4.2 GEOLOGY AND GEOMORPHOLOGY

4.2.1 Introduction

Potential direct and indirect impacts to the geology and geomorphology of the LOMR system are associated with dredging under each alternative. Direct impacts include changes in local sediment loads and river bed composition, and changes in river bed elevations. Indirect impacts include changes in channel geometry, which result in changes in low-flow and high-flow water surface elevations and tributary degradation. For purposes of the impact analysis, the proposed level of dredging under each alternative was compared to existing conditions, which include dredging and are described in Section 3.4.

The impact assessment is organized into the following sections:

- Potential impacts from dredging on the geomorphology of the LOMR system;
- Analysis methods, metrics, and assumptions;
- Potential impacts of the Proposed Action;
- Potential impacts of the No Action Alternative; and
- Potential impacts of Alternatives A, B, and C.

4.2.2 Potential Geomorphic Impacts from Dredging in the Lower Missouri River

Four potential impacts on the LOMR system that may arise from dredging were evaluated in the analysis. These include:

- Changes in sediment loads and river bed composition;
- Changes in river bed elevation;
- Changes in channel geometry and water surface elevation; and
- Tributary degradation.

4.2.2.1 Changes in Sediment Loads and River Bed Composition

Dredging affects the sediment load by removing sand and gravel-sized sediment from the river bed. Two potential impacts of dredging on the sediment load and river bed composition were considered:

(1) the effect of removing sand and gravel by commercial dredging on sediment loads in a reach; and (2) the change in size of the particles that compose the river bed (Kondolf 1997).

As described in Section 3.4.5.4, most of the sediment transported by the LOMR consists of "wash load," which is fine sand-, silt-, and clay-sized particles that typically remain in suspension and do not interact with the river bed. The "bed material load" consists of medium to coarse sand and gravel-sized particles moving along the river bed and some of the coarser sand transported in the water column. The amount and size of material transported by the river depend primarily on the volume and velocity of the water moving through a reach of the river; as flows increase, the amount and size of sediment that the river can transport increase (see Section 3.4.5 for more detail on sediment loads). Material extracted by commercial dredging consists primarily of bed material load. Wash load-sized material is generally a smaller particle size, and is either not found in the river bed or is discharged back into the river during dredging (see Section 3.4.5.4 for additional detail).

A depression forms in places where sediment is dredged from the river bed. When dredging at that location has finished, the depression refills over time with material moving along the river bed (bed load) or with material from the water column (suspended sediment) (Simons, Li, and Associates 1985). Erosion of the river bed occurs both upriver as a headcut and downriver from the dredging depression, as the river entrains sediment to replenish its transport capacity (Kondolf 1997; Simons, Li, and Associates 1985; Rinaldi, Wyzga, and Surian 2005).

Because most of the commercially dredged material must meet detailed specifications, dredging operations return the material that is too fine or too coarse to the river. This results in an increase in fine sediment transported downriver as this fine material is discharged into the river from the dredging operation (Kondolf et al. 2002). Depending on the type of dredge, coarse material is deposited on the river bed below the dredge or to the side of the dredge (see Section 2.2.2 for pictures and details of the different types of dredging operations). Consequently, 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; Rinaldi, Wyzga, and Surian 2005).

These effects are relatively local and tend to accumulate in areas with the most dredging (Simons, Li, and Associates 1985). Therefore, changes in sediment loads and river bed composition are considered dredging-related impacts that occur in the vicinity of the dredging operation.

4.2.2.2 Changes in River Bed Elevation

Degradation (lowering of the river bed elevation) on the LOMR can result in the failure of in-river structures, such as dikes and revetments, and exposure of buried pipes. These effects are described in Section 3.5. Factors contributing to degradation are described in Section 3.4.6 and include changes in sediment supply, flow modification by dams, major flood events, BSNP structures, and commercial dredging. The relative contribution of each factor varies at different locations on the river, as does the extent of degradation.

Dredging contributes to river bed degradation in two ways: (1) by directly removing sediment from the river bed; and (2) by reducing the amount of sediment transported through a reach (Kondolf 1997; Simons, Li, and Associates 1985; Rinaldi, Wyzga, and Surian 2005). Degradation has been most pronounced on the LOMR in areas with the most dredging (Figure 3.4-20 in Section 3.4.6.2).

A "headcut," or sudden change in the river bed elevation, can occur if enough sediment is removed from a reach of the river by dredging (Kondolf et al. 2002; Simon, Li, and Associates 1985). In the case of headcuts caused by dredging, erosion occurs on the upriver side, as well as on the downriver side. A headcut will migrate up the river until the average channel slope returns to the pre-headcut level or the headcut encounters substrate that is resistant to erosion (Papanicolaou et al. 2008). The rate at which a headcut advances is determined by bed substrate properties such as particle size, density, and erodibility—as well as factors affecting the flow hydraulics such as flow rate, overfall height, and tailwater conditions. If the bed material is sandy alluvium, such as in the LOMR system, bed erosion and headcut movement can occur relatively quickly (Papanicolauo et al. 2008). Headcuts in the mainstem LOMR have been observed in association with channel cutoffs during construction of the BSNP and in association with dredging in the Kansas City segment (see Sections 3.4.3.2 and 3.4.6.3 for details regarding the effects of cutoffs and dredging).

Aggradation (raising of the river bed elevation) could occur in areas degraded by past dredging when proposed dredging would be less than past dredging. However, because it was designed to maintain a self-scouring navigation channel that reduces deposition, the BSNP may prevent a degraded reach from recovering even if commercial dredging is reduced.

4.2.2.3 Changes in Channel Geometry and Water Surface Elevations

Changes to both low-flow and high-flow water surface elevations may result from changes in channel geometry (USACE 2007; Rinaldi, Wyzga, and Surian 2005). "Channel geometry" refers to the shape of

a channel, which is altered when the river bed degrades or aggrades in a reach, or when bank erosion or deposition occurs in the active channel.

At low flows, water depths are shallow and more closely track changes in the river bed. Therefore, river bed degradation is likely to cause water surface elevations to decrease during periods of low flows. For the purpose of this analysis, low flows were considered to be 40,000 cfs or less. Changes in low-flow water surface elevations can affect municipal water intakes, boat ramps, and BSNP structures; can affect shallow-water habitat, wetlands, and groundwater water surfaces; and can result in tributary degradation (USACE 2007).

Reduced low-flow water surface elevations also allow vegetation to become established along the river banks and on sand bars, especially if periods of low flows become prolonged. The increased amount of vegetation traps sediment, building up land in the channel and reducing the amount of area in the channel to convey high flows. The smaller area in the channel cross section reduces conveyance capacity, resulting in increased water surface elevations at high flows. Figures 3.4-3 and 3.4-4 illustrate how the river channel has narrowed over time and how the high-flow water surface elevations increase as a result. High-flow water surface elevations have increased at most gage locations in the Project area over the past 20 years (USACE 2007).

Floods are instances of rare high-flow events that are of particular concern. Increases in high-flow water surface elevations can increase flood stages and the likelihood of breaching levees that would result in flood-related damage. Higher flood stages also increase the potential for bed scour and degradation from a flood event, which would reduce the river bed elevation and the low-flow water surface elevation. For this analysis, high flows were considered to be 200,000 cfs or greater. Floods were not considered because they cannot be predicted.

Conversely, high-flow water surface elevations may be reduced in the short term in areas where rapid channel degradation occurs. If the channel bed degrades more quickly than vegetation can become established and trap sediment in the channel, a deeper channel cross section is created and the high-flow water surface elevation may decline temporarily.

Due to the complex relationship between channel geometry and water surface elevations, the uncertainty related to estimating changes in water surface elevation is greater than that for other parameters.

Historical water surface elevations at USGS gages on the LOMR are displayed in Figures 3.4-21, 3.4-22, 3.4-28, and 3.4-31; the change in low-flow water surface elevation for the whole length of the LOMR between 1990 and 2005 is displayed in Figure 3.4-20.

4.2.2.4 Tributary Degradation

Degradation on tributaries to the LOMR occurs when the mainstem LOMR channel bed at the confluence of a tributary degrades or when the low-flow water surface elevation on the mainstem drops below typical levels. Tributary degradation has been observed in the Kansas City segment in areas with substantial mainstem degradation (USACE 2009). A tributary will adjust to a new base level in the mainstem by eroding its bed to match the new elevation at the confluence with the LOMR. This often occurs in the form of a headcut, or sudden drop in channel elevation, that erodes and moves upstream until it reaches a geomorphic control point such as a bedrock exposure, dam, or other structure (e.g., culverts, bridge crossings, and rip-rap) that is resistant to erosion. Geomorphic controls usually occur within a few thousand feet of the mainstem LOMR due to the extensive development and dikes constructed in the LOMR floodplain. Consequently, tributary degradation is likely to occur between the confluence with the LOMR and the first geomorphic control point.

Tributary degradation is most likely to occur in areas of concentrated dredging, where river bed degradation and reductions in low-flow water surface elevations are expected to occur as a result of dredging. Table 4.2-1 lists the tributaries by river segment in the areas where existing dredging has been concentrated.[1] These tributaries are at greatest risk of degradation under alternatives where low-flow water surface elevations are expected to decline as a result of dredging in those areas.

Tributary headcutting and degradation can affect infrastructure (including the geomorphic control) by eroding material from around and underneath the structure. For example, if a headcut eroding upstream reaches a bridge crossing, the headcut can erode the material around the bridge foundation and weaken the foundation (Kondolf 1997). These effects are addressed in Section 4.3.

Aggradation on the mainstem LOMR increases in the mainstem low-flow water surface elevations, and changes in high-flow water surface elevations are unlikely to cause tributary bed degradation and are not considered in this analysis.

[1] The Waverly segment is not included in Table 4.2-1 because dredging is not concentrated in any one portion of the segment.

Table 4.2-1 Perennial Tributary Streams in Areas with the Most Dredging under Existing Conditions

River Mile	Tributary Name
St. Joseph Segment	
453.8	Mace Creek
450.1	*
Kansas City Segment	
382.9	Brush Creek
382.2	*
377.4	White Branch
377.4	*
375.9	Burlington Creek
372.1	Line Creek
367.8	Jersey Creek
358.0	*
356.9	Blue River
351.6	*
350.6	Mill Creek
Jefferson City Segment	
148.2	Cedar Creek
145.6	Grays Creek
144.3	Turkey Creek
143.4	Wears Creek
141.3	*
141.0	*
St. Charles Segment	
49.0	Femme Osage Creek
48.2	*
41.8	*
41.7	*
38.8	*
38.4	Bonhomme Creek
37.7	*
34.0	*

Table 4.2-1 Perennial Tributary Streams in Areas with the Most Dredging under Existing Conditions

River Mile	Tributary Name
St. Charles Segment (continued)	
33.4	Duckett Creek
30.7	Creve Coeur Creek
29.1	*
28.3	*
21.3	*
17.8	*
11.9	*
7.3	*
6.9	Mill Creek
2.7	*
1.9	*

Note: The Waverly segment is not included because dredging is not concentrated in any one portion of the segment.

* Tributary was not named in the U.S. Army Corps of Engineers geographic information systems database.

4.2.3 Assessment Methods

The LOMR system described in the affected environment (Section 3.4) was used as a baseline for the impact analysis. Long-term records from the USGS gage stations were reviewed in the context of systemic changes, including changes in flow and sediment resulting from construction of the mainstem dams and the BSNP, and historical dredging levels. Emphasis was placed on recent trends because changes associated with the BSNP have mostly stabilized since it was completed in the 1980s (USACE 2009). Changes in CRP-adjusted low-water surface elevations between 1990 and 2005 were reviewed, as were changes in channel bed cross sections between 1998, 2007, 2008, and 2009 (see Appendix A and Section 3.4.6.1 for details on these analyses). In addition to the trends indicated by these analyses, proposed dredging for each alternative and segment was compared to the bed material load estimates for each segment to determine what percent of the sediment load would be removed by dredging. The results of the bed material load calculations provided one piece of the geomorphic assessment, which was considered in conjunction with all the other available data.

Bed material load estimates were developed for three USGS gage locations (St. Joseph, Kansas City, and Hermann) in the Project area using the best data available at the time the Draft EIS was prepared (Section 3.4.5). Because the bed material load is similar in size to the material being extracted by commercial dredging, it is an approximate indicator of the amount of dredging-sized sediment currently moving through the system (see Figure 3.4-15). The amount of material to be removed by dredging was compared to the estimated bed material loads in areas where river bed degradation has occurred, and in areas without much river bed change, to determine the proportion of the bed material load removed by dredging in those areas. Bed material load estimates were extrapolated between stations for the Waverly and Jefferson City segments as a gage with sediment data was not available in these segments. The average annual bed material load estimates used in the impacts analysis were based on below-average flow conditions from 2000 to 2009, which represent a worst-case scenario for estimating impacts.

4.2.3.1 Changes in Sediment Loads and River Bed Composition

To provide a basis for estimating potential changes to the sediment loads from dredging proposed under each alternative, the percent of the average annual bed material load transported by dredging was calculated for each segment. This gives a relative comparison between the amount dredged and the sediment load for the segment. Dredging generally removes the bed material load-sized sediment and returns the finer sediment and the coarser gravel and cobbles to the river. The analysis also estimated whether sediment availability, fine sediment, and coarse material were likely to increase or decrease in relation to the increase or decrease in the amount of dredging that occurs at a location.

4.2.3.2 Changes in River Bed Elevation

The analysis methods described above were used to estimate potential changes in river bed elevations associated with the Proposed Action and the alternatives. They include:

- Review of past river bed elevation and water surface elevation trends, including river bed elevation changes, stage changes, and slopes;
- Comparison of dredging levels with bed material load estimates to determine the proportion removed by dredging; and
- Comparison of calculated equilibrium slopes with measured river bed slopes at three gage locations to determine whether the existing slope is in equilibrium with flows and sediment loads.

Trends in river bed elevation and water surface elevations, stage changes, slopes, and bed material load estimates are described above and in detail in Section 3.4.

Equilibrium Slope Analysis

In addition to the above analyses, the channel equilibrium slope was calculated at each gage location with adequate sediment data. The calculation was based on the channel geometry, flows, and estimated bed material load (see Appendix A for details regarding bed material load calculations and the equilibrium slope calculation). The calculated channel equilibrium slope was then compared to actual slope measurements based on water surface elevations or channel bed slopes. Where the measured slopes are similar to the calculated results at a gage location, the channel is likely to be close to equilibrium with respect to flows and sediment loads. If the results of the calculation differ from the measured slope, the channel may be out of equilibrium and may respond by aggrading or degrading.

The calculated channel equilibrium slope for cross sections of the river at the St. Joseph and Hermann gages are similar to the measured slopes for those gages, indicating that they are close to equilibrium. The measured slope for the cross section at the Kansas City gage, however, is lower than the calculated slope, indicating that the channel may be out of equilibrium. In this case, the channel would be expected to adjust if the factor that is causing the disequilibrium is removed.

Categories of Bed Elevation Change

Changes in average river bed elevation were classified into three categories: slight change (less than approximately 2 feet), moderate change (approximately 2–4 feet), and substantial change (greater than approximately 4 feet). The categories were selected based on average river bed elevation and low-flow water surface elevation changes observed over the past 20 years. Slight changes in average river bed elevations and water surface elevations occur naturally and may be within measurement error for the methods used to estimate change. Slight aggradation or degradation can occur in a segment independent of dredging and can result from variations in flow conditions and sediment supply. In the absence of dredging and in areas where dredging is not concentrated, these variations may outweigh dredging effects at the segment scale. For example, aggradation occurred in the St. Joseph segment between 2007 and 2009 (see Figure 3.4-21 for details). A moderate change is less likely to be caused by natural variation but is also less likely to cause significant impacts to infrastructure and resources. Substantial change, as has occurred in the Kansas City segment and near the urban areas of Jefferson City and St. Charles (as recorded from the CRP-adjusted low-flow water surface elevations), is more likely to affect infrastructure and other resources.

The amount of change also was linked to the period of analysis. Average river bed elevation changes were determined for the short term (approximately 5 years) and the long term (approximately 5–20 years).

Moderate change in river bed elevations can occur due to migration of sand dunes and inter-annual variability in flows and sediment loads (Abraham pers. comm.). Aggradation and degradation in this analysis refer to longer-term trends in *average* river bed elevation rather than temporary fluctuations in local river bed elevations.

4.2.3.3 Changes in Channel Geometry and Water Surface Elevations

Changes in low-flow water surface elevations were estimated based on the data and trends analyses described above. Changes in low-flow water surface elevations were estimated using 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 estimated based on past trends and the change in low-flow water surface elevations in the short term and the long term. Due to the complexity regarding changes in high-flow water surfaces, the impact assessment assesses only whether high-flow water surfaces elevations are likely to increase or decrease as a result of each alternative.

4.2.3.4 Tributary Degradation

Because tributary degradation has not been well quantified on the LOMR, and each tributary is different with regard to size, degree of modification, length between the main channel and control points, degradation, and other factors, each tributary was not analyzed individually. Instead, the impact assessment characterizes the likelihood that tributary degradation would increase under an alternative based on the change in low-flow water surface elevations on the mainstem LOMR occurring near the tributary. The analysis focused on tributaries in areas with concentrated dredging and degradation under existing conditions, such as the areas around St. Joseph, Kansas City, Jefferson City, and St. Charles (Table 4.2-1). In general, low-flow water surface elevations would need to decrease a moderate or substantial amount before tributaries are likely to be affected. Tributary degradation has been documented in the Kansas City segment, which experienced a decrease in low-flow water surface elevations of approximately 2–7 feet between 1990 and 2005 (USACE 2009). Slight changes in low-flow water surface elevation were considered unlikely to affect tributary degradation because slight changes range from 0 to 2 feet and are likely too small to cause tributary degradation with any certainty.

4.2.3.5 Assumptions

Key assumptions used in the impact analysis include the following:

- Period of analysis – The period of analysis is 20 years. Change that would occur from approximately 0 to 5 years is considered short term, while change between approximately 5 and 20 years is considered long term. It should be noted that the impacts described in this analysis follow trends that may not coincide with the transition from short term to long term. For example, a segment or reach projected to experience a moderate amount of degradation in the long term may transition from a slight to moderate amount of degradation at any time between approximately 5 and 20 years.
- Flow conditions – The impact analysis assumed that flow conditions were below average and similar to the flows from 2000 to 2009. This is consistent with the bed material load analysis in Section 3.4.5 and provides an estimate of worst-case impacts because potential degradation under normal-flow conditions would be less. Although they can measurably affect river bed elevations, extreme flood or drought scenarios were not considered in the analysis because they cannot be accurately predicted.
- Dredging locations – To estimate impacts from dredging, the analysis assumed that most dredging would occur near existing dredging locations, which are typically within 10 miles upriver and 5 miles downriver of a sand plant. Dredging and sand plant locations are shown in Figure 2.2-1 (Sheets 1 through 5) in Section 2.2.
- Other actions affecting geomorphology – Other activities that could affect the geomorphology of the LOMR in the short term and the long term include implementation of the MRRP by the USACE in compliance with the 2003 Biological Opinion for the project (USFWS 2003). These activities are not addressed in the impacts analysis but are addressed in the cumulative effects analysis (Chapter 5).

4.2.4 Proposed Action

The Proposed Action would permit approximately 11,615,000[2] tons of commercial dredging from the five segments of the LOMR. This would increase the amount of material dredged in each segment, with the greatest increases occurring in the St. Joseph and St. Charles segments. Table 4.2-2 shows the amount dredged under existing conditions (2004–2008), the amount of dredging proposed under the Proposed Action, the amount dredged as a percent of the bed material load for both existing

[2] The total permitted under the Proposed Action would be limited to 11,615,000 tons even though the total amount analyzed is 13,350,000 tons due to permit requests that overlap segment boundaries.

conditions and the Proposed Action, and the portion of the segment where dredging is concentrated under existing conditions.

Table 4.2-2 Dredging under Existing Conditions and the Proposed Action

Segment	Dredging – Existing Conditions (tons/year)	Dredging Percent of Bed Material Load – Existing Conditions	Dredging – Proposed Action (tons/year)	Dredging Percent of Bed Material Load – Proposed Action	Percent Increase in Dredging from Existing Conditions	Primary Dredging Location – Existing Conditions
St. Joseph	326,928	9%	1,150,000	33%	252%	RM 445 – RM 455
Kansas City	2,658,831	50%	4,060,000	76%	53%	Throughout segment
Waverly	677,987	14%	1,005,600	20%	48%	Throughout segment
Jefferson City	1,578,858	37%	2,750,000	65%	74%	RM 140 – RM 150
St. Charles	1,649,326	45%	4,384,400	119%	166%	Below RM 50

Note: RM = River mile.

4.2.4.1 Changes in Sediment Loads and River Bed Composition

All Segments

Localized changes in sediment loads and river bed composition occur in the vicinity of the dredging operation and are proportional to the amount of dredging occurring. Table 4.2-2 lists the amount of dredging proposed for each segment under the Proposed Action, compares the proposed level to existing conditions, and describes where dredging is concentrated in the segment. Increased dredging to the levels described in the Proposed Action would result in the following effects in all segments:

- Short-term impacts in all segments under the Proposed Action would include a local decrease in sediment availability as the dredged area captures sediment transported by the river, and erosion occurs downriver as the river replaces the captured sediment. The amount of fine sediment in the water column would increase below the active dredge location as the dredging operation discharges unusable material back into the river.
- Long-term impacts in all segments under the Proposed Action would include an increase in the concentration of coarse gravel and cobbles on or near the surface of the river bed as material is dredged from the river bed and the material that is too coarse to retain is deposited back onto the surface of the river bed.

St. Joseph, Kansas City, and Waverly Segments

Because of the additional amount of dredging required to obtain material that meets specifications, the effects of dredging on sediment availability and coarse sediment would be greater for the St. Joseph, Kansas City, and Waverly segments than for the Jefferson City and St. Charles segments. In general, the bed material in the St. Joseph, Kansas City, and Waverly segments tends to be finer than the specifications for concrete sand, requiring that additional material be dredged from the river bed (see Figures 3.4-14 and 3.4-15 for the size distribution of bed material relative to the specifications). For example, 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. As a result, the actual volume of material extracted from the river bed may be three times greater than the dredging records indicate, increasing local impacts on sediment availability and coarse sediment.

4.2.4.2 Changes in River Bed Elevation

St. Joseph Segment

The Proposed Action would permit 1,150,000 tons of dredging per year in the St. Joseph segment. From 2004 to 2008 (existing conditions), dredging occurred mainly in the St. Joseph area between RM 445 and RM 455, and averaged 326,928 tons per year.

The Proposed Action would increase the amount dredged in the St. Joseph segment by approximately 2.5 times the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from approximately 9 percent (existing conditions) to 33 percent. By comparison, this level of dredging as a percent of the bed material load is similar to the level that occurred in the Jefferson City segment from 2004 to 2008, where dredging-related degradation has occurred. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 20 percent.

If the proposed level of dredging in the St. Joseph segment occurs in the same area that past dredging occurred (in the St. Joseph area between RM 445 and RM 455), slight dredging-related degradation in that area would be expected in the short term, and moderate to substantial dredging-related degradation would be expected in the long term.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the

reach. The result would be a slight aggradation or degradation throughout the reach in the short term and slight degradation in the long term.

Kansas City Segment

The Proposed Action is to permit 4,060,000 tons of dredging per year in the Kansas City segment. From 2004 to 2008 (existing conditions), dredging averaged 2,658,831 tons per year in the Kansas City segment. The segment is relatively short compared to the other segments, and past dredging has occurred throughout the segment.

The Proposed Action would increase the amount dredged in the Kansas City segment by 53 percent above the annual average dredged from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from 50 percent to approximately 76 percent. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 49 percent. The Kansas City segment has experienced the most river bed degradation of any of the segments based on both the low-flow analysis and the 1998–2009 HBED cross section analysis.

Dredging under the Proposed Action would result in continued river bed degradation in the Kansas City segment, in both the short term and the long term. Projecting the past degradation trend into the future, moderate additional river bed degradation likely would occur in the short term, and substantial river bed degradation would occur in the long term (see Section 3.4.6 for details on past trends).

Other factors likely to contribute to the effects of dredging on the channel bed elevation include the BSNP structures in the Kansas City segment that effectively scour the navigation channel and reduce deposition of new sediment; flow modification from upstream dams that increase moderate flows and eliminate the lowest pre-dam flows from the annual hydrograph; and the Kansas River, which contributes flows but likely has reduced sediment delivery due to dredging and dams. These factors reduce deposition of sediment in this segment and, along with dredging, contribute to the ongoing degradation of the river bed in the segment (see Section 3.4.6.3 for details).

Waverly Segment

The Proposed Action is to permit 1,005,600 tons of dredging per year in the Waverly segment. From 2004 to 2008 (existing conditions), dredging averaged 677,987 tons per year in this segment. Past dredging has been limited and not concentrated in any portion of the segment.

The Proposed Action would increase the amount of dredging in the Waverly segment by 48 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from 14 percent to approximately 20 percent. The amount dredged under the Proposed Action as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 13 percent.

The USGS gage at Waverly indicates that the river bed elevation has been stable since approximately the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation in the middle portion of the segment (RM 255 to RM 325). Increasing the dredging from 14 to 20 percent of the bed material load in the Waverly segment, particularly if it is spread throughout the reach as is currently done, could cause slight degradation or aggradation in the short term and slight degradation in the long term. Changes in river bed elevations would be subject to normal variability on the river, which would result in some areas with aggradation and some areas with degradation.

Jefferson City Segment

The Proposed Action is to permit 2,750,000 tons of dredging per year in the Jefferson City segment. From 2004 to 2008 (existing conditions), dredging averaged 1,578,858 tons per year in this segment. More dredging occurred in the Jefferson City area between RM 140 and RM 150 than in other portions of the segment. Moderate degradation occurs in the Jefferson City portion of the segment, with upriver portions experiencing less degradation (as indicated at the Boonville gage) or aggradation (above RM 225).

The Proposed Action would increase the amount of dredging in the Jefferson City segment by 74 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from 37 percent to approximately 65 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 42 percent.

The USGS gage at Boonville indicates that the river bed elevation has declined slightly in the Jefferson City segment since the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation throughout most of the segment, except for the Jefferson City area. Increasing the dredging from 37 to 65 percent of the bed material load, particularly if it is concentrated in the Jefferson City area as is currently done, would cause moderate river bed degradation in the short term and

substantial river bed degradation in the long term in the Jefferson City area. An additional potential impact from this level of dredging is development of a headcut that could migrate upriver and cause degradation above the area of active dredging and erosion of the river bed downriver. The rest of the segment outside the area of concentrated dredging near Jefferson City would experience slight degradation or aggradation in the short term and the long term.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight amount of bed degradation or aggradation throughout the reach in the short term and slight to moderate degradation in the long term.

St. Charles Segment

The Proposed Action is to permit 4,384,400 tons of dredging per year in the St. Charles segment. From 2004 to 2008 (existing conditions), dredging averaged 1,649,326 tons per year in the segment. Most of the dredging in this segment occurs near St. Charles, below RM 50.

The Proposed Action would increase the amount of dredging in the St. Charles segment by approximately 166 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from 45 percent to approximately 119 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 78 percent.

Average river bed elevation trends at the USGS gage at Hermann (RM 98) indicate that the river bed elevation has been declining steadily in the St. Charles segment since approximately 1959. The 1998–2009 HBED cross section analysis shows some areas of aggradation, with degradation occurring in the area with the most dredging. Increasing the dredging from 45 to 119 percent of the bed material load, particularly if it is concentrated in the St. Charles area, would cause moderate degradation in the short term and substantial degradation in the long term in the St. Charles area. An additional potential impact from this level of dredging is development of a headcut that could migrate upriver and cause degradation above the area of active dredging and erosion of the river bed downriver. Areas outside the St. Charles area would experience slight degradation in the short term and the long term.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach.

The result would be a slight to moderate amount of dredging-related river bed degradation throughout the St. Charles segment in the short term and moderate river bed degradation in the long term.

4.2.4.3 Changes in Channel Geometry and Water Surface Elevations

St. Joseph Segment

If the proposed level of dredging in the St. Joseph segment occurs in the same area that past dredging occurred (in the St. Joseph area between RM 445 and RM 455), slight dredging-related river bed degradation in that area would be expected in the short term, and moderate to substantial dredging-related river bed degradation would be anticipated in the long term.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight reduction in low-flow water surface elevations in the short term and moderate to substantial reductions in the long term in the St. Joseph area.

High-flow water surface elevations likely would increase in the long term in the St. Joseph area, as vegetation becomes established and deposition occurs in the river channel.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the segment. The result would be a slight amount of dredging-related low-flow water surface reductions throughout the segment in the long term.

If dredging was evenly distributed throughout the St. Joseph segment, changes in high-flow water surface elevations are unlikely to change from existing trends, which have been stable over the past 30 years.

Kansas City Segment

Dredging under the Proposed Action likely would result in continued river bed degradation in the Kansas City segment in both the short term and long term, and at a similar or slightly faster rate than has occurred over the past 10 years. Moderate degradation likely would occur in the short term, while substantial degradation likely would occur in the long term.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels in the Kansas City segment likely would result in a moderate reduction in low-flow water surface elevations in the short term and moderate to substantial reductions in the long term.

High-flow water surface elevations in the Kansas City segment could increase or decrease in the short term, and likely would increase in the long term as vegetation becomes established and deposition occurs in the river channel.

Waverly Segment

Increasing dredging from 14 to 20 percent of the bed material load in the Waverly segment, particularly if it is spread throughout the reach as is currently done, likely would cause slight degradation or aggradation in the short term and slight degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, the low-flow water surface elevation in the Waverly segment likely would increase or decrease slightly in the short term and decrease slightly in the long term.

Changes in high-flow water surface elevations in the Waverly segment are unlikely to change from existing trends, which have increased slightly in the past 30 years.

Jefferson City Segment

Increasing the dredging from 37 to 65 percent of the bed material load, particularly if it is concentrated in the Jefferson City area as is currently done, would cause moderate river bed degradation in the short term and substantial degradation in the long term in the Jefferson City area.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight reduction in low-flow water surface elevations in the short term and moderate reductions in the long term in the Jefferson City area.

High-flow surface elevations likely would increase in the long term in the vicinity of Jefferson City.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight decrease or increase in the low-flow water surface throughout the Jefferson City segment in the short term and a slight decrease in the long term. Changes in high-flow water surface elevations are unlikely to change from existing trends, which have increased slightly in the past 30 years.

St. Charles Segment

Increasing the dredging from 45 to 119 percent of the bed material load under the Proposed Action, particularly if it is concentrated in the St. Charles area, would cause moderate degradation in the short term and substantial degradation in the long term in the St. Charles area.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a moderate reduction in low-flow water surface elevations in the short term and moderate to substantial reductions in the long term in the St. Charles area.

High-flow water surface elevations in the St. Charles area could decrease in the short term and likely would increase in the long term as vegetation becomes established and deposition occurs in the floodplain channel.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight to moderate reduction in the low-flow water surface elevation throughout the reach in the short term and a moderate reduction in the long term. High-flow water surface elevations could slightly increase in the long term in the St. Charles area as the channel degrades, vegetation becomes established, and deposition occurs in the floodplain channel.

4.2.4.4 Tributary Degradation

Tributary degradation is linked to low-flow water surface elevations in the main channel. In general, a moderate to substantial decrease in LOMR low-flow water surface elevations would need to occur before tributaries are likely to be affected (see Section 4.2.3.4 for details).

St. Joseph Segment

Dredging at the proposed levels likely would result in a slight reduction in low-flow water surface elevations in the short term, and moderate to substantial reductions in the long term in the St. Joseph area.

Tributary degradation is likely to increase in the long term in the St. Joseph area under the Proposed Action.

Kansas City Segment

Dredging under the Proposed Action likely would result in a moderate reduction in low-flow water surface elevations in the Kansas City segment in the short term, and moderate to substantial reductions in the long term.

Tributary degradation is likely to increase in the short term and the long term in the Kansas City segment under the Proposed Action.

Waverly Segment

Dredging under the Proposed Action likely would result in a slight reduction in low-flow water surface elevations in the Waverly segment in the long term.

Because dredging under the Proposed Action would not result in moderate or substantial decreases in low-flow water surface elevations in the Waverly segment, dredging-related tributary degradation would be unlikely to increase.

Jefferson City Segment

Dredging under the Proposed Action likely would result in a slight reduction in low-flow water surface elevations in the Jefferson City segment in the short term, and moderate reductions in the long term. If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight reduction or increase in the low-flow water surface throughout the Jefferson City segment in the short term and a slight decrease in the long term.

Tributary degradation is likely to increase in the long term in the Jefferson City portion of the segment under the Proposed Action. If dredging was spread throughout the reach, tributary degradation would be unlikely in the short term or the long term.

St. Charles Segment

Dredging under the Proposed Action likely would result in a moderate reduction in low-flow water surface elevations in the St. Charles segment in the short term, and moderate to substantial reductions in the long term. If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight to moderate reduction in the low-flow water surface elevation throughout the reach in the short term and a moderate reduction in the long term.

Tributary degradation is likely to increase in the short term and the long term in the St. Charles area under the Proposed Action. Degradation also is likely to occur in the short term and the long term if dredging was spread throughout the reach. The St. Charles segment has more side channels than other segments, and degradation would occur in those areas as well as in the tributaries.

4.2.5 No Action Alternative

Under the No Action Alternative, no commercial dredging would occur in any segment. Table 4.2-3 shows the amount dredged under existing conditions (2004–2008), the dredging proposed under the No Action Alternative, the amount dredged as a percent of the bed material load for existing conditions and the No Action Alternative, and the portion of the segment where dredging is concentrated under existing conditions.

Table 4.2-3 Dredging under Existing Conditions and the No Action Alternative

Segment	Dredging – Existing Conditions (tons/year)	Dredging Percent of Bed Material Load – Existing Conditions	Dredging – No Action Alternative (tons/year)	Dredging Percent of Bed Material Load – No Action Alternative	Primary Dredging Location – Existing Conditions
St. Joseph	326,928	9%	0	0%	RM 445 – RM 455
Kansas City	2,658,831	50%	0	0%	Throughout segment
Waverly	677,987	14%	0	0%	Throughout segment
Jefferson City	1,578,858	37%	0	0%	RM 140 – RM 150
St. Charles	1,649,326	45%	0	0%	Below RM 50

Note: RM = River mile.

4.2.5.1 Changes in Sediment Loads and River Bed Composition

All Segments

Changes in sediment loads and river bed composition occur in the vicinity of the dredging operation and are proportional to the amount of dredging occurring. Because no commercial dredging would take place under the No Action Alternative, no impacts related to dredging would occur in any segment. Dredging would not remove any portion of the bed material load from areas in any segment that experienced concentrated dredging under existing conditions. Coarse material deposited on the river bed from past dredging would be mixed into the river bed over time and would be transported downriver during higher flow events.

4.2.5.2 Changes in River Bed Elevation

All Segments

Under the No Action Alternative, no dredging-related river bed degradation would occur in any segment. Aggradation likely would occur in areas where concentrated dredging occurred recently as the river bed responded to influxes of bed material load in the absence of dredging.

St. Joseph Segment

Under the No Action Alternative, the St. Joseph area (RM 445 to RM 455, where past dredging has been concentrated) would experience slight to moderate aggradation in the short term and the long term. Changes in river bed elevations in the rest of the St. Joseph segment would be subject to normal variability in flows and sediment delivery, which would result in some areas with aggradation and some with degradation.

Kansas City Segment

Under the No Action Alternative, the Kansas City segment likely would experience slight to moderate aggradation in the short term and moderate to substantial aggradation in the long term. Other factors likely to influence the amount of aggradation in this segment include the BSNP structures in the segment that effectively scour the navigation channel and reduce deposition of new sediment; flow modification from upstream dams that increase moderate flows and eliminate the lowest pre-dam flows from the annual hydrograph; and the Kansas River, which contributes flows but likely has reduced sediment delivery due to dredging and dams. These factors reduce deposition of sediment in this segment and may limit aggradation or recovery of the river bed in this segment.

Waverly Segment

Because dredging has not been concentrated in any one portion of the segment in the past, and past dredging has not exceeded 10 percent of the bed material load, impacts from past dredging have been minimal in the Waverly segment. Under the No Action Alternative, the Waverly segment likely would experience slight aggradation or degradation in the short term and the long term in different portions of the segment, in response to inter-annual changes in flows and sediment supply.

Jefferson City Segment

The Jefferson City segment has experienced moderate degradation in the Jefferson City portion of the segment near RM 140 and RM 150. Under the No Action Alternative, the Jefferson City area would

experience slight to moderate aggradation in the short term and slight aggradation or degradation in the long term once that portion of the river bed had recovered from past dredging. The rest of the segment likely would experience slight aggradation or degradation in the short term and the long term in different portions of the segment, in response to inter-annual changes in flows and sediment supply.

St. Charles Segment

Average river bed elevation trends at the USGS gage at Hermann indicate that the river bed elevation has been declining steadily since approximately 1959. The 1998–2009 HBED cross section analysis shows some areas of aggradation, with degradation occurring in the area with the most dredging below RM 50. Under the No Action Alternative, the St. Charles area likely would experience slight to moderate aggradation in the short term and slight aggradation or degradation in the long term once that portion of the river bed had recovered from past dredging. The rest of the segment likely would experience slight aggradation or degradation in the short term and the long term in different portions of the segment, in response to inter-annual changes in flows and sediment supply.

4.2.5.3 Changes in Channel Geometry and Water Surface Elevations

St. Joseph Segment

Under the No Action Alternative, the St. Joseph segment would experience slight to moderate aggradation in the short term and the long term in the St. Joseph area (in the vicinity of RM 445 to RM 455, where past dredging has been concentrated).

Water surface elevations for 20,000-cfs flows have been slightly declining for the last 10 years at the USGS gage at St. Joseph. Because low-flow water surface elevations are linked to river bed elevation changes, low-flow water surface elevations in the St. Joseph segment likely would increase slightly in the short term and the long term in the vicinity of past concentrated dredging.

High-flow water surface elevations in the vicinity of St. Joseph also would follow existing trends and likely would increase in the long term as the river bed aggrades.

Kansas City Segment

Under the No Action Alternative, the Kansas City segment likely would experience slight to moderate aggradation in the short term and moderate to substantial aggradation in the long term.

Low-flow water surface elevations have been declining at the USGS gage in Kansas City for over 50 years, and the rate of decline has increased over the past 15 years. In addition to dredging, other factors likely have affected degradation in the Kansas City segment under existing conditions. Because low-flow water surface elevations are linked to river bed elevation changes, low-flow water surface elevations likely would experience a slight to moderate increase in the short term and moderate to substantial increases in the long term, in the areas with the greatest past degradation.

High-flow water surface elevations in the Kansas City segment likely would increase in the short term and the long term as the river bed aggrades.

Waverly Segment

Under the No Action Alternative, the Waverly segment likely would experience aggradation or degradation in the short term and the long term in different portions of the segment, in response to changes in flows and sediment supply.

Low-flow water surface elevations at the USGS gage at Waverly have been comparatively stable for the past 30 years. This trend likely would continue under the No Action Alternative.

High-flow water surface elevations have increased slightly in the Waverly segment over the past 30 years. This trend would not be affected by the No Action Alternative and likely would continue.

Jefferson City Segment

Under the No Action Alternative, the Jefferson City area would experience slight to moderate aggradation in the short term and slight aggradation or degradation in the long term once that portion of the river bed has recovered from past dredging. The rest of the segment likely would experience slight aggradation or degradation in the short term and the long term in different portions of the segment, in response to changes in flows and sediment supply.

Because low-flow water surface elevations are linked to river bed elevation changes, low-flow water surface elevations likely would experience a slight increase in the short term and the long term in the Jefferson City area. Other portions of the segment would be subject to normal variability on the river, resulting in slight increases or decreases in low-flow water surface elevations in the long term.

Under the No Action Alternative, high-flow water surface elevations likely would continue to follow existing long-term trends and likely would increase in the long term in the vicinity of Jefferson City.

St. Charles Segment

Under the No Action Alternative, the St. Charles portion of the segment likely would experience slight to moderate aggradation in the short term and slight aggradation or degradation in the long term once that portion of the river bed has recovered from past dredging. The rest of the segment likely would experience slight aggradation or degradation in the short term and the long term in different portions of the segment, in response to changes in flows and sediment supply.

Because low-flow water surface elevations are linked to river bed elevation changes, low-flow water surface elevations likely would experience a slight increase in the short term and the long term in the vicinity of past concentrated dredging. Other portions of the St. Charles segment would be subject to normal variability on the river resulting in slight increases or decreases in low-flow water surface elevations in the long term.

High-flow water surface elevations have not changed much over the past 30 years at the USGS gage at Hermann. This trend is likely to continue for most of the segment. In the St. Charles area, an increase in high-flow water surface elevations may occur under the No Action Alternative as the river bed aggrades in the short term after the cessation of dredging.

4.2.5.4 Tributary Degradation

All Segments

No further degradation or reduction of low-flow water surface elevations would be expected under the No Action Alternative. Tributary headcutting and degradation that had already initiated in all segments as a result of dredging under existing conditions likely would continue in the short term and the long term under the No Action Alternative, but new tributary headcuts or degradation would be unlikely to occur under this alternative.

4.2.6 Alternative A

Alternative A would permit approximately 2,190,000 tons of commercial dredging from the five segments of the LOMR. This would decrease the amount dredged in the Kansas City, Jefferson City, and St. Charles segments and would increase the amount dredged in the St. Joseph and Waverly segments. Table 4.2-4 shows the amount dredged under existing conditions (2004–2008), the dredging proposed under Alternative A, the amount dredged as a percent of the bed material load for

existing conditions and Alternative A, the percent change in dredging between existing conditions and Alternative A, and the portion of the segment where dredging is concentrated under existing conditions.

Table 4.2-4 Dredging under Existing Conditions and Alternative A

Segment	Dredging – Existing Conditions (tons/year)	Dredging Percent of Bed Material Load – Existing Conditions	Dredging – Alternative A (tons/year)	Dredging Percent of Bed Material Load – Alternative A	Percent Change in Dredging from Existing Conditions	Primary Dredging Location – Existing Conditions
St. Joseph	326,928	9%	350,000	10%	7%	RM 445 – RM 455
Kansas City	2,658,831	50%	540,000	10%	-80%	Throughout segment
Waverly	677,987	14%	500,000	10%	-26%	Throughout segment
Jefferson City	1,578,858	37%	430,000	10%	-73%	RM 140 – RM 150
St. Charles	1,649,326	45%	370,000	10%	-78%	Below RM 50

Note: RM = River mile.

4.2.6.1 Changes in Sediment Loads and River Bed Composition

All Segments

Localized changes in sediment loads and river bed composition occur in the vicinity of the dredging operation and are proportional to the amount of dredging occurring. Dredging proposed under Alternative A would result in the following effects in all segments:

- Short-term impacts in all segments would include a local decrease in sediment availability as the dredged area captures sediment transported by the river, and erosion occurs downriver as the river replaces the captured sediment. The amount of fine sediment in the water column would increase below the active dredge location as the dredging operation discharges unusable material back into the river.
- Long-term impacts in all segments under Alternative A would include an increase in the concentration of coarse gravel and cobbles on or near the surface of the river bed as material is dredged from the river bed and the material that is too coarse to retain is deposited back onto the surface of the river bed.

St. Joseph, Kansas City, and Waverly Segments

Because of the additional amount of dredging required to obtain material that meets specifications, the effects of dredging on sediment availability and coarse sediment would be greater for the St. Joseph, Kansas City, and Waverly segments under Alternative A than for the Jefferson City and St. Charles segments. In general, the bed material in the St. Joseph, Kansas City, and Waverly segments tends to be finer than the specifications for concrete sand, requiring additional material to be dredged from the river bed (see Figures 3.4-14 and 3.4-15 for the size distribution of bed material relative to the specifications). For example, 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. As a result, the actual volume of material extracted from the river bed may be three times greater than the retained dredging volumes indicate, increasing local impacts on sediment availability and coarse sediment.

4.2.6.2 Changes in River Bed Elevation

St. Joseph Segment

Alternative A would permit 350,000 tons of dredging per year in the St. Joseph segment. From 2004 to 2008 (existing conditions), dredging has occurred mainly in the St. Joseph area between RM 445 and RM 455, and has averaged 326,928 tons per year.

Alternative A would increase the amount dredged in the St. Joseph segment by 7 percent over the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from approximately 9 percent (existing conditions) to 10 percent. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 6 percent.

If the proposed level of dredging occurs in the same area that past dredging took place (in the St. Joseph area between RM 445 and RM 455), no change in existing degradation trends would be likely. Slight degradation or aggradation would be likely in the short term, with a potential for slight degradation in the long term in the St. Joseph area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from the removal of sediment from the river bed would be spread throughout

the reach. The result would be a slight amount of degradation or aggradation in the short term and the long term.

Kansas City Segment

Alternative A would permit 540,000 tons of dredging per year in the Kansas City segment. From 2004 to 2008 (existing conditions), dredging averaged 2,658,831 tons per year in this segment. The segment is relatively short compared to the other analysis segments, and past dredging has occurred throughout the segment. The Kansas City segment has experienced the most river bed degradation of any of the analysis segments based on both the low-flow analysis and the 1998–2009 HBED cross section analysis.

Alternative A would decrease the amount dredged in the Kansas City segment by approximately 80 percent below the annual average dredged from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would decrease from 50 to 10 percent. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 7 percent.

Dredging at the proposed level would reduce dredging-related degradation in the Kansas City segment in the short term and the long term. Slight degradation or aggradation of the river bed would be possible in the short term, and slight aggradation would be possible in the long term.

Other factors likely to influence the potential for aggradation include the BSNP structures in the Kansas City segment that effectively scour the navigation channel and reduce deposition of new sediment; flow modification from upstream dams that increase moderate flows and eliminate the lowest pre-dam flows from the annual hydrograph; and the Kansas River, which contributes flows but likely has reduced sediment delivery due to dredging and dams (see Section 3.4.6.3 for details). These factors reduce deposition of sediment in this segment and may limit aggradation or recovery of the river bed in this segment.

Waverly Segment

Alternative A would permit 500,000 tons of dredging per year in the Waverly segment. Past dredging has been limited and has not been concentrated in any portion of the segment.

Alternative A would decrease the amount of dredging in the Waverly segment by 26 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of

the bed material load at below-average flows would decrease from 14 to 10 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 7 percent.

The USGS gage at Waverly indicates that the river bed elevation has been stable since approximately the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation in the middle portion of the segment (RM 255 to RM 325). Decreasing dredging from 14 to 10 percent of the bed material load, particularly if it is spread throughout the reach as is currently done, could cause slight degradation or aggradation in the short term and the long term. Changes in river bed elevations would be subject to normal variability on the river, which would result in some areas with aggradation and some with degradation.

Jefferson City Segment

Alternative A would permit 430,000 tons of dredging per year in the Jefferson City segment. From 2004 to 2008, dredging averaged 1,578,858 tons per year in the Jefferson City segment. More dredging occurred in the Jefferson City area between RM 140 and RM 150 than in other portions of the segment. Moderate river bed degradation in this segment is concentrated in the Jefferson City area, with upriver portions experiencing less degradation (as indicated at the Boonville gage) or aggradation (above RM 225).

Alternative A would decrease the amount of dredging in the Jefferson City segment by 73 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would decrease from 37 to 10 percent. The amount dredged as a percent of the bed material load under average flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 7 percent.

The USGS gage at Boonville indicates that the river bed elevation in the Jefferson City segment has declined slightly since the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation throughout most of the segment except for the Jefferson City area, which showed slight to moderate degradation. Decreasing the amount dredged from 37 to 10 percent of the bed material load would cause slight degradation or aggradation in the short term and the potential for slight degradation in the long term in the Jefferson City area. Areas outside of the Jefferson City area would experience slight degradation or aggradation in the short term and the long term.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight amount of river bed degradation or aggradation throughout the reach in the short term and the long term.

St. Charles Segment

Alternative A would permit 370,000 tons of dredging per year in the St. Charles segment. From 2004 to 2008, dredging averaged 1,649,326 tons per year in the St. Charles segment. Most of the dredging in this segment occurred near St. Charles, below RM 50.

Alternative A would decrease the amount of dredging in the segment by 78 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would decrease from 45 to 10 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 7 percent.

Average river bed elevation trends at the USGS gage at Hermann indicate that the river bed elevation has been declining steadily since approximately 1959. The 1990–2005 low-flow analysis shows degradation occurring in the area with the most dredging near St. Charles. Decreasing the dredging from 45 to 10 percent of the bed material load, particularly if it is concentrated in the St. Charles area, would cause slight degradation or aggradation in the short term and the long term in the St. Charles area.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be slight degradation or aggradation in the segment in the short term and the long term.

4.2.6.3 Changes in Channel Geometry and Water Surface Elevations

St. Joseph Segment

Dredging proposed under Alternative A, particularly if concentrated in the St. Joseph area, likely would result in slight degradation or aggradation in the short term and a potential for slight degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, the low-flow water surface elevations likely would be slightly reduced in the long term in the St. Joseph area. Water surface elevations for 20,000-cfs flows have been slightly declining for the last 10 years.

High-flow water surface elevations could increase or decrease in the long term in the St. Joseph area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

Kansas City Segment

Dredging proposed under Alternative A likely would result in slight degradation or aggradation in the Kansas City segment in the short term and slight aggradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, the low-flow water surface elevation in the Kansas City segment could increase or decrease slightly in the short term and likely would increase slightly in the long term.

High-flow water surface elevations in the Kansas City segment could increase or decrease slightly in the short term and might increase slightly in the long term as the river bed aggrades.

Waverly Segment

Dredging proposed in the Waverly segment under Alternative A likely would result in slight degradation or aggradation in the short term and the long term.

Low-flow and high-flow water surface elevations are unlikely to change from existing trends. Low-flow water surface elevations have not changed much in the past 20 years in the Waverly segment, and high-flow water surface elevations have increased a slight to moderate amount in the past 20 years.

Jefferson City Segment

Dredging proposed under Alternative A would cause slight degradation or aggradation in the short term and the potential for slight degradation in the long term in the Jefferson City area. Areas outside of the Jefferson City area would experience slight degradation or aggradation in the short term and the long term.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight reduction or increase in low-flow water surface elevations in the short term and a slight decrease in the long term in the Jefferson City area.

Under Alternative A, high-flow water surface elevations likely would continue to follow long-term trends and likely would increase in the long term in the vicinity of Jefferson City.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

St. Charles Segment

Dredging proposed under Alternative A could cause slight degradation or aggradation in the short term and the long term in the St. Charles area.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels could result in slight decreases or increases in low-flow water surface elevations in the short term and the long term in the St. Charles area.

The effects of dredging on high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations in the short term or the long term in the St. Charles area.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

4.2.6.4 Tributary Degradation

All Segments

Because dredging under Alternative A would not result in moderate or substantial decreases in low-flow water surface elevations for any of the segments, dredging-related tributary degradation would be unlikely to increase in any segment under this alternative.

4.2.7 Alternative B

Alternative B would permit 5,050,000 tons of commercial dredging from the five segments of the LOMR. This would decrease the amount dredged in the Kansas City, Jefferson City, and St. Charles segments and increase the amount dredged in the St. Joseph and Waverly segments. Table 4.2-5 shows the amount dredged under existing conditions (2004–2008), the dredging proposed under Alternative B, the amount dredged as a percent of the bed material load for existing conditions and Alternative B, the percent change in dredging between existing conditions and Alternative B, and the portion of the segment where dredging is concentrated under existing conditions.

Table 4.2-5 Dredging under Existing Conditions and Alternative B

Segment	Dredging – Existing Conditions (tons/year)	Dredging Percent of Bed Material Load – Existing Conditions	Dredging – Alternative B (tons/year)	Dredging Percent of Bed Material Load – Alternative B	Percent Change in Dredging from Existing Conditions	Primary Dredging Location – Existing Conditions
St. Joseph	326,928	9%	860,000	25%	163%	RM 445 – RM 455
Kansas City	2,658,831	50%	1,230,000	23%	-54%	Throughout segment
Waverly	677,987	14%	1,140,000	23%	68%	Throughout segment
Jefferson City	1,578,858	37%	980,000	23%	-38%	RM 140 – RM 150
St. Charles	1,649,326	45%	840,000	23%	-49%	Below RM 50

Note: RM = River mile.

4.2.7.1 Changes in Sediment Loads and River Bed Composition

All Segments

Localized changes in sediment loads and river bed composition occur in the vicinity of the dredging operation and are proportional to the amount of dredging occurring. Dredging under Alternative B would result in the following effects in all segments:

- Short-term impacts in all segments would include a local decrease in sediment availability as the dredged area captures sediment transported by the river, and erosion occurs downriver as the river replaces the captured sediment. The amount of fine sediment in the water column would increase below the active dredge location as the dredging operation discharges unusable material back into the river.

- Long-term impacts in all segments under the Alternative B would include an increase in the concentration of coarse gravel and cobbles on or near the surface of the river bed as material is dredged from the river bed and the material that is too coarse to retain is deposited back onto the surface of the river bed.

St. Joseph, Kansas City, and Waverly Segments

Because of the additional amount of dredging required to obtain material that meets specifications, the effects of dredging on sediment availability and coarse sediment would be greater for the St. Joseph, Kansas City, and Waverly segments under Alternative B than for the Jefferson City and St. Charles segments. In general, the bed material in the St. Joseph, Kansas City, and Waverly segments tends to be finer than the specifications for concrete sand, requiring additional material to be dredged from the river bed (see Figures 3.4-14 and 3.4-15 for the size distribution of bed material relative to the specifications). For example, 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. As a result, the actual volume of material extracted from the river bed may be three times greater than the retained dredging volumes indicate, increasing local impacts on sediment availability and coarse sediment.

4.2.7.2 Changes in River Bed Elevation

St. Joseph Segment

Alternative B would permit 860,000 tons of dredging per year in the St. Joseph segment. From 2004 to 2008 (existing conditions), dredging has occurred mainly in the St. Joseph area between RM 445 and RM 455, and averaged 326,928 tons per year.

Alternative B would increase the amount dredged by 163 percent over the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from approximately 9 percent (existing conditions) to 25 percent. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 15 percent.

If the proposed level of dredging occurs in the same area that past dredging occurred, in the St. Joseph area between RM 445 and RM 455, there likely would be slight degradation in the short term and slight to moderate degradation in the long term in the St. Joseph area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight amount of degradation or aggradation in the short term and the potential for slight degradation in the long term.

Kansas City Segment

Alternative B would permit 1,230,000 tons of dredging per year in the Kansas City segment. From 2004 to 2008 (existing conditions), dredging averaged 2,658,831 tons per year in this segment. The segment is relatively short compared to the other analysis segments, and past dredging has occurred throughout the segment. The Kansas City segment has experienced the most river bed degradation of any of the analysis segments based on both the low-flow analysis and the 1998–2009 HBED cross section analysis.

Alternative B would decrease the amount dredged in the Kansas City segment by 54 percent below the annual average dredged from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would decrease from 48 to 23 percent. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 15 percent.

Dredging at the proposed level would reduce dredging-related degradation in the Kansas City segment in both the short term and the long term, and would result in slight degradation in the short term and moderate degradation in the long term.

Other factors likely contribute to the effects of dredging on the channel bed elevation in this segment. These include the BSNP structures in the Kansas City segment that effectively scour the navigation channel and reduce deposition of new sediment; flow modification from upstream dams that increase moderate flows and eliminate the lowest pre-dam flows from the annual hydrograph; and the Kansas River, which contributes flows but likely has reduced sediment delivery due to dredging and dams. These factors reduce deposition of sediment in this segment and, along with dredging, contribute to the ongoing degradation of the river bed in this segment (see Section 3.4.6.3 for details).

Waverly Segment

Alternative B would permit 1,140,000 tons of dredging per year in the Waverly segment. From 2004 to 2008 (existing conditions), dredging averaged 677,987 tons per year in this segment. Past dredging has been limited and has not been concentrated in any portion of the segment.

Alternative B would increase the amount of dredging in the Waverly segment by 68 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would increase from 14 to 23 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 15 percent.

The USGS gage at Waverly indicates that the river bed elevation has been stable since approximately the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation in the middle portion of the segment (RM 255 to RM 325). Increasing the dredging from 14 to 23 percent of the bed material load, particularly if it is spread throughout the reach as is currently done, could cause slight degradation or aggradation in the short term and slight degradation in the long term. Changes in river bed elevations would also be subject to normal variability on the river, which would result in some areas with aggradation and some areas with degradation.

Jefferson City Segment

Alternative B would permit 980,000 tons of dredging per year in the Jefferson City segment. From 2004 to 2008, dredging averaged 1,578,858 tons per year in the Jefferson City segment. More dredging occurred in the Jefferson City area between RM 140 and RM 150 than in other portions of the segment. Moderate river bed degradation in this segment occurred in the Jefferson City portion of the segment, with upriver portions experiencing less degradation (as indicated at the Boonville gage) or aggradation (above RM 225).

Alternative B would decrease the amount of dredging in the Jefferson City segment by 38 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would decrease from 37 to 23 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 15 percent.

The USGS gage at Boonville indicates that the river bed elevation has declined slightly since the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation throughout most of the segment except for the Jefferson City area, which showed slight to moderate degradation. Decreasing the amount dredged from 37 to 23 percent of the bed material load would cause slight degradation in the short term and slight to moderate degradation in the long term in the Jefferson City area. Areas outside of the Jefferson City area would experience slight degradation or aggradation in the short term and the long term.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight amount of river bed degradation or aggradation throughout the reach in the short term and slight degradation in the long term.

St. Charles Segment

Alternative B would permit 840,000 tons of dredging per year in the St. Charles segment. From 2004 to 2008, dredging averaged 1,649,326 tons per year in the St. Charles segment. Most of the dredging in this segment occurred below RM 50 near St. Charles.

Alternative B would decrease the amount of dredging in the segment by approximately 49 percent compared to the annual average from 2004 to 2008. Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would decrease from 45 to 23 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 15 percent.

Average river bed elevation trends at the USGS gage at Hermann indicate that the bed elevation has been declining steadily since approximately 1959. The 1990–2005 low-flow analysis shows some areas of aggradation, with degradation occurring in the area with the most dredging in the St. Charles area. Decreasing the dredge amount from 45 to 23 percent of the bed material load, particularly if it is concentrated in the St. Charles area, would cause slight degradation in the short term and slight to moderate degradation in the long term in the St. Charles area.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight degradation or aggradation in the short term and slight degradation in the long term.

4.2.7.3 Changes in Channel Geometry and Water Surface Elevations

St. Joseph Segment

Dredging proposed under Alternative B, particularly if it was concentrated in the St. Joseph area, likely would result in slight degradation or aggradation in the short term and a potential for slight to moderate degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, low-flow water surface elevations likely would be slightly reduced in the short term and slightly to moderately decreased in the long term in the St. Joseph area. Water surface elevations for 20,000-cfs flows have been slightly declining for the last 10 years.

High-flow water surface elevations would follow existing trends and likely would increase in the long term in the St. Joseph area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

Kansas City Segment

Dredging proposed under Alternative B likely would result in slight degradation in the Kansas City segment in the short term and moderate degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, the low-flow water surface elevation in the Kansas City segment likely would decrease slightly in the short term and decrease slightly to moderately in the long term.

High-flow water surface elevations in the Kansas City segment likely would increase in the long term.

Waverly Segment

Dredging proposed under Alternative B could cause slight degradation or aggradation in the short term and slight degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, the low-flow water surface elevation in the Waverly segment likely would increase or decrease slightly in the short term and decrease slightly in the long term.

Changes in high-flow water surface elevations in the Waverly segment are unlikely to change from existing trends, which have increased slightly in the past 30 years.

Jefferson City Segment

Dredging proposed under Alternative B would cause slight degradation in the short term and slight to moderate degradation in the long term in the Jefferson City area. Areas outside of the Jefferson City area would experience slight degradation or aggradation in the short term and the long term.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight reduction in low-flow water surface elevations in the long term in the Jefferson City area.

Under Alternative B, high-flow water surface elevations likely would continue to follow long-term trends and likely would increase in the long term in the vicinity of Jefferson City.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

St. Charles Segment

Dredging proposed under Alternative B would cause slight degradation in the short term and slight to moderate degradation in the long term in the St. Charles area.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight to moderate decrease in low-flow water surface elevations in the long term in the St. Charles area.

High-flow surface elevations likely would increase in the long term in the St. Charles area.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

4.2.7.4 Tributary Degradation

Tributary degradation is linked to low-flow water surface elevations in the main channel. In general, a moderate to substantial decrease in LOMR low-flow water surface elevations would need to occur

before tributaries are likely to be affected. Therefore, degradation is unlikely to occur in the Waverly segment.

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

Under Alternative B, moderate decreases in low-flow water surface elevations would occur in the long term in areas with concentrated dredging in the St. Joseph, Kansas City, Jefferson City, and St. Charles segments. Tributary degradation is likely to increase in the vicinity of concentrated dredging in these segments as a result of dredging under Alternative B. Tributary degradation would be unlikely to increase if dredging was spread throughout the reach rather than concentrated in the urban areas.

4.2.8 Alternative C

Alternative C would permit approximately 6,900,000 tons of commercial dredging from the five segments of the LOMR. This would be the same as the average annual amount of dredging from 2004 to 2008. Table 4.2-6 shows the amount dredged under existing conditions (2004–2008), the dredging proposed under Alternative C, the amount dredged as a percent of the bed material load for existing conditions and Alternative C, the percent change in dredging between existing conditions and Alternative C, and the portion of the segment where dredging is concentrated under existing conditions.

Table 4.2-6 Dredging under Existing Conditions and Alternative C

Segment	Dredging – Existing Conditions (tons/year)	Dredging Percent of Bed Material Load – Existing Conditions	Dredging – Alternative C (tons/year)	Dredging Percent of Bed Material Load – Alternative C	Percent Change in Dredging from Existing Conditions	Primary Dredging Location – Existing Conditions
St. Joseph	326,928	9%	330,000	9%	1%	RM 445 – RM 455
Kansas City	2,658,831	50%	2,660,000	50%	0%	Throughout segment
Waverly	677,987	14%	680,000	14%	0%	Throughout segment
Jefferson City	1,578,858	37%	1,580,000	37%	0%	RM 140 – RM 150
St. Charles	1,649,326	45%	1,650,000	45%	0.0%	Below RM 50

Note: RM = River mile.

4.2.8.1 Changes in Sediment Loads and River Bed Composition

All Segments

Localized changes in sediment loads and river bed composition occur in the vicinity of the dredging operation and are proportional to the amount of dredging occurring. Dredging ***proposed under Alternative C would result in the following effects in all segments:

- Short-term impacts in all segments would include a local decrease in sediment availability as the dredged area captures sediment transported by the river, and erosion occurs downriver as the river replaces the captured sediment. The amount of fine sediment in the water column would increase below the active dredge location as the dredging operation discharges unusable material back into the river.
- Long-term impacts in all segments under Alternative C would include an increase in the concentration of coarse gravel and cobbles on or near the surface of the river bed as material is dredged from the river bed and the material that is too coarse to retain is deposited back onto the surface of the river bed.

St. Joseph, Kansas City, and Waverly Segments

Because of the additional amount of dredging required to obtain material that meets specifications, the effects of dredging on sediment availability and coarse sediment would be greater for the St. Joseph, Kansas City, and Waverly segments under Alternative A than for the Jefferson City and St. Charles segments. In general, the bed material in the St. Joseph, Kansas City, and Waverly segments tends to be finer than the specifications for concrete sand, requiring additional material to be dredged from the river bed (see Figures 3.4-14 and 3.4-15 for the size distribution of bed material relative to the specifications). For example, 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. As a result, the actual volume of material extracted from the river bed may be three times greater than the retained dredging volumes indicate, increasing local impacts on sediment availability and coarse sediment.

4.2.8.2 Changes in River Bed Elevation

St. Joseph Segment

Alternative C would permit 330,000 tons of dredging per year in the St. Joseph segment. This approximates the level of dredging that occurred from 2004 to 2008 (existing conditions), which has occurred mainly in the St. Joseph area between RM 445 and RM 455.

Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would remain at approximately nine percent. The amount proposed to be dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would remain approximately 6 percent.

If the proposed level of dredging occurs in the same area that past dredging occurred (in the St. Joseph area between RM 445 and RM 455), existing degradation trends would not change. Slight degradation or aggradation would be expected in the short term, with a potential for slight degradation in the long term in the St. Joseph area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight amount of degradation or aggradation in the short term and the long term.

Kansas City Segment

Alternative C would permit 2,660,000 tons of dredging per year in the Kansas City segment. This approximates the level of dredging that occurred from 2004 to 2008 (existing conditions). The segment is relatively short compared to the other analysis segments, and past dredging has occurred throughout the segment. The Kansas City segment has experienced the most river bed degradation of any of the analysis segments based on both the low-flow analysis and the 1998–2009 HBED cross section analysis.

Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would remain at approximately 50 percent. The amount dredged under this alternative as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would remain at approximately 32 percent.

Dredging at the proposed level would result in a continuation of current trends (see Section 3.4.6 for details on current trends) in the Kansas City segment, resulting in slight to moderate degradation in the short term and substantial degradation in the long term.

Other factors likely contribute to the effects of dredging on the channel bed elevation in this segment. These include the BSNP structures in the Kansas City segment that effectively scour the navigation channel and reduce deposition of new sediment; flow modification from upstream dams that increase moderate flows and eliminate the lowest pre-dam flows from the annual hydrograph; and the Kansas River, which contributes flows but likely has reduced sediment delivery due to dredging and dams. These factors reduce deposition of sediment in this segment and, along with dredging, contribute to the ongoing degradation of the river bed in the segment (see Section 3.4.6.3 for details).

Waverly Segment

Alternative C would permit 680,000 tons of dredging per year in the Waverly segment. This approximates the level of dredging that occurred from 2004 to 2008 (existing conditions). Past dredging has been limited and has not been concentrated in any portion of the segment.

Under this alternative, the amount dredged as a percent of the bed material load at below-average flows would remain at approximately 14 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would remain at approximately 9 percent.

The USGS gage at Waverly (RM 293) indicates that the river bed elevation has been stable since approximately the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation in the middle portion of the segment (RM 255 to RM 325). Maintaining dredging at 14 percent of the bed material load, particularly if it is spread throughout the reach as is currently done, would cause slight degradation or aggradation in the short term and the long term. Changes in river bed elevations would be subject to normal variability on the river, which would result in some areas with aggradation and other areas with degradation.

Jefferson City Segment

Alternative C would permit 1,580,000 tons of dredging per year in the Jefferson City segment. This approximates the level of dredging that occurred from 2004 to 2008 (existing conditions). More dredging occurred in the Jefferson City area between RM 140 and RM 150 than in other portions of the segment. River bed degradation in this segment occurs in the Jefferson City portion of the segment,

with upriver portions experiencing less degradation (as indicated at the Boonville gage) or aggradation (above RM 225).

Under Alternative C, the amount dredged at below-average flows would remain at 37 percent of the bed material load. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would remain at approximately 24 percent.

The USGS gage at Boonville indicates that the river bed elevation has declined slightly since the 1993 flood event. The 1998–2009 HBED cross section analysis shows areas of aggradation throughout most of the segment except for the Jefferson City area, which shows moderate degradation. Maintaining dredging at 37 percent of the bed material load would cause slight degradation in the short term and moderate to substantial degradation in the long term in the Jefferson City area. Areas outside of the Jefferson City area would experience slight degradation or aggradation in the short term and the long term.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight amount of bed degradation or aggradation throughout the reach in the short term and slight degradation in the long term.

St. Charles Segment

Alternative C would permit 1,650,000 tons of dredging per year in the St. Charles segment. This approximates the level of dredging that occurred from 2004 to 2008 (existing conditions). Most of the dredging in this segment occurred below RM 50 near St. Charles.

Under Alternative C, the amount dredged as a percent of the bed material load at below-average flows would remain at 45 percent. The amount dredged as a percent of the bed material load under average-flow conditions (as estimated from the 1994–2009 analysis period) would be approximately 29 percent.

Average river bed elevation trends at the USGS gage at Hermann indicate that the bed elevation has been declining steadily since approximately 1959. The 1990–2005 low-flow analysis shows areas of degradation occurring in the area with the most dredging. Maintaining dredging at 45 percent of the bed material load, particularly if it is concentrated in the St. Charles area, would cause slight degradation in the short term and moderate to substantial degradation in the long term in the St. Charles area.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The result would be a slight degradation or aggradation in the short term and slight degradation in the long term.

4.2.8.3 Changes in Channel Geometry and Water Surface Elevations

St. Joseph Segment

Dredging proposed under Alternative C, particularly if it was concentrated in the St. Joseph area, likely would result in slight degradation or aggradation in the short term and a potential for slight degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, low-flow water surface elevations likely would be slightly reduced in the long term in the St. Joseph area. Water surface elevations for 20,000-cfs flows have been slightly declining for the last 10 years at the USGS gage at St. Joseph.

High-flow water surface elevations would follow existing trends and could increase or decrease slightly in the long term in the St. Joseph area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near St. Joseph, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

Kansas City Segment

Dredging proposed under Alternative C in the Kansas City segment likely would result in slight to moderate degradation in the short term and moderate to substantial degradation in the long term.

Because low-flow water surface elevations are linked to river bed elevation changes, the low-flow water surface elevation in the Kansas City segment likely would decrease a slight to moderate amount in the short term and a moderate to substantial amount in the long term.

High-flow water surface elevations in the Kansas City segment likely would increase in the long term.

Waverly Segment

Dredging proposed under Alternative C in the Waverly segment likely would result in slight degradation or aggradation in the short term and the long term.

Low-flow and high-flow water surface elevations in the Waverly segment are unlikely to change from existing trends. Low-flow water surface elevations have not changed much in the past 20 years, and high-flow water surface elevations have increased a slight to moderate amount in the past 20 years.

Jefferson City Segment

Dredging proposed under Alternative C would cause slight degradation in the short term and moderate to substantial degradation in the long term in the Jefferson City area. Areas outside of the Jefferson City area would experience slight degradation or aggradation in the short term and the long term.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight reduction in low-flow water surface elevations in the short term and a moderate to substantial reduction in the long term in the Jefferson City area.

In response to dredging proposed under Alternative C and long-term trends, high-flow water surface elevations likely would increase in the long term in the Jefferson City area.

If dredging was evenly distributed throughout the segment rather than within a 10-mile reach near Jefferson City, direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

St. Charles Segment

Dredging proposed under Alternative C would cause slight degradation in the short term and moderate to substantial degradation in the long term in the St. Charles area.

Because low-flow water surface elevations are linked to river bed elevations, dredging at the proposed levels likely would result in a slight decrease in low-flow water surface elevations in the short term and a slight to moderate decrease in the long term in the St. Charles area.

High-flow water surface elevations likely would increase in the long term in the St. Charles area.

If dredging was evenly distributed throughout the segment rather than concentrated near St. Charles, the direct impacts from removal of sediment from the river bed would be spread throughout the reach. The effects of dredging on low-flow and high-flow water surface elevations would not be distinguishable from other factors affecting water surface elevations.

4.2.8.4 Tributary Degradation

Tributary degradation is linked to low-flow water surface elevations in the main channel. In general, a moderate to substantial decrease in LOMR low-flow water surface elevations would need to occur before tributaries are likely to be affected. Therefore, tributary degradation is unlikely to occur in the St. Joseph and Waverly segments.

Kansas City, Jefferson City, and St. Charles Segments

Under Alternative C, moderate decreases in low-flow water surface elevations would occur in the short term in the Kansas City segment, and moderate to substantial decreases would occur in the long term in areas with concentrated dredging in the Kansas City, Jefferson City, and St. Charles segments. Tributary degradation is likely to increase in the vicinity of concentrated dredging in these segments under Alternative C in the short term and the long term in the Kansas City segment, and in the long term in the Jefferson City and St. Charles segments. Tributary degradation would be unlikely to increase if dredging was spread throughout the reach rather than concentrated in the urban areas.

4.2.9 Alternate Sources

The No Action Alternative and Alternatives A and B rely to varying degrees on alternate sources of commercial sand and gravel to meet regional demand, as discussed in Section 2.3.2. Alternate sources of supply include increased dredging on the Mississippi and Kansas Rivers to the extent that additional capacity is available under existing dredging permits, off-river open-pit mines and in-river mining operations on other rivers. The alternate sources would make up for supply lost from the LOMR in response to market factors; therefore, the specific locations that would provide supplies are not known and impacts related to the geomorphology of associated rivers and streams cannot be determined. In the short term, existing alternate sources are expected to provide needed sand and gravel, and impacts to the geomorphology of any stream or rivers associated with existing alternate sources are expected to be minimal. In the long term, expanding existing alternate sources and developing new sources may affect the geomorphology of adjacent rivers and streams.

4.2.10 Summary of Impacts

Table 4.2-7 contains a summary of potential impacts on geology and geomorphology for the Proposed Action and alternatives.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
St. Joseph Segment					
Changes in sediment loads and river bed composition[a]	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the St. Joseph segment due to increased amount of dredging required to obtain material that meets specifications.	• No impacts.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the St. Joseph segment due to increased amount of dredging required to obtain material that meets specifications.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the St. Joseph segment due to increased amount of dredging required to obtain material that meets specifications.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the St. Joseph segment due to increased amount of dredging required to obtain material that meets specifications.
Changes in river bed elevation[b]	• Slight degradation in the short term and moderate to substantial degradation in the long term in the St. Joseph area.	• Slight to moderate aggradation in the short term and the long term in the St. Joseph area.	• Slight degradation or aggradation likely in the short term, potential for slight degradation in the long term in the St. Joseph area.	• Slight degradation in the short term and slight to moderate degradation in the long term in the St. Joseph area.	• Slight degradation or aggradation likely in the short term, potential for slight degradation in the long term in the St. Joseph area.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
St. Joseph Segment (continued)					
Changes in channel geometry and water surface elevations[b]	• Moderate reduction in low-flow water surface elevations in the short term and moderate to substantial reductions in the long term in the St. Joseph area. • High-flow water surface elevations likely would increase in the long term in the St. Joseph area.	• Low-flow water surface elevations likely would slightly increase in the short term and in the long term in the St. Joseph area. • High-flow water surface elevations in the vicinity of St. Joseph likely would increase in the long term as the river bed aggrades.	• Low-flow water surface elevations likely would be slightly reduced in the long term in the St. Joseph area. • High-flow water surface elevations could increase or decrease in the long term in the St. Joseph area.	• Low-flow water surface elevations likely would be slightly reduced in the short term and slightly to moderately decreased in the long term in the St. Joseph area. • High-flow water surface elevations likely would increase in the long term in the St. Joseph area.	• Low-flow water surface elevations likely would be slightly reduced in the long term in the St. Joseph area. • High-flow water surface elevations would increase or decrease slightly in the long term in the St. Joseph area.
Tributary degradation	• Tributary degradation is likely to increase in the long term in the St. Joseph area.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is likely to increase in the long term in the St. Joseph area.	• Tributary degradation is unlikely to increase.
Kansas City Segment					
Changes in sediment loads and river bed composition[a]	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas.	• No impacts.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
Kansas City Segment (continued)					
Changes in sediment loads and river bed composition[a] (continued)	• Potential impacts are proportional to the amount of dredging and would be greater in the Kansas City segment due to increased amount of dredging required to obtain material that meets specifications.		• Potential impacts are proportional to the amount of dredging and would be greater in the Kansas City segment due to increased amount of dredging required to obtain material that meets specifications.	• Potential impacts are proportional to the amount of dredging and would be greater in the Kansas City segment due to increased amount of dredging required to obtain material that meets specifications.	• Potential impacts are proportional to the amount of dredging and would be greater in the Kansas City segment due to increased amount of dredging required to obtain material that meets specifications.
Changes in river bed elevation[b]	• Moderate additional degradation likely in the short term and substantial degradation likely in the long term.	• Slight to moderate aggradation likely in the short term and moderate to substantial aggradation likely in the long term.	• Slight degradation or aggradation likely in the short term and slight aggradation likely in the long term.	• Slight degradation likely in the short term and moderate degradation likely in the long term.	• Slight to moderate degradation likely in the short term and substantial degradation likely in the long term.
Changes in channel geometry and water surface elevations[b]	• Moderate reduction in low-flow water surface elevations in the short term and substantial reductions in the long term. • High-flow water surface elevations could increase or decrease in the short term and likely would increase in the long term.	• Low-flow water surface elevations likely would slightly to moderately increase in the short term and moderately to substantially increase in the long term • High-flow water surface elevations likely would increase in the short term and the long term as the river bed aggrades.	• Low-flow water surface elevations could increase or decrease slightly in the short term and likely would increase slightly in the long term. • High-flow water surface elevations could increase or decrease slightly in the short term and likely would increase in the long term as the river bed aggrades.	• Low-flow water surface elevations likely would decrease slightly in the short term and decrease slightly to moderately in the long term. • High-flow water surface elevations likely would increase in the long term.	• Low-flow water surface elevations likely would decrease slightly to moderately in the short term and moderately to substantially in the long term. • High-flow water surface elevations likely would increase in the long term.
Tributary degradation	• Tributary degradation is likely to increase in the short term and the long term.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is likely to increase in the long term.	• Tributary degradation is likely to increase in the short term and the long term.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
Waverly Segment					
Changes in sediment loads and river bed composition[a]	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the Waverly segment due to increased amount of dredging required to obtain material that meets specifications.	• No impacts	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the Waverly segment due to increased amount of dredging required to obtain material that meets specifications.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the Waverly segment due to increased amount of dredging required to obtain material that meets specifications.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging and would be greater in the Waverly segment due to increased amount of dredging required to obtain material that meets specifications.
Changes in river bed elevation[b]	• Slight degradation or aggradation likely in the short term and slight degradation in the long term.	• Slight aggradation or degradation likely in the short term and the long term.	• Slight degradation or aggradation likely in the short term and the long term.	• Slight degradation or aggradation likely in the short term and slight degradation in the long term.	• Slight degradation or aggradation likely in the short term and the long term.
Changes in channel geometry and water surface elevations[b]	• Low-flow water surface elevation likely would increase or decrease slightly in the short term and decrease slightly in the long term. • No change from existing trends for high flows.	• No change from existing trends for low flows or high flows.	• No change from existing trends for low flows or high flows.	• Low-flow water surface elevation likely would increase or decrease slightly in the short term and decrease slightly in the long term. • No change from existing trends for high flows.	• No change from existing trends for low flows or high flows.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
Waverly Segment (continued)					
Tributary degradation	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.
Jefferson City Segment					
Changes in sediment loads and river bed composition[a]	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas. • Potential impacts are proportional to the amount of dredging.	• No impacts	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas. • Potential impacts are proportional to the amount of dredging.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas. • Potential impacts are proportional to the amount of dredging.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in coarse gravel and cobbles in dredged areas. • Potential impacts are proportional to the amount of dredging.
Changes in river bed elevation[b]	• Moderate degradation likely in the short term and substantial degradation likely in the long term in the Jefferson City area.	• Slight to moderate aggradation in the short term and slight aggradation or degradation in the long term in the Jefferson City area.	• Slight degradation or aggradation likely in the short term and slight degradation likely in the long term in the Jefferson City area.	• Slight degradation likely in the short term and slight to moderate degradation likely in the long term in the Jefferson City area.	• Slight degradation likely in the short term and moderate to substantial degradation likely in the long term in the Jefferson City area.
Changes in channel geometry and water surface elevations[b]	• Slight reduction in low-flow water surface elevations in the short term and moderate reductions in the long term in the Jefferson City area.	• Low-flow water surface elevations likely would experience a slight increase in the short term and the long term in the Jefferson City area.	• Slight reduction or increase in low-flow water surface elevations in the short term and a slight decrease in the long term in the Jefferson City area.	• Slight reduction in low-flow water surface elevations in the long term in the Jefferson City area.	• Slight reduction in low-flow water surface elevations in the short term and a moderate to substantial reduction in the long term in the Jefferson City area.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
Jefferson City Segment (continued)					
Changes in channel geometry and water surface elevations[b] (continued)	• High-flow surface elevations likely would increase in the long term in the vicinity of Jefferson City.	• High-flow water surface elevations likely would continue to follow existing long-term trends and likely would increase in the long term in the vicinity of Jefferson City.	• High-flow water surface elevations likely would continue to follow long-term trends and likely would increase in the long term in the vicinity of Jefferson City.	• High-flow water surface elevations likely would continue to follow long-term trends and likely would increase in the long term in the vicinity of Jefferson City.	• High-flow surface elevations likely would increase in the long term in the Jefferson City area.
Tributary degradation	• Tributary degradation is likely to increase in the long term in the Jefferson City area.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is likely to increase in the long term in the Jefferson City area.	• Tributary degradation is likely to increase in the long term in the Jefferson City area.
St. Charles Segment					
Changes in sediment loads and river bed composition[a]	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging.	• No impacts	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging.	• Local short-term decrease in sediment availability. • Fine sediment in the water column would increase below the active dredge location. • Long-term increase in concentration of coarse gravel and cobbles on or near the surface of the river bed in dredged areas. • Potential impacts are proportional to the amount of dredging.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Category of Impact	Proposed Action	No Action Alternative	Alternative A	Alternative B	Alternative C
St. Charles Segment (continued)					
Changes in river bed elevation[b]	• Moderate degradation likely in the short term and substantial degradation likely in the long term in the St. Charles area	• Slight to moderate aggradation likely in the short term and slight aggradation or degradation likely in the long term in the St. Charles area.	• Slight degradation or aggradation likely in the short term and the long term in the St. Charles area.	• Slight degradation likely in the short term and slight to moderate degradation likely in the long term in the St. Charles area	• Slight degradation likely in the short term and moderate to substantial degradation likely in the long term in the St. Charles area.
Changes in channel geometry and water surface elevations[b]	• Moderate reduction in low-flow water surface elevations in the short term and moderate to substantial reductions in the long term in the St. Charles area. • High-flow water surface elevations could decrease in the short term and likely would increase in the long term in the St. Charles area.	• Low-flow water surface elevations likely would experience a slight increase in the short term and the long term in the St. Charles area. • High-flow water surface elevations are likely to increase as the river bed aggrades in the short term and the long term in the St. Charles area.	• Slight decreases or increases in low-flow water surface elevations in the short term and the long term in the St. Charles area. • No change from existing trends for high-flows in the short and long term.	• Slight to moderate decrease in low-flow water surface elevations in the long term, in the St. Charles area. • High-flow surface elevations likely would increase in the long term in the St. Charles area.	• Slight decrease in low-flow water surface elevations in the short term and a slight to moderate decrease in the long term in the St. Charles area. • High-flow water surface elevations likely would increase in the long term in the St. Charles area.
Tributary degradation	• Tributary degradation is likely to increase in the short term and the long term in the St. Charles area.	• Tributary degradation is unlikely to increase.	• Tributary degradation is unlikely to increase.	• Tributary degradation is likely to increase in the long term in the St. Charles area.	• Tributary degradation is likely to increase in the long term in the St. Charles area.

Table 4.2-7 Summary of Potential Impacts on Geology and Geomorphology

Notes:

Assumptions:

Elevation Changes. Changes in average river bed elevation and low-flow water surface elevations were estimated using three categories: slight change (less than approximately 2 feet), moderate change (approximately 2 to 4 feet), and substantial change (greater than approximately 4 feet).

Period of Analysis. The period of analysis is 20 years. Changes that would occur from approximately 0 to 5 years are considered short term and changes between approximately 5 and 20 years are considered long term.

Flow Conditions. The impact analysis assumed that flow conditions were below average and similar to the flows from 2000 to 2009 that were used in the bed material load analysis.

Dredging Locations. To estimate impacts from dredging, the analysis assumed that most dredging would occur near the same locations that dredging occurred under existing conditions, which are typically within 10 miles upriver and 5 miles downriver of a sand plant.

[a] Impacts are local and increase with increased amounts of dredging.

[b] Impacts are based on the assumption that most dredging would occur near existing dredging locations, typically near urban areas.

4.2.11 References

4.2.11.1 Printed Literature

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4.2.11.2 Personal Communication

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