4.6 AQUATIC RESOURCES

4.6.1 Introduction

The aquatic resources impact analysis addresses direct and indirect consequences to the quality and quantity of aquatic habitats and organisms resulting from dredging. The analysis provides the basis for understanding the extent, duration, and degree of impact from dredging under the Proposed Action and the alternatives.

Dredging could directly affect fish and benthic invertebrates by capturing and removing aquatic organisms via the dredge head or push boat propeller (entrainment), causing injury or mortality (Section 4.6.3.1 and 4.6.3.2). Dredging also may cause behavioral changes of aquatic organisms because of dredging noise and physical habitat disturbance (Section 4.6.3.3). Potential indirect effects include changes to aquatic habitats due to river bed degradation. Direct impacts would be limited to the period during or shortly after dredging and typically would be localized and temporary. Indirect impacts could occur in localized areas or river-wide and could extend in time from short term (approximately 5 years) to long term (approximately 20 years).

The potential effects of dredging on aquatic resources were evaluated for both aquatic habitat and species. For the purpose of this analysis, it is important to note that there still is uncertainty regarding aquatic species habitats, distribution, and their response to dredging in the LOMR. Aquatic resource impacts would be linked to changes in water quality (Section 4.5) and geomorphology (Section 4.2). Water quality impacts that could affect individuals include potential temporary elevated levels of suspended sediment. Geomorphic impacts that could affect aquatic habitat include changes in river bed elevation and the associated changes in water surface elevations.

4.6.2 Potential Impacts on Aquatic Habitat

In addition to direct habitat disturbance from dredging, potential indirect impacts to aquatic habitat—particularly shallow-water habitat—may be associated with river bed degradation (USACE 2009). The potential indirect alteration of shallow water habitat is discussed fully in Section 4.6.2.2. These indirect impacts to aquatic habitat also could result from potential geomorphic changes that alter shallow-water connectivity due to changes in surface water levels. Data have not been collected documenting the quantity of shallow-water habitat present in the LOMR, or the potential quantity of shallow-water habitat that would be lost or gained due to river bed degradation (USACE 2009); therefore, the potential dredging-related effects of dredging and river bed degradation cannot be fully quantified at this time.

4.6.2.1 Direct Alteration of Habitat

As discussed in Section 3.4, the main channel benthic habitat of the LOMR is a dynamic system in which the bed load and associated benthic habitats often are changing. Benthic fish use habitats in and adjacent to main channels, where dredging is primarily concentrated, with environmental conditions that can include bed load sediment transport and high near-bed flow velocities (Hurley et al. 2004). Macroinvertebrate density and diversity increase with sediment stability, decreased water velocities, and increasing silt and organic matter (Galat et al. 2005); therefore, macroinvertebrate diversity and density are likely to be reduced in the channelized LOMR main channel, compared to unchannelized and shallow-water habitats. Further, these species are typically found on hard substrates, opposed to shifting sand substrates (such as in those areas where dredging occurs [Galat et al. 2005]).

The magnitude and duration of direct impacts on aquatic habitat at the dredge site would be determined by the time required for recovery and repopulation of the benthic areas (USACE 1978). Typically, the more naturally variable an aquatic habitat, the less the direct effect of dredging on that habitat (USACE 1978). Aquatic organisms common to these naturally variable areas are adapted to unstable sediment conditions and can better withstand the stresses imposed by dredging (USACE 1978). Thus, due to the high level of variability in the benthic habitats in the LOMR, aquatic species present in these habitats are likely be better able to withstand and recover from the localized alteration of benthic habitat due to dredging. Current dredging is largely restricted, and is likely to be restricted under the new permits, from shallow-water habitat (as discussed in Section 4.6.2.2), in side channel areas, at tributary junctions, and near dikes and revetments. The maintenance and establishment of these chutes and side channel areas that mimic historical depth and velocity patterns in the LOMR would assist in the restoration and maintenance of native fish communities (Latka, Nestler, and Hesse 1993).

Many areas of coarse aggregate sediments (e.g., cobble and bedrock) that substrate-spawning species (e.g., sturgeon and sauger) are known to use are found on outside bends that are constantly flushed free of fine sediment (DeLonay et al. 2009). As discussed in Chapter 2, multiple dredging exclusion areas have been established for recent dredging activities, and these exclusion areas are likely to be continued under future dredging actions (if approved), to protect course aggregate sediments. Laustrup, Jacobson, and Simpkins (2007) surveyed the LOMR during low water conditions to identify and map coarse substrate deposits and bedrock exposures. These particular areas likely would serve as coarse aggregate spawner habitat, although preferred spawning habitat for various species has not been definitively identified in the LOMR (Laustrup, Jacobson, and Simpkins 2007). A GIS coverage of the locations of aggregate areas was overlain with the dredge areas (assuming that future dredging

under all alternatives [except the No Action Alternative] would occur in the vicinity of historically dredged areas) to estimate the quantity of dredging that would occur in areas containing potential spawning habitat. Approximately 219 acres of aggregate were identified in the Project area between Rulo, Nebraska and St. Louis, Missouri. Of this quantity, a small amount (approximately 0.4 percent [0.8 acre]) of potential aggregate spawning habitat was found to be potentially subject to dredging. This would represent a small quantity of the mapped aggregate habitat in the Project area.

Dredging also can result in short-term and long-term changes to benthic substrate composition downstream of dredging sites. Alterations of benthic substrate can diversify local benthic habitats. As dredging removes sand and gravel, coarser-grained material is returned to the river bed (see Section 4.2). Depending on the type of dredge, coarse material is deposited on the river bed below the dredge or to the side of the dredge. As a result, rows of coarse material can form on the river bottom as the dredge moves up and down the river. Bed sediment also can become coarser below dredging operations as finer material is picked up by the river to replenish what was deposited in the dredging depression (Kondolf 1997). These effects are relatively local and tend to accumulate in the areas with the most dredging (Simons, Li, and Associates 1985); they can result in a localized alteration of benthic habitat used by aquatic species. Data have not been collected in the LOMR to definitively characterize the dispersal patterns of coarse-grained sediment after dredging or determine how areas with altered sediment concentrations are used by aquatic species.

4.6.2.2 Indirect Alteration of Shallow-Water Habitat Abundance

Riverine habitat loss or alteration in the LOMR has been implicated in the loss of several native Missouri River fishes (Johnson, Jacobson, and DeLonay 2006). Many of the resource management and restoration plans currently in place identify and attempt to mediate processes that operate both at the coarse scale (e.g., land use and flow modification) and at finer scales (e.g., localized habitat restoration and connection to the floodplain) (Pegg and Taylor 2007).

As discussed in Section 3.8, shallow-water habitat is an important riverine habitat in the LOMR that provides for primary and secondary productivity, forage fish production, and early life stage development for native Missouri river fishes (Jacobson, Blevins, and Bitner 2008; Johnson, Jacobson, and DeLonay 2006; Hesse et al. 1993, 1989; Galat et al. 2005). Shallow-water habitat is recognized as a highly underrepresented aquatic habitat type that was characteristic of the historic Missouri River (USACE 2010). Historical changes, such as flow alterations and channelization of the LOMR, likely have substantially decreased the availability of shallow, slow-moving water (Johnson, Jacobson, and DeLonay 2006). Further, the LOMR has been and still is affected by reduced sediment inputs; these

are important to creating and maintaining the diversity of habitats used by native fish such as the pallid sturgeon for reproduction and survival (USFWS 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) (USFWS 2003) indicated that the portion of the LOMR between the Platte River, Nebraska and the LOMR confluence with the Mississippi River is lacking sediment transport and sediment availability, which adversely affects pallid sturgeon habitat development and maintenance (USFWS 2003). Further, USFWS has stated that larval and juvenile pallid sturgeon are limited by the quantity of shallow-water habitat that provides rearing and refugia habitat (USFWS 2003). Shallow-water habitat is defined as aquatic habitat that is less than 5 feet deep with velocities of less than 2 feet per second as measured during the August median discharge (USFWS 2003). A recent clarification to the definition further defines shallow-water habitat as habitat with a high degree of diversity in depths and velocity that contains dynamic alluvial processes. While the USFWS in the 2003 Biological Opinion concluded that pallid sturgeon are limited by the lack of shallow-water habitat, others have indicated that additional studies and modeling are needed to clearly establish which aquatic habitats are limiting to the survival of sturgeon and other native fish populations (Johnson, Jacobson, and DeLonay 2006; DeLonay et al. 2009).

As discussed in Section 3.4, river flows and the corresponding river stage fluctuates daily, seasonally, and annually. Within the highly modified LOMR, the presence of shallow-water habitat is highly sensitive to flow regime (Johnson, Jacobson, and DeLonay 2006, Jacobson and Galat 2006). Availability of shallow-water habitat is high at the lowest discharges when water is shallow and slow over marginal sand bars and when river discharges are just over bankfull stage (Johnson, Jacobson, and DeLonay 2006, Jacobson and Galat 2006). As river flows and stages change, the quantity of aquatic habitat with shallow-water and slow velocities changes. Additional studies are underway in the LOMR to better understand the role and importance of SWH and its locations, relationship to channel morphology, and flows (DeLonay et al. 2010).

The LOMR is managed for shallow-water habitat, and several programs have been implemented (such as the MRRP) to create shallow-water habitat through mechanical techniques and LOMR flow modification (MRRP 2007). Shallow-water habitat is being created by a variety of mechanisms, including excavation of side channel chutes, dike notching, bank notching, and construction of chevrons (Jacobson, Johnson, and Dietsch 2009). The Reasonable and Prudent Alternatives in the 2000 and

Revised 2003 BiOps required reconstruction or rehabilitation of 20 percent of the SWH that existed prior to construction of the BSNP. The project area for the Shallow Water Habitat Program extends from near Ponca, Nebraska downstream to the mouth of the Missouri River at St. Louis. Plans are to ensure that 20–30 acres of shallow/slow-water habitat per river mile exist below Ponca, Nebraska by 2020 to meet this requirement; the program is generally on target as of 2010 (NAS 2010).

As discussed above, the 2003 Biological Opinion indicated that the LOMR is lacking sediment transport and sediment availability (USFWS 2003). Creation and maintenance of shallow-water habitat are brought about by sediment transport and deposition, which has been reduced (USFWS 2003). As sediment is removed from active transport, the river erodes material from the river bed downriver from the dredged area to replace the material removed from active transport (see Section 3.4). Hesse et al. (1989) suggest that restoration of sediment flow into the free-flowing portions of the Missouri River below dams may contribute organic matter to downstream habitats.

River bed degradation also can alter the quantity of shallow-water habitat in the LOMR (USACE 2009). River bed degradation can worsen the adverse biologic impacts of channelization by reducing the amount of shallow-water habitat available for primary production of plankton and invertebrates, and fish spawning and nursery areas (USACE 2009). Hesse et al. (1989) indicated that river bed degradation in the free-flowing portions of the Missouri River eliminated many backwater and subsidiary channels. Continued riverbed degradation could affect the long-term stability and functioning of shallow-water habitat restored by the MRRP (USACE 2009). As described above, for some of the river located outside of the navigation channel, depths are greater than 5 feet in August. Therefore, the low-flow water surface elevations caused by river bed degradation could expose some shallow-water habitat, while shallow-water habitat in other areas could be created. Although this response of shallow-water habitat to alterations of surface water flow may be occurring, it is important to note that these effects cannot be quantified at this time, and that additional studies are needed to fully determine and quantify the impacts of river bed degradation on shallow-water habitat (USACE 2009). For the purposes of the effects analysis, it was assumed that river bed degradation, in conjunction with the local (reach-scale) removal of sand and gravel, could affect the quantity and distribution of natural or created SWH in the LOMR. Because the linkage between river bed degradation, sediment availability, and the quantity of SWH has not been quantified, levels of potential river bed degradation were used in the Section 4.6.5 as a proxy for the potential for changes in the quantities of shallow-water habitat. .

Potential river bed degradation, in conjunction with the removal of potential shallow-water habitat forming base load sediments, may change the quantity and distribution of natural or created shallow-

water habitat in the LOMR. In those river segments with increased dredging-related river bed degradation, the quantity of natural or created shallow-water habitat could decrease because of river bed modification. However, because the rate of erosion of natural and created shallow-water habitat from river bed degradation is not known at this time, the expected rate of erosion of these habitats due to the Proposed Action or Alternative A, B, or C cannot be determined.

4.6.2.3 Sand Plant Construction

Sand plant construction under the Proposed Action and Alternatives A, B, and C will require land-clearing activities that could result in overland runoff or erosion from uncontained storm water. In general, the potential introduction of contaminants to adjacent water bodies could result in changes in holding, feeding, or migratory behavior of fish (Kondolf 2006).

A bedrock patch on an outside meander bend is located approximately 1 mile downstream of The Master's Dredging Company proposed sand plant at Waldron. Fish using this potential spawning habitat may be exposed to elevated suspended sediment from storm water runoff during construction. However, elevated suspended sediment from sand plant construction is not anticipated to result in a substantial impact to this habitat due to its distance downstream from the proposed sand plant.

Overall, due to the best management practices and storm water permitting that would be required during construction of the proposed sand plants—in conjunction with the background flows and natural suspended sediment levels in the LOMR, sand plant construction is not anticipated to result in a significant impact to aquatic organisms or their habitats. Therefore, potential impacts associated with construction of sand plants are not evaluated further in this section.

4.6.3 Potential Impacts on Aquatic Species

Potential direct impacts on individual aquatic species include entrainment, alterations of habitat from increased turbidity, and behavioral changes due to increased noise. Benthic organisms (fish and macroinvertebrates) living near the river bottom or in the substrate in the main channel areas could be subject to entrainment during dredging. The individual's response to elevated suspended sediment would be determined by the size, shape, and duration of the elevated suspended sediment plume, the tolerance of the fish, and the location of the dredge areas.

4.6.3.1 Dredge Entrainment

Removal of substrate and benthic organisms at the dredging site by the dredge (entrainment) would result in immediate localized effects on the benthic community (USACE 1998a, Harvey and Lisle 1998). This direct effect on benthic organisms would be confined primarily to the mid-channel areas where dredging would be allowed.

Intake water velocity and the organism's susceptibility to entrainment in the intake water flow are the primary determinant for entrainment; but secondary variables affecting swimming behavior and performance also could influence and determine species' entrainment rates (Boyson and Hoover 2009). Site-specific physical factors, such as a constricted river area, biological factors, such as habitat near the dredge, and dredge operation and type would also determine the rate of entrainment (USACE 1998a). Fish may swim toward the dredge head for various reasons including visual, electro-receptive, or audible stimulation (Boyson and Hoover 2009). Boyson and Hoover (2009) identified the need for future research to evaluate the effect of these variables on entrainment rates.

The USACE conducted dredging entrainment susceptibility studies of sturgeon and paddlefish species (Hoover et al. 2005). Researchers found that the rate of fish entrainment would be determined, in part, by the organism's location relative to the dredge in the water column, its swim speed, and whether the species readily swims against the current (rheotaxis) (Hoover et al. 2005). While these factors are important to determining entrainment levels, other factors—such as the species' response to noise and turbidity, and its localized abundance and distribution—also would affect entrainment rates (Hoover et al. 2005). Although these results are likely to be applicable to other free-swimming aquatic organisms, it is important to note that swimming performance and behavior models are substantially different for each species; and recent studies have shown differences between populations of the same species (Boyson and Hoover 2009).

Cutter-head dredges can create a suction field effect of approximately 1.6 feet per second (50 centimeters per second) up to a distance of 4.9 feet (1.5 meters) from the dredge intake (Hoover et al. 2005). In the escapement studies conducted by Hoover et al. (2005), researchers found that many pelagic, free-swimming fish (such as paddlefish), with an escape speed equal to or greater than the intake velocity and those that are able to orient themselves with the flow would have a higher likelihood of escapement, compared to slow-moving fish (such as pallid sturgeon) that cannot orient themselves toward the dredge flow field. In a study that evaluated entrainment of white sturgeon, researchers found that similar variables dictated escapement rate for different life history stages of that species (Boyson and Hoover 2009). Boyson and Hoover (2009) found that smaller fish as a group, compared

to larger juveniles and adults, had less endurance and slower swim speeds, which increased their risk of entrainment.

The USACE (1998a) conducted a literature review of studies evaluating the effects of dredging entrainment on aquatic organisms. Entrainment ranges for various fish species have been reported to range from less than 0.001 fish per cubic yard to 0.594 fish per cubic yard of dredge extraction (USACE 1998a). In general, the literature review concludes that the results of the limited studies have been inconclusive in determining the absolute entrainment rates or the population-level consequences for larval, juvenile, and adult fish and aquatic invertebrates (USACE 1998a). Studies by the USACE to determine precise estimates of absolute entrainment rates found that additional studies are required to quantify entrainment rates and to identify any potential dredging windows that would minimize entrainment rates (USACE 1998a).

No definitive mortality estimates are available for the potential quantity or rate of fishes or their larvae that could be subject to entrainment from dredging in the LOMR. The most conservative assumption is that 100 percent of all entrained animals die; however, depending on the taxon, size, and age, entrainment processes may generate non-uniform mortalities (USACE 1998b).

In general, the USACE (1998b) concluded that dredging would not likely be a substantial problem for many fish or shellfish species in water bodies experiencing periodic dredging; however, dredging may pose a more substantial risk to some sensitive aquatic resources. As discussed throughout this section, species-specific entrainment rates and the site-specific factors that dictate entrainment rates are poorly understood. Studies showing the effects of entrainment at an individual or population level are lacking for many aquatic species and for the LOMR. As suggested by research on entrainment susceptibility (Hoover et al. 2005), entrainment impacts in the LOMR would likely be concentrated among those species and life history stages with an escape speed less than the intake velocity.

4.6.3.2 Propeller Entrainment

Dredge barges and transport barges (barges used for transporting excavated material to sand plants or other terminal locations) are anticipated to be positioned or moved using towboats (see Section 2.2.2). The effect of towboat propellers on fishes and other aquatic resources between the dredging sites and various sand plants is a concern associated with the magnitude of towboat traffic and the river channel geometry.

Studies on the upper Mississippi River found that towboats entrain large volumes of water through their propellers. Towboat propellers often exceed 8 feet (~2.5 meters) in diameter and were found to span between 20 and 100 percent of the depth of a confined navigation channel in the upper Mississippi (Gutreuter, Dettmers, and Wahl 2003). The area within which water is entrained by propellers (referred to as the "inflow zone") for tow barges on the Mississippi was found to extend approximately 20 percent wider than the beam of the tow from centerline (Maynord 2000).

Ship propellers cause abrupt changes in hydraulic patterns due to increased turbulence and water velocities, pressure changes, and shear forces (Maynord 1990, Hyun and Patel 1991). Ship propellers also can injure or kill fish if fish come in contact with the blades (Gutreuter, Dettmers, and Wahl 2003). Cada (1990) reported that fish eggs and larvae that pass through water currents induced by a propeller may come in contact with the blade and can experience stresses from pressure changes and shear forces. Killgore et al. (2001) evaluated mortality of icthyoplankton entrained through a scale model of a towboat propeller. They found mortality to be a linear function of shear stress for all species and life stages. Larger larvae (e.g., shovelnose sturgeon) experienced lower mortality, while smaller larvae (e.g., lake sturgeon and blue suckers) experienced higher mortality. All larval species experienced delayed mortality, particularly at higher stress levels. Killgore et al. (2001) concluded that shear stress caused by towboat traffic is probably a primary force contributing to the mortality of icthyoplankton entrained during vessel passage, but the magnitude of mortality is dependent on the individual size of icthyoplankton. The extent of mortality would be a function of the amount of tow traffic on a given river system, towboat speed, and traffic volumes during the period when larvae are most susceptible to shear stress (i.e., the early developmental phase) (Killgore et al. 2001).

Gutreuter, Dettmers, and Wahl (2003) developed a method to estimate mortality rates of adult fish from entrainment through propellers of commercial towboats. The method combined trawling for fish while following the towboats and the use of a hydrodynamic diffusion model. Trawling recovered a fraction of the fish killed by vessel traffic and the hydrodynamic model was used to estimate the fraction of total mortality collected in the trawls. Examining observed propeller entrainment rates in study locations on the Mississippi and Illinois Rivers, Gutreuter, Dettmers, and Wahl (2003) estimated entrainment mortality rates between 0.2 fish/ mile (0.13 fish/km) of towboat travel for skipjack herring (*Alosa chrysochloris*), 0.84 fish/mile (0.53 fish/km) for shovelnose sturgeon (*Scaphirhynchus platorychus*), and 4.0 fish/mile (2.52 fish/km) for gizzard shad (*Dorosoma cepedianum*). The estimation approach may apply broadly to commercial vessels operating in confined channels, including large rivers (Gutreuter, Dettmers, and Wahl 2003). No comparable propeller entrainment studies have been identified for the LOMR. Rates of entrainment on the LOMR may vary from these estimates based on site-specific and

species-specific conditions, including river hydrology, seasonal distribution of fish species, and the life history stage of particular fish species during the period of traffic.

4.6.3.3 Sound and Noise Impacts

Fishes produce and use sounds in a wide variety of behaviors (Zelick, Mann, and Popper 1999). Fish detect and respond to sound, utilizing its cues to hunt for prey, to avoid predators, and for social interaction. Sound production has been recently discovered in several species of sturgeon (Johnston and Phillips 2003). Pallid and shovelnose sturgeon produce sounds during the breeding season. In a naturally turbid environment such as the Missouri River, sound cues may play a significant role in communication.

Underwater human-caused noise has been documented to influence fish behavior in general (Nightingale and Simenstad 2001). Exposure to sound includes a measure of both the received level and the duration of the signal. For example, the received noise level can be expressed in terms of acoustic pressure, particle velocity, or intensity (energy flux), which all vary with time over the duration of the signal. Most noise impacts to fishes have been observed in situations of intense energy flux, such as construction-related pile driving or explosions, or propeller and engine noise from high-speed boats.

Dredging operations generally produce lower levels of sound energy over prolonged periods (Nightingale and Simenstad 2001). Nightingale and Simenstad (2001) conducted a literature review of potential dredging-related noise impacts on several fish species. The authors concluded that further research into the effects of noises specific to dredging are required to determine the potential effects of dredging noise on fishes. It is expected that noise from the operation of dredges—while not as intense as pile driving or explosions—may result in avoidance of the dredging area by fish species sensitive to noise over the duration of the activity. DeLonay et al (2009) document spring migrations of reproductive pallid sturgeon to be 10's to 100's of kilometers and migrations have been documented through some dredging reaches (such as Jefferson City, Waverly, and Kansas City). The effect of dredging, such as noise impacts, specifically on migrating reproductive sturgeon has not been documented (Jacobson personal communication).

Hearing generalists are fish that lack adaptations or have not developed hearing specializations to enhance auditory sensitivity. Hearing generalists generally cannot hear sounds above 500–1,500 Hz (depending on the species). Dredging noise occupies the mid- to low-frequency range, is tonal and continuous, and is likely tolerable by the hearing generalists.

Sturgeon have been reported to hear sound frequencies in the range of sounds produced by dredge operations (J. J. Hoover, unpublished data as cited in Boyson and Hoover 2009); and it has been reported that dredge sounds could attract, disperse, or cause sturgeon to rise in the water column (Boyson and Hoover 2009). However, adult pallid sturgeon have been observed using radio telemetry near dredge boats (DeLonay pers. comm.), which suggests that this species may not be particularly sensitive to dredging noise.

4.6.3.4 Elevated Suspended Sediment and Turbidity

Native organisms that evolved and are naturally associated with turbid environments typically are highly tolerant of elevated suspended sediment (USACE 1978). The highest suspended sediment loads in the downstream channelized section of the LOMR are only 0.2 to 17 percent of pre-dam values (Jacobson, Blevins and Bitner 2009). The combination of channelization and flow modifications in the LOMR has collectively resulted in a reduction of habitat and caused a substantial change in river species composition (Pegg and Taylor 2007). Species that have become more abundant as turbidity has decreased include site-feeding carnivores and pelagic planktivores, while some native big-river fishes with morphological adaptations to use high-turbidity and high-velocity main-channel habitats have declined (Galat et al. 2005). The reduction of turbidity in the LOMR has affected the capability of pallid sturgeon, and other native fish, to forage successfully, which has increased competition with other non-native species (USFWS 2003). Table 4.6-1 describes the various reproductive strategies for native and non-native fish found in the LOMR.

As described in Section 4.5, USACE sampling below a cutter-head dredge in the LOMR near the confluence of the Kansas and Missouri Rivers indicated that suspended solid concentrations typically returned to background concentrations within approximately 1,300 feet (USACE 1990). The size of the elevated suspended sediment plume downstream of the dredge depends on a variety of factors, including the hydrodynamic conditions of the dredging site, the type of dredge used, operational methods, and sediment type. It was concluded that fine sediment discharge likely would not be of sufficient quantity to differ substantially from the maximum natural suspended sediment levels in receiving waters. While dredging may result in a temporary, localized elevation of suspended sediment, these changes in water quality are not anticipated to differ substantially from naturally occurring levels. Studies conducted by the USACE found that most organisms studied were relatively insensitive to the effects of sediment suspensions in the water and that, in general, dredging-induced turbidity is probably not of major environmental concern in most cases (USACE 1978).

Table 4.6-1 Reproductive Strategies of Selected Common Fish in the Lower Missouri River

Open Substratum Spawners (Broadcast)	Open Substratum Spawners (Submerged Objects)	Brood Hiders (Redds)	Brood Hiders (Crevice Spawners)	Nest Spawners (Hole –Burrows)	Nest Spawners (Rock and Gravel)
• Blue sucker[a,b] • River carpsucker[b] • Brassy minnow • Sand shiner[b] • Pallid sturgeon[a,b] • Sauger[b] • Plains minnow[a,b] • Shorthead redhorse[b] • Shovelnose sturgeon[a,b] • Smallmouth buffalo[b] • W. Silvery minnow[a,b] • White sucker[b] • River shiner[a] • Emerald shiner • Silver chub[a] • Silverband shiner[a] • Goldeye • Bigmouth buffalo[b] • Freshwater drum[b] • Paddlefish	• Common carp • White bass	• Chestnut lamprey[a]	• Tadpole madtom[a] • Fathead minnow • Red shiner	• Blue catfish[b] • Channel catfish[b] • Flathead catfish[b] • Stonecat[b]	• Flathead chub[a,b] • Sicklefin chub[a,b] • Sturgeon chub[a,b] • Bluegill • Crappie

Note: "Reproductive strategy" is defined as a group with similar strategies to raise their young (i.e., parental care).

References: Common Missouri River species as identified in Section 3.8. Reproductive strategies determined from general species descriptions found at Montana Field Guide 2010, PFBC 2010, TSU 2010.

[a] Indicates that the fish is a state or federal special-status species.

[b] Indicates that the fish is also in the benthic fish guild.

Non-native fish species that are not as tolerant of elevated suspended sediment would be most affected by dredging if particular species are more sensitive to elevated suspended sediments (e.g., non-native bass may experience slowed egg development; non-native site feeders may experience reduced feeding success) (Blevins 2006). Depending on fish reproductive strategy (see Table 4.6-1), the physiological impacts associated with increased suspended sediments may include reduced fecundity and brood size in fish, and retarded development of eggs and larvae (Kerr 1995). Exposed fish eggs (broadcast strategy) are generally more sensitive (and vulnerable) than eggs buried in the substrate (nest or brood-hiding strategy) (Kerr 1995). Information is limited about the incubation

success of fish spawning in the LOMR in aggregate habitat, but non-native fish species that are not as tolerant of elevated suspended sediment, compared to native species, may be more sensitive to elevated turbidity levels.

As discussed above, native aquatic species evolved in the LOMR under historically turbid conditions, and turbid conditions that mimic the historical environment have largely been eliminated in the LOMR (see Section 3.7). Because of the historical context and role of suspended sediment in the LOMR system and the general reduction in suspended sediment in recent history, the introduction of suspended sediment, while localized to a short distance downstream of the dredge (see Section 4.5), would likely result in a temporary improvement in habitat conditions for native aquatic species.

4.6.4 Assessment Methods

Because aquatic resources and potential impacts to aquatic resources are specific to local conditions and shift according to season, migration, and flow conditions, potential consequences to these resources were evaluated in a qualitative fashion that includes a narrative discussion of potential impacts under each alternative scenario. Further, as discussed throughout Sections 4.6.2 and 4.6.3, most of the potential aquatic resource impacts from dredging cannot be quantified due to the lack of dredging-related impact data and LOMR-specific studies. Impacts to aquatic habitat are discussed at a general reach scale, while impacts to aquatic species are addressed at a local scale.

Individual organisms are primarily affected by the occurrences and magnitude of dredging activities, and primarily through localized direct and indirect impacts. The quantity of dredging under the Proposed Action and each alternative was compared to recent dredging (defined in Chapter 2 as the average annual dredging from 2004 to 2008) to determine the relative increase and the corresponding change in magnitude of these localized individual impacts. The habitat impacts are primarily driven by changes to the LOMR bed profile and low-flow surface water elevation due to river bed degradation. These potential impacts to aquatic habitat are evaluated in the context of potential river bed degradation and are tied to the geomorphology discussion presented in Section 4.2.

The geomorphology analysis described the estimated changes in average river bed elevations and low-flow and high-flow water surface elevations using the following three categories:

- Slight change (less than approximately 2 feet);
- Moderate change (approximately 2–4 feet); and
- Substantial change (greater than approximately 4 feet).

Changes in high-flow water surface elevations were characterized as likely to increase or likely to decrease for the Proposed Action and the alternatives. Because the linkage between river bed degradation, sediment availability, and the quantity of shallow-water habitat has not been quantified (USACE 2009), levels of potential river bed degradation were used as a proxy for the potential for changes in the quantities of shallow-water habitats.

4.6.5 Proposed Action

4.6.5.1 Potential Impacts on Aquatic Habitat

All Segments

The Proposed Action would substantially increase the amount of dredging, by approximately 93 percent when compared to recent dredging in the LOMR. In general, it is anticipated that this increase in dredging effort would result in a corresponding increase in the locations, frequencies, and quantities of benthic habitats that would be subject to direct disruption. The disruption of habitat quality and availability would be temporary.

St. Joseph Segment

The Proposed Action would result in moderate to substantial long-term river bed degradation in the St. Joseph segment. The effects of river bed degradation and reduced sediment bed load on shallow-water habitat and quantity have not yet been quantified (USACE 2009). If these geomorphic processes are linked to the erosion of shallow-water habitat, this level of river bed degradation would be more likely to affect the abundance of shallow-water habitat.

Kansas City, Jefferson City, and St. Charles Segments

The Proposed Action would result in substantial long-term river bed degradation in the Kansas City, Jefferson City, and St. Charles segments, which could alter the quantity and distribution of shallow-water habitat. The effects of river bed degradation and reduced sediment bed load on shallow-water habitat and quantity have not yet been quantified (USACE 2009). Alteration of shallow-water habitat could occur through river bed degradation, resulting in decreased water surface elevations and less sediment that would expose shallow areas, or physical erosion of shallow-water habitats.

Waverly Segment

Potential short-term aggradation or slight river bed degradation could occur in the Waverly segment under the Proposed Action. Depending on the sediment deposition patterns, shallow-water habitat may be created in this segment under the Proposed Action. Low-flow water surface elevations are not anticipated to change significantly and may not have a potential to alter the abundance of shallow-water habitat in this segment.

Alternate Sources

No alternate sources of supply would be required under the Proposed Action; therefore, no aquatic habitat disturbance or modification would occur as a result of instream mining of sand and gravel or dredging in the Kansas or Mississippi River. Alternate sources of sand from floodplain or upland open-pit mines would not be needed under the Proposed Action; therefore, the potential for sediment and contaminant delivery from these operations to water bodies would not increase.

4.6.5.2 Potential Impacts on Aquatic Species

All Segments

The Proposed Action would substantially increase the amount of dredging, by approximately 93 percent when compared to recent dredging in the LOMR. In general, it is anticipated that this increase in dredging effort would result in a corresponding increase in the potential for entrainment of aquatic species along with direct and indirect effects associated with dredging-related noise and elevated turbidity levels. The Proposed Action may result in an increase in localized, although temporary, injury or mortality to fish by entrainment. Localized increases in suspended sediment downstream of the dredge may temporarily benefit native species that are associated with turbid environments and could potentially adversely affect those species with greater sensitivity to increased levels of suspended sediment (such as non-native species).

Alternate Sources

No alternate sources of supply would be required under the Proposed Action; therefore, no instream gravel mining or dredging would take place in the Kansas or Mississippi River with associated behavioral changes, decreased reproductive success, mortality through entrainment, or modification of habitat. Alternate sources of sand from floodplain or upland open-pit mines would not be needed under the Proposed Action; therefore, no increased potential for sediment and contaminant delivery from

these operations to the river and no increased potential for behavioral, reproductive, or mortality effects on aquatic species would be associated with alternate sources of supply.

4.6.6 No Action Alternative

4.6.6.1 Potential Impacts on Aquatic Habitat

All Segments

Under the No Action Alternative, all segments would experience long-term aggradation or potentially slight degradation that may stabilize shallow-water habitats. Depending on the sediment deposition and aggradation patterns, shallow-water habitat may be created in some segments under this alternative. Further, under the No Action Alternative, the direct benthic habitat disturbance from commercial sand dredging activities would halt.

Alternate Sources

Development or expansion of upland and floodplain open-pit mines under the No Action Alternative may not directly affect aquatic resources but could result in destruction of riparian or wetland habitat and introduction of contaminants and sediment via storm water runoff (see Section 4.5) (Roell 1999, Brown, Lyttle, and Brown 1998). These changes in water quality could result in decreased aquatic habitat quality or quantity. For example, the increased introduction of sediment in water bodies from floodplain open-pit mining runoff could result in habitat degradation through filling of interstitial spaces in stream substrates and decreased depths of pools that are habitat for larger fish species (Brown, Lyttle, and Brown 1998). Additional aquatic habitat alteration from floodplain open-pit mining would occur if the excavation pit was captured by the active stream channel during flooding, which would cause an abrupt relocation of the channel and extensive channel instability (Roell 1999, Kondolf 1997). Captured pits that are large relative to the stream channel create lake-like environments that can locally change aquatic habitat type and conditions and the associated biological community (Roell 1999).

Similar impacts would be associated with instream mining operations, such as potential spills of diesel fuel or other contaminants, as those discussed for upland mining (Kondolf 2006). Further, stream mining activities could destabilize the stream bed and banks, which causes simplification of aquatic habitats (Roell 1999, Kondolf 2006). Instream sand and gravel mining in streams and rivers could result in a variety of alterations to those stream channels—including the possible formation of wide, shallow channels with bank erosion, braided flows, and increased water temperatures—if the excavation is done improperly; and elimination of side channels, relocation of the thalweg, and

increased mobilization of sediments could occur (Roell 1999). Channel widening could result in shallowing of the stream bed that could produce braided flow or subsurface inter-gravel flow in riffle areas; these conditions could hinder fish movement between pools or increase stream temperatures (Brown, Lyttle, and Brown 1998). Further, instream mining could reduce habitat complexity through sedimentation of deep pools (Brown, Lyttle, and Brown 1998). These changes in physical habitat can affect species interactions and community composition (Brown, Lyttle, and Brown 1998), as discussed in Section 4.6.6.2. This potential degradation of aquatic habitat from instream sand and gravel mining could extend beyond the boundaries of the immediate gravel mining areas (Brown, Lyttle, and Brown 1998).

4.6.6.2 Potential Impacts on Aquatic Species

All Segments

Because the No Action Alternative does not involve dredging in the LOMR, no individuals in any segment would be entrained or experience temporary behavioral modifications due to noise from dredging activities. Entrainment would decrease compared to the rates of entrainment under recent levels of commercial dredging. Because dredging would cease, localized elevated suspended sediment plumes would not occur downstream of the dredges and native species would not benefit from turbidity associated with the temporary increase in suspended sediment.

Alternate Sources

Regardless of the location (the Mississippi and Kansas Rivers or other rivers), dredging under the No Action Alternative would result in similar general impacts on aquatic species related to entrainment, noise, and turbidity as described for the LOMR (USACE 1978).

As discussed above, development or expansion of upland or floodplain open-pit mines may not directly affect aquatic resources but may result in destruction of riparian or wetland habitat and introduction of contaminants and sediment via storm water (see Section 4.5). The potential introduction of contaminants in water bodies from upland mining may result in changes in holding, feeding, or migratory behavior of fish (Kondolf 2006). In addition to the habitat alterations discussed above, the introduction of sediment from these operations into aquatic habitat would result in suffocation of eggs, larvae, and benthic invertebrates and could decrease pool depths used by larger fish species (Brown et al. 1998). The downstream effects (up to several miles downstream of mining sites) of elevated turbidity could reduce species abundance and result in a change in species composition (Kondolf

2006). Brown et al. (1998) found higher total densities and diversity of fish families captured in reference streams compared to mined stream reaches for most fish species.

The most widespread effects of instream mineral extraction on aquatic habitats are channel alterations and sedimentation, which can cause substantial negative effects on aquatic life (Roell 1999, Kondolf 1997). Instream mining can result in impacts to aquatic species similar to those described for open-pit mines, which could result in reduction or elimination of populations of aquatic species (Roell 1999). Alterations of pool and riffle habitat characteristics and frequency, as discussed above, can change the aquatic biotic community composition through changes to food production or retention, distance between patches, refuge security, and refuge distribution (Brown, Lyttle, and Brown 1998). These environmental degradations to biotic communities are likely to extend far beyond the boundaries of the immediate gravel mining areas (Brown, Lyttle, and Brown 1998).

4.6.7 Alternative A

4.6.7.1 Potential Impacts on Aquatic Habitat

All Segments

Under Alternative A, the St. Joseph, Kansas City, Waverly, Jefferson City, and St. Charles segments are expected to experience long-term aggradation or slight long-term degradation. Depending on the sediment deposition patterns, shallow-water habitat may be created in segments under this alternative. Low-flow water surface elevations are not anticipated to change significantly and may not have a potential to alter the abundance of shallow-water habitat in these segments.

St. Joseph Segment

Under Alternative A, dredging is expected to slightly increase (by approximately 7 percent compared to recent dredging) in the St. Joseph segment, which would result in a corresponding slight increase in the locations and frequencies that benthic habitats would be subject to a temporary direct disruption of habitat quality and availability.

Kansas City, Waverly, Jefferson City, and St. Charles Segments

Although direct benthic habitat disturbance would occur under Alternative A, the frequency of disturbances would decrease compared to recent dredging.

Alternate Sources

Because fewer alternate sources would be required under Alternative A (a decrease of approximately 32 percent compared to the No Action Alternative level), the impacts of alternate sources would be similar to those described for the No Action Alternative, but the impacts would occur at a reduced frequency. Open-pit upland and floodplain mining could result in destruction of riparian or wetland habitat and introduction of contaminants and sediment via storm water (see Section 4.5) (Roell 1999; Brown, Lyttle, and Brown 1998), which would decrease habitat quality. Further, additional aquatic habitat alteration from floodplain open-pit mining would occur if the excavation pit was captured by the active stream channel during flooding, which would cause an abrupt relocation of the channel and extensive channel instability (Roell 1999, Kondolf 1997).

The impacts of instream mining operations would be similar to those discussed for upland mining (e.g., potential spills of diesel fuel or other contaminants) (Kondolf 2006). Further, instream mining activities could destabilize the stream bed and banks, which causes simplification of aquatic habitats (Roell 1999, Kondolf 2006). Channel widening could result in shallowing of the stream bed, which could produce braided flow or subsurface intergravel flow in riffle areas; these conditions could hinder fish movement between pools or increase stream temperature (Brown, Lyttle, and Brown 1998).

4.6.7.2 Potential Impacts on Aquatic Species

St. Joseph Segment

Under Alternative A, dredging would slightly increase (by approximately 7 percent compared to recent dredging) in the St. Joseph segment. The rate of entrainment and noise disturbance also would slightly increase under Alternative A. Elevated suspended sediment plumes would result in a temporary, localized positive effect on native fish species by increasing, temporarily, local turbidity at and downstream of the dredging location.

Kansas City, Waverly, Jefferson City, and St. Charles Segments

Under Alternative A, dredging would decrease relative to recent dredging in the Kansas City, Waverly, Jefferson City, and St. Charles segments. Overall, dredging would decrease (between 26 and 79 percent of recent dredging) in these segments, with a corresponding decrease in the number of organisms that would be expected to be entrained. Because elevated underwater noise from dredge vessels would not occur as frequently, short-term localized avoidance behaviors in noise-sensitive fish species are expected to decrease. Given that dredging impacts on suspended sediment levels are

localized and temporary, Alternative A is expected to decrease the frequency of elevated suspended sediment plumes compared to recent dredging, which would decrease the availability of temporary habitat cover (i.e., turbidity) for native fish species.

Alternate Sources

The impacts on aquatic species associated with alternate sources of sand and gravel under Alternative A would be similar to those described for the No Action Alternative but of less magnitude (a decrease of approximately 32 percent compared to the No Action Alternative level). Dredging in the Mississippi and Kansas Rivers and other rivers under Alternative A would result in similar impacts on aquatic species related to entrainment, noise, and turbidity as described for the LOMR.

The potential introduction of contaminants in water bodies from upland and floodplain open-pit mining may result in changes in holding, feeding, or migratory behavior of fish (Kondolf 2006) and reproductive success of fish and macroinvertebrates (Brown et al. 1998). These changes may result in reduced species abundance and changes in species composition (Kondolf 2006).

Instream mining may result in impacts to aquatic species similar to those described for open-pit mines, which could result in reduction or elimination of populations of aquatic species (Roell 1999). Alterations of pool and riffle habitat characteristics and frequency due to sedimentation and channel widening can change the aquatic biotic community composition through changes to food production or retention, distance between patches, refuge security, and refuge distribution (Brown, Lyttle, and Brown 1998).

4.6.8 Alternative B

4.6.8.1 Potential Impacts on Aquatic Habitat

St. Joseph Segment

Under Alternative B, dredging in the St. Joseph segment would result in slight to moderate long-term river bed degradation. The effects of river bed degradation and reduced sediment bed load on shallow-water habitat distribution and availability have not yet been quantified (USACE 2009), but if these geomorphic processes are linked to the erosion of shallow-water habitat, this level of river bed degradation would be more likely to affect the abundance of shallow-water habitat in this segment.

Under Alternative B, the location and frequency of dredging in the St. Joseph segment would substantially increase (to approximately 163 percent compared to recent dredging). This increase in dredging would result in a corresponding increase in the locations and frequencies that benthic habitats

would be subject to direct disruption, even though temporary, and would affect habitat quality and availability.

Kansas City and St. Charles Segments

Under Alternative B, dredging in the Kansas City and St. Charles segments would likely result in moderate long-term river bed degradation and the potential for alteration of shallow-water habitat abundance and connectivity. The effects of river bed degradation and reduced sediment bed load on shallow-water habitat and quantity have not yet been quantified (USACE 2009), but if these geomorphic processes are linked to the erosion of shallow-water habitat, this level of river bed degradation would be more likely to affect the abundance of shallow-water habitat.

Under Alternative B, dredging would decrease in the Kansas City and St. Charles segments compared to recent dredging. Dredging would be between 49 and 53 percent of recent dredging, with a corresponding reduction in the frequency of direct benthic habitat disturbance.

Waverly Segment

Slight long-term river bed degradation or aggradation would occur in the Waverly segment under Alternative B. This may stabilize or slightly decrease the quantity of shallow-water habitat. Depending on the sediment deposition patterns, shallow-water habitat may be created in segments under this alternative. Low-flow water surface elevations are not anticipated to change significantly and may not have a potential to alter the abundance of shallow-water habitat in the Waverly segment.

Under Alternative B, dredging levels would substantially increase in the Waverly segment (approximately 68 percent of recent dredging). This increase in dredging would result in a corresponding increase in the locations and frequencies that benthic habitats would be subject to direct disruption, even though temporary, of habitat quality and availability.

Jefferson City Segment

Under Alternative B, dredging in the Jefferson City segment would result in slight to moderate long-term river bed degradation, resulting in the potential for alteration of shallow-water habitat abundance and connectivity. The effects of river bed degradation and reduced sediment bed load on shallow-water habitat and quantity have not yet been quantified (USACE 2009), but if these geomorphic processes are linked to the erosion of shallow-water habitat, this level of river bed degradation would be more likely to affect the abundance of shallow-water habitat.

Under Alternative B, dredging would decrease in the Jefferson City segment. Dredging would be 37 percent of recent dredging, with a corresponding reduction in the frequency of direct, temporary benthic habitat disturbance.

Alternate Sources

Impacts on aquatic resources from alternate sources of sand and gravel under Alternative B would be similar to those described for the No Action Alternative and Alternative A but of substantially less magnitude (an approximately 73-percent decrease compared to the No Action Alternative). Open-pit upland and floodplain mining could result in destruction of riparian or wetland habitat and introduction of contaminants and sediment via storm water (see Section 4.5) (Roell 1999; Brown, Lyttle, and Brown 1998), which would decrease habitat quality. Further, additional aquatic habitat alteration from floodplain open-pit mining would occur if the excavation pit was captured by the active stream channel during flooding, which would cause an abrupt relocation of the channel and extensive channel instability (Roell 1999, Kondolf 1997).

Impacts related to instream mining operations would be similar to those discussed for upland mining impacts, such as potential spills of diesel fuel or other contaminants (Kondolf 2006). Further, instream mining activities could destabilize the stream bed and banks, which causes simplification of aquatic habitats (Roell 1999, Kondolf 2006). Channel widening could result in shallowing of the stream bed, which could produce braided flow or subsurface intergravel flow in riffle areas; these conditions could hinder fish movement between pools or increase stream water temperature (Brown, Lyttle, and Brown 1998).

4.6.8.2 Potential Impacts on Aquatic Species

St. Joseph and Waverly Segments

Under Alternative B, dredging in the St. Joseph and Waverly segments would increase (by approximately 163 percent and 68 percent, respectively, compared to recent dredging). Increased dredging would result in a corresponding increase in the potential for entrainment, noise, and elevated turbidity. Alternative B would result in an increase in temporary localized injury or mortality to fish by entrainment. Localized increases in suspended sediment downstream of the dredge would temporarily benefit native species that are associated with turbid environments and have the potential to adversely affect those species with greater sensitivity to increased levels of suspended sediment (such as non-natives).

Kansas City, Jefferson City and St. Charles Segments

Under Alternative B, dredging would decrease in the Kansas City, Jefferson City, and St. Charles segments. Overall, dredging levels would be between 37 and 53 percent of recent dredging, with a corresponding decrease in the number of organisms expected to be entrained. Because elevated underwater noise from dredge vessels would decrease, the short-term localized avoidance behaviors in noise-sensitive fish species are expected to decrease. Given that dredging impacts on suspended sediment levels are localized and temporary, Alternative B is expected to decrease the frequency of elevated suspended sediment plumes, which would decrease the availability of temporary habitat cover for native fish species.

Alternate Sources

Impacts on aquatic resources from alternate sources of sand and gravel under Alternative B would be similar to those described for the No Action Alternative and Alternative A but of substantially less magnitude (an approximately 73 percent decrease compared to the No Action Alternative). Similar impacts related to localized entrainment, noise, and turbidity would occur at dredging sites in the Mississippi and Kansas Rivers and other rivers, as described for the LOMR.

The potential introduction of contaminants in water bodies from upland and floodplain open-pit mining may result in changes in holding, feeding, or migratory behavior of fish (Kondolf 2006) and reproductive success of fish and macroinvertebrates (Brown et al. 1998). These changes may result in reduced species abundance and changes in species composition (Kondolf 2006).

Instream mining also may result in impacts to aquatic species similar to those described for open-pit mines, which could result in reduction or elimination of populations of aquatic species (Roell 1999). Alterations of pool and riffle habitat characteristics and frequency due to sedimentation and channel widening can change the aquatic biotic community composition through changes to food production or retention, distance between patches, refuge security, and refuge distribution (Brown, Lyttle, and Brown 1998).

4.6.9 Alternative C

4.6.9.1 Potential Impacts on Aquatic Habitat

All Segments

Under Alternative C, the frequency of dredging would be similar in magnitude, but not necessarily in location or distribution, to recent dredging (as described in Chapter 2). The quantity of dredging activity would not change substantially; therefore, the rate of temporary benthic habitat disruption would be similar to recent levels of benthic habitat disturbance.

St. Joseph and Waverly Segments

Long-term aggradation or slight long-term degradation may occur in the St. Joseph and Waverly segments under Alternative C, which would stabilize or slightly alter the quantity of shallow-water habitat. Depending on the sediment deposition patterns, shallow-water habitat may be created under this alternative. Low-flow water surface elevations are not anticipated to change significantly and may not have a potential to alter the abundance of shallow-water habitat in these segments.

Kansas City, Jefferson City, and St. Charles Segments

Alternative C would result in moderate to substantial long-term river bed degradation in the Kansas City, Jefferson City, and St. Charles segments, which may result in alteration of shallow-water habitat abundance or connectivity. The effects of river bed degradation and reduced sediment bed load on shallow-water habitat and quantity have not yet been quantified (USACE 2009), but if these geomorphic processes are linked to the erosion of shallow-water habitat, this level of river bed degradation would be more likely to affect the abundance of shallow-water habitat.

Alternate Sources

No alternate sources of supply would be required under Alternative C; therefore, no aquatic habitat disturbance or modification would occur as a result of instream mining of sand and gravel or dredging. Under Alternative C, alternate sources of sand from floodplain or upland open-pit mines would not be needed; therefore, the potential for sediment and contaminant delivery from these operations to water bodies would not increase.

4.6.9.2 Potential Impacts on Aquatic Species

All Segments

Under Alternative C, the frequency of elevated suspended sediment plumes downstream of dredging would be similar, but not necessarily in the location or distribution, to recent dredging (as described in Chapter 2). The quantity of dredging activity would not change substantially; therefore, the rate of entrainment and noise production would not change substantially. Potential effects associated with recent dredging are evaluated in the Affected Environment discussion for aquatic resources (Section 3.8).

Alternate Sources

No alternate sources of supply would be required under Alternative C; therefore, neither instream gravel mining nor dredging in the Kansas or Mississippi Rivers would take place with associated behavioral changes, decreased reproductive success, mortality through entrainment, or modification of habitat. Alternate sources of sand from floodplain or upland open-pit mines would not be needed under Alternative C, with no increased potential for sediment or contaminant delivery from these operations to the river and no increased potential for behavioral, reproductive, or mortality effects on aquatic species.

4.6.10 Summary of Impacts

Table 4.6-2 contains a summary of the potential impacts on aquatic resources associated with the Proposed Action and alternatives.

Table 4.6-2 Summary of Potential Impacts on Aquatic Resources

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
Potential impacts on aquatic habitat	• Potential alteration of shallow-water habitat and connectivity in those segments most affected by river bed degradation, removal of sediment load, and decreased low-flow surface water elevation.	• Increase in or stabilization of shallow-water habitat in the mainstem. • Potential degradation of aquatic habitat from contaminated runoff and stream geomorphology changes from the use of open-pit and instream mining.	• Increase in or stabilization of shallow-water habitat in the mainstem in most areas. • Potential degradation of aquatic habitat from contaminated runoff and stream geomorphology changes from the use of open-pit and instream mining.	• Potential alteration of shallow-water habitat and connectivity in those segments most affected by river bed degradation, removal of sediment load, and decreased low-flow surface water elevation. • Potential degradation of aquatic habitat from contaminated runoff and stream geomorphology changes from the use of open-pit and instream mining.	• Potential alteration of shallow-water habitat and connectivity in those segments most affected by river bed degradation, removal of sediment load, and decreased low-flow water surface elevations.
Potential impacts on individual aquatic species	• Substantial increase in the rate of entrainment, noise disturbance, and elevated suspended sediment.	• No entrainment, noise disturbance, or elevated suspended sediment caused by dredging. • Potential reduction reproductive success, behavioral changes, or mortality through the introduction of contaminants and aquatic habitat alterations from alternate sources.	• Substantial decrease in entrainment, noise disturbance, and elevated suspended sediment caused by dredging. • Potential reduction reproductive success, behavioral changes, or mortality through the introduction of contaminants and aquatic habitat alterations from alternate sources.	• Decrease in entrainment, noise disturbance, and elevated suspended sediment caused by dredging. • Potential reduction reproductive success, behavioral changes, or mortality through the introduction of contaminants and aquatic habitat alterations from alternate sources.	• Entrainment, noise disturbance, or elevated suspended sediment rates similar to recent dredging.

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4.6.11.2 Personal Communication

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