantly altered the Missouri River while creating the largest reservoir system in North America (Jacobson, Blevins, and Bitner 2009). Operation of these dams has changed the Missouri River flow regime, water temperatures, and sediment fluxes. The effects of the dams are most dramatic in the upper portion of the river. Although the effects of the dams diminish farther downriver as numerous tributaries contribute sediment and flows to the mainstem, hydrographs and suspended sediment loads are still affected all the way to the confluence with the Mississippi River. In addition, water releases from the dams are managed to reduce spring flood pulses and to augment late-summer and fall flows to improve river navigation.

The Bank Stabilization and Navigation Project

To meet the BSNP objectives of bank stabilization and navigation, the river was trained into a series of smoothly curved bends of the appropriate radii and channel width. The overall effect of the BSNP was to change the geomorphologic character of the river from a wide, braided, free-moving river with multiple channels and with relatively unrestricted access to its floodplain to a more stable, single-channel river suitable for navigation (USACE 1980). Typical BSNP engineered structures include the system of dikes and revetments, river bed and side channel cutoffs, and levees. The following sections describe these structures and their impacts in more detail.

Dikes

Various techniques, including fascine pile and concrete crib dikes and “Kellner jetties,” were used to train the river channel to cease meandering and remain in one location. Prior to 1930, dikes were used primarily to stabilize banks. During the 1930s, long dikes were built perpendicular to the flow across chutes and side channels and inside bank lines to promote sediment accretion in those places and confine the river to the intended navigation channel. Before 1949, pike dikes and woven mattress revetments were the standard methods; in 1949, the Office of Chief Engineers approved the use of quarry–run stone as an alternative construction method for river improvements projects (USACE 1996). By 1960, the modern river channel had been established and the 1930-era dikes were mostly covered by accreted land. After 1960, low-elevation dikes (dike sills) and L-shaped dikes and revetments were introduced. These dikes were generally shorter and built off of the land that had previously accreted

behind the first phase of dikes. Dikes prior to 1960 were generally constructed to the height of the navigation flow, while dikes constructed after 1960 were built to be overtopped for a portion of the navigation season (USACE 1980). Throughout the 1980s, dikes were extended to focus flows into the navigation channel, and more recently were notched in some areas to make the flows less constrictive and to produce shallow-water habitat.

Figure 3.4-4 shows the number of dikes constructed on the LOMR since 1880. With more than 4,500 dikes built between Rulo, Nebraska and the confluence with the Mississippi River, there is an average of nine dikes per mile. The highest density is in the St. Joseph segment, and the lowest is in the Kansas City segment (Table 3.4-3). It is estimated that, because of the BSNP, the active channel top width has decreased by approximately two-thirds, resulting in approximately 150 square miles of accreted land throughout the length of the BSNP (Jacobson, Blevins, and Bitner 2009).

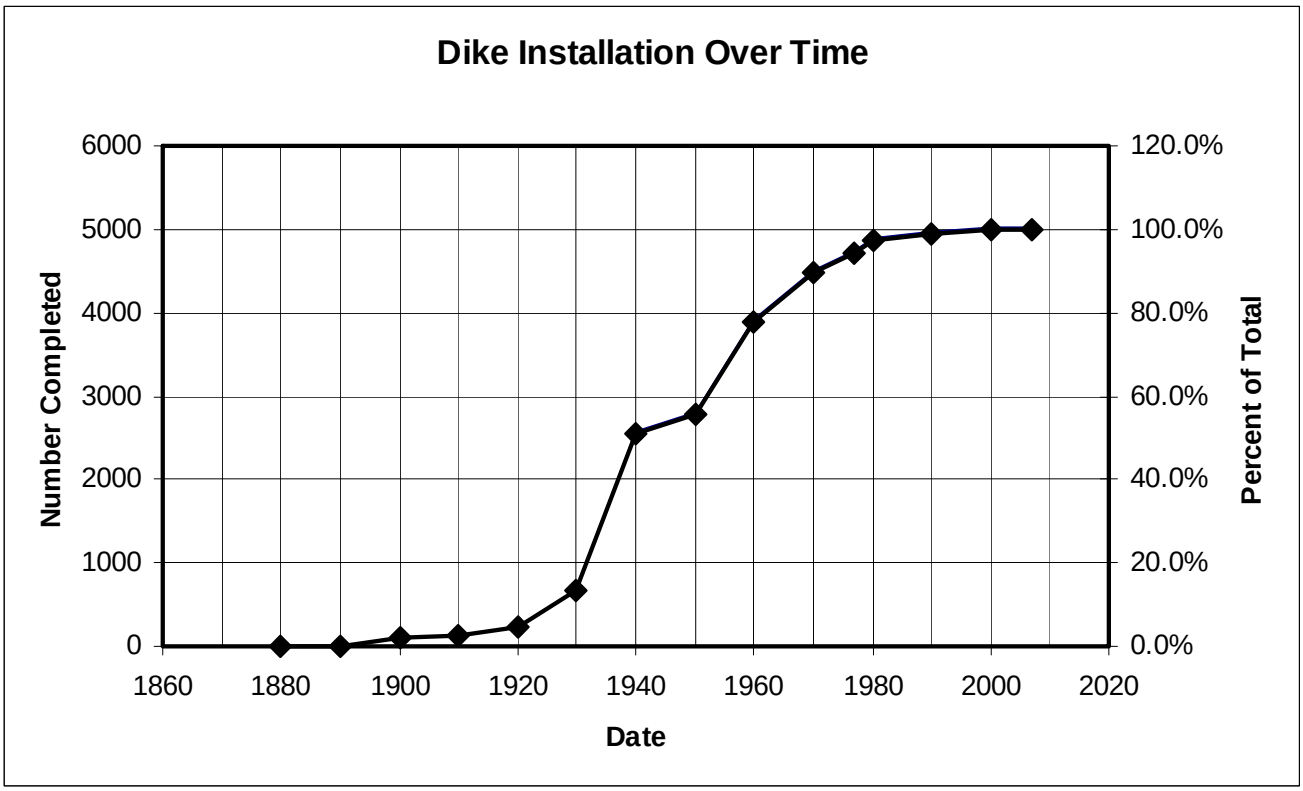


Figure 3.4-4 Number of Dikes Constructed below Rulo, Nebraska and Cumulative Percent of Total

Source: USACE 2009c.

Table 3.4-3 Revetments and Dikes in the Lower Missouri River

Feature	St. Joseph	Kansas City	Waverly	Jefferson City	St. Charles
Revetments (miles)					
Left bank	60	21.6	59.2	61.5	73
Right bank	60.6	22.9	51.5	65.5	54.5
Average miles of revetment per river mile for segment (both banks)	*1.13*	*1.30*	*1.03*	*1.06*	*0.98*
Dikes (count)					
Left bank	523	141	422	545	584
Right bank	599	130	453	556	595
Average number of dikes per river mile for segment (both banks)	*10.49*	*7.92*	*8.18*	*9.18*	*9.08*
Dikes (length in miles)					
Left bank	78.2	21.2	65.1	88	93.7
Right bank	91.9	20.6	69.4	78.4	101.4
Average miles of dikes per river mile for segment (both banks)	*1.59*	*1.22*	*1.26*	*1.39*	*1.50*

Figure 3.4-5 shows a time series of photos taken at the same point over a period of 69 years. The photos were taken upriver of the Project area at Indian Cave Bend (RM 517). The first photo was taken in 1934 and shows initial dike construction. The second photo from 1935 shows the finished dikes on the right side of the photo and sediment starting to fill in. The sand bars in the main part of the river are already gone. The third and fourth photos from 1935 and 1936 show the dike fields rapidly filling with sediment and vegetation establishing on the filled area. The fifth photo, taken 10 years later, shows the dike fields almost completely filled in and forested. The final photo in 2003 shows farm fields and a levee constructed across the edge of the accreted dike fields. This series of photos illustrates how the first phase of dikes (1930–1950) defined the modern river channel.

Revetments

Revetments were one of the first methods used in the early 1900s to protect river banks from erosion and to stabilize the channel location.

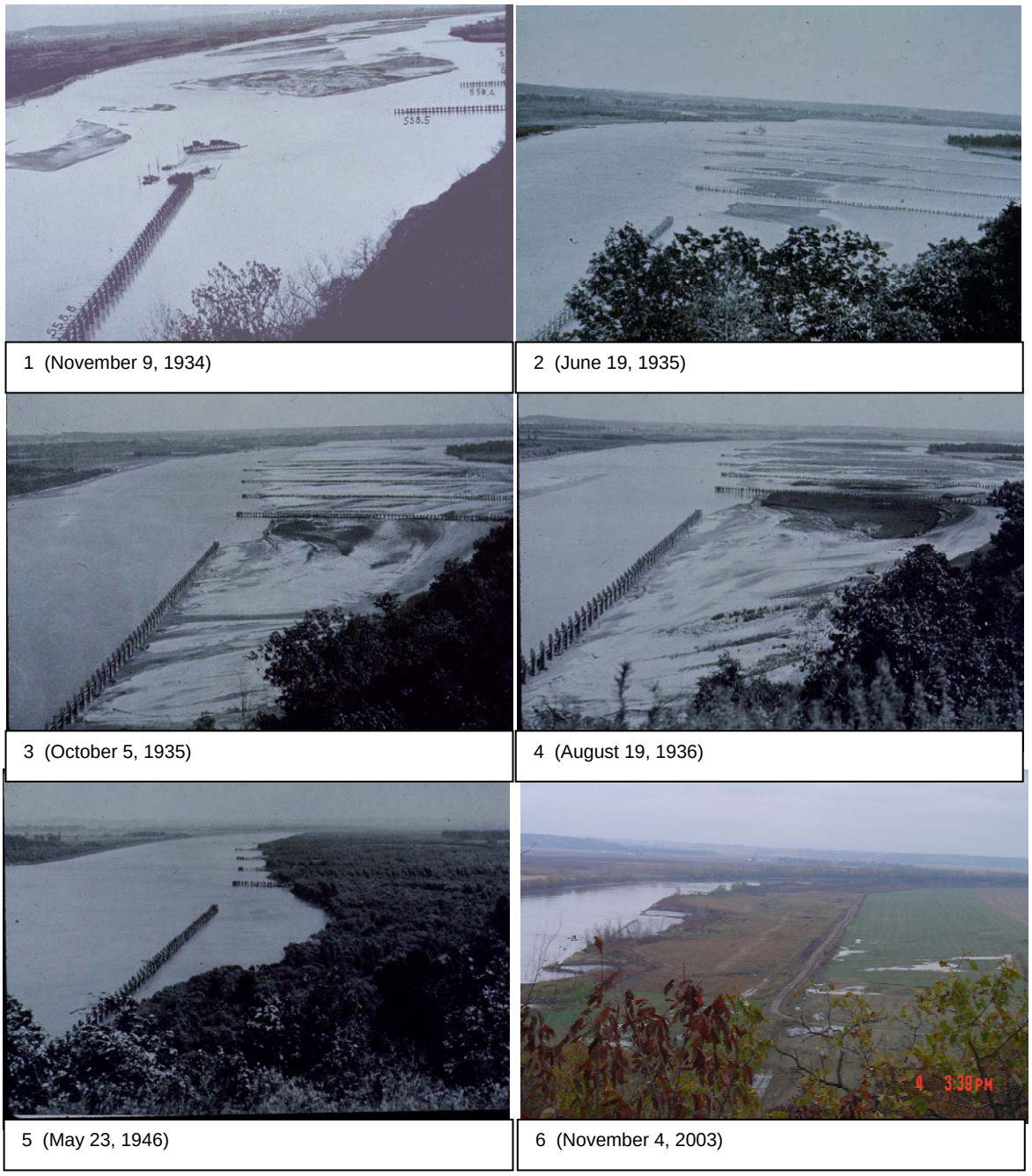


Figure 3.4-5 Time Series of Photos from RM 517 Showing Construction and Filling of Dike Field

Revetments typically consisted of woven willow or beam mats covered with rock. Table 3.4-3 shows the length of revetments for each segment. The Kansas City segment has the highest average number of miles of revetment, and the St. Charles segment has the least.

Figure 3.4-2 shows the locations of dikes and revetments on the river in each segment. At many locations (RM 380, for example, Figure 3.4-2, Sheet 2) long dikes extend from the river's edge into adjacent agricultural fields. These are the areas where the original river channel was narrowed using dike fields. Sediment filled in the area between the dikes, and the area was ultimately converted to agricultural use. The extensive use of revetments on the outside of river bends to prevent erosion and confine the river channel is also illustrated in this figure.

Cutoffs

Since 1890, the length of the Missouri River between Sioux City and the confluence with the Mississippi River has been shortened by approximately 75 miles, or 10 percent. Two-thirds of this shortening was concentrated in two reaches: between Sioux City to Omaha and between Kansas City and Waverly. The overall reduction in river length between 1890 and 1960, primarily by cutting off oxbow bends, is shown in Table 3.4-4. Cutoffs, constructed since 1941, were primarily installed to improve ease of navigation (Figure 3.4-2). Shortening the river increases the local slope of the river because the river bed elevation drops essentially the same amount over a much shorter distance. This typically results in headcuts moving upriver from the cutoff and aggradation occurring downriver from the cutoff as the river adjusts to a new slope.

Table 3.4-4 Changes in Distances between Locations on the Lower Missouri River

	Missouri River Length between Locations (miles)			1890–1960 Change in Length	
Locations	1890	1941	1960	Miles	Percent
Sioux City to Omaha	147.7	128.0	116.4	-31.3	-21.2
Omaha to Nebraska City	52.1	52.7	54.0	1.9	3.6
Nebraska City to St. Joseph	129.0	119.3	114.0	-15.0	-11.6
St. Joseph to Kansas City	88.0	82.5	81.8	-6.2	-7.1
Kansas City to Waverly	91.5	80.3	72.7	-18.8	-20.5
Waverly to Boonville	93.8	101.0	96.8	3.0	3.2
Boonville to Hermann	101.9	99.3	98.7	-3.2	-3.1
Hermann to mouth	103.5	96.9	97.9	-5.6	-5.4
Total (Sioux City to mouth)	807.5	760.0	732.3	-75.2	-9.3

Source: USACE 2007c.

Table 3.4-5 lists significant cutoffs between St. Joseph and Waverly. The Liberty Bend cutoff (Figure 3.4-2, Sheet 2) at RM 352 is indicative of riverbed morphology changes associated with river

shortening. Prior to the cutoff, the slope through the oxbow was 0.77 foot per mile (0.0146 percent); a survey of the channel 7 years after the cutoff was opened indicated that the slope had almost doubled to 1.3 feet per mile (0.0246 percent). After 7 years, the channel bottom was 1.3 feet lower at the cutoff, and river bed degradation decreased upriver to a point 8.3 miles above the cutoff where the channel bed elevation had not changed. River bed aggradation occurred for 21.3 miles downriver and reached a maximum bed elevation increase of 2 feet 10.5 miles downriver (USACE 1980).

Table 3.4-5 Significant Cutoffs between St. Joseph and Waverly

Cutoff	River Mile	Decrease in River Length (miles)	Year Completed
Napoleon Bend	324	8.2	1915 (natural)
Big Blue Bend	357–358	0.8	1941
Liberty Bend	350–354	4.3	1949
Jackass Bend	337–339	2.5	1957
St. Joseph	450	6.2	1956

Levees

Levees restrict the river's access to floodplain flow buffering and sediment recruitment. When waters rise, flows are routed between the levees, thus increasing the height of the floodwaters and eliminating floodplain energy dissipation. Figure 3.4-2 shows federal and non-federal levees for each segment. Levees are frequently built away from the mainstem LOMR along tributaries to protect against floodwater from the LOMR flowing up the tributaries, particularly within the valley bottom. Virtually all of the LOMR from the mouth to Rulo has a federal or non-federal levee along its banks (Figure 3.4-2).

Federal levees on the LOMR (Table 3.4-6) are primarily located between Kansas City and Rulo, although two are downstream of Kansas City. Five urban levees are located in the Kansas City metropolitan area, and the rest are between Kansas City and Rulo. These levees, constructed since 1950, protect approximately 153,000 acres; in St. Joseph, Kansas City, and St. Charles, they constrict the floodway to less than 0.5 mile wide (USACE 2004).

Almost 100 non-federal agricultural levees along the LOMR protect approximately 476,000 acres of primarily agricultural land (USACE 2004). These levees are managed by private levee districts and often extend up tributaries or away from the LOMR to protect agricultural lands from moderate floods, with 5- to 25-year return intervals. Three non-federal levees protect urban areas below RM 45 in the St. Charles area (USACE 2004). The non-federal levees below RM 535 on the Missouri River failed during the 1993 flood, except for several in the St. Louis area (USACE 2004).

Table 3.4-6 Federal Levees on the Lower Missouri River

Levee Unit	Location along the Missouri River
R-513	RM 497.5 – RM 495
R-500	RM 484.4 – RM 480
L-497	RM 482.4 – RM 476.7
L-488	RM 475.3 – RM 465.2
R-482	RM 468.4 – RM 458
L-476	RM 461.0 – RM 454.0
R-471-460	RM 456.5 – RM 441.8
L-455	RM 445.6 – RM 437.6
L-448-443	RM 437.6 – RM 428
R-440	RM 431 – RM 424.3
L-408	RM 401.3 – RM 391.5
L-400	RM 391 – RM 385
Fairfax-Jersey Creek	RM 374 – RM 367.5
North Kansas City	RM 370.5 – RM 363.5
Central Industrial District (CID)	RM 367.4 – RM 365.7
East Bottoms	RM 365.7 – RM 357.5
Birmingham	RM 360.3 – RM 354.0
R-351	RM 350 – RM 339.7
L-246	RM 250 – RM 239
Chariton River Mainstem	RM 238.8 – RM 227.3
New Haven	RM 81.7 – RM 81.4

Note: RM = River mile.
Source: USACE 2004.

Current Channel Configuration of the Lower Missouri River

The BSNP created a navigation channel on the LOMR that is a minimum of 300 feet wide and 9 feet deep during a typical navigation season (Table 3.4-7). The BSNP, in combination with the levee system and controlled releases from the upstream reservoirs, has fundamentally changed the geomorphic nature of the river. Prior to the BSNP, the river would deposit sediment on the floodplain during flood events, erode and deposit extensive in-river bars and islands, and erode river banks as the channel moved back and forth across the valley. The pre-BSNP river (Figure 3.4-6) had multiple side

channels, a deeper center channel, oxbow lakes, islands, sand bars and dunes, and backwater habitats with areas of higher ground (NRC 2002).

Table 3.4-7 Design Widths for the Missouri River Bank Stabilization and Navigation Project

Reach	Channel Width (feet)	Channel Width to Sills (feet)
Rulo to Kansas River (RM 498 – RM 367)	800	550
Kansas River to Grand River (RM 367 – RM 250)	900	600
Grand River to Osage River (RM 250 – RM 130)	1000	650
Osage River to mouth (RM 130 – RM 0)	1,100	750

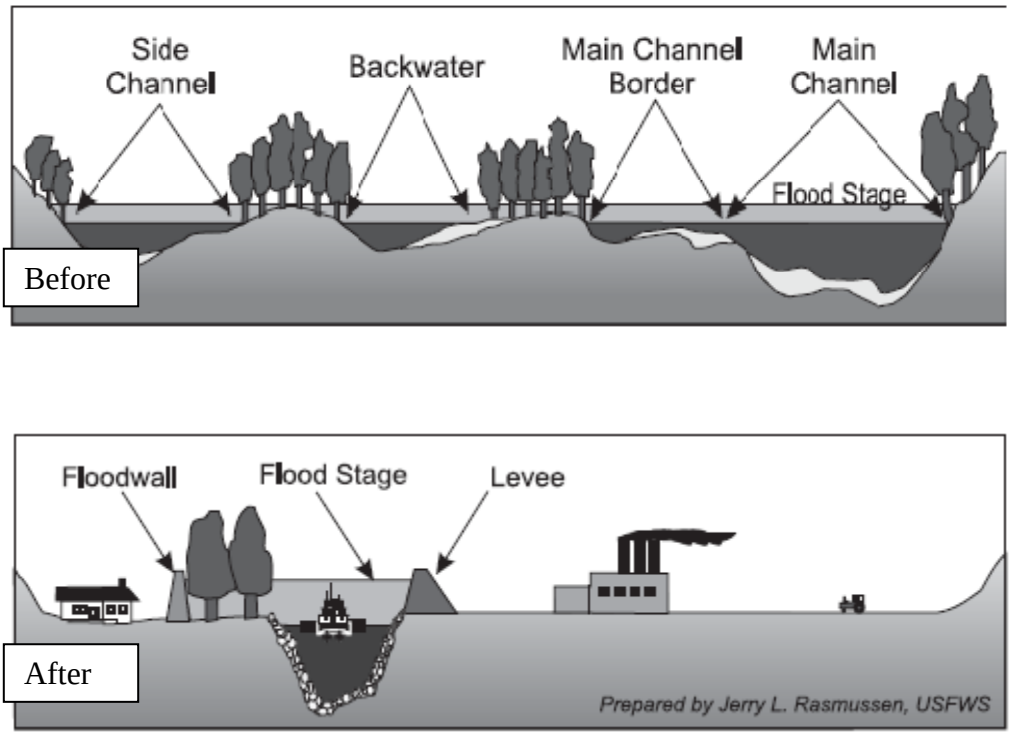


Figure 3.4-6 Typical Cross Section before and after the Missouri River Bank Stabilization and Navigation Project

Source: NRC 2002; Original source: Rasmussen 1999.

Since construction of the BSNP and other infrastructure along the river, flows are constrained to a designed channel that efficiently routes sediment through the system to maintain a clear navigation

channel. Bank erosion and river channel migration have largely been eliminated. Levees constrain flood flows along most of the river to the floodway channel, resulting in increased stages at higher flows at most gage locations along the river.

3.4.4 Hydrology

Flows in the LOMR drive the geomorphic processes that shape the river. Water flow volume and velocity are the main factors in sediment movement through the system. Flows are driven by a combination of natural and human-induced factors and vary by season and year. Dams built over 50 years ago upriver from the Project area have affected the magnitude and timing of flows, and levees and dikes have constrained flows and altered flood peaks.

3.4.4.1 Lower Missouri River Basin and Tributaries

The Missouri River is the longest river in the continental United States (2,315 miles) with a drainage area of 524,110 square miles. Its basin comprises 74 percent of the total upper Mississippi River basin. The Missouri River contributes approximately 42 percent of the long-term average annual flow of the Mississippi River at St. Louis (USACE 2004). Approximately 109,200 square miles of the Missouri River basin occurs within the Project area, and its river bed elevation drops 451 feet—with an average slope of 0.8–1.0 feet per mile.

Flow measurements and other data have been collected at multiple sites along the mainstem Missouri River (Table 3.4-8, Figure 3.4-2) and at sites on most of its major tributaries.

Table 3.4-8 Flow Data on the Lower Missouri River

Gage Name	USGS Gage Number	River Mile	Number of Years of Record			
			Discharge	Stage	Annual Peak	Field Measurements
Missouri River at St. Charles, MO	6935965	28	9	25	8	16
Missouri River at Hermann, MO	6934500	97.9	81	22	82	81
Missouri River at Jefferson City, MO	6910450	143.9	0	15	0	0
Missouri River at Boonville, MO	6909000	197.1	84	17	85	84
Missouri River at Glasgow, MO	6906500	226.3	9	9	9	60
Missouri River at Waverly, MO	6895500	293.2	81	19	79	81
Missouri River at Kansas City, MO	6893000	366.1	81	19	81	81
Missouri River at St. Joseph, MO	6818000	448.1	81	18	89	81
Missouri River at Rulo, NE	6813500	498	59	24	61	59

Notes:

MO = Missouri.
NE = Nebraska.
USGS = U.S. Geological Survey.

Sediment sampling data in addition to flow data are available for the highlighted gages and were used in the sediment load analysis.

The flow contribution to the mainstem LOMR from each tributary (Table 3.4-9) cannot be estimated because there are no gaging stations at the confluence of the tributaries with the mainstem of the Missouri River. However, the drainage area for each tributary provides a relative measure of the flow it contributes to the LOMR. Figure 3.4-7 shows the percent increase in flow on the mainstem Missouri River at gage locations moving down the river as a function of the additional drainage areas contributed by major tributaries. For example, the drainage area increases significantly (by 15 percent) between the St. Joseph and Kansas City gages where the Kansas and Platte Rivers join the Missouri River, resulting in a 19.9-percent increase in mean annual flow. Between the Boonville and Hermann gages, the drainage area increases 4 percent with the contributions of the Gasconade and Osage Rivers, resulting in a 28.4-percent increase in mean annual flow. This illustrates the differences in annual

precipitation in the Missouri River basin, with much less to the west where the Kansas and Platte Rivers flow, compared to tributaries flowing from the wetter south and east (see Section 3.4.4.2 for details).

Table 3.4-9 Significant Tributaries to the Lower Missouri River

Tributary Name	River Mile/Side of River (Facing Downstream)	Drainage Area (square miles)	Dams or Flow-Regulating Structures?
Big Nemaha	494.9 Right	1,926	No
Nodaway	462.3 Left	1,935	No
Platte (Missouri)	391.1 Left	2,503	Smithville Lake on Little Platte
Kansas	367.5 Right	60,580	Seven USACE reservoirs and 11 USBR reservoirs
Big Blue	356.9 Right	307	No
Little Blue	339.5 Right	409	Two USACE reservoirs and a county lake
Grand	249.9 Left	7,883	No
Chariton	238.8 Left	2,566	USACE reservoir 140 miles upstream
Little Chariton	227.2 Left	761	One USACE reservoir, one private
Lamine	202.5 Right	2,783	No
Osage	129.9 Right	15,088	Seven major impoundments, the lowest 80 miles from mouth
Gasconade	104.4 Right	3,582	No

Notes:

USACE = U.S. Army Corps of Engineers.
USBR = U.S. Bureau of Reclamation.

Source: USACE 2004.

The flows from major tributaries are nearly equally distributed between the right and left river banks of the LOMR (USACE 2006). The Platte, Kansas, Little Blue, Chariton, Little Chariton, and Osage Rivers—along with some of their tributaries—are regulated by dams (USACE 2008) (Figure 3.4-2). Water releases from some of the USACE and U.S. Bureau of Reclamation (USBR) dams are coordinated with dam releases on the mainstem Missouri River to reduce flooding and maintain navigation depths.

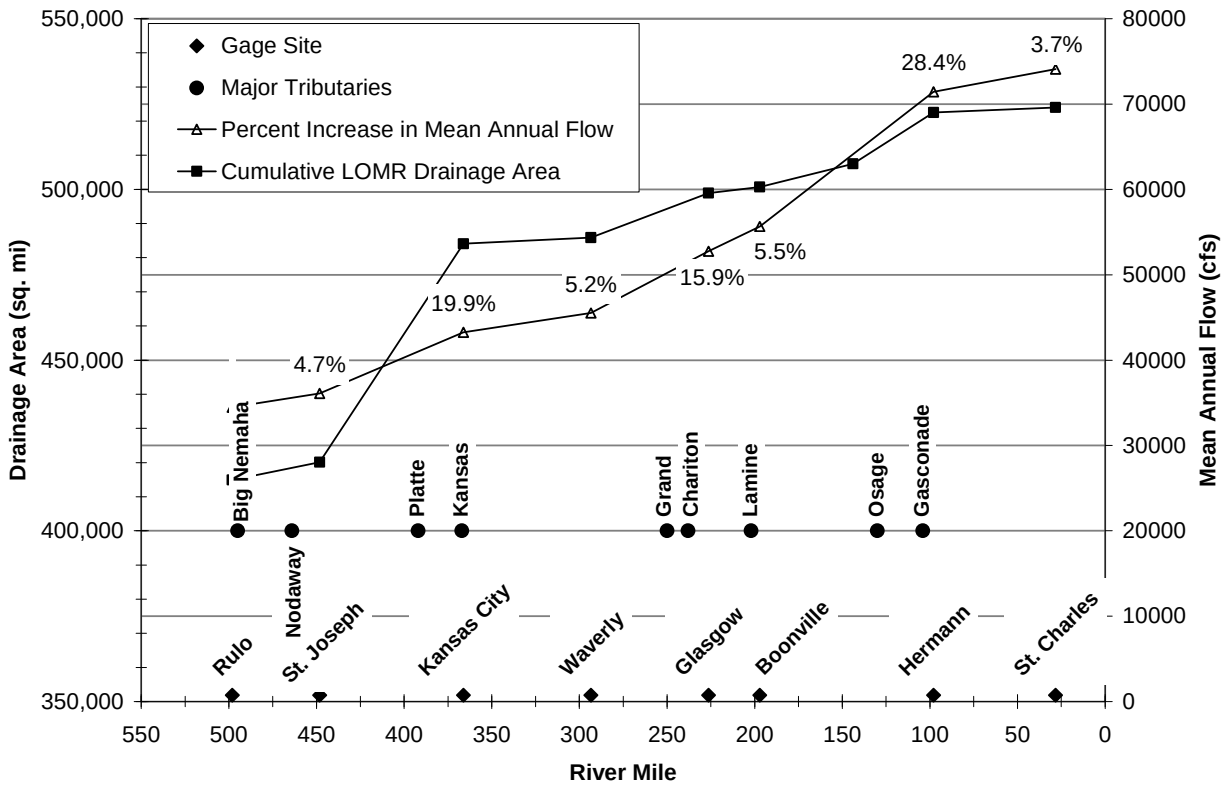


Figure 3.4-7 Cumulative Drainage Area and Mean Annual Flows for the Lower Missouri River

3.4.4.2 Precipitation Patterns

Drainage basin precipitation and releases from upstream reservoirs determine the amount of water flowing in the LOMR. Precipitation patterns vary in three ways:

- Spatial distribution across the LOMR basin;
- Year to year variation; and
- Monthly variations in precipitation within the annual cycle.

Each is important to define the overall hydrology of the LOMR.

Average annual precipitation patterns vary spatially across the Missouri River basin. Precipitation is lowest near the headwaters in the upper basin and is highest in the lower basin near the confluence with the Mississippi River. The average annual precipitation throughout most of the LOMR basin is

between 30 and 40 inches, while the average annual precipitation within the basin south of Kansas City and Jefferson City, Missouri is between 40 and 50 inches (USACE 2006). Typically, weather systems bring moist air and precipitation from the Gulf of Mexico. Precipitation trends in the Kansas City and St. Louis areas show increases from approximately 35 inches per year at both locations to 40 inches per year from 1948 to 2005 (Figure 3.4-8). Precipitation in the LOMR basin is quite variable and subject to multiple-year droughts, with frequent periods of dry conditions interspersed with periods of abundant or excessive precipitation (USACE 2006) (Figure 3.4-8).

The monthly distribution of rainfall between Kansas City and St. Louis differs even though the average annual precipitation is similar (Figure 3.4-9). St. Louis generally has drier summers and wetter winters than Kansas City and less variability between summer and winter precipitation levels. Precipitation during winter typically falls as snow in both cities. Precipitation is generally greatest in late spring and early summer, with June typically being the wettest month of the year (USACE 2006).

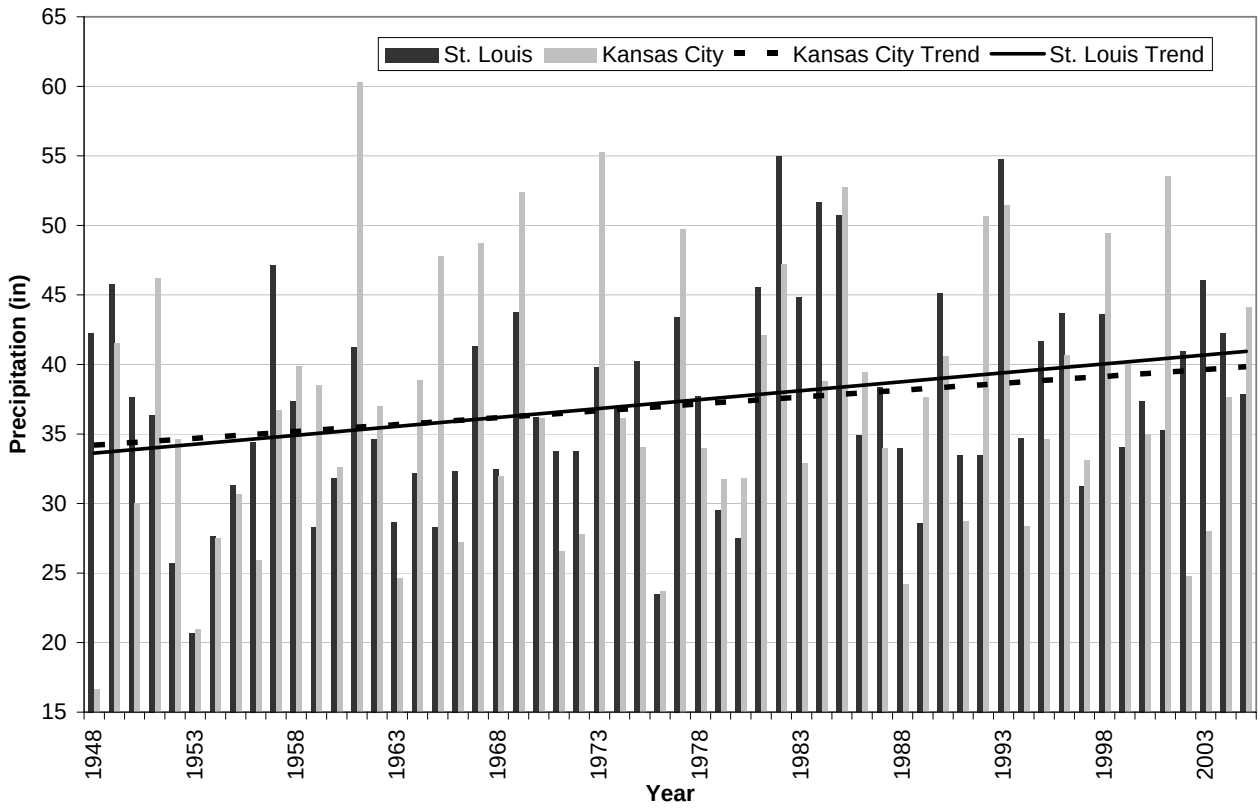


Figure 3.4-8 Annual Precipitation and Long-Term Trends for Kansas City and St. Louis, Missouri (1948–2005)

3.4.4.3 Flow Modifications

As described in Section 3.2.4, the LOMR is a highly regulated system with multiple dams upstream of the proposed Project area that alters the natural flow regime (USACE 2006, Pegg, Pierce, and Roy 2003). The lowest mainstem dam (Gavin's Point at RM 811) was completed in 1955 and has regulated downstream LOMR flows since that time. Flow regulation has primarily changed the timing and quantity of flows immediately downriver of the dam. Further downstream however, these changes are reduced due to inflows from major tributaries (Pegg, Pierce, and Roy 2003; Jemberie, Pintner, and Reno 2008). Figure 3.4-10 shows how the annual hydrograph for the Kansas City and Hermann gages changed from before the dam was completed to after the dam was completed.

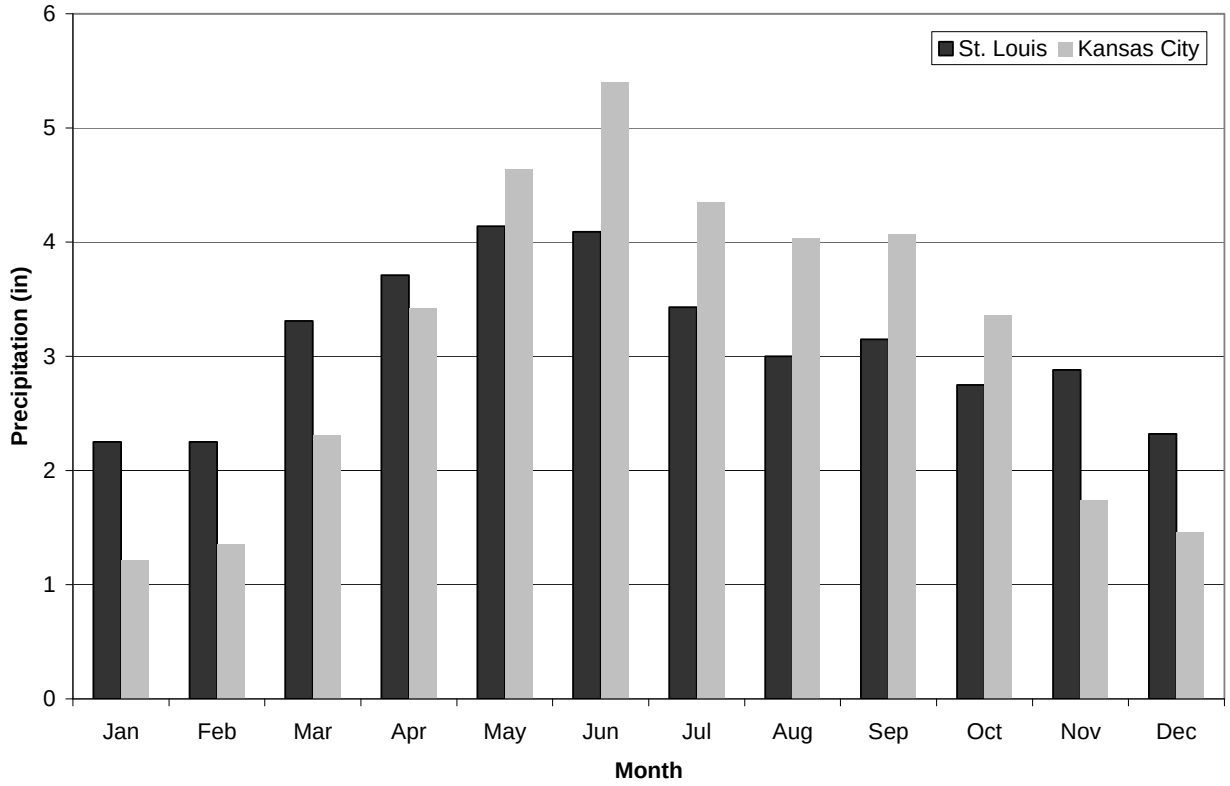
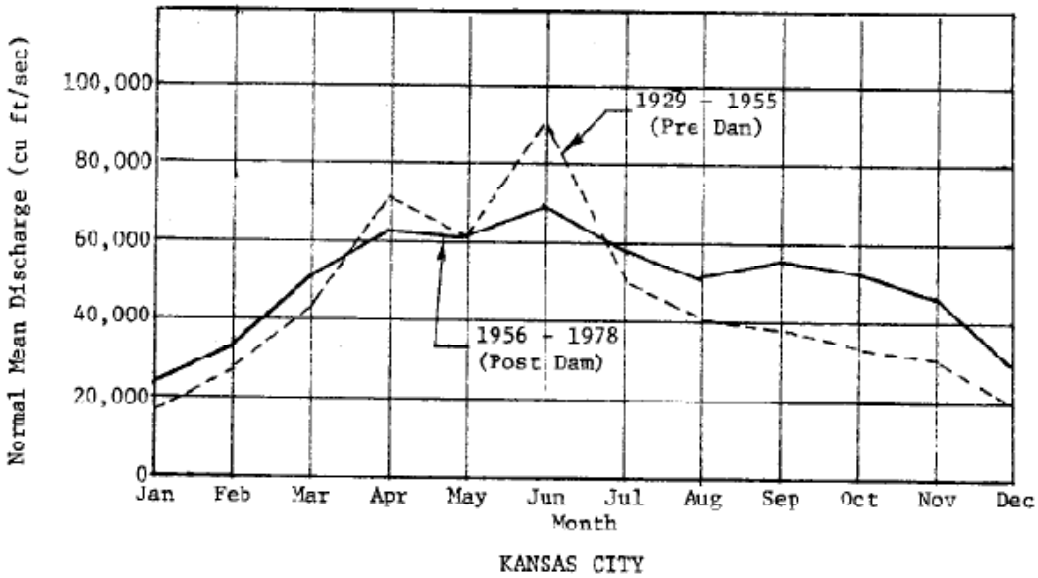


Figure 3.4-9 Mean Monthly Precipitation for Kansas City and St. Louis, Missouri (1948–2005)



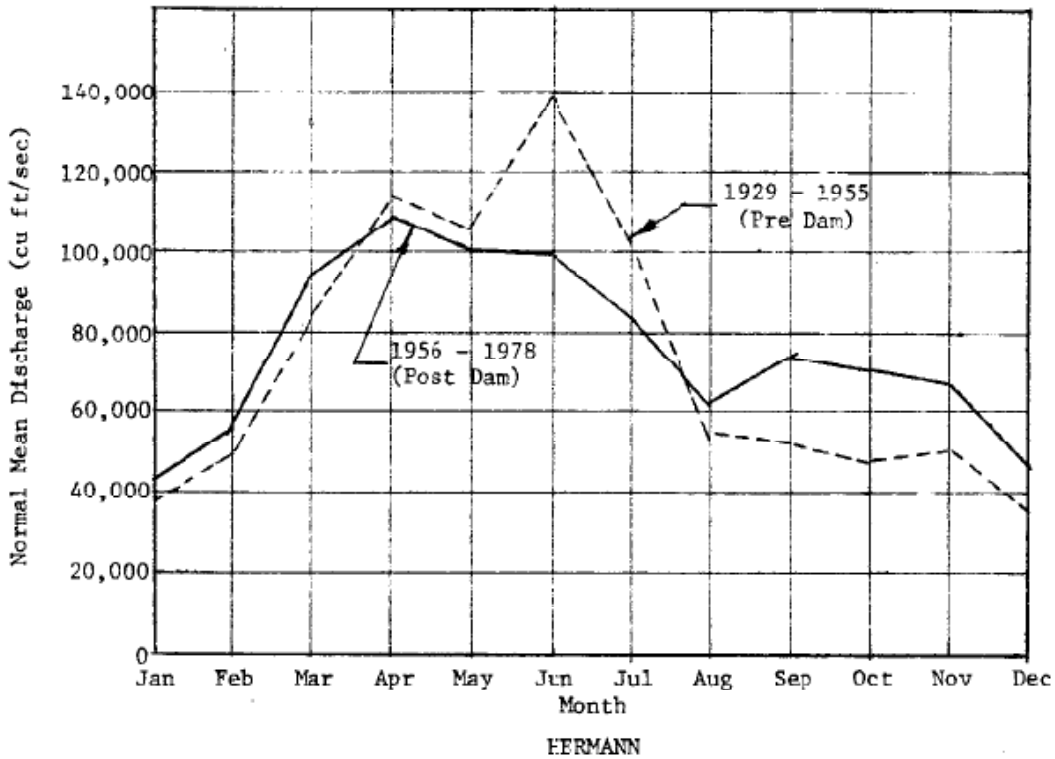


Figure 3.4-10 Mean Monthly Discharge for 1929–1955 and 1956–1978 on the Missouri River at Kansas City and Hermann, Missouri

Source: USACE 1980.

Under current regulation, peak runoff from the spring melt and summer peaks from rainstorms in the upper portions of the Missouri River basin are captured behind the dams and discharged to supplement low flows in the late summer, fall, and winter (USACE 2006). Flow duration curves for four different time periods at the Kansas City gage on the mainstem Missouri River illustrate the effects of the implementation of flow regulations on the LOMR system (Figure 3.4-11). Two of the periods (1928–1946 and 1947–1964) are prior to complete implementation of flow regulation, and two are after full flow regulation implementation. Since full flow regulation, high flows have been reduced in frequency, and periods of low flows have been reduced compared to historical conditions. Moderate flows have increased substantially, as peak flows stored in reservoirs behind the dams are released during the rest of the year. Because flow is a key variable in sediment transport, long-term changes in flow regime can result in significant changes in sediment loads, particle sizes, and channel shape.

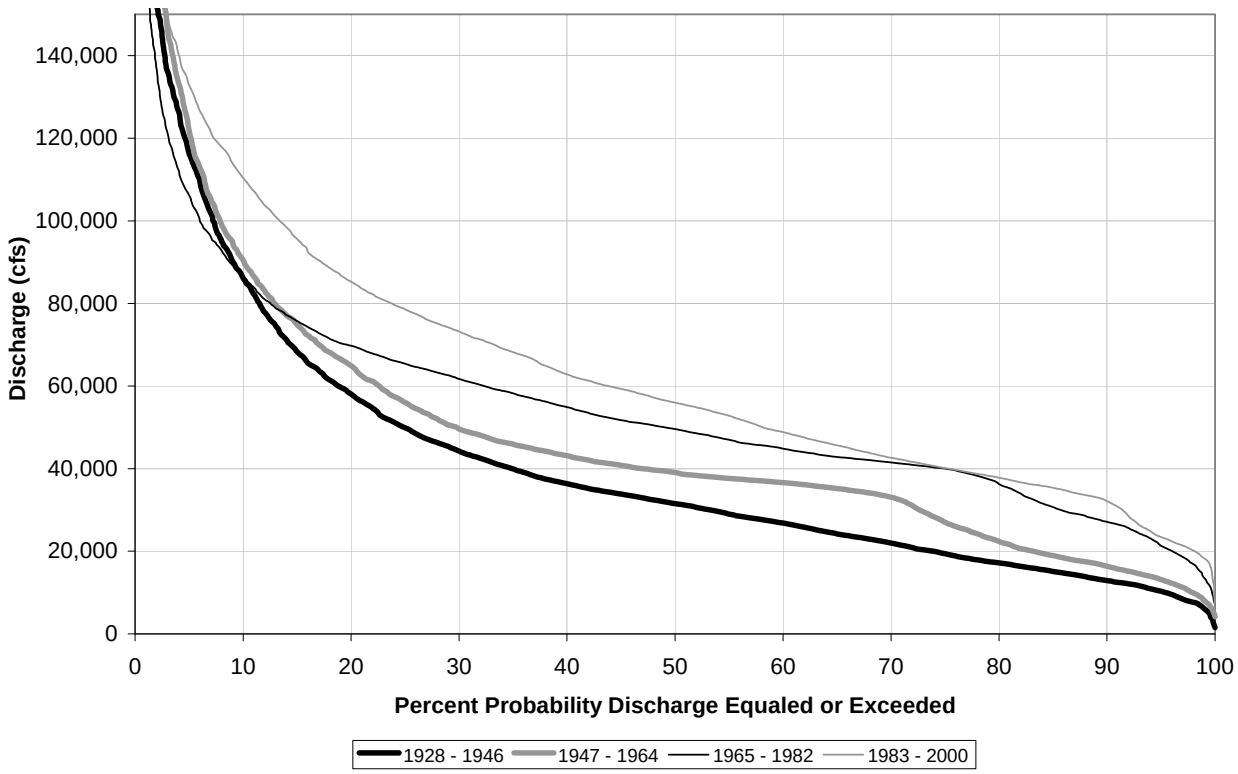
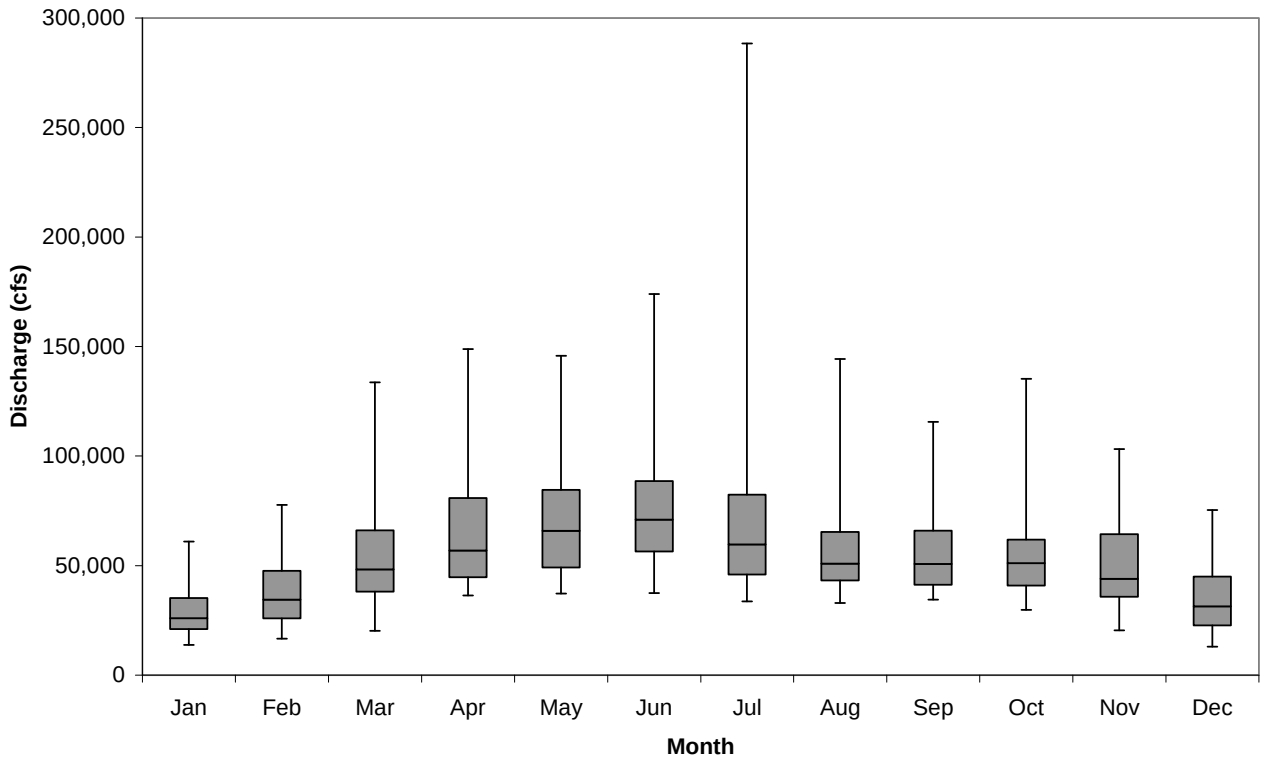


Figure 3.4-11 Flow Duration Curves on the Missouri River Measured at Kansas City, Missouri

Source: USACE spreadsheet "FlowDuration_MoRgages_Qdur.xls.

3.4.4.4 Flow Regime

Typically, during March and April, the accumulated ice and snow in the upper Missouri River basin melts, resulting in an early spring rise (Figure 3.4-12). The highest peak discharges between the headwaters and the Kansas River during the spring rise result from the spring break-up of ice jams in the upper basin (USACE 2006). Snowmelt from the plains and subsequent rainfall in the lower basin also contribute a substantial quantity of spring flow to the LOMR. Summer and fall are characterized by diminished rainfall and runoff, but severe storms during this period have caused severe flooding along the LOMR and its tributaries (USACE 2006). Winter flows are typically low due to the general lack of precipitation (Figure 3.4-9), although occasional large precipitation events have resulted in occasional winter flooding (USACE 2006).



Boxes represent the upper and lower quartile [25% and 75%] above and below the median, displayed as the line in the box. Lines above and below represent the whole range of recorded values.

Figure 3.4-12 Monthly Flow Statistics Measured on the Missouri River at Kansas City, Missouri (1929–2008).

The two largest peak flow events recorded at the Missouri River Kansas City gage occurred in 1951 and 1993 (Figure 3.4-13). Periods of low flow occurred during the 1950s, the 1980s and early 1990s, and the 2000s. Although mean flows are usually less than 100,000 cubic feet per second (cfs), flows above 200,000 cfs are not uncommon.

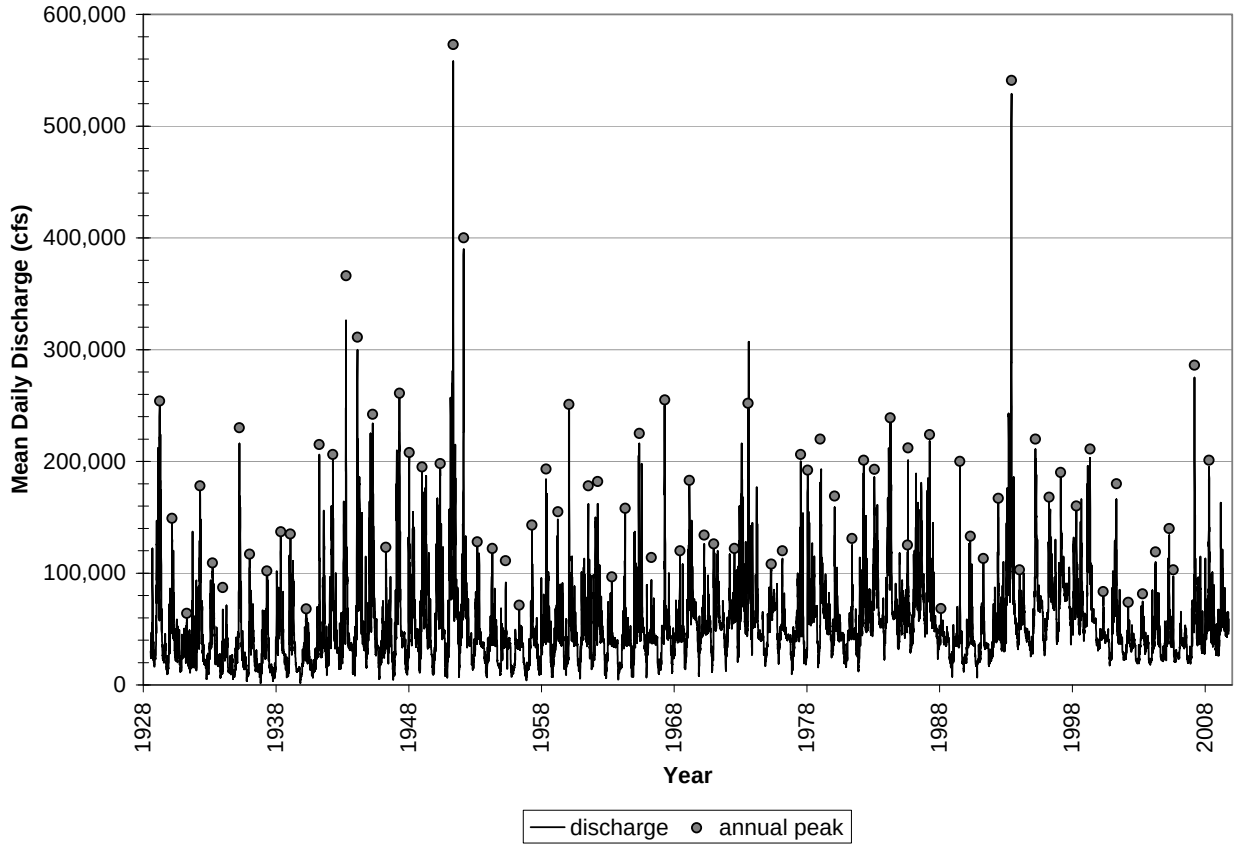


Figure 3.4-13 Mean Daily Discharge and Annual Flow Peaks Measured on the Missouri River at Kansas City, Missouri (1929–2008)

Mean annual flows at the gages on the Missouri River at St. Joseph, Kansas City, and Hermann, Missouri (Figure 3.4-14) demonstrate how inputs from tributaries and precipitation variability (Figure 3.4-8) influence downriver annual mean flows. All three gage locations show increasing flows over the period of record, with the Hermann gage showing the greatest increase.

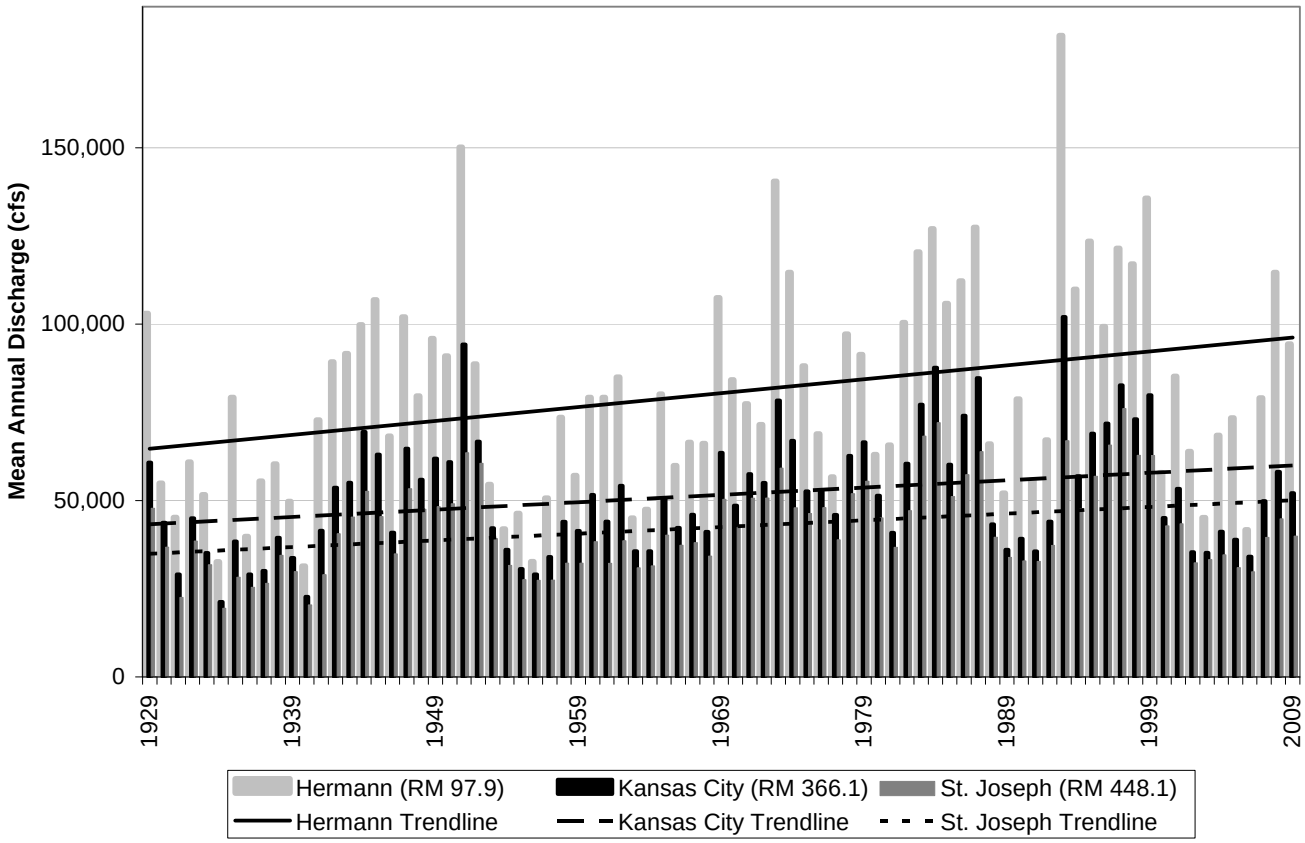


Figure 3.4-14 Mean Annual Discharge and Long-Term Trends Measured on the Missouri River at St. Joseph, Kansas City, and Hermann, Missouri (1929–2009)

The variability of flows on the LOMR is shown by the range of annual (Table 3.4-10) and seasonal (Table 3.4-11) minimum, maximum, and average daily flows. The table shows that maximum discharges vary from approximately 287,000 cfs at Rulo to approximately 739,000 cfs at Hermann, a more than two-fold difference. Average daily flows approximately double from Rulo to Hermann, illustrating the significant difference in hydrologic conditions between the upper portion of the LOMR in the St. Joseph and Kansas City segments and the lower portion of the LOMR in the Hermann and St. Charles segments.

Table 3.4-10 Minimum Daily, Maximum Daily, and Average Daily Discharge on the Lower Missouri River

Monitoring Station	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)
Missouri River at Rulo, NE [a]	289,000	4,420	42,470
Missouri River at Kansas City, MO [b]	529,000	4,730	57,000
Missouri River at Waverly, MO [b]	611,000	5,000	58,720
Missouri River at Boonville, MO [b]	721,000	5,000	69,200
Missouri River at Hermann, MO [b]	739,000	6,210	87,950

Notes:

cfs = Cubic feet per second.
MO = Missouri.
NE = Nebraska.

[a] Period of record between 1953 and 2001.
[b] Period of record between 1958 and 2001.

Source: USACE 2006.

Navigation Flows

The USACE regulates releases from upstream dams to support navigation in the LOMR, one of the congressionally authorized purposes of the upstream dams. The Missouri River navigation channel extends for approximately 735 miles from Sioux City, Iowa to the Missouri River confluence with the Mississippi River (USACE 2007b). The normal navigation period typically extends from the spring rise through an average 8-month ice-free season that can run (depending on the river segment) from late March/early April to late November/early December (USACE 2006). During this 8-month period water is released from upstream dams and combined with tributary inflows to meet target downstream flows (USACE 2006). Due to the evolving nature of the LOMR channel (see Section 3.4.2), navigation levels are determined based on flow targets instead of river stage. Downstream target navigation flow volume and duration are based on the actual quantity of water in storage in the reservoir system.

Target flows at four downstream locations are used to plan the quantity of water to be released in order to provide full or minimal navigation services in a particular year (USACE 2006). Target navigation flow discharges at Kansas City (one of the four downstream control locations) are 41,000 cfs during full-service years and 35,000 cfs during minimum service years. Navigation targets are generally exceeded during flood periods, when system releases are based on appropriate floodwater evacuation from the dam/reservoir systems (USACE 2000).

Table 3.4-11 Minimum Daily, Maximum Daily, and Average Daily Seasonal Discharges on the Lower Missouri River

	Winter Runoff (December, January, February)			Plains Snowmelt and Rainfall (March, April, May)			High Mountain Snowmelt and Rainfall (June, July, August)			Fall Runoff (September, October, November)		
Monitoring Station	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)
Missouri River at Rulo, NE [a]	57,400	10,000	26,300	106,000	15,400	48,500	165,000	29,800	51,100	83,900	17,000	43,800
Missouri River at Kansas City, MO [b]	77,700	13,000	35,200	149,000	20,200	67,200	288,000	33,800	69,100	135,000	20,600	56,100
Missouri River at Waverly, MO [b]	79,800	13,000	36,500	168,000	19,200	69,400	306,000	34,400	71,600	142,000	21,600	56,700
Missouri River at Boonville, MO [b]	106,000	13,800	43,900	235,000	19,500	85,700	375,000	36,600	82,000	188,000	24,600	65,200
Missouri River at Hermann, MO [b]	179,000	17,100	61,500	333,000	22,800	115,000	376,000	39,500	99,900	287,000	29,400	79,200

Notes:

cfs = Cubic feet per second.
MO = Missouri.
NE = Nebraska.

[a] Period of record between 1953 and 2001.
[b] Period of record between 1958 and 2001.

Source: USACE 2006.

In 2003, the USFWS issued an amended biological opinion for the operation of the Missouri River mainstem reservoir system operations (USFWS 2003, USACE 2008). Under the amended biological opinion, USFWS called for a bi-modal spring flow release from the Missouri River dams to benefit pallid sturgeon. These pulses are timed with the commencement of navigation flows and include downstream flow limits to minimize the risk of flood damage (USACE 2009b). To manage the bi-modal spring flow releases, the USACE has implemented adaptive management techniques that include system storage, downstream flows, and regulated tributary releases in order to achieve desired flow levels in an initial pulse in March and a secondary pulse in May (USACE 2008).

3.4.4.5 Droughts and Floods

Droughts and floods are significant because they affect flows that govern sediment transport and storage.

Significant Droughts

Detailed basin runoff records extending back to 1898 document four significant periods of drought (USACE 2006). The 12-year-duration Depression-era drought (1930–1941) is the longest on record and included the three lowest runoff years on record. A second significant drought that extended the reservoir filling time of newly constructed dams occurred from 1954 to 1961. Both of these droughts occurred prior to completion of construction of all of the Missouri River dams and reservoirs. Two additional droughts have been documented since the dams were completed in 1967. The shortest recorded drought from 1987 to 1992 had the fourth lowest recorded runoff year (1988). In 1989, the navigation season was shortened, and service levels were 3,000 cfs below full service, resulting in numerous groundings of ships on the LOMR. Subsequent years saw further shortening of the navigation season and lowering of service levels. The 1989 drought triggered revisions to the Master Water Control Manual to improve the implementation and timing of water conservation measures. During the recent drought (2000–2007), similar water conservation actions were implemented, with record low river levels from October through December and a 30-day shorter navigation season (USACE 2006).

Significant Floods

Due to flow regulation by mainstem dams, annual flooding on the Missouri River between Gavins Point Dam and the Platte River in Nebraska (RM 590) has been essentially eliminated (USACE 2006); however, portions of the LOMR downstream of the Platte River in Nebraska have sufficient tributary inflow to result in over-bank events (USACE 2006). The USACE Kansas City District manages 18 flood

control reservoirs on tributaries to the Missouri River, and the USBR operates 11 lake projects primarily for irrigation purposes that also provide flood control on the Kansas River (USACE 2004).

The 10 largest floods recorded at gage stations along the LOMR from 1898 to 1997 are listed in Table 3.4-12. The earliest recorded flood on the Missouri River with sufficient information for analysis occurred in 1844. This largest known flood within the LOMR system set river stage records throughout the river basin. The early spring floods of 1881 resulted in major flooding in the upper basin. Heavy snows during the winter of 1880–1881 combined with an early spring thaw in the upper basin to produce multiple ice jams. Severe floods from prolonged heavy rainfall occurred in 1903, 1908, and 1927. Severe floods in 1943 and 1947 resulted primarily from melting snow and ice jam formation in the upper basin (USACE 2006).

Table 3.4-12 Ten Largest Floods Recorded at Gage Locations on the Lower Missouri River (1898–1997)

	Gaging Station					
Rank	Rulo	St. Joseph	Kansas City	Waverly	Boonville	Hermann
1	1952	1952	1951	1993	1993	1993
2	1993	1993	1903	1951	1903	1903
3	1984	1903	1993	1952	1951	1951
4	1947	1908	1952	1944	1944	1995
5	1949	1917	1908	1943	1947	1944
6	1944	1909	1943	1965	1909	1943
7	1950	1912	1915	1947	1908	1986
8	1943	1987	1974	1915	1927	1973
9	1960	1920	1944	1995	1943	1947
10	1951	1929	1909	1929	1995	1935

Source: NRC 2002.

The magnitude of the 1951 flood on the lower basin was similar to the 1844 flood. Above-average late spring rain followed by heavy rains during summer resulted in record flood levels at many locations on the LOMR (USACE 2006). The following year, a broad area of the upper basin was covered in deep snow and sustained a prolonged period of sub-freezing temperatures. In late March 1952, a rapid warm-up resulted in severe flood conditions throughout the upper basin of the Missouri River and its tributaries. This flood resulted in the most extensive (both the upper and lower basins) flooding to affect the entire Missouri River basin (USACE 2006).

After completion of the upper basin dams in 1967, the snowmelt- and precipitation-driven floods originating in the upper basin could be dampened or eliminated. Floods originating in the upper basin in 1967, 1975, 1978, 1984, 1986, and 1987 were suppressed by reservoir storage (USACE 2006). In 1993, following 6 years of drought, late spring and persistent summer rains resulted in major flooding on the LOMR. Although most of the precipitation and runoff occurred in downstream reaches, the dams were instrumental in flow controls that prevented overtopping of the federal levees in Kansas City and St. Louis. The 1993 flood breached the non-federal levees between Brownsville, Nebraska (RM 535) and the confluence with the Mississippi River (USACE 2004), except for several in the St. Louis metropolitan area. Subsequent upstream floods in 1995, 1996, 1997, and 1999 were successfully suppressed by the dams reducing downstream flooding impacts.

Although flooding in the LOMR typically occurs during the March to July flood season, flooding outside of this season has occurred due to excessive rains within the tributary basins (USACE 2006). Based on past, current, and forecasted hydrometeorological conditions, minimum- and full-target flows can be modified and system releases can be decreased to provide greater flood control during the flood runoff season (USACE 2006). When significant runoff could result in the loss of life or property, the flood control capability of the upstream regulation system becomes the highest system management priority (USACE 2006).

3.4.5 Sediment Transport and Loads on the Lower Missouri River

3.4.5.1 Introduction

Water flow and sediment transport are the primary variables that govern river bed aggradation and degradation, as well as the volume of sediment that may be available for commercial sand and gravel dredging. The type and distribution of sediment in the river is also important for analyzing changes in river geomorphology and channel configuration over time. Key variables on the LOMR analyzed relative to potential dredging impacts include:

- Historical sediment loads;
- Sources and classification of river sediment;
- Sediment transport mechanisms;
- Particle size distribution of suspended and deposited sediment;
- Suspended sediment (including sand) loads on the mainstem and tributaries; and

- Bed material load estimates.

3.4.5.2 Historical Sediment Loads

Prior to dam construction and flow regulation, the Missouri River existed in a dynamic equilibrium with its floodplain, frequently redistributing sediment between its channel and floodplain (NRC 2002, pg 56). Sediment transport loads were substantially higher; and sediment recruitment through erosion tended to be most severe as flood waters were rising, with substantial deposition of sediment occurring as flood waters receded. Comparatively little data exist relative to historical bed load or bed load transport in the Missouri River; however, measurements of turbidity and suspended sediment have been collected in recent decades, and these variables have changed dramatically as a result of construction of dams and the BSNP.

Information on the range of suspended sediment loads in the Missouri River prior to dams and the BSNP is available from some late 19th century and early 20th century data collection. For example, samples collected by the USACE in 1879 from the River at St. Charles, Missouri yielded 4,100 milligrams per liter (mg/l) of suspended sediment. Samples collected from the same location in 1900 and 1907 had median concentrations of suspended sediment ranging from approximately 1,600 to approximately 2,320 mg/l for lower and higher flows, respectively. In contrast, median suspended sediment concentrations for samples collected from 1973 to 2002 (after construction of upstream dams and the BSNP) from Hermann, Missouri were less than 10 percent of the median concentration in the 1879 measurements and less than 25 percent of the median concentration in 1907. The reduction in suspended sediment and turbidity is attributed to the mainstem dams and later bank stabilization efforts. After the dams were completed, "…almost immediately turbidity decreased by more than 50 percent… later dams and further bank stabilization likely decreased turbidity even more" (Blevins 2006).

Changes in average annual suspended sediment load measured at four gages on the LOMR are shown in Table 3.4-13. These measurements are based on a recent study by Jacobson, Blevins, and Bitner (2009) that included historical sediment load estimates.

Table 3.4-13 Annual Suspended Sediment Loads at Four Locations on the Lower Missouri River (tons/year)

Gaging Station	Nebraska City	St. Joseph	Kansas City	Hermann
River Mile	562.6	448.2	366.1	97.9
1949–1952	N/A	297,844,432	308,867,542	359,794,310
1968–1980	32,407,943	70,106,980	67,240,971	84,877,947
1981–1993	45,304,982	85,539,334	58,422,483	80,358,472
Percent change (from 1949–1952 to 1981–1993)	N/A	-76%	-78%	-76%
Percent change (from 1968-–1980 to 1981–1993)	40%	22%	-13%	-5%

Note: N/A = Not available.

Source: Jacobson, Blevins, and Bitner 2009.

The first filling of the six Missouri River mainstem reservoirs occurred between 1937 and 1963 (Jacobson, Blevins, and Bitner 2009). The BSNP was being constructed during the same period. Jacobson, Blevins, and Bitner consider the 1949–1952 period representative of the pre-dam suspended sediment loads but not prior to the influence of the BSNP. The two 12-year periods after the upstream dams were completed and filled address post-dam trends[2]. The Missouri River at St. Joseph, Kansas City, and Hermann experienced 76- to 78-percent decreases in suspended sediment loads.

Sediment from upstream is effectively trapped behind the lowermost mainstem dam (Gavin's Point Dam) at RM 811, and degradation and channel coarsening has occurred downriver from the dam as a result of reduced sediment load. Downriver from Gavin's Point, the sediment load increases with recruitment from tributaries and channel/bank erosion. For example, the sediment load at Omaha, Nebraska (RM 616) is less than 15 percent of pre-dam conditions, while further downstream current sediment loads are estimated to range between 16 and 50 percent of historical levels (Jacobson, Blevins, and Bitner 2009; USACE 2006).

[2] Jacobson, Blevins, and Bitner (2009) also report average annual sediment loads for the 1994–2006 period. These values are not presented in this report because the USGS recently completed a study to generate new values dating back to 1994 using recently acquired records. The new values are included in Table 3.4-16.

3.4.5.3 Sources of Sediment

Sediment carried by the LOMR comes from a variety of sources and occurs in a variety of sizes. While some fine-grained suspended sediment likely originates upstream of the dams, the majority of the sediment moving within the river erodes from remaining unprotected bank areas along the river or from tributaries eroding the surrounding watersheds. The amount of sediment in the river is influenced by several factors, including:

- Land use practices;
- River bank and floodplain erosion; and
- Geology of surrounding watersheds.

Land use practices play a significant role in the amount of sediment produced by a watershed, and changing land use in the LOMR watershed has affected sediment recruitment. For example, one study estimated that soil erosion on cropland in the Missouri River basin decreased on average 38 percent between 1982 and 2003 due to erosion control practices (Jacobson, Blevins, and Bitner 2009).

It is unlikely that the river banks or the floodplain of the LOMR supply much sediment to the river due to the extensive engineering structures to prevent erosion and channel the river (Jacobson, Blevins, and Bitner 2009, pg 9). However, the sandy river bottom likely contributes sediment in degrading reaches, as do tributaries that undergo headcutting as a result of degradation in the main river channel.

The geology and soil characteristics in the surrounding watershed also affect the type and availability of sediment. The LOMR watershed in northern Missouri has extensive deposits of fine-grained, wind-deposited loess soil. These deposits are the source of much of the fine material carried as suspended sediment by the LOMR. Other sources of material include coarser sand and cobbles deposited as glacial outwash in the glacially carved bedrock canyon, and sediment delivered by tributaries such as the Osage River (now blocked by dams) and the Gasconade River that originate in the Ozark plateau to the south (Section 3.4.2 and Table 3.4-14).

Table 3.4-14 Cumulative Frequency Particle Sizes of Bed Material at Four Gage Locations on the Lower Missouri River

Cumulative Frequency Particle Size (mm)	Gaging Station			
	Nebraska City	St. Joseph	Kansas City	Hermann
D_{10}	0.20	0.20	0.19	0.23
D_{16}	0.25	0.23	0.22	0.25
D_{50}	0.45	0.35	0.36	0.55
D_{65}	0.70	0.45	0.50	0.78
D_{84}	1.50	0.75	1.00	1.60
D_{90}	2.00	0.85	2.00	1.90

Notes:

mm = Millimeter.

The cumulative frequency particle size ranges from D_{10} (equals the diameter of a particle where 10 percent of the material in the bed is finer) to D_{90} (the diameter of a particle where 90 percent of the bed is finer). These gradations represent the typical bed material sizes at the locations shown.

Sources: USGS and USACE 2001–2009 data (see Appendix A).

3.4.5.4 Sediment Particle Sizes and Transport Mechanisms

Several terms are used to describe the size, source, and transport mechanism of sediment in the LOMR system. Figure 3.4-15 shows the relationship between sediment particle sizes (silt, sand, and clay), the transport mechanism (bed load or suspended sediment), and the source of the material (wash load or bed material load).

The size of individual sediment particles determines how they are transported by the river and how they interact with the river bed. The Udden-Wentworth scale is used to classify particle sizes into silt-, sand-, and gravel-sized material (Wentworth 1922). Particle sizes smaller than 0.0625 mm are in the silt and clay size category and are generally carried by the river suspended in the water column. Sand-sized particles range from 0.0625 to 2.0 mm and are transported both as suspended sediment and along the river bed as bed material load. Gravel-sized particles larger than 2.0 mm occur in the river bed and are transported as bed load. Sediment dredged for commercial sand and gravel production typically ranges from fine sand- through gravel-sized particles (Figure 3.4-15).

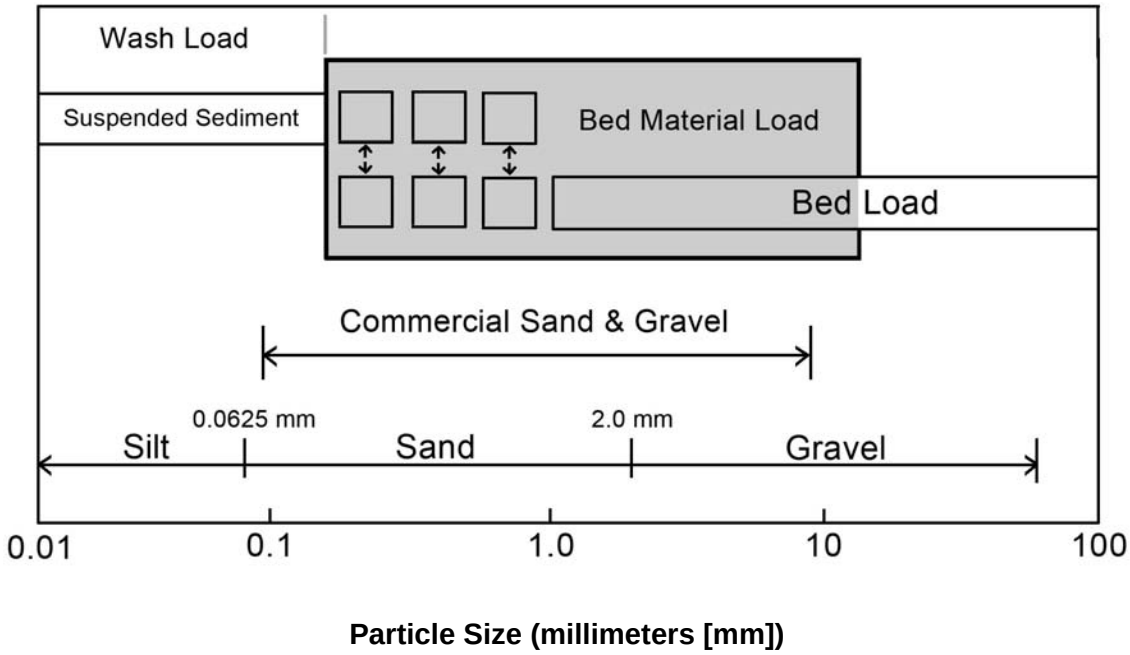


Figure 3.4-15 Sediment Transport Mechanisms and Sediment Sources

Suspended Sediment and Bed Load

Suspended sediment consists of material that is transported by the river in the water column. At low to moderate flows, turbulent eddies may not be sufficiently strong to transport fine- and medium-sized sand in suspension; thus, the sand is deposited on the river bed and transported as bed load. As flow strength increases with higher flow, turbulent eddies bring up the sand from the bed into suspension in the water column, where it is transported. On the LOMR, suspended sediment sizes range from silt and clay to approximately 1-mm sand-sized particles. Particles that may be part of the bed load at a specific flow rate become re-entrained as suspended load if the flow velocity increases (Figure 3.4-15). Because flow velocity constantly changes, the relative proportion of bed load and suspended sediment load also constantly changes.

Medium to coarse sand and gravel particles are generally transported as bed load in migrating dunes on the river bed. Bed load consists of particles moving along or near the bed by rolling, sliding, or saltating (hopping) depending on flow strength and random flow turbulence. Because the source of bed load is scour of the bed material, the same particle sizes moving as bed load comprise the majority of the particle sizes in the bed substrate. Further, because the channel bed is composed of the same material being transported as bed load, changes in bed load transport rates directly influence channel

morphology and channel stability. Imbalance between the capacity of the river to transport sediment (the transport capacity) and the supply of bed material affects the river bed. If the energy available to transport bed material exceeds the sediment supply (for example, at higher flows) the river will scour the bed. Conversely, if the energy for transport is less than the sediment supply, sediment will deposit on the bed.

Wash Load and Bed Material Load

Wash load (Figure 3.4-15) consists predominantly of sediment derived from sources other than the river bed, such as channel bank erosion and runoff from the watershed. Turbulent eddies keep these particles suspended in the flow, with minimal interaction with the active channel bed. The largest wash load particle size has been defined as the grain size at which 10 percent of the bed material (bed substrate) is finer; this is called the "D_{10}" of the bed sediment (Einstein 1950). Although the exact value can differ, wash load particle sizes are found in small amounts in the bed sediment. The volume of wash load transported in the river is principally limited by the supply of material, rather than by the transport capacity. Because wash load is transported in suspension at nearly the same velocity as the river's flow, it can be transported through the system during one runoff event. Importantly, increases or decreases in wash load generally do not affect degradation or changes in the shape of a river (Biedenharn et al. 2006).

Bed material load is the sediment that moves down the river in suspension or as bed load. Unlike wash load, the bed material load does not remain in suspension at lower flows. Bed material load (Figure 3.4-15) includes both the portion of the suspended load that interacts with the river bed and the bed load itself. The bed material load is a key parameter because its size distribution closely approximates the size distribution of the material extracted for commercial sand and gravel production by dredging in the LOMR (Section 2.2). The sum of the bed material load and wash load is the total sediment load.

Determining the Boundary between Wash Load and Bed Material Load

The relative proportion of wash load and bed material load in sediment transport is a key factor in sediment supply analysis. The majority of the LOMR total sediment load is silt- and clay-sized wash load that is transported in continuous suspension. To quantify the percentage of the total sediment load that is bed material load, and thus important to the channel shape and potential degradation, it is necessary to determine more specific boundaries between wash load and bed material load.

An index called the "Rouse number" indicates whether a particle of a certain size will remain in suspension as wash load or settle out of the water column. Rouse number calculations were performed at four locations on the Missouri River. Details on the calculations are presented in Appendix A. The Rouse number analysis found that, at the Nebraska City (upriver of the Project area), St. Joseph, and Kansas City gages, sand particles finer than approximately 0.25 mm (and 0.2 mm at the Hermann gage) remain in suspension at all discharges and should be considered wash load.

Bed Material Particle Size

The USGS and USACE have an established record of sampling bed material sediment (see Appendix A for a description). Select particle sizes are available from three gage sites in the Project area, as well as the upriver Nebraska gage, ranging from the D_{10} (the diameter of a particle where 10 percent of the material in the bed is finer) to the D_{90} (the diameter of a particle where 90 percent of the bed is finer). Table 3.4-14 lists the particle sizes of the river bed at four gages at various percent of size fractions (referred to as "cumulative frequencies" or "cumulative percent finer than"). For example, the D_{10} for the Nebraska City gage means that 10 percent of the material in the river bed is finer than 0.20 mm, and the D_{90} means that 90 percent is finer than 2.00 mm. This is illustrated in Figure 3.4-14, with the cumulative percent finer (D_{10} to D_{90}) on the Y-axis, and the particle size on the X-axis. These gradations represent the typical bed material sizes at these locations and correspond to the average of 10 years of USGS data for the larger size fractions and USACE values at the finest fraction (D_{10}) (the USGS did not sieve any sediment between 0.0625 and 0.125 mm). In general, the particle sizes recorded at the Hermann gage are coarser than the Nebraska City, St. Joseph, and Kansas City gages for all fractions other than the D_{90}.

It is common for the maximum particle size of the wash load to be similar to the D_{10} of the bed material (Einstein 1950). Comparison of the values in Table 3.4-14 with the Rouse number results shows a similar result between material that is nearly always in suspension (wash load) and the D_{10} of the bed material. The Rouse number results predicted that particles from 0.2 to 0.25 mm remain in suspension at all discharges throughout the LOMR and should be considered wash load. Particle sizes of 0.2 to 0.25 mm are very similar to the D_{10} of the bed material.

The particle size data from Table 3.4-14 are plotted on a graph in Figure 3.4-16, which also includes the particle size requirements for commercial sand according to Missouri State Concrete specifications. Most commercially dredged material is used to make concrete that must meet various standards and specifications. Although there are several different specifications for concrete sand, the Missouri State specifications for concrete sand are representative. Sand sizes must fall between the minimum and

maximum curves to meet the specification. At the St. Joseph and Kansas City gage locations, river bed sediment is generally finer than the Missouri State specifications for concrete sand. River bed sediment size distributions at the Hermann and Nebraska City gages meet the specification but are closer to the minimum specification than the maximum.

Figure 3.4-17 shows the particle sizes for the D_{10} and D_{50} every 10 miles for the LOMR. Except for the upriver Nebraska City location, particle size distributions become slightly coarser moving downriver. Laustrup, Jacobson, and Simpkins (2007) showed a similar trend in spawning gravels and bedrock outcrops increasing toward the confluence with the Mississippi River (Figure 3.4-2). These data are evidence that the bed material of the LOMR is composed primarily of medium-size sand particles, with a slight increase in coarseness downriver within the Project area. In addition, the variability in particle sizes increases below approximately RM 150.

While this section summarizes the D_{10}, $D_{50,}$ and average particle size distribution for the LOMR, the river sorts sediment based on flow velocities, resulting in a patchy, continuously changing distribution of particle sizes. In general, the particle size distribution in the bed at any point on the river is determined by the size of particles available for transport and the transport capacity of the river.

Suspended Sediment Particle Size

The USGS periodically collects and analyzes the particle sizes of suspended sediment while measuring suspended sediment loads at their gage sites. Available data from 1981 to1991 at Nebraska City, from 1994 to 2005 at St. Joseph, from 1994 to 2002 at Kansas City, and from 1994 to 2005 at Hermann were reviewed.

The average suspended sediment gradations for each location (Figure 3.4-18) show the representative particle size cumulative frequency curves for each location (individual plots are included in Appendix A). On all of the average gradation plots, the D_{50} value is finer than the finest particle size analyzed by the USGS (0.063 mm), which is the boundary between silt and very fine sand. Thus, the median grain diameter is in the silt/clay fraction.

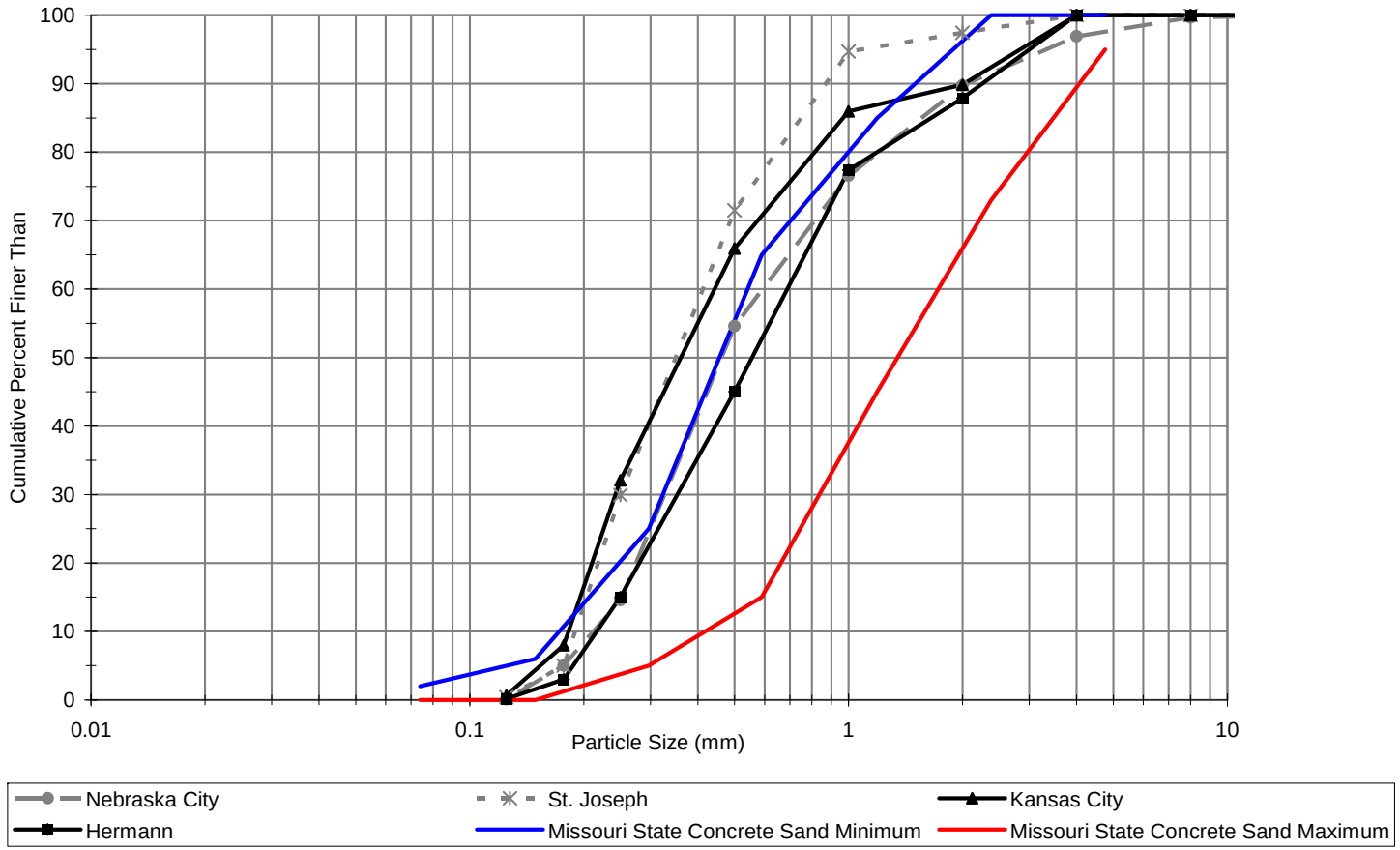


Figure 3.4-16 Cumulative Frequency Particle Sizes in Bed Material at Three Locations on the Lower Missouri River and at Nebraska City

Note: The Missouri State specifications for concrete sand also are shown.

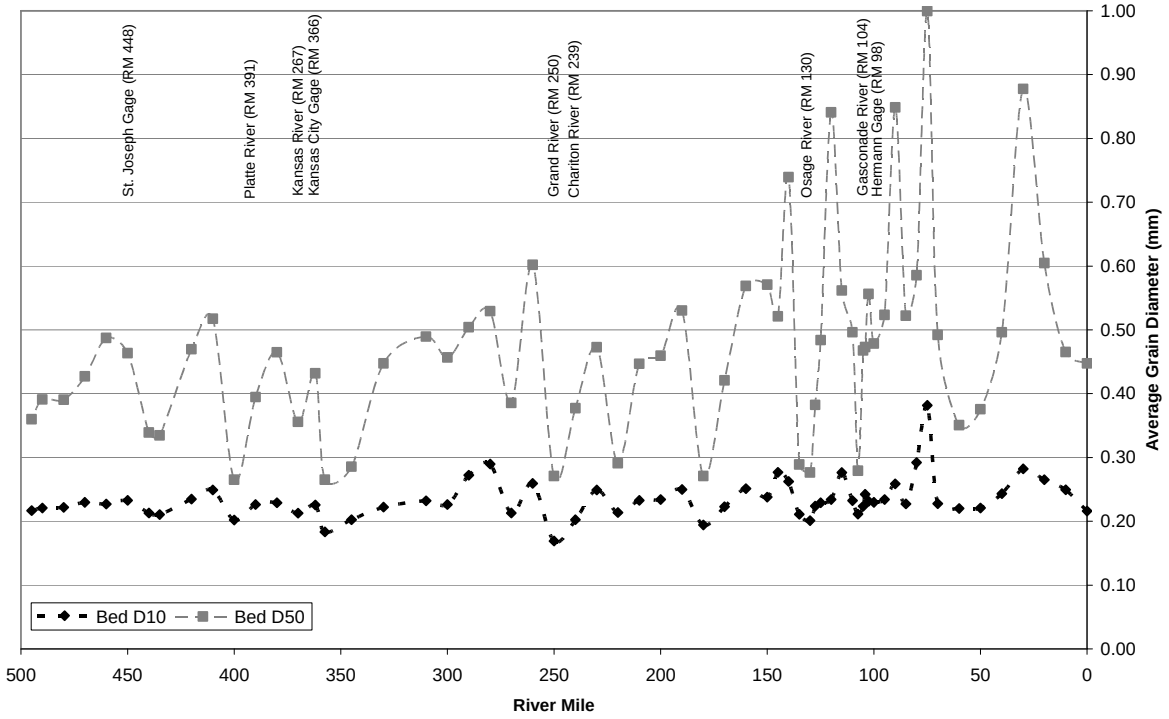


Figure 3.4-17 Particle Sizes of D_{10} and D_{50} for the Lower Missouri River (1994)

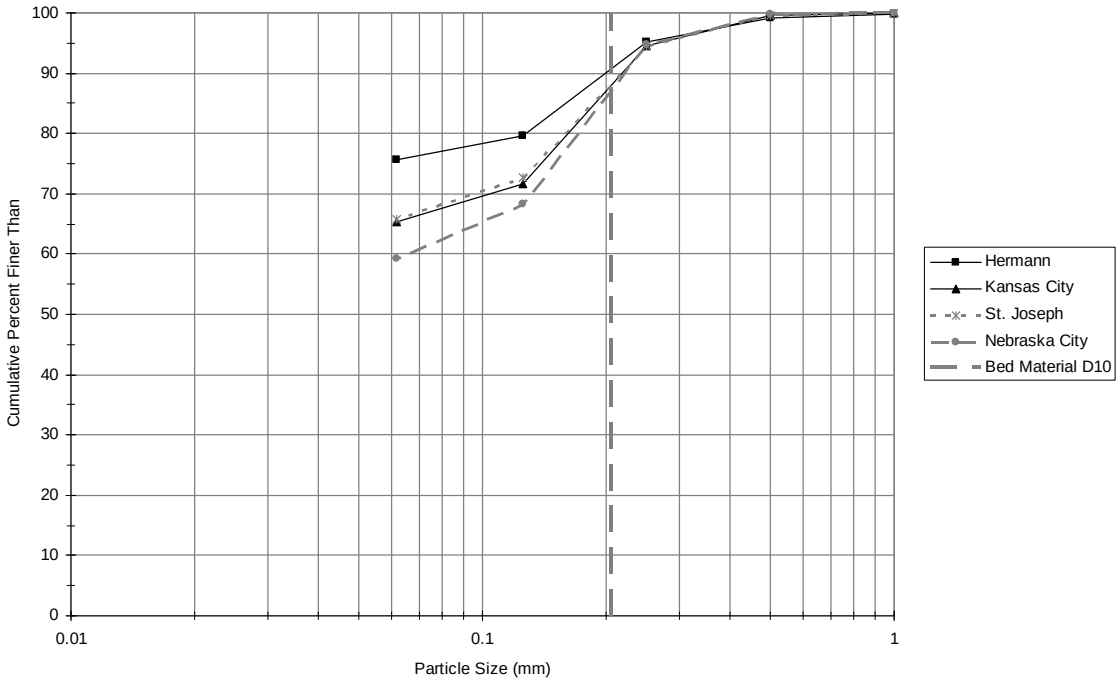


Figure 3.4-18 Representative Suspended Particle Size Gradations at Three Gage Locations on the Lower Missouri River and at Nebraska City

Note: The average bed material D_{10} for the four sites is shown for reference.

Because the USGS does not determine particle sizes finer than sand, USACE mechanical analysis curves of suspended sediment samples dating from 1963 to1965 (for which the silt and clay fraction was determined) were reviewed. The D_{50} values were all in the silt size range (0.014 mm at St. Joseph, 0.012 mm at Kansas City, and 0.012 mm at Hermann).

The percent of sand within the USGS suspended sediment particle size gradations was assessed (Table 3.4-15) for the time periods listed. The sand percentages decrease downstream, from 41 percent at Nebraska City to 24 percent at Hermann. Conversely, the percent of the suspended sediment finer than the D_{10} of the bed material increases downstream, from 87 percent in Nebraska City to 94 percent in Hermann. These results indicate that the percentage of the fine wash load material increases with additional drainage area, which is likely attributable to increased tributary inputs of fine wash load sediment that dilutes the suspended sediment load (Jacobson, Blevins, and Bitner 2009). When the percent of sand in the measured suspended sediment loads is plotted against the discharge at the time of the measurement, there is no correlation between percent of sand content and discharge (see Appendix A for details). One exception is at Kansas City. When flows exceed approximately 85,000 cfs at Kansas City, the sand content is always less than 30 percent. The lack of any strong correlation for the majority of the locations sampled supports the argument that the vast majority of the suspended sediment load is fine-grained wash load and indicates that the river's ability to transport the finer suspended sand fraction is likely more dependent on the size fractions available for transport than on flow strength.

Table 3.4-15 Summary Results for Suspended Sediment Particle Size Analysis

Location	Nebraska City	St. Joseph	Kansas City	Hermann
Period of available data	1981–1991	1994–2005	1994–2002	1994–2005
Percent of sand in the total suspended sediment load (%)	41	33	35	24
Percent of total suspended sediment load finer than the bed material D_{10} (%)	87	87	85	94
Percent of total suspended sediment load coarser than the bed material D_{10} (%)	13	13	15	6

The last row in Table 3.4-15 is the percentage of the total suspended sediment load with particle sizes coarser than the D_{10} of the bed material. These percentages represent the amount of the total suspended sediment load that can be considered part of the bed material load instead of the wash

load. Thus, depending on the location, less than 6–15 percent of the total suspended sediment load likely interacts with the channel bed and affects the river bed and channel shape.

3.4.5.5 Sediment Load Estimates

Bed material loads for the LOMR were estimated to provide a basis for determining the potential contribution of dredging to river bed degradation and potential impacts on channel stability. As described above, the sediment that composes bed material load is very similar in size to the material dredged to make concrete and asphalt.

To estimate bed material loads, the results of measured suspended sediment loads at four gaging stations were reviewed, and estimates of bed material load were calculated. Estimates included the portion of the sediment not measured by the suspended sediment sampling.

Measurements of Suspended Sediment

The USGS worked with the USACE to compile, analyze, and calculate total suspended sediment and suspended sand loads using all available measured data on the LOMR and its major tributaries (Heimann et al 2010). The USGS has compiled measurements of suspended sediment, including measurements made by the USACE and the USGS, and other measurements reported in concentrations and daily loads. The effort also included compilation of all information on bed material and suspended sediment particle size gradations.

Using these data, the USGS calculated estimates of annual total suspended sediment and suspended sand loads for the St. Joseph, Kansas City, and Hermann gages; these were the only gages on the LOMR with sufficient measurement records. A 3-year moving average was used to calculate annual loads (see Appendix A for details). The results for the Nebraska City gage are based on published daily suspended loads rather than estimated values. Suspended sand loads include both wash load (fine-grained sand) and bed material load (coarse-grained sand) components.

USGS results for total suspended sediment and sand are provided in Table 3.4-16. Total suspended sediment loads are displayed for the four gaging stations for water years 1994–2008. The data show the annual variability in both total suspended sediment loads and suspended sand loads. For example, the Kansas City gage shows a greater than 7-fold difference between the lowest recorded suspended sediment load in 2006 (15 million tons) and the highest in 1999 (114 million tons). There is less variability in the suspended sand loads. The average annual suspended sediment load and suspended sand loads increase farther down river, as expected.

The percent of the total suspended sediment that is composed of suspended sand (Table 3.4-16) differs somewhat from the suspended sediment particle size analysis (Table 3.4-15) because of different estimating methods. The most significant difference is for the Kansas City gage, with the USGS study reporting lower suspended sand loads (25 percent) than those listed in Table 3.4-15 (35 percent). . It should also be noted that the total suspended sand loads listed in Table 3.4-16 include sand that is finer than is typically dredged for commercial sand and gravel production, and is therefore not a good estimate for the amount of material available for dredging. Comparison of Figure 3.4-18 for the average size fractions included in the total suspended sediment measurements (which include sand) and Figure 3.4-16, which shows the Missouri State specifications for concrete sand, illustrates this difference. Bed material load-sized sediment more closely matches commercial sand specifications and is estimated below.

Data for the Hermann gage (Figure 3.4-19) include mean annual flow for reference. The trends are similar between total suspended sediment and suspended sand loads with mean annual flows, but there appears to be less inter-annual variability in the suspended sand loads. The mean annual flow aggregates all of the flow data for a year but averages other factors that influence sediment transport such as peak flows, floods, and where in the watershed peak flows originate. For example, peak flows in 2008 and 1997 were similar, but total suspended sediment loads in 2008 were much lower compared to 1997 and suspended sand loads were similar. Figure 3.4-19 also illustrates the annual variability in the LOMR system for flows and sediment loads, even for the relatively short period from 1994 to 2008.

Table 3.4-16 Estimates of Annual Total Suspended Sediment and Total Suspended Sand Loads (1994–2008)

	Nebraska City Gage			St. Joseph Gage			Kansas City Gage			Hermann Gage		
Water Year	Total Suspended Sediment Load (tons)	Total Suspended Sand Load (tons)	Percent of Total Sediment Load as Sand	Total Suspended Sediment Load (tons)	Total Suspended Sand Load (tons)	Percent of Total Sediment Load as Sand	Total Suspended Sediment Load (tons)	Total Suspended Sand Load (tons)	Percent of Total Sediment Load as Sand	Total Suspended Sediment Load (tons)	Total Suspended Sand Load (tons)	Percent of Total Sediment Load as Sand
1994	18,900,000	--	--	26,900,000	8,880,000	33%	35,600,000	11,900,000	33%	58,300,000	20,900,000	36%
1995	46,100,000	--	--	31,900,000	10,600,000	33%	59,000,000	14,200,000	24%	103,000,000	25,600,000	25%
1996	26,200,000	--	--	38,800,000	14,800,000	38%	40,200,000	20,700,000	51%	63,500,000	14,400,000	23%
1997	29,100,000	--	--	60,600,000	22,800,000	38%	94,000,000	31,200,000	33%	96,000,000	27,600,000	29%
1998	51,400,000	--	--	47,700,000	14,700,000	31%	68,500,000	18,000,000	26%	75,200,000	21,000,000	28%
1999	41,200,000	--	--	61,500,000	13,300,000	22%	114,000,000	16,500,000	14%	110,600,000	30,400,000	27%
2000	38,700,000	--	--	15,600,000	6,120,000	39%	16,800,000	5,380,000	32%	14,100,000	4,700,000	33%
2001	31,500,000	--	--	37,400,000	7,400,000	20%	43,200,000	6,000,000	14%	69,200,000	13,900,000	20%
2002	14,200,000	--	--	13,600,000	3,790,000	28%	15,600,000	3,480,000	22%	44,700,000	8,290,000	19%
2003	23,000,000	--	--	20,700,000	3,910,000	19%	17,300,000	3,550,000	21%	11,500,000	3,070,000	27%
2004	11,200,000	--	--	26,200,000	4,840,000	18%	30,700,000	5,400,000	18%	40,500,000	8,920,000	22%
2005	14,700,000	--	--	16,100,000	2,860,000	18%	30,200,000	4,300,000	14%	51,900,000	13,900,000	27%
2006	16,300,000	--	--	11,500,000	--	--	15,000,000	--	--	8,880,000	2,770,000	31%
2007	14,300,000	--	--	29,200,000	--	--	56,300,000	--	--	36,200,000	10,200,000	28%
2008	9,330,000	--	--	39,300,000	--	--	59,200,000	--	--	88,600,000	20,400,000	23%
Average	25,135,000			31,800,000			46,373,000			58,145,000		
Sand Average		--	--		*9,500,000*	*30%*		*11,717,500*	*25%*		*15,070,000*	*26%*

Notes:

-- = No data.

Source: Heimann et al. 2010.

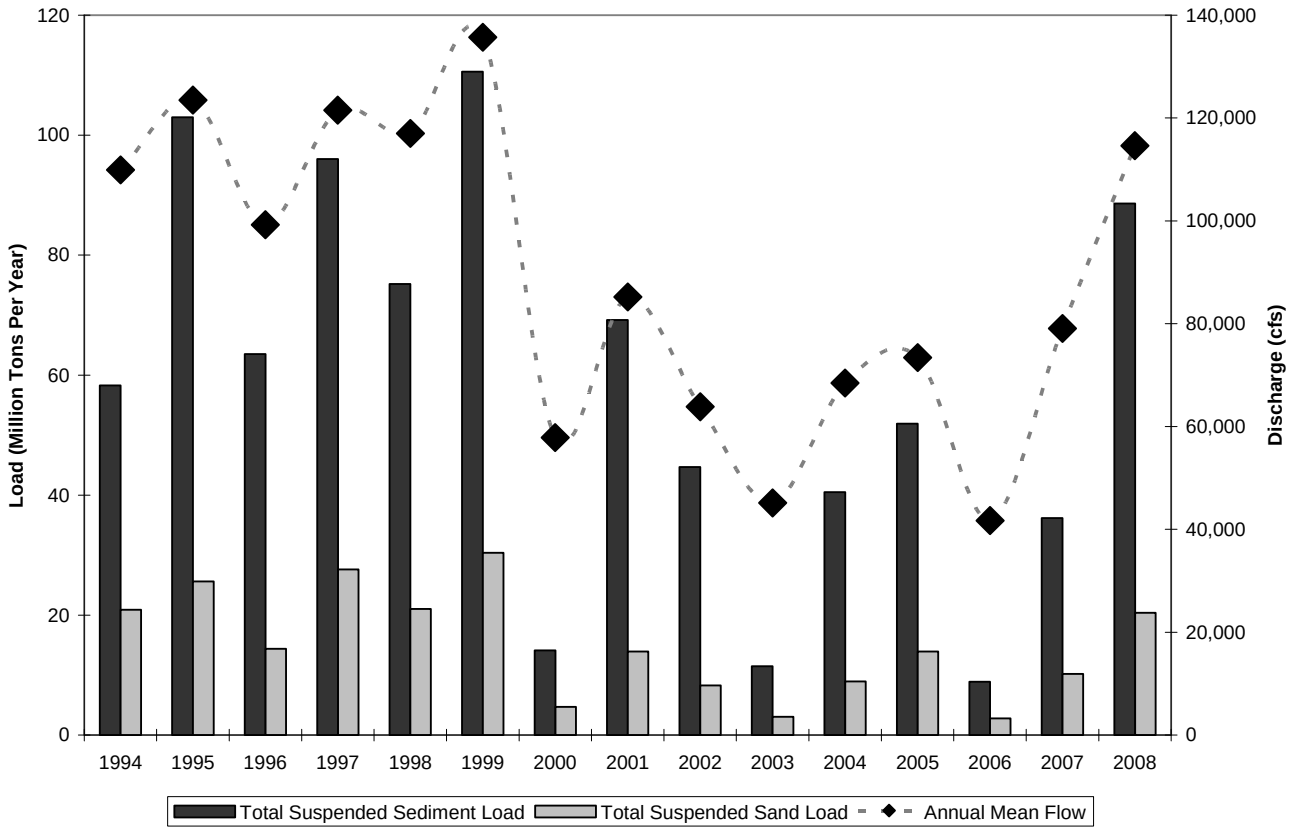


Figure 3.4-19 Total Suspended Sediment Load, Suspended Sand Load, and Annual Mean Flow at Hermann, Missouri (1994–2008)

Suspended Sediment Loads from Tributaries

Limited sediment data are available for some of the tributaries to the LOMR. Total suspended sediment and suspended sand load data were compiled for six gage locations on tributaries to the LOMR (Table 3.4-17). The data provide some indication of the relative contributions of suspended sediment by tributaries, but the data are limited to drawing general comparisons for the following reasons:

- Gage locations are located upstream from the mouth of the tributary and may not represent loads at the mouth. The gage location on the Gasconade River is 104 miles from the mouth, and the data do not include sediment inputs from the lower portion of the river.

Table 3.4-17 Estimated Average Annual Suspended Sediment Loads and Suspended Sand Loads for Tributaries to the Lower Missouri River with Comparisons to the Nearest Gage on the Mainstem (Mainstem Gages are Shaded)

Location	Missouri River Mile	Location of Gage on Tributary[a]	Period of Record	Average Annual Suspended Sediment Load (tons)	Average Annual Suspended Sand Load	Suspended Sand / Suspended Load (%)	Nearest Gage on the Mainstem	Tributary Percentage of Suspended Sediment Load of Nearest Gage on the Mainstem[b]	Tributary Percentage of Suspended Sand Load of Nearest Gage on the Mainstem[b]
Missouri River at St. Joseph	448	N/A	1981–1993	85,539,358	18,298,368	21%	N/A	N/A	N/A
Platte River at Sharp Station	391	24	1980–1992	4,813,000	248,000	5%	Kansas City 25 miles downstream	8%	1%
Kansas River at Desoto	367	31	1976–1981	9,102,000	1,321,000	15%	Kansas City 1 mile downstream	16%	7%
Missouri River at Kansas City	366	N/A	1981–1993	58,422,500	18,408,599	32%	N/A	N/A	N/A
Grand River at Sumner	250	36	1976–1992[c]	11,991,000	1,419,000	12%	Kansas City 116 miles upstream	21%	8%
Chariton River at Prairie Hill	239	20	1979–1986	3,675,000	1,244,000	34%	Kansas City 127 miles upstream	6%	7%
Osage River at St. Thomas	130	34	1976–1994	702,000	313,000	45%	Hermann 32 miles downstream	0.9%	0.6%
Gasconade River at Jerome	104	104[d]	1978–1992	201,000	51,000	25%	Hermann 6 miles downstream	0.3%	0.1%
Missouri River at Hermann	98	N/A	1981–1993	80,358,495	47,178,924	59%	N/A	N/A	N/A

Notes:

N/A = Not available.

[a] River miles on the tributary from confluence with the Missouri River.

[b] Calculated by dividing the tributary suspended load or suspended sand load by corresponding values at the nearest U.S. Geological Survey gage on the lower Missouri River.

[c] Data from 1993 were excluded from the average due to the extreme values reported from the 1993 flood, which were as much as 200 times the annual average for other years in the series.

[d] This gage is much farther upriver than the other gages and does not represent the majority of the watershed.

Sources: Heimann et al. 2010 for tributary data and Jacobson, Blevins, and Bitner 2009 for mainstem data (shaded).

- The time periods covered by the tributary gage data are limited and do not fully overlap with the time periods covered by gage data from the sites on the mainstem Missouri River. Because measured sediment load is a function of flows and flows vary over time, comparisons of these data sets must consider the effects of flow variations from year to year.
- Based on the sand fraction of the suspended sediment load, most of the suspended sediment loads and sand loads within the tributaries would translate to wash load in the LOMR and therefore would neither contribute to LOMR bed material load nor contribute sediment-size fractions to the LOMR suitable for commercial dredging.
- The Grand River at RM 250 is undammed and contributes more suspended sediment and suspended sand to the LOMR than most of the other tributaries, including the Kansas River.

While the Kansas River has a much larger drainage, two primary factors inhibit its sediment contribution to the LOMR: numerous impoundments on its tributaries and dredging in the lower portions.

Most of the other tributaries, except for the Gasconade River, have impoundments or other sediment-trapping structures (Table 3.4-9). The available data suggest that the Osage River and Gasconade River are not contributing much sediment to the LOMR. The lack of substantial sediment contribution from the Osage River is consistent with the major impoundments that exist along its channel. The Gasconade River, however, is likely contributing more sediment to the LOMR than the data indicate because the gage location is a considerable distance upstream from its confluence with the LOMR.

Bed Material Load Estimates for This Analysis

The amount of bed material load transported by the LOMR is equivalent to the sum of the bed load and bed material load component of the suspended load. The LOMR bed material load was estimated using five different equations appropriate for large sand-bed rivers like the Missouri River (García 2008, Molinas and Wu 2000), including:

- Yang (1973);
- Ackers and White (1973) with adjusted coefficients according to H. R. Wallingford (1990);
- Molinas and Wu (2001);
- Engelund and Hansen (1967); and
- Series Expansion of the Modified Einstein Procedure (SEMEP) (Shah-Fairbank 2009).

The Yang, Ackers and White, and Engelund and Hansen equations were used in fractional form to estimate the transport for each particle size fraction of the bed material (Molinas and Wu 2000). The transport rates for each particle fraction were summed to obtain the total bed material load. The Molinas and Wu, and SEMEP equations are based on the median particle diameter (D_{50}) of the bed material.

The bed material equation calculations were performed using data from the Nebraska City, St. Joseph, Kansas City, and Hermann gaging locations. The bed material particle size gradations (Figure 3.4-18) and average hydraulic output (including channel depths, velocities, shear stresses, and widths) for the several cross sections that comprise the HEC-RAS modeling for each reach were used in the calculations. Because hydraulics and bed material load estimates can vary between nearby cross sections, the average of several cross sections was used to best represent the typical hydraulic conditions within each reach (see Appendix A for details).

Four of the five bed material load equations are largely based on the hydraulic parameters of the river channel that define the energy available to transport the river bed material particle sizes. These empirically based equations represent an estimate of the transport capacity at that location in that they calculate the amount of sediment that would be transported given an adequate supply of sediment. The SEMEP equation, however, calculates the amount of bed material in transport using a relationship between the material in the bed substrate and the particle size and concentration of material measured in suspension. It is designed to estimate the actual amount of sediment in transport rather than an equilibrium sediment load, or the maximum amount of sediment that could be transported at a particular location on the river if the sediment was available. The SEMEP equation uses measured total suspended sediment concentrations, bed sediment (D_{10}, D_{50}, and D_{65}) and suspended sediment (D_{50}) particle sizes, and channel hydraulics to determine the amount of sediment being transported in the unmeasured zone. The unmeasured zone includes bed load and suspended sediment in transport near the channel bottom beneath the maximum depth a suspended sediment sampler can sample (typically less than 0.5 foot). The bed material portion of the total suspended load is based on the percent of the total suspended load that is coarser than the D_{10} of the bed material. The Modified Einstein method, on which the SEMEP is based, is well-established and a recommended approach where restrictions on the sand supply may exist (Hicks and Gomez 2003). It was used in the only other study to estimate bed material loads on the LOMR, the *Missouri River Levee Unit L-385 Sediment Analysis* by West Consultants (1999).

Although each of the five equations uses different methods and makes different assumptions, each can be used to estimate the total amount of bed material transported by the Missouri River at the four gage locations. Estimates of bed material transport resulting from each of the five equations were similar at three of the four gaging stations. For the Hermann gage location, however, the SEMEP equation yielded an estimate that is slightly more than half of the average of the other four equations (Table 3.4-18). The SEMEP equation incorporates measured suspended sediment data and represents an actual estimate of bed material load rather than transport capacity. The SEMEP bed material transport estimate was therefore given equal weight to the average of the other four equations in order to yield a single estimate of bed material load for each gage location (see Appendix A for details). It should be noted that although a single averaged result is provided in Tables 3.4-18 and 3.4-19, and in the Environmental Consequences Section 4.2, it represents a range of results averaged from five equations that use data with underlying variability (see Appendix A for details). The standard deviation of the unweighted average of the five equations is listed in Table 3.4-18.

Bed material loads were estimated for two time ranges, 2000–2009 and 1994–2009. The period from 2000 to 2009 was calculated so that the results could be compared to the amount of material dredged during the same period. On average, this period experienced below-average annual flows when compared to the overall period of record. Because bed load transport is correlated to mean annual flows, the estimated bed material load for this period would be lower, representing bed material loads under below-average flow conditions. (See Figure 3.4-19 for an illustration of sediment loads relative to flows and Figure 3.4-14 for mean annual flows and the long-term trend.) The mean annual flow for the Kansas City gage is 51,588 cfs for the entire period of record from 1929 to 2008, 54,974 cfs for the period from 1994 to 2008, and 43,465 cfs for the period from 2000 to 2008. Data were available for analysis for the period from 1994 to 2009, and this period was selected as representative of average conditions because the mean annual flows were slightly higher than the long-term mean for the period and lower than the long-term trend line flow for 2009 (see the trend line for the Kansas City gage in Figure 3.4-14).

Table 3.4-18 Total Bed Material Loads Estimated from Bed Material Load Equations (tons/year)

Location	Ackers & White (1973)	Engelund & Hansen (1967)	Molinas & Wu (2001)	Yang (1973)	Average (AVG) of Four Bed-Material Equations (no SEMEP)	SEMEP (2009)	Weighted AVG – AVG of SEMEP and AVG of Four Bed-Material Equations	Standard Deviation of the Unweighted Average of the Five Bed Material Equations
2000–2009								
Nebraska City	3,858,310	3,345,360	3,735,295	4,289,933	3,807,225	2,442,765	3,124,995	623,460
St. Joseph	4,342,438	3,316,504	4,141,181	3,030,405	3,707,632	3,308,508	3,508,070	515,752
Kansas City	7,147,775	5,032,985	5,991,383	5,834,135	6,001,569	4,702,736	5,352,153	852,016
Hermann	5,303,880	3,726,159	5,187,083	5,301,546	4,879,667	2,517,785	3,698,726	1,117,659
1994–2009								
Nebraska City	5,956,510	5,092,627	5,507,685	6,508,525	5,766,337	5,365,748	5,566,042	497,227
St. Joseph	7,144,192	5,455,947	6,467,546	5,020,173	6,021,965	5,410,855	5,716,410	784,941
Kansas City	10,584,323	7,305,296	8,550,699	8,576,194	8,754,128	7,650,806	8,202,467	1,139,792
Hermann	7,912,424	5,553,251	7,561,138	7,969,907	7,249,180	3,956,009	5,602,594	1,588,006

Table 3.4-19 Comparison of Estimated Average Annual Bed Material Loads at Four Gaging Stations on the Lower Missouri River

Source	Period	Average Annual Bed Material Load Estimate (tons/year)			
		Nebraska City	St. Joseph	Kansas City	Hermann
This analysis	2000–2009	3,124,995	3,508,070	5,352,153	3,698,726
	1994–2009	5,566,042	5,716,410	8,202,467	5,602,594
Missouri River Levee Unit L-385 Sediment Analysis (West Consultants 1999)	1967–1997	N/A	8,954,994	10,881,367	N/A

Note:

N/A = Not available.

The estimated bed material loads (Table 3.4-19) show similar trends to the measured total suspended loads (Table 3.4-14). Both parameters increase between Nebraska City and St. Joseph and between St. Joseph and Kansas City. Between Kansas City and Hermann, however, the bed material load estimate decreases by approximately 32 percent. Although the cause of the decrease in bed material load between the Kansas City gage and the Hermann gage is unclear, it may partially result from (1) the contribution of flows from the Osage and Gasconade Rivers without an equivalent contribution of sediment; (2) addition of coarse sediment from the Gasconade and Osage Rivers; and (3) a difference in sediment sizes from sites upriver and their allocation between wash load and bed material load.

Comparison with Other Bed Material Load Estimates

The *Missouri River Levee Unit L-385 Sediment Analysis* (West Consultants 1999) estimated bed material loads to determine the impact of dredging up to 3.5 million cubic yards of sediment from the Missouri River for use in levee construction upstream of the confluence with the Kansas River. The 1999 study used the Modified Einstein Method (Appendix A) to calculate the total bed material load. A particle size of 0.125 mm (the boundary of very fine to fine sand) was specified as the cutoff between wash load and bed material load. The report did not explain how this was determined other than,

> …Based on a comparison of size characteristics from suspended sediment samples and bed material samples, suspended bed material load is assumed to be the portion of the suspended sediment load that is coarser than 0.125 mm (fine sand sizes and coarser). The finer material is assumed to be wash load. (West Consultants 1999)

For the 1967–1997 period, which had higher than average mean annual flows at 59,837 cfs (the mean annual flow for the period of record is 51,588 cfs), the report estimated an average bed material load of 10,881,367 tons/year at Kansas City and 8,954,994 tons/year at St. Joseph (Table 3.4-18). The estimates from the current study for the 1994–2009 period for Kansas City and St. Joseph are 8,202,467 and 5,716,410 tons/year, respectively, which are 25 percent and 36 percent lower than the L-385 results, respectively. Given the difference in analysis periods, flow variations within those periods, differences in the lower range of bed material load grain size (0.125 mm in the L-385 study and 0.2 mm in the current study) for calculation purposes, and the resultant variability in estimated bed material loads, the results from the L-385 study and the results from the current study fall within a similar range (See Section A.5 in Appendix A for a discussion of the accuracy of equations and comparisons with other results).

Influence of Dredging on Estimated Bed Material Loads

In each case, the gage locations used for bed material load estimations and measurements of suspended sediment loads are downriver from commercial dredging operations that occurred during the period used for analysis. Although commercial dredging represents a removal of bed material load-sized sediment from the system, the amount dredged upriver from the gage locations was not added back into the calculations estimating bed material loads. There is a dynamic equilibrium between the bed material load and the transport capacity of the river (Lane 1955). As sediment is removed from active transport (for example, as a previously dredged area refills), the river erodes material from the river bed downriver from the dredged area to replace the material removed from active transport (Kondolf 1997; Simons, Li, and Associates 1985). Therefore, the transported sediment that is removed from active transport above the gage location (as it refills a dredged area) is replaced by sediment recruited from the bed between the dredged area and the gage, causing river bed degradation (Simons, Li, and Associates 1985). For recruitment of sediment from the river bed into active transport to occur, bed material load-sized sediment in the river bed must be readily available. Because the banks of the LOMR are largely protected by revetments and vegetation and are generally stable, evidence of river bed degradation at locations near dredging operations indicates that dredged material is primarily being replaced by sediment recruited from the bed.

Bed material load-sized sediment appears to be available based on samples of bed material along the river and at the gage sites (see Figures 3.4-16 and 3.4-17). In addition, the four bed material load equations (excluding the SEMEP) calculate sediment transport capacity based on the geomorphic and hydraulic characteristics of the river rather than measured bed material loads; results therefore

represent the amount of sediment that can be transported by the river assuming a readily available supply of sediment. The SEMEP calculation is based on measured suspended sediment loads and, with the possible exception of the Hermann gage, shows similar levels of bed material load transport as the four transport capacity equations. This similarity in levels of bed material transport indicates that the river is likely recruiting new bed material from the river bed upstream of the gage in response to the loss of supply in dredged areas.

Other Estimates of Bed Load

Gaeuman and Jacobson (2007) used an acoustic Doppler current profiler (ADCP) to quantify the bed load sediment transport rate on the Missouri River approximately 9.3 miles downstream from Booneville (RM 197). Assuming an active bed width of 656 feet, an annual bed load rate of approximately 6,900,000 tons, or approximately 8 percent of the total annual Missouri River suspended sediment load, was calculated (Gaeuman and Jacobson 2007). The authors do not state the time period for which the annual load was computed. They define the bed load as the portion of the sediment load captured in a bed load sediment sampler. Assuming that a typical Helley-Smith bed load sampler collects anything transported within 3 inches from the bed, the estimated bed load from this analysis would include suspended sediment moving in the unmeasured zone.

The USACE Engineer Research and Development Center (ERDC)[3] is also using ADCP technology to track sand dune movement in order to estimate bed load transport on the LOMR. A few preliminary bed load estimates have been made at two sites on the LOMR: the Kansas City reach above the Kansas River (~RM 370) and at Washington, Missouri at RM 67. The study is in the preliminary stages, and additional results at different flows are expected for the two locations. The measured bed load in the Kansas City reach ranged from 3,471 tons/day at a flow of 44,877 cfs to 5,226 tons/day at a flow of 47,507 cfs. At the Washington site, the measured bed load ranged from 1,987 tons/day at a flow of 57,530 cfs to 10,003 tons/day at a flow of approximately 169,300 cfs (measured at a nearby gage). For the discharge of 47,507 cfs at Kansas City, the bed material load estimate (based on the average of the SEMEP and the other four equations) would be 12,823 tons/day. For a discharge of 140,425 cfs at the Hermann gage, the bed material load estimate would be 26,784 tons/day, and the measured ADCP bed load estimate by the ERDC at the nearby Washington site was 6,458 tons/day (Abraham pers. comm.).

[3] David Abraham of the USACE Engineer Research Development Center is leading this study.

The ADCP bed load measurements are lower than the total bed material load equation results. This is expected, given that the ADCP study is reporting bed load measurements that include sediment particles moving on or very near the bed in dune formations and does not include suspended sediment. Unlike the bed material load estimates, which do not distinguish between the percent of the total bed material load that is bed load or suspended sediment load, the ADCP measurements aim to exclude the bed material load moving in suspension during the time of measurement. It is not known how much of the sediment moving in suspension near the bed is included in the ADCP measurements.

3.4.6 River Bed Degradation

3.4.6.1 Methods of Measuring River Bed Changes

The LOMR is a dynamic system altered by the completion of flow-regulating dams and instream structures to create and maintain the navigation channel. The USGS and the USACE are primarily responsible for collecting data along the LOMR. In the past 20–30 years, the USACE has collected data to assess the potential impacts of the mainstem dams and the BSNP on the LOMR. As technology and interest in monitoring environmental impacts has changed over time, so has the type and quantity of data collected.

While different types of records and measurements are available for different aspects of the LOMR system, the parameter of primary interest for this assessment is river bed elevation over time. Bed degradation and the potential for continued degradation pose risks to a variety of resources. Measuring the extent and rate of bed degradation is challenging on the LOMR because elevations of the river bed can change over time scales ranging from hours, weeks, years, and decades. Various sets of data are available, but few data sets directly measure river bed degradation. Changes in river bed elevation are therefore estimated using other studies.

The most useful data sets for river bed degradation assessment fall into two broad categories: data collected over time at one location and data collected within a wide area. Time series data can reveal long-term trends as well as short-term variability. Time series data can also provide insights on river system responses to the many management changes that have occurred over the past century, including flow regulation and the BSNP.

The USGS gages at Rulo, St. Joseph, Kansas City, Waverly, Boonville, and Hermann provide long-term records of flow, channel characteristics, and other parameters (see Table 3.4-8 for details on the location and period of record for the gages). USGS gages are located at stable cross sections to

minimize the effects of changes in channel geometry on gage readings. Based on channel top width and flow, an average river bed elevation can be calculated based on the depth of the flow relative to the stage and the elevation of the gage. This method was used to calculate average annual river bed elevations for the time series at the USGS gages; it represents an average bed elevation across the channel and throughout the year for given flows rather than an exact measurement of the bed elevation at any given time or position on the cross section. Since this method averages the depth across time and the cross section at the gage, it is useful for representing long-term trends. Stage heights for the time series also were plotted to show trends and gross changes in channel geometry. Applying the results from USGS gage sites to other locations on the river must be done carefully given the changes in channel geometry and flows at different locations.

Other time series data include river hydrographic surveys collected for many years between 1942 and the late 1980s. These surveys include navigational aid maps of the LOMR that provide depths at various locations along the river. The usefulness of these data for this analysis was limited because of limitations in the format of the data (only hard-copy maps) and the difficulty of reliably relating measurements shown on the maps to a specific location and benchmark elevation.

To evaluate changes in river bed elevation and low-flow water surfaces, data with a common datum are required. The low-flow water surface elevation data collected for at least 10 years between 1990 and 2009 and adjusted to the Construction Reference Plane (CRP) established by the USACE represent such a dataset. The CRP is an imaginary sloping plane that extends the length of the LOMR and is used by the USACE as a benchmark for building and maintaining structures in the river (USACE 2005). The CRP has been revised periodically due to changing conditions on the river; the most recent update occurred in 2010. Recent revisions have based the CRP on the 75-percent exceedance flow, or a flow determined from flow records over the past approximately 30 years that is likely to be exceeded approximately 75 percent of the time during the navigation season. The CRP is calculated by measuring the low-flow water elevation of the river at various points along the river, adjusting them to nearby gage benchmarks, and then interpolating water surface elevations between measured locations at 0.1-mile increments (USACE 2005). Figure 3.4-20 shows the 2002, 2005, and 2010 CRP relative to the 1990 CRP. The 2010 CRP is based on low-flow measurements from 2008 and 2009, and used the same flow data as the 2005 CRP (USACE 2010). The 2010 CRP uses additional data from the St. Charles gage that was not used in previous CRP estimates. The CRP was adjusted downward in the Kansas City and St. Charles segments in 2002, 2005, and 2010.

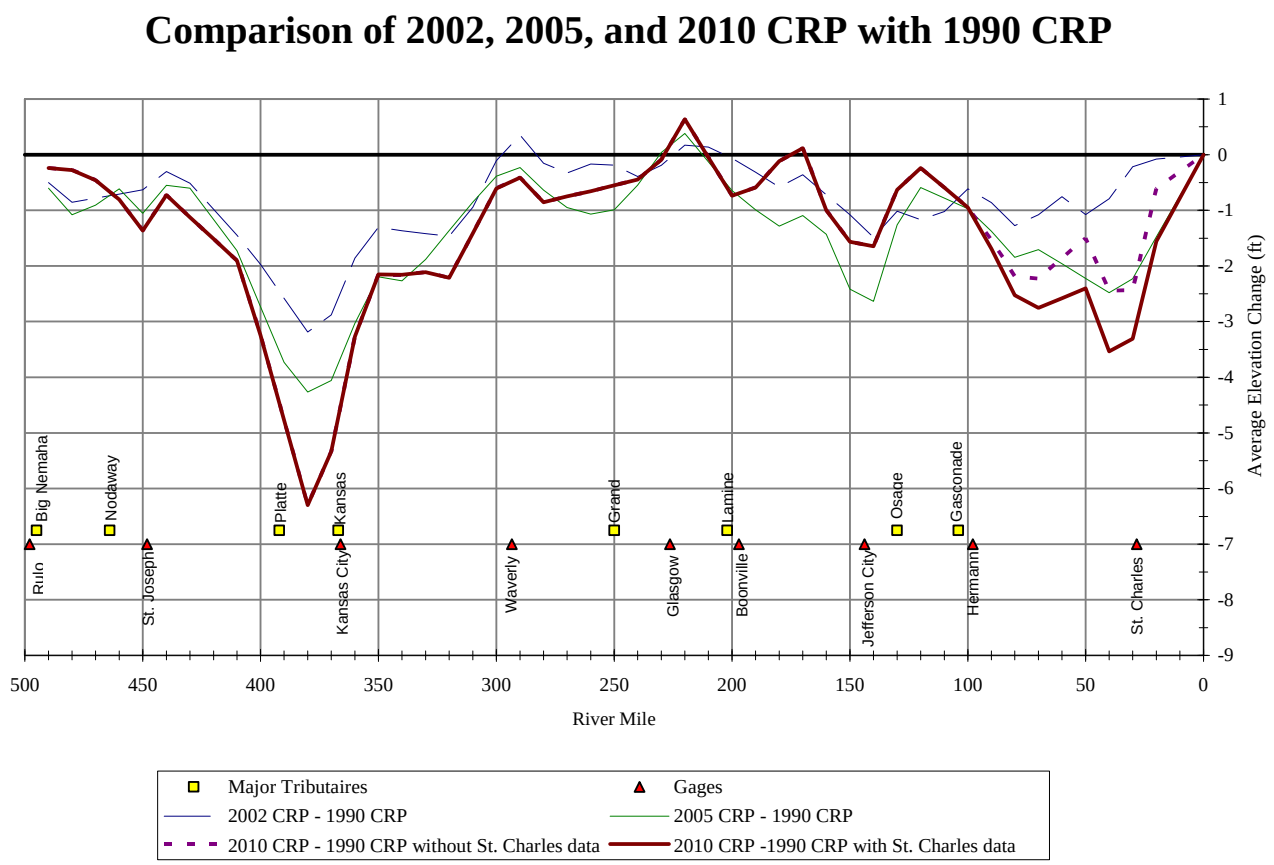


Figure 3.4-20 Differences in CRP Elevations for 2002, 2005, and 2010 Relative to the 1990 CRP Elevation

Low-flow water surface elevations from different years are not directly comparable due to differences in flows at the time the data were collected. However, they can be compared by adjusting to common flows for both profiles. This was done in the current study by adjusting low-flow water surface profiles to the flow values determined for the 2005 CRP. Figure 3.4-21 shows the difference in CRP water surface elevations from approximately RM 750 to Rulo between 1990 and 2005, and the net change in CRP-adjusted low-flow water surface elevation between 1990 and 2005 between Rulo and the mouth.

Water surface elevations do not exactly parallel river bed elevations because water surface elevations result from a combination of factors, including discharge, slope, velocity, and channel roughness. The water surface tends to smooth out the highly variable and changing river bed surface.

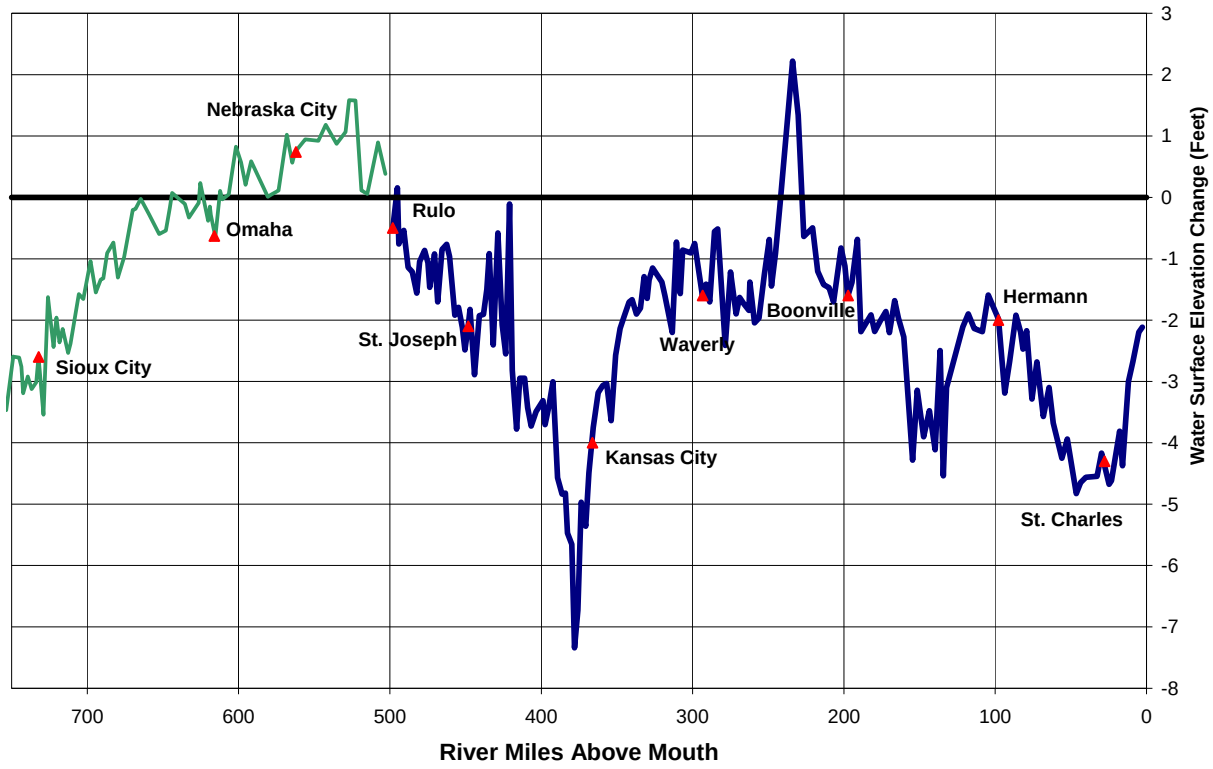


Figure 3.4-21 Change in CRP Water Surface Elevations between 1990 and 2005 (RM 750 to Rulo – shown in green) and Change in CRP-Adjusted Low-Flow Water Surface Profiles between 1990 and 2005 (Rulo, NE to the mouth – shown in blue)

Note: The water profile estimate above Rulo uses a different data set.

Source: USACE spreadsheet "Public_mtg_posters_6_2_2009.xls" and USACE spreadsheet "2002 to 2005 CRP Comparison vs Dredging.xls."

In addition to the analyses described above, a third set of longitudinal data collected by the USACE was analyzed for this EIS. In 1998 and 1999, hydroacoustic bed elevation data (HBED) were collected along the LOMR in a "serpentine" manner with approximately 50 feet between survey points. In 2007, 2008, and 2009, the USACE collected hydroacoustic survey data at cross sections established every 250 feet at most locations in the river and every 87 feet at Habitat Monitoring Assessment Program locations, with river bed elevation points collected every 0.5 feet. 2008 data were collected only at locations with active dredging. The 2009 data set had not been finalized by the USACE at the time of this analysis, but the draft 2009 data were processed to obtain results that are comparable to the data from 1999, 2007, and 2008 (see Appendix A for details).

All points on each transect within 200 feet of the "sailing line" were selected and averaged to obtain an average river bed elevation for each transect and for each year. The sailing line follows the navigation channel and tracks the outside portion of the channel where flow strength is greatest and the channel is usually the deepest. The average river bed elevation for each transect was then averaged by river mile and compared by river mile to the survey results from the other years. The results from any given survey year can therefore be compared to other survey years by river mile to determine changes in average river bed elevation within 200 feet of the sailing line. Figure 3.4-22 displays the change in river bed elevation between 1998 and 2007, 2008, and 2009. The data were smoothed using a 5-mile moving average.

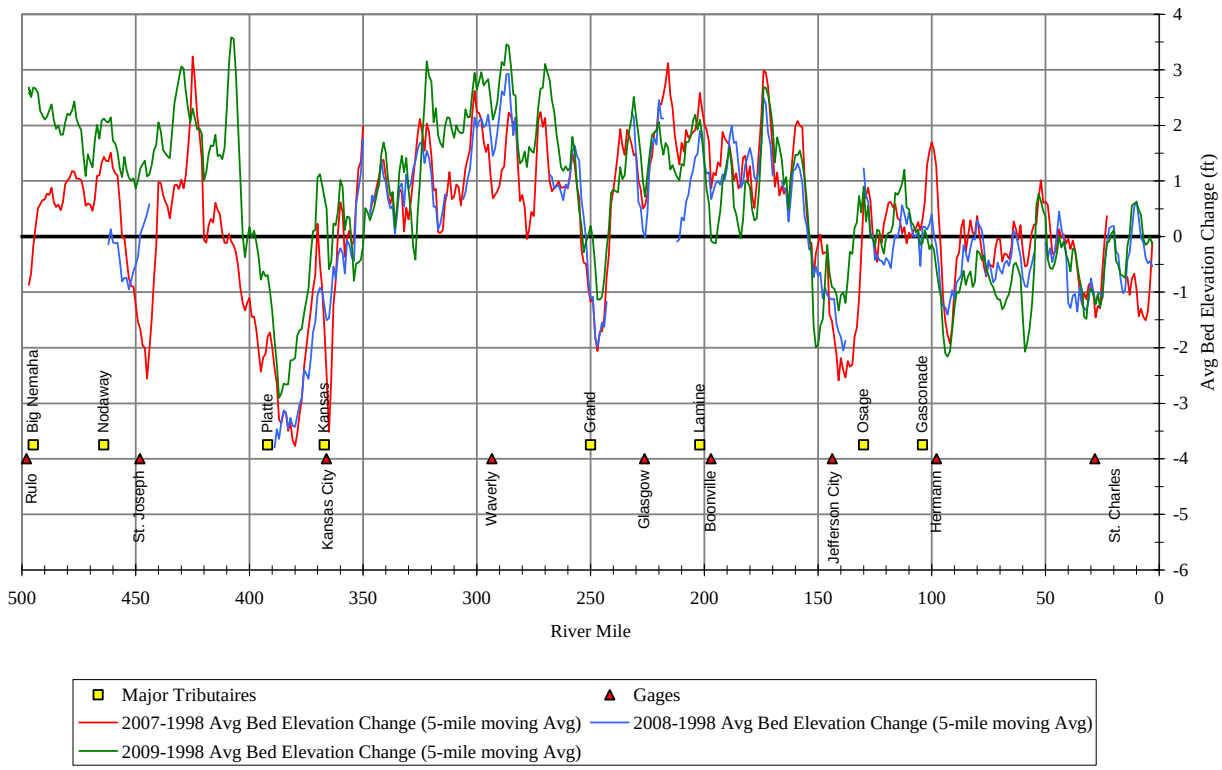


Figure 3.4-22 Change in Average River Bed Elevation between 1998 and 2007–2009 Using a 5-Mile Moving Average

The results using the HBED are not directly comparable to the CRP-adjusted low-flow water surface elevation data because of the difference in data collection methods and time periods analyzed. For issues such as water levels dropping below water intakes along the LOMR and tributary degradation, changes in low-flow water surface elevations are the key factor for assessing change and potential

impacts. The HBED, in contrast, directly measures river bed elevations at known locations over time and is useful for assessing potential impacts on infrastructure such as bridge pilings, pipeline crossings, revetments, and levees.

The analysis period for the low-flow water surface elevation data spans 15 years from 1990 to 2005 and includes the 1993 flood event and several years of above-average flows during the 1990s. The 1998–2009 HBED analysis period is shorter and includes several years of below-average mean annual flows during the early 2000s (see Figure 3.4-14 for mean annual flows). The period of overlap between the two datasets is 7 years between 1998 and 2005, which corresponds to a period with below-average flows (Figure 3.4-14) and above-average dredging rates (Figure 1.5-1).

3.4.6.2 Changes in River Bed Elevations and Surface Water Profiles

Upriver Conditions

Upriver of the Project area, from Rulo, Nebraska (RM 498) to the Gavins Point Dam (RM 811), the river is managed by the USACE Omaha District. The BSNP continues upstream from Rulo, Nebraska to near Sioux City, Iowa at RM 732. Here, the BSNP ends; but structures continue to stabilize the channel until approximately RM 750. The upstream river is unconstrained until it reaches Gavins Point Dam (USACE 2001). Construction of Gavins Point Dam and other upstream dams changed both the flow regime and sediment transport for this segment of the Missouri River.

When Gavins Point Dam was completed in 1955, the estimated average annual sediment load immediately below the dam changed from approximately 135,000,000 tons per year to essentially zero (USACE 2001). A 1949 report projected that approximately 15 feet of river bed degradation would occur just below the dam. As of 2007, the channel had degraded approximately 11 feet, with lower rates of degradation occurring during the period of comparatively low flows from 1987 to 1993 and from 2000 to 2006 (USACE 2007c). A reduction in sediment load while flow and channel geometry remain constant results in increased erosive power, as exhibited by the channel degradation below the dam.

For segments of the river farther downstream from the dam (beginning with the BSNP at RM 735), changes in flow regime, channel cutoffs, changes in sediment inputs, channel stabilization, and construction of levees have contributed to degradation since the dam was completed (USACE 2001). Dredging has not occurred above Rulo, Nebraska at RM 498. Sioux City, Iowa has experienced approximately 11 feet of degradation since completion of Gavins Point Dam, similar to the level experienced at the dam itself. Rates of degradation have tended to stabilize during periods of lower

flow and to increase during periods of higher flow. The amount of degradation has stabilized since 1999 (USACE 2007c). Figure 3.4-21 shows changes in low-flow water surfaces between 1990 and 2005 from RM 750 to the mouth.

At Omaha, Nebraska (RM 616), river bed degradation (as indicated by lower flow stage at 10,000 cfs) occurred from approximately the mid-1930s until the 1950s, and from the early 1970s until the present. The 1950s saw stable or aggrading channels. Between Sioux City and Omaha, the river channel was shortened over 31 miles (21 percent) as a result of cutting off river bends between 1890 and 1960 (USACE 2007c).

Nebraska City, Nebraska (RM 562) lies below the confluence of the Missouri River and the undammed Platte River (RM 590). Here, the Missouri River receives an input of flow and sediment load in the form of coarse and fine sand (NRC 2002). Approximately 1–3 feet of degradation (based on 20,000-cfs flows and calculated average river bed elevations) occurred from approximately 1930 until the late 1970s. The channel then began to stabilize or slightly aggrade until approximately 2000, when the river bed dropped approximately 2 feet. Higher flows have increased in stage due to a reduction in channel width, increasing the likelihood of flooding (USACE 2007c). Changes in low-water profiles between the 1990 CRP and the 2005 CRP indicate that aggradation has occurred between RM 600 and RM 500 (Figure 3.4-21).

St. Joseph Segment

The St. Joseph segment extends from Rulo, Nebraska (RM 498) to the confluence of the Platte River (in Missouri at RM 391.1) just above Kansas City.

Average river bed elevation estimates available for the USGS gage at Rulo from 1949 to 2009 (Figure 3.4-23) indicate declining river bed elevations from 1952 to 1965 and stable to slightly aggrading conditions until 1997. Between 1997 and 1998, the USGS changed the method it used to collect data at this and most of the other LOMR sites, resulting in a potential shift in average bed elevations. These data are shown on the subsequent graphs as points rather than a continuous line, and likely explain the sharp increase in bed elevation at the Rulo gage between 1997 and 1998. The average bed elevation was relatively stable between 1998 and 2009.

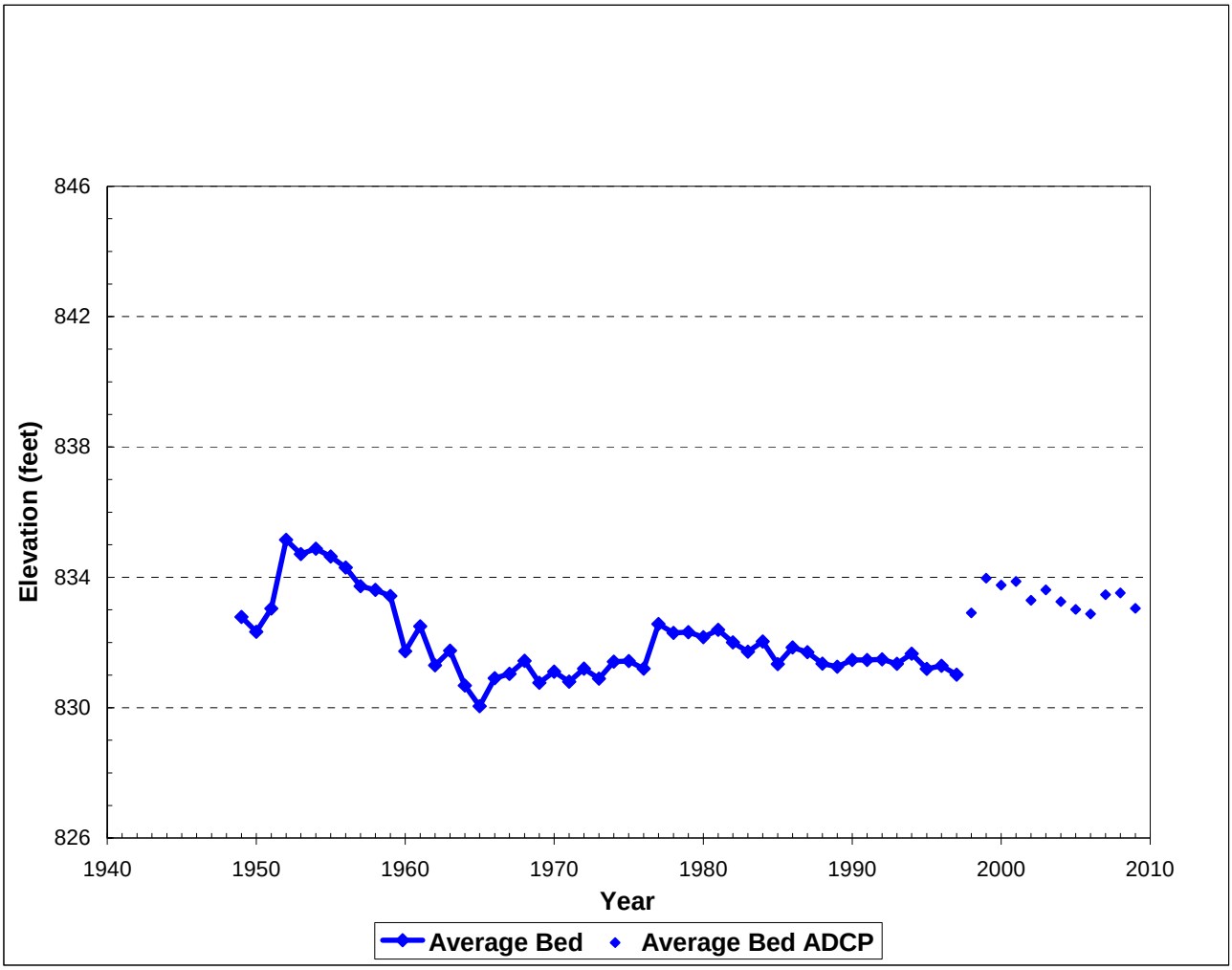


Figure 3.4-23 Missouri River Stage and Average Bed Trends at Rulo, Nebraska (RM 498.1)

Source: USACE spreadsheet "AveBed all gages upto Dec 5 2008.xls" updated with USGS gage data through 2009.

Average river bed elevations and stage trends at the St. Joseph gage (RM 448) from 1928 to 2008 (Figure 3.4-24) indicate that river bed elevations were stable from approximately 1930 to the 1952 flood. The bed then rises several feet and stabilizes until the early 1960s. It then drops below the previous level until the early 1980s, when it rises several feet and stabilizes until the present. The measurement in 2008 is the same as the first measurement in 1928. Lower flows (20,000 cfs), however, have been declining on average since soon after the 1952 flood and have dropped approximately 4.3 feet from 1956 to 2006 and approximately 2.6 feet since 1951. Flows at 40,000 cfs have remained approximately the same, and flows at 70,000 cfs and 100,000 cfs experienced stage increases since the 1940s. The increases seem to have stabilized since the 1960s for 70,000-cfs flows

and since the 1980s for 100,000-cfs flows. The divergence in stages between high flows and low flows is moderately pronounced at this gage. It results from the narrowing of the top width of the channel over time as a result of the BSNP stabilization structures and levees, along with vegetation establishing on the former floodplain.

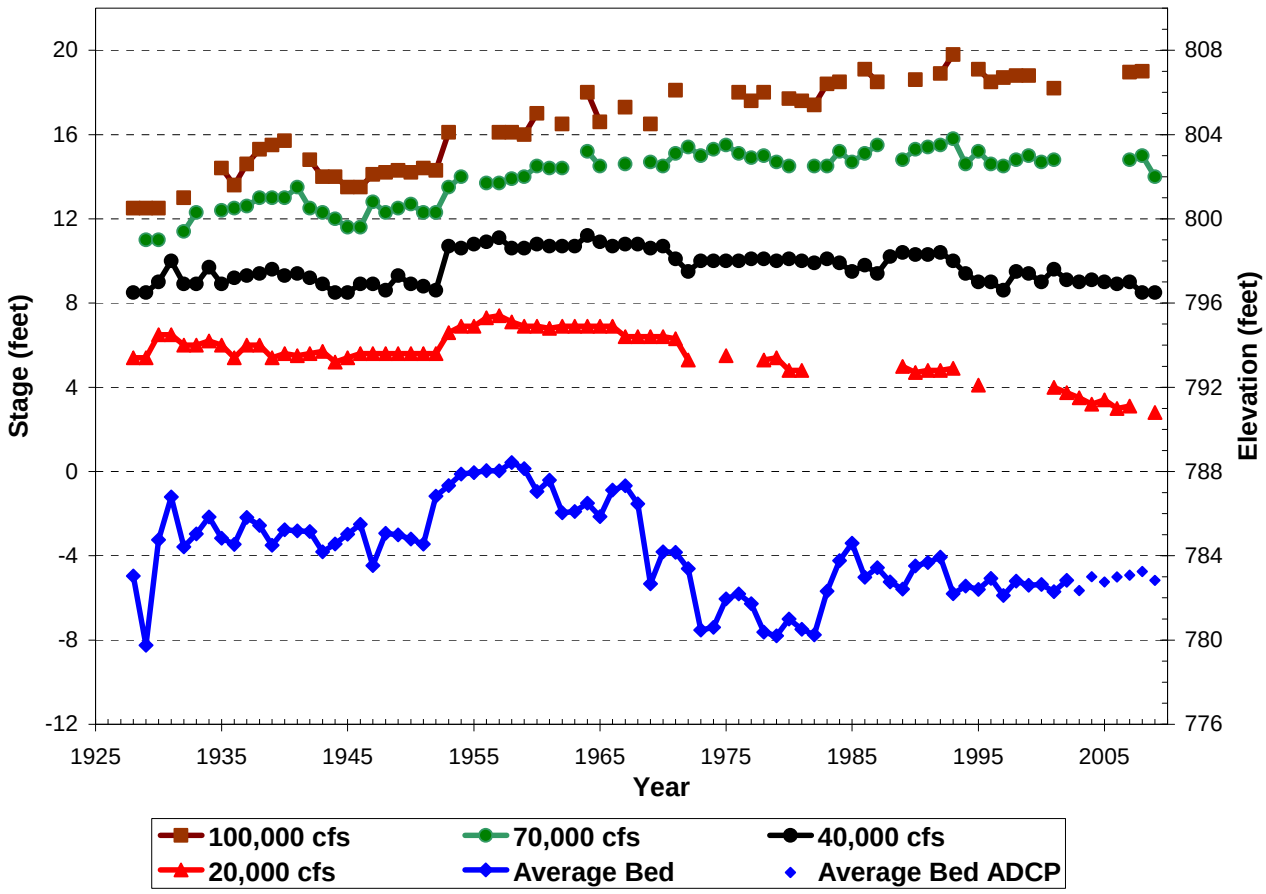


Figure 3.4-24 Missouri River Stage and Average River Bed Trends at St. Joseph, Missouri (RM 448.2)

Source: USACE spreadsheet "AveBed all gages upto Dec 5 2008.xls" updated with USGS gage data through 2009.

Changes in CRP-adjusted low-flow water surface elevations between 1990 and 2005 indicate an approximate 2-foot drop in water surface elevation over that period at the St. Joseph gage, a small drop near Rulo and at approximately RM 422, and a 2- to 3-foot drop in the St. Joseph area and also in the reach from approximately RM 420 to RM 390 near Kansas City (Figure 3.4-21).

Analysis of average river bed elevations based on the HBED shows a 2.5-foot drop in the river bed elevation between 1998 and 2007 at St. Joseph, but a 1-foot increase between 1990 and 2009

(Figure 3.4-21). The river bed also shows approximately 2 feet of degradation near Kansas City at RM 390. Average river bed elevations appear to have increased approximately 1–2 feet through most of the segment between 2007 and 2009.

Boring logs from 1978 for the Route 36 Bridge in St. Joseph (RM 447.9) were compared to river bed elevations collected from underwater surveys conducted in 2009. The results show very little change at the downstream side of the in-channel bridge pier and a 5- to 10-foot lowering of the river bed elevation on the upstream side of the pier, where the effects of local scour from the bridge pier are likely to be greatest.

Kansas City Segment

The Kansas City segment extends from the Platte River in Missouri at RM 391.1 through Kansas City to the Big Blue River at RM 356.9. This segment of the river has experienced more degradation than anywhere else in the Project area. It is also one of the most developed segments of the river and consequently has been studied extensively due to potential risks and costs to infrastructure in the Kansas City metropolitan area.

Average annual river bed elevations have been declining at the Kansas City gage since approximately 1940 and have dropped approximately 12 feet since that time, although elevation increased in 2008 and 2009 (Figure 3.4-25). The rate of decline in average river bed elevation appears to have been relatively steady from 1955 until the 1993 flood event. At that time, the river bed dropped 4 feet, then recovered 2 feet, and then stabilized for a few years before continuing its downward trend after 2000.

The Missouri River stage trend at Kansas City also has been consistently downward for all discharge levels up through 100,000 cfs (Figure 3.4-25). This trend began in approximately 1940, in contrast to trends at nearby upstream and downstream stations. Generally, stages average 8–12 feet lower than those experienced in the 1930s for 20,000 and 40,000 cfs, and 6–9 feet lower for 70,000 and 100,000 cfs. Kansas City stages for 40,000 and 70,000 cfs recovered 1 to 2 feet during the drought years of 1987 to early 1993 and then declined dramatically following the 1993 flood, with little recovery since. Stage estimates for 2006 indicate a 2- to 4-foot drop from the 1993 pre-flood stages in the 20,000- to 70,000-cfs range. Stage observations in 1995 indicated only a partial recovery to the pre-1993 level following the dramatic shift after the 1993 flood.

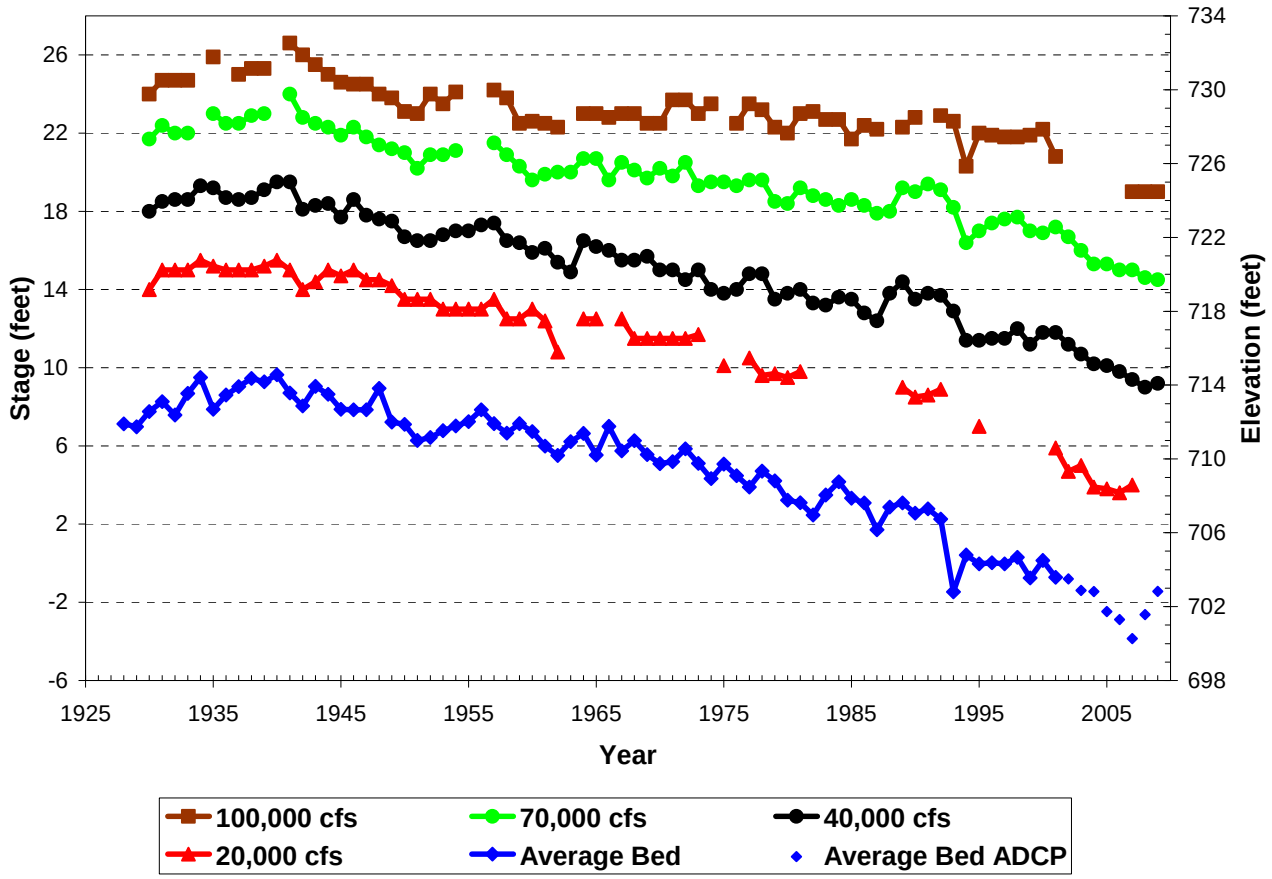


Figure 3.4-25 Missouri River Stage and Average River Bed Trends at Kansas City, Missouri (RM 366.1)

Source: USACE spreadsheet "AveBed all gages upto Dec 5 2008.xls" updated with USGS gage data through 2009.

The CRP-adjusted low-flow water surface elevations (Figure 3.4-21) between 1990 and 2005 show a drop of approximately 4 feet at the gage, similar to the drop in river bed elevation over the same period (-5.36 feet) and similar to the drop in the 20,000-cfs-flow water level (-4.7 feet) at the same location. The low-flow water profile graph shows the greatest amount of change in the longitudinal profile of the water surface elevation (over 7 feet) occurring at approximately RM 378 upriver from the gage and from the mouth of the Kansas River. Moving upriver from the point of greatest decline in the low-flow water surface elevation (RM 378), it is approximately 14 miles until the water surface decline is 3 feet (RM 392), and approximately 43 miles until the decline is 2 feet (RM 421). Moving downriver from the point of greatest decline in the low-flow water surface elevation (RM 378), it is approximately 18 miles until the surface decline is 3 feet (RM 360), and approximately 33 miles until the decline is 2 feet (RM 345) (Figure 3.4-21).

Analysis of average river bed elevations based on the HBED shows a drop of approximately 3.5 feet just downriver from the gage (RM 365) between 1998 and 2007, but only a 0.5-foot drop between 1990 and 2009 (Figure 3.4-22). The maximum drop in river bed elevation of approximately 3.8 feet occurs at RM 381 between 1998 and 2007, and at RM 387 with a drop of approximately 2.9 feet between 1998 and 2009. Between approximately RM 350 and RM 370, the HBED analysis indicates areas of both aggradation and degradation, although the change is generally less than 1 foot. The river bed aggraded between 2007 and 2009 for most of the segment, which is consistent with what was observed at the Kansas City gage between 2007 and 2009 (Figure 3.4-25).

An approximate 15- to 30-foot drop in river bed elevation at the center pier of the Broadway Bridge (RM 366) between 1954 and 2009 is indicated by a comparison between the construction boring logs from 1954 and a 2009 underwater bridge survey. This drop in river bed elevation is likely influenced by localized scouring around the bridge pier. Even though the water surface elevations were within a few feet of each other at the time of the original borings and at the time of the survey in 2009, the piers on both sides of the channel that were in the water in 1954 are now both dry. The left bank pier, which was under approximately 6 feet of water in 1954, is now 40 feet from the water's edge. This illustrates the extent of channel degradation and changes in channel geometry over the past 50 years at this location.

Tributaries to the LOMR in the Kansas City segment also have experienced degradation, although the extent of the problem has not been documented. In the USACE (2009a) Degradation Reconnaissance Study, the USACE stated:

> Head cuts are occurring on several of the tributaries. These head cuts are affecting bank stability, causing scour and exposure of bridge piers, and causing potential loss of habitat as banks of tributary streams erode. An example is a bridge at Line Creek, located near RM 385 in the Kansas City reach. In this location, a traffic bridge located just upstream of the tributary mouth was shut down temporarily for safety concerns while temporary measures were implemented to ensure the bridge's safety. This incident occurred in FY 2009 and is an indication of the active nature of the river bed degradation and its impacts. The head cut on this tributary has now migrated to the point that a railroad bridge further upstream is also at risk. (USACE 2009a)

Waverly Segment

The Waverly segment extends from the Big Blue River at RM 356.9 to the Grand River at RM 249.9. This segment has no major metropolitan areas and no major tributaries.

There is one USGS gage in this segment at Waverly, Missouri (RM 293.1). This gage has been collecting data from 1928 until the present. The average annual river bed elevation has been steady to slightly declining over the period of record, with periods of relative stability before and after the flood event in 1993. That event caused a drop in river bed elevation of approximately 1 foot. Most recent data points are within 1 foot of the first measurements collected in the late 1920s (Figure 3.4-26).

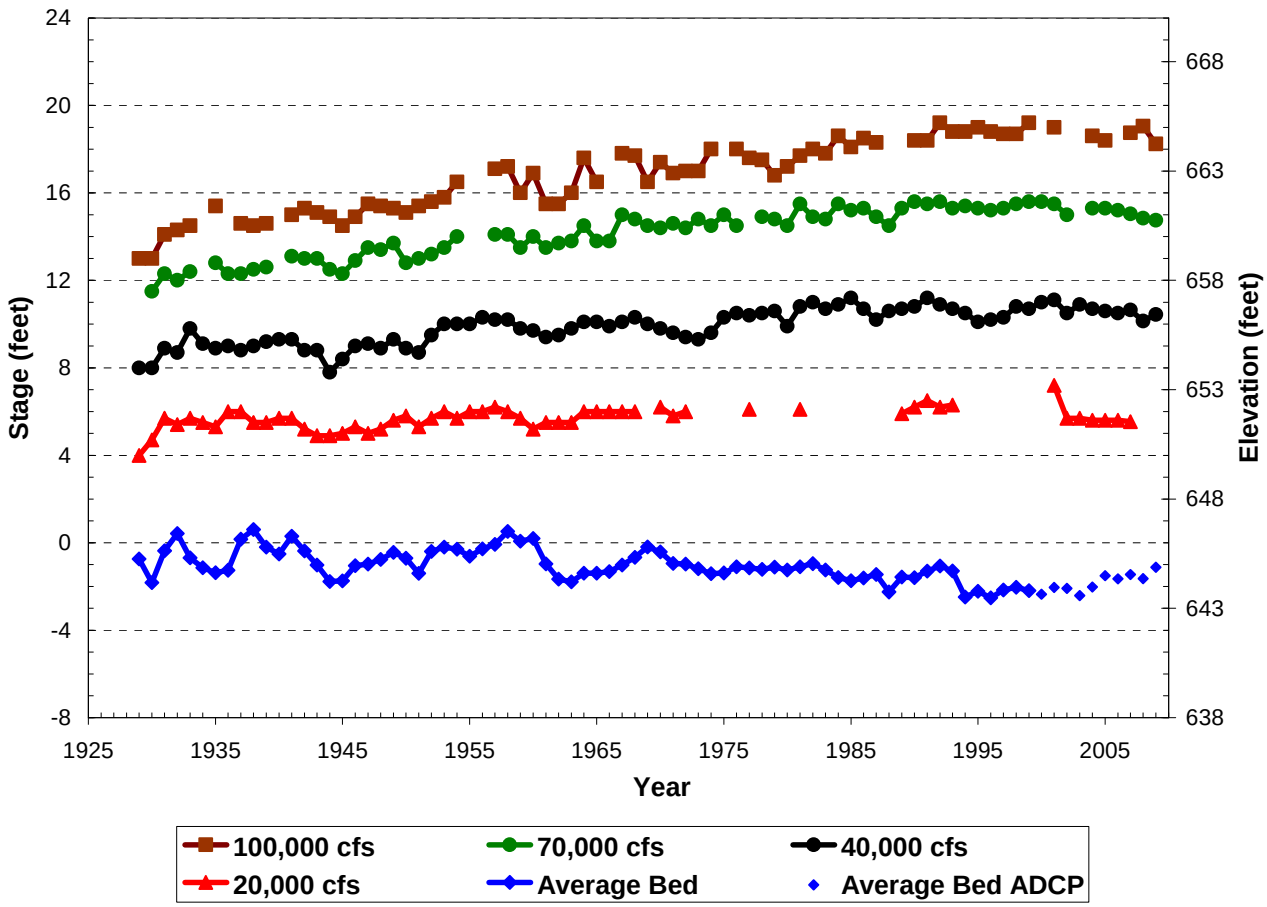


Figure 3.4-26 Missouri River Stage and Average Bed Trends at Waverly, Missouri (RM 293.4)

Source: USACE spreadsheet "AveBed all gages upto Dec 5 2008.xls" updated with USGS gage data through 2009.

Water surface elevations during low-flow stages (20,000 cfs) have been stable to slightly increasing over the period of record. Water surface elevations during higher flows have been increasing over the period of record, with the flows equal to or greater than 70,000 cfs recording stages 3–5 feet higher than during the 1930s (USACE 2007c).

The difference in CRP-adjusted low-flow water surface elevations between 1990 and 2005 (Figure 3.4-21) indicate that most of the Waverly segment has experienced moderate declines in the 0.5- to 2-foot range, except for the most upriver portion near Kansas City where the surface has dropped approximately 3.5 feet around RM 354.

Analysis of average river bed elevations based on the HBED shows an average of approximately 1 foot of aggradation between 1998 and 2007, and 1.7 feet of aggradation between 1998 and 2009 for the Waverly segment (Figure 3.4-22).

Jefferson City Segment

The Jefferson City segment extends from the Grand River at RM 249.9 to the Osage River at RM 129.9. This segment includes Jefferson City, where dredging occurs to provide sand for Jefferson City and the surrounding area.

There are two USGS gages in this analysis segment. The Glasgow gage located at RM 226.3 has limited data. A small number of average river bed elevation measurements were taken around 1950, and approximately 10 data points have been collected over the past 10 years. The average river bed elevations from the past 10 years are within 1–2 feet of the 1950s values, showing no discernible trend.

The difference in CRP-adjusted low-flow water surface elevations between 1990 and 2005 (Figure 3.4-21) shows a decline of approximately 0.5 foot at the Glasgow gage, but it is immediately downriver from the only point on the graph that shows aggradation. The aggradation occurs below the confluence with the Grand and the Chariton Rivers, which appear to contribute a considerable amount of sand compared to other tributaries to the LOMR (see Table 3.4-17).

Records at the Boonville gage (RM 197.1) date back to 1930, and provide stage and average river bed elevation trends (Figure 3.4-27). The average river bed elevations are variable but do not exhibit a trend until approximately 1970, when a downward trend begins, with an uptick in the last couple years of data (2007 and 2008). The maximum difference is approximately 5 feet between 1970 and 2006, and the difference is approximately 2.8 feet between 1990 and 2005. Lower flow stages (20,000 cfs) also show some decline, even though stages for 40,000–100,000 cfs have remained fairly constant. Flows greater than 100,000 cfs show an upward trend of 2–4 feet (USACE 2007c).

The difference in CRP-adjusted low-flow water surface elevations between 1990 and 2005 (Figure 3.4-21) is approximately 1.5 feet at the Boonville gage.

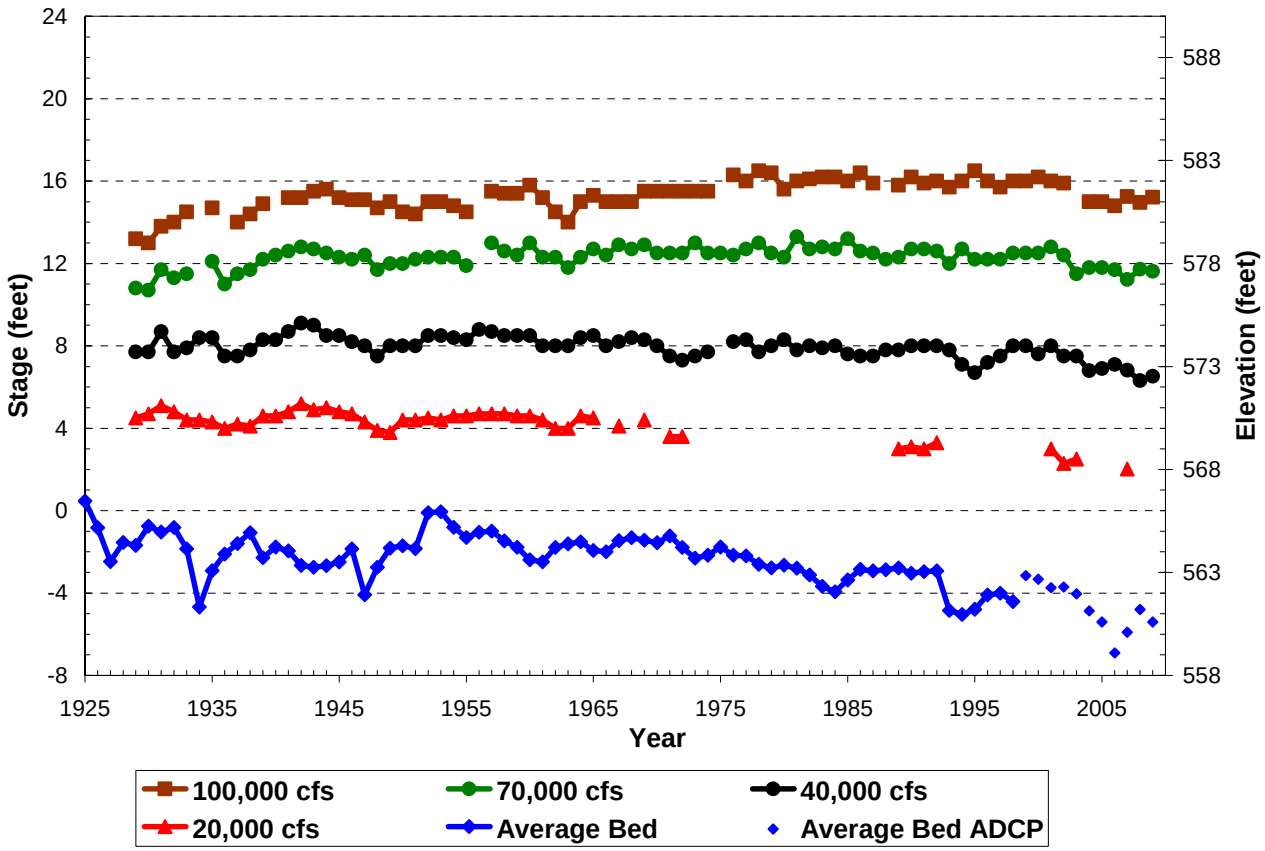


Figure 3.4-27 Missouri River Stage and Average River Bed Trends at Boonville, Missouri (RM 197.1)

Source: USACE spreadsheet "AveBed all gages upto Dec 5 2008.xls" updated with USGS gage data through 2009.

No rated gage is in the vicinity of Jefferson City, but water surface elevations between 1990 and 2005 show a decline of approximately 3.0–4.5 feet between RM 160 and RM 130.

Analysis of average river bed elevations based on the HBED shows aggradation between approximately RM 155 and RM 240 for the period from 1998 to 2007–2009 (Figure 3.4-22). Unlike the Waverly segment, however, slight degradation was present between 2007 and 2009 for most of the segment. Approximately 1–2 feet of degradation was present at RM 250 near the confluence with the Grand River, and 2–2.5 feet of degradation in the Jefferson City area (RM 135 to RM 150).

A comparison of boring logs taken in 1954 from the US 54W Bridge in Jefferson City (approximately RM 144) to recent underwater surveys conducted in 2009 indicates a drop in the river bed elevation of 20–30 feet around the bridge pier located in the active flow channel, although this drop is likely

influenced by local scour surrounding the bridge pier. Underwater surveys at points surrounding the piers show a general decline in river bed elevation from 2004 to 2009; however, a survey conducted in December 2008 showed higher bed elevations than did surveys conducted in May, July, and August of the same year.

St. Charles Segment

The St. Charles segment extends from the Osage River (RM 129.9) to the confluence with the Mississippi River (RM 0). This segment includes a major tributary (the Osage River) at RM 104.4, and the city of St. Charles within the St. Louis metropolitan area, approximately 30 miles upriver from the confluence with the Mississippi River.

There are two USGS gages in this segment. Records for the Hermann, Missouri gage at RM 97.9 date back to approximately 1930, while the St. Charles gage has recorded average bed data since 2000.

The average annual river bed elevations for the Hermann gage (Figure 3.4-28) trend slightly upward from approximately 1930 to approximately 1960 and then begin to trend steadily downward until 2006. In 2007, the river bed elevation rose approximately 2 feet. This increase is not thought to be indicative of recovery of the bed, in light of the long term downward trend. The maximum decline between 1959 and 2006 is approximately 7.5 feet. The change from 1990 to 2005 is approximately 2.8 feet. Stages for flows below 100,000 cfs have been declining slightly since approximately 1970, and higher flows have been declining since the 1993 flood (USACE 2007c).

The average river bed elevations for the St. Charles gage have been generally stable over the short period of record (10 data points, no figure), declining approximately 1 foot between 2000 and 2009.

The difference in CRP-adjusted low-flow water surface elevations between 1990 and 2005 (Figure 3.4-21) is approximately 2 feet at the Hermann gage and approximately 4.3 feet for the St. Charles gage. From 1990 to 2005, the water surface elevation changes approximately 2 feet at RM 85 and almost 5 feet at RM 48. It changes between 4 and 5 feet from RM 52 to RM 20. The lowest 15 miles of the LOMR near the confluence with the Mississippi River are subject to backwater influences from the Mississippi River that affect low-water profile readings, flows, sediment transport, and related parameters.

Analysis of average river bed elevations based on the HBED shows less than 1 foot of aggradation between RM 95 and RM 129, and an average of less than 1 foot of degradation between RM 0 and RM 98. The maximum degradation of approximately 2 feet occurs near the Hermann gage at RM 95

for the 1998 to 2007–2009 period and at RM 60 for the 1998–2009 period. The river bed in the St. Charles area (RM 25 to RM 40) dropped approximately 1.5 feet between 1998 and 2007–2009.

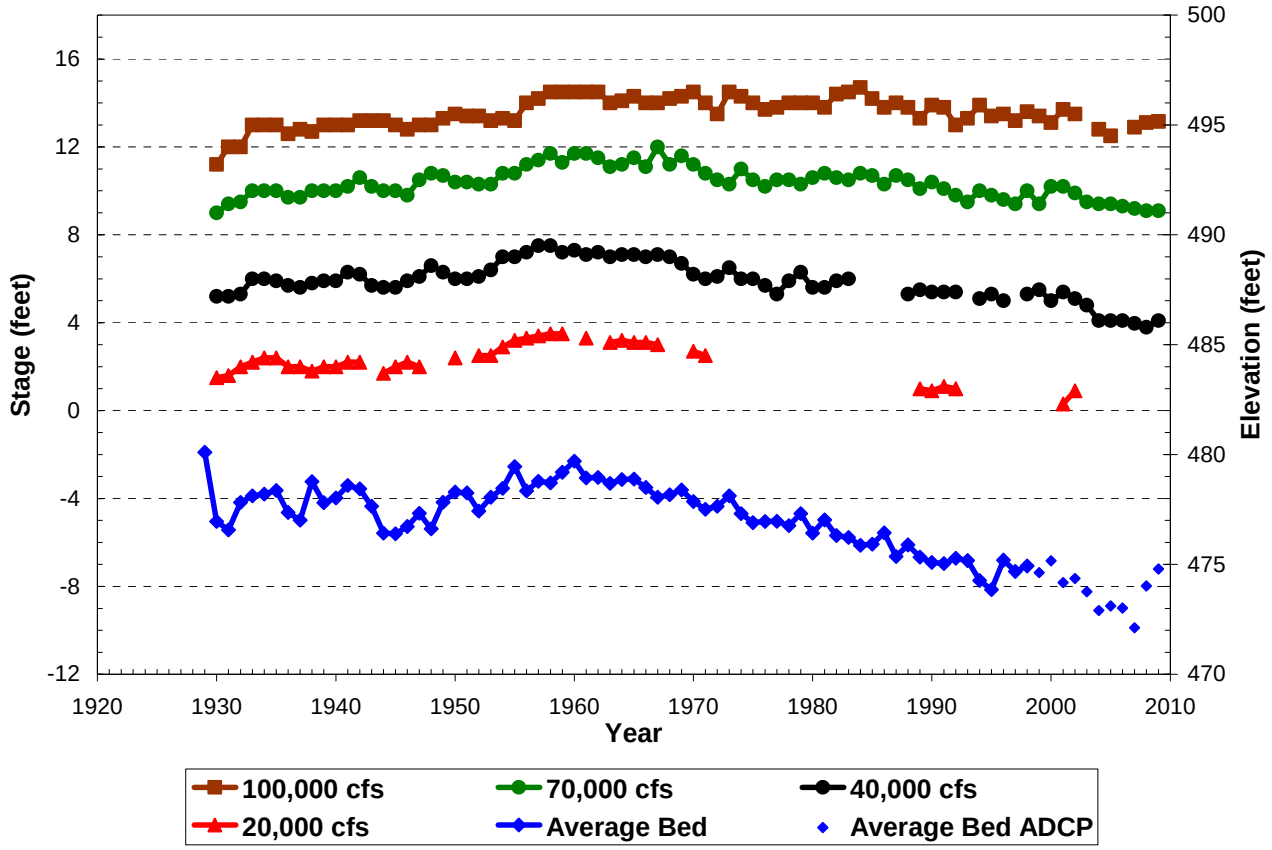


Figure 3.4-28 Missouri River Stage and Average River Bed Trends at Hermann, Missouri (RM 97.9)

Source: USACE spreadsheet "AveBed all gages upto Dec 5 2008.xls" updated with USGS gage data through 2009.

A comparison of river bed elevations from bore hole logs taken in 1996 to river bed elevations from a 2008 underwater survey for the Route 364 bridge (RM 32.6) revealed negligible changes in river bed elevations at most locations and a maximum of approximately 6 feet of bed lowering at the upstream side of one bridge pier. At the Interstate 70W bridge (approximately RM 29), bore logs from 1954 and surveys from 2008 indicate an approximate drop of 7–10 feet in average river bed surface elevation with a maximum drop of approximately 22 feet. The maximum drop was measured at the pier, however, and is likely influenced by localized scouring.

3.4.6.3 Potential Causes of River Bed Degradation

River bed degradation has been identified as an issue for the past 10–15 years on the Missouri River and since the 1970s on the Kansas River. More effort has been focused on the study of the Kansas City segment of the LOMR than on other portions of the river due to the magnitude of the bed degradation occurring in this area and the amount of infrastructure at risk. In addition, the rate of bed degradation in this segment accelerated in recent years (USACE 2007a). A number of studies and summary documents have been produced by the USACE and the USGS documenting the degree of bed degradation and examining its causes (Jacobson, Blevins, and Bitner 2009; USACE 2009a, 2009b). As a result of these analyses, dredging volumes authorized under recently approved commercial dredging permits for the Kansas City segment have decreased.

As described in earlier sections, the geomorphic character of a river is controlled by interacting variables including slope, sediment grain size, flow regime, flow discharge, flow velocity, sediment loads, flood frequencies, structures in and near the river, and other factors. As a matter of general principal, river bed degradation occurs when more material is leaving a reach of a river than is entering it. The historical unconstrained Missouri River—prior to construction and operation of the BSNP and the dam-reservoir complex—was a dynamic system that constantly changed bed elevations, channel location, channel sinuosity, and sediment load. The current Missouri River, particularly in the Kansas City segment, is constrained by dikes and revetments, bridge abutments and pilings, levees, and floodwalls. Geomorphic adjustments normally available to unconstrained rivers in the form of bank erosion, sand bar formation, lateral migration, and channel avulsions are not available to the LOMR. Consequently, when geomorphic variables change, such as increased flows or a reduction in sediment loads, the only geomorphic response remaining to the LOMR is adjustment in the river bed elevation.

Several factors have been identified that may be contributing to degradation in the Kansas City and other segments of the LOMR, including:

- Reduction in sediment loads by dams;
- Flow modification by regulation;
- Major flood events;
- Dikes and structures;
- River cutoffs; and
- Commercial dredging for sand and aggregate.

Reduction in Sediment Loads by Dams

All six mainstem dams on the Missouri River were completed and brought into service between 1940 and 1964, with the most downstream dam (Gavins Point Dam) becoming operational in 1955. The most downstream dam is approximately 450 miles upstream of Kansas City, Missouri. Degradation downstream of the dams as a result of sediment trapped in the upstream reservoirs has been well documented (USACE 2001). Sediment trapping occurs in the reservoirs when flow velocities drop as a stream enters the quiet waters of the reservoirs. All but the finest-grained sediments settle to the bottom and are trapped upstream of the dam. Degradation downstream of a dam occurs as a result of sediment-free water released from the reservoir scouring the channel to reestablish the sediment load characteristics of the stream.

Evaluations of USGS gage data and other data collected by the USACE indicate that the degradation caused by mainstem reservoirs does not likely extend below the Rulo, Nebraska gage (Section 4.4.6.2, St. Joseph segment). In fact, the data reveal a trend of deposition from Rulo, Nebraska (RM 498) upriver to Nebraska City, Nebraska (RM 562) as shown in Figure 3.4-21. The low-flow water surface at Nebraska City, Nebraska, is clearly stable or rising with time. By contrast, Omaha, Nebraska (RM 616) shows a slight drop in stage at low flows; and Sioux City, Iowa (RM 732) shows a steep, downward trend for all discharges.

Data taken at these USGS gaging locations indicate that degradation associated with mainstem dam construction extends through Omaha, Nebraska but ends upstream of Rulo, Nebraska. Because the river is aggrading at that point it can be concluded that recent degradation trends in the portion of the LOMR from RM 0 to RMR 498 are likely not a result of the capture of sediment in the reservoirs in the upper river. It has been more than 50 years since completion of the most downriver dam on the mainstem (Gavins Point Dam) at RM 811.1, and 30 years since the BSNP was completed. Therefore, sediment transport blocked by the upstream dams is not likely affecting riverbed degradation at or downstream of Rulo, Nebraska (USACE 2009a).

The Kansas River has seven reservoirs that control most of the flow from the river's tributaries. The USACE has developed some evidence that these reservoirs have contributed to bed degradation of the Kansas River (USACE 1984), although it has not been determined whether this effect carries downstream to the Missouri River. Approximately 55 percent of the Kansas River watershed has been cut off from sediment delivery; consequently, the post-dam suspended sediment loads are approximately 36 percent of the pre-dam levels (USACE 1981). The Kansas River has seen a decrease in dredging over the last decade but still has been dredged for an average of over 2,120,000

tons of sand and aggregate annually between 1992 and 2007. Other local reservoirs near Kansas City are assumed to be too small to affect the Missouri River (USACE 2009a).

The reduction in sediment delivery from the Kansas River may contribute to the sediment deficiency and river bed degradation on the Missouri River downriver from the confluence with the Kansas River. This effect is likely minor, however, because the upper portion of the Waverly segment (downstream of the confluence with the Kansas River) appears to have aggraded from 1998 to 2007–2009 based on the HBED analysis.

In contrast, bed degradation in the St. Charles segment may be affected by reduced sediment loads from the Osage River (USACE 2009a). The Bagnell Dam, 80 miles upriver from the confluence of the Osage River and the LOMR, traps sediment from 92 percent of the Osage watershed (USACE 2009a). Neither the Osage River nor the Gasconade River contribute much sediment relative to the Missouri River or other tributaries upriver (Table 3.4-17), but they do contribute a significant amount of flow (Figure 3.4-7). The Hermann gage (RM 97.9), below both the Osage River (RM 129.9) and the undammed Gasconade River (RM 104.4), has experienced long-term bed degradation (Figure 3.4-21). The HBED analysis shows the St. Charles segment below the Hermann gage to have degraded, on the order of 1 foot from 1998 to 2007–2009, with slight degradation continuing between 2007 and 2009 between RM 15 and RM 98.

Flow Modification by Regulation

As described in the hydrology section (Section 3.4.4), the flow regime of the LOMR has been altered by both the mainstem dams and dams on tributaries to the LOMR. Two objectives of the mainstem dams on the Missouri River are to control flooding and to provide navigation flows. Spring and early summer peaks are captured by the reservoirs and released during the late summer and fall, maintaining flows in the river sufficient for barge traffic (Figures 3.4-10 and 3.4-11). The relationship between sediment deposition and erosion and flows is complex; in general, most sediment gets deposited as flows are decreasing. The mainstem dams reduce the variability in flows, thus smoothing out peaks and low flows, which in turn affects sediment transport and deposition in the river. The moderating effects of the dams are reduced moving downriver as tributaries contribute variable flows.

Although the erosive power of peak flows is reduced by the upstream dams, peak flows tend to transport more sediment, thus making more sediment available for deposition on the falling limb of the hydrograph. The higher average low flows caused by the upstream dams, in combination with the

design of the BSNP to maintain a self-scouring navigation channel, reduce the amount of sediment deposition that would occur at lower flows.

A feedback loop exists with river bed degradation, navigation flows, and the BSNP structures. In areas with bed degradation, the water surface elevation at navigation flows lowers as the bed degrades; and dike structures designed to have overtopping flows divert more water into the navigation channel, resulting in increased flow velocities that scour the channel more effectively.

Controlled release from the upstream dams is likely affecting the transport and deposition of sediment in the LOMR system. Mean annual flows also have increased over the period of record, with greater increases occurring farther downriver (Figure 3.4-14). Increased mean annual flows and increased low and moderate flows due to controlled releases (Figure 3.4-11) likely increase the overall transport capacity of the river (Figures A-34 through A-37 in Appendix A show the relationship between higher flows and higher bed material load transport rates). In the Kansas City segment in particular, the constrained nature of the river through the highly urbanized area likely reduces opportunities for deposition even at lower flows.

Major Flood Events

The impact of major flood events on river bed degradation is variable and depends in part on where in the watershed the floodwaters originate. Significant flood events are described in Section 3.4.4.5. The floods of 1951, 1952, and 1993 rank among the top floods for most gages on the LOMR. The floods of 1951 and 1993 had similar genesis in that both were the result of spring and summer precipitation events in the lower Missouri rather than a snowmelt event similar to the one that triggered the floods of 1952. The floods from the 1950s affected river bed elevations differently from the flood event of 1993. Nonetheless, all three flood events caused tremendous amounts of flooding and damage to communities along the river.

The floods of the 1950s caused noticeable aggradation for several years following each flood event at most gage sites on the LOMR. The most pronounced effect was observed at the St. Joseph gage, and minor effects were recorded at Kansas City and Waverly (Figures 3.4-24 to 3.4-26). The 1993 flood, in contrast, caused a noticeable drop in river bed elevations at most of the gage sites, with the most pronounced drop at Kansas City (Figure 3.4-25) and no noticeable impact at the Rulo gage (Figure 3.4-23). Average river bed elevations both before and after the 1993 flood for the Kansas City gage (Figures 3.4-29 and 3.4-25) indicate that the river bed did not recover in the vicinity of the gage

after that flood. River bed elevations recovered quickly at the Hermann gage; recovered more slowly at Boonville; and continued their previous downward trends at St. Joseph, Kansas City, and Waverly.

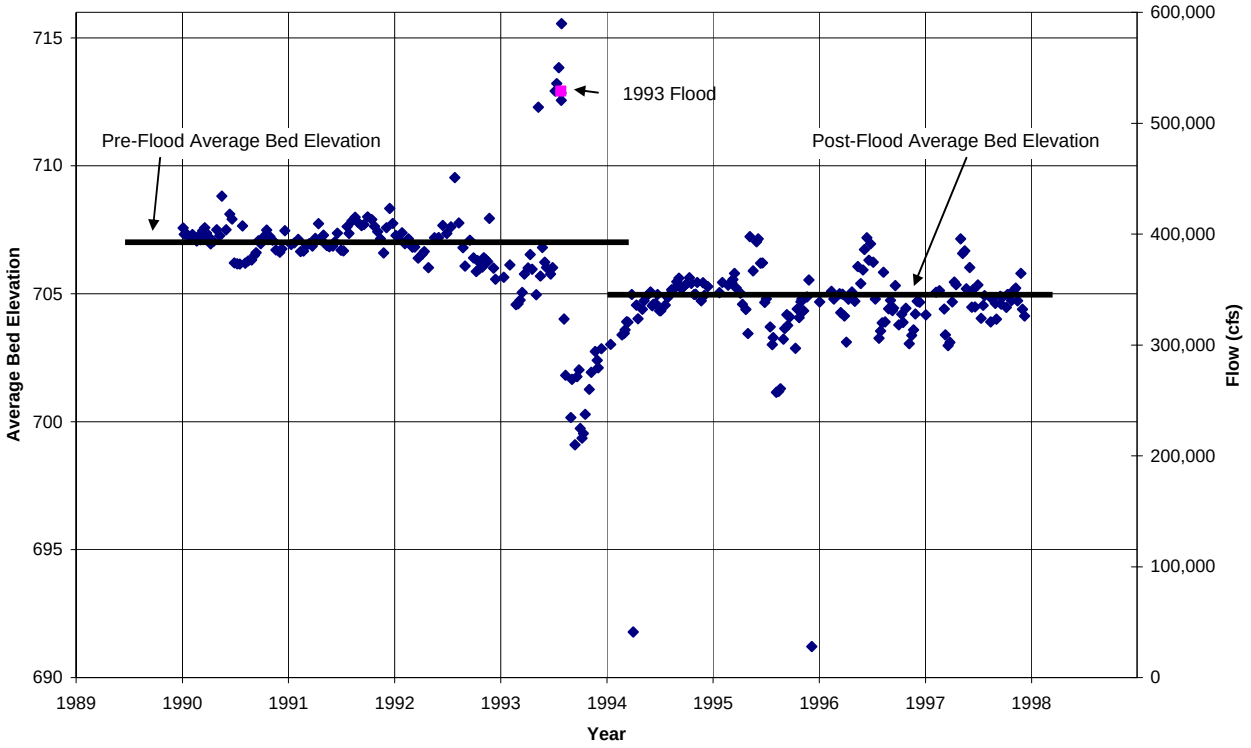


Figure 3.4-29 River Bed Elevations Based on Hydraulic Depth before and after the 1993 Flood at the Kansas City Gage

Source: USACE spreadsheet "KCmeasurements (y3).xls".

No two floods are the same, even if they are caused by similar meteorological conditions. Although both the 1951 and 1993 floods were caused by spring storm events, the Kansas River contributed 87 percent of the peak flows measured at the Kansas City gage during the 1951 flood but only 31 percent of the peak flows measured at the same gage during the 1993 flood (Niesen 2004). While natural storm variability is important in the river's response to these flood events, of far more significance are the engineering changes that occurred on the river in the intervening years between the two storms. More than one- half of the dams and reservoirs affecting the timing of flows and sediment delivery were completed after the 1951 flood event. By 1951, a reasonably stable channel of 6- to 9-foot depth from St. Louis to Kansas City had been established. By 1993, the BSNP had been completed, which constrained the channel with in-river dikes designed to maintain the 9-foot depth of

the navigational channel without maintenance dredging. Most federal flood protection levees were completed after 1950. By 1993, sediment had accreted between many of the dikes—further narrowing the river channel.

Consequently, stages for high-discharge events such as the 1993 flood have increased at all gage sites since the 1950s (USACE 2007c). Higher stages increase the shear stress on the river bed, and these higher stresses can result in river bed degradation and increased sediment transport capacity during storm events.

Dikes and Structures

As described in Section 3.4.5.2, the BSNP has caused major changes to the geomorphic character of the LOMR. The extensive system of dikes and revetments is designed to maintain a self-scouring navigation channel that is 300 feet wide and 9 feet deep, even at lower flows. By design, the structures reduce sediment deposition at lower flows and reduce the likelihood of recovery from scouring events such as floods and dredging.

Construction of the BSNP occurred at the same time as construction of the dams, cutoffs, and side channel eliminations that changed the length of the river. In some places, navigation channel scouring as a result of BSNP structures may be contributing to ongoing bed degradation.

In particular, the Kansas City segment is more constrained than other segments of the LOMR. This is due to the extensive infrastructure in the Kansas City metropolitan area and the location of the Kansas River confluence. As stated in the 2009 USACE Reconnaissance Study Report:

> This set of river conditions has resulted in the installation of a very constrictive dike system to maintain a navigation channel. The construction of that dike system has resulted in a reach of river that is very efficient at “cleaning” and maintaining the low-flow channel (USACE 2009a).

In the river segments with limited river bed degradation since the BSNP was completed, it appears that the river has stabilized relative to the BSNP, dam-release flows, and modern sediment loads.

River Cutoffs

River cutoffs were an element of the BSNP process of creating a navigation channel. At several locations, sharp bends and loops were cut off to shorten the navigation channel and make curves easier for barges to navigate tight turns. As described in Section 3.4.3.2, most of the cutoffs in the

Project area occurred between Kansas City and Waverly. Table 3.4-5 lists some of the significant cutoffs upriver from Waverly.

Rivers normally meander, creating loops and bends to achieve a slope that is in equilibrium with the size and volume of sediment that it is carrying in relation to the velocity and discharge of the flowing water. A river's pattern and form rarely stay unchanged due to constant variation in flows and sediment loads, as well as heterogeneity in the floodplain. With the BSNP in place, the river cannot adjust its length to compensate for changes in sediment loads, flows or, in this case, cutoffs in the river. Cutoffs shorten the river and increase the local slope, increasing flow velocities and sediment transport capacity. Assuming that the sediment size distribution does not change significantly, and with the river banks stabilized with revetments and dikes, the river can adjust its slope only by eroding the river bed upriver from the cutoff and depositing the sediment downriver from the cutoff.

The effects of the cutoff on the channel slope can be estimated based on information collected before and after the cutoff of the Liberty Bend in 1949, and on river slope data collected at various times for the Kansas City to Waverly segment. The Liberty Bend was shortened approximately 4.3 miles, and the slope was increased from 0.77 to 1.3 feet per mile (Section 3.4.3.2). Seven years after the cutoff was completed, the channel bottom had dropped 1.3 feet at the cutoff, and the channel had degraded to a point 8.3 miles above the cutoff while aggrading to a point 21.3 miles downriver of the cutoff; the point of maximum aggradation occurred 10.5 miles downstream. Assuming that the headcut kept migrating upriver at the same rate since 1949, the upriver extent of the channel change would be 72 miles from the cutoff and over 50 miles upriver from Kansas City. A review of slope changes over time between Kansas City and Waverly—although a gross-scale estimate—shows that the slope increased substantially after the Liberty and Jackass cutoffs were completed, as expected, and then quickly decreased by 1963 and returned almost to pre-cutoff levels by 1978 as shown in Figure 3.4-30 (USACE 1980). The channel slope increased in response to the sudden change in channel length but stabilized as the channel headcut migrated upriver and re-established an equilibrium slope similar to pre-cutoff conditions.

Slopes also were calculated from the CRP water surfaces for 1990, 2002, and 2005. Although the CRP uses a different method to calculate slopes, the 1990 value is similar to the slopes measured in the 1950s. However, the CRP values show reduced slopes for the 2002 and 2005 water surface elevations. As indicated by the graph, the recent slope changes are unlikely the result of cutoffs completed in the 1950s.

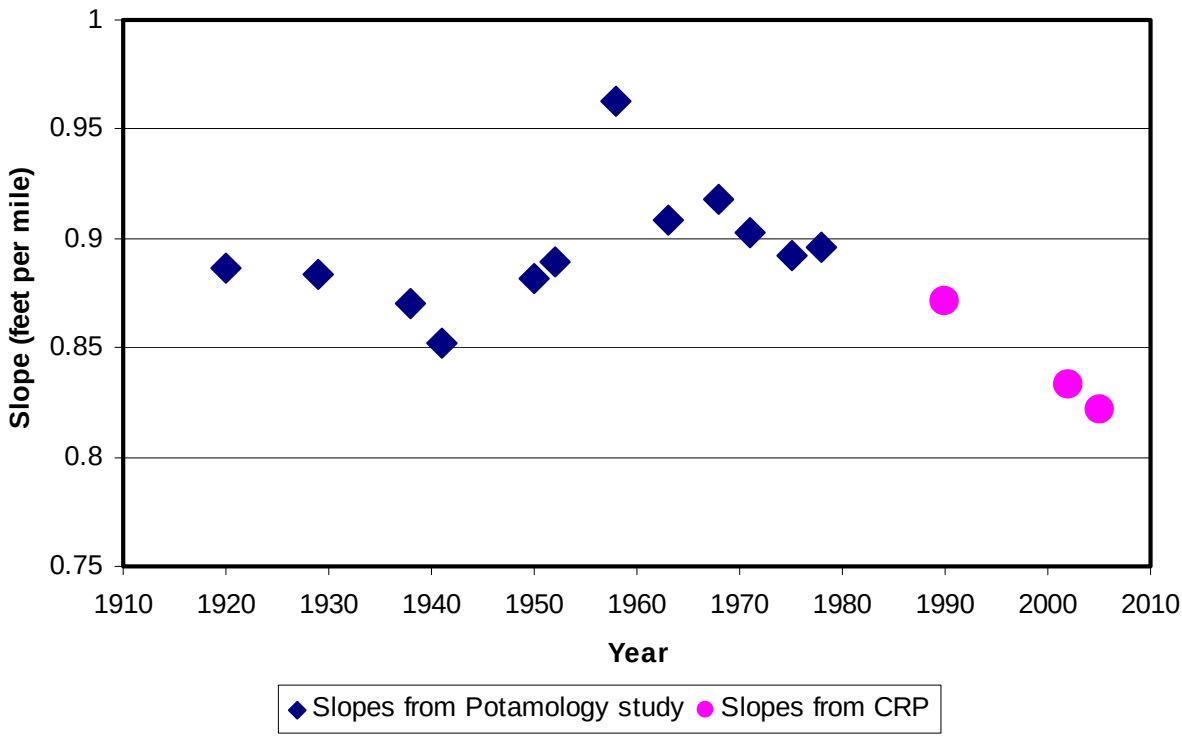


Figure 3.4-30 Water Surface Slope between the Kansas City Gage and the Waverly Gage (1920–2005)

Source: USACE 1980, USACE spreadsheet "2002 to 2005 CRP Camparison vs Dredging.xls."

Commercial Dredging

Commercial dredging has occurred to various degrees at different locations along the LOMR for the past 75 years (Figure 1.5-1). It was not until 1958 that levels exceeded 1 million tons per year. In 1965, dredging amounts exceeded 2 million tons per year. Dredging levels generally increased to a peak in 2002, at 8.7 million tons per year. Figure 1.5-2 shows dredging levels by river mile for dredging that has occurred in the last 10 years.

Concerns regarding the effects of river bed degradation on infrastructure and flood control structures have increased in the past 10–15 years. As a result, the USACE has conducted analyses and studies on the extent of river bed degradation and dredging. The methods used to measure river bed degradation and the extent of river bed degradation by segment are described in Sections 3.4.6.1 and 3.4.6.2, respectively.

Evidence of Degradation Caused by Commercial Dredging

The impacts of dredging on river systems have been documented in publications at the local level and worldwide (Jacobson, Blevins, and Bitner 2009; Kondolf 1997; Simons, Li, and Associates 1985;

Rinaldi et al. 2005). There is strong evidence that dredging has contributed to degradation at several locations on the LOMR. The evidence comes from the following sources:

- Changes in water surface elevations compared with dredging locations (1990–2005);
- Changes in river bed elevations compared with dredging locations (1998 to 2007–2009);
- Correlation between changes in stage elevation and dredging amounts at USGS gage locations (2000–2005); and
- Comparison of bed material loads with dredging amounts for stable and degrading segments (1999–2008).

CHANGES IN WATER SURFACE ELEVATIONS COMPARED WITH DREDGING LOCATIONS

Figure 3.4-31 shows the change in CRP-adjusted low-flow water surface profiles between 1990 and 2005 overlain with dredging amounts at corresponding locations. Water surface levels have fallen throughout the LOMR except for a small reach in the Jefferson City segment at RM 240. The portions of the LOMR where dredging has been concentrated experienced the greatest change in water surface elevations. This includes locations such as Jefferson City (RM 144) and St. Charles (~RM 28) that do not have the same constricted flow issues found in the Kansas City segment.

CHANGES IN RIVER BED ELEVATIONS COMPARED WITH DREDGING LOCATIONS OR AMOUNTS

Dredging amounts in the Kansas City segment are significant when compared to the volume of the river bed. An analysis conducted by the USACE estimated that dredged materials removed from RM 353 to RM 378 between 1990 and 2005 represent a volume of in-situ material roughly equivalent to a change in river bed elevation over the same distance of approximately 9 feet (USACE 2009a). The low-flow water surface elevation dropped between 3 and 7.5 feet at that location during the same period (Figure 3.4-31). If the volume of dredged material was spread over the reach between RM 290 and RM 440, an equivalent change in river bed elevation of between 1 and 2 feet would result (USACE 2009a).

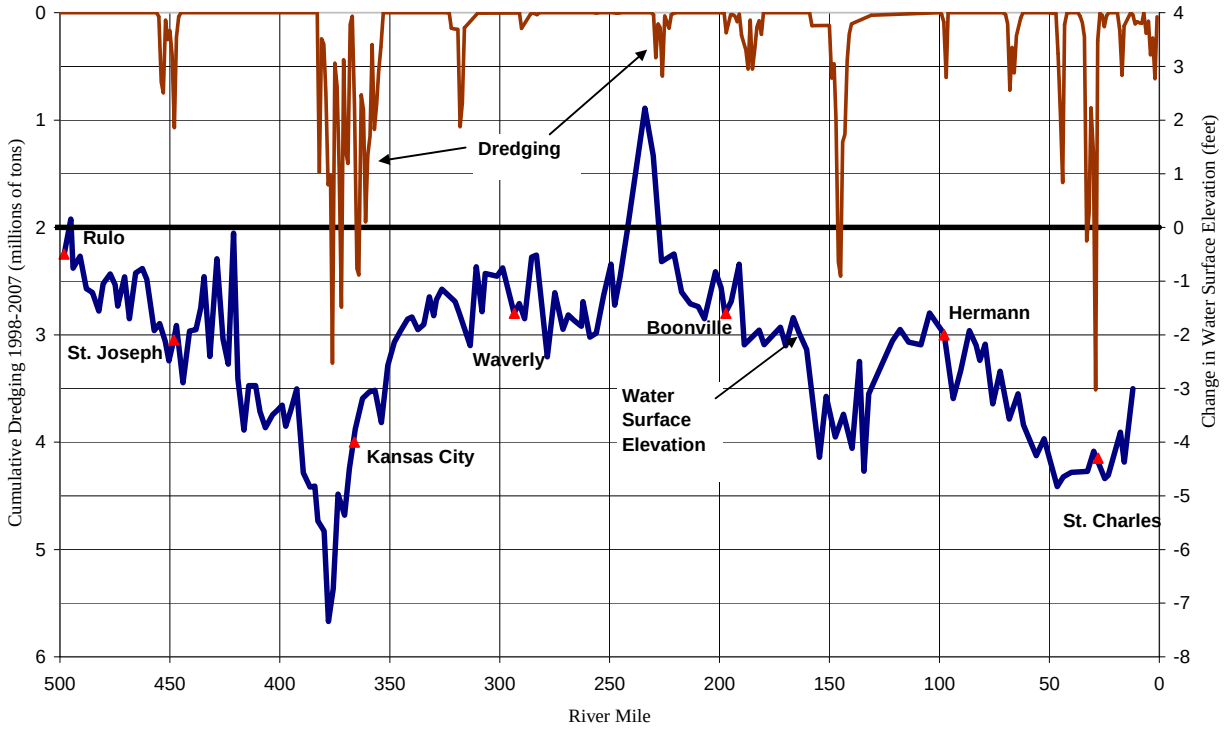


Figure 3.4-31 Cumulative Dredging (1998–2007) and Changes in the CRP-Adjusted Low-Flow Water Profile between 1990 and 2005

Source: USACE spreadsheet "Public_mtg_posters_6_2_2009.xls" and USACE spreadsheet "MO Dredging Master 1935 to 2009.xls."

The HBED analysis measured changes in average river bed elevations between 1998 and 2007–2009 (Figure 3.4-32). Changes between 2007 and 2009 give an indication of the variability of the system while changes between 1998 and 2007–2009 indicate the longer term trend. With the exception of the confluence of the Grand River at RM 250 and the general slight degradation trend through the St. Charles segment, areas with the most dredging evidenced the most degradation between 1998 and 2007–2009. Both the CRP-adjusted low-flow water surface elevation change results and the HBED results show greater degradation in areas with concentrated dredging.

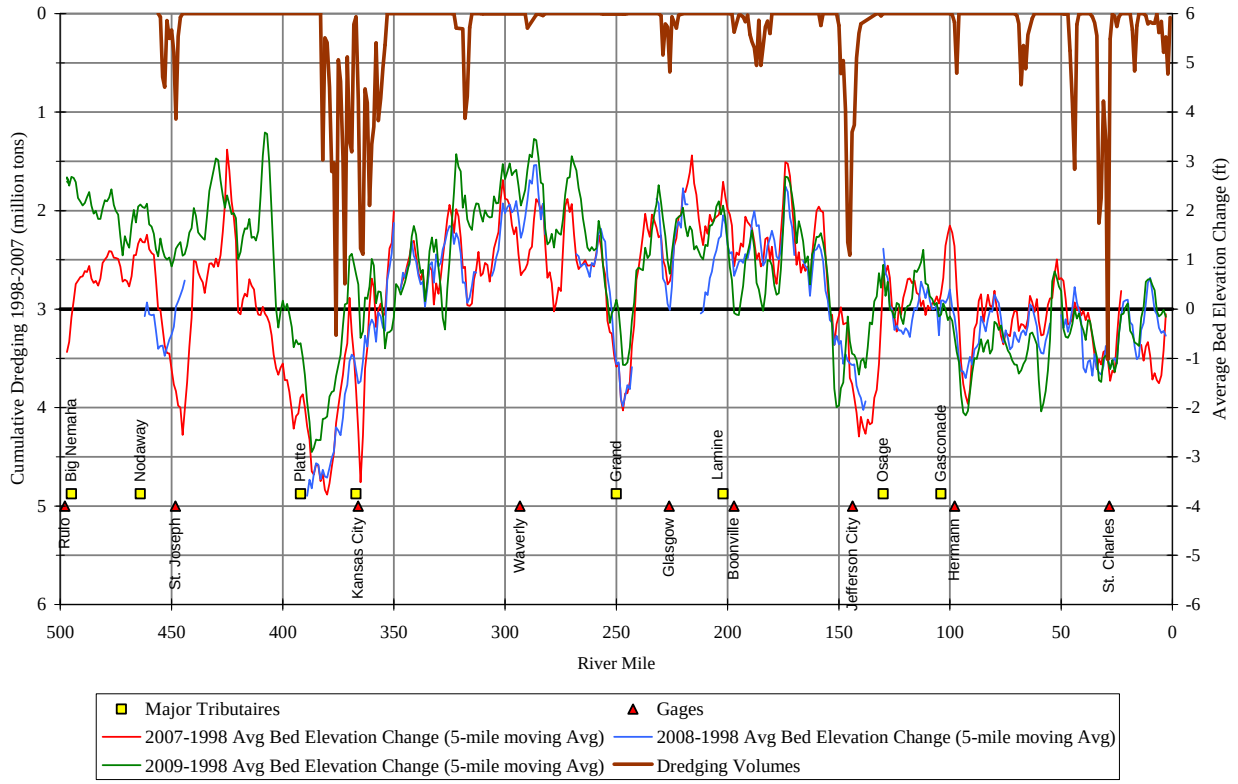


Figure 3.4-32 Cumulative Dredging (1998 to 2007) and Change in Average River Bed Elevation between 1998 and 2007–2009 Using a 5-Mile Moving Average

Source: For dredging data: USACE spreadsheet "MO Dredging Master 1935 to 2009.xls."

In the Kansas City segment, degradation also has occurred upriver from the area of heaviest dredging, and is likely the result of river bed erosion on the upriver side of a dredging depression in the river bed (Kondolf 1997; Simons, Li, and Associates 1985; Rinaldi et al. 2005).

COMPARISON OF BED MATERIAL LOADS WITH DREDGING AMOUNTS FOR STABLE AND DEGRADING SEGMENTS

To explore the relationship between dredging amounts, rates of river bed degradation, and bed material loads, dredging amounts were compared with bed material loads for the St. Joseph, Kansas City, Waverly, and St. Charles segments. These segments were selected because they allowed a comparison of relatively stable versus degraded river beds. The bed material load is composed of sediment that is on average smaller in size than the material removed from the river bed by dredging (see the particle size gradation comparison of bed material and concrete sand specification in Figure 3.4-16). The average annual amount of sediment dredged in a segment can be compared to the amount moving as bed material load at nearby gages at St. Joseph, Kansas City, and Hermann

(Table 3.4-20). In addition to the river bed elevation and sediment data available at the three gaging stations, long-term river bed elevation trend data are available for the Waverly gage at RM 293. For analysis purposes, the St. Joseph and Waverly segments, which have experienced minimal bed degradation over time, were compared with the Kansas City, Jefferson City, and St. Charles segments, where degradation has occurred over time.

Table 3.4-20 Comparison of Dredging Amounts to Bed Material Loads on the Lower Missouri River (2000–2009)

Segment	St. Joseph	Kansas City	Waverly	Jefferson City	St. Charles
Nearest gage	St. Joseph (RM 448)	Kansas City (RM 366)	Waverly (RM 293)	Hermann (RM 98)	Hermann (RM 98)
River bed status at gage	Stable	Substantially degraded	Stable	Locally degraded	Degraded
Average annual amount dredged (2000–2009) (tons/year)	343,231	2,855,073	500,143	1,479,733	1,716,518
Average annual bed material load (2000–2009) (tons/year)	3,508,000	5,352,000	4,956,000[a]	4,261,000[a]	3,699,000
Dredged percent of bed material load	9.8%	53.3%	10.1%	34.7%	46.4%

[a] The bed material loads for the Waverly and Jefferson City segments were estimated by interpolating the values between the Kansas City gage and the Hermann gage.

For the St. Joseph segment, which has not degraded between 2000 and 2009 (based on the HBED analysis and river bed elevation records from the gage), the average annual amount dredged from 2000 to 2009 is approximately 9.8 percent of the bed material load estimate at the St. Joseph gage. The Kansas City segment has experienced substantial ongoing degradation over time, and dredging represents 53.3 percent of the bed material load calculated at the Kansas City gage. Based on a bed material load estimate interpolated between the upriver Kansas City gage and the downriver Hermann gage, sediment removal by dredging represents approximately 10.1 percent of the bed material load in the Waverly segment and 34.7 percent in the Jefferson City segment. The Waverly segment has experienced little or no degradation, and the Jefferson City segment has experienced some aggradation and moderate degradation in the Jefferson City area based on the HBED and the CRP-adjusted low-flow water surface elevation data. For the St. Charles segment, dredging represents

approximately 46.4 percent of the bed material load estimate at the Hermann gage, which has experienced long-term degradation.

The results show that the Kansas City and St. Charles segments with degrading river bed elevations over time are also the reaches with the most dredging; dredging amounts equal approximately 46 to 53 percent of the bed material load estimates for nearby gages. In contrast, river bed degradation appears to be minimal in the St. Joseph and Waverly segments, where dredging represents approximately 10 percent of the bed material loads. The Jefferson City segment has experienced aggradation in areas with minimal dredging and degradation in the Jefferson City area where dredging has been concentrated.

COMMERCIAL DREDGING AND LOCAL BED DEGRADATION

Historical dredging data were used to estimate the effects of dredging on local bed degradation. Patterns of commercial dredging (total amount and dredging intensity) were analyzed and compared with observed patterns of local bed degradation by using linear regression. A more detailed description of the analysis is found in Appendix A.

A review of dredging location and volume records for 1998–2009 shows that dredging activities were concentrated in certain areas of the river (Figure 3.4-33), identified as dredging reaches. As described in Chapter 2, areas with the most dredging were generally clustered near major urban centers where market demand for sand and gravel is greatest. Eleven dredging reaches were identified with records for at least 2 consecutive miles and at least 2 years of dredging between 1998 and 2009. The dredging reach identified near the confluence with the Mississippi River was not included in the analysis due to backwater effects near the mouth; consequently, 10 dredging reaches were selected for the analysis (Figure 3.4-33).

To estimate the effects of dredging on local bed elevation change, the change in bed elevations in each dredging reach was compared with the average bed elevation of the adjacent reaches upriver and downriver from the dredging reach. This was done for the 2007 and 2009 HBED data, which are the only two recent datasets with measurements for most of the LOMR (Figure 3.4-22, Appendix A). The variable length of each dredging reach was addressed in the analysis by using one dredging reach length upriver and one dredging reach length downriver to determine the average bed elevation in the vicinity of the dredging reach.

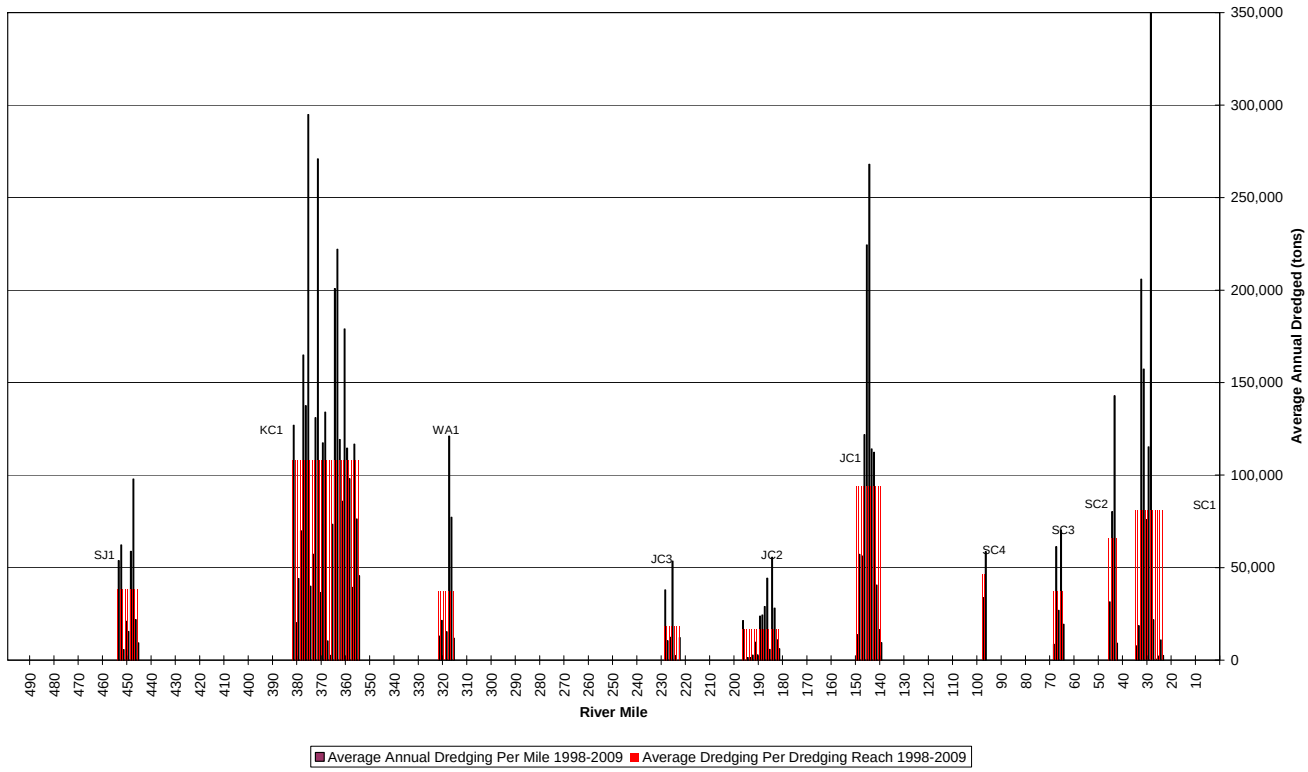


Figure 3.4-33 Average Annual Dredging (1998–2009) by River Mile and Identified Dredging Reach

Note: Each dredging reach has a label that indicates the segment and dredging reach number (e.g., JC1= dredging reach 1 in the Jefferson City segment). See Appendix A for details.

For example, dredging occurred in the JC1 dredging reach[4] in the Jefferson City segment on 11 miles of the river (Figure 3.4-33). The average bed elevation for the 11-mile dredging reach was compared to the average bed elevation of the 11-mile section of river upstream and the 11-mile section of river downstream of the dredging reach (a total of 22 miles). The difference between the average bed elevation for the dredging reach and the average bed elevation for the same length reach above and below the dredging reach was calculated. This enabled the effects of dredging on average bed elevation to be compared to the average river bed elevation in the vicinity of, but outside of, the area directly affected by dredging.

Linear regression was used to assess the relationship between dredging and changes in local bed elevations. Figure 3.4-34 illustrates the relationship between the total average annual amount dredged

[4] Each dredging reach has a label that indicates the segment and dredging reach number (e.g., JC1= dredging reach 1 in the Jefferson City segment). See Appendix A for a table of the dredging reach codes, locations, and lengths.

in a dredging reach as a percent of the 2000–2009 bed material load estimate for each segment[5] and local bed degradation for each dredging reach. The regression results show a strong relationship between average annual dredging from 1998 to 2007 and the 2007 bed elevation data (R^2=0.76), and for the 1998–2009 dredging data and the 2009 bed elevation data (R^2=0.93). R^2 values range between zero and one, and indicate the strength of the relationship; higher values indicate a better fit (zero = no relationship and 1.0 = perfect correspondence).

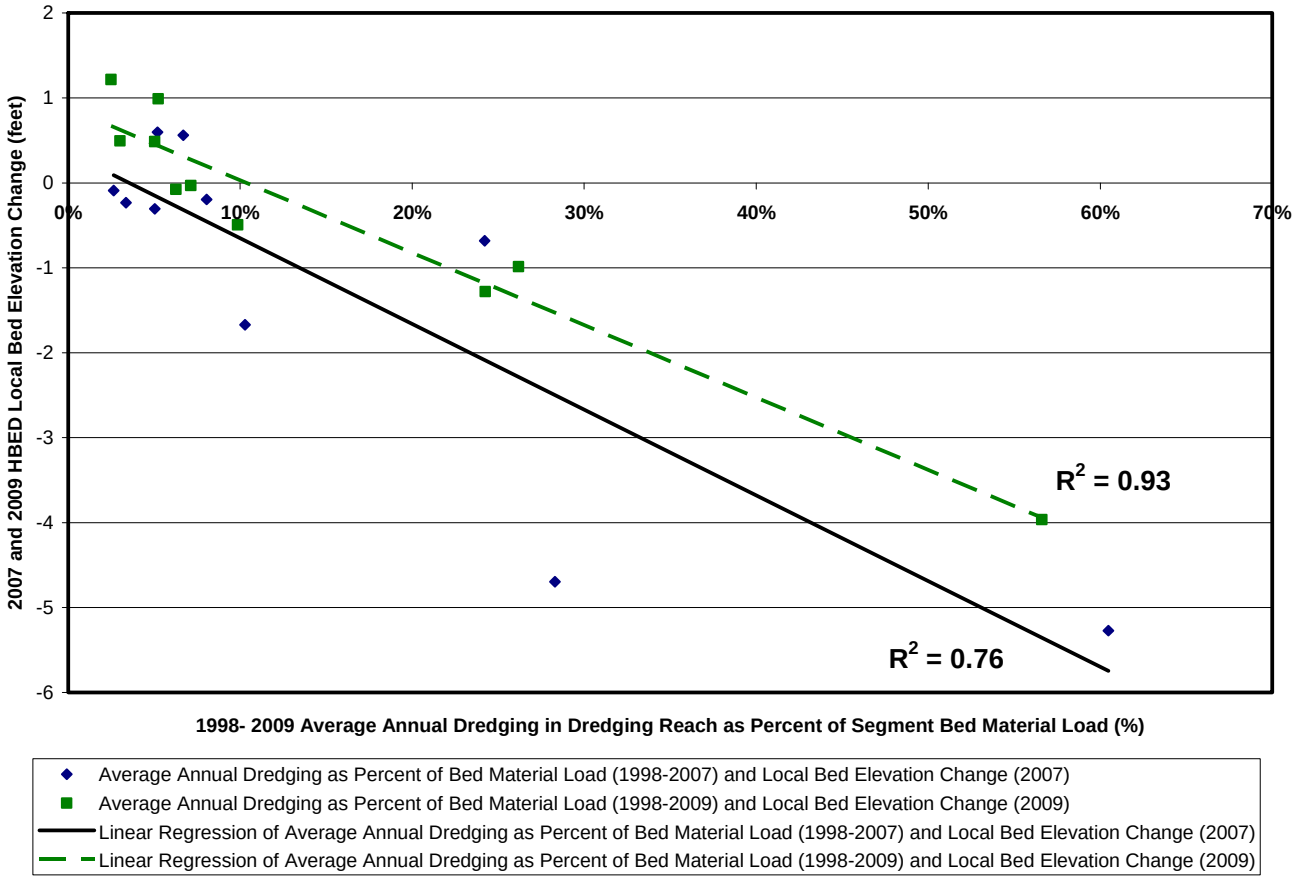


Figure 3.4-34 Linear Regression of Average Annual Dredging in Dredging Reach as a Percent of Bed Material Load and Local Bed Elevation Change for 1998–2007 and 1998–2009

The results indicate that approximately 76 and 93 percent of the variability in the 2007 and 2009 local bed elevation changes, respectively, can be explained by average annual dredging as a percent of bed

[5] See the previous section and Appendix A on how the bed material load was estimated at the St. Joseph, Kansas City, and Hermann USGS gage locations. Bed material load estimates for segments without USGS gages, Waverly and Jefferson City, were interpolated from the Kansas City and Hermann gage locations.

material load. The results are significant at the 95-percent confidence level, which indicates that the regression line is unlikely to be the result of chance association (see Appendix A for details).

The regression line crosses the line of zero bed elevation change (i.e., x-intercept) between 0 and 10 percent of the bed material load, indicating that dredging levels higher than this would likely result in degradation and that dredging levels lower than this are unlikely to cause local bed degradation in a dredging reach. The regression results show a strong ability to explain increased bed degradation as a function of increasing total dredging levels (as a percent of bed material load) at the dredging reach scale, even though the results do not confirm direct causality.

In addition to the amount dredged as a percent of bed material load for each dredging reach, the intensity of dredging was analyzed. Average annual dredging intensity is the average amount of material dredged per mile per year, expressed as tons per river mile per year.

Figure 3.4-35 shows the relationship between average dredging intensity for each dredging reach and local bed degradation. The regression has an R^2 of 0.55 for dredging data from 1998 to 2007, and 0.62 for dredging data from 1998 to 2009. Although the relationship between average dredging intensity and local bed degradation is statistically significant at the 95-percent confidence level, the ability to explain the variability in local bed degradation is less than for dredging expressed as a percentage of bed material load.

The regression line crosses the zero degradation line (i.e., the x-intercept) at approximately 30,000 tons/mile/year for the 1998–2007 dredging data, which can be interpreted to represent the level of dredging intensity that is unlikely to cause local bed degradation in a dredging reach. Although 30,000 tons/mile/year is where the best fit line crosses the zero degradation line for the 1998–2007 data, the 95-percent confidence bands indicate that dredging in the range of 0 to 61,000 tons/mile/year are statistically similar (see Appendix A for details). The 1998–2007 data were used as an example because the 2007 HBED data were collected prior to two changes that likely affected the relationship in the 2009 data: (1) average to above-average flows in 2008 and 2009 (compared to below-average flows from 2000 to 2007); and (2) a 22-percent and 34-percent reduction in dredging in 2008 and 2009, respectively, when compared to the average for 2004–2008.

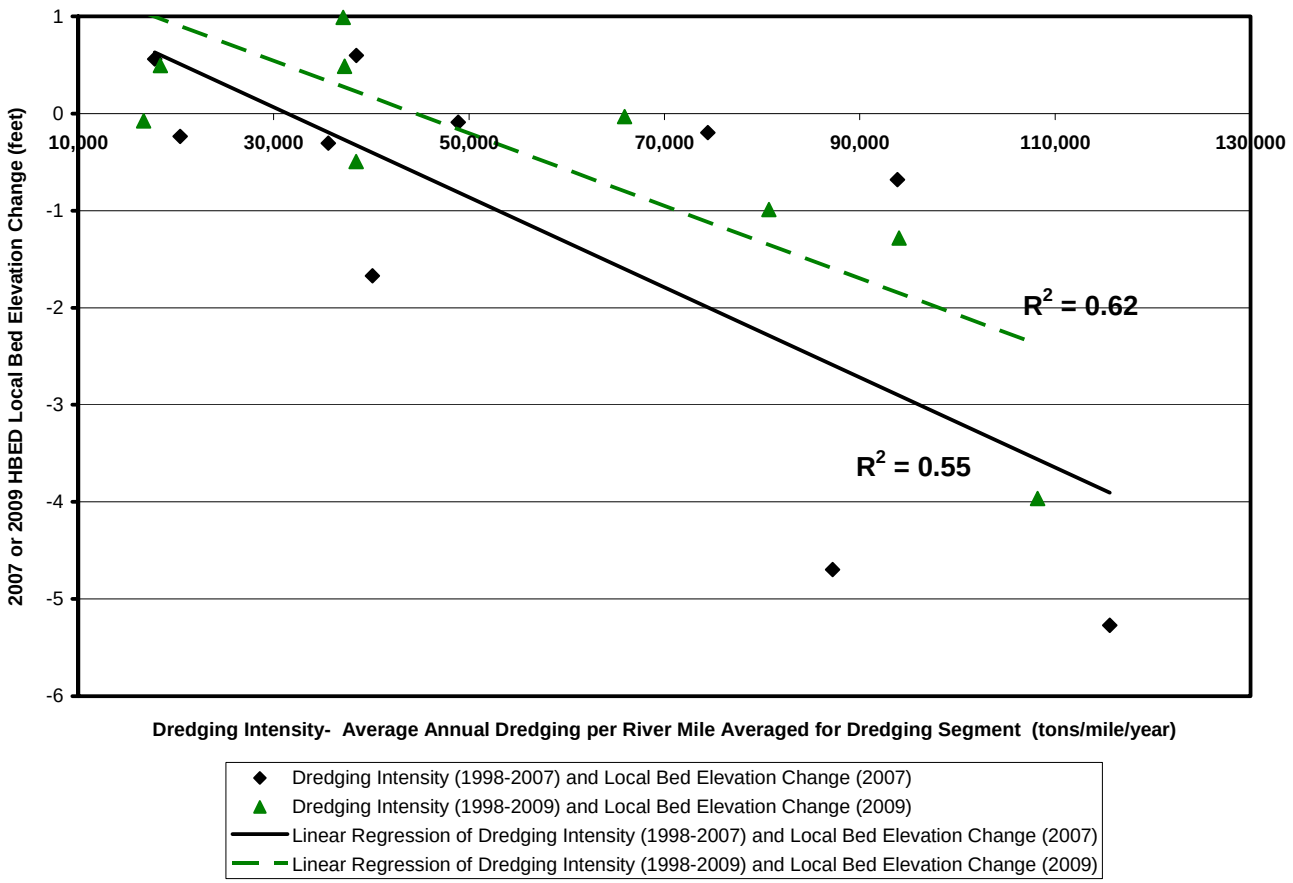


Figure 3.4-35 Linear Regression of Dredging Intensity and Local Bed Elevation Change for 1998–2007 and 1998–2009

The R^2 values and significance levels for dredging levels as a percent of bed material load are quite high for a river system of this complexity, indicating a strong relationship between dredging levels as a percent of bed material load and bed degradation. R^2 values and significance levels are lower for dredging intensity but still show a significant relationship. It should be noted that the results of the local bed degradation analysis described in this section are not directly comparable to the results in the previous section that evaluate dredging as a percent of bed material load and degradation at a segment scale. The previous analysis considered changes in bed elevation over time, based on the analysis represented in Figures 3.4-31 and 3.4-32. This analysis considers local change in bed elevation in a dredging reach relative to the bed elevation immediately upriver and downriver from the dredging reach and is based on data collected during the same year.

Other Effects of Commercial Dredging

MINING GLACIAL DEPOSITS

As described earlier, river bed degradation occurs when more sediment leaves a river reach than enters it. Dredging operates independently from other geomorphic variables such as sediment loads and transport capacity in that it removes bed material directly from the bottom of the river. Limited studies and anecdotal evidence on dredge depression refilling have shown that dredge depressions may take several days to over a week to refill at navigation flows in the main channel, and longer if the dredging occurs off the main channel behind dikes (USACE 2007d).

The dredge depression does not refill with the same material that was extracted. Dredge heads used on the LOMR may be over 50 feet long; depending on the angle that it is deployed and the depth of the water, material can be dredged up to approximately 30 feet below the surface of the river bed. At normal flows, bed load typically moves as dunes that migrate down the river. Depending on flows, dunes may range from 1.7 to 4.8 feet high and from 16.5 to 127.0 feet long (Elliott, Reuter, and Jacobson 2009). River bed sediment below the dune migration zone is mobilized only during flood events; and even during one of the most extreme events on record (the 1993 flood), the average river bed elevation dropped only approximately 7–10 feet (Figure 3.4-29).

The layer of river bed sediment actively transported is likely approximately 10–15 feet deep based on boring log records. Boring logs from the 1954 engineering plans for the Broadway Bridge (Kansas City, RM 366) indicate that the top layer of fine brown sand in the center of the river channel is approximately 10–15 feet deep, which likely represents the material that has been transported in modern times at that location.

The modern LOMR channel sits in a trench filled with alluvial material deposited from glaciers over 10,000 years ago (see Section 4.4.2). Although the glacial deposits are highly variable, they tend to consist mainly of coarser and more densely packed sand than is transported by the modern Missouri River; this glacially deposited material tends to get coarser with depth (Kelly 2003). The glacial deposits also include gravels, cobbles, and boulders near the bedrock bottom of the trench, which at the Broadway Bridge is approximately 40 to 45 feet below the river bed at that location.

An active dredging depth of up to 30 feet, the use of cutter-head dredges, and the retention of a coarser fraction of material than typically found in bed surface samples, in combination with the long-term lowering of the river bed indicates that some portion of the dredged material is being mined from glacial deposits. The underlying glacial sediments may provide some erosion resistance to all but the most

extreme flood events, and the larger size fraction resists transport and degradation more effectively than finer size fractions. With the removal of the glacial deposits, the river bed is both physically lowered and more prone to scour if the material that refills in the dredge depressions is a finer size fraction.

Reductions in water surface elevations have occurred with dredging in the Jefferson City and St. Charles metropolitan areas as well. Permits authorized by the USACE St. Louis District for the lower St. Charles reach allow only the use of suction-type dredges, not cutter-head dredges. Some Dredgers in Jefferson City use cutter heads, and some use suction heads. In the St. Charles segment, Dredgers can dredge to approximately 30 feet below the river bed surface but stop when they hit the "hardpan," which can be felt by the dredge operator. The exact nature of the hardpan is unclear, but a review of bridge boring logs for the Interstate 70 bridge (~RM 29), and the Route 364 bridge (RM 32.6) shows that there is a general transition from more heterogeneous sand to sand with clay, gravel, or cobbles at approximately 15 to 30 feet below the river bed surface. The combination of less aggressive dredging techniques with a more resistant geological layer in the St. Charles segment may reduce rates of bed degradation from commercial dredging in that segment.

EFFECTS OF REMOVING COARSER MATERIAL FROM THE RIVERBED

Up to two-thirds of the material dredged in some areas of the Kansas City segment is too fine to meet specifications for making concrete and is discharged back into the river. Consequently, the actual volume of material extracted from the river bed may be up to three times greater than the retained dredging volumes indicate. The practice of retaining the coarser fraction of the dredged material likely increases the effect of dredging on bed degradation for two related reasons: (1) The portion of the dredged material that is returned to the river as a slurry is finer and more likely to remain in suspension and become part of the suspended bed material load than if it remained in the bed; and (2) even if the material discharged from the dredge becomes part of the bed, the process of extracting the coarser fraction of the bed material decreases the mean sediment size and increases the likelihood that the bed material will be eroded and transported at equivalent flows. The dredging process also deposits material too coarse to meet specifications back onto the river bed, resulting in a river bed that is composed of coarse material in rows near the surface and more fine material than the original bed.

3.4.6.4 Conclusion

This geomorphic assessment relies on a combination of new analyses developed for this EIS; analyses and data supplied by the USACE, the USGS, and other cooperating agencies; and other published

literature. The new analyses primarily include estimation of bed material loads at three gage locations in the Project area, linear regression analyses, and compilation and review of the HBED.

Comparison of low-flow water surface elevation changes, average bed elevation changes, HBED cross section changes, and the percent of bed material load extracted by commercial dredging clearly indicate that those areas where river bed degradation is most pronounced are the same areas where commercial dredging has been most active. Linear regression analyses show a statistically significant relationship between dredging intensity and dredging level (as a percent of bed material load) and local bed degradation, based on an analysis of 10 dredging reaches.

While other factors such as the BSNP, river bend cutoffs, and flow modification also have contributed to degradation in areas both with and without dredging, they have been in place for decades and the river has largely adjusted to those factors. The 1993 flood was an unusual event that caused widespread degradation and the drop in overall low-flow water surface elevations between 1990 and 2005, as indicated in Figure 3.4-31. However, local declines in river bed elevations near areas of dredging and long-term degradation trends are not the result of the 1993 flood.

For the St. Joseph segment, low-flow water elevations have declined moderately from 1990 to 2005, and the river bed has been stable based on gage data from Rulo and St. Joseph. The HBED analysis shows aggradation throughout the reach from 1998 to 2009. Dredging in the segment has been less than 10 percent of the bed material load during the past decade. Although the river bed at the St. Joseph gage has fluctuated in the past, particularly from approximately 1965 to approximately 1985, it has been stable since the early 1990s based on the average river bed elevation data at the gage locations.

For the Kansas City segment, the river bed and low-flow water surface elevations have dropped 10–15 feet over the past 50 years, with approximately half of the degradation occurring in the past 15 years. Multiple factors are likely influencing bed degradation rates. The BSNP structures and more moderate but slightly higher than average river flows from construction of upstream dams are likely contributing to increased sediment transport capacity, which results in scour in the Kansas City segment. Dredging is likely the key factor in causing bed degradation in the Kansas City segment based on the results of the bed material load estimates, the HBED analysis, and the change in CRP-adjusted low-flow water surface elevations compared with dredging locations. The volume dredged is over one-half of the total bed material load transported by the river over the past 10 years, which is substantially higher than

dredging rates in reaches with little or no degradation. Given the extent of ongoing bed degradation, dredging in the Kansas City segment is likely mining from glacial deposits in the river bed.

The Waverly segment has been stable or aggrading based on river bed elevation and water surface profiles. Comparison of water surface profiles between 1990 and 2005 show a moderate decline of 0.5–2 feet, and the HBED analysis shows river bed aggradation from 1998 to 2007–2009. Dredging in this segment has been less than 10 percent of bed material loads estimated for this segment.

The Jefferson City segment has experienced moderate degradation over the past 40 years of approximately 3–5 feet at the Boonville gage, which is located approximately 50 miles upriver from Jefferson City. The low-flow water surface elevation data show that the only area of increase in the Project area occurred in this segment below the confluence of the Grand and Chariton Rivers. Based on water surface elevation data and the HBED analysis, the greatest amount of degradation in the segment appears to be occurring at the same location on the river as the highest levels of dredging—in the Jefferson City area. Degradation also is occurring at the confluence with the Grand River, where no dredging has occurred. The Jefferson City portion of the segment is not affected by the additional factors that affect the Kansas City segment, such as a major tributary confluence, flow-restricting infrastructure, or nearby river bend cutoffs. The only factor that appears to differentiate the Jefferson City portion of the segment from the rest of the segment is the amount of dredging.

The St. Charles segment also has experienced degradation near the urban area, although the trend is less certain because of limited gage data in that section of the river. The HBED analysis shows some degradation occurring throughout most of the segment below approximately RM 100, including the St. Charles area. The average river bed elevation at the Hermann gage has shown a long-term downward trend since approximately 1960, even though dredging levels have been moderate around the Hermann gage. The sediment-limited Osage River and the Gasconade River may be contributing flows that increase the sediment transport capacity below their confluence without contributing much sediment, thus initiating bed degradation. Sediment extracted by dredging, primarily in the St. Charles area, represents over 40 percent of the bed material load estimated to be passing the Hermann gage and is a likely contributor to the degradation indicated by low-flow water level reductions in the St. Charles area.

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3.5 INFRASTRUCTURE

3.5.1 Introduction

Commercial dredging activity could contribute to the ongoing river bed degradation in the LOMR, creating maintenance and operational impacts for infrastructure that relies on predictable minimum water levels and stable stream channels. These infrastructure facilities include water intakes for municipal water supply and power generation processes; federal and non-federal levees; BSNP dikes and revetments; vehicle and railroad bridge crossings; pipeline, power line, and telecommunication line crossings; and docks, ramps, wharfs, and marinas associated with industrial and recreational land uses.

This section begins with a brief overview of the regulatory setting that pertains to construction, operation, and maintenance of infrastructure on the LOMR. The general types of infrastructure present in the Project area (i.e., between RM 498 and RM 0) is presented, followed by a more detailed description of infrastructure by river segment.

3.5.2 Infrastructure Categories

The following general categories of infrastructure facilities are addressed in this section:

- Water intake facilities – water supply facilities that operate and maintain intakes within the Missouri River channel;
- Water supply wells – horizontal collector wells along the Missouri River that rely on river bed filtration to remove turbidity, pathogens, bacteria, and viruses;
- Levees – federal and non-federal levees maintained by local levee unit authorities to protect those levee districts from flooding;
- BSNP structures – dikes and revetments that stabilize the banks and form and maintain the navigation project;
- Bridge, pipeline, and cable crossings – facilities that cross the LOMR with support structures in the main channel or buried within the channel bottom; and
- Wharf and dock facilities – wharves, docks, material loading and offloading structures (conveyors, for example), ramps, and marinas.

3.5.2.1 Water Intake Facilities

Water is withdrawn from the Missouri River for make-up and cooling purposes in the production of electricity; for municipal water supply; and for commercial, industrial, domestic, and public uses. Water intake facilities on the LOMR are the primary water source for many municipalities and utilities. Groundwater wells near and under the river channel serve as primary sources of water in some cases and as a secondary or backup source in other cases. The Missouri River Navigation Charts (Sioux City, Iowa to Kansas City, Missouri; Kansas City, Missouri to the Mouth) and others identify 31 water intake facilities in the Project area between RM 498 and RM 0.[1] Most of these intakes are located in river segments that are currently being dredged and are also experiencing river bed degradation. These intakes provide drinking water to approximately 2.2 million people, and cooling and process water to power plants that generate over 6,000 megawatts (MW) of electricity (Kelly 2004).

Water intake facilities rely on a predictable minimum water level at each river intake structure. Low pool levels in upstream reservoirs and below-normal project releases during recent drought conditions forced many intake operators to make modifications, including to the intake structures themselves (Kelly 2004). Even with strict water conservation measures in place, most water purveyors with water supply intakes have only approximately 1–2 days of water supply in storage. To increase the amount of water available, some municipalities have drilled new wells (as an alternate water source) or increased pumping capacities at existing wells (Kelly 2004).

Dredging is currently prohibited within a zone extending 4,000 feet upstream and 500 feet downstream from any municipal drinking water intake structure located along either bank of the river; and within a zone extending 500 feet upstream and 500 feet downstream from any other water intake structure, other than those used for municipal drinking water. This condition may be exempted by the USACE if requested by the Dredger and approved by the company owning and operating the water intake.

3.5.2.2 Water Supply Wells

Several large-capacity collector wells are located in the Project area that supply drinking water to thousands of customers, including wells operated by the Kansas City Board of Public Utilities that provide water to over 145,000 residents in Kansas City and Wyandotte County, Kansas; by the Missouri American Water Company in St. Joseph that provide water to over 30,000 customers in

[1] Note that names of water intake facilities included in the segment-specific tables were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

northwest Missouri; and by the Water District No. 1 of Johnson County, Kansas (WaterOne) that serves 15 cities and approximately 408,000 individuals throughout Johnson County.

These wells are horizontal collector wells, which are different from traditional vertical water wells that are unlikely to be affected by river bed degradation or low-flow water elevations. Horizontal collector wells have a vertical shaft extending down 75–100 feet near the river. At the bottom, numerous lateral shafts radiate out horizontally from the central shaft into the alluvial aquifer that is under and adjacent to the river. Several water purveyors that operate these types of wells in the Project area are concerned that dredging operations could remove significant amounts of permeable aquifer materials and disrupt the natural filtration capacity of the streambed (Uden pers. comm.).

Dredging is currently prohibited within a zone extending 1,000 feet upstream and 1,000 feet downstream from any municipal drinking water horizontal collector well located along either bank of the river. This condition may be exempted by the USACE if requested by the Dredger and approved by the company owning and operating the water intake.

3.5.2.3 Levees

Levees are among the most noticeable and extensive infrastructure features along the LOMR; levees line hundreds of miles of river bank and protect thousands of acres of developed land and agricultural fields. Levees on the LOMR and major tributaries have been constructed by the USACE and a variety of local sponsors, including levee districts, drainage districts, conservation districts, and not-for-profit levee associations. The federal and non-federal levees located in the Project area are described below.

Federal Levees

Table 3.5-1 lists the 144.2 miles of federal levees located on the LOMR, including the land area, resident population, total investment protected, and the estimated damages prevented by each levee from the project's implementation date through fiscal year 2009 (see also Figure 3.4-2).

The Kansas City's Metropolitan Levee System is the most extensive levee system in the Project area. The system includes seven federal levee units initially constructed in the 1950s as part of the federal Flood Risk Management (FRM) system to provide flood protection for Kansas City and several surrounding communities. The system includes channel improvements, levees, and floodwalls on both the LOMR and the Kansas River; it covers a two-state and multi-community area with multiple levee districts and supporting agencies (USACE 2009a).

Table 3.5-1 Federal Levees on the Lower Missouri River

Levee Unit[a]	River Mile	Areas Protected (acres)	Affected Population	Investment (2010 dollars)	Damages Prevented to Property through 2009 (dollars)
R-513-512	497.5–495	11,800	17	8,065,000	6,534,000
R-500	484.4–480	1,550	--	795,000	1,272,000
L-497	482.4–476.7	6,840	18	17,779,000	5,650,000
L-488	475.3–465.2	8,365	5	44,649,000	7,009,000
R-482	468.4–458	4,730	12	15,178,000	3,943,000
L-476	461.0–454.0	6,000	136	23,710,000	4,605,000
R-471-460	456.5–441.8	13,424	1,631	637,810,000	8,0085,000
L-455	445.6–437.6	7,519	3,838	1,594,126,000	179,084,000
L-448-443	437.6–428	18,080	48	80,771,000	17,922,000
R-440	431–424.3	4,100	--	250,000	4,681,000
L-408	401.3–391.5	9,595	219	29,850,000	10,112,000
L-400	391–385	9,595	6	21,140,000	4,331,000
Kansas City's seven levees[b]	374–354.0	153,000	23,124	18,793,000,000	5,783,116,000
L-385	372.1-375.9	1,566	731	460,382,000	Unknown
R-351	350–339.7	8,861	265	15,000,000	5,033,000
L-246	250–239	25,000	161	36,784,000	28,688,000
L-234/Lower Chariton	238.8–227.3	19,200	72	30,717,000	14,545,000
New Haven	81.7–81.4	15	15	10,847,000	19,114,000
Total	144.2	309,240	30,298	21,820,853,000	6,175,724,000

Note: -- = Not available.

[a] R and L refer to right and left descending banks, respectively. The number is the river mile at the center point of the levee at the time it was authorized. The river miles do not match up exactly now, because of river cutoffs constructed since the levee was authorized.

[b] Includes Fairfax-Jersey Creek, North Kansas City, Central Industrial District, East Bottoms, Birmingham, Armourdale, and Argentine Levee Units.

Source: USACE 2010b.

The federal FRM systems are operated and maintained by public entities as sanctioned by the statutes of their respective states. In some cases, the FRM system structures share boundaries with BSNP structures. Maintenance responsibilities in these instances have been generally defined by the sloping reference plane called the CRP (see Section 3.4.6.1 for further information on the CRP).

Non-Federal Levees

In addition to the system of federal levees, approximately 97 systems of non-federal levees of 100 acres or more are located along the LOMR and its tributaries (Figure 3.4-2). These levees vary with respect to maintenance standards and levels of protection. In most cases, the levees range between 6 and 16 feet above the landside natural ground surface and provide a level of flood protection that exceeds the 5- or 10-year flood event. Non-federal levees provide protection to at least 476,000 acres of primarily agricultural lands in the Project area.

The USACE currently prohibits dredging within 500 feet of any levee centerline built or authorized by the U.S. Government.

3.5.2.4 Bank Stabilization and Navigation Project

The USACE Kansas City and Omaha Districts are responsible for construction, operation, and maintenance of the BSNP. The BSNP was first authorized by the RHA of 1912 and subsequent authorizations in 1925, 1927, and 1945. The 1912 RHA authorized a 6-foot-deep channel from the mouth to Kansas City, Missouri, and the 1925 RHA authorized a 200-foot-wide channel over the same area. The 1927 RHA extended the BSNP to Sioux City, Iowa. The 1945 RHA increased the authorized channel to 9 feet deep by 300 feet wide. The existing BSNP extends 735 miles from Sioux City, Iowa to the mouth near St. Louis, Missouri; within the states of Missouri, Kansas, Iowa, and Nebraska; and maintains a 9-foot deep by 300-foot-wide navigation channel (USACE 2003).

The BSNP structures consist mainly of revetments along the outsides of bends and transverse dikes along the insides of bends that force the river into a single active channel that is self-maintaining (USACE 2003). The USACE maintains more than 2,700 dike structures and approximately 540 miles of bank revetments in the Project area as part of the BSNP. These structures are maintained to achieve the design function (i.e., a self-maintaining navigation channel) as measured against the CRP. The current CRP elevations are presented in Table 3.5-2 (USACE 2010a).

While the river essentially has been stabilized into a single channel that is self-maintained by the BSNP infrastructure, individual flood events and river bed degradation require review of BSNP structure elevations and comparison to the CRP. If the channel degrades and navigation season flows cannot meet the previous CRP elevations, the infrastructure—including the BSNP features—must be altered to maintain the design water surface elevations in a given river segment.

Table 3.5-2 Construction Reference Plane Adjusted Elevations (2010)

Gage Location (river mile)	Construction Reference Plane Adjusted Elevation (feet above mean sea level)
Rulo (498.10)	846.48
St. Joseph (448.20)	796.66
Kansas City (366.10)	716.36
Waverly (293.40)	657.07
Booneville (197.10)	573.47
Hermann (96.90)	488.68
Mouth (0.00)	400.00

Source: USACE 2010a.

Over time, the need to revise the CRP arises because of changes in the basin resulting from drought conditions, heavy flows, mitigation work related to endangered species, degradation, aggradation, and other river-related circumstances. The current CRP was revised in 2010.

Dredging is currently prohibited within 200 feet of any dike, revetment, or other structure built or authorized by the U.S. Government as part of the BSNP.

3.5.2.5 Bridge, Pipeline, and Cable Crossings

There are 38 bridge crossings, 31 pipeline crossings, nine cable crossings, and one water tunnel crossing along the mainstem of the Missouri River in the Project area. These include state and local bridges, railroad bridges, and numerous public and commercial pipeline and cable crossings. Bridges over rivers are held up by pylons or piers that extend deep into the ground, using the stability of the earth to strengthen foundational support. River bed degradation can erode river beds, exposing pylons and piers, and diminishing the support for the bridge (USACE 2009a). Pipelines and underwater cable crossings rely on relatively consistent river bed elevations to provide adequate cover to subsurface infrastructure. Pipeline and underwater cable crossings that become exposed are susceptible to damage from debris flows and vessel anchors. Exposed pipelines can also be at risk of failure due to buoyancy effects. Overhead utility crossings are constructed at heights above the water surface that provide more than minimal levels of clearance for navigation purposes and therefore were not investigated.

Dredging is currently prohibited within 500 feet of any bridge pier or abutment or the centerline of any pipeline or submerged utility crossing.

3.5.2.6 Wharf and Dock Facilities

Wharf and dock facilities include wharves, docks, boat ramps, and other shoreline loading facilities along the LOMR. There are 154 wharf and dock facilities along the mainstem of the Missouri River in the Project area. These facilities are sensitive to changes in water surface elevation and channel bed elevation; they require a fairly consistent depth and elevation to service vessels, and a fairly consistent distance to shore to maintain landward access. These facilities are susceptible to local scour and deposition as channel flow characteristics and the river bed change over time.

3.5.3 Availability of Data

Data requests were issued for operation criteria related to water surface and river bed elevations, maintenance records, annual maintenance costs, and as-built drawings for each facility were requested. Infrastructure data gathered to date are limited, due to the limited response from facility operators. Water intakes and water supply wells are operated by several private entities whose information is considered confidential and not publically available.

The USACE maintains federal levee information but does not separate the LOMR segments from the larger system. Levees include a mix of federal and non-federal interests with varying levels of reporting and record keeping. General BSNP structures were tallied from the USACE navigational charts. The MoDOT, KDOT, Union Pacific Railroad (UPRR), Burlington Northern Santa Fe Railway (BNSF), Norfolk Southern Railway, and Kansas City Southern Railway were contacted to collect information about major bridge crossings. Only limited information was available from private companies that own and maintain pipelines, and no major issues were reported. Investigations into wharf and dock facilities determined that most commercial/industrial wharves and docks have been abandoned due to lack of use. However, boat ramps and marinas are widely used and require regular maintenance stemming from changes in water level and river bed degradation. State and local parks departments provided information for many of the boat ramp facilities.

Key sources of information used to describe the existing condition of infrastructure on the LOMR in the Project area include:

- Interviews with USACE staff;
- Interviews with staff who operate and maintain potentially affected infrastructure;
- *Final Report, Missouri River Levee Unit L-385 Sediment Analysis* (West Consultants 1999);
- Master Water Control Manual, Appendix E (USACE 2006);
- Missouri River Navigation Charts—the Orange and Green Books (USACE 1991a, 1991b);
- Missouri River stage trends technical report (USACE 2007);
- *Missouri River Bed Degradation Reconnaissance Study* (USACE 2009a); and
- *Missouri River Degradation and Causes (Lower 498 River Miles)* (USACE 2009b).

3.5.4 Existing Infrastructure

This section describes the type and location of existing infrastructure on the LOMR in the Project area. Water intake facilities, levees, BSNP structures, bridges, pipelines, underwater cable crossings, and wharf and dock facilities are identified and described by river segment.

3.5.4.1 St. Joseph Segment

One sand plant is located in the St. Joseph area. One company dredges the area around St. Joseph from that sand plant and dredges the lower portion of the St. Joseph segment from a sand plant situated in the Kansas City segment. A second company has proposed a new sand plant and dredging operation in the lower end of the St. Joseph segment. Several locations downstream of the City of St. Joseph have experienced river bed degradation greater than 3 feet (USACE 2009b).

Water Intake Facilities

Table 3.5-3 lists the six water intake facilities identified in the St. Joseph segment. Two of these intake facilities provide cooling and process water for two power plants, and four facilities withdraw water for public water supply.

Table 3.5-3 Water Intake Facilities – St. Joseph Segment

Facility Name[a]	River Mile
St. Joseph Water[b]	452.2
St. Joseph Power & Light	445.9
Atchison Water	423.3
Atchison Water Department	422.5
Iatan Power Plant	411.1
Leavenworth Water Company	398.0

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

[b] A water intake facility for St. Joseph Water is shown on the Missouri River navigation charts; however, water supply for the area around St. Joseph is currently provided by Missouri American Water and its system of wells.

Intake Systems for Power Plant Cooling and Process Water

The intake system at RM 411.1 provides cooling and process water for the Iatan Power Plant. The Iatan Power Plant is comprised of two coal-fired power stations operated by Kansas City Power & Light (KCP&L). Iatan Plant 1 opened in 1980 and has a 651-MW capacity. Iatan Plant 2 is scheduled to open in 2010 and will generate 850 MW. The Iatan Power Plant is the largest coal-burning power plant in Missouri and generates 25 percent of the power that KCP&L generates and provides to more than 820,000 customers in 47 northwestern Missouri and eastern Kansas counties. The KCP&L also operates a 100-MW coal-fired plant in St. Joseph (the Aquila Lake Road Power Station) that relies on an intake system located at RM 445.9 (Burse pers. comm.).

Intake Systems for Public Water Supply

Missouri American Water owns a water intake facility for St. Joseph Water at RM 452.2; however, according to the current owner/operator, the intake has not been in service since 2000 when the company converted to an all-well water supply system (Fuerman pers. comm. [a]).

The Leavenworth Water Company operates north and south plants that rely on the intake facility at RM 398. The intake grate is set on bedrock, and the operations of the plant are not affected by silt. Each winter, the intake facility is inoperable because of low flows and ice, requiring use of alternate sources; this condition has persisted for the past 20 years (Kowalewski pers. comm.).

The City of Atchison operates two water supply intake facilities within this segment (RM 423.3 to RM 422.5). The capacity of the City's system is 10 million gallons per day (gpd), supplying water to over 4,000 accounts and five rural water districts (City of Atchison 2005).

Water Supply Wells

Several notable water supply wells systems are located along this segment. Missouri American Water operates a collector well and seven vertical wells at approximately RM 454.75. The company is concerned that dredging in this area will decrease the yield of their wells by introducing finer material and reducing the permeability of the aquifer, as well as increasing the risk of microbial contamination by reducing the effectiveness of river bed filtration (Fuerman pers. comm. [b]). The Leavenworth Water Company operates groundwater wells near RM 398.0. No problems with well production have been reported to date (Kowalewski pers. comm.).

Levees

Table 3.5-4 lists the 94.4 miles of federal levees in the St. Joseph segment. These levees are concentrated primarily along the LOMR mainstem and on several major tributaries approximately 30 river miles upriver and downriver of the City of St. Joseph (Figure 3.4-2, Sheet 1).

In the St. Joseph area between RM 456.5 and RM 437.6, the federal Levee Units R-471-460 and L-455 alone protect 20,000 acres of industrial, commercial, residential, and agricultural land uses; approximately 5,469 residents; and approximately $2.2 billion in investment. Another concentration of federal levees begins near Leavenworth, Kansas and extends downriver for approximately 15 miles. These two areas represent the second largest concentration of federal levees outside of the Kansas City segment. Together, the federal levees in this segment protect approximately 101,598 acres of urban, commercial/industrial, residential, and agricultural land use; a population of approximately 5,930; and approximately $2.4 billion in investment, primarily in and around the communities of St. Joseph, Elwood, and Atchison (USACE 2010b).

Non-federal levees are more evenly distributed along the St. Joseph segment than federal levees. Approximately 32 miles of levees in eight separate units protect over 55,000 acres of primarily agricultural uses along the mainstem LOMR and major tributaries (Figure 3.4-2, Sheet 1).

Table 3.5-4 Federal Levee Units – St. Joseph Segment

Unit Name[a]	River Miles
Levee Unit R-513-512	497.5–495.0
Levee Unit R-500	484.5–480.0
Levee Unit 497	482.4–476.7
Levee Unit L-488	475.3–465.2
Levee Unit R-482	468.4–458.0
Levee Unit L-476	461.0–454.0
Levee Unit R-471-460	456.5–441.8
Levee Unit L-455	445.6–437.6
Levee Unit L 448-443	437.6–428.0
Levee Unit R-440	431.0–424.3
Levee Unit L-408	401.3–391.5
Levee Unit L-400	391.0–385.0

[a] R and L refer to right and left descending banks, respectively. The number is the river mile at the center point of the levee at the time it was authorized. The river miles do not match up exactly now, because of river cutoffs constructed since the levee was authorized.

Bank Stabilization and Navigation Project Facilities

The USACE maintains over 600 wooden pile and rock rip-rap dikes and more than 121 miles of rock revetments along the navigation channel in the St. Joseph segment as part of the BSNP (Figure 3.4-2, Sheet 1). The heights of all dikes and revetments within the St. Joseph segment are maintained by the USACE, as measured against the CRP.

Bridge, Pipeline, and Cable Crossings

Four vehicle bridges and three railroad bridges cross the Missouri River in the St. Joseph segment (Table 3.5-5). The vehicle bridges provide interstate connections for Route 159, US 36, US 59, and Route 92 (Figure 3.4-2, Sheet 1). These bridges are operated and maintained jointly by the KDOT and the MoDOT, except for the Rulo Highway Bridge (Route 159) which is operated and maintained jointly by the NDOR and the MoDOT. In 2009, the average annual daily traffic (AADT) volume was 1,006 on the Rulo Highway Bridge at RM 498.1, 8,849 on the St. Joseph Highway Bridge (US 36) at RM 447.9, 9,432 on the Atchison Highway Bridge (US 59) at RM 422.5, and 14,914 on the Leavenworth Highway Bridge (Route 92) at RM 397.6 (MoDOT 2009).

Table 3.5-5 Bridge Crossings – St. Joseph Segment

Crossing Name (Route Number)	River Mile	Pile Cap Elevation	River Bed Elevation
Rulo Highway (US 159)	498.1	Unknown	Unknown
Burlington Northern	498.1	Unknown	Unknown
Union Pacific Railroad	448.2	Unknown	Unknown
St. Joseph Highway (US 36)[a]	447.9	Unknown	Unknown
Atchison Railroad	422.8	Unknown	Unknown
Atchison Highway (US 59)	422.5	Unknown	Unknown
Leavenworth Highway (Route 92)	397.6	Unknown	Unknown

[a] Includes separate westbound and eastbound spans.

All highway bridges across the Missouri River are regularly inspected, and if necessary, reinforced against scour. While river bed degradation may be occurring in certain areas, routine inspections have determined that the foundations are stable, with footings or piles secured to bedrock material. The Leavenworth Highway Bridge (Route 92) is supported by concrete spread footings 30 feet deep. Surveys by the KDOT show negligible degradation at this bridge crossing. The new Atchison Highway Bridge (US 59) is supported by drilled shafts founded 85 feet below the streambed (Orth pers. comm.). The three railroad bridges—one each for the Atchison Railroad, the UPRR, and the BNSF—are located at RM 422.8, RM 448.2, and RM 498.1, respectively. No information on the condition of these bridges was available.

More than six pipelines transporting liquid petroleum, natural gas, and water are located in the St. Joseph segment (Table 3.5-6). Two communication cable crossings also are located in this segment. Cable crossings are typically encased in steel pipes for protection. No issues related to river bed degradation at these crossing locations have been reported.

Table 3.5-6 Pipeline and Cable Crossings – St. Joseph Segment

Crossing Name	Utility Type	River Mile
Michigan and Wisconsin Pipelines	Pipeline	497.3
Williams Brothers Oil	Pipeline	455.5
City of St. Joseph (water)	Pipeline	450.4
Platte Pipeline Co.	Pipeline	437.3
AT&T	Cable	431.2
AT&T	Cable	431.1
Hydrocarbon Pipeline Transport, Inc.	Pipeline	414.1
Mid-America	Pipeline(s)	406.7

Wharf and Dock Facilities

There are 43 wharf and dock facilities in the St. Joseph segment (Table 3.5.7). These facilities service commerce and recreation. In addition to loading and unloading facilities, boat ramp access is scattered throughout the segment. The segment is served by one marina (Island Marina) at RM 462.6.

3.5.4.2 Kansas City Segment

Two existing sand plants are located in the Kansas City segment, and one dredging company is actively mining in this portion of the river. The Kansas City segment has experienced the greatest amount of river bed degradation. Individual locations have degraded from 2 to 7 feet since 1990 (USACE 2009b).

Water Intake Facilities

Eight water intake facilities are located in the Kansas City segment (Table 3.5-8). Four of these intake facilities provide cooling and process water for power plants, three provide public water supply, and one provides industrial process water for asphalt production. The KCP&L, the Kansas City (Kansas) Board of Public Utilities, the Kansas City (Missouri) Water Services Department, and WaterOne rely on these intake facilities.

Table 3.5-7 Wharf and Dock Facilities – St. Joseph Segment

Facility Name	Facility Type	River Mile
Rulo Boat Dock	Dock	498.0
Rulo Boat Club	Ramp	497.7
Unlabeled	Ramp	495.6
Unlabeled	Ramp	495.4
White Cloud Grain Co.	Grain loading dock	488.0
Buffalo Hollow Quarry	Rock loading dock	478.0
Paynes Landing Access	Ramp	477.1
Wolf Creek Rock Quarry	Dock	474.5
Mount Vernon Quarry	Rock loading dock	473.6
Mount Vernon Ranch Quarry Dock	Dock	468.9
unnamed	Ramp	468.3
Island Marina	Gas, docking, food	462.6
Nodaway Island Recreation Facility	Ramp	462.2
Studer (Westlake) Quarry	Dock	456.9
St. Joseph boat ramp	Ramp	452.1
D.L.W., Inc.	Ramp	452.0
Spirit of St. Joseph	Landing	449.0
Holliday Sand and Gravel Co.	Sand and gravel unloading dock	447.6
Bartlett and Company, Inc.	Grain loading dock	446.6
AG Processing	Dock, derrick, grain conveyor	446.1
Farmland Industries, Inc.	Dock	445.5
Chemical Operations	Chemical unloading dock	445.4
Flathead Fishing Club	Ramp	444.6
St. Joseph Outboard Motor and Yacht Club	Ramp and dock	444.0
Wathena Boat Ramp	Ramp	440.9
Scholz (Roundy) (Westlake) Quarry	Dock	432.8
Bromely & Sons Quarry	Dock	423.9
Maczuk, Inc.	Fertilizer unloading dock	423.2
Elders Grain, Inc.	Grain loading conveyor	423.1
Atchison Municipal Dock	Loading dock	423.0
Atchison Independent Park	Ramp	423.0

Table 3.5-7 Wharf and Dock Facilities – St. Joseph Segment

Facility Name	Facility Type	River Mile
Atchison Dock	Loading and unloading dock	421.1
Atchison County Co-Op Association	Grain unloading dock	420.9
Boldridge Quarry	Dock	418.5
Oak Mills Quarry	Dock	413.5
Westlake Quarry	Dock	413.0
West Bend State Park	Ramp	403.1
Hull Quarry	Dock	403.0
Leavenworth Park	Ramp	397.6
U.S. Coast Guard (Leavenworth)	Transfer of government materials dock	397.3
Leavenworth Boat Club	Ramp	396.8
Leavenworth Municipal Dock	Dock	396.1
Missouri Valley Steel Shipyard	Dock	395.6
Smoot Grain Co.	Grain loading dock	386.5
Cargill Inc.	Molasses unloading dock	386.4
Holliday Sand and Gravel Co.	Sand and gravel unloading dock	386.2
Massman Construction Co., Inc.	Construction materials and rock loading dock	385.0

Intake Systems for Power Plant Cooling and Process Water

The intake facility located at RM 378.7 provides cooling and process water to the 261-MW Nearman Bottoms coal-fired power plant operated by Kansas City Board of Public Utilities. The publicly owned utility serves approximately 65,000 electric customers in Wyandotte and Johnson Counties, Kansas.

A water intake facility located at RM 373.4 provides cooling and process water to the 239-MW coal-fired Quindaro Station operated by the Kansas City Board of Public Utilities. The Kansas City Board of Public Utilities abandoned one pump intake at this location and installed two new intakes to replace the original (USACE 2010c).

Table 3.5-8 Water Intake Facilities – Kansas City Segment

Facility Name[a]	River Mile
Johnson Co. Water District No. 1 (WaterOne)	380.0
Nearman Bottoms Power Plant (KCBPU)	378.7
Mid-Continent Asphalt & Paving	378.4
Kansas City, KS Water Co. (KCBPU)	373.5
Kansas City, KS Power & Light (KCBPU)	373.4
Kansas City, MO Water Department	371.0
Kansas City Power & Light Co. (KCP&L)	365.8
Kansas City Power & Light Co. (KCP&L)	358.2

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

The intake facility located at RM 365.8 is used to withdraw water for the Trigen-Kansas City plant that provides heating and cooling for approximately one-third of the buildings in downtown Kansas City, Missouri and for a major industrial facility in North Kansas City.

The water intake facility at RM 358.2 provides cooling and process water to the Hawthorn Generating Station operated by the KCP&L. The plant can generate up to 565 MW of electricity, approximately 26 percent of the company's total production capacity. The KCP&L has installed new circulating water pumps and modified its intake structures in response to ongoing river bed degradation (of more than 5 feet) near these intake facilities (Heidtbrink pers. comm.).

Intake Systems for Public Water Supply

WaterOne operates an intake facility at RM 380.0 that currently supplies 125 million gpd of the District's 180-mgd total (Schrempp pers. comm. [b]). The facility was retrofitted in early 2004 with supplemental pumps to draw from lower elevations, at a cost of approximately $2 million, in order to guarantee service to 402,000 persons. The supplemental pump system lacks the intake capacity of the original design main pumps. When the Nearman Power Plant shuts down because of intake issues, the power supply to the WaterOne pumps is limited, which reduces the maximum pumping rate (Schrempp pers. comm. [c]).

The Kansas City Board of Public Utilities operates an intake facility at RM 373.5. The utility operates a collector well and treatment plant providing up to 45 mgd of water to approximately 51,000 water customers in Wyandotte and Johnson Counties, Kansas.

The Kansas City, Missouri Water Services Department (WSD), Water Supply Division processes drinking water for Kansas City residents and 33 wholesale customers in the greater Kansas City area. The division treats an average of 113 million gpd and supplies approximately 44 billion gallons of water annually (City of Kansas City, MO. 2010). A WSD intake facility is located at RM 371.0. One intake at this location was abandoned in the 1990s. The current intake facility operates six individual pumps. During periods of low flow, river bed degradation requires installation of four supplemental pumps that, combined, provide 50-percent capacity of the current intake system (Klender pers. comm.).

Water Supply Wells

The Kansas City Board of Public Utilities operates two horizontal collector wells in this segment that are capable of producing more than 80 million gallons of source water per day. These wells are the only water source for the Nearman Water Treatment Plant, which serves over 145,000 residents in Kansas City, Kansas and Wyandotte County. The State of Kansas has approved water rights for these wells based on scientific data demonstrating that the wells acquire 90 percent of their water from surface water (the Missouri River) and the remainder from groundwater. Within the next 2 years, these two wells will become the utility's sole source for water (Uden pers. comm.).

In March, 2010 WaterOne began operating a new horizontal collector well located on the Missouri River at approximately RM 385.5. The well includes approximately twelve 250-foot long radial collectors located approximately 90 feet below the ground surface, several of which are located approximately 50 feet below the river bed. The well is capable of producing 30 million gallons per day (Schrempp pers. comm. [d]).

Levees

Approximately 24 miles of federal levees are located along the LOMR in the Kansas City segment (Table 3.5-9). The Kansas City's Levee system is comprised of seven separate federal levee units: Fairfax-Jersey, North Kansas City, Central Industrial District, East Bottoms, Birmingham, Armourdale, and Argentine. The Armourdale and Argentine units are located on the Kansas River, but function as part of the Kansas City's Levee system. Levee Unit L-385 near the community of Riverside, Missouri was completed in 2005 and is located just upriver from the Kansas City's Levee system.

Together, the Kansas City's levee system and Levee Unit L-385 protect 154,566 acres of industrial, commercial, manufacturing, warehouse, retail, and residential land uses—including critical facilities such as power plants and water treatment plants. The levees protect approximately $19 billion of investment, including businesses and industries that provide nearly 100,000 jobs. Approximately 24,000 residents live behind these levees (USACE 2010b). Additional details on Levee Unit L-385 and the Fairfax-Jersey, North Kansas City, and East Bottoms Levee Units is presented below

Table 3.5-9 Federal Levee Units – Kansas City Segment

Unit Name	River Miles
Levee Unit L-385[a]	372.1–375.9
Levee Unit Fairfax-Jersey	374.0–367.5
Levee Unit North Kansas City	370.5–363.5
Levee Unit Central Industrial District	367.4–365.7
Levee Unit East Bottoms	365.7–357.5
Levee Unit Birmingham	360.3–354.0
Levee Unit Armourdale	Kansas River 2.1–6.5
Levee Unit Argentine	Kansas River 4.5–9.5

[a] L refers to left descending bank. The number is the river mile at the center point of the levee at the time it was authorized. The river miles do not match up exactly now, because of river cutoffs constructed since the levee was authorized.

Levee Unit L-385 (Riverside-Quindaro Bend)

The Riverside-Quindaro Bend Levee (Levee Unit L-385) consists of 4.7 miles of earthen levee along the left descending bank of the Missouri River at Riverside, Missouri. The levee system averages approximately 20 feet in height, varying from 15 feet to 23 feet, and provides 500-year floodplain protection to approximately 1,200 acres of land in the Missouri River valley, including undeveloped property, farm land, and a border area of light industrial development. The project was planned and implemented by the Quindaro Bend Drainage District and the USACE at a cost of over $87 million dollars. The undeveloped property in this flood-protected area includes the site of the Horizons Projects. The site is bounded by Interstate 635, has railroad access, and is near downtown Kansas City. The master plan calls for mixed-use development incorporating "new urbanism" design concepts. Levee Unit L-385 is the first levee in Missouri to integrate a trail for walking and running atop the levee. The Missouri Riverfront Trail winds through trees, past wetlands and bluffs, and connects with several

parks including E. H. Young Riverfront Park in Riverside, Missouri and English Landing Park in neighboring Parkville, Missouri (City of Riverside 2010).

North Kansas City Levee Unit

The North Kansas City Levee Unit protects a left bank area across the Missouri River from downtown Kansas City, Missouri. The protected area, which is essentially the city of North Kansas City, Missouri, includes nearly 1,100 residential units—home to almost 4,900 residents—and almost 500 businesses and facilities, including Kansas City's Charles B. Wheeler Downtown Airport. The BNSF and Norfolk Southern railroad yards are protected, in addition to a significant retail sector, numerous small businesses, warehouses, and industrial sites. Approximately 26,700 people work in North Kansas City. The levee unit's estimated protected investment is almost $3.5 billion, based on October 2008 prices. The existing condition of the river bed at RM 370.1, near the Charles B. Wheeler Downtown Airport, is estimated to have dropped 24 feet, resulting in loss of rock fill toe protection at one storm sewer outlet (USACE 2009a).

Fairfax-Jersey Levee Unit

The Fairfax-Jersey Levee Unit protects a right bank industrial area in Kansas City, Kansas. The protected area includes approximately 350 businesses and facilities, with a total estimated investment of almost $3.5 billion. A General Motors assembly plant anchors the area, which also includes large commercial, industrial, and public facilities such as Owens-Corning, Weyerhauser, and Certainteed. The area has no residents; however, the area's workforce exceeds 11,100 people. Analysis of the existing river bed condition at RM 367.8 indicates that a drop of 20 feet in the river bed already has occurred and is threatening a slide in the riverside bank (USACE 2009a).

East Bottoms Levee Unit

The East Bottoms Levee Unit protects a right bank industrial area of Kansas City, Missouri. The protected area contains approximately 750 businesses and homes with a total estimated value of approximately $5.4 billion. The industrial structure includes manufacturing, transportation, and major warehouse storage, as well as retail businesses. The approximately 500 companies and facilities in the area include a KCP&L plant, a water treatment plant, a Sears distribution center, Cargill, the Isle of Capri Casino, General Mills, and Bayer Corporation. Approximately 250 residential units also are protected. More than 3,200 residents live in the area, and more than 20,100 people are employed in East Bottoms businesses. At RM 364.5, a 15-foot drop in the river bed already has occurred (USACE 2009a).

Non-Federal Levees

Non-federal levees in the Kansas City segment are concentrated primarily upriver from Kansas City. Approximately 10 miles of levees in four separate units protect over 5,200 acres of primarily agricultural use along the mainstem LOMR (Figure 3.4-2, Sheet 2).

Bank Stabilization and Navigation Project Facilities

The USACE maintains 149 wooden pile and rock rip-rap dikes and approximately 42 miles of rock revetments along the navigation channel in the Kansas City segment as part of the BSNP (Figure 3.4-2, Sheet 2). The Kansas City reach has required installation of additional dikes to manage the sediment load from the Kansas River. The dike system has resulted in a reach of river that is very efficient at "cleaning" and maintaining the low-flow channel (USACE 2009a). As in other segments, the height of the dikes and revetments are maintained by the USACE, as measured against the CRP.

Bridge, Pipeline, and Cable Crossings

Eight vehicle bridges and three railroad bridges cross the Missouri River in the Kansas City segment (Table 3.5-10). Vehicle bridges carry large volumes of automobile and truck traffic in and through the Kansas City metropolitan area.

Table 3.5-10 Bridge Crossings – Kansas City Segment

Crossing Name (Route Number)	River Mile
Wolcott Highway Bridges (Interstate 435)	383.3
Kansas City Highway Bridge (Interstate 635)	374.1
Fairfax Highway Bridges (US 69)	372.6
Broadway Avenue Bridge	366.2
Hannibal Railroad Bridge	366.1
A.S.B. Railroad Bridge	365.6
Heart of America Bridge (Route 9)	365.5
Paseo Bridge (Interstate 29 & 35)	364.8
Chouteau Highway (Route 269)	362.3
Interstate 435 Bridge	360.3
Harry S. Truman Railroad Bridge	359.3

Highway bridges connecting Kansas and Missouri are jointly operated and maintained by the KDOT and the MoDOT. The Broadway Avenue Bridge is operated and maintained by the Kansas City, Missouri Department of Public Works. In 2009, the average AADT volume was 14,705 on the Fairfax Highway Bridges (US 69), 24,500 on the Wolcott Highway Bridges (Interstate 435), 46,640 on the Kansas City Highway Bridge (Interstate 635), 72,782 on the Paseo Bridge (Interstate 29 and 35), and 83,379 on the Interstate 435 Bridge (MoDOT 2009).

The Wolcott Highway Bridges carrying Interstate 435 over the Missouri River at RM 383.3 are founded on deep-drilled shafts 62 feet below the streambed (Orth pers. comm.). The Wolcott Highway Bridges are currently being monitored by the MoDOT for scour. If necessary, the MoDOT will use countermeasures to control river bed degradation and scour by installing spur dikes (finger dikes that project out into the river to direct water back toward the channel) or by placing gabions (large rectangular wire baskets containing rock) or dumping rock around bridge footings (Stotlemeyer pers. comm.).

The three railroad bridges in the Kansas City segment are located in the urban/industrial portions of Kansas City at RM 366.1, RM 365.6, and RM 359.3. Kansas City is the second largest rail hub in the United States, and is a major distribution and intermodal center. No information on the condition of these bridges was available.

The natural gas, liquid petroleum, water and sewer, and telecommunication lines in the Kansas City segment are concentrated in the urbanized areas approximately 10 miles upriver and downriver from the heart of Kansas City (Table 3.5-11). Williams Brothers Pipeline Company (RM 372.5) owns and operates six pipelines in the area. AT&T operates one telecommunication line, and the City of Kansas City, Missouri operates water and sewer lines in this area. An inspection report completed in February 1999 reported that pipelines in this area were exposed and sensitive to changes in river bed elevations (West Consultants 1999). No additional inspection data have been obtained.

Wharf and Dock Facilities

There are 35 wharf and dock facilities in the Kansas City segment (Table 3.5-12). These facilities service commerce and recreation. In addition to loading and unloading facilities, boat ramp access is scattered throughout the segment. The segment is served by one fuel dock at RM 364.1.

Table 3.5-11 Pipeline and Cable Crossings – Kansas City Segment

Crossing Name	Utility Type	River Mile
Williams Natural Gas	Pipeline	375.2
AT&T	Cable	374.0
Williams Brothers	Pipeline	374.0
Skelly Pipeline	Pipeline	373.9
Williams Brothers	Pipeline(s)	372.5
Williams Brothers	Pipeline	369.5
Kansas City, MO Water	Tunnel	366.1
Kansas City, MO Sewer	Pipeline(s)	361.2
American Oil	Pipeline	356.5

Table 3.5-12 Wharf and Dock Facilities – Kansas City Segment

Facility Name	Facility Type	River Mile
Smoot Grain Co.	Grain loading dock	386.5
Cargill, Inc.	Molasses unloading dock	386.4
Holliday Sand and Gravel Co.	Sand and gravel unloading dock	371.8
Massman Construction Co., Inc.	Construction materials and rock loading dock	385.0
Holliday Sand and Gravel Co.	Sand and gravel unloading dock	378.3
English Landing Park	Ramp	377.3
Texaco Oil Co.	Bulk petroleum storage	376.3
Intercontinental Engineering and Manufacturing Co.	Loading and unloading dock	375.6
Union Equity Co-Op	Grain loading dock	373.0
Bennett Rogers Pipe Coating, Inc.	Bulk and liquid unloading dock	372.4
William Brothers Pipeline Fertilizer	Liquid fertilizer solutions unloading dock	368.2
Bartlett and Company Inc.	Grain loading dock	367.7
Kansas City, KS Public Terminal	Loading and unloading dock	367.7
Missouri River Queen	Loading and unloading dock	367.4

Table 3.5-12 Wharf and Dock Facilities – Kansas City Segment

Facility Name	Facility Type	River Mile
Holliday Sand and Gravel Co.	Sand and gravel unloading dock	371.8
Midwest Term. Warehouse Co.	Grain loading dock and warehouse	367.1
Kansas City, MO Public Terminal	Loading and unloading dock	367.1
American Compressed Steel Co.	Scrap and steel loading dock	366.9
Kansas City, MO	Warehouse, dock, and platform	365.9
Kansas City, MO	Loading dock	365.4
Cargill Grain, Inc.	Grain loading dock	364.2
Brochers Fuel	Fuel dock	364.1
Kansas City River Access	Ramp	363.0
Continental Grain Co.	Grain loading dock	361.6
K.C. Terminal Elevator Co.	Grain loading dock	361.0
Chemtech Corp.	Chemical loading and unloading dock	360.6
La Moth Landing	Coke loading and unloading dock	360.4
Midwest Precote Quarry	Dock	359.9
Armco Steel Co.	Scrap steel unloading dock	357.6
Amoco Oil Co. (Distribution Center)	Unloading dock	356.6
Chevron Chemical Co.	Fertilizer unloading dock	355.8
Kansas City River Terminal	Fertilizer unloading dock	355.8
Mo. Portland Cement Co.	Cement loading dock	354.8
La Benite Recreation Park	Ramp	352.6
Eton Tower (Wake) Quarry	Dock	350.4

3.5.4.3 Waverly Segment

Two dredging sand plants are located in the Waverly segment, and two dredging companies are actively mining in the segment. The Waverly segment has experienced an average of approximately 1 foot of aggradation between 1998 and 2007, and 1.7 feet of aggradation between 1998 and 2009.

Water Intake Facilities

Five water intake facilities are located in the Waverly segment (Table 3.5-13). Two of these intake facilities provide cooling and process water for power plant processes. The City of Independence, the Sibley Power Station, U.S. Water Company, and Higginsville Municipal Utilities rely on these intake facilities.

Intake Systems for Power Plant Cooling and Process Water

In the Waverly segment, the intake system at RM 345.2 provides cooling and process water for the 46-MW coal-fired Independence Power Plant owned and operated by Independence Power & Light (IPL). IPL is a non-profit, municipally owned electric utility serving more than 50,000 consumers in Independence, Missouri. A water intake system for the Sibley Power Plant is located at RM 336.5. The Sibley plant is a 524-MW coal-fired power plant owned and operated by the KCP&L. The KCP&L services more than 820,000 customers in 47 northwestern Missouri and eastern Kansas counties with 15 generating facilities that generate over 6,100 MW. The Sibley plant generates approximately 8.6 percent of the company's electric power.

Table 3.5-13 Water Intakes – Waverly Segment

Facility Name[a]	River Mile
Independence Power Plant	345.2
Sibley Power Plant	336.5
U.S. Water Company	322.0
U.S. Water Company	317.0
Higginsville Water Department	307.0

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

Intake Systems for Public Water Supply

Two intake facilities on the LOMR in the Waverly segment (at approximately RM 322 and RM 317) are owned and operated by the U.S. Water Company. These intakes supply a single water filtration plant that serves approximately 2,300 customers (Luehrs. pers. comm.). Average consumption is 560,000 gpd, with peak consumption at 700,000 gpd.

The Higginsville Water Department operates a movable pump intake system at RM 307. The intake hose is laid along the river bottom and is used to supplement water supply in a city-owned lake located

approximately 2 miles east of Higginsville, Missouri. When water levels at the lake are low, the intake system withdraws water that is pumped 11 miles to the lake (MDNR 2002). The intake location is underlain with rock, but sand and silts have buried this area, requiring increased maintenance and frequent replacement of the pump shaft (Urfer pers. comm.). The intake requires constant maintenance and adjustment due to sediment accumulation at the facility, as it is located in an area where the river bed is aggrading. The Higginsville system can produce up to 2.5 million gpd and supplies the citizens of Higginsvillle, three other communities, and a rural water district. It also has sufficient excess capacity to meet the needs of new large industrial customers.

Water Supply Wells

The City of Independence, Missouri operates a horizontal collector well that collects water from beneath the Missouri River at RM 353.5. This well produces 6,940 gallons per minute which accounts for a significant percentage of the water provided to the City's customers (Kelly. 2010).

Levees

Only one federal levee unit is located in the Waverly segment. Levee Unit R-351 extends approximately 10.3 miles from RM 350.0 to RM 339.7. The levee protects a large agricultural area located on the right bank (south side) of the river. Levee Unit R-351 protects approximately 8,861 acres of rural agricultural land use, a population of approximately 265, and approximately $15 million in investment (USACE 2010b).

Non-federal levees in the Waverly segment are more common than in all the other segments combined. Over 130 miles of levees in approximately 25 separate units protect over 362,000 acres of primarily agricultural lands, small towns, and farms along the mainstem LOMR (Figure 3.4-2, Sheet 3).

Bank Stabilization and Navigation Project Facilities

The USACE maintains approximately 558 wooden pile and rock rip-rap dikes and approximately 127 miles of rock revetments along the navigation channel in the Waverly segment as part of the BSNP (Figure 3.4-2, Sheet 3). As in other segments, the height of dikes and revetments are maintained by the USACE, as measured against the CRP.

Bridge, Pipeline, and Cable Crossings

Four vehicle bridges and one railroad line cross the Missouri River in the Waverly segment (Table 3.5-14). The highway bridges are operated and maintained by the MoDOT. In 2009, the AADT

volume was 22,313 on Independence Liberty Highway (US 291), 4,579 on Lexington Highway (Route 224), 3,736 on Waverly Highway (US 65), and 2,140 on Miami Highway (Route 41). These numbers show a clear decline in traffic volumes the farther one travels east of Kansas City (MoDOT 2009). The MoDOT has not reported any major scour problems at these bridges.

Table 3.5-14 Bridge Crossings – Waverly Segment

Crossing Name (Route Number)	River Mile
Independence Liberty Highway (US 291)	352.7
Sibley Railroad	336.2
Lexington Highway (Route 224)	317.3
Waverly Highway (US 65)	293.4
Miami Highway (Route 41)	262.2

The BNSF owns and operates the Sibley Railroad Bridge at RM 336.2. No information on the condition of this bridge was available.

Multiple pipeline crossings occur in the Waverly segment (Table 3.5-15). Based on the identified ownership, these pipelines were assumed to be transporting liquid petroleum products. No issues have been reported with these crossings.

Table 3.5-15 Pipeline Crossings – Waverly Segment

Crossing Name	Utility Type	River Mile
Sinclair Refining	Pipeline(s)	333.9
Service Co.	Pipeline	297.8
Amoco	Pipeline(s)	296.0

Wharf and Dock Facilities

Twenty wharf and dock facilities are located in the Waverly segment (Table 3.5-16). These facilities service commerce and recreation. In addition to loading and unloading facilities, boat ramp access is scattered throughout the segment.

Table 3.5-16 Wharf and Dock Facilities – Waverly Segment

Facility Name	Facility Type	River Mile
Missouri Rock Quarry	Unloading dock	345.7
Independence Power Plant	Unloading dock	345.3
Little Blue Recreation Park	Ramp	339.4
Fort Osage	Ramp	337.2
Sibley Power Plant	Coal unloading	336.7
Orrick (Jefferies) Quarry	Rock loading	333.5
U.S. Army Corps of Engineers	Transfer of government materials dock	328.6
M.F.A. Central Co-Op	Grain loading	318.2
Raymond Driver Sand Co.	Sand unloading	317.9
Green Quarries	Sand unloading	317.1
Battle of Lexington State Park	Ramp	316.4
Port of Waverly Recreation Area	Ramp	293.5
Alma Farmers Co-Op Association	Grain loading	293.3
Bartlett and Company, Inc.	Grain loading	293.0
Green Quarries	Sand unloading	286.9
Blue Mound (Green) Quarry	Dock	269.8
Malan Quarry	Dock	263.2
Snake Bluff Recreation Park	Ramp	262.8
Slater Cooperative Association No. 1	Grain loading	262.7
Brunswick River Terminal, Inc.	Bulk fertilizer unloading	256.3

3.5.4.4 Jefferson City Segment

Five dredging sand plants are located in the Jefferson City segment, and three dredging companies are actively mining in the segment. Several miles of river bed in the segment have aggraded as much as 2 feet since 1990. However, just downstream of this aggradation, the dredging locations correlate to a reversal in river bed trends. Downstream of Booneville, the river bed has degraded as much as 4 feet (USACE 2009a).

Water Intake Facilities

Three municipal water intake facilities are located in the Jefferson City segment (Table 3.5-17). The City of Glasgow, the Boonville Public Works Department, and the Missouri-American Water Company rely on these intakes.

Table 3.5-17 Water Intake Facilities – Jefferson City Segment

Facility Name[a]	River Mile
Glasgow Waterworks	226.8
Boonville Water Company	197.5
Jefferson City Water Company	144.0

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

The water intake at RM 226.8 provides water to the small town of Glasgow, Missouri (population 1,199 in 2008). The MDNR reports that the pump capacity at this intake system is 500 gallons per minute (gpm) (720,000 gallons per day) (MDNR 2010).

A similar intake serving the town of Boonville (population 8,770 in 2008) is located at RM 197.5. The intake structure was reconstructed approximately 15 years ago to improve performance and reduce maintenance. There is adequate armoring around the intakes, and no erosion problems are known (Cauthon pers. comm.). The MDNR reports that the pump capacity for this intake system is 20,000 gpm (28,000,000 gallons per day) (MDNR 2010).

The Missouri American Water Company operates an intake system at RM 144.0 that supplies a water treatment plant in Jefferson City. The MDNR reports that the pump capacity for this intake system is 4,875 gpm (7,020,000 gallons per day) (MDNR 2010).

Water Supply Wells

No horizontal collector wells have been identified in the Jefferson City segment.

Levees

Two federal levee units are located in the Jefferson City segment (Table 3.5-18). These levees extend for approximately 22.5 miles along the left bank of the Missouri River from the town of Brunswick on the

Grand River to the town of Glasgow. These levees protect approximately 44,200 acres of agricultural lands, homes, and businesses; a population of approximately 233; and approximately $67 million in investments (USACE 2010b).

Non-federal levees along the LOMR and its major tributaries are distributed throughout the Jefferson City segment. Nearly 100 miles of levees in approximately 25 separate units protect over 91,000 acres of primarily agricultural lands, small towns, and farms along the mainstem LOMR (Figure 3.4-2, Sheet 4).

Table 3.5-18 Levee Units – Jefferson City Segment

Unit Name	River Miles
Levee Unit L-246[a]	250.0–239.0
Levee Unit L-234/Lower Chariton	238.8–227.3

[a] L refers to left descending bank. The number is the river mile at the center point of the levee at the time it was authorized. The river miles do not match up exactly now, because of river cutoffs constructed since the levee was authorized.

Bank Stabilization and Navigation Project Facilities

The USACE maintains approximately 735 wooden pile and rock rip-rap dikes and over 121 miles of rock revetments along the navigation channel in the Jefferson City segment as part of the BSNP (Figure 3.4-2, Sheet 4). As in other segments the height of dikes and revetments are maintained by the USACE, as measured against the CRP.

Bridge, Pipeline, and Cable Crossings

Four vehicle bridges and two railroad lines cross the Missouri River within the Jefferson City segment (Table 3.5-19). The highway bridges are operated and maintained by the MoDOT. In 2009, the AADT volume was approximately 1,149 on the Glasgow Highway (Route 240), 6,670 on the Boonville Highway (Routes 5 and 87), 31,421 on the Rocheport Highway (Interstate 70), and 29,832 on the Jefferson City Highway (US 63 and US 54) (MoDOT 2009). The MoDOT has reported that Jefferson City Highway (US 63 and US 54) is currently being monitored for scour problems (Stotlemeyer pers. comm.).

The M.K.T. railroad bridge located at RM 197.1 crosses the Missouri River near the town of Boonville. This bridge is no longer in operation, and the movable span has been left in the elevated, non-passable

position. The Chicago, Missouri & Western Railroad located at RM 226.3 crosses the river in the town of Glasgow. No information on the condition of these bridges was available.

Table 3.5-19 Bridge Crossings – Jefferson City Segment

Crossing Name (Route Number)	River Mile
Chicago, Missouri & Western Railroad	226.3
Glasgow Highway (Route 240)	226.3
M.K.T. Railroad	197.1
Boonville Highway (Routes 5 and 87)	196.6
Rocheport Highway (Interstate 70)	185.0
Jefferson City Highway (US 63 and US 54)	143.9

There are eight pipeline crossings and three cable crossings in the Jefferson City segment (Table 3.5-20). One of the cable crossings is operated by Missouri River Light and Power, and another by Columbia Power. The third cable crossing is an AT&T communication line. Panhandle Eastern maintains two pipeline crossings near Boonville (RM 198.3 and RM 199.3). Currently, the pipelines are buried and threatened only by potential flooding. Pipelines are inspected by divers every 3 years (Howard pers. comm.). Divers investigate river channel bottoms along pipeline alignments to determine whether pipelines are exposed. If pipelines are exposed, they are also inspected for signs of damage.

Wharf and Dock Facilities

There are 25 wharf and dock facilities in the Jefferson City segment (Table 3.5-21). These facilities serve commerce and recreation. In addition to loading and unloading facilities, boat ramp access is scattered throughout the segment.

Table 3.5-20 Pipeline and Cable Crossings – Jefferson City Segment

Crossing Name	Utility Type	River Mile
Sinclair Refining	Pipeline	242.5
Panhandle Eastern	Pipeline	199.3
Panhandle Eastern	Pipeline	198.3
Panhandle Eastern	Pipeline	197.4
AT&T	Cable	186.5
Columbia Power	Cable	182.2
Texas Empire	Pipeline	175.2
Williams Brothers	Pipeline	174.6
Texas Empire	Pipeline	174.5
Missouri River Light and Power	Cable	143.8
City of Jefferson City Sewer	Pipeline	143.5

Table 3.5-21 Wharf and Dock Facilities – Jefferson City Segment

Facility Name	Facility Type	River Mile
Franklin (Woods) Quarry	Dock	245.1
Glasgow Co-Op Association	Grain loading	226.4
U.S. Army Corps of Engineers	Loading platform	226.4
Capitol Sand Co.	Sand and gravel unloading dock	226.2
Stump Island Recreation Park	Ramp	226.1
Glasgow Quarries	Rock loading dock	219.0
Sites Quarry	Dock	207.0
Missouri River Sand and Gravel Co.	Sand and gravel unloading dock	197.0
Interstate Marine Terminal	Fertilizer, grain, and molasses	196.4
Howard-Cooper Co. Port Authority	Loading and unloading dock	196.4
Franklin Island Access	Ramp	195.5
Columbia (Missouri River) Sand Co.	Sand and gravel unloading dock	186.3
George Russell Quarry	Dock	185.6
Taylors Landing Recreation Park	Ramp	185.1
Capitol Sand Co.	Sand and gravel unloading dock	181.6
Hunts Quarry	Dock	181.5

Table 3.5-21 Wharf and Dock Facilities – Jefferson City Segment

Facility Name	Facility Type	River Mile
Murrell Quarry	Dock	177.1
Sandy Hook Quarry	Dock	164.2
Wilton Boat Club	Ramp	161.0
Marion Access	Ramp	158.0
Marion Quarry	Dock	157.6
Amoco Oil Co.	Unloading dock	148.7
U.S. Army Corps of Engineers	Transfer of government materials dock	143.6
Jefferson City River Terminal Co.	Loading and unloading dock	143.3
Capitol Sand Co.	Sand and gravel unloading dock	143.2

3.5.4.5 St. Charles Segment

Eight dredging sand plants are located in this segment, and five dredging companies are actively mining. River bed degradation for the entire segment has ranged from 2 to 5 feet since 1990, and the greatest degradation is near the most intense dredging for gravel extraction (USACE 2009b).

Water Intake Facilities

Nine water intake facilities are located in this segment (Table 3.5-22). The St. Charles segment services a highly urbanized portion of the LOMR. Three intake facilities provide cooling and process water for power plants, while the remainder serve as municipal water supply intakes. The City of St. Louis Water Division, the Ameren Callaway Nuclear Power Plant, the Ameren Labadie Power Plant, and the Central Electric Power Cooperative rely on these intake facilities.

Intake Systems for Power Plant Cooling and Process Water

The water intake structure at RM 117.0 provides cooling and process water to the Chamois Power Plant owned and operated by the Central Electric Power Cooperative, headquartered in Jefferson City, Missouri. The electric generation and transmission cooperative and is an independent, locally-owned business. The 68-MW Chamois Power Plant is coal-based and delivers power to eight distribution cooperatives covering a 22,000-square-mile area in central Missouri.

Table 3.5-22 Water Intake Facilities – St. Charles Segment

Facility Name[a]	River Mile
Chamois Power Plant	117.0
Callaway Power Plant	115.4
Labadie Power Plant	57.7
City of St. Louis Waterworks[b]	37.0
St. Louis County Waterworks	36.3
St. Louis County Waterworks	36.2
St. Louis County Waterworks	20.5
St. Louis County Water Dept.	20.2

[a] Names of water intake facilities were obtained from the Missouri River Navigation Charts and may not correspond to the current facility name or operating utility.

[b] This is the Howard Bend Plant which is capable of pumping 236 Million gallons per day and is protected from flooding by a flood wall.

The water intake facility at RM 115.4 provides cooling and process water to the Callaway Nuclear Generating Station located near Fulton, Missouri. The Callaway plant has generating capacity of 1,190 MW and is owned and operated by AmerenUE (AmerenUE 2010). According to the MDNR, the pumping capacity at the intake facility is 42,000 gpm (MDNR 2010).

AmerenUE also owns and operates the Labadie Power Station that withdraws cooling and process water from an intake facility located at RM 57.7. The Labadie coal-fired plant is capable of generating 2,389 MW of electricity (AmerenUE 2010). According to the MDNR, the pumping capacity at the intake facility is 1,021,064 gpm (MDNR 2010).

AmerenUE is Missouri's largest electric utility and provides electric service to approximately 1.2 million customers across central and eastern Missouri, including the greater St. Louis area. AmerenUE serves 57 Missouri counties and 500 towns; more than one-half (55 percent) of AmerenUE's electric customers are located in the St. Louis metropolitan area (AmerenUE 2010).

Intake Systems for Public Water Supply

Six additional water intakes located between RM 37.0 and RM 20.2 supply drinking water to more than 1 million people, including business and industry, within the greater St. Louis metropolitan area.

Water Supply Wells

No horizontal collector wells have been identified in the St. Charles segment.

Levees

One small federal levee (New Haven) is located on the right bank of the Missouri River in the St. Charles segment, between RM 81.7 and RM 81.4 in the town of New Haven. The levee protects 15 acres, 15 residents, and nearly $11 million in investment.

An extensive network of non-federal levees is located along this segment, extending from approximately RM 130 to RM 55. Nearly 90 miles of levees in approximately 20 separate units protect approximately 58,000 acres of primarily agricultural lands, small towns, and farms along the mainstem LOMR (Figure 3.4-2, Sheet 5). Additional non-federal levees are located between RM 55 and RM 0, but detailed information on these levees was not available.

Bank Stabilization and Navigation Project Facilities

The USACE maintains approximately 729 wooden pile and rock rip-rap dikes and over 129 miles of rock revetments along the navigation channel in the St. Charles segment as part of the BSNP (Figure 3.4-2, Sheet 5). As in other segments the height of dikes and revetments are maintained by the USACE, as measured against the CRP.

Bridge, Pipeline, and Cable Crossings

There are nine bridges crossing on the Missouri River in the St. Charles segment, seven highway crossings, and two railroad line crossings (Table 3.5-23). The MoDOT reports that the bridges in this segment have deep foundations secured to competent material. No information was available on the condition of the railroad bridges. Traffic volumes on the highway bridges range from approximately 5,325 AADT at the Hermann Highway Bridge crossing (Route 19) at RM 97.9 to approximately 166,242 AADT at the Interstate 70 crossing at RM 29.6 (MoDOT 2009).

There are seven pipeline crossings and three cable crossings in the St. Charles segment (Table 3.5-24). One of the cable crossings is operated by Union Electric Company and another by Central Electric Power. The third cable crossing is an AT&T communication line.

Table 3.5-23 Bridge Crossings – St. Charles Segment

Crossing Name (Route Number)	River Mile
Bellefontaine Highway (US 67)	8.1
Burlington Northern Inc. Railroad	8.2
Proposed New Highway (MO 115)	27.0
Norfolk & Southern Railroad	27.1
St. Charles Highway (MO 115)	28.2
Interstate 70 & US 40	29.6
Weldon Springs Highway (US 40 & 61)	43.9
Washington Highway (Route 47)	67.6
Hermann Highway (MO 19)	97.9

Table 3.5-24 Pipeline and Cable Crossings – St. Charles Segment

Crossing Name	Utility Type	River Mile
Laclede Gas Co.	Pipeline	8.0
Union Electric Co.	Cable	19.6
AT&T	Cable	26.5
St. Peters Water	Pipeline	34.5
Shell	Pipeline	44.2
Shell	Pipeline	44.5
Explorer	Pipeline	54.4
Ajax	Pipeline	66.0
Gulf Central	Pipeline	101.1
Central Electric Power	Cable	113.9

Wharf and Dock Facilities

There are 31 wharf and dock facilities in the St. Charles segment (Table 3.5-25). These facilities service commerce and recreation. In addition to loading and unloading facilities, boat ramp access is scattered throughout the segment. The segment is served by one marina (Olympic Marina and Harbor Services).

Table 3.5-25 Wharf and Dock Facilities – St. Charles Segment

Facility Name	Facility Type	River Mile
Central Stone Company	Loading dock	7.8
West Lake Quarry Material Co., Inc.	Rock loading, sand and gravel unloading	8.4
Masker Marine Railway	Dock	8.6
Sioux Passage Park	Ramp	10.4
Riverview Sand and Dredging Co.	Rock loading, sand and unloading	16.7
Tiemann Boat Ramp	Ramp	18.3
Blanchette Access	Ramp	27.2
St. Charles Sand Co.	Sand and gravel unloading dock	27.8
St. Charles Sand Co.	Sand, salt and lightweight materials unloading	28.1
Frontier Park	Ramp	28.5
St. Charles Quarry Co.	Rock loading, sand and gravel unloading	31.3
St. Charles Sand Co.	Sand and gravel unloading dock	43.9
Hamberg Quarry	Dock	47.3
Weldon Spring Access	Ramp	48.4
Daniel Boone Access Area	Ramp	55.5
Berg (Matson) Quarry	Dock & Ramp	56.2
Washington Sand Co.	Sand and gravel unloading dock	68.1
Washington Public Boat Ramp	Ramp	68.2
Washington Boat Club	Ramp	68.3
Olympic Marina and Harbor Services	Gas and oil	68.6
New Haven	Ramp	81.5
Maczuk Industries, Inc.	Loading dock	81.7
Meyer Quarry	Dock	85.4
Hermann Sand and Gravel, Inc.	Sand unloading	96.9
U.S. Army Corps of Engineers	Dock, harbor, and boatyard	104.4
Two Rivers Sand and Gravel	Dock	114.1
Chamois Power Plant	Coal unloading	117.1
Chamois Access Area	Ramp	118.0
Callaway County Sand Co.	Sand and gravel unloading dock	124.5
Mokane Access Area	Ramp	124.7
Massaman Quarry	Dock	126.2

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3.6 NAVIGATION AND TRANSPORTATION

3.6.1 Introduction

This section describes the affected environment associated with navigation and transportation along approximately 500 miles of the LOMR from Rulo, Nebraska (RM 498) to St. Louis, Missouri. The focus is on the existing navigation and surface transportation resources, including riverborne commerce and commercial dredging operations that may be affected by the Proposed Action and alternatives. A summary of management and operation of the Missouri River system by the USACE for navigation and other congressionally authorized purposes provides the context within which navigation occurs on the LOMR. The regulatory setting provides regulations applicable to navigation and transportation and the agencies with jurisdiction in the Project area.

Changes in the production of commercial sand and gravel resulting from changes in permitted dredging under the Proposed Action and alternatives could affect navigation and riverborne commerce and traffic and transportation patterns. Sand and gravel produced from dredging in the LOMR dominates the navigation and riverborne commerce on the river (on a tonnage and barge trip basis). Therefore, changes in production of these commodities could affect not only the barge traffic associated with commercial dredging but also recreational and other commerce-related vessels. Furthermore, because sand and gravel are trucked from onshore sand plants to their market destinations, any significant change in the volume of this material sourced from the river would affect the number of trucks and truck trips on the major transportation corridors.

The existing navigation and surface transportation resources described in the section and the regulatory setting were used as a baseline to evaluate the potential impacts of the Proposed Action and alternatives.

Information used in the preparation of this section came from a variety of sources, including the USACE, roadway maps of the Project area, and aerial photos.

3.6.2 Regulatory Setting

This section describes regulations pertaining to navigation and transportation, as well as agencies that may be responsible for these resources, in the areas that could be affected by the Proposed Action and alternatives.

3.6.2.1 Federal

U.S. Coast Guard

The U. S. Coast Guard (USCG) is one of the five armed forces of the United States. The USCG protects the maritime economy and the environment, and defends the maritime borders of the United States.

The USCG Sector Commander Upper Mississippi is responsible for safety of navigation, security, and law enforcement along the Missouri River. The USCG Sector Upper Mississippi River Prevention Department is responsible for maintaining and setting buoys and shore aids along the Missouri River. The Prevention Department also focuses on licensed mariner issues, permits, casualty investigations, and security verifications. The USCG Sector Upper Mississippi River Response Department uses USCG small boats, other law enforcement partnerships, and first responders to patrol and respond to emergencies and incidents on the Missouri River.

The USCG District Commander, Eighth Coast Guard District, has administrative supervision over reaches of the Missouri River within the limits of the district and is responsible for enforcement of emergency regulations to govern navigation on the river. During critical flood stages on the river, when lives, major shore installations, or levees are endangered, the District Commander in charge of the locality has the authority to declare the reach of the river closed to navigation or to prescribe temporary speed regulations if necessary to prevent immediate human suffering or to mitigate major property damage or destruction from wave action.

U.S. Army Corps of Engineers

Operation and maintenance (O&M) of the BSNP is managed by two USACE Districts. The river from Rulo to the mouth is managed by the Kansas City District, which has a river field office at Napoleon Missouri. The river from Sioux City Iowa to Rulo is managed by the Omaha District, which has a river field office immediately upstream of Omaha. These districts have water management functions for regulation of tributary dams in the Missouri River basin. The Northwestern Division has water management responsibilities for the Missouri River Mainstem System and coordinating responsibilities for tributary reservoir regulation.

Waterways Action Plan

The Waterways Action Plan (WAP) provides general information and target gauges to be used as a guideline for a crisis on the waterways in the Mississippi River basin. The WAP is intended to serve as

a guide for officials of the USCG, the USACE, and the marine industry to facilitate the safe and orderly movement of traffic during a navigational crisis, while minimizing the loss of life and damage to the environment and equipment. This is achieved by comprehensive contingency planning for response actions that addresses all extreme river conditions—high water, high velocity, low water, and ice conditions—on the major inland rivers of the United States and their tributaries, as well as how to respond at the different response phases.

The annexes of the WAP (i.e., the Upper Mississippi River, Illinois River, and Missouri River annexes) break down these response actions by geographic segments of the inland rivers and apply trigger points and recommended actions for each phase of response. The WAP and its annexes are reviewed annually by the USCG, the USACE, and river industry representatives (i.e., the River Industry Action Committee and the Missouri River Action Committee).

River and Harbors Appropriation Act of 1899

Section 10 of the River and Harbors Appropriation Act (RHA) requires authorization from the Secretary of the Army, acting through the USACE, for construction of any structure in, under, or over any navigable water of the United States. Structures or work outside the limits defined for navigable waters of the United States require a Section 10 permit if the structure or work would affect the course, location, or condition of the water body. The law applies to any dredging or disposal of dredged materials, excavation, filling, re-channelization, or any other modification of a navigable water of the United States. It applies to all structures, from the smallest floating dock to the largest commercial undertaking. It further includes, without limitation, any wharf; dolphin; weir; boom breakwater; jetty; groin; bank protection (e.g., riprap, revetment, and bulkhead); mooring structures such as pilings; aerial or sub-aqueous power transmission lines; intake or outfall pipes; permanently moored floating vessel, tunnel, artificial canal, boat ramp, and aids to navigation; and any other permanent or semi-permanent obstacle or obstruction.

Federal Highway Administration

The Federal Highway Administration (FHWA) is a division of the U.S. Department of Transportation that specializes in highway transportation. The agency's primary activities are grouped into the Federal-Aid Highway Program and the Federal Lands Highway Program. The role of the FHWA in the Federal-Aid Highway Program is to oversee federal funds used for constructing and maintaining the national highway system (primarily interstate highways, U.S. routes, and most state routes). The FHWA oversees projects using these funds to ensure adherence to federal requirements for project eligibility,

contract administration, and construction standards. Under the Federal Lands Highway Program, the FHWA provides highway design and construction services for various federal land management agencies, such as the U.S. Department of Agriculture (USDA) Forest Service and the National Park Service (NPS). In addition to these programs, the FHWA performs research in the areas of automobile safety, congestion, highway materials, and construction methods.

U.S. Department of Transportation Marine Highway Program

In April 2010, the U.S. Department of Transportation implemented the Marine Highway Program (website: http://edocket.access.gpo.gov/2010/pdf/2010-7899.pdf). The Marine Highway Program is a grant program administered by the Maritime Administration that identifies major marine corridors within the U.S. where water transportation presents an opportunity to offer relief to landside corridors that suffer from traffic congestion, excessive air emissions or other environmental concerns and other challenges. Designation as a marine corridor makes the corridor eligible for special federal funding that would provide port improvements for shippers along the identified marine corridors (USDOT 2010). A large portion of the M-70 corridor includes the Missouri River from Kansas City to St. Louis. The M-70 Corridor includes the Ohio, Mississippi, and Missouri Rivers, and connecting commercial navigation channels, ports, and harbors, from Pittsburgh to Kansas City. It is named the M-70 marine corridor because it would potentially reduce freight truck congestion on Interstate 70 (MoDOT 2010).

3.6.2.2 State

Nebraska Department of Roads

The Nebraska Department of Roads (NDOR) is responsible for building and maintaining the state and federal highways in the state of Nebraska. Eight NDOR district offices are located across the state. That portion of the Project area located in Nebraska falls within District 1 of the NDOR.

Illinois Department of Transportation

The Illinois Department of Transportation (IDOT) has responsibility for planning, construction, and maintenance of the Illinois transportation network, which encompasses highways and bridges, airports, public transit, rail freight, and rail passenger systems.

Kansas Department of Transportation

The Kansas Department of Transportation (KDOT) is responsible for road and bridge maintenance, transportation planning, contract compliance, and transportation-related administrative support for the state of Kansas.

Missouri Department of Transportation

The Missouri Department of Transpiration (MoDOT) is headquartered in Jefferson City and has functional control over 10 geographical transportation districts. Each district contains approximately 10 percent of the total road mileage in the state highway system. Each district is under the direction of a district engineer, who is responsible for administering all department activities in the region. The Project area falls within six of these districts: Northwest (District 1), North Central (District 2), Northeast (District 3), Kansas City Area (District 4), Central (District 5), and St. Louis Area (District 6).

The MoDOT is responsible for five major transportation alternatives in the state, including highways, aviation, waterways, public transit, and railroads. Those responsibilities include total operation of the 32,000-mile highway system, including highway location, design, construction, and maintenance. Additionally, MoDOT cooperates and coordinates with owners and operators of the four other modal systems in the development and improvement of airports, rail facilities, and ports and the operational cost of transit systems.

3.6.3 Navigation on the Lower Missouri River

3.6.3.1 Bank Stabilization and Navigation Project

For the purposes of this analysis, navigation on the LOMR consists primarily of the transport of freight and raw materials via barges. Navigation on the LOMR is made possible by the navigational channel created by the BSNP (see Sections 3.2 and 3.4). As described in Section 3.2, the primary goal of the BSNP was to provide a continuous open-river navigation channel, 9 feet deep and 300 feet wide, from Sioux City, Iowa to the Mississippi River.

Maintenance of the BSNP continues in response to weathering and subsequent removal of rock from the tops of the dikes and revetments, and new structures occasionally built in response to changes in channel configuration. In general, the maintenance program is focused on maintaining the dikes at their design elevations based on the CRP (USACE 2009). See Section 3.4 for a more in-depth discussion of the CRP. Maintenance also requires reservoir releases and infrequent dredging activities

by the USACE, particularly during periods of below-normal water supply (USACE 2006a). Maintenance dredging has been done on occasion during drought periods, mostly in downstream reaches (USACE 2008). During the 12-year period from 1994 to 2006, two dredging projects were conducted by the USACE that resulted in removal of 111,333 cubic yards of dredged material from a shallow location in the channel to an in-river disposal area within 500 feet of the dredged site (GAO 2009). Generally speaking, commercial dredging is not required for maintenance of the navigation channel because the dikes and revetments prevent bed material load from settling out and creating shoals (USACE 2008).

3.6.3.2 Management of Navigation on the Lower Missouri River

Water levels on the Missouri River are partially regulated by the USACE through controlled releases from six dams and associated reservoirs that comprise the Missouri River Mainstem Reservoir System (System). The System is congressionally authorized (Section 9 of the 1944 Flood Control Act) to be operated for the purposes of navigation as well as flood control, irrigation, power, water supply, water quality control, recreation, and fish and wildlife.

The USACE manages the System according to the water control plan of the Master Manual (USACE 2006a). The Master Manual provides criteria for releases from System storage for flood control, navigation service, and non-navigation service. Each criterion relates to the amount of water in System storage.

Releasing water from the System to augment downstream tributary flows provides navigation support on the Missouri River below Sioux City. Navigation conditions on the LOMR are governed in part by controlled releases from Gavins Point Dam, the farthest downstream of the six System dams. It is located on the Nebraska-South Dakota border, and its primary function is reregulating releases from the upper System dams. Gavins Point Dam releases provide most of the water at Sioux City because there is minimal inflow to the river between the dam and Sioux City. At Kansas City, System flows are augmented by major tributaries, including the Kansas and Platte Rivers.

Navigation Season

Navigation season length and service levels are determined by moisture conditions in the basin. During periods of drought, storage of water in the System is limited. The navigation season may be shortened, and navigation service reduced due to reductions in water releases.

On March 15 of every year, a water-in-storage check of the System is performed to determine whether navigation flows will be supported for that year, and if so, whether flows will be for full service or

minimum service. On July 1 of every year, a second water-in-storage check of the System is performed to determine the length of the navigation season. The navigation season is limited to the ice-free season, based on historical records of ice formation on the Missouri River (Table 3.6-1).

Table 3.6-1 Navigation Season Schedule on the Missouri River

Location	Opening Date	Closing Date
Sioux City, Nebraska	March	November
Omaha, Nebraska	March	November
Kansas City, Missouri	March	November
Missouri River mouth	April	December

Source: USACE 2006a.

In years when the System water-in-storage is at or below 31 million acre-feet on March 15, navigation support is suspended (USACE 2006a); however, no condition in the current commercial dredging permits suspends dredging under these same conditions. When water levels are low, commercial dredgers may need to dredge closer to their sand plants and use their dredges to maintain adequate depths for the dredge barges. Commercial dredging generally occurs year-round when the wind chill is above freezing.

Releases from the System to support full-service or minimum-service navigation are based on flow target values at four downstream locations on the Missouri River: Sioux City, Omaha, Nebraska City, and Kansas City. The minimum-service level provides an 8-foot depth in the navigation channel, and the full-service level (6,000 cfs greater than minimum service) provides a 9-foot depth. For full navigation service, target flows of 31,000 cfs are set at Sioux City and Omaha, 37,000 cfs at Nebraska City, and 41,000 cfs at Kansas City (USACE 2006a). For minimum navigation service, target flows of 25,000 cfs are set at Sioux City and Omaha, 31,000 cfs at Nebraska City, and 35,000 cfs at Kansas City (USACE 2006a).

Low Flows in the Missouri River

In general, water level is the major factor affecting commercial barge operations on the Missouri River (TranSystems and MoDOT 2008). As described above, water levels on the Missouri River are regulated via the CWCP. During periods of drought, the commercial barge transport season is shortened or not supported Recent investigations have indicated that the most common practice on

U.S. inland waterway systems, including the Missouri River, for accommodating freight barge traffic during low-flow conditions is barge light loading (TranSystems and MoDOT 2008). Barge light loading is the practice of loading a barge only to the point where the resulting loaded draft of the barge will safely navigate the applicable river draft.

3.6.4 Riverborne Commerce

Iowa, Nebraska, Kansas, and Missouri border the Missouri River and are served by barge traffic along the river. Freight traffic commodities transported on the Missouri River by private companies include various types of agricultural products; chemicals and fertilizers; petroleum products; building materials; and river-related materials such as rock, sand, and gravel dredged from the river (Table 3.6-2). In addition, the USACE implements river maintenance and habitat recovery projects that require shipment of waterway improvement materials, such as stone or rock (GAO 2009).

Commodity shipment data (Table 3.6-2) were obtained from the USACE Waterborne Commerce Statistics Center. Commodity data were not available for each of the five river segments (St. Joseph, Kansas City, Waverly, Jefferson City, and St. Charles) but are presented for the following two segments of the Missouri River: from the mouth of the river to Kansas City (RM 0 – RM 374.8) and from Kansas City to Omaha (RM 374.8 – RM 627). The majority of commodity shipments on the Missouri River are sand and gravel dredged from the river, and the segment of the Missouri River from the mouth to Kansas City accounts for the majority of commodity movement. Between 1997 and 2007, sand and gravel accounted for nearly 87 percent (approximately 76.1 million short tons)[1] of the total tonnage shipped on the Missouri River between the mouth and Kansas City, and nearly 80 percent (approximately 14 million short tons) of the total tonnage shipped between Omaha, Nebraska, and Kansas City, Missouri.

In general, the cargo volume is currently higher than the period from 1960 to 1990 due to expansion of local cargo, primarily sand and gravel (TranSystems and MoDOT 2008). Investigations have shown that outbound cargo has declined relative to earlier decades due to a variety of factors, including competition for grain shipments from other locations, drought periods, and poor service reliability (TranSystems and MoDOT 2008). In the 10-year period from 1997 to 2007, total annual commercial shipments on the river peaked in 2001 and declined to approximately 7.6 million short tons in 2007, the lowest annual commodity volume for that 10-year period (Table 3.6-2). This period covered the 8-year drought period (1999–2007).

[1] Measurements for tons in this section represent short tons.

Table 3.6-2 Commodity Shipment Data (tons)

Commodity	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Kansas City to Mouth (RM 374.8 to RM 0)											
Petroleum products	289	239	278	256	217	173	213	216	180	81	132
Chemicals and related products	516	462	336	289	334	246	118	48	7	14	8
Sand and gravel	5,969	6,104	7,155	6,844	7,985	6,763	7,095	7,317	7,242	7,679	5,983
Waterway improvement materials	194	91	133	153	22	112	5	60	82	57	101
Crude materials (except sand, gravel, and waterway improvement materials)	39	45	66	34	30	17	5	0	0	0	2
Primary manufactured goods	185	235	156	233	198	202	206	221	88	67	130
Food and farm products	589	704	727	530	508	388	128	41	10	34	28
Manufactured equipment, machinery, and products	1	3	3	1	0	0	0	0	0	1	3
Subtotal	*7,782*	*7,883*	*8,854*	*8,340*	*9,294*	*7,901*	*7,770*	*7,903*	*7,609*	*7,933*	*6,387*
Omaha to Kansas City (RM 627 to RM 374.8)											
Petroleum products	77	82	81	58	12	42	18	56	10	0	0
Chemicals and related products	313	212	146	167	193	123	39	7	3	2	2
Sand and gravel	663	1,393	954	1,248	923	1,172	1,068	1,976	1,880	1,663	1,221
Waterway improvement materials	13	81	10	12	10	0	0	0	29	0	0
Clay and non-metal minerals	27	29	30	19	16	8	0	0	0	0	0
Primary manufactured goods	5	62	24	26	7	67	2	0	0	0	0
Food and farm products	278	407	420	270	250	142	68	2	0	21	28
Manufactured equipment, machinery, and products	0	2	1	1	0	0	0	0	0	1	0
Subtotal	*1,376*	*2,268*	*1,666*	*1,801*	*1,801*	*1,411*	*1,195*	*2,041*	*1,922*	*1,687*	*1,251*
Total (mouth to Omaha)	9,158	10,151	10,520	10,141	10,705	9,455	8,965	9,944	9,531	9,620	7,638

Notes: • Measurements of tons represent short tons. • The 8-year period of 1999–2007 was a period of drought.

Sources: USACE 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006b, 2007.

Commercial shipments, including sand and gravel, move throughout the navigation season but tend to peak in spring and fall (USACE 2006b). Missouri is an origin or destination for more than one-half of commercial shipments on the Missouri River; the Port of Kansas City serves as an origin or destination for approximately one-third to one-half of Missouri River commercial tonnage (USACE 2006b).

3.6.4.1 Dredging Barges and Tugs

Barge and tug traffic on the LOMR is primarily related to commercial dredging and generally is limited to areas on the river within 7−10 miles upstream of the onshore sand plants. This range is dictated by travel times to move loaded barges downstream and return empty barges upstream, and by associated fuel costs. Operation is typically from March through December, 10−12 hours per day, 5−6 days per week. Information provided by the commercial Dredgers indicates that, during this period, up to 18 barges and 11 tugs may be present in the St. Charles segment (RM 0 – RM 130), six barges and two tugs in the Jefferson City segment (RM 130 – RM 250), four barges and one tug in the Waverly segment (RM 250 – RM 357), 11 barges and four tugs in the Kansas City segment (RM 357 – RM 391), and two barges and one tug in the St. Joseph segment (RM 391 – RM 498). A description of dredging activities and the associated movement of barges and tugs from dredging sites to sand plants and back is provided in Section 2.2.

3.6.4.2 Commerce-Related Vessels

On the Missouri River, commodities are transported by barges pushed by towboats, with a towboat and barge combination called a “tow.” Tow size varies by reach, barge size, and product. Typical tow sizes for dry bulk products, including grains and most fertilizers, are four to six barges per tow below Kansas City and two to four barges per tow between Omaha and Kansas City; liquids and other specialized products typically are transported by two barges per tow (USACE 1998). Average annual commerce-related vessel trips on the LOMR are provided in Table 3.6-3.

Table 3.6-3 Average Annual Commerce-Related Navigation Traffic on the Lower Missouri River (2003–2007)

Segment	Trips		
	Self-Propelled Vessels[a] (Dry Cargo Vessels, Tow and Tug Boats)	Non-Self-Propelled Vessels[a] (Dry Cargo and Tanker Barges)	Total (All Vessel Trips)
Kansas City to mouth (RM 374.8 to RM 0)	83,502	24,098	107,600
Omaha to Kansas City (RM 627 to RM 374.8)	4,748	4,084	9,552
Total (mouth to Omaha)	88,250	28,902	117,152

[a] Commercial tug and barge traffic is included.

Sources: USACE 2003, 2004, 2005, 2006b, 2007.

Trip data were not available for each of the five river segments but are presented for the following two segments of the Missouri River: from the mouth of the river to Kansas City (RM 0 – RM 374.8), and from Kansas City to Omaha (RM 374.8 – RM 627). A "trip" is defined as a vessel movement. For self-propelled vessels, a trip is logged between every point of departure and every point of arrival. For loaded barges, a trip is logged from the point of loading the barge to the point of unloading the barge (excluding fleeting areas). For empty barges, trips are logged from the point of unloading to the point of loading, counting the fleeting areas in between (for example, if an empty barge moved from Dock A to Dock B and the barge stopped at three fleeting areas in between, four trips would be logged). Some tow boat trips and empty barge moves are estimated from a sample to expedite processing and reduce costs. The number of trips also includes vessels engaged in foreign trade.

Depending on the product (e.g., grain, liquid chemical, and mineral products), covered, open, and tank barges are used to transport commodities on the river (USACE 1998). The covered barge fleet has declined in the past few years and is more than 800 units smaller than it was in 2004 (TranSystems and MoDOT 2008). High rates of retirements in the open and tank barge fleets are due to an aging fleet; the average operating life for open and tank barges is 25−30 years and 30−40 years, respectively (TranSystems and MoDOT 2008). In general, smaller commercial vessels are more common on the river. The small tank barge (10,000 barrels or less) fleet has increased somewhat in recent years, but the jumbo barge (greater than 10,000 barrels) fleet has decreased due to fewer deliveries (TranSystems and MoDOT 2008).

3.6.4.3 Other Vessels

There are no ferries operating on the LOMR in the Project area (MoDOT 2009). Other navigation in the Project area is limited to seasonal recreational watercraft, such as motor boats, canoes, and kayaks.

3.6.5 Surface Transportation

This section describes the regional roadway transportation system that provides for transportation of bulk materials near the sand plants in the Project area or has the potential to be affected by the Proposed Action and the alternatives. Because sand and gravel are trucked from onshore sand plants to their market destinations, any significant change in the volume of this material sourced from the river would affect the number of trucks and truck trips on the major transportation corridors. The estimated annual sand and gravel haul truck trips under existing conditions is presented in Table 3.6-4. Truck trips are based on the annual production capacity of each facility.

In general, each onshore processing facility serves a localized market that is within a 20- to 60-mile radius of the sand plant. Given the proximity of most of the commercial sand plants to major urban areas and points of delivery, haul routes for sand and gravel transport do not typically include rural roads in the Project area. The areas in the vicinity of the sand plants contain an extensive network of roadways, including state and interstate highways and secondary and municipal roads. All sand shipped from the permitted dredging operations occurs by truck. Sand plants have direct access to the state and interstate highway system for sand and gravel transport to places of use and distributor facilities.

The range of average daily traffic (ADT) values for these transportation corridors is provided in Table 3.6-5. The ADT is the mean daily traffic volume on a roadway over a 24-hour period. As indicated in the table, the sources for the data are ADT maps published by the KDOT, MoDOT, and IDOT. ADT counts are taken at multiple locations along a road, and each of these counts is indicated on the ADT map for the respective state. The ranges for the road types indicated in Table 3.6-5 show the low and high ADT values for sections of the transportation corridors within each of the five river segments shown in Figure 3.6-1 (Sheets 1–5).

Table 3.6-4 Estimated Annual Haul Truck Trips under Existing Conditions by River Segment

Segment	Facility Name (Company)	River Mile	Annual Tons Delivered	Estimated Tons Delivered per Day[b]	Trips per Day
St. Joseph	St. Joseph (Holliday)	447.8	326,928	1,514	151
	Total		326,928	1,514	151
Kansas City	Riverside (Holliday)	372	1,450,773	6,717	672
	Randolph (Holliday)	360	1,516,925	7,023	630
	Total		2,967,698	13,739	1,374
Waverly	Lexington (Capital SL)	318	346,202	1,603	160
	Carrollton (Capital SL)	287	22,918	106	11
	Total		369,120	1,709	171
Jefferson City	Glasgow (Capital SL)	226	136,273	631	63
	Boonville (Capital SL)	196	11,338	52	5
	Rocheport (Capital SL)	186	272,709	1,263	126
	Jefferson City (Herman)	146	64,861	300	30
	Jefferson City (Capital SL)	144	1,093,679	5,063	506
	Total		1,578,858	7,310	731
St. Charles	Hermann (Hermann)	97	61,097	283	28
	Washington (Rau)[a]	68	NA	NA	NA
	Washington (Capital SL)	66	136,463	632	63
	Bridgeton (Limited)	44	288,607	1,336	134
	St. Charles (J.T.R.)	32	402,245	1,862	186
	Chesterfield (Limited)	28	535,985	2,481	248
	Riverview (J.T.R.)	16	60,011	278	28
	Fort Belle (Limited)	8	82,459	382	38
	Alton (Limited)[c]	NA	82,459	382	38
	Total		1,649,326	7,636	764

[a] No existing facility.

[b] Assumes average truck capacity of 20 tons and 216 delivery days per year.

[c] The Alton facility is located on the Mississippi River.

Table 3.6-5 Average Daily Traffic Volume Ranges for Major Transportation Corridors in the Project Area

Segment	Interstate	State Route	U.S. Highway
St. Joseph	4,718–40,031	447–26,328	1,168–24,690
Kansas City	14,435–135,239	3,225–38,010	10,616–88,265
Waverly	18,288–24,702	228–17,506	1,792–16,666
Jefferson City	21,679–36,330	127–15,010	8,096–49,468
St. Charles	28,871–182,064	630–78,422	16,853–129,520

Sources: IDOT 2007, KDOT 2010, MoDOT 2008.

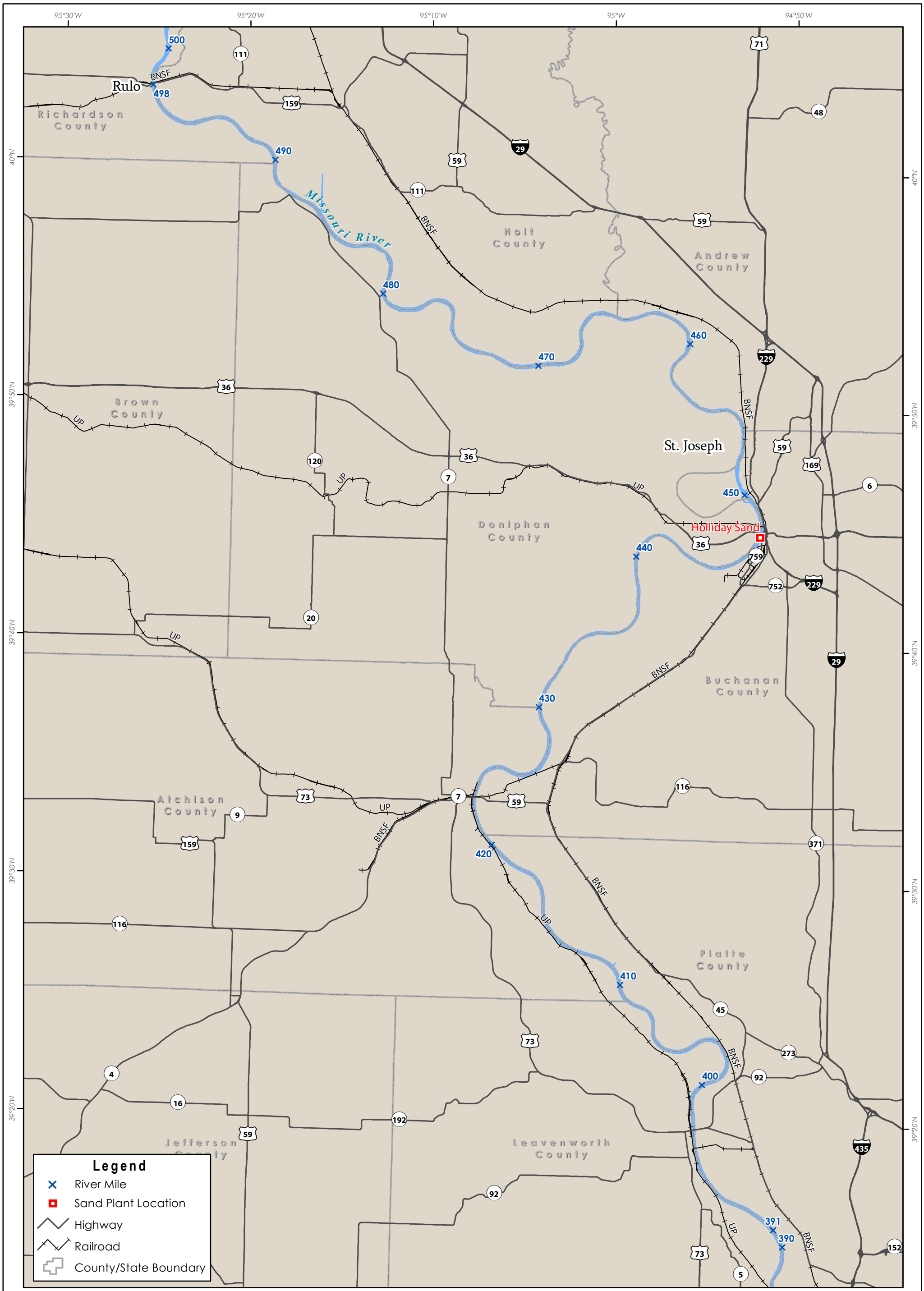

Figure 3.6-1
Major Transportation Corridors in the Project Area
Sheet 1 - St. Joseph Segment

Missouri River Commercial Dredging EIS

0 5 Miles

0 5 Kilometers

Figure 3.6-1
Major Transportation Corridors in the Project Area
Sheet 2 - Kansas City Segment

Missouri River Commercial Dredging EIS

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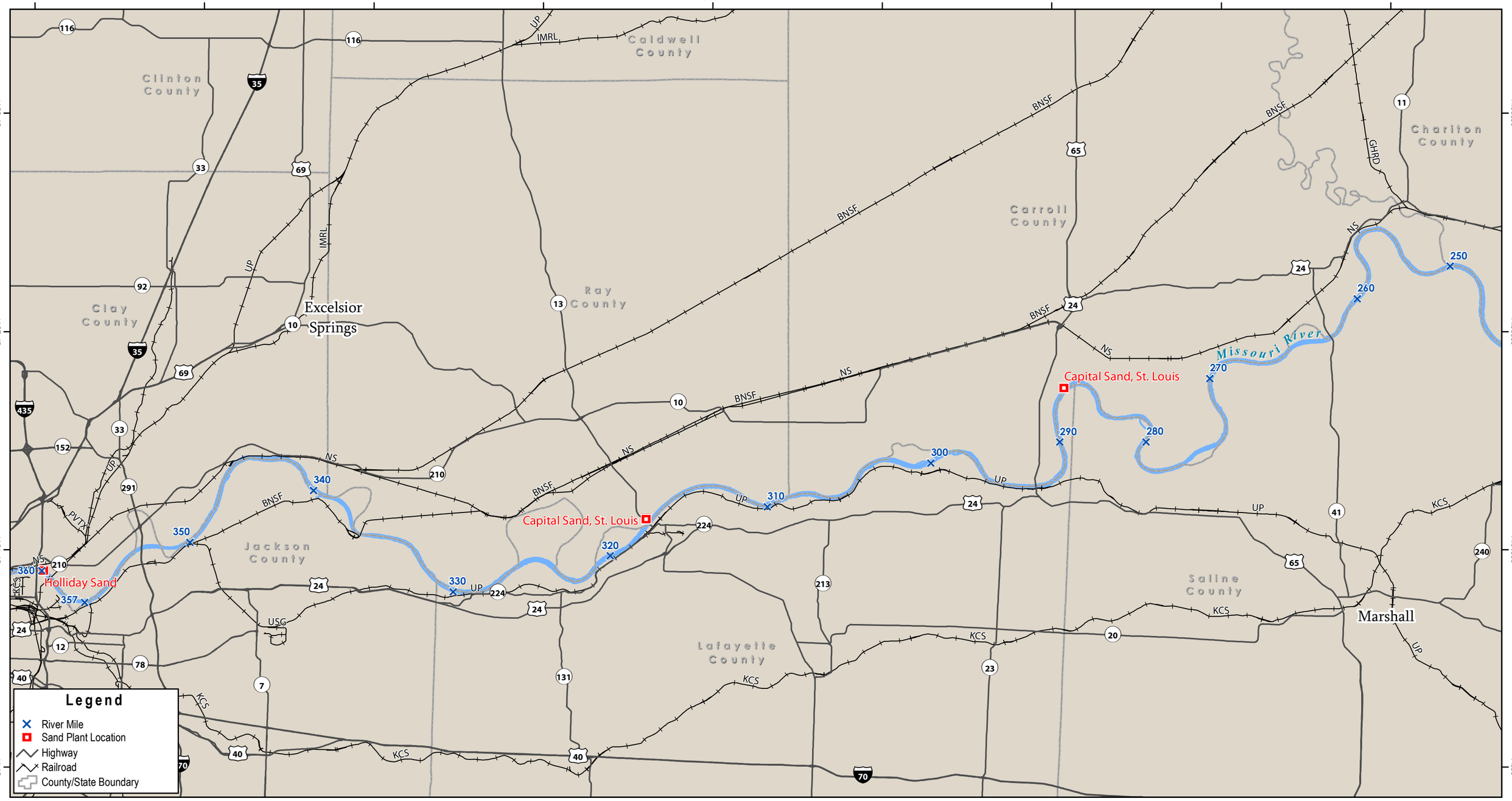
Map Projection: NAD83 UTM Zone15 North



0 10 20 Miles

0 10 20 Kilometers

Figure 3.6-1
Major Transportation Corridors in Project Area
Sheet 3 - Waverly Segment

Missouri River Commercial Dredging EIS

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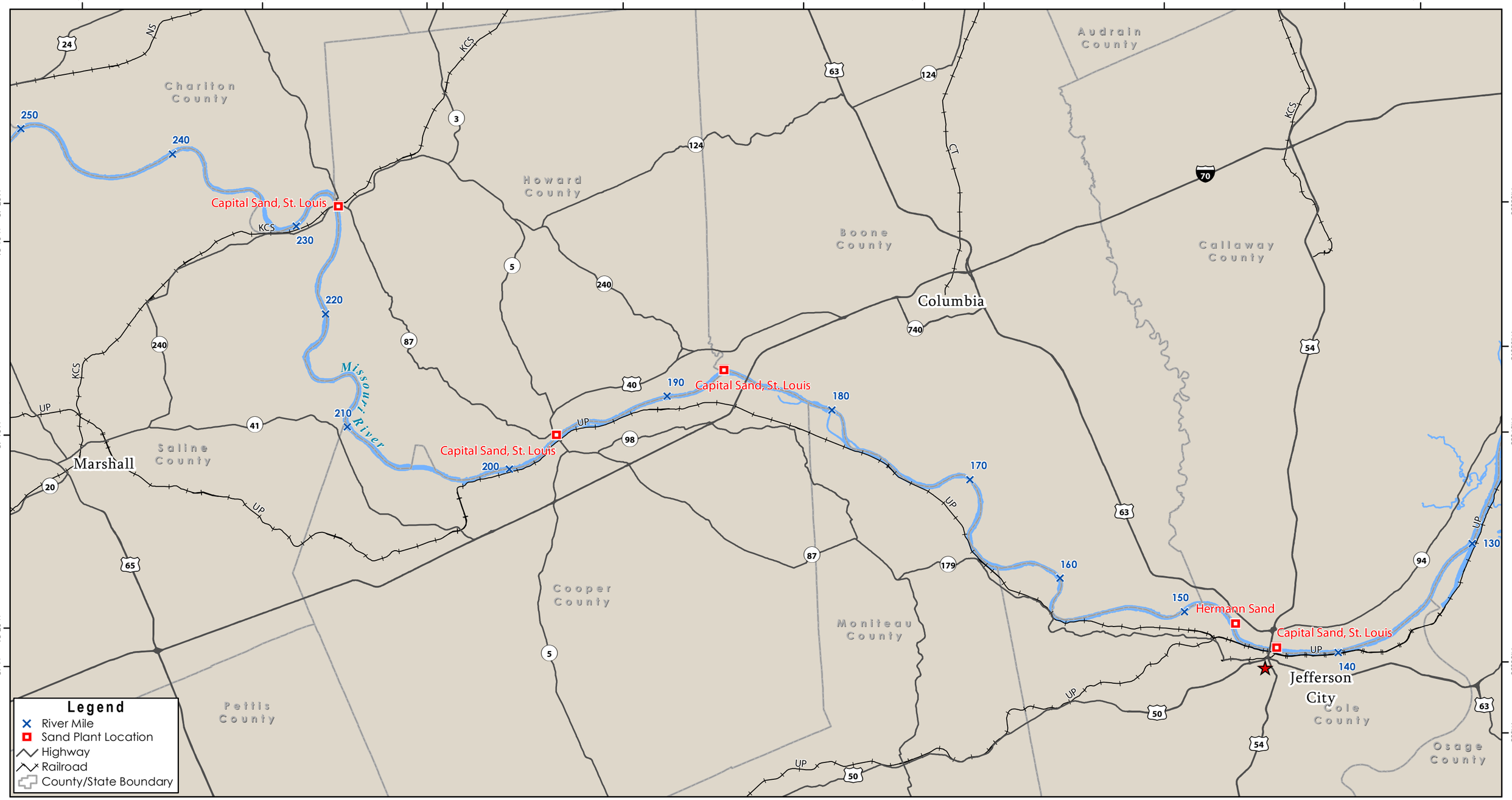
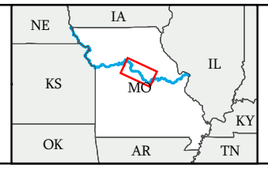
Map Projection: NAD83 UTM Zone15 North



0 5 10 15 20 Miles

0 5 10 15 20 Kilometers

Figure 3.6-1
Major Transportation Corridors in the Project Area
Sheet 4 - Jefferson City Segment
Missouri River Commercial Dredging EIS



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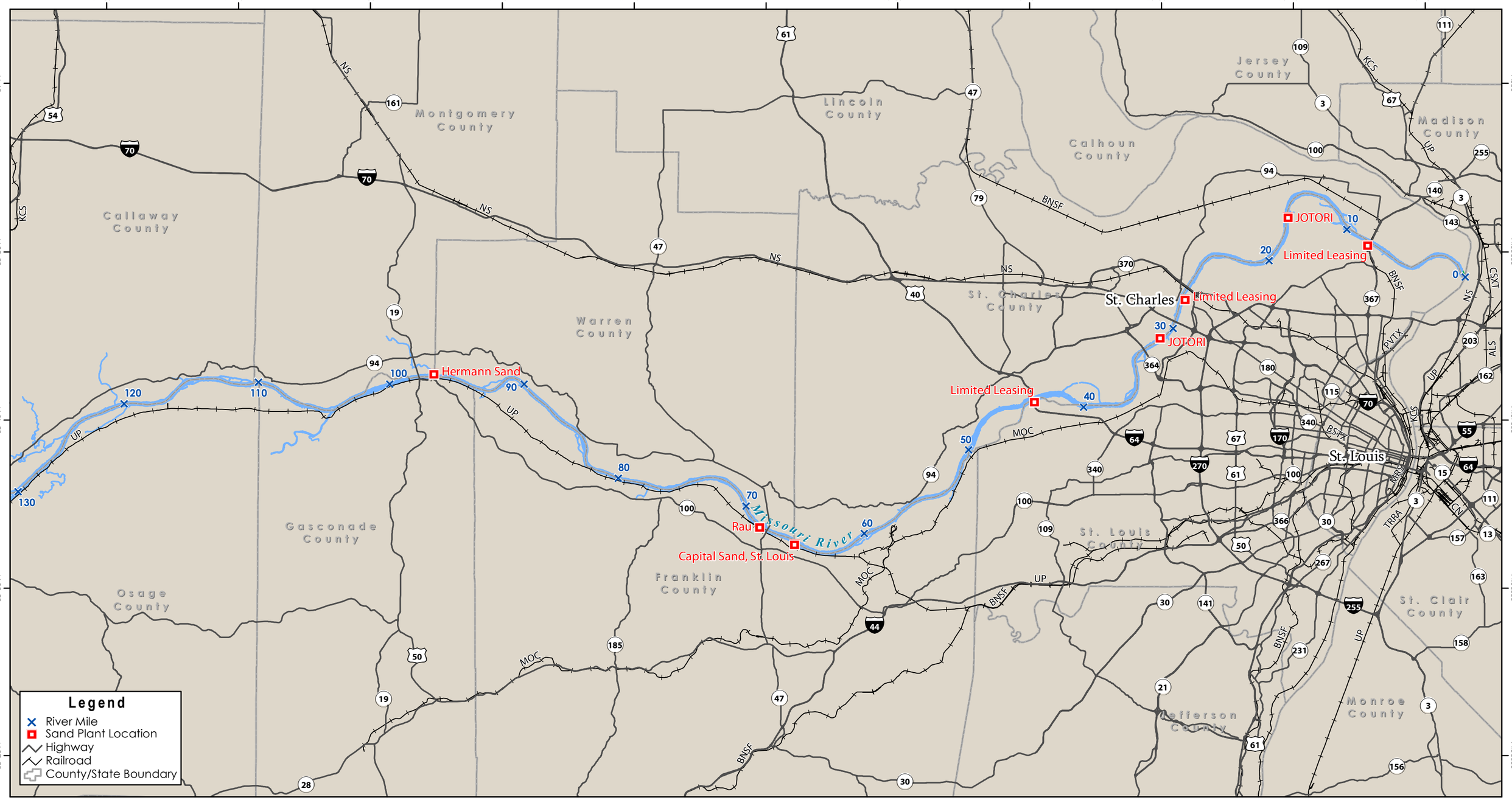
Map Projection: NAD83 UTM Zone15 North



0 5 10 15 20 25 30 Miles

0 5 10 15 20 25 30 Kilometers

Figure 3.6-1
Major Transportation Corridors in the Project Area
Sheet 5 - St. Charles Segment

Missouri River Commercial Dredging EIS

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Map Projection: NAD83 UTM Zone15 North

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3.7 WATER RESOURCES

3.7.1 Introduction

This section describes existing surface water quality and groundwater resources to serve as a baseline from which the Proposed Action and alternatives will be evaluated. Section 3.7.2 discusses the relevant regulatory framework surrounding water resources. Section 3.7.3 examines multiple surface water quality parameters in the context of ongoing dredging activities and the current regulatory standards that characterize current surface water conditions in the LOMR. Existing dredging operations in the LOMR suspend sediment during dredging and during the return of slurry to the river from the dredging barge after sorting. This disturbance temporarily introduces suspended sediment, and potentially also introduces associated nutrients and contaminants, into the water column.

Section 3.7.4 describes the groundwater interactions between the LOMR and the Missouri River alluvial aquifer (alluvial aquifer) and its linkage to LOMR stage. Because of the linkage between the alluvial aquifer and river stage, long-term and short-term alterations in river stage may affect alluvial aquifer levels. Changes in alluvial aquifer levels may influence water availability for wetlands (discussed in Section 3.9) and withdrawal of water for municipal, agricultural, and commercial uses (discussed in Section 3.5)

3.7.2 Regulatory Setting

Activities that may impact waters of the United States may require various permits or authorizations under the CWA. Sections of the CWA are enforced at both the federal and state level. There are no relevant state or federal regulations pertaining to groundwater resources.

3.7.2.1 Federal

Clean Water Act – Sections 303(d) and 305 (b)

Biennially, each state is required by the CWA to submit a report to the USEPA describing the status of surface waters in the state and listing the water bodies that are not achieving water quality standards. Section 303(d) of the CWA requires a list of water bodies in the state that are impaired, and Section 305 (b) requires a report on the overall condition of water bodies in the state. Generally, these lists are provided to the USEPA in an Integrated 303(d)/305(b) Report (Integrated Report). Water body

uses are classified as “fully supported,” “fully supported but threatened,” “partially supported,” or “not supported” based on achievement of relevant water quality criteria standards. A use is said to be “impaired” when it is partially supported or not supported. Section 303(d) also requires a total maximum daily load (TMDL) to be established for those waterways that do not meet their designated water quality standards for a particular pollutant. A TMDL calculates the maximum amount of a pollutant that can be allowed to enter a water body and still meet the water quality standard specified for the pollutant and allocates that pollutant load from point and non-point sources.

Clean Water Act – Section 404

Section 404 of the CWA establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States. State authority under Section 401 of the CWA is discussed in Section 3.7.2.2.

Under Section 404(b)(1) of the CWA, individual permit issuance requires that the USACE make a factual determination based on a written review process that evaluates short- and long-term aquatic impacts of the proposed permitted action and the proposed avoidance, minimization, and mitigation measures. This factual determination is used to determine compliance or non-compliance with discharge restrictions.

3.7.2.2 State

No high-quality or state resource waters have been designated on the LOMR in the Project area (e.g., Outstanding State Resource Water, Outstanding National Resource Water, National Wild and Scenic River, or listing in the Nationwide Rivers Inventory) (MDNR 2007a and 2007b, nationalatlas.gov 2009, NPS 2008).

Clean Water Act – Sections 401 and 402

According to the CWA, any activity requiring a federal permit that may result in a discharge to waters of the United States must obtain a state Section 401 water quality certification. The state regulatory agency evaluates applications to determine whether the proposed activity would comply with state

water quality standards. If the activity is likely to violate state water quality standards, conditions for complying with the state standards will be issued with the certification or the certification will be denied.

Among other things, Section 402 under the CWA requires that direct and stormwater discharges into state waters from industrial activities be controlled by a National Pollutant Discharge Elimination System (NPDES) permit. The USEPA has authorized Missouri, Kansas, and Nebraska to issue NPDES permits for activities in their respective states.

3.7.3 Surface Water Quality

The following discussion of surface water quality provides a background in the context of ongoing dredging activities and regulatory standards.

Section 303(c) of the CWA requires states to review, establish, and revise water quality standards for all surface waters in the state. Designated uses are assigned to water bodies by the states; specific water quality criteria standards are determined based on the designated use for each water body. Table 3.7-1 lists the designated uses that apply to water bodies in the Project area.

Table 3.7-1 State Designated Uses and Attainment Status in the Lower Missouri River by River Segment

Segment	Designated Use	2008 Designated Use Attainment [a,b]	Parameter of Concern	Total Maximum Daily Load (Date of USEPA Approval)
Missouri				
All segments	Irrigation	S		
	Livestock and wildlife watering	S		
	Protection of aquatic life and human health	S		Chlordane, polychlorinated biphenyls (PCBs) (2006)
	Whole body contact recreation	I[c]	Bacteria	
	Secondary contact recreation	S		
	Drinking water supply	S		
	Industrial	S		

Table 3.7-1 State Designated Uses and Attainment Status in the Lower Missouri River by River Segment

Segment	Designated Use	2008 Designated Use Attainment [a,b]	Parameter of Concern	Total Maximum Daily Load (Date of USEPA Approval)
Kansas				
St. Joseph[d] Kansas City	Aquatic life	S		
	Contact recreational	S		
	Domestic water supply	S		
	Food procurement	S		
	Groundwater recharge	S		
	Industrial water supply	S		
	Irrigation	S		
	Livestock watering	S		
Nebraska				
St. Joseph	Primary contact recreation	I	*Escherichia coli* (*E. coli*)	*E. coli* (2007)
	Aquatic life (cold and warm water)	I	Dieldrin, PCBs	
	Water supply (public drinking water, agricultural, industrial)	S		
	Aesthetics	S		

Note: USEPA = U.S. Environmental Protection Agency.

[a] S= Use supported; I = Use impaired.

[b] Impairment determined by listing in 2008 Integrated Report for the respective state.

[c] The final 2008 303(d) list does not include an impaired use designation but does list the segment as impaired for bacteria (MDNR 2009a). The draft 2010 303(d) list indicates that a portion of the Lower Missouri River crossing Missouri is impaired for whole body contact recreation due to bacteria (MDNR 2010).

[d] Only a portion of the St. Joseph segment is located in Kansas.

Sources: MDNR 2009a, 2009b, 2006c; NDEQ 2008, 2007; KDHE 2008a; USEPA 2008; Missouri 10CSR 20-7.031(C); Kansas K.A.R. 28-16-28d; Nebraska 117NAC4.

There are no 303(d) listings or TMDLs for the LOMR flowing through Kansas (KDHE 2008b, 2009). The portion of the LOMR flowing between St. Louis and Gasconade Counties in Missouri has been listed on the final, USEPA-approved Missouri 2008 303(d) list for bacteria impairment. The proposed 2010 303(d) list expands the area of the LOMR listed as impaired for bacteria (MDNR 2010). The MDNR has proposed classifying the LOMR flowing between Atchison and Jackson Counties and Gasconades and St. Charles Counties in Missouri as impaired in the proposed 2010 303(d) list. The 2008 Integrated Report also identified the LOMR as potentially impaired for habitat degradation due to channelization in Holt, Carroll, Calloway, and St. Charles Counties (MDNR 2009a). Habitat

degradation due to channelization is from both historical large-scale and current minor channelization projects that have reduced the river length and the availability of aquatic habitat. TMDLs have been established for PCBs and chlordane in the LOMR in Missouri (MDNR 2006a).

In general, water quality in the LOMR differs substantially compared to historical conditions. As discussed in Section 3.4.5.2, the hydrology and the sediment load delivered to the LOMR have been altered through construction and operation of upstream dams, and channelization and stabilization of the LOMR banks. The resultant changes to stream flow quantity and timing have affected sediment inputs, eliminated off-channel habitats, and isolated the LOMR from its floodplain. Compared to historical levels, turbidity and TSS concentrations decreased after installation of upstream dams and channelization (Blevins 2006, MDNR 2006b). Further, due to industrial, agricultural, and residential land uses in the LOMR watershed, contaminants such as nutrients, pathogens, metals, and pesticides can be found in the water, sediment, and fish.

Integrated Reports for the respective states and USGS current water-year annual reports constitute the most comprehensive data sets available for recent water quality in the LOMR and were used to summarize recent conditions in the LOMR, as described below.

The Missouri Clean Water Commission raised concerns about the water quality impacts in the LOMR associated with adding sediment to the LOMR (MRRP 2007, Gossenauer 2009). Although USACE testing and monitoring of shallow-water habitat construction sites showed that activities were in compliance with Missouri water quality standards (USACE 2007), the Missouri Clean Water Commission issued orders in September 2007 and March 2008 to cease all shallow-water habitat construction activities that resulted in adding sediment to the LOMR (Gossenauer 2009). In response to the Missouri Clean Water Commission orders, the USACE ceased construction of in-river shallow-water habitat in Missouri and commissioned the National Academy of Science to complete an independent assessment of the impacts of adding sediment to the LOMR (MRRP 2007, Gossenauer 2009). The National Academy of Science released the prepublication of the report in the fall of 2010 (NAS 2010).

3.7.3.1 Nutrients

As described further in Section 3.7.3.4, the Missouri River historically conveyed a substantial sediment load, and the accompanying nutrients that were associated with that sediment load (NAS 2010). MDNR monitoring data at St. Joseph, Missouri have shown a general long-term increase, compared to

recent post modification levels, in nitrate plus nitrite levels from point and non-point sources (MDNR 2006b). Nitrogen from the Mississippi River basin, into which the Missouri River basin empties, has been implicated as one of the primary causes of hypoxia in the Gulf of Mexico (USGS 2000). The role of phosphorous in Gulf of Mexico hypoxia is unclear (USACE 2007). The USGS annually predicts the extent of the Gulf of Mexico hypoxic zone based on upstream hydrologic and nutrient data. The net nutrient flux contributed by the Missouri River is modeled through data obtained from the Hermann, Missouri sampling station (USGS 2007). Typically, the Missouri River basin contributes between approximately 17 and 20 percent of the total phosphorous and 13 to 15 percent of the total nitrogen loads to the Gulf of Mexico via the Mississippi River (Soballe 2009, NAS 2010).

The National Academy of Science conducted a review of literature and data to determine if nutrients introduced into the LOMR via sediment from shallow-water habitat creation would contribute to Gulf of Mexico hypoxia (NAS 2010). The report concluded that the USACE shallow-water habitat projects would result in some releases of nitrogen and phosphorus to the LOMR (NAS 2010). It was concluded that nitrogen loadings to the river from these activities would be likely to constitute a smaller fraction of the current load than additional phosphorus loadings. USACE testing has found that the total phosphorous concentration of elutriate water (measuring the potential release of water-soluble constituents from sediment to the water column) at five shallow-water habitat creation sites was approximately 66 percent lower than concentrations present in the river water (USACE 2007). The NAS concluded that potential phosphorus loads from the USACE shallow water habitat projects would not significantly change the extent of the hypoxic area in the Gulf of Mexico (NAS 2010). Nutrients associated with resuspension of sediments already present in the LOMR that would occur with dredging are likely to be even less than those from USACE shallow-water habitat creation sites.

3.7.3.2 Temperature

Missouri State water quality requirements stipulate that water bodies not be in excess of 90 degrees Fahrenheit (°F) (32 degrees Celsius [°C]) and that no action shall raise or lower the temperature of a water body greater than 5 °F (3 °C) (Missouri 10CSR 20-7.31). Kansas water quality regulations stipulate that the temperature of receiving water shall not be increased by a total of more than 5 °F (3 °C) from natural background outside the mixing zone (Kansas K.A.R. 28-16-28e). The Nebraska maximum water temperature limit is 85°F (29°C), and regulations limit water temperature change to a maximum of 4 °F (2 °C) from natural background temperatures.

None of the LOMR segments flowing through Nebraska, Kansas, or Missouri are listed as impaired for temperature (MDNR 2009a, KDHE 2008b, NDEQ 2008). In general, summer water temperatures at Gavins Point Dam, located upstream of the Project area, range from 75.2 °F (24 °C) to 78.8 °F (26 °C) (USACE 2003). Water temperatures generally increase downstream from this point and peak near Kansas City, Missouri (USACE 2003). USGS gage data collected and compiled by the MDNR and USGS were used to determine the maximum and minimum daily temperatures at representative monitoring stations near each segment (Table 3.7-2).

Water temperature fluctuates with season, hydrology, and non-point and point source discharges into the river. Factors historically affecting water temperatures in the Missouri River include heated effluent from power plants and the contribution of water from tributaries to the LOMR (USACE 2003). The small amount of water required for dredging operations relative to the overall quantity of water in the LOMR, combined with the short duration during which water is removed, makes it unlikely that dredging measurably changes the water temperature in the LOMR.

3.7.3.3 Dissolved Oxygen

DO levels fluctuate monthly, daily, and hourly. The State of Missouri requires that constituents added to the water not reduce dissolved oxygen (DO) levels to less than 5.0 mg/l (Missouri 10CSR 20-7.31). The State of Missouri determines water bodies to be impaired if more than 10 percent of the days monitored fail to meet the water quality standard for DO (MDNR 2009c). Nebraska requires that a 1-day minimum of not less than 5.0 mg/l for early life stages is present between April 1 and September 30, and a 1-day minimum of not less than 3.0 mg/l for all life stages other than early life stages is present from October 1 through March 31 (Nebraska 117NAC4). Kansas maintains a 5.0-mg/l DO criterion for aquatic life and stipulates that no pollutant may influence the lowering of DO levels in surface waters.

Table 3.7-2 Representative High and Low Temperatures in the Lower Missouri River by River Segment

Segment	Sampling Location	Sampling Period	Maximum Daily Temperature	Minimum Daily Temperature
St. Joseph	St. Joseph, MO[a]	2000–2006	87.3°F (30.7 °C)	32°F (0.0°C)
Kansas City	NA	NA	NA	NA
Waverly	Waverly, MO[a]	March to September 2006	89.6 °F (32°C)	43.5°F (6.4°C)[b]
Jefferson City	Booneville, MO[a]	March 2006 to September 2008	90.5 °F (32.5°C)	36.1°F (2.3°C)[b]
St. Charles	St. Charles, MO[a]	October 2007 to September 2008	77.0°F (25.0°C)	34.9°F (1.6°C)
St. Charles	Hermann, MO[a]	2000–2006	89.6 °F (32°C)	32.4°F (0.2°C)

Notes:

C = Celsius.
F = Fahrenheit.
MO = Missouri.
NA = Data not available for this river segment.

[a] Daily temperature data record has not been completed. Disruptions in temperature data availability due to freezing conditions, instrument failure, or no flow at monitoring location.

[b] Winter data were not collected for this location; therefore, the winter low water temperature was likely lower than the reported low.

Sources: MDNR 2009c; USGS 2008a, 2008b, 2008c, 2008d, 2008e, 2008f.

Table 3.7-3 depicts maximum and minimum daily DO concentrations measured at various stations along the LOMR. During summer, DO levels often measure less than 5 mg/l and can reach as low as 1 mg/l (Blevins and Fairchild 2001). DO levels for the LOMR in Missouri have dropped below the minimum DO level of 5 mg/l, the level established to protect aquatic life at multiple locations (Table 3.7-3); however, because none of the segments were impaired greater than 10 percent of the days monitored, inclusion on the 2008 303(d) list was not warranted. No segment of the LOMR in the Project area in Missouri, Nebraska, or Kansas has been listed as impaired for DO in the USEPA-approved 2008 Integrated Reports (MDNR 2009a, KDHE 2008b, NDEQ 2008).

Table 3.7-3 Representative High and Low Dissolved Oxygen Levels in the Lower Missouri River by River Segment

Segment	Sampling Location	Sampling Period	Maximum Daily DO Concentration (mg/l)	Minimum Daily DO Concentration (mg/l)
St. Joseph	St. Joseph, MO[a]	2000–2006	15.5	3.8
Kansas City	NA	NA	NA	NA
Jefferson City	Booneville, MO[a]	February 2006 to September 2008	15.6	2.9
Waverly	Waverly, MO[a]	March 2006 to September 2008	12.9	1.9
St. Charles	Columbia Bottom, MO[a]	2004–2006	15.2	5.7
St. Charles	Hermann, MO[a]	2000–2006	16.0	2.1

Notes:

DO = Dissolved oxygen.
mg/l = Milligrams per liter.
MO = Missouri.
NA = Data not available for this river segment.

[a] The daily DO data record has not been completed. Disruptions in DO data availability due to freezing conditions, instrument failure, or no flow at monitoring location. Minimum daily DO may have been lower during periods of missing records.

Sources: MDNR 2009c; USGS 2008a, 2008b, 2008c, 2008d, 2008e, 2008f.

The MDNR reports that DO levels in the LOMR generally appear to be most affected by non-point pollution sources during runoff events (MDNR 2006b). Current dredging operations temporarily suspend sediment, which may release DO-lowering nutrients into the LOMR water column (see Section 3.7.3.1). Inorganic sand, which is largely inert and does not result in a depletion of DO, typically comprises half of the suspended sediment in the LOMR (Blevins and Fairchild 2001). Phosphorous typically adsorbs to fine sediment and is closely correlated with sediment (Soballe 2009, NAS 2010). Nitrogen is typically in a dissolved state and is only indirectly linked to sediment (Soballe 2009). As discussed in Section 3.7.3.1, the disturbance of sediment during current dredging operations is not likely to greatly increase the nutrient load of the LOMR; therefore, dredging is not likely to substantially lower DO levels.

3.7.3.4 Total Suspended Solids and Turbidity

Total suspended solids (TSS) is a measure of both inorganic and organic suspended solids, while turbidity is an optical property that causes light to be scattered and absorbed (USACE 2000). Water quality standards for these parameters in the LOMR are largely qualitative. Missouri State turbidity and color standards on the LOMR require that an action shall not cause a substantial visible contrast with

the natural appearance of the water body (Missouri 10CSR 20-7.31). The Missouri Clean Water Commission considers organic and inorganic sediment a contaminant because nutrients and metals are typically delivered to water bodies via sediment (MDNR 2009b). In Kansas, TSS must not interfere with the "behavior, reproduction, physical habitat, or other factors related to the survival and propagation of aquatic or semi-aquatic life or terrestrial wildlife" (Kansas K.A.R. 28-16-28e). Nebraska requires that water shall be free from human-induced pollution that causes floating, suspended, colloidal, or settleable materials that produce objectionable films, colors, turbidity, or deposits (Nebraska 117NAC4).

Factors affecting TSS loads include hydraulics, erosion, runoff, and river impoundments. Natural erosion introduces inorganic sediments and organic matter to the LOMR. Historically, the LOMR was known as the "Big Muddy" due to the high levels of sediment in the water caused by the highly erodible banks (Blevins 2006). Upstream reservoirs and bank stabilization have decreased suspended sediment and turbidity in the LOMR (Blevins 2006). The USGS estimates that median suspended sediment concentrations in the LOMR have decreased at least 70–80 percent from predevelopment conditions (Blevins 2006). For example, the USACE data collected between February 1 and October 31, 1879 at St. Charles, Missouri (St. Charles segment) showed an average suspended sediment concentration of 4,100 mg/l (Blevins 2006), which exceeds the maximum value of 3,560 mg/l recorded by the USGS at this location between 2005 and 2008 (USGS 2008f). The minimum daily suspended sediment concentration at this location between 2005 and 2008 was 82 mg/l (USGS 2008f).

The USEPA collected TSS data through grab samples collected throughout the LOMR during summer months (July, August, and September) between 2004 and 2006 as part of the Environmental Monitoring and Assessment of Great River Ecosystems program (USEPA 2009). An average TSS concentration of 203.4 mg/l was recorded for all segments of the LOMR (USEPA 2009). The highest concentration found was 1,161.7 mg/l at a sampling site in the St. Joseph segment; the lowest was 61.4 mg/l in the St. Charles segment (USEPA 2009).

The USGS primarily reports turbidity measurements, as opposed to TSS concentrations. Table 3.7-4 reports USGS turbidity measurements in the river segments from 2006 to 2008. While no historical turbidity data directly correlate with the data presented in Table 3.7-4, it is likely that a decrease in suspended sediment concentration is indicative of a decrease in current turbidity levels compared to historical levels.

Table 3.7-4 Representative High and Low Turbidity in the Lower Missouri River by River Segment

Segment	Sampling Location	Sampling Period	Maximum Daily Turbidity (FNU)	Minimum Daily Turbidity (FNU)
St. Joseph	St. Joseph, MO[a]	2006–2008	1,990 FNU	2.5 FNU
Kansas City	NA	NA	NA	NA
Waverly	Waverly, MO[a]	2006–2008	1,180 FNU	24 FNU
Jefferson City	Booneville, MO[a]	2006–2008	1,630 FNU	15 FNU
St. Charles	Hermann, MO[a]	2006–2008	1,430 FNU	15 FNU

Notes:

FNU = Formazin nephelometric unit.
MO = Missouri.
NA = Data not available for this river segment.

[a] The daily turbidity data record has not been completed. Disruptions in turbidity data availability due to freezing conditions, instrument failure, or no flow at monitoring location. Minimum and maximum daily turbidity may have been lower during periods of missing records.

Sources: USGS 2008a, 2008b, 2008c, 2008d, 2008e, 2008f.

Current dredging activities result in temporary resuspension of sediment, which increases TSS concentrations immediately downstream of the dredge head and the slurry discharge. The dissipation rate and the associated level of TSS in the water column as a result of bed disturbance and slurry discharge is dependent on multiple factors, including the hydrodynamic conditions of the dredging site, type of dredge used, operational methods, and sediment type and the associated settling rate (USACE 1986).

As described in Chapter 2, a higher proportion of bed load meets material specifications in the St. Charles and Jefferson City segments; therefore, slurry water returned to the LOMR at these locations contains a lower percentage of sediment, compared to discharge in the upper segments of the LOMR. Approximately 60–70 percent of all dredged sediment from the Kansas City and St. Joseph segments does not meet the required materials specifications and is discharged into the LOMR via the slurry water.

The USACE assessed the quantity of sediment particles in the water column that do not rapidly settle out of the water column following resuspension from various dredging activities (USACE 1986). The USACE reported that, based on studies conducted in the James River in Virginia and the Savannah River in Georgia, the cutter-head dredge removed bed sediment with a relatively small amount of suspended sediment extending beyond the immediate vicinity of the dredge (USACE 1986). The study showed that a cutter-head dredge produced between 25 and 250 mg/l of suspended solids within 100

feet of the dredge and that the quantity of suspended solids decreased to between 10 and 150 mg/l within 400 feet of the dredge (USACE 1986). As stated above, the USEPA reported an average suspended solid concentration of 203.4 mg/l in all LOMR river segments (USEPA 2009). The addition of suspended sediment levels from dredging, as reported by the USACE, would represent a small, temporary increase in suspended sediment levels above average ambient conditions in areas that are near the dredging operation. The USACE reports that elevated suspended sediment plumes from dredging in the Missouri River typically extend for less than 1,000 feet downstream of a dredge site (USACE 1990).

As discussed above, turbidity and TSS levels in the LOMR have been greatly reduced compared to historical levels. At current levels, however, the LOMR is still a relatively turbid river. A large number of studies show that dredging activity produces a temporary increase in turbidity near the dredging operation, but turbidity and suspended sediment levels quickly dissipate to background levels (USEPA 1996, Thackston et al. 2000, USACE 1990).

3.7.3.5 Sediment Quality and Toxicity

The LOMR historically received and currently receives point-source and non-point-source pollutant inputs from agricultural, urban, and industrial sources. Current and past pesticide use for agricultural applications throughout the LOMR basin has resulted in the introduction of pesticides, such as chlordane, dieldrin, and dichlorodiphenyltrichloroethane (DDT), into the LOMR water and sediment. Polychlorinated biphenyls (PCBs), which were used in industrial applications, remain at industrial sites near the LOMR and in river sediment. Depending on their chemical and physical properties, contaminants present in sediment, interstitial pore water (water contained in the spaces between sediment grains), and surface waters of the LOMR can be available for biological uptake and have the potential to bioaccumulate in aquatic organisms.

Depending on the properties of the contaminant, higher concentrations could be present in the sediment, the interstitial pore water, and/or the water column. Many organic chemicals are not water soluble (referred to as “hydrophobic”) and adsorb to sediment or animal fatty tissue; therefore, these hydrophobic chemicals are highly related to sediment deposition and bioaccumulation (Blevins and Fairchild 2001). For chemicals that are not hydrophobic, interstitial pore water typically is in constant contact with sediments in which contaminants may be present for a longer period of time—compared to the water column, which results in restricted mixing with surface waters. Due to the prolonged exposure to sediment, and any associated contaminants present, pore water often has elevated

concentrations of water-soluble sediment-associated contaminants (Chapman et al. 2001). The regular movement and transport of river sediments in the LOMR allows for dilution and mixing of pore water with the water column.

Sediment contamination in the LOMR has been documented in some recent studies that have shown areas with pesticide, chemical, and metal contamination; but overall, sediment contamination has had limited documentation (Jacobson, Blevins, and Bitner 2008; Echols et al. 2008). Data from fine sediment in depositional areas were analyzed for pesticides, polycyclic aromatic hydrocarbons (PAHs), and PCBs at sampling sites between Omaha, Nebraska and Jefferson City, Missouri (encompassing all river segments). In general, pesticide concentrations (DDT, chlorodanes, cyclodiene pesticides, trifluralin, diazinon, chlorpyrifos, and permethrins) were greater at sampling sites downstream and in Kansas City, Missouri (the Kansas City, Waverly, Jefferson City, and St. Charles segments) (Echols et al. 2008). For example, on average, sites downstream of Kansas City were found to have a higher mean total chlorodane concentrations (3.0 +/- 1.3 nanograms per gram [ng/g]) compared to upstream sites (1.1+/-0.3 ng/g) (Echols et al. 2008). Echols et al. (2008) compared the levels found at the sampling sites with “probable effects levels,” those levels of contaminants that, if exposed, would likely cause adverse effects to an organism. For those pesticides with established probable effects levels, none of the pesticide sediment concentrations exceeded probable effect level thresholds. Similar to pesticide concentrations, all sampling sites downstream of and in Kansas City (the Kansas City, Waverly, Jefferson City, and St. Charles segments) had higher than average PCB levels, compared to upstream sites (Echols et al. 2008). Sampling sites downstream of urban areas in the St. Joseph, Jefferson City, and St. Charles segment were found to have elevated PAH levels compared to upstream sampling sites. While elevated PAH concentrations were observed, all PAH concentrations were found to be below published levels that would cause adverse effects to organisms.

As discussed in Section 3.4.3, the LOMR underwent a large flood event in 1993. Petty et al. (1998) sampled the water of the mainstem LOMR following the 1993 flooding event to determine the presence of bioavailable organochlorine pesticides (OCs), PCBs, and PAHs at sites located in the Kansas City, Jefferson City, and St. Charles segments. Contaminants were found at all sites and were found to be at higher concentrations than those observed prior to the 1993 flood event (Petty et al. 1998). Results suggested that the disturbance of OC-, PAH-, and PCB-contaminated sediment in the floodplain as a result of the 1993 flooding increased levels of these pollutants in the LOMR, as opposed to their being flushed and rapidly dissipating. The change in concentration was attributed to the mobilization of soil and sediment with OC, PCB, and PAH residues (Petty et al. 1998). While herbicide transport during the 1993 flood was not studied in the LOMR, a study by Goolsby et al. (1993) in the Mississippi River

following the 1993 flood identified a similar phenomenon. Goolsby et al. (1993) identified increased levels of herbicide residues, which the authors attributed to the contribution of large quantities of soil-bound herbicide residues from the floodplain into the Mississippi River.

While limited direct sediment and water testing has occurred in the LOMR, several federal agencies (including the USFWS, USGS, and USEPA) and several state agencies conduct fish tissue and egg sampling to determine the presence of bioavailable contaminants. Sampling conducted in support of development of the Missouri 303(d) list identified elevated levels of chlordane and PCBs in fish tissue sampled at multiple sites in all river segments; consequently, the LOMR was included on Missouri's 2002 303(d) list. MDNR then developed a TMDL for chlordane and PCBs (MDNR 2006a). Subsequent review of fish tissue data for the 2004/2006 and 2008 303(d) lists indicates that chlordane and PCB levels meet current MDNR water quality guidelines.

Chlordane is an OC pesticide that was used in the United States between 1948 and 1988 that entered water bodies via runoff (MDNR 2006a). Because the United States banned use of the chemical in 1988, no additional loading of the chemical into water bodies is anticipated (MDNR 2006a). Chlordane degrades very slowly; therefore, residual quantities of the chemical are still present in Missouri River sediments. Because its use has been banned, the MDNR expects that chlordane levels will decrease over time.

PCBs are comprised of chlorinated compounds that had wide industrial applications (MDNR 2006a). Production of PCBs in the United States was halted in 1977, but approximately 60 percent of the PCBs produced in the United States are still in use (MDNR 2006a). Generally, the MDNR reports that these compounds are relatively insoluble and absorb into organic matter (MDNR 2006a).

Both chlordane and PCBs degrade slowly and are persistent in the environment. Because production of both of these pollutants has been banned in the United States, the MDNR anticipates that levels of both of these pollutants will decline in the future (MDNR 2006a). Neither pollutant is water soluble and therefore is not readily present in the water column. Both adsorb to sediments in the Missouri River and can bioaccumulate in fish tissue. Bioaccumulation of PCBs and chlordane in aquatic organisms (such as carp) is primarily driven by consumption of or exposure to sediments containing these chemical constituents (MDNR 2006a). The MDNR TMDL indicates that the presence of these compounds is "mainly a sediment issue and amounts in the water column are virtually non-detectable" (MDNR 2006a). Because of the low solubility of both of these contaminants, they would generally be prevented from reaching high concentrations in LOMR water.

Current dredging operations disturb sediments and the associated pore water, some of which may contain contaminants. The LOMR is a large river with a high potential for mixing and dispersion (USACE 1990); therefore, most elevated levels of contaminants due to dredging would quickly return to background levels. Most organic contaminants are hydrophobic; therefore, sediment resuspension (see Section 3.7.2.3) during dredging is a relative measure of the potential for contaminant release (USACE 1986). The extent of this potential desorption and dispersal of interstitial pore water would depend on the concentration and properties of the suspended contaminant and site-specific conditions. Those soluble contaminants contained within sediment pore water that are released during dredging would be quickly flushed due to the high potential for mixing.

In support of the L-385 project, the USACE conducted testing to determine the mixing zone for dilution of dissolved contaminants and for settling of suspended materials (USACE 1990). The study found that some contaminant sample concentrations exceeded receiving water concentrations, but none exceeded the water quality standards in place at the time. While elevated concentrations of contaminants were detected, the researchers concluded that the mixing would quickly reduce any elevated contaminant concentration to background levels and that no significant release of contaminants would occur due to dredging in sand bed sediments (USACE 1990).

Dredging has been an ongoing activity in the LOMR that may temporarily, slightly increase contaminant concentrations in the water column. The Missouri Department of Health and Senior Services has recommended limited fish consumption due to the presence of PCBs, chlordane, and mercury (MDHSS 2010). While current dredging potentially increases the potential number of areas where sediments with PCBs or chlordane adsorbed are redistributed through the water column and on the river bottom, it does not serve as a source of these contaminants.

3.7.3.6 Metals

The Missouri River historically had naturally high concentrations of metals such as selenium and arsenic that are related to underlying geology and soils. Metals enter the waterway via natural sources, as well as by point and non-point sources. In general, no long-term monitoring in Missouri's larger rivers (including the LOMR) has indicated any issues related to heavy metals (MDNR 2006b). Metal concentrations that exceed state water quality standards have not been detected within the Project area, and none of the Project area has been included on a state 303(d) list for metal impairment. While extensive contamination has not been documented, background sediment contamination in some locations of the LOMR is likely (Jacobson, Blevins, and Bitner 2008). In general, though, metals

concentrations sampled along the LOMR were not remarkably elevated, and the acid-volatile sulfides concentration values suggest a low potential for toxicity from these metals (Poulton et al. 2005).

Echols et al. (2008) also analyzed metal (nickel, zinc, copper, cadmium, and lead) concentrations in LOMR depositional sediments. Metal concentrations in the depositional sediments of the LOMR were found to be within the following ranges: 9.4 ± 1.8 micrograms per gram (µg/g) for nickel, 6.4 ± 1.4 µg/g for copper, 28 ± 18 µg/g for zinc, 0.42 ± 0.11 µg/g for cadmium, and 13 ± 6 µg/g for lead (Echols et al. 2008). Metal concentrations tended to increase downstream of Kansas City in the Kansas City, Waverly, Jefferson City, and St. Charles segments, particularly near the Blue River confluence with the LOMR (Echols et al. 2008). Despite the increase of metal concentrations in depositional sediment downstream of Kansas City, metals concentrations found were below published levels that would cause adverse effects to organisms.

Acid-volatile sulfides typically interact with metals to render the metal biologically immobile by interacting with the metal to form a highly insoluble and stable sulfide. Echols et al. (2008) also found moderately high levels of acid-volatile sulfide in the tested depositional sediments. Testing in the LOMR that found high levels of acid-volatile sulfide concentrations relative to metals suggest a low potential toxicity and bioavailability of zinc, copper, cadmium, and lead in the tested sediments (Echols et al. 2008).

Due to the exchange of water between the alluvial aquifer and the LOMR (see Section 3.7.3), there is a potential for contaminated groundwater to enter interstitial pore water in the river, as well as the water column. A USGS study at a site located upstream of the Project area near Omaha, Nebraska found that, even with a constant influx of metal-contaminated groundwater into the sediment pore water near an abandoned lead refinery, none of the USEPA toxicity thresholds were exceeded (Chapman et al. 2001). This study suggests that, even in areas where there are known consistent metal inputs into the sediment via groundwater, pore water may not exceed USEPA toxicity thresholds.

Ongoing dredging operations disturb sediment and pore water that may contain elevated metal concentrations. The USGS study in Omaha, Nebraska suggests that, even if metal-contaminated pore water is released, waters would not be sufficiently toxic to exceed USEPA toxicity thresholds. The mobilization of fine suspended sediments during current dredging activities could alter the acid-volatile sulfides concentration, which would alter the bioavailability of any metals present in the sediment (Echols et al. 2008). Because the testing at the 19 sites in the LOMR did not identify any metal concentrations in sediments that were above probable effects level guidelines, Echols et al. (2008)

concluded that any alteration of the acid-volatile sulfide content as a result of sediment mobilization would not result in the bioavailability of metals in sufficiently high concentrations to cause toxicological effects. The results of these two studies suggest that the disturbance of any sediment contaminated with metals, such as through dredging, would not result in a significant increase in toxicity.

3.7.4 Groundwater

The LOMR alluvial aquifer serves as a water source for municipal drinking water and several commercial uses; including irrigation, manufacturing, and food processing (see Section 3.5). Extending from the Iowa/Missouri border to the confluence of the LOMR with the Mississippi River, the alluvial aquifer is comprised of sediment from glacial drift and loess in the LOMR floodplain that lie atop shale, limestone, and sandstone bedrock (Miller and Appel 1997, Hedman and Jorgenson 1990, USGS 2003, Emmett and Jeffery 1970). These alluvial deposits sitting atop the bedrock form the alluvial aquifer. Figure 3.7-1 depicts an average cross section of the LOMR and the geologic composition of the alluvial aquifer. A typical alluvial deposit cross section includes several meters of fine-grained clays and silts; underlain by a thick layer of sand and gravel-sand; followed by a thin layer of sandy-gravel, gravel, and/or boulders in the deepest part of the aquifer (USGS 2003). These alluvial deposits typically increase in coarseness (from sand to cobble), with depth and sediment increases in age from recent Holocene to Wisconsinan-age alluvial deposits of glacial origin (USGS 2003, Kelly 2004). Pennsylvanian-aged shale, limestone, and sandstone bedrock form the bottom and side boundaries of the alluvial aquifer (USGS 2003).

Alluvial deposits fill the entrenched bedrock valley, which typically ranges between 4 and 15 miles in width (Hedman and Jorgenson 1990). In several locations, however, the LOMR hugs the bluff line, limiting the alluvial aquifer width to near nothing (Miller and Vandike 1997). In general, the alluvial aquifer is widest upstream of Howard County, Missouri (the St. Joseph, Kansas City, Waverly, and Jefferson City segments) (Miller and Vandike 1997). The alluvial aquifer thickness is reported as typically from 80 to 90 feet (Miller and Appel 1997, USGS 2003, Emmett and Jeffery 1970, Kelly 2004), but the thickness can locally range from 3 to 300 feet (USGS 2003, Hedman and Jorgenson 1990, USACE 2008). Locally, the alluvial aquifer can be confined or unconfined, depending on site geology and groundwater levels that typically range from 1 foot to more than 20 feet below ground surface (Miller and Vandike 1997).

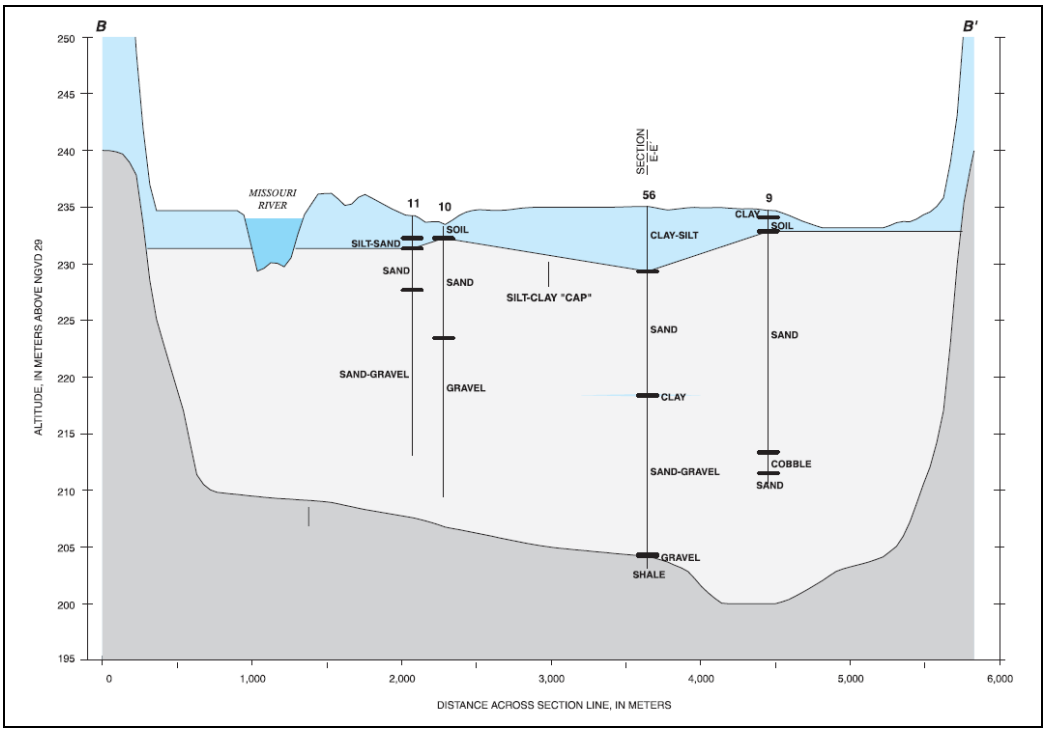

Figure 3.7-1 Cross Section of the Missouri River Alluvial Aquifer

Source: Kelly 2004.

Recharge of the alluvial aquifer can vary locally, depending on specific hydrologic characteristics of the alluvial material (Miller and Vandike 1997). In general, recharge is driven by water exchange from the LOMR during high stream flow, precipitation, and groundwater inflow from underlying, permeable bedrock aquifers (Miller and Appel 1997). The rate of exchange between bedrock aquifers and the alluvial aquifer have largely not been quantified, but the rate is believed to be negligible compared to the rate of exchange between the LOMR and the alluvial aquifer (USGS 2003). Similarly, the alluvial aquifer does not respond appreciably to precipitation (Miller and Vandike 1997). Because the LOMR stream bed has a high hydraulic conductivity and the bottom of the river channel is below the top of the groundwater potentiometric surface (the level to which groundwater would rise if not trapped in a confined aquifer) in most areas, the LOMR is hydraulically linked to the alluvial aquifer, which results in the river stage having a large impact on the alluvial aquifer (Hedman and Jorgenson 1990, Miller and Vandike 1997, Kelly 2004). Because of the hydrologic connection between the LOMR and the alluvial aquifer, increases in LOMR stage—with respect to the potentiometric surface—result in water flow from the LOMR to the alluvial aquifer (Kelly 2004). Conversely, decreased river stage results in water flowing from the alluvial aquifer to the LOMR (Kelly 2004).

The magnitude of change in the potentiometric surface altitude and the associated response in groundwater levels at a particular location are controlled by multiple factors, including the magnitude of river stage change, the length of time the river maintains a particular stage, the localized hydraulic properties of the aquifer materials, and distance from the river (Kelly 2004). Flood pulse simulations indicate that groundwater levels show little response to small, temporary river stage fluctuations; but large river-stage increases of long duration affect groundwater levels (Kelly 2000). Groundwater flow modeling conducted by Kelly (2000, 2001) indicated that groundwater changes rose during flood pulses at shorter distances from the river and then continued through the alluvium at a delay as distance from the river increased. Groundwater levels continued to rise at distances farther from the river after the flood pulse. Because the groundwater changes associated with river stage lag behind the actual changes in river stage, the rate that groundwater responds with increasing distance from the river is less in magnitude (Kelly 2000, 2001). Typically, due to the delayed response of groundwater at greater distances from the LOMR, changes to river stage that occur over a short duration have an effect (or more dramatic effect) on groundwater levels close to the river, compared to areas close to the outer periphery of the aquifer (Kelly 2004).

The USACE, in coordination with the USGS, operates several alluvial aquifer groundwater monitoring wells along the LOMR (near Forest City, Atherton, and Hermann). Initial data were collected in support of the Master Manual Review and Update EIS (USACE 2004). Three of the five monitoring wells are located within the Project area (at RM 96, RM 345, and RM 471) and are used to conduct annual monitoring of groundwater responses to river stage (USACE 2008). All monitoring wells were installed within 1,000 feet of the LOMR to capture groundwater-level responses to changes in river stages (USACE 2008). Of these three monitoring wells, two (located near Atherton and Hermann) were very responsive to river stage. Figure 3.7-2 depicts the 2008 groundwater response at Atherton, Missouri compared to river stage at the Kansas City, Missouri river gage. As shown in Figure 3.7-2, the maximum groundwater change over the monitoring period was approximately 13 feet, while the maximum change in river stage was 17 feet (USACE 2008).

Several localized conditions may alter groundwater well production with river stage, including the localized hydraulic properties of the aquifer near a well field, the pumping rate from the field, and the proximity to other pumping wells (USGS 2003). As described above, typically, increased river stage results in a lowering of the regional groundwater gradient between the alluvial aquifer and the river (Kelly 2004). As can be seen with the USACE monitoring wells described above, depending on site-specific factors, this connection between the LOMR stage and groundwater levels does not occur uniformly.

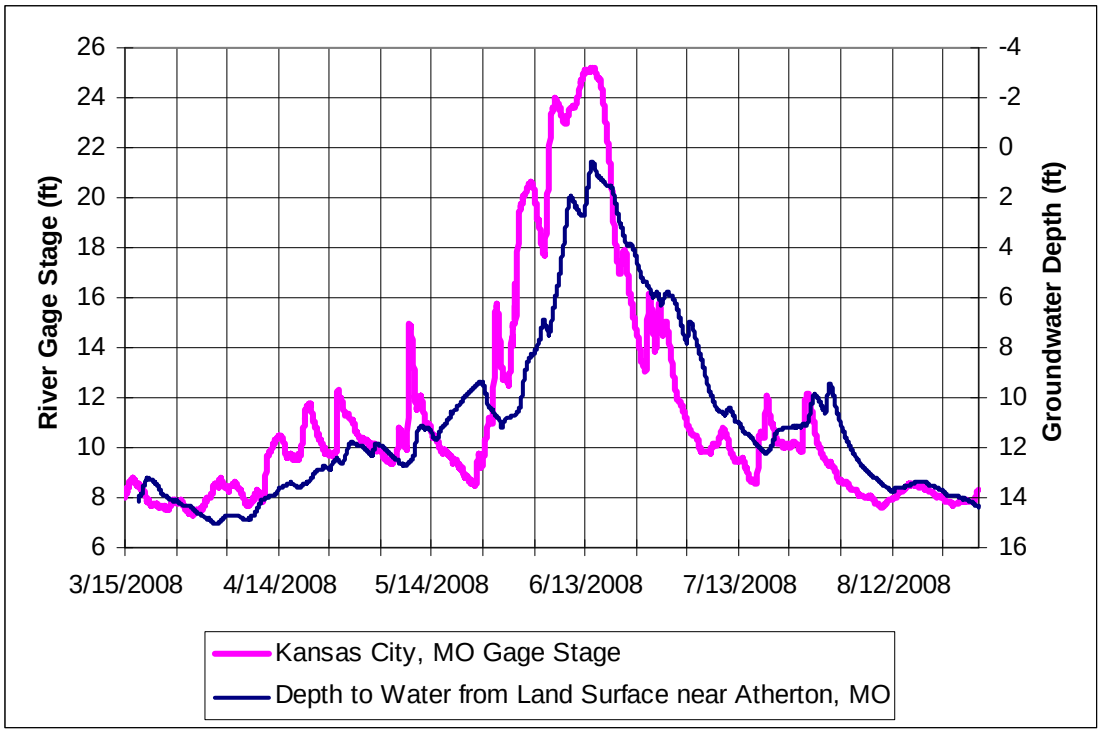

Figure 3.7-2 Depth to Groundwater at a Monitoring Well in Atherton, Missouri and River Stage Data at Kansas City, Missouri (March 15 to August 28, 2008)

Source: USACE 2008.

As discussed in Section 3.4.5.4, several factors contribute to river bed degradation in the LOMR, including commercial dredging for sand and aggregate. River stage at various flows is determined by a number of channel geometry and hydraulic factors. At lower flows, when most of the flow of the Missouri River is through the navigation channel, the bottom elevation of the general area of the navigation channel has a direct effect on river stage. At higher flows, the entire cross-sectional geometry of the river, including elevations and confinement of the channel by the banks, revetments, and dikes, becomes the controlling hydraulic feature; and the importance of the bottom elevation of the navigation channel decreases substantially. For this reason, degradation has a greater effect on water surface elevation at lower flows and less effect on river stage at higher flows. As discussed above, river stage is one of the primary drivers of alluvial aquifer levels in most locations along the LOMR.

Due to the interaction between the alluvial aquifer and the river stage, it can be inferred that river bed degradation that affects river stage would affect water levels in the alluvial aquifer. But river stages at lower flows are not the only factor determining alluvial aquifer levels (Kelly 2000). The influences of

river stage on alluvial aquifer levels are complex. They depend on the magnitude and duration of medium to high flows as well as low-flow conditions, and they change seasonally and annually. To date, no definitive studies have been completed that document the dynamic interaction between river bed degradation and alluvial aquifer levels (Kelly pers. comm.). Correspondence with the USGS has indicated that a study evaluating the changes in groundwater levels in the alluvial aquifer associated with river bed degradation between St. Joseph and Waverly, Missouri will commence in summer 2010 (Kelly pers. comm.).

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3.7.5.1 Personal Communication

Kelly, B. P. U.S. Geological Survey. Telephone conversation between B. Kelly and Katey Grange (ENTRIX) regarding the linkage between river bed degradation and alluvial aquifer levels on the Lower Missouri River. February 2, 2010.

3.8 AQUATIC RESOURCES

3.8.1 Introduction

This section describes the aquatic habitats and organisms occurring in the LOMR that may be affected by the Proposed Action or the alternatives. The existing conditions described in this section are based on the current state of the Missouri River, in contrast to its historical condition, which was very different from today. Various sources of information were used to compile the affected environment, including field investigation reports, geographic information systems (GIS) data, literature searches, and review of maps and aerial photography. The spatial scope of the aquatic resources assessment includes the main channel and floodplain of the LOMR and main tributary mouths from Gavins Point Dam and the LOMR confluence with the Mississippi River.

3.8.2 Regulatory Setting

Aquatic resources in the Project area are protected or regulated by a variety of federal and state laws and policies. Key regulatory and conservation planning issues applicable to the Proposed Action and the alternatives are discussed below.

3.8.2.1 Federal

The Missouri River Recovery Program and the Missouri River Mitigation Project are related projects with objectives to enhance, restore, and mitigate the Missouri River's fish and wildlife habitat and hydrology. The locations and types of mitigation projects implemented by these programs and the potential for overlap with areas of the Proposed Action and the alternatives were considered in the analysis.

The Missouri River Recovery Program is a partnership between the USACE and the USFWS. They are conducting a collaborative, long-term study authorized by the Water Resources Development Act of 2007. The Missouri River Ecosystem Restoration Plan and Environmental Impact Statement will identify the actions required to mitigate losses of aquatic and terrestrial habitat; recover federally listed species under the Endangered Species Act; and restore the ecosystem to prevent further declines among other native species. The Missouri River Recovery Program will result in a plan that guides the USACE mitigation, restoration, and recovery efforts for the Missouri River for the next 30–50 years.

The USACE, in cooperation with state and federal fish and wildlife agencies as well as interested state and local groups, formed the Missouri River Mitigation Project. The project extends from Sioux City, Iowa to the mouth of the Missouri River near St. Louis, a length of 735 river miles. The Project's goal is to develop, on a site-by-site basis, mitigation for fish and wildlife habitat losses that resulted from past channelization efforts on the Missouri River. This is achieved by acquiring and developing aquatic and terrestrial habitat on individual sites, creating new wildlife areas, improving existing areas, and returning certain river features to historical conditions.

3.8.2.2 State

Bordering states of the LOMR manage sensitive species lists and conservation areas through their respective conservation programs (see Table 3.8-1).

Table 3.8-1 Governing Agencies Maintaining Special-Status Species List

State	Agency
Kansas	Kansas Department of Wildlife and Parks
Missouri	Missouri Department of Conservation
Nebraska	Nebraska Game and Parks Commission

3.8.3 Status of Aquatic Resources

The aquatic resources of the LOMR have been considerably altered because of development of the river during the 1900s for hydropower, flood control, navigation, and bank stabilization. The habitat available to aquatic organisms has been greatly simplified—chutes and side channels have been blocked and diverted, converting the once structurally complex, multi-channeled river into a single, stationary thread of deep, fast-moving water (Hesse 1995).

To mitigate these effects, aquatic habitats have been and continue to be constructed along the LOMR under the authority of the USACE Missouri River Recovery Program, in cooperation with local, state, and federal agencies (Van Sterner et al. 2009). These include bank notches, dike notches, and chute construction to create shallow-water habitat for warm-water fishes; and there are plans for additional similar projects.

To evaluate effects on aquatic resources, species were organized into guilds and communities and are described in the following sections.

3.8.4 Fishes

Fish species documented in the Missouri River include a wide variety of native and introduced species. Approximately 150 fish species are known to occur in the Missouri River basin (Hesse 1995, Galat et al. 2005). Fifty-four percent of the fish are classified as residing primarily in the main channel, and 93 percent of these are fluvial (river) dependent or fluvial specialists (Berry, Wildhaber, and Galat 2004).

Common fish species in the lower Missouri River include emerald shiner (*Notropis atherinoides*), river carpsucker (*Carpiodes carpio*), channel catfish (*Ictalurus punctatus*), gizzard shad (*Dorosoma cepedianum*), red shiner (*N. lutrensis*), shorthead redhorse (*Moxostoma macrolepidotum*), carp (*Cyprinus carpio*), bighead carp *(Hypophthalmichthys nobilis)*, silver carp (*Hypophthalmichthys molitrix*), and goldeye (*Hiodon alosoides*) (USACE 2004).

Sport fish include channel catfish, blue catfish *(Ictalurus furcatus)* crappie (*Pomoxis* spp.), sauger (*Stizostedion canadense*), flathead catfish (*Pylodictus olivaris*), white bass (*Morone chrysops*), bluegill (*Lepomis macrochirus*), and paddlefish (USACE 2004). Species important to the commercial fishery on the lower Missouri River include buffalo (*Ictiobus* spp.), carp, carpsucker, and freshwater drum (*Aplodinotus grunniens*).

3.8.4.1 Fish Guilds

Use of fish guilds for the effects analysis is a practical and useful method for large-scale projects (Austen, Bayley, and Menzel 1994). Galat et al. (2004) used occurrence and distribution data on Missouri River fishes from recent publications (Hesse et al. 1989, 1993) and summarized fish use of habitats by placing each species into a macrohabitat guild category.

Benthic Fish Guild

Benthic fishes are species that use the river bottom for much of their life requirements, rather than using mid-depths or off channel habitats. The benthic fish guild includes commercial and recreational species, and a group of prey species that are important to river ecology and to the food webs of fish predators. Table 3.8-2 lists species grouped in the benthic fish guild.

Table 3.8-2 Common and Scientific Names of Species in the Benthic Fish Guild [a].

Federally and State-Listed Species[a]	Recreational Species	Commercial Species	Prey Species
Pallid sturgeon *Scaphirhynchus albus*	Channel catfish *Ictalurus punctatus*	Bigmouth buffalo *Ictiobus cyprinellus*	White sucker *Catostomus commersonii*
Flathead chub *Platygobio gracilis*	Blue catfish *Ictalurus furcatus*	Common carp *Cyprinus carpio*	Stonecat *Noturus flavus*
Sturgeon chub *Macrhybopsis gelida*	Flathead catfish *Plyodictis olivaris*	Smallmouth buffalo *Ictiobus bubalus*	Shorthead redhorse *Moxostoma macrolepidotum*
Sicklefin chub *Macrhybopsis meeki*	Walleye *Sander vitreum*		Fathead minnow *Pimephales promelas*
W. Silvery minnow *Hybognathus argyritis*	Sauger *Sander canadense*		Brassy minnow *Hybognathus hankinsoni*
Plains minnow *Hybognathus placitus*	Freshwater drum *Aplodinotus grunniens*		Sand shiner *Notropis stramineus*
Blue sucker *Cycleptus elongatus*			River carpsucker *Carpiodes carpio*
Shovelnose sturgeon *Scaphirhynchus platorynchus*			

[a] The "Federally and State-Listed Species" category refers to federally listed species and species listed by states as "species of concern" (modified from Berry, Wildhaber, and Galat 2004).

3.8.5 Other Aquatic Biota

Benthic Macroinvertebrates

Benthic invertebrates are a crucial part of the food web and an important food source for fishes, waterfowl, and shorebirds (Augustin, Grubaugh, and Marshall 1999; Brown et al. 2001). Migrant shorebirds spend most of their time foraging (Brown et al. 2001), thus invertebrate abundance and availability are important to meet the nutritional requirements for migration and recruitment.

Rich communities of benthic macroinvertebrates occur in the Missouri River, but their abundance is greater in the upper reaches (Galat et al. 2005, Poulton et al. 2003). Poulton (2004) identified benthic macroinvertebrate communities in the channelized reach of the lower Missouri River. Nearly one third of these taxa collected belonged to the sensitive insect orders (*Ephemeroptera*, *Plecoptera*, *Odonata*, and *Trichoptera*). In addition, Poulton et al. (2003) and Poulton (2004) found that artificial rock (material placed for bank and channel stability or for dike structures) contained a diverse macroinvertebrate community.

Freshwater Mussels

Prior to dam installation and channelization, mussel populations were noted in upper Missouri River tributaries but not in the mainstem (Hayden 1862; Over 1915; Coker and Southall 1915, as cited in Shearer et al. 2005). The mainstem Missouri River had been regarded as too turbid, sandy, and unstable to provide suitable habitat for mussels. After dam installation and channelization, Hoke (1983 as cited in Shearer, Backlund, and Wilson 2005) observed 13 mussel in the LOMR species along the Nebraska border; Perkins and Backlund's (2000) observed 19 species of freshwater mussels in a survey from Gavins Point Dam downstream to Ponca, Nebraska.

Recent literature reviews identified dams as one of the primary causes for mussel declines and extinctions (Freeman et al. 2003, Lydeard et al. 2004). Upstream of dams, mussels depend on migratory fish hosts because their distribution is blocked by the dam. The area immediately downstream of the dams provides some suitable habitat for mussels. Perkins and Backlund (2000) note that conditions immediately downstream of Gavins Point Dam appear more productive for mussels due to firm substrates and nutrient-rich waters. Watters and Dunn (1995) support those observations by stating that, after dam construction in the Muskingam River in Ohio, widespread mussel distribution was drastically reduced to within a few miles of the dam–where oxygen-rich, clearer water and silt-free, stable substrate existed. Farther downstream of the dams, however, substrate instability and degradation from hydraulic regulation make it difficult for populations to persist or establish. Although mussel species are capable of reestablishing after being displaced (Waller, Gutreuter, and Rach 1999), evidence supports the need for stable environments for productive shellfish communities.

Historically, natural flood events mobilized the benthic environment, which resulted in mortality of some individuals, but this mortality was compensated for on a population level through species diversity, abundance, and widespread use of the benthic environment. Channel bottoms also maintained variable substrate sizes that provided a more stable environment in flood stages. Today, easily-mobilized sand and silt loads route through the Missouri River. Formerly seasonal, flood-related sediment movement is now continual because of decreased width and incised channel characteristics, and dike-diverted flows that have reduced the amount of stable habitats for mussels to establish. Mussels that establish in dredge areas can be destroyed by entrainment or mechanical damage. Mussels directly downstream of dredging activity could be smothered, in particular those species not tolerant to fine sediment or silt, or they can be adversely affected by the re-suspension of contaminants because they are filter feeders (Waters 2000). Headcutting in areas upstream of dredging and

tributaries can also affect mussels by mobilizing sediment, creating loss of habitat, and displacing shellfish (Waters 2000).

Plankton and Periphyton

Few studies have focused specifically on phytoplankton, zooplankton, and periphyton assemblages in the LOMR. Less is known regarding the effects of flooding on zooplankton in regulated rivers where floods are infrequent and water movement between the main channel and floodplain is limited (Hesse, Wolfe, and Cole 1988). In general, phytoplankton populations in the Project area are environmentally regulated by light, temperature, nutrients, and predation by zooplankton. If toxic levels of contaminants are present, they may result in local and temporary adverse effects on populations. Recent studies have shown that algal abundance in some rivers is comparable to moderately productive lentic (still water) systems with a well established plankton-based food web (Saunders and Lewis 1989).

Aquatic Plants

Aquatic vegetation is almost non-existent in the main channel of the LOMR because of high turbidity, unstable substrate, and variable discharge (Galat et al. 2005, 2001). Young cottonwoods (*Populus deltoides*) and willows (*Salix* sp.) primarily comprise the sparse vegetation found on sand bars (Galat, Wildhaber, and Dieterman 2005).

3.8.6 Special-Status Species

Special-status aquatic species that have not been federally listed as threatened or endangered with the potential to occur in the Project area are listed in Table 3.8-3. This table also identifies their habitat requirements, and assesses the likelihood of their occurrence in the Project area. Further, several fish species have been identified by the Kansas Department of Wildlife and Parks as potentially having state-listed critical habitat in the portions of the LOMR crossing through Kansas. Fish with potential critical habitat within the Project area include chestnut lamprey, flathead chub, pallid sturgeon (see Section 3.10), sicklefin chub, silver, chub, silverband shiner, sturgeon chub, and western silvery minnow. Federally listed special-status aquatic species are further addressed in Section 3.10.

Table 3.8-3 Special-Status Aquatic Species with the Potential to Occur in the Project Area

Common Name *Scientific Name*	Federal Status[a]	Missouri Status	Kansas Status	Nebraska Status	Habitat	Likelihood of Occurrence in the Study Area	Species Assessed in this Document?
Blue sucker *Cycleptus elongatus*			SINC		Species concentrates in chutes or rapids where the water is deep and the bottom is rocky, free of silt.	Occurs in the Missouri and Kansas Rivers	Yes
Brassy minnow *Hybognathus hankinsoni*			SINC		Prefers small clear streams with sluggish current and sandy bottoms overlaid by organic sediment, but this species is found in a small portion of the Missouri River.	Occurs in the Missouri River in Atchison County, Kansas	Yes
Chestnut lamprey *Ichthyomyzon castaneus*			T-CH		Species is parasitic to large fish (such as carp) in adult stage and larvae remain in bottom sediment of pools.	Species may occur in the Missouri River and lower Kansas River	Yes
Flathead chub *Platygobio gracilis*		E	T-CH		Species occurs in diverse habitats: pools of small creeks with moderately clear water over gravel and bedrock bottom or in large, turbid rivers with swift current and bottom of fine sand and gravel.	Occurs in the Missouri River	Yes
Lake sturgeon *Acipenser fulvescens*		E		T	Species occurs in large rivers over firm sand, gravel, or rocky bottom.	Species may occur in the Missouri River, in Missouri	Yes
Plains minnow *Hybognathus placitus*			SINC		Species prefers streams where sediments accumulate in shallow backwaters.	Species may occur in backwaters in the Missouri River	Yes
River shiner *Notropis blennius*			SINC		Species prefers flowing water over sand bottoms in large streams with broad, exposed channels.	Occurs in the Missouri River	Yes
Shovelnose sturgeon *Scaphirhynchus platorynchus*					Species inhabits open channels of large rivers with a swift current over a sand or gravel bottom. Species tolerates high turbidity.	Occurs commonly in the Missouri River	Yes

Table 3.8-3 Special-Status Aquatic Species with the Potential to Occur in the Project Area

Sicklefin chub *Macrhybopsis meeki*		S3	E-CH		Species prefers the main channels of large turbid rivers with sand or fine gravel bottoms and strong current	Occurs in the mainstem Missouri River	Yes
Silver chub *Macrhybopsis storeriana*		S3	E-CH		Species is found in large sandy rivers near bottom sediments.	Occurs in the mainstem Missouri River	Yes
Silverband shiner *Notropis shumardi*		S3	T-CH		Species inhabits deep water where flow is sluggish and bottoms are silted but also occurs in strong currents of the main channel.	Occurs in the mainstem Missouri River	Yes
Sturgeon chub *Macrhybopsis gelida*		S3	T-CH	E (Nemaha County)	Species prefers large, turbid sandy rivers over substrate of small gravel and coarse sand.	Occurs in the mainstem Missouri River	Yes
Tadpole madtom *Norturus gyrinus*			SINC		Species is found beneath woody debris or vegetation during the day. Usually lives on a mud bottom.	Occurs in tributaries of the Missouri River near Atchison	Yes
Western silvery minnow *Hybognathus argyritis*		S2	T-CH		Species prefers relatively deep water where flow is sluggish and bottoms are silted, but it does occur in strong currents of the mainstream.	Occurs in the mainstem Missouri River	Yes

[a] Species Status:

C = Candidate for federal listing as endangered under the Endangered Species Act.
CH = Critical habitat has been designated in the State of Kansas.
SINC = Species in Need of Conservation in the State of Kansas.
E = Endangered.
KS = Kansas.
MO = Missouri.
NE = Nebraska.
T = Threatened.

Sources: www.ngpc.state.ne.us, www.mdc.mo.gov/nathis/endangered/endanger/, mdc4.mdc.mo.gov/applications/mofwis/Mofwis_Search1.aspx, kdwp.state.ks.us/news/Other-Services/Threatened-and-Endangered-Species.

3.8.7 Habitats of the of the Lower Missouri River

This section describes the habitat types within with the Project area and the species commonly associated with those habitat types that could be affected by the Proposed Action or the alternatives. Habitat for aquatic organisms is generally defined as the three-dimensional structure of physical and chemical characteristics in which the organism lives and varies spatially within a river channel and over time (Poff and Ward 1989). The combination of physical characteristics (velocity, depth, turbidity, and substrate size) and other factors, such as temperature, combine to create a range of habitats. Riverine physical aquatic habitat is substantially dependent on the interaction between flow regime and channel morphology (Jacobson and Galat 2006). Spatial variation of habitat in the LOMR is due to the hydraulic influence of wing dikes and other navigation structures (Jacobson, Laustrup, and Reuter 2002). Habitat varies over time with discharge, resulting in new combinations of depth, velocity, and substrate for a given discharge (Jacobson, Laustrup, and Reuter 2002). In general, habitats associated with islands, sand bars, and backwaters have declined over time in the LOMR; whereas deep and swift main channel habitats have increased (NRC 2002). The primary habitats in the Project area that are important to the life history needs of aquatic organisms are defined below. Figure 3.8-1 shows the general layout of habitats found in the LOMR.

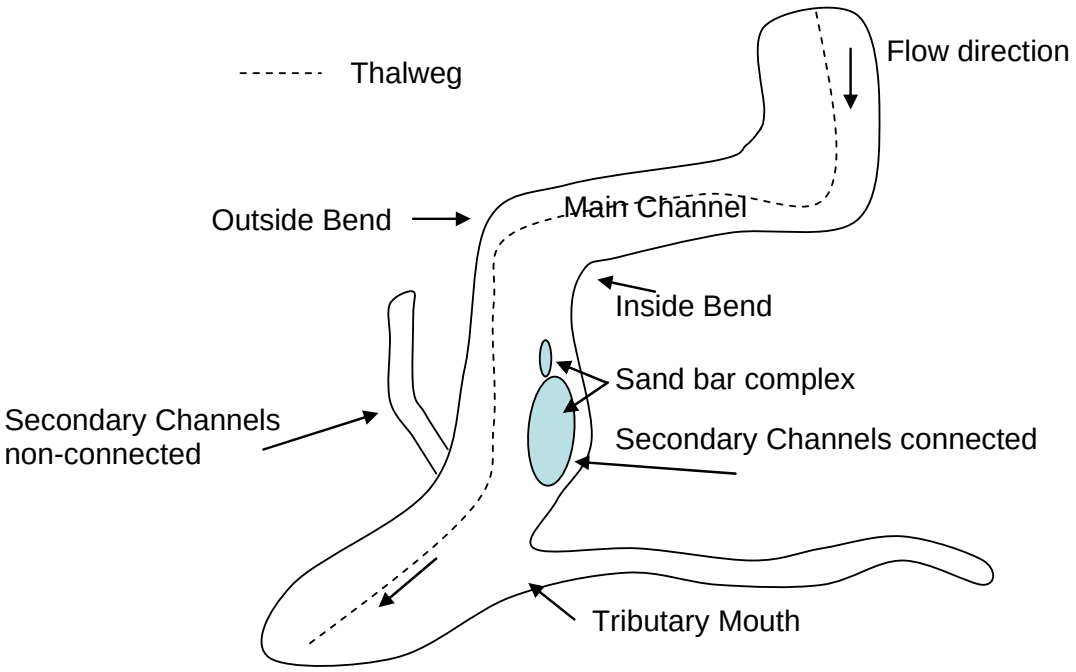

Figure 3.8-1 Schematic of Habitats Found in the Lower Missouri River (modified from Berry et al. 2004)

The dynamic condition of the LOMR prior to channelization and impoundment was one of annual flow fluctuations and large amounts of suspended sediment. The reduction of bed roughness and substrate diversity subsequent to channelization and impoundment has affected the overall productivity of the river, and in particular, the reproductive success of substrate spawners (Hesse et al. 1993).

3.8.7.1 Main Channel

The main channel conveys the majority of the river discharge and has the highest water velocities. The deepest part of the main channel is typically defined as the thalweg and is usually associated with the middle parts of the river. Certain benthic fish, such as adult and juvenile sturgeon, tend to use habitats in and adjacent to main channels where environmental conditions can include bed load sediment transport and high near-bed flow velocities (Hurley et al. 2004). The main channel habitat can be grouped into three macrohabitat types: slow-velocity macrohabitats (tributary mouth, secondary channel non-connected), moderate-velocity areas (inside bends, secondary channels connected), and high-velocity areas (channel crossovers, outside bends).

3.8.7.2 Sand Bar Complexes

Sand bars in large rivers are generally defined by a ridge of silt or sand formed by the action of currents. Lee (2007) found that macroinvertebrate and larval fish abundance and distribution on sand bars were dependent on fine substrates, habitat complexity (e.g., the presence of tertiary channels), low current velocity, and temperature. The most common aquatic macroinvertebrate orders collected by Lee (2007) in sand bar complexes were *Diptera*, *Hemiptera*, *Coleoptera*, *Bivalvia*, and *Ephemeroptera*; the most frequent families were *Chironomidae*, *Ceratopogonidae*, *Corixidae*, *Heteroceridae*, and *Sphaeriidae*.

3.8.7.3 Shallow-Water Habitat

Shallow-water habitat is considered by the USFWS (2003) as shallow open water areas (e.g., submerged sand bars, main channel/side channel convergence areas, and island tips) connected to the Missouri River channel that are less than 5 feet deep and have a variable velocity of flow. Construction of dikes and revetments has narrowed and deepened the LOMR main channel and has prevented channel migration, which has greatly eliminated shallow-water habitat and increased water depth and current velocity (NRC 2002). In general, depths of 0–7 feet (0–2.1 m), and velocities less than 2.5 feet per second (76 centimeters per second) over sand bars are the preferred main channel habitat of

species such as sauger, channel catfish, shovelnose sturgeon, and blue sucker during all or some of their life history (USFWS 2000). Survival and growth of many juvenile riverine fish are associated with the availability of shallow water with slower water velocities (Hesse et al. 1993, 1989; Galat et al. 2005). Several species spawn in shallow-water habitat. After hatching, the juveniles rear in low water-velocity regions until the juveniles are large enough to survive and avoid predation in the main channel, which has higher water velocities. While some species are dependent on shallow-water habitats for spawning and juvenile stages, many aquatic species spend their entire lifetime in the portions of the river with low water velocities.

3.8.8 References

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3.9 WETLANDS, FLOODPLAINS, AND TERRESTRIAL RESOURCES

3.9.1 Introduction

The Proposed Action and alternatives have the potential to indirectly affect wildlife and wetland habitats and functions. Ongoing commercial dredging in the Missouri River has contributed to degradation of the river bed, especially in the Kansas City segment (Stark et al. 2000, USACE 2008 and 2009). River bed degradation affects the river stage level. River stage levels affect the frequency, depth, and duration of surface water interaction with adjacent wetlands in the floodplain, as well as the level of the alluvial aquifer that supports groundwater wetlands. Consequently, commercial dredging has the potential to indirectly affect wetland habitats adjacent to the Missouri River and its floodplain.

This section presents an overview of wetland and terrestrial wildlife resources that could be directly or indirectly affected by commercial dredging under the Proposed Action and the alternatives. A description of wetland types in the Project area and their characteristic vegetation (Section 3.9.4) is provided, along with a discussion of the hydrologic connections between the Missouri River and adjacent wetlands (Section 3.9.5), and a general discussion of functions and values of Project area wetlands (Section 3.9.6). Terrestrial wildlife resources, including special-status species and managed wildlife habitat, are presented in Sections 3.9.7 and 3.9.8. Information used in the preparation of this section was collected from existing sources, including published literature and technical reports.

The LOMR ecosystem from RM 0 to RM 489 includes both the channel of the LOMR and its floodplain, which is the area adjacent to the LOMR that is subject to flooding. The floodplain generally includes all of the land area between the bluffs bordering the river; and the floodplain typically ranges from 1 to 17 miles in width, with an average width of 5 miles (Weaver 1960; Galat, Robinson, and Hesse 1994). Between RM 0 and RM 489, the floodplain is generally 2 to 3 miles wide (Burns and McDonnell 1995). Although much of the floodplain has been converted to agriculture and other uses, substantial amounts of wetlands and riparian forest are still present.

According to the federal definition, wetlands are “those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (33 CFR 328.3[b]; 40 CFR 2303.[t]). Wetlands normally support, and are identified by, hydrophytic vegetation, hydric soil, and wetland hydrology (Environmental Laboratory 1987). Wetlands are distributed along the LOMR. They usually occur as small patches along the river banks; on islands

in the river channel; in association with streams, ponds, oxbow lakes and mudflats; or in managed wetland areas (Burns and McDonnell 1995, Kelly 2001).

3.9.2 Regulatory Setting

3.9.2.1 Federal

Clean Water Act Section 404

Section 404 of the CWA requires authorization from the Secretary of the Army, acting through the USACE, for the discharge of dredged or fill material into all waters of the United States, including wetlands. Discharges of fill material generally include, without limitation, placement of fill that is necessary for the construction of any structure or impoundment requiring rock, sand, dirt, or other material for its construction; site-development fills for recreational, industrial, commercial, residential, and other uses; causeways or road fills; dams and dikes; artificial islands; property protection or reclamation devices such as riprap, groins, seawalls, breakwaters, and revetments; beach nourishment; levees; fill for intake and outfall pipes and subaqueous utility lines; fill associated with the creation of ponds; and any other work involving the discharge of fill or dredged material. A USACE permit is required whether the work is permanent or temporary. Examples of temporary discharges include dewatering of dredged material prior to final disposal and temporary fills for access roadways, cofferdams, and storage and work areas.

Executive Order 11990: Protection of Wetlands

EO 11990 (May 24, 1977) directs all federal agencies to refrain from assisting in or giving financial support to projects that encroach on public or privately owned wetlands. It further requires that federal agencies must support a policy to minimize the destruction, loss, or degradation of wetlands. Such a project (that encroaches on wetlands) may not be undertaken unless the agency has determined that (1) there are no practical alternatives to such construction; (2) the proposed action includes all practical measures to minimize harm to wetlands that would be affected by the project; and (3) the impact will be minor.

U.S. Department of Agricultural Programs

Under the Food, Conservation, and Energy Act of 2008 (referred to as the 2008 Farm Bill), the USDA continued the Wetland Reserve Program (WRP). The WRP is a voluntary landowner program to protect, restore, and enhance wetlands on their property (NRCS 2010a). This program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection on their property. Landowners obtain technical and financial support for wetland restoration efforts from the USDA Natural Resources Conservation Service (NRCS). The NRCS goal is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. Other USDA programs, among many, that target habitat creation, restoration, enhancement, and conservation in agricultural lands include the Environmental Quality Incentives Program, the Conservation Reserve Program (CRP), and the Conservation Stewardship Program (NRCS 2010b).

Water Resources Development Act of 1986

The Water Resources Development Act of 1986 authorized implementation of the Missouri River Mitigation Project. The act provided for acquisition and development of 29,900 acres of land, and development of fish and wildlife habitat on an additional 18,200 acres of existing public land in the states of Iowa, Nebraska, Kansas, and Missouri.

Water Resources Development Act of 1999

The Water Resources Development Act of 1999 authorized modifying the Missouri River Mitigation Project by increasing the amount of acquisition acreage to 118,650 acres.

Water Resources Development Act of 2007

The Water Resources Development Act of 2007 authorized a study of the Missouri River to determine actions required to mitigate the loss of aquatic and terrestrial habitat, recover federally listed species, and restore the ecosystem.

Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act[1] (16 USC 668-668c), enacted in 1940 and amended several times, prohibits "taking" bald eagles (*Haliaeetus leucocephalus),* including their parts, nests, or eggs, without a permit issued by the Secretary of the Interior.

Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) of 1918, as amended[2] is regulated by the USFWS. The MBTA was proposed to put an end to the commercial trade in birds and their feathers that, by the early years of the 20th century, had wreaked havoc on the populations of many native bird species. The MBTA makes it illegal to pursue, hunt, take, capture, or kill or attempt to take, capture, or kill any migratory bird or “any part, nest, or egg of any such bird by any means or in any manner,” except as allowed by permit. While the ESA defines the term “take” to include “to harm and harass,” including habitat modification, “take” under the MBTA is not as broadly defined and thus includes only direct killing of protected birds.

3.9.2.2 State

Clean Water Act Section 401

The USACE cannot issue or verify any permit under Section 404 of the CWA until a water quality certification, or waiver of certification, has been issued pursuant to CWA Section 401. Section 401 gives the USEPA review authority over issuance of Section 404 permits, although Section 401 allows the states to assume the authority for water quality review. Under state laws in Missouri, Kansas, and Nebraska, state agencies review whether an activity might result in a discharge that violates state or federal water quality standards, and the state provides a Water Quality Certification if these standards would be met.

[1] Bald Eagle Protection Act of 1940 (16 USC. 668–668d, 54 Stat. 250) as amended – Approved June 8, 1940, and amended by Public Law (PL) 86-70 (73 Stat. 143) June 25, 1959; PL 87-884 (76 Stat. 1346) October 24, 1962; PL 92-535 (86 Stat. 1064) October 23, 1972; and PL 95-616 (92 Stat. 3114) November 8, 1978.

[2] Migratory Bird Treaty Act of 1918 (16 USC 703–712; Ch. 128; July 13, 1918; 40 Stat. 755) as amended by: Chapter 634; June 20, 1936; 49 Stat. 1556; PL 86-732; September 8, 1960; 74 Stat. 866; PL 90-578; October 17, 1968; 82 Stat. 1118; PL 91-135; December 5, 1969; 83 Stat. 282; PL 93-300; June 1, 1974; 88 Stat. 190; PL 95-616; November 8, 1978; 92 Stat. 3111; PL 99-645; November 10, 1986; 100 Stat. 3590 and PL 105-312; October 30, 1998; 112 Stat. 2956.

Missouri Clean Water Law of 1973

In Missouri, the Clean Water Law of 1973 directs the MDNR to issue Section 401 Water Quality Certification.

Kansas Surface Water Quality Standards

The KDEH prepares Section 401 Water Quality Certification for projects in Kansas.

Nebraska Surface Water Quality Standards

The NDEQ oversees Section 401 Water Quality Certification for projects in Nebraska.

Missouri State Wildlife Conservation

The Missouri Department of Conservation is responsible for managing and protecting wildlife resources in the state of Missouri pursuant to the Code of State Regulations (CSR), Title 3 – Department of Conservation. Game and nongame species are identified and protected under Chapter 4 – Wildlife Code. Rule 3 CSR 10-4.110 prohibits the pursuit, taking, possession, or any use of wildlife except as provided in the Code. Rule 3 CSR 10-4.111 extends "special protection to endangered species and lists those species considered to be threatened with extinction [in the State of Missouri]."

Kansas State Wildlife Conservation

The KDWP is responsible for managing and protecting wildlife resources in the state of Kansas pursuant to the Kansas Nongame and Endangered Species Conservation Act of 1975. This act is defined under the Kansas Statutes, specifically Chapter 32 Wildlife, Parks and Recreation; Article 9 Licenses, Permits, Stamps and Other Issues; Statutes 32-957 through 963; 32-1009 through 1012; and 32-1033; and Kansas Statute Amendments 32960a and 32-960b. These statutes and regulations also regulate special permits for development projects affecting critical habitats of threatened or endangered species.

Statute 32-959, Nongame and Endangered Species Conservation Act, Nongame Species, provides the Secretary of the KDWP with the authority to identify nongame species in need of protection and "establishes limitations relating to taking, possessing, transporting, exporting…nongame species." Statute 32-960, Nongame and Endangered Species Conservation Act, Endangered Species, provides

the Secretary of the KDWP with the authority to identify species that should be considered threatened or endangered by the State of Kansas and provides guidelines on the process of listing such species.

Nebraska State Wildlife Conservation

The Nebraska Game and Parks Commission is responsible for managing and protecting wildlife resources in the state of Nebraska pursuant to the Nongame and Endangered Species Conservation Act. This act is defined under the Nebraska Revised Statutes of 1943, specifically Chapter 37, Game and Park Article 8: Nongame and Endangered Species Conservation Act; Revised Statutes 37-801 through 811. These statutes and regulations also regulate special permits for development projects affecting critical habitats of threatened or endangered species.

Statute 37-806 states that species listed as endangered or threatened under the federal ESA also shall be considered to be endangered or threatened under the Nongame and Endangered Species Conservation Act. The state has the authority to list other species not covered under the ESA. This statute also regulates take of state-listed species.

3.9.3 Floodplains

Floodplain management is regulated by the FEMA and is implemented by local agencies. Federal floodplain maps, called Digital Flood Insurance Rate Maps (DFIRMs) delineate the floodway and the 100-year and 500-year recurrence interval flood levels for floodplains across the country. These maps are used by FEMA to define areas eligible for participation in the NFIP. By participation in the NFIP, local entities are required to implement certain floodplain management regulations, making local floodplain property owners eligible to purchase federal flood insurance. Much of the Project area falls within areas mapped as floodway and 100-year or 500-year floodplain on FEMA floodplain maps. Specific floodplain management regulations in effect at any given location are determined by the local entity responsible for floodplain management.

3.9.4 Wetland Systems and Classes

By indirectly altering wetland hydrology, commercial dredging activity in the LOMR could alter the amount and types of wetlands along and adjacent to the river. If degradation of the river bed resulted in reduced frequency, depth, or duration of flooding, or lowered groundwater levels, wetlands could be

converted to non-wetlands or the vegetation species composition could be altered, changing the type of wetlands present.

Various estimates of the amount of wetland habitat along the LOMR have been made. Table 3.9-1 lists wetland acreages estimated from three different sources. Wetland studies for the Missouri River Master Water Control Manual Review and Update (USACE 1994) estimated that 15,581 acres of wetlands with surface connections to the river were present in the LOMR floodplain between Rulo and St. Louis, and 68,520 acres of rivers and lakes were present in the LOMR floodplain. The environmental resource inventory compiled for the Missouri River Fish and Wildlife Mitigation Project (Burns and McDonnell 1995) used two data sources to estimate the amount of wetlands in the Missouri River floodplain. Based on Landstat imagery, an estimated 77,485 acres of wetlands and 69,820 acres of open-water habitat were present in the floodplain between Rulo, Nebraska and the LOMR confluence with the Mississippi River. Based on the National Wetlands Inventory (NWI) maps, an estimated 96,477 acres of wetlands and 6,170 acres of lacustrine habitat were present in the same area. The large discrepancies between these wetland acreage estimates are caused by the studies using different methods and assumptions. For the purpose of the analysis in this EIS (in Section 4.7), the geospatial data from the USFWS NWI website were used to determine the extent of wetlands in the Project area.

Wetlands in the floodplain are dynamic and change over time; flooding creates new wetlands through scouring and deposits sediment in other wetlands, and some wetlands would silt in without flooding (USACE 1994, Chapman et al. 2003). In addition, a recent study found that many wetlands in the LOMR floodplain were misclassified in the NWI (Kriz et al. 2007). The wetland acreages in Table 3.9-1 were determined prior to 1993 and later flood events; therefore, the effects of these events are not accounted for in the estimates.

The wetlands and deepwater habitats of the United States can be classified according to general similarities in hydrology, geomorphology, chemistry, and biology (Cowardin et al. 1979). Along the LOMR, three habitat systems are present: riverine, palustrine, and lacustrine. Riverine habitats are present in the Project area along rivers, streams, canals, and ditches. Palustrine habitats consist of all wetlands dominated by trees, shrubs, and emergent herbaceous plants. Lacustrine habitats are situated in topographic depressions that are more than 20 acres in size (lakes and ponds). Similar habitats less than 20 acres are also included in the lacustrine system if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 meters (m) (6.6 feet) at low water. Each habitat system encompasses several

wetland classes, which are based on the dominant life forms of the vegetation or on the form and composition of the substrate. Wetland classes in the Project area include emergent, scrub-shrub, and forested wetlands; other non-wetland classes include unconsolidated bottom and unconsolidated shore.

Table 3.9-1 Wetland Types and Estimated Quantities in the Project Area[a]

	Wetland Class			
	Forested (acres)	Scrub-Shrub (acres)	Emergent (acres)	Total (acres)
Burns and McDonnell (1995) – based on land use analysis	39,656	9,254	28,575	77,485
Burns and McDonnell (1995) – based on NWI maps	49,375	11,523	35,579	96,477
USACE (1994)[a]	7,974	1,860	5,747	15,581

Notes:

NWI = National Wetlands Inventory.

USACE = U.S. Army Corps of Engineers.

[a] Only includes wetlands with a direct surface connection with the Missouri River.

Sources: Burns and McDonnell 1995, USACE 1994.

Floodplain wetlands along the LOMR also can be characterized according to the flooding history (pre-flood vs. post-flood, referring to the 1993 flood event) and proximity to the river (frequently flooded vs. more influenced by runoff and groundwater) (Galat et al. 1998; Bodie, Semlitsch, and Renken 2000; Kelly 2001). Remnant wetlands are former oxbows or sloughs that are no longer connected with the river but are permanently or semi-permanently flooded. Scours are deep basins excavated by recent flood events and include connected scours (with a direct surface connection to river) and isolated scours (basins formed by floods with no surface connection to the river). Temporary wetlands have seasonal or intermittent flooding, are remnants or are more recently formed, and may be farmed or unfarmed. Managed wetlands are irrigated and managed for the benefit of waterfowl (for hunting).

In addition, the LOMR floodplain wetlands include cropland areas enrolled to USDA programs, such as the Wetland Restoration Program and CRP, where previously manipulated wetland sites, and wetlands farmed under natural conditions, have been restored, enhanced or created. Some cropland soils quickly assume hydric characteristics upon cessation of agricultural disturbances. These previously farmed sites become colonized with forest vegetation, while others remain as herbaceous wetlands. Many of these previously farmed wetland sites are not subject to irrigation, relying on surface runoff and sub-surface hydrology. The enrollment of these sites can last from 10–15 years (in the CRP) to a permanent easement (in the Wetland Restoration Program).

Most of the wetlands remaining in the LOMR floodplain are forested wetlands. The dominant floodplain trees are black willow (*Salix nigra*), peach-leaved willow (*Salix amygdaloides*), cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), box elder (*Acer negundo*), American elm (*Ulmus americana*), American sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), and red mulberry (*Morus rubra*) (Weaver 1960, Munger et al. 1972 and 1974, USACE 1994, Galat et al. 1998); common understory shrubs and woody vines include dogwood (*Cornus stolonifera*), Virginia creeper (*Parthenocissus quinquefolia*) and grape (*Vitis vulpina*).

Emergent wetlands, dominated by herbaceous perennials, are also common in the LOMR floodplain. The species composition of the plant communities is dependent on water depth and the amount of sedimentation (Sluis and Tandarich 2004). In temporary wetlands, reed canarygrass (*Phalaris arundinacea*) is often the dominant species, but sedges (*Carex* spp.), nutsedges (*Cyperus* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), rice cutgrass (*Leersia oryzoides*), and smartweeds (*Polygonum* spp.) are also common (Weaver 1960, USACE 1994, Chapman et al. 2003). In permanently or semi-permanently flooded wetlands, the characteristic plants include bulrushes (*Scirpus* spp.), cattails (*Typha latifolia*), common reed (*Phragmites australis*), bur reeds (*Sparganium* spp.), and arrowhead (*Sagittaria* spp.) (Weaver 1960, USACE 1994, Galat et al. 1998, Blevins 2004, Sluis and Tandarich 2004). Recently formed or disturbed wetlands are typically vegetated by colonizing species such as prairie cordgrass (*Spartina pectinata*), reed canarygrass, pigweed (*Amaranthus rudis*), eclipta (*Eclipta alba*), millet (*Echinochloa* spp.), foxtail (*Setaria* spp.), and nutsedges (Weaver 1960, Galat et al. 1998).

Wetlands dominated by shrubs are uncommon along the LOMR floodplain. These are generally dominated by small black willow and cottonwood trees, with some sandbar willow (*Salix interior*), and buttonbush *(Cephalanthus occidentalis)* (USACE 1994).

3.9.5 Wetlands and Missouri River Hydrology and Geomorphology

Historically, most of the LOMR floodplain was inundated on a regular basis, which resulted in extensive and diverse wetlands (Galat et al. 1998). A direct surface water connection between the LOMR river and floodplain wetlands no longer is common outside of the levees and occurs only during large flood events (Kelly 2001, Blevins 2004). The hydrology of many wetlands along the LOMR is dependent on the groundwater level, although shallow wetlands may be more dependent on rainfall and surface runoff (Blevins 2004, Kelly 2006). Because groundwater levels are directly correlated with river stage, the river stage affects wetlands that are supported by groundwater (Kelly 2001, Chapman et al. 2003,

Kelly 2006). In wetlands deep enough to intersect the groundwater table, the movement of ground water into wetlands in response to rising river stage has the greatest effect on wetland hydrology (Kelly 2006). Kelly (2000) used hydraulic modeling to predict the effect of river stage on groundwater levels. The primary predicted response would be a result of the duration of the flood pulse; the height of the flood pulse would have less effect. Deeper wetlands that receive groundwater discharge, such as lakes, ponds, and scour wetlands, are deep enough to be affected by changes in alluvial aquifer levels as a result of river stage level; shallow wetlands or wetlands farther from the river would be less likely to be affected (Chapman et al. 2003, Blevins 2004). Section 3.6.2.1 provides additional detail about the connection between river stage and groundwater levels.

USACE (1994) modeled the effects of changing river stage levels on surface water–supported wetlands and found that lower river stages resulted in both a decrease in wetland acreage and a change in wetland types. Although no similar studies have been done on the effects of changing groundwater levels on wetland amounts or types, a long-term decrease in river stage and the surface water elevation resulting from river bed degradation would be expected to cause a similar adverse effect on groundwater-supported wetlands.

3.9.6 Wetland Functions and Values

Wetland functions are the processes by which the normal physical and biological properties of wetlands are supported and maintained (Brinson 1993, Smith et al. 1995). Wetland values are benefits that wetland functions provide to human society, such as flood protection, maintenance of water quality, and recreation (Mitsch and Gosselink 2007). Not all wetlands perform the same functions or level of function; rather, these vary with the wetland category, size, proximity to other wetlands, type and degree of previous and current disturbances, and adjacent land uses. Indirect effects of commercial dredging activity in the LOMR on wetlands adjacent to the river could affect wetland functions.

The specific ecological services historically provided by wetland functions in the Missouri River floodplain are not well documented because few ecological studies were carried out until the latter part of the 20th century, as higher priorities were placed on economic concerns (National Research Council Committee on Missouri River Ecosystem Science 2002, USACE 2004). In general, however, wetlands in the Project area perform functions in three basic categories: hydrology, biogeochemistry, and flora and fauna habitat support.

Wetland hydrology comprises "all hydrologic characteristics of areas that are periodically inundated or have soils saturated to the surface at some time during the growing season" (Environmental Laboratory 1987). Wetland hydrology provides the basis for all wetland functions. Wetlands in the Project area carry out three general hydrologic functions: groundwater recharge, groundwater discharge, and flood flow alteration.

Groundwater recharge is the process in which surface flows are stored for a period sufficient for water to percolate into the soil or into the groundwater table. In the Project area, the potential for groundwater recharge is generally low. The terrain is relatively flat, with little runoff because of the sandy soils and presence of ditches and levees (Blevins 2004). Groundwater discharge occurs where wetland basins intercept the groundwater table surface. As noted above, the hydrology of many wetlands along the LOMR is dependent on the groundwater level, and discharge into the wetlands typically exceeds recharge from the wetlands to the groundwater table (Blevins 2004).

Wetlands contribute to flood flow alteration, as short-term water storage decreases the amount and velocity of runoff, reducing peak floods and distributing storm flows over longer periods of time. The dissipation of energy in moving water lessens its erosive impact and contributes to reducing downstream sedimentation. Ditches and levees in the floodplain minimize the flood flow alteration function of the wetlands; however, the wetlands have tremendous potential for flood flow alteration should flood flows top or breach the levees.

Biogeochemistry functions are the characteristics that enable wetland ecosystems to transport and transform chemicals. Wetlands remove dissolved substances from water through various mechanisms such as absorption, adsorption, solubilization, oxidation, biological transformation, and precipitation. Wetlands, by definition, are vegetated; and it is the vegetation, along with microbial organisms that exist on the surface of the plants and in the substrate, that are responsible for a wide range of physical and biochemical processes. Wetlands in the Project area potentially carry out three general biogeochemistry functions: sediment/toxicant retention, nutrient removal/transformation, and production export.

Vegetation slows the velocity of water, reducing its ability to hold particles in suspension. Water in watersheds basins with more wetlands tends to have lower specific conductance (a measure of the total concentration of dissolved substances) and lower concentrations of chloride, lead, inorganic nitrogen, suspended solids, and total and dissolved phosphorus than does water in watershed basins

with fewer wetlands. Certain wetland plants also help remove heavy metals. Wetlands, therefore, improve water quality by removing both dissolved substances and suspended particulates.

Growing vegetation removes dissolved nutrients and compounds other substances from the water and soil, often metabolizing them and sometimes sequestering them within plant tissues. Bacteria growing in the soil or in plant roots also break down or alter these substances so that they are removed from the water, either by plants or as a gas. Missouri River wetlands have a high potential for removing nutrients, including both nitrogen and phosphorus, with high levels of denitrification and nitrogen-uptake (Blevins 2004).

Wetlands are productive environments that provide diversity in the landscape. The flux of nutrients and energy in wetlands is relatively high because of the high growth rate and rapid turnover of the wetland vegetation. The nutrients and carbon fixed by the plants are cycled through the wetlands when the plants are eaten by herbivores or when the plants die and decompose. Nutrients and compounds and other organic matter in wetlands are broken down into organic compounds by bacterial action, which provides food for invertebrates. These invertebrates are the foundation of the food web that supports vast and varied numbers of wildlife species, from shorebirds to amphibians. The flow of water through wetlands provides for the efficient movement and distribution of nutrients and energy throughout the entire ecosystem. Wetlands that are affected by flooding have higher primary and secondary production (transference of energy) (Chapman et al. 2003).

Wetlands provide habitat where many plants and animals fulfill one or more life cycle stages. Wetlands in the Project area carry out two general flora and fauna habitat support functions: maintaining wildlife habitat diversity and abundance, and maintaining aquatic habitat diversity and abundance.

Missouri River wetlands generally have moderate to high potential for wildlife habitat function. Wetlands in the Project area provide habitat for migratory birds and other wildlife and are important habitat for turtles (Funk and Robinson 1974; Bodie, Semlitsch, and Renken 2000). Wetlands also provide support for a diverse array of trophic levels (feeding levels) in both the wetlands and the surrounding upland environments. Many species use wetlands for feeding and uplands for nesting. Forested wetlands and scrub-shrub wetlands have high structural diversity with open-water areas that provide both foraging and breeding habitat. Emergent wetlands have low structural diversity, but emergent wetlands with high plant diversity support birds and amphibians use.

Natural disturbances have influenced wetlands in many ways. Some plant species evolved under specific hydrologic conditions and have a narrow range of tolerance to disturbance. Other plant

species have evolved to tolerate a wide range of hydrologic conditions. The effects of fire (anthropogenic and natural) can influence the vegetation community structure and composition. Historically, much of the wetland micro-topography was influence by flooding in the LOMR, with specific wetlands subject to erosive forces, while other wetlands were recipients of sediment. Disturbance due to flood scouring from the LOMR is much reduced in modern times.

Habitat connectivity, fragmentation, and patchiness all affect the capability of wildlife to move within a wetland, and between the wetland and adjacent upland or aquatic habitats. Barriers between the wetlands and the adjacent uplands and aquatic habitats prevent some species from moving into or out of the wetlands, making the species unable to reproduce or compete their life cycle. Animal species such as large mammals, birds, and flying insects are less affected by these barriers. Changing land uses in or adjacent to wetlands, in addition to altering wetland function as habitat; limit the ability of wildlife to move throughout wetland and aquatic and upland habitats.

Missouri River wetlands historically were extremely important habitat for fish and benthic organisms (Weeks, Vana-Miller, and Pranger 2005). Additional information on aquatic habitat diversity and abundance can be found in Section 3.8.

Anthropogenic disturbance can lower the wildlife habitat function of wetlands and the adjacent upland and aquatic habitats. The more intensely land use disturbs the landscape, the more the characteristic vegetation can change. With disturbance from grazing, plowing, or grading, the characteristic vegetation also can be susceptible to invasive species (both native and exotic). When wetlands are farmed or overgrazed so that the existing wetland vegetation is removed from the soil surface, wildlife usage changes. Habitat for some species is diminished because the vegetation is insufficient to provide food, shelter, or nesting opportunities; while habitat value for other wildlife species may increase due to foraging attributes.

Wetlands along the LOMR have values in addition to the ecological services they provide. Perhaps the most widely recognized value of Missouri River wetlands is for recreation, as discussed in Section 3.11. Because many Missouri River wetlands have been filled or drained, the remaining natural wetlands are important models for restoration efforts (Blevins 2004), and these areas serve as sources of seed stock for population dispersal. In addition to providing general habitat functions, wetlands may provide unique habitat functions for federally listed species (see Section 3.10).

3.9.7 Terrestrial Wildlife Resources in the Project Area

Below is a discussion of the common terrestrial wildlife species and their habitats in the LOMR floodplain. Because dredging-related impacts primarily result in indirect impacts to wetland habitat in the LOMR floodplain, this section focuses on special wetland habitats and species in the floodplain.

3.9.7.1 Special-Status Wildlife Species and Management Areas

Special Wildlife Management Areas

Numerous wildlife habitat areas are managed by federal, state, and local agencies in the LOMR floodplain. Multiple non-governmental organizations (such as the National Audubon Society) also maintain wetland wildlife habitats along the LOMR floodplain.

Some floodplains and lands adjacent to the Missouri River are protected as part of the Big Muddy National Fish and Wildlife Refuge, managed by the USFWS. The refuge was established in September 1994 to conserve and protect fish and wildlife resources, and is part of the National Wildlife Refuge System—a network of approximately 550 refuges across the United States (USFWS 2009). To date, the refuge encompasses over 11,000 acres and consists of eight units, as shown in Figure 3.9-1.

The units range from 343 to 2,550 acres (Table 3.9-2) and consist of a variety of habitats, including chutes, backwaters, scours/ponds, sandbars, bottomland forests, wet prairie/grasslands, and seasonal and permanent wetlands. These units provide excellent refuges for wildlife along the Missouri River, such as scour holes as pools for aquatic turtles and sandbars as important resting and feeding areas for migrating shorebirds.

The USFWS has approval through Congress to allow the refuge to acquire up to 60,000 acres of floodplains and adjacent lands on the LOMR between Kansas City and St. Louis, Missouri, and the USFWS continues to acquire land from willing sellers with Land and Water Conservation Funds (USFWS 2009).

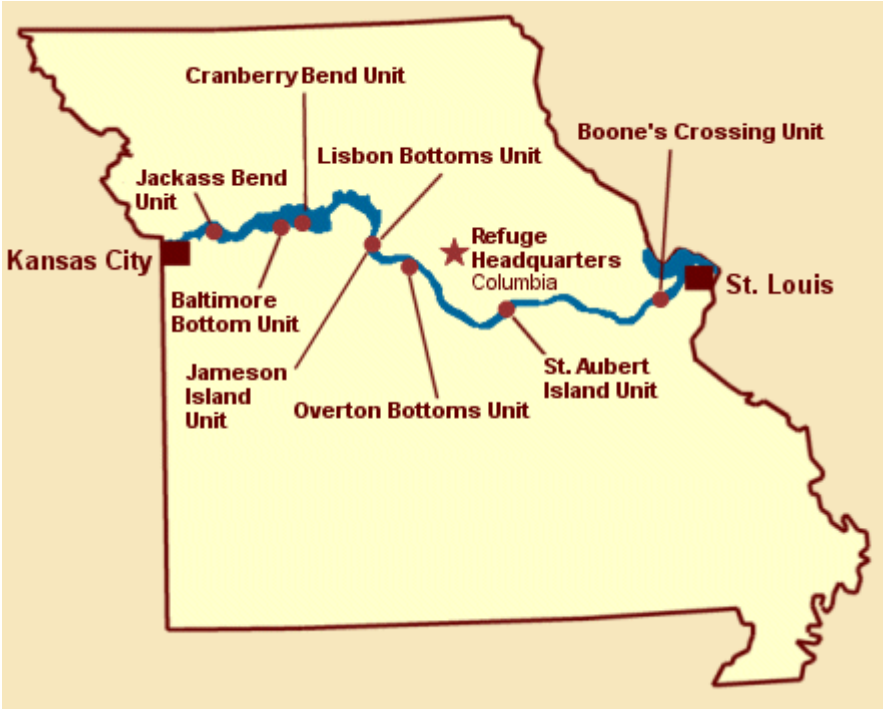

Figure 3.9-1 Big Muddy National Fish and Wildlife Refuge Units

Table 3.9-2 Big Muddy National Fish and Wildlife Refuge Units

Unit Name	Location (County)	Number of Acres
Boone's Crossing Unit	St. Louis County	572
St. Aubert Island Unit	Osage County	1,126
Overton Bottoms Unit	Cooper County	2,550
Jameson Island Unit	Saline County	1,871
Lisbon Bottom Unit	Saline County	2,014
Cranberry Bend Unit	Saline and Lafayette Counties	507
Baltimore Bottom Unit	Lafayette County	1,626
Jackass Bend Unit	Jackson and Ray Counties	343

Multiple additional lands within the LOMR floodplain have been designated or protected by local, state, and federal agencies. Approximately 27,000 acres of land have been purchased from willing sellers, and easements on another 13,200 acres of existing public lands have been obtained in which USACE mitigation efforts are underway or completed. Mitigation efforts include measures such as river structure modification, side channel/backwater and floodplain reconnection; to date, over 50 different

mitigation sites are in various stages of acquisition and development (USACE 2009a, 2010a). In the Water Resources Development Act of 1999 (Section 334[b]), the Missouri River Fish and Wildlife Mitigation Project was reauthorized to include an additional 118,650 acres of land to be purchased from willing sellers on which to develop, restore, or enhance fish and wildlife mitigation sites. Further, the Missouri Department of Conservation has established several Conservation Opportunity Areas, which are priority places identified for wildlife conservation, along the LOMR floodplain (MDC 2010). Some identified areas along the LOMR floodplain include the Loess Hills, Iatan/Weston Missouri River Corridor, Bonne Femme Karst, Missouri River Hills, and Missouri/Mississippi River Confluence Conservation Opportunity Areas. Further, there are multiple state and local parks that are located within the LOMR floodplain.

Special-Status Species

Based on the review of habitat requirements of special-status species, most terrestrial special-status species would not be directly affected by in-channel dredging. Special-status wildlife species present in the habitats located along the LOMR could be impacted by dredging in the same manner as other species that use the same wetland habitats. As such, special-status wildlife species potentially in the LOMR floodplain have been included with the common wildlife species listed in Table 3.9-3 (in Section 3.9.7.2). Bald eagles and migratory birds may be present in riparian and forested wetland habitats along the LOMR floodplain. Below is a description of the use of floodplain wetland habitats by special-status species in the Project area.

Bald Eagle

As of August 9, 2007, the bald eagle is no longer protected under the federal ESA, and Section 7 consultation with the USFWS is no longer necessary. However, the bald eagle remains protected under the Bald and Golden Eagle Protection Act.

Bald eagles are large, opportunistic birds of prey that feed largely on fish and waterfowl (Peterson 1986). Eagles tend to use rivers, lakes, and reservoirs where large trees provide perch sites for roosting and for locating prey. This species prefers trees greater than 11 inches (27.9 centimeters) diameter at breast height (DBH) that are located within 100–600 feet (30.5–182.9 m) of water bodies. Nesting activity is most often initiated between January 1 and March 1, and the most critical time for incubation and rearing of young is between March 1 and May 15. During winter, they gather near large open water areas, usually occupying river habitats between November 15 and March 1. At night, wintering bald eagles may congregate at communal roosts and may travel as much as 12 miles

(19.3 kilometers [km]) from feeding areas to a roost site. Bald eagles are common migrants and winter residents throughout Missouri, Kansas, and Nebraska and since the 1990's the number of bald eagle nests in these states have increased. Bald eagle nests have been observed throughout Missouri, including along the LOMR in some locations (MDC 2007). The bald eagle and their nests has the potential to occur in wooded corridors along the LOMR within the Project area.

Migratory Birds

Several species of migratory birds and their habitats can be found along the LOMR floodplain. Typical bird species are identified in Table 3.9-3. Throughout the United States, 836 bird species are protected under the MBTA (USFWS 2010), several of these species are located along the LOMR for at least part of the year. Migratory birds have use a variety of habitats, but several important bird areas (IBAs) have been identified within and near the LOMR floodplain (National Audubon Society 2010). Most identified IBAs consist of wetlands, prairies, marshlands, and forested areas that are managed by various federal, state, and private partners.

3.9.7.2 Common LOMR Wildlife Species

Species assemblages are a group of closely-related species that co-occur within a particular habitat. Table 3.9-3 includes a list of common terrestrial wildlife species found along the LOMR floodplain. Note that this table is not intended to be an exhaustive list of wildlife species, but its purpose is to highlight the most common species potentially present in the LOMR floodplain.

3.9.8 Upland Terrestrial Land Cover Types at Sand Plant Locations

Potential direct effects of the Project to terrestrial habitats would occur only from construction of sand plants. Land cover on the sand plant parcels was identified using University of Missouri 2005 land cover GIS data. Land cover types included cropland, grassland, woody-dominated wetlands, herbaceous-dominated wetlands, low-density urban, and impervious surface (MSDIS 2010). Wetland vegetation and wildlife were described in Sections 3.9.4 and 3.9.7. Because low-density urban and impervious surface cover types would not likely contain significant wildlife habitat, they are not discussed further in this section. Croplands and grasslands, while subject to different disturbance intervals, serve similar habitat functions. Below is a discussion of common wildlife species that typically would be present in these habitat types.

3.9.8.1 Croplands and Grasslands

Agricultural land is the most common land cover type in the LOMR floodplain. Cropland occupies 64.8 percent of the land area in the LOMR floodplain and ranges from 52.7 percent in the St. Joseph segment to 78.4 percent in the Waverly segment (MSDIS 2010). Agricultural lands may be seasonally or occasionally inundated during periods of high water stage in the LOMR. Crops grown in agricultural lands along the LOMR typically consist of row, close-grown, and forage crops such as small grains, corn, and alfalfa. Grassland occupies 6.3 percent of the land area in the LOMR floodplain and ranges from 3.9 percent in the Waverly segment to 12.3 percent in the St. Joseph segment (MSDIS 2010). Grasslands are typically dominated by native warm season or non-native cool season grasses (MSDIS 2010).

Open lands generally provide poor to moderate quality wildlife habitat relative to the higher quality mixed forest habitat, but herbaceous vegetation within open land areas does provide habitat for small and large mammals, birds, and other species. Small mammals are commonly hunted by raptors, and many of the bird species that use mixed forest habitats also occur within open lands.

Table 3.9-3 Common Wildlife Species found in the Lower Missouri River Floodplain

Wildlife Assemblage	Common Species	Common Habitat Type
Waterfowl, wading, water, and shore birds	Great Blue Heron (*Ardea herodias*) Green Heron (*Butorides virescens*) Canada Goose (*Branta canadensis)* Wood Duck (*Aix sponsa*) Mallard (*Anas platyrhynchos*) Northern Pintail (*Anas acuta*) American Wigeon (*Anas Americana*)	Wetlands
	Killdeer (*Charadrius vociferous*)	Grasslands
Songbirds	House Sparrow (*Passer domesticus*) European Starling (*Sturnus vulgaris*) House Wren (*Troglodytes aedon*) Barn Swallow (*Hirundo rustica*) Blue Jay (Cyanocitta cristata) Eastern Bluebird (*Sialia sialis*) American Robin (*Turdus migratorius*) Dickcissel (*Spiza Americana*) Eastern Meadowlark (*Sturnella magna*)	Farms/towns, grasslands
	Song Sparrow (*Melospiza melodia*) Gray Catbird (*Dumetella carolinensis*) Northern Mockingbird (*Mimus polyglottos*) Brown Thrasher (*Toxostoma rufum*)	Shrubs/brush
	Red-Bellied Woodpecker (*Melanerpes carolinus*) Purple Martin (*Progne subis*) Downy Woodpecker (*Picoides pubescens*) American Crow (Corvus brachyrhynchos) Carolina Chickadee (*Poecile carolinensis*) Black-Capped Chickadee (*Poecile atricapillus*) Tufted Titmouse (*Baeolophus bicolor*) White-Breasted Nuthatch (*Sitta carolinensis*) Blue-Gray Gnatcatcher (Blue-gray Gnatcatcher) Northern Cardinal (*Cardinalis cardinalis*) Indigo Bunting (*Passerina cyanea*) Eastern Towhee (*Pipilo erythrophthalmus*)	Forest
	Red-Winged Blackbird (Agelaius phoeniceus)	Wetlands
Raptors	Bald Eagle (*Haliaeetus leucocephalus)* Northern Harrier or Marsh Hawk (*Circus cyaneus)* Red-Shouldered Hawk (*Buteo lineatus)*	Wetlands, shores of reservoirs, streams, rivers
	Red-Tailed Hawk (*Buteo jamaicensis)* Northern Rough-Legged Hawk (*Buteo lagopus)* Black Vulture (*Coragyps atratus)* Turkey Vulture (*Carthartes aura)* American Kestrel (*Falco sparverius)*	Forest, farmland
	Broad-Winged Hawk (*Buteo platypterus)* Swainson's Hawk (*Buteo swainsonii)*	Migrates through the Project area
Upland game birds	Greater Prairie Chicken (*Tympanuchus cupido*) Mourning Dove (*Zenaida macroura*)	Prairie
	Wild Turkey (*Meleagris gallopavo*)	Forest
	Northern Bobwhite (*Colinus virginianus*)	Shrub/brush
	Rock Dove (*Columba livia*)	Towns/yards

Table 3.9-3 Common Wildlife Species found in the Lower Missouri River Floodplain

Wildlife Assemblage	Common Species	Common Habitat Type
Amphibians	Plains Spadefoot (*Spea bombifrons*) Great Plains Toad (*Bufo cognatus*) Fowler's Toad (*Bufo fowleri*) Woodhouse's Toad (*Bufo woodhousii*) Blanchard's Cricket Frog (*Acris crepitans blanchardi*) Western Chorus Frog (*Pseudacris triseriata*) Northern Crayfish Frog (*Rana areolata circulosa*) Eastern American Toad (*Bufo americanus americanus*) Plains Leopard Frog (*Rana blairi*)	Floodplain
	Gray Treefrog (*Hyla chrysoscelis and Hyla versicolor*) Northern Spring Peeper (*Pseudicris crucifer crucifer*) Great Plains Narrow-mouthed Toad (*Gastrophryne olivacea*) Eastern Narrow-Mouthed Toad (*Gastrophryne carolinensis*) Green Frog *(Rana clamitans melanota*) Pickerel Frog (*Rana palustris*)	Forest, grasslands, wooded hills, marshes
	Bullfrog (*Rana catesbeiana*) Southern Leopard Frog (*Rana sphenocephala*)	Permanent aquatic habitats
Reptiles	Western Painted Turtle (*Chrysemys picta bellii*) Red-Eared Slider (*Trachemys scripta elegans*) Common (Northern) Map Turtle (*Graptemys geographica*) False Map Turtle (*Graptemys pseudogeographica pseudogeographica)* Ouachita Map Turtle (*Graptemys ouachitensis ouachitensis*)	Rivers, sloughs, oxbow lakes, ponds, drainage ditches (semi-aquatic)
	Graham's Crayfish Snake (*Regina grahamii)* Western Ribbon Snake (*Thamnophis proximus proximus)*	Edges of streams, marshes, sloughs, ponds, wooded areas near water
	Ornate Box Turtle (*Terrapene ornate ornate*) Southern Coal Skink (*Eumeces anthracinus pluvialis*) Racerunner (*Cnemidophorus sexlineatus*) Western Slender Grass Lizard (*Ophisaurus attenuatus attenuatus*) Eastern Yellow-Bellied Racer (*Coluber constrictor flaviventris*) Black Rat Snake (*Elaphe obsoleta*) Eastern Hog Nosed Snake (*Heterodon platirhinos*) Prairie Kingnose (*Lampropeltis calligaster calligaster*) Speckled Kingsnake *(Lampropeltis getula holbrooki*) Red Milk Snake (*Lampropeltis triangulum syspila*) Bullsnake (*Pituophis catenifer sayi)*	Pastures, open woods, glades, and prairies
	Three-Toed Box Turtle (*Terrapene Carolina triungulis*) Northern Fence Lizard (*Sceloporus undulates hyacinthinus*) Ground Skink (*Scincella lateralis*) Five-Lined Skink (*Eumeces faciatus*) Broadhead Skink (*Eumeces laticeps*) Western Worm Snake (*Carphophis vermis*) Prairie Ring-necked Snake (*Diadophis punctatus arnyl*) Great Plains Rat Snake (*Elaphe guttata*) Midland Brown Snake *(Storeria dekayi wrightorum)* Northern Red-Bellied Snake (*Storeria occipitomaculata occipitomaculata)* Osage Copperhead (*Agkistrodon contortrix phaeogaster*) Western Ribbon Snake (*Thamnophis proximus proximus)* Osage Copperhead (*Agkistrodon contortrix phaeogaster*) Timber Rattlesnake (*Crotalus horridus)*	Forest, woodlands

Table 3.9-3 Common Wildlife Species found in the Lower Missouri River Floodplain

Wildlife Assemblage	Common Species	Common Habitat Type
Mammals	Raccoon (*Procyon lotor*) Eastern Gray Squirrel (*Sciurus niger*)	Hardwood forests
	River Otter(*Lutra canadensis*) Mink (*Mustela vison*) Opossum (*Didelphis viginiana*) Long-Tailed Weasel (*Mustela frenata*) Beaver (*Castor canadensis*) Muskrat (*Ondatra zibethicus*) Swamp Rabbit (*Sylviagus aquaticus*)	Along rivers, streams, lakes; wooded areas along streams
	Striped Skunk (*Mephitis mephitis*) Red Fox (*Vulped fulva)* White-Tailed Deer (*Odocoileus virginianus*) Gray Fox (Urucyon *cineoargentus*) Coyote (*Canis latrans*) Eastern Cottontail Rabbit (*Sylvilagus aquaticus*)	Forest borders, brushy fields near water
	White-Tailed jackrabbit (*Lepus californicus*) Badger (*Taxidea taxus*) Spotted Skunk (*Civet*) (*Spilogale interrupta*)	Prairie

3.9.9 References

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3.10 FEDERALLY LISTED SPECIES

3.10.1 Introduction

This section discusses the presence, potential occurrence, and status of animal and plant species that are listed as threatened or endangered under Section 4 of the ESA of 1973 (50 CFR Section 402.02 [federally listed species]), and describes the habitat necessary to support these species. The term ‘‘endangered species’’ means any species that is in danger of extinction throughout all or a significant portion of its range. The term ‘‘threatened species’’ means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. “Candidate species” are plants and animals for which the USFWS has sufficient information on their biological status and threats to propose them as endangered or threatened under the ESA, but for which development of a proposed listing regulation is precluded by other higher priority listing activities.

State-listed species of conservation concern, federal candidate and delisted species, migratory birds, and other sensitive species are addressed in Section 3.8 (Aquatic Resources) and Section 3.9 (Wetlands, Floodplains, and Terrestrial Resources). Information presented for species occurrence and life history is based on available literature, correspondence and communications with federal and state agencies, websites, and a thorough review of state natural heritage programs.

The Action Area is the geographic region encompassing the channel and floodplain of the Missouri River and main tributary confluences to the Missouri River from RM 0 to RM 489. Land cover types include riverine, riparian, wetlands, agricultural, and other uses. The Action Area also encompasses areas where alternate sources of sand are identified in the Project Description (Section 3.2).

3.10.2 Regulatory Setting

3.10.2.1 Federal

The ESA is the primary federal law protecting threatened and endangered species. The ESA and its subsequent amendments provide for the protection and conservation of federally listed species and the habitats upon which they depend. Under Section 7 of the ESA, federal agencies (such as the USACE) are required to consult with the USFWS to ensure that any federal undertaking, funding, permitting, or authorizing actions would not likely jeopardize the continued existence of listed species or destroy or

adversely modify designated critical habitat. "Critical habitat" refers to a specific geographic area(s) that contains features essential for the conservation of a threatened or endangered species, and that may require special management and protection (a more complete definition can be found in the ESA).

In this case, Section 7 requires the USACE to determine the effects of the Environmentally Preferred Alternative on federally listed species and their critical habitat in a Biological Assessment (BA). Upon reviewing the BA, if the USFWS concurs that the Proposed Action is will not affect or may affect but is not likely to adversely affect listed species or their critical habitat, then the informal consultation is complete and the USACE can proceed with the Proposed Action. If the USACE determines that the Environmentally Preferred Alternative is likely to adversely affect listed species or critical habitat or if the USFWS does not concur with a determination that the Environmentally Preferred Alternative is not likely to adversely affect, then the USACE and USFWS will enter formal consultation and the USFWS will write a Biological Opinion which may include Reasonable and Prudent Measures and a jeopardy statement if they conclude that the Environmentally Preferred Alternative will jeopardize the continued existence of a listed species.

3.10.2.2 Consultation with USFWS

On October 30, 2009, the USACE sent a letter requesting USFWS concurrence with their determination that a 1-year extension of the current Missouri River commercial dredging permits would not adversely affect federally listed species. The USACE requested that the concurrence extension last through December 31, 2010. The USFWS replied in a letter dated December 3, 2009, and agreed with the USACE determination that the proposed 1-year permit extension would not adversely affect the pallid sturgeon, piping plover, interior least tern, or their habitats (Scott pers. comm.). During informal consultation, the USFWS stated that additional research had been conducted and new information had become available on the pallid sturgeon since the 2003 biological opinion (USFWS 2003).

The USFWS indicated that a new BA would need to be developed to incorporate recent research in order to support an effects analysis beyond the 1-year extension of the current dredging permits. The USACE sent a letter to the USFWS on January 22, 2010, requesting a list of species potentially affected by dredging in the LOMR. The USFWS responded via email on February 10, 2010, identifying the potential for Project-related effects on the piping plover, interior least tern, pallid sturgeon, and Indiana bat. Further, the USFWS indicated that no federally designated critical habitat occurs in the Action Area. A follow-up conversation with the USFWS on March 23, 2010, identified the potential

occurrence of the decurrent false aster in the portion of the Action Area located in St. Charles County, Missouri.

On January 13, 2011, the USACE sent a Draft BA to the USFWS that concluded that the Proposed Action may affect, but is not likely to adversely affect the pallid sturgeon, least tern, and piping plover and would have no effect on the Indiana bat and decurrent false aster. The USACE and USFWS are still in informal consultation as the USFWS continues to review the Draft BA.

3.10.3 Federally Listed Species

Federally listed threatened or endangered species that are known to occur or with the potential to occur in the general Action Area and that may be affected by the Proposed Action and the alternatives are listed in Table 3.10-1. County-specific lists obtained through the state natural heritage programs were used in combination with species habitat information to determine the species potentially occurring in the Action Area. This list was further refined based on consultations with the USFWS, as described in Section 3.10.2. Table 3.10-1 identifies 11 federally listed species, including one mammal, two birds, three fish, two invertebrates, and three plant species. As noted, no designated critical habitat for any of the species listed in Table 3.10-1 occurs in the Action Area.

Table 3.10-1 also provides a preliminary determination of the potential for the Proposed Action to affect each species or its habitat, which serves as a screening to determine which species will be assessed. This determination is based on the likelihood of occurrence of the species or its habitat in the Action Area. Further, all species assessed in this document are consistent with the species identified by the USFWS as potentially occurring in the Action Area (see Section 3.10.2). Note that on September 1, 2010, the USFWS issued a final rule determining that shovelnose sturgeon (*Scaphirhynchus platorynchus*) should be treated as threatened due to similarity of appearance to the endangered pallid sturgeon in areas where they commonly coexist, such as the Missouri River (75 FR 53598). However, the ruling extends take prohibitions only to activities associated with commercial fishing. All other activities in areas where the two species overlap and which are conducted in accordance with applicable laws and regulations will not be considered take under the regulations designating shovelnose sturgeon as threatened (75 FR 53598). Shovelnose sturgeon have been included in Table 3.10-1, but because impacts to this species due to the proposed Project and alternatives would not be considered take, shovelnose sturgeon are not discussed beyond Table 3.10-1 in this section or in Section 4.8. The five species judged to be potentially affected by the Proposed Action or alternatives are further described in Sections 3.10.3.1 through 3.10.3.5 and in Section 4.8.

3.10.3.1 Indiana Bat

The Indiana bat (*Myotis sodalis*) was listed as endangered on 11 March 1967 (USFWS 2006). Critical habitat for the species was designated on September 24, 1976 (41 FR 41914). Indiana bat critical habitat has only been designated in caves that contain winter roosting habitat (USFWS 1976). Wintering cave habitats are not located within the LOMR floodplains; therefore, no critical habitat for this species is present in the Action Area.

Table 3.10-1 Preliminary Effects Determination for Federally Listed Threatened and Endangered Species

Common Name *Scientific Name*	Federal Status[a]	MO Status[a]	KS Status[a]	NE Status[a]	Habitat	Likelihood of Occurrence in the Action Area	Preliminary Effects Determination [b]
Mammals							
Indiana bat *Myotis sodalis*	E				Occurs seasonally during summer along streams and rivers in northern Missouri. Females raise young in maternal colonies under the bark of trees. Males may summer in riparian and floodplain areas or in caves. The species hibernates through the winter in caves and abandoned mines in the Ozarks.	Maternal colonies may occur in riparian or upland trees on river banks.	Yes
Birds							
Least tern (interior population) *Sterna antillarum*	E	E	E	E	Breeding birds nest on sparsely vegetated sand bars and the shoreline of rivers, lakes, and reservoirs. Coastal breeding birds nest on sandy shorelines of beaches and estuaries.	Species is a migrant through the Action Area. Species may nest in suitable habitat on the Missouri River and its tributaries.	Yes
Piping plover *Charadrius melodus*	T		T	T	Breeding birds nest on sparsely vegetated sandy or gravel beaches on the shoreline of rivers, lakes, and reservoirs and alkali lakes. Coastal breeding birds nest primarily on sandy beaches and barrier islands.	Species is a migrant through the Action Area. Species may nest in suitable habitat on the Missouri River and its tributaries.	Yes
Fish							
Pallid sturgeon *Scaphirhyncus albus*	E	E	E-CH	E	Inhabits large, turbid rivers with swift current and firm sand or gravel bottom.	Species mostly confined to the Missouri and lower Mississippi Rivers.	Yes

Table 3.10-1 Preliminary Effects Determination for Federally Listed Threatened and Endangered Species

Common Name *Scientific Name*	Federal Status[a]	MO Status[a]	KS Status[a]	NE Status[a]	Habitat	Likelihood of Occurrence in the Action Area	Preliminary Effects Determination [b]
Fish (continued)							
Shovelnose sturgeon *Scaphirhynchus platorynchus*	T[c]				Inhabits main channel of large rivers with swift currents and firm substrate. Can be found in deep scours or along sand and gravel bars during certain times of the year.	Species occurs the Missouri and Mississippi River basins.	No. Take prohibitions only apply to activities associated with commercial fishing [c]
Topeka shiner *Notropis topeka*	E	E		E	Inhabits pools of small streams with clear water and sand, gravel, or rubble bottoms.	Species occurs in central Missouri and northward into the prairie region. The strongest population is in the Moniteau Creek watershed, outside of the Action Area.	No. The Action Area is outside of the species known range.
Invertebrates							
American burying beetle *Nicrophorus americanus*	E		E	E	Historical habitat preferences are unknown. Occurs in grasslands and oak-hickory forest with an open understory.	The Action Area is outside of the species known range.	No. The Action Area is outside of the species known range.
Scaleshell mussel *Leptodea leptodon*	E	E			Occurs in clear, nonpolluted riffles with moderate current and firm gravel, cobble, or sand substrates.	None. Species is considered extirpated by the USFWS.	No. Species does not currently exist in the Action Area.
Plants							
Decurrent false aster *Boltonia decurrens*	T	E			Occurs in moist, sandy soil in floodplains, along shores of lakes, banks of streams, and in disturbed lowland areas or open wetlands.	Species occurs in the eastern half of St. Charles County.	Yes
Eastern prairie fringed orchid *Platanthera leucophaea*	T	E			Occurs in wet prairies and fens, sometimes in wet sites along spring branches and streams.	Species historically occurred in eastern Missouri.	No. Species does not currently exist in the Action Area.
Western prairie fringed orchid *Platanthera praeclara*	T	E		T[d]	Occurs in mesic portions of upland prairies and bottomland prairies.	Species occurs in northwest Missouri (Atchison and Holt Counties).	No. Species not likely to occur in the Action Area.

Table 3.10-1 Preliminary Effects Determination for Federally Listed Threatened and Endangered Species

[a] Species Status:

CH = Critical habitat has been designated in the State of Kansas.
E = Endangered.
T = Threatened.
KS = Kansas.
MO = Missouri.
NE = Nebraska.
USFWS = U.S. Fish and Wildlife Service.

[b] Preliminary Effects Determination: A "Yes" indicates that the species will be addressed in the effects analysis. A "No" indicates that the Proposed Action and the alternatives are not likely to affect the species. The 'No" determination reason is provided, and the species is not addressed in the effects analysis.

[c] On September 1, 2010, the USFWS issued a final rule determining that shovelnose sturgeon (*Scaphirhynchus platorynchus*) should be treated as threatened due to similarity of appearance to the endangered pallid sturgeon in areas where they commonly coexist, such as the Missouri River (75 FR 53598). However, the ruling extends take prohibitions only to activities associated with commercial fishing. All other activities in areas where the two species overlap and which are conducted in accordance with applicable laws and regulations will not be considered take under the regulations designating shovelnose sturgeon as threatened (75 FR 53598).. Therefore, shovelnose sturgeon will not be considered further in Section 4.8 as take is not currently prohibited for activities associated with commercial sand and gravel dredging within the LOMR.

[d] Nemaha County, Nebraska.

Sources: www.ngpc.state.ne.us/, www.mdc.mo.gov/nathis/endangered/endanger/, www.kdwp.state.ks.us/news/Other-Services/Threatened-and-Endangered-Species/Threatened-and-Endangered-Species/County-Lists

The Indiana bat weighs approximately one-quarter of an ounce and has a wingspan of 9–11 inches (USFWS 2006). The fur is dark-brown to black and is similar in appearance to many other related species. The Indiana bat is a very social species, and large numbers of individuals cluster together during hibernation (USFWS 2006). The Indiana bat mates during fall before they enter caves to hibernate. During hibernation, the bats cluster in groups of up to 500 individuals per square foot, and the largest hibernation caves can support from 20,000 to 50,000 bats. Common prey includes a variety of flying insects found along rivers or lakes and in uplands.

Summer habitat located in riparian or upland trees on river banks may contain maternal colonies, and the Indiana bat also forages in or along the edges of forested areas during summer. After migrating to summer areas, females roost under the peeling bark of dead and dying trees in maternity colonies of 100 or more bats. Young bats are nursed by the mother, who leaves the roost tree only to forage for food. The young stay with the maternity colony throughout their first summer (USFWS 2006).

The USFWS developed a recovery plan in 1976 which was revised in 1983 (USFWS 2006) and again in 2007 (USFWS 2007a). Some public lands such as national wildlife refuges, military areas, and U.S. Forest Service lands are managed for Indiana bats, but none of the potential summer habitat in the Action Area was specifically identified in the recovery plan. Measures have been implemented, such as gate installation, at important wintering caves in Missouri to reduce cave disturbance (MDC 2000).

The Indiana bat is found throughout most of the eastern half of the United States. Almost half of all Indiana bats hibernate in caves in southern Indiana, and states with Indiana bat populations over 40,000 (in 2005) included Missouri, Kentucky, Illinois, and New York. Other states within the current range of the Indiana bat include Alabama, Arkansas, Connecticut, Iowa, Maryland, Michigan, New Jersey, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, Virginia, and West Virginia (USFWS 2006).

Indiana bats are permanent residents along the entire Action Area. The Indiana bat occurs seasonally during summer along streams and rivers in northern Missouri. The species hibernates through winter in caves and abandoned mines in the Ozarks. Between early spring and autumn, Indiana bats migrate to and use summer roosting and foraging areas located in riparian, floodplain, and upland forests (MDC 2010b, USFWS 2007a). Between 2007 and 2009, the Missouri population of Indiana bat has declined by 14 percent (USFWS 2010a). Current threats to the species include changes in summer habitats from alterations to land cover, reduction of roosting and foraging forested habitat, and white-nose syndrome (MDC 2010b, USFWS 2010b). Because alteration and elimination of forested areas have

been found to impact Indiana bat summer habitat, the elimination of roosting trees could adversely impact Indiana bats. As stated above, the Action Area does not contain designated critical habitat for the Indiana bat.

3.10.3.2 Interior Least Tern

The interior population of the least tern (*Sterna antillarum*) was listed as endangered on June 27, 1985 (50 FR 21,784-21,792) (USFWS 1990). The least tern is also listed as a state endangered species by Missouri, Kansas, and Nebraska. The state of Kansas has designated five locations along the Kansas River, extending upstream from its confluence with the Missouri River, as critical habitat for the interior least tern (KDWP 2009). No critical habitat has been designated on the LOMR.

The interior least tern is a migratory species with recognized distinct interior and coastal populations. The interior population occurs along major rivers in the interior United States, including the Missouri and Mississippi Rivers and their major tributaries. The coastal populations nest on sandy substrate of barrier islands, beaches, and estuaries. Coastal breeding areas in North America include the Pacific Coast south of the San Francisco Bay region, the Gulf Coast, and the Atlantic Coast up to central Maine. The least tern winters in coastal areas of Central and South America.

The interior least tern is the smallest North American tern and is a colonial nester (Thompson et al. 1997). Shallow nests, or scrapes, are built in sand or fine substrate gravel with sparse vegetation. A 2005 breeding bird distribution survey (USFWS 1990) identified that, although least tern populations occurred over much of the species historical range, populations were limited to river reaches with suitable nesting habitat along rivers and reservoir shorelines. Colonies also were identified at sand pits, industrial sites, alkali flats, and on rooftops (Lott 2006). The 2005 breeding bird survey identified 17,591 interior least tern individuals (USFWS 1990).

The interior least tern is primarily piscivorous (fish-eating) but may occasionally consume aquatic invertebrates (Thompson et al. 1997). Least terns feed in shallow waters of rivers, reservoirs, and lakes and forage by hovering over and diving into the water to catch fish (USFWS 1990).

The USFWS published a recovery plan for the interior population of least terns in 1990 (USFWS 1990). The recovery plan identified threats to this species, which included the physical and functional loss of breeding habitat due to river management actions. Loss of habitat results from channelization, dredging, and impoundment of rivers that eliminates nesting habitat. Further, nesting habitat is

functionally affected by managed water levels which have the potential to inundate occupied or potential nesting habitat.

Small flocks of interior least terns migrate between wintering and nesting habitat through Missouri from late April to mid-May and from August through September (MDC 2010a). The distribution of least tern colonies in Missouri is limited to the Mississippi River south of St. Louis. Historical interior least tern breeding habitat was located along the Missouri River (USFWS 1992); however, the 2005 breeding bird survey (Lott 2006) did not identify any least tern nest sites in Missouri, and no nest sites were observed on the Missouri River south of its confluence with the Lower Platte River in Nebraska. Suitable sand bar nesting habitat has been mostly eliminated in the proposed Action Area because of river channelization (Smith and Renken 1991, USFWS 2003). Past channelization projects along the LOMR have resulted in a 97-percent reduction in sand bar areas (Galat et al. 2005).

The distribution of least tern colonies in Kansas is limited to two colonies on the Kansas River and two populations on the Arkansas River system. Although state-designated critical habitat has been identified along a portion of the Kansas River near its confluence with the Missouri River, no colonies were observed in the designated critical habitat.

While interior least tern individuals may occur along the LOMR during migration, nesting has not been found to occur within the Action Area. Historically, the interior least tern nested along the LOMR to St. Louis, Missouri (USACE 2004); therefore, this species may use the LOMR for breeding if suitable nesting habitat is present.

3.10.3.3 Piping Plover

The piping plover (*Charadrius melodus*) was federally listed on December 11, 1985 (50 FR, 50726–50734) (USFWS 1990). The populations in the Great Lakes–Big Rivers region, which does not include the Action Area, are listed as endangered. Piping plover populations outside of this region are listed as threatened. The state of Missouri considers the piping plover a transient species in Missouri.

The USFWS has designated critical habitat for this species in the northern Great Plains, which includes portions of Nebraska (50 FR 67, 57638–57717). However, critical habitat in Nebraska is outside of the Action Area. Kansas has designated critical habitat for piping plover on the Kansas River for the segment that extends from the confluence of the Smoky Hill River and Republican River downstream to the confluence of the Kansas and Missouri Rivers in Kansas City, Missouri (KDWP 2009).

The piping plover is a migratory species with recognized distinct interior and coastal populations. The interior populations include the Great Lake–Big Rivers population and those that occur in the Great Plains region. This species breeds along major rivers in the interior United States, including the Missouri and Mississippi Rivers and their major tributaries. The coastal populations nest on sandy substrate of barrier islands, beaches, and estuaries on the Atlantic Coast from North Carolina to Maine. The piping plover winters on the Atlantic and Gulf Coasts from North Carolina to Texas, Mexico, Central America, and the Caribbean.

Piping plovers are a transient species that rarely occur in Missouri during migration between wintering grounds and breeding areas (The Audubon Society of Missouri 2009). Migration habitat use is poorly understood, but plovers likely use inland and coastal stopover sites when completing this migration (USFWS 2008). The importance of the Missouri River as migration habitat is unknown (USFWS 2003). Typically, the piping plover migration between wintering and nesting habitats peaks in spring and fall (USFWS 2008).

The USFWS published a recovery plan for the Great Lakes and Great Plains piping plover (USFWS 1988). The Great Plains region, as defined for the recovery plan, did not include rivers in Missouri or Kansas. The recovery plan identified threats to this species as the physical and functional loss of breeding habitat due to recreational activities and river management actions. Recreational effects to habitat include vehicular and pedestrian traffic on suitable nesting sites. Channelization, dredging, and impoundment of rivers also eliminates sand bar nesting habitat.

Piping plover nests consist of shallow scrapes in sand on sand bars, beaches, or shorelines. Piping plovers feed on freshwater and marine benthic invertebrates and terrestrial invertebrates (Elliott-Smith and Haig 2004). They feed in shallow waters near the shoreline or on beaches (USFWS 1990).

Historical breeding habitat primarily consisted of unvegetated sand bars within major river systems, alkali wetlands, and lake and reservoir shorelines with suitable nesting substrate (USFWS 1988). A 1986–1987 breeding survey identified 680 pairs of piping plover in the Great Plains region, which includes portions of the LOMR flowing through Nebraska (USFWS 1988). Breeding of piping plovers was documented in northern Kansas along portions of the Kansas River in 1996 and 1997 (Busby et al. 1997). Two to four breeding pairs were observed along the Kansas River between 1998 and 2006, but no nests were documented in 2007 or 2008 (USFWS 2009b).

The 1998 recovery plan goal was 465 piping plover breeding pairs throughout their range. The number of breeding pairs has increased steadily since 1998 until it surpassed the recovery plan goal in 2005.

The number of breeding pairs has fluctuated below the recovery plan goal since 2005 but has been approximately three times the baseline number of breeding pairs identified in the recovery plan (USFWS 2009b). Piping plover breeding has not been documented in the Action Area. Due to impoundment and channelization of the LOMR, virtually no piping plover nesting habitat is located along the Action Area (USFWS 2003). Further, no portion of the LOMR in the Action Area has been designated as critical piping plover habitat (USFWS 2002).

3.10.3.4 Pallid Sturgeon

The pallid sturgeon *(Scaphirhyncus albus)* was listed as endangered on September 6, 1990 (55 FR 36641). The pallid sturgeon is also listed as endangered by the states of Missouri, Kansas, and Nebraska. The USFWS has not designated critical habitat for this species (USFWS 2010c). Kansas has designated critical habitat for pallid sturgeon in portions of the Missouri River in Kansas (KDWP 2004).

In 1993, the USFWS released the Pallid Sturgeon Recovery Plan (USFWS 1993). The short-term recovery objective was to prevent species extinction by establishing three captive broodstock populations in separate hatcheries. The long-term objectives were to downlist and, eventually, delist the species through protection, habitat restoration, and propagation activities by 2040 (USFWS 1993). In addition, the Pallid Sturgeon Recovery Plan (USFWS 1993) identified six Recovery Priority Management Areas (RPMAs) for implementation of recovery tasks based on the most recent pallid sturgeon records of occurrence and the potential of these areas to contribute to the recovery of the species. The Action Area falls within the RPMA 4, which consists of the portion of the LOMR downstream of Gavins Point Dam to the confluence of the Missouri and Mississippi Rivers (USFWS 1993).

The primary range and habitat of the pallid sturgeon are located in the Missouri River and the portions of the Mississippi River and some of its tributaries downstream of the Mississippi River confluence with the Missouri River (USFWS 2010c). The distribution of the pallid sturgeon in Missouri, Kansas, and Nebraska is restricted to the LOMR mainstem, with some limited use of the downstream portions of some large tributaries. Since 1994, pallid sturgeon populations have been augmented with hatchery-reared fish (USFWS 2007b). Pallid sturgeon stocking data between 1994 and 2009 are presented in Table 3.10-2 and illustrated in Figure 3.10-1. The collection of individuals from all stocked cohorts indicates that hatchery supplementation is contributing to the pallid sturgeon population in RPMA 4. Between 1999 and 2005, 156 pallid sturgeon were captured in RPMA 4. Wild fish comprised 51 of the

captured fish, while 82 captured fish were of hatchery origin and 24 fish were of unknown origin (USFWS 2007b). Unpublished 2009 sampling data provided by the USACE showed the capture of 589 hatchery-reared pallid sturgeon, 81 wild fish, and 26 fish of unknown origin; a total of 696 pallid sturgeon were captured in RPMA 4 in 2009 (Covington pers. comm. [a]).

Table 3.10-2 Pallid Sturgeon Stocking Data (1994–2009)

Year	Number Stocked	Year	Number Stocked
1994	2,412	2002	0
1995	0	2003	14,555
1996	0	2004	35,372
1997	2,012	2005	8,611
1998	0	2006	4,658
1999	0	2007	5,643
2000	0	2008	6,101
2001	6,864	2009	7,604

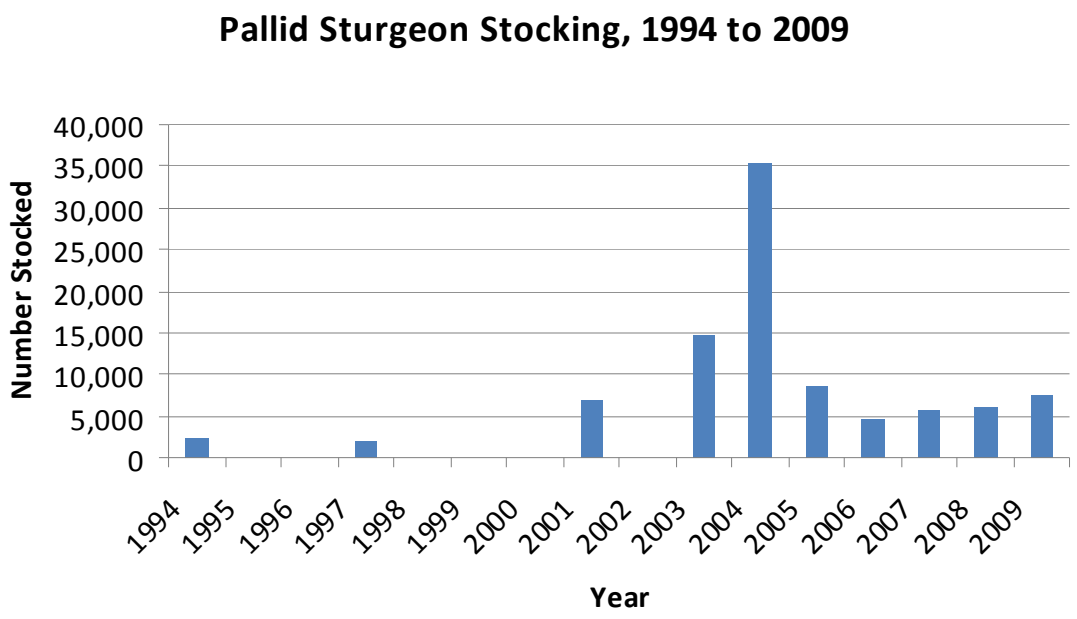

Figure 3.10-1 Pallid Sturgeon Stocking in the Missouri River (1994–2009)

Source: Covington pers. comm. [b].

The pallid sturgeon is morphologically adapted to life in swift waters on the bottom of large, turbid, free-flowing rivers (Kallemeyn 1983, Gilbraith et al. 1988). This species evolved in the diverse environments of the Missouri and Mississippi Rivers where the floodplain, backwaters, chutes, sloughs, islands, sand bars, and main channel provided numerous microhabitats (USFWS 1993). Historically, these habitats were constantly changing. Since the 1930s, construction of dams on the upper river and channelization of the LOMR have resulted in dramatic long-term changes to the character of the LOMR (see Chapter 1). As a result of these modifications, much of the dynamic nature of the LOMR system has been eliminated (see Chapter 1).

According to the USFWS (2003), the pallid sturgeon has been captured in tributary mouths, over sand bars, along main channel borders, and in deep holes—all of which can provide overwintering habitat. The importance of tributaries of the LOMR to pallid sturgeon is largely unknown. Tagged wild pallid sturgeon have been found to move short distances up some tributaries, which suggests that pallid sturgeon use tributaries opportunistically for feeding when conditions allow (DeLonay et al. 2009). In addition, small pallid sturgeon have been captured in off-channel shallow-water habitat areas (USFWS 2003). Fishery sampling programs conducted by the USFWS have often found pallid sturgeon along with shovelnose sturgeon (*Scaphirhynchus platorhynchus)* indicating some overlap in habitat requirements. Within their range, pallid sturgeon migrate both daily and seasonally. Bramblett (1996) found that pallid sturgeon can move as far as 13 miles a day, at a rate as fast as 6 miles per hour (mph). Home range for the pallid sturgeon was found to be greatest during spring, presumably associated with spawning, and could be as large as 198 miles (Bramblett 1996). The size of the home range during spring and summer was not found to be significantly different, but the size of the home range in fall and winter was found to be significantly different from that of the spring (Bramblett 1996).

The pallid sturgeon can also be found at a variety of depths. A recent study (DeLonay et al. 2009) in the LOMR documented the sturgeon's movement and water depth occurrence over a year long period. A male and female were implanted with ultrasonic telemetry transmitters and archival temperature/depth recording tags in 2003. Within a year, the female remained within a 2-mile (3.2-km) reach of the river. The tagged male traveled 100 miles (161 km) in a 3-month period. Both fish inhabited depths ranging from 4.5 to 35.4 feet (1.4 to 10.8 m), with an average depth of 13 feet (4 m). Areas with less than 6.5 feet (2 m) were rarely used by the tagged fish.

River discharge and photoperiod (ratio of light and dark hours) may contain important environmental cues for the timing of migration and other movements (Bramblett 1996). With increasing discharge, the pallid sturgeon tends to be found farther upstream (Bramblett 1996). Because the pallid sturgeon is not

thought to spawn every year, Bramblett (1996) suggests that their relative location in the river from year to year may be indicative of whether individuals are spawning.

Within the LOMR, Delonay et al. (2009) conducted telemetry studies in 2007 and 2008 with female pallid sturgeon to determine spawning migrations in the upper (Platte River, Nebraska to Big Sioux River, Iowa) and lower (Osage River, Missouri and Grand River, Missouri) segments of the LOMR. During the studies, 218 pallid sturgeon were captured; of these, 190 were of hatchery origin and 28 were wild fish. Four gravid females were implanted with telemetry devices; no ripe males were collected. Three of the four gravid females were observed to travel a distance of between 85 and 185 river miles upstream to their presumed spawning grounds located near Glasgow, Missouri (RM 230.1), downstream of the Kansas River confluence with the LOMR (RM 366.4) and slightly upstream of the Kansas River confluence with the LOMR (RM 369.5). All three females in the downstream LOMR study area, when recollected, were determined to have spawned. The females were observed, after reaching their upstream migratory destination, swimming back and forth within approximately 0.3- to 0.5-mile-long portions of the LOMR along revetted outside bends. Delonay et al. concluded that these movements were characteristic of spawning behavior. The spawning location of the fourth female in the upper segment of the LOMR could not be determined because of disruptions of upstream movements due to periods of lowered water temperatures. This presumed spawning all occurred in early May, when water temperatures were between 60 and 64 °F. Post-spawning downstream movement was variable, but all three tagged females had migrated downstream into the Mississippi River by fall. The authors noted that, although the study demonstrated that pallid sturgeon are spawning in the LOMR, researchers do not know if spawning was conducted under optimal conditions, if the eggs hatched, and if any juvenile fish survived.

For the portion of the LOMR between the Platte River and its confluence with the Mississippi River, the USFWS determined that larval and juvenile pallid sturgeon abundance is limited by the quantity of shallow-water habitat that provides rearing and refugia habitat for this life stage (USFWS 2003).

3.10.3.5 Shovelnose Sturgeon

On September 1, 2010, the USFWS issued a final rule determining that shovelnose sturgeon (*Scaphirhynchus platorynchus*) should be treated as threatened due to similarity of appearance to the endangered pallid sturgeon in areas where they commonly coexist, such as the Missouri River (75 FR 53598). However, the ruling extends take prohibitions only to activities associated with commercial fishing. All other activities in areas where the two species overlap and which are conducted in

accordance with applicable laws and regulations will not be considered take under the regulations designating shovelnose sturgeon as threatened (75 FR 53598). Therefore, shovelnose sturgeon will not be considered further in Section 4.8 as take is not currently prohibited for activities associated with commercial sand and gravel dredging within the LOMR.

3.10.3.6 Decurrent False Aster

The decurrent false aster *(Boltonia decurrens)* is listed as threatened and occurs in the eastern half of St. Charles County, Missouri. The decurrent false aster is a perennial plant that grows from 1 to 5 feet tall and occasionally reaches heights of over 6 feet (MDC 2010a). This species blooms from July to October and bears seeds from August to October. The blooms occur in branched groups of composite heads with yellow disk flowers and white to purplish ray flowers. Decurrent false aster is closely related to *Boltonia asteroides* var. *recognita*, which is a common weedy species of false aster. Both of these species are sometimes found in the same habitat.

Habitat for this species is located in moist, sandy soils and is primarily found in wetlands, on the borders of marshes and lakes, and on the margins of bottomland oxbows and sloughs (Missouri Department of Conservation 2010). Decurrent false aster favors colonization in recently disturbed areas, and flooding may play a role in maintaining its habitat. The primary threat to the decurrent false aster is the loss of suitable wetland habitat (MDC 2010).

The distribution of decurrent false aster is restricted to the portion of the Mississippi River floodplain south of the confluence of the Illinois River with the Mississippi River (MDC 2010, NatureServe 2009). Decurrent false aster has the potential to occur along Missouri River floodplains within St. Charles County, Missouri (in the St. Charles segment) (MDC 2010, Ledwin pers. comm.).

3.10.4 References

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3.11 LAND USE AND RECREATION

3.11.1 Introduction

This section describes the existing land use and recreation resources that could be affected by the proposed Project or the alternatives. The changes in dredging operations that would occur under the Proposed Action and alternatives have the potential to affect land use and recreational resources adjacent to the river through changes in water levels, changes in river bed degradation, and the presence of dredging facilities and associated activities.

This description of the affected environment focuses on land uses associated with the onshore facilities currently used for dredging and other notable land uses in each river segment, including recreational facilities. A reach in each river segment was analyzed from 3 miles downstream of an onshore facility to 10 miles upstream of the facility in order to cover the potential range of dredging activities. The analysis includes the land uses, zoning designations, and recreational uses mandated by city, county, state, and federal government entities in the affected reach. For the counties and incorporated areas where land use or zoning maps were not available, GIS land cover data were used to identify the existing land uses along each of the reaches, as displayed in Figure 3.11-1 (Sheets 1 through 5).

In general, the land uses along the Missouri River vary only slightly. Agriculture is the predominant use along the river. A handful of urban centers exist along the river, including St. Charles, Jefferson City, Kansas City (Missouri and Kansas), and St. Joseph. Small towns are scattered along the river banks. Open space along the river includes areas dedicated for conservation and wildlife, some of which are also used for recreational purposes.

The LOMR is widely utilized for recreation. Many public and private boat ramps provide access to the LOMR, but few marinas, piers, or fueling facilities are located on the LOMR. Fishing occurs from boats, the riverbank, and dikes. A growing form of Missouri River recreation is canoeing or kayaking. Since its start in 2006, the annual Missouri River 340 canoe and kayak race from Kansas City to St. Louis has grown from 15 teams in the initial race to 320 teams registered to race in summer 2010. More canoes and kayaks are generally seen on the river throughout the year.

This section discusses the formal recreation areas and facilities such as boat access areas, conservation areas, and designated recreational parks that may be used to access the river. In general, the undeveloped areas are sources of informal recreational use such as hiking, boating, and

fishing. The locations of recreation and access facilities discussed for each of the reaches are displayed in Figure 3.11-2 (Sheets 1 through 5).

The Lewis and Clark National Historic Trail (Historic Trail) follows the Missouri River along entire length of the Project area, from RM 0 at St. Louis to RM 498 at Rulo, Nebraska and several visitor centers are located along its shores. The National Park Service manages the Historic Trail, which extends 3,700 miles from Wood River, Illinois, to Oregon (NPS 2010). The Historic Trail includes many points of interest along the LOMR, which are discussed below for individual segments. The Katy Trail is a 225-mile-long Missouri state park created by the National Trails System Act (MDNR 2008). The 165 miles of the Katy Trail between St. Charles and Boonville have been designated as an official segment of the Lewis and Clark National Historic Trail. The Katy Trail occasionally experiences washouts or can become flooded temporarily during extreme flooding events (MDNR 2010). Rough areas can occur at any time as a result of weather variations that may wash debris onto the trail.

3.11.2 Sources of Information

Information used in the preparation of this section includes the following:

- Land use plans and county general plans and accompanying GIS data;
- Missouri Department of Conservation (2010);
- U.S. Fish and Wildlife Service (USFWS) documents;
- USACE Lewis and Clark Bicentennial map; and
- GIS data for recreation areas and facilities.

3.11.3 St. Joseph Segment

The existing Holliday Sand & Gravel Company – St. Joseph facility (Holliday–St. Joseph) is located in the St. Joseph segment. St. Joseph is the major urban center, and most of the land use in this segment is agricultural or rural. The formal recreation facilities in the segment are primarily located in the reach where the Holliday–St. Joseph facility is located. Lewis and Clark Historic Trail points of interest along the St. Joseph segment include Independence Park and the Frontier Army Museum (NPS 2010). Figure 3.11-1 (Sheet 1) shows land uses and dredging areas in this segment. Figure 3.11-2 (Sheet 1) shows recreation facilities and access to the LOMR in the segment.

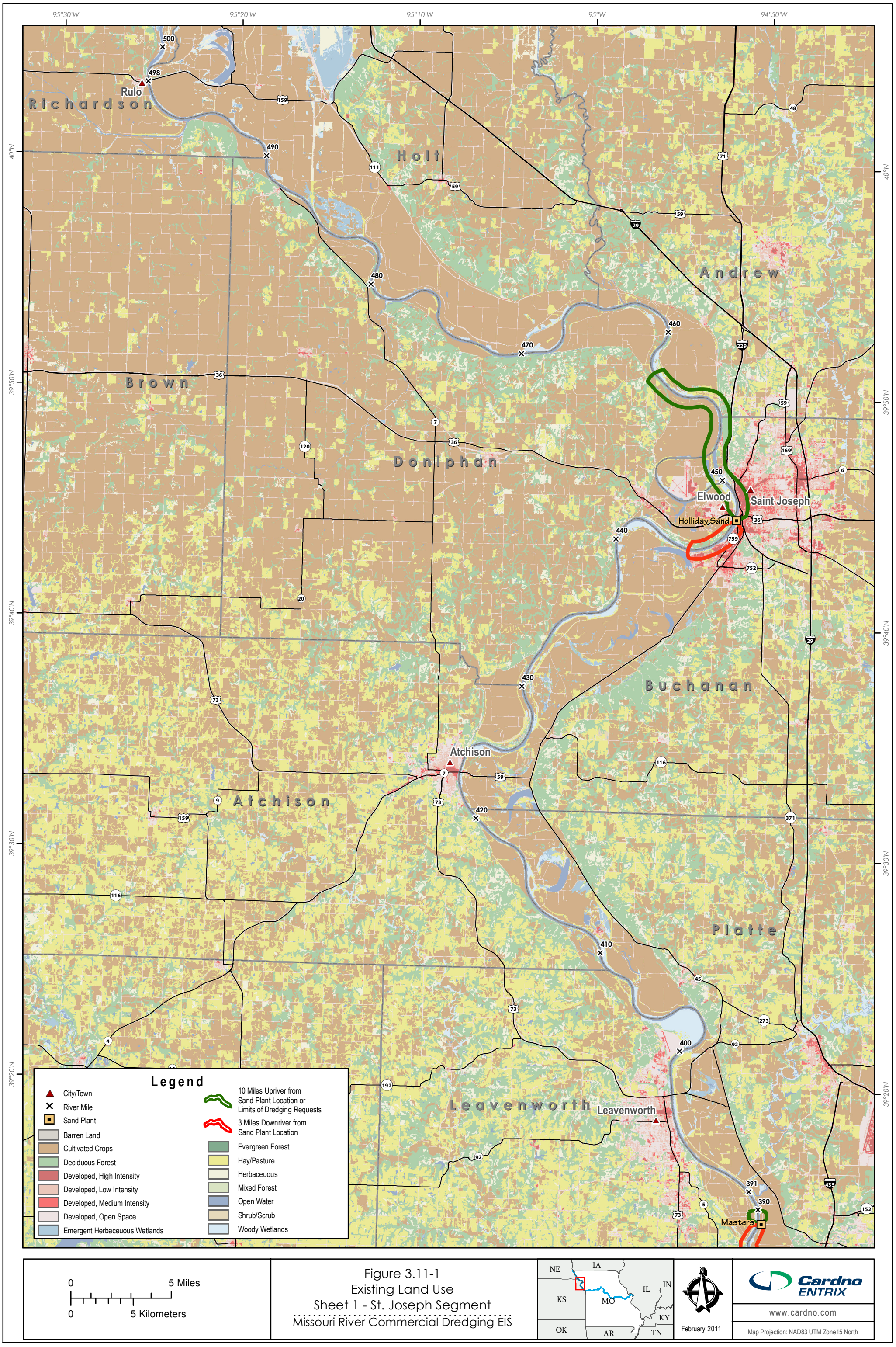
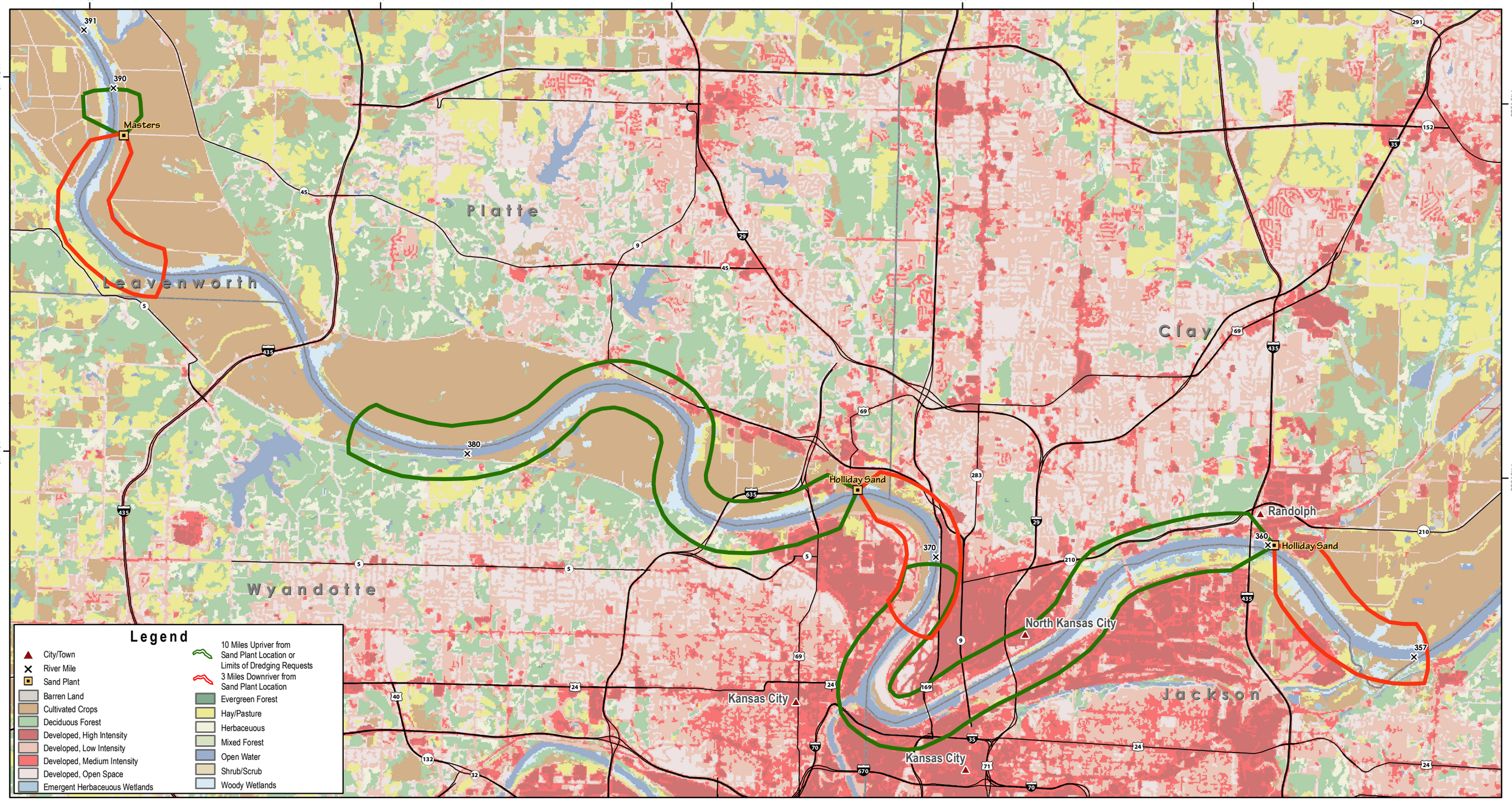


Figure 3.11-1
Existing Land Use
Sheet 1 - St. Joseph Segment
Missouri River Commercial Dredging EIS



0 5 Miles

0 5 Kilometers

Figure 3.11-1
Existing Land Use
Sheet 2 - Kansas City Segment

Missouri River Commercial Dredging EIS

February 2011

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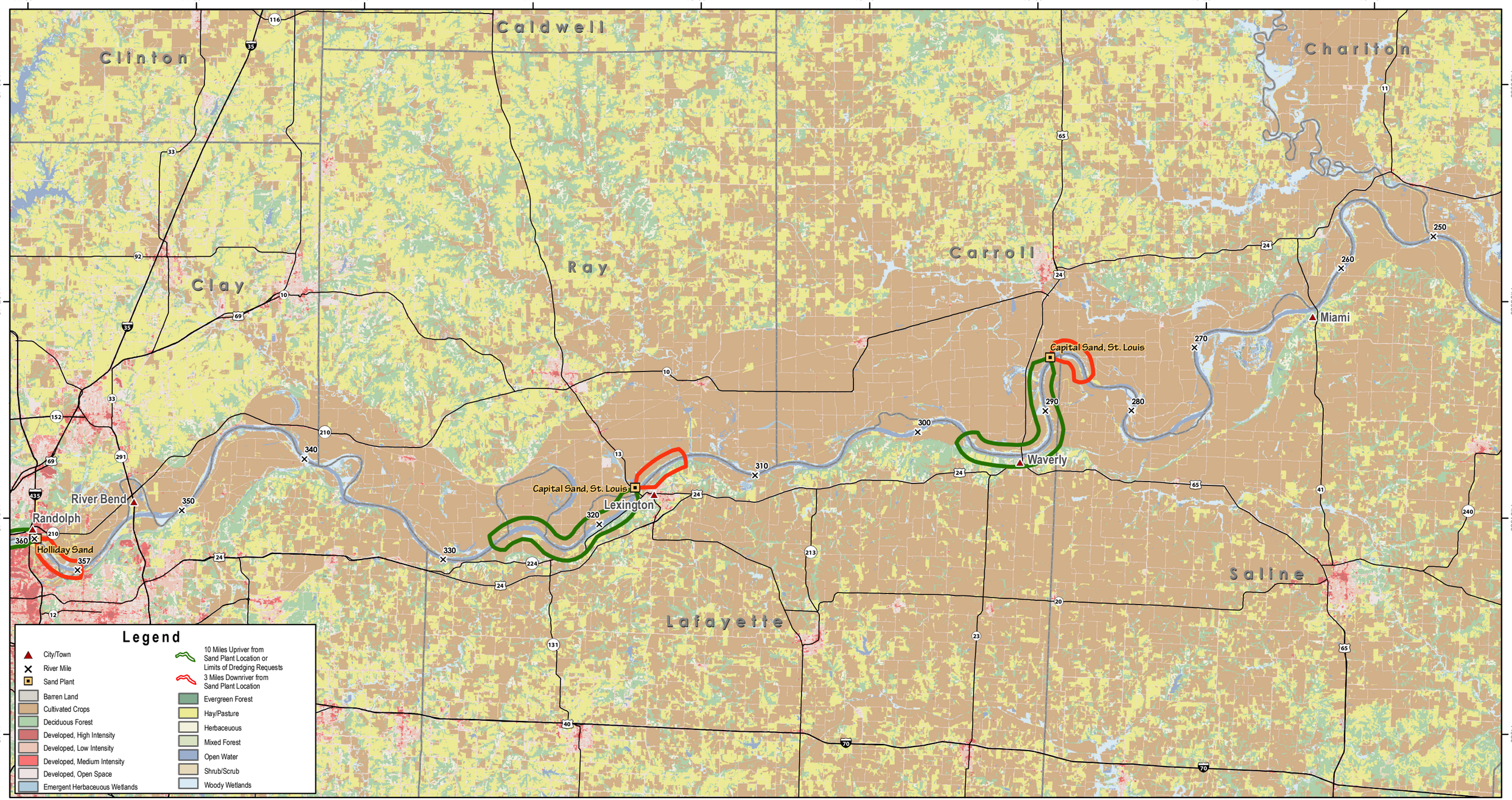
Map Projection: NAD83 UTM Zone15 North



0 5 10 15 20 Miles

0 5 10 15 20 Kilometers

Figure 3.11-1
Existing Land Use
Sheet 3 - Waverly Segment

Missouri River Commercial Dredging EIS

February 2011

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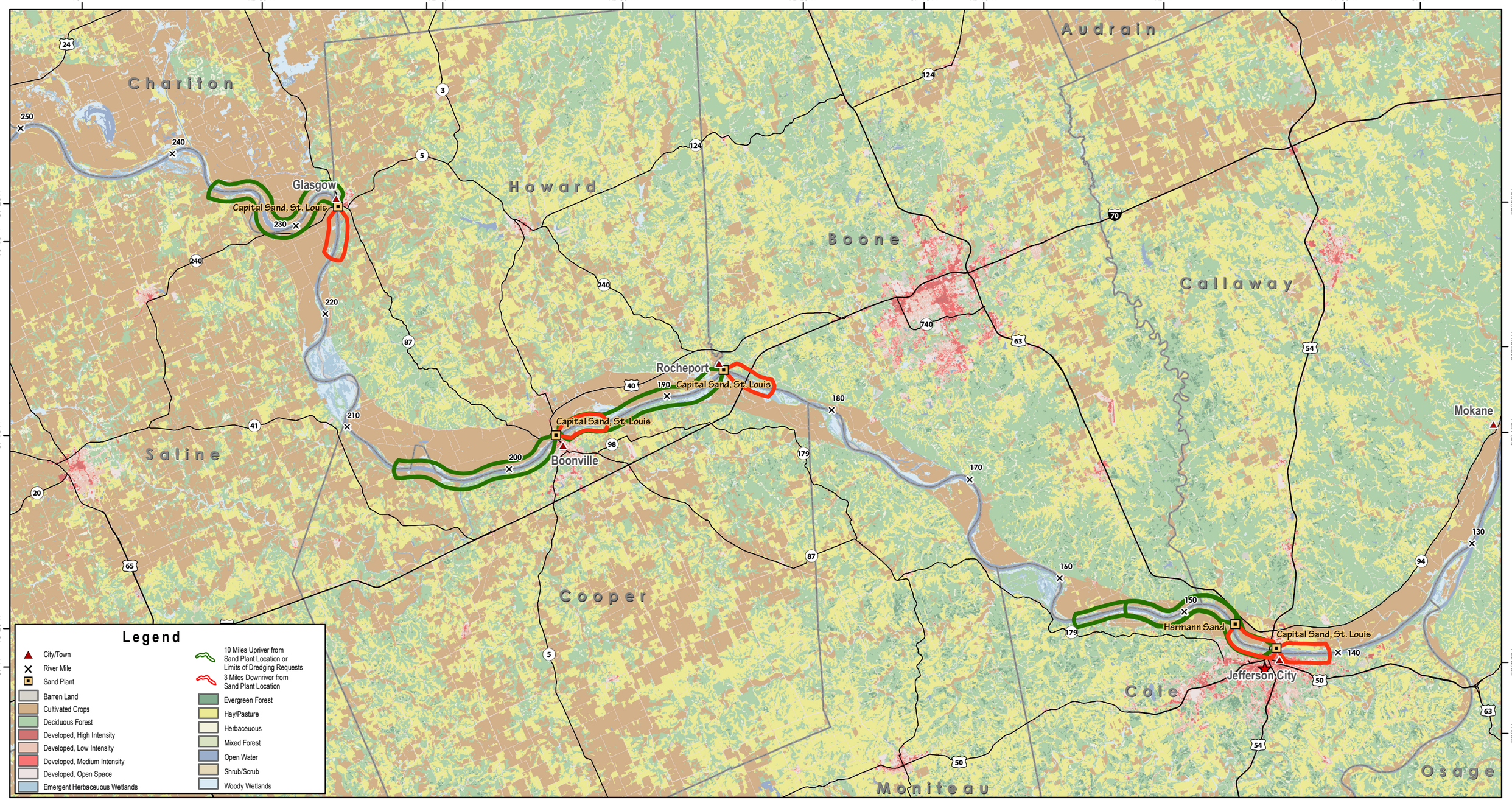
Map Projection: NAD83 UTM Zone15 North



0 5 10 15 20 Miles

0 5 10 15 20 Kilometers

Figure 3.11-1
Existing Land Use
Sheet 4 - Jefferson City Segment

Missouri River Commercial Dredging EIS

February 2011

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Map Projection: NAD83 UTM Zone15 North

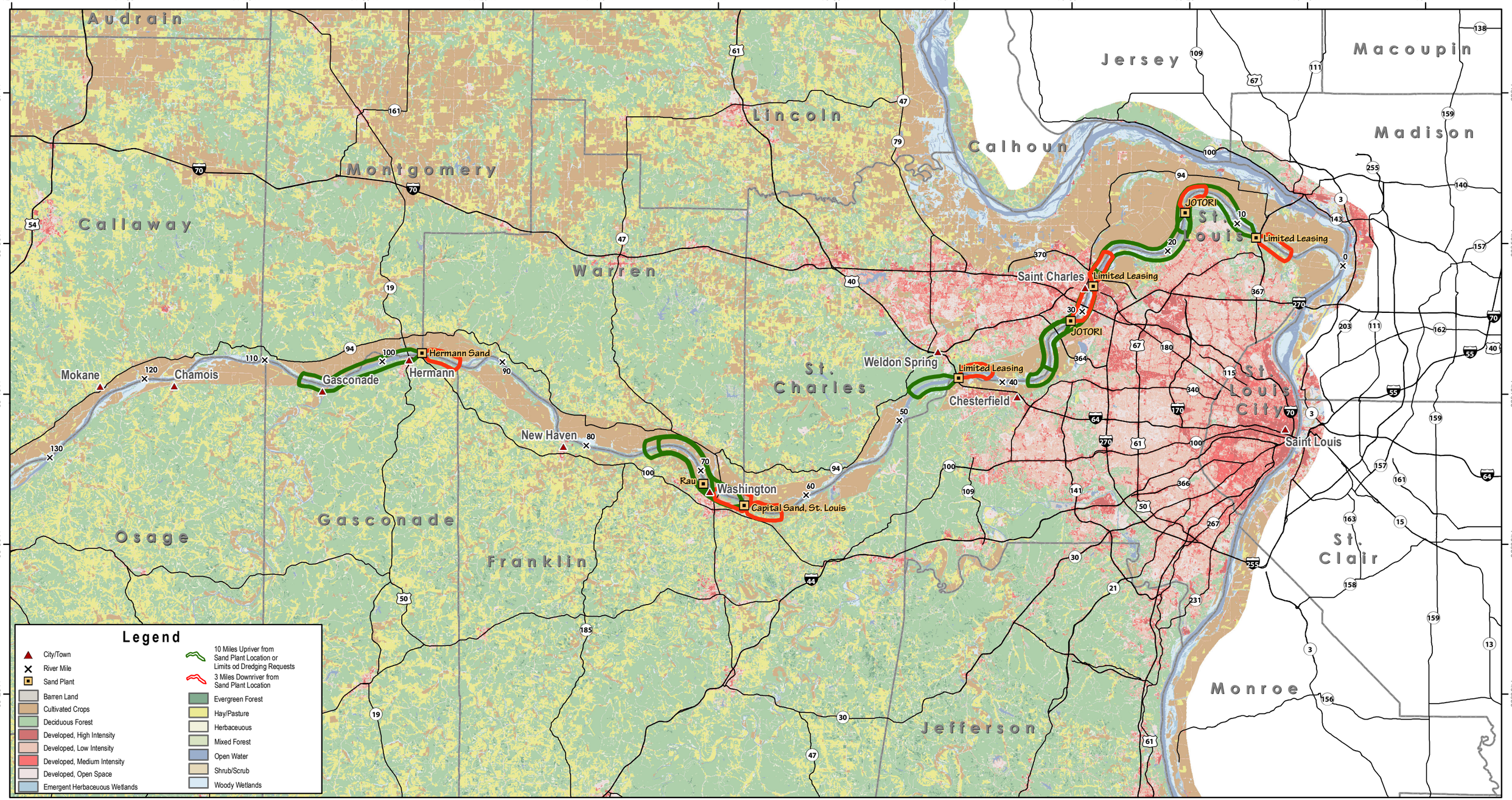
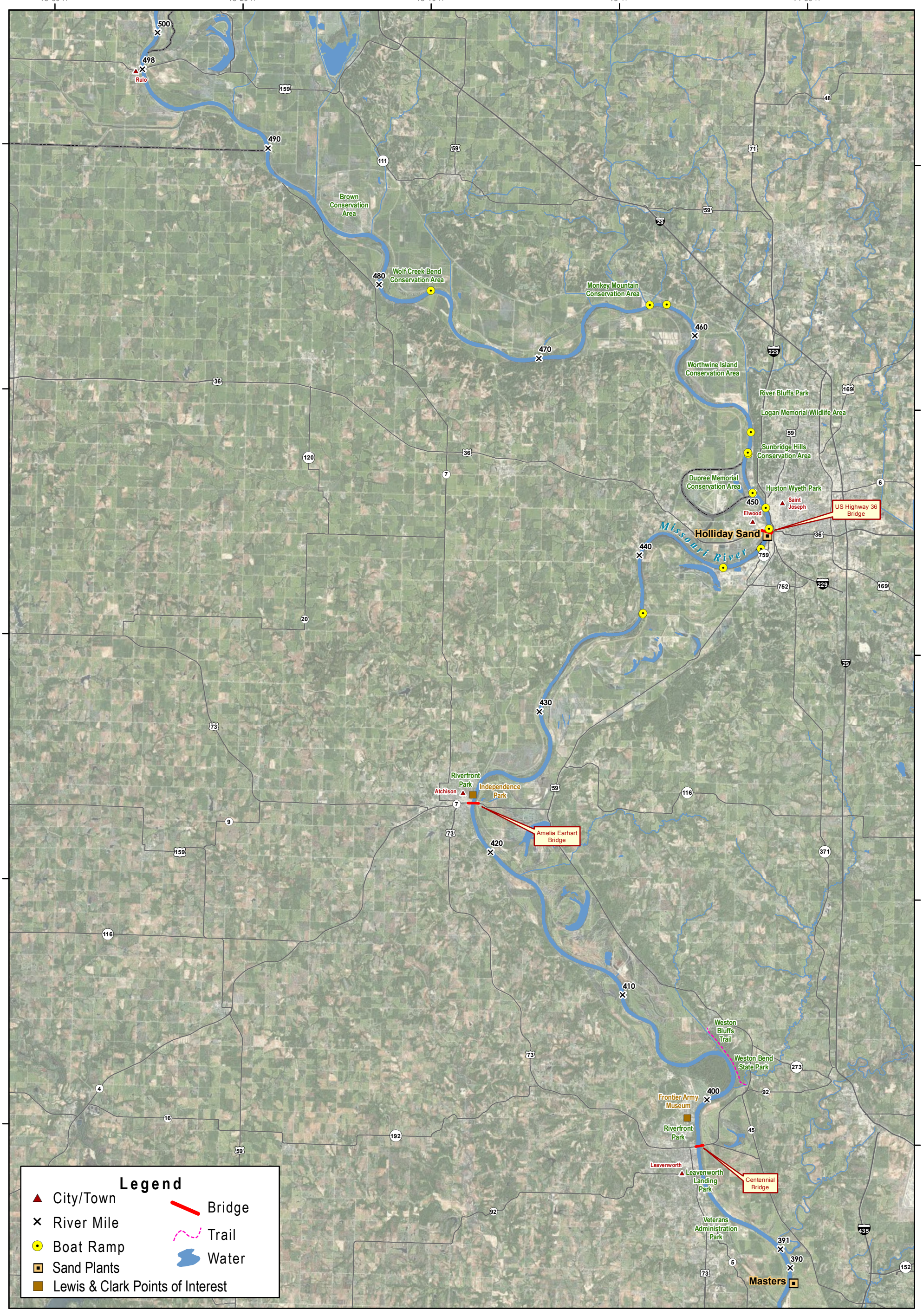


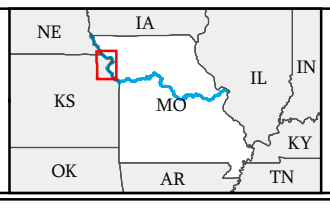
Figure 3.11-1
Existing Land Use
Sheet 5 - St. Charles Segment

Missouri River Commercial Dredging EIS



0 5 Miles
0 5 Kilometers

Figure 3.11-2
Recreation and Access Features
Sheet 1 - St. Joseph Segment
Missouri River Commercial Dredging EIS



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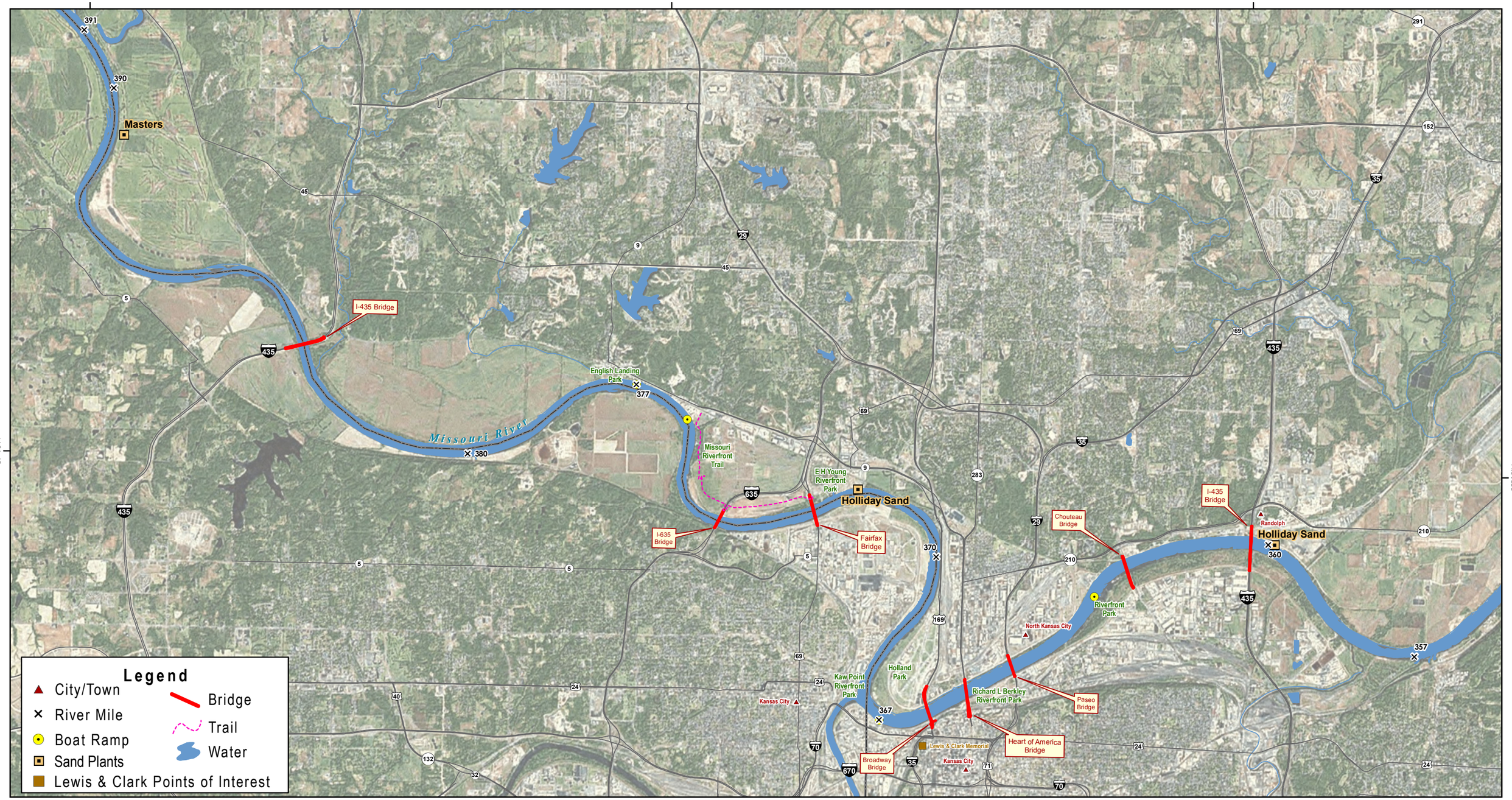
Map Projection: NAD83 UTM Zone15 North



0 5 Miles

0 5 Kilometers

Figure 3.11-2
Recreation and Access Features
Sheet 2 - Kansas City Segment

Missouri River Commercial Dredging EIS

February 2011

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Map Projection: NAD83 UTM Zone15 North

0 5 10 15 20 Miles

0 5 10 15 20 Kilometers

Figure 3.11-2
Recreation and Access Features
Sheet 3 - Waverly Segment

Missouri River Commercial Dredging EIS

February 2011

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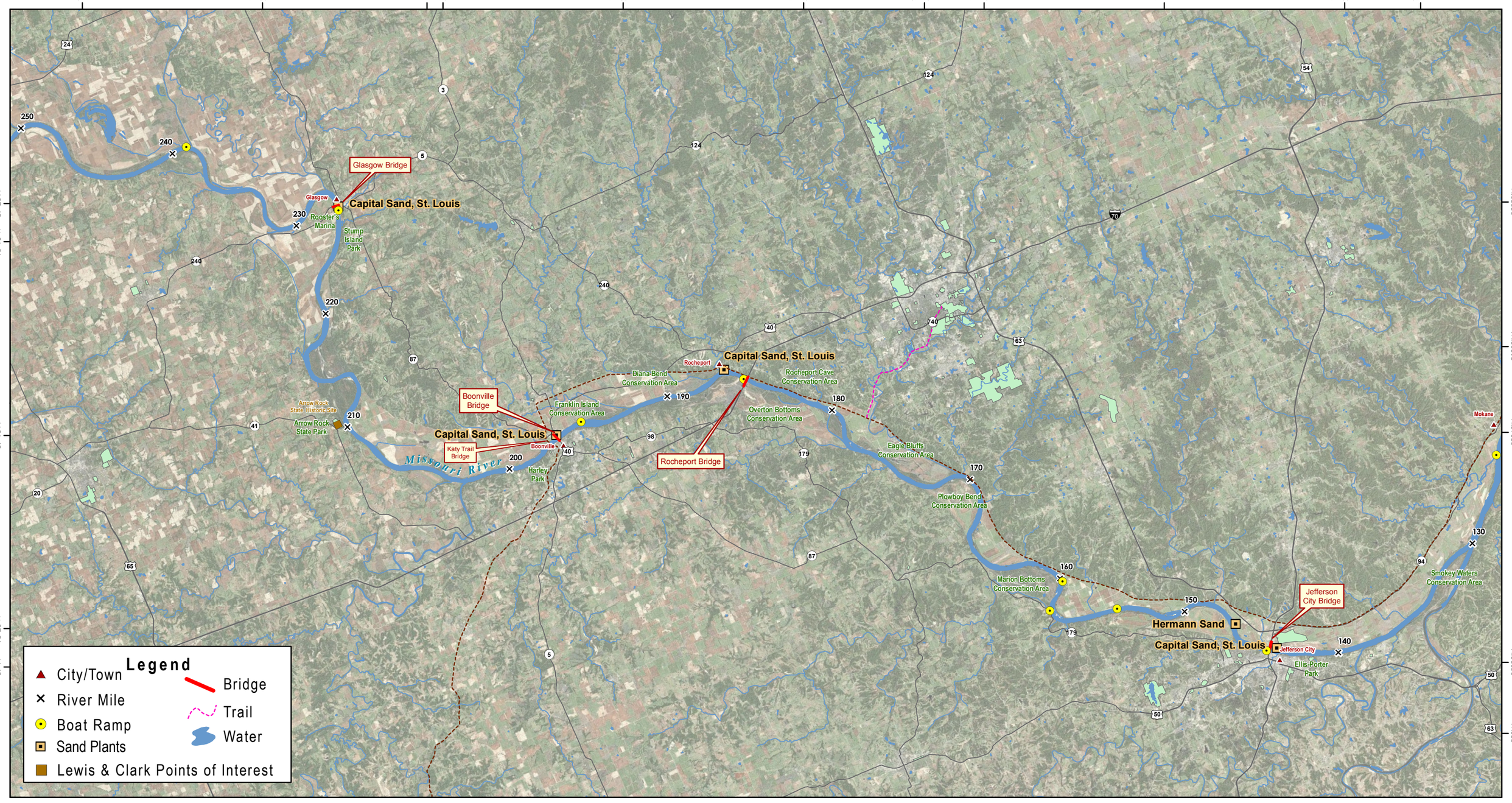
Map Projection: NAD83 UTM Zone15 North

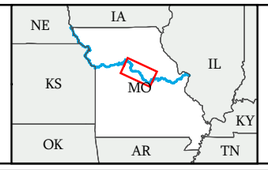


0 5 10 15 20 Miles

0 5 10 15 20 Kilometers

Figure 3.11-2
Recreation and Access Features
Sheet 4 - Jefferson City Segment

Missouri River Commercial Dredging EIS



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Cardno ENTRIX

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Map Projection: NAD83 UTM Zone15 North

0 5 10 15 20 Miles

0 5 10 15 20 Kilometers

Figure 3.11-2
Recreation and Access Features
Sheet 5 - St. Charles Segment

Missouri River Commercial Dredging EIS

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Map Projection: NAD83 UTM Zone15 North

3.11.3.1 Holliday Sand & Gravel Company – St. Joseph Facility

Holliday–St. Joseph is located in the City of St. Joseph in Buchanan County (Missouri); the reach for the facility runs adjacent to lands in the counties of Buchanan, Doniphan (Kansas), and Andrew (Missouri). The facility is located on lands designated as industrial (City of St. Joseph 2009). Land uses adjacent to the reach that lie in the City of St. Joseph are designated as industrial, parks/parkway, and commercial. The unincorporated portions of Buchanan County that are downstream and adjacent to the reach are designated as recreation areas (Buchanan County 2006). The unincorporated parts of Doniphan County that are adjacent to the reach are designated for agriculture (Doniphan County 2009). A portion of Doniphan County is incorporated (the Town of Elwood). Elwood's lands adjacent to the reach are used for industrial purposes. Andrew County has no zoning ordinances (Andrew County 2010).

Recreational facilities along the Holliday–St. Joseph reach include the Arthur DuPree Memorial Conservation Area (CA) (RM 449.8 to RM 451.6), Huston Wyeth Park (RM 450), Sunbridge Hills CA (RM 452 to RM 453.2), Logan Memorial Wildlife Area (RM 453.2), River Bluffs Park (RM 453.2), Worthwine Island CA (RM 456.2 to RM 459.9), Flathead Fishing Club boat ramp (RM 444.7), Elwood access ramp (RM 447.8), Show Boat Landing boat ramp (RM 449), French Bottom boat ramp (RM 450.4), Sunset Grill boat ramp (RM 451.9), and two unnamed boat ramps (RM 447 and RM 453).

The Arthur DuPree CA accommodates bird watching, fishing, hiking, hunting, and trapping. Hunting in this area is limited to deer, dove, pheasant, quail, rabbit, squirrel, turkey, and waterfowl. The Sunbridge Hills CA accommodates bird watching, hiking, hunting, and trapping. Hunting in this area is limited to deer, squirrel, and turkey. The Logan Memorial Wildlife Area accommodates bird watching, hiking, hunting, and trapping. Hunting in the area is limited to deer, squirrel, and turkey. The Worthwine Island CA accommodates bird watching, camping, fishing, hiking, hunting, and trapping. Hunting on the island is limited to deer, pheasant, rabbit, squirrel, turkey, and waterfowl. Huston Wyeth Park in the City of St. Joseph is also adjacent to the reach.

3.11.4 Kansas City Segment

The Master's Dredging Company proposed Waldron facility (Master's–Waldron), the Holliday Sand & Gravel Company – Randolph facility (Holliday–Randolph), and the Holliday Sand & Gravel Company – Riverside facility (Holliday–Riverside) are located in the Kansas City segment. Kansas City, Missouri and Kansas City, Kansas are the major urban centers in this segment, and most of the land adjacent to the segment is used for industrial purposes. Consequently, most of the recreational opportunities in

this segment are located in open space areas neighboring the urban centers. The only Lewis and Clark Historic Trail point of interest along the Kansas City segment is the Lewis and Clark Memorial in Kansas City (NPS 2010). Figure 3.11-1 (Sheet 2) shows land uses and dredging areas in this segment. Figure 3.11-2 (Sheet 2) shows recreation and access to the LOMR in the segment.

3.11.4.1 The Master's Dredging Company – Waldron Facility

The two proposed sites for the Master's–Waldron facility are located in Platte County (Missouri); the reach for the proposed facility runs adjacent to lands in the counties of Platte, Wyandotte (Missouri), and Leavenworth (Kansas). The two sites are located within 0.25 mile of each other along the LOMR, in areas zoned for agriculture. One site is on the waterside of the levee, and the other is located on the landside. The land at both sites is considered prime farmland, of which there are approximately 93,138.7 acres in Platte County (NRCS 2010). Land uses adjacent to the reach that lie in unincorporated Platte County are agricultural. Unincorporated areas of Wyandotte County that are adjacent to the reach are designated as floodplain (Unified Government of Wyandotte County and Kansas City, Kansas 2004). Land uses adjacent to the reach that lie in the boundaries of the City of Lansing, Kansas, are designated for agricultural use (City of Lansing 2008). Land uses adjacent to the reach that lie in the boundaries of the City of Leavenworth, Kansas, are designated as planned unit development, light industrial, and heavy industrial (City of Leavenworth 2009). Unincorporated lands in Leavenworth County that are adjacent to the reach are designated as floodplain (Leavenworth County 2008).

No recreational facilities are located along the proposed Master's–Waldron reach.

3.11.4.2 Holliday Sand & Gravel Company – Randolph Facility

The Holliday–Randolph facility is located in the City of Randolph, Missouri; the reach for the facility runs adjacent to lands in the counties of Jackson (Missouri), Clay (Missouri), and Wyandotte. The facility is located on land zoned for industrial purposes (City of Kansas City 2009). Lands in the City of Independence, Missouri that are adjacent to the reach are designated as industrial (City of Independence 2009). Lands in the City of Kansas City, Missouri, that are adjacent to the reach are designated as light industrial, general industrial, and agricultural. Lands in the City of North Kansas City, Missouri that are adjacent to the reach are designated as light industrial, general industrial, and gaming and amusement (City of North Kansas City 2008). Lands in the City of Kansas City, Kansas, that are adjacent to the reach are designated as heavy industrial (City of Kansas City 2007).

Recreational facilities along the Holliday–Randolph reach include Riverfront Park (RM 362.3 to RM 364), Richard L. Berkley Riverfront Park (RM 365), Holland Park (RM 366.3 to RM 369.7), Kaw Point Riverfront Park (RM 367), the Riverfront Park boat ramp (RM 363), and the Kaw Point boat ramp (RM 367.5).

3.11.4.3 Holliday Sand & Gravel Company – Riverside Facility

Holliday–Riverside is located in the City of Riverside in Platte County. The reach for the facility runs adjacent to lands in the counties of Clay, Wyandotte, and Platte. The facility is located on land designated as general industrial (City of Riverside 2009). Land downstream of the facility that lies in the boundaries of the City of Kansas City, Missouri is designated as heavy industrial and single-family residential (City of Kansas City 2009). Lands downstream of the facility that lie in the boundaries of the City of North Kansas City, Missouri are designated as general industrial (City of North Kansas City 2008). Land adjacent to the reach on the City of Kansas City, Kansas side of the river is designated as heavy industrial, single-family residential, and agricultural (City of Kansas City 2007). Lands adjacent to the reach that lie in the City of Riverside are designated for general industrial use (City of Riverside 2009). Lands adjacent to the reach that are in the City of Parkville (Platte County) are primarily designated as parks/open space, although small areas are designated for commercial, mixed-use, office/business park, and residential purposes near RM 376 (City of Parkville 2009).

Recreational facilities along the Holliday–Riverside reach include Holland Park (RM 366.3 to RM 369.7), E.H. Young Riverfront Park (RM 372), English Landing Park (RM 377), the Missouri Riverfront Trail (RM 372 to RM 376), the English Landing boat ramp (RM 377.4), and an unnamed boat ramp (RM 376). Riverfront Park in the City of Riverside and English Landing Park in the City of Parkville are also adjacent to the reach.

3.11.5 Waverly Segment

The Capital Sand Company – Carrollton facility (Capital–Carrollton) and the Capital Sand Company – Lexington facility (Capital–Lexington) are located in the Waverly segment. No major urban centers are located along this segment, but the towns of Waverly and Lexington are nearby. Most of the land in these reaches is rural and agricultural, with few formal recreational opportunities. Lewis and Clark Historic Trail points of interest along the Waverly Segment include the National Frontier Trails Center and the Fort Osage National Historic Landmark (NPS 2010). Figure 3.11-1 (Sheet 3) shows land uses and dredging areas in this segment. Figure 3.11-2 (Sheet 3) shows recreation and access to the LOMR along the segment.

3.11.5.1 Capital Sand Company – Carrollton Facility

The Capital–Carrollton facility is located in an unincorporated portion of Carroll County (Missouri); the reach for the facility runs adjacent to lands in the counties of Saline (Missouri), Carroll, and Lafayette (Missouri). Based on land cover data, the facility is located in an area that is almost entirely cropland, with surrounding areas of wetland and pasture. Lands adjacent to the reach that are in Saline County are pasture and deciduous forest. Adjacent land in Carroll County is mostly cropland, with areas of wetland and pasture.

Adjacent lands in Lafayette County are designated as agricultural, except for land in the Town of Waverly (Lafayette County 2004). Lands adjacent to the reach that are a part of the Town of Waverly are mostly open space and low-intensity development, with very little medium- to high-intensity development.

Recreational facilities along the Capital–Carrollton reach include the Cranberry Bend CA (RM 291.5), the Baltimore Bend CA (RM 292 to RM 300), Port of Waverly Park (RM 293.5), the Waverly boat ramp (RM 293), and the Port of Waverly Park boat ramp (RM 293.2). Cranberry Bend CA and Baltimore Bend CA are part of the Big Muddy National Fish and Wildlife refuge and are managed by the USFWS (USFWS 2008). All legal methods of hunting are permitted in the boundaries of these conservation areas.

3.11.5.2 Capital Sand Company – Lexington Facility

The Capital–Lexington facility is located across the Missouri River from the City of Lexington, in unincorporated Ray County (Missouri); the reach for the Capital–Lexington facility runs adjacent to lands in the counties of Lafayette and Ray. Based on land cover data, the facility is located in an area that is mostly cropland, with a small portion of pasture, wetlands, and deciduous forest. Adjacent lands in Lafayette County are designated as agricultural, except for lands in the towns of Lexington and Wellington (Lafayette County 2004).

Recreational facilities along the Capital–Lexington reach include Lexington Riverfront Park (RM 316.4) and the two boat ramps located at Riverfront Park (RM 316.4) in the City of Lexington.

3.11.6 Jefferson City Segment

The Capital Sand Company – Jefferson City facility (Capital–Jefferson), Capital Sand Company – Rocheport facility (Capital–Rocheport), Capital Sand Company – Boonville facility (Capital–Boonville)

and Capital Sand Company – Glasgow facility (Capital–Glasgow) are located in the Jefferson City segment. The Hermann Sand & Gravel – Jefferson City facility (Hermann–Jefferson City) also is located in the Jefferson City segment. The City of Jefferson City is the major urban center in this segment, with several small rural towns located upstream. For the reaches located in Jefferson City, most of the adjacent land is open space or agricultural, and the urban areas of the city are located across the river from the facilities. Few recreational opportunities are located near the urban reaches, and boat ramps are the primary recreation-related facilities in the outlying reaches. The only Lewis and Clark Historic Trail point of interest along the Jefferson City segment is Arrow Rock State Historic Site (NPS 2010). Figure 3.11-1 (Sheet 4) shows land uses and dredging areas in this segment. Figure 3.11-2 (Sheet 4) shows recreation and access to the LOMR along the segment.

3.11.6.1 Capital Sand Company – Jefferson City Facility

The Capital–Jefferson City facility is located in the City of Jefferson City in Callaway County (Missouri); the reach for the facility runs adjacent to lands in the counties of Callaway, Cole (Missouri), and Boone (Missouri). The facility is located on land designated as a conservation district for maintenance of rural areas (City of Jefferson 2007). Other areas adjacent to this reach, in Jefferson City, are zoned as conservation district along most of the river, with an additional portion designated as rural. The adjacent land cover in Cole County that is outside the boundaries of the City of Jefferson City is generally cropland; however, small areas of deciduous forest and grassland exist here as well. Adjacent lands in Boone County are designated for agricultural purposes (Boone County 2009).

Ellis–Porter Park (RM 141.5) and Noren boat ramp (RM 144) are the recreational facilities located along the Capital–Jefferson City reach. A portion of the Katy Trail State Park bike trail runs parallel to the reach.

3.11.6.2 Hermann Sand & Gravel – Jefferson City Facility

Hermann–Jefferson City is located in an unincorporated part of Callaway County; the reach for the facility runs adjacent to lands in the counties of Callaway, Cole, and Boone. Based on land cover data, the facility is located in an area of Callaway County that is predominantly cropland with interspersed areas of pasture and deciduous forest. Adjacent lands in Boone County are designated as agricultural land, with a small portion near RM 149 designated for urban agriculture (Boone County 2009).

Recreational facilities along the Hermann–Jefferson City reach include boat ramps, including Noren boat ramp (RM 144) and Busch Landing (RM 154). A portion of the Katy Trail State Park bike trail runs parallel to the reach.

3.11.6.3 Capital Sand Company – Rocheport Facility

The Capital–Rocheport facility is located in unincorporated Howard County; the reach for the facility runs adjacent to lands in the counties of Boone, Cooper (Missouri), and Howard (Missouri). Based on land cover data, the facility is located in a largely cropland area, with smaller areas identified as wetlands, pasture, and deciduous forest. Land adjacent to the reach that is in Boone County is designated for urban agriculture (Boone County 2009). The City of Boonville is located at the upstream end of the reach. Based on land cover data, adjacent lands in City of Boonville are mostly deciduous forest, with smaller areas of pasture, wetlands, and cropland.

Recreational facilities along the Capital–Rocheport reach consist of the Overton Bottoms North Unit (RM 178 to RM 185.1), Diana Bend CA (RM 186.6 to RM 190.2), Franklin Island CA (RM 192 to RM 195.4), Taylor's Landing boat ramp (RM 185.2), and Franklin Island boat ramp (RM 195.1).

Diana Bend CA accommodates camping, fishing, hiking, hunting, and trapping. Hunting at Diana Bend CA is limited to deer, dove, quail, rabbit, turkey, and waterfowl. Franklin Island CA accommodates camping, fishing, hiking, hunting, and trapping. Hunting on Franklin Island CA is limited to deer, dove, quail, turkey, and waterfowl. The Overton Bottoms North Unit is part of the Big Muddy National Fish and Wildlife Refuge, which is run by USFWS, and allows all legal methods of hunting in its boundaries (USFWS 2008). The Katy Trail State Park bike trail and the Missouri-Kansas-Texas trail run parallel to a portion of the reach.

3.11.6.4 Capital Sand Company – Boonville Facility

The Capital–Boonville facility is located across the Missouri River from the City of Boonville, in an unincorporated part of Howard County. The reach for the facility runs adjacent to lands in the counties of Howard and Cooper. Based on land cover data, unincorporated lands in Howard and Cooper Counties are primarily cropland, with large areas of wetland, and smaller areas of deciduous forest, and pasture. The City of Boonville includes mostly low-intensity development, with small portions of medium- and high-density development.

Recreational facilities along the reach include Franklin Island CA (RM 192 to RM 195.4), Harley Park (RM 197.4), and Franklin Island boat ramp (RM 195.1). The Katy Trail State Park bicycle trail crosses the Capital–Boonville reach near RM 197, along the Missouri-Kansas-Texas Bridge.

3.11.6.5 Capital Sand Company – Glasgow Facility

The Capital–Glasgow facility is located in the City of Glasgow in Howard County; the reach for the facility runs adjacent to lands in the counties of Howard, Saline, and Chariton (Missouri). Based on land cover data, the facility is located in an area that is primarily cropland, with a large amount of wetlands and small areas of pasture and deciduous forest. The nearby Town of Glasgow is mostly open space development and low-intensity development.

Recreational facilities along the Capital–Glasgow reach include Stump Island Park (RM 226), Rooster's Marina (RM 226.4), Stump Island boat ramp (RM 226), and an unnamed boat ramp (RM 226).

3.11.7 St. Charles Segment

The Limited Leasing Company – Fort Belle facility (Limited–Fort Belle), Limited Leasing Company – Bridgeton facility (Limited–Bridgeton), and Limited Leasing Company – Chesterfield facility (Limited–Chesterfield) are in the St. Charles segment. The J.T.R. – Riverview facility (J.T.R.–Riverview), J.T.R. – St. Charles facility (J.T.R.–St. Charles), Capital Sand Company – Washington facility (Capital–Washington), and Hermann Sand & Gravel – Hermann facility (Hermann–Hermann) also are in the St. Charles segment. In addition, the proposed Edward N. Rau Contractor Company – Washington facility (Rau–Washington) is in this segment. The major urban center in the segment is the City of St. Charles, with suburban areas of St. Louis located across the river. Most of the reaches with existing or proposed facilities are adjacent to the urban areas, and a majority of the land in these reaches is used for industrial or parks/open space purposes. Several reaches have multiple recreational opportunities located nearby. Lewis and Clark Historic Trail points of interest along the St. Charles Segment include the Katy Trail State Park and the Lewis and Clark Center (NPS 2010). Figure 3.11-1 (Sheet 5) shows land uses and dredging areas in this segment. Figure 3.11-2 (Sheet 5) shows recreation and access to the LOMR along the segment.

3.11.7.1 Limited Leasing Company – Fort Belle Facility

Limited–Fort Belle is located in unincorporated part St. Louis County (Missouri); the reach for the facility runs adjacent to lands in the counties of St. Louis and St. Charles (Missouri). The land on which the Fort Belle facility is located is designated for industrial purposes (St. Louis County 2008). The

surrounding unincorporated St. Louis County lands are designated as industrial, residential, parks, and agricultural/vacant. Land uses in the unincorporated portions of the St. Charles County side of the reach are designated as agricultural (St. Charles County 2008).

Recreational areas in the reach include Fort Bellefontaine County Park (RM 6.7), Sioux Passage Park (RM 10.4), and Pelican Island Natural Area (RM 10.5 to RM 16). Activities allowed on Pelican Island include bird watching, fishing, hiking, and deer hunting. Boat ramps along the reach include Central Stone Company Dock (RM 7), West Lake Quarry ramp (RM 8), Pelican Island boat ramp (RM 10.3), Sioux Passage County Park ramp (RM 10.4), Brickhouse Bend ramp (RM 12.5), Tiemann boat ramp (RM 17), and three unnamed ramps (RM 12, RM 17, and RM 18).

3.11.7.2 J.T.R. – Riverview Facility

J.T.R.–Riverview is located in an unincorporated portion of St. Louis County; the reach for the facility runs adjacent to lands in the counties of St. Louis and St. Charles and lands in the cities of Florissant, Hazelwood, and Bridgeton. The facility is located on land designated as industrial (St. Louis County 2008). The surrounding unincorporated St. Louis County lands are designated as industrial, agricultural/vacant, residential, and park. Adjacent City of Florissant lands are designated mostly as agricultural/vacant and industrial, with small pockets of residential (St. Louis County 2008). Adjacent City of Hazelwood lands are designated as park and agricultural/vacant (St. Louis County 2008). Adjacent City of Bridgeton lands are designated as rural and residential (City of Bridgeton 2008). Land uses on the St. Charles County side of the reach are designated primarily as agricultural, with small sections near RM 24 and RM 26 designated as parks and open space (St. Charles County 2008).

The section of parks/open space near RM 24 is part of the Greenway Trails System (St. Charles County 2008). Other recreational areas along the J.T.R.–Riverview reach include Pelican Island Natural Area (RM 10.5 to RM 16), Sunset Park (RM 19.5), St. Stanislaus County Park (RM 22), St. Stanislaus CA (RM 21 to RM 23.5), and Ed Bales Memorial Park (RM 26.7). St. Stanislaus CA accommodates bird watching, fishing, hiking, and deer hunting (managed hunts only). Boat ramps along the reach include Tiemann boat ramp (RM 17) and two unnamed boat ramps (RM 17 and RM 18).

3.11.7.3 Limited Leasing Company – Bridgeton Facility

Limited–Bridgeton is located in the City of Bridgeton in St. Louis County; the reach for the facility runs adjacent to lands in the counties of St. Louis and St. Charles and adjacent to lands in the cities of

St. Charles, Hazelwood, Maryland Heights, and Chesterfield. The facility is located on land designated by the City of Bridgeton as manufacturing (City of Bridgeton 2008). Adjacent unincorporated St. Louis County lands are designated as agricultural/vacant (St. Louis County 2008). Adjacent City of Bridgeton lands are designated for manufacturing, rural, and residential purposes. Adjacent City of Hazelwood lands are designated as park and agricultural/vacant (St. Louis County 2008). Adjacent City of St. Charles lands are designated as heavy industrial, residential, and commercial (City of St. Charles 2008). Adjacent City of Maryland Heights lands are designated as planned district (manufacturing) and non-urban (City of Maryland Heights 2010). Adjacent City of Chesterfield lands are designated as agricultural/floodplain (City of Chesterfield 2005). Land uses on the St. Charles County side of the reach are designated primarily as parks/open space, with a small portion of land designated as commercial near RM 29.5.

The Greenway Trail System runs through the parks/open space area in this reach (St. Charles County 2008). Other recreation areas in the reach include Ed Bales Memorial Park (RM 26.7); Frontier Park (RM 28.9); and Louis H. Bangert Memorial Wildlife Area (RM 30), which are available for biking, bird watching, and fishing. Hunting is prohibited in the wildlife area, which is managed by the St. Charles County Parks and Recreation Department. Boat ramps along the reach include Blanchette Landing (RM 27.5) and Frontier Park access ramps (RM 28.9). Katy Trail State Park runs parallel to the reach.

3.11.7.4 J.T.R. – St. Charles Facility

J.T.R.–St. Charles is located in the City of St. Charles in St. Charles County. The reach for the facility runs adjacent to unincorporated lands in the counties of St. Charles and St. Louis and in the cities of Maryland Heights and Chesterfield. The facility is located on land designated as heavy industrial; and the surrounding land in the City of St. Charles is designated as heavy industrial, residential, and commercial (City of St. Charles 2008). Adjacent unincorporated St. Louis County lands are designated as agricultural/vacant (St. Louis County 2008). Adjacent Chesterfield lands are designated as agricultural/floodplain (City of Chesterfield 2005). Adjacent Maryland Heights lands are designated as non-urban (City of Maryland Heights 2010). Land uses in the unincorporated portions of the St. Charles County side of the reach are designated as primarily agricultural. The Greenway Trail System runs through the parks/open space area in this reach (St. Charles County 2008).

The Katy Trail State Park bike trail runs parallel to part of the J.T.R.–St. Charles reach, as well as Frontier Park (RM 28.9) and Louis H. Bangert Memorial Wildlife Area (RM 30). The Frontier Park access ramp is the only boat ramp along the reach (RM 28.9).

3.11.7.5 Limited Leasing Company – Chesterfield Facility

Limited–Chesterfield is located in the City of Chesterfield in St. Louis County; the reach for the facility runs adjacent to lands in the counties of St. Louis, St. Charles, and Franklin (Missouri). The facility is located on land designated as agricultural/floodplain (City of Chesterfield 2005). Adjacent Chesterfield land is also designated as agricultural/floodplain. Land uses in the St. Charles portion of the reach are designated as parks/open space and agricultural (St. Charles County 2008). Land uses in the Franklin County portion of the reach are designated primarily as agricultural, with a small area of single-family residential use near RM 53 (Franklin County, 2002).

The Katy Trail State Park bike trail runs parallel to a portion of the Limited–Chesterfield reach. Other recreation areas along this reach are Johnson Island (RM 43), Boone's Crossing (RM 43), Weldon Springs CA (RM 44 to RM 49.4 and RM 52 to RM 55), and Howell Island CA (RM 44.7 to RM 49.7). Johnson Island and Boone's Crossing are part of the Big Muddy National Fish and Wildlife Refuge run by USFWS (USFWS 2008). Johnson Island allows all legal hunting methods, whereas Boone's Crossing allows only archery hunting. Weldon Springs CA provides opportunities for biking, bird watching, camping, fishing, hiking, hunting, and trapping. Hunting in Weldon Springs CA is limited to deer (managed hunts only), dove, rabbit, squirrel, turkey (managed hunts only), and waterfowl. Howell Island CA provides opportunities for bird watching, camping, fishing, hiking, hunting, and trapping. Hunting on Howell Island CA is limited to deer (archery methods only), squirrel, and turkey. The only boat access ramp located along the reach is the Weldon Springs boat access ramp (RM 48.5).

3.11.7.6 Capital Sand Company – Washington Facility

The Capital–Washington facility is located in unincorporated Franklin County; the reach for the facility runs adjacent to lands in the counties of Franklin, St. Charles, and Warren (Missouri). The facility is located on land designated as agricultural. Lands upstream of the facility that are in the City of Washington are designated as single-family residential, light industrial, commercial, and heavy industrial (City of Washington 2007). Unincorporated lands on the Franklin County side of the reach are designated as agricultural (Franklin County 2002). Land uses in the St. Charles County portion of the reach are designated as agricultural (St. Charles County 2008). Based on land cover data, land in the Warren County portion of the reach is cropland and wetland, with smaller areas of deciduous forest and pasture.

The Washington public boat ramp (RM 68.3) is the only recreation facility located along the Capital–Washington reach. Hunting waterfowl on the Missouri River is allowed from boats that have been launched from this ramp.

3.11.7.7 Edward N. Rau Contractor Company – Washington Facility

The proposed site of the Rau–Washington facility is located in the City of Washington in Franklin County; the reach for the proposed facility runs adjacent to lands in the counties of Franklin and Warren. The proposed onshore facility would be located in an area of the City of Washington that is designated as light industrial. Lands upstream of the facility that are in the City of Washington are designated as commercial and heavy industrial (City of Washington 2007). Unincorporated lands on the Franklin County side of the reach are designated as agricultural, with small areas of single-family residential (Franklin County 2002). Based on land cover data, land in the Warren County portion of the reach is mostly cropland and wetland, with smaller areas of deciduous forest and pasture.

Recreational facilities along the Rau–Washington reach consist of the Washington public boat ramp (RM 68.3). Hunting waterfowl on the Missouri River is allowed from boats that have been launched from the Washington ramp.

3.11.7.8 Hermann Sand & Gravel – Hermann Facility

Hermann–Hermann is located across the Missouri River from the Town of Hermann in Montgomery County; the reach for the facility runs adjacent to lands in the counties of Montgomery (Missouri), Warren, and Gasconade (Missouri). Based on land cover data, the facility is located in an area with large portions of cropland, with small pockets of pasture, deciduous forest, and barren land. Land cover in the Gasconade County portion of the reach is mostly deciduous forest, with small areas of cropland, open space development, and wetland. The town of Hermann is mostly open space and low-intensity development, with smaller areas of medium- and high-intensity development.

Recreational facilities along the Hermann–Hermann reach consist of Hermann Riverfront Park (RM 97.5), Gasconade Park (RM 104.5), the two Hermann Riverfront Park boat ramps (RM 97.5), and the Gasconade Park boat ramp (RM 104.5).

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3.12 ECONOMICS AND DEMOGRAPHICS

3.12.1 Introduction

In addition to potential effects on environmental resources, changes in commercial dredging activity on the Missouri River could generate a range of socioeconomic impacts or benefits. Potential socioeconomic effects would result from changes in the production of commercial sand and gravel associated with changes in the annual amount of permitted dredging. This would not only result in direct economic impacts on current dredging operations but also would affect market prices for construction sand and gravel, and the local and regional economy—in particular, industries that are dependent on sand and gravel as an input to production. Changes in dredging could result in fiscal impacts from changes in royalties or tax revenues generated by sand and gravel production. Conversely, ongoing commercial dredging could result in continuation of indirect economic impacts associated with direct effects on agricultural production, recreation use levels, infrastructure repair and maintenance, shoreline maintenance, water supply availability, water quality, and maritime (barge shipping) activity.

This section describes the regulatory setting related to socioeconomics and the existing economic and demographic conditions in those regions affected by commercial sand and gravel dredging in the Missouri River. The section focuses on the socioeconomic resources likely to be affected by the Proposed Action or the alternatives, including cessation of commercial dredging under the No Action Alternative or continued dredging at recent, increased, or reduced levels under the other alternatives. The description of existing conditions begins with information on the economic, demographic, and social characteristics of the study area, which is useful in understanding the affected population and is used to evaluate the Project in the context of environmental justice. Next is an overview of the regional economy and local economic conditions, including information on major industries and trends in employment and income levels. The remainder of the section focuses on the sand and gravel industry, specifically the economic parameters associated with existing sand and gravel dredging operations and the markets they serve. This section also addresses alternate sources of sand and gravel in the region.

3.12.2 Regulatory Setting

The regulatory environment related to socioeconomic resources is limited to NEPA requirements for economic analyses and policies and regulations related to environmental justice[1]. In the context of NEPA, Section 1502.1 of the CEQ Regulations for Implementing NEPA describes as one of the purposes of NEPA to "inform decision-makers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment," where the human environment "shall be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment." Further, the regulations state that "when an environmental impact statement is prepared and economic or social and natural or physical environmental effects are interrelated, then the environmental impact statement will discuss all of these effects on the human environment" (Section 1508.14). The relationship between the physical effects of commercial dredging (sand and gravel production) and the commercial sand and gravel market warrants consideration of economic effects in this EIS.

The regulatory environment related to environmental justice is tied primarily to EO 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations) dated February 11, 1994. EO 12898 requires each federal agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." The CEQ has oversight responsibility of the federal government's compliance with EO 12898 and NEPA. The CEQ, in consultation with the USEPA and other agencies, has developed guidance to assist federal agencies with their NEPA procedures so that environmental justice concerns are effectively identified and addressed. This guidance is presented in Environmental Justice Guidance under the National Environmental Policy Act (CEQ 1997). (This section presents a range of socioeconomic information for the population in the study area, while Section 4.10 provides the analysis of whether the Proposed Action or alternatives could result in a disproportionately high and adverse effect on minority or low-income populations.)

3.12.3 Study Area

The focus of this EIS is on commercial dredging of sand and gravel in the Missouri River between RM 0 and RM 498, which extends from the confluence with the Mississippi River (adjacent to the state of

[1] All other regulations, such as permits, licenses, and approvals, for mining operations in Missouri are presented in Chapter 7.

Illinois) to Rulo, Nebraska. The area studied for the economic and demographic analysis also captures the primary market area[2] served by commercial sand and gravel produced from the LOMR. For this analysis, the "primary market area" is defined as the area encompassing an approximately 25-mile-wide radius[3] from the processing facilities (sand plants) associated with existing and proposed dredging operations (Figure 3.12-1). Commodity shipments to locations beyond the primary market area are known to occur based on information provided by commercial dredgers operating on the LOMR, particularly for rural projects, which may require transport of sand and gravel up to about 65 miles. In addition, contract shipments may exceed 100 miles. For example, some customers in the Springfield area use sand from the LOMR, approximately 130 miles away.

The primary market area is also representative of the functional economic area associated with commercial dredging. Conceptually, a "functional economic area" is a semi-sufficient economic unit. In the context of potential impacts of the Project, it can be based on the location of affected people and businesses (e.g., consumers of sand and gravel products, employees of dredging operations, and support industries that provide inputs and services to existing dredging operations). It can be further defined by the geographic extent of potential indirect impacts associated with commercial dredging on affected parties, such as cities that rely on potentially endangered water intakes for their drinking water, residents that rely on potentially endangered levees for their protection from flood damage, and electric power customers whose electricity supply may be cut back if a power plant is unable to obtain cooling water for its intakes.

For analytical purposes, the "primary market area" represents the total of the five individual market areas serving each segment. Based on the 25-mile-radius criterion,[4] the study area for the socioeconomic analysis covers a 40-county[5] region that extends across Missouri and into portions of Kansas and Illinois, capturing the major metropolitan areas of St. Louis/St. Charles, Jefferson City,

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2 It is acknowledged that commercial aggregate produced from the LOMR is used throughout Missouri and in other states; however, the majority of customers are local manufacturers or contractors within the primary market area.

3 The 25-mile radius was selected based on discussions with existing dredge operators and is indicative of the relative low-value product and high transportation costs required to ship aggregates longer distances.

4 The study area includes all counties with at least 25 percent of their land area within a 25-mile radius of existing or proposed sand plants on the LOMR.

5 It is acknowledged that using a spatial approach to defining the primary market area may lead to exclusion of certain counties that are commonly associated with regional market areas and other geographic definitions; however, the primary market area, as defined, is based on the economic and financial constraints associated with transportation costs, which is specific to the construction sand and gravel industry.

Kansas City, and St. Joseph.[6] Table 3.12-1 identifies the counties included in the primary market area[7].

Table 3.12-1 Primary Market Area for Sand and Gravel Production in the Lower Missouri River[a]

Market Area	States and Counties
St. Joseph	Missouri: Andrew, Buchanan, Clinton, DeKalb, Holt
	Kansas: Atchison, Doniphan
	Illinois: none
Kansas City	Missouri: Clay, Jackson, Platte
	Kansas: Johnson, Leavenworth, Wyandotte
	Illinois: none
Waverly	Missouri: Carroll, Lafayette, Ray
	Kansas: none
	Illinois: none
Jefferson City	Missouri: Boone, Callaway, Chariton, Cole, Cooper, Howard, Moniteau, Osage, Randolph, Saline
	Kansas: none
	Illinois: none
St. Charles	Missouri: Franklin, Gasconade, Jefferson, Lincoln, Montgomery, St. Charles, St. Louis, St. Louis City, Warren
	Kansas: none
	Illinois: Calhoun, Jersey, Macoupin, Madison, St. Clair

[a] The "primary market area" represents the total of the five individual market areas serving each segment.

Based on the proximity of the Missouri River to the major urban areas in Missouri and adjacent states, commercial sand and gravel production has a substantial role in the statewide and regional economies. Accordingly, the regional economic analysis, which measures the indirect (and induced) economic effects associated with sand and gravel production from the LOMR, has been conducted at the state level for the purposes of the affected environment. This macro-level analysis serves a key role because it allows decision makers to realize the regional importance of sand and gravel production.

6 The study area includes counties in Kansas and Illinois that are likely served primarily by sand and gravel production in the Kansas and Mississippi Rivers, respectively; however, they are included in the analysis based on their proximity to LOMR dredging activity.

7 Several counties are recognized as being in the same market area served by processing facilities in different river segments but were assigned to only one market area for presentation purposes.

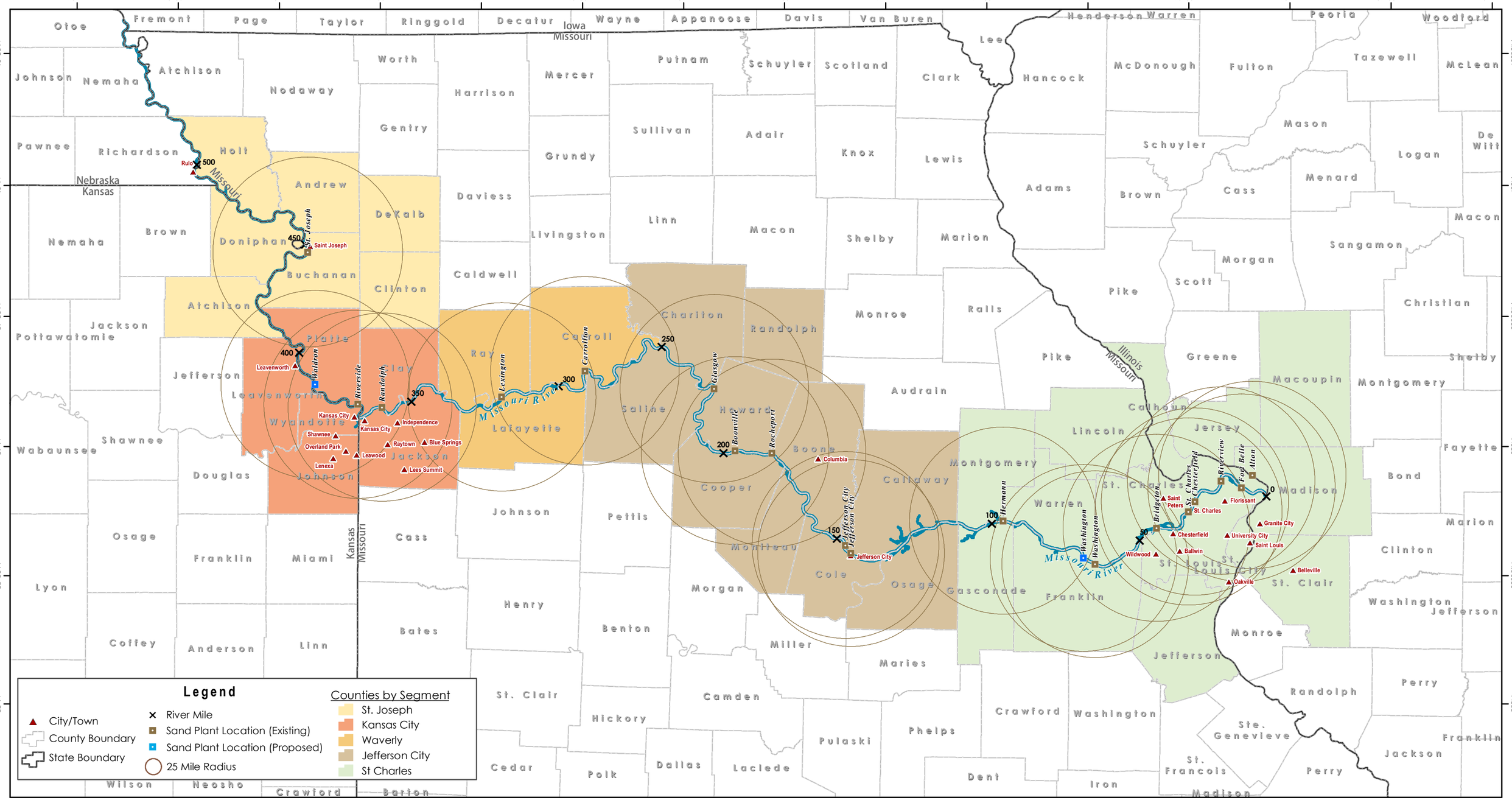

Figure 3.12-1
Primary Market Area Served by Commercial Sand and Gravel Produced from the Lower Missouri River

Missouri River Commercial Dredging EIS

February 2011

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Map Projection: Mercator, WGS84

The analysis also includes those areas that produce and use sand and gravel, acknowledging that many stakeholders are concerned about economic impacts at the local level. The analysis of regional economic impacts at the local (county) level is presented where relevant and data are available. Finally, the socioeconomic impact analysis covers the production of sand and gravel from not only the LOMR but also from alternate sources that may extend into nearby states, such as Illinois and Kansas; the regional economic effects anticipated in these neighboring states are assessed qualitatively.

3.12.4 Demographic and Social Characteristics

3.12.4.1 Population

Commercial sand and gravel produced from the LOMR is used primarily to support the construction industry, but also supports other industries that serve the population in the primary market area and throughout the state of Missouri. Population estimates, organized by market area, are presented in Table 3.12-2. As shown in the table, the population in the primary market area along the LOMR represents a substantial component of the population base in Missouri, indicative of the large urban centers that are located proximate to the river. In 2008, approximately 5.1 million people lived in the 40 counties comprising the primary market area. Across market areas, the largest population is found in the counties comprising the St. Charles market area (approximately 2.7 million people), followed by the Kansas City market area (1.7 million people), Jefferson City market area (384,000 people), St. Joseph market area (169,000 people), and Waverly market area (66,000 people). To provide context, the total population in the state of Missouri was just over 5.9 million in 2008. Accounting for counties in Missouri only, the primary market area represents approximately 62 percent of the total statewide population. In terms of population trends, population in the primary market area has grown at an average rate of 0.7 percent annually between 2000 and 2008.

Population projections can provide insight about future demand for commercial sand and gravel in the region. Population projections for the primary market area through 2030 are shown in Table 3.12-3. Between 2000 and 2030, population is projected to grow by approximately 0.7 percent annually in the primary market area, increasing from approximately 4.8 million in 2000 to nearly 6.0 million by 2030. The Kansas City market area is expected to experience the greatest population growth increasing by approximately 1.2 percent annually during the 30-year projection period, followed by the Jefferson City market area (0.8 percent), St. Charles market area (0.4 percent), St. Joseph market area (0.3 percent), and Waverly market area (0.0 percent). These population projections are comparable to statewide

estimates that show population growing at an annual rate of 0.6 percent for the state of Missouri as a whole. Although population is projected to increase over time, it is difficult to estimate the effect on demand for construction sand and gravel, which is driven in large part by economic conditions and trends in the construction industry.

Table 3.12-2 Population Estimates for the Study Area

Market Area	Population (2000)[a]	Population (2008)	Population Growth (Annual)
St. Joseph	165,089	168,839	0.3%
Kansas City	1,596,155	1,732,676	1.0%
Waverly	66,662	66,114	-0.1%
Jefferson City	359,865	384,149	0.8%
St. Charles	2,624,685	2,731,459	0.5%
Primary market area[b]	4,812,456	5,083,237	0.7%
State of Missouri	5,605,868	5,911,605	0.7%

[a] Based on population estimates dated July 1, 2000.

[b] Includes counties in Missouri, Kansas, and Illinois; the "primary market area" represents the total of the five individual market areas serving each segment.

Sources: U.S. Census Bureau 2009a, 2009b, 2009c.

Table 3.12-3 Population Projections for the Study Area (2000–2030)[a]

Market Area	Population (2000)[b]	Population (2010)	Population (2020)	Population (2030)
St. Joseph	164,920	167,802 (0.2%)	174,955 (0.3%)	181,128 (0.3%)
Kansas City	1,590,719	1,771,349 (1.1%)	1,994,120 (1.1%)	2,265,598 (1.2%)
Waverly	66,599	66,184 (-0.1%)	66,113 (0.0%)	66,113 (0.0%)
Jefferson City	359,245	389,988 (0.8%)	426,958 (0.9%)	459,621 (0.8%)
St. Charles	2,623,051	2,746,023 (0.5%)	2,882,674 (0.5%)	2,983,194 (0.4%)
Primary market area[c]	4,804,534	5,141,346 (0.7%)	5,544,820 (0.7%)	5,955,653 (0.7%)
State of Missouri	5,596,687	5,979,344 (0.7%)	6,389,850 (0.7%)	6,746,762 (0.6%)

[a] Numbers in parentheses represent average annual percentage changes from base period (2000).

[b] Based on population estimates dated April 1, 2000 (U.S. census data).

[c] Includes counties in Missouri, Kansas, and Illinois; the "primary market area" represents the total of the five individual market areas serving each segment.

Sources: State of Missouri, Office of Administration, Budget and Planning undated; State of Illinois, Department of Commerce and Economic Opportunity undated; University of Kansas, Institute for Policy and Social Research 2009.

3.12.4.2 Race and Ethnicity

Knowledge of the racial and ethnic composition of the primary market area is an important component in understanding whether the Project would result in environmental justice-related effects. The race and ethnicity of the population in the primary market area is presented in Table 3.12-4. The two largest racial groups are White and Black/African American; together, these groups comprise approximately 95.4 percent of the total population in the primary market area. Other racial groups primarily represent the remaining 4.6 percent of the regional total, led by people identifying with more than one race and Asians. The proportion of people of Hispanic ethnicity living in the primary market area is 2.9 percent, greater than the statewide average. Generally, the racial/ethnic composition in the primary market area is more diverse than in the state.

Table 3.12-4 Race and Ethnicity of the Study Area Population (2000)

	Race (Percentage of Total Population)							Ethnicity
Market Area	White	Black/ African American	American Indian/ Alaska Native	Asian	Native American/ Pacific Islander	Other Race	Multi-Racial	Hispanic/ Latino
St. Joseph	93.7%	3.8%	0.5%	0.3%	0.0%	0.5%	1.2%	1.8%
Kansas City	79.1%	14.1%	0.5%	1.8%	0.1%	2.5%	2.1%	5.7%
Waverly	96.1%	1.9%	0.3%	0.2%	0.0%	0.4%	1.1%	1.1%
Jefferson City	88.5%	7.5%	0.4%	1.5%	0.0%	0.6%	1.5%	1.6%
St. Charles	78.4%	18.1%	0.2%	1.4%	0.0%	0.5%	1.3%	1.5%
Primary market area [a, b]	80.1%	15.3%	0.3%	1.5%	0.0%	1.2%	1.5%	2.9%
State of Missouri	84.9%	11.2%	0.4%	1.1%	0.1%	0.0%	1.5%	2.1%

[a] Includes counties in Missouri, Kansas, and Illinois; the "primary market area" represents the total of the five individual market areas serving each segment.

[b] Represents an average for the primary market area counties, weighted by population.

Source: U.S. Census Bureau 2000.

Racial composition varies among the market areas. The Kansas City market area is the most racially diverse, having the lowest White population at 79.1 percent, highest Asian population at 1.8 percent, highest Native Hawaiian/Pacific Islander population at 0.1 percent, highest Other Race population at 2.5 percent, highest Multi-Race population at 2.1 percent, and the highest Hispanic population at 5.7 percent; the racial composition of this market area is representative of areas with large urban centers. Similarly, the St. Charles Segment is racially diversified, with the highest Black/African American population (18.1 percent). Conversely, the St. Joseph, Waverly, and Jefferson City market

areas have relatively higher White populations and lower minority populations, representative of their more rural character.

3.12.4.3 Economic Indicators of Social Well-Being

Several key economic indicators of the status of social well-being within a geographic region are unemployment, per-capita income, and poverty rates. Table 3.12-5 presents a summary of these three indicators for the primary market area and the state of Missouri.

Table 3.12-5 Economic Indicators of Social Well-Being in the Study Area

Market Area	Unemployment (2008–2009)[a]		Per-Capita Income (2007)	Poverty Rate (2007)
	Labor Force	Unemployment Rate		
St. Joseph	88,735	5.5%	$28,589	13.6%
Kansas City	901,549	6.2%	$40,505	10.4%
Waverly	32,327	6.6%	$30,698	12.1%
Jefferson City	206,334	5.0%	$30,967	14.2%
St. Charles	1,386,329	7.1%	$39,475	11.2%
Primary market area[b]	2,615,274	6.6%	$38,707	11.2%
State of Missouri	3,007,020	8.3%	$33,964	13.3%

[a] October 2008 to November 2009.

[b] Includes counties in Missouri, Kansas, and Illinois; the "primary market area" represents the total of the five individual market areas serving each segment.

Sources: Bureau of Labor Statistics 2009a, Bureau of Economic Analysis 2007a, U.S. Census Bureau 2007.

Unemployment within the primary market area averaged 6.6 percent between October 2008 and November 2009, which was lower than the statewide average of 8.3 percent for the same period. Unemployment patterns varied among market areas. The highest unemployment rate was in the St. Charles market area (7.1 percent); followed by the Waverly market area (6.6 percent) and the Kansas City market area (6.2 percent). Unemployment rates were lowest in the St. Joseph and Jefferson City market areas at 5.5 and 5.0 percent, respectively.

Per-capita personal income in the primary market area (on a weighted average basis) was $38,707 in 2007, which was higher than the statewide figure of $33,964. Across market areas, per-capita income levels were highest in the Kansas City ($40,505) and St. Charles ($39,475) market areas and were lowest in the Jefferson City ($30,967), Waverly ($30,698), and St. Joseph ($28,589) market areas.

Poverty rates represent the percentage of an area's total population living at or below the poverty threshold established by the U.S. Census Bureau. Overall, the poverty rate in the primary market area was 11.2 percent, which is lower than the statewide rate of 13.3 percent and consistent with other economic indicators. The poverty rate was highest in the Jefferson City market area (14.2 percent), followed by the St. Joseph (13.6 percent), Waverly (12.1 percent), St. Charles (11.2 percent), and Kansas City (10.4 percent) market areas.

3.12.5 Overview of the Regional Economy

This section presents an economic overview of the primary market area and the state of Missouri, based primarily on measures of employment and income. In addition, information at the industry level is presented to provide an understanding of which industries represent the significant sources of jobs and income throughout the state. This information is intended to provide a general understanding of the economic climate characterizing the various regions of the state and to place perspective on the role that commercial sand and gravel production plays in the economy.

3.12.5.1 Employment and Major Industries

Data on total employment and employment by industry provide insights into the size, strength, and diversity of a local economy. These data are presented in Table 3.12-6. In 2007, almost 3.3 million part-time and full-time jobs were supported in the primary market area (across three states), and nearly 3.7 million jobs in the state of Missouri. The largest concentration of employment was in the St. Charles market area, with 1.7 million jobs constituting 51.8 percent of the primary market area, followed closely by the Kansas City market area with nearly 1.2 million jobs. The Jefferson City, St. Joseph, and Waverly market areas had the smallest employment bases with 259,800 jobs, 96,500 jobs, and 30,200 jobs, respectively. Based on the information on employment by industry, the economy in the primary market area is diverse. The largest economic sectors in the primary market area were Other Services, Wholesale and Retail Trade, and Government (federal and state/local); the Natural Resources and Mining sector accounts for a relatively small proportion (less than 1 percent) of total employment in the primary market area and the state. The Construction sector that relies on sand and gravel as a production input supports over 235,200 jobs in Missouri and represents approximately 6.4 percent of the employment base in the state.

3.12.5.2 Earnings and Income

Table 3.12-7 presents earnings by industry (a component of total personal income) in the primary market area in 2007. The measure of earnings by industry is more relevant than total personal income in evaluating the potential impacts of changes in commercial dredging on the local economy because it focuses on the wages and salaries of employees and the business income of proprietors. In addition, it excludes factors such as transfer payments that are unlikely to be affected by changes in commercial dredging.

Total earnings in the primary market area were $155.1 billion in 2007, which includes counties in Missouri, Kansas, and Illinois. In the state of Missouri alone, earnings totaled approximately $153.3 billion. Earnings by place of work across market areas were the highest in the St. Charles market area (approximately $81.4 billion), followed by the Kansas City ($60.6 billion), Jefferson City ($9.2 billion), St. Joseph ($3.2 billion), and Waverly ($0.7 billion) market areas. Following patterns similar to employment, the level of earnings was highest in the Other Services sector. Other sectors that provided a relatively high proportion of employment earnings include Government, Manufacturing, and Wholesale and Retail Trade. The Natural Resources and Mining and the Construction sectors generated relatively limited employment earnings relative to all other sectors in the primary market area and the state.

3.12.6 Overview of the Construction Sand and Gravel Industry

The purpose of commercial dredging in the Missouri River is the production of construction sand and gravel. This section provides a general overview of the construction sand and gravel industry, focusing on production characteristics and levels, economic benefits, and the markets for sand and gravel materials. The information presented in this section primarily addresses the state (Missouri) level. The following section describes the economic conditions of existing commercial dredging operations on the Missouri River.

Table 3.12-6 Total Employment and Employment by Industry in the Study Area (2007)

Segment/ Area	Industry / Sector[a]											
	Farm / Agriculture	Natural Resources and Mining	Construction	Manufacturing	Wholesale and Retail Trade	Transportation and Warehousing	Utilities	Finance and Insurance	All Other Services[b]	Government	Not Disclosed	Total
St. Joseph	5,408	249 [c]	5,768	13,158 [c]	14,740 [c]	1,837 [c]	225 [c]	3,625 [c]	31,072 [c]	13,479 [c]	6,910	96,471
Kansas City	4,695	2,571 [c]	67,036	80,696	170,951 [c]	47,375	4,160 [c]	72,953	582,146	150,648	6,263	1,189,494
Waverly	3,487	55 [c]	2,706	1,925	3,907 [c]	670 [c]	0	1,157	7,083 [c]	4,684	4,548	30,222
Jefferson City	11,732	411 [c]	15,191 [c]	13,439 [c]	24,027 [c]	3,416 [c]	241 [c]	9,708	87,153 [c]	66,843	17,642	259,803
St. Charles	12,326	2,942 [c]	96,260 [c]	137,047 [c]	243,051[c]	44,723 [c]	2,743 [c]	82,000	854,106 [c]	183,257	32,254	1,690,709
Primary market area[d]	37,648	6,228 [c]	188,961 [c]	246,265 [c]	466,676 [c]	98,021 [c]	7,369 [c]	169,443 [c]	1,561,560[c]	418,911 [c]	67,617	3,266,699
State of Missouri	114,477	20,741	235,206	312,651	534,971	128,932	12,705	163,104	1,653,795	486,709	0	3,663,291

[a] Industry/Sectors are based on a summary of North American Industry Classification Systems categories.

[b] All Other Services include Information; Real Estate and Leasing; Professional; Professional, Scientific, and Technical Services; Management of Companies and Enterprises; Administrative and Waste Services; Educational Services; Health Care and Social Assistance; Arts, Entertainment, and Recreation; Accommodation and Food Services; and Other Services except Public Administration.

[c] Does not represent actual total due to missing estimates for counties avoiding disclosure of confidential information; included in market area and state totals.

[d] Includes counties in Missouri, Kansas, and Illinois; the "primary market area" represents the total of the five individual market areas serving each segment.

Source: Bureau of Economic Analysis 2007b.

Table 3.12-7 Earnings by Industry in the Study Area (2007)[a]

Segment / Area	Industry / Sector[b]											
	Farm / Agriculture	Natural Resources and Mining	Construction	Manufacturing	Wholesale and Retail Trade	Transportation and Warehousing	Utilities	Finance and Insurance	All Other Services[c]	Government	Not Disclosed	Total
St. Joseph	$58,747	$9,591[d]	$214,237	$670,940[d]	$415,634[d]	$77,174[d]	$13,756[d]	$143,479[d]	$875,206[d]	$562,572[d]	$207,437	$3,248,773
Kansas City	$23,634	$218,667[d]	$3,770,212	$6,031,012	$7,308,868[d]	$2,348,156	$415,882[d]	$4,802,480	$26,533,770	$8,784,620	$363,253	$60,600,554
Waverly	$39,285	$87[d]	$60,814	$79,042	$91,500[d]	$18,043[d]	$872[d]	$38,130	$109,203[d]	$180,904	$127,783	$745,663
Jefferson City	$92,668	$12,761[d]	$554,236[d]	$636,009[d]	$914,276[d]	$135,201[d]	$22,336[d]	$438,294	$2,515,121[d]	$3,107,299	$729,107	$9,157,308
St. Charles	$88,696	$257,932[d]	$4,990,542[d]	$11,152,290	$9,709,463[d]	$2,107,050[d]	$284,119[d]	$4,969,154	$35,840,742[d]	$10,269,190	$1,699,453	$81,368,631
Primary market area[e]	$303,030	$499,038[d]	$9,590,041[d]	$18,569,293[d]	$18,439,741[d]	$4,685,624[d]	$736,965[d]	$10,391,537[d]	$65,874,042[d]	$22,904,585	$3,127,033	$155,120,929
State of Missouri	$941,008	$949,889	$10,136,133	$19,837,452	$18,875,112	$5,878,761	$1,259,667	$9,154,011	$61,800,372	$24,451,390	$0	$153,283,795

[a] Values in thousands ($1,000) of dollars.

[b] Industry/sectors based on a summary of North American Industry Classification Systems categories.

[c] All Other Services include Information; Real Estate and Leasing; Professional; Professional, Scientific, and Technical Services; Management of Companies and Enterprises; Administrative and Waste Services; Educational Services; Health Care and Social Assistance; Arts, Entertainment, and Recreation; Accommodation and Food Services; and Other Services except Public Administration.

[d] Does not represent actual total due to missing estimates for counties avoiding disclosure of confidential information; included in market area and state totals.

[e] Includes counties in Missouri, Kansas, and Illinois; the "primary market area" represents the total of the five individual market areas serving each segment.

Source: Bureau of Economic Analysis 2007c.

3.12.6.1 Industry Background

The principal activities of the construction sand and gravel industry are operating sand and gravel pits and dredges and washing, screening, or otherwise preparing sand and gravel for construction uses. Construction sand and gravel is a traditional basic building material that is used by the construction industry for concrete and asphalt manufacturing, road base, fill, and other miscellaneous uses. A key feature of construction sand and gravel is that it is a relatively accessible natural resource found in rivers and streams and associated floodplains and in natural glacial deposits. As a primary input to the construction industry, the production of sand and gravel is tied heavily to construction trends, which in turn fluctuate with economic conditions.

The different grades of construction sand and gravel reflect the different specifications required for end use. Sand and gravel are graded for commercial use by passing the material through standardized sieves, which yield varying classifications of materials. Acceptable sizes for commercial sand and gravel vary according to the applicable standards set by the construction industry, highway department, or government agency. The term “fine aggregate” is often used to describe commercial sand and “coarse aggregate” to describe gravel. The optimal sand and gravel deposit contains a wide range of particle sizes (from fine to coarse), is free of organic matter, lacks substantial overburden (overlaying soil), and contains sufficient quantities to justify extraction from an economic perspective. Ideally, the deposit is also located near transportation routes and a permanent source of demand for the processed product. In certain cases, manufactured sand and gravel (crushed stone) made from crushed bedrock serves as an alternative to natural sand and gravel deposits.

The sand and gravel mining industry is distinguished from other mining industries by the number and size of its mining operations. Other mining operations, including metal and other industrial mineral mines, are typically fewer in number and larger in size than sand and gravel operations because they have a larger market area. Conversely, the market for construction sand and gravel and other aggregates is highly localized (generally within 25–50 miles of the operation), which is due in part to the relatively low value of the material and the associated high transportation costs. In addition, developing a metal mine generally requires greater capital investment, time, and financial risk than developing a sand and gravel operation.

Because of its high availability and low unit value, the economic viability of commercial sand and gravel operations is generally determined by operating costs (e.g., labor and equipment) and transportation costs to final markets. In fact, transportation costs in the construction sand and gravel industry as a

whole has averaged approximately 50 percent of the price paid by customers. As a result, deposits located far from transportation options or large markets might not be economically viable. Typical transportation options are truck, rail, or barge. According to the USGS, approximately 80 percent of construction sand and gravel was transported by truck, 3 percent by waterway, and 1 percent by rail; the remaining 15 percent was not transported and was used at or near the production site (USGS 2009a).

In addition, start-up costs and time must be considered when evaluating the economic viability of sand and gravel operations. The USGS reports that the length of time needed to put a new operation into production is, on average, approximately 5–10 years. The extended start-up period is attributed to time required to develop reserves, acquire zoning and permit approvals, and deliver and install the necessary production equipment. Other factors to be considered for new mining operations include local community opinions and permit or zoning constraints.

3.12.6.2 Sand and Gravel Production and Value

According to the USGS, 1.23 billion metric tons of construction sand and gravel was produced in the United States in 2007 by nearly 6,700 active operations (USGS 2009a). Production in 2007 represents an approximate 6.6-percent decline relative to record-high production levels in 2006. The decline is attributed primarily to the economic downturn that resulted in reductions in demand from home builders and road and highway projects, which were partially offset by increased demand in the commercial and public sectors.

At the state level, production of construction sand and gravel, masonry cement, industrial sand and gravel, and common clays occurs throughout Missouri. Specifically, approximately 17 million metric tons[8] of construction sand and gravel were produced in Missouri in 2006 with a value of $92.1 million; this equates to an average value (price) of $5.41 per metric ton. In 2007, sand and gravel production declined to approximately 14 million metric tons valued at $77.4 million, with an associated slight increase in price of 1.5 percent to $5.51 per metric ton. To put these figures in context, the Missouri Economic Research and Information Center (MERIC) estimates that the gross state product (GSP) in Missouri fluctuated between $220.1 and $229.5 billion between 2006 and 2007 (MERIC 2008). Based on these figures, construction sand and gravel production contributes less than 0.1 percent to the

[8] USGS reports volumes in metric tons, while extraction data from the LOMR are presented in U.S. tons. For this analysis, a conversion factor of 1.1023 U.S. tons per metric ton is used.

Missouri GSP. Table 3.12-8 provides historical production and values for construction sand and gravel in Missouri.

Table 3.12-8 Construction Sand and Gravel Production and Value in Missouri (2005–2007)

	2005	2006	2007
Quantity (thousand metric tons)	12,200	17,000	14,000
Value (thousand dollars)	$61,600	$92,100	$77,400
Price (dollars/metric ton)	$5.05	$5.43	$5.51

Prices reflect all uses of construction sand and gravel, not just concrete and asphalt manufacturing

Sources: USGS 2009b, USGS undated.

3.12.6.3 Economic Benefits of Construction Sand and Gravel Production

Production of construction aggregate (which includes sand and gravel and crushed stone) provides an array of economic benefits at the national level and in producing states. In this section, the economic benefits on sand and gravel production are described, including the value of production, and employment and income parameters. These benefits are attributed not only to direct production but also to the inter-industry linkages implicit in the production process. Specifically, the full economic impact of construction sand and gravel production must account for the subsequent economic benefits resulting from the purchases by these industries in support of their operations (indirect impacts) and re-spending of payroll income and proceeds of the industry's sales throughout the national economy (induced impacts). The construction sand and gravel industry also produces primary inputs for many other industries (e.g., agriculture, manufacturing, and construction) across the national and regional economies, thereby supporting additional economic activity. The contribution of construction sand and gravel to the intermediate and final products of these industries (forward-linkages) is an important component of the total economic benefits generated by commercial dredging and is noted accordingly; however, these benefits are not quantified as part of the benefit estimates presented in this section.

As shown in Table 3.12-9, the value of construction aggregate at the national level was an estimated $14.44 billion in 2003, which includes the production of crushed stone ($8.63 billion in total sales) and sand and gravel ($5.81 billion in total sales); these are the direct output benefits of the industry (or contribution to gross domestic product [GDP]). The indirect and induced benefits of the construction aggregate industry are founded on the "multiplier" effect, which represents the additional economic activity generated through inter-industry purchases. Accounting for these indirect and induced effects,

the total output supported by the construction aggregate industry represents a contribution of approximately $37.2 billion to the national economy (GDP). It also supports over 281,200 jobs in all sectors of the economy, with personal earnings totaling $10.64 billion.

At the state level, the construction aggregate industry also contributes substantially to the Missouri economy but is driven primarily by the production of crushed stone rather than construction sand and gravel. The total value of construction sand and gravel produced in Missouri in 2001 was approximately $46 million, which accounted for approximately 11 percent of the total production value of construction aggregates statewide. Taking into account inter-industry linkages, construction sand and gravel production supported approximately $89 million in total output, $25 million in personal income, and 733 jobs in Missouri.

Table 3.12-9 Economic Benefits of the Construction Aggregate Industry[a]

Industry	Total Sales (Direct Output)	Total Output	Total Personal Income	Total Employment
United States[b]				
Crushed stone	$8.63	$22.55	$6.24	165,600
Sand and gravel	$5.81	$14.63	$4.40	115,612
Total	$14.44	$37.18	$10.64	281,212
State of Missouri[c]				
Crushed stone	$0.41	$0.82	$0.21	6,247
Sand and gravel	$0.05	$0.09	$0.03	733
Total	$0.46	$0.90	$0.23	6,980

[a] Reported in billions ($1,000,000,000) of dollars.

[b] Estimates for the United States are based on 2003 production and reported in 2003 dollars.

[c] Estimates for the state of Missouri are based on 2001 production and reported in 2001 dollars.

Source: George Mason University, Center for Regional Analysis, School of Public Policy 2004.

3.12.6.4 Markets for Construction Sand and Gravel Materials

As described elsewhere, construction sand and gravel generally are used in the production of other intermediate products and, eventually, final products for consumers and businesses. Sand and gravel are primarily used by private construction firms and government agencies in construction (residential and non-residential) and paving activities. Because of the reliance on construction sand and gravel in

the production of other goods, fluctuations in the construction sand and gravel industry is considered a reliable indicator of the economic activity in any particular region.

Based on USGS data (2009a) on reported uses in 2007, construction sand and gravel at the national level was primarily used for concrete production (44.3 percent), followed by road base and coverings and road stabilization (23.6 percent), construction fill (13.8 percent), asphaltic and other bituminous mixtures (11.7 percent), plaster and gunite sands (2.6 percent), and concrete products (1.0 percent). The remaining 3.0 percent was for miscellaneous uses, including filtration, railroad ballast, roofing granules, snow and ice control, and related uses (USGS 2009a). In the state of Missouri, the use of construction sand and gravel is concentrated in the production of concrete, accounting for 79.1 percent of total reported use (USGS undated).

3.12.7 Economic Activity from Missouri River Dredging Operations

This section describes the economic activity and other economic factors related to commercial sand and gravel production by existing commercial dredging operations on the LOMR. The section discusses an overview of existing operations, including operating costs and employment; production levels and values; markets and demand for Missouri River sand natural river sand; tax benefits; and the regional economic benefits of existing dredging operations. The information presented here is based on information collected from dredge operators, supplemented by data collected from public agencies and other standardized sources of economic information.

3.12.7.1 Overview of Existing Dredge Operators

Five commercial operators (with six active permits) dredge in the LOMR. These operators use varying techniques to extract sand and gravel from the river channel for commercial sale. Most of the saleable product is high-quality natural sand that serves the concrete and asphalt manufacturing market. Overall, based on information collected from the dredge operators, it is estimated that natural sand accounts for approximately 90–95 percent of all saleable product extracted from the river[9]. Based on its quality, Missouri River sand generally meets most technical specifications for inputs to concrete and asphalt production, including specifications maintained by the MoDOT for use in road construction

[9] Because natural sand production represents the bulk of commercial product extracted from the river, it is the focus of this section and the associated economic analysis.

projects. Other saleable by-products that come from commercial dredging include mason sand, fill sand, pea gravel, and other landscape-grade gravel products that vary based on material size.

Commercial sand and gravel extracted from the LOMR are processed and distributed at sand plants adjacent to the river. A total of 18 existing sand plants process and distribute the sand and gravel extracted from the Missouri River; two additional facilities are proposed by new permit applicants who do not currently dredge in the LOMR (see Figure 3.12-1). Based on the costs associated with barging sand and gravel, sand plants generally are located in proximity to market areas that have historically been permitted for dredging. After the sand and gravel is processed, sorted, and stored, these facilities also serve as the distribution point for sales to customers. Customers typically are responsible for shipping the sand and gravel they purchase, thereby incurring shipping costs. As such, the price paid to dredge operators represents the free-on-board (FOB) price of sand and gravel at any given location.

3.12.7.2 Existing Sand and Gravel Production and Values

The volume of commercial sand and gravel dredged on the LOMR fluctuates annually based on economic conditions (primarily market demand), availability of materials in the river system, and other factors. Table 3.12.10 provides a summary of historical production of construction sand and gravel from the LOMR. Over the 5-year period between 2004 and 2008, commercial dredging on the LOMR averaged 6.89 million tons annually and ranged from a low of 5.48 million tons in 2008 to a high of 7.68 million tons in 2005. Across market areas, sand and gravel production has been concentrated in the Kansas City market area (38.6 percent), followed by the St. Charles (23.9 percent), Jefferson City (22.9 percent), Waverly (9.8 percent), and St. Joseph (4.7 percent) market areas.

Table 3.12-10 Annual Production of Construction Sand and Gravel from the Lower Missouri River (2004–2008)

	Production (tons)					
Market Area[a]	2004	2005	2006	2007	2008	Average
St. Joseph	327,260	362,520	364,830	298,440	281,592	326,928
Kansas City	3,215,385	2,611,848	2,819,465	2,526,890	2,120,567	2,658,831
Waverly	530,540	1,148,373	866,665	247,000	597,355	677,987
Jefferson City	1,627,600	1,507,323	1,645,550	1,734,829	1,378,990	1,578,858
St. Charles	1,875,720	2,054,620	1,771,782	1,444,750	1,099,758	1,649,326
Total	7,576,505	7,684,684	7,468,292	6,251,909	5,478,262	6,891,930

[a] Represents location of dredging in the LOMR based on river segments.

Source: USACE 2009.

The value of commercial sand and gravel produced from the LOMR is based on production levels and price estimates for construction sand and gravel across the state[10]. Table 3.12-11 presents a summary of historical production values and prices for construction sand and gravel. Generally, the price for construction sand and gravel used in concrete and asphalt production has remained relatively constant between 2004 and 2008, at approximately $4 to $5 per U.S. ton, although sand and gravel prices have trended upward during this period. Overall, the weighted average price of construction sand and gravel in the state of Missouri is $4.40 per U.S. ton for the period between 2004 and 2008. Applying statewide prices to production levels from the LOMR provides estimates of the total production value. The average nominal value of commercial sand and gravel from the LOMR is approximately $30.3 million annually, and has fluctuated between $26.6 and $33.4 million from 2004 to 2008. For comparative purposes, the GSP in the state of Missouri was approximately $237.8 billion in 2008 (MERIC 2008).

Table 3.12-11 Annual Production Value of Construction Sand and Gravel from the Lower Missouri River (2004–2008)[a]

	Production (tons)					
Market Area[b]	2004	2005	2006	2007	2008	Average
St. Joseph	$1,330,503	$1,513,158	$1,633,928	$1,363,960	$1,365,828	$1,441,475
Kansas City	$13,072,419	$10,901,853	$12,627,255	$11,548,639	$10,285,565	$11,687,146
Waverly	$2,156,955	$4,793,307	$3,881,446	$1,128,863	$2,897,401	$2,971,594
Jefferson City	$6,617,145	$6,291,568	$7,369,760	$7,928,685	$6,688,631	$6,979,158
St. Charles	$7,625,898	$8,575,983	$7,935,102	$6,602,937	$5,334,248	$7,214,834
Total	$30,802,919	$32,075,869	$33,447,491	$28,573,084	$26,571,673	$30,294,207
Average price ($/U.S. ton)[c]	$4.07	$4.17	$4.48	$4.57	$4.85	$4.40

[a] Nominal dollars.

[b] Represents location of dredging in the LOMR based on river segments.

[c] Average prices for construction sand and gravel are based on statewide data reported by the U.S. Geological Survey and adjusted to reflect prices of sand and gravel used specifically in concrete and asphalt production.

Source: USACE 2009.

[10] The unit value (or price) of construction sand and aggregate was obtained from the USGS Minerals Yearbook for the state of Missouri for the years 2004 through 2007 and was adjusted to reflect values per U.S. ton. For 2008, prices were projected based on the national price trends as reported by the USGS (2009a).

3.12.7.3 Costs of Production

As with most businesses, the costs of commercial dredging on the Missouri River can be organized into start-up, capital, and operating costs. Typical start-up expenditures are associated with planning and engineering, environmental compliance and permitting, and land acquisition (for sand plants). Further, commercial dredging is a capital-intensive activity requiring major equipment, including dredges, barges (used to transport sand and gravel to the plant), processing equipment, and other heavy machinery. During operations, the primary components of production costs are labor payments and expenditures on fuel, miscellaneous parts and equipment, and related maintenance activities.

Based on industry data for the sand mining sector in state of Missouri, it is estimated that value-added[11] factors, including labor payments, account for the majority (55.6 percent) of production costs, while the purchase of input commodities and services account for the remaining 44.4 percent of costs (Minnesota IMPLAN Group 2008). (However, because each mining operation is unique and such information is proprietary, it is not possible to estimate production costs for each dredging operation or market area.)

Although not a cost of production, shipping costs represent a large component of the delivered price of construction sand and gravel from the LOMR. As indicated above, most commercial dredging operations do not provide transportation of materials to customers; customers arrange for their own truck transportation and incur the related costs. Shipping costs vary based on location, length of trip, availability of return loads, and fuel costs. Generally, shipping costs for construction sand and gravel in the market area range between $0.10 and $0.25 per ton per mile, as estimated by dredgers on the LOMR.

3.12.7.4 Employment and Income Supported by Dredging Operations

Estimated employment supported by existing dredging operations is based on operations data provided by the permit applicants. In total, existing commercial dredging operations on the LOMR directly support an estimated 196 jobs in the mining industry. The types of job opportunities provided by these operations include dredge operators, barge captains, heavy machinery operators, mechanics and machinery service technicians, and administrative and management staff. The associated labor income attributed to these jobs, including wage earnings and proprietor income, is estimated at

[11] Value-added factors include employee compensation, proprietor income, other property-type income, and indirect business taxes. Source: IMPLAN data and software.

approximately $13.9 million. Additional jobs and income are indirectly supported by commercial dredging operations, such as the trucking operators who deliver sand and gravel to customers.

3.12.7.5 Market and Demand for Missouri River Sand and Gravel

Commercial sand and gravel produced from the LOMR are used primarily in the construction industry, including road and highway construction undertaken by local transportation agencies. The MoDOT represents one of the largest customers for natural sand produced from the Missouri River based on MoDOT specifications for Class A (natural) sand. As such, sand and gravel from the LOMR serve as one the primary inputs required for infrastructure development throughout the state. Similarly, construction sand and gravel from the LOMR, specifically the Kansas City market area, is used by the KDOT in some of its transportation projects in eastern Kansas.

The MoDOT estimates that it used an average of approximately 872,140 tons of natural river sand on an annual basis between 2004 and 2008, of which approximately 240,969 tons (27.6 percent) is asphalt sand and approximately 631,171 tons (62.4 percent) is concrete sand (MoDOT 2009). However, not all sand used is obtained from the LOMR; it also comes from the Mississippi River and elsewhere. Accounting for only those MoDOT districts that rely on sand from the LOMR (Districts 1, 2, 4, 5, 7, 8, and 9), approximately 57 percent of total sand used by the MoDOT comes from the LOMR. Applying this figure to average sand use between 2004 and 2008 suggests that the MoDOT has average demand for sand from the LOMR of approximately 497,000 tons annually. The KDOT use of Missouri River sand is substantially more limited. Between 2005 and 2009, the KDOT used an average of 56,076 tons of sand dredged from the LOMR on an annual basis (KDOT 2010). Most sand from the LOMR used by the KDOT comes from the Kansas City market area (92.9 percent, or approximately 52,090 tons/year); the remaining 7.1 percent (or approximately 3,986 tons/year) is obtained from the St. Joseph market area. Overlaying the demand for construction sand and gravel by state transportation departments on the total production from the LOMR provides insight into the market allocation of sand and gravel across end uses and consumers. Overall, it is estimated that approximately only 8.0 percent of the total tonnage of commercial sand and gravel dredged from the LOMR (or approximately 553,100 tons/year) is used by state transportation departments for roadway construction projects. Due to the material specifications required for transportation projects, the market area serving these types of projects is relatively large, thereby resulting in potentially longer transportation distances and higher delivered costs.

Although road construction represents a significant source of demand, the data suggest that the majority of construction sand and gravel from the LOMR is used to meet demand generated by general construction activities in the market area. In total, approximately 6.34 million tons (92.0 percent) of commercial sand and gravel from the LOMR is used by the general public for residential and non-residential construction (excluding state transportation projects). According to the commercial dredgers and industry research, the primary market area served by existing dredging operations is generally 20–50 miles from the sand plants. The size of the market area is generally driven by transportation costs, particularly because of the low-unit value of sand and gravel. Assuming that the market area is generally defined by a 25-mile radius around each distribution point, commercial sand and gravel production primarily serves 40 counties across three states, with a primary population of nearly 5.1 million (see Section 3.12.1 for details on the study area).

3.12.7.6 Tax Benefits

The tax benefits of existing dredging operations are several-fold. Typical taxes paid as part of ongoing operations include sales taxes (on taxable inputs to production), payroll taxes in accordance with the Federal Insurance Contributions Act (FICA) (on employee compensation and labor payments), income taxes (on profits and wages earned), excise taxes (on specific products produced or used), franchise taxes (payments for doing business within the state), and property taxes (on property used in conducting business). In addition, royalty payments are levied on producers of sand adjacent to and within the state of Kansas; no royalty payments are required in Missouri. Aside from royalty payments, the tax benefits from existing dredging operations have not been quantified in this EIS, although it is acknowledged that commercial dredging does generate substantial tax revenue for local, state, and federal governments.

The fiscal benefits accruing to the state of Kansas from sand production have been estimated based on production levels and royalty rates (see Table 3.12-12). Based on information obtained from the Kansas Department of Revenue (KDOR), total production of sand obtained from the LOMR adjacent to the state of Kansas (and thereby subject to royalty payments) has averaged approximately 754,100 tons annually between 2004 and 2008 (KDOR 2009).

Table 3.12-12 Annual Royalty Payments to the State of Kansas for Sand Production from the Lower Missouri River

	Royalty Payments					
Market Area[a]	2004	2005	2006	2007	2008	Average
St. Joseph[b]	$51,400	$57,500	$55,500	$44,100	$36,600	$49,000
Kansas City[b]	$67,200	$75,100	$72,600	$57,700	$47,900	$64,100
Waverly	$0	$0	$0	$0	$0	$0
Jefferson City	$0	$0	$0	$0	$0	$0
St. Charles	$0	$0	$0	$0	$0	$0
Total	$118,600	$132,500	$128,100	$101,800	$84,500	$113,100

[a] Represents location of dredging in the LOMR based on river segments.

[b] Sand production data and royalty payments paid to the state of Kansas are not available by market area. For this analysis, it was assumed that all sand production from the St. Joseph market area and approximately 16 percent of sand production from the Kansas City market area is subject to sand royalties.

Source: KDOR 2009.

The royalty rate on sand production in or adjacent to Kansas is $0.15 per ton removed. Based on these figures, royalty payments generated by sand production in the LOMR have averaged approximately $113,100 per year. Sand production subject to royalty payments comes exclusively from two market areas on the LOMR – Kansas City and St. Joseph.[12] It is estimated that production in the Kansas City and St. Joseph market areas, on average, generate approximately $64,100 and $49,000, respectively, in royalty payments on an annual basis.

3.12.7.7 Regional Economic Benefits of Existing Dredging Operations

This section presents estimates of the regional economic impacts of ongoing commercial dredging of construction sand and gravel in the LOMR, focusing on the output, income, and employment parameters. The economic costs and benefits described above focus on the direct effects of existing dredging operations based on the location of production across market areas. This section builds on those direct effects by identifying the market area where benefits are expected,[13] and utilizing a

[12] For this analysis, it was assumed that all sand production from the St. Joseph market area is subject to sand royalties. Based on this assumption, it was estimated that sand royalties are paid on approximately 16 percent of sand production in the Kansas City market area.

[13] The regional economic benefits of dredging are attributed to the location of sand and gravel plants that serve as distribution points to the market. Accordingly, the economic activity associated with production that occurs in one market area, but is distributed in another market area, is assigned to the market area where distribution occurs.

regional economic model, estimating additional economic activity that is generated throughout the state of Missouri by sand and gravel production from the LOMR.[14]

Economic Model

The regional economic impacts of existing dredging were estimated using IMPLAN (IMpact Analysis for PLANning), an economic input-output (I-O) model[15]. The I-O framework within IMPLAN allows users to estimate the total economic activity generated by projects and policies, as measured by changes in economic output, labor income, and employment. Total economic effects include direct[16] effects attributed to the activity being analyzed and the additional indirect[17] and induced[18] effects resulting from money circulating throughout the economy. These multiplier (or "ripple") effects are based on inter-industry linkages and household spending patterns in the study area. For this analysis, a 2008 economic model for the state of Missouri was constructed and used to estimate economic impacts.

Model Results and Analysis

The ongoing economic benefits of commercial dredging to the state of Missouri are founded on the value of production; expenditures made in the statewide economy in support of dredging operations; and the size, location, and estimated payroll associated with the operations workforce. Table 3.12-13 presents the results of the regional economic analysis for all industries, and Table 3.12-14 presents the results across affected industries.

Direct Economic Effects

The direct economic effects of commercial dredging in the state of Missouri are presented in Tables 3.12-13 and 3.12-14. The estimated value of commercial sand and gravel produced in the

14 The regional economic analysis focuses on sand and gravel production within the state of Missouri. Accordingly, it excludes production associated with the existing sand plant in Alton, Illinois.

15 IMPLAN is a computer-based system of software and data that was originally developed by the U.S. Forest Service to assist in land and resource management planning and is now a widely used tool for applied economic analysis.

16 "Direct economic effects" refer to changes in output, income, and employment attributed to the expenditures and/or production values specified as direct final demand changes.

17 "Indirect economic effects" refer to changes in output, income, and employment resulting from the iterations of businesses in some industries purchasing from businesses in other industries and initially caused by the direct economic effects.

18 "Induced economic effects" refer to changes in output, income, and employment caused by the expenditures associated with new household income generated by direct and indirect economic effects.

LOMR is approximately $33.3 million annually[19], which represents the direct output effect of existing dredging. This level of production supports approximately 193 jobs and $13.7 million in annual labor payments within Missouri. All of the direct economic impacts occur exclusively within the mining sector.

Table 3.12-13 Statewide Economic Benefits of Sand and Gravel Production from the Lower Missouri River[a]

	Direct Impacts			Total Impacts (Statewide)		
Market Area[b]	Output	Jobs	Income	Output	Jobs	Income
St. Joseph	$1,615,000	9	$489,000	$2,594,000	16	$807,000
Kansas City	$14,087,000	82	$5,853,000	$23,863,000	153	$9,018,000
Waverly	$1,824,000	11	$663,000	$3,015,000	19	$1,049,000
Jefferson City	$8,244,000	48	$3,165,000	$13,761,000	88	$4,952,000
St. Charles[c]	$7,512,000	44	$3,533,000	$13,143,000	85	$5,353,000
Total	$33,281,000	193	$13,703,000	$56,377,000	361	$21,178,000

[a] Monetary values reported in 2008 dollars.

[b] Represents the market area served by sand and gravel production from the LOMR and captures the economic activity associated with sand and gravel distribution rather than location of production across river segments.

[c] Excludes production associated with the existing sand plant in Alton, Illinois because it is located outside the state of Missouri.

Total Economic Effects

The total economic effects of Project operations include the direct, indirect, and induced economic impacts. As explained above, the indirect effects are generated by expenditures on goods and services needed to support ongoing dredging operations, the proportion of inputs that are procured locally (as estimated by the I-O model), and inter-industry linkages throughout the state. The induced effects are associated with existing operation payrolls and labor earnings generated from indirect effects. The total ongoing benefits attributed to economic activity generated by the commercial dredging operations are substantial.

In addition to the $33.3 million in the direct value of sand and gravel production, the statewide economy of Missouri realizes an additional $23.1 million in economic output annually attributed to the indirect and induced economic activity generated by dredging activities, for a total of $56.4 million in total output. Direct income benefits are supplemented by an additional $7.5 million in annual labor income throughout all industries in the state, for a total of $21.2 million in labor income benefits. Existing

[19] This figure is calculated using the average annual production between 2004 and 2008 and the estimated 2008 price for construction sand and gravel for use in concrete and asphalt manufacturing in the primary market areas in Missouri. This value differs from Table 3.12-11, which considers price fluctuations over the 5-year period and does not exclude production outside the state of Missouri.

dredging also supports a total of 361 jobs throughout the state, which consist of direct employment at the existing operations (193 jobs) and another 168 jobs in other industries. At the industry level, the total economic benefits are driven primarily by economic activity in the services sector.

Table 3.12-14 Statewide Economic Benefits of Sand and Gravel Production from the Lower Missouri River by Economic Sector[a, b]

	Direct Impacts			Total Impacts (Statewide)		
Economic Sector	Output	Jobs	Labor Income	Output	Jobs	Labor Income
Agriculture	$0	0	$0	$65,000	1	$8,000
Mining	$33,281,000	193	$13,703,000	$34,362,000	197	$13,964,000
Utilities	$0	0	$0	$1,559,000	2	$276,000
Construction	$0	0	$0	$147,000	2	$72,000
Manufacturing	$0	0	$0	$1,131,000	3	$157,000
Wholesale Trade	$0	0	$0	$1,054,000	6	$398,000
Retail Trade	$0	0	$0	$1,573,000	25	$649,000
Transportation & Warehousing	$0	0	$0	$1,094,000	8	$400,000
Services	$0	0	$0	$14,607,000	116	$5,022,000
Government	$0	0	$0	$784,000	3	$232,000
Total	$33,281,000	193	$13,703,000	$56,377,000	361	$21,178,000

[a] Monetary values reported in 2008 dollars.

[b] Excludes production associated with the existing sand plant in Alton, Illinois because it is located outside the state of Missouri.

3.12.7.8 Other Economic Impacts of Existing Dredging Operations

Ongoing dredging generates a range of other economic impacts that are tied to physical impacts within and adjacent to the LOMR, including effects associated with river bed degradation. Data collected by the USACE over the last 15 years suggest that increased removal of bed sediment, working in concert with the BSNP, has become the dominant cause of river bed degradation. In conjunction with previous reviews of applications for renewed dredging permits, the USACE Kansas City District has determined that significant bed degradation was occurring in portions of the LOMR, and that the most degraded reaches coincided with areas where commercial sand and gravel dredging was the greatest (i.e., the Kansas City, Jefferson City, and St. Charles reaches).

Infrastructure Costs

Several different types of infrastructure in the LOMR are subject to potential damage from river bed degradation, as described in Section 3.5. Infrastructure in the river is organized into six general categories: (1) water intake facilities; (2) water supply wells; (3) levees; (4) BSNP structures, including dikes and revetments; (5) bridge, pipeline, and cable crossings; and (6) wharf and dock facilities. To the extent that existing commercial dredging in the LOMR contributes to river bed degradation, it represents one factor influencing the level of infrastructure damages and related repair, maintenance, and replacement costs incurred by local agencies responsible for these facilities, as well as potential emergency costs and damages associated with catastrophic events such as levee failures. It is difficult to estimate existing costs associated with infrastructure affected by river bed degradation in the LOMR, and even more difficult to ascertain the proportion of these costs attributed directly or indirectly to dredging. Nevertheless, it is likely that river bed degradation and resultant infrastructure costs, including protection of levees at risk and modification of intakes at risk, total many millions of dollars.

The discussion below is based on the representative types of costs associated with river bed degradation as documented in the Degradation Study (USACE 2009) and other planning data collected by the USACE. For more information, refer to Section 3.5.

The 2009 USACE study indicates that ongoing river bed degradation in the Missouri River has resulted in the need to adjust or extend water supply intakes to accommodate changing water surface elevations, thereby increasing capital costs incurred by local municipalities that provide water supplies to the public and electrical utilities that are dependent on the LOMR for cooling water. For example, in Kansas City, Missouri, low flows have forced the city to spend more than $4 million to extend water intakes and drinking water pumps to reach lower river levels. One municipal water intake in the Kansas City reach was retrofitted in early 2004 with supplemental pumps to draw from lower elevations, at a cost of approximately $2 million; and Kansas City, Kansas, has spent $22.6 million on a cooling tower and emergency pumps to retrofit two electrical generating facilities. It also has been noted that continued river bed degradation may require replacement of intake structures, at even higher capital costs. Moreover, ongoing maintenance and pumping costs associated with water intakes also may increase. Should water levels fall below threshold levels for intake operations, water supplies could be compromised. This could require using higher cost alternative sources (e.g., groundwater wells) or shutting down electrical generation facilities at the expense of utility operators. Ultimately, these costs likely would be passed along to customers in the form of higher water and electricity rates.

In total, there are 31 water intake facilities in the Project area between RM 498 and RM 0. Public drinking water intakes in the Kansas City segment include the intake for Kansas City, Missouri; Kansas City, Kansas; and the Johnson County Kansas Water District 1. These intake facilities serve nearly 1.1 million people. In the St. Joseph segment, water supply facilities supply drinking water to nearly 160,000 persons. In the St. Charles reach, public drinking water is supplied by at least three water plants serving approximately 940,000 persons. Overall, water supply intakes in the Project area provide water to approximately 2.2 million persons (Kelly 2004).

In addition, baseload power plants in the Kansas City segment that withdraw cooling water have a gross capacity of nearly 1,200 MW. In the St. Joseph reach, three baseload plants have a gross capacity of approximately 1,026 MW. In the lowest segment of the Missouri (near St. Charles), power plants at risk have a gross capacity of more than 3,700 MW. Power plant intakes in the Project area account for 41 percent of all the power plant production on the mainstem and LOMR system, generating over 6,000 MW (Kelly 2004). The value of power production at these facilities is substantial.

River bed degradation also can reduce levee stability. Levees are constructed with the minimum distance from the bank or with the revetment armoring the bank needed to have stability under the conditions at the time of construction. As river bed degradation removes bed material from the toe of the bank or revetment, levees become more vulnerable to collapse. Underwater damage to the revetment toe can go undetected and unrepaired without some sort of underwater survey or inspection. If the revetment is an extension of the levee toe or if the bank buffering the levee is eroded away by river bed degradation, the potential for levee failure during high-flow water events increases. Failure of a levee during a high-flow water event could be sudden and irreparable during the flood and could result in property damages in affected areas, including the Kansas City region. The Kansas City system of levees protects more than $19 billion of investment. Employment in the Kansas City levee units approaches nearly 100,000 jobs. Approximately 23,000 residents (including many minority and low-income individuals) live behind the Kansas City levees. In total, federal levees on the LOMR protect approximately $21.4 billion in investment and have prevented approximately $6.1 billion in property damages through 2009 (USACE 2010). Continued river bed degradation could contribute to catastrophic levee failure, resulting in loss of life and potentially substantial economic damages.

Similarly, BSNP structures; bridges, pipeline and cable crossings; and wharf and dock facilities are susceptible to failure and related property damages from river bed degradation and associated headcutting. Because many of these facilities are operated and maintained by private companies, it is difficult to estimate ongoing maintenance costs and damages related to river bed degradation.

However, it has been estimated that LOMR bridges typically cost between $1 and $2 million per bridge to remediate scour and river bed degradation problems that arise (Heckman pers. comm.). Continued river bed degradation also could contribute to the sudden catastrophic failure of a bridge or a petro-chemical pipeline, resulting in loss of life or an accidental release of petro-chemicals with various environmental consequences.

Effects on Agricultural Production

Agricultural land uses are found throughout the floodplain adjacent to the Missouri River (see Section 3.11). Agriculture in the area along the river typically relies on natural precipitation, and to a more limited extent, groundwater from private wells for irrigation. River bed degradation could adversely affect groundwater levels based on the hydrologic connection between the river channel and the surrounding water table. A reduction in groundwater levels could increase groundwater pumping depths and increase the associated pumping costs. In cases where costs would be prohibitive, agricultural land could be left unirrigated, resulting in potential economic impacts to farmers in the form of reduced crop yields and agricultural revenues.

Effects on Recreation Use

As described in Section 3.11, recreation facilities are found interspersed along the shore of the LOMR, including boat launches and designated recreation areas. Recreation activity also occurs on the water surface, primarily boating and fishing. Existing dredging operations can affect recreation use in several ways, including contributing to river bed degradation that may hinder recreation boating access and navigability. The presence of commercial barges in the river also may compromise the overall recreational quality of the river. Such effects could result in a reduction in recreation visitation to the study area, thereby decreasing recreation expenditures and the associated regional economic benefits attributed to recreation spending.

Effects on Missouri River Navigation

Section 3.6 describes the use of the Missouri River for commercial navigation. Although most of the commodity movements and tonnage shipped on the LOMR is associated with commercial dredging of sand and gravel by the permit applicants, other goods also are shipped along the river. Navigation benefits within the LOMR are provided primarily by the BSNP, which was designed and built to create and maintain a self-scouring navigation channel and for management of navigation flows by the USACE using storage in the upstream reservoir system. Limited dredging has been needed at certain points in the river to maintain the river channel, occurring in specific locations on an as-needed basis as

determined by the USACE. The navigation benefit provided by commercial dredging is limited to providing dredges that can be used by the USACE when needed. Without these dredges, the cost of occasional maintenance dredging would be somewhat higher due to the costs associated with mobilizing dredging equipment on the LOMR from other locations; these avoided costs realized by the USACE are considered an economic benefit to the public

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3.13 NOISE

3.13.1 Introduction

The area potentially affected by the Proposed Action and alternatives extends 498 miles along the LOMR between St. Louis, Missouri, and Rulo, Nebraska. Proposed changes in commercial dredging activity on the LOMR could change the level of noise generated by this activity and related onshore activities. Sources of noise include operation of tug boats, engines, and processing equipment associated with dredging, and operation of onshore terminal facilities (use of front-end loaders, cranes, conveyors, and other processing equipment, and delivery trucks).

This section describes the existing noise conditions in areas affected by commercial dredging of sand and gravel in the LOMR. The information presented is intended to provide a general overview of noise conditions in the Project area and the land uses that would be affected by the Project. It also establishes the context within which the potential impacts of the Proposed Action and alternatives will be evaluated.

This section begins with definitions of noise terminology. The regulatory setting discusses applicable noise regulations and policies in the Project area. A discussion of existing noise-sensitive land uses in the Project area is followed by a discussion of the existing ambient noise levels in the Project area and noise levels generated by existing dredging and processing facilities.

3.13.2 Noise Terminology

Noise is commonly defined as unwanted sound (mechanical energy transmitted by pressure waves through a medium such as air) that annoys or disturbs people and may cause adverse psychological or physiological effects on human health. Because noise is an environmental issue that can interfere with human activities, evaluation of noise is necessary when considering the environmental impacts of a proposed project.

Sound pressure level using the decibel (dB) scale is most commonly used to characterize the loudness of sound. Because the human ear is not equally sensitive to all sound frequencies, noise measurements are weighted more heavily for frequencies to which humans are sensitive in a process called A-weighting. A-weighted decibels are written as dBA. Table 3.13-1 summarizes typical A-weighted sound levels for common noise sources.

Table 3.13-1 Typical A-Weighted Sound Levels

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	—110—	Rock band
Jet flyover at 1,000 feet		
	—100—	
Gas lawnmower at 3 feet		
	—90—	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	—80—	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawnmower at 100 feet	—70—	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	—60—	
		Large business office
Quiet urban daytime	—50—	Dishwasher in next room
Quiet urban nighttime	—40—	Theater, large conference room (background)
Quiet suburban nighttime		
	—30—	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	—20—	
		Broadcast/recording studio
	—10—	
	—0—	

Notes:

dBA = A-weighted decibel.
mph = Miles per hour.

Source: Caltrans 1998.

Because sound levels often vary over time, the equivalent sound level (L_{eq}) is used to represent the average sound energy over a given period of time. Noise impacts from a temporary mobile noise source such as a dredge operation are typically evaluated against a 1-hour L_{eq} noise standard. Noise impacts from a permanent stationary facility such as a sand plant are typically evaluated against a 24-hour weighted average such as the day-night level (L_{dn}). L_{dn} is the energy average of the A-weighted sound levels occurring during a 24-hour period, with 10 dB added to the A-weighted sound levels occurring during the period from 10:00 p.m. to 7:00 a.m. to account for increased sensitivity to noise during those hours.

In general, human sound perception is such that a change in sound level of 1 dB cannot typically be perceived by the human ear, a change of 3 dB is just noticeable, a change of 5 dB is clearly noticeable, and a change of 10 dB is perceived as doubling or halving the sound level. A doubling of sound energy results in a 3-dB increase in sound level. An example of this is a roadway where the volume of traffic

doubles. Although this is a substantial increase in traffic volume, the increase in noise would be only 3 dB (i.e., just noticeable).

When evaluating noise from equipment operations, the noise level produced by the equipment is typically characterized in terms of a measured sound level at a specific distance, typically 50 feet. This "source" information can be determined from measurements or from standard reference data. With the source sound level, the sound level at various distances—including the sound level at specific receiver locations—can be predicted. The rate at which sound attenuates over distance depends on several factors, described below.

For a point source such as a stationary compressor or construction equipment, sound attenuates based on distance at a rate of 6 dB per doubling of distance. For example, if a point sound source produces a sound level of 85 dBA at 50 feet, the sound level at 100 feet would be 79 dBA and the sound level at 200 feet would be 73 dBA. For a line source such as free-flowing traffic on a freeway, sound attenuates at a rate of 3 dB per doubling of distance (Caltrans 1998).

Atmospheric conditions such as wind, temperature gradients, and humidity can change how sound propagates over distance and can affect the level of sound received at a given location. The degree to which the ground surface absorbs acoustical energy also affects sound propagation. Sound that travels over an acoustically absorptive surface such as grass attenuates at a greater rate than sound that travels over a hard surface such as pavement or water. The increased attenuation is typically in the range of 1–2 dB per doubling of distance. This increases the attenuation rate for point sources to 7–8 dB per doubling of distance and the attenuation rate for line sources to 4–6 dB per doubling of distance. Barriers such as buildings and topography that block the line of sight between a source and receiver also increase the attenuation of sound over distance. Typically, a barrier that blocks the line of sight between a noise source and a receiver will reduce sound by at least 5 dB.

3.13.3 Regulatory Setting

3.13.3.1 Federal

Noise Control Act of 1972

The federal Noise Control Act of 1972 (PL 92-574) established a requirement that all federal agencies administer their programs to promote an environment free of noise that would jeopardize public health or welfare. The USEPA was given the responsibility for:

- Providing information to the public regarding identifiable effects of noise on public health and welfare;
- Publishing information on the levels of environmental noise that will protect the public health and welfare with an adequate margin of safety;
- Coordinating federal research and activities related to noise control; and
- Establishing federal noise emission standards for selected products distributed in interstate commerce.

U.S. Army Corps of Engineers

Chapter 14, Operational Noise, of U.S. Army Regulation 200-1 "Environmental Protection and Enhancement" (U.S. Army 2007) provides guidance for evaluating noise associated with Army operations. This regulation provides noise criteria for military operations. Accordingly, these criteria are not directly applicable to the Proposed Action. Section 4-14a(10) does, however, state: "Transportation and industrial noise will be assessed on a case by case basis using appropriate noise metrics, including U.S. Department of Transportation guidelines."

In 2004, the USEPA (Region 2), in coordination with the USACE Kansas City District, published a document entitled *Hudson River PCBs Superfund Site Quality of Life Performance Standards* (USEPA 2004). This document provides specific guidance on noise standards for dredging activities, processing facility operations, and material transfer operations associated with PCB cleanup operations on the Hudson River. Table 3.13-2 summarizes the noise standards recommended in the USEPA 2004 document for residential uses.

3.13.3.2 State

Missouri, Kansas, and Nebraska do not have specific noise standards that relate to dredging and material processing activities. Each state is required to adopt highway noise and abatement policies for implementing federal-aid highway projects in each state. However, these policy documents do not relate to dredging and material processing activities.

3.13.3.3 Local

The Proposed Action lies within the jurisdiction of various counties and cities along the LOMR in the states of Missouri and Kansas. Some counties and cities have established policies and codes concerning the generation and control of noise that could adversely affect citizens and noise-sensitive

land uses. Appendix C provides a discussion of the counties and cities with applicable noise ordinances designed to protect its citizens from adverse noise.

Table 3.13-2 Noise Standards for Residential Uses[a]

Short-Term Impacts[b]: Facility Construction and Dredging

Mitigation recommended	Daytime: 75 dBA (maximum hourly average)
Mitigation required	Nighttime: 65 dBA (maximum hourly average)
	Daytime: 80 dBA (maximum hourly average)

Long-Term Impacts[c]: Processing Facility and Transfer Operations

	65 L_{dn}

Notes:

Daytime: 7:00 a.m. to 10:00 p.m. Nighttime: 10:00 p.m. to 7:00 a.m.

dBA = A-weighted decibel.
L_{dn} = Day-night level.

[a] Specific guidance on noise standards for dredging activities, processing facility operations, and material transfer operations associated with PCB cleanup operations on the Hudson River.

[b] Short-term is defined as activities that would occur during a 3- to 6-month period.

[c] Long-term is defined as activities that would occur during the 6-year life of the Hudson River project.

Source: USEPA 2004.

3.13.4 Noise-Sensitive Land Uses

Noise-sensitive land uses are generally considered to be places where people have an expectation of reasonable quiet, such as residences, health care facilities, and educational facilities. Other land uses such as parks, where quiet can be an important part of how the area is used, also can be considered sensitive to noise.

Numerous small towns and several cities are located near the river in the Project area; however, most of the land along the river is undeveloped agricultural land with scattered rural residences. The focus of the noise impact analysis is on residential uses where recurrent exposure to noise from dredging activity cannot be avoided by residents. For the purposes of this assessment, schools and health care facilities are treated as residential uses. Although parks, wildlife refuges, conservation areas, and day-use picnic areas exist in the Project area, these areas are not considered as sensitive as residential areas because use areas exposed to noise can temporarily be avoided if necessary during dredging activities. Table 3.13-3 lists cities and towns located along the river in the Project area by river segment. The county and state where each city or town is located is identified, along with the

approximate distance from the edge of the river to the nearest residential use. These distances range from 110 to 5,000 feet.

3.13.5 Noise Levels in the Project Area

3.13.5.1 Existing Ambient Noise Levels

Ambient noise levels depend to a great extent on the amount of development in an area. In a developed urban area, ambient noise levels are governed primarily by traffic on roadways and highways. Other forms of transportation including aircraft and trains are intermittent sources of noise in areas near airports and train tracks. The ambient noise levels in a rural agricultural area are governed primarily by farming activities and traffic on local roadways. In areas with no development-induced noise from sources such as farming or highway traffic, the primary sound is from natural sources such as wind and birds. Existing dredging operations and related processing facilities are sources of noise where those operations are located.

Population density and ambient noise levels tend to be closely correlated. Areas that are not urbanized are relatively quiet; while more urbanized areas are subjected to higher noise levels from roadway traffic, industrial activities, and other human activities. Table 3.13-3 summarizes typical ambient noise levels for various general location types.

Table 3.13-3 identifies location types in the Project area for each segment, and the typical ambient noise levels are based on those in Table 3.13-4.

3.13.5.2 Existing Dredging and Terminal Facility Noise

Each operator has provided information on existing dredging and terminal facility operations, including the number and size of engines used on each dredge and tugboat. Noise from dredging and tugboat operations has been estimated from these data using methods recommended by Hoover & Keith (2000). Tables 3.13-5 and 3.13-6 summarize the noise levels generated by each dredge or tug boat. Dredging would typically occur within a few miles upstream of a company's sand plant; dredging typically occurs no more than 7–10 miles upstream of the sand plant. Temporary mobile noise sources such as this are typically evaluated using a short-term average noise level. Accordingly, noise levels are reported in terms of L_{eq}. Tables 3.13-5 and 3.13-6 report the distance to the 75-dBA-L_{eq} and 65-dBA-L_{eq} noise contours. Residences located within the 65-dBA-L_{eq} contour potentially are exposed to noise impacts.

Table 3.13-3 Existing Ambient Noise Levels at Noise-Sensitive Land Uses in the Project Area (dB)

Segment	Company, Facility Name, River Mile	City/Town	State	County	Distance to Edge of River from Residences (feet)	Population	General Location Type	Ambient Noise Level (dB)[a]
		Rulo	Nebraska	Richardson	125	226	Small town	50
RM 489								
St. Joseph		White Cloud	Kansas	Doniphan	250	239	Small town	50
		Nodaway	Missouri	Andrew	2,600	6,000	Small town	50
		Elwood	Kansas	Doniphan	2,300	1,145	Quiet suburban residential	50
	Holliday Sand & Gravel Company, St. Joseph Plant, RM 447.8	St. Joseph	Missouri	Buchanan	175	72,651	Quiet suburban residential	50
		Palermo	Kansas	Doniphan	500	Unknown (unincorporated county area)	Small town	50
		Atchison	Kansas	Atchison	230	10,154	Quite suburban residential	50
		Leavenworth	Kansas	Leavenworth	300	35,420	Quiet suburban residential	50
		Lansing	Kansas	Leavenworth	4,700	10,705	Quiet suburban residential	50
		Weston	Missouri	Platte	4,500	1,631	Small town	50
		Weston Bend State Park	Missouri	Platte	100	NA	Quiet suburban residential	50
		Farley	Missouri	Platte	5,000	226	Small town	50

Table 3.13-3 Existing Ambient Noise Levels at Noise-Sensitive Land Uses in the Project Area (dB)

Segment	Company, Facility Name, River Mile	City/Town	State	County	Distance to Edge of River from Residences (feet)	Population	General Location Type	Ambient Noise Level (dB)[a]
RM 391								
Kansas City	The Master's Dredging Company, Waldron Site[b], RM 385	Waldron	Missouri	Platte	2,800	Unknown (unincorporated county area)	Small town	50
		Parkville	Missouri	Platte	1,700	4,059	Quiet suburban residential	50
		Riverside	Missouri	Platte	2,000	2,979	Quiet suburban residential	50
	Holliday Sand & Gravel Company, Randolph Plant, RM 360	Randolph	Missouri	Clay	1,200	47	Rural	40–50
		Kansas City	Kansas	Wyandotte	1,800	146,867	Quiet suburban residential	50
		Kansas City	Missouri	Jackson	1,800	447,306	Normal suburban residential	50
RM 357								
Waverly		River Bend	Missouri	Clay	630	10	Rural	40–50
		Missouri City	Missouri	Clay	130	295	Small town	50
		Sibley	Missouri	Jackson	720	347	Small town	50
		Napoleon	Missouri	Lafayette	125	208	Small town	50
		Wellington	Missouri	Lafayette	2,400	784	Small town	50
	Capital Sand Company, Lexington Plant, RM 317.5	Lexington	Missouri	Lafayette	1,100	4,453	Quiet suburban residential	50
	Capital Sand Company, Carrollton Plant, RM 287	Waverly	Missouri	Lafayette	190	806	Small town	50
		Miami	Missouri	Saline	140	160	Small town	50

Table 3.13-3 Existing Ambient Noise Levels at Noise-Sensitive Land Uses in the Project Area (dB)

Segment	Company, Facility Name, River Mile	City/Town	State	County	Distance to Edge of River from Residences (feet)	Population	General Location Type	Ambient Noise Level (dB)[a]
RM 250								
Jefferson City	Capital Sand Company, Glasgow Plant, RM 226.2	Glasgow	Missouri	Chariton, Howard	110	1,263	Small town	50
		Arrow Rock	Missouri	Saline	760	79	Small town	50
	Capital Sand Company, Boonville Plant, RM 196.2	Boonville	Missouri	Cooper	140	8,202	Quiet suburban residential	50
	Capital Sand Company, Rocheport Plant, RM 186.5	Rocheport	Missouri	Boone	270	208	Small town	50
		Huntsdale	Missouri	Boone	1,600	31	Rural	40–50
		Lupus	Missouri	Moniteau	250	29	Small town	50
		Sandy Hook	Missouri	Moniteau	200	Unknown (unincorporated county area)	Small town	50
		Marion	Missouri	Cole	500	Unknown (unincorporated county area)	Small town	50
	Hermann Sand & Gravel, Jefferson City Plant, RM 146.5			Callaway				
	Capital Sand Company, Jefferson City Plant, RM 143.5			Callaway				
		Jefferson City	Missouri	Cole	220	39,274	Quiet suburban residential	50
		Osage City	Missouri	Cole	1,150	Unknown (unincorporated county area)	Small town	50

Table 3.13-3 Existing Ambient Noise Levels at Noise-Sensitive Land Uses in the Project Area (dB)

Segment	Company, Facility Name, River Mile	City/Town	State	County	Distance to Edge of River from Residences (feet)	Population	General Location Type	Ambient Noise Level (dB)[a]
RM 130								
St. Charles		Chamois	Missouri	Osage	780	456	Small town	50
		Gasconade	Missouri	Gasconade	120	267	Small town	50
		Hermann	Missouri	Gasconade	140	2,674	Small town	50
		New Haven	Missouri	Franklin	200	1,867	Small town	50
	Edward N. Rau Contractor Company, Washington Site[b], RM 68			Franklin				
	Capital Sand Company, Washington Plant, RM 66	Washington	Missouri	Franklin	430	13,243	Quiet suburban residential	50
		Bernie E. Hillerman Park	Missouri	Franklin	1,000	NA	Quiet suburban residential	50
		Wildwood	Missouri	St. Charles	3,000	32,884	Normal suburban residential	55
	Limited Leasing Company, Bridgeton Plant, RM 44			St. Louis				
		Weldon Springs	Missouri	St. Charles	>5,000	527	Normal suburban residential	55
		Chesterfield	Missouri	St. Louis	>5,000	46,802	Normal suburban residential	55
	J.T.R., St. Charles Plant, RM 31.5			St. Charles				
		Maryland Heights	Missouri	St. Louis	>5,000	26,339	Normal suburban residential	55

Table 3.13-3 Existing Ambient Noise Levels at Noise-Sensitive Land Uses in the Project Area (dB)

Segment	Company, Facility Name, River Mile	City/Town	State	County	Distance to Edge of River from Residences (feet)	Population	General Location Type	Ambient Noise Level (dB)[a]
RM 130 (continued)								
St. Charles (continued)	Limited Leasing Company, Chesterfield Plant, RM 28							
		St. Charles	Missouri	St. Charles	450	63,009	Normal suburban residential	55
		Bridgeton	Missouri	St. Louis	>5,000	15,555	Normal suburban residential	55
		Hazelwood	Missouri	St. Louis	2,700	25,523	Normal suburban residential	55
	J.T.R., Riverview Plant, RM 16.5	Florissant	Missouri	St. Louis	1,000	51,387	Normal suburban residential	55
	Limited Leasing Company, Fort Belle Plant, RM 8	Spanish Lake	Missouri	St. Louis	300	21,337	Normal suburban residential	55

Notes:

dB = Decibel.

RM = River mile.

[a] Refer to Table 3.13-4 for typical ambient noise levels associated with location types.

[b] Not currently an operating facility but a proposed site under the Proposed Action and alternatives. Shown here for general reference.

Table 3.13-4 Typical Ambient Noise Levels by General Location Type

Location Type	dBA-L_{dn}
Rural	40–50
Small town or quiet suburban residential	50
Normal suburban residential	55
Urban residential	60
Noisy urban residential	65
Very noisy urban residential	70
Downtown, major metropolis	75–80
Adjoining freeway or near a major airport	80–90

Notes:

dBA = A-weighted decibel.
L_{dn} = Day-night level.

Source: Hoover and Keith 2000.

Existing terminal facilities in the Project area use front-end loaders, cranes, conveyors, and other processing equipment. Based on information provided by the MDNR (Zeaman pers. comm.), it was assumed that each plant has a crane, four loaders, and one dozer. Noise generated by this equipment has been estimated using noise source levels developed by the Federal Highway Administration (FHWA) (2006). Simultaneous operation of this equipment would result in a noise level of 83 dBA-L_{eq} at 50 feet from the source. Existing noise from other equipment at these facilities has been estimated using data from a plant with screens, crushers, conveyor belts, cyclones, sand classifiers, and screws (Bauer and Spencer 2008). This facility produces a reference sound level of approximately 89 dBA at 50 feet. The combined sound level of all of the equipment is 90 dBA-L_{eq} at 50 feet. Assuming continuous operation between 7:00 a.m. and 7:00 p.m., this level of noise corresponds to 87 L_{dn} at 50 feet.

For this assessment, it was assumed that all facilities with annual production of 250,000 tons or less produce a sound level of 87 L_{dn} at 50 feet. For larger facilities, the source noise level is scaled up based on the amount of production in excess of 250,000 tons/yr. As discussed in Section 3.13.2, a doubling of sound energy corresponds to a 3-dB increase in noise. Therefore, a doubling of delivered product volume is assumed to result in a 3-dB increase in facility noise. The change in noise level associated with larger or smaller changes in product volume also can be calculated directly. For example, a 10-percent increase in product volume would result in a 0.4-dB increase in noise.

Table 3.13-5 Tug Boat Noise Levels

Company	Tug Name	Engine(s)	Engine Horsepower	Sound Level at 50 Feet (dBA-L_{eq})[a]	Company Activity	Distance to 75-dBA-L_{eq} Contour (feet)[b]	Distance to 65-dBA-L_{eq} Contour (feet)[b]
J.T.R	Barbara Sue	2 – GM 8V-71	470	89	9.5 hours per day, (Monday–Friday)	251	792
	Shelby J	2 – 12V-71	680	91		315	998
	William Powell	2 – Cummins KTA19	1,200	93		397	1,256
Limited Leasing Company	Atlas	3 – Luggar L6140	1,500	96	10 hours per day, (Monday–Friday)	561	1,774
	Janet	2 – Detroit 8V71	460	89		251	792
	Joanne	2 – Detroit 8V71	460	89		251	792
	Leona	2 – Detroit 12V71	660	91		315	998
	Patricia	2 – Detroit 12V71	660	91		315	998
	Piasa	2 – Detroit 12V71	660	91		315	998
Capital Sand Company	Marge [a]	2 – Caterpillar 3412	600	90	10 hours per day, (Monday–Friday)	281	889
	Allison Marie	3 – Caterpillar 3412	600	92		354	1,119
	Tarkio	2 – Caterpillar 3412	600	90		281	889
Hermann Sand & Gravel	Kathryn	2 – Cummins N-14	880	92	12 hours per day, (Monday–Friday)	354	1,119
	Mel Sue	2 – NH 220 Cummins	400	89		251	792
Holliday Sand & Gravel Company	Chouteau	2 – Caterpillar C12	680	91	12 hours per day, (4–6 days per week)	315	998
	Sibley	2 – Caterpillar 3406	950	92		354	1,119
	Dakota	2 – Caterpillar 3412C	1,040	93		397	1,256
	Fairfax	2 – Caterpillar 3412C	1,300	94		446	1,409
	Edward Perry	2 – Caterpillar 3406	730	91		315	998

Notes:

dBA = A-weighted decibel.

L_{eq} = Equivalent sound level.

[a] Based on reciprocating engine horsepower (Hoover & Keith 2000).

[b] Based on point source attenuation of 6 dB per doubling of distance.

Table 3.13-6 Dredger Operation Noise Levels

Company	Dredge Name	Engines(s)	Engine Horsepower	Sound Level at 50 Feet (dBA-L_{eq})[a]	Company Activity	Distance to 75-dBA-L_{eq} Contour (feet)[b]	Distance to 65-dBA-L_{eq} Contour (feet)[b]
J.T.R.	Queenfish	Cummins 1710	425	86	10.5 hours per day, (Monday–Friday)	177	561
	Mark V	Caterpillar 3408	455	86		177	561
	JTR	Caterpillar 3408	455	86		177	561
Limited Leasing Company	St Charles	Caterpillar 3406	365	85	10 hours per day, (Monday–Friday)	158	500
	Traveler	Caterpillar 3406	365	85		158	500
	Chesterfield	Caterpillar 3406	365	85		158	500
Capital Sand Company	Kathy Lee	Caterpillar 3512	1,150	90	10 hours per day, (Monday–Friday)	281	889
	Sandy K	Caterpillar C18	450	86		177	561
	Rae Marie	Caterpillar 3412	450	86		177	561
		Caterpillar 3412	600	87		199	629
		Caterpillar 3406	450	86		177	561
Hermann Sand & Gravel	Arl-501	Cummins	335	85	12 hours per day, (Monday–Friday)	158	500
Holliday Sand & Gravel Company	Randolph	EMD 16-645-E6	1,200	90	12 hours per day, (Monday–Friday)	281	889
	Riverside	EMD 12-645E2	900	89		251	792
	St. Joseph	John Deere 6125AFM	400	86		177	561
The Master's Dredging Company	Penny	Caterpillar D 398 TA	825	89	10 hours per day, (Monday–Friday)	251	792
	Oklahoma	Caterpillar 3516 TA	2,450	93		397	1,256

Notes:

dBA = A-weighted decibel.

L_{eq} = Equivalent sound level.

[a] Based on reciprocating engine horsepower (Hoover & Keith 2000).

[b] Based on point source attenuation of 6 dB per doubling of distance.

For a permanent stationary facility such as a sand plant, noise levels typically are evaluated using L_{dn}. An adverse effect is considered to occur at residences where the noise levels exceed 65 L_{dn}. This threshold has been used by the USACE for similar dredging projects (USEPA 2004). The distance to the 65-L_{dn} contour is 630 feet based on point-source attenuation of 6 dB per doubling of distance.

Table 3.13-7 shows the distance between each existing plant and the nearest residence. Currently, residences are located within 630 feet of primary plant operations for two facilities (Glasgow, St. Charles and Alton). Table 3.13-7 also provides an estimate of existing haul truck noise levels based on the annual production capacity of each facility and daily average delivery estimates. The results in Table 3.13-7 indicate that existing haul truck noise from deliveries does not exceed 65 L_{dn} within 50 feet of the roadway at any of the existing facilities. Based on the assumptions stated in Table 3.13-7, deliveries would need to exceed 760 per day before truck noise would exceed 65 L_{dn} within 50 feet of the roadway and potentially result in a noise impact at residences along the roadway.

Table 3.13-7 Summary of Facility Processing and Haul Truck Noise

Facility Name (Company)	River Mile	Segment	Annual Tons Delivered	Facility Reference Noise Level (L_{eq} at 50 feet)[a]	Distance to Processing Noise 65-L_{dn} Contour (feet)	Distance to Nearest Residence (feet)	65 L_{dn} Exceeded at Nearest Residence?	Estimated Tons per Day[c]	Estimated Truck Deliveries Per Day[d]	Trips Per Day	Haul Truck Noise Level (L_{dn} at 50 feet)[e]
St. Joseph (Holliday)	447.8	St. Joseph	326, 928	88	720	850	No	1,514	76	151	56
Waldron (Masters)[b]	385	Kansas City	NA	NA	NA	3,300	NA	NA	NA	NA	NA
Riverside (Holliday)	372	Kansas City	1,450,773	95	1,516	2,900	No	6,717	336	672	62
Randolph (Holliday)	360	Kansas City	1,516529	94	1,551	3,800	No	7,023	351	702	63
Lexington (Capital)	317.5	Waverly	346,202	88	741	2,700	No	1,603	80	160	57
Carrollton (Capital)	287	Waverly	22,918	87	629	4,000	No	106	5	11	48
Glasgow (Capital)	226.2	Jefferson City	136,273	87	629	600	Yes	631	32	63	53
Boonville (Capital)	196.2	Jefferson City	11,338	87	629	1,900	No	52	3	5	47
Rocheport (Capital)	186.5	Jefferson City	272,709	87	657	1,350	No	1,263	63	126	56
Jefferson City (Hermann)	146.5	Jefferson City	64,861	87	629	5,200	No	300	15	30	51
Jefferson City (Capital)	143.5	Jefferson City	1,093,679	93	1,317	1,900	No	5,063	253	506	61
Hermann (Hermann)	97	St. Charles	61,097	87	629	1,900	No	283	14	28	51
Washington (Rau)[b]	68	St. Charles	NA	NA	NA	250	NA	NA	NA	NA	NA
Washington (Capital)	66	St. Charles	136,463	87	629	1,700	No	632	32	63	53
Bridgeton (Limited)	44	St. Charles	288,607	88	676	2,800	No	1,336	67	134	56
St. Charles (J.T.R.)	31.5	St. Charles	402,245	89	798	600	Yes	1,862	93	186	57
Chesterfield (Limited)	28	St. Charles	535,985	90	922	2,400	No	2,481	124	248	58

Table 3.13-7 Summary of Facility Processing and Haul Truck Noise

Facility Name (Company)	River Mile	Segment	Annual Tons Delivered	Facility Reference Noise Level (L_{eq} at 50 feet)[a]	Distance to Processing Noise 65-L_{dn} Contour (feet)	Distance to Nearest Residence (feet)	65 L_{dn} Exceeded at Nearest Residence?	Estimated Tons per Day[c]	Estimated Truck Deliveries Per Day[d]	Trips Per Day	Haul Truck Noise Level (L_{dn} at 50 feet)[e]
Riverview (J.T.R.)	16.5	St. Charles	60,011	87	629	2,300	No	278	14	28	51
Fort Belle (Limited)	8	St. Charles	82,459	87	629	850	No	382	19	38	51
Alton (Limted)	On Mississippi	On Mississippi	82,459	87	629	220	Yes	382	19	38	51

Notes:

L_{dn} = Day-night level.

L_{eq} = Equivalent sound level.

[a] Based on processing source level of 90 dBA-L_{eq} at 50 feet and continuous operation between 7:00 a.m and 7:00 p.m. (87 L_{dn} at 50 feet) for facilities producing 250,000 tons/year or less. Source level scaled up for larger facilities.

[b] New proposed facility.

[c] Assumes 216 delivery days per year (10 months of operation per year, 5 days a week.)

[d] Assumes average truck capacity of 20 tons

[e] Calculated using Federal Highway Administration Traffic Noise Model Version 2.1, assuming average truck speed of 45 miles per hour (mph) on local road near plant:

- Two truck trips (out and in from facility) per delivery.
- Daily truck trips equally distributed over 8-hour work day during daytime hours.
- Average truck speed of 45 mph on local road near plant.

3.13.6 References

3.13.6.1 Printed Literature

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U.S. Army. 2007. Environmental Quality Environmental Protection and Enhancement. (Army Regulation 200-1.) Washington, DC.

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3.13.6.2 Personal Communication

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3.14 VISUAL AND AESTHETIC RESOURCES

3.14.1 Introduction

This section describes visual resources in the Project area. The purpose of this information is to establish the existing visual context, against which the reader can understand the visual changes related to the Proposed Action and alternatives. This section also establishes a structure for the discussion of impacts in Section 4.12. For example, this discussion of the visual setting identifies groups of people who have views of the Project area because the Project could change their views and experiences. Section 4.12 analyzes visual impacts to these same viewer groups.

The Project area consists of five river segments: St. Joseph (RM 391 – RM 498), Kansas City (RM 357 – RM 391), Waverly (RM 250 – RM 357), Jefferson City (RM 130 – RM 250), and St. Charles (RM 0 – RM 130). The LOMR is known for its fertile floodplains suitable for agricultural purposes, and the river and its riparian corridor are the predominant visual features in the Project area landscape and viewshed.

The majority of development along the river is comprised of rural areas and small towns and cities with roots as agricultural communities. The cities of St. Joseph, Kansas City, North Kansas City, and the outlying suburbs of St. Louis are larger metropolitan centers in the Project area and along the river; these areas add to the view characteristics in the Project area. Recreational uses are located in both the rural and developed areas, and primarily consist of parks and trails, conservation and wildlife areas, river access points, and recreational uses on the river itself (see Figure 3.14-1). Views associated with the river, urban areas, and recreational areas are discussed by river segment in Section 3.14.5.

Onshore and offshore dredging operations, and the associated equipment on the river, are features in the river landscape (see Figure 3.14-2). These operations introduce barges and heavy equipment into the viewshed of the river, a valued visual resource, and detract from views associated with the river itself. While operations, in their entirety, may detract from views associated with the river, some viewers are likely to regard barges and tows as an aesthetic resource that add to the interest of views. Conversely, other viewers may seek out areas on the river that do not have views of barges, high boating activity, and development in search of views with fewer human and more natural influences. Viewer groups affected by dredging activities include residents in riverside communities and recreationists along the Project segments in rural and developed areas, who have a higher sense of ownership of views of the river. Residents near dredging operations, however, see these operations as

part of their existing visual environment (see Figure 3.14-3). Those employed at riverside places of business and industrial areas and motorists using adjacent roadways are moderately affected by dredging operations because, although they value views of the river, they are more focused on work or driving activities when viewing dredging operations. Agricultural areas are the least affected by dredging operations because visual access to dredging operations is often limited by the presence of vegetation along the riverbanks and the absence of visual access points.

Figure 3.14-1 Recreational Viewers Canoeing on the River

3.14.2 Regulatory Setting

This section describes the regulations that apply to visual and aesthetic resources that could be affected by the Proposed Action and alternatives.

Figure 3.14-2 Onshore Dredging Facilities and Equipment

3.14.2.1 Federal

There are no federally designated roadways in the Project area.

3.14.2.2 State

Missouri Statewide Comprehensive Outdoor Recreation Plan

The Missouri Statewide Comprehensive Outdoor Recreation Plan (SCORP) includes inventories and assessments of current recreation resources (local, state, and federal) within the state (MDNR 2008). The Missouri SCORP is used as a reference by local community recreation planners, park

departments, and the MDNR Grants Management staff when considering grant applications for funding from the Land Water Conservation Fund, the Recreational Trails Program, and other outdoor recreation funding agencies and sources.

Figure 3.14-3 Residence on Riverbank with Views of Dredging Operations on the River

Wetlands also are identified as an important recreational feature, as they provide opportunities for wildlife viewing, bird watching, hiking, hunting, and education. Protecting, restoring, and creating new wetlands are stated to be a high priority for Missouri's recreational interests. Protection of fish and wildlife habitat also is listed as a high priority.

The Missouri SCORP identifies the Katy Trail and the Lewis and Clark Water Trail as trails of statewide importance. The 165-mile segment of the Katy Trail between St. Charles and Boonville is officially designated as part of the Lewis and Clark National Historic Trail and American Discovery Trail. The Katy Trail is also designated as a Millennium Legacy Trail. The Lewis and Clark Water Trail follows RM 0 to RM 554.4 of the Missouri River and is the longest river trail in the nation. The Missouri SCORP indicates that these important trails are or should be supported by local communities as well as state and federal trail funding agencies.

Katy Trail State Park

Katy Trail State Park is a state park administered by the MDNR. Title 10, Division 90, Chapter 1—Organization and Description establishes that:

> …The activities of the division consist of making the various state-owned facilities accessible to all segments of today's society including the youth, handicapped, senior citizens and the disadvantaged through a systematic program which will permit the division to acquire, protect, develop and interpret for the inspiration, use and enjoyment of the people of the state a well balanced system of areas of outstanding scenic, recreational and historic significance (Missouri Secretary of the State 2010).

3.14.2.3 Local

This section identifies counties in the Project area for which there were readily available policies regarding visual resources.

FOCUS – Kansas City, Missouri

FOCUS (Forging Our Comprehensive Urban Strategy) is Kansas City's comprehensive and strategic plan. The seven FOCUS component plans include a Preservation Plan, Northland Plan, and Physical Framework Plan.

Preservation Plan

The *Preservation Plan—A Plan for Meaningful Communities* has an action to "develop programs to protect significant abandoned and endangered historic properties" in part by "developing a land conservation program to protect historic, natural and scenic resources, including parks, open space, scenic views, trails, archaeological sites, and other landscape elements" (Kansas City 1997).

Northland Plan

The Northland Plan guides development of northern Kansas City. It states that "because of the area's long history of agricultural and urban use, only remnants of natural vegetation remain. Together with

steep slopes and floodplains, areas of natural vegetation in the Northland are largely concentrated along stream corridors. These corridors provide a host of environmental benefits, such as attenuation of flooding, water quality protection, habitat for wildlife, and scenic quality." (Kansas City 1998a)

The plan includes an initiative to "protect sensitive natural resources such as stream corridors, floodplains, woodlands, and steep slopes," that would, in turn, protect scenic resources (Kansas City 1998a). It also promotes development of the Kansas City Metropolitan Greenway System (Metro Green) along the Missouri River to link north and south Kansas City.

Physical Framework Plan

Under "Natural Systems and Historic Resources," the Physical Framework Plan states that "beyond simple objective measures of risks and costs, natural systems also can be seen as form-givers, through 'quality of life' and scenic attributes. In this way, natural features such as vistas, waterfronts, and woodlands attract development by adding value." It identifies historic resources, slope and topography, vegetation and habitat types, water resources and floodplains, and soils as the form-givers that have and do shape Kansas City (Kansas City 1998b).

St. Louis County Zoning Ordinance, Missouri

St. Louis County zoning includes the "Park and Scenic" (PS) Zoning District. Under the PS regulations, "land, owned by public agencies or in which public agencies have some lesser legal interest, which has recreational, scenic, and health value [is subject to PS regulations] and is established to preserve the community's cultural values by preserving this land in an essentially natural or native condition" (St. Louis County 2010).

St. Charles County Master Plan, Missouri

The Natural Resources section of the master plan states that the "Highway 94 corridor between U.S. Highway 40/61 and the Warren County line contains a unique set of scenic features. In a study of this area prepared in 2002, approximately 30 scenic vistas or view sheds were identified along this 21-mile section of highway." The master plan identifies a goal to "protect and manage natural resources to retain the benefits they provide by "[minimizing] the impacts of development encroaching on natural resource areas" (St. Charles County 2008).

City-Wide Master Plan of Wyandotte County/Kansas City, Kansas

The City-Wide Master Plan states that parks, open space, and trails "offer unspoiled views and interactions with wildlife" and recommends actions to:

- Enhance the Missouri and Kansas River corridors;
- Promote cluster development along the Missouri River Bluffs to preserve key view sheds, open space and trail connections;
- Develop portholes along the River Corridors to allow safe and convenient public access to the rivers;
- Protect the Missouri and Kansas Rivers, streams and creeks from encroaching development;
- Increase public access to and public ownership of stream corridors; [and]
- Protect, restore and create wetlands in riparian corridors to promote aquatic and wildlife breeding grounds, store floodwaters and provide aesthetic value." (Wyandotte County 2008) "

3.14.3 Concepts and Terminology

Identifying the visual conditions of a Project area involves three steps:

1. Identifying the visual resources of the landscape;
2. Assessing the character and quality of those resources relative to the overall regional visual character; and
3. Determining the importance of views of the visual resources to the people who view them.

The aesthetic value of an area is a measure of its visual character and quality, combined with the viewer response to the area (FHWA 1988). Visual quality can best be described as the overall impression that an individual viewer retains after driving through, walking through, or flying over an area (BLM 1980). Viewer response is a combination of viewer exposure and viewer sensitivity. Viewer exposure is a function of the number of viewers, number of views seen, distance of the viewers, and viewing duration. Viewer sensitivity relates to the extent of the public's concern for a particular viewshed. These terms and criteria are described in detail below.

3.14.3.1 Visual Character

Natural and artificial landscape features contribute to the visual character of an area or view. Visual character is influenced by geologic, hydrologic, botanical, wildlife, recreational, rural, and urban features and is intrinsically tied to land use. Urban features are those associated with landscape settlements and development, including roads, utilities, structures, earthworks, and the results of other human activities. The perception of visual character can vary significantly seasonally, and even hourly, as weather, light, shadow, and elements that compose the viewshed change. The basic components used to describe visual character for most visual assessments are the elements of form, line, color, and texture of the landscape features (USFS 1995, FHWA 1988). The appearance of the landscape is

described in terms of the dominance of each of these components. For the purpose of this analysis, aerial imagery and the interactive capabilities of Google Earth and Google Maps were used to evaluate the existing visual character the five river segments.

3.14.3.2 Visual Quality

Visual quality is evaluated using the well-established approach to visual analysis adopted by the Federal Highway Administration, using the concepts of vividness, intactness, and unity (FHWA 1988, Jones et al. 1975), which are described below.

- Vividness is the visual power or memorability of landscape components as they combine in striking and distinctive visual patterns.
- Intactness is the visual integrity of the natural and human-built landscape and its freedom from encroaching elements; this factor can be present in well-kept urban and rural landscapes and in natural settings.
- Unity is the visual coherence and compositional harmony of the landscape considered as a whole; it frequently attests to the careful design of individual components in the landscape.

Visual quality is evaluated based on the relative degree of vividness, intactness, and unity, as modified by its visual sensitivity. High-quality views are highly vivid and relatively intact, and exhibit a high degree of visual unity. Low-quality views lack vividness, are not visually intact, and possess a low degree of visual unity.

3.14.3.3 Visual Exposure and Sensitivity

Viewer exposure is based on the visibility of resources in the landscape, proximity of viewers to the visual resource, elevation of viewers relative to the visual resource, frequency and duration of views, number of viewers, and type and expectations of individuals and viewer groups.

To identify the importance of views of a resource, a viewshed can be broken into distance zones of foreground, middleground, and background. Generally, the closer a resource is to the viewer, the more dominant it is and the greater its importance to the viewer. Although distance zones in a viewshed may vary between different geographic regions or types of terrain, the standard foreground zone is 0.25–0.5 mile from the viewer, the middleground zone from the foreground zone is 3–5 miles from the viewer, and the background zone is from the middleground to infinity (USFS 1995).

The measure of the quality of a view is tempered by the overall sensitivity of the viewer. Visual sensitivity depends on the number and type of viewers, and the frequency and duration of views. Visual sensitivity also is modified by viewer activity, awareness, and visual expectations in relation to the number of viewers and viewing duration. For example, visual sensitivity is generally higher for views seen by people who are driving for pleasure; people engaging in recreational activities such as hiking, biking or camping; and homeowners. Sensitivity tends to be lower for views seen by people driving to and from work or as part of their work (USFS 1995, FHWA 1988, SCS 1978). Commuters and non-recreational travelers generally have fleeting views and tend to focus on commute traffic, not on the surrounding scenery; therefore, these viewers generally are considered to have low visual sensitivity. Residential viewers typically have extended viewing periods and are concerned about changes in the views from their homes; therefore, they generally are considered to have high visual sensitivity. Viewers using recreation trails and areas, scenic highways, and scenic overlooks are usually assessed as having high visual sensitivity.

Judgments of visual quality and viewer response must be based in a regional frame of reference (SCS 1978). The same landform or visual resource appearing in different geographic areas could have a different degree of visual quality and sensitivity in each setting. For example, a small hill may be a significant visual element on a flat landscape but have very little significance in mountainous terrain.

3.14.4 Sources of Information

Information used in the preparation of this section included:

- General plans;
- Google Earth and Google Maps; and
- Project area maps.

3.14.5 Viewer Groups and Viewer Responses

The primary viewer groups in the Project area are persons living or conducting business near dredging operations; travelers using the interstates, highways, and smaller local roads; and recreationists (boaters, fishermen, and swimmers using the Missouri River; trail users; bicyclists; and joggers). All viewer groups have direct views of the Project areas described in this document.

3.14.5.1 Residents

Suburban and rural residences are located directly adjacent to riverbanks or are separated from them by local streets, agricultural lands, industrial districts, or open land. Suburban residences are mostly oriented inward toward the developments; and only residents along the water's edge have a full view of the LOMR, including current dredging operations. Both suburban and rural residents are likely to have a high sense of ownership over their adjacent waterways, the open space that surrounds them, the recreational opportunities they provide, and their inherent scenic quality. Because of the sense of ownership and their extended viewing times of the river, residents would be highly sensitive to visual changes associated with the river.

3.14.5.2 Businesses

Viewers from industrial, commercial, government, and educational facilities have semi-permanent views of the LOMR from their respective facilities. Situated in different locations throughout the Project area, these facilities' views differ depending on the placement of the dredging operations and other activities on the river. Employees and users of these facilities are likely to be occupied with their work activities and tasks at hand, have intermittent visual access to the river, and would have moderate sensitivity to visual changes associated with the river.

3.14.5.3 Roadway Users

The vantages of roadway users differ based on the roadway they are traveling and the elevation of the roadway. The majority of views are limited to the foreground by suburban, commercial, and industrial development. However, if the vantage is elevated, as on bridges crossing the Missouri River and other local roadways along the river banks, the viewer has a greater chance of viewing the river, dredging operations, and other activities.

Travelers use roadways at varying speed. Normal highway and roadway speeds differ based on the traveler's familiarity with the route and roadway conditions (for example, presence or absence of rain or snow). Single views typically are of short duration, except on straighter stretches where views last slightly longer. Viewers who frequently travel these routes generally possess moderate visual sensitivity to their surroundings. The passing landscape becomes familiar to these viewers, and their attention typically is not focused on the passing views but on the roadway, roadway signs, and surrounding traffic. Viewers who travel local routes for their scenic quality generally possess a higher regard for the visual experience. Roadway users would have low sensitivity to visual changes

associated with the river because of the intermittent and sometimes limited visual access to the river combined with the short duration of views allowed by normal roadway speeds.

3.14.5.4 Recreationists

Recreational users view the Project area from parks, waterways, roadways, and trails. Recreational uses consist of boating and fishing, hunting, birding, walking, running, jogging, and bicycling in and around the river and along trails and local roads. Users of the waterways are likely to seek out natural areas within the corridor, such as sand and gravel bars and beaches, in addition to using the waterways as a resource. Waterway users have differing views based on their location in the landscape and are accustomed to variations in the level of industrial, commercial, suburban, and recreational activities occurring within the Project area. Viewer sensitivity is high among recreationists because they are more likely to regard the natural and built surroundings as a holistic visual experience.

3.14.6 Existing Visual Conditions

The Project area is located between the riverbanks of the Missouri River, starting in the east at the confluence of the Missouri River with the Mississippi River (RM 0), approximately at St. Louis, Missouri, and extending west to approximately Rulo, Nebraska (RM 498). Agriculture located along the banks of the Missouri River is the predominant land use type in the Project area. However, many cities and towns are near the Missouri River; the largest is Kansas City, with a population exceeding 400,000. A patchwork of fields separates the urban center of Kansas City, Missouri, and its suburban and rural communities. Overall, a mix of developed and natural landscapes characterizes the areas adjacent to the river.

The alternatives to the Proposed Action may include impacts outside the floodplain (for example, if upland mining becomes a source of sand and gravel). This would affect a broader viewer group and may include more recreationists, motorists, and residents than those limited to the area in and around the Missouri River.

The Project has been broken into five segments between the riverbanks of the Missouri River, described below. Using aerial imagery and the interactive capabilities of Google Earth and Google Maps, the five river segments were evaluated for their existing visual conditions. Google Earth was used to determine places that accommodate recreationists, such as state and local parks.
Figure 3.11-1 (Sheets 1 through 5) shows land cover types along the river that play a large role in

determining the visual conditions of the Project area. There are public recreation areas and river access areas (public boat ramp facilities) in all of the river segments. Locations of these public access boat ramps and other recreational land use locations are described in detail in Section 3.11. Tables 3.14-1 through 3.14-5 show major river access points (boat ramps) within the Project area but do not serve as a comprehensive list. Figure 3.11-2 (Sheets 1 through 5) shows recreational facilities and bridges that offer views of the Project area. In addition to public boat access points, many private access points are located in the river segments.

3.14.6.1 Visual Condition of St. Joseph Segment

The St. Joseph segment extends along the Missouri River from RM 391 to RM 498. Table 3.14-1 summarizes the towns and cities, bridges, recreation facilities, and dredging operations in the St. Joseph segment with views of the river. Figures 3.11-1 (Sheet 1) and 3.11-2 (Sheet 1) in Land Use and Recreation show the land covers and recreational features, respectively, that affect this segment. A rural visual character comprised of agricultural fields in the floodplain on both banks of the Missouri River dominates views in the segment. A patchwork of cultivated fields reach toward the water's edge but are separated from the river by bands of riparian vegetation. These bands of vegetation vary from thin and sparsely vegetated to wide and densely vegetated, and frequently obstruct views of and from the river. Local roadways sometimes skirt close to the river's edge; however, riparian vegetation often blocks views of the river. Where roadway travelers do have views of the river, they are often brief because they are offered through breaks in vegetation and roadways typically parallel the river for only short intervals. In rural areas of the segment, few residences are located close to the river's edge. However, rural lands transition from agricultural fields to the suburban and urban land uses of St. Joseph, Atchison, and Leavenworth that have developed the river's edge.

Land uses along the river in these towns and cities include industrial, residential, and open space land uses. Industrial uses along the river are comprised of large warehouse facilities and infrastructure with little vegetation; industrial uses offer few public views of the river. Views of the river can be seen by those working at industrial facilities located at the river's edge. Residential areas along the river tend be large, stately homes that are located higher up on the river's banks, with elevated views out over the river and its lush riparian corridor. The riparian corridor can limit views of the river, dependent on location in the landscape. Open spaces such as parks and conservation areas often provide the most direct and unobstructed public views of the river, along with providing boating access points to the river. The river corridor creates a noticeable contrast to the surrounding area and is used and enjoyed for its vegetation and wildlife, recreational opportunities, and scenic quality. Views of the river have vivid

seasonal contrast in spring and summer when vegetation and agricultural fields are green and in leaf, and higher water flows hide the river bed—compared to fall and winter when vegetation browns and the leaves have fallen, and lower waters expose sand and gravel bars, or when snow blankets the landscape in white. Views from the river to surrounding areas often are limited to the foreground and bluffs in the background by bends in the river, the riverbanks, levees, vegetated riparian corridors, and development. However, in rural locations where the terrain is flatter and riparian vegetation is sparse, limited views of agricultural fields may be possible if a levee is not present.

In addition to open space along the river, bridge crossings often provide scenic views of the Missouri River as roadway travelers cross them. These bridges do not support pedestrian and bicycle traffic in this segment, as identified in Table 3.14-1. Views from bridges may extend to the middleground and background; but a notable part of the viewshed consists of the wide, meandering river corridor that is framed by lush riparian vegetation. Development along the river bank may also be seen when crossing bridges, such as from the Highway 59 Bridge. Most of the roadways in rural areas are set back from and do not offer views of the river. Where roadways travel along the river, scenic views of the river corridor typically are present. Some of these views may be obstructed by roadside or riparian vegetation, crops, or other features. In developed areas, roads pass by the river with open views of the waterway, or these views may be partially or fully obstructed by infrastructure and development.

Holliday Sand & Gravel Company has a dredging operation in this segment (see Table 3.14-1 and Figures 3.11-1 [Sheet 1] and 3.11-2 [Sheet 1] in Land Use and Recreation). Dredging operations include barges with heavy equipment on the river's water surface and onshore stockpile operations that use heavy equipment and have related infrastructure.

The Holliday Sand & Gravel Company onshore facility in St. Joseph is located in an established industrial area on the river bank with agricultural land beyond a thickly wooded corridor and levee on the opposite bank. The industrial, open space, and wooded corridor areas limit views of operation from the banks below the U.S. Highway 36 Bridge. However, motorists traveling over the U.S. Highway 36 Bridge are able to see the onshore facility and some of the dredging operations. In addition, for approximately 6,000 feet immediately upstream from the C.R.I. & P. Railroad Bridge, Interstate 229 (I-229) runs along the east bank of the river providing motorists unobstructed view of the barges and dredging operations. Going north, I-229 provides limited views of the river as it moves away from the river bank and follows the top of the heavily forested bluff for approximately 3 miles before moving farther away from the river. Below the bluff is a relatively narrow strip of generally open floodplain with some agricultural land, a nature center, casino, public ball fields, public waterworks, and a public and

commercial boat ramp. The west bank is primarily open agricultural land. Recreationists on the river have an unobstructed view of barges and dredging operations.

Table 3.14-1 Notable Locations with Views of the Missouri River in the St. Joseph Segment

	Name	River Mile (RM)
Towns and cities	Leavenworth, Kansas	RM 396
	Atchison, Kansas	RM 422
	Elwood, Kansas	RM 448
	St. Joseph, Missouri	RM 448
Bridges	Centennial Bridge (State Route 92) [N]	RM 397.5
	Amelia Earhart Bridge (U.S. Highway 59) [N]	RM 422.5
	U.S. Highway 36 Bridge [N]	RM 447.8
	U.S. Highway 159 Bridge [N]	RM 498
Parks and trails	Veterans Administration Park	RM 394 – RM 395.4
	Landing Park	RM 397
	Riverfront Park	RM 397.5 – RM 399.3
	Weston Bend State Park and Weston Bluffs Trail	RM 402 – RM 403
	Jackson Park	RM 422
	Independence Park	RM 422.9
	Huston Wyeth Park	RM 450
	Remington Nature Center of St. Joseph	RM 450.4
	River Bluffs Park	RM 453.2
Conservation areas (CAs), wildlife areas (WAs), and USACE mitigation sites[a]	Benedictine Bottoms Mitigation Site	RM 424 – RM 428
	Arthur Dupree Memorial CA	RM 449.8 – RM 451.6
	Sunbridge Hills CA	RM 452 – RM 453.2
	Logan Memorial WA	RM 453.2
	Worthwine Island CA	RM 456.2 – RM 459.9
	Monkey Mountain CA	RM 464 – RM 466
	Wolf Creek Bend CA	RM 477 – RM 482
	Bob Brown CA	RM 483 – RM 486

Table 3.14-1 Notable Locations with Views of the Missouri River in the St. Joseph Segment

	Name	River Mile (RM)
River access (RA)	Riverfront Park	RM 397.5
	Independence Park	RM 422.9
	Jentell Brees RA	RM 437.2
	Wathena RA	RM 441
	St. Joseph Yacht Club	RM 444
	Flathead Fishing Club RA	RM 444.7
	Elwood RA	RM 447.8
	Show Boat Landing RA	RM 449
	French Bottom RA	RM 450.4
	Sunset Grill (St. Joseph) RA	RM 451.9
	Nodaway Island RA	RM 462.1
	Brown RA	RM 462.9
	Charles Bend RA	RM 468.4
	Payne Landing RA	RM 477
	Iowa Point Bend RA	RM 485.9
	White Cloud	RM 488
	Rulo Park	RM 498
Existing dredging operations	Holliday Sand & Gravel Company–St. Joseph	RM 447.5

Notes:

[P] = Pedestrian and [B] = Bicycle traffic on bridges. [N] = No or [U] = Undeterminable pedestrian or bicycle traffic on bridges.

[a] Locations provided by the U.S. Army Corps of Engineers (USACE).

Sources: Google Earth 2009, 2010; USACE et al. 2003.

Views of and from the river in the St. Joseph segment are moderately vivid. While views of waterways are often highly valued, the visual character of the river corridor in this segment is typical of upstream and downstream portions of the river. The intactness and unity of the viewshed is also moderate because transitions between rural and suburban and urban landscapes are gradual, not abrupt. In addition, each of the rural and developed areas within the segment has the visual cohesion typical of such land uses.

A wide variety of viewer groups in the St. Joseph segment would be affected by proposed dredging operations. Motorists traveling along state and county roads along the river and over bridge crossings are exposed to dredging activities in the Project area. Residents and recreationists, including bicyclists,

pedestrians, and boaters, can view dredging operations along the river. Those employed at businesses and industrial districts along the riverfront of this segment would be exposed to visual changes along the river.

3.14.6.2 Visual Condition of Kansas City Segment

The Kansas City segment extends along the Missouri River from RM 357 through RM 391. Table 3.14-2 summarizes the towns and cities, bridges, recreation facilities, and dredging operations with views of the river. Figures 3.11-1 (Sheet 2) and 3.11-2 (Sheet 2), respectively, in Land Use and Recreation show land cover and recreational features that affect this segment. Kansas City, Kansas, Kansas City, Missouri, and North Kansas City, Missouri, and their outskirts dominate this segment. Land uses on the floodplain along the river in the urban areas are largely industrial, commercial, and open space, and are comprised of large warehouse and commercial facilities and parks. Only narrow bands of riparian vegetation remain along these river reaches.

Views of the river can be seen by those working at industrial facilities located at the river's edge. Industrial and commercial facilities and infrastructure offer few public views of the river. No major residential areas on the flood plain flank the river in these urban areas. Residential areas generally begin at the edge of the floodplain. Those residential areas may have middle- or background views of the river if located on the bluff, or foreground views if the river bends close to the bluff. Open spaces such as parks often provide the most direct and unobstructed public views of the river, along with providing boating access points to the river (see Figure 3.14-4).

Segments of the river east and west of Kansas City are agricultural lands that reach toward the water's edge but are separated from the river by bands of riparian vegetation. The patchwork of agricultural fields creates a rural visual character that contrasts with the urban nature of the rest of the segment. Within the rural areas, bands of riparian vegetation along the river vary from thin and sparsely vegetated to wide and densely vegetated, and frequently obstruct views of and from the river. Local roadways sometimes skirt close to the river's edge; however, riparian vegetation often precludes views of the river. Where roadway travelers do have views of the river, they are often brief because they are offered through breaks in vegetation and roadways typically parallel the river for only short intervals. In rural areas of the segment, few residences are located close to the river's edge.

Table 3.14-2 Notable Locations with Views of the Missouri River in the Kansas City Segment

	Name	River Mile (RM)
Towns and cities	Randolph, Missouri	RM 360
	Kansas City, Missouri	RM 365
	North Kansas City, Missouri	RM 365
	Kansas City, Kansas	RM 368
	Riverside, Missouri	RM 373
	Parkville, Missouri	RM 377.5
Bridges	Interstate 435 Bridge [N]	RM 360.3
	Chouteau Bridge (State Route 269) [N]	RM 362.3
	Paseo Bridge (Interstate 29/35) [N]	RM 364.7
	Heart of America Bridge (U.S. Highway 71/State Highway 9) [N]	RM 365.5
	Broadway Bridge (U.S. Highway 169) [N]	RM 366.2
	Fairfax Bridge (U.S. Highway 69) [N]	RM 372.5
	Interstate 635 Bridge [N]	RM 374.1
	Interstate 435 Bridge [N]	RM 383.5
Parks and trails	Riverfront Park	RM 362.3 – RM 364
	Richard L. Berkley Riverfront Park	RM 365
	Holland Park	RM 366.3 – RM 369.7
	Kaw Point Riverfront Park	RM 367.5
	EH Young Riverfront Park	RM 372
	English Landing Park	RM 377
	Missouri Riverfront Trail (Platte County Parks & Recreation 2010)	RM 372 – RM 376
Conservation areas (CAs), Wildlife areas (WAs), and USACE mitigation sites	Liberty Bend CA	RM 351
River access (RA)	Riverfront Park RA	RM 363
	Kaw Point Riverfront Park RA	RM 367.5
	English Landing Park RA	RM 377.4
	Leavenworth Boat Club	RM 396.7
Existing dredging operations	Holliday Sand & Gravel Company–Randolph	RM 360
	Holliday Sand & Gravel Company–Riverside	RM 372

Notes:

[P] = Pedestrian and [B] = Bicycle traffic on bridges. [N] = No or [U] = Undeterminable pedestrian or bicycle traffic on bridges.

Sources: Google Earth 2009, 2010; USACE et al. 2003.

Figure 3.14-4 View of a River Access Point from the Missouri River

In addition to open spaces along the river, bridge crossings often provide scenic views of the Missouri River as roadway travelers cross them (see Figure 3.14-5). These bridges do not support pedestrian and bicycle traffic, as identified in Table 3.14-2. Views from bridges may extend to the middleground, with views to the background limited by development. However, a notable part of the viewshed consists of the wide, meandering river corridor that is framed by urban development. Views from bridges may extend to the background, where development is limited and bends in the river allow such views. Roadways in developed areas often pass by the river with open views of the waterway, or these views may be partially or fully obstructed by infrastructure and development. Roadways in rural areas are often set back from and do not offer views of the river. Where roadways travel along the river, scenic views of the river corridor typically are present. However, some of these views may be obstructed by roadside or riparian vegetation, crops, or other features.

While mostly developed in this segment, the river corridor creates a noticeable contrast to the surrounding area and is used and enjoyed for its recreational opportunities, scenic quality, vegetation, and wildlife. Views of the river have vivid seasonal contrast in spring and summer when vegetation and agricultural fields are green and in leaf, and higher water flows hide the river bed—compared to fall and winter when vegetation browns and the leaves have fallen, and lower waters expose sand and gravel bars or when snow blankets the landscape in white. Views from the river to surrounding areas are often limited to the foreground by bends in the river, development, the riverbanks, and vegetated riparian corridor.

Figure 3.14-5 Views of the Fairfax Bridge from West of RM 372

Holliday Sand & Gravel Company has two existing dredging operations in this segment, and The Master's Dredging Company has proposed one (see Table 3.14-2 and Figures 3.11-1 [Sheet 2] and

3.11-2 [Sheet 2] in Land Use and Recreation). Dredging operations include barges with heavy equipment on the river's water surface and onshore stockpile operations that also use heavy equipment and have related infrastructure (see Figure 3.14-6). Onshore facilities have converted areas that would typically be vegetated to large, unvegetated piles of sand and sediment along the river's edge. These features contrast with the more natural areas surrounding the facilities and detract from scenic views of the river corridor. In addition, dredge facilities create noise and movement that draw viewers' attention toward these areas, making them more noticeable to viewer groups.

Figure 3.14-6 Views of Holliday's Riverside Dredging Operation at RM 372

Holliday Sand & Gravel Company's dredging operations are located in more developed areas of the segment. The Holliday Sand & Gravel Company onshore sites are just outside of the urbanized reaches of Kansas City, Missouri. Light industrial land uses, which separate dredging operations from

nearby residential areas, surround these onshore facilities. The opposite shore is used for limited industrial uses that are set back from the water's edge. The Holliday Sand & Gravel Company–Riverside onshore facility is also located directly east of and bordering the EH Young Riverfront Park; the highly visible views of dredging operations detract from the riverfront viewshed.

The vividness, intactness, and unity of views of and from the river in the segment are moderate to moderately low. While views of waterways are often highly valued, the visual character of the river corridor in this segment is substantially developed with industrial and commercial land uses. Agricultural lands with riparian corridors and open spaces in the urban areas create attractive riverside vantages, providing smaller areas with higher visual quality. However, the predominance of intense development and distinct change from developed to more rural lands visually dissects this segment. Vegetated river banks sometimes act to soften the scale and dominance of industrial areas located adjacent to the river in certain locations.

A wide variety of viewer groups in the Kansas City segment would be affected by proposed dredging operations. Motorists traveling along state and county roads along the river and over bridge crossings are exposed to dredging activities in the Project area. Residents and recreationists, including bicyclists, pedestrians, and boaters, can view dredging operations along the river. Those employed at businesses and industrial districts along the riverfront of this segment would be exposed to visual changes along the river.

3.14.6.3 Visual Condition of Waverly Segment

The Waverly segment extends along the Missouri River from RM 250 through RM 357. Table 3.14-3 summarizes the towns and cities, bridges, recreation facilities, and dredging operations with views of the river. Figures 3.11-1 (Sheet 3) and 3.11-2 (Sheet 3) in Land Use and Recreation show the land covers and recreational features, respectively, that affect this segment.

The land use patterns and visual character along this segment remain consistent throughout the entire extent—agriculture, interspersed with small, residential areas. The river slowly winds through primarily rural and agricultural land uses in the Waverly segment. Quaint rural communities are sporadically interspersed among the predominantly agricultural landscape. Gently rolling terrain transports the viewer throughout this pastoral landscape, where local roadways deliver them to the next agriculture-based community (Google Maps 2009). The nearly continuous band of lush riparian vegetation provides an attractive river edge and acts as a beneficial buffer between viewer groups and potential

dredging operations. Scenic views of the river are accessible to those traveling or working along the river.

Table 3.14-3 Notable Locations with Views of the Missouri River in the Waverly Segment

	Name	River Mile (RM)
Towns and cities	Miami, Missouri	RM 263
	Waverly, Missouri	RM 293.5
	Lexington, Missouri	RM 317
	Wellington	RM 323
	Napoleon	RM 329
	Sibley	RM 337
	River Bend, Missouri	RM 352.5
Bridges	Miami Bridge (State Route 41) [N]	RM 262.6
	Waverly Bridge (U.S. Highway 65) [N]	RM 293.2
	Lexington Bridge (State Route 13) [N]	RM 314.9
	Liberty Bend Bridge (State Route 291) [N]	RM 352.7
Parks and trails	Snake Bluff Recreation Park	RM 262.8
	Van Meter State Park	RM 265
	Port of Waverly Park	RM 293.5
	Lexington Riverfront Park	RM 316.4
	Fort Osage County Park	RM 337
	Mouth of the Little Blue Park	RM 338 – RM 339
	La Benite Park	RM 350.6 – RM 353
Conservation areas (CAs), wildlife areas (WAs), and USACE mitigation sites	Grand Pass CA	RM 266 – RM 272
	Cranberry Bend (USFWS)	RM 280.5 – RM 281.5 and RM 291.5
	Baltimore Bend CA	RM 292 – RM 300
	Jackass Bend (USFWS)	RM 337
	Cooley Lake CA	RM 340 – RM 342
River access (RA)	Miami/Snake Bluff Recreation Park RA	RM 262.8
	Waverly RA	RM 293.2
	Lexington Riverfront Park RA	RM 316.4
	USACE RA	RM 328.6
	Fort Osage County Park RA	RM 337.2
	Cooley Lake RA	RM 341.2
	Pigg's Landing	3 miles up Fishing River
	La Benite Park	RM 352.7

Table 3.14-3 Notable Locations with Views of the Missouri River in the Waverly Segment

	Name	River Mile (RM)
Existing dredging operations	Capital Sand Company, Kansas City–Carrollton	RM 287
	Capital Sand Company, Kansas City–Lexington	RM 317

Notes:

B = Bicycle traffic on bridges.

N = No pedestrian or bicycle traffic on bridges.

P=Pedestrian traffic on bridges.

U = Undeterminable pedestrian or bicycle traffic on bridges.

USFWS = U.S. Fish and Wildlife Service.

Sources: Google Earth 2009, 2010; USACE et al. 2003.

Recreational uses in this segment include those associated with the river. The river corridor creates a noticeable contrast to the surrounding area and is used and enjoyed for its vegetation and wildlife, recreational opportunities, and high visual quality. Views of the river have vivid seasonal contrast in spring and summer when vegetation and agricultural fields are green and in leaf, and higher water flows hide the river bed—compared to fall and winter when vegetation browns and the leaves have fallen, and lower waters expose sand and gravel bars, or when snow blankets the landscape in white. Most views of the river are limited to the foreground by bends in the river, vegetation, and development where it occurs. Bridge crossings often provide scenic views of the Missouri River as roadway travelers cross them. These bridges do not support pedestrian and bicycle traffic, as identified in Table 3.14-3. Views from bridges may extend to the middleground and background; but a notable part of the viewshed consists of the wide, meandering river corridor framed by lush riparian vegetation. Most of the roadways in rural areas are set back from and do not offer views of the river. Where roadways travel along the river, scenic views of the river corridor typically are present. Some of these views may be obstructed by roadside or riparian vegetation, crops, or other features. In developed areas, roads often pass by the river with open views of the waterway that may be partially or fully obstructed by infrastructure and development.

Capital Sand Company has two dredging operations in this segment (see Table 3.14-3 and Figures 3.11-1 [Sheet 3] and 3.11-2 [Sheet 3] in Land Use and Recreation). Dredging operations include barges with heavy equipment on the river's water surface and onshore stockpile operations that also use heavy equipment and have related infrastructure. Onshore facilities have converted areas that would typically be vegetated to large, unvegetated piles of sand and sediment along the river's edge. These features contrast with the more natural areas surrounding the facilities and detract from scenic

views of the river corridor. Both dredging sites are located in rural, minimally developed areas, reducing the amount of viewer groups affected.

Both Capital Sand Company operations are surrounded by agricultural land uses buffered from the river by thick bands of riparian vegetation that block most views of dredging operations from land. The facility across from Lexington is located less than 1 mile southwest of Lexington Riverfront Park, which supports river access. Views of dredging operations are likely visible from the park and detract from the riverfront viewshed. Motorists with views of dredging operations are limited to those using local roads next to the dredging operations. Recreationists utilizing the open waters of the Missouri River have direct views of both operations.

Views of and from the river in this segment are moderately vivid. While views of waterways are often highly valued, the visual character of the river corridor in this segment is typical of upstream and downstream portions of the river. The intactness and unity of the viewshed is also moderate because there is a gradual change into riverside, agricultural communities and a seamless transition back into expansive, fertile agricultural and riparian landscapes along the river. In addition, each agricultural and developed portion in the segment has the visual cohesion typical of such land uses.

Viewer groups in the Waverly segment that would be affected by proposed dredging operations and exposed to visual changes along the river include motorists traveling along state and county roads along the river and over bridge crossings, residents and recreationists with views of the river, and employees of businesses along this segment's riverfront.

3.14.6.4 Visual Condition of Jefferson City Segment

The Jefferson City segment extends along the Missouri River from RM 130 through RM 250. Table 3.14-4 summarizes the towns and cities, bridges, recreation facilities, and dredging operations with views of the river. Figures 3.11-1 (Sheet 4) and 3.11-2 (Sheet 4) in Land Use and Recreation show the land covers and recreational features, respectively, in this segment. Similar to the Waverly segment, the river slowly winds through the Jefferson City segment primarily through rural and agricultural land uses. Quaint rural communities are sporadically interspersed among the predominantly agricultural landscape. Gently rolling terrain transports the viewer throughout this pastoral landscape, where local roadways deliver them to the next agriculture-based community (Google Maps 2009). The nearly continuous band of lush riparian vegetation provides an attractive river edge and acts as a beneficial buffer between viewer groups and potential dredging operations. Scenic views of the river are accessible to those traveling or working along the river.

Table 3.14-4 Notable Locations with Views of the Missouri River in the Jefferson City Segment

	Name	River Mile (RM)
Towns and cities	Jefferson City, Missouri	RM 144
	Booneville, Missouri	RM 196
	Rocheport, Missouri	RM 186
	Glasgow, Missouri	RM 226.5
Bridges	Jefferson City Bridge (U.S. Highway 54) [N]	RM 145
	Rocheport Bridge (Interstate 70) [N]	RM 185.1
	Boonslick Bridge (State Route 5 and 87/U.S. Highway 40) [P/B]	RM 196.6
	Missouri-Kansas-Texas Bridge (Katy Trail) [P/B]	RM 197
	Glasgow Bridge (State Route 240) [N]	RM 226.3
Parks and trails	Katy Trail	RM 149, RM 160.5 – RM 162, RM 168.5 – RM 170.5, RM 180 – RM 186, RM 197.1
	Ellis-Porter Park	RM 141.5
	Harley Park	RM 197.4
	Arrow Rock State Park	RM 210
	Stump Island Park	RM 226
Conservation areas (CAs), wildlife areas (WAs), and USACE mitigation sites	Smokey Waters CA	RM 130.3 – RM 135.8
	Marion Bottoms CA	RM 158 – RM 164
	Plowboy Bend CA	RM 166 – RM 173
	Eagle Bluffs CA	RM 170.6 – RM 177.3
	Overton Bottoms CA	RM 178 – RM 185.1
	Rocheport Cave CA	RM 183
	Diana Bend CA	RM 186.6 – RM 190.2
	Franklin Island CA	RM 192 – RM 195.4
	Jameson Island CA	RM 210 – RM 215
	Lisbon Bottoms CA	RM 213.5 – RM 219
River access (RA)	Noren RA	RM 144
	Marion RA	RM 158
	Hartsburg RA	RM 159.8
	Easely RA	RM 169.2
	Cooper’s Landing RA	RM 170.3
	Taylor’s Landing	RM 185.2
	Franklin Island	RM 195.1
	Rooster’s Marina	RM 226.4
	Dalton Bottoms RA	RM 239

Table 3.14-4 Notable Locations with Views of the Missouri River in the Jefferson City Segment

	Name	River Mile (RM)
Existing dredging operations	Capital Sand, Kansas City-Jefferson City	RM 143.5
	Hermann Sand–Jefferson City	RM 146.5
	Capital Sand, Kansas City–Rocheport	RM 186
	Capital Sand, Kansas City–Boonville	RM 196.5
	Capital Sand, Kansas City–Glasgow	RM 226.5

Notes:

B = Bicycle traffic on bridges.

N = No pedestrian or bicycle traffic on bridges.

P=Pedestrian traffic on bridges.

U = Undeterminable pedestrian or bicycle traffic on bridges.

Sources: Google Earth 2009, 2010; USACE et al. 2003.

Known for its scenic views, the Katy Trail is a 225-mile bike path stretching across most of the state of Missouri. This trail was once the Missouri-Kansas-Texas rail line and now serves as a historical and recreational corridor accessible to the public year-round (MDNR 2009). The trail travels along the river and winds from its edge to within 2 miles of the river. Views from the trail can include expansive views of the river, lush vegetation lining the river and trail, agricultural fields, parks, towns and cities, and other points of interest that recreationists pass by on the trail. Views of the river are present, at various points, where the trail travels along the bank; but the majority of the trail does not have views of the river because of its distance from the river and vegetation or infrastructure that prevents such views.

Similar to the St. Charles segment, recreational uses in this segment include those associated with the river. The river corridor creates a noticeable contrast to the surrounding area and is used and enjoyed for its vegetation and wildlife, recreational opportunities, and high visual quality. Views of the river have vivid seasonal contrast in spring and summer when vegetation and agricultural fields are green and in leaf, and higher water flows hide the river bed—compared to fall and winter when vegetation browns and the leaves have fallen, and lower waters expose sand and gravel bars, or when snow blankets the landscape in white. Most views of the river are limited to the foreground by bends in the river, vegetation, and development where it occurs. Bridge crossings often provide scenic views of the Missouri River as roadway travelers cross them. The Boonslick Bridge in Booneville also supports pedestrian and bicycle traffic, as identified in Table 3.14-2. Views from bridges may extend to the middleground and background; but a notable part of the viewshed consists of the wide, meandering river corridor that is framed by lush riparian vegetation. Most of the roadways in this area are set back from and do not offer views of the river. Where roadways travel along the river, scenic views of the

river corridor typically are present. Some of these views may be obstructed by roadside or riparian vegetation, crops, or other features.

Hermann Sand & Gravel and Capital Sand Company have dredging operations in this segment (see Table 3.14-4 and Figures 3.11-1 [Sheet 4] and 3.11-2 [Sheet 4] in Land Use and Recreation). Dredging operations include barges with heavy equipment on the river's water surface and onshore stockpile operations that also use heavy equipment and have related infrastructure. Onshore facilities have converted areas that typically would be vegetated to large, unvegetated piles of sand and sediment along the river's edge. These features contrast with the more natural areas surrounding the facilities and detract from scenic views of the river corridor. In addition, dredge facilities create noise and movement that draw viewers' attention toward these areas, making them more noticeable to viewer groups.

Dredging operations in this segment are located adjacent to residential, agricultural, open space, and industrial areas located along the river bank. Views of the barges and dredging operations are frequently obscured by riparian vegetation along the rivers' edge. Motorists traveling across bridges and on local roads near the dredging operations would have more direct views of the barges and other dredging operations. Recreationists utilizing the open waters of the Missouri River have direct views of all operations. The Capital Sand Company–Jefferson City operation is located across the river from Jefferson City and the state capital building. This operation is highly visible to Jefferson City residents, businesses, recreationists, and roadway motorists near the river's edge in this location, and from the U.S. Highway 54 Bridge. The Capital Sand Company–Rocheport facility is located within 800 feet of the Katy Trail, but the facility and trail are both surrounded by dense vegetation that does not allow views of the facility from the trail. The Capital Sand Company–Glasgow facility is also located directly south of and bordering Stump Island Park, but the facility is separated from the park by a thick vegetative border. A river access point in the park allows views of dredging operations on the river and riverbank that detract from the riverfront viewshed. Views of this operation are also offered via the State Route 240 Bridge.

Views of and from the river in this segment are moderately vivid. While views of waterways are often highly valued, the visual character of the river corridor in this segment is typical of upstream and downstream portions of the river. The intactness and unity of the viewshed is also moderate because there is a gradual change into riverside, agricultural communities and a seamless transition back into expansive, fertile agricultural and riparian landscapes along the river. In addition, each of the agricultural and developed portions in the segment has the visual cohesion typical of such land uses.

Viewer groups within the Jefferson City Segment that would be affected by proposed dredging operations and exposed to visual changes along the river include motorists traveling along state and county roads along the river and over bridge crossings, residents and recreationists with views of the river, and employees of businesses and government agencies along this segment's riverfront.

3.14.6.5 Visual Condition of St. Charles Segment

The St. Charles segment extends along the Missouri River from RM 0, at its confluence with the Mississippi River, through RM 130. Table 3.14-5 summarizes the towns and cities, bridges, recreation facilities, and dredging operations with views of the river. Figures 3.11-1 (Sheet 5) and 3.11-2 (Sheet 5) in the Land Use and Recreation section show the land covers and recreational features, respectively, that affect this segment. The St. Charles segment begins in the silted floodplains located at the confluence of the Missouri and Mississippi Rivers. The convergence of the Missouri River with the Mississippi River, to the east, is visually important to this segment and the Project in that it provides a physical feature that acts as a visual limit to the Project area. The beginning of this river segment is characterized by scattered residential, commercial, industrial, and open space land uses that are often separated from the river by a band of agriculture located on the river's floodplain. The more developed portions of this segment of the Missouri River give way to a pastoral landscape with expansive agricultural land uses on the floodplains that are dotted with rural communities and small towns and cities. Being near the confluence of two rivers, the land in this portion of the segment has been shaped by the Missouri River overtopping its banks and flowing over land during flood events. This has left behind remnant oxbow lake and flow pattern scars, but these are not readily apparent from ground level views, especially when row crops are growing and cover the landscape. This seamless ebb and flow between fertile agricultural fields and rural communities continues on throughout the extent of the St. Charles segment.

The Katy Trail also travels along portions of this segment. Similar to the Jefferson City segment, the trail travels along the river and winds from its edge to within 2 miles of the river. Views from the trail can include expansive views of the river, lush vegetation lining the river and trail, agricultural fields, parks, towns and cities, and other points of interest that recreationists pass by on the trail. A large portion of the trail travels along the riverbank in this segment, offering views of the river. The remainder of the trail does not have views of the river because of its distance from the river and vegetation or infrastructure that prevents such views. The river corridor creates a noticeable contrast to the surrounding area and is used and enjoyed for its vegetation and wildlife, recreational opportunities, and high scenic quality. Most views on the river are limited to the foreground by bends in the river,

vegetation, and development where it occurs. Views of the river have vivid seasonal contrast in spring and summer when vegetation and agricultural fields are green and in leaf, and higher water flows hide the river bed–compared to fall and winter when vegetation browns and the leaves have fallen, and lower waters expose sand and gravel bars, or when snow blankets the landscape in white.

Table 3.14-5 Notable Locations with Views of the Missouri River in the St. Charles Segment

	Name	River Mile (RM)
Towns and cities	St. Charles, Kansas	RM 28
	Chesterfield, Missouri	RM 39
	Weldon Spring, Kansas	RM 44
	Washington, Missouri	RM 67.5
	New Haven, Missouri	RM 81.5
	Hermann, Missouri	RM 98
	Gasconade, Kansas	RM 105
	Chamois, Kansas	RM 118
	Mokane, Missouri	RM 123
Bridges	Lewis Bridge (U.S. Highway67/367) [N]	RM 8
	Discovery Bridge (State Route 370) [N]	RM 27
	Interstate 70 [N]	RM 29.5
	Veterans Memorial Bridge (State Route 364) [P/B]	RM 32.7
	Daniel Boone Bridge (Interstate 64) [N]	RM 44
	Washington Bridge (State Route 47) [N]	RM 67.5
	Hermann Bridge (State Route 19) [P/B]	RM 97.9
Parks and trails	Edward and Pate Jones Confluence Point State Park	RM 0.5-2
	Fort Bellefontaine County Park	RM 6.7
	Sioux Passage County Park	RM 10.4
	Sunset Park	RM 19.5
	St. Stanislaus County Park	RM 22
	Ed Bales Memorial Park	RM 26.7
	Frontier Park	RM 28.9
	Hermann Riverfront Park	RM 97.5
	Gasconade Park	RM 104.5
	Katy Trail	RM 27 – RM 33.5, RM 42 – RM 48, RM 55.5 – RM 56.5, RM 84.5 – RM 90.5, RM 109.3 – RM 115

Table 3.14-5 Notable Locations with Views of the Missouri River in the St. Charles Segment

	Name	River Mile (RM)
Conservation areas (CAs), wildlife areas (WAs), and USACE mitigation sites	Colombia Bottom CA	RM 0 – RM 5
	Pelican Island Natural Area	RM 10.5 – RM 16
	St. Stanislaus CA	RM 21 – RM 23.5
	Bangert Memorial WA	RM 30
	Weldon Springs CA	RM 44 – RM 49.4, RM 52 – RM 55
	Howell Island CA	RM 44.7 – RM 49.7
	Tate Island CA	RM 110.3 – RM 113.3
	Saint Aubert Island CA	RM 120 – RM 125
River access (RA)	Columbia Bottom RA	RM 3.5
	Sioux Passage County Park RA	RM 10.4
	Pelican Island RA	RM 10.3
	Blanchette Landing RA	RM 27.5
	Frontier Park RA	RM 28.9
	Washington City RA	RM 68.3
	Weldon Spring RA	RM 48.5
	New Haven RA	RM 81.4
	Hermann Riverfront Park RA/Olympic Marine	RM 97.5
	Gasconade Park RA	RM 104.5
	Chamois RA	RM 117.8
	Mokane RA	RM 124.5
Existing dredging operations	Limited Leasing–Fort Belle	RM 8
	J.T.R.–Riverview	RM 16.5
	Limited Leasing–Bridgeton	RM 28
	J.T.R.–St. Charles	RM 31
	Limited Leasing–Chesterfield	RM 44
	Capital Sand, Kansas City–Washington	RM 65.5
	Hermann Sand–Hermann	RM 96.8

Notes:

B = Bicycle traffic on bridges.

N = No pedestrian or bicycle traffic on bridges.

P=Pedestrian traffic on bridges.

U = Undeterminable pedestrian or bicycle traffic on bridges.

Sources: Google Earth 2009, 2010; USACE et al. 2003.

In addition to open spaces along the river, bridge crossings often provide scenic views of the Missouri River as roadway travelers cross them. The Veterans Memorial and Hermann Bridges also support

pedestrian and bicycle traffic. Views from bridges may extend to the middleground, with views to the background limited by development. However, a notable part of the viewshed consists of the wide, meandering river corridor that is framed by urban development (see Figure 3.14-7). Views from bridges may extend to the background where development is limited and bends in the river allow such views. Roadways in developed areas often pass by the river with open views of the waterway, or these views may be partially or fully obstructed by infrastructure and development. Roadways in rural areas are often set back from and do not offer views of the river. Where roadways travel along the river, scenic views of the river corridor typically are present. Some of these views may be obstructed by roadside or riparian vegetation, crops, or other features.

The Capital Sand Company (see Figure 3.14-8), Hermann Sand & Gravel Company, Limited Leasing Company, and J.T.R. have dredging operations in this segment (see Table 3.14-5 and Figures 3.11-1 [Sheet 5] and 3.11-2 [Sheet 5] in Land Use and Recreation). Dredging operations include barges with heavy equipment on the river's water surface and onshore stockpile operations that also have heavy equipment and infrastructure. Onshore facilities have converted areas that typically would be vegetated to large, unvegetated piles of sand and sediment along the river's edge (see Figure 3.14-9). These features contrast with the more natural areas surrounding the facility and detract from scenic views of the river corridor. In addition, dredge facilities create noise and movement that draw viewers' attention toward these areas, making them more noticeable to viewer groups.

These dredging operations are located adjacent to residential, agricultural, open space, and industrial areas located along the river bank. Dredging operations are often buffered from adjacent land uses by thick bands of riparian vegetation that block views of dredging equipment and barges. Motorists traveling across bridges and on local roads located near the dredging operations would have more direct views of the barges and other dredging operations. Recreationists utilizing the open waters of the Missouri River have direct views of all operations. The Edward N. Rau Contractor Company proposed facility is located directly southeast of and bordering the Washington City River Access point. The highly visible views of dredging operations detract from the riverfront viewshed. The Hermann Sand & Gravel–Hermann facility is also located less than 1 mile northeast, and across the river, from Hermann Riverfront Park (see Figure 3.14-10). A river access point in the park allows views of dredging operations on the river and riverbank that detract from the riverfront viewshed.

Figure 3.14-7 Views of Bridgeton, Interstate 70 Bridge, and Dredging on the River from Limited Leasing–Bridgeton Dredging Operation at RM 28

The vividness, intactness, and unity of views of and from the river in the segment are moderate to moderately low. While views of waterways are often highly valued, the visual character of the river corridor in this segment is substantially developed with industrial and commercial land uses near the confluence. Open spaces along the river in the urban areas create attractive riverside vantages, providing smaller areas with higher visual quality. Vividness increases as the landscape provides viewer groups with intact views of lush riparian habitat along the rivers' edge in rural areas outside of the St. Louis metropolitan region. Within the St. Louis metropolitan region, agricultural land uses often bound the river, and urban development is located abruptly beyond the patchwork of fields. The rolling terrain on the outskirts of St. Louis act to create an attractive, yet distinct separation between developed lands to the east and more rural lands to the west. These distinct changes create visually contrasting portions of the segment, affecting and lowering the intactness and unity within the transition zone and the St. Louis metropolitan areas. Outside of the transition zone, and within rural areas to the

west, intactness and unity increase due to gradual changes between rural communities and smaller towns and cities to agricultural areas.

Figure 3.14-8 Views of Capital Sand Company, St. Louis–Washington Dredging Operation and River beyond at RM 65.5

A wide variety of viewer groups in the St. Charles segment would be affected by proposed dredging operations. Motorists traveling along state and county roads along the river and over bridge crossings are exposed to dredging activities in the Project area. Residents and recreationists, including bicyclists, pedestrians, and boaters, can view dredging operations along the river. Those employed at businesses and industrial districts along the riverfront of this segment would be exposed to visual changes along the river.

Figure 3.14-9 Views of Limited Leasing Company–Bridgeton Dredging Operation and Large Sand Piles at RM 28

Figure 3.14-10 Views of the River, Hermann, and the Hermann Bridge from Hermann Sand & Gravel–Hermann Dredging Operations at RM 96.8

3.14.7 References

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3.15 CULTURAL RESOURCES

3.15.1 Introduction

"Cultural resources" are defined as the broad pattern of events, real properties, and cultural life ways or practices that have significance to humans. Buildings and places where events have occurred, archeological sites containing information about human activities, traditional places or activities that hold special significance, and folkways that are practiced as either cultural or life sustaining are all part of the broad category features of groups of people. Cultural resources typically found in or near the LOMR include Native American habitation and burial sites, historic trails, settlements, farmsteads, shipwrecks, bridges, and dams.

3.15.2 Regulatory Setting

Projects involving federal land, funds, review, or permitting are subject to compliance with Section 106 of the NHPA of 1966 (16 USC 470). Section 106 requires federal agencies such as the USACE to take into account the effects of their undertakings on historic properties. An "historic property" is any district, archeological site, structure, sacred site, or object that is included on or eligible for inclusion in the National Register of Historic Places (NRHP). As the lead federal agency with jurisdiction over the permitting of commercial dredging along the LOMR, the USACE is responsible for ensuring compliance with Section 106 of the NHPA and other pertinent cultural resource laws and regulations. Section 106 also requires that the USACE consult with SHPOs, federally recognized Native American tribes, local governments, and other interested parties regarding the proposed undertaking. In addition, the Advisory Council on Historic Preservation (ACHP) would be consulted for projects adversely impacting historic properties.

Part of the USACE's responsibility under the NHPA is to determine areas that may be affected by the undertaking, or the Area of Potential Effect (APE). Project-related activities with the potential to directly affect historic properties include excavation and removal of sand and gravel from the main channel of the LOMR. Potential indirect effects that may result from increased river bed degradation related to dredging include erosion, induced instability, headcutting, and related channel effects from dredging activities. Areas affected by erosion induced by headcutting could include banks of the LOMR and localized areas of tributaries. Because of the above known and potential impacts, the APE for this Project was determined to include the main channel of the LOMR from the confluence of the Missouri

and Mississippi Rivers in St. Louis, Missouri (RM 0) to Rulo, Nebraska at RM 498 and extending from the top of bank to approximately 50 feet below the river bottom (i.e., the greatest potential depth of dredging activities). The APE also includes perennial tributaries joining the LOMR for a distance of 0.25 mile upstream or to the first upstream control point. A "control point" includes any natural streambed feature or human-made structure that provides grade control and controls or impedes the upstream progress of a headcut. Because degradation of the tributaries is not likely to extend more than 20 feet beyond the current banks of the LOMR and its tributaries, the APE extends 20 feet landward of each bank.

Sand plants owned and operated by the dredging permit applicants are not included in the APE as they were previously permitted by the USACE, if authorization was required. It is reasonably foreseeable that some alternatives may result in extraction of sand or gravel from new upland mining sources. These upland mining sources are not included in the APE for this Project because actions related to the upland mining sources would not be subject to any of the USACE permits that would be issued under this Project. Construction and operation of proposed sand plants and alternate mining sources were considered in the indirect effects analysis (See Section 4.13).

3.15.3 Cultural Resources Setting

The cultural setting establishes the prehistoric and historic context from which to identify and evaluate historic properties. The setting focuses on major prehistoric and historic themes that have occurred in the area over time.

3.15.3.1 Prehistoric Context

The regional precontact chronology for Missouri has been divided into the following five cultural periods: Paleoindian (12,000–8,000 before Christ [BC]), Dalton (8,000–7,000 BC), Archaic (7,000–1,000 BC), Woodland (1,000 BC – *Anno domini* [AD] 900), and Mississippian (AD 900–1,700) (Chapman 1975, 1980). Each time period can be further subdivided into further defined periods (i.e. Early, Middle, and Late Archaic). Also, because the Project area is long, roughly 517 river miles in length, localized cultural expressions in some portions of the Project area differ somewhat from other areas (e.g., the Kansas City Hopewell and Steed-Kisker cultural components found near Kansas City and the Cahokia cultural complex found near St. Louis). The following discussion traces the broad periods of human settlement and the associated artifacts and sites that may exist within the APE.

The Paleoindian Period (12,000–8,000 BC) is defined by nomadic hunters whose ancestors migrated to North America from northeast Asia (Chapman 1975). These highly mobile hunters subsisted on large game, including the mammoth, mastodon, and giant bison. Numerous Paleoindian sites have been reported in the LOMR Valley near the greater vicinity of St. Louis (Chapman 1975, Warren and O'Brien 1982).

The Dalton Period (8,000–7,000 BC) was similar to the preceding Paleoindian Period. However, due to late Pleistocene/early Holocene environmental changes, subsistence strategies also changed. Changes from nomadic hunting to hunter-gatherer (forager) subsistence are indicated by a greater reliance on smaller game animals (Chapman 1975).

The Archaic Period (7,000–1,000 BC) is defined by a shift in subsistence strategies and technological change, evidenced through artifacts and faunal remains. The Archaic Period experienced a warming climate that created a wider variety of food sources, including riverine resources such as shellfish, turtles, and fish; plant foods; and game animals (Chapman 1975, Warren and O'Brien 1982). The shifted subsistence strategy used a greater diversity of resources and shifted to smaller animals, following the disappearance of the mega fauna. The increase in food resource variety initiated a general trend toward sedentary subsistence (Warren and O'Brien 1982). The appearance of large shell midden sites indicates an increase in the exploitation of aquatic resources in some major river valleys. Site numbers and densities increased throughout the Archaic Period. Archaic sites are present in all major river drainages in north Missouri.

The Woodland Period (1,000 BC – AD 900) saw an increase in settlement size and sedentary behavior (Warren and O'Brien 1982: 79). The most notable technological change was the introduction of pottery. Early Woodland sites along the LOMR are characterized by Black Sand Pottery, which likely was introduced from the north (Chapman and Chapman 1983). The middle Woodland Period is characterized by mound building, more refined grit-tempered ceramics, and greater importance on horticulture. The Middle Woodland is further associated with the Hopewellian Interaction Sphere (Caldwell 1964), which is reflected by specific design motifs on ceramic vessels, elite burials, and exotic exchange goods.

The Mississippian Period (AD 900–1,700) saw a rise in social complexity, extensive maize agriculture, mound construction, and long-distance trade (Chapman 1980). The most diagnostic artifact of the Mississippian Period is shell-tempered ceramics such as jars, bowls, plates, beakers, bottles, and large pans. The Mississippian site of Cahokia, near the City of St. Louis, is the largest precontact site north

of Mexico. The Mississippian culture spread from Cahokia up the Missouri River into Kansas, and a second center was located near Kansas City, Missouri (Chapman and Chapman 1983, Shippee 1972).

During the Protohistoric through early historic periods (approximately AD 1400 to AD 1820) the LOMR was within the territory of a number of tribes, including the Osage, Sauk, Otoe, Missouria, Kansa, and Peoria. The Missouria occupied villages along the Missouri River. One of the largest villages, Missouri Village, was documented west of the confluence of the Grand and LOMR (Chapman and Chapman 1983). Sometime between 1723 and 1728, the Osage moved next to the Missouri Village to be close to the French Orleans Fort so that they could engage in trade (Chapman and Chapman 1983). By 1800, following wars with neighboring tribes, the Sauk moved into the upper Mississippi in the vicinity of St. Louis.

3.15.3.2 Historic Context

This section outlines the major historic themes that shaped the development of the Missouri River basin.

Exploration and Settlement

Spanish explorers, followed by French and British fur traders, were the first Europeans to enter the Missouri River basin. In 1763, French authorities in New Orleans granted Maxent, Laclede, and Company exclusive rights to the fur trade on the Missouri River. The company began construction of a post in 1764, which was named for King Louis IX of France. By the end of 1764, approximately 40 families had settled in the new village of St. Louis. The settlers called the village *Pain Court* (short of bread), perhaps indicating early hardships or simply the lack of agriculture. St. Louis, as well as the future state of Missouri, became part of the Spanish Empire after the French were defeated in the Seven Years' War. In 1765, St. Louis became the capital of Spanish Upper Louisiana. Under the Spanish, residents were ethnically French; and French fur companies, in particular Laclede, dominated the economy (Journal Entry December 11, 1803 [The Journals of the Lewis and Clark Expedition 2005]).

In 1803, the Missouri River basin became part of the United States with the Louisiana Purchase. President Thomas Jefferson's interests in the basin's physical geography and ecology, and its Native American tribes led to the Lewis and Clark Expedition. The expedition explored the Missouri River basin from December 1803 to July 1804. During this time, Lewis and Clark documented the lifeways

and material culture of tribes, including the "Sauckee and Kickapoos;" numerous French settlements along the banks of the Missouri River, including St. Charles, La Charette, Jefferson City, Arrow Rock, Kansas City, and St. Joseph; and early American farmsteads (Journal Entry December 8, 1803, May 5, 1804 –June 1804 [The Journals of the Lewis and Clark Expedition 2005]).

After the Louisiana Purchase, most Americans moved into the established French villages, as well as St. Louis, as towns and cities expanded (Violette 1918: 43; City of St. Louis 2009). Other communities, such as St. Joseph, became remote outposts. St. Joseph served as a last supply point before the western frontier. From 1821 to 1826, St. Charles served as Missouri's first state capital (Violette 1918: 39). In 1826, the capital moved to Jefferson City—a trading post between St. Louis and Kansas City (McMillen and Murphy 1996).

Transportation

The steamboat contributed to further development of the Missouri River basin. Sixteen steamboats were operating in spring 1837; 4 years later, 26 boats were engaged in trade along the Lower Missouri (Petersen 1955: 101). Some steamboat landings were incorporated into towns, while others served simply as a point of transport. For example, Keytesville Landing (located in what is now Chariton County, Missouri) served as a landing for goods shipped to Keytesville about 6 miles north of the Missouri River. At one time, the landing consisted of a tobacco warehouse and general trading post (Smith and Gehrig 1923: 230).

Steamboats also drastically altered the riverine environment. For example, "One steamboat consumed 20 cords of wood a day on an upstream journey, which resulted in the elimination of forests along the riverbanks (Galat et al. 2005: 438)." The river was further altered to improve navigation and safety (see Sections 4.2.3 through 4.2.5). As early as 1824, Congress appropriated funds for the USACE to remove large tree snags and other obstacles in the Missouri River channel. Government snag boats and river-based work crews continued their efforts to improve navigability through the late 1870s (Missouri River Ecosystem 2002: 26).

The hazards associated with steamboat navigation were greater along the Missouri River than along the Mississippi River. During the early- to mid-18th century, hundreds of ships were lost due to snags, explosions, and collisions (Larson and Norris 2008: 65). The steamer *Saluda* exploded near Lexington, Missouri in 1852; the *Arabia*, a side-wheel steamboat, hit a snag in the Missouri River and sank near present day Parkville, Missouri in 1856; and the *Princess*, a stern-wheel steamer, sank at Napoleon,

Missouri in 1868 (Corbin 2000: 11-20, 147-157). Fluctuations in the main river channel have left many shipwrecks, such as the *Bedford* and *Argonaut*, miles away from the Missouri River (Larson and Norris 2008). The remains of wrecked steamboats serve to document specific stages of technology and a manner of commerce that was eventually replaced by railroads and automobiles.

Steamboating on the river reached its peak in the late 1850s and declined following development of the railroads. On July 4, 1851, at St. Louis, Missouri, ground-breaking for the Pacific Railroad marked the beginning of what would later be known as the Missouri Pacific Railroad (Sabin 1919). The first section of track was completed in 1852. In 1865, it became the first railroad to serve Kansas City. The Hannibal and Saint Joseph Railroad, which was completed in 1859 and linked the communities of Hannibal and St. Joseph, was the first to cross the Missouri River (Violette 1918: 237). Railroads would ultimately have a greater influence on the Missouri River basin's settlement patterns when compared to steamboats (Missouri River Ecosystem 2002: 24).

Bridges were necessary to the success of Missouri's transportation systems. Originally simply built, locally maintained structures, Missouri's bridges eventually reflected innovative designs and the use of stronger building materials, such as steel and concrete (Fraser 1996: 10). Bridges accommodating both railways and roadways were constructed into the 1940s. One of the more noteworthy railroad bridges is Kansas City's Armor, Swift, Burlington (ASB) Bridge, which sported a unique double-neck, vertical-lift structure that carried railroad and highway traffic. Originally, the bridge carried railroad traffic on its lower deck and automobile traffic on its upper deck (1996: 16). Bridge building advanced during the late 19th and early 20th centuries with the formation of national and local bridge companies. Construction companies followed national trends, which were moving away from regionally influenced designs, such as wooden covered bridges and various truss and arched styles, to more durable designs of pressed concrete.

3.15.4 Background Research

A background review of the APE and adjacent areas was conducted to identify specific previously recorded cultural resources within the APE. The research consisted of a review of the NRHP, *Abandoned Shipwrecks on Missouri River Channel Maps of 1879 and 1954* (USACE Kansas City District 2000), *Missouri Historic Bridge Inventory* (FRASER design 1996), Lewis and Clark Expedition data from the USACE GIS files, and GIS data and survey reports from the SHPOs of Missouri, Kansas, and Nebraska. Where possible, NRHP eligibility determinations for specific sites were noted. The primary resource types identified from the records search were archaeology sites, shipwrecks, bridges,

and the Lewis and Clark Trail and campsites. A total of 128 cultural resources were identified in the Project APE. These resources include 91 shipwrecks, 12 Lewis and Clark campsites, 10 archaeology sites, and fifteen bridges. The majority of sites (112 or 88 percent) have not been relocated or evaluated for inclusion in the NRHP. In terms of location, 113 sites were identified in the main channel, 13 were identified along the banks of tributaries, and two were identified at a proposed sand plant location.

The general location of most cultural resources such as shipwrecks, bridges, and Lewis and Clark campsites are known; but many shipwrecks are reported in more than one location that are often widely separated. Also, because only part of the Project area previously has been inventoried for archeological sites, unrecorded prehistoric archeological sites could occur in the APE. Prehistoric sites are not likely within the active Missouri River channel or immediately adjacent to it through most of the LOMR area, however, because of scouring from the meandering river over the last 150 years.

The known cultural resources in the St. Joseph, Kansas City, Waverly, Jefferson City, and St. Charles segments of the LOMR are discussed in the following sections. Specific site type, name, and eligibility status of cultural resources in each segment are presented in Tables 3.15-1 through 3.15-5. To protect sites from looting or vandalism, specific site locations for archeological sites and shipwrecks are not presented in this document. Most of the cultural resources listed in the tables are reported as unevaluated because they have not been formally evaluated for eligibility for listing in the NRHP, either because they have not been evaluated as part of the Section 106 process or because the physical remains have not been identified. If identified and evaluated, all of the Lewis and Clark sites and most of the shipwrecks would be eligible for listing in the NRHP.

St. Joseph Segment

Table 3.15-1 outlines the 21 sites identified in the St. Joseph segment, which include 14 shipwrecks, two Lewis and Clark campsites, three bridges, and two archaeology sites. The three bridges are the only properties in this segment that are listed, or eligible for listing, in the NRHP. No cultural resources were identified within the perennial tributary buffer (0.25 mile upstream or to the first control point and 20 feet landward of each bank) in this segment. Two sites were identified at a potential sand plant location, and 18 sites were identified within the main channel of the LOMR.

Table 3.15-1 Cultural Resources in the St. Joseph Segment

Site Type	Site Name/No.	Location[a]	NRHP Eligibility
Bridge	Rulo	MC (RM 498)	Listed
Shipwreck	*Bertha*	MC	Unevaluated
Campsite	1806 Lewis and Clark	MC (RM 448.8)	Unevaluated
Shipwreck	*Emilie No. 2*	MC	Unevaluated
Shipwreck	*Denver City*	MC	Unevaluated
Shipwreck	*Dorothy*	MC	Unevaluated
Shipwreck	*Mt. Sterling*	MC	Unevaluated
Shipwreck	*Pathfinder*	MC	Unevaluated
Campsite	1806 Lewis and Clark	MC (RM 442.3)	Unevaluated
Shipwreck	*Missouri Mail*	MC	Unevaluated
Shipwreck	*Della*	MC	Unevaluated
Bridge	Atchison	MC (RM 422.6)	Eligible
Bridge	Leavenworth	MC	Eligible
Shipwreck	*Arabian*	MC	Unevaluated
Shipwreck	*Hesperian*	MC	Unevaluated
Shipwreck	*Platte Valley*	MC	Unevaluated
Shipwreck	*Tom Morgan*	MC	Unevaluated
Shipwreck	*Minnie*	MC	Unevaluated
Shipwreck	*Express*	MC	Unevaluated
Archaeology site	PL341	SP	Unevaluated
Archaeology site	PL110	SP	Unevaluated

Note: NRHP = National Register of Historic Places.

[a] Location: MC = Main channel; SP = Proposed sand plant location.

Sources: USACE 2000, FRASER Design 1996, USACE n.d.

Kansas City Segment

Table 3.15-2 outlines the 12 sites indentified in the Kansas City segment, which include five shipwrecks, six bridges, and one archaeology site. The six bridges are eligible for listing in the NRHP. All five shipwrecks are unevaluated as to their NRHP eligibility. One site, archaeology site PL288, was identified within the perennial tributary buffer. This site was determined ineligible for listing in the NRHP through survey and evaluation.

Table 3.15-2 Cultural Resources in the Kansas City Segment

Site Type	Site Name	Location [a]	NRHP Eligibility
Archaeology site	PL288	T	Not eligible
Bridge	Fairfax	MC (RM 372.6)	Eligible
Bridge	Fairfax (1955)	MC (RM 372.6)	Eligible
Bridge	Broadway	MC	Eligible
Shipwreck	*Fire Canoe*	MC	Unevaluated
Shipwreck	*Bennett*	MC	Unevaluated
Shipwreck	*Mike Bauer*	MC	Unevaluated
Bridge	Armour-Swift-Burlington (ASB) Railroad Bridge	MC (RM 365.6)	Eligible
Shipwreck	*Glenmore*	MC	Unevaluated
Bridge	Paseo	MC (RM 364.8)	Eligible
Bridge	Liberty Bend	MC (RM 352.7)	Eligible
Shipwreck	Corvette	MC	Unevaluated

Note: NRHP = National Register of Historic Places.

[a] Location: MC = Main channel; T = Tributary.

Sources: USACE 2000, FRASER Design 1996, USACE n.d.

Waverly Segment

Table 3.15-3 outlines the 15 shipwrecks that are located in the Waverly segment. None of the shipwrecks has been evaluated for their NRHP eligibility. The USACE established a no-dredge zone for the *Saluda*, which is located near the town of Lexington, Missouri. No cultural resources were identified within the perennial tributary buffer in the Waverly segment.

Table 3.15-3 Cultural Resources in the Waverly Segment

Site Type	Site Name	Location[a]	NRHP Eligibility
Shipwreck	*Wakendah*	MC	Unevaluated
Shipwreck	*Saluda*	MC	Unevaluated
Shipwreck	*Nymph*	MC	Unevaluated
Shipwreck	*Zephyr*	MC	Unevaluated
Shipwreck	*Missouri*	MC	Unevaluated
Shipwreck	*Princess*	MC	Unevaluated

Table 3.15-3 Cultural Resources in the Waverly Segment

Site Type	Site Name	Location[a]	NRHP Eligibility
Shipwreck	*Leavenworth*	MC	Unevaluated
Shipwreck	*Ariel*	MC	Unevaluated
Shipwreck	*Roy Lynds*	MC	Unevaluated
Shipwreck	*Eagle*	MC	Unevaluated
Shipwreck	*Diana*	MC	Unevaluated
Shipwreck	*Tropic*	MC	Unevaluated
Shipwreck	*John Golong*	MC	Unevaluated
Shipwreck	*Govener Allen*	MC	Unevaluated
Shipwreck	*T.T. Hilman*	MC	Unevaluated

Note: NRHP = National Register of Historic Places.

[a] Location: MC = Main channel.

Sources: USACE 2000, FRASER Design 1996, USACE n.d.

Jefferson City Segment

Table 3.15-4 outlines the 29 sites identified in the Jefferson City segment, which include 19 shipwrecks, six archaeology sites, three bridges, and one campsite. The Rocheport Bridge, Jefferson City Bridge and shipwreck *Radnor* were determined eligible for listing in the NRHP. The remaining sites have not been evaluated for their eligibility for listing in the NRHP. Eight sites were identified within the perennial tributary buffer, and 21 were identified within the main channel of the LOMR.

Table 3.15-4 Cultural Resources in the Jefferson City Segment

Site Type	Site Name/No.	Location[a]	NRHP Eligibility
Shipwreck	*Joseph Kinney*	MC	Unevaluated
Shipwreck	*Dart*	MC	Unevaluated
Shipwreck	*Timour*	MC	Unevaluated
Shipwreck	*Naomi*	MC	Unevaluated
Shipwreck	*Sonora*	MC	Unevaluated
Shipwreck	*West Wind*	MC	Unevaluated
Bridge	Glasgow Railroad Bridge	MC (RM 226.3)	Not Eligible
Bridge	Rocheport Bridge	MC	Eligible
Bridge	Jefferson City	MC	Eligible
Shipwreck	*Annie Lee*	MC	Unevaluated

Table 3.15-4 Cultural Resources in the Jefferson City Segment

Site Type	Site Name/No.	Location[a]	NRHP Eligibility
Shipwreck	*Chariton*	MC	Unevaluated
Shipwreck	*Plow Boy No. 2*	MC	Unevaluated
Shipwreck	*Radnor*	MC	Eligible
Archaeology Site	MU134/MU135	T	Unevaluated
Archaeology Site	BO1000	T	Unevaluated
Shipwreck	*Little Dick*	T	Unevaluated
Archaeology Site	BO1100	T	Unevaluated
Shipwreck	*Marie*	MC	Unevaluated
Shipwreck	*Bright Light*	MC	Unevaluated
Shipwreck	*Martha Stevens*	MC	Unevaluated
Shipwreck	*Floyd*	MC	Unevaluated
Shipwreck	*Diana*	MC	Unevaluated
Archaeology site	CY28	T	Unevaluated
Archaeology site	CO52	T	Unevaluated
Shipwreck	*Statie Fisher*	MC	Unevaluated
Archaeology site	CO108	T	Unevaluated
Campsite	Lewis and Clark 1804	T	Unevaluated
Shipwreck	*Emma*	MC	Unevaluated
Shipwreck	*Dew Drop*	MC	Unevaluated

Note: NRHP = National Register of Historic Places.

[a] Location: MC = Main channel; T = Tributary.

Sources: USACE 2000, FRASER Design 1996, USACE n.d.

St. Charles Segment

Table 3.15-5 outlines the 51 sites that are located in the St. Charles segment. These sites include 38 shipwrecks, nine Lewis and Clark campsites, three bridges, and one archaeology site. Washington Bridge, Blanchette Bridge, and Daniel Boone Bridge are eligible for listing in the NRHP. The remaining sites and shipwrecks have not been evaluated for eligibility for the NRHP. Four sites were identified within the perennial tributary buffer, and 47 sites were identified within the main channel of the LOMR.

Table 3.15-5 Cultural Resources in the St. Charles Segment

Site Type	Site Name/No.	Location[a]	NRHP Eligibility
Shipwreck	*E.H. Durfee*	MC	Unevaluated
Shipwreck	*Camden*	MC	Unevaluated
Shipwreck	*Gus Fowler*	MC	Unevaluated
Shipwreck	*New St. Paul*	MC	Unevaluated
Shipwreck	*Nodaway*	MC	Unevaluated
Shipwreck	*Lancaster*	MC	Unevaluated
Shipwreck	*Robert Emmett*	MC	Unevaluated
Campsite	1804 Lewis and Clark	MC (RM 108.2)	Unevaluated
Shipwreck	*Lancaster (1932)*	MC	Unevaluated
Shipwreck	*Mandan*	MC	Unevaluated
Archaeology Site	GA184	T	Unevaluated
Campsite	1804 Lewis and Clark	MC (RM 104.3)	Unevaluated
Shipwreck	*Chariton*	MC	Unevaluated
Shipwreck	*Cappa*	MC	Unevaluated
Shipwreck	*Alert*	MC	Unevaluated
Shipwreck	*Washington*	MC	Unevaluated
Shipwreck	*Lynchburgh*	MC	Unevaluated
Shipwreck	*Petral*	T	Unevaluated
Campsite	1804 Lewis and Clark	MC (RM 72.5)	Unevaluated
Campsite	1806 Lewis and Clark	MC (RM 72.1)	Unevaluated
Bridge	Washington Bridge	MC (RM 67.5)	Eligible
Bridge	Blanchette Bridge	MC	Eligible
Shipwreck	*Seventy-Six*	MC	Unevaluated
Shipwreck	*John Bell*	MC	Unevaluated
Shipwreck	*Duncan S. Carter*	MC	Unevaluated
Shipwreck	*Montana*	MC	Unevaluated
Shipwreck	*Lily*	T	Unevaluated
Campsite	1804 Lewis and Clark	MC (RM 46.1)	Unevaluated
Bridge	Daniel Boone Bridge	MC (RM 43.9)	Eligible
Shipwreck	*James Lyons*	MC	Unevaluated
Shipwreck	*General McNeil*	MC	Unevaluated
Shipwreck	*Ella Kimbrough*	MC	Unevaluated
Campsite	1804 Lewis and Clark	MC (RM 29.0)	Unevaluated

Table 3.15-5 Cultural Resources in the St. Charles Segment

Site Type	Site Name/No.	Location[a]	NRHP Eligibility
Shipwreck	*Tyler*	MC	Unevaluated
Campsite	1806 Lewis and Clark	MC (RM 28.4)	Unevaluated
Shipwreck	*Hermann*	MC	Unevaluated
Shipwreck	*St. Anthony*	MC	Unevaluated
Shipwreck	*Hermann*	MC	Unevaluated
Shipwreck	*St. Luke*	MC	Unevaluated
Shipwreck	*Benton No. 1*	MC	Unevaluated
Shipwreck	*Far West*	MC	Unevaluated
Shipwreck	*Halycyon*	MC	Unevaluated
Shipwreck	*Haidee*	MC	Unevaluated
Shipwreck	*Car of Commerce*	MC	Unevaluated
Shipwreck	*John Hancock*	MC	Unevaluated
Shipwreck	*New Georgetown*	MC	Unevaluated
Shipwreck	*Julia*	MC	Unevaluated
Campsite	1806 Lewis and Clark	MC (RM 7.0)	Unevaluated
Shipwreck	*Georgetown*	MC	Unevaluated
Campsite	*Lewis and Clark*	T (RM 7.0)	Unevaluated
Shipwreck	*Bald Eagle*	MC	Unevaluated

Note: NRHP = National Register of Historic Places.

[a] Location: MC = Main channel; T = Tributary.

Sources: USACE 2000, FRASER Design 1996, USACE n.d.

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3.16 AIR QUALITY AND CLIMATE CHANGE

3.16.1 Introduction

This section provides the context necessary to understand air quality and climate change effects in the Project area resulting from the Proposed Action and alternatives. Operation of dredges, tugboats, and materials-handling equipment powered by internal combustion engines emits pollutants as exhaust, which affects local and regional air quality. These emissions can cause deterioration of ambient air quality and expose sensitive populations to increased health risks, including cancer and respiratory diseases, while GHG emissions can contribute to global warming and climate change.

This section focuses on existing air quality conditions in the Project area, including emissions associated with the existing operation of dredges, tugboats, and materials-handling equipment powered by internal combustion engines, that may be affected by the Proposed Action and alternatives. It begins with a summary of the federal, state, and local regulatory settings, followed by discussion of the common air pollutants and local monitoring data. These data are important because they highlight pre-existing air quality concerns in the St. Charles segment of the Missouri River. While the Proposed Action and alternatives encompass other counties, this section focuses on the St. Charles segment (which includes St. Louis, Franklin, St. Charles, and Madison[1] Counties), as it is the only river segment in an area that is in nonattainment with regard to the national ambient air quality standards (NAAQS). Changes in dredging operations that may increase pollutant emissions therefore would result in the most profound effect on air quality in this segment.

The section summarizes climatic and atmospheric conditions along the LOMR; these conditions determine the movement and dispersion of air pollutants. The section also provides an overview of sensitive land uses that may be exposed to pollutant emissions as a result of the Proposed Action and Project alternatives.

Information used in the preparation of this section came from a variety of sources, including the USACE and the USEPA.

[1] Madison County, Illinois is the location of one onshore facility owned by Limited Leasing. Because material dredged from the Missouri River in the St. Charles segment will be processed at this location, Madison County is considered part of the St. Charles segment.

3.16.2 Regulatory Setting

This section describes the regulatory framework for the Project area and the standards that will be used to determine whether implementation of the Proposed Action or alternatives would result in potential adverse effects to air quality or climate change.

Federal

National Ambient Air Quality Standards

The federal Clean Air Act (CAA), enacted in 1963 and amended several times thereafter (including the 1990 Clean Air Act Amendments), establishes the framework for modern air pollution control. The CAA directs the USEPA to establish NAAQS for the six criteria pollutants listed in Table 3.16-1.

Regional attainment with the NAAQS is based on local monitoring data. If monitored pollutant concentrations meet federal standards over a designated period, the area is classified as being in attainment for that pollutant. If monitored pollutant concentrations violate the standards, the area is considered a nonattainment area for that pollutant. Regions previously designated as nonattainment areas that have since obtained attainment are designated as maintenance areas. For the ozone standards, nonattainment and maintenance areas are further categorized into groups according to the increasing severity of the exceedance (for example, marginal, moderate, serious, severe, and extreme). Likewise, for the CO standard, areas are grouped into moderate or serious nonattainment or maintenance areas, depending on the severity of the exceedance. If data are insufficient to determine whether a pollutant is violating the standard, the area is designated as unclassified.

Table 3.16-1 National Ambient Air Quality Standards

	Primary Standards[a]		Secondary Standards[b]	
Pollutant	Level	Average Time	Level	Average Time
Carbon monoxide	9 ppm (10 mg/m^3)	8-hour [c]	None	
	35 ppm (40 mg/m^3)	1-hour [c]		
Lead	(0.15 µg/m^3) [d]	Rolling 3-month average	Same as primary	
	1.5 µg/m^3	Quarterly average	Same as primary	
Nitrogen dioxide	0.053 ppm (100 µg/m^3)	Annual (arithmetic mean)	Same as primary	
Particulate matter (PM_{10})	150 µg/m^3	24-hour [e]	Same as primary	

Table 3.16-1 National Ambient Air Quality Standards

	Primary Standards[a]		Secondary Standards[b]	
Pollutant	Level	Average Time	Level	Average Time
Particulate matter ($PM_{2.5}$)	15.0 μg/m³	Annual [f] (arithmetic mean)	Same as primary	
	35 μg/m³	24-hour [g]	Same as primary	
Ozone	0.075 ppm (2008 std)	8-hour [h]	Same as primary	
	0.08 ppm (1997 std)	8-hour [i]	Same as primary	
	0.12 ppm	1-hour [j]	Same as primary	
Sulfur dioxide	0.03 ppm	Annual (arithmetic mean)	0.5 ppm (1300 μg/m³)	3-hour [c]
	0.14 ppm	24-hour [c]		

Notes:

μg/m³ = Microgram(s) per cubic meter; mg/m³ = Milligrams per cubic meter; ppm = Parts per million; Std = Standard.

[a] Primary standards refer to limits set to protect public health, including the health of "sensitive" populations.

[b] Secondary standards refer to limits to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

[c] Not to be exceeded more than once per year.

[d] Final Rule signed on October 15, 2008.

[e] Not to be exceeded more than once per year on average over 3 years.

[f] To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15.0 μg/m³.

[g] To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 μg/m³ (effective December 17, 2006).

[h] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm (effective May 27, 2008).

[i] (1) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.

(2) The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as the U.S. Environmental Protection Agency (USEPA) undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.

[j] (1) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is <1.

(2) As of June 15, 2005, the USEPA has revoked the 1-hour ozone standard in all areas except the 14 8-hour ozone nonattainment Early Action Compact (EAC) areas.

For one of the 14 EAC areas (Denver, CO), the 1-hour standard was revoked on November 20, 2008. For the other 13 EAC areas, the 1-hour standard was revoked on April 15, 2009.

Source: USEPA 2009d.

Of all the counties where dredging would occur under the Proposed Action or alternatives, the USEPA has classified St. Louis, St. Charles, Franklin, and Madison Counties as moderate nonattainment areas for the 8-hour ozone standard. All of the remaining counties where dredging would occur under the Proposed Action or alternatives are classified as in attainment or unclassified for all other criteria pollutants (USEPA 2009e).

Federal Conformity Requirements

The CAA requires that the federal government not engage, support, or provide financial assistance for licensing or permitting, or approve any activity not conforming to the appropriate State Implementation Plan (SIP). The rule applies to federal projects in areas designated as nonattainment areas and ensures that they will not interfere with strategies implemented to attain the NAAQS for any of the six criteria pollutants and in some areas designated as maintenance areas. Project-level conformance with the SIP is demonstrated through a general conformity analysis.

As previously indicated, the following counties within the Project area are classified as federal nonattainment areas for the 8-hour ozone standard: St. Louis, Franklin, St. Charles, and Madison (USEPA 2009e). These areas constitute the St. Charles segment of the Missouri River. Although the Proposed Action and alternatives encompass other counties, this analysis focuses on the St. Charles segment (which includes St. Louis, Franklin, St. Charles, and Madison Counties) of the Missouri River, as it is the only Project area segment located in a federal nonattainment area. Consequently, a general conformity determination must be performed to demonstrate that total direct and indirect emissions of ozone would conform to the applicable SIP. More specifically, the general conformity analysis must identify whether Project emissions of ozone precursors (ROG/VOC and NO_X) in these counties meet the following conditions:

- Are below the appropriate *de minimis* threshold (based on the nonattainment level of the Project area, the threshold is 100 tons per year) (40 CFR 51.853); and
- Are regionally insignificant (total emissions are less than 10 percent of the area's total emissions inventory for that pollutant). Regional emissions for ROG and NO_X are presented in Table 3.16-2. Note that the emissions in Table 3.16-2 are from 2002 as this was the most recent information available on the USEPA website.

If the two conditions above are not met, a general conformity determination must be performed to demonstrate that the total direct and indirect emissions for each affected pollutant for which the region is classified as a maintenance or nonattainment area for the national standards would conform to the applicable SIP.

State

Dredging operations associated with the Proposed Action and alternatives would occur in Missouri, Kansas, Nebraska, and Illinois. The following four agencies are responsible for maintaining federal air

quality standards within each of these states: MDNR, KDHE Bureau of Air, NDEQ, and Illinois Environmental Protection Agency (IEPA). The primary tools used by each of these state agencies to implement air quality regulations are construction and stationary source permits:

Table 3.16-2 Regional Emissions for the *de Minimis* Conformity Analysis of Ozone (tons/year)

County	VOC	NO_X
St. Louis	60,120	64,860
St. Charles	13,645	28,037
Franklin	6,091	14,647
Madison	16,471	21,961
10% of Regional Emissions		
County	VOC	NO_X
St. Louis	6,012	6,486
St. Charles	1,365	2,804
Franklin	609	1,465
Madison	1,647	2,196

Notes:

NO_X = Oxides of nitrogen.
VOC = Volatile organic compounds.

Source: USEPA 2009f.

- The MDNR currently requires state permits for construction activities and stationary source facilities that exceed *de minimis* thresholds based on their potential to emit. These permits are in accordance with standards established in Title 10 of the Missouri Code of State Regulations, Rules 10 CSR 10-6.060 Construction Permits Required and 10 CSR 10-6.065 Operating Permits (Basham pers. comm.).
- The KDHE construction permits ensure that emissions from new or modified equipment comply with the New Source Performance Standards (40 CFR Parts 60, 61, and 62), and the National Standards for Hazardous Air Pollutants. Operating permits are based on a facility's potential to emit. These permits satisfy the requirements of the federal CAA Title V program and closely parallel the requirements of 40 CFR Part 70 (KDHE n.d.).
- The NDEQ has established specific pollutant thresholds for determination of the air quality permits. Construction activities or facilities exceeding these thresholds are subject to NDEQ permitting in accordance with Title 129 of the State Code (NDEQ n.d.).

- The IEPA requires operating permits in accordance with State Regulation 201. The type of permit required is based on a facility's potential to emit. Smaller sources (sources with potential emissions less than 100 tons per year of particulate matter) have fewer restrictions and requirements than larger facilities. Certain activities and classes of equipment, which are summarized in 35 IAC 201.146, are not subject to state permit requirements. It is anticipated that the onshore facility located in Madison County would qualify for several of these exemptions (Schnepp pers. comm.).

According to the agencies listed above, commercial dredges and tugboats are exempt from state permitting requirements. However, onshore materials-handling equipment and facilities exceeding applicable thresholds may be subject to state permits (Basham pers. comm., Schnepp pers. comm.). To the extent that the Proposed Action or alternatives increase pollutant emissions, state permitting requirements may be triggered. In addition, depending on their potential to emit, onshore equipment and facilities may be subject to state rules and regulations. Table 3.16-3 summarizes rules and regulations that may apply to the Proposed Action or alternatives as a result of changing emissions levels. Failure to comply with any applicable State regulation would be a violation subject to enforcement action.

Table 3.16-3 State Rules and Regulations Restricting Emissions

State	Rule	Description
Missouri	10 CSR 10-5.385	Restricts heavy duty diesel vehicles with a gross vehicle weight greater than 10,000 pounds that operate in the counties of Franklin, Jefferson, St. Charles and St. Louis, and the City of St. Louis from idling more than five (5) minutes in any sixty (60) minute period except as otherwise exempted from the rule.
	10 CSR 10-6.170	Restricts the dispersion of PM from the premises of origin through various control measures.
	10 CSR 10-6.045	Limits open burning of combustible materials. Specifically, open burning outside of major metropolitan areas may not occur within 200 yards of the nearest occupied structure.
	10 CSR 10-6.220	Specifies the maximum allowable opacity of visible air contaminants and requires use of continuous opacity monitor systems on certain air contaminant sources.
	10 CSR 10-6.24/ 10 CSR 10-6.250	Apply to projects with the potential to emit asbestos and requires project proponents to register with the Missouri Department of Natural Resources and allow period asbestos inspections.
	10 CSR 10-6.345	Protects air quality in the St. Louis area by addressing NO_X sources proposed for construction outside and upwind of the St. Louis nonattainment area. Applies to major sources in Perry, St. Genevieve, St. Francois, Washington, and Warren Counties that trigger Prevention of Significant Deterioration review for NO_X or emit more than 900 tons of NO_X during the ozone season.

Table 3.16-3 State Rules and Regulations Restricting Emissions

State	Rule	Description
Kansas	28-19-20	Limits the amount of PM from any processing machine, equipment, or other device.
	28-19-21	Regulates unique chemical or physical compounds that require emissions rates lower than those in Rule 28-19-20.
	28-19-31	Restricts PM emissions from sources used for indirect heating.
	28-19-57	Establishes emissions restrictions for times designated as an air pollution alert period and an air pollution warning period.
	28-19-650	Establishes emissions opacity limits for sources not covered by other regulations.
Nebraska	Title 29 Chapter 20	Reduces the amount of PM emitted from sources used for purposes other than indirect heating.
	Title 29 Chapter 24	Limits the amount of sulfur oxides emitted by any existing fossil fuel–burning equipment in excess of 2.5 pounds per million British thermal unit input, maximum 2-hour average.
	Title 29 Chapter 32	Prohibits handling, transporting, or storage of any material in a manner that may allow PM to become airborne in such quantities that it remains visible in the ambient air beyond the premises where it originates.
	Title 29 Chapter 38	Establishes emissions restrictions for times designated as an air pollution alert period and an air pollution warning period.
	Title 29 Chapter 39	Prohibits operation of a diesel-powered motor vehicle on any public street or highway in such a manner that smoke discharged inhibits visibility.
Illinois	Rule 212	Limits the amount of visible PM emissions. Rule requirements most applicable to the Proposed Action or alternatives include 212.304 through 212.314.
	Rules 214 through 217	Limit emissions of sulfur, organic material, CO, and NO_X in the state through various control measures.
	Rule 228	Prohibits discharge of visible amount of asbestos fiber or asbestos-containing materials unless the actions summarized in Section 228.121 are met.

Notes:

CO = Carbon monoxide.
NO_X = Oxides of nitrogen.
PM = Particulate matter.

Sources: Basham pers. comm., Schnepp pers. comm., MDNR 2009, KDHE 2007, NDEQ 2009, Illinois Pollution Control Board 2002.

Local

Two local agencies in Missouri and one local agency in Kansas have jurisdiction over potential emission sources at the county level in the Project area. The St. Louis County Air Pollution Control Program (St. Louis) is the official regulatory agency in St. Louis County, and the Kansas City Air Quality (Kansas City) is the official regulatory agency in the Kansas City Metropolitan Area. Likewise, the Wyandotte County Department of Air Quality (Wyandotte County) has local jurisdiction over potential emission sources in Wyandotte County. All three of these local agencies enforce state rules and

require construction and operating permits for facilities exceeding applicable thresholds. Permits issued at the local level function as state permits. In the State of Missouri, these permits are in effect for the life of the equipment until change of ownership (St. Louis n.d., Manning pers. comm.).

In addition to enforcing state regulations, St. Louis and Kansas City have established air quality codes to address the unique air pollution problems in their respective regions (Froeschner pers. comm., Manning pers. comm.). Chapter 2 and Chapter 5 of Title 10 of the Missouri Code of State Regulations outline air quality standards specific to the Kansas City Metropolitan Area and the St. Louis Metropolitan Area, respectively. Table 3.16-4 summarizes rules that may apply to the Proposed Action or alternatives as a result of changing emissions levels.

Table 3.16-4 Local Agency Rules and Regulations Restricting Emissions

Authority	Rule	Description
St. Louis County Air Pollution Control Program	10 CSR 10-5.510	Reduces emissions of NO_X in ozone nonattainment areas. Requires major sources of NO_X to install or comply with reasonably available control technology as required under the Clean Air Act. Applies to all installations located in Franklin, Jefferson, St. Charles, and St. Louis Counties and in the city of St. Louis with the potential to emit 100 tons or greater per year of NO_X.
	10 CSR 10-5.520	Reduces VOC emissions from major sources that have not been affected by other rulemakings (one or more rules under Title 10, Division 10, Chapter 5). Applies to any installation in St. Charles, St. Louis, Franklin, and Jefferson Counties and in the city of St. Louis with the potential to emit more than 100 tons per year of VOCs.
Kansas City Air Quality	10 CSR 10-2.385	Restricts the idling time of heavy-duty vehicles in the Kansas City area so that no owner/operator of a heavy-duty diesel vehicle covered may idle the vehicle for more than 5 minutes in any 60-minute period, except for those operators exempted from the rule as noted in Section C. Applies throughout Clay, Platte, and Jackson Counties.

Notes:

NO_X = Oxides of nitrogen.
VOC = Volatile organic compounds.

Source: MDNR 2009.

3.16.3 Common Pollutants Emitted during Sand and Gravel Operations

Air pollutants of concern associated with sand and gravel operations include carbon monoxide (CO), nitrogen oxides (NO_X), ozone, and particulate matter (PM). The federal government has set standards for six commonly found criteria air pollutants: CO, nitrogen dioxide (nitrogen dioxide is a species of NO_X), ozone, sulfur dioxide (SO_2), PM, and lead (Pb). In addition, dredging operations generate toxic air contaminates (TACs) and GHGs. Ozone and NO_X typically affect air quality on a regional scale, while CO, TACs, and PM tend to accumulate locally.

Table 3.16-5 Pollutants Commonly Emitted during Sand and Gravel Operations

Pollutant	Comments
Ozone	• Respiratory irritant not emitted into the air, but formed by a photochemical reaction in the atmosphere between ozone precursors (reactive organic gases [ROG]/volatile organic compounds [VOC] and NO_X) and sunlight. • Pollutant of greatest concern within the Project area.
Carbon monoxide (CO)	• Local pollutant combines readily with hemoglobin. • Reduces amount of oxygen transported in bloodstream. • High CO levels develop primarily during winter, when atmospheric dispersion is reduced due to cold temperatures and light winds.
Nitrogen oxides (NO_X)	• Major component of acid rain and ground-level ozone. • Considerable human health risks, including chronic bronchitis and lung irritation.
Particulate matter (PM)	• High concentrations can reduce visibility and corrode materials. • Inhaled particulate matter less than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$) in diameter can damage human and animal lung tissue.
Toxic air contaminates (TACs)	• Pollutants that may result increased mortality or serious illness or may pose potential hazard to human health. • Diesel particulate matter (DPM) from heavy use of diesel-powered combustion engines during dredging operations is the TAC of greatest concern.
Greenhouse gases (GHGs)	• Most common GHGs generated by dredging activities are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). • CO_2 accounts for more than 75% of all anthropogenic GHG emissions. • GHGs emissions typically reported in terms of carbon dioxide equivalents (CO_2e). • Scientific consensus concludes that emissions of GHGs directly contribute to climate change and global warming.

Note:
For more information on these and other pollutants, please see USEPA 2009a, 2009b, and 2010.

GHGs are the only pollutants considered to affect air quality on a global scale. This is because GHGs can reside in the atmosphere for hundreds of years and thus be dispersed throughout the globe. Table 3.16-5 briefly describes the characteristics of each of these pollutants, as well as any concerns they pose to human health or the environment.

3.16.4 Local Air Quality Conditions

Existing local air quality conditions can be characterized by local air monitoring data and emissions associated with existing sand and gravel operations. A discussion of local existing air quality conditions

helps to identify the overall air quality conditions within the Project area and how emissions associated with the Proposed Action and alternatives may degrade air quality.

3.16.5 Local Air Monitoring Data

The existing air quality conditions along the LOMR can be characterized by monitoring data collected in the region. The USEPA maintains an extensive network of monitoring stations throughout the United States that monitor criteria air pollutants. Tables 3.16-6 through 3.16-9 summarize air quality monitoring data from the nearest monitoring stations along the LOMR for the last 3 years. Data are presented for each pollutant of concern (ozone, PM_{10}, $PM_{2.5}$, and CO) monitored at the respective station. Note that not all stations monitor for the same pollutants. As indicated in Table 3.16-6, monitoring stations in the Project area have indicated frequent violations of federal ozone standards, while Tables 3.16-7 through 3.16-9 indicate no violations of the PM_{10}, $PM_{2.5}$, and CO standards, respectively.

Table 3.16-6 Background Ambient Air Quality Data for 8-Hour Ozone

Air Resources Board Air Monitoring Station	Maximum 8-Hour Concentration (ppm)			Second Highest 8-Hour Concentration (ppm)			Number of Days Exceeding 8-Hour NAAQS (0.075 ppm)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Maryland Heights—St. Louis County	0.09	0.10	0.07	0.08	0.10	0.07	15	20	1
General Electric Store—St. Charles County	0.09	0.09	0.08	0.09	0.09	0.07	19	24	4
Orchard Farm—St. Charles County	0.09	0.09	0.08	0.09	0.08	0.07	12	14	2
Highway 33 and County Home Road—Clay County	0.10	0.09	0.07	0.09	0.08	0.07	23	10	0
2010 Metropolitan—Leavenworth County	0.08	0.09	0.06	0.08	0.08	0.06	3	6	0
1210 N 10th Street, JFK Recreation Center—Wyandotte County	0.09	0.07	0.06	0.08	0.07	0.06	10	3	0

Notes:

NAAQS = National Ambient Air Quality Standards.
ppm = Parts per million.

Source: USEPA 2009c.

Table 3.16-7 Background Ambient Air Quality Data for PM10

Air Resources Board Air Monitoring Station	Annual Average (µg/m³)			Maximum National 24-Hour Concentration NAAQS (150 µg/m³)			Days Exceeding NAAQS (>150 µg/m³)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
3400 Pershall Road—St. Louis County	15	17	18	33	55	60	0	0	0
South 759 Highway, Pump Station—Buchanan County	30	29	32	76	68	88	0	0	0
Fire Station #3—Wyandotte County	40	35	32	92	92	80	0	0	0
1210 N 10th Street, JFK Recreation Center—Wyandotte County	31	29	26	80	63	53	0	0	0
724 Troost (Rear)—Jackson County	23	27	24	58	51	56	0	0	0
27th and Van Brunt—Jackson County	19	20	21	40	38	51	0	0	0

Notes:

µg/m³ = Microgram(s) per cubic meter.
NAAQS = National Ambient Air Quality Standards.

Source: USEPA 2009c.

Table 3.16-8 Background Ambient Air Quality Data for $PM_{2.5}$

Air Resources Board Air Monitoring Station	Annual Average(ppm)			Maximum 24-Hour Concentration			Days Exceeding NAAQS (>35 µg/m³)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
General Electric Store—St. Charles County	11.56	13.20	12.24	32.0	49.7	28.0	0	0	0
Highway 33 and County Home Road—Clay County	10.49	11.07	10.41	27.3	31.3	28.2	0	0	0
South 759 Highway, Pump Station—Buchanan County	12.03	12.05	12.41	27.4	34.6	29.6	0	0	0
1210 N 10th Street, JFK Recreation Center—Wyandotte County	11.64	11.86	10.43	26.9	25.8	25.8	0	0	0

Notes:

µg/m³ = Microgram(s) per cubic meter.
NAAQS = National Ambient Air Quality Standards
ppm = Parts per million.

Source: USEPA 2009c.

Table 3.16-9 Background Ambient Air Quality Data for CO

Air Resources Board Air Monitoring Station	Maximum 1-Hour Concentration			Days Exceeding NAAQS 1-hour (35 ppm)			Days Exceeding NAAQS 8-hour (>9.0 ppm)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
1210 N 10th Street, JFK Recreation Center—Wyandotte County	3.5	3.0	2.2	0	0	0	0	0	0

Notes:

NAAQS = National Ambient Air Quality Standards.
ppm = Parts per million.

Source: USEPA 2009c.

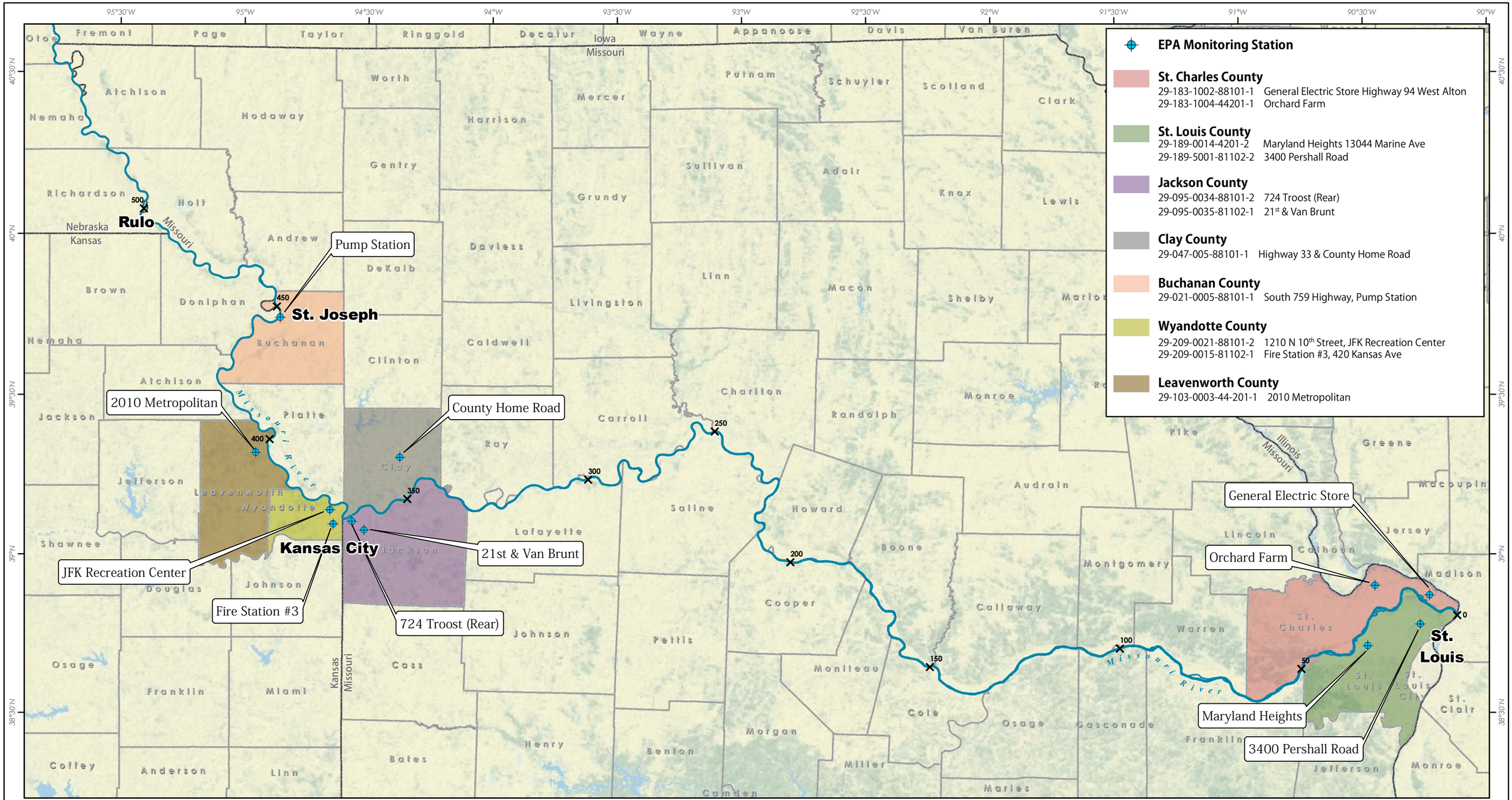
The location of the monitoring stations relative to the LOMR is depicted in Figure 3.16-1. As shown in the figure, the majority of the stations are concentrated near the major metropolitan areas of St. Louis and Kansas City. Consequently, data are limited for the much of the Project area. Given the rural character of the region, however, it can be assumed that pollutant concentrations along much of the LOMR are relatively low.

3.16.5.1 Existing Emissions from Current Dredging Operations

Dredging is a current and ongoing activity along the LOMR. Consequently, existing air quality is affected by current dredging operations and their associated effects.

Emissions from existing sand and gravel operations were estimated by dividing operations into three activities:

- Dredging (removal of sand and gravel from the river bed and transport of that material onshore);
- Onshore materials handing (use of earth-moving equipment to transport the dredged material); and
- Hauling sand and gravel.
- Emissions from each of these activities were estimated using information supplied by the Dredgers and source material from prior studies (ICF International 2009; Starcrest Consulting 2007, 2009). When companies did not supply complete information, assumptions were made using the most conservative scenarios so that potential emissions would not be underrepresented.



0 20 40 60 80 100 Miles

0 50 100 150 Kilometers

Figure 3.16-1
USEPA Air Quality Monitoring Stations
Missouri River Commercial Dredging EIS

February 2011

Cardno ENTRIX
www.cardno.com
Map Projection: Mercator, WGS84

Note that emissions from onshore facilities, such as fugitive dust from processed materials and air pollutants from the maintenance and upkeep of offices and employee vehicle trips, would be generated from facility operations. Dust emissions can occur during materials processing. However, these materials are typically wet or moist when handled, which serves to minimize and suppress dust emissions. Information on facility upkeep was not provided by the existing companies; consequently, these types of emissions were not included in this emissions analysis. However, any criteria pollutant or GHG emissions generated by these facilities are expected to be minimal compared to soil hauling activities and operation of dredging equipment.

Table 3.16-10 presents existing emissions from dredging, onshore materials handling, and sand and gravel hauling by river segment. Please refer to Section 4.14 and Appendix D for a detailed description of the methodologies and assumptions used in the emissions modeling for existing sources, which is consistent with the methodology used to estimate emissions associated with the Proposed Action and alternatives.

Table 3.16-10 Estimated Existing Emissions Inventory by River Segment (tons/year)

Segment	Source	VOC	NO_X	CO	PM_{10}	$PM_{2.5}$	CO_2e[a]
RM 489							
St. Joseph[b]	Dredging	0.48	11.40	5.62	0.64	0.59	823
	Handling	0.57	5.95	2.44	0.47	0.39	801
	Hauling	0.29	3.76	1.09	0.20	0.18	0.31
	Subtotal	*1.34*	*21.11*	*9.15*	*1.31*	*1.16*	*1,624*
RM 383							
Kansas City[c]	Dredging	3.87	92.72	45.69	5.22	4.80	6,692
	Handling	1.15	11.89	4.88	0.95	0.78	1,603
	Hauling	2.66	34.11	9.93	1.79	1.61	2.80
	Subtotal	*7.67*	*138.73*	*60.50*	*7.96*	*7.19*	*8,297*
RM 350							
Waverly[d]	Dredging	0.60	16.40	6.72	0.74	0.68	1,216
	Handling	0.95	9.26	4.17	0.79	0.65	1,234
	Hauling	0.33	4.24	1.24	0.22	0.20	0.35
	Subtotal	*1.88*	*29.91*	*12.13*	*1.75*	*1.53*	*2,450*

Table 3.16-10 Estimated Existing Emissions Inventory by River Segment (tons/year)

Segment	Source	VOC	NO_X	CO	PM_{10}	$PM_{2.5}$	CO_2e[a]
RM 254							
Jefferson City[e]	Dredging	1.55	42.72	18.31	1.89	1.74	3,222
	Handling	2.48	24.47	10.78	2.05	1.69	3,269
	Hauling	1.41	18.15	5.28	0.95	0.85	1.49
	Subtotal	*5.45*	*85.33*	*34.38*	*4.90*	*4.29*	*6,493*
RM 127							
St. Charles[f]	Dredging	3.48	102.96	21.40	4.32	3.98	7,263
	Handling	4.44	45.67	18.93	3.66	3.01	6,775
	Hauling	1.48	18.96	5.52	1.00	0.89	1.56
	Subtotal	*9.40*	*167.58*	*45.85*	*8.98*	*7.88*	*14,039*
Total		26	443	162	25	22	32,904

Notes:

CO = Carbon monoxide.
CO_2e = Carbon dioxide equivalent.
NO_X = Nitrogen dioxide.
PM_{10} = Particulate matter less than 10 microns.
$PM_{2.5}$ = Particulate matter less than 2.5 microns.
RM = River mile.

VOC = Volatile organic compounds.[a] Presented in metric tons per year.

[b] Companies with dredging activity: Holliday Sand & Gravel Company.
[c] Companies with dredging activity: Holliday Sand & Gravel Company.
[d] Companies with dredging activity: Capital Sand Company.
[e] Companies with dredging activity: Capital Sand Company and Hermann Sand & Gravel.
[f] Companies with dredging activity: Capital Sand Company, Hermann Sand & Gravel, Limited Leasing, and J.T.R.

Please see Section 4.14 and Appendix D for further detail on company operations and quantification methods.

3.16.6 Climate and Meteorology in the Missouri River Basin

Although the primary factors that determine air quality are the locations of air pollutant sources and the amount of pollutants emitted from those sources, meteorological conditions (such as precipitation, wind, and temperature) and topography also are important factors. For example, atmospheric conditions (such as wind speed, wind direction, and air temperature gradients) interact with the physical features of the landscape to determine the movement and dispersal of air pollutants. This section discusses the meteorological conditions and topography in the Missouri River Basin, which includes the Project area.

The discussion focuses on the southeastern portions of the basin, where monitoring data indicate pre-existing air quality concerns (see Tables 3.16-6 through 3.16-9).

3.16.6.1 Topography

The Missouri River Basin has exceptionally rugged topography along its westernmost borders, as well as rolling plains in the interior. The southern and eastern portions of the basin are classified as the central lowlands. The central lowlands include approximately 90,000 square miles and extend from Jamestown, North Dakota eastward to the divide between the Missouri and Mississippi Rivers. The area is relatively level with general rolling till-plains (USACE 2006).

Topographical features, such as surrounding hills, create areas of high pollutant concentrations by hindering their dispersal. Nearby hills can affect airflow by causing shallow vertical mixing, directing surface air flows, and creating areas of high pollutant concentrations. Because the topography along the LOMR is relatively flat, it serves to promote pollutant dispersion and prevent stagnant air masses that trap pollutants near the ground.

3.16.6.2 Precipitation

Given its extensive area, the basin experiences a large range of average annual precipitation. Along the LOMR, average annual precipitation is highest near the confluence of the Mississippi River. In particular, areas south of Jefferson City receive approximately 40–50 inches of precipitation, and the region between Jefferson City and Lincoln receives approximately 30–40 inches of precipitation. June is generally the wettest month, when much of the southeastern portion of the basin receives more than 5 inches of precipitation.

Summer precipitation is generally dominated by short-duration thunderstorms with small centers of high intensity. Widespread rains occur occasionally through October, especially in the lower basin. Precipitation depths during winter months are considerably less than during summer months. In the southeastern portion of the basin, January is typically the driest month. Winter precipitation occurs as either rain or snow, or a mixture, and is a result of well-developed low-pressure systems and active fronts (USACE 2006).

Heavy rains during summer help to reduce certain pollutant concentrations along the LOMR. Ozone needs sunlight for its formation, and clouds block the required radiation. Because CO is slightly water

soluble, precipitation and fog tend to "reduce" CO concentrations in the atmosphere. Finally, PM_{10} is somewhat "washed" from the atmosphere with precipitation.

3.16.6.3 Wind

Because the Project area is located mid-continent, the most extreme winds are caused by thunderstorms and frontal passages (movement of a front across an area), as well as air flows from a variety of bordering regions. For example, the area is subject to warm air with high humidity from the Gulf of Mexico and dry air from the arid southwest. Systems originating over the Rocky Mountains also bring warm dry air to the region and create northwesterly surface winds. Occasionally, abnormally cold air will enter the region from a northeasterly direction. In general, the wind flow from one region will last for a few days before being replaced by a different air flow from another region. Wind speed and direction influence the dispersion and transport of PM and CO: the more wind flow, the less accumulation of these pollutants.

3.16.6.4 Temperature

Similar to precipitation patterns, large temperature fluctuations and extremes are common in the basin. Along the LOMR, average annual maximum temperatures are experienced during summer and range from 95 to 105 °F. Average winter lows range from minus 29 to minus 10 °F, with the coldest temperatures along the northern reaches of the Project area (USACE 2006).

The extreme temperatures along the LOMR tend to exacerbate formation of ozone and accumulation of CO. High temperatures during summer months, combined with stagnant air, provide conditions suitable for formation of ozone. During winter, extremely cold temperatures and light winds form ground-level temperature inversions (typically from the evening through early morning) that result in reduced dispersion of CO emissions from vehicles. Motor vehicles also produce increased CO emission rates at low air temperatures.

3.16.7 Sensitive Receptors

Sensitive receptors are generally defined as locations where people reside or where the presence of air emissions could adversely affect the use of the land. Sensitive receptors are locations and land uses that are more susceptible to health problems associated with air pollutants. Typical sensitive receptors include residences, schools, hospitals, clinics, and housing for elderly.

Sensitive receptors that may be exposed to increased levels of pollutants during dredging activities include residences, schools, and parks located along the river edge. In general, these sensitive receptors are concentrated in major cities. However, scattered rural residences are located throughout the undeveloped agricultural land along the river.

Table 3.14-3 in Section 3.14 summarizes the cities and towns located along the river where sensitive receptors may be concentrated. In addition, Table 3.14-3 identifies the distance between existing sand and gravel facilities and the nearest residences. Residences and other sensitive land uses within 0.5 mile of dredging-related operations may be exposed to increases in pollutant concentrations.

3.16.7.1 Climate Change

Only recently has climate change been widely recognized as an imminent threat to the global climate, economy, and population. Thus, the climate change regulatory setting—nationally and statewide—is complex and evolving, and the Proposed Action and alternatives are currently not subject to any GHG regulation. The following section identifies key legislation, executive orders, and seminal court cases relevant to the environmental assessment of Project-related GHG emissions.

Federal Regulatory Setting for Greenhouse Gas Emissions

Federal Action

In 2002, President George W. Bush set a national policy goal of reducing the GHG emission intensity (tons of GHG emissions per million dollars of gross domestic product) of the U.S. economy by 18 percent by 2012. No binding reductions were associated with the goal. Rather, the USEPA administers a variety of voluntary programs and partnerships with emitters of GHG in which the USEPA collaborates with industries producing and using synthetic gases to reduce emissions of these particularly potent GHGs.

On September 30, 2009, the USEPA proposed a new rule that would establish significance thresholds for six GHGs. The rule would define when CAA permits under the New Source Review (NSR) and Title V operation permit programs would be required for new and existing facilities. The proposed threshold is 25,000 tons of carbon dioxide equivalent (CO_2e) per year. Facilities exceeding this threshold would be required to obtain a permit that would demonstrate they are using Best Management Practices (BMPs). The USEPA estimates that 14,000 large sources would need to obtain permits, the majority of

which would be municipal solid waste landfills. The USEPA is evaluating the proposal and will issue final guidance once a ruling has been made (USEPA 2009g).

USEPA Proposed Rule – Mandatory Greenhouse Gas Reporting

On October 30, 2009, the USEPA signed a rule that requires mandatory reporting of emissions of GHGs from large sources in the United States. Under the rule, suppliers of fossil fuels or industrial GHGs, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions are required to report annual emissions to the USEPA. The rule went into effect on January 1, 2010. The first annual reports for the largest emitting facilities, covering calendar year 2010, will be submitted to USEPA in 2011.

USEPA Finding of Endangerment

On December 7, 2009, the USEPA Administrator found that current and projected concentrations of GHGs threaten the public health and welfare of current and future generations. Additionally, the Administrator found that combined emissions of CO_2, CH_4, N_2O, and fluorinated compounds from motor vehicles contribute to the atmospheric concentrations and thus to the threat of climate change. Although the endangerment finding in itself does not place requirements on industry, it is an important step in the USEPA process to develop regulation of GHGs.

The USEPA has prepared various documents in support of the endangerment finding, including a *Summary of the Science Supporting EPA's Finding that Greenhouse Gases Threaten Public Health and Welfare* (USEPA 2009h). The summary notes that "Climate change is expected to worsen regional ozone pollution, with associated risks in respiratory infection, aggravation of asthma, and premature death. The impact on particulate matter remains less certain."

Draft NEPA Guidance

On February 18, 2010, Nancy Sutley, Chair of the White House Council on Environmental Quality (CEQ), issued a memorandum (Draft Guidance) providing guidance on consideration of the effects of climate change and GHG emissions under NEPA. The Draft Guidance suggests that the effects of projects directly emitting GHGs in excess of 25,000 tons annually be considered in a qualitative and quantitative manner. The CEQ does not propose this reference as a threshold for determining significance but as "a minimum standard for reporting emissions under the CAA." The Draft Guidance also recommends that the cumulative effects of climate change on the proposed project be evaluated.

The Draft Guidance is still undergoing public comments and is not effective until issued in final form (Sutley 2010).

State Regulatory Setting for Greenhouse Gas Emissions

According to the MDNR, KDHE, NDEQ, and IEPA, no agency has adopted state GHG regulations applicable to the Proposed Action or alternatives (Basham pers. comm., Schnepp pers. comm.). Further consultation with agency staff indicates that Missouri, Kansas, Nebraska, and Illinois will develop GHG emission rules and regulations following more definitive federal guidance. In the interim, all agencies recommend and support voluntary GHG emission reductions efforts.

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